Electronic Supplementary Material (ESI) for Organic & Biomolecular Chemistry

Supporting Information

Electrophilicity of α-Oxo Gold carbene Intermediate: Halogen Abstraction from Halogenated Solvent Leading to the Formation of Chloro/Bromomethyl Ketone

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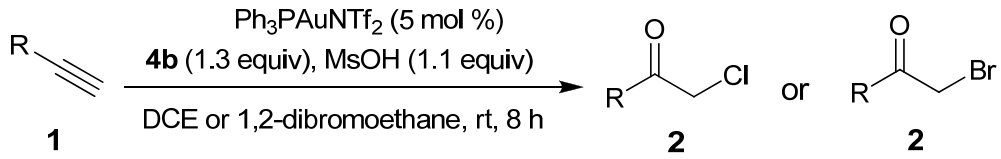
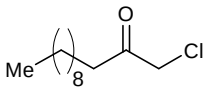
General. Ethyl acetate (ACS grade), hexanes (ACS grade) were purchased from J&K Scientific Ltd. and used without further purification. Commercially available reagents were used without further purification. Reactions were monitored by thin layer chromatography (TLC) using silicycle pre-coated silica gel plates. Flash column chromatography was performed over silicycle silica gel (230-400 mesh). ^{1}H NMR and ^{13}C NMR spectra were recorded on a Brucker ARX 400 FT NMR plus spectrometer using residue solvent peaks as internal standards. Infrared spectra were recorded with FD-5DX spectrometer and are reported in reciprocal centimeter (cm^{-1}). Mass spectra were recorded with aZABHS using electron spray ionization.

General procedure for the formation of chloro/bromomethyl ketones via gold-catalyzed intermolecular oxidation of terminal alkynes



4b *N*-oxide (0.39 mmol, 62.01mg) and $Au(PPh_3)NTf_2$ (11.1 mg, 0.015 mmol) were added to a solution of alkyne(0.30 mmol) in DCE or 1,2-dibromoethane (3 mL) at room temperature. The reaction mixture was stirred at room temperature and the progress of the reaction was monitored by TLC. The reaction typically took 8 h. Upon completion, the mixture was concentrated and the residue was purified by chromatography on silica gel (eluent: hexanes/ethyl acetate) to afford the desired products **2**.

1-chlorododecan-2-one (2a)

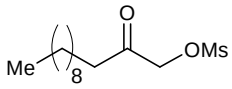


2a

Compound **2a** was prepared in 63% yield according to the general procedure. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.08 (s, 2H), 2.58 (t, 2H, *J* = 7.2 Hz), 1.61 – 1.57 (m, 2H), 1.33 – 1.22 (m, 14H), 0.87 (t, 3H, *J* = 7.2 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 202.80, 48.20,

39.70, 31.85, 29.50, 29.39, 29.28, 29.26, 29.04, 23.58, 22.64, 14.08; IR (neat): 3713, 2919, 1721, 1467, 1045, 784; MS (ES^+) Calculated for $[C_{12}H_{24}ClO]^+$: 219.1; Found: 219.1.

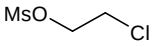
2-oxododecyl methanesulfonate (3a)



3a

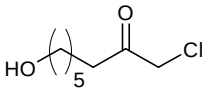
Compound **3a** was prepared in 5% yield according to the general procedure. ^1H NMR (400 MHz, $CDCl_3$) δ 4.80 (s, 2H), 3.21 (s, 3H), 2.45 (t, 2H, *J* = 7.2 Hz), 1.62 – 1.57 (m, 2H), 1.33 – 1.23 (m, 14H), 0.87 (t, 3H, *J* = 7.2 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 203.11, 71.53, 38.88, 38.60, 31.84, 29.67, 29.49, 29.36, 29.26, 29.01, 23.10, 22.64, 14.09; IR (neat): 3653, 2922, 2310, 1731, 1166, 759; MS (ES^+) Calculated for $[C_{13}H_{27}O_4S]^+$: 279.2; Found: 279.2.

2-chloroethyl methanesulfonate



2-chloroethyl methanesulfonate was prepared in 46% yield according to the general procedure and its spectroscopic data match well with those reported. ^1H NMR (400 MHz, $CDCl_3$) δ 4.43 (t, 2H, *J* = 5.6 Hz), 3.75 (t, 2H, *J* = 5.6 Hz), 3.08 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 68.64, 41.20, 37.70; IR (neat): 3736, 2960, 1346, 937, 529; MS (ES^+) Calculated for $[C_3H_8ClO_3S]^+$: 159.0; Found: 159.0.

1-chloro-7-hydroxyheptan-2-one (2b)

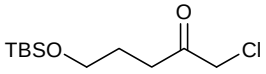


2b

Compound **2b** was prepared in 58% yield according to the general procedure. ^1H NMR (400 MHz, $CDCl_3$) δ 4.07 (s, 2H), 3.63 (t, 2H, *J* = 5.6 Hz), 2.60 (t, 2H, *J* = 5.6 Hz), 1.71

– 1.68 (brs, 1H), 1.67 – 1.61 (m, 2H), 1.60 – 1.54 (m, 2H), 1.41 – 1.34 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ202.72, 62.46, 48.17, 39.52, 32.24, 25.14, 23.17; IR (neat): 3365, 2926, 1725, 1416, 1035, 740; MS (ES^+) Calculated for $[C_7H_{14}ClO_2]^+$: 165.1; Found: 165.1.

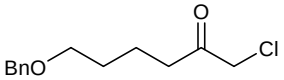
5-(tert-butyldimethylsilyloxy)-1-chloropentan-2-one (2c)



2c

Compound **2c** was prepared in 42% according to the general procedure. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.11 (s, 2H), 3.63 (t, 2H, *J* = 4.8 Hz), 2.66 (t, 2H, *J* = 5.6 Hz), 1.87 – 1.81 (m, 2H), 0.88 (s, 9H), 0.04 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 202.58, 61.89, 48.23, 36.31, 26.80, 25.89, -5.44; IR (neat): 3070, 2919, 1730, 1066, 766; MS (ES^+) Calculated for $[C_{11}H_{24}ClO_2Si]^+$: 251.1; Found: 251.1.

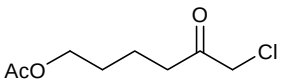
6-(benzyloxy)-1-chlorohexan-2-one (2d)



2d

Compound **2d** was prepared in 62% yield according to the general procedure. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36 – 7.26 (m, 5H), 4.48 (s, 2H), 4.05 (s, 2H), 3.48 (t, 2H, *J* = 4.8 Hz), 2.60 (t, 2H, *J* = 5.6 Hz), 1.76 – 1.70 (m, 2H), 1.66 – 1.61 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 202.41, 138.34, 128.32, 127.59, 127.52, 72.86, 69.76, 48.16, 39.27, 28.88, 20.41; IR (neat):): 2920, 1776, 1614, 1226, 1026, 746; MS (ES^+) Calculated for $[C_{13}H_{18}ClO_2]^+$: 241.1; Found: 241.1.

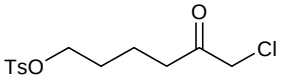
6-chloro-5-oxohexyl acetate (2e)



2e

Compound **2e** was prepared in 55% according to the general procedure. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.06 (s, 2H), 4.04 (t, 2H, *J* = 4.8 Hz), 2.62 (t, 2H, *J* = 5.2 Hz), 2.02 (s, 3H), 1.70 – 1.60 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 202.26, 171.14, 63.82, 48.12, 38.94, 27.75, 20.91, 19.86; IR (neat): 2942, 1764, 1336, 1056, 736; Calculated for $[C_8H_{14}ClO_3]^+$: 193.1; Found: 193.1.

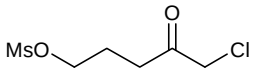
6-chloro-5-oxohexyl 4-methylbenzenesulfonate (2f)



2f

Compound **2f** was prepared in 65% yield according to the general procedure. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.76 (d, 2H, , *J* = 8.0 Hz), 7.34 (d, 2H, *J* = 8.0 Hz), 4.04 (s, 2H), 4.01 (t, 2H, *J* = 6.0 Hz), 2.56 (t, 2H, *J* = 6.4 Hz), 2.44 (s, 3H), 1.70 – 1.61 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.91, 144.85, 132.70, 129.83, 127.79, 69.93, 48.07, 38.50, 27.87, 21.58, 19.36; IR (neat): 2930, 1764, 1600, 1366, 1106, 741; MS (ES^+) Calculated for $[C_{13}H_{18}ClO_4S]^+$: 305.1; Found: 305.1.

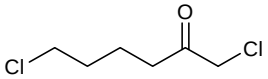
5-chloro-4-oxopentyl methanesulfonate (2g)



2g

Compound **2g** was prepared in 53% yield according to the general procedure. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.27 (t, 2H, *J* = 6.0 Hz), 4.12 (s, 2H), 3.01 (s, 3H), 2.76 (t, 2H, *J* = 6.4 Hz), 2.11 – 2.04 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.52, 68.66, 48.12, 37.30, 35.12, 23.00; IR (neat): 3745, 2941, 1732, 1347, 1172, 935, 800 ; MS (ES^+) Calculated for $[C_6H_{12}ClO_4S]^+$: 215.0; Found: 215.0.

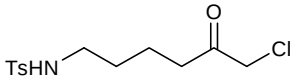
1,6-dichlorohexan-2-one (2h)



2h

Compound **2h** was prepared in 51% according to the general procedure, and its spectroscopic data match well with those reported.[1] ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.06 (s, 2H), 3.53 (t, 2H, *J* = 5.6 Hz), 2.64 (t, 2H, *J* = 5.6 Hz), 1.82 – 1.74 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 202.12, 48.00, 44.41, 38.63, 31.64, 20.78; IR (neat): 2934, 1716, 1476, 1034, 756; Calculated for $[C_6H_{11}Cl_2O]^+$: 169.0; Found: 169.0.

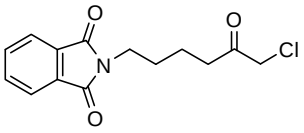
N-(6-chloro-5-oxohexyl)-4-methylbenzenesulfonamide (2i)



2i

Compound **2i** was prepared in 56% yield according to the general procedure. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.73 (d, 2H, *J* = 7.6 Hz), 7.30 (d, 2H, *J* = 7.6 Hz), 4.97 (t, 1H, *J* = 6.4 Hz), 4.05 (s, 2H), 2.90 (dd, 2H, *J* = 6.8 Hz, *J* = 6.8 Hz), 2.54 (t, 2H, *J* = 6.8 Hz), 2.41 (s, 3H), 1.63 – 1.56 (m, 2H), 1.51 – 1.44 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 202.30, 143.43, 136.69, 129.69, 127.01, 48.10, 42.62, 38.75, 28.67, 21.46, 20.18; IR (neat): 3085, 2944, 1736, 1699, 1356, 1104, 761; MS (ES^+) Calculated for $[C_{13}H_{19}ClNO_3S]^+$: 304.1; Found: 304.1.

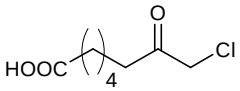
2-(6-chloro-5-oxohexyl)isoindoline-1,3-dione (2j)



2j

Compound **2j** was prepared in 70% yield according to the general procedure. ^{1}H NMR (400 MHz, $CDCl_3$) δ), 7.83 (dd, 2H, *J* = 3.2 Hz, *J* = 3.2 Hz), 7.71 (dd, 2H, *J* = 3.2 Hz, *J* = 3.2 Hz), 4.08 (s, 2H), 3.69 (t, 2H, *J* = 7.2 Hz), 2.66 (t, 2H, *J* = 7.2 Hz), 1.75 – 1.62 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 202.10, 168.36, 133.94, 131.99, 123.20, 48.14, 38.78, 37.25, 27.74, 20.52; IR (neat): 2971, 1778, 1386, 1084, 760; MS (ES^+) Calculated for $[C_{14}H_{15}ClNO_3]^+$: 280.1; Found: 280.1.

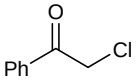
7-chloro-6-oxoheptanoic acid (2k)



2k

Compound **2k** was prepared in 60% according to the general procedure. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.07 (s, 2H), 2.63 (t, 2H, *J* = 5.6 Hz), 2.38 (t, 2H, *J* = 5.6 Hz), 1.73 – 1.62 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 202.30, 179.01, 48.05, 39.15, 33.58.23.92, 22.80; IR (neat): 3144, 2936, 1752, 1695, 1014, 734; Calculated for $[C_7H_{12}ClO_3]^+$: 179.0; Found: 179.0.

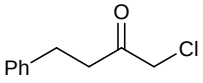
2-chloro-1-phenylethanone (2l)



2l

Compound **1l** was prepared in 41% yield according to the general procedure, and its spectroscopic data match well with those reported.[2] ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.52 (t, 2H, *J* = 7.8 Hz), 7.63 (t, 2H, *J* = 7.8 Hz), 7.50 (t, 2H, *J* = 7.8 Hz), 4.73 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.05, 134.20, 134.00, 128.89, 128.50, 46.01; IR (neat): 3064, 2980,1700, 1572, 1184,756; Calculated for $[C_8H_8ClO]^+$: 155.0; Found: 155.0.

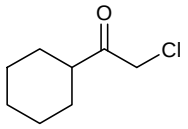
1-chloro-4-phenylbutan-2-one (2m)



2m

Compound **1l** was prepared in 43% yield according to the general procedure, and its spectroscopic data match well with those reported.[2] ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.30 (t, 2H, *J* = 7.2 Hz), 7.23 – 7.18 (m, 3H), 4.04 (s, 2H), 2.98 – 2.89 (m, 4H);^{13}C NMR (100 MHz, $CDCl_3$) δ 201.86, 140.23, 128.57, 128.28, 126.34, 48.31, 41.30, 29.52; IR (neat): 3031, 2942, 1735, 1466, 1060, 780; Calculated for $[C_{10}H_{12}ClO]^+$: 183.1; Found: 183.1.

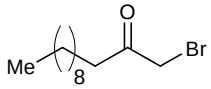
2-chloro-1-cyclohexylethanone (2n)



2n

Compound **2n** was prepared in 37% yield according to the general procedure. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.17 (s, 2H), 2.66 – 2.58 (m, 1H), 1.87 – 1.78 (m, 4H), 1.70 – 1.66 (m, 1H), 1.43 – 1.18 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 205.00, 47.79, 47.27, 28.39, 25.57, 25.41; IR (neat): 2928, 2860, 1740, 1462, 1184, 766; MS (ES^+) Calculated for $[C_8H_{14}ClO]^+$: 161.1; Found: 161.1.

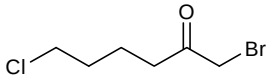
1-bromododecan-2-one (2o)



2o

Compound **2o** was prepared in 68% yield using BrettPhosAuNTf2 (15.3 mg, 0.015 mmol), according to the general procedure. The reaction time was 6h. ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.90 (s, 2H), 2.66 (t, 2H, *J* = 6.0 Hz), 1.67 – 1.59 (m, 2H), 1.30 – 1.21 (m, 14H), 0.89 (t, 3H, *J* = 5.6 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 202.28, 39.84, 34.29, 31.86, 29.69, 29.51, 29.41, 29.30, 29.01, 23.84, 22.66.14.09; IR (neat): 3024, 2935, 1730, 1474, 1215, 724, 686； MS (ES^+) Calculated for $[C_{12}H_{24}BrO]^+$: 263.1; Found: 263.1.

