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Supporting Material

for

Synthesis of β-enaminodicarbonyl derivatives in the Titanium（IV) chloride-promoted reactions of β-dicarbonyl compounds with nitriles

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Experimental details and characterization data of synthesized compounds, ^{1}H NMR and ^{13}C NMR

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General

Unless otherwise noted, materials were obtained from commercial suppliers and were used without further purification. All manipulations involving air-sensitive materials were performed under argon.

TLC was performed using precoated silica gel GF254 (0.2mm), while column chromatography was performed using silica gel (100-200 mesh). The melting point was measured on a YRT-3 melting point apparatus (Shantou Keyi instrument & Equipment Co. Ltd, Shantou, China). IR spectra were obtained on a Perkin Elmer983 (Perkin Elmer, Norwalk, CT, USA). 1H-NMR spectra were taken on a Varian INOVA400 (Varian, Palo Alto, CA, USA) using $CDCl_3$, as solvent. Chemical shifts are expressed in δ (ppm), with tetramethylsilane (TMS) functioning as the internal reference, and coupling constants (J) were expressed in Hz. Mass spectra were recorded on an Agilent 1946B ESI-MS instrument (Agilent, Palo Alto, CA, USA).

Characterization data

Ethyl 2-(amino(phenyl)methylene)-3-oxobutanoate (1a)

Colorless oil; ^{1}H NMR ($CDCl_3$, 400 MHz, δ ppm): 11.18 (s, 1H), 7.42-7.23 (m, 5H), 5.52 (s, 1H), 3.78 (q, 2H, *J* = 7.2), 2.41 (s, 3H), 0.75 (t, 3H, *J* = 7.2); HRMS: m/z (+ESI) Calcd: 233.1153, Found: 234.2849 $[M+H]^+$.

The observed data was consistent with that previously reported.[1]

Ethyl 2-(amino(2-nitrophenyl)methylene)-3-oxobutanoate (2b)

Yellow solid; m.p 72-75^{o}C; ^{1}H NMR ($CDCl_3$, 400 MHz, δ ppm): 11.35 (s, 1H), 7.18 (d, 1H, *J* = 7.6), 7.69 (t, 1H, *J* = 7.6), 7.60 (t, 1H, *J* = 7.6), 7.36 (d, 1H, *J* = 7.6), 5.74 (s, 1H), 3.76 (m, 2H), 2.40 (s, 3H), 0.80 (t, 3H, *J* = 4.8); ^{13}C NMR ($CDCl_3$, 100 MHz, δ ppm): 198.53, 167.60, 165.58, 146.29, 133.56, 133.08, 129.79, 128.75, 124.09, 102.20, 59.64, 30.46, 13.30. HRMS: m/z (+ESI) Calcd: 278.0936, Found: 279.2132 $[M+H]^+$, Anal. Calcd. For $C_{13}H_{14}N_2O_5$: C, 56.11%; H, 5.07%; N, 10.07%. Found: C, 56.42%; H, 4.98%; N, 10.12%.

Ethyl 2-(amino(4-nitrophenyl)methylene)-3-oxobutanoate (3c)

Yellow soild; m.p 78-80^{o}C; ^{1}H NMR ($CDCl_3$, 400 MHz, δ ppm): 11.00 (s, 1H), 8.28 (d, 2H, *J* = 8.4), 7.55 (d, 2H, *J* = 8.8), 5.52 (s, 1H), 3.83 (d, 2H, *J* =6.0), 2.39 (s, 3H), 0.84 (m, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz, δ ppm): 199.03, 168.02, 165.73, 147.56, 133.59, 133.07, 129.27, 128.22, 123.63, 102.35, 59.25, 30.93, 13.69. HRMS: m/z (+ESI) Calcd: 278.0936, Found: 279.1983 $[M+H]^+$, Anal. Calcd. For $C_{13}H_{14}N_2O_5$: C, 56.11%; H, 5.07%; N, 10.07%. Found: C, 56.27%; H, 5.05%; N, 10.16%.

Ethyl 2-(amino(2-methoxyphenyl)methylene)-3-oxobutanoate (4d)

White soild; m.p 98-100^{o}C ^{1}H NMR ($CDCl_3$, 400 MHz, δ ppm): 11.20 (s, 1H), 7.37 (t, 1H, *J* = 8.0), 7.18 (d, 1H, *J* = 7.6),6.97 (m, 2H), 5.75 (s, 1H), 3.82 (s,3H), 3.70 (m, 2H), 2.36 (s, 3H), 0.86 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz, δ ppm):197.04, 169.29, 164.83, 155.57, 130.76, 128.15, 127.24, 120.47, 110.97, 104.17, 59.61, 55.61, 29.77, 13.38; HRMS: m/z (+ESI) Calcd: 263.1272,

Found: 264.2365 $[M+H]^+$, Anal. Calcd. For $C_{14}H_{17}NO_4$: C, 63.87%; H, 6.51%; N, 5.32%. Found: C, 63.27%; H, 6.48%; N, 5.20%.

Ethyl 2-(amino(2,4-dimethoxyphenyl)methylene)-3-oxobutanoate (5e)

White soild; m.p 124-127^oC; ^1H NMR ($CDCl_3$, 400 MHz, δ ppm): 11.15 (s, 1H), 7.46 (d, 1H, *J* = 8.4), 6.57 (d, 1H, *J* = 8.4),6.46 (s, 1H), 5.65 (s, 1H), 4.16 (q, 2H, *J* = 7.2), 3.85 (s, 3H), 3.72 (s, 3H), 2.72 (s, 3H), 1.24 (m, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz, δ ppm):197.43, 169.91, 165.14, 160.17, 155.94, 131.12, 128.44, 120.47, 110.24, 104.32, 60.76, 56.15, 55.84, 29.74, 13.37; HRMS: m/z (+ESI) Calcd: 293.1326, Found: 294.0934 $[M+H]^+$, Anal. Calcd. For $C_{15}H_{19}NO_5$: C, 61.42%; H, 6.53%; N, 4.78%. Found: C, 61.28%; H, 6.42%; N, 4.69%.

Ethyl 2-(amino(2-chlorophenyl)methylene)-3-oxobutanoate (6f)

Colorless oil; ^1H NMR ($CDCl_3$, 400 MHz, δ ppm): 11.32 (s, 1H), 7.43-7.06 (m, 4H), 5.54 (s, 1H), 3.91 (q, 2H, *J* = 6.8), 2.03 (s, 3H), 1.07 (t, 3H, *J* = 6.8); ^{13}C NMR ($CDCl_3$, 100 MHz, δ ppm): 198.93, 167.43, 163.96, 133.56, 133.08, 131.16, 129.96, 128.88, 123.78, 102.01, 59.97, 29.95, 13.06; HRMS: m/z (+ESI) Calcd: 267.0734, Found: 268.1082 $[M+H]^+$, Anal. Calcd. For $C_{13}H_{14}ClNO_3$: C, 58.32%; H, 5.27%; Cl, 13.24%; N, 5.32%. Found: C, 58.14%; H, 5.20%; Cl, 13.28%; N, 5.26%.

Ethyl 2-(amino(2-methoxypyridin-3-yl)methylene)-3-oxobutanoate (7g)

Yellow oil; ^1H NMR ($CDCl_3$, 400 MHz, δ ppm): 11.22 (s, 1H), 8.20 (d, 1H, *J* = 4.8), 7.50 (d, 1H, *J* = 7.2), 6.93 (d, 1H, *J* = 7.2), 5.70 (s, 1H), 3.95 (s, 3H), 3.81 (q, 2H, *J* = 6.8), 2.38 (s, 3H), 0.80 (t, 3H, *J* = 6.8); ^{13}C NMR ($CDCl_3$, 100 MHz, δ ppm):197.77, 169.74, 164.92, 162.17, 148.32, 140.32, 120.15, 118.55, 103.87, 59.96, 53.51, 29.71, 13.22; HRMS: m/z (+ESI) Calcd: 264.1168, Found: 265.2843 $[M+H]^+$, Anal. Calcd. For $C_{13}H_{16}N_2O_4$: C, 59.08%; H, 6.10%; N, 10.60%. Found: C, 59.00%; H, 6.02%; N, 10.49%.

Ethyl 2-(amino(furan-2-yl)methylene)-3-oxobutanoate (8h)

Yellow oil; ^1H NMR ($CDCl_3$, 400 MHz, δ ppm): 10.68 (s, 1H), 7.52 (d, 1H, *J* = 0.8), 6.77 (d, 1H, *J* = 2.8), 6.50 (dd, 1H, J_1 = 2.4, J_2 = 3.2), 5.92 (s, 1H), 4.14 (q, 2H, *J* = 7.2), 2.95 (s, 3H), 1.17 (t, 3H, *J* = 7.2); HRMS: m/z (+ESI) Calcd: 223.0823, Found: 224.1283 $[M+H]^+$.

The observed data was consistent with that previously reported. [2]

Ethyl 2-acetyl-3-amino-4-phenylbut-2-enoate (9i)

White soild; m.p 89-92^oC ^1H NMR ($CDCl_3$, 400 MHz, δ ppm): 11.24 (s, 1H), 7.37-7.30 (m, 3H), 7.28-7.21 (m, 2H), 5.47 (s, 1H), 4.23 (q, 2H, *J* = 7.2), 3.96 (s, 2H), 2.31 (s, 3H), 1.29 (t, 3H, *J* = 7.2); HRMS: m/z (+ESI) Calcd: 247.1247, Found: 248.3824 $[M+H]^+$.

The observed data was consistent with that previously reported. [3]

(4E)-ethyl 2-acetyl-3-amino-5-phenylpenta-2, 4-dienoate (10j)

Colorless oil; ^1H NMR ($CDCl_3$, 400 MHz, δ ppm): 11.04 (s, 1H), 7.48 (d, 2H, *J* = 6.8), 7.37 (d, 3H, *J* = 6.8), 7.19 (d, 1H, *J* = 1.6), 7.05 (d, 1H, *J* = 1.6), 5.63 (s, 1H), 4.27 (q, 2H, *J* = 7.2), 2.37 (s, 3H), 1.31 (t, 3H, *J* = 7.2); ^{13}C NMR ($CDCl_3$, 100 MHz, δ ppm):169.25, 161.98, 161.93, 135.36, 135.00, 129.30, 129.11, 128.70, 127.27, 127.08, 124.30, 60.24, 30.19, 14.15; HRMS: m/z (+ESI)

Calcd: 259.1258, Found: 260.0464 $[M+H]^+$, Anal. Calcd. For $C_{15}H_{17}NO_3$: C, 69.48%; H, 6.61%; N, 5.40%. Found: C, 69.39%; H, 6.53%; N, 5.29%.

