

NEW APPLICATIONS OF THE PAUSON-KHAND REACTION
AND STUDIES TOWARDS THE SYNTHESIS
OF THE HAMIGERANS

by

CHRISTIAN E. MADU

Presented to the Faculty of the Graduate School of
The University of Texas at Arlington in Partial Fulfillment
of the Requirements
for the Degree of

DOCTOR OF PHILOSOPHY

THE UNIVERSITY OF TEXAS AT ARLINGTON

May 2007

ACKNOWLEDGEMENTS

I would like to express my sincere thanks to my advisor, Professor Carl Lovely for his patience, help, guidance and encouragement throughout my graduate studies. His vast knowledge of chemistry helped me overcome the different obstacles that I encountered during my research. I would also like to thank the members of my committee, Professors Rasika Dias, Martin Pomerantz, Dmitry Rudkevich and Edward Bellion for their valuable time and advice during the course of my research.

I would also like to thank the past and present members of the Lovely group, Dr. Hema Seshadri, Dr. Yingzhong Chen, Dr. Greg Browning, Dr. Hongwang Du, Dr. Yong He, Dr. Vivek Badarinarayana, Dr. Sivappa Rasapalli, Dr. Pasupathy Krishnamoorthy, Lesley Schmid, Sabuj Mukherjee, Panduka Koswatta, Vindana Ekanayake, Heather Fenton, Karuna Koda, and Manoj Bhandari, Tom Doundoulakis. Additionally, my special thanks go to Dr. Nora Hernandez, for making time to proof read this dissertation. My thanks also go to Mr. Chuck Savage and all the administrative staff of the chemistry and biochemistry department for their assistance during the course of my study.

Financial support from the Robert A. Welch Foundation, National Institute of Health, THECB-ARP and The University of Texas at Arlington are gratefully acknowledged.

I owe a debt of gratitude to my mother, sisters and brothers for their continued prayer, guidance and encouragement. Finally, I would like to thank my wife, Celia Madu, and my kids, Emeka, Natasha and Mabel, for their support, patience and encouragement during the past five years; none of this would have been possible without them.

Now unto the King eternal, immortal, invisible and the only wise God be all glory and honor for ever and ever.

May 01, 2007

ABSTRACT

NEW APPLICATIONS OF THE PAUSON-KHAND REACTION
AND STUDIES TOWARDS THE SYNTHESIS
OF THE HAMIGERANS

Publication No. _____

Christian E. Madu, PhD.

The University of Texas at Arlington, 2007

Supervising Professor: Carl J. Lovely

This dissertation is divided into two parts. The first part describes the dicobalt octacarbonyl mediated synthesis of medium sized rings via the intramolecular Pauson-Khand (IMPK) reaction. The cyclization of 1,8-enynes has proved to be difficult via the IMPK reaction due to entropy reasons. To overcome this limitation we attempted this cyclization in the presence of an *ortho*- buttressing group (*t*-butyl group) on the aromatic ring so as to reduce the conformationally allowed volume of the alkene arm of the substrate. The construction of the substrates started with *O*-alkenylation of the commercially available 3,5 di-*tert*-butyl-2-hydroxybenzaldehyde and then the *O*-alkenylation products were alkynylated using ethynyl Grignard reagents to afford the

corresponding enynes. These enynes successfully engaged in the both thermal and oxidative IMPK reaction to afford 5,7,6-tricyclic systems. With the parent enynes we observed diketo-compounds as the major product and traces of the expected PK product. When the alkyne arm of the enynes was substituted, the cyclization gave both the reduced PK product and the expected PK product. In general, the thermal mode gave a better diastereoselectivity when compared to the oxidative mode. Attempts to extend these result to a higher homolog to provide 5,8,6 tricyclic systems unfortunately failed. Thus this work describes a new methodology for the construction of medium (>6) sized rings via IMPK reaction.

A second system was investigated which examined whether highly congested systems, related to those found in the hamigeran benzannulated terpenes, could be constructed. These experiments were successful, setting the stage for the studies described in the second section.

The second part describes approach to the synthesis of the hamigerans by the application of the above developed IMPK methodology. The cyclization substrate was accessed from commercially available salicylic acid. The directed ortho metalation of the amide and treatment with iodine gave the iodo aryl amide. This was subsequently alkynylated using a Sonogashira cross-coupling reaction and then alkenylated via a Grignard reaction. The enyne was the subjected to IMPK reaction to afford the tricyclic core of the hamigerans.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS.....	ii
ABSTRACT	iv
LIST OF ILLUSTRATIONS.....	xx
LIST OF TABLES.....	xxi
PART I – MEDIUM SIZED RINGS SYNTHESIS VIA THE PAUSON-KHAND REACTION.....	1
1. INTRODUCTION.....	2
1.1 Pauson-Khand Reaction.....	2
1.2 Thermal Pauson-Khand Reaction.....	3
1.3 Proposed PKR Mechanism	5
1.4 Promoters of the Pauson-Khand Cycloaddition	7
1.5 Other Metals that effect the Pauson-Khand Reaction.....	9
1.6 Stereoselective Pauson-Khand Reaction.....	10
1.6.1 Chiral Precursors.....	10
1.6.2 Chiral Auxiliaries.....	11
1.6.3 Chiral Cobalt Complexes.....	12
1.6.4 Chiral Amine <i>N</i> -Oxides	14
1.7 Catalytic Pauson-Khand Reaction.....	16
1.8 PKR in Medium Sized Ring Synthesis.....	21

1.9 Project Strategy.....	27
2. RESULTS AND DISCUSSIONS	29
2.1 Preliminary Results.....	29
2.2 Type I Substrates.....	32
2.3 Type II Substrates.....	64
3. EXPERIMENTAL SECTION.....	80
3.1 General Methods.....	80
3.1.1 General procedure for the <i>O</i> -alkylation reaction.....	81
3.1.2 General procedure for the reaction of the <i>O</i> -alkylated Product with Grignard reagent.....	81
3.1.3 General procedure for the Pauson Khand reaction.....	82
PART II – APPROACH TO THE TOTAL SYNTHESIS OF HAMIGERAN VIA THE PAUSON-KHAND REACTION.....	157
4. TOTAL SYNTHESIS OF HAMIGERANS.....	158
4.1 Introduction.....	158
4.1.1 Hamigerans.....	159
4.1.2 Synthetic Approaches.....	160
4.2 Project Strategy.....	164
5. RESULTS AND DISCUSSIONS	167
5.1 IMPK Reaction in Total Synthesis of the Hamigerans.....	167
5.2 Retrosynthesis.....	167
5.3 Total Synthesis.....	169
6. EXPERIMENTALS.....	184

6.1 General Methods.....	184
Appendix	
1. ¹ H and ¹³ C NMR SPECTRA OF 2-(-2-Propenyloxy)benzaldehyde (2).....	206
2. ¹ H and ¹³ C NMR SPECTRA OF 2-(1-Hydroxy-2-propynyl)-(2-propenyloxy) benzene (3).....	210
3. ¹ H and ¹³ C NMR SPECTRA OF 2-(1-Hydroxy-3-trimethylsilyl- 2-propynyl)- (-2-propenyloxy) benzene (4)	214
4. ¹ H and ¹³ C NMR SPECTRA OF 2-(1-Hydroxy-3-phenyl-2-propynyl)-(2-propenyloxy benzene (5)	218
5. ¹ H and ¹³ C NMR SPECTRA OF 10-Hydroxy-1-phenyl-4,4a-dihydro- 3 <i>H</i> ,10 <i>H</i> -5-oxabenzof[<i>f</i>]azulen-2-one (8)	222
6. ¹ H and ¹³ C NMR SPECTRA OF 2-(-1- <i>tert</i> -Butyl-dimethylsilyloxy-3- phenyl-2-propynyl)-(2-propenyloxy) benzene (9).....	226
7. ¹ H and ¹³ C NMR SPECTRA OF 10- <i>t</i> -Butyldimethylsilyloxy-1-phenyl-4,4a- dihydro-3 <i>H</i> ,10 <i>H</i> -5-oxabenzof[<i>f</i>]azulen-2-one (10).....	230
8. ¹ H and ¹³ C NMR SPECTRA OF 3,5-Di- <i>tert</i> -butyl-2-(-2-propenyloxy) benzaldehyde (12).....	234
9. ¹ H and ¹³ C NMR SPECTRA OF 3,5-Di- <i>tert</i> -butyl-2-(3-methyl-2-propenyloxy) benzaldehyde (14).....	238

10. ^1H and ^{13}C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-(1-hydroxy-2-propynyl)	
-2-propenyloxy)benzene (15c).....	242
11. ^1H and ^{13}C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-(1-hydroxy-3-phenyl	
-2-propynyl)-2-propenyloxybenzene (15b).....	246
12. ^1H and ^{13}C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-(1-hydroxy-3-trimethylsilyl-	
2-propynyl)-(-2-propenyloxy) benzene (15a)	250
13. ^1H and ^{13}C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-(-1-hydroxy-2-propynyl)	
-1-(-2- butenyloxy)benzene (17c)	254
14. ^1H and ^{13}C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-(-1-hydroxy-3-phenyl	
-2-propynyl)-1-(-2- butenyloxy)benzene (17b).....	258
15. ^1H and ^{13}C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-(-1-hydroxy-3-trimethylsilyl	
-2-propynyl)-1-(-2- butenyloxy)benzene (17a).....	262
16. ^1H and ^{13}C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-iodophenol (19).....	266
17. ^1H and ^{13}C NMR SPECTRA OF	
1,5-Di- <i>tert</i> -butyl-3-iodo-2-(-3-phenyl-2-propenyloxy)benzene (20).....	269
18. ^1H and ^{13}C NMR SPECTRA OF	
3,5-Di- <i>tert</i> -butyl-2-(-3'-phenyl-2'-propenyloxy) benzaldehyde (21).....	273

19. ¹ H and ¹³ C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-(1-hydroxy-2-propynyl)	
-1-(-3-phenyl-2-propenyloxy) benzene (22c).....	277
20. ¹ H and ¹³ C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-(1-hydroxy-3-phenyl-2-propynyl)	
-1-(-3-phenyl-2-propenyloxy) benzene (22b).....	280
21. ¹ H and ¹³ C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-(3-trimethylsilyl	
-2-propynyl)-(-2-propenyloxy) benzene (26a).....	284
22. ¹ H and ¹³ C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-(-3-phenyl-2-	
propynyl)-2-propenyloxybenzene (26b).....	288
23. ¹ H and ¹³ C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-prop-2-ynyl-(2-propenyloxy)benzene (26c).....	292
24. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-1-trimethylsilyl-4,4a-	
dihydro-3 <i>H</i> ,10 <i>H</i> -5-oxabenzof]azulen-2-one (23).....	296
25. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-1-phenyl-4,4a-dihydro	
-3 <i>H</i> ,10 <i>H</i> -5-oxabenzof]azulen-2-one (24)	300
26. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-10-hydroxy-1-trimethylsilyl	
-4,4a-dihydro-3 <i>H</i> ,10 <i>H</i> -5-oxabenzof] azulen-2-one (28).....	305
27. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-10-hydroxy-1-phenyl-4,4a-dihydro	
-3 <i>H</i> ,10 <i>H</i> -5-oxabenzof] azulen-2-one (29).....	309

28. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-1,1a,4,4a-tetrahydro-3 <i>H</i> -5-oxabenzof]azulen-2,10-dione (syn isomer, 35).....	314
29. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-1,1a,4,4a-tetrahydro-3 <i>H</i> -5-oxabenzof]azulen-2,10-dione (<i>anti</i> -isomer, 35).....	319
30. ¹ H and ¹³ C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-(-1- <i>tert</i> -butyl-dimethylsilyloxy-3-phenyl-2-propynyl)-(-2-propenyloxy)benzene (30).....	323
31. ¹ H and ¹³ C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-(-1- <i>tert</i> -butyl-dimethylsilyloxy-3-trimethylsilyl-2-propynyl)-(-2-propenyloxy)benzene (31).....	327
32. ¹ H and ¹³ C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-(-1- <i>tert</i> -butyl-dimethylsilyloxy-2-propynyl)-(-2-propenyloxy) benzene (36).....	331
33. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-10- <i>t</i> -butyldimethylsilyloxy-1-phenyl-4,4a-dihydro-3 <i>H</i> ,10 <i>H</i> -5-oxabenzof]azulen-2-one (32).....	335
34. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-10- <i>t</i> -butyldimethylsilyloxy-1-trimethylsilyl-4,4a-dihydro-3 <i>H</i> ,10 <i>H</i> -5-oxabenzof]azulen-2-one (33).....	339
35. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-10- <i>t</i> -butyldimethylsilyloxy-4,4a-dihydro-3 <i>H</i> ,10 <i>H</i> -5-oxabenzof]azulen-2-one (<i>exo</i> product, 37).....	343

36. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-10- <i>t</i> -butyldimethylsilyloxy-4,4a-dihydro-3 <i>H</i> ,10 <i>H</i> -5-oxabenzof]azulen-2-one (<i>endo</i> product, 37).....	347
37. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-1-phenyl-3-methyl-4,4a-dihydro-3 <i>H</i> ,10 <i>H</i> -5-oxabenzof]azulen-2-one (39).....	351
38. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-10-hydroxy-3-methyl-1-phenyl-4,4a-dihydro-3 <i>H</i> ,10 <i>H</i> -5-oxabenzof]azulen-2-one (<i>endo</i> product, 40).....	356
39. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-10-hydroxy-3-methyl-1-phenyl-4,4a-dihydro-3 <i>H</i> ,10 <i>H</i> -5-oxabenzof]azulen-2-one (<i>exo</i> product, 41).....	360
40. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-10-hydroxy-3-methyl-1-trimethylsilyl-4,4a-dihydro-3 <i>H</i> ,10 <i>H</i> -5-oxabenzof]azulen-2-one (42).....	364
41. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-3-methyl-1,1a,4,4a-tetrahydro-1 <i>H</i> ,3 <i>H</i> -5-oxabenzof]azulen-2,10-dione (<i>anti</i> -product, 43).....	368
42. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-3-methyl-1,1a,4,4a-tetrahydro-1 <i>H</i> ,3 <i>H</i> -5-oxabenzof]azulen-2,10-dione (<i>syn</i> -product, 43).....	372
43. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-3-methyl-4,4a-dihydro-3 <i>H</i> ,10 <i>H</i> -5-oxabenzof]azulen-2-one (44).....	376
44. ¹ H and ¹³ C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-(-1- <i>tert</i> -butyl-dimethylsilyloxy-3-phenyl-2-propynyl)-(-2-butenyloxy)benzene (45).....	380

45. ¹ H and ¹³ C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-(-1- <i>tert</i> -butyl dimethylsilyloxy	
-3-trimethylsilyl-2-propynyl)-(-2- butenyloxy) benzene (46).....	383
46. ¹ H and ¹³ C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-(-1- <i>tert</i> -butyl dimethylsilyloxy	
-2-propynyl)-(-2- butenyloxy) benzene (49).....	386
47. ¹ H and ¹³ C NMR SPECTRA OF	
6, 8-Di- <i>tert</i> -butyl-10- <i>t</i> -butyldimethylsilyloxy-3-methyl-1-phenyl	
-4,4a-dihydro-3 <i>H</i> ,10 <i>H</i> -5-oxabenzof]azulen-2-one (47).....	390
48. ¹ H and ¹³ C NMR SPECTRA OF	
6, 8-Di- <i>tert</i> -butyl-10- <i>t</i> -butyldimethylsilyloxy-3-methyl-1-trimethylsilyl	
-4,4a-dihydro-3 <i>H</i> ,10 <i>H</i> -5-oxabenzof]azulen-2-one (48).....	394
49. ¹ H and ¹³ C NMR SPECTRA OF	
6, 8-Di- <i>tert</i> -butyl-10- <i>t</i> -butyldimethylsilyloxy-3-methyl	
-4,4a-dihydro-3 <i>H</i> ,10 <i>H</i> -5-oxabenzof]azulen-2-one (50).....	398
50. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-1,3-diphenyl-4,4a-dihydro	
-3 <i>H</i> ,10 <i>H</i> -5-oxabenzof]azulen-2-one (51).....	402
51. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-10-hydroxy-1,3-diphenyl-4,4a-dihydro	
-3 <i>H</i> ,10 <i>H</i> -5-oxabenzof] azulen-2-one (52).....	406
52. ¹ H and ¹³ C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-(1- <i>tert</i> -butyldimethylsilyloxy	
-3-phenyl -2-propynyl)-1-(3-phenyl -2-propenyloxy) benzene (53).....	410

53. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-10-- <i>t</i> -butyldimethylsilyloxy-1,3-diphenyl -4,4a-dihydro-3 <i>H</i> ,10 <i>H</i> -5-oxabenzof]azulen-2-one (54).....	415
54. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-3-phenyl-1,1a,4,4a-tetrahydro -3 <i>H</i> -5-oxabenzof]azulen-2, 10-dione (55).....	418
55. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-10-hydroxy-3-phenyl-4,4a-dihydro -3 <i>H</i> ,10 <i>H</i> -5-oxabenzof] azulen-2-one (56).....	422
56. ¹ H and ¹³ C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-(1- <i>tert</i> -butyldimethylsilyloxy-2-propynyl) -1-(3-phenyl-2-propenyloxy) benzene (57).....	426
57. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-10-- <i>t</i> -butyldimethylsilyloxy-3-phenyl -4,4a-dihydro-3 <i>H</i> ,10 <i>H</i> -5-oxa benzo[f]azulen-2-one (58).....	430
58. ¹ H and ¹³ C NMR SPECTRA OF	
Di- <i>tert</i> -butyl-2-trimethylsilylethynyl-(-2-propenyloxy) benzene (62).....	434
59. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-1-trimethylsilyl-3a,4-dihydro -3 <i>H</i> - cyclopenta[c]chromen-2-one (64).....	438
60. ¹ H and ¹³ C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-trimethylsilylethynyl -(-2-methylallyloxy)benzene (66).....	442
61. ¹ H and ¹³ C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-ethynyl-(-2-methylallyloxy)benzene (67).....	445

62. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-1-trimethylsilyl -3a-methyl -4-hydro-3 <i>H</i> -cyclopenta[<i>c</i>]chromen-2-one (68).....	448
63. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-3a-methyl-3a,4-dihydro -3 <i>H</i> -cyclopenta[<i>c</i>]chromen-2-one (69).....	452
64. ¹ H and ¹³ C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-trimethylsilylethynyl -(-3-phenyl-2-propenyloxy)benzene (71).....	456
65. ¹ H and ¹³ C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-ethynyl -(-3-phenyl-2-propenyloxy)benzene (72).....	460
66. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-3-phenyl-1-trimethylsilyl-3a,4-dihydro -3 <i>H</i> - cyclopenta[<i>c</i>]chromen-2-one (73).....	464
67. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-3-phenyl-3a,4-dihydro -3 <i>H</i> - cyclopenta[<i>c</i>]chromen-2-one (74).....	468
68. ¹ H and ¹³ C NMR SPECTRA OF	
3-Butenyloxy-4,6-di- <i>tert</i> -butyl -2-trimethylsilylethynylbenzene (75).....	472
69. ¹ H and ¹³ C NMR SPECTRA OF	
7,9-Di- <i>tert</i> -butyl-1-trimethylsilyl -4,4a-dihydro -3 <i>H</i> ,5 <i>H</i> -6-oxabenzof[<i>f</i>]azulen-2-one (77).....	476

70. ¹ H and ¹³ C NMR SPECTRA OF	
(7,9-Di- <i>tert</i> -butyl-4-methylene -3,4-dihydro -2 <i>H</i> -benzo[<i>b</i>]oxepin-5-ylidenemethyl)-trimethylsilane (78).....	480
71. ¹ H and ¹³ C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-14-hydroxy-8-oxa -tricyclo[9.2.1.0 ^{2,7}]tetradeca-2,4,6-triene-13-one (81).....	484
72. ¹ H and ¹³ C NMR SPECTRA OF	
2,4-Di- <i>tert</i> -butyl-6-(-3-hydroxy-3-methylbut-1-ynyl)phenol (84).....	488
73. ¹ H and ¹³ C NMR SPECTRA OF	
2,4-Di- <i>tert</i> -butyl-6-(-3-methylbut-1-ynyl)phenol (85).....	491
74. ¹ H and ¹³ C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-(-2-methylbut-3-yn-2-ol) -(-2-methylallyloxy)benzene (86).....	494
75. ¹ H and ¹³ C NMR SPECTRA OF	
4,6-Di- <i>tert</i> -butyl-2-(-2-methylbut-3-ynyl) -(-2-methylallyloxy)benzene (87).....	497
76. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-1-(-1-hydroxy-1-methylethyl)-3a-methyl -3a,4-dihydro-3 <i>H</i> -cyclopenta[<i>c</i>]chromen-2-one (88).....	500
77. ¹ H and ¹³ C NMR SPECTRA OF	
6,8-Di- <i>tert</i> -butyl-1-isopropyl-3a-methyl -3a,4-dihydro-3 <i>H</i> -cyclopenta[<i>c</i>]chromen-2-one (89).....	504
78. ¹ H and ¹³ C NMR SPECTRA OF	
2-Methoxy-4-methylbenzoic acid (99)	508

79. ^1H and ^{13}C NMR SPECTRA OF	
<i>N-tert</i> -butyl-2-methoxy-4-methylbenzamide (100).....	511
80. ^1H and ^{13}C NMR SPECTRA OF	
<i>N-tert</i> -butyl-6-iodo-2-methoxy-4-methylbenzamide (91).....	514
81. ^1H and ^{13}C NMR SPECTRA OF	
<i>N-tert</i> -butyl-6-iodo-2-hydroxy-4-methylbenzamide (101).....	517
82. ^1H and ^{13}C NMR SPECTRA OF	
2-Hydroxy-6-iodo-4-methyl-methylbenzoate (102).....	520
83. ^1H and ^{13}C NMR SPECTRA OF	
2-Methoxy-6-iodo-4-methyl-methylbenzoate (103).....	523
84. ^1H and ^{13}C NMR SPECTRA OF	
2- Iodo-4-methyl-6-methoxy-benzylalcohol (104).....	526
85. ^1H and ^{13}C NMR SPECTRA OF	
2- Iodo-4-methyl-6-methoxy-benzylaldehyde (105).....	529
86. ^1H and ^{13}C NMR SPECTRA OF	
3,4,6-Tribromo-2,5-dimethylphenol (109).....	532
87. ^1H and ^{13}C NMR SPECTRA OF	
3-Bromo-2,5-dimethylphenol (110)	535
88. ^1H and ^{13}C NMR SPECTRA OF	
3-Bromo-2,5-dimethylanisole (111).....	538
89. ^1H and ^{13}C NMR SPECTRA OF	
2-Bromo-6-methoxy-4-methylbenzaldehyde (112).....	541

90. ^1H and ^{13}C NMR SPECTRA OF	
2-(3-Hydroxy-3-methyl-1-butynyl)- 4-methyl-6-methoxy-benzaldehyde (91).....	544
91. ^1H and ^{13}C NMR SPECTRA OF	
2-(1-Hydroxy-3-methyl-3-butenyl) -3-(3-hydroxy-3-methyl-1-butynyl)-5-methyl anisole (93).....	547
92. ^1H and ^{13}C NMR SPECTRA OF	
<i>N,N</i> -Diethyl-2-hydroxy-4-methylbenzamide (114).....	551
93. ^1H and ^{13}C NMR SPECTRA OF	
<i>N,N</i> -Diethyl-2-(<i>tert</i> -butyl-dimethylsilyloxy) -4-methylbenzamide (115).....	555
94. ^1H and ^{13}C NMR SPECTRA OF	
2-(<i>tert</i> -Butyl-dimethylsilyloxy)- 6-iodo -4-methyl- <i>N,N</i> -diethylbenzamide (116).....	558
95. ^1H and ^{13}C NMR SPECTRA OF	
2-(3-Hydroxy-3-methyl-1-butynyl)-4-methyl-6- (<i>tert</i> -butyl-dimethylsilyloxy)- <i>N,N</i> -diethylbenzamide (117).....	562
96. ^1H and ^{13}C NMR SPECTRA OF	
2-(3-Hydroxy-3-methyl-1-butynyl) -6-hydroxy-4-methyl-methylbenzoate (118).....	566
97. ^1H and ^{13}C NMR SPECTRA OF	
2-(3-Hydroxy-3-methyl-1-butynyl) -6-hydroxy -4-methyl -benzylalcohol (119).....	569
98. ^1H and ^{13}C NMR SPECTRA OF	
2-(3-Hydroxy-3-methyl-1-butynyl) -6-hydroxy -4-methyl -benzaldehyde (120).....	572

99. ¹ H and ¹³ C NMR SPECTRA OF	
2-(1-Hydroxy-3-methyl-3-butenyl)-3-	
(3-hydroxy-3-methyl-1-butyne)-5-methyl phenol (121).....	575
100. ¹ H and ¹³ C NMR SPECTRA OF	
2-(3-hydroxy-3-methyl-1-butyne)	
-6-(<i>t</i> -butyldimethylsilyloxy)-4-methyl-methylbenzoate (124).....	579
101. ¹ H and ¹³ C NMR SPECTRA OF	
2-(3-Hydroxy-3-methyl-1-butyne)	
-6-(<i>t</i> -butyldimethylsilyloxy) -4-methyl -benzyl alcohol (125).....	582
102. ¹ H and ¹³ C NMR SPECTRA OF	
2-(3-Hydroxy-3-methyl-1-butyne)	
-6-(<i>t</i> -butyldimethylsilyloxy)-4-methyl -benzaldehyde (126).....	585
103. ¹ H and ¹³ C NMR SPECTRA OF	
4-[2,2-Di- <i>tert</i> -butyl-7-methyl-4-(2-methyl-allyl)	
-4 <i>H</i> -benzo[1,3,2]dioxasilin-5-yl]-2-methyl-but-3-yn-2-ol (128).....	588
104. ¹ H and ¹³ C NMR SPECTRA OF	
5,5-Di- <i>tert</i> -butyl-10-(1-hydroxy-1-methyl-ethyl)-2,7a-dimethyl-6a,7,7a,8	
-tetra hydro-4,6-dioxa-5-sila-cyclopenta[<i>a</i>]phenalen-9-one (129).....	592
SUPPORTING INFORMATION FOR CRYSTAL STRUCTURE.....	597
REFERENCES.....	601
BIOGRAPHICAL INFORMATION.....	609

LIST OF ILLUSTRATIONS

Figure	Page
1.1 Chiral amine <i>N</i> -oxides.....	16
1.2 Preferred conformation of 1,9-enynes.....	23
1.3 Proposed cyclization mode.....	26
1.4 Type 1 and Type 2 Substrates	28
2.1 Alkyne polarization of substrate 25c	36
2.2 X-ray crystal structure of 24	41
2.3 X-ray crystallography of the <i>exo</i> product of compound 29	45
2.4 Unfavorable Steric Interaction of enynes with internally substituted alkene margin	53
2.5 X-ray Crystallography of <i>exo</i> -product 41	55
2.6 NOESY confirmation of the stereochemistry of the <i>cis</i> -isomer of 43	56
2.7 NOESY interaction of <i>cis</i> -isomer of 55	62
4.1 Some Natural Products Synthesized via PK Reaction	159
4.2 The hamigeran family	159
4.3 Rings Assembled via IMPK reaction	164
4.4 Hamigeran core assembly via IMPK reaction.....	165
5.1 Rotational isomers of substrate 93	177

LIST OF TABLES

Table	Page
2.1 Result of the enyne construction	33
2.2 Oxidative cyclisation result of electron deficient alkynes	38

PART I

**MEDIUM SIZED RINGS SYNTHESIS VIA
THE PAUSON-KHAND REACTION**

CHAPTER 1

INTRODUCTION

In recent years, the use of transition metal complexes in the total synthesis of natural products has attracted a lot of attention, and this area has been thoroughly reviewed in the literature.¹⁻⁴ This increased interest is due to the fact that transition metal-mediated reactions, when compared to their classical organic counterparts, proved to be advantageous when the issues of selectivity and atom economy were considered. As a result, these types of reactions have become powerful tools for the construction of complex cyclic structures from simple and in many cases readily available starting materials. The Pauson-Khand reaction is among such reactions that make use of transition metal complexes to effect C-C bond formation.

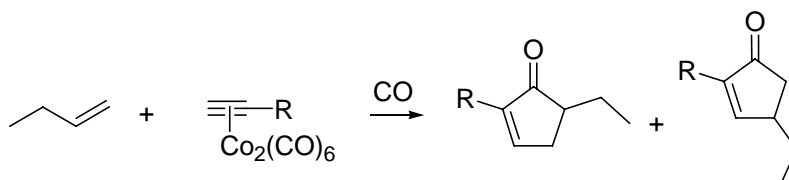
1.1 Pauson-Khand Reaction

The Pauson-Khand (PK) reaction is a transition metal-mediated reaction that has attracted substantial interest^{3, 4} in recent years due to its usefulness in total synthesis. The PK reaction is both known intra- and intermolecularly. The synthetic attractiveness of the intramolecular variant is due to the fact that it permits the rapid increase of molecular complexity in a single step. Hence, it offers the opportunity for the rapid

construction of a variety of carbon skeletons resembling many known polycyclic terpenes.

The PK reaction, formally a [2+2+1] cycloaddition reaction, is the cobalt-mediated cyclization between an alkyne, an alkene and carbon monoxide to form a cyclopentenone. Prof. Peter L. Pauson first reported the use of this synthetic method in the early 1970's^{5, 6} and was initially carried out with strained olefins. The reaction proceeded with high regioselectivity in the case of unsymmetrical alkynes, placing the larger substituent of the alkyne in the α -position of the cyclopentenone. On the other hand, the use of an unsymmetrical olefin with a terminal alkyne yields regioisomeric mixtures (1:1) of the cyclopentenones as shown in Scheme 1.1.⁷

Scheme 1.1

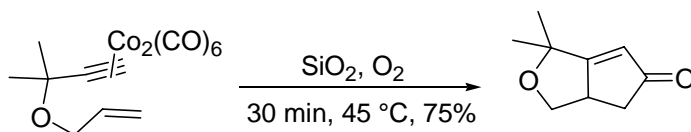


1.2 Thermal Pauson-Khand Reaction

Initially, the intermolecular PK reaction was carried out under thermal conditions. The cobalt-alkyne complex was generated first by using a stoichiometric amount of $\text{Co}_2(\text{CO})_8$ in the presence of an alkyne. The cobalt-alkyne complex, in an ethereal solvent, was then heated with a wide variety of alkenes under N_2 or CO atmosphere to afford the corresponding cyclopentenones. One of the disadvantages of

these initial thermal PK reactions is that relatively high temperatures (70 - 110 °C) and long reaction times (hours to days) were required; many times resulting in decomposition of the starting materials and/or product. The intramolecular version of PK reaction was introduced using systems related to 1,6-heptynyne and was most frequently carried out under the thermal conditions described above. Schore, in 1981, was the first to demonstrate the feasibility of an intramolecular PK cycloaddition by connecting the alkene to the alkyne via a carbon tether.⁸ Subsequent to the reports of these thermal reactions, a number of experimental variants were introduced which extended the scope of this reaction. In the mid 1980's, Smit and Caple were the first to report that adsorbing the cobalt complexed enynes onto silica gel or alumina, allows the reaction to proceed at a lower temperature and with shorter reaction time (Scheme 1.2).⁹

Scheme 1.2

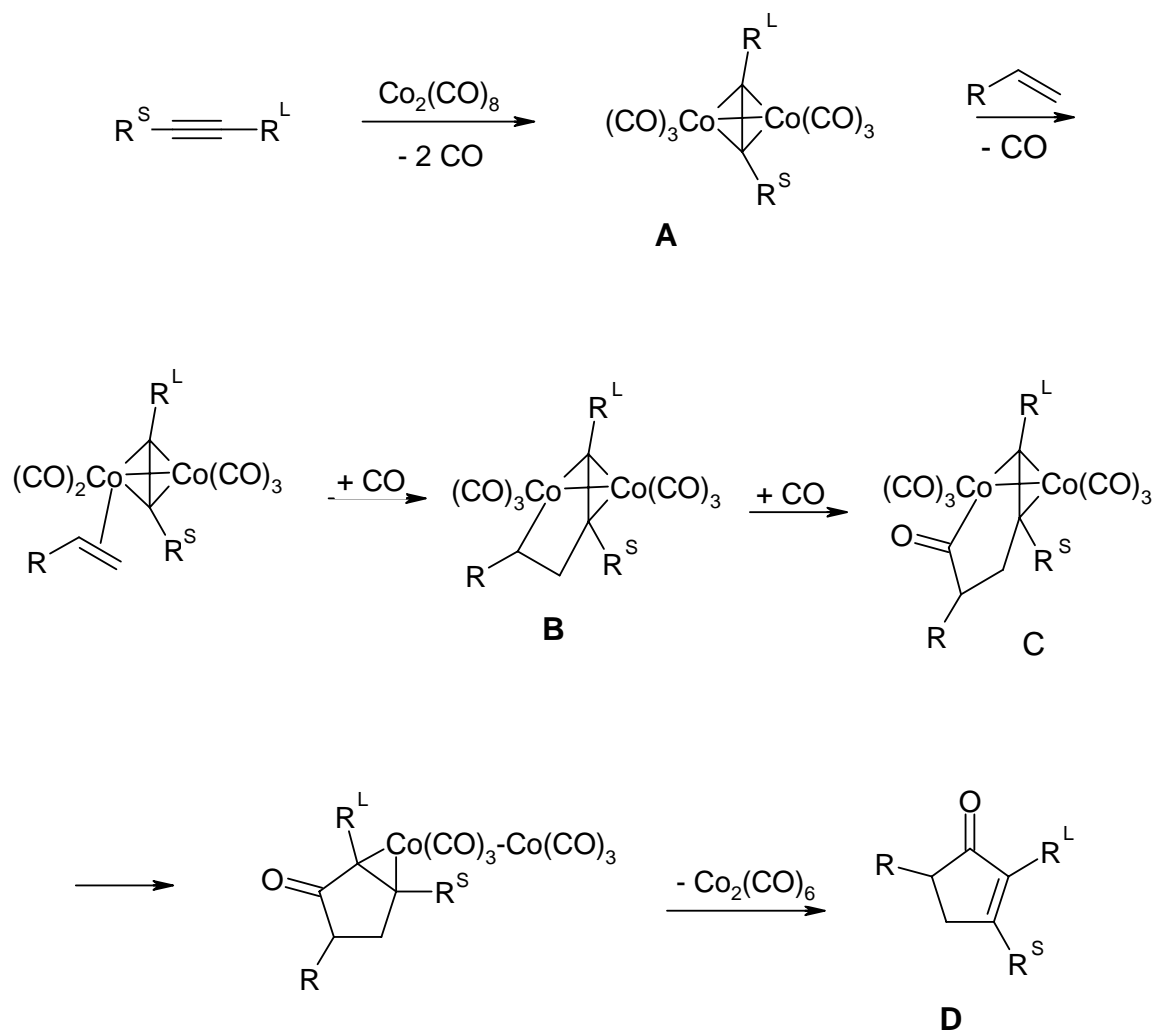


Moreover, Marie Krafft incorporated a directing and accelerating ligand to an unstrained alkene to get high levels of regiocontrol and high yield in the intermolecular PK reaction.¹⁰ The PK cyclization was now regioselective with respect to the olefin and as a result, strained olefins were no longer required, thereby increasing the synthetic utility of the reaction.

1.3 Proposed PK Reaction Mechanism

The mechanism of the Pauson-Khand reaction was initially proposed by Magnus¹¹ and has been widely accepted (Scheme 1.3) despite the lack of firm experimental evidence. After this dissertation was completed, this mechanistic pathway was validated by kinetic studies on the intermolecular PK reaction carried out by Cabot *et al.*⁸⁸ First, the alkyne reacts with a stoichiometric amount of $\text{Co}_2(\text{CO})_8$ to give the alkyne-cobalt hexacarbonyl complex **A**. This is then followed by the loss of CO to open up a coordination site on the metal center for the alkene to coordinate. This step follows a dissociative mechanism, thus explaining the need for heat (or additives) that can promote the loss of CO. This step is then followed by the formation of the C-C bond between the alkyne and alkene to give the metallocycle **B**. This step has been confirmed to be the rate determining and product determining step.⁸⁸ If the alkyne is unsymmetrical, insertion and carbon-carbon bond formation proceeds exclusively at the alkyne carbon with the smaller substituent. Next, CO inserts into the metal-carbon bond leading to the metallocycle **C**. Then reductive elimination of the $\text{Co}(\text{CO})_3$ fragment followed by the decomplexation of the $\text{Co}_2(\text{CO})_6$ fragment gives the cyclopentenone **D** completing the reaction as shown in Scheme 1.3.¹²

Scheme 1.3



The above mechanism was inferred from observations of regio- and stereochemistry results in a large number of cycloadditions; however no intermediate beyond the cobalt-alkyne complex has been isolated in the PK cyclization.

Moreover, theoretical studies have been used to further understand the mechanistic interpretation of the PK reaction. These studies also gave practical models which can be used to predict the diastereoselectivity of the cycloaddition.¹³⁻²³

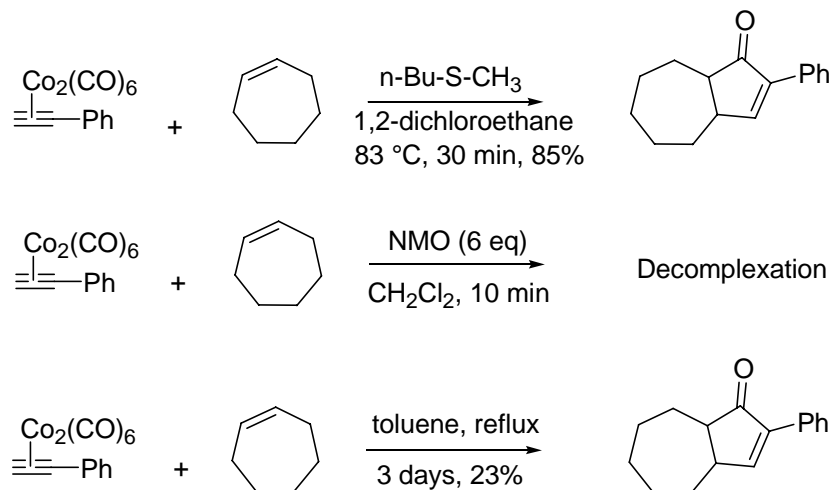
1.4 Promoters of the Pauson-Khand Cycloaddition

Originally, the PK reaction was effected using the traditional method of first forming the alkyne-cobalt complex before heating in the presence of the alkene to form the cyclopentenone. The disadvantage of this methodology is that it can require extended reaction times and relatively high temperatures to effect the formation of the cyclopentenone. Consequently, attempts have been made for more than a decade by different groups to find reaction conditions that would accelerate the PK reaction while also reducing the reaction temperature. Smith and Caple⁹ in 1986 were the first to report success in improving the reaction rate for PK reaction by using alumina or silica gel for adsorption of the enyne, thereby reducing the reaction time and temperature. Then in the early 1990's, the use of various promoters (e.g., *N*-methylmorpholine oxide and trimethylamine *N*-oxide) were reported by Schreiber²⁴ and Jeong²⁵ respectively. The use of promoters made it possible for the reaction to be carried out at room temperature (or below), thereby allowing the use of sensitive functionality in the cyclization precursors. It is widely accepted that these *N*-oxides act as oxidants creating a vacant coordination site on the cobalt by oxidative removal of the carbon monoxide ligands. This vacant site on the metal center allows for the oxidative addition of the olefin at a faster rate. As mentioned earlier, the oxidative addition of the olefin is considered to be the rate determining step for this reaction.

Sugihara and Yamaguchi²⁶ reported that sulfur additives promoted both inter- and intramolecular PK reaction (85% yield in 30 minutes) better than *N*-oxides or the

thermal mode which gave either the decomplexation product or poor yields of the PK product (Scheme 1.4).

Scheme 1.4



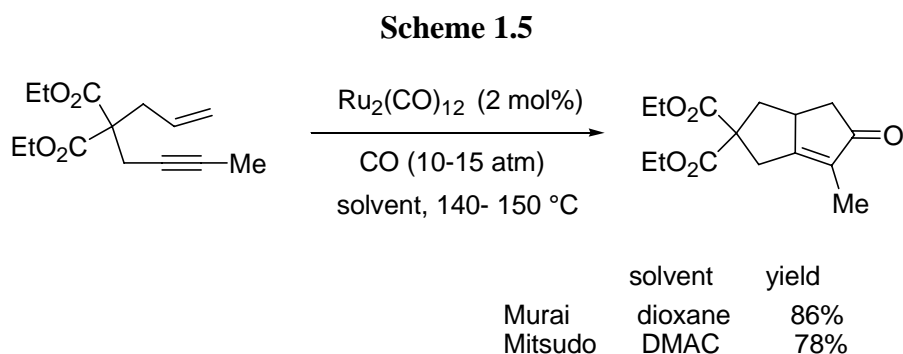
Sugihara and Yamaguchi also showed that 3.5 equivalents of the alkyl or aryl methyl sulfide (R-S-CH_3 , where $\text{R} = \text{Ph}, i\text{-Pr}, n\text{-Bu}, t\text{-Bu}$) afford excellent yields of the cycloadducts.²⁶ Also electron donating groups attached to an aromatic ring enhance the yield in comparison to electron withdrawing groups. Moreover, they established that less sterically hindered sulfides functioned as better promoters.

1.5 Other Metals that effect the Pauson-Khand Reaction

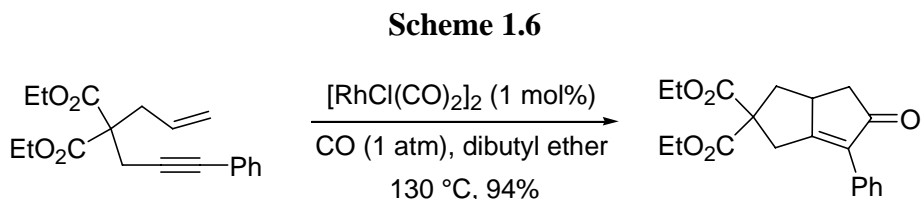
Apart from cobalt, several other metal complexes such as those of Fe ,²⁷ Ir ,²⁸ Rh ,²⁹ Ti ,³⁰ Ni ,³¹ Zr ,³² Ru ,^{33, 34} etc. have been used in a similar type of transformation. Yet cobalt remains the metal of choice for this type of cycloadditions reactions. These

metal complexes have been used in stoichiometric and catalytic fashion. A few of the catalytic versions are herewith discussed.

Murai³⁴ and Mitsudo³³ at about the same time reported the use of $\text{Ru}_2(\text{CO})_{12}$ to effect the intramolecular cycloaddition of enynes to give the cyclopentenones. Both groups used similar reaction conditions except that their choice of solvent is different (dioxane versus dimethyl acetamide) as shown in the Scheme 1.5.



Rhodium metal complexes are among the other transition metals that have been extensively used in PK reaction. Narasaka established that $[\text{RhCl}(\text{CO})_2]_2$ (1-5 mol%) promotes the PK cyclization of the 1,6-enynes in CO atmosphere, to give the bicyclic enones in good yields (Scheme 1.6).²⁹



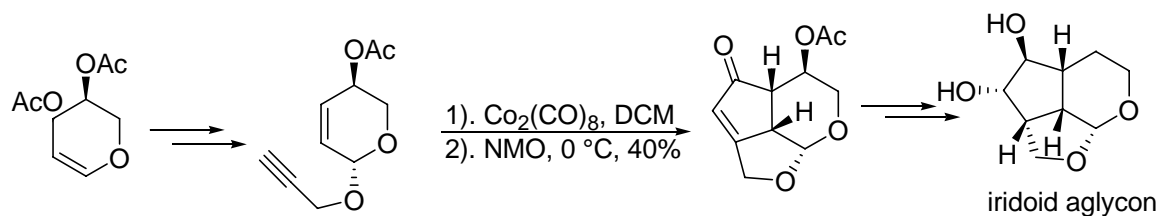
1.6 Stereoselective Pauson-Khand Reaction

Control of the absolute stereochemistry in the PK reaction has attracted a great deal of attention. Various methods for making the PK reaction stereoselective have been introduced. Approaches aimed at preparing chiral cyclopentenones have involved the use of the following four strategies: (i) chiral precursors, (ii) chiral auxiliaries, (iii) chiral cobalt complexes and (iv) chiral additives.

1.6.1 Chiral Precursors

The most obvious method for promoting stereoselectivity would be to begin with a non-racemic starting material. Incorporation of chirality in the starting material would then make it possible for the transfer of chirality into the Pauson-Khand cycloadduct. Marco-Contelles and co-workers used the ex-chiral pool strategy to obtain the iridoid aglycon (Scheme 1.7).³⁵ They converted a carbohydrate derived enol ether to a chiral enyne, which then underwent an NMO promoted PK reaction to give the tricyclic cyclopentenones. The cyclopentenone was then further functionalized to give the targeted iridoid aglycon.

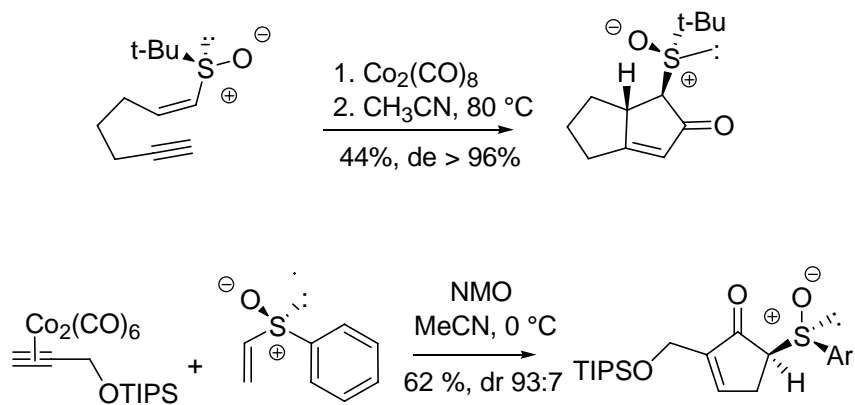
Scheme 1.7



1.6.2. Chiral Auxiliaries

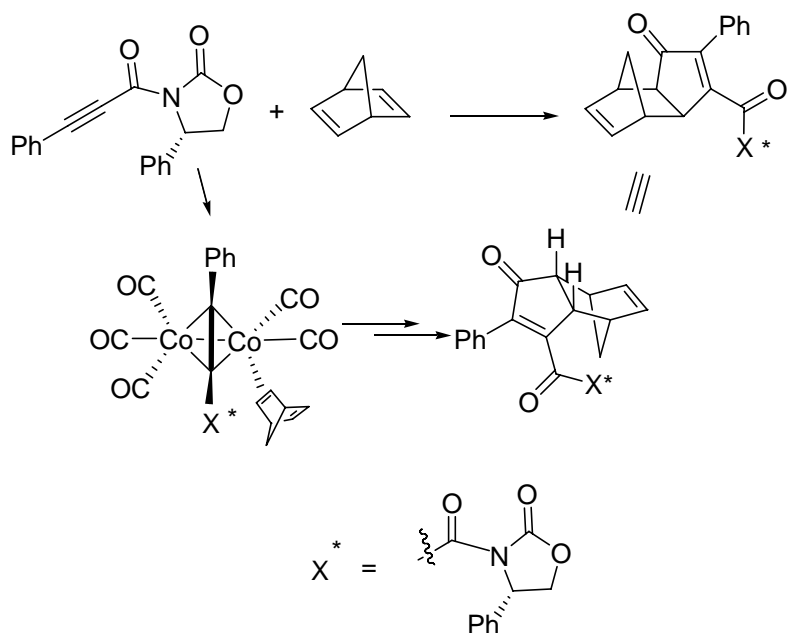
Chiral auxiliaries can also be used for stereoselective intramolecular PK reaction and they are attached to either the alkene or alkyne arm. Carretero^{36, 37} has shown that chiral sulfinylated enynes can furnish the PK product with excellent diastereoselectivity (Scheme 1.8).

Scheme 1.8



Moyano and Perricas³⁸ showed that chiral oxazolidin-2-ones are very useful auxiliaries for alkynes (Scheme 1.9).

Scheme 1.9



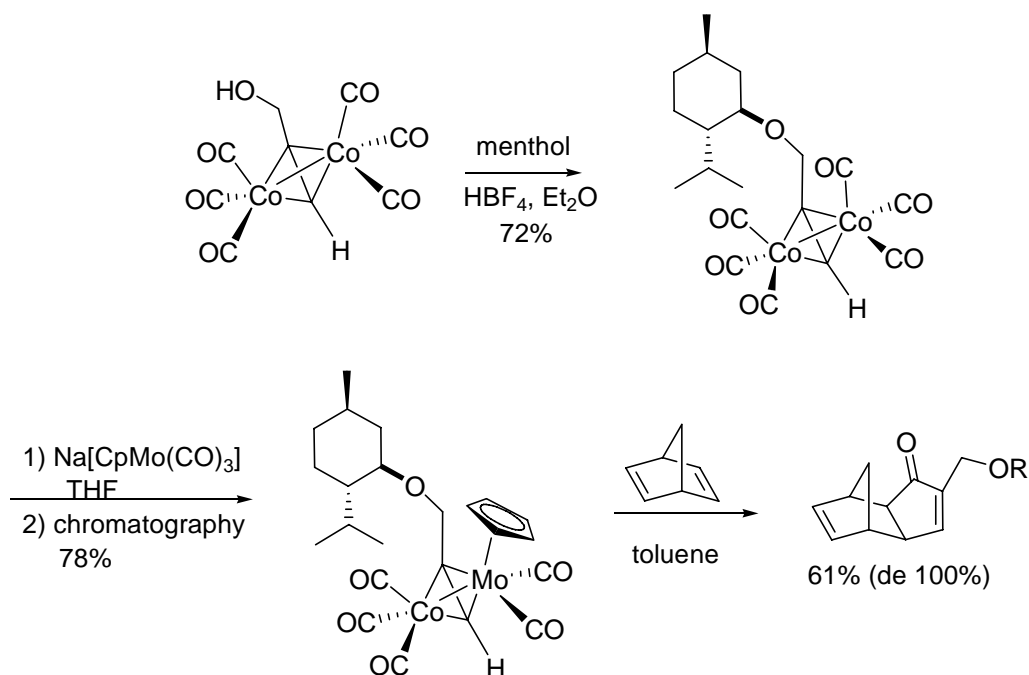
It was noted through semi-empirical calculations (PM3) on the cobalt-alkyne complexes clearly indicated that the *S*-configured chiral auxiliary effectively shields the *Re* face of the tetrahedral cobalt cluster. Therefore, the alkene is directed to an equatorial anti-position of the *Si* face as depicted in Scheme 1.9. Subsequent insertion of the alkene, followed by CO insertion and cleavage of the cobalt fragment gives the *exo*-product as the major diastereomer. Both thermal and oxidative mode gave similar yields and diastereoselectivity.³⁸

1.6.3. Chiral Cobalt Complexes

Christie^{39, 40} was the first to demonstrate the use of chiral heterobimetallic alkyne complexes in an asymmetric variant of the PK reaction. The chiral mixed metal

complex was prepared by etherification of the cobalt-alkyne complex followed by treatment with Na[CpMo(CO)₃]. This complex was then heated with norbornadiene to afford the cyclopentenone as a single diastereomer (*exo*-product) as shown in Scheme 1.10 below.

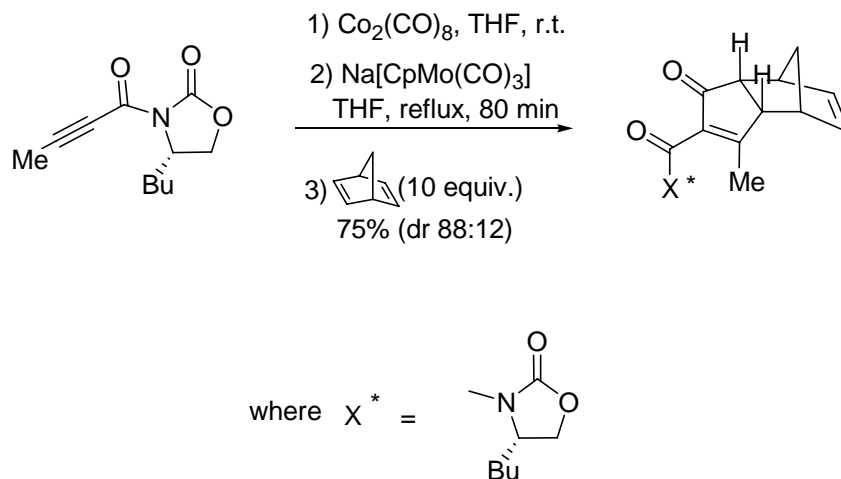
Scheme 1.10



These complexes can be handled under atmospheric conditions for extended periods of time and are also thermally stable. The observed diastereoselectivity is due to the fact that the reaction occurs selectively with one chiral metal site over the other.

Pericas and Moyano,^{41, 42} while studying heterobimetallic W-Co and Mo-Co systems, found that the PK reaction proceeded diastereoselectively to give the *endo* product. They attributed the chirality of the C₂MoCo core to be responsible for the diastereoselectivity of the *endo*-product (Scheme 1.11).

Scheme 1.11

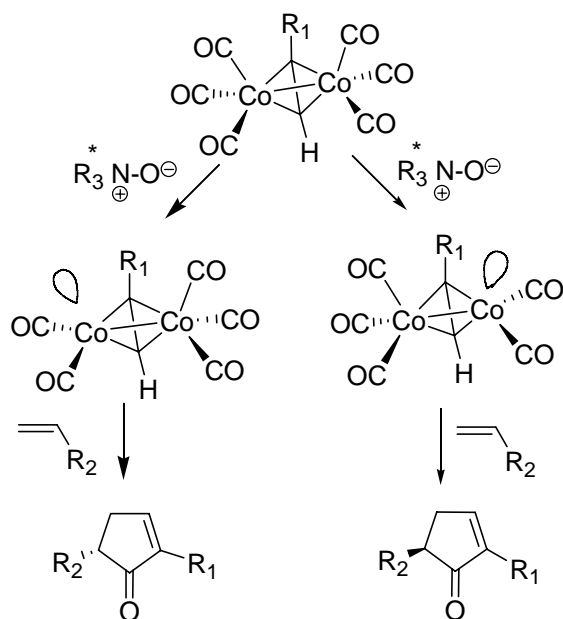


On the other hand, the corresponding $[\text{MoCp}(\text{CO})_2]_2$ complex did not react with norbornadiene to give the cyclopentenone. This clearly indicates that the cobalt atom is the active species in the heterobimetallic complexes.

1.6.4 Chiral Amine *N*-Oxides

Kerr was the first to report the use of chiral amine *N*-oxides for the asymmetric variant of the PK reaction.⁴³ The prochiral cobalt-alkyne complex is desymmetrized by the chiral amine *N*-oxide which then leads to the preferred decarbonylation of either the *Re* face or the *Si* face. This ultimately results in the formation of one of the two enantiomeric cyclopentenones as show in the Scheme 1.12.

Scheme 1.12



Kerr⁴³ used brucine *N*-oxide as a promoter for the formation of the cycloadduct, disappointingly, this gave the cyclo-adduct in low enantiomeric excess. Laschat^{44, 45} in an attempt to study the scope and limitation of PK reaction in the presence of chiral amine *N*-oxide used different chiral *N*-oxides such as (+)-sparteine *N*1-oxide, (-)-sparteine *N*16-oxide, (-)-17-oxosparteine *N*-oxide, (-)-nicotine *N*1-oxide and (-)-nicotine *N*1, *N*1'-bisoxide, but they all gave low enantioselectivities (up to 16% ee) regardless of the alkyne. They were able to increase the enantioselectivity up to 42% ee by using amine *N*-oxides with additional donor functionalities like (-)-quinine *N*-oxide, tetracyclic *N*-oxide and (-)-brucine *N*-oxide (see Fig 1.1 below).

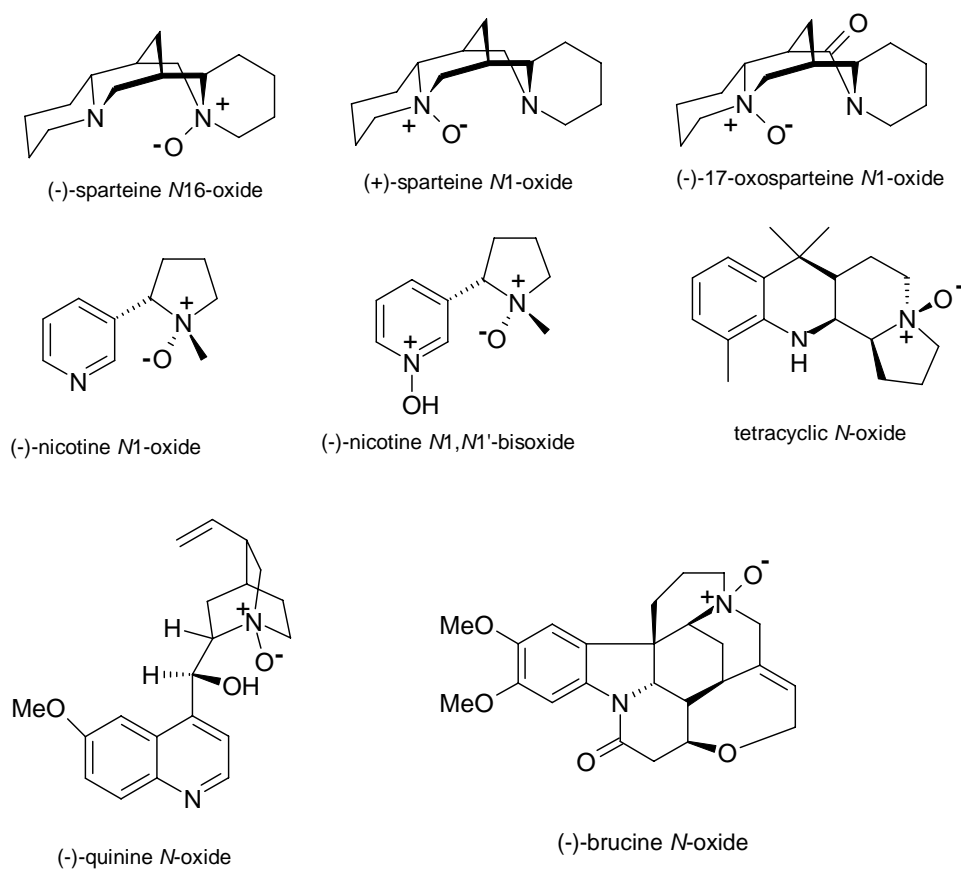
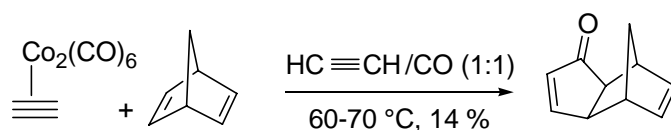


Fig 1.1: Chiral Amine *N*-Oxides

1.7 Catalytic Pauson-Khand Reaction

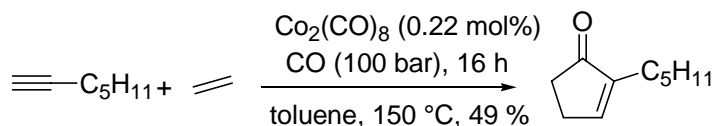
Pauson⁵ was one of the first to develop a catalytic PK reaction. At that time, he used strained reactive alkenes like norbornene and norbornadiene with 10 mol% of (acetylene)-Co₂(CO)₆ in the presence of acetylene and CO at 60-70 °C which gave only 14% of the cyclopentenone (Scheme 1.13).

Scheme 1.13



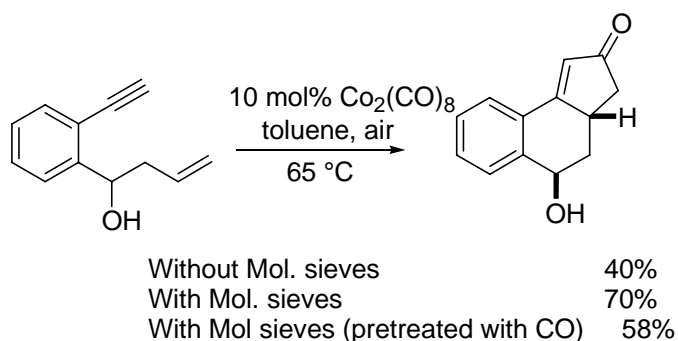
Rautenstrauch^{46, 47} reported (20 years later) the use of much lower quantities of cobalt (0.22 mol%) and non-strained alkenes in the presence CO (100 bar) to afford the PK product in 49% yield (Scheme 1.14). The relatively low yield was attributed to the formation of $\text{Co}_4(\text{CO})_{12}$ cluster which may inhibit the catalytic cycle.

Scheme 1.14



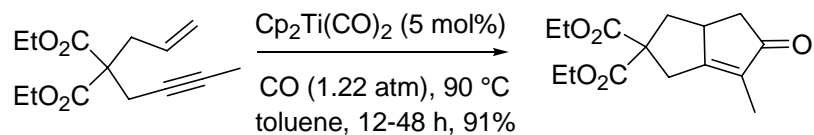
Blanco-Urgoiti et al.⁴⁸ were able to improve the catalytic Pauson-Khand Reaction by using molecular sieves and a catalytic amount of $\text{Co}_2(\text{CO})_8$ at 65 °C. They concluded that this improvement is possible probably due to the ability of molecular sieves to adsorb and keep CO making it possible to effect the reaction even in the absence of CO atmosphere (Scheme 1.15).

Scheme 1.15



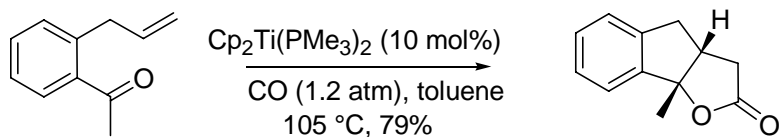
In 1996 Buchwald⁴⁹ reported the use of a titanocene complex to catalyze the intramolecular PK reaction. When titanocene (5 mol%) and CO (1 atm.) was used to effect cyclization, it gave 91% yield of the tricyclic enone (Scheme 1.16).

Scheme 1.16



Buchwald also reported the synthesis of γ -butrolactones via a catalytic hetero-PK cyclization using $\text{Cp}_2\text{Ti}(\text{PMe}_3)_2$ starting from 1,6-enone (Scheme 1.17).⁵⁰

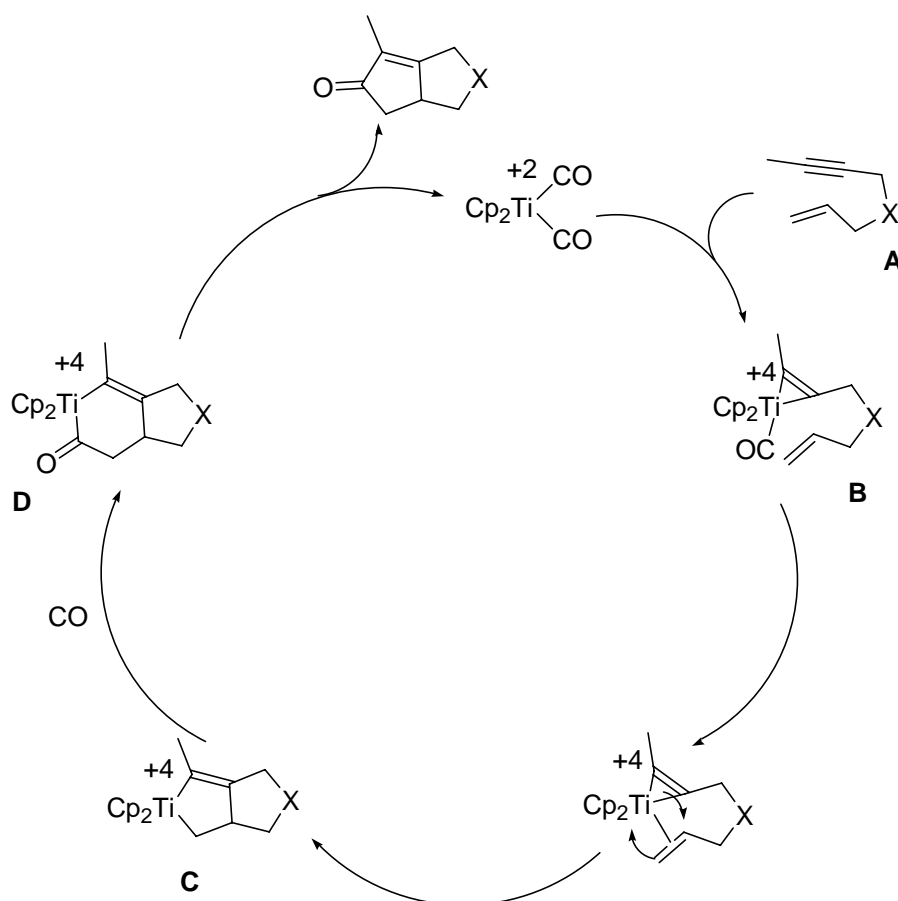
Scheme 1.17



The catalytic cycle (Scheme 1.18) was proposed to proceed via an oxidative addition of the enyne **A** to the titanocene dicarbonyl complex to give the titanacyclopropene

complex **B**. This then undergoes decarbonylation followed by insertion of the alkene to give the titanocyclopentene complex **C**. The titanocyclopentene complex **C** then undergoes CO insertion to give the metallocycle **D**. This then undergoes reductive elimination to give the final PK product.

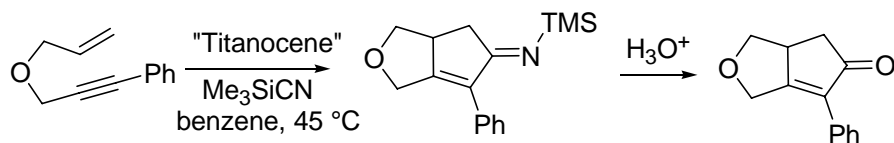
Scheme 1.18



Buchwald^{51, 52} also reacted 10 mol% of the titanocene [Cp₂Ti(PMe₃)₂] with a slight excess of (trialkylsilyl)cyanide to give the intramolecular cycloaddition product in 42-

80% yield after hydrolysis of the resultant imine. The use of nickel(0) to catalyze the isocyanide cycloaddition reaction was also investigated (Scheme 1.19).⁵³

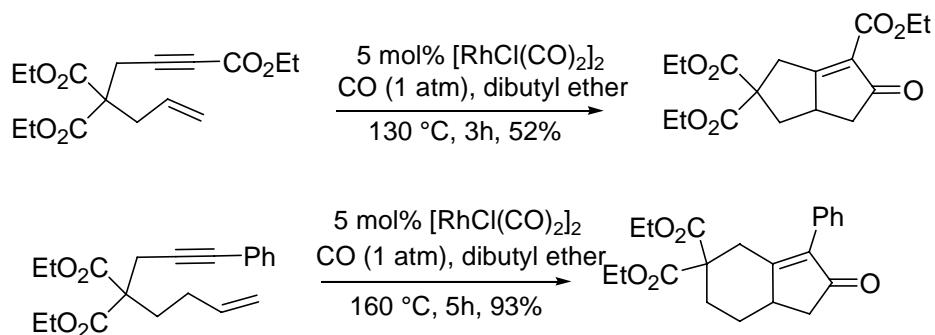
Scheme 1.19



catalyst	mol%	yeild
$\text{Cp}_2\text{Ti}(\text{PMe}_3)_2$	10	80%
$\text{Cp}_2\text{TiCl}_2/n\text{-BuLi}$	10	82%
$\text{Ni}(\text{COD})_2/\text{Ligand}$	5	60%

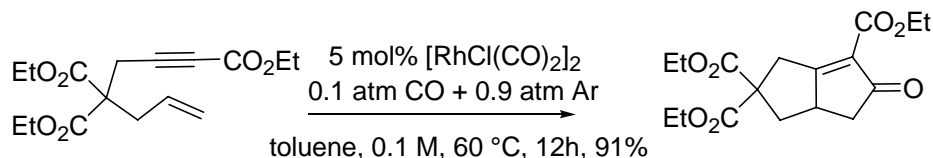
Kobayashi et al.²⁹ also reported converting 1,6- and 1,7-enynes having various substituents at the alkenyl or alkynyl moiety to the cyclopentenone products in high yield. Catalytic amounts of $[\text{RhCl}(\text{CO})_2]_2$ under 1 atmosphere of CO and at $130\text{-}160^\circ\text{C}$ (Scheme 1.20).

Scheme 1.20



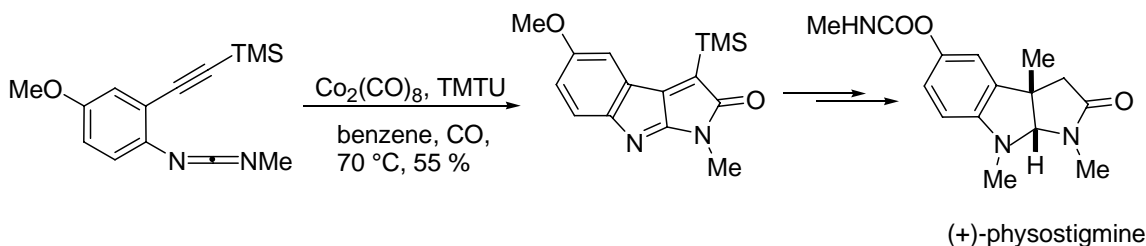
They also noticed that by reducing the partial pressure of CO to 0.1 atmosphere and using 0.9 atmosphere of argon, the reaction was accelerated and proceeded at a lower temperature (Scheme 1.21).

Scheme 1.21



Mukai and co-workers recently reported the use of a catalytic amount of $\text{Co}_2(\text{CO})_8$ to effect the hetero-PK reaction of alkynecarbodiimide. They ultimately used this methodology for the synthesis of (+)-physostigmine.⁵⁴ They employed 20 mol% of $\text{Co}_2(\text{CO})_8$ and tetramethylthiourea (TMTU) in benzene at 70 °C under an atmosphere of CO to effect cyclization in 55% yield (Scheme 1.22).

Scheme 1.22

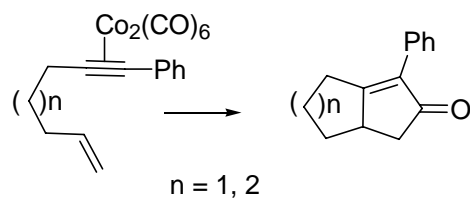


1.8 PK Reaction in Medium Sized Ring Synthesis

The application of the intramolecular Pauson-Khand (IMPK) reaction is an attractive approach to the synthesis of medium sized rings. The IMPK reaction permits a rapid increase in molecular complexity in one step and also affords the construction of

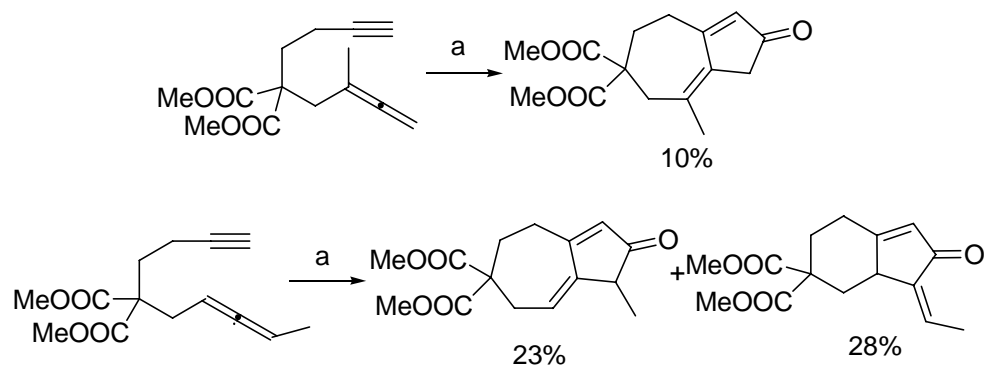
the carbon skeleton resembling a variety of known polycyclic natural products. The IMPK reaction has proved to be an efficient tool in the synthesis of bicyclo[3.3.0]octenones and bicyclo[4.3.0]nonenones via the corresponding 1,6- and 1,7-enynes as shown in Scheme 1.23

Scheme 1.23



Cazes and coworkers were able to construct medium rings via allenic PK reaction. They used 3,3-disubstituted and 1,3-disubstituted allenynes in NMO promoted PK reaction to furnish the bicyclo[5.3.0]octane system, albeit in very low yields (10-23%) (Scheme 1.24).⁵⁵

Scheme 1.24

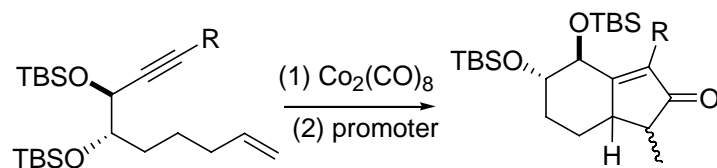


Reagents and conditions: (a) $\text{Co}_2(\text{CO})_8$, NMO, DCM, 3 h, rt.

Later, Brummond greatly improved on the yield of this reaction to approximately 77% by using a catalytic amount of $[\text{Rh}(\text{CO})_2\text{Cl}]_2$ ⁵⁶ in place of the $\text{Co}_2(\text{CO})_8$.

Yet, the construction of bicyclo[5.3.0] decenones and bicyclo[6.3.0] undecenones have proved more difficult via IMPK cyclization of 1,8- and 1,9-enynes, respectively.⁵⁷ Mukai and coworkers attempted to cyclize 1,8-enyne but discovered that instead of leading to the medium ring system, bicyclo[5.3.0]nonenone, it gave bicyclo[4.3.0]nonenone system as a mixture of diastereomers (Scheme 1.25) due to migration of the terminal double bond.⁵⁸

Scheme 1.25



The failure of 1,8- and 1,9-enyne to cyclize to give the corresponding 7- and 8-membered rings may be attributed to the fact that the alkyne and alkene termini need to be close in space as in **A** before cyclization can take place and this is not entropically favorable. Hence structure **B** is the preferred conformation, but this conformation cannot lead to cyclization (Figure 1.2).

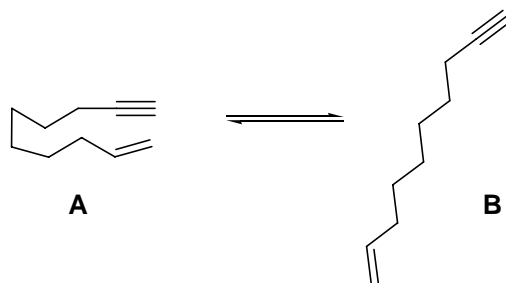
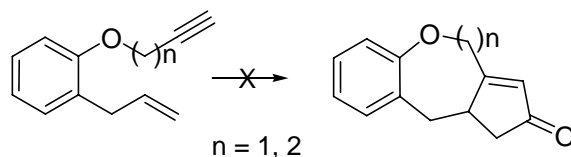


Figure 1.2 Preferred conformation of 1,9-enynes.

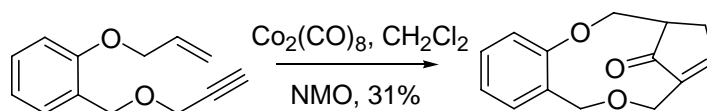
In an effort to circumvent this problem Krafft and co-workers⁵⁹ reported the use of an aromatic template so as to help in pre-organizing the alkene and alkyne arms of the substrate. As a result, the conformational degrees of freedom which the alkene and alkyne termini can adopt are reduced. The use of an aromatic template enhanced the formation of five or six membered rings annulated to cyclopentenone rings. However, the formation of the medium sized rings still proved difficult or at best gave a very low yield.^{59, 60}

Scheme 1.26



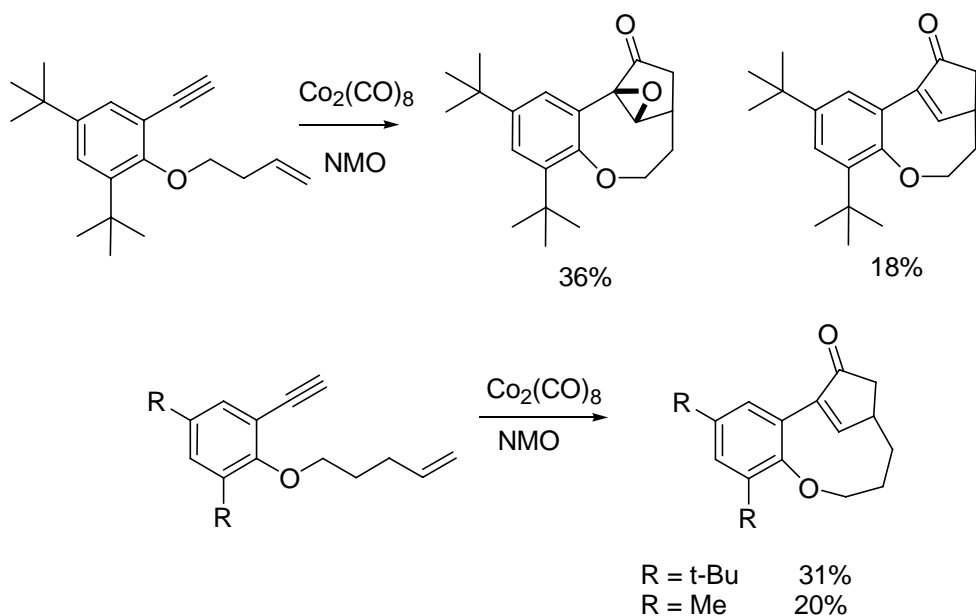
Interestingly, Krafft et al.⁵⁹ reported unusual regioselectivity in the cyclization reaction of 1, 10-enyne to give a 10-membered ring as shown in Scheme 1.27.

Scheme 1.27



All attempts made to improve the yield of this reaction proved futile and in some case lead to decomplexation of the starting material. Lovely and coworkers⁶¹ using enynes constructed around an aromatic template and by making use of buttressing group effects, reported the unusual cyclization mode of PK reaction leading to medium ring systems (Scheme 1.28).

Scheme 1.28



This unusual cyclization mode was attributed to be caused by both steric and electronic factors. The steric interaction between the internal methylene carbon and the cobalt complex is thought to force the alkene to rotate and orient itself toward the cobalt alkyne complex in order to avoid an unfavorable steric interaction (Fig 1.3).

Moreover, electron rich substituents tend to orient α -position to the carbonyl function.⁶⁶ Hence the alkene is forced to rotate so as to place the electron rich aromatic ring next to the carbonyl group in the cyclopentenone.

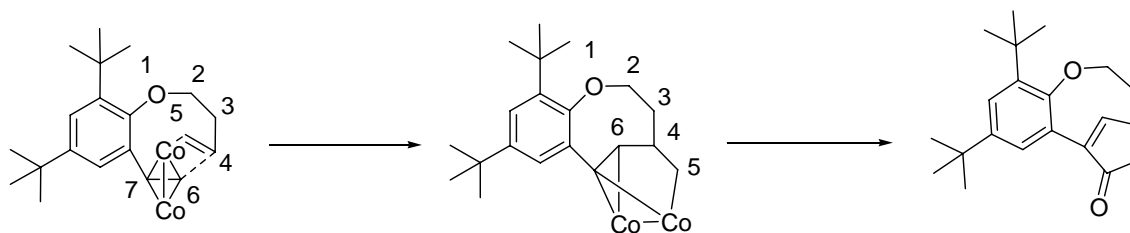
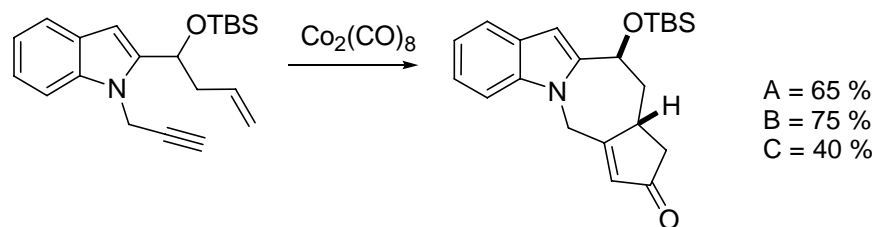


Fig. 1.3. Proposed cyclization mode

Subsequently, Perez-Castells and coworkers⁶² described the formation of seven membered rings via intramolecular Pauson-Khand reaction in good yield. They made use of the planarity of the indole nucleus and also the effect of heteroatom coupled with the buttressing effect of OTBS group to effect cyclization of the enyne (Scheme 1.29).

Scheme 1.29



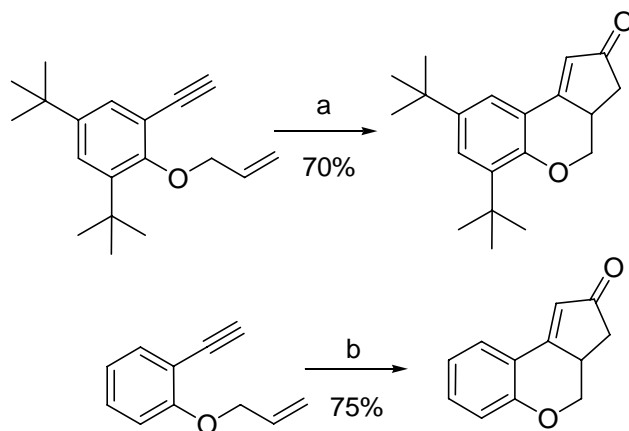
Reagents and conditions: (A) TMANO -molecular sieves, rt.
 (B) molecular sieves, toluene, reflux
 (C) refluxing toluene

1.9 Project Strategy

Based on the limitations of existing studies, it is the intent of this project to discover possible experimental solutions to this problem of medium sized ring construction via IMPK reaction. Rigid templates, such as aromatic systems, will be used to pre-organize the alkene and alkyne side chains thus forcing them to be close enough for cyclization to take place.

Also in this study we intend to introduce a buttressing group on the aromatic ring which will further help to reduce the conformational degrees of freedom of the alkene and alkyne termini. This has been previously demonstrated in our research group⁶⁰ to reduce the cyclization time and also improve the yield of the reaction (Scheme 1.30).

Scheme 1.30



Reagents and conditions: $\text{Co}_2(\text{CO})_8$, NMO, CH_2Cl_2 , (a) 30 min.; (b) 8 h.

This design paradigm has several advantages. The cyclization precursor is simply and easily assembled. It also includes a heteroatom, which can provide an additional site for the transition metal to coordinate. Kafft and coworkers. showed that the presences of heteroatoms like sulfur and oxygen enhance the rate of the intramolecular cyclization.⁶³

In this study, we are focusing on two types of 1,8-enynes as shown in Figure 1.4 below. For the purposes of this dissertation, the 1,8-enynes will be classified as Type 1 and Type 2.

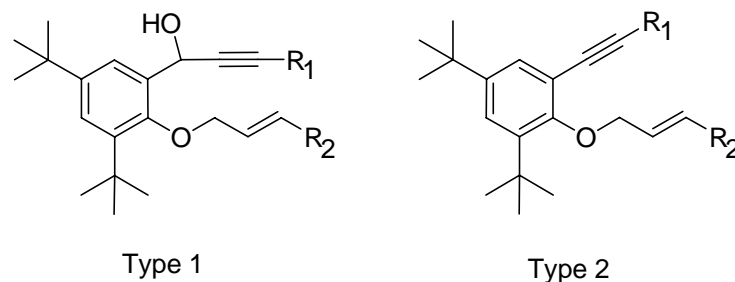


Fig. 1.4: Type 1 and Type 2 substrates

This dissertation will present the results of both the oxidative and thermal cyclization mode of Type 1 substrates and the result of the thermal cyclizations of type 2 substrates. The oxidative cyclization of several Type 2 substrates has previously been studied and the results of this investigation have been report by Dr. Seshadri in our research group.⁶⁰

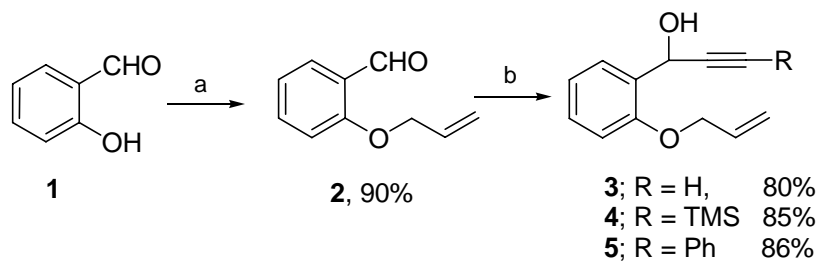
CHAPTER 2

RESULTS AND DISCUSSION

2.1 Preliminary Results

To substantiate our hypothesis that an aromatic template is not sufficient to effect a good cyclization yield, substrates which contained only an aromatic template were used to initiate this investigation. These substrates lacked the buttressing group effect afforded by the presence of an *ortho* substituent. Preparation of these substrates involved a straightforward process. *O*-alkylation of the commercially available 2-hydroxybenzaldehyde **1** with allyl bromide was achieved in the presence of K_2CO_3 to furnish **2** in 90% yield. The *O*-alkylated benzaldehyde **2** was then alkynylated using the alkynyl Grignard reagent to afford the enynes **3**, **4** and **5** in 80, 85 and 86% yield respectively (Scheme 2.1).

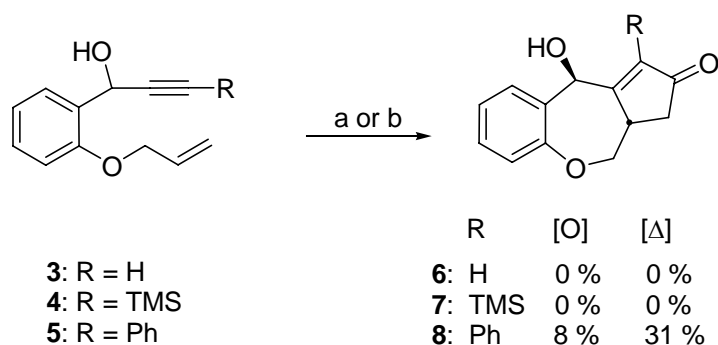
Scheme 2.1



Reagents and conditions: (a) allyl bromide, DMF, K_2CO_3 ;
(b) THF, 0 °C, $BrMgC\equiv CR$

With these enynes in hand, the PK cyclizations were investigated under standard oxidative conditions in dichloromethane using with *N*-methylmorpholine (NMO) as the promoter. Disappointingly but not surprisingly, substrates **3** and **4** failed to give the cyclic products **6** and **7**. Moreover, substrate **5** gave only 8% of the cyclic product **8**. Similar results were obtained under the thermal conditions. Substrates **3** and **4** did not undergo a cyclization reaction, while **5** gave 31% of the cyclized product **8**. This result shows that substrate **5** seems to be better PK substrates. A higher yield of the cyclized product **8** was obtained under the thermal activation compared to the oxidative mode. In contrast, both the oxidative and the thermal mode failed to give the cyclized products **6** and **7** (Scheme 2.2).

Scheme 2.2



Reagents and conditions: a; $\text{Co}_2(\text{CO})_8$ (1.1 eq.), CH_2Cl_2 , NMO;

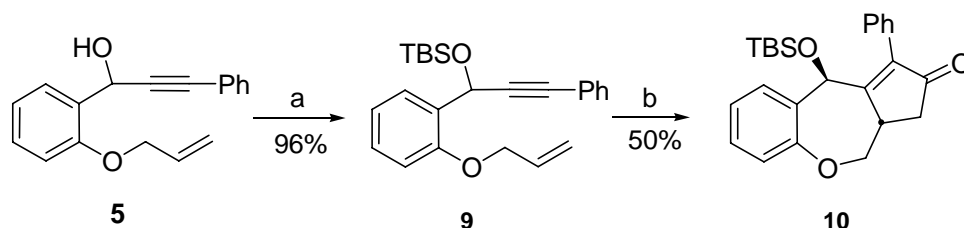
b; $\text{Co}_2(\text{CO})_8$ (1.1 eq.), toluene, 70 °C.

Although the aromatic backbone of the enyne provides some reduction in the conformational degrees of freedom of the side chains, preorganization of the alkyne and

alkene is not sufficiently complete for effective cyclization to occur. Hence to further reduce the conformational degrees of freedom of the side chain, it was decided to investigate the introduction of a buttressing group at the propargylic hydroxyl group to see whether this will enhance the cyclization efficiency of the substrate.

Elaboration of the phenyl protected alkyne **5** was further explored based on the results mentioned above which showed higher yields for this substrate under the thermal conditions. The alkyne **5** was treated with *tert*-butyl-dimethylsilylchloride (TBSCl) to afford the enyne **9** in 98% yield and then **9** was subsequently subjected to the thermal conditions to give the cyclic product **10** in 50% yield as shown in Scheme 2.3.

Scheme 2.3



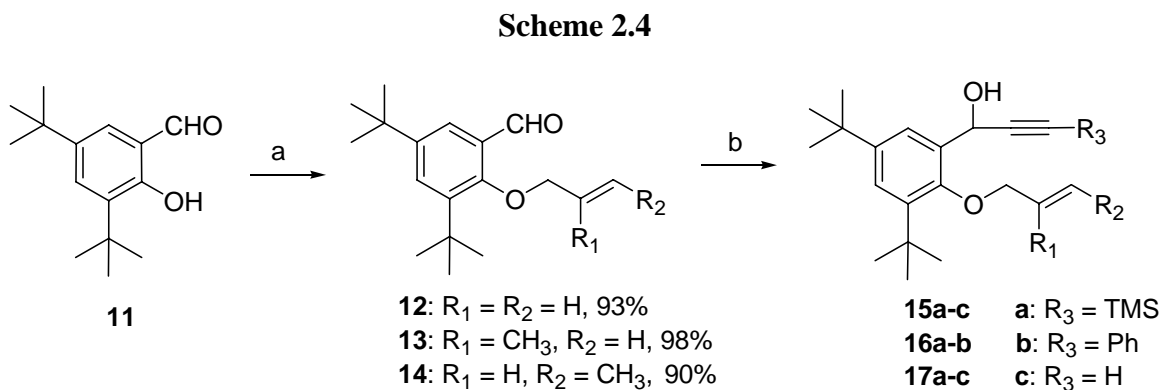
Reagent and conditions: (a). TBSCl, imidazole, DMF, 50 °C, 4.5 h.

(b). $\text{Co}_2(\text{CO})_8$ (1.1 eq.), toluene, 70 °C.

The result above indicates that the steric bulk of the OTBS group helped in increasing the reactive rotamer population of the enyne. Hence, it may be concluded that incorporating a bulky group to the aromatic ring will enhance the cyclization yield of the 1,8-enyne leading to construction of medium size rings.

2.2 Type I Substrates

Type I substrates were prepared via the two step process discussed above, beginning with *o*-alkylation and followed by Grignard reaction. Commercially available 3, 5-di-*tert*-butyl-2-hydroxybenzaldehyde (**11**) was *O*-alkylated using allyl bromide, 3-chloro-2-methylpropene, or 4-chloro-2-butene in the presence of K_2CO_3 with DMF as solvent to give the substituted aldehydes **12-14**. The yields of these aldehydes range from 93-96% as shown in the Scheme 2.4 below. The aldehydes **12**, **13** and **14** were then subjected to a Grignard reaction using ethynylmagnesium bromide, phenylethynylmagnesium bromide and trimethylsilylethynylmagnesium bromide at 0 °C under a nitrogen atmosphere to afford the enynes **15a-c**, **16a-b** and **17a-c** (Scheme 2.4).



Reagents and conditions: (a) alkenyl halides, DMF, rt;

(b) $BrMg-C\equiv C-R_3$, THF, 0 °C

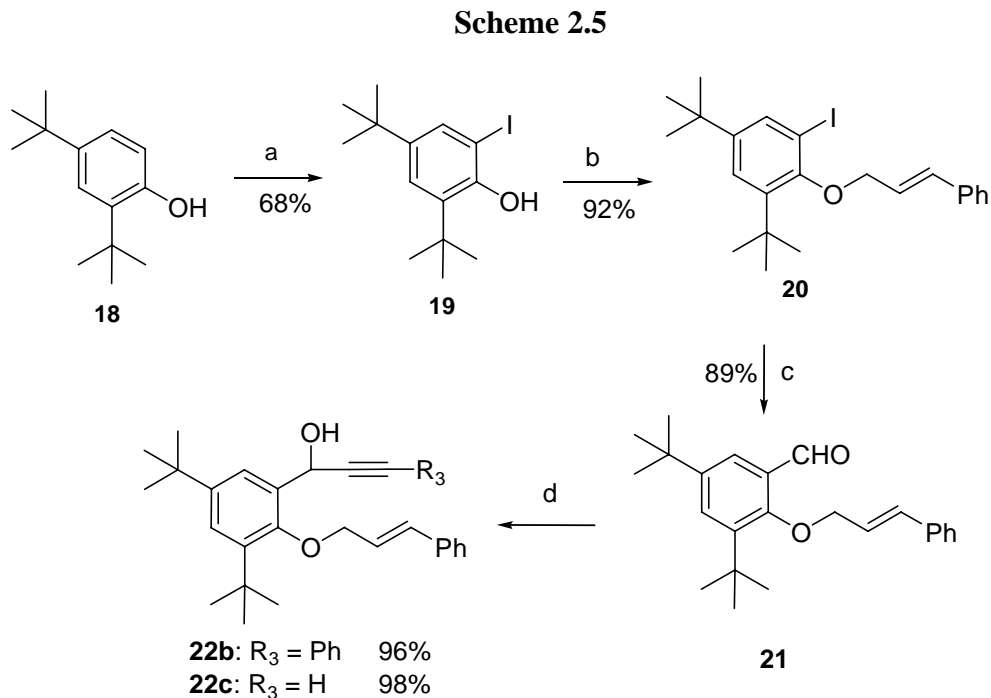
The results of the Grignard reaction for the different substrates are summarized in Table 2.1.

Table 2.1: Result of the enyne construction

Enynes	% Yield	Mp. (°C)
15a	74	95- 96
15b	75	92- 93
15c	75	94- 95
16a	75	oil
16b	74	oil
16a	92	49- 51
17b	97	oil
17c	98	oil

Attempts to prepare the enynes **22a**, **22b** and **22c** containing the *o*-cinnamyl moiety via this procedure described above gave only a black colored reaction mixture which could not be purified or characterized. Hence, an alternative approach using a Mitsunobu reaction was used to access these enynes. The substituted phenol **19** was prepared in 68% yield by reacting **18** with *N*-iodosuccinamide. This iodophenol **19** was then subjected to the Mitsunobu protocol utilizing cinnamyl alcohol to afford **20**. The *O*-cinnamyl phenol **20** was then treated with *i*-PrMgBr at -30 °C and then quenched with 1.0 eq. of DMF to give **21** in 89% yield. Substrate **21** was subsequently treated

with alkynyl Grignard reagents to give **22a-c** in 92, 96 and 98% yields respectively (Scheme 2.5).



Reagents and conditions: (a) NIS, THF, 0 °C; (b) Cinnamyl alcohol, DEAD, PPh₃, THF

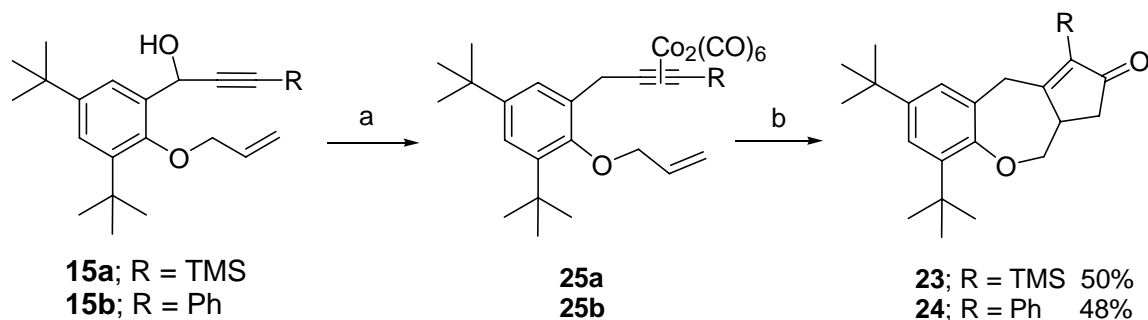
(c). *i*-PrMgBr, THF, -30 °C, DMF; (d) BrMg—C≡C—R₃, THF, 0 °C

With the enynes **15a-c**, **16a-b**, **17a-c** and **22a-c** in hand, the Pauson-Khand reactions were investigated.

The enynes **15a-c** were subjected to the Pauson-Khand protocol first. These enynes appeared to undergo reaction to give cyclization products which were anticipated to be PK products, but proved to be difficult to purify due to the formation of multiple products (see below). The multiple products formed were due to the presence of the α -hydroxyl group of the enyne. Consequently, the α -hydroxyl group of

the enynes **15a-c** was removed, thereby simplifying the possible products by removing the stereochemical element on the propynyl arm. These reduced materials were obtained from the $\text{Co}_2(\text{CO})_6$ -alkyne complex by treatment with trifluoroacetic acid (TFA) and NaBH_4 ^{64, 65} and then treating this material with a promoter, NMO, to give the expected PKR product **23** and **24** from **15a** and **15b** respectively. The combined yield for the two steps, reduction and cyclization, from enynes **15a** and **15b** is approximately 50% (Scheme 2.6).

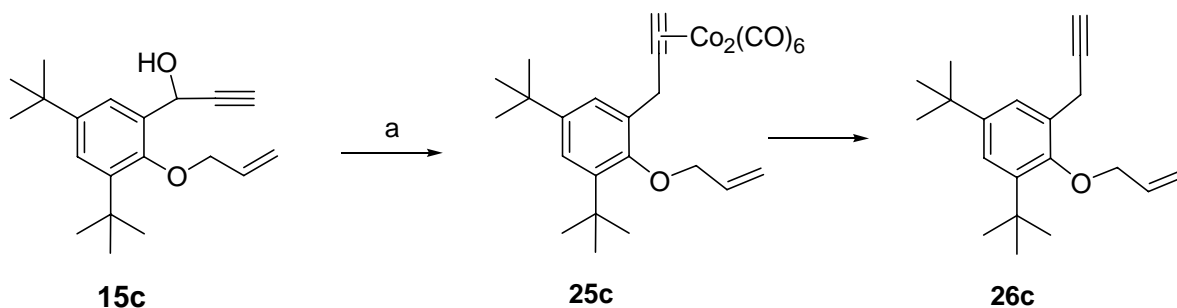
Scheme 2.6



Reagents and conditions: a. (i) $\text{Co}_2(\text{CO})_8$, DCM; (ii). TFA, NaBH_4 ; (b). NMO

In the case of the enyne **15c**, no cyclized product was obtained. Instead, the reduced enyne **26c** was isolated as the only product (Scheme 2.7).

Scheme 2.7



Reagents and conditions: a. (i) $\text{Co}_2(\text{CO})_8$, CH_2Cl_2 ; (ii) TFA, NaBH_4 ; (iii). NMO

The inhibition of this cyclization of this substrate can be rationalized by taking alkyne polarization effects into consideration.⁶⁶ Generally, in the reaction of unsymmetrical alkynes, the large and electron rich group is placed α to the carbonyl in the product cyclopentenone. Carbon-carbon bond formation of the alkene occurs with alkyne carbon having a higher electropositive character leading to the metallocycle. With substrate **15c**, the C1 carbon has a higher electropositive character than the C2 carbon. Hence for the alkene to insert to form the C-C bond there will be a strain in the intermediate step which will inhibit formation of the metallocycle (Figure 2.1).

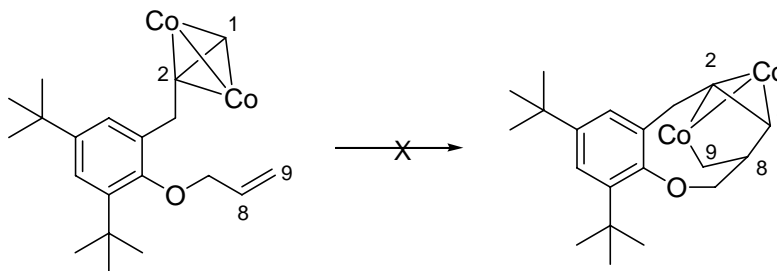
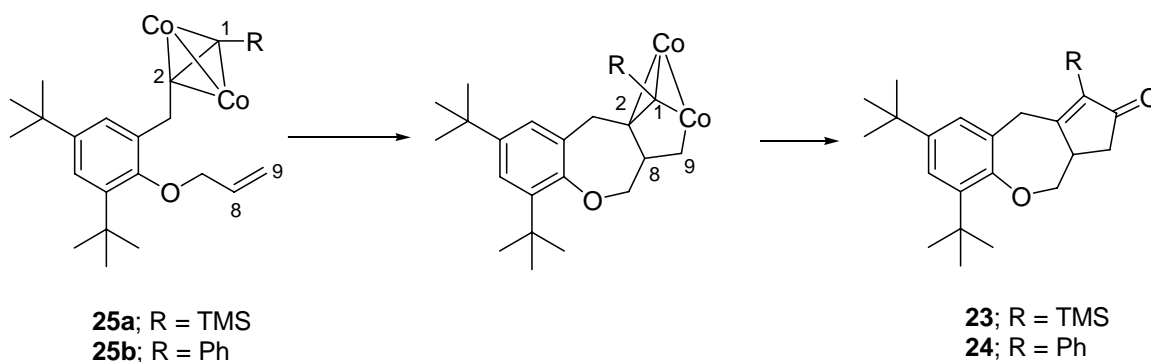


Figure 2.1. Alkyne polarization of substrate **25c**

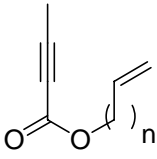
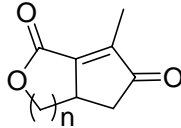
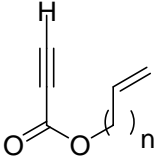
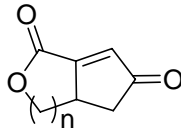
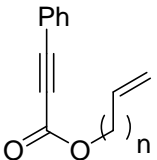
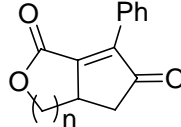
Substrates **15a** and **15b** undergo cyclization reaction due to the presence of the TMS and phenyl groups in the intermediates **25a** and **25b** which increases the electron density at the C₁ position. With the alkyne C₂ carbon more electropositive than C₁, the carbon-carbon bond formation with the alkene favors the formation of the “normal” metallocycle intermediate, leading to the cyclized products **23** and **24** as shown in Scheme 2.8.

Scheme 2.8



The above result is similar to those reported by Krafft⁶⁷ where electron deficient alkynes were used for the Pauson-Khand reaction. She reported that the terminal alkyne did not give any cyclized product whereas substituted alkyne gave the cyclized product under the oxidative conditions (Table 2.2). She also invoked an alkyne polarization model to explain these results.

Table 2.2. Oxidative cyclization result of electron deficient alkynes

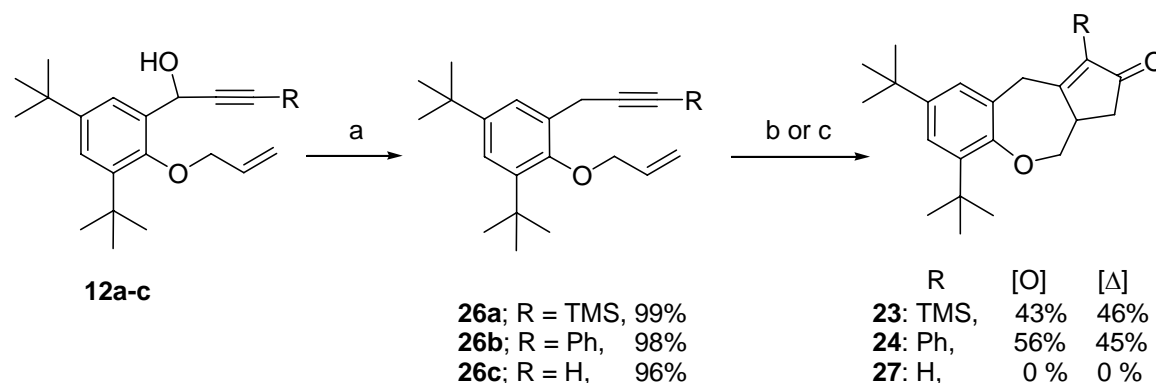
<u>enyne</u>	<u>condns</u>	<u>product</u>	<u>yield (%)</u>
 $n = 1$	A	 $n = 1$	72
 $n = 1$	A	 $n = 1$	0
 $n = 1$	A	 $n = 1$	41

A : $\text{Co}_2(\text{CO})_8$, NMO, rt, CH_2Cl_2 , 4-5 h

Further investigation of the PK reaction of **15a-c** in scheme 2.6 was carried out in order to find the step that was responsible for the low yield observed. It is conceivable that the reduction step was particularly inefficient for the parent substrate. Hence the isolation of the reduced enynes **26a-c** became necessary before subjecting them to the PK conditions to see if the results were consistent with those obtained in Scheme 2.6 and Scheme 2.7 above.

The reduction of the α -hydroxyl group of **15a-c** using TFA and triethylsilane (Et_3SiH) gave 96-99% of the reduced enynes, **26a-c**. The reduced enyne, after formation of the cobalt complex was then subjected to oxidative PK conditions to afford the cyclized products. The results obtained were similar to those reported in Scheme 2.6 and Scheme 2.7 above. From these observations, it may be concluded that the cyclization step was responsible for the low yield. These results are summarized in Scheme 2.9 below. The reduction of the α -hydroxyl group increases the conformational degrees of freedom of the alkyne termini. As a result, the population of the reactive rotamer was decreased.

Scheme 2.9



Reagents and condition: (a) Et_3SiH , TFA, CH_2Cl_2 ;
 (b) $\text{Co}_2(\text{CO})_8$, NMO, CH_2Cl_2 ; (c) $\text{Co}_2(\text{CO})_8$, toluene, 70 °C

The PK reaction of these substrates was also investigated under the thermal conditions. The yield for the thermal condition reactions were found to be comparable to those obtained under the oxidative conditions including the failure of the parent system to cyclize. These results show that the cyclization of the 1,8-enynes are possible under

both oxidative and thermal conditions (Scheme 2.9). Although the NMR data for these compounds was completely consistent the expected structures, this was confirmed independently through X-ray crystallography of compound **24** (Figure 2.2).

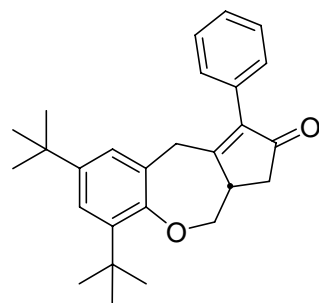
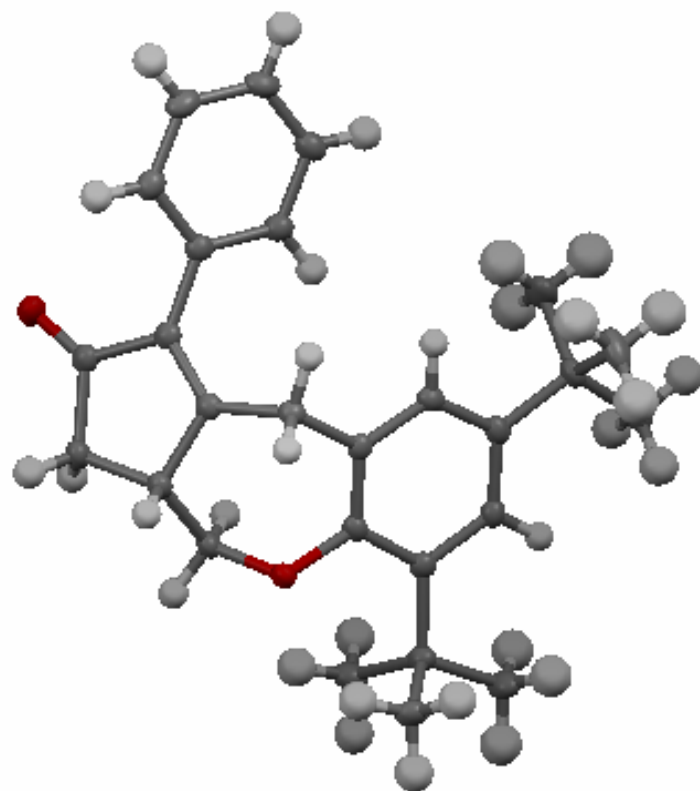
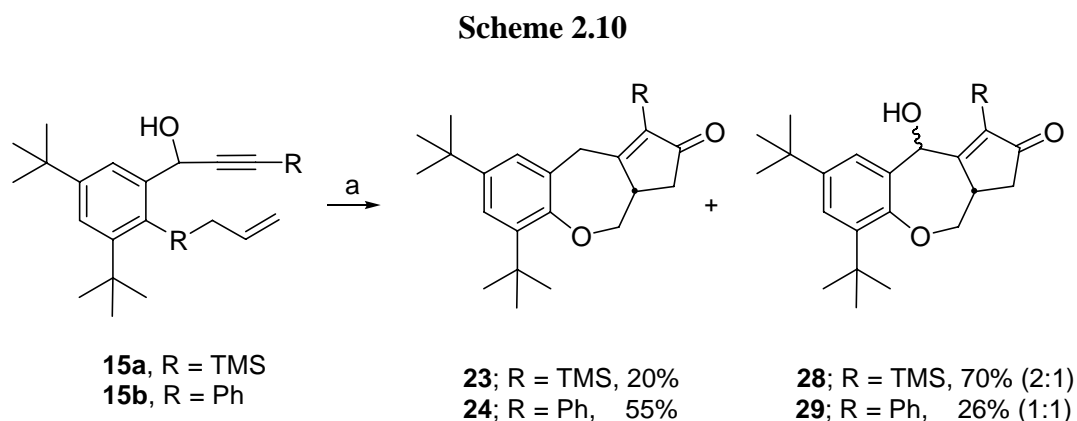


Fig 2.2. X-ray crystal structure of **24**.

Once it was demonstrated that the 1,8-enynes can lead to a cyclized product, the $\text{Co}_2(\text{CO})_6$ complexes of enynes **15a** and **15b** were again subjected directly to the oxidative PK condition, without the reduction of the α -hydroxyl group. The PK reaction proceeded to give a reasonably complexed mixture of products as shown in Scheme 2.10.

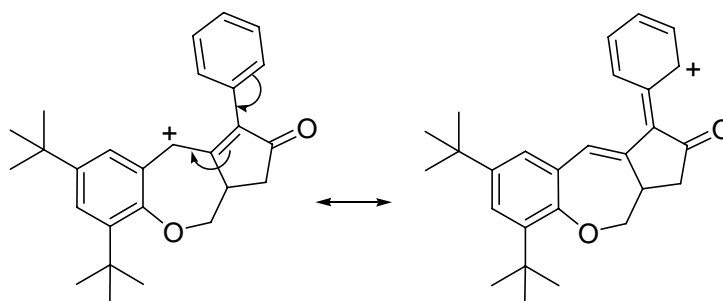


Reagents and conditions: (a) $\text{Co}_2(\text{CO})_8$, CH_2Cl_2 , NMO

The cyclization of the substrates **15a** and **15b** gave the reduced PK products **23** and **24**, as well as the expected PK products **28** and **29** as a mixture of diastereomers. With enyne **15b** (R = Ph) the reduced product **24**, was isolated as the major product in 55% yield along with the expected PK product **29**, as the minor product in 26% yield as a 1:1 mixture of diastereomers. On the other hand, enyne **15a** (R = TMS) gave the expected PK products, **28** (2:1 ratio of diastereomers) as the major product in 70% yield of the epimeric mixture along with the reduced PK product **23** as a minor product in 20% yield. We attribute the variation of product constitution is due to the fact that the phenyl

group in **15b** stabilizes the carbocation intermediate, through resonance leading to the formation of the reduced product as the major product (Scheme 2.11). This resonance stabilization is not possible with the TMS substrate **15a**.

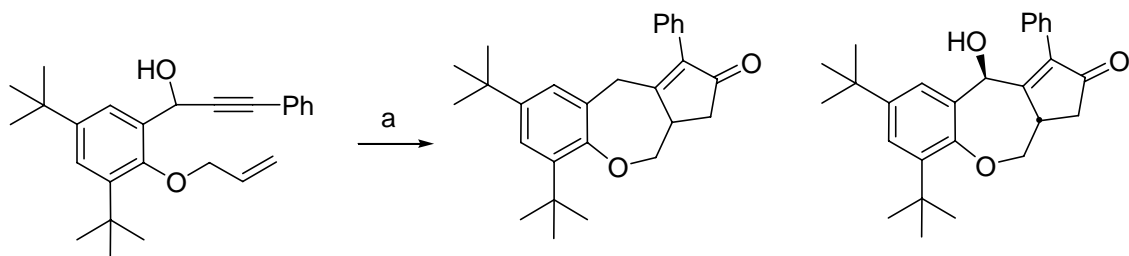
Scheme 2.11



Attempts were made to establish the appropriate reaction conditions for the thermal PK reaction. Substrates **15a** and **15b** were used to investigate the optimal thermal condition.

Substrate **15b** was stirred and heated to reflux in CH_2Cl_2 for 4 hours and only the *exo* epimer of **29** was isolated in 63% yield. Extending the reaction time to 72 hours led to a slight increase in yield of *exo* isomer of **29** (75%) but also to the appearance of a the reduction product **24** (8%). With the solvent changed to toluene and the reaction mixture heated at 70 °C,⁶⁸ the *exo*-epimer of **29** was isolated exclusively in 99% yield (Scheme 2.12).

Scheme 2.12



15b	<u>Solvent</u>	<u>Time</u>	<u>24</u>	<u>29</u>
	Dichloromethane	4 h	0%	63%
		72 h	8%	75%
	Toluene (70 °C)	18 h	0%	99% (X-ray)

Reagents and condition: (a). $\text{Co}_2(\text{CO})_8$, solvent, reflux

Also the spectroscopic data for *exo* compound **29** was completely consistent with expected structure and this was confirmed independently through X-ray crystallography of compound **29** (Figure 2.3).

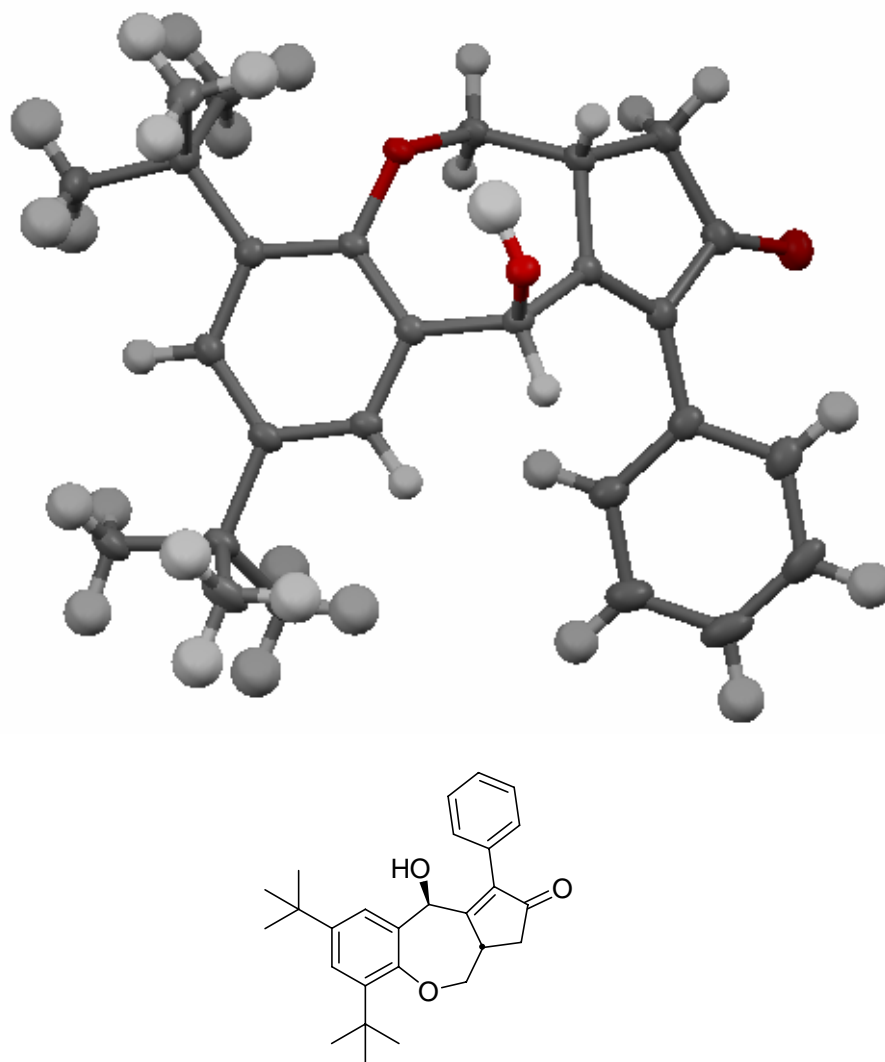
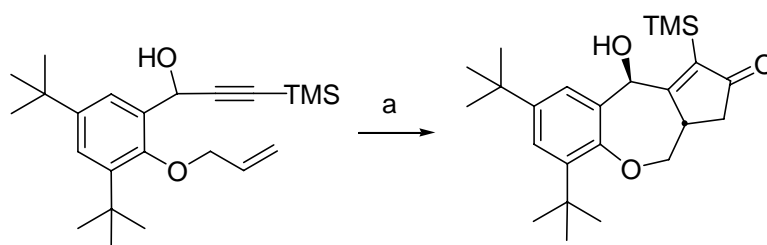


Figure 2.3. X-ray crystallography of the *exo* product of compound **29**

Substrate **15a** also showed a similar trend to those of substrate **15b**. Substrate **15a** was stirred at reflux in dichloromethane for 72 hours, but only starting material, enyne **15a** was recovered. When the reaction was carried out in toluene at 70 °C, the *exo* epimer of **28** was isolated in 58% (Scheme 2.13).

Scheme 2.13



15a

Solvent

Time

28

Dichloromethane 72 h 0%

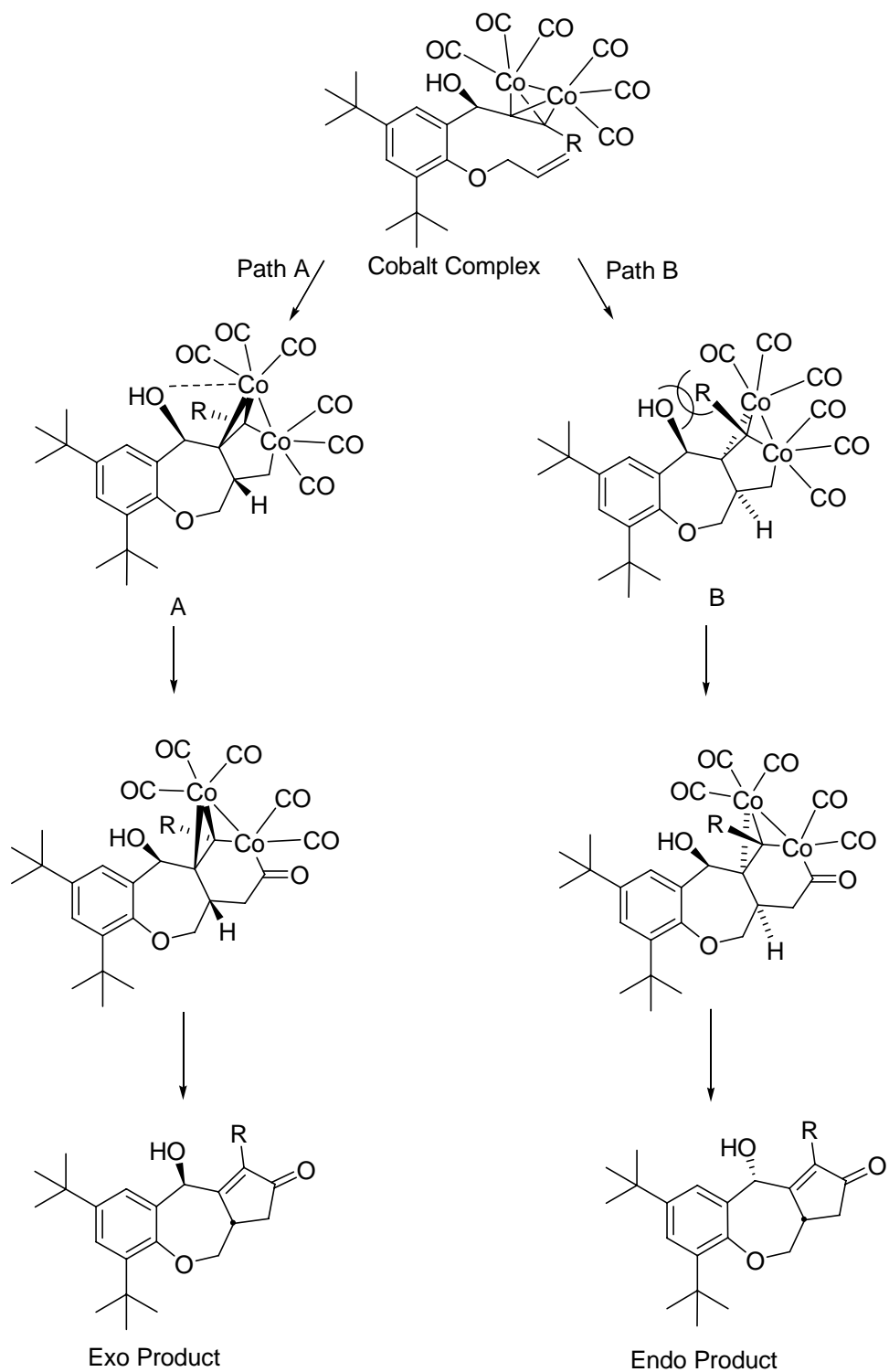
Toluene (70 °C) 24 h 58%

Reagents and conditions: $\text{Co}_2(\text{CO})_8$, solvent, reflux.

A mechanistic rationale depicted in Scheme 2.14 below has been proposed to account for the observed stereochemical outcome of the thermal mode.⁶⁹ Once the alkyne-cobalt complex is formed, it can either undergo cyclization via path **A** or **B** leading to the *exo*- or *endo*-products respectively, since the cobalt complex and the angular H are always *syn* to each other.⁷⁰ The nonbonding (steric) interaction between the OH group and the bulky R-group make pathway **B** very unfavorable whereas pathway **A** has little or no such steric interaction.^{69, 70} Moreover, the rate of intramolecular cycloadditions is greatly increased by the presence of a heteroatom like oxygen or sulfur at the propargylic or homopropargylic position of the 1,6-enyne, by coordinating to the cobalt metal and thereby stabilizing the complex.^{71, 72} Hence, the hydroxyl group at the propargylic position may coordinate to the cobalt metal in the intermediate complex in pathway **A**. The cobalt-metallocycle **A** is stabilized leading to the *exo*-product. Therefore, the first step (formation of intermediates **A** and **B**) would be

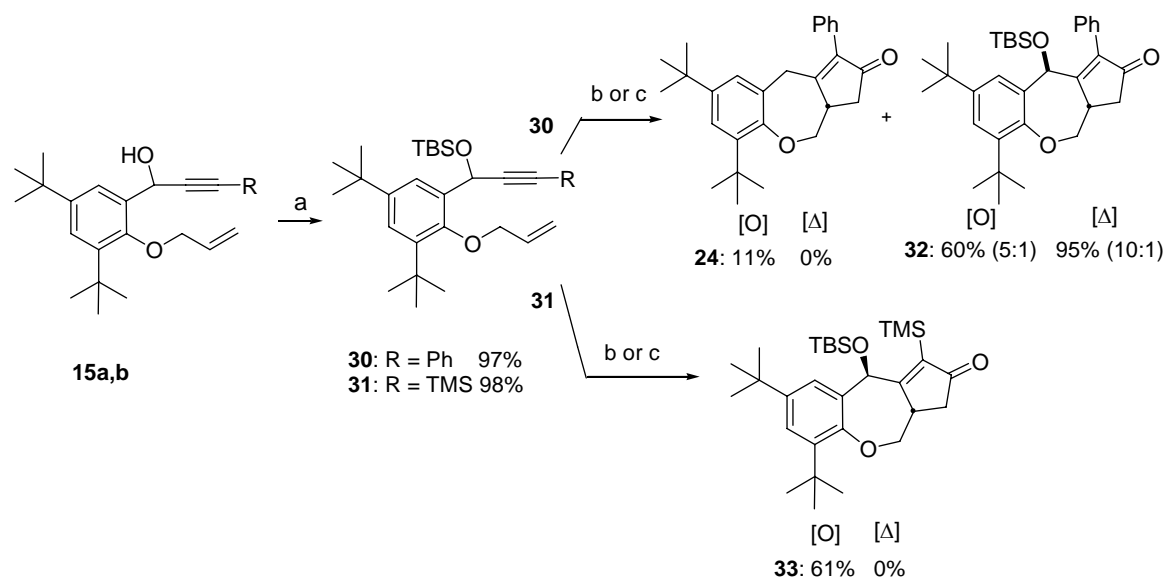
considered to be the process determining the reaction's stereochemical outcome. The scheme also explains why the TMS substrate gives lower yield compared to the phenyl substrate. Since the TMS is a very bulky group, both pathway **A** and **B** experience considerable steric interactions. As a result, lower yields of the *exo*-product, for the TMS substrate, are observed when compared to the phenyl substrate presumably due to competing non-productive pathways⁶⁹ as shown in Scheme 2.14 which is the possible mechanistic pathway for the thermal PK reaction.

Scheme 2.14



The effect of increased steric interaction in these substrates was further investigated. The steric bulk of the α -hydroxyl function was increased by reacting **15a** and **15b** with TBSCl to give the silyl ethers **30** and **31** in 97% and 98% yield respectively (Scheme 2.15). With compound **30**, when subjected to the oxidative conditions, led to a reversal of the product distribution when compared to the result shown in Scheme 2.9. In this case, the expected PK product **32** became the major product in 60% yield with 5:1 ratio of the stereoisomers, while the reduced PK product **24** was isolated as the minor product in 11%. On the other hand, when the silyl ether **30** was subjected to the thermal PK condition, it gave only **32** in 95% yield with higher diastereoselectivity (10:1) when compared to the oxidative condition. No formation of the reduced product was observed under the thermal reaction conditions (Scheme 2.15).

Scheme 2.15



Reagents and conditions: (a) TBSCl, DMF, imidazole, 50 °C; (b) $\text{Co}_2(\text{CO})_8$, CH_2Cl_2 , NMO;

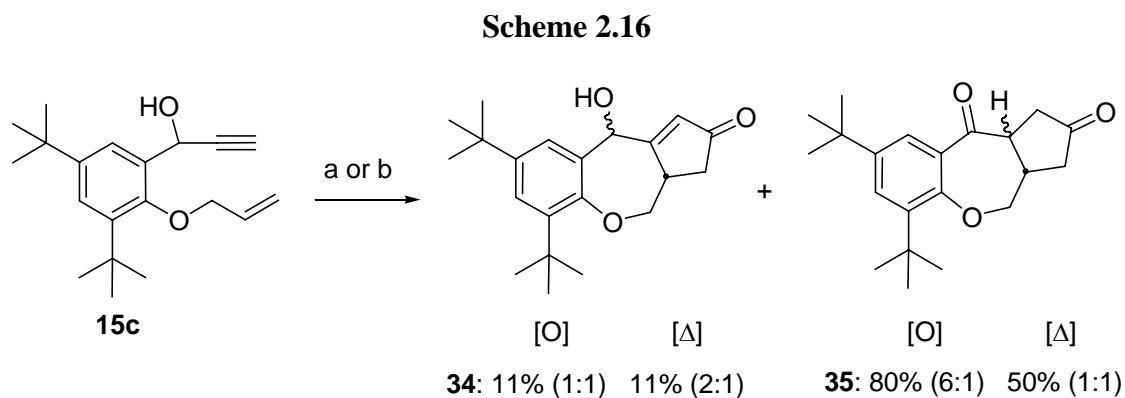
(c) $\text{Co}_2(\text{CO})_8$, toluene, 70 °C

Compound **32** was treated with TBAF in THF to give **29** as the major product identical in all respects to that obtained from **15a**. This confirms the stereochemical outcome of the cyclization of **30** as shown in Scheme 2.15.

The slight reduction of diastereoselectivity in the OTBS protected enyne **30** cyclization for the thermal mode may be explained by the fact that the OTBS protection reduces the stabilization due to the coordination of the free hydroxyl group to the cobalt metal as shown in the mechanistic pathway **A** in Scheme 2.14 above.

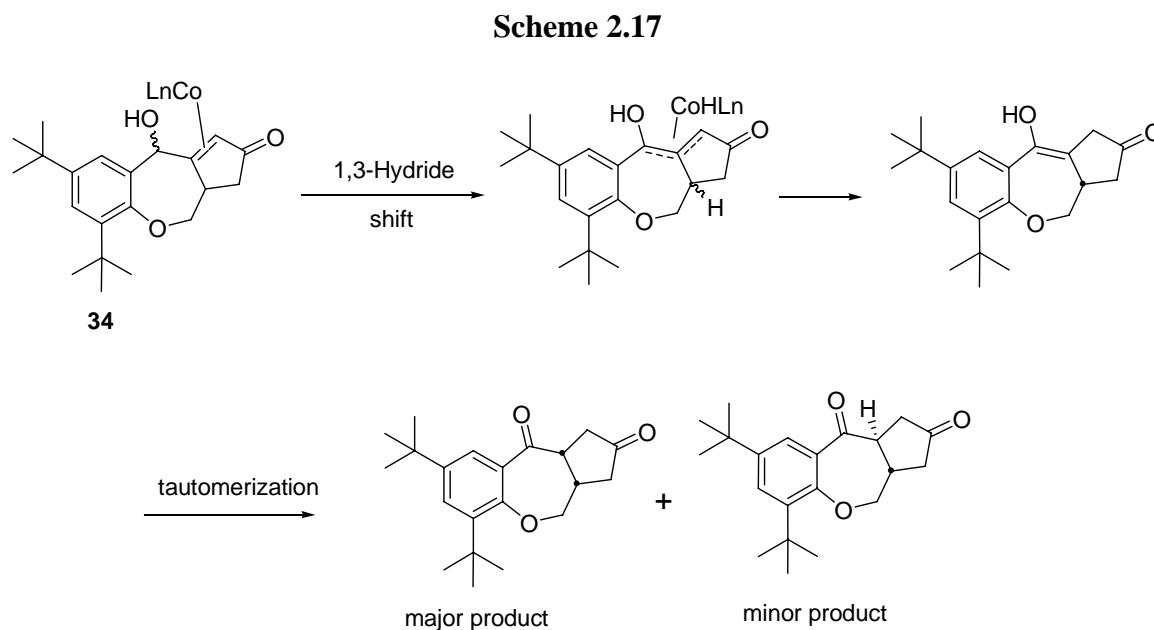
With substrate **31**, the oxidative PK reaction became completely stereoselective with respect to the epimeric products. The *syn*-epimer (*exo*-product) **33** was only cycloadducts, isolated in 61% yield. No cyclized product was formed when **31** was subjected to the thermal PK condition (Scheme 2.15). This may be due to steric hindrance preventing the formation of the intermediate metallocycle and thus decomposition (presumably by decomplexation) becomes the dominant pathway.

With a better idea of some of the products from these reactions, the PK reaction of substrate **15c** was then re-investigated. The cyclization products of substrate **15c** were different from those observed with **15a** and **15b**. With substrate **15c**, no reduced PKR product was observed. Instead the anticipated PK product **34** was isolated in 11% (1:1 ratio of diastereomers), along with the diketone **35** in 80% yield (6:1 ratio of isomers) as shown in Scheme 2.16. Also, the thermal cyclization of **15c** gave 11% (2:1) of **34** and 50% of **35** in 1:1 ratio of the *syn*- and *anti*-isomers. The thermal PK of **15c** did not show any stereoselectivity (Scheme 2.16).



Reagents and conditions: (a) $\text{Co}_2(\text{CO})_8$, CH_2Cl_2 , NMO;
 (b) $\text{Co}_2(\text{CO})_8$, toluene, 70 °C

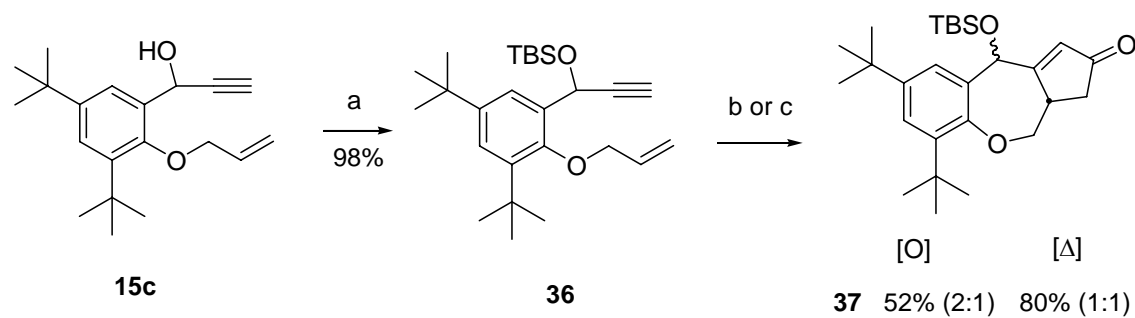
The diketone, **35**, was believed to have been formed from the expected PK product **34** by undergoing transition metal mediated 1,3-hydride shift followed by tautomerization to furnish **35** as shown in Scheme 2.17.⁷³⁻⁷⁵



The TBSCl protection of the α -hydroxyl function of **15c** gave the silyl ether **36** in 98% yield. Substrate **36** was subjected to both oxidative and thermal Pauson–Khand

conditions. The oxidative mode gave 52% of product **37** as a 2:1 mixture of the epimers. The thermal mode gave 80% of the expected PK product **37** as a 1:1 mixture of epimers (Scheme 2.18). The stereochemical outcome of the thermal reaction is consistent with the thermal mechanistic pathway shown in Scheme 2.14 above. The steric interaction experienced in pathway B does not exist with this substrate since the alkynyl group (R = H) is very small. This makes it possible for the reaction to go through both pathway A and B, leading to the observed reduced diastereoselectivity. This reduction in diastereoselectivity is consistent with small alkyne moiety. Moreover, OTBS group does not coordinate with the cobalt metal center. As a result pathway A for this substrate loses the extra stabilization due to such coordination with the metal center, making it less diastereoselective.

Scheme 2.18



Reagents and conditions: (a) TBSCl, DMF, imidazole, 50 °C;
 (b) Co₂(CO)₈, CH₂Cl₂, NMO; (c) Co₂(CO)₈, toluene, 70 °C

Although enynes containing terminally substituents participated in the PK reaction, enynes with the internal methyl substituent **16a** and **16b** did not, only decomplexation of these enynes was observed. This may be attributed to the

unfavorable steric interaction between the internal methyl and the cobalt alkyne complex as shown in Figure 2.3.

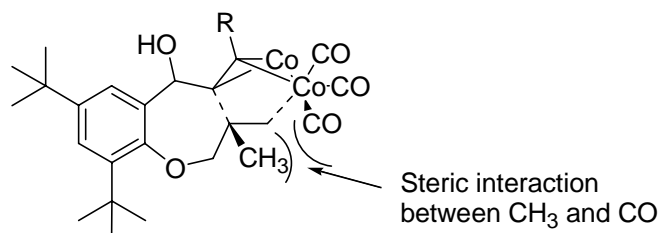
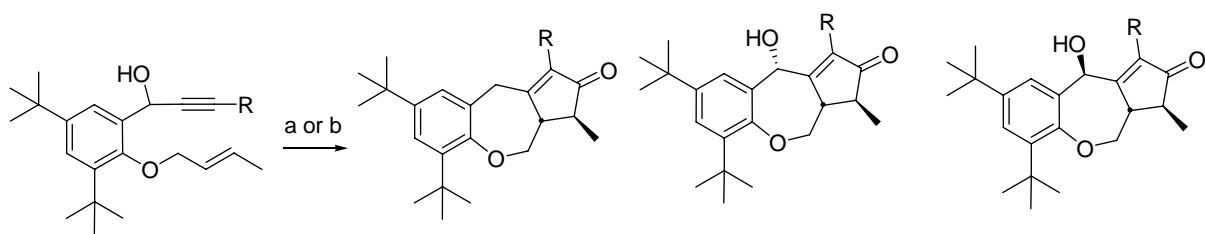


Figure 2.4. Unfavorable steric interaction of enynes with internal Methyl substitution

Interestingly, the terminal alkenyl substituted enynes were found to participate in the PK reaction. Substrates **17a** (R = TMS) and **17b** (R = Ph), containing an internal alkene, were subjected to both the oxidative and thermal conditions. Under oxidative conditions, substrate **17b** gave the reduced PK product **39** as a minor product in 18% yield. It also gave the *endo*-product **40** in 36% yield and the *exo*-product **41** in 45% yield. On the other hand, the thermal mode with substrate **17b** gave the *endo*-product **40** in 9% yield and *exo*-product **41** in 90% yield. Thermal conditions were found to lead to diastereoselective cycloadditions providing the *exo*-epimer as shown in the thermal mechanistic pathway. Substrate **17a** gave only 7% of *exo*-product **42** under the oxidative conditions while the thermal condition gave 12% of the same product. No reduced PK product was observed. The low yield obtained with substrate **17a** may be due to increased steric crowding in the intermediate metallocycle (Scheme 2.19).

Scheme 2.19



17a,b

	[O]	[Δ]		[O]	[Δ]		[O]	[Δ]
R = Ph	39 : 18%	0%		40 : 36%	9%		41 : 45%	90%
R = TMS	0%	0%		0%	0%		42 : 7%	12%

Reagents and conditions: (a) $\text{Co}_2(\text{CO})_8$, DCM, then NMO;

(b) $\text{Co}_2(\text{CO})_8$, toluene, 70 °C

The spectroscopic data for the *exo*-compound **41** was completely consistent with expected structure and this was confirmed through X-ray crystallography of compound **41** (Figure 2.5).

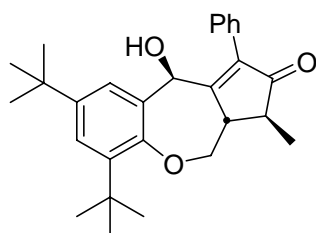
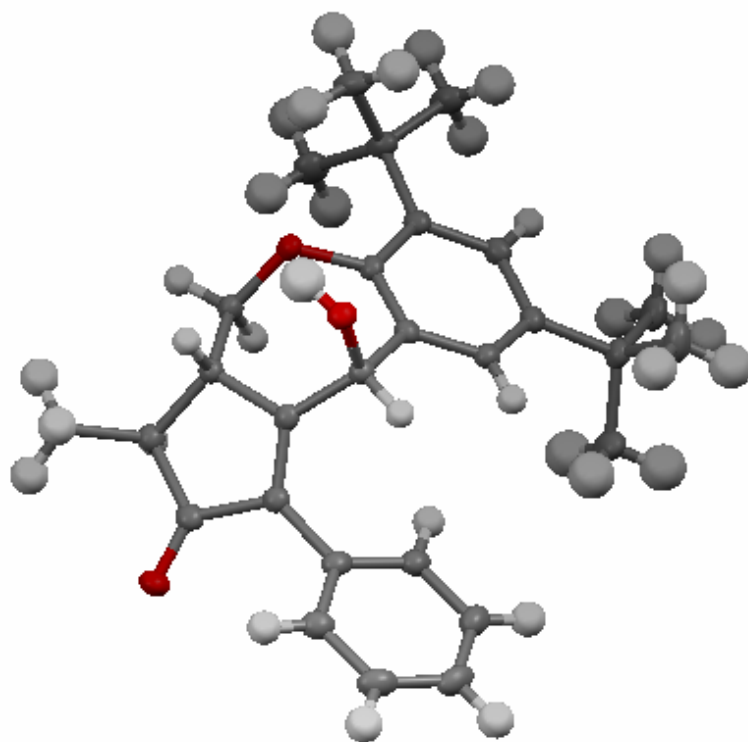
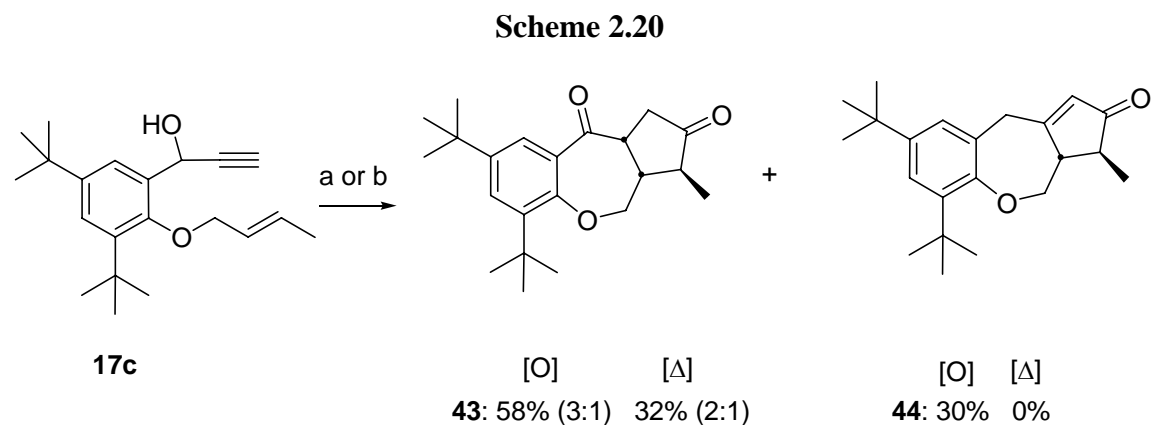


Figure 2.5. X-ray crystallography of the *exo* product of compound **41**

For the substrate **17c** (R = H), the oxidative mode gave the diketone products **43** in 58% yield (1:3 ratio of the isomers), along with 30% of the reduced product **44**. Under thermal PK conditions, **17c** gave only 32% of **43** in 1:2 ratios of the *syn* and *anti*

isomers (Scheme 2.20). In addition, substrate **17c** showed low stereoselectivity for the thermal conditions compared to the result obtained with substrates **17a** and **17b**.



Reagents and conditions: (a) $\text{Co}_2(\text{CO})_8$, CH_2Cl_2 , then NMO

(b) $\text{Co}_2(\text{CO})_8$, toluene, 70 °C

The two isomers of the diketo compound were separated by chromatography and a subsequent NOESY experiment confirmed the stereochemistry of the major product to be the cis-isomer (Figure 2.6)

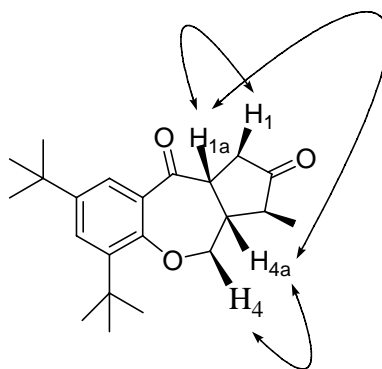
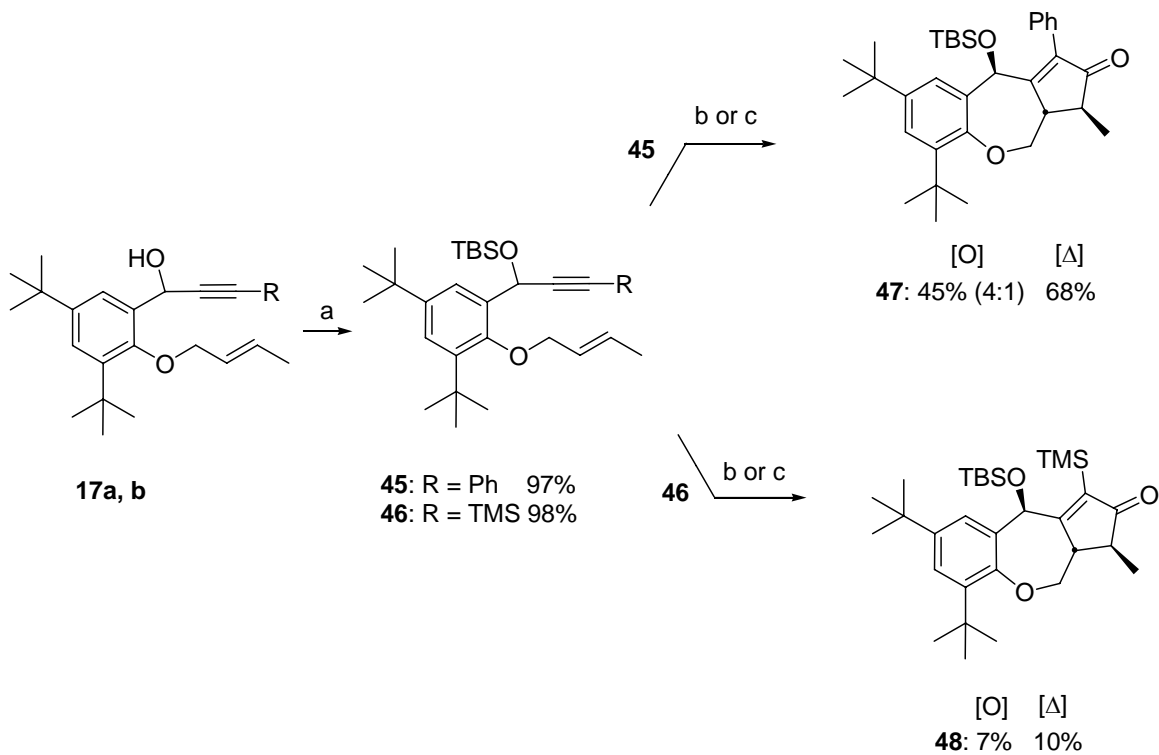


Figure 2.6. NOESY confirmation of the stereochemistry of the cis-isomer of **43**

Next, steric effects imparted by introducing a bulky group on the α -hydroxyl moiety of the substrates, were investigated. Substrate **17a** and **17b** were reacted with TBSCl to give **45** and **46** in 97% and 98% yield respectively (Scheme 2.21). Then, substrate **45** was subjected to oxidative PK conditions to furnish **47** in 45% yield as 4:1 mixture of epimers. When substrate **45** was subjected to the thermal mode gave 68% yield of the *exo*-product of compound **47**. On the other hand, the TMS-derivative, **46**, afforded mainly small amounts of cyclized product along with the recovery of the starting materials when exposed to both NMO and thermal promoted PK conditions. Substrate **46** gave 7% of **48** when subjected to oxidative PK condition. Under thermal condition it gave only 10% of **48** (Scheme 2.21). The low yields obtained from substrate **46** could be due to the steric hindrance formation in the metallocycle from the intermediate alkyne-dicobalt hexacarbonyl complex.

Scheme 2.21

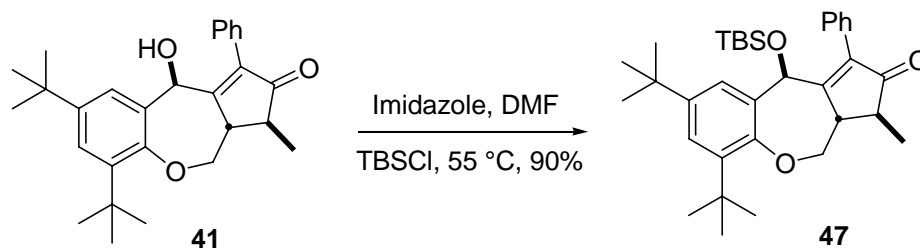


Reagents and conditions: (a) TBSCl, DMF, imidazole, 50 °C;

(b) $\text{Co}_2(\text{CO})_8$, CH_2Cl_2 , NMO; (c) $\text{Co}_2(\text{CO})_8$, toluene, 70 °C

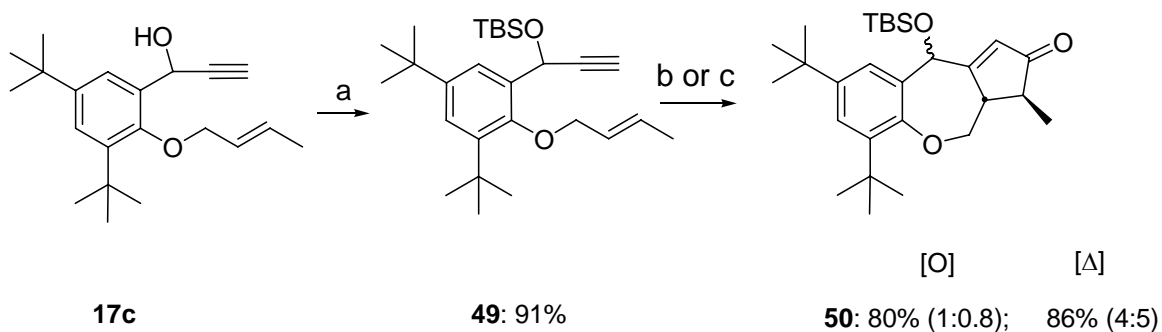
When *exo*-product **41** was treated with TBSCl and heated to 55 °C for 4 h it gave exclusively *exo*-product of **47** (Scheme 2.22). This also confirms the stereochemical result of the phenyl substrate in Scheme 2.21 to be mainly *exo*-product.

Scheme 2.22



Similarly to the previous examples, the α -hydroxyl group of the parent substrate **17c** was treated with TBSCl to furnish 91% yield of substrate **49**. With the cyclization substrate in hand, the oxidative and thermal PK cyclization reactions were investigated. The oxidative PK condition afforded 80% yield of **50** in 1:0.8 ratio of the epimers and thermal condition gave 85% yield of **50** in 4:5 ratio of the diastereomers as shown in Scheme 2.23.

Scheme 2.23



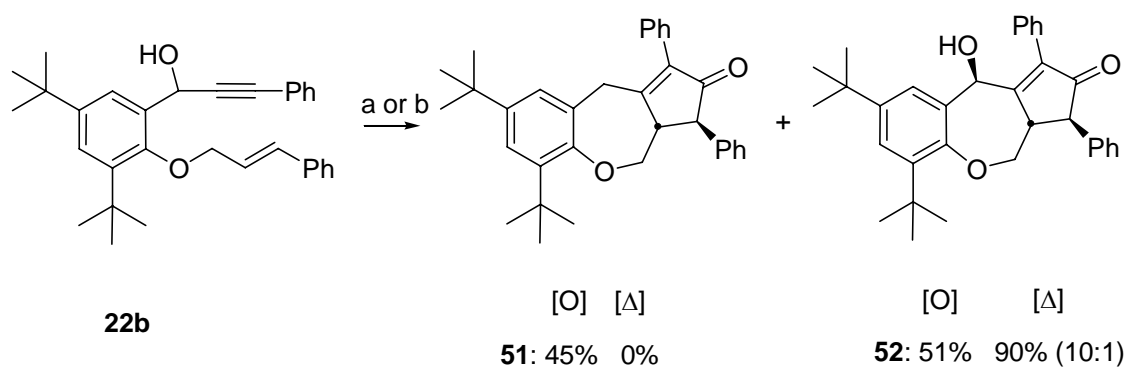
Reagents and conditions: (a) TBSCl, DMF, imidazole, 50 °C;

(b) $\text{Co}_2(\text{CO})_8$, CH_2Cl_2 , NMO; (c) $\text{Co}_2(\text{CO})_8$, toluene, 70 °C

So far the enynes containing a phenyl substituted alkyne have proven to be the best cyclization substrates. Therefore, it was decided to explore the effect of substituting

the alkene arm of the enyne with a phenyl group to see if it will enhance the PK cyclization. Hence, the substrates **22a**, **22b** and **22c** were constructed as previously stated above. These substrates were then subjected to both oxidative and thermal PK conditions. Under the oxidative PK conditions the substrate **22b** gave both the reduced PK product **51** in 45% yield and the *exo*- PK product of **52** in 51% yield. On the other hand, the thermal mode gave 90% yield of **52** in 10:1 ratios of the diastereomers, with the *exo*-isomer being the major product.^{69, 70} The thermal mode did not give the reduced PK product **51** (Scheme 2.24).

Scheme 2.24



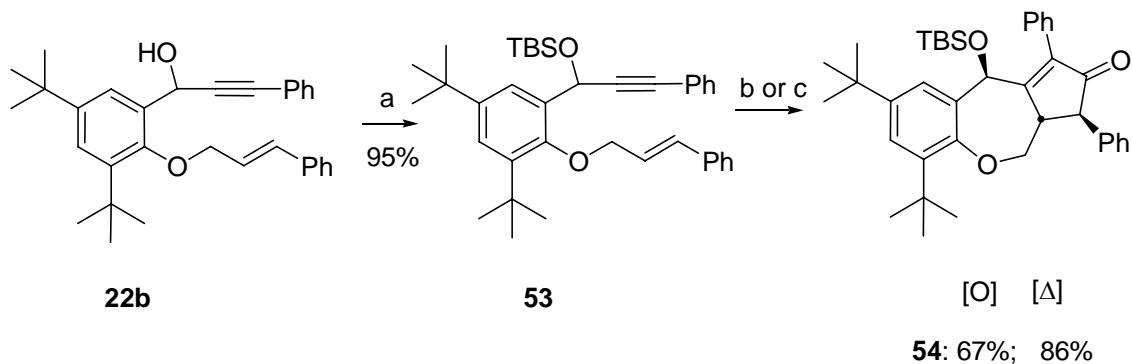
Reagents and conditions: (a) $\text{Co}_2(\text{CO})_8$, dichloromethane, then NMO

(b) $\text{Co}_2(\text{CO})_8$, toluene, 70 °C

Once again, the steric effect of increasing the bulkiness of the α -hydroxyl group was investigated. Substrate **22b** was protected with TBSCl to give **53** in 95% yield. Compound **53** was then cyclized under oxidative PK conditions to give the *exo*- product

54 in 67% yield, while the thermal condition gave 86% of the same product **54** (Scheme 2.25).

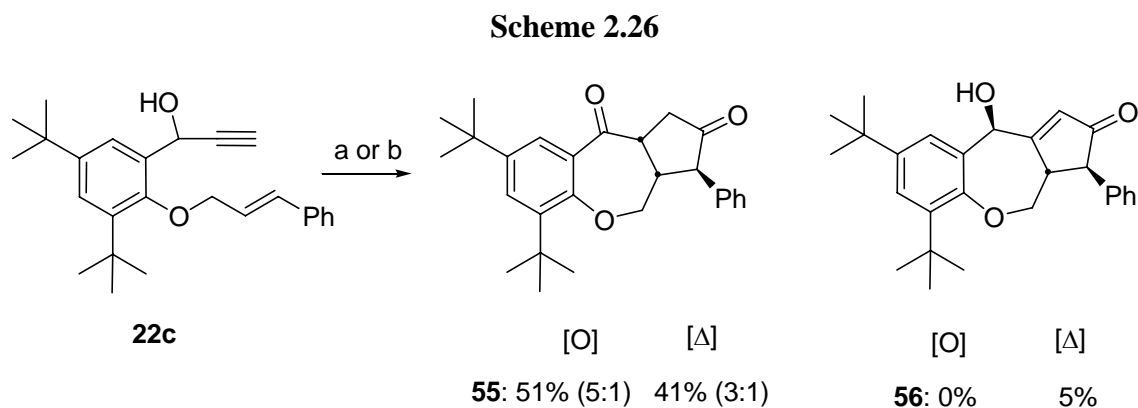
Scheme 2.25



Reagents and conditions: (a) TBSCl, DMF, imidazole, 50 °C;

(b) $\text{Co}_2(\text{CO})_8$, CH_2Cl_2 , NMO; (c) $\text{Co}_2(\text{CO})_8$, toluene, 70 °C

On the other hand, substrate **22c** participated in oxidative PKR to give the diketone **55** in 51% yield in 5:1 ratio of the *syn* and *anti*-isomers, with the *syn*-product as the major product. A somewhat lower yield of **55** was obtained with the thermal PK of this substrate. The thermal reaction of substrate **22c** gave 41% yield of **55** in 3:1 ratio of the *syn* and *anti*-isomer. The normal PK product **56** was isolated in 5% yield (Scheme 2.26).



Reagents and conditions: (a) $\text{Co}_2(\text{CO})_8$, CH_2Cl_2 , then NMO;

(b) $\text{Co}_2(\text{CO})_8$, toluene, 70 °C

The stereochemistry of the major diketone product was confirmed by a NOESY experiment to be the *syn*-isomer as shown in figure 2.7.

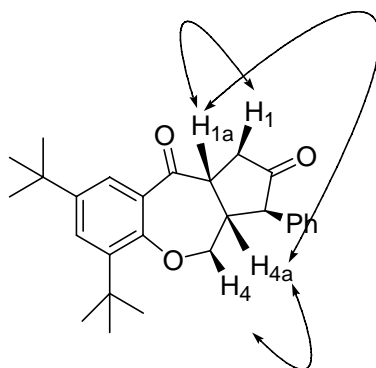
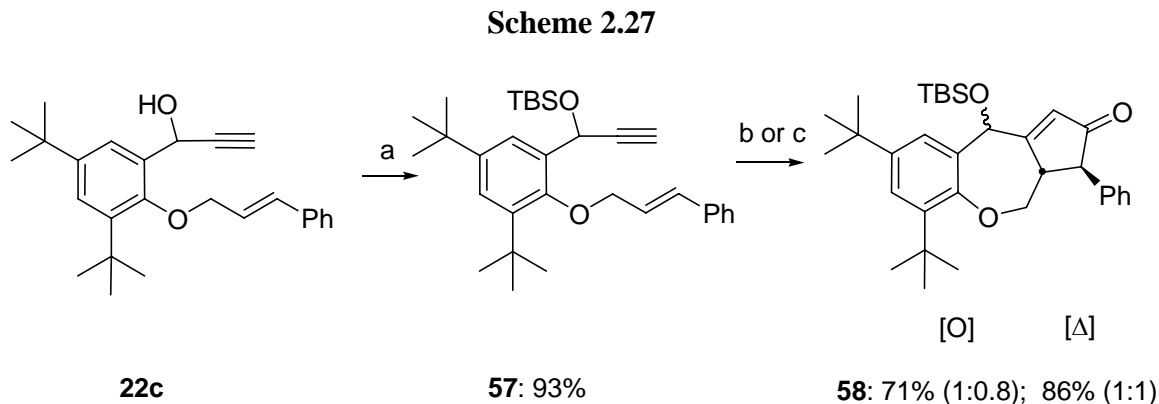


Figure 2.7. NOESY interaction of *cis*-isomer of **55**

In addition, TBSCl was used to protect the α -hydroxyl function of substrate **22c** leading to the silyl ether **57** in 93% yield. Then compound **57** was treated under the oxidative PKR conditions to afford 71% yield of **58** in 1:0.8 ratios of the epimers.

Under the thermal condition, substrate **57** gave 86% yield of the PK product **58** in 1:1 ratios of the epimers as shown in Scheme 2.27.



Reagents and conditions: (a) TBSCl, THF, imidazole, 50 °C;

(b) $\text{Co}_2(\text{CO})_8$, CH_2Cl_2 , NMO; (c) $\text{Co}_2(\text{CO})_8$, toluene, 70 °C

Generally, these results have shown that once the alkyne is substituted, the PK reaction tends to be diastereoselective towards the *exo*-product. It has been established from the mechanistic rationalization that the substituent on a terminal alkyne provides a greater degree of steric control. Hence, bulky substituents on the on the alkyne arm drives the cyclization to be more stereoselective, leading to the *exo*-compounds as the major product under the PK conditions.^{70, 76-78} Furthermore, protection of the propargylic hydroxyl group reduces side reaction (reduces isomerization) which led to a reduction of the yield of the expected products.

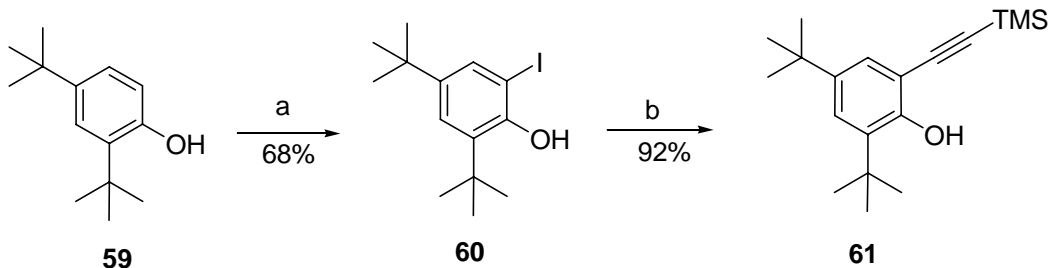
This work confirms that aromatic ring alone does not sufficiently preorganize the enyne substrate for cyclization leading to medium size rings. However,

incorporation of conformational constraints induced by bulky *ortho* substituent enhances the efficiency of enyne cyclization.

2.3 Type II Substrates

Substrates that we have designated as Type II have been studied previously under the oxidative PK conditions. Therefore, this part of the project focuses on the thermal PK of Type II of substrates. These substrates were assembled from commercially available 2,4-di-*tert*-butylphenol (**59**) by iodination with *N*-iodosuccinamide to give **60**. Compound **60** was subjected to a Sonogashira reaction with TMS-acetylene to afford **61** in 92% yield (Scheme 2.28).⁷⁹⁻⁸¹

Scheme 2.28

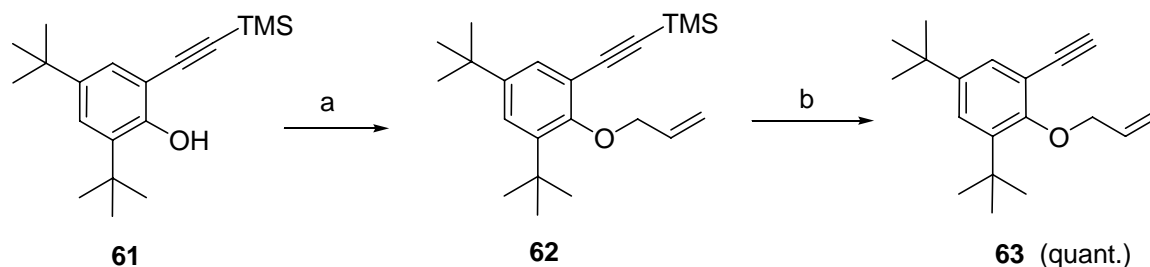


Reagents and conditions: (a) *N*-iodosuccinamide, 0 °C, DMF, 68%;

(b) HC≡C-TMS, Et₃N, dioxane, Pd(PPh₃)₂Cl₂, CuI.

The phenol **61** was then allylated to give **62** followed by a deprotection of the acetylene functionality by stirring in a mixture of THF/MeOH (1:1) in the presence of K₂CO₃. This reaction gave **63**, the cyclization precursor, in quantitative yields (Scheme 2.29).

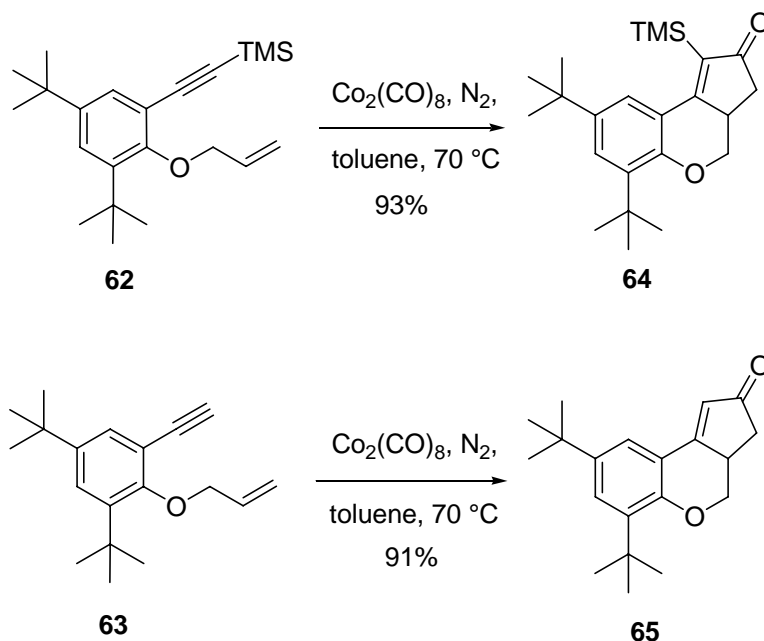
Scheme 2.29



Reagents and conditions: (a) K_2CO_3 , DMF, $\text{BrCH}_2\text{CH}=\text{CH}_2$; (b) K_2CO_3 , THF, MeOH.

With both enynes **62** and **63** in hand, they were subjected to the thermal Pauson-Khand reaction protocol. Substrate **62** provided 93% of the six member cyclic product **64**. On the other hand, enyne **63** gave 91% of the cyclic product **65** (Scheme 2.30).

Scheme 2.30

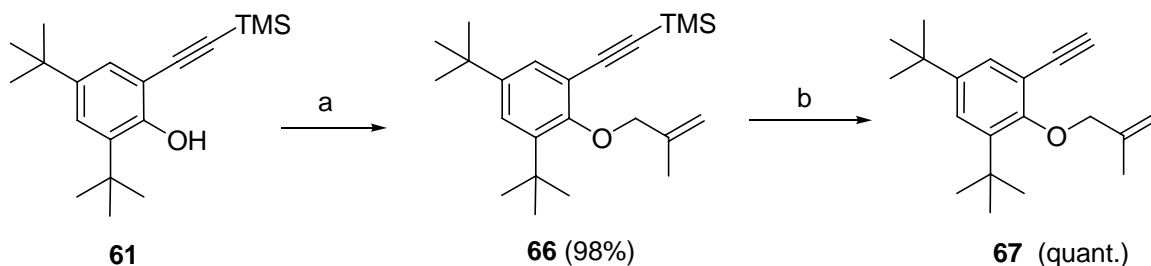


Thermal PK conditions for these substrates gave a higher yield compared to the NMO promoted PK reaction. The oxidative PK reactions have been investigated earlier

by Dr. Seshadri in our laboratory.⁶⁰ Under oxidative conditions, Dr. Seshadri reported the cyclization of **63** to give 70% yield of the PK product **65**.

The influence of substituted alkene moiety on the efficiency of the cyclization was of interest in this investigation. In earlier studies from our group, it had been established that alkene substitution was detrimental to cyclization in substrates which lacked the *o*-*tert*-butyl group. Hence, the internal methyl alkene substituted enyne was synthesized. Substrate **61** was treated with 2-methylallyl chloride in the presence of NaI and K₂CO₃ to afford enyne **66**. Subsequently, it was desilylated by stirring in THF and methanol mixture in the presence of K₂CO₃ to give quantitative yield of **67** as shown in Scheme 2.31.

Scheme 2.31

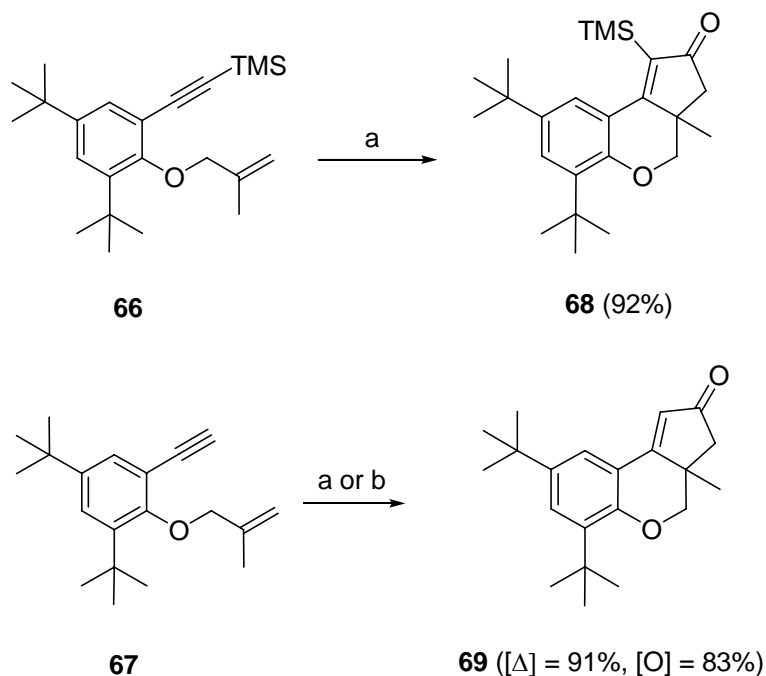


Reagents and conditions: (a) K₂CO₃, NaI, DMF, BrCH₂(CH₃)C=CH₂; (b) K₂CO₃, THF, MeOH.

Enynes **66** and **67**, upon conversion to the cobalt alkyne complexes, were subjected to the PK conditions to give the corresponding cyclic products. Under the thermal conditions, the enyne **66** furnished the tricyclic compound **68** in 92% yield. Since enyne **67** was not previously investigated under the oxidative conditions, and so was subjected

to both thermal and oxidative conditions. When enyne **67** was subjected to the thermal PK conditions 91% yield of the tricyclic product **69** was isolated. Under the oxidative mode enyne **67** gave 83% yield of the cyclic product **69** (Scheme 2.32).

Scheme 2.32



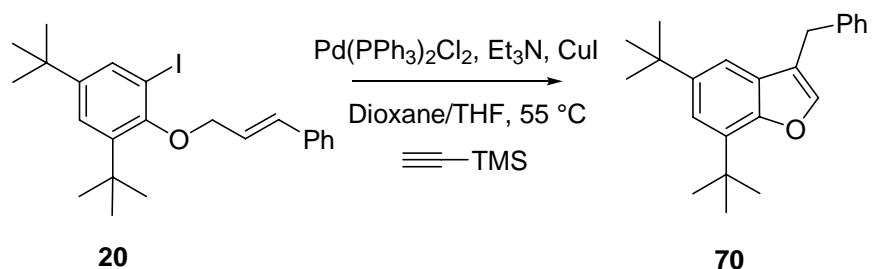
Reagents and conditions: (a) $\text{Co}_2(\text{CO})_8$, toluene, 70 °C, 91%

(b) $\text{Co}_2(\text{CO})_8$, NMO, CH_2Cl_2 , 83%

Apparently, these substrates tend to give better yields for the thermal PK reactions when compared to the yields obtained for the oxidative PK reactions.

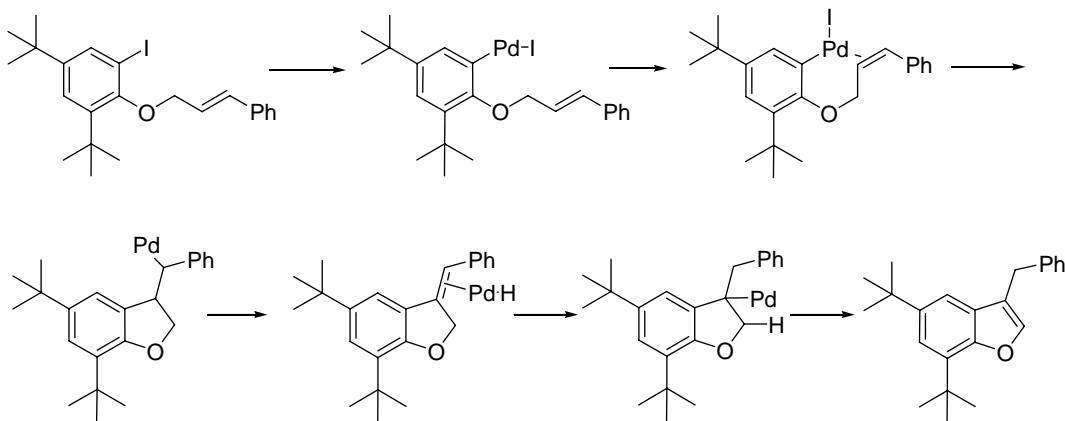
Enynes with an internal alkene were also investigated. In an attempt to synthesize substrate **71**, substrate **20** and TMS protected acetylene were subjected to Sonogashira protocol. Unfortunately, instead of giving the expected Sonogashira product, it gave a cyclized product **70**, as shown in the Scheme 2.33 below.

Scheme 2.33



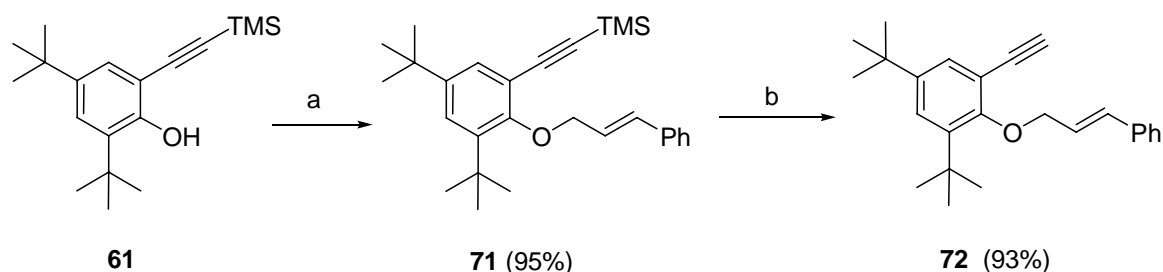
This product **70** was formed via the mechanistic path depicted below in Scheme 2.34. Initially, Pd inserts into the aryl halide bond followed by coordination of the C-C double bond to the metal center. Conjugative addition of the double bond then occurs to give a cyclic compound with an exocyclic double bond. This compound then underwent a transition metal-mediated hydride shift to give product **70** (Scheme 2.34).⁸²

Scheme 2.34



A different approach was then taken to prepare substrate **71**. From substrate **61**, a Mitsunobu protocol with cinnamyl alcohol was followed to afford **71** in 95% yield. Substrate **71** was desilylated to give 93% yield of the enyne **72** (Scheme 2.35).

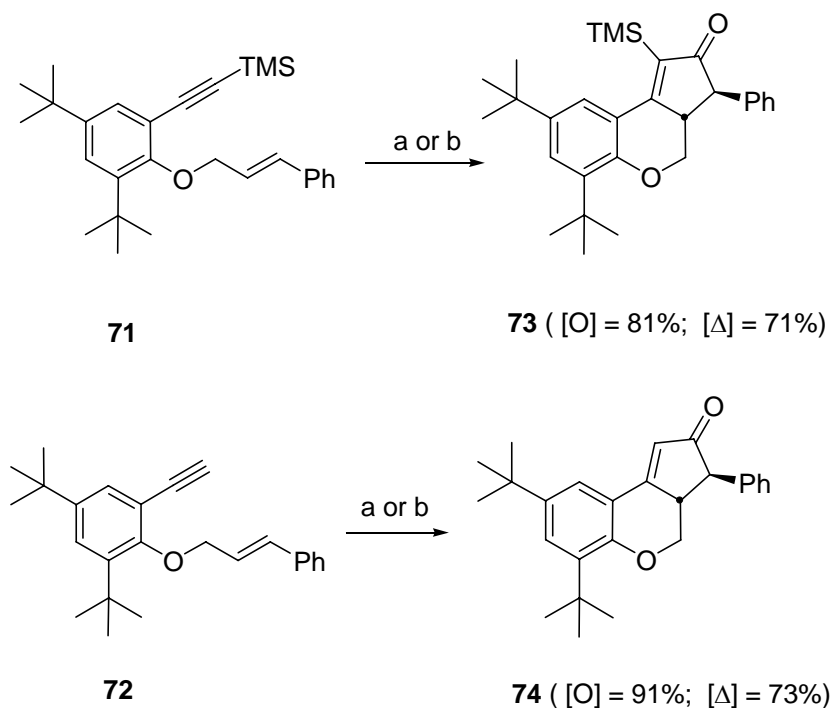
Scheme 2.35



Reagents and conditions: (a) HOCH₂HC=CHPh, DEAD, THF, PPh₃; (b) K₂CO₃, THF, MeOH.

With substrates **71** and **72** in hand, both the thermal and NMO promoted PKR were investigated. The TMS protected alkynyl enyne **71**, under NMO promoted PK condition, gave 81% yield of the cyclic product **73**. However, lower yields of the cyclized product **73** were obtained under the thermal PK conditions (71% yield). On the other hand, substrate **72** under oxidative PK condition gave 91% yield of the cyclic product **74**. In comparison, 73% yield of the cyclic product **74** was obtained under thermal conditions (Scheme 2.36).

Scheme 2.36

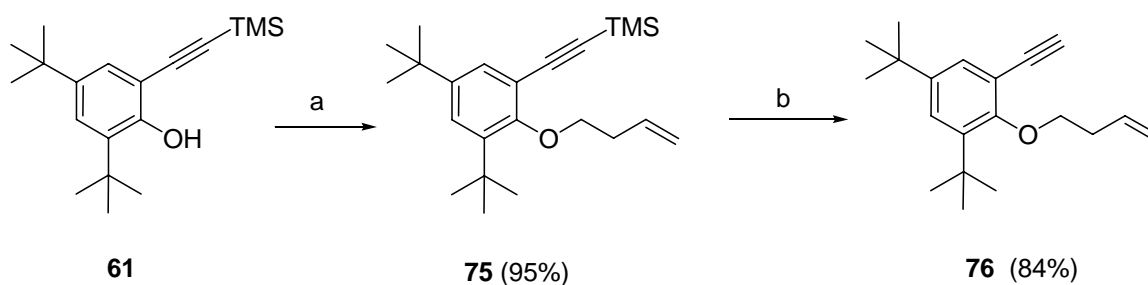


Reagents and conditions: (a) $\text{Co}_2(\text{CO})_8$, CH_2Cl_2 , the NMO;

(b) $\text{Co}_2(\text{CO})_8$, toluene, 70 °C

In general, the thermal PK reaction results were viewed extremely encouraging. To utilize this approach for the assembly of larger sized rings, the precursor enynes which upon cyclization would provide seven or eight membered rings was synthesized. Butenyl substituted enyne **75** was constructed by subjecting **61** to a Mitsunobu protocol with 3-buten-1-ol in 95% yield. The TMS group was then cleaved to afford the enyne **76** in 84% yield as shown in Scheme 2.37 below.

Scheme 2.37

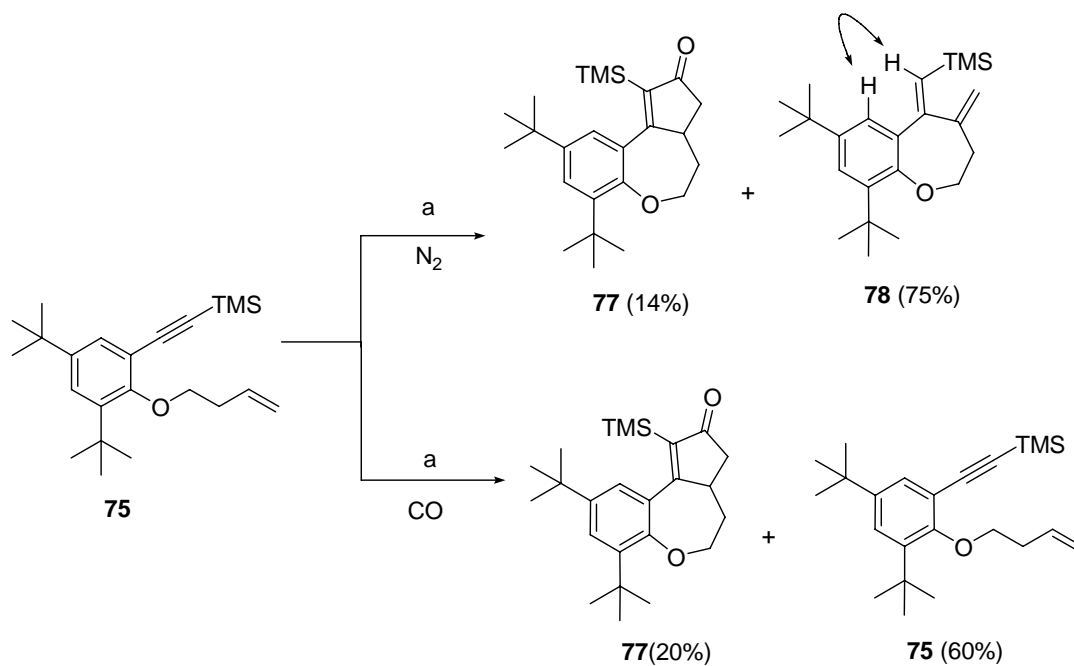


Reagents and conditions: (a) HOCH₂CH₂HC=CH₂, DEAD, THF, PPh₃;

(b) K₂CO₃, THF, MeOH.

When substrate **75** was subjected to thermal PK condition under N₂ atmosphere, the anticipated PK product **77** was obtained in only 14% yield. The major product was instead the diene **78** (75% yield), which resulted from a β -hydride elimination from the intermediate complex. NOESY experiment was used to assign the stereochemistry at the TMS-substituted diene and the indicated NOE was particularly diagnostic. The insertion of CO into the metallocycle was inhibited as a result of the β -hydride elimination. On the other hand, when the reaction was done under CO atmosphere, the yield of PK product **77** was improved to 20%. However, 60% of the starting material **75** was recovered (Scheme 2.38).

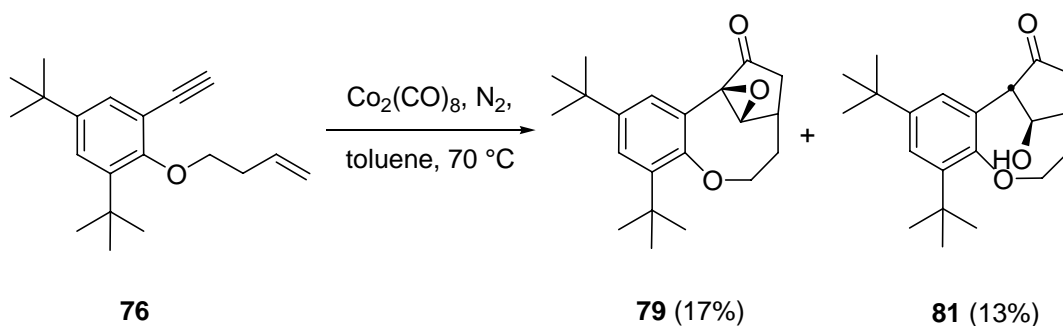
Scheme 2.38



Reagents and conditions: (a) $Co_2(CO)_8$, toluene, 70 °C

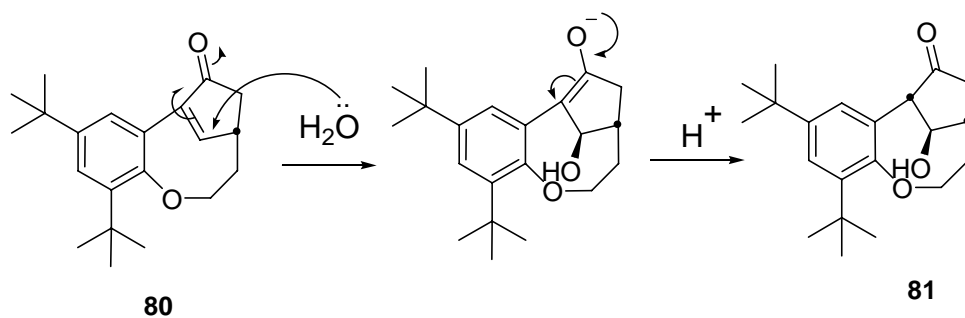
When the desilylated substrate **76** was subjected to thermal PK cyclization, two unique products **79** and **81** were isolated in 17% and 13% yield respectively (Scheme 2.39). Compound **79** is the unusual epoxide product reported earlier by Lovely and coworker.⁶¹

Scheme 2.39



Product **81** seems unusual since it did not resemble any of the anticipated products and its molecular weight is 330 g/mol. The IR showed the presence of a hydroxyl group at $\nu_{\text{OH}} = 3396\text{ cm}^{-1}$ and carbonyl group at $\nu_{\text{C=O}} = 1735\text{ cm}^{-1}$. This absorption is typical for non-conjugated carbonyl groups. Also, the ^1H NMR showed two additional protons more than was anticipated for the conjugated carbonyl product. Therefore, it was concluded that the cyclized product **81** was a product of Michael addition of H_2O on the α,β -unsaturated carbonyl compound **80** (Scheme 2.40).

Scheme 2.40

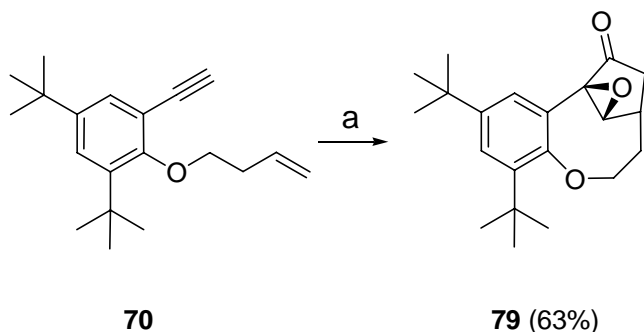


The epoxidation and hydroxylation products are consistent with the literature reports. It has been demonstrated that strained enones generated from PK reactions undergoes

subsequent processes in order to reduce the inherent strain in the molecule.^{61, 83-86} A molecular model of **80** clearly exhibits strain.

Krafft and coworkers have demonstrated that normal PK reaction takes a different route in the presence of oxygen, leading to interrupted PK reaction resulting in the formation of a non-cyclic enone.^{89, 90} Further investigation was carried out in order to explain how the epoxide **79** was formed. Enyne **76** was subjected to the oxidative condition, but in this case instead of carrying out the reaction under the N₂ atmosphere it was done under O₂ atmosphere. The cyclization gave the epoxide **79** exclusively in 63% yield (Scheme 2.41).

Scheme 2.41



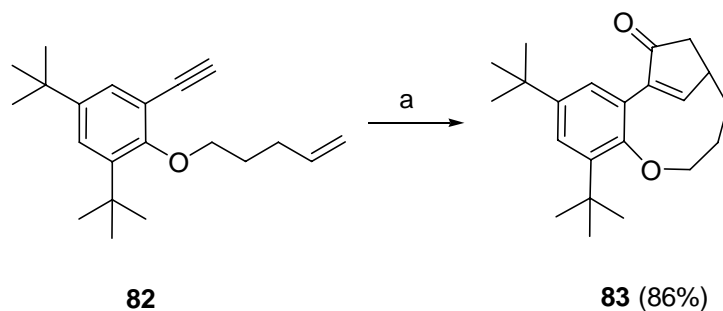
Reagents and conditions: (a) Co₂(CO)₈, CH₂Cl₂, NMO, O₂

This result suggests that oxygen inserts into the cobalt presumably forming a Co=O species. The oxygen is then delivered to the strained bridge head double bond, leading to the formation of the epoxide product **79**.

The higher homologue of the butenyl enyne **76** was prepared next to give **82**. Then substrate **82** was subjected to the thermal PK to give cyclic compound **83** of identical regiochemistry to that of the butenyl system in 86% yield. The thermal PK

conditions gave a higher yield of compound **83** compared to the NMO promoted PK yield earlier reported by Dr Seshadri (Scheme 2.42).⁶¹

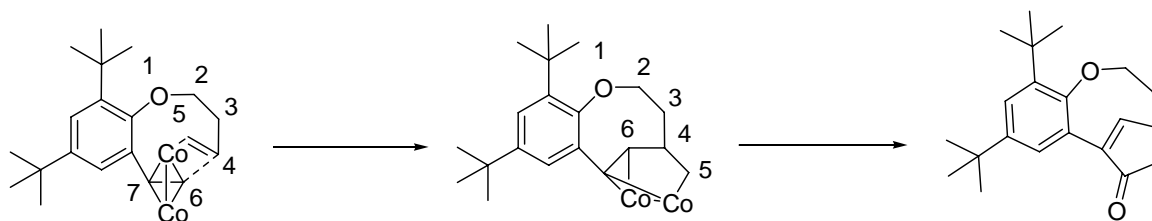
Scheme 2.42



Reagents and conditions: (a) $\text{Co}_2(\text{CO})_8$, toluene, 70 °C

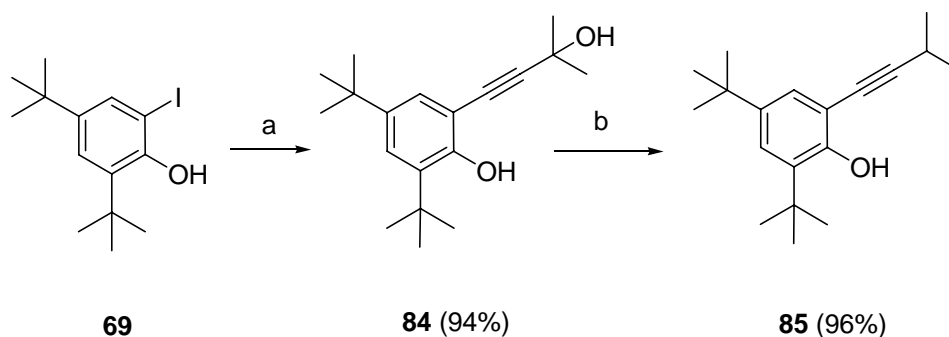
This unusual cyclization mode was attributed by Dr. Seshadri^{60, 61} to be caused by both steric and electronic factors. The steric interaction between the internal methylene carbon and the cobalt complex probably forced the alkene to rotate and orient itself toward the cobalt alkyne complex in order to avoid an unfavorable steric interaction (Fig 1.3).

Moreover, electron rich substituent tends to orient α -position to the carbonyl function. Hence the alkene is forced to rotate placing the electron rich aromatic ring next to the carbonyl group in the cyclopentenone.



Since one of the aims of this study was to establish whether the PK reaction could be used in the total synthesis of the hamigeran family, an attempt was made to prepare enynes that can cyclized to give a product similar to the core of the hamigeran A and B. To accomplish this, the iodophenol **69** was subjected to a Sonogashira protocol with 2-methyl-2-hydroxy-1-butyne. From this reaction, compound **84** was obtained in 94% yield. The compound **84** was then reduced with NaBH₄ in the presence of TFA to give 96% yield of **85** (Scheme 2.43).

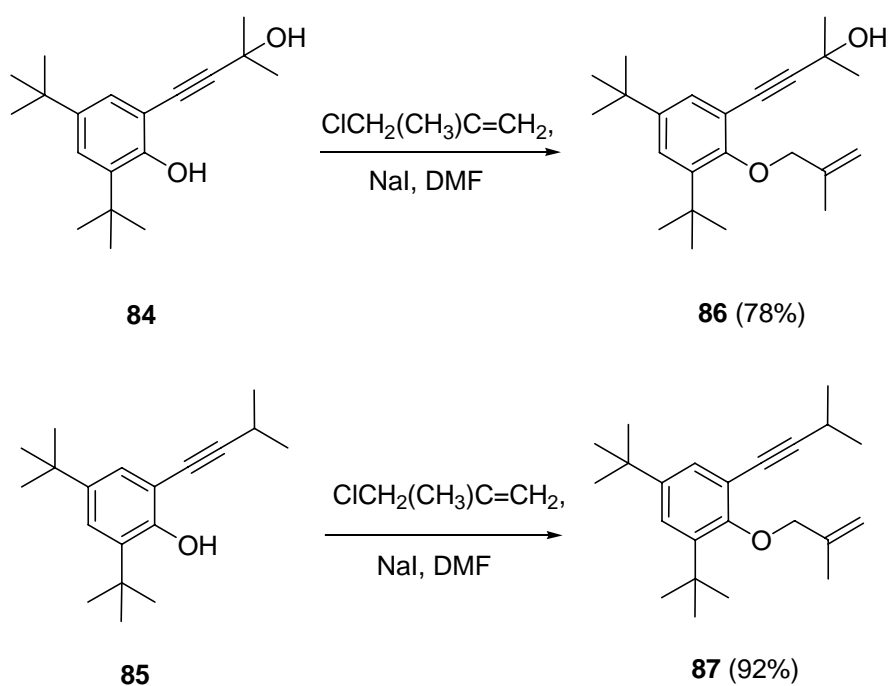
Scheme 2.43



Reagents and conditions: (a) 2-methyl-2-hydroxybut-1-yne, Pd(PPh₃)₂Cl₂, CuI, Et₃N, dioxane; (b) NaBH₄, trifluoroacetic acid, dichloromethane, 0 °C

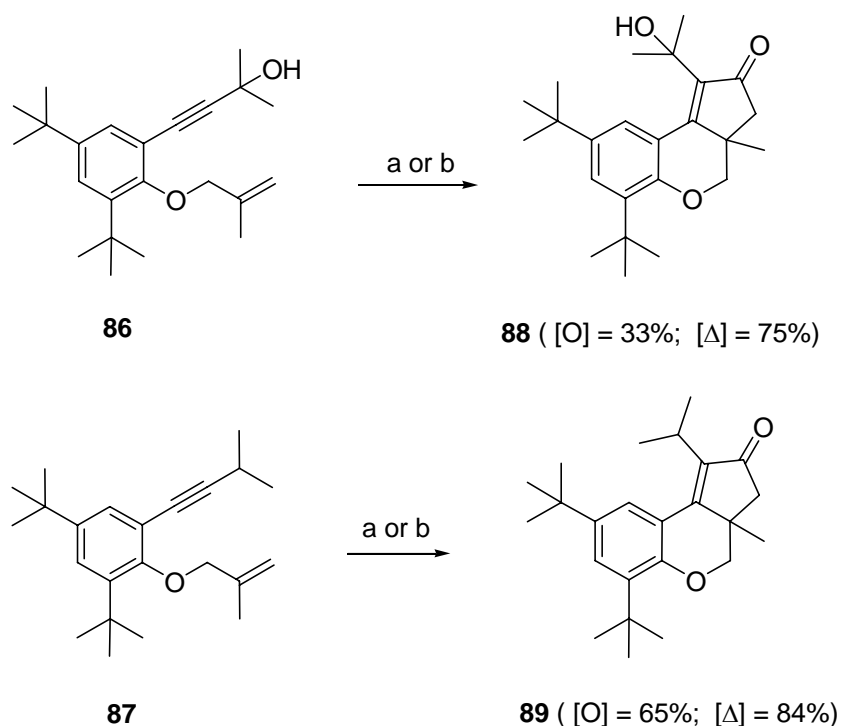
Compounds **84** and **85** were then reacted with 2-methylallyl chloride and NaI to afford **86** and **87** in 78% and 92% yields respectively (Scheme 2.44).

Scheme 2.44



Both substrates **86** and **87** were subjected to both the thermal PK and NMO promoted PK conditions to afford cyclic products. Substrate **86**, under oxidative condition gave 33% of the cyclized product **88**, whereas under the thermal condition, 85% yield of cyclized product **88** was obtained. On the other hand, substrate **87** under the oxidative condition gave 65% of **89**, while the thermal condition afforded 84% of the cyclized product **89** (Scheme 2.45).

Scheme 2.45



Reagents and conditions: (a) $\text{Co}_2(\text{CO})_8$, CH_2Cl_2 , the NMO;

(b) $\text{Co}_2(\text{CO})_8$, toluene, 70 °C

This result clearly indicates that the P-K methodology will be an effective method for the total synthesis of the hamigeran family and other natural products with 5-membered ring annulated to medium sized rings. Hence with the PK reaction the tricyclic core of the hamigerans will easily be accessed. Our approach to this family of natural products base on this disconnection will be described in the later chapters.

This work clearly confirms our hypothesis that aryl ring could function as a suitable scaffold for the Pauson-Khand cyclization of the enynes. Also, introduction of additional conformational constraints induced by an ortho substituent further restricts

the conformational space available to the enyne arms, thus forcing alkene arm into close proximity with the alkynyl group thereby giving access to medium sized rings as well as congested cyclopentenones.

CHAPTER 3

EXPERIMENTAL SECTION

3.1 General Methods

All reagents were purchased from commercial suppliers and were used as received unless otherwise noted. Solvents were dried by distillation over appropriate drying agents: tetrahydrofuran and diethyl ether were distilled from sodium/benzophenone ketyl; benzene and dichloromethane were distilled over calcium hydride or purified using Innovative Technologies Inc Pure Solv SPS-400-05 solvent purification system. ^1H and ^{13}C NMR (δ in ppm) spectra were recorded in CDCl_3 (unless otherwise noted) at 500 and 125.8 MHz, respectively; using a JEOL Eclipse+ 500 spectrometer. Also ^1H and ^{13}C NMR (δ in ppm) spectra were recorded sometimes at 300 and 75 MHz respectively; using a JEOL Eclipse 300 spectrometer as otherwise noted using residual CHCl_3 ($\delta = 7.26$) as reference for ^1H NMR and carbon absorption of CDCl_3 ($\delta = 77.0$) as internal reference for ^{13}C NMR. Infrared spectra were recorded either as neat films or as KBr pellets using a Bruker Vector 22 FT-IR spectrometer. All mass spectra data are reported as m/z (relative intensity).

Electrospray ionization (ESI-MS) was obtained from HT labs Inc, San Diego, CA. High resolution mass spectra (HR-MS) were obtained from Dr. Powell's lab in University of Florida, Gainesville, Florida. Elemental analyses were performed using a Perkin-Elmer 2400 CHN analyzer. Analytical thin layer chromatography (TLC) was

performed on Whatman silica gel 60F₂₅₄ aluminum precoated plates (0.25 mm layer).

All chromatographic purifications were performed using ICN silica gel (200-400 mesh).

3.1.1 General procedure for the *O*-alkylation reaction:

The bromoalkene (11.0 mmol) was added to a suspension of K₂CO₃ (14.4 mmol) and 3,5-di-*tert*-butyl-2-hydroxybenzaldehyde (11.0 mmol) in DMF (50 mL) and stirred at room temperature for 12 h. The product was extracted with CH₂Cl₂ (25 mL) and washed twice with water, dried using Na₂SO₄ (anhydrous) and concentrated under reduced pressure. The crude product was purified by flash chromatography (SiO₂: hexane/EtOAc, 15:1).

3.1.2 General procedure for the reaction of the *O*-alkylated Product with Grignard reagent.

The Grignard reagent (1.5 eq.) was added to a solution of aldehyde in dry THF (10 mL) under N₂ at 0 °C. The mixture was stirred and gradually allowed to warm up to room temperature and stirred for 3 h. The reaction was quenched with aqueous NH₄Cl and then extracted with CH₂Cl₂. The organic layers were then washed with water, brine and concentrated under reduced pressure. The crude product was purified by flash chromatography (SiO₂, hexane/EtOAc, 80:20).

3.1.3 General procedure for the Pauson-Khand Cyclization

3.1.3.1 General procedure for the reduced PKR (Procedure A)

1.1 eq of $\text{Co}_2(\text{CO})_8$ was added to a stirred solution of enyne in CH_2Cl_2 and under N_2 at room temperature. The reaction mixture was stirred for 5 h at rt. The reaction mixture was then cooled to $0\text{ }^\circ\text{C}$ before adding NaBH_4 . Subsequently, TFA was added over 10 minutes at $0\text{ }^\circ\text{C}$. The reaction mixture was decanted into 300 mL iced water and the organic layer separated, washed with water and dried (Na_2SO_4). The organic layers were concentrated and cooled to $0\text{ }^\circ\text{C}$ before NMO (12 eq.) was added and stirred for 2 h. The reaction mixture was then poured into a sintered glass funnel with Celite and SiO_2 and filtered. The solid packing was washed with EtOAc to extract the remaining product. The filtrates were combined and concentrated under reduced pressure. The crude product was purified by flash chromatography (hexane/EtOAc, 20/1.5).

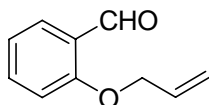
3.1.3.2 General procedure for the Oxidative Pauson-Khand Method (Procedure B)

1.1 eq of $\text{Co}_2(\text{CO})_8$ was added to a stirred solution of enyne in CH_2Cl_2 and under N_2 at room temperature. The reaction mixture was stirred for 5 h at rt. The reaction mixture was cooled to $0\text{ }^\circ\text{C}$ before NMO (12eq.) was added in three portions at 30 minutes intervals and then left to stir for 2 h. The reaction mixture was then poured into a sintered glass funnel packed with Celite and SiO_2 and washed with EtOAc. The crude product was purified by flash chromatography (hexane/EtOAc, 20/1.5).

3.1.3.3 General procedure for the Thermal Pauson-Khand Method (Procedure C)

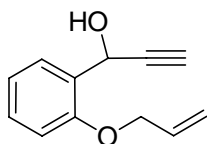
1.1 eq of $\text{Co}_2(\text{CO})_8$ was added to a stirred solution of enyne in toluene and under N_2 and stirred for 5 h at room temperature. The reaction mixture was then heated at $70\text{ }^\circ\text{C}$ under N_2 for overnight. The reaction mixture was then poured into a sintered glass funnel packed with Celite and SiO_2 and first washed with hexane to remove the alkyne- $\text{Co}_2(\text{CO})_6$ remaining and then washed with ethyl acetate to remove any remaining cyclized product. The crude product was purified by flash chromatography (hexane/EtOAc, 20/1.5).

2-(-2-Propenyloxy)benzaldehyde (**2**)



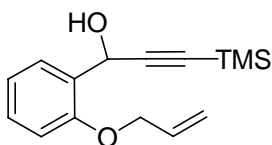
Allyl bromide (19.8 g, 160 mmol) was added to a suspension of K_2CO_3 (23.0 g) and 2-hydroxybenzaldehyde (20.0 g, 160 mmol) in DMF (100 mL) and stirred for 12 h according to the general procedure 3.1.1. The crude product was purified by flash chromatography (hexane/EtOAc, 15:1) to give **2** as a brown oil (18.5 g, 70%). ^1H NMR (500 MHz): δ = 10.41 (s, 1H), 7.70 (dd, J = 1.4, 7.8 Hz, 1H), 7.40 (dt, J = 1.8, 8.7 Hz, 1H), 6.90 (t, J = 7.8 Hz, 1H), 6.86 (d, J = 8.7 Hz, 1H), 6.95 (ddt, J = 5.5, 10.5, 17.0 Hz, 1H), 5.33 (dd, J = 1.4, 17.4 Hz, 1H), 5.21 (dd, J = 1.4, 10.5 Hz, 1H), 4.52 (d, J = 5.0 Hz, 2H); ^{13}C NMR (125 MHz): δ = 189.7, 161.0, 136.1, 132.6, 128.4, 125.1, 120.9, 118.1, 113.1, 69.2; IR (neat, cm^{-1}) = 3079, 2866, 1685, 1599, 1483, 1286, 995, 759; HRMS (ESI): Calcd. for $\text{C}_{10}\text{H}_{11}\text{O}_2$ (m/z): 163.0759. Found 163.0749 $[\text{M}+\text{H}]^+$.

2-(1-Hydroxy-2-propynyl)-(2-propenyloxy) benzene (3)



0.5 M solution of ethynylmagnesium bromide (55.6 mL, 28.0 mmol) in THF was added at 0 °C to a solution of **2** (3.00 g, 19.0 mmol) in THF (20 mL) under N₂ atmosphere according to the general procedure above. The reaction was worked up according to the general procedure 3.1.2 to give **3** (3.31 g, 95%) as a brown oil after chromatographic purification. ¹H NMR (500 MHz): δ = 7.57 (dd, *J* = 1.8, 7.3 Hz, 1H), 7.28 (dt, *J* = 1.8, 7.3 Hz, 1H), 6.98 (dt, *J* = 1.0, 7.3 Hz, 1H), 6.88 (d, *J* = 7.8 Hz, 1H), 6.05 (ddt, *J* = 5.5, 10.5, 17.0 Hz, 1H), 5.73 (d, *J* = 2.3 Hz, 1H), 5.45 (dq, *J* = 1.8, 17.0 Hz, 1H), 5.30 (dq, *J* = 1.4, 10.5 Hz, 1H), 4.58 (ddt, *J* = 1.4, 3.2, 5.0 Hz, 2H), 3.44 (s, 1H), 2.61 (d, *J* = 2.3, 1H); ¹³C NMR (125 MHz, CDCl₃): δ = 153.2, 133.0, 129.8, 128.7, 128.0, 121.2, 118.0, 112.3, 83.4, 74.2, 69.2, 60.9; IR (neat, cm⁻¹) = 3392, 3287, 3077, 2870, 2116, 1648, 1601, 1490, 1453; HRMS (CI): Calcd. For C₁₂H₁₂O₂ (*m/z*): 188.0837. Found 188.0829 [M⁺].

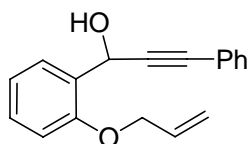
2-(1-Hydroxy-3-trimethylsilyl-2-propynyl)-(2-propenyloxy)benzene (4)



Trimethylsilylethynylmagnesium chloride in dry THF was prepared by adding ethynyltrimethylsilane (3.33 g, 34.0 mmol) to 2.0 M solution of *iso*-propylmagnesium chloride (14.0 mL, 28.0 mmol) under N₂ at 0 °C and the mixture was stirred for 30 minutes before allowing to gradually warm up to room temperature and then stirred further for 10 minutes. To this thus prepared solution of trimethylsilylethynylmagnesium chloride was added a solution of **2** (3.00 g, 19.0 mmol) in dry THF (20 mL) under N₂ atmosphere at -78 °C and then stirred for 2.5 h at

-78 °C. The reaction was then allowed to warm up to room temperature and stirred overnight. The reaction was worked up according to the general procedure 3.1.2 to give **4** (4.97 g, 93%) as a brown oil. ¹H NMR (300 MHz), δ = 7.56 (dd, *J* = 1.7, 7.6 Hz, 1H), 7.27 (dt, *J* = 1.7, 8.3 Hz, 1H), 6.99 (dt, *J* = 1.0, 7.2 Hz, 1H), 6.89 (d, *J* = 8.3 Hz, 1H), 6.02 (ddt, *J* = 4.8, 10.7, 17.2 Hz, 1H), 5.71 (s, 1H), 5.46 (dq, *J* = 1.7, 17.2 Hz, 1H), 5.31 (dq, *J* = 1.4, 10.7 Hz, 1H), 4.58 (ddt, *J* = 1.7, 3.5, 5.2 Hz, 2H), 3.09 (s, 1H), 0.20 (s, 9H). ¹³C NMR (75 MHz), δ = 160.0, 132.9, 129.7, 129.0, 128.2, 121.2, 117.8, 112.3, 104.7, 90.9, 69.1, 61.9, -0.1; IR (neat, cm⁻¹) = 3403, 2960, 2173, 1601, 1490, 1455, 1249; HRMS (ESI): Calcd. for C₁₅H₂₀O₂Na (*m/z*): 283.1125. Found 283.1124 [M+Na]⁺.

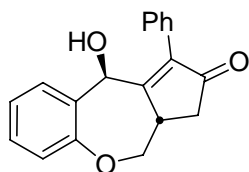
2-(1-Hydroxy-3-phenyl-2-propynyl)-(2-propenyloxy)benzene (**5**)



1.0 M solution of phenylethyne magnesium bromide (24.6 mL, 25.0 mmol) in THF was added at 0 °C to the solution of **2** (3.00 g, 19.0 mmol) in THF (20 mL) under N₂ atmosphere according to the general procedure above. The reaction was worked up according to the general procedure 3.1.2 to give **5** (2.04 g, 47%) as a brown oil. ¹H NMR (500 MHz): δ = 7.64 (dd, *J* = 1.8, 7.8 Hz, 1H), 7.47 (dd, *J* = 2.3, 7.3 Hz, 2H), 7.32 (m, 4H), 7.02 (dt, *J* = 1.0, 7.3 Hz, 1H), 6.93 (d, *J* = 8.3 Hz, 1H), 6.07 (ddt, *J* = 5.0, 10.5, 17.4 Hz, 1H), 5.96 (d, *J* = 6.0 Hz, 1H), 5.47 (dd, *J* = 1.4, 17.4 Hz, 1H), 5.32 (dq, *J* = 1.4, 10.5 Hz, 1H), 4.65 (ddt, *J* = 1.8, 3.7, 5.0 Hz, 2H), 3.25 (d, *J* = 6.0 Hz, 1H). ¹³C NMR (125 MHz, CDCl₃): δ = 156.0, 133.0, 131.9, 129.7, 129.3, 128.5, 128.4, 128.2, 122.9, 121.2, 117.9, 112.3, 88.7, 86.0, 69.2, 62.0; IR (neat,

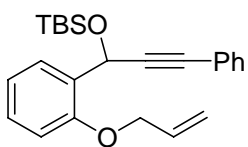
cm^{-1}) = 3413, 3079, 2870, 2198, 1560, 1490; HRMS (ESI): Calcd. For $\text{C}_{18}\text{H}_{16}\text{O}_2\text{Na}$ (m/z): 287.1043. Found 287.1038 $[\text{M}+\text{Na}]^+$.

10-Hydroxy-1-phenyl-4,4a-dihydro-3H,10H-5-oxabenzofazulen-2-one (8).