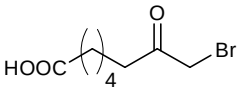
1-bromo-6-chlorohexan-2-one (2p)



2p

Compound **2o** was prepared in 60% yield using BrettPhosAuNTf2 (15.3 mg, 0.015 mmol), according to the general procedure. The reaction time was 6 h.^{1}H NMR (400 MHz, $CDCl_3$) δ 3.88 (s, 2H), 3.54 (t, 2H, *J* = 6.8 Hz), 2.70 (t, 2H, *J* = 6.8 Hz), 1.82 – 1.72 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.55, 44.45, 38.73, 34.05, 31.55, 20.98; IR (neat): 3006, 2931, 1727, 1421, 1020, 729; Calculated for $[C_6H_{11}BrClO]^+$: 215.0; Found: 215.0.

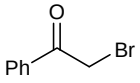
7-bromo-6-oxoheptanoic acid (2q)



2q

Compound **2q** was prepared in 56% yield using BrettPhosAuNTf2 (15.3 mg, 0.015 mmol), according to the general procedure. The reaction time was 6 h.^{1}H NMR (500 MHz, $CDCl_3$) δ 3.87 (s, 2H), 2.70 (t, 2H, *J* = 5.6 Hz), 2.39 (t, 2H, *J* = 5.6 Hz), 1.67 – 1.58 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.76, 179.47, 39.26, 34.08, 33.59, 23.85, 23.03; IR (neat): 3044, 2946, 1732, 1688, 1084, 744; MS (ES^+) Calculated for $[C_7H_{12}BrO_3]^+$: 223.0; Found: 223.0.

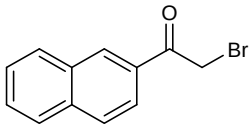
2-bromo-1-phenylethanone (2r)



2r

Compound **2r** was prepared in 43% yield using BrettPhosAuNTf2 (15.3 mg, 0.015 mmol), according to the general procedure. The reaction time was 6 h. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99(d, 2H, *J* = 7.4 Hz), 7.62 (t, 1H, *J* = 7.4 Hz), 7.50 (t, 2H, *J* = 7.4 Hz), 4.47(s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.27, 133.96, 133.87, 128.91, 128.85, 30.99; IR (neat): 3088,1710, 1265, 1166, 946, 695; Calculated for $[C_8H_8BrO]^+$: 199.0; Found: 199.0

2-bromo-1-(naphthalen-2-yl)ethanone (2s)

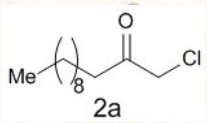


2s

Compound **2o** was prepared in 42% yield using BrettPhosAuNTf2 (15.3 mg, 0.015 mmol), according to the general procedure. The reaction time was 6 h. NMR (500 MHz, $CDCl_3$) δ 8.52 (s, 1H), 8.03 (d, 1H, *J* = 6.8 Hz), 7.98 (d, 1H, *J* = 6.8 Hz), 7.91(dd, 2H, *J* = 6.8 Hz, *J* = 6.8 Hz), 7.64 (t, 1H, *J* = 6.0 Hz), 7.58 (t, 1H, *J* = 6.0 Hz), 4.59 (s, 2H); ^{13}C NMR (100

MHz, CDCl3) δ 191.25, 135.80, 132.30, 131.17, 130.93, 129.65, 129.01, 128.79, 127.8, 127.03, 123.09, 31.00; IR (neat): 3022, 2916, 1695, 1601, 1386, 786; $[C_{12}H_{10}BrO]^+$: 249.0; Found: 249.0

1.Burkamp, F.; Fletcher, S. R. *J. Heterocyclic Chem.* **2002,** *39*, 1177-1187.
2.Ram, R. N.; Manoj, T. P. *J. Org. Chem.* **2008,** *73*, 5633-5635.



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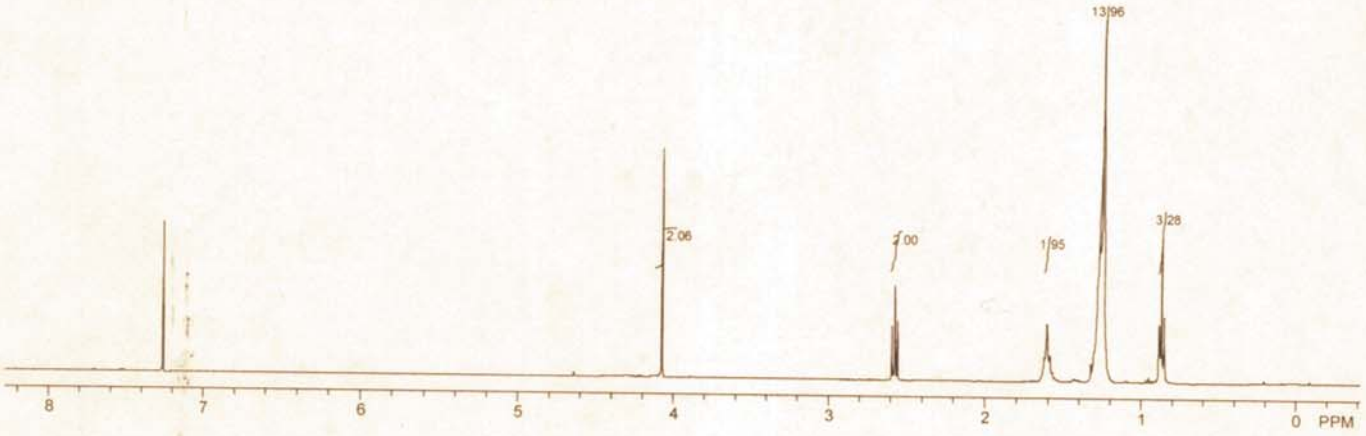

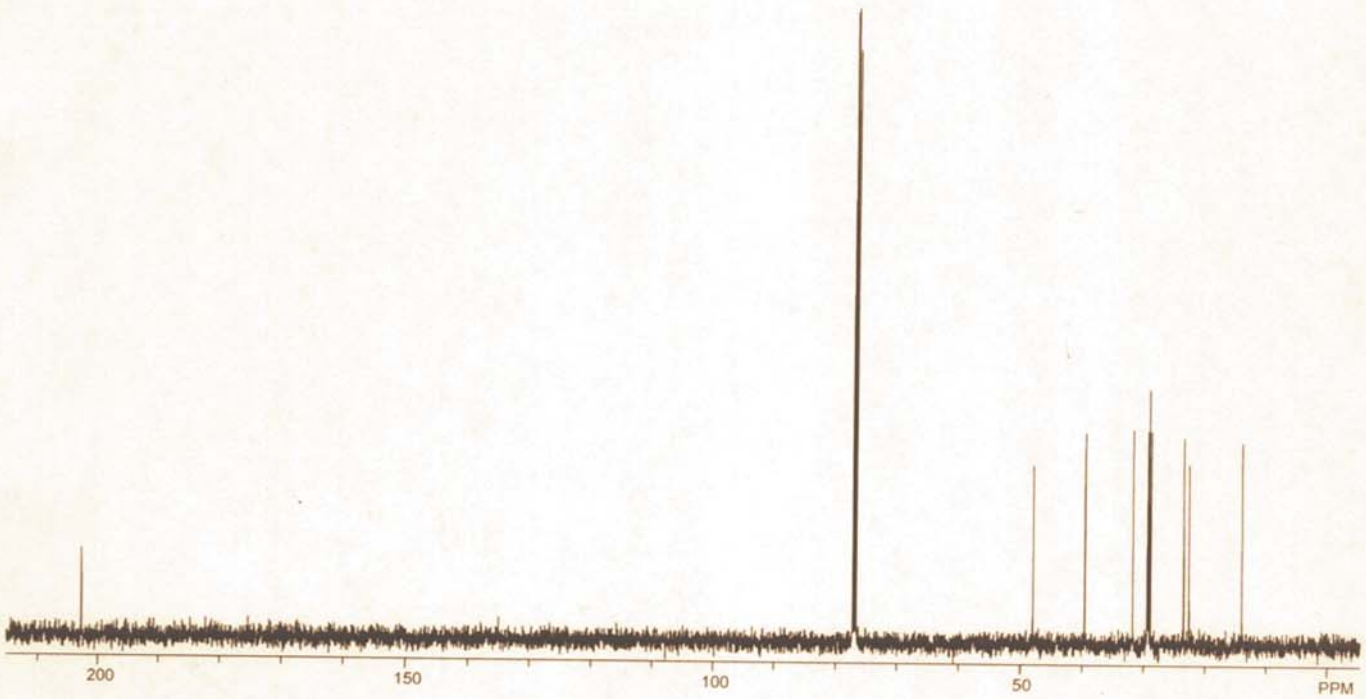

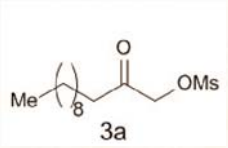

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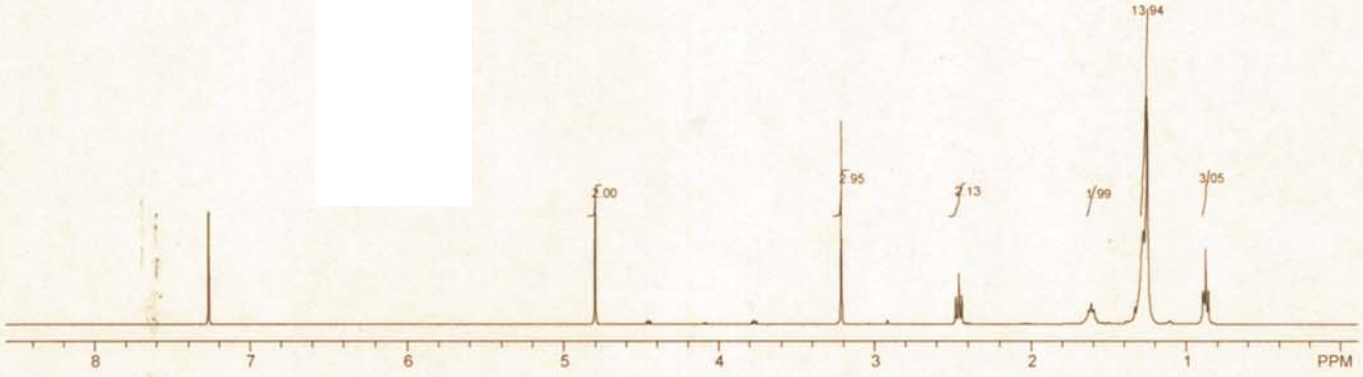