Ethyl 2-acetyl-3-aminobut-2-enoate (11k)

White solid; m.p 50-52°C. ^{1}H NMR ($CDCl_3$, 400 MHz, δ ppm): 11.05 (s, 1H), 5.66 (s, 1H), 4.23 (q, 2H, *J* = 7.2), 2.30 (s, 3H), 2.23 (s, 3H), 1.32 (t, 3H, *J* = 7.2); ^{13}C NMR ($CDCl_3$, 100 MHz, δ ppm):196.88, 169.53, 167.48, 167.43, 102.70, 59.85, 30.02, 23.00, 22.98, 22.95, 13.98; HRMS: m/z (+ESI) Calcd: 171.0925, Found: 172.1452 $[M+H]^+$, Anal. Calcd. For $C_8H_{13}NO_3$: C, 56.13%; H, 7.65%; N, 8.18%. Found: C, 56.03%; H, 7.58%; N, 8.02%.

Ethyl 2-acetyl-3-amino-5-bromopent-2-enoate (12l)

Yellow oil; ^{1}H NMR ($CDCl_3$, 400 MHz, δ ppm): 11.03 (s, 1H), 5.68 (s, 1H), 4.20 (q, 2H, *J* = 7.2), 2.65 (t, 2H, *J* = 8.0), 2.48 (t, 2H, *J* = 8.0), 2.31 (s, 3H), 1.32 (t, 3H, *J* = 7.2);
^{13}C NMR ($CDCl_3$, 100 MHz, δ ppm):197.13, 170.10, 167.31, 167.25, 103.25, 59.52, 38.32, 29.98, 27.23, 13.68; HRMS: m/z (+ESI) Calcd: 263.0247, Found: 264.1872 $[M+H]^+$, Anal. Calcd. For $C_9H_{14}BrNO_3$: C, 40.93%; H, 5.34%; Br, 30.25%; N, 5.30%. Found: C, 40.88%; H, 5.28%; Br, 30.20%; N, 5.21%.

3-(amino (phenyl)methylene)pentane-2,4-dione (13m)

White solid; m.p 89-92°C. ^{1}H NMR ($CDCl_3$, 400 MHz, δ ppm): 10.94 (s, 1H), 7.52-7.27 (m, 5H), 5.50 (s, 1H), 2.97 (s, 3H), 1.74 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz, δ ppm):200.11, 198.30, 166.43, `38.52, 133.30, 131.73, 130.20, 128.47, 126.38, 112.27, 30.02, 29.17; HRMS: m/z (+ESI) Calcd: 203.0948, Found: 204.2587 $[M+H]^+$, Anal. Calcd. For $C_{12}H_{13}NO_2$: C, 70.92%; H, 6.54%; N, 6.89%. Found: C, 70.83%; H, 6.47%; N, 6.80%.

Diethyl 2-(amino(phenyl)methylene)malonate (14n)

White solid; m.p 125-128°C. ^{1}H NMR ($CDCl_3$, 400 MHz, δ ppm): 8.96 (s, 1H), 7.45-7.26 (m, 5H), 5.07 (s, 1H), 4.24 (d, 2H, *J* = 6.8), 3.83 (d, 2H, *J* = 6.8), 1.30 (m, 3H), 0.82 (m, 3H). HRMS: m/z (+ESI) Calcd: 263.1254, Found: 264.3721 $[M+H]^+$.
The observed data was consistent with that previously reported. [4]

Notes and references

1 Y. O. Ko, Y. S. Chun, C.-L. Park, Y. Kim, H. Shin, S. Ahn, J. Hong and S.-g. Lee, *Org. Biomol. Chem*., 2009, **7**, 1132–1136.

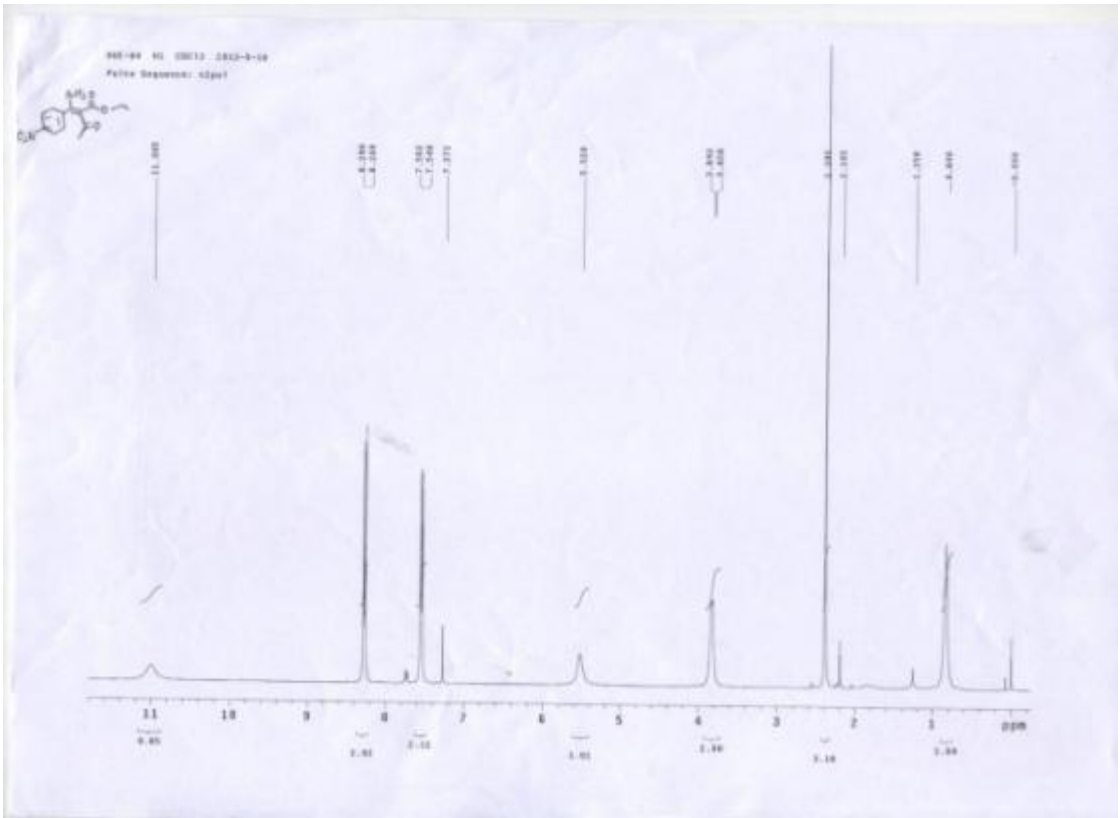
2 D. McGregor, N. Corbin, U. Swigor, J. E. Cheney and C. Lee, *Tetrahedron*, 1969, **25**, 389–395.

3 M. Nicolini and C. Attilio, *Org. Prep. Proced. Int*., 1993, **25**, 229–231.

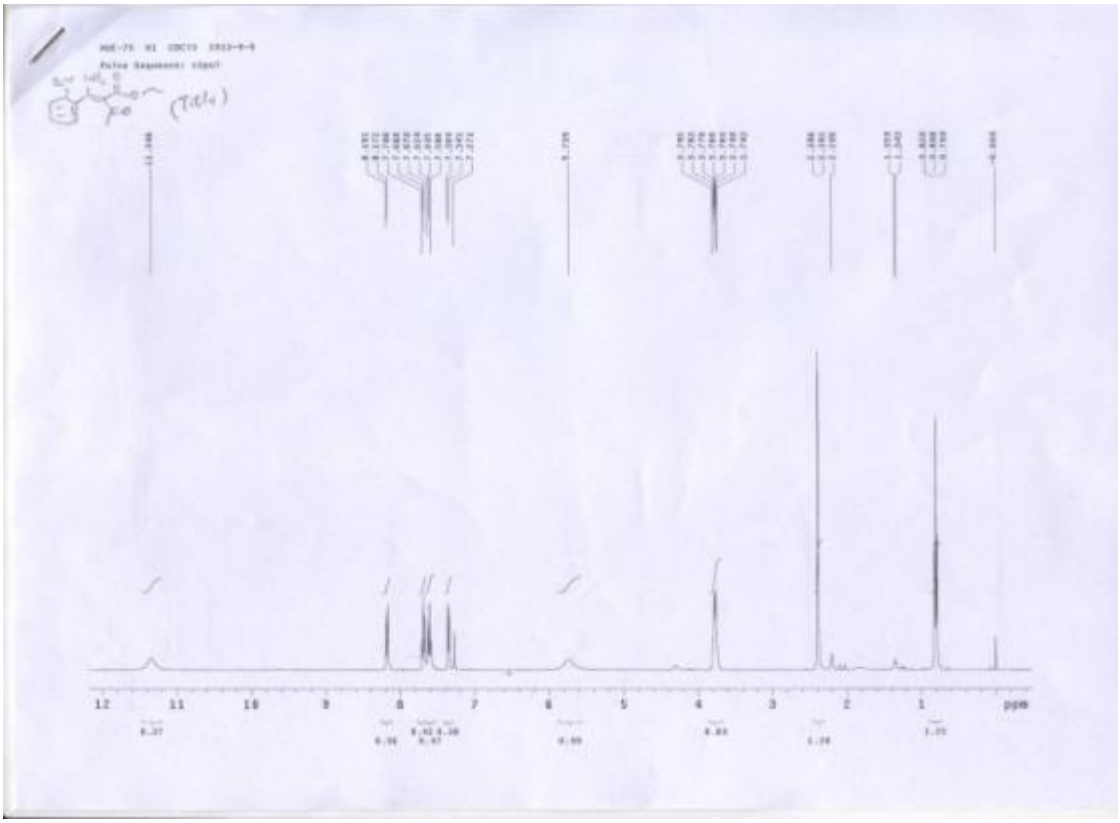
4 Y. S. Chun, K. K. Lee, Y. O. Ko, H. Shin and S.-g. Lee, *Chem. Commun*., 2008, 5098–5100.