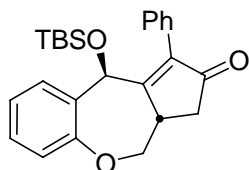
The Pauson-Khand cyclization was carried out according to the general procedures **3.1.3.2** and **3.1.3.3**. The enyne **5** (200 mg, 0.76 mmol) was dissolved in 10 mL of the appropriate solvent and $\text{Co}_2(\text{CO})_8$ (285 mg, 0.83 mmol) and NMO (975 mg, 8.30 mmol) were added following the general procedures. The crude product was purified by flash chromatography (silica gel, *n*-hexane/EtOAc, 90:10) to afford **8** (17.6 mg, 8% using procedure **3.1.3.2** and 70.0 mg, 31% using procedure **3.1.3.3**) as a light yellow waxy solid. ^1H NMR (500 MHz): δ = 7.57 (m, 4H), 7.09 (m, 5H), 5.59 (d, J = 6.0 Hz, 1H), 4.68 (dd, J = 5.5, 11.5 Hz, 1H), 3.99 (m, 1H), 3.67 (app.t, J = 10.5 Hz, 1H), 2.97 (d, J = 6.0 Hz, 1H), 2.75 (dd, J = 7.0, 19.0 Hz, 1H), 2.09 (d, J = 20.0 Hz, 1H); ^{13}C NMR (125 MHz): δ = 205.5, 171.1, 159.8, 140.2, 132.1, 130.6, 130.5, 130.1, 129.4, 128.5, 128.5, 125.1, 123.0, 76.7, 72.3, 39.3, 37.1; IR (neat, cm^{-1}) = 3418, 3058, 2953, 1702, 1601, 1486, 1016; HRMS (ESI): Calcd. For $\text{C}_{19}\text{H}_{16}\text{O}_3\text{Na}$ (m/z): 315.0991. Found 315.0988 $[\text{M}+\text{Na}]^+$; and Calcd. for $\text{C}_{38}\text{H}_{32}\text{O}_6\text{Na}$ (m/z): 607.2091. Found 607.2089 $[2\text{M}+\text{Na}]^+$; Calcd. for $\text{C}_{19}\text{H}_{17}\text{O}_3$ (m/z): 293.1178. Found 293.1166 $[\text{M}+\text{H}]^+$.

2-(-1-*tert*-Butyldimethylsilyloxy -3-phenyl-2-propynyl)-(2-propenyloxy)benzene (9)



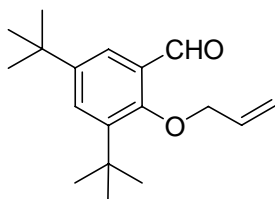
Tert-Butyldimethylsilyl chloride (1.51 g, 1.00 mmol) was added at room temperature to a mixture of **5** (880 mg, 3.33 mmol) and imidazole (600 mg, 1.00 mmol) in DMF (10 mL). Then the mixture was heated at 50 °C for 4.5 h. The reaction was quenched by the addition of NaHCO₃ and extracted with Et₂O. The organic layer separated, washed with water, brine and dried with Na₂SO₄ (anhydrous). The organic layer was concentrated to give a dark colored liquid. The crude product was purified by flash chromatography (SiO₂, hexane/EtOAc, 19:1) to give **9** (1.21 g, 96%) as viscous brown liquid. ¹H NMR (500 MHz): δ = 7.76 (dd, *J* = 1.4, 7.3 Hz, 1H), 7.42 (dd, *J* = 2.3, 4.1 Hz, 2H), 7.29 (m, 4H), 7.02 (t, *J* = 7.3 Hz, 1H), 6.88 (d, *J* = 7.8 Hz, 1H), 6.07 (m, 2H), 5.48 (dq, *J* = 1.4, 17.4 Hz, 1H), 5.29 (dq, *J* = 1.4, 10.5 Hz, 1H), 4.63 (app. t, *J* = 4.6 Hz, 2H), 0.99 (s, 9H), 0.29 (s, 3H), 0.20 (s, 3H). ¹³C NMR (125 MHz): δ = 154.9, 133.5, 131.7, 130.7, 128.8, 128.3, 128.1, 127.6, 123.5, 121.0, 117.3, 111.8, 90.7, 84.2, 69.0, 59.9, 26.0, 18.5, -4.4, -4.7; IR (neat, cm⁻¹) = 3080, 2929, 2857, 2175, 1601, 1490; HRMS (ESI): Calcd. for C₂₄H₃₀O₂SiNa (*m/z*): 401.1907. Found 401.1902 [M+Na]⁺.

10-*tert*-Butyldimethylsilyloxy-1-phenyl-4,4a-dihydro-3H,10H-5-oxabenzof]azulen-2-One (10).



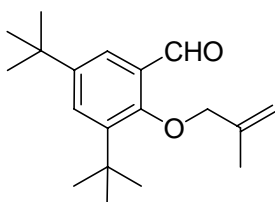
The Pauson-Khand cyclization was carried out according to the general procedures **3.1.3.2** and **3.1.3.3**. The enyne **9** (200 mg, 0.53 mmol) was dissolved in 10 mL of appropriate solvent, $\text{Co}_2(\text{CO})_8$ (200 mg, 0.58 mmol) and NMO (680 mg, 5.85 mmol) were added following the general procedures. The crude product was purified by flash chromatography (hexane/EtOAc, 90:10) to afford **10** (110 mg, 50%) using procedure **C** as a light brown waxy solid. Procedure **B** gave no cyclized product with only starting material being recovered. ^1H NMR (500 MHz): δ = 7.36 (m, 3H), 7.26 (dt, J = 1.8, 9.2 Hz, 1H), 7.19 (dd, J = 1.8, 7.3 Hz, 1H), 7.10 (m, 2H), 7.08 (d, J = 7.3 Hz, 1H), 7.03 (d, J = 7.8 Hz, 1H), 5.63 (s, 1H), 4.71 (d, J = 7.5 Hz, 1H), 3.86 (m, 2H), 2.79 (dd, J = 6.4, 18.8 Hz, 1H), 2.27 (d, J = 18.8 Hz, 1H), 0.80 (s, 9H), -0.07 (s, 3H), -0.18 (s, 3H); ^{13}C NMR (125 MHz): δ = 206.1, 172.3, 160.4, 139.0, 131.0, 130.9, 130.7, 130.1, 129.1, 128.4, 123.8, 122.5, 110.9, 72.6, 60.2, 40.2, 38.1, 25.8, 18.1, -4.6, -4.8; IR (neat, cm^{-1}) = 2954, 1711, 1486, 1251, 1068, 836; HRMS (ESI): Calcd. For $\text{C}_{25}\text{H}_{31}\text{O}_3\text{Si}$ (m/z): 407.2037. Found 407.2030 $[\text{M}+\text{H}]^+$; and Calcd. For $\text{C}_{25}\text{H}_{30}\text{O}_3\text{SiNa}$ (m/z): 429.1856. Found 429.1858 $[\text{M}+\text{Na}]^+$.

3,5-Di-*tert*-butyl-2-(-2-propenyloxy)benzaldehyde (**12**)



Allyl bromide (1.29 g, 11.0 mmol) was added to a suspension of K_2CO_3 (2.00 g, 14.4 mmol) and 3,5-di-*tert*-butyl-2-hydroxybenzaldehyde (2.50 g, 11.0 mmol) in DMF (50 mL) and stirred at room temperature for 12 h according to the general procedure 3.1.1. The crude product was purified by flash chromatography (hexane/EtOAc, 15:1) to give **12** as a light yellow oil (2.72 g, 93%). 1H NMR (500 MHz): δ = 10.29 (s, 1H), 7.74 (d, J = 2.8 Hz, 1H), 7.65 (d, J = 2.8 Hz, 1H), 6.08 (ddt, J = 4.6, 11.0, 17.0 Hz, 1H), 5.51 (dq, J = 1.8, 17.0 Hz, 1H), 5.31 (dq, J = 1.4, 10.5 Hz, 1H), 4.47 (dt, J = 1.4, 5.0 Hz, 2H), 1.42 (s, 9H), 1.31 (s, 9H); ^{13}C NMR (125 MHz): δ = 190.9, 159.8, 146.5, 143.1, 140.3, 132.9, 130.9, 129.4, 123.9, 117.5, 79.4, 35.4, 31.4, 30.9; IR (neat, cm^{-1}): 2962, 2871, 1690, 1472, 1231, 928; HRMS (ESI): Calcd. for $C_{18}H_{26}O_2$ (m/z): Calcd. For $C_{18}H_{27}O_2$ (m/z): 275.2006. Found 275.1995 $[M+H]^+$.

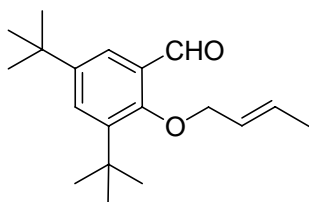
3,5-Di-*tert*-butyl-2-(2-methyl-2-propenyloxy)benzaldehyde (**13**)



3-Chloro-2-methylpropene (1.16 g, 18.0 mmol) was added to a suspension of K_2CO_3 (2.00 g, 14.4 mmol) and 3,5-di-*tert*-butyl-2-hydroxybenzaldehyde (1.00 g, 4.26 mmol) in DMF (10 mL) and stirred for 12 h according to the general procedure 3.1.1. The crude product was purified by flash chromatography (hexane/EtOAc, 15:1) to give **13** (1.21 g, 98%) as a light yellow solid: mp. 49-51 °C, 1H NMR (500 MHz): δ = 10.29 (s, 1H), 7.74 (d, J = 2.7 Hz, 1H), 7.65 (d, J = 2.7 Hz, 1H), 5.55 (s, 1H), 5.35 (s, 1H), 4.36 (s, 2H), 1.85 (s,

3H), 1.42 (s, 9H), 1.31 (s, 9H); ^{13}C NMR (125 MHz): $\delta = 191.2, 159.6, 146.5, 143.1, 140.4, 130.9, 129.4, 123.6, 110.2, 82.2, 35.4, 34.8, 31.4, 30.9, 19.6$; IR (neat, cm^{-1}) = 2962, 2869, 1688, 1597, 1478, 993, 896; HRMS (CI): Calcd. For $\text{C}_{19}\text{H}_{28}\text{O}_2^+$ (m/z): 288.2084. Found 288.2082 $[\text{M}]^+$.

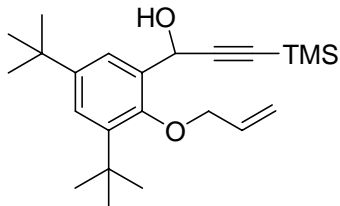
3,5-Di-*tert*-butyl-2-(3-methyl-2-propenyloxy) benzaldehyde (**14**)



Crotyl chloride (95% *trans*, 1.16 g, 18.0 mmol) was added to a suspension of K_2CO_3 (2.00 g, 14.4 mmol) and 3,5-di-*tert*-butyl-2-hydroxybenzaldehyde (1.00 g, 4.26 mmol) in DMF (10 mL) and stirred for 12 h according to the general procedure 3.1.1. The crude product was purified by flash chromatography (hexane/EtOAc, 15:1) to give **14** (1.22 g, 99%) as a brown oil. The proton NMR spectrum indicated that it was a 5:1 mixture of the *E/Z*-isomers. ^1H NMR of the major isomer (500 MHz): $\delta = 10.29$ (s, 1H), 7.69 (d, $J = 2.7$ Hz, 1H), 7.58 (d, $J = 2.3$ Hz, 1H), 5.88 (m, 1H), 5.80 (m, 1H), 4.39 (dd, $J = 1.4, 6.0$ Hz, 2H), 1.78 (dd, $J = 1.4, 6.4$ Hz, 3H), 1.42 (s, 9H), 1.31 (s, 9H); ^{13}C NMR (125 MHz): $\delta = 191.2, 160.0, 146.4, 143.1, 130.9, 130.7, 129.5, 126.0, 123.8, 79.7, 35.4, 34.8, 31.4, 31.0, 18.0$; IR (neat, cm^{-1}) = 2958, 1690, 1593, 1460, 1374, 1220, 970; HRMS (ESI): Calcd. For $\text{C}_{19}\text{H}_{28}\text{NaO}_2^+$ (m/z): 311.1981. Found 311.1951 $[\text{M}+\text{Na}]^+$.

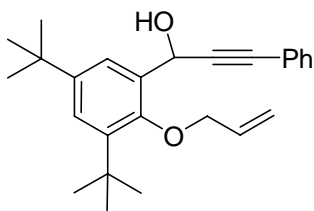
4,6-Di-*tert*-butyl-2-(1-hydroxy-3-trimethylsilyl-2-propynyl)-(-2-propenyloxy)

benzene (**15a**)



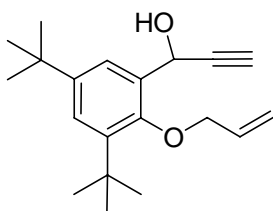
A solution of trimethylsilylethynylmagnesium chloride in dry THF was prepared by adding ethynyltrimethylsilane (2.47 g, 25.0 mmol) to 3.0 M solution of ethylmagnesium chloride (8.40 mL, 25.0 mmol.) in THF under N₂ at 0 °C and stirred for 30 minutes before allowing the reaction to warm up to room temperature and stirred for additional 10 minutes. To this thus prepared solution of trimethylsilylethynylmagnesium chloride, was added a solution of **12** (3.00 g, 11.0 mmol) in dry THF (20 mL) under N₂ atmosphere at -78 °C. The reaction mixture was stirred for 2.5 h at -78 °C before allowing to warm up to rt. The reaction was then stirred overnight and worked up according to the general procedure 3.1.2 to give **15a** (3.05 g, 75%) as a light yellow solid, mp: 94-95 °C. ¹H NMR (500 MHz): δ = 7.61 (d, *J* = 2.3 Hz, 1H), 7.35 (d, *J* = 2.3 Hz, 1H), 6.09 (ddt, *J* = 5.0, 10.5, 17.0 Hz, 1H), 5.73 (d, *J* = 5.5 Hz, 1H), 5.52 (dq, *J* = 1.4, 17.0 Hz, 1H), 5.28 (dq, *J* = 1.4, 10.5 Hz, 1H), 4.64 (ddt, *J* = 1.8, 5.0, 13.0 Hz, 1H), 4.43 (ddt, *J* = 1.8, 5.0, 13.0 Hz, 1H), 2.50 (d, *J* = 5.5 Hz, 1H), 1.41 (s, 9H), 1.30 (s, 9H), 0.19 (s, 9H); ¹³C NMR (125 MHz): δ = 153.4, 146.5, 142.3, 134.0, 133.9, 125.19, 124.1, 116.7, 106.0, 91.1, 76.1, 60.6, 35.6, 34.8, 31.5, 31.3, -0.09; IR (neat, cm⁻¹) = 3454, 2960, 2172; HRMS (ESI): Calcd. for C₂₃H₃₆O₂SiNa (*m/z*): 395.2377. Found 395.2373 [M+Na]⁺.

4,6-Di-*tert*-butyl-2-(1-hydroxy-3-phenyl-2-propynyl)-2-propenyloxybenzene (**15b**)



1.0M solution of phenylethynglymagnesium bromide (15.0 mL, 15.0 mmol) was added at 0 °C to the solution of **12** (3.00 g, 11.0 mmol) in dry THF (20 mL) under N₂ atmosphere according to the general procedure 3.1.2 to give **15b** (3.07 g, 75%) as a light yellow solid, mp 92-93 °C. ¹H NMR (500 MHz): δ = 7.69 (d, *J* = 2.8 Hz, 1H), 7.46 (m, 2H), 7.38 (d, *J* = 2.8 Hz, 1H), 7.30 (m, 3H), 6.13 (ddt, *J* = 4.6, 11.0, 17.0 Hz, 1H), 5.98 (s, 1H), 5.55 (dq, *J* = 1.8, 17.4 Hz, 1H), 5.32 (dq, *J* = 1.8, 10.5 Hz, 1H), 4.65 (ddt, *J* = 1.8, 4.6, 13.3 Hz, 1H), 4.50 (ddt, *J* = 1.8, 4.6, 13.3 Hz, 1H), 2.58 (d, *J* = 5.5 Hz, 1H), 1.44 (s, 9H), 1.34 (s, 9H); ¹³C NMR (125 MHz): δ = 171.3, 153.3, 146.6, 142.4, 134.4, 133.9, 131.8, 128.4, 125.1, 123.9, 122.8, 116.8, 89.7, 86.1, 76.3, 60.6, 35.6, 34.8, 31.6, 31.3; IR (neat, cm⁻¹) = 3414, 2959, 2223, 1479, 1280; HRMS (ESI): Calcd. for C₂₆H₃₃O₂ (*m/z*): 377.2475. Found 377.2471 [M+H]⁺.

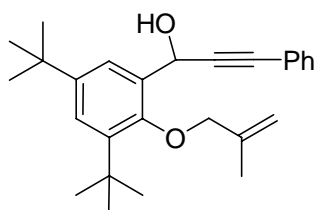
4,6-Di-*tert*-butyl-2-(1-hydroxy-2-propynyl)-(2-propenyloxy)benzene (**15c**)



0.5 M solution of ethynylmagnesium bromide (30.0 mL, 15.0 mmol) THF was added to a solution of **12** (2.72 g, 9.92 mmol.) in dry THF (20 mL) under N₂ atmosphere at 0 °C according to the general procedure 3.1.2 to give **15c** (2.75 g, 92%) as a light yellow solid, mp: 95-96 °C. ¹H NMR (500 MHz): δ = 7.58 (d, *J* = 2.8 Hz, 1H), 7.36 (d, *J* = 2.3 Hz, 1H), 6.10 (ddt, *J* = 4.6, 11.0, 17.0 Hz, 1H), 5.76 (d, *J* = 2.3, 1H), 5.55 (dq, *J* = 1.8, 17.0, 1H), 5.30 (dq, *J* = 1.4, 10.5, 1H), 4.59 (ddt, *J* = 1.8, 4.6, 13.3 Hz, 1H),

4.43 (ddt, $J = 1.8, 5.0, 13.3$ Hz, 1H), 2.62 (d, $J = 1.8$ Hz, 1H), 2.46 (s, 1H), 1.41 (s, 9H), 1.30 (s, 9H); ^{13}C NMR (125 MHz): $\delta = 153.2, 146.7, 142.4, 133.8, 125.3, 123.6, 116.8, 84.6, 76.1, 74.3, 59.8, 35.6, 34.8, 31.6, 31.3$ (only 15 signals out of 16 carbon types were observed); IR (neat, cm^{-1}) = 3304, 2960, 2219, 1470, 1281, 989; HRMS (CI): Calcd. for $\text{C}_{20}\text{H}_{28}\text{O}_2$ (m/z): 300.2089. Found 300.2091 $[\text{M}]^+$.

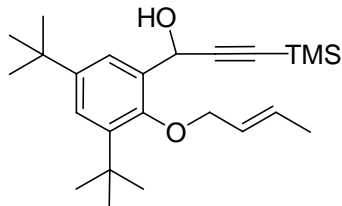
4,6-Di-*tert*-butyl-2-(-1-hydroxy-3-phenyl-2-propynyl)-(2-methyl-2-propenyloxy) benzene (16b)



A 1.0 M solution of phenylethynylmagnesium bromide (15.6 mL, 16.0 mmol.) in THF was added to a solution of **13** (3.00 g, 10.0 mmol.) in THF (20 mL) under N_2 atmosphere at $0\text{ }^\circ\text{C}$ according to the general procedure 3.1.2 to give **16b** (4.00 g, 98%) as a light yellow solid, mp: $49\text{-}51\text{ }^\circ\text{C}$. ^1H NMR (500 MHz): $\delta = 7.71$ (d, $J = 2.7$ Hz, 1H), 7.45 (m, 2H), 7.37 (d, $J = 2.7$ Hz, 1H), 7.30 (m, 3H), 6.01 (s, 1H), 5.30 (s, 1H), 5.05 (s, 1H), 4.59 (d, $J = 13.1$ Hz, 1H), 4.41 (d, $J = 13.1$ Hz, 1H), 2.62 (s, 1H), 1.89 (s, 3H), 1.45 (s, 9H), 1.37 (s, 9H); ^{13}C NMR (125 MHz): $\delta = 153.4, 146.6, 142.4, 141.5, 134.3, 131.8, 128.6, 128.4, 125.1, 123.9, 122.8, 111.4, 90.0, 86.1, 78.6, 60.5, 35.6, 34.9, 31.6, 31.3, 19.7$; IR (neat, cm^{-1}) = 3452, 2963, 2908, 2224, 1658, 1599; HRMS (ESI): Calcd. for $\text{C}_{27}\text{H}_{34}\text{O}_2\text{Na}^+$ (m/z): 413.2451. Found 413.2442 $[\text{M}+\text{Na}]^+$; Calcd. for $\text{C}_{54}\text{H}_{68}\text{O}_4\text{Na}^+$ (m/z): 803.5015. Found 803.5058 $[2\text{M}+\text{Na}]^+$.

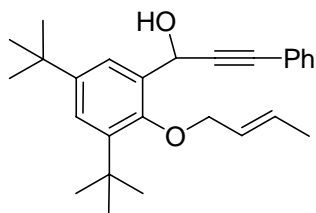
4,6-Di-*tert*-butyl-2-(-1-hydroxy-3-trimethylsilyl-2-propynyl)-1-(-2-butenyloxy)

benzene (**17a**)



A solution of trimethylsilylethynylmagnesium chloride in dry THF was prepared by adding ethynyltrimethylsilane (2.47 g, 25.0 mmol) to 3.0 M solution of ethylmagnesiumchloride (8.27 mL, 25.0 mmol) THF under N₂ at 0 °C and stirred for 30 minutes before allowing the reaction to warm up to room temperature. The reaction was further stirred for 10 minutes at room temperature. To this aliquot of trimethylsilylethynylmagnesium chloride was added a solution of **14** (2.27 g, 7.87 mmol.) in THF (20 mL) under N₂ atmosphere at -78 °C and stirred for 2.5 h at -78 °C before allowing it to warm up to rt. This was then stirred overnight and then worked up according to the general procedure 3.1.2 to give **17a** (3.00 g, 99%) as a light yellow waxy solid; ¹H NMR (500 MHz): δ = 7.54 (d, *J* = 2.7 Hz, 1H), 7.27 (d, *J* = 2.3 Hz, 1H), 5.84 (m, 1H), 5.75 (m, 1H), 5.68 (s, 1H), 4.47 (dd, *J* = 6.0, 11.5 Hz, 1H), 4.35 (dd, *J* = 6.0, 11.5 Hz, 1H), 1.71 (d, *J* = 6.4 Hz, 3H), 1.34 (s, 9H), 1.25 (s, 9H), 0.12 (s, 9H); ¹³C NMR (125 MHz): δ = 153.5, 146.3, 142.2, 134.1, 129.6, 126.8, 125.1, 124.0, 106.0, 90.9, 76.2, 60.8, 35.5, 34.7, 31.5, 31.3, 18.0, -0.1; IR (neat, cm⁻¹) = 3361, 2960, 2172, 1462; HRMS (ESI): Calcd. For C₄₈H₇₆O₄Si₂Na⁺ (*m/z*): 795.5178. Found 795.5212 [2M+Na]⁺.

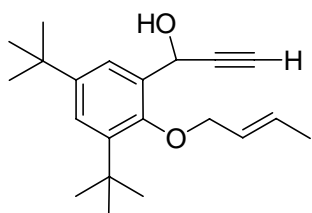
4,6-Di-*tert*-butyl-2-(-1-hydroxy-3-phenyl-2-propynyl)-(2- butenyloxy)benzene (**17b**)



A 1.0 M solution in THF of phenylethyne magnesium bromide (15.6 mL, 16.0 mmol) was added to the solution of **14** (3.0 g, 10.0 mmol) in dry THF (20 mL) under N₂ atmosphere at 0 °C according to the general procedure 3.1.2

to give **17b** (3.00 g, 74%) as a light yellow liquid; ¹H NMR (500 MHz): δ = 7.75 (d, *J* = 2.3 Hz, 1H), 7.49 (m, 2H), 7.44 (d, *J* = 2.7 Hz, 1H), 7.32 (m, 3H), 6.03 (d, *J* = 4.0 Hz, 1H), 5.98 (m, 1H), 5.88 (m, 1H), 4.59 (dd, *J* = 6.0, 7.3 Hz, 1H), 4.44 (dd, *J* = 6.0, 7.3 Hz, 1H), 2.85 (d, *J* = 5.0 Hz, 1H), 1.80 (d, *J* = 5.5 Hz, 3H), 1.44 (s, 9H), 1.37 (s, 9H); ¹³C NMR (125 MHz): δ = 153.4, 146.5, 142.4, 134.4, 131.8, 129.8, 128.5, 128.4, 126.9, 125.2, 123.8, 122.8, 89.9, 86.1, 76.4, 60.8, 35.6, 34.8, 31.6, 31.4, 18.0; IR (neat, cm⁻¹) = 3357, 2955, 2179, 1463, 1374, 1223; HRMS (ESI): Calcd. for C₂₇H₃₄O₂Na (*m/z*): 413.2451. Found 413.2461 [M+Na]⁺.

4,6-Di-*tert*-butyl-2-(-1-hydroxy-2-propynyl)-1-(-2- butenyloxy)benzene (**17c**)

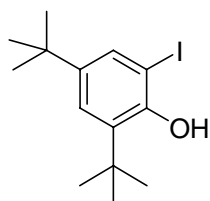


A 0.5 M solution in THF of ethynylmagnesium bromide (12.7 mL, 6.35 mmol.) was added at 0 °C to the solution of **14** (1.22 g, 4.23 mmol.) in dry THF (10 mL) under N₂ atmosphere according to the general procedure 3.1.2 to give

17c as a viscous brown liquid (1.32 g, 99%). ¹H NMR (300 MHz): δ = 7.56 (d, *J* = 2.3 Hz, 1H), 7.35 (d, *J* = 2.7 Hz, 1H), 5.91 (q, *J* = 6.2 Hz, 1H), 5.81 (dt, *J* = 1.0, 5.5 Hz, 1H), 5.77 (d, *J* = 2.1 Hz, 1H), 4.51 (ddt, *J* = 1.0, 5.5, 11.7 Hz, 1H), 4.34 (ddt, *J* = 1.0,

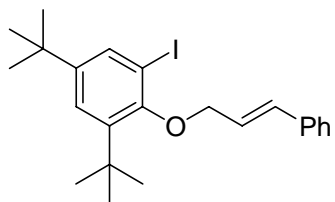
5.9, 11.7 Hz, 1H), 2.61 (d, $J = 2.4$ Hz, 1H), 1.78 (d, $J = 5.2$ Hz, 3H), 1.40 (s, 9H), 1.32 (s, 9H); ^{13}C NMR (75 MHz): $\delta = 153.3, 146.6, 142.4, 133.7, 129.8, 126.7, 125.3, 123.5, 84.4, 76.3, 74.2, 60.1, 35.6, 34.8, 31.5, 31.3, 18.0$; IR (neat, cm^{-1}) = 3298, 2958, 2103, 1602, 1277; HRMS (ESI): Calcd. for $\text{C}_{42}\text{H}_{60}\text{O}_4\text{Na}^+$ (m/z): 651.4384. Found 651.4334 $[\text{2M}+\text{Na}]^+$.

4,6-Di-tert-butyl-2-iodophenol (**19**)^{80, 87}



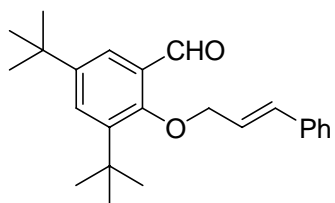
To a stirred solution of 2,4-di-tert-butylphenol (0.50 g, 2.4 mmol) in DMF (80 mL), a dropwise addition of *N*-iodosuccinimide (0.66 g, 3.0 mmol) in acetone (20 mL) was done. The reaction mixture was stirred at 0 °C for 8 h. H_2O (50 mL) was added and the resulting solution was extracted with EtOAc (3x25 mL). The organic phase was combined and treated with 0.1 M HCl (50 mL), washed with saturated NaHCO_3 (50 mL), dried (MgSO_4) and concentrated under reduced pressure. The crude product was purified *via* flash chromatography (SiO_2 , hexane) to afford the **19** (0.55 g, 68%) as a solid: mp: 76-78 °C (lit.^{69, 76} 77-79 °C); ^1H NMR (500 MHz): $\delta = 7.48$ (d, $J = 2.3$ Hz, 1H), 7.25 (d, $J = 2.3$ Hz, 1H), 5.36 (s, 1H), 1.37 (s, 9H), 1.26 (s, 9H); ^{13}C NMR (125 MHz): $\delta = 150.5, 145.1, 136.3, 132.7, 125.1, 89.4, 35.7, 34.3, 31.6, 29.4$.

1,5-Di-tert-butyl-3-iodo-2-(3-phenyl-2-propenyloxy)benzene (*E*-isomer, **20**)



A solution of diethyl azodicarboxylate (15.7 g, 90.4 mmol) in dry THF (50 mL) was added dropwise to a solution of iodophenol **19** (10.0 g, 30.1 mmol), cinnamyl alcohol (8.08 g, 60.2 mmol) and PPh₃ (23.7 g, 90.4 mmol) in dry THF (100 mL) at 0 °C and stirred for 3 h. The solvent was removed in vacuo at the end of the reaction. The crude product was purified by flash chromatography (hexane) to give the product **20** (12.4 g, 92.0 %) as a white solid, mp: 120-122 °C; ¹H NMR (300 MHz): δ = (*E*-isomer) 7.69 (d, *J* = 2.41 Hz, 1H), 7.26-7.50 (m, 6H), 6.82 (d, *J* = 15.8 Hz, 1H), 6.50 (dt, *J* = 5.5, 16.2 Hz, 1H), 4.69 (d, *J* = 5.5 Hz, 2H), 1.43 (s, 9H), 1.31 (s, 9H); ¹³C NMR (75 MHz): δ = 155.1, 148.2, 143.9, 136.9, 135.4, 132.6, 128.7, 127.9, 126.7, 125.3, 124.9, 93.4, 73.9, 34.5, 34.0, 31.5, 31.3; IR (neat, cm⁻¹) = 3100, 2960, 2872, 1772, 1434, 1394, 1234, 1087, 963; HRMS (CI): Calcd. for C₂₃H₂₉IO (*m/z*): 448.1257. Found 448.1218 [M⁺].

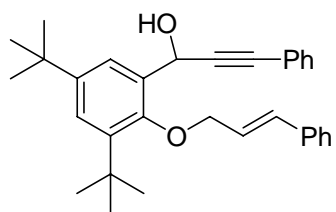
3,5-Di-tert-butyl-2-(3-phenyl-2-propenyloxy) benzaldehyde (**21**)



A solution of 1,5-di-tert-butyl-3-iodo-2-(3-phenyl-2-propenyloxy)benzene **20** (5.00 g, 11.2 mmol) in dry THF (20 mL) was cooled to -30 °C and 2.0 M solution of *i*-propylmagnesium chloride (1.38 g, 13.5 mmol) in THF was added and the reaction mixture stirred for 20 minutes at -30 °C. The reaction was then allowed to warm up to room temperature and stirred for 20 min. Next the reaction mixture was cooled to 0 °C and DMF (1.30 mL, 16.7 mmol) was added dropwise. The reaction was warmed up to

room temperature and stirred for 2 h. The reaction was quenched with water and extracted with CH₂Cl₂. The organic layer was separated, concentrated under reduced pressure and dried (MgSO₄). The crude product was purified by flash chromatography (SiO₂, hexane/EtOAc, 5:1) to give **21** (4.51 g, 98%) as white solid, mp: 123-125 °C; ¹H NMR (300 MHz): δ = (*E*-isomer) 10.37 (s, 1H), 7.73 (d, *J* = 2.4 Hz, 1H), 7.65 (d, *J* = 2.4 Hz, 1H), 7.26-7.47 (m, 5H), 6.80 (d, *J* = 15.8 Hz, 1H), 6.50 (dt, *J* = 5.5, 16.2 Hz, 1H), 4.64 (d, *J* = 5.9 Hz, 2H), 1.46 (s, 9H), 1.33 (s, 9H); ¹³C NMR (75 MHz): δ = 191.0, 159.8, 146.6, 143.2, 136.4, 133.0, 131.0, 129.4, 128.8, 128.1, 126.8, 124.1, 124.0, 79.4, 35.5, 34.8, 31.4, 31.0; IR (neat, cm⁻¹) = 3049, 2920, 2150, 1667, 1592, 1485, 1362, 1231, 915, 755, 687; HRMS (ESI): Calcd. for C₂₄H₃₁O₂ (*m/z*): 351.2319. Found 351.2325 [M+H]⁺.

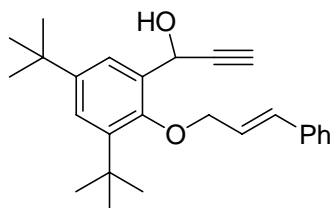
4,6-Di-*tert*-butyl-2-(1-hydroxy-3-phenyl-2-propynyl)-1-(-3-phenyl-2-propenyloxy) benzene (22b)



1.0 M solution of phenylethyneylmagnesium bromide (8.59 mL, 8.59 mmol) in THF was added at 0 °C to a solution of **21** (2.00 g, 5.71 mmol.) in dry THF (20 mL) under N₂ atmosphere. The reaction mixture was allowed to warm up to room temperature and stirred for 3 h. The reaction was quenched with NH₄Cl and extracted with CH₂Cl₂. The organic extract was washed with water, dried (Na₂SO₄) and concentrated under reduced pressure. The crude product was purified by flash chromatography (SiO₂, hexane/EtOAc, 10:1) to give **22b** (2.0 g, 78%) as a white solid. Mp: 133-134 °C; ¹H

NMR (500 MHz): δ = 7.25-7.70 (m, 12H), 6.84 (d, J = 16.0 Hz, 1H), 6.49 (dt, J = 5.5, 15.6 Hz, 1H), 6.04 (s, 1H), 4.81 (ddd, J = 1.8, 5.5, 12.8 Hz, 1H), 4.65 (ddd, J = 1.8, 5.5, 12.8 Hz, 1H), 2.60 (s, 1H), 1.45 (s, 9H), 1.36 (s, 9H); ^{13}C NMR (75 MHz): δ = 153.3, 146.7, 142.4, 136.8, 134.4, 132.2, 131.8, 128.7, 128.6, 128.5, 128.4, 127.9, 126.7, 125.3, 125.2, 123.9, 89.8, 86.2, 76.1, 60.7, 35.7, 34.8, 31.6, 31.4; IR (neat, cm^{-1}) = 3441, 2961, 1599, 1444, 1362, 1222, 1159, 1119, 965, 883, 756; HRMS (ESI): Calcd. for $\text{C}_{24}\text{H}_{31}\text{O}_2$ (m/z): 475.2608. Found 475.2613 $[\text{M}+\text{Na}]^+$.

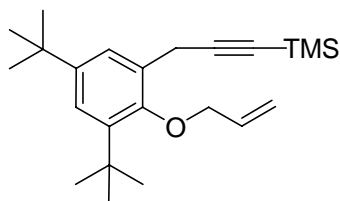
4,6-Di-*tert*-butyl-2-(1-hydroxy-2-propynyl)-1-(3-phenyl-2-propenyloxy) benzene (22c)



A 0.5 M solution of ethynylmagnesium bromide (17.2 mL, 8.61 mmol) in THF was added at 0 °C to the solution of **21** (2.00 g, 5.71 mmol) in dry THF (20 mL) under N_2 atmosphere. The reaction mixture was allowed to warm up to rt and stirred for 3 h. The reaction was quenched with NH_4Cl and extracted with CH_2Cl_2 . The organic extract was washed with water, dried (Na_2SO_4) and concentrated under reduced pressure. The crude product was purified by flash chromatography (SiO_2 , hexane/EtOAc, 10:1) to give **22c** (3.11 g, 99%) as a yellow solid, mp: 136-138 °C; ^1H NMR (300 MHz): δ = 7.26-7.61 (m, 7H), 6.81 (d, J = 15.6 Hz, 1H), 6.46 (dt, J = 5.4, 16.2 Hz, 1H), 5.84 (s, 1H), 4.74 (ddd, J = 1.5, 5.7, 13.2 Hz, 1H), 4.58 (ddd, J = 1.5, 5.7, 13.2 Hz, 1H), 2.64 (d, J = 1.2 Hz, 1H), 2.52 (s, 1H), 1.44 (s, 9H), 1.34 (s, 9H); ^{13}C NMR (75 MHz): δ = 153.3, 146.8, 142.4, 136.7, 133.8, 132.2, 128.7, 127.9, 126.7, 125.4, 125.0, 123.6, 84.5, 76.1, 74.4,

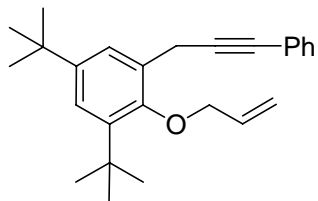
59.9, 35.7, 34.9, 31.6, 31.4; IR (neat, cm^{-1}) = 3550, 3279, 2962, 2159, 1476, 1362, 1230, 1159, 1118, 1021, 965, 884, 748; HRMS (ESI) Calcd. for $\text{C}_{26}\text{H}_{36}\text{O}_2\text{Na}^+$ (m/z): 399.2295. Found 399.2293 $[\text{M}+\text{Na}]^+$.

4,6-Di-*tert*-butyl-2-(3-trimethylsilyl-2-propynyl)-(-2-propenyloxy) benzene (**26a**)



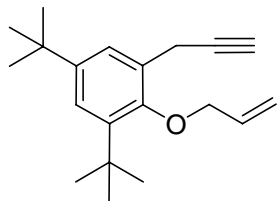
Triethylsilane (1.24 g, 10.7 mmol) was added at room temperature to a solution of **15a** (1.98 g, 5.30 mmol) in CH_2Cl_2 (10 mL) under N_2 atmosphere. Then trifluoroacetic acid (2.43 g, 21.3 mmol) was added and the reaction was stirred for 20 minutes. The reaction mixture was quenched with aqueous NaHCO_3 and extracted with dichloromethane (2 x 10mL) to give a yellow liquid after removal of the solvent. The crude product purified by flash chromatography (hexane/EtOAc, 95:5) to give **26a** as a light yellow liquid (1.87 g, 99.0%). ^1H NMR (500 MHz): δ = 7.47 (d, J = 2.5 Hz, 1H), 7.25 (d, J = 2.5 Hz, 1H), 6.05 (ddt, J = 5.0, 10.5, 17.0 Hz, 1H), 5.49 (dq, J = 1.8, 17.0 Hz, 1H), 5.26 (dq, J = 1.8, 10.5 Hz, 1H), 4.35 (dt, J = 1.8, 5.0 Hz, 2H), 3.64 (s, 2H), 1.39 (s, 9H), 1.32 (s, 9H), 0.18 (s, 9H); ^{13}C NMR (75 MHz): δ = 153.6, 145.9, 141.9, 133.9, 129.5, 125.4, 123.1, 116.5, 105.5, 86.8, 73.9, 35.5, 34.8, 31.6, 31.3, 21.4, 0.2; IR (neat, cm^{-1}) = 2960, 2874, 2177; HRMS (ESI): Calcd. For $\text{C}_{23}\text{H}_{37}\text{OSi}$ (m/z): 357.2608. Found 357.2618 $[\text{M}+\text{H}]^+$.

4,6-Di-*tert*-butyl-2-(3-phenyl-2-propynyl)-2-propenyloxybenzene(26b)



Triethylsilane (1.24 g, 10.7 mmol) was added at room temperature to a solution of **15b** (2.0 g, 5.3 mmol) in CH₂Cl₂ (10 mL) under N₂ atmosphere. Then trifluoroacetic acid (2.43 g, 21.3 mmol) was added and stirred for 20 minutes. The reaction mixture was quenched with aqueous NaHCO₃ and extracted with CH₂Cl₂ (2 x 10mL) to give a yellow liquid. The crude product was purified by flash chromatography (hexane/EtOAc, 95:5) to give **26b** as a light yellow liquid (1.87 g, 98%). ¹H NMR (500 MHz): δ = 7.52 (d, *J* = 2.5 Hz, 1H), 7.44 (m, 2H), 7.30 (d, *J* = 2.5 Hz, 1H), 7.29 (d, *J* = 3.0 Hz, 3H), 6.11 (ddt, *J* = 4.6, 11.0, 17.0 Hz, 1H), 5.55 (dq, *J* = 1.8, 17.4 Hz, 1H), 5.32 (dq, *J* = 1.8, 10.5 Hz, 1H), 4.46 (dt, *J* = 1.8, 4.6 Hz, 2H), 3.83 (d, *J* = 5.0 Hz, 2H), 1.46 (s, 9H), 1.38 (s, 9H); ¹³C NMR (125 MHz): δ = 153.6, 146.1, 142.0, 134.0, 131.7, 129.9, 128.3, 127.8, 125.5, 124.0, 123.2, 116.5, 88.7, 82.1, 74.1, 35.5, 34.7, 31.6, 31.3, 20.9; IR (neat, cm⁻¹) = 2959, 2870, 1451, 1225, 991, 755; HRMS (ESI): Calcd. For C₂₆H₃₃O (*m/z*): 361.2526. Found 361.2538 [M+H]⁺, Calcd. For C₂₆H₃₂ONa (*m/z*): 383.2345. Found 383.2360 [M+Na]⁺.

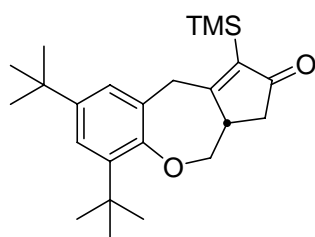
4,6-Di-*tert*-butyl-2-prop-2-ynyl-(2-propenyloxy)benzene (26c)



Triethylsilane (1.24 g, 10.7 mmol) was added at room temperature to the solution of **15c** (1.60 g, 5.30 mmol) in CH₂Cl₂ (10 mL) under N₂ atmosphere. Then trifluoroacetic acid (2.43 g, 21.3 mmol) was added and stirred for 20 minutes. The reaction mixture was quenched

with aqueous NaHCO₃ and then extracted with CH₂Cl₂ (2 x 10mL) to give a yellow liquid. The crude product was purified by flash chromatography (hexane/EtOAc 95:5) to give **26c** as a light yellow liquid (1.45 g, 96%). ¹H NMR (500 MHz, CDCl₃): δ = 7.39 (d, *J* = 2.8 Hz, 1H), 7.25 (d, *J* = 2.8 Hz, 1H), 6.07 (ddt, *J* = 5.0, 10.5, 17.0 Hz, 1H), 5.51 (dq, *J* = 1.8, 17.0 Hz, 1H), 5.29 (dq, *J* = 1.8, 10.5 Hz, 1H), 4.38 (dt, *J* = 1.4, 5.0 Hz, 2H), 3.58 (d, *J* = 2.3 Hz, 2H), 2.12 (t, *J* = 2.8 Hz, 1H), 1.39 (s, 9H), 1.32 (s, 9H); ¹³C NMR (125 MHz, CDCl₃): δ = 148.9, 142.0, 133.5, 128.9, 125.0, 122.9, 116.6, 83.0, 73.9, 69.7, 35.5, 34.6, 31.6, 31.3, 6.7, 5.9; IR (neat, cm⁻¹) = 3312, 2959, 2872, 2176, 1715, 1507; HRMS (CI): Calcd. For C₂₀H₂₈O⁺ (*m/z*): 284.2135. Found 284.2132 [M⁺].

6,8-Di-*tert*-butyl-1-trimethylsilyl-4,4a-dihydro-3*H*,10*H*-5-oxabenzof[*f*]azulen-2-one
(**23**)

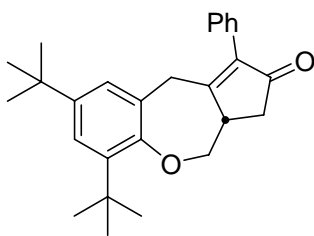


The Pauson-Khand cyclization was carried out according to the general procedures **3.1.3.2** and **3.1.3.3**. The enyne **26a** (124 mg, 0.35 mmol) was dissolved in 10 mL of the appropriate solvent. Co₂(CO)₈ (200 mg, 0.590 mmol) and NMO (408 mg, 3.48 mmol) were added according to the general procedure. The crude product was purified by flash chromatography (silica gel, hexane/EtOAc, 90:10) to afford **23** (75.0 mg, 56% using procedure **3.1.3.2** and 60.0 mg, 45% using procedure **3.1.3.3**) as a yellow solid.

Method II: The cyclization of **15a** (500 mg, 1.34 mmol) in 10 mL CH₂Cl₂ was carried out following the general procedures **3.1.3.1**. Co₂(CO)₈ (506 mg, 1.47 mmol) was added

under N₂ and stirred at room temperature for 5 h. The reaction mixture was then cooled in an ice bath before adding NaBH₄ (153 mg, 4.03 mmol). Subsequently, TFA (15 mL) was added over 10 minutes at 0 °C. The reaction mixture was decanted into 300 mL of iced water and the organic layer was separated, washed with water and dried (Na₂SO₄). The organic layer was concentrated, redissolved in CH₂Cl₂ (10mL) and cooled to 0 °C before NMO (2.08 g, 17.8 mmol) was added in three portions and then left to stir for 2 h. The reaction mixture was then poured into a sintered glass funnel with Celite and SiO₂ pad and washed with EtOAc to remove any remaining product. The filtrates were combined and concentrated. The crude product was purified by flash chromatography (hexane/EtOAc, 20:1.5) to afford **23** (240 mg, 48%) as a yellow solid. Mp: 89-91 °C; ¹H NMR (500 MHz): δ = 7.24 (s, 1H), 7.10 (s, 1H), 4.54 (dd, *J* = 5.3, 5.6 Hz, 1H), 3.91 (s, 2H), 3.41 (m, 1H), 3.24 (t, *J* = 11.4 Hz, 1H), 2.52 (dd, *J* = 7.1, 18.8 Hz, 1H), 1.82 (dd, *J* = 1.6, 18.8 Hz, 1H), 1.38 (s, 9H), 1.30 (s, 9H), 0.31 (s, 9H); ¹³C NMR (125 MHz): δ = 211.8, 184.9, 156.5, 146.3, 141.6, 139.2, 129.6, 125.2, 123.0, 76.0, 47.5, 38.4, 38.2, 35.2, 34.6, 31.6, 30.7, -0.03; IR (neat, cm⁻¹) = 2958.3, 1693.5, 1587.2, 1249.7; HRMS (ESI): Calcd. for C₂₄H₃₆O₂SiNa (M+Na): 407.2377. Found 407.2376, Calcd. for C₂₄H₃₆O₂SiK (M+K): 423.2116. Found 423.2108, Calcd. for C₄₈H₇₂O₄Si₂Na (2M+Na): 791.4861. Found 791.4884.

6,8-Di-*tert*-butyl-1-phenyl-4,4a-dihydro-3*H*,10*H*-5-oxabenzof]azulen-2-one (**24**)



The Pauson-Khand cyclization was carried out according to the general procedures **3.1.3.2** and **3.1.3.3**. The enyne **26b** (130 mg, 0.36 mmol) was dissolved in 10 mL of the appropriate solvent. $\text{Co}_2(\text{CO})_8$ (136 mg, 0.40 mmol) and NMO (460 mg, 3.93 mmol) were added according to the general procedure. The crude product was purified by flash chromatography (silica gel, *n*-hexane/EtOAc, 90:10) to afford **24** (60 mg, 43% using procedure **3.1.3.2** and 64 mg, 46% using procedure **C**) as a yellow solid.

Method II: The cyclization of **15b** (290 mg, 0.77 mmol) in 10 mL CH_2Cl_2 was carried out following the general procedures **3.1.3.1**. $\text{Co}_2(\text{CO})_8$ (136 mg, 0.40 mmol) was added under N_2 and stirred at room temperature for 5 h. The reaction mixture was then cooled in an ice bath before adding NaBH_4 (88.0 mg, 2.31 mmol). Subsequently, TFA (10 mL) was added over 10 minutes at 0 °C. The reaction mixture was decanted into 300 mL of iced water and the organic layer was separated, washed with water and dried (Na_2SO_4). The organic layer was then concentrated, redissolved in CH_2Cl_2 (10 mL) and cooled to 0 °C before NMO (1.22 g, 10.4 mmol) was added in three portions and then left to stir for 2 h. The reaction mixture was then poured into a sintered glass funnel with Celite and SiO_2 pad and washed with EtOAc to remove any remaining product. The filtrates were combined and concentrated. The crude product was purified by flash chromatography (hexane/EtOAc, 20:1.5) to afford **24** (150 mg, 50%) as a yellow solid. Mp: 160-162 °C; ^1H NMR (500 MHz): δ = 7.46 (t, J = 7.8 Hz, 2H). 7.40 (d, J = 2.8 Hz,

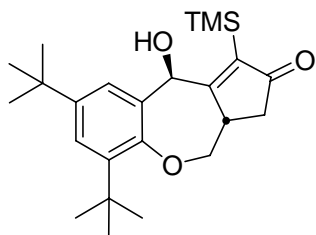
1H), 7.34 (d, $J = 2.8$ Hz, 2H), 7.30 (s, 1H), 7.14 (s, 1H), 4.67 (dd, $J = 5.5, 11.5$ Hz, 1H), 3.91 (d, $J = 12.8$ Hz, 1H), 3.76 (d, $J = 12.8$ Hz, 1H), 3.54 (m, 1H), 3.35 (t, $J = 11.5$ Hz, 1H), 2.75 (dd, $J = 7.1, 18.9$ Hz, 1H), 2.03 (dd, $J = 2.8, 18.8$ Hz, 1H), 1.41 (s, 9H), 1.35 (s, 9H); ^{13}C NMR (125 MHz): $\delta = 205.5, 172.0, 156.8, 146.7, 141.9, 139.7, 131.3, 129.7, 129.6, 128.3, 128.2, 125.3, 123.0, 76.2, 44.1, 36.9, 36.7, 35.2, 34.7, 31.6, 30.7$; IR (neat, cm^{-1}) = 2958, 1705, 1474, 758; HRMS (ESI): Calcd. for $\text{C}_{27}\text{H}_{32}\text{O}_2\text{Na}$ (m/z): 411.2295. Found 411.2266, Calcd. For $\text{C}_{54}\text{H}_{64}\text{O}_4\text{Na}$ ($2\text{M}+\text{Na}$): 799.4697. Found 799.4698.

Cyclization 4,6-Di-*tert*-butyl-2-(1-hydroxy-3-trimethylsilyl-2-propynyl)-(-2-propenyloxy)benzene (15a)

The Pauson-Khand cyclization of the enyne **15a** (102 mg, 0.27 mmol) in 10 mL of the appropriate solvent, was carried out following the general procedures **3.1.3.2** and **3.1.3.3**. $\text{Co}_2(\text{CO})_8$ (103 mg, 0.30 mmol) and NMO (230 mg, 2.74 mmol) were added according to the general procedures. The reaction mixture was filtered using a sintered glass funnel packed with a short layer of Celite and SiO_2 . The crude product was purified by flash chromatography (hexane/EtOAc, 90:10) to afford the reduced PK product **23** (21.0 mg, 20%) and the expected PK product **28** (78.0 mg, 70% as a 1:2 mixture of **28** epimers) using the oxidative procedure **3.1.3.2**. On the other hand, when the enyne was heated to reflux for 1 day in CH_2Cl_2 under the thermal procedure **3.1.3.3**, it gave the *exo*- product of **28** (3.3 mg, 3%). However, when enyne **15a** was subjected to

procedure **3.1.3.3** conditions at using toluene as the solvent and heated to 70 °C, the yield of the *exo*- product of **28** (64.0 mg, 58%) was improved.

6,8-Di-*tert*-butyl-10-hydroxy-1-trimethylsilyl-4,4a-dihydro-3*H*,10*H*-5-oxabenzof] azulen-2-one (28)



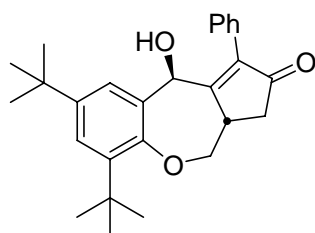
A light yellow solid, mp: 110-112 °C; ¹H NMR (500 MHz): δ = 7.32 (d, J = 2.3 Hz, 1H), 7.17 (d, J = 2.3 Hz, 1H), 5.68 (d, J = 9.2 Hz, 1H), 4.58 (dd, J = 6.0, 11.5 Hz, 1H), 3.96 (m, 1H), 3.37 (t, J = 11.5 Hz, 1H), 3.25 (d, J = 9.2 Hz, 1H), 2.55 (dd, J = 7.3, 18.8 Hz, 1H), 1.82 (dd, J = 2.8, 18.3 Hz, 1H), 1.37 (s, 9H) 1.30 (s, 9H), 0.29 (s, 9H); ¹³C NMR (125 MHz): δ = 211.4, 185.1, 155.9, 147.1, 142.5, 140.0, 132.9, 125.0, 124.9, 77.6, 75.0, 41.8, 37.7, 35.3, 34.9, 31.5, 30.7, -0.12; IR (neat, cm⁻¹) = 3396, 2958, 1710, 1606, 1471, 1367, 1236, 1013; HRMS (ESI): Calcd. for C₂₄H₃₇O₃Si (m/z): 401.2506. Found 401.2500 [M+H]⁺;

Cyclization of 4,6-Di-*tert*-butyl-2-(1-hydroxy-3-phenyl-2-propynyl)-2-propenyloxy benzene (15b)

The Pauson-Khand cyclization of the enyne **15b** (250 mg, 0.67 mmol) in 10 mL of the appropriate solvent, was carried out following the general procedures **3.1.3.2** and **3.1.3.3**. Co₂(CO)₈ (250 mg, 0.73 mmol) and NMO (1.22 g, 10.4 mmol) were added according to the general procedures. The reaction mixture was filtered using a sintered glass funnel packed with a short layer of Celite and SiO₂. The crude product was

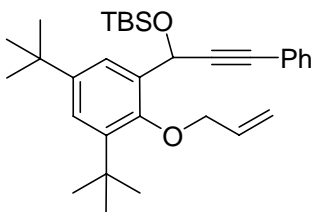
purified by flash chromatography (silica gel, hexane/EtOAc, 90:10) to afford the reduced PK product **24** (142 mg, 55%) and the expected PK product **29** (70 mg, 26% as a 1:1 mixture of **29** epimers) using the oxidative procedure **3.1.3.2**. On the other hand, when the enyne was heated to reflux for 3 days in CH₂Cl₂ under the thermal procedure **3.1.3.3**, it gave the reduced PK product **24** (21 mg, 8%) and the *exo*-product of **29** (193 mg, 75%). However, when procedure **3.1.3.3** was carried out at the same temperature but using toluene as the solvent instead, the reaction only gave the *exo*- product of **29** (255 mg, 99%).

6,8-Di-*tert*-butyl-10-hydroxy-1-phenyl-4,4a-dihydro-3*H*,10*H*-5-oxabenzof[*f*] azulene-2-one (29)



A light yellow solid, mp: 171-173 °C; ¹H NMR (500 MHz):
 δ = 7.46 (m, 3H), 7.35 (d, *J* = 2.8 Hz, 1H), 7.23 (m, 2H), 7.14 (d, *J* = 2.8 Hz, 1H), 5.49 (d, *J* = 9.2 Hz, 1H), 4.61 (dd, *J* = 5.7, 11.5 Hz, 1H), 4.09 (m, 1H), 3.51 (t, *J* = 11.9 Hz, 1H), 3.15 (d, *J* = 8.7 Hz, 1H), 2.76 (dd, *J* = 6.9, 19.3 Hz, 1H), 2.03 (dd, *J* = 2.8, 18.8 Hz, 1H), 1.40 (s, 9H), 1.32 (s, 9H); ¹³C NMR (125 MHz); δ = 205.3, 172.3, 156.3, 147.3, 142.8, 139.6, 133.0, 130.7, 129.6, 128.5, 128.3, 125.1, 125.0, 77.9, 73.7, 38.8, 36.7, 35.3, 34.7, 31.5, 30.7; IR (neat, cm⁻¹) = 3435, 2959, 1702, 1598, 756; HRMS (ESI): Calcd. for C₂₇H₃₃O₃ (*m/z*): 405.2424. Found 405.2425 [M+H]⁺;

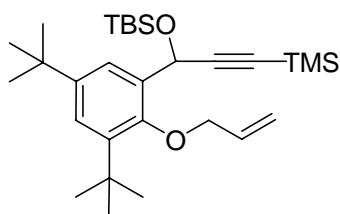
4,6-Di-*tert*-butyl-2-(-1-*tert*-butyl-dimethylsilyloxy -3-phenyl-2-propynyl)-(-2-propenyloxy)benzene (30)



tert-Butyldimethylsilyl chloride (0.410 g, 2.71 mmol) was added at room temperature to a mixture of **15b** (0.340 g, 0.900 mmol) and imidazole (0.300 g, 2.71 mmol) in DMF (10 mL).

The mixture was heated at 50 °C for 4.5 h. The reaction was quenched by the addition of aqueous NaHCO₃ and extracted with Et₂O. The organic layer was separated, washed with water and brine, dried with Na₂SO₄ (anhydrous). The organic layer was concentrated to give a dark colored liquid. The crude product was purified by flash chromatography (hexane/EtOAc; 19:1) to give **30** as viscous brown liquid (0.420 g, 95%). ¹H NMR (500 MHz): δ = 7.65 (d, *J* = 2.5 Hz, 1H), 7.41 (d, *J* = 2.5 Hz, 1H), 7.40 (d, *J* = 4.0 Hz, 1H), 7.27-7.30 (m, 4H), 6.09 (ddt, *J* = 4.6, 10.5, 17.4 Hz, 1H), 5.93 (s, 1H), 5.56 (dq, *J* = 1.8, 17.0 Hz, 1H), 5.29 (dq, *J* = 1.8, 10.5 Hz, 1H), 4.56 (ddt, *J* = 1.8, 4.6, 13.8 Hz, 1H), 4.50 (ddt, *J* = 1.8, 4.1, 13.8 Hz, 1H), 1.42 (s, 9H), 1.33 (s, 9H), 0.86 (s, 9H), 0.14 (s, 3H), 0.02 (s, 3H); ¹³C NMR (75 MHz): δ = 152.5, 146.2, 141.5, 135.8, 134.0, 131.7, 128.3, 124.5, 123.9, 123.3, 116.5, 91.4, 84.7, 75.8, 60.1, 35.5, 34.8, 31.6, 31.2, 25.9, 18.4, -4.4, -4.8 (only 23 signals were observed out of 24 carbon types); IR (neat, cm⁻¹) = 2959, 2864, 1600, 1362, 1063; HRMS (CI): Calcd. for C₃₂H₄₆O₂Si (*m/z*): 490.3262. Found 490.3277 [M⁺].

4,6-Di-*tert*-butyl-2-(-1-*tert*-butyl-dimethylsilyloxy-3- trimethylsilyl -2-propynyl)-(-2-propenyloxy)benzene (31)



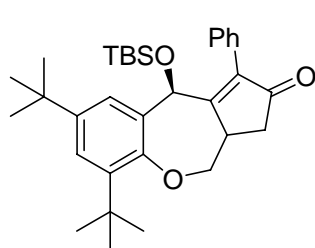
tert-Butyldimethylsilyl chloride (0.500 g, 3.31 mmol) was added at room temperature to a mixture of **15a** (0.410 g, 1.10 mmol) and imidazole (0.440 g, 3.31 mmol) in DMF (10 mL). Then the mixture was heated at 50 °C for 4.5 h. The reaction was quenched by the addition of aqueous NaHCO₃ and extracted with Et₂O. The organic layer was separated, washed with water and brine and dried (Na₂SO₄). The organic layer was concentrated to give a dark liquid. The crude was purified by flash chromatography (hexane/EtOAc; 19:1) to give **31** as a viscous brown oil (0.510 g, 95%). ¹H NMR (500 MHz): δ = 7.57 (d, *J* = 2.3 Hz, 1H), 7.28 (d, *J* = 2.3 Hz, 1H), 6.05 (ddt, *J* = 4.6, 10.5, 17.4 Hz, 1H), 5.70 (s, 1H), 5.51 (dq, *J* = 1.8, 17.4 Hz, 1H), 5.29 (dq, *J* = 1.8, 10.5 Hz, 1H), 4.48 (dt, *J* = 1.4, 5.0 Hz, 2H), 1.39 (s, 9H), 1.32 (s, 9H), 0.83 (s, 9H), 0.15 (s, 9H), 0.10 (s, 3H), 0.07 (s, 3H); ¹³C NMR (75 MHz): δ = 152.7, 146.0, 141.4, 135.6, 134.1, 124.7, 123.9, 116.0, 107.7, 85.9, 75.7, 60.2, 35.5, 34.8, 31.6, 31.2, 25.9, 18.4, -0.1, -4.4, -4.7; IR (neat, cm⁻¹) = 2960, 2173, 1470, 1252, 1070; HRMS (CI): Calcd. for C₂₉H₅₀O₂Si₂ (*m/z*): 486.3344. Found 486.3355 [M⁺].

Cyclization of 4,6-di-*tert*-butyl-2-(-1-*tert*-butyl-dimethylsilyloxy -3-phenyl-2-propynyl)-(-2-propenyloxy)benzene (30)

The Pauson-Khand cyclization of the enyne **30** (101 mg, 0.21 mmol) in 10 mL of the appropriate solvent, was carried out following the general procedures **3.1.3.2** and

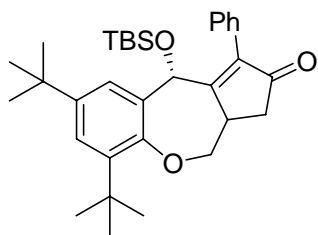
3.1.3.3. $\text{Co}_2(\text{CO})_8$ (141 mg, 0.41 mmol) and NMO (529 mg, 4.52 mmol) were added according to the general procedures. The reaction mixture was filtered using a sintered glass funnel with a short layer of Celite and SiO_2 pad. The crude product was purified by flash chromatography (hexane/EtOAc, 90:10) to afford the reduced PK product **24** (11.2 mg, 11%) and the PK product **32** (62.9 mg, 60% as a 1:5 mixture of **32** epimers) using the oxidative procedure **3.1.3.2**. On the other hand, when the enyne was heated to 70 °C for 1 day in toluene under the thermal procedure **3.1.3.3**, only the PK product of **32** (101 mg, 95% in a 1:10 ratio of epimers) was isolated. The isomers were separated by preparatory thin layer chromatography.

6,8-Di-*tert*-butyl-10-*t*-butyldimethylsilyloxy-1-phenyl-4,4a-dihydro-3*H*,10*H*-5-oxabenzof]azulen-2-one (32**, *exo* product)**



Yellow oil, ^1H NMR (500 MHz): δ = 7.39 (m, 3H), 7.31 (d, J = 2.3 Hz, 1H), 7.21 (dd, J = 1.8, 7.8 Hz, 2H), 7.05 (d, J = 2.8 Hz, 1H), 5.55 (s, 1H), 4.62 (dd, J = 5.0, 11.9 Hz, 1H), 4.01 (m, 1H), 3.54 (t, J = 10.5 Hz, 1H), 2.78 (dd, J = 7.3, 18.8 Hz, 1H), 2.10 (d, J = 18.8 Hz, 1H), 1.38 (s, 9H), 1.32 (s, 9H), 0.77 (s, 9H), -0.12 (s, 3H), -0.33 (s, 3H); ^{13}C NMR (125 MHz): δ = 206.3, 173.9, 157.3, 145.6, 142.4, 138.2, 132.0, 131.0, 129.5, 128.3, 126.1, 126.1, 124.3, 124.2, 74.2, 39.2, 37.3, 35.4, 34.6, 31.5, 30.5, 25.8, 18.2, -4.8; IR (neat, cm^{-1}) = 2959, 1709, 849; HRMS (ESI): Calcd. for $\text{C}_{33}\text{H}_{47}\text{O}_3\text{Si}$ (m/z): 519.3289. Found 519.3295 [M+H].

6,8-Di-*tert*-butyl-10-*t*-butyldimethylsilyloxy-1-phenyl-4,4a-dihydro-3*H*,10*H*-5-oxabenzof]azulen-2-one (32, *endo* product).



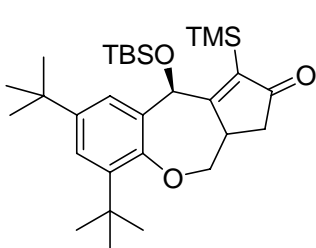
Yellow liquid, ^1H NMR (500 MHz): δ = 7.69 (d, J = 2.5 Hz, 1H), 7.29-7.23 (m, 6H), 5.90 (s, 1H), 4.62 (dd, J = 5.5, 11.5 Hz, 1H), 3.53 (m, 1H), 3.23 (t, J = 11.5 Hz, 1H), 2.75 (dd, J = 6.9, 18.8 Hz, 1H), 1.94 (dd, J = 2.3, 18.8 Hz, 1H), 1.41 (s, 9H), 1.37 (s, 9H), 0.60 (s, 9H), -0.14 (s, 3H), -0.28 (s, 3H); ^{13}C NMR (125 MHz): δ = 205.4, 173.7, 146.5, 141.1, 138.2, 134.0, 132.2, 130.4, 127.7, 127.2, 126.2, 123.0, 120.9, 72.2, 61.8, 42.2, 36.6, 35.1, 35.0, 31.6, 30.8, 25.6, 18.1, -5.5; IR (neat, cm^{-1}) = 2959, 1709, 1623, 849; HRMS (ESI): Calcd. for $\text{C}_{33}\text{H}_{47}\text{O}_3\text{Si}$ (m/z): 519.3289. Found 519.3250 $[\text{M}+\text{H}]^+$.

Cyclization of 4,6-di-*tert*-butyl-2-(-1-*tert*-butyl-dimethylsilyloxy-3-trimethylsilyl-2-propynyl)-(-2-propenyloxy)benzene (31)

The Pauson-Khand cyclization of the enyne **31** (100 mg, 0.21 mmol) in 10 mL of the appropriate solvent, was carried out following the general procedures **3.1.3.2** and **3.1.3.3**. $\text{Co}_2(\text{CO})_8$ (141 mg, 0.41 mmol) and NMO (530 mg, 4.52 mmol) were added according to the general procedures. The reaction mixture was filtered using a sintered glass funnel packed with a short layer of Celite and SiO_2 pad. The crude product was purified by flash chromatography (hexane/EtOAc, 90:10) to afford only the *exo*-isomer of the PK product **33** (57.5 mg, 61% yield) using the oxidative procedure

3.1.3.2. On the other hand, when the enyne **31** was heated to 70 °C for 1 day in toluene under the thermal procedure **3.1.3.3**, no cyclized product was isolated.

6,8-Di-*tert*-butyl-10-*t*-butyldimethylsilyloxy-1-trimethylsilyl-4,4a-dihydro-3*H*,10*H*-5-oxabenzof]azulen-2-one (33)



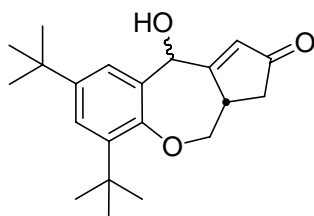
^1H NMR (500 MHz): δ = 7.26 (d, J = 2.5 Hz, 1H), 7.07 (d, J = 2.3 Hz, 1H), 5.78 (s, 1H), 4.51 (dd, J = 4.6, 11.9 Hz, 1H), 4.18 (dd, J = 4.6, 8.7 Hz, 1H), 3.89 (m, 1H), 3.52 (t, J = 11.5 Hz, 1H), 2.56 (dd, J = 6.9, 18.8 Hz, 1H), 1.94 (d, J = 17.9 Hz, 1H), 1.34 (s, 9H), 1.29 (s, 9H), 0.82 (s, 9H), 0.23 (s, 9H), 0.03 (s, 3H), -0.21 (s, 3H); ^{13}C NMR (125 MHz): δ = 212.6, 186.9, 157.1, 145.0, 141.9, 138.5, 131.4, 126.3, 124.0, 75.4, 38.8, 38.7, 35.3, 34.5, 31.5, 30.4, 25.8, 18.2, 14.2, 11.0, -0.2, -4.6; IR (neat, cm^{-1}) = 3433.6, 2956.3, 2859.6, 1732.2, 1698.8, 1594.5, 1477.2, 1250.8; HRMS (ESI): Calcd. for $\text{C}_{30}\text{H}_{51}\text{O}_3\text{Si}_2$ (m/z): 515.3371. Found 515.3389 $[\text{M}+\text{H}]^+$.

Cyclization of 4,6-di-*tert*-butyl-2-(1-hydroxy-2-propynyl)-(2-propenyloxy)benzene (15c)

The Pauson-Khand cyclization of the enyne **15c** (80 mg, 0.27 mmol) in 10 mL of the appropriate solvent, was carried out following the general procedures **3.1.3.2** and **3.1.3.3**. $\text{Co}_2(\text{CO})_8$ (100 mg, 0.29 mmol) and NMO (312 mg, 2.67 mmol) were added according to the general procedures. The reaction mixture was filtered using a sintered glass funnel with a short layer of Celite and SiO_2 pad. The crude product was purified

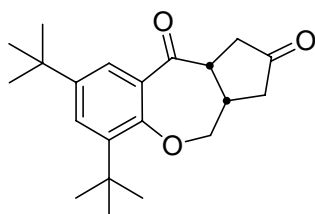
by flash chromatography (silica gel, hexane/EtOAc, 90:10) to afford the PK product **34** (14.7 mg, 17% in a 1:1 ratio of **34** epimers) and the diketone product **35** (80 mg, 80% as a 1:6 mixture of the *syn*- and *anti*- isomers) using the oxidative procedure **3.1.3.2**. On the other hand, when the enyne was heated to 70 °C for 1 days in toluene under the thermal procedure **3.1.3.3**, it gave the PK product of **34** (9.6 mg, 11% in a 1:2 ratio of **34** epimers) along with the diketone product **35** (44 mg, 50% as a 1:1 mixture of the *syn* and *anti* isomers) .

6,8-Di-*tert*-butyl-10-hydroxyl-4,4a-dihydro-3*H*,10*H*-5-oxabenzof[*f*]azulen-2-one (34)



Yellow oil, ¹H NMR (500 MHz): δ = 7.56 (d, *J* = 2.3 Hz, 1H), 7.48 (d, *J* = 2.3 Hz, 1H), 6.29 (s, 1H), 4.71 (dd, *J* = 6.0, 11.5 Hz, 1H), 3.85 (td, *J* = 2.8, 11.5 Hz, 1H), 3.55 (m, 1H), 2.93 (d, *J* = 19.3 Hz, 1H), 2.38 (dd, *J* = 8.3, 17.9 Hz, 1H), 2.04 (dd, *J* = 11.0, 22.5 Hz, 1H), 1.38 (s, 9H), 1.31 (s, 9H); ¹³C NMR (125 MHz): δ = 205.4, 181.9, 152.6, 147.5, 140.6, 134.3, 128.4, 122.5, 120.6, 77.4, 74.6, 42.3, 36.5, 35.1, 31.6, 30.7, 25.5; HRMS (ESI): Calcd. for C₂₁H₂₈NaO₃⁺ (*m/z*): 351.1931. Found 351.1957 [M+Na]⁺.

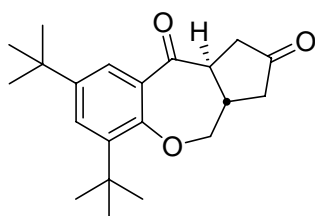
6,8-Di-*tert*-butyl-1,1a,4,4a-tetrahydro-3*H*-5-oxabenzof[*f*]azulen-2,10-dione (syn isomer 35)



Yellow waxy solid, ¹H NMR (500 MHz): δ = 7.57 (d, *J* = 2.3 Hz, 1H), 7.49 (d, *J* = 2.3 Hz, 1H), 4.71 (dd, *J* = 6.0, 12.4

Hz, 1H), 3.85 (dt, $J = 2.8, 8.7$ Hz, 1H), 3.76 (dd, $J = 10.1, 12.4$ Hz, 1H), 3.33 (dddd, $J = 6.0, 8.7, 10.1, 18.8$ Hz, 1H), 2.91 (d, $J = 18.8$ Hz, 1H), 2.41 (dd, $J = 8.3, 18.3$ Hz, 1H), 2.29 (dd, $J = 8.7, 18.8$ Hz, 1H), 2.04 (dd, $J = 10.1, 17.4$ Hz, 1H), 1.40 (s, 9H), 1.30 (s, 9H); ^{13}C NMR (125 MHz): $\delta = 215.3, 200.9, 160.1, 144.6, 139.9, 128.4, 127.5, 124.3, 51.0, 42.4, 39.5, 39.4, 35.4, 34.7, 31.5, 30.7, 30.2$; IR (neat, cm^{-1}) = 2960, 2871, 1750, 1678, 1597, 1474, 1439, 1365; HRMS (ESI): Calcd. for $\text{C}_{21}\text{H}_{29}\text{O}_3$ (m/z): 329.2111. Found 329.2098 $[\text{M}+\text{H}]^+$.

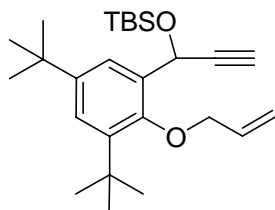
6,8-Di-*tert*-butyl-1,1a,4,4a-tetrahydro-3*H*-5-oxabenzof]azulen-2,10-dione (anti isomer 35)



Yellow waxy solid, ^1H NMR (500 MHz): $\delta = 7.83$ (d, $J = 2.3$ Hz, 1H), 7.61 (d, $J = 2.3$ Hz, 1H), 4.25 (m, 2H), 3.67 (dd, $J = 11.5, 19.3$ Hz, 1H), 2.87 (dd, $J = 11.5, 19.3$ Hz, 1H), 2.66 (t, $J = 8.3$ Hz, 2H), 2.63 (s, 1H), 2.27 (dt, $J = 3.2, 14.7$ Hz, 1H), 1.43 (s, 9H), 1.32 (s, 9H); ^{13}C NMR (125 MHz): $\delta = 214.4, 198.7, 167.6, 146.4, 142.8, 130.0, 129.9, 124.8, 74.3, 52.0, 44.3, 39.8, 39.6, 35.6, 34.8, 31.4, 30.8$; IR (neat, cm^{-1}) = 2960, 2871, 1750, 1678, 1597, 1474, 1439, 1365; HRMS (ESI): Calcd. For $\text{C}_{42}\text{H}_{56}\text{NaO}_6^+$ (m/z): 679.3969. Found 679.4005 $[2\text{M}+\text{Na}]^+$.

4,6-Di-*tert*-butyl-2-(-1-*tert*-butyl-dimethylsilyloxy-2-propynyl)-(-2-propenyloxy)

benzene (**36**)



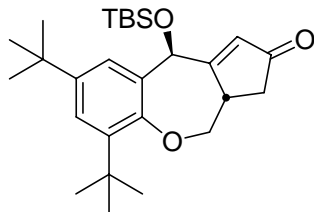
tert-Butyldimethylsilyl chloride (0.750 g, 5.00 mmol) was added at room temperature to a mixture of **15c** (0.500 g, 1.67 mmol) and imidazole (0.300 g, 5.00 mmol) in DMF (10 mL). The reaction mixture was heated at 50 °C for 4.5 h. The reaction was quenched by the addition of aqueous NaHCO₃ and extracted with Et₂O. The organic layer was separated, washed with water and brine and dried (Na₂SO₄). The organic layer was concentrated to give a dark liquid. The crude product was purified by flash chromatography (hexane/EtOAc; 19:1) to give **36** as a viscous brown oil, (0.680 g, 99%). ¹H NMR (500 MHz): δ = 7.56 (d, *J* = 2.8 Hz, 1H), 7.28 (d, *J* = 2.8 Hz, 1H), 6.06 (ddt, *J* = 4.6, 11.0, 17.0 Hz, 1H), 5.69 (d, *J* = 2.3 Hz, 1H), 5.55 (dq, *J* = 1.8, 17.4 Hz, 1H), 5.29 (dq, *J* = 1.4, 10.5 Hz, 1H), 4.48 (ddt, *J* = 1.8, 4.6, 13.8 Hz, 1H), 4.42 (ddt, *J* = 1.8, 4.6, 13.8 Hz, 1H), 2.49 (d, *J* = 1.8 Hz, 1H), 1.39 (s, 9H), 1.31 (s, 9H), 0.82 (s, 9H), 0.07 (s, 3H), -0.08 (s, 3H); ¹³C NMR (125 MHz): δ = 152.4, 146.3, 141.5, 135.5, 133.9, 124.2, 124.0, 116.1, 85.9, 75.8, 72.6, 59.3, 35.5, 34.8, 31.6, 31.1, 25.8, 18.3, -4.8, -5.0; IR (neat, cm⁻¹) = 3299, 2956, 2867, 2175, 1466, 1252, 1069; HRMS (ESI): Calcd. for C₂₆H₄₃O₂Si (*m/z*): 415.3027. Found 415.3045 [M+H]⁺.

Cyclization of 4,6-di-*tert*-butyl-2-(-1-*tert*-butyl-dimethylsilyloxy-2-propynyl)-(-2-propenyloxy) benzene (36)

The Pauson-Khand cyclization of the enyne **36** (80 mg, 0.19 mmol) in 10 mL of the appropriate solvent, was carried out following the general procedures **3.1.3.2** and **3.1.3.3**. $\text{Co}_2(\text{CO})_8$ (91 mg, 0.27 mmol) and NMO (310 mg, 2.65 mmol) were added according to the general procedures. The reaction mixture was filtered using a sintered glass funnel packed with a short layer of Celite and SiO_2 . The crude product was purified by flash chromatography (hexane/EtOAc, 90:10) to afford the expected PK product **37** (45 mg, 52% as a 2:1 mixture of **37** epimers) using the oxidative procedure **3.1.3.2**. On the other hand, when the enyne was heated to 70 °C for 1 day in toluene under the thermal procedure **3.1.3.3**, only the PK product of **37** (68.3 mg, 80% in a 1:1 ratio of **37** stereoisomers) was isolated. The stereoisomers of **37** were separated by preparatory thin layer chromatography to give the *exo*- and *endo*-products.

6,8-Di-*tert*-butyl-10-*t*-butyldimethylsilyloxy-4,4a-dihydro-3*H*,10*H*-5-oxabenzof

[*f*]azulen-2-one (37**, *exo*-product).**

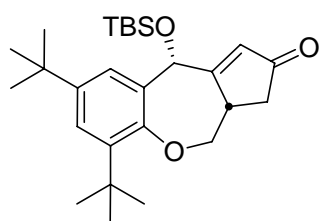


Brown waxy solid, ^1H NMR (300 MHz): $\delta = 7.55$ (d, $J = 2.1$ Hz, 1H), 7.26 (d, $J = 2.4$ Hz, 1H), 6.25 (s, 1H), 5.75 (s, 1H), 4.51 (dd, $J = 6.2, 11.4$ Hz, 1H), 3.52 (m, 1H), 3.09 (t, $J = 11.7$ Hz, 1H), 2.58 (dd, $J = 6.9, 18.6$ Hz, 1H), 1.87 (dd, $J = 2.8, 18.6$ Hz, 1H), 1.34 (s, 9H), 1.31 (s, 9H), 1.00 (s, 9H), 0.07 (s, 6H), ^{13}C NMR (75 MHz): $\delta = 206.6, 182.8, 153.8, 146.6, 140.9, 133.0, 127.4, 123.4, 120.5, 75.8, 71.1, 43.1, 37.4,$

35.0, 31.7, 30.8, 25.9, 18.4, -4.9, -5.1, only 20 carbons were observed out of 21 carbon types; IR (neat, cm^{-1}) = 2954, 2862, 1718, 1623, 1475; HRMS (ESI): Calcd. for $\text{C}_{27}\text{H}_{43}\text{O}_3\text{Si}$ (m/z): 443.2976. Found 443.3002 $[\text{M}+\text{H}]^+$.

6,8-Di-*tert*-butyl-10-*t*-butyldimethylsilyloxy-4,4a-dihydro-3*H*,10*H*-5-oxabenzo

[*f*]azulen-2-one (**37**, *endo* product).



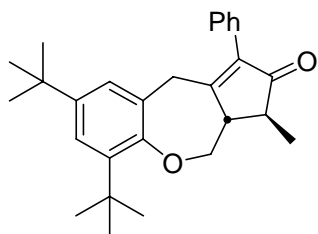
Brown waxy solid, ^1H NMR (300 MHz): δ = 7.29 (d, J = 2.1 Hz, 1H), 7.11 (d, J = 2.4 Hz, 1H), 6.06 (s, 1H), 5.61 (s, 1H), 4.49 (dd, J = 5.2, 11.0 Hz, 1H), 3.73 (m, 1H), 3.73 (t, J = 11.0 Hz, 1H), 2.62 (dd, J = 6.9, 18.9 Hz, 1H), 1.95 (dd, J = 2.1, 18.6 Hz, 1H), 1.36 (s, 9H), 1.30 (s, 9H), 0.85 (s, 9H), 0.04 (s, 3H), -0.19 (s, 3H); ^{13}C NMR (75 MHz): δ = 207.8, 181.2, 155.4, 145.7, 142.2, 132.2, 128.1, 124.9, 124.3, 75.2, 40.7, 38.0, 35.3, 34.6, 31.6, 30.6, 25.8, 18.3, -4.76, -4.8; IR (neat, cm^{-1}) = 2952, 2860, 1716, 1620, 1472; HRMS (ESI): Calcd. for $\text{C}_{54}\text{H}_{84}\text{NaO}_6\text{Si}_2^+$ (m/z): 907.5699. Found 907.5636 $[2\text{M}+\text{Na}]^+$.

Cyclization of 4,6-di-*tert*-butyl-2-(1-hydroxy-3-phenyl-2-propynyl)-1-(3-methyl-2-propenyloxy) benzene (**17b**)

The Pauson-Khand cyclization of the enyne **17b** (630 mg, 0.16 mmol) was carried out following the general procedures **3.1.3.2** and **3.1.3.3** in 5 mL of the appropriate solvent. $\text{Co}_2(\text{CO})_8$ (61 mg, 0.18 mmol) and NMO (189 mg, 1.62 mmol) were added according to the general procedures. The reaction mixture was filtered using a sintered glass funnel

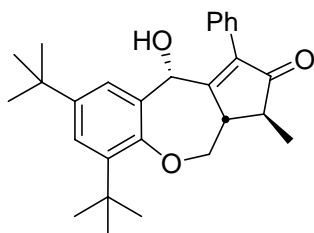
packed with a short layer of Celite and SiO₂. The crude product was purified by flash chromatography (hexane/EtOAc, 87:13) to afford the reduced PK Product **39** (12 mg, 18%), the *endo*- product **40** (26 mg, 36%) and the *exo*-product **41** (31 mg, 45%) for the oxidative method. The thermal method gave the *endo*-product **40** (6.1 mg, 9%) and the *exo*- PK product **41** (25 mg, 12%) as a light yellow liquid.

6,8-Di-*tert*-butyl-1-phenyl-3-methyl-4,4a-dihydro-3*H*,10*H*-5-oxabenzof[*f*]azulen-2-one (39)



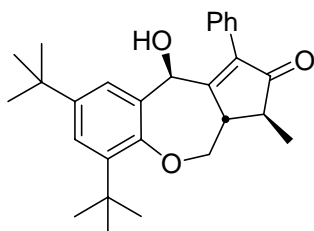
Light yellow solid, mp: 80-82 °C; ¹H NMR (500 MHz): δ = 7.45 (t, *J* = 7.3 Hz, 2H), 7.38 (t, *J* = 6.9 Hz, 1H), 7.34 (d, *J* = 7.3 Hz, 2H), 7.28 (d, *J* = 2.3 Hz, 1H), 7.14 (d, *J* = 1.8 Hz, 1H), 4.72 (dd, *J* = 5.5, 11.5 Hz, 1H), 3.87 (d, *J* = 12.8 Hz, 1H), 3.77 (d, *J* = 12.8 Hz, 1H), 3.37 (t, *J* = 11.5 Hz, 1H), 3.10 (m, 1H), 1.96 (dd, *J* = 2.8, 8.7 Hz, 1H), 1.42 (s, 9H), 1.36 (d, *J* = 7.8 Hz, 3H), 1.34 (s, 9H); ¹³C NMR (125 MHz): δ = 207.7, 169.9, 157.0, 146.7, 141.8, 138.4, 131.5, 129.7, 128.3, 128.1, 125.3, 123.0, 75.5, 52.9, 42.4, 36.5, 35.2, 34.7, 31.6, 30.7, 15.3 (21 carbon was observed out of 22 carbon types); IR (Neat, cm⁻¹) = 2957, 1705, 1466, 752; HRMS (ESI): Calcd. For C₂₈H₃₅O₂ (*m/z*): 403.2632. Found 403.2636 [M+H]⁺.

6,8-Di-*tert*-butyl-10-hydroxy-3-methyl-1-phenyl-4,4a-dihydro-3*H*,10*H*-5-oxabenzof]azulen-2-one (40, *endo*-product).



Yellow liquid, ^1H NMR (500 MHz): δ = 7.37 (m, 3H), 7.34 (d, J = 2.8 Hz, 1H), 7.20 (dd, J = 1.8, 8.3 Hz, 2H), 7.14 (d, J = 2.8 Hz, 1H), 5.53 (s, 1H), 4.73 (dd, J = 5.5, 11.5 Hz, 1H), 4.13 (d, J = 7.3 Hz, 1H), 4.10 (d, J = 7.3 Hz, 1H), 3.64 (t, J = 11.0 Hz, 1H), 2.83 (ddd, J = 7.3, 7.8, 11.5 Hz, 1H), 1.40 (s, 9H), 1.32 (s, 9H), 1.16 (d, J = 7.8 Hz, 3H); ^{13}C NMR (125 MHz): δ = 208.8, 171.5, 156.4, 147.3, 142.7, 138.5, 132.8, 130.9, 129.7, 128.4, 128.3, 125.3, 124.9, 73.5, 42.0, 41.7, 35.3, 34.7, 31.5, 30.7, 14.3, 10.5; IR (Neat, cm^{-1}) = 3434, 3055, 2960, 2870, 1703, 1477, 1444; HRMS (ESI): Calcd. For $\text{C}_{56}\text{H}_{68}\text{NaO}_6$ (m/z) 859.4908, Found 859.4955 [2M+Na]

6,8-Di-*tert*-butyl-10-hydroxy-3-methyl-1-phenyl-4,4a-dihydro-3*H*,10*H*-5-oxabenzof]azulen-2-one (41, *exo* product).



Yellow solid, mp 158-160 °C, ^1H NMR (500 MHz): δ = 7.42-7.35 (m, 3H), 7.34 (d, J = 2.8 Hz, 1H), 7.23 (d, J = 6.5 Hz, 2H), 7.18 (d, J = 2.8 Hz, 1H), 5.53 (d, J = 8.3 Hz, 1H), 4.76 (dd, J = 5.0, 11.0 Hz, 1H), 4.12 (dd, J = 7.3, 14.2 Hz, 1H), 3.60 (m, 1H), 3.54 (t, J = 11.0 Hz, 1H), 3.14 (d, J = 8.7 Hz, 1H), 1.41 (s, 9H), 1.38 (d, J = 7.3 Hz, 3H), 1.32 (s, 9H); ^{13}C NMR (125 MHz): δ = 207.5, 170.0, 156.5, 147.3, 142.7, 138.5, 132.9, 130.9, 129.6, 128.4, 128.3, 125.2, 124.9, 73.5, 60.5, 47.7, 42.5,

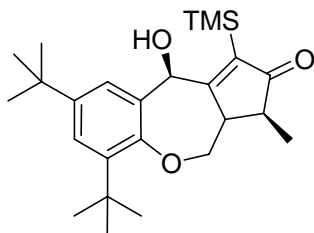
35.3, 34.7, 31.5, 30.7, 15.2; IR (Neat, cm^{-1}) = 3498, 2955, 1701, 1468; HRMS (ESI):

Calcd. For $\text{C}_{28}\text{H}_{35}\text{O}_3$ 419.2581, Found 419.2577 $[\text{M}+\text{H}]^+$.

Cyclization of 4,6-di-*tert*-butyl-2-(1-hydroxy-3-trimethylsilyl-2-propynyl)-1-(3-methyl-2-propenyloxy) benzene (17a)

The Pauson-Khand cyclization of the enyne **17a** (200 mg, 0.52 mmol) was carried out following the general procedures **3.1.3.2** and **3.1.3.3** in 5 mL of the appropriate solvent. $\text{Co}_2(\text{CO})_8$ (195 mg, 0.57 mmol) and NMO (606 mg, 5.18 mmol) were added according to the general procedures. The reaction mixture was filtered using a sintered glass funnel packed with a short layer of Celite and SiO_2 . The crude product was purified by flash chromatography (hexane/EtOAc, 87:13) to afford the PK Product **42** (15 mg, 7%) for the oxidative method. Thermal method gave **42** (25 mg, 12%) as a light yellow liquid.

6,8-Di-*tert*-butyl-10-hydroxy-3-methyl-1-trimethylsilyl-4,4a-dihydro-3*H*,10*H*-5-oxabenzof]azulen-2-one 42



Yellow liquid, ^1H NMR (500 MHz): δ = 7.32 (d, J = 2.8 Hz, 1H), 7.18 (d, J = 2.8 Hz, 1H), 5.69 (s, 1H), 4.65 (dd, J = 5.0, 11.0 Hz, 1H), 3.50 (ddd, J = 3.2, 5.0, 11.0 Hz, 1H), 3.47 (t, J = 11.0 Hz, 1H), 1.85 (ddd, J = 3.2, 7.3, 14.7 Hz, 1H), 1.38 (s, 9H), 1.29 (s, 9H), 1.23 (d, J = 7.8 Hz, 3H), 0.29 (s, 9H); ^{13}C NMR (125 MHz): δ = 213.5, 182.6, 156.2, 146.9, 142.4, 139.0, 132.7, 125.1, 124.9, 75.0, 60.5, 50.6, 43.6,

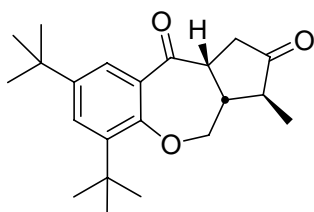
35.3, 34.7, 31.5, 30.7, 15.0, -0.09; IR (neat, cm^{-1}) = 3498, 2960, 1697, 1590, 1478;

HRMS (CI): Calcd. for $\text{C}_{25}\text{H}_{38}\text{O}_3\text{Si}$ (m/z): 414.2590. Found 414.2593 [M^+].

Cyclization of 4,6-di-*tert*-butyl-2-(-1-hydroxy-2-propynyl)-1-(-2-butenyloxy) benzene (17c)

The Pauson-Khand cyclization of the enyne **17c** (420 mg, 1.34 mmol) was carried out following the general procedures **3.1.3.2** and **3.1.3.3** in 5 mL of the appropriate solvent. $\text{Co}_2(\text{CO})_8$ (500 mg, 1.46 mmol) and NMO (1.72 g, 14.7 mmol) were added according to the general procedures. The reaction mixture was filtered using a sintered glass funnel packed with a short layer of Celite and SiO_2 . The crude product was purified by flash chromatography (hexane/EtOAc, 87:13) to afford the reduced PK Product **44** (131 mg, 30%) and the PK product **43** (253 mg, 58.0% as a 1:3 ratio of *syn* and *anti* isomers) using the oxidative method. Thermal method only gave **43** (146 mg, 32.0%, 1:2 ratio of *syn* and *anti* isomers). Preparatory TLC was used to separate the *syn*- and *anti*-products.

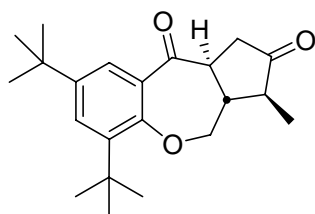
6,8-Di-*tert*-butyl-3-methyl-1,1a,4,4a-tetrahydro-1H,3H-5-oxabenzof]azulen-2,10-Dione (43, *syn*-product).



Brown solid, mp: 134-136 °C, ^1H NMR (500 MHz): δ = 7.56 (d, J = 2.8 Hz, 1H), 7.49 (d, J = 2.8 Hz, 1H), 4.84 (dd, J = 6.45, 11.9 Hz, 1H), 3.81 (dt, J = 1.8, 8.7 Hz, 1H), 3.70 (t, J = 11.9 Hz, 1H), 3.16 (dt, J = 1.8, 19.3 Hz, 1H), 2.93 (m, 1H), 2.25 (dd, J = 8.3, 19.3 Hz, 1H), 1.94 (m, 1H), 1.42 (s, 9H), 1.30 (s, 9H), 1.09 (d, J = 6.9

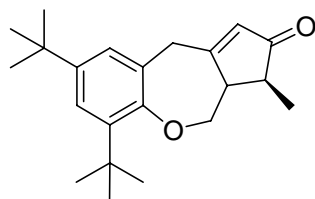
Hz, 3H); ^{13}C NMR (125 MHz): $\delta = 217.0, 200.5, 160.3, 144.4, 139.9, 128.3, 128.0, 124.3, 76.8, 50.0, 48.6, 44.4, 37.4, 35.4, 34.6, 31.5, 30.2, 12.8$; IR (neat, cm^{-1}) = 2960, 1748, 1680, 1463, 757; HRMS (ESI): Theoretical Calcd. for $\text{C}_{22}\text{H}_{31}\text{O}_3$ (m/z) 343.2268, Found 343.2272 $[\text{M}+\text{H}]^+$.

6,8-Di-*tert*-butyl-3-methyl-1,1a,4,4a-tetrahydro-1*H*,3*H*-5-oxabenzof]azulen-2,10-dione. (43, *anti*-product)



Yellow waxy solid, ^1H NMR (500 MHz): $\delta = 7.53$ (d, $J = 2.5$ Hz, 1H), 7.39 (d, $J = 2.5$ Hz, 1H), 4.45 (dd, $J = 2.3, 12.8$ Hz, 1H), 3.99 (dd, $J = 3.7, 12.3$ Hz, 1H), 3.59 (dt, $J = 8.7, 10.5$ Hz, 1H), 2.95 (tt, $J = 2.8, 8.7$ Hz, 1H), 2.49 (t, $J = 8.7$ Hz, 1H), 2.41 (ddd, $J = 1.8, 8.7, 10.5$ Hz, 1H), 2.33 (dd, $J = 8.3, 19.3$ Hz, 1H), 1.25 (s, 9H), 1.22 (s, 9H), 1.21 (d, $J = 2.3$ Hz, 3H); ^{13}C NMR (125 MHz): $\delta = 215.9, 202.7, 158.8, 145.1, 140.1, 128.6, 125.2, 125.0, 74.0, 51.1, 45.3, 45.1, 39.8, 35.2, 34.7, 31.5, 30.2, 10.3$; IR (neat, cm^{-1}) = 2960, 1742, 1678, 1463, 755; HRMS (ESI): Calcd. for $\text{C}_{44}\text{H}_{60}\text{NaO}_6^+$ (m/z) 707.4282, Found 707.4352 $[2\text{M}+\text{Na}]^+$.

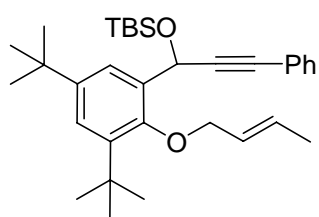
6,8-Di-*tert*-butyl-3-methyl-4,4a-dihydro-3*H*,10*H*-5-oxabenzof]azulen-2-one (44)



Light yellow oily waxy solid, ^1H NMR (500 MHz): $\delta = 7.25$ (d, $J = 2.5$ Hz, 1H), 7.06 (d, $J = 2.5$ Hz, 1H), 6.0 (s, 1H), 4.59 (dd, $J = 5.5, 11.5$ Hz, 1H), 3.94 (d, $J = 13.3$ Hz, 1H), 3.73 (d, J

=13.3 Hz, 1H), 3.24 (t, $J = 11.9$ Hz, 1H), 3.03 (m 1H), 1.86 (ddd, $J = 3.2, 7.3, 14.7$ Hz, 1H), 1.38 (s, 9H), 1.29 (s, 9H), 1.23 (d, $J = 7.3$ Hz, 3H); ^{13}C NMR (125 MHz): $\delta = 210.0, 176.5, 156.6, 146.6, 141.6, 129.2, 128.4, 125.2, 123.3, 75.0, 54.1, 43.6, 38.6, 35.1, 34.6, 31.6, 30.7, 14.9$; IR (neat, cm^{-1}) = 2959, 1707, 1620, 1468, 1232, 1000; HRMS (ESI): Calcd. for $\text{C}_{22}\text{H}_{31}\text{O}_2$ (m/z): 327.2319. Found 327.2312 $[\text{M}+\text{H}]^+$.

4,6-Di-*tert*-butyl-2-(-1-*tert*-butyl-dimethylsilyloxy -3-phenyl-2-propynyl)-(-2-butenyloxy)benzene (45)



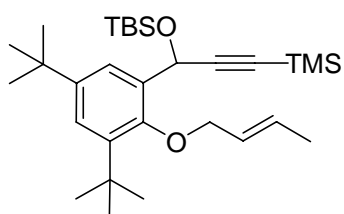
tert-Butyldimethylsilyl chloride (1.16 g, 7.69 mmol) was added at room temperature to a mixture of **17b** (1.00 g, 2.60 mmol) and imidazole (0.460 g, 7.69 mmol) in DMF (10 mL).

The reaction mixture was heated at 50 °C for 4.5 h. The reaction was quenched by the addition of aqueous NaHCO_3 and extracted with Et_2O . The organic layer was separated, washed with water and brine and dried (Na_2SO_4). The organic layer was concentrated to give a dark liquid. The crude product was purified by flash chromatography (hexane/ EtOAc , 19:1) to give **45** as viscous brown liquid (1.28 g, 98.0%). ^1H NMR (500 MHz): $\delta = 7.67$ (d, 1H, $J = 3.0$ Hz), 7.47 (m, 2H), 7.31 (d, 1H, $J = 3.0$ Hz), 7.29 (m, 3H), 6.01 (m, 1H), 5.98 (s, 1H), 5.86 (m, 1H), 4.46 (dd, 2H, $J = 5.5, 11.0$ Hz), 1.83 (d, 3H, $J = 6.5$ Hz), 1.42 (s, 9H), 1.34 (s, 9H), 0.89 (s, 9H), 0.17 (s, 3H), 0.04 (s, 3H); ^{13}C NMR (125 MHz): $\delta = 152.7, 146.1, 141.5, 135.9, 131.7, 128.9, 128.3, 127.1, 124.5, 123.8, 123.4, 91.5, 84.6, 76.0, 60.2, 35.6, 34.8, 31.6, 31.2, 25.9,$

25.8, 18.4, 18.1, -4.4, -4.7, IR (neat, cm^{-1}) = 2960, 2300, 1560, 1475, 1252, 1064;

HRMS (ESI): Calcd. for $\text{C}_{33}\text{H}_{48}\text{O}_2\text{SiNa}$ (m/z): 527.3316. Found 527.3345 $[\text{M}+\text{Na}]^+$.

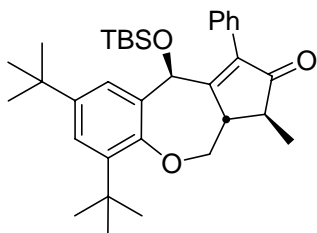
4,6-Di-*tert*-butyl-2-(-1-*tert*-butyl-dimethylsilyloxy-3-trimethylsilyl-2-propynyl)-(2-butenyloxy)benzene (46)



tert-Butyldimethylsilyl chloride (0.940 g, 6.22 mmol) was added at room temperature to a mixture of **17a** (0.800 g, 2.07 mmol) and imidazole (0.400 g mL). The reaction mixture was heated at 50 °C for 4.5 h.

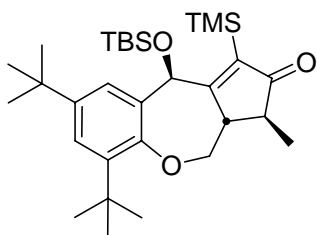
The reaction was quenched by the addition of aqueous NaHCO_3 and extracted with Et_2O . The organic layer was separated, washed with water and brine and dried (Na_2SO_4). The organic layer was concentrated to give a dark colored liquid. The crude product was purified by flash chromatography (hexane/ EtOAc , 19:1) to give **46** as viscous brown oil, (1.02 g, 98%). ^1H NMR (500 MHz) δ = 7.58 (d, J = 3.0 Hz, 1H), 7.28 (d, J = 3.0 Hz, 1H), 5.94 (dq, J = 6.4, 15.5 Hz, 1H), 5.81 (dt, J = 6.0, 15.6 Hz, 1H), 5.73 (s, 1H), 4.52 (d, J = 4.5 Hz, 2H), 1.81 (d, J = 6.5 Hz, 3H), 1.40 (s, 9H), 1.30 (s, 9H), 0.85 (s, 9H), 0.16 (s, 9H), 0.12 (s, 3H), 0.02 (s, 3H); ^{13}C NMR (125 MHz): δ = 152.9, 145.6, 141.4, 135.7, 128.7, 127.2, 124.6, 123.8, 107.8, 89.4, 76.0, 60.3, 35.5, 34.8, 31.6, 31.2, 25.8, 18.4, 18.1, -0.1, -4.4, -4.6; IR (neat, cm^{-1}) = 2959, 2216, 1469, 1251; HRMS (ESI): Calcd. For $\text{C}_{30}\text{H}_{52}\text{O}_2\text{Si}_2\text{Na}$ (m/z): 523.3398. Found 523.3412 $[\text{M}+\text{Na}]^+$.

6, 8-Di-*tert*-butyl-10-*t*-butyldimethylsilyloxy-3-methyl-1-phenyl-4,4a-dihydro-3H,10H-5-oxabenzof]azulen-2-one (47)



The Pauson-Khand cyclization of the enyne **45** (210 mg, 0.400 mmol) was carried out following the general procedures **3.1.3.2** and **3.1.3.3** in 5 mL of the appropriate solvent. $\text{Co}_2(\text{CO})_8$ (150 mg, 0.440 mmol) and NMO (510 mg, 4.36 mmol) were added according to the general procedures. The reaction mixture was filtered using a sintered glass funnel packed with a short layer of Celite and SiO_2 . The crude product was purified by flash chromatography (SiO_2 , hexane/EtOAc, 87:13) to afford the PK Product **45** (99.8 mg, 45.0%, 1:4 ratio of the diastereomers) for the oxidative method. Thermal method gave **45** (151 mg, 68.0%) as a brown waxy solid, ^1H NMR (500 MHz): δ = 7.36 (m, 3H), 7.31 (d, J = 2.5 Hz, 1H), 7.21 (d, J = 7.0 Hz, 2H), 7.09 (d, J = 2.5 Hz, 1H), 5.60 (s, 1H), 4.68 (dd, J = 5.0, 12.0 Hz, 1H), 3.68 (t, J = 9.5 Hz, 1H), 3.51 (d, J = 3.5 Hz, 1H), 2.15 (d, J = 5.0 Hz, 1H), 1.40 (s, 9H), 1.38 (d, J = 5.0 Hz, 3H), 1.33 (s, 9H), 0.78 (s, 9H), -0.11 (s, 3H), -0.27 (s, 3H); ^{13}C NMR (125 MHz): δ = 208.4, 171.5, 157.4, 145.4, 142.1, 137.2, 131.7, 131.1, 129.4, 128.2, 126.3, 124.2, 75.1, 73.8, 48.4, 43.2, 35.4, 34.6, 31.7, 31.6, 30.5, 25.8, 18.2, 15.1, -4.75, -4.79; IR (neat, cm^{-1}) = 2957, 1709, 1465, 1066, 841; HRMS (ESI): Calcd. for $\text{C}_{34}\text{H}_{49}\text{O}_3\text{Si}$ (m/z): 533.3445. Found 533.3468.

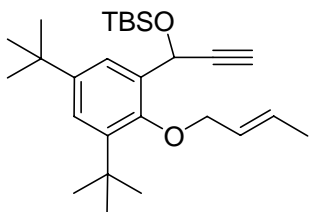
6,8-Di-*tert*-butyl-10-*t*-butyldimethylsilyloxy-3-methyl-1-trimethylsilyl-4,4a-dihydro-3*H*,10*H*-5-oxabenzof]azulen-2-one (48)



The Pauson-Khand cyclization of the enyne **46** (100 mg, 0.200 mmol) was carried out following the general procedures **3.1.3.2** and **3.1.3.3** in 5 mL of the appropriate solvent. $\text{Co}_2(\text{CO})_8$ (75 mg, 0.22 mmol) and NMO (260 mg, 2.20 mmol) were added according to the general procedures. The reaction mixture was filtered using a sintered glass funnel packed with a short layer of Celite and SiO_2 . The crude product was purified by flash chromatography (SiO_2 , hexane/EtOAc, 87:13) to afford only the *exo* PK Product **48** (7.8 mg, 7.0%) for the oxidative method. Thermal method gave also the *exo*-product **48** (10.4 mg, 10.0%) as a brown waxy solid, ^1H NMR (500 MHz): $\delta = 7.26$ (d, $J = 2.5$ Hz, 1H), 7.06 (d, $J = 2.5$ Hz, 1H), 5.78 (s, 1H), 4.58 (dd, $J = 4.6, 11.5$ Hz, 1H), 3.71 (t, $J = 9.5$ Hz, 1H), 3.34 (m, 1H), 2.06 (m, 1H), 1.34 (s, 9H), 1.30 (s, 9H), 1.23 (d, $J = 5.0$ Hz, 3H), 0.83 (s, 9H), 0.21 (s, 9H), 0.06 (s, 3H), -0.14 (s, 3H); ^{13}C NMR (125 MHz) $\delta = 214.6, 177.1, 168.7, 163.0, 155.4, 138.6, 121.7, 114.5, 82.2, 71.8, 44.5, 35.4, 34.5, 33.2, 31.5, 30.4, 30.3, 29.8, 25.8, 18.2, 6.1, -0.2, -4.5$; IR (neat, cm^{-1}) = 2957, 1709, 1465, 1066, 841; HRMS (ESI): Calcd. for $\text{C}_{31}\text{H}_{53}\text{O}_3\text{Si}_2$ (m/z): 529.3528. Found 529.3500 $[\text{M}+\text{H}]^+$.

4,6-Di-*tert*-butyl-2-(-1-*tert*-butyl-dimethylsilyloxy-2-propynyl)-(2-butenyloxy)

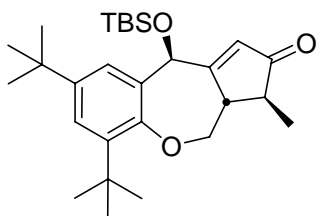
benzene (**49**)



tert-Butyldimethylsilyl chloride (2.20 g, 14.3 mmol) was added at room temperature to a mixture of **17c** (1.50 g, 4.78 mmol) and imidazole (0.980 g, 14.3 mmol) in DMF (10 mL). The reaction mixture was heated at 50 °C for 4.5 h.

The reaction was quenched by the addition of aqueous NaHCO₃ and extracted with Et₂O. The organic layer was separated, washed with water and brine and dried (Na₂SO₄). The organic layer was concentrated to give a dark liquid. The crude product purified by flash chromatography (hexane/EtOAc; 19:1) to give **49** as viscous brown oil, (2.03 g, 99.0%). ¹H NMR (500 MHz): δ = 7.58 (d, *J* = 2.8 Hz, 1H), 7.28 (d, *J* = 2.8 Hz, 1H), 5.94 (dq, *J* = 6.4, 15.1 Hz, 1H), 5.81 (dt, *J* = 6.0, 15.1 Hz, 1H), 5.73 (d, *J* = 2.3 Hz, 1H), 4.28 (ddt, *J* = 1.4, 5.5, 10.5 Hz, 1H), 4.21 (ddt, *J* = 1.4, 5.5, 12.4 Hz, 1H), 2.49 (d, *J* = 2.3 Hz, 1H), 1.81 (dd, *J* = 6.5, Hz, 3H), 1.41 (s, 9H), 1.33 (s, 9H), 0.85 (s, 9H), 0.09 (s, 3H), 0.05 (s, 3H); ¹³C NMR (125 MHz): δ = 152.6, 146.2, 141.5, 135.6, 128.8, 126.9, 124.1, 124.0, 86.0, 76.0, 72.6, 59.5, 35.5, 34.8, 31.6, 31.2, 25.8, 18.3, 18.0, -4.8, -5.0; IR (neat, cm⁻¹) = 3311, 2960, 2934, 2118, 1649, 1474; HRMS (ESI): Calcd. for C₂₇H₄₄O₂SiNa (*m/z*): 451.3003. Found 451.3010 [M+Na]⁺.

**6,8-Di-*tert*-butyl-10-*t*-butyldimethylsilyloxy-3-methyl-4,4a-dihydro-3*H*,10*H*-5-oxa
benzo[*f*]azulen-2-one (50)**



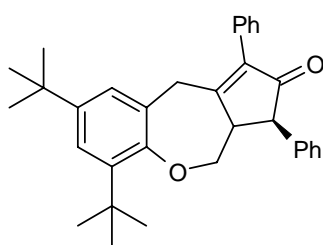
The Pauson-Khand cyclization of the enyne **49** (200 mg, 0.470 mmol) was carried out following the general procedures **B** and **C** in 5 mL of the appropriate solvent. $\text{Co}_2(\text{CO})_8$ (180 mg, 0.530 mmol) and NMO (620 mg, 5.30 mmol) were added according to the general procedures. The reaction mixture was filtered using a sintered glass funnel packed with a short layer of Celite and SiO_2 . The crude product was purified by flash chromatography (hexane/EtOAc, 87:13) to afford the PK product **50** (170 mg, 80%, with the ratio of the epimers being 1:0.8) for the oxidative method. Thermal method gave also the PK product **50** (180 mg, 85%, 5:4 mixture of isomers) as a brown waxy solid; ^1H NMR (300 MHz): δ = 7.29 (d, J = 2.5 Hz, 1H), 7.13 (d, J = 2.5 Hz, 1H), 6.06 (s, 1H), 5.63 (s, 1H), 4.59 (dd, J = 5.1, 11.4 Hz, 1H), 3.72 (app. t, J = 10.2 Hz, 1H), 3.20 (d, J = 3.5 Hz, 1H), 2.07 (d, J = 3.9 Hz, 1H), 1.31 (s, 9H), 1.30 (s, 9H), 1.23 (d, J = 3.9 Hz, 3H), 0.86 (s, 9H), 0.07 (s, 6H); ^{13}C NMR (75 MHz): δ = 210.2, 178.9, 153.9, 145.5, 142.0, 131.9, 127.1, 124.3, 120.6, 75.4, 71.1, 49.6, 44.1, 35.3, 34.6, 31.6, 30.7, 25.8, 18.3, 14.6, -4.7, -4.8; IR (neat, cm^{-1}) = 2957, 1712, 1624, 1474; HRMS (ESI): Calcd. for $\text{C}_{28}\text{H}_{45}\text{O}_3\text{Si}$ (m/z): 457.3132. Found 457.3131 $[\text{M}+\text{H}]^+$.

Cyclization of 4,6-di-*tert*-butyl-2-(1-hydroxy-3-phenyl-2-propynyl)-1-(3-phenyl-2-propenyloxy) benzene (22b)

The Pauson-Khand cyclization of the enyne **22b** (110 mg, 0.240 mmol) was carried out following the general procedures **3.1.3.2** and **3.1.3.3** in 5 mL of the appropriate solvent. $\text{Co}_2(\text{CO})_8$ (92 mg, 0.27 mmol) and NMO (310 mg, 2.65 mmol) were added according to the general procedures. The reaction mixture was filtered using a sintered glass funnel packed with a short layer of Celite and SiO_2 . The crude product was purified by flash chromatography (SiO_2 , hexane/EtOAc, 87:13) to afford the reduced product **51** (50 mg, 45%) as a yellow waxy solid and *exo*-PK products of **52** (60 mg, 51%) for the oxidative method. The thermal method gave only the PK product **52** (110 mg, 90%, 1:10 ratio of the epimers) as a yellow solid. No reduced PK product **51** was isolated.

6,8-Di-*tert*-butyl-1,3-diphenyl-4,4a-dihydro-3*H*,10*H*-5-oxabenzof[*f*]azulen-2-one

(51)

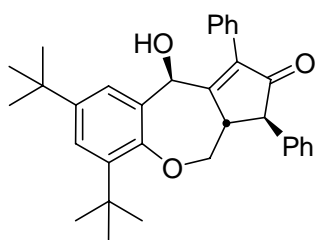


Yellow waxy solid, ^1H NMR (300 MHz): δ = 7.27-7.51 (m, 10H), 7.25 (d, J = 2.1 Hz, 1H), 7.19 (d, J = 2.4 Hz, 1H), 4.78 (dd, J = 4.5, 10.2 Hz, 1H), 3.96 (d, J = 13.2 Hz, 1H), 3.84 (d, J = 12.9 Hz, 1H), 3.55 (m, 1H), 3.48 (t, J = 11.4

Hz, 1H), 3.13 (d, J = 3.0 Hz, 1H), 1.42 (s, 9H), 1.37 (s, 9H), ^{13}C NMR (75 MHz): δ = 204.7, 170.7, 157.0, 146.8, 141.9, 138.8, 138.6, 131.3, 129.8, 129.5, 129.1, 128.4, 128.3, 128.2, 127.4, 125.3, 123.1, 75.4, 54.2, 53.8, 36.6, 35.2, 34.7, 31.6, 30.7; IR (neat,

cm⁻¹) = 3059, 3029, 2961, 2869, 1707, 1638, 1599, 1476; HRMS (ESI): Calcd. For C₃₃H₃₆O₂Na (*m/z*): 487.2608. Found 487.2625 [M+Na]⁺.

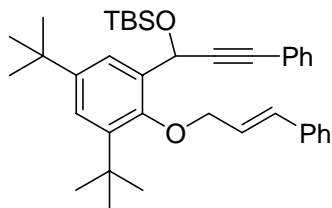
6,8-Di-*tert*-butyl-10-hydroxy-1,3-diphenyl-4,4a-dihydro-3*H*,10*H*-5-oxabenzof] azulen-2-one (52)



Yellow solid, mp: 173-175 °C. ¹H NMR (500 MHz): δ = 7.36 (m, 6H), 7.25 (m, 5H), 7.22 (d, *J* = 2.3 Hz, 1H), 5.60 (s, 1H), 4.81 (dd, *J* = 5.5, 11.5 Hz, 1H), 4.10 (m, 1H), 3.68 (t, *J* = 11.5 Hz, 1H), 3.17 (d, *J* = 2.8 Hz, 1H), 1.41 (s, 9H), 1.35 (s, 9H);

¹³C NMR (75 MHz): δ = 204.5, 170.9, 156.4, 147.4, 142.8, 138.7, 138.2, 132.7, 130.7, 129.7, 129.1, 128.6, 128.3, 128.2, 127.5, 125.2, 125.1, 73.5, 60.5, 54.2, 48.6, 35.4, 34.8, 31.5, 30.7; IR (neat, cm⁻¹) = 3450, 3058, 2956, 1700, 1638, 1600, 1477, 1361, 1266; HRMS (ESI): Calcd. For C₃₃H₃₆O₃Na (*m/z*): 503.2557. Found 503.2548 [M+Na]⁺.

4,6-Di-*tert*-butyl-2-(1-*tert*-butyldimethylsilyloxy-3-phenyl -2-propynyl)-1-(3-phenyl -2-propenyloxy) benzene (53)

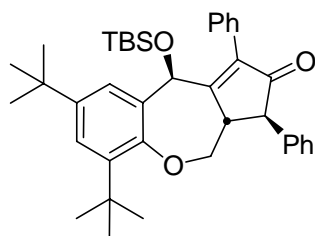


tert-Butyldimethylsilyl chloride (1.00 g, 6.64 mmol) was added at room temperature to a mixture of **22b** (1.00 g, 2.21 mmol) and imidazole (450 mg, 6.64 mmol) in DMF (10 mL). The reaction mixture was then heated at 50 °C for 4.5

h. The reaction was quenched with aqueous NaHCO₃ and extracted with Et₂O. The organic layer separated, washed with water and brine, dried (Na₂SO₄) and concentrated

to give a dark liquid. The crude product was purified by flash chromatography (hexane/EtOAc, 19:1) to give **53** (1.23 g, 98%) as dark brown oil. ^1H NMR (500 MHz): $\delta = 7.73$ (d, $J = 2.8$ Hz, 1H), 7.29-7.51 (m, 11H), 6.92 (d, $J = 16.0$ Hz, 1H), 6.53 (dt, $J = 5.0, 15.6$ Hz, 1H), 6.06 (s, 1H), 4.77 (ddd, $J = 1.8, 5.5, 15.0$ Hz, 1H), 4.70 (ddd, $J = 1.8, 5.5, 15.0$ Hz, 1H), 1.49 (s, 9H), 1.40 (s, 9H), 0.92 (s, 9H), 0.20 (s, 3H), 0.09 (s, 3H); ^{13}C NMR (125 MHz): $\delta = 152.6, 146.3, 141.6, 137.0, 135.9, 131.8, 131.6, 128.7, 128.3, 128.3, 127.8, 126.7, 125.5, 124.6, 124.0, 123.3, 91.5, 84.9, 75.8, 60.4, 35.6, 34.9, 31.7, 31.3, 26.0, 18.4, -4.3, -4.6$; IR (neat, cm^{-1}) = 3102, 2928, 2709, 2223, 1946, 1659, 1599, 1472; HRMS (ESI): Calcd. for $\text{C}_{38}\text{H}_{50}\text{O}_2\text{SiNa}$ (m/z): 589.3472. Found 589.3505 $[\text{M}+\text{Na}]^+$.

6,8-Di-*tert*-butyl-10-*t*-butyldimethylsilyloxy-1,3-diphenyl-4,4a-dihydro-3*H*,10*H*-5-oxabenzof]azulen-2-one (54**)**



The Pauson-Khand cyclization of the enyne **53** (200 mg, 0.35 mmol) was carried out following the general procedures **3.1.3.2** and **3.1.3.3** in 10 mL of the appropriate solvent. $\text{Co}_2(\text{CO})_8$ (140 mg, 0.41 mmol) and NMO (490 mg, 4.19 mmol) were added according to the general procedures. The reaction mixture was filtered using a sintered glass funnel packed with a short layer of Celite and SiO_2 . The crude product was purified by flash chromatography (hexane/EtOAc, 87:13) to afford only the *exo*-PK products of **54** (140 mg, 67.0%) for the oxidative method. The thermal method gave also the *exo*-PK product **54** (180 mg, 86%) as a yellow viscous liquid. ^1H

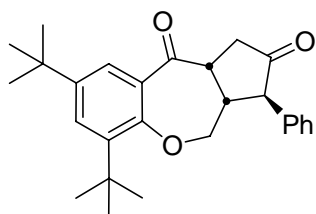
NMR (500 MHz): δ = 7.16-7.42 (m, 12H), 4.71 (s, 1H), 4.75 (dd, J = 4.6, 11.5 Hz, 1H), 4.10 (m, 1H), 3.83 (t, J = 10.0 Hz, 1H), 3.31 (s, 1H), 1.42 (s, 9H), 1.37 (s, 9H), 0.81 (s, 9H), -0.05 (s, 3H), -0.24 (s, 3H); ^{13}C NMR (75 MHz): δ = 205.3, 172.5, 157.4, 145.6, 142.3, 138.7, 137.2, 131.9, 130.9, 129.6, 129.1, 128.4, 128.3, 128.2, 127.3, 126.3, 124.3, 73.9, 60.5, 54.6, 49.2, 35.5, 34.6, 31.6, 30.5, 25.8, 18.2, 14.3, -4.8; IR (neat, cm^{-1}) = 3098, 2955, 1712, 1600, 1477, 1361, 1254; HRMS (ESI): Calcd. For $\text{C}_{39}\text{H}_{51}\text{O}_3\text{Si}$ (m/z): 595.3602. Found 595.3605 $[\text{M}+\text{H}]^+$.

Cyclization of 4,6-di-*tert*-butyl-2-(1-hydroxy-2-propynyl)-1-(-3-phenyl -2-propenyloxy) benzene. (22c)

The Pauson-Khand cyclization of the enyne **22c** (200 mg, 0.530 mmol) was carried out following the general procedures **B** and **C** in 5 mL of the appropriate solvent. $\text{Co}_2(\text{CO})_8$ (200 mg, 0.590 mmol) and NMO (680 mg, 5.85 mmol) were added according to the general procedures. The reaction mixture was filtered using a sintered glass funnel packed with a short layer of Celite and SiO_2 . The crude product was purified by flash chromatography (SiO_2 , hexane/EtOAc, 87:13) to afford the diketone product **55** (130 mg, 51%, 1:5 ratio of the *syn*- and *trans*-isomers) as a yellow waxy solid, for the oxidative method. The thermal method gave the **55** (90 mg, 41%, 3:1 ratio of the *syn* and *trans*-isomers) and the normal PK product **56** (10 mg, 5.0%).

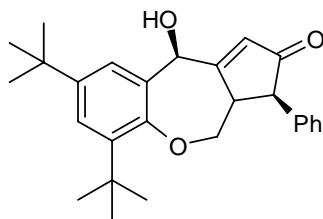
6,8-Di-*tert*-butyl-3-phenyl-1,1a,4,4a-tetrahydro-3*H*-5-oxabenzof]azulen-2,10-dione

(55)



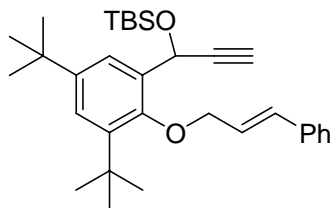
For the major Isomer (obtained pure). ^1H NMR (300 MHz): δ = 7.62 (d, J = 2.4 Hz, 1H), 7.50 (d, J = 2.4 Hz, 1H), 7.29 (m, 3H), 7.08 (d, J = 6.9 Hz, 2H), 4.67 (dd, J = 6.2, 12.0 Hz, 1H), 3.94 (dt, J = 1.2, 8.6 Hz, 1H), 3.73 (t, J = 12.0 Hz, 1H), 3.53 (ddt, J = 6.2, 8.6, 19.2 Hz, 1H), 3.29 (d, J = 19.2 Hz, 1H), 3.12 (d, J = 12.9 Hz, 1H), 2.40 (dd, J = 8.4, 18.9 Hz, 1H), 1.39 (s, 9H), 1.32 (s, 9H); ^{13}C NMR (75 MHz): δ = 214.0, 200.4, 160.5, 144.5, 140.0, 136.0, 129.1, 128.5, 128.4, 128.1, 127.8, 124.3, 76.7, 56.4, 49.7, 48.4, 38.2, 35.4, 34.7, 31.5, 30.2, 29.8; IR (neat, cm^{-1}) = 3099, 2959, 2869, 2360, 1750, 1676, 1597, 1438; HRMS (ESI): Calcd. for $\text{C}_{27}\text{H}_{33}\text{O}_3^+$ (m/z): 405.2424. Found 405.2432 $[\text{M}+\text{H}]^+$.

6,8-Di-*tert*-butyl-10-hydroxy-3-phenyl-4,4a-dihydro-3*H*,10*H*-5-oxabenzof] azulen-2-one (56)



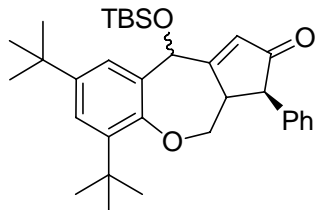
It gave yellow waxy solid, ^1H NMR (300 MHz): δ = 7.19-7.36 (m, 7H), 6.20 (s, 1H), 5.56 (s, 1H), 4.69 (dd, J = 5.40, 11.4 Hz, 1H), 4.21 (dd, J = 3.6, 5.4 Hz, 1H), 3.96 (m, 1H), 3.57 (t, J = 10.8 Hz, 1H), 3.08 (d, J = 3.3 Hz, 1H), 1.38 (s, 9H), 1.32 (s, 9H); ^{13}C NMR (75 MHz): δ = 206.4, 177.8, 147.4, 142.6, 129.1, 128.9, 128.4, 128.1, 127.5, 125.4, 125.0, 111.2, 89.8, 77.3, 75.6, 50.4, 35.3, 34.8, 31.5, 30.7, 29.8; IR (neat, cm^{-1}) = 3451, 2959, 2926, 2869, 2360, 1712, 1476, 1362, 1269; HRMS (ESI): Calcd. For $\text{C}_{27}\text{H}_{32}\text{NaO}_3$ (m/z): 427.2244. Found 427.2216 $[\text{M}+\text{Na}]^+$.

4,6-Di-*tert*-butyl-2-(1-*tert*-butyldimethylsilyloxy -2-propynyl)-1-(3-phenyl -2-propenyloxy) benzene (57)



tert-Butyldimethylsilyl chloride (1.20 g, 7.98 mmol) was added at room temperature to a mixture of the **22c** (1.0 g, 2.66 mmol) and imidazole (0.54 g, 7.98 mmol) in DMF (10 mL). Then the mixture was heated at 50 °C for 4.5h. The reaction was quenched by the addition of aqueous NaHCO₃ and extracted with Et₂O. The organic layer separated, washed with water and brine, dried with anhydrous Na₂SO₄ and then concentrated to give a dark liquid. Purification was by flash chromatography (hexane/EtOAc; 19:1) to give **57** (1.29 g, 99%) as dark red oil. ¹H NMR (500 MHz): δ = 7.59 (d, *J* = 2.8 Hz, 1H), 7.46 (d, *J* = 7.8 Hz, 2H), 7.34 (t, *J* = 7.8 Hz, 2H), 7.30 (d, *J* = 2.3 Hz, 1H), 7.29 (d, *J* = 7.3 Hz, 1H), 6.85 (d, *J* = 16.0 Hz, 1H), 6.44 (dt, *J* = 5.1, 16.0 Hz, 1H), 5.76 (s, 1H), 4.62 (dd, *J* = 5.1, 13.8 Hz, 2H), 2.52 (s, 1H), 1.42 (s, 9H), 1.33 (s, 9H), 0.82 (s, 9H), 0.07 (s, 3H), -0.06 (s, 3H); ¹³C NMR (75 MHz): δ = 152.44, 146.4, 141.6, 136.9, 135.5, 131.5, 128.7, 127.8, 126.7, 125.3, 124.2, 124.1, 85.9, 75.7, 72.8, 59.5, 35.6, 34.8, 31.6, 31.2, 25.8, 18.3, -4.7, -4.9; IR (neat, cm⁻¹) = 3308, 3027, 2963, 2223, 1601, 1472, 1362, 1289, 1159, 1119, 1068, 965; HRMS (ESI): Calcd. For C₃₂H₄₇O₂Si (*m/z*): 491.3340. Found 491.3343 [M+H]⁺; Calcd. For C₃₂H₄₆O₂SiNa (*m/z*): 513.3159. Found 513.3155 [M+Na]⁺.

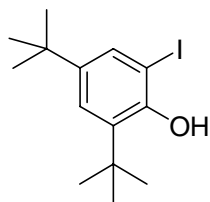
6,8-Di-*tert*-butyl-10--*t*-butyldimethylsilyloxy -3-phenyl-4,4a-dihydro-3H,10H-5-oxa benzo[f]azulen-2-one (58)



The Pauson-Khand cyclization of the enyne **57** (200 mg, 0.410 mmol) was carried out following the general procedures **B** and **C** in 10 mL of the appropriate solvent. $\text{Co}_2(\text{CO})_8$ (153 mg, 0.450 mmol) and NMO (525 mg, 4.49 mmol) were added according to the general procedures. The reaction mixture was filtered using a sintered glass funnel packed with a short layer of Celite and SiO_2 . The crude product was purified by flash chromatography (SiO_2 , hexane/EtOAc, 87:13) to afford the PK products of **58** (150 mg, 71%, 1:0.8 ratio of the epimers) for the oxidative method. Thermal method gave also the PK product **58** (180 mg, 86%, 1:1 ratio of the epimers) as a yellow viscous liquid. ^1H NMR (500 MHz): δ = (1:1 mixture of *exo*- and *endo*-compound) 7.62 (d, J = 2.3 Hz, 1H), 7.27-7.36 (m, 8H), 7.19-7.15 (m, 5H), 6.38 (s, 1H), 6.17 (s, 1H), 5.83 (s, 1H), 5.69 (s, 1H), 4.67 (dd, J = 6.4, 11.5 Hz, 1H), 4.59 (dd, J = 6.4, 11.9 Hz, 1H), 3.82 (broad s, 2H), 3.62 (m, 1H), 3.32 (t, J = 11.9 Hz, 1H), 3.24 (s, 1H), 3.02 (d, J = 3.2 Hz, 1H), 1.41 (s, 9H), 1.38 (s, 9H), 1.35 (s, 9H), 1.34 (s, 9H), 1.06 (s, 9H), 0.89 (s, 9H), 0.16 (s, 3H), 0.13 (s, 3H), 0.12 (s, 3H), -0.10 (s, 3H); ^{13}C NMR (125 MHz): δ = 207.0, 205.8, 181.6, 179.5, 155.8, 155.7, 153.9, 146.7, 145.6, 142.1, 141.0, 138.4, 138.3, 132.7, 131.6, 129.1, 129.0, 128.2, 127.9, 127.4, 127.3, 127.2, 126.3, 125.5, 124.4, 123.5, 120.6, 75.1, 71.1, 55.9, 54.9, 52.8, 50.8, 35.4, 35.1, 34.6, 31.7, 31.6, 30.9, 30.6, 26.0, 25.8, 18.5, 18.3, 14.3, -4.7, -4.7, -4.8, -5.1; IR (neat, cm^{-1}) = 3105, 2955, 1710,

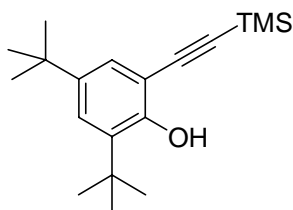
1625, 1476, 1390, 1361, 1254, 1230; HRMS (ESI): Calcd. for $C_{33}H_{47}O_3Si^+$ (m/z), 519.3289. Found 519.3296 $[M+H]^+$.

4,6-Di-tert-butyl-2-iodophenol (**60**)^{80, 87}



To a stirred solution of 2,4-di-tert-butylphenol (0.50 g, 2.4 mmol) in DMF (80 mL), a dropwise addition of *N*-iodosuccinimide (0.66 g, 3.0 mmol) in acetone (20 mL) was done. The reaction mixture was stirred at 0 °C for 8 h. H₂O (50 mL) was added and the resulting solution was extracted with EtOAc (3x25 mL). The organic phase was combined and treated with 0.1 M HCl (50 mL), washed with saturated NaHCO₃ (50 mL), dried (MgSO₄) and concentrated under reduced pressure. The crude product was purified *via* flash chromatography (SiO₂, hexane) to afford the **60** (0.55 g, 68%) as a solid: mp: 76-78 °C (lit.^{69, 76} 77-79 °C); ¹H NMR (500 MHz): δ = 7.48 (d, J = 2.3 Hz, 1H), 7.25 (d, J = 2.3 Hz, 1H), 5.36 (s, 1H), 1.37 (s, 9H), 1.26 (s, 9H); ¹³C NMR (125 MHz): δ = 150.5, 145.1, 136.3, 132.7, 125.1, 89.4, 35.7, 34.3, 31.6, 29.4.

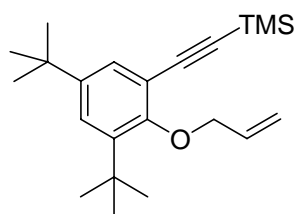
4,6-Di-tert-butyl-2-trimethylsilylethynylphenol (**61**)⁶¹



To a stirred solution of **60** (3.54 g, 10.7 mmol) and Et₃N (5.9 mL) in dioxane (5.9 mL), was added trimethylsilyl acetylene (1.37 g, 13.9 mmol), PdCl₂(PPh₃)₂ (78 mg, 0.12 mmol) and CuI (41 mg, 0.24 mmol). The reaction mixture was stirred at 55 °C (oil bath temperature) under N₂ for 5 h. At the end of reaction time, Et₂O (50 mL) and 1 M HCl

(20 mL) were added and the organic layer was separated, neutralized with a saturated NaHCO₃ (30 mL) solution, washed with H₂O and dried (Na₂SO₄). The organic layer was concentrated under reduced pressure. The crude product was purified by flash chromatography (SiO₂, hexane) to afford **61** (3.03 g, 93.0%), as a solid. mp: 114-116 °C (lit.⁵⁰ 114-116 °C). ¹H NMR (500 MHz): δ = 7.27 (d, *J* = 2.4 Hz, 1H), 7.20 (d, *J* = 2.4 Hz, 1H), 6.08 (s, 1H), 1.39 (s, 9H), 1.39 (s, 9H), 0.27 (s, 9H); ¹³C NMR (125 MHz): δ = 153.6, 142.1, 134.8, 125.7, 109.2, 102.5, 100.3, 76.8, 35.0, 34.3, 31.5, 29.5, 0.1.

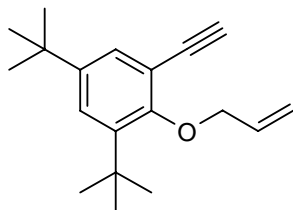
4,6-Di-tert-butyl-2-trimethylsilylethynyl-(-2-propenyloxy)benzene (**62**)



Allyl bromide (1.35 g, 14.9 mmol) was added to a suspension of K₂CO₃ (2.06 g, 14.9 mmol) and **61** (1.50 g, 4.97 mmol) in DMF (20 mL). The reaction mixture was stirred at room temperature for 8 h. This was then quenched with excess water (100 mL) and extract with CH₂Cl₂. The organic layer was then separated, dried (Na₂SO₄) and concentrated under reduced pressure. The residue was then purified by flash chromatography (SiO₂, hexane/EtOAc, 91:9) to furnish **62** (1.74 g, 98.0%) as a light yellow oil. ¹H NMR (300 MHz): δ = 7.30 (d, *J* = 2.4 Hz, 1H), 7.28 (d, *J* = 2.4 Hz, 1H), 6.07 (ddt, *J* = 5.2, 10.7, 17.2 Hz, 1H), 5.41 (dd, *J* = 1.7, 17.2 Hz, 1H), 5.22 (dd, *J* = 1.4, 10.7 Hz, 1H), 4.77 (dd, *J* = 1.4, 5.2 Hz, 2H), 1.37 (s, 9H), 1.28 (s, 9H), 0.24 (s, 9H); ¹³C NMR (75 MHz): δ = 157.5, 145.2, 142.0, 134.4, 129.2, 125.3, 116.6, 116.4, 103.2, 98.5, 73.2, 35.3, 34.5, 30.5, 30.7, 0.1; IR (neat, cm⁻¹) = 3082, 2963, 2864, 2151, 1466, 1361, 1303, 1229,

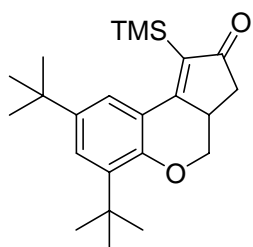
1203, 1123; HRMS (ESI): Calcd. For C₂₂H₃₅OSi (*m/z*): 343.2452. Found 343.2446 [M+H]⁺.

4,6-Di-*tert*-butyl-2-ethynyl-(2-propenyloxy)benzene (**63**)⁶¹



K₂CO₃ (0.49 g, 3.6 mmol) was added to a solution of **62** (0.62 g, 1.7 mmol) in 1:1 mixture of MeOH/THF (10 mL). The reaction mixture was stirred at rt for 4 h. At the end of the reaction time, the reaction mixture was concentrated under reduced pressure and filtered through a plug of silica gel plug (EtOAc). The crude product was purified by flash chromatography (SiO₂, hexane/ether, 83:17) to furnish **63** (0.50 g, quantitative) as colorless liquid: ¹H NMR (500 MHz), δ = 7.38 (d, *J* = 2.5 Hz, 1H), 7.36 (d, *J* = 2.5 Hz, 1H), 6.17 (m, 1H), 5.49 (dd, *J* = 1.3, 10.4 Hz, 1H), 5.29 (dd, *J* = 1.3, 17.2 Hz, 1H), 4.81 (d, *J* = 5.3 Hz, 2H), 3.31 (s, 1H), 1.42 (s, 9H), 1.32 (s, 9H); ¹³C NMR (125 MHz), δ = 157.7, 145.4, 142.2, 134.2, 129.5, 125.6, 116.8, 115.5, 81.9, 81.5, 73.6, 35.3, 34.5, 31.4, 30.7.

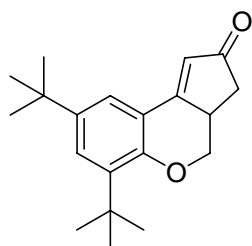
6,8-Di-*tert*-butyl-1-trimethylsilyl-3a,4-dihydro-3*H*-cyclopenta[*c*]chromen-2-one (**64**)



The enyne **62** (100 mg, 0.29 mmol) was cyclized in toluene (5 mL) following the general thermal PK procedures **3.1.3.3** in the presence of Co₂(CO)₈ (110 mg, 0.32 mmol). The reaction was

worked up as indicated in the general procedure. The crude product was purified by flash chromatography (SiO₂, hexane/EtOAc, 90:10) to afford **64** (100 mg, 93%) as a light yellow solid, mp: 132-134 °C; ¹H NMR (500 MHz), δ = 7.41 (d, *J* = 2.4 Hz, 1H), 7.28 (d, *J* = 2.4 Hz, 1H), 4.67 (dd, *J* = 5.7, 10.4 Hz, 1H), 3.87 (dd, *J* = 10.4, 13.4 Hz, 1H), 3.15 (m, 1H), 2.62 (dd, *J* = 7.0, 17.8 Hz, 1H), 1.95 (dd, *J* = 4.5, 17.8 Hz, 1H), 1.39 (s, 9H), 1.31 (s, 9H), 0.33 (s, 9H); ¹³C NMR (125 MHz), δ = 210.7, 177.3, 152.5, 141.1, 137.4, 133.3, 128.0, 124.5, 119.0, 70.2, 38.2, 37.2, 35.3, 34.7, 31.6, 29.8, 0.1; IR (neat, cm⁻¹) = 2960, 1693, 1578, 1440, 1248, 844; HRMS (ESI): Calcd. For C₂₃H₃₅O₂Si (*m/z*): 371.2401. Found 371.2402 [M+H]⁺; Anal. Calcd. for C₂₃H₃₄O₂Si: C, 74.54; H, 9.25. Found: C, 74.13; H, 9.33.

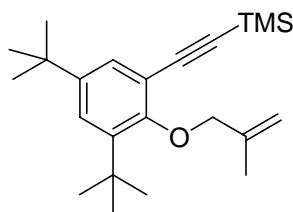
6,8-Di-*tert*-butyl-3a,4-dihydro-3*H*-cyclopenta[*c*]chromen-2-one (65)^{60, 61}



The enyne **63** (100 mg, 0.37 mmol) was cyclized in toluene (5 mL) following the general thermal PK procedures **3.1.3.3** in the presence of Co₂(CO)₈ (140 mg, 0.41 mmol). The reaction was worked up as indicated in the general procedure. The crude product was purified by flash chromatography (hexane/EtOAc, 90:10) to afford **65** (100 mg, 91%) as a solid, m.p: 178-179 °C (lit.^{60, 61} 179-180 °C). ¹H NMR (500 MHz): δ = 7.44 (d, *J* = 2.4 Hz, 1H), 7.39 (d, *J* = 2.4 Hz, 1H), 6.35 (d, *J* = 1.7 Hz, 1H), 4.64 (dd, *J* = 5.5, 10.7 Hz, 1H), 3.80 (dd, *J* = 10.3, 13.4 Hz, 1H), 3.28 (m, 1H), 2.67 (dd, *J* = 6.9, 17.9 Hz, 1H), 2.04 (dd, *J* = 4.1, 17.9 Hz, 1H), 1.39 (s, 9H), 1.32 (s, 9H); ¹³C NMR (125 MHz): δ = 206.3,

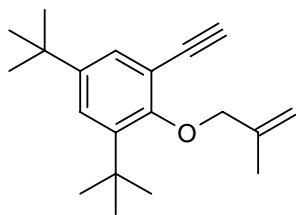
170.6, 153.1, 143.3, 138.5, 128.5, 121.4, 121.2, 117.1, 69.8, 38.1, 36.5, 34.5, 35.3, 31.4, 29.7.

4,6-Di-tert-butyl-2-trimethylsilylethynyl-(2-methylallyloxy)benzene (**66**)



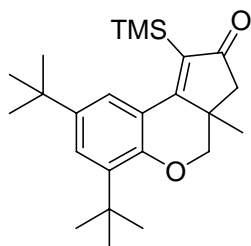
3-Chloro-2-methylpropene (1.35 g, 14.9 mmol) was added to a suspension of K_2CO_3 (2.06 g, 14.9 mmol), NaI (2.34 g, 14.9 mmol), and **61** (1.50 g, 4.97 mmol) in DMF (20 mL). The reaction mixture was stirred for 12 h. The reaction was then quenched with water (100 mL) and extracted with CH_2Cl_2 . The organic layers were combined, dried (Na_2SO_4) and concentrated under reduced pressure. The crude product was purified by flash chromatography (SiO_2 , hexane/EtOAc, 91:9) to furnish **66** (1.74 g, 98.0%) as yellow liquid. ^1H NMR (500 MHz): δ = 7.32 (d, J = 2.3 Hz, 1H), 7.30 (d, J = 2.8 Hz, 1H), 5.20 (s, 1H), 4.97 (s, 1H), 4.69 (s, 2H), 1.86 (s, 3H), 1.37 (s, 9H), 1.29 (s, 9H), 0.24 (s, 9H); ^{13}C NMR (125 MHz): δ = 157.4, 145.2, 142.1, 141.5, 129.4, 125.3, 116.4, 111.1, 103.2, 98.6, 75.5, 35.2, 34.5, 31.4, 30.7, 19.7, 0.02; IR (neat, cm^{-1}) = 2961, 2151, 1436, 1249, 960; HRMS (ESI): Calcd. For $\text{C}_{23}\text{H}_{37}\text{OSi}$ (m/z): 357.2608. Found 357.2613 $[\text{M}+\text{H}]^+$.

4,6-Di-*tert*-butyl-2-ethynyl-(2-methylallyloxy)benzene (**67**)



K_2CO_3 (0.49 g, 3.55 mmol) was added to a solution of **66** (0.62 g, 1.7 mmol) in MeOH/THF (10 mL/1:1). The mixture was stirred at room temperature for 4 h. The reaction mixture was concentrated under reduced pressure and filtered through a plug of silica gel plug (EtOAc). The residue was purified by flash chromatography (SiO_2 , hexane/ether, 83:17) to furnish **67** (0.50 g, quantitative) as yellow liquid. 1H NMR (300 MHz): δ = 7.38 (d, J = 2.4 Hz, 1H), 7.36 (d, J = 2.4 Hz, 1H), 5.20 (s, 1H), 5.00 (s, 1H), 4.70 (s, 2H), 3.30 (s, 1H), 1.90 (s, 3H), 1.41 (s, 9H), 1.32 (s, 9H); ^{13}C NMR (75 MHz): δ = 157.7, 145.3, 142.2, 141.7, 129.6, 125.6, 115.5, 111.8, 81.9, 81.6, 76.0, 35.3, 34.5, 31.5, 30.7, 19.8; IR (neat, cm^{-1}) = 3313, 3108, 2974, 2107, 1658, 1438, 1233, 1165, 1123, 1042; HRMS (ESI): Calcd. For $C_{20}H_{28}ONa$ (m/z): 307.2032. Found 307.2037, and Calcd. for $C_{20}H_{29}O$ (m/z): 285.2213. Found 285.2211 $[M+Na]^+$.

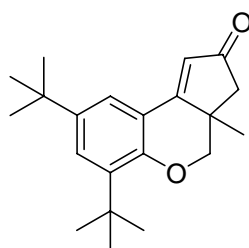
6,8-Di-*tert*-butyl-1-trimethylsilyl-3a-methyl-4-hydro-3*H*-cyclopenta[*c*]chromen-2-one (**68**);



The enyne **66** (240 mg, 0.64 mmol) was cyclized in toluene (10 mL) following the general thermal PK procedures **3.1.3.3** in the presence of $Co_2(CO)_8$ (240 mg, 0.74 mmol). The reaction was worked up as indicated in the general procedure. The crude product was purified by flash chromatography (hexane/EtOAc, 90:10) to afford **68** (240 mg, 92%) as a solid, m.p: 156-157 °C; 1H NMR (500 MHz), δ = 7.40 (d, J = 2.3 Hz, 1H),

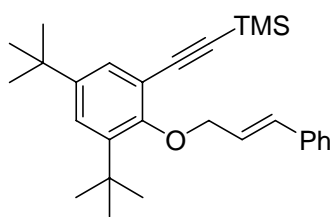
7.24 (d, $J = 2.3$ Hz, 1H), 6.23 (s, 1H), 4.32 (d, $J = 10.7$ Hz, 1H), 3.96 (d, $J = 10.7$ Hz, 1H), 2.31 (d, $J = 17.2$ Hz, 1H), 2.02 (d, $J = 17.5$ Hz, 1H), 1.39 (s, 9H), 1.32 (s, 9H), 1.19 (s, 3H), 0.30 (s, 9H); ^{13}C NMR (125 MHz), $\delta = 210.1, 181.4, 151.3, 141.2, 137.1, 132.1, 127.9, 124.8, 117.8, 74.6, 47.3, 39.0, 35.2, 34.6, 31.6, 29.7, 22.9, 0.2$; IR (neat, cm^{-1}) = 2959, 1691, 1529, 1255, 1028, 938; HRMS (ESI): Calcd. For $\text{C}_{24}\text{H}_{37}\text{O}_2\text{Si}$ (m/z): 385.2557. Found 385.2559 $[\text{M}+\text{H}]^+$; Anal. Calcd. for $\text{C}_{24}\text{H}_{36}\text{O}_2\text{Si}$: C, 74.94; H, 9.43. Found: C, 74.77; H, 9.23.

6,8-Di-*tert*-butyl-3a-methyl-3a,4-dihydro-3*H*-cyclopenta[*c*]chromen-2-one (69);



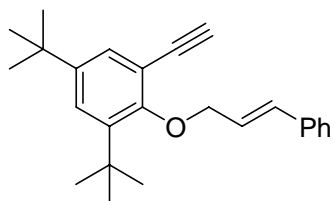
The enyne **67** (110 mg, 0.39 mmol) was cyclized in toluene (5 mL) following the general oxidative and thermal PK procedures **3.1.3.2** and **3.1.3.3** in the presence of $\text{Co}_2(\text{CO})_8$ (130 mg, 0.380 mmol) and NMO (453 mg, 3.87 mmol). The reaction was worked up as indicated in the general procedure. The crude product was purified by flash chromatography (hexane/EtOAc, 90:10) to afford **69** (97.9 mg, 81.0%) for the oxidative mode. The thermal condition also gave **69** (110 mg, 91%) as a solid, m.p: 130-132 °C; ^1H NMR (300 MHz): $\delta = 7.43$ (d, $J = 2.4$ Hz, 1H), 7.36 (d, $J = 2.1$ Hz, 1H), 6.23 (s, 1H), 4.33 (d, $J = 10.4$ Hz, 1H), 3.87 (d, $J = 10.7$ Hz, 1H), 2.39 (d, $J = 17.5$ Hz, 1H), 2.20 (d, $J = 17.5$ Hz, 1H), 1.40 (s, 9H), 1.31 (s, 9H), 1.30 (s, 3H); ^{13}C NMR (75 MHz): $\delta = 205.8, 174.9, 151.7, 143.2, 138.3, 128.4, 121.5, 120.0, 116.2, 73.9, 47.0, 38.8, 35.2, 34.4, 31.4, , 29.7, 23.8$; IR (neat, cm^{-1}) = 3098, 2962, 1700, 1594, 1463, 1183, 1011; HRMS (ESI): Calcd. For $\text{C}_{21}\text{H}_{29}\text{O}_2$ (m/z): 313.2162. Found 313.2164 $[\text{M}+\text{H}]^+$.

4,6-Di-tert-butyl-2-trimethylsilylethynyl-(-3-phenyl-2-propenyloxy)benzene (**71**)



DEAD (3.46 g, 19.9 mmol) in THF (10 mL) was added dropwise to a solution of **61** (2.0 g, 6.60 mmol), cinnamyl alcohol (1.78 g, 13.3 mmol) and PPh₃ (5.21 g, 19.9 mmol) in THF (20 mL) and stirred at 0 °C for 6 h. The solvent was removed in vacuum. The crude product was purified by flash chromatography (hexane) to give the product **71** (2.70 g, 95%) as a white solid, mp. 123-125 °C; ¹H NMR (500 MHz): δ = 7.45 (d, *J* = 7.3 Hz, 2H), 7.33-7.36 (m, 4H), 7.25-7.28 (m, 1H), 6.82 (d, *J* = 16.0 Hz, 1H), 6.50 (dt, *J* = 6.0, 15.8 Hz, 1H), 4.97 (dd, *J* = 1.8, 5.5 Hz, 2H), 1.42 (s, 9H), 1.31 (s, 9H), 0.27 (s, 9H); ¹³C NMR (125 MHz): δ = 157.5, 145.3, 142.1, 137.0, 132.0, 129.3, 128.6, 127.7, 126.6, 125.8, 125.4, 116.5, 103.3, 98.7, 73.2, 35.3, 34.5, 31.5, 30.8, 0.15; IR (neat, cm⁻¹) = 3109, 2960, 2152, 1434, 1371, 1229, 1120; HRMS (ESI): Calcd for C₂₈H₃₉OSi (*m/z*): 419.2765. Found 419.2767 [M+H]⁺. Calcd for C₂₈H₃₉NaOSi (*m/z*): 441.2584. Found 441.2589 [M+Na]⁺.

4,6-Di-tert-butyl-2-ethynyl-(-3-phenyl-2-propenyloxy)benzene (**72**)

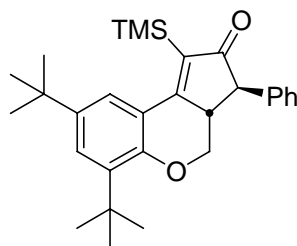


K₂CO₃ (1.32 g, 9.57 mmol) was added to a solution of **71** (1.0 g, 2.4 mmol) in 1:1 mixture of MeOH/THF (10 mL). The reaction mixture was stirred at room temperature for 4 h. At the end of the reaction time, the reaction mixture was concentrated under reduced pressure and filtered through a plug of silica gel plug (EtOAc). The residue was purified by flash chromatography (hexane/ether, 83:17) to furnish **72** (0.77 g, 93%) as colorless

liquid which later solidified to give a purple solid. mp: 100-102 °C; ¹H NMR (500 MHz): δ = 7.45 (d, *J* = 7.3 Hz, 2H), 7.24-7.38 (m, 5H), 6.78 (d, *J* = 16.0 Hz, 1H), 6.51 (dt, *J* = 5.5, 15.6 Hz, 1H), 4.94 (dd, *J* = 1.8, 6.0 Hz, 2H), 3.34 (s, 1H), 1.42 (s, 9H), 1.31 (s, 9H); ¹³C NMR (125 MHz): δ = 157.8, 145.5, 142.3, 137.0, 132.2, 129.5, 128.6, 127.8, 126.7, 125.7, 125.6, 115.6, 82.0, 81.6, 73.6, 35.3, 34.5, 31.5, 30.8; LRMS (ESI): for C₂₅H₃₁O: 347 (M+H), for C₂₅H₃₀ONa: 369 (M+Na); IR (neat, cm⁻¹) = 3298, 2959, 2103, 1658, 1578, 1435, 1368, 1230, 1121; Anal. Calcd. for C₂₅H₃₀O: C, 86.66; H, 8.73. Found: C, 86.40; H, 8.86.

6,8-Di-*tert*-butyl-3-phenyl-1-trimethylsilyl-3a,4-dihydro-3*H*-cyclopenta[*c*]

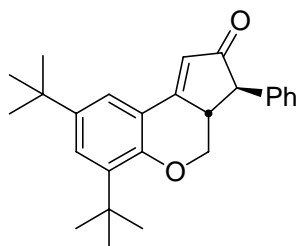
chromen-2-one (**73**)



The enyne **71** (200 mg, 0.48 mmol) was cyclized in (10 mL) of the appropriate solvent following the general oxidative and thermal PK procedures **3.1.3.2** and **3.1.3.3** in the presence of Co₂(CO)₈ (180 mg, 0.53 mmol) and NMO (620 mg, 5.26 mmol). The reaction was worked up as indicated in the general procedure. The crude product was purified by flash chromatography (hexane/EtOAc, 90:10) to afford **73** (170 mg, 81%) for the oxidative mode. The thermal condition also gave **73** (150 mg, 71%) as a light yellow solid, m.p: 129-131 °C; ¹H NMR (500 MHz): δ = 7.46 (d, *J* = 2.3 Hz, 1H), 7.42 (d, *J* = 2.3 Hz, 1H), 7.34 (t, *J* = 7.3 Hz, 2H), 7.28 (d, *J* = 7.3 Hz, 1H), 7.19 (d, *J* = 6.9 Hz, 2H), 4.77 (dd, *J* = 5.5, 10.5 Hz, 1H), 4.01 (dd, *J* = 10.5, 13.3 Hz, 1H), 3.30 (dt, *J* = 5.5, 12.8 Hz, 1H), 3.14 (d, *J* = 5.0 Hz, 1H), 1.39 (s, 9H), 1.36 (s, 9H), 0.39 (s,

9H); ^{13}C NMR (125 MHz): δ = 209.5, 174.7, 153.0, 141.5, 138.2, 137.7, 132.2, 128.9, 128.7, 128.3, 127.2, 124.7, 118.7, 69.6, 56.1, 46.2, 35.4, 34.8, 31.7, 29.8, 0.1; IR (neat, cm^{-1}) = 3106, 2961, 1687, 1581, 1441, 1249, 1007, 939; LRMS (ESI): for $\text{C}_{29}\text{H}_{39}\text{SiO}_2$: 447 $[\text{M}+\text{H}^+]$, for $\text{C}_{29}\text{H}_{38}\text{SiO}_2\text{Na}$: 469 $[\text{M}+\text{Na}^+]$, for $\text{C}_{29}\text{H}_{37}\text{SiO}_2$: 445 $[\text{M}-\text{H}]$; HRMS (ESI): Calcd. For $\text{C}_{29}\text{H}_{38}\text{SiO}_2\text{Na}$ (m/z): 469.2533. Found 469.2579 $[\text{M}+\text{Na}]^+$.

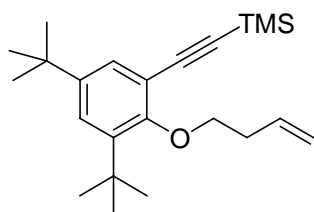
6,8-Di-*tert*-butyl-3-phenyl-3a,4-dihydro-3H-cyclopenta[c]chromen-2-one (74);



The enyne **72** (200 mg, 0.58 mmol) was cyclized in (10 mL) of the appropriate solvent following the general oxidative and thermal PK procedures **3.1.3.2** and **3.1.3.3** in the presence $\text{Co}_2(\text{CO})_8$ (220 mg, 0.64 mmol) and NMO (740 mg, 6.40 mmol). The reaction was worked up as indicated in the general procedure. The crude product was purified by flash chromatography (hexane/EtOAc, 90:10) to afford **74** (200 mg, 91.0%) for the oxidative mode. The thermal condition also gave **74** (160 mg, 73%) as a light yellow solid, m.p: 155-157 $^\circ\text{C}$; ^1H NMR (500 MHz): δ = 7.49 (d, J = 2.3 Hz, 1H), 7.47 (d, J = 2.3 Hz, 1H), 7.36 (t, J = 7.3 Hz, 2H), 7.30 (d, J = 7.3 Hz, 1H), 7.21 (d, J = 7.3 Hz, 2H), 6.47 (d, J = 1.8 Hz, 1H), 4.74 (dd, J = 5.5, 10.5 Hz, 1H), 3.96 (dd, J = 10.5, 13.3 Hz, 1H), 3.36 (ddt, J = 1.8, 5.5, 12.5 Hz, 1H), 3.26 (d, J = 4.6 Hz, 1H), 1.39 (s, 9H), 1.35 (s, 9H); ^{13}C NMR (125 MHz): δ = 205.6, 168.2, 153.4, 143.5, 138.7, 137.9, 129.0, 128.8, 128.6, 127.4, 121.3, 119.9, 116.8, 69.2, 56.0, 45.6, 35.3, 34.5, 30.4, 29.7; IR (neat, cm^{-1}) = 3105, 2959, 2864, 1712, 1607, 1476, 1214, 1151, 1005; LRMS

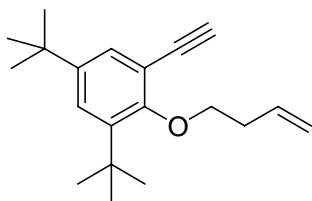
(ESI): for $C_{26}H_{30}O_2K$: 413 [M+K], for $C_{26}H_{30}O_2Na$: 397 [M+Na], for $C_{26}H_{31}O_2$: 375 [M+H]; Anal. Calcd. for $C_{26}H_{30}O_2$: C, 83.38; H, 8.07. Found: C, 83.25; H, 8.18.

3-Butenyloxy-4,6-di-*tert*-butyl-2-trimethylsilylethynylbenzene (75)



A solution of diethyl azodicarboxylate (3.46 g, 19.9 mmol) in THF (20 mL) was added dropwise to a stirred solution of **61** (2.0 g, 6.6 mmol), 3-buten-1-ol (0.96 g, 13.3 mmol) and PPh_3 (5.22 g, 19.9 mmol) in THF (50 mL) at 0 °C. The reaction mixture was then stirred for 6 h. At the end of the reaction, the solvent was removed in vacuo. The crude product was purified by flash chromatography (hexane) to give the product **75** (2.35 g, 99%) as a clear liquid. 1H NMR (300 MHz): δ = 7.31 (d, J = 2.8 Hz, 1H), 7.30 (d, J = 2.8 Hz, 1H), 5.92 (ddt, J = 6.9, 10.3, 17.2 Hz, 1H), 5.15 (dd, J = 3.1, 17.2 Hz, 1H), 5.09 (dd, J = 3.1, 10.3 Hz, 1H), 4.29 (t, J = 6.9 Hz, 2H), 2.61 (dt (app, q), J = 6.9, 6.9 Hz, 2H), 1.38 (s, 9H), 1.29 (s, 9H), 0.27 (s, 9H), ^{13}C NMR (75 MHz): δ = 157.8, 145.0, 141.9, 134.9, 129.4, 125.3, 116.8, 116.4, 103.5, 98.3, 71.8, 35.3, 34.7, 34.5, 31.5, 30.8, 0.13; IR (neat, cm^{-1}) = 3106, 2959, 2151, 1437, 1235, 1123, 960, 912; HRMS (ESI): Calcd. For $C_{23}H_{37}OSi$ (m/z): 357.2608. Found 357.2613.

3-Butenyloxy-4,6-di-*tert*-butyl-2-ethynylbenzene (**76**)^{60, 61}



K_2CO_3 (1.13 g, 8.20 mmol) was added to a solution of **75** (1.41 g, 4.10 mmol) in 1;1 mixture of MeOH/THF (10 mL).

The mixture was stirred at room temperature for 4 h. The

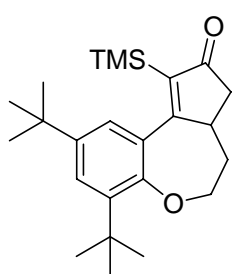
reaction mixture was concentrated under reduced pressure and filtered through a plug of silica gel using EtOAc. The crude product was purified by flash chromatography (hexane/ether, 83:17) to furnish **76** (0.75 g, 80%) as a colorless liquid. ^1H NMR (500 MHz): δ = 7.34 (d, J = 2.4 Hz, 1H), 7.33 (d, J = 2.4 Hz, 1H), 5.98 (ddt, J = 6.8, 10.3, 17.0 Hz, 1H), 5.16-5.20 (m, 1H), 5.09-5.11 (m, 1H), 4.30 (t, J = 7.0 Hz, 2H), 3.30 (s, 1H), 2.62-2.67 (m, 2H), 1.39 (s, 9H), 1.29 (s, 9H); ^{13}C NMR (125 MHz): δ = 158.1, 145.1, 142.0, 134.9, 129.5, 125.5, 116.8, 115.4, 82.1, 81.3, 72.2, 35.3, 34.8, 34.5, 31.5, 30.8; IR (neat, cm^{-1}): 3304, 2959, 2107, 1656, 1122, 727.

Thermal cyclization of 3-butenyloxy-4,6-di-*tert*-butyl-2-trimethylsilylethynyl benzene (**75**)

The enyne **75** (0.20 g, 0.56 mmol) was cyclized in toluene (10 mL) following the general thermal PK procedure **3.1.3.3** in the presence $\text{Co}_2(\text{CO})_8$ (0.21 g, 0.62 mmol) and heated at 70 °C. The reaction was worked up as indicated in the general procedure. The crude product was purified by flash chromatography (SiO_2 , hexane/EtOAc, 90:10) to afford the expected PK product **77** (30 mg, 14%) as a brown waxy solid and a diene **78** (150 mg, 75%) as a yellow solid. When the reaction was carried out under CO (1 atm)

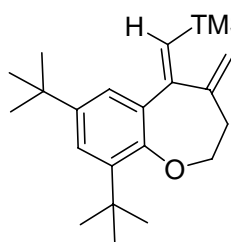
conditions, the yield of the product **77** increased to 22% and also starting material was recovered.

7,9-Di-*tert*-butyl-1-trimethylsilyl-4,4a-dihydro-3*H*,5*H*-6-oxabenzof]azulen-2-one
(77);



^1H NMR (300 MHz): δ = 7.33 (d, J = 3.0 Hz, 1H), 6.90 (d, J = 2.4 Hz, 1H), 4.37 (dt, J = 3.3, 9.0 Hz, 1H), 3.76 (dt, J = 1.2, 11.4 Hz, 1H), 2.98 (p, J = 5.1 Hz, 1H), 2.70 (dd, J = 6.6, 18.6 Hz, 1H), 2.18 (m, 1H), 2.12 (dd, J = 1.8, 18.6 Hz, 1H), 1.76 (dq, J = 3.0, 10.2 Hz, 1H), 1.39 (s, 9H), 1.30 (s, 9H), -0.03 (s, 9H); ^{13}C NMR (75 MHz): δ = 212.5, 189.4, 154.6, 144.7, 141.5, 132.6, 125.5, 125.2, 125.2, 72.7, 43.8, 43.7, 35.2, 31.6, 34.7, 31.6, 30.4, -0.7; IR (neat, cm^{-1}) = 2954, 1692, 1587, 1560, 1432, 1360, 1248, 1224, 1123, 1068, 1025, 936; HRMS (ESI): Calcd. For $\text{C}_{24}\text{H}_{36}\text{O}_2\text{SiNa}$ (m/z): 407.2377. Found 407.2397 $[\text{M}+\text{Na}]^+$.

(7,9-Di-*tert*-butyl-4-methylene -3,4-dihydro-2*H*-benzo[*b*]oxepin-5-ylidenemethyl)-
trimethylsilane (78)



Mp. 105-107 °C ^1H NMR (500 MHz): δ = 7.23 (d, J = 1.8 Hz, 1H), 7.19 (d, J = 1.8 Hz, 1H), 5.77 (s, 1H), 4.94 (d, J = 6.4 Hz, 2H), 4.16 (t, J = 5.1 Hz, 2H), 2.76 (t, J = 5.1 Hz, 2H), 1.37 (s, 9H), 1.32 (s, 9H), 0.5 (s, 9H); ^{13}C NMR (125 MHz): δ = 159.1, 153.5, 148.9, 144.4, 139.7, 134.9, 130.5, 123.5, 123.4, 111.8, 70.4, 39.8, 35.3, 34.6, 31.7, 30.6,

0.6; IR (neat, cm^{-1}) = 2955, 1639, 1571, 1468, 1433, 1361, 1245, 1166; HRMS (CI): Calcd. For $\text{C}_{23}\text{H}_{36}\text{SiO}$ (m/z): 356.2530. Found 356.2533 $[\text{M}]^+$.

Thermal cyclization of 3-butenyloxy-4,6-di-tert-butylethynylbenzene (76)

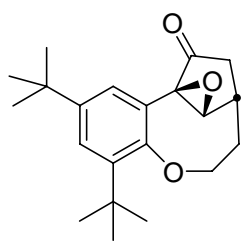
The enyne **76** (200 mg, 0.70 mmol) was cyclized in 10 mL of toluene following the general thermal PK procedure **3.1.3.3** in the presence $\text{Co}_2(\text{CO})_8$ (270 mg, 0.78 mmol) and heated at 70 °C. The reaction was worked up as indicated in the general procedure. The crude product was purified by flash chromatography (hexane/EtOAc, 90:10) to afford epoxide **79** (40 mg, 17%) and Michael addition product **81** (30 mg, 13%) as a colorless solid.

Oxidative cyclization of 3-butenyloxy-4,6-di-tert-butylethynylbenzene (76) under oxygen atmosphere.

The enyne **76** (300 mg, 1.06 mmol) was dissolved in 10 mL of CH_2Cl_2 and $\text{Co}_2(\text{CO})_8$ (400 mg, 1.16 mmol) was added under N_2 and stirred for 2 h. The reaction mixture was then purged with O_2 and then NMO (1.24 g, 10.6 mmol) was added in three portions at 0 °C and the reaction was left to stir to room temperature under oxygen atmosphere. The reaction was worked up as indicated in the general procedure. The crude product was purified by flash chromatography (hexane/EtOAc, 90:10) to afford only the epoxide **79** (220 mg, 63%)

4,6-Di-*tert*-butyl-8-13-dioxatetracyclo[9.2.2.0^{2,7}.0^{1,12}]tetradeca-2,4,6-triene-14-one

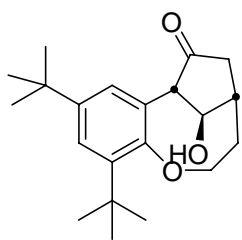
(79)⁶¹



¹H NMR (500 MHz): δ = 7.40 (d, J = 3.0 Hz, 1H), 7.37 (d, J = 3.0 Hz, 1H), 4.46 (d, J = 13.5 Hz, 1H), 4.05 (s, 1H), 3.41 (t, J = 13.5 Hz, 1H), 2.96 (s, 1H), 2.74 (ddd, J = 1.0, 6.5, 18.5 Hz, 1H), 2.52 (t, J = 15.5 Hz, 1H), 1.97 (d, J = 18.5 Hz, 1H), 1.91 (d, J = 15.0 Hz, 1H), 1.34 (s, 9H), 1.32 (s, 9H), ¹³C NMR (125 MHz): δ = 207.9, 157.7, 145.5, 141.3, 125.5, 125.1, 70.1, 67.5, 37.5, 36.6, 35.2, 34.7, 32.4, 31.6, 31.6, 31.3, 30.7.

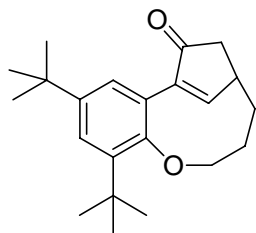
4,6-Di-*tert*-butyl-14-hydroxy-8-oxa-tricyclo[9.2.1.0^{2,7}]tetradeca-2,4,6-triene-13-one

(81)



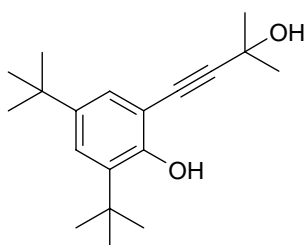
Mp. 192-194 °C ¹H NMR (500 MHz): δ = 7.23 (d, J = 2.3 Hz, 1H), 7.07 (d, J = 2.3 Hz, 1H), 4.18 (d, J = 11.9 Hz, 1H), 3.51 (t, J = 10.5 Hz, 1H), 3.27 (s, 1H), 3.06 (dd, J = 8.7, 18.3 Hz, 1H), 2.66 (s, 1H), 2.38 (m, 1H), 2.16 (d, J = 18.3 Hz, 1H), 1.96 (s, 1H), 1.72 (d, J = 14.7 Hz, 1H), 1.33 (s, 9H), 1.31 (s, 9H); ¹³C NMR (125 MHz): δ = 219.2, 145.5, 142.0, 129.0, 123.4, 71.1, 63.0, 43.0, 41.2, 35.5, 35.2, 34.5, 31.6, 31.2; IR (neat, cm⁻¹) = 3396, 2957, 1734; LRMS (ESI): for C₂₁H₃₀O₃Na: 353 [M+Na], for C₂₁H₃₀O₃Cl: 365 [MCl], for C₂₁H₂₉O₃: 329 [M-H]; Anal. Calcd. for C₂₁H₃₀O₃: C, 76.33; H, 9.15. Found: C, 76.17; H, 9.31.

4,6-Di-*tert*-butyl-8-oxa-tricyclo[10.2.1.0^{2,7}]pentadeca-1(15),2,4,6-tetraene-14-one^{60,61} (83**)**



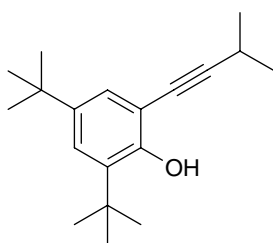
The enyne **82** (130mg, 0.44 mmol) was cyclized in 10 mL of toluene following the general thermal PK procedure **3.1.3.3** in the presence $\text{Co}_2(\text{CO})_8$ (164 mg, 0.48 mmol) and heated at 70 °C. The reaction was worked up as indicated in the general procedure. The crude product was purified by flash chromatography (hexane/EtOAc, 90:10) to afford the cyclization compound **83** (120 mg, 86%) as a colorless solid, m.p.:190-192 °C (lit.^{49, 50} mp. 191-192 °C); ^1H NMR (300 MHz): δ = 7.28 (d, J = 2.5 Hz, 1H), 7.52 (s, 1H), 7.07 (d, J = 2.5 Hz, 1H), 4.37 (t, J = 10.3 Hz, 1H), 3.34-3.35 (m, 1H), 3.20-3.22 (m, 1H), 2.67 (dd, J = 5.8, 18.0 Hz, 1H), 2.27 (d, J = 18.0 Hz, 1H), 1.93-2.04 (m, 1H), 1.80-1.89 (m, 1H), 1.42-1.47 (m, 1H), 1.34 (s, 9H), 1.30 (s, 9H), ^{13}C NMR (75 MHz), δ = 208.5, 166.5, 153.3, 145.3, 141.5, 141.1, 127.8, 123.9, 123.6, 76.3, 40.5, 39.3, 35.0, 34.6, 33.7, 31.6, 31.2, 25.6; IR (KBr, cm^{-1}) 2956, 1706, 1594, 1441, 1110, 750; HRMS (ESI): Calcd. For $\text{C}_{22}\text{H}_{30}\text{O}_2\text{Na}$ (m/z): 349.2138. Found 349.2159 $[\text{M}+\text{Na}]^+$; Calcd. For $\text{C}_{44}\text{H}_{60}\text{O}_4\text{Na}$ (m/z): 675.4384. Found 675.4326 $[2\text{M}+\text{Na}]^+$.

2,4-Di-*tert*-butyl-6-(-3-hydroxy-3-methylbut-1-ynyl)phenol (**84**)



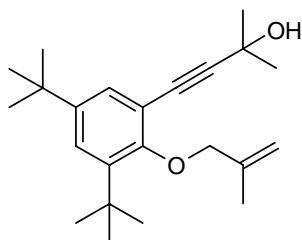
To a stirred solution of **60** (2.82 g, 8.50 mmol) and Et₃N (5.9 mL) in dioxane (5.9 mL) was added 2-hydroxy-2-methylbut-1-yne (2.14 g, 25.5 mmol), PdCl₂(PPh₃)₂ (0.30 g, 0.43 mmol) and CuI (0.16 g, 0.84 mmol). The reaction mixture was stirred at 55 °C (oil bath temperature) under N₂ for 5 h. At the end of reaction time, Et₂O (50 mL) and 1 M HCl (20 mL) were added and the organic layer was separated, neutralized with a saturated NaHCO₃ (30 mL) solution, washed with H₂O and dried (Na₂SO₄). The organic layer was concentrated under reduced pressure. The crude product was purified by flash chromatography (SiO₂, hexane) to afford **84** (2.30 g, 94%), as a golden yellow solid. mp: 97-99 °C. ¹H NMR (300 MHz): δ = 7.27 (d, *J* = 2.4 Hz, 1H), 7.18 (d, *J* = 2.4 Hz, 1H), 6.02 (s, 1H), 2.31 (s, 1H), 1.66 (s, 6H), 1.40 (s, 9H), 1.28 (s, 9H); ¹³C NMR (75 MHz): δ = 153.0, 142.1, 134.9, 125.8, 125.3, 108.6, 100.7, 77.7, 66.0, 35.0, 34.3, 31.7, 31.5, 29.5; IR (neat, cm⁻¹) = 3358, 2959, 2223, 1443, 1415, 1363, 1197; HRMS (ESI): Calcd. for C₁₉H₂₈O₂Na (*m/z*): 311.1982. Found 311.1985 (M+Na)⁺.

2,4-Di-*tert*-butyl-6-(-3-methylbut-1-ynyl)phenol (**85**)



To a stirred solution of **84** (0.10 g, 0.35 mmol) and NaBH₄ (0.13 g, 3.5 mmol) in dichloromethane (5.0 mL) at 0 °C, was added TFA (3 mL) over a period of 10 minutes. The reaction mixture was then decanted into 300 mL of iced water and extracted with CH₂Cl₂ (20 mL). The organic layer was separated, neutralized with a saturated NaHCO₃ (30 mL) solution, washed with H₂O and dried (Na₂SO₄). The organic layer was then concentrated under reduced pressure. The crude product was purified by flash chromatography (silica gel, *n*-hexane) to afford **85** (0.90 g, 96%), as a golden yellow oil. ¹H NMR (500 MHz): δ = 7.23 (d, *J* = 2.8 Hz, 1H), 7.17 (d, *J* = 2.8 Hz, 1H), 6.03 (s, 1H), 1.28 (s, 9H), 2.86 (sept, *J* = 6.9 Hz, 1H), 1.40 (s, 9H), 1.30 (d, *J* = 6.9 Hz, 6H); ¹³C NMR (125 MHz): δ = 152.8, 141.9, 134.5, 125.6, 124.4, 109.9, 102.8, 74.8, 35.0, 34.3, 31.6, 29.5, 23.3, 21.5; IR (neat, cm⁻¹) = 3497, 2959, 1443, 1363, 1234, 880; HRMS (ESI): Calcd. for C₁₉H₂₉O (*m/z*), 273.2213. Found 273.2221.

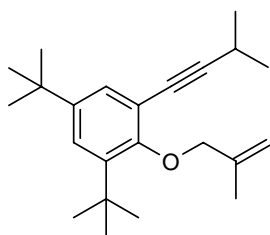
4,6-Di-*tert*-butyl-2-(-2-methylbut-3-yn-2-ol)-(-2-methylallyloxy)benzene (**86**)



3-Chloro-2-methylpropene (1.26 g, 13.9 mmol) was added to a suspension of K₂CO₃ (1.92 g, 13.9 mmol), NaI (2.08 g, 13.9 mmol), and **84** (1.0 g, 3.47 mmol) in DMF (20 mL). The reaction mixture was stirred for 12 h. The was then quenched with excess of water (100 mL) and extract with CH₂Cl₂. The organic layers were combined and dried (Na₂SO₄). The organic layer was concentrated under reduced

pressure. The residue was then purified by flash chromatography (SiO₂, hexane/EtOAc, 91:9) to furnish **86** (0.88 g, 74%) as a light yellow solid, mp: 91-93 °C. ¹H NMR (500 MHz): δ = 7.31 (d, *J* = 2.7 Hz, 1H), 7.25 (d, *J* = 2.7 Hz, 1H), 5.25 (s, 1H), 4.99 (s, 1H), 4.63 (s, 2H), 2.12 (s, 1H), 1.85 (s, 3H), 1.60 (s, 6H), 1.38 (s, 9H), 1.29 (s, 9H); ¹³C NMR (75 MHz): δ = 157.0, 145.3, 142.1, 141.9, 128.8, 125.0, 116.1, 110.7, 97.9, 80.1, 75.5, 65.8, 35.3, 34.5, 31.7, 31.4, 30.7, 29.7, 19.7; IR (neat, cm⁻¹) = 3331, 2956, 2866, 1657, 1467, 1436, 1410, 1361, 1316, 1229, 1200, 1166, 1125, 1038; HRMS (ESI): Calcd. for C₂₃H₃₄NaO₂⁺ *m/z*, 365.2451, found *m/z*, 365.2450 [M+Na]⁺; Anal. Calcd. for C₂₃H₃₄O₂: C, 80.65; H, 10.01. Found: C, 80.11; H, 9.89.

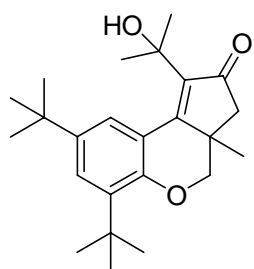
4,6-Di-*tert*-butyl-2-(-2-methylbut-3-ynyl)-(-2-methylallyloxy)benzene (**87**)



3-Chloro-2-methylpropene (0.15 g, 1.7 mmol) was added to a suspension of K₂CO₃ (0.11 g, 0.81 mmol), NaI (0.25 g, 1.7 mmol) and **85** (0.11 g, 0.40 mmol) in DMF (20 mL). The reaction mixture was stirred for 12 h. The reaction was then quenched with water (100 mL) and extracted with CH₂Cl₂. The organic layers were separated, dried (Na₂SO₄) and concentrated under reduced pressure. The crude product was purified by flash chromatography (SiO₂, hexane/EtOAc, 91:9) to furnish **87** (0.12 g, 92%) as a light yellow oil. ¹H NMR (300 MHz): δ = 7.27 (d, *J* = 2.7 Hz, 1H), 7.24 (d, *J* = 2.7 Hz, 1H), 5.21 (t, *J* = 1.0 Hz, 1H), 4.98 (t, *J* = 1.4 Hz, 1H), 4.67 (s, 2H), 2.74-2.88 (sept, *J* = 6.9 Hz, 1H), 1.87 (s, 3H), 1.38 (s, 9H), 1.29 (s, 9H), 1.26 (d, *J* = 7.2 Hz, 6H); ¹³C NMR (75 MHz): δ = 156.8, 145.1, 141.9, 141.7, 128.9, 124.2, 117.2, 110.9, 99.9,

75.2, 35.2, 34.5, 31.5, 30.7, 29.4, 23.0, 21.6, 19.7; IR (neat, cm^{-1}) = 2964, 2871, 2229, 1660, 1595, 1437, 1362, 1260; HRMS (CI): Calcd. For $\text{C}_{23}\text{H}_{34}\text{O}^+$ (m/z): 326.2604. Found 326.2585 $[\text{M}]^+$.

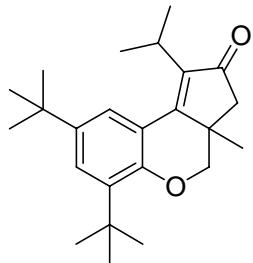
6,8-Di-*tert*-butyl-1-(1-hydroxy-1-methylethyl)-3a-methyl-3a,4-dihydro-3H-cyclopenta[c]chromen-2-one (88);



The enyne **86** (110 mg, 0.32 mmol) was cyclized in the appropriate solvent (10 mL) following the general oxidative and thermal PK procedures **3.1.3.2** and **3.1.3.3** in the presence $\text{Co}_2(\text{CO})_8$ (120 mg, 0.35 mmol) and NMO (410 mg, 3.51 mmol).

The reaction was worked up as indicated in the general procedure. The crude product was purified by flash chromatography (hexane/EtOAc, 90:10) to afford **88** (40 mg, 33%) for the oxidative mode. The thermal condition also gave **88** (91 mg, 75%) as a light yellow liquid. ^1H NMR (300 MHz): δ = 7.39 (d, J = 2.4 Hz, 1H), 7.37 (d, J = 2.4 Hz, 1H), 4.72 (s, 1H), 4.32 (d, J = 10.7 Hz, 1H), 3.96 (d, J = 11.0 Hz, 1H), 2.38 (d, J = 18.2 Hz, 1H), 2.16 (d, J = 18.2 Hz, 1H), 1.69 (s, 3H), 1.56 (s, 3H), 1.38 (s, 9H), 1.31 (s, 9H), 1.16 (s, 3H); ^{13}C NMR (75 MHz): δ = 207.9, 166.4, 151.1, 141.0, 138.5, 136.7, 127.4, 125.8, 116.6, 74.7, 71.4, 46.0, 36.2, 35.2, 34.5, 31.5, 31.4, 29.6, 27.8, 22.6; IR (neat, cm^{-1}) = 3393, 2956, 2869, 1680, 1603, 1467, 1438, 1025; HRMS (ESI): Calcd. for $\text{C}_{24}\text{H}_{35}\text{O}_3$ (m/z): 371.2581. Found 371.2587 $[\text{M}+\text{H}]^+$.

6,8-Di-*tert*-butyl-1-isopropyl-3a-methyl-3a,4-dihydro-3H-cyclopenta[c]chromen-2-one (89)



The enyne **87** (110 mg, 0.34 mmol) was cyclized in (10 mL) of the appropriate solvent following the general oxidative and thermal PK procedures **3.1.3.2** and **3.1.3.3** in the presence $\text{Co}_2(\text{CO})_8$ (130 mg, 0.370 mmol) and NMO (395 mg, 3.37 mmol). The reaction was worked up as indicated in the general procedure. The crude product was purified by flash chromatography (hexane/EtOAc, 90:10) to afford **89** (77.6 mg, 65%) for the oxidative mode. The thermal condition also gave **89** (100 mg, 84%) as a solid: mp: 147-149 °C; ^1H NMR (300 MHz): δ = 7.40 (d, J = 2.3 Hz, 1H), 7.34 (d, J = 2.3 Hz, 1H), 4.31 (d, J = 10.5 Hz, 1H), 3.90 (d, J = 10.5 Hz, 1H), 3.14 (m, 1H), 2.28 (d, J = 17.9 Hz, 1H), 2.04 (d, J = 17.9 Hz, 1H), 1.40 (s, 9H), 1.38 (d, J = 6.8 Hz, 3H), 1.32 (s, 9H), 1.26 (d, J = 6.8 Hz, 3H), 1.19 (s, 3H); ^{13}C NMR (75 MHz): δ = 206.2, 164.9, 150.9, 142.0, 138.8, 137.3, 126.9, 123.0, 117.1, 74.9, 46.2, 35.8, 35.3, 34.4, 31.5, 29.6, 25.9, 22.9, 20.6, 19.7; IR (neat, cm^{-1}) = 3375, 2962, 1698, 1611, 1474, 1386, 1363, 1307, 1231, 1166, 1129, 1021; HRMS (ESI): Calcd. for $\text{C}_{24}\text{H}_{35}\text{O}_2$ (m/z): 355.2632. Found 355.2635 $[\text{M}+\text{H}]^+$.

PART II

**APPROACH TO THE TOTAL SYNTHESIS OF HAMIGERAN
VIA THE PAUSON-KHAND REACTION**

CHAPTER 4

TOTAL SYNTHESIS OF HAMIGERANS

4.1 Introduction

Total synthesis of natural products is one of the most vigorous research frontiers in chemistry of our times. It is considered by most people as the engine that drives organic synthesis forward, this endeavor combines elements of art, science, and technology and provides a strong and indispensable foundation for drug discovery. The pharmaceutical and biotechnology sectors are the driving force behind this field of study. Apparently this is due to its potential applications in these industries and by the discovery of naturally occurring novel bioactive molecules that are relevant to disease. The examples of aspirin, penicillin, and paclitaxel come to mind, but these are only a few of the myriad of naturally occurring lead compounds that provided us with medical breakthroughs. With recent progress made in molecular and cell biology, the science of chemical synthesis do promise to become even more effective in the hands of medicinal chemists who are poised to synthesize the next generation of drugs against disease.

Since the discovery of the Pauson-Khand (PK) reaction (formally a [2+2+1] cycloaddition) in the early 70's,¹ a great deal of work has transpired to increase the synthetic value of this method and it is now regarded as a method of choice when preparing cyclopentenones.² The synthetic utility of the PK reaction has been

demonstrated by the utilization of this cyclopentenone forming reaction, in the total synthesis of numerous natural products including pentalene,³ coriolin and hirsutic acid,⁴ among others.

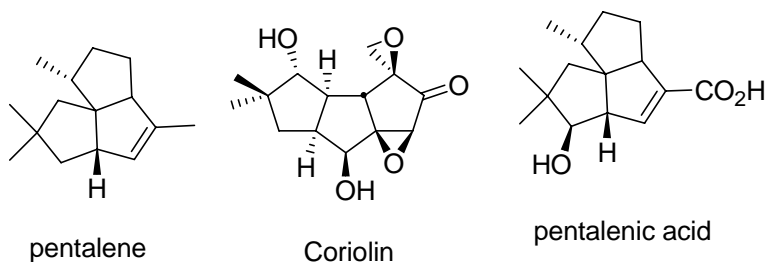


Fig 4.1. Some natural products synthesized *via* PK reaction.

4.1.1 Hamigerans

It was demonstrated earlier in this work that it is possible to construct highly congested cyclopentenones via the PK reaction. Given this success, we intend to explore the application of this strategy in the total synthesis of hamigeran family of natural products. Hamigerans are halogenated marine natural products isolated by Cambie and co-workers.

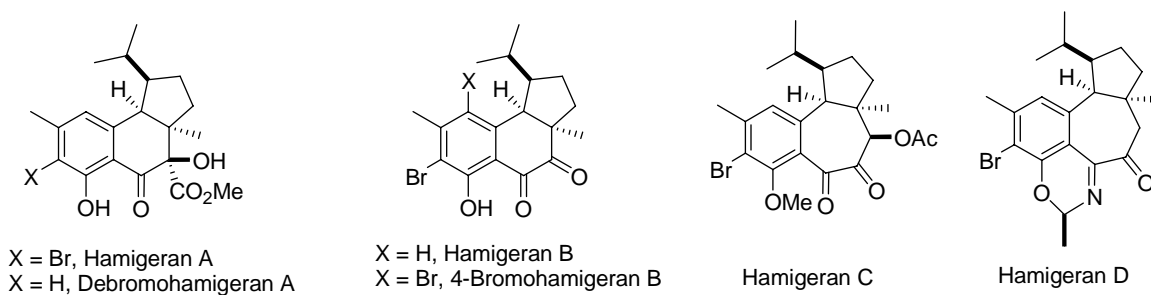


Fig 4.2. The hamigeran family

The hamigerans are benzannulated terpenes isolated from the marine sponge *Hamigerans tarangaensis* Bergquist and Fromont (family Anchinoidae, syn. Phorbasidae) collected from the Hen and Chicken Islands in New Zealand.⁵ These natural products contains a carbon skeleton with a polysubstituted aromatic ring fused to [4.3.0] or [5.3.0] bicyclic system containing three to four stereogenic centers and an isopropyl group.

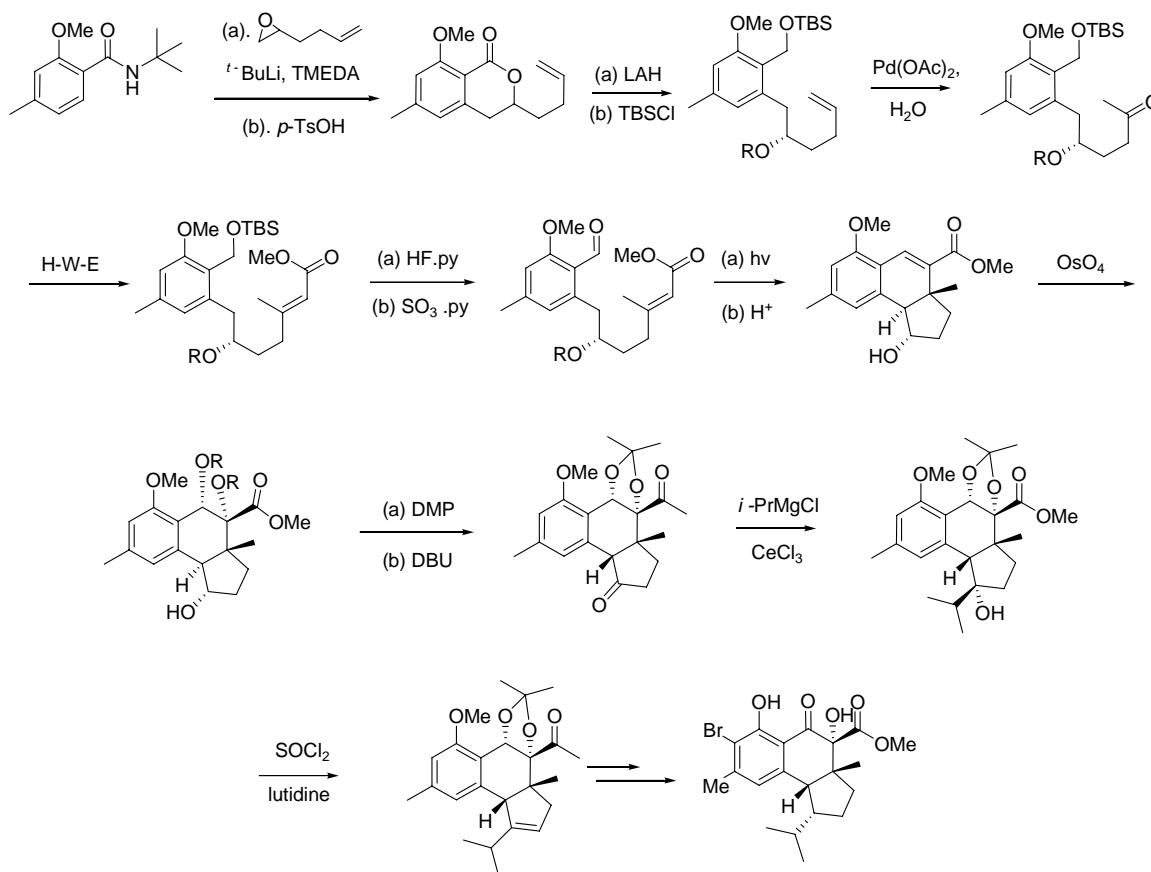
Evaluation of these compounds for biological activity showed hamigeran D having the strongest in-vitro antitumor activity against P-388 (a murine leukemia) with an IC₅₀ of 8 μM . Similar biological activity was described for both hamigeran B and 4-bromohamigeran B with IC₅₀s of 13.5 and 13.9 μM respectively against P-388. Hamigeran C had IC₅₀ of 16.0 μM . Hamigeran A has low cytotoxicity with IC₅₀ of 31.6 μM . Furthermore when screened against the Gram-positive bacterium *Bacillum subtilis*, hamigeran C and D showed a 3-mm inhibition zone outside the disk at assay loadings of 96 and 150 μg respectively.

4.1.2 Synthetic Approaches

These natural products have attracted attention from the synthetic community leading to the report of several synthetic approaches. Nicolaou reported a rather lengthy synthetic route to hamigeran A and B via an intramolecular Diels-Alder reaction of *o*-enolquinodimethane that was generated in situ.⁶⁻⁸ A photoenolization of the substituted aldehyde and subsequent Diels-Alder (PEDA) trapping of the generated hydroxyl-*o*-

quinodimethanes to get to the hamigeran A and B core. Upon further functionalization, the natural products were obtained (Scheme 4.1).

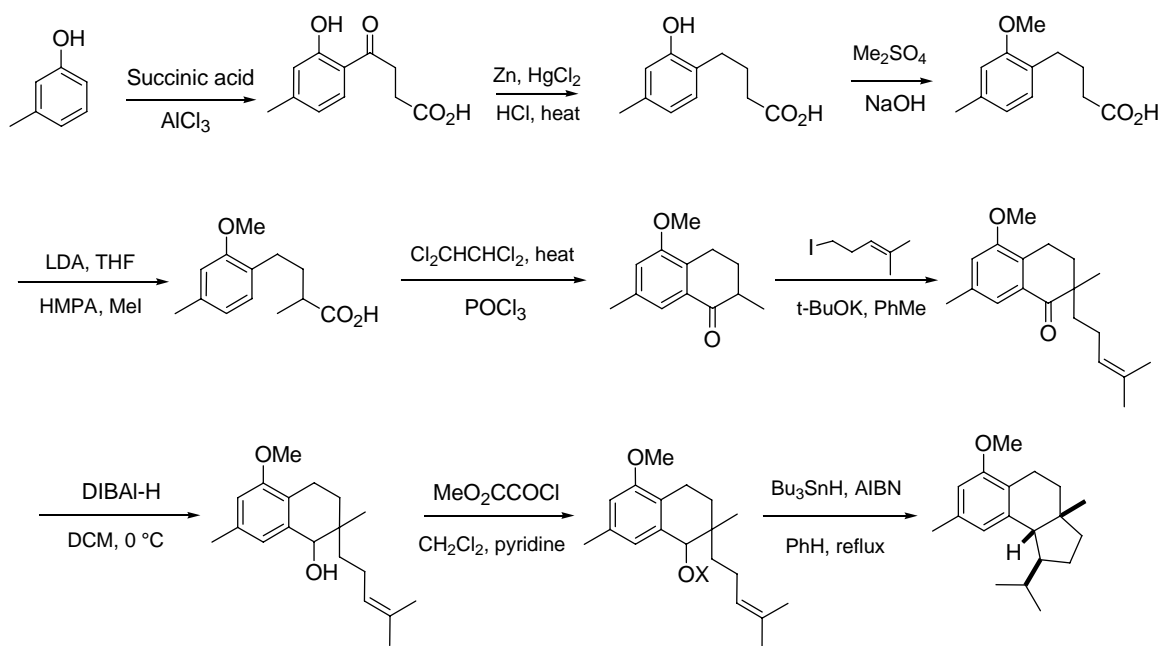
Scheme 4.1



Clive and Wang^{9, 10} used free radical processes to annulate the five membered ring onto a tetralone derivative. They began their synthesis by conversion of commercially available *m*-cresol to phenolic acid with succinic acid. The phenolic acid was further functionalized and then cyclized to give the tetralone. The tetralone was then alkylated before using a free radical method to annulate the five membered ring

onto the tetralone. This reaction gave the undesired stereochemistry at C-1 position as shown in the Scheme 4.2 below.

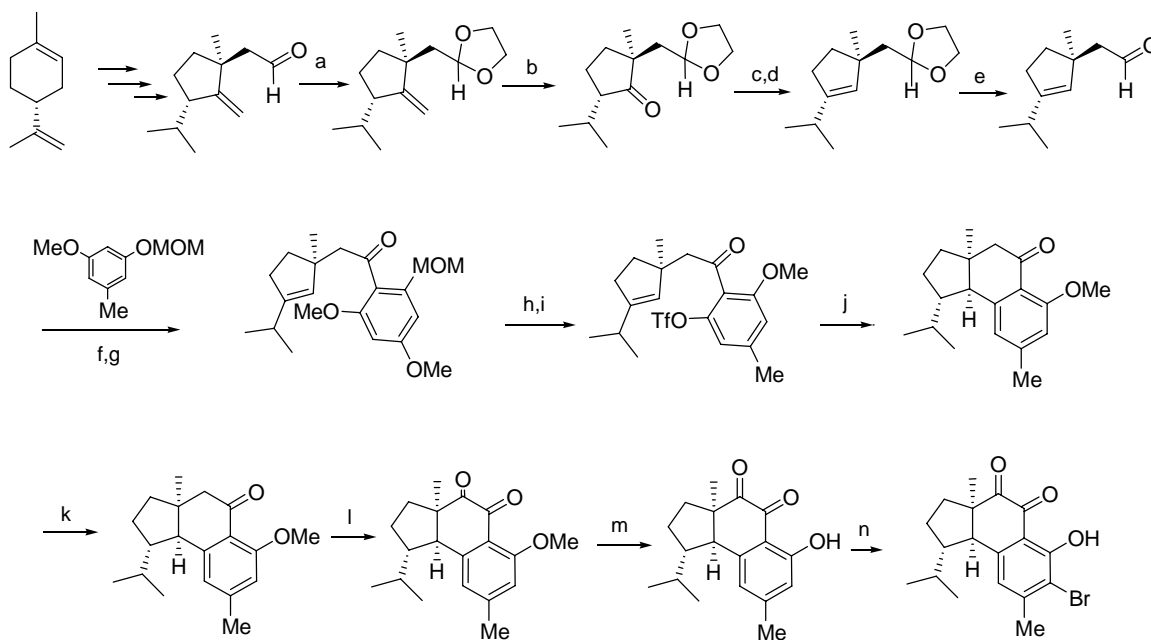
Scheme 4.2



Trost and coworkers¹¹ used a palladium catalyzed coupling strategy in an asymmetric synthesis of Hamigeran B. While Mehta and Shende¹² synthesized 6-epi-hamigeran B by using a Heck cyclization as the key step. Limonene was converted to the cyclopentane aldehyde containing an appropriately positioned quaternary methyl and isopropyl group. The cyclopentane aldehyde was subsequently functionalized to give the cyclopentane aldehyde which was then coupled to the aromatic ring to give the aryl ketone. The aryl triflate derivative was subjected to the Heck reaction to furnish the

tricyclic framework of the Hamigeran B. This tricyclic core was then converted to the 6-epi-(-)-hamigeran B through a few more steps (Scheme 4.3).

Scheme 4.3

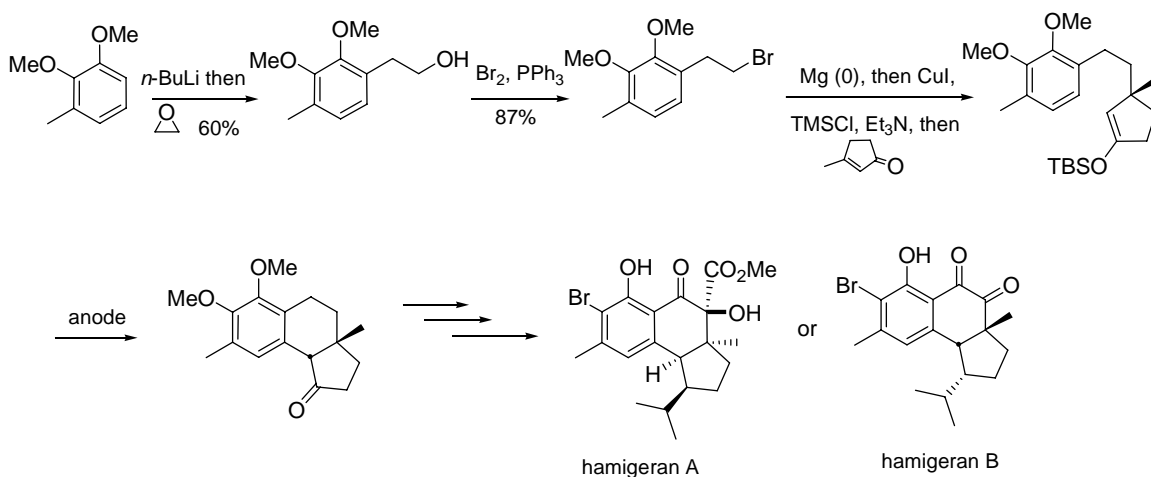


Reagents and conditions: (a) BTSE, TMSOTf (0.01 eq.), DCM, -78 °C; (b) O₃, MeOH, -78 °C DMS, -78 °C; (c) NaBH₄, MeOH, 0 °C; (d) POCl₃, pyridine, 0 °C-rt; (e) HCl, THF, rt, 6 h; (f) *t*-BuLi, hexane, 0 °C, 1 h, then -78 °C to 0 °C; (g) PDC, 4 Å mol. sieves, DCM, 10 h; (h) 20% HCl, THF, 5 h; (i) Tf₂O, pyridine, rt, 10 h (j) Pd(OAc)₂ (20 mol%), DPPP (20 mol%), NEt₃, DMF, 90 °C, 10 h; (k) 10% Pd/C, H₂, 5 h; (l) SeO₂, AcOH (cat.), aq. dioxane, reflux, 24 h (m) BBr₃, DCM, -20 °C, 5 h; (n) NBS, DIPA (cat.), DCM, 0 °C, 3 h.

Wright and Sperry¹³ were able to obtain the hamigeran core through a two-step electrochemical benzannulation reaction. The annulation was effected by an initial conjugate addition of a phenethyl cuprate to 3-methylcyclopentenone with *in situ* silylation of the resulting enolate. An anodic oxidation was employed to effectively couple the pendant arene and the silyl enol ether to produce the key intermediate for the synthesis of the natural product. Hence this method allowed the preparation of the

tricyclic core of hamigeran A and B in just four steps from the commercially available starting materials (Scheme 4.4).

Scheme 4.4



4.2 Project Strategy

As mentioned earlier in this dissertation the intramolecular mode of the Pauson-Khand (IMPK) reaction is a particularly attractive tool as it permits the rapid increase of molecular complexity in a single synthetic step. It has been extensively used in the synthesis of bicyclo[3.3.0]octanes and bicyclo[4.3.0]nonanes ring system via the IMPK cyclization of 1,6- and 1,7-enynes respectively (Figure 4.3).

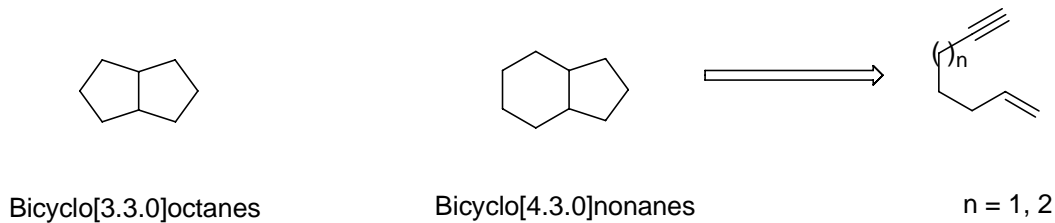


Figure 4.3. Rings assembled via the IMPK reaction

In this study we believe that the IMPK cyclization method will be an effective way to access the tricyclic core of the hamigerans. The tricyclic cores of both hamigeran A, B and hamigeran C, D can be obtained from the PK products of 1,7- and 1,8-enynes respectively (Figure 4.4). It should be noted that the core of hamigeran C and D can be obtained from the lower homolog via a ring expansion.

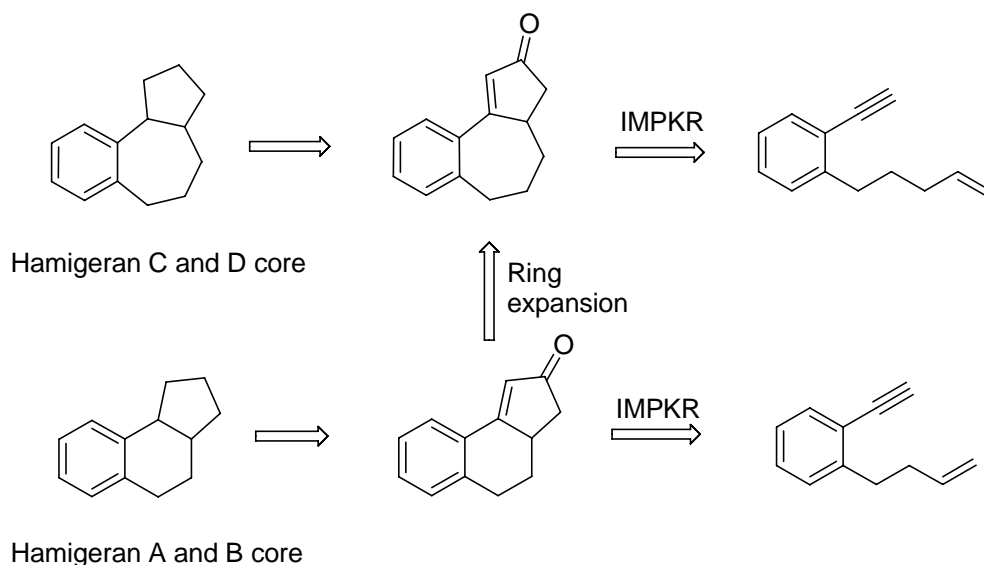
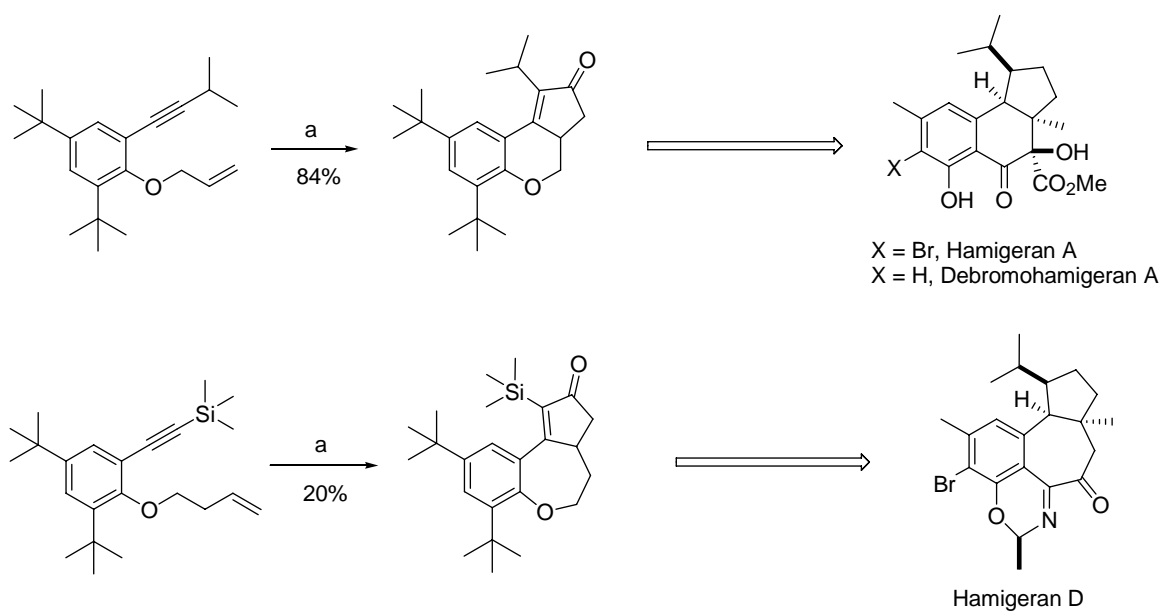


Figure 4.4. Hamigeran core assembly via IMPK reaction

From our previous studies, where we used steric buttressing elements to enhance the IMPK reaction to cyclize successfully 1,7- and 1,8-enynes leading to benzo[c]bicyclo[4.3.0] and benzo[c]bicyclo[5.3.0] systems. These appeared to provide ample precedence for application of this tactic in a total synthesis of the hamigerans. (Scheme 4.5).