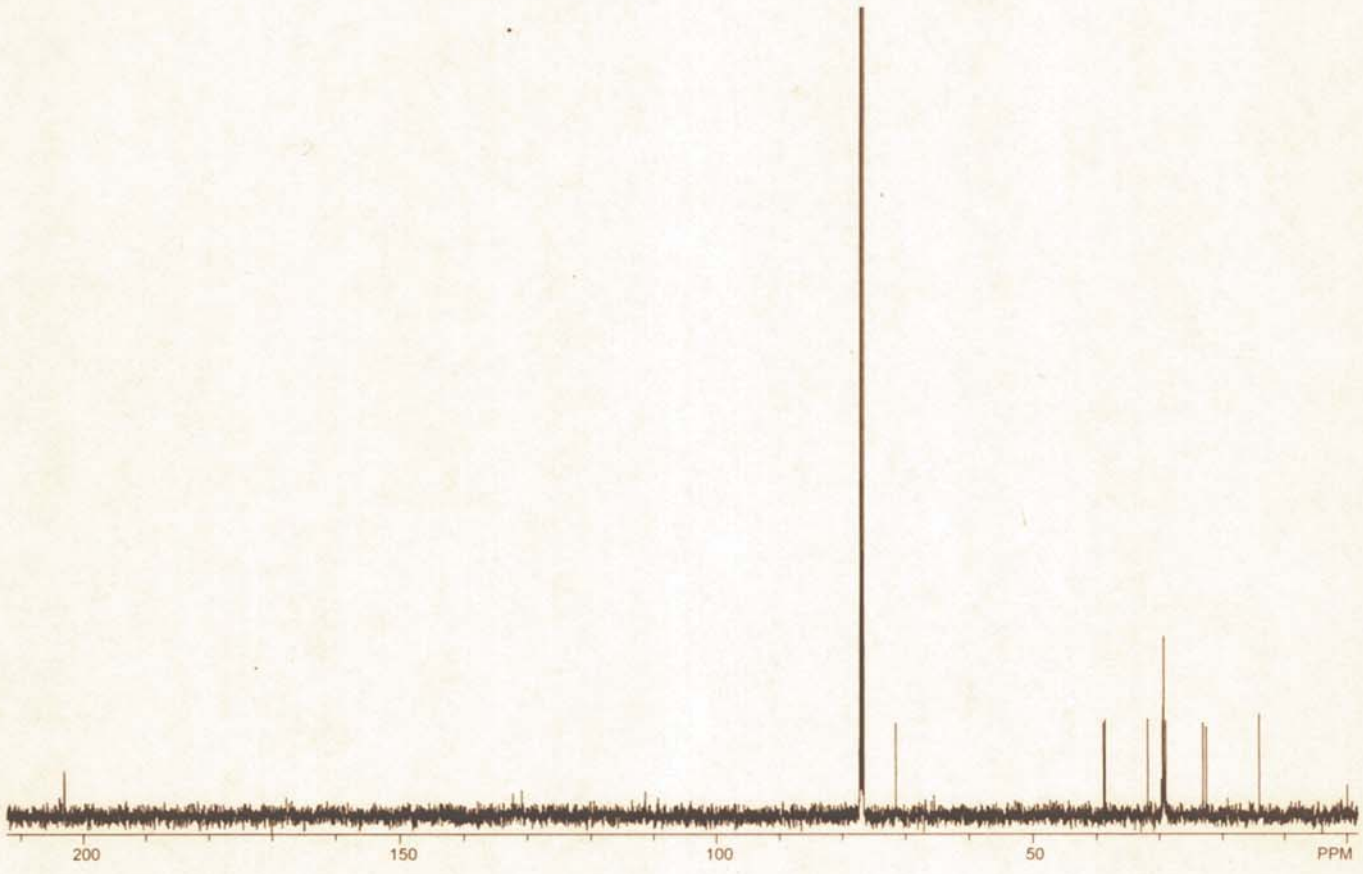

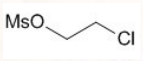

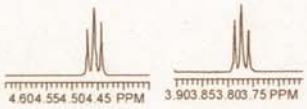

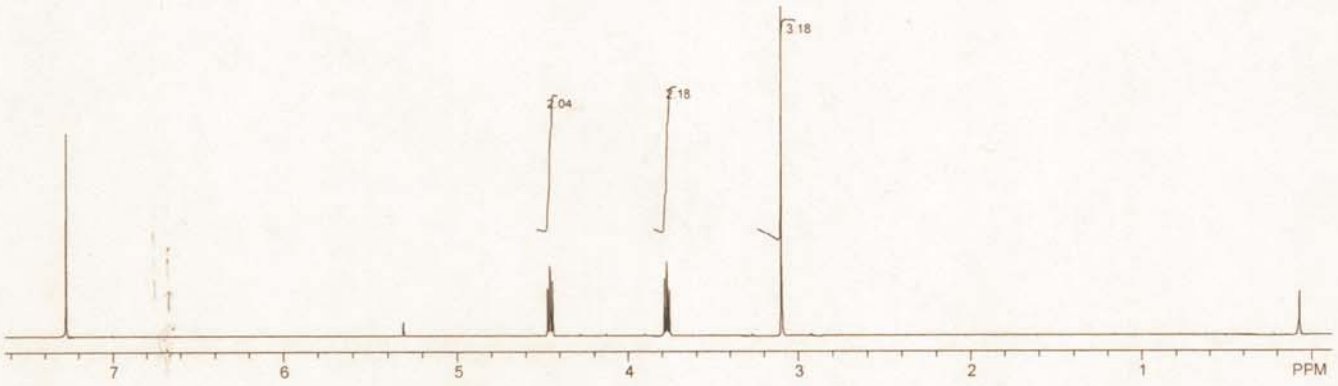

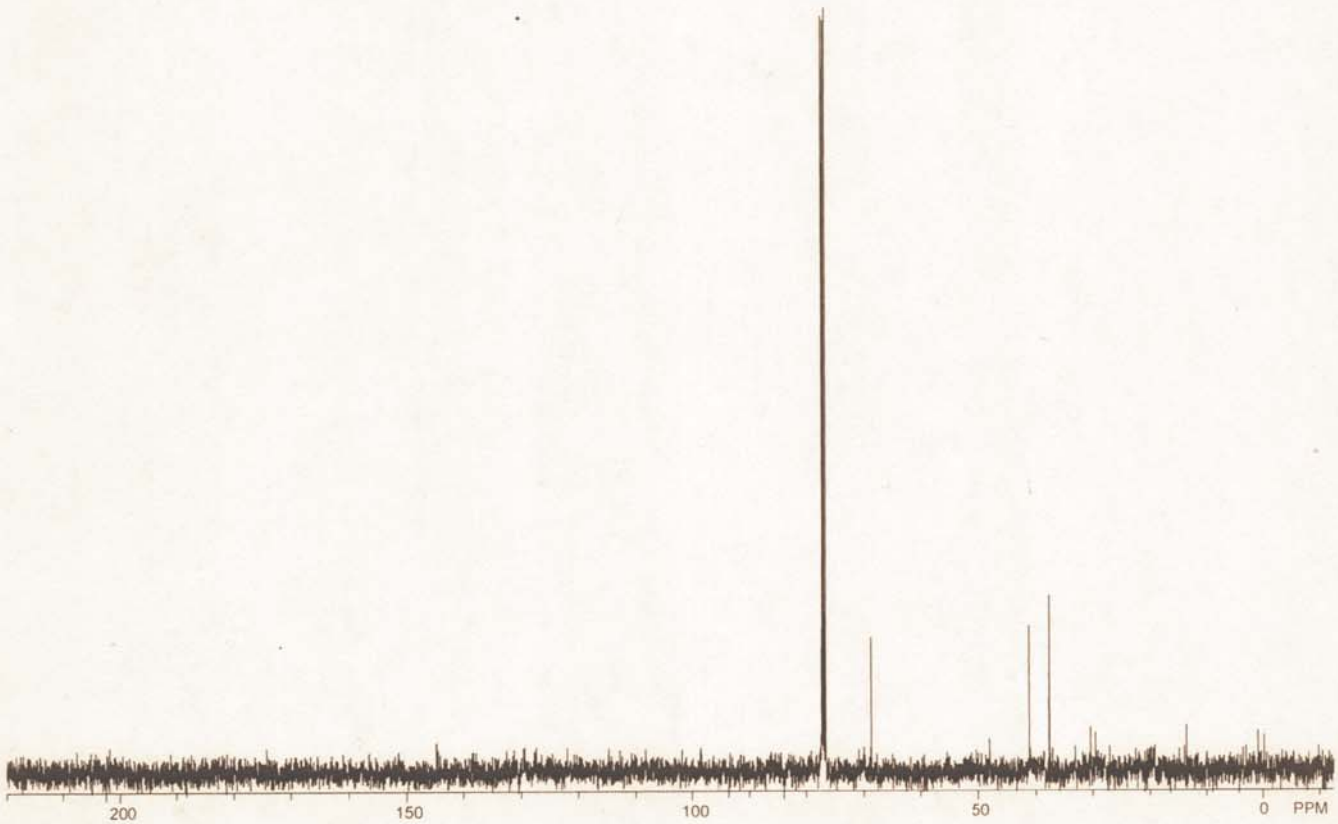

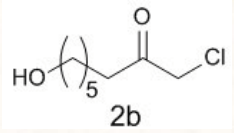

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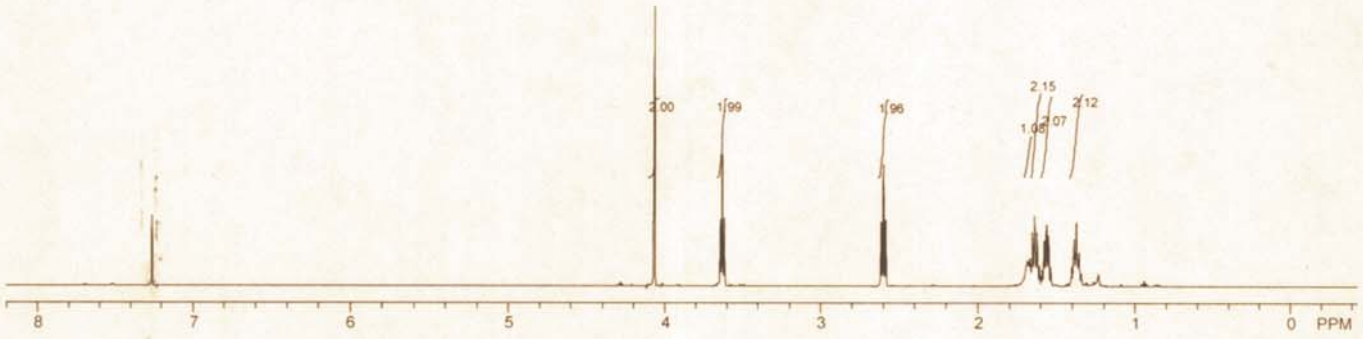

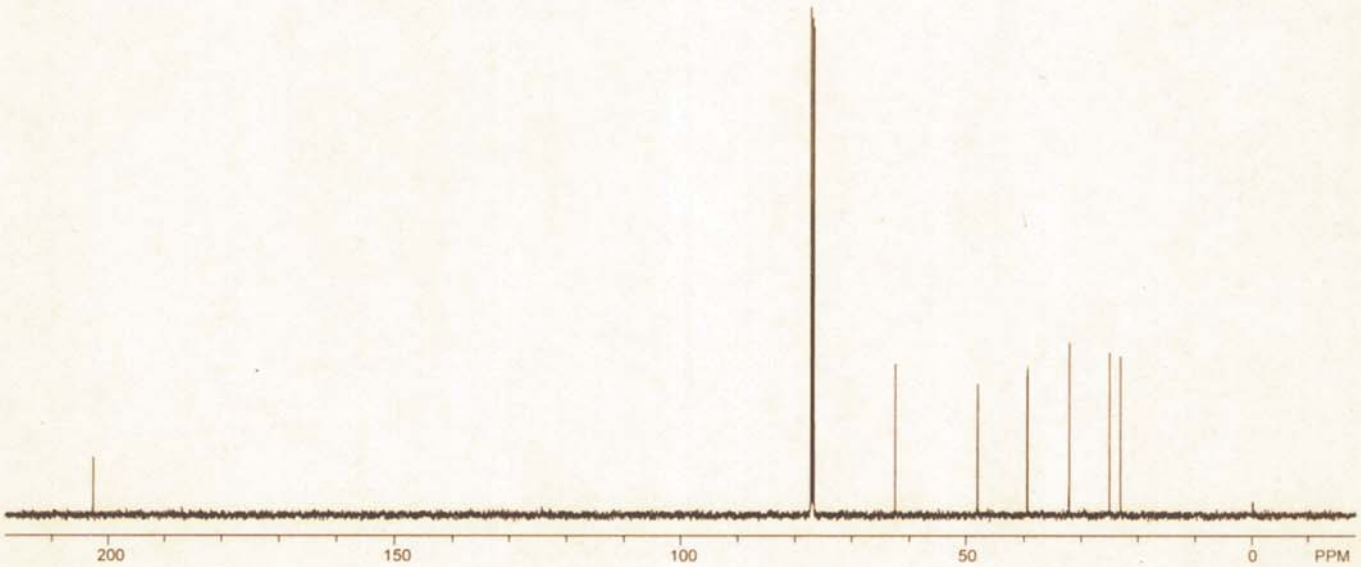

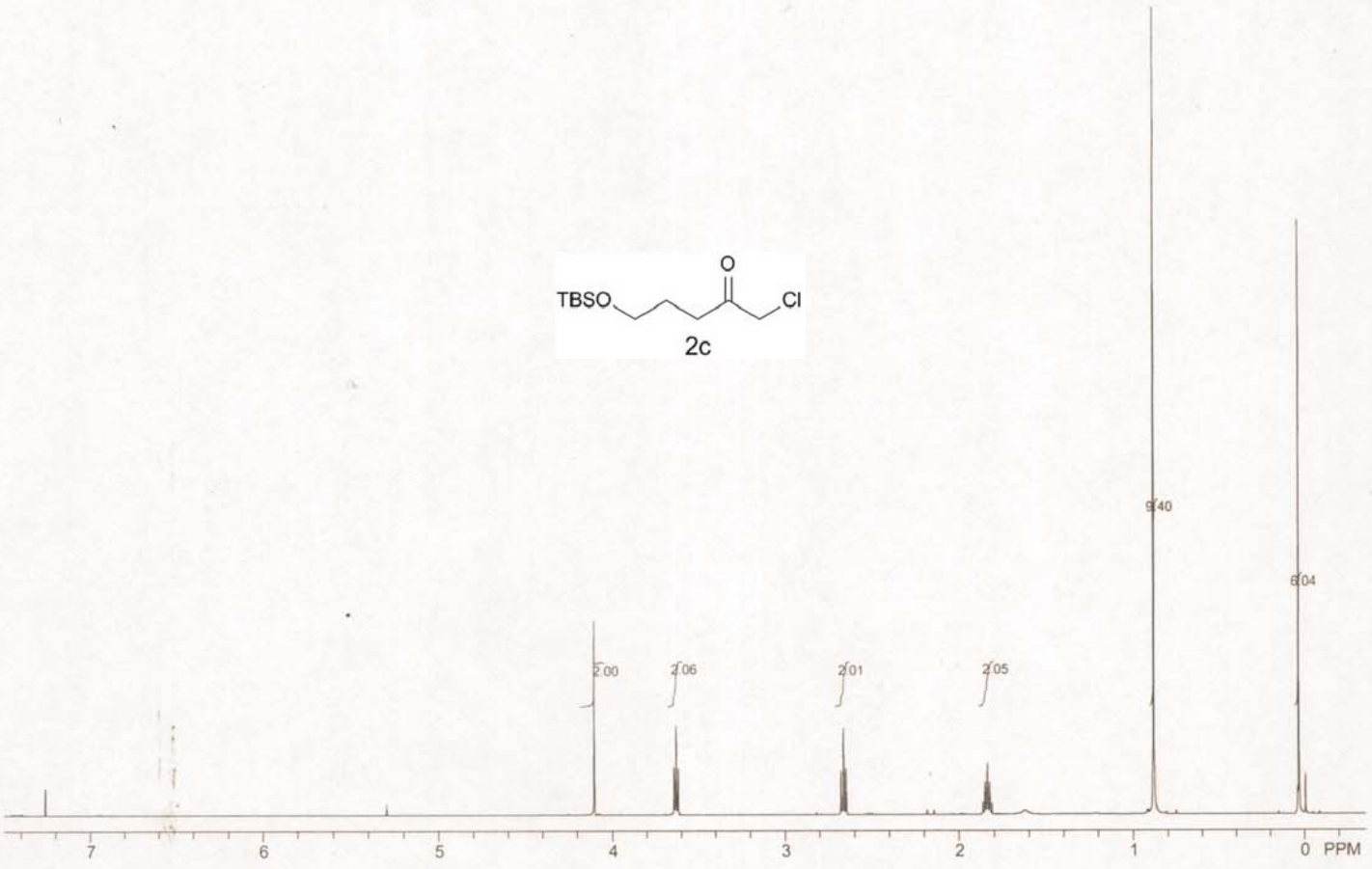

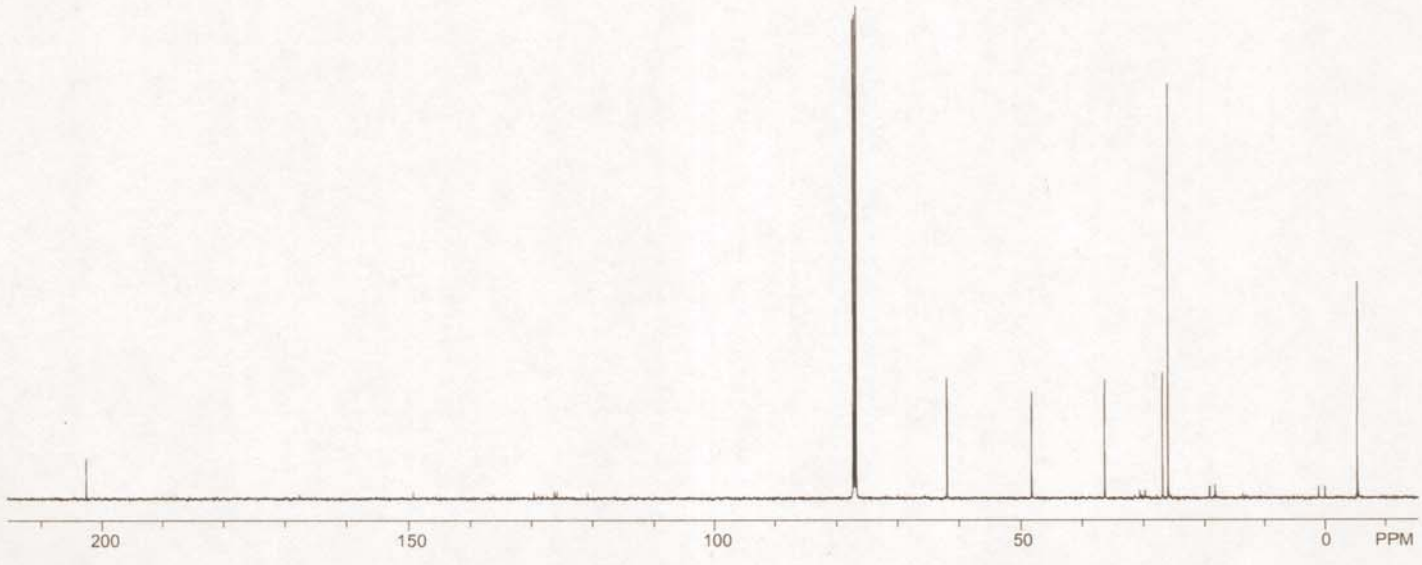

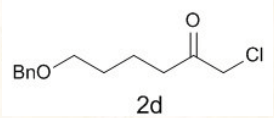

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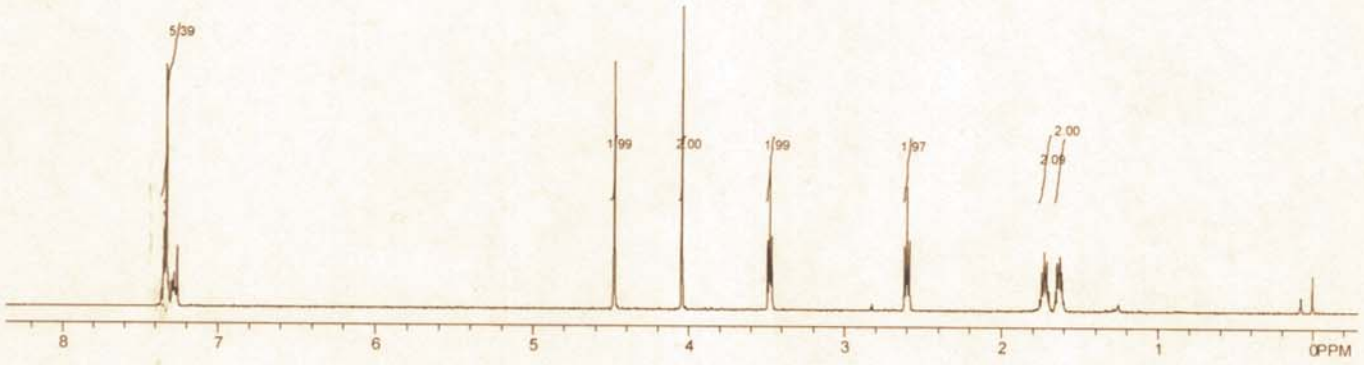