^{1}H NMR and ^{13}C NMR spectra for synthesized compounds

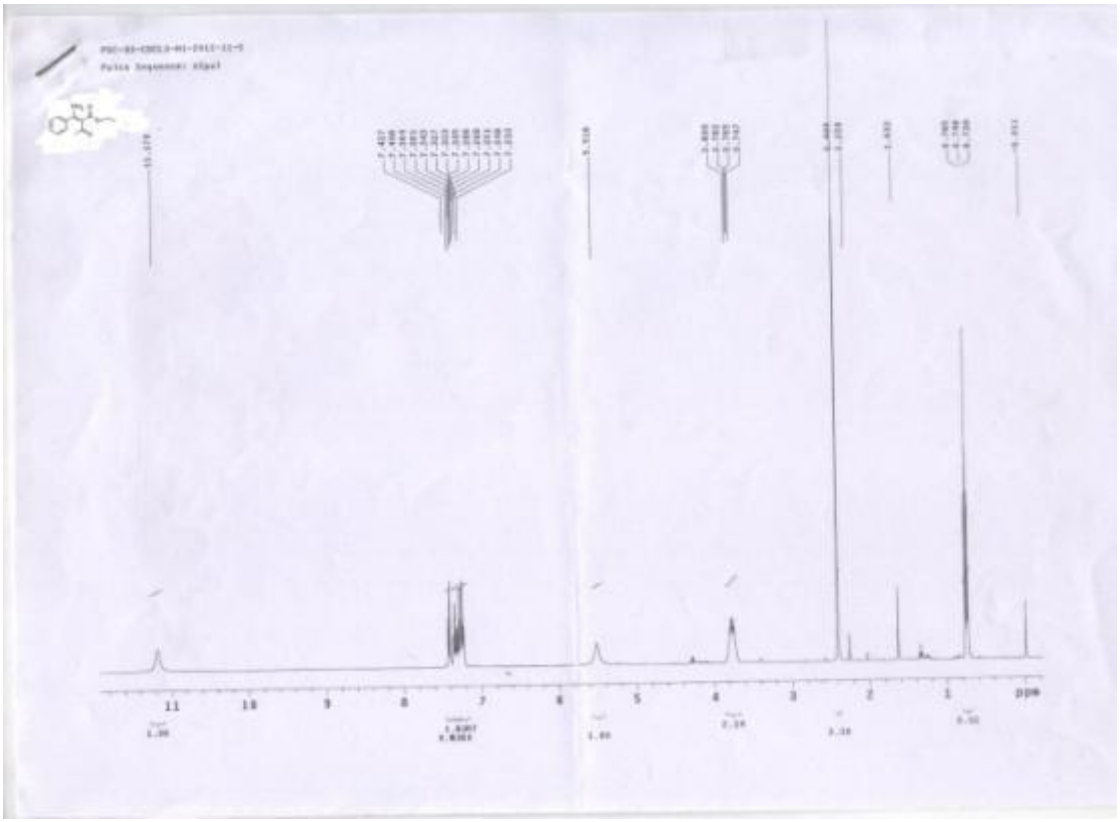
^{1}H NMR spectra for compound **6f**



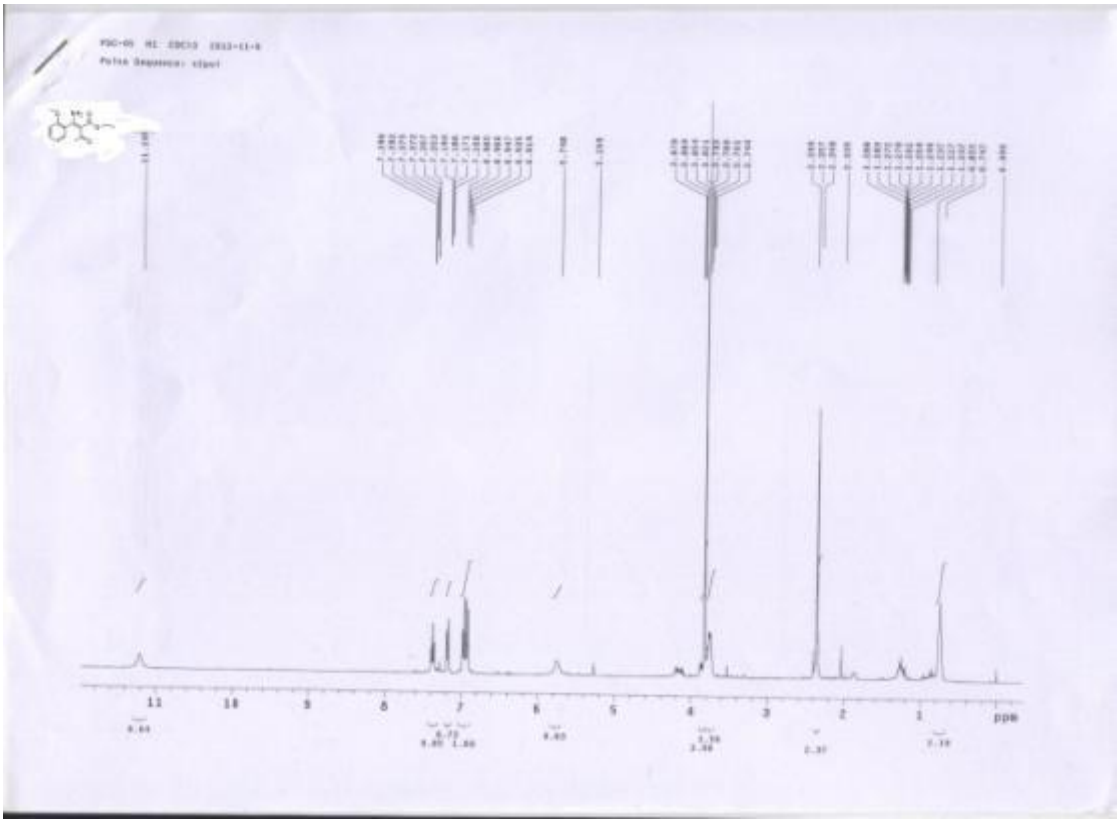
^{1}H NMR spectra for compound **3c**



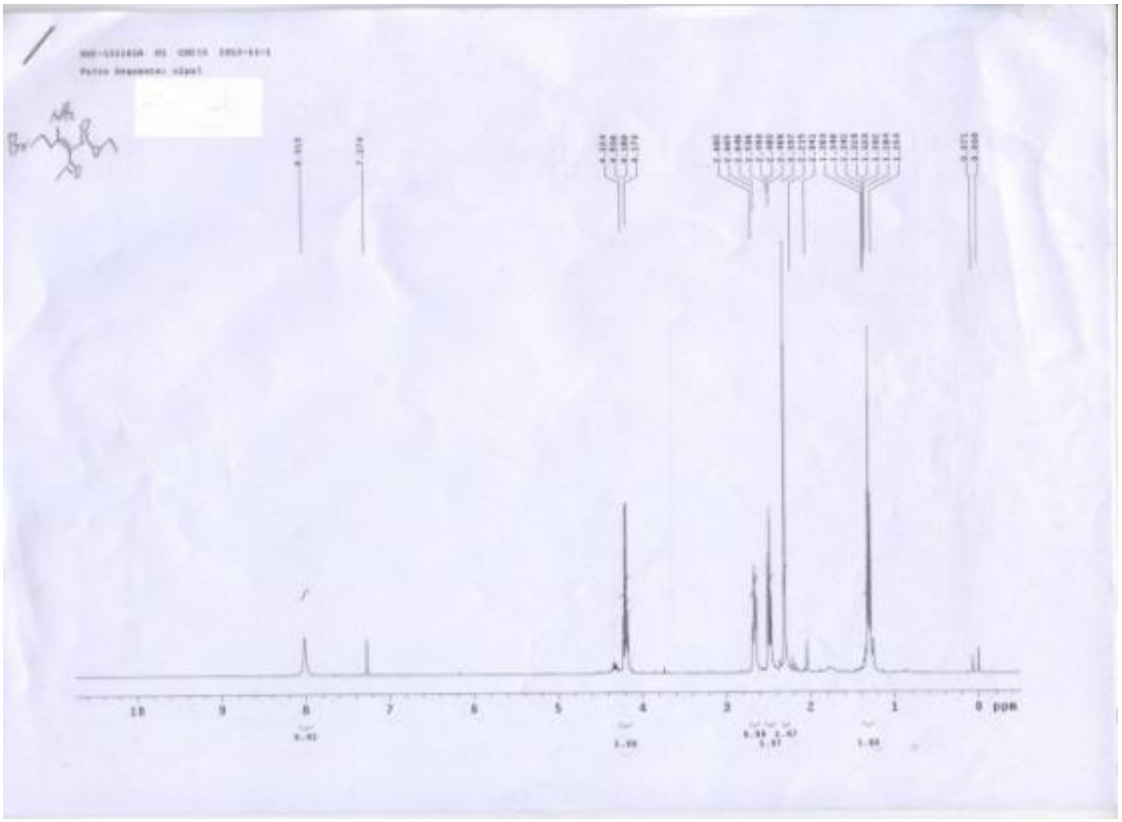
^{1}H NMR spectra for compound **2b**