Scheme 4.5



Reagents and conditions: (a) $\text{Co}_2(\text{CO})_8$, toluene, 70 °C

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 IMPK Reaction in Total Synthesis of the Hamigerans

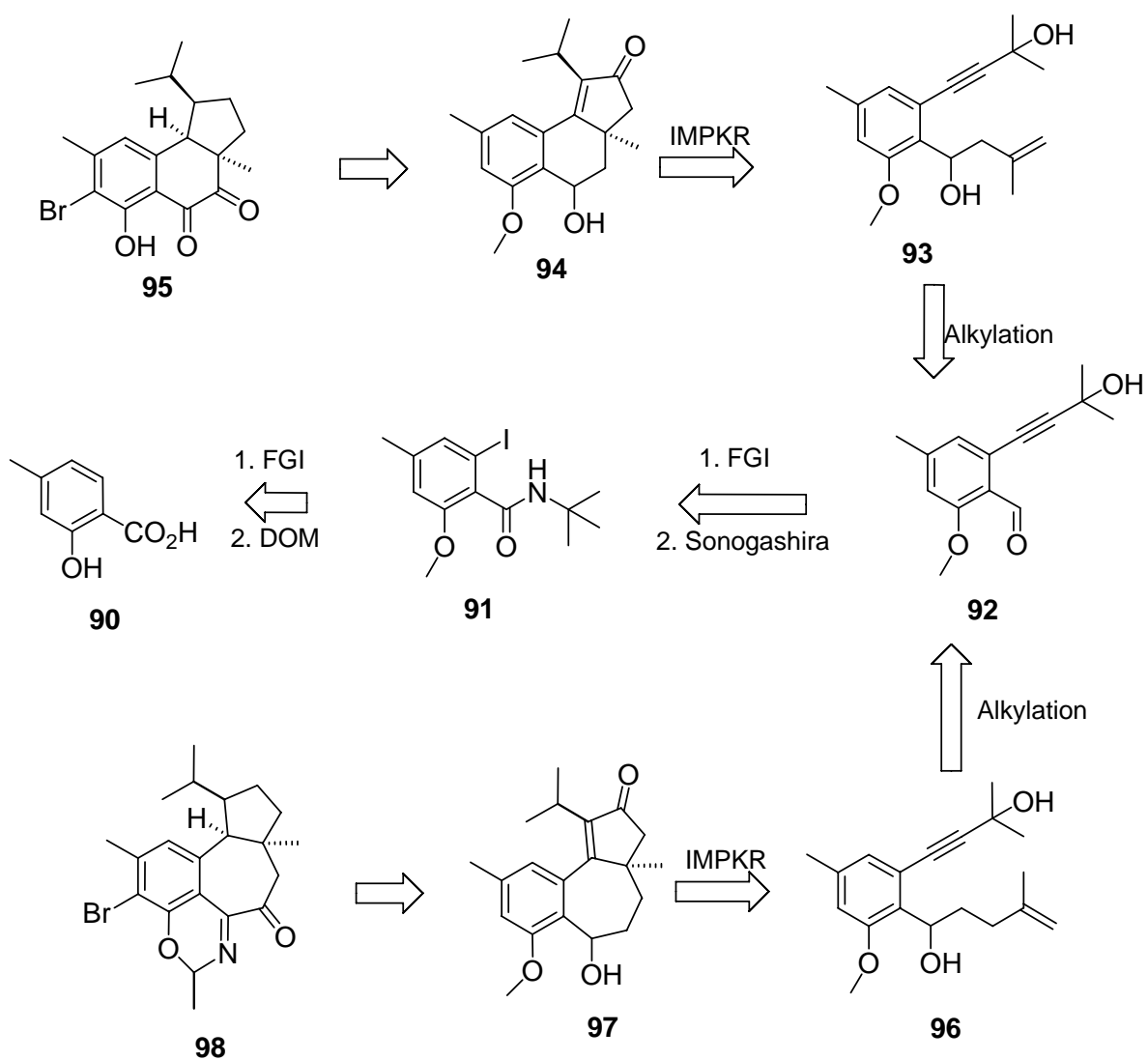
To date, no total synthesis has been reported in the literature for the larger hamigeran C and D. We intend to employ a synthetic approach to hamigerans with an identical starting material to that used in the Nicolaou approach (Scheme 4.1). Also, we intend to use a similar ortho lithiation method to obtain the tetrasubstituted aryl derivative.

5.2 Retrosynthesis

The proposed retrosynthesis is given below (Scheme 5.1). From our retrosynthesis hamigeran A and B have a common tricyclic core, while hamigeran C and D also has a same tricyclic core. These cores can be obtained from the functionalization of the PK product **94** for hamigeran A and B core and the hamigeran C and D core from PK product **97**. The PK products **94** and **97** can be obtained from the IMPK cyclization of the 1,7-enyne **93** and 1,8-enyne **96** respectively. Both enynes **93** and **96** can be accessed by the alkenylation of a common precursor, benzaldehyde **92**. This benzaldehyde **92** in turn can be obtained in several steps from the aryl iodide **91**. This iodo aryl amide **91** can be accessed from commercially available salicylic acid **90** by subjecting the acid to

functional group interconversion to give amide before treating it with *t*-BuLi / I₂ to afford **91**.

Scheme 5.1



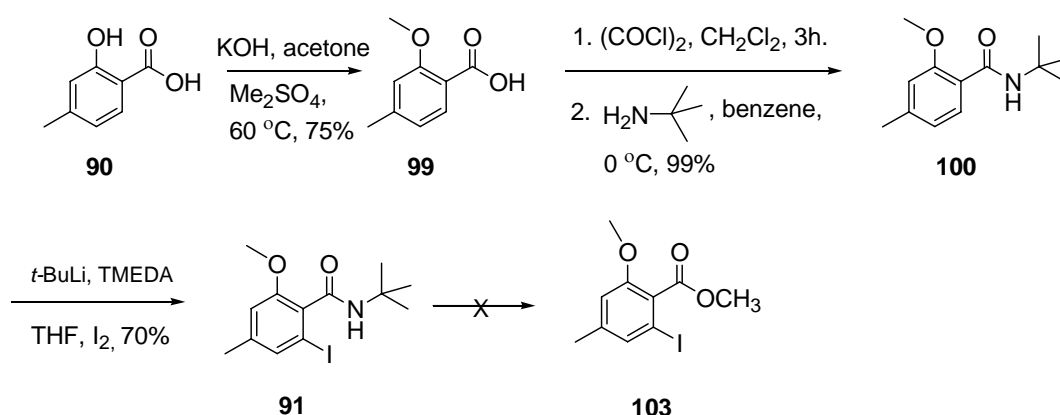
5.3 Total Synthesis

The total synthesis will be done in three different stages. The first stage was to prepare the aryl iodide **91** which is the precursor to substrate **92**. The second stage will be to get to the hamigeran core which can be accessed through the PK cyclization reaction. The final stage will be the functionalization of the core to provide the various hamigeran natural products.

Stage 1

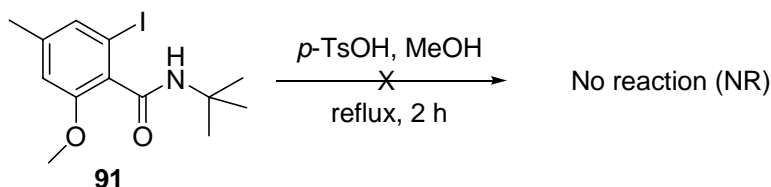
The first stage of the total synthesis started with the protection of the hydroxyl function of the commercially available 4-methyl salicylic acid **90** by treating it with Me_2SO_4 in the presence of KOH to give **99** (Scheme 5.2). The 2-methoxy-4-methylbenzoic acid **99** was subjected to functional group interconversion by reacting it with oxalyl chloride and *t*-butylamine to give the amide **100**.⁶⁻⁸ A directed *ortho* metalation reaction was carried out on compound **100** using 2.2 equivalents of *t*-BuLi and then quenched with I_2 to compound **91** in 70% yield (Scheme 5.2).

Scheme 5.2



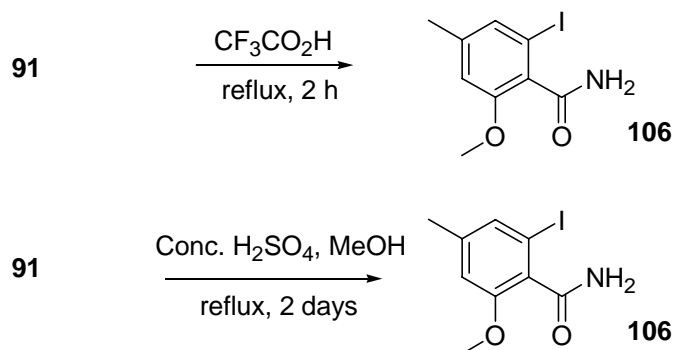
Initially, attempts were made to convert the amide **91** to an ester function **103** but these were not successful. When **91** was heated to reflux for 2 hours with *p*-TsOH, an approach we had found successful in another context in our group,^{6-8, 14} no reaction was observed. The starting material was recovered as shown in Scheme 5.3.

Scheme 5.3



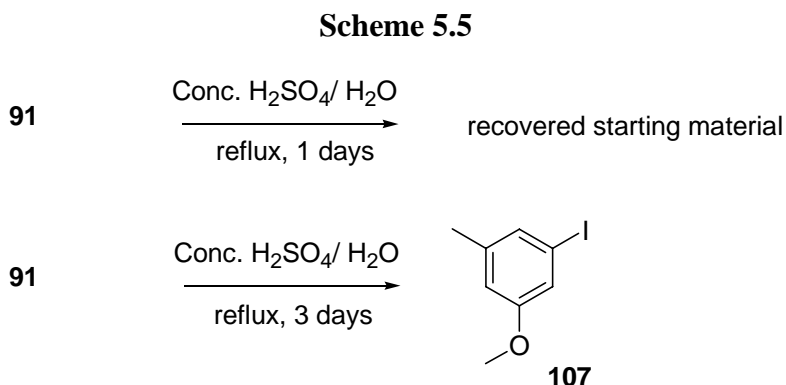
Under more acidic conditions, the amide **91** gave only a primary amide **106** with the loss of *i*-butene as shown in Scheme 5.4 below. The amide **91** was also heated to reflux in concentrated H₂SO₄ for 2 days, but the expected product was not obtained, instead, the primary amide **106** was isolated.

Scheme 5.4

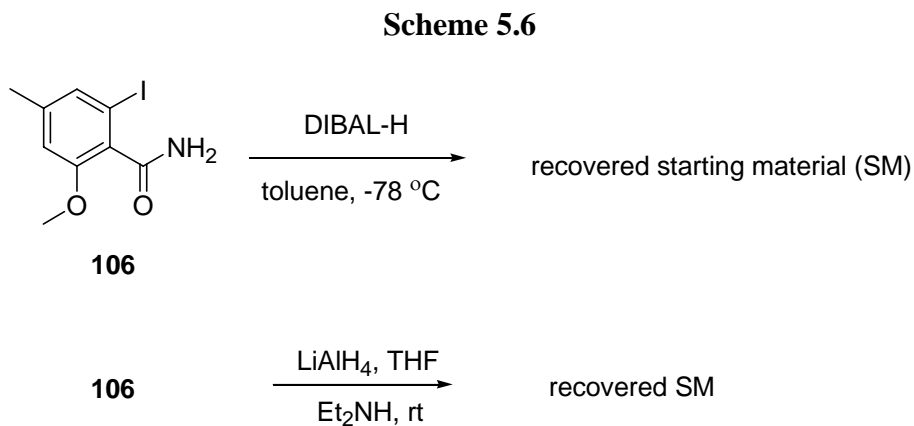


Furthermore, an attempt to convert the secondary amide to the carboxylic acid by heating to reflux in a mixture of conc. H₂SO₄/H₂O (1:2 v/v) for just one day only led to the recovery of the starting material. However when the mixture was heated to reflux for 3 days it led to a complete loss of the amide function to give the anisole **107**

(Scheme 5.5). Compound **107** may be formed by initial conversion of the secondary amide to the carboxylic acid and subsequent decarboxylation.^{15, 16}



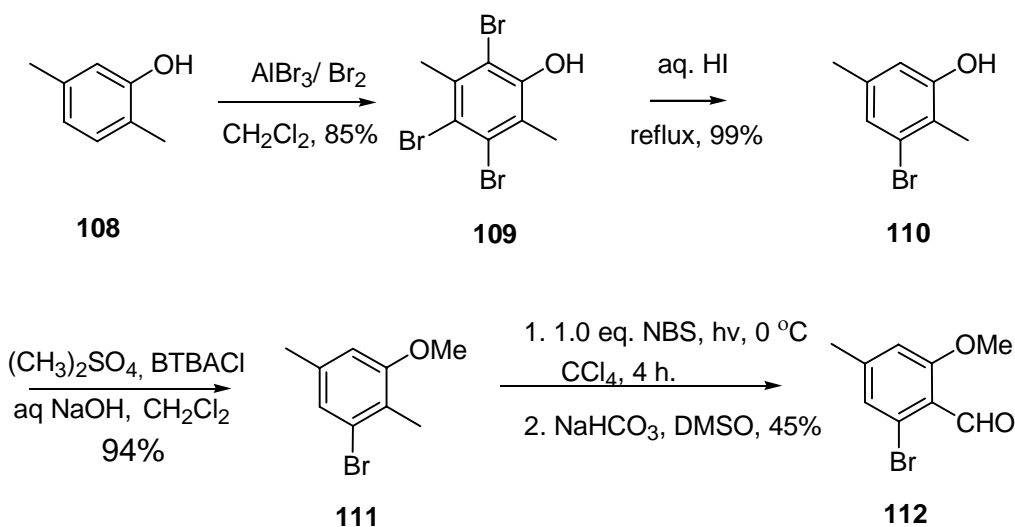
At this point, we decided to reduce the primary amide **106** formed in the reaction shown in Scheme 5.4 to the aldehyde functionality using DIBAL-H or LiAlH₄. Under both conditions, only the starting material was recovered as shown in Scheme 5.6.



Therefore, an alternative route to the aldehyde **112** was devised. We brominated the commercially available 2,5-dimethylphenol **108** in the presence of aluminum and Br₂ to give the perbrominated product **109**.^{17, 18} The perbromophenol **109** was debrominated

compound **106** by heating to reflux in 45% aqueous hydroiodic acid to give the 3-bromo-2,5-dimethyl phenol **110**.¹⁹ The protection of the phenolic function using dimethyl sulfate gave the 3-bromo-2,5-dimethylanisole **111**. This compound was then subjected to a free radical reaction with NBS using AIBN as the initiator followed by oxidation with DMSO and NaHCO₃ to give the aldehyde **112** in 45% yield as shown in Scheme 5.7.

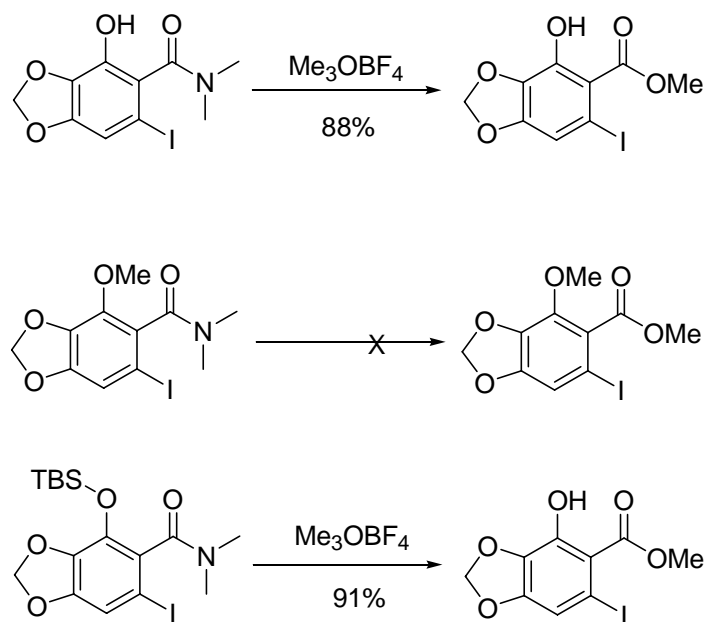
Scheme 5.7



At this point we came across a report by Keck et al.²⁰ that helped to explain the difficulties encountered in amide **91** conversion to the ester **103** (Scheme 5.2). They reported a two-step, one pot procedure, in which a tertiary amide is first treated with trimethyloxonium tetrafluoroborate to generate an imidate intermediate. This imidate intermediate was then hydrolyzed, generally by the addition of saturated aqueous sodium bicarbonate solution. Interestingly, it was reported that if the two *ortho*

positions of the aromatic amide were substituted, the conversion does not take place. However if one of the two *ortho* substituent is a free hydroxyl group the conversion proceeds smoothly. It was also reported that if this hydroxyl function is protected, the conversion to the ester will be hindered, except when protected with TBS group. Their results show that in the presence of trimethyloxonium tetrafluoroborate, the OTBS function was deprotected first before the conversion to a free phenolic ester takes place (Scheme 5.8).

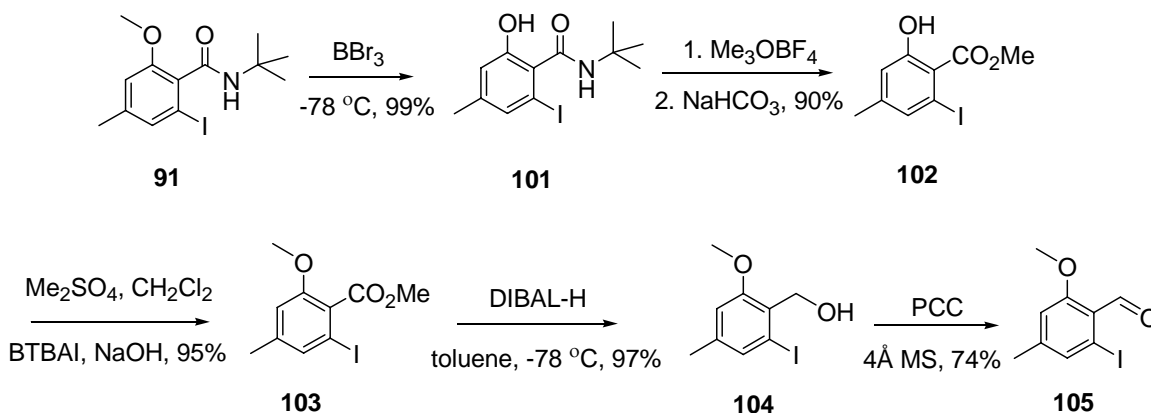
Scheme 5.8



Based on these results, we decided to investigate the procedure using our compound **91**. Deprotection of compound **91** using BBr_3 gave compound **101**. Then **101** was reacted with the trimethyloxonium tetrafluoroborate to give the imidate ester which was hydrolyzed with NaHCO_3 to give the ester **102** (Scheme 5.2). With **102** in hand, the

free hydroxyl group was protected with Me_2SO_4 and then the ester was reduced with DIBAL-H to the benzylic alcohol **104**. Pyridinium chlorochromate (PCC) was then used to oxidize the benzylic alcohol to benzaldehyde **105** in good yield as shown in Scheme 5.9.

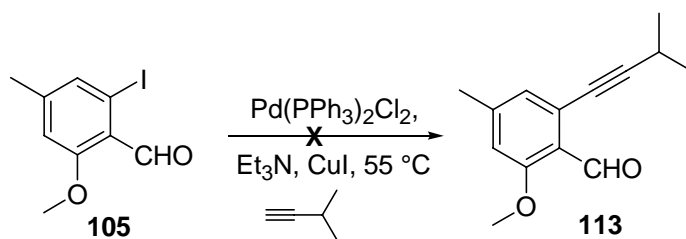
Scheme 5.9



Stage 2

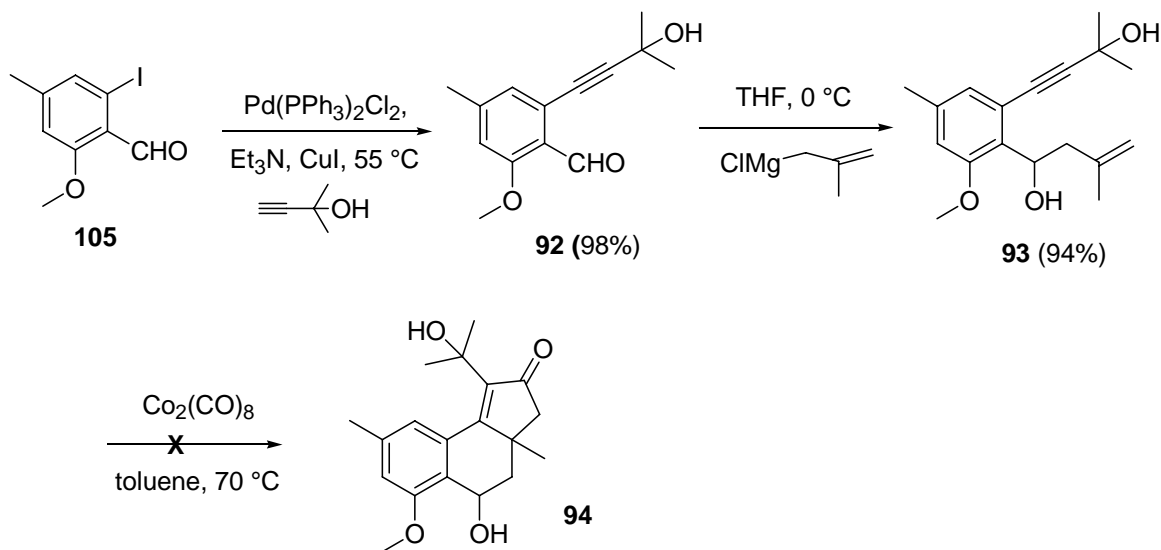
This stage of the total synthesis focuses on the construction of the enyne **93** and the cyclization of this enyne to give the PK cyclization product **94**. Initially the substrate **105** was subjected to palladium catalyzed Sonogashira reaction with 3-methyl-1-butyne. However, only the starting material was recovered. Several conditions reported for effecting the Sonogashira reaction were employed to promote this coupling, but with no success. We attributed this failure to the volatility of the alkyne which has a boiling point of 23 °C; hence under the Sonogashira conditions the alkyne evaporates before the coupling reaction takes place (Scheme 5.10).

Scheme 5.10



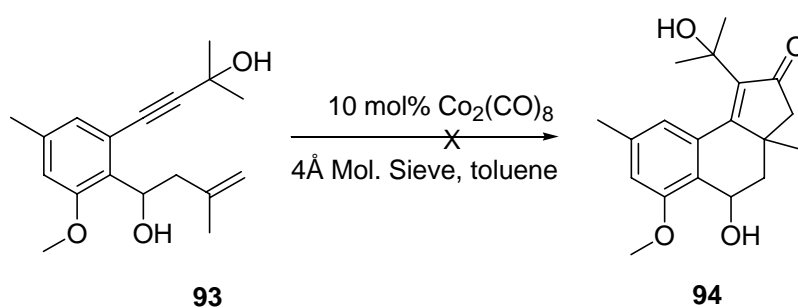
The substrate **105** was then subjected to the Sonogashira reaction with 3-hydroxy-3-methyl-1-butyne, which has a higher boiling point. From this reaction, the Sonogashira product **92** was isolated in excellent yield.²¹ A Grignard reaction was then carried out with compound **92** and 2-methylallylmagnesium chloride to give the enyne **93**. Disappointingly when substrate **93** was subjected to the thermal PK conditions, the reaction did not give the expected PK product, rather only starting material was recovered (Scheme 5.11).

Scheme 5.11



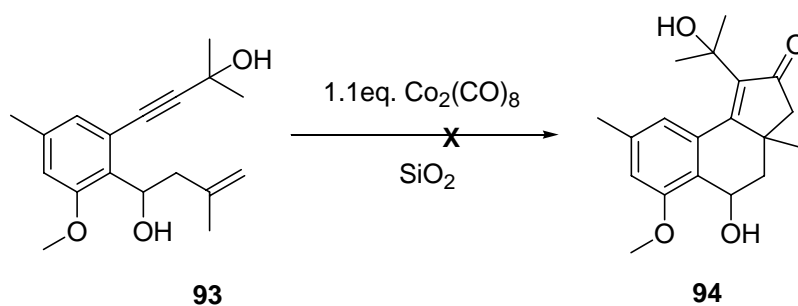
The cyclization method used by Blanco-Urgoiti *et al.*²² was attempted next. Preheated 4Å molecular sieves were used in an attempt to cyclize the enyne **93** in the presence of 10 mol% of the catalyst in toluene at 65 °C. However, this reaction did not give the cyclization product either, again only the starting material was recovered (Scheme 5.12).

Scheme 5.12



Also the cyclization of enyne **93** was attempted by adsorbing the alkyne-dicobalt hexacarbonyl complex of **93** to SiO_2 before heating it at 65 °C for 3 h.²³ In this case also only the starting material was also recovered (Scheme 5.12).

Scheme 5.12



The reason for the failure of this cyclization may be due to the facile free rotation of the alkene arm of enyne **93**. This free rotation of the alkene arm makes it

difficult for the alkene and alkyne arms to come in close proximity for the cyclization to occur. Hence the reactive rotamer is not the most stable one. The most stable rotamer places the alkene and alkyne moieties far apart from each other as shown in Figure 5.1. Thus, heating the $\text{Co}_2(\text{CO})_8$ complex simply leads to thermal decomplexation and recovery of starting material.

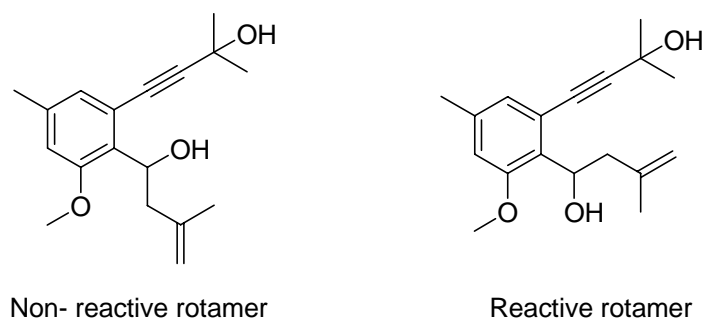
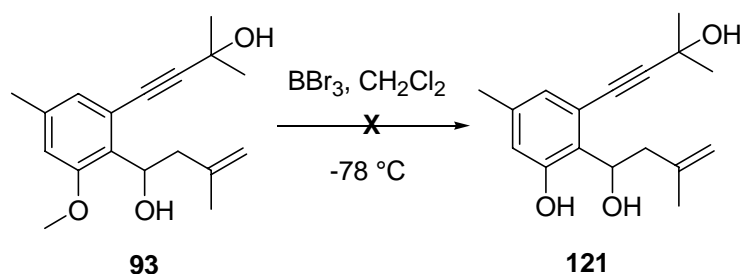


Figure 5.1. Rotational isomers of substrate **93**

We have shown in the earlier chapter that the presence of a large *o*-substituent can promote cyclization. However, the buttressing effect of the aromatic methoxy group is very minimal, so increasing the steric bulk of the phenolic group may increase the population of the reactive rotamer leading to cyclization. Alternatively, deprotection of the phenolic group and then locking up the phenolic and the benzylic hydroxyl group will reduce the rotational degree of freedom of the alkene arm. Hence, the population of the reactive rotamer of the substrate **93** will be increased.

Initial attempts to deprotect the methoxy group of compound **93** with BBr_3 did not give the expected enyne **121**. Instead it gave a dark complex mixture which could not be purified or characterized (Scheme 5.14).

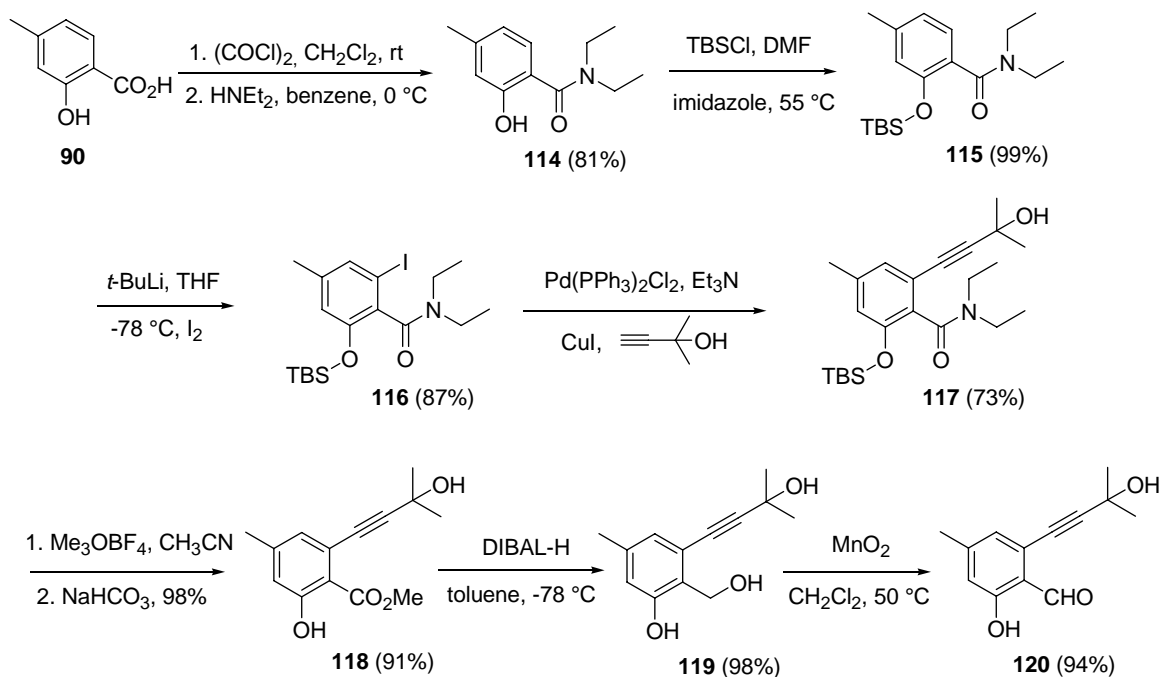
Scheme 5.14



At this point, a slight modification of the synthetic scheme became necessary so as to permit the incorporation of a bulkier buttressing group at the phenolic function. Hence, *t*-butyldimethylsilyl group was used instead of using the methyl group to protect the phenol function. The commercially available 4-methylsalicylic acid **90** was converted to acid chloride with oxalyl chloride. The formed acid chloride was then reacted with *N,N*-diethylamine to give the amide **114**. The hydroxyl moiety of compound **114** was then protected by reacting it with *t*-butyldimethylsilyl chloride in the presence of imidazole as a base to give compound **115**. Since tertiary amides have been known to be good *ortho* directing metalation groups,²⁴ iodination of compound **115** was then carried out by subjecting it to directed *ortho* metalation reaction using *tert*-butyllithium and the reaction was subsequently quenched with iodine to afford the aryl iodide **116**. With **116** in hand, the amide was subjected to the Sonogashira reaction with 3-hydroxy-3-methyl-1-butyne in the presence of Pd(PPh₃)₂Cl₂ and CuI as catalysts to give the alkynylated aryl amide **117**. Trimethyloxonium tetrafluoroborate was then used to convert the amide **117** to the salicylate derivative **118** as shown in Scheme 5.15. The methyl salicylate **118** was then reduced to a benzyl alcohol **119** in the presence of DIBAL-H. Finally, the

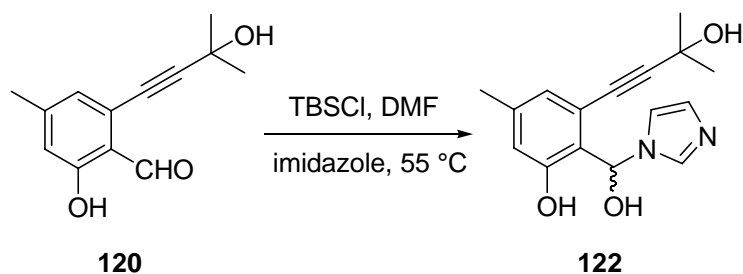
benzyl alcohol **119** was oxidized to salicylaldehyde **120** using manganese (IV) oxide (Scheme 5.15).

Scheme 5.15



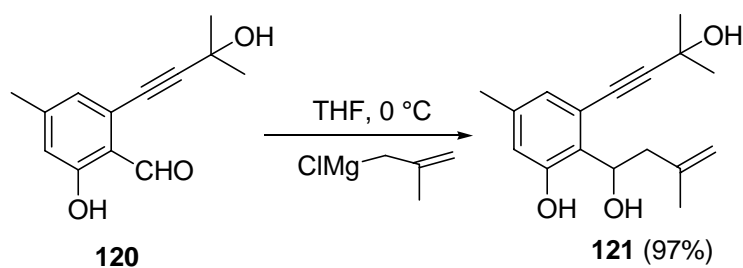
With compound **120** in hand, the aldehyde was treated with *t*-butyldimethylsilyl chloride in the presence of imidazole in an attempt to protect the phenolic function. This reaction did not give the expected product, instead the imidazole reacted with the aldehyde group to give compound **122** (Scheme 5.16).

Scheme 5.16



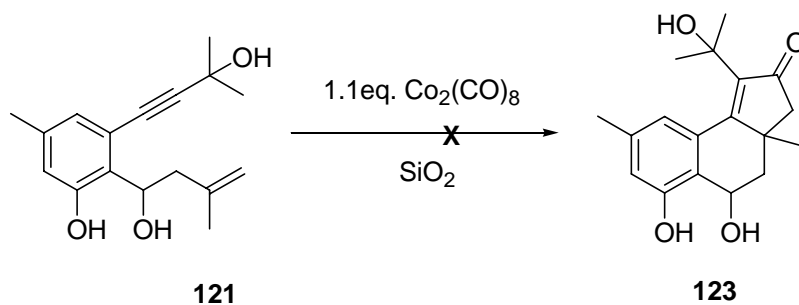
Meanwhile compound **120** was reacted with a Grignard reagent, 2-methylallyl magnesium chloride to give the 1,7-enyne **121** (Scheme 5.17).

Scheme 5.17



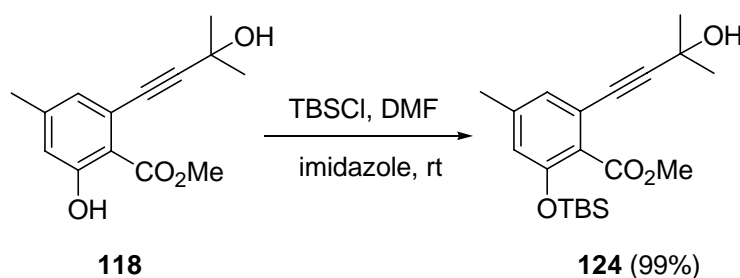
Cyclization of the 1,7-enyne **121** was attempted by adsorbing the alkyne-dicobalt hexacarbonyl complex of **121** to SiO₂ before heating it at 65 °C for 3 h.²⁵ In this case also only the starting material was also recovered (Scheme 5.18).

Scheme 5.18



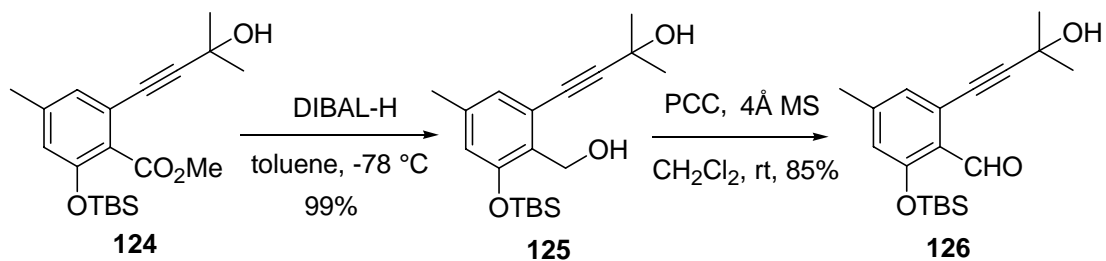
The alkynylated methyl salicylate **118** was subjected to protection with TBSCl at 55 °C, but this did not give the expected product. Instead, the starting material was recovered. This result was explained to be due to the fact that TBS protected phenols can easily be deprotected at elevated temperature. Hence, the reaction was then carried out at room temperature to give the phenolic silyl ether **124** in excellent yield (Scheme 5.19).

Scheme 5.19



The TBS-protected methyl salicylate **124** was reduced with DIBAL-H to give the benzylic alcohol **125** in 99% yield. Then the alcohol was oxidized with pyridinium chlorochromate to the benzaldehyde **126** in 85% yield (Scheme 5.20).

Scheme 5.20

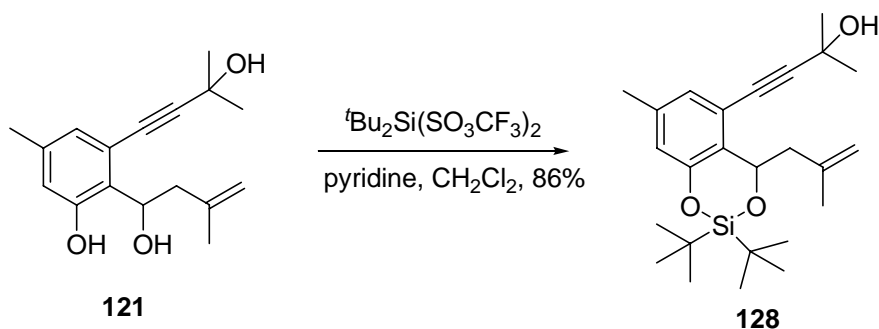


When the benzaldehyde **126** was reacted with 2-methylallylmagnesium chloride it gave a complex mixture. This may have been due to the easy migration of the silyl group to

the benzylic hydroxyl group after the Grignard reaction.²⁶ Moreover the reaction mixture was difficult to purify by SiO₂ chromatography.

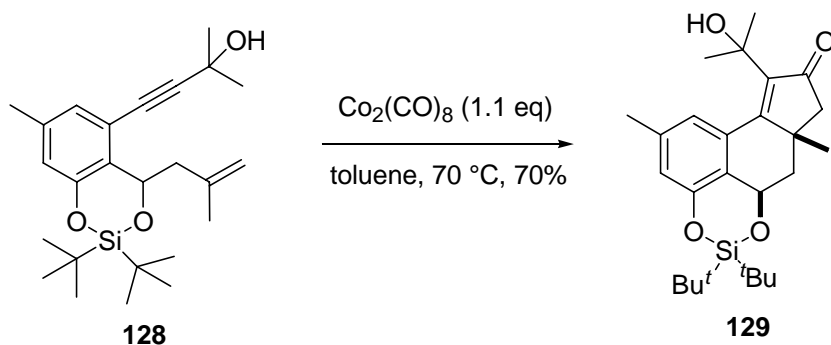
This problem was then resolved by using the enyne **121** and then carrying out silylene protection of both hydroxyl groups to give 86% of enyne **128** (Scheme 5.21).

Scheme 5.21



Silylene protected enyne **128** is believed to be rigid enough to reduce the free rotation of the alkene arm, hence making it possible for the enyne to participate in PK reaction. With enyne **128** at hand it was subjected to thermal PK conditions to give the expected cyclized product **129** (Scheme 5.22)

Scheme 5.22



Hence the silylene protection effectively preorganized and reduced the degree of free rotation of the alkene arm thereby forcing it to cyclize to give the tricycle core of the hamigerans. Further functionalization of this core will give hamigeran A and B.

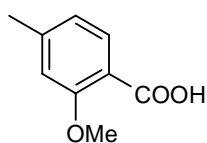
CHAPTER 6

EXPERIMENTAL

6.1 General Methods

See Page 83 for general methods used earlier.

2-Methoxy-4-methylbenzoic acid (**99**)⁶⁻⁸

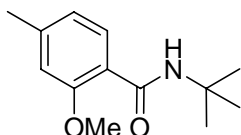


Dimethyl sulfate (37.3 mL, 0.395 mol) in acetone (100 mL) was added dropwise to a mixture of KOH (22.2 g, 395 mmol) and 2-hydroxy-4-methylbenzoic acid **90** (20.0 g, 132 mmol) in acetone (100 mL) and heated to reflux for 3 h at 60 °C. The reaction mixture was then filtered through a pad of Celite and washed with acetone to remove the remaining product. The organic phase was washed with water, dried (Na₂SO₄) and concentrated. The residue was then dissolved in 60% methanol and KOH (20.0 g, 0.357 mmol) was added. The reaction mixture was heated to reflux for 2 h. The reaction mixture was then allowed to cool to rt, acidified to pH ~1 with conc HCl and extracted with EtOAc. The organic phase was washed with water and brine, dried (Na₂SO₄) and concentrated in vacuo. Purification was done by flash chromatography (hexane/EtOAc, 10:3) to afford the pure product **99** (20.4 g, 93%). ¹H NMR (500 MHz): δ = 10.75 (broad s, 1H), 8.03 (d, *J* = 7.5 Hz, 1H), 6.92 (d, *J* = 7.5 Hz, 1H), 6.84 (s, 1H), 4.07 (s, 1H), 2.41 (s, 3H); ¹³C NMR (125 MHz): δ = 165.6, 158.1, 146.6, 133.8, 123.2, 114.9, 112.3, 56.7, 22.1; IR (neat,

cm^{-1}) = 2974, 1677, 1612, 1464, 1414, 1300, 1251, 1151, 1093, 784, 587; HRMS (ESI):

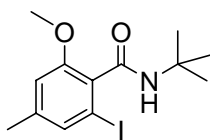
Calcd. for $\text{C}_9\text{H}_{11}\text{O}_3$ (m/z): 189.0522. Found 189.0514 $[\text{M}+\text{Na}]^+$.

***N*-tert-Butyl-2-methoxy-4-methylbenzamide (100)**⁶⁻⁸



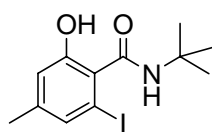
Oxalyl chloride (31.5 g, 0.368 mmol) was added to a solution of **99** (20.4 g, 0.122 mmol) in CH_2Cl_2 (100 mL) followed by the addition of catalytic amount of DMF. The reaction mixture was then stirred at rt for 4 h. At the end of the reaction period the excess oxalyl chloride and solvent were removed under aspirator pressure. The crude benzoyl chloride product was dissolved in benzene (120 mL) and cooled to 0 °C. *N*-tert-butylamine (25.3 mL, 0.246 mol) was then added dropwise with evolution of gas. The reaction temperature was then allowed to warm up to rt and stirred for 12 h. At the end of the reaction period, the mixture was then washed with 1N HCl, brine and dried (Na_2SO_4). The organic layer was concentrated and purified by flash chromatography (hexane/EtOAc, 10:3) to give a viscous liquid **100** (27.1 g, 99.9 %); ^1H NMR (500 MHz): δ = 8.00 (d, J = 7.5 Hz, 1H), 7.79 (broad s, 1H), 6.79 (d, J = 8.0 Hz, 1H), 6.67 (s, 1H), 3.85 (s, 3H), 2.30 (s, 3H), 1.40 (s, 9H); ^{13}C NMR (125 MHz), δ = 164.3, 157.2, 143.1, 131.8, 122.1, 120.0, 112.1, 55.9, 50.9, 29.0, 21.7; IR (neat, cm^{-1}) = 3398, 2967, 1661, 1613; HRMS (ESI): Calcd. for $\text{C}_{26}\text{H}_{39}\text{N}_2\text{O}_4^+$ (m/z): 443.2904. Found 443.2881 $[\text{2M}+\text{H}]^+$; Anal. Calcd. for $\text{C}_{13}\text{H}_{19}\text{NO}_2$: C, 70.56; H, 8.65; N, 6.33. Found: C, 70.17; H, 8.64; N, 6.30.

N-*tert*-Butyl-6-iodo-2-methoxy-4-methylbenzamide (**91**)



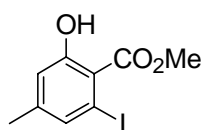
A solution of benzamide **100** (20.0 g, 90.5 mmol) in anhydrous THF (20 mL) was added dropwise to a mixture of *tert*-butyllithium (117 mL, 100 mmol) and *N,N,N,N*-tetramethylethylenediamine (27.3 mL, 181 mmol) in anhydrous THF (100 mL) at -78 °C under N₂ and stirred for 1 h. At the end of the reaction period, the reaction mixture was quenched with a solution of iodine (29.9 g, 118 mmol) in THF (80 mL). The reaction was then allowed to warm up to ambient temperature and stirred overnight. The reaction was then quenched with NH₄Cl solution (100 mL) and the mixture decolorized with Na₂S₂O₃ solution and extracted with CH₂Cl₂. The organic layer was washed with water, dried (Na₂SO₄) and concentrated under reduced pressure to afford the crude product. Purification was done by flash chromatography using gradient elution (hexane/EtOAc, 10:1 - 10:3) to give a light yellow liquid **91** (22.0 g, 70%) ¹H NMR (300 MHz): δ = 7.21 (s, 1H), 6.65 (s, 1H), 5.41 (s, 1H), 3.77 (s, 3H), 2.28 (s, 3H), 1.46 (s, 9H) ; ¹³C NMR (75 MHz) δ = 166.9, 156.4, 141.5, 131.6, 130.8, 111.9, 94.0, 56.1, 52.1, 28.9, 21.2; IR (neat, cm⁻¹) = 3301, 2959, 2918, 1648, 1619; HRMS (ESI): Calcd. for C₂₆H₃₆I₂N₂O₄Na⁺ (*m/z*): 717.0657. Found 717.0596 [2M+Na]⁺; Anal. Calcd. for C₁₃H₁₈INO₂: C, 44.97; H, 5.23; N, 4.03. Found: C, 45.17; H, 5.17; N, 4.03.

***N*-tert-Butyl-6-iodo-2-hydroxy-4-methylbenzamide (101)**



1.0 M solution of BBr_3 (23.1 mL, 23.1 mmol) in CH_2Cl_2 was added dropwise to a solution of **91** (2.00 g, 5.76 mmol) in CH_2Cl_2 (20 mL) at $-78\text{ }^\circ\text{C}$ under N_2 . The solution was then stirred at room temperature overnight. The mixture was cooled to $-78\text{ }^\circ\text{C}$ and quenched with methanol and washed with water. The organic layer was separated, dried (Na_2SO_4) and concentrated under reduced pressure to give the crude product **101**. Purification was done by flash chromatography with gradient elution (hexane/EtOAc, 10:3 -1:1) to give a white solid (1.89 g, 99.5 %) mp: $185\text{-}187\text{ }^\circ\text{C}$ ^1H NMR (300 MHz): $\delta = 10.93$ (s, 1H), 7.26 (s, 1H), 6.75 (s, 1H), 6.51 (s, 1H), 2.23 (s, 3H), 1.49 (s, 9H); ^{13}C NMR (75 MHz): $\delta = 168.4, 160.2, 141.2, 133.3, 119.6, 118.8, 91.9, 53.0, 28.7, 20.8$; IR (neat, cm^{-1}) = 3321, 2962, 2991, 1609, 1549; HRMS (ESI): Calcd. for $\text{C}_{24}\text{H}_{32}\text{I}_2\text{N}_2\text{O}_4\text{Na}^+$ (m/z): 689.0344. Found 689.0300 [$2\text{M}+\text{Na}$] $^+$.

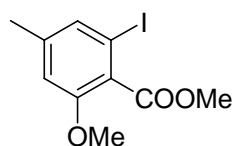
2-Hydroxy-6-iodo-4-methyl-methylbenzoate (102)



NaHPO_4 (1.22 g, 8.60 mmol) and $(\text{CH}_3)_3\text{OBF}_4$ (2.53 g, 17.1 mmol) was added at rt to a solution of **101** (1.90 g, 5.70 mmol) in CH_3CN (50 mL) and stirred for 18 h. Saturated aqueous NaHCO_3 solution (20 mL) was then added slowly followed by the addition of solid NaHCO_3 (1.44 g, 17.1 mmol) and stirred for another 18 h at rt. The product was extracted with EtOAc (3 x 20 mL), dried (Na_2SO_4) and concentrated under reduced pressure. The crude product was purified by flash chromatography (hexane/EtOAc, 10:1) to give a white solid **102** (1.51 g, 90%); mp: $80\text{-}82\text{ }^\circ\text{C}$; ^1H NMR (500 MHz): $\delta = 10.95$ (s, 1H), 7.44 (d, $J = 1.0$ Hz, 1H), 6.76 (d, $J =$

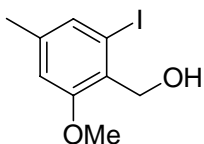
0.5 Hz, 1H), 3.95 (s, 3H), 2.24 (s, 3H); ^{13}C NMR (125 MHz): δ = 169.1, 162.5, 146.6, 135.3, 118.6, 113.9, 93.8, 51.8, 21.0. IR (neat, cm^{-1}) = 3030, 3002, 2948, 1652, 1434, 1345; HRMS (ESI): Calcd. for $\text{C}_9\text{H}_9\text{IO}_3\text{Na}^+$ (m/z): 314.9489. Found 314.9459 $[\text{M}+\text{Na}]^+$; Calcd. for $\text{C}_9\text{H}_{10}\text{IO}_3^+$ (m/z): 292.9669. Found 292.9638 $[\text{M}+\text{H}]^+$.

2-Methoxy-6-iodo-4-methyl-methylbenzoate (**103**)



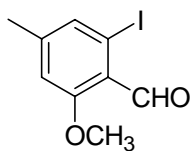
Dimethyl sulfate (9.18 g, 72.9 mmol) was added to a mixture of **102** (9.49 g, 32.5 mmol) and benzyltributylammonium chloride (1.36 g, 4.34 mmol) in CH_2Cl_2 (150 mL). Then 1.4 M aqueous NaOH (100mL) was added and stirred vigorously for 4 h at rt. The organic layer was the separated and the aqueous layer was extracted twice with CH_2Cl_2 . The combined organic layers were washed with water, dried (Na_2SO_4) and concentrated under reduced pressure. Purification by flash chromatography (EtOAc/hexane, 1:9) gave **103** (9.61 g, 97%) as a white solid, mp: 77-79 $^\circ\text{C}$. ^1H NMR (500 MHz): δ = 7.16 (s, 1H), 6.67 (s, 1H), 3.87 (s, 3H), 3.72 (s, 3H), 2.24 (s, 3H); ^{13}C NMR (125 MHz): δ = 168.0, 156.7, 142.4, 131.4, 127.5, 111.9, 92.4, 56.1, 52.7, 21.3, IR (neat, cm^{-1}) = 1732, 1597, 1556, 1272, 1039; HRMS (ESI): Calcd. For $\text{C}_{20}\text{H}_{22}\text{I}_2\text{O}_6\text{Na}^+$ (m/z): 634.9398. Found 634.9337 $[\text{2M}+\text{Na}]^+$.

2-iodo-4-methyl-6-Methoxy-benzylalcohol (**104**)¹⁶



DIBAL (1.0 M in hexane, 55.5 mL) was added dropwise to a stirred solution of **103** (8.50 g, 27.8 mmol) in dry toluene (250 mL) at -78 °C. The mixture was stirred at -78 °C for 2 h and then stirred at 0 °C (iced bath) for 1 h. The reaction was stirred for 6 h while gradually allowing the temperature to warm up to rt. The solution was then cooled to -78 °C and MeOH (10 mL), Na₂SO₄·10H₂O (4.0 g), Celite (6.0 g) and water (2 mL) were added successively. The cold bath was then removed and stirring was continued for 30 min before filtering the slurry through a sintered glass funnel. The organic layer was washed with water, dried (Na₂SO₄) and the concentrate under reduced pressure to give **104** as a milky solid (7.45 g, 97%); Mp: 68 -70 °C; ¹H NMR (500 MHz): δ = 7.28 (s, 1H), 6.67 (s, 1H), 4.80 (s, 2H), 3.83 (s, 3H), 2.28 (s, 3H), 2.31 (s, 3H); ¹³C NMR (125 MHz): δ = 157.7, 141.0, 132.2, 128.8, 112.0, 101.0, 65.0, 55.8, 21.1; IR (neat, cm⁻¹) = 3395, 2959, 2938, 1598, 1557, 1457, 1402, 1270, 1043; HRMS (ESI): Calcd. for C₁₈H₂₂I₂NaO₄S (*m/z*): 578.9500. Found 578.9449 [2M+Na]⁺.

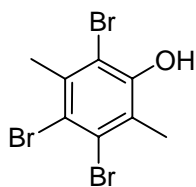
2-Iodo-4-methyl-6-methoxy-benzaldehyde (**105**)¹⁶



A mixture of pyridinium chlorochromate (8.07 g, 37.4 mmol) and powdered 4 Å molecular sieves (3.0 g) was added to a stirred solution of **104** (7.43 g, 26.7 mmol) in dry CH₂Cl₂ (200mL). Stirring was continued at room temperature for 10 h by which time the oxidation was completed. The solvent was evaporated to approximately 50 mL and the slurry was filtered through

a pad of SiO₂ and washed with 1:1 EtOAc-hexane. The filtrate was concentrated and purified by flash chromatography (SiO₂, EtOAc/hexane 2:3) to give the aldehyde **105** as a yellow solid (5.43 g, 74%). mp: 86- 88 °C. ¹H NMR (300 MHz): δ = 10.19 (s, 1H), 7.43 (s, 1H), 6.77 (s, 1H), 3.89 (s, 3H), 2.34 (s, 3H); ¹³C NMR (75 MHz): δ = 191.5, 161.9, 146.9, 134.8, 122.2, 112.9, 97.0, 56.0, 21.6; IR (Neat, cm⁻¹) = 2986, 1739, 1681, 1589, 1036; HRMS (ESI): Calcd. for C₁₈H₁₈I₂NaO₄ (*m/z*): 574.9187. Found 574.9153 [2M+Na]⁺.

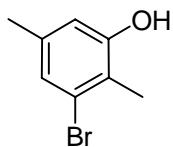
3,4,6-Tribromo-2,5-dimethylphenol (**109**)¹⁸



Aluminum (0.50 g, 18.5 mmol) was cautiously added in small portions to Br₂ (12.5 mL, 243 mmol) cooled to 0 °C. The mixture was stirred until the sparks ceases (50 min). A solution of the 2,5-dimethylphenol (5.0 g, 41 mmol) in dry CH₂Cl₂ (12.5 mL) was added dropwise and the mixture stirred for an additional 2h (The HBr gas evolved during the reaction was trapped by a water trap connected to an aqueous Na₂CO₃ scrubber). The solvent and excess Br₂ were removed at reduced pressure using a water aspirator (with the trap still in place). The residue was then stirred overnight with 10% HCl. Then sodium thiosulfate was added to decolorize the solution and filtered to give a yellow precipitate which can be recrystallized from hot ethanol to give pure white needles of 3,4,6-tribromo-2,5-dimethylphenol **109** (12.51 g, 85%); mp = 176-177 °C (lit¹⁷ mp = 175-177 °C). ¹H NMR (300 MHz): δ = 5.81 (s, 1H), 2.63 (s, 3H), 2.44 (s, 3H), ¹³C NMR (75 MHz): δ =

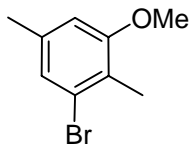
149.9, 136.0, 128.0, 125.1, 118.2, 112.5, 26.3, 18.9; IR (neat, cm^{-1}) = 3505, 2952, 2923, 1456; HRMS (CI): Calcd. for $\text{C}_8\text{H}_7\text{Br}_3\text{O}^+$ (m/z): 355.8079. Found 355.8096 [M^+].

3-Bromo-2,5-dimethylphenol (**110**)¹⁹



The de la Mare's procedure was followed. A suspension of the perbromophenol **109** (2.31g, 6.43 mmol) in aqueous HI (57 wt %, 25 mL) was heated at reflux under N_2 for 3 h. At the end of the reaction period, the reaction mixture was cooled to rt before adding CHCl_3 (20 mL). $\text{Na}_2\text{S}_2\text{O}_3$ was then added to decolorize and extracted with CHCl_3 (3 x 20 mL). The organic layers were combined, dried (Na_2SO_4) and concentrated to give a yellow powder. Recrystallization from hexane and charcoal was used to decolorize the product to give white crystal of the product **110** (1.28 g, 99%). Mp: 90- 92 °C (lit¹⁸ mp: 90-92 °C). ^1H NMR (300 MHz): δ = 6.98 (s, 1H), 6.54 (s, 1H), 2.29 (s, 3H), 2.24 (s, 3H). ^{13}C NMR (75 MHz): δ = 154.0, 137.8, 125.8, 120.9, 115.0, 71.5, 20.8, 15.2; IR (neat, cm^{-1}) = 3316, 2918, 1602; HRMS (CI): Calcd. for $\text{C}_8\text{H}_9\text{BrO}^+$ (m/z): 199.9868. Found 199.9858 [M^+].

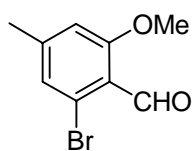
3-Bromo-2, 5-dimethylanisole (**111**)



Dimethyl sulfate (0.94 mL, 9.95 mmol) was added to a mixture of the bromophenol **110** (1.0 g, 5.0 mmol), benzyltributylammonium chloride (0.19 g, 0.60 mmol) in CH_2Cl_2 (10 mL) and 1.4 M aqueous NaOH (20 mL). The reaction mixture was stirred vigorously for 4 h. The organic layer separated

and the aqueous layer was further extracted with CH₂Cl₂. The combined organic layers were then washed with water, dried (Na₂SO₄) and concentrated to give yellow oil. Flash chromatography (SiO₂, hexane/EtOAc, 9:1) was used for purification to give **111** (1.01 g, 94%) as a colorless oil. ¹H NMR (300 MHz): δ = 6.99 (s, 1H), 6.59 (s, 1H), 3.80 (s, 3H), 2.29 (s, 3H), 2.26 (s, 3H). ¹³C NMR (75 MHz): δ = 158.1, 137.4, 125.5, 124.9, 123.7, 110.3, 55.8, 21.2, 15.4; IR (neat, cm⁻¹) = 2927, 2863, 1607, 1567; HRMS (CI): Calcd. For C₉H₁₁BrO⁺ (*m/z*): 213.9997. Found 213.9981 [M⁺].

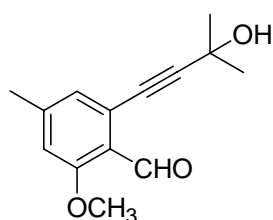
2-Bromo-6-methoxy-4-methylbenzaldehyde (**112**).



3-Bromo-2,5-dimethylanisole **111** (23.4 g, 110 mmol) was dissolved in CCl₄ (100 mL) and thoroughly purged with N₂ by repeated evacuation. *N*-Bromosuccinimide (19.6 g, 110 mmol) and AIBN (540 mg, 0.33 mmol) was added in one portion. The reaction mixture was heated to reflux until the NBS was converted to succinimide, which then floated on the surface of the CCl₄. The reaction mixture was then cooled to room temperature and then filtered through a Celite pad to remove the residual succinimide. The filtrate was concentrated under reduced pressure. The crude product was then redissolved in dry DMSO (100 mL) and then NaHCO₃ (54.0 g, 660 mmol) was added, and the mixture was heated at 110 °C for 15 h and cooled to rt. The reaction mixture was quenched with ice water (400 mL) and extracted with Et₂O. The combined organic extracts were washed with brine (400 mL), dried (Na₂SO₄) and concentrated under reduced pressure. Purification was done by flash chromatography using gradient elution (SiO₂, hexane/EtOAc, 19:1 to

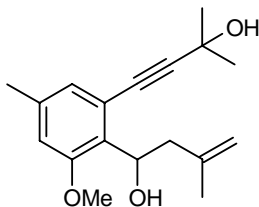
3:1) to give the aldehyde **112** (12.2 g, 49%) as a yellow waxy solid. Mp: 50- 52 °C; ¹H NMR (300 MHz): δ = 10.36 (s, 1H), 7.07 (s, 1H), 6.73 (s, 1H), 3.89 (s, 3H), 2.36 (s, 3H); ¹³C NMR (75 MHz): δ = 190.1, 162.1, 146.6, 127.3, 125.3, 120.9, 112.0, 56.2, 21.9; IR (neat, cm⁻¹) = 2942, 2852, 2784, 1730, 1690, 1602, 1562; HRMS (ESI): Calcd. for C₉H₁₀BrO₂⁺ (*m/z*): 228.9859. Found 228.9835 [M+H]⁺.

2-(3-Hydroxy-3-methyl-1-butynyl)-4-methyl-6-methoxy-benzaldehyde (**91**)¹⁶



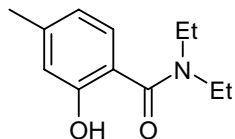
A solution of **105** (5.00 g, 18.1 mmol) in Et₃N (20 mL) was purged with N₂ for about 30 min. The solution was then cooled to 0 °C. To the purged solution of **105** was added PdCl₂(PPh₃)₂ (0.25 g, 0.36 mmol) and CuI (35.0 mg, 0.18 mmol) and stirred at 0 °C for 10 minutes. To the reaction mixture was added 2-hydroxy-2-methylbut-1-yne (2.29 g, 18.1 mmol) and stirred at 55 °C (bath temperature) under N₂ for 5 h. Et₂O (50 mL) and 1.0 M HCl (20 mL) were added and the organic layer was separated. The reaction was neutralized with a saturated NaHCO₃ (30 mL) solution, washed with H₂O, dried (Na₂SO₄) and concentrated under reduced pressure. The residue was purified by flash chromatography (SiO₂, hexane) to afford **91** (4.14 g, 99%) as a yellow waxy solid. ¹H NMR (300 MHz): δ = 10.44 (s, 1H), 6.76 (s, 1H), 6.56 (s, 1H), 3.90 (s, 3H), 2.38 (s, 3H), 1.52 (s, 6H); ¹³C NMR (75 MHz): δ = 190.2, 161.2, 146.1, 127.0, 126.2, 122.5, 112.5, 100.1, 82.1, 65.4, 55.9, 31.2, 21.1; IR (neat, cm⁻¹) = 3446, 2981, 2936, 2359, 1715, 1681, 1609; HRMS (ESI): Calcd. For C₁₄H₁₇O₃⁺ (*m/z*): 233.1171. Found 233.1141 [M+H]⁺.

2-(1-Hydroxy-3-methyl-3-butenyl)-3-(3-hydroxy-3-methyl-1-butynyl)-5-methyl anisole (93)



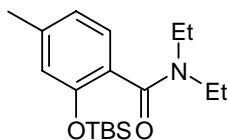
0.5 M solution of 2-methylallylmagnesiumchloride (4.48 mL, 2.24 mmol) in THF was added dropwise to a solution of **91** (0.26 g, 1.1 mmol) in THF (10 mL) at 0 °C under N₂ atmosphere and stirred to warm up to room temperature. The mixture was further stirred at room temperature for 3 h. The reaction mixture was quenched with NH₄Cl, extracted with dichloromethane and washed severally with water and brine solution. The organic layer was the dried with Na₂SO₄ and concentrated under reduced pressure. Purification was by flash chromatography (hexane/EtOAc; 1:2) to afford compound **93** (0.3 g, 94%) as a light yellow liquid. ¹H NMR (500 MHz): δ = 6.85 (s, 1H), 6.68 (s, 1H), 5.31 (m, 1H), 4.79 (s, 1H), 4.73 (s, 1H), 3.84 (s, 3H), 3.52 (d, *J* = 11.0 Hz, 1H), 2.62 (dd, *J* = 9.2, 13.7 Hz, 1H), 2.42 (dd, *J* = 5.0, 13.7 Hz, 1H), 2.36 (s, 1H), 2.27 (s, 3H), 1.81 (s, 3H), 1.58 (s, 6H); ¹³C NMR (125 MHz): δ = 157.2, 143.1, 137.9, 130.5, 125.9, 121.6, 112.8, 112.6, 98.2, 80.4, 70.6, 65.6, 55.6, 45.7, 31.5, 22.6, 21.3; IR (neat, cm⁻¹) = 3404, 3071, 2979, 1717, 1676, 1607, 1575, 1459; HRMS (ESI): Calcd. For C₃₆H₄₈NaO₆ (*m/z*): 599.3343. Found 599.3342 [2M+Na]⁺.

N,N-Diethyl-2-hydroxy-4-methylbenzamide (**114**)



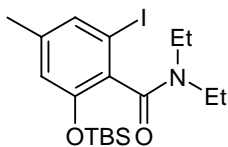
Oxalyl chloride (5.1 g, 40.2 mmol) was added to a solution of **90** (3.0 g, 19.7 mmol) in CH₂Cl₂ followed by the addition of a catalytic amount of DMF (3 drops). The reaction mixture was stirred at room temperature for 4 h. The excess oxalyl chloride and solvent were removed and the residue was dried under vacuum pump to give the crude acid chloride. The crude benzoyl chloride was dissolved in benzene (120 mL) and cooled to 0 °C. Next, *N,N*-diethylamine (4.10 mL, 55.8 mmol) was added dropwise with the evolution of gas. The reaction temperature was then warmed up to rt and stirred for 12 h. The reaction mixture was washed with 1N HCl and brine solution. The organic layer was separated, dried (Na₂SO₄) and concentrated. The crude product was purified by flash chromatography (hexane/EtOAc, 10:3) to give **114** (3.81 g, 93%) as a brown viscous liquid. ¹H NMR (300 MHz): δ = 7.14 (d, *J* = 7.8 Hz, 1H), 6.81 (s, 1H), 6.63 (dd, *J* = 1.2, 7.8 Hz, 1H), 3.47 (q, *J* = 7.2 Hz, 4H), 2.31 (s, 3H), 1.24 (t, *J* = 7.2 Hz, 6H); ¹³C NMR (75 MHz): δ = 171.8, 159.1, 143.2, 127.3, 119.4, 118.4, 115.2, 42.3, 21.6, 13.5; IR (neat, cm⁻¹) = 3166, 2976, 1599, 1439, 1297, 1130; HRMS (ESI): Calcd. For C₁₂H₁₇NaNO₂ (*m/z*): 230.1152. Found 230.1145 [M+Na]⁺.

N,N-Diethyl-2-(*tert*-butyl-dimethylsilyloxy)-4-methylbenzamide (**115**)



To a solution of **114** (3.30 g, 15.9 mmol) and imidazole (3.26 g, 47.8 mmol) in DMF (50 mL) was added TBSCl (7.21 g, 47.8 mmol) at rt. The reaction mixture was heated at 50 °C for 4.5 h. The reaction was then quenched with saturated aqueous NaHCO₃ (50 mL) and extracted twice with Et₂O (20 mL). The combined organic layers were washed with water and brine, dried (Na₂SO₄) and concentrated under reduced pressure. Purification was done by flash chromatography (SiO₂, hexane/EtOAc, 10:2) to give **115** (5.1g, 99 %) as a light yellow liquid. ¹H NMR (500MHz): δ = 7.01 (d, *J* = 7.3 Hz, 1H), 6.72 (d, *J* = 7.3 Hz, 1H), 6.57 (s, 1H), 3.53 (p, *J* = 6.4 Hz, 1H), 3.41 (p, *J* = 6.9 Hz, 1H), 3.18 (p, *J* = 6.9 Hz, 1H), 3.06 (p, *J* = 6.9 Hz, 1H), 2.25 (s, 3H), 1.17 (t, *J* = 7.3 Hz, 3H), 0.95 (t, *J* = 7.3 Hz, 3H), 0.92 (s, 9H), 0.16 (s, 3H), 0.15 (s, 3H); ¹³C NMR (125 MHz): δ = 169.2, 151.0, 139.7, 127.7, 127.0, 122.2, 120.0, 42.9, 39.2, 25.8, 25.7, 21.4, 18.1, 14.2, 13.3, -4.1, -4.05; IR (neat, cm⁻¹) = 2930, 1636, 1427, 1291, 1165, 1133, 1084. 971; HRMS (ESI): Calcd. for C₃₂H₆₂N₂O₄Si₂Na⁺ (*m/z*): 665.4140. Found 665.4068 [2M+Na]⁺; Anal. Calcd. for C₁₈H₃₁NO₂Si: C, 67.24; H, 9.72; N, 4.36. Found: C, 66.96; H, 9.46; N, 4.39.

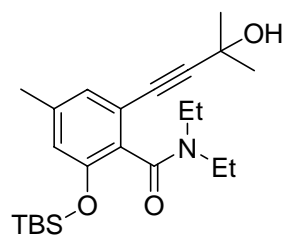
2-(*tert*-Butyl-dimethylsilyloxy)-6-iodo-4-methyl-*N,N*-diethylbenzamide (**116**)



A solution of benzamide **115** (13.4 g, 41.8 mmol) in dried Et₂O (100 mL) was added dropwise to a mixture of *tert*-butyllithium (26.6 mL, 45.2 mmol) at -78 °C under N₂ and stirred for 1 h. After 1h at -78 °C, the reaction mixture was quenched by adding a solution of iodine

(11.3 g, 44.4 mmol) in THF dropwise. The resulting solution was then allowed to warm up to ambient temperature overnight. Saturated NH₄Cl solution (100 mL) was added followed by Na₂S₂O₃ solution to decolorize the reaction mixture. The reaction was then extracted with CH₂Cl₂. The organic layer was separated, washed with water, dried (Na₂SO₄) and concentrated under reduced pressure to afford the crude product. Purification was done by flash chromatography using gradient elution (hexane/EtOAc, 10:1 - 10:3) to give **116** (16.34 g, 87%) as a light yellow solid, mp: 66- 68 °C. ¹H NMR (300 MHz), δ = 6.97 (s, 1H), 6.55 (s, 1H), 3.72 (m, 1H), 3.25 (m, 1H), 3.12 (qd, *J* = 2.8, 7.2 Hz, 2H), 2.28 (s, 3H), 1.21 (t, *J* = 6.9 Hz, 3H), 1.05 (t, *J* = 7.2 Hz, 3H), 0.94 (s, 9H), 0.23 (s, 3H), 0.20 (s, 3H), ¹³C NMR (75 MHz): δ = 166.4, 152.5, 140.4, 128.4, 125.9, 120.1, 118.8, 42.9, 39.2, 25.6, 21.2, 18.2, 14.0, 12.8, -3.9, -4.6; IR (neat, cm⁻¹) = 2932, 2859, 1638, 1472, 1292, 1255; HRMS (ESI): Calcd. For C₁₈H₃₁INO₃Si (*m/z*): 448.1163. Found 448.1167 [M+H]⁺;

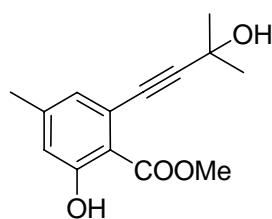
2-(3-Hydroxy-3-methyl-1-butyne)-4-methyl-6-(*tert*-butyl-dimethylsilyloxy)-*N,N*-diethylbenzamide (117)



A solution of **116** (5.33 g, 11.9 mmol) in Et₃N (30 mL) was purged with N₂ for about 30 min and then cooled to -78 °C. To the purged solution of **116** was added PdCl₂(PPh₃)₂ (0.17 g, 0.24 mmol) and CuI (23.0 mg, 0.12 mmol) and stirred at -78 °C for 10 min. To the reaction mixture, was then added 2-hydroxy-2-methylbut-1-yne (1.72 g, 20.5 mmol) and stirred at 55 °C for 5 h. Next, Et₂O (50 mL) and 1 M HCl (20 mL) were

added. The organic layer was separated, neutralized with saturated NaHCO₃ (30 mL) solution, washed with H₂O, dried (Na₂SO₄) and concentrated under reduced pressure. The residue was purified by flash chromatography (silica gel, n-hexane) to afford **117** (3.50 g, 73%) as a yellow waxy solid. ¹H NMR (500 MHz): δ = 6.86 (s, 1H), 6.58 (s, 1H), 3.68 (sext, *J* = 7.0 Hz, 1H), 3.42 (sext, *J* = 7.0 Hz, 1H), 3.21-3.08 (m, 2H), 2.26 (s, 3H), 1.71 (s, 1H), 1.53 (s, 6H), 1.28 (t, *J* = 7.5 Hz, 3H), 1.08 (t, *J* = 7.5 Hz, 3H), 0.94 (s, 9H), 0.22 (s, 3H), 0.18 (s, 3H); ¹³C NMR (75 MHz): δ = 167.5, 151.3, 139.1, 129.5, 125.7, 120.3, 107.4, 65.4, 43.2, 39.4, 31.4, 31.3, 25.6, 21.3, 18.1, 14.0, 13.4, -3.9, -4.6; IR (neat, cm⁻¹) = 3382, 2931, 2859, 1619, 1568, 1428, 1285, 1075; HRMS (ESI): Calcd. for C₂₃H₃₈NO₃Si⁺ (*m/z*): 404.2615. Found 404.2616 [M+H]⁺;

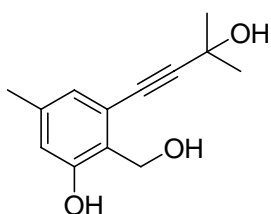
2-(3-Hydroxy-3-methyl-1-butynyl)-6-hydroxy-4-methyl-methylbenzoate (**118**)



NaHPO₄ (1.67 g, 11.8 mmol) and (CH₃)₃OBF₄ (3.48 g, 23.5 mmol) were added at rt to a solution of **117** (3.16 g, 7.80 mmol) in CH₃CN (50 mL) and stirred for 18 h. Then saturated NaHCO₃ solution (20 mL) was added slowly followed by addition of solid NaHCO₃ (3.29 g, 39.2 mmol) and stirred for another 18 h at rt. The product was extracted using EtOAc (3 x 20 mL), dried (Na₂SO₄) and concentrated under reduced pressure. The crude product was purified by flash chromatography (SiO₂, hexane/EtOAc, 10:1) to give **118** (1.76 g, 90 %) as a viscous brown waxy solid. ¹H NMR (500 MHz): δ = 11.17 (s, 1H), 6.67 (s, 1H), 6.58 (s, 1H), 3.78 (s, 3H), 2.07 (s, 3H), 1.50 (s, 6H); ¹³C NMR (125 MHz): δ = 170.7, 162.0, 145.0, 127.3, 123.7, 118.3,

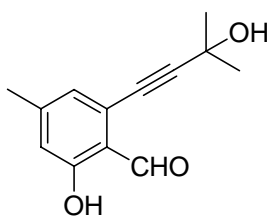
110.3, 98.3, 81.5, 65.4, 51.8, 31.4, 21.2; IR (neat, cm^{-1}) = 3435, 2982, 1663, 1605, 1571, 1440, 1164; HRMS (TOF-MS): Calcd. For $\text{C}_{14}\text{H}_{16}\text{O}_4\text{Na}^+$ (m/z): 271.0946. Found 271.0939 $[\text{M}+\text{Na}]^+$.

2-(3-Hydroxy-3-methyl-1-butynyl)-6-hydroxy-4-methyl-benzylalcohol (**119**)



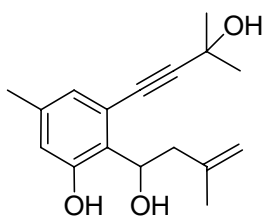
DIBAL (1.0M in hexane, 5.16 mL, 5.16 mmol) was added dropwise to a stirred and cooled ($-78\text{ }^\circ\text{C}$) solution of **118** (640 mg, 2.58 mmol) in dry toluene (10 mL). The mixture was then stirred at $-78\text{ }^\circ\text{C}$ for 2 h and then stirred at $0\text{ }^\circ\text{C}$ for 1 h. The stirring was continued for 6 h without recharging the ice bath. The solution was then recooled to $-78\text{ }^\circ\text{C}$ and MeOH (10mL), $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ (2.0 g), Celite (3.0 g) and water (2 mL) were added successively. The cold bath was then removed and stirring continued for 30 minutes before filtering the slurry through a sintered glass funnel and washed with EtOAc. The organic layer was then concentrate under reduced pressure to give **119** (560 mg, 98%) as a yellow liquid. ^1H NMR (500 MHz): δ = 6.76 (s, 1H), 6.65 (s, 1H), 5.01 (s, 2H), 2.22 (s, 3H), 1.59 (s, 6H); ^{13}C NMR (125 MHz): δ = 156.3, 139.0, 124.9, 122.9, 121.1, 118.1, 79.9, 65.8, 62.1, 31.5, 21.1; IR (neat, cm^{-1}) = 3345, 2981, 2935, 2222, 1611, 1582, 1141; HRMS (ESI): Calcd. For $\text{C}_{13}\text{H}_{16}\text{NaO}_3$ (m/z): 243.0992. Found 243.1012 $[\text{M}+\text{Na}]$.

2-(3-Hydroxy-3-methyl-1-butynyl)-6-hydroxy-4-methyl-benzaldehyde (**120**)



Manganese (IV) oxide (360 mg, 4.02 mmol) was added to a stirred solution of **119** (300 mg, 1.36 mmol) in dry CH₂Cl₂ (10mL). The reaction mixture was then heated to reflux for 10 h by which time oxidation was completed. The solvent was evaporated to approximately 50 mL and the slurry was filtered through a pad of SiO₂ and washed with CH₂Cl₂. The filtrate was concentrated and purified by flash chromatography (SiO₂, EtOAc-hexane 2:3) to give the aldehyde **120** (280 mg, 94%) as a viscous brown waxy solid. ¹H NMR (500 MHz): δ = 11.58 (s, 1H), 10.23 (s, 1H), 6.75 (s, 1H), 6.63 (s, 1H), 3.25 (broad s, 1H), 2.23 (s, 3H), 1.59 (s, 6H); ¹³C NMR (125 MHz): δ = 196.2, 162.4, 148.5, 126.8, 125.8, 118.4, 117.6, 100.8, 77.4, 65.6, 31.3, 21.9; IR (neat, cm⁻¹) = 3352, 2983, 2935, 2221, 1652, 1616, 1567, 1411; HRMS (ESI): Calcd. for C₁₃H₁₄NaO₃ (*m/z*): 241.0835. Found 241.0833 [M+Na]⁺.

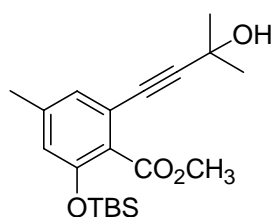
2-(1-Hydroxy-3-methyl-3-butenyl)-3-(3-hydroxy-3-methyl-1-butynyl)-5-methylphenol (**121**)



2-Methylallylmagnesium chloride (6.90 mL, 3.44 mmol) was added dropwise to a solution of **120** (0.25 g, 1.15 mmol) in THF (10 mL) at 0 °C under N₂ atmosphere. The reaction mixture was then allowed to warm up to rt and stirred for 3 h. The reaction mixture was quenched with NH₄Cl, extracted with dichloromethane and washed with water and brine solution. The organic layer was dried (Na₂SO₄) and concentrated under reduced pressure.

Purification was done by flash chromatography (SiO₂, hexane/EtOAc; 1:2) to afford compound **121** (300 mg, 97%) as a light yellow liquid. ¹H NMR (500 MHz): δ = 8.79 (broad s, 1H), 6.74 (s, 1H), 6.63 (s, 1H), 5.40 (dd, *J* = 3.7, 10.1 Hz, 1H), 4.95 (s, 1H), 4.88 (s, 1H), 3.47 (broad s, 1H), 2.64 (broad s, 1H), 2.53 (dd, *J* = 10.5, 14.2 Hz, 1H), 2.44 (dd, *J* = 2.8, 14.2 Hz, 1H), 2.19 (s, 3H), 1.84 (s, 3H), 1.57 (s, 6H); ¹³C NMR (125 MHz): δ = 155.8, 142.3, 138.5, 125.1, 124.9, 120.3, 118.8, 114.5, 97.9, 79.9, 71.6, 65.7, 45.2, 31.6, 22.3, 20.9; IR (neat, cm⁻¹) = 3311, 3073, 2980, 2221, 1650, 1614, 1577, 1162; HRMS (ESI): Calcd. for C₁₇H₂₂NaO₃ (*m/z*): 297.1512. Found 297.1502 [M+Na]⁺.

2-(3-hydroxy-3-methyl-1-butynyl)-6-(*t*-butyldimethylsilyloxy)-4-methylmethylbenzoate (124)

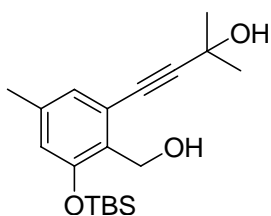


A solution of 2-(3-hydroxy-3-methyl-1-butynyl)-6-Hydroxy-4-methyl-methylbenzoate **118** (3.00 g, 12.1 mmol), imidazole (2.47 g, 36.3 mmol) and *t*-butyldimethylsilyl chloride (2.19 g, 14.5 mmol) in dry DMF (30 mL) was stirred for 18 h. The reaction mixture was diluted with water and extracted with EtOAc (2 x 20 mL). The combined extracts were washed with brine, dried (Na₂SO₄) and evaporated to yield oil. The crude product was purified by flash chromatography (SiO₂, hexane/EtOAc, 10:3) to give **124** (4.35 g, 99%) as a light yellow oil. ¹H NMR (500 MHz): δ = 6.85 (s, 1H), 6.58 (s, 1H), 3.84 (s, 3H), 2.25 (s, 3H), 1.55 (s, 6H), 0.94 (s, 9H), 0.18 (s, 6H); ¹³C NMR (125 MHz): δ = 167.8, 152.4, 140.7, 125.7, 121.6, 120.6, 97.0, 65.4, 52.2, 31.4, 25.7, 21.3,

18.1, 14.3; IR (neat, cm^{-1}) = 3456, 2953, 2859, 2237, 1738, 1567; HRMS (ESI): Calcd.

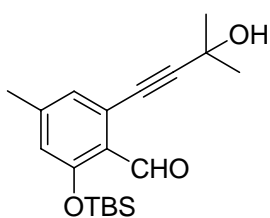
For $\text{C}_{20}\text{H}_{30}\text{SiO}_4\text{Na}^+$ (m/z): 385.1806. Found 385.1816 $[\text{M}+\text{Na}]^+$.

2-(3-Hydroxy-3-methyl-1-butynyl) -6-(*t*-butyldimethylsilyloxy) -4-methyl -benzyl alcohol (125)



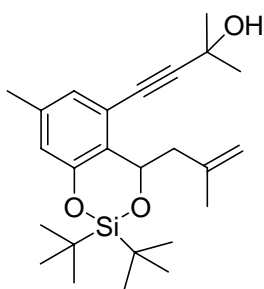
DIBAL (1.0 M in hexane, 24.4 mL, 24.4 mmol) was added dropwise to a stirred and cooled ($-78\text{ }^\circ\text{C}$) solution of **124** (4.42 g, 12.2 mmol) in dry toluene (10 mL). The mixture was then stirred at $-78\text{ }^\circ\text{C}$ for 2 h and then stirred at $0\text{ }^\circ\text{C}$ (iced bath) for 1 h. The stirring was continued for 6 h without recharging the ice bath. The solution was then recooled to $-78\text{ }^\circ\text{C}$ and MeOH (10 mL), $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ (2.0 g), Celite (3.0 g) and water (2 mL) were added successively. The cold bath was then removed and stirring continued for 2 h before filtering the slurry through a sintered disk funnel and wash with EtOAc. The organic layer was then concentrate under reduced pressure to give **125** (3.67 g, 90%) as a yellow liquid. ^1H NMR (300 MHz): δ = 6.86 (d, J = 0.7 Hz, 1H), 6.58 (d, J = 0.7 Hz, 1H), 4.75 (s, 2H), 2.23 (s, 3H), 1.59 (s, 6H), 1.00 (s, 9H), 0.22 (s, 6H); ^{13}C NMR (75 MHz): δ = 153.9, 138.7, 130.0, 126.2, 123.8, 120.4, 97.9, 80.0, 65.4, 58.6, 31.5, 25.9, 21.2, 18.3, -4.1; IR (neat, cm^{-1}) = 3364, 2956, 2931, 2246, 1600, 1572, 1326, 1253; HRMS (ESI): Calcd. For $\text{C}_{19}\text{H}_{30}\text{NaO}_3\text{Si}$ (m/z): 357.1856. Found 357.1873 $[\text{M}+\text{Na}]^+$.

2-(3-Hydroxy-3-methyl-1-butynyl) -6-(*t*-butyldimethylsilyloxy)-4-methyl - benzaldehyde (126)



Pyridinium chlorochromate (2.54 g, 11.8 mmol) and powdered 4A molecular sieves (3.0 g) was added to a stirred solution of **125** (2.81 g, 8.41 mmol) in dry CH₂Cl₂ (10mL). The reaction mixture was then stirred at rt for 10 h by which time oxidation was completed. The solvent was evaporated to approximately 50 mL and the slurry was filtered through a pad of SiO₂ and washed with CH₂Cl₂. The filtrate was concentrated and purified by flash chromatography (SiO₂, EtOAc-hexane 2:3) to give the aldehyde **126** (2.35 g, 84%) as a yellow waxy solid. ¹H NMR (300 MHz): δ = 10.40 (s, 1H), 6.88 (s, 1H), 6.56 (s, 1H), 2.23 (s, 3H), 1.59 (s, 6H), 0.95 (s, 9H), 0.19 (s, 6H); ¹³C NMR (75 MHz): δ = 189.7, 158.3, 145.4, 128.1, 125.2, 124.9, 121.3, 99.5, 80.1, 65.5, 31.3, 25.8, 21.7, 18.4, -4.2; IR (neat, cm⁻¹) = 3442, 2981, 2931, 2860, 2246, 1696, 1593, 1562; HRMS (ESI): Calcd. For C₁₉H₂₈NaSiO₃ (*m/z*): 355.1699. Found 355.1716 [M+Na]⁺.

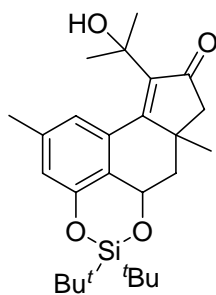
4-[2,2-Di-*tert*-butyl-7-methyl-4-(2-methyl-allyl)-4*H*-benzo[1,3,2]dioxasilin-5-yl]-2-methyl-but-3-yn-2-ol (128)



Pyridine (0.21 mL, 2.63 mmol) and ^tBu₂Si(SO₃CF₃)₂ (0.23 mL, 0.70 mmol) were added to ice-cooled solution of **121** (0.10g, 0.37 mmol) in dry CH₂Cl₂ (10 mL) under N₂ atmosphere and stirred to warm up to room temperature. The mixture was

further stirred at room temperature for 2 h. The reaction mixture was concentrated under reduced pressure and purified by flash chromatography (hexane/EtOAc; 10:2) to afford compound **128** (0.13 g, 86%) as a colorless liquid. $^1\text{H NMR}$ (300 MHz): δ = 6.84 (s, 1H), 6.72 (s, 1H), 5.49 (dd, J = 2.4, 10.7 Hz, 1H), 4.92 (s, 1H), 4.90 (s, 1H), 2.61 (d, J = 15.1 Hz, 1H), 2.42 (dd, J = 10.7, 15.5 Hz, 1H), 2.24 (s, 3H), 1.88 (s, 3H), 1.59 (s, 6H), 1.10 (s, 9H), 0.91 (s, 9H); $^{13}\text{C NMR}$ (75 MHz, CD_3Cl): δ = 153.3, 143.3, 137.9, 128.9, 126.4, 121.2, 120.1, 112.1, 98.9, 80.0, 72.7, 65.7, 47.0, 31.6, 31.5, 27.5, 26.9, 22.7, 22.2, 20.8, 19.8; IR (neat, cm^{-1}) = 3366, 2967, 2934, 2860, 2221, 1651, 1607, 1569; HRMS (ESI): Calcd. For $\text{C}_{25}\text{H}_{38}\text{NaO}_3\text{Si}$ (m/z): 437.2482. Found 437.2481 [M+Na];

5,5-Di-tert-butyl-10-(1-hydroxy-1-methyl-ethyl)-2,7a-dimethyl-6a,7,7a,8-tetrahydro-4,6-dioxa-5-sila-cyclopenta[a]phenalen-9-one (129)

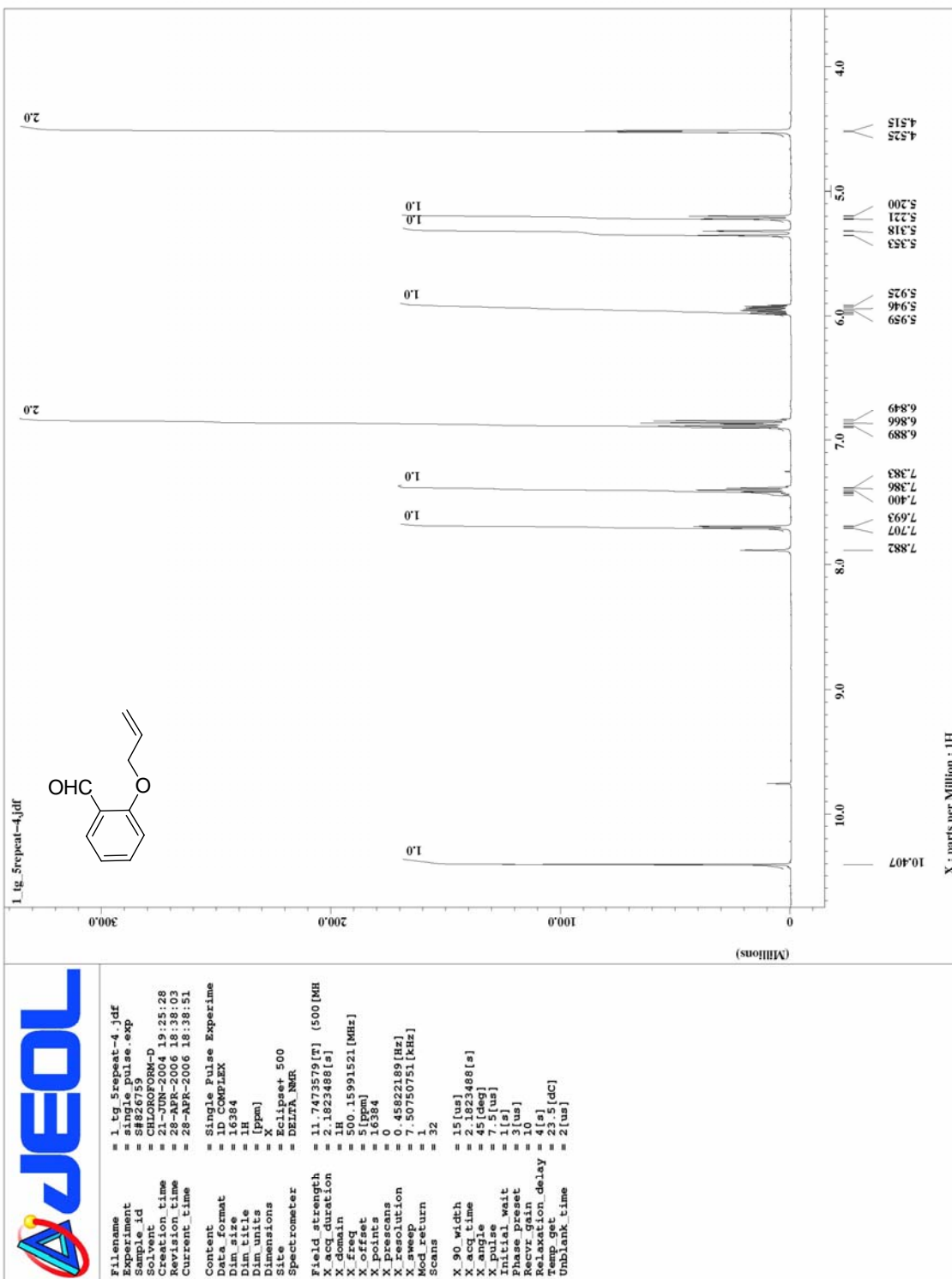


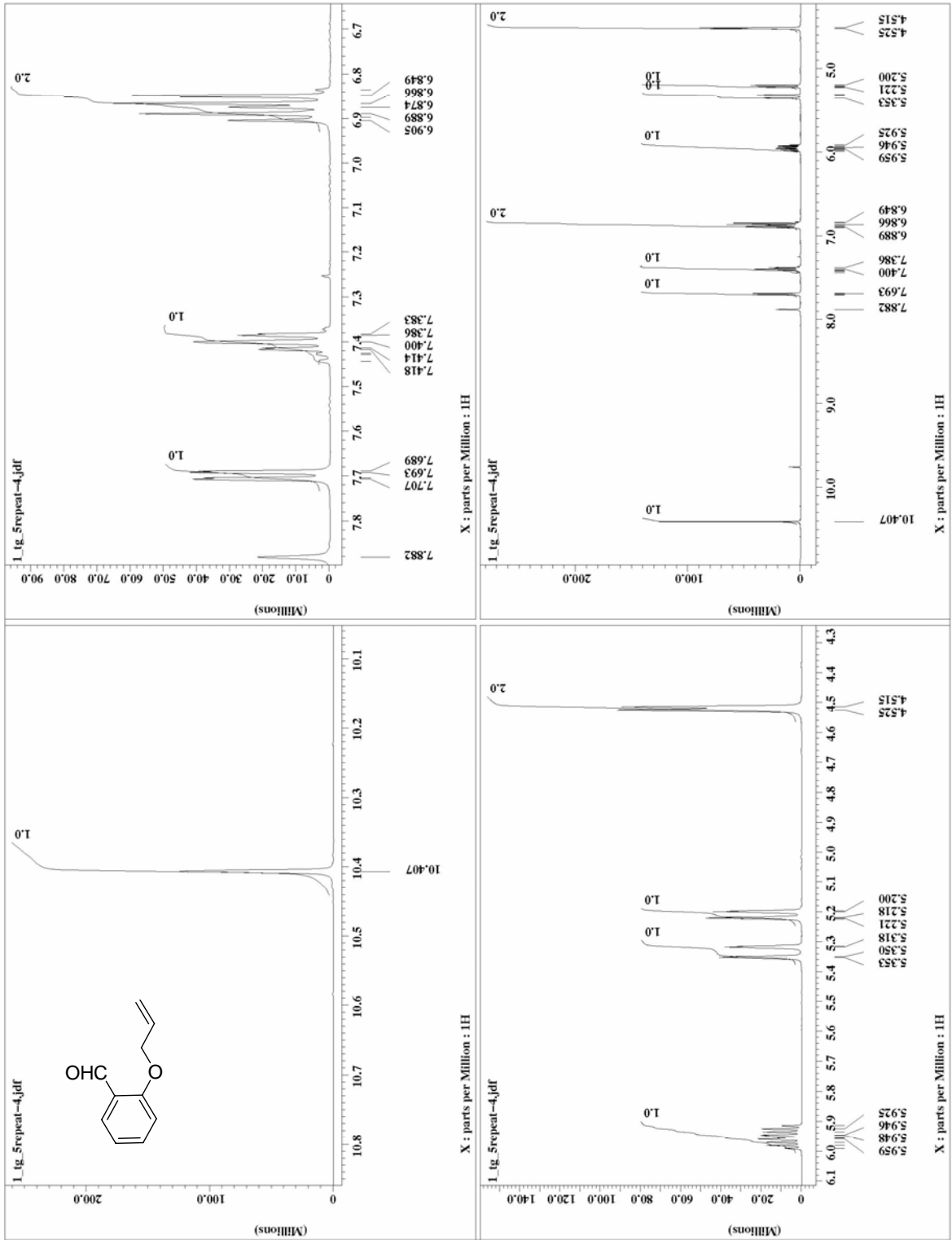
$\text{Co}_2(\text{CO})_8$ (82 mg, 0.24 mmol) was added to the solution of enyne **128** (90 mg, 0.22 mmol) in toluene (10 mL) under N_2 and stirred for 2 h at room temperature. The reaction mixture was then heated at 70 $^\circ\text{C}$ under N_2 for overnight. The reaction mixture was then poured into a sintered glass funnel packed with Celite and SiO_2 and first washed with hexane to remove the alkyne- $\text{Co}_2(\text{CO})_6$ remaining and then washed with ethyl acetate to remove any remaining cyclized product. The crude product was purified by flash chromatography (hexane/EtOAc, 20/1.5) to give **129** (67 mg, 70%) as a colorless liquid.

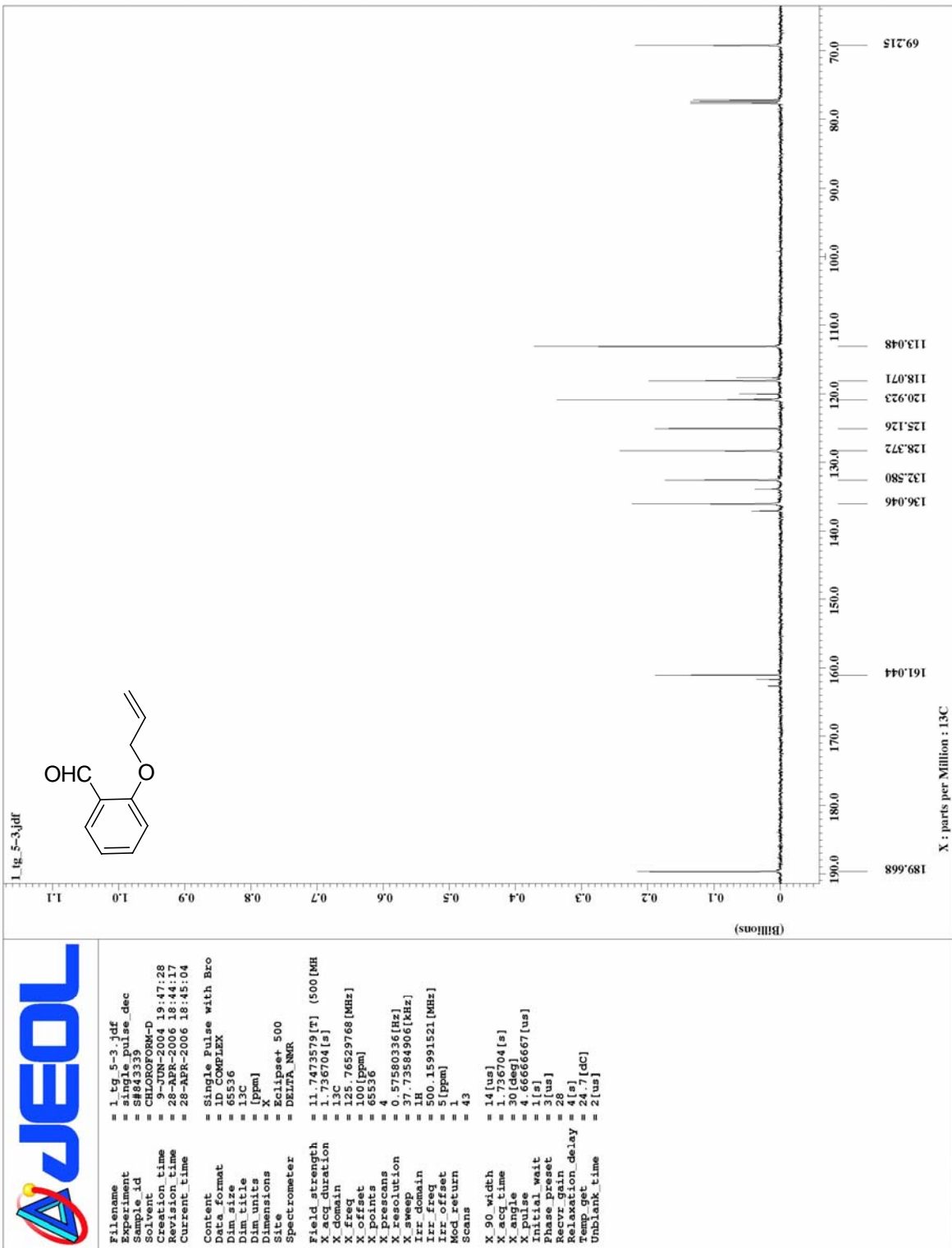
^1H NMR (500 MHz): δ = 6.84 (s, 1H), 6.78 (s, 1H), 5.01 (dd, J = 4.6, 7.8 Hz, 1H), 4.78 (s, 1H), 2.48 (AB q, J = 18.6 Hz, 2H), 2.34 (s, 3H), 2.25 (dd, J = 7.3, 14.2 Hz, 1H), 2.02 (dd, J = 5.04, 13.8 Hz, 1H), 1.61 (s, 3H), 1.34 (s, 3H), 1.10 (s, 9H), 1.06 (s, 3H), 0.97 (s, 9H); ^{13}C NMR (125 MHz): δ = 210.1, 170.6, 153.6, 140.7, 138.1, 131.0, 124.1, 122.1, 121.6, 77.3, 71.3, 66.4, 51.3, 45.3, 39.1, 31.7, 28.1, 27.6, 27.1, 21.8, 21.4, 20.9; IR (neat, cm^{-1}) = 3452, 2964, 2934, 2861, 1730, 1684, 1569, 1473, 1331, 1285, 1009, 828; HRMS (ESI): Calcd. For $\text{C}_{26}\text{H}_{38}\text{SiO}_4\text{Na}$ (m/z): 465.2432. Found 465.2470 $[\text{M}+\text{Na}]^+$; Calcd. For $\text{C}_{52}\text{H}_{76}\text{Si}_2\text{O}_8\text{Na}$ (m/z): 907.4971. Found 907.4991 $[2\text{M}+\text{Na}]^+$.

APPENDIX 1

**¹H and ¹³C NMR SPECTRA OF
2-(-2-Propenyloxy)benzaldehyde (2)**







APPENDIX 2

¹H and ¹³C NMR SPECTRA OF

2-(1-Hydroxy-2-propynyl)-(2-propenyloxy) benzene (3)



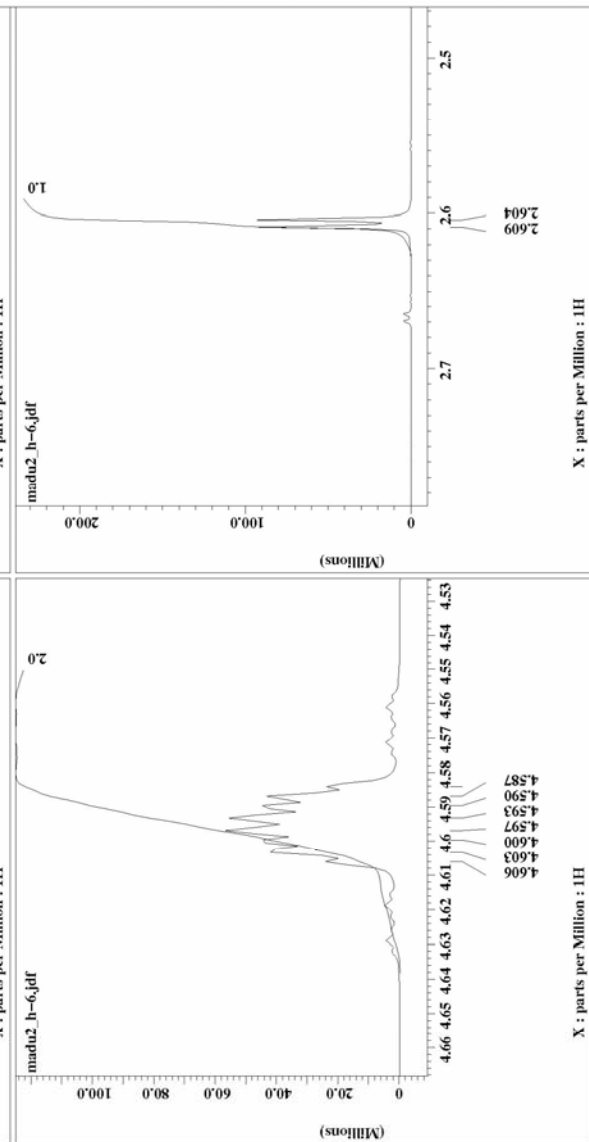
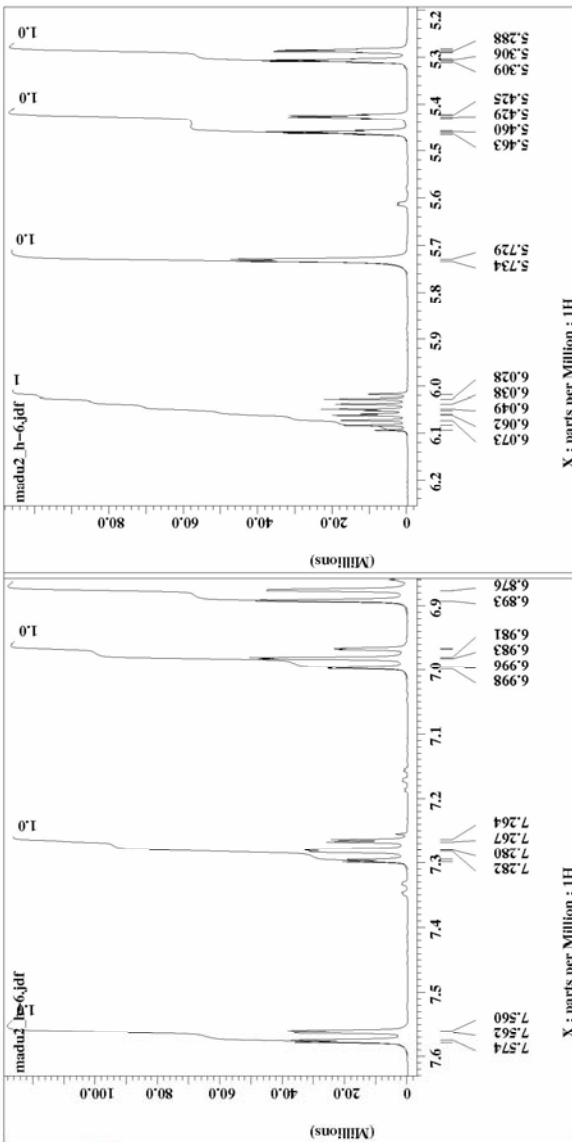
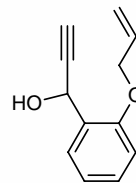
```

Filename = madu2_h-6_jdf
Experiment = single pulse.exp
Sample_id = S826871
Solvent = CHLOROFORM-D
Creation_time = 21:28:59
Last_modified_time = 28-APR-2006 19:19:43
Current_time = 28-APR-2006 19:20:06

Content = Single Pulse Experiment
Data_format = 1D COMPLEX
Dim_size = 16384
Dim_title = 1H
Dim_units = [ppm]
Dimensions = 1
Site = Kollins+ 500
Spectrometer = DELTA_NMR

Field_strength = 11.7473579[T] (500[MH]
X_acq_duration = 2.1823488[s]
X_domain = 1H
X_freq = 500.15991521[MHz]
X_offset = 16384
X_points = 16384
X_presat = 0
X_resolution = 0.45822189[Hz]
X_sweep_rate = 7.50750751[kHz]
Mod_return = 1
Scans = 32

X_90_width = 15[us]
X_acq_time = 2.1823488[s]
X_angle = 45[deg]
X_pulse_wait = 15[us]
X_pulse_wait = 15[us]
Phase_Preset = 3[us]
Recvr_Gain = 10
Relaxation_delay = 1[s]
Temp_get = 23.7[dc]
Unblank_time = 2[us]
  
```





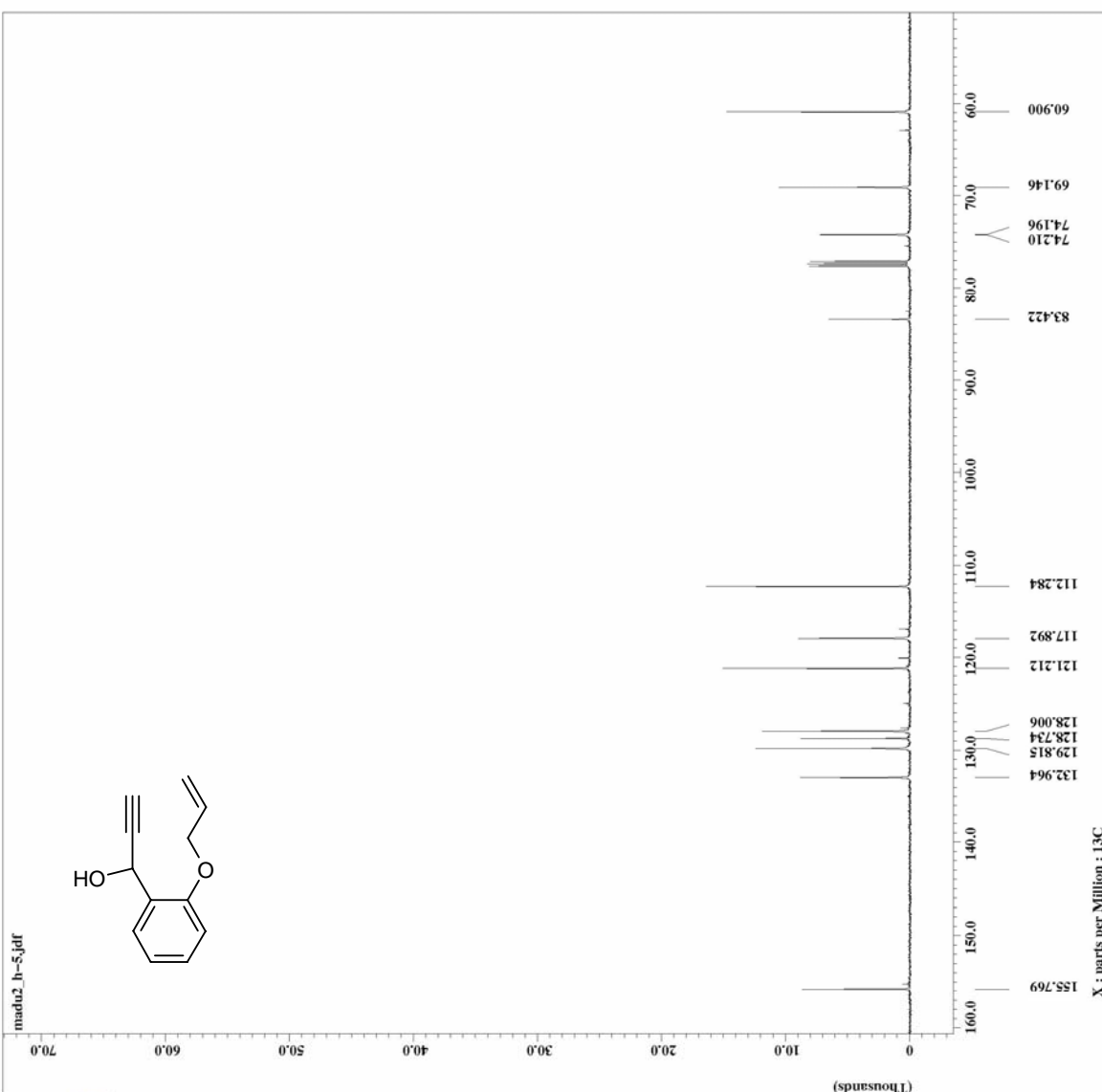
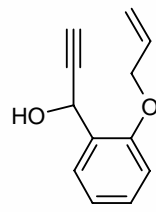
```

File name      = madu2_h-5_jdf
Experiment     = single pulse_dec
Sample id     = S#19212
Solvent       = CHLOROFORM-D
Creation time  = 22-JUL-2004 01:22:11
Revision time = 28-APR-2006 19:22:46
Current time  = 28-APR-2006 19:23:41

Content       = Single Pulse with Bro
Dim format   = 1D COMPLEX
Dim size     = 65536
Dim title    = 13C
Dim units    = [ppm]
Dimensions   = X
Site         = Eclipse+ 500
Spectrometer = DELTA_NMR

Field strength = 125.76529768 [MHz]
X_domain      = 100 [ppm]
X_offset      = 65536
X_points      = 4
X_prescans    = 4
X_resolution  = 0.57580336 [Hz]
X_sweep       = 37.73584906 [KHz]
Irr_domain    = H
Irr_freq      = 500.15991521 [MHz]
Irr_offset    = 5 [ppm]
Mod return    = 1
Scans         = 131

X_90_width    = 14 [us]
X_acq_time    = 1.736704 [s]
X_angle       = 30 [deg]
X_pulse       = 4.6666667 [us]
Prtcl_wait    = 3 [s]
Phase_offset  = 29
Recvr_gain    = 29
Relaxation_delay = 4 [s]
Temp_get      = 24.3 [dC]
Unblank_time  = 2 [us]
  
```



APPENDIX 3

^1H and ^{13}C NMR SPECTRA OF

2-(1-Hydroxy-3-trimethylsilyl-2-propynyl)-(-2-propenyloxy) benzene (4)

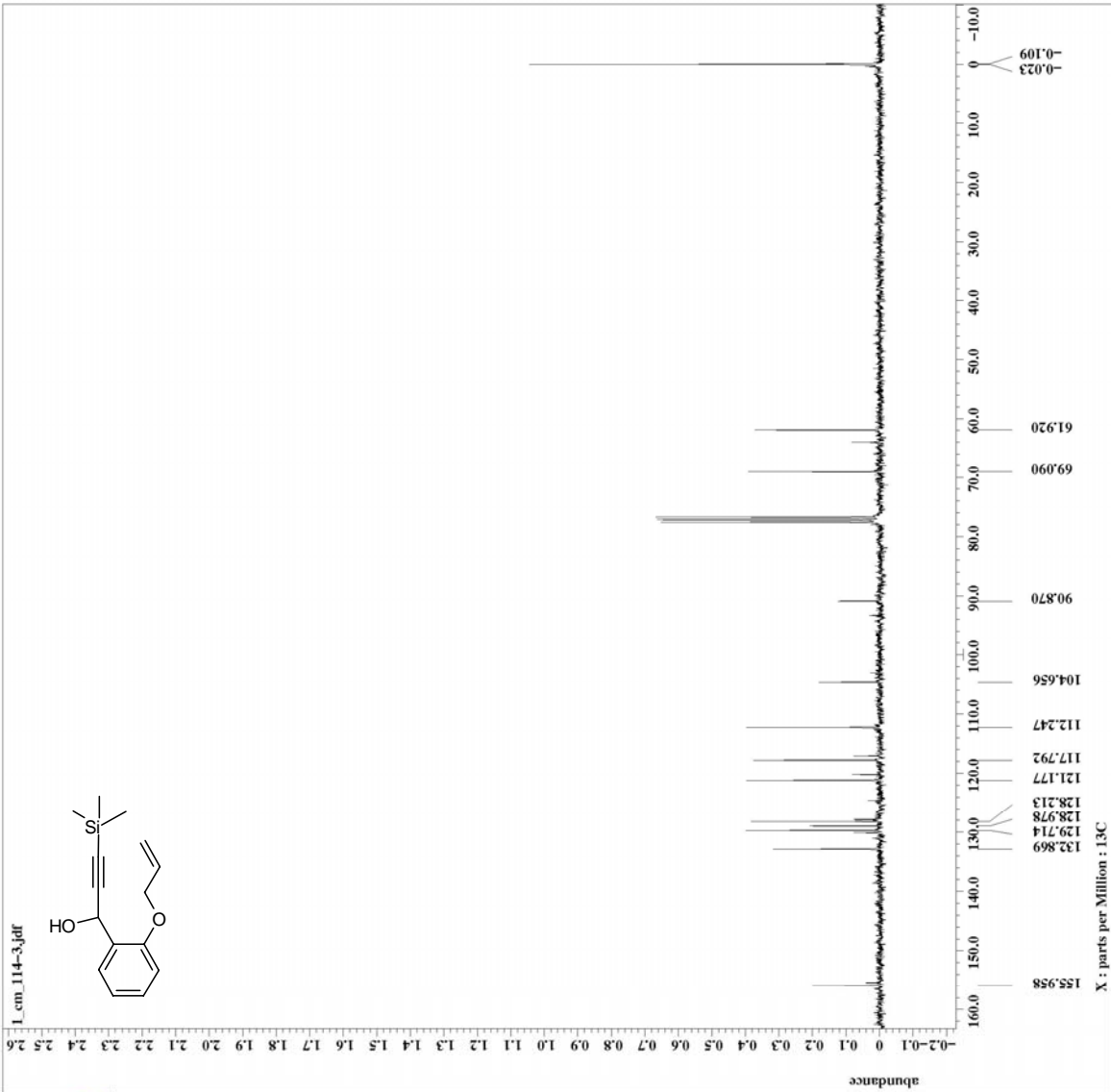


Filename = l_cm_114-3_jdf
Author = delta
Experiment = single_pulse_dec
Sample_id = CHLORFORM-D
Solvent = CHLORFORM-D
Creation_time = 20-DEC-2004 12:26:31
Revision_time = 28-APR-2006 19:50:02
Current_time = 28-APR-2006 19:50:56

Content = single pulse decouple
Data_format = ID COMPLEX
Dim_size = 26214
Dim_title = 13C
Dim_units = X [ppm]
Dimensions = X
Site = ECX 300
Spectrometer = DELTA2_NMR

Field_strength = 7.0586013 [T] (300 [MHz])
X_acq_duration = 1.38412032 [s]
X_domain = 13C
X_freq = 75.56823426 [MHz]
X_offset = 10.0 [ppm]
X_points = 32768
X_prescans = 4
X_resolution = 0.72248054 [Hz]
X_sweep = 23.67424242 [kHz]
Irr_domain = 1H
Irr_freq = 300.52965592 [MHz]
Irr_offset = 5 [ppm]
Clipped = FALSE
Soda_return = 123
Scan = 123
Total_scans = 123

X_90_width = 9.75 [us]
X_acq_time = 1.38412032 [s]
X_angle = 30 [deg]
X_atn = 8 [dB]
X_pulse = 3.25 [us]
Irr_atn_dec = 25 [dB]
Irr_atn_noe = WAJZ
Irr_noise = WAJZ
Decoupling = TRUE
Initial_wait = 1 [s]
Noe = TRUE
Noe_time = 3 [s]
Recvr_gain = 58
Relaxation_delay = 3 [s]
Repetition_time = 1.38412032 [s]
Temp_get = 23 [C]



APPENDIX 4

¹H and ¹³C NMR SPECTRA OF

2-(1-Hydroxy-3-phenyl-2-propynyl)-(2-propenyloxy)benzene (5)



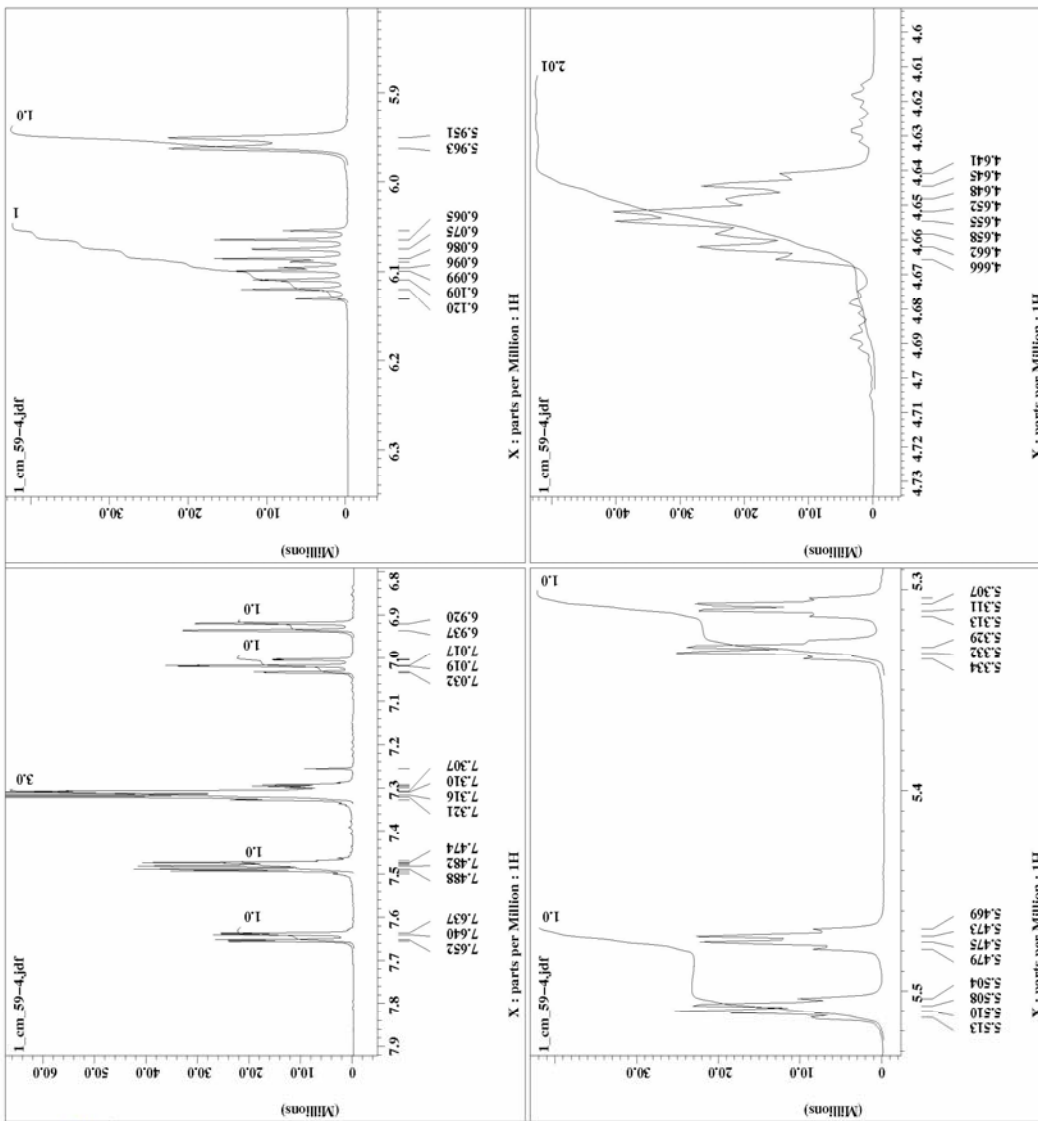
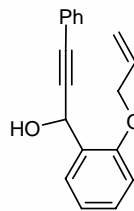
```

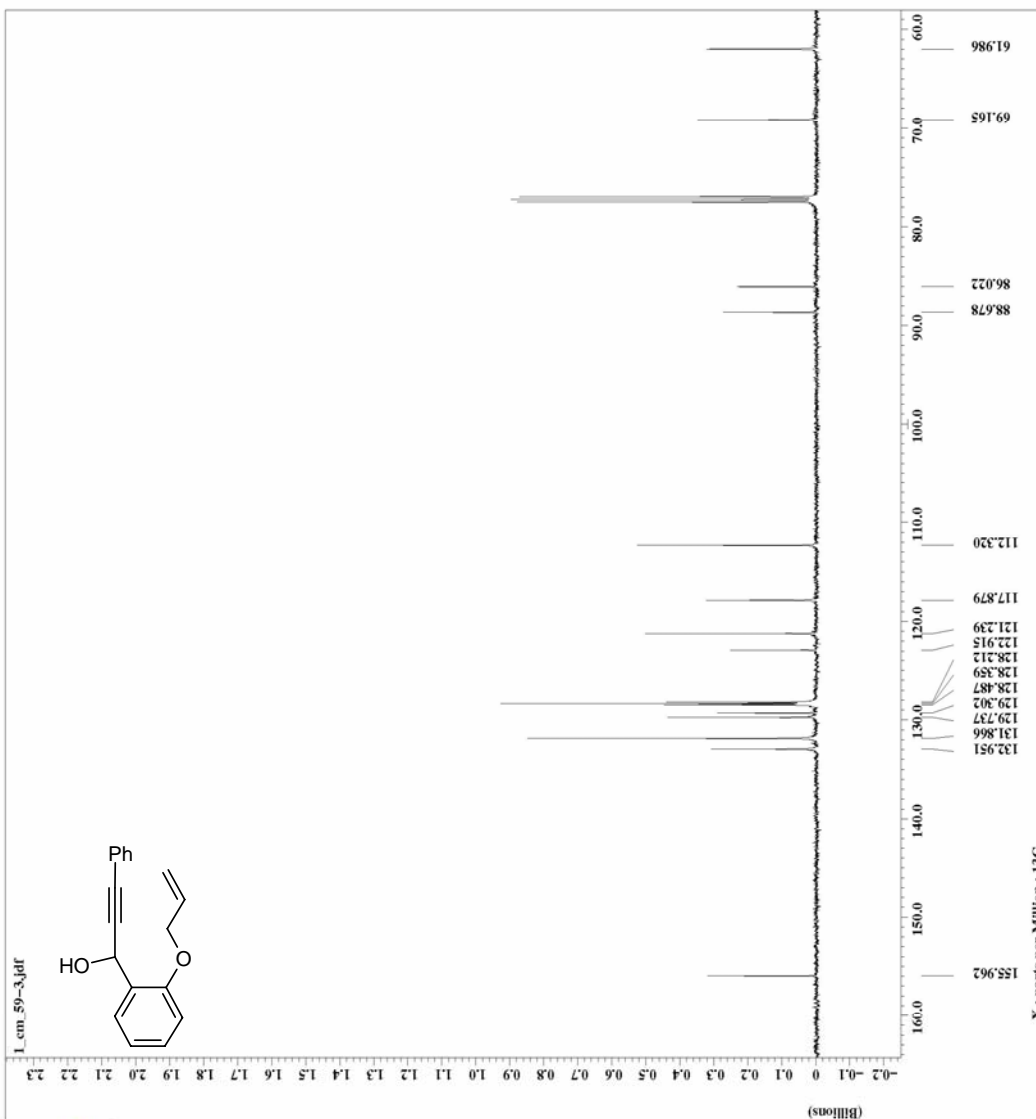
Filename = 1_cm_59-4.jdf
Experiment = Single Pulse Exp
Pulse program = SPP04
Solvent = CHLOROFORM-D
Creation_time = 2-OCT-2004 21:24:31
Revision_time = 28-APR-2006 20:04:35
Current_time = 28-APR-2006 20:05:32

Content = Single Pulse Experiment
Data format = 1D COMPLEX
Data size = 16384
Dim title = 1H
Dim x1 = 5 [ppm]
Dimensions = X
Site = Eclipset 500
Spectrometer = DELTA_NMR

Field strength = 11.7473579 [T] (500 [MH]
X acq duration = 2.1823488 [s]
X domain = 1H
X freq = 500.15991521 [MHz]
X offset = 5 [ppm]
X prescan = 0
X prescans = 0
X resolution = 0.45822189 [Hz]
X sweep = 7.50750751 [kHz]
Mod return = 1
Scans = 32

X 90 width = 15 [us]
X acq time = 2.1823488 [s]
X angle = 45 [deg]
X delay = 1 [s]
Initial wait = 1 [s]
Phase preset = 3 [us]
Recvr gain = 12
Relaxation delay = 1 [s]
Sens.get = 1 [dB]
Unblank_time = 2 [us]
  
```





1_cm_59-3.jdf

Oc1ccc(OCC#Cc2ccccc2)cc1

Filename = 1_cm_59-3.jdf
 Experiment = Single Pulse Dec
 Solvent = CHLOROFORM-D
 Creation_time = 2-OCT-2004 21:45:55
 Revision_time = 28-APR-2006 20:08:33
 Current_time = 28-APR-2006 20:10:28

Content = Single Pulse with Bro
 Data_format = 1D_COMPLEX
 Dim_size = 65536
 Dim_title = 13C
 Dimensions = X
 Site = Eclipse+ 500
 Spectrometer = DELTA_NMR

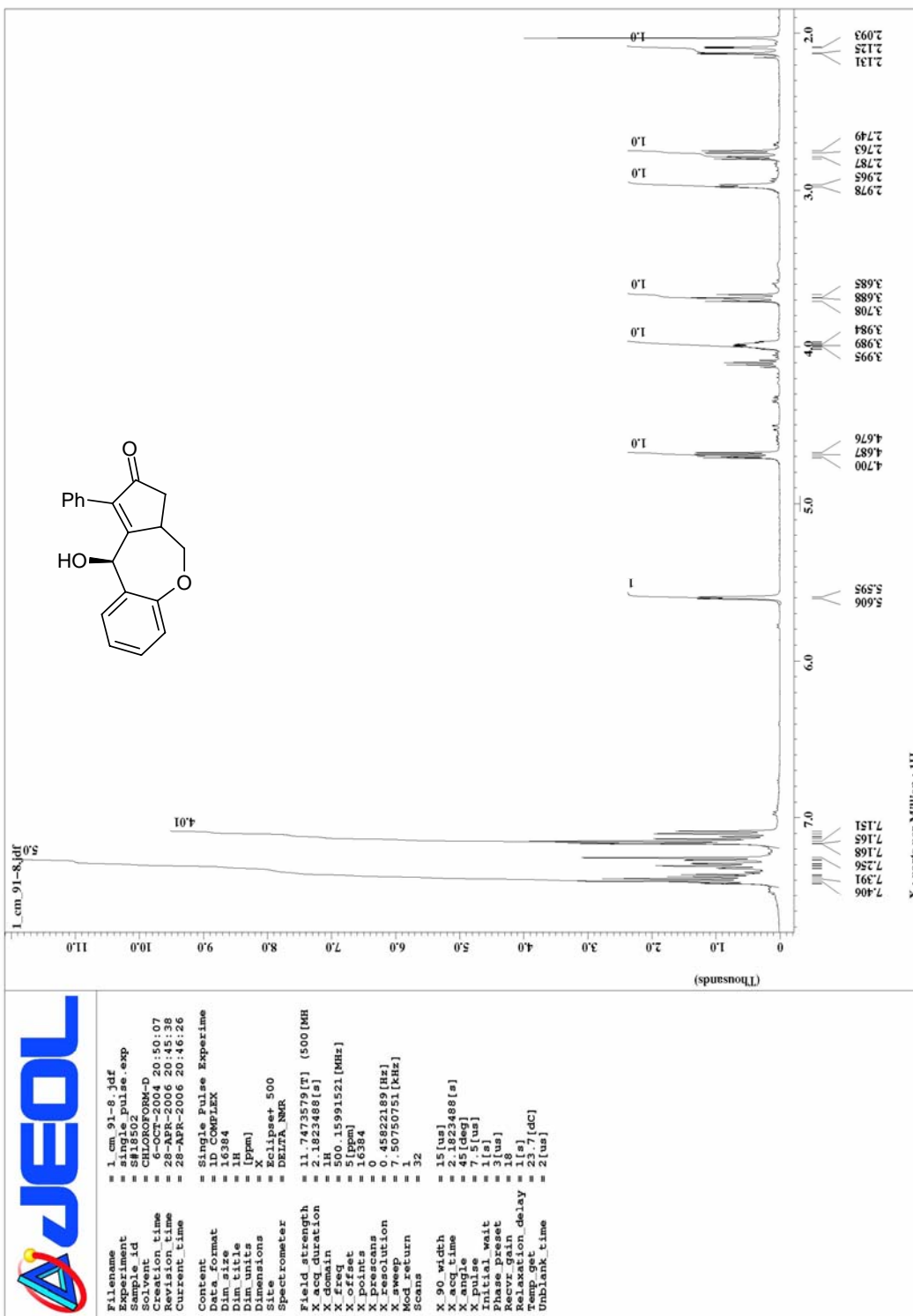
Field_strength = 11.7473578[T] (500[MH
 X_acq_duration = 1.736704[s]
 X_domain = 13C
 X_freq = 125.76529768[MHz]
 X_offset = 100[ppm]
 X_prescans = 4
 X_resolution = 0.57580336[Hz]
 X_sweep = 180.15991521[MHz]
 X_domain = 13C
 X_offset = 5[ppm]
 Mod_return = 1
 Scans = 200

X_90_width = 14[us]
 X_acq_time = 1.736704[s]
 X_angle = 30[deg]
 X_pulse = 4.66666667[us]
 Initial_wait = 1[s]
 Phase_preset = 23
 Relaxation_delay = 4[s]
 Temp_get = 24.7[dc]
 Unblank_time = 2[us]

APPENDIX 5

¹H and ¹³C NMR SPECTRA OF

10-hydroxy-1-phenyl-4,4a-dihydro-3*H*,10*H*-5-oxabenzof]azulen-2-one (8)





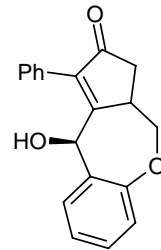
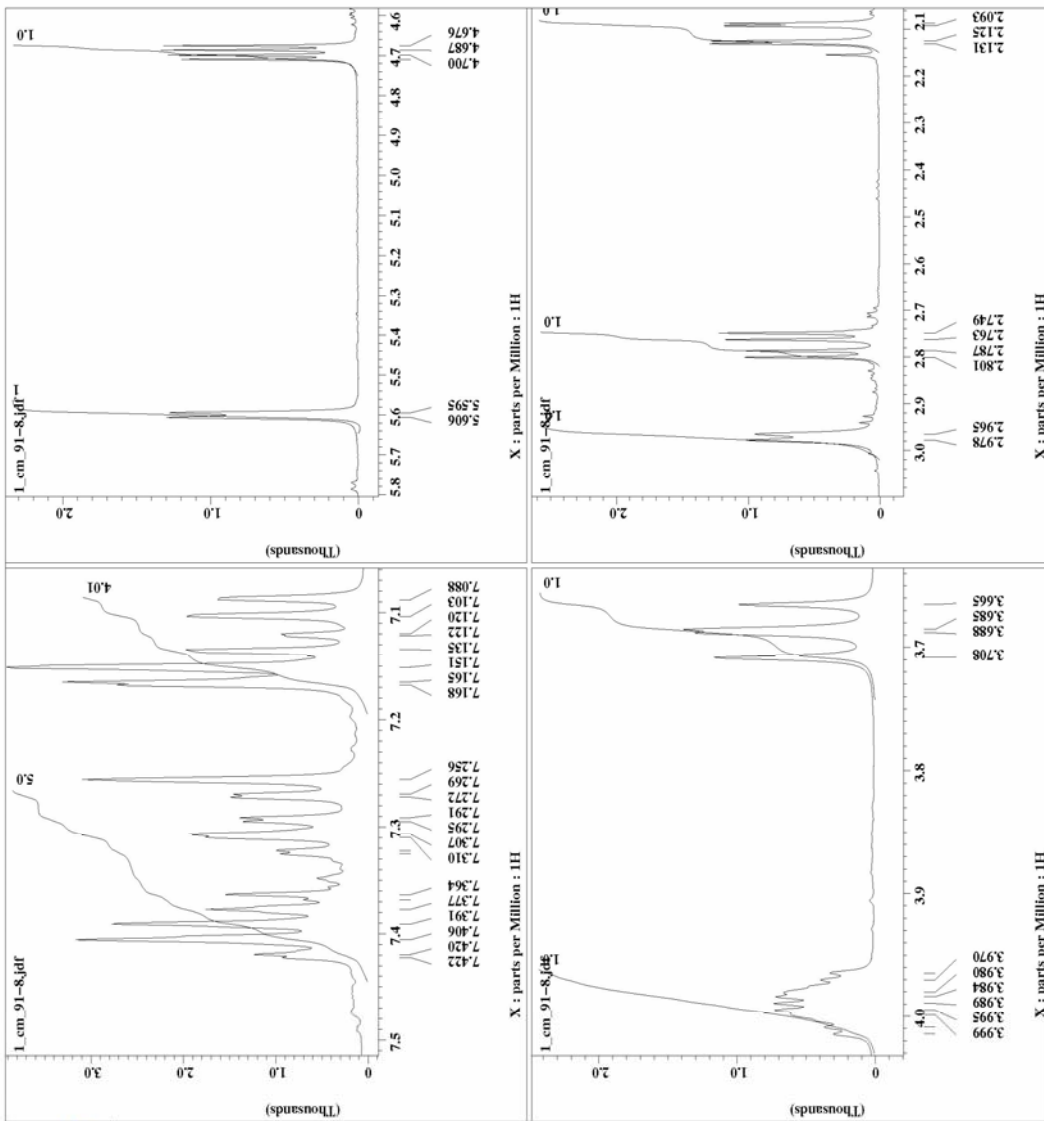
```

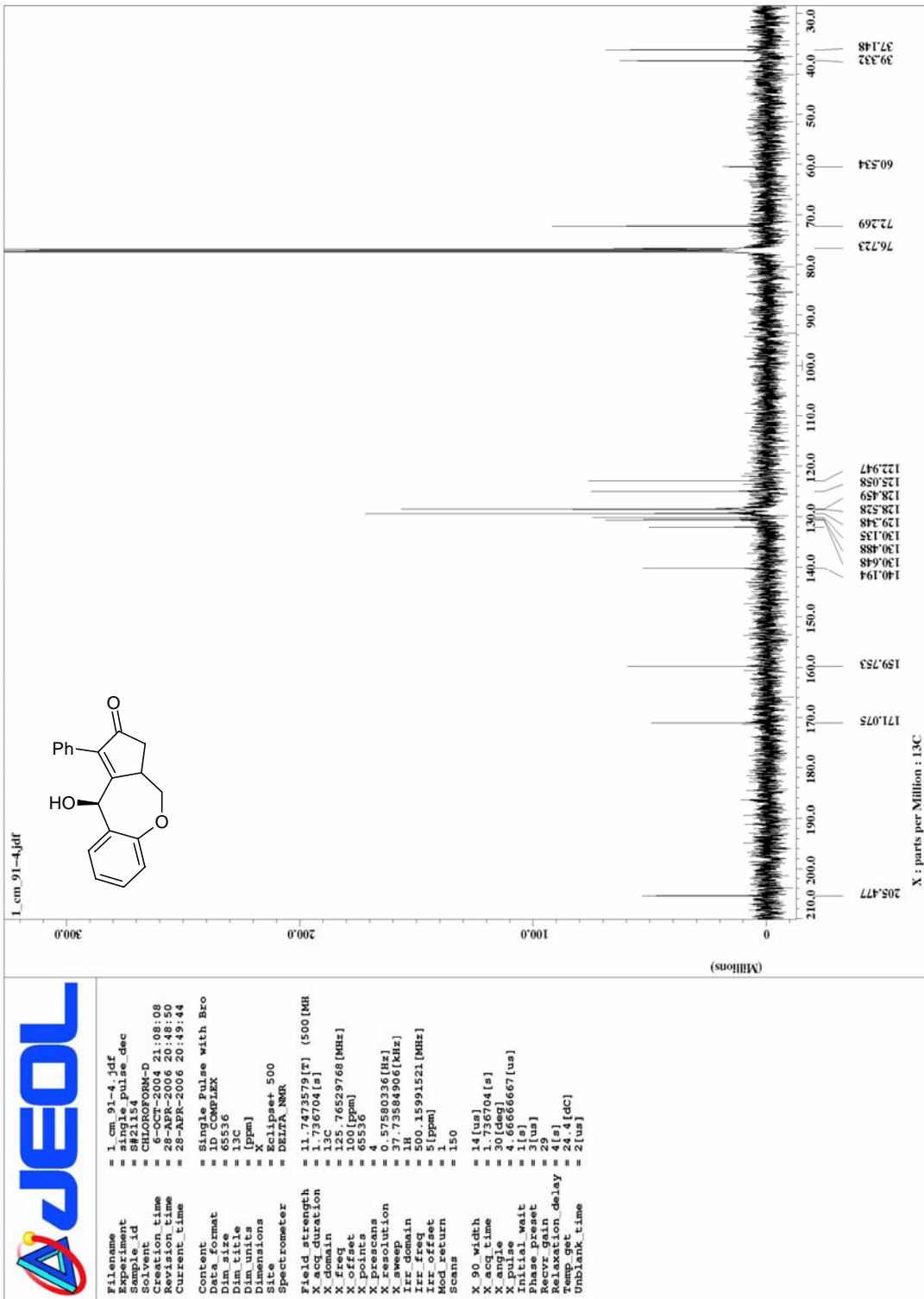
Filename = l_cm_91-8.jdf
Experiment = Single Pulse Exp
Date_Exp = 041502
Solvent = CHLOROFORM-D
Creation_time = 6-OCT-2004 20:50:07
Revision_time = 28-APR-2006 20:45:38
Current_time = 28-APR-2006 20:48:00

Content = Single Pulse Experiment
Data_format = 1D COMPLEX
Dim_size = 16384
Dim_title = 1H
Dimensions = X [ppm]
Site = X
Spectrometer = Eclipse+ 500
Spectrometer = DELTA NMR

Field_strength = 11.7473578 [T] (500 [MH]
X_acq_duration = 2.1623468 [s]
X_domain = 1H
X_freq = 500.15991521 [MHz]
X_offset = 5 [ppm]
X_p1 = 0.384
X_p2 = 0.384
X_resolution = 0.45822189 [Hz]
X_sweep = 7.50750751 [kHz]
Mod_return = 1
Scans = 32

X_90_width = 15 [us]
X_acq_time = 2.1623468 [s]
X_angle = 45 [deg]
X_p1 = 5 [us]
X_p2 = 1 [us]
X_pulse_wait = 1 [us]
Phase_preset = 3 [us]
Recvr_gain = 18
Relaxation_delay = 1 [s]
Temp_get = 23.7 [c]
UNBlank_time = 2 [us]
  
```





```

Filename = 1_cm_91-4.jdf
Experiment = single_pulse_dec
Sample_id = S2115409K-D
Chemical = 6-OCF-2004
Creation time = 6-OCF-2004 21:08:08
Revision time = 28-APR-2006 20:48:50
Current time = 28-APR-2006 20:49:44

Content = Single Pulse with Bro
Chemical = DELTA.DMX
Dim size = 65536
Dim title = 13C
Dim units = [ppm]
Dimensions = X
Site = RELIPRESAT 500
Spectrometer = DELTA_NMR

Field strength = 11.7473579[T] (500[MH
X_acq_duration = 1.726704[s]
X_domain = 13C
X_freq = 76529768[MHz]
X_offset = 100[ppm]
X_points = 65536
X_prescans = 4
X_resolution = 0.57580336[Hz]
X_sweep = 37.73584906[MHz]
X_gain = 1.00000000
Irr_freq = 500.15991521[MHz]
Irr_offset = 5[ppm]
Mod_return = 1
Scans = 150

X_90_width = 14[us]
X_acq_time = 1.726704[s]
X_angle = 30[deg]
X_pulse = 4.66666667[us]
Initial_wait = 1[s]
Phase_preset = 2b[us]
Relaxation_delay = 4[s]
Temp_get = 24.4[dc]
Unblank_time = 2[us]

```

APPENDIX 6

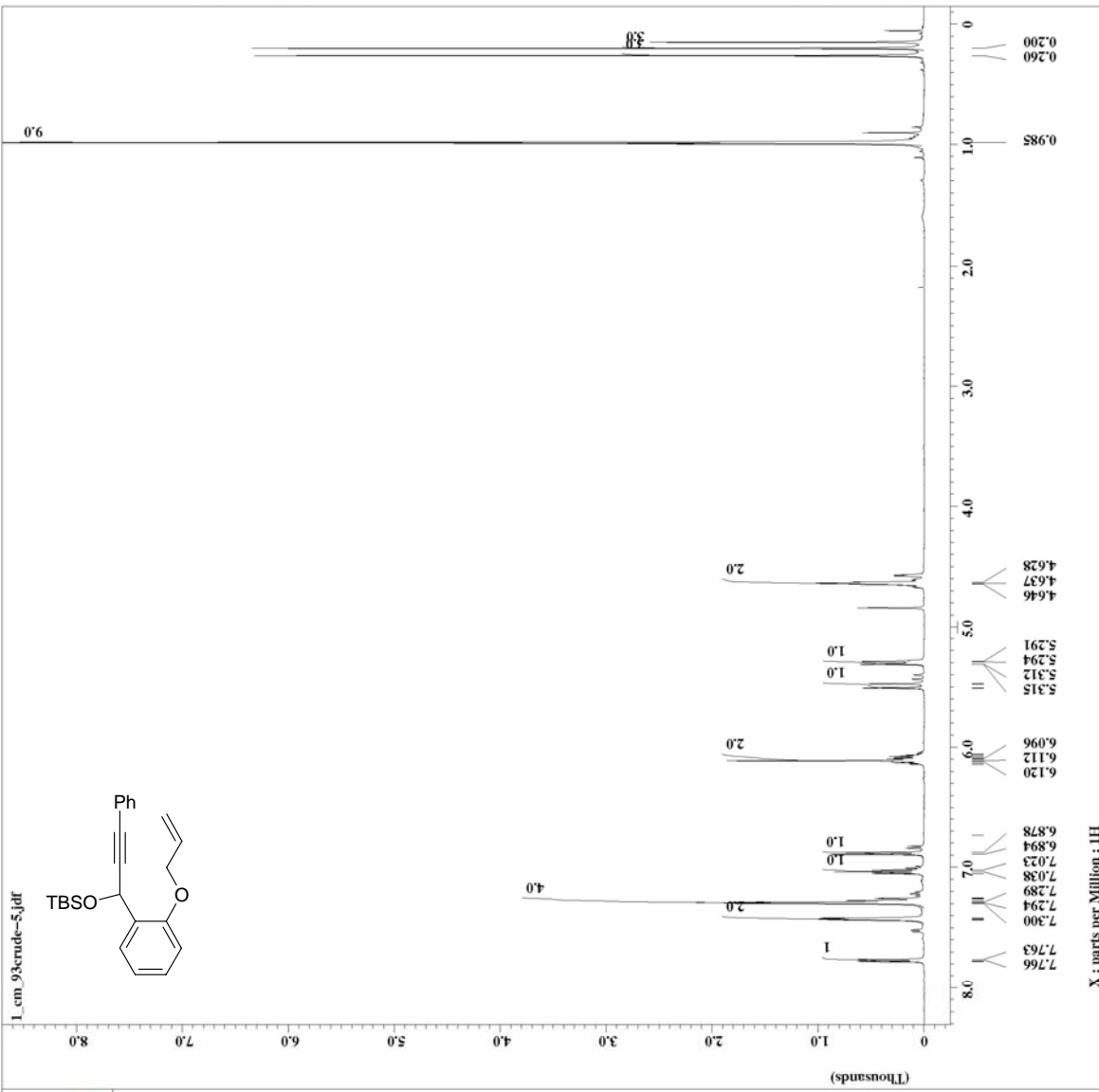
^1H and ^{13}C NMR SPECTRA OF

2-(-1-*tert*-butyl-dimethylsilyloxy -3-phenyl-2-propynyl)-(2-propenyloxy)benzene (9)



```

Filename = 1_cm_93crude-5.jdf
Experiment = single_pulse.exp
Sample_id = S#261824
Solvent = CHLOROFORM-D
Creation time = 6-OCT-2004 03:35:04
Revision time = 28-APR-2006 21:10:18
Current time = 28-APR-2006 21:11:33
Content = Single Pulse Experiment
Data format = ID_COMPLEX
Data size = 16384
Dim title = 1H
Dim units = [ppm]
Dimensions = X
Site = Eclipse+ 500
Spectrometer = DELTA_NMR
Field strength = 11.7473579[T] (500[MH
X_acq duration = 1.1823488[s]
X_sweep = 1.1823488[s]
X_freq = 500.15991521[MHz]
X_offset = 5[ppm]
X_points = 16384
X_prescans = 0
X_resolution = 0.45822189[Hz]
X_sweep = 7.50750751[kHz]
Mod_return = 1
Scans = 32
X_90 width = 15[us]
X_acq time = 2.1823488[s]
X_angle = 45[deg]
X_pulse = 7.5[us]
Initial_wait = 1[s]
Phase preset = 3[us]
Recvr gain = 12
Relaxation_delay = 1[s]
Temp_get = 23.8[degC]
Unblank_time = 2[us]
  
```





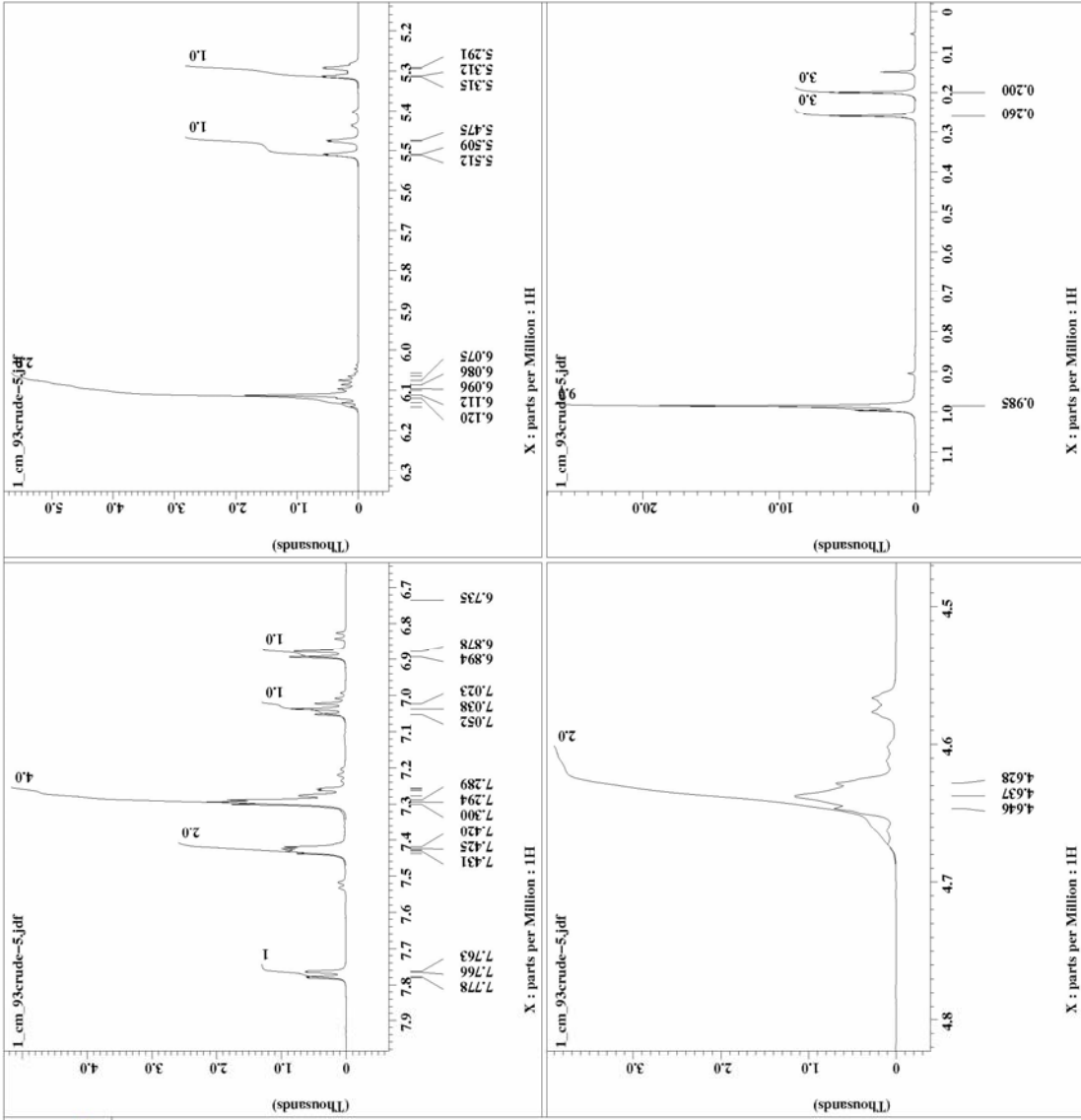
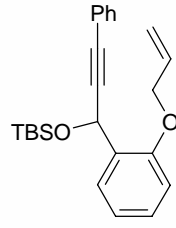
```

Filename = 1_cm_93crude-5.jdf
Experiment = single_pulse_exp
Sample_id = S#261824
Solvent = CHLOROFORM-D
Creation time = 6-OCT-2004 03:35:04
Revision time = 28-APR-2006 11:13:10
Current_time = 28-APR-2006 21:13:10

Content = Single Pulse Experiment
Data_format = ID COMPLEX
Dim_size = 16384
Dim_title = 1H
Dimensions = X
Site = Eclipse+ 500
Spectrometer = DELTA_NMR

Field_strength = 11.7473579[T] (500 [MH]
Freq_station = 2.1823488[s]
X_dwell = 1H
X_freq = 500.15991521 [MHz]
X_offset = 16384
X_points = 0
X_prescans = 0
X_resolution = 7.45920189 [Hz]
X_resolution = 7.80750751 [kHz]
Mod_return = 32
Scans = 15

X_90_width = 15 [us]
X_acq_time = 2.1823488 [s]
X_pulse = 7.5 [us]
X_pulse = 7.5 [us]
Initial_wait = 1 [s]
Phase_preset = 3 [us]
Recvr_gain = 12
Relaxation_delay = 1 [s]
Temp_get = 33.8 [dc]
Unblank_time = 2 [us]
  
```





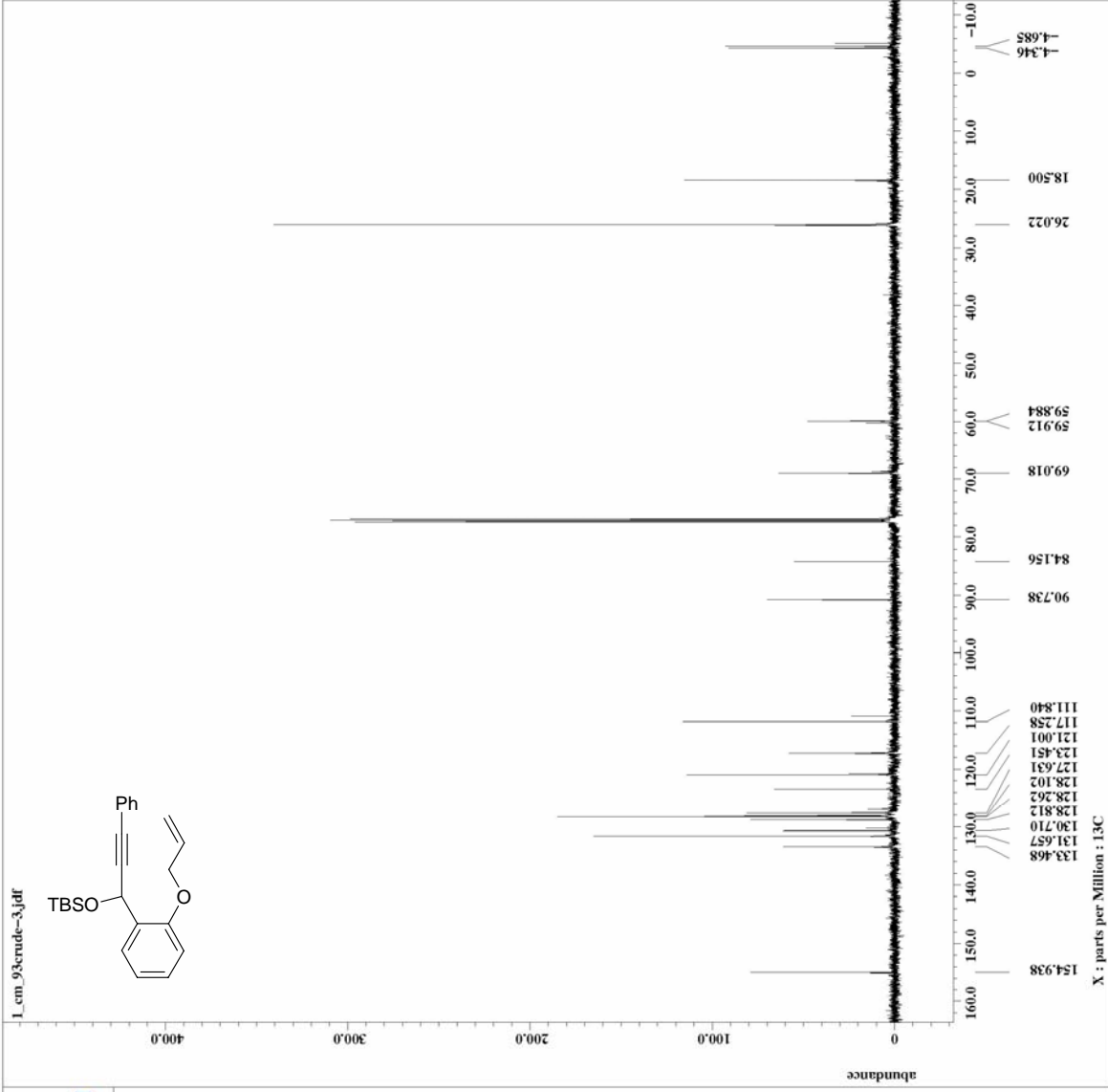
```

File Name      = l_cm_93crude-3.jdf
Experiment     = single_pulse_dec
Sample_id      = S263417
Solvent        = CDCl3
Chemical Shift = 6-CGT-2004 03:55:16
Revision time  = 28-APR-2006 21:16:48
Current_time   = 28-APR-2006 21:18:09

Content        = Single Pulse with Bro
Data_format    = 1D COMPLEX
Dim_size       = 65536
Dim_title      = 13C
Dim_units       = X[ppm]
Dimensions     = X[ppm]
Site           = Eclipset 500
Spectrometer   = DELTA_NMR

Field strength = 11.7473579[T] (500[MH
X_acq_duration = 1.736704[s]
X_domain       = 13C
X_freq         = 125.76529768[MHz]
X_offset       = 100[ppm]
X_points       = 4
X_resolution   = 0.57580336[KHz]
X_sweep        = 37.73584906[KHz]
Irr_domain     = 1H
Irr_freq       = 500.15991521[MHz]
Irr_offset     = 5[ppm]
Mod_return     = 1
Scans          = 202

X_90_width    = 14[us]
X_acq_time     = 1.736704[s]
X_angle        = 30[deg]
X_pulse        = 4.66666667[us]
Initial_wait   = 1[s]
Phase_preset   = 3[us]
Recvr_gain     = 15
Relaxation_delay = 4[s]
Temp_get       = 24.6[dc]
Ombiank_time   = 2[us]
  
```

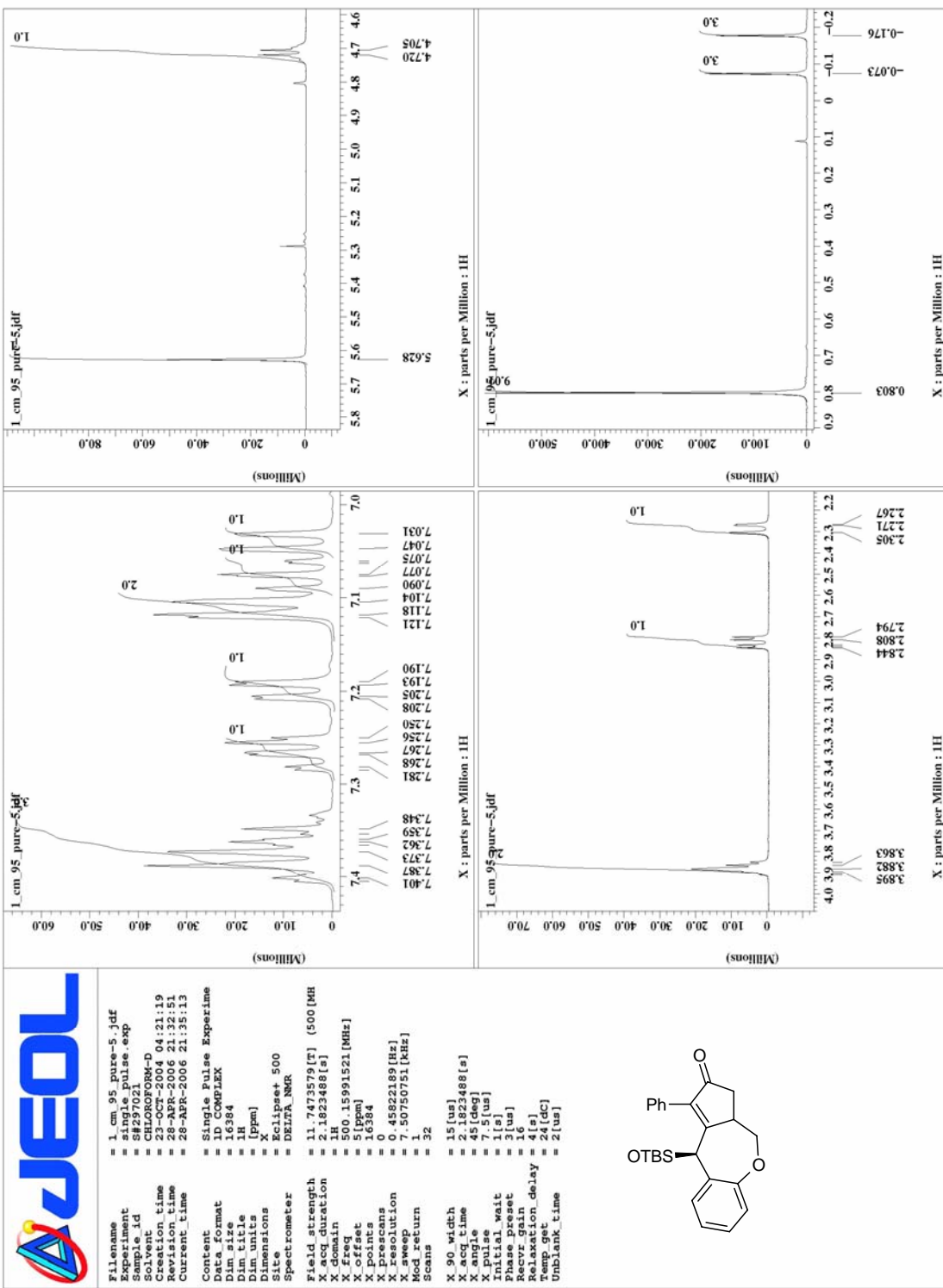


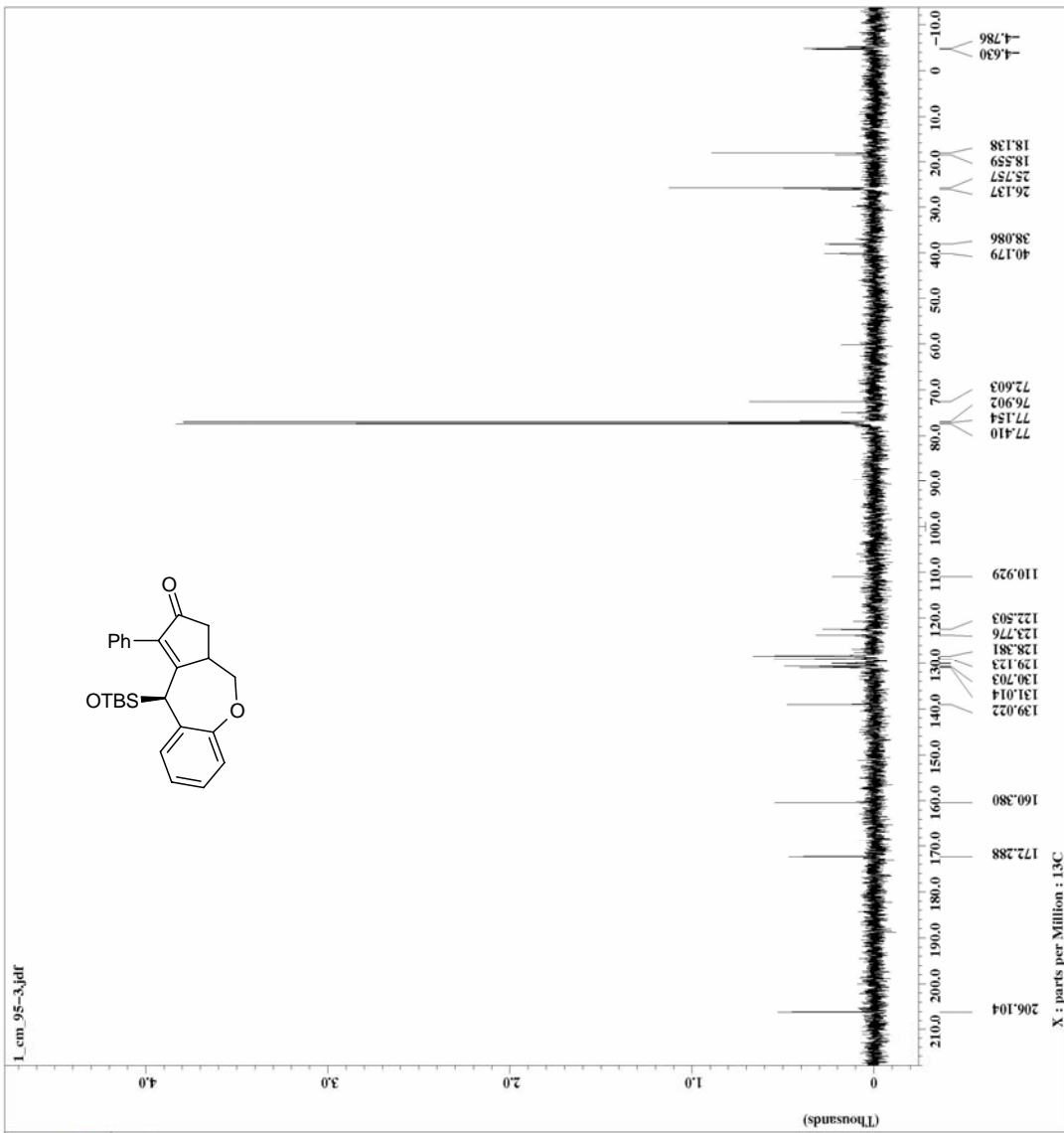
APPENDIX 7

¹H and ¹³C NMR SPECTRA OF

10-*t*-butyldimethylsilyloxy-1-phenyl-4,4a-dihydro-

3*H*,10*H*-5-oxabenzof]azulen-2-one (10)





1_cm_95-3.jdf

JEOL

```

Filename = 1_cm_95-3.jdf
Experiment = single_pulse_dec
Sample_id = S#126831
Date_UTC = 2006-04-28 00:00:25
Time = 12-0CT-2006
Revision_time = 28-APR-2006 21:38:23
Current_time = 28-APR-2006 21:39:47

Content = Single Pulse with Bro
Dim_format = DEPTX
Dim_size = 65536
Dim_title = 13C
Dim_units = [ppm]
Dimensions = X
Site = Eclipse 500
Spectrometer = DEIRA_NMR

Field_strength = 11.7473579[T] (500[MH
X_acq_duration = 1.736704[s]
X_domain = 13C
X_freq = 125.76529768[MHz]
X_offset = 0.00000000[ppm]
X_points = 65536
X_prescans = 4
X_resolution = 0.57580336[Hz]
X_sweep = 37.73584906[kHz]
Irr_domain = 13C
Irr_offset = 500.15991521[MHz]
Mod_return = 1
Scans = 55

X_90_width = 14[us]
X_acq_time = 1.736704[s]
X_angle = 30[deg]
X_pulse = 4.66666667[us]
Initial_wait = 1[s]
Phase_preset = 2[us]
Relaxation_delay = 4[s]
Temp_get = 24.4[dc]
Unblank_time = 2[us]

```

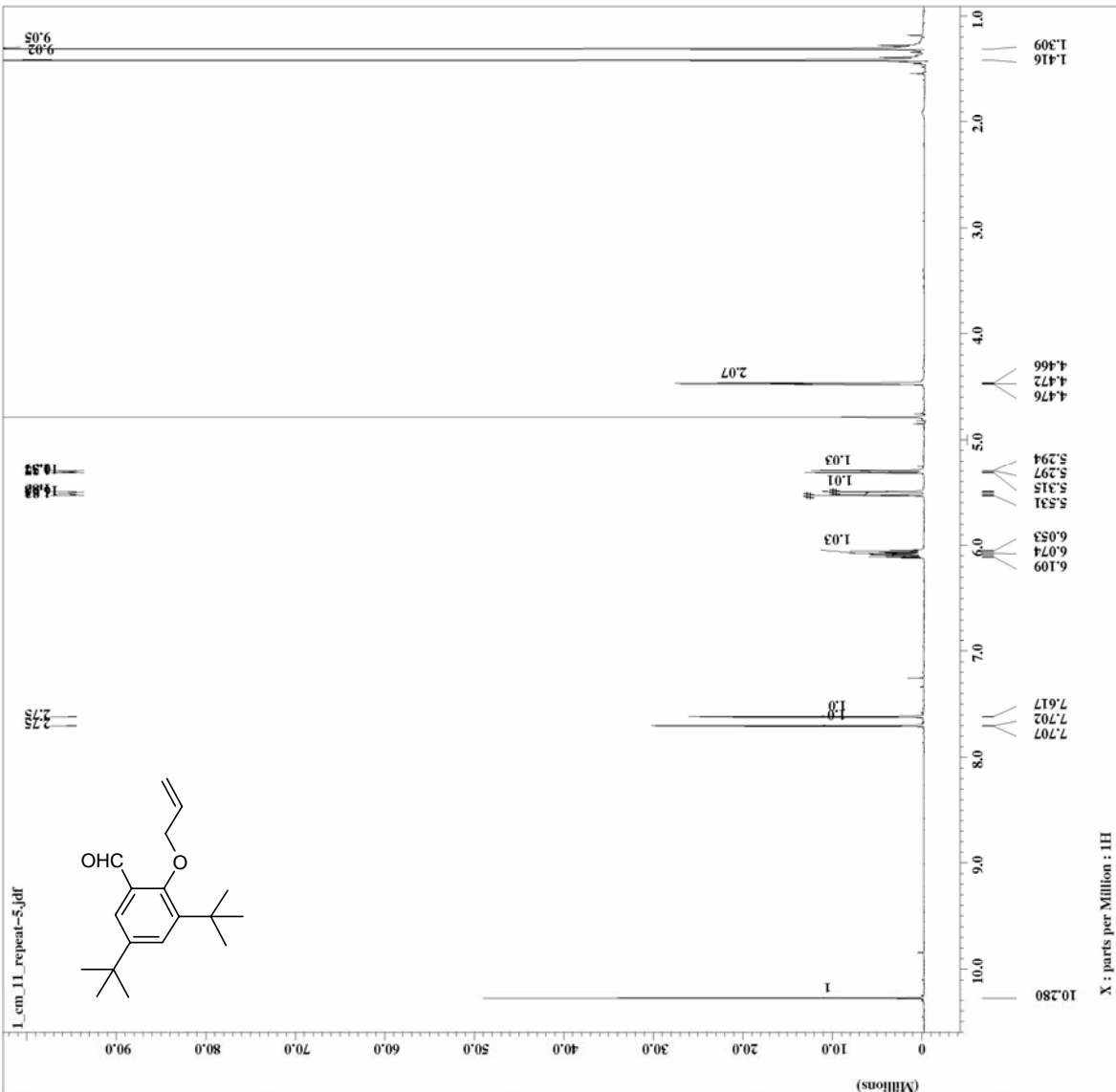
APPENDIX 8

¹H and ¹³C NMR SPECTRA OF

3,5-Di-*tert*-butyl-2-(-2-propenyloxy)benzaldehyde (12)



File name = 1_cm_11_repeat-5.jdf
Experiment = single_pulse.exp
Sample ID = S845356
Solvent = CHLOROFORM-D
Acquisition time = 2006 APR 28 12:01:32
Resolution time = 28-APR-2006 21:55:56
Current time = 28-APR-2006 21:56:20
Content = Single Pulse Experiment
Data format = 1D COMPLEX
Data size = 16384
Dim title = 1H
Dim units = [ppm]
Dimensions = X
Site = Kilisbet 500
Spectrometer = DELTA_NMR
Field strength = 11.7473579 [T] (500 [MH]
X acq duration = 2.1823488 [s]
X domain = 1H
X freq = 500.15991521 [MHz]
X offset = 16384
X points = 0
X prescans = 0
X resolution = 45822189 [Hz]
X resolution = 7.50750751 [kHz]
Mod return = 1
Scans = 22
X 90 width = 15 [us]
X acq time = 2.1823488 [s]
X angle = 45 [deg]
X pulse = 7.5 [us]
Initial wait = 1 [s]
Pulse preset = 8 [us]
Relaxation delay = 4 [s]
Temp get = 23.4 [dC]
Unblank time = 2 [us]





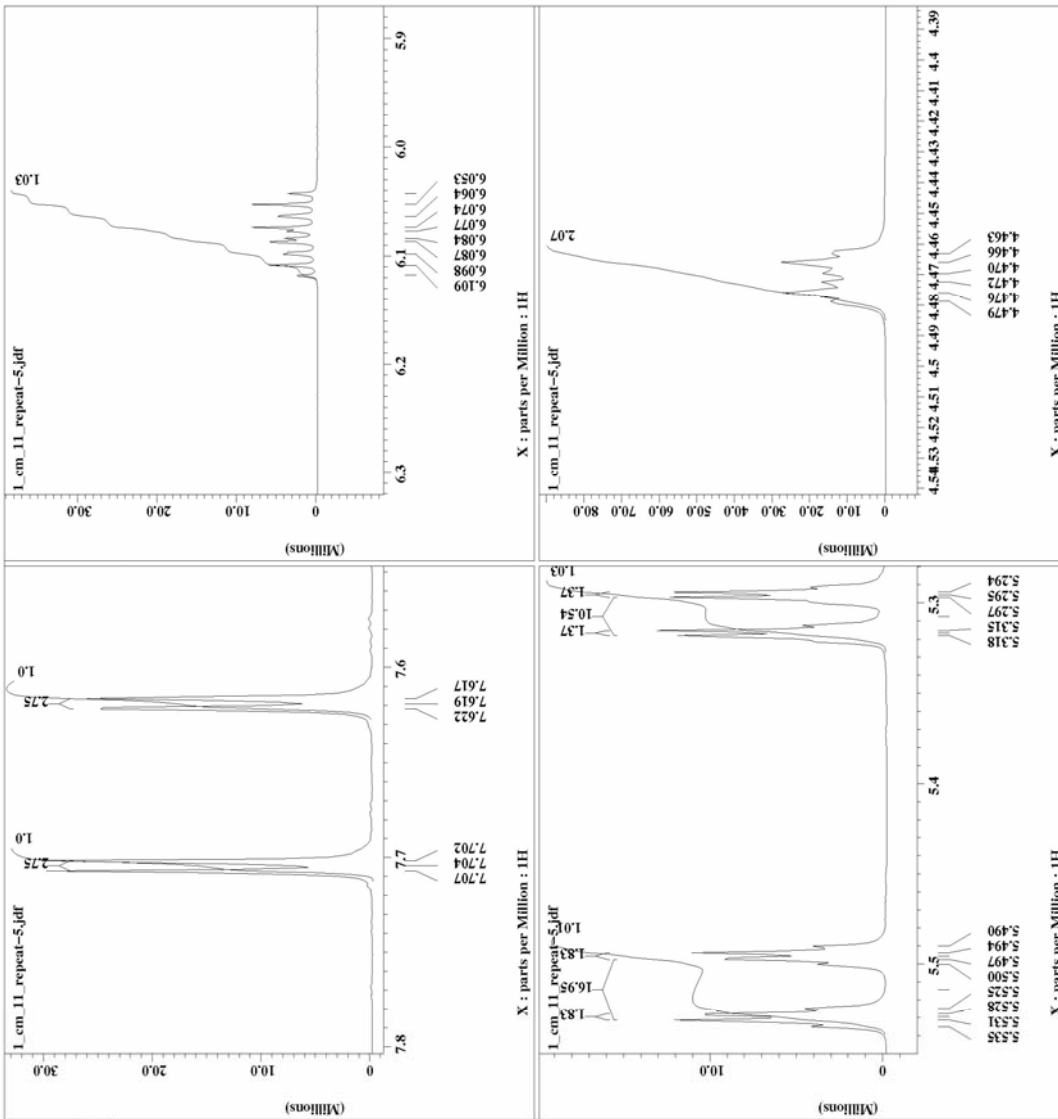
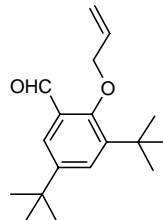
```

Filename = 1_cm_11_repeat-5_jdf
Experiment = single_pulse_exp
Sample Id = S8453584-D
Date_ = 06-APR-2006 08:00
Creation time = 3-APR-2004 12:01:32
Revision time = 28-APR-2006 21:58:37
Current time = 28-APR-2006 21:59:00

Content =
Data format = 1D_COMPLEX
Dim size = 16384
Dim title = 1H
Dim units = [ppm]
Dimensions = X
Scales = 1
Spectrometer = DELTA_NMR

Field strength = 11.747375[T] (500 MH
X_acq duration = 2.1823488[s]
X_domain = 500.15991521[MHz]
X_offset = 5[ppm]
X_points = 16384
X_prescans = 0
X_resolution = 0.45922189[Hz]
X_sweep = 1.50750751[MHz]
Mod return = 1
Scans = 22

X_90_width = 15[us]
X_acq time = 45[us]
X_pulse = 7.5[us]
Initial wait = 1[s]
Phase preset = 3[us]
Recvr gain = 8
Relaxation delay = 23.4[dc]
Temp set time = 2[us]
Unblank_time = 2[us]
  
```



JEOL

```

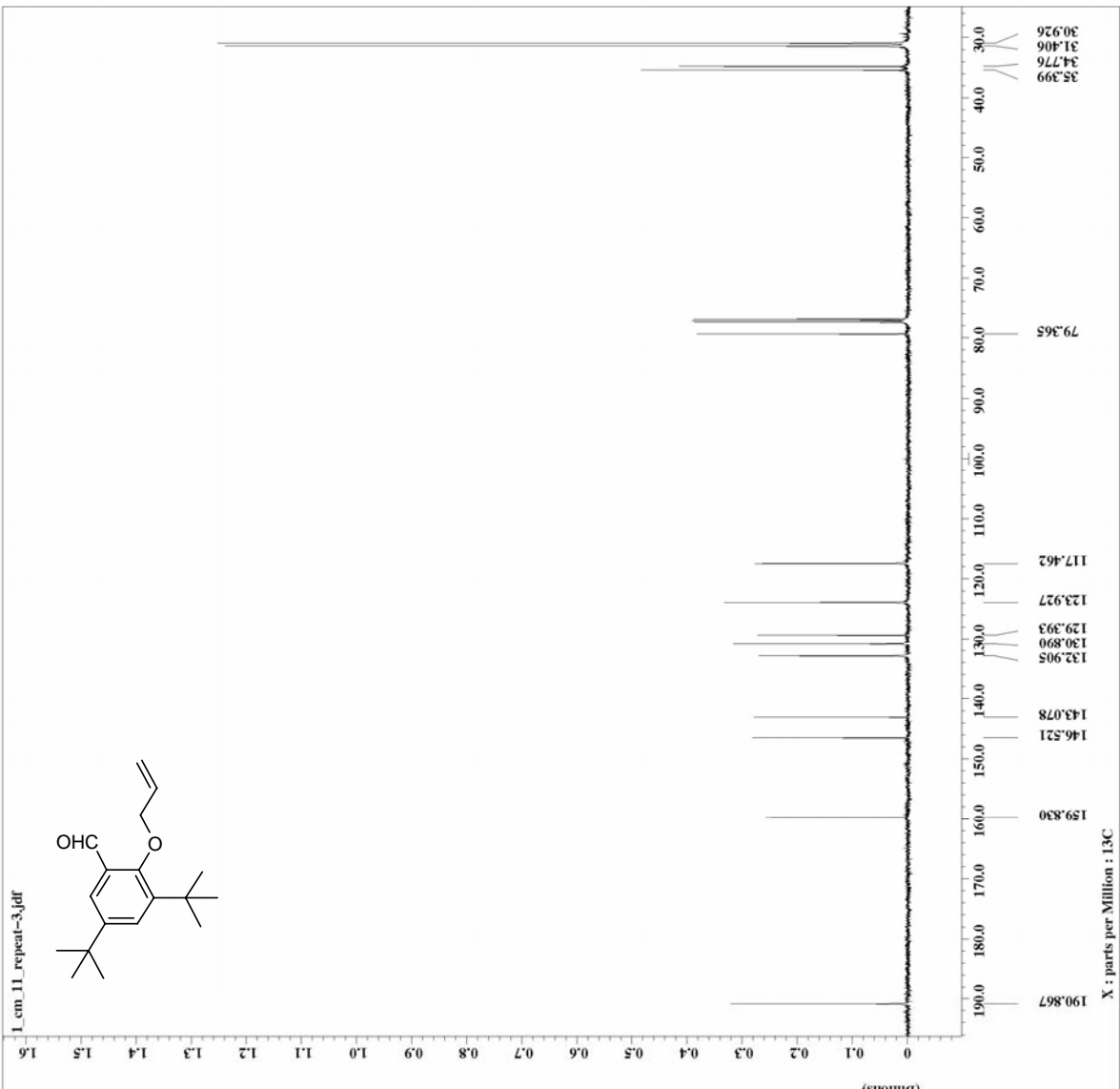
File name      = 1_cm_11_repeat-3_jdf
Experiment    = single_pulse_dec
Sample id     = S#84909
Solvent       = CHLOROFORM-D
Creation time  = 3-APR-2004 12:17:39
Revision time  = 28-APR-2006 21:59:56
Current time   = 28-APR-2006 22:00:25

Content       = Single Pulse with Bro
Date format   = COMPLEX
Data file     = 68536
Dim title     = 13C
Dim units     = [ppm]
Dimensions    = X
Site          = Eclipse+ 500
Spectrometer = DELTA_NMR

Field strength = 11.7473579[T] (500 [MH
X_acq_duration = 1.736704[s]
X_domain       = 13C 76529768 [MHz]
X_freq         = 100.628150 [ppm]
X_points       = 68536
X_prescans     = 4
X_resolution   = 0.57580336 [Hz]
X_sweep        = 37.73584906 [kHz]
Irr_domain     = 1H
Irr_freq       = 500.15991521 [MHz]
Irr_offset     = 5 [ppm]
Mod_return     = 1
Scans          = 105

X_90_width    = 14 [us]
X_acq_time     = 1.736704 [s]
X_angle        = 30 [deg]
X_pulse        = 4.66666667 [us]
Initial_wait   = 1 [s]
Phase_preset   = 3 [us]
Recvr_gain     = 28
Relaxation_delay = 4 [s]
Temp_get       = 24.1 [dC]
Unblank_time   = 2 [us]

```



APPENDIX 9

^1H and ^{13}C NMR SPECTRA OF

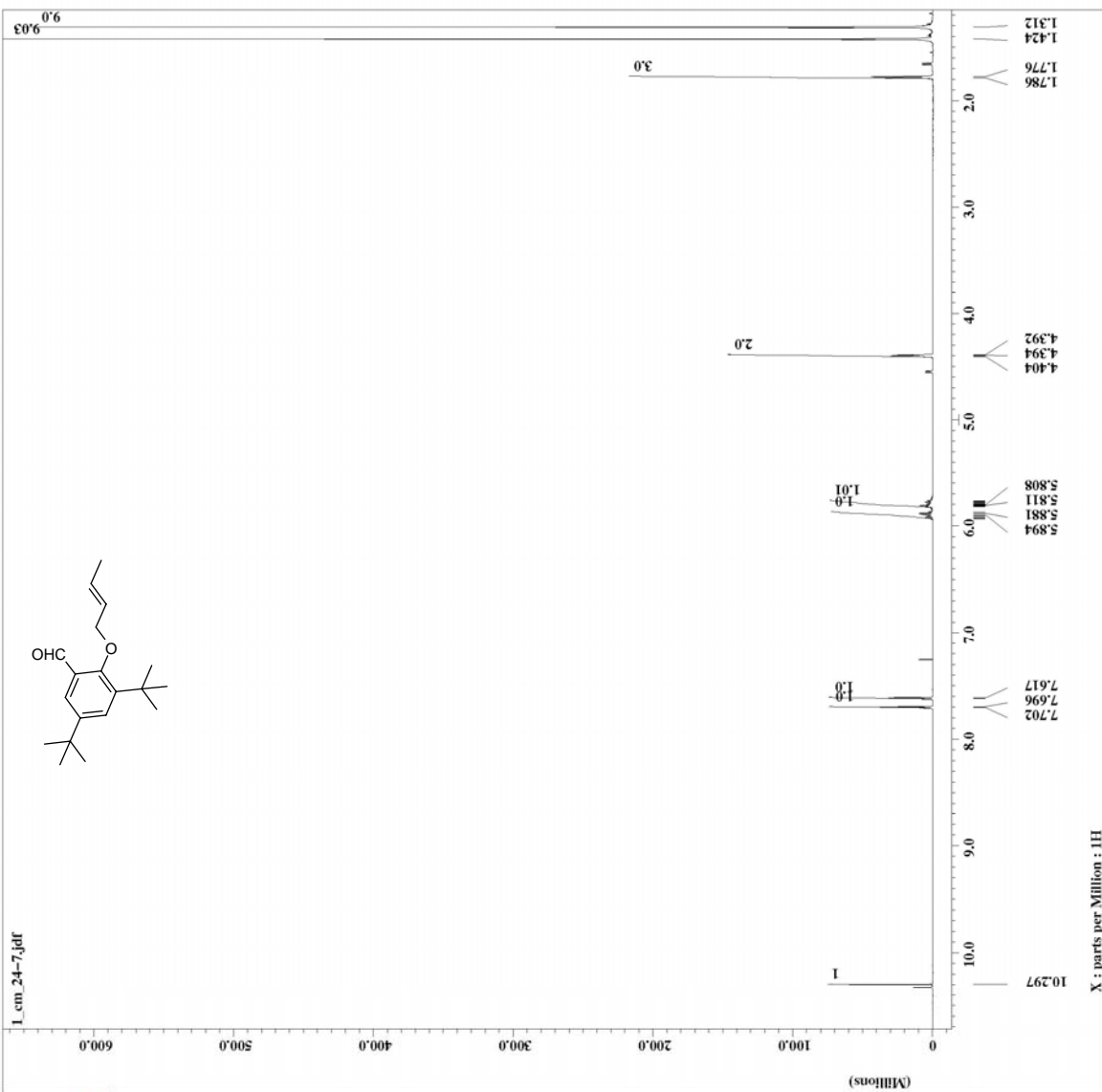
3,5-Di-*tert*-butyl-2-(3-methyl-2-propenyloxy) benzaldehyde (14)

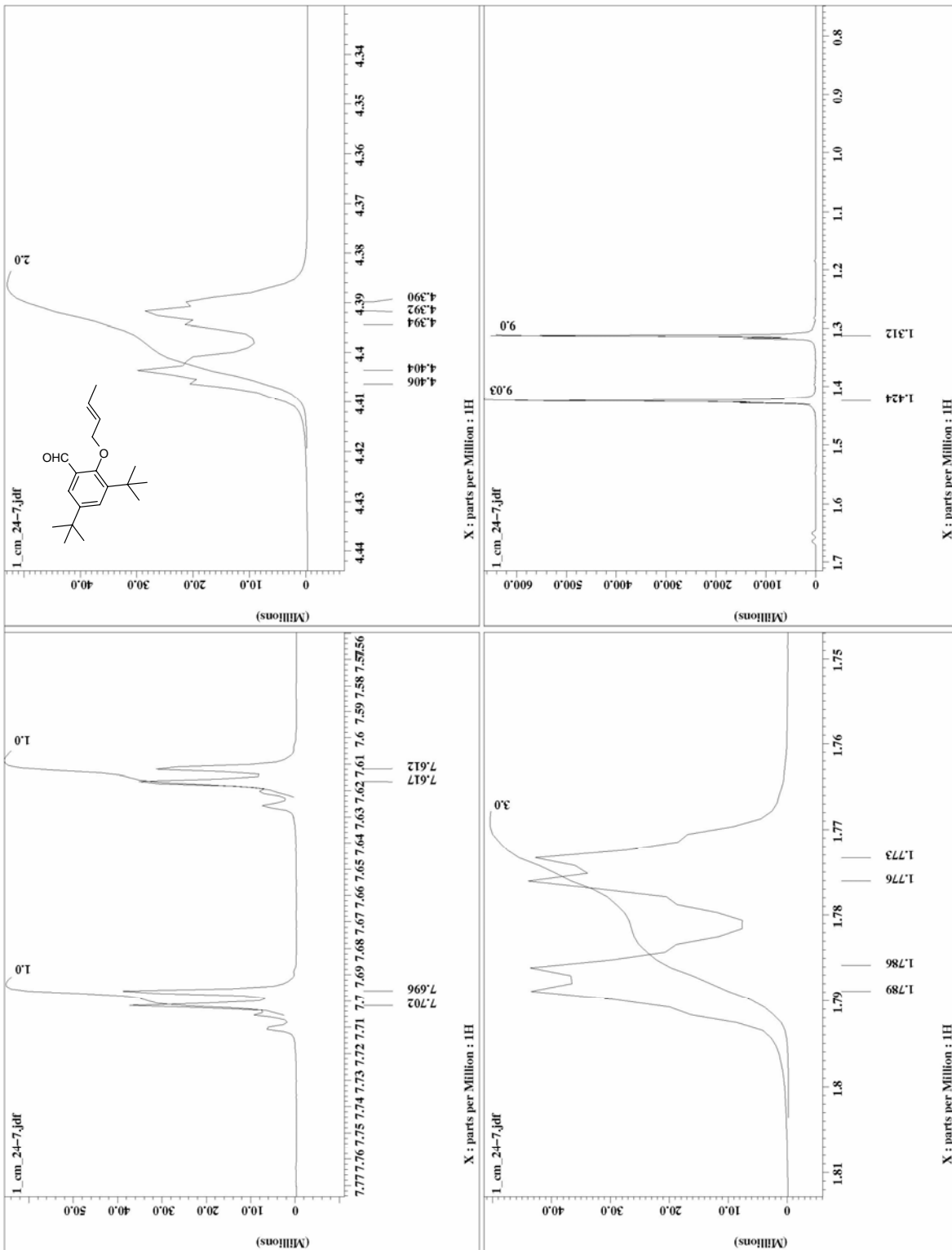


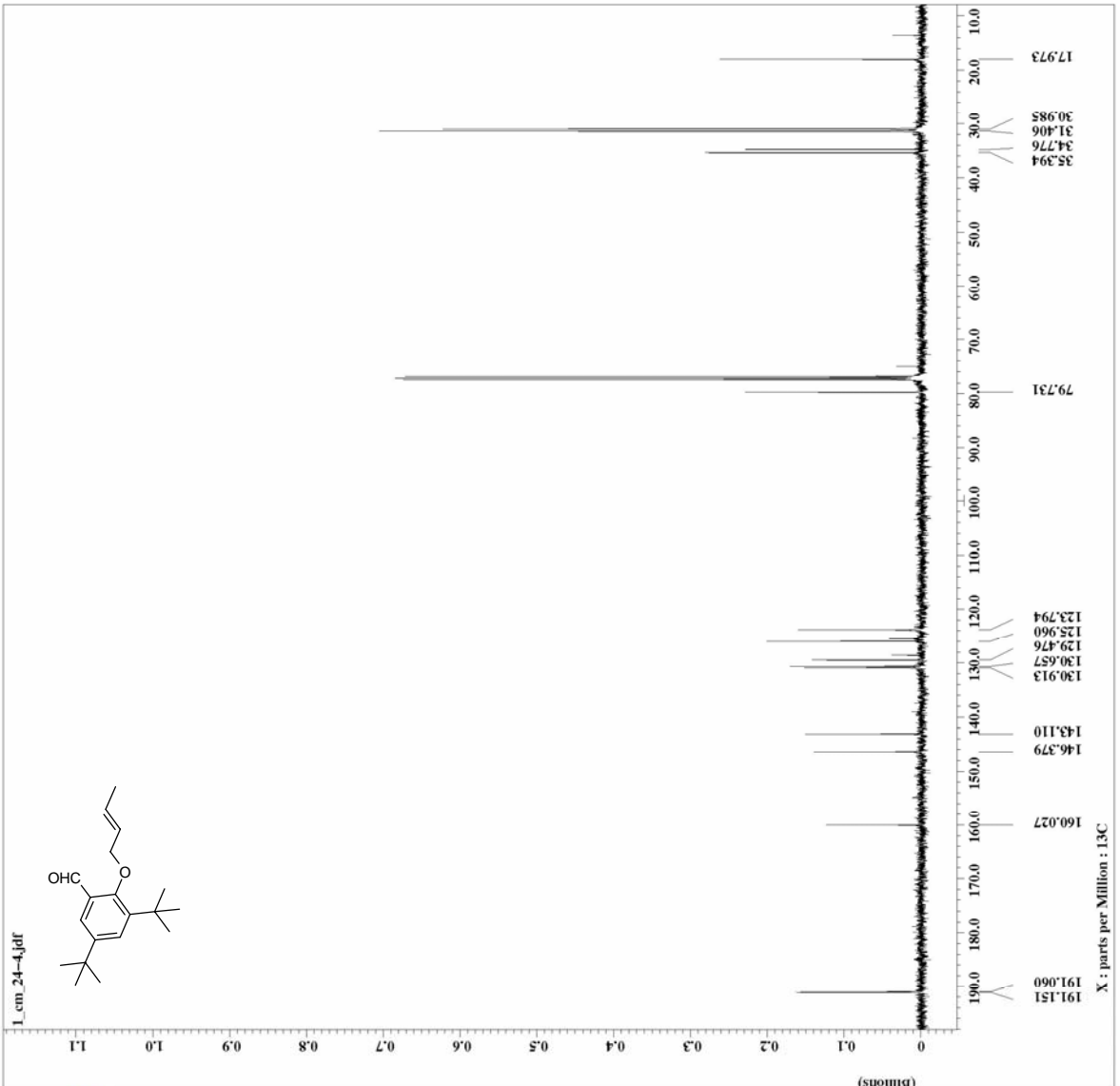
```

Filename = 1_cm_24-7_jdf
Experiment = single_pulse_exp
Sample_id = S#836794
Solvent = CHLOROFORM-D
Creation_time = 31-MAY-2004 19:28:56
Revision_time = 4-MAY-2006 18:46:21
Current_time = 4-MAY-2006 18:46:50
Content = Single Pulse Experime
Data_format = ID_COMPLEX
Data_size = 16384
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Site = Eclipse+ 500
Spectrometer = DELTA_NMR
Field_strength = 11.7473578[T] (500[MH
X_acq_duration = 2.1823488[s]
X_domain = 1H
X_freq = 500.15991521[MHz]
X_offset = 5[ppm]
X_points = 16384
X_prescans = 0
X_resolution = 0.45822189[Hz]
X_sweep = 7.50750751[KHz]
Sof_return = 32
Scans = 32
X_90_width = 15[us]
X_acq_time = 2.1823488[s]
X_angle = 45[deg]
X_pulse = 7.5[us]
Initial_wait = 1[s]
Phase_preset = 3[us]
Refvz_gain = 42
Relaxation_delay = 4[s]
Temp_set = 23.7[dc]
Unblank_time = 2[us]

```







```

Filename = 1_cm_24-4_jdf
Experiment = single_pulse_dec
Sample_id = S839499
Solvent = CHLOROFORM-D
Acq_date_time = 21-MAY-2006 19:45:23
Exp_date_time = 4-MAY-2006 18:40:45
Current_time = 4-MAY-2006 18:51:06

Content = Single Pulse with Bro
Data_format = ID COMPLEX
Dim_size = 65536
Dim_title = 13C
Dim_units = [ppm]
Dimensions = X
Site = Reimsat_500
Spectrometer = DELTA_NMR

Field_strength = 11.7473579 [T] (500 [MH]
X_acq_duration = 1.736704 [s]
X_domain = 13C
X_freq = 125.76529768 [MHz]
X_offset = 100 [ppm]
X_points = 65536
X_prescans = 4
X_resolution = 97580336 [Hz]
X_sweep = 11.73584906 [kHz]
Irr_domain = 1H
Irr_freq = 500.15991521 [MHz]
Irr_offset = 5 [ppm]
Mod_return = 1
Scans = 149

X_90_width = 14 [us]
X_acq_time = 1.736704 [s]
X_angle = 30 [deg]
X_pulprg = zgpg30
Initial_wait = 1 [s]
Phase_preset = 3 [us]
Recvr_gain = 29
Relaxation_delay = 4 [s]
Temp_get = 24.4 [dC]
Unblank_time = 2 [us]

```

APPENDIX 10

^1H and ^{13}C NMR SPECTRA OF

4,6-Di-*tert*-butyl-2-(1-hydroxy-2-propynyl)-(2-propenyloxy)benzene (15c)



```

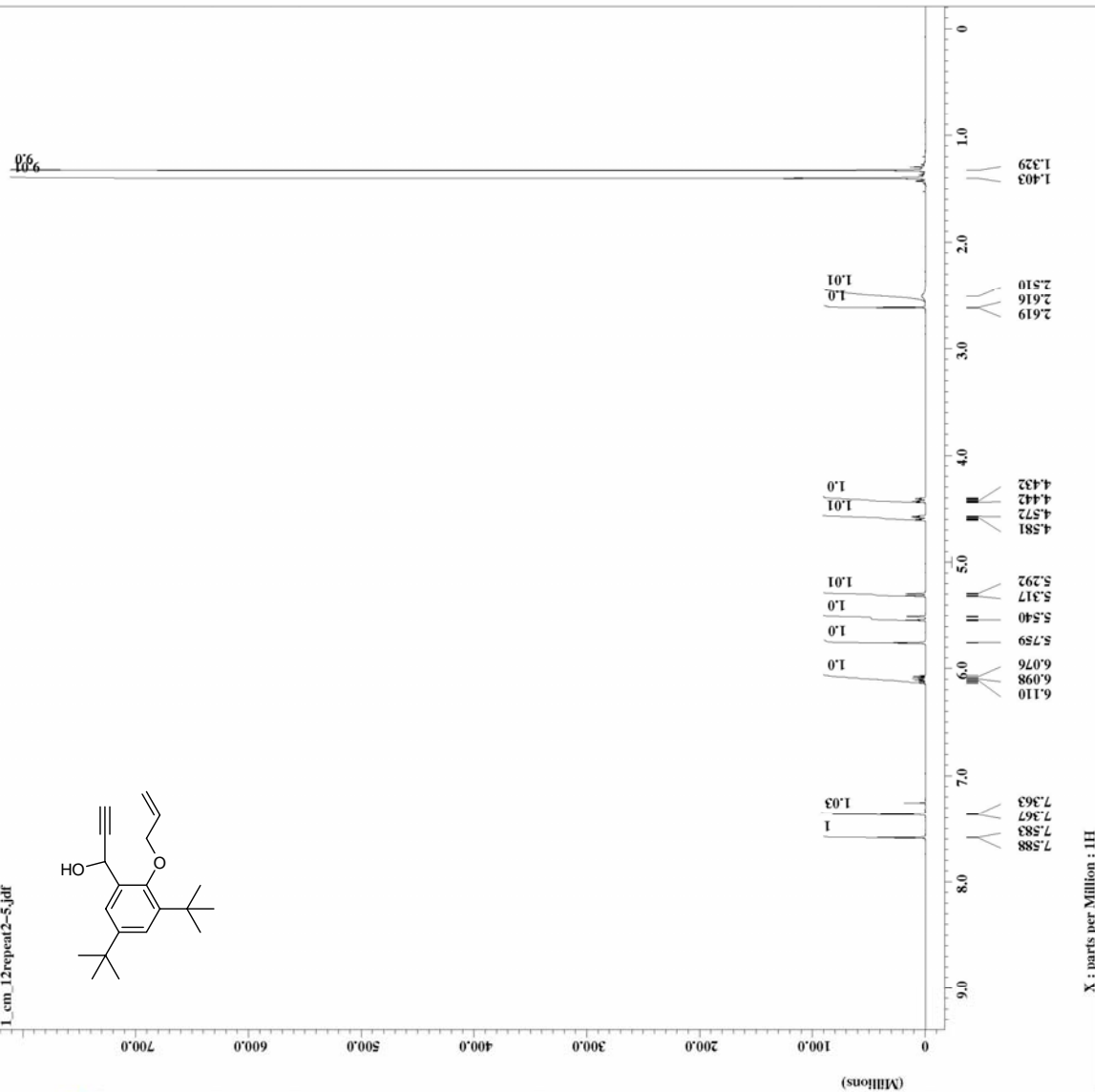
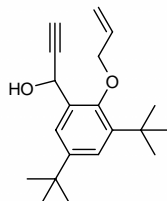
Filename = 1_cm_12repeat2-5.jdf
Experiment = single_pulse_exp
Sample_id = SF811961
Solvent = CDCl3
Acq_date_time = 2006-05-04 13:22:39
Revision_time = 4-MAY-2006 19:43:50
Current_time = 4-MAY-2006 19:44:32

Content = Single Pulse Experi
Data_format = 1D COMPLEX
Dim_size = 16384
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Spectrometer = Xolipse+ 500
Pulse_program = DELTA_NMR

Field_strength = 11.7473579[T] (500[MH
X_acq_duration = 2.1823488[s]
X_domain = 1H
X_freq = 500.15991521[MHz]
X_offset = 5[ppm]
X_points = 16384
X_resolution = 0.45822189[Hz]
X_sweep = 7.50750751[kHz]
Mod_return = 1
Scans = 32

X_90_width = 15[us]
X_acq_time = 2.1823488[s]
X_angle = 45[deg]
X_pulse = 175[us]
X_pulse_wait = 3[us]
Phase_Preset = 3[us]
Recvr_Gain = 14
Relaxation_delay = 4[s]
Temp_get = 23.7[degC]
Unblank_time = 2[us]
  
```

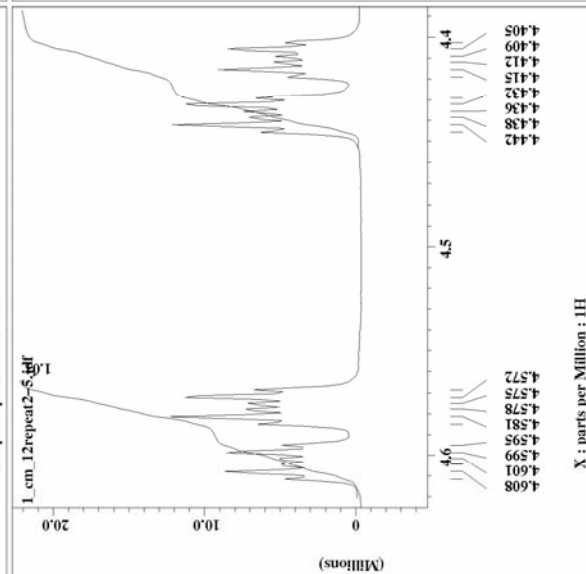
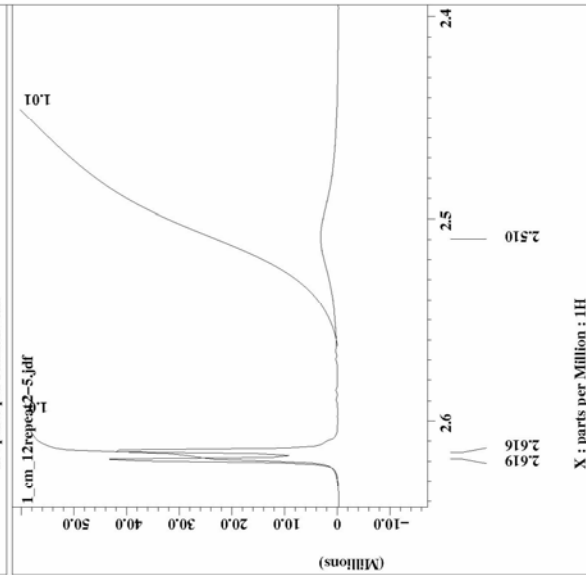
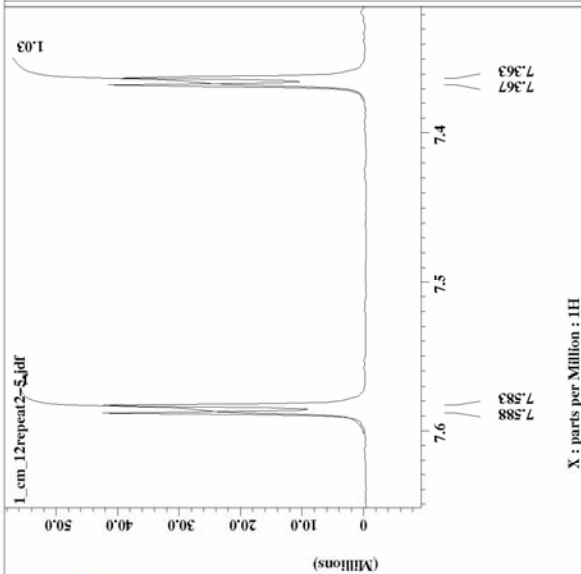
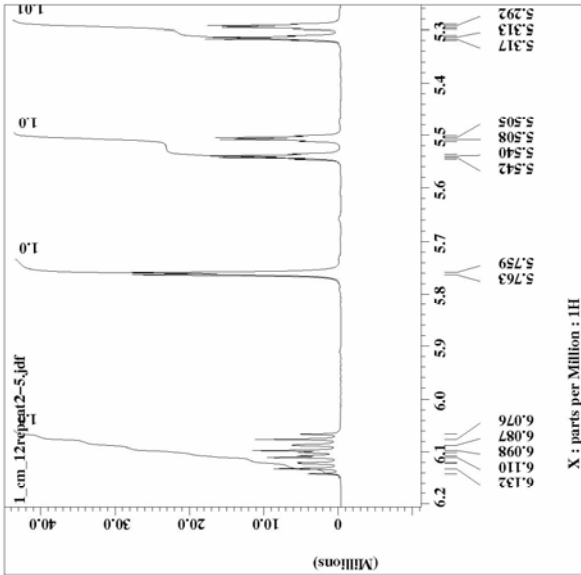
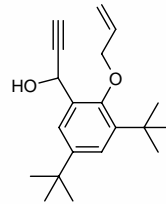
1_cm_12repeat2-5.jdf

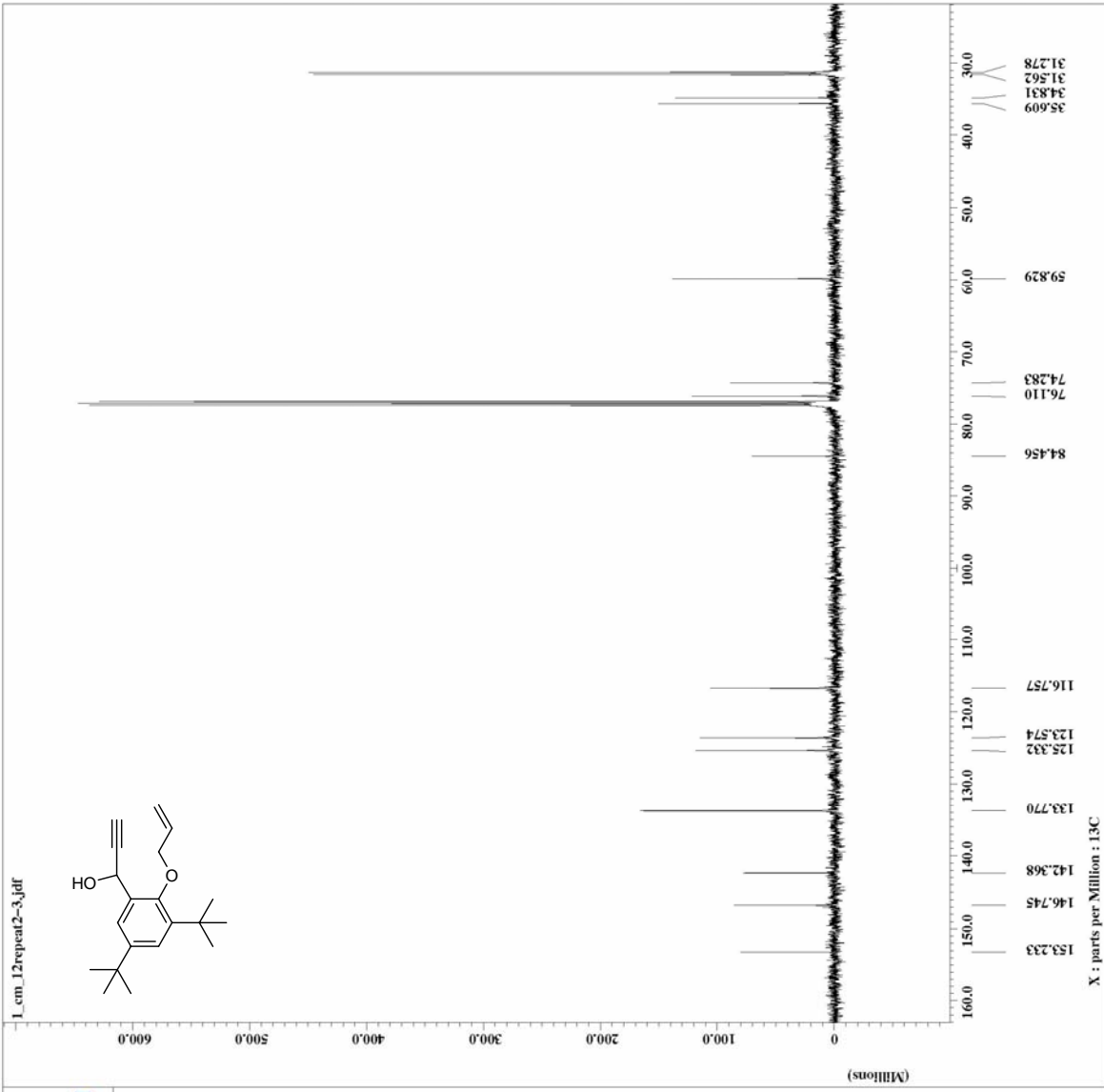




```

Filename = 1_cm_12repeat2-5_jdf
Experiment = single_pulse_exp
Sample_id = S811961
Solvent = CHLOROFORM-D
Creation_time = 28-APR-2004 13:22:39
Revision_time = 4-MAY-2006 19:43:50
Current_time = 4-MAY-2006 19:45:50
Content = Single_Pulse_Expetime
Dirname = 16384MPLEX
Date_acq = 16384
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Site = Eclipse+ 500
Spectrometer = DELTA_NMR
Field_strength = 11.7473579[T] (500[MH]
X_acq_duration = 2.1823488[s]
X_f0_mhz = 500.15991521[MHz]
X_offset = 5[ppm]
X_points = 16384
X_prescans = 0
X_resolution = 0.45822189[Hz]
X_sweep = 7.50750751[kHz]
Mod_return = 1
Scans = 32
X_90_width = 15[us]
X_acq_time = 2.1823488[s]
X_angle = 45[deg]
X_pulse = 7.5[us]
Initial_wait = 1[s]
Phase_preset = 3[us]
Recvr_gain = 14
Relaxation_delay = 4[s]
Temp_get = 23.7[dc]
Unblank_time = 2[us]
  