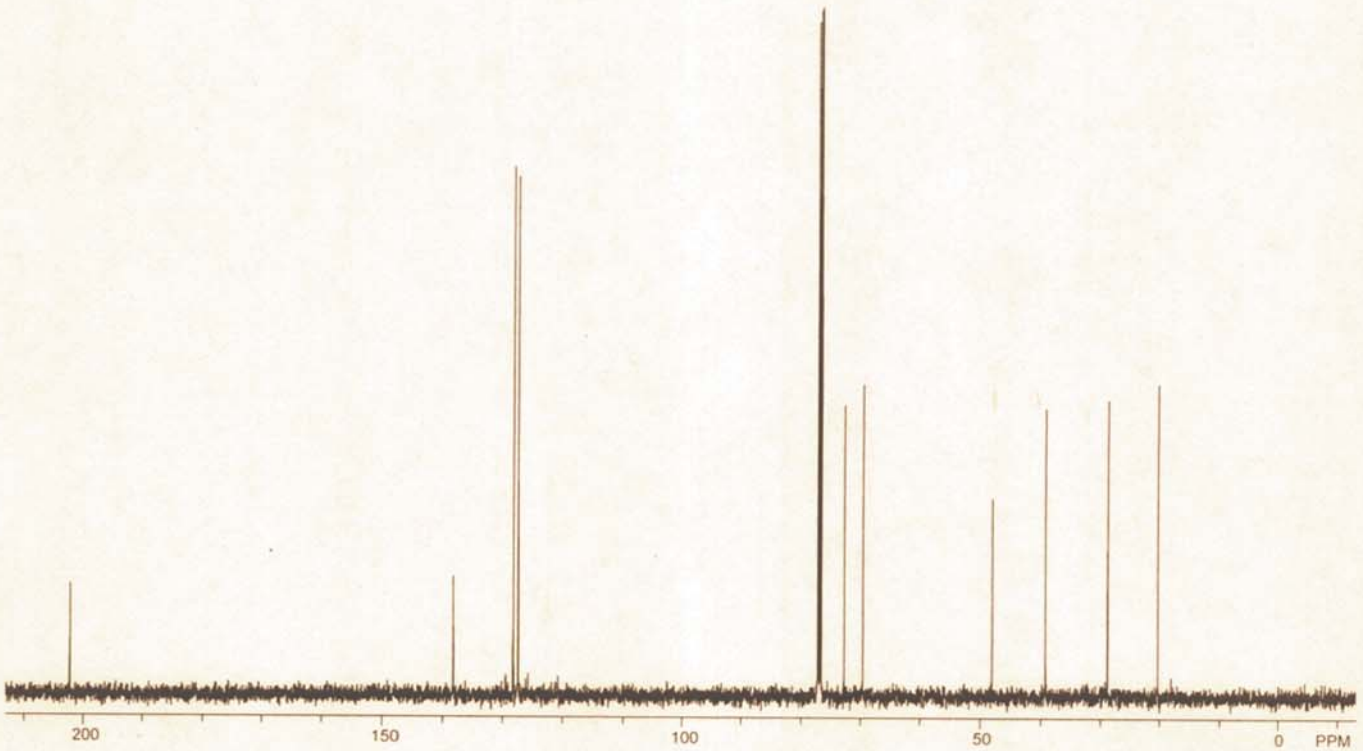

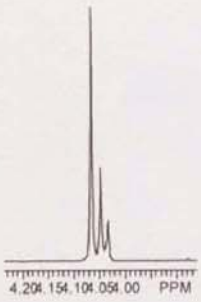

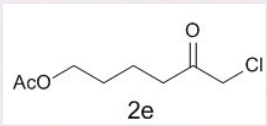

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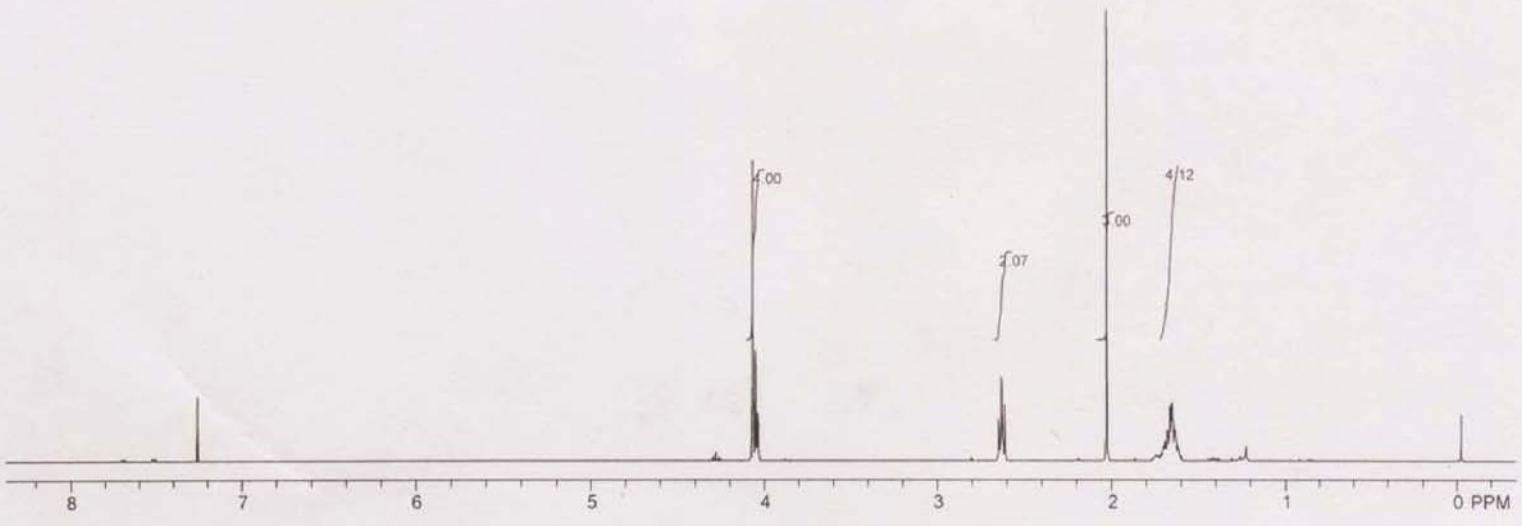

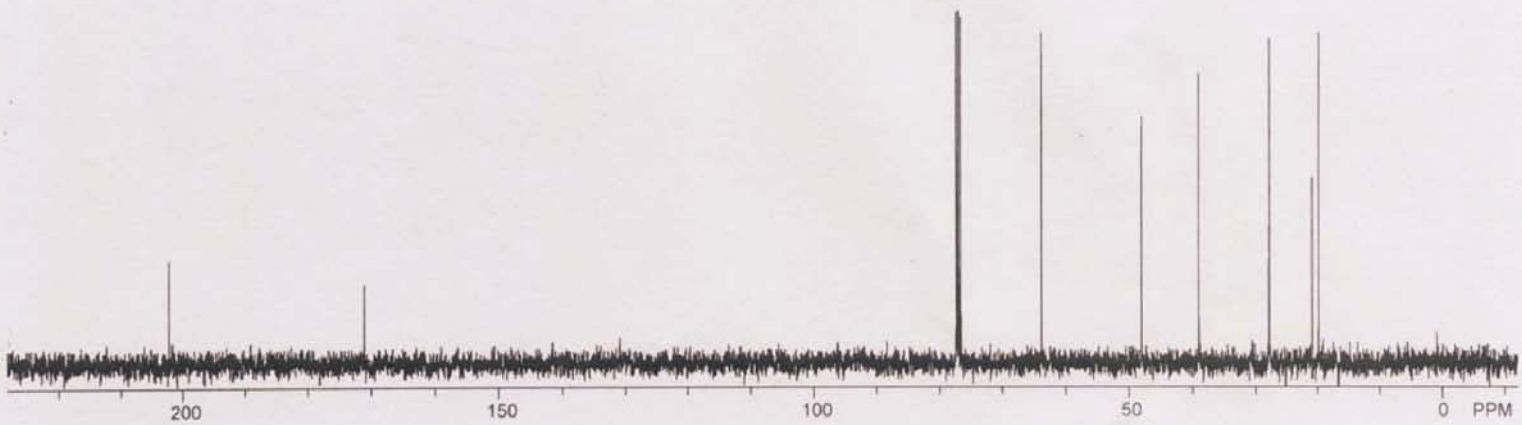

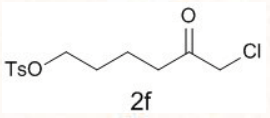

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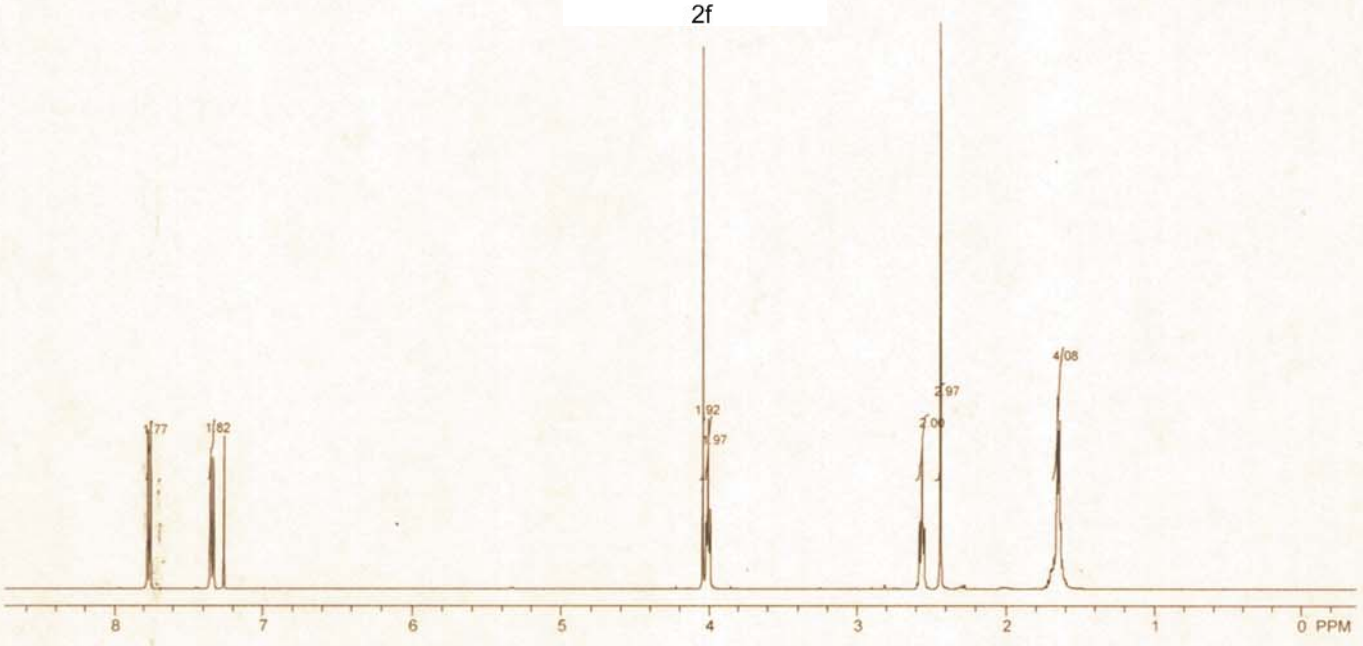

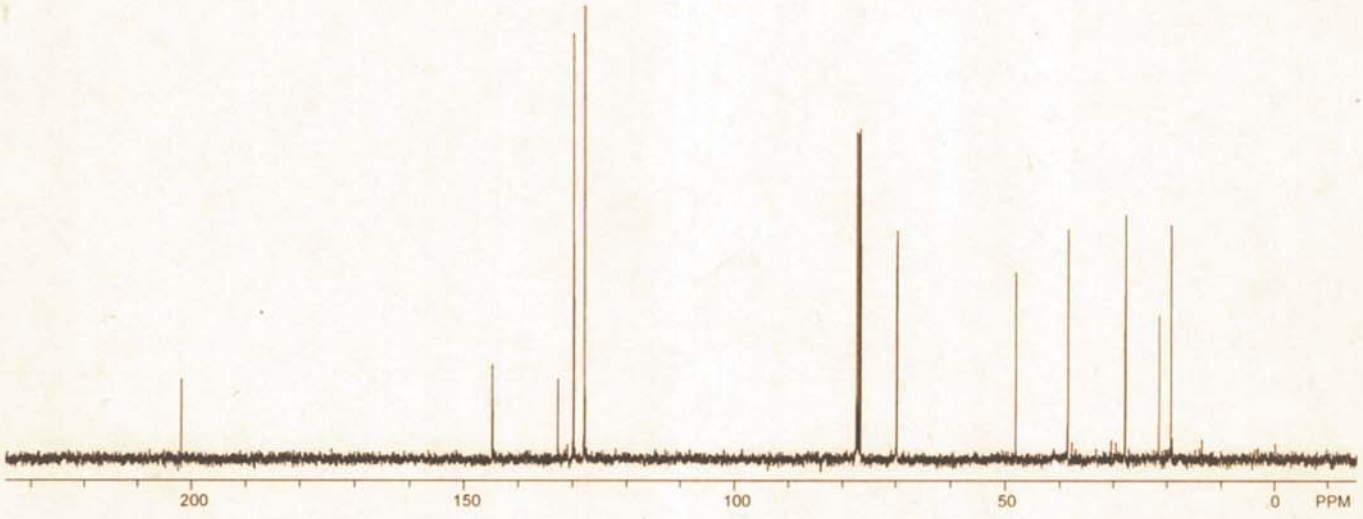

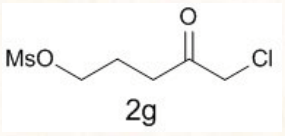

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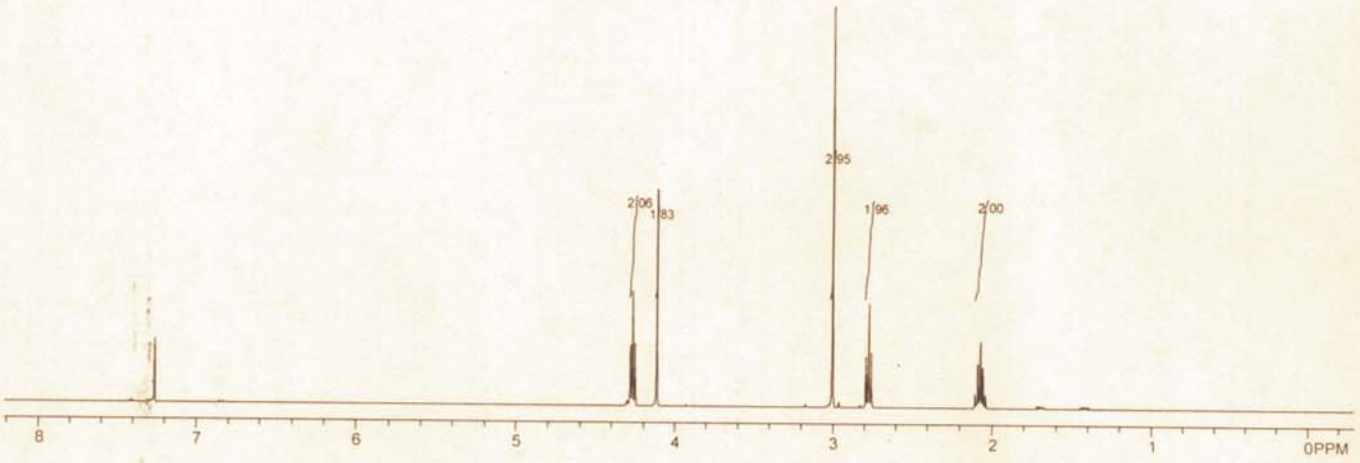