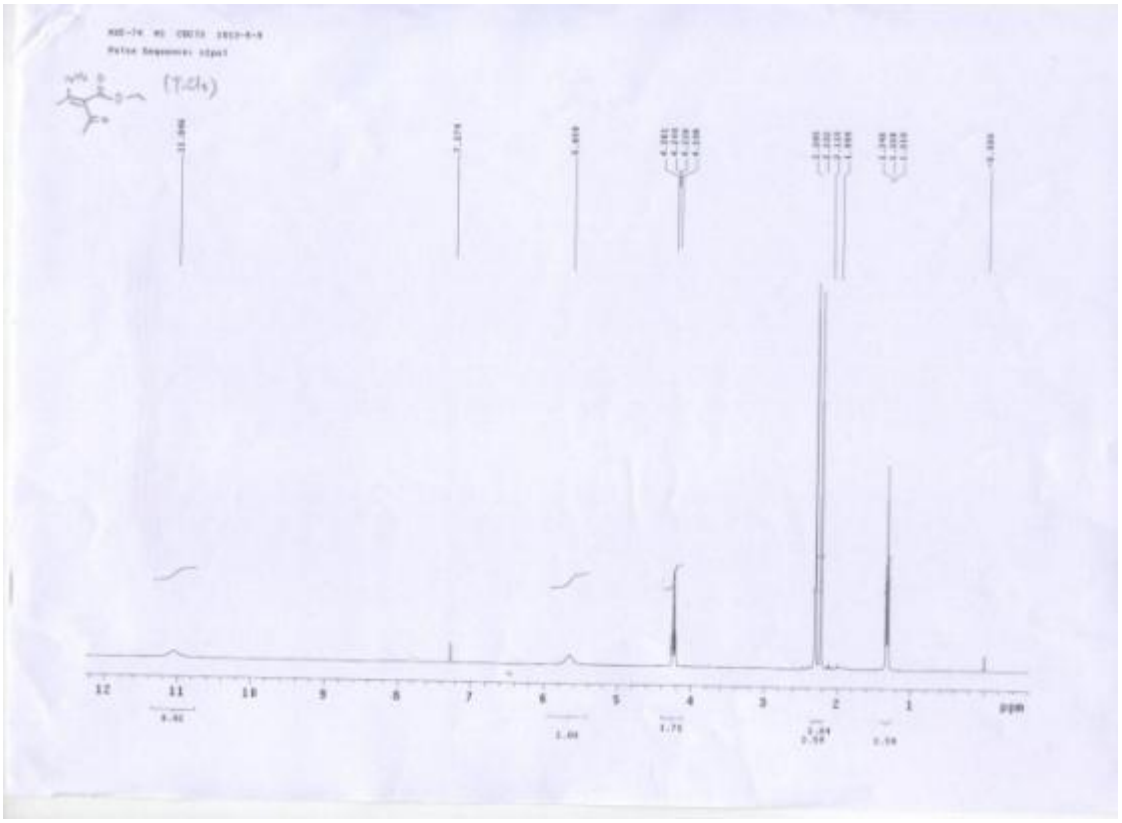
^{1}H NMR spectra for compound **1a**



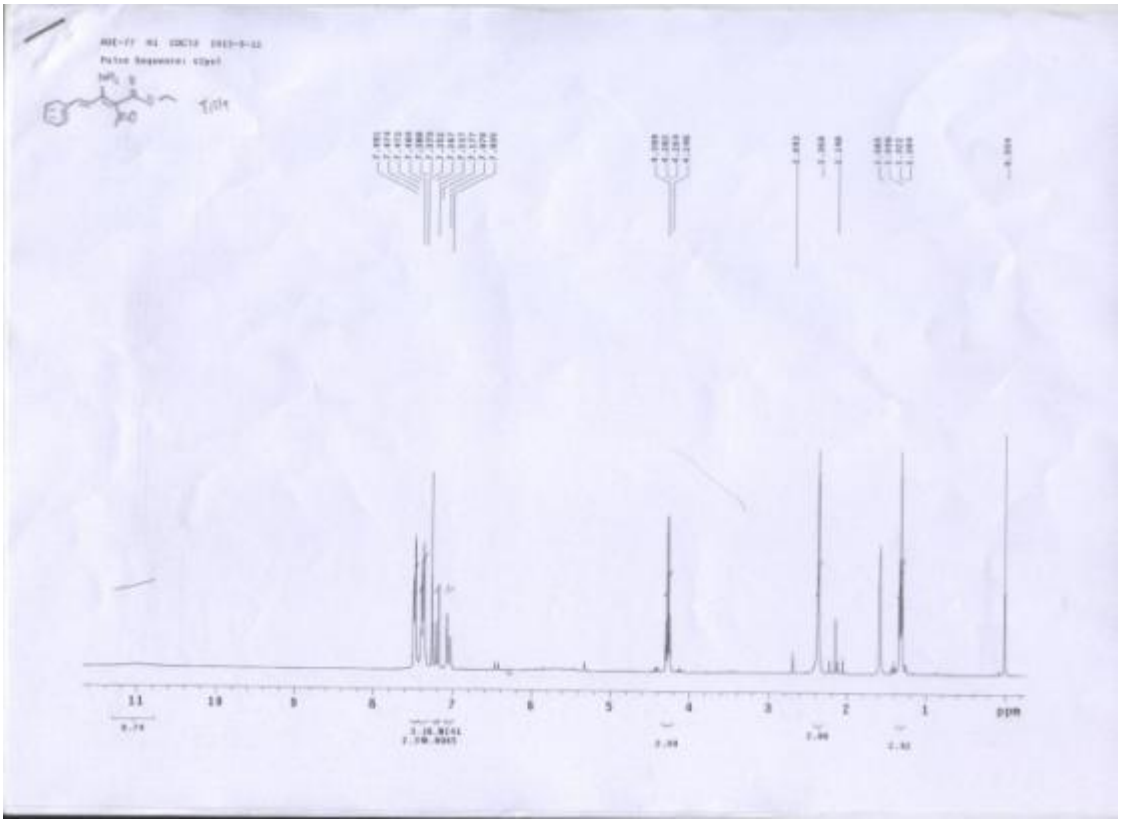
^{1}H NMR spectra for compound **4d**



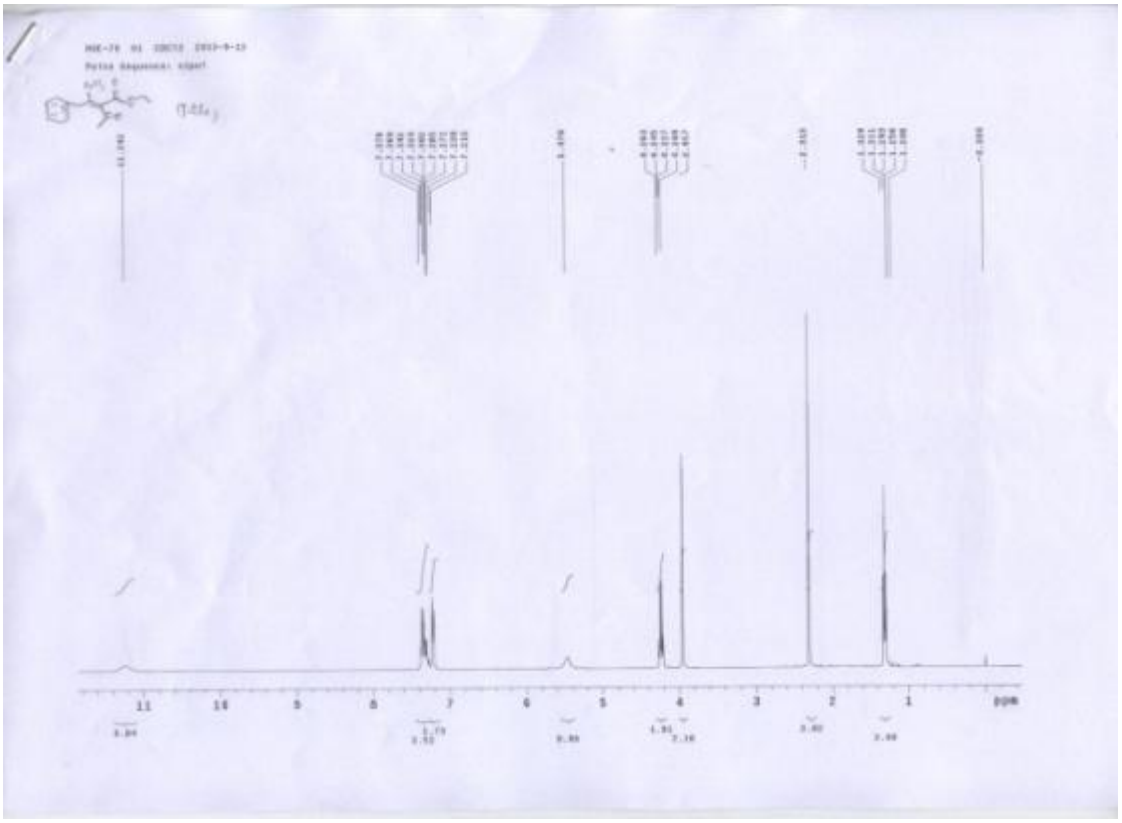
^{1}H NMR spectra for compound **12l**



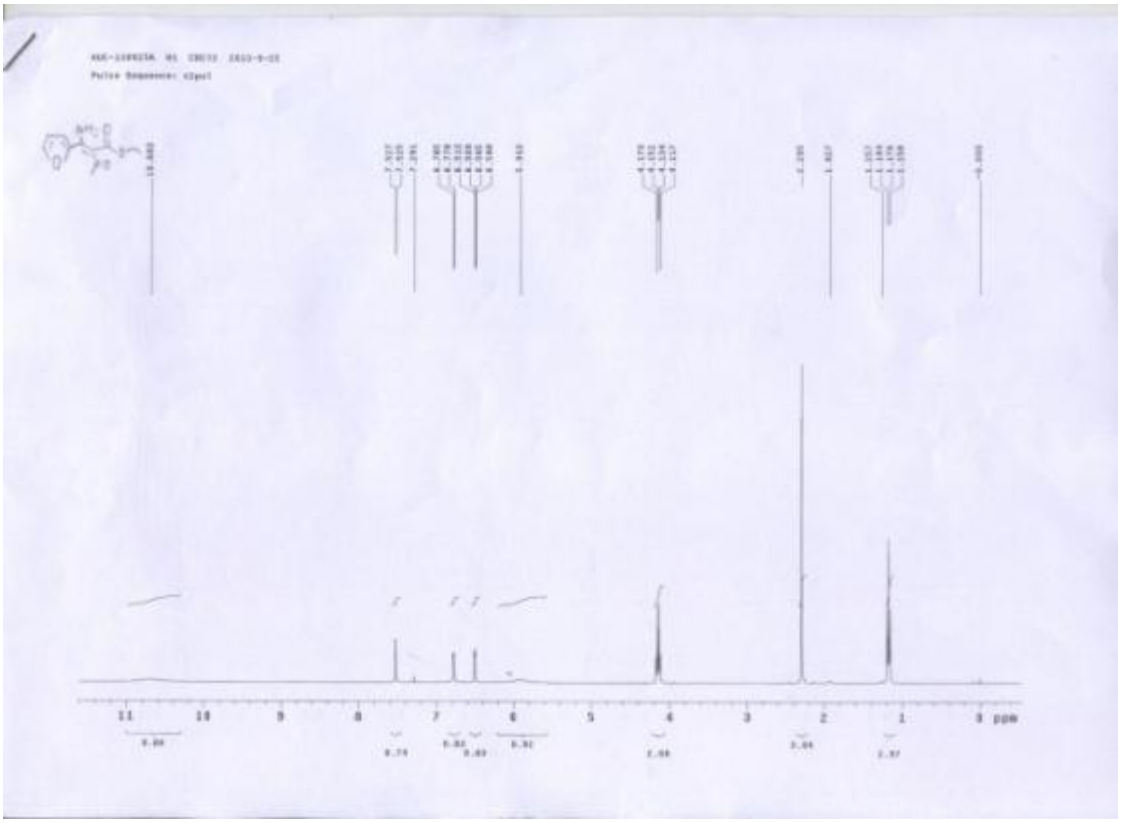
^{1}H NMR spectra for compound **11k**