```





```

Filename = 1_cm_12repeat2-3.jdf
Experiment = single_pulse_dec
Sample_id = S815038
Solvent = CDCl3
Solvent_nm = 77.0
Acq_date = 28-APR-2004 13:40:53
Revision_time = 4-MAY-2006 19:46:27
Current_time = 4-MAY-2006 19:46:58

Content = Single Pulse with Bro
Data_format = ID COMPLEX
Dim_size = 65536
Dim_title = 13C
Dim_units = X[ppm]
Site_dimensions = Eclipset 500
Spectrometer = DELTA_NMR

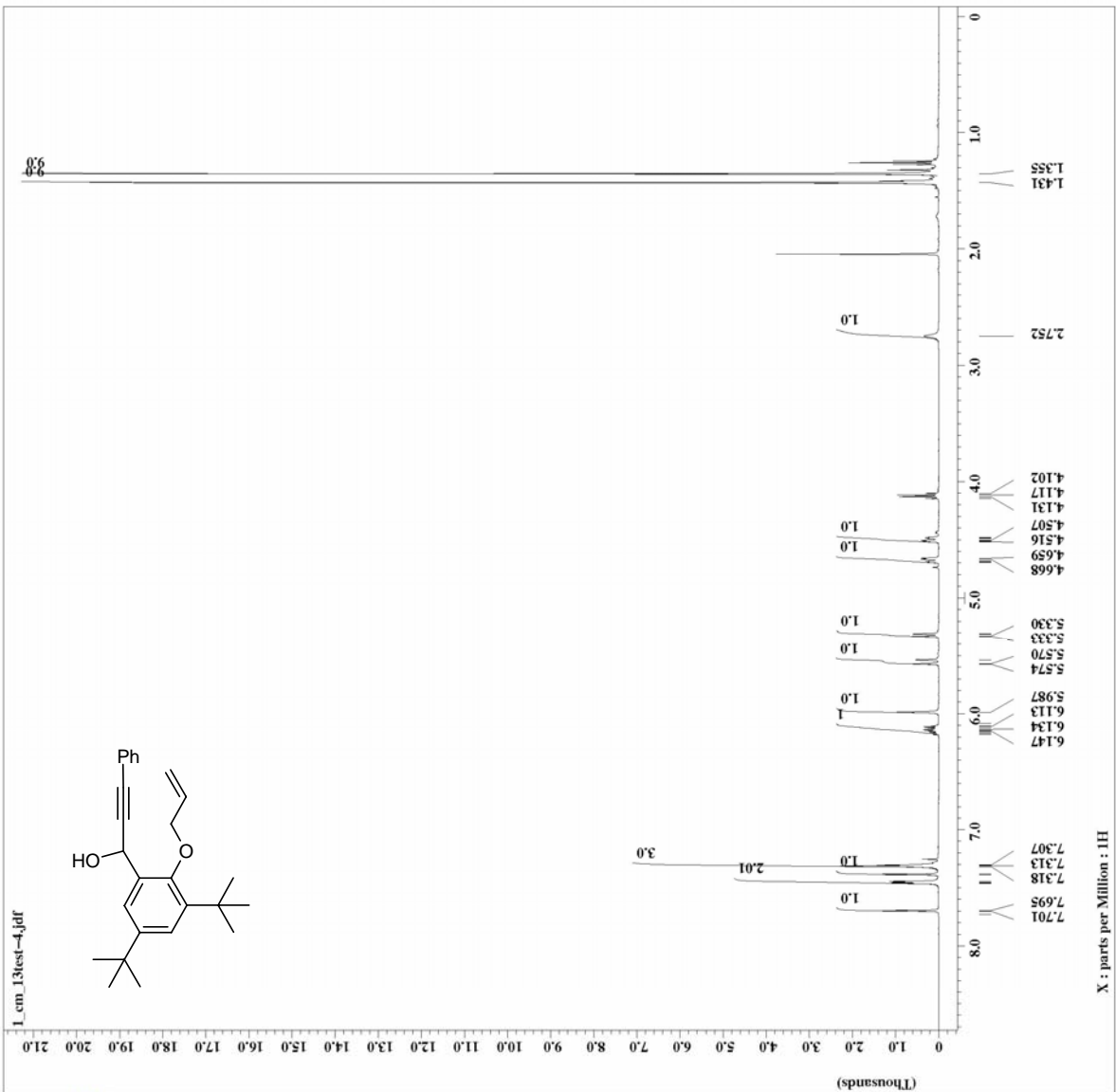
Field_strength = 11.7473579[T] (500 [MH
X_acq_duration = 1.736704[s]
X_domain = 13C
X_freq = 125.76529768 [MHz]
X_offset = 100 [ppm]
Points = 48536
Points_per_sweep = 4
X_resolution = 0.57580336 [Hz]
X_sweep = 37.73584906 [kHz]
Irr_domain = 1H
Irr_freq = 500.15991521 [MHz]
Irr_offset = 5 [ppm]
Mod_return = 1
Scans = 166

X_90_width = 14 [us]
X_acq_time = 1.736704 [s]
X_angle = 30 [deg]
X_pulse = 4.66666667 [us]
Initial_wait = 1 [s]
Phase_preset = 3 [us]
Recvr_gain = 28
Relaxation_delay = 4 [s]
Temp_get = 24.3 [dc]
Ombiack_time = 2 [us]
  
```

APPENDIX 11

¹H and ¹³C NMR SPECTRA OF

4,6-Di-*tert*-butyl-2-(1-hydroxy-3-phenyl-2-propynyl)-2-propenyloxybenzene (15b)



```

File name      = 1_cm_13test-4_jdf
Experiment     = single_pulse_exp
Sample ID     = S#157176
Solvent       = CHLOROFORM-D
Creation time  = 15-MAY-2004 18:03:21
Revision time  = 4-MAY-2006 19:59:42
Current time   = 4-MAY-2006 19:59:42

Content       = Single Pulse Experiment
Data format  = 1D COMPLEX
Data size    = 16384
Dim size     = 1H
Dim title    = 1H
Dim units    = [ppm]
Dimensions   = X
Site         = Eclipse+ 500
Spectrometer = DELTA_NMR

Field strength = 11.7473579[T] (500 [MH]
X acq duration = 2.1823488[s]
X domain      = 1H
X freq        = 500.15991521 [MHz]
X offset      = 16384
X points      = 0
X prescans    = 0
X resolution  = 0.45822189 [Hz]
X sweep       = 1.50750751 [kHz]
X return      = 1
Scans         = 32

X 90 width    = 15 [us]
X acq time    = 2.1823488 [s]
X angle       = 45 [deg]
X pulse       = 7.5 [us]
Initial wait  = 1 [s]
Phase preset  = 3 [us]
Recvr gain    = 42
Relaxation delay = 23.4 [dc]
Sweep_start   = 0
Unblank_time  = 2 [us]
  
```



```

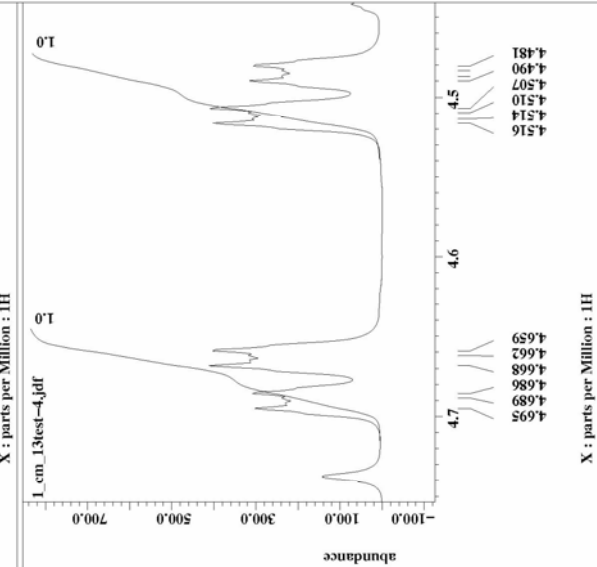
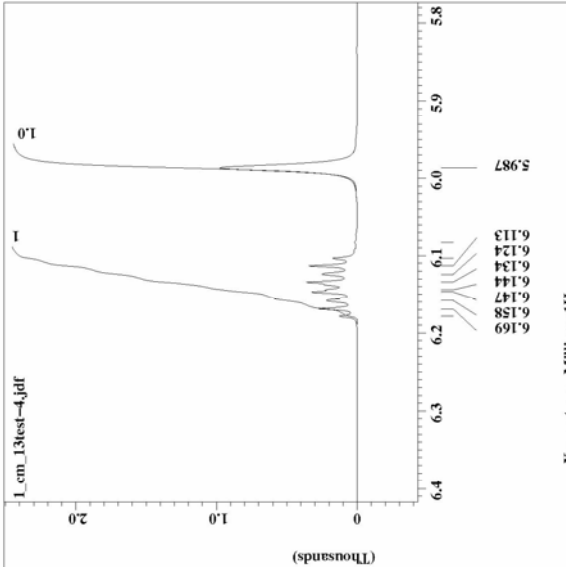
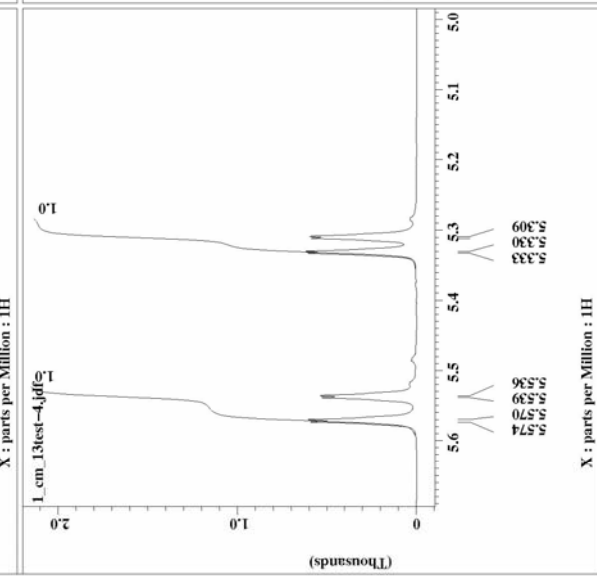
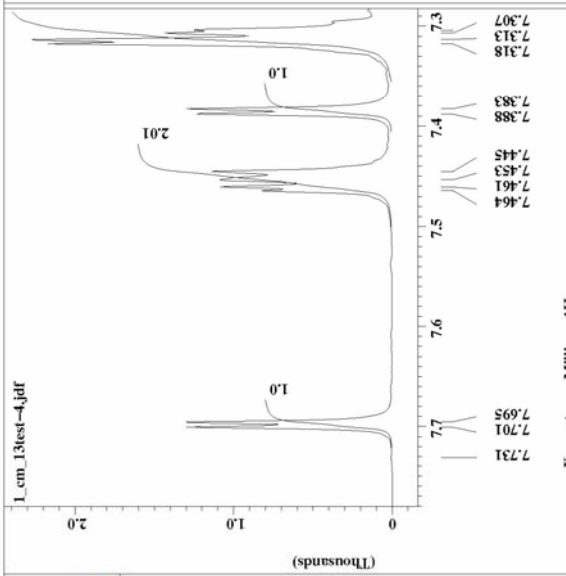
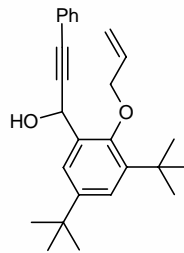
Filename = 1_cm_13test-4_jdf
Experiment = single_pulse_exp
Sample_id = SH157176
Operator = JMK-D
Acq date time = 12-APR-2004 18:03:21
Revision time = 4-MAY-2006 19:59:14
Current_time = 4-MAY-2006 20:00:52

Content = Single Pulse Experiment
Data_format = 1D COMPLEX
Dim_size = 16384
Dim_title = 1H
Dim_units = [ppm]
Dimensions =
Site = Eclipse+ 500
Spectrometer = DELTA_NMR

Field strength = 11.7473579[T] (500[MH]
X_acq duration = 2.1823488[s]
X_domain = 1H
X_freq = 500.15991521[Mhz]
X_offset = 5[ppm]
X_points = 6384
X_resolution = 0.45822189[Hz]
X_sweep = 7.50750751[kHz]
Mod return = 1
Scans = 32

X_90_width = 18[us]
X_acq time = 2.1823488[s]
X_angle = 9[deg]
X_pulse = 7[us]
Initial wait = 11[s]
Phase preset = 3[us]
Recvr gain = 12
Relaxation_delay = 4[s]
Temp_get = 22.4[degC]
Unblank_time = 2[us]

```





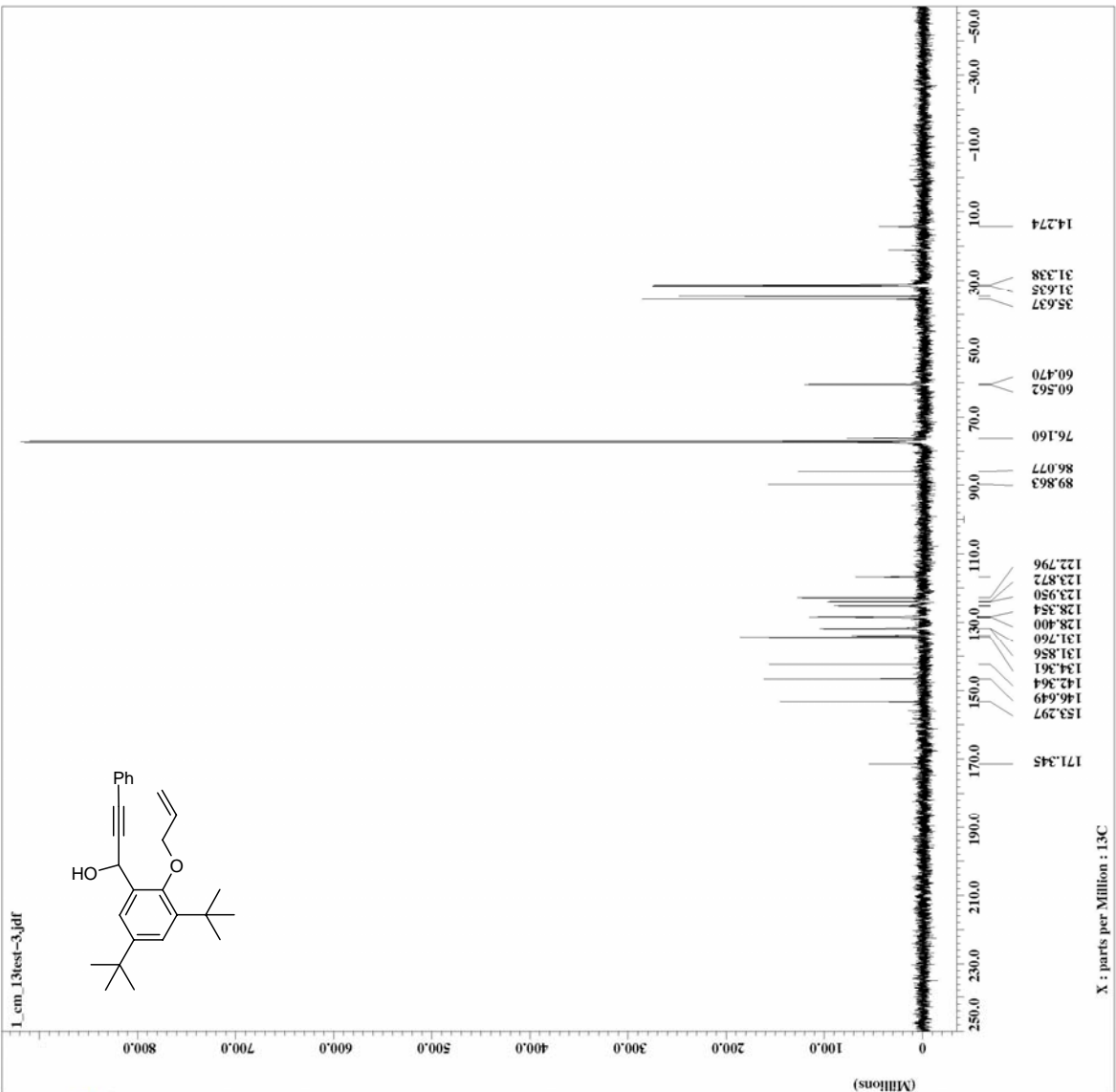
```

Filename = 1_cm_13test-3.fid
Experiment = single pulse_dec
Sample_id = S#159864
Solvent = CHLOROFORM-D
Creation time = 15-APR-2004 18:24:38
Revision time = 4-MAY-2006 20:03:30
Current_time = 4-MAY-2006 20:04:18

Content = Single Pulse with Bro
Date format = DD_MM_YY
Dim size = 65536
Dim title = 13C
Dim units = [ppm]
Dimensions = X
Site = Eclipse+ 500
Spectrometer = DELTA_NMR

Field strength = 125.76529768 [MHz]
X_domain = 13C
X_freq = 125.76529768 [MHz]
X_offset = 100 [ppm]
X_points = 65536
X_prescans = 4
X_resolution = 0.57580336 [Hz]
X_sweep = 37.73584906 [kHz]
F1_domain = 1H
F1_freq = 500.15991521 [MHz]
F1_offset = 0 [ppm]
Mod return = 1
Scans = 200

X_90_width = 14 [us]
X_acq_time = 1.736704 [s]
X_angle = 30 [deg]
X_pulse = 4.66666667 [us]
Initial_wait = 1 [s]
Phase preset = 2b [us]
Relaxation delay = 4 [s]
Temp_get = 23.7 [dC]
Unblank_time = 2 [us]
  
```



X : parts per Million : 13C

APPENDIX 12

¹H and ¹³C NMR SPECTRA OF

4,6-Di-*tert*-butyl-2-(1-hydroxy-3-trimethylsilyl-2-propynyl)-

(-2-propenyloxy) benzene (15a)



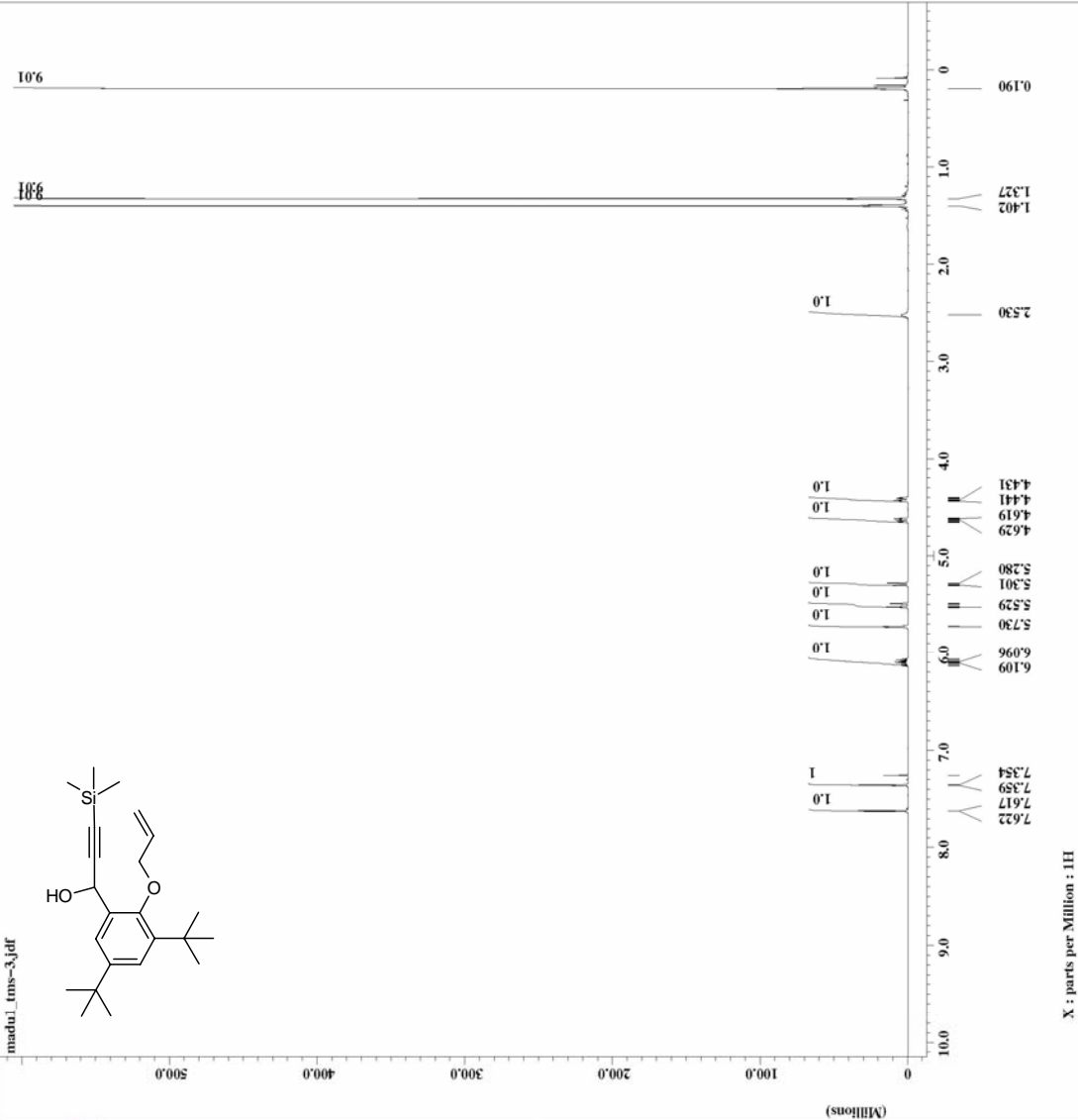
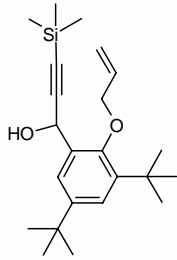
```

Filename = madul_tms-3.jdf
Experiment = single_pulse_exp
Sample_id = S#19691
Solvent = CHLOROFORM-D
Creation time = 21-JUL-2004 21:19:59
Revision time = 04-MAY-2006 20:18:11
Current_time = 4-MAY-2006 20:18:11

Content = Single Pulse Experiment
Data_format = ID COMPLEX
Dim_size = 16384
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Site = Eclipse+ 500
Spectrometer = DELTA_NMR

Field_strength = 11.7473579[T] (500 [MH
Pulse_program =
X.duration = 2.1823488[s]
X.freq = 500.15991521 [MHz]
X.offset = 5 [ppm]
X.points = 16384
X.prescans = 0
X.resolution = 0.45820188 [Hz]
X.sweep_rate = 7.80750751 [kHz]
Mod_return = 1
Scans = 32

X_90_width = 15 [us]
X_acq_time = 2.1823488 [s]
X_couple =
X_pulse = 7.5 [us]
Initial_wait = 1 [s]
Phase_preset = 3 [us]
Recvr_gain = 14
Relaxation_delay = 1 [s]
Temp_get = 33.7 [dc]
Unblank_time = 2 [us]
  
```



X : parts per Million : 1H



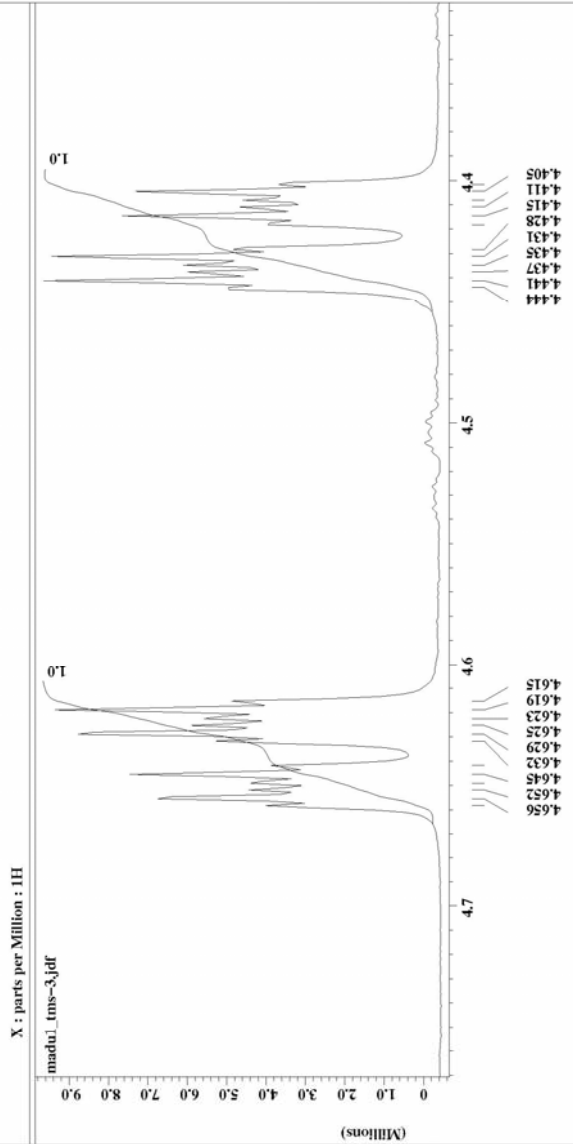
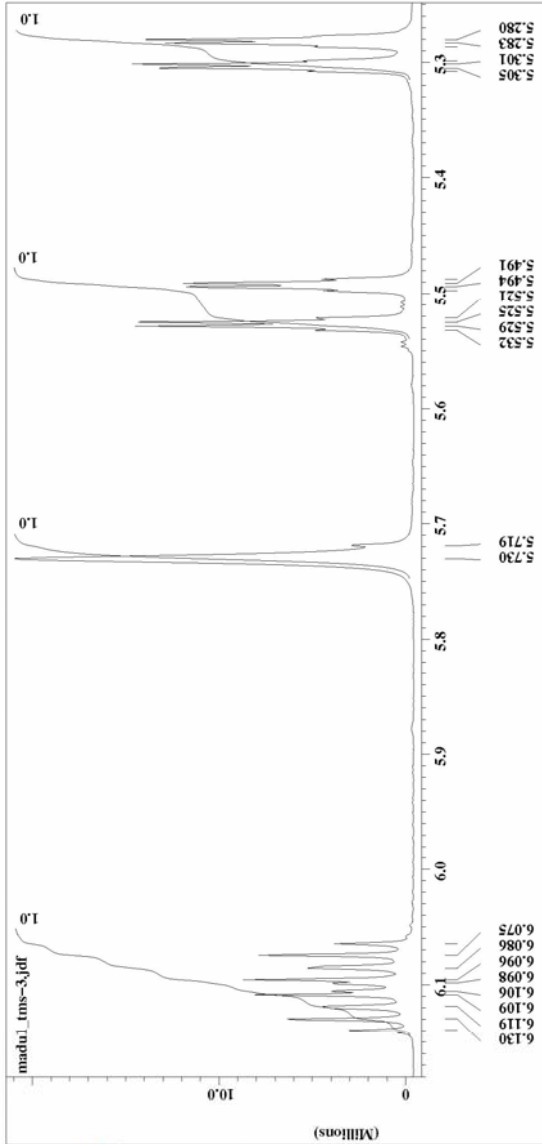
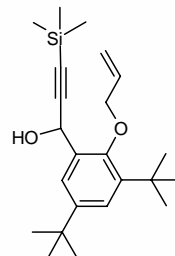
```

Filename = madul_tms-3.jdf
Experiment = single_pulse.exp
Sample_id = S#19691
Solvent = CHLOROFORM-D
Acquisition_time = 21:18:59
Revision_time = 2-FEB-2006 19:20:35
Current_time = 2-FEB-2006 19:25:29

Content = Single Pulse Experi
Data_format = 1D COMPLEX
Data_size = 16384
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
X_resolution = 500
Spectrometer = DELTA_NMR

Field strength = 11.7473579[T] (500[MH
X_acq duration = 2.1823488[s]
X_domain = 1H
X_freq = 500.15991521[MHz]
X_offset = 5[ppm]
X_points = 16384
X_prescans = 0
X_resolution = 45822189[Hz]
X_sweep_rate = 7.50750751[kHz]
Mod return = 1
Scans = 32

X_90_width = 15[us]
X_acq_time = 2.1823488[s]
X_angle = 45[deg]
X_pulse = 7.5[us]
p1:relax_wait = 3[s]
p2:relax_wait = 14[us]
Relaxation_delay = 1[s]
Temp_get = 23.7[dc]
Unblank_time = 2[us]
  
```





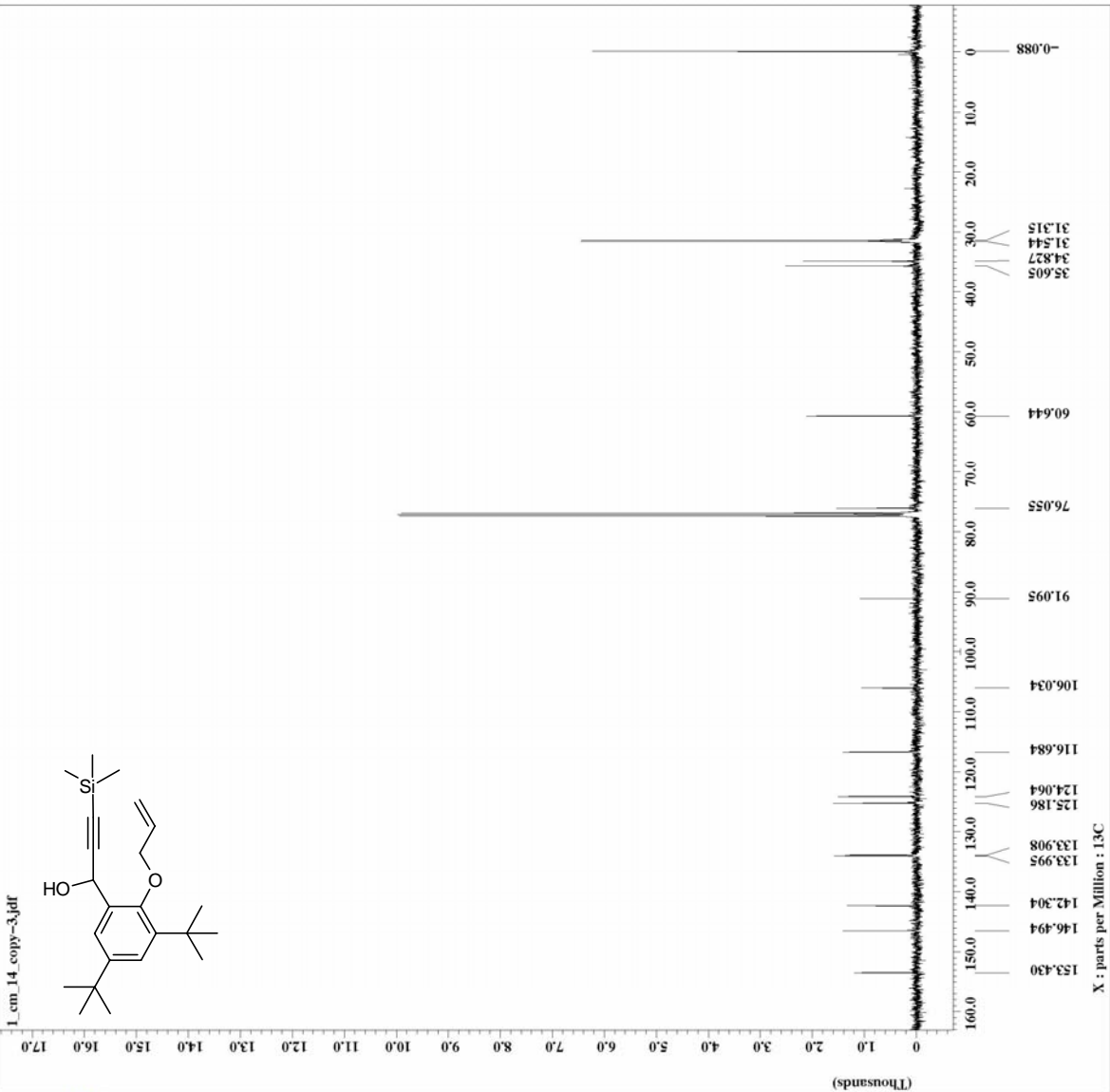
```

File name      = 1_cm_14_copy-3_idf
Experiment     = single_pulse_dec
Sample id      = S#7073
Solvent        = CHLOROFORM-D
Creation time   = 12-JUL-2004 21:04:14
Revision time  = 4-MAY-2006 20:20:33
Current time   = 4-MAY-2006 20:21:05

Content        = Single Pulse with Bro
Data format    = ORFLEX
Date_         = 65536
File          = 13C
Dim title     = 13C
Dim units    = [ppm]
Dimensions    = X
Site         = Eclipse+ 500
Spectrometer = DELTA_NMR

Field strength = 11.7473579 [T] (500 [MH
X_acq_duration = 1.736704 [s]
X_domain       = 13C
X_freq         = 100.76529768 [MHz]
X_offset      = 100 [ppm]
X_points       = 65536
X_prescans     = 4
X_resolution   = 0.57580336 [Hz]
X_sweep        = 37.73584906 [kHz]
Irr_domain     = 1H
Irr_freq       = 500.15991521 [MHz]
Irr_offset     = 5 [ppm]
Mod_return     = 1
Scans          = 149

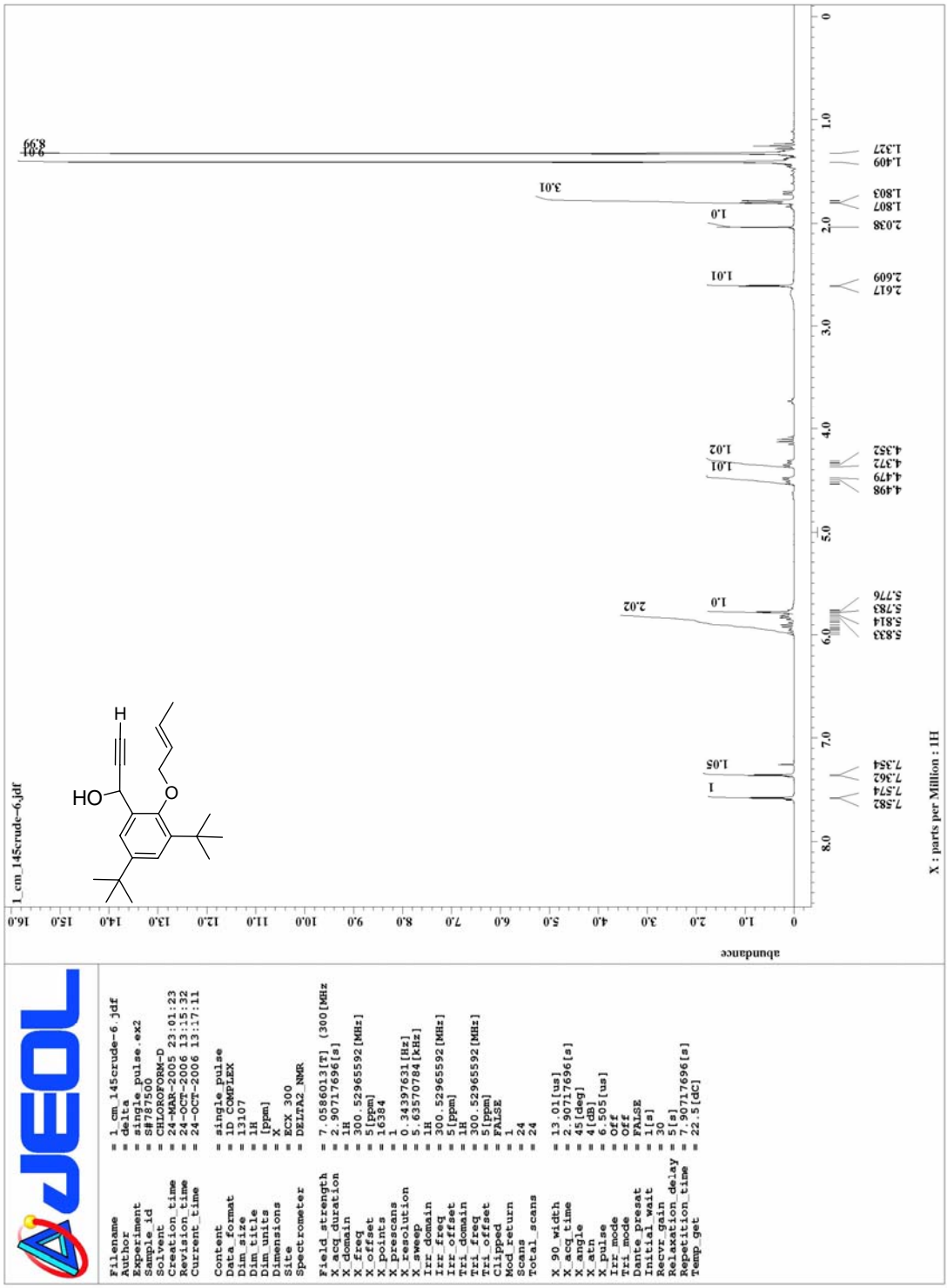
X_90_width    = 14 [us]
X_acq_time     = 1.736704 [s]
X_angle        = 30 [deg]
X_pulse        = 4.66666667 [us]
Initial_wait   = 1 [s]
Phase_preset   = 3 [us]
Recvr_gain     = 29
Relaxation_delay = 4 [s]
Temp_get       = 25.2 [dC]
Onblank_time   = 2 [us]
  
```



APPENDIX 13

¹H and ¹³C NMR SPECTRA OF

4,6-Di-*tert*-butyl-2-(-1-hydroxy-2-propynyl)-1-(-2- butenyloxy)benzene (17c)





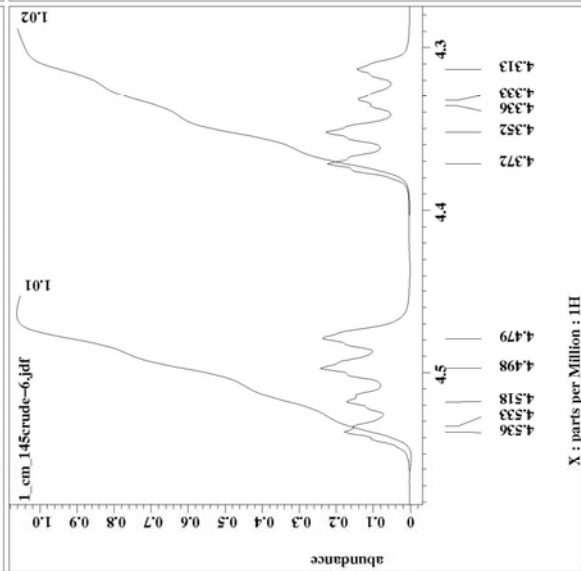
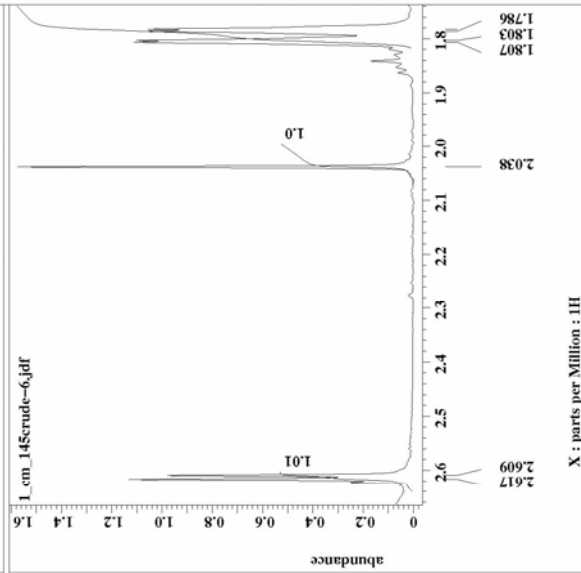
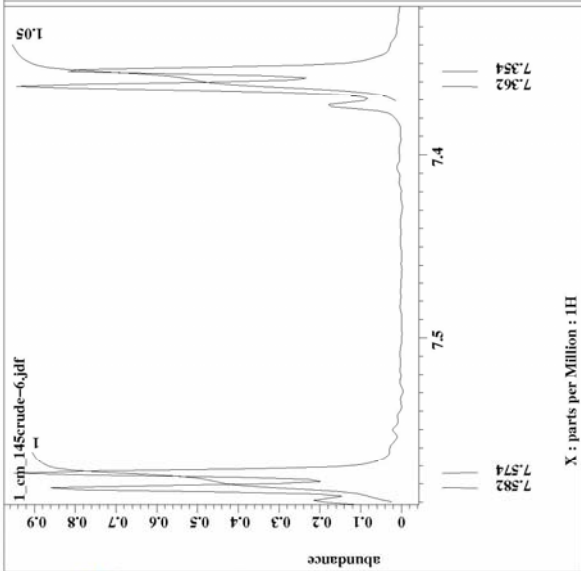
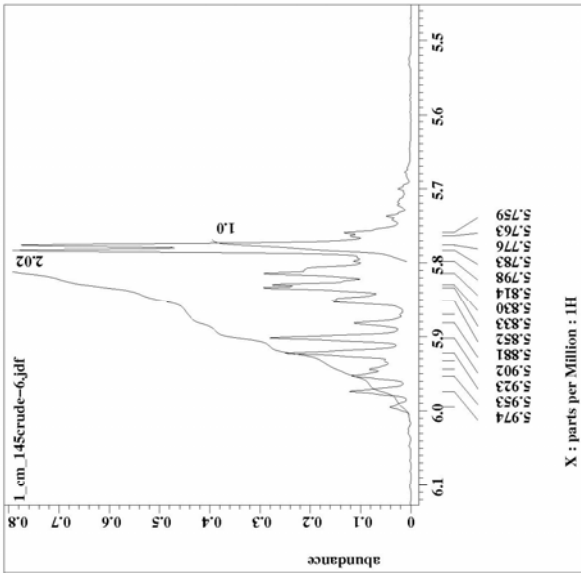
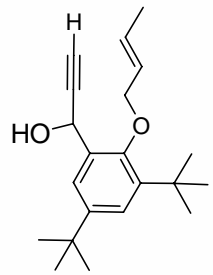
```

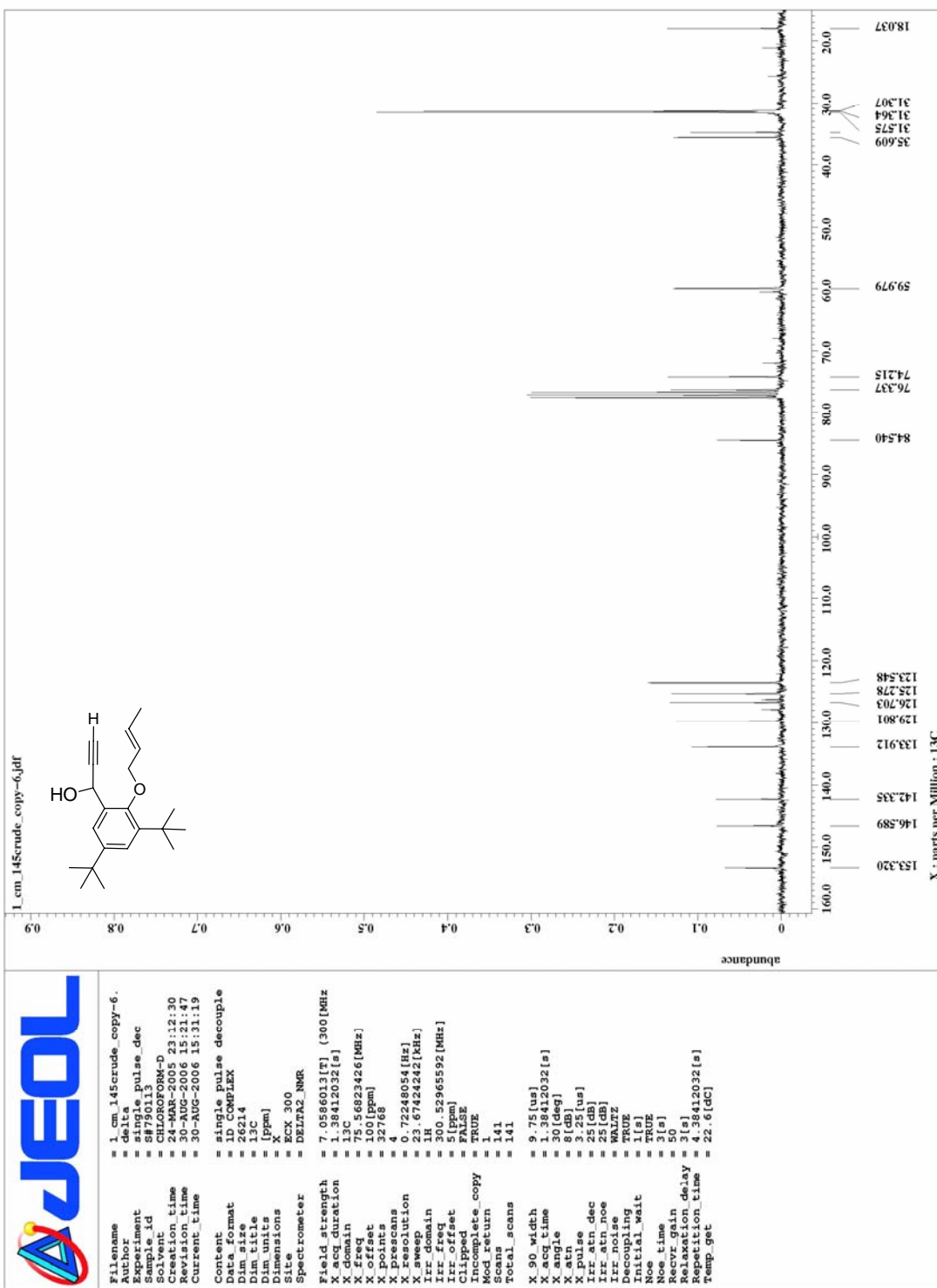
Filename = 1_cm_145crude-6.jdf
Author = delta
Experiment = single pulse.ex2
Sample_id = SH787500
Solvent = CHLOROFORM-D
Creation_time = 24-MAR-2005 23:01:23
Revision_time = 24-OCT-2006 13:17:32
Current_time = 24-OCT-2006 13:19:00

Content =
Data format = ID COMPLEX
Dim size = 13107
Dim title =
Dim units = 1H
Dimensions = [ppm]
Site = X
Spectrometer = ECK 300
P1 = DELTA2_NMR

Field strength = 7.0586013 [T] (300 [MHz]
X1 = 2.90717696 [s]
X2 = 2.90717696 [s]
X domain = 1H
X freq = 300.52965592 [MHz]
X offset = 5 [ppm]
X points = 16384
X prescans = 1
X resolution = 0.34397631 [Hz]
X sweep = 5.63570784 [kHz]
Irr domain = 1H
Irr freq = 500.52965592 [MHz]
Irr offset = 5 [ppm]
Tri domain = 1H
Tri freq = 300.52965592 [MHz]
Tri offset = 5 [ppm]
Clipped = FALSE
Mod return = 1
Scans = 24
Total_scans = 24

X 90_width = 13.01 [us]
X acq_time = 2.90717696 [s]
X angle = 45 [deg]
X atn = 41 [dB]
X pulse = 6.505 [us]
Irr mode = Off
Tri mode = Off
Dante_preset = FALSE
Initial_wait = 1 [s]
Recvr_gain = 30
Relaxation_delay = 7 [s]
Repetition_time = 7.190717696 [s]
Temp_get = 22.5 [degC]
  
```

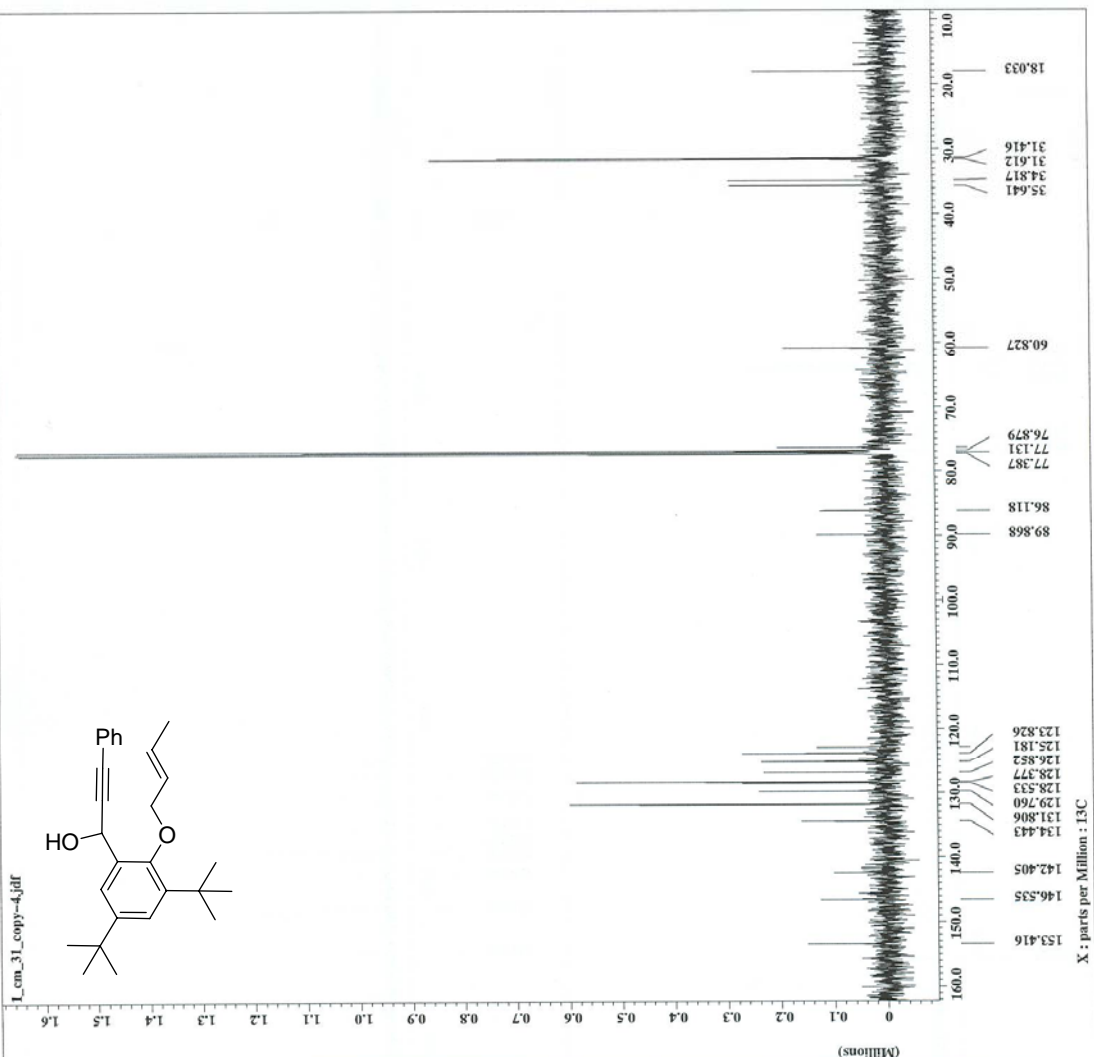




APPENDIX 14

^1H and ^{13}C NMR SPECTRA OF

**4,6-Di-*tert*-butyl-2-(1-hydroxy-3-phenyl-2-propynyl)-1-(2-butenyloxy)
benzene (17b)**



JEOL
 I_cm_31_copy-4.jdf
 File name = I_cm_31_copy-4.jdf
 Author = delta
 Experiment = single_pulse_desc
 Sample_id = 13C
 Sample_name = CHLOROPHYLL-B
 Creation_time = 24-AUG-2006 14:01:54
 Revision_time = 24-AUG-2006 12:51:59
 Current_time = 24-AUG-2006 12:52:25
 Content = Single Pulse with Bro
 Date_acq = 24-AUG-2006 12:52:25
 ID_COMPLEX =
 Dim_size = 65536
 Dim_title = 13C
 Dim_units = [ppm]
 Dimensions = X
 Site = Reilpas: 500
 Spectrometer = ENUFA_NMR
 Field_strength = 11.7473579 [T] (500 [MHZ])
 X_acq_duration = 1.736704 [s]
 X_domain = 13C
 X_freq = 125.7652976 [MHz]
 X_offset = 0 [ppm]
 X_offset2 = 65536 [ppm]
 X_pulses = 4
 X_resolution = 0.57580336 [Hz]
 X_sweep = 37.73584906 [kHz]
 Irr_domain = IR
 Irr_freq = 10.15991521 [MHz]
 Irr_offset = 0 [ppm]
 Modulated = FALSE
 Mod_return = 1
 Scans = 236
 Total_scans = 236
 X_90_width = 14.2 [us]
 X_acq_time = 1.736704 [s]
 X_angle = 30 [deg]
 X_pulse = 4.7333332 [us]
 Initial_wait = 1 [s]
 Phase_preset = 3 [us]
 Recv_start = 0 [us]
 Recv_end = 4 [us]
 Temp_get = 27.7 [dC]
 Unblank_time = 2 [us]

APPENDIX 15

¹H and ¹³C NMR SPECTRA OF

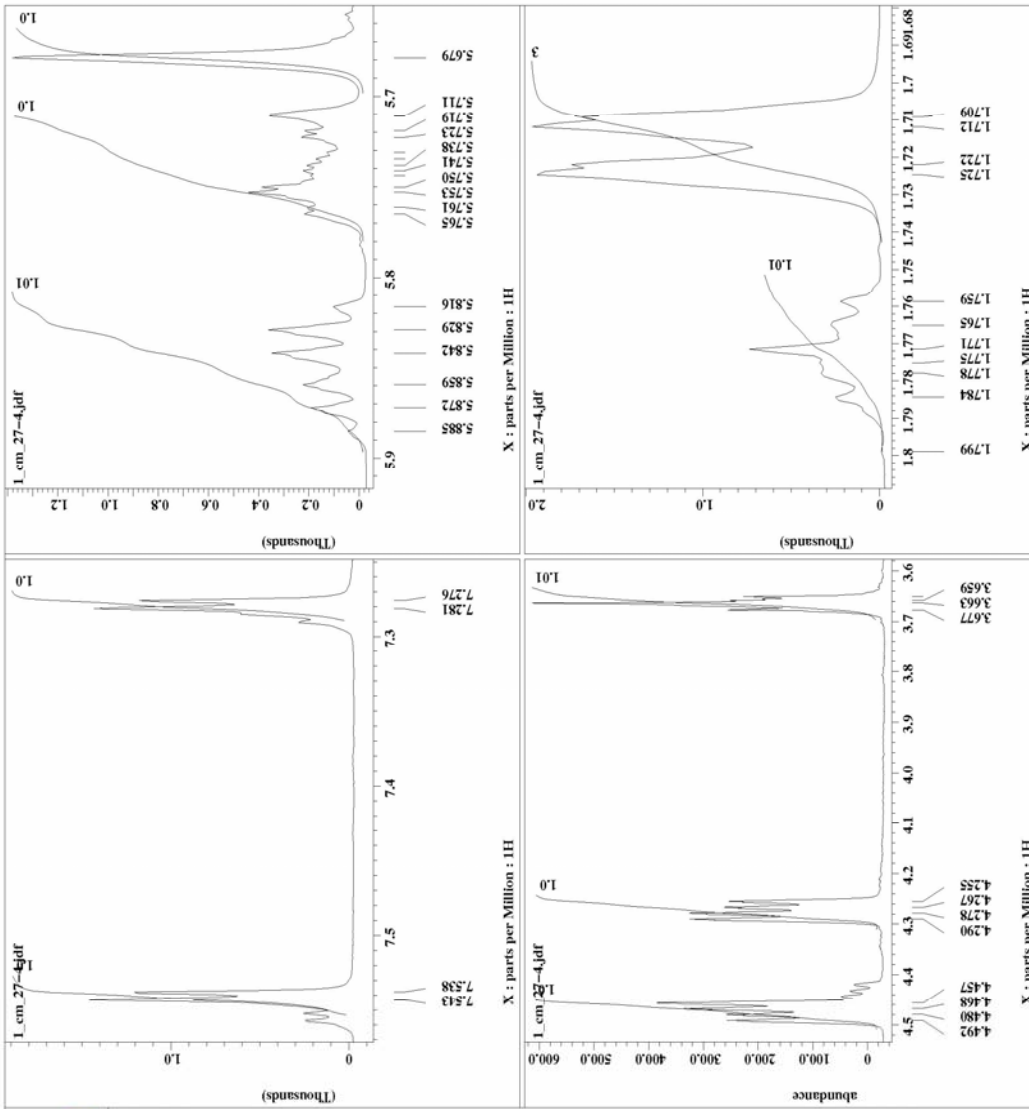
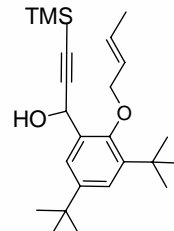
4,6-Di-*tert*-butyl-2-(-1-hydroxy-3-trimethylsilyl-2-propynyl)

-1-(-2- butenyloxy)benzene (17a)



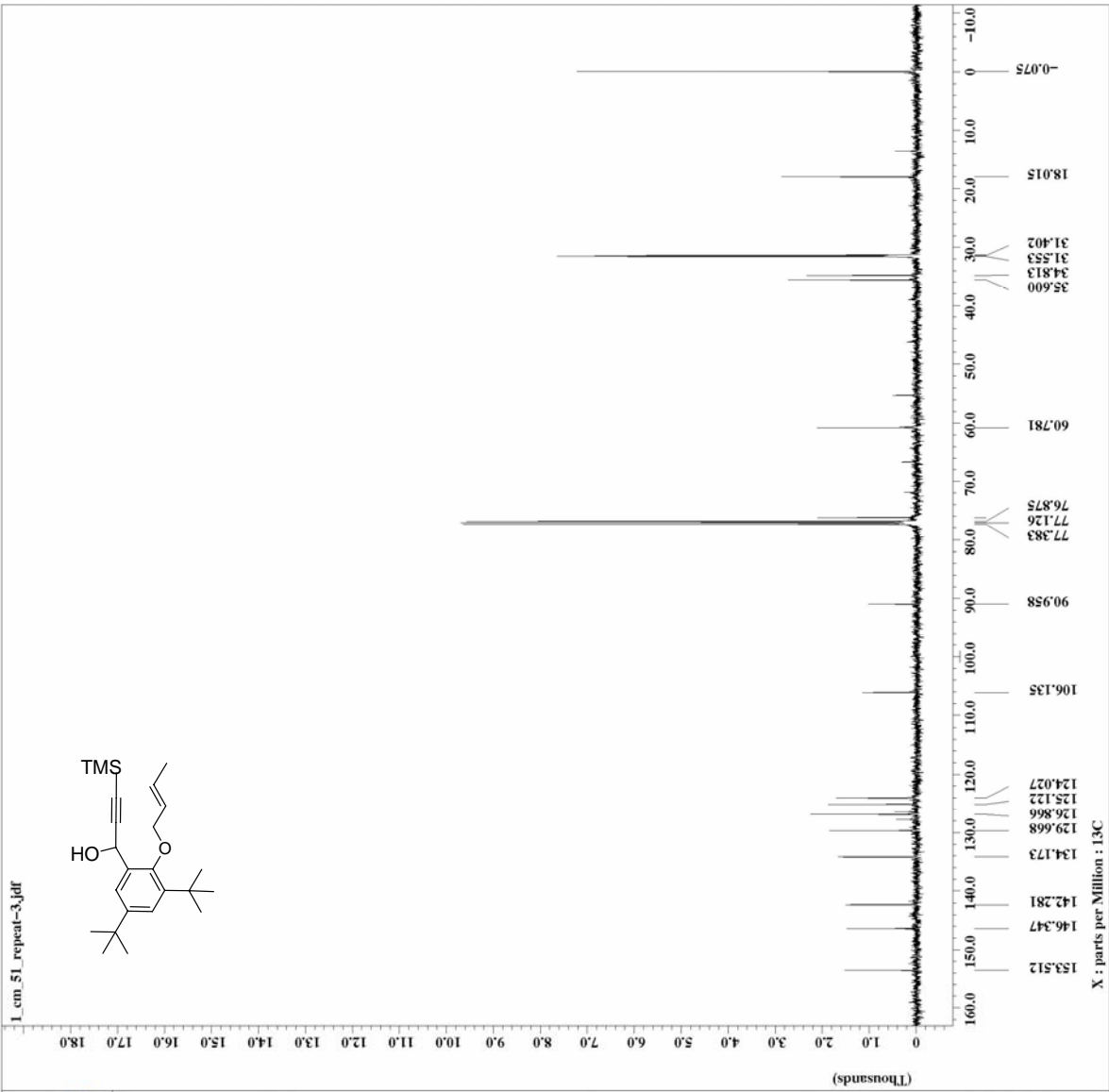
```

Filename      = 1_cm_27-4_jdf
Experiment    = Single Pulse Exp
Pulseprg     = zgpg30
Acqdate      = 08-08-04
Acqtime      = 16:38
Solvent       = CHLOROFORM-D
Creation_time = 8-JUN-2004 20:03:36
Revision_time = 24-OCT-2006 14:14:17
Current_time  = 24-OCT-2006 14:19:17
Content       = Single Pulse Experiment
Data_format  = 1D COMPLEX
Dim size     = 16384
Dim 1       = F2
Dim 2       = F1
Dim 3       = X
Dimensions   = X
Site         = Eclipset 500
Spectrometer = DELTA_NMR
Field strength = 11.7473579[T] (500[MH
X acq duration = 2.1823488[s]
X domain      = 1H
X freq        = 500.15991521[MHz]
X points      = 16384
X prescans    = 0
X resolution  = 0.45822189[Hz]
X sweep       = 7.50750751[KHz]
X temp        = 300.2[degK]
X 1st return  = 32
Scans         = 32
X 90_width   = 15[us]
X acq time    = 2.1823488[s]
X delay       = 2.50[us]
X pulse       = 7.5[us]
Initial wait  = 1[s]
Phase preset  = 3[us]
Recvr gain    = 12
Relaxation delay = 23.9[s]
Temp set      = 23.9[degC]
Unblank time  = 2[us]
  
```





Filename = 1_cm_51_repeat-3.jdf
Experiment = single_pulse_dec
Sample_id = SF3048
Solvent = CHLOROFORM-D
Acquisition_time = 21:39:04
Start_time = 24-OCT-2006 14:22:25
End_time = 24-OCT-2006 14:23:02
Current_time = 24-OCT-2006 14:23:02
Content = Single Pulse with Bro
Data_format = 1D COMPLEX
Dim_size = 65536
Dim_title = 13C
Dim_units = [ppm]
Dimensions = X
Site = Xclipse+ 500
Spectrometer = DELTA_NMR
Field_strength = 11.7473579[T] (500 [MH
X_acq_duration = 1.736704 [s]
X_domain = 13C
X_freq = 125.76529768 [MHz]
X_offset = 100 [ppm]
X_points = 65536
X_prescans = 4
X_resolution = 9.57580336 [Hz]
X_sweep = 17.73584906 [kHz]
X_sweep_rate = 14
X_t1_rho = 500.15991521 [MHz]
X_t1_rho_offset = 5 [ppm]
Mod_return = 1
Scans = 143
X_90_width = 14 [us]
X_acq_time = 1.736704 [s]
X_angle = 30 [deg]
X_pulse = 1.6666667 [us]
Phase_wait = 3 [us]
Pulse_program = zgpg30
Recvr_gain = 29
Relaxation_delay = 4 [s]
Temp_get = 24.9 [dc]
Unblank_time = 2 [us]



APPENDIX 16

^1H and ^{13}C NMR SPECTRA OF

4,6-Di-tert-butyl-2-iodophenol (19)



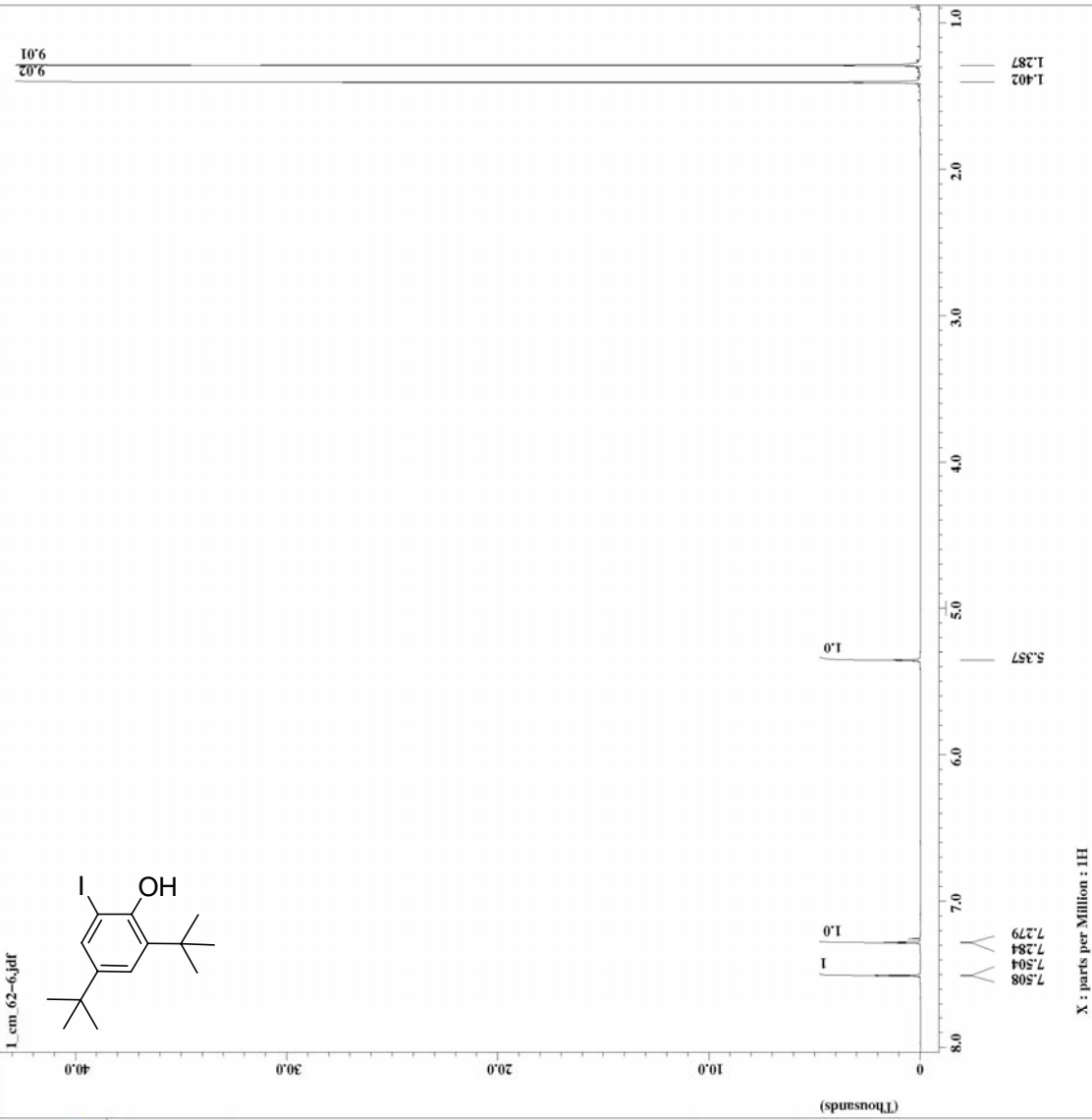
```

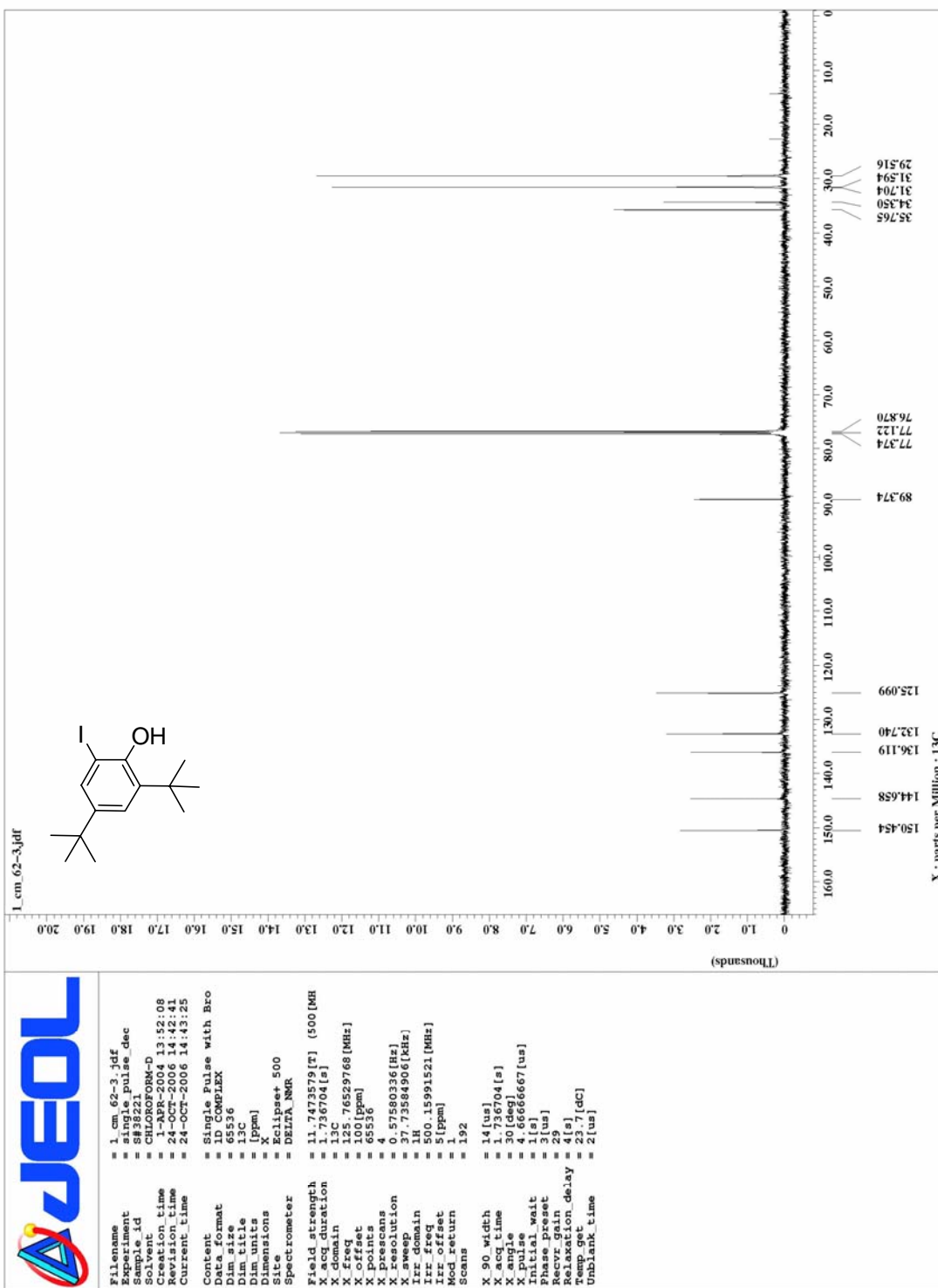
Filename = 1_cm_62-6_jdf
Experiment = single_pulse.exp
Sample id = S841149
Solvent = CHLOROFORM-D
Creation time = 1-APR-2004 11:53:41
Revision time = 24-OCT-2006 14:39:23
Current time = 24-OCT-2006 14:42:00

Content = Single Pulse Experiment
Data format = 1D COMPLEX
Dim size = 16384
Dim title = 1H
Dim units = [ppm]
Dimensions = X
Site = Eclipse+ 500
Spectrometer = DEIRA_NMR

Field strength = 11.7473579[T] (500 [MH]
X.acq_duration = 2.1823488[s]
X.domain = 1H
X.freq = 500.15991521 [MHz]
X.offset = 5 [ppm]
X.puls = 16384
X.procs = 0
X.resolution = 0.45822189 [Hz]
X.sweep = 7.50750751 [kHz]
Mod.return = 1
Scans = 23

X.90_width = 15 [us]
X.acq_time = 2.1823488 [s]
X.angle = 45 [deg]
X.pulse = 7.5 [us]
Initial.wait = 1 [s]
Phase.preset = 3 [us]
Recvr.gain = 13
Relaxation.delay = 23 [dc]
Unblank_time = 2 [us]
  
```

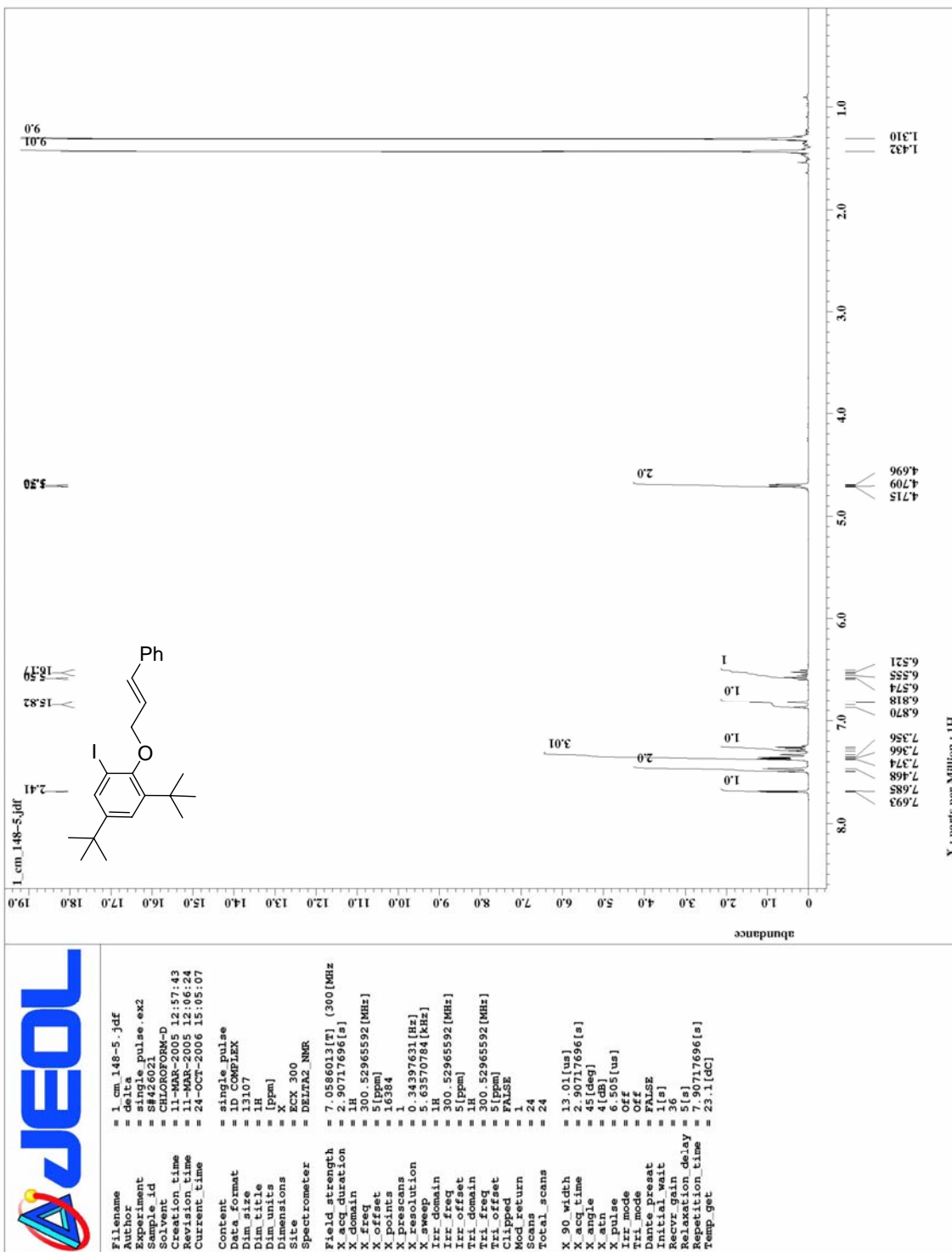




APPENDIX 17

¹H and ¹³C NMR SPECTRA OF

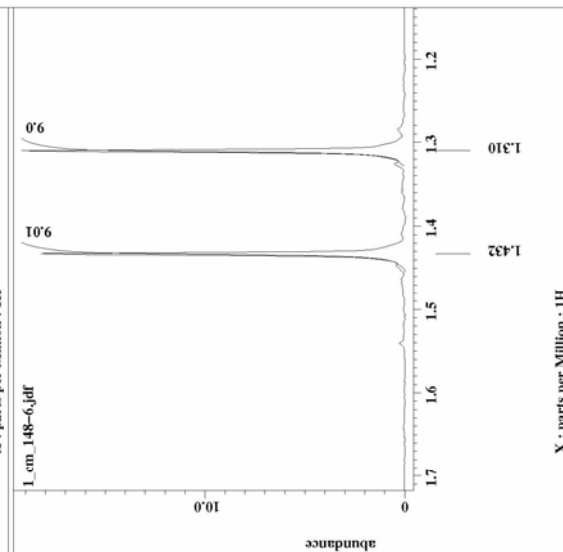
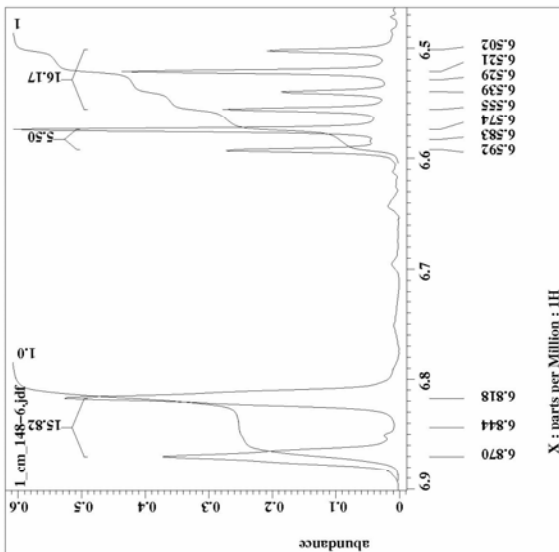
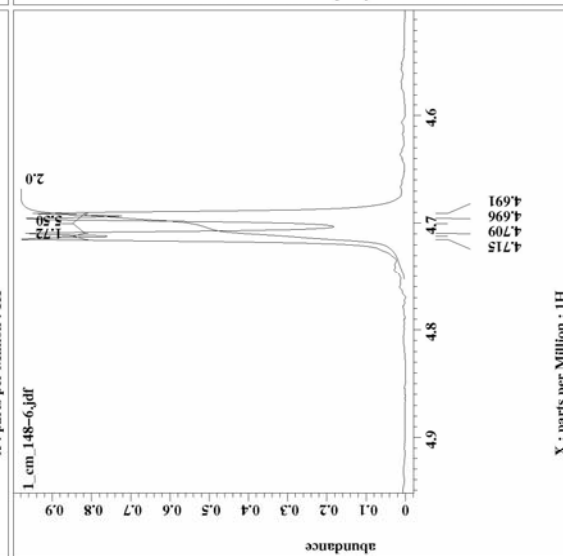
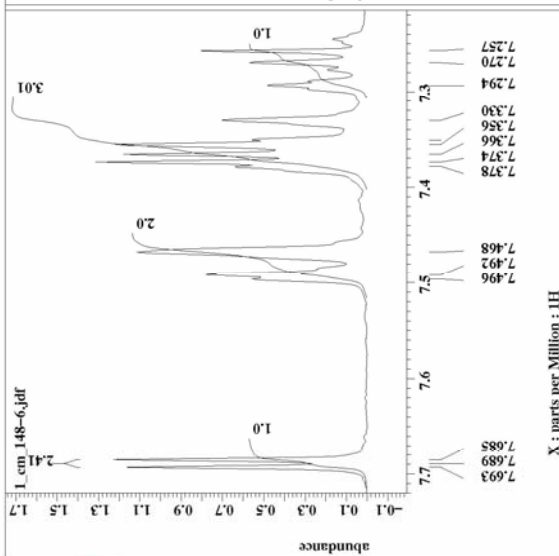
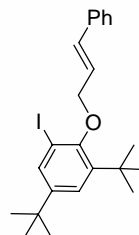
1,5-Di-tert-butyl-3-iodo-2-(-3-phenyl-2-propenyloxy)benzene (20)

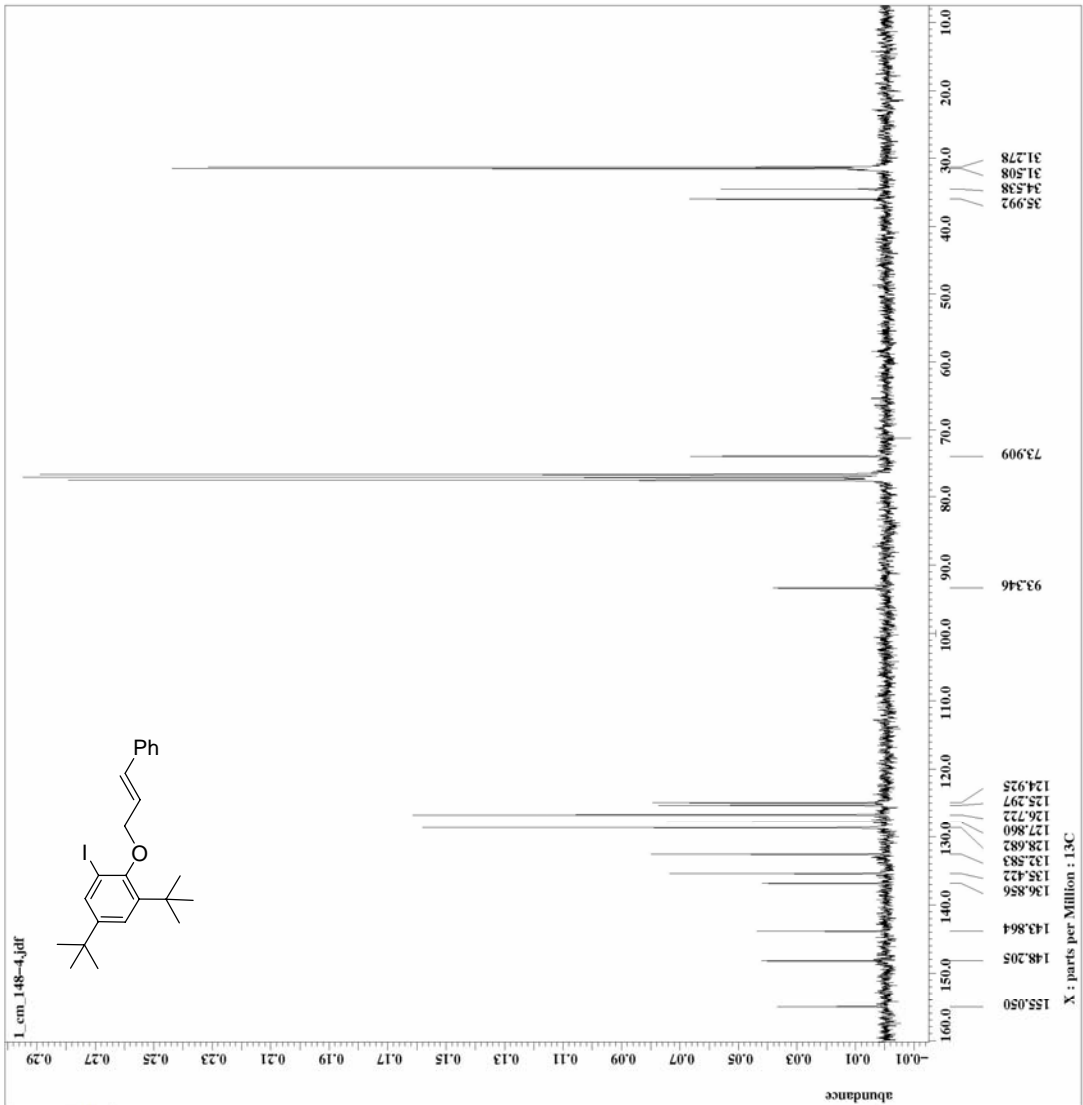




```

Filename = 1_cm_148-6_jdf
Sample = 148-6
Experiment = single_pulse.ex2
Sample_id = SM426021
Solvent = CHLOROFORM-D
Creation_time = 11-MAR-2005 12:57:43
Revision_time = 24-OCT-2006 15:05:16
Current_time = 24-OCT-2006 15:05:59
Content = single_pulse
Data_format = ID_COMPLEX
Dim_size = 13107
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Site = ECX 300
Spectrometer = DELTA2_NMR
Field_strength = 7.0586013[T] (300[MHz]
X_acq_duration = 2.90717696[s]
X_domain = 1H
X_freq = 300.52965592[MHz]
X_offset = 5[ppm]
X_points = 16384
X_resolution = 0.34397631[Hz]
X_swept = 5.63570784[MHz]
Irr_domain = 1H
Irr_freq = 300.52965592[MHz]
Irr_offset = 5[ppm]
Tri_domain = 1H
Tri_freq = 300.52965592[MHz]
Tri_offset = 5[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 24
Total_scans = 24
X_90_width = 13.01[us]
X_acq_time = 4.90717696[s]
X_pulse_width = 4[us]
X_atp = 4[dB]
X_pulse = 6.505[us]
Irr_mode = Off
Tri_mode = Off
Dante_preset = FALSE
Initial_wait = 1[s]
Recvr_gain = 5[s]
Repetition_delay = 7[s]
Repetition_time = 7.90717696[s]
Temp_get = 23.1[dc]
  
```



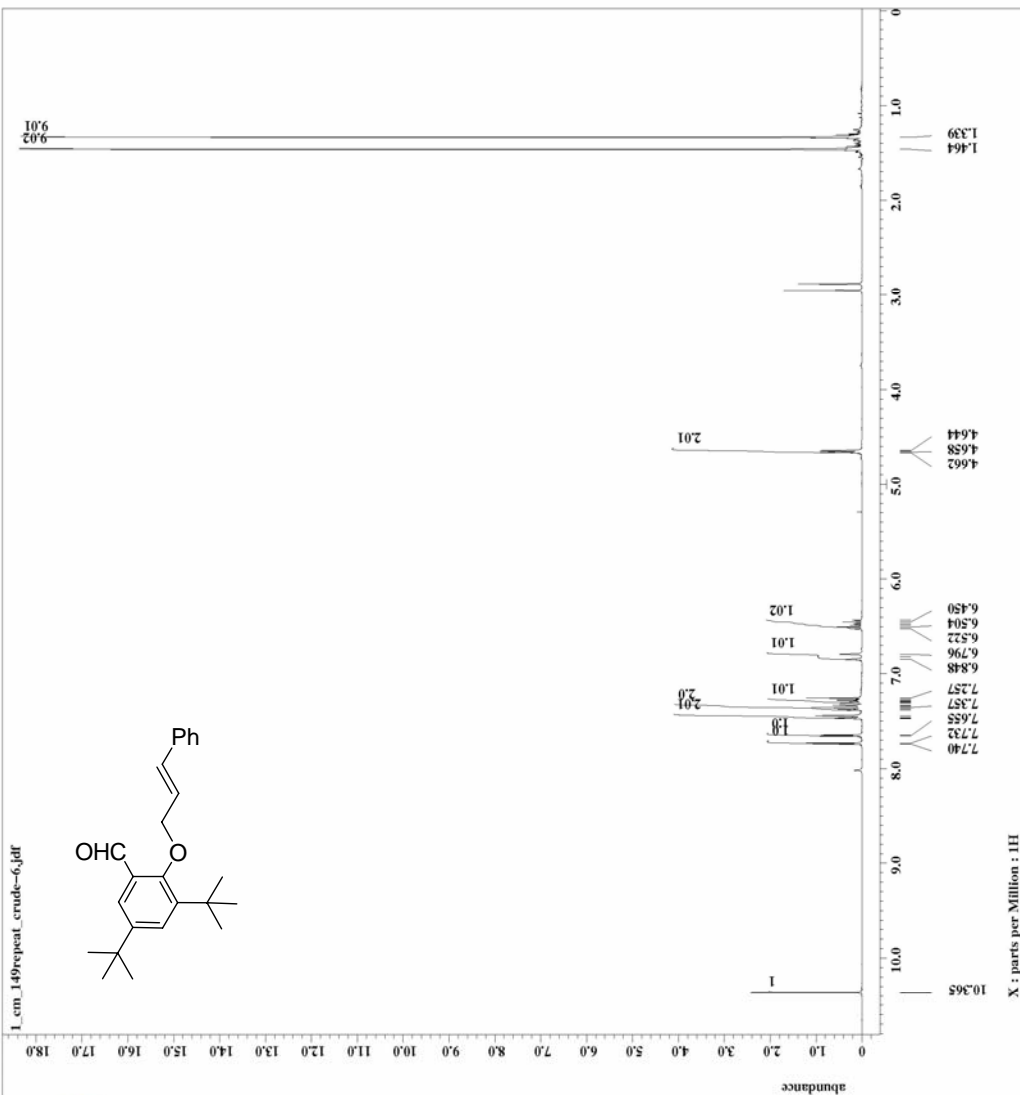


Filename = 1_cm_148-4.jdf
 Author = delta
 Experiment = single_pulse_dec
 Sample Id = SM28029M-D
 Sample Name = 148-4
 Creation time = 11-MAR-2005 13:25:17
 Revision time = 24-OCT-2006 15:06:36
 Current time = 24-OCT-2006 15:10:57
 Content = single_pulse_decouple
 Date Acquired = 20050311
 Dim size = 26214
 Dim title = 13C
 Dim units = [ppm]
 Dimensions = X
 Site = ECX 300
 Spectrometer = DELTA3_NMR
 Field strength = 7.0586013[T] (300[MHz]
 X_acq_duration = 1.38412032[s]
 X_domain = 13C
 X_freq = 100.6223426[MHz]
 X_offset = 100.6223426[MHz]
 X_points = 32768
 X_prescans = 4
 X_resolution = 0.72248054[Hz]
 X_sweep = 23.67424242[kHz]
 Irr_domain = 13C
 Irr_freq = 30.52965592[MHz]
 Irr_offset = 5[ppm]
 Clipped = FALSE
 Mod_return = 1
 Scans = 370
 Total_scans = 370
 X_90_width = 9.75[us]
 X_acq_time = 1.38412032[s]
 X_angle = 30[deg]
 X_atn = 8[db]
 X_atn2 = 25[db]
 X_pulse_dec = 25[us]
 Irr_atn = 25[db]
 Irr_atn_noe = 25[db]
 Irr_noise = WALTZ
 Decoupling = TRUE
 Initial_wait = 1[s]
 Recv_time = 3[s]
 Recv_time2 = 50[s]
 Relaxation_delay = 3[s]
 Repetition_time = 4.38412032[s]
 Temp_get = 23.1[dc]

APPENDIX 18

^1H and ^{13}C NMR SPECTRA OF

3,5-Di-*tert*-butyl-2-(-3'-phenyl-2'-propenyloxy) benzaldehyde (21)



1_cm_149repeat_crude-6.fdr

Abundance

X : parts per Million : 1H

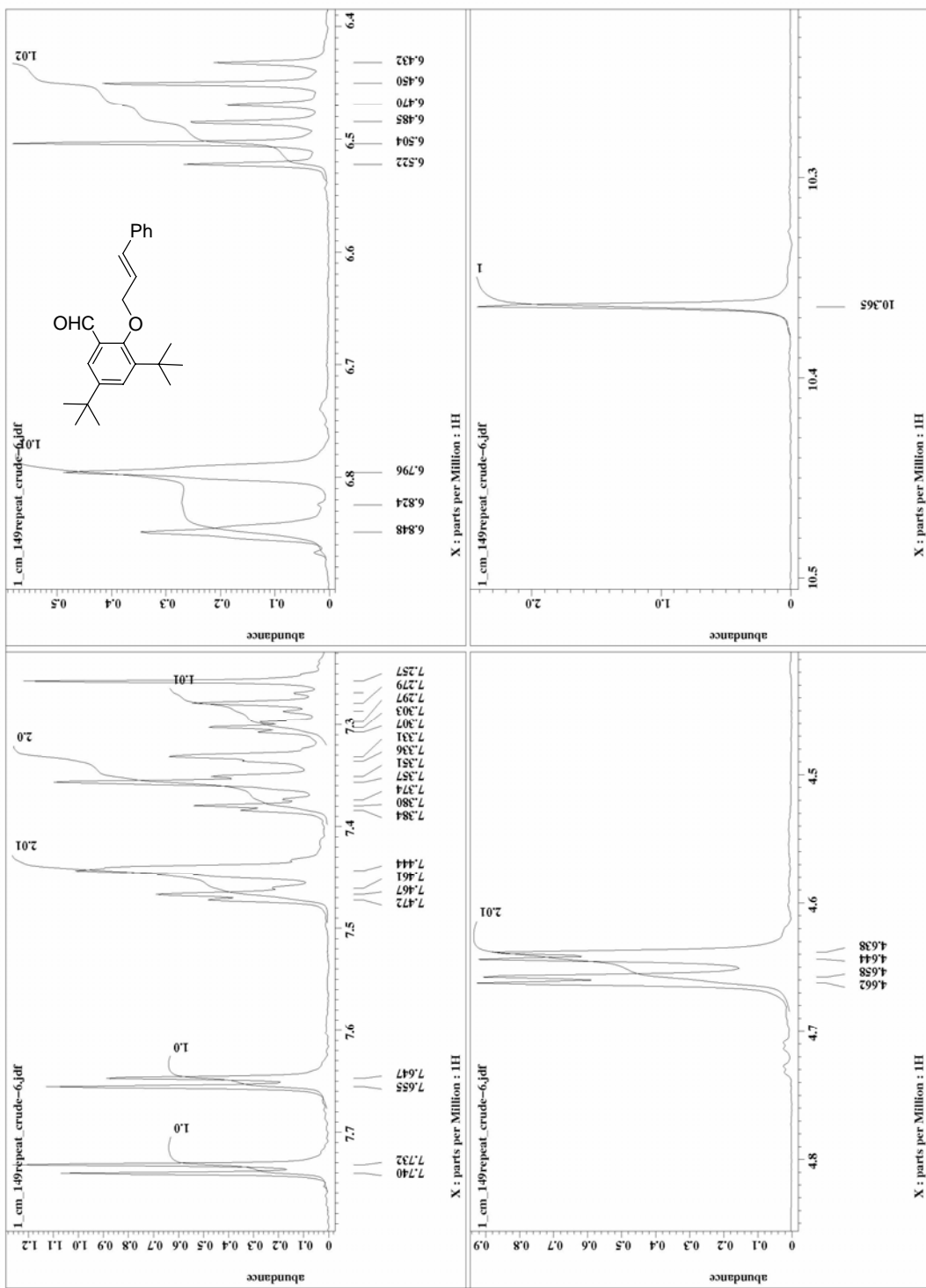
JEOL

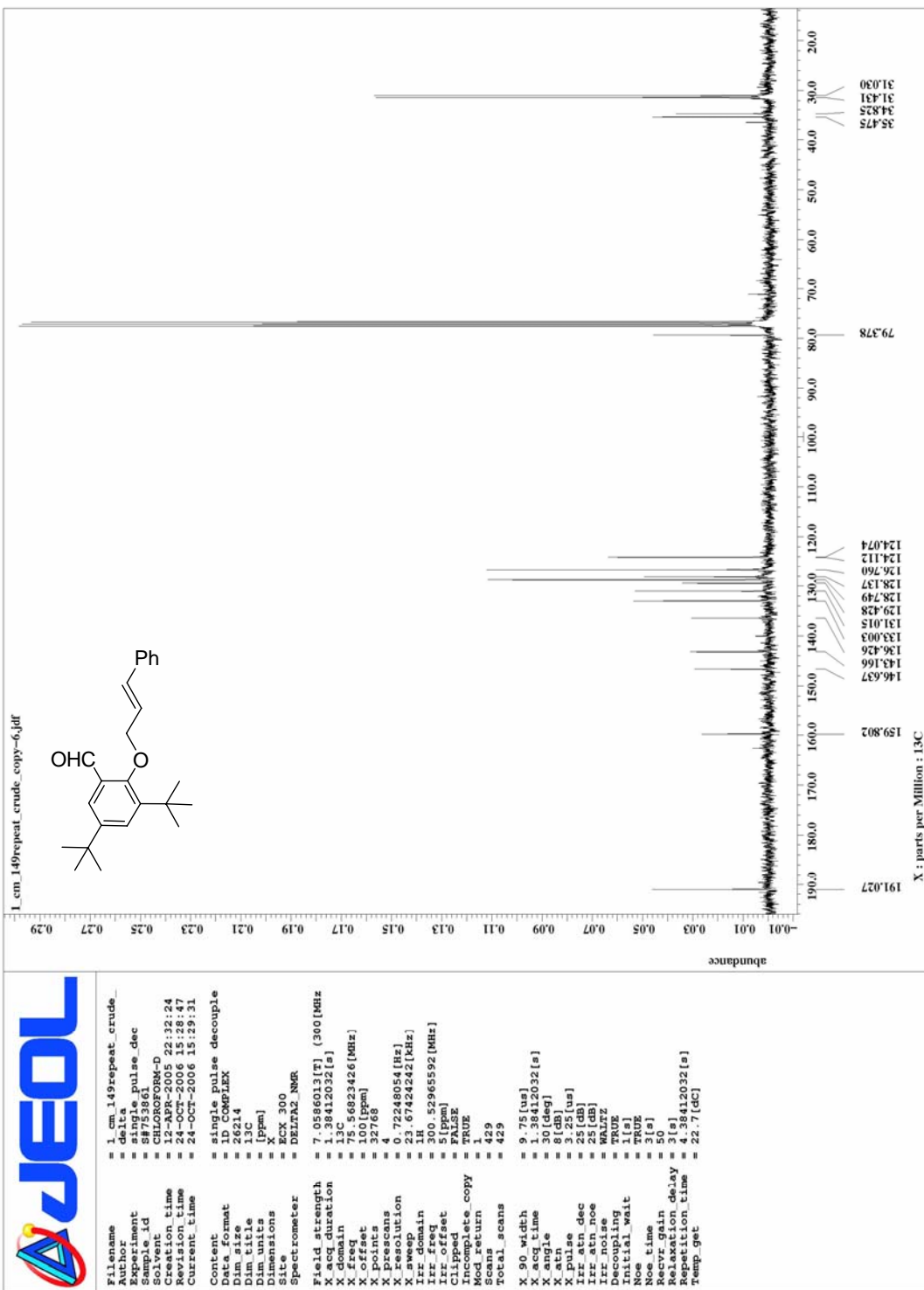
```

Filename == 1_cm_149repeat_crude-
Author == delta
Experiment == single_pulse.ex2
Acq_date == 20061017
Solvent == CHLOROFORM-D
Creation_time == 12-APR-2005 22:00:36
Revision_time == 24-OCT-2006 15:26:24
Current_time == 24-OCT-2006 15:26:52

Content == single_pulse
Data_format == ID COMPLEX
Dim_size == 13107
Dim_units == [Hz]
Dim == [ppm]
Dimensions == X
Site == ECK 300
Spectrometer == DELTA2_NMR

Field_strength == 7.0586013[T] (300[MHz]
X_acq_duration == 2.90717696[s]
X_domain == IN
X_freq == 300.52965592[MHz]
X_offset == 16384
X_points == 1
X_prescans == 1
X_resolution == 0.34397631[Hz]
X_sweep == 5H
X_sweep_rate == 63570784[KHz]
Irr_freq == 300.52965592[MHz]
Irr_offset == 5[ppm]
Tri_domain == IN
Tri_freq == 300.52965592[MHz]
Tri_offset == 0
Clipped == FALSE
Mod_return == 1
Scans == 24
Total_scans == 24
X_90_width == 13.01[us]
X_acq_time == 2.90717696[s]
X_angle == 45[deg]
X_pulse == 6.505[us]
Irr_pulse == off
Irr_mode == Off
Dante_preset == FALSE
Relaxation_delay == 5[s]
Recvr_gain == 28
Repetition_time == 7.90717696[s]
Temp_get == 22.5[dc]
  
```

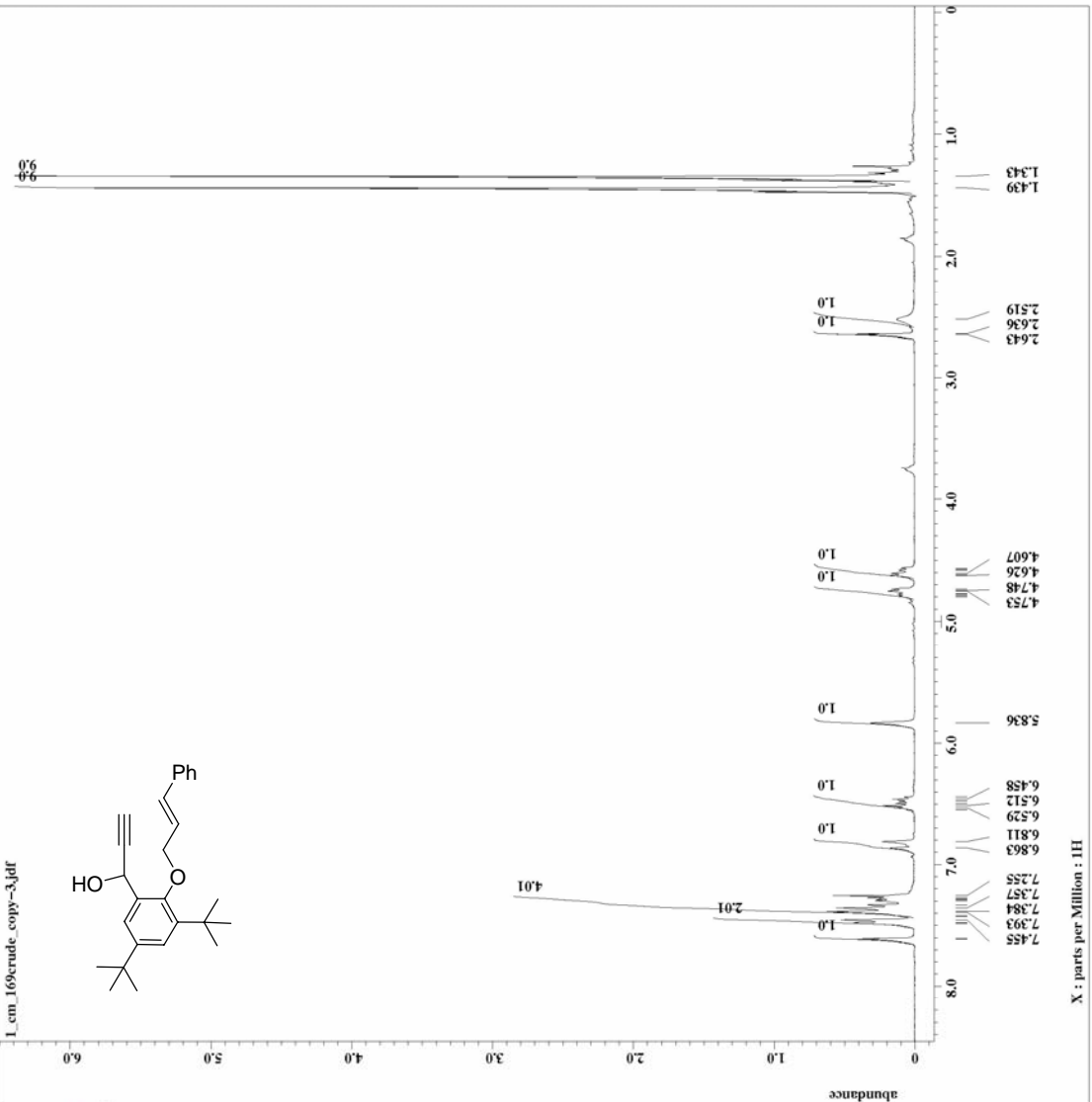




APPENDIX 19

¹H and ¹³C NMR SPECTRA OF

**4,6-Di-*tert*-butyl-2-(1-hydroxy-2-propynyl)
-1-(3-phenyl-2-propenyloxy)benzene (22c)**



JEOL

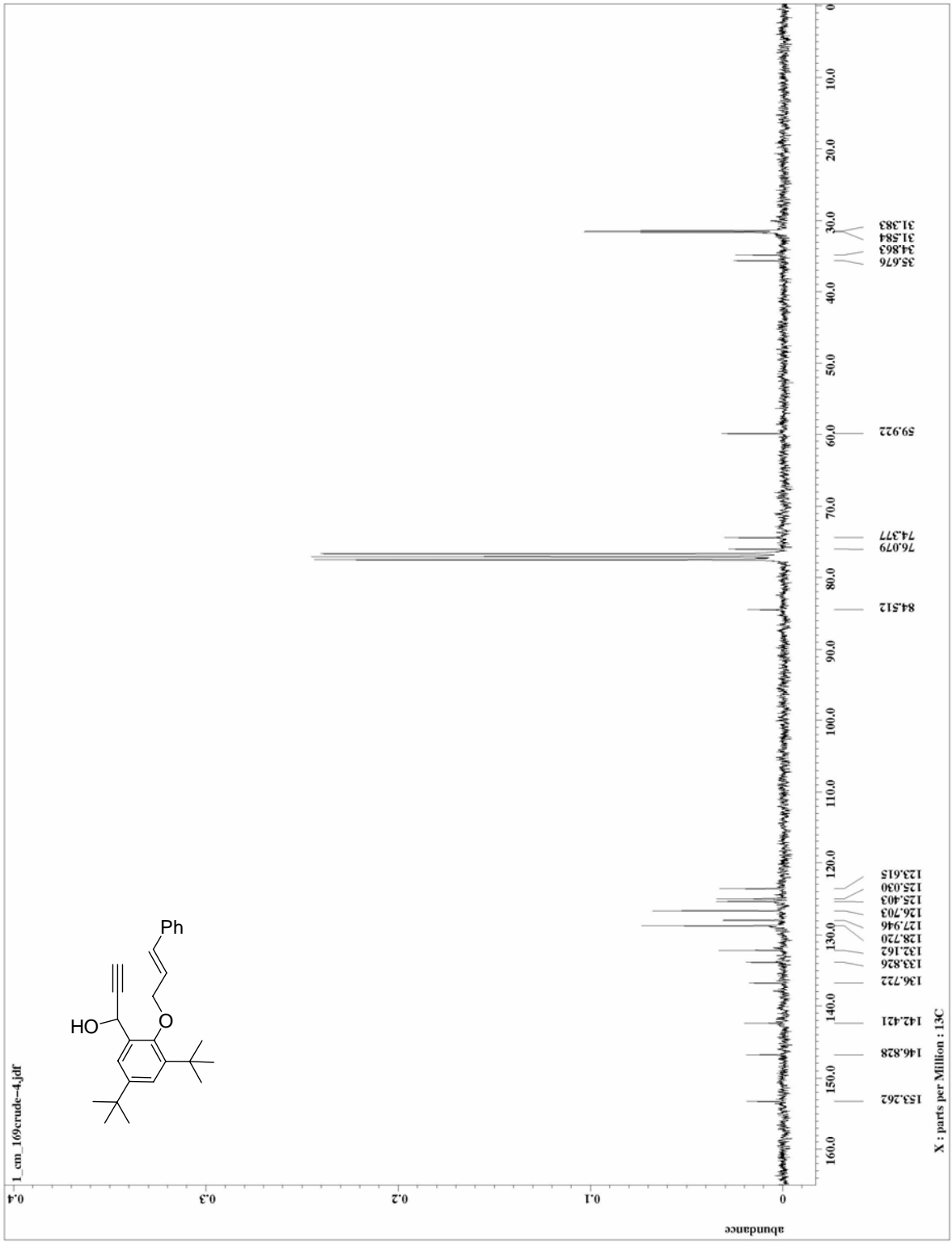
```

Filename = 1 cm_169crude_copy-3.
Author = delta
Experiment = single pulse.ex2
Sample_id = S#517256
Solvent = CHLOROFORM-D
Creation_time = 14-APR-2005 15:30:56
Revision_time = 24-OCT-2006 15:44:02
Current_time = 24-OCT-2006 15:44:36

Content = single pulse
Data_format = ID COMPLEX
Dim_size = 13107
Dim_title = 1H
Dim_units = [ppm]
Dimensions = 1
Site = ECX 300
Spectrometer = DELTA2_NMR

Field_strength = 7.0586013[T] (300[MHz]
X_acq_duration = 2.90717696[s]
X_domain = 1
X_offset = 300.52965592[MHz]
X_ppm = 5[ppm]
X_points = 16384
X_prescans = 1
X_resolution = 0.34397631[Hz]
X_sweep = 5.63570784[KHz]
IRF_domain = 1
IRF_freq = 300.52965592[MHz]
IRF_offset = 5[ppm]
Tri_domain = 1H
Tri_freq = 300.52965592[MHz]
Tri_offset = 5[ppm]
Clipped = FALSE
Acquire_mode = 1
Mod_return = 1
Total_scans = 13

X_90_width = 13.01[us]
X_acq_time = 2.90717696[s]
X_angle = 4[deg]
X_attn = 41[dB]
X_pulse = 6.505[us]
IRF_mode = Off
Tri_mode = Off
Dante_presat = FALSE
Initial_wait = 1[s]
Relaxation_delay = 10[s]
Repetition_delay = 12.90717696[s]
Temp_get = 23.5[dc]
  
```

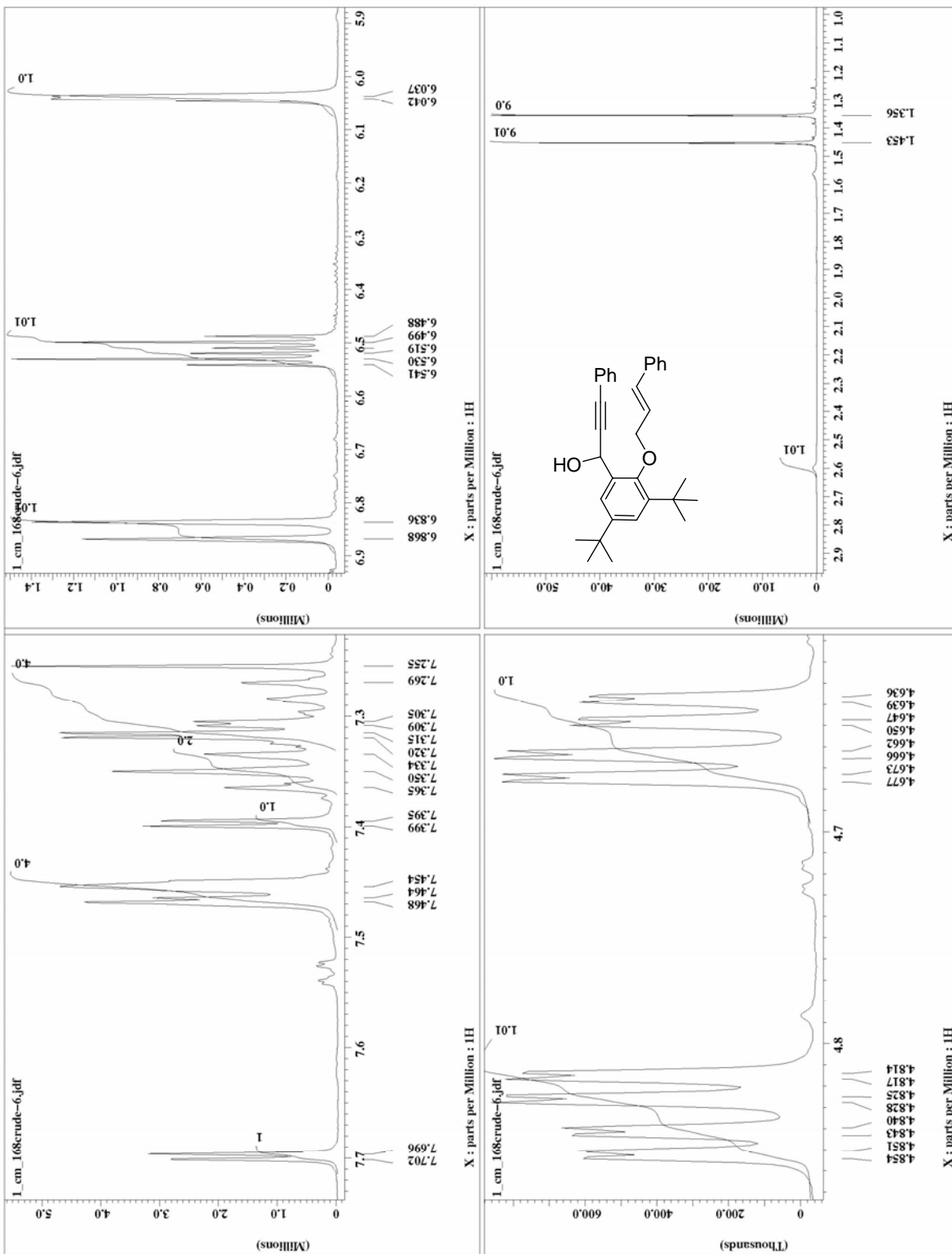


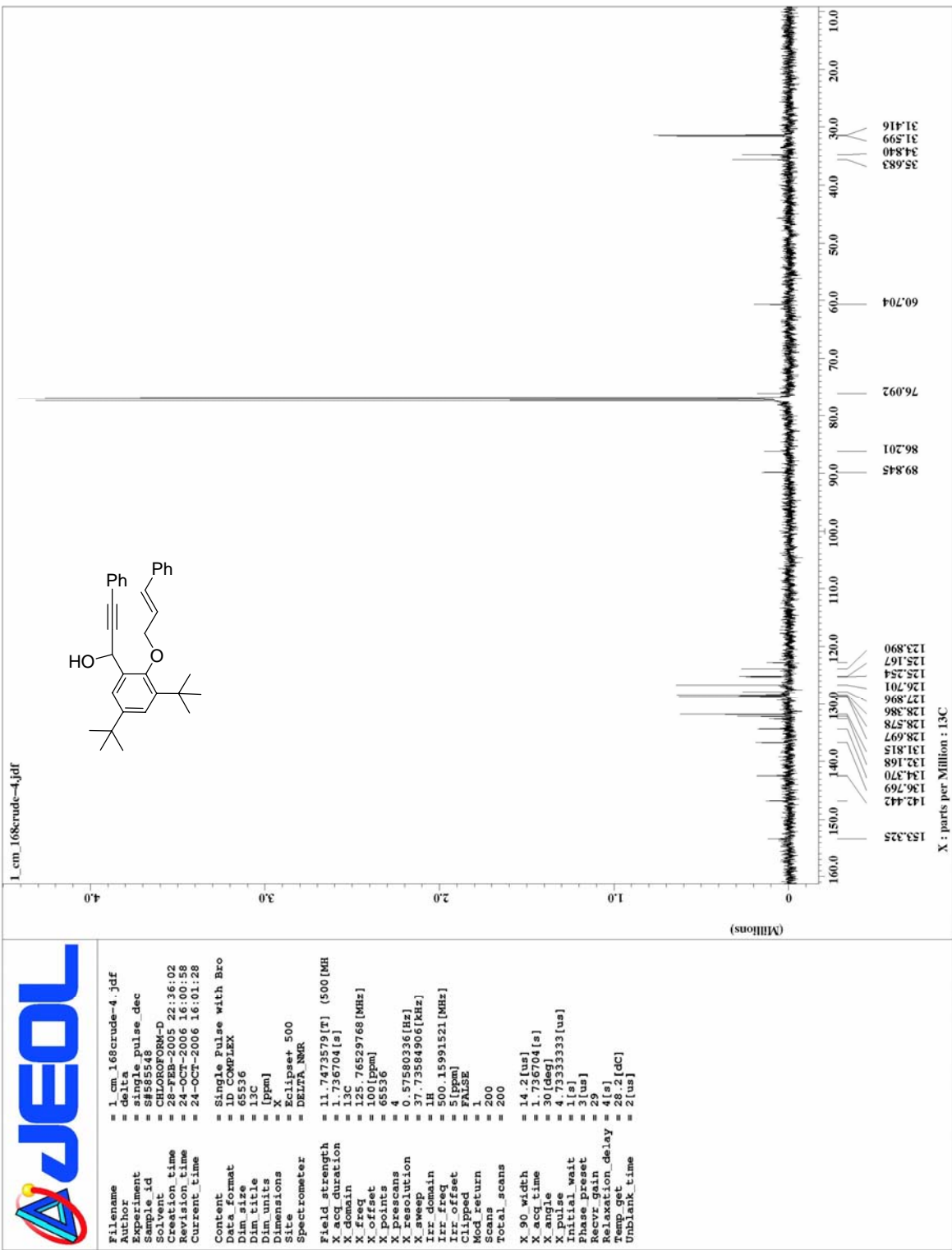
APPENDIX 20

^1H and ^{13}C NMR SPECTRA OF

4,6-Di-*tert*-butyl-2-(1-hydroxy-3-phenyl-2-propynyl)

-1-(-3-phenyl-2-propenyloxy) benzene (22b)



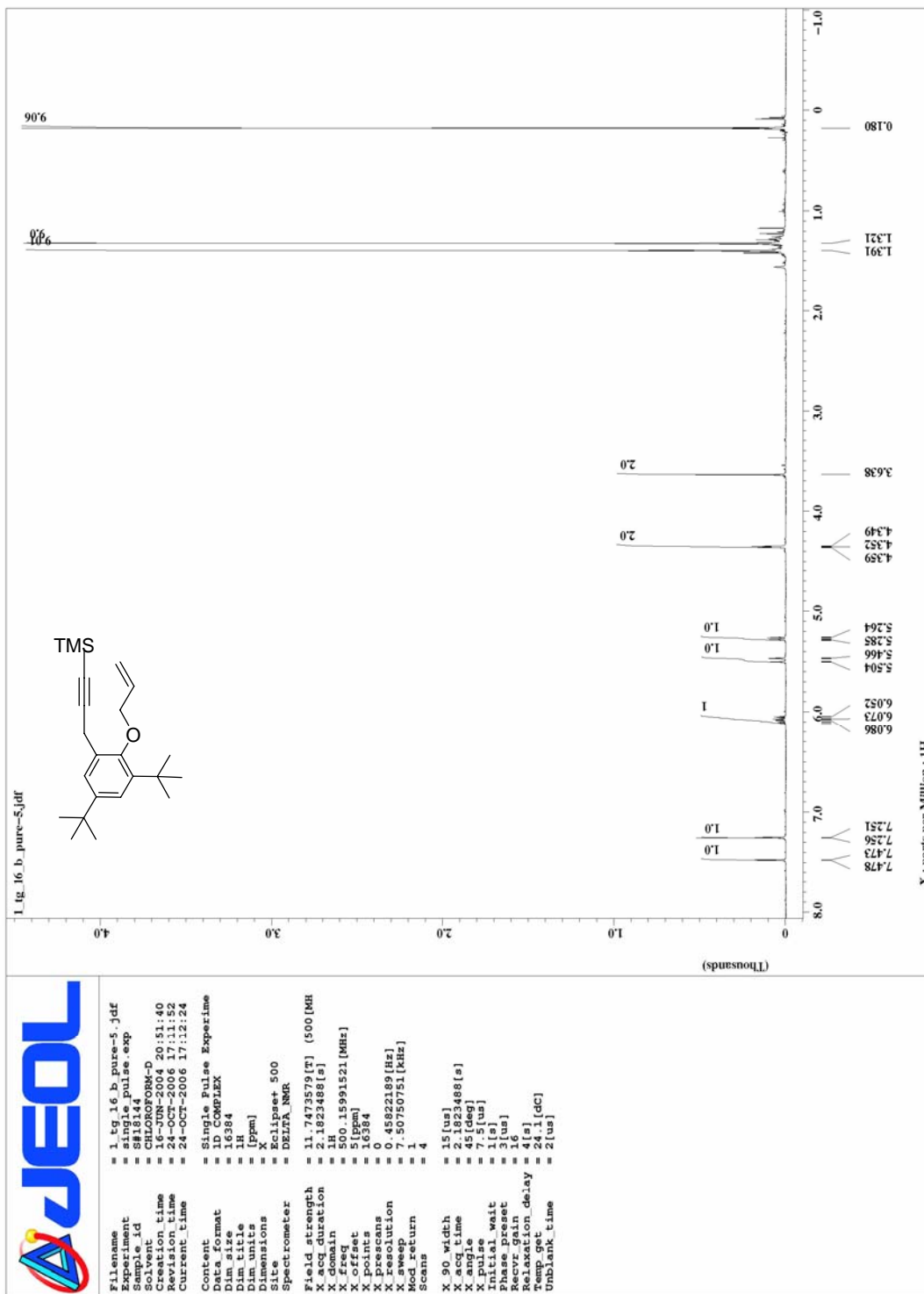


APPENDIX 21

¹H and ¹³C NMR SPECTRA OF

4,6-Di-*tert*-butyl-2-(3-trimethylsilyl-2-propynyl)

-(-2-propenyloxy) benzene (26a)





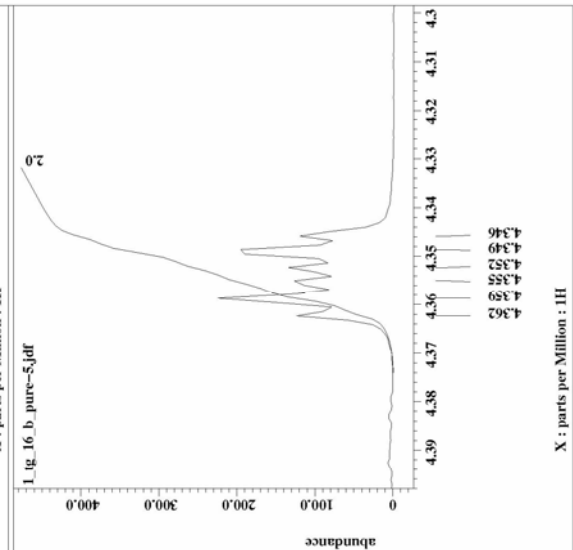
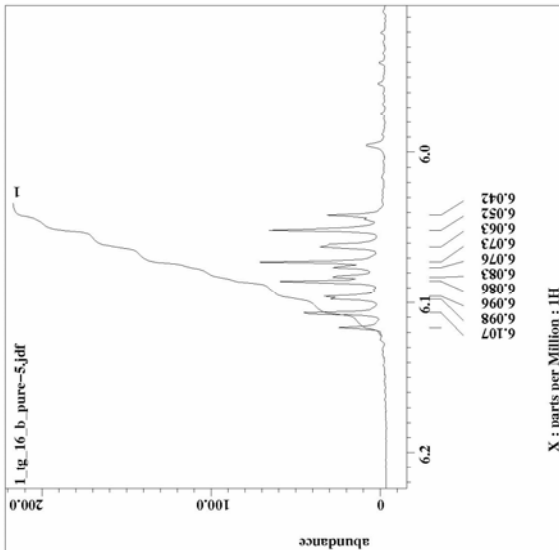
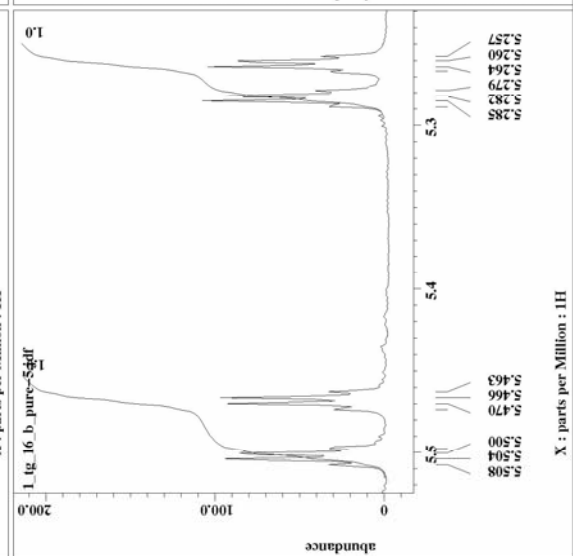
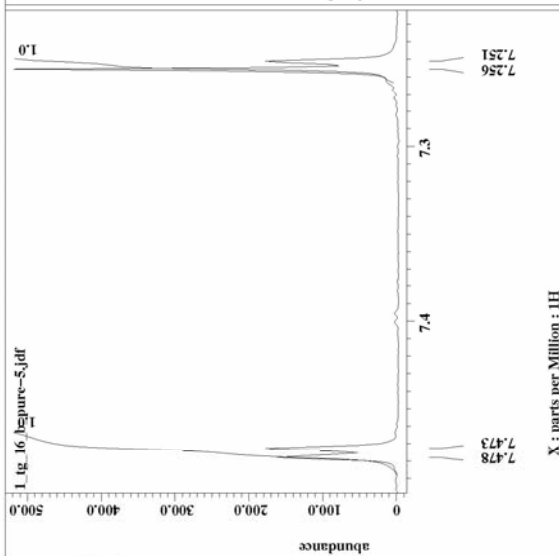
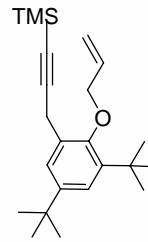
```

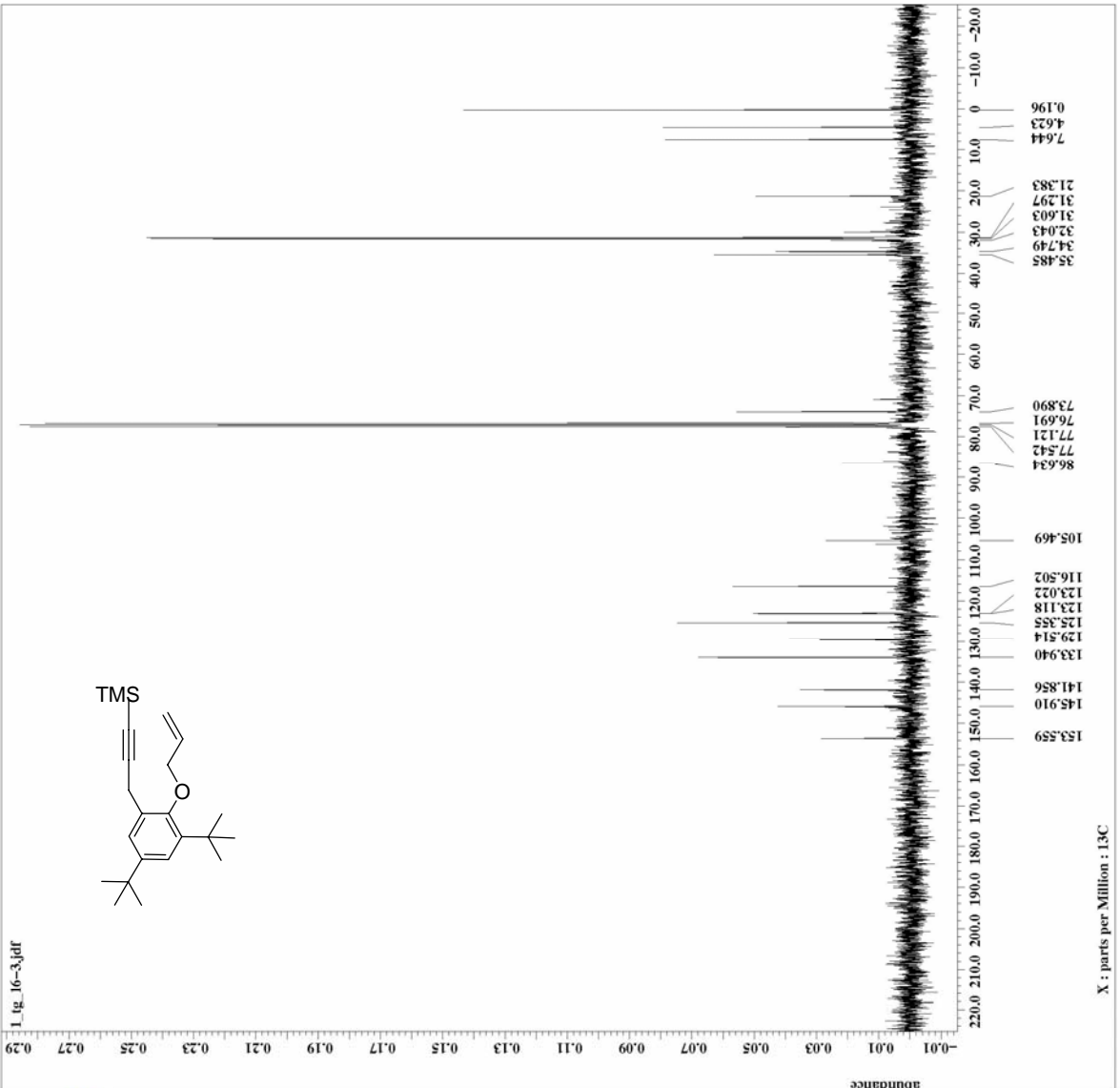
Filename = 1_tg_16_b_pure-5_.jdf
Experiment = 1_tg_16_b_pure-5_.exp
Sample_id = S81814
Solvent = CHLOROFORM-D
Creation_time = 16-JUN-2004 20:51:40
Revision_time = 24-OCT-2006 17:11:52
Current_time = 24-OCT-2006 17:14:02

Content = Single Pulse Exptime
Date_acqmat = 1D-COMPLEX
Dim_size = 16384
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Site = Eclipset 500
Spectrometer = DELTA_NMR

Field strength = 11.7473579[T] (500[MH]
X_acq duration = 2.1823488[s]
X_domain = 1H
X_freq = 500.15991521[MHz]
X_offset = 5[ppm]
X_points = 16384
X_prescans = 0
X_resolution = 0.45822189[Hz]
X_sweep = 7.50750751[kHz]
Mod return = 1
Scans = 4

X_90_width = 15[us]
X_acq_time = 2.1823488[s]
X_delay = 2.50[us]
X_pulse = 7.5[us]
X_pulse_prog = 1[us]
Initial wait = 3[us]
Phase preset = 16
Recvr_gain = 16
Relaxation_delay = 4[s]
Temp_get = 24.1[dc]
Unblank_time = 2[us]
  
```





JEOL
 1_fg_16-3.jdf
 Author = delta
 Experiment = single_pulse_dec
 Sample_id = CH2OFORM-D
 Creation_time = 27-SEP-2006 17:19:29
 Revision_time = 25-JAN-2007 15:02:32
 Current_time = 25-JAN-2007 15:02:56
 Content = single pulse decouple
 Data_format = ID COMPLEX
 Dim_size = 26214
 Dim_title = 13C
 Dim_units = [ppm]
 Dimensions = 1
 Site = ECX 300
 Spectrometer = DELTA2_NMR
 Field_strength = 7.0586013[T] (300[MHz])
 X_acq_duration = 1.38412032[s]
 X_domain = 13C
 X_freq = 75.56823426[MHz]
 X_offset = 100[ppm]
 X_points = 32768
 X_prescans = 6
 X_resolution = 6.72248054[Hz]
 X_sweep = 23.67424242[kHz]
 Irr_domain = 1H
 Irr_freq = 300.52965592[MHz]
 Irr_offset = 5[ppm]
 Clipped = FALSE
 Mod_return = 1
 Scans = 112
 Total_scans = 112
 X_90_width = 9.75[us]
 X_acq_time = 1.38412032[s]
 X_angle = 30[deg]
 X_atn = 8[db]
 X_pulse = 3.25[us]
 Irr_atn_dec = 25[db]
 Irr_atn_hoe = 25[db]
 Irr_noise = WALTZ
 Decoupling = TRUE
 Initial_wait = 1[s]
 Noe_time = 3[s]
 Recvr_gain = 50
 Relaxation_delay = 3[s]
 Repetition_time = 4.38412032[s]
 Temp_get = 23[dc]

APPENDIX 22

¹H and ¹³C NMR SPECTRA OF

4,6-Di-*tert*-butyl-2-(-3-phenyl-2-propynyl)-2-propenyloxybenzene (26b)



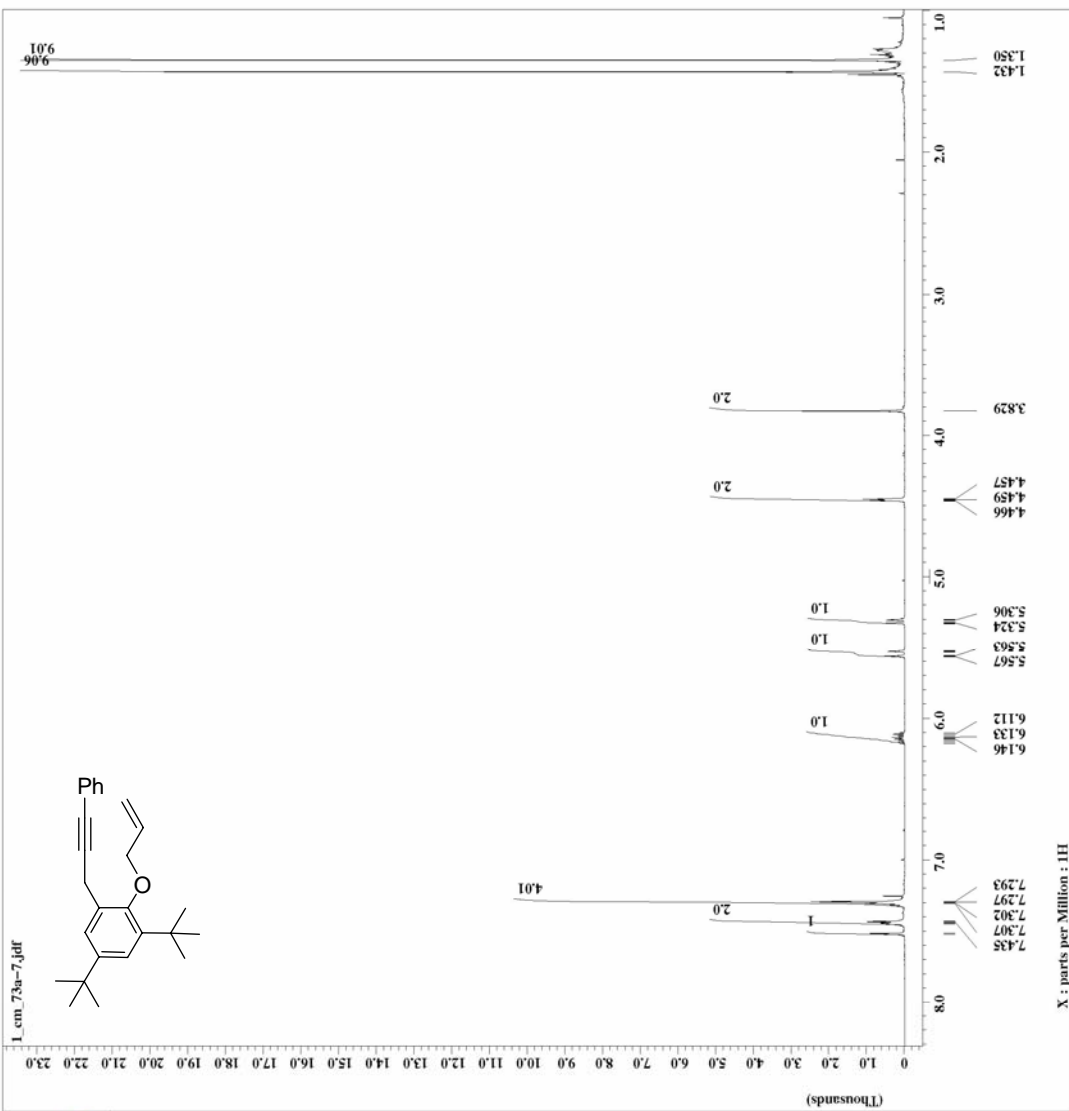
```

Filename      = 1_cm_73a-7.jdf
Experiment    = single_pulse.exp
Sample_id     = 8F151172
Date_ime     = 26-OCT-2006 17:22:32
Creation time = 26-OCT-2006 17:22:32
Revision time = 24-OCT-2006 17:46:49
Current time  = 24-OCT-2006 17:47:28

Content       = Single Pulse Experiment
Date_acq     = 26-OCT-2006
Dim size     = 16384
Dim title    = 1H
Dim units    = [ppm]
Dimensions   = X
Site         = Eclipret_500
Spectrometer = DMR4_NMR

Field strength = 11.7473579[T] (500[MH]
X.acq.duration = 2.1823488[s]
X.domain       = 1H
X.freq         = 500.15991521[MHz]
X.gate         = 1[us]
X.points       = 16384
X.prescans     = 0
X.prescans     = 0
X.resolution   = 0.45822185[Hz]
X.sweep        = 7.50750751[KHz]
Xod.return     = 32
Scans          = 32

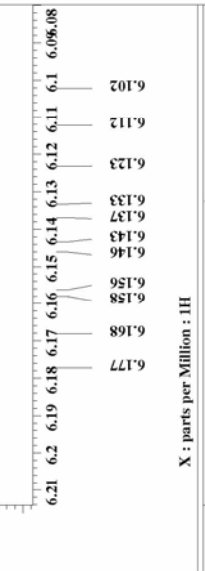
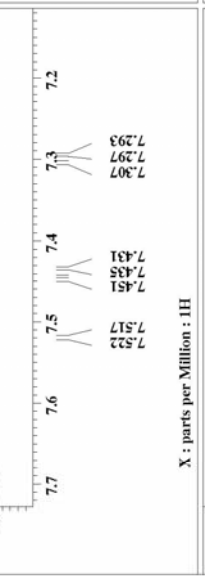
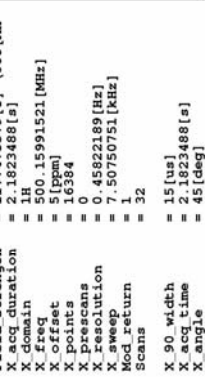
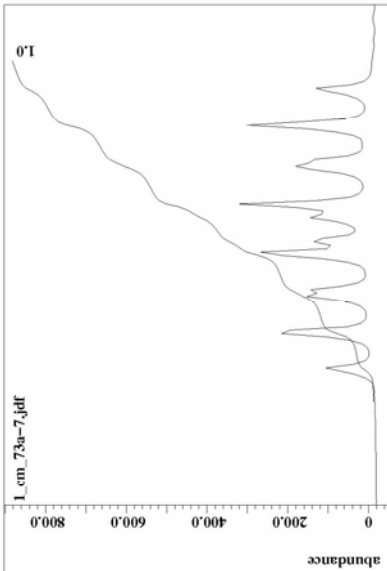
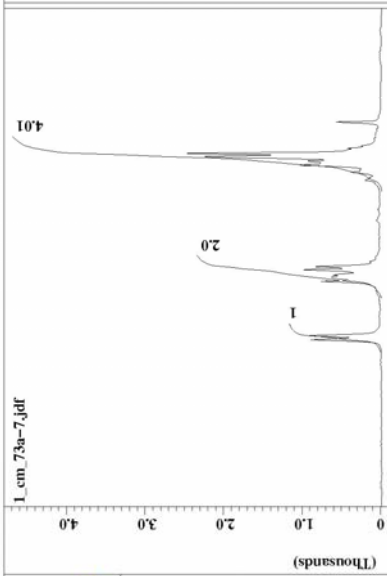
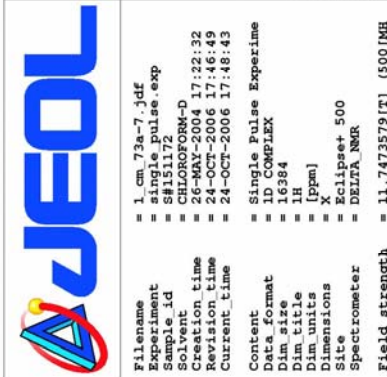
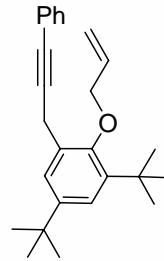
X.90.width     = 15[us]
X.acq.time     = 2.1823488[s]
X.angle        = 45[deg]
X.delay        = 1[us]
X.delay2       = 1[us]
Initial wait   = 1[s]
Phase preset   = 3[us]
Recvr_gain     = 13
Relaxation_delay = 4[s]
Temp.get       = 24[dc]
Onblank_time   = 2[us]
  
```





```

Filename = 1_cm_73a-7.jdf
Experiment = single pulse exp
Sample_id = S#151172
Solvent = CHLOROFORM-D
Creation_time = 26-MAY-2004 17:22:32
Revision_time = 24-OCT-2006 17:46:49
Current_time = 24-OCT-2006 17:48:43
Content = Single Pulse Experiment
Data_format = 1D_COMPLEX
Dim_size = 16384
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Site = Eclipse+ 500
Spectrometer = DELTA_NMR
Field_strength = 11.747379[T] (500[MH
X_duration = 2.1823488[s]
X_domain = 1H
X_freq = 500.15991521[MHz]
X_offset = 5[ppm]
X_points = 16384
X_prescans = 0
X_resolution = 0.45822189[Hz]
X_sweep = 7.50750751[kHz]
Mod_return = 1
Scans = 32
X_90_width = 15[us]
X_acq_time = 2.1823488[s]
X_angle = 45[deg]
X_pulse = 7.5[us]
Initial_wait = 1[s]
Phase_preset = 3[us]
Recvr_gain = 13
Relaxation_delay = 4[s]
Temp_get_time = 4[dc]
Unblank_time = 2[us]
  
```





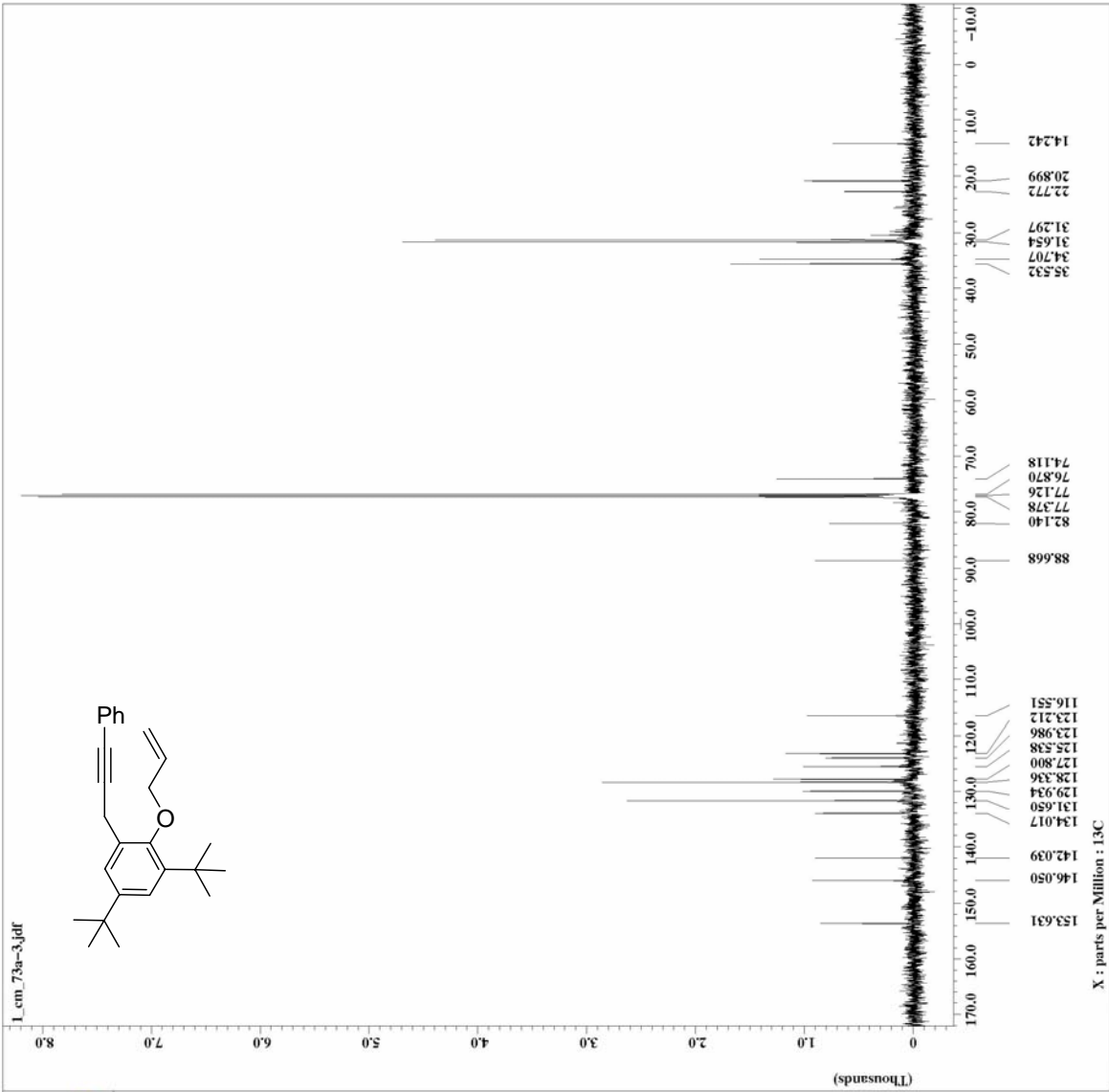
```

Filename      = 1_cm_73a-3.jdf
Experiment    = single_pulse_dec
Sample_id     = S#154168
Solvent       = CDCl3
Date_         = 26-MAY-2004 17:37:32
Collection   = 26-MAY-2004 17:37:32
Revision     = 24-OCT-2006 17:41:31
Current_time  = 24-OCT-2006 17:41:52

Content       = Single Pulse with Bro
Data_format  = ID COMPLEX
Data_size    = 65536
Dim_title    = 13C
Dim_units    = [ppm]
Dimensions   = X(ppm)
Site         = DELTA_500
Spectrometer = DELTA_NMR

Field_strength = 11.7473579[T] (500 [MH]
X_acq_duration = 1.736704[s]
X_domain       = 13C
X_freq         = 125.76529768 [MHz]
X_offset       = 600 [ppm]
X_resolution   = 65536
X_sweeps       = 4
X_prescans     = 4
X_resolution   = 0.57580336 [Hz]
X_sweep        = 37.73584906 [kHz]
Irr_domain     = 1H
Irr_freq       = 500.15991521 [MHz]
Irr_offset     = 5 [ppm]
Mod_return     = 1
Scans          = 121

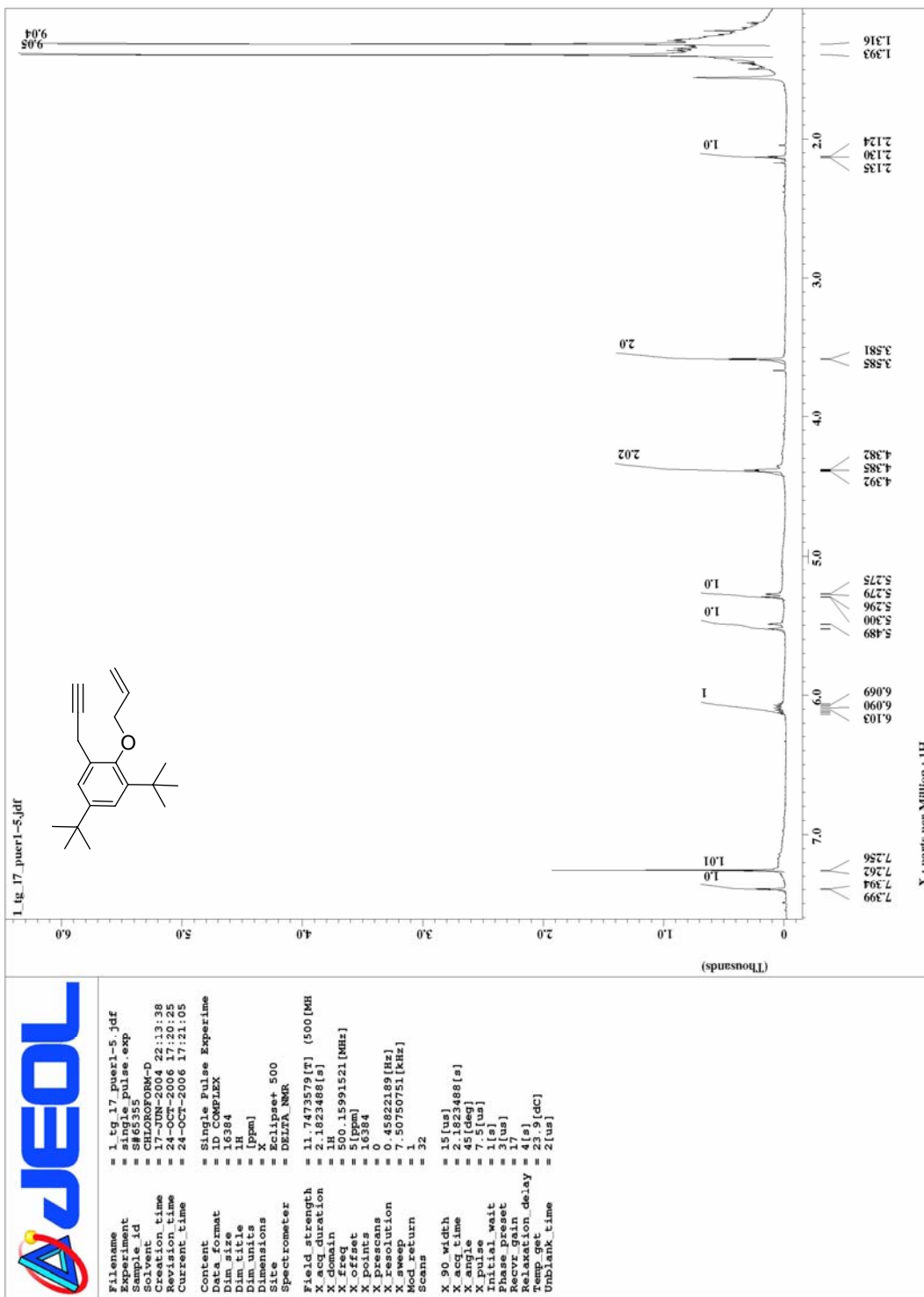
X_90_width    = 14 [us]
X_acq_time     = 1.736704 [s]
X_angle        = 30 [deg]
X_pulse        = 4.66666667 [us]
Initial_wait   = 1 [s]
Phase_preset   = 3 [us]
Recvr_gain     = 29
Relaxation_delay = 4 [s]
Temp_get       = 24.6 [dc]
Unblank_time   = 2 [us]
  
```

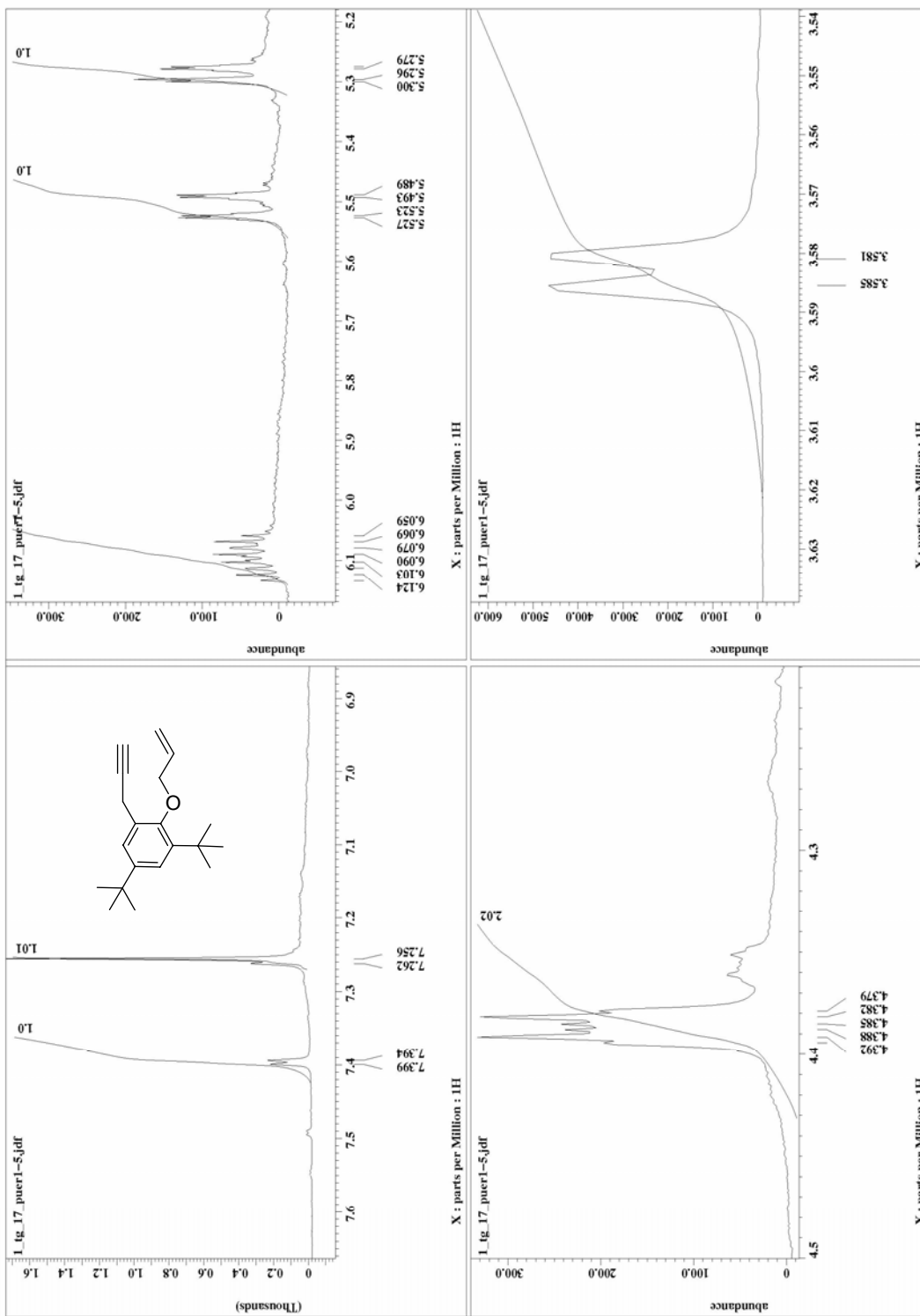


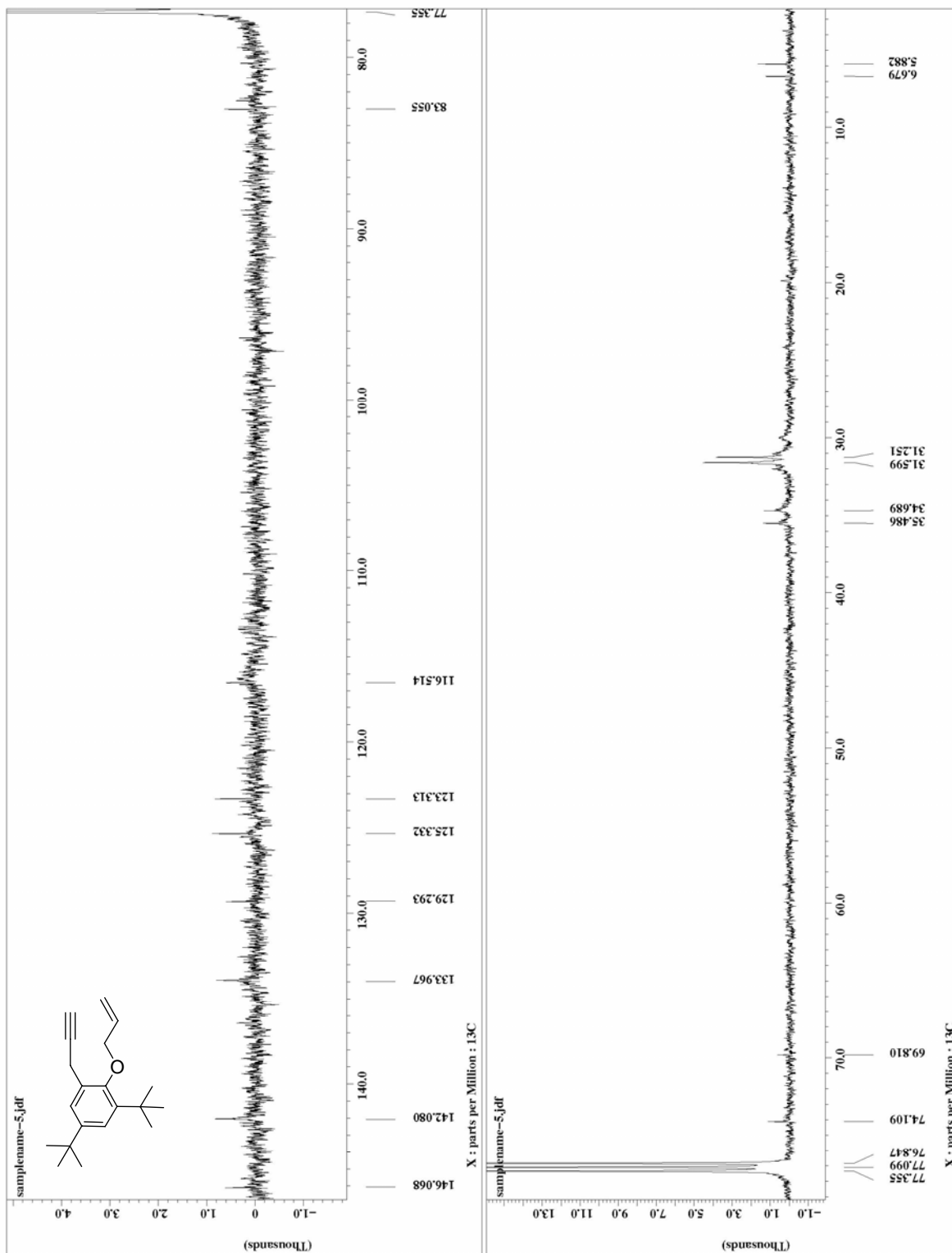
APPENDIX 23

^1H and ^{13}C NMR SPECTRA OF

4,6-Di-*tert*-butyl-2-prop-2-ynyl-(2-propenyloxy)benzene (26a)







APPENDIX 24

¹H and ¹³C NMR SPECTRA OF

**6,8-Di-*tert*-butyl-1-trimethylsilyl-4,4a-dihydro
-3*H*,10*H*-5-oxabenzof]azulen-2-one (23)**

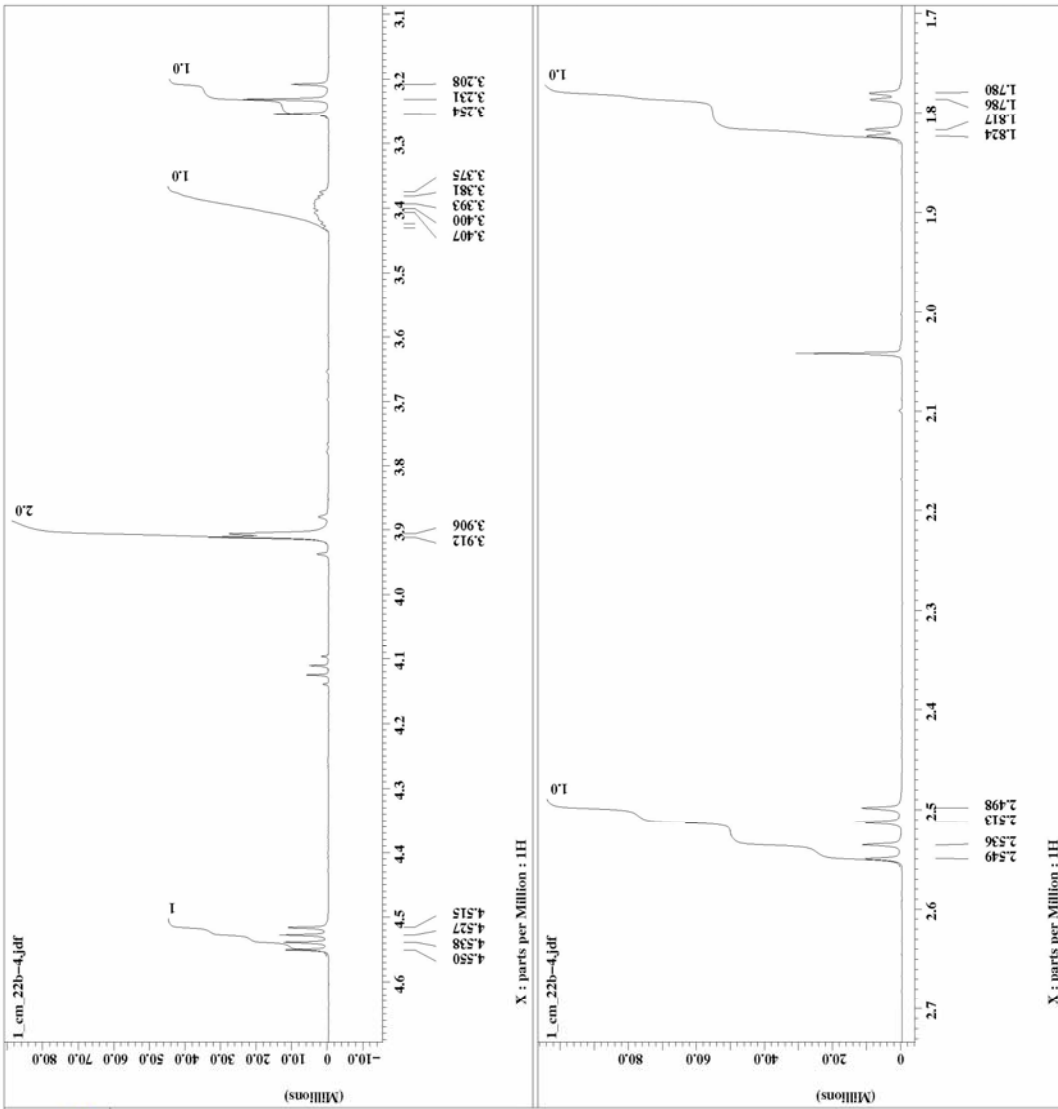
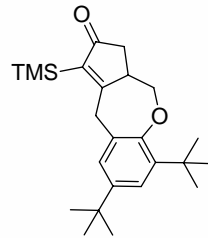


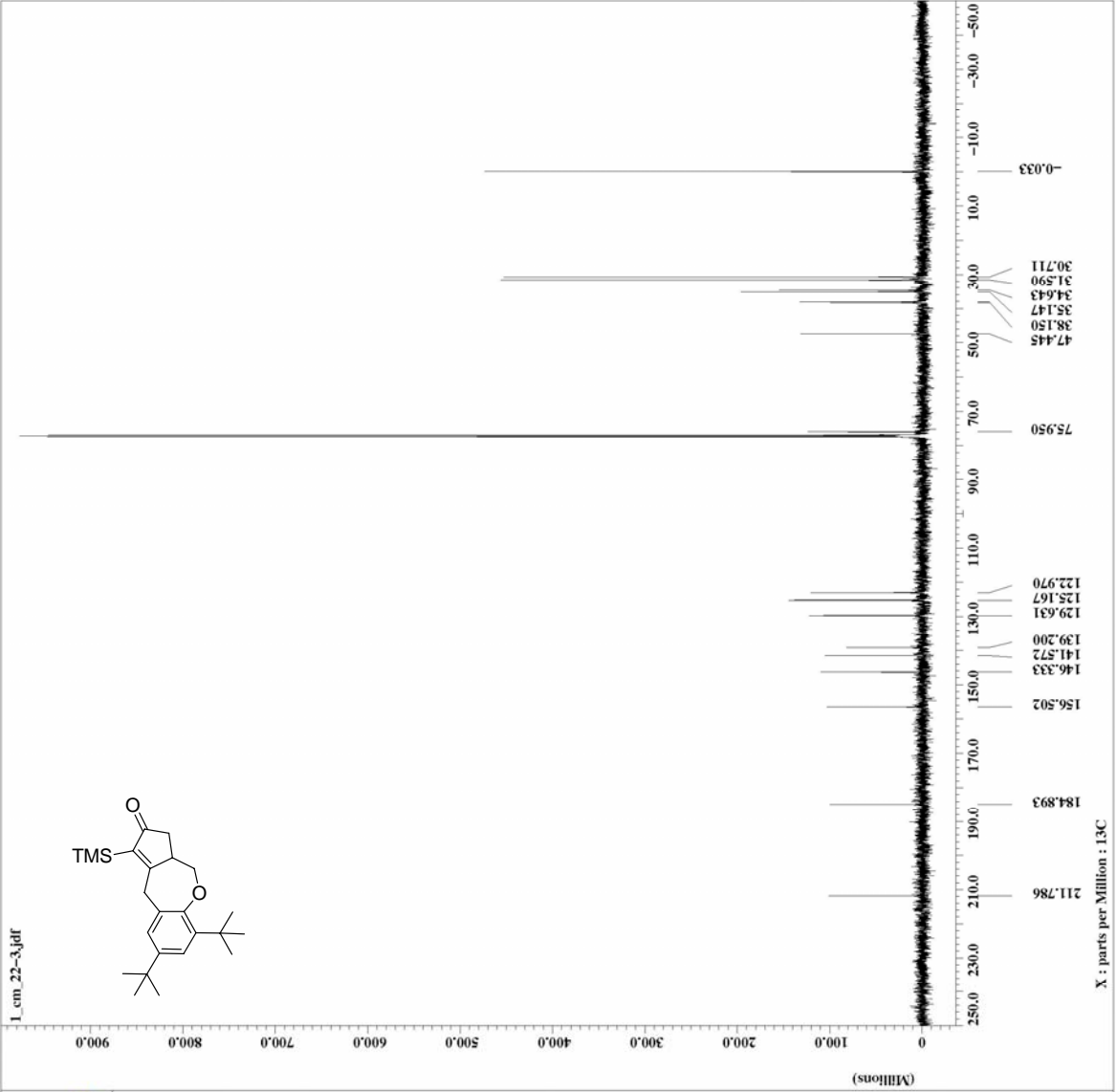
```

Filename      = 1_cm_22b-4.jdf
Experiment    = single_pulse_exp
Sample Id     = CHC7000
Sample Name   = CHC7000
Creation time  = 31-OCT-2002 19:05:32
Revision time = 9-FEB-2006 23:06:22
Current time  = 9-FEB-2006 23:08:49
Content       = Single Pulse Experiment
Data format   = 1D_COMPLEX
Dim size      = 16384
Dim title     = 1H
Dim units     = [ppm]
Dimensions    = X:Klipsat 500
Spectrometer  = DELTA_NMR

Field strength = 11.747375[T] (500 [MH]
X_acq duration = 2.182348[s]
X_solv         = CDCl3
X_freq         = 500.15991521 [MHz]
X_offset       = 5 [ppm]
X_points       = 16384
X_prescans     = 0
X_resolution   = 0.45820189 [Hz]
X_resolution   = 7.50750751 [kHz]
Mod return    = 1
Scans          = 32

X_90_width    = 15 [us]
X_acq_time     = 1.4888[s]
X_angle        = 45 [deg]
X_pulprg       = zgpg30
X_pulse        = 7.5 [us]
Initial wait   = 1 [s]
Phase preset   = 3 [us]
Recvr_gain     = 4 [s]
Refine_gain    = 22.7 [dc]
Temp_get       = 22.7 [dc]
Unblank time   = 2 [us]
  
```





1_cm_22-3.jdf

JEOL

```

Filename = 1_cm_22-3.jdf
Experiment = single_pulse_dec
Sample_id = CH76689M-D
Date_ime = 22-JUN-2004 23:25:18
Creation time = 9-FEB-2006 23:09:40
Revision time = 9-FEB-2006 23:10:10
Current_time = 9-FEB-2006 23:10:10

Content = Single Pulse with Bro
Data_format = 1D COMPLEX
Dim_size = 65536
Dim_title = 13C
Dim_units = Y[ppm]
Dimensions = Y
Site = Eclipse+ 500
Spectrometer = DELTA_NMR

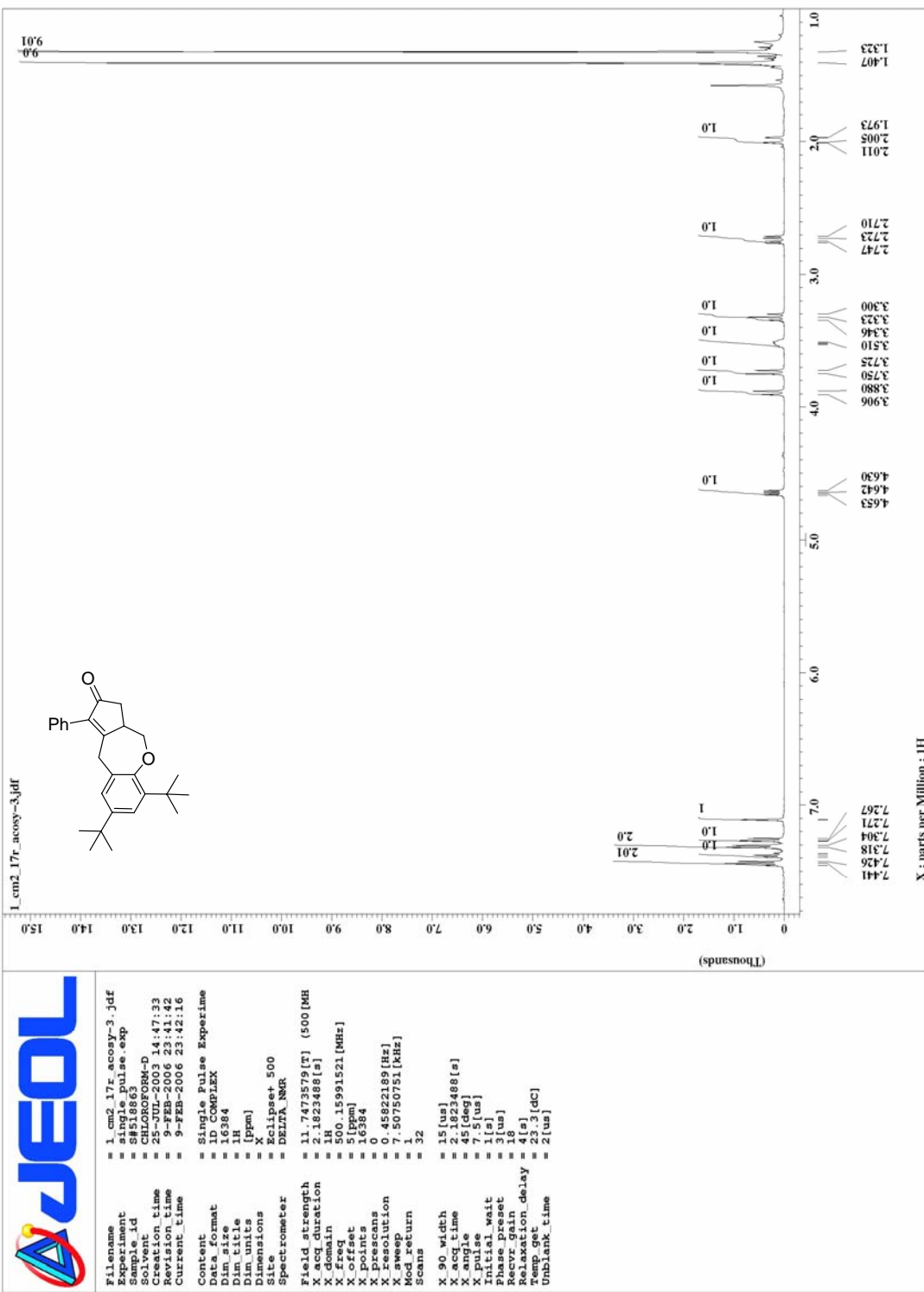
Field_strength = 11.7473579[T] (500[MH
X_acq_duration = 1.736704[s]
X_domain = 13C
X_freq = 125.76529768[MHz]
X_offset = 100[ppm]
X_points = 4
X_resolution = 0.57580336[Hz]
X_sweep = 37.73584906[KHz]
Irr_domain = 1H
Irr_freq = 500.15991521[MHz]
Irr_offset = 5[ppm]
Mod_return = 1
Scans = 214

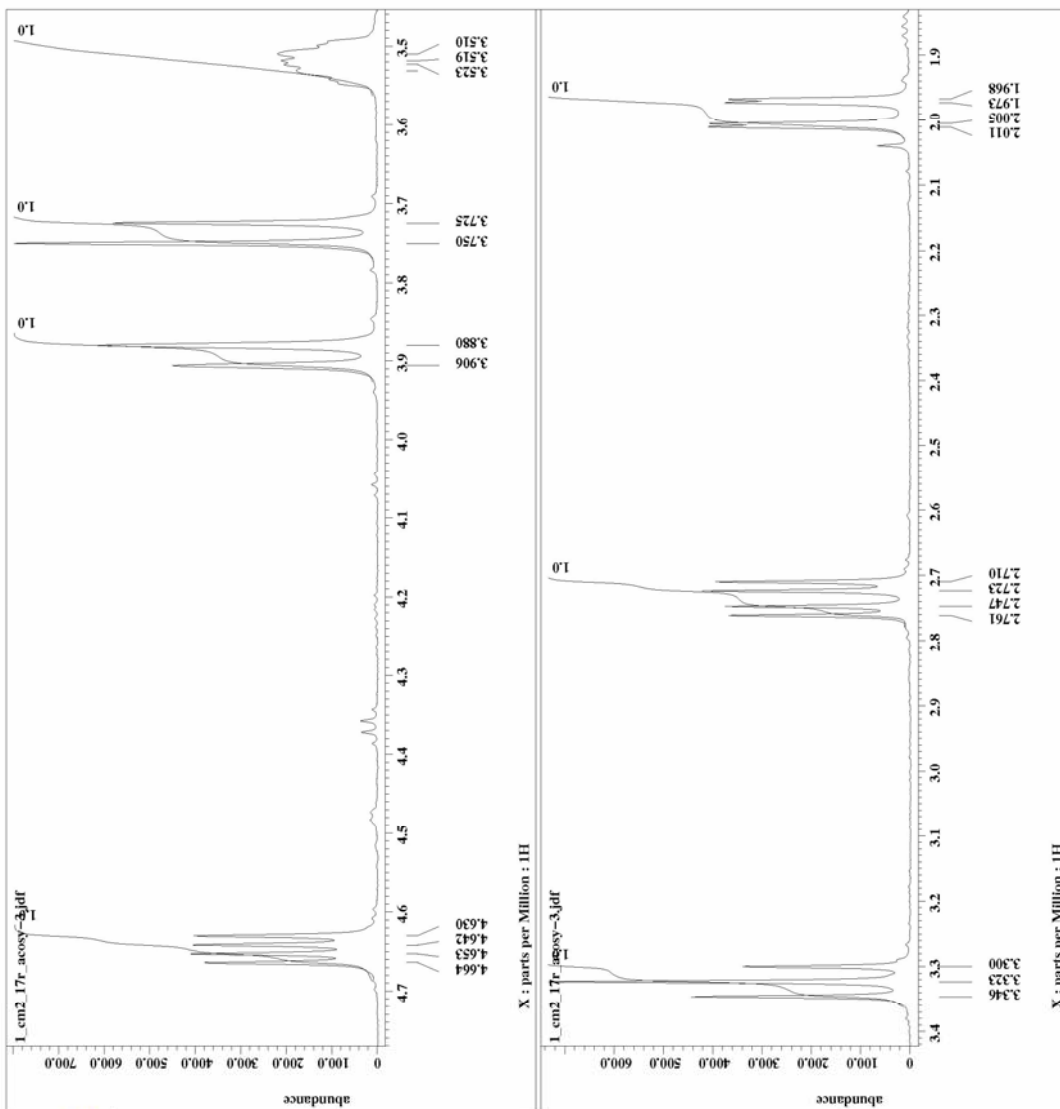
X_90_width = 14[us]
X_acq_time = 1.736704[s]
X_angle = 30[deg]
X_pulse = 4.66666667[us]
Initial_wait = 1[s]
Phase_preset = 3[us]
Recvr_gain = 29
Relaxation_delay = 4[s]
Temp_get = 24.2[degC]
Unblank_time = 2[us]
  
```



APPENDIX 25

^1H and ^{13}C NMR SPECTRA OF

6,8-Di-*tert*-butyl-1-phenyl-4,4a-dihydro-3*H*,10*H*-5-oxabenzof]azulen-2-one (24)







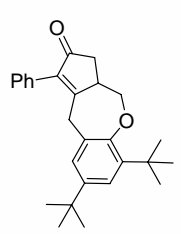
```

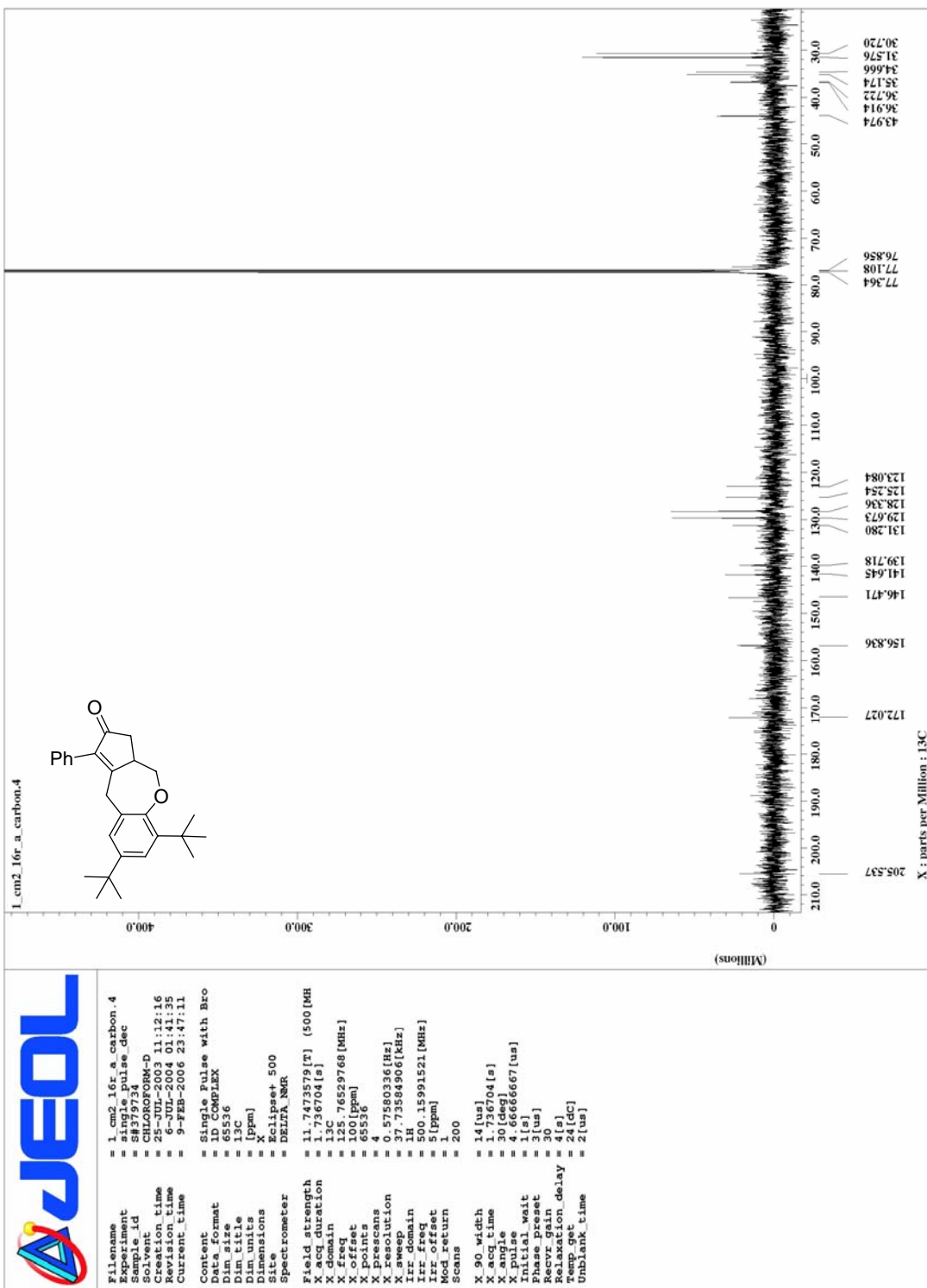
Filename = 1_cm2_17r_acosy-3.jdf
Experiment = single_pulse_exp
Sample_Id = 8F18625
Sample_Name = 8F18625BM-D
Creation_time = 25-JUL-2003 14:47:33
Revision_time = 9-FEB-2006 23:41:42
Current_time = 9-FEB-2006 23:42:32
Content = Single_Pulse Experiment
Data_format = ID_COMPLEX
Dim_size = 16384
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Pulseprg = zgpg30
Spectrometer = DELTA_NMR

Field_strength = 11.747375[T] (500[MH
X_acq_duration = 2.182348[s]
X_domain = 10
X_freq = 500.15991521[MHz]
X_offset = 5[ppm]
X_points = 16384
X_prescans = 0
X_resolution = 0.4582189[Hz]
X_sweep = 1.30750751[KHz]
Mod_return = 1
Scans = 32

X_90_width = 15[us]
X_acq_time = 45[deg]48[s]
X_delay = 7.5[us]
X_pulse = 7.5[us]
Initial_wait = 1[s]
Phase_preset = 3[us]
Recvr_gain = 18
Relaxation_delay = 23.3[dc]
Temp_get = 23.3[dc]
Unblank_time = 2[us]

```







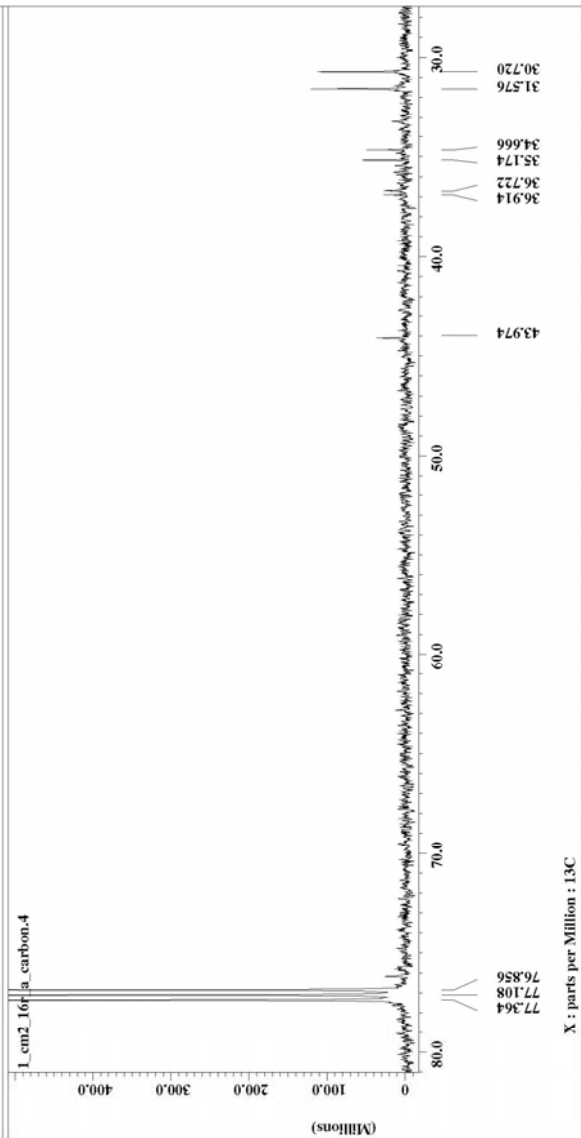
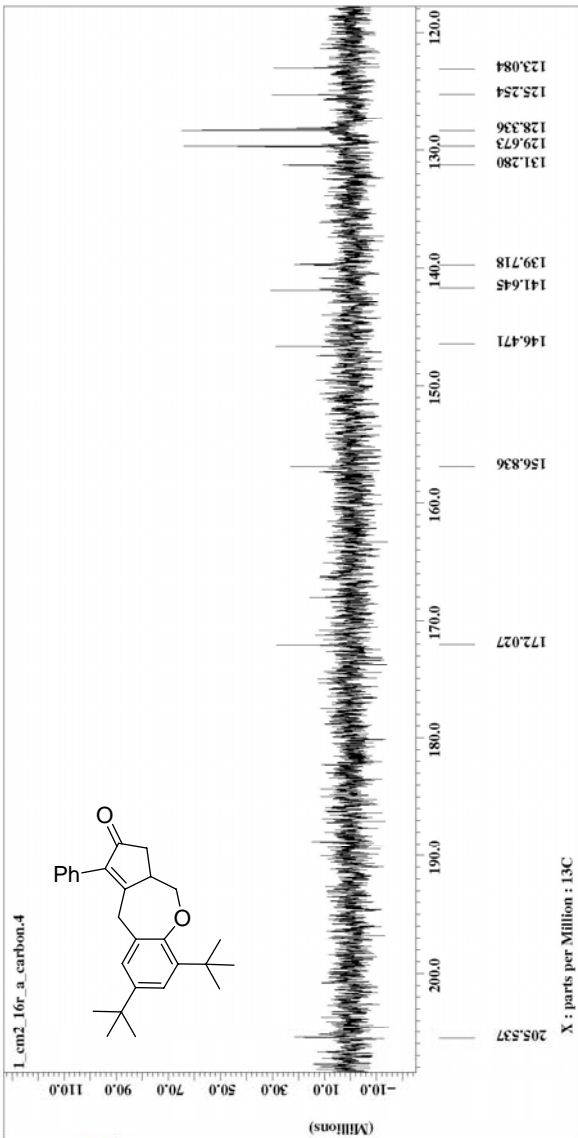
```

Filename = 1_cm2_16r_a_carbon.4
Experiment = single_pulse_dec
Sample_id = S#379734
Solvent = CHLOROFORM-D
Creation time = 25-JUL-2003 11:12:16
Revision time = 6-JUL-2004 01:41:35
Current time = 9-FEB-2006 23:47:32

Content = Single Pulse with Bro
Data format = 1D COMPLEX
Data size = 65536
Dim size = 13C
Dim title = 13C
Dim units = [ppm]
Dimensions = X
Site = Eclipse+ 500
Spectrometer = DELTA_NMR

Field strength = 11.7473579 [T] (500 [MH]
X_acq duration = 1.736704 [s]
X_domain = 13C
X_freq = 125.76529768 [MHz]
X_offset = 100 [ppm]
X_points = 65536
X_prescans = 4
X_resolution = 0.57560336 [Hz]
X_sweep = 14.73584906 [kHz]
T1_rho = 1.00 [s]
T1_rho_gain = 500.15991521 [MHz]
Irr_offset = 5 [ppm]
Mod return = 1
Scans = 200

X_90_width = 14 [us]
X_acq_time = 1.736704 [s]
X_angle = 40 [deg]
X_cp = 4.6866667 [us]
Initial wait = 1 [s]
Phase preset = 3 [us]
Recvr_gain = 30
Relaxation delay = 4 [s]
Temp_get = 24 [dc]
Unblank_time = 2 [us]
  
```

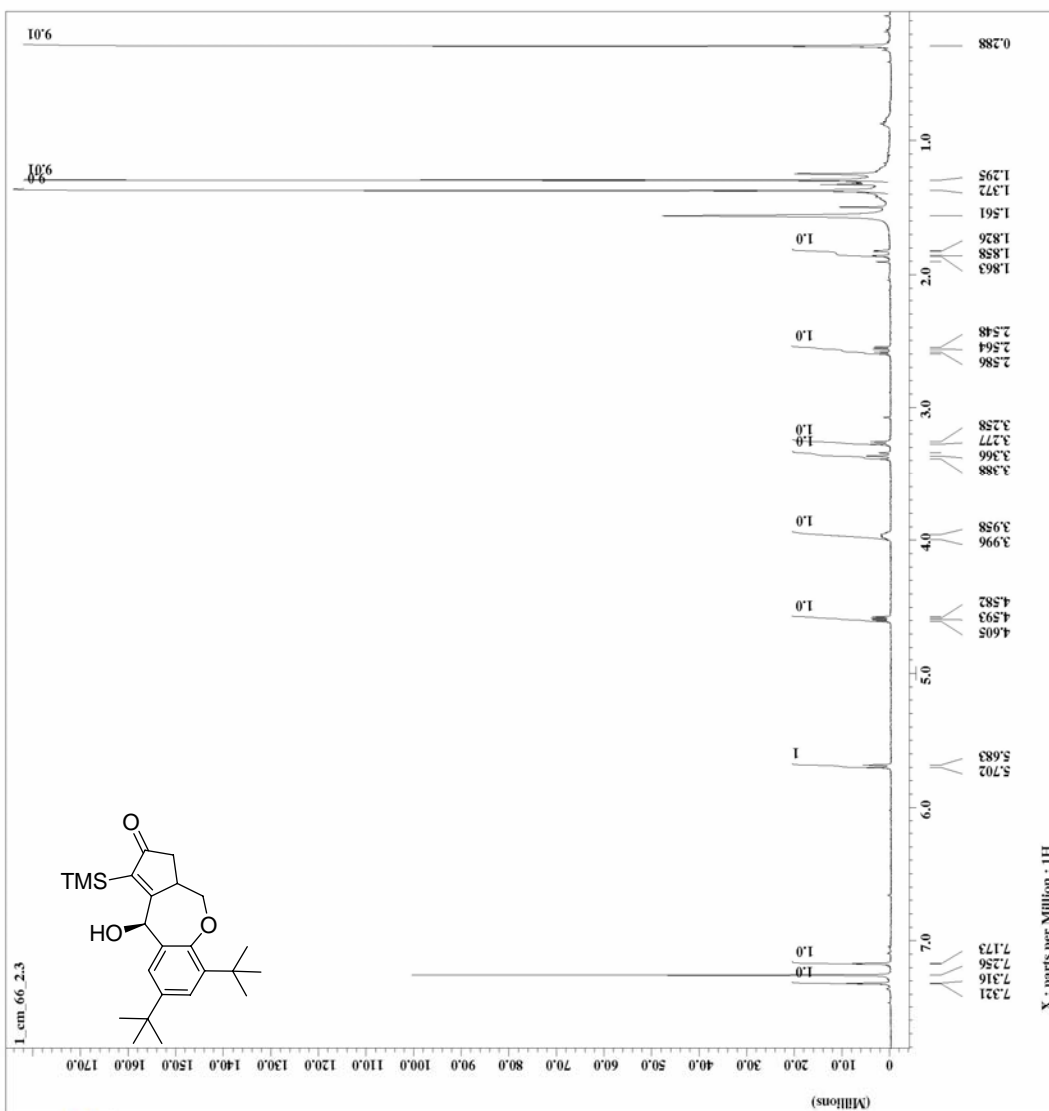


APPENDIX 26

¹H and ¹³C NMR SPECTRA OF

6,8-Di-*tert*-butyl-10-hydroxy-1-trimethylsilyl-4,4a-dihydro

-3*H*,10*H*-5-oxabenzof] azulen-2-one (28)



```

Filename      = 1_cm_66_2_3
Experiment    = single_pulse_exp
Sample       = 1
Solvent      = CHLOROFORM-D
Creation time = 20-JUL-2004 21:19:15
Revision time = 27-JUL-2004 00:44:44
Current time  = 9-FEB-2006 22:18:42

Content      = Single Pulse Experiment
Data format  = 1D COMPLEX
Dim size     = 16384
Dim title    = 1H
Dim units    = [ppm]
Dimensions   = 
Site        = Eclipse+ 500
Spectrometer = DELTA_NMR

Field strength = 11.7473579[T] (500[MH
Acquisition   = 18.623468[s]
X domain      = 
X freq        = 500.15991521[MHz]
X offset      = 5[ppm]
X points      = 16384
X prescan    = 0
X resolution  = 0.45822189[Hz]
X sweep       = 7.50750751[KHz]
Mod return    = 1
Scans         = 32
X 90 width   = 15[us]
X acq time    = 2.1823488[s]
X angle       = 45[deg]
X pulse       = 7.5[us]
Initial wait  = 1[s]
Purge delay   = 23[us]
Recvr Gain    = 23
Relaxation delay = 1[s]
Temp_get      = 23.7[dc]
Unblank time  = 2[us]
  
```


APPENDIX 27

¹H and ¹³C NMR SPECTRA OF

6,8-Di-*tert*-butyl-10-hydroxy-1-phenyl-4,4a-dihydro

-3*H*,10*H*-5-oxabenzof] azulen-2-one (29)



```

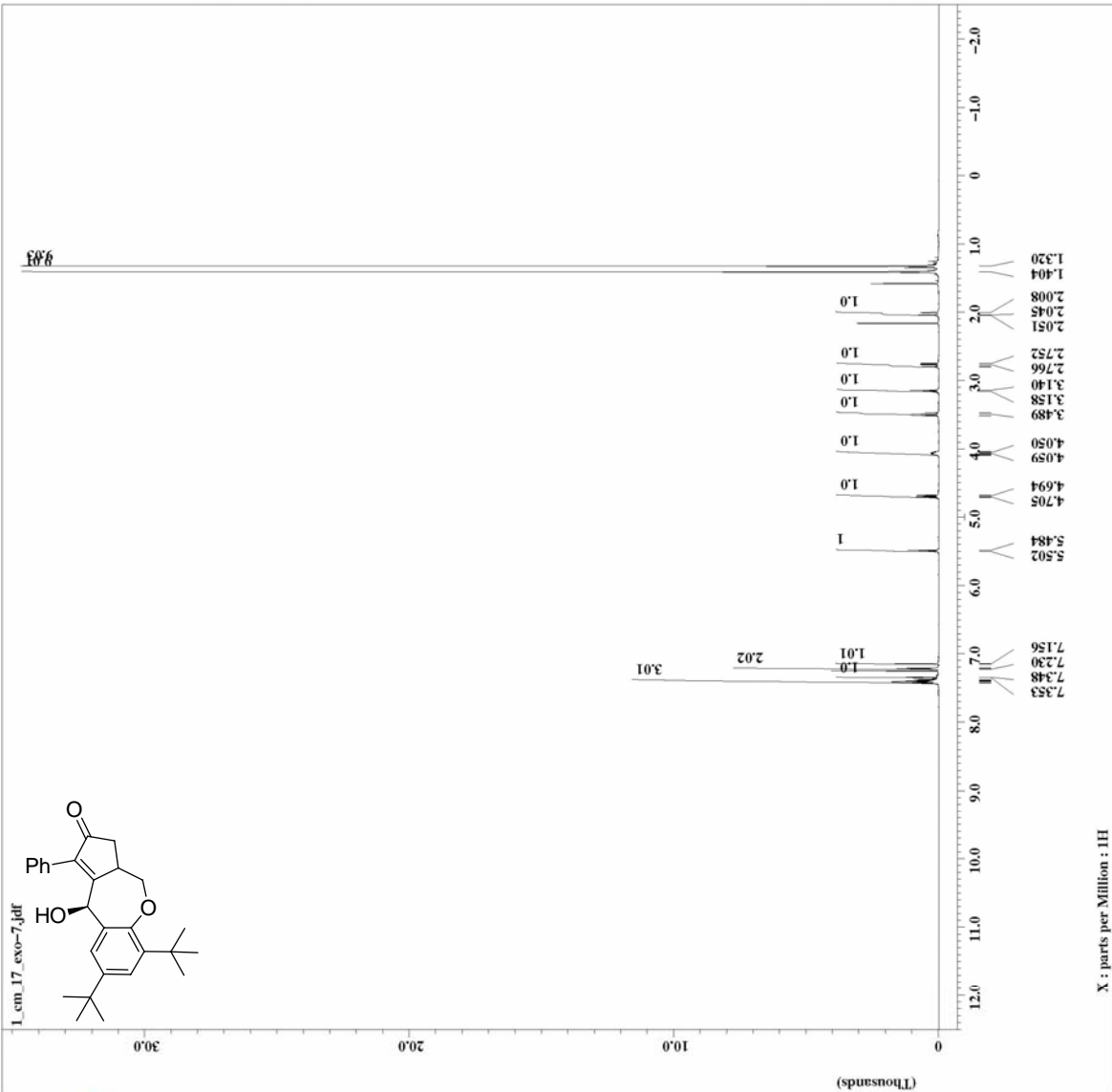
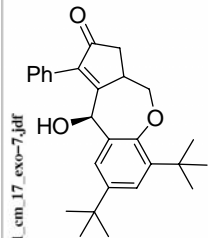
Filename = 1_cm_17_exo-7.jdf
Experiment = single pulse.exp
Sample_id = S#840484
Solvent = CHLOROFORM-D
Creation_time = 1-OCT-2004 20:50:50
Revision_time = 24-OCT-2006 18:50:15
Current_time = 24-OCT-2006 18:50:42

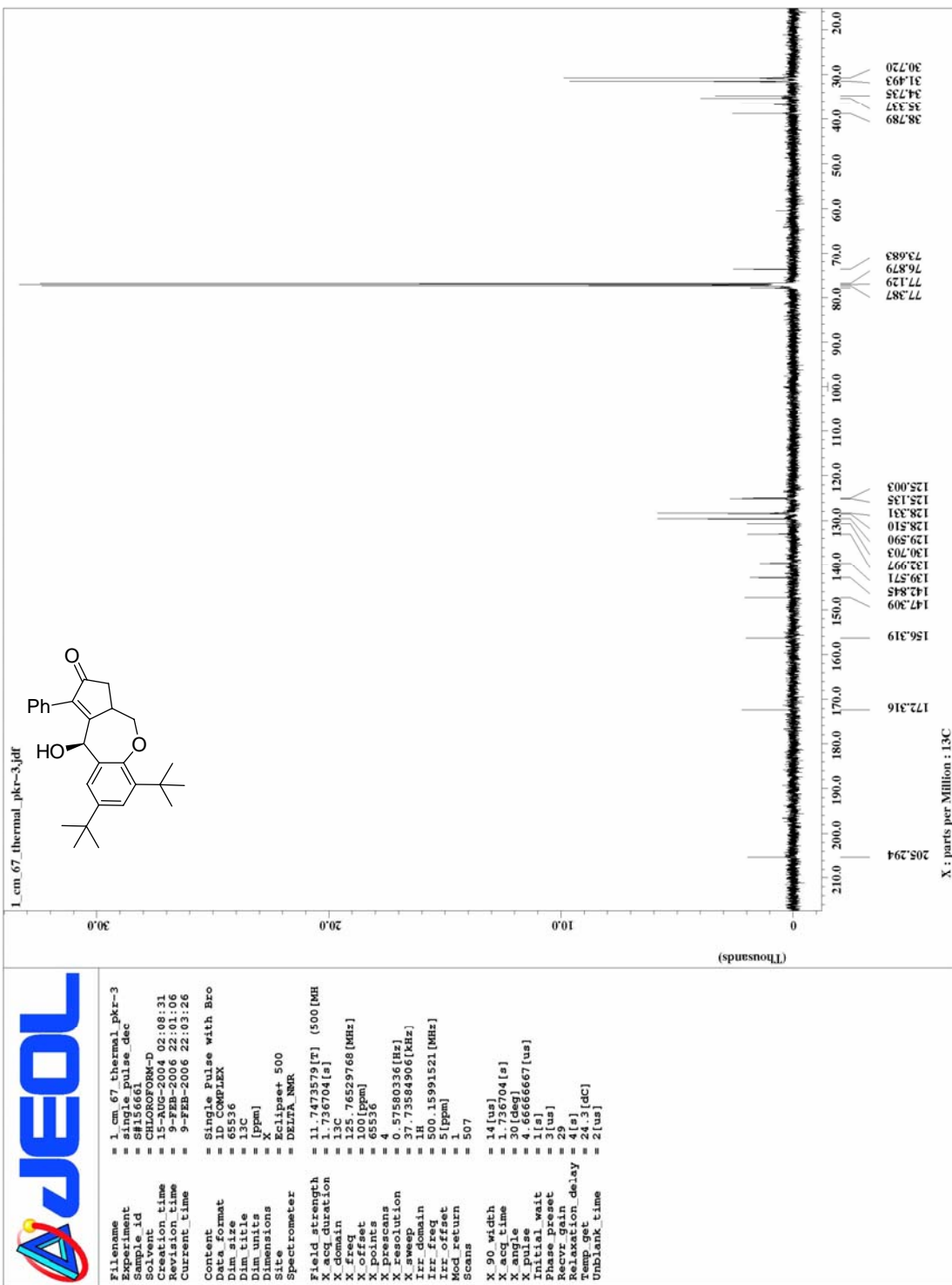
Content = Single Pulse Experiment
Det_format = 1D COMPLEX
Dir_size = 16384
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Site = Eclipse+ 500
Spectrometer = DELTA_NMR

Field_strength = 11.7473879[T] (500[MH]
X_acq_duration = 1.1823488[s]
X_freq = 500.15991521[MHz]
X_offset = 5[ppm]
X_points = 16384
X_prescans = 0
X_resolution = 0.45822189[Hz]
X_sweep = 7.50750751[kHz]
Mod_return = 1
Scans = 32

X_90_width = 15[us]
X_acq_time = 2.1823488[s]
X_angle = 45[deg]
X_pulse = 7.5[us]
Initial_wait = 1[s]
Phase_preset = 3[us]
Recvr_gain = 19
Relaxation_delay = 1[s]
Temp_get = 23.3[dc]
Unblank_time = 2[us]

```







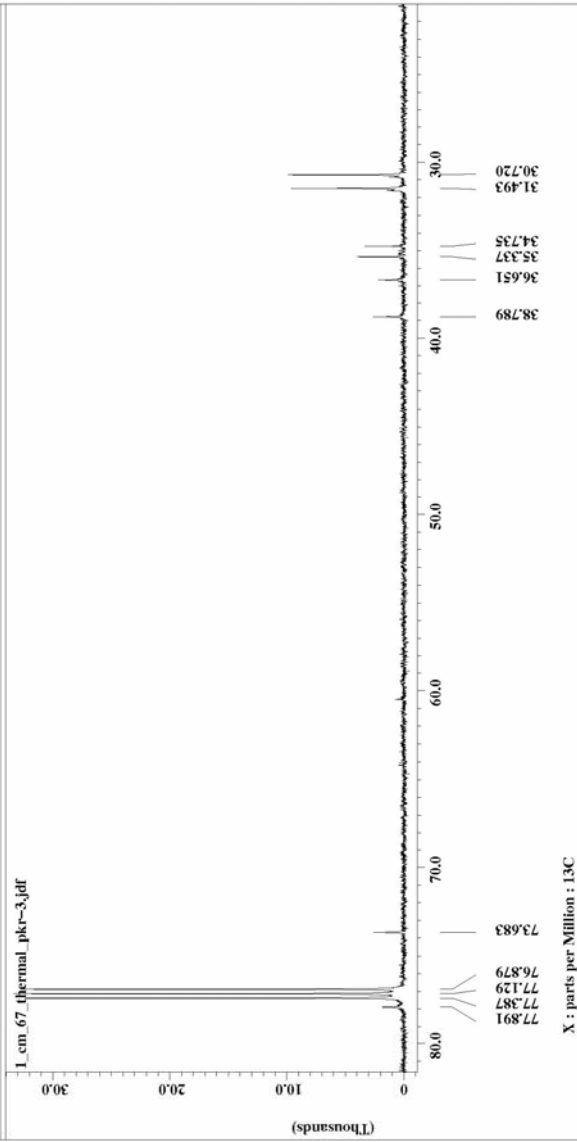
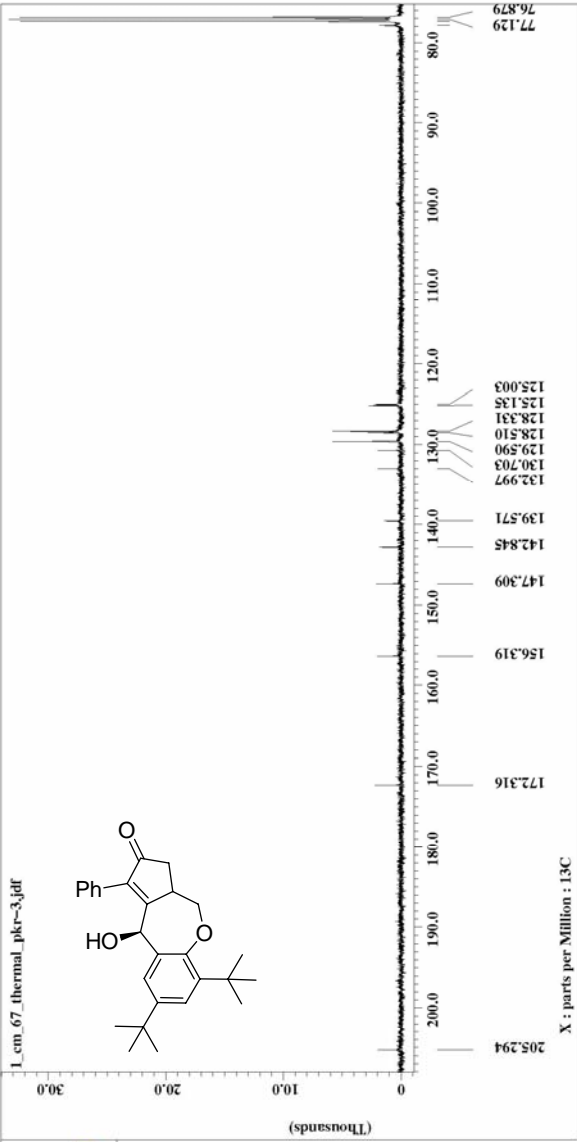
```

Filename = 1_cm_67_thermal_pkr-3
Experiment = single pulse_dec
Pulse_id = CHLORFORM-D
Solvent = CHLORFORM-D
Creation_time = 15-AUG-2004 02:08:31
Revision_time = 9-FEB-2006 22:01:06
Current_time = 9-FEB-2006 22:04:58

Content = Single Pulse with Bro
Data_format = ID COMPLEX
Dim_size = 65536
Dim_title = 13C
Dimensions = X
Site = Eclipse+ 500
Spectrometer = DELTA_NMR

Field_strength = 11.7473579[T] (500 [MH
X_acq_duration = 1.736704[s]
X_domain = 13C
X_freq = 125.76529768 [MHz]
X_offset = 180 [ppm]
X_pbits = 65536
X_prescans = 4
X_resolution = 0.57580336 [Hz]
X_sweep = 37.73584906 [kHz]
Irr_domain = 1H
Irr_freq = 500.15991521 [MHz]
Irr_offset = 5 [ppm]
Mod_return = 1
Scans = 507

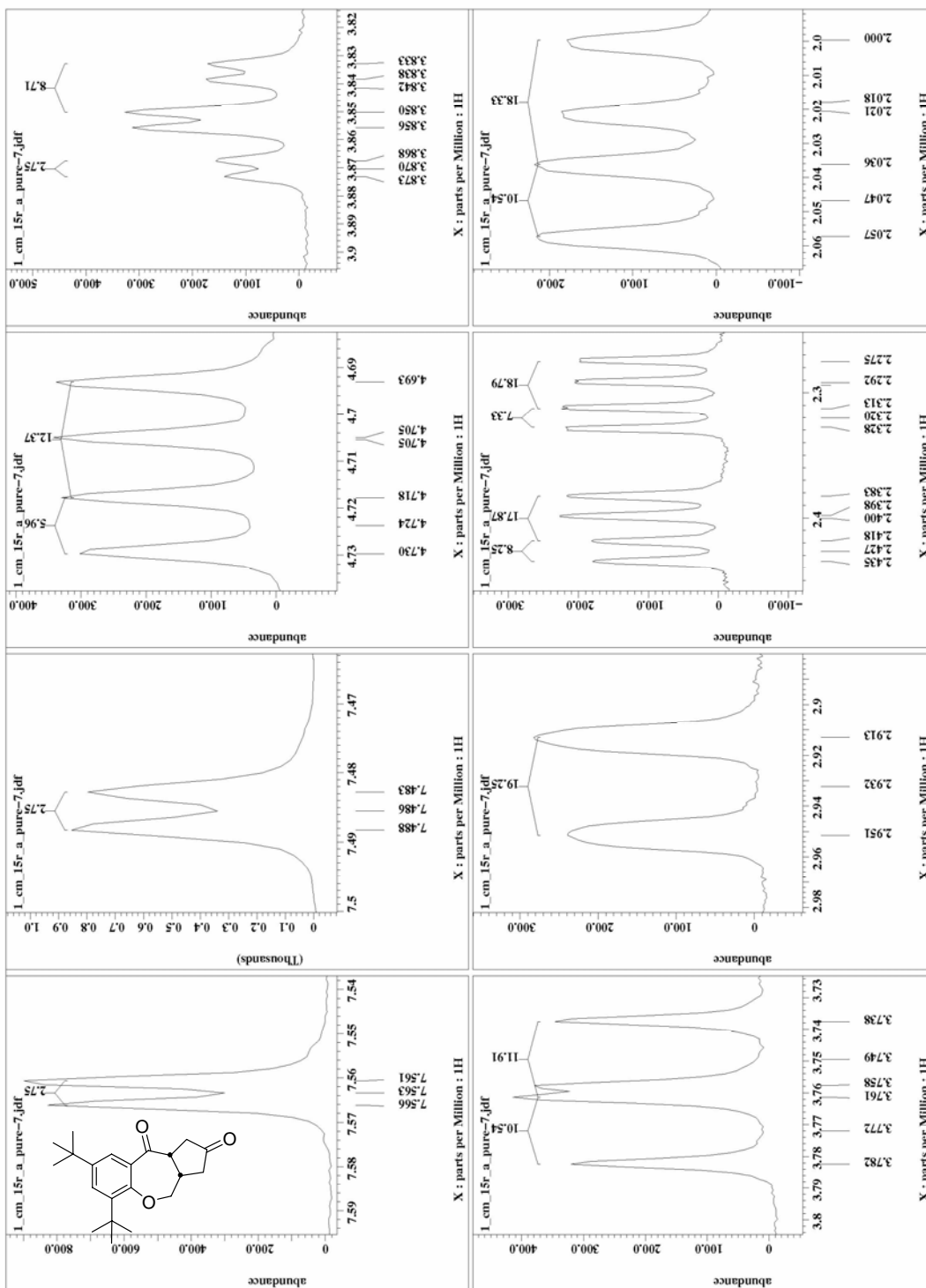
X_90_width = 14 [us]
X_acq_time = 1.736704 [s]
X_angle = 30 [deg]
X_pulse = 4.66666667 [us]
Initial_wait = 1 [s]
Phase_preset = 3 [us]
Recvr_gain = 29
Relaxation_delay = 2 [s]
Temp = 29.3 [dC]
Unblank_time = 2 [us]
  