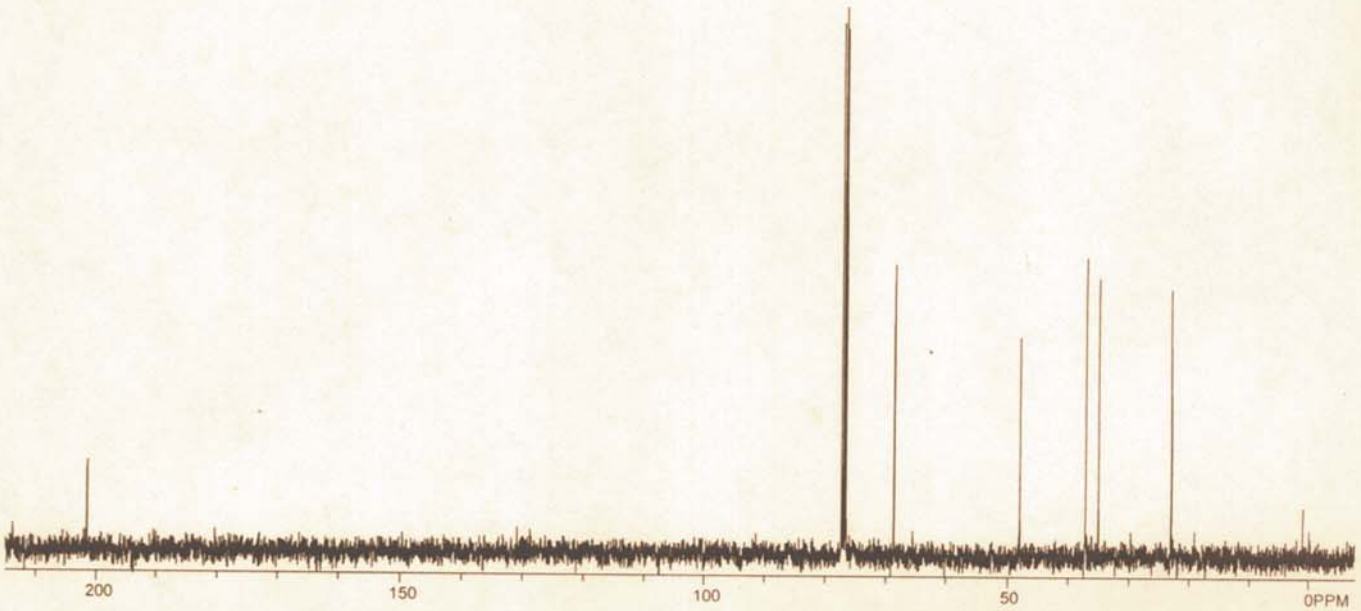

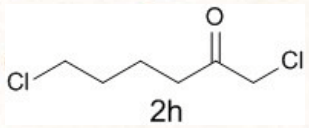

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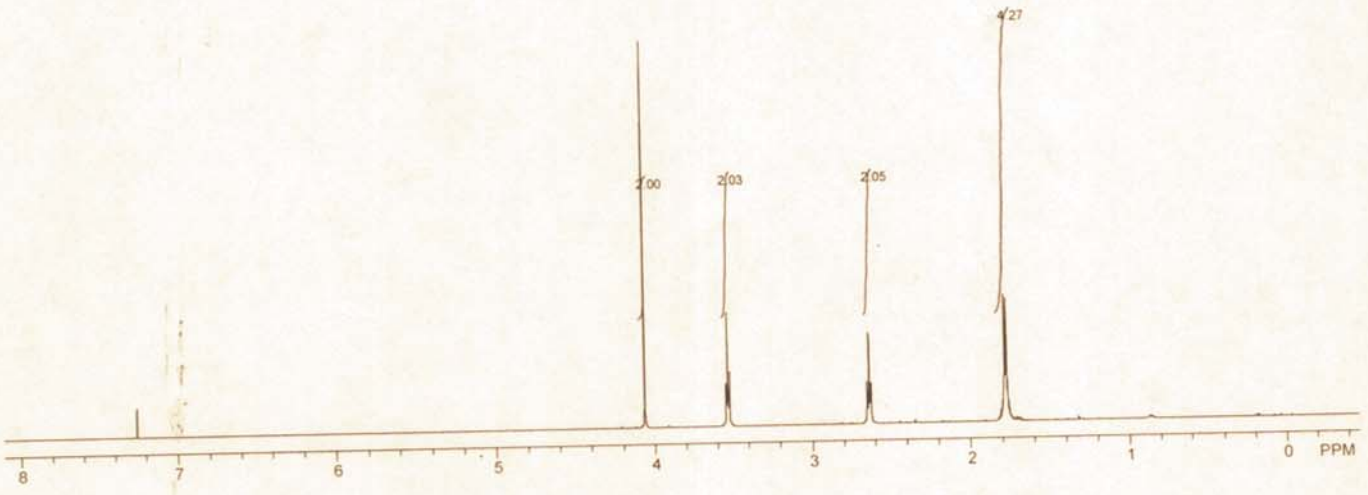

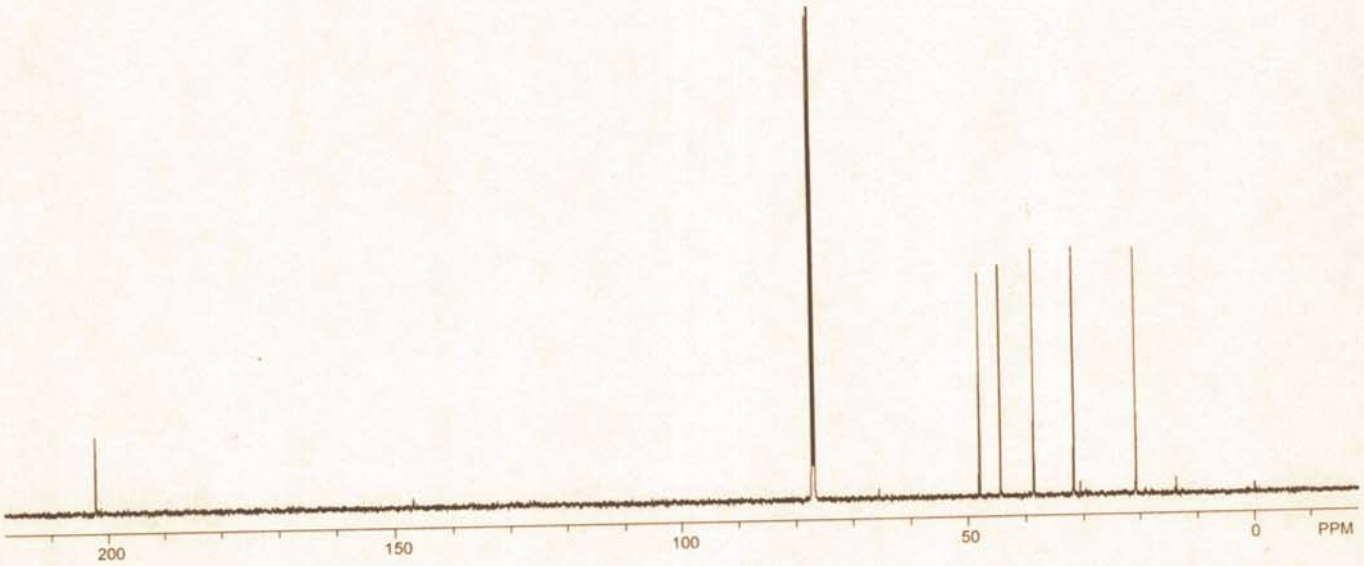

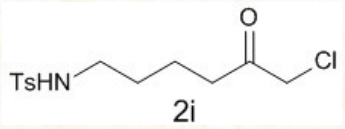

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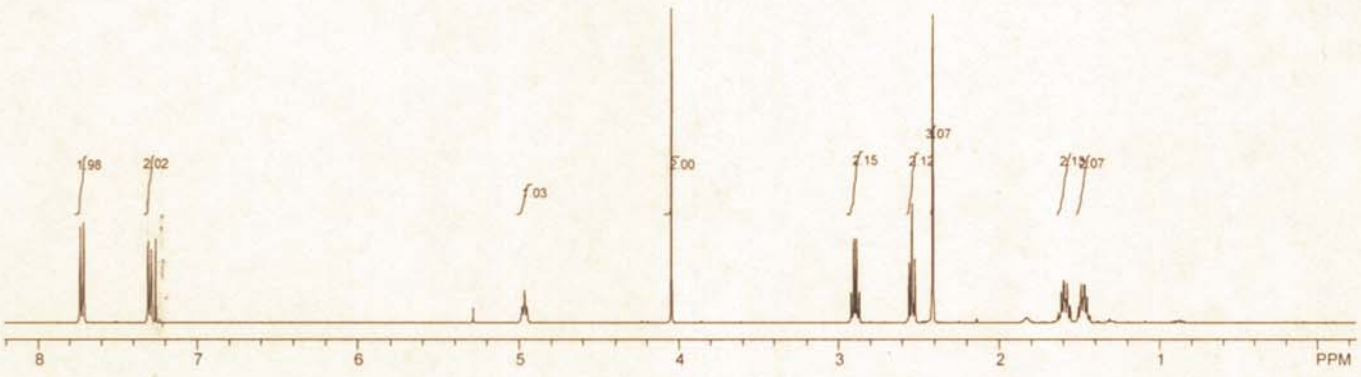

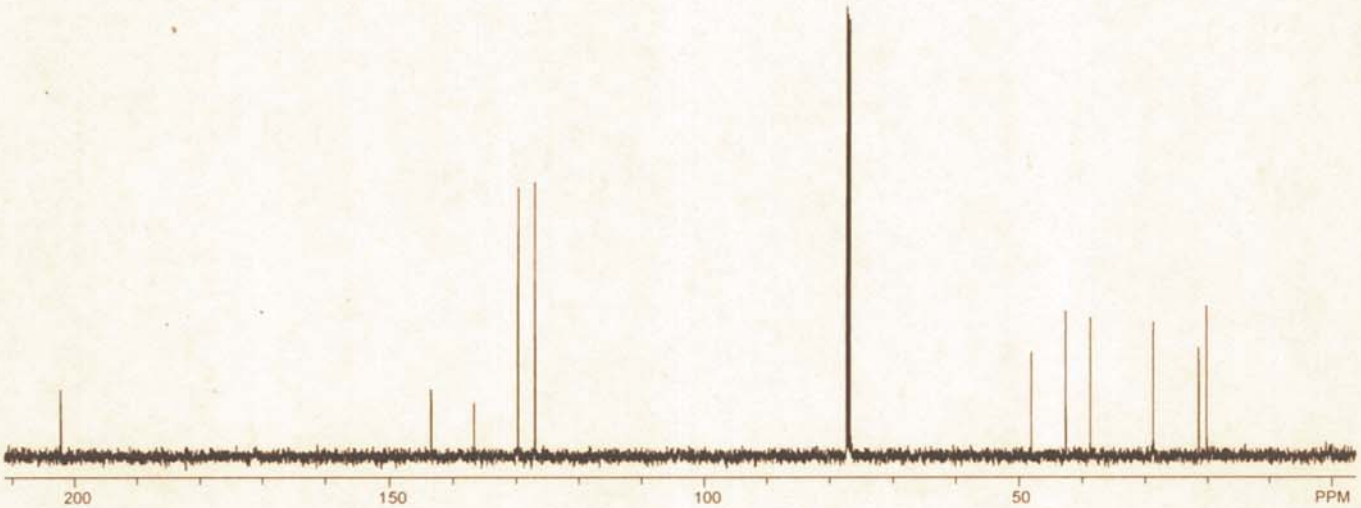

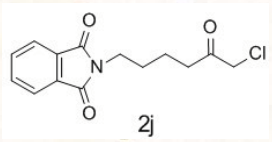

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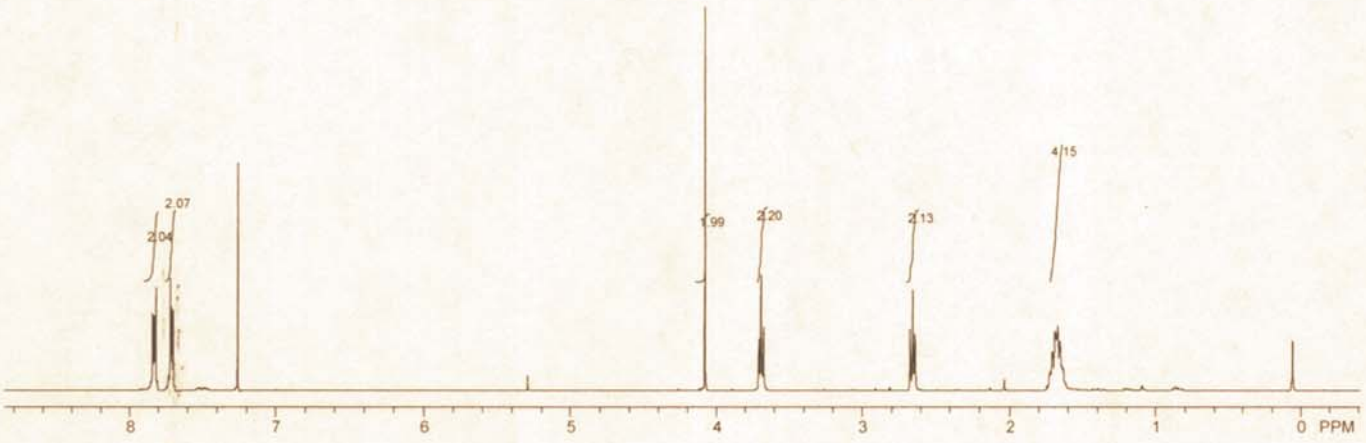