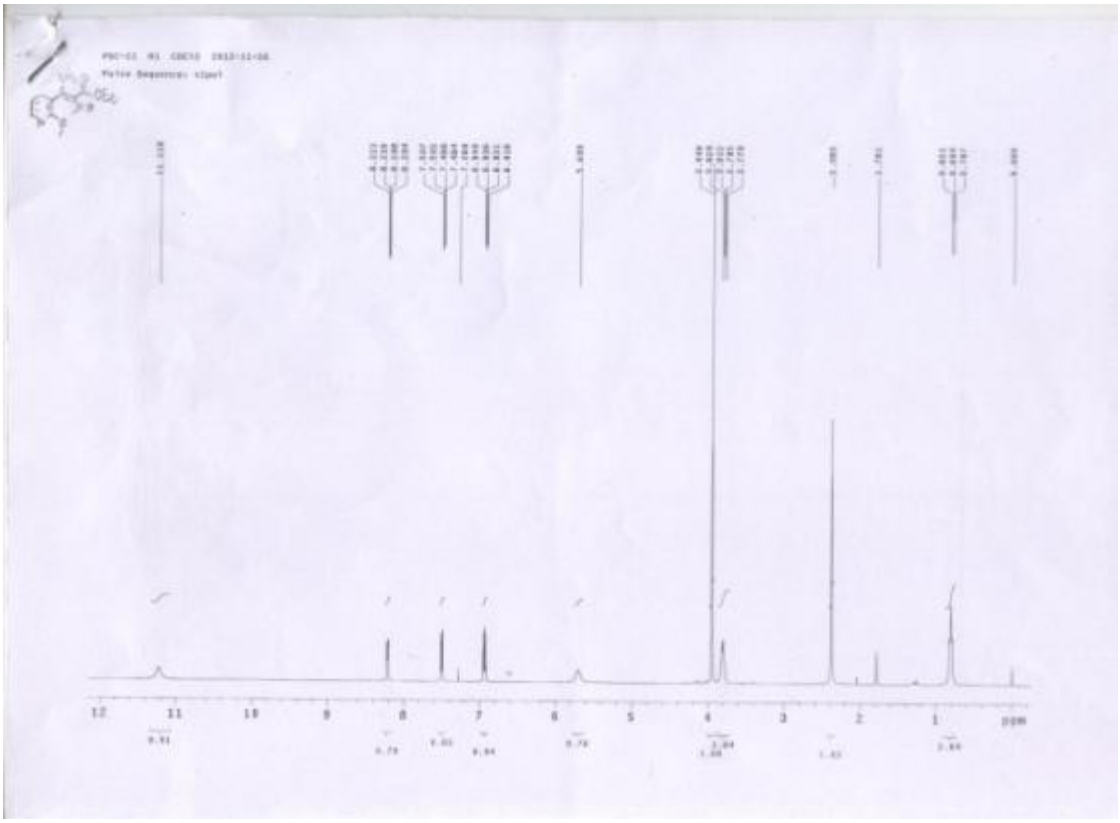
^{1}H NMR spectra for compound **10j**



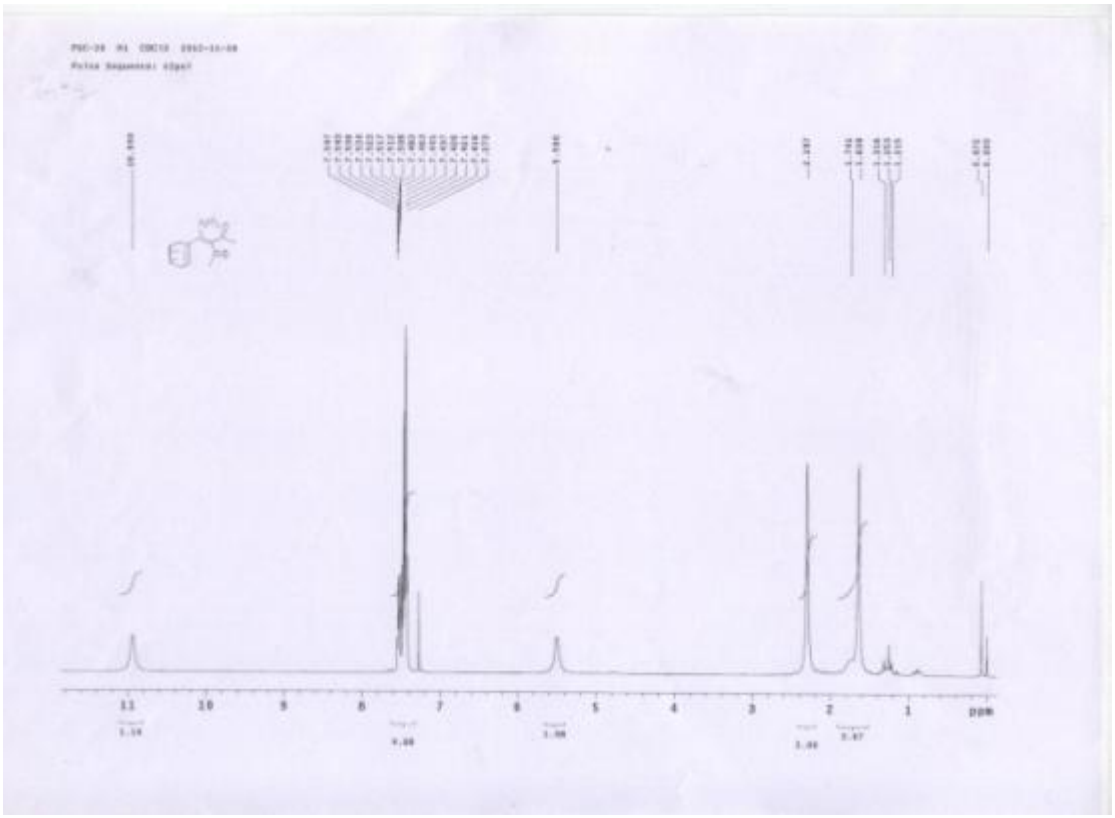
^{1}H NMR spectra for compound **9i**



^{1}H NMR spectra for compound **8h**



^{1}H NMR spectra for compound **7g**



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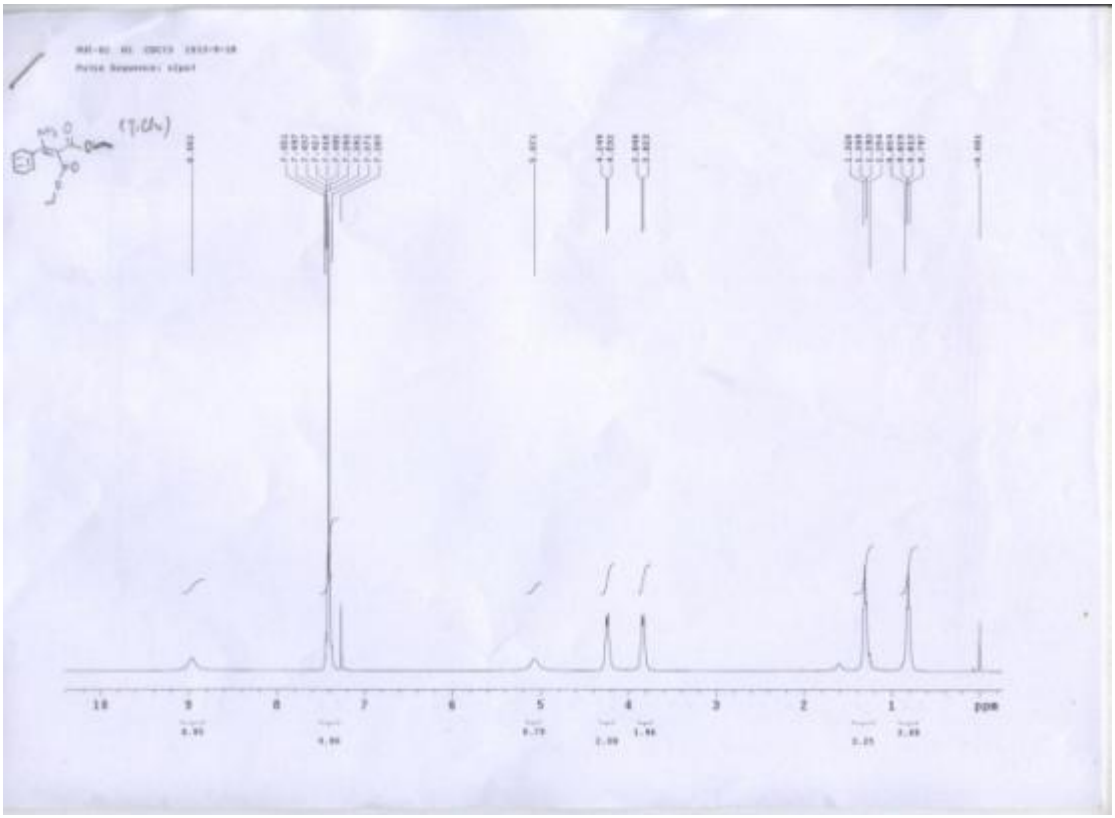

