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Palladium catalyzed C(sp^2)-C(sp^2) bond formation. A highly regio- and chemoselective dehydrogenative C-3 alkenylation of pyrones and pyridones

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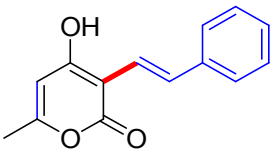
General information

^{1}H and ^{13}C NMR spectra were recorded on Bruker 400 MHz spectrometer with TMS as the internal standard. Chemical shifts are expressed in parts per million (δ ppm). Silica gel coated aluminium plates were used for TLC. The molecular formula of the compounds was analysed through HRMS with a QTOF analyser. Reagents used were mostly purchased from Sigma-Aldrich. The solvents used were mostly of LR grade.

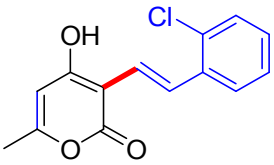
Experimenatl procedures and spectral analysis.

Synthesis of 3-alkenylated -4-hydroxy-6-methyl-pyrones

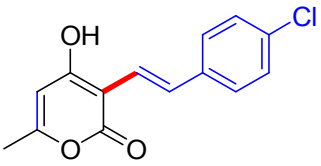
General procedure: **3-alkenylated -4-hydroxy-6-methyl-pyrones**. To a solution of the 4-Hydoxy-6-methyl-2-pyrone (0.4 mmol, 1.0 equiv.) in DMF:DMSO (8:2) 2ml, was added styrene (0.44 mmol, 1.1 equiv.), 5 mol % $Pd(OAc)_2$ and 5 mol % $Cu(OTf)_2$ in open air flask. The reaction mixture was allowed to stirr at room temperature for 16 h. The completion of the reaction was monitored through TLC followed by extraction using ethyl acetate and water. The organic layer was concentrated in rotary evaporator and the crude mixture was subjected to column chromatography using DCM:CH_3OH as eluent to yield the desired product.



4-Hydroxy-6-methyl-3-styryl-pyran-2-one (3): The title compound was prepared by using general procedure using 4-hydroxy-6-methyl-2-pyrone (0.4 mmol, 50 mg) and styrene (0.44 mmol, 50 µl) to yield **3** as semisolid **(**70%, 62 mg). The product was purified using column chromatography [eluent; hexane : ethylacetate (60:40), R_f value 0.44. in 70:30 ethylacetate : hexane]. ^{1}H NMR (400 MHz, MeOD) δ 7.60 (d, *J* = 16.5 Hz, 1H), 7.40 (d, *J* = 7.7 Hz, 2H), 7.25 (t, *J* = 7.6 Hz, 2H), 7.14 (dd, *J* = 14.7, 9.0 Hz, 2H), 6.03 (s, 1H), 2.20 (s, 3H). ^{13}C NMR (101 MHz, MeOD), δ 168.1, 166.3, 162.3, 140.2, 131.3, 129.6 x 2, 128.0, 127.2 x 2, 119.0, 101.7, 101.3, 19.9. HRMS (ESI$^+$) m/z calcd for $C_{14}H_{12}NaO_3$ $(M+Na)^+$ 251.0684, found; 251.0693.

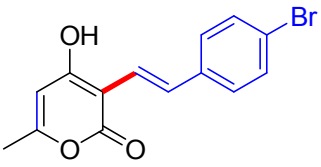


3-[2-(2-Chloro-phenyl)-vinyl]-4-hydroxy-6-methyl-pyran-2-one (4): The title compound was prepared by the general procedure using 4-hydroxy-6-methyl-2-pyrone (0.4 mmol, 50 mg) and 3-chlorostyrene (0.44 mmol, 58 µl) to yield **4** as semisolid **(**67%, 71 mg). The product was purified using column chromatography [eluent; hexane : ethylacetate (60:40), R_f value 0.43. in 70:30 ethylacetate : hexane]. ^{1}H NMR (400 MHz, MeOD) δ 8.05 (d, *J* = 16.4Hz, 1H), 7.70 (t, *J* = 9.3 Hz, 1H), 7.35 (d, *J* = 7.9 Hz, 1H), 7.30 – 7.10 (m, 3H), 6.09 (s, 1H), 2.27 (s, 3H). ^{13}C NMR (101 MHz, MeOD), δ 168.1, 166.0, 162.4, 137.9, 134.0, 130.4, 128.8, 127.7, 127.1, 126.9, 121.4, 101.5, 101.2, 20.0. HRMS (ESI$^+$) m/z calcd for $C_{14}H_{11}NaClO_3$ $(M+Na)^+$ 285.0294, found; 285.0286.

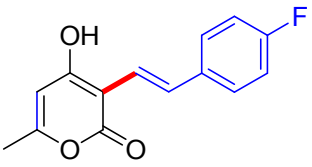


3-[2-(4-Chloro-phenyl)-vinyl]-4-hydroxy-6-methyl-pyran-2-one (5*)*: The title compound was prepared by the general procedure using 4-hydroxy-6-methyl-2-pyrone (0.4 mmol, 50 mg) and 4-chlorostyrene (0.44 mmol, 54 µl) to yield **5** as semisolid **(**68%, 72 mg). The product was purified using column chromatography [eluent; hexane : ethylacetate (60:40), R_f

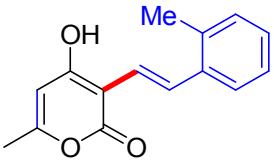
value 0.43. in 70:30 ethylacetate : hexane]. ^{1}H NMR (400 MHz, DMSO-d_6) δ 7.56 (d, *J* = 16.4 Hz, 1H), 7.46 (d, *J* = 8.5 Hz, 2H), 7.36 (d, *J* = 8.5 Hz, 2H), 7.15 (d, *J* = 16.4 Hz, 1H), 6.13 (s, 1H), 2.21 (s, 3H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 166.5, 162.4, 161.6, 137.3, 131.1, 128.6 x 2, 127.4 x 2, 126.8, 119.4, 100.0, 98.6, 19.5. HRMS (ESI$^+$) m/z calcd for $C_{14}H_{11}NaClO_3$ $(M+Na)^+$ 285.0294, found; 285.0283.



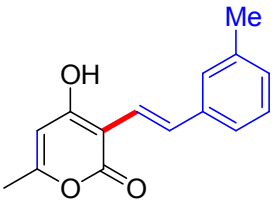
3-[2-(4-Bromo-phenyl)-vinyl]-4-hydroxy-6-methyl-pyran-2-one (6): The title compound was prepared by the general procedure using 4-hydroxy-6-methyl-2-pyrone (0.4 mmol, 50 mg) and 4-bromostyrene (0.57 mmol, 75 µl) to yield **6** as semisolid **(**64%, 79 mg). The product was purified using column chromatography [eluent; hexane : ethylacetate (60:40), R_f value 0.43. in 70:30 ethylacetate : hexane]. ^{1}H NMR (400 MHz, MeOD) δ 7.56 (d, *J* = 16.4 Hz, 1H), 7.42 – 7.37 (m, 2H), 7.31 (d, *J* = 8.5 Hz, 2H), 7.19 (d, *J* = 16.4 Hz, 1H), 6.03 (s, 1H), 2.21 (s, 3H). ^{13}C NMR (101 MHz, MeOD), δ 168.4, 166.2, 163.0, 139.5, 132.8 x 2, 130.0, 129.0 x 2, 121.6, 120.0, 101.6, 101.3, 19.9. HRMS (ESI$^+$) m/z calcd for $C_{14}H_{11}NaBrO_3$ $(M+Na)^+$ 328.9789, found; 328.9796.



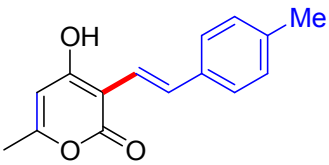
3-[2-(4-Fluoro-phenyl)-vinyl]-4-hydroxy-6-methyl-pyran-2-one (7): The title compound was prepared by the general procedure using 4-hydroxy-6-methyl-2-pyrone (0.4 mmol, 50 mg) and 4-fluorostyrene (0.44 mmol, 56 µl) to yield **7** as semisolid **(**70%, 69 mg). The product was purified using column chromatography [eluent; hexane : ethylacetate (60:40), R_f value 0.43. in 70:30 ethylacetate : hexane]. ^{1}H NMR (400 MHz, DMSO) δ 7.58 (d, *J* = 16.4 Hz, 1H), 7.48 (dd, *J* = 8.6, 5.6 Hz, 2H), 7.17 – 7.05 (m, 3H), 6.12 (s, 1H), 2.23 (m, 3H). ^{13}C NMR (101 MHz, DMSO) δ 166.22, 162.59, 162.54, 161.31, 160.12, 135.03, 135.00, 127.68, 127.61, 127.21, 118.51, 118.49, 115.67, 115.45, 100.07, 98.81, 19.4. HRMS (ESI$^+$) m/z calcd for $C_{14}H_{11}NaFO_3$ $(M+Na)^+$ 269.0590, found; 269.0597.



4-Hydroxy-6-methyl-3-(2-o-tolyl-vinyl)-pyran-2-one (8): The title compound was prepared by the general procedure using 4-hydroxy-6-methyl-2-pyrone (0.4 mmol, 50 mg) and 2-methylstyrene (0.44 mmol, 47 µl) to yield **8** as semisolid **(**70%). The product was purified using column chromatography [eluent; hexane : ethylacetate (60:40), R_f value 0.43. in 70:30 ethylacetate : hexane]. ^{1}H NMR (400 MHz, DMSO) δ 7.82 (d, *J* = 16.2 Hz, 1H), 7.50 (d, *J* = 7.7 Hz, 1H), 7.20 – 7.09 (m, 3H), 7.03 (d, *J* = 16.2 Hz, 1H), 6.13 (s, 1H), 2.30 (s, 3H), 2.21 (s, 3H). ^{13}C NMR (101 MHz, DMSO) δ 166.16, 162.64, 161.28, 137.32, 134.83, 130.28, 126.85, 126.25, 126.06, 124.20, 119.47, 100.04, 99.18, 19.51, 19.51. HRMS (ESI$^+$) m/z calcd for $C_{15}H_{14}NaO_3$ $(M+Na)^+$ 265.0841, found; 265.0849.

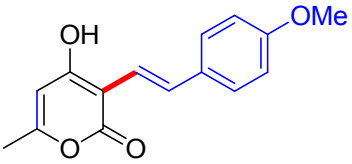


4-Hydroxy-6-methyl-3-(2-m-tolyl-vinyl)-pyran-2-one (9): The title compound was prepared by the general procedure using 4-hydroxy-6-methyl-2-pyrone (0.4 mmol, 50 mg) and 3-methylstyrene (0.44 mmol, 47 µl) to yield **9** as semisolid **(**70%). The product was purified using column chromatography [eluent; hexane : ethylacetate (60:40), R_f value 0.44. in 70:30 ethylacetate : hexane]. ^{1}H NMR (400 MHz, DMSO) δ 7.56 (d, *J* = 16.4 Hz, 1H), 7.27 – 7.18 (m, 3H), 7.16 – 7.10 (m, 1H), 7.02 (d, *J* = 4.1 Hz, 1H), 6.13 (s, 1H), 2.30 (s, 3H), 2.20 (s, 3H). ^{13}C NMR (101 MHz, DMSO) δ 166.14, 162.64, 161.24, 138.37, 137.81, 128.65, 128.57, 127.76, 126.35, 123.22, 118.31, 100.07, 98.94, 21.04, 19.50. HRMS (ESI$^+$) m/z calcd for $C_{15}H_{14}NaO_3$ $(M+Na)^+$ 265.0841, found; 265.0840.

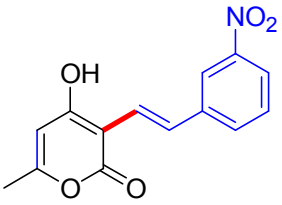


4.2.1.6. 4-Hydroxy-6-methyl-3-(2-m-tolyl-vinyl)-pyran-2-one (10): Prepared by the general procedure **1** using 4-hydroxy-6-methyl-2-pyrone (0.4 mmol, 50 mg) and 3-methylstyrene (0.44 mmol, 47µl) to yield **10** as semisolid **(**69%, 67 mg). The product was

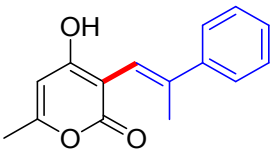
purified using column chromatography [eluent; hexane : ethylacetate (60:40), R_f value 0.45. in 70:30 ethylacetate : hexane]. ^{1}H NMR (400 MHz, DMSO) δ 7.56 (d, *J* = 16.3 Hz, 1H), 7.25 (d, *J* = 16.8 Hz, 3H), 7.18 – 6.98 (m, 2H), 6.14 (s, 1H), 2.51 (s, 3H), 2.22 (s, 3H). HRMS (ESI$^+$) m/z calcd for $C_{15}H_{14}NaO_3$ $(M+Na)^+$ 265.0841, found; 265.0845.



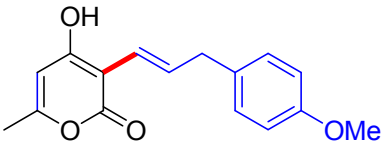
4-Hydroxy-3-[2-(4-methoxy-phenyl)-vinyl]-6-methyl-pyran-2-one (11): The title compound was prepared by the general procedure using 4-hydroxy-6-methyl-2-pyrone (0.4 mmol, 50 mg) and 4-methoxystyrene (0.44mmol, 59µl) to yield **11** as semisolid **(**70%, 73 mg). The product was purified using column chromatography [eluent; hexane : ethylacetate (60:40), R_f value 0.45. in 70:30 ethylacetate : hexane]. ^{1}H NMR (400 MHz, MeOD) δ 7.65 (d, *J* = 16.5 Hz, 1H), 7.45 (d, *J* = 8.6 Hz, 2H), 7.13-7.05 (m, 1H), 7.91 (d, *J* = 8.6 Hz, 2H), 6.09 (s, 1H), 3.85 (bs, 3H), 2.21 (s, 3H).^{13}C NMR (101 MHz, MeOD), δ 167.0, 166.2, 161.3, 160.0, 132.6, 130.9, 128.2 x 2, 116.6, 114.8 x 2, 101.5, 98.8, 55.7, 19.9. HRMS (ESI$^+$) m/z calcd for $C_{15}H_{14}NaO_4$ $(M+Na)^+$ 281.0790, found; 281.0798.



4-Hydroxy-6-methyl-3-[2-(3-nitro-phenyl)-vinyl]-pyran-2-one (12): Prepared by the general procedure **1** using 4-hydroxy-6-methyl-2-pyrone (0.4 mmol, 50 mg) and 3-nitrostyrene (0.44 mmol, 66µl) to yield **12** as semisolid **(**69%, 76 mg). The product was purified using column chromatography [eluent; hexane : ethylacetate (50:50), R_f value 0.38. in 70:30 ethylacetate : hexane]. ^{1}H NMR (400 MHz, DMSO) δ 8.21 (s, 1H), 8.03 (dd, *J* = 8.1, 1.1 Hz, 1H), 7.89 (d, *J* = 7.8 Hz, 1H), 7.73 – 7.55 (m, 2H), 7.30 (d, *J* = 16.3 Hz, 1H), 6.15 (s, 1H), 2.22 (s, 3H). ^{13}C NMR (101 MHz, MeOD), δ 167.2, 162.3, 162.1, 148.4, 140.3, 132.2, 130.1, 125.7, 121.4, 121.2, 119.6, 100.0, 98.3, 19.5. HRMS (ESI$^+$) m/z calcd for $C_{14}H_{11}NaNO_5$ $(M+Na)^+$ 296.0535, found; 296.0542.



4-Hydroxy-6-methyl-3-(2-phenyl-propenyl)-pyran-2-one (13): The title compound was prepared by general procedure using 4-hydroxy-6-methyl-2-pyrone (0.4 mmol, 50 mg) and alpha methyl styrene (1.1 equiv.) to yield **13** as semisolid (70 %). The product was purified using column chromatography [eluent; hexane : ethylacetate (60:40), R_f value 0.50. in 70:30 ethylacetate : hexane]. ^{1}H NMR (400 MHz, DMSO) δ 7.54 – 7.46 (m, 1H), 7.35 (t, *J* = 7.5 Hz, 1H), 7.27 (t, *J* = 7.3 Hz, 1H), 6.27 (s, 1H), 6.10 (s, 1H), 2.20 (s, 1H), 1.91 (s, 1H). ^{13}C NMR (101 MHz, DMSO) δ 165.48, 162.98, 161.25, 142.35, 138.02, 128.31, 127.13, 125.57, 117.44, 99.99, 99.33, 19.38, 18.14. HRMS (ESI$^+$) m/z calcd for $C_{14}H_{15}NaO_3$ $(M+Na)^+$ 265.2699, found; 265.2693. Anal cal. for $C_{14}H_{15}O_3$; C, 74.36, H, 5.82; observed C, 74.30, H, 5.89.

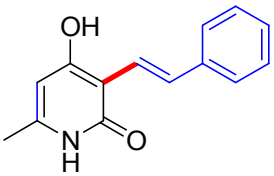


4-Hydroxy-3-[3-(4-methoxy-phenyl)-propenyl]-6-methyl-pyran-2-one (14): The title compound was prepared by general procedure using 4-hydroxy-6-methyl-2-pyrone (0.4 mmol, 50 mg) and 4-methoxy allyl benzene (1 .1 equiv.) to afford **14** as semisolid in 70 % yield. The product was purified using column chromatography [eluent; hexane : ethylacetate (60:40), R_f value 0.48. in 70:30 ethylacetate : hexane]. ^{1}H NMR (400 MHz, DMSO) δ 7.56 (d, *J* = 16.4 Hz, 1H), 7.27 – 7.18 (m, 3H), 7.16 – 7.10 (m, 1H), 7.02 (d, *J* = 4.1 Hz, 1H), 6.13 (s, 1H), 2.30 (s, 3H), 2.20 (s, 3H). ^{13}C NMR (101 MHz, DMSO) δ 166.14, 162.64, 161.24, 138.37, 137.81, 128.65, 128.57, 127.76, 126.35, 123.22, 118.31, 100.07, 98.94, 21.04, 19.50. HRMS (ESI$^+$) m/z calcd for $C_{16}H_{16}NaO_4$ $(M+Na)^+$ 295.2958, found; 295.2951.

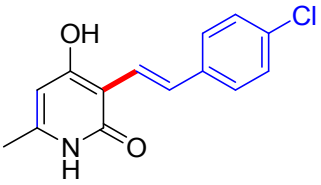
Synthesis of 3-alkenylated -4-hydroxy-6-methyl-pyridones.

General procedure (2): To a solution of the 4-Hydoxy-6-methyl-2-pyridone/4-chloro-6-methyl-2-pyrone/4-methoxy-6-methyl-2-pyrone (0.4 mmol, 1.0 equiv.) in DMF:DMSO (8:2) 2ml, was added styrene (0.44 mmol, 1.1 equiv.), 5 mole % $Pd(OAc)_2$ and 5 mole % $Cu(OTf)_2$ in open air flask . The reaction mixture was stirred at 80 ^{o}C for 16h. The completion of the reaction was monitored through TLC followed by extraction with ethyl acetate and water. The organic layer was concentrated in rotary evaporator and the crude

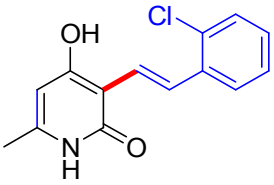
mixture was subjected to column chromatography using DCM:CH_3OH in case of 4-Hydoxy-6-methyl-2-pyridone and Hexane : Ethyl acetate in case of 4-chloro-6-methyl-2-pyrone and 4-methoxy-6-methyl-2-pyrone as eluent to yield the desired product.



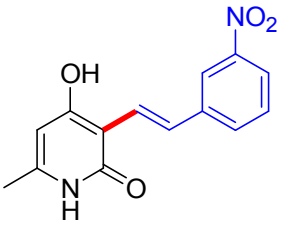
4-Hydroxy-6-methyl-3-styryl-1H-pyridin-2-one (15): Prepared by the general procedure **2** using 4-hydroxy-6-methyl-2-pyridone (0.4 mmol, 50 mg) and styrene (0.44 mmol, 50µl) to yield **11** as semisolid **(**70%, 62 mg) The product was purified using column chromatography [eluent; DCM : MeOH (98:2), R_f value 0.50. in 90:10 DCM:MeOH].^{1}H NMR (400 MHz, MeOH) δ 7.71 (d, *J* = 16.5 Hz, 1H), 7.41 (d, *J* = 7.7 Hz, 2H), 7.25 (dd, *J* = 13.9, 6.4 Hz, 2H), 7.11 (t, *J* = 7.3 Hz, 1H), 5.89 (s, 1H), 2.20 (s, 3H). HRMS (ESI$^+$) m/z calcd for $C_{14}H_{13}NaNO_2$ $(M+Na)^+$ 250.0844, found; 250.0849.



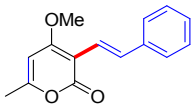
3-[2-(4-Chloro-phenyl)-vinyl]-4-hydroxy-6-methyl-1H-pyridin-2-one (16): Prepared by the general procedure **2** using 4-hydroxy-6-methyl-2-pyridone (0.4 mmol, 50 mg) and 4-chlorostyrene (0.44mmol, 54µl) to yield **16** as semisolid (65%, 68 mg). The product was purified using column chromatography [eluent; DCM : MeOH (98:2), R_f value 0.48. in 90:10 DCM:MeOH]. ^{1}H NMR (400 MHz, DMSO) δ 7.56 (d, *J* = 16.4 Hz, 1H), 7.46 (d, *J* = 8.5 Hz, 2H), 7.36 (d, *J* = 8.5 Hz, 2H), 7.15 (d, *J* = 16.4 Hz, 1H), 6.13 (s, 1H), 2.21 (s, 3H). ^{13}C NMR (101 MHz, DMSO) δ 166.5, 162.4, 161.6, 137.3, 131.1, 128.6 x 2, 127.4 x 2, 126.8, 119.4, 100.0, 98.6, 19.5. HRMS (ESI$^+$) m/z calcd for $C_{14}H_{12}NaClNO_2$ $(M+Na)^+$ 284.0454, found; 284.0448.



.**3-[2-(2-Chloro-phenyl)-vinyl]-4-hydroxy-6-methyl-1H-pyridin-2-one (17):** Prepared by the general procedure **2** using 4-hydroxy-6-methyl-2-pyridone (0.4 mmol, 50mg) and 3-chlorostyrene (0.44mmol, 58µl) to yield **17** as semisolid **(**67%, 70 mg). The product was purified using column chromatography [eluent; DCM : MeOH (98:2), R_f value 0.48. in 90:10 DCM:MeOH].^{1}H NMR (400 MHz, DMSO) δ 8.14 (d, *J* = 16.3 Hz, 1H), 7.68 (d, *J* = 7.6 Hz, 1H), 7.40 (d, *J* = 7.9 Hz, 1H), 7.29 (dd, *J* = 12.1, 4.1 Hz, 2H), 7.18 (dd, *J* = 11.1, 4.1 Hz, 1H), 5.81 (s, 1H), 2.14 (s, 3H). ^{13}C NMR (101 MHz, DMSO) δ 164.8, 163.2, 144.9, 137.2, 131.6, 129.5, 127.6, 127.4, 125.6, 123.3, 122.6, 104.8, 97.9, 18.5. HRMS (ESI$^+$) m/z calcd for $C_{14}H_{12}NaClNO_2$ $(M+Na)^+$ 284.0454, found; 284.0459.



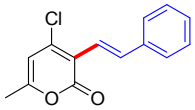
4-Hydroxy-6-methyl-3-[2-(3-nitro-phenyl)-vinyl]-1H-pyridin-2-one (18): Prepared by the general procedure **2** using 4-hydroxy-6-methyl-2-pyridone (0.4 mmol, 50 mg) and 3-nitrostyrene (0.44 mmol, 66µl) to yield **18** as semisolid **(**67%, 72 mg) . The product was purified using column chromatography [eluent; DCM : MeOH (97:3), R_f value 0.40. in 90:10 DCM:MeOH]. ^{1}H NMR (400 MHz, DMSO) δ 8.21 (d, *J* = 10.5 Hz, 1H), 8.04 (d, *J* = 7.5 Hz, 1H), 7.90 (d, *J* = 7.8 Hz, 1H), 7.68 (d, *J* = 16.4 Hz, 1H), 7.61 (t, *J* = 8.0 Hz, 1H), 7.32 (d, *J* = 16.3 Hz, 1H), 6.15 (s, 1H), 2.23 (s, 3H). ^{13}C NMR (101 MHz, DMSO) δ 167.3, 162.4, 162.1, 148.4, 140.3, 132.2, 130.1, 125.6, 121.5, 121.2, 119.5, 100.1, 98.1, 19.5. HRMS (ESI$^+$) m/z calcd for $C_{14}H_{12}NaN_2O_4$ $(M+Na)^+$ 295.0695, found; 295.0689. Anal cal. for $C_{14}H_{12}N_2O_4$; C, 61.76, H, 4.44, N, 10.29; observed C, 61.70, H, 4.48, N, 10.32.