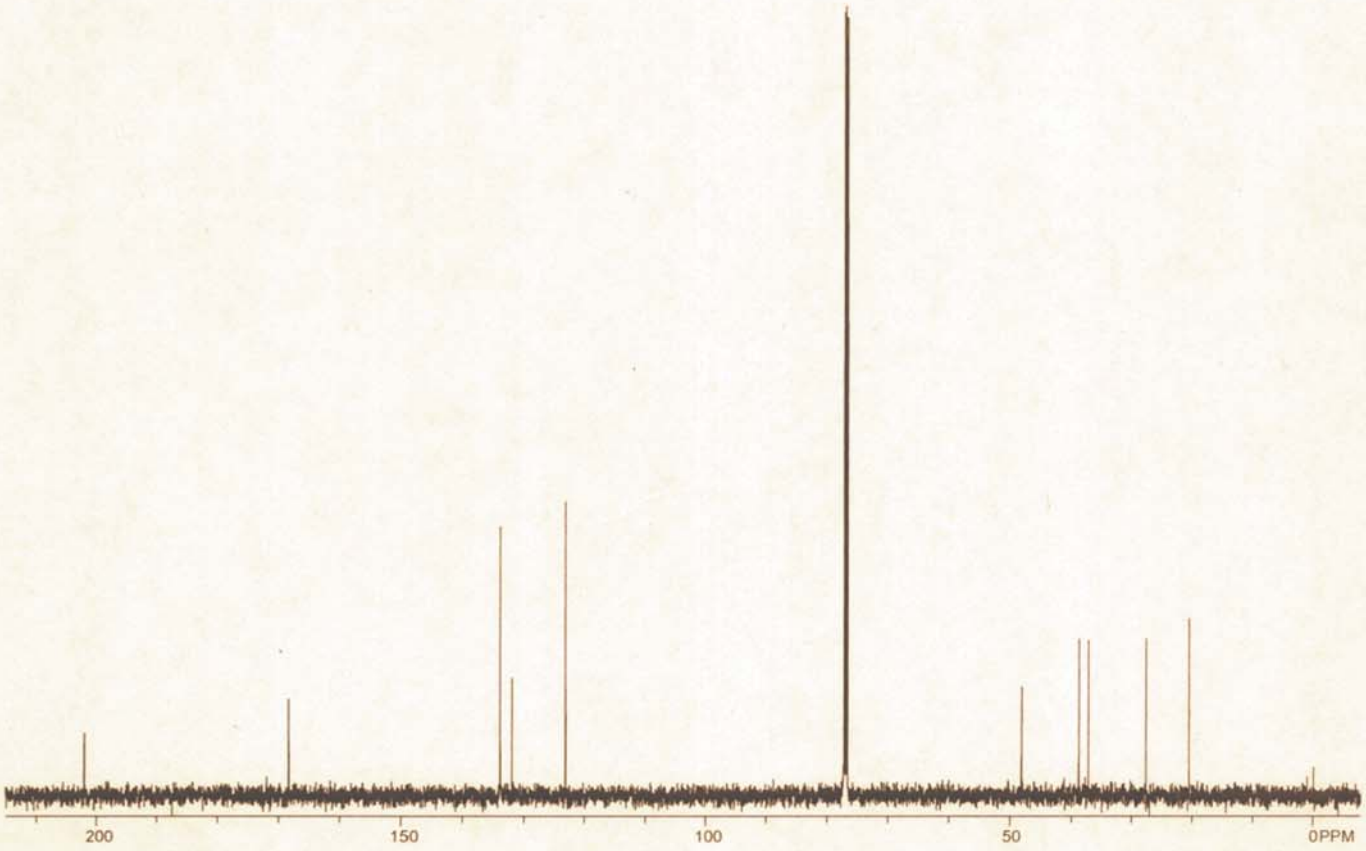

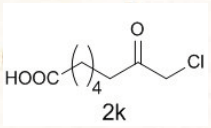

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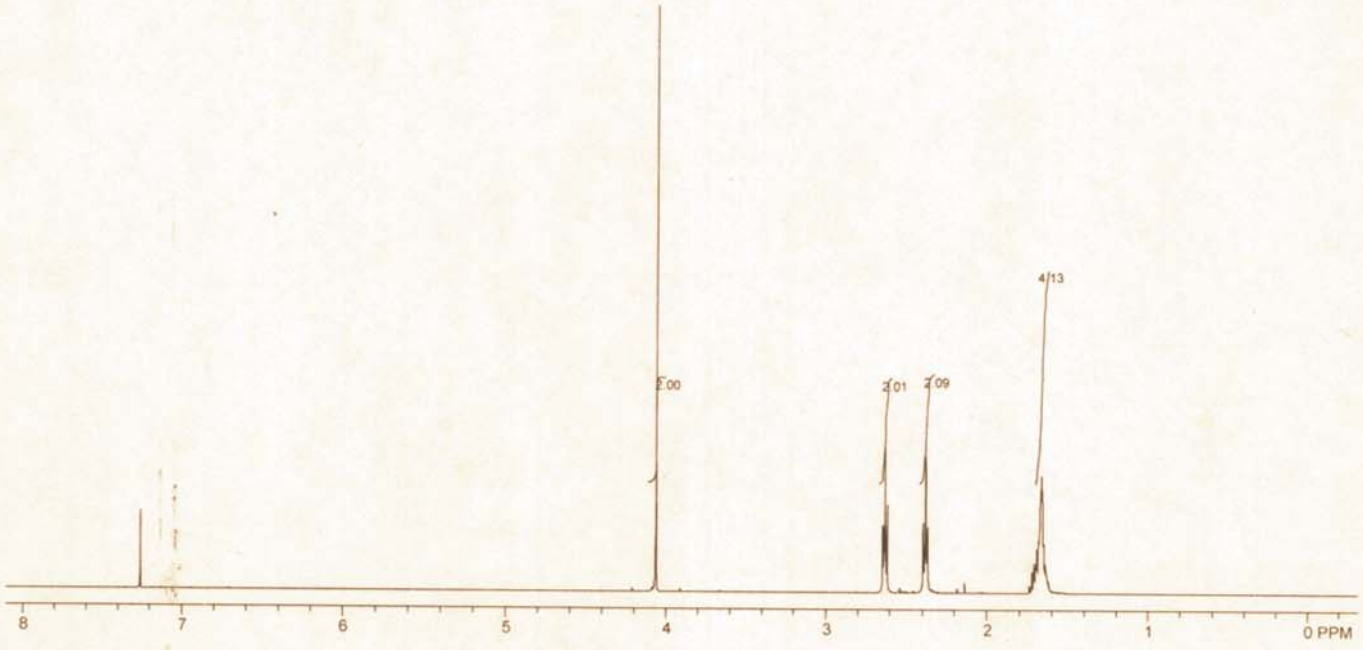