```

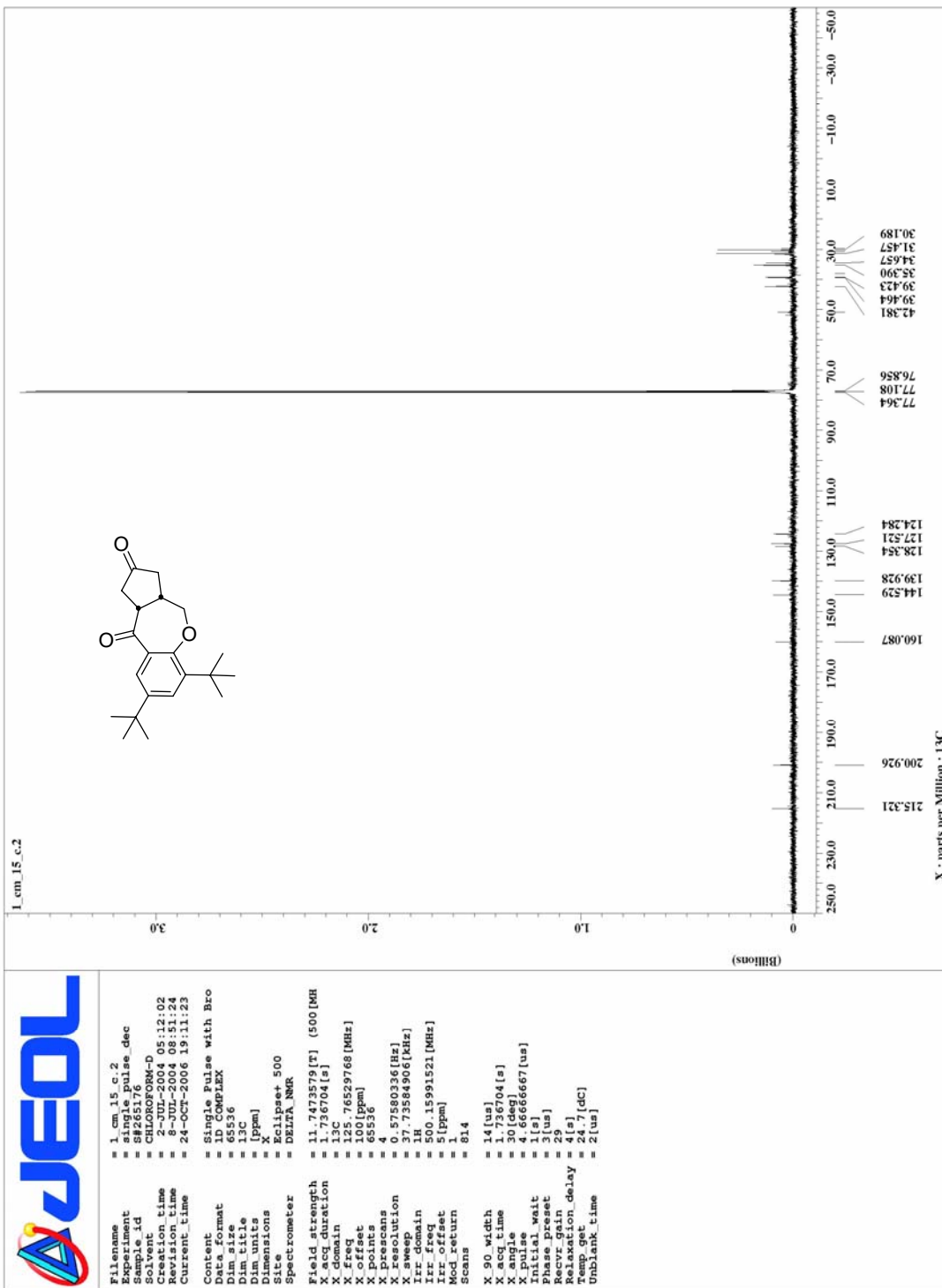


APPENDIX 28

¹H and ¹³C NMR SPECTRA OF

6,8-Di-*tert*-butyl-1,1a,4,4a-tetrahydro-3H-5-oxabenzof]azulen-2,10-dione (syn isomer, 35)

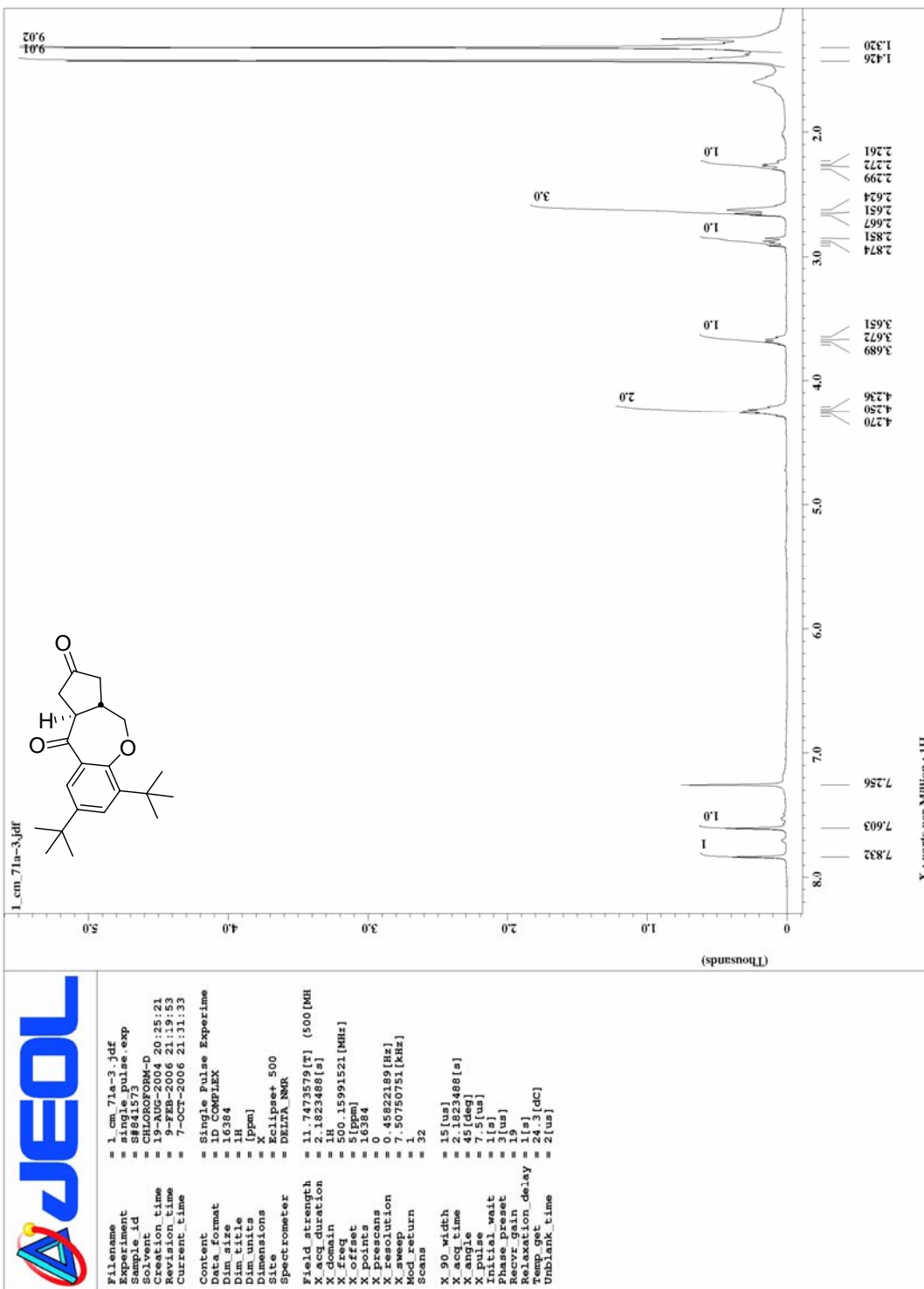


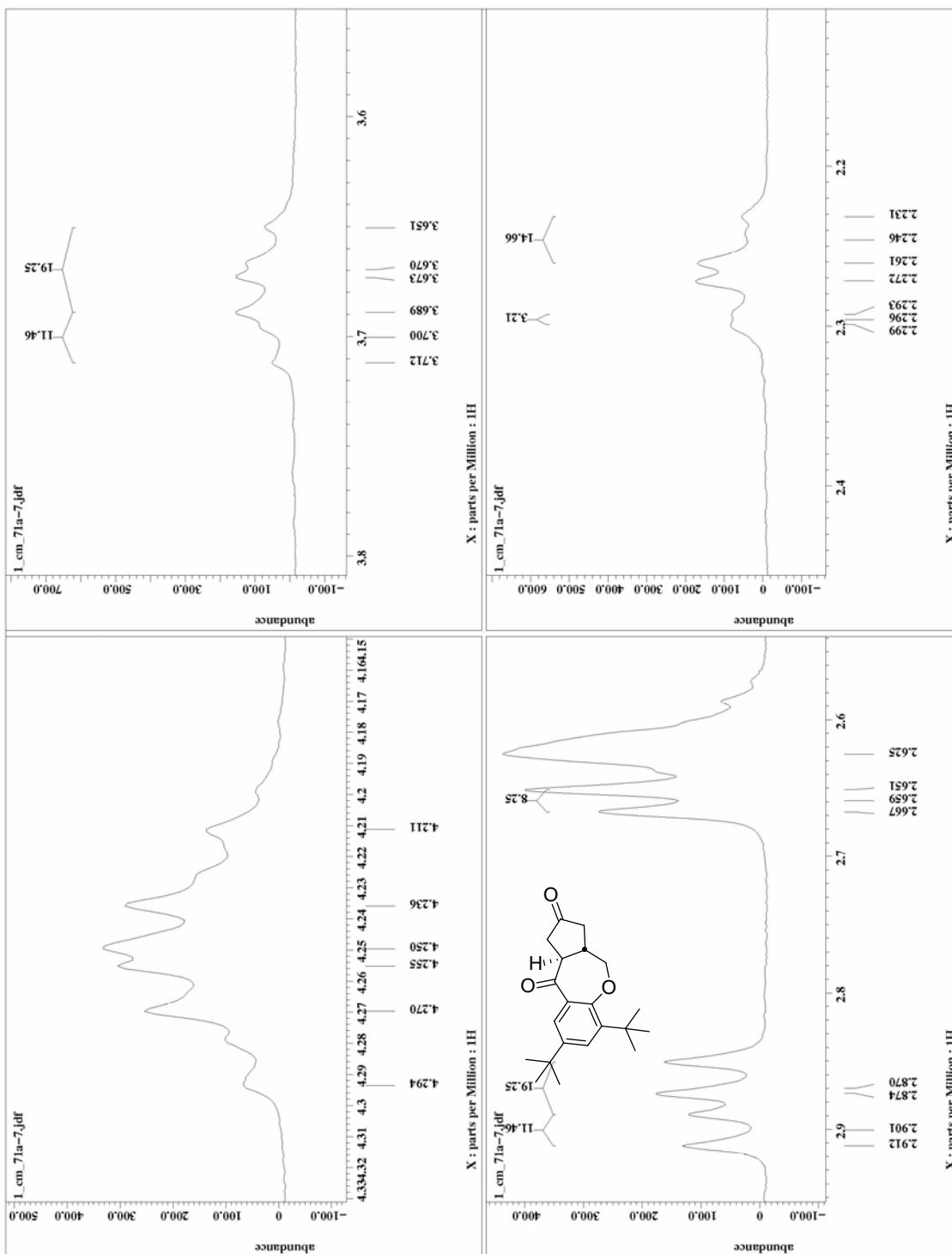


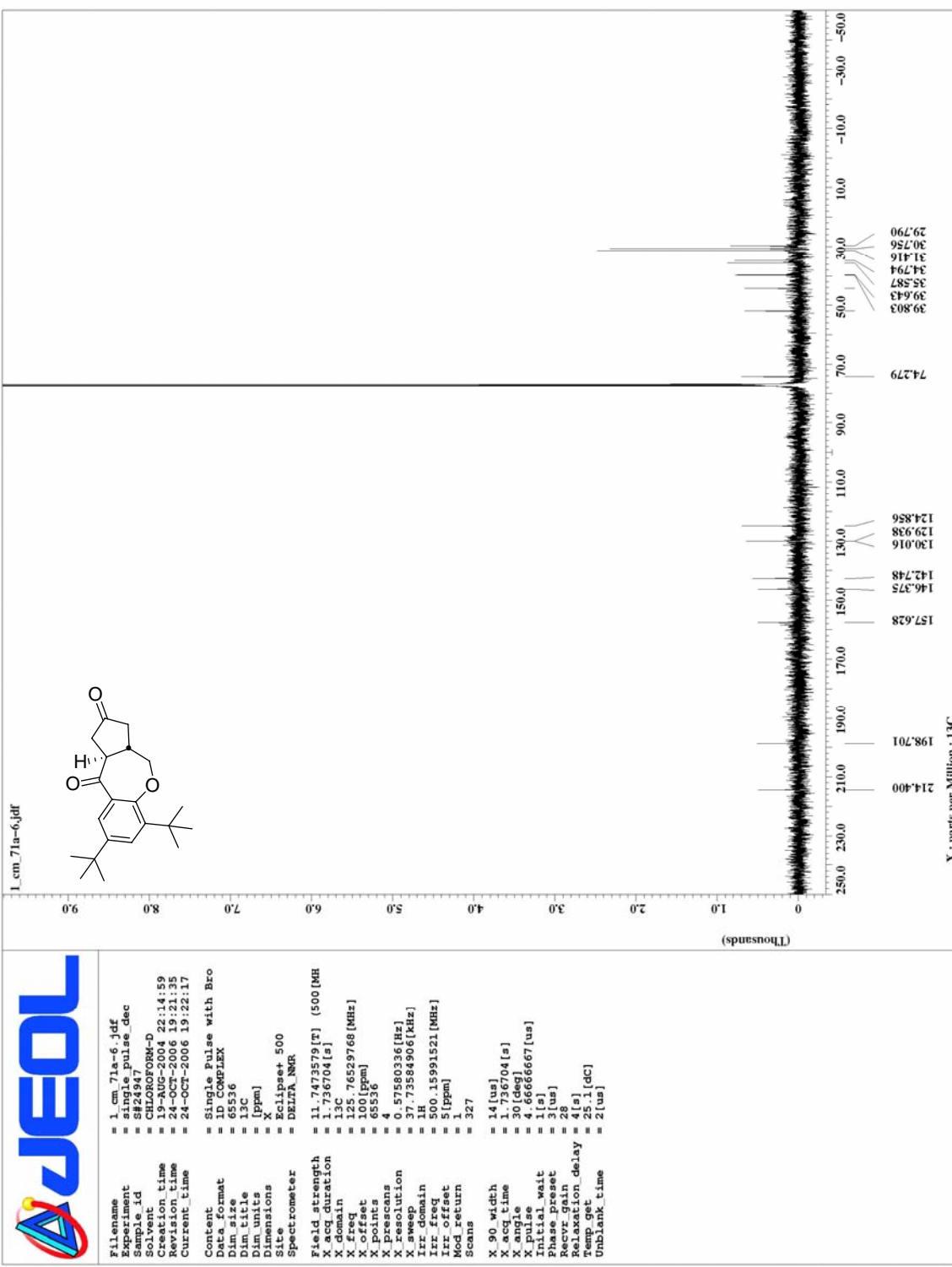
APPENDIX 29

¹H and ¹³C NMR SPECTRA OF

6,8-Di-*tert*-butyl-1,1a,4,4a-tetrahydro-3H-5-oxabenzof]azulen-2,10-dione (*anti*-isomer, 35)



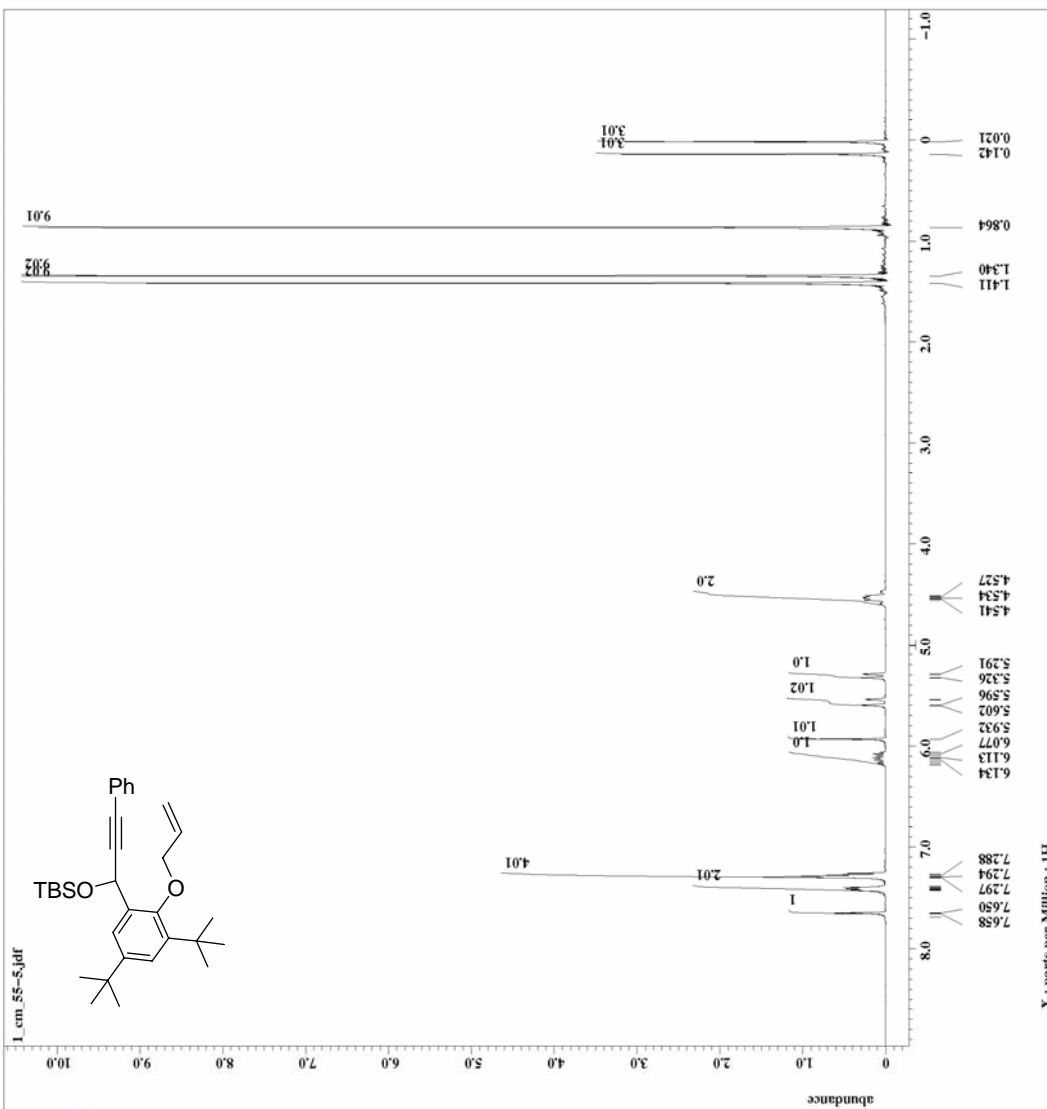




APPENDIX 30

¹H and ¹³C NMR SPECTRA OF

**4,6-Di-*tert*-butyl-2-(-1-*tert*-butyl-dimethylsilyloxy -3-phenyl-2-propynyl)
-(-2-propenyloxy)benzene (30)**



JEOL
 File name = 1_cm_55-5.jdf
 Author = delta
 Experiment = 1
 Sample name = 5873935
 Sample id = 5873935
 Solvent = CHLOROFORM-D
 Creation time = 27-SEP-2006 16:40:48
 Revision time = 24-OCT-2006 19:46:50
 Current time = 24-OCT-2006 19:47:21
 Content = single pulse
 Data format = ID COMPLEX
 Dim size = 13107
 Dim title = IR
 Dimensions = X [ppm]
 Site = ECX 300
 Spectrometer = DELTA2_NMR
 Field strength = 7.0586013 [T] (300 [MHz])
 X domain = 1H
 X freq = 300.52965592 [MHz]
 X offset = 5 [ppm]
 X points = 16384
 X resolution = 0.34397631 [Hz]
 X sweep = 5.63570784 [kHz]
 Irf domain = 1H
 Irf freq = 300.52965592 [MHz]
 Irf offset = 5 [ppm]
 Tri domain = 1H
 Tri freq = 300.52965592 [MHz]
 Tri offset = 5 [ppm]
 Clipped = FALSE
 Recv return = 1
 Total_scans = 6
 X 90_width = 13.01 [us]
 X acq_time = 2.90717696 [s]
 X angle = 4 [dB]
 X pulse = 6.505 [us]
 Irf mode = Off
 Tri mode = Off
 Data_preat = 4 [us]
 Data_post = 4 [us]
 Recv_gain = 40
 Relaxation_delay = 5 [s]
 Repetition_time = 7.90717696 [s]
 Temp_get = 22.8 [dC]



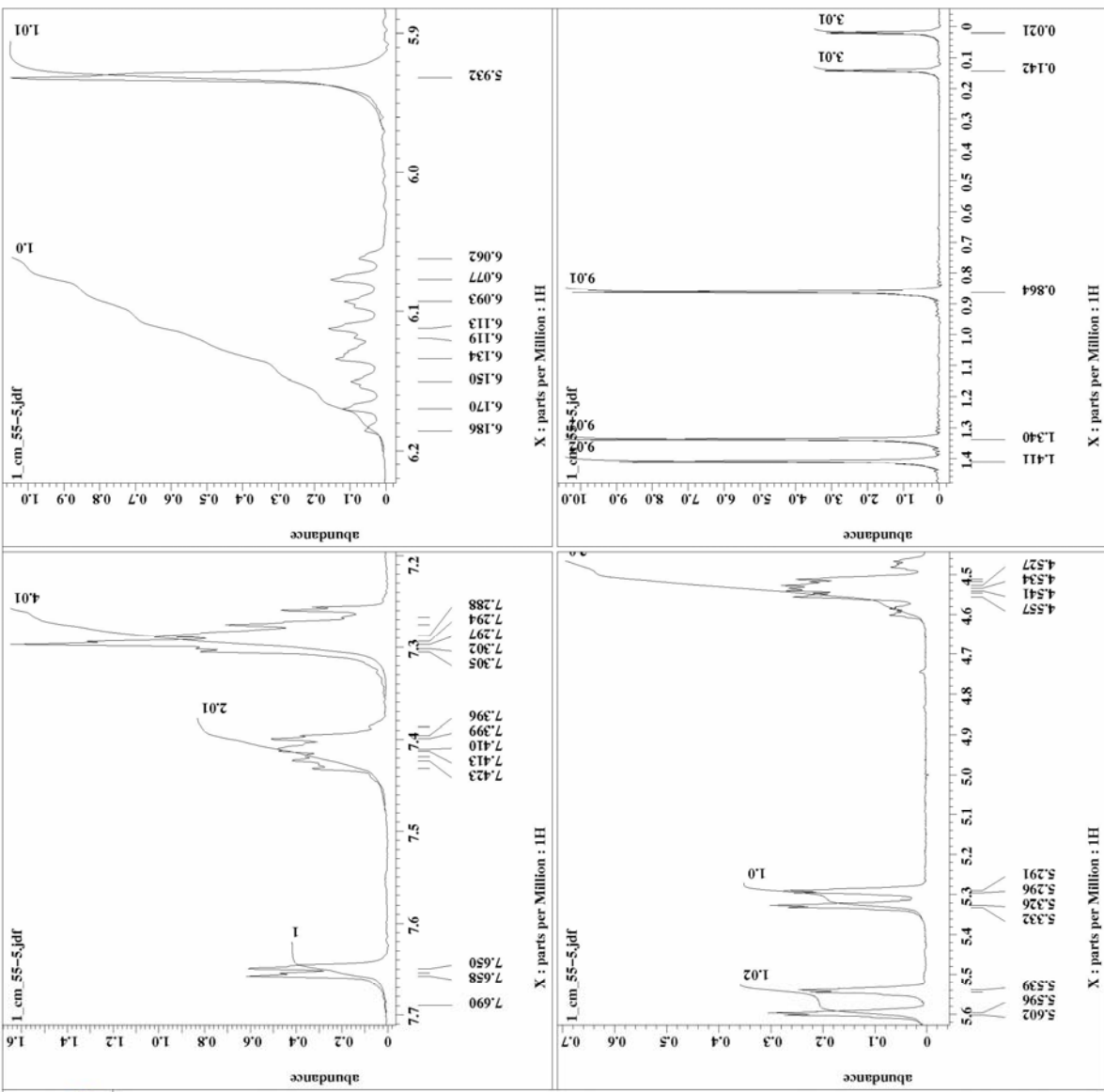
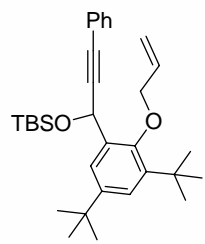
```

Filename = 1_cm_55-5_jdf
Author = delta
Experiment = single pulse.ex2
Sample_id = S#573935
Solvent = CHLOROFORM-D
Creation_time = 27-SEP-2006 16:40:48
Revision_time = 24-OCT-2006 19:46:50
Current_time = 24-OCT-2006 19:48:51

Content = single pulse
Date_format = DDMMYY
Date_acq = 27092006
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Site = ECX 300
Spectrometer = DELTA2_NMR

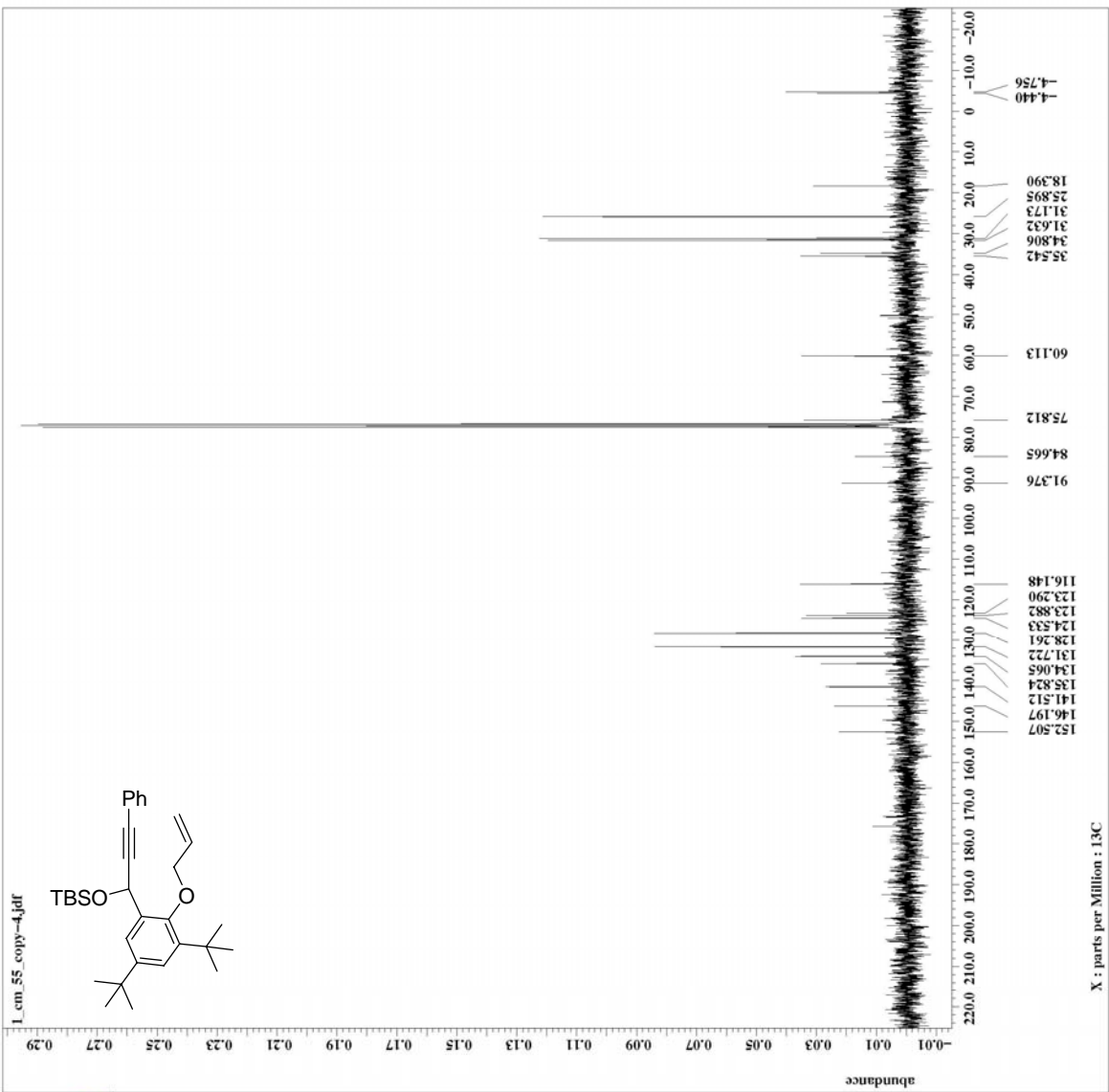
Field_strength = 7.0586013[T] (300[Mhz]
X_acq_duration = 2.90717696[s]
X_domain = 1H
X_freq = 300.52965592[MHz]
X_gain = 51[um]
X_points = 16384
X_prescans = 1
X_resolution = 0.34397631[Hz]
X_sweep = 5.63570784[kHz]
Irr_domain = 1H
Irr_freq = 300.52965592[MHz]
Irr_offset = 5[ppm]
Irr_domain = 1H
Tri_freq = 100.52965592[MHz]
Tri_offset = 51[ppm]
Clip_level = FALSE
Mod_return = 1
Total_scans = 6

X_90_width = 13.01[us]
X_acq_time = 2.90717696[s]
X_angle = 45[deg]
X_atn = 4[db]
X_pulse = 6.505[us]
Tri_mode = Off
Dante_preset = FALSE
Initial_wait = 1[s]
Recvr_gain = 40
Relaxation_delay = 5[s]
Repetition_time = 7.90717696[s]
Temp_get = 22.8[dc]
  
```





File name = 1_cm_55_copy-4_.jdf
Author = delta
Experiment = single_pulse_dec
Solvent = CDCl3
Solvent_id = CHLORFORM-D
Creation time = 27-SEP-2006 16:49:13
Revision time = 27-SEP-2006 16:10:29
Current time = 24-OCT-2006 19:50:31
Content = single pulse decouple
Data format = ID COMPLEX
Data size = 26214
Dim title = 13C
Dim_x = Y[ppm]
Dimensions = X[ppm]
Site = ECX 300
Spectrometer = DELTA2_NMR
Field_strength = 7.0586013[T] (300[MHz])
X_acq_duration = 1.38412032[s]
X_domain = 13C
X_freq = 75.56823426[MHz]
X_gain = 32768
X_points = 4
X_prescans = 4
X_resolution = 0.72248054[Hz]
X_sweep = 23.67424242[kHz]
Irr_domain = 1H
Irr_freq = 300.52965592[MHz]
Irr_offset = 5[ppm]
Clipped = FALSE
Incomplete_copy = TRUE
Missettup = TRUE
Scans = 110
Total_scans = 110
X_90_width = 9.75[us]
X_acq_time = 1.38412032[s]
X_angle = 30[deg]
X_atn = 8[dB]
X_pulse = 25[us]
X_pulse_dec = 25[us]
Irr_atn_noe = 25[dB]
Irr_noise = WAITZ
Decoupling = TRUE
Initial_wait = 1[s]
Noe = TRUE
Noe_time = 3[s]
Recvr_gain = 50
Relaxation_delay = 3[s]
Repetition_time = 1.38412032[s]
Temp_set = 22.3[degC]



APPENDIX 31

¹H and ¹³C NMR SPECTRA OF

4,6-Di-*tert*-butyl-2-(-1-*tert*-butyl-dimethylsilyloxy-3-trimethylsilyl-2-propynyl)

-(-2-propenyloxy)benzene (31)



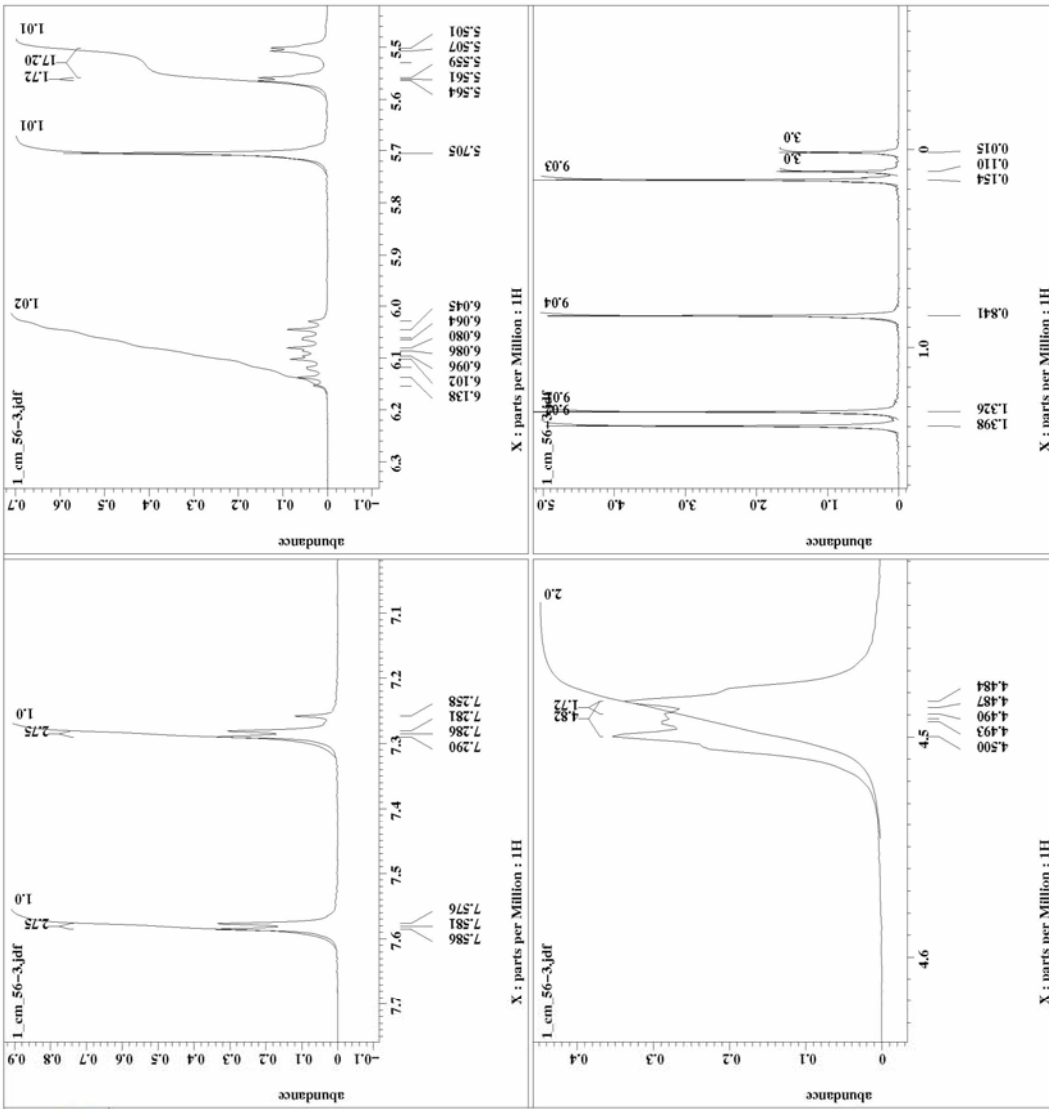
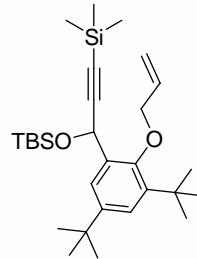
```

Filename = 1_cm_56-3_jdf
Author = delta
Experiment = delta_pulse_ex2
Sample_id = SR9256
Solvent = CHLOROFORM-D
Creation_time = 27-SEP-2006 16:55:45
Revision_time = 27-SEP-2006 16:22:08
Current_time = 24-OCT-2006 20:02:24

Content = single_pulse
Data_format = ID_COMPLEX
Dim_size = 13107
Dim_title = 1H
Dim_x = X [ppm]
Dimensions = X
Site = ECK 300
Spectrometer = DELTA2_NMR

Field_strength = 7.05860131[T] (300[MHz]
X_acq_duration = 2.90717696[s]
X_domain = 1H
X_freq = 300.52965592[MHz]
X_offset = 5[ppm]
X_points = 16384
X_resolution = 0.34397631[Hz]
X_sweep = 5.63570784[kHz]
Irr_domain = 1H
Irr_freq = 300.52965592[MHz]
Irr_offset = 5[ppm]
Tri_domain = 1H
Tri_freq = 300.52965592[MHz]
Tri_offset = 5[ppm]
Clipped = FALSE
Ssd_return = 11
Total_scans = 11

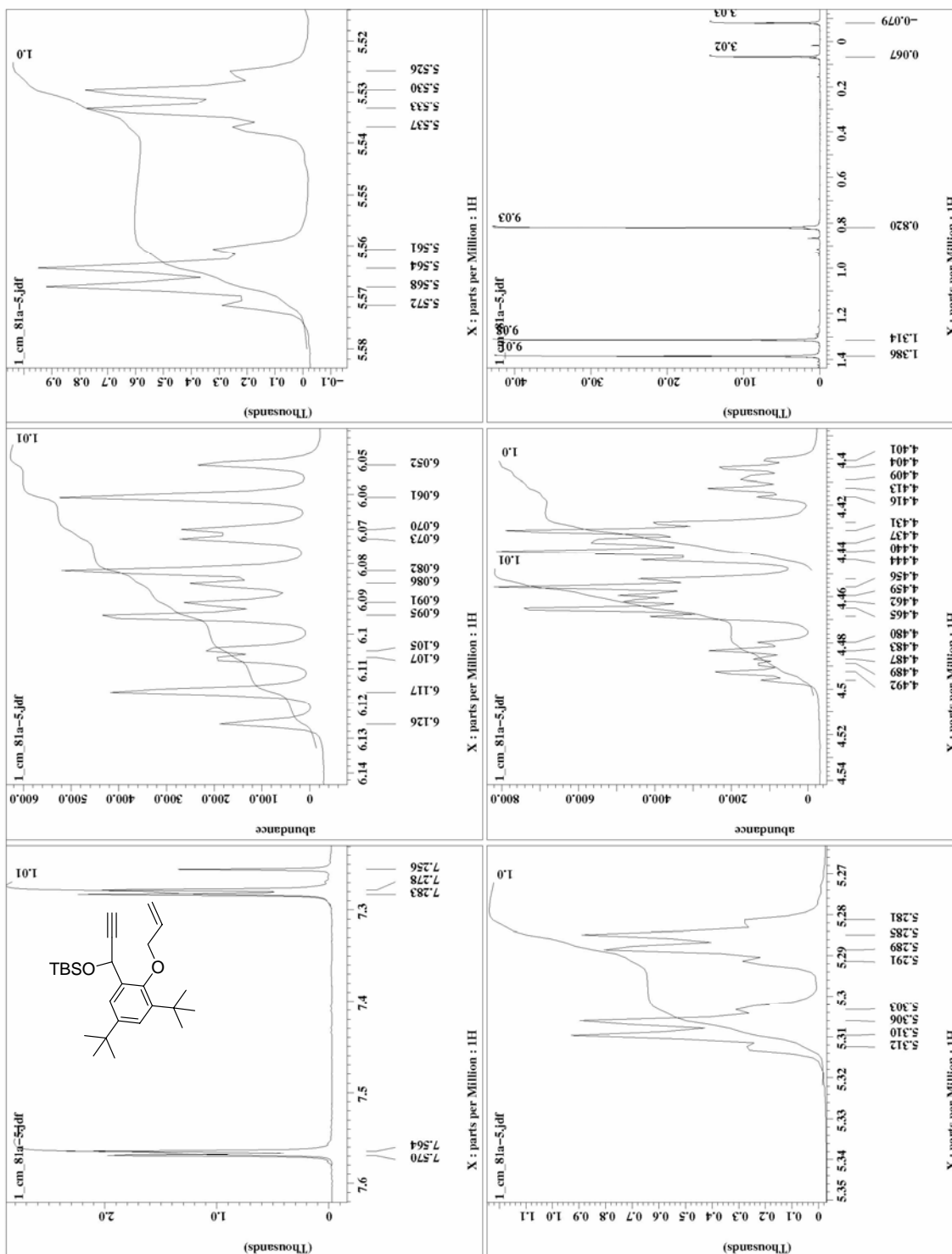
X_90_width = 13.01[us]
X_acq_time = 2.90717696[s]
X_gate = 4[deg]
X_gain = 41[dB]
X_atn = 6.505[us]
X_pulse = off
Irr_mode = off
Tri_mode = off
Auto_shut = off
Initial_wait = 11[s]
Relaxation_delay = 5[s]
Repetition_delay = 7.90717696[s]
Repetition_time = 22.8[dc]
Temp_get =
  
```



APPENDIX 32

¹H and ¹³C NMR SPECTRA OF

**4,6-Di-*tert*-butyl-2-(-1-*tert*-butyl-dimethylsilyloxy-2-propynyl)
-(2-propenyloxy) benzene (36)**





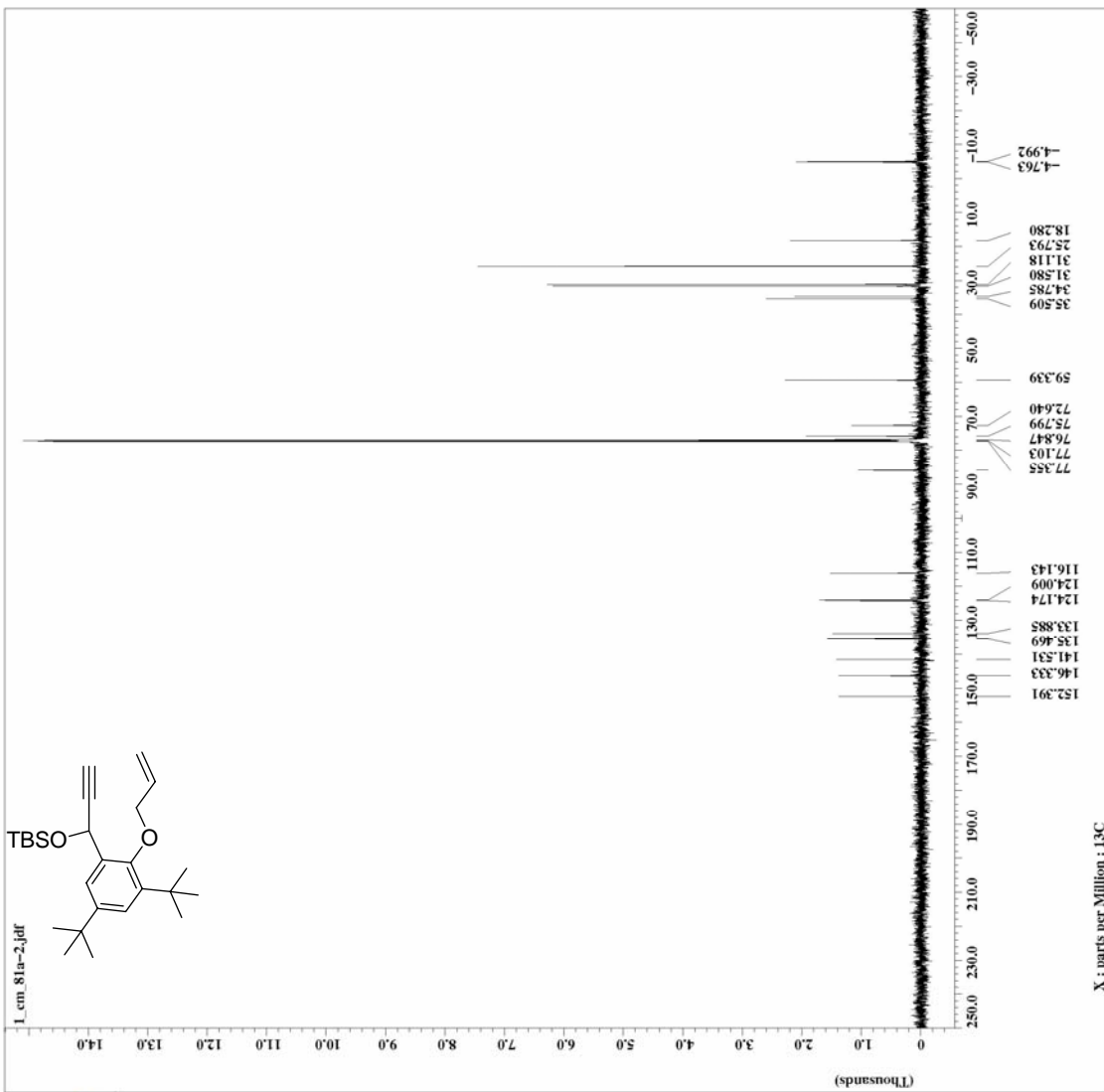
```

Filename = 1_cm_81a-2.jdf
Experiment = single_pulse_dec
Sample_id = S81634
Operator = JMW-D
Collection_time = 13-AUG-2004 23:36:31
Revision_time = 24-OCT-2006 20:14:00
Current_time = 24-OCT-2006 20:14:23

Content = Single Pulse with Bro
Data_format = ID COMPLEX
Dim_1 = 3276
Dim_2 = 3276
Dim_units = [ppm]
Dimensions = X
Site = Eclipse+ 500
Spectrometer = DELTA_NMR

Field_strength = 11.7473579 [T] (500 [MH
X_duration = 1.738704 [s]
X_domain = 13C
X_freq = 125.76529768 [MHz]
X_offset = 100 [ppm]
X_points = 65536
X_prescans = 4
X_resolution = 57580336 [Hz]
X_resolution = 97.73584906 [kHz]
Irr_domain = 1H
Irr_freq = 500.15991521 [MHz]
Irr_offset = 5 [ppm]
Mod_return = 1
Scans = 232.0

X_90_width = 14 [us]
X_acq_time = 1.738704 [s]
X_angle = 30 [deg]
X_pulse = 4.66666667 [us]
Initial_wait = 1 [s]
Phase_preset = 3 [us]
Recvr_gain = 29
Relaxation_delay = 24.3 [dc]
Temp_get_time = 2 [us]
Unblank_time = 2 [us]
  
```

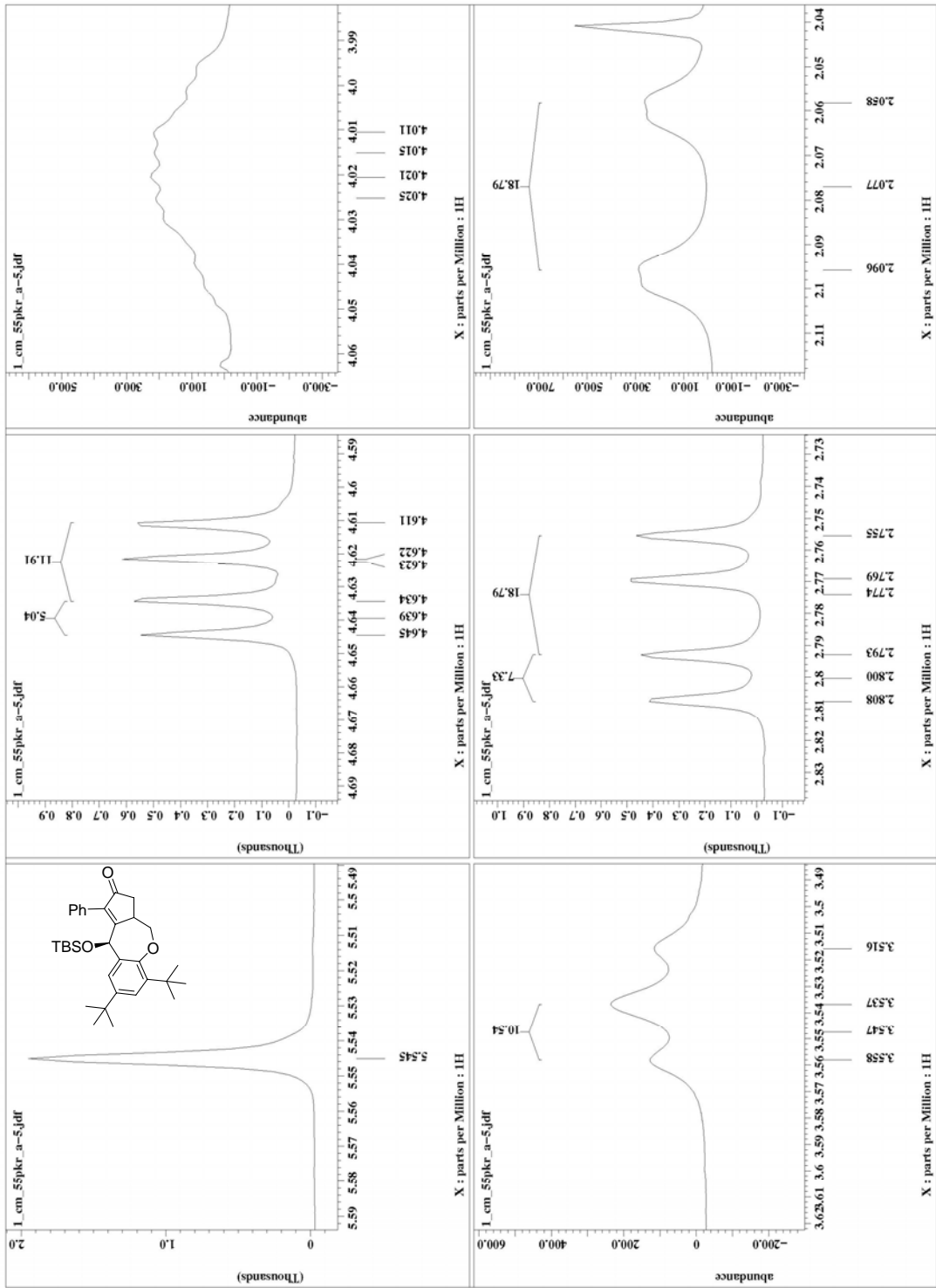


X : parts per Million : 13C

APPENDIX 33

¹H and ¹³C NMR SPECTRA OF

**6,8-Di-*tert*-butyl-10-*t*-butyldimethylsilyloxy-1-phenyl-4,4a- dihydro
-3*H*,10*H*-5-oxabenzof]azulen-2-one (32)**





```

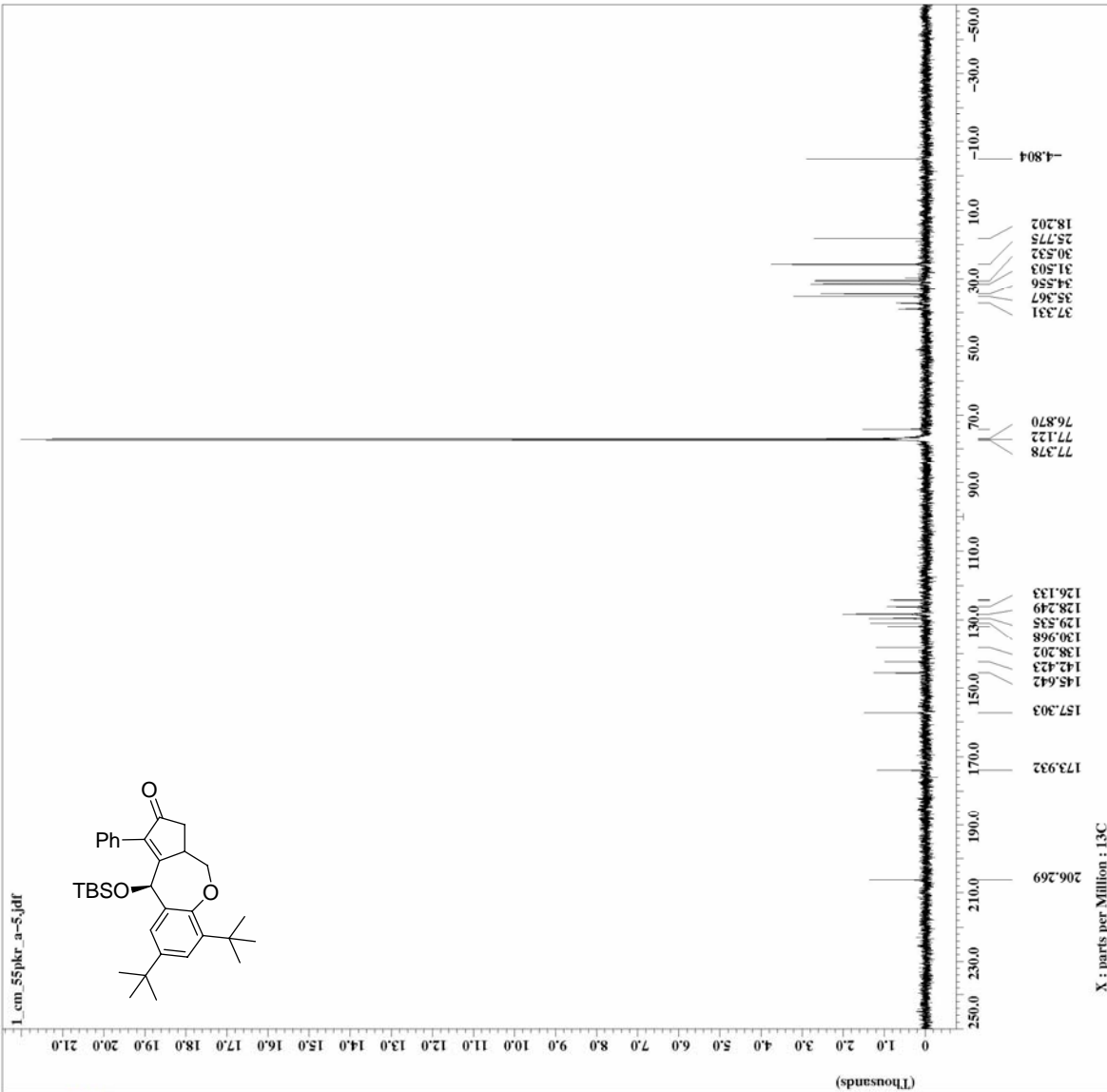
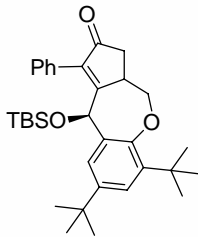
Filename = 1_cm_55pkr_a-5_jdf
Experiment = single_pulse_dec
Sample_id = S#76761
Solvent = CHLOROFORM-D
Creation_time = 13-MAR-2004 11:15:41
Revision_time = 24-OCT-2006 20:28:44
Current_time = 24-OCT-2006 20:29:11

Content = Single Pulse with Bro
Date_acqmat = SMPLEX
Date_time = 65536
Dim_title = 13C
Dim_units = [ppm]
Dimensions = X
Site = Eclipset 500
Spectrometer = DELTA_NMR

Field_strength = 11.7473579 [T] (500 [MH
X_acq_duration = 1.736704 [s]
X_domain = 125
X_freq = 125.76529768 [MHz]
X_offset = 100 [ppm]
X_points = 65536
X_prescans = 4
X_resolution = 0.57580336 [Hz]
X_sweep = 37.73584906 [kHz]
Irr_domain = IH
Irr_freq = 500.15991521 [MHz]
Irr_offset = 5 [ppm]
Modi_return = 350
Scans = 14 [us]
X_90_width = 14 [us]
X_acq_time = 1.736704 [s]
X_angle = 30 [deg]
X_pulse = 4.66666667 [us]
Initial_wait = 1 [s]
Phase_preset = 2 [us]
Recvr_gain = 29
Relaxation_delay = 2 [s]
Temperature = 23.8 [dC]
Unblent_time = 2 [us]

```

1_cm_55pkr_a-5_jdf



APPENDIX 34

¹H and ¹³C NMR SPECTRA OF

**6,8-Di-*tert*-butyl-10-*t*-butyldimethylsilyloxy-1-trimethylsilyl-4,4a-dihydro
-3*H*,10*H*-5-oxabenzof]azulen-2-one (33)**

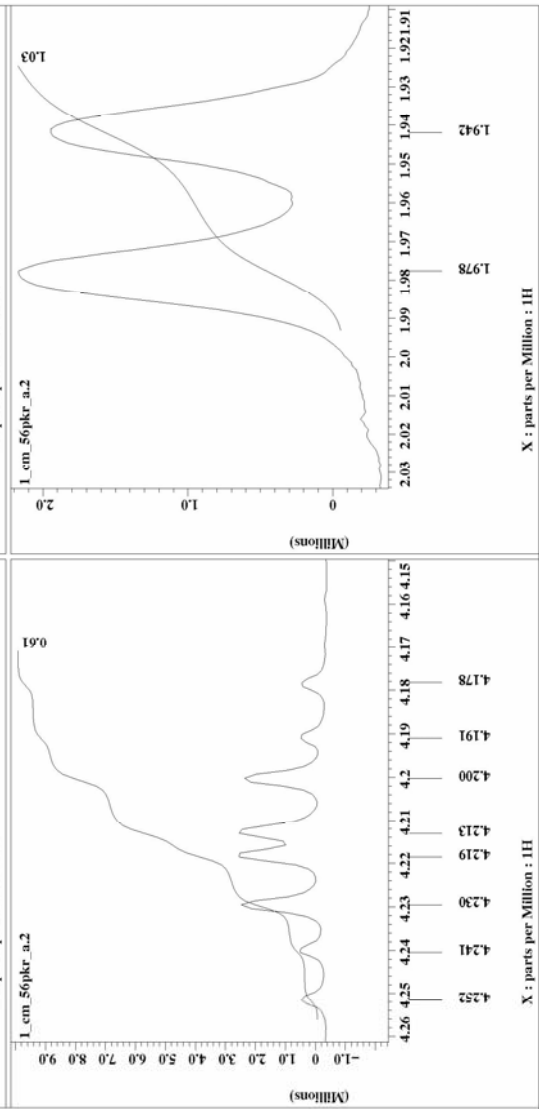
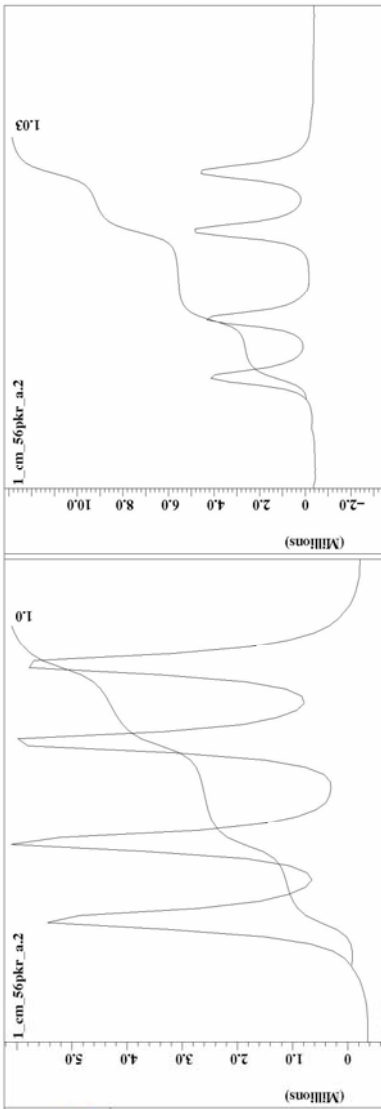
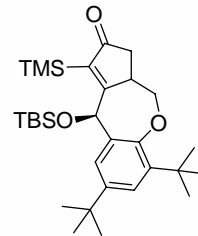


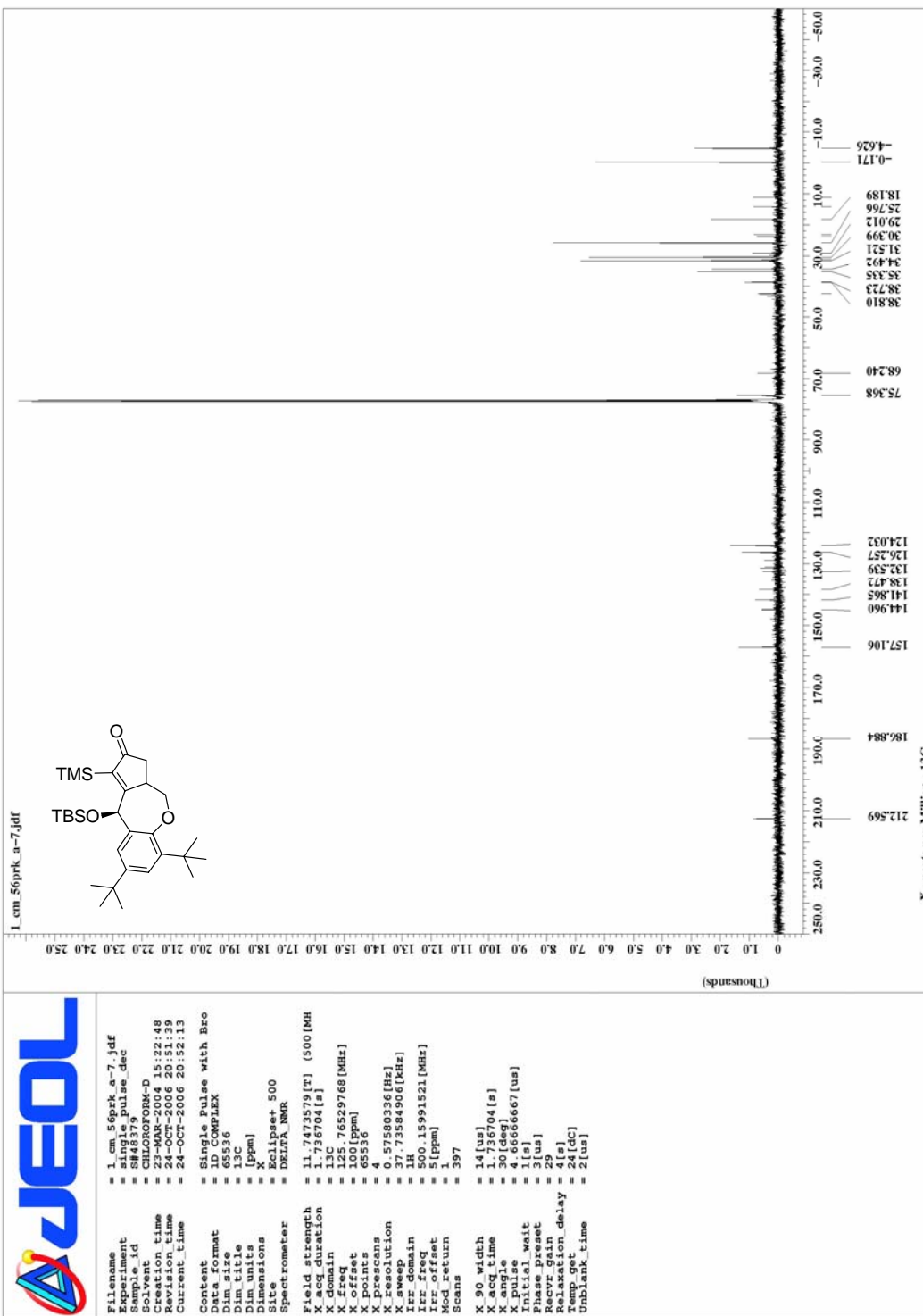
```

Filename      = 1_cm_56pkr_a.2
Experiment    = single_pulse_exp
Sample Id     = 8H750203M-D
Sample Name   = 17-MAR-2004 10:13:32
Creation time = 17-MAR-2004 10:13:32
Revision time = 22-MAR-2004 21:16:14
Current time  = 24-OCT-2006 20:47:28
Content       = Single Pulse Exptime
Data format  = 1D_COMPLEX
Dim size     = 16384
Dim title    = 1H
Dim units    = [ppm]
Dimensions   = X: 16384, 500
Spectrometer = DELTA_NMR

Field strength = 11.747375[T] (500[MH
X_acq duration = 2.1823488[s]
X_t1           = 1.50750751[Hz]
X_f2          = 400.15991521[MHz]
X_offset      = 5[ppm]
X_points      = 16384
X_prescans    = 0
X_resolution  = 0.4582189[Hz]
X_sweep       = 1.50750751[KHz]
Mod return    = 1
Scans         = 32

X_90_width    = 15[us]
X_acq time    = 45[deg]
X_pulse       = 7.5[us]
Initial wait  = 1[s]
Phase preset  = 3[us]
Recvr gain    = 15
Relaxation delay = 23.1[dc]
Temp_get      = 23.1[dc]
Unblank_time  = 2[us]
  
```





APPENDIX 35

¹H and ¹³C NMR SPECTRA OF

6,8-Di-*tert*-butyl-10-*t*-butyldimethylsilyloxy-4,4a-dihydro

-3*H*,10*H*-5-oxabenzof]azulen-2-one (*exo* product, 37)



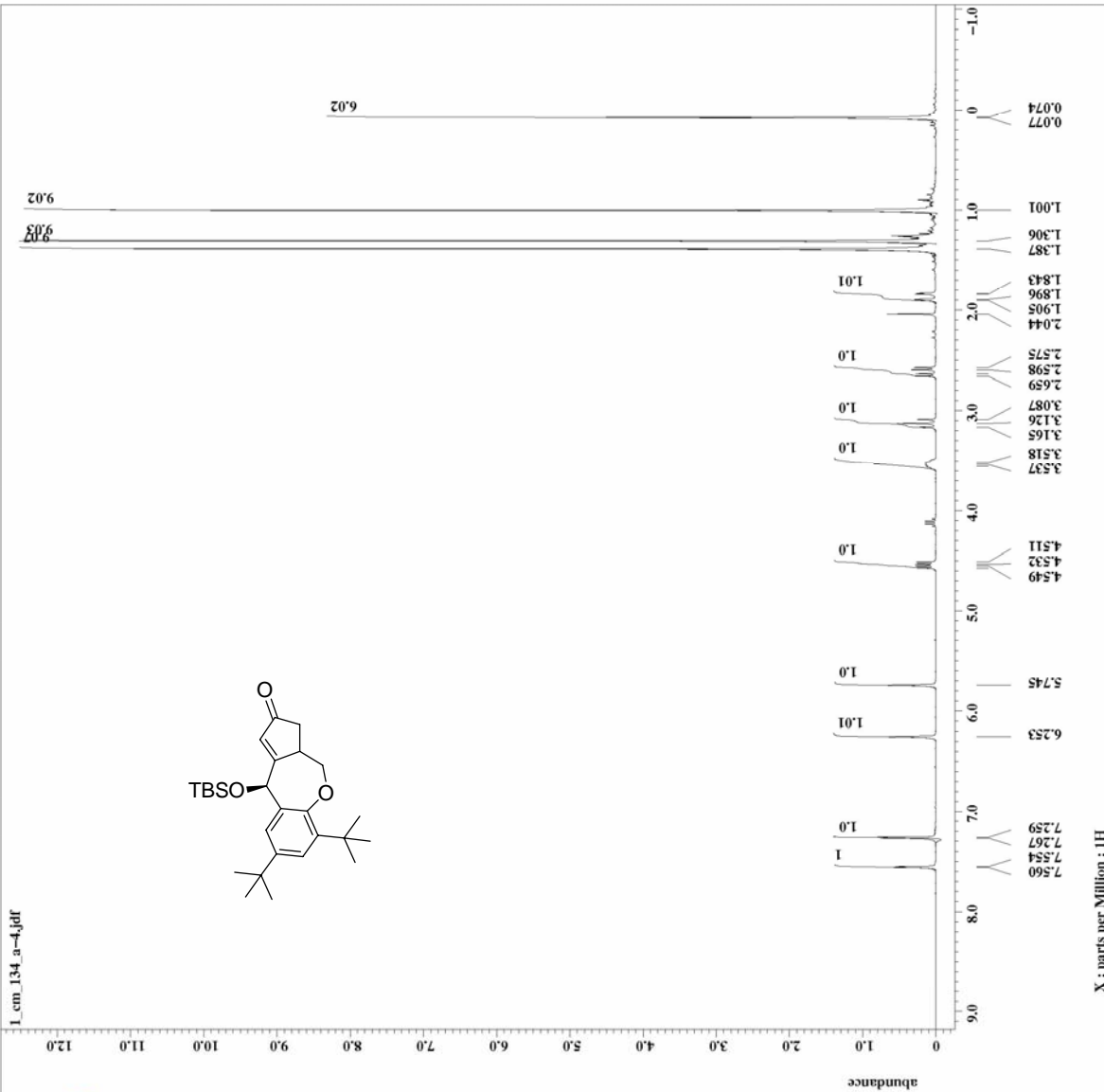
```

Filename = 1_cm_134_a-4.jdf
Author = delta
Experiment = single_pulse.ex2
Sample_id = SF720770
Solvent = CHLOROFORM-D
Creation_time = 18-FEB-2005 21:07:16
Revision_time = 18-FEB-2005 20:13:22
Current_time = 9-OCT-2006 18:05:24

Content = single_pulse
Data format = 1D COMPLEX
Dim size = 13107
Dim title = 1H
Dim units = [ppm]
Dimensions = X
Site = ECK 300
Spectrometer = DELTA2_NMR

Field strength = 7.0586013[T] (300[MHz]
X_acq_duration = 1.90717696[s]
X_chan = 1H
X_freq = 300.52965592[MHz]
X_offset = 5[ppm]
X_points = 16384
X_prescans = 1
X_resolution = 0.34397631[Hz]
X_sweep = 5.63570784[kHz]
Irr_domain = 1H
Irr_freq = 300.52965592[MHz]
Irr_offset = 5[ppm]
Irr_domain = 1H
Irr_freq = 300.52965592[MHz]
Tri_offset = 5[ppm]
Tri_offset = FALSE
Clipped = FALSE
Mod return = 1
Scans = 24
Total_scans = 24

X_90_width = 13.01[us]
X_acq_time = 2.90717696[s]
X_angle = 45[deg]
X_atn = 4[dB]
X_pulse = 6.805[us]
Irr_mode = Off
Tri_mode = Off
Dante_preat = FALSE
Initial_wait = 1[s]
Recvr_gain = 40
Relaxation_delay = 5[s]
Repetition_time = 7.90717696[s]
Temp_get = 22.1[dc]
  
```



X : parts per Million : 1H



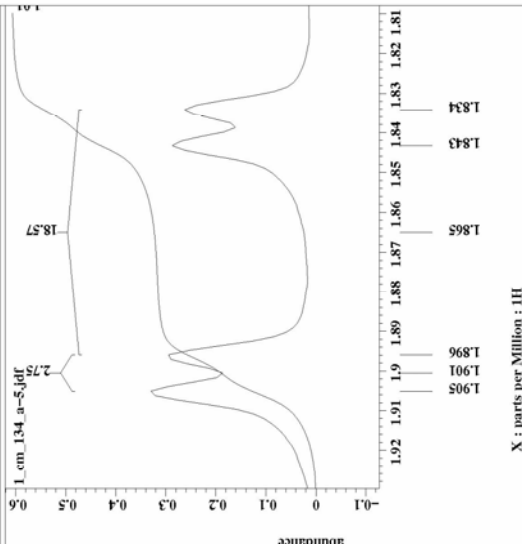
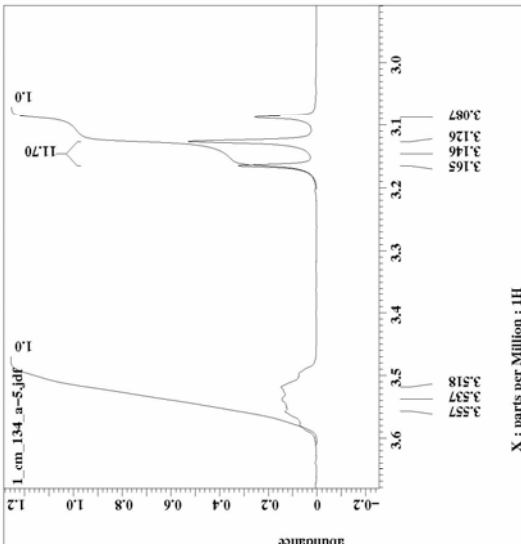
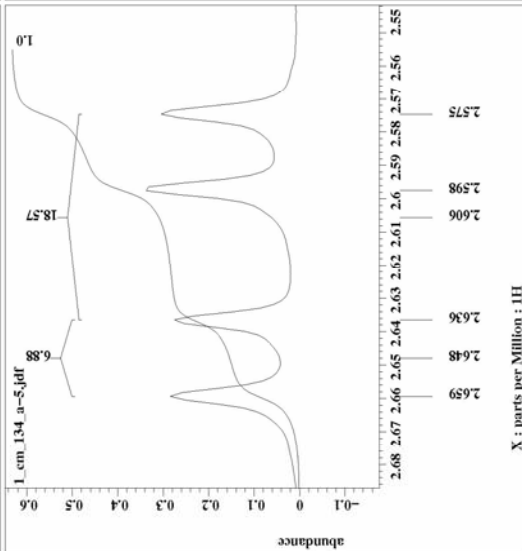
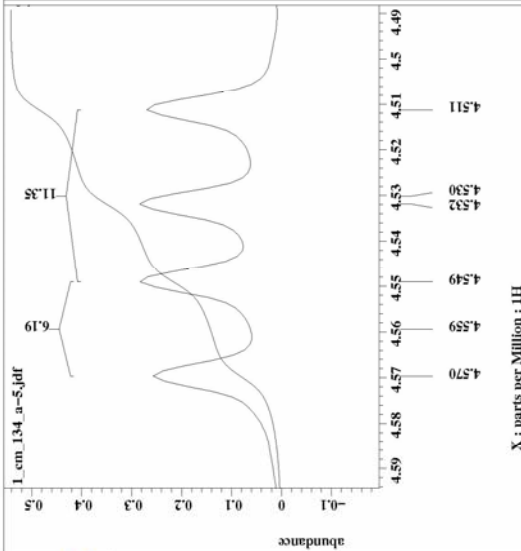
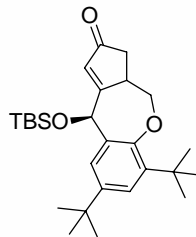
```

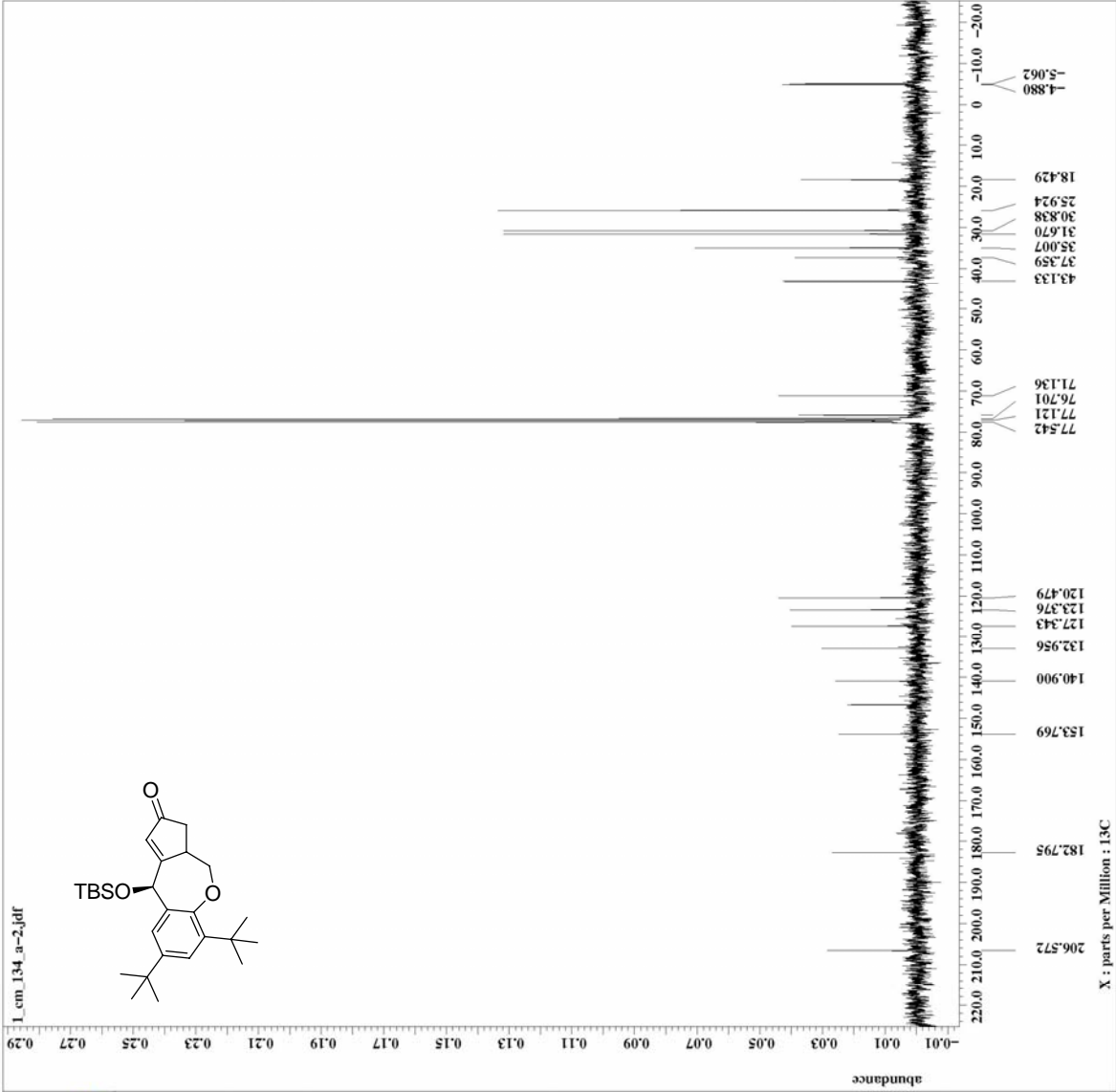
Filename = 1_cm_134_a-5_jdf
Author = delta
Experiment = 5h134a
Sample_id = SH720770
Solvent = CHLOROFORM-D
Creation_time = 18-FEB-2005 21:07:16
Revision_time = 9-OCT-2006 18:09:31
Current_time = 9-OCT-2006 18:23:25

Content = single pulse
Data_format = ID COMPLEX
Dim_size = 13107
Dim_title = 1H
Dim_units = Hz
Dimensions = X
Site = ECK300
Spectrometer = DELTA2_NMR

Field_strength = 7.05860131(T) (300[MHz]
X_acq_duration = 2.90717696(S)
X_domain = 1H
X_freq = 300.52965592[MHz]
X_offset = 5[ppm]
X_points = 16384
X_resolution = 0.34397631[Hz]
X_sweep = 5.63570784[kHz]
Irr_domain = 1H
Irr_freq = 300.52965592[MHz]
Irr_offset = 5[ppm]
Irr_return = FALSE
Total_scans = 24

X_90_width = 13.01[us]
X_acq_time = 7.90717696[s]
X_delay = 45[deg]
X_atn = 41[db]
X_pulse = 6.505[us]
Irr_mode = Off
Tri_mode = Off
Auto_shut_off = FALSE
Initial_wait = 11[s]
Recvr_gain = 40
Relaxation_delay = 5[s]
Repetition_time = 7.90717696[s]
Temp_get = 22.1[degC]
  
```





1_cm_134_a-2.jdf

abundance

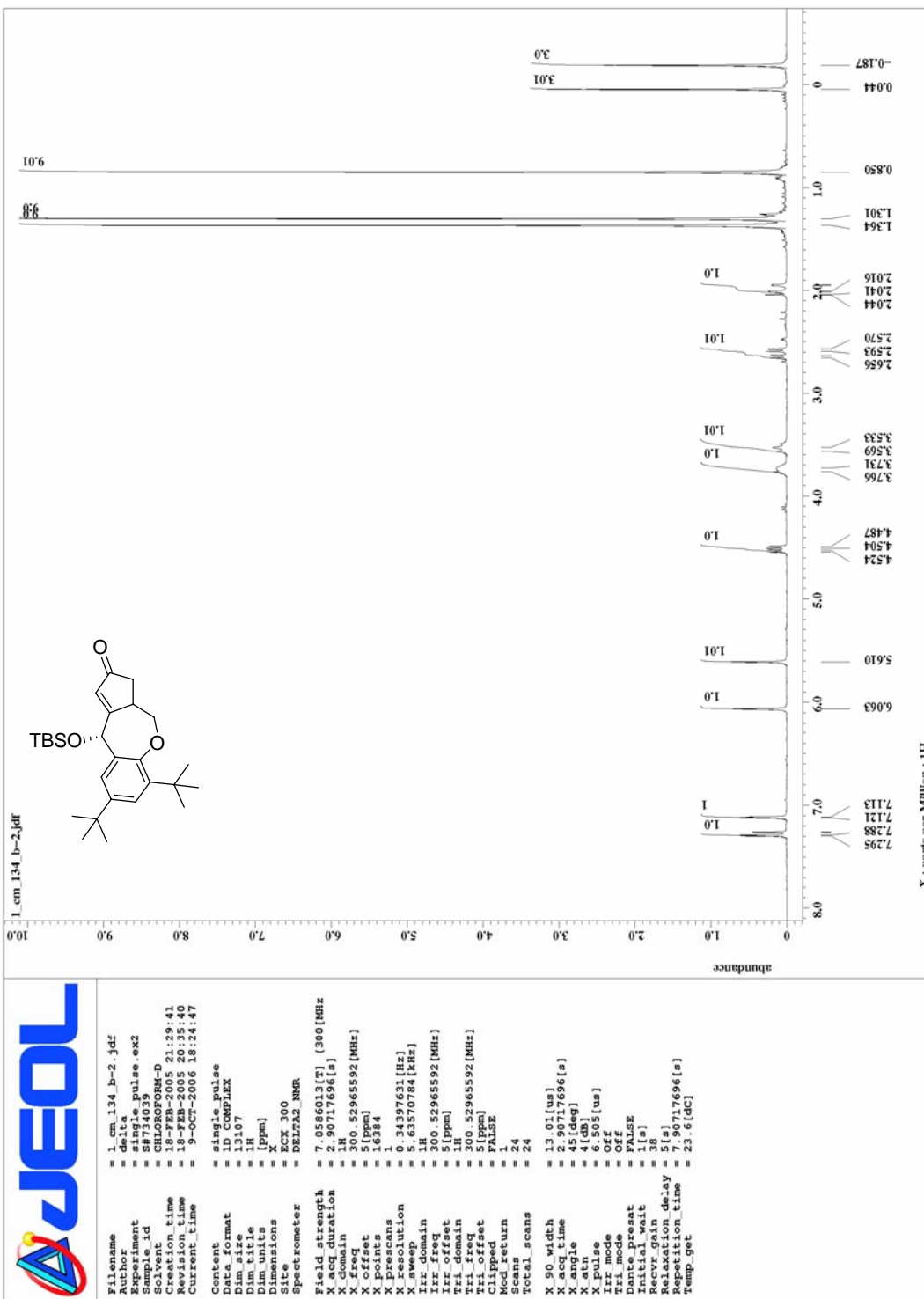
X : parts per Million : 13C

JEOL
 Filename = 1_cm_134_a-2.jdf
 Author = delta
 Experiment = single_pulse_dec
 Sample_id = SF724235
 Solvent = CDCl3-M-D
 Collection_time = 18-FEB-2005 21:23:00
 Revision_time = 18-FEB-2005 20:23:56
 Current_time = 24-OCT-2006 21:07:04
 Content = single pulse decouple
 Data_format = 1D COMPLEX
 Dim_size = 26214
 Dim_title = 13C
 Dim_units = [ppm]
 Dimensions = KX 300
 Spectrometer = DELTA2_NMR
 Field_strength = 7.0586013[T] (300[MHZ]
 X_acq_duration = 1.38412032[s]
 X_domain = 13C
 X_freq = 75.56823426[MHZ]
 X_offset = 100[ppm]
 X_points = 32768
 X_prescans = 0
 X_resolution = 72248054[Hz]
 X_sweep = 23.67424242[kHz]
 Irr_domain = 1H
 Irr_freq = 300.52965592[MHZ]
 Irr_offset = 5[ppm]
 Clipped = FALSE
 Mod_return = 1
 Scans = 196
 Total_scans = 196
 X_90_width = 9.75[us]
 X_acq_time = 1.38412032[s]
 X_angle = 30[deg]
 X_atn = 8[db]
 X_pulse = 3.25[us]
 Irr_atn_dec = 25[db]
 Irr_atn_noe = 25[db]
 Irr_noise = WALTZ
 Decoupling = TRUE
 Initial_wait = 1[s]
 Noe_time = 3[s]
 Recvr_gain = 50
 Relaxation_delay = 3[s]
 Repetition_time = 4.38412032[s]
 Temp_get = 22.9[dc]

APPENDIX 36

^1H and ^{13}C NMR SPECTRA OF

**6,8-Di-*tert*-butyl-10-*t*-butyldimethylsilyloxy-4,4a-dihydro
-3*H*,10*H*-5-oxabenzof]azulen-2-one (*endo* product, 37)**





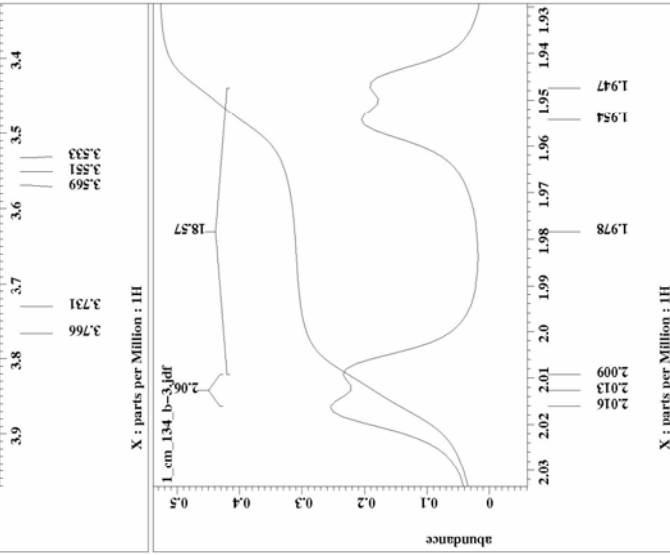
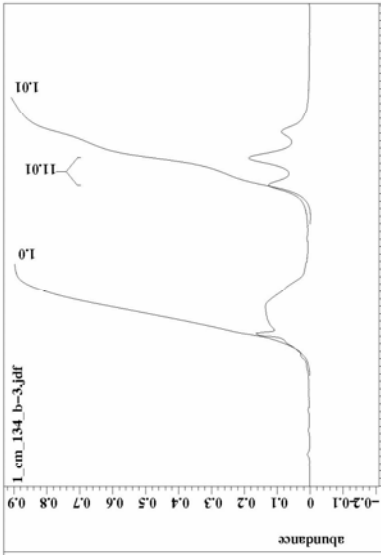
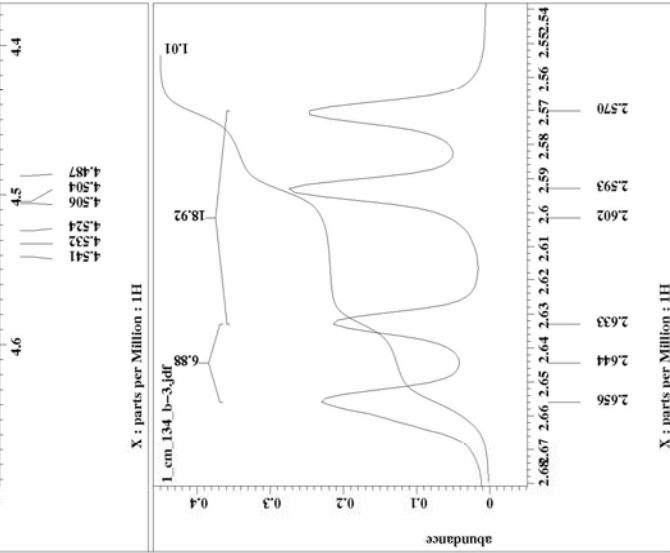
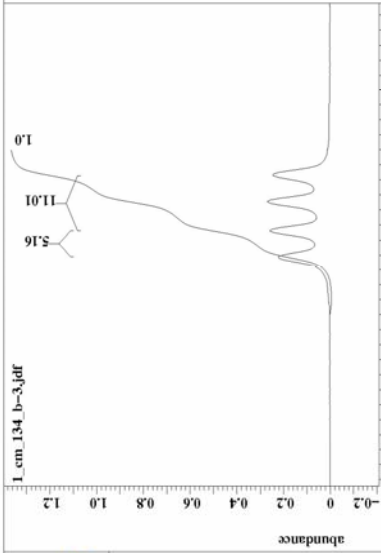
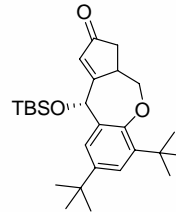
```

Filename = 1_cm_134_b-3_jdf
Author = delta
Experiment = delta_pulse_ex2
Sample_id = SH734039
Solvent = CHLOROFORM-D
Creation_time = 18-FEB-2005 21:29:41
Revision_time = 9-OCT-2006 18:28:22
Current_time = 9-OCT-2006 18:29:36

Content = single_pulse
Data_format = ID COMPLEX
Dim_size = 13107
Dim_title = 1H
Dim_units = X [ppm]
Dimensions = X
Site = ECK300
Spectrometer = DELTA2_NMR

Field_strength = 7.05860131[T] (300[MHz])
X_acq_duration = 2.90717696[s]
X_domain = 1H
X_freq = 300.52965592[MHz]
X_offset = 5[ppm]
X_points = 16384
X_resolution = 1[ppm]
X_sweep = 0.34397631[Hz]
Irr_domain = 1H
Irr_freq = 300.52965592[MHz]
Irr_offset = 5[ppm]
Tri_domain = 1H
Tri_freq = 300.52965592[MHz]
Tri_offset = 5[ppm]
Clipped = FALSE
Ssd_return = 24
Total_scans = 24

X_90_width = 13.01[us]
X_acq_time = 7.90717696[s]
X_gate = 45[deg]
X_atn = 41[db]
X_pulse = 6.505[us]
Irr_mode = off
Tri_mode = off
Auto_shut_off = FALSE
Initial_wait = 11[s]
Recvr_gain = 38
Relaxation_delay = 5[s]
Repetition_time = 7.90717696[s]
Temp_get = 23.6[degC]
  
```





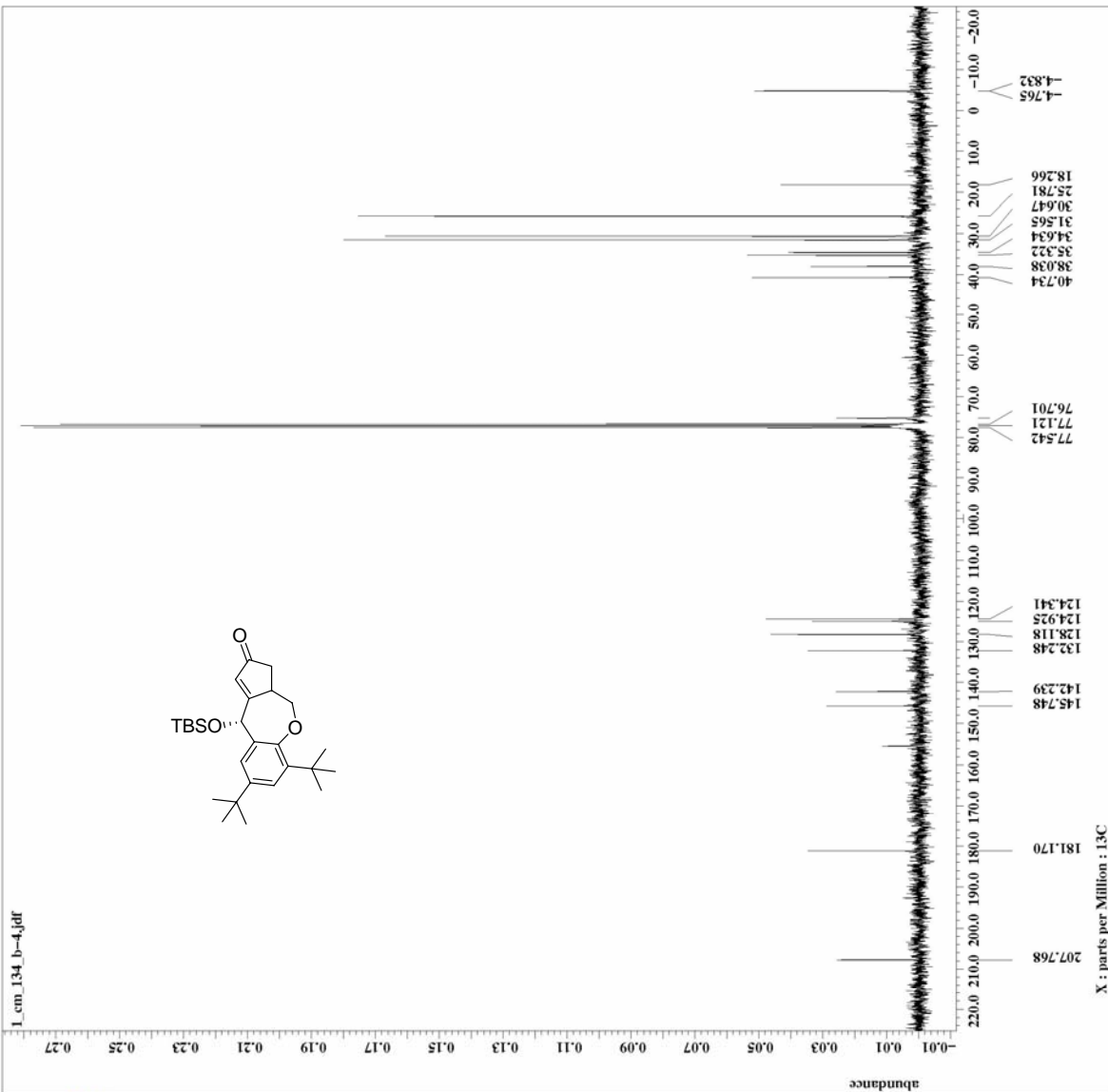
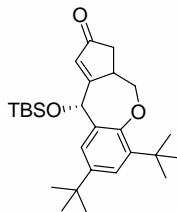
```

Filename = 1_cm_134_b-4_jdf
Author = delta
Experiment = single_pulse_dec
Sample_id = S#737521
Solvent = CHLOROFORM-D
Creation_time = 18-FEB-2005 21:55:50
Revision_time = 24-OCT-2006 21:07:19
Current_time = 24-OCT-2006 21:07:37

Content = single_pulse_decouple
Data_mat = ID_CompLEX
Dim_size = 26214
Dim_title = 13C
Dim_units = [ppm]
Dimensions = X
Site = ECX 300
Spectrometer = DELTA2_NMR

Field_strength = 7.0586013[T] (300[MHz]
X_acq_duration = 1.38412032[s]
X_chan = 13C
X_freq = 75.56823426[MHz]
X_offset = 100[ppm]
X_points = 32768
X_prescans = 4
X_resolution = 0.72248054[Hz]
X_sweep = 23.67424242[kHz]
Irr_domain = 1H
Irr_freq = 300.52965592[MHz]
Irr_offset = 2[ppm]
Mappped = PAUSE
Msd_return = 1
Scans = 342
Total_scans = 342

X_90_width = 9.75[us]
X_acq_time = 1.38412032[s]
X_angle = 30[deg]
X_atn = 8[db]
X_pulse = 2.25[us]
Irr_atn_dec = 25[db]
Irr_atn_noe = 25[db]
Irr_noise = WAITZ
Decoupling = TRUE
Initial_wait = 1[s]
Noe_time = TRUE
Noe_time = 3[s]
Recvr_gain = 50
Relaxation_delay = 3[s]
Repetition_time = 4.38412032[s]
Temp_get = 22.8[degC]
  
```

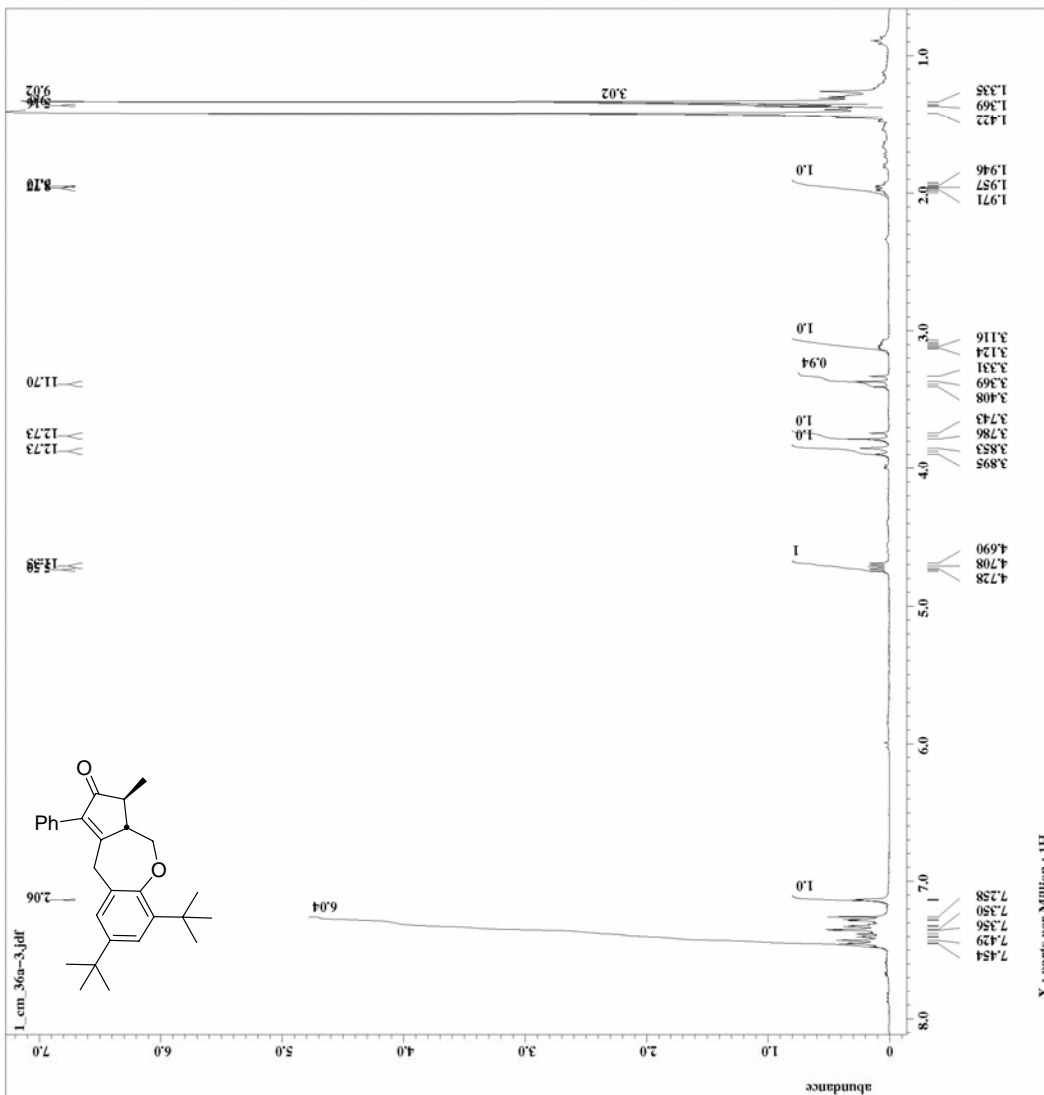


X : parts per Million : 13C

APPENDIX 37

^1H and ^{13}C NMR SPECTRA OF

**6,8-Di-*tert*-butyl-1-phenyl-3-methyl-4,4a-dihydro
-3*H*,10*H*-5-oxabenzof]azulen-2-one (39)**



1_cm_36a-3.jdf

Abundance

Chemical structure: CC(C)C1=CC=C(C=C1)C2=CC(=C(C=C2)OC3C(C)C(=O)C=C3)C(C)C

7.0 6.0 5.0 4.0 3.0 2.0 1.0 0

0.8 1.0 2.0 3.0 4.0 5.0 6.0 7.0

X : parts per Million : 1H

JEOL

```

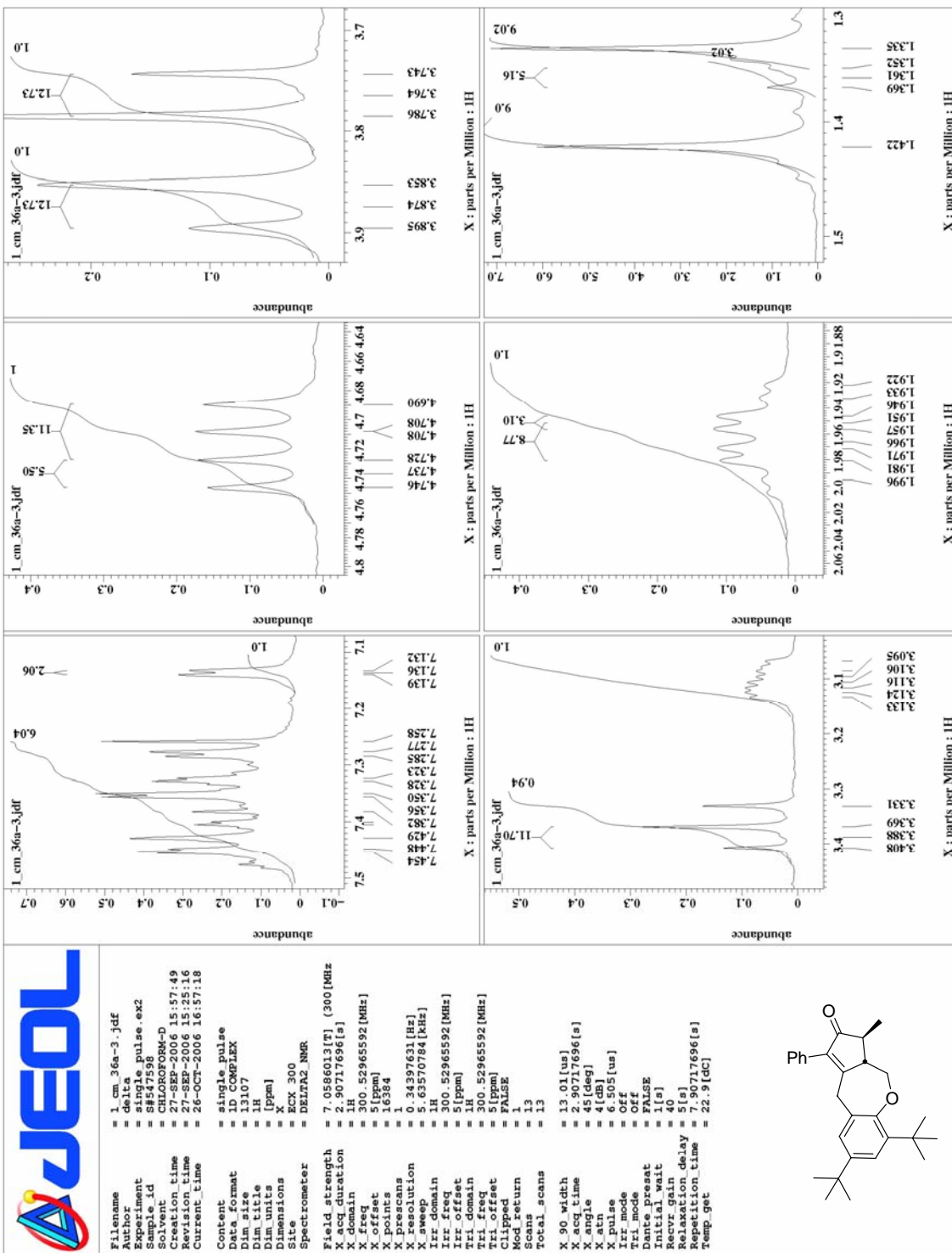
Filename == 1_cm_36a-3.jdf
Author ==
Acquisition == delta_pulse.ex2
Sample_id == S847598
Solvent == CHLOROFORM-D
Creation_time == 27-SEP-2006 15:57:49
Revision_time == 27-SEP-2006 15:25:16
Current_time == 26-OCT-2006 16:34:43

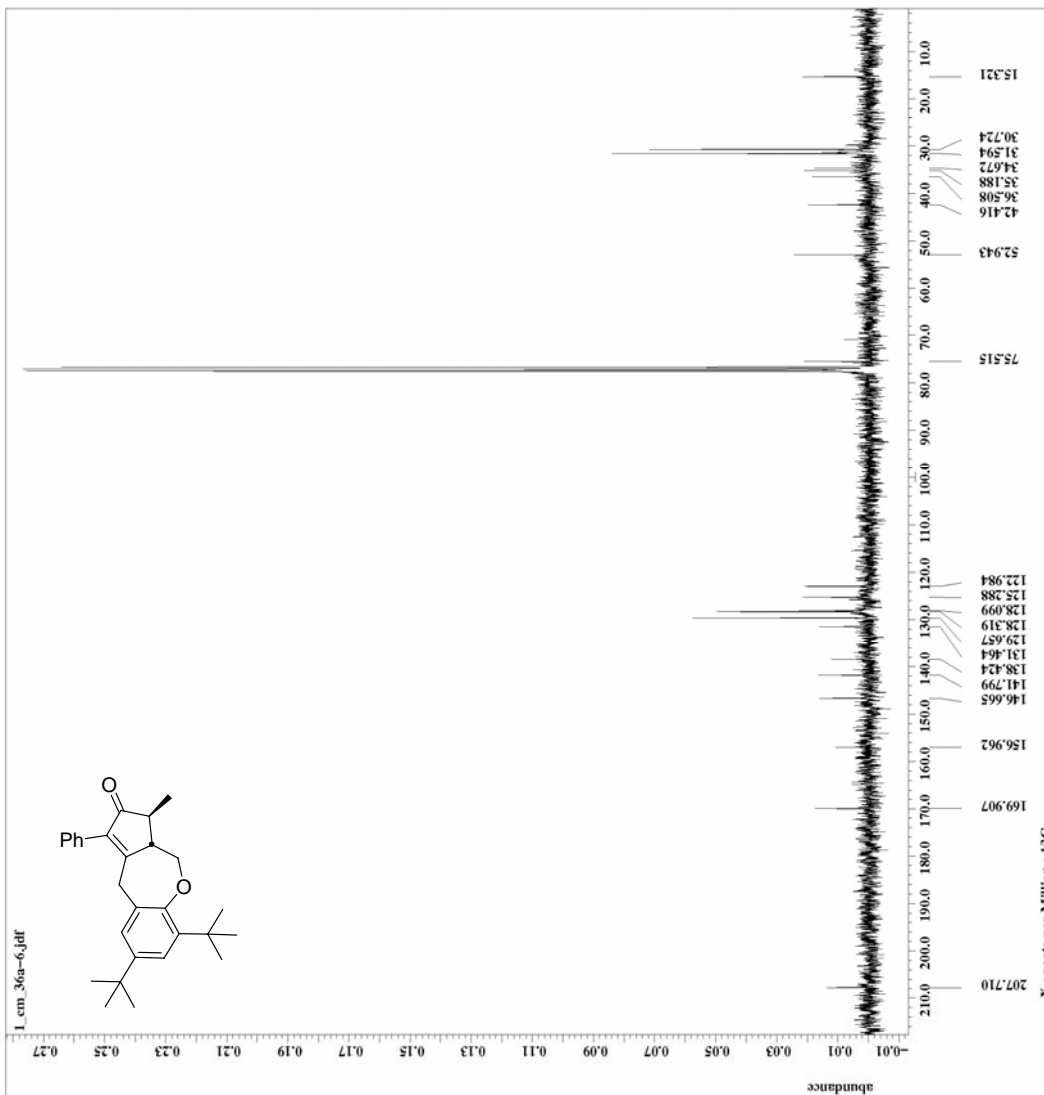
Content == single_pulse
Data_format == ID COMPLEX
Dim_size == 13107
Dim_title ==
Dim_units == IN
Dimensions == X
Site == ECX 300
Spectrometer == DELTA2_NMR

Field_strength == 7.0586013[T] (300[MHz]
X_acq_duration == 2.90717696[s]
X_domain ==
X_freq == 300.52965592[MHz]
X_offset == 5[ppm]
X_phase == 16384
X_pulses ==
X_resolution == 0.34397631[Hz]
X_sweep ==
Irr_domain == IN
Irr_freq == 0.52965592[MHz]
Irr_offset == 20[ppm]
Irr_phase == IN
Tri_domain == IN
Tri_freq == 300.52965592[MHz]
Tri_offset == 5[ppm]
Clipped == FALSE
No_return ==
Scans == 13
Total_scans == 13

X_90_width == 13.01[us]
X_acq_time == 2.90717696[s]
X_angle == 45[deg]
X_atn == 4[db]
X_pulse == 6.505[us]
Irr_mode == off
Tri_mode == off
Data_release == FALSE
Initial_wait == 1[s]
Recvr_gain == 40
Relaxation_delay == 5[s]
Repetition_time == 2.90717696[s]
Temp_get == 22.3[degC]

```





JEOL
 Filename = 1_cm_36a-6.jdf
 Author = delta
 Experiment = pulse_dec
 Sample_id = S847791
 Solvent = CHLOROFORM-D
 Creation_time = 27-SEP-2006 16:14:35
 Revision_time = 26-OCT-2006 16:48:05
 Current_time = 26-OCT-2006 16:30:10
 Content = single pulse decouple
 Data_format = ID COMPLEX
 Dim_size = 26214
 Dim_title = 13C
 Dimensions = X (ppm)
 Site = ECX 300
 Spectrometer = DELTA2_NMR
 Field_strength = 7.0586013 [T] (300 [MHz])
 X_acq_duration = 1.38412032 [s]
 X_domain = 13C
 X_freq = 75.56823426 [MHz]
 X_offset = 100 [ppm]
 X_points = 2768
 X_resolution = 0.72248054 [Hz]
 X_sweep = 23.67424242 [kHz]
 Irr_domain = IN
 Irr_freq = 200.52965592 [MHz]
 Irr_offset = FALSE
 Mod_return = 1
 Scans = 224
 Total_scans = 224
 X_90_width = 9.75 [us]
 X_acq_time = 1.38412032 [s]
 X_angle = 30 [deg]
 X_atn = 8 [dB]
 X_pulse = 25 [us]
 X_pulse_dec = 25 [us]
 Irr_atn_noe = 25 [dB]
 Irr_noise = WALTZ
 Decoupling = TRUE
 Initial_wait = 1 [s]
 Noe_time = 3 [s]
 Recvr_gain = 50
 Relaxation_delay = 3 [s]
 Repetition_time = 4.38412032 [s]
 Temp_get = 23 [C]



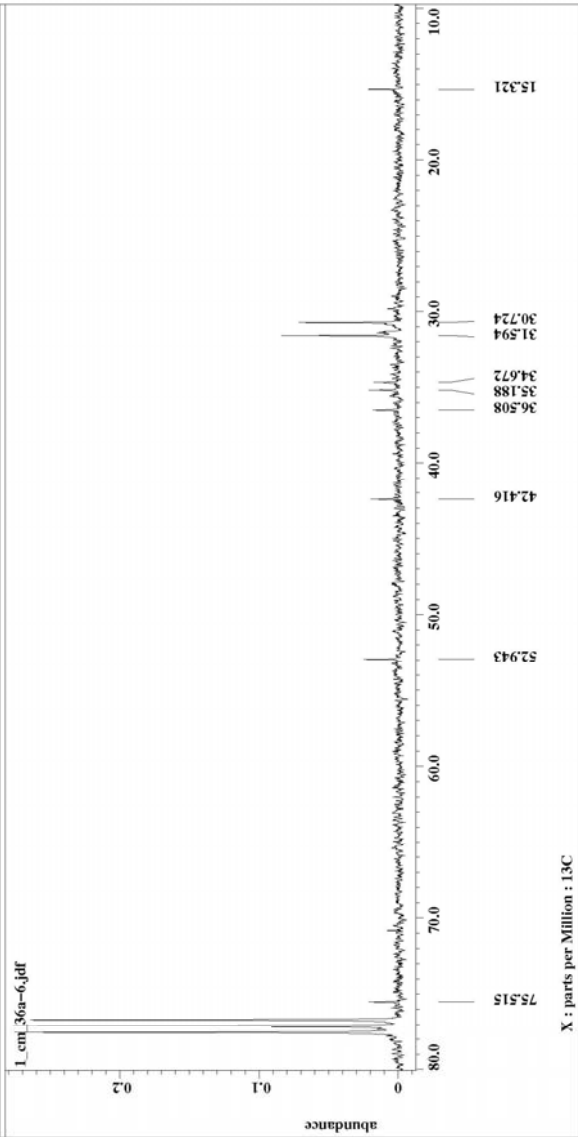
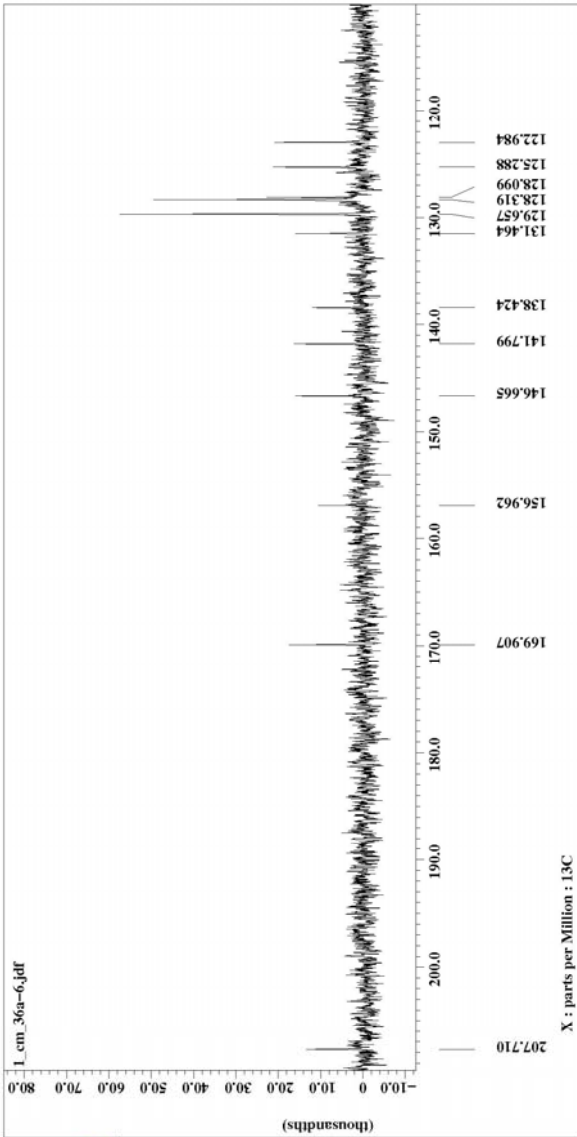
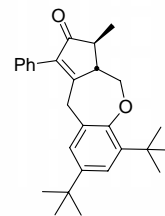
```

Filename = 1_cm_36a-6.jdf
Author = delta
Experiment = single_pulse_dec
Sample_id = S#547791
Solvent = CHLOROFORM-D
Creation_time = 27-SEP-2006 16:14:35
Revision_time = 26-OCT-2006 16:48:05
Current_time = 26-OCT-2006 16:49:34

Content = single_pulse_decouple
Data_format = 1D COMPLEX
Dim_size = 26214
Dim_title = 13C
Dim_units = [ppm]
Dimensions = X
Site = ECX 300
Spectrometer = DELTAZ_NMR

Field_strength = 7.0586013[T] (300[MHZ]
X_acq_duration = 1.38412032[s]
X_domain = 13C
X_freq = 75.56923426[MHZ]
X_offset = 100[ppm]
X_points = 32768
X_prescans = 4
X_resolution = 2.72248054[Hz]
X_sweep = 2.67424242[kHz]
Irr_detain = 1H
Irr_freq = 300.52965592[MHZ]
Irr_offset = 5[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 224
Total_scans = 224

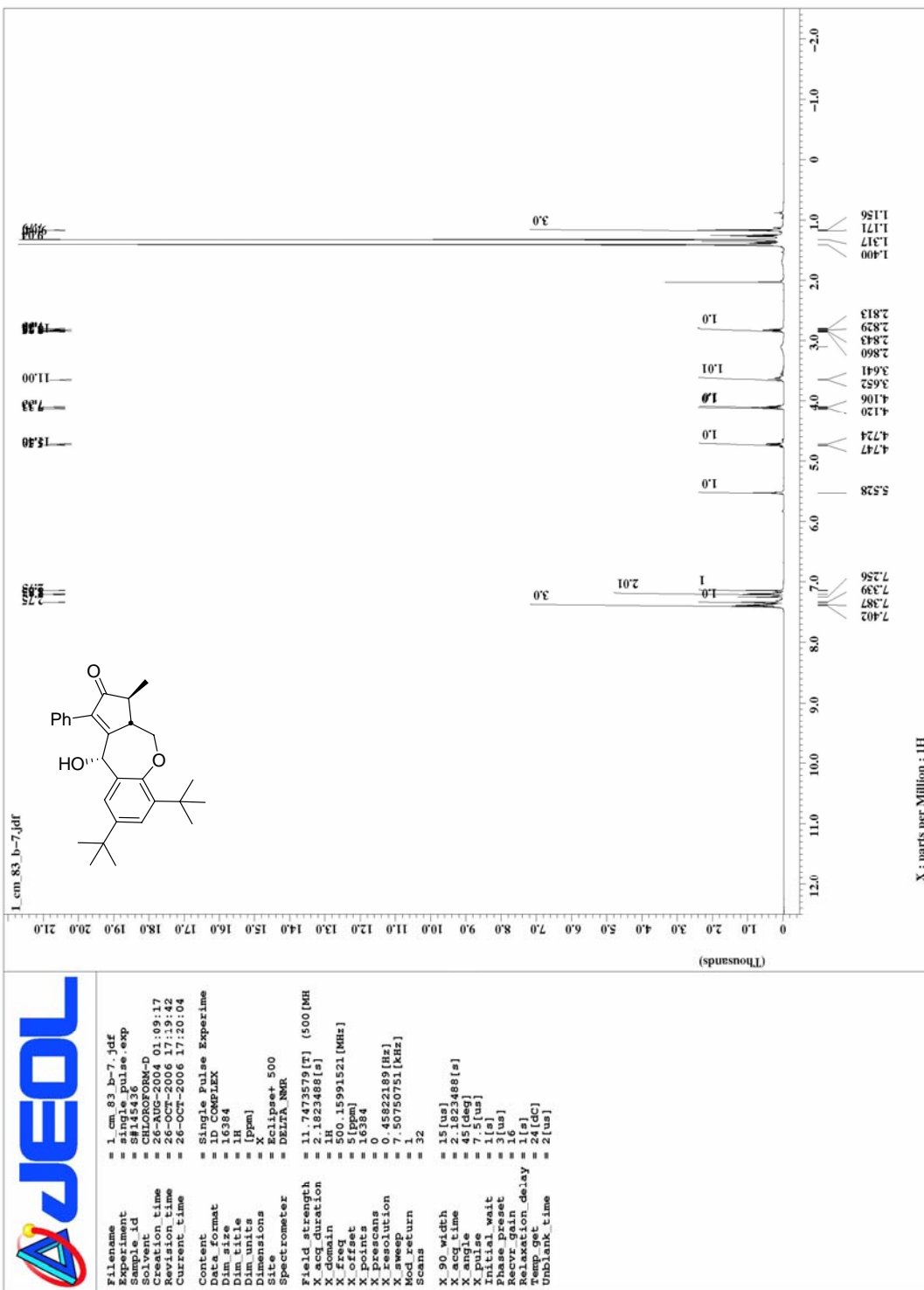
X_90_width = 9.75[us]
X_acq_time = 1.38412032[s]
X_angle = 30[deg]
X_atn = 8[db]
X_pulse = 3.25[us]
Irr_stn_dec = 25[db]
Irr_stn_hoe = 25[db]
Irr_noise = WALTZ
Decoupling = TRUE
X_initial_wait = 1[s]
X_wait = 3[s]
Xee_time = 3[s]
Recvr_gain = 50
Relaxation_delay = 3[s]
Repetition_time = 4.38412032[s]
Temp_get = 23[dc]
  
```



APPENDIX 38

¹H and ¹³C NMR SPECTRA OF

**6,8-Di-*tert*-butyl-10-hydroxy-3-methyl-1-phenyl-4,4a-dihydro
-3*H*,10*H*-5-oxabenzof]azulen-2-one (*endo* product, 40)**



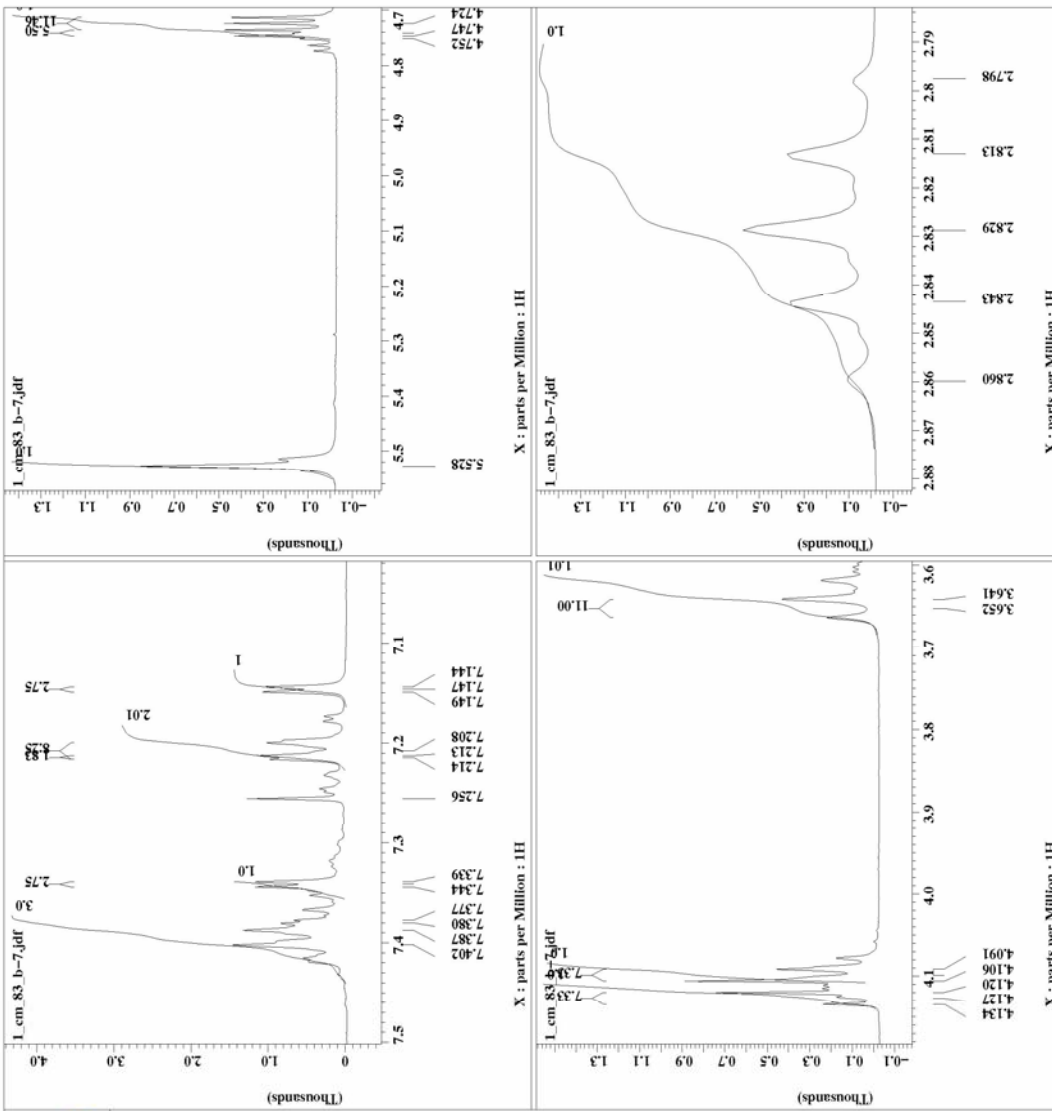
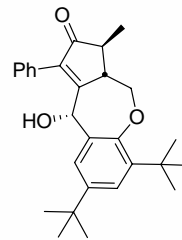


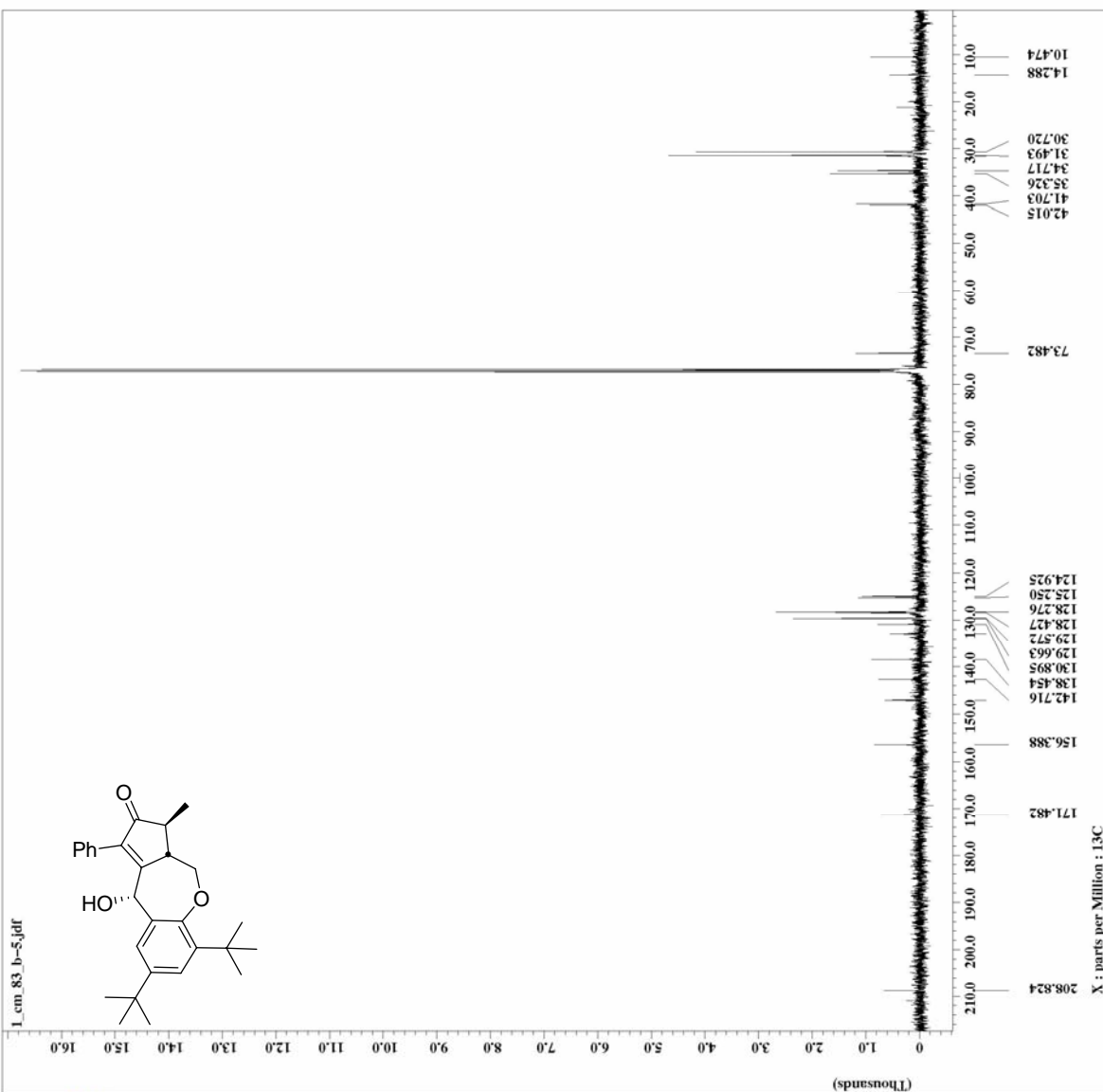
```

Filename      = 1_cm_83_b-7.jdf
Experiment    = single_pulse_exp
Sample Id     = CHLQKFBM-D
Solvent       = CDCl3
Creation time  = 26-AUG-2004 01:09:17
Revision time  = 26-OCT-2006 17:23:13
Current time   = 26-OCT-2006 17:23:50
Content       = Single Pulse Experiment
Data format   = 1D COMPLEX
Dim size      = 16384
Dim title     = 1H
Dim units     = [ppm]
Dimensions    = 500
Site          = Eclipse-500
Spectrometer = DELTA-NMR

Field strength = 11.7473752[T] (500[MH]
X acq duration = 2.1823488[s]
X gain         = 2.1823488[s]
X freq         = 500.15991521[MHz]
X offset       = 5[ppm]
X points       = 16384
X prescans     = 0
X prescan     = 45822189[Hz]
X resolution   = 7.50750751[kHz]
X sweep        = 1
Mod return     = 32
Scans          = 32

X 90 width     = 15[us]
X 90 time      = 2.1823488[s]
X angle        = 45[deg]
X pulse        = 7.5[us]
Initial wait   = 1[s]
Phase preset   = 3[us]
Relaxation     = 1[s]
Relaxation delay = 4[s]
Temp get       = 24[dc]
Unblank time   = 2[us]
  
```





1_cm_83_b-5.jdf

File name = 1_cm_83_b-5.jdf
 Experiment = single_pulse_dec
 Sample id = S#147064
 Solvent = CHLOROFORM-D
 Creation time = 26-AUG-2004 01:34:40
 Revision time = 26-OCT-2006 17:25:25
 Current time = 26-OCT-2006 17:25:54

Content = Single Pulse with Bro
 Data format = DELTA
 Data size = 65536
 Dim title = 13C
 Dim units = [ppm]
 Dimensions = X
 Site = Eclipset 500
 Spectrometer = DELTA_NMR

Field strength = 11.7473579 [T] (500 [MH
 X_acq duration = 1.736704 [s]
 X_domain = 125
 X_freq = 125.76529768 [MHz]
 X_offset = 100 [ppm]
 X_points = 65536
 X_prescans = 4
 X_resolution = 0.57580336 [Hz]
 X_sweep = 37.73584906 [kHz]
 Irr_domain = 1H
 Irr_freq = 500.15991521 [MHz]
 Irr_offset = 5 [ppm]
 Mod_return = 244
 Scans = 14 [us]
 X_90 width = 14 [us]
 X_acq time = 1.736704 [s]
 X_angle = 30 [deg]
 X_pulse = 4.66666667 [us]
 Initial_wait = 1 [s]
 Phase_preset = 5 [us]
 Recvr_gain = 29
 Relaxation_delay = 4 [s]
 Temp = 29 [dC]
 Unblank_time = 2 [us]

APPENDIX 39

¹H and ¹³C NMR SPECTRA OF

**6,8-Di-*tert*-butyl-10-hydroxy-3-methyl-1-phenyl-4,4a-dihydro
-3*H*,10*H*-5-oxabenzof]azulen-2-one (*exo* product, 41)**



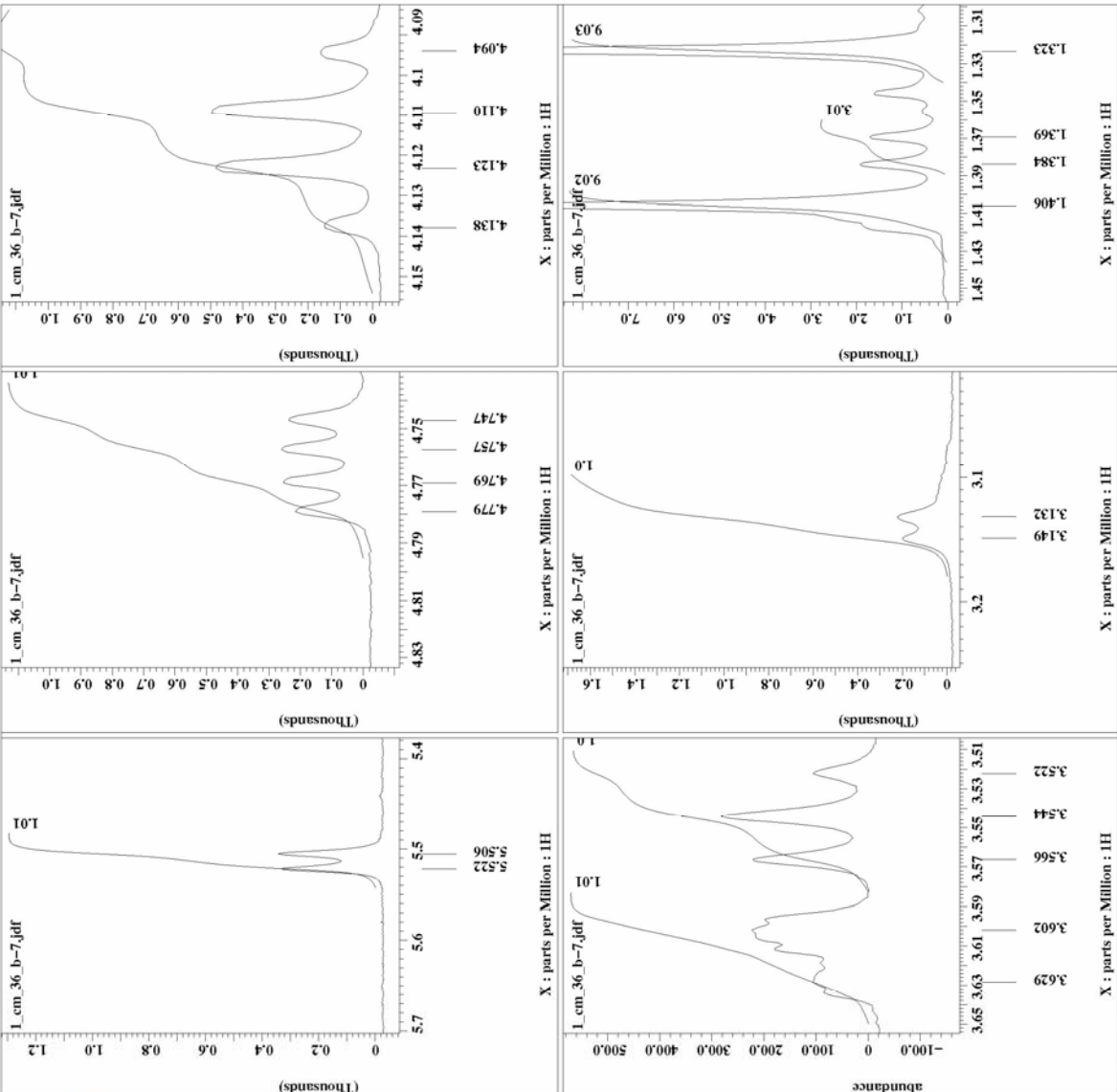
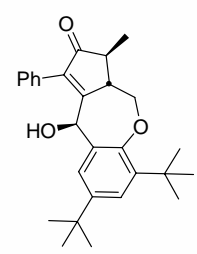
```

Filename = 1_cm_36_b-7.jdf
Experiment = single_pulse.exp
Sample_id = SF82586
Acq_date = 28-OCT-2003 09:57:36
Creation_time = 28-OCT-2003 09:57:36
Revision_time = 26-OCT-2006 17:48:37
Current_time = 26-OCT-2006 17:50:43

Content = Single Pulse Experime
Data_format = ID COMPLEX
Dir_size = 16384
Dir_title = IR
Dir_units = [ppm]
Dimensions = Scilpset 500
Spectrometer = DELTA_NMR

Field_strength = 11.7473579[T] (500[MH
X_acq_duration = 2.1823488[s]
X_domain = IR
X_freq = 500.15991521[MHz]
X_offset = 5[ppm]
X_points = 16384
X_prescans = 1
X_resolution = 0.45822189[Hz]
X_sweep = 7.50750751[KHz]
Mod_return = 1
Scans = 32

X_90_width = 15[us]
X_acq_time = 2.1823488[s]
X_angle = 45[deg]
X_pulse = 1[us]
X_pulse_width = 1[us]
Phase_offset = 3[us]
Recvr_gain = 21
Relaxation_delay = 4[s]
Temp_get = 22.5[dc]
Unblank_time = 2[us]
  
```





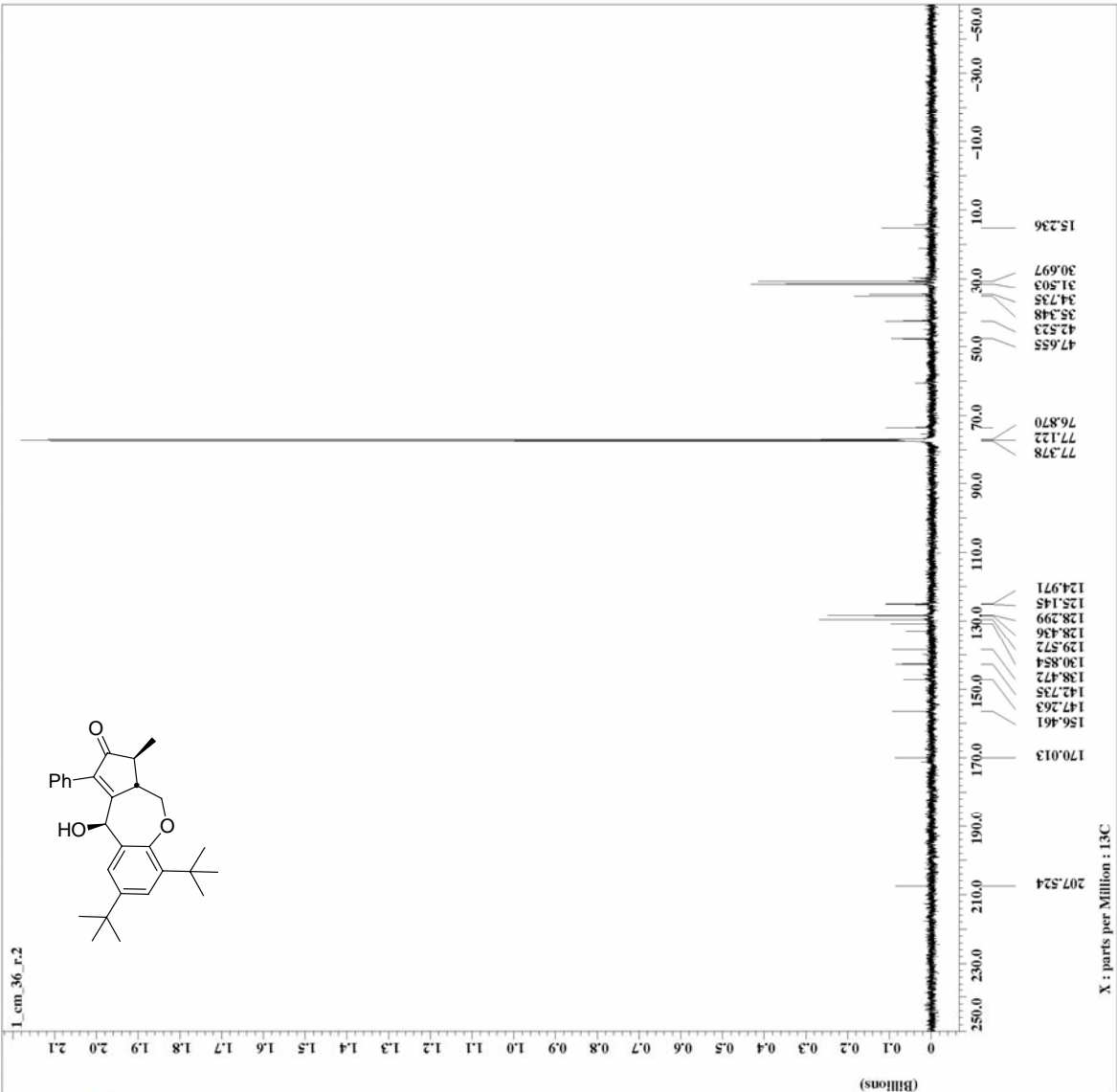
```

Filename = 1_cm_36_r_2
Experiment = single_pulse_dec
Sample_id = S#34477
Solvent = CHLOROFORM-D
Creation_time = 23-NOV-2003 12:31:17
Revision_time = 25-NOV-2003 02:02:52
Current_time = 26-OCT-2006 17:52:30

Content = Single Pulse with Bro
Date_ = 1D
Dim_format = COMPLEX
Dim_size = 65536
Dim_title = 13C
Dim_units = [ppm]
Dimensions = X
Site = Eclipse+ 500
Spectrometer = DELTA_NMR

Field_strength = 11.7473579[T] (500[MH
X_acq_duration = 1.736704[s]
X_sweep = 13C
X_freq = 125.76529768[MHz]
X_offset = 100[ppm]
X_points = 65536
X_prescans = 4
X_resolution = 0.57580336[Hz]
X_sweep = 37.73584906[KHz]
Irr_domain = 1H
Irr_freq = 500.15991521[MHz]
Irr_offset = 1[ppm]
Mag_return = 500

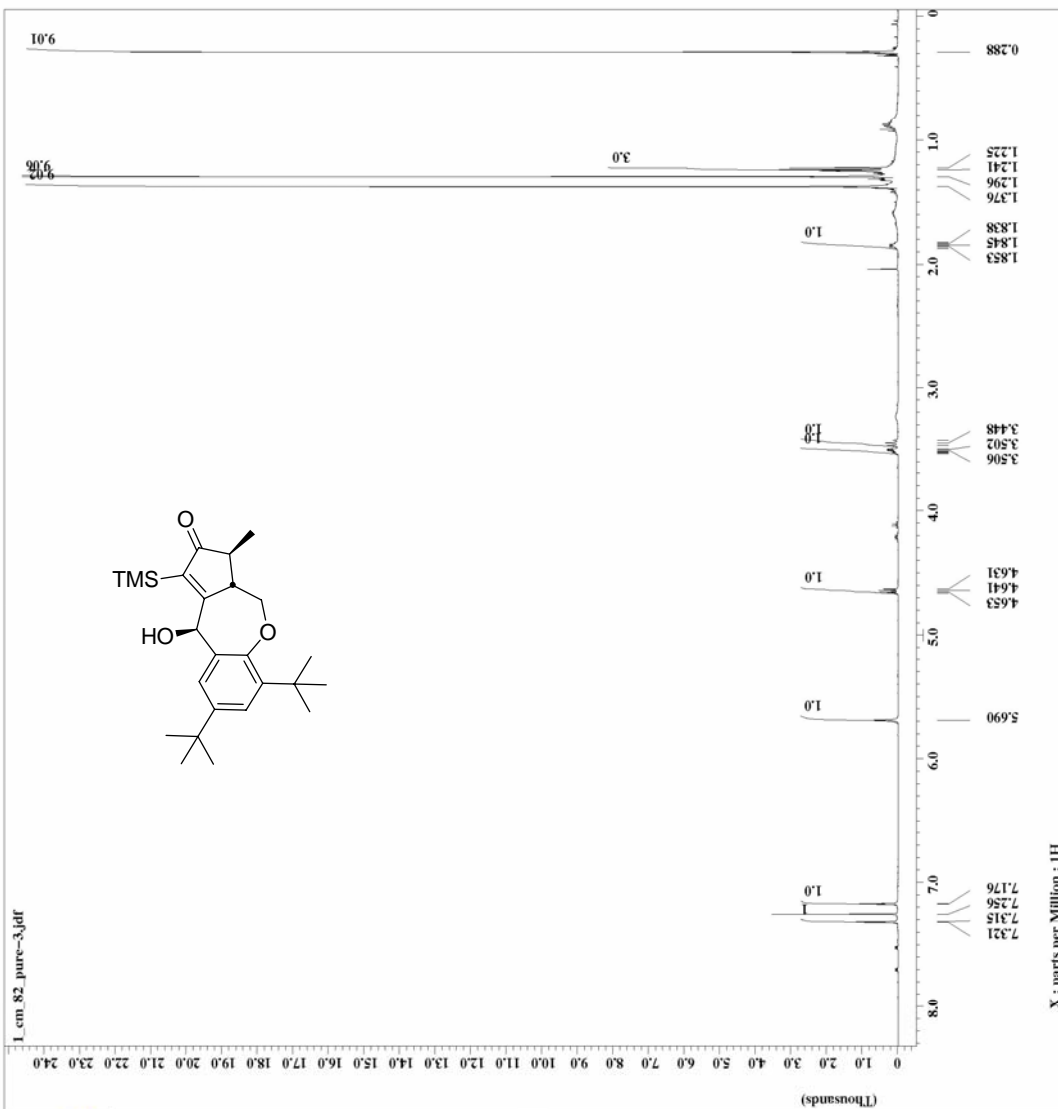
X_90_width = 14[us]
X_acq_time = 1.736704[s]
X_angle = 30[deg]
X_pulse = 4.66666667[us]
Initial_wait = 1[s]
Phase_preset = 3[us]
Relaxation = 4[s]
Relaxation_delay = 4[s]
Temp_get_delay = 22[dc]
Unblank_time = 2[us]
  
```



APPENDIX 40

^1H and ^{13}C NMR SPECTRA OF

**6,8-Di-*tert*-butyl-10-hydroxy-3-methyl-1-trimethylsilyl
-4,4a- dihydro-3*H*,10*H*-5-oxabenzof]azulen-2-one (42)**



1_cm_82_pure-3.jdf

(Thousands)

X : parts per Million : 1H

JEOL

```

Filename = 1_cm_82_pure-3.jdf
Experiment = single_pulse_exp
Sample Id = 8H120K0M-D
Sample Name = 8H120K0M-D
Creation time = 14-SEP-2004 22:27:40
Revision time = 9-OCT-2006 19:03:30
Current time = 9-OCT-2006 19:04:01
Content = Single Pulse Experiment
Data format = ID_COMPLEX
Dim size = 16384
Dim title = 1H
Dim units = [ppm]
Dimensions = X
Scale = X
Spectrometer = DELTA_NMR
Field strength = 11.7473752[T] (500[MH
X_acq_duration = 2.1823488[s]
X_domain = 10.0000000
X_freq = 500.15991521[MHz]
X_offset = 5[ppm]
X_points = 16384
X_prescans = 0
X_resolution = 0.4582189[Hz]
X_swept = 1.50750751[kHz]
Mod return = 1
Scans = 32
X_90_width = 15[us]
X_acq_time = 45[deg]48[s]
X_pulse = 7.5[us]
Initial wait = 1[s]
Phase preset = 3[us]
Recvr_gain = 18
Relaxation_delay = 24[s]
Temp_get_delay = 24.1[dc]
Unblank_time = 2[us]

```



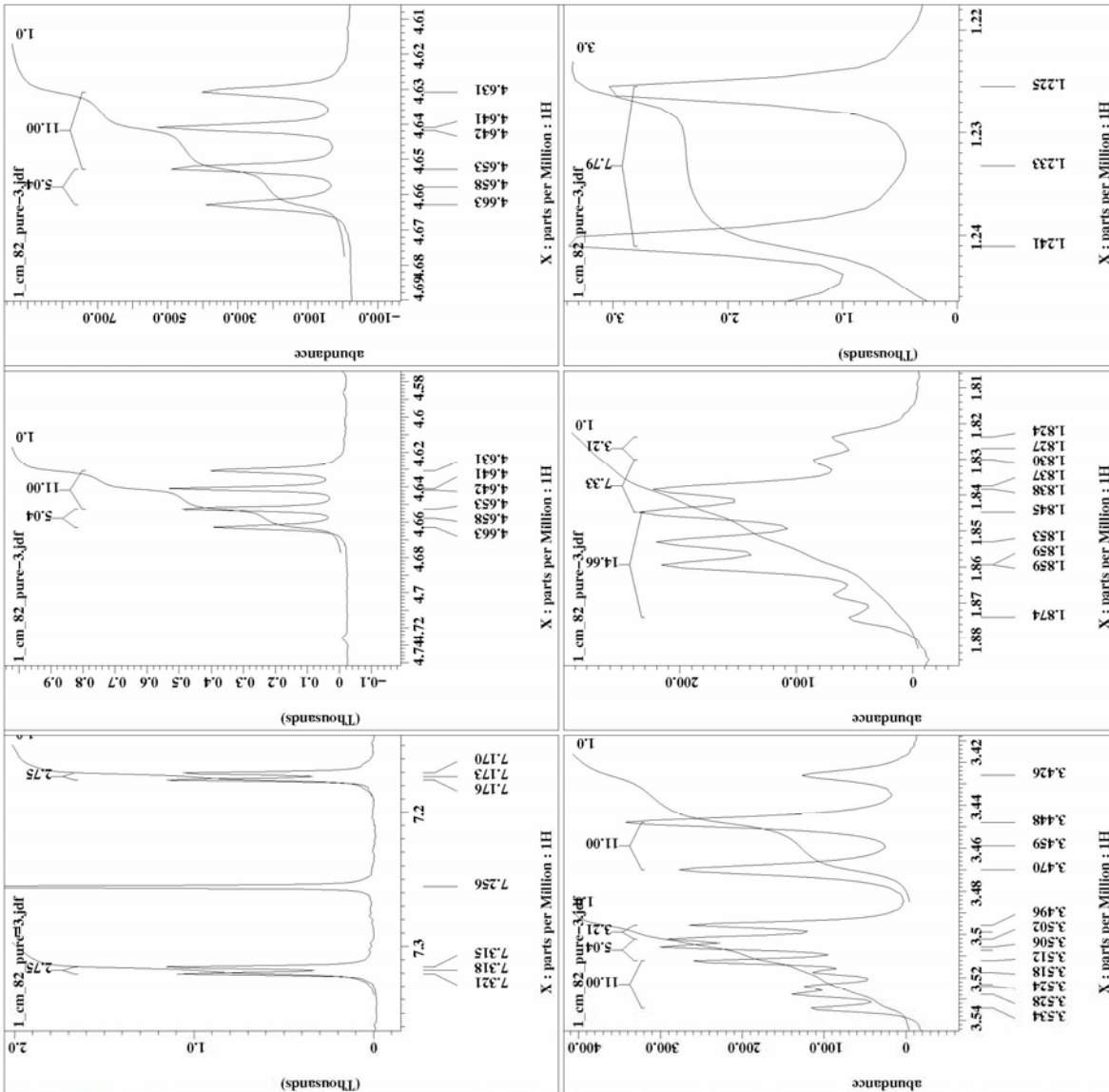
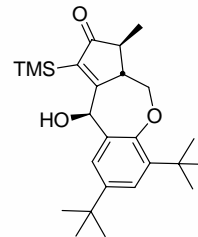
```

Filename = 1_cm_82_pure-3_jdf
Experiment = single_pulse_exp
Sample_id = S#41304
Solvent = CHLOROFORM-D
Creation_time = 14-SEP-2004 22:27:40
Revision_time = 9-OCT-2006 19:10:13
Current_time = 9-OCT-2006 19:12:57

Content = Single Pulse Experiments
Data_format = GDFEX
Dir = 16384
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Site = Eclipse+ 500
Spectrometer = DELTA_NMR

Field_strength = 11.7473579 [T] (500 [MH]
X_acq_duration = 2.1823488 [s]
X_contain = 500.15991521 [MHz]
X_offset = 5 [ppm]
X_points = 16384
X_prescans = 0
X_resolution = 0.45822189 [Hz]
X_sweep = 7.50750751 [kHz]
Mod_return = 1
Scans = 32

X_90_width = 15 [us]
X_acq_time = 2.1823488 [s]
X_angle = 45 [deg]
X_pulse = 7.5 [us]
Initial_wait = 1 [s]
Phase_preset = 3 [us]
Recvr_gain = 18
Relaxation_delay = 1 [s]
Temp_get = 24.1 [dC]
Unblank_time = 2 [us]
  
```





```

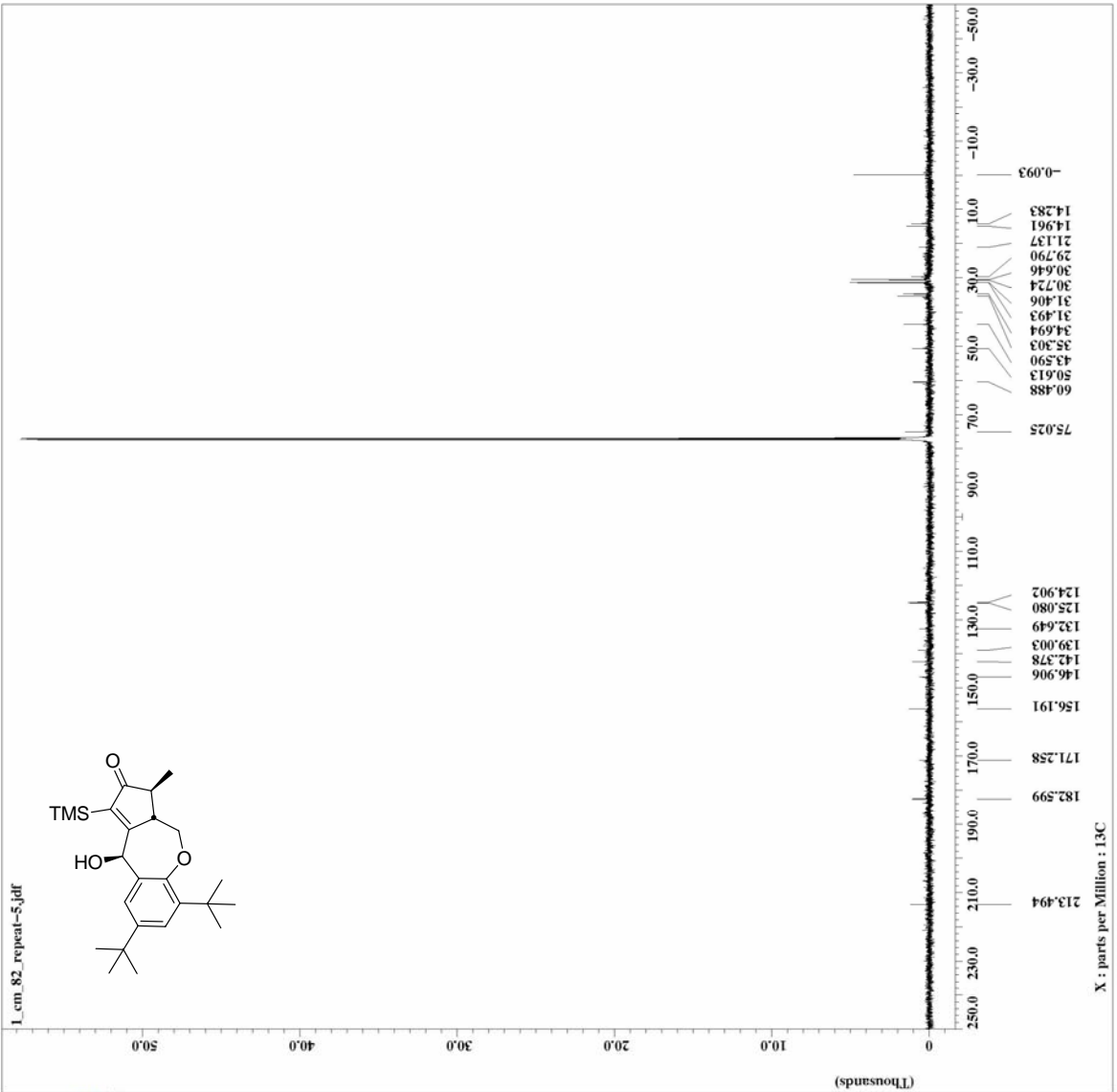
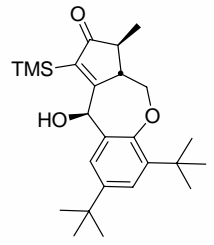
Filename      = 1_cm_82_repeat-5.jdf
Experiment    = single_pulse_dec
Sample_id     = S#47817
Solvent       = CHLOROFORM-D
Creation_time = 13-SEP-2004 23:59:35
Revision_time = 26-OCT-2006 18:11:30
Current_time  = 26-OCT-2006 18:12:27

Content       = Single Pulse with Bro
Data format   = 1D COMPLEX
Dim size      = 65536
Dim title     = 13C
Dim units     = [ppm]
Dimensions    = X
Site          = Eclipse+ 500
Spectrometer = DELTA_NMR

Field strength = 11.7473579[T] (500 [MH
X_acq_date    = 1.736704[s]
X_domain      = 13C
X_freq        = 125.76529768 [MHz]
X_offset      = 100[ppm]
X_points      = 65536
X_prescans    = 4
X_resolution  = 0.57580336 [Hz]
X_sweep       = 37.73584906 [KHz]
Xr_domain     = 500.15991521 [MHz]
Xr_offset     = 51[ppm]
Mod return    = 1
Scans         = 861

X_90_width    = 14[us]
X_acq_time    = 1.736704[s]
X_angle       = 30[deg]
X_pulse       = 4.6666667[us]
P1          = 3[s]
P2          = 3[s]
P3          = 29
Recvr Gain    = 4[s]
Relaxation_delay = 25.1[dc]
Temp_get     = 25.1[dc]
Unblank_time  = 2[us]
  
```

1_cm_82_repeat-5.jdf



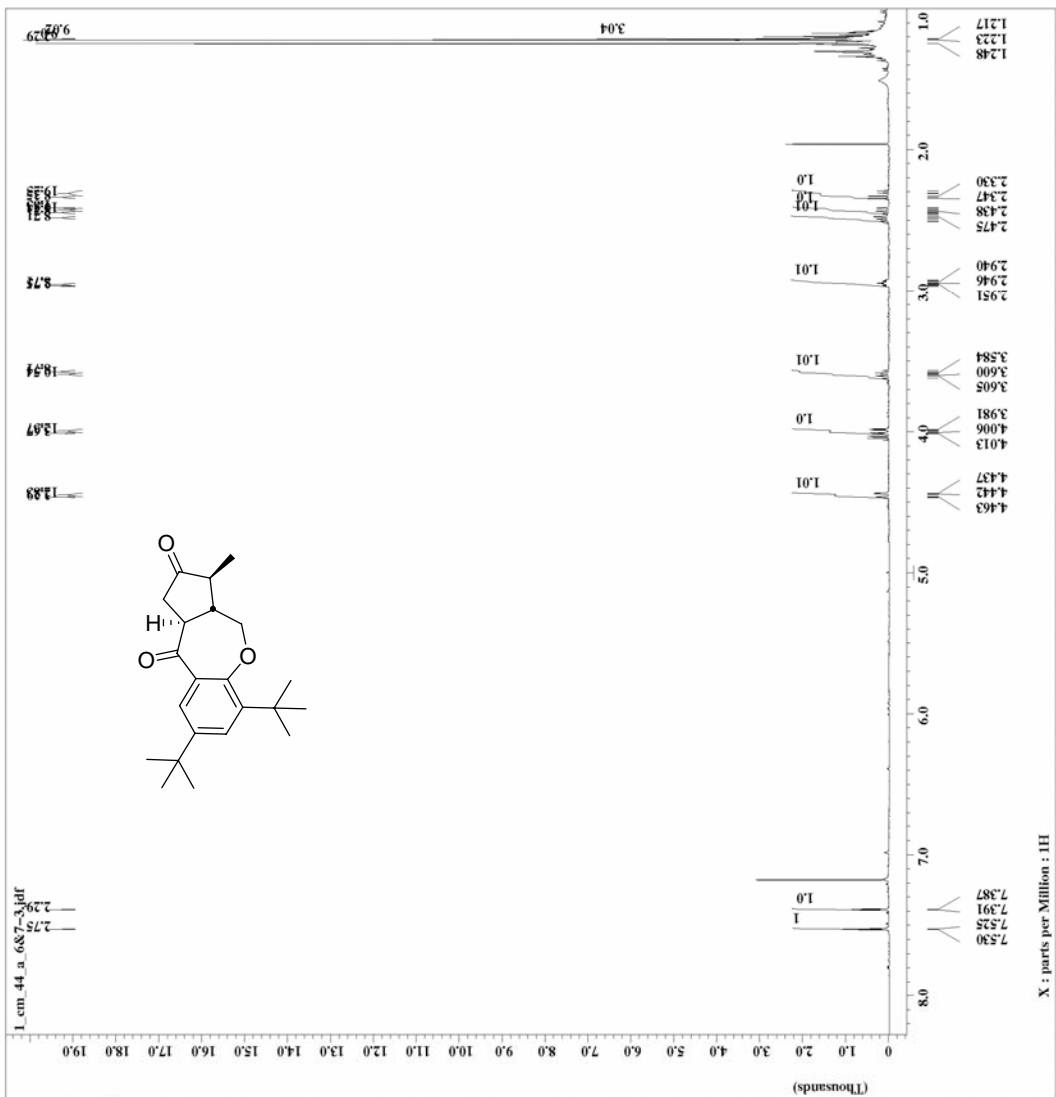
APPENDIX 41

¹H and ¹³C NMR SPECTRA OF

6,8-Di-*tert*-butyl-3-methyl-1,1a,4,4a-tetrahydro-1*H*,3*H*-5-oxabenzof]azulen-2,10-dione (*anti*-product, 43)



Filename = 1_cm_44_a_667-3_jdf
 Experiment = single_pulse_exp
 Date_Exp = 03-SEP-2004 05:53:51
 Solvent = CHLOROFORM-D
 Creation_time = 3-SEP-2004 05:53:51
 Revision_time = 9-OCT-2006 22:23:48
 Current_time = 9-OCT-2006 22:24:53
 Content = Single Pulse Experiment
 Data_format = ID COMPLEX
 Dim_size = 16384
 Dim_title = 1H
 Dim_units = [ppm]
 Dimensions = 1
 Site = Eclipset 500
 Spectrometer = DELTA_NMR
 Field_strength = 11.747879[T] (500[MH
 X_nucleation = 2.1823488[s]
 X_domain = 1H.1823488[s]
 X_freq = 500.15991521[MHz]
 X_offset = 5[ppm]
 X_points = 16384
 X_resolution = 0.45822189[Hz]
 X_sweep = 7.50750751[kHz]
 Mod_return = 1
 Scans = 32
 X_90_width = 15[us]
 X_acq_time = 2.1823488[s]
 X_angle = 45[deg]
 X_pulse = 7.5[us]
 Phase_exit = 3[s]
 Pulse_preset = 19[us]
 Recvr_gain = 1[s]
 Relaxation_delay = 1[s]
 Temp_get = 24[dc]
 Unblank_time = 2[us]



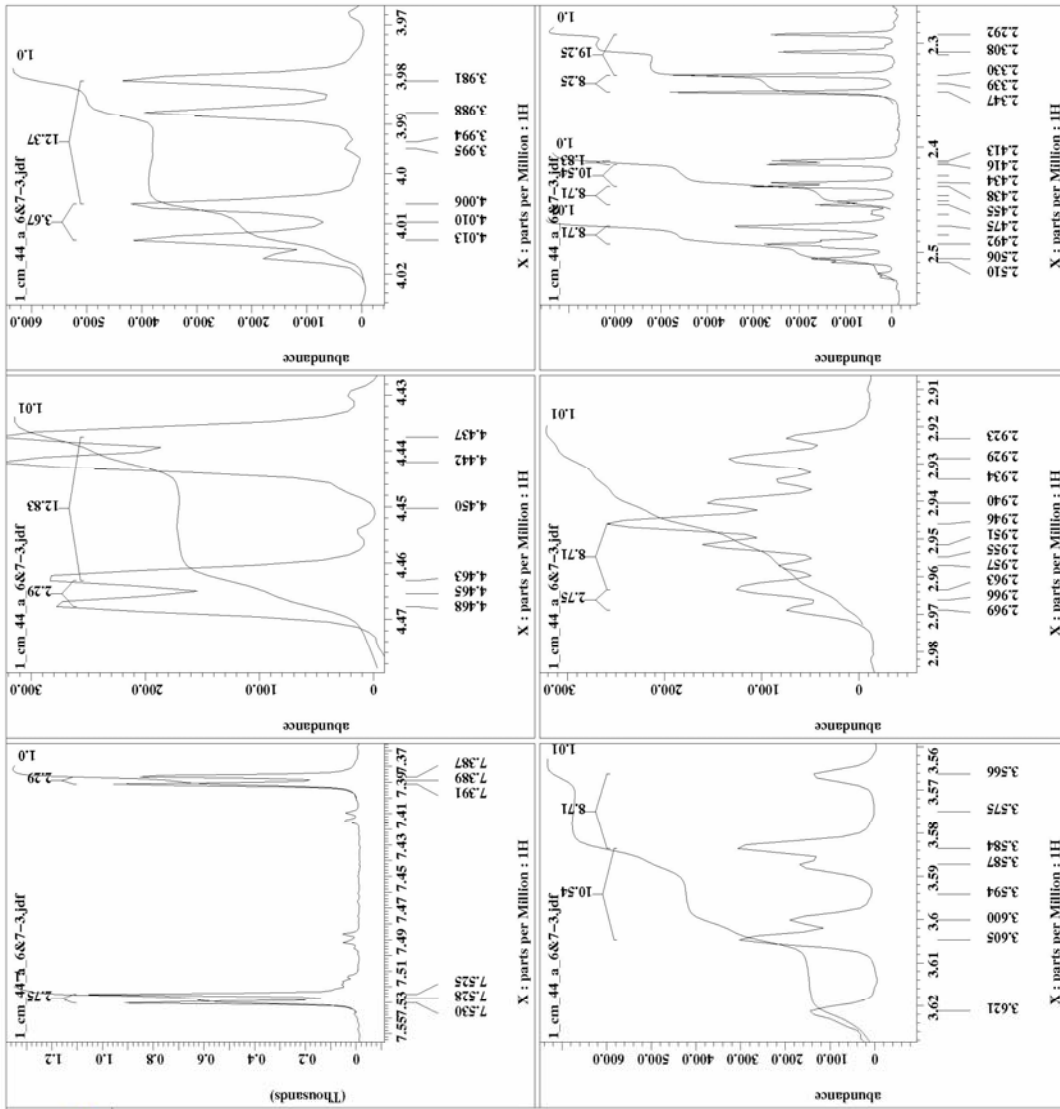
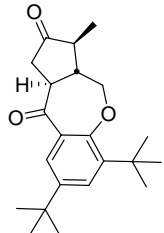


```

File name      = 1_cm_44_a_687-3_jdf
Experiment     = single_pulse_exp
Sample Id      = 101
Sample name    = CHLORFORM-D
Creation time   = 3-SEP-2004 05:53:51
Revision time  = 9-OCT-2006 22:23:48
Current time   = 26-OCT-2006 18:28:48
Content        = Single Pulse Experiment
Data format    = 1D COMPLEX
Dim size       = 16384
Dim title      = 1H
Dim units      = [ppm]
Dimensions     = F1=500
Spectrometer   = DELTA_NMR

Field strength = 11.7473575[T] (500 [MH
X acq duration = 2.1823488[s]
X delay         = 1.0000000[s]
X freq          = 500.15991521 [MHz]
X offset        = 5 [ppm]
X points        = 16384
X prescans      = 0
X resolution    = 0.45820189 [Hz]
X resolution    = 7.40750751 [kHz]
Mod return      = 1
Scans           = 32

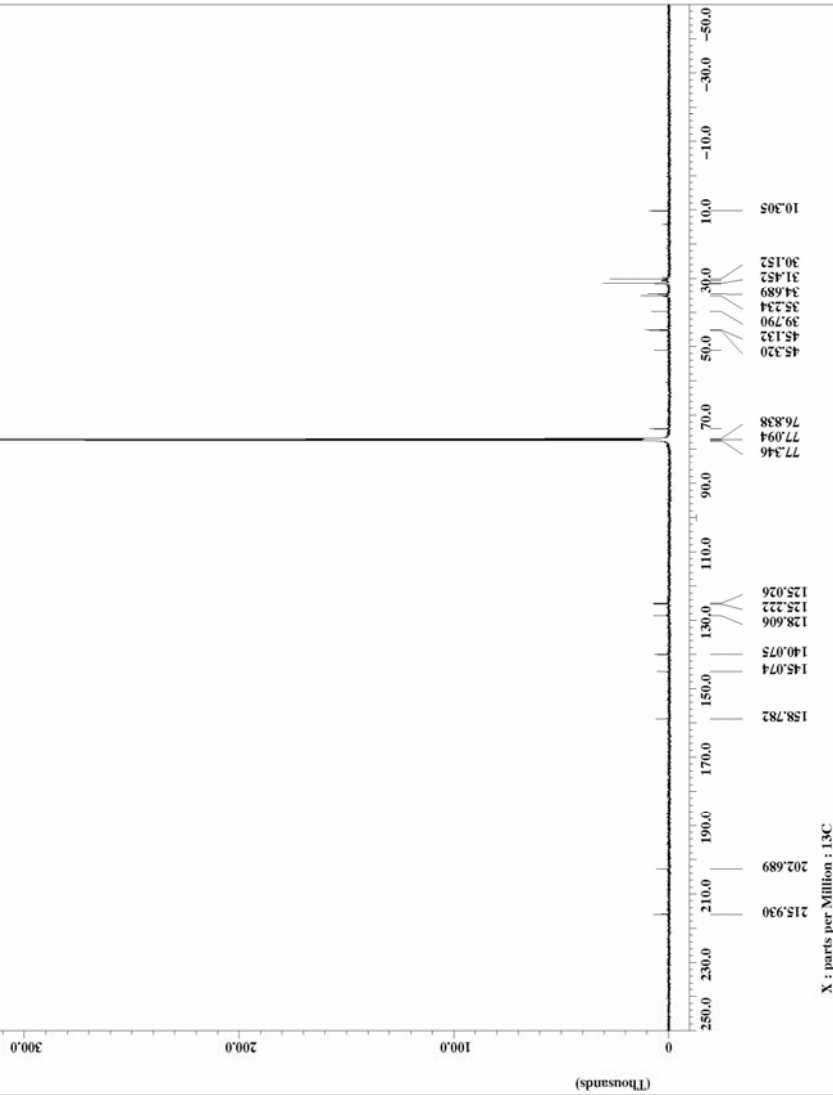
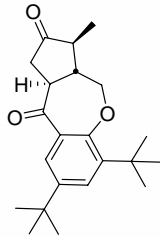
X 90_width      = 15 [us]
X 90_angle       = 45 [deg]
X pulse          = 7.5 [us]
Initial wait     = 1 [s]
Phase preset     = 3 [us]
Recvr gain       = 1 [s]
Temp set on delay = 24 [s]
Temp get         = 2 [us]
Unblank time    = 2 [us]
  
```





Filename = l_cm_44_a_6&7_2ndtrial-4.jdt
Experiment = single_pulse_dec
Date_Exp = 20060914
Solvent = CHLOROFORM-D
Creation_time = 5-SEP-2004 16:41:30
Revision_time = 26-OCT-2006 18:19:44
Current_time = 26-OCT-2006 18:20:47
Content = Single Pulse with Broc
Data_format = ID COMPLEX
Dim_size = 65536
Dim_title = 13C
Dim_units = [ppm]
Dimensions = 1
Site = Eclipset 500
Spectrometer = DELTA_NMR
Field_strength = 125.76529768 [MHz]
X_acq_time = 1.736704 [s]
X_domain = 13C
X_freq = 125.76529768 [MHz]
X_offset = 100 [ppm]
X_points = 65536
X_resolution = 0.57580336 [Hz]
X_sweep = 37.73584906 [kHz]
Irr_domain = 1H
Irr_freq = 500.15991521 [MHz]
Irr_offset = 5 [ppm]
Mag_return = 1
Scans = 7383
X_90_width = 14 [us]
X_acq_time = 1.736704 [s]
X_delay = 1.000000 [s]
X_pulse = 4.66666667 [us]
Initial_wait = 1 [s]
Phase_preset = 2 [us]
Recvr_gain = 29
Relaxation_delay = 24.9 [dc]
Temp_get_time = 2 [us]
Unblank_time = 2 [us]

l_cm_44_a_6&7_2ndtrial-4.jdt



APPENDIX 42

¹H and ¹³C NMR SPECTRA OF

6,8-Di-*tert*-butyl-3-methyl-1,1a,4,4a-tetrahydro-1*H*,3*H*-5-oxabenzof]azulen-2,10-dione (*syn*-product, 43)



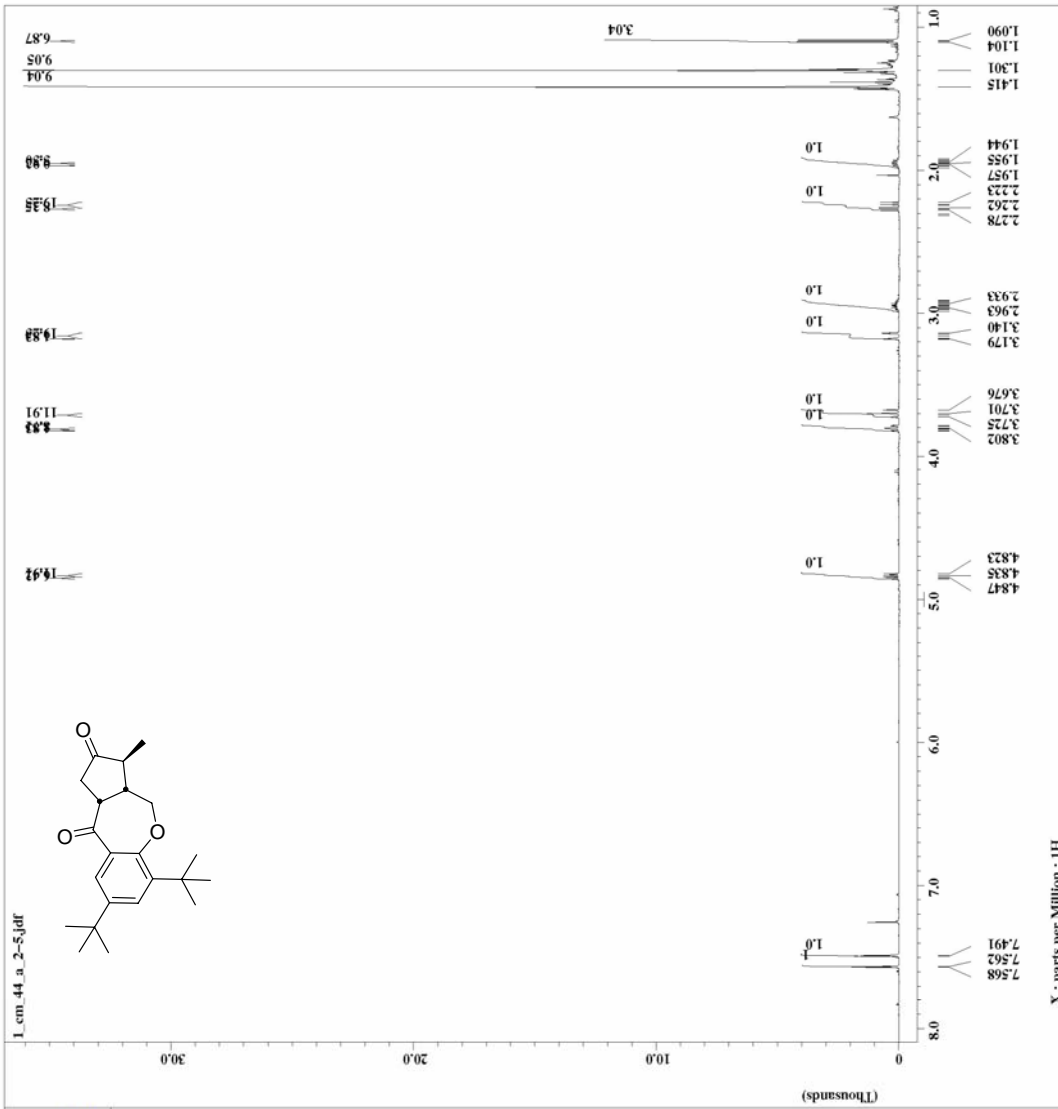
```

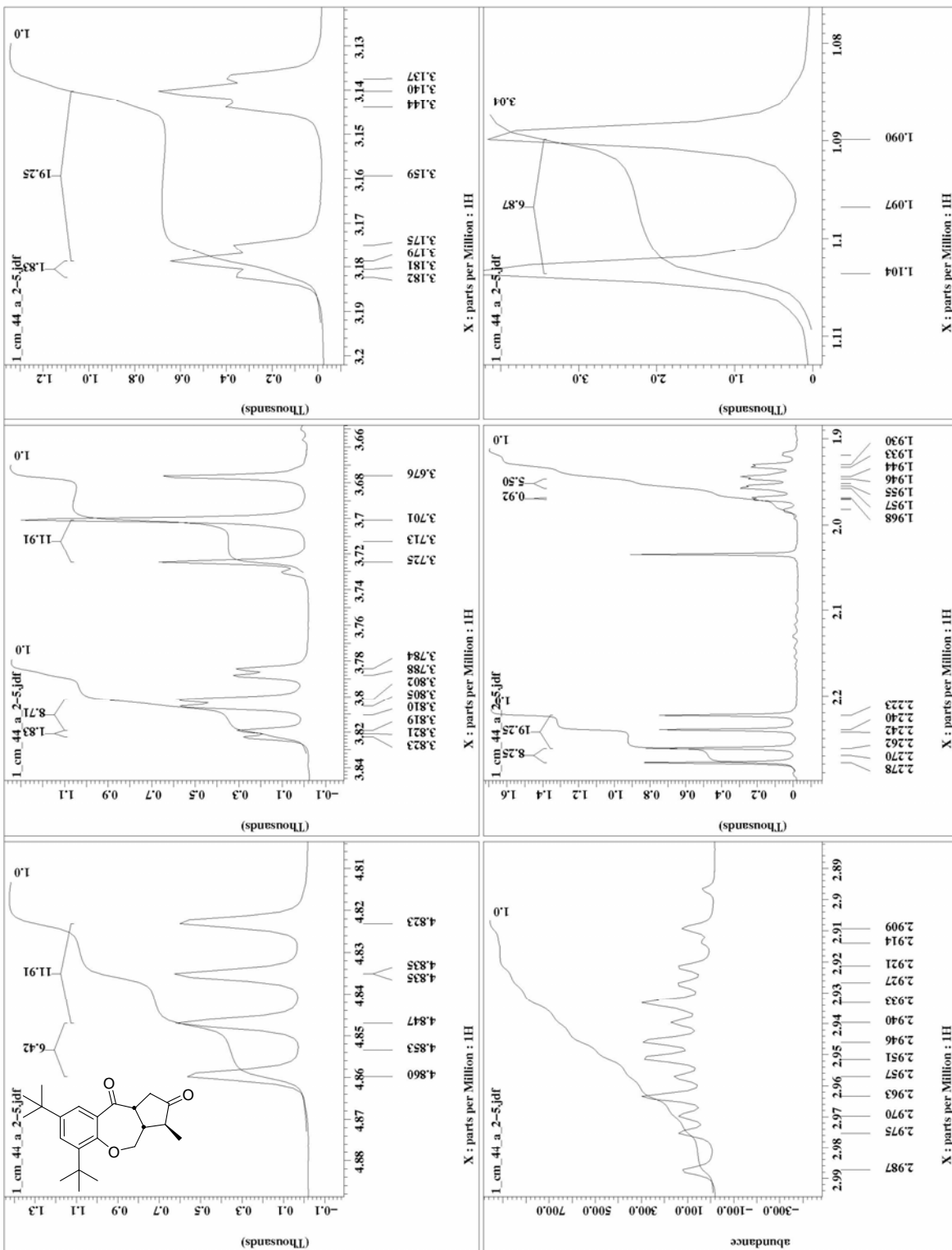
Filename      = 1_cm_44_a_2-5_jdf
Experiment    = single_pulse_exp
Sample Id     = SM2976
Sample Name   = 3-SEP-2004
Creation time = 3-SEP-2004 05:29:30
Revision time = 9-OCT-2006 22:05:34
Current time  = 9-OCT-2006 22:07:33

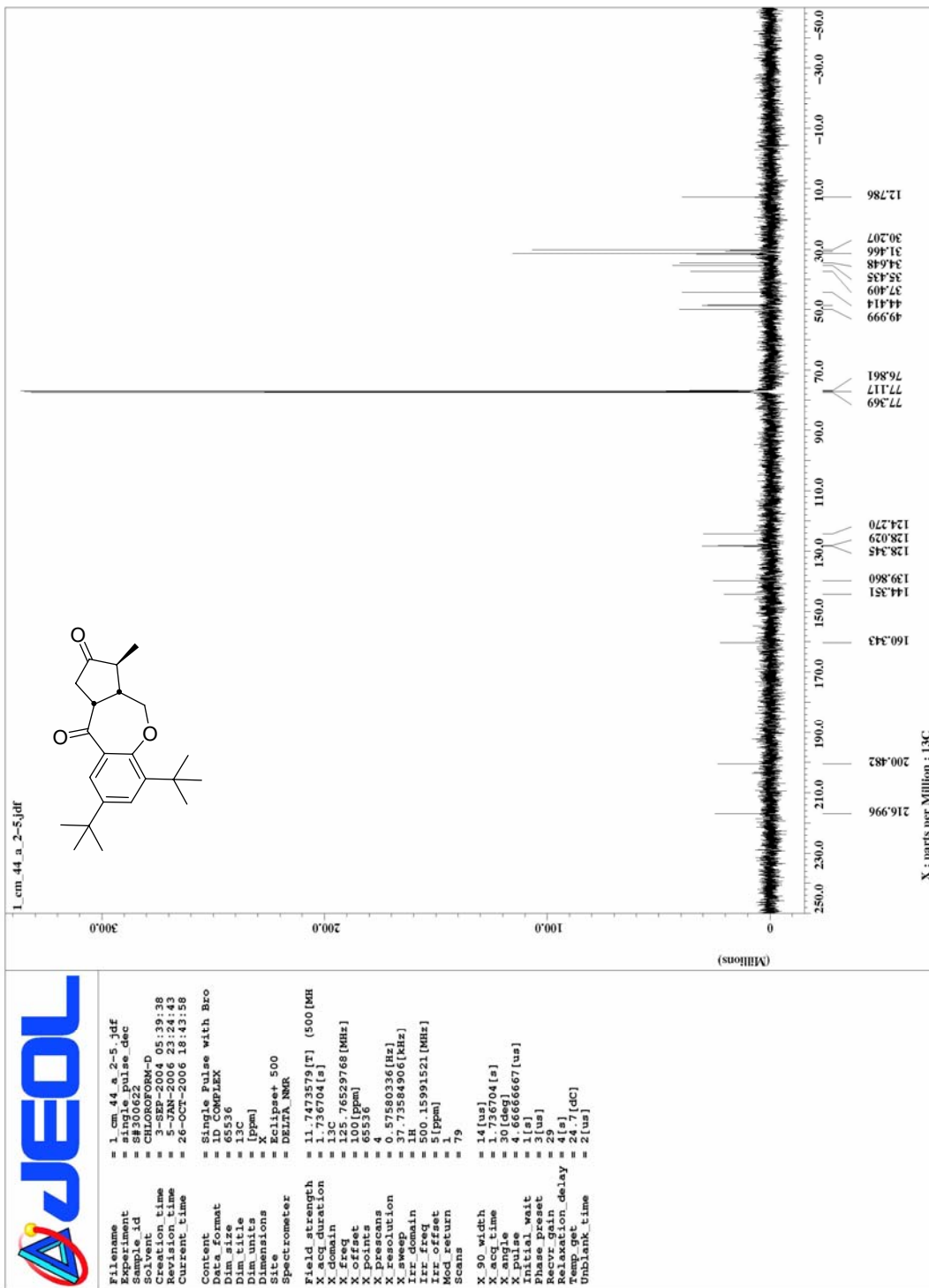
Content       = Single Pulse Exptime
Data format   = 1D-COMPLEX
Data size     = 16384
Dim title     = 1H
Dim units     = [ppm]
Dimensions    = X
Scales        = X, 11ppm, 500
Spectrometer  = DELTA_500

Field strength = 11.7473575[T] (500[MH
X_acq_duration = 2.1823488[s]
X_domain       = 400.15991521[MHz]
X_fwhm         = 5[ppm]
X_offset       = 16384
X_points       = 0
X_prescans    = 0
X_resolution   = 0.45822189[Hz]
X_sweep        = 1.50750751[KHz]
Mod return    = 1
Scans         = 32

X_90_width    = 15[us]
X_acq_time    = 45[3.468[s]
X_delay       = 7.5[us]
X_pulse       = 7.5[us]
Initial wait  = 1[s]
Phase preset  = 3[us]
Recvr_gain    = 15
Relaxation delay = 24.1[dc]
Temp_get      = 24.1[dc]
Unblank_time  = 2[us]
  
```







APPENDIX 43

¹H and ¹³C NMR SPECTRA OF

6,8-Di-*tert*-butyl-3-methyl-4,4a-dihydro-3*H*,10*H*-5-oxabenzof]azulen-2-one (44)



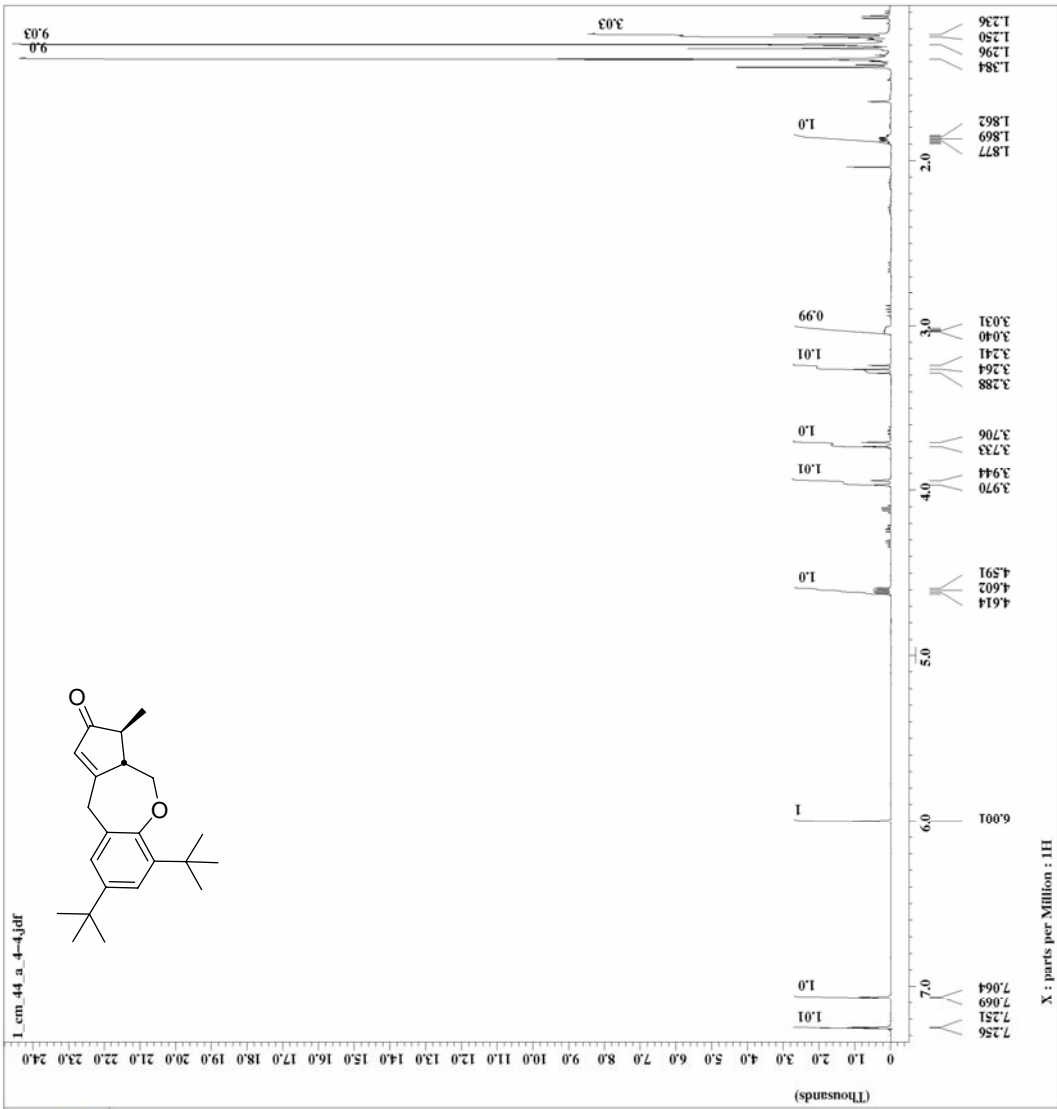
```

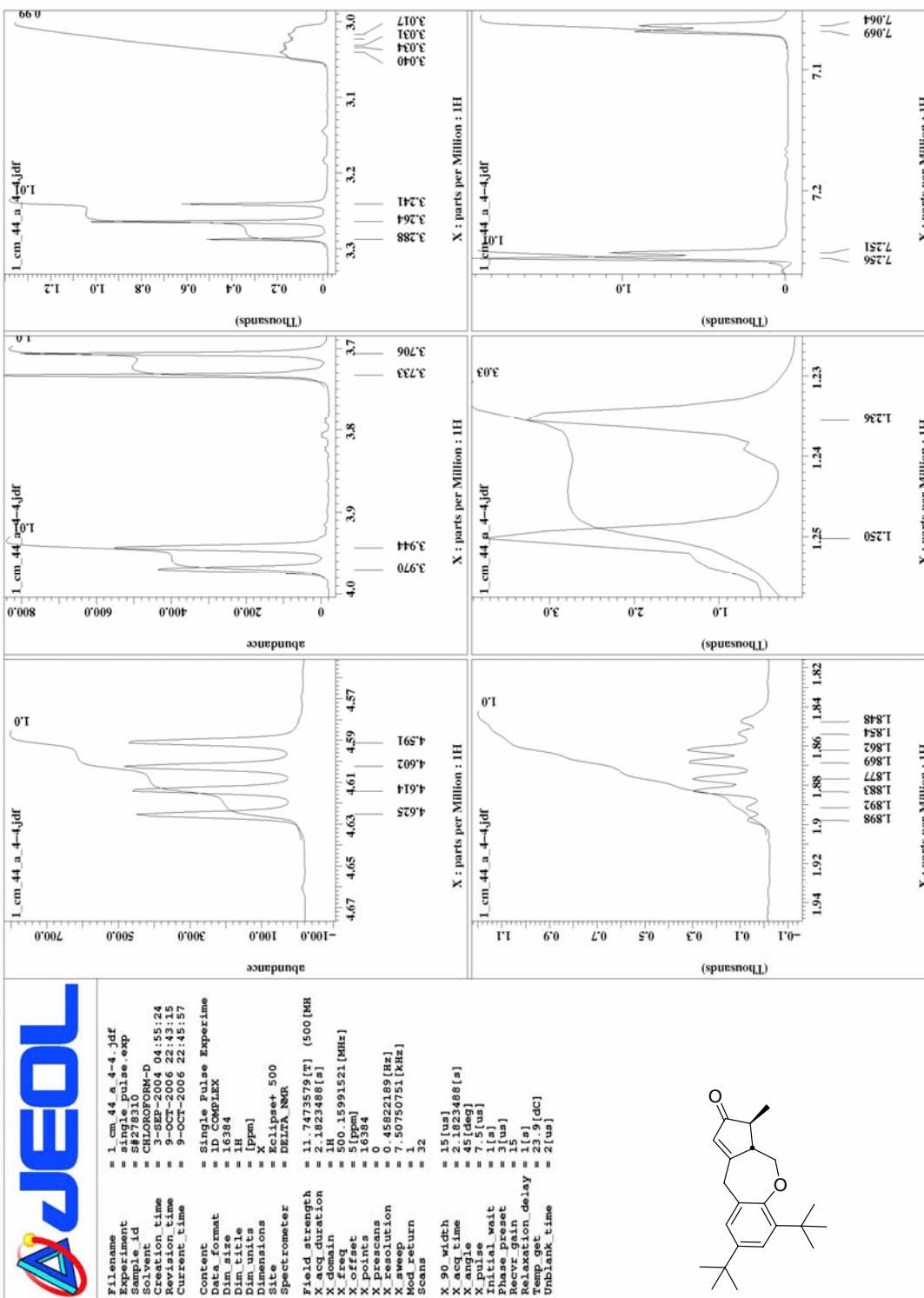
Filename = 1_cm_44_a_4-4.jdf
Experiment = single_pulse_exp
Sample_id = 1
Solvent = CHLOROFORM-D
Creation_time = 3-SEP-2004 04:55:24
Revision_time = 9-OCT-2006 22:43:15
Current_time = 9-OCT-2006 22:44:09

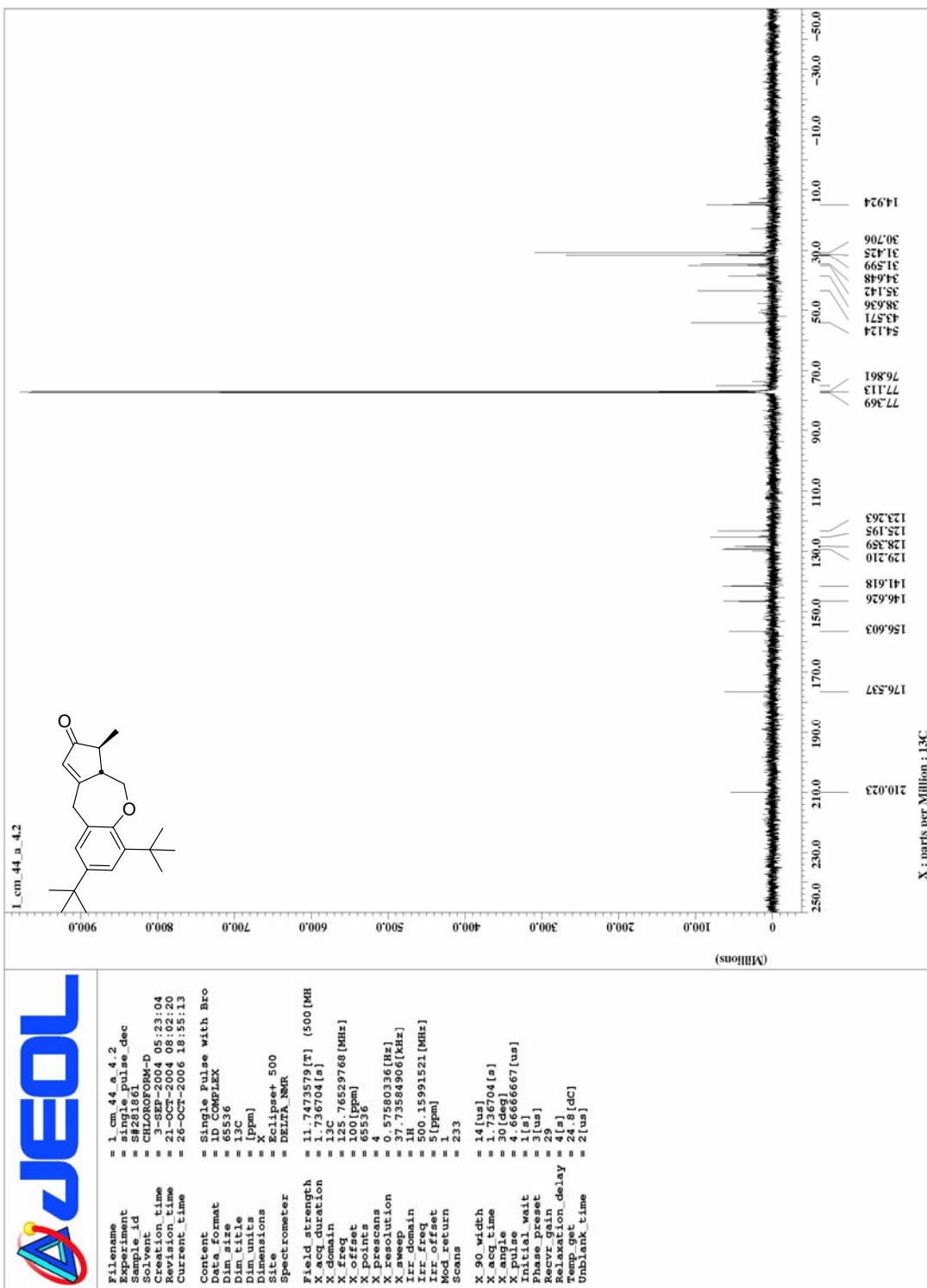
Content = Single Pulse Experiment
Data_format = 1D_COMPLEX
Dim_size = 16384
Dim_title = 1H
Dim_units = [ppm]
Dimensions = 
Site = Eclipse+ 500
Spectrometer = DELTA_NMR

Field_strength = 11.7473575[T] (500 [MH
Acq_duration = 1.1823468[s]
X_domain = 
X_freq = 500.15991521 [MHz]
X_offset = 5 [ppm]
X_points = 16384
X_prescans = 0
X_resolution = 0.45822189 [Hz]
X_sweep = 7.50750751 [kHz]
Mod_return = 1
Scans = 32

X_90_width = 15 [us]
X_acq_time = 2.1823468 [s]
X_angle = 45 [deg]
X_pulse = 7.5 [us]
Initial_wait = 1 [s]
Phase_reset = 15 [us]
Recv_wait = 15 [us]
Relaxation_delay = 1 [s]
Temp_get = 23.9 [dC]
Unblank_time = 2 [us]
  
```



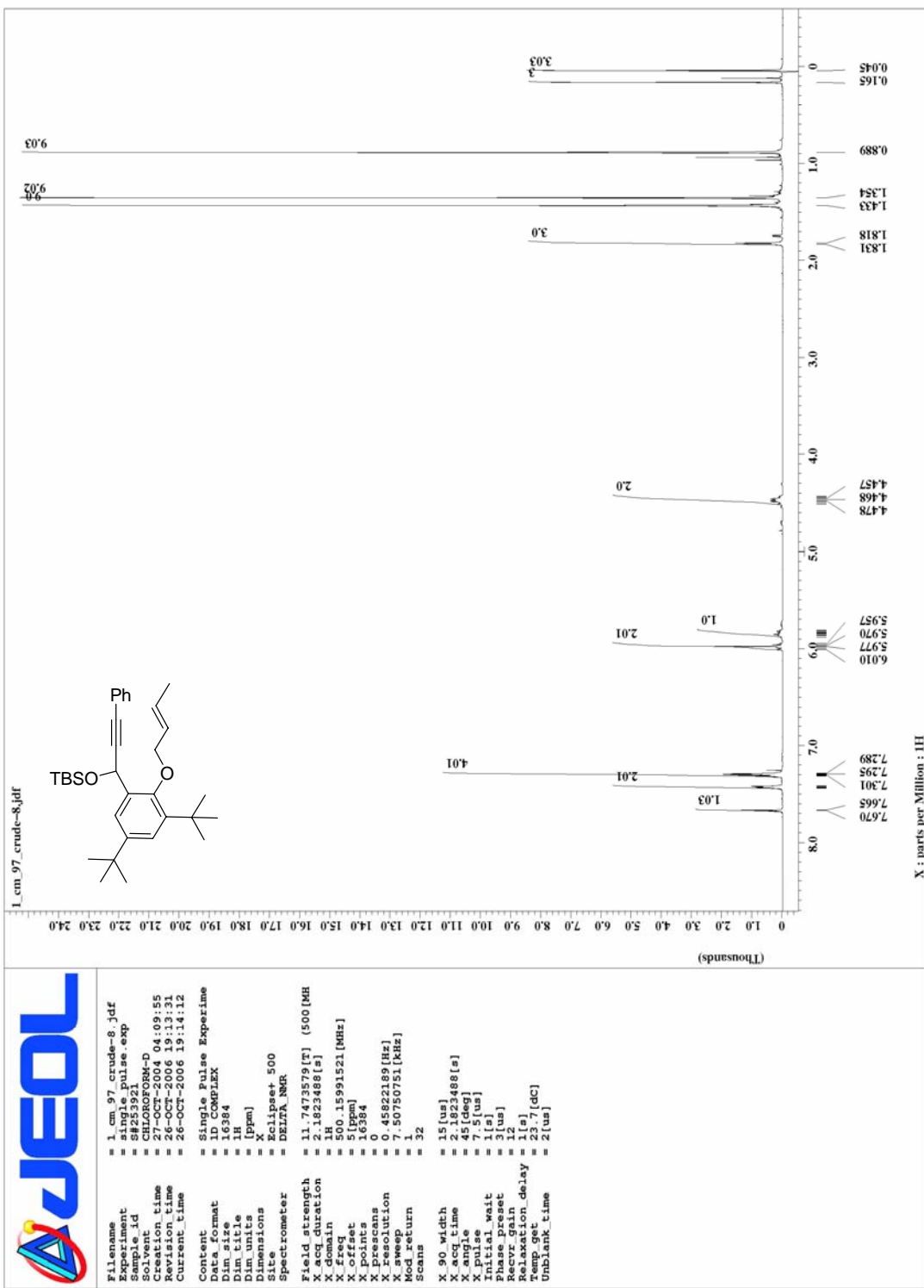


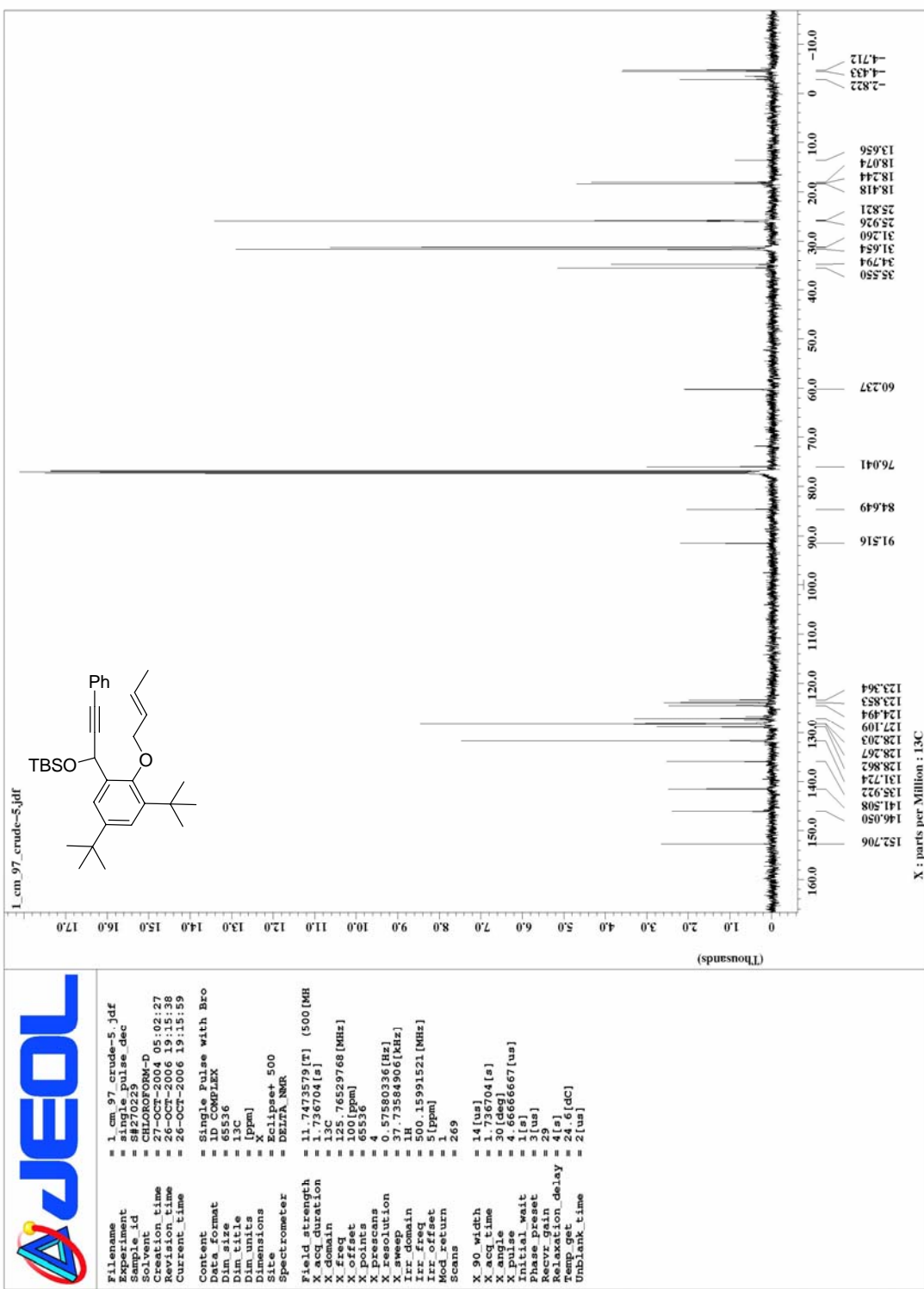


APPENDIX 44

¹H and ¹³C NMR SPECTRA OF

**4,6-Di-*tert*-butyl-2-(-1-*tert*-butyl-dimethylsilyloxy
-3-phenyl-2-propynyl)-(-2- butenyloxy)benzene (45)**





APPENDIX 45

¹H and ¹³C NMR SPECTRA OF

**4,6-Di-*tert*-butyl-2-(-1-*tert*-butyl dimethylsilyloxy
-3-trimethylsilyl-2-propynyl)-(-2- butenyloxy) benzene (46)**



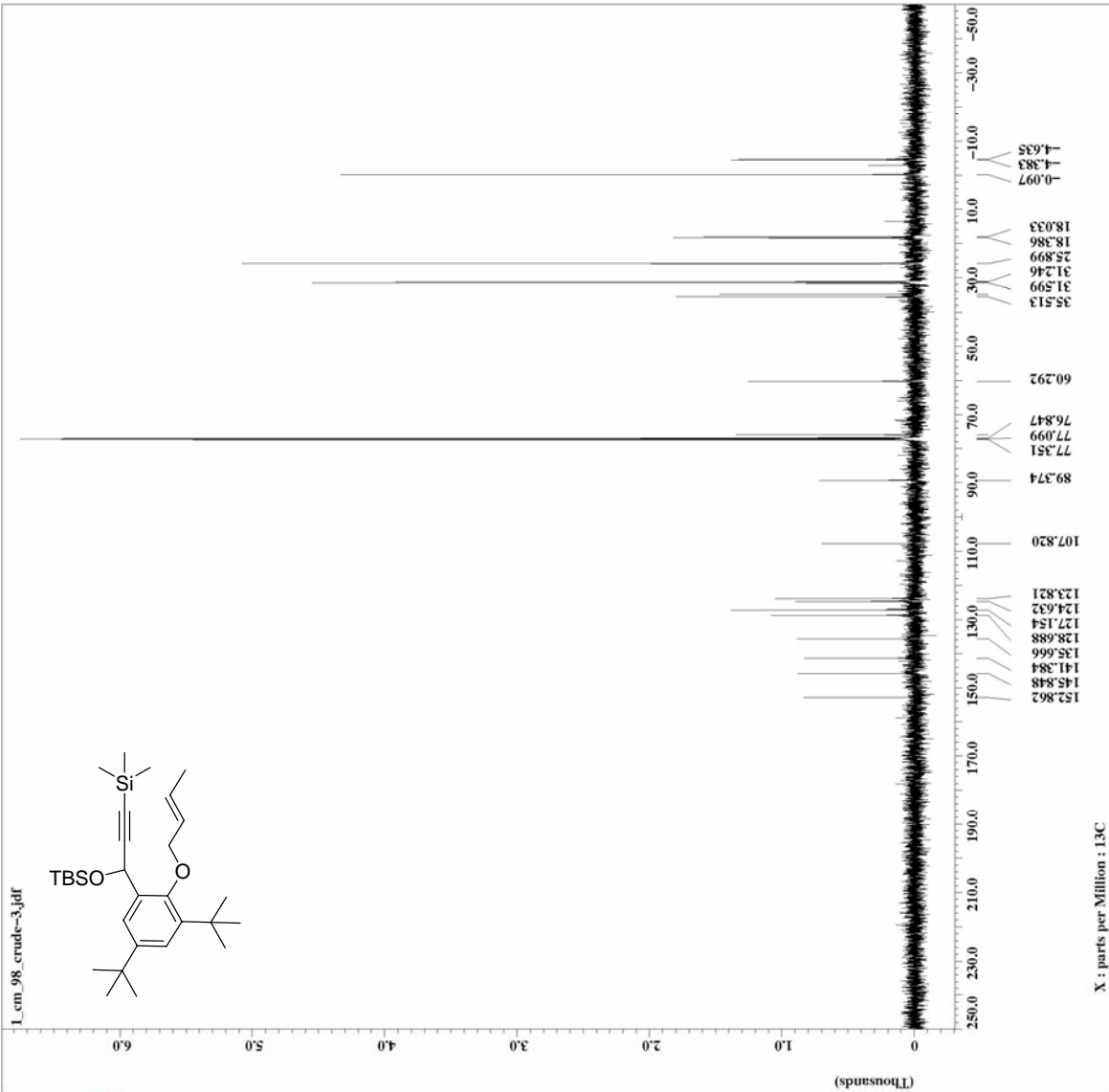
```

Filename = 1_cm_98_crude-3.jdf
Experiment = single_pulse_dec
Sample_id = S#59692
Solvent = CHLOROFORM-D
Creation_time = 27-OCT-2004 22:56:18
Revision_time = 26-OCT-2006 19:27:25
Current_time = 26-OCT-2006 19:27:52

Content = Single Pulse with Bro
Data_format = 1D_COMPLEX
Dim_size = 65536
Dim_title = 13C
Dim_units = [ppm]
Dimensions = X
Site = Eclipse+ 500
Spectrometer = DELTA_NMR

Field_strength = 11.7473579[T] (500[MH
X_resolution = 1.736704[s]
X_domain = 13C
X_freq = 125.76529768[MHz]
X_offset = 100[ppm]
X_points = 65536
X_prescans = 4
X_resolution = 0.57580336[Hz]
X_sweep = 37.73584906[KHz]
Irr_domain = 13C
Irr_freq = 500.15991521[MHz]
Irr_offset = 5[ppm]
Mod_return = 1
Scans = 104

X_90_width = 14[us]
X_acq_time = 1.736704[s]
X_angle = 30[deg]
X_pulse = 4.6666667[us]
Prtcl_wait = 3[s]
Prtcl_delay = 3[us]
Recvr_gain = 29
Relaxation_delay = 4[s]
Temp_get = 24.5[dc]
Unblank_time = 2[us]
  
```



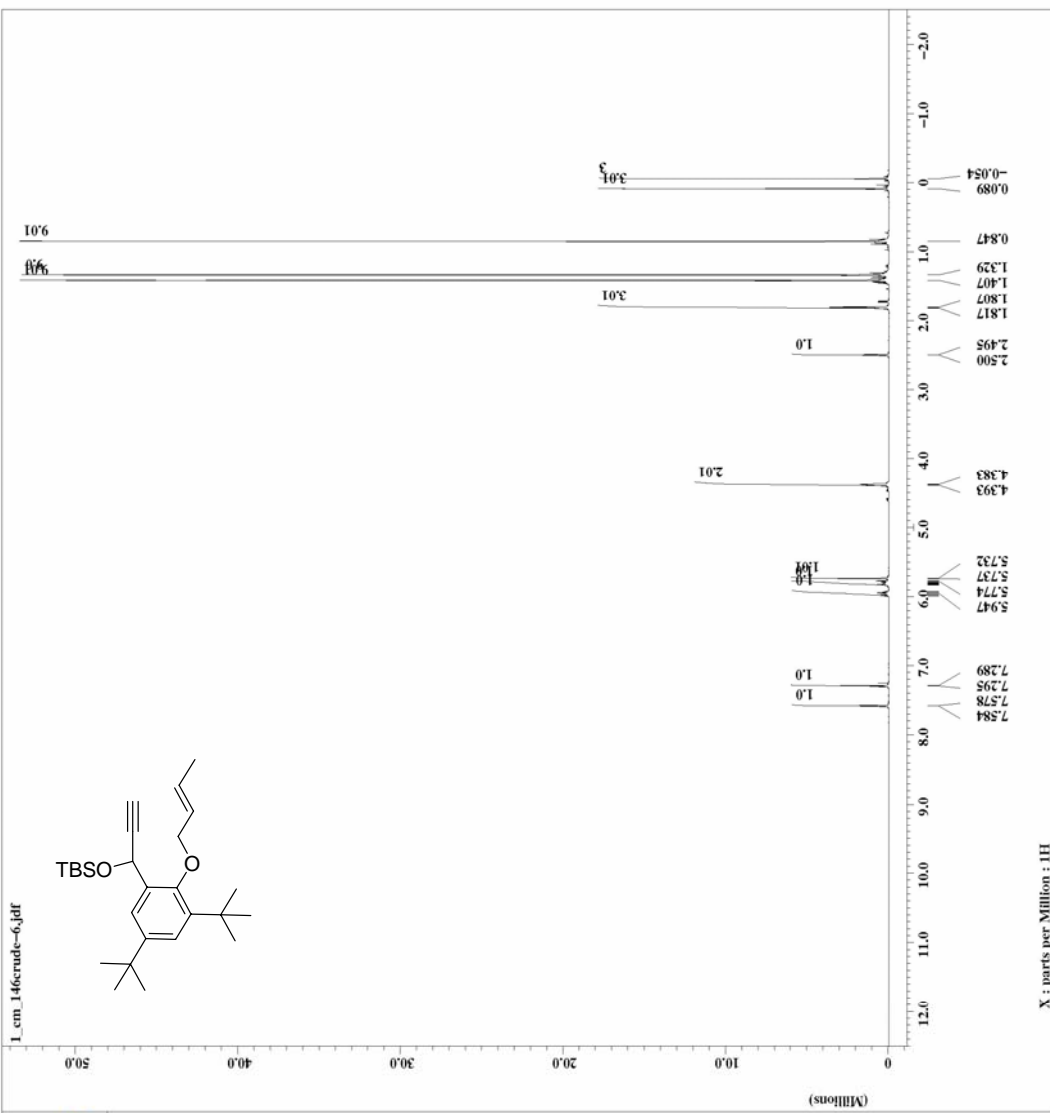
APPENDIX 46

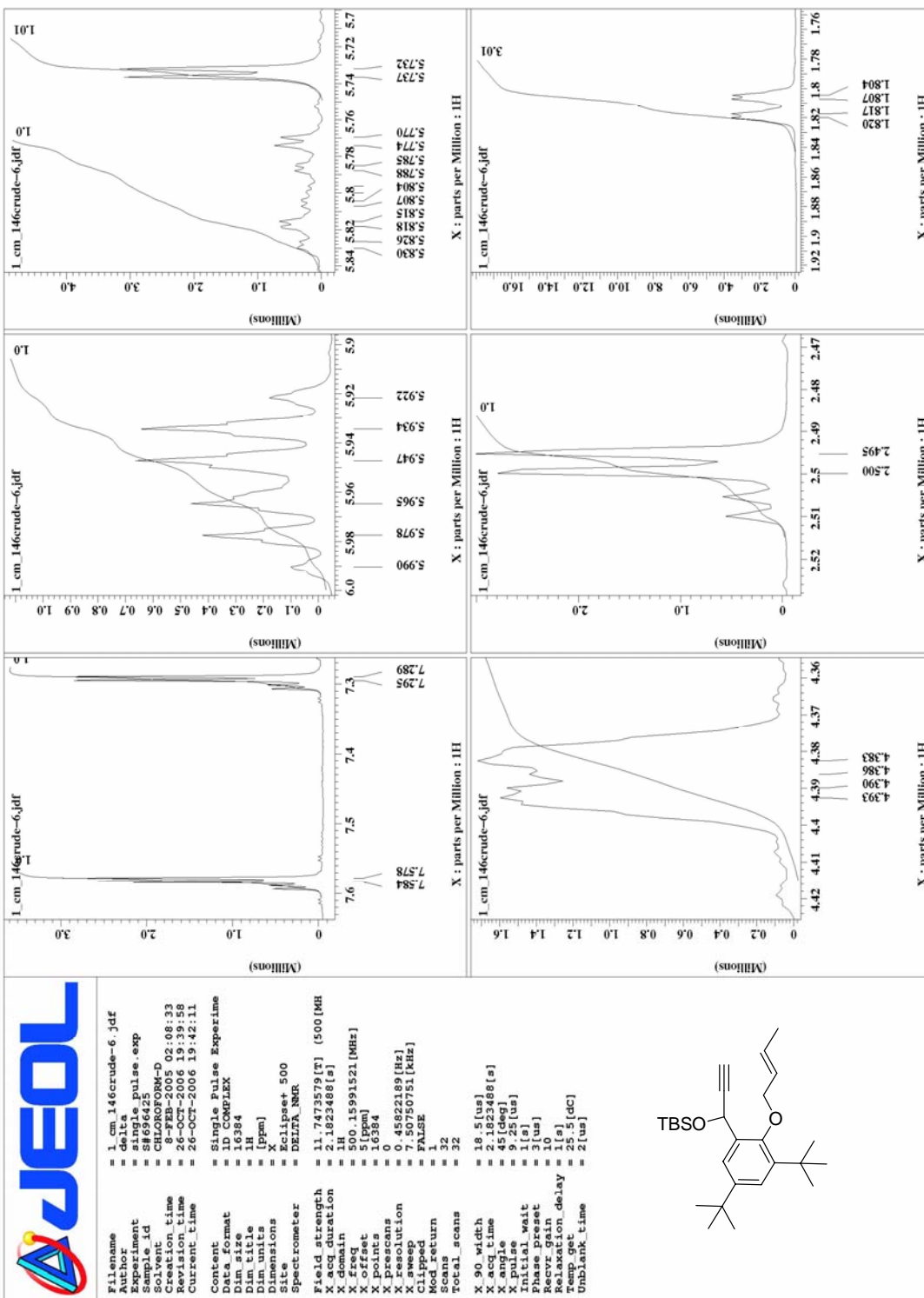
^1H and ^{13}C NMR SPECTRA OF

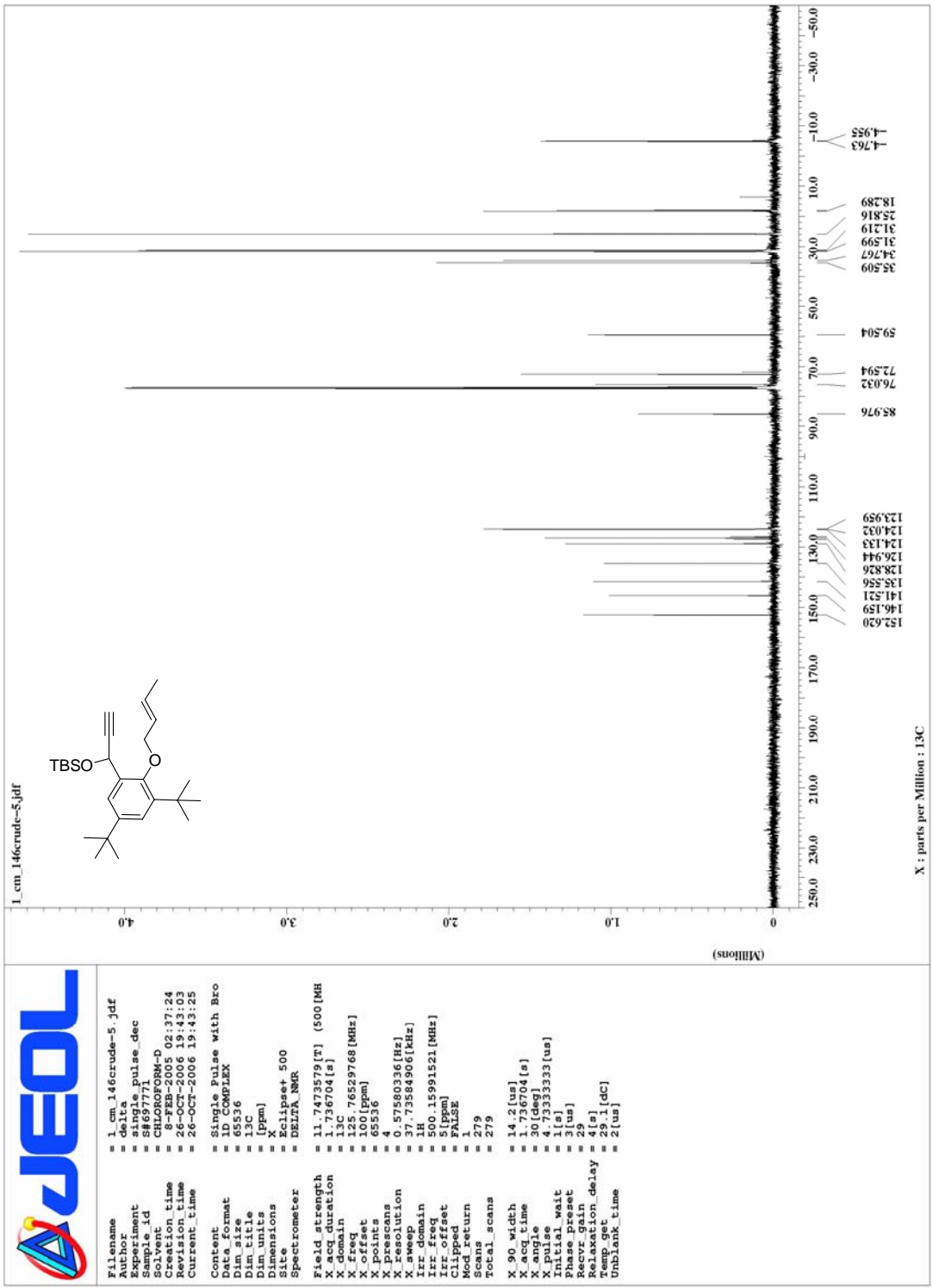
**4,6-Di-*tert*-butyl-2-(1-*tert*-butyl dimethylsilyloxy
-2-propynyl)-(2-butenyloxy) benzene (49)**



Filename = 1_cm_146crude-6.jdf
 Author = delta
 Experiment = single pulse exp
 Sample_id = SH96425
 Solvent = CHLOROFORM-D
 Creation_time = 8-FEB-2005 02:08:33
 Revision_time = 26-OCT-2006 19:39:58
 Current_time = 26-OCT-2006 19:40:22
 Content = Single Pulse Experiment
 Data_format = 1D COMPLEX
 Dim_size = 16384
 Dim_title = H
 Dimensions = X
 Site = Eclipse+ 500
 Spectrometer = DELTA_NMR
 Field_strength = 11.7473579 [T] (500 [MHZ])
 X_acq_duration = 2.1823488 [s]
 X_domain = 1H-1823488 [s]
 X_freq = 500.15991521 [MHZ]
 X_offset = 5 [ppm]
 X_points = 16384
 X_resolution = 0.45822189 [Hz]
 X_sweep = 7.50750751 [KHz]
 Clipped = FALSE
 Mod_return = 1
 Scans = 32
 Total_scans = 32
 X_90_width = 18.5 [us]
 X_acq_time = 2.1823488 [s]
 X_delay = 9 [us]
 X_pulse = 9 [us]
 Initial_wait = 1 [s]
 Phase_preset = 3 [us]
 Recvr_gain = 10
 Relaxation_delay = 25 [s]
 Temperature = 25 [dC]
 Unblank_time = 2 [us]







```

Filename = 1_cm_146crude-5.jdf
Author = delta
Experiment = single_pulse_dec
Sample Id = CH2BR0004-D
Creation time = 8-FEB-2005 02:37:24
Revision time = 26-OCT-2006 19:43:03
Current time = 26-OCT-2006 19:43:25
Content = single_pulse_with Бро
Dim format = 1D_COMPLEX
Dim size = 65536
Dim title = 13C
Dim units = [ppm]
Dimensions = X
Site = Xlipset_500
Spectrometer = DELTA_NMR
Field strength = 11.7473579[T] (500[MH
X_acq duration = 1.736704[s]
X_domain = 13C 76529768 [MHz]
X_offset = 100 [ppm]
X_points = 65536
X_prescans = 4
X_resolution = 0.57580336 [Hz]
X_sweep = 37.73584906 [kHz]
Irr_gain = 500
Irr_freq = 500.15991521 [MHz]
Irr_offset = 5 [ppm]
Clipped = FALSE
Mod return = 1
Total_scans = 279
X_90_width = 14.2 [us]
X_acq_time = 1.736704 [s]
X_angle = 30 [deg]
X_pulse = 4.73333333 [us]
Phase_wait = 1 [us]
Phase_preset = 3 [us]
Recvr_gain = 29
Relaxation_delay = 4 [s]
Temp_get = 29.1 [dC]
Unblank_time = 2 [us]

```

APPENDIX 47

¹H and ¹³C NMR SPECTRA OF

6, 8-Di-*tert*-butyl-10-*t*-butyldimethylsilyloxy-3-methyl-1-phenyl

-4,4a-dihydro-3*H*,10*H*-5-oxabenzof]azulen-2-one (47)

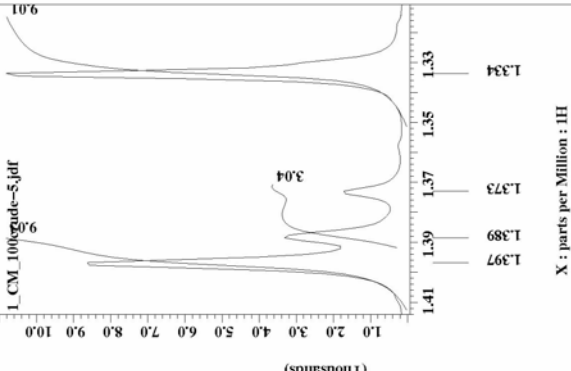
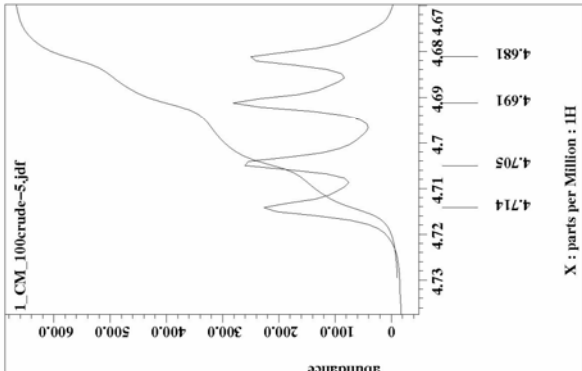
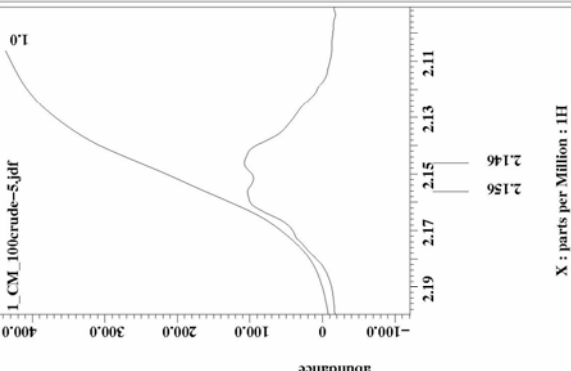
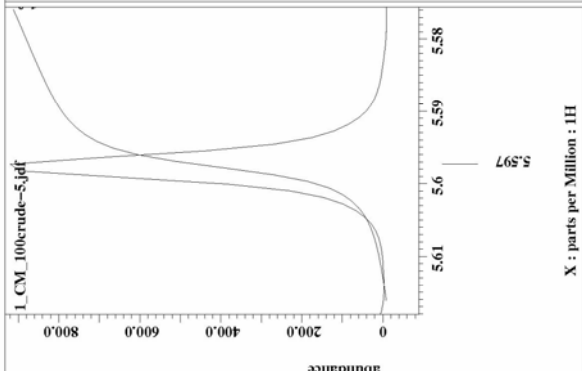
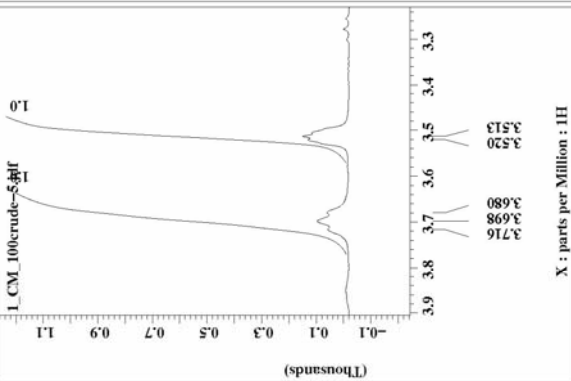
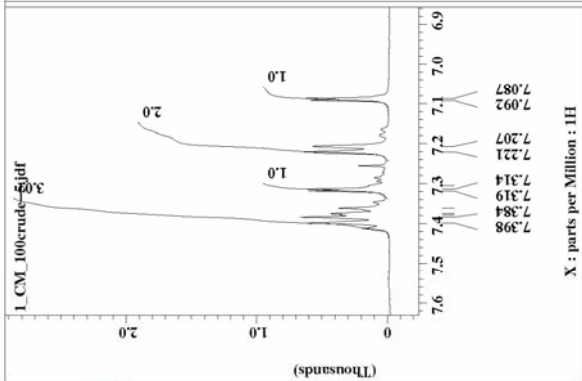
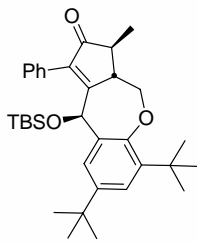


```

Filename = 1_CM_100crude-5_jdf
Experiment = single_pulse.exp
Sample_id = S#4781
Solvent = CHLOROFORM-D
Creation_time = 1-NOV-2004 20:18:37
Revision_time = 26-OCT-2006 20:22:49
Current_time = 26-OCT-2006 20:24:17

Content = Single Pulse Experiment
Data format = 1D COMPLEX
Dim size = 16384
Dim title = 1H
Dim units = [ppm]
Dimensions = X
Site = Eclipse+ 500
Spectrometer = DELTA_NMR

Field strength = 11.7473579[T] (500 [MH]
X1_acq duration = 2.1823488[s]
X domain = 1H
X freq = 500.15991521 [MHz]
X offset = 16384
X points = 0
X prescans = 0
X resolution = 0.45822189 [Hz]
X sweep = 7.50750751 [kHz]
X2_return = 32
Scans = 15 [us]
X 90 width = 2.1823488[s]
X acq time = 45 [deg]
X angle = 7.5 [us]
Initial wait = 1[s]
Phase preset = 3[us]
Recvr gain = 11
Referenceon_delay = 21.6 [dc]
Unblank_time = 2 [us]
  
```





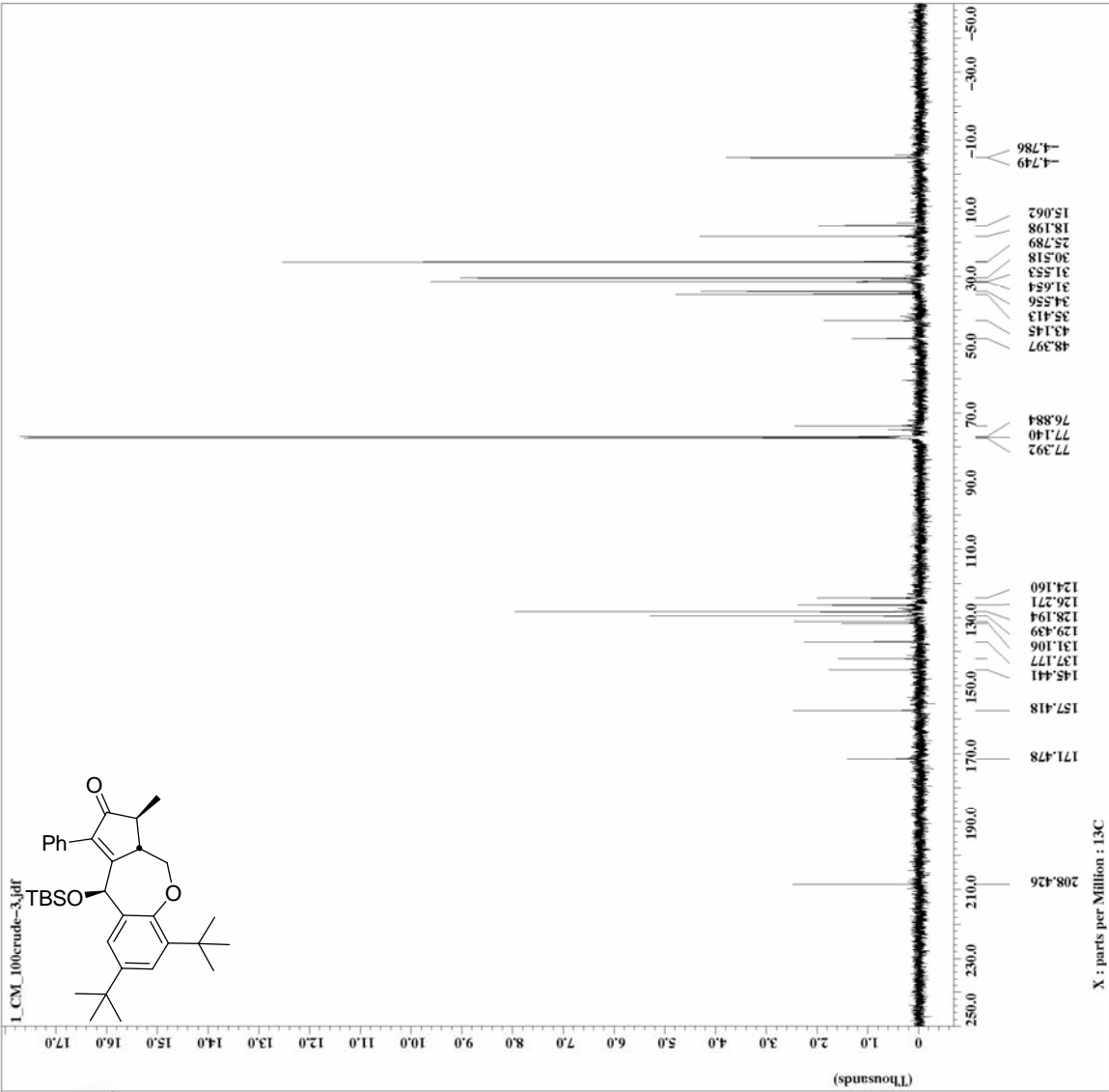
```

Filename = 1_CM_100crude-3.jdf
Experiment = single pulse dec
Sample_id = S#57150
Solvent = CHLOROFORM-D
Creation time = 1-NOV-2004 22:10:58
Revision time = 26-OCT-2006 20:26:04
Current_time = 26-OCT-2006 20:26:28

Content = Single Pulse with Bro
Data format = 1D COMPLEX
Dim size = 65536
Dim title = 13C
Dim units = [ppm]
Dimensions = X
Site = Eclipse+ 500
Spectrometer = DELTA_NMR

Field strength = 11.7473579[T] (500[MH
X acq duration = 1.736704[s]
X domain = 13C
X freq = 125.76529768[MHz]
X offset = 100[ppm]
X points = 65536
X prescans = 0
X resolution = 0.57580336[Hz]
X sweep = 37.73584906[kHz]
X sweep_rate = 18
X domain = 13C
X offset = 100[ppm]
X freq = 500.15991521[MHz]
X offset = 5[ppm]
Mod return = 1
Scans = 267

X 90 width = 14[us]
X 90 time = 1.710704[s]
X angle = 30[deg]
X pulse = 4.66666667[us]
Initial wait = 1[s]
Phase preset = 3[us]
Recvr gain = 29
Relaxation delay = 4[s]
Temp_get = 24.5[degC]
Unblank_time = 2[us]
  
```



APPENDIX 48

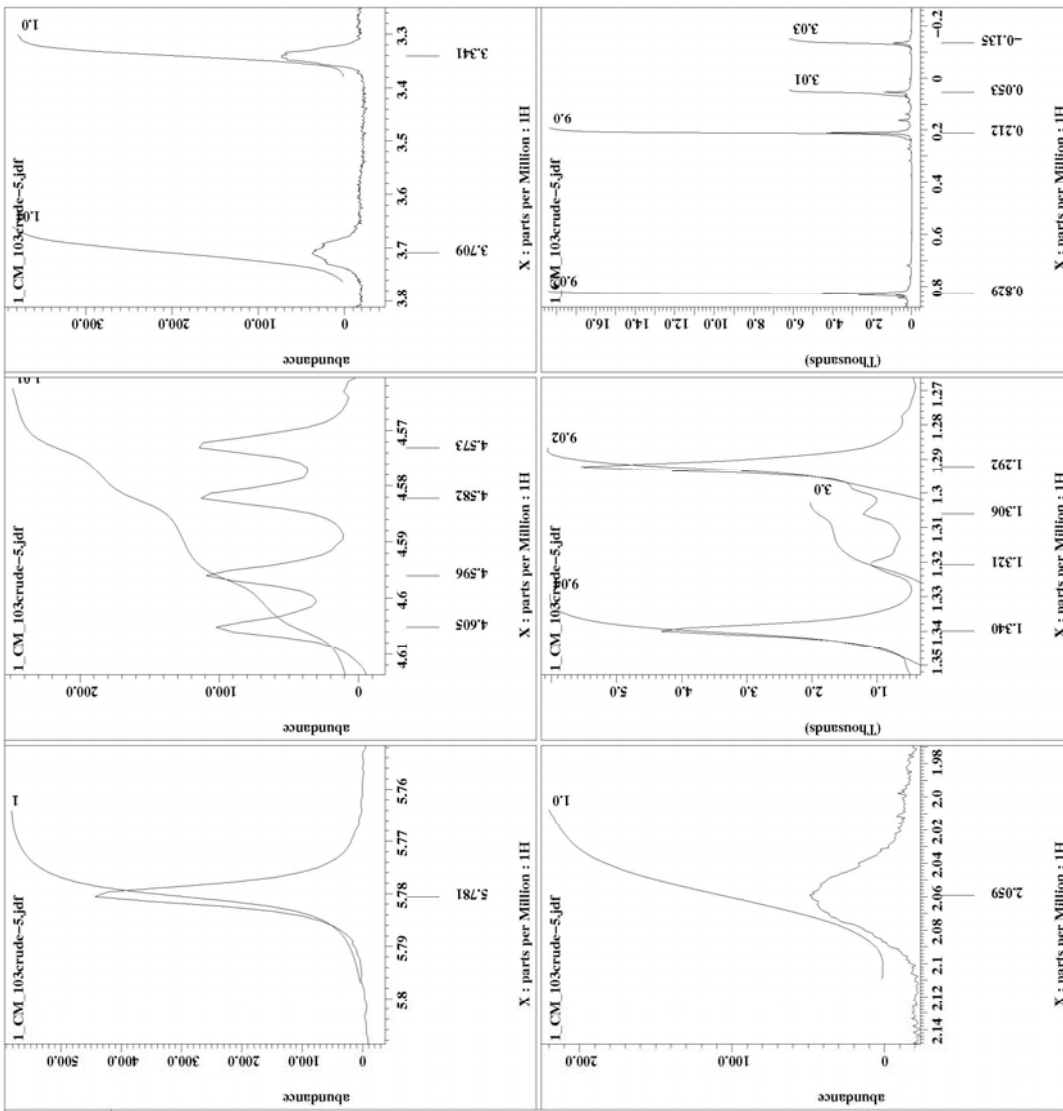
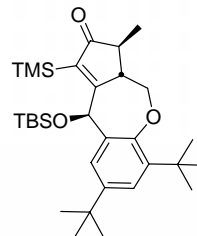
¹H and ¹³C NMR SPECTRA OF

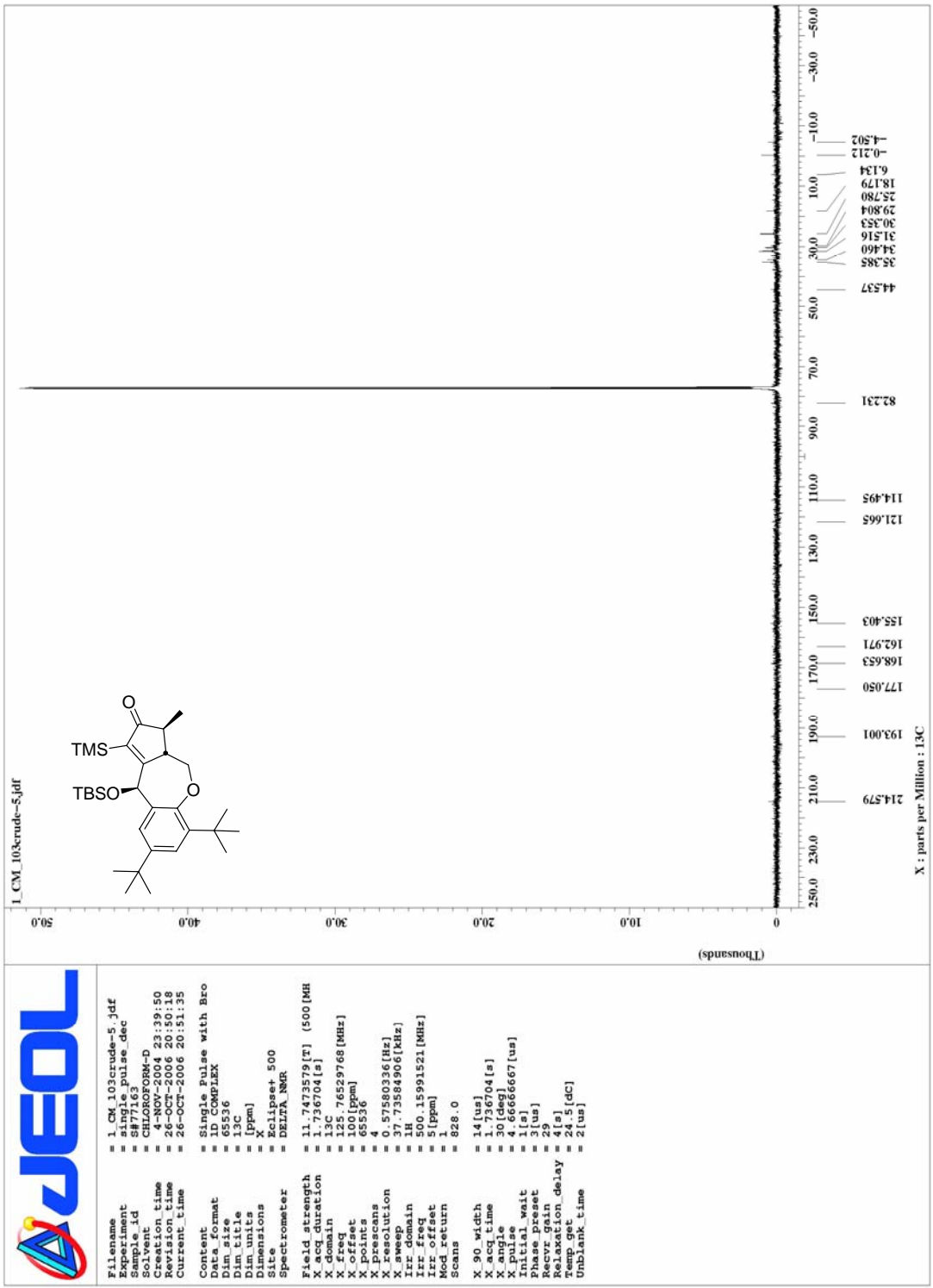
6, 8-Di-*tert*-butyl-10-*t*-butyldimethylsilyloxy-3-methyl-1-trimethylsilyl

-4,4a-dihydro-3*H*,10*H*-5-oxabenzof]azulen-2-one (48)



Filename = 1_CM_103crude-5_jdf
Experiment = single_pulse_exp
Sample_id = 8F75584
Date_ime = 26-OCT-2006 22:18:40
Operator = RM-D
Creation_time = 4-NOV-2004 22:18:40
Revision_time = 26-OCT-2006 21:03:20
Current_time = 26-OCT-2006 21:07:37
Content = 61mgls. Pulse Experiments
Date_ime = 1D-COMPLEX
Dim_size = 16384
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Gate = 411passt_500
Spectrometer = DELTA_NMR
Field_strength = 11.7473579[T] (500[MH
X_acq_duration = 2.1823488[s]
X_domain = 1H
X_offset = 10.15991521[MHz]
X_points = 5[ppm]
X_prescans = 16384
X_prescans = 0
X_resolution = 0.45922189[Hz]
X_sweep = 7.50750751[KHz]
X_return = 32
X_90_width = 15[us]
X_acq_time = 2.1823488[s]
X_delay = 7.5[us]
X_pulse = 7.5[us]
Initial_wait = 1[s]
Phase_preset = 3[us]
Recvr_gain = 18
Relaxation_delay = 2[s]
Temperature = 300[degC]
Unblank_time = 2[us]

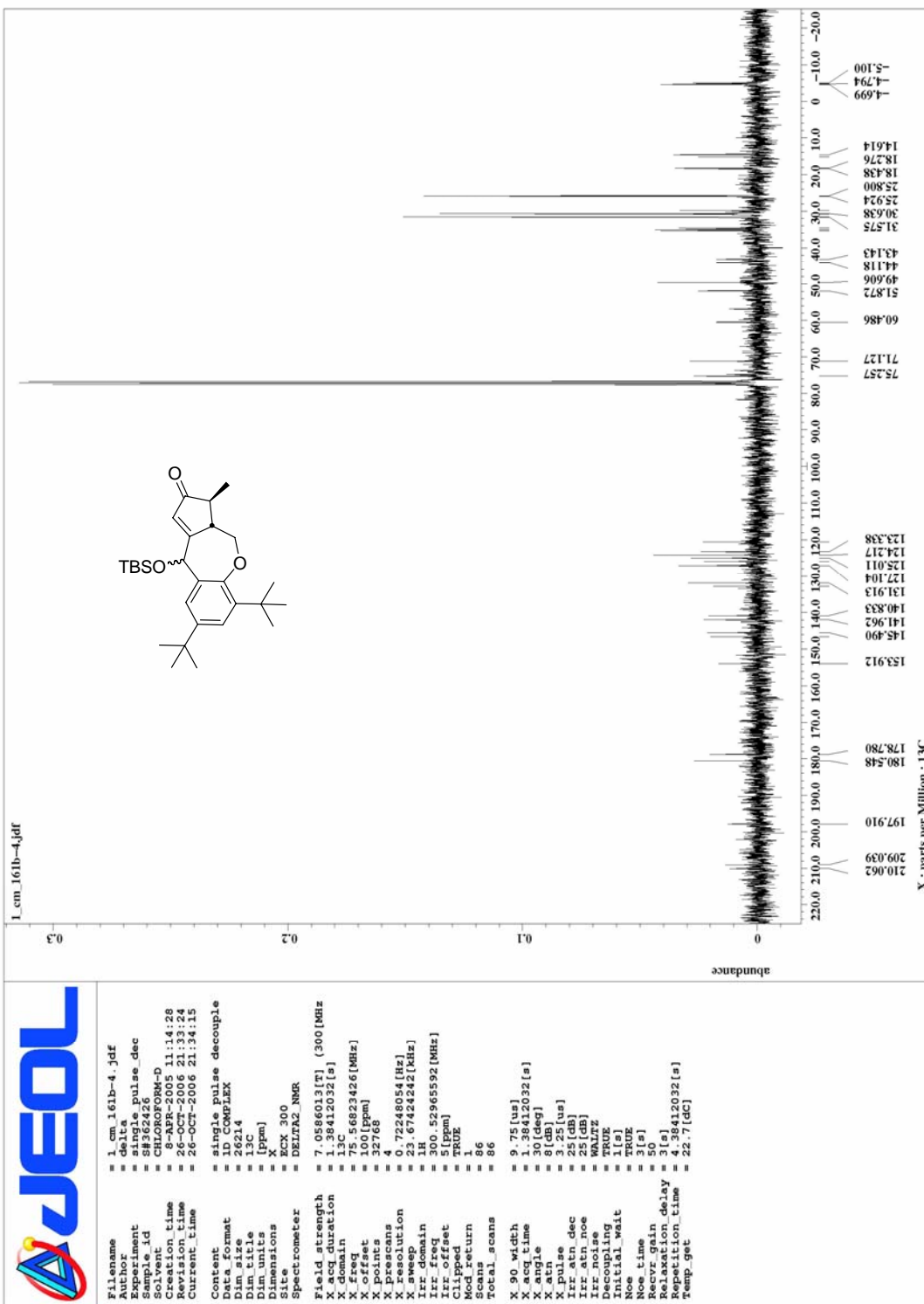




APPENDIX 49

¹H and ¹³C NMR SPECTRA OF

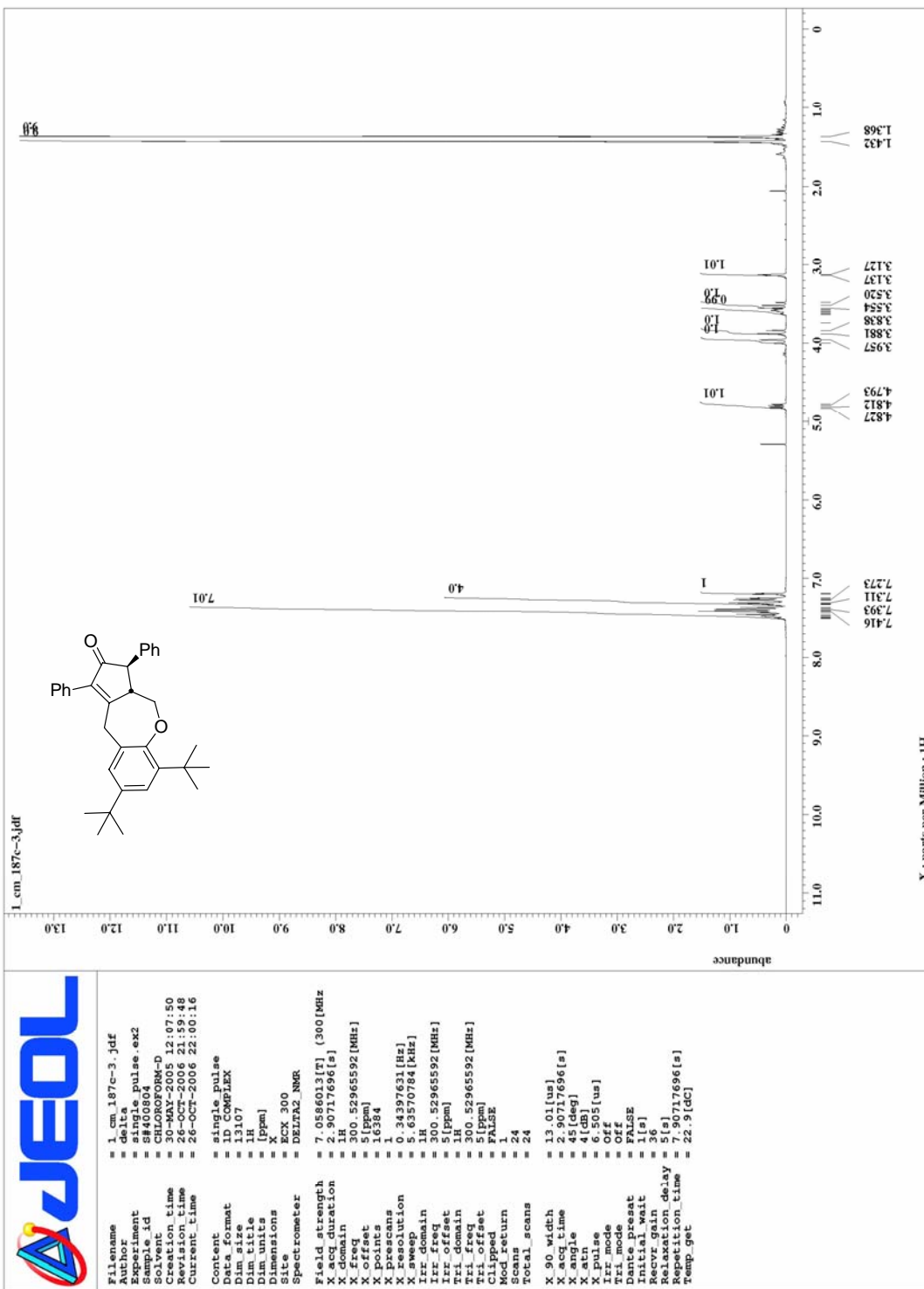
**6, 8-Di-*tert*-butyl-10-*t*-butyldimethylsilyloxy-3-methyl
-4,4a-dihydro-3*H*,10*H*-5-oxabenzof]azulen-2-one (50)**



APPENDIX 50

^1H and ^{13}C NMR SPECTRA OF

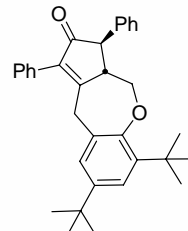
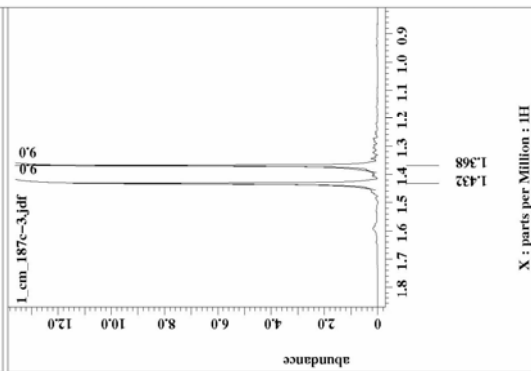
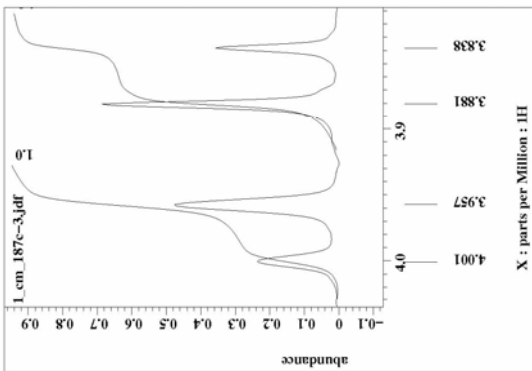
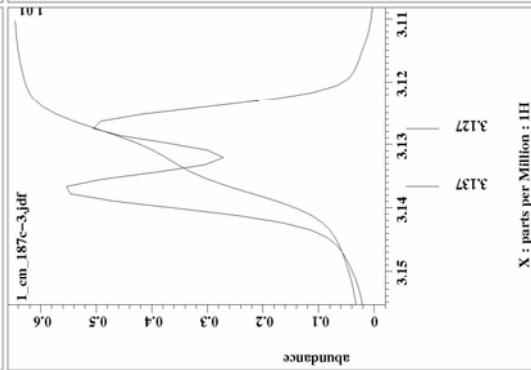
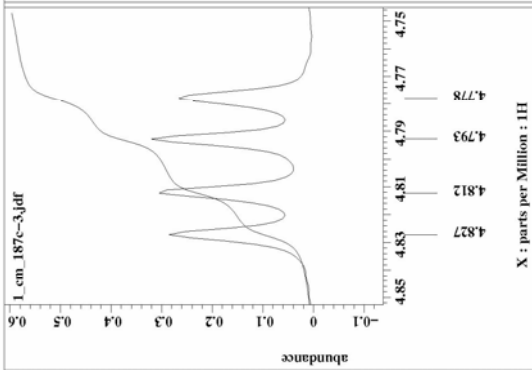
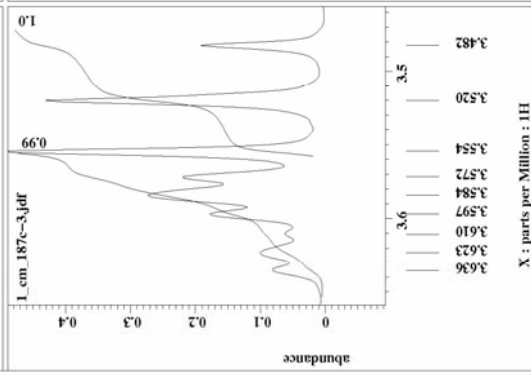
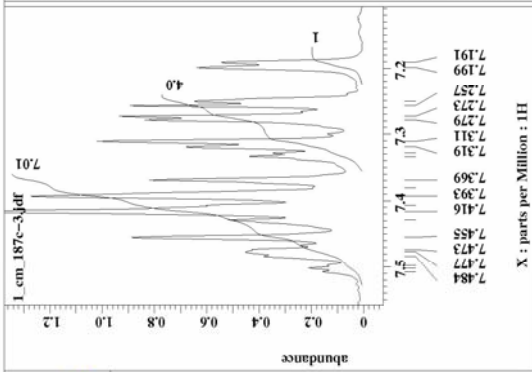
**6,8-Di-*tert*-butyl-1,3-diphenyl-4,4a-dihydro
-3*H*,10*H*-5-oxabenzof]azulen-2-one (51)**

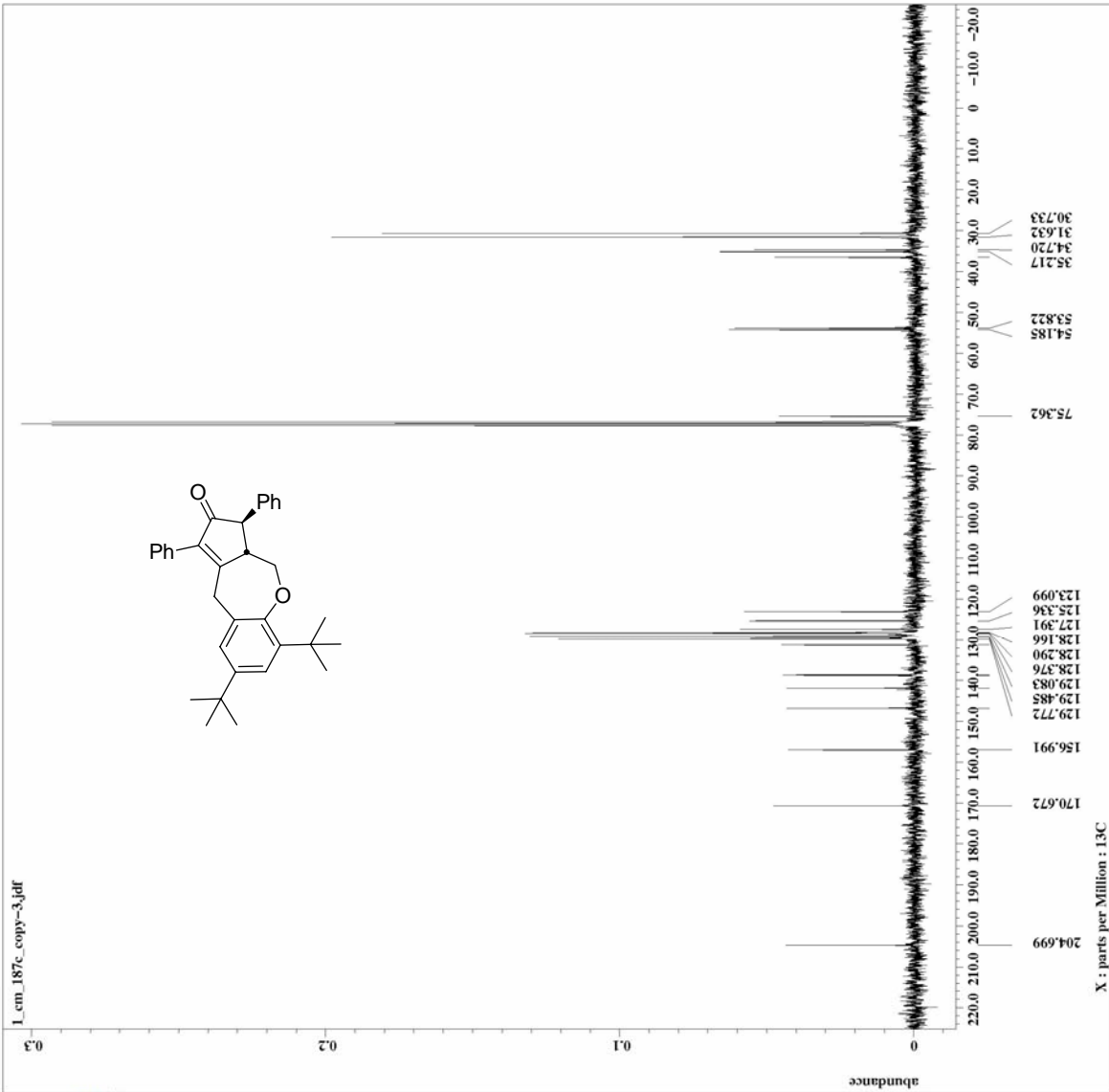




```

Filename = 1_cm_187c-3.jdf
Author = data
Experiment = single pulse.ex2
Pulse program = zgpg30
Solvent = CHLOROFORM-D
Creation time = 30-MAY-2005 12:07:50
Revision time = 26-OCT-2006 21:59:48
Current time = 26-OCT-2006 22:01:34
Content = single pulse
Data format = 1D COMPLEX
Dim size = 13107
Dim title = 1H
Dim units = [ppm]
Dimensions =
Site = ECX 300
Spectrometer = DELTA2_NMR
Field strength = 7.0586013 [T] (300 [MHz]
X acq duration = 1.90717696 [s]
X freq = 300.52965592 [MHz]
X offset = 5 [ppm]
X points = 16384
X prescans = 1
X resolution = 1.34397631 [Hz]
X sweep = 5.43570784 [kHz]
X sweep domain = 1H
X1 freq = 300.52965592 [MHz]
X1 offset = 5 [ppm]
X1 domain = 1H
X2 freq = 300.52965592 [MHz]
X2 offset = 5 [ppm]
X2 domain = 1H
Clipped = FALSE
Mod return = 1
Total scans = 24
X 90 width = 13.01 [us]
X acq time = 2.90717696 [s]
X angle = 45 [deg]
X atn = 4 [dB]
X pulse = 605 [us]
X pulse program = off
X1 mode = off
X2 mode = off
Dante preset = FALSE
Initial wait = 1 [s]
Recvr gain = 18 [dB]
Repetition delay = 8 [s]
Repetition time = 7.90717696 [s]
Temp_get = 22.9 [dC]
  
```





File: i_cm_187c_copy-3.jdf

Author = delta

Experiment = single pulse_dec

Sample_id = CH2RO30M-D

Creation_time = 30-MAY-2005 12:28:58

Revision_time = 30-MAY-2005 11:34:46

Current_time = 26-OCT-2006 21:52:23

Content = single pulse decouple

Data_format = 1D COMPLEX

Dim_size = 26214

Dim_title = 13C

Dim_units = X[ppm]

Dimensions = X

Site = ECK 300

Spectrometer = DELTA2_NMR

Field_strength = 7.0586013[T] (300[MHz])

X_acq_duration = 1.38412032[s]

X_domain = 13C

X_freq = 75.56823426[MHz]

X_offset = 100[ppm]

X_points = 42768

X_resolution = 4

X_resolution = 0.72248054[Hz]

X_sweep = 23.67424242[KHz]

Irr_domain = 1H

Irr_freq = 300.52965592[MHz]

Irr_offset = 5[ppm]

Clipped = FALSE

Incomplete_copy = TRUE

Mod_return = 283

Scans = 283

Total_scans = 283

X_90_width = 9.75[us]

X_acq_time = 1.38412032[s]

X_angle = 30[deg]

X_atn = 8[db]

X_atn = 3.25[us]

Irr_atn_dec = 25[db]

Irr_atn_noe = 45[db]

Pre_solvent = H2O

Decoupling = TRUE

Initial_wait = 1[s]

Noe_time = TRUE

Noe_time = 3[s]

Recvr_gain = 50

Relaxation_delay = 3[s]

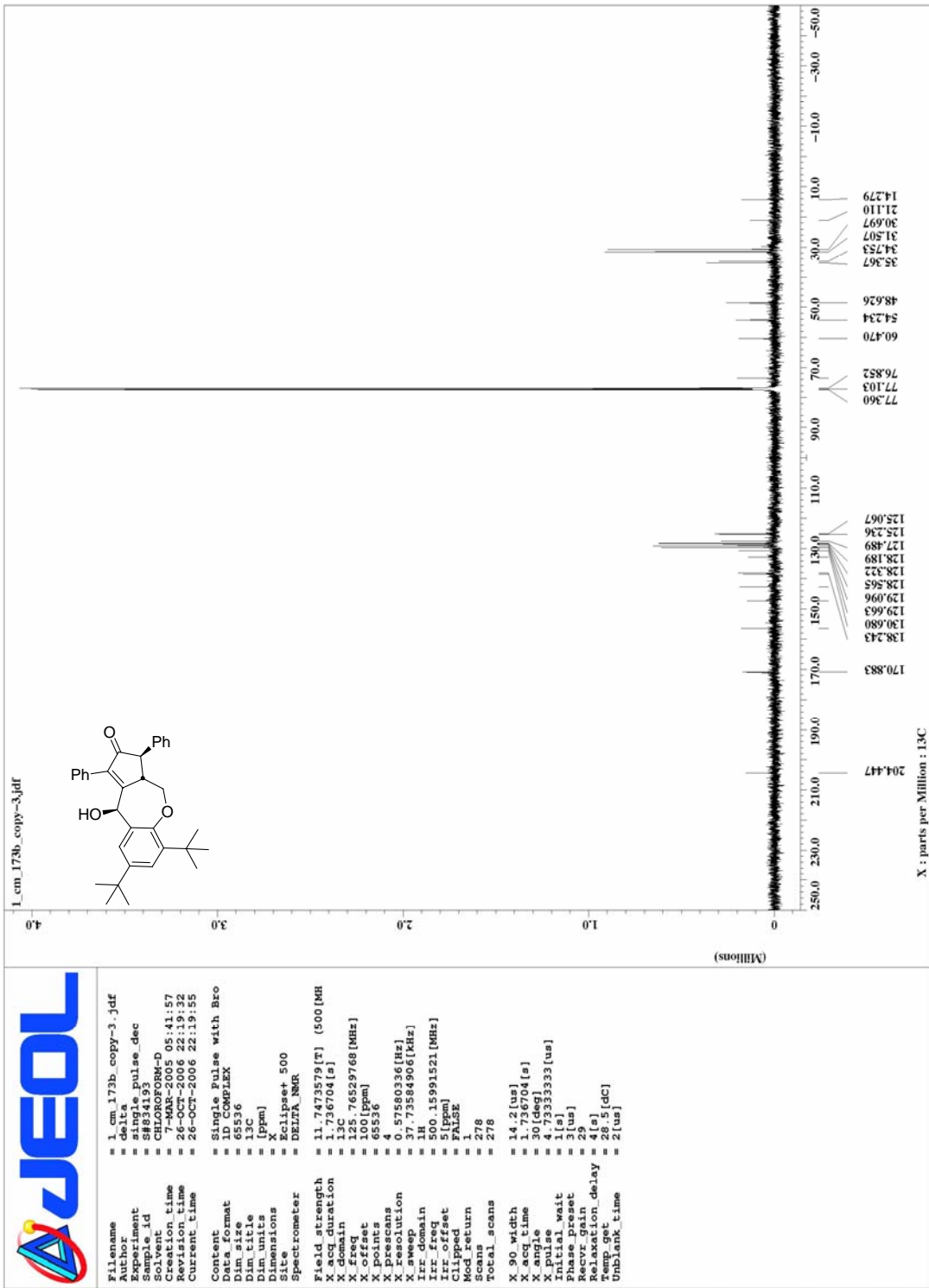
Repetition_time = 4.38412032[s]

Temp_get = 23[dc]

APPENDIX 51

^1H and ^{13}C NMR SPECTRA OF

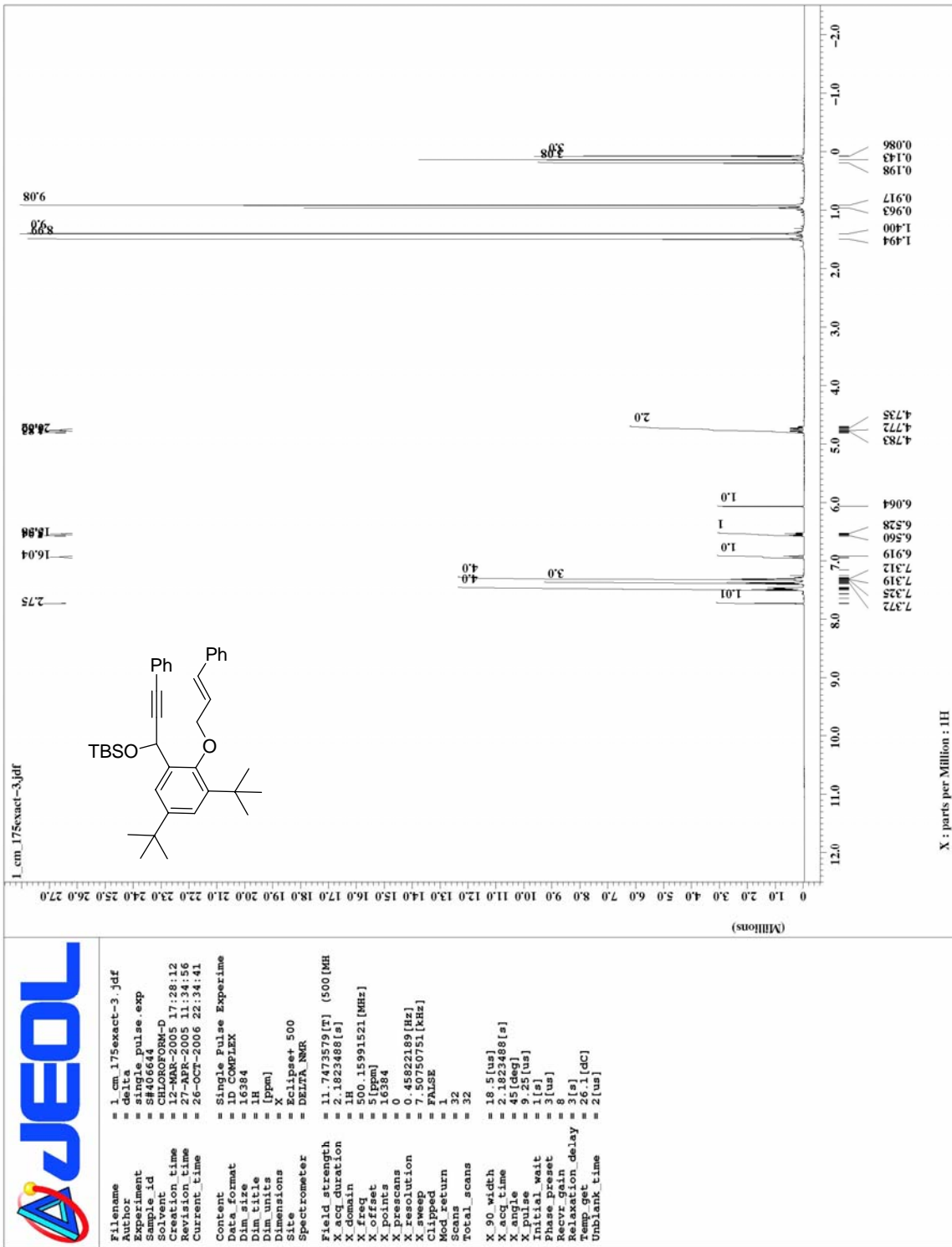
**6,8-Di-*tert*-butyl-10-hydroxy-1,3-diphenyl-4,4a-dihydro
-3*H*,10*H*-5-oxabenzof] azulene-2-one (52)**



APPENDIX 52

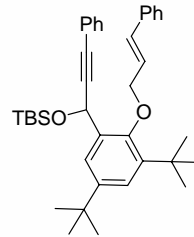
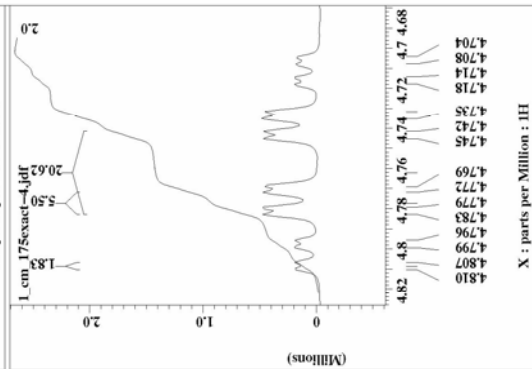
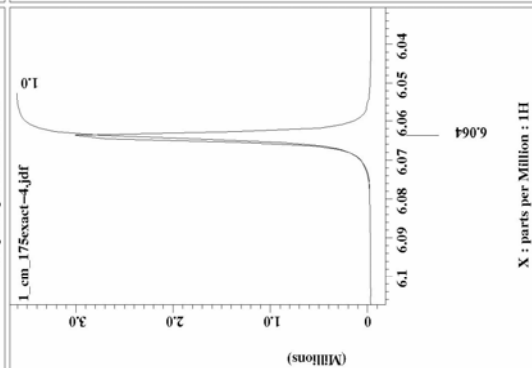
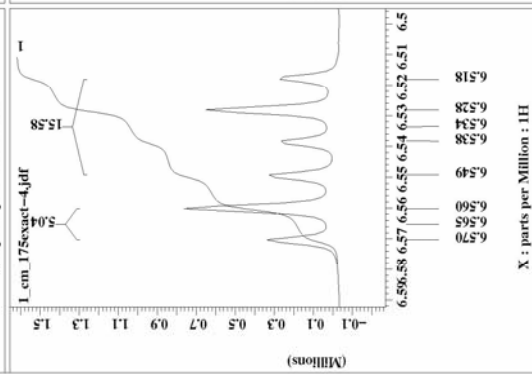
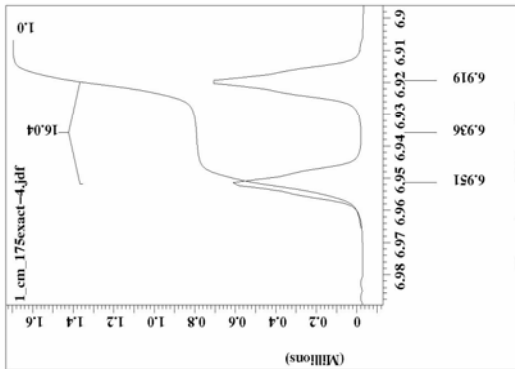
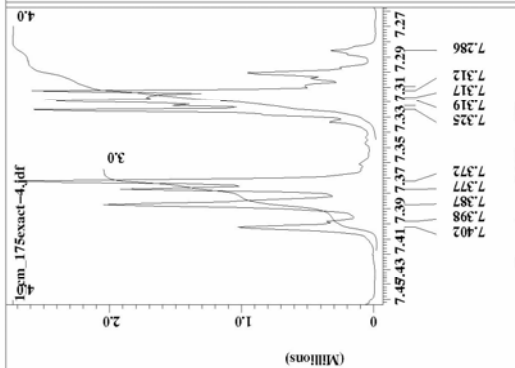
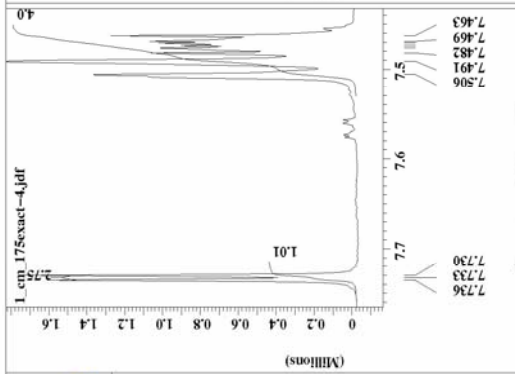
¹H and ¹³C NMR SPECTRA OF

**4,6-Di-*tert*-butyl-2-(1-*tert*-butyldimethylsilyloxy-3-phenyl -2-propynyl)
-1-(3-phenyl -2-propenyloxy) benzene (53)**





Filename = 1_cm_175exact-4.jdf
Author = delta
Experiment = delta_pulse_exp
Sample_id = SHG6644
Solvent = CHLOROFORM-D
Creation_time = 12-MAR-2005 17:28:12
Revision_time = 26-OCT-2006 22:37:18
Current_time = 26-OCT-2006 22:39:51
Content = Single Pulse Experiment
Data_format = ID COMPLEX
Dim_size = 16384
Dim_title = HR
Dim_x = X [ppm]
Dimensions = X
Site = Eclipse+ 500
Spectrometer = DELTA_NMR
Field_strength = 11.747379 [T] (500 [MHZ])
Pulsation = 2.1823488 [s]
X_domain = 1H.1823488 [MHz]
X_freq = 500.15991521 [MHz]
X_offset = 5 [ppm]
X_points = 16384
X_resolution = 0.45822189 [Hz]
X_sweep = 7.50750751 [kHz]
Mod_return = FALSE
Scans = 1
Total_scans = 32
X_90_width = 18.5 [us]
X_acq_time = 2.1823488 [s]
X_angle = 45 [deg]
X_delay = 5 [us]
Initial_wait = 1 [s]
Phase_preset = 3 [us]
Recvr_gain = 8
Relaxation_delay = 3 [s]
Temp_get = 29.5 [degC]
Unblank_time = 2 [us]





```

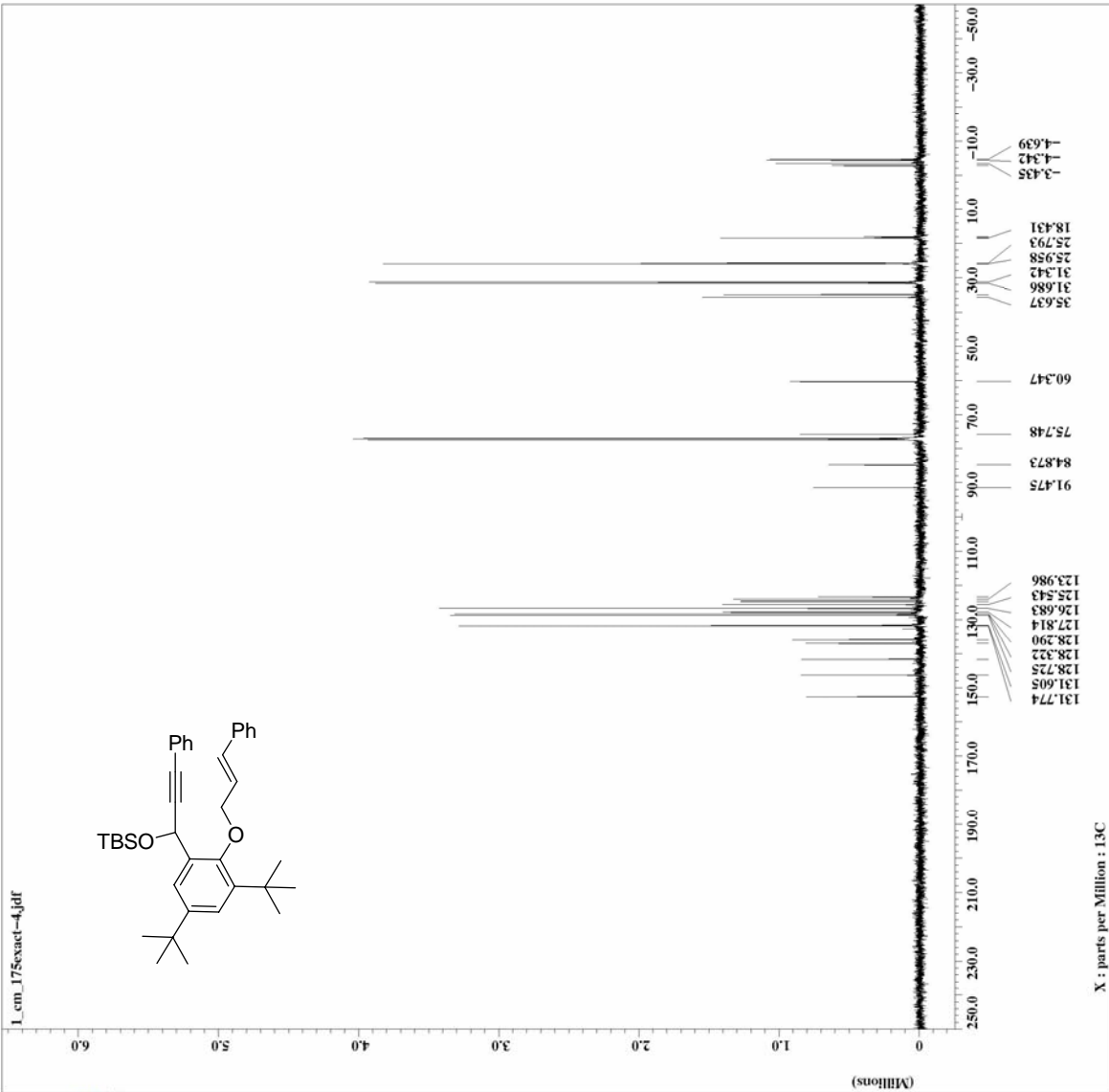
Filename = 1_cm_175exact-4.jdf
Author = delta
Experiment = single_pulse_dec
Sample_id = SH409000
Solvent = CHLOROFORM-D
Creation_time = 12-MAR-2005 17:49:33
Revision_time = 28-OCT-2006 22:30:06
Current_time = 28-OCT-2006 22:30:49

Content = Single Pulse with Bro
Data format = 1D COMPLEX
Dim size = 65536
Dim title = 13C
Dim units = [ppm]
Dimensions = X
Site = Eclipse+ 500
Spectrometer = DELTA_MXR

Field strength = 11.7473579[T] (500 [MH
X acq duration = 1.736704[s]
X domain = 13C
X freq = 125.76529768 [MHz]
X offset = 100[ppm]
X points = 65536
X prescans = 4
X resolution = 0.57580336[Hz]
X sweep = 17.73584906 [kHz]
X domain = 13C
X freq = 500.15991521 [MHz]
X offset = 5[ppm]
Clipped = FALSE
Mod Return = 1
Scans = 201.0
Total_scans = 201.0

X_90_width = 14.2[us]
X_acq_time = 30.76704[s]
X_resolution = 0.57580336 [Hz]
X_pulse = 4.73333333[us]
Initial wait = 1[s]
Phase preset = 3[us]
Recvr Gain = 29
Relaxation delay = 4[s]
Temp_get = 28.6[dc]
Unblank_time = 2[us]

```



X : parts per Million : 13C

APPENDIX 53

¹H and ¹³C NMR SPECTRA OF

**6,8-Di-*tert*-butyl-10--*t*-butyldimethylsilyloxy-1,3-diphenyl
-4,4a-dihydro-3*H*,10*H*-5-oxabenzof]azulen-2-one (54)**

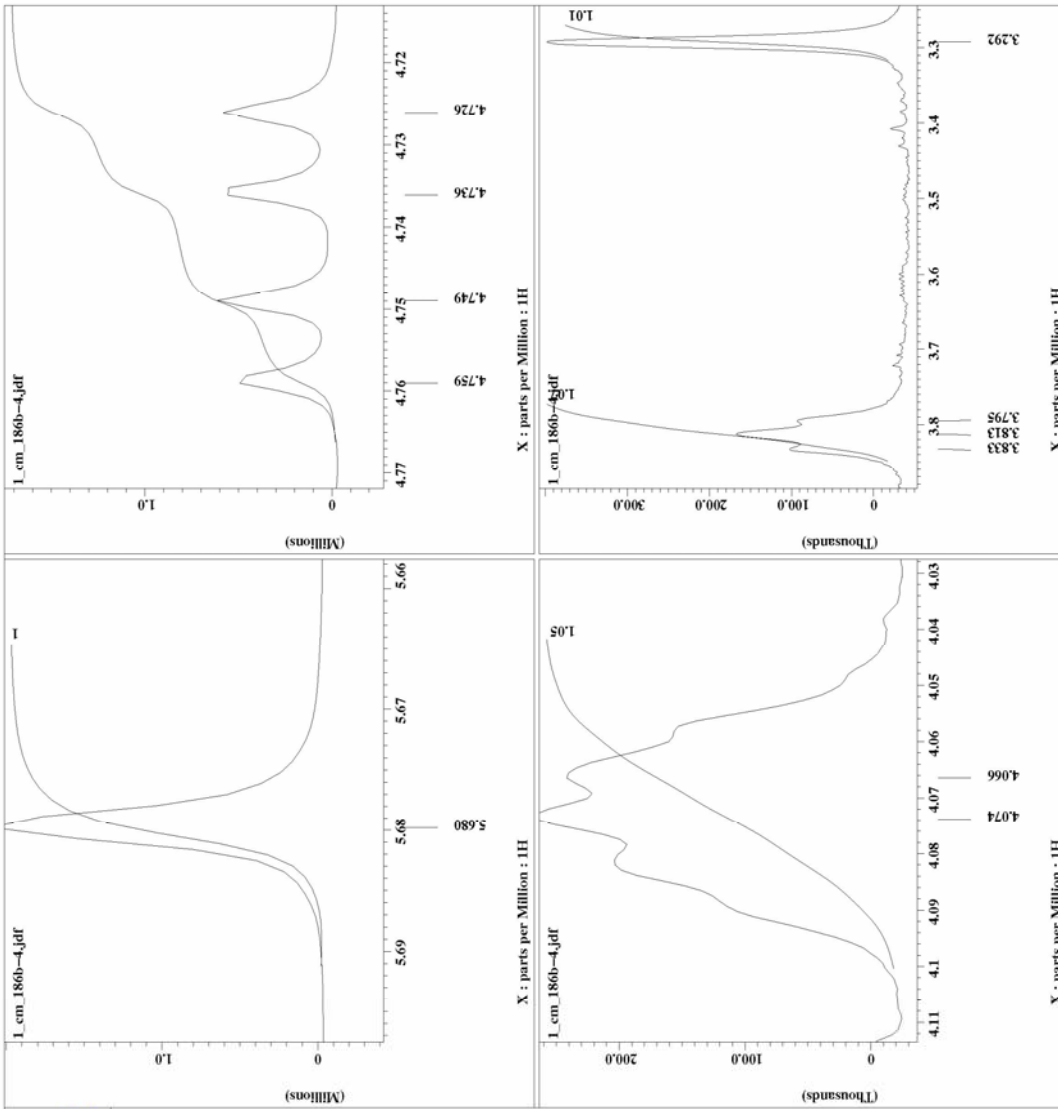
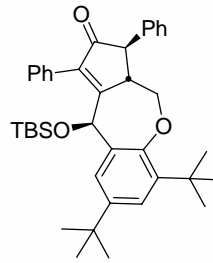


```

Filename = 1_cm_186b-4.jdf
Author = delta
Experiment = single_pulse_exp
Pulse_program = zgpg30
Solvent = CHLOROFORM-D
Creation_time = 8-JUN-2005 16:06:10
Revision_time = 26-OCT-2006 22:50:44
Current_time = 26-OCT-2006 22:51:19
Content = Single Pulse Experiment
Data_format = 1D COMPLEX
Dim_size = 16384
Dim_title = 1H
Dim_units = [ppm]
Dimensions = 1
Site = ECLIPSE+ 500
Spectrometer = DELTA NMR

Field_strength = 11.7473579[T] (500 [MH]
X_acq_duration = 18.23468[s]
X_chan = 1H
X_freq = 500.15991521 [MHz]
X_offset = 5 [ppm]
X_points = 16384
X_prescans = 0
X_prescan_delay = 45822189 [Hz]
X_resolution = 7.40750751 [kHz]
X_sweep = FALSE
Clipped = 1
Mod_return = 1
Scans = 32
Total_scans = 32

X_90_width = 18.5 [us]
X_acq_time = 2.1823468[s]
X_angle = 45 [deg]
X_pulse = 9.25 [us]
X_pulse_delay = 2 [us]
X_acquire_wait = 2 [us]
Phase_preset = 15 [us]
Recvr_gain = 15 [us]
Relaxation_delay = 5 [s]
Temp_get = 25.9 [dC]
Unblank_time = 2 [us]
  
```





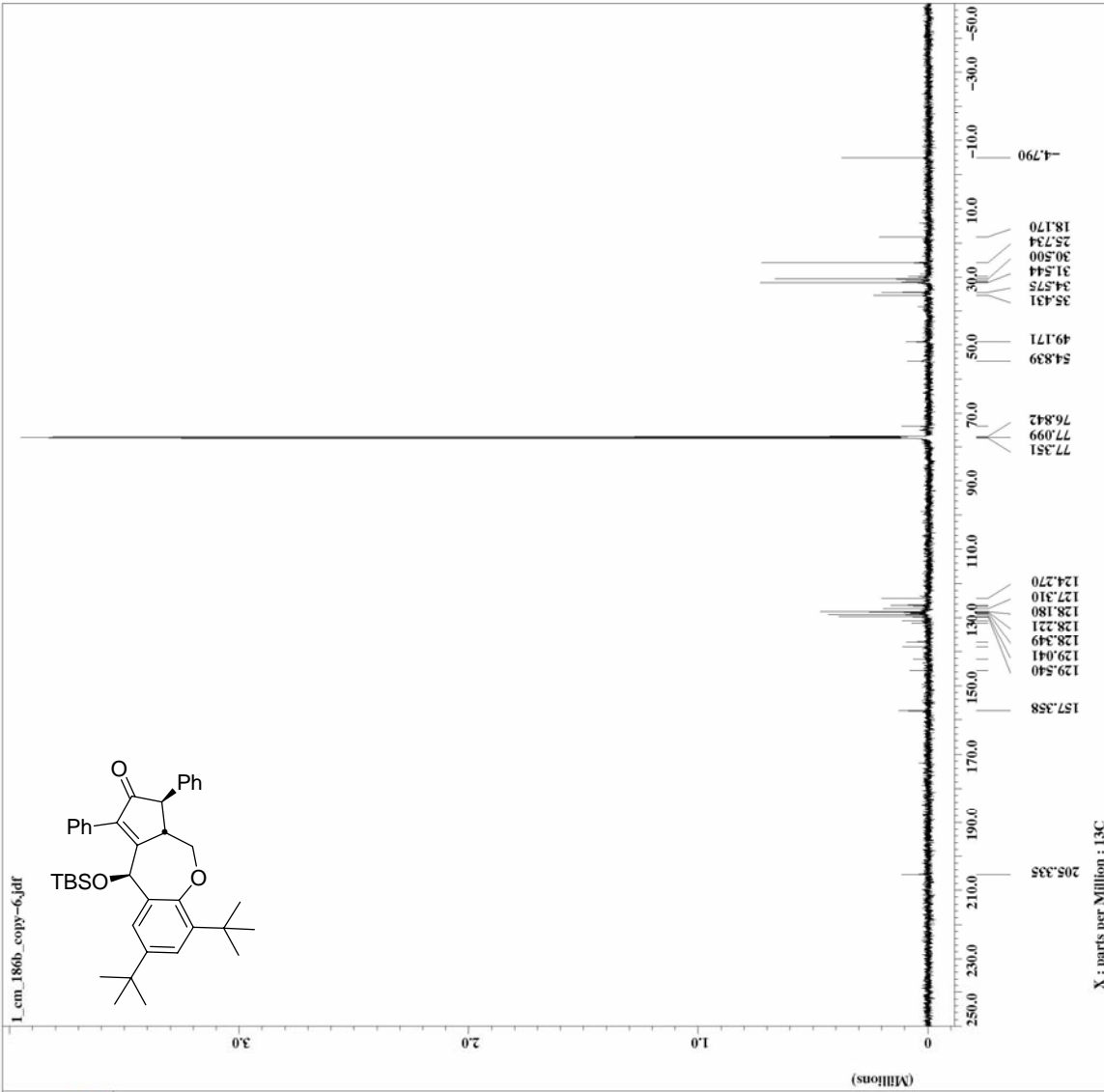
```

Filename = 1_cm_186b_copy-6.jdf
Experiment = delta_pulse_dec
Sample_id = 1_cm_186b
Solvent = CHLOROFORM-D
Creation time = 9-JUN-2005 13:29:34
Revision time = 9-JUN-2005 13:30:20
Current time = 26-OCT-2006 22:52:40

Content = Single Pulse with Bro
Data_format = 1D COMPLEX
Pulse_program = zgpg30
Dim title = 13C
Dim units = [ppm]
Dimensions = X
Site = Eclips+ 500
Spectrometer = DELTA_NMR

Field_strength = 11.7473579[T] (500[MH
X_acq_duration = 1.736704[s]
X_sweep = 0.000000[Hz]
X_freq = 125.76529768[MHz]
X_offset = 100[ppm]
X_points = 65536
X_prescans = 4
X_resolution = 0.57580336[Hz]
X_sweep = 37.73584906[KHz]
Irr_domain = 1H
Irr_freq = 500.15991521[MHz]
Irr_power = 15.000000[W]
Clipped = FALSE
Mod_return = 1
Total_scans = 817

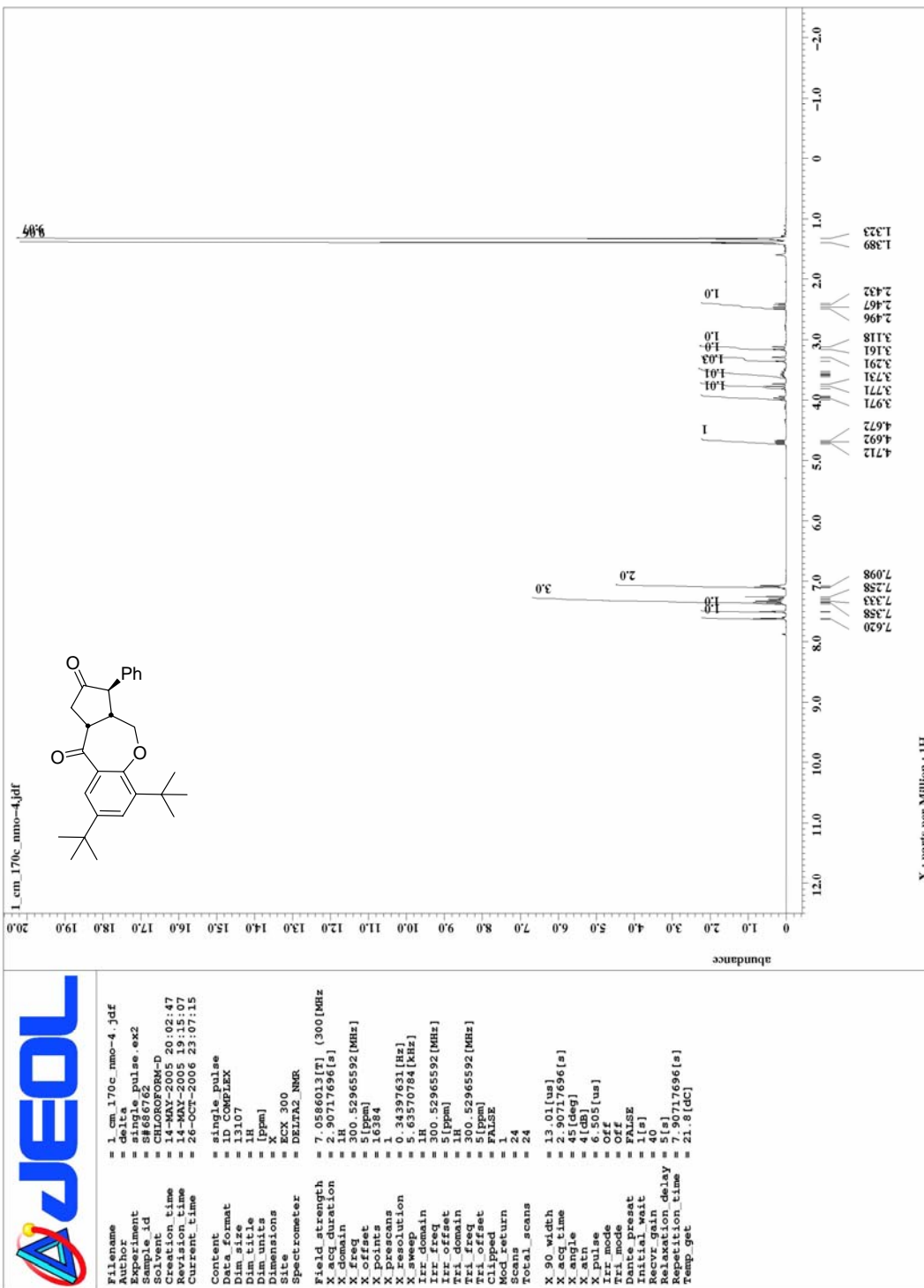
X_90_width = 14.2[us]
X_acq_time = 1.736704[s]
X_angle = 30[deg]
X_delay = 17.333333[us]
Initial_wait = 1[s]
Phase_preset = 3[us]
Recvr_gain = 29
Relaxation_delay = 4[s]
Temp_get = 28.3[ac]
Unblank_time = 2[us]
  
```

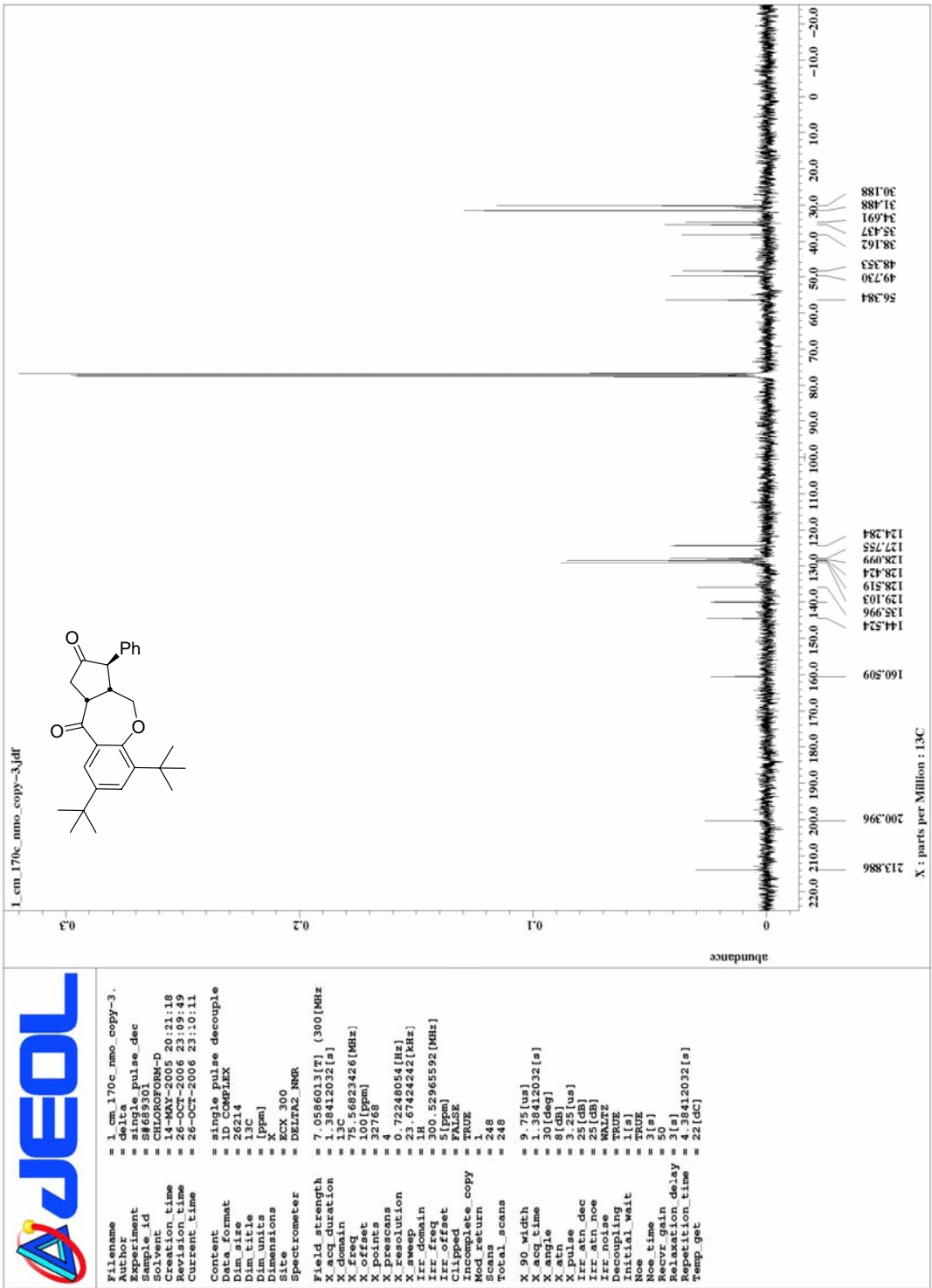


APPENDIX 54

¹H and ¹³C NMR SPECTRA OF

**6,8-Di-*tert*-butyl-3-phenyl-1,1a,4,4a-tetrahydro
-3*H*-5-oxabenzof]azulen-2, 10-dione (55)**



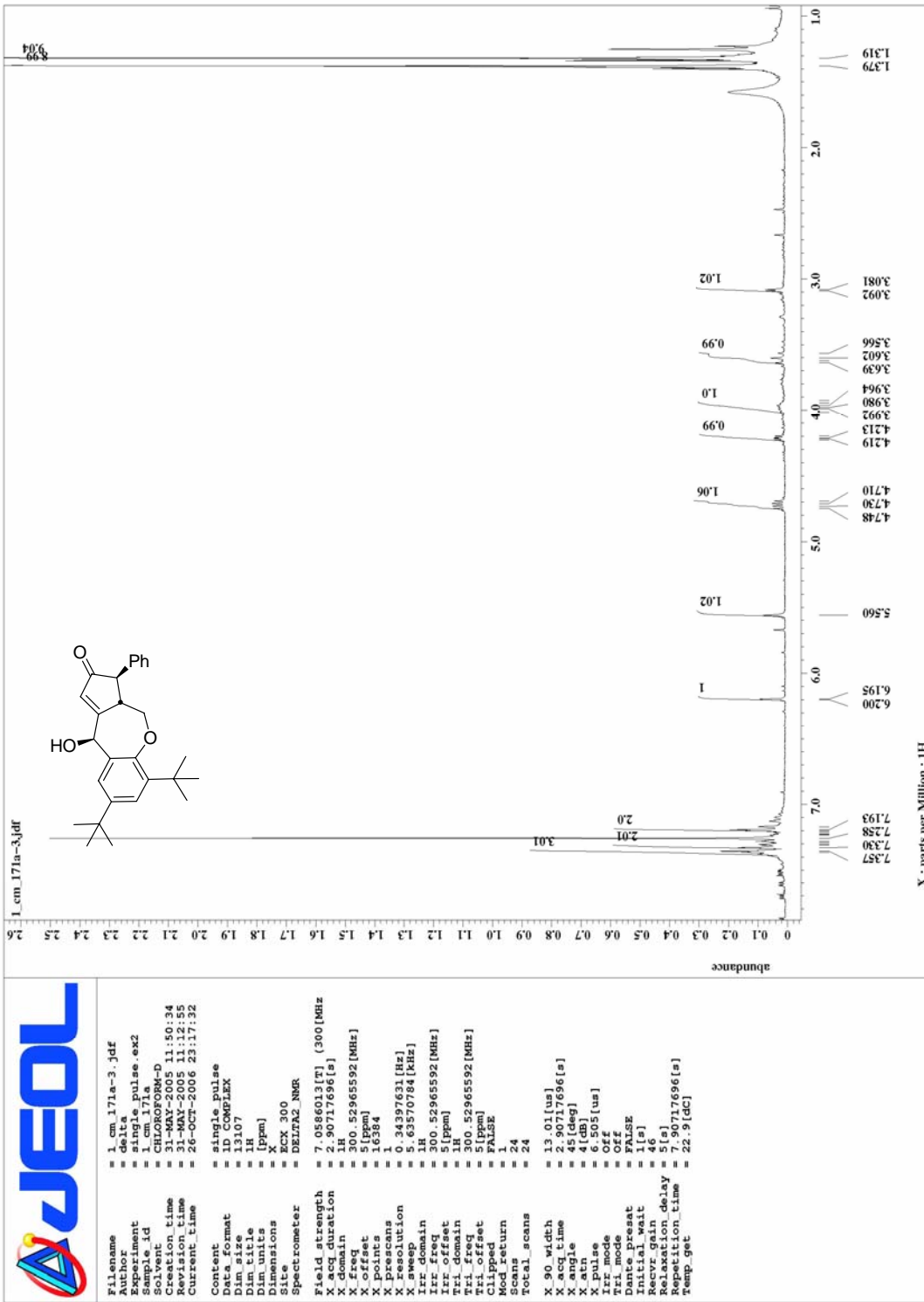


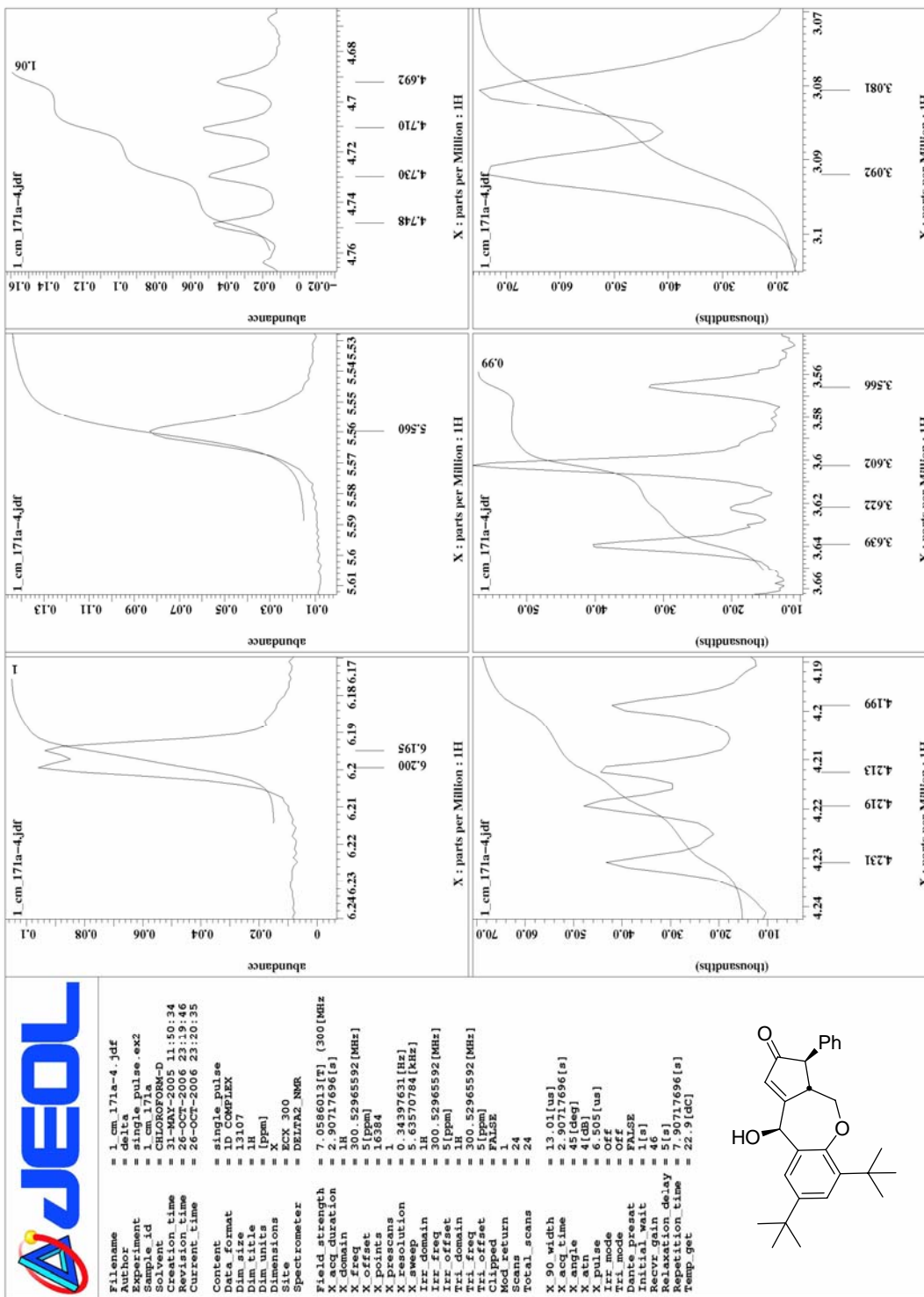
APPENDIX 55

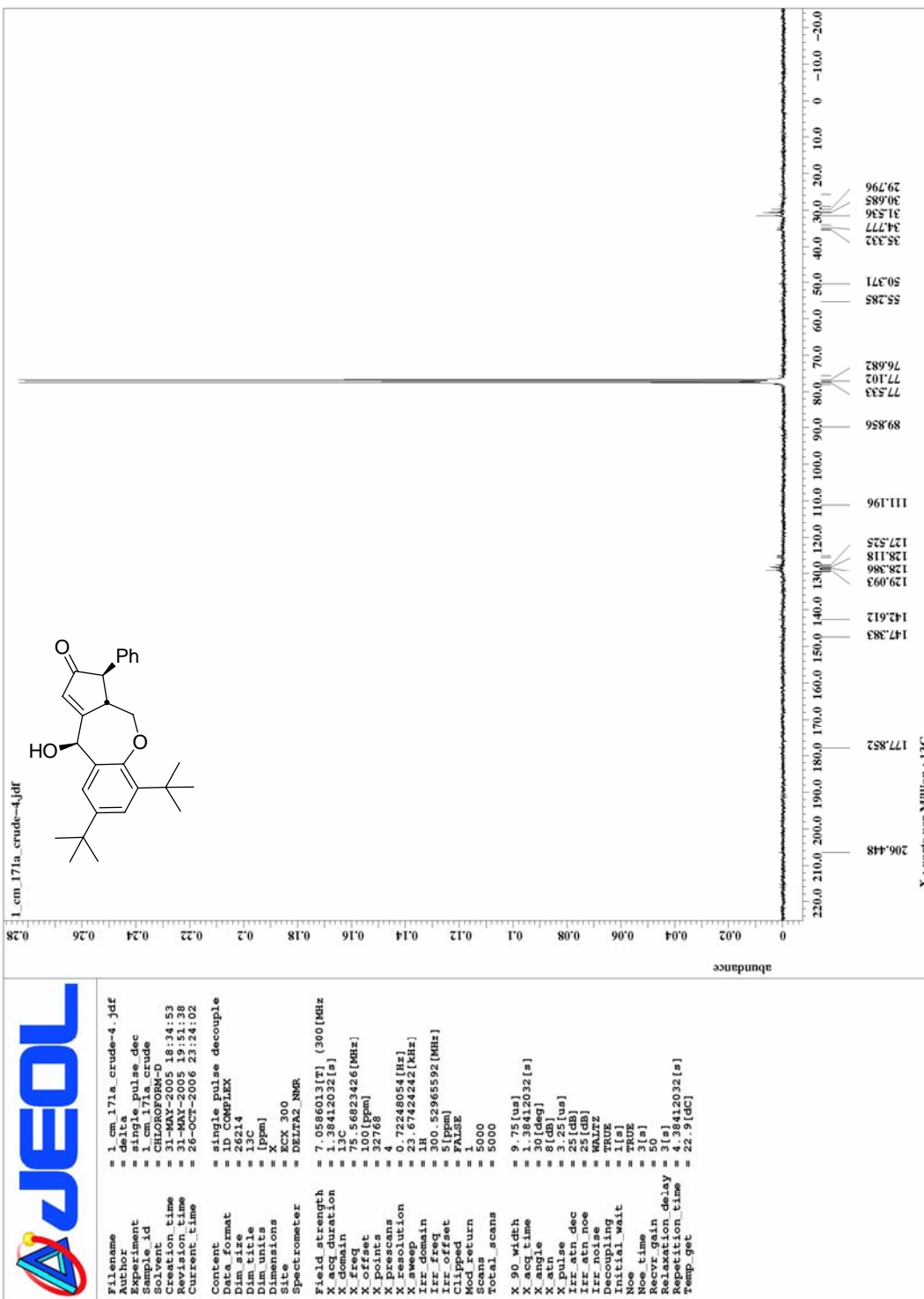
¹H and ¹³C NMR SPECTRA OF

6,8-Di-*tert*-butyl-10-hydroxy-3-phenyl-4,4a-dihydro

-3*H*,10*H*-5-oxabenzof] azulen-2-one (56)





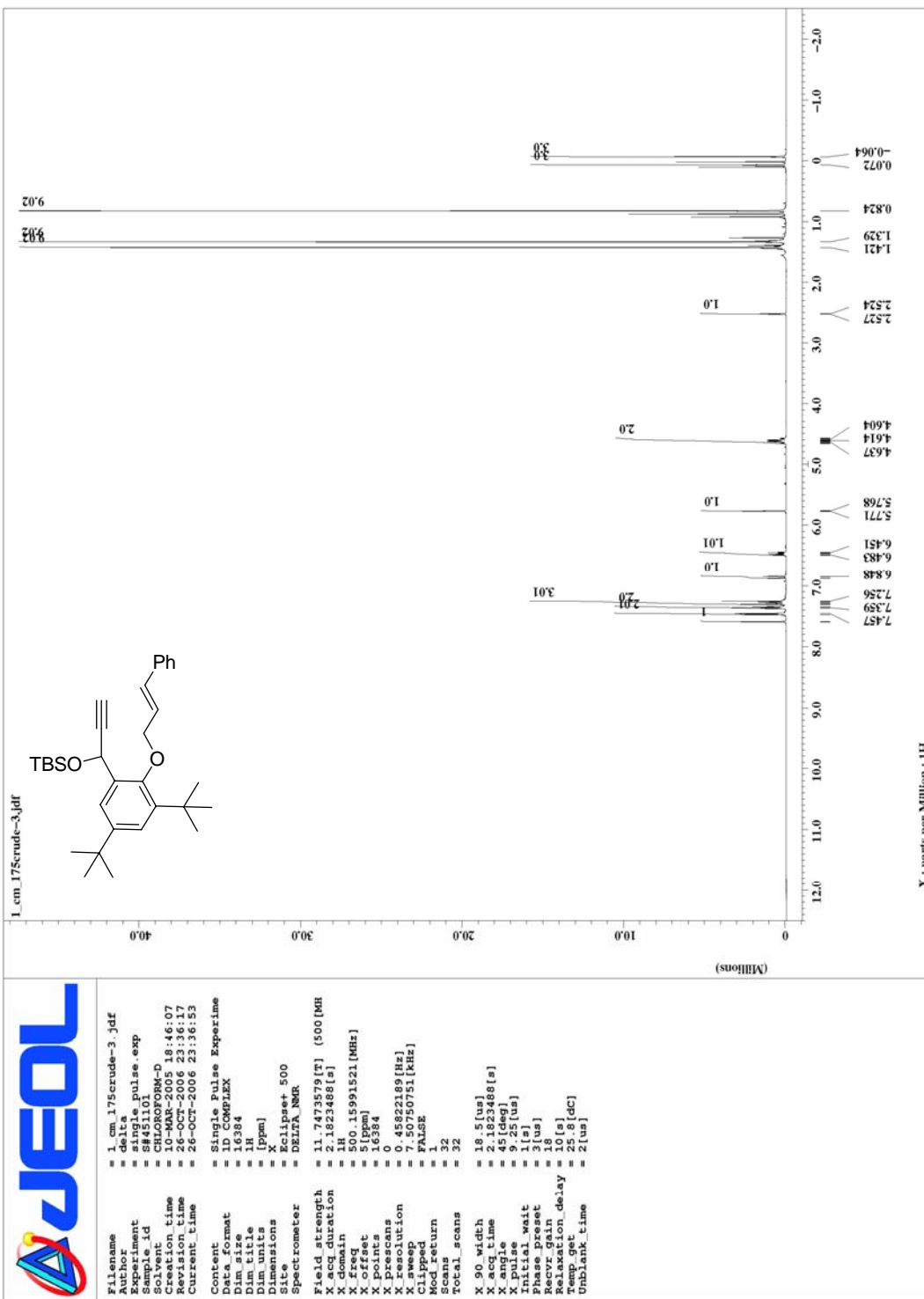


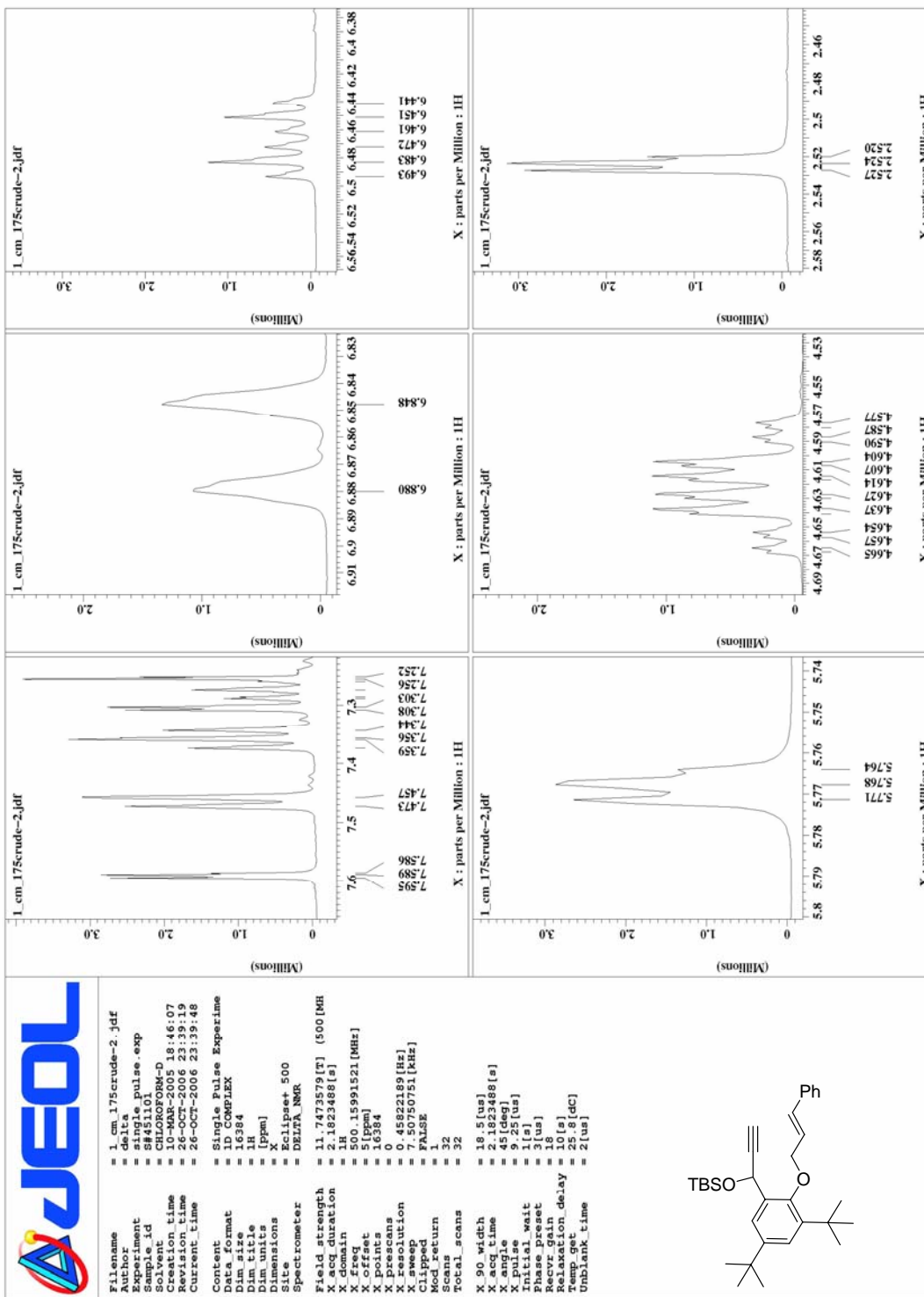
APPENDIX 56

¹H and ¹³C NMR SPECTRA OF

4,6-Di-*tert*-butyl-2-(1-*tert*-butyldimethylsilyloxy -2-propynyl)

-1-(-3-phenyl -2-propenyloxy) benzene (57)

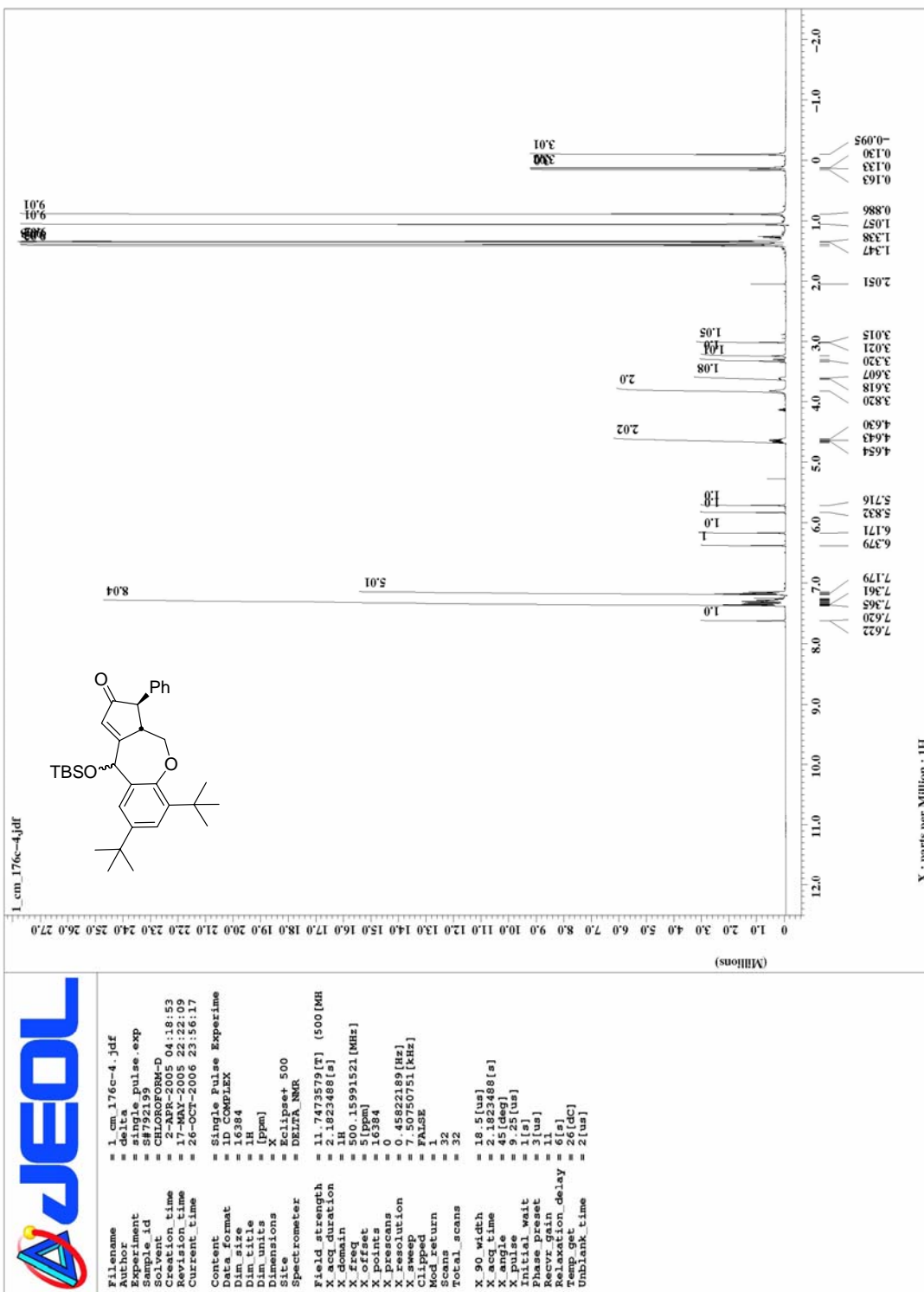




APPENDIX 57

¹H and ¹³C NMR SPECTRA OF

**6,8-Di-*tert*-butyl-10--*t*-butyldimethylsilyloxy -3-phenyl
-4,4a-dihydro-3*H*,10*H*-5-oxa benzo[*f*]azulen-2-one (58)**





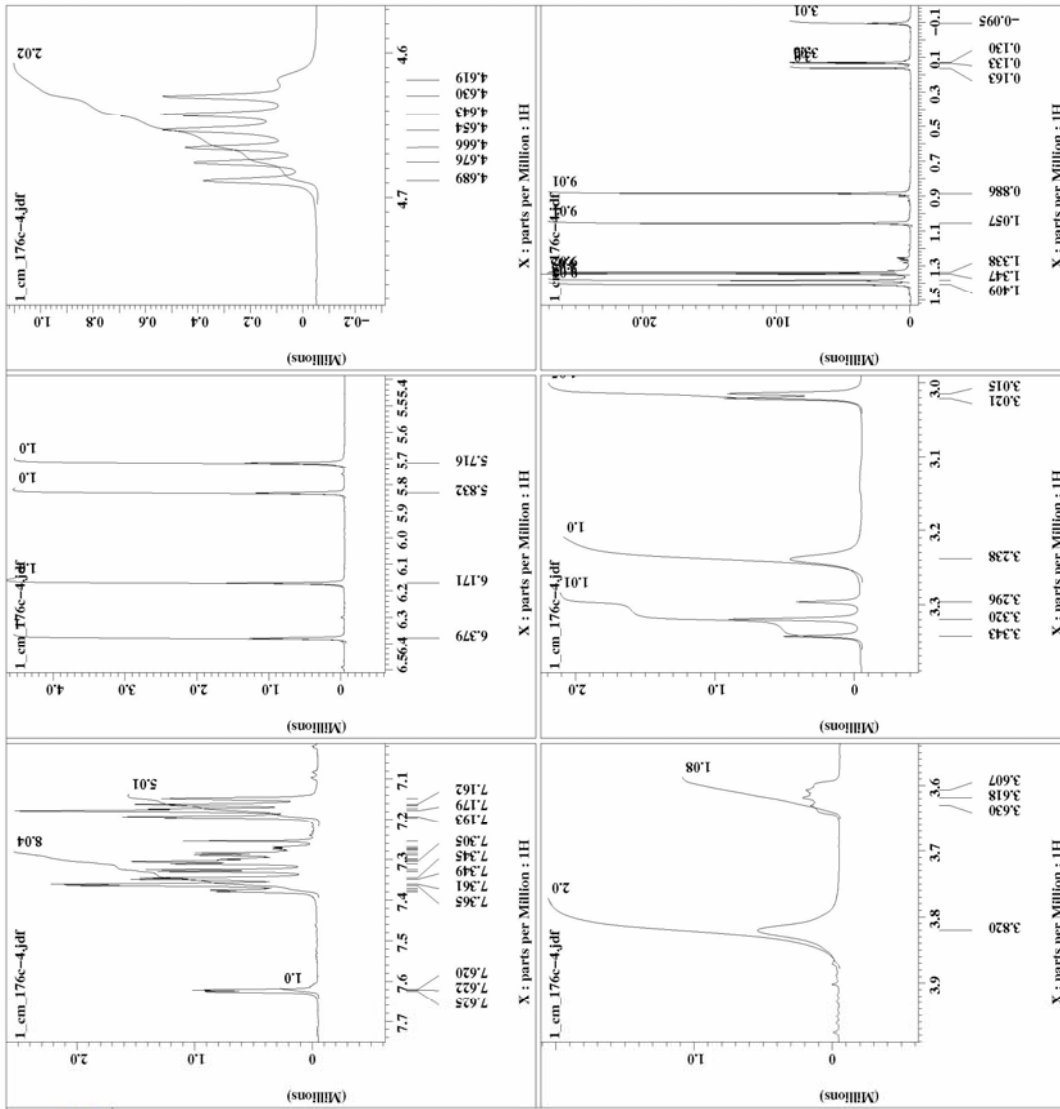
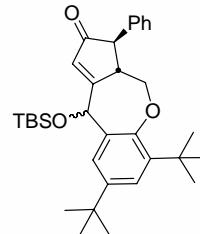
```

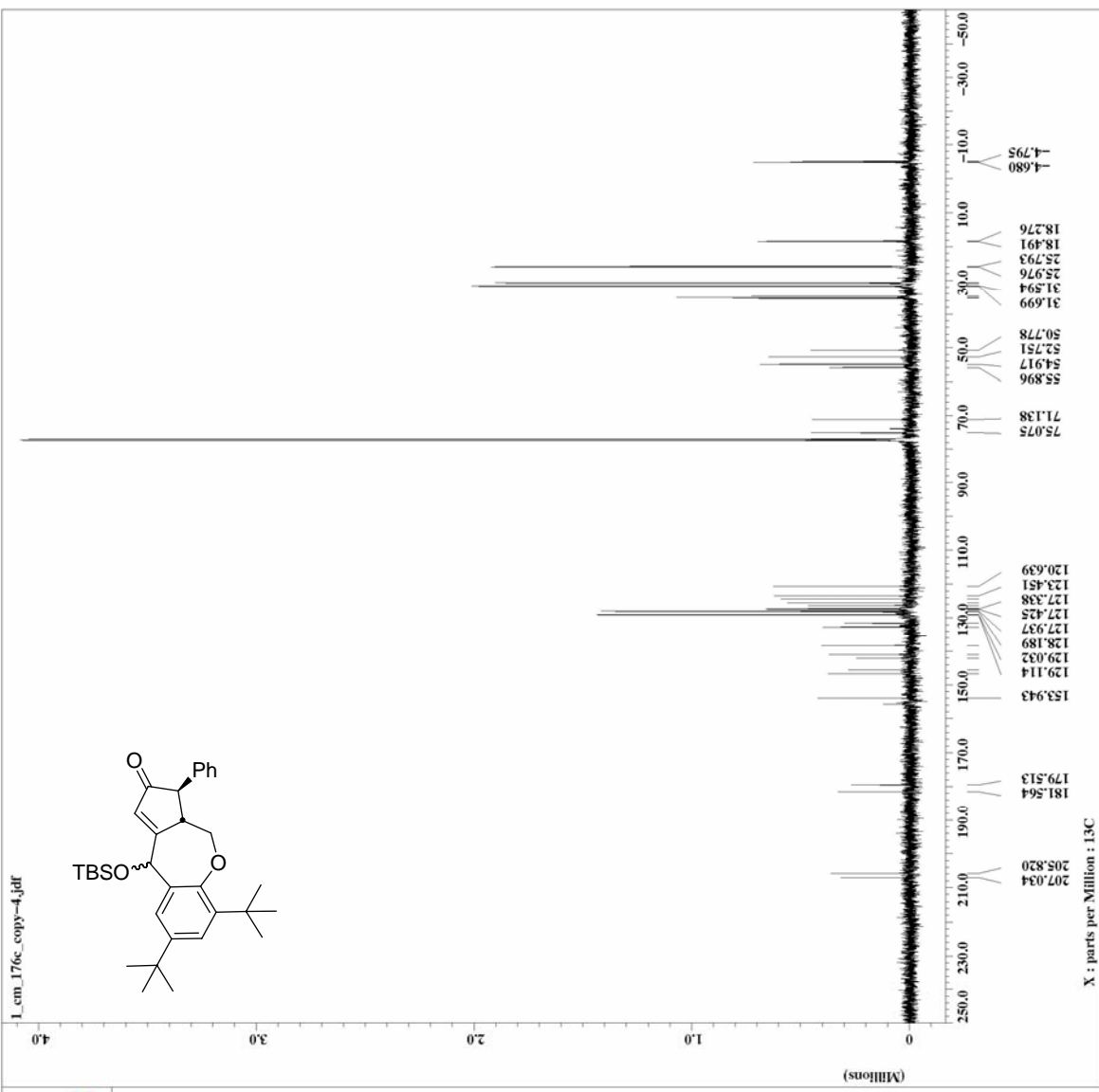
Filename = 1_cm_176c-4.jdf
Author = data
Experiment = single pulse exp
Date_Exp = 20050517
Solvent = CHLOROFORM-D
Creation_time = 2-APR-2005 04:18:53
Revision_time = 17-MAY-2005 22:22:09
Current_time = 26-OCT-2006 23:58:17

Content = Single Pulse Experiment
Data_format = 1D COMPLEX
Dim_size = 16384
Dim_title = 1H
Dim_units = [ppm]
Dimensions = 1
Site = Eclipsat 500
Spectrometer = DELTA NMR

Field_strength = 11.7473579[T] (500 [MH]
X_acq_duration = 18.23468[s]
X_freq = 500.15991521[MHz]
X_offset = 5[ppm]
X_points = 16384
X_prescans = 0
X_resolution = 0.45822189[Hz]
X_sweep = 7.50750751[MHz]
Clipped = FALSE
Mod_return = 1
Scans = 32
Total_scans = 32

X_90_width = 18.5[us]
X_acq_time = 2.1823468[s]
X_angle = 45[deg]
X_pulse = 9.25[us]
X_pulse_wait = 2[us]
Phase_preset = 31[us]
Recvr_gain = 11
Relaxation_delay = 6[s]
Temp_get = 26[dc]
Unblank_time = 2[us]
  
```





1_cm_176c_copy-4.jdf

File name = 1_cm_176c_copy-4.jdf
 Author = delta
 Experiment = single_pulse_dec
 Sample_id = SF795850
 Solvent = CHLOROFORM-D
 Creation_time = 2-APR-2005 04:40:58
 Revision_time = 17-MAY-2005 22:30:24
 Current_time = 26-OCT-2006 23:59:16

Content = Single Pulse with Bro
 Data format = 1D COMPLEX
 Dim size = 65536
 Dim title = 13C
 Dim units = [ppm]
 Dimensions = X
 Site = Eclipse+ 500
 Spectrometer = DELTA_NMR

Field strength = 11.7473579[T] (500 [MH
 X_acq_duration = 1.736704[s]
 X_domain = 13C
 X_freq = 125.76529768[MHz]
 X_offset = 100[ppm]
 X_points = 65536
 X_prescans = 4
 X_resolution = 0.57580336[Hz]
 X_sweep = 17.73584906[KHz]
 X_domain = 13C
 X_freq = 500.15991521[MHz]
 X_offset = 5[ppm]
 Clipped = FALSE
 Mod_return = 1
 Scans = 208
 Total_scans = 208

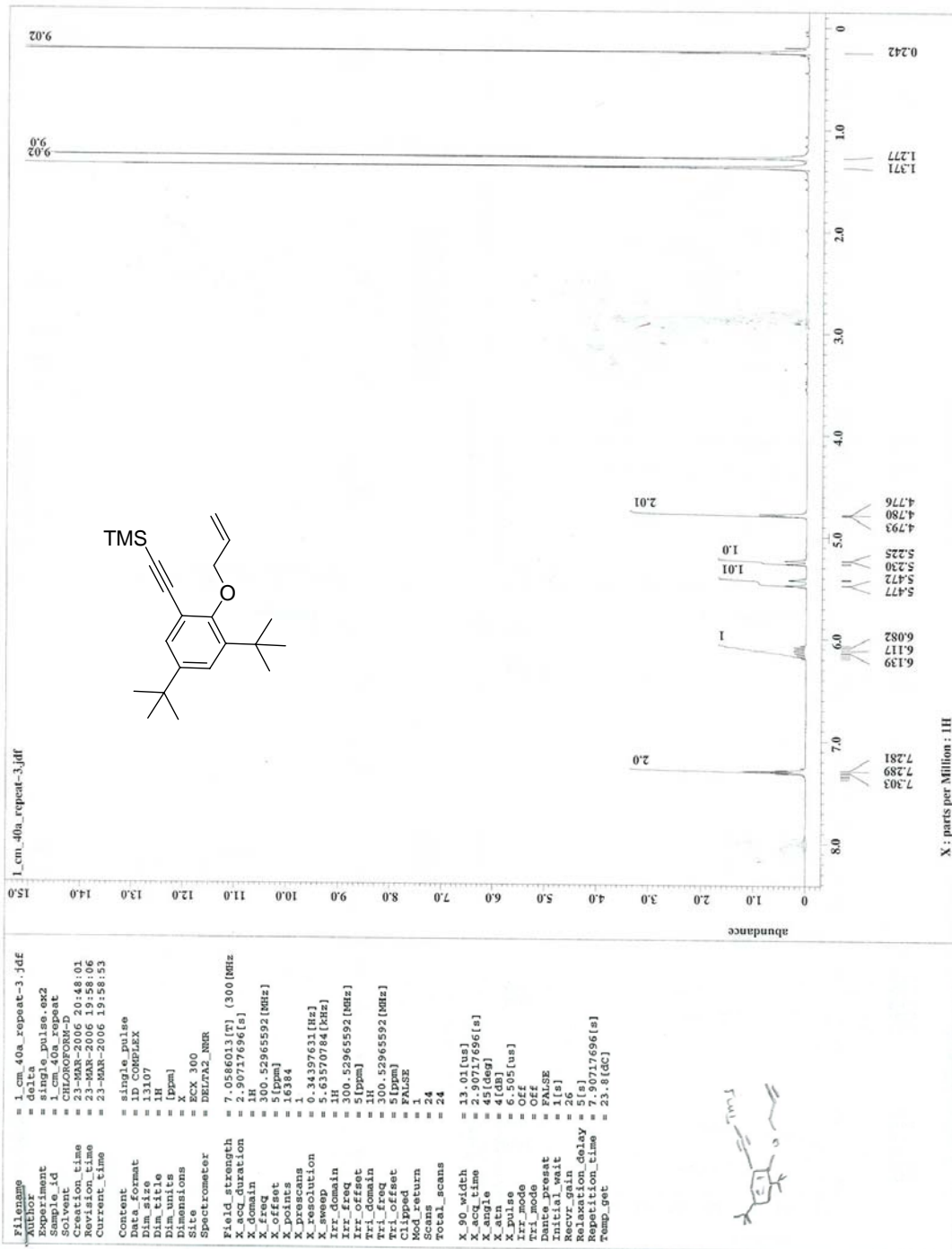
X_90_width = 14.2[us]
 X_acq_time = 30.76704[s]
 X_delay = 3.000000[s]
 X_pulse = 4.73333333[us]
 Initial_wait = 1[s]
 Phase_preset = 3[us]
 Recvr_gain = 29
 Relaxation_delay = 4[s]
 Temp_get = 28.1[dc]
 Unblank_time = 2[us]

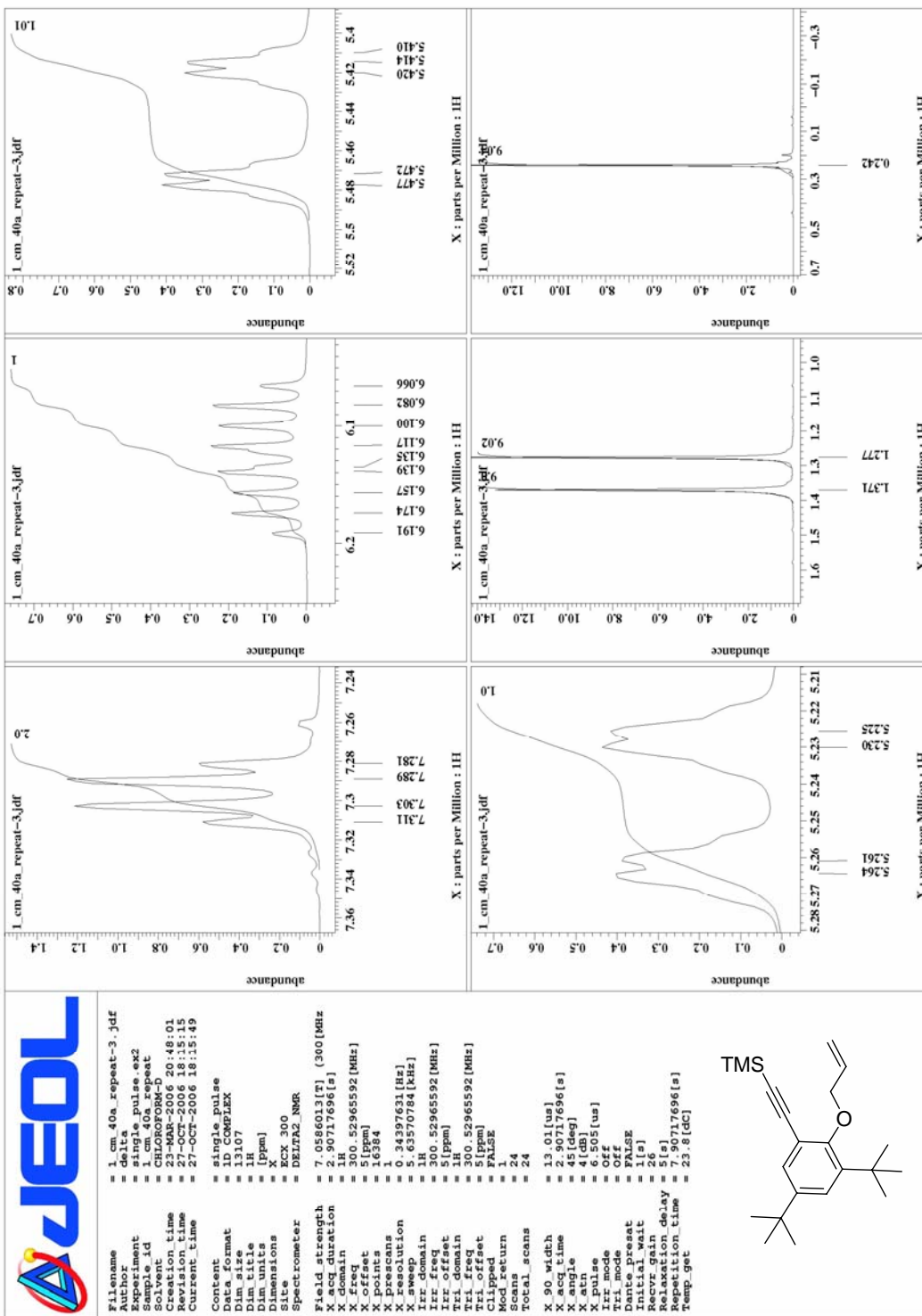
APPENDIX 58

^1H and ^{13}C NMR SPECTRA OF

Di-tert-butyl-2-trimethylsilylethynyl

-(-2-propenyloxy)benzene (62)







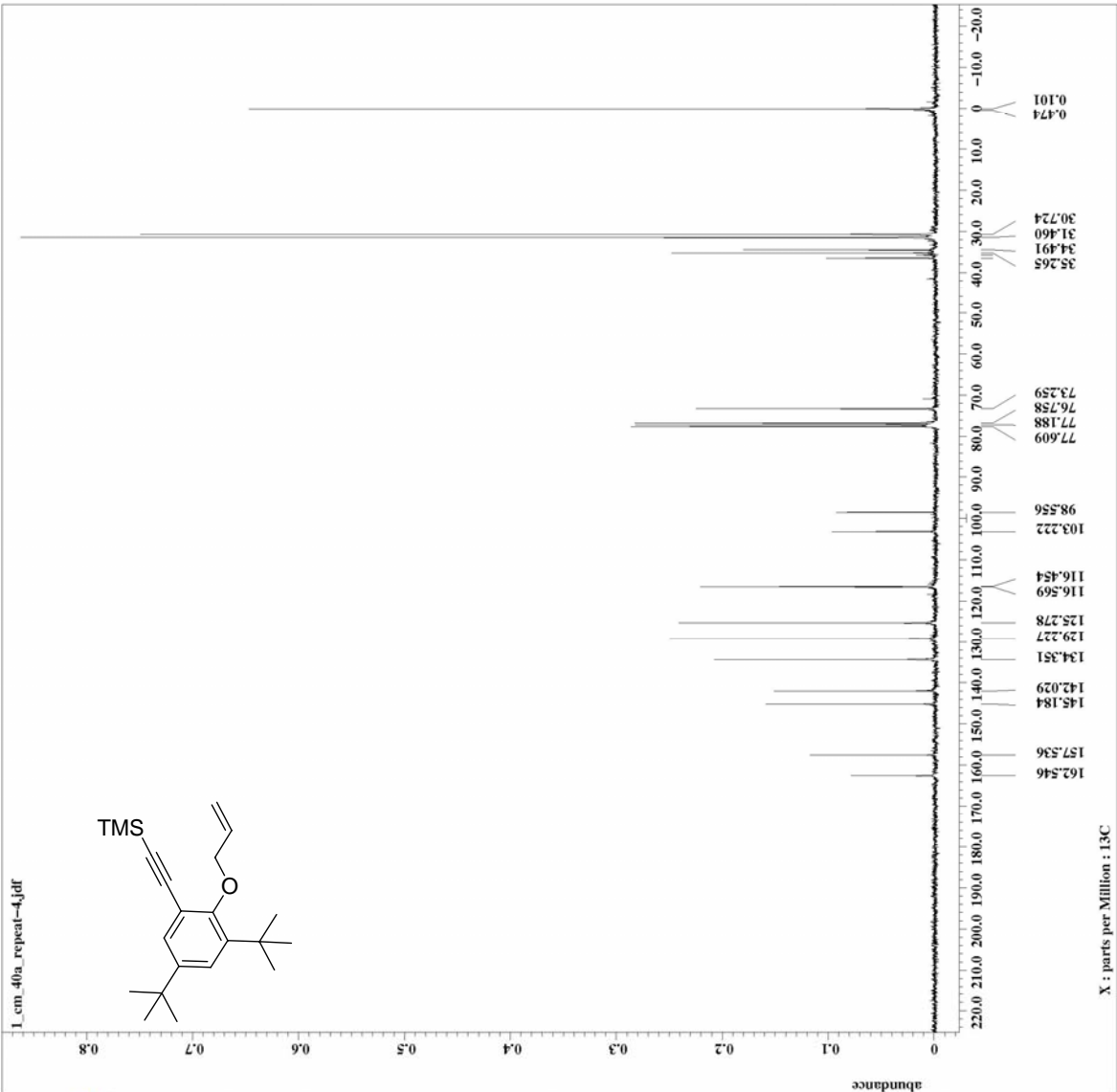
```

Filename = 1_cm_40a_repeat-4.jdf
Author = delta
Experiment = single pulse dec
Sample_id = 1_cm_40a_repeat
Solvent = CHLOROFORM-D
Creation_time = 23-MAR-2006 21:22:15
Revision_time = 27-OCT-2006 18:17:15
Current_time = 27-OCT-2006 18:17:38

Content = single pulse decouple
Data_format = 1D, COMPLEX
Dim_size = 26214
Dim_title = 13C
Dim_units = [ppm]
Dimensions = X
Site = ECX 300
Spectrometer = DELTA2_NMR

Field_strength = 7.0586013[T] (300[MHz]
X_calibration = 1.38412032[s]
X_domain = 13C
X_freq = 75.56823426[MHz]
X_offset = 100[ppm]
X_points = 32768
X_prescans = 4
X_resolution = 0.72248054[Hz]
X_sweep = 23.67424242[KHz]
Irr_domain = 1H
Irr_freq = 500.52965592[MHz]
Irr_offset = 0[ppm]
Clip_level = FALSE
Mod_return = 1
Scans = 464.0
Total_scans = 464.0

X_90_width = 9.75[us]
X_acq_time = 1.38412032[s]
X_angle = 30[deg]
X_atn = 8[us]
X_pulse = 8[us]
Irr_atn_dec = 25[dB]
Irr_atn_noe = 25[dB]
Irr_noise = WALTZ
Decoupling = TRUE
Initial_wait = 1[s]
Noe = TRUE
Noe_time = 3[s]
Recvr_gain = 50
Relaxation_delay = 3[s]
Repetition_time = 1.38412032[s]
Temp_set = 22.2[degC]
  
```

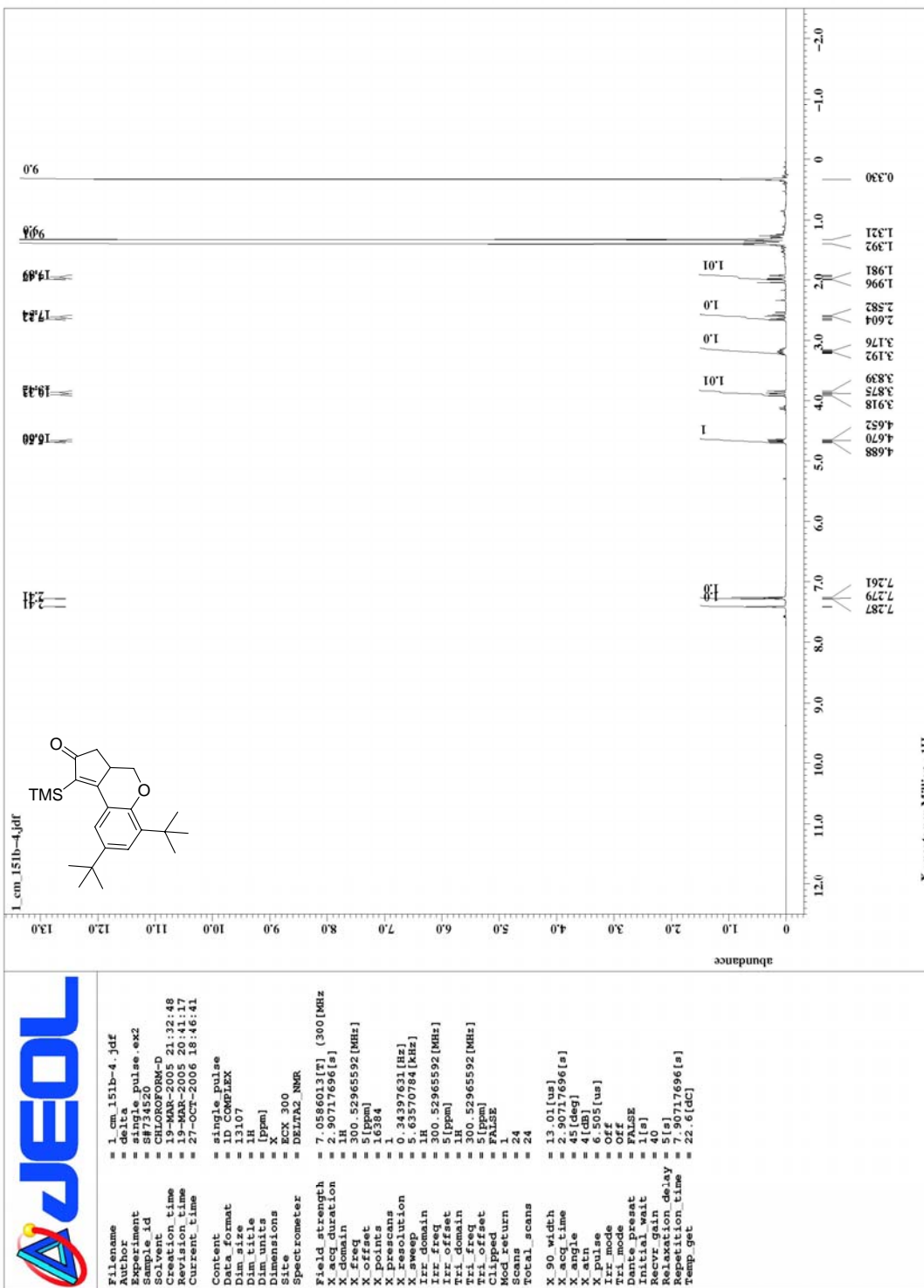


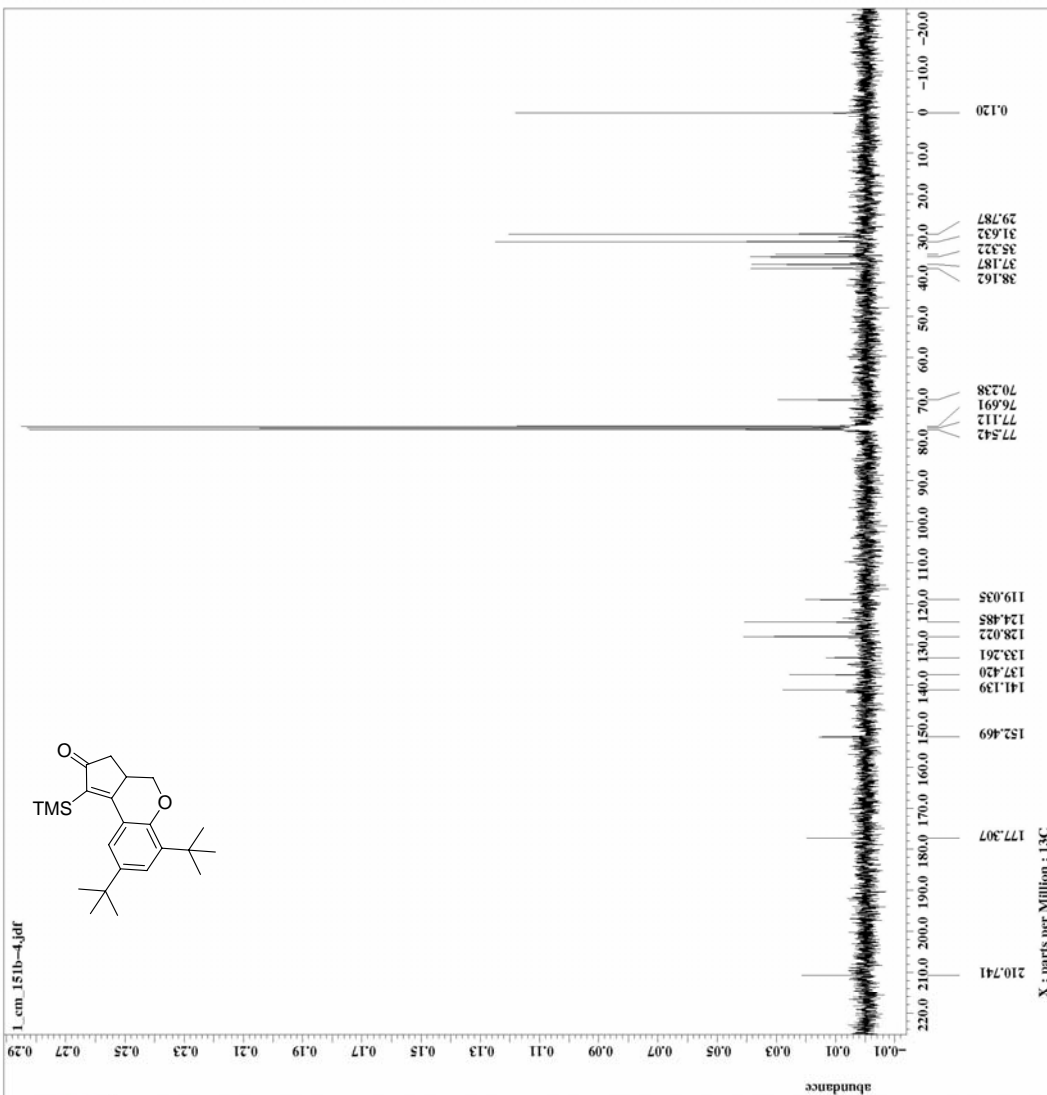
APPENDIX 59

^1H and ^{13}C NMR SPECTRA OF

6,8-Di-*tert*-butyl-1-trimethylsilyl-3a,4-dihydro

-3*H*-cyclopenta[*c*]chromen-2-one (64)





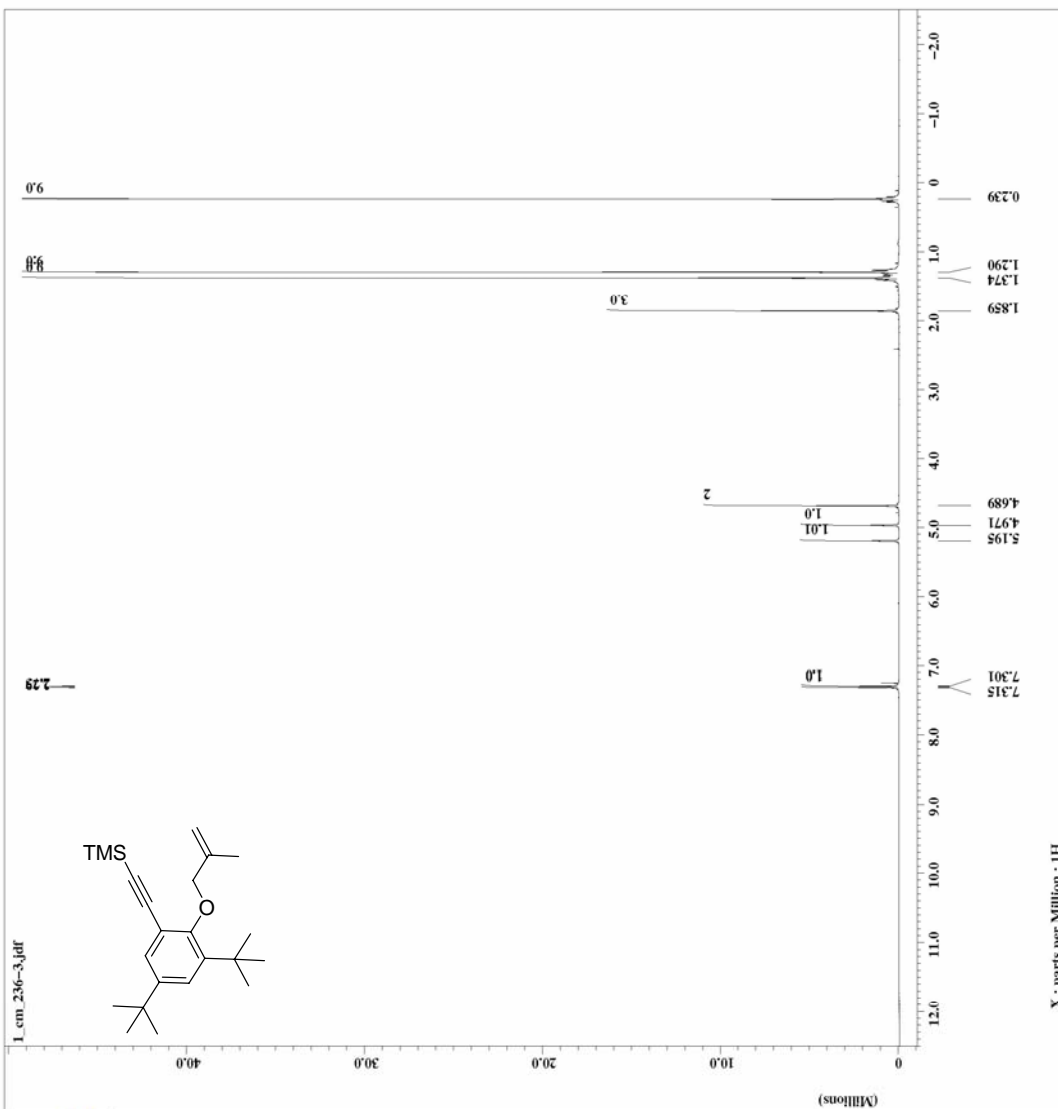
JEOL
 Filename = 1_cm_151b-4.jdf
 Author = delta
 Experiment = pulse_dec
 Sample_id = S873131
 Solvent = CHLOROFORM-D
 Creation_time = 19-MAR-2005 21:46:24
 Revision_time = 19-MAR-2005 20:43:47
 Current_time = 27-OCT-2006 18:48:54
 Content = single pulse decouple
 Data_format = ID COMPLEX
 Dim_size = 26214
 Dim_title = 13C
 Dimensions = X (ppm)
 Site = ECX 300
 Spectrometer = DELTA2_NMR
 Field_strength = 7.0586013[T] (300[MHz]
 X_acq_duration = 1.38412032[s]
 X_domain = 13C
 X_freq = 75.56823426[MHz]
 X_offset = 100[ppm]
 X_points = 2768
 X_resolution = 0.72248054[Hz]
 X_sweep = 23.67424242[kHz]
 Irr_domain = IN
 Irr_freq = 200.52965592[MHz]
 Irr_offset = TRUE
 Clipped = TRUE
 Mod_return = 1
 Scans = 179
 Total_scans = 179
 X_90_width = 9.75[us]
 X_acq_time = 1.38412032[s]
 X_angle = 30[deg]
 X_atn = 8[db]
 X_pulse = 25[us]
 X_pulse_dec = 25[us]
 Irr_atn_noe = 25[db]
 Irr_noise = WALTZ
 Decoupling = TRUE
 Initial_wait = 1[s]
 Noe_time = 3[s]
 Recvr_gain = 50
 Relaxation_delay = 2[s]
 Repetition_time = 4.38412032[s]
 Temp_get = 22.6[degC]

APPENDIX 60

^1H and ^{13}C NMR SPECTRA OF

4,6-Di-tert-butyl-2-trimethylsilylethynyl

-(-2-methylallyloxy)benzene (66)



JEOL

Filename = 1. cm_236-3.jdf
 Author = delta
 Experiment = singl_pulse.exp
 Solvent = CHLOROFORM-D
 Creation_time = 14-DEC-2005 13:21:09
 Revision_time = 14-DEC-2005 11:48:50
 Current_time = 27-OCT-2006 18:56:28

Content = Single Pulse Experiment
 Data_format = 1D COMPLEX
 Dim_size = 16384
 Dim_title = 1H
 Dim_units = [ppm]
 Dimensions = 2
 Site = Eclipse+ 500
 Spectrometer = DELTA_NMR

Field_strength = 11.7473579[T] (500 [MH]
 X_acq_duration = 2.1823468[s]
 X_acq_time = 2.1823468[s]
 X_freq = 500.15991521 [MHz]
 X_offset = 5 [ppm]
 X_points = 16384
 X_prescans = 0
 X_resolution = 458221.89 [Hz]
 X_sweep = 7.40750751 [kHz]
 Clipped = FALSE
 Mod_return = 1
 Scans = 25
 Total_scans = 25

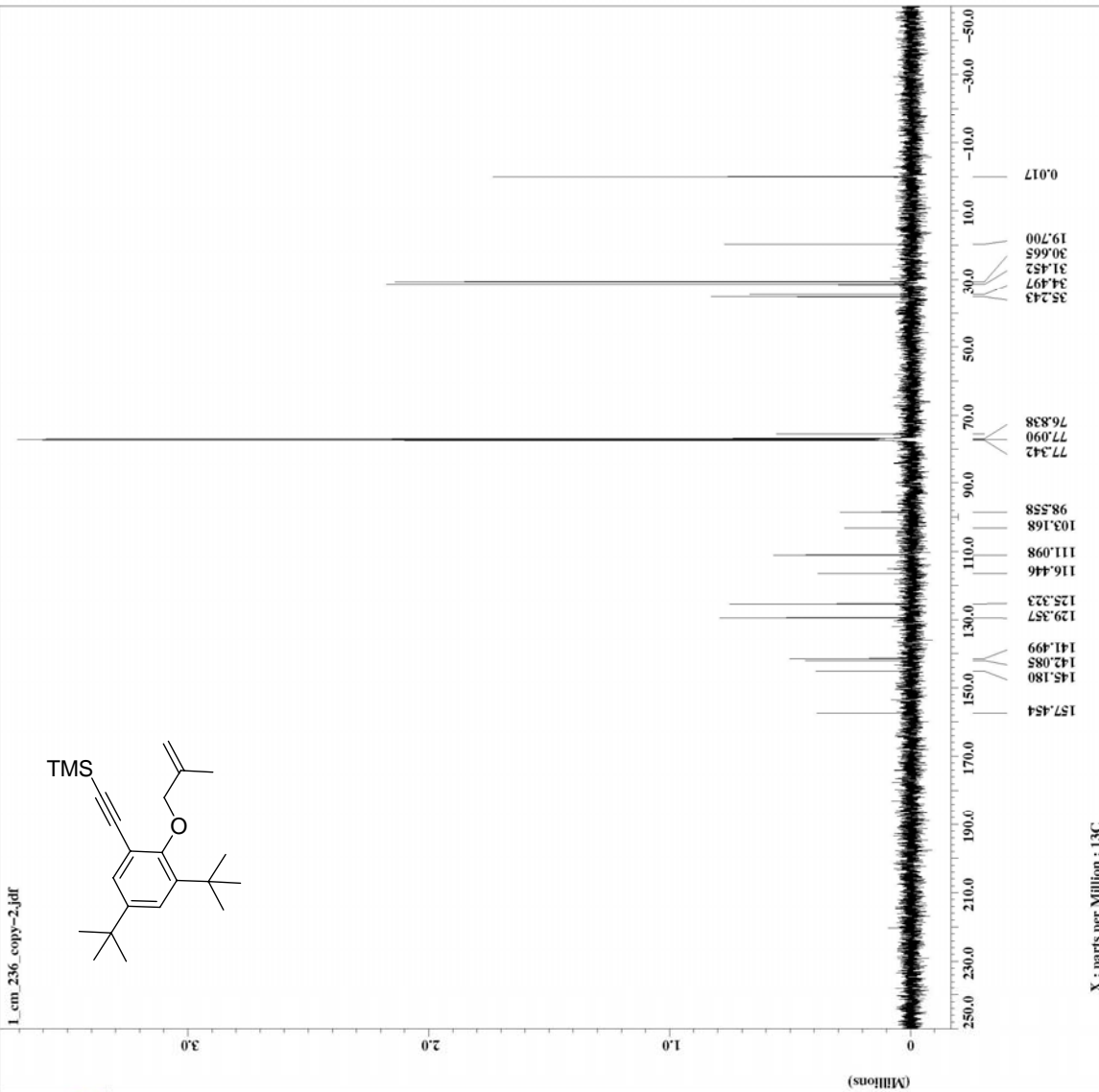
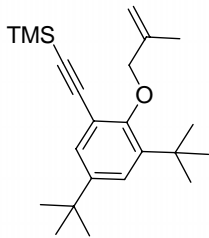
X_90_width = 18.5 [us]
 X_acq_time = 2.1823468[s]
 X_angle = 45 [deg]
 X_pulse = 9.25 [us]
 X_pulse_wait = 2 [us]
 Phase_preset = 31 [us]
 Recvr_gain = 14
 Relaxation_delay = 1 [s]
 Temp_get = 25.6 [dC]
 Unblank_time = 2 [us]

X : parts per Million : 1H



Filename = 1_cm_236_copy-2.jdf
Author = delta
Experiment = single_pulse_dec
Sample_id = 1_cm_236
Solvent = CHLOROFORM-D
Creation_time = 14-DEC-2005 13:33:47
Revision_time = 27-OCT-2006 18:56:57
Current_time = 27-OCT-2006 18:57:15
Content = Single Pulse with Bro
Data_format = 1D COMPLEX
Dim_size = 65536
Dim_title = 13C
Dim_units = [ppm]
Dimensions = X
Site = Eclipse 500
Spectrometer = DELTA_NMR
Field_strength = 11.7473579[T] (500[MH
X_acq_duration = 1.736704[s]
X_domain = 13C
X_freq = 125.76529768[MHz]
X_offset = 100[ppm]
X_points = 65536
X_prescans = 4
X_resolution = 5758036[Hz]
X_sweep = 97.7584906[RHz]
Irr_domain = 1H
Irr_freq = 500.15991521[MHz]
Irr_offset = 5[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 110
Total_scans = 110
X_90_width = 14.2[us]
X_acq_time = 1.736704[s]
X_angle = 30[deg]
X_pulse = 4.73333333[us]
Initial_wait = 1[s]
Phase_preset = 3[us]
Recvr_gain = 29
Relaxation_delay = 4[s]
Temp_get = 27.9[dc]
Unblank_time = 2[us]

1_cm_236_copy-2.jdf



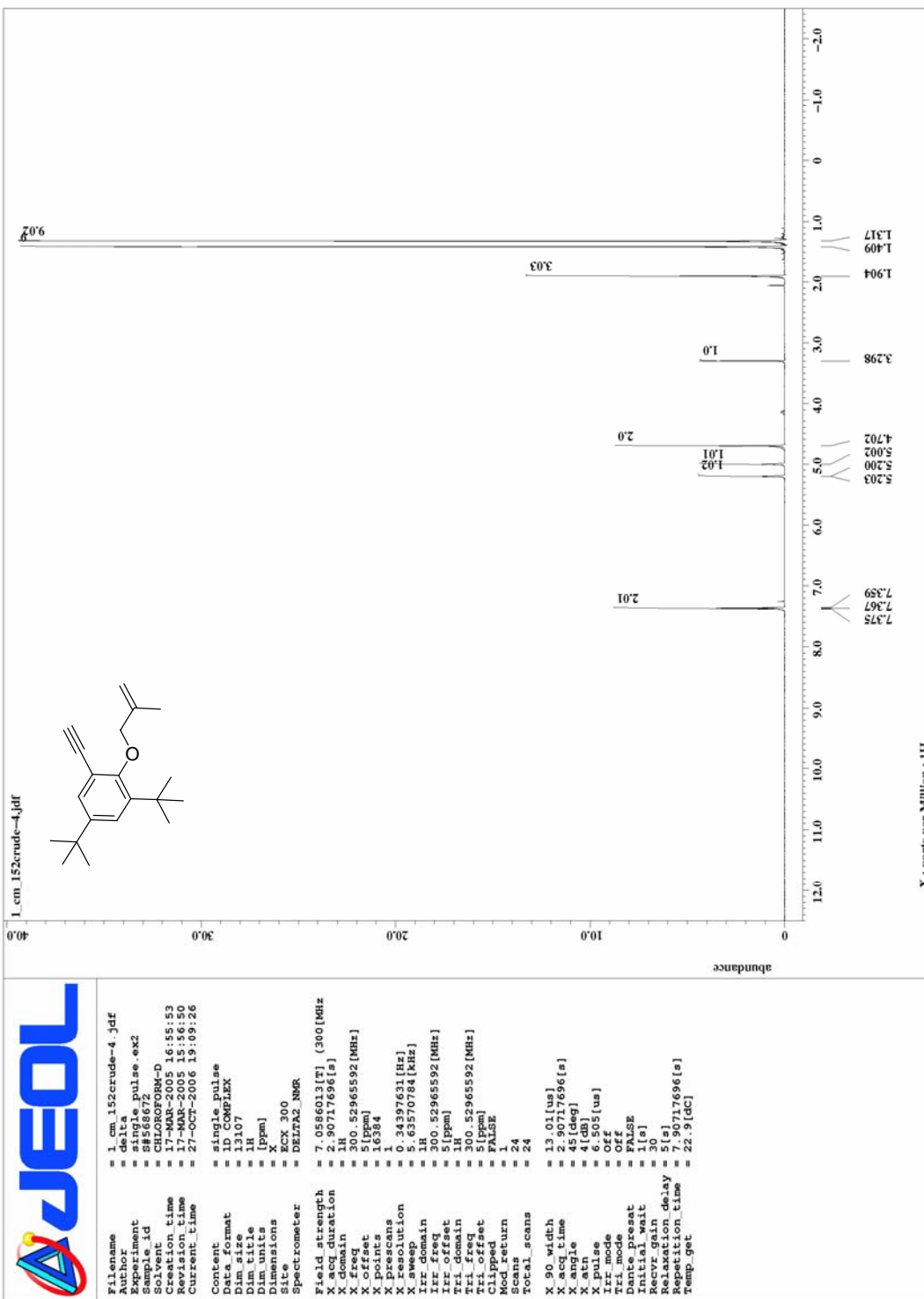
X : parts per Million : 13C

APPENDIX 61

^1H and ^{13}C NMR SPECTRA OF

4,6-Di-tert-butyl-2-ethynyl

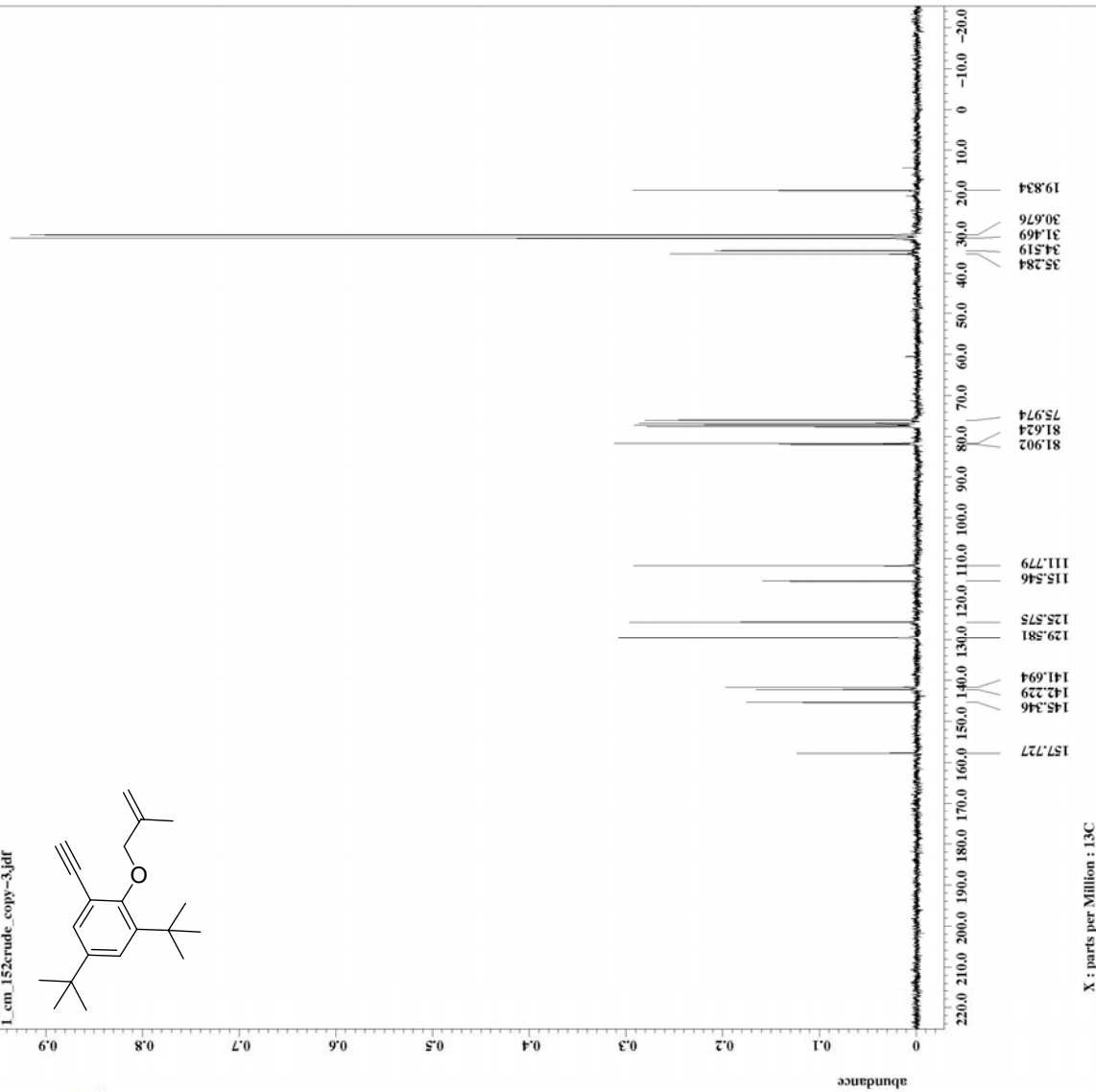
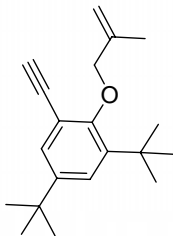
-(-2-methylallyloxy)benzene (67)





Filename = 1_cm_152crude_copy-3.
Author = delta
Experiment = single_pulse_dec
Sample_id = S#571058
Solvent = CHLOROFORM-D
Creation_time = 17-MAR-2005 17:10:58
Revision_time = 17-MAR-2005 16:10:08
Current_time = 27-OCT-2006 19:10:50
Content = single pulse decouple
Data_format = 1D COMPLEX
Dir_size = 26214
Dir_title = 13C
Dim_units = [ppm]
Dimensions = X
Site = ECX 300
Spectrometer = DELTA2_NMR
Field_strength = 7.0586013[T] (300[MHz]
X_acq_duration = 1.38412032[s]
X_domain = 13C
X_freq = 75.56823426[MHz]
X_offset = 100[ppm]
X_points = 32768
X_prescans = 4
X_resolution = 0.72248054[Hz]
X_sweep = 1H.67424242[KHz]
X_t1_rho = 1H.67424242[KHz]
Irr_freq = 300.52965592[MHz]
Irr_offset = 5[ppm]
Clipped = FALSE
Incomplete_copy = TRUE
Mod_return = 1
Scans = 185
Total_scans = 185
X_90_width = 9.75[us]
X_acq_time = 1.38412032[s]
X_angle = 30[deg]
X_atn = 8[db]
X_pulse = 3.25[us]
Irr_atn_dec = 25[db]
Irr_atn_hoe = 25[db]
Irr_noise = WALTZ
Decoupling = TRUE
Initial_wait = TRUE
Nuc1 = 13C
Nuc2 = 13C
Nuc_time = 3[s]
Recvr_gain = 50
Relaxation_delay = 3[s]
Repetition_time = 4.38412032[s]
Temp_get = 23[dc]

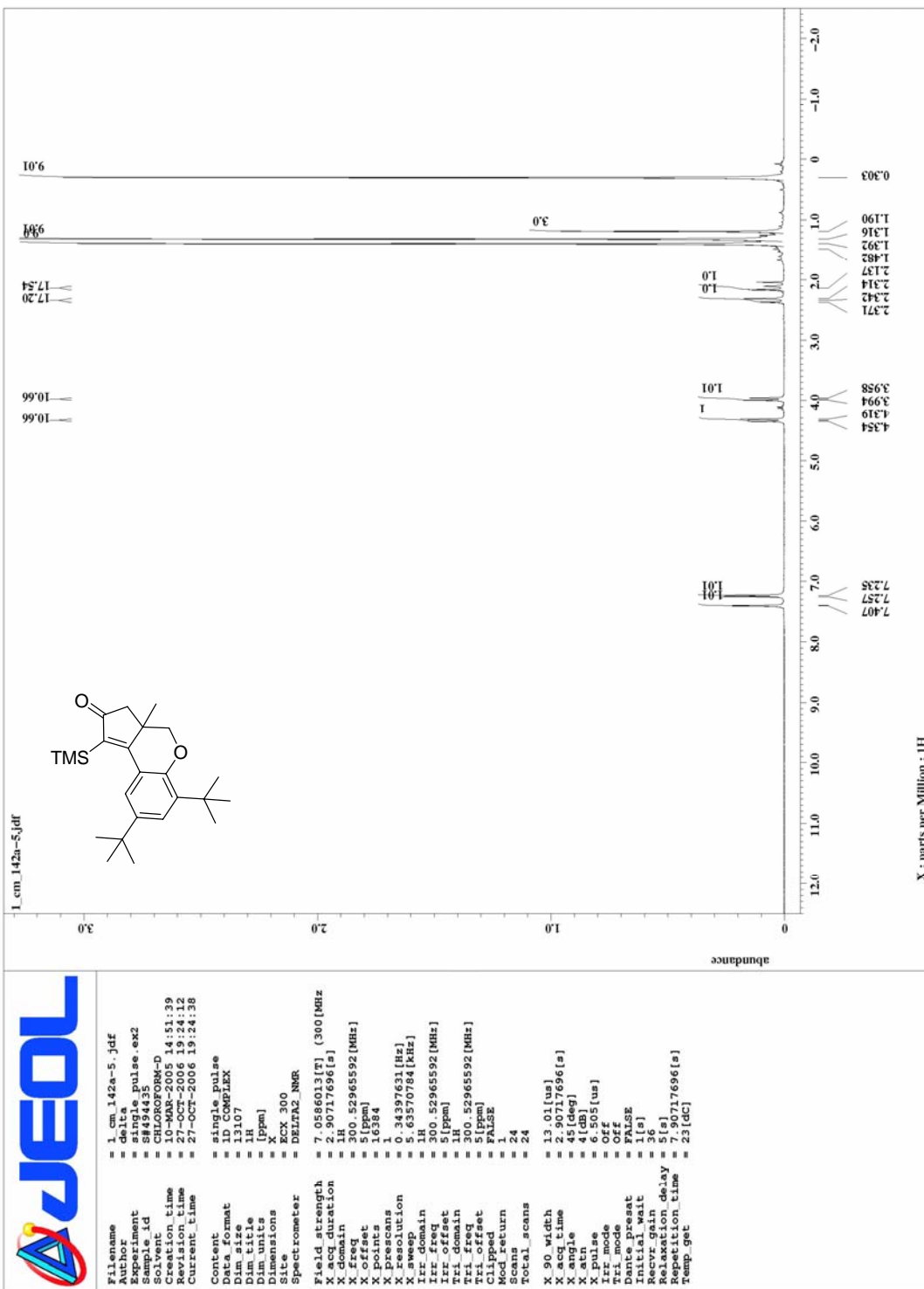
1_cm_152crude_copy-3.jdf



APPENDIX 62

^1H and ^{13}C NMR SPECTRA OF

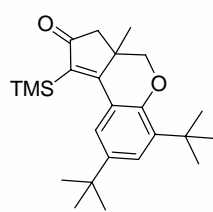
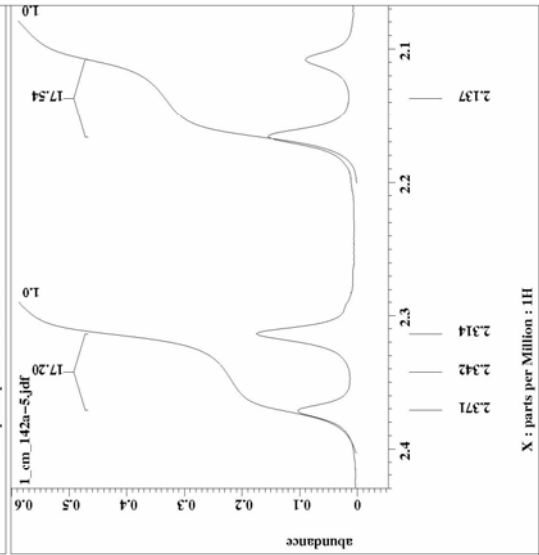
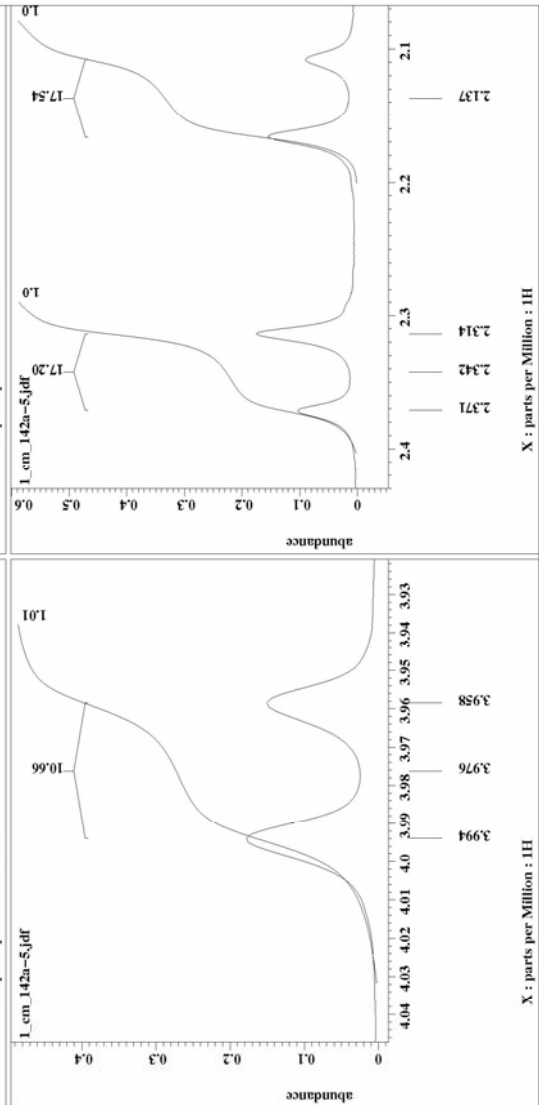
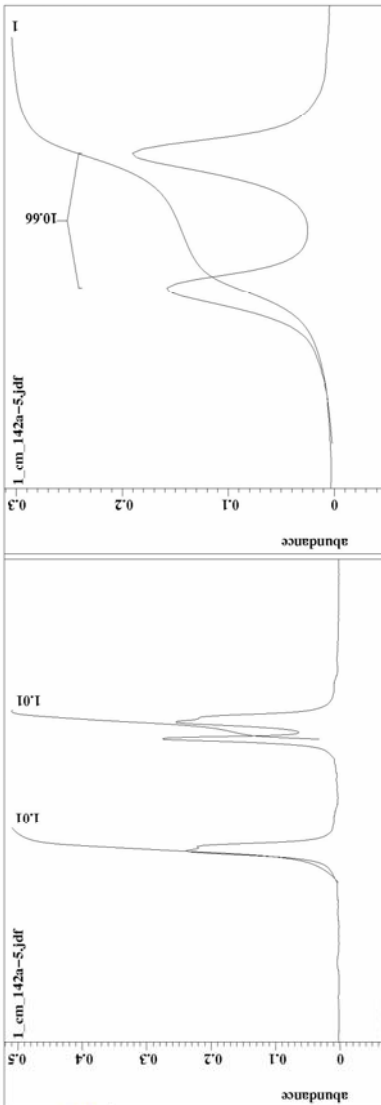
**6,8-Di-*tert*-butyl-1-trimethylsilyl -3a-methyl
-4-hydro-3*H*-cyclopenta[*c*]chromen-2-one (68)**

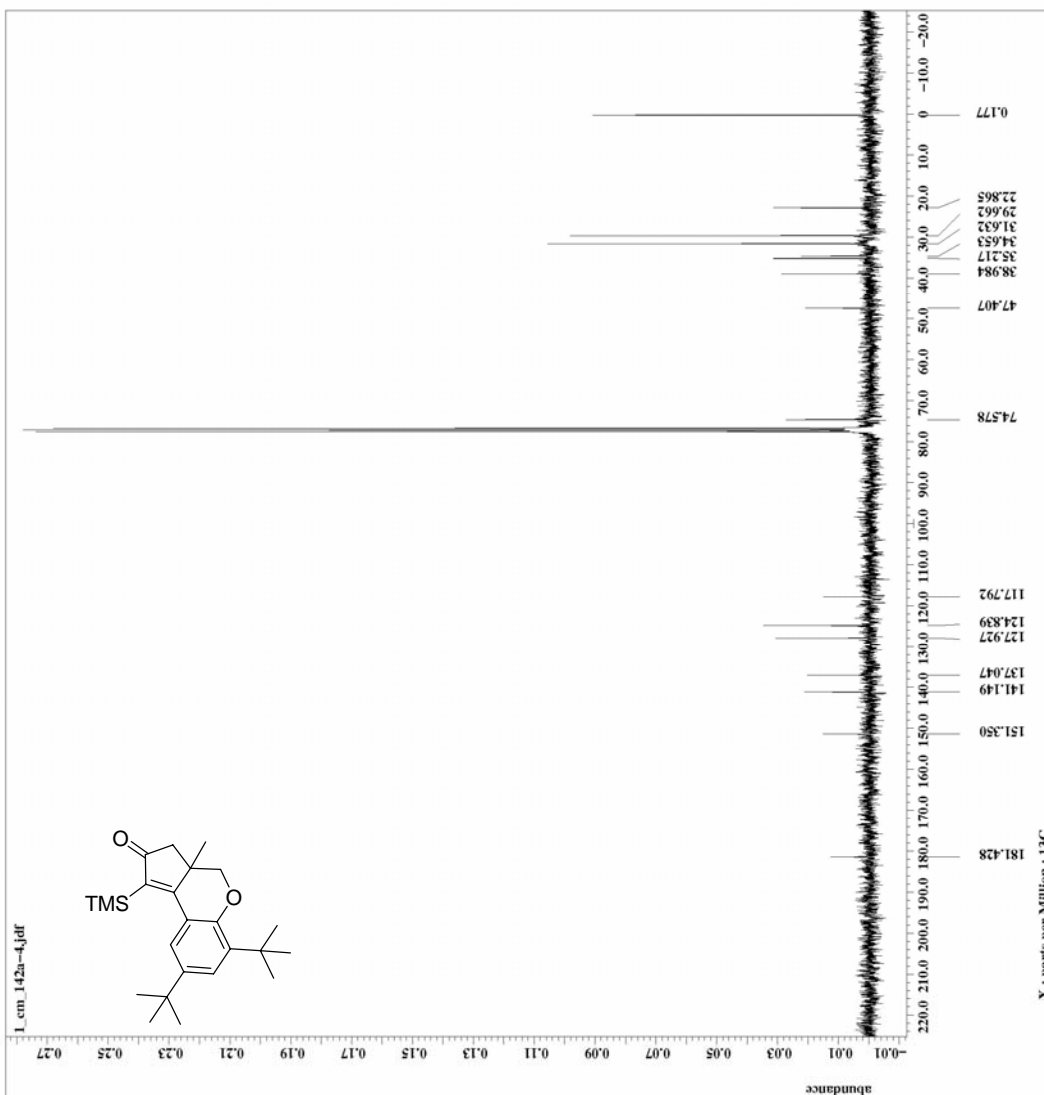




```

Filename = 1_cm_142a-5.jdf
Author = data
Experiment = single pulse.ex2
Solvent = CHLOROFORM-D
Creation time = 10-MAR-2005 14:51:39
Revision time = 27-OCT-2006 19:24:12
Current time = 27-OCT-2006 19:26:21
Content = single pulse
Data format = 1D COMPLEX
Dim size = 13107
Dim title = 1H
Dim units = [ppm]
Dimensions =
Site = ECX 300
Spectrometer = DELTA2_NMR
Field strength = 7.0586013[T] (300[Mhz])
X_acq_duration = 1.90717696[s]
X_freq = 300.52965592[MHz]
X_offset = 5[ppm]
X_points = 16384
X_resolution = 1.34397631[Hz]
X_resolution_ppm = 5.43570784[MHz]
Irr_domain = 1H
Irr_freq = 300.52965592[MHz]
Irr_offset = 5[ppm]
Irr_domain_ppm = 10.52965592[MHz]
Tri_offset = 5[ppm]
Clipped = FALSE
Mod return = 1
Scans = 24
Total_scans = 24
X_90_width = 13.01[us]
X_acq_time = 2.90717696[s]
X_angle = 45[deg]
X_atn = 4[db]
Pulse = 605[us]
Pulse_program = off
Tri_mode = off
Dante_preset = FALSE
Initial_wait = 1[s]
Recvr_gain_delay = 8[s]
Repetition_time = 7.90717696[s]
Temp_get = 23[dc]
  
```





JEOL
 I_cm_142a-4.jdf
 File name = I_cm_142a-4.jdf
 Author = delta
 Experiment = pulse_dec
 Sample ID = SM496987
 Solvent = CHLOROFORM-D
 Creation time = 10-MAR-2005 15:13:50
 Revision time = 27-OCT-2006 19:19:56
 Current time = 27-OCT-2006 19:20:47
 Content = single pulse decouple
 Data format = ID COMPLEX
 Dim size = 26214
 Dim title = 13C
 Dim unit = X[ppm]
 Dimensions = X
 Site = ECX 300
 Spectrometer = DELTA2_NMR
 Field strength = 7.0586013[T] (300[MHz]
 X_acq duration = 1.38412032[s]
 X_domain = 13C
 X_freq = 75.56823426[MHz]
 X_offset = 100[ppm]
 X_offset2 = 2768
 X_procsns = 1
 X_resolution = 0.72248054[Hz]
 X_sweep = IN
 Irr_domain = 13C
 Irr_freq = 200.52965592[MHz]
 Irr_offset = FALSE
 Clipped = FALSE
 Mod return = 1
 Scans = 298
 Total_scans = 298
 X_90 width = 9.75[us]
 X_acq time = 1.38412032[s]
 X_angle = 30[deg]
 X_atn = 8[db]
 X_pulse = 12[us]
 Irr_atn dec = 25[db]
 Irr_atn noe = 25[db]
 Irr_noise = WALTZ
 Decoupling = TRUE
 Initial_wait = 10[s]
 Noe time = 3[s]
 Recvr gain = 50
 Relaxation_delay = 3[s]
 Repetition_time = 2.38412032[s]
 Temp_get = 22.3[degC]

APPENDIX 63

¹H and ¹³C NMR SPECTRA OF

6,8-Di-*tert*-butyl-3a-methyl-3a,4-dihydro

-3*H*-cyclopenta[*c*]chromen-2-one (69)



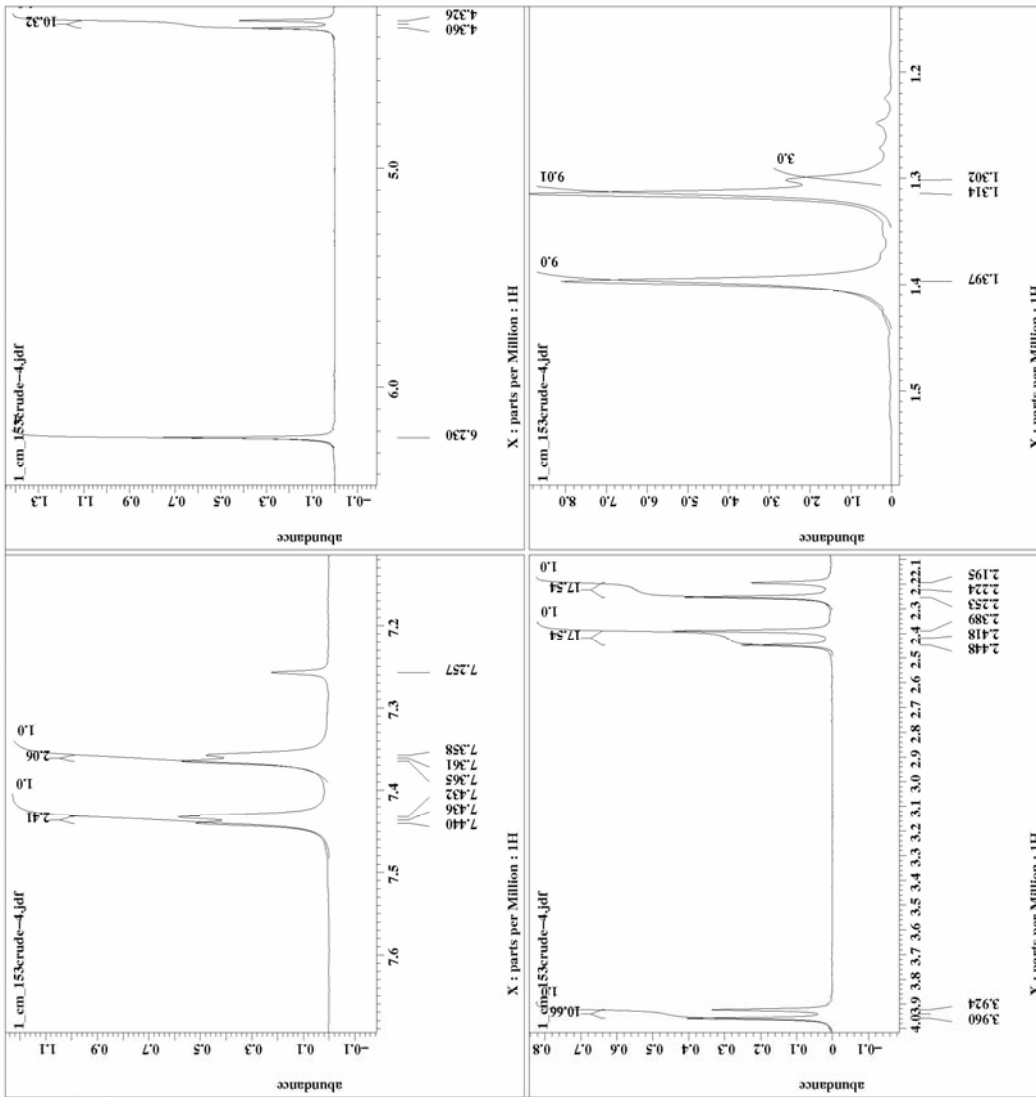
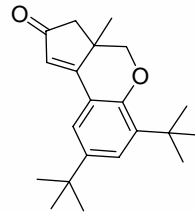
```

Filename = 1_cm_153crude-4.jdf
Date_UTC = 20050318_1307
Experiment = single_pulse.ex2
Sample_id = 1 PKR 153
Solvent = CHLOROFORM-D
Creation_time = 18-MAR-2005 16:06:18
Revision_time = 18-MAR-2005 18:13:07
Current_time = 27-03-2006 18:33:01

Content = single_pulse
Data_format = ID COMPLEX
Dim_size = 13107
Dim_units = [ppm]
Dimensions = X
Site = ECX 300
Spectrometer = DELTA2_NMR

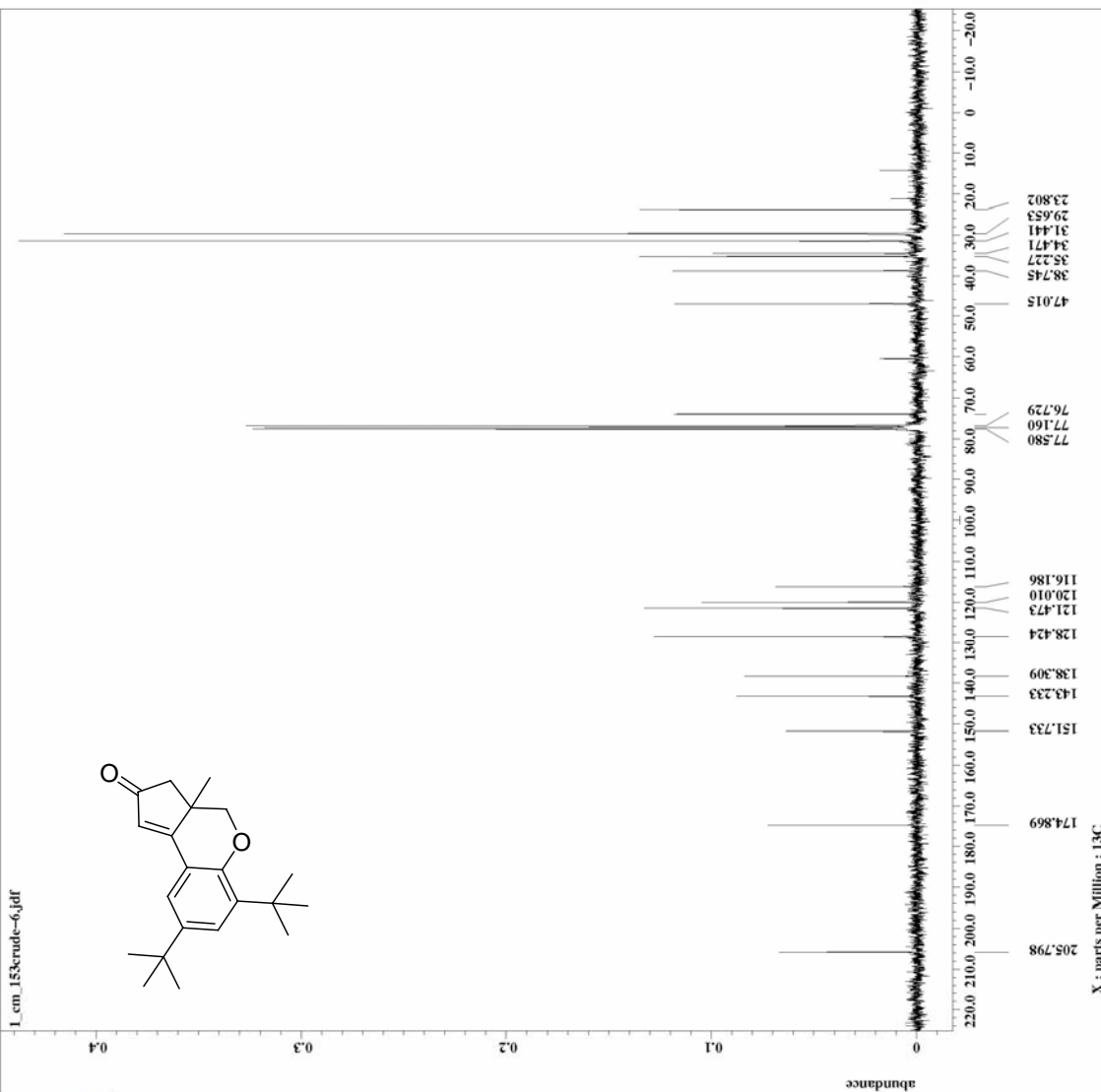
Field strength = 7.0586013[T] (300[MHz]
X_acq_duration = 2.90717696[s]
X_domain = 1H
X_freq = 300.52965592[MHz]
X_gain = 16354
X_points = 1
X_prescans = 1
X_resolution = 0.34397631[Hz]
X_sweep = 5.63570784[KHz]
IR_freq = 300.52965592[MHz]
IR_offset = 5[ppm]
Tri_domain = 1H
Tri_freq = 300.52965592[MHz]
Tri_offset = FALSE
Mod_return = 1
Total_scans = 24

X_90_width = 13.01[us]
X_acq_time = 2.90717696[s]
X_angle = 45[deg]
X_atn = 4[db]
X_pulse = 605[us]
Tri_mode = Off
Dante_preset = FALSE
Initial_wait = 1[s]
Recvr_gain = 20
Recvr_gain_delay = 20
Repetition_time = 7.90717696[s]
Temp_get = 22.5[dc]
  
```





Filename = 1_cm_153crude-6.jdf
Author = delta
Experiment = single_pulse_dec
Sample_id = 153crude
Sample_name = C10H16O3C8H14
Creation_time = 18-MAR-2005 16:23:03
Revision_time = 27-OCT-2006 18:34:30
Current_time = 27-OCT-2006 18:35:25
Content = single pulse decouple
Data_format = ID_COMPLEX
Dim_size = 327.4
Dim_units = [ppm]
Dimensions = X
Site = ECX 300
Spectrometer = DELTA2_NMR
Field_strength = 7.0586013[T] (300[MHz])
X_acq_duration = 130.412032[s]
X_sweep = 75.56823426[MHz]
X_offset = 100[ppm]
X_points = 32768
X_prescans = 4
X_resolution = 0.72248054[Hz]
X_sweep = 23.67424242[kHz]
Irr_gain = 300.52965592[MHz]
Irr_freq = 5[ppm]
Irr_offset = FALSE
Clipped = FALSE
Mod_return = 1
Scans = 223
Total_scans = 223
X_90_width = 9.75[us]
X_acq_time = 1.38412032[s]
X_angle = 30[deg]
X_atn = 8[db]
X_atn = 3.25[us]
X_pulse = 25[db]
Irr_atn_dec = 25[db]
Irr_atn_noe = 25[db]
Irr_noise = TRUE
Waltz16 = TRUE
Initial_wait = 1[s]
Noe_time = TRUE
Noe_time = 3[s]
Recvr_gain = 50
Relaxation_delay = 3[s]
Repetition_time = 4.38412032[s]
Temp_get = 22.6[degC]

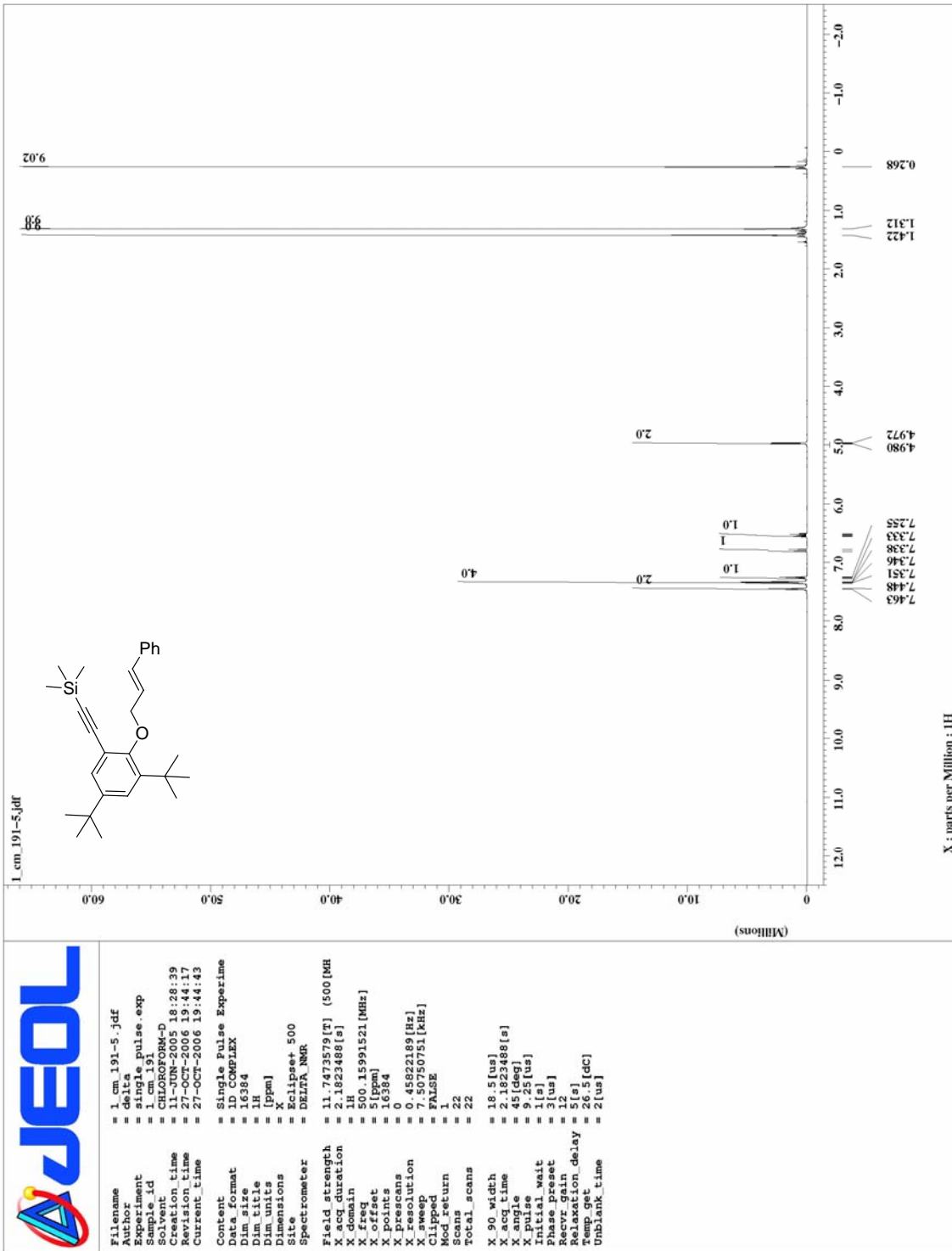


APPENDIX 64

^1H and ^{13}C NMR SPECTRA OF

4,6-Di-tert-butyl-2-trimethylsilylethynyl

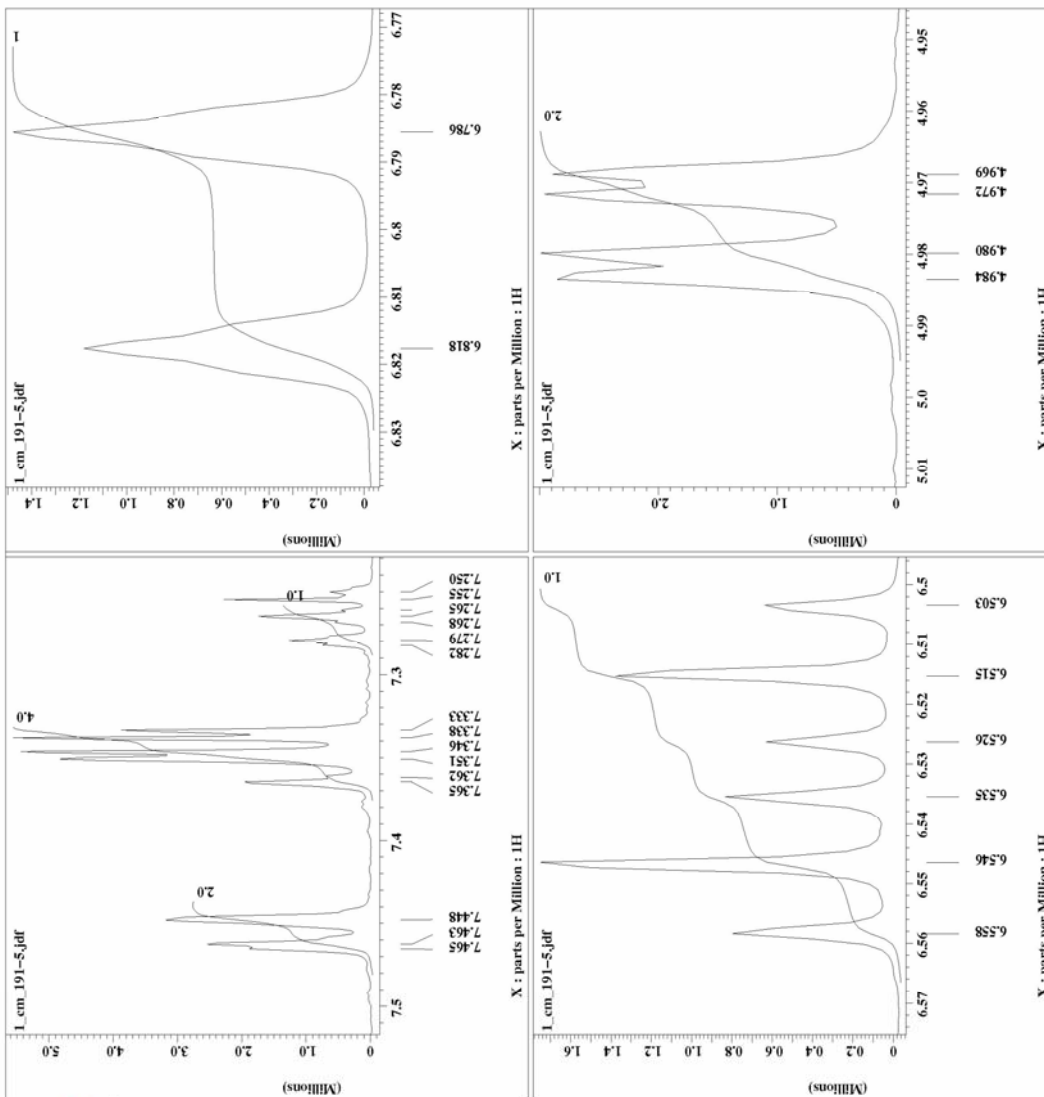
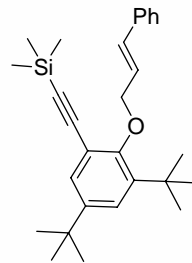
-(-3-phenyl-2-propenyloxy)benzene (71)





```

Filename == 1_cm_191-5_jdf
Author == delta
Experiment == delta_pulse_exp
Sample id == 1_cm_191
Solvent == CHLOROFORM-D
Creation time == 11-JUN-2005 18:28:39
Revision time == 27-OCT-2006 19:44:17
Current time == 27-OCT-2006 19:46:34
Content == Single Pulse Experime
Data format == ID COMPLEX
Dim size == 16384
Dim units == [ppm]
Dimensions == X
Site == Eclipser 500
Spectrometer == DELTA_NMR
Field strength == 11.7473579[T] (500 [MH
X acq duration == 2.1823488[s]
X domain == 1H
X freq == 500.15991521 [MHz]
X offset == 0
X prescans == 0
X prescans == 0
X resolution == 0.45822189 [Hz]
X sweep == 7.50750751 [kHz]
Clipped == FALSE
No. of scans == 22
Total scans == 22
X 90_width == 18.5 [us]
X acq time == 45.1623468[s]
X delay == 9.25 [us]
X pulse == 9.25 [us]
Initial wait == 1[s]
Phase preset == 2[us]
Recvr gain == 15 [dB]
Relaxation delay == 26.5 [dc]
Temp get time == 2 [us]
  
```





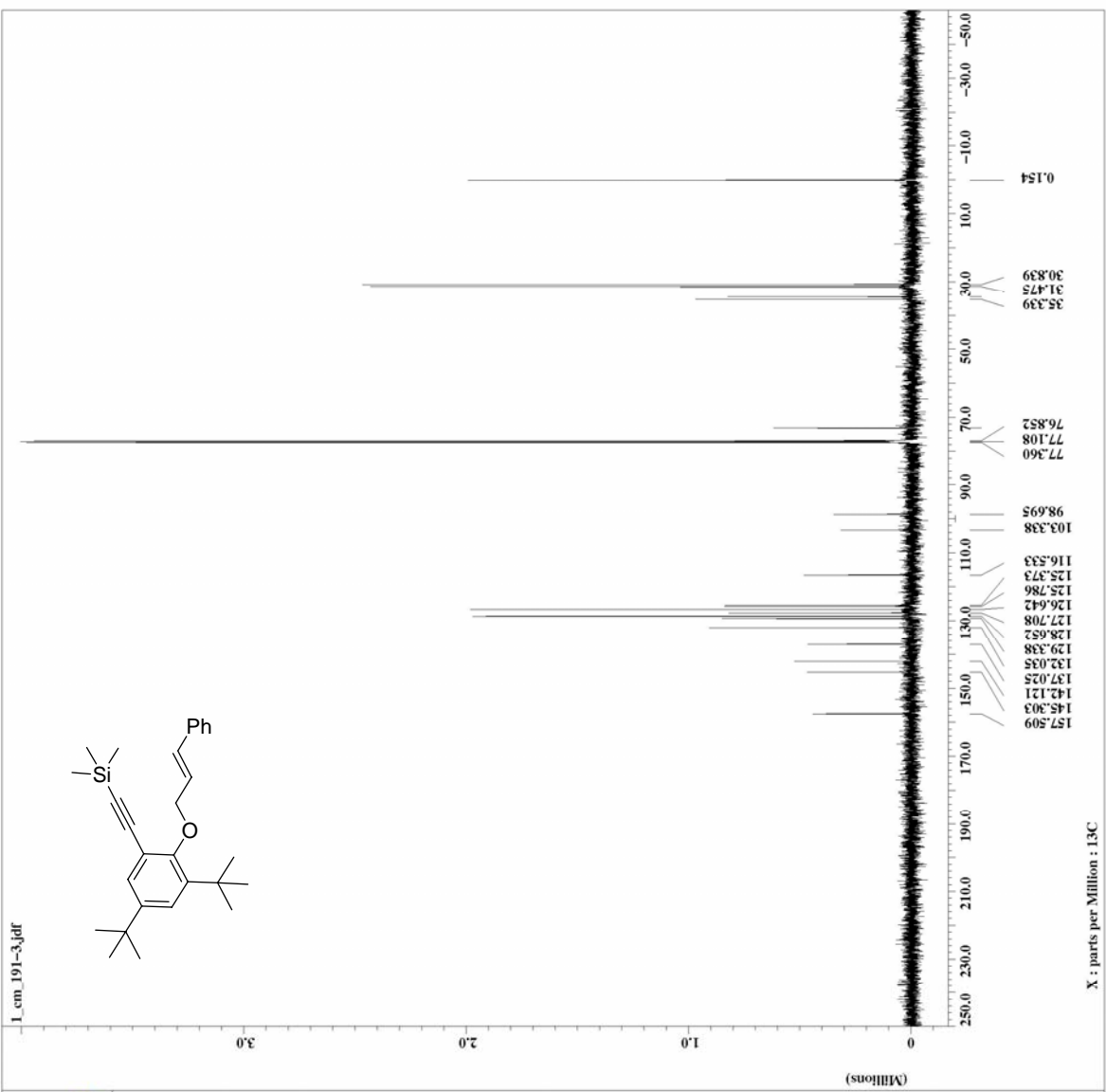
```

Filename = 1_cm_191-3_jdf
Author = delta
Experiment = single pulse_dec
Sample_id = 1_cm_191
Solvent = CHLOROFORM-D
Creation_time = 11-JUN-2005 19:01:48
Revision_time = 27-OCT-2006 19:47:15
Current_time = 27-OCT-2006 19:47:40

Content = Single Pulse with Bro
Data_format = 1D COMPLEX
Dim_size = 65536
Dim_title = 13C
Dim_units = [ppm]
Dimensions = X
Site = Eclipse+ 500
Spectrometer = DELTA_NMR

Field_strength = 11.7473579[T] (500[MH
X_acq_duration = 1.736704[s]
X_domain = 13C
X_freq = 125.76529768[MHz]
X_offset = 100[ppm]
X_points = 65536
X_prescans = 4
X_resolution = 0.57580336[Hz]
X_sweep = 37.73584906[KHz]
Irr_domain = 500
Irr_freq = 500.15991521[MHz]
Irr_offset = 5[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 158
Total_scans = 158

X_90_width = 14.2[us]
X_acq_time = 1.736704[s]
X_angle = 30[deg]
X_pulse_program = zgpg30
Initial_wait = 17353333[us]
Phase_preset = 1[s]
Recvr_gain = 3[us]
Relaxation_delay = 29
Relaxation_delay = 4[s]
Temp_get = 28.7[dc]
Unblank_time = 2[us]
  
```

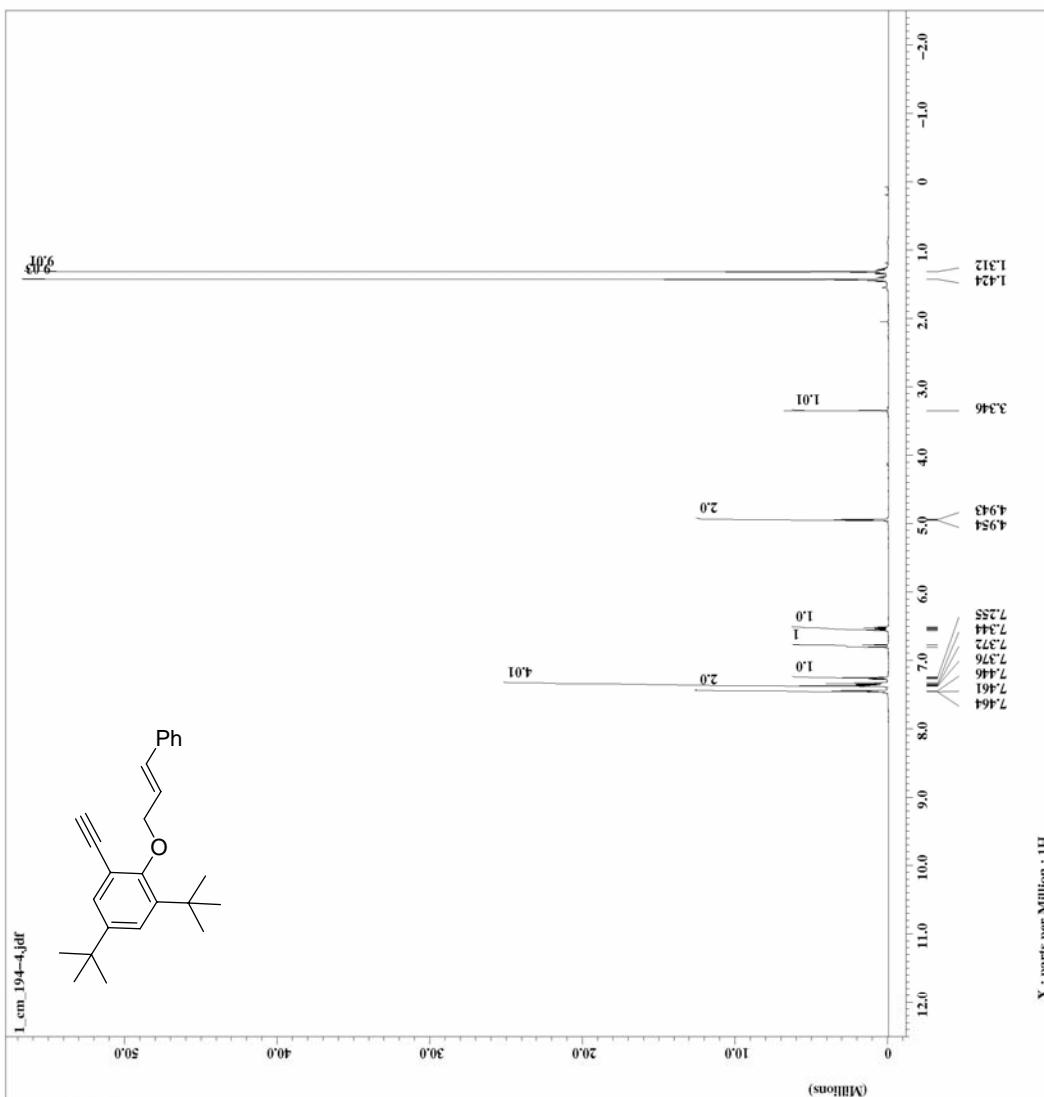


X : parts per Million : 13C

APPENDIX 65

^1H and ^{13}C NMR SPECTRA OF

**4,6-Di-tert-butyl-2-ethynyl
-(-3-phenyl-2-propenyloxy)benzene (72)**



JEOL

Filename = 1_cm_194-4.jdf
 Author = delta
 Experiment = delta_pulse.exp
 Sample id = 1_cm_194
 Solvent = CHLOROFORM-D
 Creation time = 14-JUN-2005 15:15:50
 Revision time = 14-JUN-2005 15:26:23
 Current time = 27-OCT-2006 19:35:45

Content = Single Pulse Experiment
 Data format = ID COMPLEX
 Dim size = 16384
 Dim units = [ppm]
 Dimensions = X
 Site = Eclipset 500
 Spectrometer = DELTA_NMR

Field strength = 11.7473579[T] (500 [MH]
 X acq duration = 2.1823488[s]
 X domain = IN
 X freq = 500.15991521 [MHz]
 X offset = 5 [ppm]
 X prescans = 0
 X resolution = 0.45822189 [Hz]
 X sweep = 7.50750751 [kHz]
 Clipped = FALSE
 Data return = 32
 Total scans = 32

X 90 width = 18.5 [us]
 X acq time = 45 [d3468[s]
 X pulse = 9.25 [us]
 Initial wait = 1[s]
 Phase preset = 2 [us]
 Recvr gain = 5 [s]
 Relaxation delay = 26.1 [dc]
 Temp get time = 2 [us]

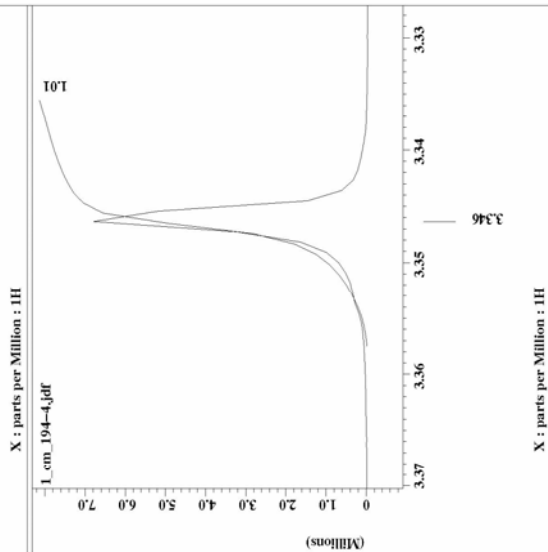
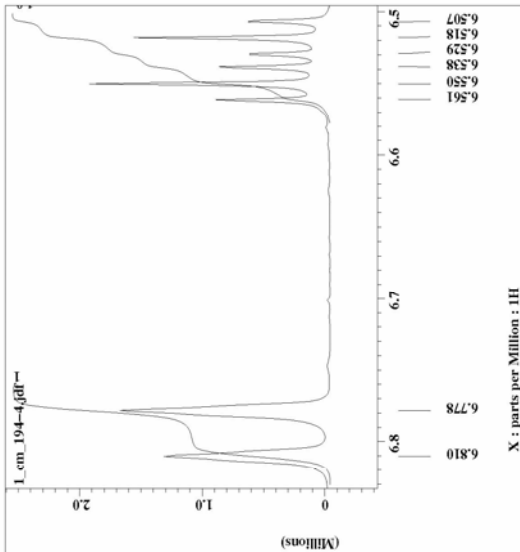
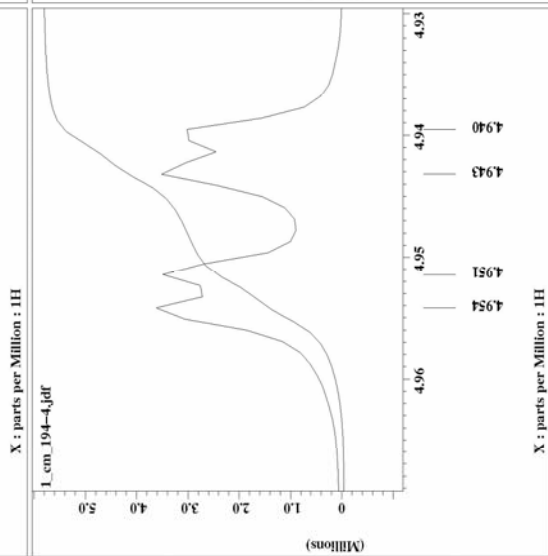
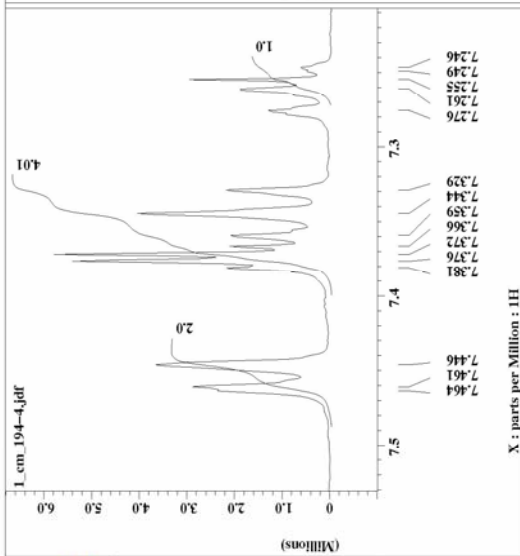
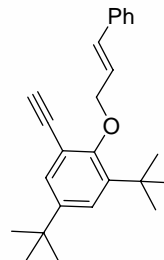


```

Filename = 1_cm_194-4.jdf
Acquisition date = 14-JUN-2005 15:59:43
Sample name = 1_cm_194
Sample id = 1_cm_194
Solvent = CHLOROFORM-D
Creation time = 14-JUN-2005 15:59:50
Revision time = 14-JUN-2005 15:59:43
Current time = 27-OCT-2006 19:37:13

Content = Single Pulse Experiment
Data format = ID COMPLEX
Dim size = 16384
Dim units = [ppm]
Dimensions = X
Site = Eclipset 500
Spectrometer = DELTA_NMR

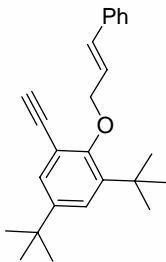
Field strength = 11.7473579[T] (500[MH
X acq duration = 2.1823488[s]
X domain = 1H
X freq = 500.15991521[MHz]
X points = 16384
X prescans = 0
X resolution = 0.45822189[Hz]
X sweep = 7.50750751[KHz]
X temp = 14.5[C]
Word return = 1
Total scans = 32
X 90 width = 19.5[us]
X acq time = 2.1823488[s]
X angle = 45[deg]
X pulse = 9.25[us]
Initial wait = 1[s]
Phase preset = 14
Relaxation delay = 5[s]
Temp_get = 26.1[dC]
Unblank time = 2[us]
  
```





1_cm_194_copy-2.jdf
Filename = 1_cm_194_copy-2.jdf
Author = delta
Experiment = single_pulse_dec
Sample_id = 1_cm_194
Solvent = CHLOROFORM-D
Creation_time = 14-JUN-2005 15:30:37
Revision_time = 27-OCT-2006 19:57:38
Current_time = 27-OCT-2006 19:57:57
Content = Single Pulse with Bro
Date_format = MM/YY/XX
Date_acq = 06/27/05
Dim_title = 13C
Dim_units = [ppm]
Dimensions = X
Site = Eclipse+ 500
Spectrometer = DELTA_NMR
Field_strength = 11.7473579[T] (500 [MH
X_acq_duration = 1.736704[s]
X_domain = 125.76529768 [MHz]
X_freq = 100 [ppm]
X_offset = 65536
X_points = 4
X_prescans = 4
X_resolution = 0.57580336 [Hz]
X_sweep = 37.73584906 [kHz]
Irr_domain = 1H
Irr_freq = 500.15991521 [MHz]
Irr_offset = FALSE
Clipped = FALSE
Mod_return = 133
Sens = 133
Total_scans = 133
X_90_width = 14.2 [us]
X_acq_time = 1.736704 [s]
X_angle = 30 [deg]
X_pulse = 4.73333333 [us]
Initial_wait = 1 [s]
Phase_preset = 3 [us]
Recvr_gain = 29
Relaxation_delay = 28 [s]
Relaxation_delay = 28.2 [dc]
Unblank_time = 2 [us]

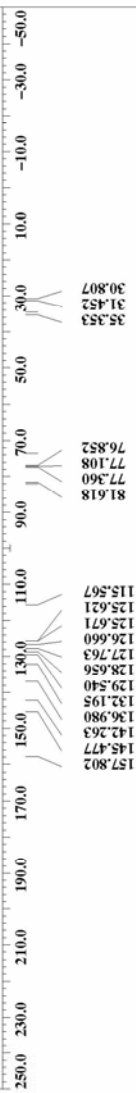
1_cm_194_copy-2.jdf



3.0

Field strength = 11.7473579[T] (500 [MH
X_acq_duration = 1.736704[s]
X_domain = 125.76529768 [MHz]
X_freq = 100 [ppm]
X_offset = 65536
X_points = 4
X_prescans = 4
X_resolution = 0.57580336 [Hz]
X_sweep = 37.73584906 [kHz]
Irr_domain = 1H
Irr_freq = 500.15991521 [MHz]
Irr_offset = FALSE
Clipped = FALSE
Mod_return = 133
Sens = 133
Total_scans = 133
X_90_width = 14.2 [us]
X_acq_time = 1.736704 [s]
X_angle = 30 [deg]
X_pulse = 4.73333333 [us]
Initial_wait = 1 [s]
Phase_preset = 3 [us]
Recvr_gain = 29
Relaxation_delay = 28 [s]
Relaxation_delay = 28.2 [dc]
Unblank_time = 2 [us]

(Millions)



X : parts per Million : 13C

APPENDIX 66

¹H and ¹³C NMR SPECTRA OF

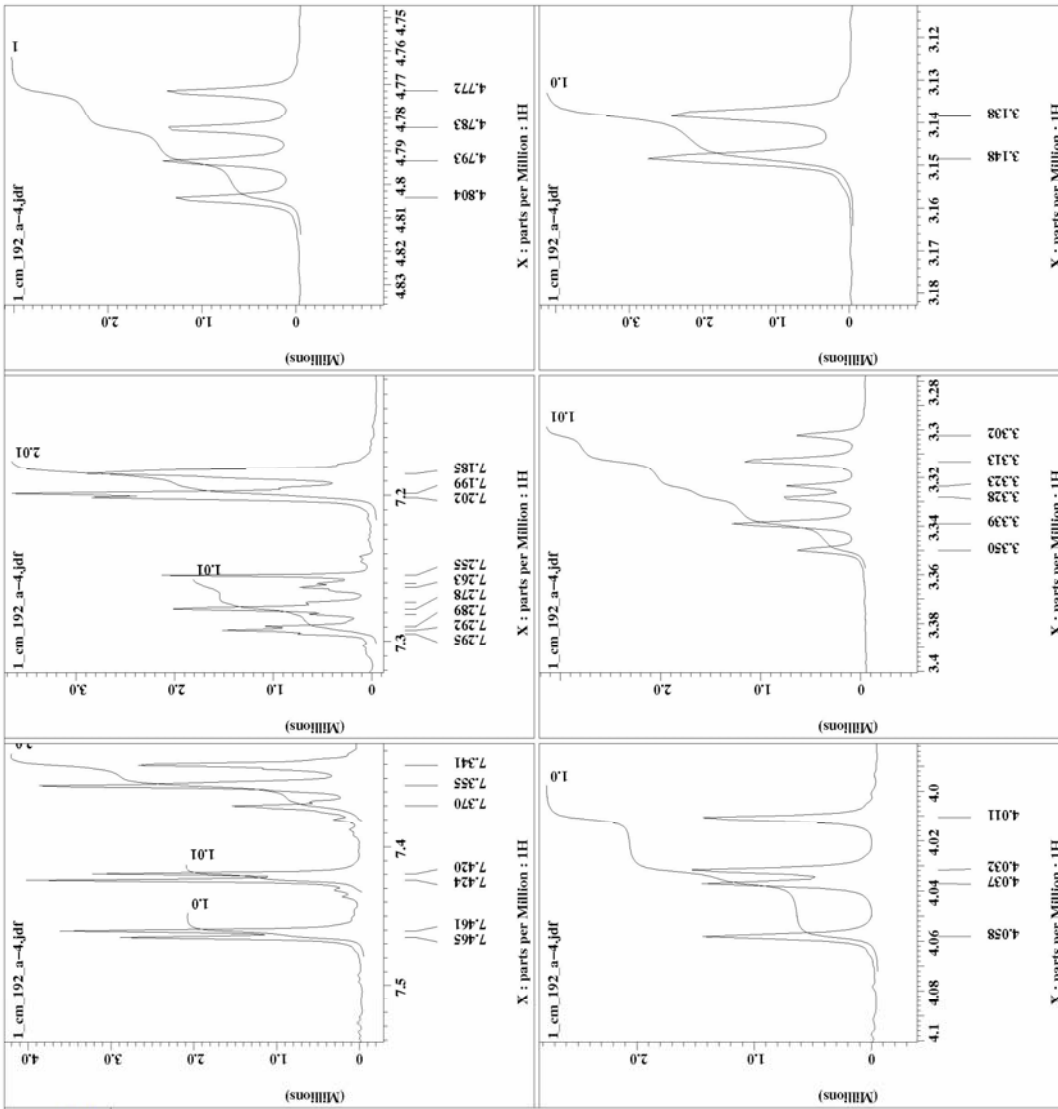
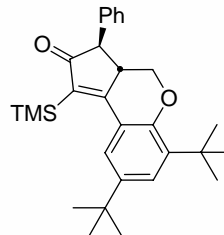
6,8-Di-*tert*-butyl-3-phenyl-1-trimethylsilyl-3a,4-dihydro

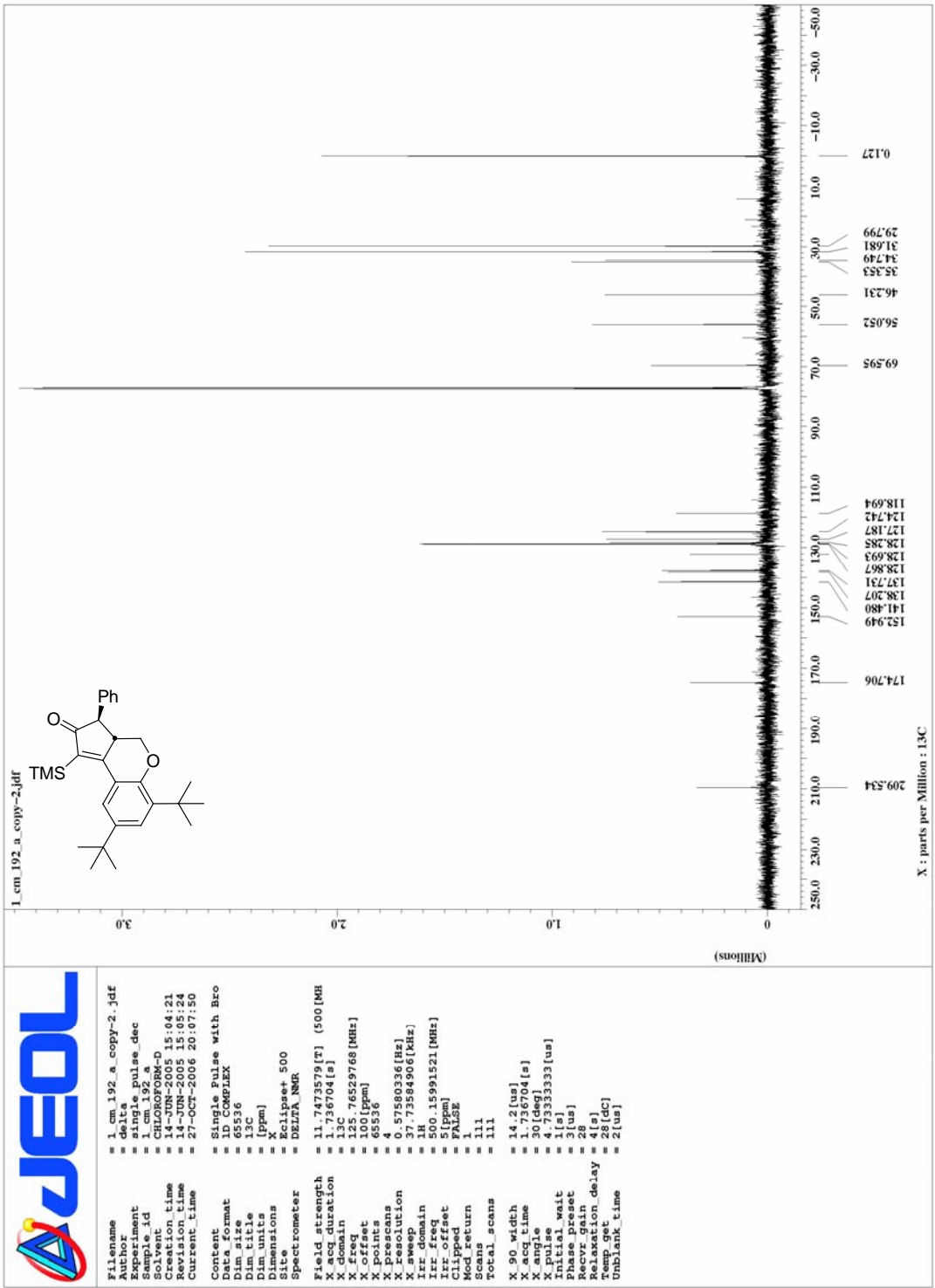
-3*H*-cyclopenta[*c*]chromen-2-one (73)



```

Filename = 1_cm_192_a-4_jdf
Author = delta
Experiment = single_pulse_exp
Pulse_program = zgpg30
Solvent = CHLOROFORM-D
Creation_time = 14-JUN-2005 14:51:56
Revision_time = 14-JUN-2005 14:59:36
Current_time = 27-OCT-2006 21:25:45
Content = Single Pulse Experiment
Data_format = 1D COMPLEX
Dim_size = 16384
Dim_title = 1H
Dim_units = [ppm]
Dimensions = 1
Site = ECLIPSE+ 500
Spectrometer = DELTA NMR
Field_strength = 11.7473579[T] (500 [MH]
X_acq_duration = 18.1823468[s]
X_freq = 500.15991521 [MHz]
X_offset = 5 [ppm]
X_points = 16384
X_prescans = 0
X_resolution = 45822189 [Hz]
X_sweep = 7.40750751 [kHz]
Clipped = FALSE
Mod_return = 1
Scans = 32
Total_scans = 32
X_90_width = 18.5 [us]
X_acq_time = 2.1823468 [s]
X_angle = 45 [deg]
X_pulse = 9.25 [us]
X_pulse_wait = 3 [us]
Phase_preset = 3 [us]
Recvr_gain = 12
Relaxation_delay = 5 [s]
Temp_get = 25.8 [dC]
Unblank_time = 2 [us]
  
```

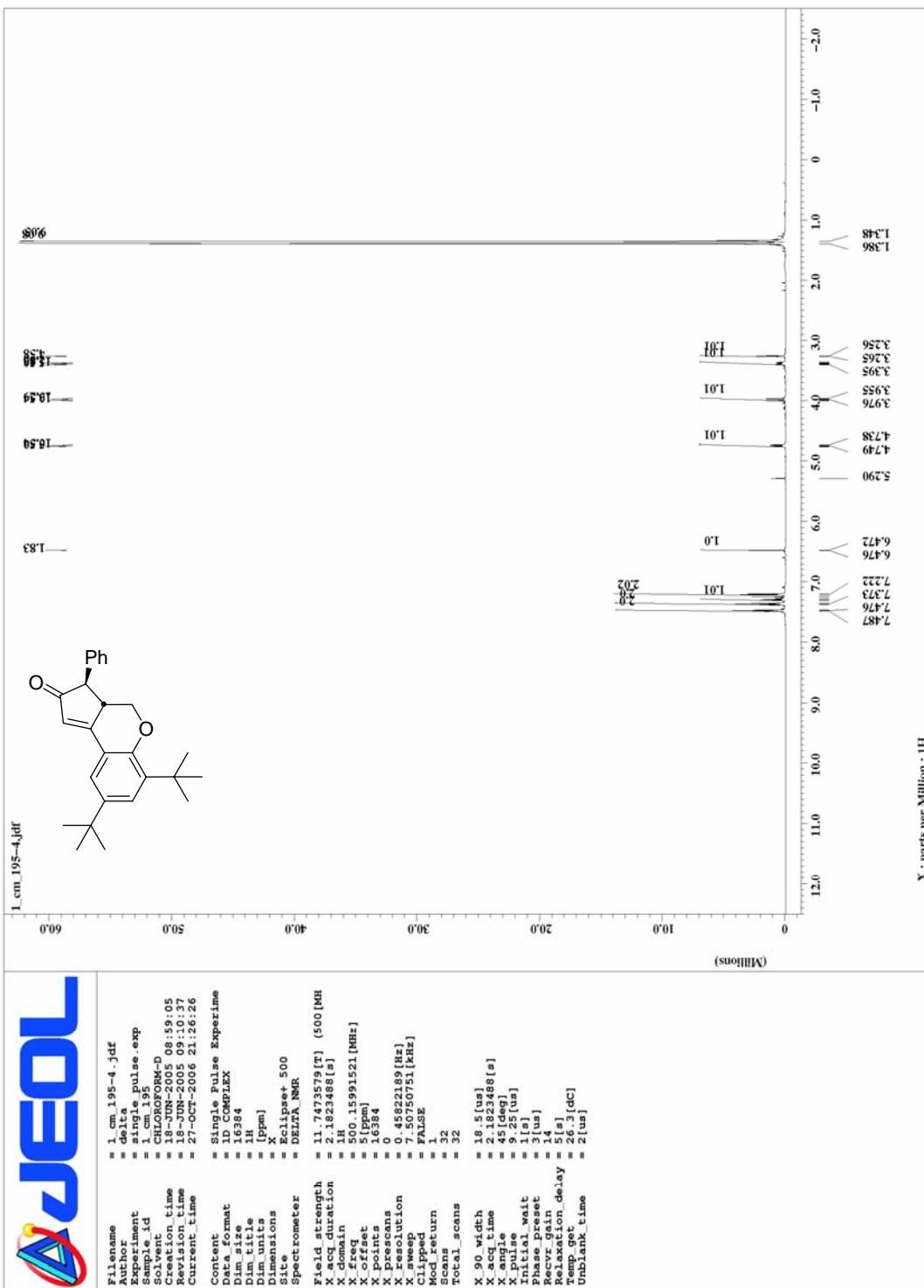


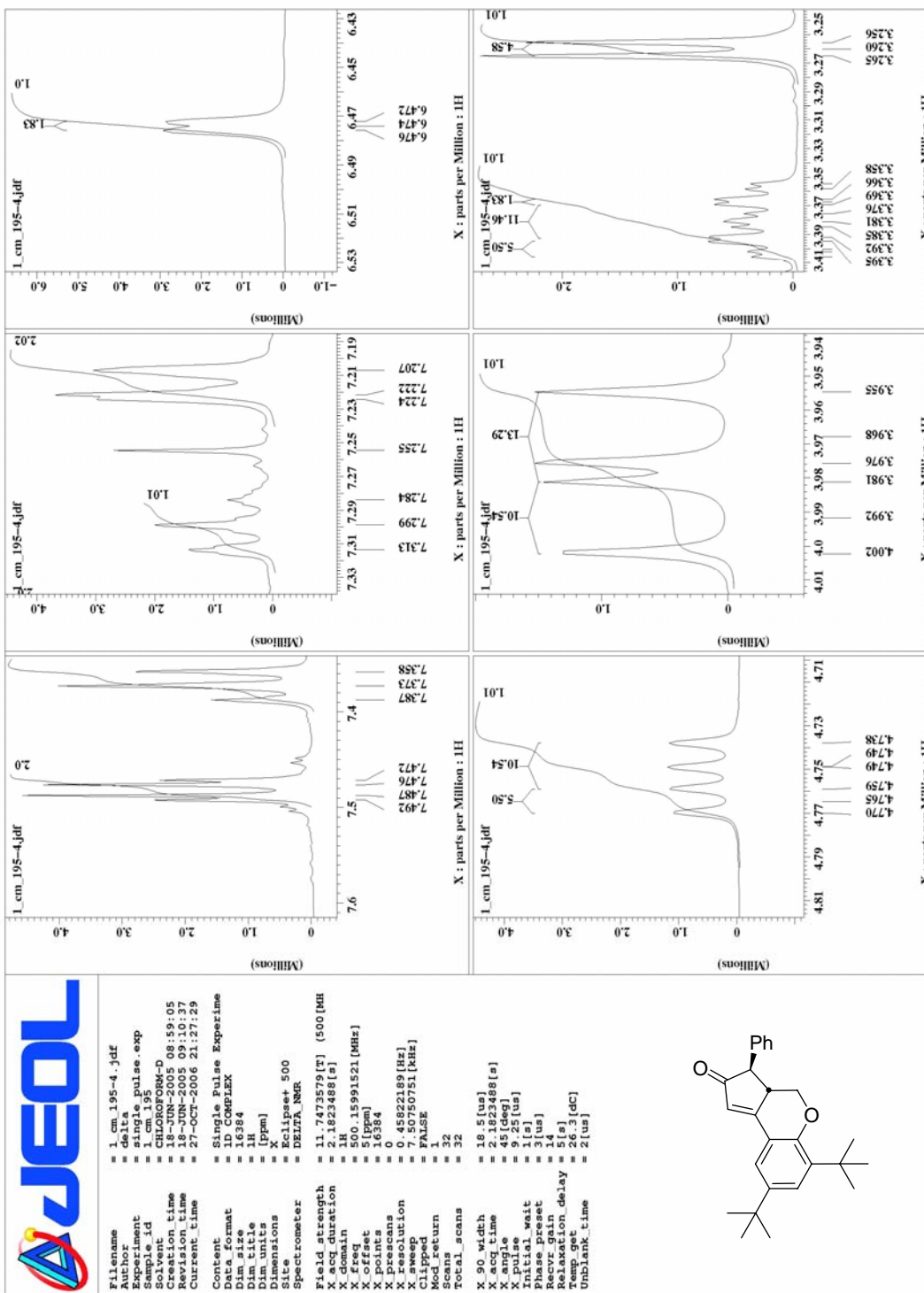


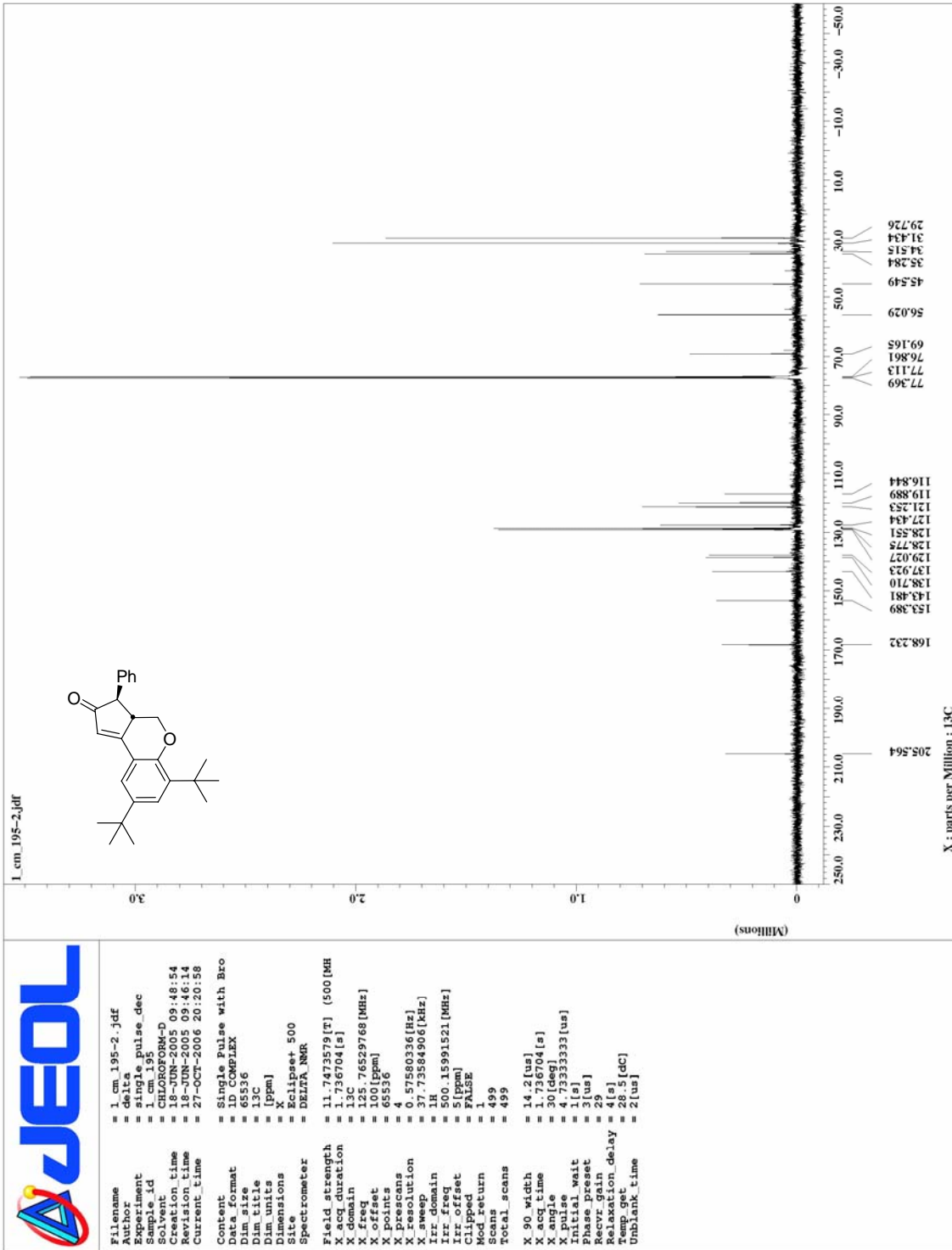
APPENDIX 67

¹H and ¹³C NMR SPECTRA OF

**6,8-Di-*tert*-butyl-3-phenyl-3a,4-dihydro
-3*H*-cyclopenta[*c*]chromen-2-one (74)**

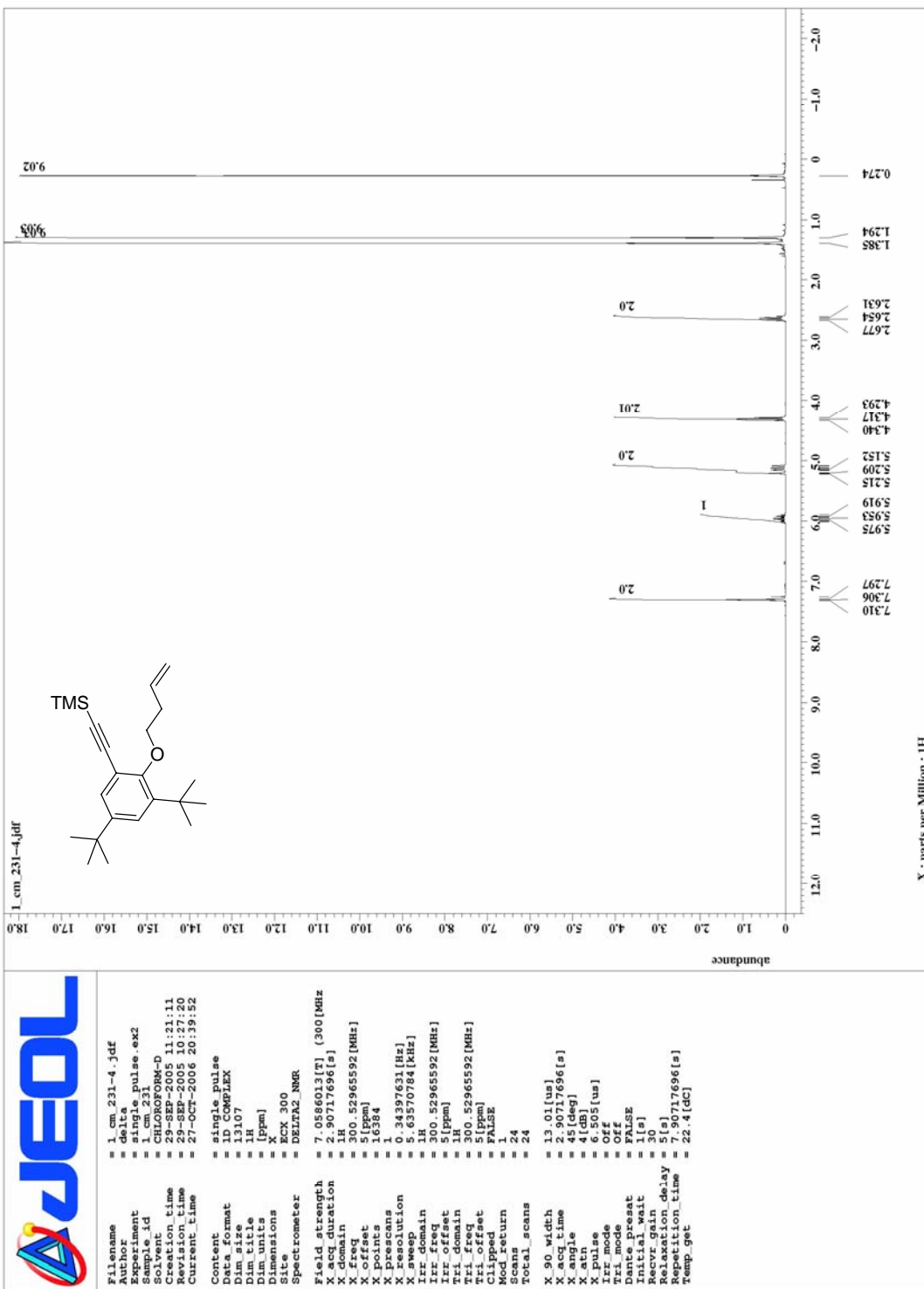


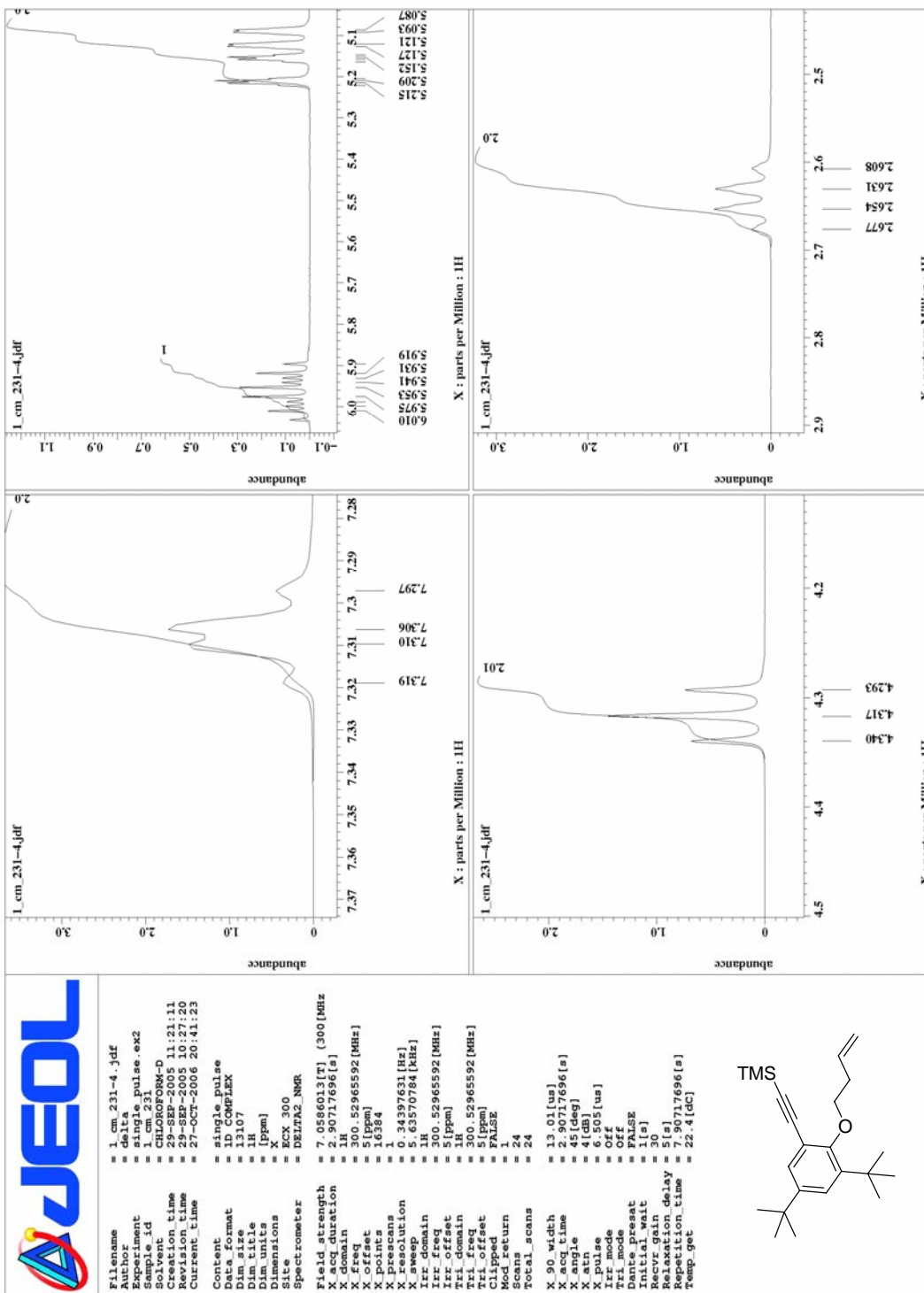


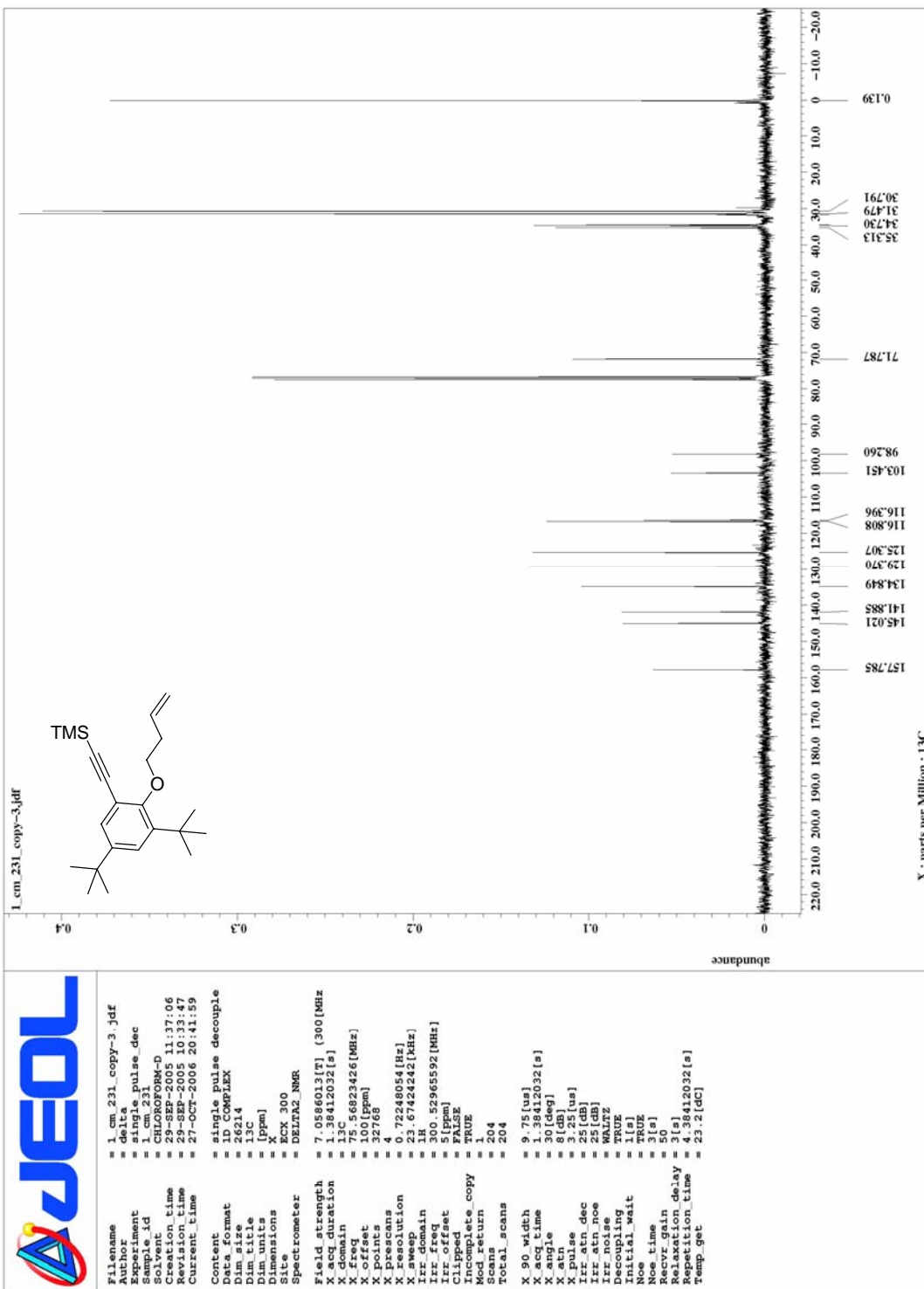


APPENDIX 68

**¹H and ¹³C NMR SPECTRA OF
3-Butenyloxy-4,6-di-*tert*-butyl
-2-trimethylsilylethynylbenzene (75)**







APPENDIX 69

¹H and ¹³C NMR SPECTRA OF

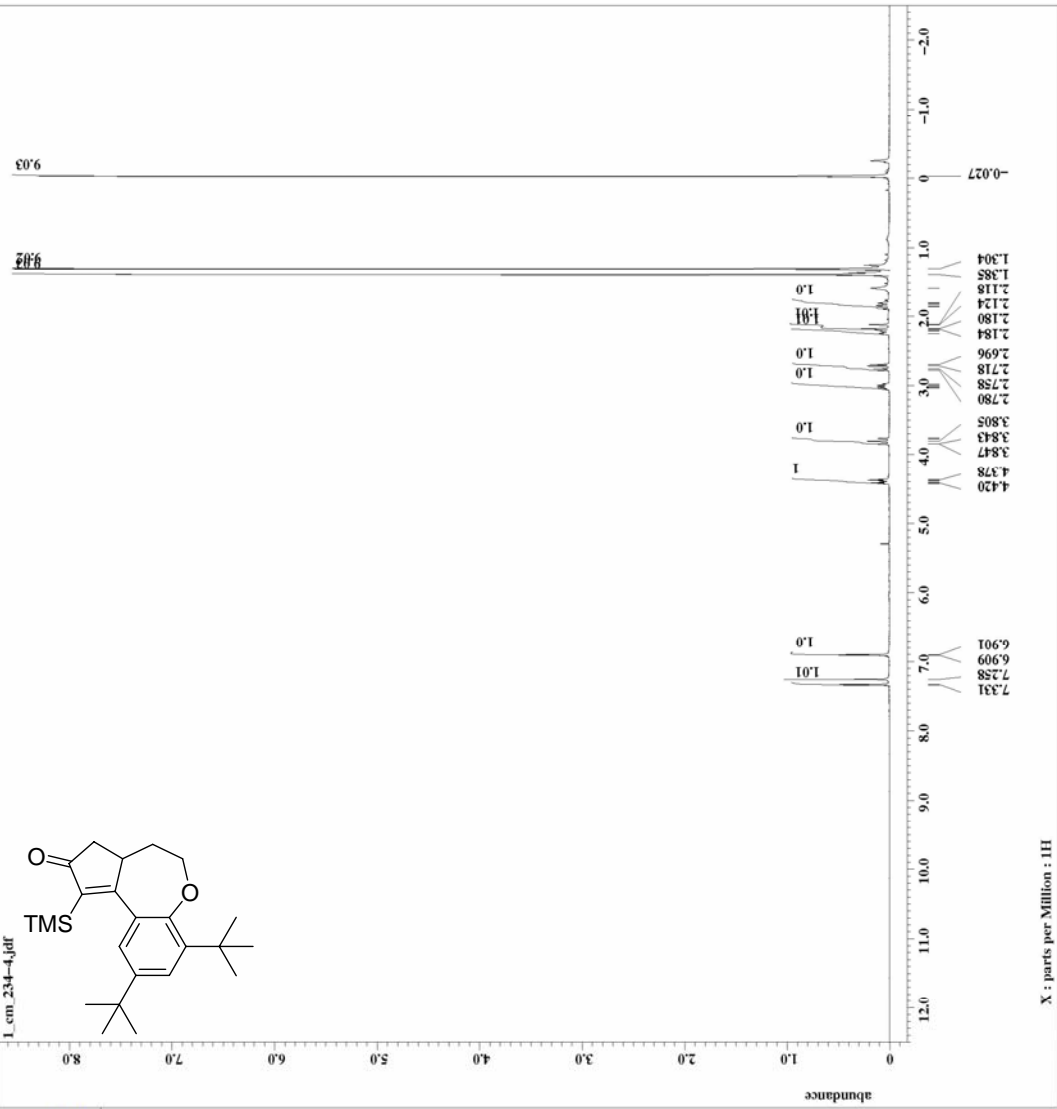
7,9-Di-*tert*-butyl-1-trimethylsilyl

-4,4a-dihydro-3*H*,5*H*-6-oxabenzof]azulen-2-one (77)



```

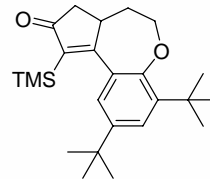
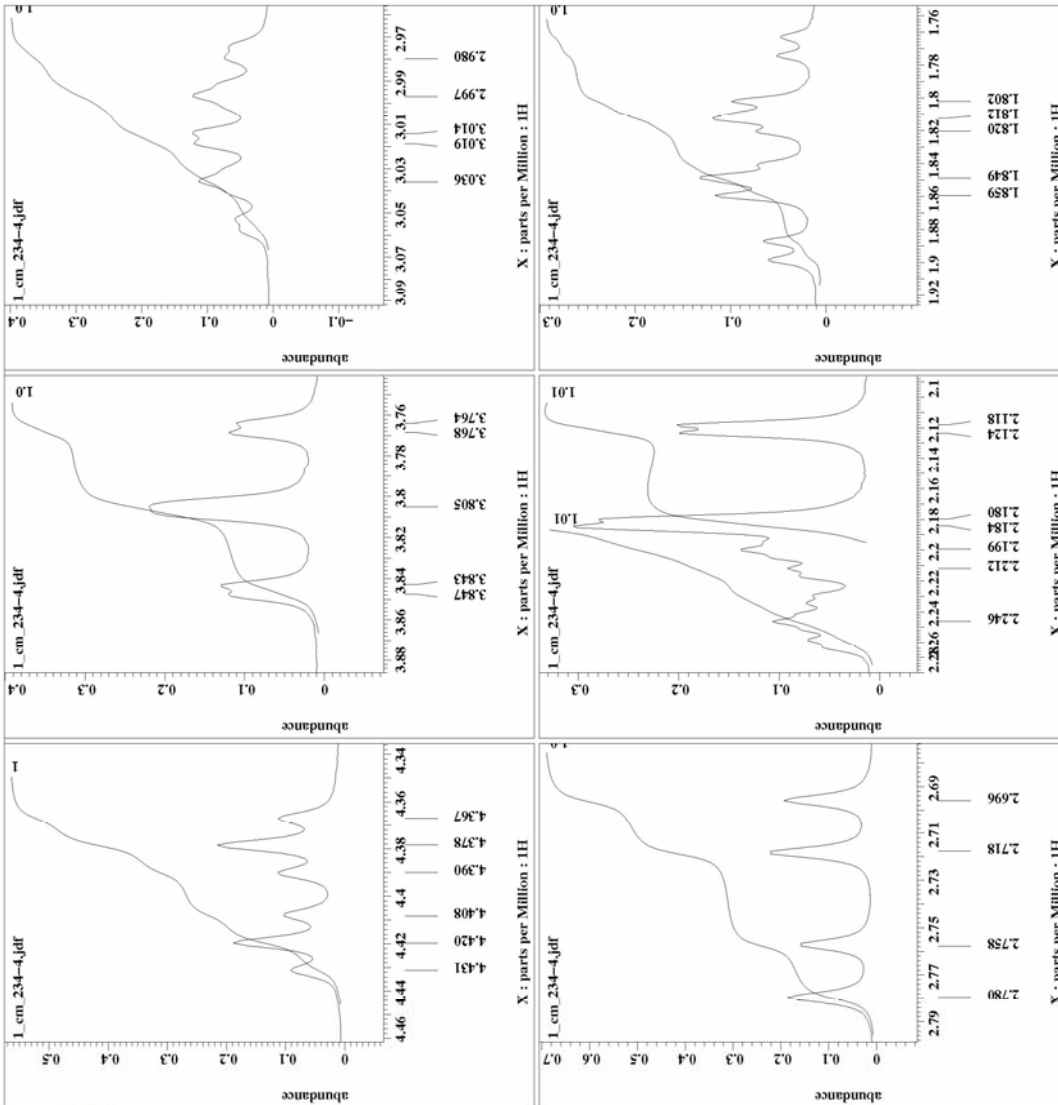
Filename = 1_cm_234-4.jdf
Author = delta
Experiment = singl_pulse.ex2
Solvent = CHLOROFORM-D
Creation_time = 3-OCT-2005 16:30:48
Revision_time = 3-OCT-2005 15:37:29
Current_time = 27-OCT-2006 20:52:38
Content = single_pulse
Data_format = 1D_COMPLEX
Dim_size = 13107
Dim_title = 1H
Dim_units = [ppm]
Dimensions =
Site = KCX 300
Spectrometer = DELTA2_NMR
Field_strength = 7.0586013[T] (300[MHz]
X_acq_duration = 2.90717696[s]
X_resolution = 16384
X_freq = 300.52965592[MHz]
X_offset = 5[ppm]
X_points = 16384
X_prescans = 1
X_resolution = 5.84397631[Hz]
X_resolution = 5.83570784[Hz]
Irr_domain = 1H
Irr_freq = 300.52965592[MHz]
Irr_offset = 5[ppm]
Irr_domain = 1H
Tri_offset = 5[ppm]
Tri_offset = 5[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 24
Total_scans = 24
X_90_width = 13.01[us]
X_acq_time = 2.90717696[s]
X_angle = 45[deg]
X_atn = 4[dB]
X_pulse = 6.505[us]
X_pulse = 6.505[us]
Tri_mode = Off
Dante_preset = FALSE
Initial_wait = 1[s]
Recvr_gain = 44
Recvr_gain_delay = 4[s]
Repetition_time = 7.90717696[s]
Temp_get = 22.7[dc]
  
```

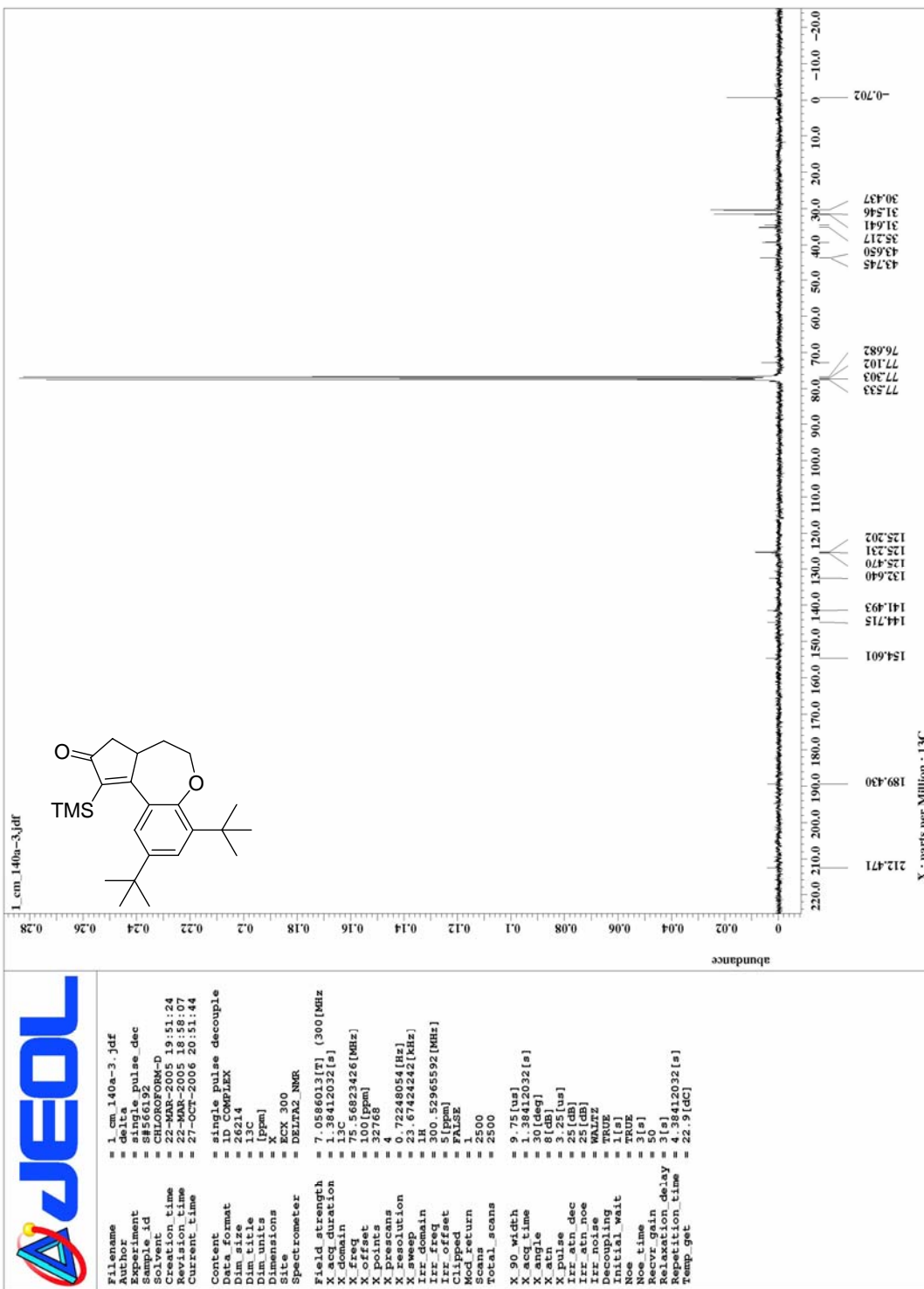




```

Filename = 1_cm_234-4.jdf
Author = delta
Experiment = sing_p_pulse.ex2
Solvent = CHLOROFORM-D
Creation_time = 3-OCT-2005 16:30:48
Revision_time = 3-OCT-2005 15:37:29
Current_time = 27-OCT-2006 20:54:38
Content = single pulse
Data format = 1D COMPLEX
Dim size = 13107
Dim title = 1H
Dim units = [ppm]
Dimensions =
Site = ECX 300
Spectrometer = DELTA2_NMR
Field strength = 7.0586013[T] (300[Mhz]
X_acq_duration = 2.90717696[s]
X_acq_time = 2.90717696[s]
X_freq = 300.52965592[MHz]
X_offset = 5[ppm]
X_points = 16384
X_prescans = 1
X_resolution = 1.34397631[Hz]
X_resolution = 5.43570784[MHz]
X_resolution = 16384
Irr_domain = 1H
Irr_freq = 300.52965592[MHz]
Irr_offset = 5[ppm]
Tri_domain = 1H
Tri_offset = 5[ppm]
Clipped = FALSE
Mod_return = 1
Total_scans = 24
X_90_width = 13.01[us]
X_acq_time = 2.90717696[s]
X_angle = 45[deg]
X_atn = 4[db]
X_pulse = 2505[us]
X_pulse = 0[us]
Tri_mode = Off
Dante_preset = FALSE
Initial_wait = 1[s]
Recvr_gain = 44
Repetition_delay = 4[s]
Repetition_time = 7.90717696[s]
Temp_get = 22.7[dc]
  
```

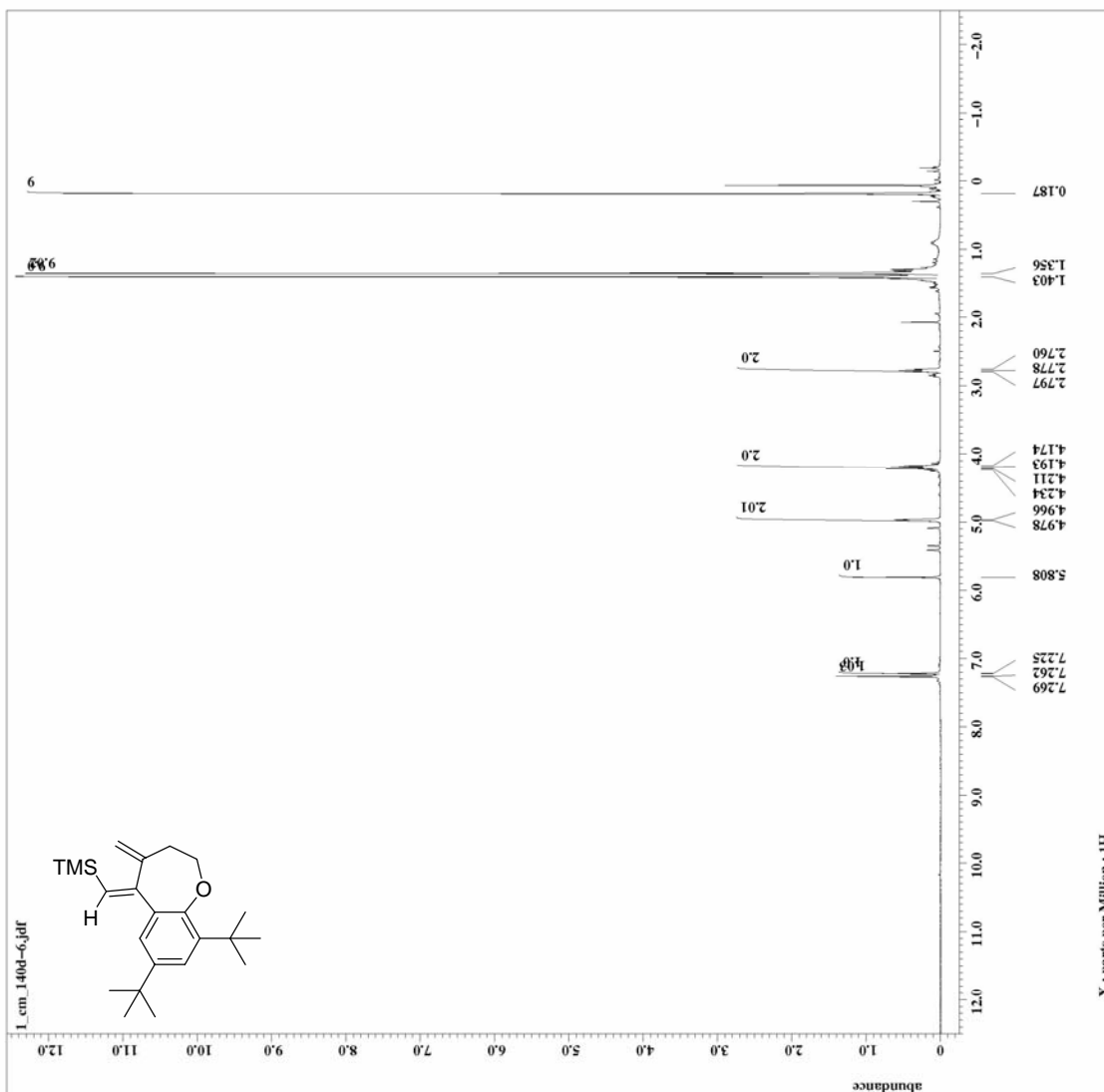




APPENDIX 70

¹H and ¹³C NMR SPECTRA OF

**(7,9-Di-*tert*-butyl-4-methylene -3,4-dihydro
-2*H*-benzo[*b*]oxepin-5-ylidenemethyl)-trimethylsilane (78)**



JEOL
 File name = 1_cm_140d-6.jdf
 Author = delta
 Experiment = single pulse.ex2
 Sample id = S#481087
 Solvent = CHLOROFORM-D
 Creation time = 23-MAR-2005 14:30:33
 Revision time = 1-NOV-2006 14:38:25
 Current time = 1-NOV-2006 14:38:30
 Data format = single pulse
 ID COMPLEX
 Dim size = 13107
 Dim title = 1H
 Dim units = [ppm]
 Dimensions = 1
 Spectrometer = ECX 300
 SPECTROMETER = DELTA2_NMR
 Field strength = 7.0586013[T] (300[MHz]
 X_acq duration = 2.90717696[s]
 X_domain = 1H
 X_freq = 300.52965592[MHz]
 X_offset = 16384
 X_points = 1
 X_prescans = 1
 X_resolution = 0.34397631[Hz]
 X_sweep = 5.63570784[kHz]
 Irr_domain = 1H
 Irr_freq = 300.52965592[MHz]
 Irr_offset = 16384
 Tri_domain = 1H
 Tri_freq = 300.52965592[MHz]
 Tri_offset = 5[ppm]
 Clipped = FALSE
 Mod return = 1
 Scans = 24
 Total_scans = 24
 X_90_width = 13.01[us]
 X_acq_time = 2.90717696[s]
 X_angle = 45[deg]
 X_atn = 4[db]
 X_pulse = 6.505[us]
 Irr_mode = Off
 Tri_mode = Off
 Dante_preset = FALSE
 Initial_wait = 1[s]
 Recvr_gain = 30
 Relaxation_delay = 5[s]
 Repetition_time = 7.90717696[s]
 Temp_get = 22.5[dc]



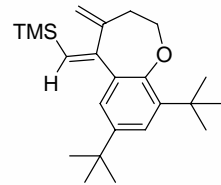
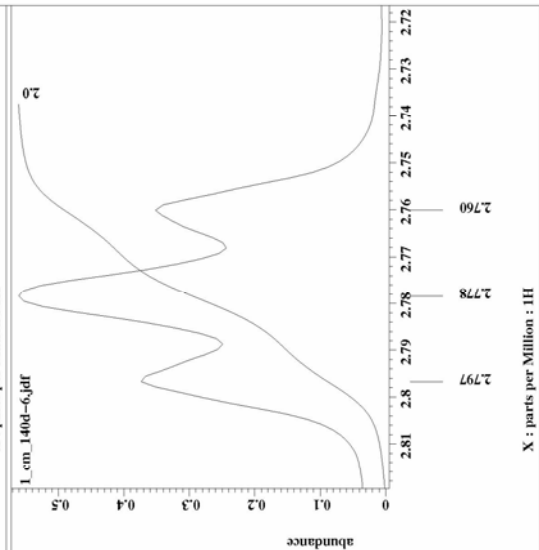
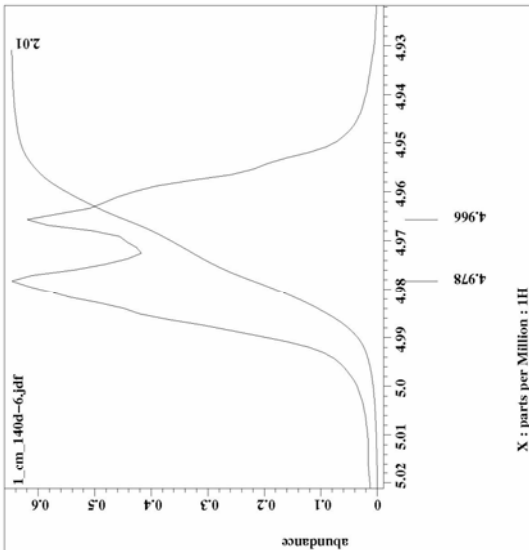
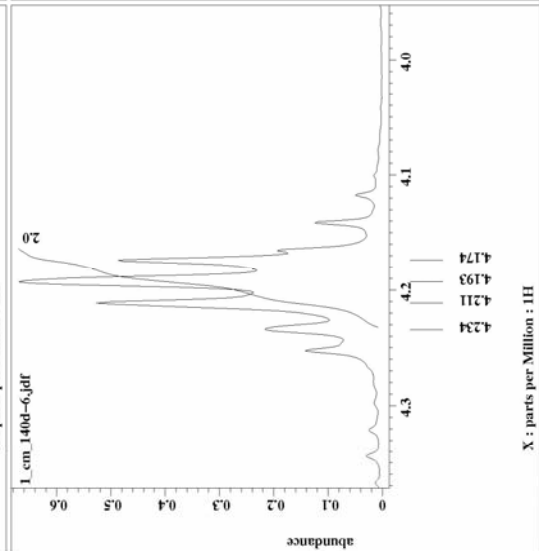
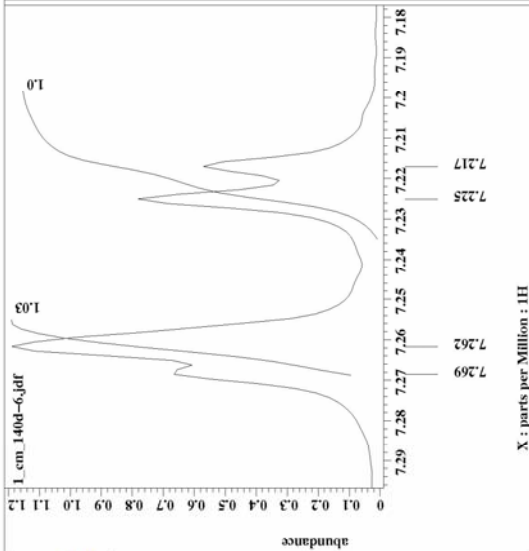
```

Filename = 1_cm_140d-6.jdf
Author = delta
Experiment = single_pulse.ex2
Pulse_program = zgpg30
Solvent = CHLOROFORM-D
Creation_time = 23-MAR-2005 14:30:33
Revision_time = 1-NOV-2006 14:38:25
Current_time = 1-NOV-2006 14:40:43

Content = single_pulse
Data_format = 1D_COMPLEX
Dim_size = 13107
Dim_title = 1H
Dim_units = [ppm]
Dimensions =
Site = KCCX 300
Spectrometer = DELTA2_NMR

Field_strength = 7.0586013[T] (300[Mhz]
X_acq_duration = 2.90717696[s]
X_delay = 1.00000000[s]
X_freq = 300.52965592[MHz]
X_offset = 5[ppm]
X_points = 16384
X_prescans = 1
X_resolution = 1.84397631[Hz]
X_resolution_hz = 5.63570784[kHz]
Irr_domain = 1H
Irr_freq = 300.52965592[MHz]
Irr_offset = 5[ppm]
Irr_domain = 1H
Tri_offset = 5[ppm]
Clipped = FALSE
Mod_return = 1
Total_scans = 24

X_90_width = 13.01[us]
X_acq_time = 2.90717696[s]
X_angle = 45[deg]
X_atn = 4[db]
X_pulses = 8
X_pulse_width = 2005[us]
Tri_mode = Off
Dante_presat = FALSE
Initial_wait = 1[s]
Recvr_gain = 30
Sensitivity_delay = 7.00000000[s]
Repetition_time = 7.90717696[s]
Temp_get = 22.5[dc]
  
```





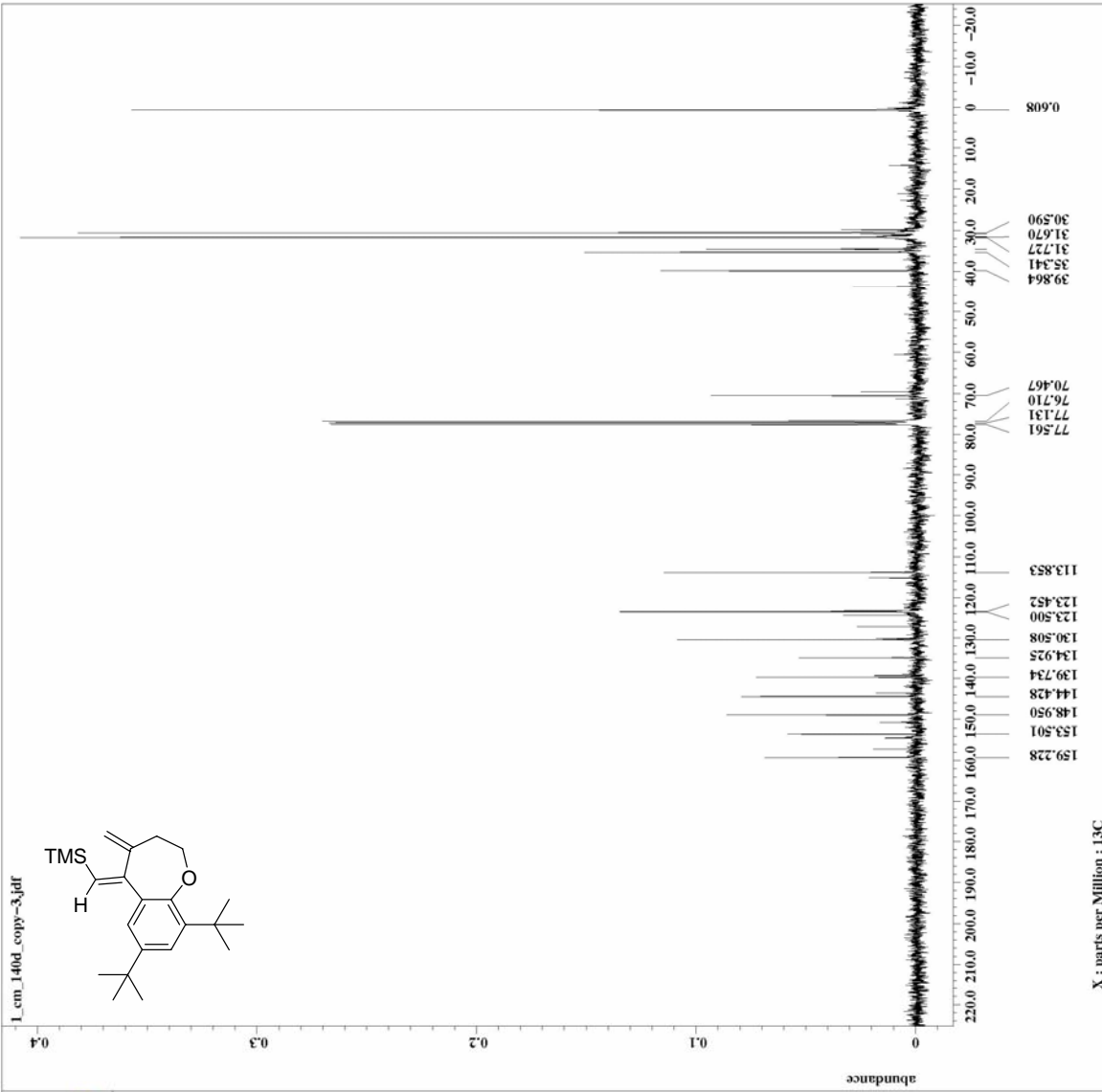
```

Filename = 1_cm_140d_copy-3.jdf
Author = delta
Experiment = single pulse_dec
Sample_id = S#483542
Solvent = CHLOROFORM-D
Creation_time = 23-MAR-2005 14:45:58
Revision_time = 23-MAR-2005 13:46:04
Current_time = 1-NOV-2006 14:41:32

Data format = single pulse decouple
ID COMPLEX
Data size = 26214
Dim size = 13C
Dim title =
Dim units = [ppm]
Dimensions = X
Site = ECX 300
Spectrometer = DELTA2_NMR

Field strength = 7.0586013[T] (300[MHz]
X_acq_duration = 1.38412032[s]
X_domain = 13C
X_freq = 75.56823426[MHz]
X_offset = 100[ppm]
X_points = 32768
X_prescans = 4
X_resolution = 0.72248054[Hz]
X_sweep = 13.67424242[kHz]
X_sweep_rate = 300.52965592[MHz]
Irr_freq = 5[ppm]
Irr_offset = FALSE
Clipped =
Incomplete copy = TRUE
Mod_return = 1
Scans = 204
Total_scans = 204

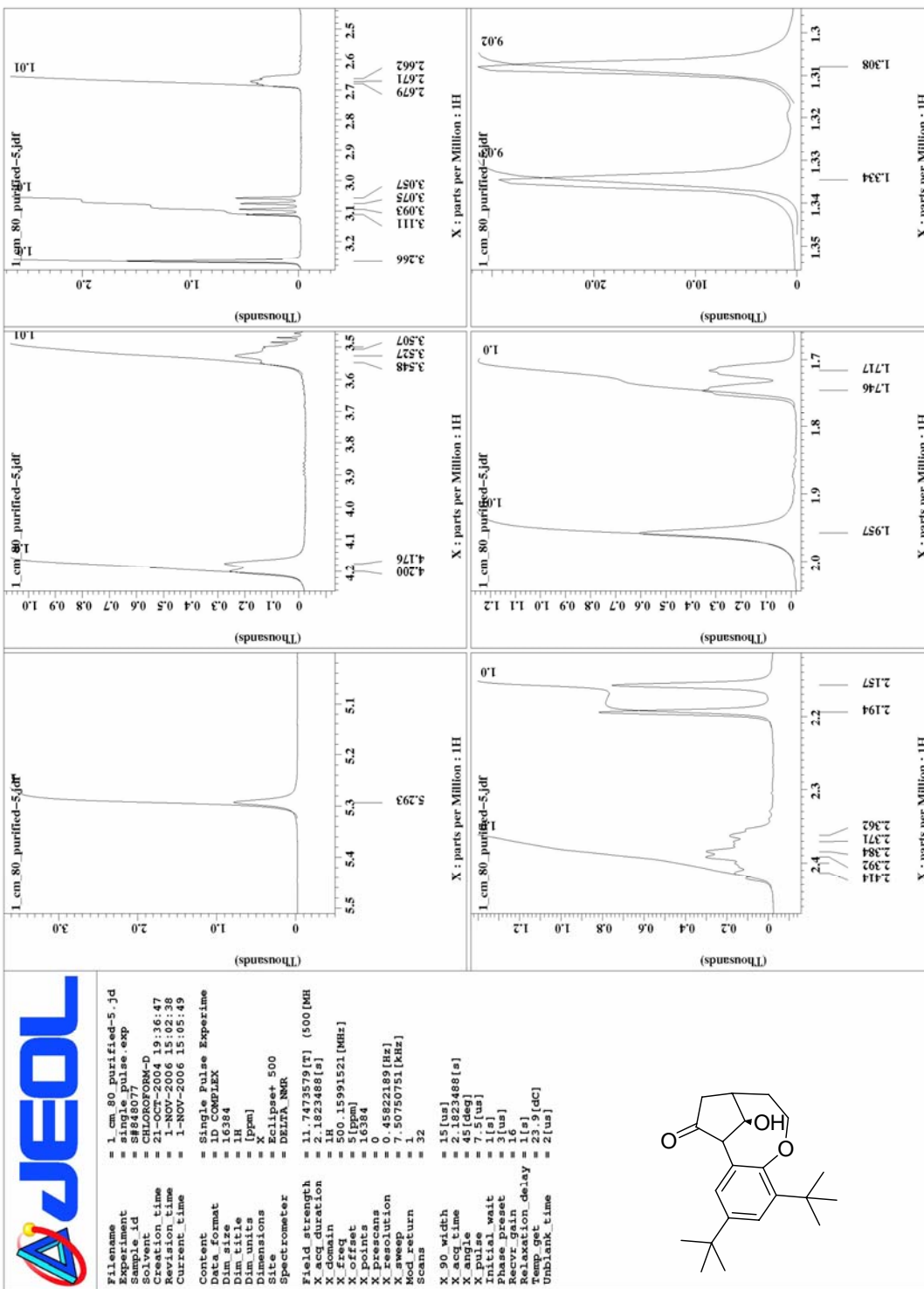
X_90_width = 9.75[us]
X_acq_time = 1.38412032[s]
X_angle = 30[deg]
X_atn = 8[db]
X_atn = 3.25[us]
X_pulse = 25[db]
Irr_atn_dec = 25[db]
Irr_atn_noe = 25[db]
Irr_noise = WALTZ
Decoupling = TRUE
Initial_wait = [s]
Final_wait = 3[s]
Noe_time = 50
Recvr_gain = 3[s]
Relaxation_delay = 4.38412032[s]
Repetition_time = 24.2[dc]
Temp_get =
  
```

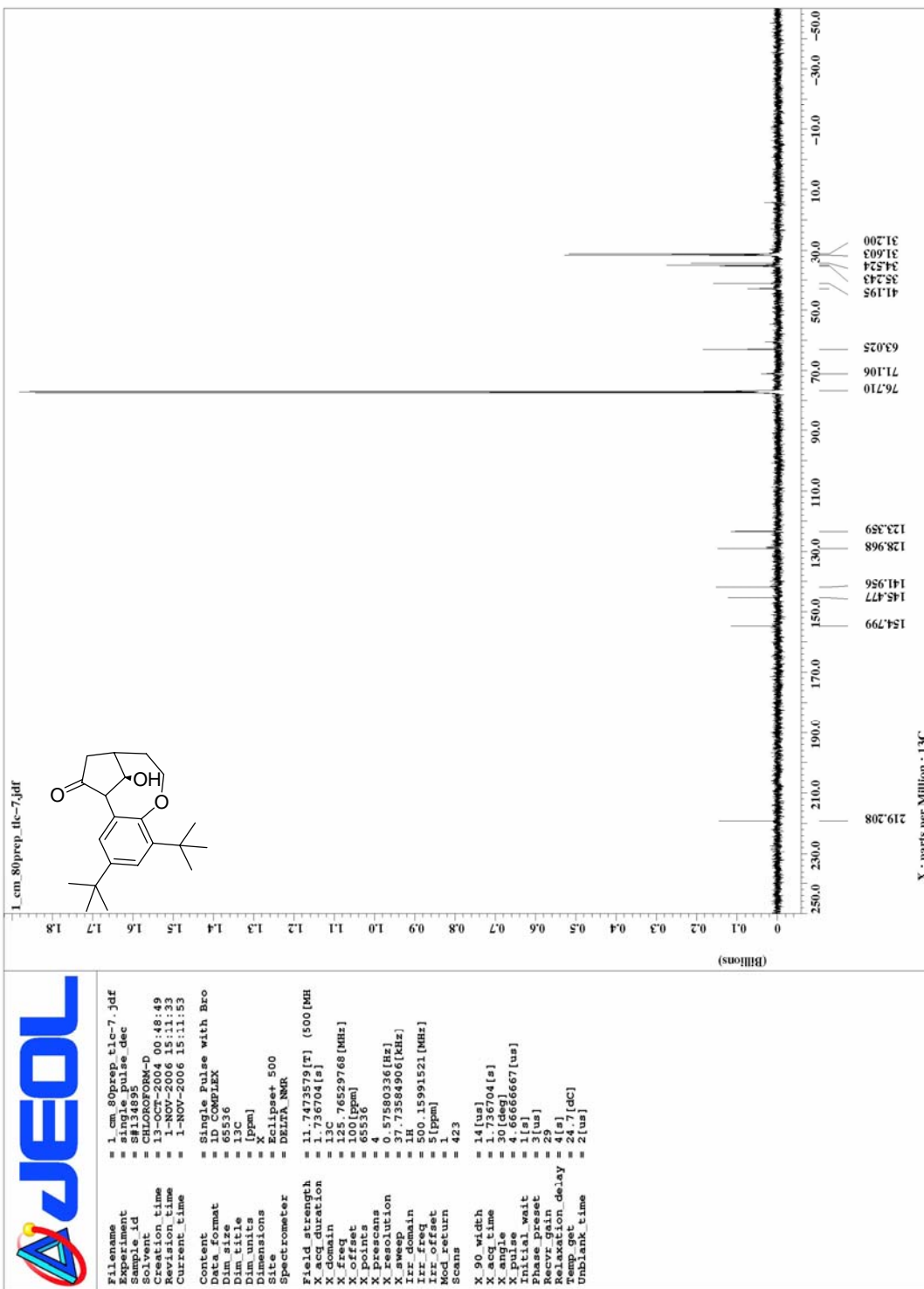


X : parts per Million : 13C

APPENDIX 71

**¹H and ¹³C NMR SPECTRA OF
4,6-Di-*tert*-butyl-14-hydroxy-8-oxa
-tricyclo[9.2.1.0]tetradeca-2,4,6-triene-13-one (81)**





APPENDIX 72

¹H and ¹³C NMR SPECTRA OF

2,4-Di-*tert*-butyl-6-(-3-hydroxy-3-methylbut-1-ynyl)phenol (84)



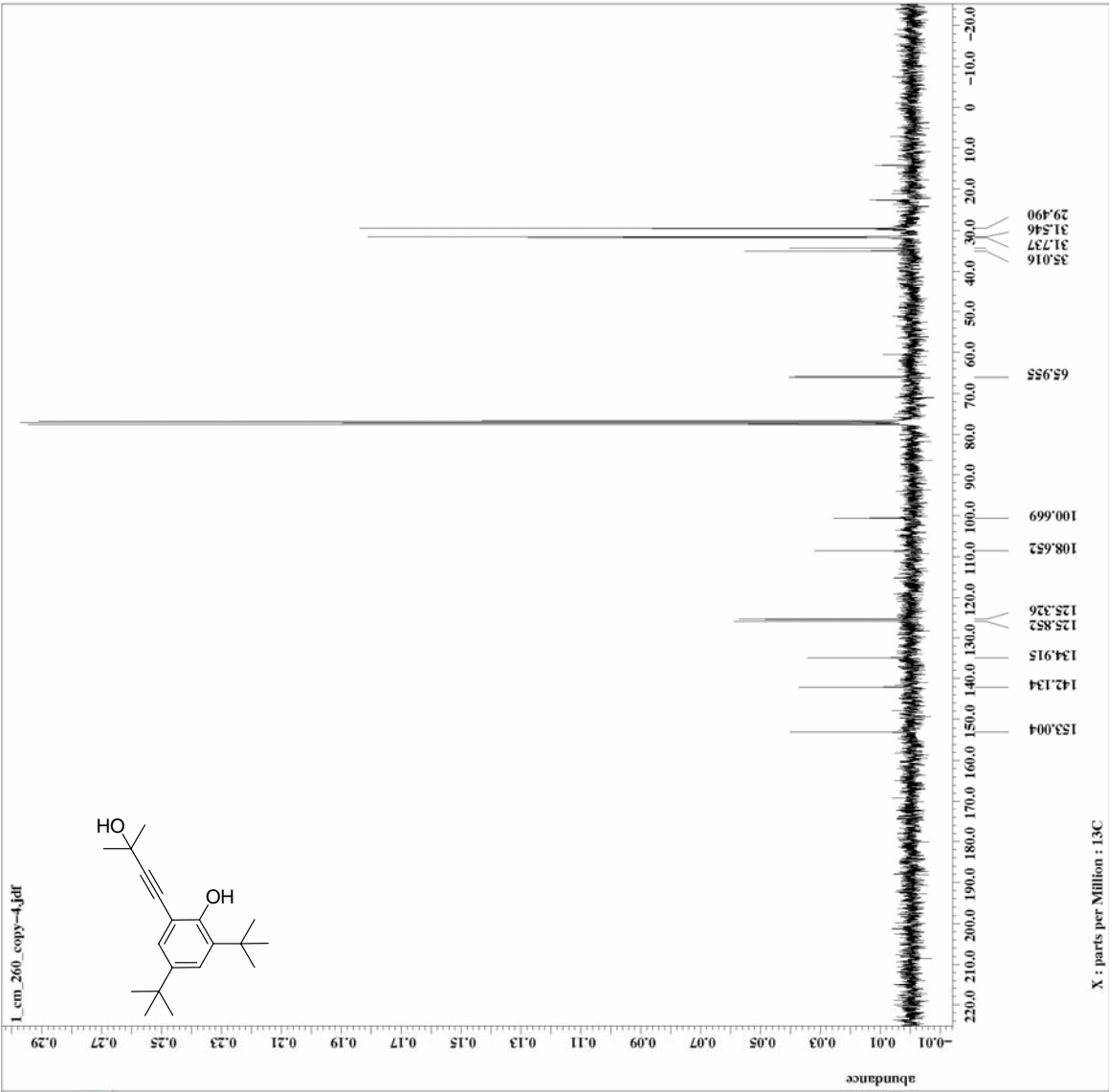
```

Filename = 1_cm_260_copy-4.jdf
Author = delta
Experiment = single pulse_dec
Sample_id = 1_cm_260
Solvent = CHLOROFORM-D
Creation_time = 6-DEC-2005 15:18:45
Revision_time = 1-NOV-2006 15:34:52
Current_time = 1-NOV-2006 15:35:44

Data format = single pulse decouple
ID COMPLEX
Data format = 1D COMPLEX
Dim size = 26214
Dim title = 13C
Dim units = [ppm]
Dimensions = X
Site = ECX 300
Spectrometer = DELTA2_NMR

Field strength = 7.0586013[T] (300[MHz]
X_acq_duration = 1.38412032[s]
X_domain = 13C
X_freq = 75.56823426[MHz]
X_offset = 100[ppm]
X_points = 32768
X_prescans = 4
X_resolution = 0.72248054[Hz]
X_sweep = 13.67424242[kHz]
X_sweep_rate = 300.52965592[MHz]
Irr_freq = 5[ppm]
Irr_offset = FALSE
Clipped = FALSE
Incomplete_copy = TRUE
Mod_return = 1
Scans = 212
Total_scans = 212

X_90_width = 9.75[us]
X_acq_time = 1.38412032[s]
X_angle = 30[deg]
X_atn = 8[db]
X_atn = 3.25[us]
X_pulse = 25[db]
Irr_atn_dec = 25[db]
Irr_atn_noe = 25[db]
Irr_noise = WALTZ
Decoupling = TRUE
Initial_wait = [s]
Wait = 3[s]
Noe_time = 50
Recvr_gain = 3[s]
Relaxation_delay = 3[s]
Repetition_time = 4.38412032[s]
Temp_get = 23.4[dc]
  
```



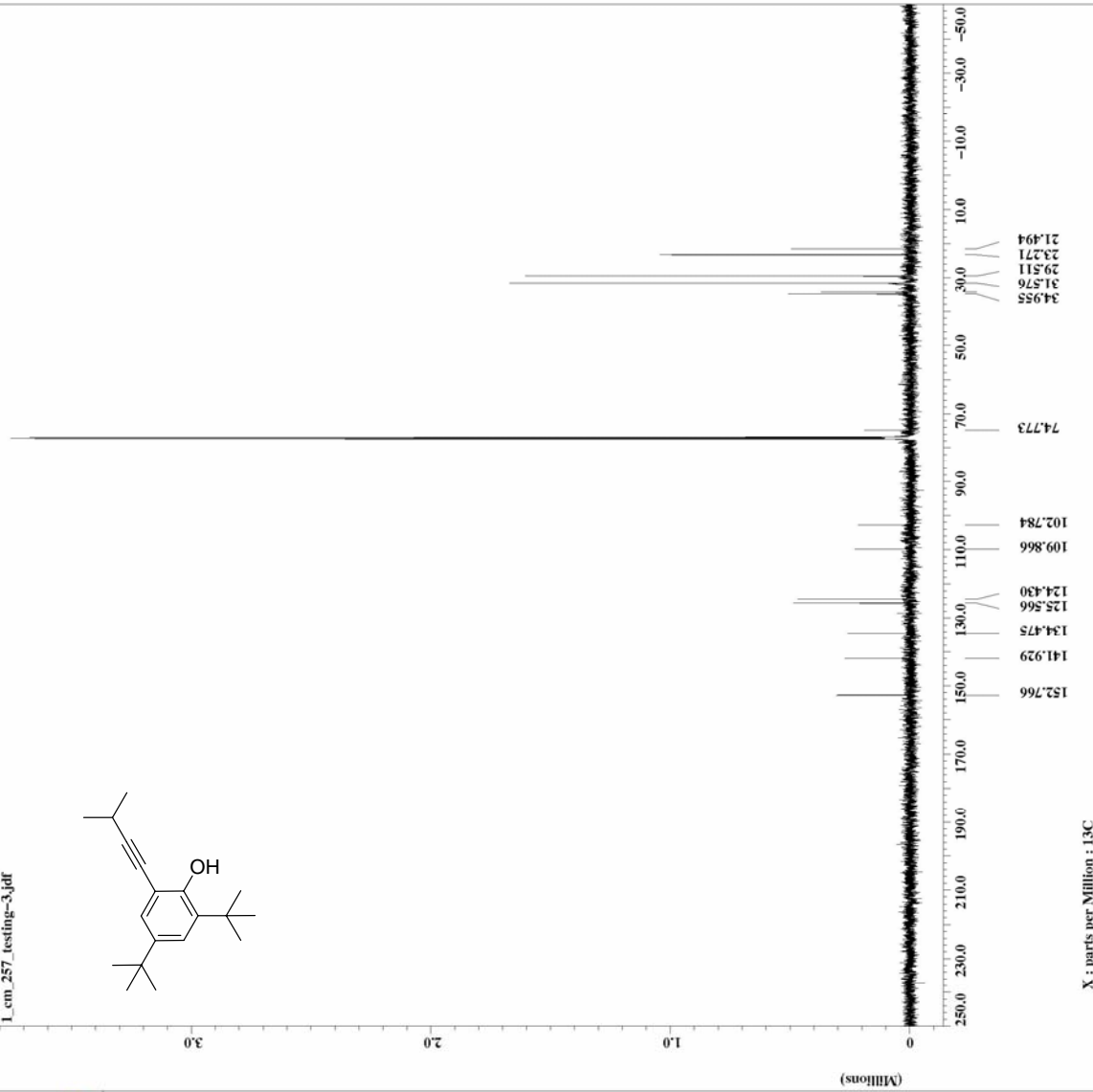
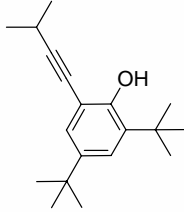
APPENDIX 73

**¹H and ¹³C NMR SPECTRA OF
2,4-Di-*tert*-butyl-6-(-3-methylbut-1-ynyl)phenol (85)**



Filename = 1_cm_257_testing-3.jd
Author = delta
Experiment = single_pulse_dec
Sample_id = 1_cm_257_testing
Solvent = CHLOROFORM-D
Creation_time = 8-DEC-2005 17:53:06
Revision_time = 1-NOV-2006 15:47:25
Current_time = 1-NOV-2006 15:47:43
Content = Single Pulse with Bro
Data_format = 1D COMPLEX
Dim_size = 65536
Dim_title = 13C
Dim_units = [ppm]
Dimensions = X
Site = Eclipse 500
Spectrometer = DELTA_NMR
Field_strength = 11.7473579 [T] (500 [MH
X_acq_duration = 1.736704 [s]
X_domain = 13C
X_freq = 125.76529768 [MHz]
X_offset = 100 [ppm]
X_points = 65536
X_prescans = 4
X_resolution = 0.5758036 [Hz]
X_sweep = 37.7584906 [kHz]
X_tau_domain = 1H
Irr_freq = 500.15991521 [MHz]
Irr_offset = 5 [ppm]
Clipped = FALSE
Mod_return = 1
Scans = 280
Total_scans = 280
X_90_width = 14.2 [us]
X_90_time = 1.726704 [s]
X_angle = 30 [deg]
X_pulse = 4.73333333 [us]
Initial_wait = 1 [s]
Phase_preset = 3 [us]
Recvr_gain = 29
Relaxation_delay = 4 [s]
Temp_get = 27.8 [dC]
Unblank_time = 2 [us]

1_cm_257_testing-3.jdf

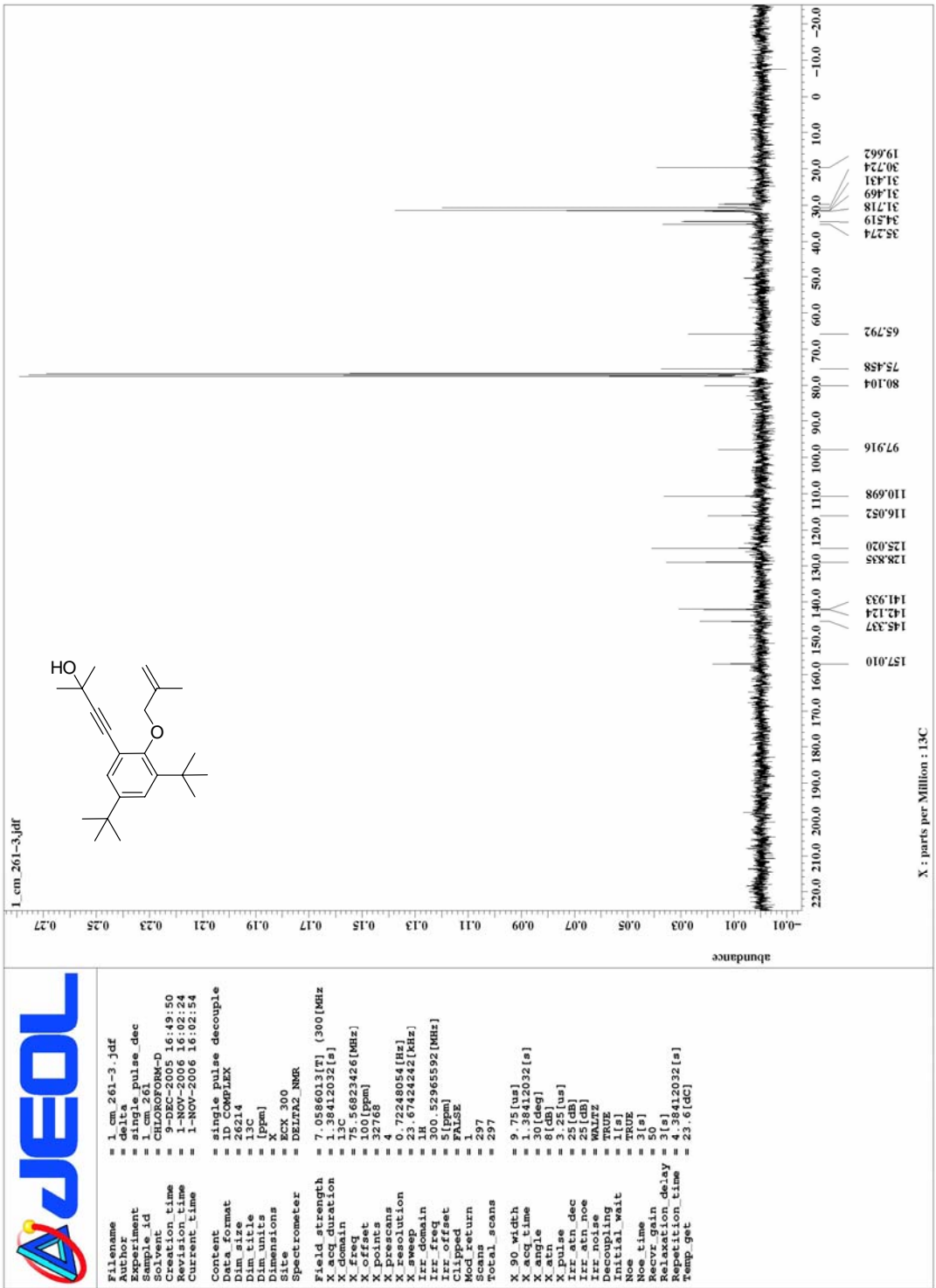


X : parts per Million : 13C

APPENDIX 74

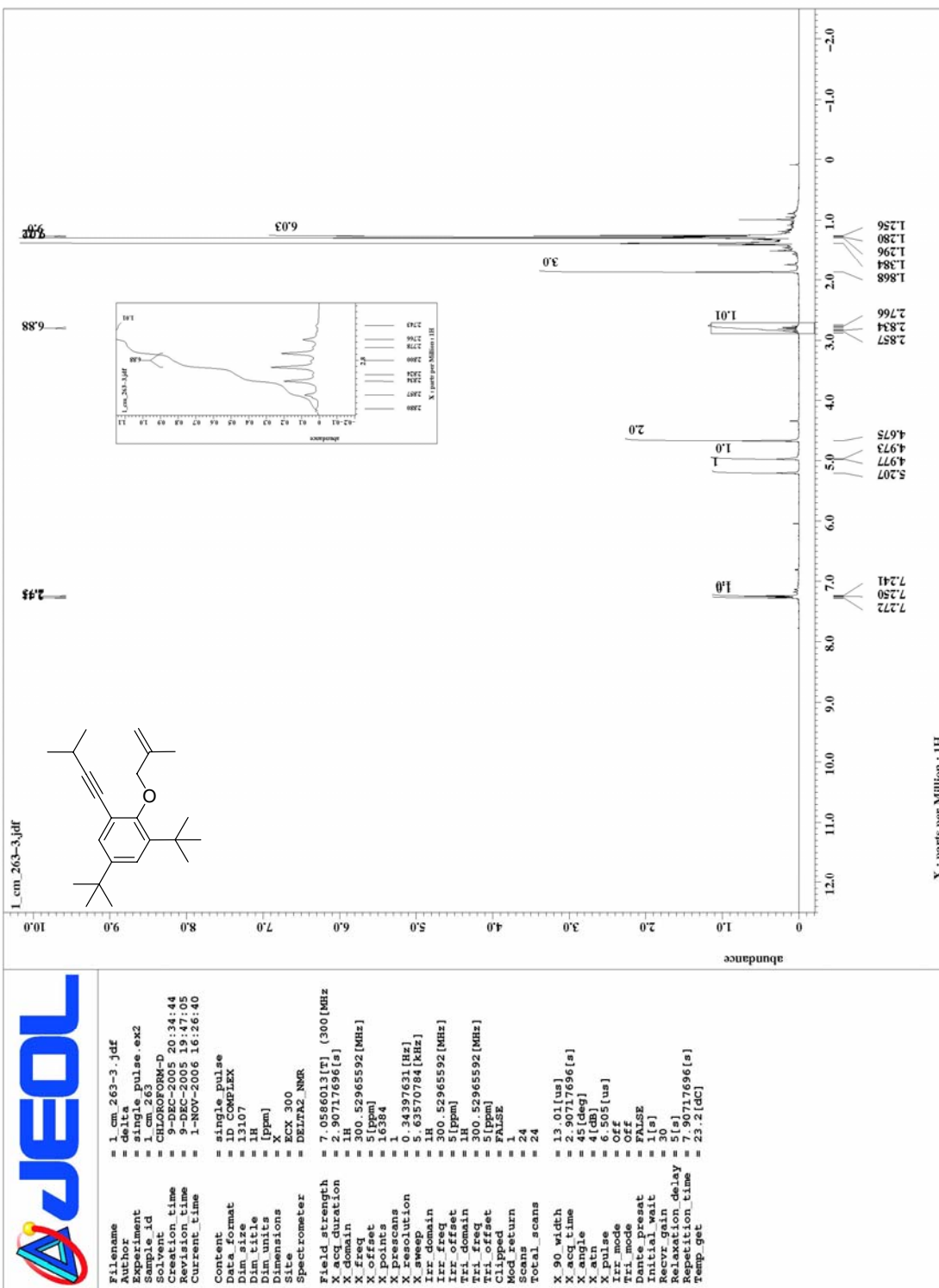
¹H and ¹³C NMR SPECTRA OF

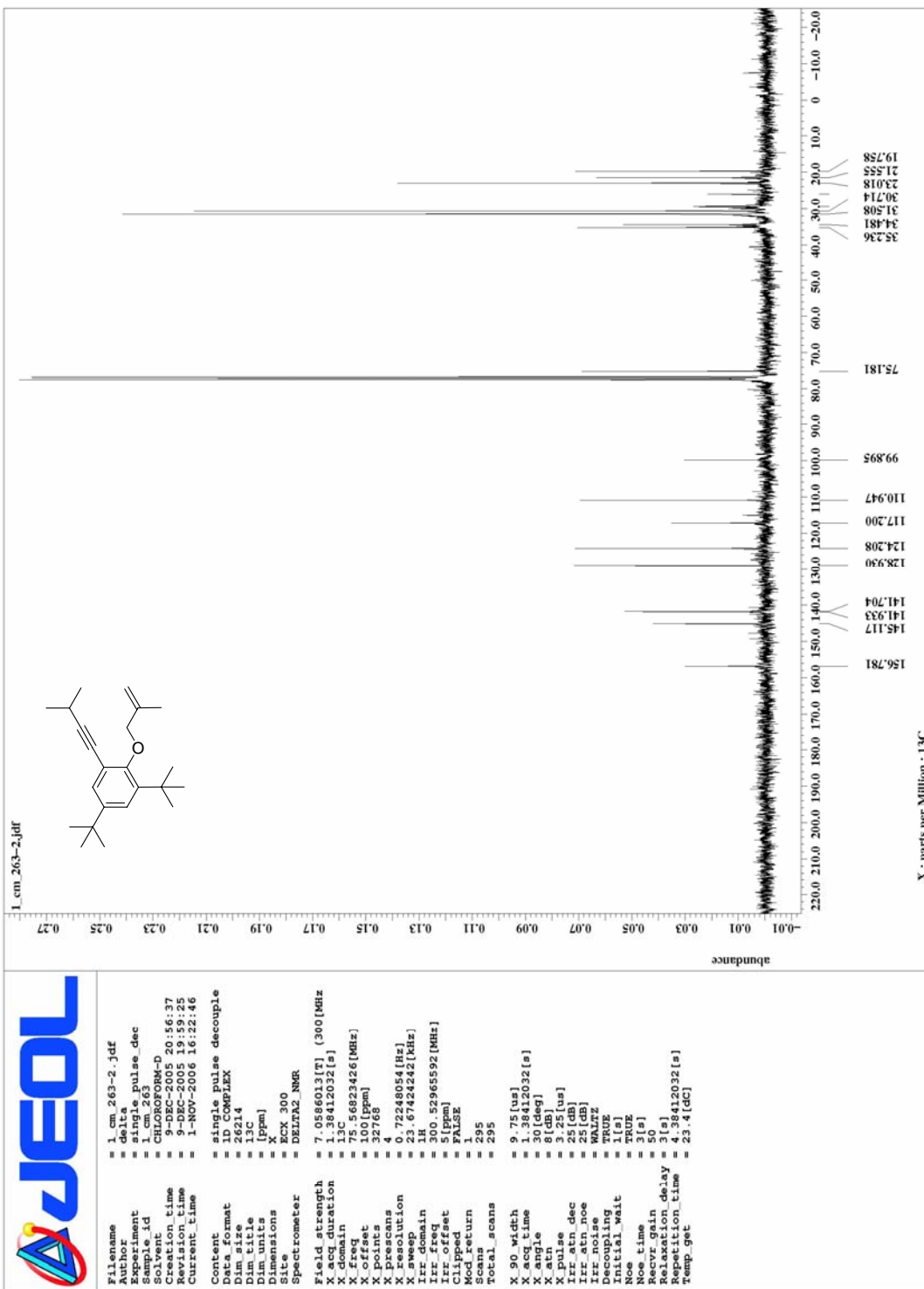
4,6-Di-*tert*-butyl-2-(-2-methylbut-3-yn-2-ol)-(-2-methylallyloxy)benzene (86)



APPENDIX 75

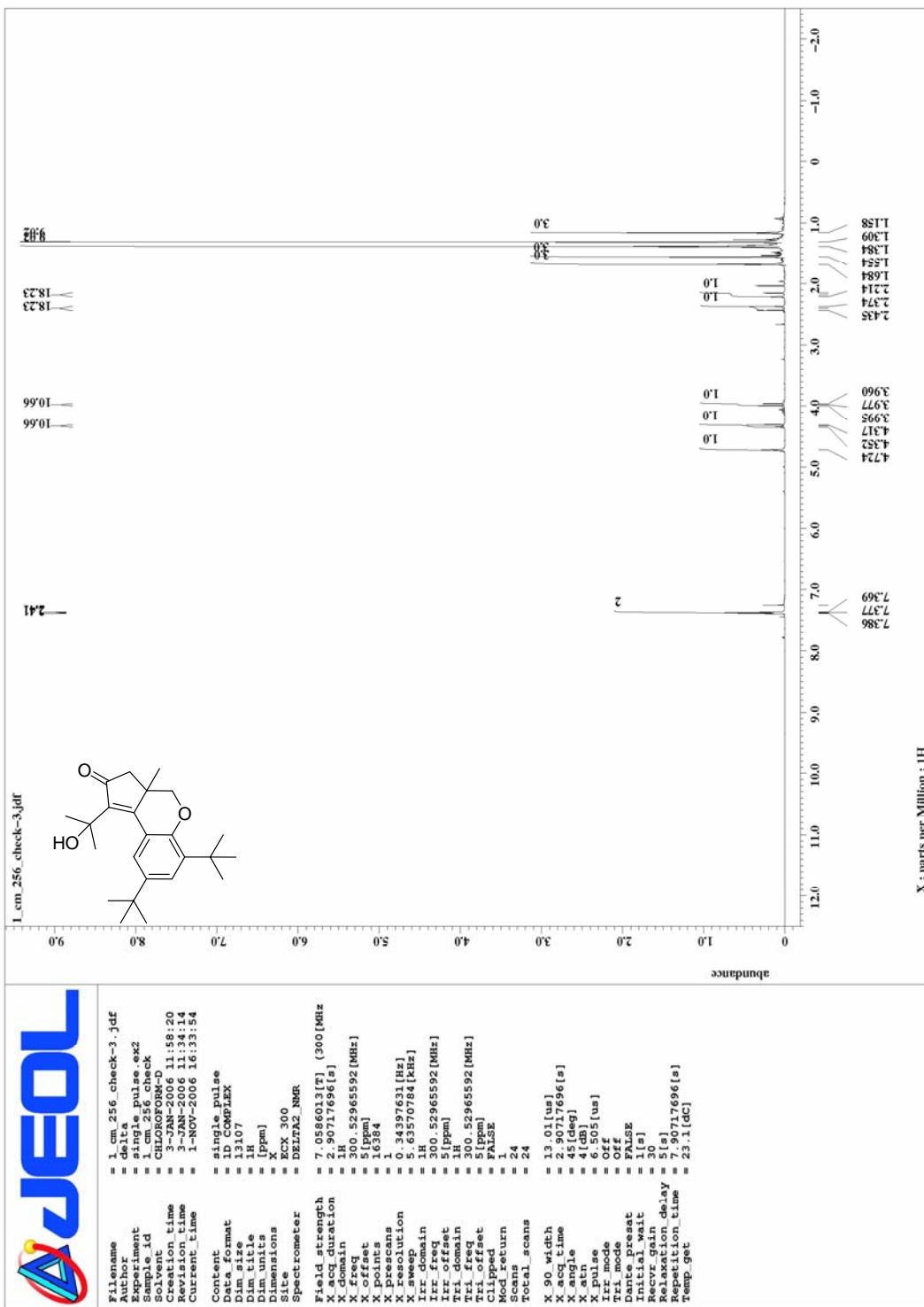
**¹H and ¹³C NMR SPECTRA OF
4,6-Di-*tert*-butyl-2-(-2-methylbut-3-ynyl)
-(-2-methylallyloxy)benzene (87)**





APPENDIX 76

**¹H and ¹³C NMR SPECTRA OF
6,8-Di-*tert*-butyl-1-(1-hydroxy-1-methylethyl)-3a-methyl
-3a,4-dihydro-3*H*-cyclopenta[*c*]chromen-2-one (88)**



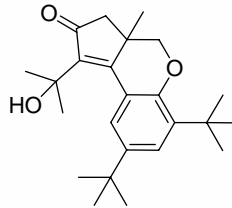
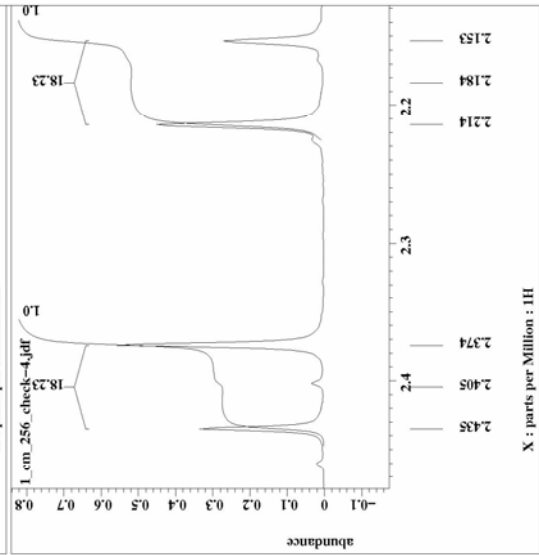
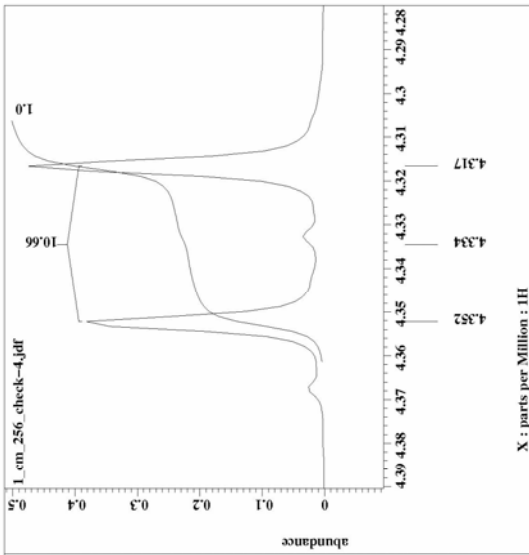
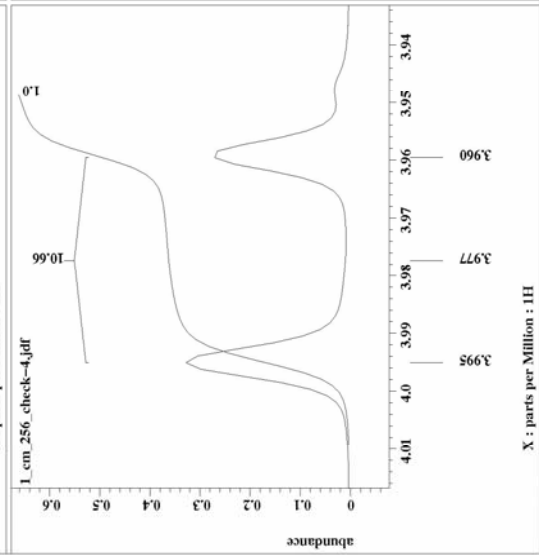
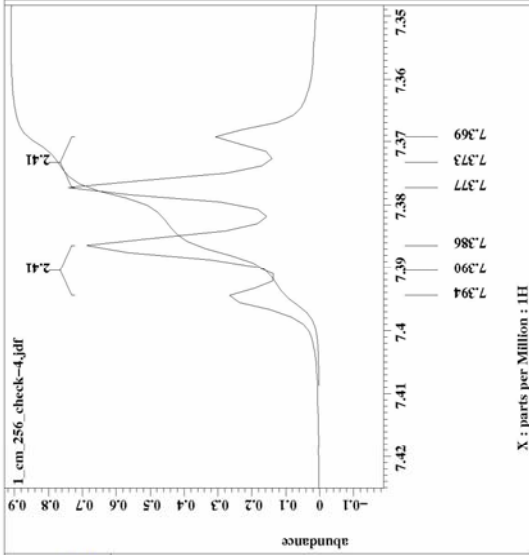


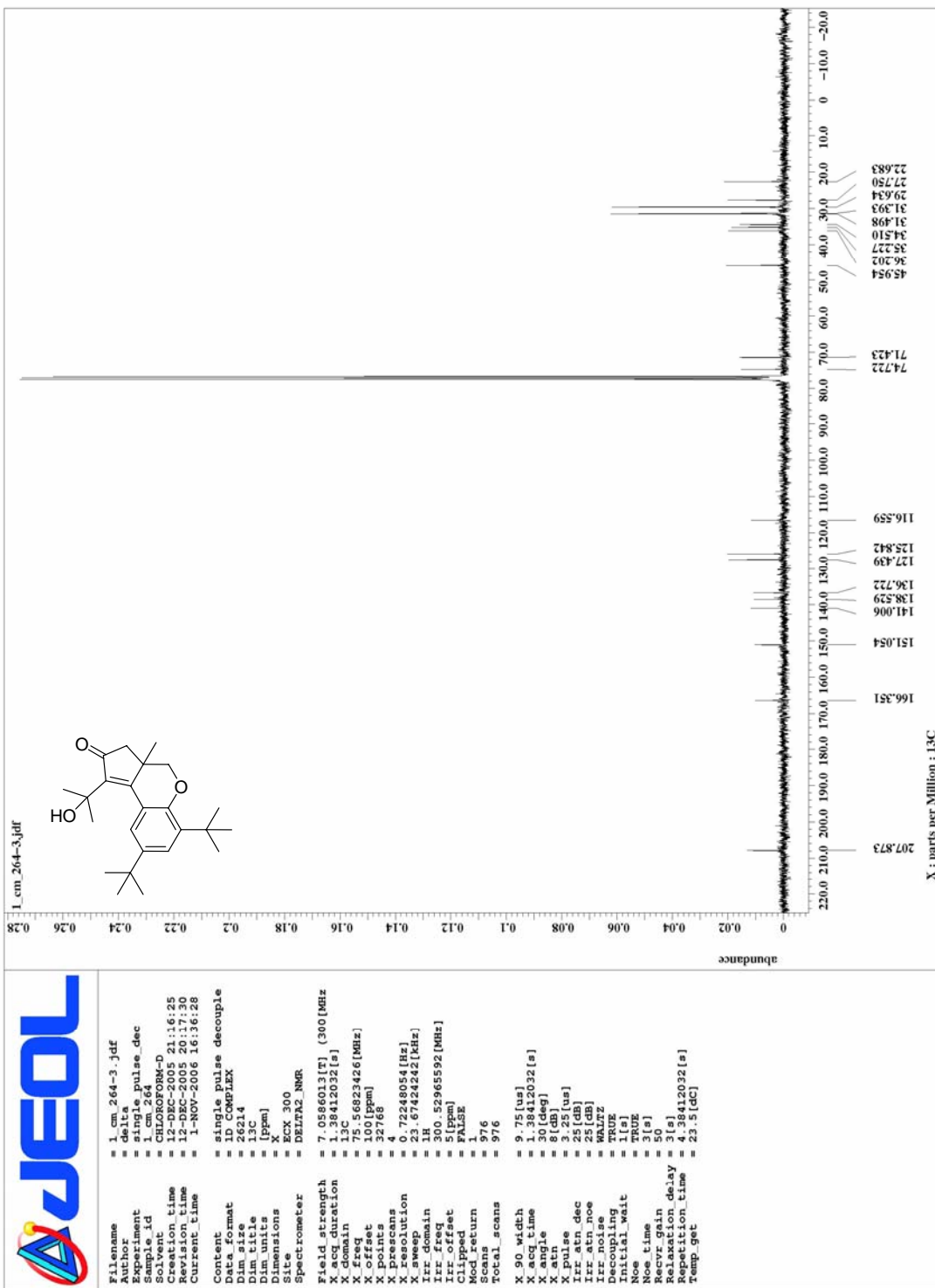
```

Filename = 1_cm_256_check-4.jdf
Author = delta
Experiment = sing_pulse.ex2
SampleName = 1066
Solvent = CHLOROFORM-D
Creation_time = 3-JAN-2006 11:58:20
Revision_time = 1-NOV-2006 16:34:50
Current_time = 1-NOV-2006 16:35:23

Content = single pulse
Data format = 1D COMPLEX
Dim size = 13107
Dim title = 1H
Dim units = [ppm]
Dimensions =
Site = KCCX 300
Spectrometer = DELTA2_NMR

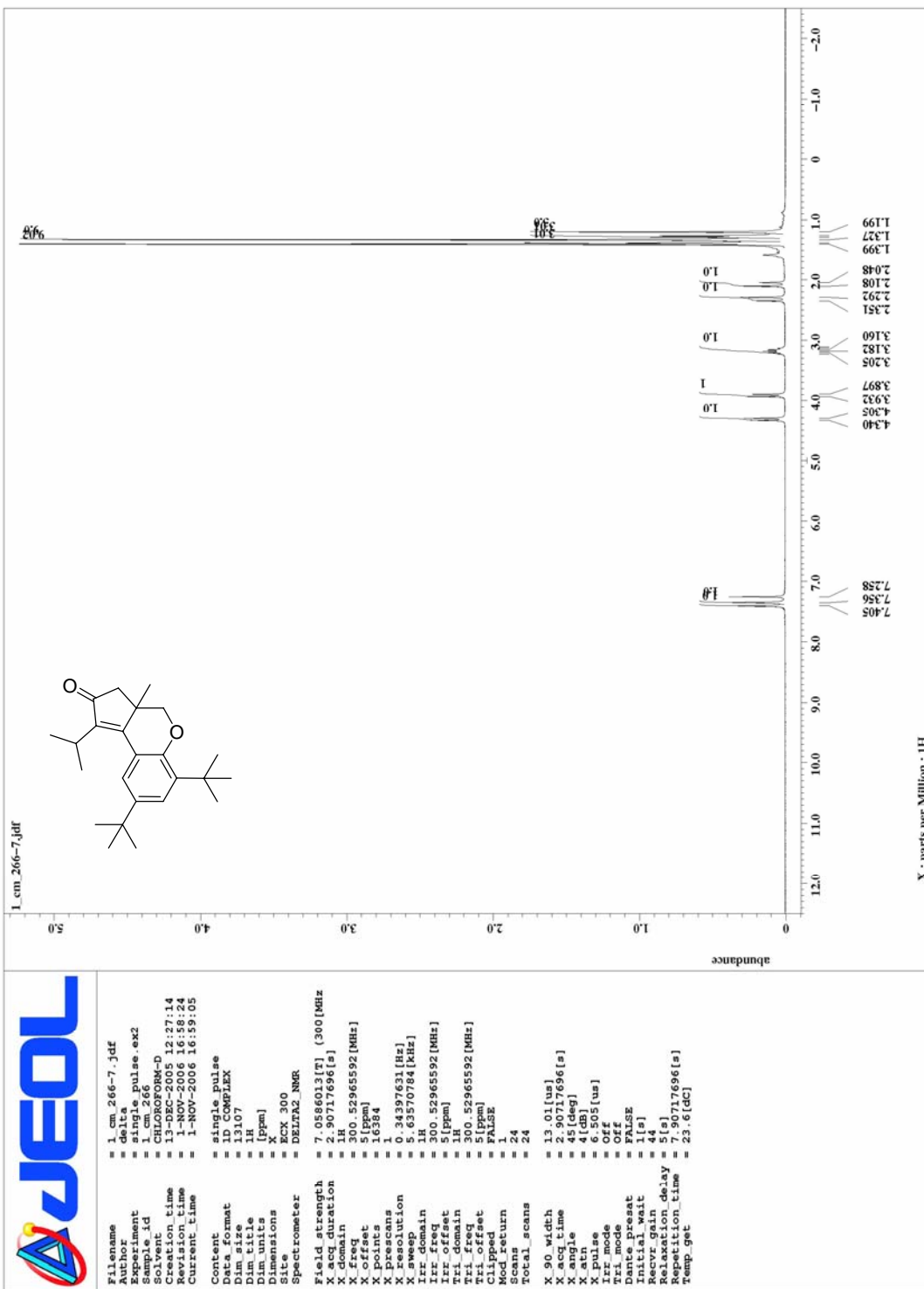
Field strength = 7.0586013[T] (300[Mhz]
X_acq_duration = 2.90717696[s]
X_resolution = 300.52965592[MHz]
X_freq = 5[ppm]
X_offset = 16384
X_points = 1
X_prescans = 1
X_resolution = 1.84397631[Hz]
X_resolution = 5.63570784[MHz]
Irr_domain = 1H
Irr_freq = 300.52965592[MHz]
Irr_offset = 5[ppm]
Tri_domain = 1H
Tri_freq = 300.52965592[MHz]
Tri_offset = 5[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 24
Total_scans = 24
X_90_width = 13.01[us]
X_acq_time = 2.90717696[s]
X_angle = 45[deg]
X_atn = 4[db]
X_pulse = 205[us]
X_pulse = 205[us]
Tri_pulse = Off
Tri_mode = Off
Dante_preset = FALSE
Initial_wait = 1[s]
Recvr_gain = 30
Recvr_gain_delay = 7.90717696[s]
Repetition_time = 23.1[dc]
Temp_get =
  
```

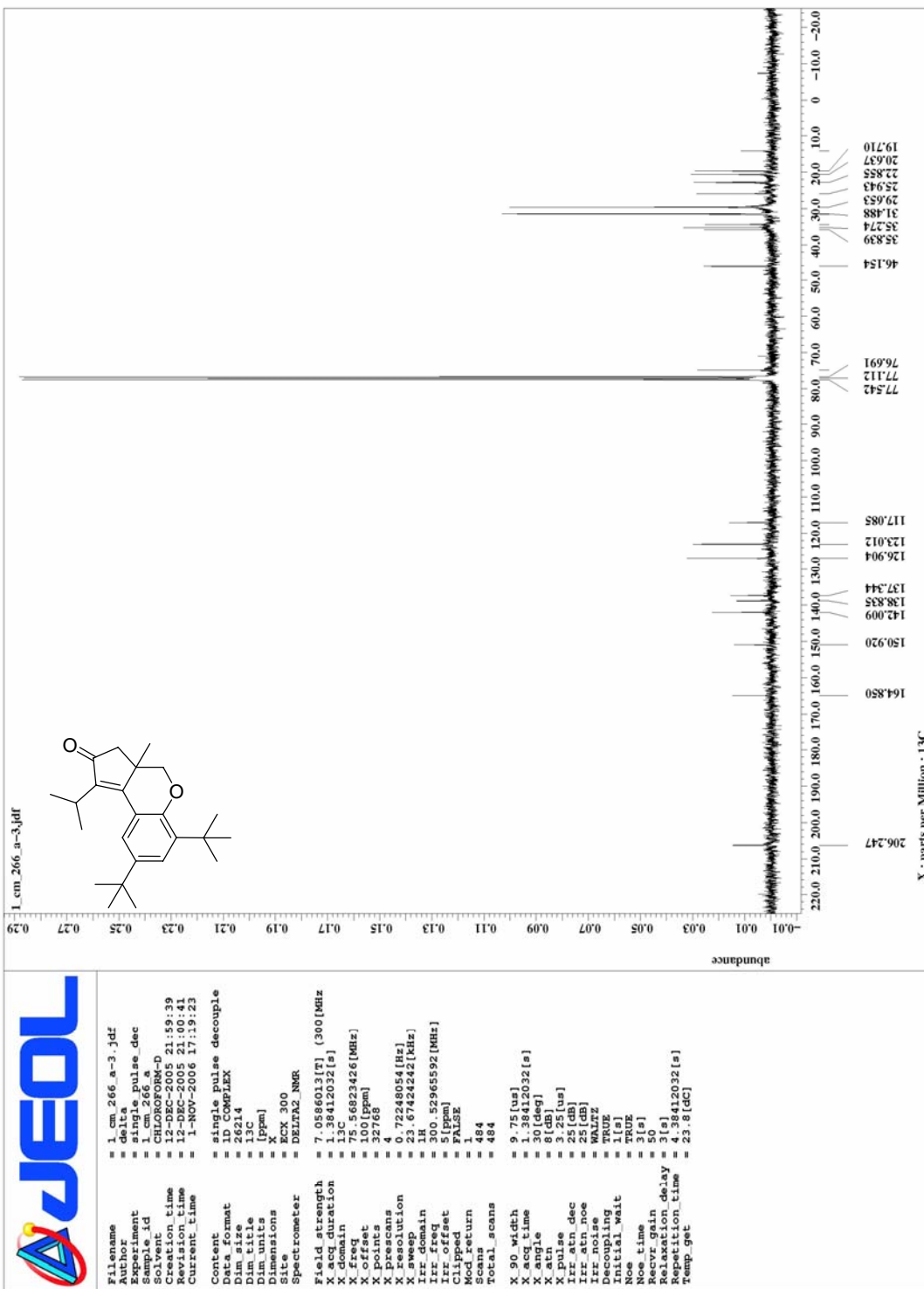




APPENDIX 77

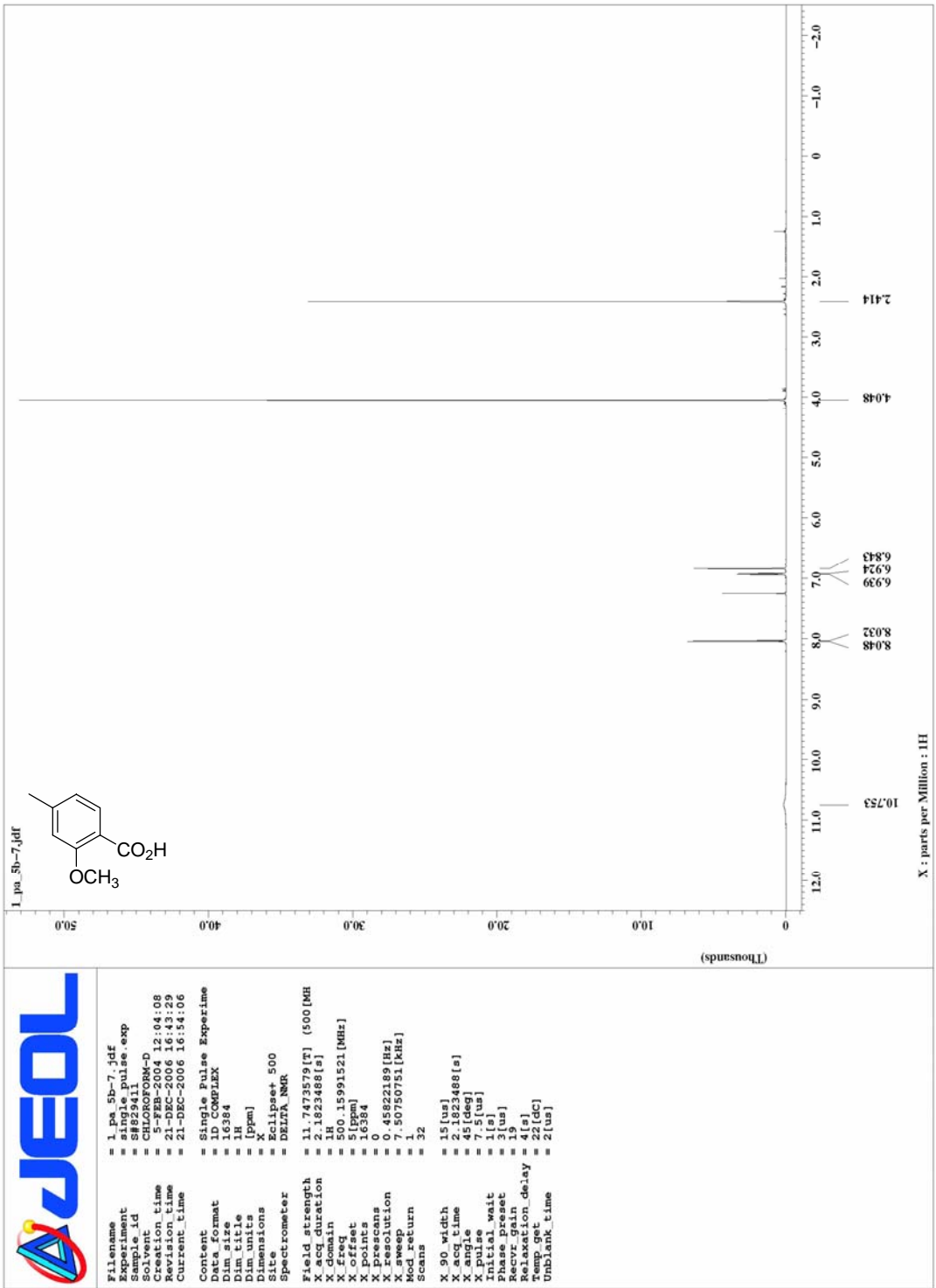
**¹H and ¹³C NMR SPECTRA OF
6,8-Di-*tert*-butyl-1-isopropyl-3a-methyl-3a,4-dihydro
-3*H*-cyclopenta[*c*]chromen-2-one (89)**





APPENDIX 78

**^1H and ^{13}C NMR SPECTRA OF
2-Methoxy-4-methylbenzoic acid (99)**





```

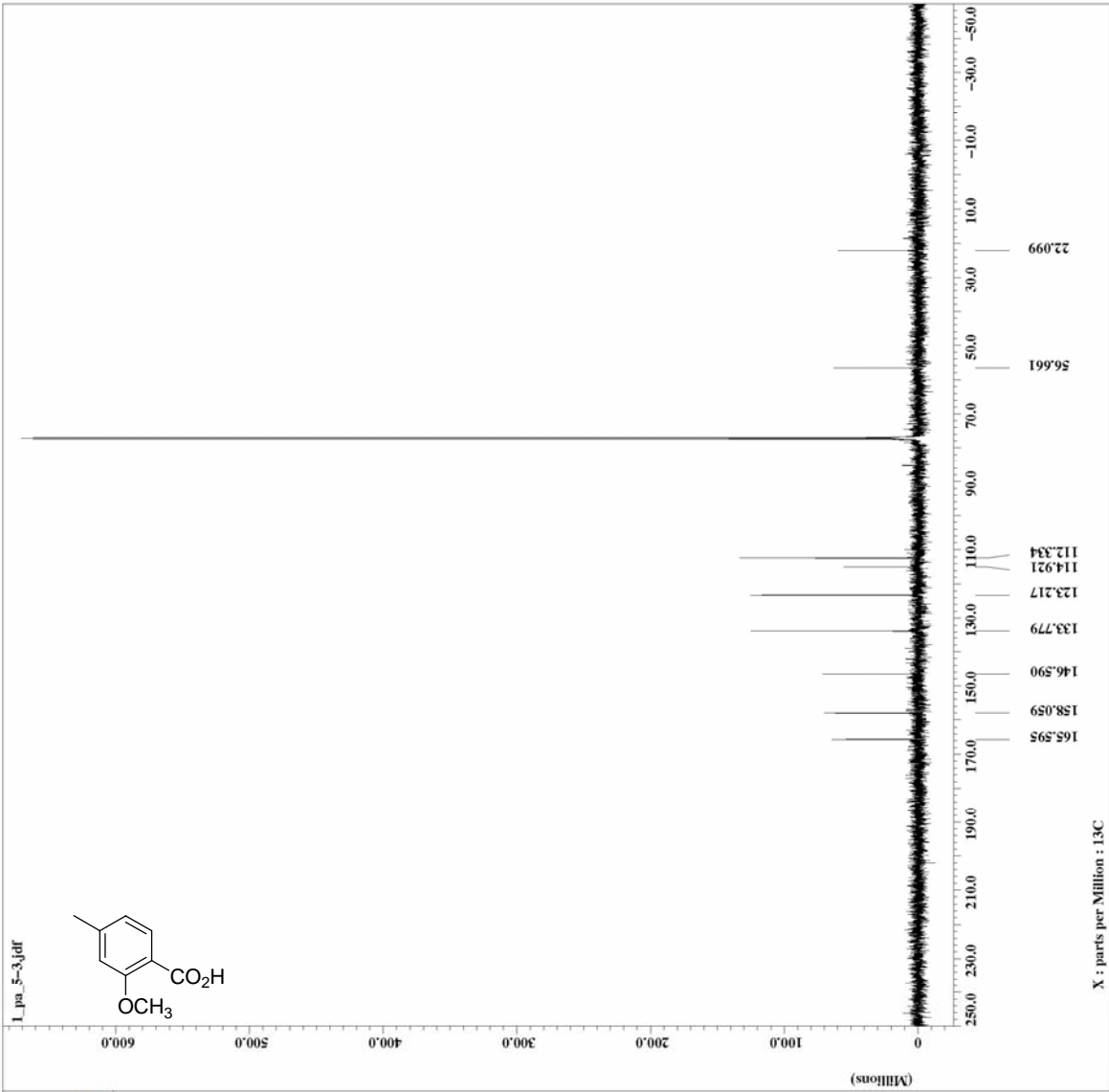
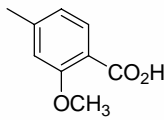
Filename      = 1_pa_5-3.jdf
Experiment    = single_pulse_dec
Sample_id     = S#83679
Solvent       = CDCl3
Date_         = 05-APR-2004 12:28:12
Collection   = 5-APR-2004 12:28:12
Revision     = 21-DEC-2006 16:48:31
Current_time  = 21-DEC-2006 16:49:03

Content       = Single Pulse with Bro
Data_format  = ID COMPLEX
Dim_size     = 65536
Dim_title    = 13C
Dim_units    = [ppm]
Dimensions   = X
Site         = DELTA_500
Spectrometer = DELTA_NMR

Field_strength = 11.7473579[T] (500 [MH
X_acq_duration = 1.736704[s]
X_domain       = 13C
X_freq         = 125.76529768 [MHz]
X_offset       = 600[ppm]
X_resolution   = 65536
X_sweeps       = 4
X_resolution   = 0.57580336 [Hz]
X_sweep        = 37.73584906 [kHz]
Irr_domain     = 1H
Irr_freq       = 500.15991521 [MHz]
Irr_offset     = 5[ppm]
Mod_return     = 1
Scans          = 152

X_90_width    = 14[us]
X_acq_time     = 1.736704 [s]
X_angle        = 30[deg]
X_pulse        = 4.66666667 [us]
Initial_wait   = 1[s]
Phase_preset   = 3[us]
Recvr_gain     = 29
Relaxation_delay = 4[s]
Temp_get       = 22.7 [dc]
Unblank_time   = 2[us]
  
```

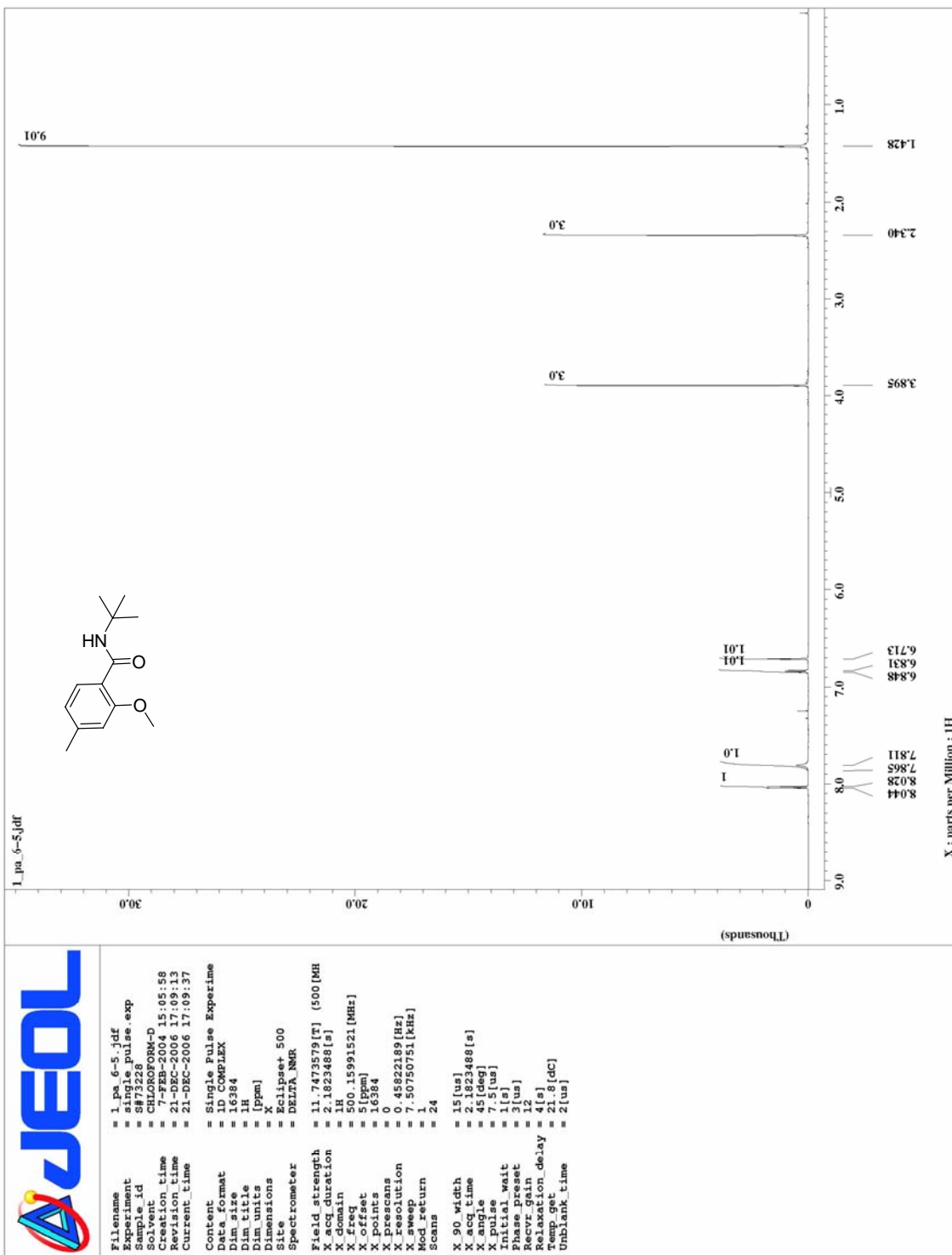
1_pa_5-3.jdf



APPENDIX 79

¹H and ¹³C NMR SPECTRA OF

***N-tert-butyl-2-methoxy-4-methylbenzamide* (100)**





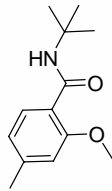
```

1_pa_6-4.jdf
Experiment = single_pulse_dec
Sample_id = S#164204
Solvent = CHLOROFORM-D
Creation time = 12-FEB-2004 18:01:31
Revision time = 21-DEC-2006 17:12:00
Current time = 21-DEC-2006 17:12:56

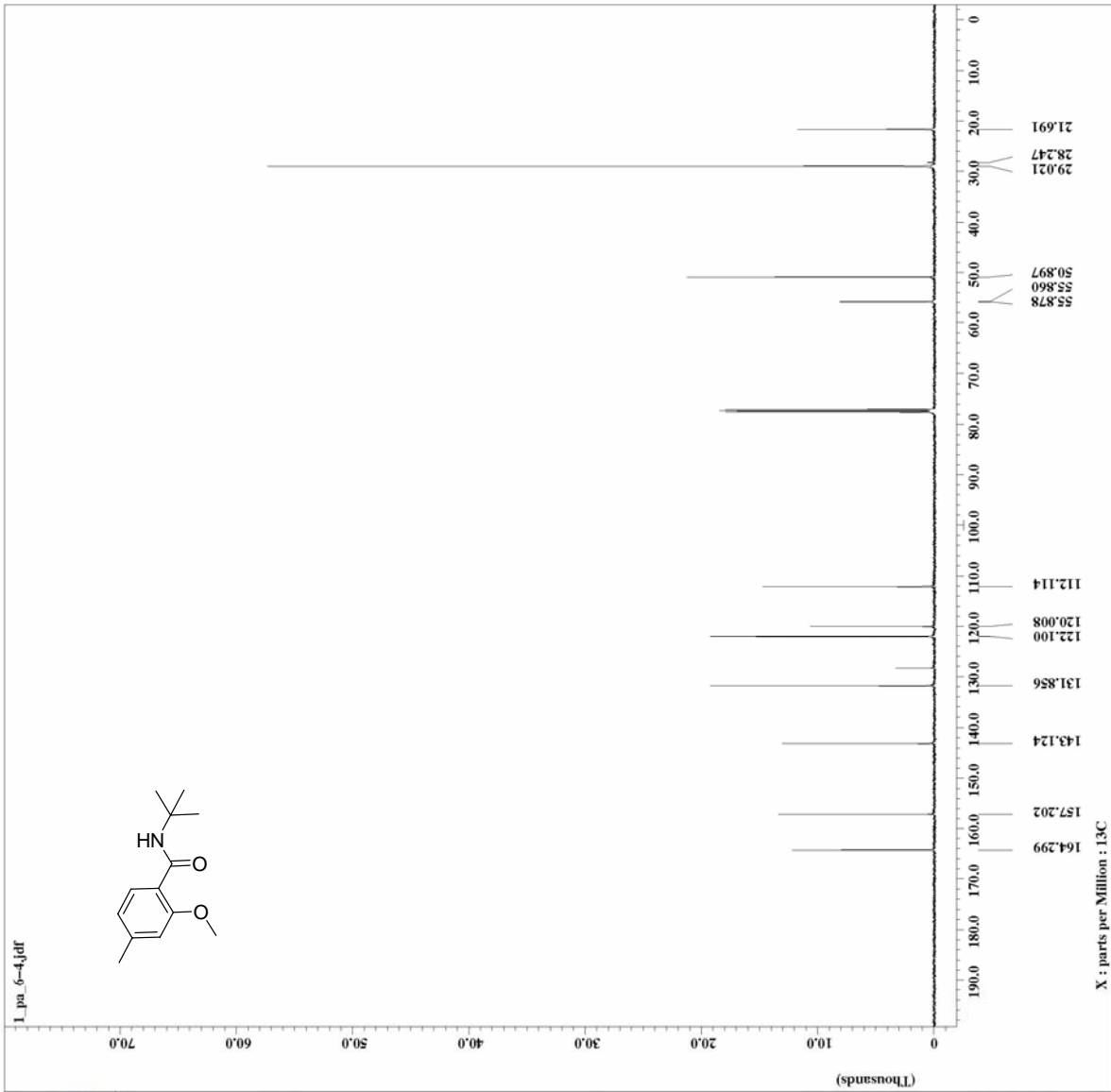
Content = Single Pulse with Bro
Data_format = 1D_COMPLEX
Dim_1 = 65536
Dim_2 = 13C
Dim_units = [ppm]
Dimensions = X
Site = Eclipse+ 500
Spectrometer = DELTA_NMR

Field_strength = 11.7473579[T] (500 [MH]
X_acq_duration = 1.736704[s]
X_domain = 13C
X_freq = 125.76529768 [MHz]
X_offset = 140.0 [ppm]
X_pulses = 65536
X_prescans = 4
X_resolution = 0.57580336 [Hz]
X_sweep = 37.73584906 [kHz]
Irr_domain = 1H
Irr_freq = 500.15991521 [MHz]
Irr_offset = 5 [ppm]
Mod_return = 1
Scans = 258

X_90_width = 14 [us]
X_acq_time = 1.736704 [s]
X_angle = 30 [deg]
X_pulse = 4.66666667 [us]
Initial_wait = 1 [s]
Phase_preset = 3 [us]
Recvr_gain = 29
Relaxation_delay = 4 [s]
Temp_get = 23.3 [dC]
Unblank_time = 2 [us]
  
```



1_pa_6-4.jdf

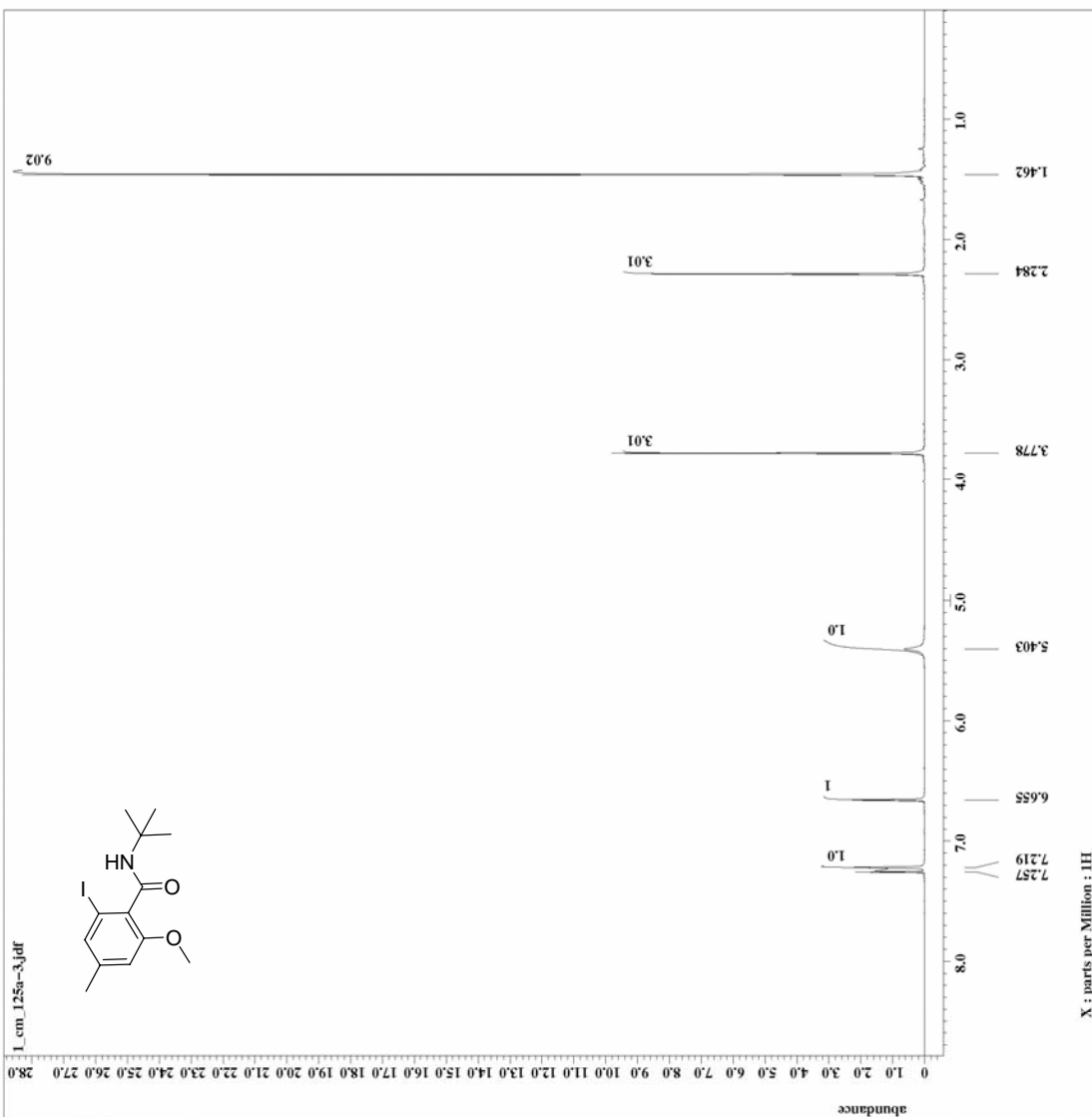


X : parts per Million : 13C

APPENDIX 80

^1H and ^{13}C NMR SPECTRA OF

N-tert-butyl-6-iodo-2-methoxy-4-methylbenzamide (91)



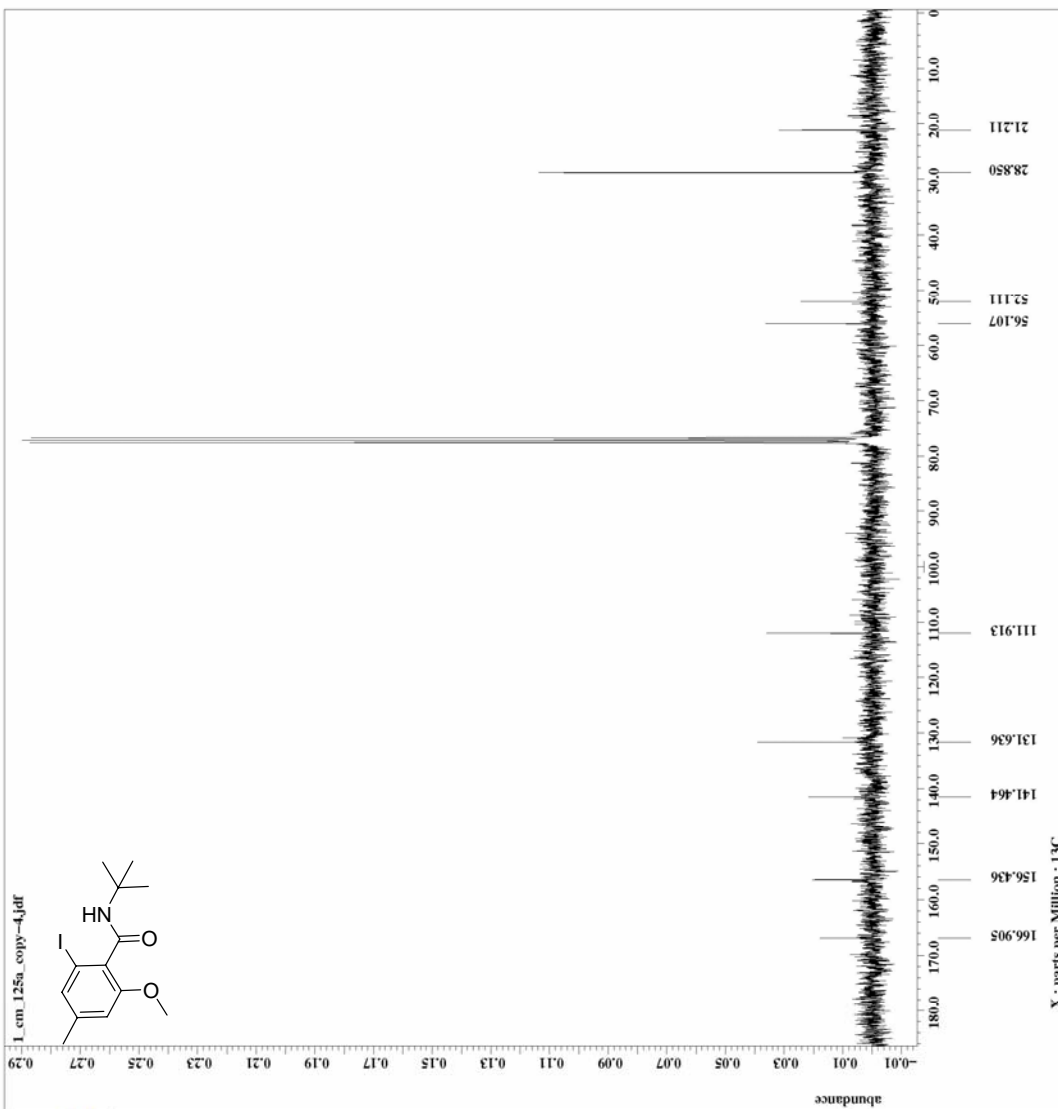
JEOL

Filename = 1_cm_125a-3.jdf
 Author = delta
 Experiment = single pulse.ex2
 Sample_id = S#432860
 Solvent = CHLOROFORM-D
 Creation_time = 2006-12-21 13:07:52
 Acquisition_time = 2006-12-21 17:31:35
 Current_time = 2006-12-21 17:33:15

Content = single pulse
 Data_format = ID COMPLEX
 Dim_size = 13107
 Dim_units = [ppm]
 Dimensions = X
 Site = ECX 300
 Spectrometer = DELTA2_NMR

Field_strength = 7.0566013[T] (300[MHz]
 X_acq_time = 2.90717696[s]
 X_domain = 1H
 X_freq = 300.52965592[MHz]
 X_offset = 5[ppm]
 X_points = 16384
 X_resolution = 1.34397631[Hz]
 X_points = 5.63570784[MHz]
 Irr_domain = 1H
 Irr_freq = 300.52965592[MHz]
 Irr_offset = 5[ppm]
 Tri_domain = 1H
 Tri_freq = 300.52965592[MHz]
 Clipped = FALSE
 Mod_return = 1
 Total_scans = 24

X_90_width = 13.01[us]
 X_acq_time = 2.90717696[s]
 X_angle = 45[deg]
 X_atn = 4[dB]
 X_pulse = 6.505[us]
 Irr_mode = Off
 Tri_mode = Off
 Initial_wait = 1[s]
 Relaxation_delay = 5[s]
 Repetition_time = 23.1[sec]
 Temp_get =



1_cm_125a_copy-4.jdf

CC(C)N(C)C(=O)c1cc(OC)c(C)c(I)c1

JEOL

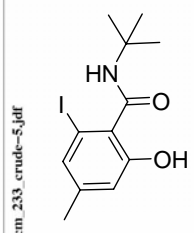
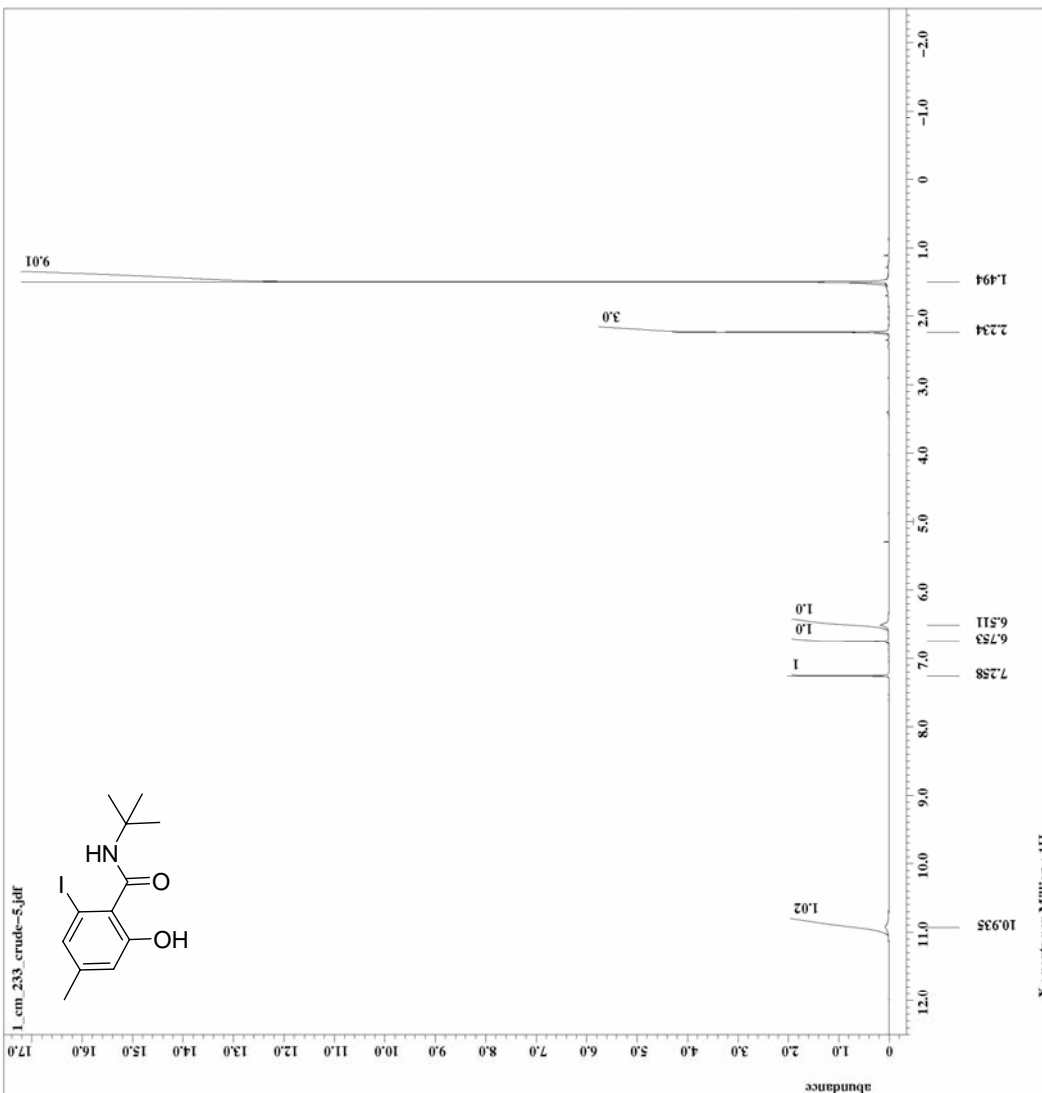
```

Filename = 1_cm_125a_copy-4.jdf
Author = delta
Experiment = single_pulse_dec
Spectrometer = DELTA2_NMR
Solvent = CHLOROFORM-D
Creation_time = 4-FEB-2005 13:19:21
Revision_time = 21-DEC-2006 17:35:35
Current_time = 21-DEC-2006 17:36:12
Content = single_pulse decouple
Data_format = 1D_COMPLEX
Dim_size = 26214
Dim_title = 13C
Dim_units = [ppm]
Dimensions =
Site = KCX 300
Spectrometer = DELTA2_NMR
Field_strength = 7.0586013[T] (300[MHz])
X_acq_duration = 1.38412032[s]
X_delay = 1.38412032[s]
X_freq = 75.56823426[MHz]
X_offset = 100[ppm]
X_points = 32768
X_prescans = 4
X_resolution = 7248054[Hz]
X_sweep_rate = 23.674242[kHz]
Irr_domain = 1H
Irr_freq = 300.52965592[MHz]
Irr_offset = 5[ppm]
Clipped = FALSE
Acquire_date_copy = 1
Mod_return = 129
Total_scans = 129
X_90_width = 9.75[us]
X_acq_time = 1.38412032[s]
X_angle = 30[deg]
X_atn = 8[dB]
X_pulse = 3.25[us]
Irr_atn_dec = 25[dB]
Irr_atn_noe = 25[dB]
Irr_atn = WAU2
Decoupling = TRUE
Initial_wait = 1[s]
Noe_time = TRUE
Noe_time = 3[s]
Relaxation_delay = 3[s]
Repetition_time = 4.38412032[s]
Temp_get = 24[dc]
  
```

APPENDIX 81

¹H and ¹³C NMR SPECTRA OF

N-tert-butyl-6-iodo-2-hydroxy-4-methylbenzamide (101)



JEOL

```

Filename = 1_cm_233_crude-5.jdf
Author =
Experiment = delta_pulse.ex2
Sample_id = 1_cm_233_crude
Solvent = CHLOROFORM-D
Creation_time = 20-DEC-2005 11:57:46
Revision_time = 21-DEC-2006 17:47:04
Current_time = 21-DEC-2006 17:47:52

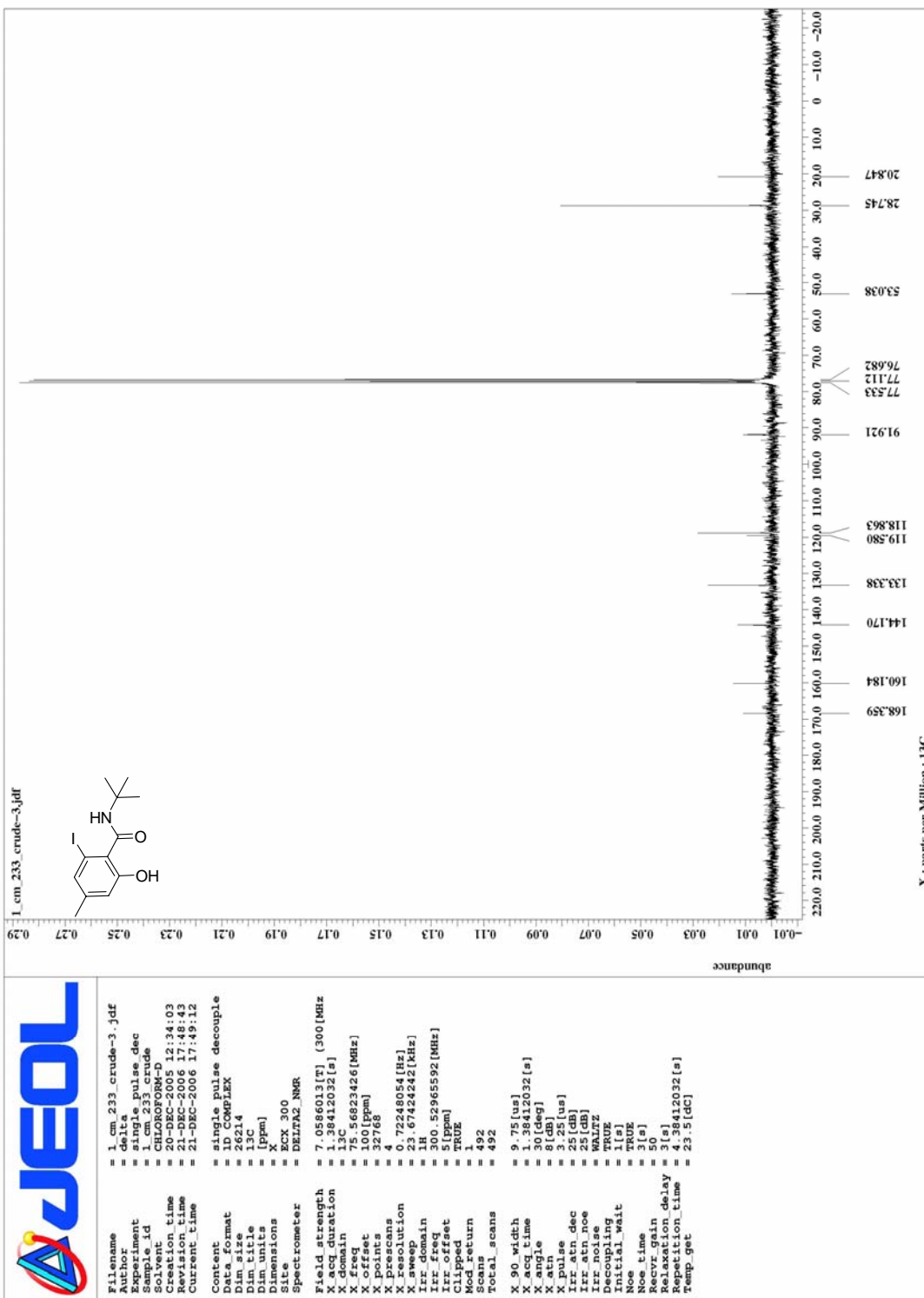
Content = single_pulse
Data_format = ID COMPLEX
Dim_size = 13107
Dim_title = 1H
Dimensions = X
Site = ECX 300
Spectrometer = DELTA2_NMR

Field_strength = 7.0586013(T) (300[MHz]
X_acq_duration = 2.90717696[s]
X_domain = 1H
X_freq = 300.52965592[MHz]
X_offset = 5[ppm]
X_points = 16384
X_resolution = 0.34397631[Hz]
X_sweep = 5.63570784[KHz]

Irr_domain = 1H
Irr_freq = 300.52965592[MHz]
Irr_mode = Off
Tri_domain = 1H
Tri_freq = 300.52965592[MHz]
Tri_offset = 5[ppm]
Clipped = FALSE
Data_return = 24
Total_scans = 24

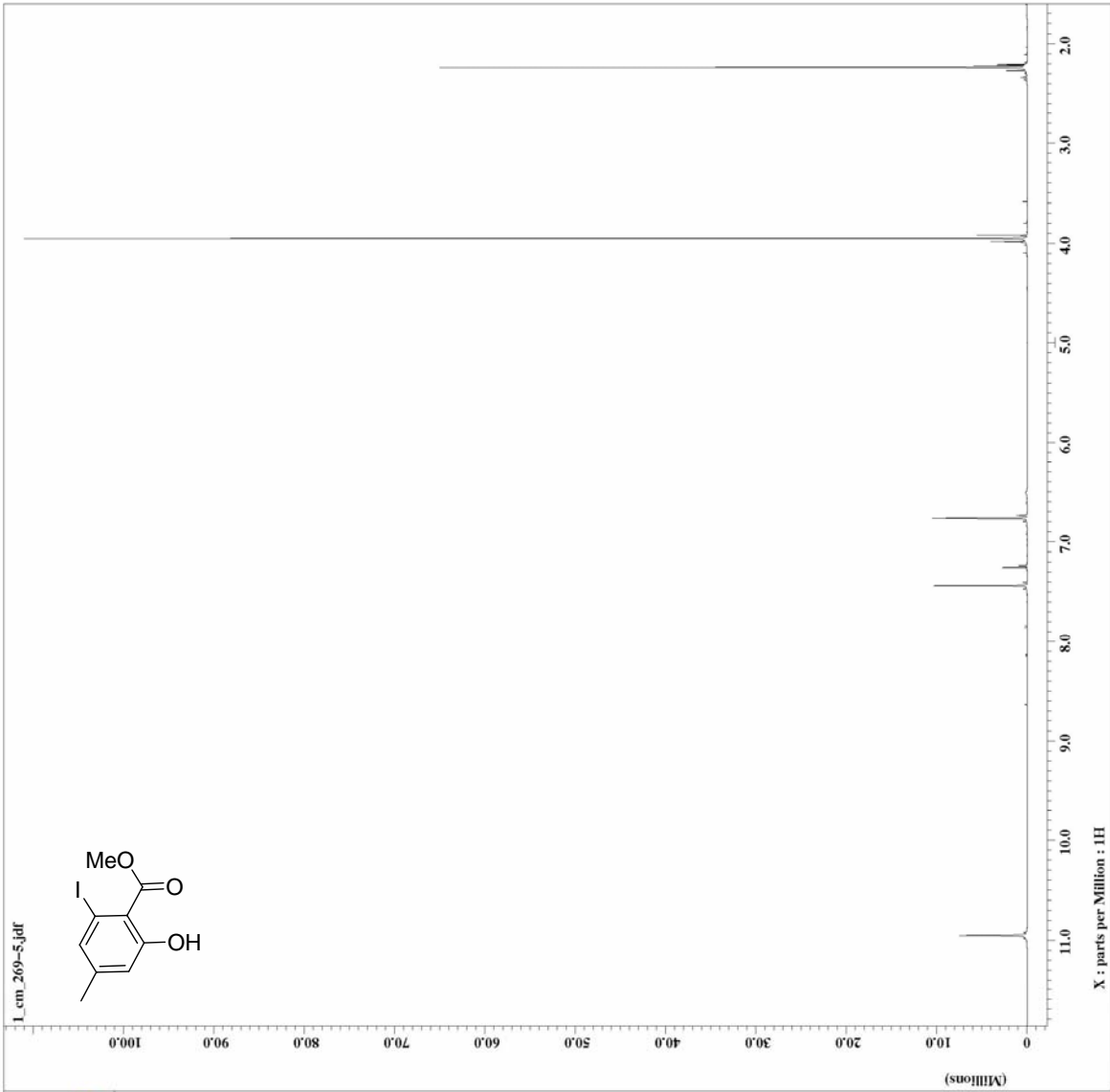
X_90_width = 13.01[us]
X_acq_time = 2.90717696[s]
X_gate = 4[us]
X_atn = 4[dB]
X_pulse = 6.505[us]
Irr_mode = Off
Tri_mode = Off
Initial_wait = 1[s]
Recvr_gain = 46
Relaxation_delay = 5[s]
Repetition_time = 7.90717696[s]
Temp_get = 23.1[DC]

```



APPENDIX 82

**¹H and ¹³C NMR SPECTRA OF
2-Hydroxy-6-iodo-4-methyl-methylbenzoate (102)**



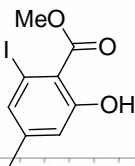
```

Filename = 1_cm_269-5.jdf
Author = delta
Experiment = single_pulse_exp
SampleId = 1
Solvent = CH3OD
Creation time = 24-DEC-2005 20:28:56
Revision time = 21-DEC-2006 18:14:35
Current_time = 21-DEC-2006 18:15:45
Content = Single Pulse Experiment
Data_format = ID COMPLEX
Dim_size = 16384
Dim_title = 1H
Dimensions = [ppm]
Site = Eclipse+ 500
Spectrometer = DELTA_NMR
Field_strength = 11.7473579[T] (500 [MH
X_acq_duration = 2.1823488[s]
X_domain = 1H
X_freq = 500.15991521[MHz]
X_offset = 16384
X_points = 16384
X_prescans = 0
X_resolution = 0.45822189[Hz]
X_sweep = 7.50750751[kHz]
Clipped = FALSE
Mod_return = 1
Scans = 32
Total_scans = 32
X_90_width = 18.5[us]
X_acq_time = 2.1823488[s]
X_angle = 45[deg]
X_pulse = 9.25[us]
Initial_wait = 1[s]
Phase_preset = 3[us]
Recvr_gain = 17
Relaxation_delay = 1[s]
Temp_get = 25.5[dc]
Unblank_time = 2[us]
  
```



Filename = 1_cm_269_copy-5.jdf
Author = delta
Experiment = single_pulse_dec
Sample_id = CHOPOROM-D
Creation_time = 21-DEC-2005 20:43:32
Revision_time = 21-DEC-2006 18:16:13
Current_time = 21-DEC-2006 18:16:30
Content = Single Pulse with Bro
Data_format = ID COMPLEX
Dim_size = 65536
Dim_title = 13C
Units = [ppm]
Dimensions = X
Site = Eclipse+ 500
Spectrometer = DELTA_NMR
Field_strength = 11.7473579[T] (500 [MH
X_acq_duration = 1.736704[s]
X_domain = 13C
X_freq = 125.76529768[MHz]
X_offset = 185 [ppm]
X_pulses = 65536
X_prescans = 4
X_resolution = 0.57580336[Hz]
X_sweep = 37.73584906[KHz]
Irr_domain = 1H
Irr_freq = 500.15991521[MHz]
Irr_offset = 5 [ppm]
Clipped = FALSE
Rod_return = 134
Total_scans = 134
X_90_width = 14.2[us]
X_acq_time = 1.736704[s]
X_angle = 30[deg]
X_pulse = 4.73333333[us]
Initial_wait = 1[s]
Phase_preset = 2[us]
Relaxation_delay = 4[s]
Temp_get = 27.9[dc]
Unblank_time = 2[us]

1_cm_269_copy-5.jdf



3.0

2.0

1.0

0

(Millions)

250.0

230.0

210.0

190.0

170.0

150.0

130.0

110.0

90.0

70.0

50.0

30.0

10.0

-10.0

-30.0

-50.0

169.120

162.509

146.581

135.267

118.556

113.895

93.805

51.835

28.737

21.032

X : parts per Million : 13C

APPENDIX 83

^1H and ^{13}C NMR SPECTRA OF

2-Methoxy-6-iodo-4-methyl-methylbenzoate (103)



```

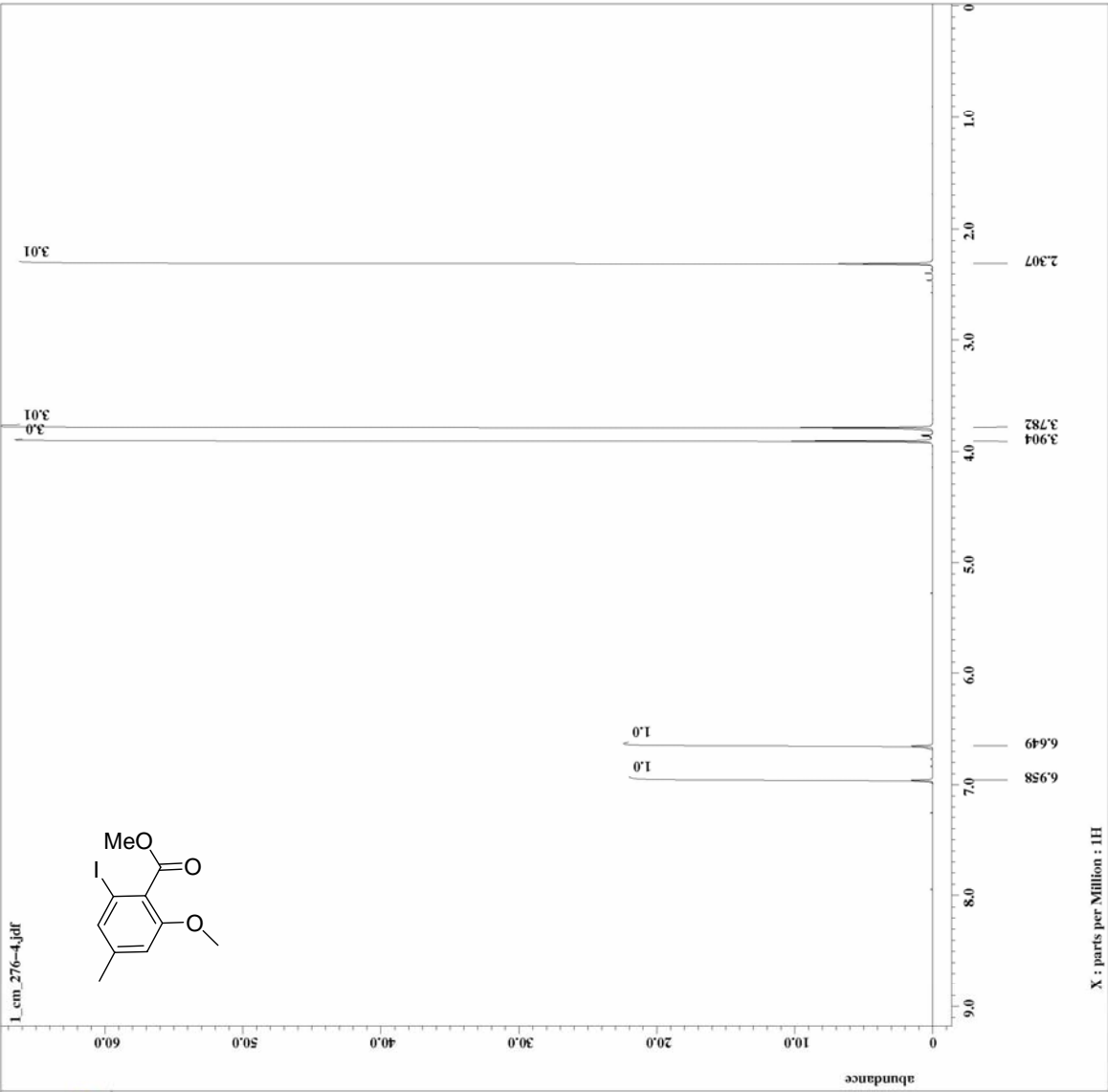
Filename = 1_cm_276-4.jdf
Author = delta
Experiment = single_pulse.ex2
Sample_id = 1_cm_276
Solvent = CHLOROFORM-D
Creation_time = 1-FEB-2006 13:49:04
Revision_time = 1-FEB-2006 12:59:32
Current_time = 21-DEC-2006 16:25:14

Content = single pulse
Data_format = 1D COMPLEX
Dim_size = 13107
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Site = ECX 300
Spectrometer = DELTA2_NMR

Field_strength = 7.0586013[T] (300[MHz]
X_acq_duration = 2.90717696[s]
X_domain = 1H
X_freq = 300.52965592[MHz]
X_offset = 5[ppm]
X_points = 16384
X_prescans = 1
X_resolution = 0.34297631[Hz]
X_sweep = 1H
X_sweep_gain = 1H 63570784[KHz]
X_sweep_rate = 1H 21875.28[KHz/s]
Irr_freq = 300.52965592[MHz]
Irr_offset = 5[ppm]
Tri_domain = 1H
Tri_freq = 300.52965592[MHz]
Tri_offset = 5[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 24
Total_scans = 24

X_90_width = 13.01[us]
X_acq_time = 2.90717696[s]
X_angle = 45[deg]
X_atn = 4[db]
X_pulse = 6.505[us]
Irr_mode = Off
Tri_mode = Off
Date_preset = FALSE
Date_acq = 1FEB2006
Recur_delay = 1[s]
Recur_gain = 30
Relaxation_delay = 5[s]
Repetition_time = 7.90717696[s]
Temp_get = 22.2[dc]

```





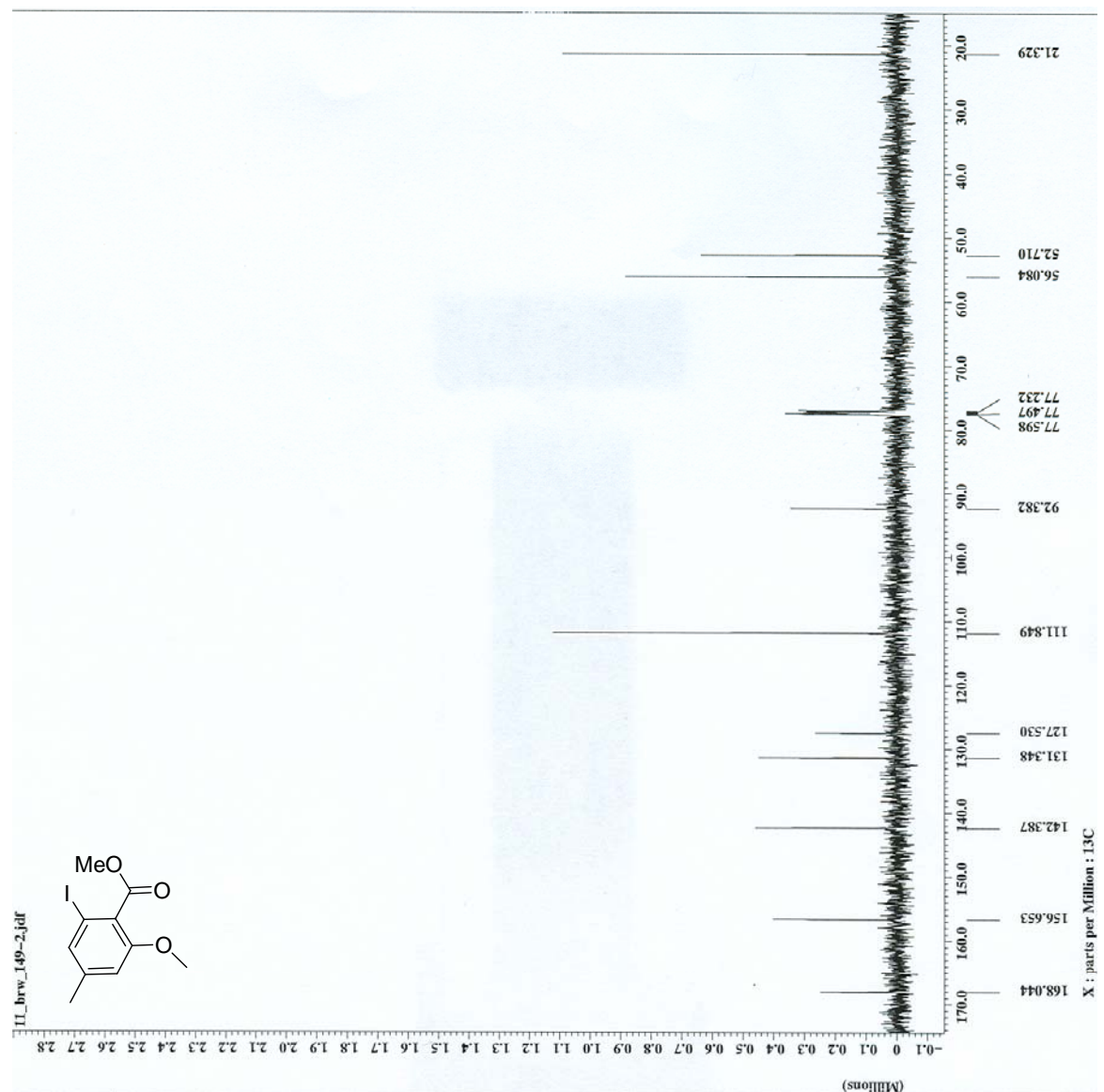
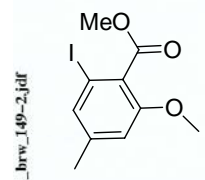
```

Filename = 11_brw_149-2.jdf
Author = delta
Experiment = single_pulse_dec
Sample_id = 11_brw_149
Solvent = CHLOROFORM-D
Acquisition_time = 11:29:35
Relaxation_time = 21-JUL-2006 10:44:41
Current_time = 21-JUL-2006 10:43:04

Content = Single Pulse with Bro
Data_format = ID COMPLEX
Dim_size = 65536
Dim_title = 13C
Dim_units = [ppm]
Dimensions = X
X_resolution = 500
Spectrometer = DELTA_NMR

Field_strength = 11.7473579 [T] (500 [MH]
X_acq_duration = 1.736704 [s]
X_domain = 13C
X_freq = 125.76529768 [MHz]
X_offset = 100 [ppm]
X_points = 65536
X_prescan = 0
X_resolution = 0.57580336 [kHz]
X_sweep = 37.73584906 [kHz]
X_domain = 1H
Irr_domain = 500.15991521 [MHz]
Irr_freq = 5 [ppm]
Irr_offset = FALSE
Clipped = 1
Mod_return = 143
Scans = 143
Total_scans = 143

X_90_width = 14.2 [us]
X_acq_time = 1.736704 [s]
X_angle = 30 [deg]
X_pulse = 4.73333333 [us]
Initial_wait = 1 [s]
Phase_preset = 3 [us]
Recvr_gain = 30
Relaxation_delay = 4 [s]
Temp_get = 27.8 [cC]
Unblank_time = 2 [us]
  
```



APPENDIX 84

^1H and ^{13}C NMR SPECTRA OF

2- Iodo-4-methyl-6-methoxy-benzylalcohol (104)



```

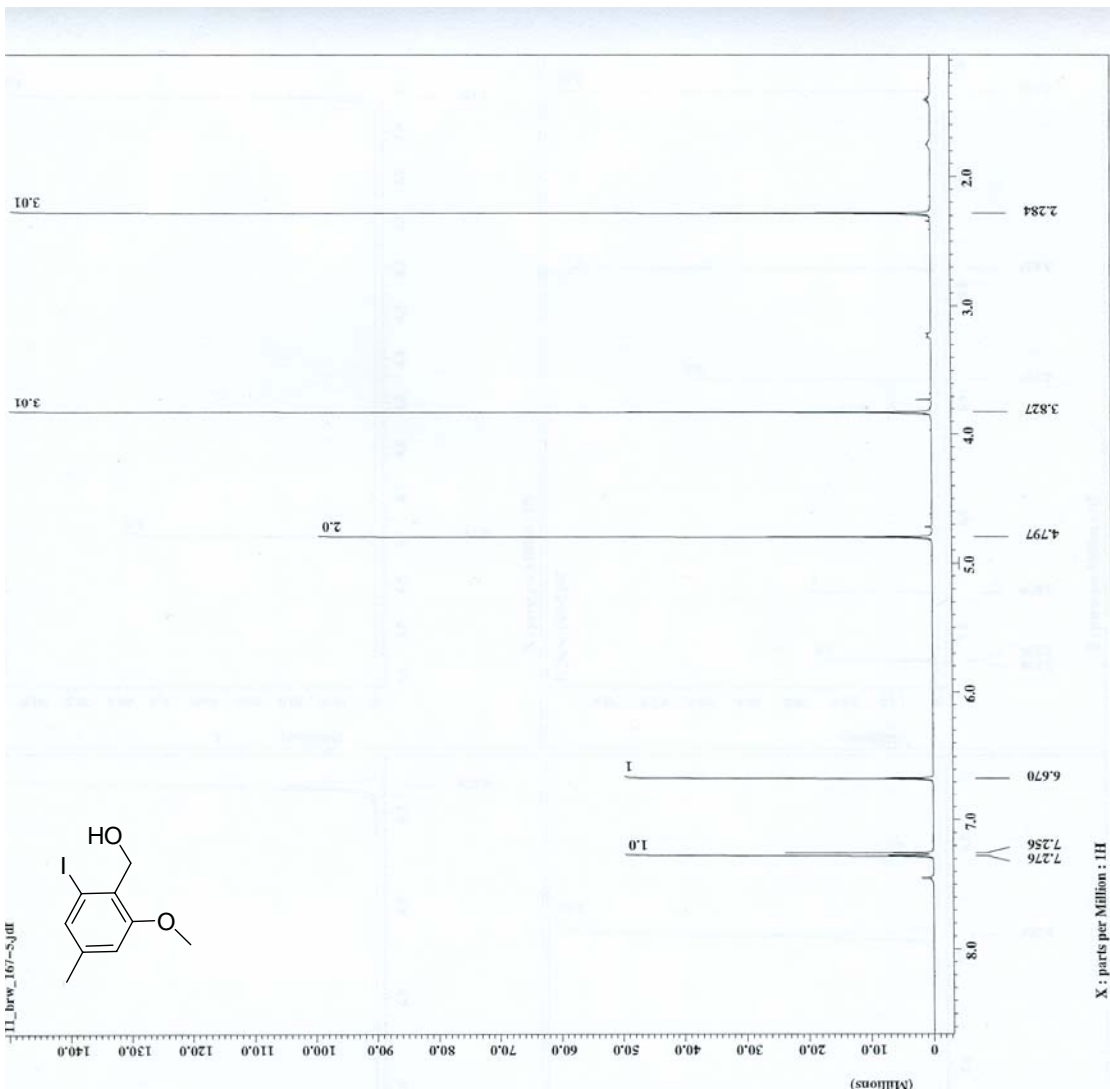
Filename      = 11_brw_167-5.jdf
Date_         = dal
Experiment    = single_pulse.exp
Sample_id     = S8449330
Solvent       = CHLOROFORM-D
Creation_Time = 7-SEP-2006 13:51:21
Revision_Time = 7-SEP-2006 12:35:02
Current_Time  = 7-SEP-2006 12:36:12

Content       = Single Pulse Experiment
Data_format  = 1D COMPLEX
Dir_size     = 16384
Dir_title    = 1H
Dir_units    = [ppm]
Dimensions   = X
Kojima+500  = X
Spectrometer = DELTA_SMR

Field_strength = 11.7473579 [T] (500 MHz)
X_acq_duration = 2.1823488 [s]
X_domain       = 1H
X_freq         = 500.1591521 [MHz]
X_gate        = 16384
X_inject      = 0
X_prescans    = 0
X_resolution  = 0.45822189 [Hz]
X_sweep       = 7.50750751 [MHz]
Clipped       = FALSE
Mod_return    = 1
Scans         = 32
Total_scans   = 32

X_90_width   = 18.5 [us]
X_acq_time   = 2.1823488 [s]
X_angle      = 45 [deg]
X_pulse      = 9.25 [us]
X_ref_delay  = 3 [us]
Recovery     = 18
Relaxation_delay = 1 [s]
Temp_get     = 25.2 [dc]
Unblank_time = 2 [us]

```





```

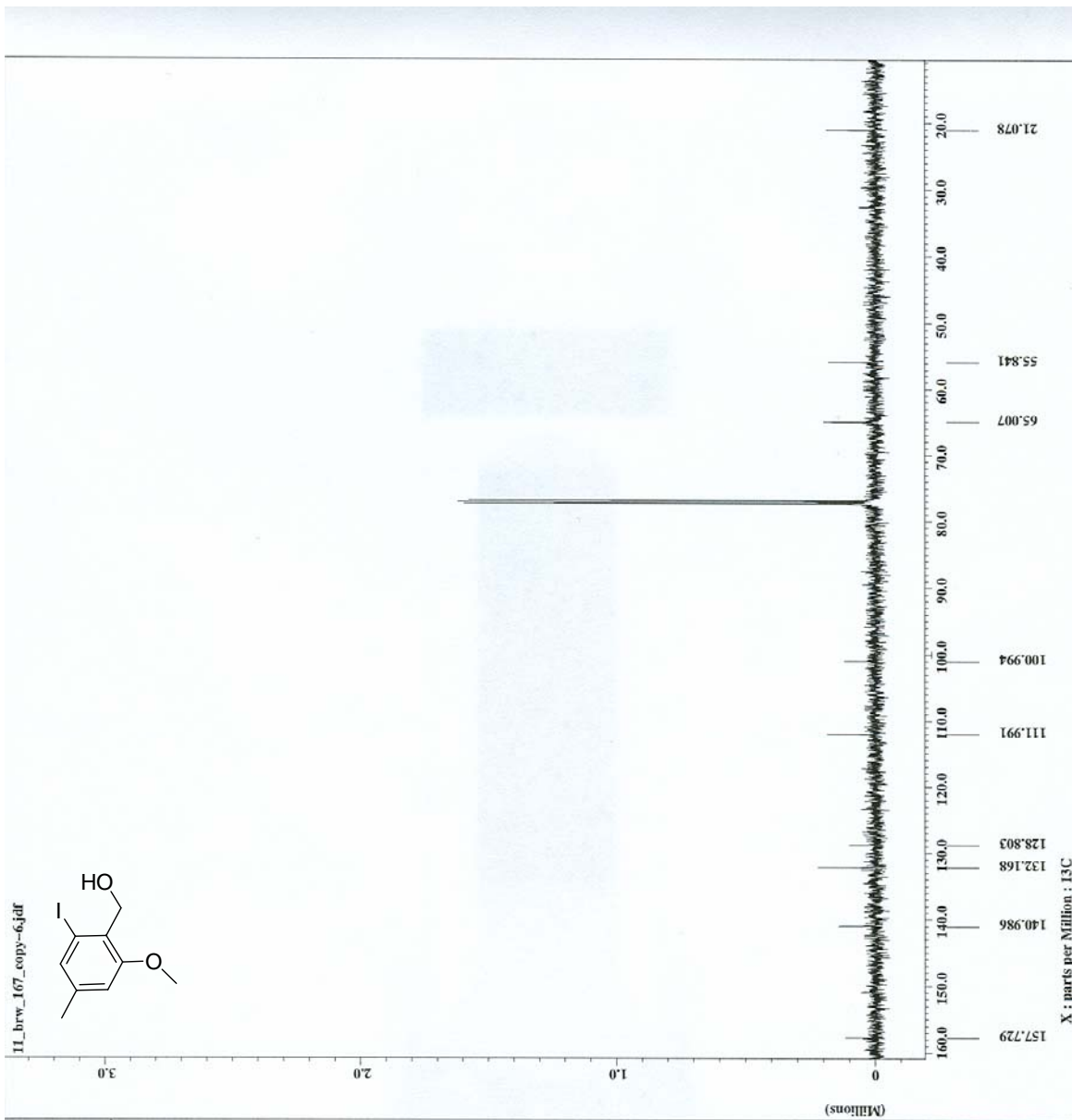
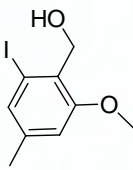
File name      = 11_brw_167_copy-6.jdf
Author        = delta_pulse_dec
Experiment     = 11_brw_167
Sample ID     = CHLOROFORM-D
Solvent       = CHLOROFORM-D
Creation time  = 7-SEP-2006 14:15:07
Revision time  = 7-SEP-2006 12:56:13
Current time   = 7-SEP-2006 12:57:33

Content       = Single Pulse with Bro
Data format   = 1D COMPLEX
Dir size      = 65536
Dir title     = 13C
Dir units     = [ppm]
Dimensions    = X
Site          = Eclipse+ 500
Spectrometer  = DELTA_NMR

Field strength = 11.7478579 [T] (500 [MH]
X_acq_duration = 1.736704 [s]
X_domain       = 13C
X_freq         = 125.76529768 [MHz]
X_offset       = 100 [ppm]
X_points       = 65536
X_prescans     = 4
X_resolution   = 0.57580336 [Hz]
X_sweep        = 37.73584906 [MHz]
F1_domain      = 500.15991521 [MHz]
F1_offset      = 5 [ppm]
Clipped        = FALSE
Mod_return     = 1
Total_scans    = 226.0

X_90_width    = 14.2 [us]
X_acq_time    = 30.736704 [s]
X_pulse       = 30.736704 [us]
X_pulse       = 4.73333333 [us]
Initial wait  = 1 [s]
Phase preset  = 3 [us]
Recvr_gain    = 30
Relaxation_delay = 4 [s]
Temp_get      = 27.3 [dC]
Unblank_time  = 2 [us]
  
```

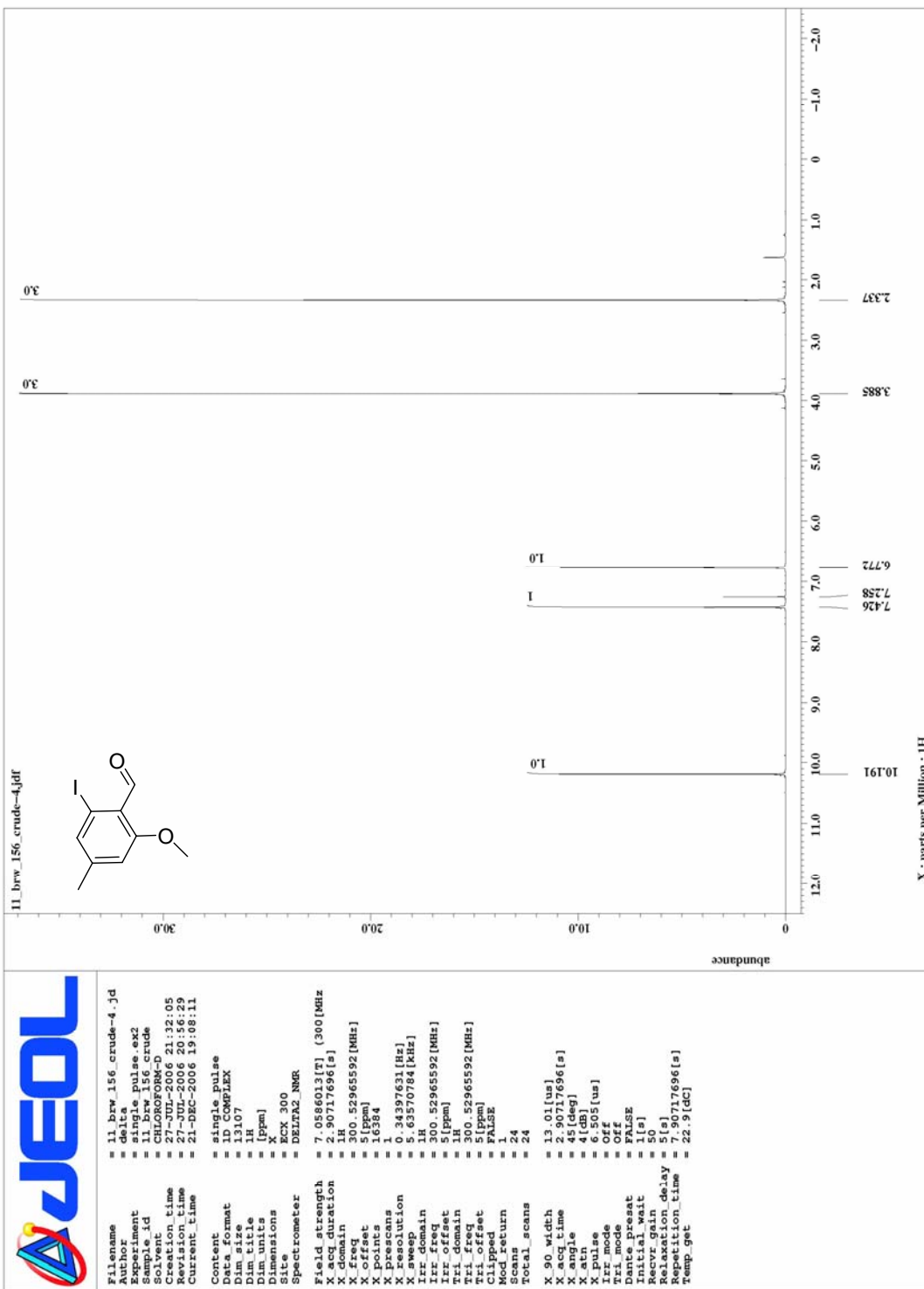
11_brw_167_copy-6.jdf



APPENDIX 85

^1H and ^{13}C NMR SPECTRA OF

2- Iodo-4-methyl-6-methoxy-benzylaldehyde (105)





```

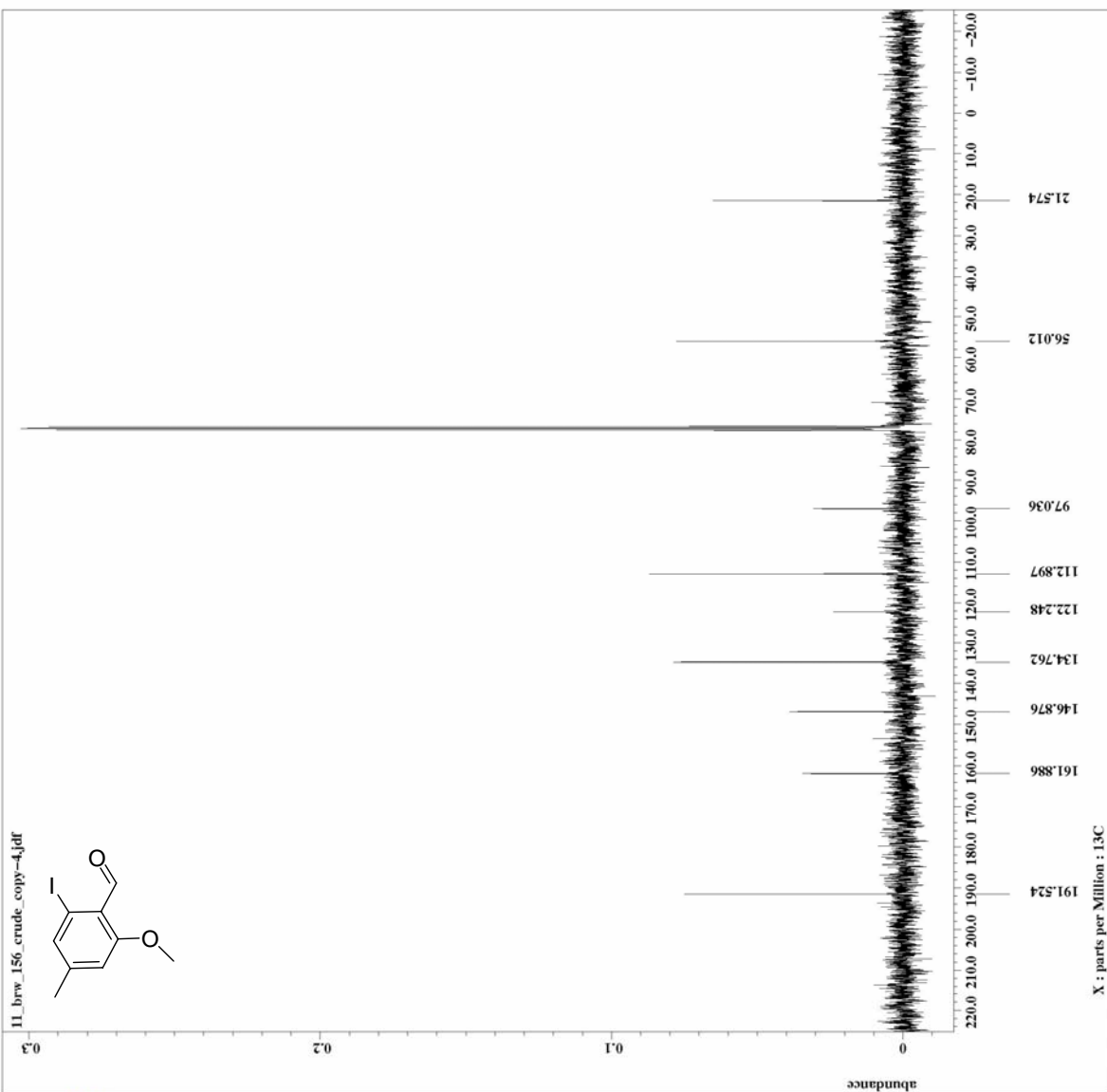
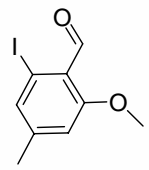
Filename = 11_brw_156_crude_copy
Author = delta
Experiment = single pulse dec
Sample_id = 11_brw_156_crude
Solvent = CHLOROFORM-D
Creation_time = 27-JUL-2006 21:39:21
Revision_time = 27-JUL-2006 21:02:35
Current_time = 21-DEC-2006 19:08:47

Content = single pulse decouple
Det_format = ID_COMPLEX
Dim_size = 26214
Dim_title = 13C
Dim_units = [ppm]
Dimensions = X
Site = ECX 300
Spectrometer = DELTA2_NMR

Field_strength = 7.0586013[T] (300[MHz]
X_acq_duration = 1.38412032[s]
X_chan = 13C
X_freq = 75.56823426[MHz]
X_offset = 100[ppm]
X_points = 32768
X_prescans = 4
X_resolution = 0.72248054[Hz]
X_sweep = 23.67424242[kHz]
Irr_domain = 1H
Irr_freq = 300.52965592[MHz]
Irr_offset = 5[ppm]
Clipped = NONE
Mod = TRUE
Mod_return = 1
Total_scans = 95

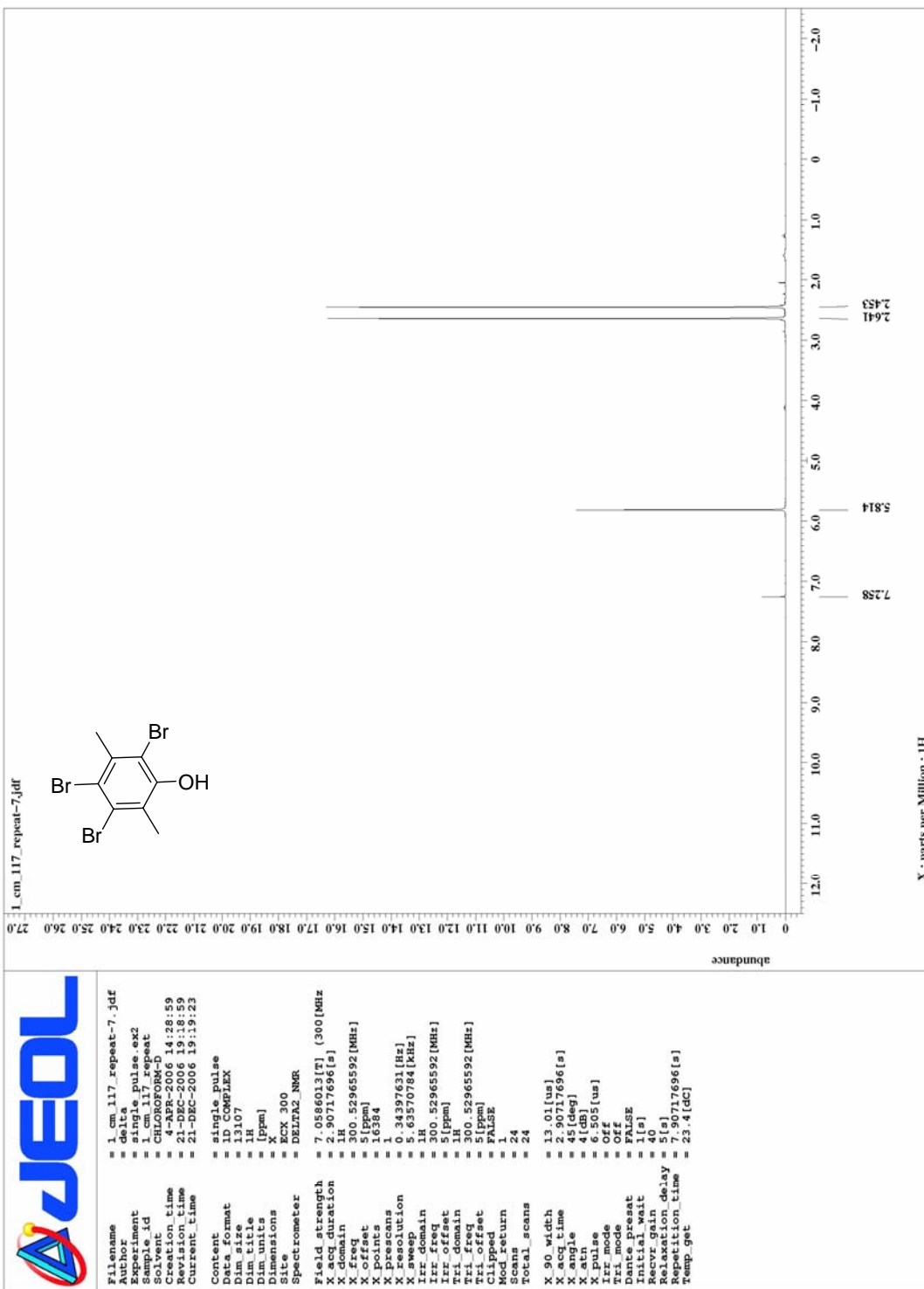
X_90_width = 9.75[us]
X_acq_time = 1.38412032[s]
X_angle = 30[deg]
X_atn = 8[db]
X_pulse = 25[us]
X_pulse_dec = 25[us]
Irr_atn_noe = 25[db]
Irr_noise = WALTZ
Decoupling = TRUE
Initial_wait = 1[s]
Noe = TRUE
Noe_time = 3[s]
Recvr_gain = 50
Relaxation_delay = 3[s]
Repetition_time = 4.38412032[s]
Temp_get = 23[degC]
  
```

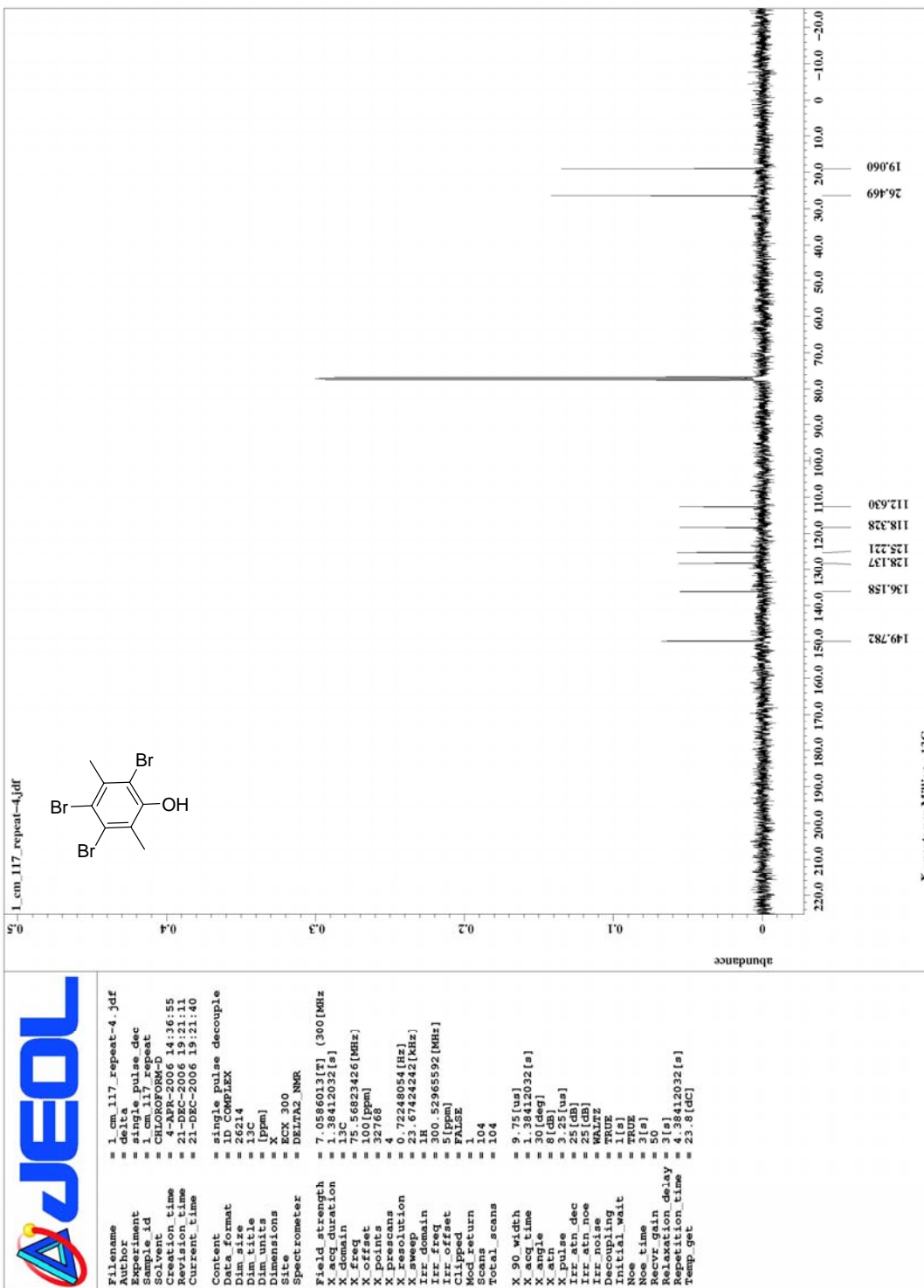
11_brw_156_crude_copy-4.jdf



APPENDIX 86

**^1H and ^{13}C NMR SPECTRA OF
3,4,6-Tribromo-2,5-dimethylphenol (109)**





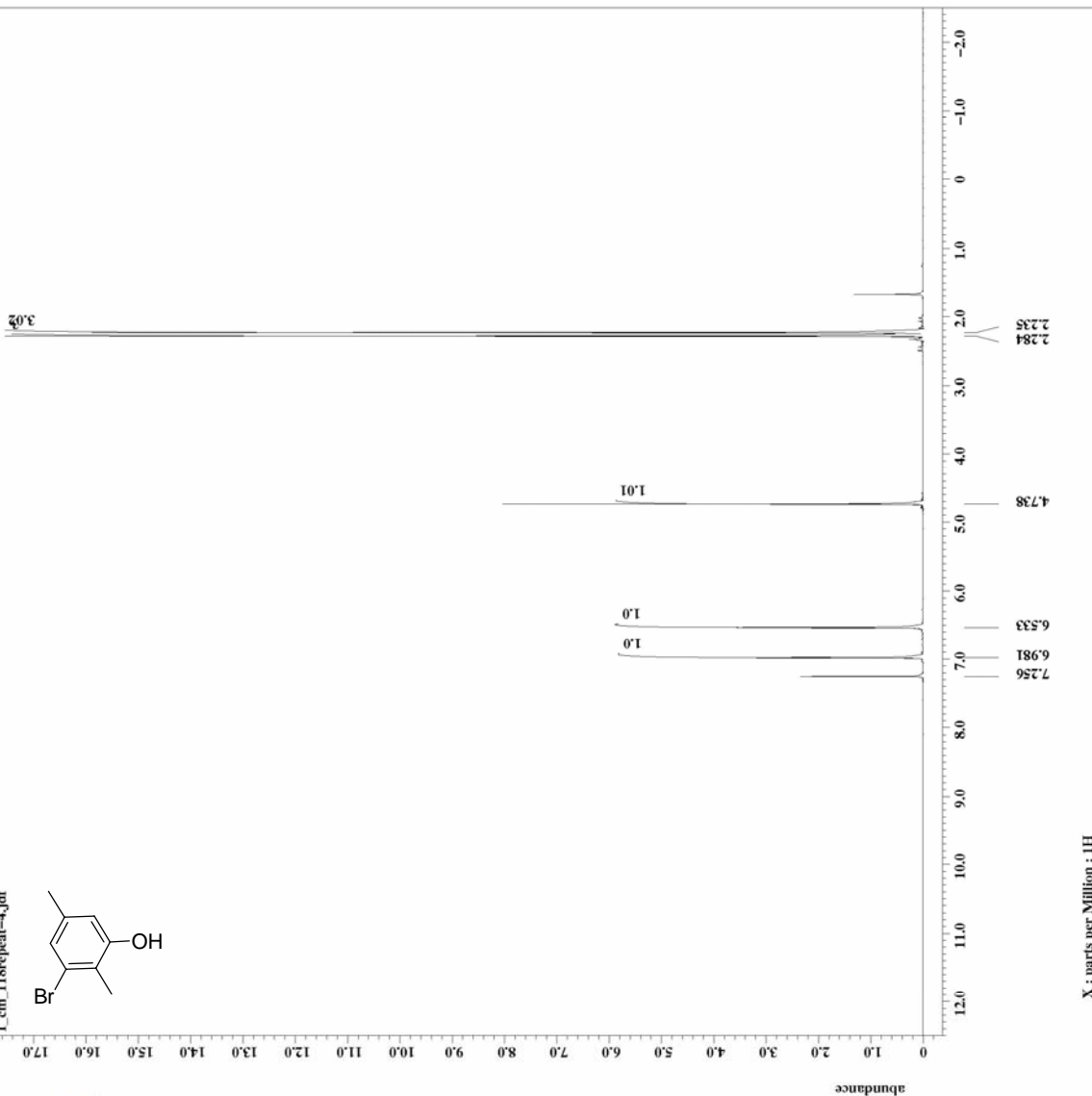
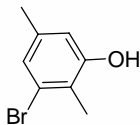
APPENDIX 87

**^1H and ^{13}C NMR SPECTRA OF
3-Bromo-2,5-dimethylphenol (110)**



Filename = 1_cm_118repeat-4_jdf
Author = delta
Experiment = single_pulse.ex2
Sample_id = S#595938
Solvent = CHLOROFORM-D
Creation_time = 24-DEC-2004 17:35:36
Revision_time = 21-DEC-2004 16:38:19
Current_time = 21-DEC-2004 19:34:06
Content = single_pulse
Data_format = 1D_COMPLEX
Dim_size = 13107
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Site = ECX 300
Spectrometer = DELTA2_NMR
Field_strength = 7.0586013[T] (300[MHz]
X_acq_duration = 2.90717696[s]
X_domain = 1H
X_freq = 300.52965592[MHz]
X_offset = 5[ppm]
X_points = 16384
X_prescans = 1
X_resolution = 0.34297621[Hz]
X_sweep = 1H
X_sweep_gain = 63570784[KHz]
Irr_freq = 300.52965592[MHz]
Irr_offset = 5[ppm]
Tri_domain = 1H
Tri_freq = 300.52965592[MHz]
Tri_offset = 5[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 1
Total_scans = 19
X_90_width = 13.01[us]
X_acq_time = 2.90717696[s]
X_angle = 45[deg]
X_atn = 4[db]
X_pulse = 6.503[us]
Irr_mode = Off
Date_preset = Off
Date_time = 20041224173536
Recvr_gain = 16[s]
Relaxation_delay = 50
Repetition_delay = 5[s]
Repetition_time = 7.90717696[s]
Temp_get = 21.7[dc]

1_cm_118repeat-4_jdf



X: parts per Million : 1H



```

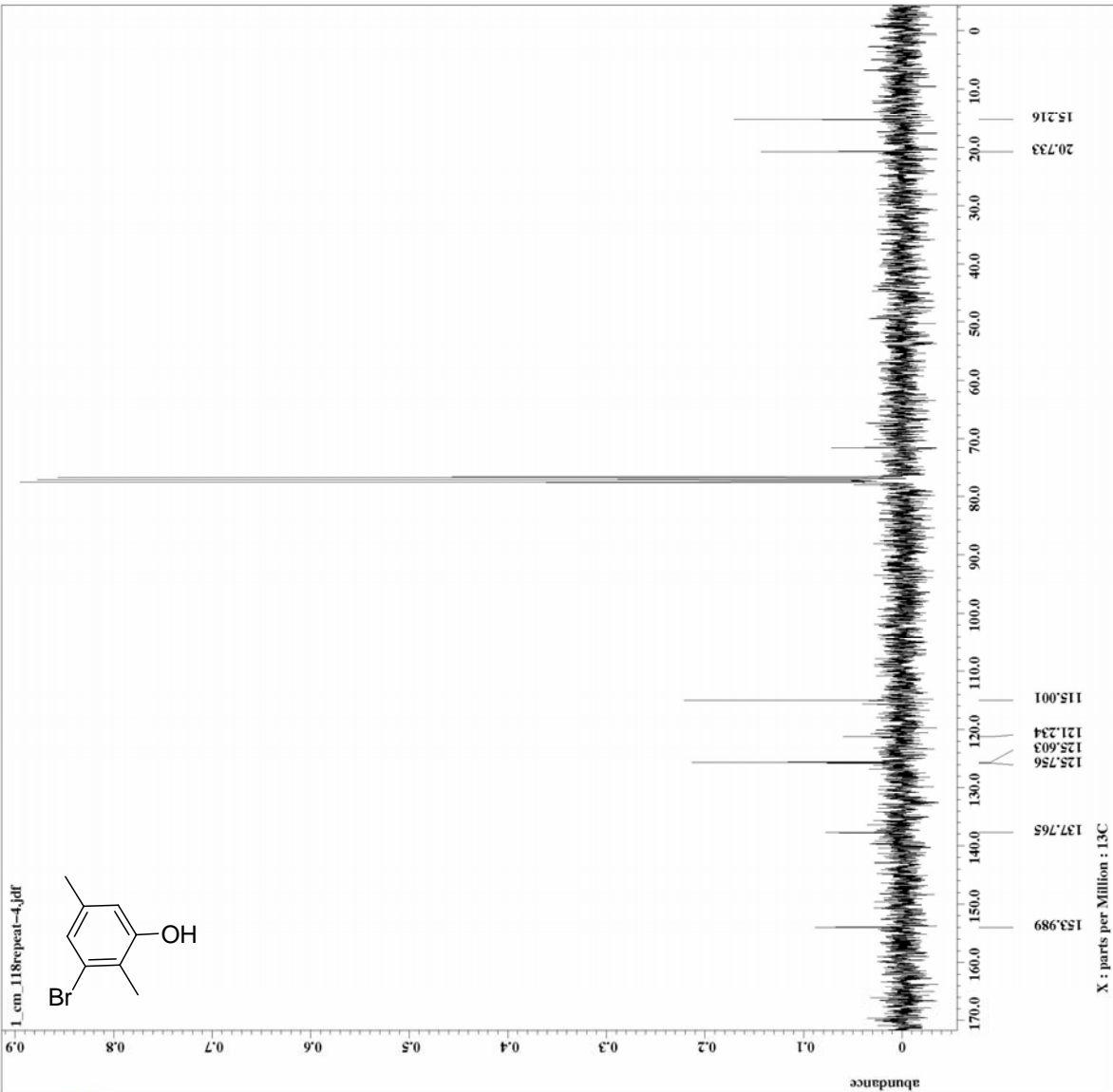
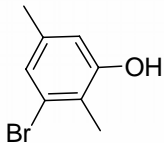
Filename = l_cm_118repeat-4.jdf
Author = delta
Experiment = single_pulse_dec
Sample_id = CH57062RM-D
Date_1 = 24-DEC-2004 17:41:08
Date_2 = 24-DEC-2004 17:41:08
Collection_time = 21-DEC-2006 19:32:04
Revision_time = 21-DEC-2006 19:33:28
Current_time = 21-DEC-2006 19:33:28

Content = single pulse decouple
Data_format = ID COMPLEX
Dim_size = 26214
Dim_title = 13C
Dim_units = [ppm]
Dimensions = 1
Spectrometer = ECX 300
P1 = DELTA2_NMR

Field_strength = 7.0586013[T] (300[MHz]
X_acq_duration = 1.38412032[s]
X_domain = 13C
X_freq = 75.56823426[MHz]
X_offset = 100[ppm]
X_points = 32768
X_prescans = 4
X_resolution = 7248054[Hz]
X_resolution_hz = 23.7248054[kHz]
X_resolution_khz = 18.67424242[kHz]
Irr_domain = 13C
Irr_freq = 300.52965592[MHz]
Irr_offset = 5[ppm]
Clipped = TRUE
Mod_return = 1
Scans = 61
Total_scans = 61

X_90_width = 9.75[us]
X_acq_time = 1.38412032[s]
X_cycle_time = 30[deg]
X_atn = 8[db]
X_pulse = 3.25[us]
Irr_atn_dec = 25[db]
Irr_atn_noe = 25[db]
Irr_noise = WALTZ
Decoupling = TRUE
Initial_wait = 1[s]
Noe_time = TRUE
Relaxation_delay = 6[s]
Repetition_delay = 3[s]
Repetition_time = 4.38412032[s]
Temp_get = 22.1[dc]
  
```

l_cm_118repeat-4.jdf



APPENDIX 88

**^1H and ^{13}C NMR SPECTRA OF
3-Bromo-2,5-dimethylanisole (111)**



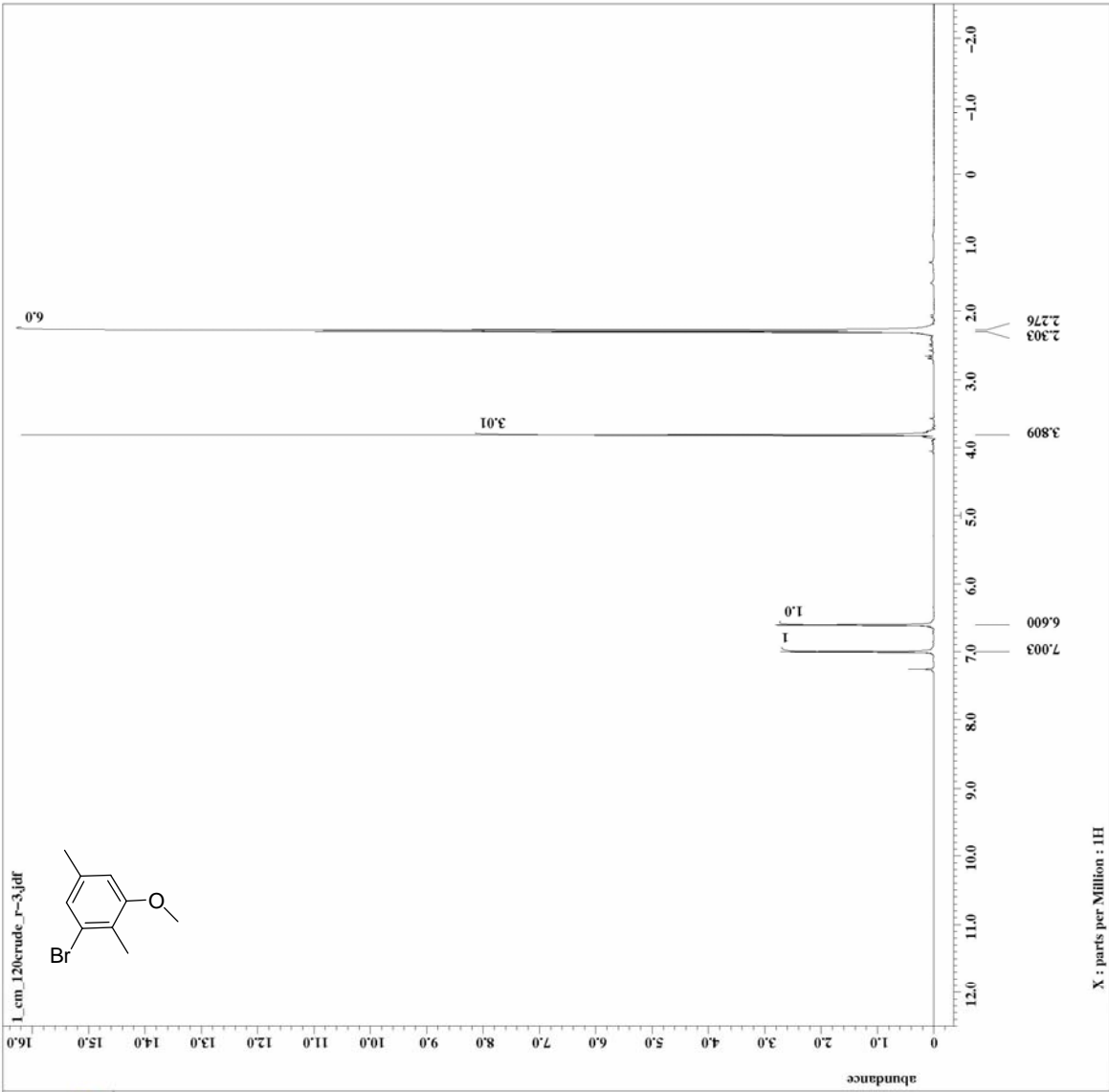
```

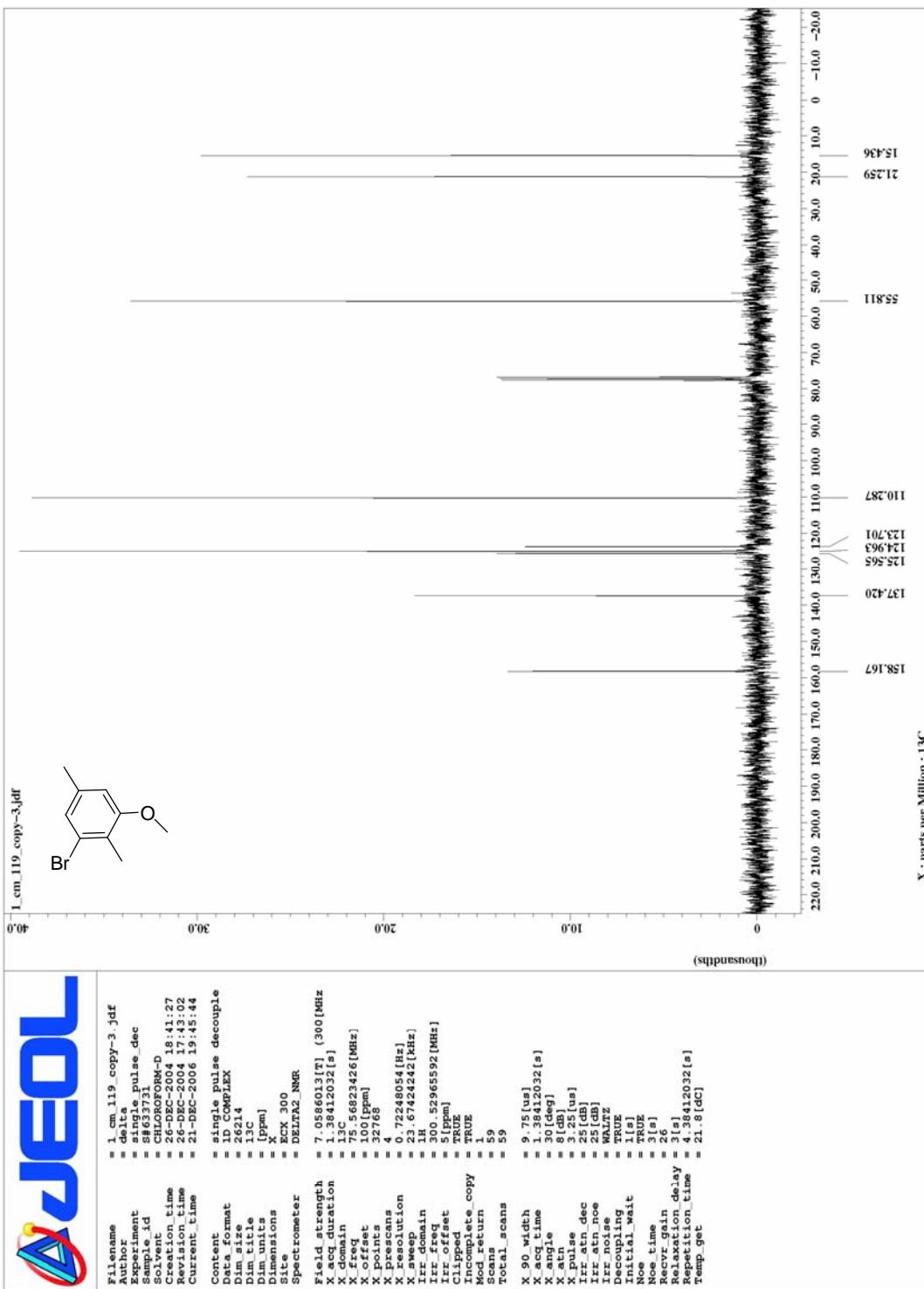
Filename = 1_cm_120crude_r-3.jdf
Author = delta
Experiment = single_pulse.ex2
Sample_id = CHLORFORM-D
Creation_time = 5-JAN-2005 21:55:02
Revision_time = 21-DEC-2006 19:43:34
Current_time = 21-DEC-2006 19:44:07

Content = single_pulse
Data_format = ID COMPLEX
Dim_size = 13107
Dim_title = 1H
Dimensions = X [ppm]
Site = ECX 300
Spectrometer = DELTA2_NMR

Field_strength = 7.0586013[T] (300[MHz]
X_acq_duration = 2.90717696[s]
X_domain = 1H
X_freq = 300.52965592[MHz]
X_offset = 16384
X_prescans = 1
X_resolution = 0.34397631[Hz]
X_sweep = 5.63570784[kHz]
Irr_domain = 1H
Irr_freq = 300.52965592[MHz]
Irr_offset = 5[ppm]
Tri_domain = 1H
Tri_freq = 300.52965592[MHz]
Tri_offset = 5[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 24
Total_scans = 24

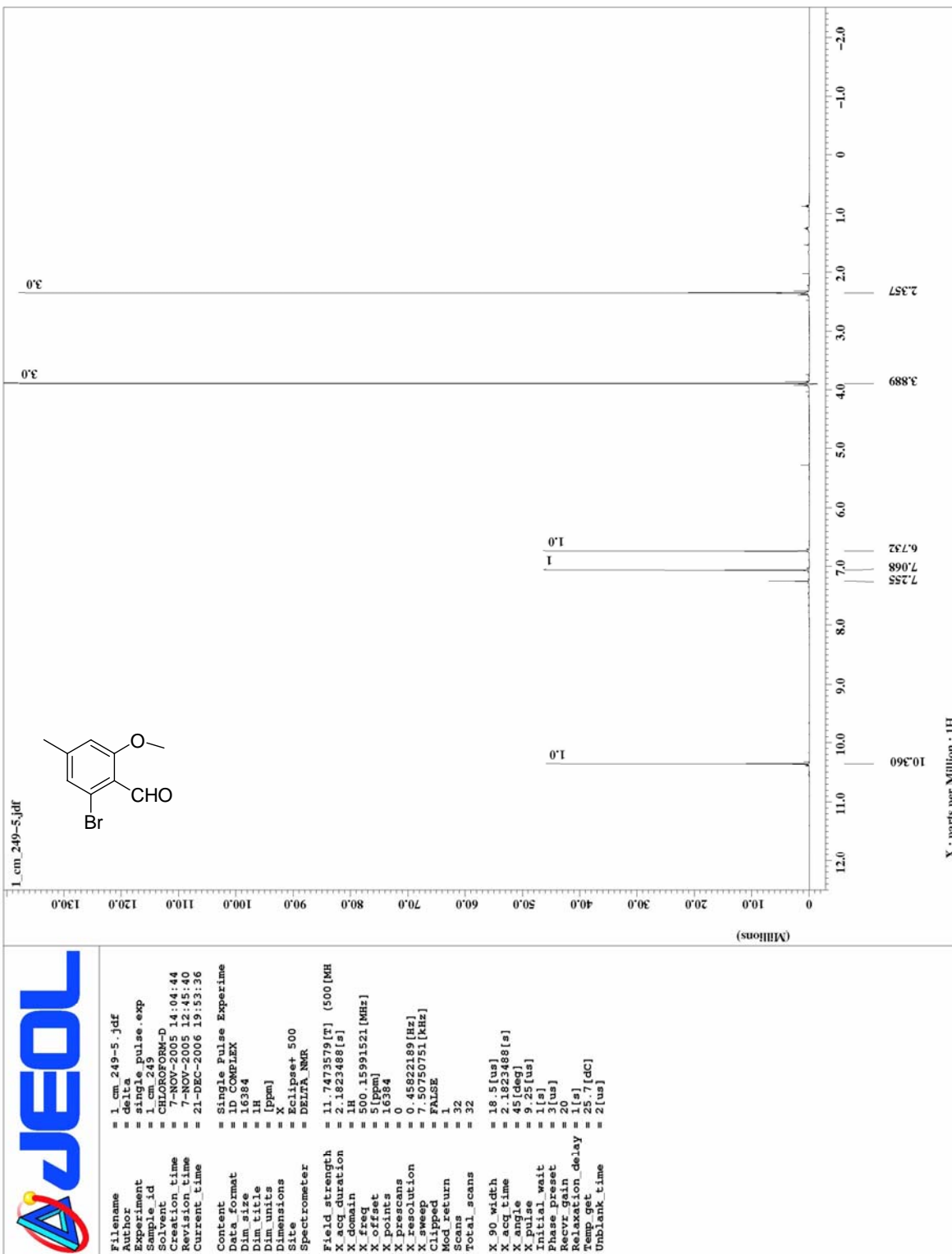
X_90_width = 13.01[us]
X_acq_time = 2.90717696[s]
X_angle = 45[deg]
X_sh = 6[us]
X_stir = 650[us]
Irr_mode = Off
Tri_mode = Off
Dante_preset = FALSE
Initial_wait = 1[s]
Recvr_gain = 40
Relaxation_delay = 5[s]
Repetition_time = 7.90717696[s]
Temp_get = 23.7[dc]
  
```





APPENDIX 89

**^1H and ^{13}C NMR SPECTRA OF
2-Bromo-6-methoxy-4-methylbenzaldehyde (112)**





```

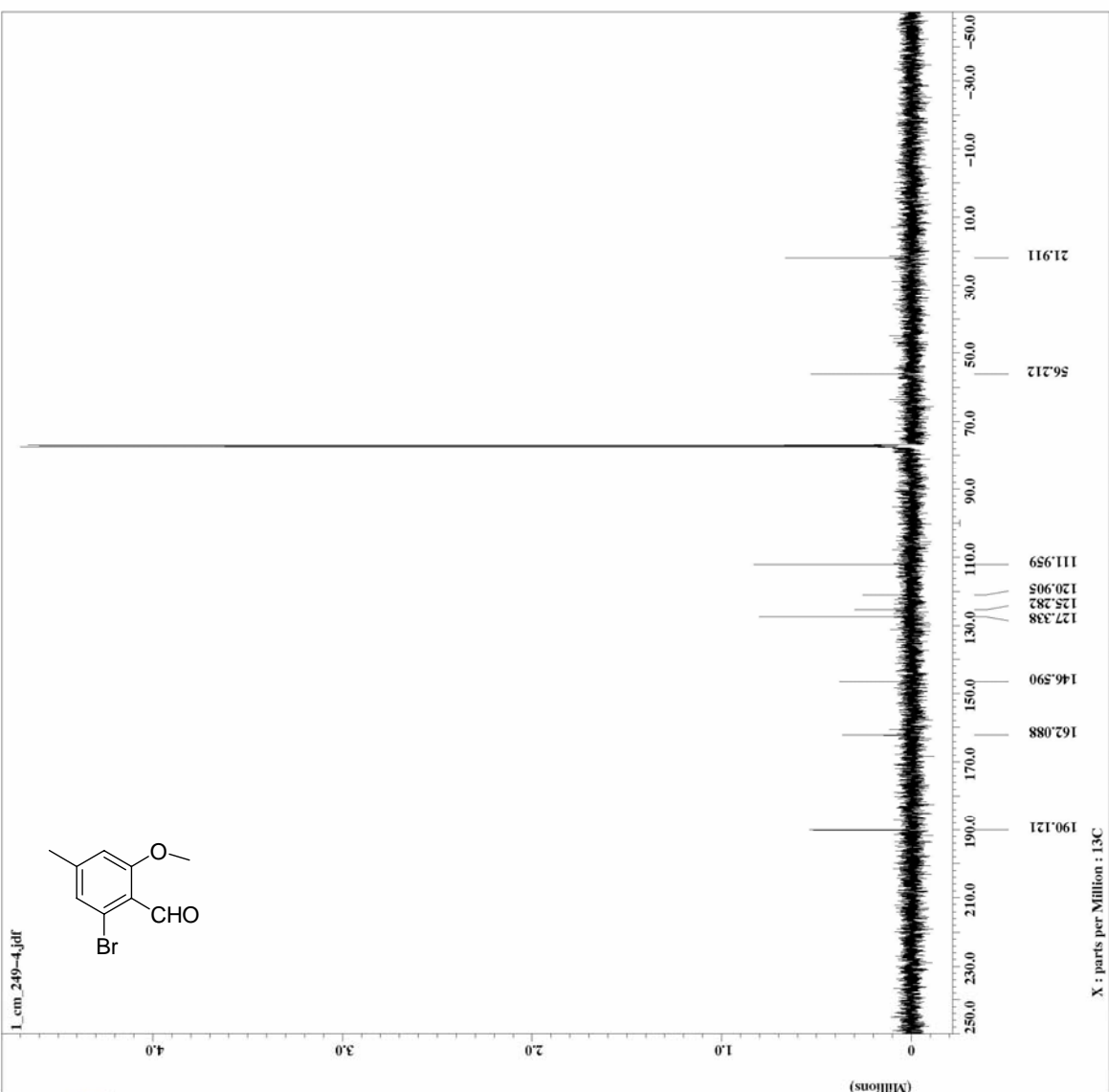
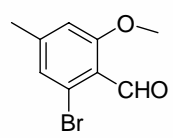
Filename = 1_cm_249-4.jdf
Author = delta
Experiment = single_pulse_dec
Sample_id = 1_cm_249
Solvent = CHLOROFORM-D
Creation_time = 7-NOV-2005 14:15:23
Revision_time = 21-DEC-2006 19:54:40
Current_time = 21-DEC-2006 19:54:57

Content = Single Pulse with Bro
Data_format = 1D COMPLEX
Dim_size = 65536
Dim_title = 13C
Dim_units = [ppm]
Dimensions = X
Site = Eclipse 500
Spectrometer = DELTA_NMR

Field_strength = 11.7473579[T] (500[MH
X_acq_duration = 1.736704[s]
X_domain = 13C
X_freq = 125.76529768[MHz]
X_offset = 100[ppm]
X_points = 65536
X_prescans = 4
X_resolution = 0.5758036[Hz]
X_sweep = 37.73584906[kHz]
X_tau = 1H
Irr_freq = 500.15991521[MHz]
Irr_offset = 5[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 90
Total_scans = 90

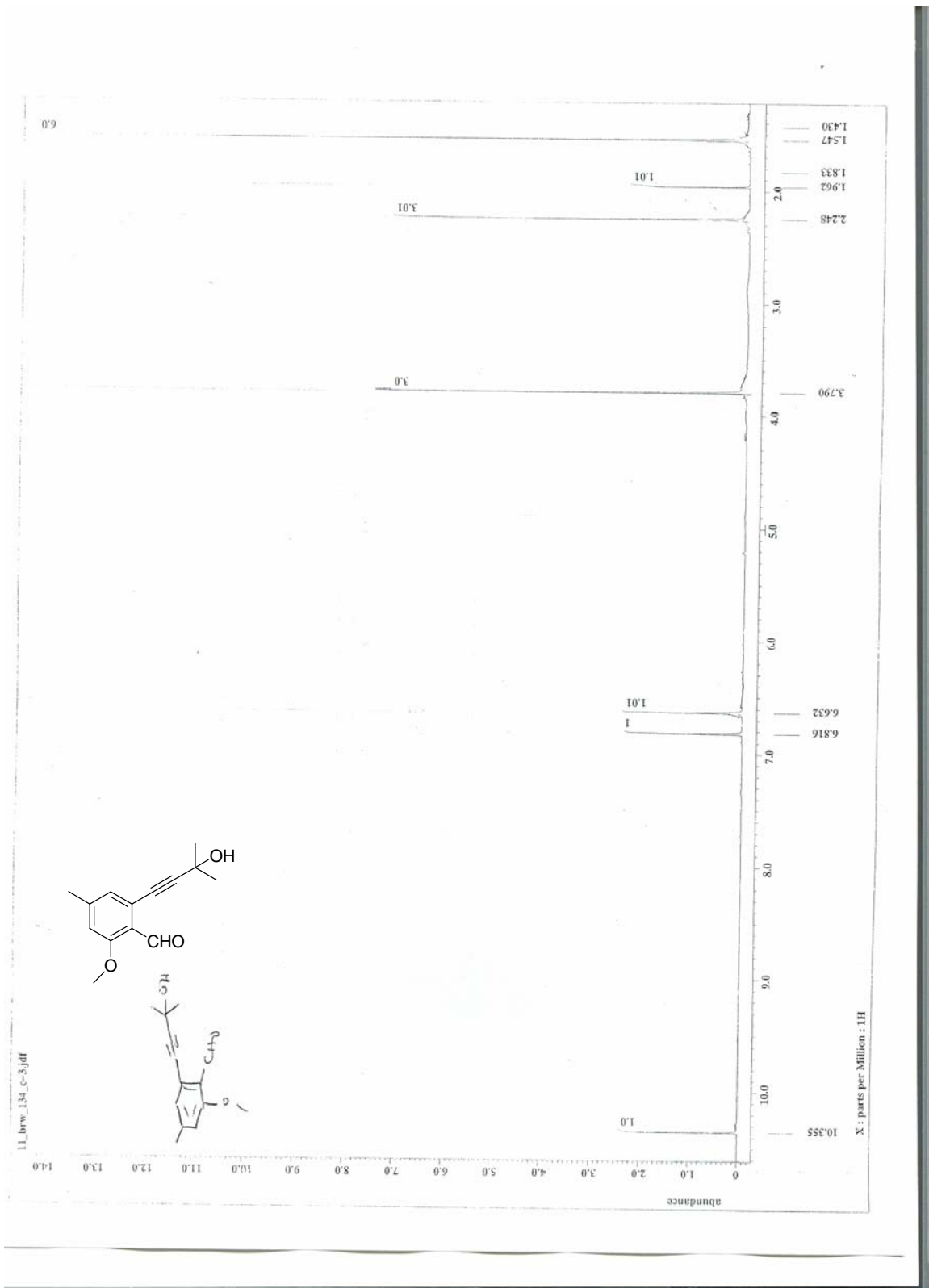
X_90_width = 14.2[us]
X_acq_time = 1.736704[s]
X_angle = 30[deg]
X_pulse = 4.73333333[us]
Initial_wait = 1[s]
Phase_preset = 3[us]
Recvr_gain = 30
Relaxation_delay = 4[s]
Temp_get = 27.9[dc]
Unblank_time = 2[us]
  
```

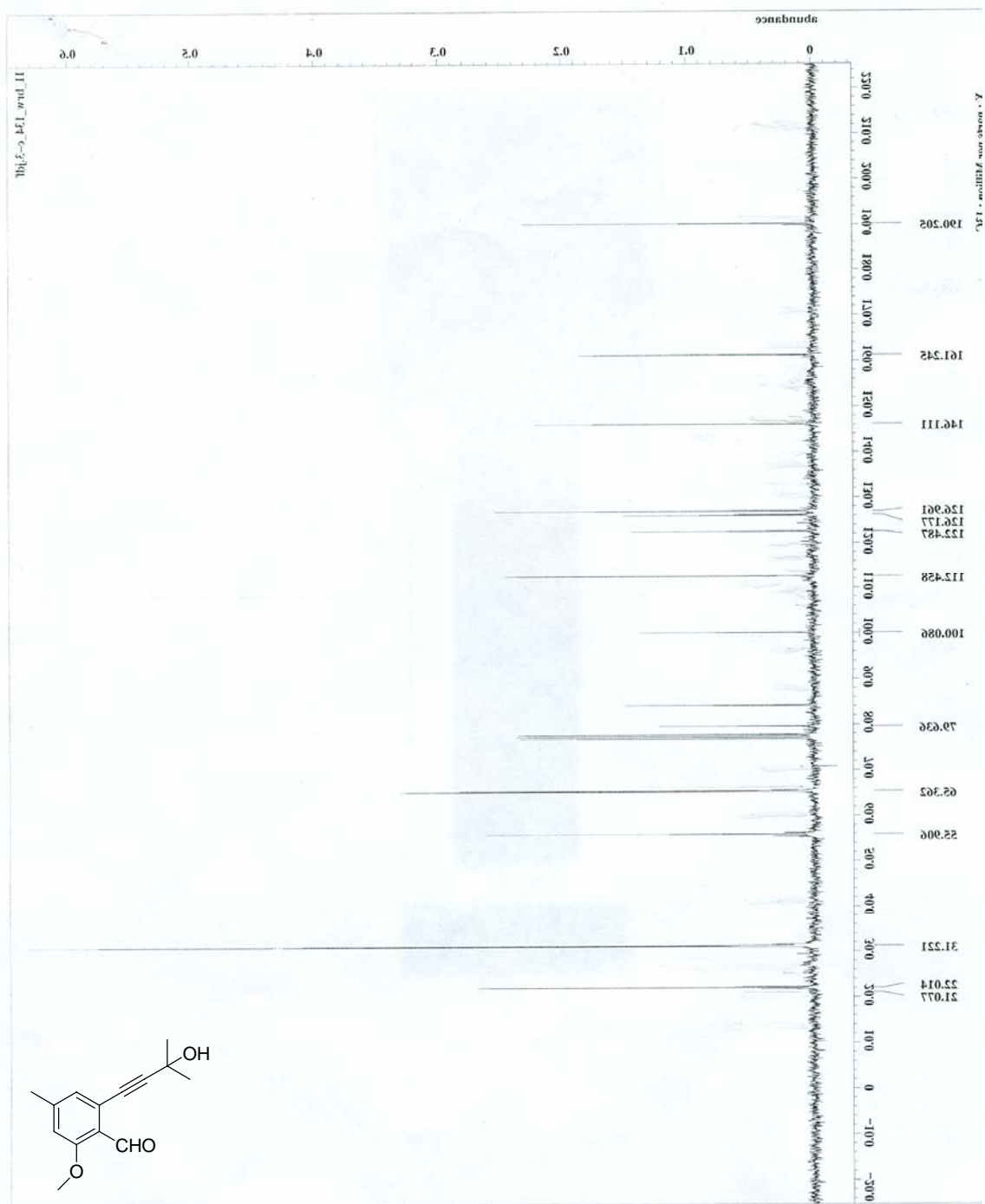
1_cm_249-4.jdf



APPENDIX 90

**¹H and ¹³C NMR SPECTRA OF
2-(3-Hydroxy-3-methyl-1-butynyl)-
4-methyl-6-methoxy-benzaldehyde (91)**





APPENDIX 91

^1H and ^{13}C NMR SPECTRA OF

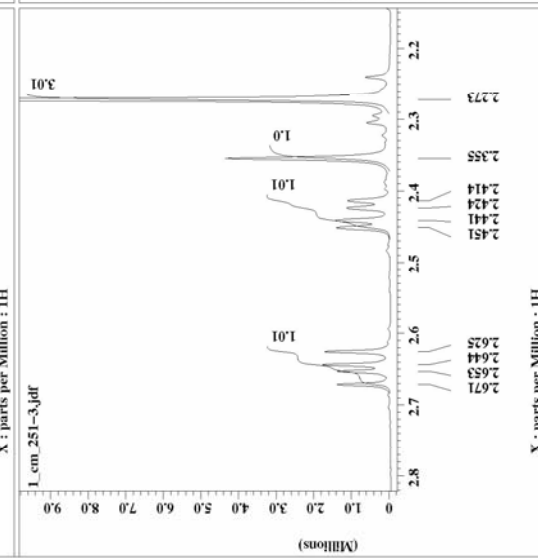
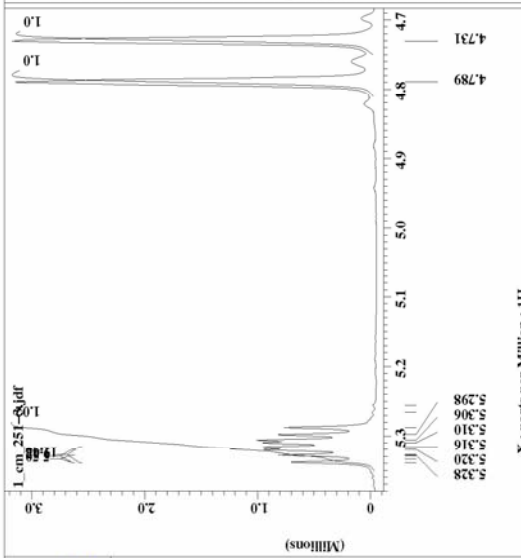
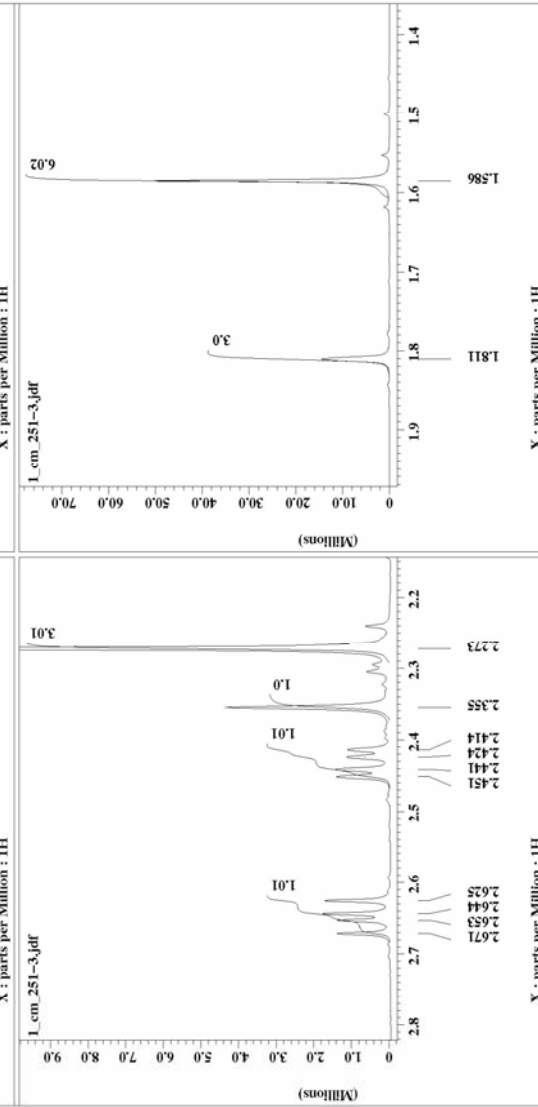
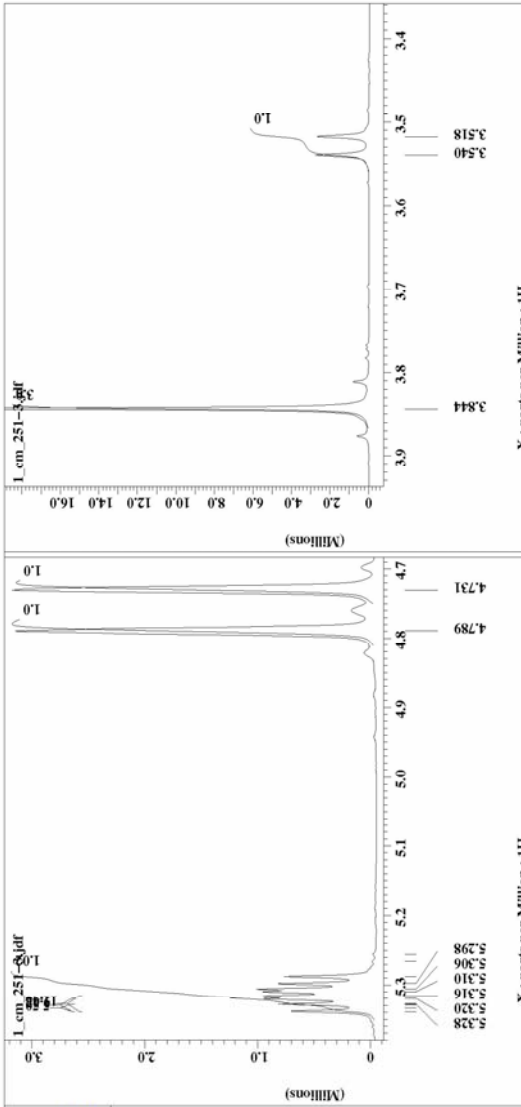
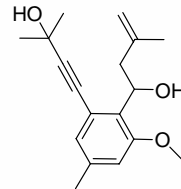
2-(1-Hydroxy-3-methyl-3-butenyl)

-3-(3-hydroxy-3-methyl-1-butynyl)-5-methyl anisole (93)



```

Filename = 1_cm_251-3.jdf
Author = delta
Experiment = sing_puls_exp
Date_Exp = 16-NOV-2005
Solvent = CHLOROFORM-D
Creation_time = 16-NOV-2005 14:39:02
Revision_time = 23-JAN-2007 15:44:52
Current_time = 23-JAN-2007 15:48:24
Content = Single Pulse Experiment
Data_format = 1D COMPLEX
Dim_size = 16384
Dim_title = 1H
Dim_units = [ppm]
Dimensions = 1
Site = ECLIPSE+ 500
Spectrometer = DELTA_NMR
Field_strength = 11.7473579[T] (500 [MH]
X_acq_duration = 18.23468[s]
X_freq = 500.15991521 [MHz]
X_offset = 5 [ppm]
X_points = 16384
X_prescans = 0
X_resolution = 0.45822189 [Hz]
X_sweep = 7.40750751 [kHz]
Clipped = FALSE
Mod_return = 1
Scans = 32
Total_scans = 32
X_90_width = 18.5 [us]
X_acq_time = 2.1823468[s]
X_angle = 45 [deg]
X_pulse = 9.25 [us]
X_wait = 2 [s]
Phase_preset = 3 [us]
Recvr_gain = 15
Relaxation_delay = 1 [s]
Temp_get = 25.9 [dC]
Unblank_time = 2 [us]
  
```





```

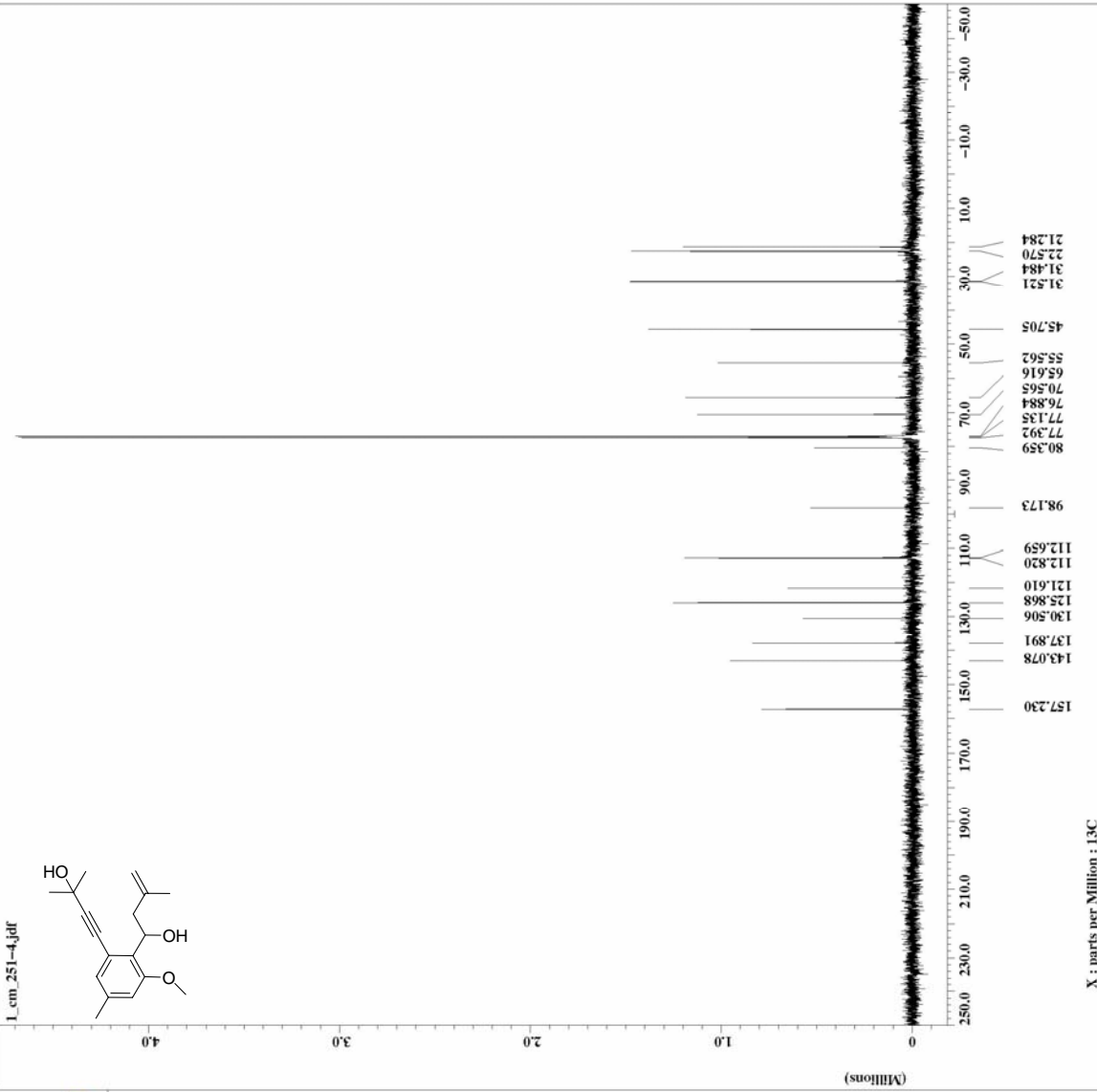
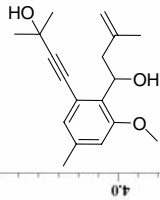
Filename = 1_cm_251-4.jdf
Author = delta
Experiment = single pulse_dec
Sample_id = 1_cm_251
Solvent = CHLOROFORM-D
Creation time = 16-NOV-2005 15:00:14
Revision time = 23-JAN-2007 15:51:09
Current time = 23-JAN-2007 15:51:28

Content = Single Pulse with Bro
Data format = 1D COMPLEX
Dim size = 65536
Dim title = 13C
Dim units = [ppm]
Dimensions = X
Site = Eclipse+ 500
Spectrometer = DELTA_NMR

Field strength = 11.7473579[T] (500 [MH
X_acq_duration = 1.736704 [s]
X_domain = 13C
X_freq = 125.76529768 [MHz]
X_offset = 100 [ppm]
X_points = 65536
X_prescans = 4
X_resolution = 57580336 [Hz]
X_sweep_rate = 97.73584506 [kHz]
X_sweep_gain = 1H
X_t1 = 500.15991521 [MHz]
X_t1_offset = 5 [ppm]
Clipped = FALSE
Mod_return = 1
Scans = 200
Total_scans = 200

X_90_width = 14.2 [us]
X_acq_time = 1.736704 [s]
X_angle = 30 [deg]
X_pulse = 4.73333333 [us]
Initial wait = 1 [s]
Phase preset = 3 [us]
Recvr_gain = 30
Relaxation_delay = 4 [s]
Temp_get = 28.3 [dc]
Unblank_time = 2 [us]
  
```

1_cm_251-4.jdf



APPENDIX 92

**¹H and ¹³C NMR SPECTRA OF
N,N-Diethyl-2-hydroxy-4-methylbenzamide (114)**



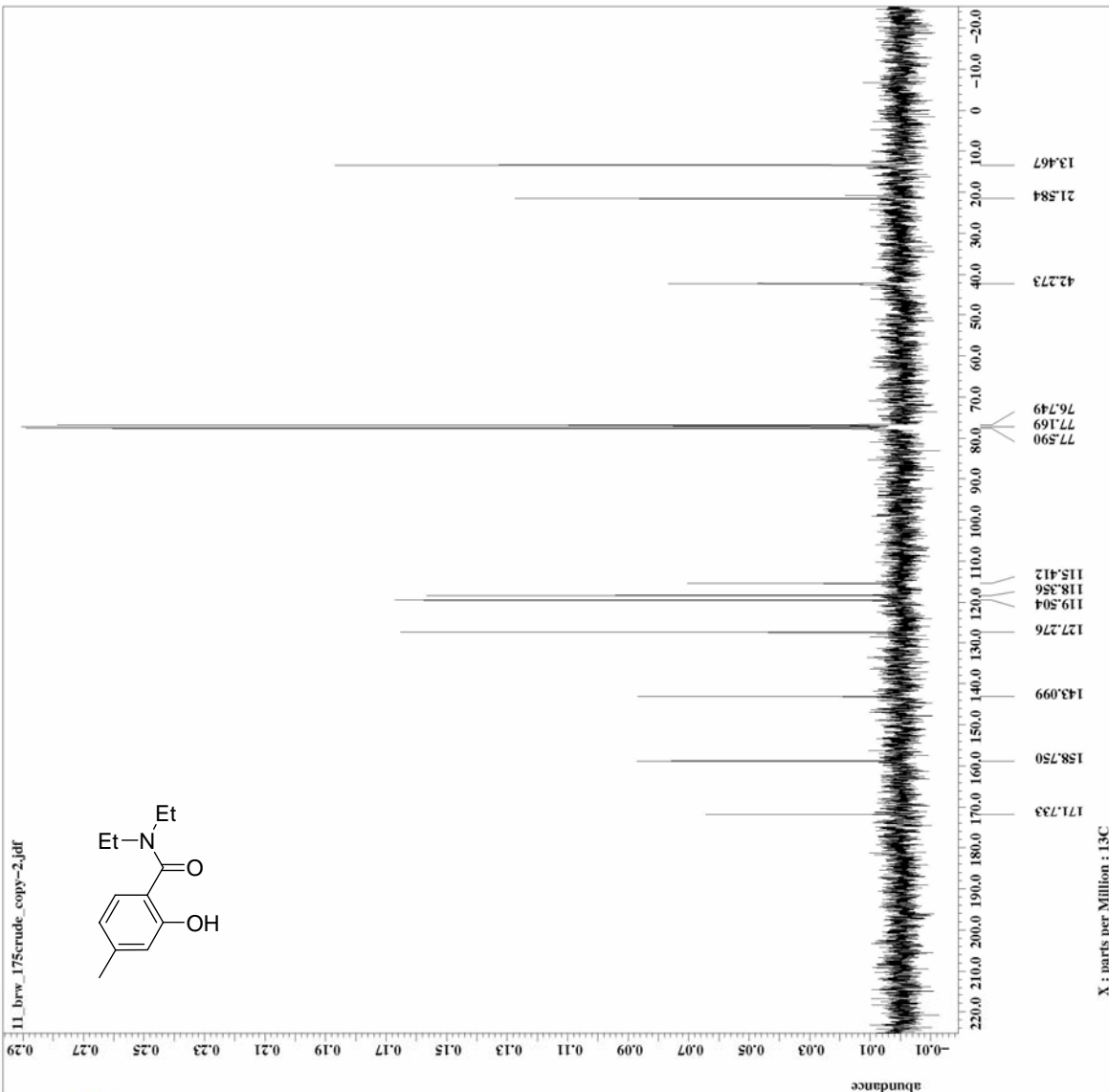
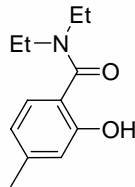
```

Filename = 11_brw_175crude_copy-
Author = delta
Experiment = single pulse_dec
Sample_id = S15423PM-D
Conv_pgm = 1D
Creation_time = 15-SEP-2006 15:41:22
Revision_time = 15-SEP-2006 15:00:21
Current_time = 23-JAN-2007 16:09:41

Content = single pulse decouple
Data_format = 1D COMPLEX
Dim_size = 26214
Dim_title = 13C
Dim_units = [ppm]
Dimensions =
Site = ECI 300
Spectrometer = DELTA2_NMR

Field_strength = 7.0586013[T] (300[MHz]
X_acq_duration = 1.38412032[s]
X_domain = 13C
X_freq = 75.56823426[MHz]
X_points = 32768
X_resolution = 0.72248054[Hz]
X_sweep = 23.67424242[kHz]
Irr_domain = 1H
Irr_freq = 300.52965592[MHz]
Irr_offset = 5[ppm]
Clipped = FALSE
Incomplete_copy = TRUE
Mod_return = 1
Scans = 67
Total_scans = 67

X_90_width = 9.75[us]
X_acq_time = 1.38412032[s]
X_angle = 30[deg]
X_atn = 8[db]
X_pulse = 3.25[us]
Irr_atn_dec = 25[db]
Irr_atn_noe = 25[db]
Irr_noise = WALTZ
Decoupling = 13C
Initial_wait = 1[s]
Noe_time = TRUE
Noe_time = 3[s]
Recvr_gain = 50
Relaxation_delay = 3[s]
Repetition_time = 4.38412032[s]
Temp_get = 23.1[dc]
  
```



X : parts per Million : 13C

APPENDIX 93

¹H and ¹³C NMR SPECTRA OF

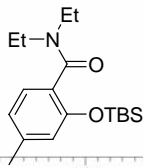
***N,N*-Diethyl-2-(*tert*-butyl-dimethylsilyloxy)-4-methylbenzamide (115)**



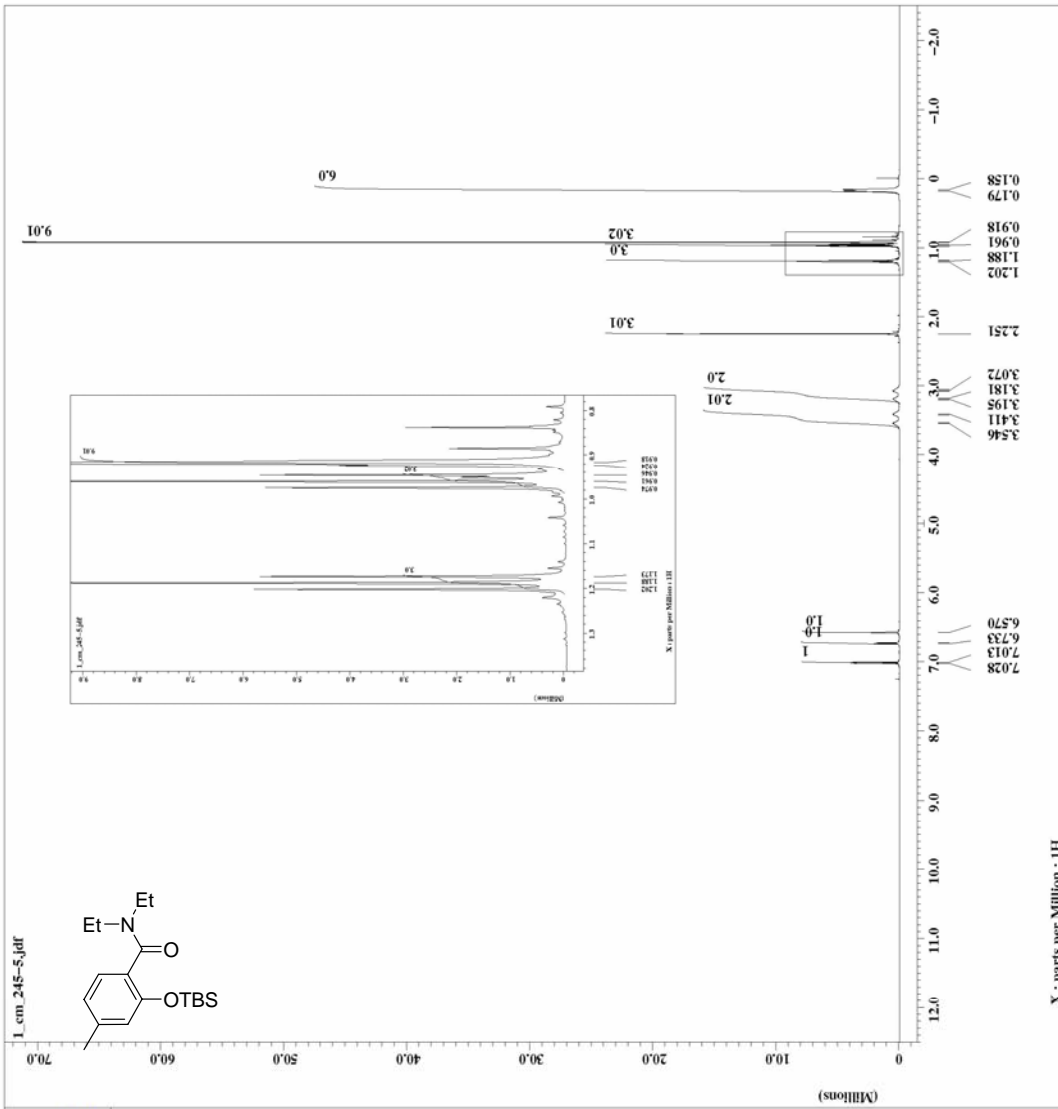
```

Filename = 1_cm_245-5.jdf
Author = delta
Experiment = single_pulse_exp
Pulse_program = zgpg30
Solvent = CHLOROFORM-D
Creation_time = 28-OCT-2005 00:38:07
Revision_time = 23-JAN-2007 16:22:47
Current_time = 23-JAN-2007 16:25:49
Content = Single Pulse Experiment
Data_format = 1D COMPLEX
Dim_size = 16384
Dim_title = 1H
Dim_units = [ppm]
Dimensions = 1
Site = ECLIPSE+ 500
Spectrometer = DELTA_NMR

Field_strength = 11.7473579[T] (500 [MH]
X_acq_duration = 1.1823468[s]
X_resolution = 400.15991521 [MHz]
X_freq = 500.15991521 [MHz]
X_offset = 5 [ppm]
X_points = 16384
X_prescans = 0
X_prescan_delay = 0.45822189 [Hz]
X_resolution = 7.40750751 [kHz]
X_sweep = FALSE
Clipped = 1
Mod_return = 1
Total_scans = 32
X_90_width = 18.5 [us]
X_acq_time = 2.1823468[s]
X_angle = 45 [deg]
X_pulse = 9.25 [us]
X_pulse_delay = 2 [us]
Phase_preset = 1 [us]
Recvr_gain = 11 [us]
Relaxation_delay = 1 [s]
Temp_get = 25.6 [dC]
Unblank_time = 2 [us]
  
```



1_cm_245-5.jdf



X : parts per Million : 1H



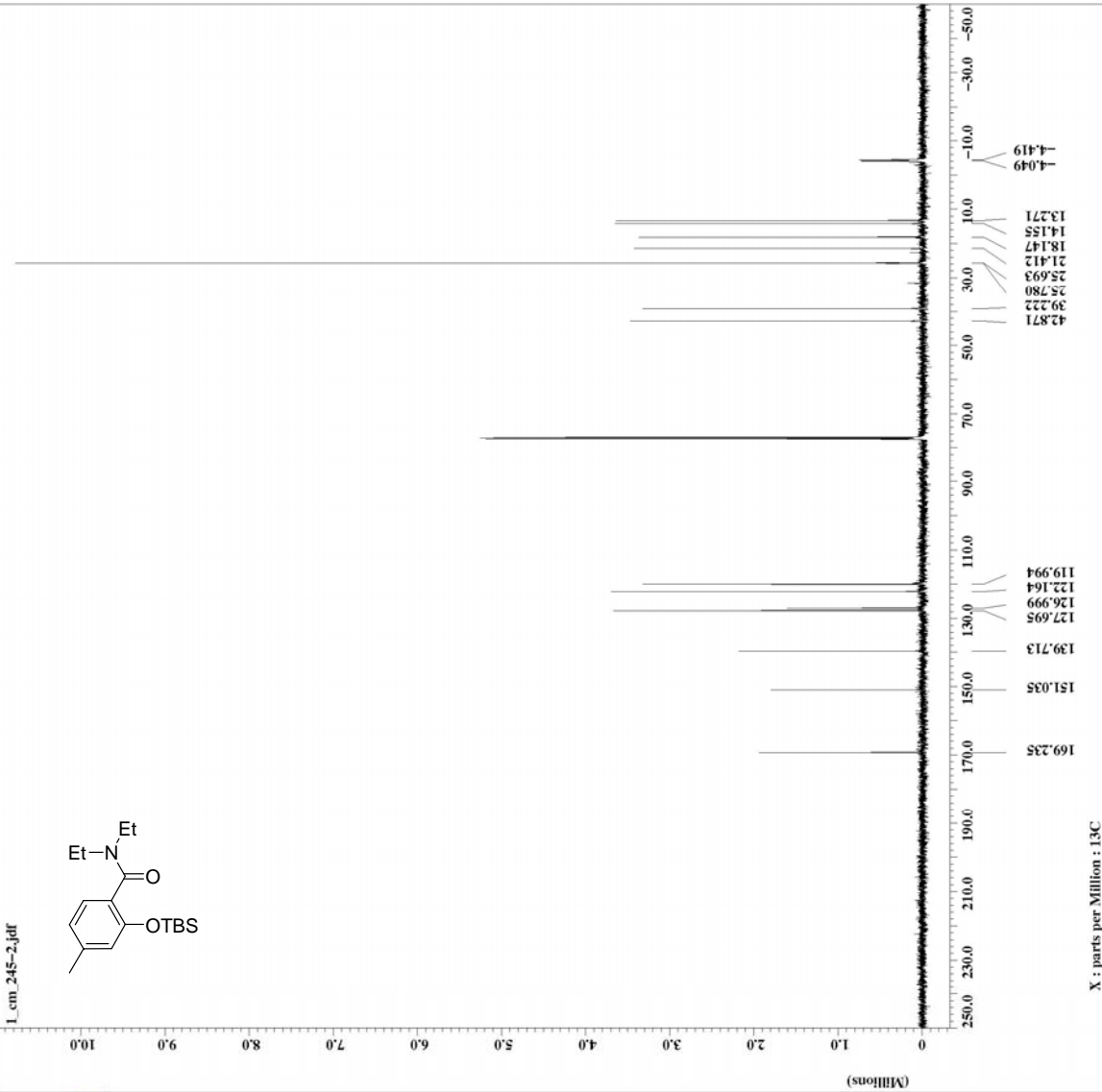
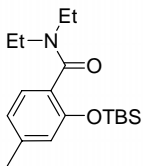
```

Filename      = 1_cm_245-2.jdf
Author        = delta
Experiment    = single_pulse_dec
Sample_id     = 1_cm_245
Solvent       = CHLOROFORM-D
Creation_time = 28-OCT-2005 00:53:41
Revision_time = 27-OCT-2005 23:37:14
Current_time  = 23-JAN-2007 16:26:58

Content       = Single Pulse with Bro
Data_format  = 1D COMPLEX
Dim_size     = 65536
Dim_title    = 13C
Dim_units    = [ppm]
Dimensions   = X
Site         = Eclipse 500
Spectrometer = DELTA_NMR

Field strength = 11.7473579 [T] (500 [MH
X_acq_duration = 1.736704 [s]
X_domain       = 13C
X_freq         = 125.76529768 [MHz]
X_offset       = 100 [ppm]
X_points       = 65536
X_prescans    = 4
X_resolution   = 5758036 [Hz]
X_sweep        = 27.7584906 [kHz]
X_t1_rho       = 1H
X_t1           = 1H.73584906 [kHz]
X_t1_freq      = 500.15991521 [MHz]
X_t1_offset    = 5 [ppm]
Clipped        = FALSE
Mod_return     = 1
Scans          = 140
Total_scans   = 140
X_90_width    = 14.2 [us]
X_acq_time    = 1.736704 [s]
X_angle       = 30 [deg]
X_pulse       = 4.73333333 [us]
Initial_wait  = 1 [s]
Phase_preset  = 3 [us]
Recvr_gain    = 30
Relaxation_delay = 4 [s]
Temp_get      = 28.3 [dc]
Unblank_time  = 2 [us]
  
```

1_cm_245-2.jdf



APPENDIX 94

^1H and ^{13}C NMR SPECTRA OF

2-(*tert*-Butyl-dimethylsilyloxy)

- 6-iodo-4-methyl- *N,N*-diethylbenzamide (116)



```

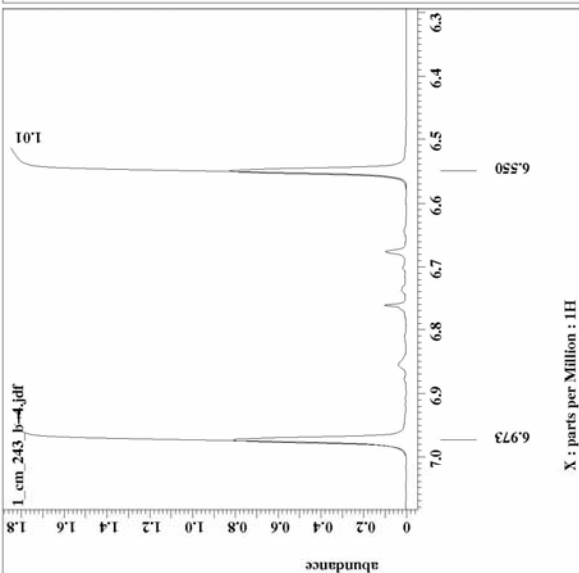
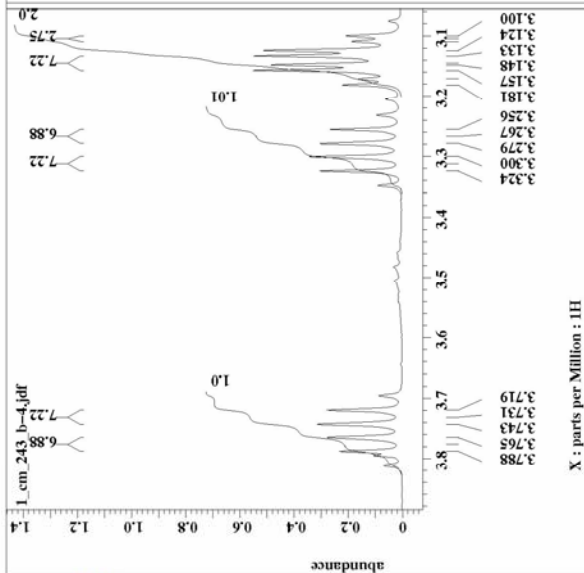
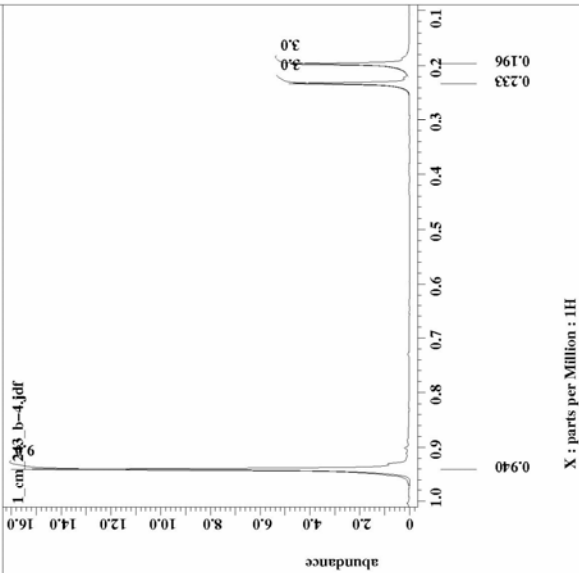
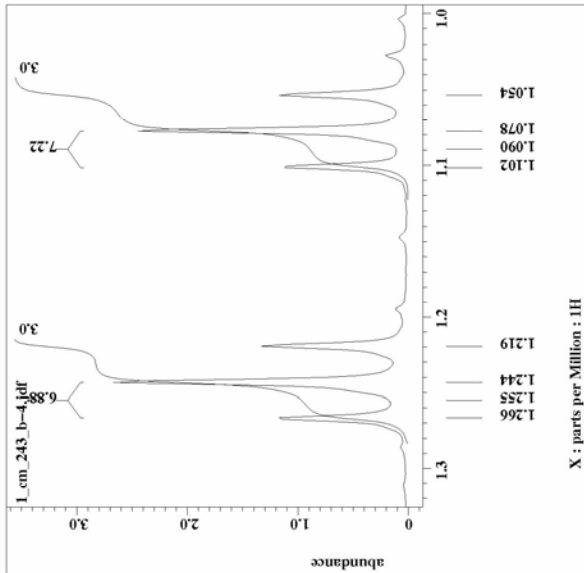
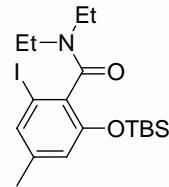
Filename = 1_cm_243_b-4_.jdf
Author = delta
Experiment = single_pulse.ex2
Sample_id = SF424408M-D
Solvent = CHLORO-D
Acq_date = 1-NOV-2005 12:46:13
Revision_time = 1-NOV-2005 12:04:11
Current_time = 23-JAN-2007 17:03:58

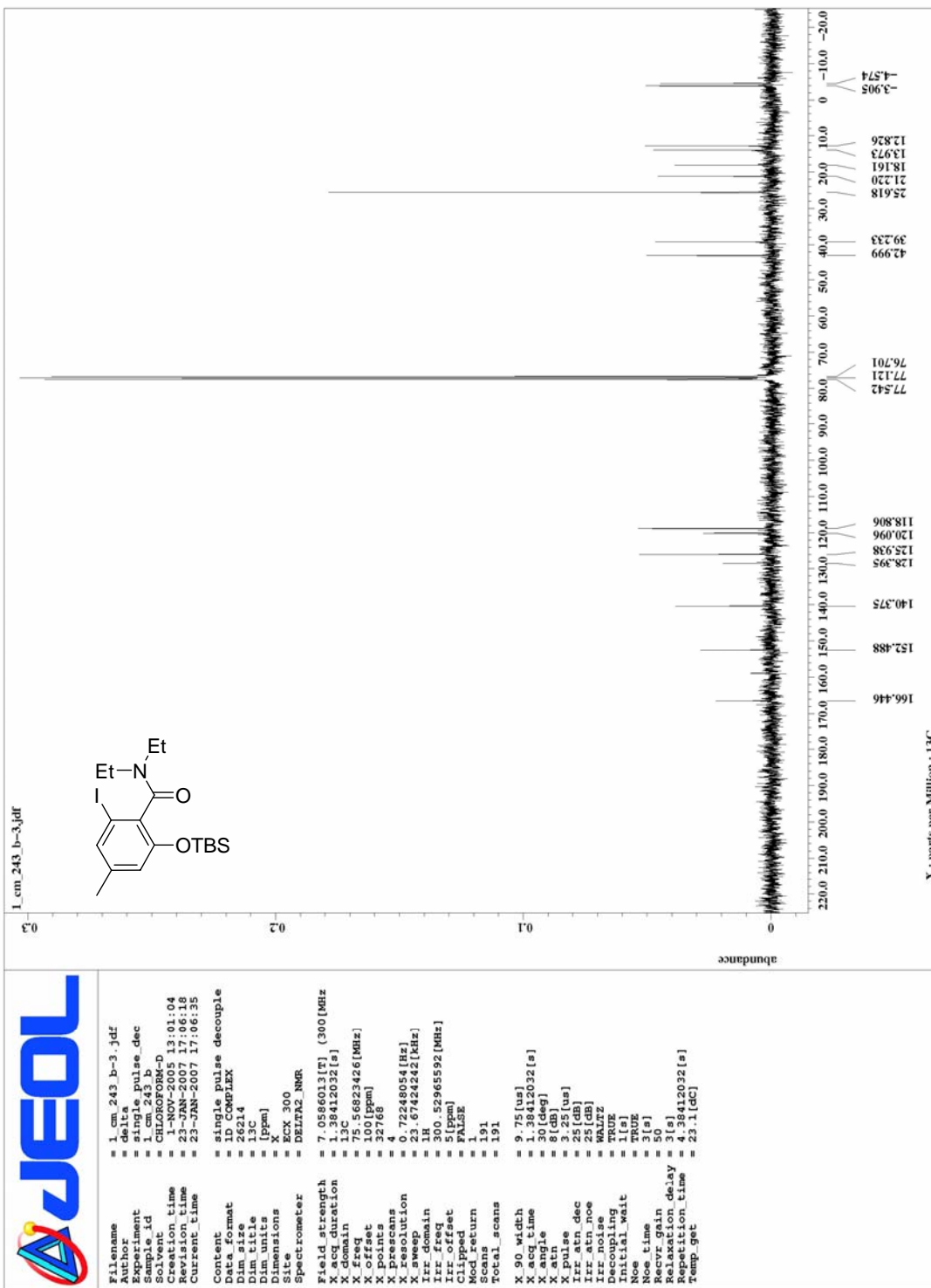
Content = single_pulse
Data_format = 1D COMPLEX
Dim_size = 13107
Dim_title = 1H
Dim_units = [ppm]
Dimensions = KCX 300
Site = DELTA2_NMR
Spectrometer = DELTA2_NMR

Field_strength = 7.0586013[T] (300[MHz]
X_acq_duration = 2.90717696[s]
X_domain = 1H
X_freq = 300.52965592[MHz]
X_offset = 5[ppm]
X_points = 16384

X_prescans = 1
X_resolution = 0.34397631[Hz]
X_resolution_ppm = 0.63570784[MHz]
Irr_domain = 1H
Irr_freq = 300.52965592[MHz]
Irr_offset = 5[ppm]
Tri_domain = 1H
Tri_freq = 300.52965592[MHz]
Tri_offset = 5[ppm]
Mod_return = FALSE
Scans = 1
Total_scans = 24

X_90_width = 13.01[us]
X_acq_time = 2.90717696[s]
X_angle = 45[deg]
X_atn = 4[db]
X_pulse = 6.505[us]
Irr_mode = Off
Tri_mode = Off
Date_preset = FALSE
Acq_date = 1-NOV-2005 12:46:13
Recur_delay = 38[s]
Relaxation_delay = 5[s]
Repetition_time = 7.90717696[s]
Temp_get = 22.7[dc]
  
```





APPENDIX 95

¹H and ¹³C NMR SPECTRA OF

**2-(3-Hydroxy-3-methyl-1-butynyl)-4-methyl-6-
(*tert*-butyl-dimethylsilyloxy)-*N,N*-diethylbenzamide (117)**

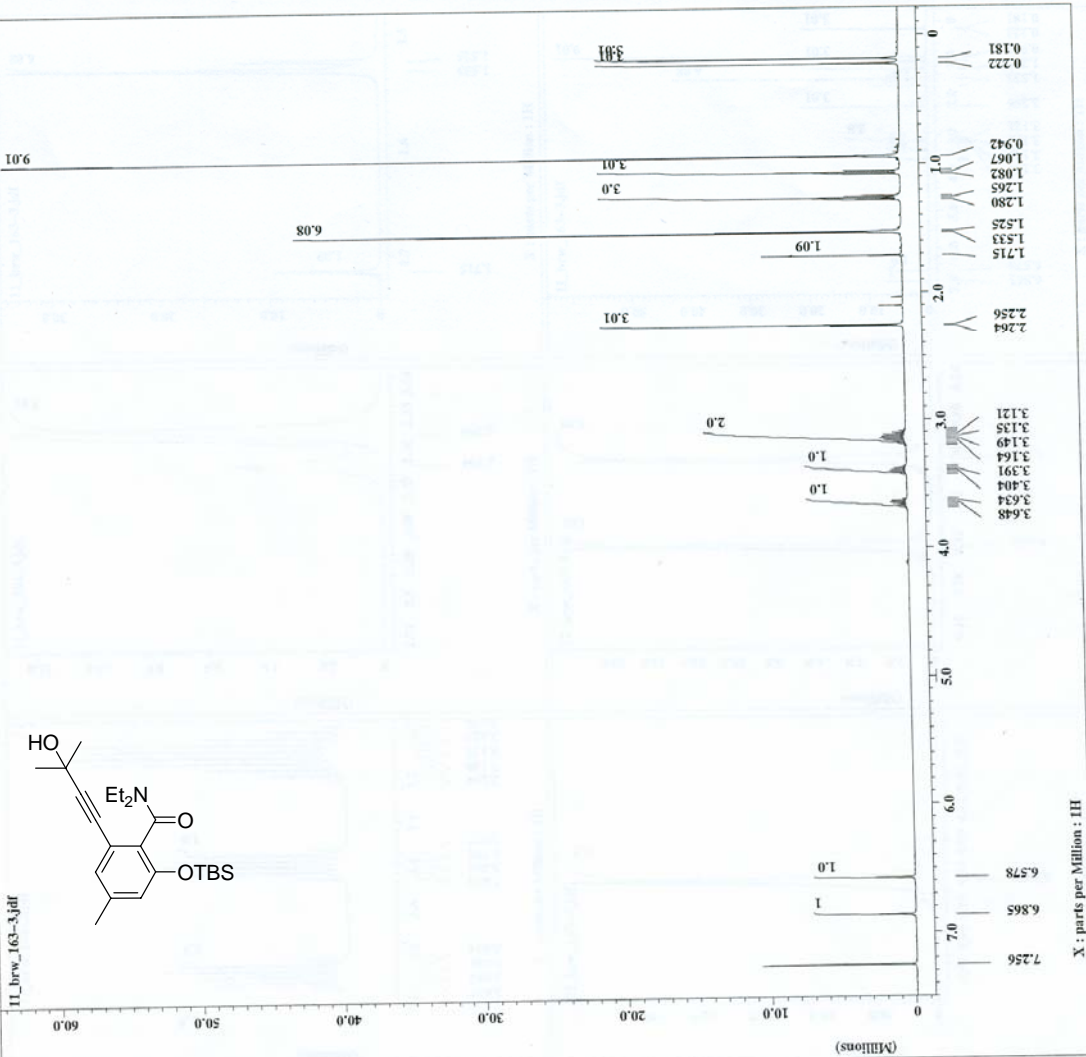
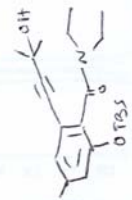


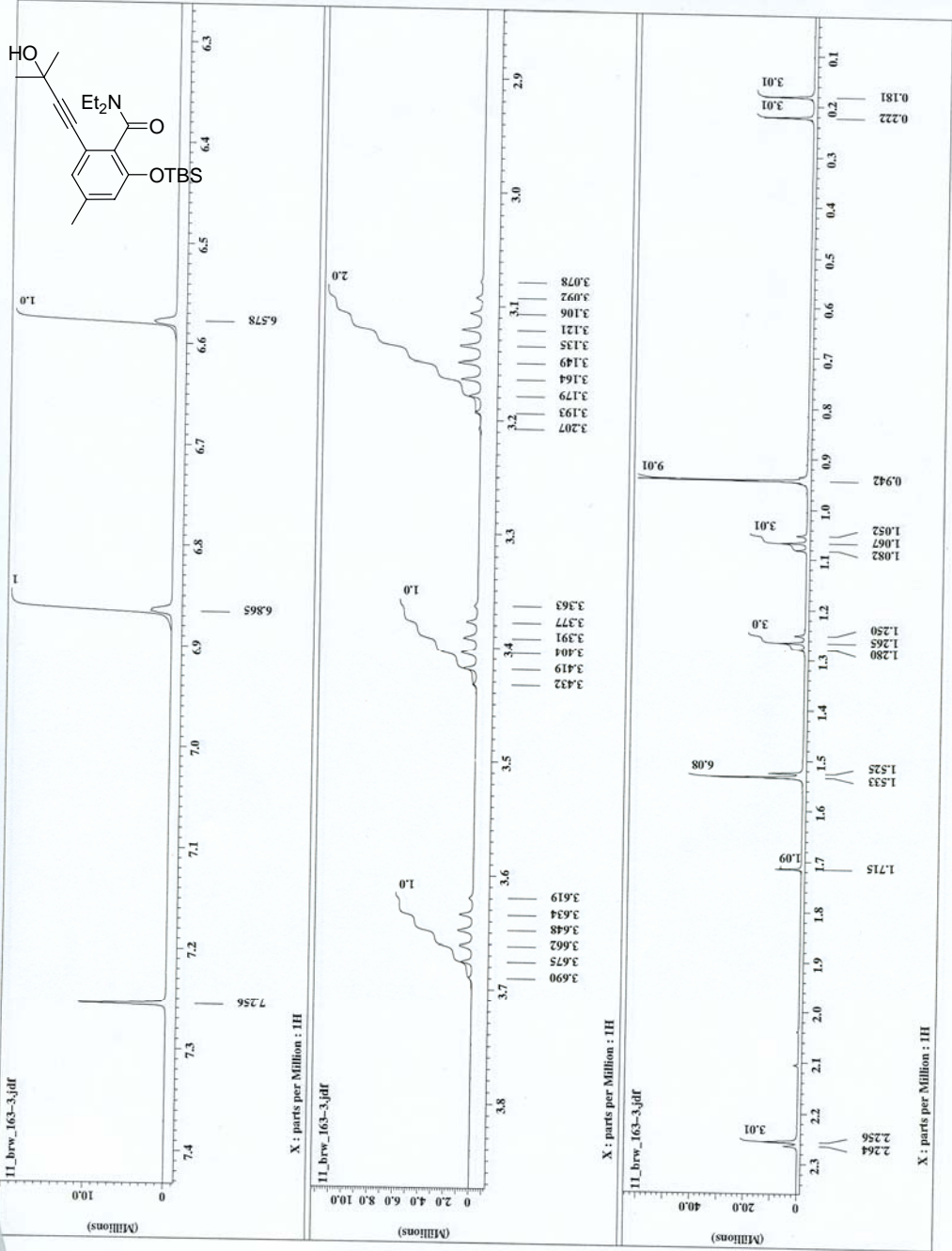
Filename = 11_brv_163-3.jdf
Acquisition = delta
Pulse_program = single_pulse.exp
Sample_id = S#461741
Solvent = CHLOROFORM-D
Creation_time = 23-AUG-2006 14:03:02
Revision_time = 23-AUG-2006 13:04:26
Current_time = 23-AUG-2006 13:04:58

Content = Single Pulse Experiment
Data_format = ID COMPLEX
Dim_size = 16384
Dim_title = 1H
Dim_units = (ppm)
Dim_dimensions = X
Site = Eclipse+ 500
Spectrometer = DELTA_NMR

Field_strength = 11.747570[G] (500[MH])
X_acq_duration = 2.1823488[s]
X_gain = 1H
X_freq = 500.15991521[MHz]
X_offset = 5[ppm]
X_points = 16384
X_prescans = 0
X_resolution = 0.45822189[Hz]
X_resolution_hz = 7.50750751[KHz]
X_sweep_rate = FALSE
Mod_return = 1
Scans = 32
Total_scans = 32

X_90_width = 18.5[us]
X_acq_time = 2.1823488[s]
X_angle = 45[deg]
X_pulse = 9.25[us]
Initial_wait = 1[s]
Phase_preset = 2[us]
Recirculation_delay = 1[s]
Temp_get = 25.1[dC]
Unblank_time = 2[us]

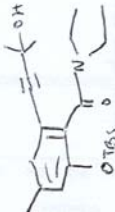




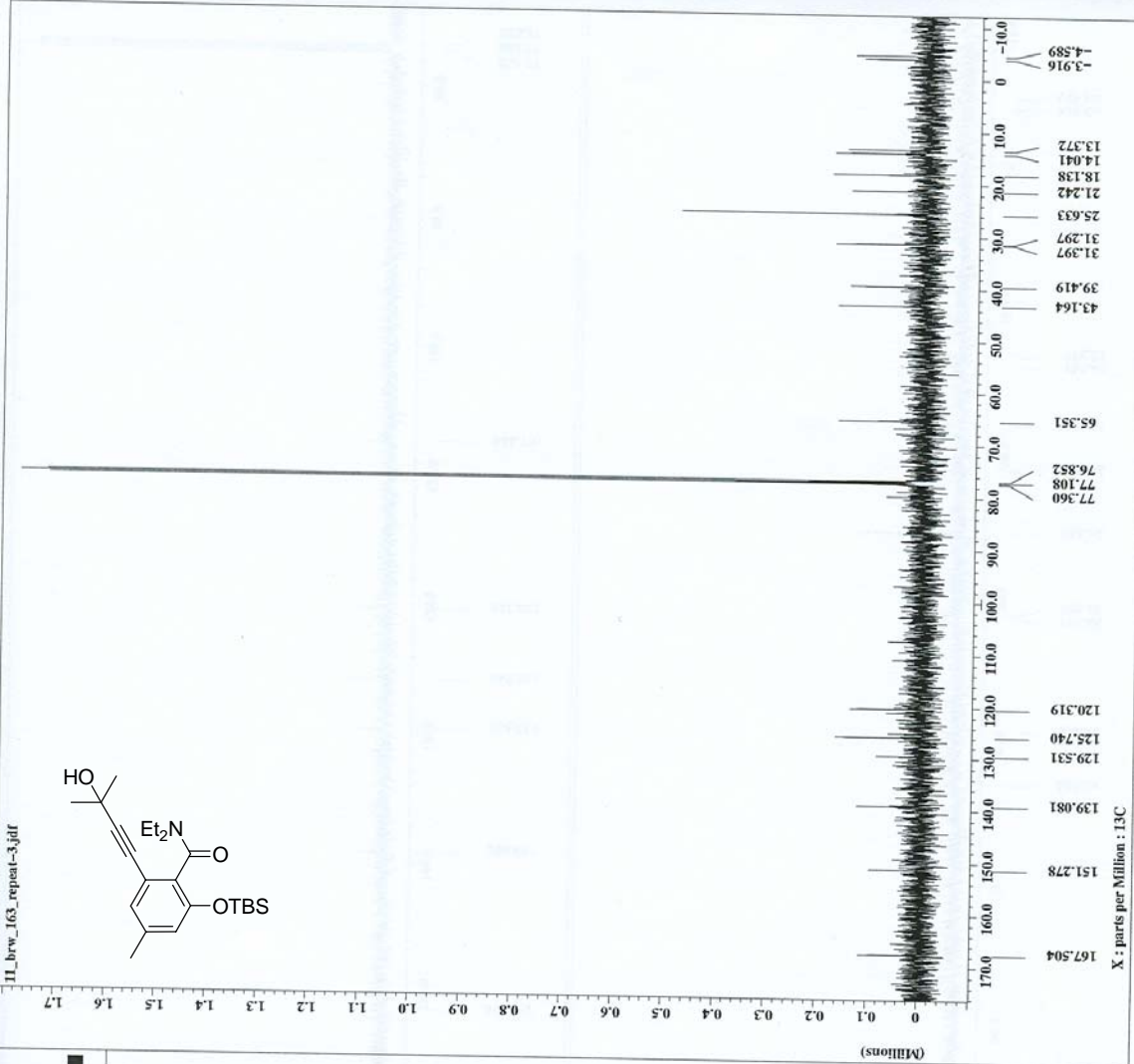
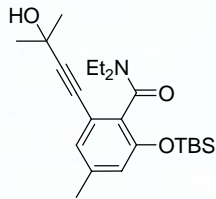


```

Filename  = 11_brw_163_repeat-3.j
Author    = delta
Experiment = single_pulse_dec
Sample_id = S8423068
Solvent   = CHLOROFORM-D
Acq Date  = 24-AUG-2006 13:17:02
Acq Time  = 24-AUG-2006 12:06:49
Serial    = 24-AUG-2006 12:07:06
Current   =
Content   = Single Pulse with Hrc
Data_format = ID COMPLEX
Dir_size  = 65536
Dir_title = 13C
Dir_units = [ppm]
Dir_path  =
Spectrum = DELTA_500
Spectrometer =
Field_strength = 11.7473579 [T] (500 [MHZ])
X_acq_duration = 1.736704 [s]
X_domain     = 13C
X_freq       = 125.76529768 [MHZ]
X_offset     = 65536 [ppm]
X_pulses    = 4
X_prescans  = 4
X_resolution = 0.57580336 [Hz]
X_sweep     = 37.73584906 [KHz]
Irr_domain  = 1H
Irr_freq    = 500.15991521 [MHZ]
C13_offset  = 5 [ppm]
Mode        = ALSE
Mod_return  = 1
Scans       = 200
Total_scans = 200
X_90_width  = 14.2 [us]
X_acq_time  = 1.736704 [s]
X_angle     = 30 [deg]
X_pulses    = 175333333 [us]
Initial_wait = 1.75333333 [us]
Phase preset = 3 [us]
Recvr_gain  = 30
Relaxation_delay = 4 [s]
Temp_get    = 27.8 [dC]
Unblank_time = 2 [us]
  
```



11_brw_163_repeat-3.jfif



APPENDIX 96

**¹H and ¹³C NMR SPECTRA OF
2-(3-Hydroxy-3-methyl-1-butynyl)
-6-hydroxy-4-methyl-methylbenzoate (118)**



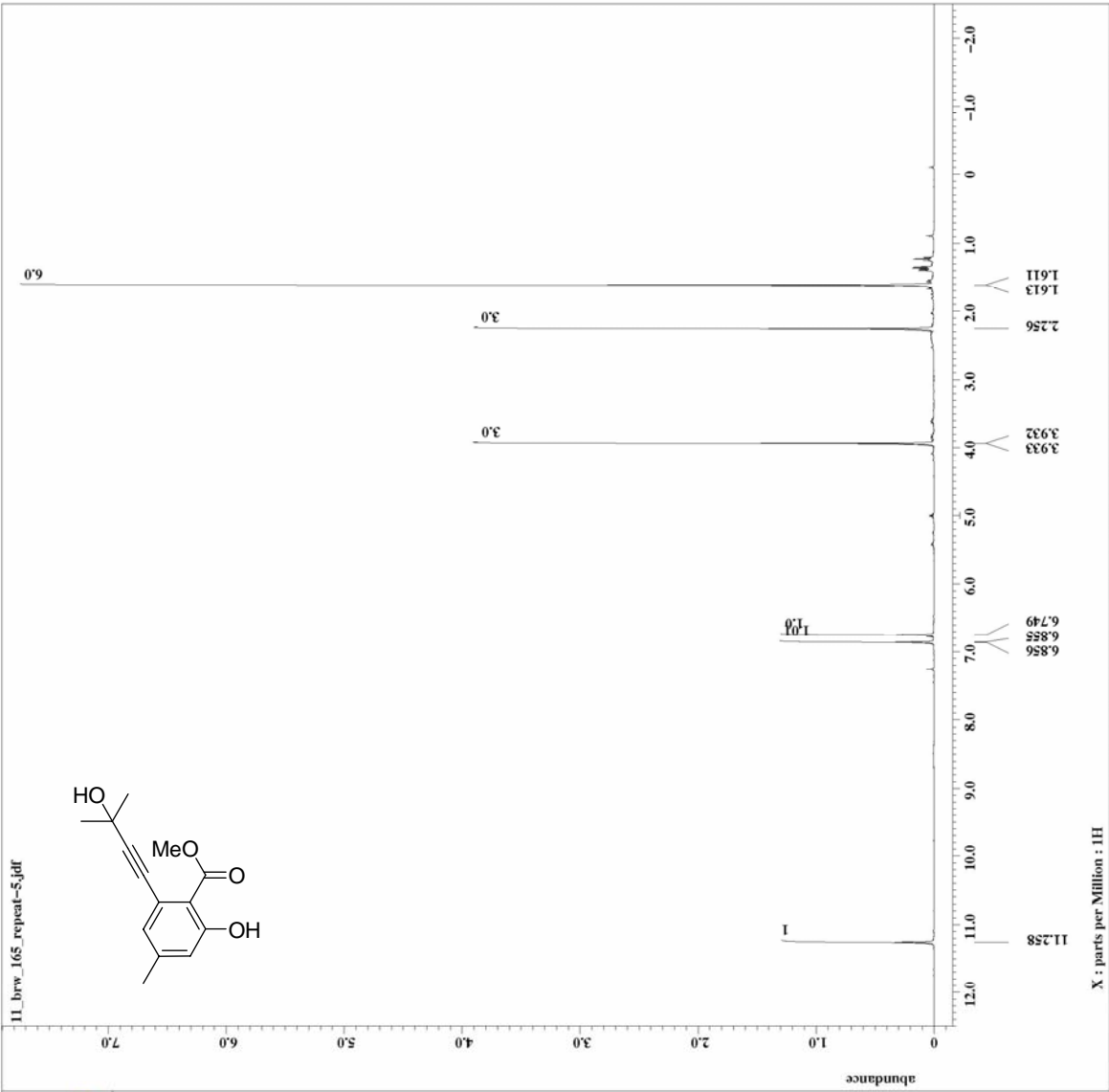
```

Filename = 11_brw_165_repeat-5.j
Author = delta
Experiment = single_pulse.ex2
Sample_id = S#497667
Solvent = CHLOROFORM-D
Creation_time = 18-DEC-2006 14:42:08
Revision_time = 23-JAN-2007 18:03:48
Current_time = 23-JAN-2007 18:04:29

Content = single_pulse
Data_format = 1D COMPLEX
Dim_size = 26214
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Site = ECX 300
Spectrometer = DELTA2_NMR

Field_strength = 7.0586013[T] (300[MHz]
X_acq_duration = 5.81435392[s]
X_domain = 1H
X_freq = 300.52965592[MHz]
X_offset = 5[ppm]
X_points = 32768
X_prescans = 1
X_resolution = 0.17198945[Hz]
X_sweep_gain = 1H
X_sweep_rate = 63570784[KHz]
Irr_freq = 300.52965592[MHz]
Irr_offset = 5[ppm]
Tri_domain = 1H
Tri_freq = 300.52965592[MHz]
Tri_offset = 5[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 24
Total_scans = 24

X_90_width = 13.01[us]
X_acq_time = 5.81435392[s]
X_angle = 45[deg]
X_atn = 4[db]
X_pulse = 6.505[us]
Irr_mode = Off
Tri_mode = Off
Date_presat = FALSE
Relaxation_delay = 1[s]
Recur_gain = 30
Relaxation_delay = 5[s]
Repetition_time = 10.81435392[s]
Temp_get = 22.5[dc]
  
```



APPENDIX 97

**^1H and ^{13}C NMR SPECTRA OF
2-(3-Hydroxy-3-methyl-1-butynyl)
-6-hydroxy -4-methyl -benzylalcohol (119))**

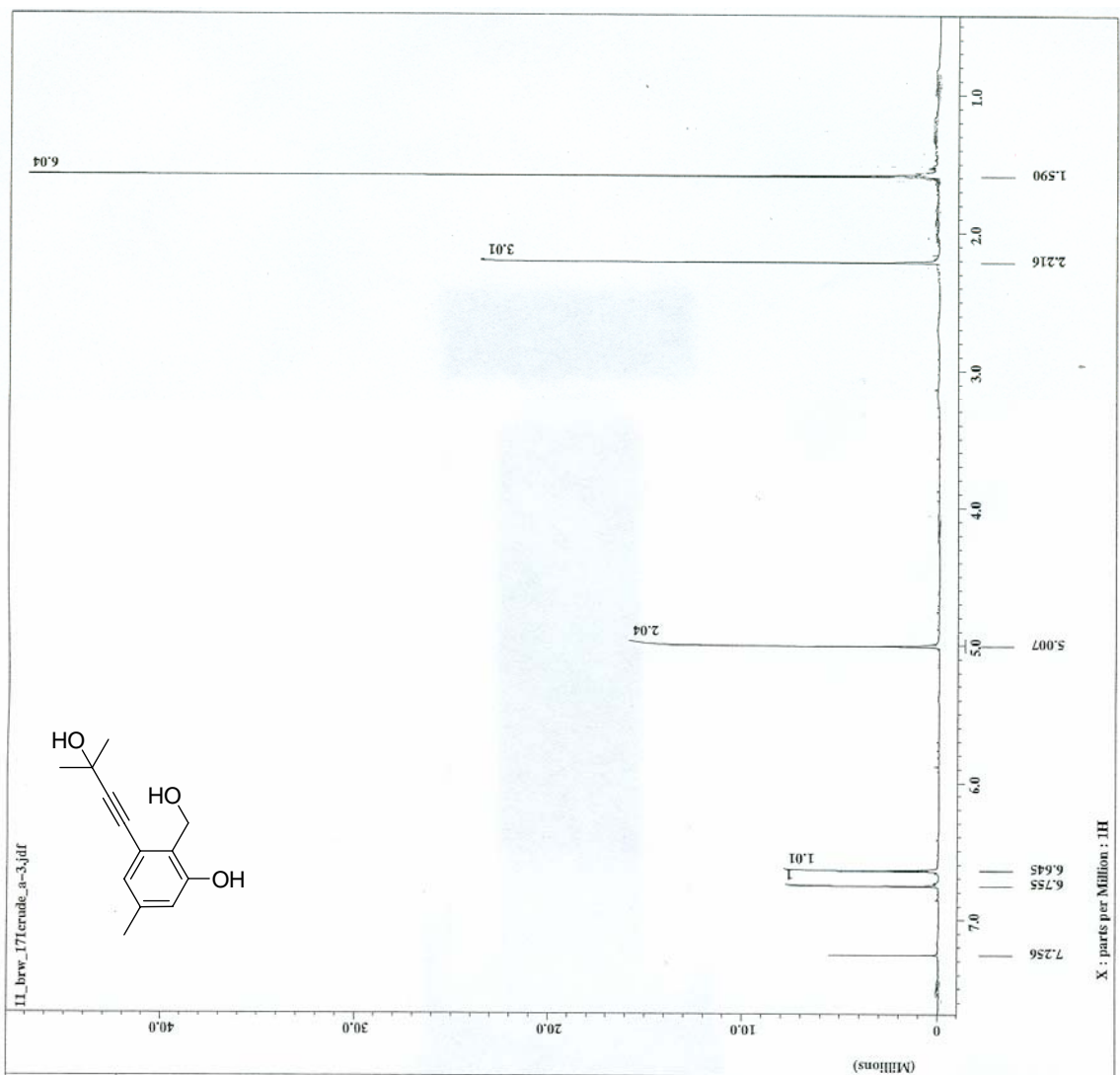
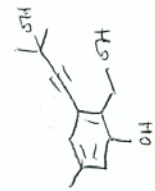


```

File name      = 11_brw_17terude_a-3-j
Date_         = 11-11-06
Experiment     = 11brw_17terude_a-3-j
Sample_id     = SF55200
Solvent       = CHLOROFORM-D
Creation_time = 12-SEP-2006 19:37:56
Revision_time = 12-SEP-2006 18:22:57
Current_time  = 12-SEP-2006 18:26:16

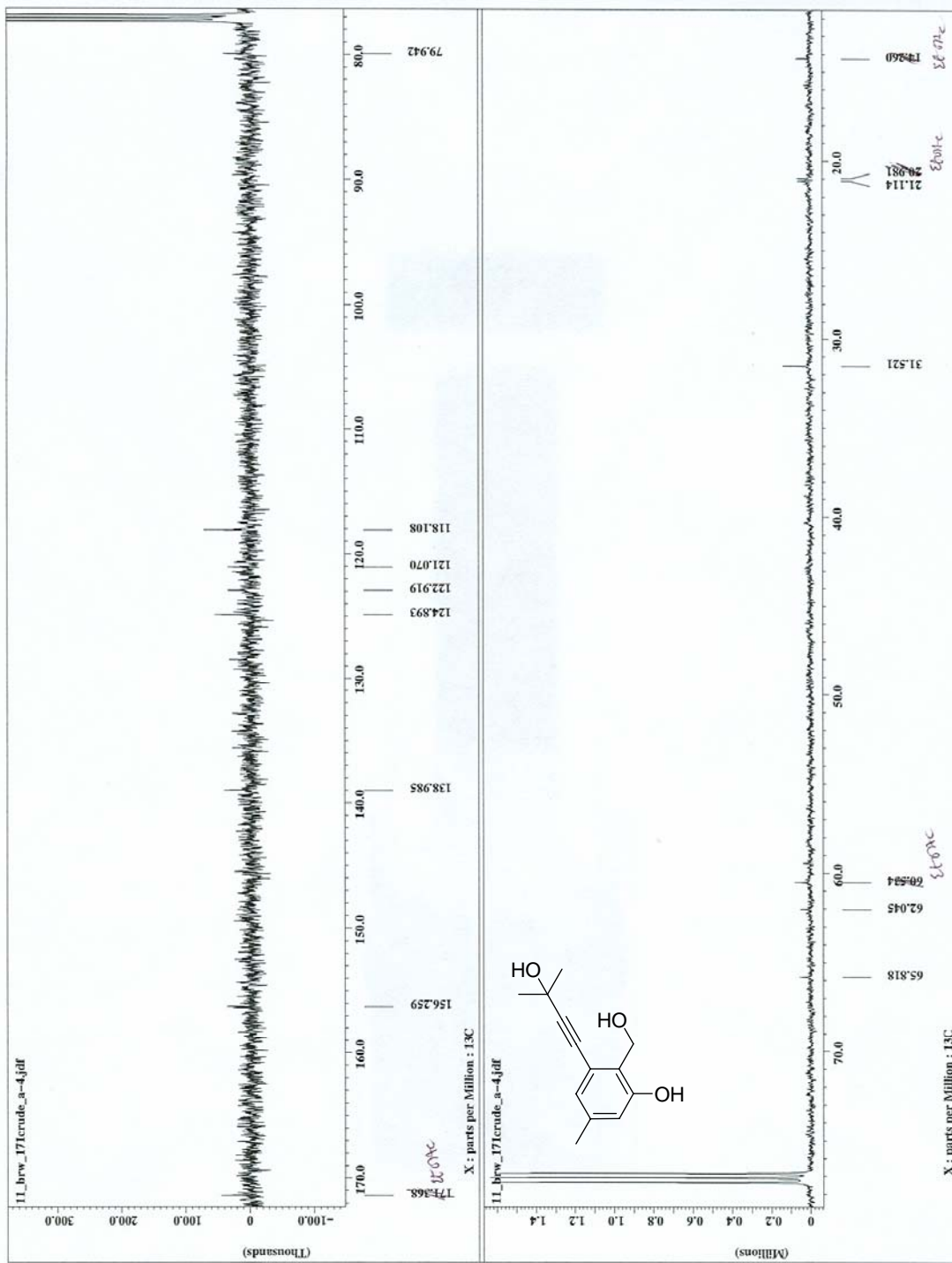
Content       = Single Pulse Experiment
Data_format  = ID COMPLEX
Dim_size     = 16384
Dim_title    = 1H
Dim_units    = [ppm]
Dimensions   = X
Site         = Eclipse 500
Spectrometer = JEOL_AMR

Field strength = 11.7473579[T] (500[MH]
X_acq_duration = 2.1823488[s]
X_domain       = 1H
X_freq         = 500.15391521[MHz]
X_offset       = 6384
X_prescans     = 6
X_resolution   = 0.45822189[Hz]
X_sweep        = 7.50750751[kHz]
Clipped       = FALSE
Mod_return     = 1
Scans          = 32
Total_scans   = 32
X_90_width    = 18.5[us]
X_acq_time    = 2.1823488[s]
X_angle       = 45[deg]
X_pulse       = 9.25[us]
Initial_wait  = 1[s]
Phase_preset = 3[us]
Relaxation    = 1[s]
Relaxation_delay = 25.1[dc]
Temp_get_time = 2[us]
Unblank_time  = 2[us]
  
```



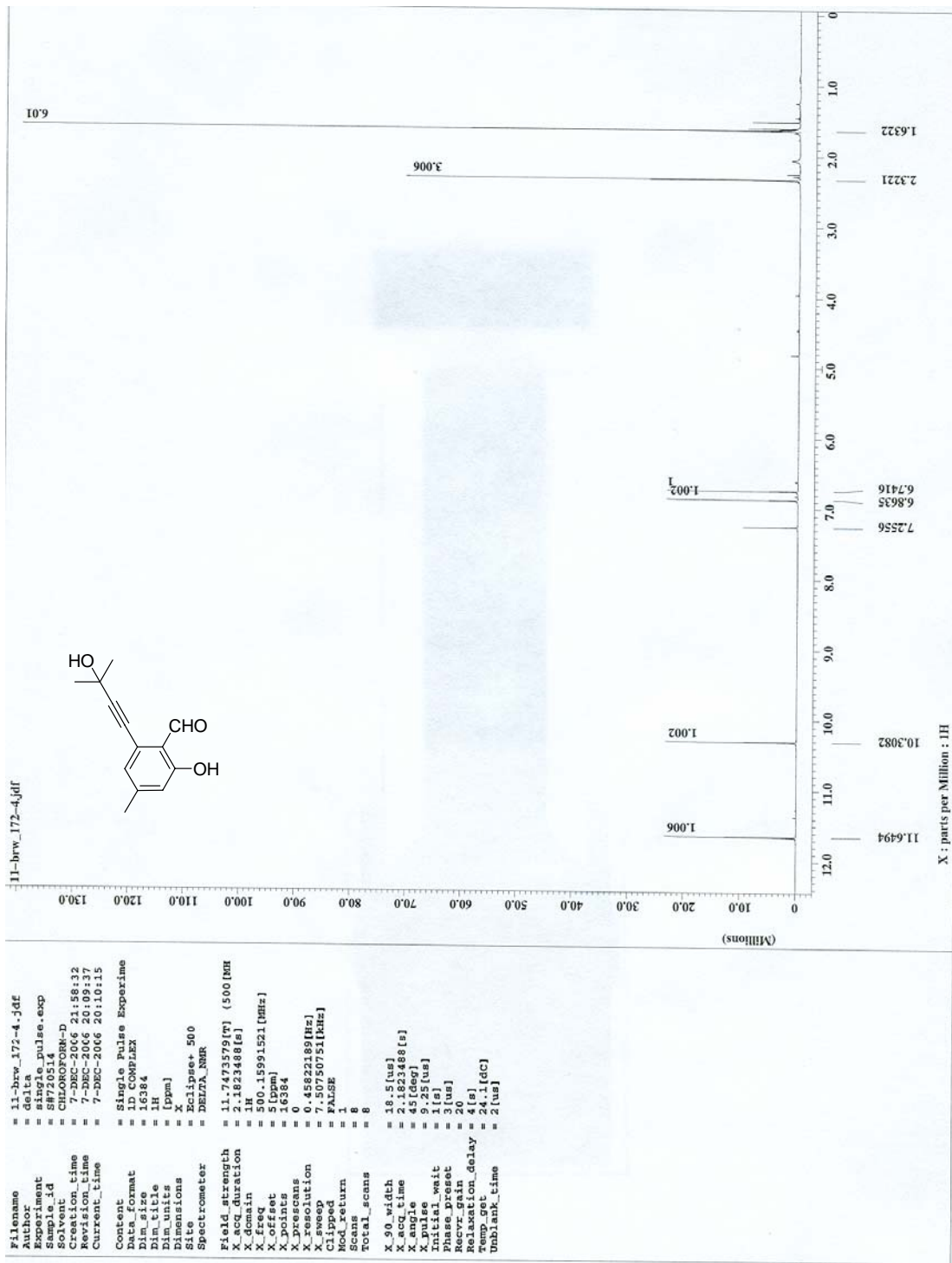
11_brw_17terude_a-3.jif

X : parts per Million : 1H



APPENDIX 98

**^1H and ^{13}C NMR SPECTRA OF
2-(3-Hydroxy-3-methyl-1-butynyl)
-6-hydroxy -4-methyl -benzaldehyde (120)**



APPENDIX 99

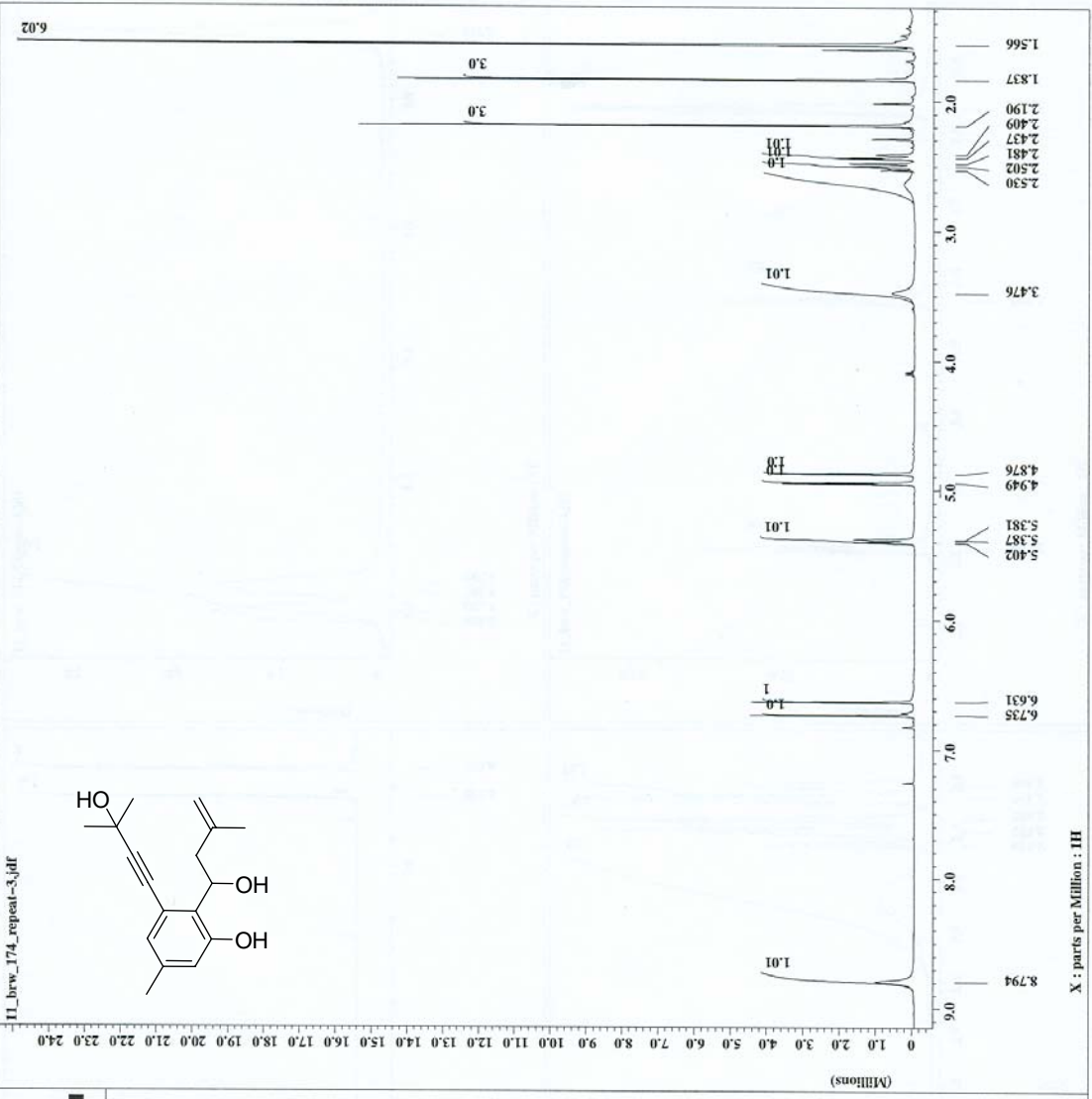
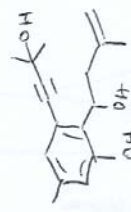
^1H and ^{13}C NMR SPECTRA OF

2-(1-Hydroxy-3-methyl-3-butenyl)-3-

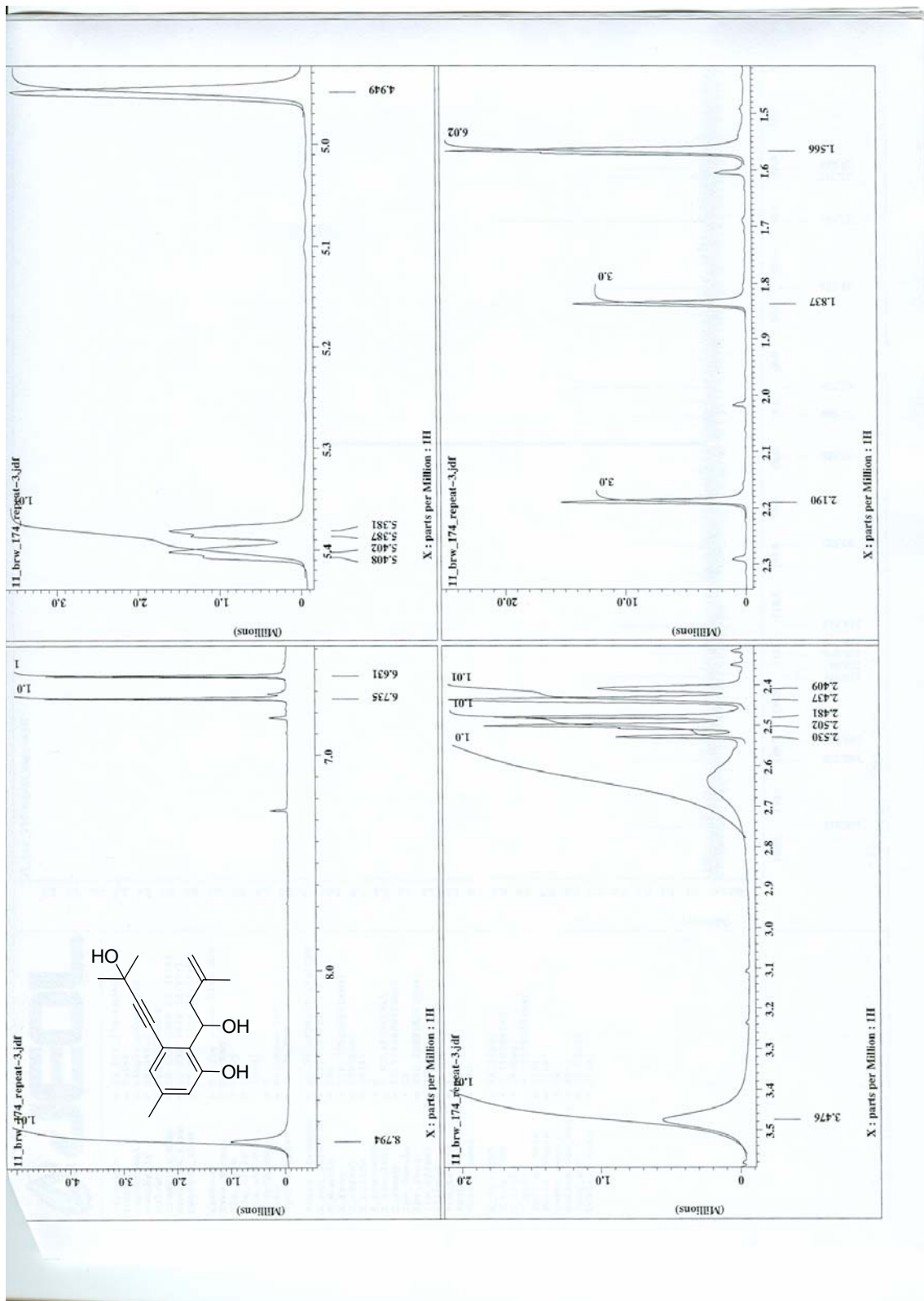
(3-hydroxy-3-methyl-1-butynyl)-5-methyl phenol (121)



11_brv_174_repeat-3.j
File Name
Author delc
Experiment single pulse.exp
Sample ID SH425944
Solvent CHLOROFORM-D
Creation_time 20-SEP-2006 13:20:54
Revision_time 20-SEP-2006 11:59:00
Current_time 20-SEP-2006 11:59:18
Content Single Pulse Experiment
Data_format ID COMPLEX
Dim_size 16384
Dim_title 1H
Date Acq 20060920
Dimensions X
Site Eolipse+ 500
Spectrometer DELTA_NMR
Field_strength 11.747379 [T] (500 MHz)
X_acq_duration 2.182348 [s]
X_delay 2.000000 [s]
X_freq 500.15991521 [MHz]
X_offset 51 [ppm]
X_points 16384
X_prescans 0
X_resolution 0.45822189 [Hz]
X_resolution_hq 0.50751 [kHz]
X_wdwd 32768
Clipped FALSE
Mod_return 1
Scans 32
Total_scans 32
X_90_width 18.5 [us]
X_90_time 2.121688 [s]
X_angle 45 [deg]
X_pulse 9.25 [us]
Initial_wait 1 [s]
Phase_Preset 3 [us]
Recvr_gain 13
Spectrum_delay 1 [s]
Temperature 21.9 [dC]
Unblank_time 2 [us]

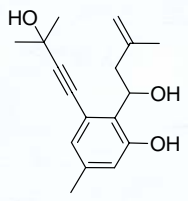


11_brv_174_repeat-3.j
6.02

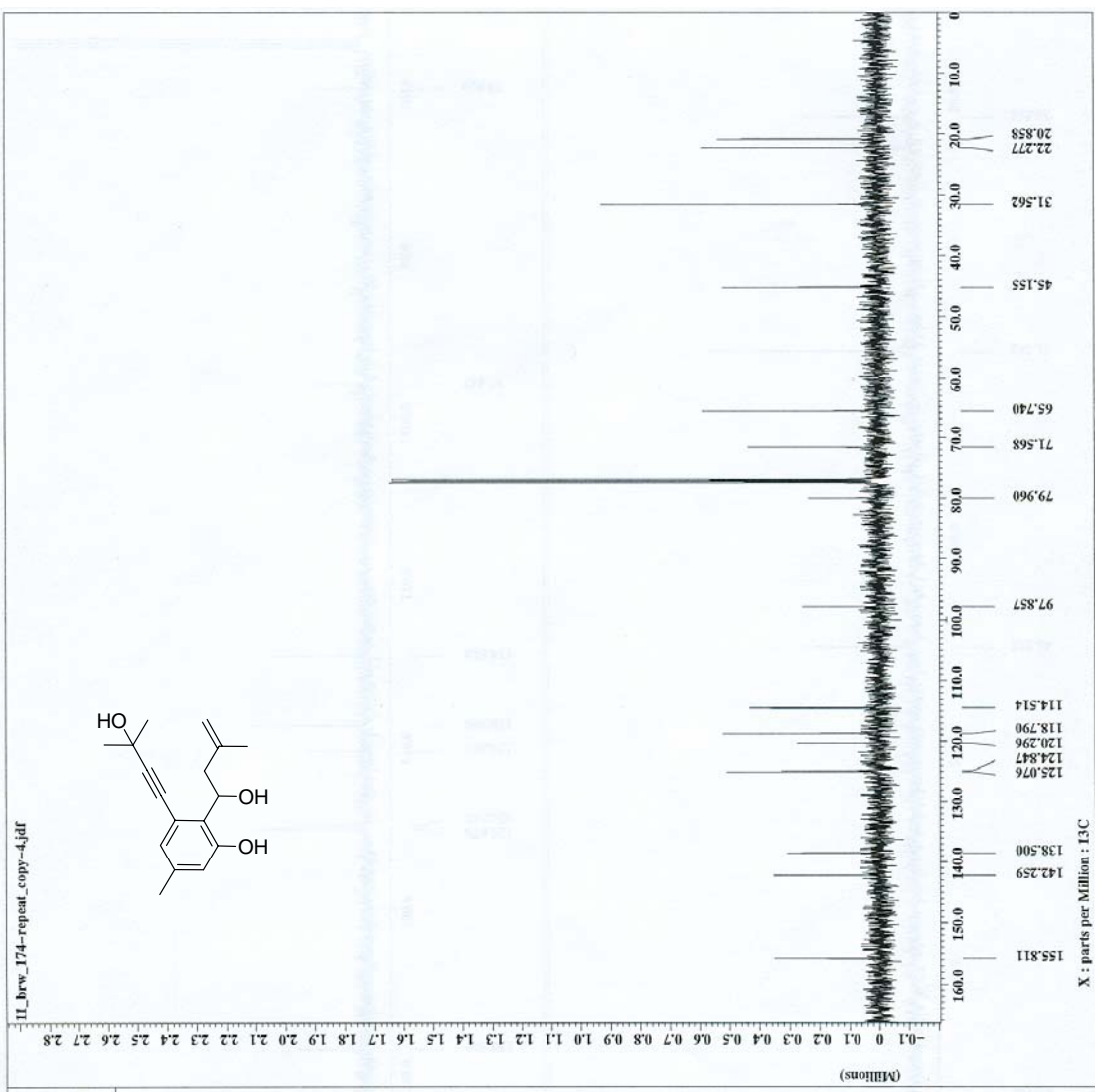




Filename = j1_brw_174-repeat_cop
Experiment = single_pulse_dec
Sample_id = SM456010
Solvent = CHLOROFORM-D
Creation_time = 20-SEP-2006 13:34:40
Revision_time = 20-SEP-2006 12:07:21
Current_time = 20-SEP-2006 12:07:59
Content = Single Pulse with Bro
Data_format = 1D COMPLEX
Data_size = 65536
Dim_title = 13C
Dim_units = [ppm]
Dimensions = Eclips+ 500
Site = DELTA_NMR
Spectrometer = DELTA_NMR
Field_strength = 11.7473579 [T] (500 MHz)
X_acq_duration = 1.736704[s]
X_freq = 125.76529768 [MHz]
X_offset = 100 [ppm]
X_points = 65536
X_prescans = 4
X_resolution = 0.57580336 [Hz]
X_sweep = 17.7358496 [MHz]
X_sweep_rate = 11.11111111 [MHz/s]
Irr_freq = 500.15991511 [MHz]
Irr_offset = 5 [ppm]
Clipped = FALSE
Mod_return = 1
Scans = 120
Total_scans = 120
X_90_width = 14.2 [us]
X_acq_time = 1.736704[s]
X_angle = 30 [deg]
X_pulse = 4.73333333 [us]
X_pulse_wait = 3 [us]
X_recycle_wait = 30 [us]
X_recovery = 30 [us]
Relaxation_delay = 4 [s]
Temp_get = 27.1 [dC]
Unblank_time = 2 [us]



j1_brw_174-repeat_copy-4.jdf

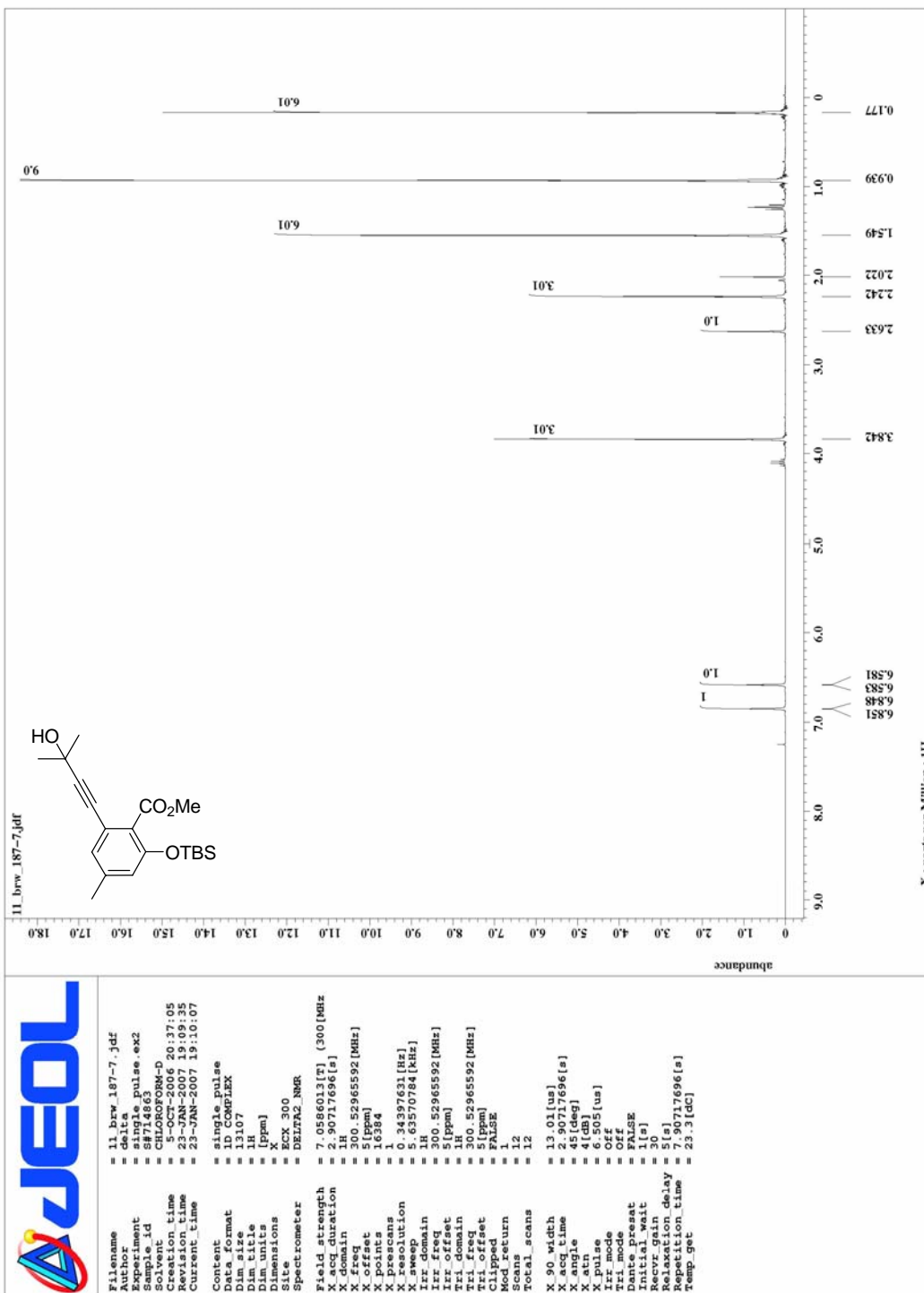


APPENDIX 100

¹H and ¹³C NMR SPECTRA OF

2-(3-hydroxy-3-methyl-1-butynyl)

-6-(*t*-butyldimethylsilyloxy)-4-methyl-methylbenzoate (124)





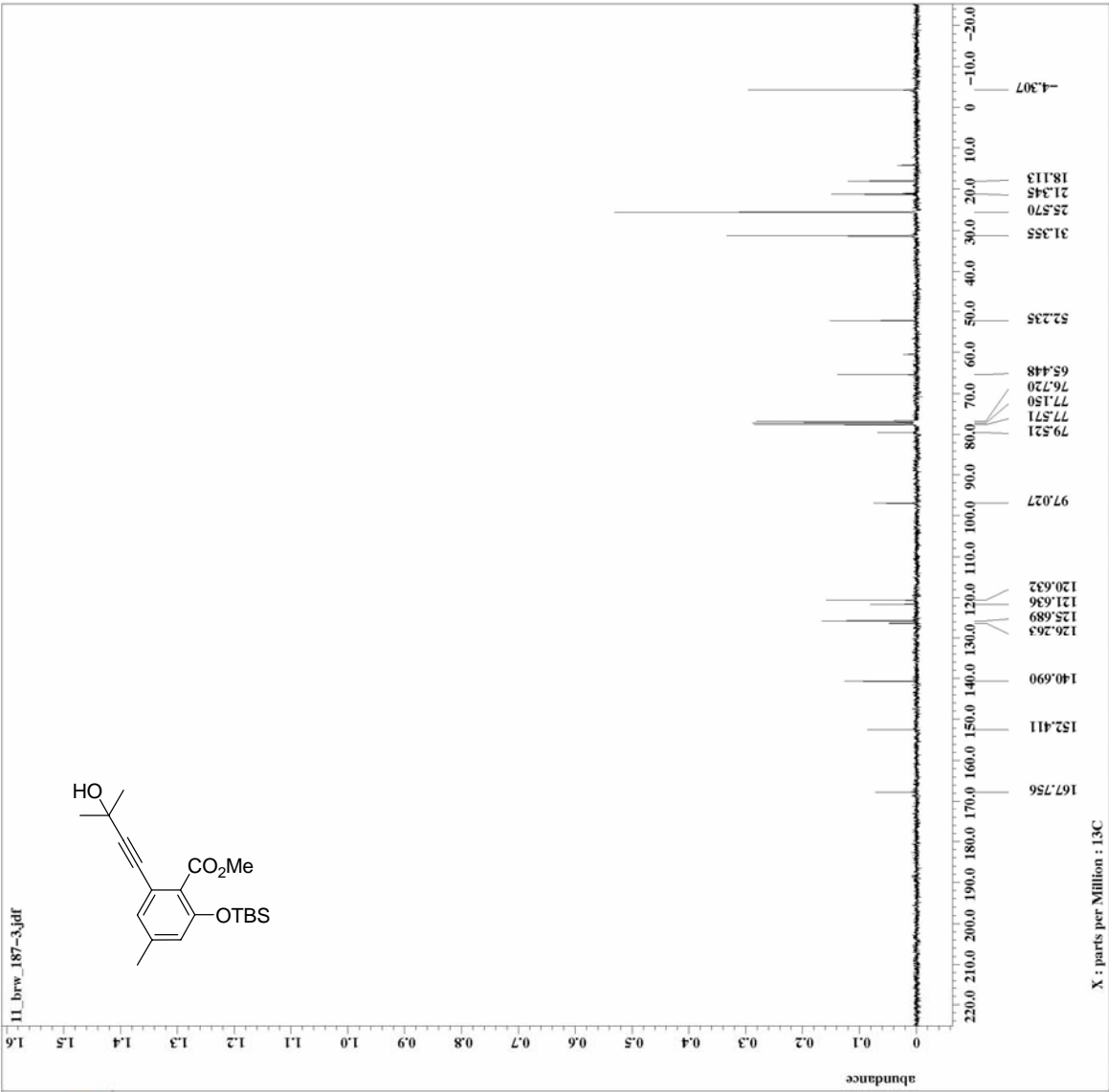
```

Filename = 11_brw_187-3.jdf
Author = delta
Experiment = single pulse_dec
Sample_id = S#714880
Solvent = CHLOROFORM-D
Creation_time = 5-OCT-2006 20:46:40
Revision_time = 23-JAN-2007 19:16:45
Current_time = 23-JAN-2007 19:17:16

Content = single pulse decouple
Data_format = 1D COMPLEX
Dim_size = 26214
Dim_title = 13C
Dim_units = [ppm]
Dimensions = X
Site = ECX 300
Spectrometer = DELTA2_NMR

Field_strength = 7.0586013[T] (300[MHz]
X_acq_duration = 1.38412032[s]
X_domain = 13C
X_freq = 75.56823426[MHz]
X_offset = 100[ppm]
X_points = 32768
X_prescans = 4
X_resolution = 0.72248054[Hz]
X_sweep_gain = 18.67424242[kHz]
X_sweep_rate = 13.45136808[kHz/s]
Irr_freq = 300.52965592[MHz]
Irr_offset = 5[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 111
Total_scans = 111

X_90_width = 9.75[us]
X_acq_time = 4.38412032[s]
X_cycle_time = 30[days]
X_gate = 8[days]
X_atn = 3.25[us]
X_pulse = 25[us]
Irr_atn_dec = 25[db]
Irr_atn_noe = 25[db]
Irr_noise = WALRZ
Decoupling = TRUE
Initial_wait = 1[s]
Noe_time = TRUE
Noe_time = 3[s]
Recur_gain = 50
Relaxation_delay = 3[s]
Repetition_time = 4.38412032[s]
Temp_get = 23.5[dc]
  
```



APPENDIX 101

^1H and ^{13}C NMR SPECTRA OF

2-(3-Hydroxy-3-methyl-1-butynyl)

-6-(*t*-butyldimethylsilyloxy) -4-methyl -benzyl alcohol (125)

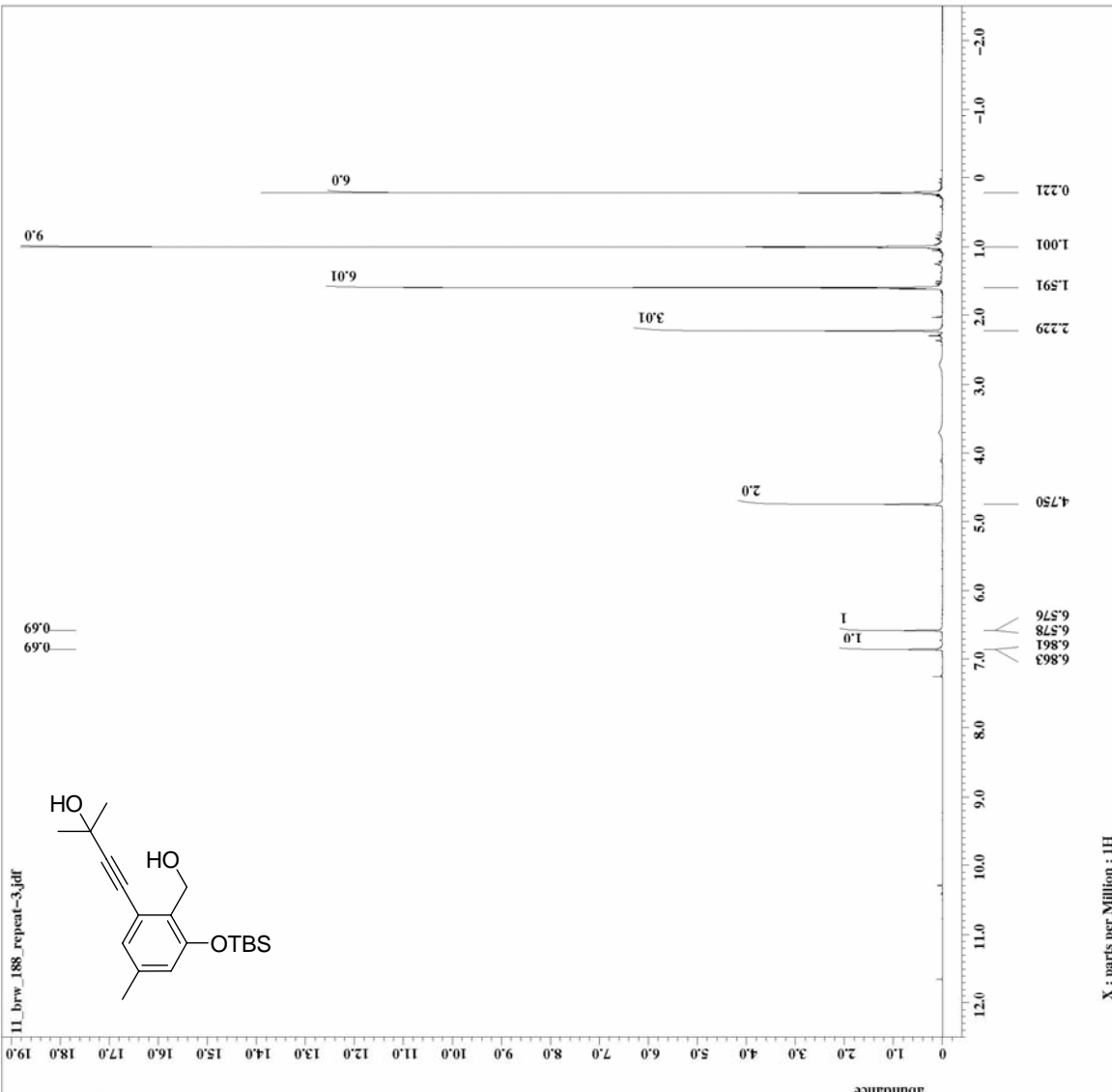


```

Filename = 11_brw_188_repeat-3.j
Author = delta
Experiment = single_pulse.ex2
Sample_id = S#429880
Solvent = CHLOROFORM-D
Creation_time = 13-OCT-2006 12:39:50
Revision_time = 13-OCT-2006 12:04:38
Current_time = 23-JAN-2007 19:38:05

Content = single_pulse
Data_format = 1D_COMPLEX
Dim_size = 13107
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Site = ECX 300
Spectrometer = DELTA2_NMR

Field_strength = 7.0586013[T] (300[MHZ]
X_acq_duration = 2.90717696[s]
X_domain = 1H
X_freq = 300.52965592[MHZ]
X_offset = 5[ppm]
X_points = 16384
X_prescans = 1
X_resolution = 0.34297631[Hz]
X_sweep = 1H
X_sweep_rate = 65570784[KHZ]
X_domain = 1H
X_freq = 300.52965592[MHZ]
X_offset = 5[ppm]
Tri_domain = 1H
Tri_freq = 300.52965592[MHZ]
Tri_offset = 5[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 24
Total_scans = 24
X_90_width = 13.01[us]
X_acq_time = 2.90717696[s]
X_angle = 45[deg]
X_atn = 4[db]
X_pulse = 6.505[us]
Irr_mode = Off
Tri_mode = Off
Pulse_program = FALSE
Pulse_program = 1s
Recvr_gain = 30
Relaxation_delay = 5[s]
Repetition_time = 7.90717696[s]
Temp_get = 22.8[dc]
  
```



X : parts per Million : 1H



```

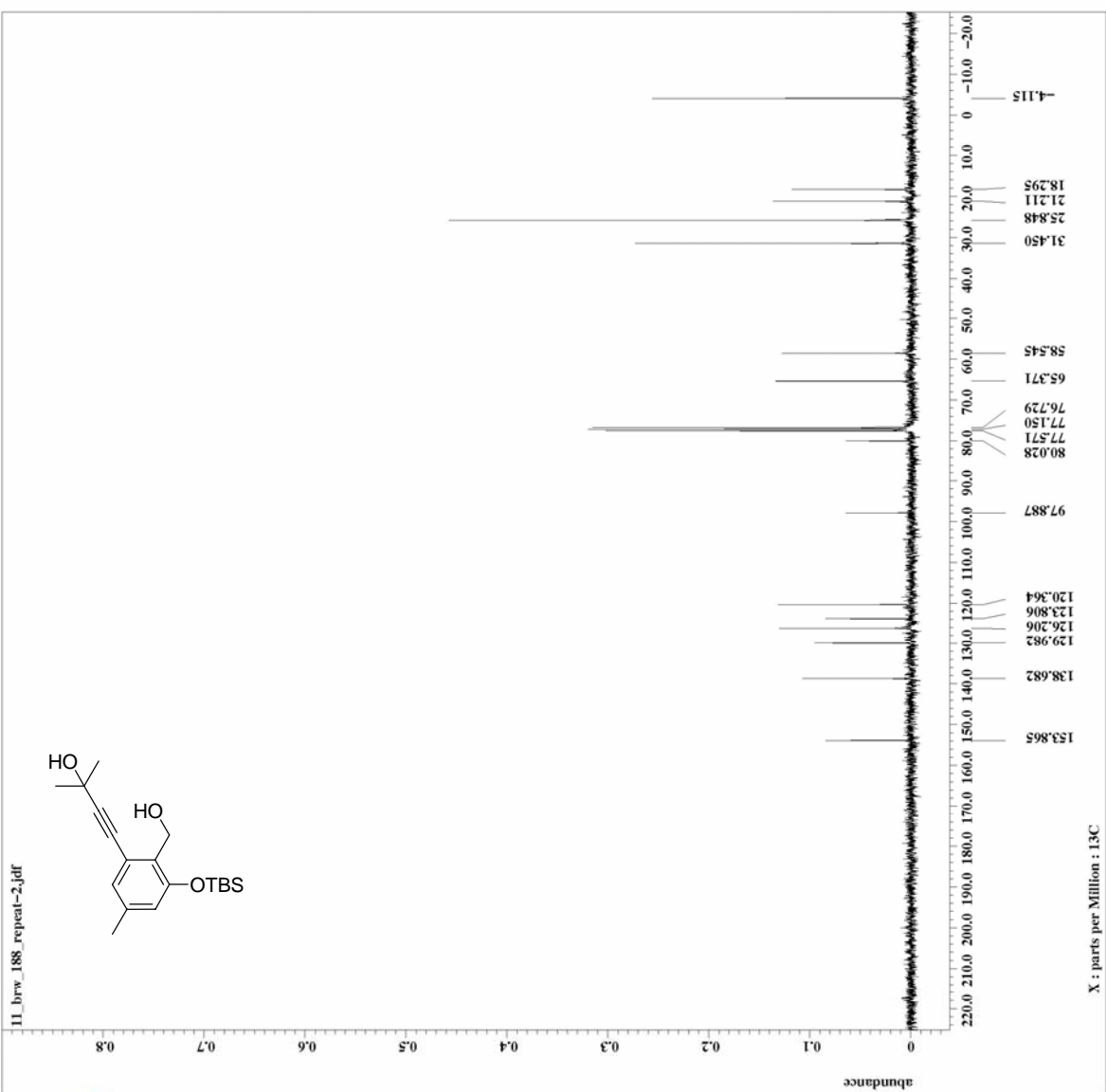
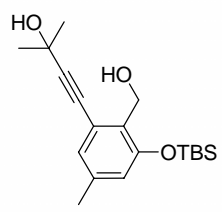
Filename = ll_brw_188_repeat-2.j
Author = delta
Experiment = single pulse_dec
Sample_id = S#430089
Solvent = CHLOROFORM-D
Creation_time = 13-OCT-2006 12:47:34
Revision_time = 13-OCT-2006 12:08:10
Current_time = 23-JAN-2007 19:36:59

Content = single pulse decouple
Data_format = 1D COMPLEX
Dim_size = 26214
Dim_title = 13C
Dim_units = [ppm]
Dimensions = X
Site = ECK 300
Spectrometer = DELTA2_NMR

Field_strength = 7.0586013[T] (300[MHz]
X_acquisition = 1.38412032[s]
X_domain = 13C
X_freq = 75.56823426[MHz]
X_offset = 100[ppm]
X_points = 32768
X_prescans = 4
X_resolution = 0.72248054[Hz]
X_sweep = 23.67424242[KHz]
Irr_domain = 1H
Irr_freq = 500.52965592[MHz]
Irr_offset = 0[ppm]
Irr_phase = FALSE
Mod_return = 1
Scans = 100
Total_scans = 100

X_90_width = 9.75[us]
X_acq_time = 1.38412032[s]
X_angle = 30[deg]
X_atn = 9[db]
X_pulse = 9[us]
Irr_atn_dec = 25[db]
Irr_atn_noe = 25[db]
Irr_noise = WALZ
Decoupling = TRUE
Initial_wait = 1[s]
Noe = TRUE
Noe_time = 3[s]
Recvr_gain = 50
Relaxation_delay = 3[s]
Repetition_time = 1.38412032[s]
Temp_get = 23[degC]
  
```

ll_brw_188_repeat-2.jdf



X : parts per Million : 13C

APPENDIX 102

¹H and ¹³C NMR SPECTRA OF

2-(3-Hydroxy-3-methyl-1-butynyl)

-6-(*t*-butyldimethylsilyloxy)-4-methyl -benzaldehyde (126)



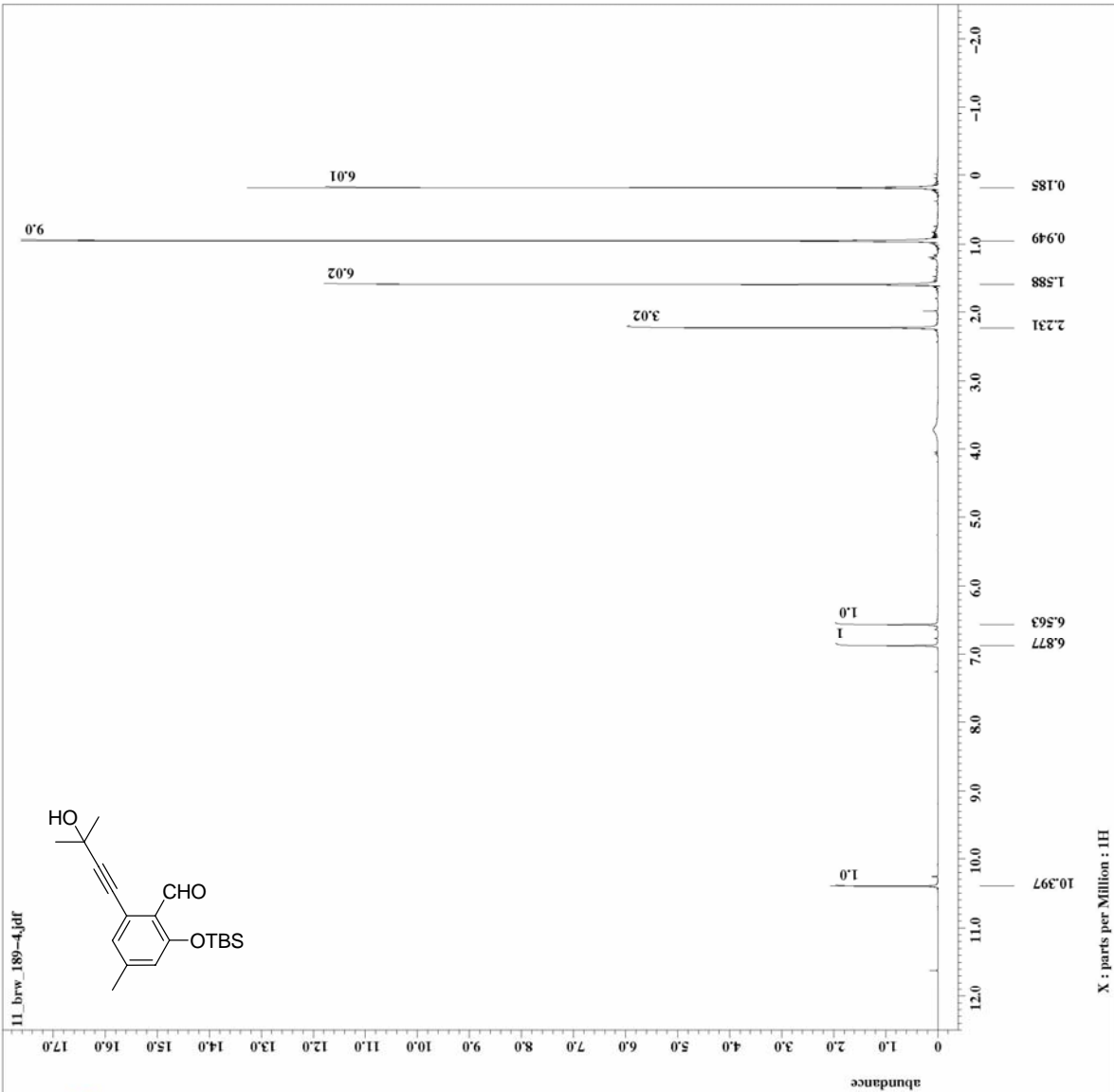
```

Filename = 11_brw_189-4.jdf
Author = delta
Experiment = single_pulse.ex2
Sample_id = S#406394
Solvent = CHLOROFORM-D
Creation_time = 13-OCT-2006 12:00:24
Revision_time = 13-OCT-2006 11:24:37
Current_time = 23-JAN-2007 19:43:05

Content = single_pulse
Data_format = 1D
Data_size = 13107
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Site = ECX 300
Spectrometer = DELTA2_NMR

Field_strength = 7.0586013[T] (300[MHz]
X_acq_duration = 2.90717696[s]
X_domain = 1H
X_freq = 300.52965592[MHz]
X_offset = 5[ppm]
X_points = 16384
X_prescans = 1
X_resolution = 0.34397631[Hz]
X_sweep = 5.63570784[kHz]
Irr_domain = 1H
Irr_freq = 300.52965592[MHz]
Irr_offset = 5[ppm]
Tri_domain = 1H
Tri_freq = 300.52965592[MHz]
Tri_offset = 5[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 18
Total_scans = 18

X_90_width = 13.01[us]
X_acq_time = 2.90717696[s]
X_angle = 45[deg]
X_atn = 4[db]
X_pulse = 6.505[us]
Tri_mode = Off
Tri_mode2 = Off
Dante_preset = FALSE
Initial_wait = 1[s]
Recvr_gain = 24
Relaxation_delay = 5[s]
Repetition_time = 7.90717696[s]
Temp_get = 23[dc]
  
```





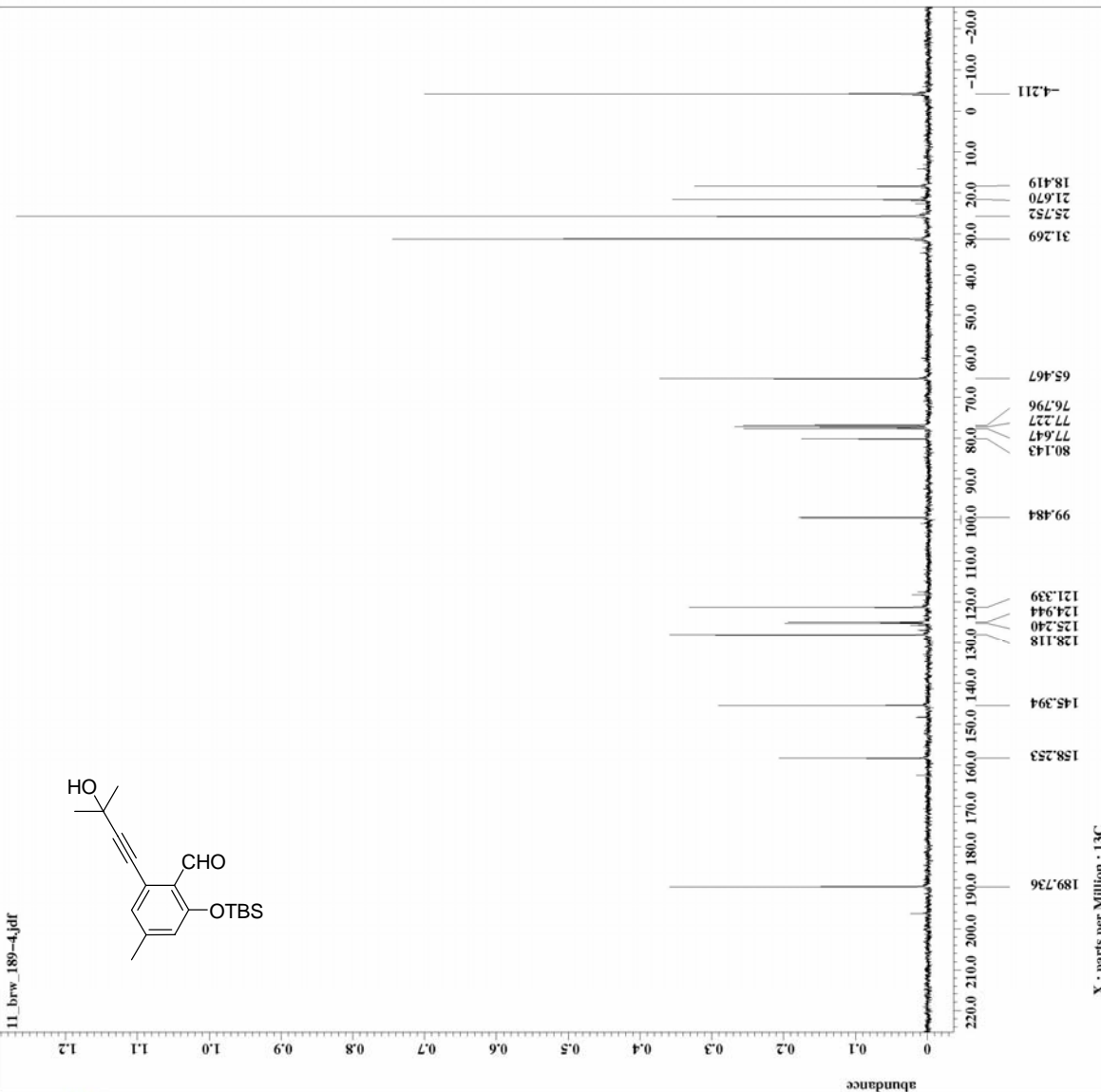
```

Filename = 11_brw_189-4_jdf
Author = delta
Experiment = single_pulse_dec
Sample_id = S#406494
Solvent = CHLOROFORM-D
Creation_time = 13-OCT-2006 12:13:00
Revision_time = 23-JAN-2007 19:43:58
Current_time = 23-JAN-2007 19:44:23

Content = single_pulse_decouple
Dim_format = GDF2EX
Dim_size = 26214
Dim_title = 13C
Dim_units = [ppm]
Dimensions = X
Site = ECX 300
Spectrometer = DELTA2_NMR

Field_strength = 7.0586013[T] (300[MHz]
X_acq_duration = 1.38412032[s]
X_domain = 75
X_freq = 75.56923426[MHz]
X_offset = 100[ppm]
X_points = 32768
X_prescans = 4
X_resolution = 0.72248054[Hz]
X_sweep = 23.67424242[kHz]
Irr_domain = 1H
Irr_freq = 300.52965592[MHz]
Irr_offset = 5[ppm]
Clipped = FALSE
Sof_return = 167
Total_scans = 167

X_90_width = 9.75[us]
X_acq_time = 1.38412032[s]
X_angle = 30[deg]
X_atn = 8[db]
X_atn2 = 3.25[us]
X_pulse = 25[db]
Irr_atn_dec = 25[db]
Irr_atn_noe = 25[db]
Irr_noise = 40[db]
Damping = TRUE
Solving = 1[s]
Initial_wait = TRUE
Noe_time = 3[s]
Recvr_gain = 50
Relaxation_delay = 3[s]
Repetition_time = 4.38412032[s]
Temp_get = 23[dc]
  
```



APPENDIX 103

¹H and ¹³C NMR SPECTRA OF

4-[2,2-Di-*tert*-butyl-7-methyl-4-(2-methyl-allyl)

-4*H*-benzo[1,3,2]dioxasilin-5-yl]-2-methyl-but-3-yn-2-ol (128)



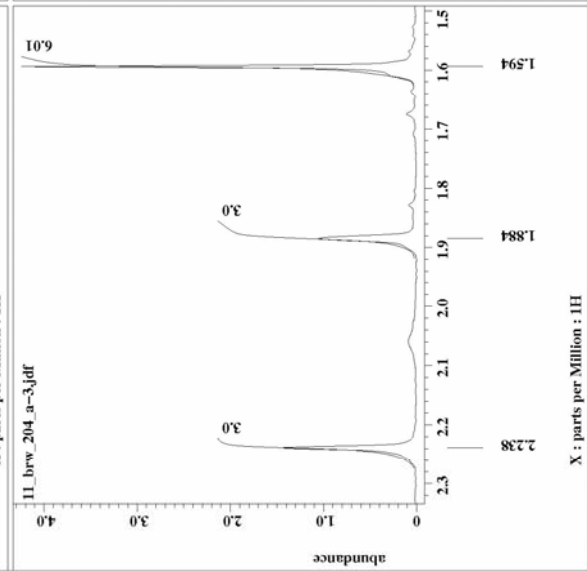
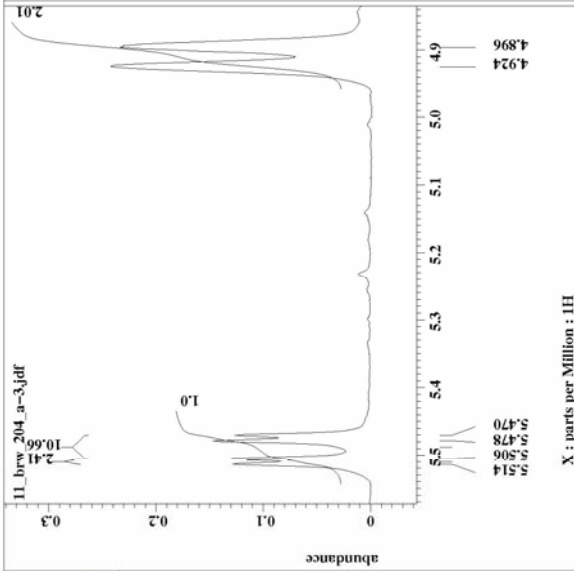
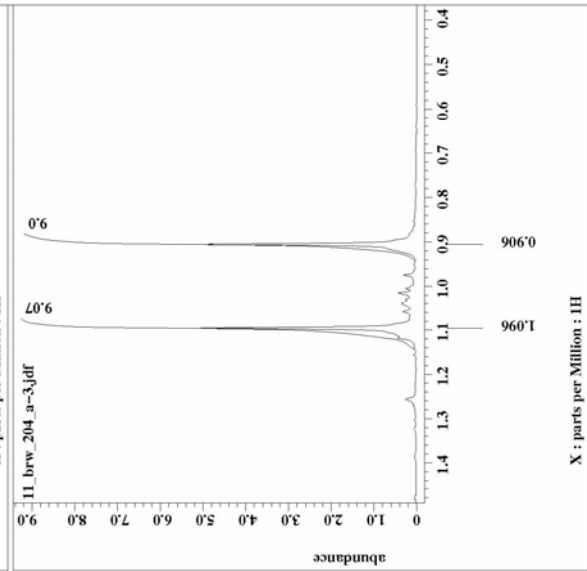
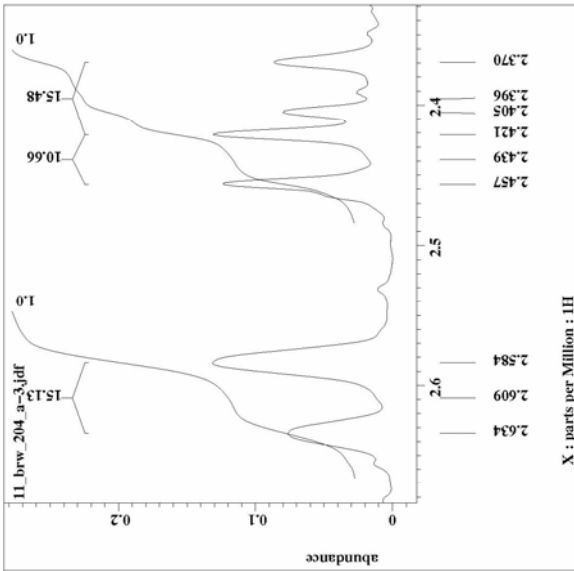
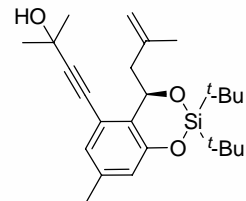
```

Filename = 11_brw_204_a-3.jdf
Author = delta
Experiment = single_pulse.ex2
Sample_id = 11-09-07
Solvent = CHLOROFORM-D
Creation_time = 11-JAN-2007 14:05:59
Revision_time = 11-JAN-2007 13:26:14
Current_time = 23-JAN-2007 19:54:26

Content = single_pulse
Data_format = 1D_COMPLEX
Dim_size = 13107
Dim_title = 1H
Dimension = X
Site = ECX 300
Spectrometer = DELTA2_NMR

Field_strength = 7.0586013[T] (300[MHz]
X_acq_duration = 2.90717696[s]
X_domain = 1H
X_freq = 300.52965592[MHz]
X_offset = 1[ppm]
X_prescans = 1
X_pulses = 1
X_resolution = 0.34397631[Hz]
X_sweep = 5.63570784[kHz]
Irr_domain = 1H
Irr_freq = 300.52965592[MHz]
Irr_offset = 1H
Tri_domain = 1H
Tri_freq = 500.52965592[MHz]
Tri_offset = 5[ppm]
Clip_start = 5[ppm]
Clip_end = 5[ppm]
Mod_return = 1
Scans = 24
Total_scans = 24

X_90_width = 13.01[us]
X_acq_time = 2.90717696[s]
X_angle = 45[deg]
X_atn = 4[cm]
X_delay = 4.005[us]
Irr_pulse = Off
Tri_mode = Off
Dante_presat = FALSE
Initial_wait = 1[s]
Recvr_gain = 30
Relaxation_delay = 5[s]
Repetition_time = 7.90717696[s]
Temp_get = 24.2[degC]
  
```





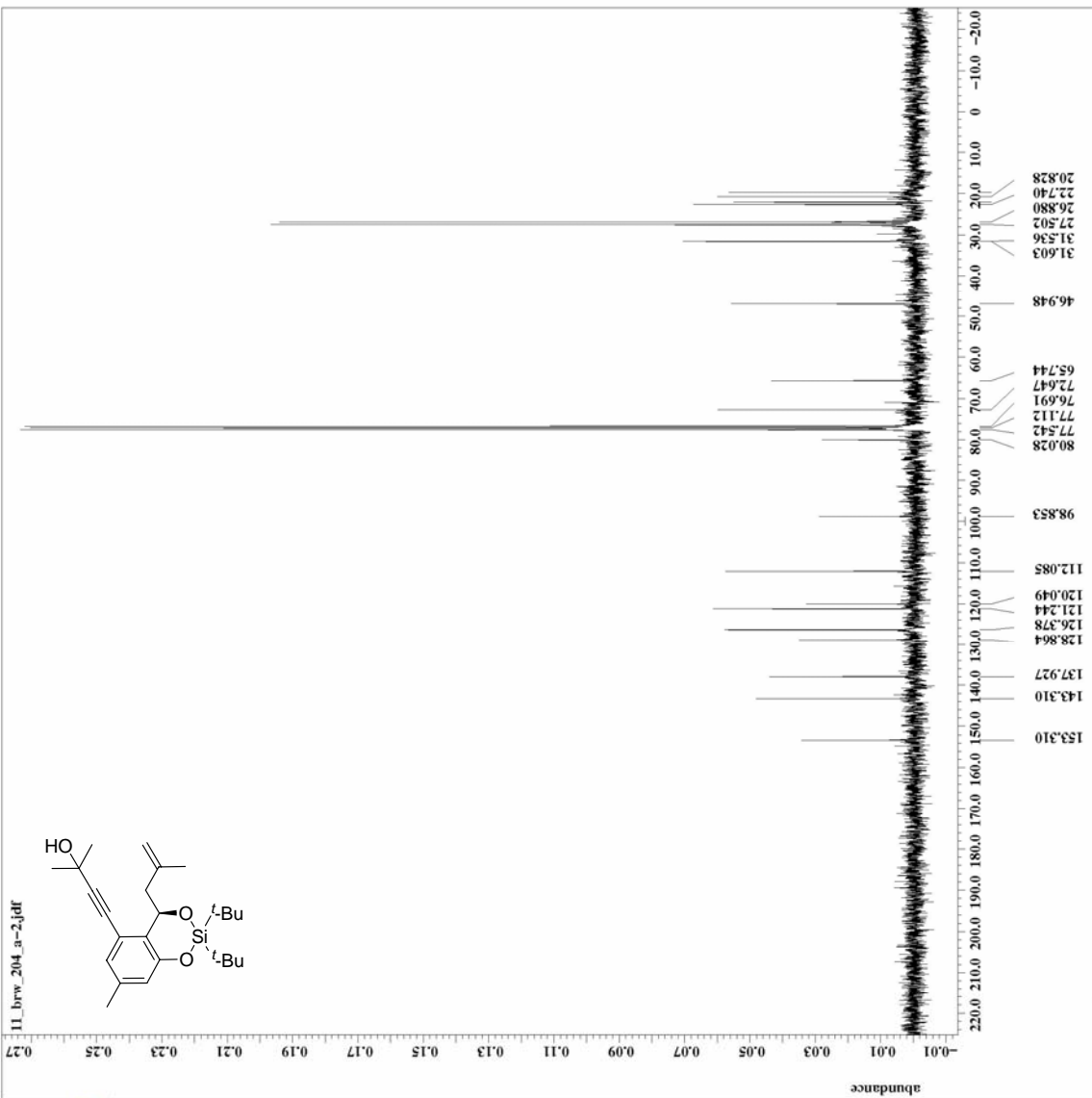
```

Filename = 11_brw_204_a-2.jdf
Author = delta
Experiment = single pulse dec
Sample_id = SH477639
Solvent = CHLOROFORM-D
Creation_time = 11-JAN-2007 14:23:55
Revision_time = 23-JAN-2007 19:56:46
Current_time = 23-JAN-2007 19:56:10

Content = single pulse decouple
Data_format = 1D COMPLEX
Dim_size = 26214
Dim_title = 13C
Dim_units = [ppm]
Dimensions = X
Site = ECX_300
Spectrometer = DELTA2_NMR

Field_strength = 7.0586013[T] (300[MHz])
X_acq_duration = 1.38412032[s]
X_domain = 13C
X_freq = 75.56823426[MHz]
X_offset = 100[ppm]
X_points = 32768
X_prescans = 4
X_resolution = 0.72248054[Hz]
X_sweep = 13
X_start_freq = 58.67424242[MHz]
X_end_freq = 300.52965592[MHz]
X_offset = 51[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 225
Total_scans = 225

X_90_width = 9.75[us]
X_acq_time = 3.38412032[s]
X_pulse_width = 30[us]
X_atn = 8[db]
X_pulse = 3.25[us]
Irr_atn_dec = 25[db]
Irr_atn_noe = 25[db]
Irr_noise = WALTZ
Decoupling = TRUE
Initial_wait = 1[s]
Nuc_time = TRUE
Nuc_gamma = 3[us]
Recvr_gain = 50
Relaxation_delay = 3[s]
Repetition_time = 4.38412032[s]
Temp_get = 22.6[dc]
  
```

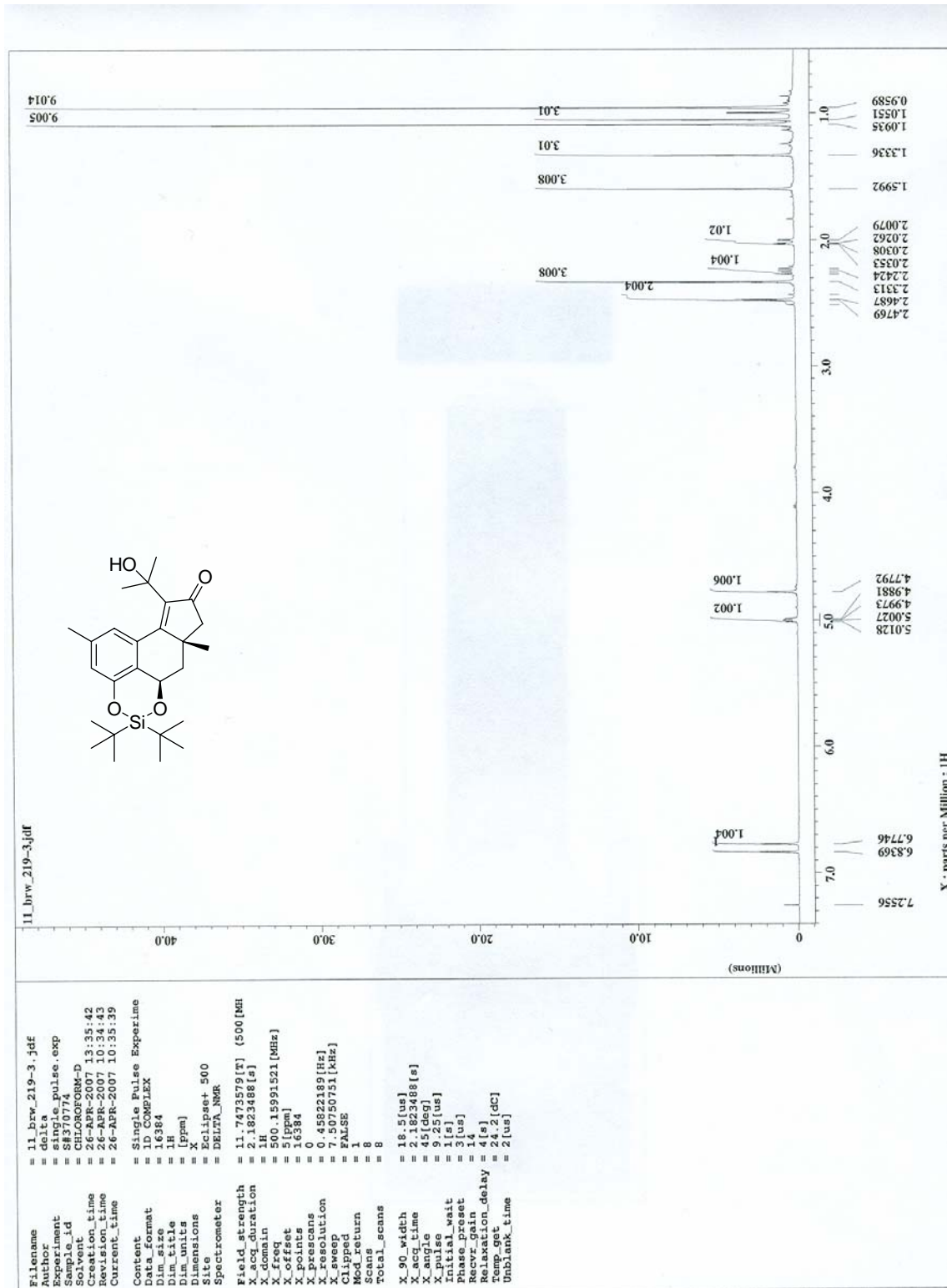


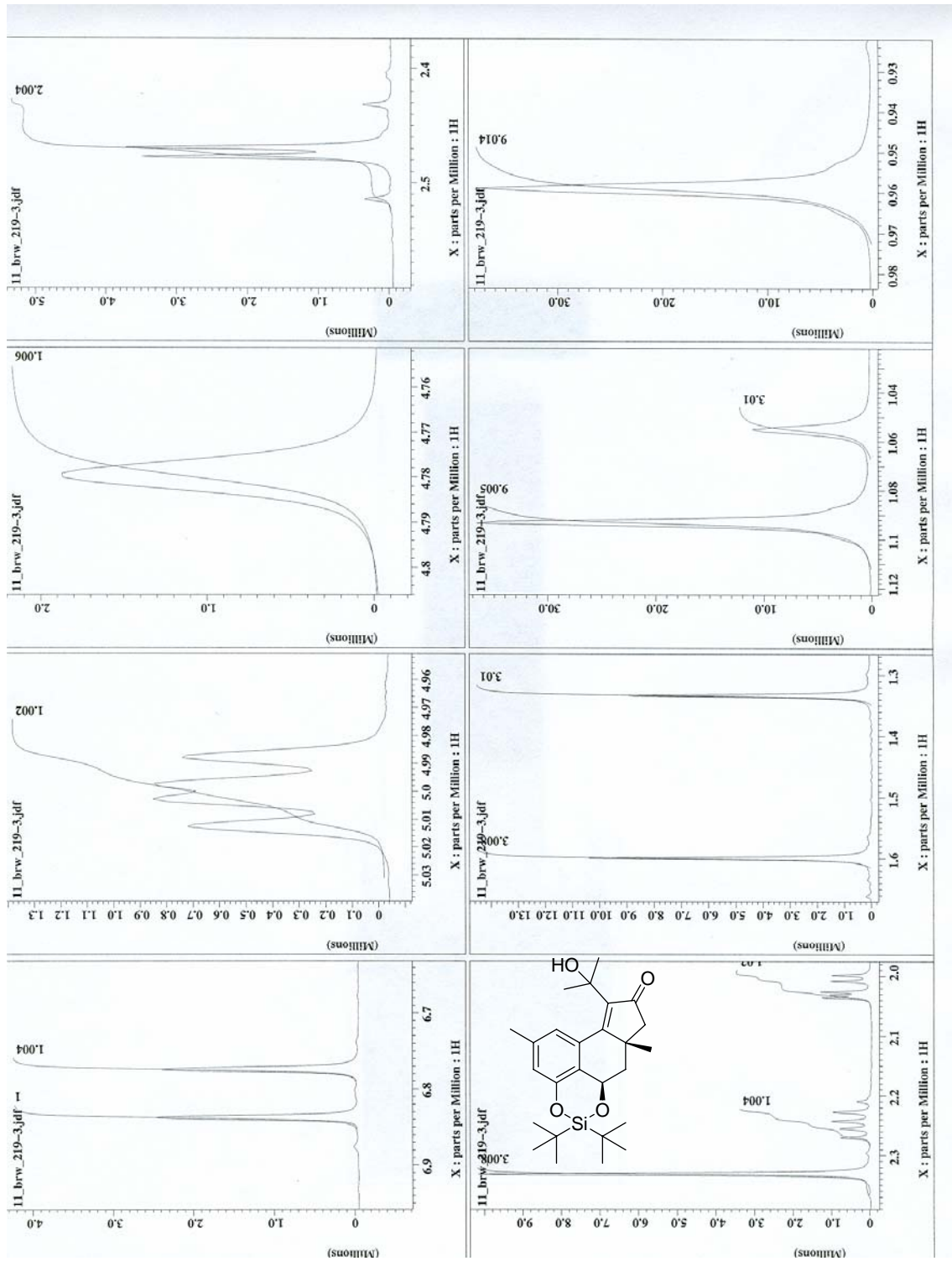
X : parts per Million : 13C

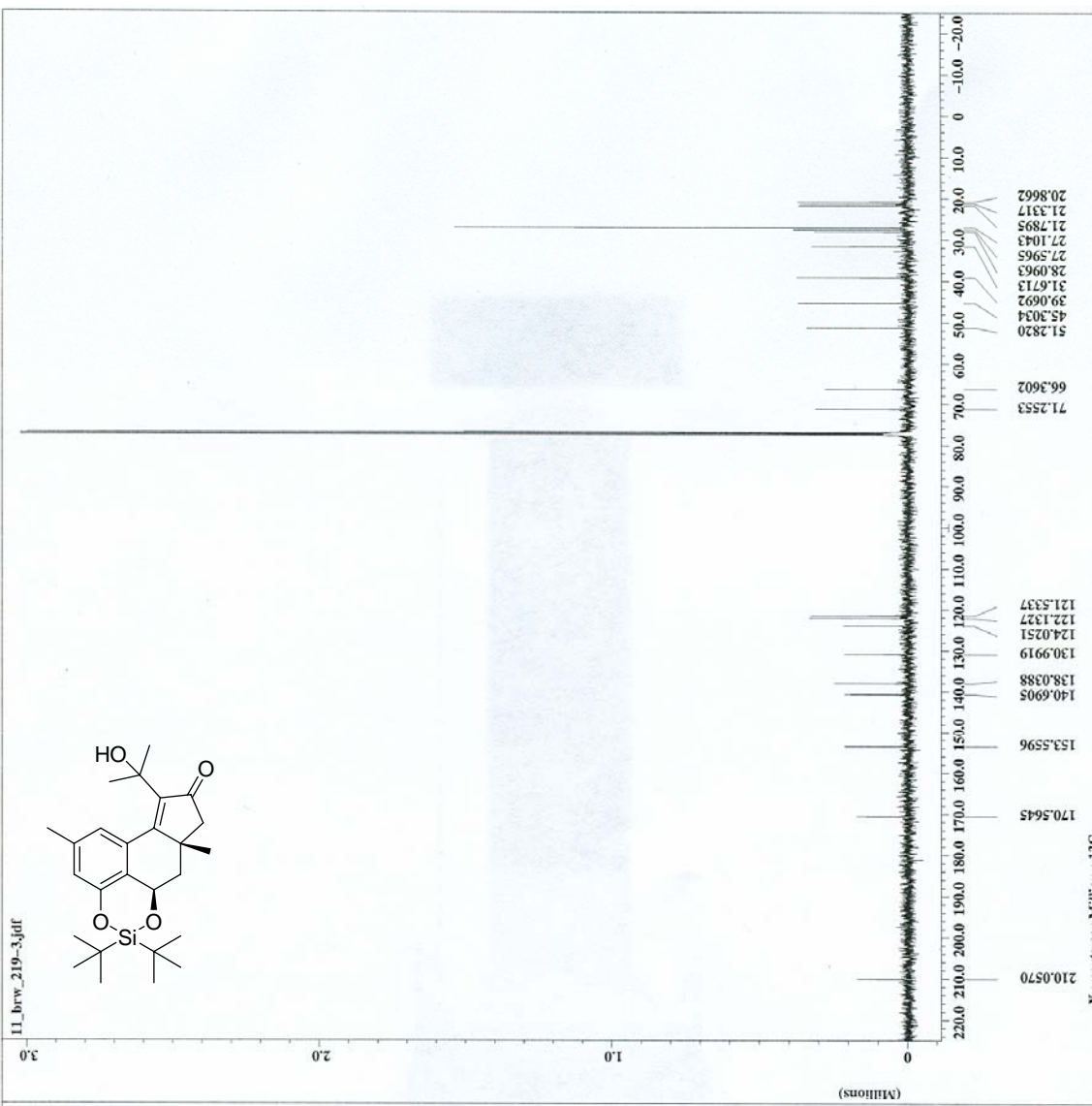
APPENDIX 104

¹H and ¹³C NMR SPECTRA OF

**5,5-Di-tert-butyl-10-(1-hydroxy-1-methyl-ethyl)
-2,7a-dimethyl-6a,7,7a,8-tetra hydro-4,6-dioxa
-5-sila-cyclopenta[a]phenalen-9-one (129)**







```

11_brv_219-3.jdf
=====
File name      = 11_brv_219-3.jdf
Acq date      = delc
Experiment    = single_pulse_dec
Sample ID     = S#527421
Solvent       = CHLOROFORM-D
Creation time  = 26-APR-2007 20:35:40
Revision time = 26-APR-2007 17:20:56
Current time  = 26-APR-2007 17:21:31
=====
Content
Data format   = single pulse decouple
Dim. size     = 1D COMPLEX
Dim. title    = 65536
Dim. units    = [ppm]
Dimensions    = X
Site          = Eclipse+ 500
Spectrometer = DELTA_NMR
=====
Field strength = 11.7473579 [T] (500 [MH
X.acq_duration = 2.0840448 [s]
X.domain       = 13C
X.freq         = 125.76529768 [MHz]
X.offset       = 100 [ppm]
X.points       = 65536
X.prescans     = 4
X.relaxation   = 4.7983613 [Hz]
X.sweep        = 31.44654088 [kHz]
Irr.domain     = 1H
Irr.freq       = 500.15991521 [MHz]
Irr.offset     = 5 [ppm]
Clipped       = TRUE
Mod.return     = 1
Scans          = 500
Total_scans   = 500
X.g0_width    = 14.2 [us]
X.acq_time     = 2.0840448 [s]
X.angle        = 30 [deg]
X.pulse        = 4.73333333 [us]
Initial_wait  = 1 [s]
Proc_time     = 3 [s]
Acq_start     = 2 [us]
Recvr_gain    = 30
Relaxation_delay = 2 [s]
Temp_get      = 27 [dc]
Unblank_time  = 2 [us]

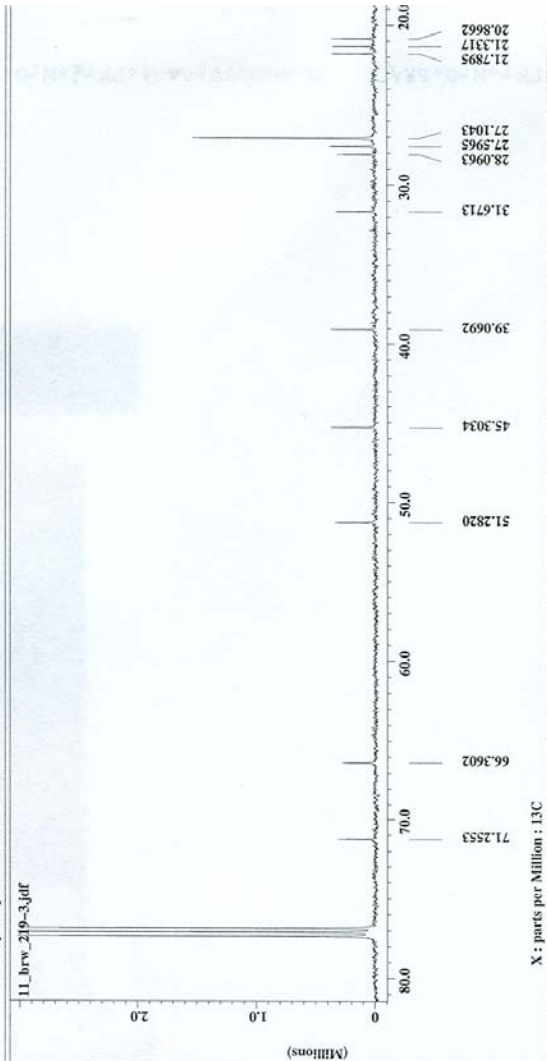
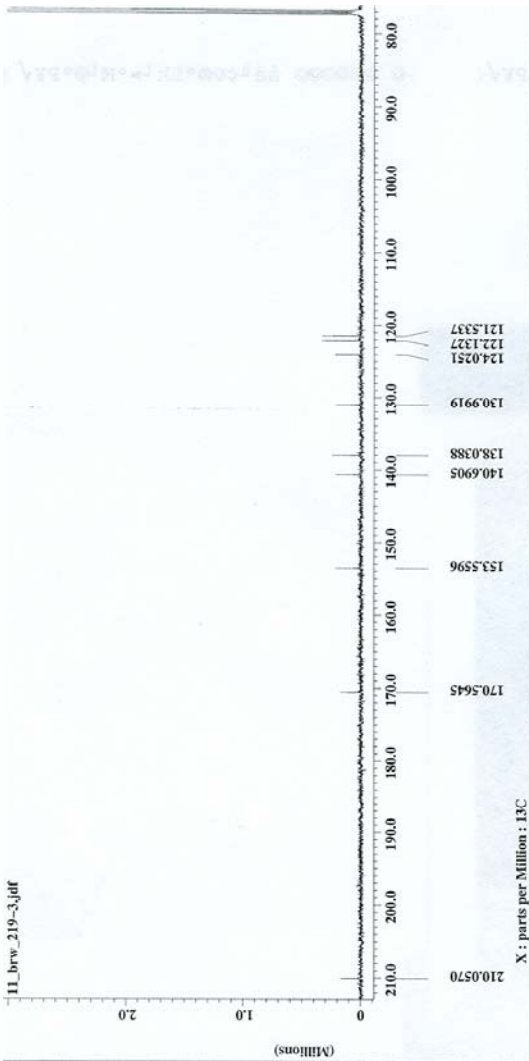
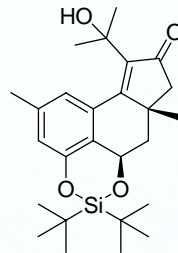
```



```

Filename = 11_brv_219-3_jdf
Author = delta
Experiment = delta_pulse_dec
Sample_id = S85721
Solvent = CHLOROFORM-D
Creation_time = 26-APR-2007 20:35:40
Revision_time = 26-APR-2007 17:20:56
Current_time = 26-APR-2007 17:22:28
Content = single pulse decouple
Data_format = 1D COMPLEX
Dim_size = 65536
Dim_title = 13C
Dim_units = [ppm]
Dimensions = 1
Site = Eclipsat 500
Spectrometer = DELTA_NMR
Field_strength = 11.7473579[T] (500 [MH
X_acq_duration = 12.0846448[s]
X_domain = 120.0000000
X_freq = 125.76529768 [MHz]
X_offset = 100 [ppm]
X_points = 65536
X_prescans = 4
X_resolution = 31.4706313 [Hz]
X_sfs = 31.44654088 [kHz]
Irr_domain = 18
Irr_freq = 500.15991521 [MHz]
Irr_offset = 5 [ppm]
Clipped = TRUE
Ssd_return = 1
Total_scans = 500
X_90_width = 14.2 [us]
X_acq_time = 2.0846448 [s]
X_delay = 0.0000000 [s]
X_pulse = 4.75333333 [us]
Initial_wait = 1 [s]
Noe_time = 1 [s]
Phase_preset = 3 [us]
Reovr_gain = 30
Ssd_wait_time = 1 [s]
Target_on_delay = 21 [dc]
Unblank_time = 2 [us]

```



SUPPORTING INFORMATION
FOR CRYSTAL STRUCTURE

Table of Contents

Table S1. Crystal, data collection, and refinement parameters for **24**

Table S2. Crystal, data collection, and refinement parameters for **29**

Table S3. Crystal, data collection, and refinement parameters for **41**

Table S1. Crystal data and structure refinement for **24**

Identification code	24	
Empirical formula	C ₂₇ H ₃₂ O ₂	
Formula weight	388.53	
Temperature	100(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group	P2(1)/n	
Unit cell dimensions	a = 12.4709(5) Å b = 11.7556(5) Å c = 15.0479(6) Å	α = 90°. β = 94.240(1)° γ = 90°.
Volume	2200.03(16) Å ³	
Z	4	
Density (calculated)	1.173 Mg/m ³	
Absorption coefficient	0.072 mm ⁻¹	
F(000)	840	
Crystal size	0.34 x 0.28 x 0.14 mm ³	
Theta range for data collection	2.05 to 26.00°	
Index ranges	-15 ≤ h ≤ 15, -14 ≤ k ≤ 14, -18 ≤ l ≤ 18	
Reflections collected	16982	
Independent reflections	4330 [R (int) = 0.0294]	
Completeness to theta = 26.00°	99.9 %	
Absorption correction	Multiscan	
Max. and min. transmission	0.9900 and 0.9760	
Refinement method	Full-matrix least-squares on F ²	
Data / restraints / parameters	4330 / 0 / 268	
Goodness-of-fit on F ²	1.032	
Final R indices [I > 2 sigma (I)]	R1 = 0.0393, wR2 = 0.1008	
R indices (all data)	R1 = 0.0426, wR2 = 0.1039	
Largest diff. peak and hole	0.332 and -0.174 e.Å ⁻³	

Table S2. Crystal data and structure refinement for **29**

Identification code	29	
Empirical formula	C ₂₇ H ₃₂ O ₃	
Formula weight	404.53	
Temperature	100(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group	P2(1)/n	
Unit cell dimensions	a = 12.6537(5) Å	α = 90°.
	b = 12.1017(5) Å	β = 91.776(1)°.
	c = 14.6631(6) Å	γ = 90°.
Volume	2244.30(16) Å ³	
Z	4	
Density (calculated)	1.197 Mg/m ³	
Absorption coefficient	0.076 mm ⁻¹	
F(000)	872	
Crystal size	0.29 x 0.26 x 0.25 mm ³	
Theta range for data collection	2.09 to 26.00°	
Index ranges	-15<=h<=15, -14<=k<=14, -18<=l<=17	
Reflections collected	16766	
Independent reflections	4409 [R (int) = 0.0636]	
Completeness to theta = 26.00°	99.9 %	
Absorption correction	Multiscan	
Max. and min. transmission	0.9808 and 0.9782	
Refinement method	Full-matrix least-squares on F ²	
Data / restraints / parameters	4409 / 0 / 281	
Goodness-of-fit on F ²	1.040	
Final R indices [I>2 sigma (I)]	R1 = 0.0526, wR2 = 0.1452	
R indices (all data)	R1 = 0.0553, wR2 = 0.1494	
Largest diff. peak and hole	0.334 and -0.311 e.Å ⁻³	

Table S3. Crystal data and structure refinement for **41**

Identification code	41	
Empirical formula	C ₂₈ H ₃₄ O ₃	
Formula weight	418.55	
Temperature	100(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group	P2(1)/n	
Unit cell dimensions	a = 13.5198(9) Å	α = 90°.
	b = 11.7482(8) Å	β = 90.675(1)°
	c = 14.8868(10) Å	γ = 90°.
Volume	2364.4(3) Å ³	
Z	4	
Density (calculated)	1.176 Mg/m ³	
Absorption coefficient	0.075 mm ⁻¹	
F(000)	904	
Crystal size	0.48 x 0.47 x 0.29 mm ³	
Theta range for data collection	2.02 to 25.99°	
Index ranges	-16 ≤ h ≤ 16, -14 ≤ k ≤ 14, -18 ≤ l ≤ 18	
Reflections collected	18090	
Independent reflections	4655 [R (int) = 0.0266]	
Completeness to theta = 25.99°	100.0 %	
Absorption correction	Multiscan	
Max. and min. transmission	0.9787 and 0.9651	
Refinement method	Full-matrix least-squares on F ²	
Data / restraints / parameters	4655 / 0 / 291	
Goodness-of-fit on F ²	1.046	
Final R indices [I > 2 sigma (I)]	R1 = 0.0433, wR2 = 0.1083	
R indices (all data)	R1 = 0.0496, wR2 = 0.1130	
Largest diff. peak and hole	0.320 and -0.162 e.Å ⁻³	

REFERENCES

PART I

1. Lautens, M.; Klute, W.; Tam, W. *Chem. Rev.* **1996**, *96*, 48.
2. (a) Ojima, I.; Tzamariaoudaki, M.; Li, Z.; Donovan, R. J. *Chem. Rev.* **1996**, *96*, 635. (b) Fletcher, A. J.; Christie, S. D. R. *J. Chem. Soc., Perkin Trans. 1*, **2000**, 1657.
3. Brummond, K.; Kent, J. L. *Tetrahedron* **2000**, *56*, 3263.
4. Laschat, S.; Becheanu, A.; Bell, T.; Baro, A. *Synlett* **2005**, *17*, 2547.
5. Pauson, P. L.; Khand, I. U.; Knox, G. R.; Watta, W. E. *J. Chem. Soc., Chem Commun.* **1974**, 379.
6. Khand, I. U.; Knox, G. R.; Pauson, P. L.; Watta, W. E.; Foreman, M. E. *J. Chem. Soc., Perkin Trans. 1* **1973**, 977.
7. Khand, I. U.; Pauson, P. L. *J. Chem. Res.* **1977**, 168.
8. Schore, N. E.; Croudace, M. C. *J. Org. Chem.* **1981**, *46*, 5436.
9. Smit, W. A.; Gybin, A. S.; Caple, R.; Swanson, E. D. *Tetrahedron Lett.* **1986**, *27*, 1241.
10. Krafft, M. E. *J. Am. Chem. Soc.* **1988**, *110*, 968.
11. Magnus, P.; Principe, L. M. *Tetrahedron Lett.* **1985**, *26*, 4851.
12. Gordon, G. M.; Kiszka, M.; Dunkin, I. R.; Kerr, W. J.; Scott, J.S.; Gebicki, J. *J. Organomet. Chem.* **1988**, *554*, 147.
13. Verdaguer, A.; Vazquez, J.; Fuster, G.; Bernardes-Genisson, V.; Greene, A. E.; Moyano, A.; Pericas, M. A.; Riera, A. *J. Org. Chem.* **1998**, *63*, 7037.

14. Robert, F.; Milet, A.; Gimbet, Y.; Konya, D.; Greene, A. E. *J. Am. Chem.* **2001**, *123*, 5396.
15. de Bruin, T. J. M.; Milet, A.; Robert, F.; Gimbet, Y.; Greene, A. E. *J. Am. Chem.* **2001**, *123*, 7184.
16. Yamanaka, M.; Nakamura, E.; *J. Am. Chem.* **2001**, *123*, 1703.
17. Breczinski, P. M.; Stumpf, A.; Hope, H.; Krafft, M. E.; casaluovo, J. A.; Schore, N. E. *Tetrahedron* **1999**, *55*, 6797.
18. MacWhorter, S. E.; Sampath, V.; Olmstead, M. M.; Schore, N. E. *J. Org. Chem.* **1988**, *53*, 203.
19. Pericas, M. A.; Balsells, J.; Castro, J.; Marchueta, I.; Moyano, A.; Riera, A.; Vazquez, J.; Verdaguer, X. *Pure Appl. Chem.* **2002**, *74*, 167.
20. Schilite, J. H.; Gkeiter, R.; Rominger, F. *Org. Lett.* **2002**, *4*, 3301.
21. Imhof, W.; Anders, E.; Gobel, A.; Gorls, H. *Chem. Eur. J.* **2003**, *9*, 1166.
22. Gimbert, Y.; Lesage, D.; Milet, A.; Fournier, F.; Greene, A. E.; Tabet, J. C. *Org. Lett.* **2003**, *5*, 4073.
23. de Bruin, T. J. M.; Milet, A.; Gimbet, Y.; Greene, A. E. *J. Org. Chem.* **2004**, *69*, 1075.
24. Shambayati, S.; Crowe, W.E.; Schrieber, S.L. *Tetrahedron Lett.* **1990**, *31*, 5289.
25. Jeong, N.; Chung, Y. K.; Lee, B.Y.; Lee, S. H.; Yoo, S. E. *Synlett* **1991**, 204.
26. Sugihara, T.; Yamada, M.; Yamaguchi, M.; Nishizawa, M. *Synlett* **1999**, 771.
27. Narasaka, K.; Shibata, T. *Chem. Lett.* **1994**, 315.
28. Shibata, T.; Takagi, K. *J. Am. Chem. Soc.* **2000**, *122*, 9852.

29. Kobayashi, T; Koga, Y; Narasaka, K. *J. Organometallics*, **2001**, 624, 73.
30. Hicks, F.A.; Kablaoui, N.M.; Buchwald, S.L. *J. Am. Chem. Soc.* **1996**, 118, 9450.
31. Tamao, K.; Kobayashi, K.; Ho, Y. *J. Am. Chem. Soc.* **1988**, 110, 1286.
32. Negishi, E. I.; Holmes, S. J.; Tour, J. M. *J. Am. Chem. Soc.* **1985**, 107, 2568.
33. Kondo, T.; Suzuki, N.; Okada, T.; Mitsudo, T. *J. Am. Chem. Soc.* **1997**, 119, 6187
34. Morimoto, T.; Chatani, N.; Fukumoto, Y.; Murai, S. *J. Org. Chem.* **1997**, 62, 3762.
35. Marco-Contelles, J.; Ruiz, J. *Tetrahedron Lett.* **1998**, 39, 6393.
36. Adrio, J.; Carretero, J. C. *J. Am. Chem. Soc.* **1999**, 121, 7411.
37. Rivero, M. R.; de la Rosa, J. C.; Carretero, J. C. *J. Am. Chem. Soc.* **2003**, 125, 14992
38. Fonquerna, S.; Rios, R.; Moyano, A.; Pericas, M. A.; Riera, A. *Eur. J. Org. Chem.* **1999**, 3459.
39. Rutherford, D. T.; Christie, S. D. R. *Tetrahedron Lett.* **1998**, 39, 9805
40. Fletcher, A. J.; Fryatt, R.; Rutherford, D. T.; Christie, S. D. R. *Tetrahedron Lett.* **2004**, 45, 5247.
41. Rios, R.; Pericas, M. A.; Moyano, A.; Maestro, M. A.; Mahia, J. *Org. Lett.* **2002**, 4, 1205.
42. Rios, R.; Pericas, M. A.; Moyano, A. *Tetrahedron Lett.* **2002**, 43, 4903.
43. Kerr, W. J.; Kirk, G. G.; Middlemiss, D. *Synlett*, **1995**, 1085.

44. Derdau, V.; Laschat, S.; Jones, P. G. *Heterocycles* **1998**, *48*, 1445.
45. Derdau, V.; Laschat, S. *J. Organomet. Chem.* **2002**, *642*, 131.
46. Rautenstrauch, V.; Megard, P.; Conesa, J.; Kester, W. *Angew. Chem., Int. Ed. Engl.* **1990**, *29*, 1413.
47. Rautenstrauch, V.; Megard, P.; Conesa, J.; Kester, W. *Angew. Chem.* **1990**, *102*, 1441.
48. Blanco-Urgoiti, J.; casarrubios, L.; Dominguez, G.; Perez-Castells, J. *Tetrahedron Lett.* **2002**, *43*, 5763.
49. Hicks, F. A.; Kablaoui, N. M.; Buchwald, S. L. *J. Am. Chem. Soc.* **1996**, *118*, 9450.
50. Hicks, F. A.; Kablaoui, N. M.; Buchwald, S. L. *J. Am. Chem. Soc.* **1996**, *118*, 5819.
51. Berk, S. C.; Grossman, R. B.; Buchwald, S. L. *J. Am. Chem. Soc.* **1993**, *115*, 4912.
52. Berk, S. C.; Grossman, R. B.; Buchwald, S. L. *J. Am. Chem. Soc.* **1994**, *116*, 8593.
53. Hicks, F. A.; Berk, S. C.; Buchwald, S. L. *J. Org. Chem.* **1996**, *61*, 2713.
54. Mukai, C.; Yoshida, T.; Sorimachi, M.; Odani, A. *Org. Lett.* **2006**, *8*, 83.
55. Ahmar, M.; Locatelli, C.; Colombiar, D.; Cazes, B. *Tetrahedron Lett.* **1997**, *38*, 5281
56. Brummond, K.M.; Chen, H.; Fisfer, K.D.; Kerekes, A.D.; Rickards, B.; Sill, P.C.; Geib, S. *J. Org. Lett.* **2002**, *4*, 1931

57. Pearson, A. J.; Yao, X. *Synlett* **1997**, 1281.
58. Mukai, C.; Sonobe, S.; Kim, J. S.; Hanoaka, M. *J. Org. Chem.* **2000**, *65*, 6654.
59. Krafft, M. E.; Fu, Z.; Bonaga, L.V.R. *Tetrahedron Lett.* **2001**, *42*, 1427.
60. Seshandri, H. *PhD thesis, University of Texas, Arlington.* **2001**.
61. Lovely, C. J.; Seshandri, H.; Wayland, B. R.; Cordes, A. W. *Org. Lett.*, **2001**, *3*, 2607.
62. Perez-Serrano, L.; Casarrubios, L.; Dominguez, G.; Perez-Castells, J. *Chem. Commun.* **2001**, 2602.
63. Krafft, M. *J. Am. Chem. Soc.* **1991**, *115*, 1693.
64. Nicholas, K. M. *Acc. Chem. Res.* **1987**, *20*, 207.
65. Nakano, K.; Katayama, M.; Ishihara, S.; Hiyama, T.; Nozaki, K. *Synlett*, **2004**, *8*, 1367-1370.
66. Antras, F.; Ahmar, M.; Cazes, B. *Tetrahedron Lett.* **2001**, *42*, 8157-8160.
67. Krafft, M. E.; Scott, I. L.; Romero, R. H. *J. Org. Chem.* **1992**, *57*, 5277-5278.
68. Krafft, M. E.; Bonaga, V. R.; Wright, J. A.; Hirose, C. *J. Org. Chem.* **2002**, *67*, 1233-1246.
69. Mukai, C.; Kim, J. S.; Uchiyama, M.; Sakamoto, S.; Hanaoka, M. *J. Chem. Soc., Perkin Trans. 1*, **1998**, 2903-2915.
70. Krafft, M. E.; Juliano, C. A.; Scott, I. L.; Wright, C.; McEachin, M. D. *J. Am. Chem. Soc.* **1991**, *113*, 1693-1703.
71. Krafft, M. E.; Scott, I. L.; Romero, R. H. *Tetrahedron Lett.* **1992**, *33*, 3829-3832.

72. Krafft, M. E.; Scott, I. L.; Romero, R. H.; Feibelman, S.; Van Pelt, C. E. *J. Am. Chem. Soc.* **1993**, *115*, 7199-7207.
73. Tanni, K.; Yamagata, T.; Akutagama, S.; Kumobayashi, H.; Taketomi, T.; Takaya, H.; Miyashita, A.; Noyori, R.; Otsuka, S. *J. Am. Chem. Soc.* **1984**, *106*, 5208-5217.
74. Parshall, G. W. "Homogenous Catalysis"; Wiley, New York, **1980**, chapter 33.
75. Stille, J. K.; Becker, Y. J. *J. Org. Chem.* **1980**, *45*, 2139.
76. Magnus, P.; Principe, L. M.; Slater, M. J. *J. Org. Chem.* **1987**, *52*, 1483-1486.
77. Magnus, P.; Principe, L. M. *Tetrahedron Lett.* **1985**, *26*, 4851-4854.
78. Exon, C.; Magnus, P. *J. Am. Chem. Soc.* **1983**, *105*, 2477-2478.
79. Arcadi, A.; Cacchi, S.; Rosario, M. D.; Giancarlo, F.; Marrinelli, F. *J. Org. Chem.* **1996**, *61*, 9280.
80. Omura, K. *J. Org. Chem.* **1984**, *49*, 3046.
81. Gnaim, J. M.; Keehn, P. H.; Green, B. S. *Tetrahedron Lett.* **1992**, *33*, 2883.
82. Larock, R. C.; Stinn, D. E. *Tetrahedron Lett.* **1988**, *29*, 4687-4690.
83. Marco-Contelles, J. *Tetrahedron Lett.* **1994**, *35*, 5059.
84. Marco-Contelles, J.; Ruiz, J. *J. Chem. Res. (S)* **1999**, 260.
85. Marco-Contelles, J.; Ruiz-Caro, J. *Carbohydr. Res.* **2001**, *335*, 71.
86. Muto, R.; Ogasawara, K. *Tetrahedron Lett.* **2001**, *42*, 4143.
87. Muller, E.; Mayer, R.; Narr, B.; Rieker, A.; Scheffler, K. *Liebige Ann. Chem.* **1961**, *645*, 25.

88. Cabot, R.; Lledo, A.; Reves, M.; Riera, A.; Verdaguer, X. *Organometallics* **2007**, *26*, 1134.
89. Bonaga, L. V. R.; Krafft, M. E. *Tetrahedron* **2004**, *60*, 9795.
90. Krafft, M. E.; Wilson, A. M.; Dasse, O. A.; Shao, B.; Cheung, Y. Y.; Fu, Z.; Bonaga, L. V. R.; Mollman, M. K. *J. Am. Chem. Soc.* **1996**, *118*, 6080.

PART II

1. Khand, I. U.; Knox, G. R.; Pauson, P. L.; Watts, W. E. *J. Chem. Soc., Chem. Comm.* **1971**, 36.
2. Schore, N.E. *In Comprehensive Organic Synthesis*; Trost, B.M., Ed. Pergamon: Oxford, **1991**; Vol. 5, p 1037.
3. Schore, N.E. Rowley, E.G. *J. Am. Chem. Soc.* **1988**, *110*, 5224.
4. Exon, C. Magnus, P. *J. Am. Chem. Soc.* **1983**, *105*, 2477.
5. Cambie, R. C.; Lal, A. R.; Kernan, M. R.; Berquist, P. R. *J. Nat. Prod.* **1995**, *58*, 940
6. Nicolaou, K. C.; Gray, D.; Tae, J. *Angew. Chem. Int. Ed.* **2001**, *40*, 3675.
7. Nicolaou, K. C.; Gray, D.; Tae, J. *Angew. Chem. Int. Ed.* **2001**, *40*, 3679.
8. Nicolaou, K. C.; Gray, D.; Tae, J. *J. Am. Chem. Soc.* **2004**, *126*, 613.
9. Clive, D. L.; Wang, J. *Tetrahedron Lett.* **2003**, *44*, 7731.
10. Clive, D. L.; Wang, J. *Angew. Chem., Int. Ed.* **2003**, *42*, 3406.
11. Trost, B. M.; Pissot-Soldermann, C.; Chen, I.; Schroeder, G. M. *J. Am. Chem. Soc.* **2004**, *126*, 4480.

12. Mehta, G.; Shinde, H. M. *Tetrahedron Lett.* **2003**, *44*, 7049.
13. Sperry, J. B.; Wright, D. L. *Tetrahedron Lett.* **2005**, *46*, 411.
14. Sivappa, R.; Lovely, C. J. unpublished results.
15. Bauta, W. E.; Lovett, D. P.; Cantrell, W. R.; Burke, B. D. *J. Org. Chem.* **2003**, *68*, 5967.
16. Diemer, V.; Chaumeil, H.; Defoin, A.; Fort, A.; boeglin, A.; Carre, C. *Eur. J. Org. Chem.* **2006**, *12*, 2727.
17. Clive, D. L.; Sannigrahi, M.; Hisaindee, S. *J. Org. Chem.* **2001**, *66*, 954.
18. Carvalho, C. F.; Sargent, M. V. *J. Chem. Soc., Perkin Trans. 1*, **1984**, 505-508.
19. Brittain, J. M., de la mare, P. B. D., Isaacs, N. S., Mcintyre, P. D. *J. Chem. Soc., Perkin Trans. II*, **1979**, 933.
20. Keck, G.E.; McLaws, M. D.; Wager, T. T. *Tetrahedron* **2000**, *56*, 9875.
21. Roesch, K. R.; Larock, R. C. *J. Org. Chem.*, **2002**, *67*, 86.
22. Blanco-Urgoiti, J.; Casarrubios, L.; Dominguez, G.; Perez-Castells, J. *Tetrahedron Lett.* **2002**, *43*, 5763.
23. Smit, W. A.; Gybin, A. S.; Shashkov, A. S.; Strychkov, Y. T.; Kyz'mina, L. G.; Mikaelian, G. S.; Caple, R.; Swanson, E. D. *Tetrahedron Lett.* **1986**, *27*, 1241.
24. Beak, P.; Brown, P. A. *J. Org. Chem.*, **1982**, *47*, 34.
25. Selles, P.; Lett, R. *Tetrahedron Lett.* **2002**, *43*, 4621.
26. Yasuyuki, K.; Yoshifumi, T.; Kiyosei, I.; Kayoko, Y.; Kenji, T.; Shuji, A. *Tetrahedron Lett.* **1996**, *37*, 7545.

BIOGRAPHICAL INFORMATION

Christian E. Madu, born in Aba, Nigeria, obtained his B.Sc. and M.S. from the University of Lagos, Nigeria in 1997. He worked as a research associate under the guidance of Professor Oluwole B. Familoni at the University of Lagos, Nigeria from 1999 to 2001. He then began his doctoral studies at the University of Texas at Arlington in Fall semester, 2001. As a graduate student he worked with Professor Carl Lovely. He obtained his doctorate in 2007.