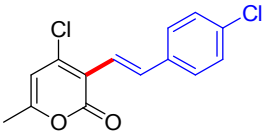
4-Methoxy-6-methyl-3-styryl-pyran-2-one (20): To a solution of 4-methoxy-6-methyl-2-pyrone (0.4 mmol, 1.0 equiv.) in DMF:DMSO (8:2) 2ml, was added styrene (0.44 mmol, 1.1 equiv.), 5 mole % $Pd(OAc)_2$ and 5 mole % $Cu(OTf)_2$ in open air flask . The reaction mixture was stirred at 80 ^oC for 10h. The completion of the reaction was monitored through TLC followed by usual procedure to obtain **20** as semisolid **(**71%, 61 mg). The product was purified using column chromatography [eluent; hexane : ethylacetate (93:7), R_f value 0.52. in 50:50 hexane : ethylacetate]. ^1H NMR (400 MHz, $CDCl_3$) δ 7.85 (d, *J* = 16.4 Hz, 1H), 7.57 (d, *J* = 7.5 Hz, 2H), 7.38 (t, *J* = 7.6 Hz, 2H), 7.33 (s, 1H), 7.25 (d, *J* = 5.7 Hz, 1H), 6.15 (s, 1H), 4.03 (s, 3H), 2.37 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.0, 163.4, 161.8, 138.8, 131.9, 128.8 x 2, 127.4, 126.8 x 2, 117.7, 102.6, 95.3, 56.7, 20.7. HRMS (ESI^+) m/z calcd for $C_{15}H_{14}NaO_3$ $(M+Na)^+$ 265.0841, found; 265.0848.

Synthesis of 3-alkenylated -4-Chloro-6-methyl-pyridones.

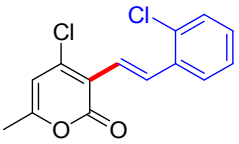
General procedure (3): To a solution of 4-chloro-6-methyl-2-pyrone (0.4 mmol, 1.0 equiv.) in DMF:DMSO (8:2) 2ml, was added styrene (0.44 mmol, 1.1 equiv.), 5 mol % $Pd(OAc)_2$ and 5 mol % $Cu(OTf)_2$ in open air flask . The reaction mixture was stirred at 80 ^oC for 16h. The completion of the reaction was monitored through TLC followed by extraction with ethyl acetate and water. The organic layer was concentrated in rotary evaporator and the crude mixture was subjected to column chromatography using Hexane : Ethyl acetate as eluent to yield the desired product.



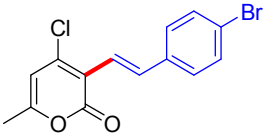
4-Chloro-6-methyl-3-styryl-pyran-2-one (22): Prepared by the general procedure **3** using 4-chloro-6-methyl-2-pyrone (0.35mmol, 50 mg) and styrene (0.39 mmol, 44µl) to yield **22** as semisolid **(**65%, 54 mg). The product was purified using column chromatography [eluent; hexane : ethylacetate (96:4), R_f value 0.55. in 20:80 hexane : ethylacetate]. ^1H NMR (400 MHz, $CDCl_3$) δ 7.47 – 7.44 (m, 2H), 7.40 – 7.35 (m, 2H), 7.32 – 7.30 (m, 1H), 6.75 (d, *J* = 16.3 Hz, 1H), 6.62 (d, *J* = 16.3 Hz, 1H), 6.37 (s, 1H), 2.43 (s, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.3, 160.0, 153.4, 137.0, 136.2, 129.0, 128.8, 126.8, 119.4, 115.3, 112.2, 111.2, 106.3, 19.6. HRMS (ESI^+) m/z calcd for $C_{14}H_{11}NaClO_2$ $(M+Na)^+$ 269.0345, found; 269.0349. Anal cal. for $C_{14}H_{11}ClO_2$; C, 68.16, H, 4.49; observed C, 68.11, H, 4.43.



4-Chloro-3-[2-(4-chloro-phenyl)-vinyl]-6-methyl-pyran-2-one (23): Prepared by the general procedure **3** using 4-chloro-6-methyl-2-pyrone (0.35 mmol, 50 mg) and 4-chlorostyrene (0.39 mmol, 48µl) to yield **23** as semisolid **(**64%, 63 mg). The product was purified using column chromatography [eluent; hexane : ethylacetate (96:4), R_f value 0.54. in 20:80 hexane : ethylacetate]. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40 – 7.31 (m, 4H), 6.78 – 6.68 (m, 1H), 6.58 (d, *J* = 16.3 Hz, 1H), 6.37 (s, 1H), 2.42 (s, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.0, 159.4, 147.2, 136.1, 134.3, 132.4, 130.1, 129.3, 127.0, 126.9, 121.7, 118.1,). 107.7, 19.8. HRMS (ESI$^+$) m/z calcd for $C_{14}H_{10}NaCl_2O_2$ $(M+Na)^+$ 302.9956, found; 302.9959. Anal cal. for $C_{14}H_{10}Cl_2O_3$; C, 59.81, H, 3.59; observed C, 59.87, H, 3.53.

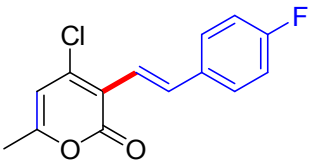


4-Chloro-3-[2-(2-chloro-phenyl)-vinyl]-6-methyl-pyran-2-one (24):): Prepared by the general procedure **3** using 4-chloro-6-methyl-2-pyrone (0.35 mmol, 50 mg) and 2-chlorostyrene (0.39 mmol, 51µl) to yield **24** as semisolid **(**65%, 64 mg). The product was purified using column chromatography [eluent; hexane : ethylacetate (96:4), R_f value 0.55. in 20:80 hexane : ethylacetate]. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.36 (d, *J* = 16.1 Hz, 1H), 7.63 (d, *J* = 7.7 Hz, 1H), 7.37 (d, *J* = 4.5 Hz, 1H), 7.27 – 7.18 (m, 2H), 7.15-7.10 (m, 1H), 6.16 (s, 1H), 2.27 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.1, 159.5, 147.3, 136.1, 134.5, 133.3, 132.4, 130.2, 129.4, 127.0, 121.7, 107.9, 20.0. . HRMS (ESI$^+$) m/z calcd for $C_{14}H_{10}NaCl_2O_2$ $(M+Na)^+$ 302.9956, found; 302.9949.

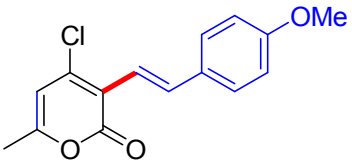


3-[2-(4-Bromo-phenyl)-vinyl]-4-chloro-6-methyl-pyran-2-one (25): Prepared by the general procedure **3** using 4-chloro-6-methyl-2-pyrone (0.35 mmol, 50 mg) and 4-bromostyrene (0.46mmol, 60µl) to yield **25** as semisolid **(**60%, 67 mg). The product was purified using column chromatography [eluent; hexane : ethylacetate (96:4), R_f value 0.55. in 20:80 hexane : ethylacetate]. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 (d, *J* = 8.4 Hz, 2H), 7.31 (d, *J* = 8.4 Hz, 2H), 6.74 (d, *J* = 16.3 Hz, 1H), 6.60 (d, *J* = 16.3 Hz, 1H), 6.37 (s, 1H), 2.42 (s,

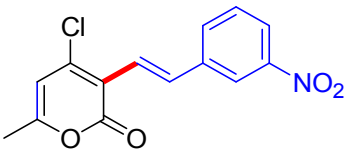
3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.2, 153.3, 135.8, 135.0, 132.1, 129.5, 128.2, 122.8, 120.2, 115.2, 112.2, 19.8. HRMS (ESI$^+$) m/z calcd for $C_{14}H_{10}NaBrClO_2$ $(M+Na)^+$ 346.9450, found; 346.9457. Anal cal. for $C_{14}H_{10}BrClO_2$; C, 51.65, H, 3.10; observed C, 51.60, H, 3.15.



4-Chloro-3-[2-(4-fluoro-phenyl)-vinyl]-6-methyl-pyran-2-one (26): Prepared by the general procedure **3** using 4-chloro-6-methyl-2-pyrone (0.35 mmol, 50 mg) and 4-bromostyrene (0.39mmol, 48µl) to yield **26** as semisolid **(**61%, 57 mg). The product was purified using column chromatography [eluent; hexane : ethylacetate (96:4), R_f value 0.55. in 20:80 hexane : ethylacetate]. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 (dd, *J* = 8.5, 5.5 Hz, 2H), 7.06 (t, *J* = 8.6 Hz, 2H), 6.62 (dd, *J* = 33.7, 16.3 Hz, 2H), 6.37 (s, 1H), 2.42 (s, 3H). HRMS (ESI$^+$) m/z calcd for $C_{14}H_{10}NaFClO_2$ $(M+Na)^+$ 346.9450, found; 346.9457.



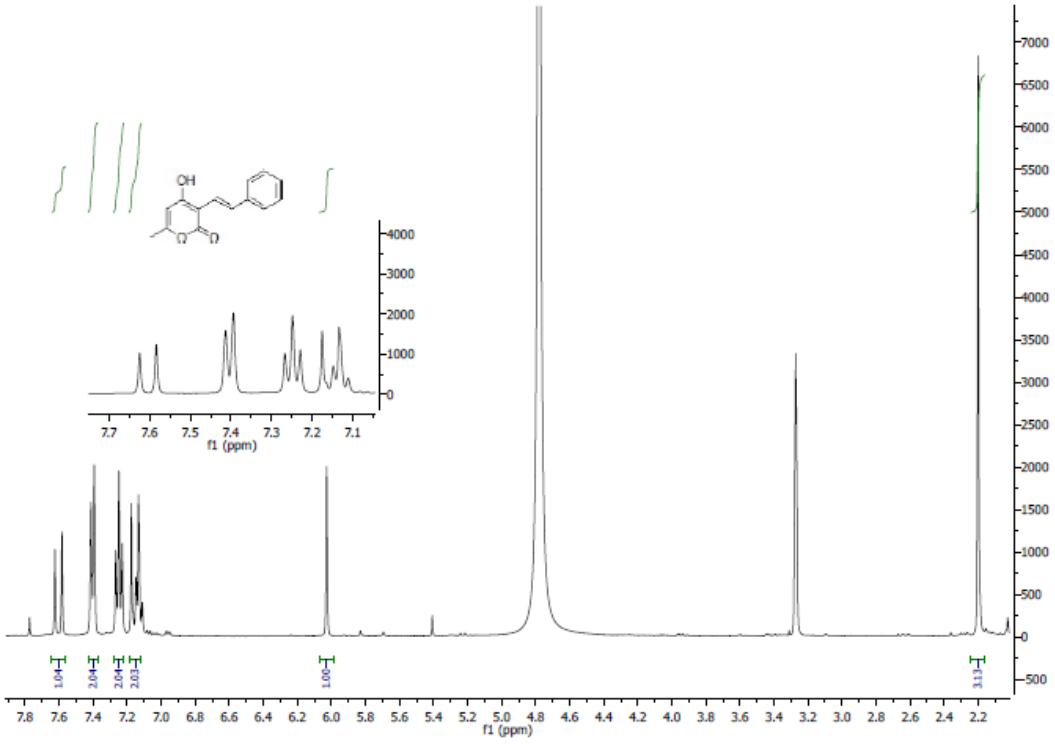
4-Chloro-3-[2-(4-methoxy-phenyl)-vinyl]-6-methyl-pyran-2-one (27): Prepared by the general procedure **3** using 4-chloro-6-methyl-2-pyrone (0.35 mmol, 50 mg) and 4-methoxystyrene (0.39 mmol, 52µl) to yield **27** as semisolid **(**66%, 64 mg). The product was purified using column chromatography [eluent; hexane : ethylacetate (96:4), R_f value 0.56. in 20:80 hexane : ethylacetate]. ^{1}H NMR (400 MHz, $CDCl_3$) δ ^{1}H NMR (400 MHz, $CDCl_3$) δ ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 (d, *J* = 8.7 Hz, 2H), 6.90 (t, *J* = 5.9 Hz, 3H), 6.57 (d, *J* = 5.9 Hz, 1H), 6.35 (s, 1H), 3.82 (s, 3H), 2.41 (s, 3H).^{13}C NMR (101 MHz, $CDCl_3$) δ 160.4, 160.2, 159.8, 153.6, 136.5, 129.0, 128.1 x 2, 117.1, 115.6, 114.5 x 2, 112.2, 55.6, 19.6. HRMS (ESI$^+$) m/z calcd for $C_{14}H_{10}NaBrClO_2$ $(M+Na)^+$ 299.0451, found; 299.0458.



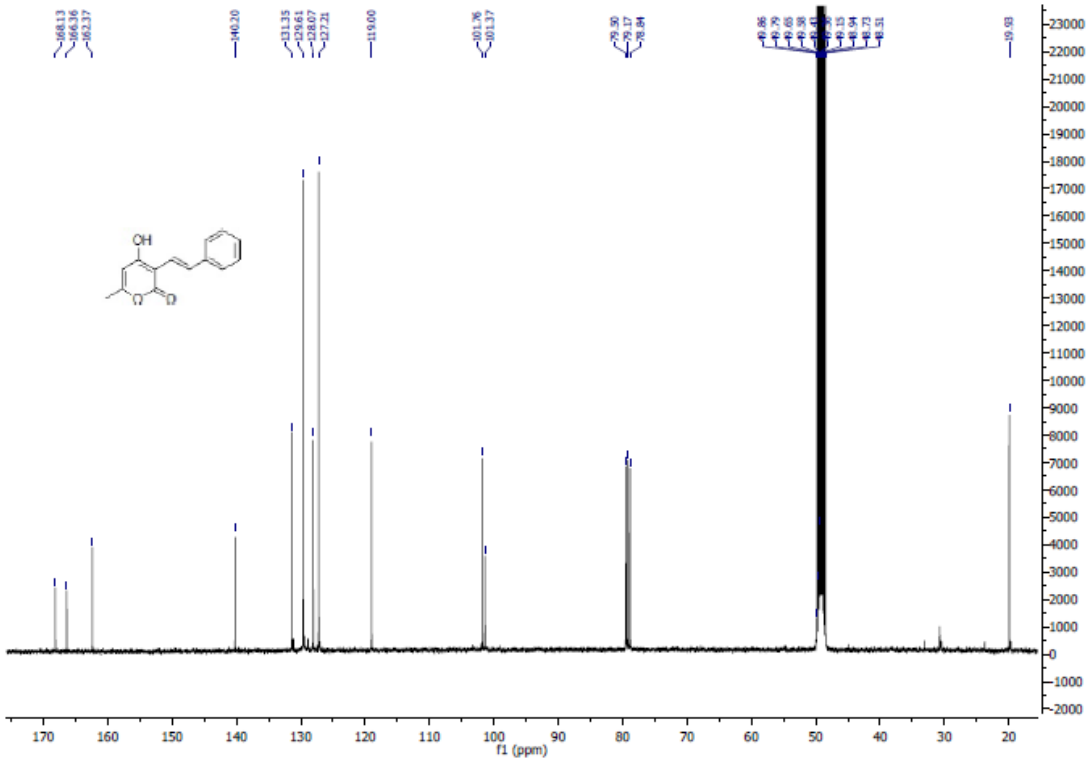
4-Chloro-6-methyl-3-[2-(3-nitro-phenyl)-vinyl]-pyran-2-one (28): Prepared by the general procedure **3** using 4-chloro-6-methyl-2-pyrone (0.35 mmol, 50mg) and 3-nitrostyrene (0.39 mmol, 56µl) to yield **28** as semisolid **(**64%, 65 mg). The product was purified using column chromatography [eluent; hexane : ethylacetate (93:7), R_f value 0.47. in 20:80 hexane : ethylacetate]. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.30 (s, 1H), 8.15 (dd, *J* = 8.2, 1.2 Hz, 1H), 7.75 (d, *J* = 7.7 Hz, 1H), 7.56 (q, *J* = 7.9 Hz, 1H), 6.91 (d, *J* = 16.3 Hz, 1H), 6.75 – 6.66 (m, 1H), 6.40 (s, 1H), 2.45 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.2, 159.9, 152.8, 148.8, 137.9, 134.4, 132.5, 130.0, 123.2, 122.7, 121.3, 114.5, 112.5, 19.7. HRMS (ESI$^+$) m/z calcd for $C_{14}H_{10}NaNClO4$ $(M+Na)^+$ 314.0196, found; 314.0189

Copies of ^{1}H and ^{13}C NMR.

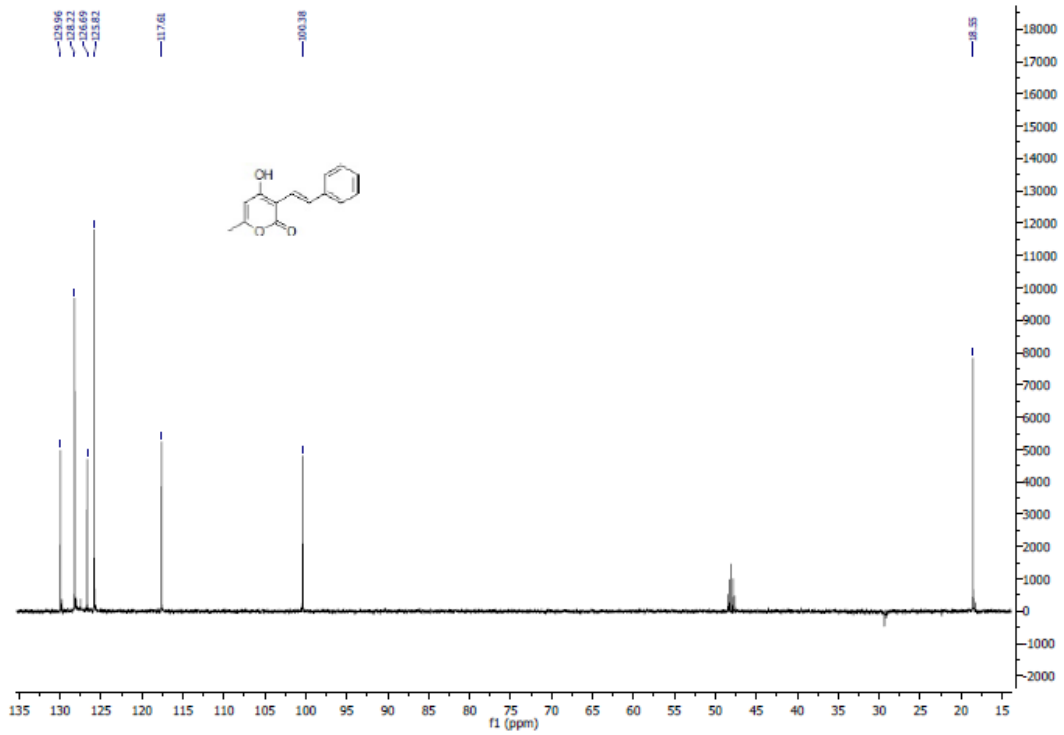
^{1}H NMR of compound 3.



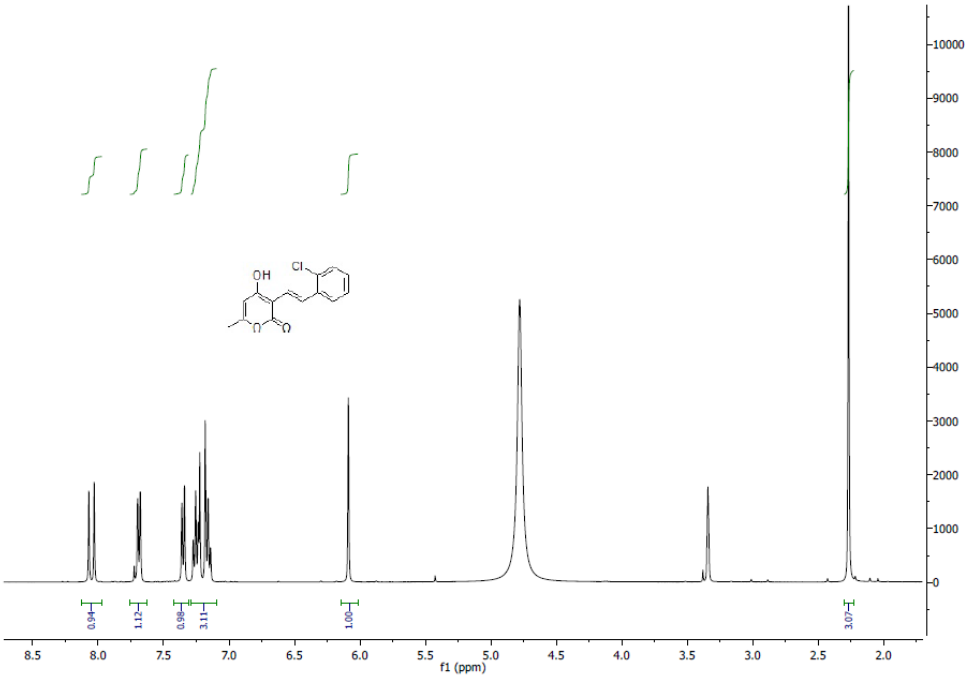
^{13}C NMR of compound 3:



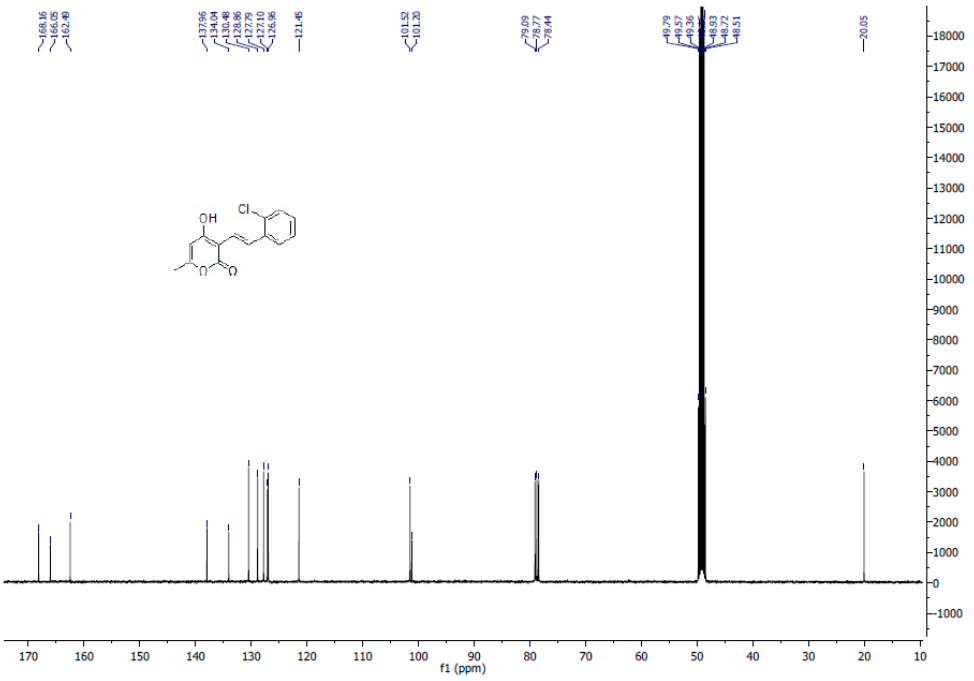
Dept of compound 3:



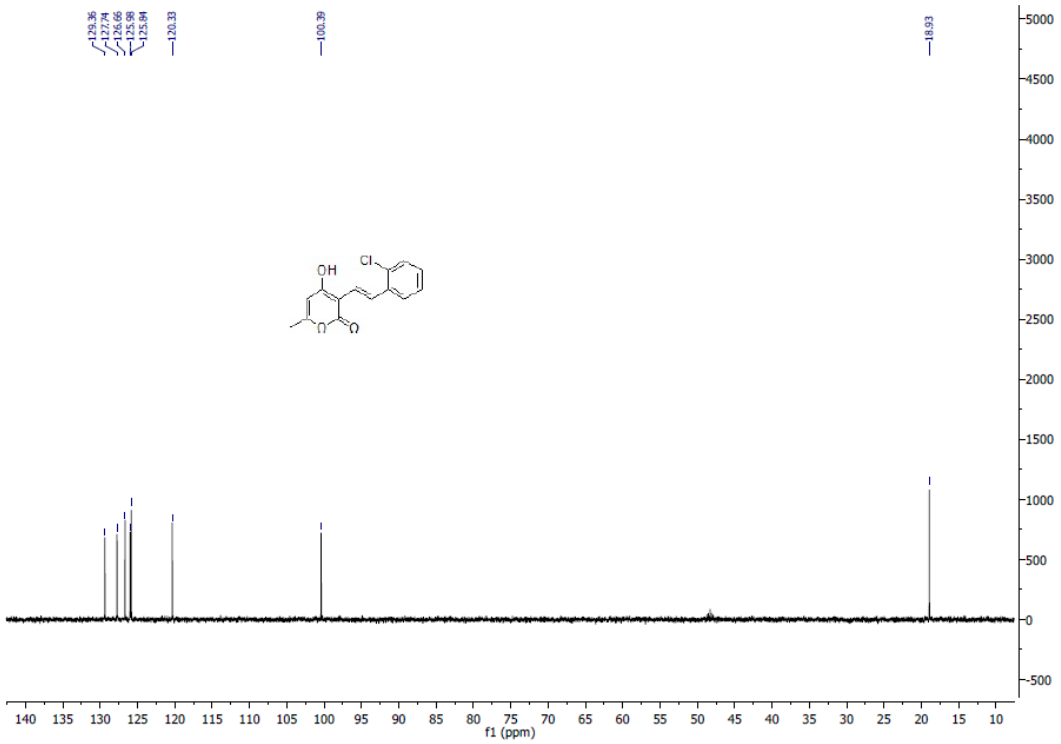
^{1}H NMR of compound 4:



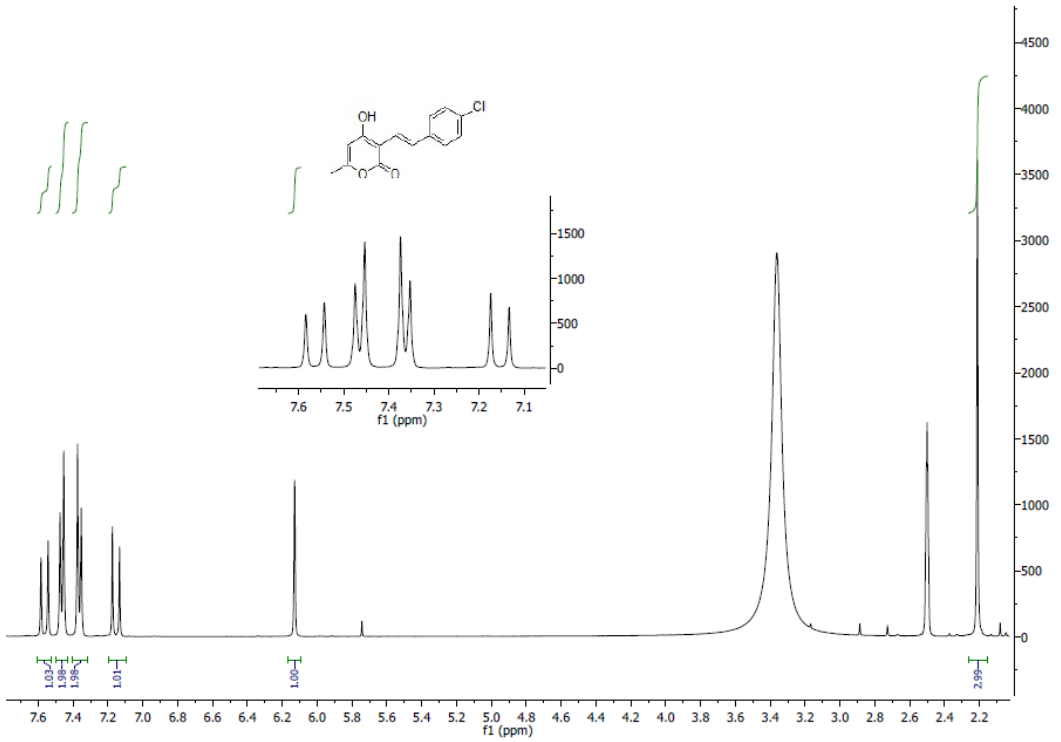
^{13}C NMR of compound 4:



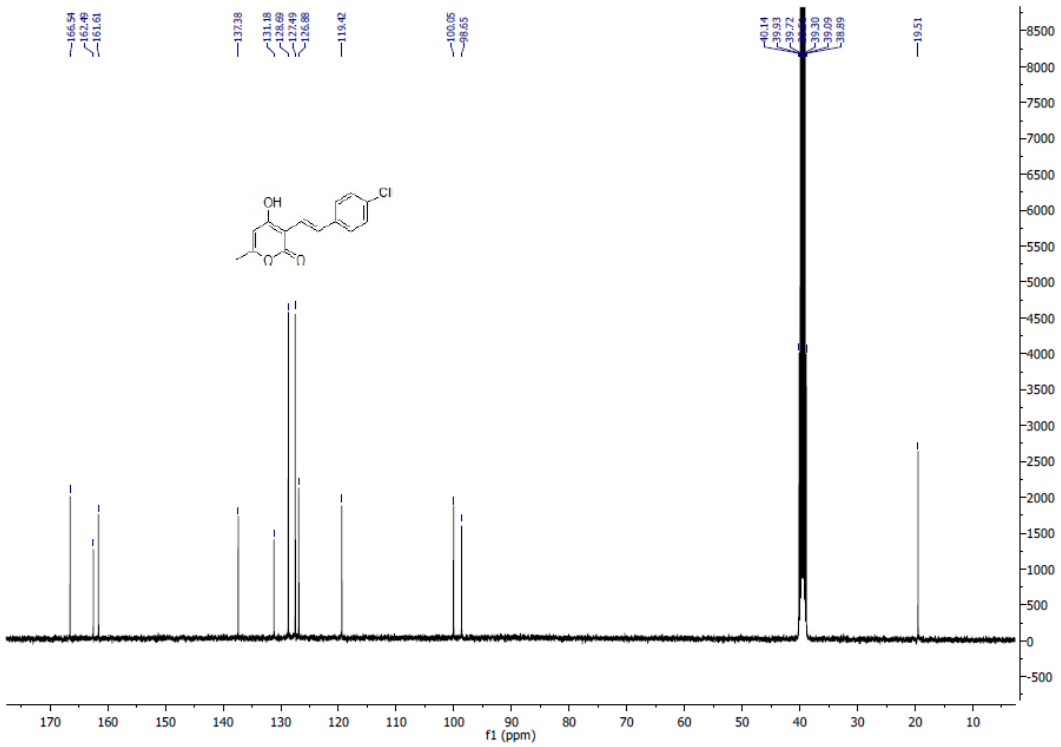
Dept of compound 4:



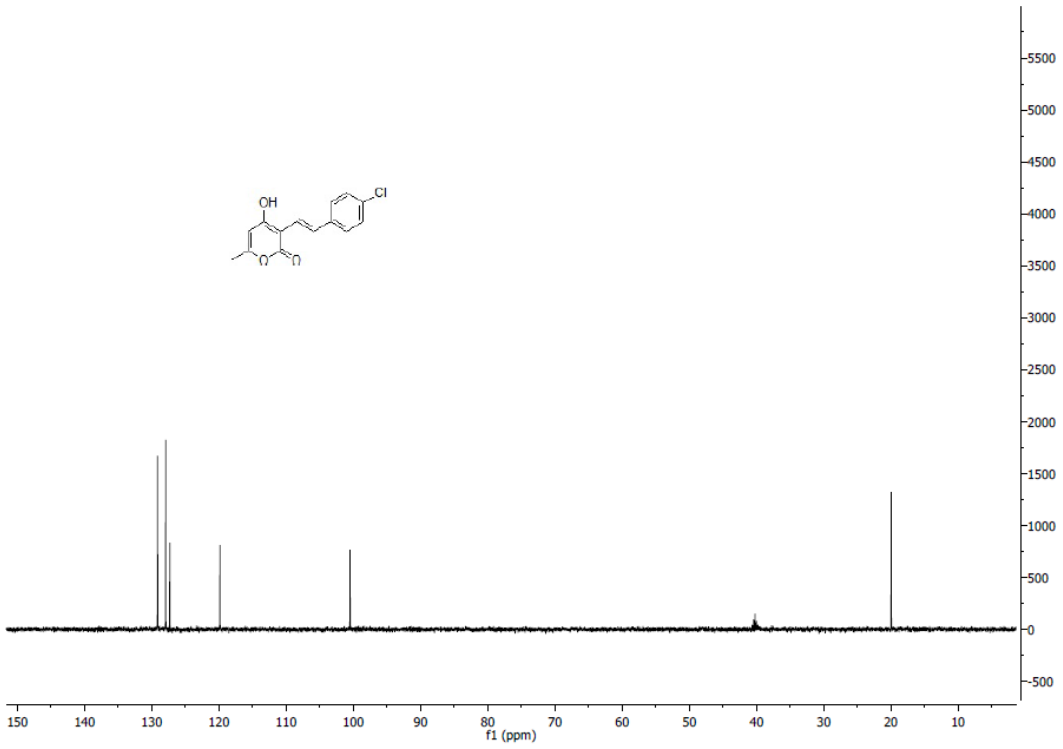
^{1}H NMR of compound 5.



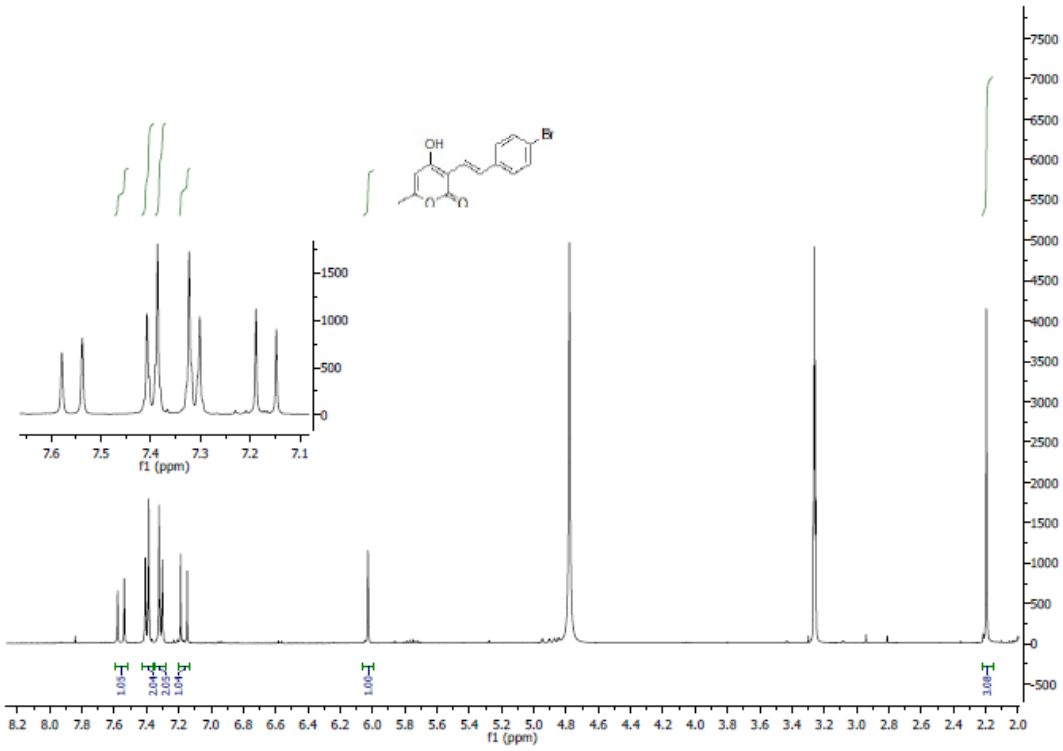
^{13}C NMR of compound 5:



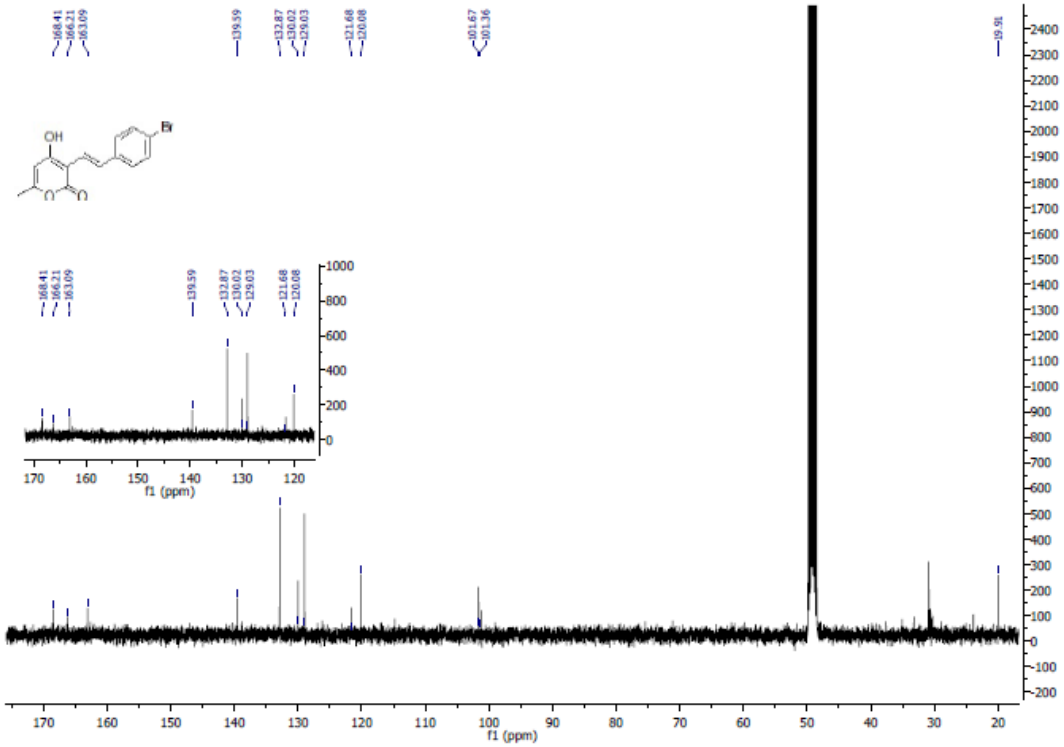
Dept of compound 5:



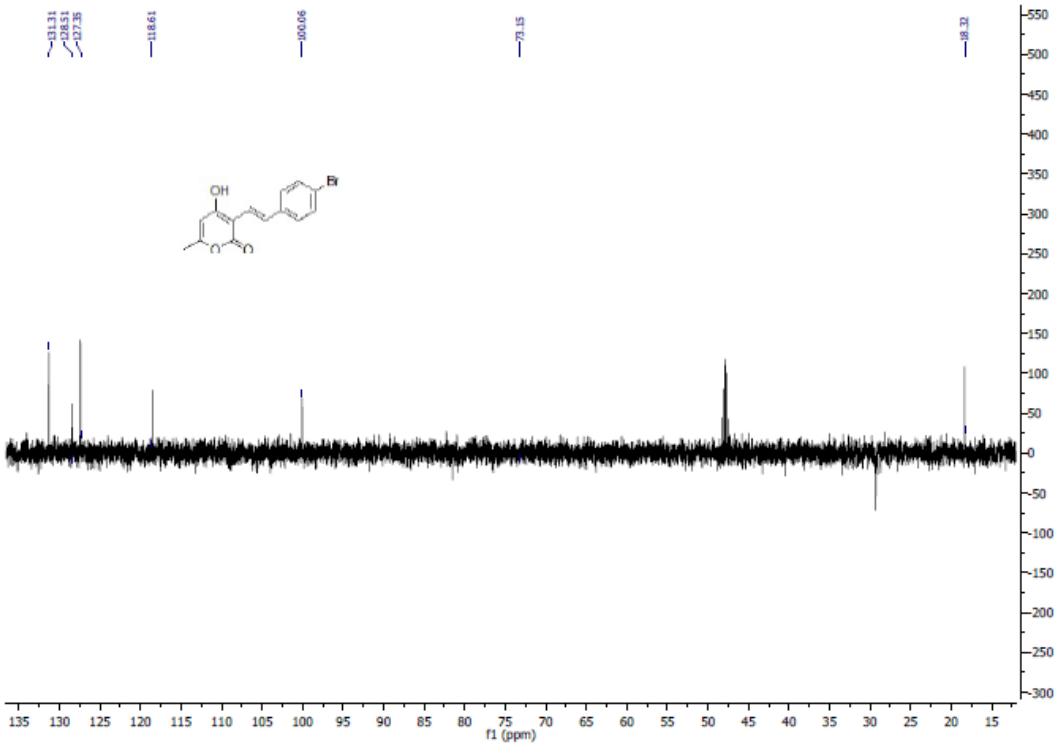
^{1}H NMR of compound 6:



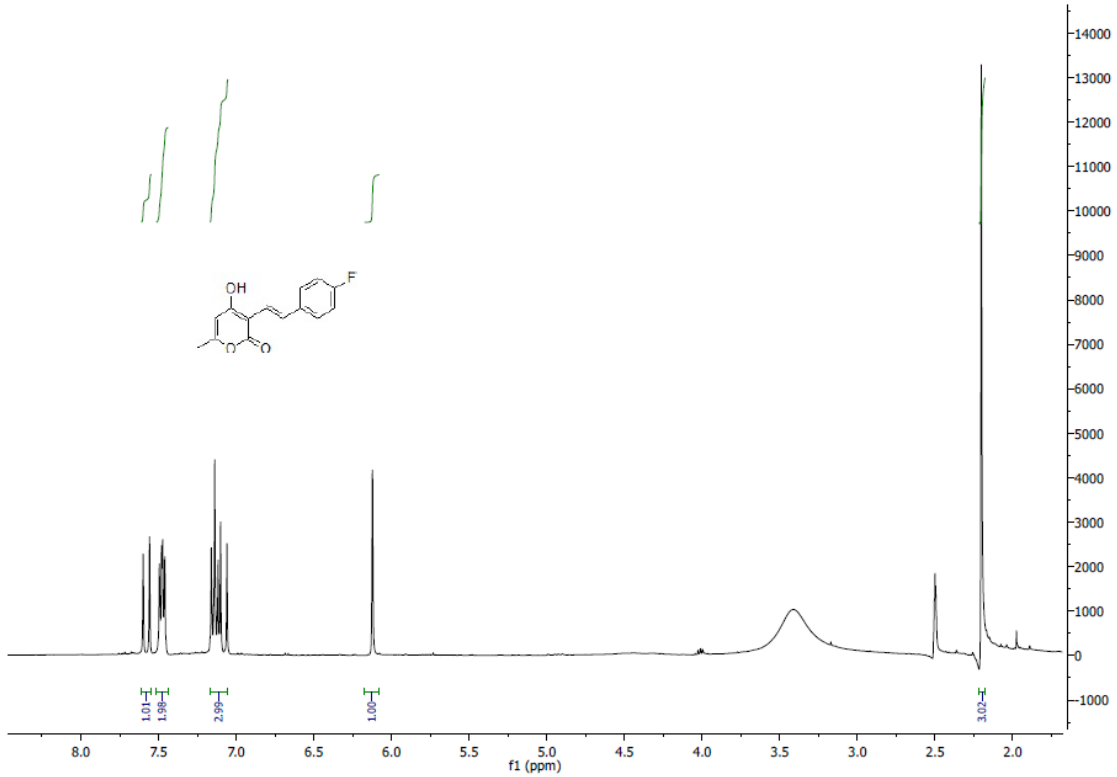
^{13}C NMR of compound 6:



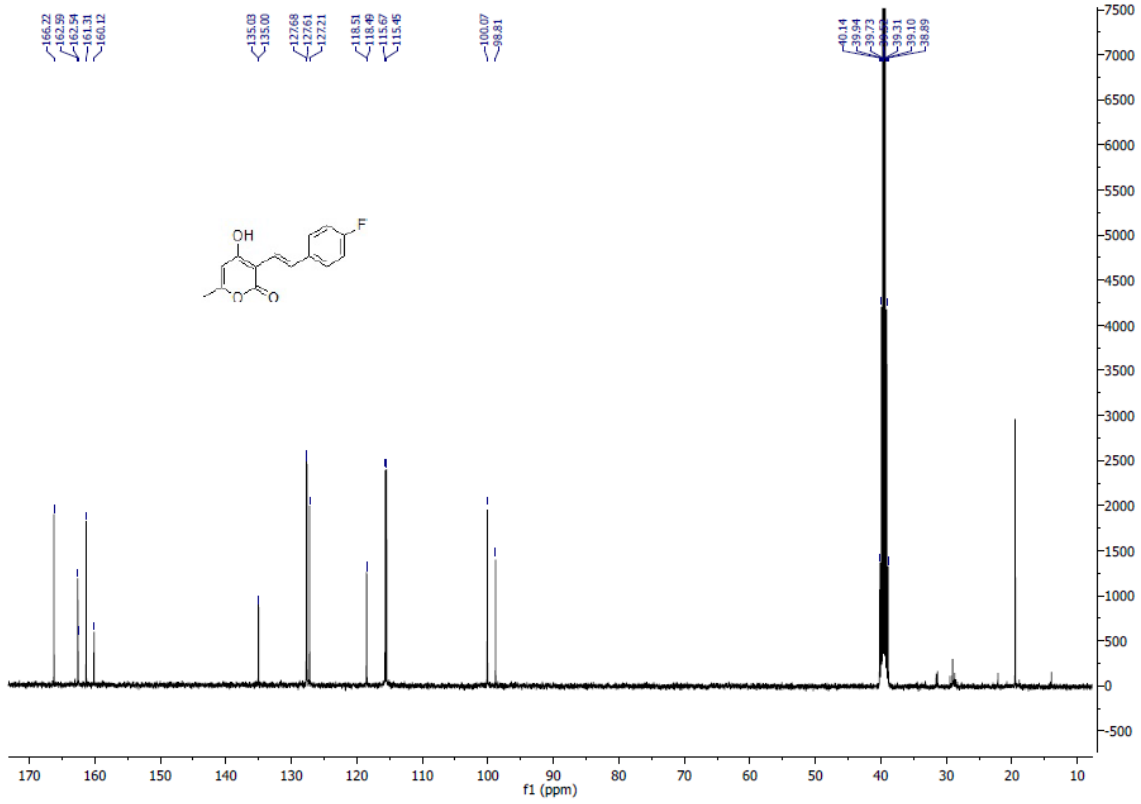
Dept of compound 6:



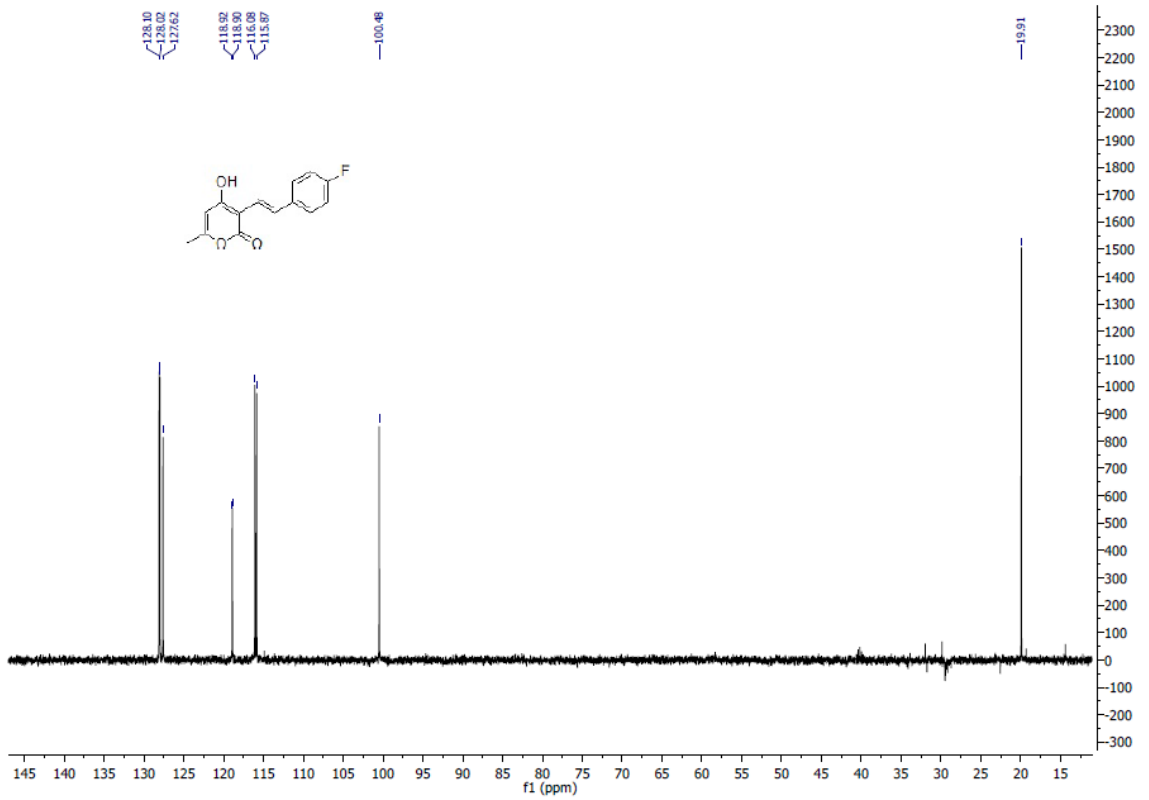
^{1}H NMR of compound 7:



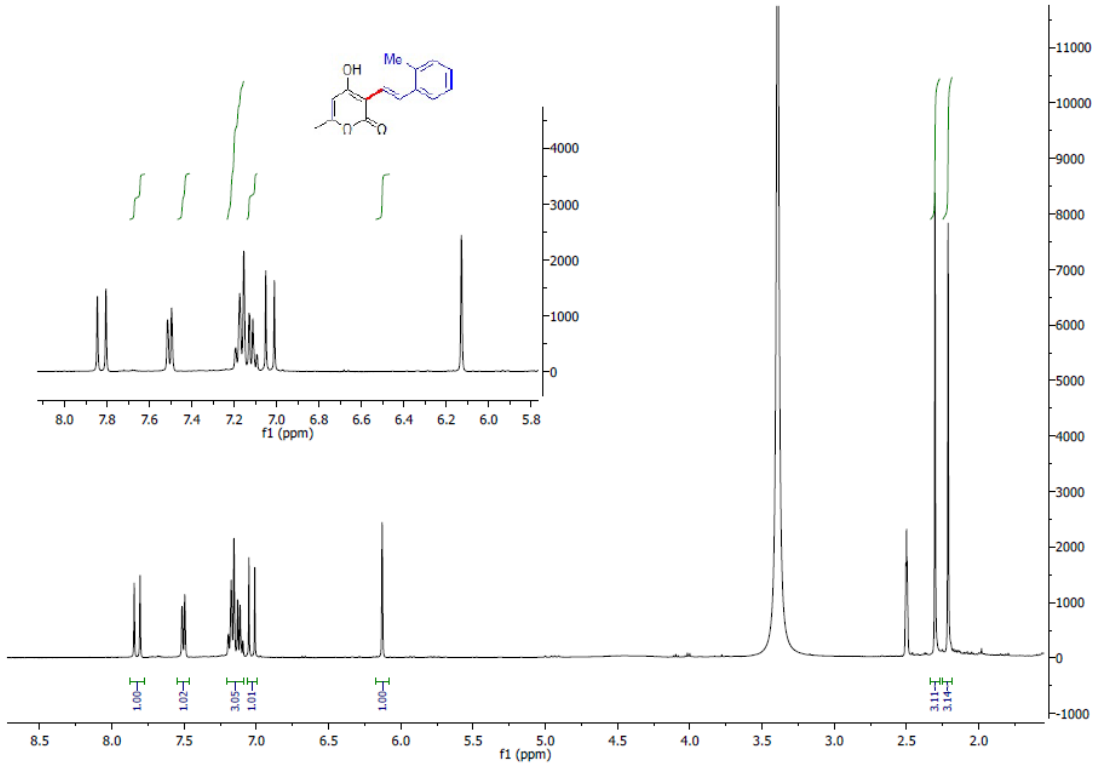
^{13}C NMR of compound 7:



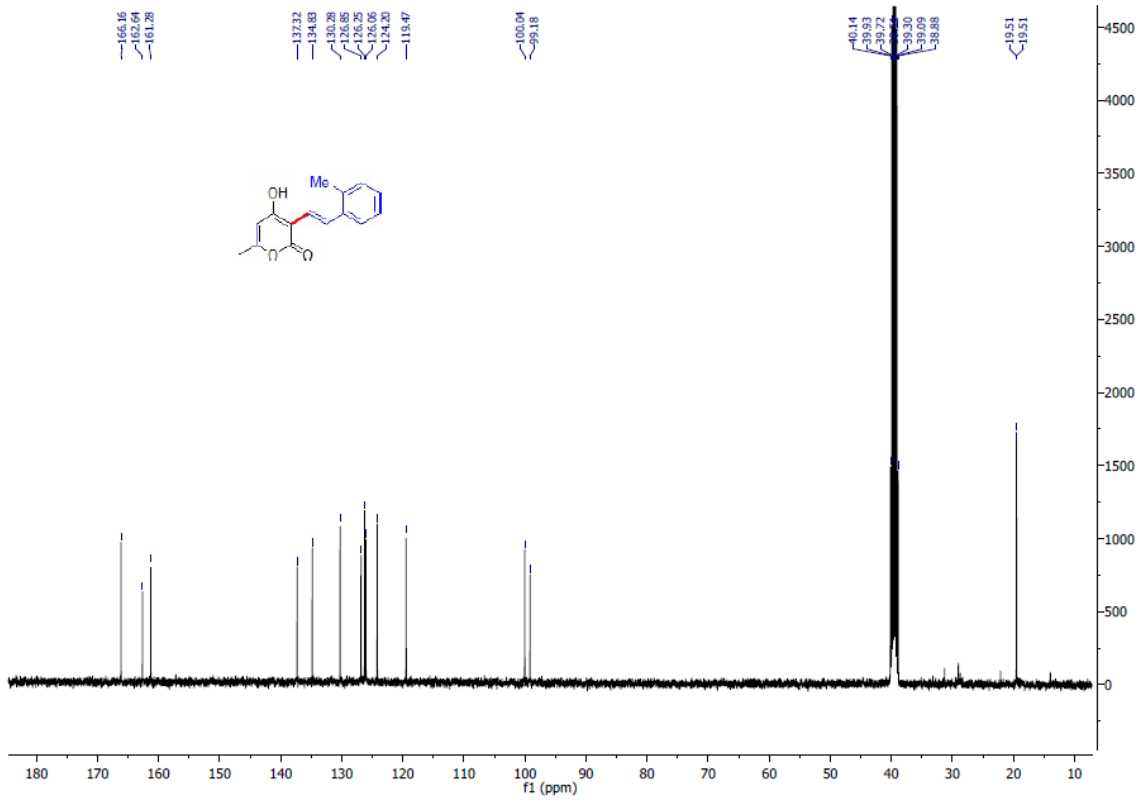
Dept of compound 7:



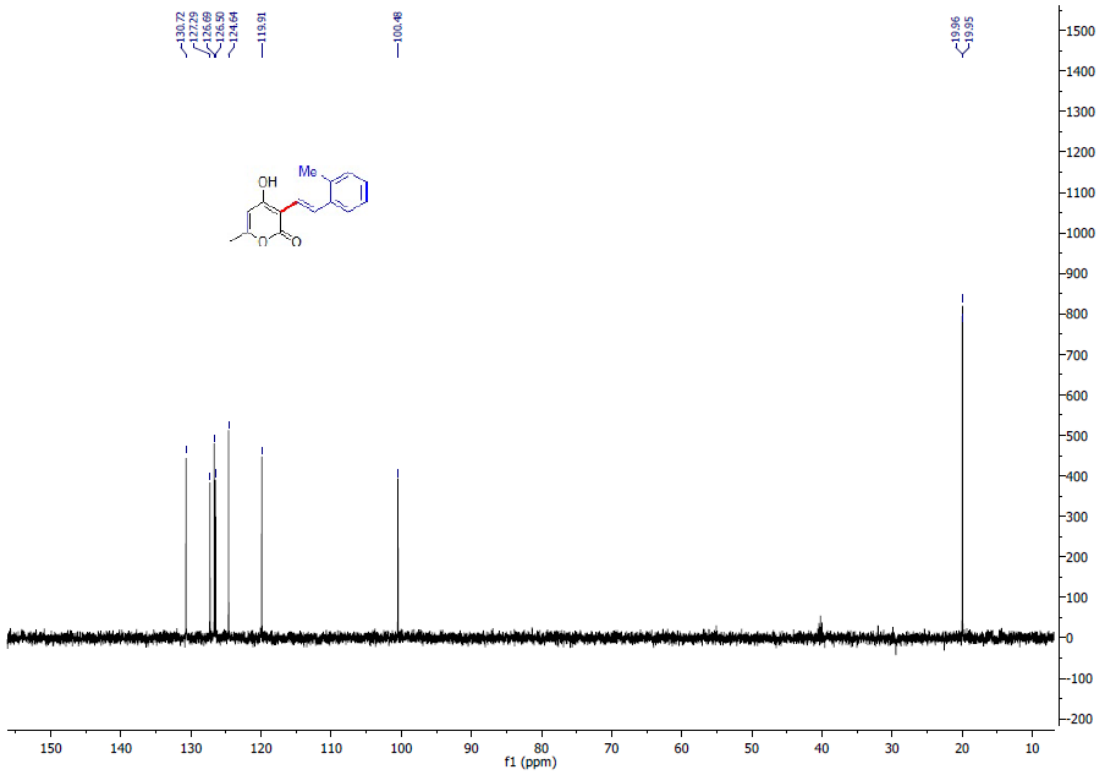
^{1}H NMR of compound 8:



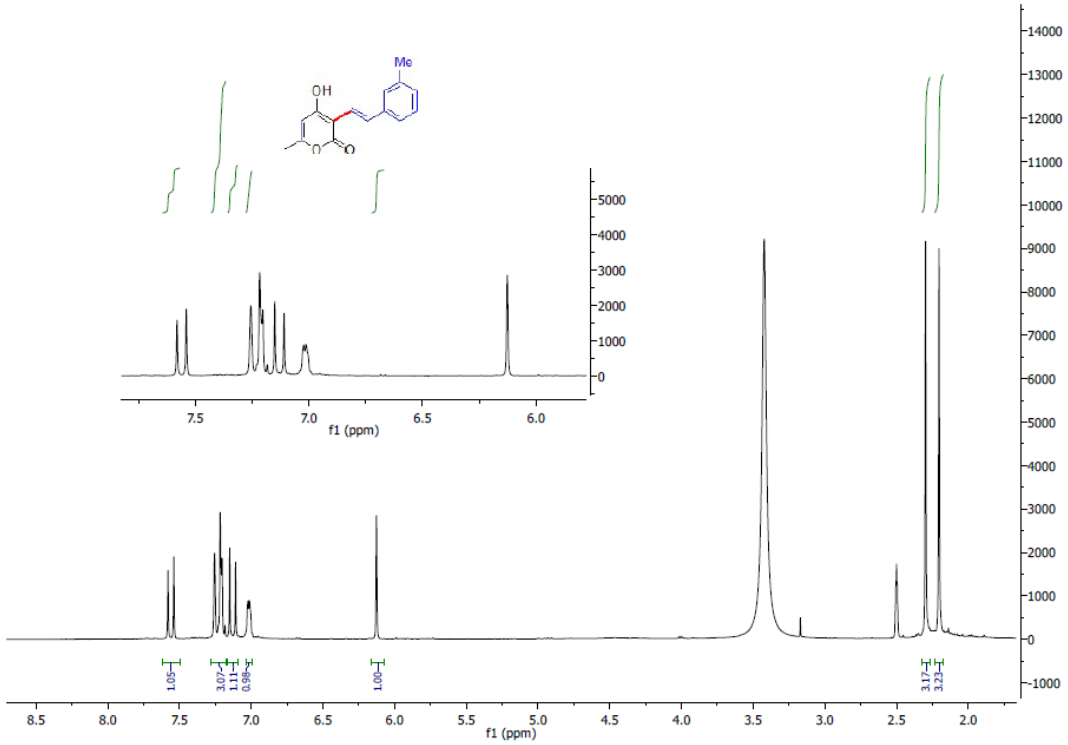
^{13}C NMR of compound 8:



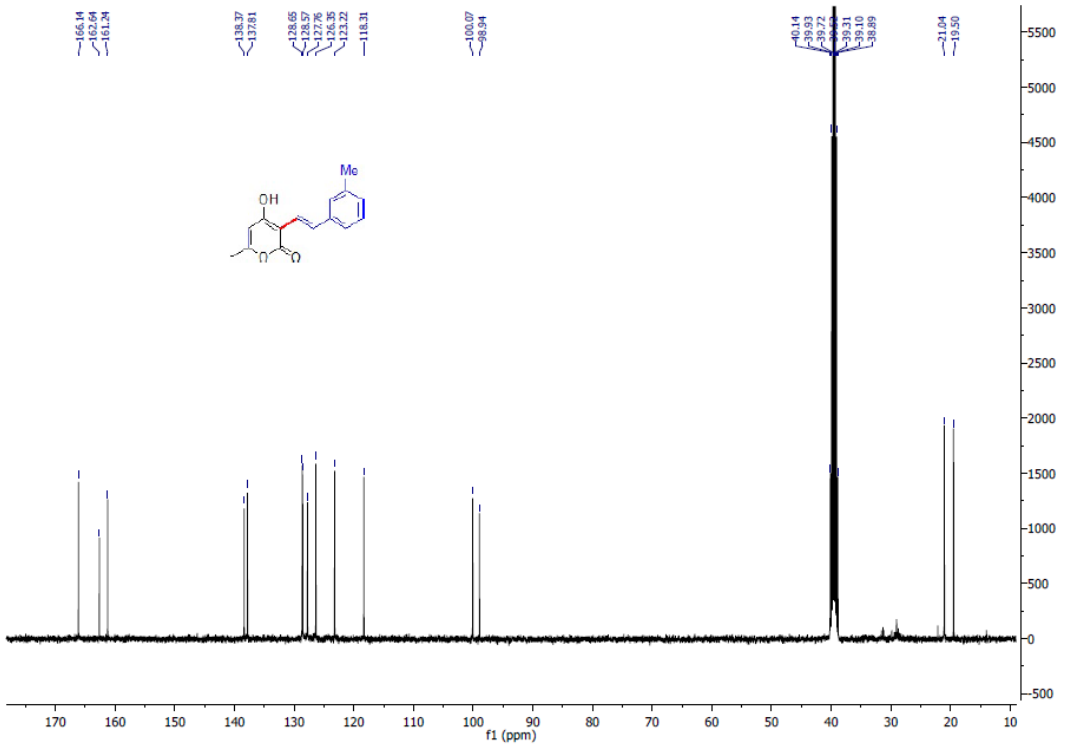
Dept of compound 8:



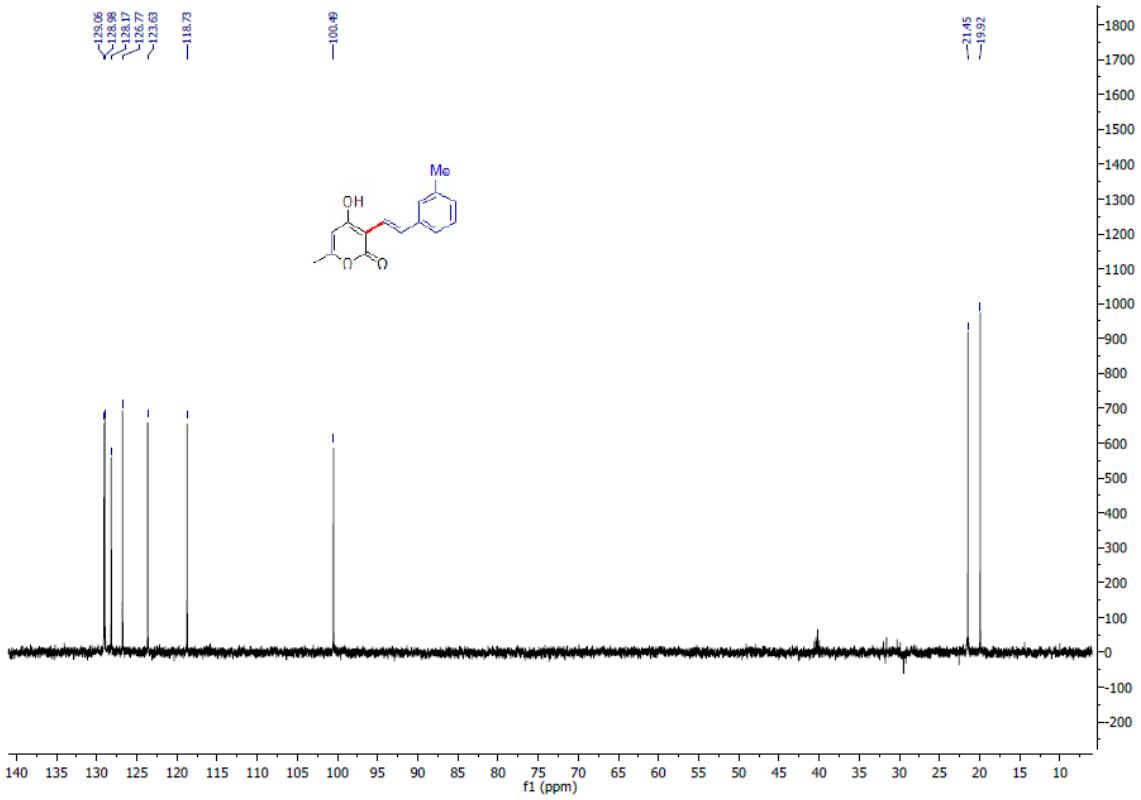
^{1}H NMR of compound 9:



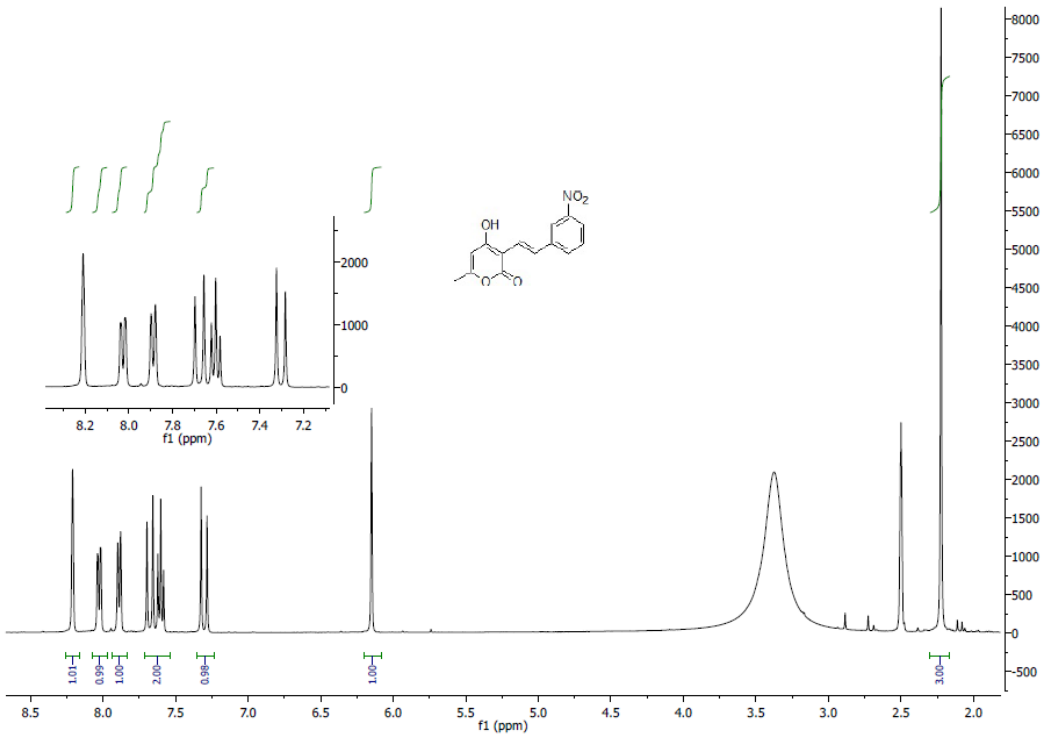
^{13}C NMR of compound 9:



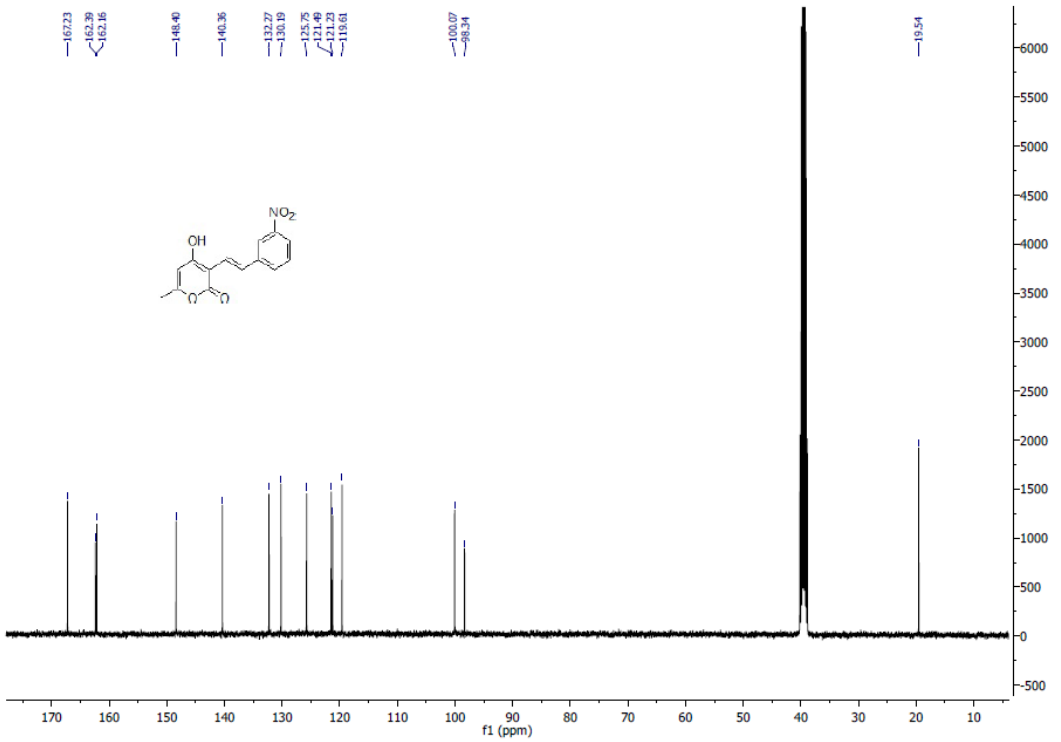
Dept of compound 9:



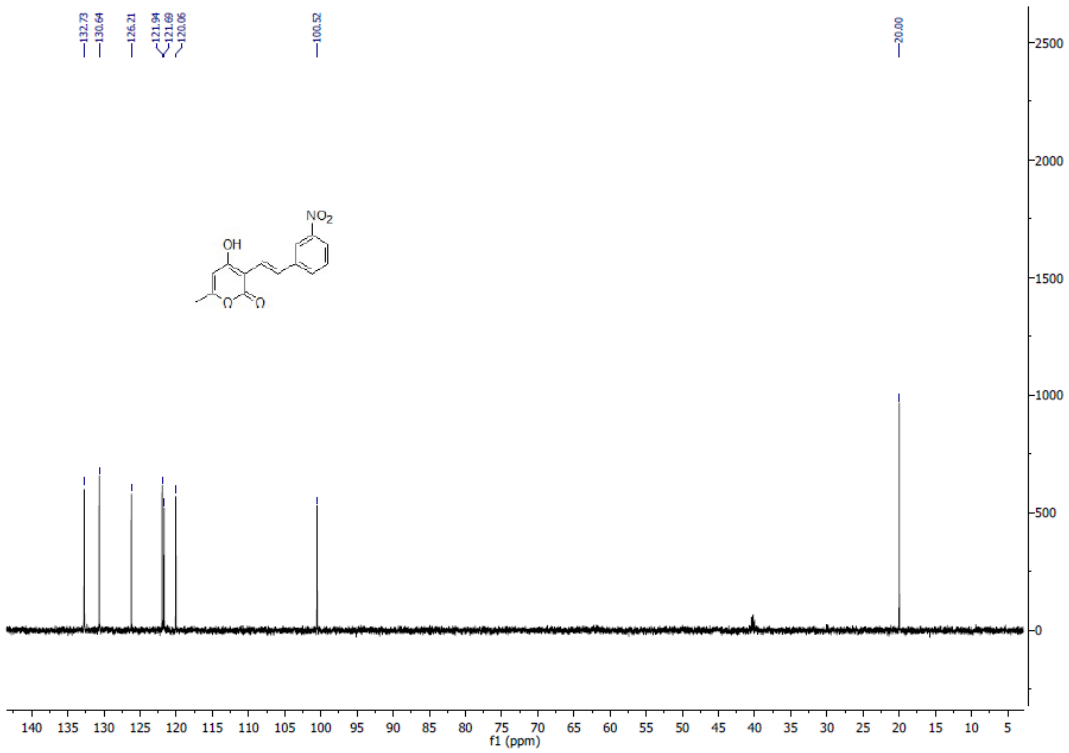
^{1}H NMR of compound 12:



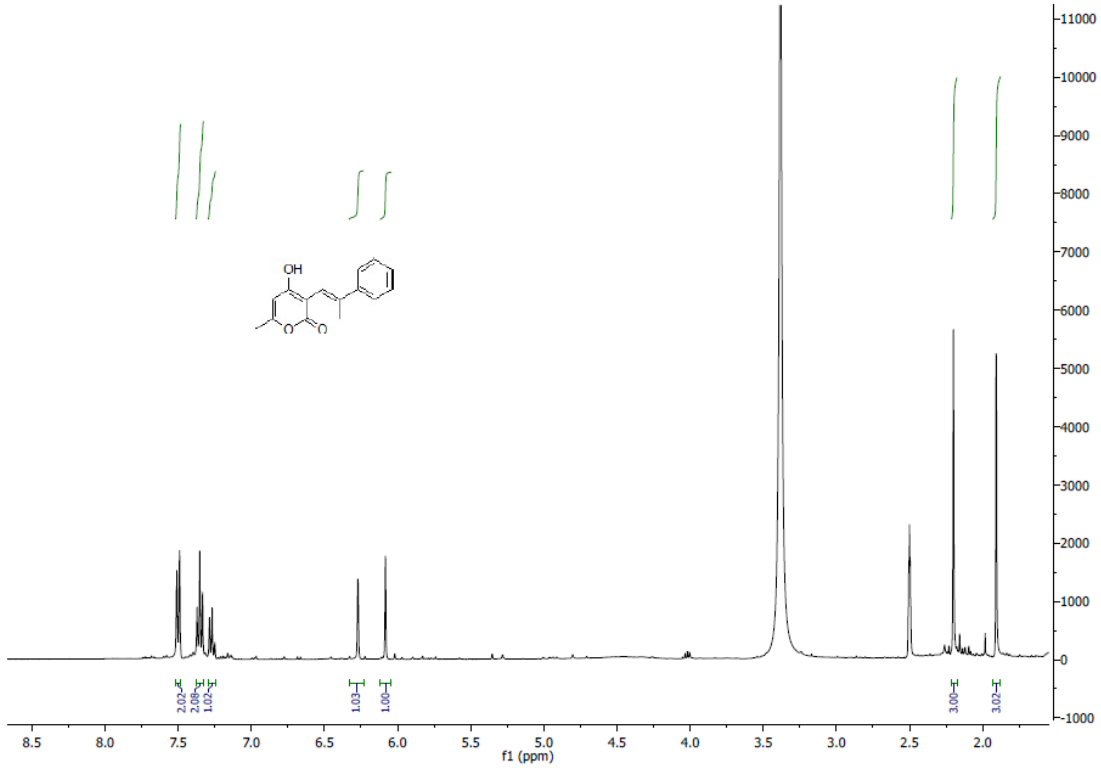
^{13}C NMR of compound 12:



Depth of compound 12:



^{1}H NMR of compound 13:



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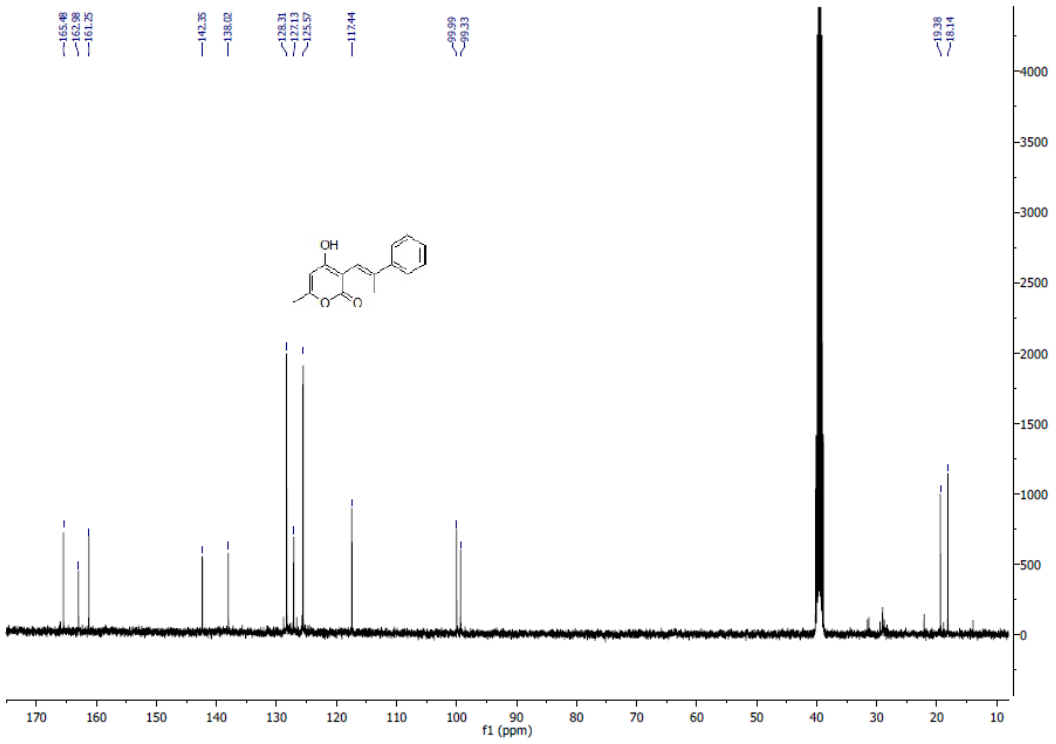
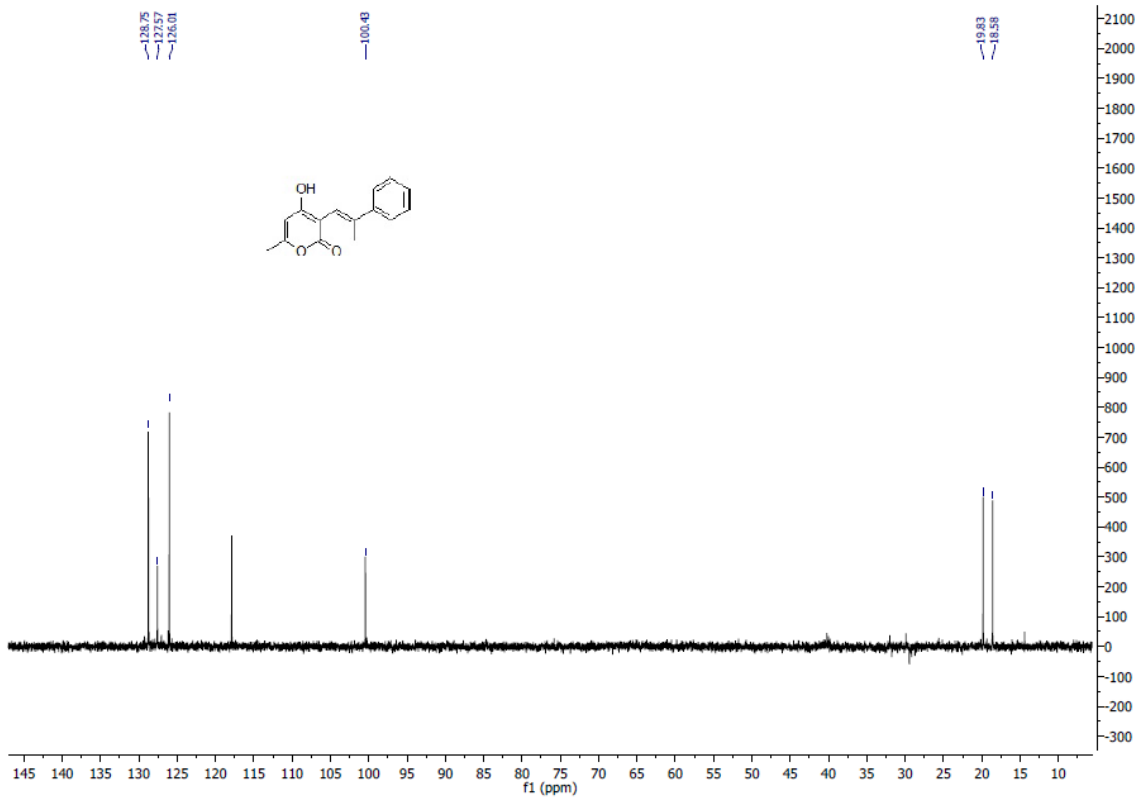
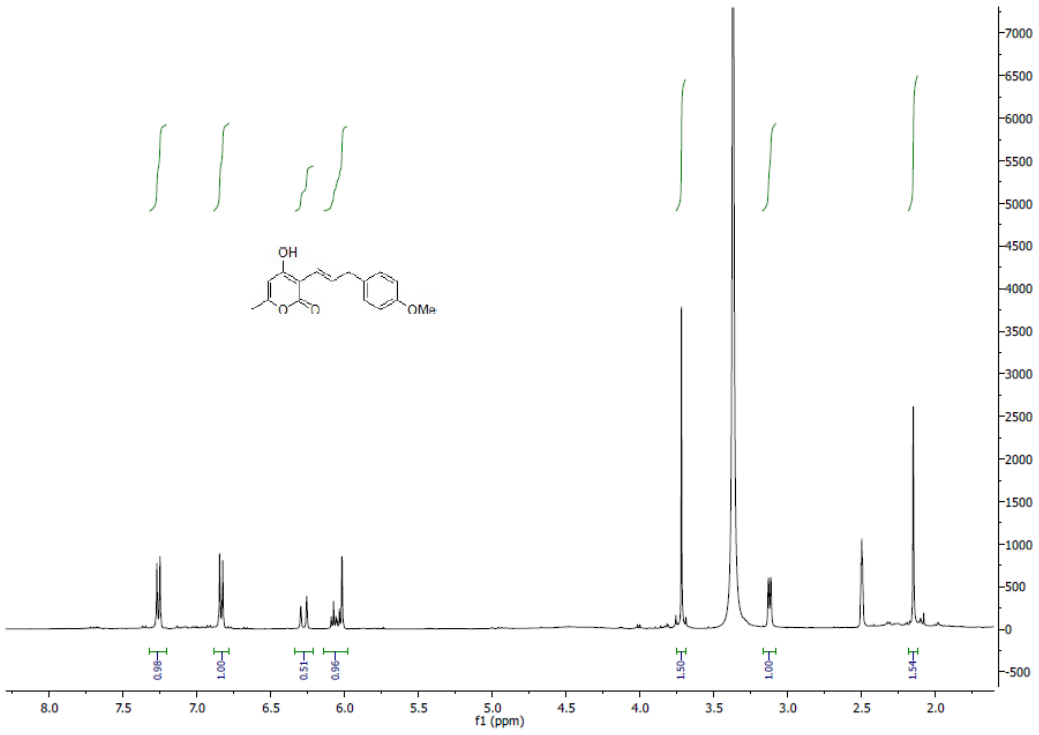


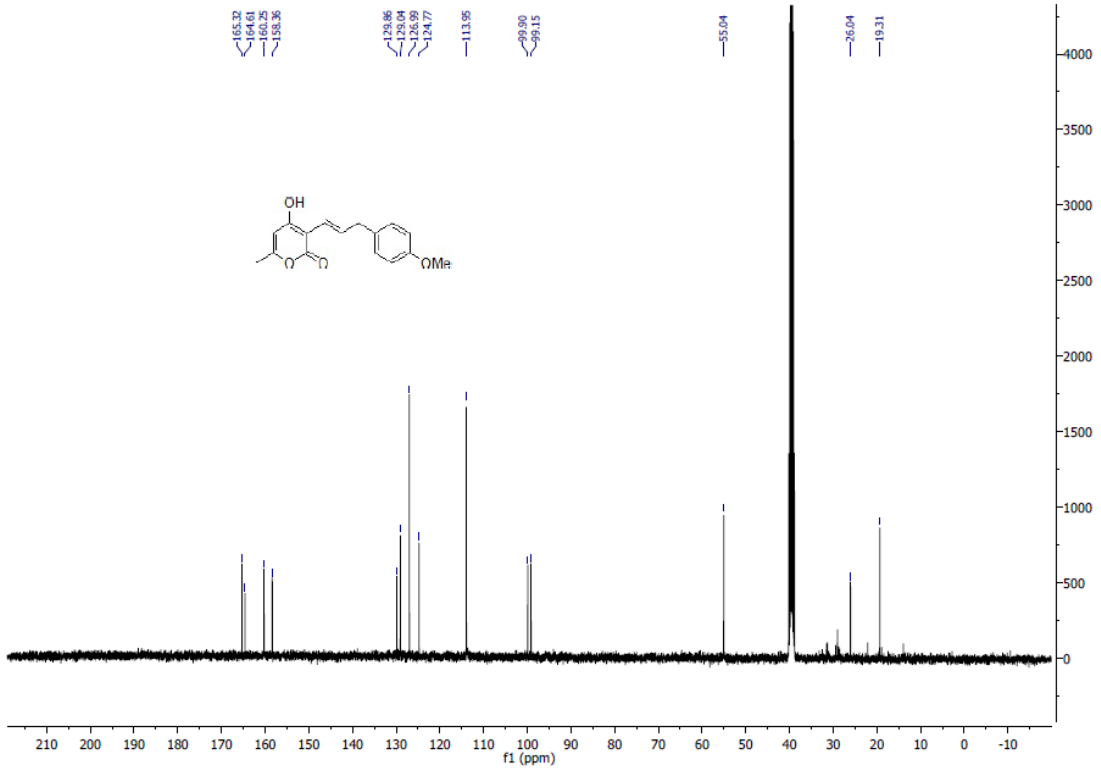
Dept of compound 13:



^{1}H NMR of compound 14:



^{13}C NMR of compound 14:



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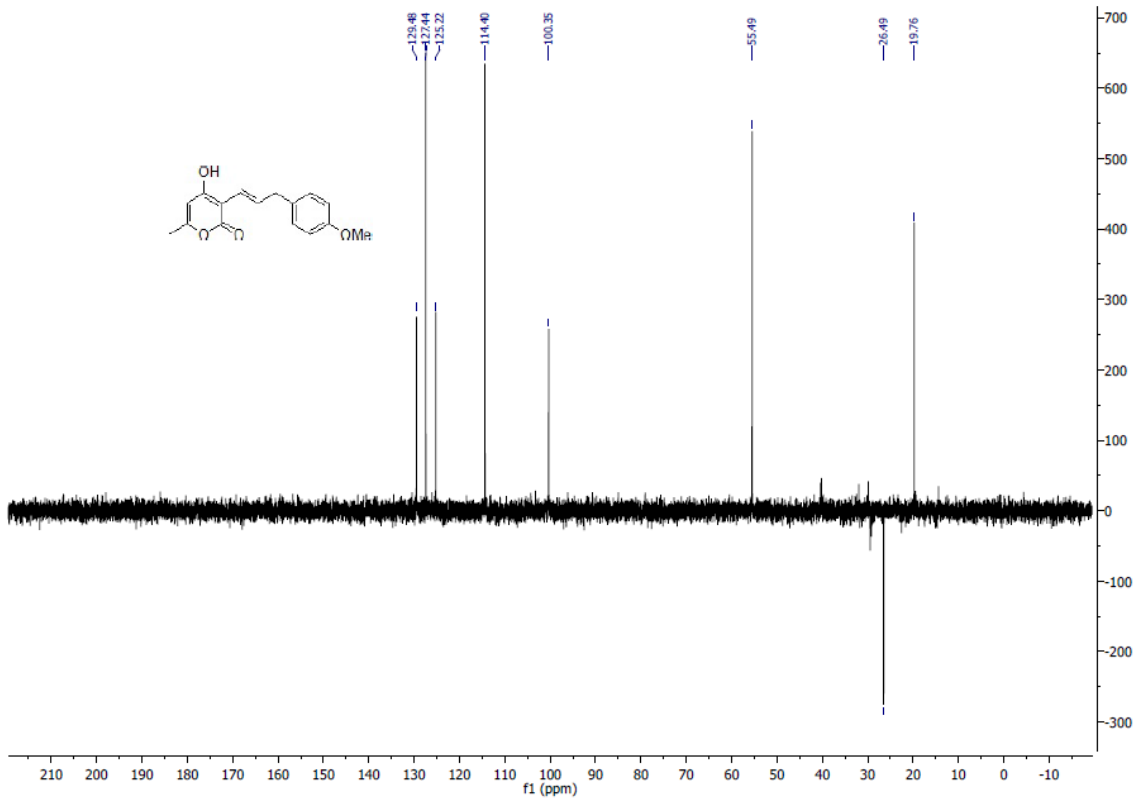
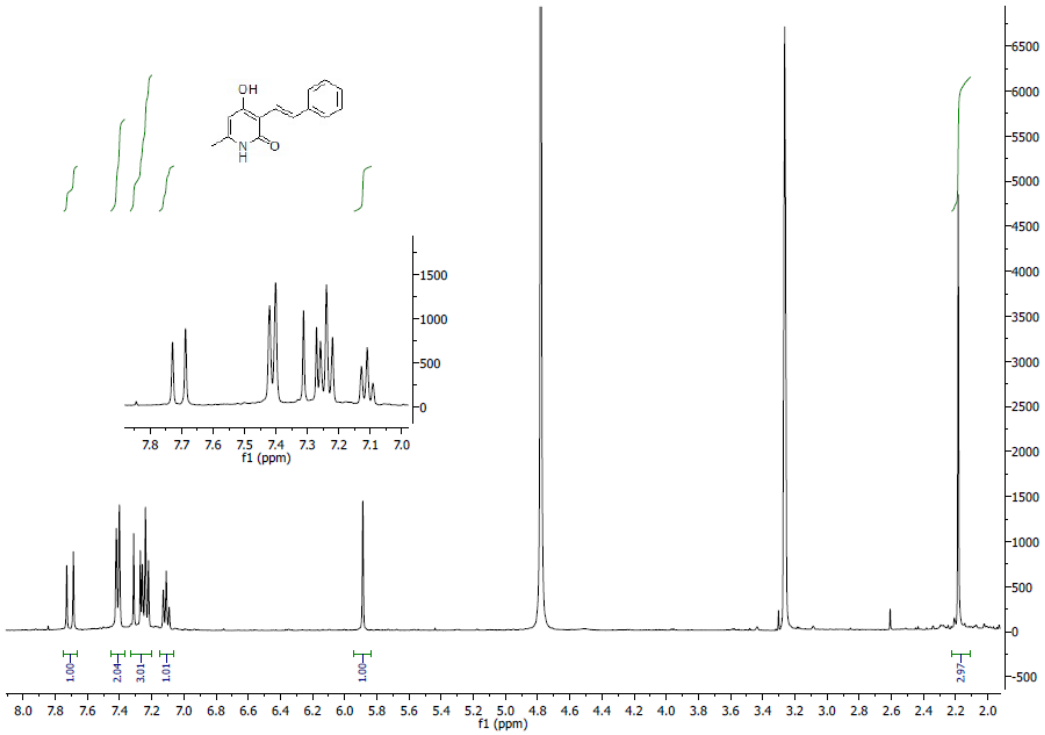
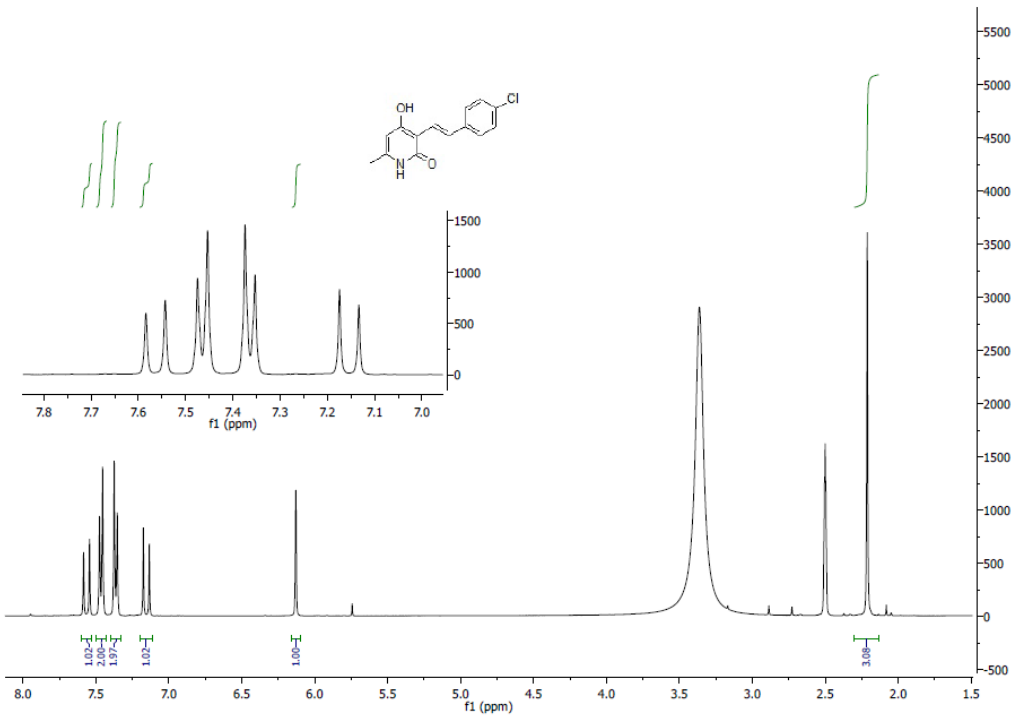


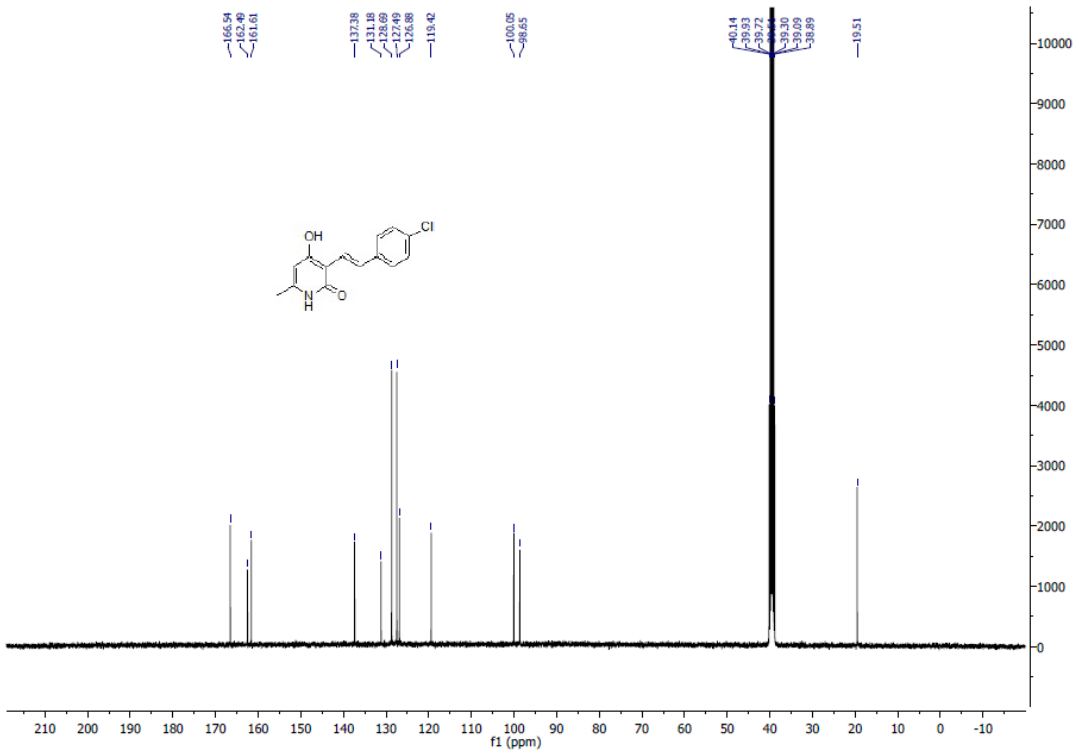
^{1}H NMR of compound 15:



^{1}H NMR of compound 16:



^{13}C NMR of compound 16:



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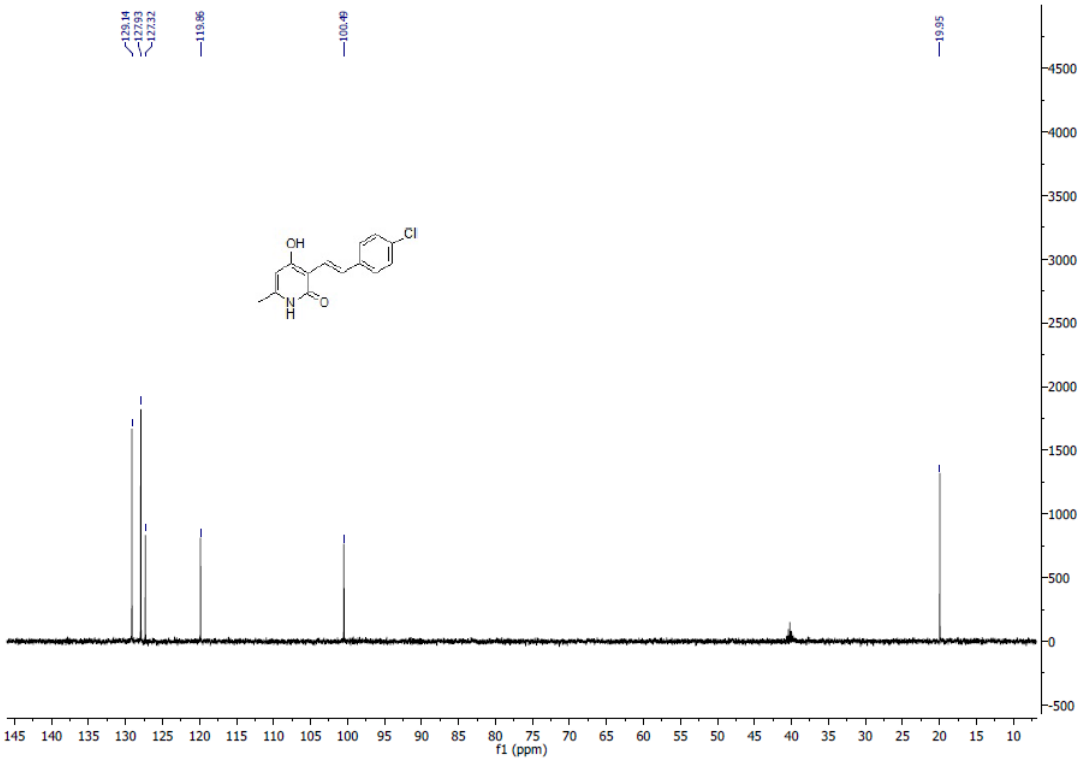
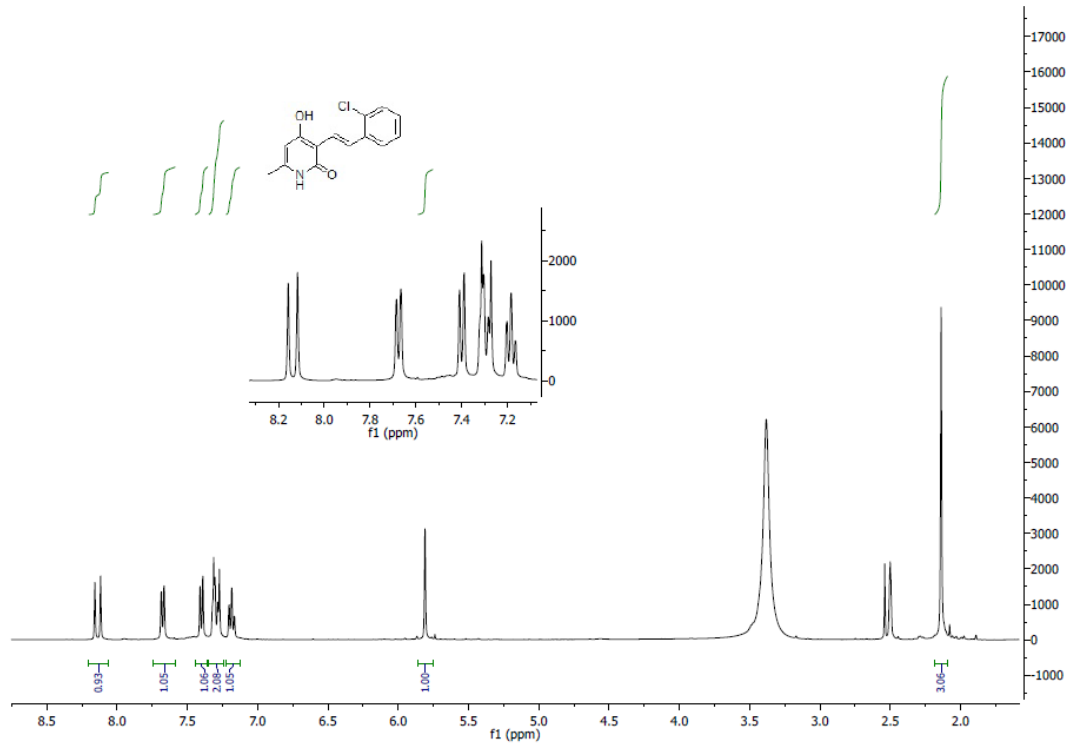


^{1}H NMR of compound 17:



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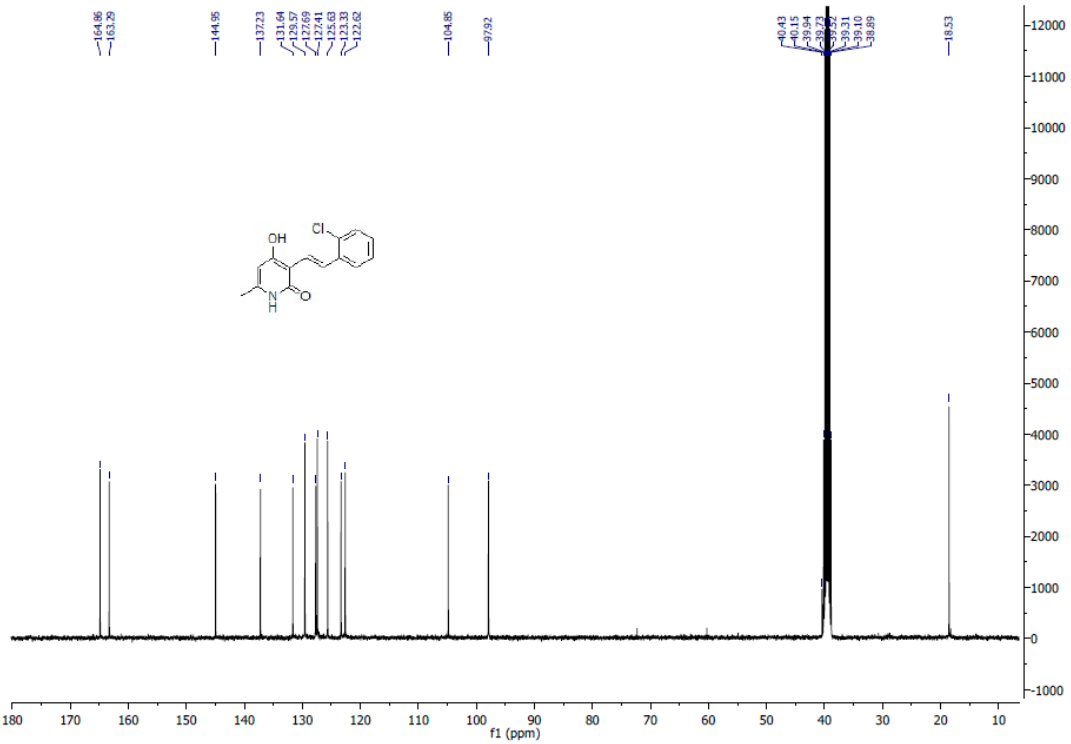

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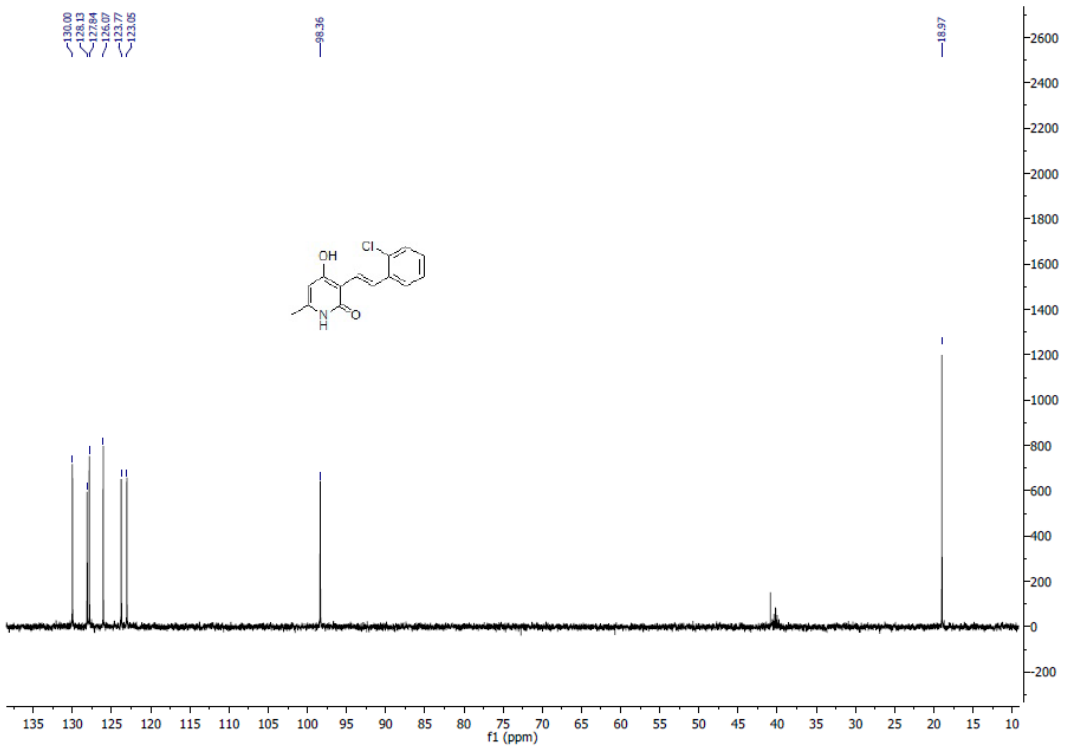
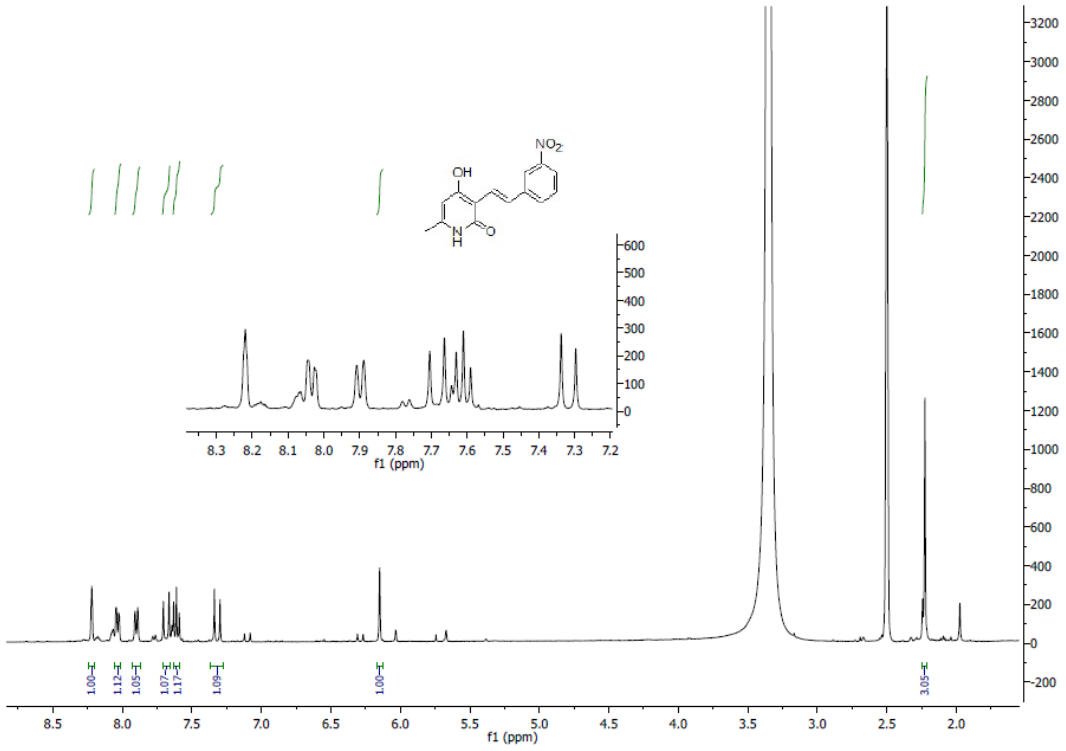


^{1}H NMR of compound 18:



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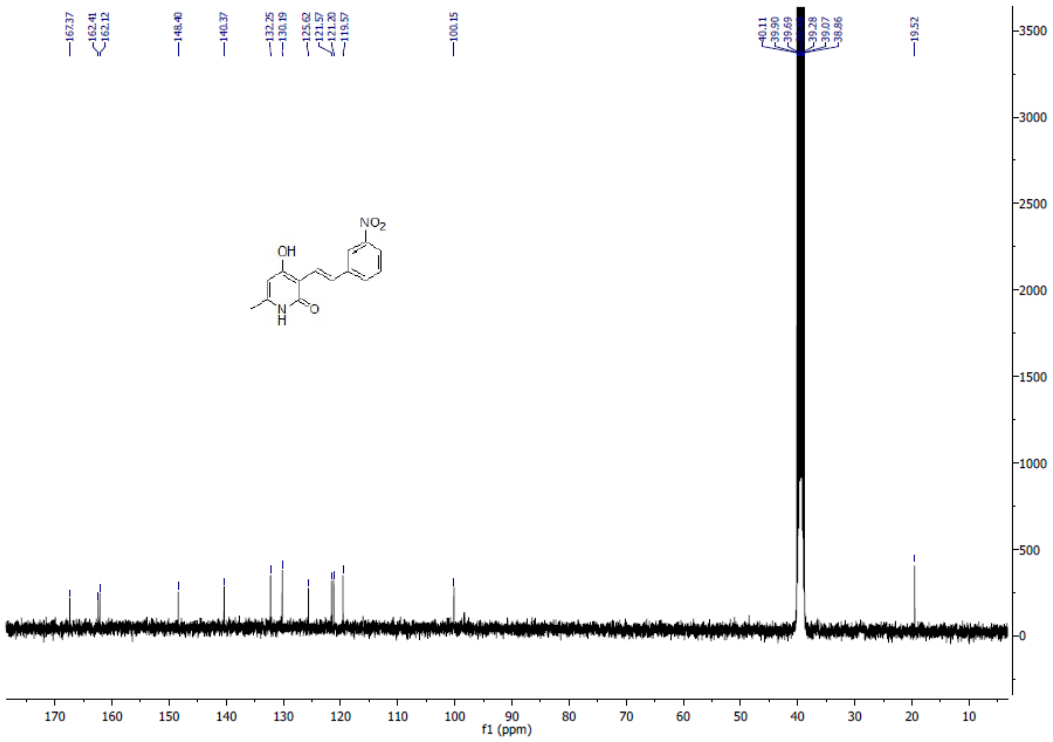
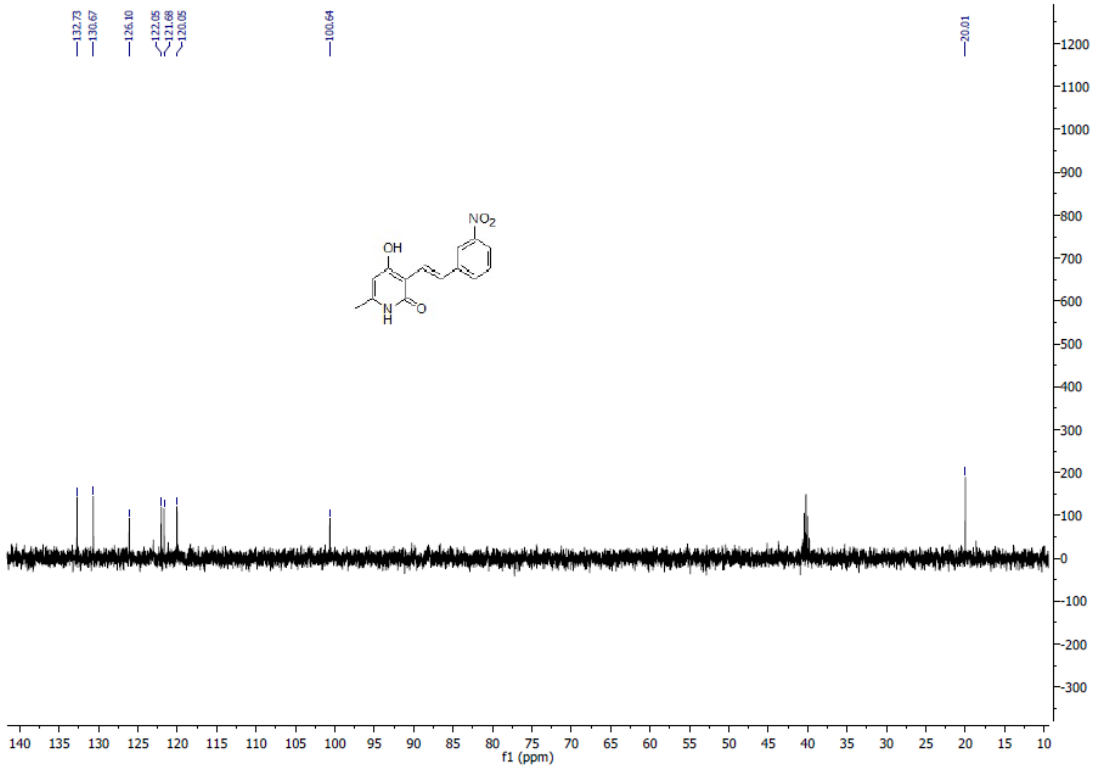
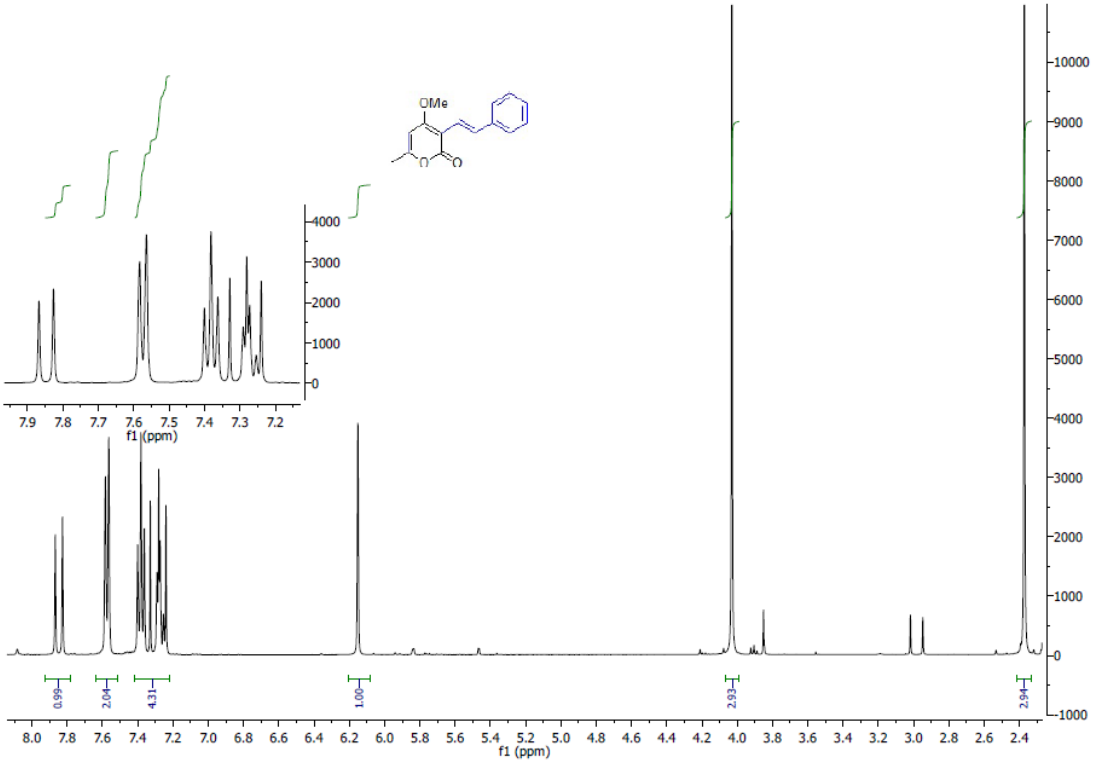


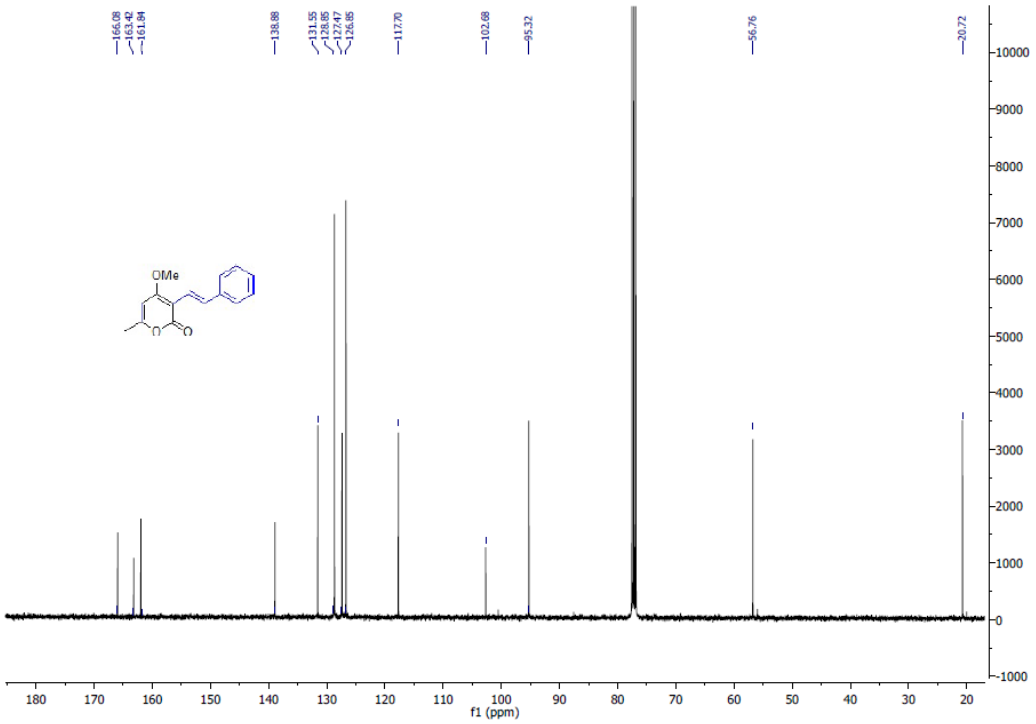
Dept of compound 18:



^{1}H NMR of compound 20:



^{13}C NMR of compound 20:



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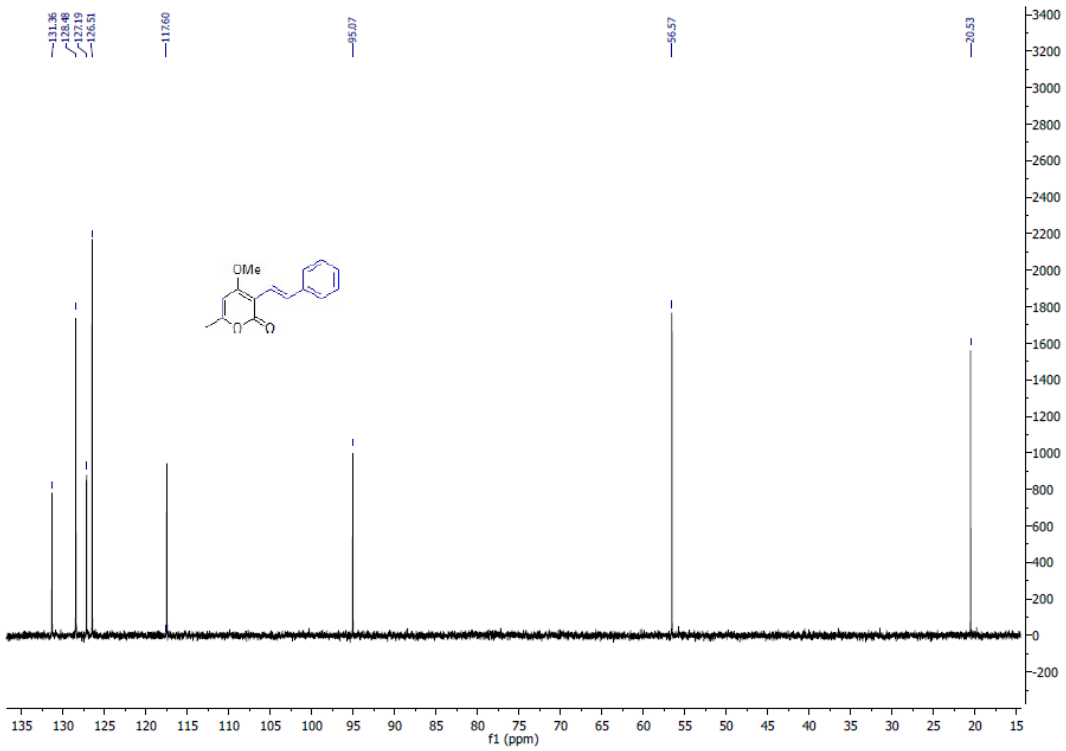
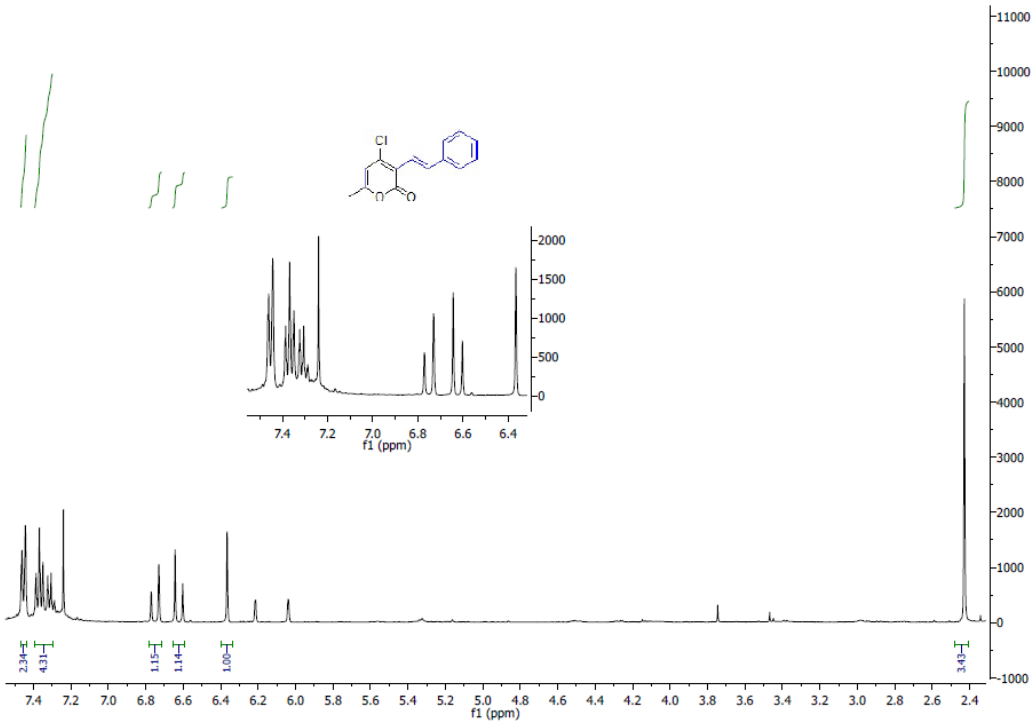


[1]H NMR of compound 22:



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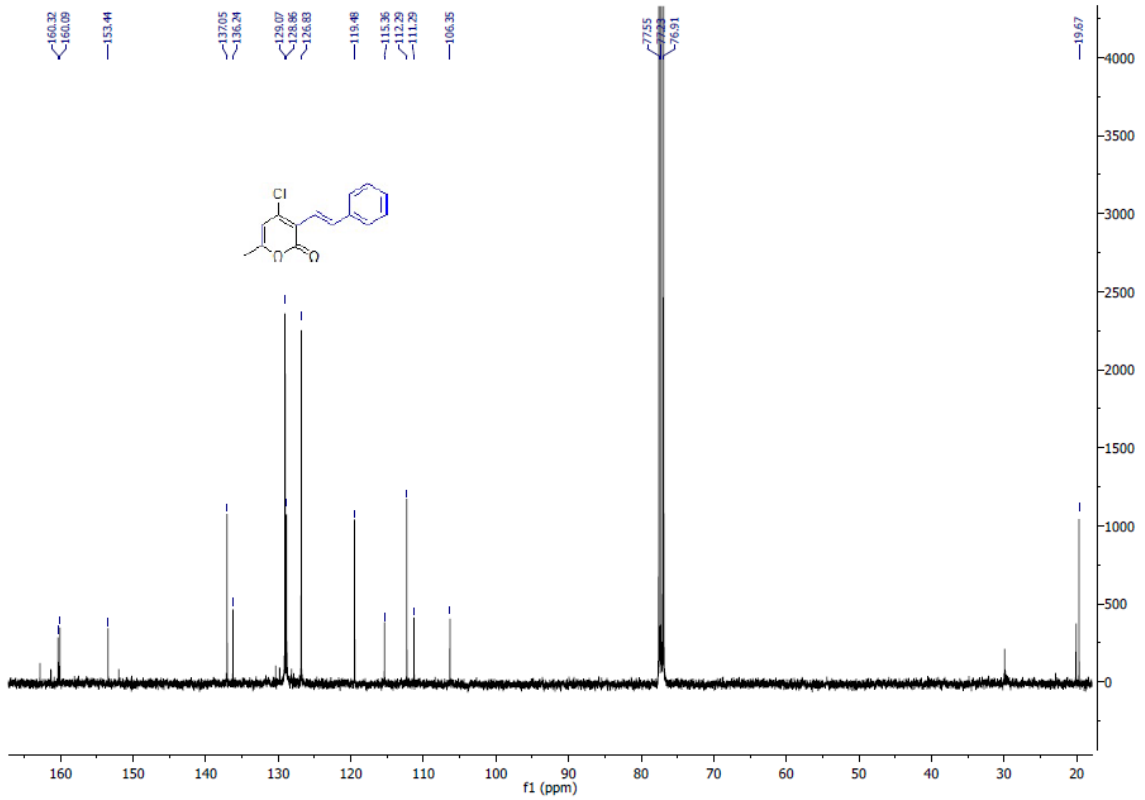

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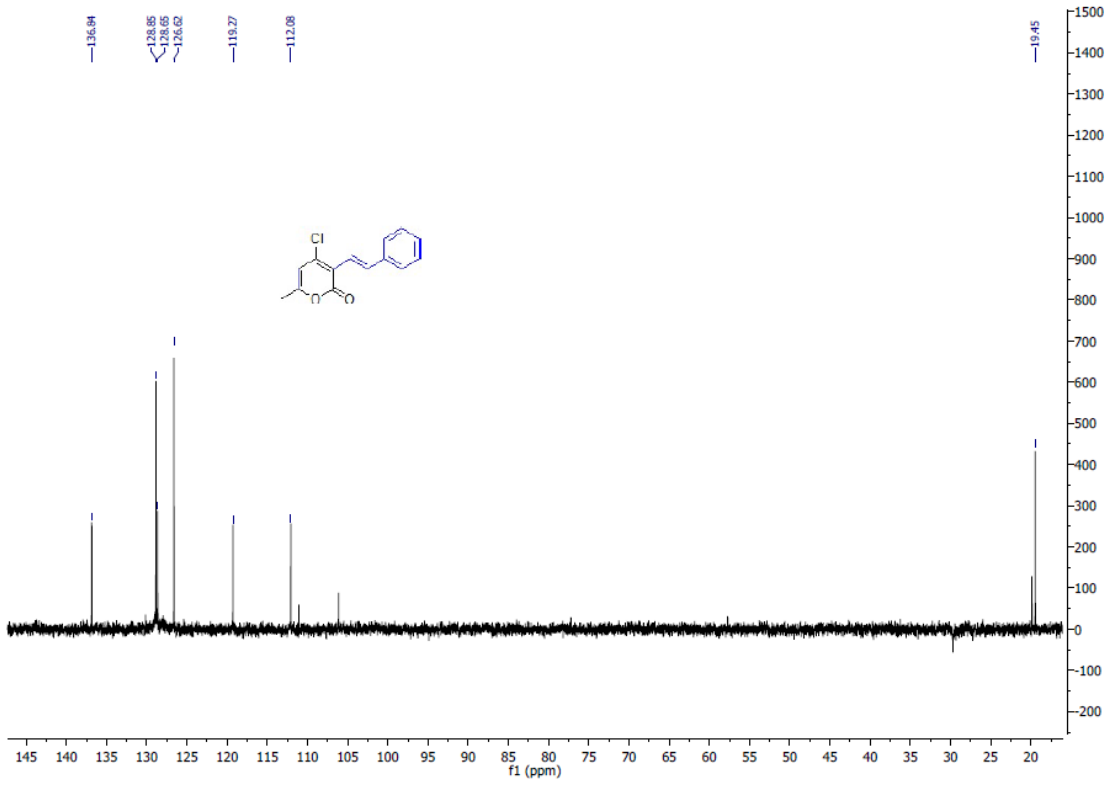

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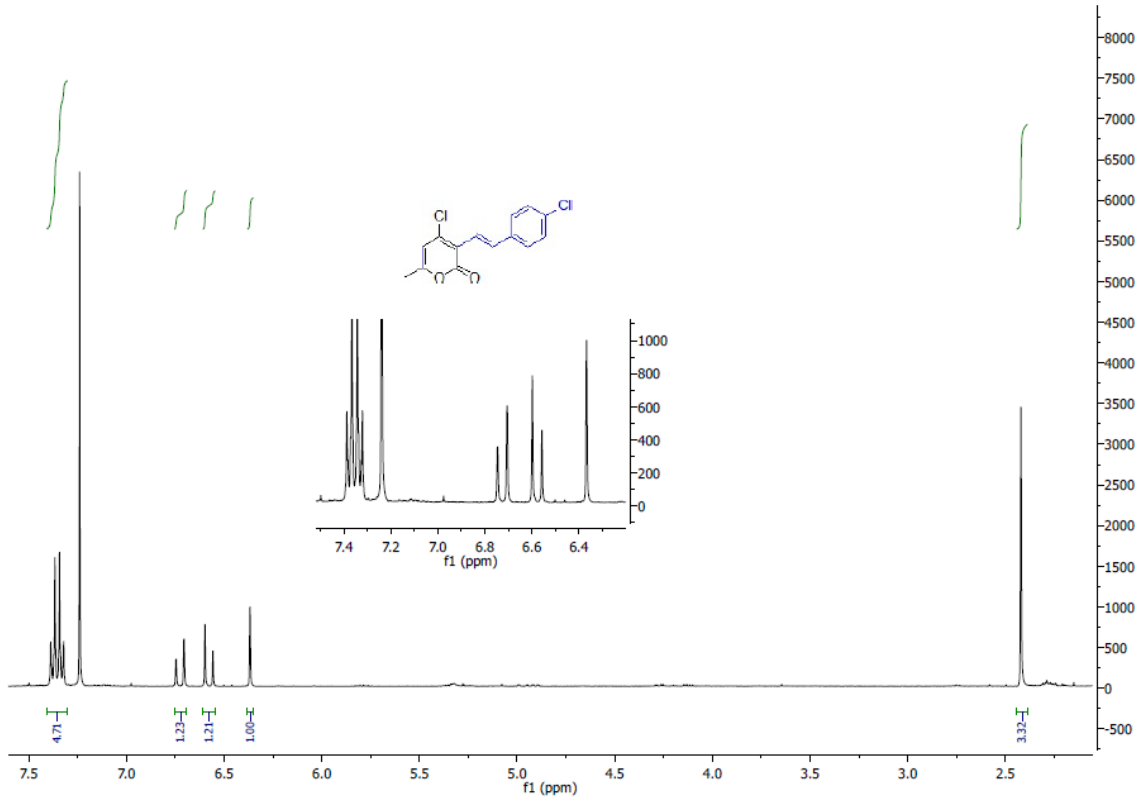
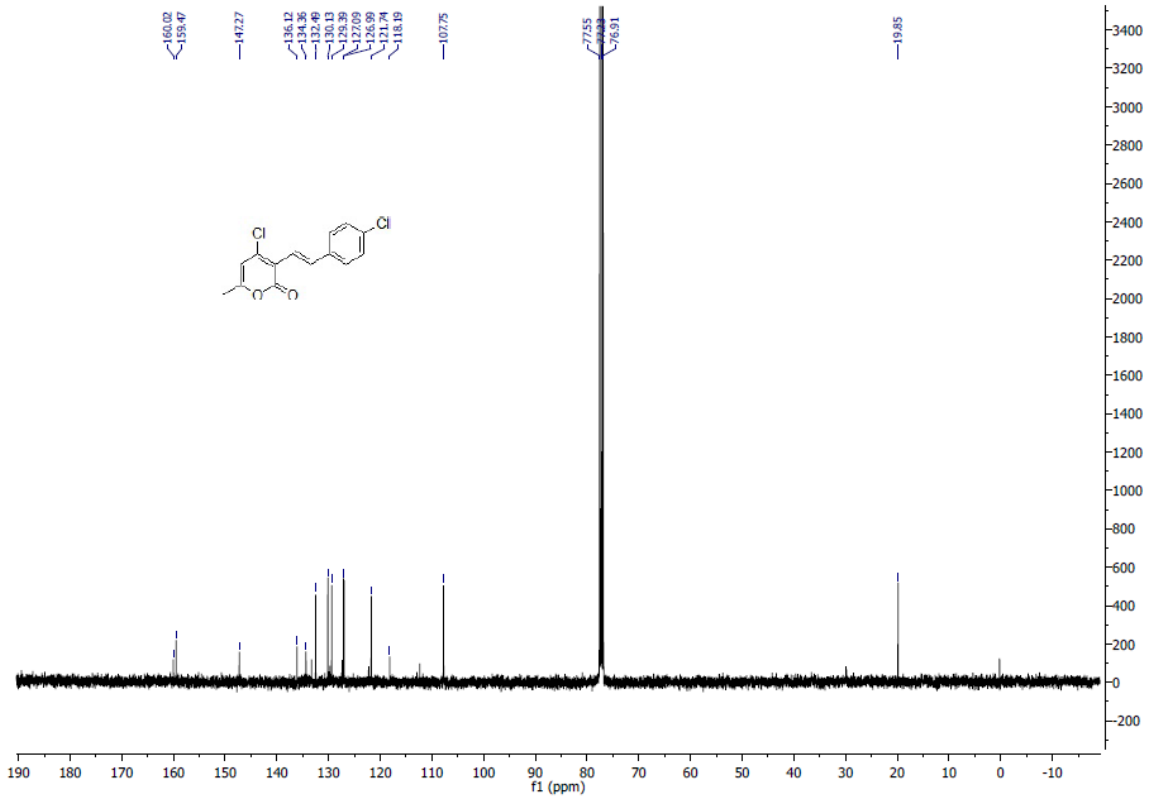


^{13}C NMR of compound 23:



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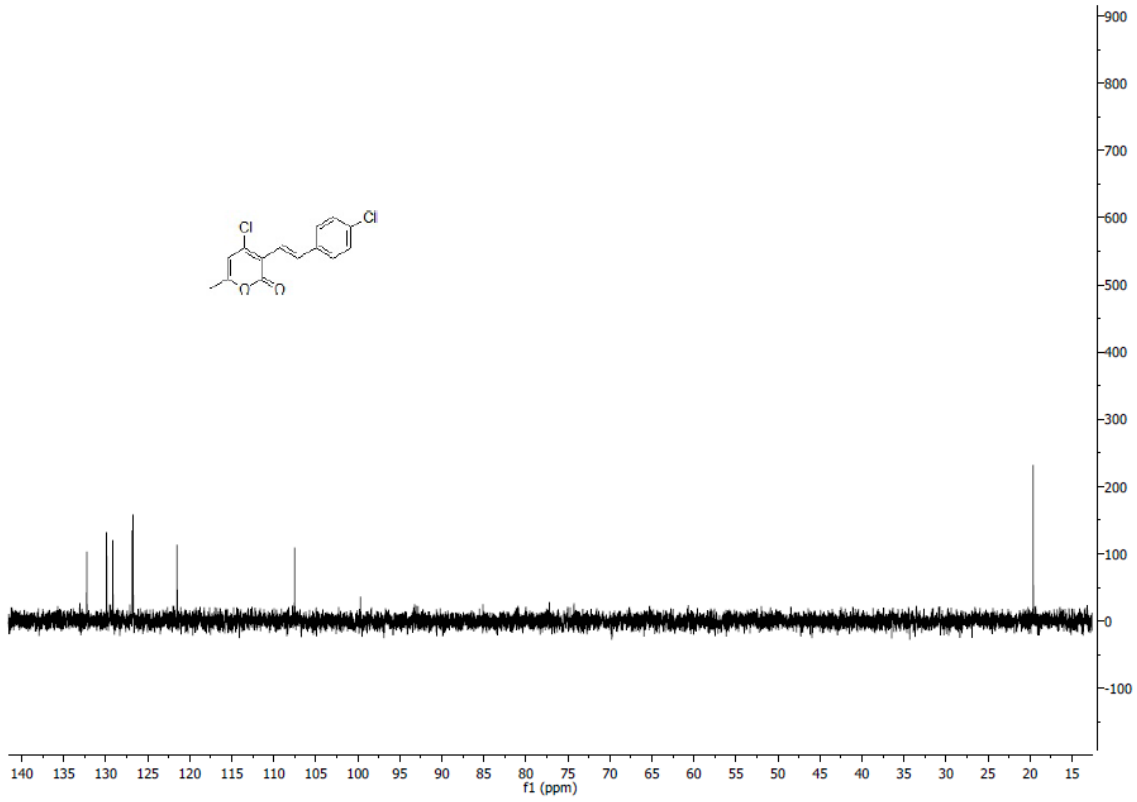
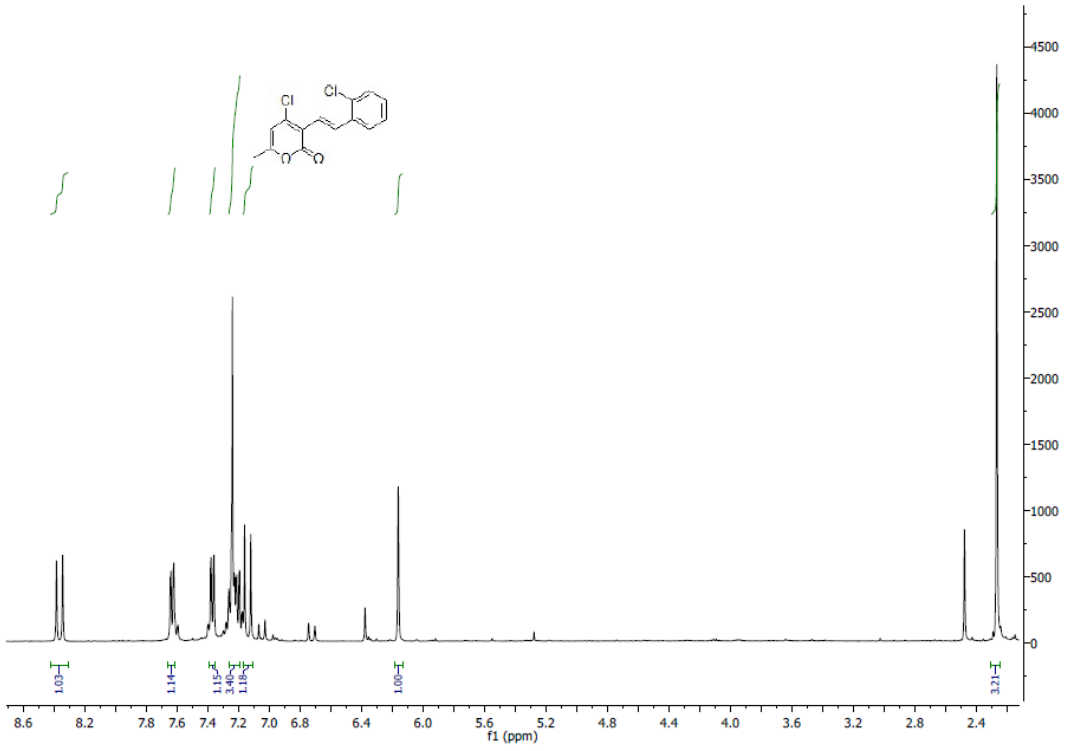
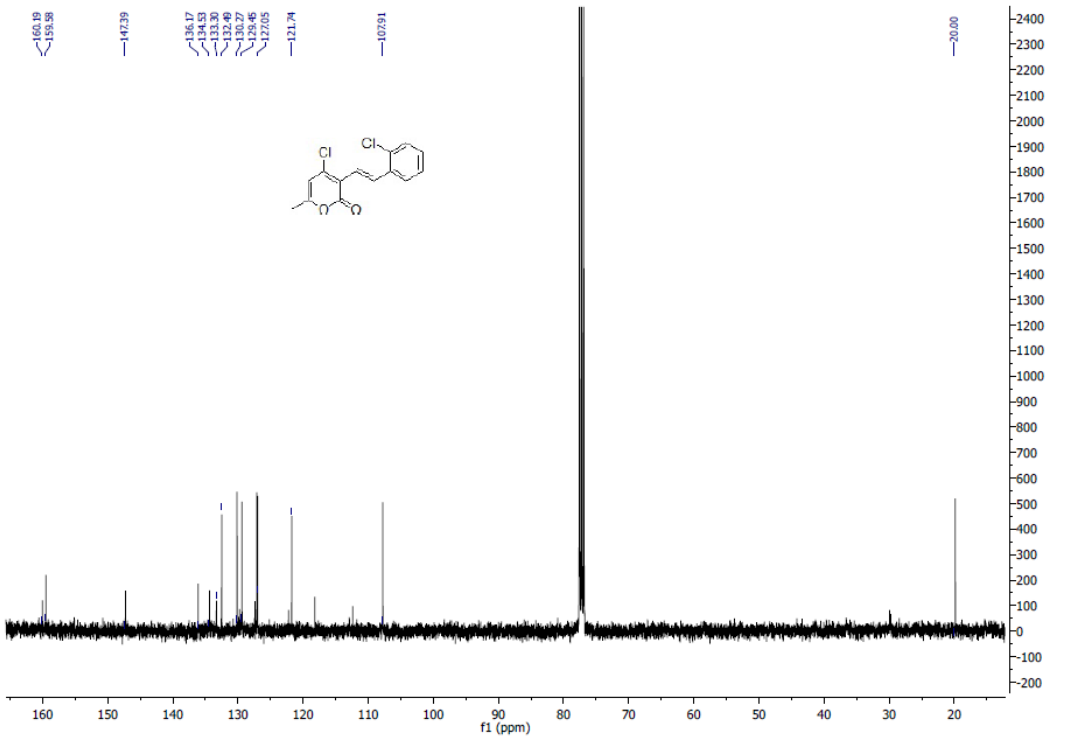