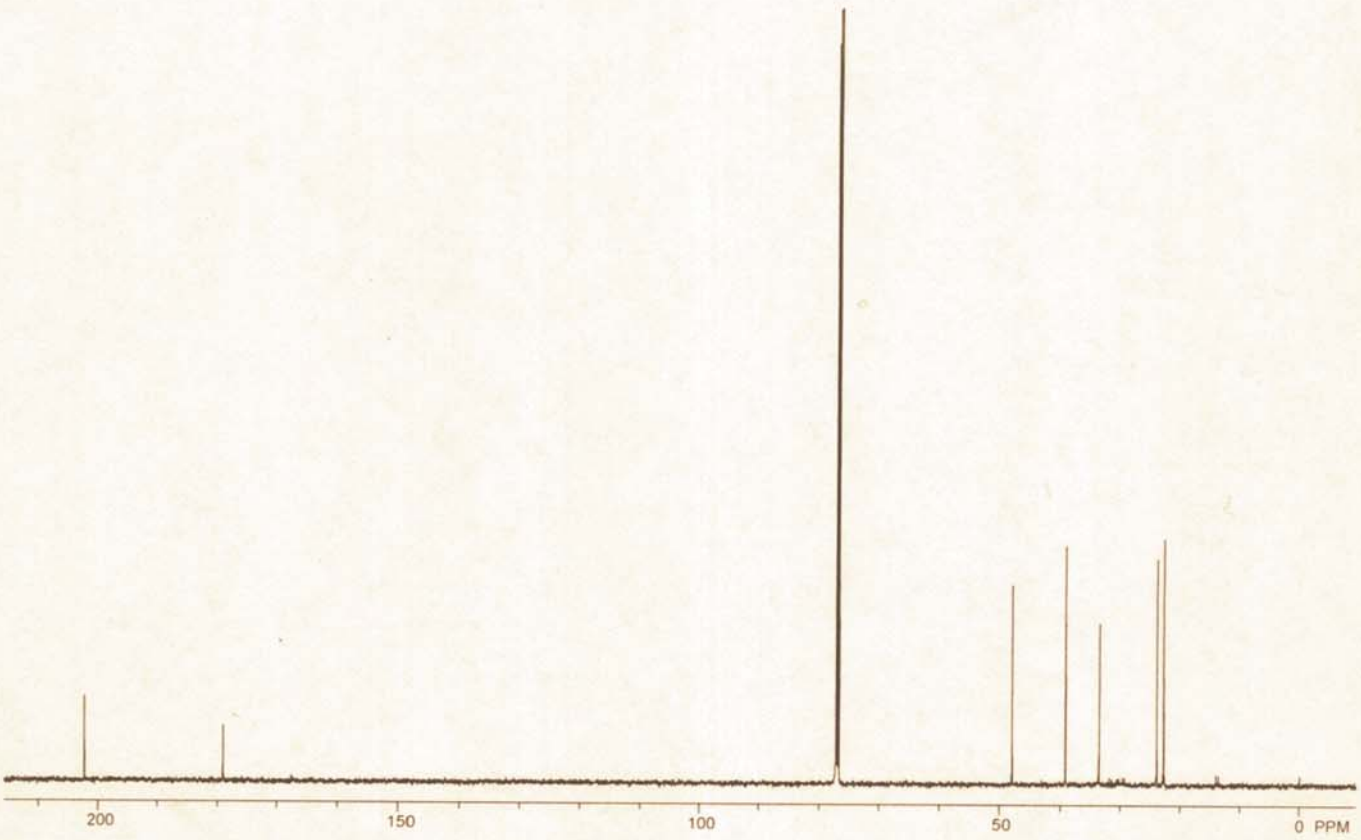

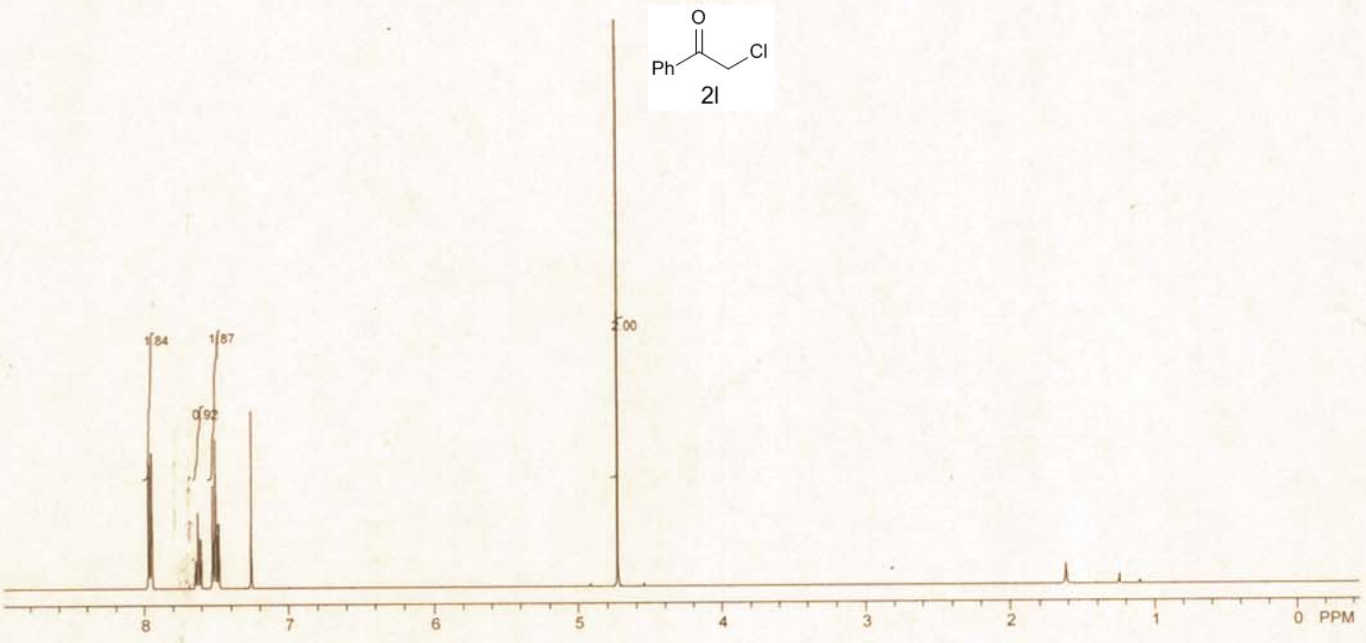

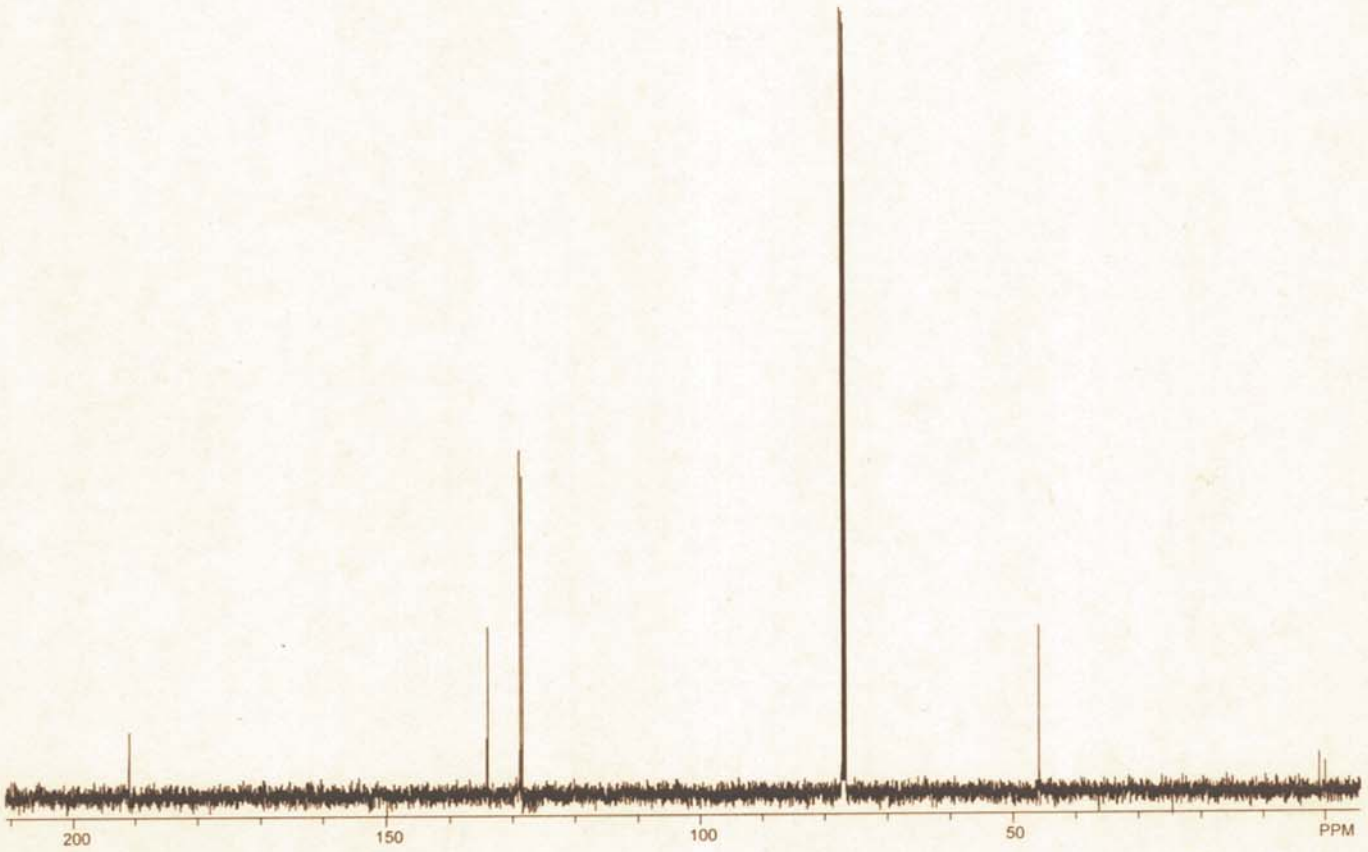

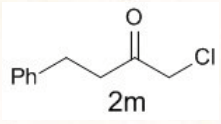

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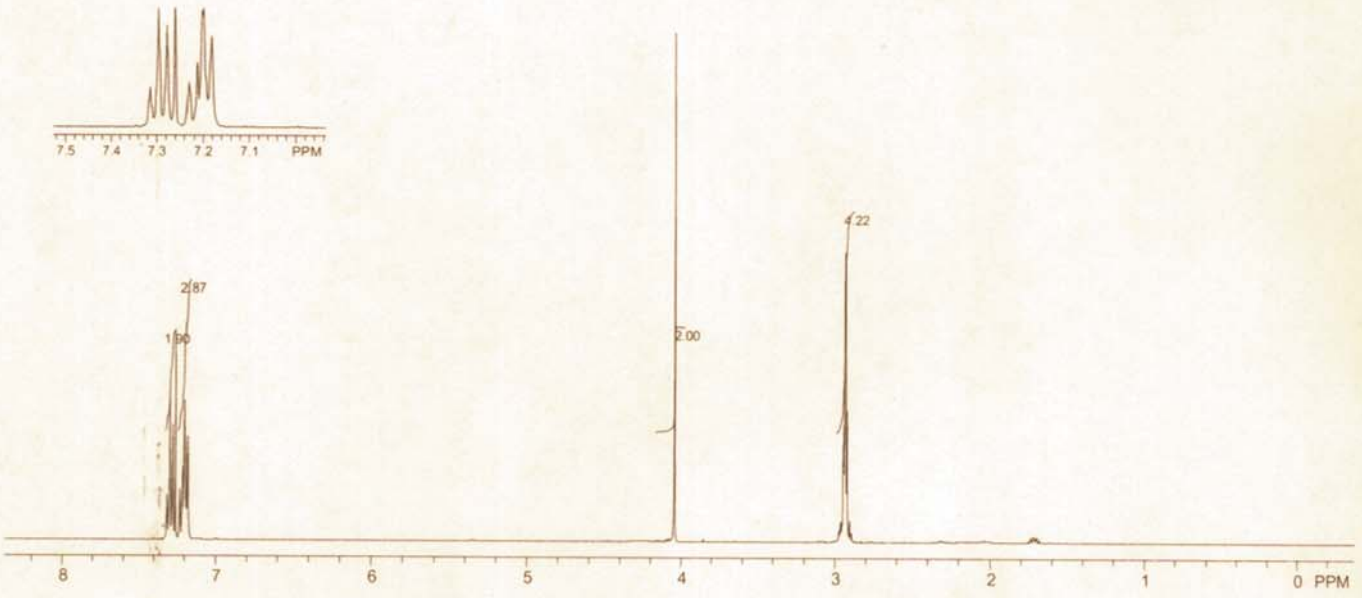

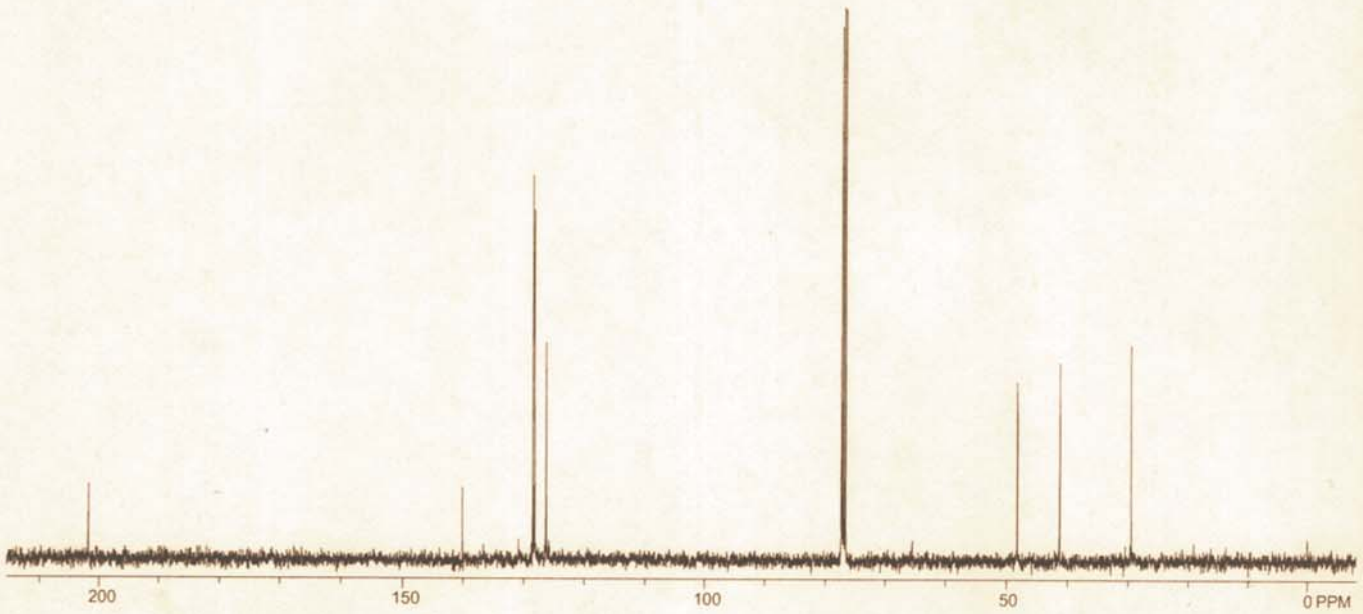

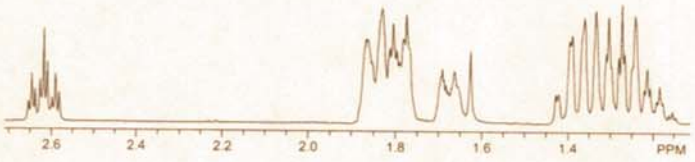

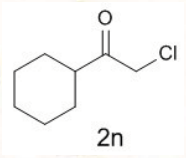

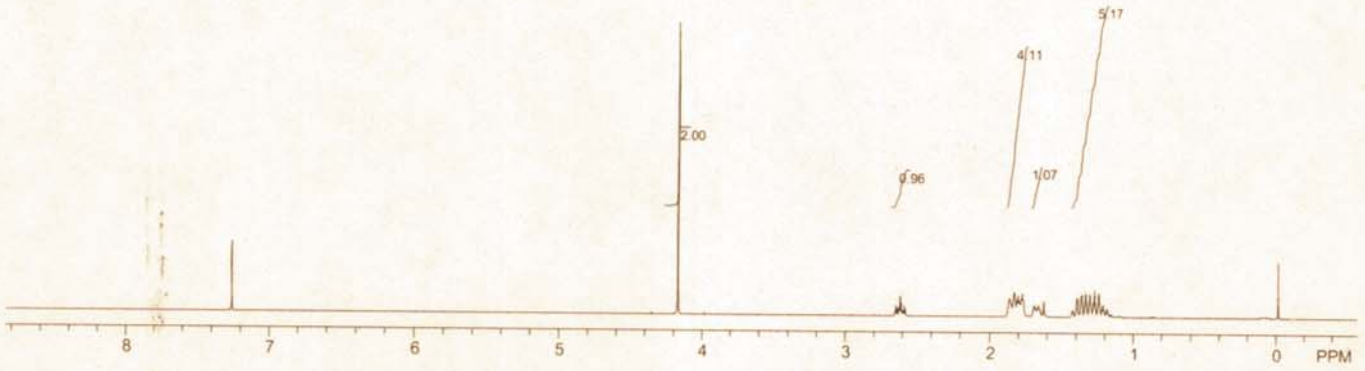

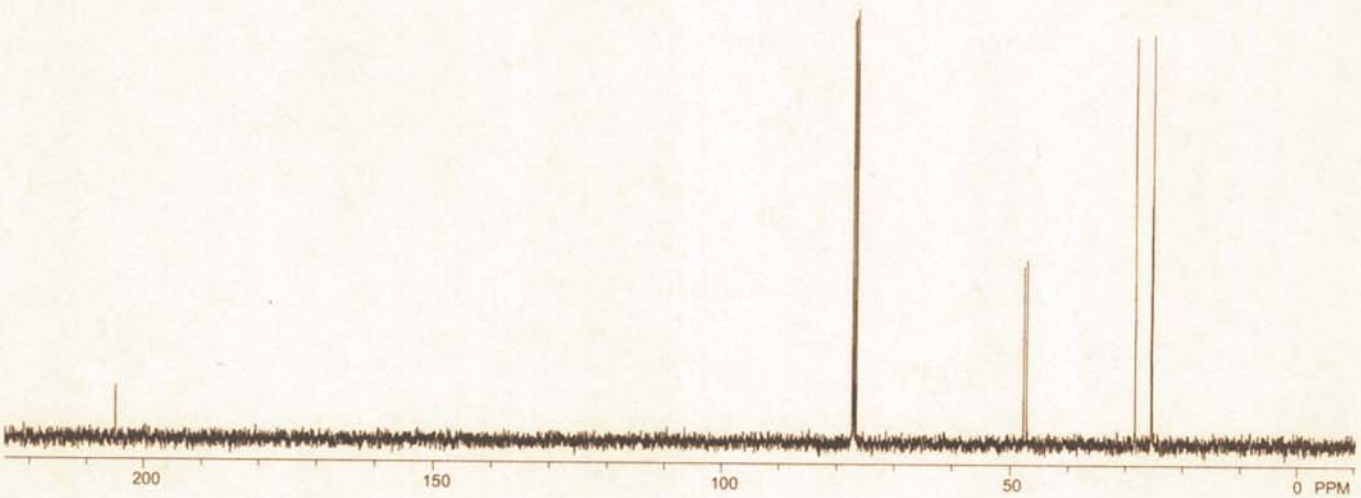

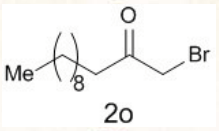

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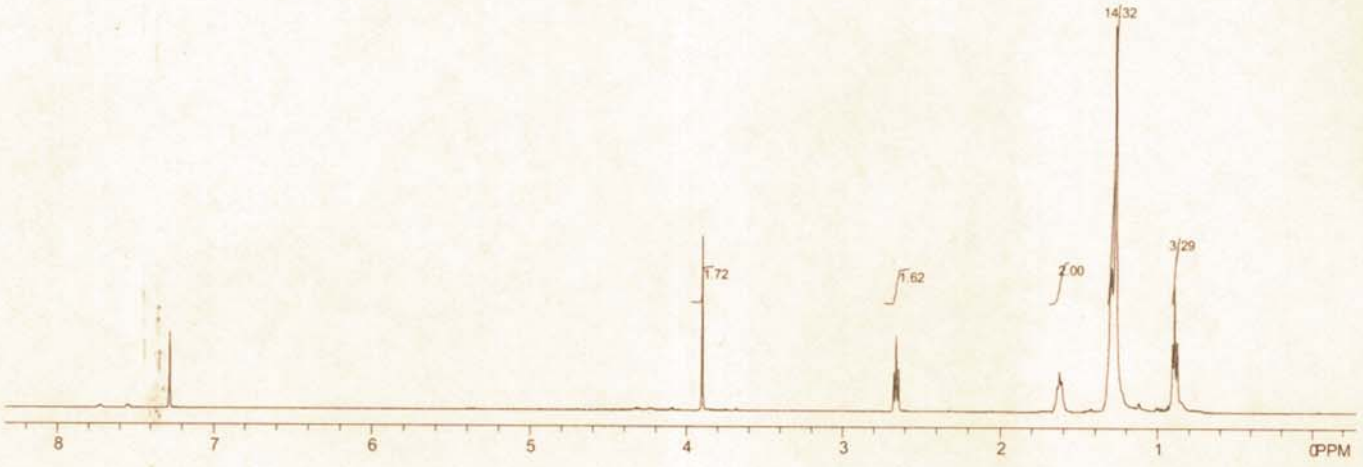

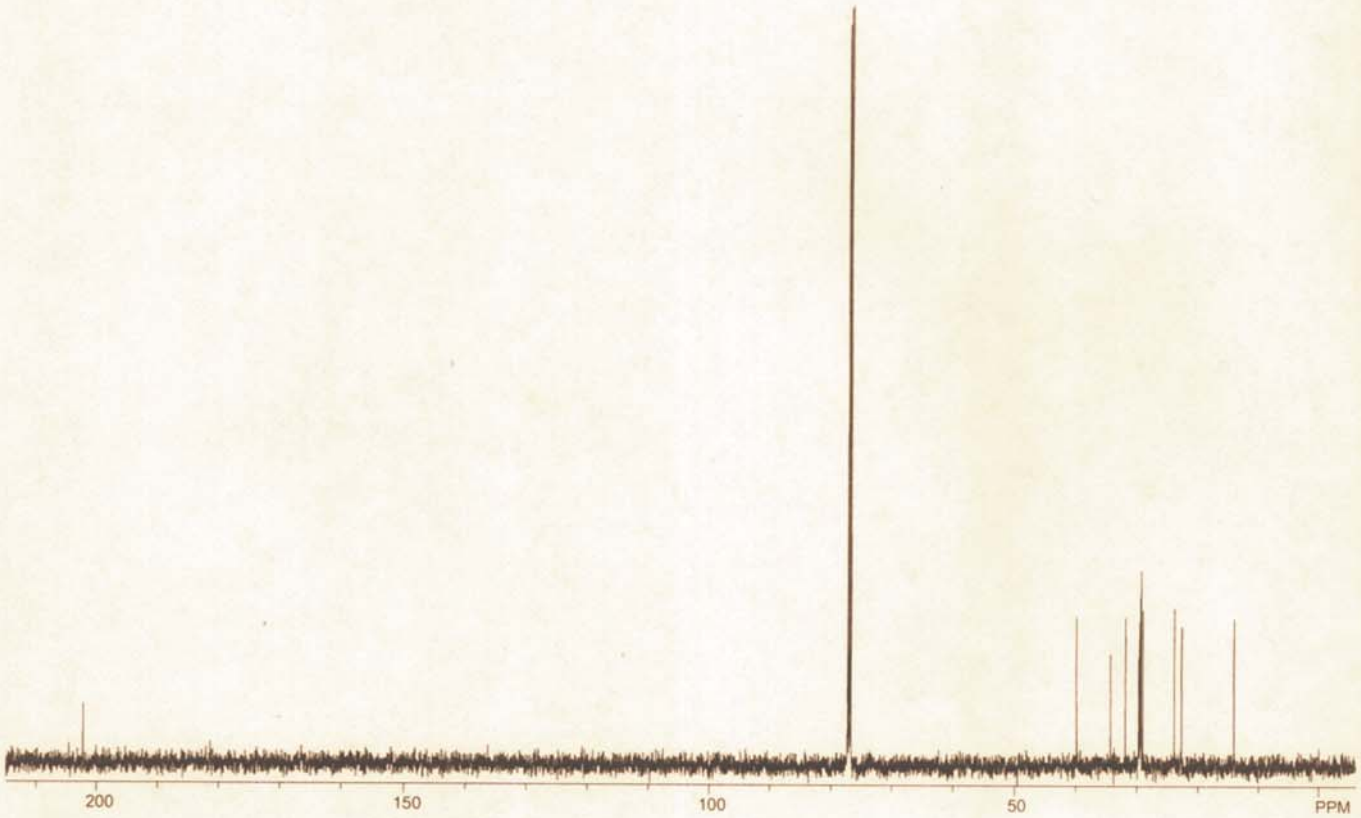

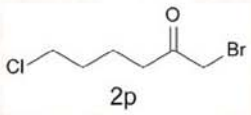

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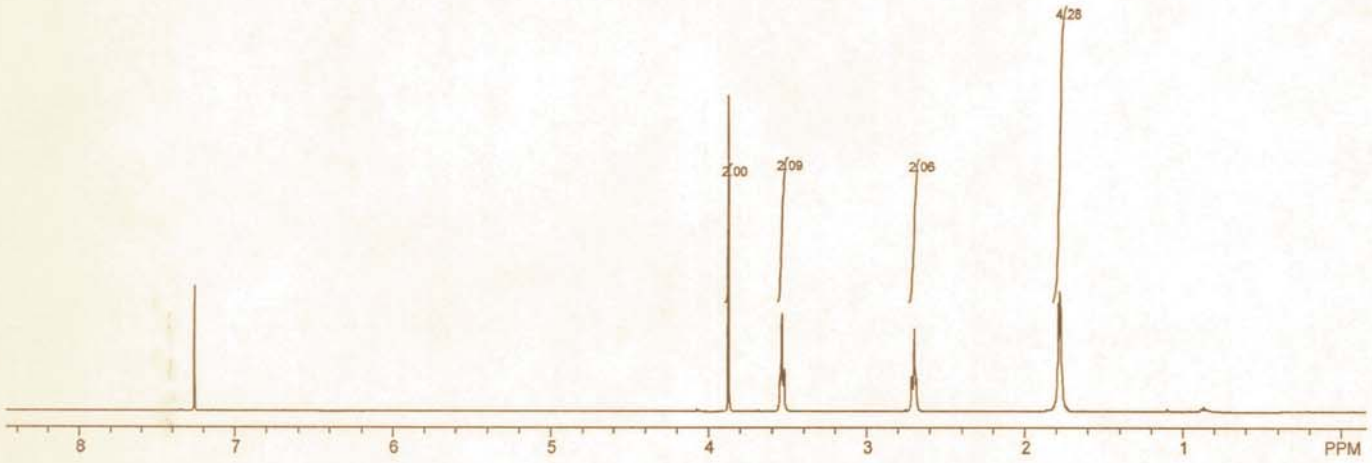

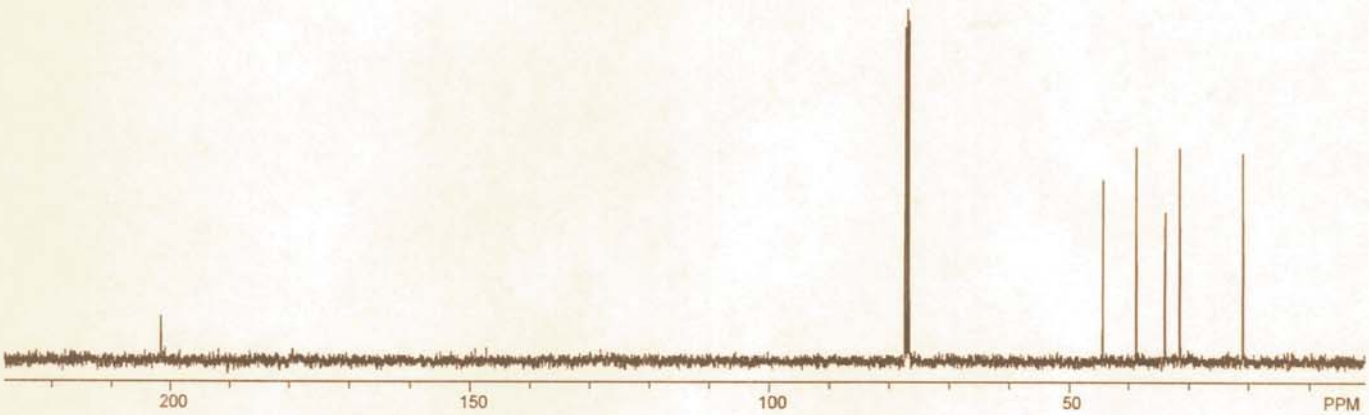

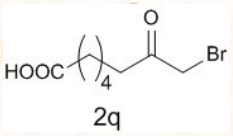

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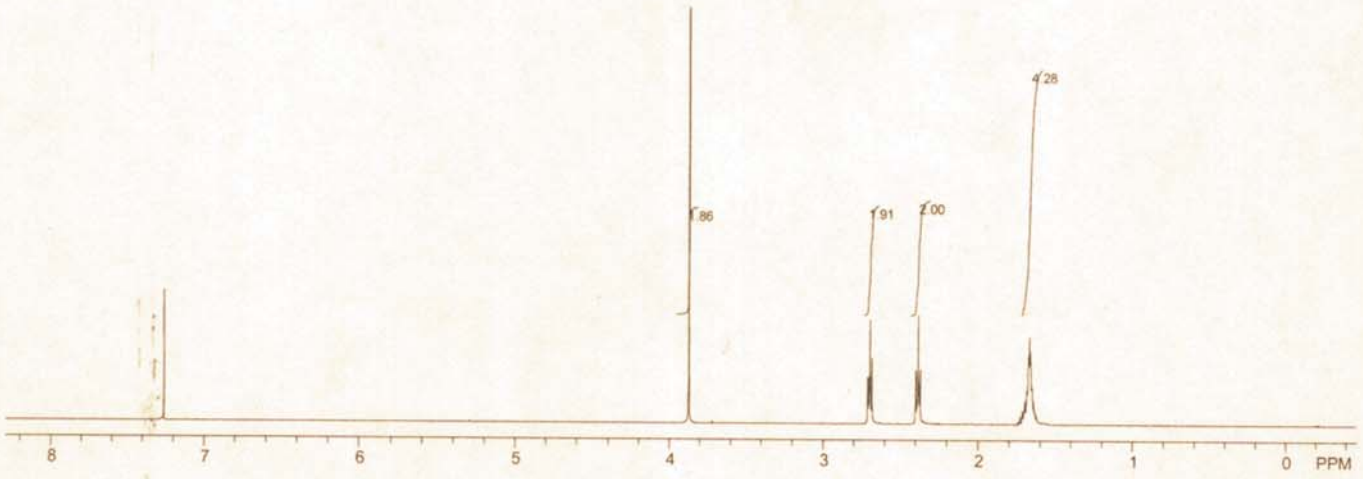

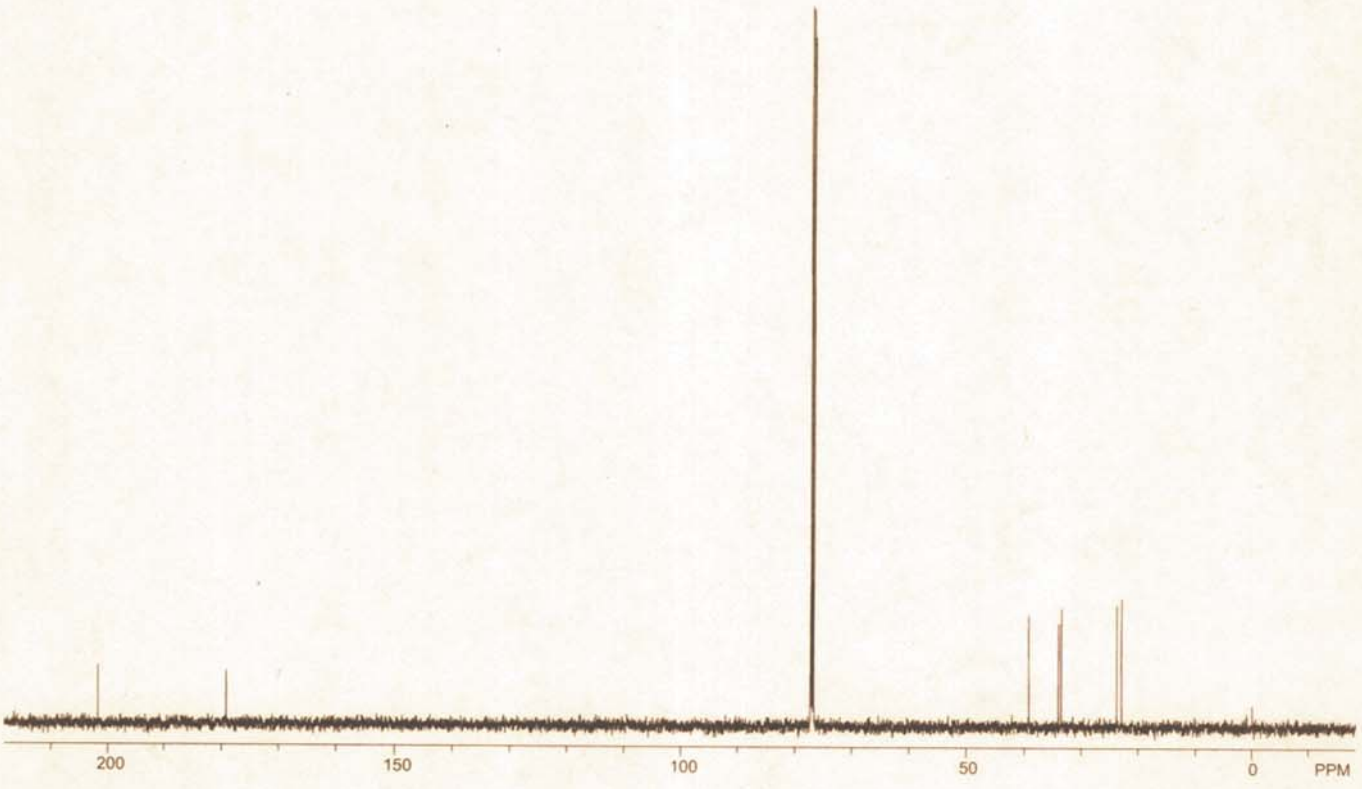

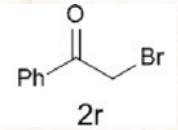

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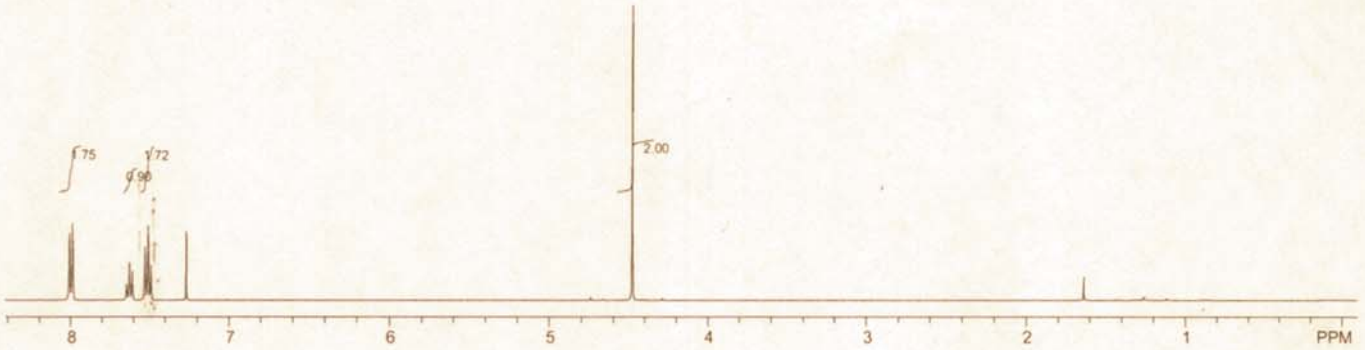

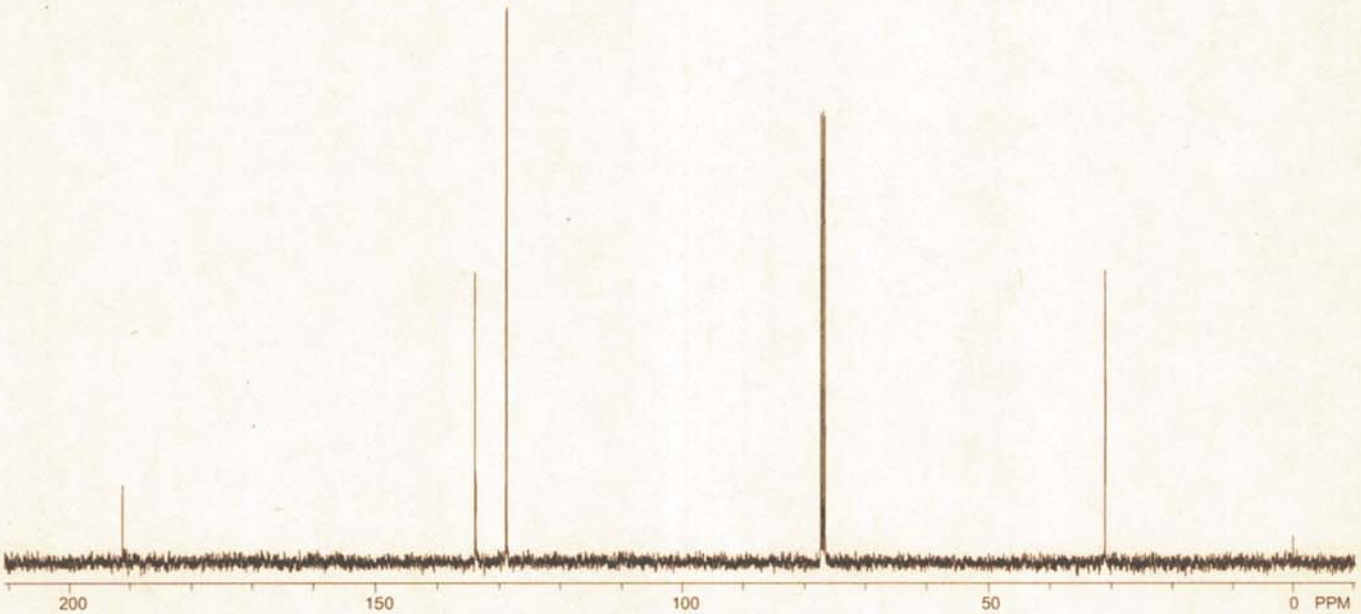

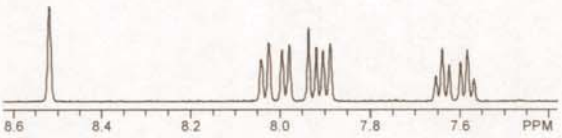

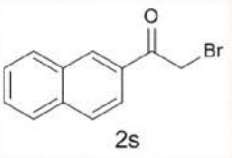

2s