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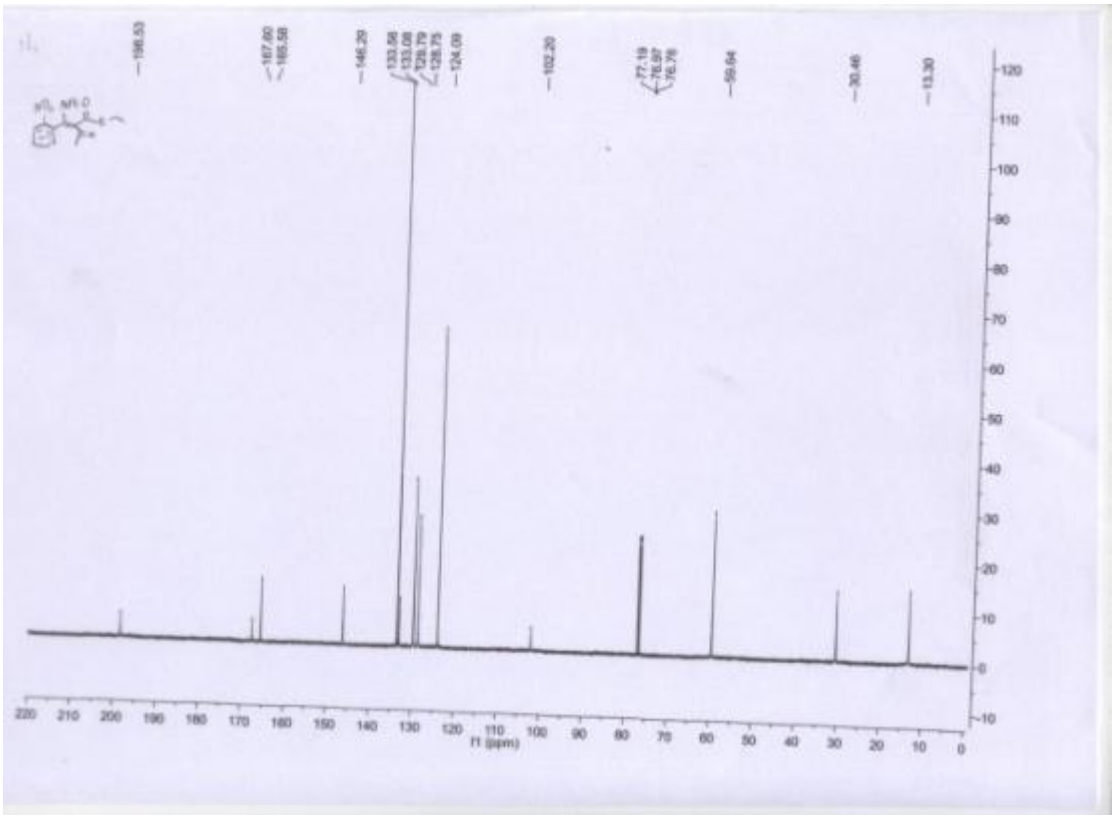
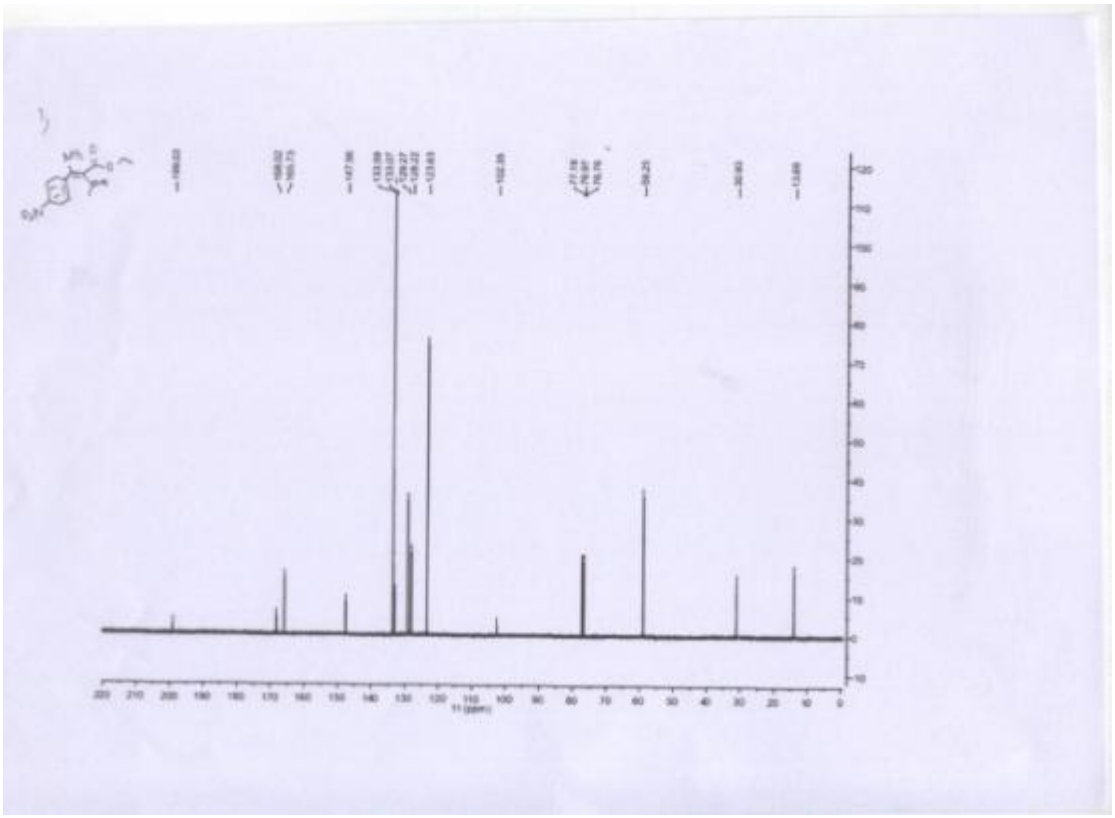
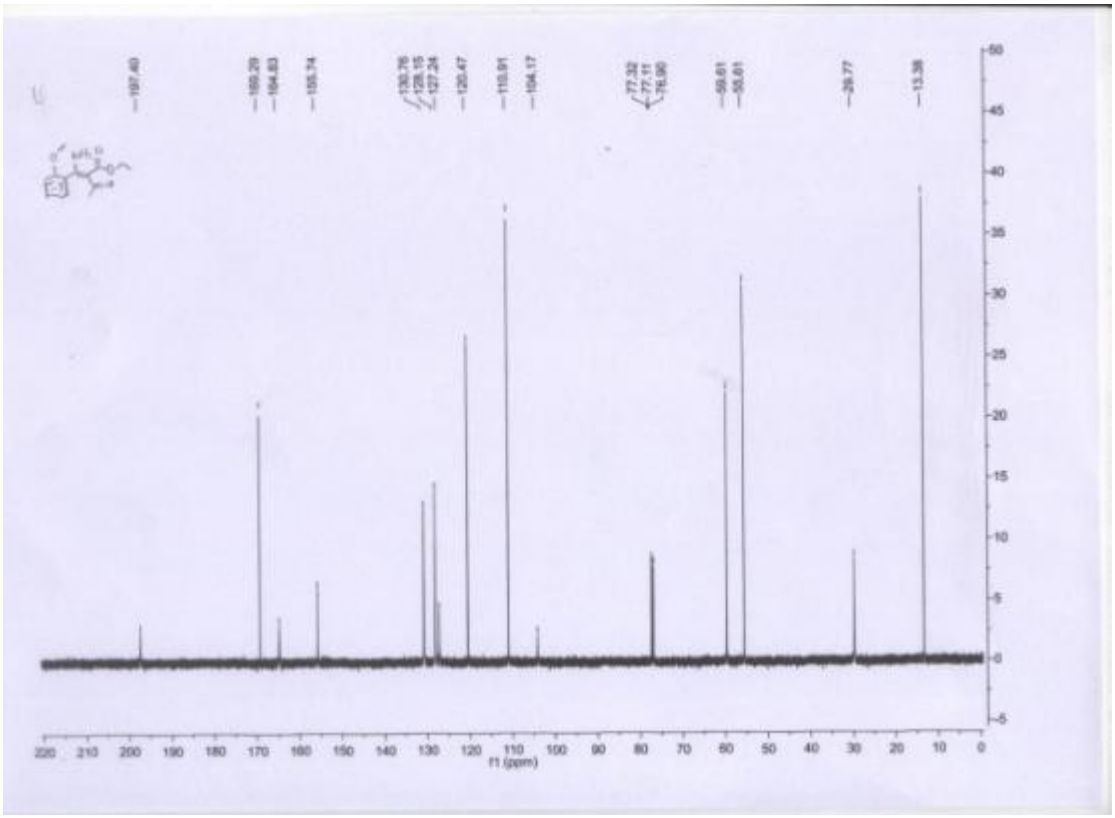


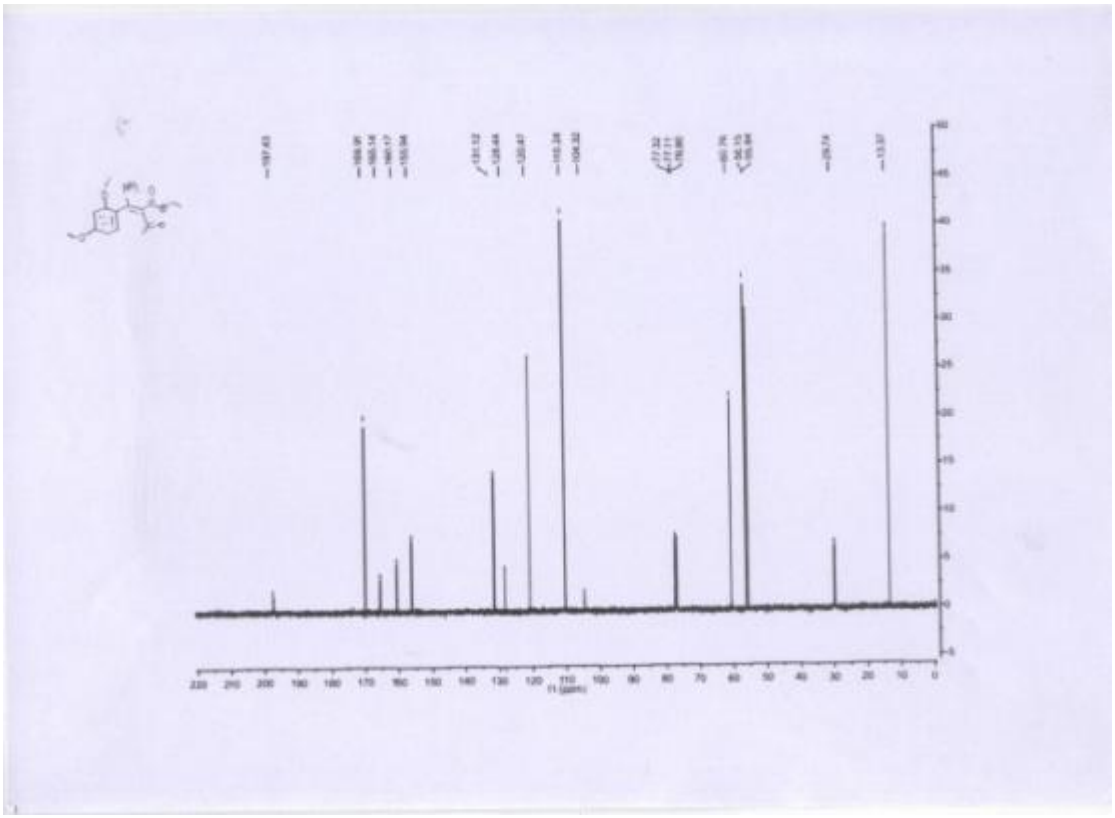
^{13}C NMR spectra for compound **2b**



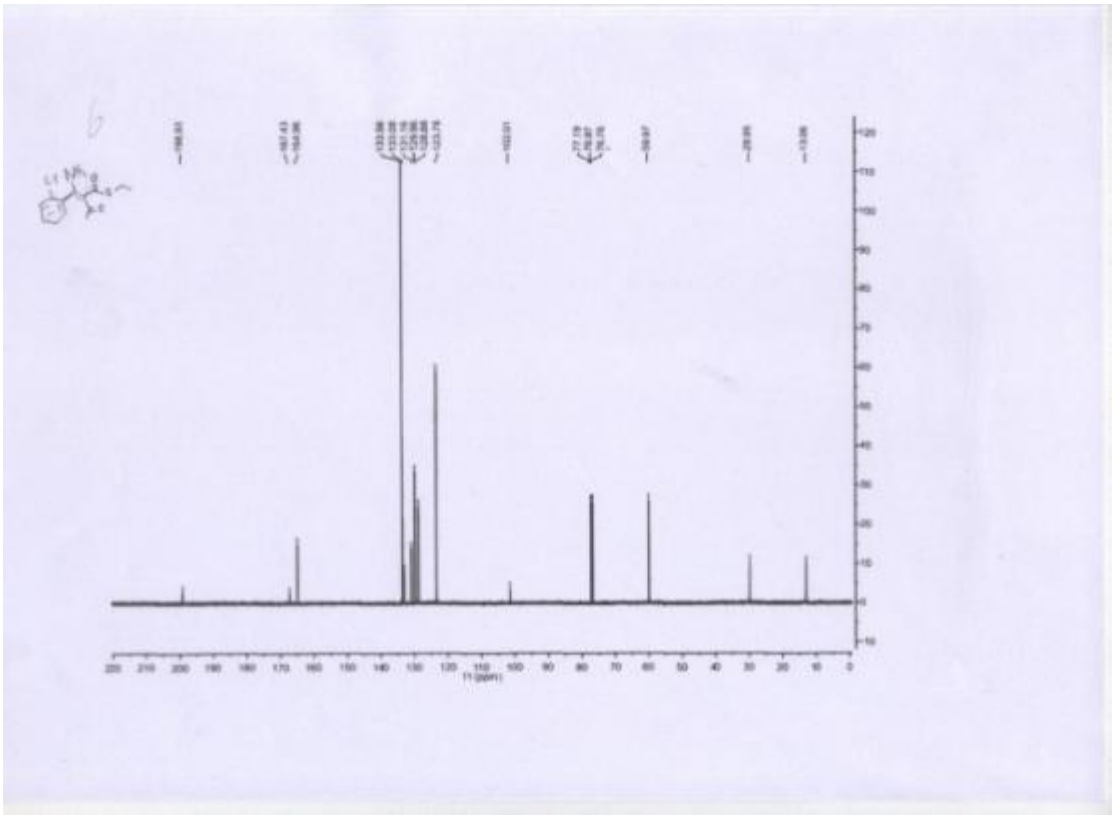
^{13}C NMR spectra for compound **3c**



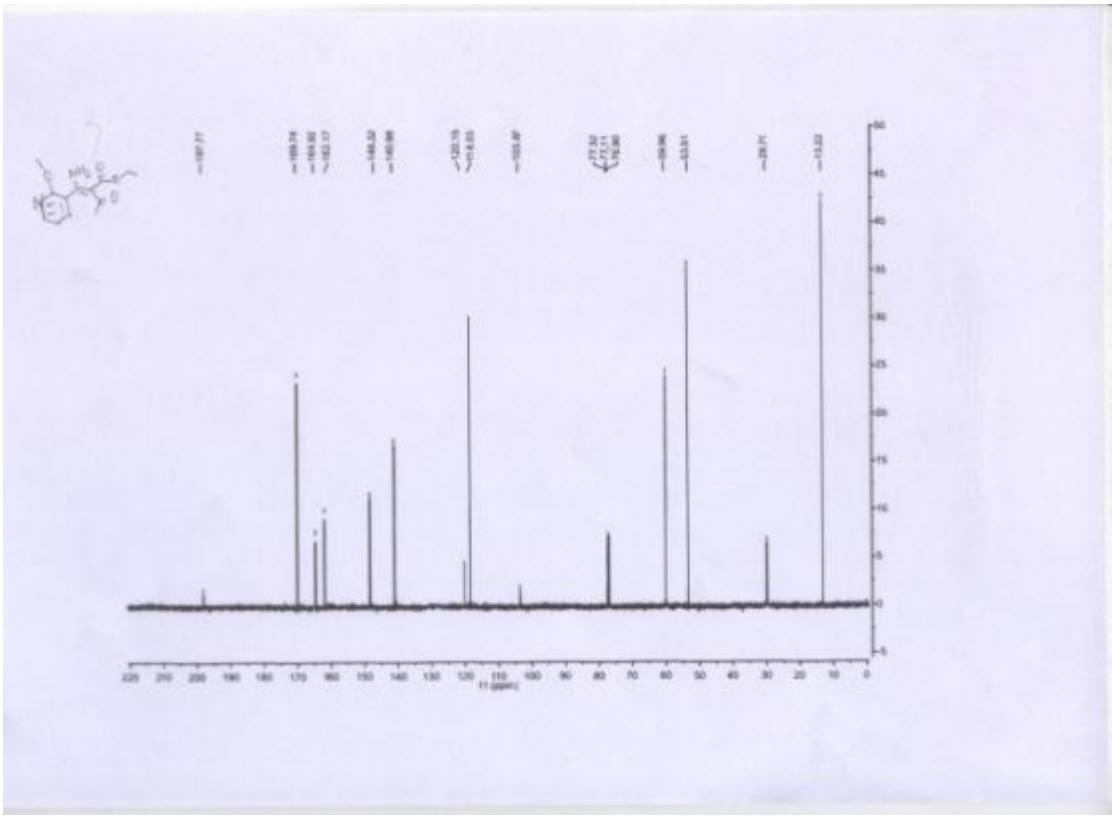
^{13}C NMR spectra for compound **4d**



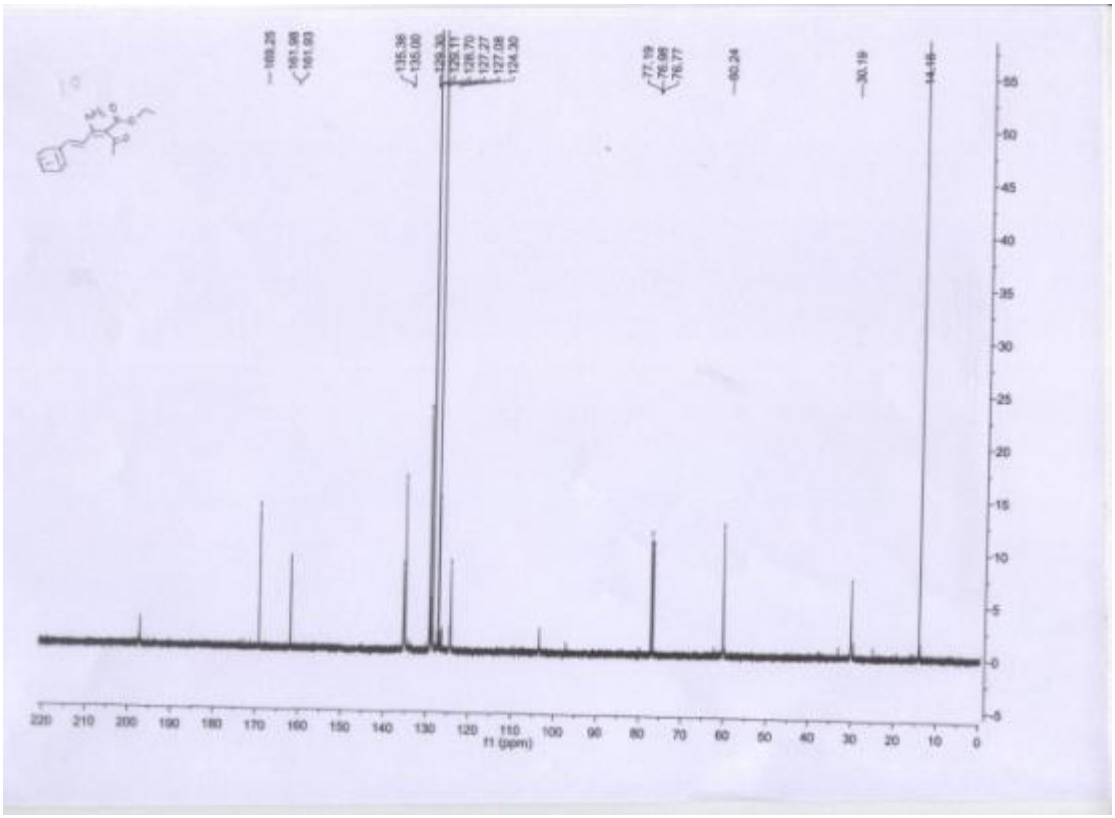
^{13}C NMR spectra for compound **5e**



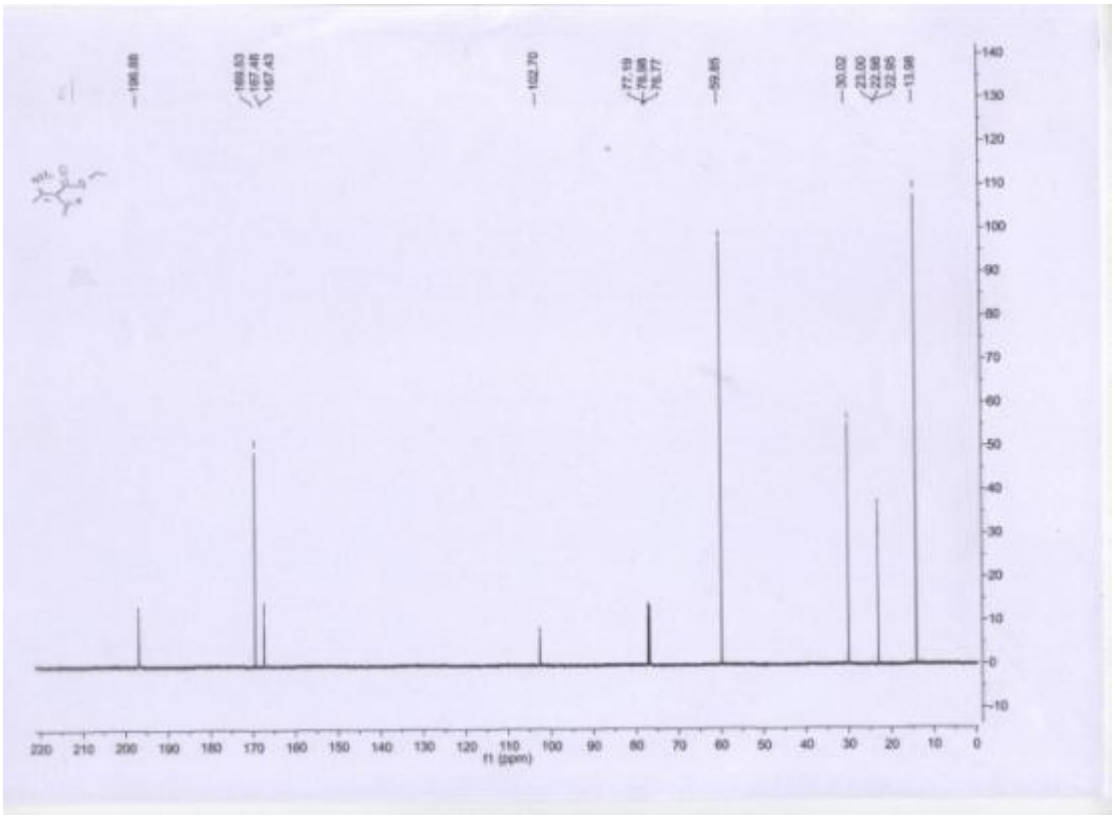
^{13}C NMR spectra for compound **6f**



^{13}C NMR spectra for compound **7g**



^{13}C NMR spectra for compound **10j**



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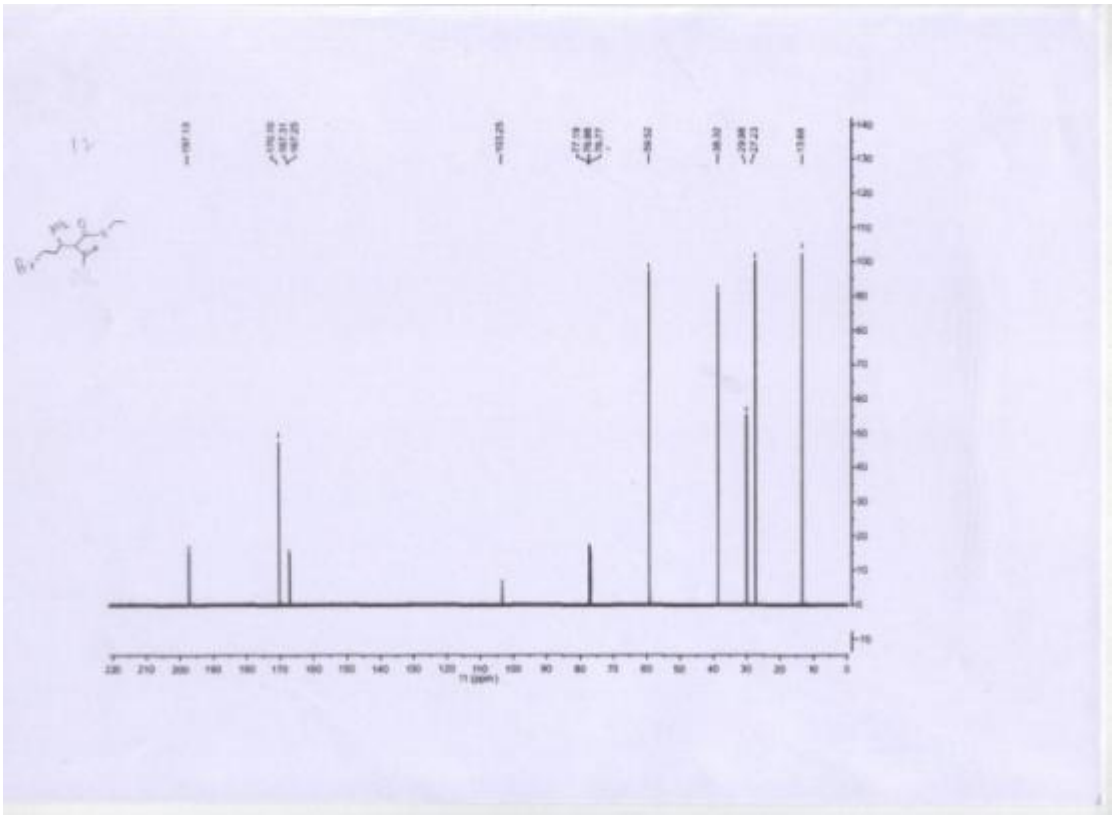
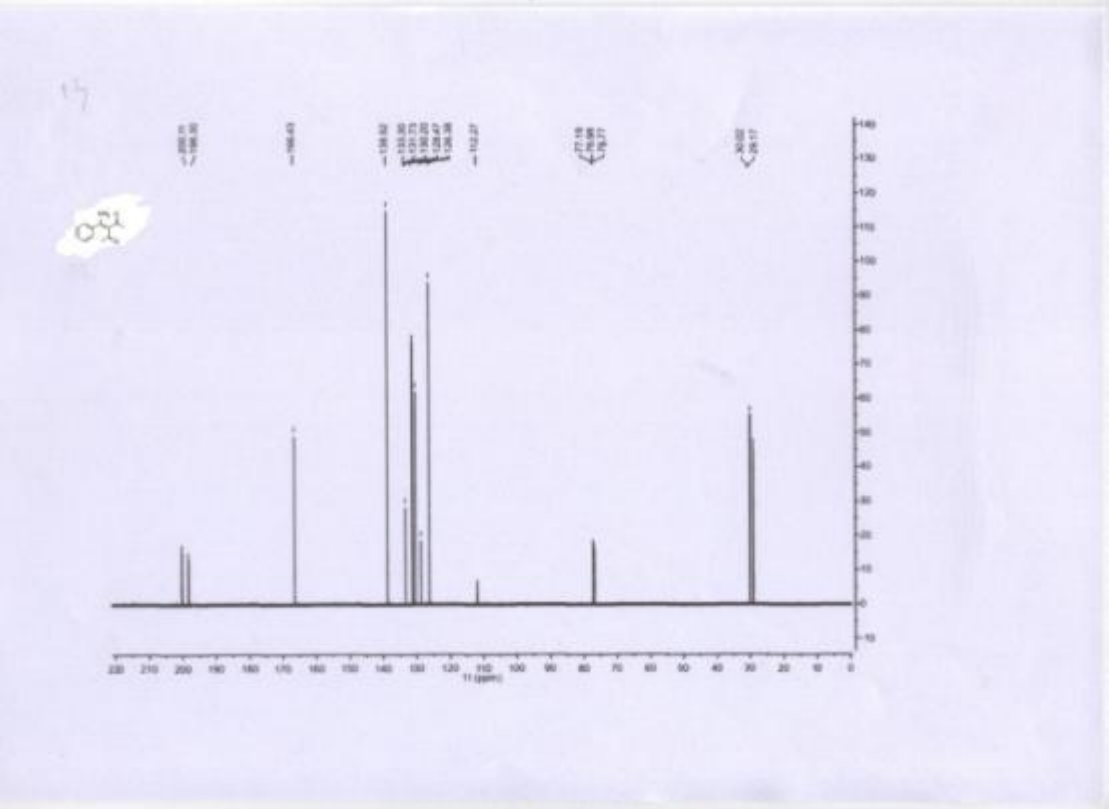


^{13}C NMR spectra for compound 1**2l**



^{13}C NMR spectra for compound **13m**