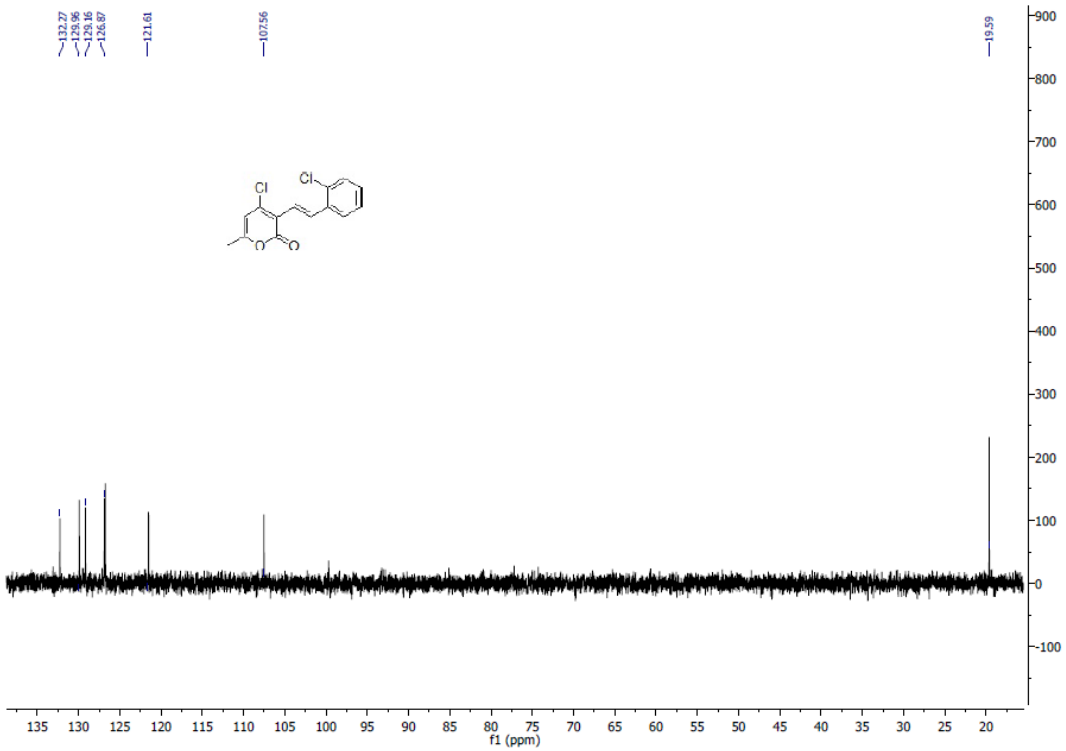
^{1}H NMR of compound 24:



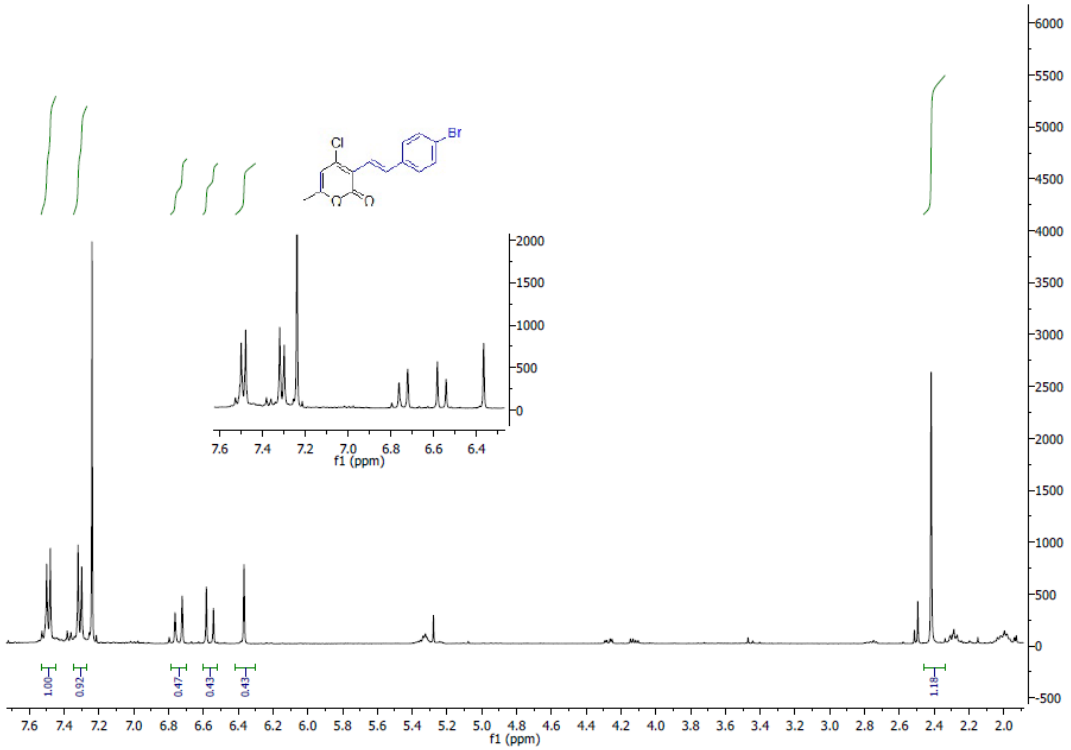
^{13}C NMR of compound 24:



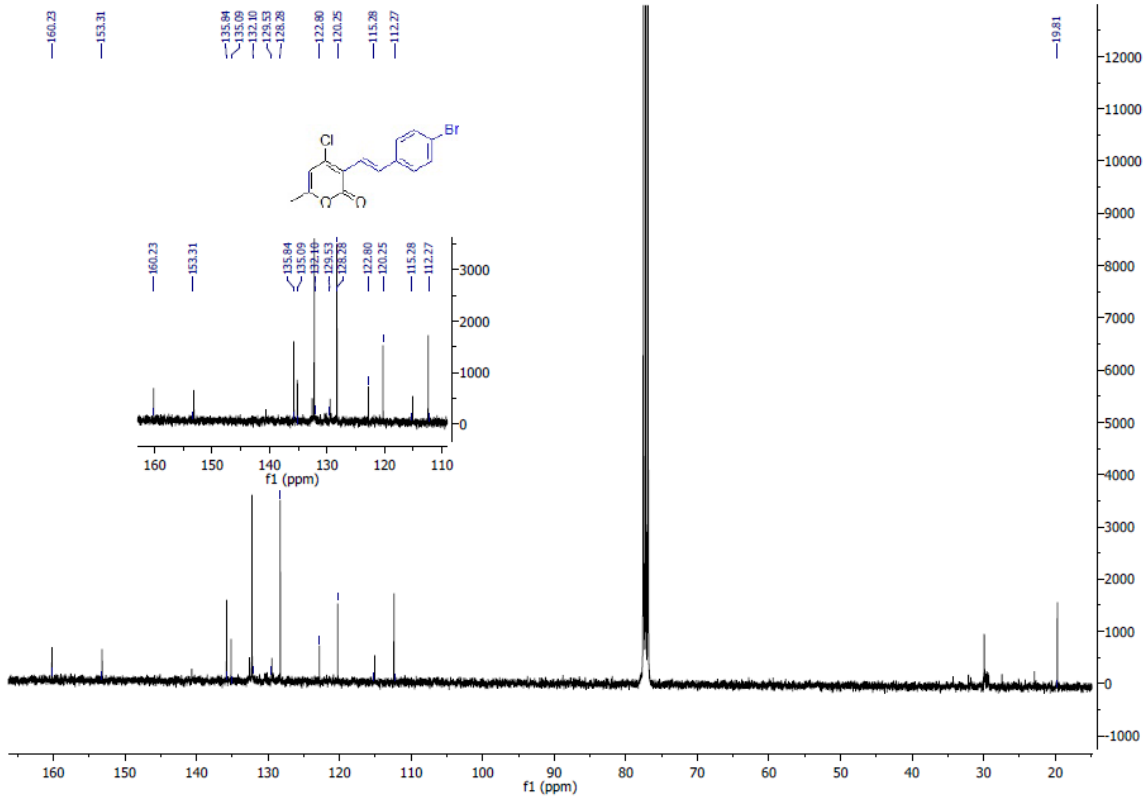
Dept of compound 24:



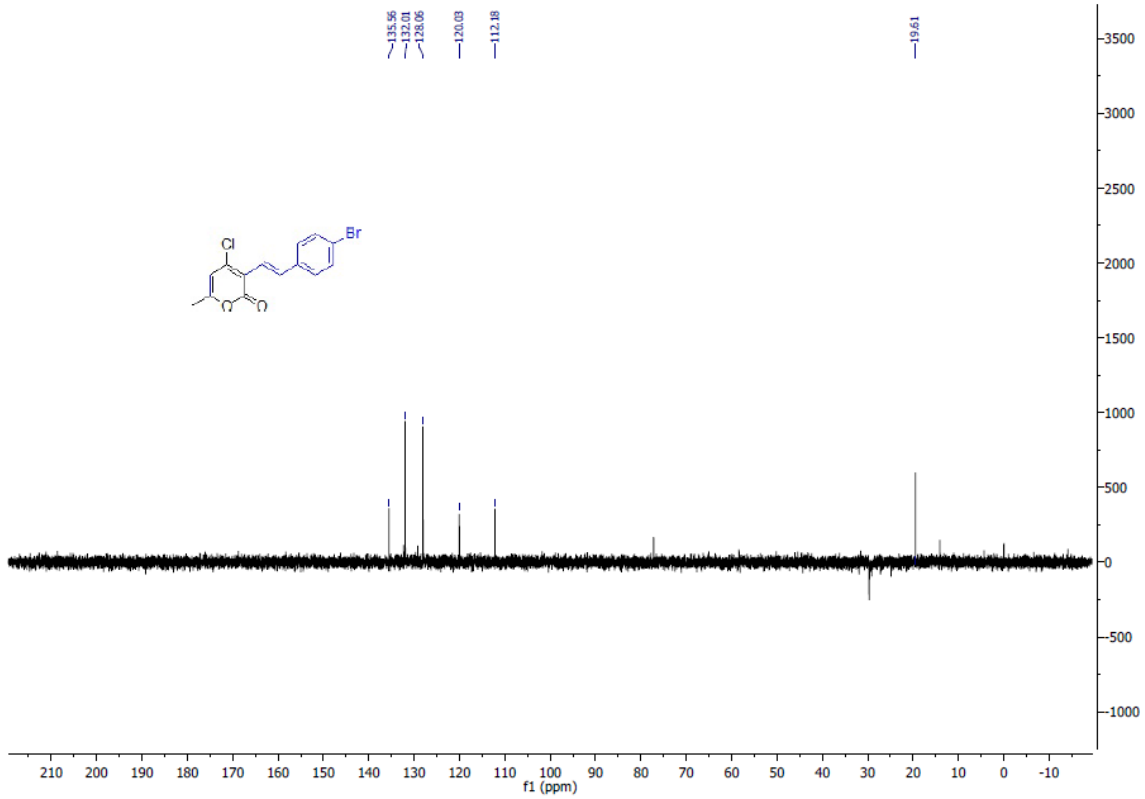
^{1}H NMR of compound 25:



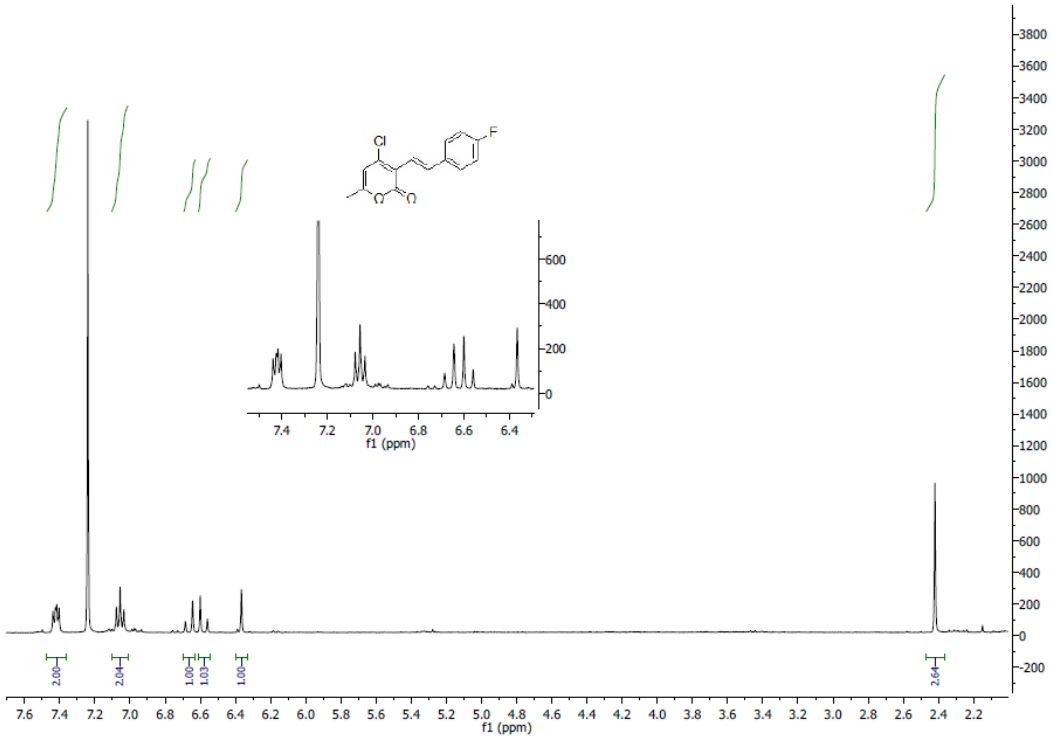
^{13}C NMR of compound 25:



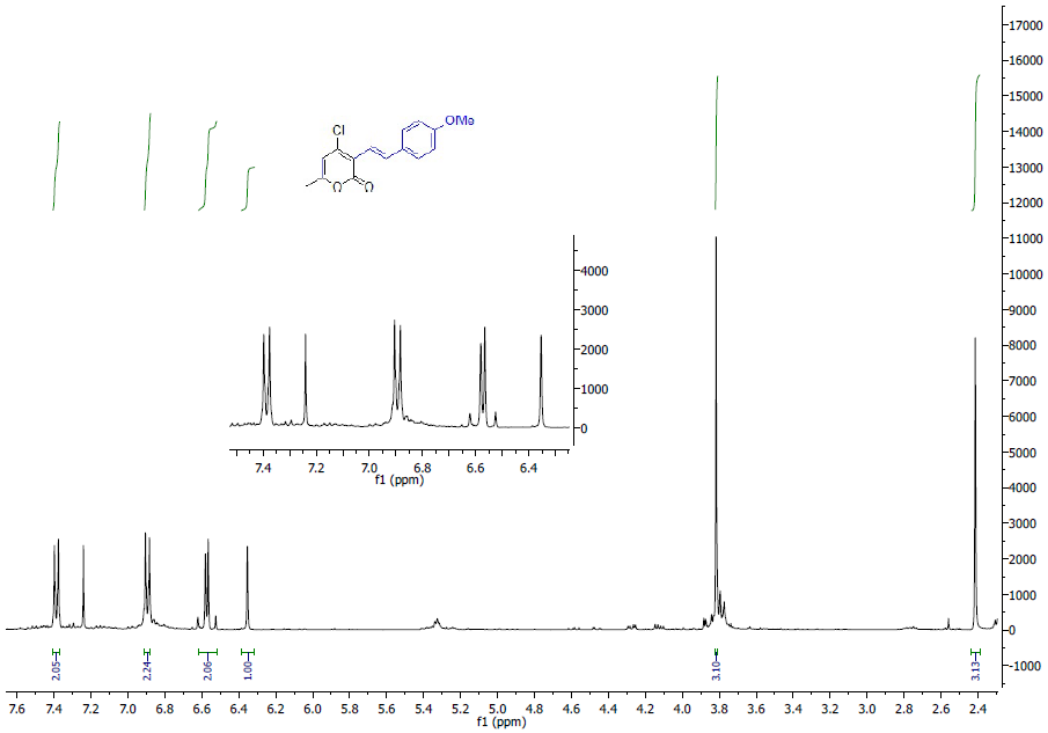
Depth of compound 25:



^{1}H NMR of compound 26:



^{1}H NMR of compound 27:



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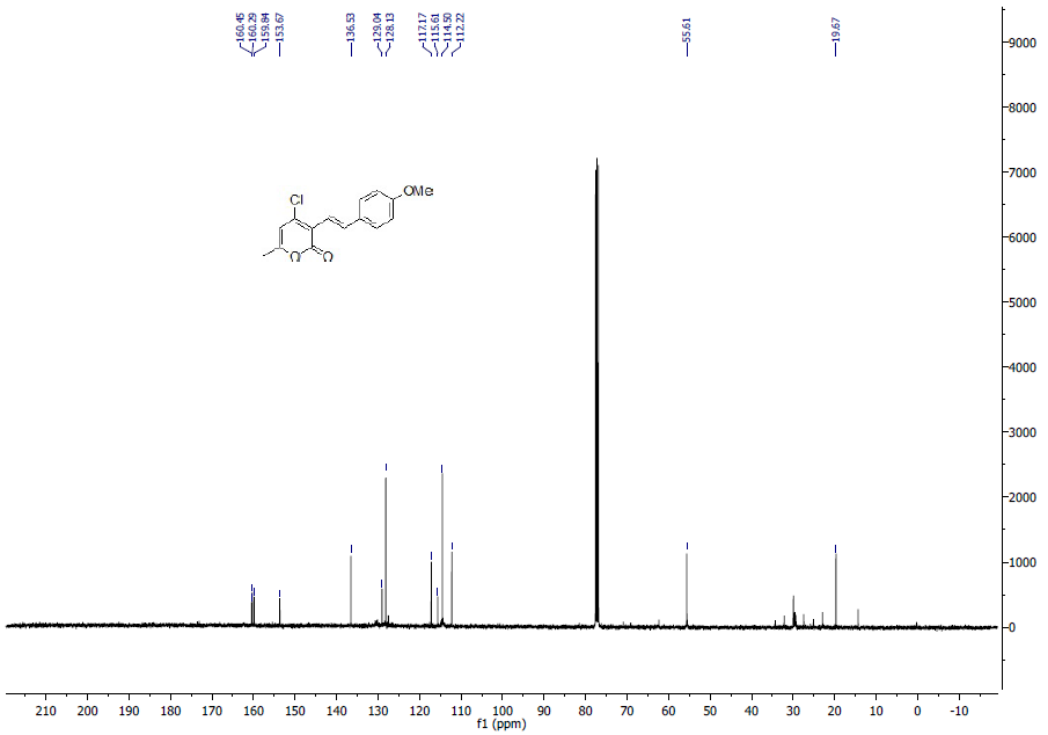

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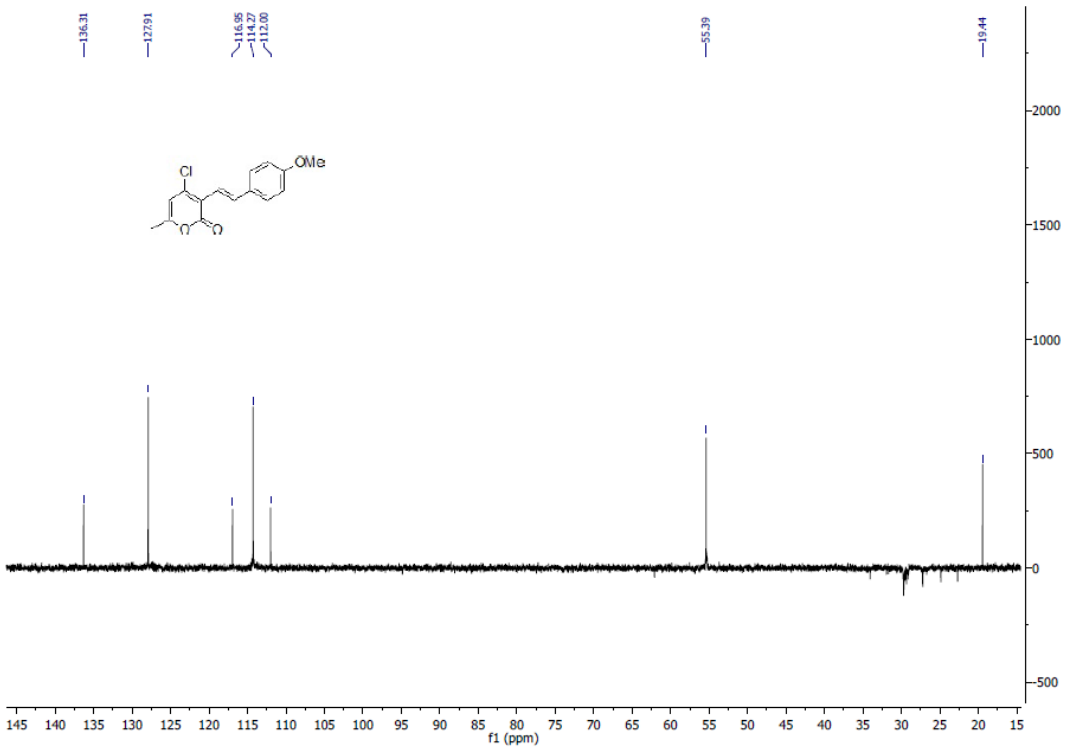
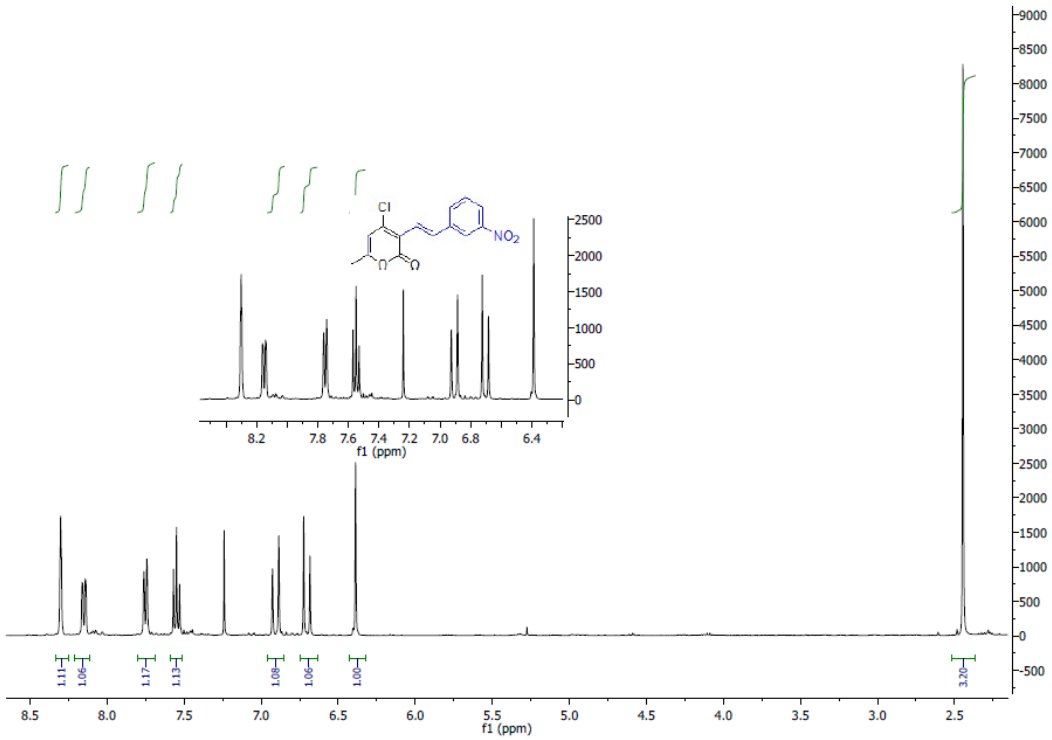


^{1}H NMR of compound 28:



^{13}C NMR of compound 28: