Triton-X-100 catalyzed synthesis of 1,4-dihydropyridines and their aromatization to pyridines and a new one pot synthesis of pyridines using visible light in aqueous media

Partha Pratim Ghosh, Prasun Mukherjee, Asish R. Das*

Department of Chemistry, University of Calcutta, Kolkata-700009, India.

*Corresponding author's E-mail address: ardchem@caluniv.ac.in, ardas66@rediffmail.com (A R Das)

*Corresponding author Tel.: +913323501014, +919433120265; fax: +913323519754

Electronic Supplementary Information (ESI) :

Experimental procedure:

1. Materials and method:

^{1}H-NMR and ^{13}C-NMR spectral analysis were carried out on Bruker-Advance Digital 300 MHz and 75 MHz instruments; tetramethylsilane (TMS) was used as internal standard. Melting points were checked on a Köfler Block apparatus. Optical images were obtained using a CARL-ZEISS Axi-Observer optical microscope. DLS study was performed in a MALVERN Zetasizer DLS. Merck aluminum-blocked silica gel plates coated with silica gel G were used for analytical TLC and monitored under UV light and also by exposure to iodine vapor. Synthetic grade chemicals from Sigma-Aldrich, Spectrochem and E-Merck were used for carrying out the organic reactions. All the solvents used in the reaction were distilled and dried properly

2. General procedure for the preparation of 1,4-dihydropyridines(4a-z):

The aldehyde(1) (1 mmol) , 1,3-diketone(2) (2 mmol) and ammonium acetate(3) (1.5 mmol) were added to a solution of triton X-100 (10 mol %) in H_2O (3 mL), and the mixture stirred at room temperature. The resulting clear solution, that gradually became

turbid, was stirred for the stipulated time mentioned in Table 2. After completion of the reaction (indicated by TLC), the free flowing solid mass was filtered and washed with water (20 mL) to afford the desired products as pale yellow solids. The product thus obtained was recrystallized from ethanol to get pure compounds as white or pale yellow crystals.

General procedure for the oxidation of 1,4-dihydropyridines to the corresponding pyridines(5a-g):

A solution of 1,4-dihydropyridine (1 mmol) in Triton –X-100(10 mol%) in 3 mL water contained in a 25 mL glass vessel, potassium persulphate(1 mmol) was added .The reaction vessel was placed 10 cm away from the visible light source (150W tungsten lamp of Philips with a cut-off light filter to allow only λ>300 nm), which has a water circulation jacket, maintaining the temperature of the reaction mixture 25^{o}C for the required period of time (TLC) (temperature inside the flask 25^{o}C). After completion of the reaction, the free flowing solid was filtered off and washed with water (20 mL) to afford the desired products with almost 100% yield.

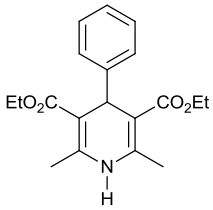
General procedure for the one pot synthesis of pyridines (5a-g):

A solution of aldehyde (1) (1 mmol) , ethyl acetoacetate (2) (2 mmol) and ammonium acetate(3) (1.5 mmol) in triton –X-100(10 mol%) in 3 mL water was taken in a 25 mL glass vessel and to this potassium persulphate(1 mmol) was added. The reaction vessel was placed 10 cm away from the visible light source (150W tungsten lamp of Philips with a cut-off light filter to allow only λ>300 nm), which has a water circulation jacket, maintaining the temperature of the reaction mixture 25^{o}C for the required period of time (TLC) (temperature inside the flask 25^{o}C).After completion of the reaction

(indicated by TLC), the free flowing solid was filtered and washed with water(20 ml) to afford the desired products as pale yellow solids. The product thus obtained was recrystallized from ethanol to get pure compounds as white or pale yellow crystals

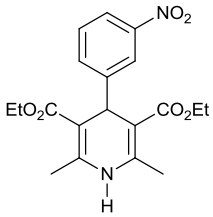
4. Spectral data:

4a. Diethyl 2,6-dimethyl-4-phenyl-1,4-dihydropyridine-3,5-dicarboxylate



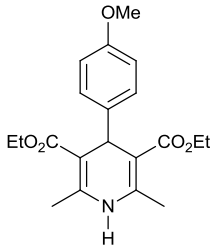
M.P.:158-160^{o}C; **^{1}H NMR ($CDCl_3$, 300MHz): δ** 1.22(t, *J*=9.7Hz, 6H), 2.32(s, 6H), 4.06 (q, *J*=6Hz, 2H), 4.11(q, *J*=6.3Hz, 2H), 4.99(s, 1H), 5.72(s, 1H), 7.09-7.29 (m, 5H); **^{13}C NMR ($CDCl_3$, 75MHz): δ** 14.23, 19.52, 39.66, 59.69, 104.21, 126.07, 127.81, 127.98, 143.79, 145.75, 167.62.

4b. Diethyl 2,6-dimethyl-4-(3-nitrophenyl)-1,4-dihydropyridine-3,5-dicarboxylate



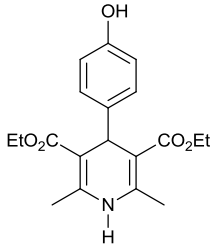
M.P.: 178-180^{o}C; **^{1}H NMR ($CDCl_3$, 300MHz): δ** 1.20(t, *J*=7.4Hz, 6H), 2.35(s, 6H), 4.06(q, *J*=8.4Hz, 2H), 4.10(q, *J*=8.7Hz, 2H), 5.08(s, 1H), 5.88(s, 1H), 7.36(t, *J*=7.9Hz, 1H), 7.63(d, *J*=7.8Hz, 1H,), 7.99(d, *J*=8.1Hz, 1H), 8.11(s, 1H); **^{13}C NMR ($CDCl_3$, 75MHz): δ** 14.19, 19.57, 39.94, 59.95, 103.32, 121.29, 123.08, 128.55, 134.47, 144.67, 148.14, 149.88, 167.08.

4c. Diethyl 4-(4-methoxyphenyl)-2,6-dimethyl-1,4-dihydropyridine-3,5-dicarboxylate



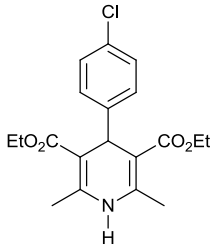
M.P. : 160-162°C ; **^{1}H NMR ($CDCl_3$, 300MHz): δ** 1.22(t, *J*=7.0Hz, 6H), 2.32(s, 6H), 3.75(s, 3H), 4.06(q, *J*=6.3Hz, 2H), 4.11(q, *J*=6.6Hz, 2H), 4.92(s, 1H), 5.61(s, 1H), 6.75(d, *J*=8.4Hz, 2H), 7.18(d, *J*=8.7Hz, ,2H); **^{13}C NMR ($CDCl_3$, 75MHz): δ** 14.27, 19.58, 38.76, 55.14, 59.68, 104.45, 113.20, 128.95, 140.32, 143.47, 157.90, 167.67.

4d. Diethyl 4-(4-hydroxyphenyl)-2,6-dimethyl-1,4-dihydropyridine-3,5-dicarboxylate



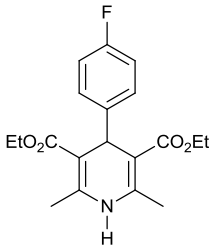
M.P.: 240-242°C ; **^{1}H NMR ($CDCl_3$, 300MHz): δ** 1.19(t, *J*=7.2Hz, 6H), 2.30(s, 6H), 4.03(q, *J*=6.6Hz, 2H), 4.08(q, *J*=6.3Hz, 2H), 4.89(s, 1H), 5.56(s, 1H), 6.63(d, *J*=8.7Hz, 2H), 7.10(d, *J*=8.4Hz, 2H), 9.84(s, 1H) ; **^{13}C NMR ($CDCl_3$, 75MHz): δ** 13.85, 18.49, 38.05, 58.86, 103.11, 114.23, 128.40, 139.09, 144.17, 154.81, 167.51.

4e. Diethyl 4-(4-chlorophenyl)-2,6-dimethyl-1,4-dihydropyridine-3,5-dicarboxylate



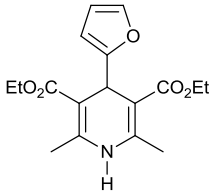
M.P.: 155-158°C; **^{1}H NMR (DMSO, 300MHz): δ** 1.08(t, *J*=7.1Hz, 6H), 2.21(s, 6H), 3.94(q, *J*=8.7Hz, 4H), 4.79(s, 1H), 7.11(d, *J*=8.4Hz, 2H), 7.21(d, J=8.1Hz, 2H), 8.81(s, 1H); **^{13}C NMR (DMSO, 75MHz): δ** 14.25, 18.32, 59.17, 101.59,117.80, 127.91, 129.31, 130.51, 145.74, 147.20, 166.85.

4f. Diethyl 4-(4-fluorophenyl)-2,6-dimethyl-1,4-dihydropyridine-3,5-dicarboxylate



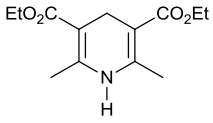
M.P.: 154-157°C; **^{1}H NMR ($CDCl_3$, 300MHz): δ** 1.13(t, *J*=7.2Hz, 6H), 2.22(s. 6H), 3.94(q, *J*=5.7Hz, 2H), 4.00(q, *J*=8.7Hz, 2H), 4.85(s, 1H), 5.57(s, 1H), 6.74-6.80(m, 2H), 7.10-7.15(m, 2H); **^{13}C NMR ($CDCl_3$, 75MHz): δ** 14.22, 19.54, 39.03, 59.74, 104.16, 114.45, 129.36, 129.47, 143.67, 162.30, 167.49.

4g. Diethyl 4-(furan-2-yl)-2,6-dimethyl-1,4-dihydropyridine-3,5-dicarboxylate



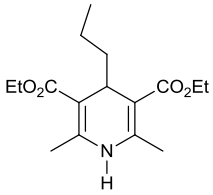
M.P.: 165-168°C; **^{1}H NMR ($CDCl_3$, 300MHz): δ** 1.16-1.41(m, 6H), 2.24-2.30(m, 6H), 4.07(q, *J*=9Hz, 2H), 4.14(q, *J*=8.4Hz, 2H), 5.11(s, 1H), 5.86-6.18(m, 3H), 7.13-7.19(m, 2H,).; **^{13}C NMR ($CDCl_3$, 75MHz): δ** 14.23, 19.52, 33.36, 59.79, 100.23, 104.21, 110.11, 140.79, 143.71, 158.75 167.46.

4h. Diethyl 2,6-dimethyl-1,4-dihydropyridine-3,5-dicarboxylate



M.P.: 126-128°C; **^{1}H NMR ($CDCl_3$, 300MHz): δ** 1.16-1.19(m, 6H), 2.10(s, 6H), 3.17(s, 2H,), 4.05(q, *J*=6.9Hz, 4H), 5.20 (br, 1H); **^{13}C NMR ($CDCl_3$, 75MHz): δ** 14.46, 19.14, 24.84, 61.44, 99.49, 123.14, 144.82, 162.17, and 165.90.

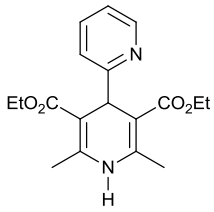
4i. Diethyl 2,6-dimethyl-4-propyl-1,4-dihydropyridine-3,5-dicarboxylate



M.P.: 126-128°C; **^{1}H NMR ($CDCl_3$, 300MHz): δ** 0.85(t, *J*=7.5Hz, 3H), 1.15-1.30(m, 10H), 2.27(s, 6H), 3.91(t, *J*=5.4Hz, 1H,), 4.13(q, *J*=6.9Hz, 2H), 4.18(q, *J*=6.3Hz, 2H),

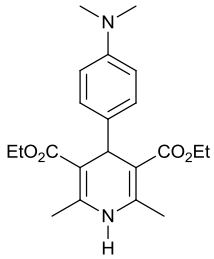
5.71(s, 1H). **^{13}C NMR ($CDCl_3$, 75MHz): δ** 14.25, 17.99, 19.35, 32.70, 39.27, 59.52, 103.34, 142.66, 144.61 and 168.15.

4j. Diethyl 2',6'-dimethyl-1',4'-dihydro-[2,4'-bipyridine]-3',5'-dicarboxylate



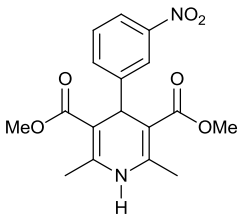
M.P.: 194-197^{o}C; **^{1}H NMR ($CDCl_3$, 300MHz): δ** 1.18(t, *J*=6.5Hz, 6H), 2.22(s, 6H), 4.06(q, *J*=8.7Hz, 4H), 5.18(s, 1H), 7.14(t, *J*=6.1Hz, 1H), 7.39(d, *J*=7.5Hz, 1H,), 7.55-7.61(m, 1H), 8.47(d, J=3.9Hz, 1H,), 9.05(s, br ,1H). **^{13}C NMR ($CDCl_3$, 75MHz): δ** 14.23, 19.52, 39.36, 59.72, 104.22, 123.21, 124.71, 136.11, 143.71, 149.79, 158.75, and 167.46.

4k. Diethyl 4-(4-(dimethylamino) phenyl)-2,6-dimethyl-1,4-dihydropyridine-3,5-dicarboxylate



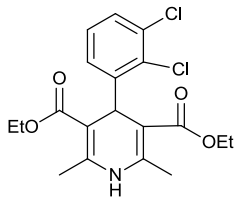
M.P.: 227-230^{o}C; **^{1}H NMR (DMSO, 300MHz): δ** 1.09(t, *J*=7.0Hz, 6H), 2.19(s, 6H), 2.75(s, 6H), 3.94(q, *J*=6.6Hz, 4H), 4.68(s, 1H), 6.51(d, *J*=8.7Hz, 2H), 6.90(d, *J*=8.4Hz, 2H,), 8.64(s, 1H), **^{13}C NMR (DMSO, 75MHz): δ** 14.29, 18.24, 38.78, 58.90, 102.41, 112.20, 117.75, 127.86, 136.53, 144.61, 148.90, 167.22 .

4l. D**imethyl 2,6-dimethyl-4-(3-nitrophenyl)-1,4-dihydropyridine-3,5-dicarboxylate**



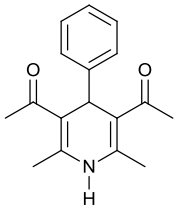
M.P.: 172-174^{o}C; **^{1}H NMR ($CDCl_3$, 300MHz): δ** 2.25(s, 6H), 3.50(s, 6H), 5.00(s, 1H), 6.16(s, 1H), 7.29(s, *J*=7.8Hz, 1H), 7.53(s, *J*=7.2Hz, 1H), 7.89(s, *J*=7.8Hz, 1H), 7.99(s, 1H); **^{13}C NMR ($CDCl_3$, 75MHz): δ** 19.45, 29.66, 39.63, 51.13, 102.95, 121.38, 122.69, 128.74, 134.20, 145.25, 148.35, 149.63, 167.62.

4m. Diethyl 4-(2,3-dichlorophenyl)-2,6-dimethyl-1,4-dihydropyridine-3,5-dicarboxylate



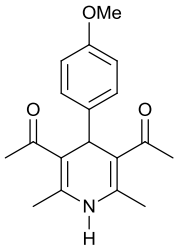
M.P.: 187-189^{o}C; **^{1}H NMR ($CDCl_3$, 300MHz):** δ 1.14(t, *J*=8.2Hz, 6H), 2.22(s, 6H), 3.92(q, *J*=5.2Hz, 4H), 4.74(s, 1H), 5.58(s, 1H), 6.69(d, *J*=8.7Hz, 1H), 7.00(d, *J*=8.7Hz, 1H), 7.28-7.34(m, 1H); **^{13}C NMR ($CDCl_3$, 75MHz): δ** 14.11**,** 19.17, 40.04, 59.05, 104.22, 121.26, 123.08, 128.55, 134.46, 140.98, 142.91,144.67, 148.61, 149.68, 156.30, 167.62.

4n. 1,1'-(2,6-dimethyl-4-phenyl-1,4-dihydropyridine-3,5-diyl)diethanone



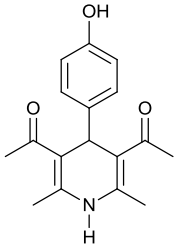
M.P.: 184-186^{o}C; **^{1}H NMR ($CDCl_3$, 300MHz): δ** 2.31(s, 6H), 2.32(s, 6H), 5.11(s, 1H), 7.13-7.26(m, 6H); **^{13}C NMR ($CDCl_3$, 75MHz): δ** 20.25, 30.07, 40.05, 113.64, 126.58, 127.38, 128.45, 143.28, 146.01, and 198.09

4o. 1,1'-(4-(4-methoxyphenyl)-2,6-dimethyl-1,4-dihydropyridine-3,5-diyl)diethanone



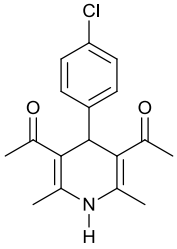
M.P.: 176-179^{o}C; **^{1}H NMR ($CDCl_3$, 300MHz): δ** 2.26(s, 6H), 2.37(s, 6H), 3.74-3.84(s, 3H), 5.03(s, 1H), 5.93(s, 1H), 6.76(d, *J*=8.7Hz, 2H), 7.13(d, *J*=8.7Hz, 2H); **^{13}C NMR ($CDCl_3$, 75MHz): δ** 20.42, 30.06, 39.25, 55.16, 113.88, 128.48, 138.38, 142.67, 143.85, 158.19, 198.10.

4p. 1,1'-(4-(4-hydroxyphenyl)-2,6-dimethyl-1,4-dihydropyridine-3,5-diyl)diethanone



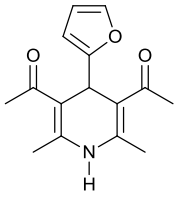
M.P.: 215-218^{o}C; **^{1}H NMR (DMSO, 300MHz): δ** 2.09(s, 6H), 2.16(s, 6H), 4.80(s, 1H), 6.51(d, *J*=8.7Hz, 2H), 6.85(d, *J*=8.4Hz, 2H,), 8.72(s, 1H), 9.05(s, 1H). **^{13}C NMR (DMSO, 75MHz): δ** 19.06, 30.04, 38.17, 114.97, 128.16, 137.88, 143.82, 155.65, 161.93, and 196.75.

4q. 1,1'-(4-(4-chlorophenyl)-2,6-dimethyl-1,4-dihydropyridine-3,5-diyl)diethanone



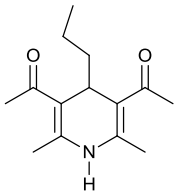
M.P.: 151-154^{o}C; **^{1}H NMR ($CDCl_3$, 300MHz): δ** 2.28(s, 6H), 2.35(s, 6H), 5.34(s, 1H), 6.14(s, 1H), 7.35-7.37(d, *J* =6Hz, 2H), 7.47-7.50 (m, 2H) ; **^{13}C NMR ($CDCl_3$, 75MHz): δ** 20.35, 30.18, 39.24, 113.53, 128.51, 128.84, 132.20, 143.34, 144.41, and 197.64.

4r. 1,1'-(4-(furan-2-yl)-2,6-dimethyl-1,4-dihydropyridine-3,5-diyl)diethanone



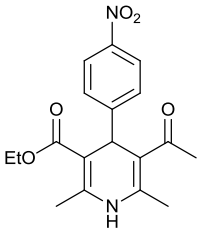
M.P.: 184-187^{o}C; **^{1}H NMR ($CDCl_3$, 300MHz): δ** 2.33- 2.43(m, 12H), 5.16(s, 1H), 5.90(s, 1H), 6.22(s, 1H), 6.40(s, 1H), 7.26(s, 1H); **^{13}C NMR ($CDCl_3$, 75MHz): δ** 19.42, 33.96, 57.96, 100.23 104.22, 112.20, 140.59, 143.51, 159.75, 196.75.

4s. 1,1'-(2,6-dimethyl-4-propyl-1,4-dihydropyridine-3,5-diyl)diethanone



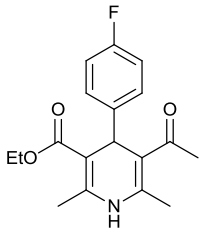
M.P.: 129-132^{o}C; **^{1}H NMR ($CDCl_3$, 300MHz): δ** 0.79(t, *J*=6.3Hz, 3H), 1.13-1.18(m, 4H), 2.26(s, 6H), 2.28(s, 6H), 3.84(t, *J*=5.6Hz, 1H), 6.84(s, 1H); **^{13}C NMR ($CDCl_3$, 75MHz): δ** 14.23, 19.79, 29.32, 34.59, 39.58, 113.05, 142.78, 143.42, 198.55.

4t. Ethyl 5-acetyl-2,6-dimethyl-4-(4-nitrophenyl)-1,4-dihydropyridine-3-carboxylate



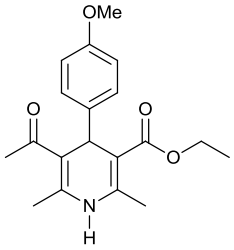
M.P.:169-171^{o}C **; ^{1}H NMR ($CDCl_3$, 300MHz): δ** 1.26(t, *J*=7.1Hz, 3H), 2.18(s, 3H), 2.33(s, 6H), 4.14(q, *J*=7.5Hz, 2H), 5.15(s, 1H), 6.32(s, 1H), 7.43(d, *J*=8.7Hz, 2H), 8.06(d, *J*=8.7Hz, 2H); **^{13}C NMR ($CDCl_3$, 75MHz): δ** 14.28, 19.49, 20.35, 30.05, 40.22, 60.16, 103.62, 111.68, 123.56, 128.57, 144.59, 146.39, 153.95, 167.03, and 197.52.

4u. Ethyl 5-acetyl-4-(4-fluorophenyl)-2,6-dimethyl-1,4-dihydropyridine-3-carboxylate



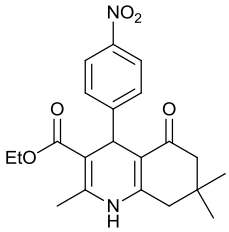
M.P.: 176-179^{o}C **; ^{1}H NMR ($CDCl_3$, 300MHz): δ** 1.27(t, *J*=7.1Hz, 3H), 2.16(s, 3H), 2.28-2.35(m, 6H), 4.16(q, *J*=7.2Hz, 2H), 4.99(s, 1H), 6.88-6.93(m, 2H,),7.20-7.26(m, 2H); **^{13}C NMR ($CDCl_3$, 75MHz): δ** 14.36, 19.72, 20.34, 29.62, 39.63, 59.99, 104.89, 112.13,114.85, 115.13, 129.17, 142.46, 143.37, 167.46, 198.58.

4v. Ethyl 5-acetyl-4-(4-methoxyphenyl)-2,6-dimethyl-1,4-dihydropyridine-3-carboxylate



M.P.: 187-190^{o}C; **^{1}H NMR ($CDCl_3$, 300MHz): δ** 1.26 (t, *J*=7.2Hz, 3H), 2.13(s, 3H), 2.25(s, 3H), 2.32(s, 3H), 3.72(s, 3H), 4.14(q, *J*=7.8Hz, 2H), 4.92(s, 3H), 5.74(br, 1H), 6.73-6.76(m, 2H), 7.14-7.17(m, 2H). **^{13}C NMR ($CDCl_3$, 75MHz): δ** 14.37, 19.71, 20.28, 29.48, 39.50, 55.17, 59.87, 105.24, 112.19, 113.66, 128.75, 139.09, 142.98, 158.21, 167.62 and 198.91.

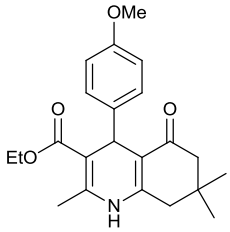
4w. Ethyl 2,7,7-trimethyl-4-(4-nitrophenyl)-5-oxo-1,4,5,6,7,8-hexahydroquinoline-3-carboxylate



M.P.: 246-249^{o}C**; ^{1}H NMR (DMSO, 300MHz): δ** 0.77(s, 3H), 0.96(s, 3H), 1.06(t, *J*=7.0Hz, 3H), 1.90-2.22(m, 2H), 2.27(s, 3H), 2.37-2.46(m, 2H), 3.92(q, *J*=6.6Hz, 2H),

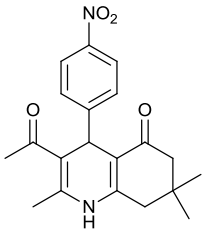
4.93(s, 1H),7.37(d, *J*=8.7Hz, 2H,), 8.04(d, *J*=8.7Hz, 2H,), 9.20(s, 1H), **^{13}C NMR (DMSO, 75MHz): δ** 14.16,18.42, 26.52, 29.08, 32.22, 36.71, 50.14, 59.33, 102.46, 109.11, 123.24, 128.84, 146.24, 150.17, 155.07, 161.96, 166.48, 194.32.

4x. Ethyl 4-(4-methoxyphenyl)-2,7,7-trimethyl-5-oxo-1,4,5,6,7,8-hexahydroquinoline-3-carboxylate



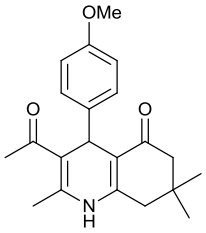
M.P.: 259-262^{o}C **; ^{1}H NMR (DMSO, 300MHz): δ** 0.96(s, 3H), 1.07- 1.18(m, 6H), 1.89- 2.46(m, 7H), 3.64(s, 3H), 3.91(q, *J*=7.1Hz, 2H), 4.74(s, 1H), 6.68(d, *J*=8.4Hz, 2H), 6.99(d, *J*=8.4Hz, 2H), 8.98(s, 1H). **^{13}C NMR (DMSO, 75MHz): δ** 14.28, 18.36, 26.60, 29.24, 32.23, 35.00, 50.37, 54.95, 59.09, 110.28, 113.18, 117.80, 128.48, 140.11, 144.72, 149.33, 161.98, 167.03, and 194.36.

4y. 3-acetyl-2,7,7-trimethyl-4-(4-nitrophenyl)-4,6,7,8-tetrahydroquinolin-5(1H)-one



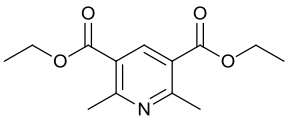
M.P.:173-176^{o}C**; ^{1}H NMR (DMSO, 300MHz): δ** 0.75(s, 3H), 0.98(s, 3H), 1.95-2.49(m, 10H), 5.06(s, 1H), 7.41(d, *J*=8.7Hz, 2H,), 8.08(d, *J*=8.5Hz, 2H), 9.23(s, 1H). **^{13}C NMR (DMSO, 75MHz): δ** 19.39, 26.36, 29.12, 30.35, 32.22, 36.57, 50.20, 109.73, 112.10, 123.43, 128.75, 142.75, 145.63, 149.87, 161.96, 194.31and 196.49.

4z. 3-acetyl-4-(4-methoxyphenyl)-2,7,7-trimethyl-4,6,7,8-tetrahydroquinolin-5(1H)-one



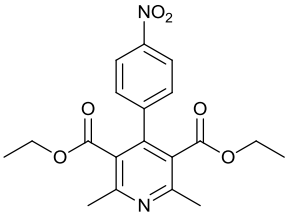
M.P.:189-191^{o}C; **^{1}H NMR (DMSO, 300MHz): δ** 0.76(s, 3H), 0.98(s, 3H), 1.93-2.48(m, 10H), 3.64(s, 3H), 4.84(s, 1H), 6.68-6.76(m, 2H), 7.02-7.08(m, 2H), 9.02(s, 1H). **^{13}C NMR (DMSO, 75MHz): δ** 19.11, 26.57, 29.71, 31.93, 35.43, 50.36, 54.89, 111.12, 112.98, 112.64, 117.75, 128.47, 139.29, 144.04, 148.70, 157.14, 194.41and 197.40.

5a. Diethyl 2,6-dimethylpyridine-3,5-dicarboxylate



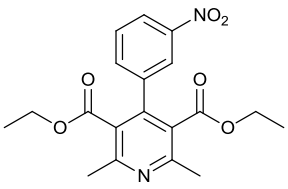
^{1}H NMR (DMSO, 300MHz): δ = 1.33 (t, *J* = 7.1Hz, 6H), 2.16 (s, 6H), 4.21 q, *J* = 7.1Hz, 4H), 7.45(s, 1H);

5b. Diethyl-4-(4-nitrophenyl)-2,6-dimethylpyridine-3,5-dicarboxylate



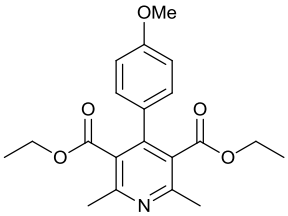
^{1}H NMR (DMSO, 300MHz): δ 1.29 (t, *J* = 7.1Hz, 6H), 2.63 (s, 6H), 4.05 (q, *J* = 7.1 Hz, 4H), 7.11 (d, *J* = 8.2 Hz), 8.22 (d, *J* = 8.2 Hz, 2H).

5c. Diethyl-4-(3-nitrophenyl)-2,6-dimethylpyridine-3,5-dicarboxylate



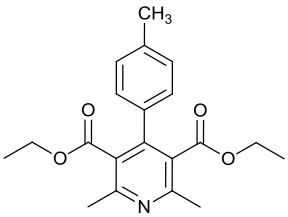
^{1}H NMR (DMSO, 300MHz): δ = 1.24 (t, *J* = 7.1Hz, 6H), 2.69 (s, 6H), 4.26 (q, *J* = 7.1Hz, 4H), 7.57–8.28 (m, 4H).

5d.Diethyl-4-(4-methoxyphenyl)-2,6-dimethylpyridine-3,5-dicarboxylate



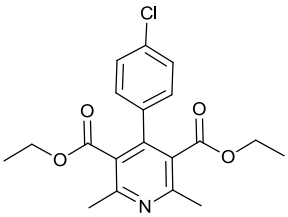
^{1}H NMR (DMSO, 300MHz): δ = 1.22 (t, *J* = 7.1Hz, 6H), 2.69 (s, 6H), 3.86 (s, 3H), 4.27 (q, *J* = 7.1Hz, 4H), 6.91 (d, *J* = 8.5Hz), 7.11 (d, *J* = 8.5Hz).

5e. Diethyl-4-(4-methylphenyl)-2,6-dimethylpyridine-3,5-dicarboxylate



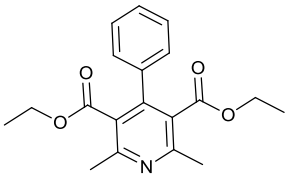
^{1}H NMR (DMSO, 300MHz): δ = 1.03 (t, *J* = 7.1Hz, 6H), 2.05 (s, 3H), 2.60 (s, 6H), 4.18 (q, *J* = 7.1Hz, 4H), 7.10 (d, *J* = 6.7Hz), 7.33 (d, *J* = 6.7Hz).

5f. Diethyl-4-(4-chlorophenyl)-2,6-dimethylpyridine-3,5-dicarboxylate



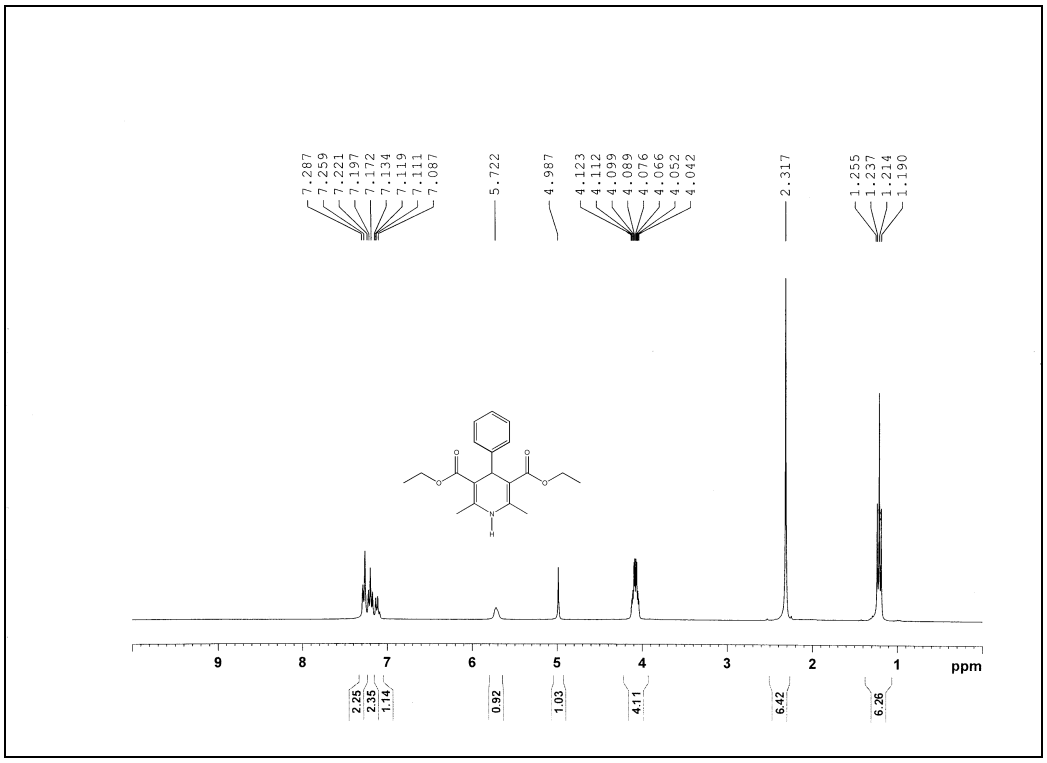
^{1}H NMR (DMSO, 300MHz): δ = 1.22 (t, *J* = 7.1Hz, 6H), 2.60 (s, 6H), 4.23 (q, *J*=7.1Hz, 4H), 7.12 (d, *J* = 8.9 Hz), 7.32 (d, *J* = 8.9 Hz).

5g. Diethyl-4-phenyl-2,6-dimethylpyridine-3,5-dicarboxylate

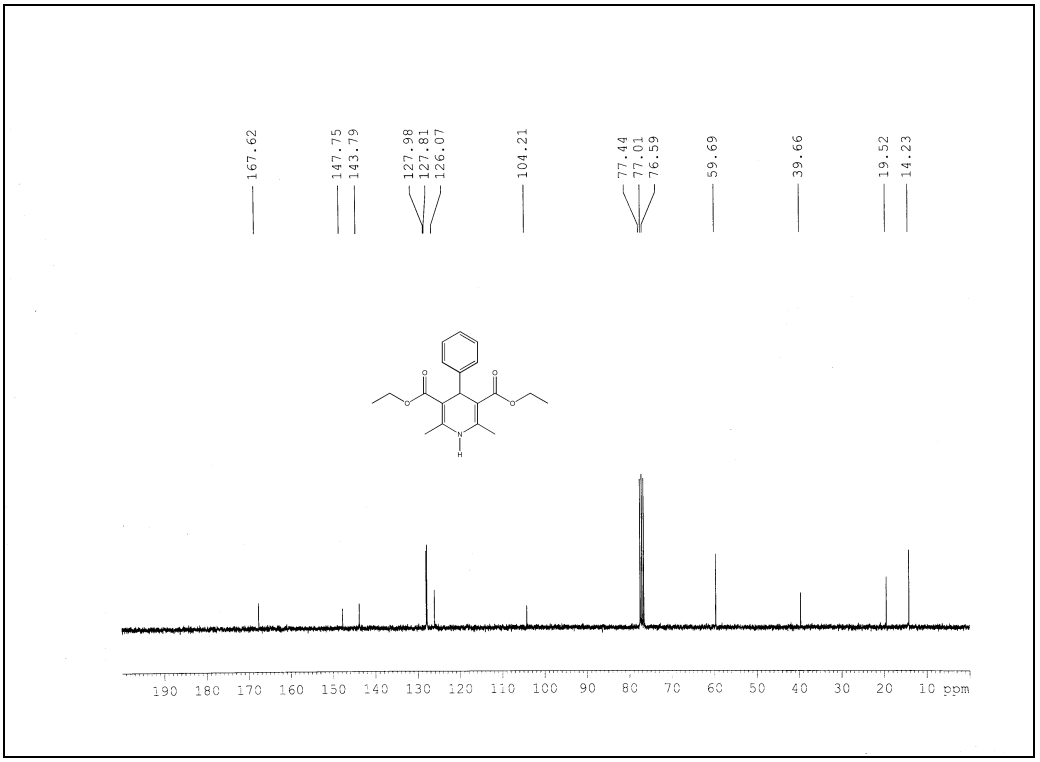


^{1}H NMR (DMSO, 300MHz): δ = 1.22 (t, *J* = 7.1Hz, 6H), 2.67 (s, 6H), 4.27 (q, *J* = 7.1 Hz, 4H), 7.18-7.23 (m, 2H), 7.30-7.32 (m, 3H).

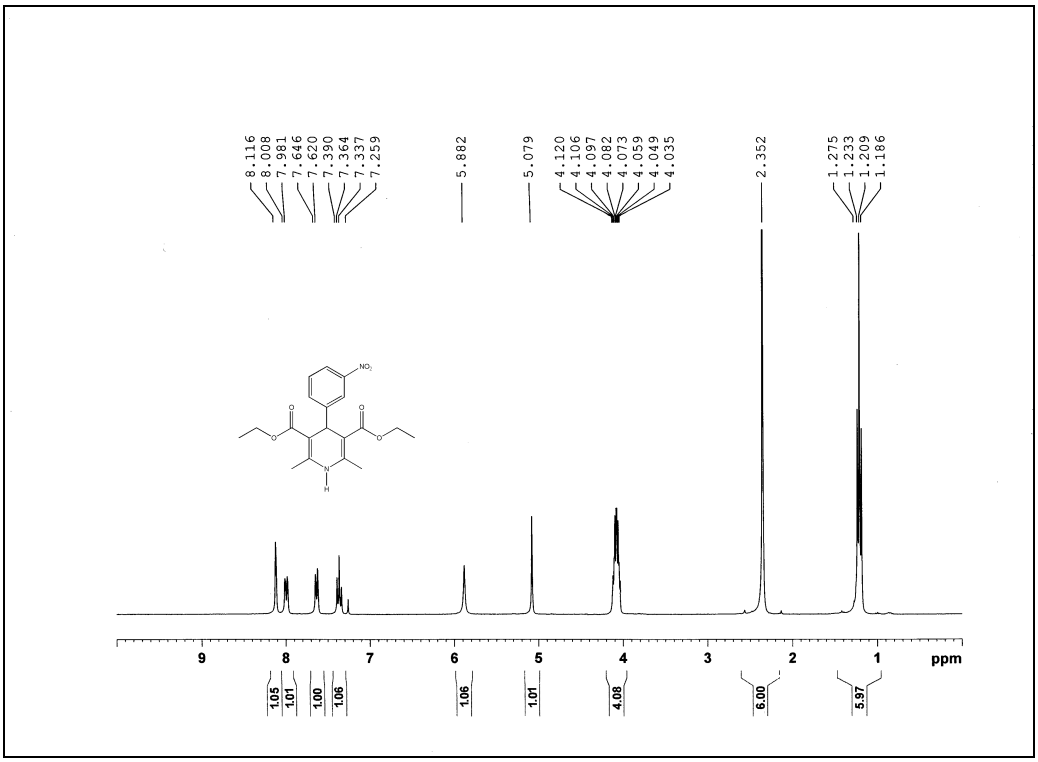
5. Spectra:



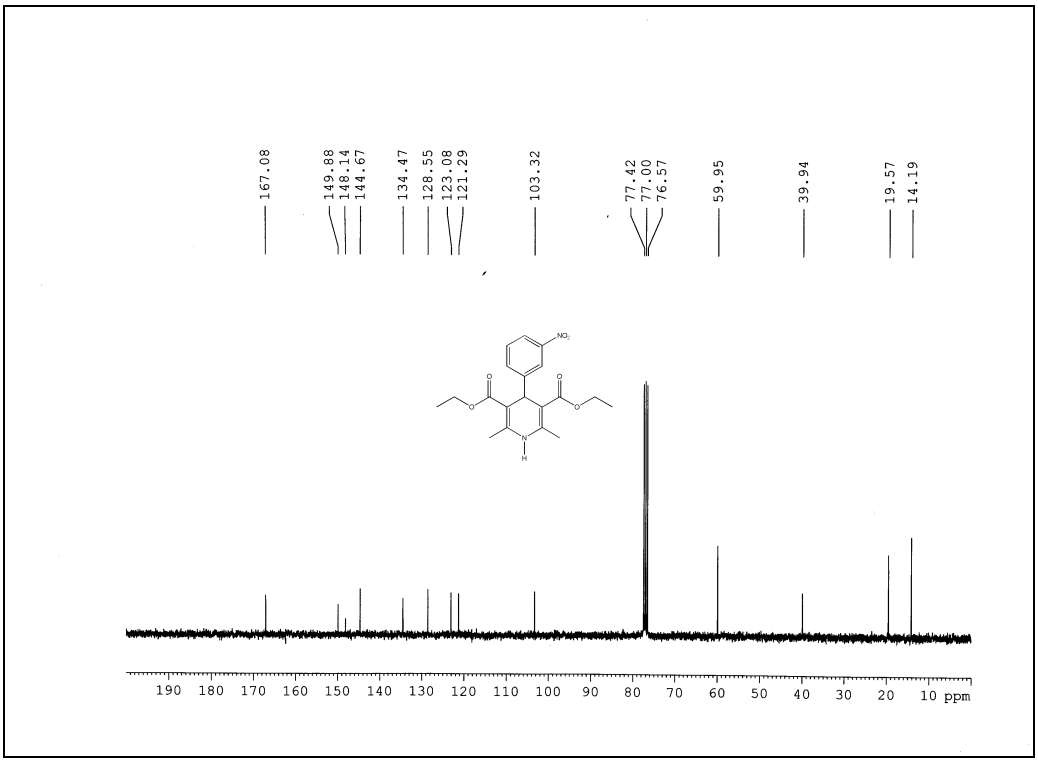
^{1}H NMR of 4a



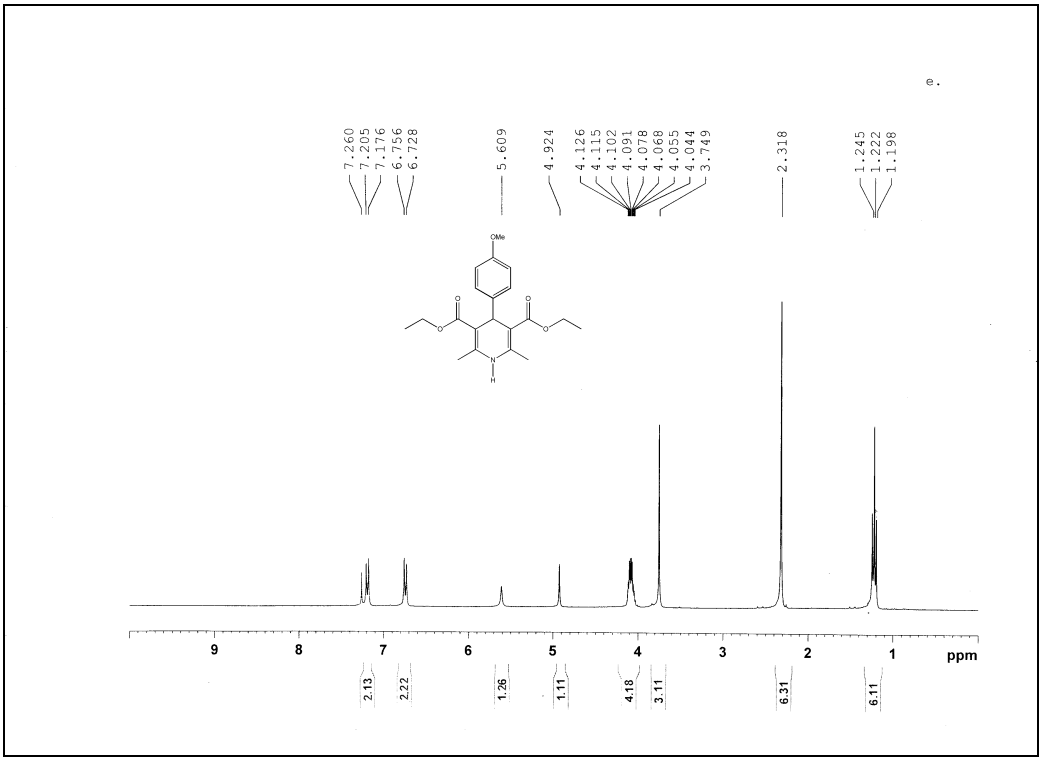
^{13}C NMR of 4a



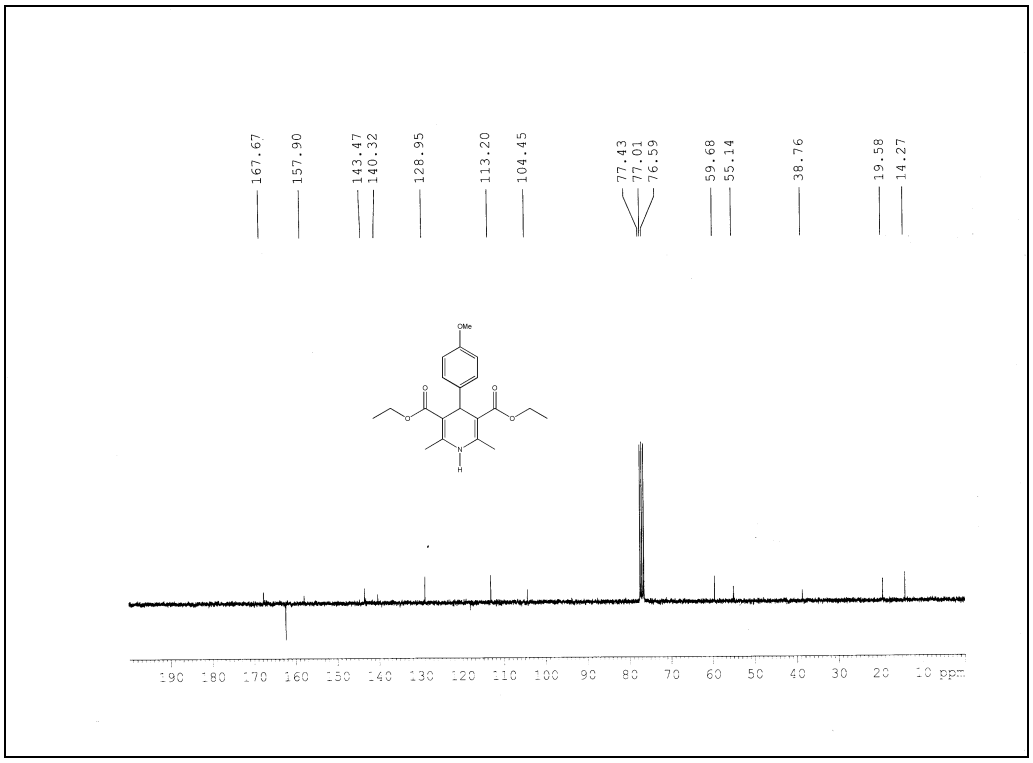
^{1}H NMR of 4b



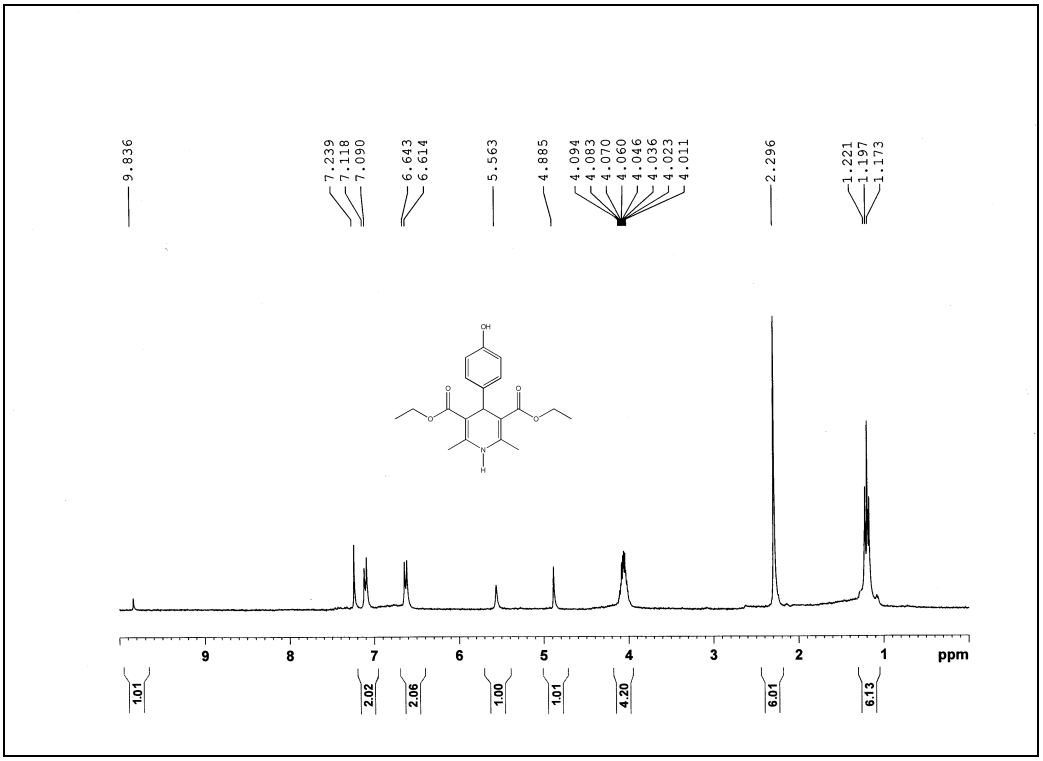
^{13}C NMR of 4b



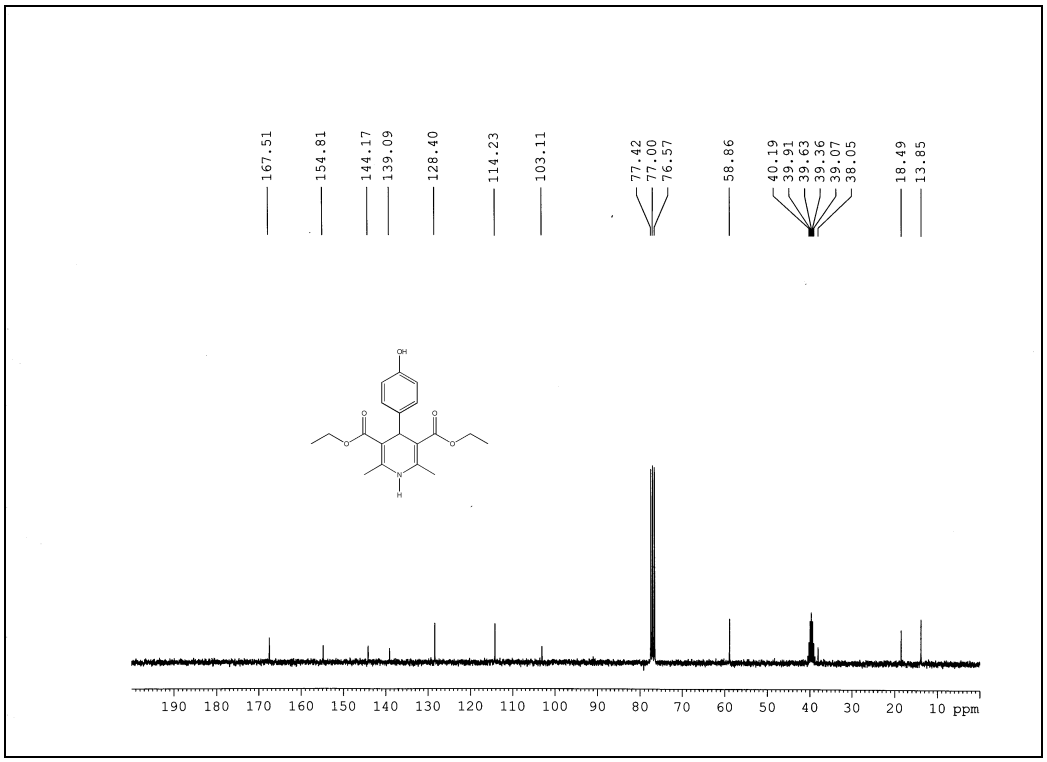
^{1}H NMR of 4c



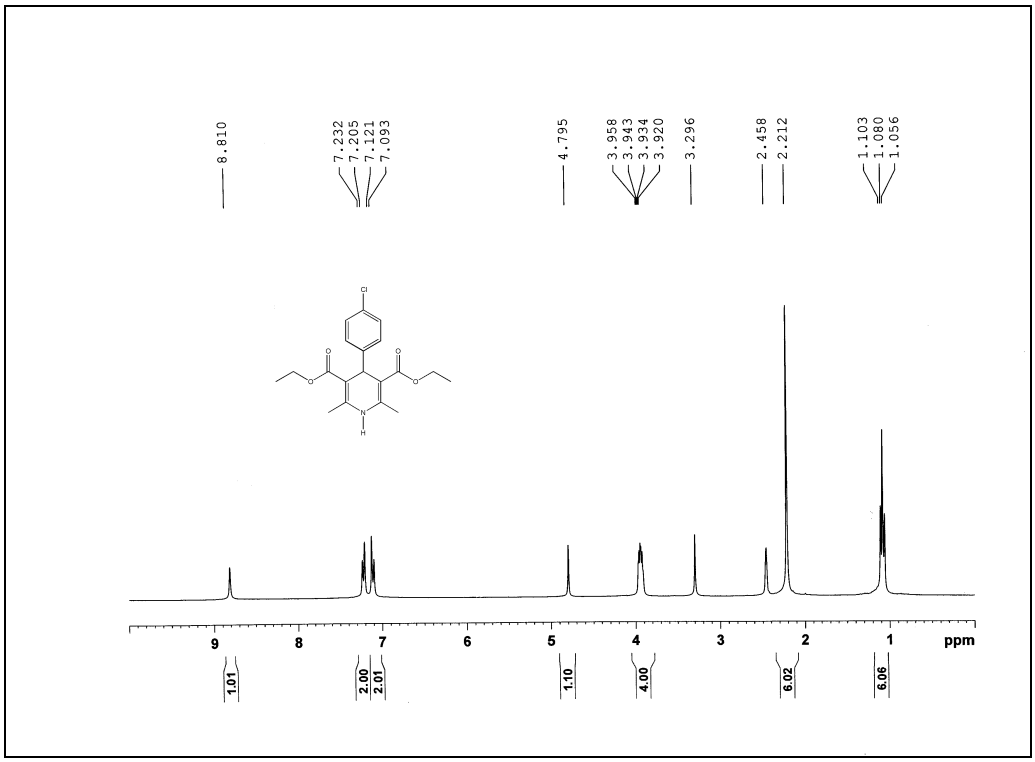
^{13}C NMR of 4c



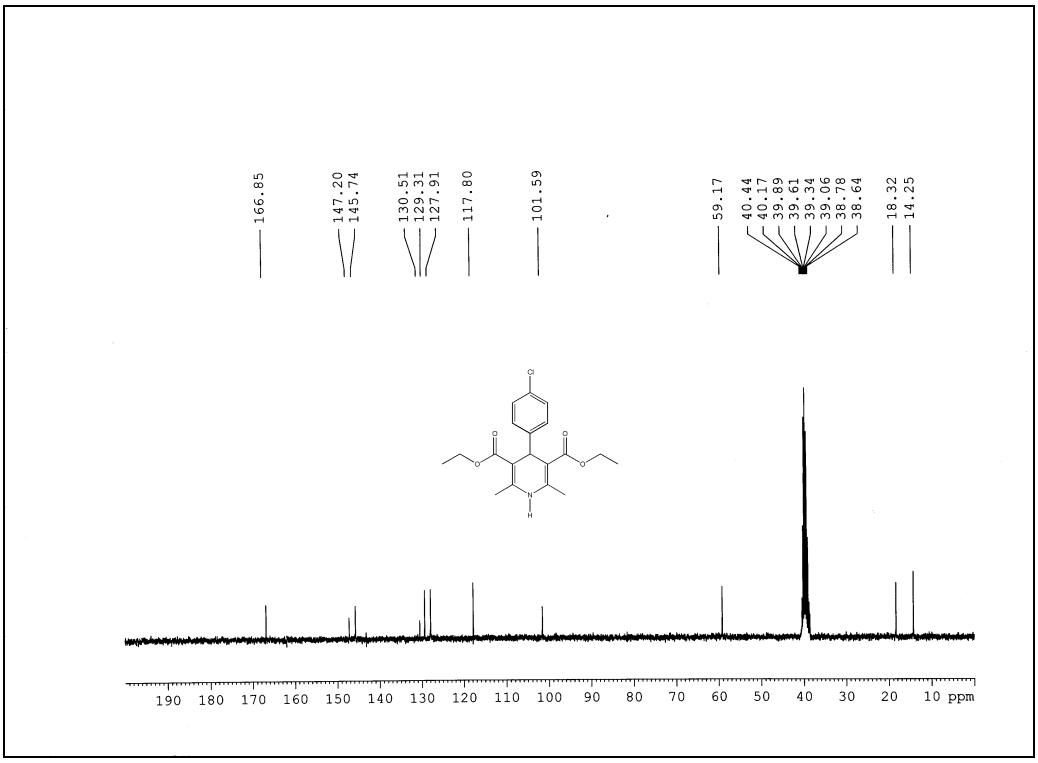
^{1}H NMR of 4d



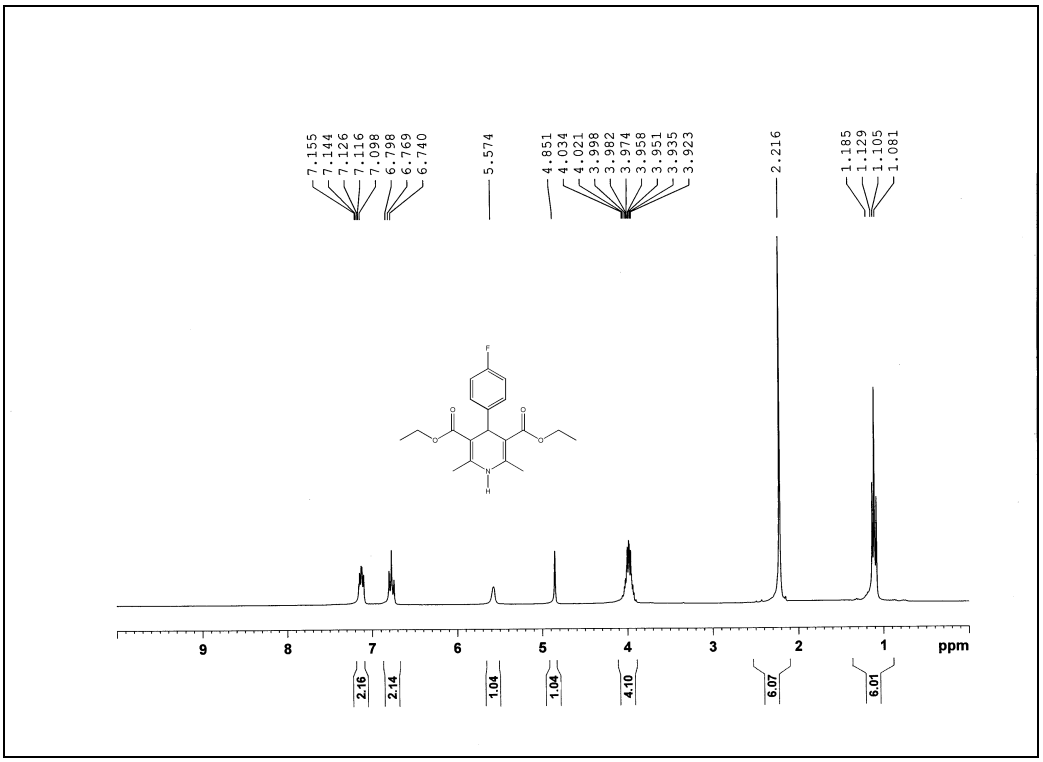
^{13}C NMR of 4d



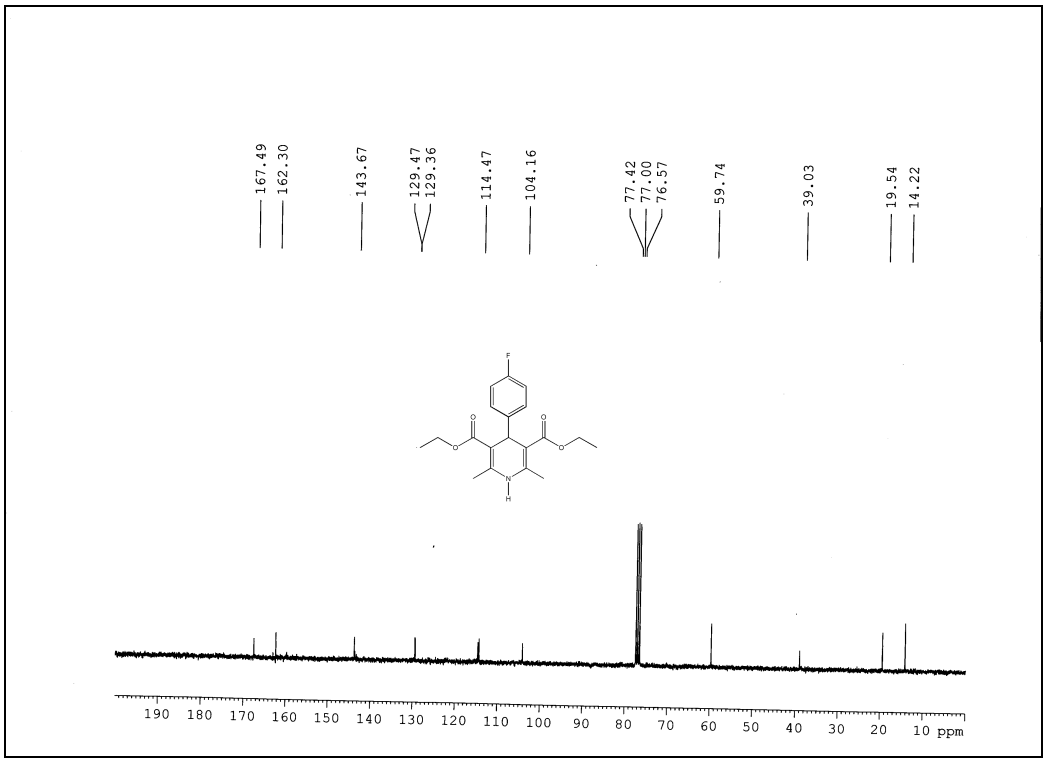
^{1}H NMR of 4e



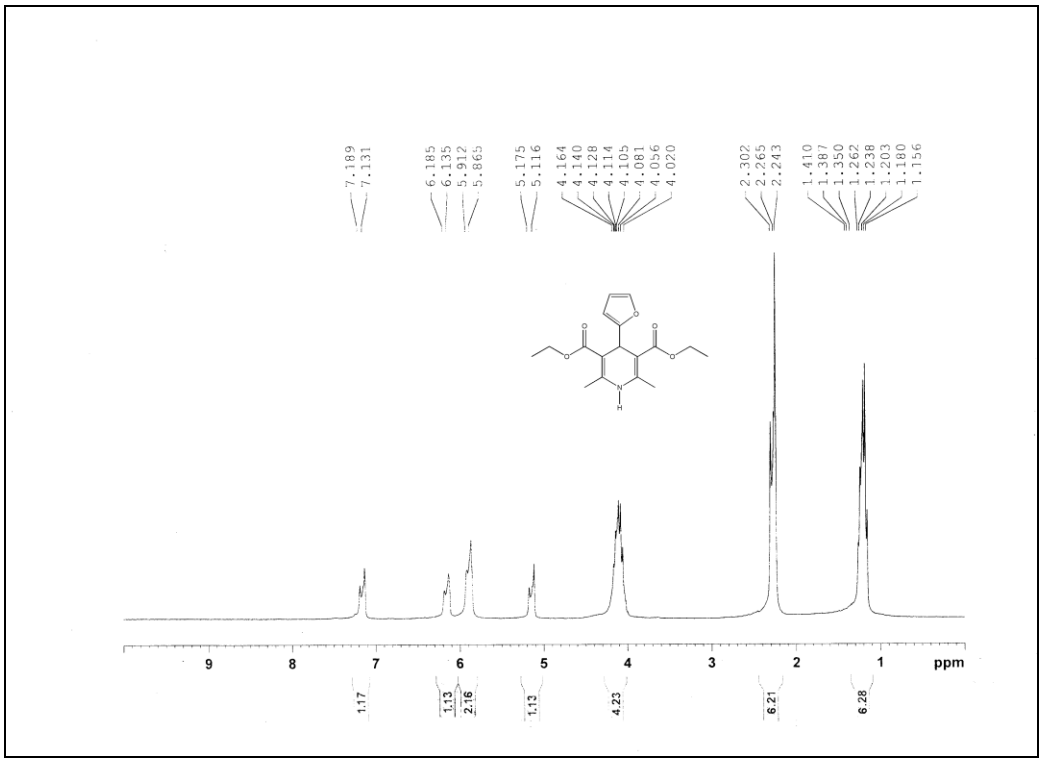
^{13}C NMR of 4e



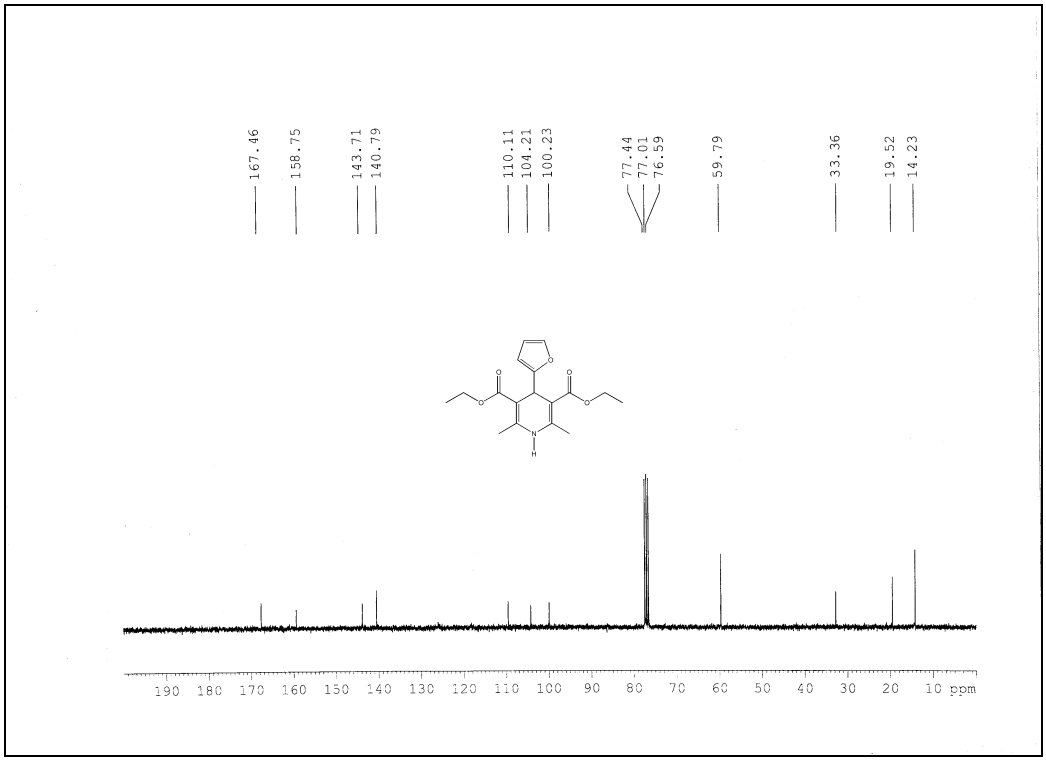
^{1}H NMR of 4f



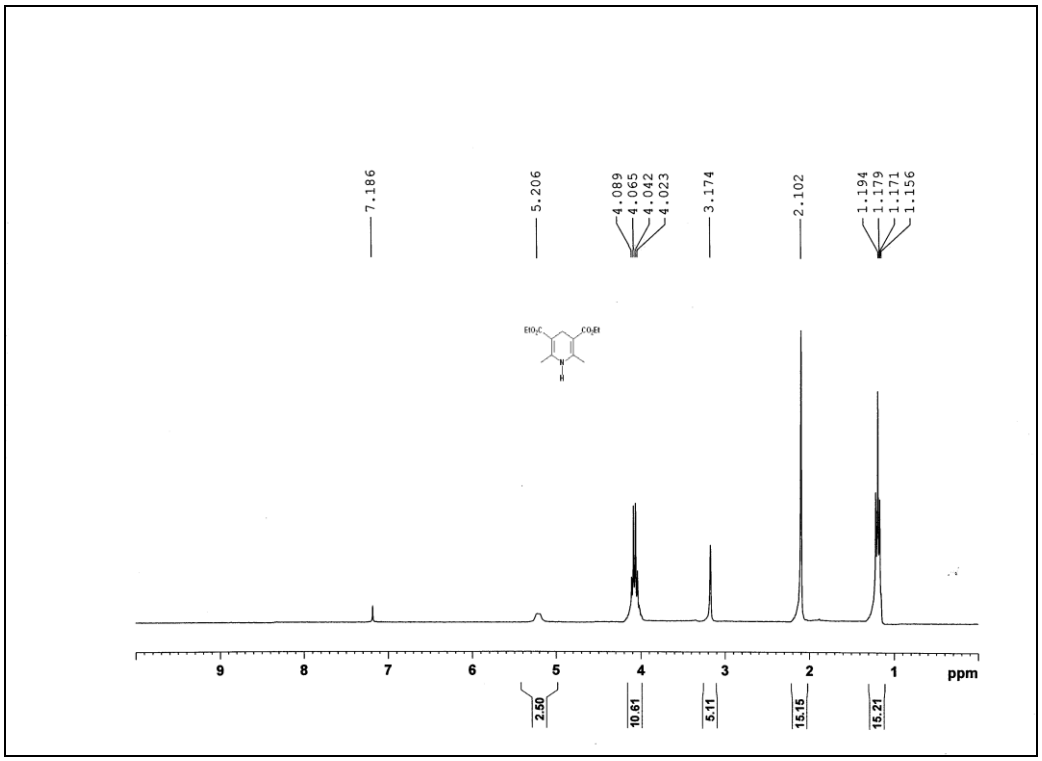
^{13}C NMR of 4f



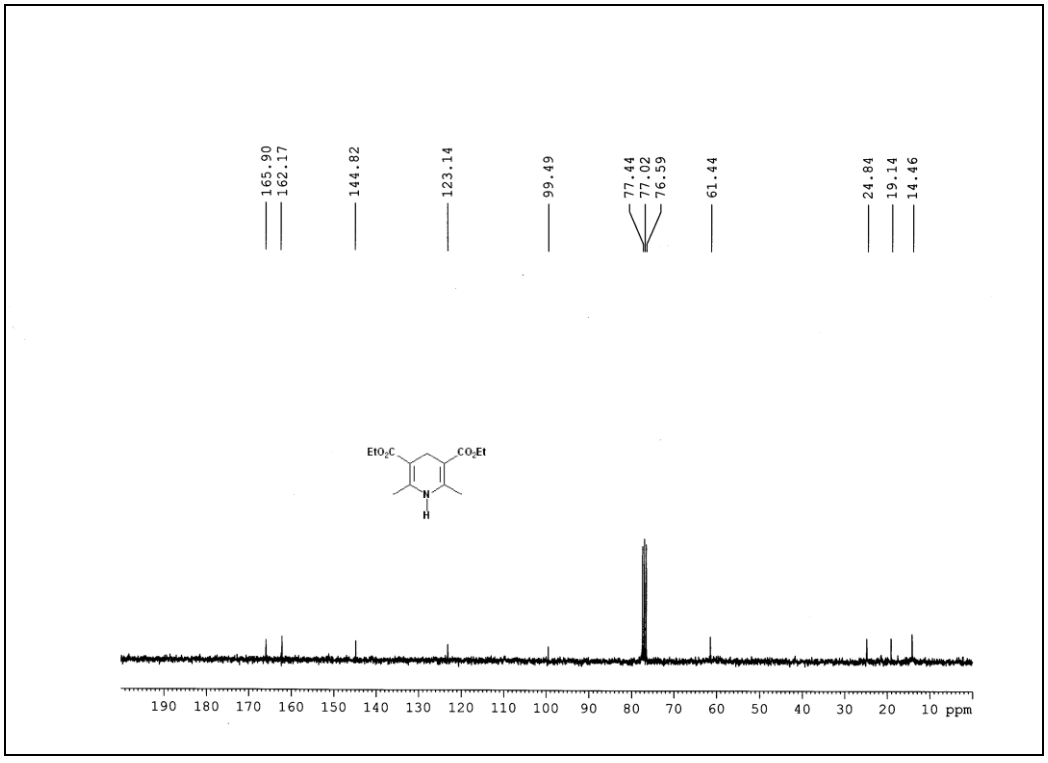
^{1}H NMR of 4g



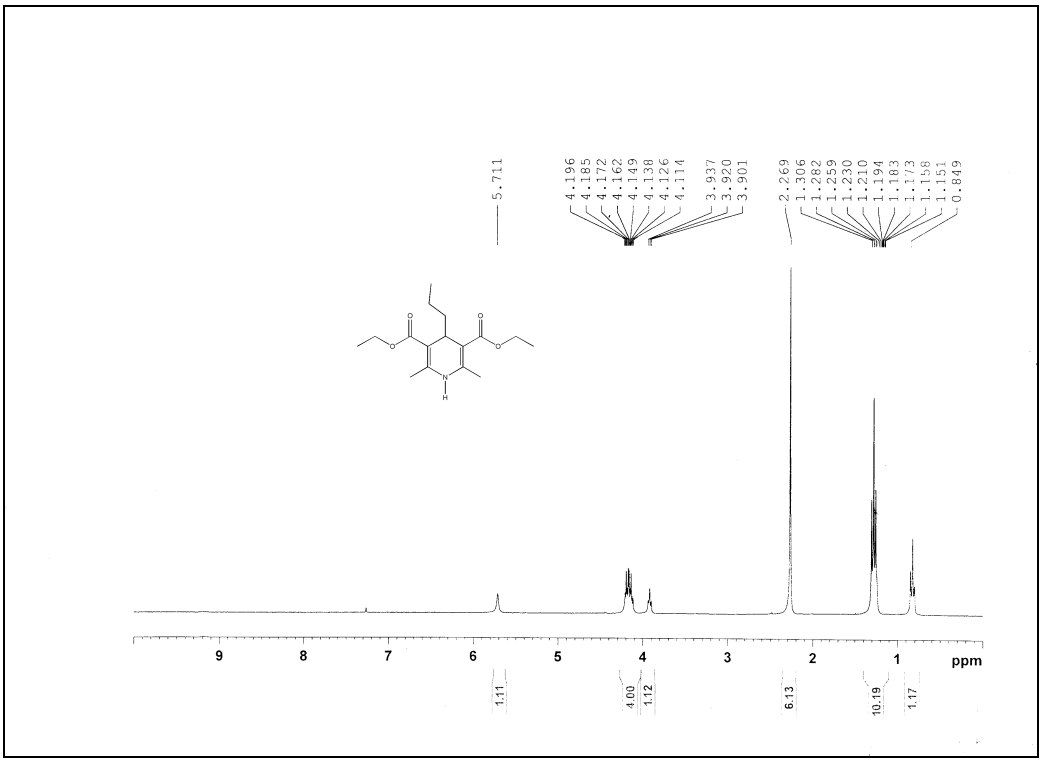
^{13}C NMR of 4g



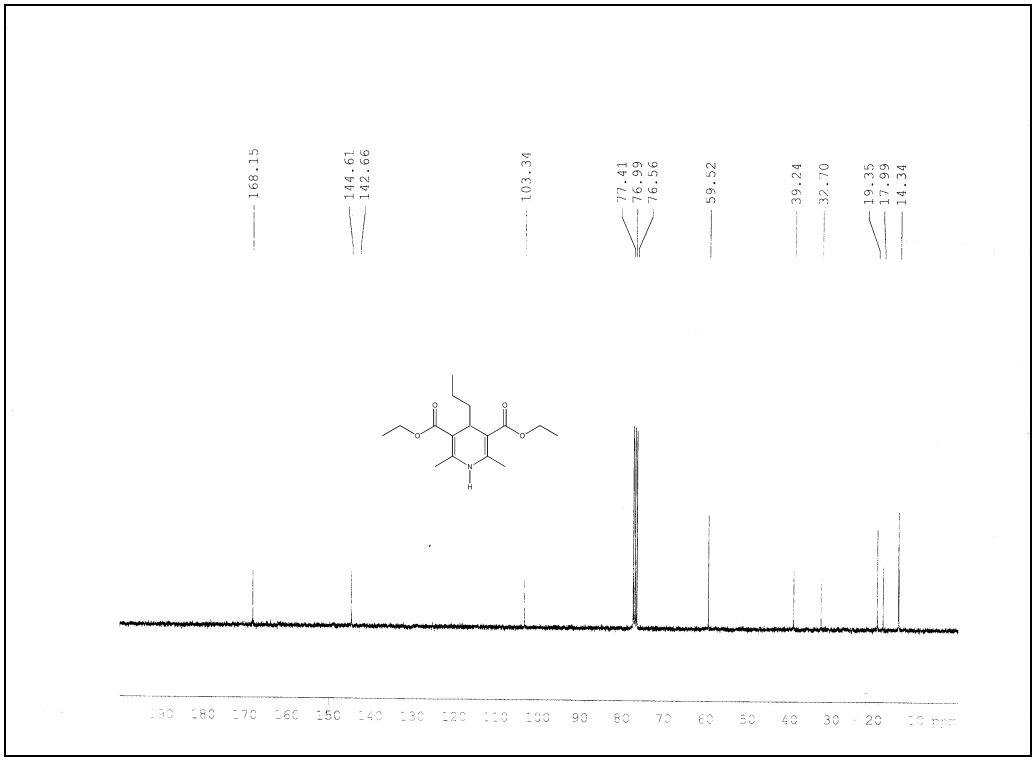
^{1}H NMR of 4h



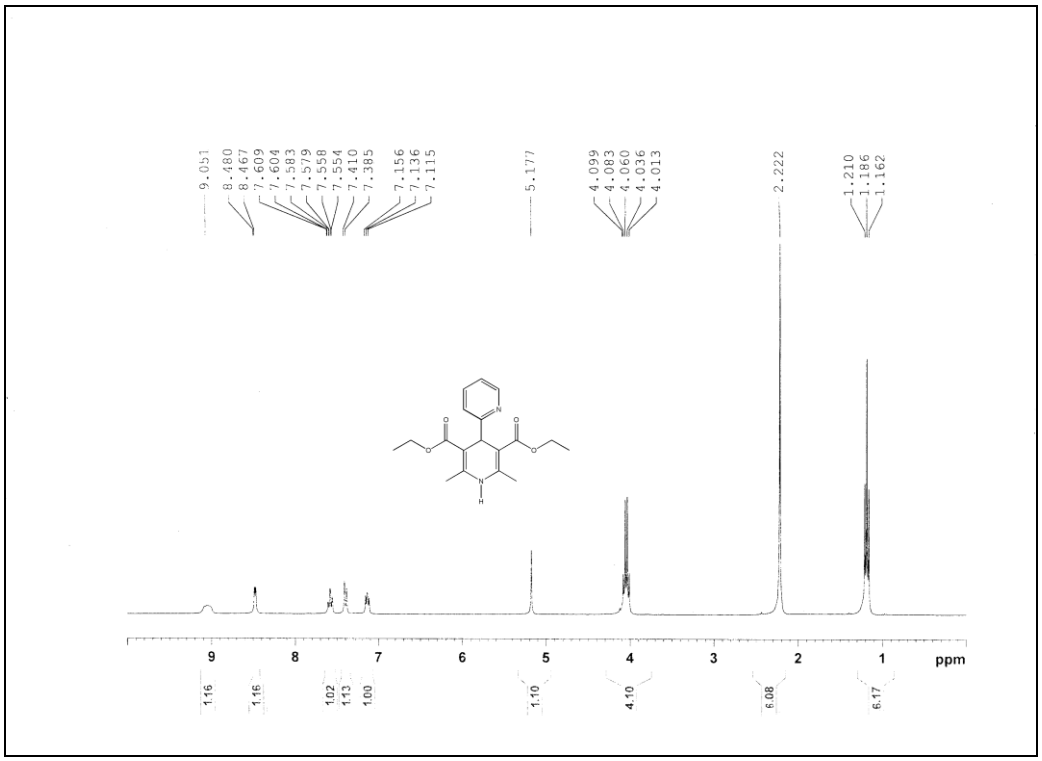
^{13}C NMR of 4h



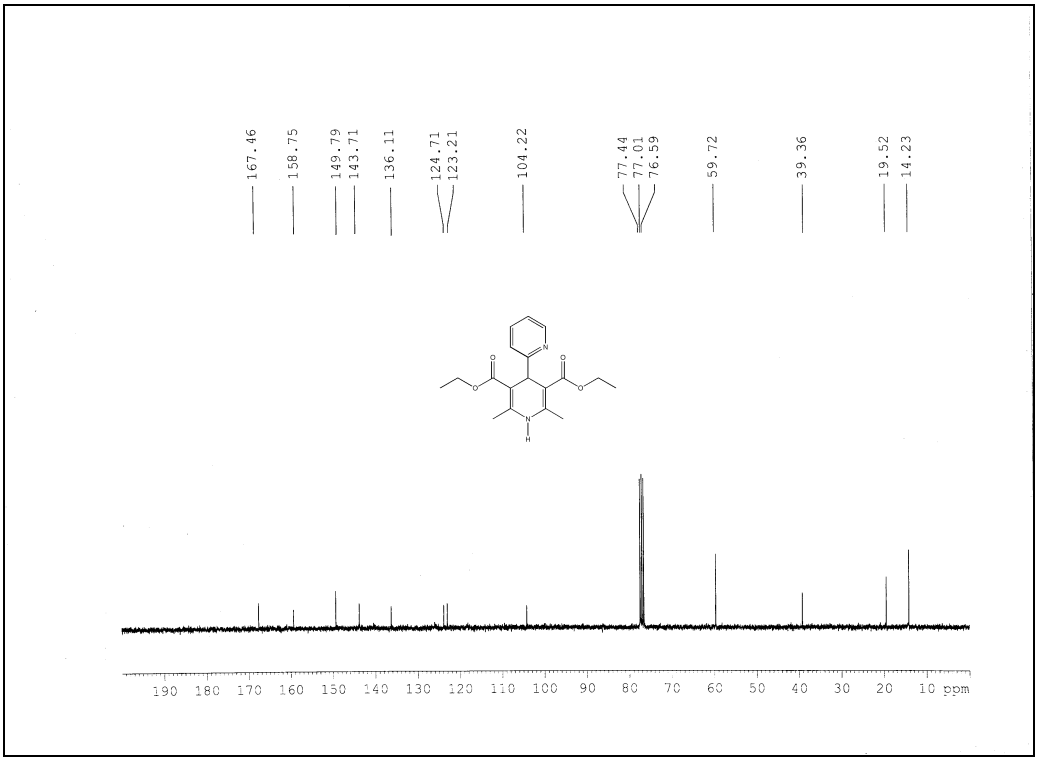
^{1}H NMR of 4i



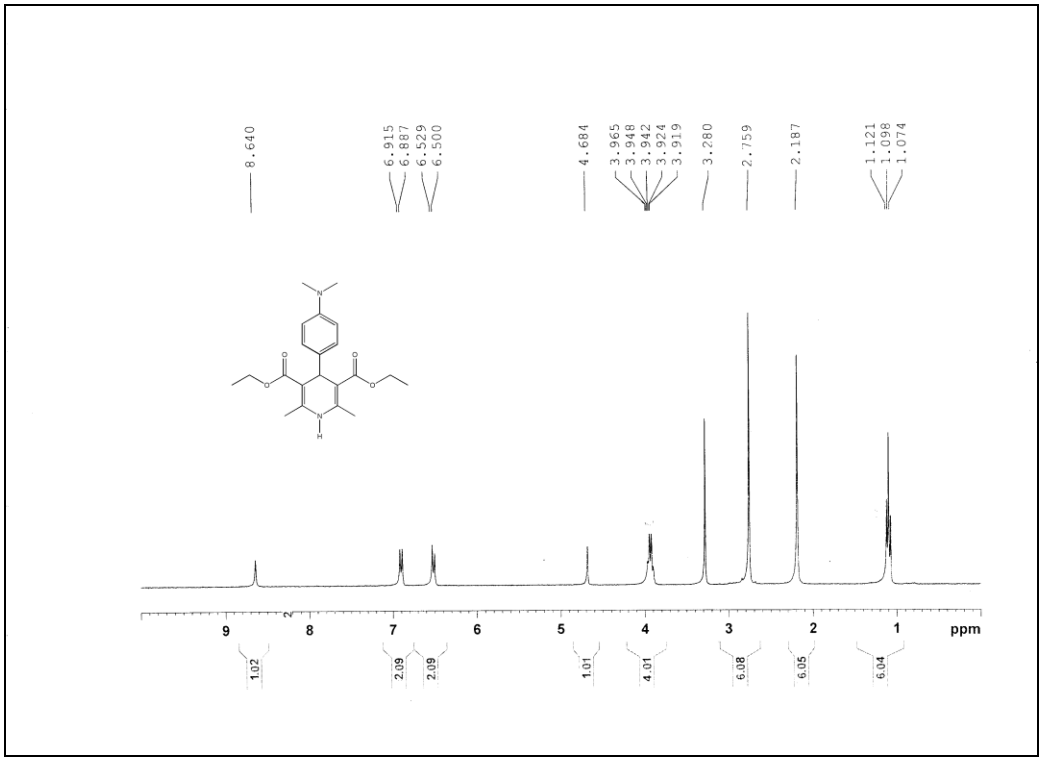
^{13}C NMR of 4i



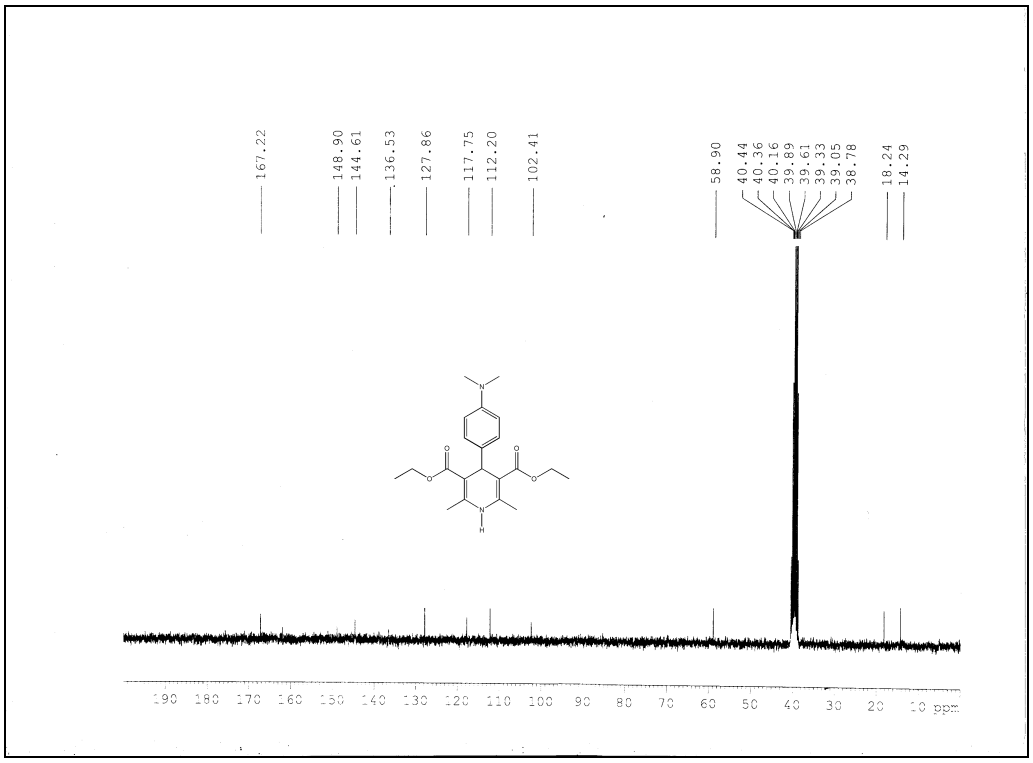
^{1}H NMR of 4j



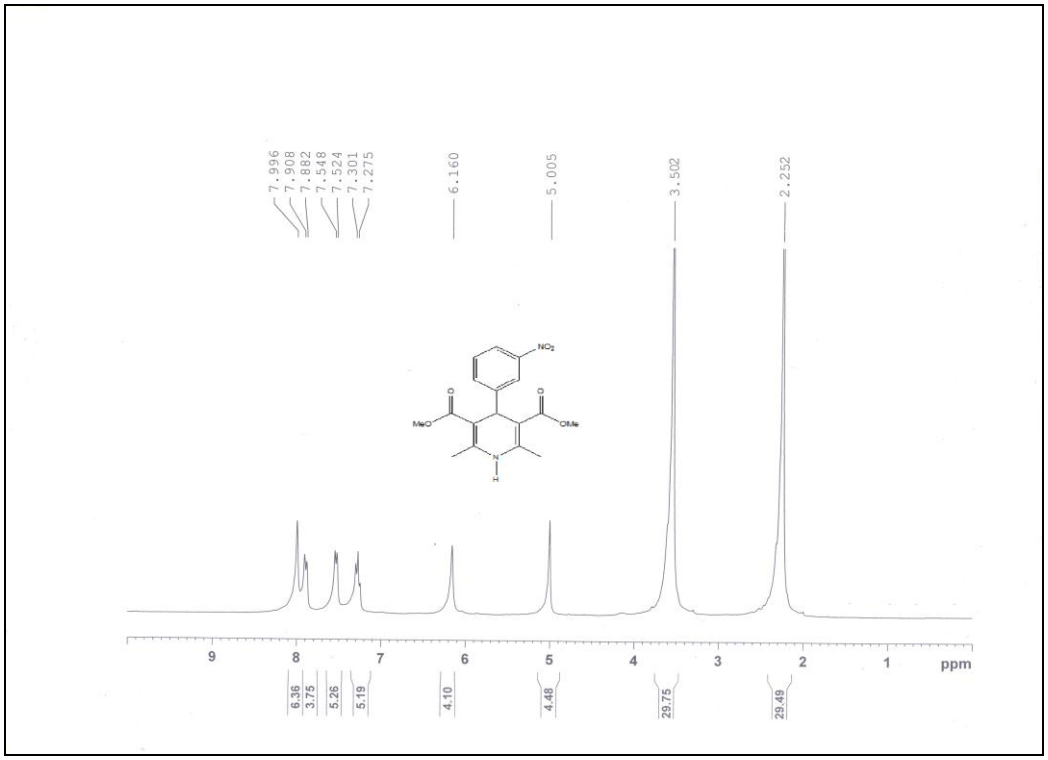
^{13}C NMR of 4j



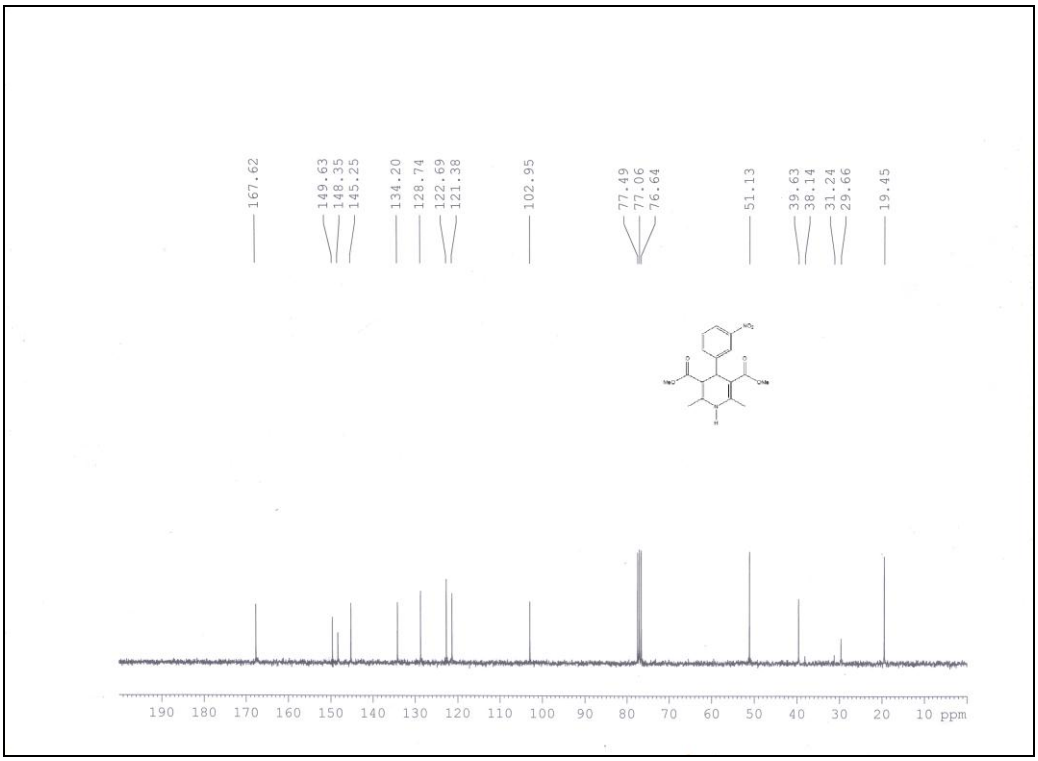
^{1}H NMR of 4k



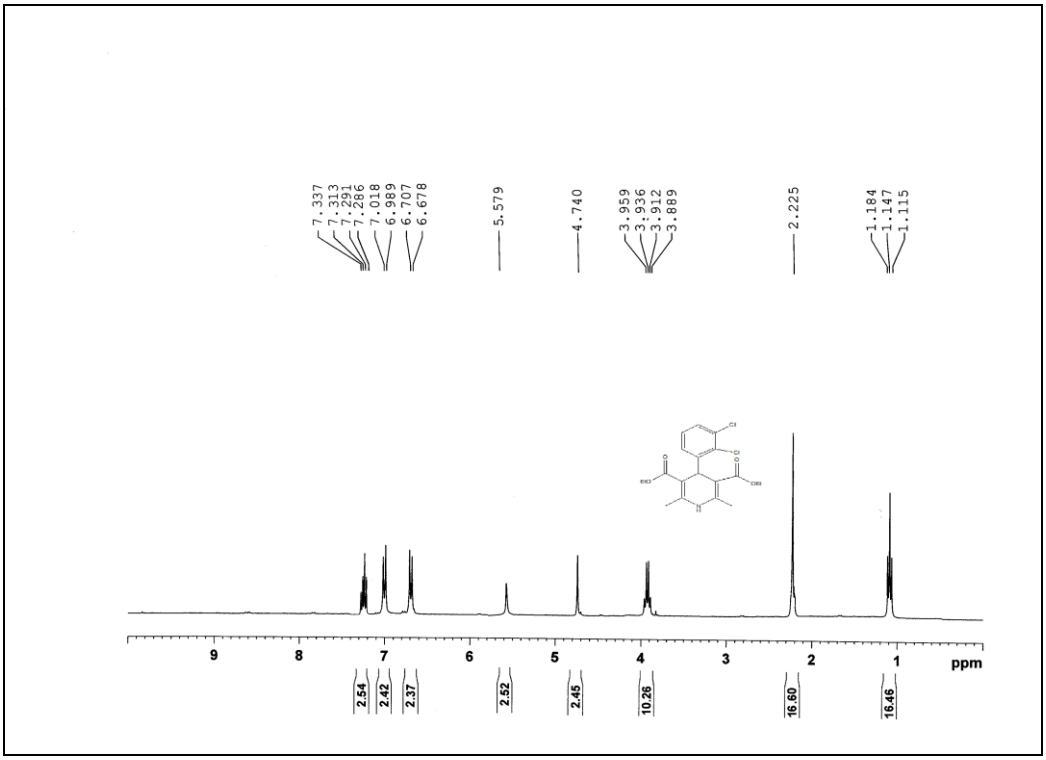
^{13}C NMR of 4k



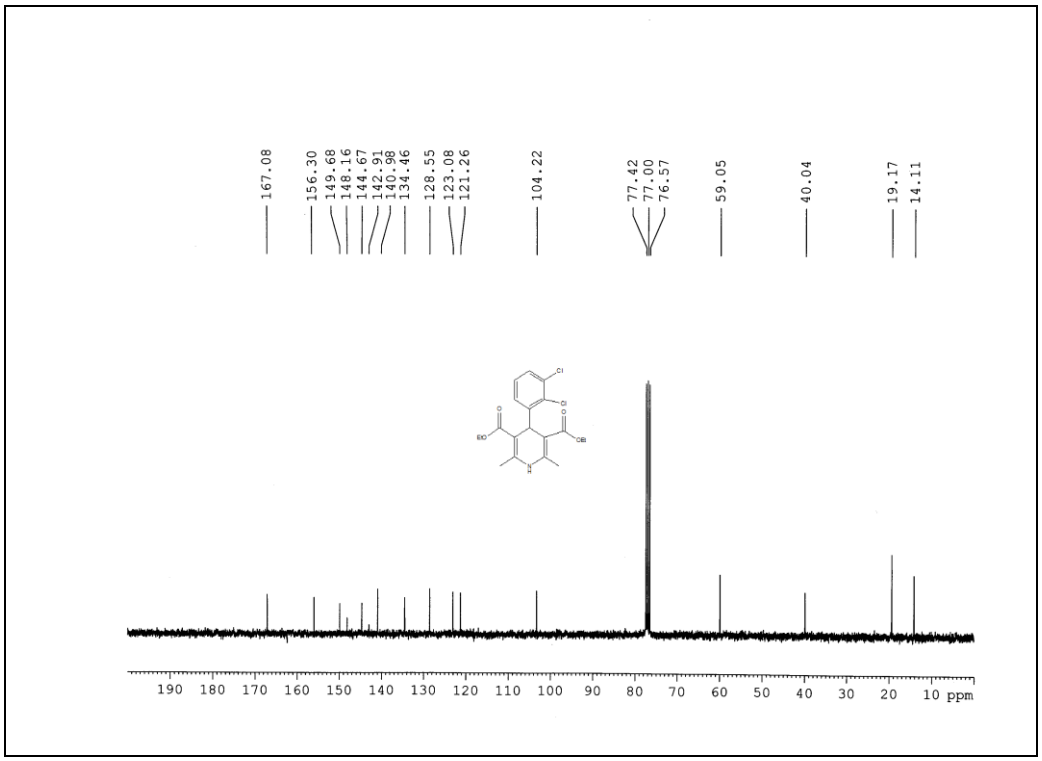
^{1}H NMR of 4l



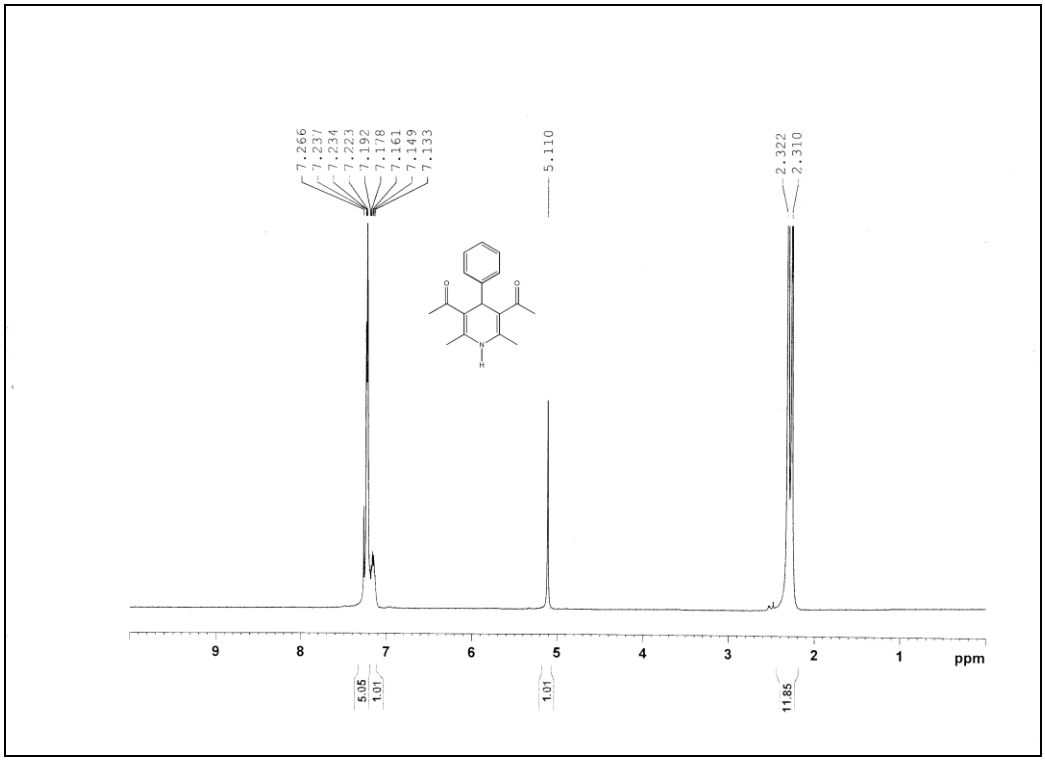
^{13}C NMR of 4l



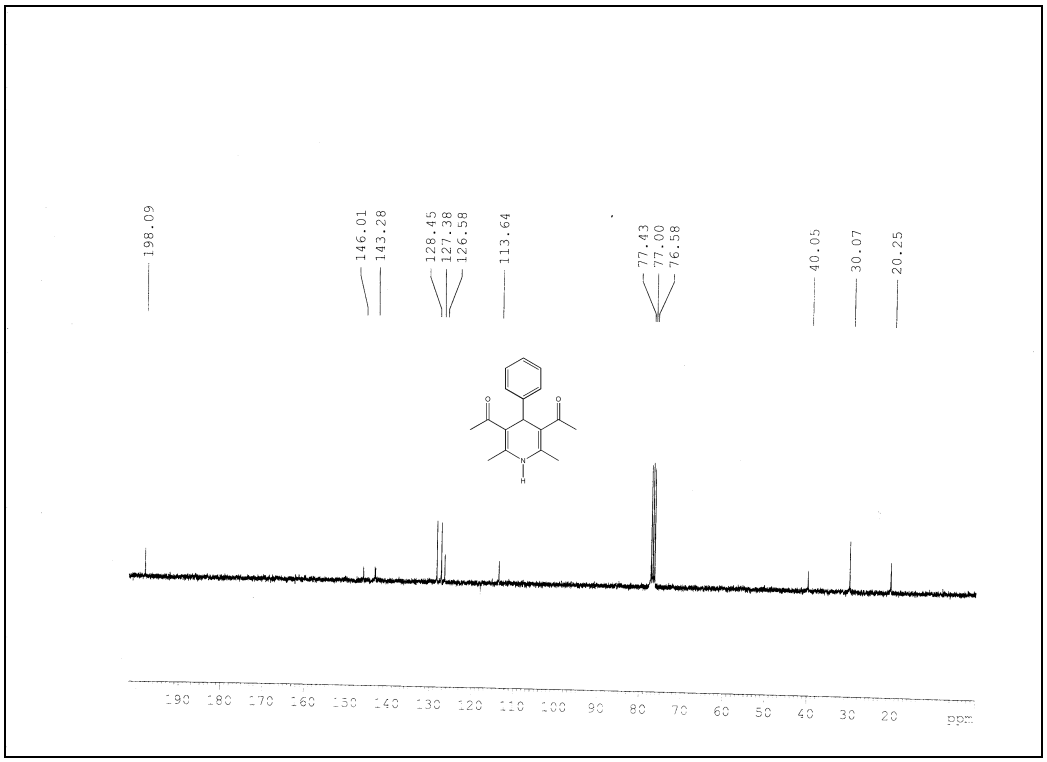
^{1}H NMR of 4m



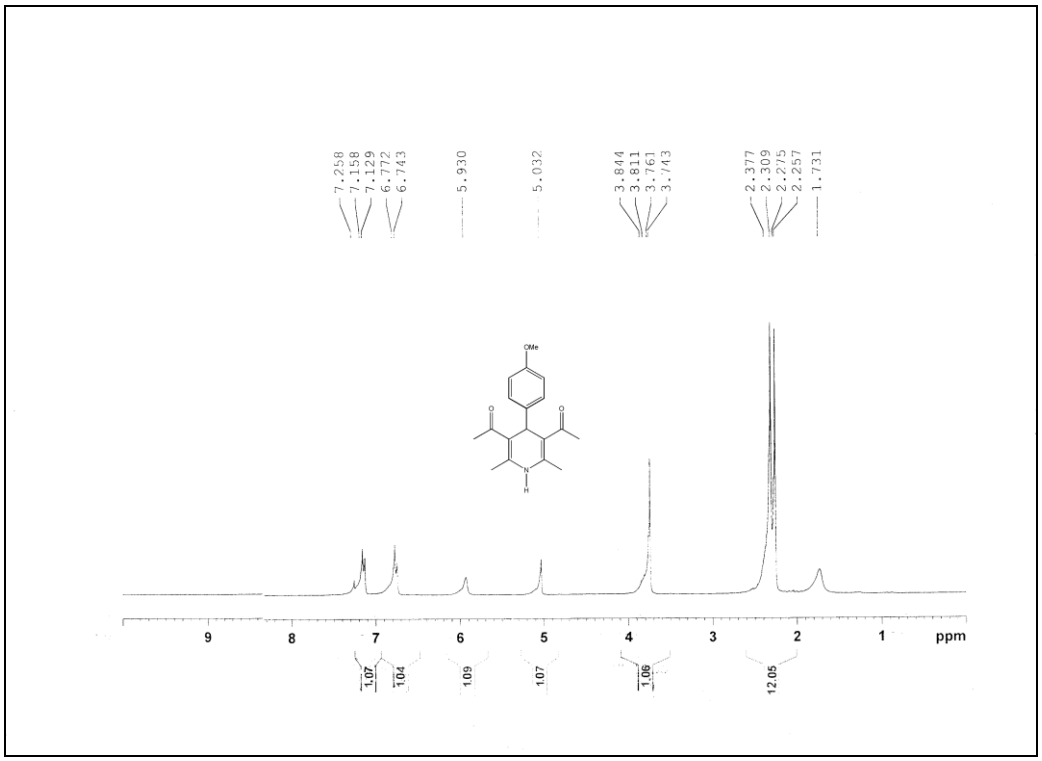
^{13}C NMR of 4m



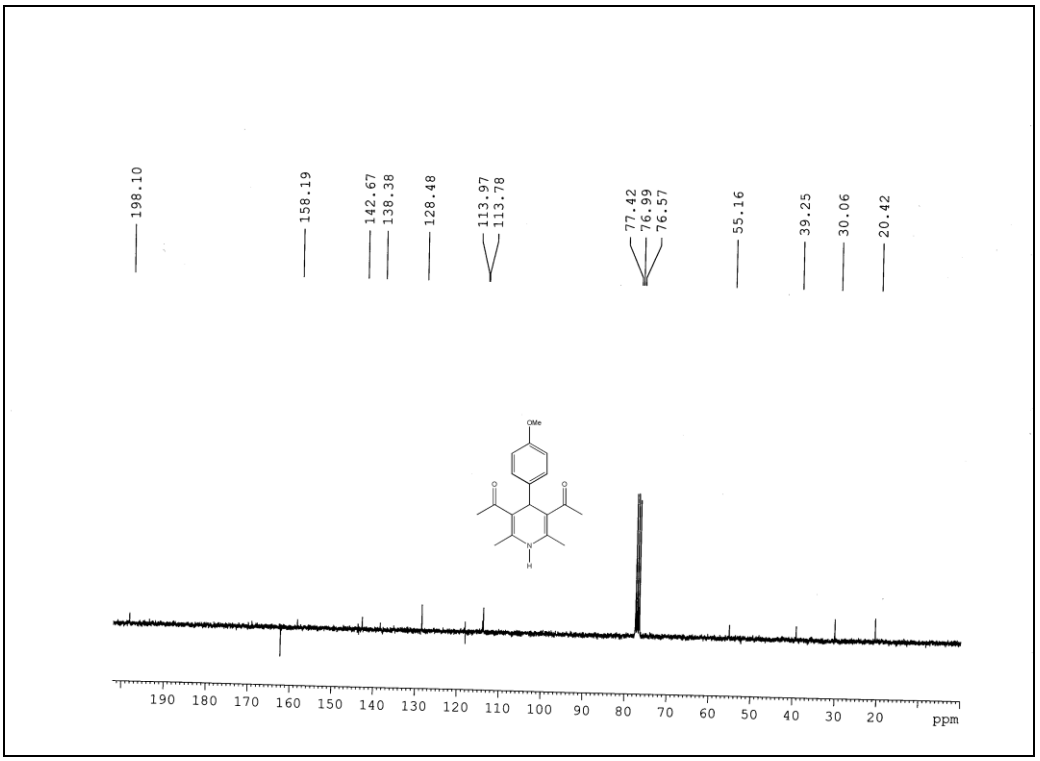
^{1}H NMR of 4n



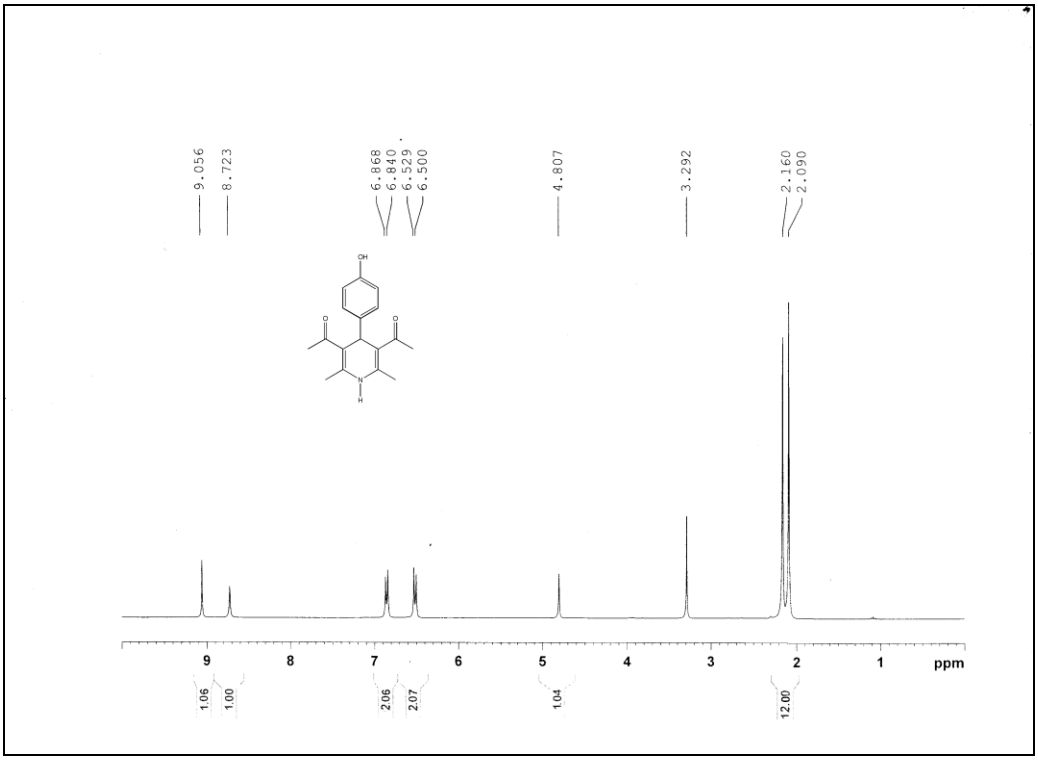
^{13}C NMR of 4n



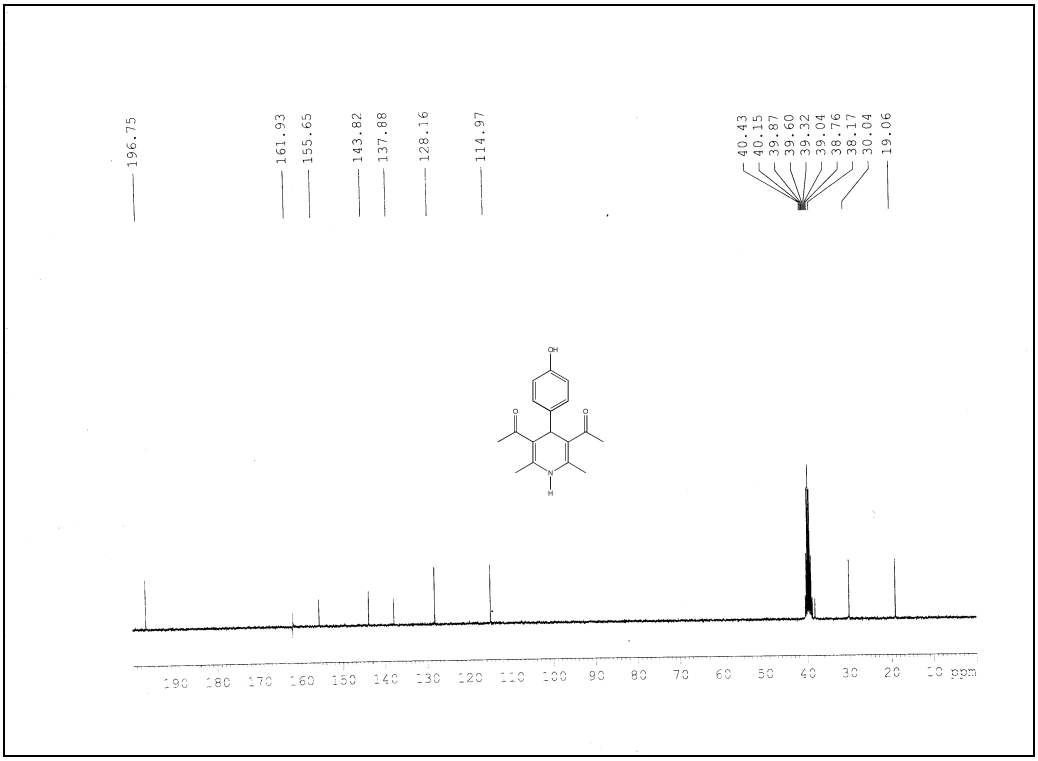
^{1}H NMR of 4o



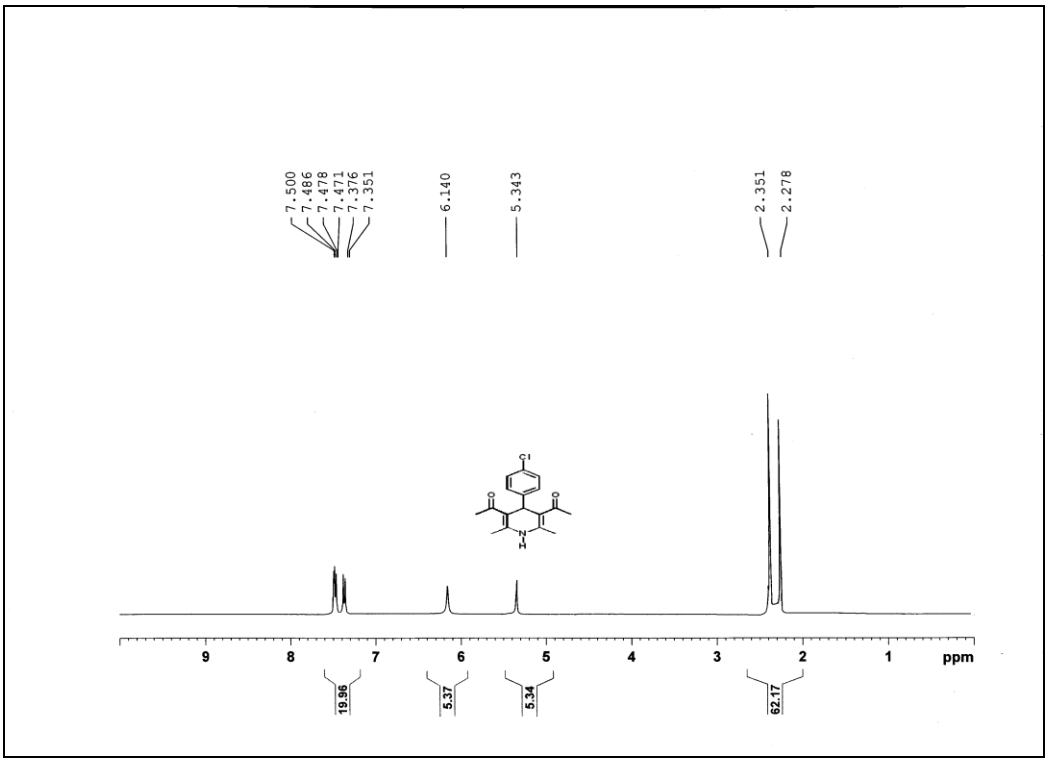
^{13}C NMR of 4o



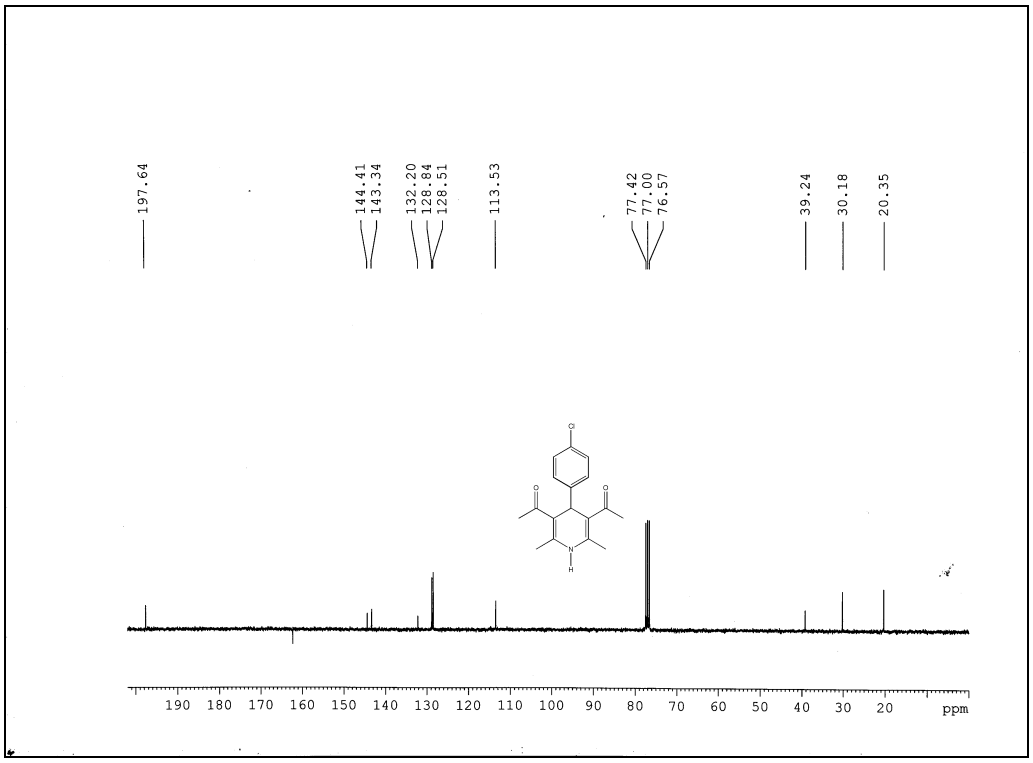
^{1}H NMR of 4p



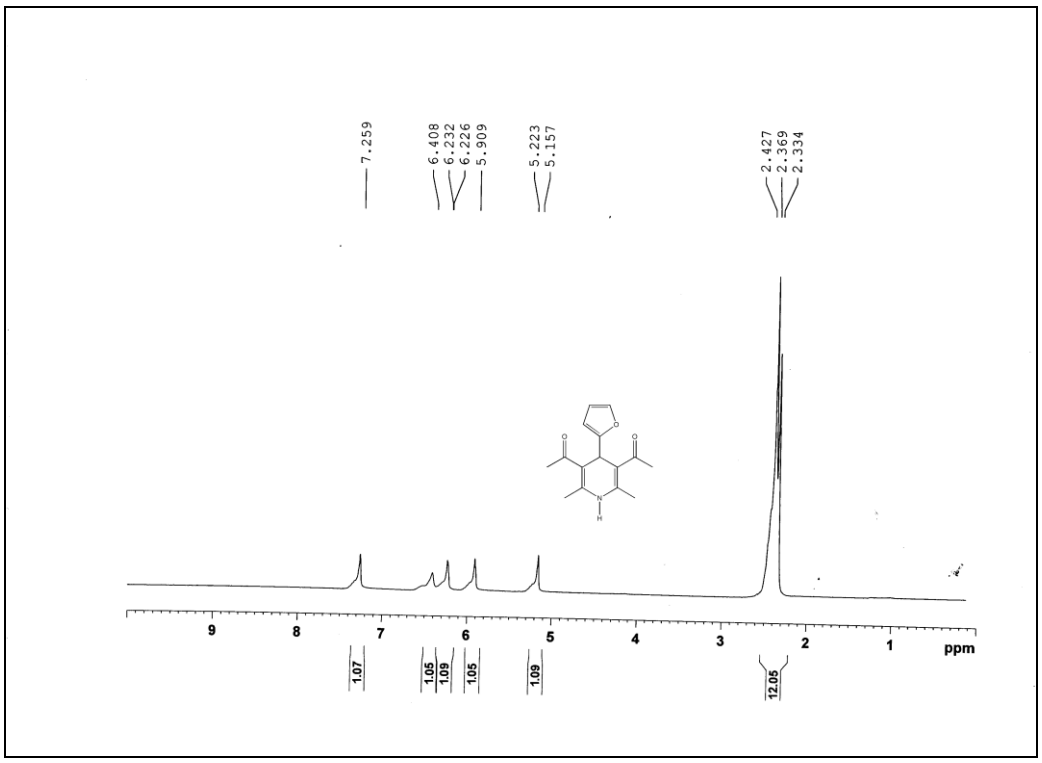
^{13}C NMR of 4p



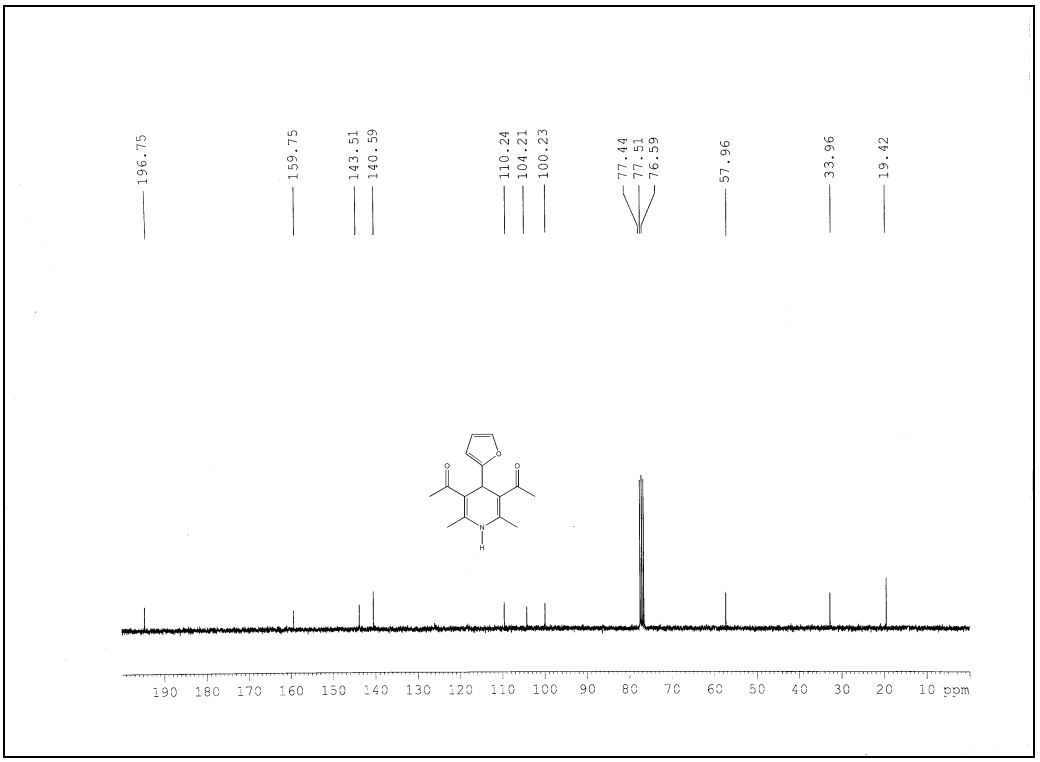
^{1}H NMR of 4q



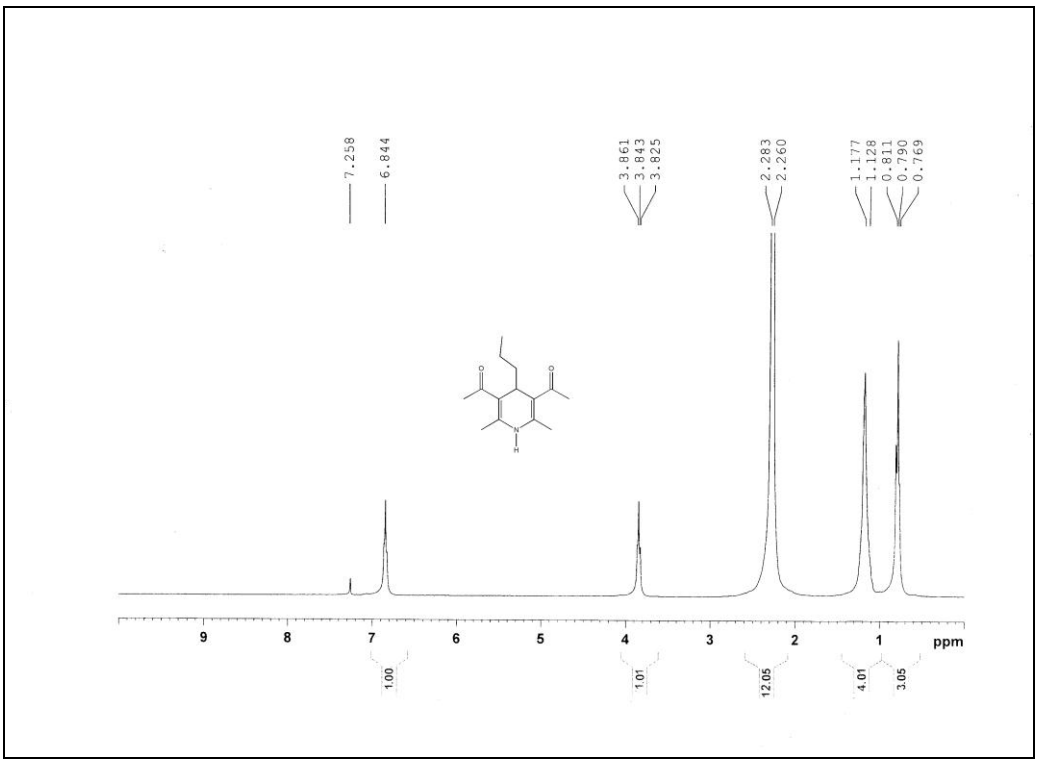
^{13}C NMR of 4q



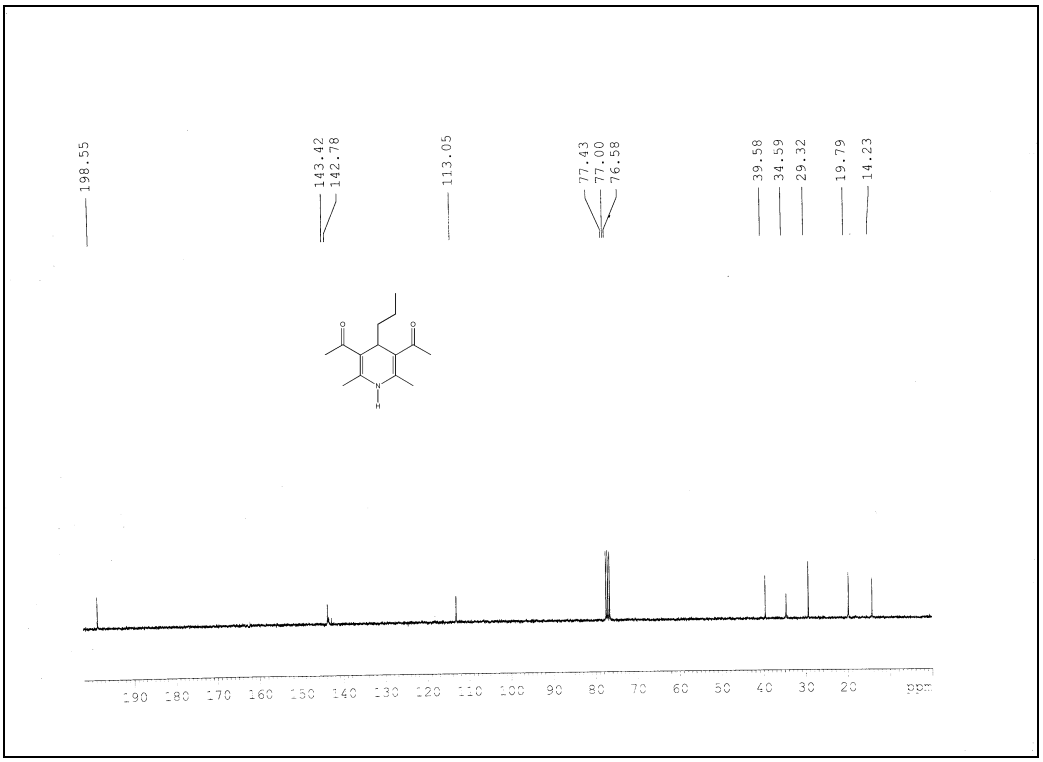
^{1}H NMR of 4r



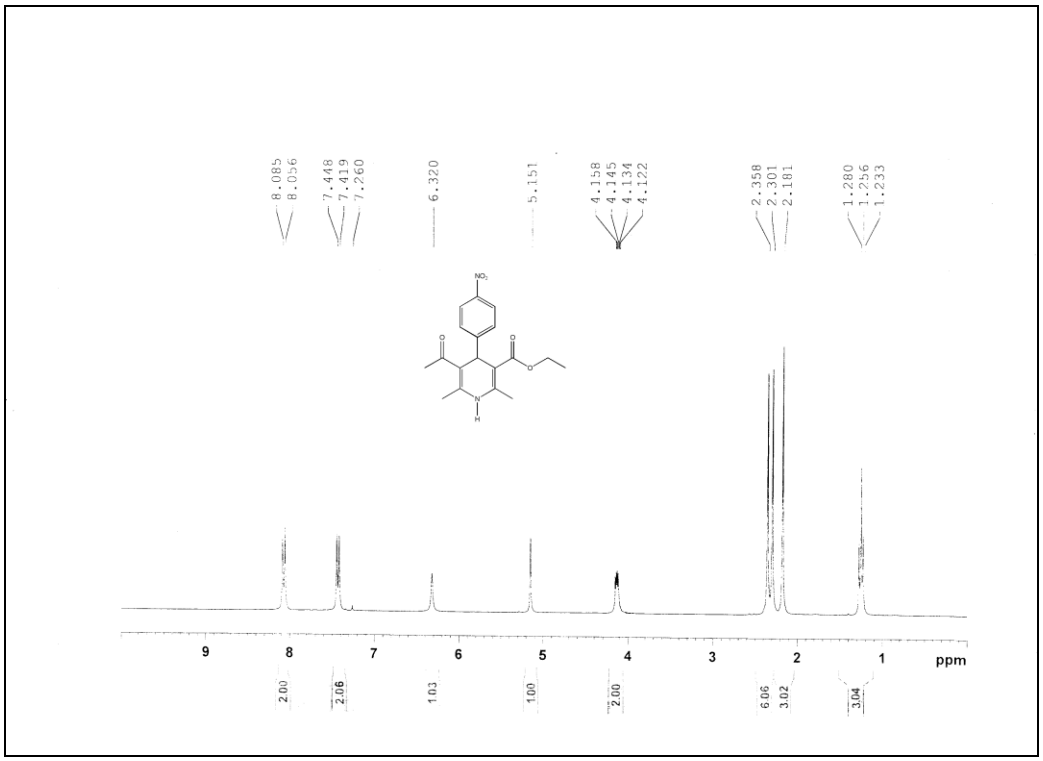
^{13}C NMR of 4r



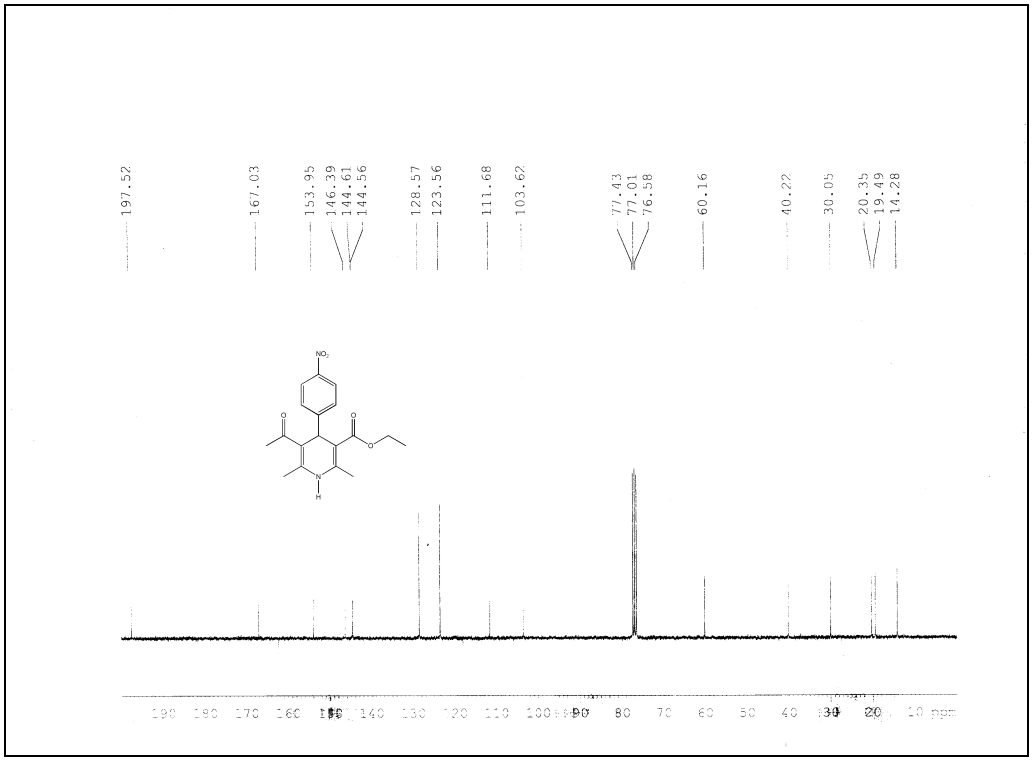
^{1}H NMR of 4s



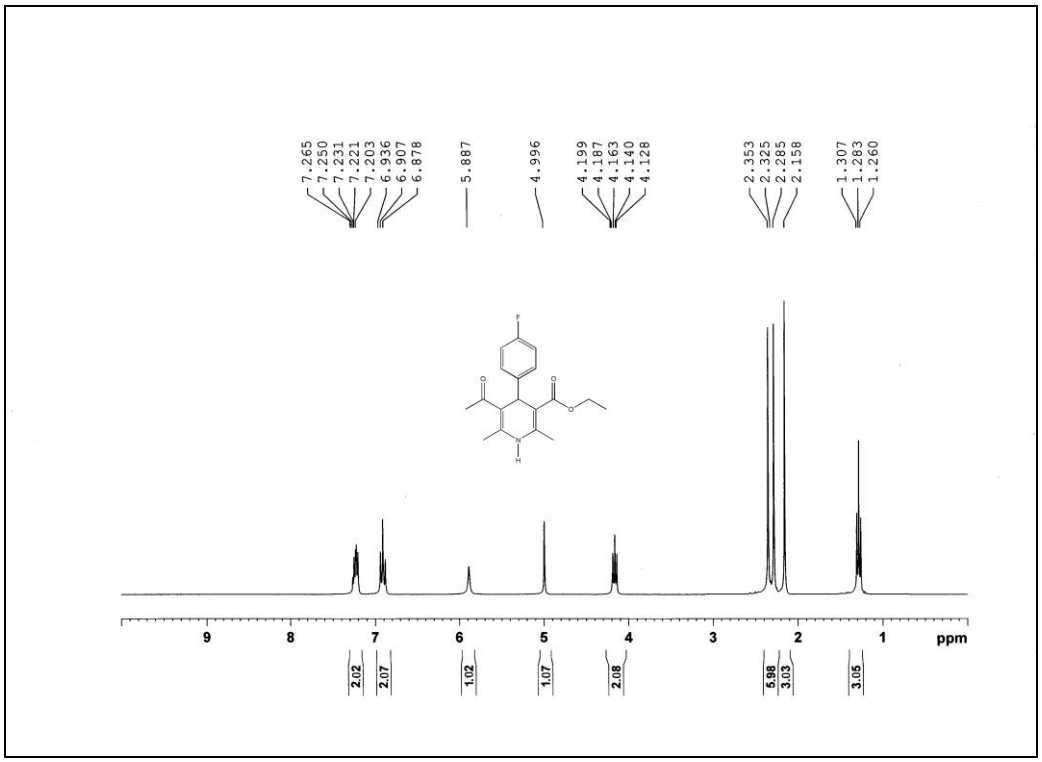
^{13}C NMR of 4s



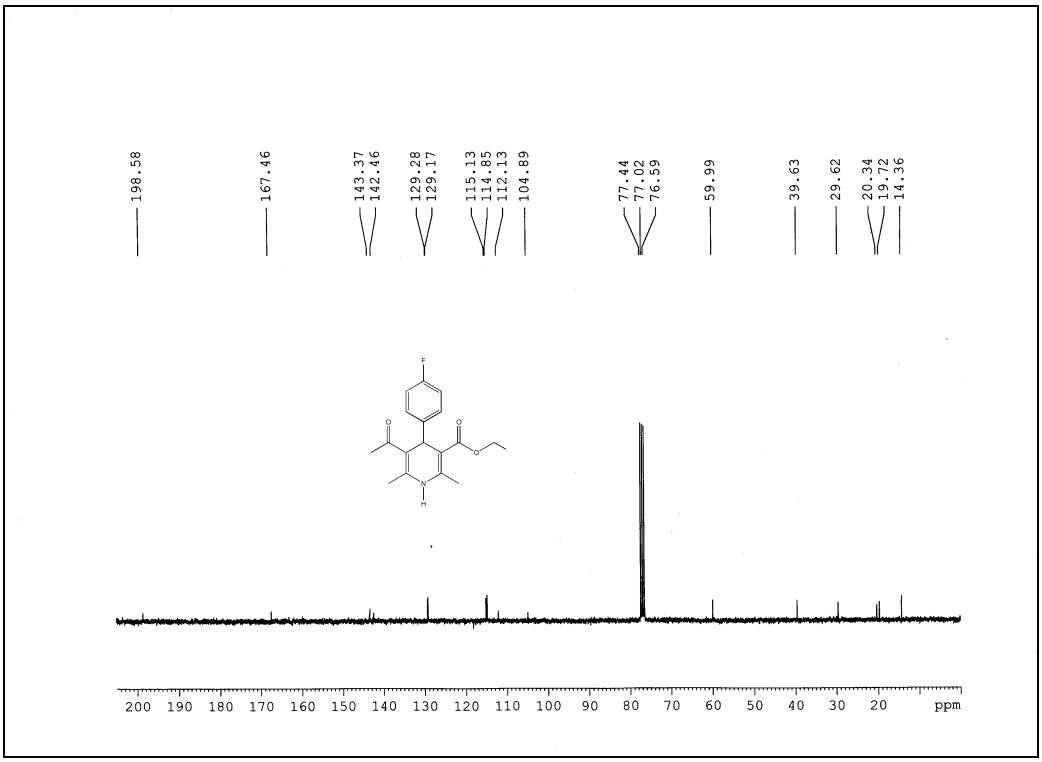
^{1}H NMR of 4t



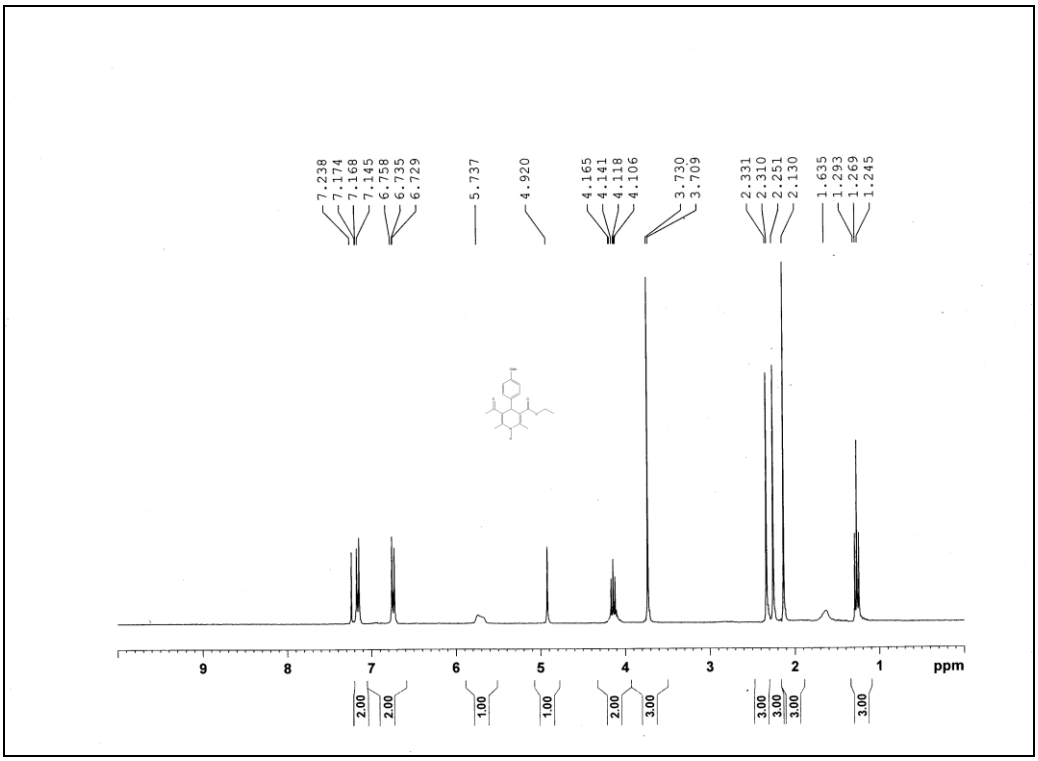
^{13}C NMR of 4t



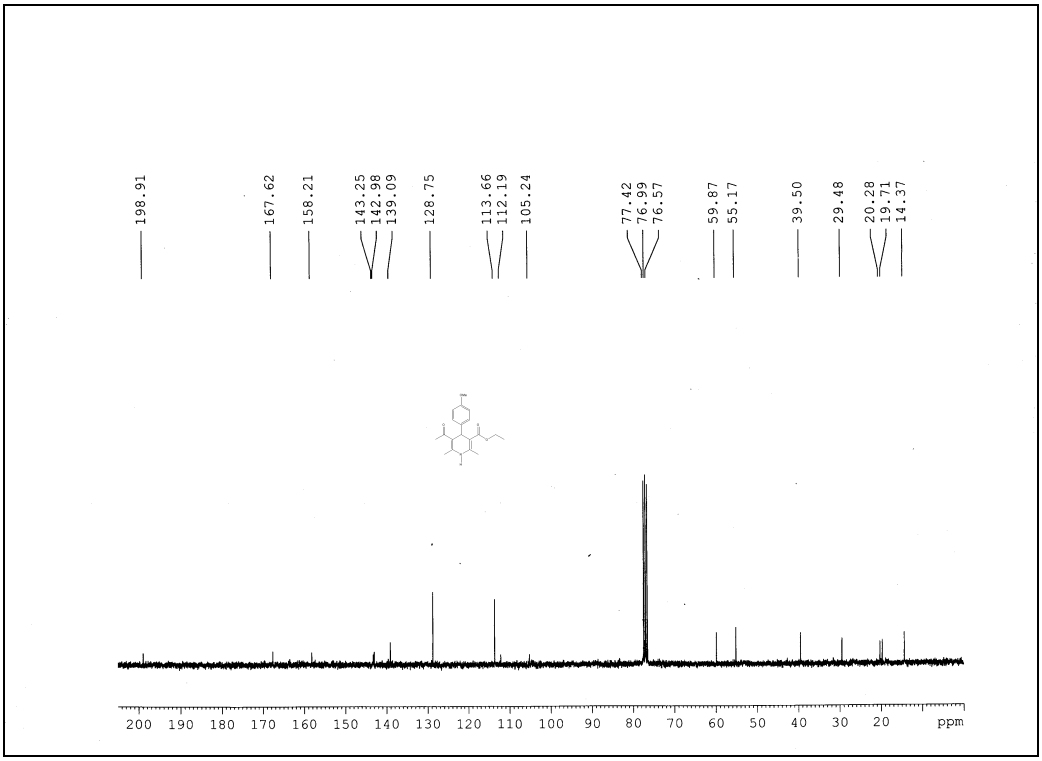
^{1}H NMR of 4u



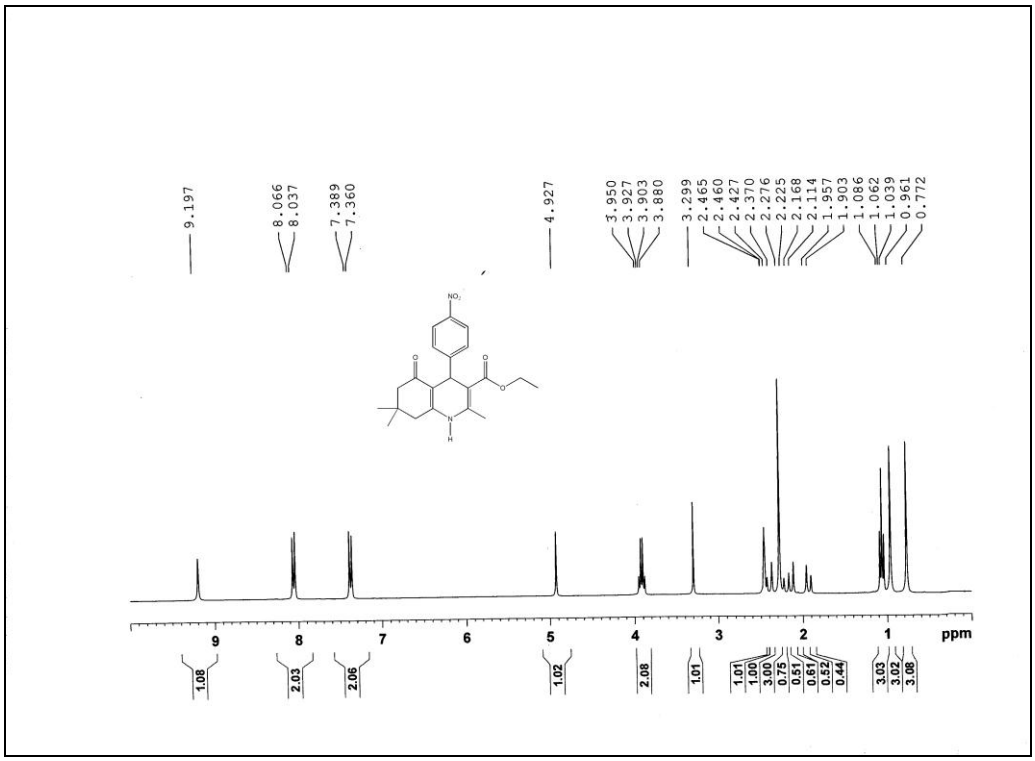
^{13}C NMR of 4u



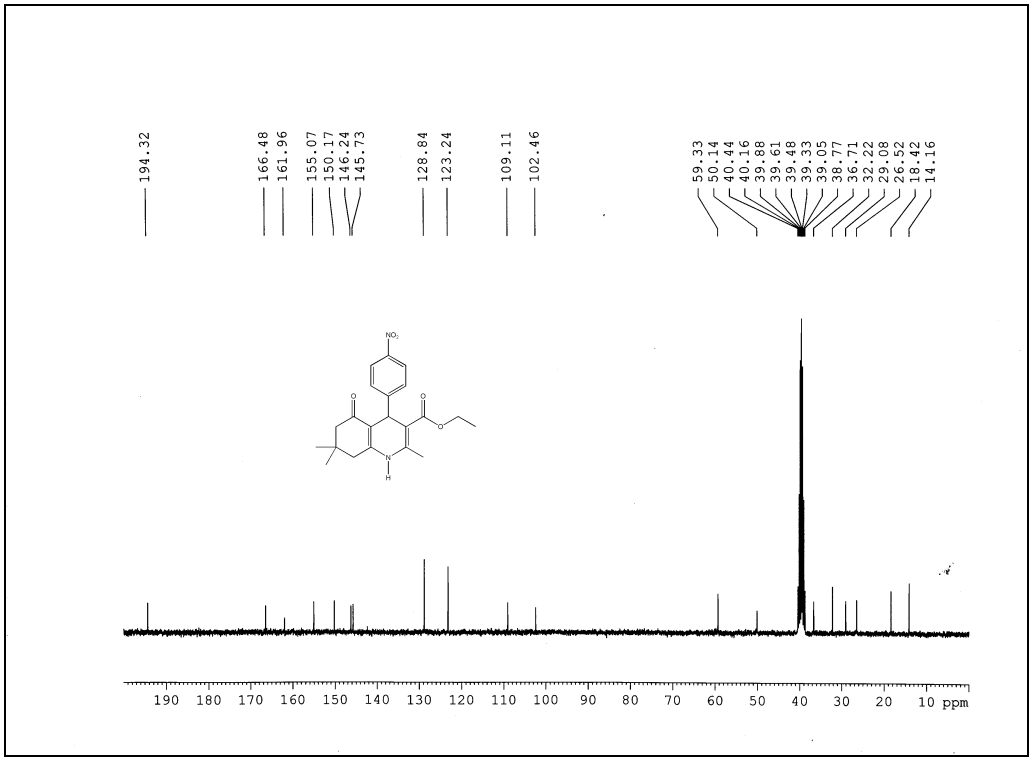
^{1}H NMR of 4v



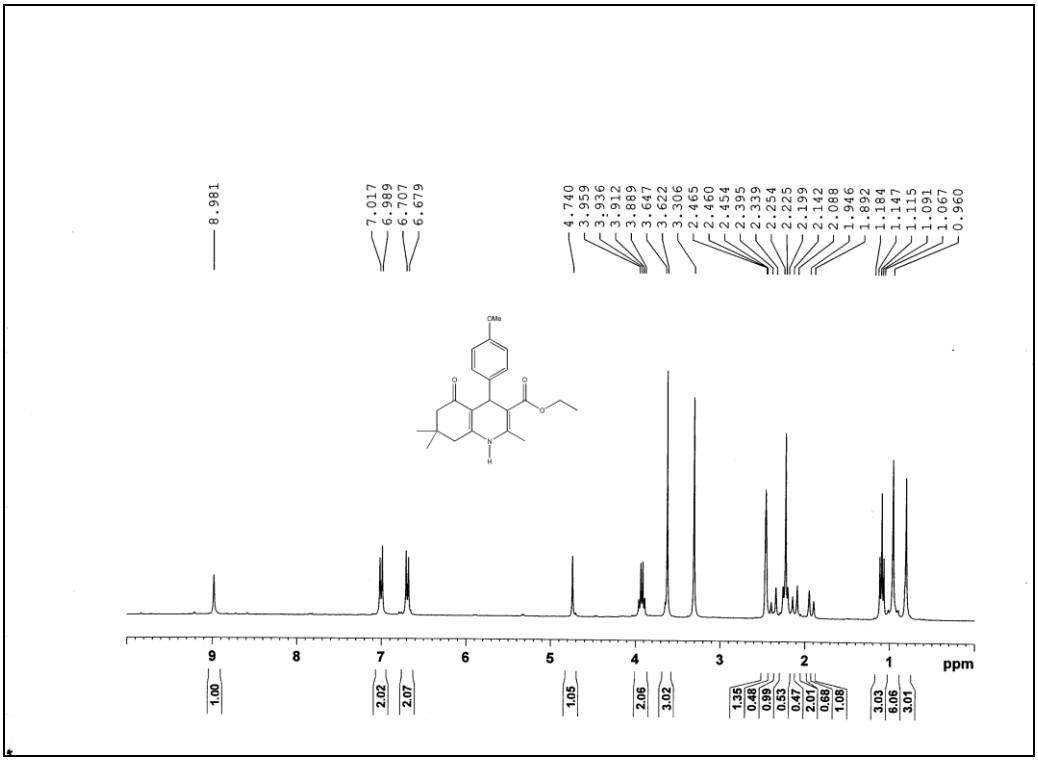
^{13}C NMR of 4v



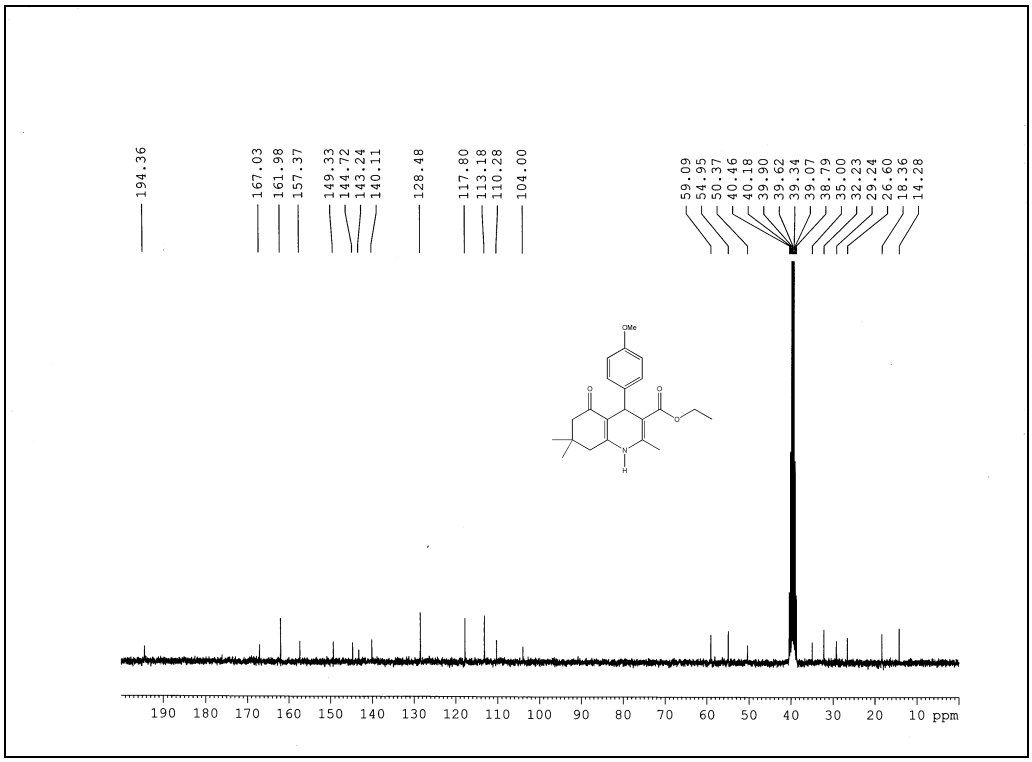
^{1}H NMR of 4w



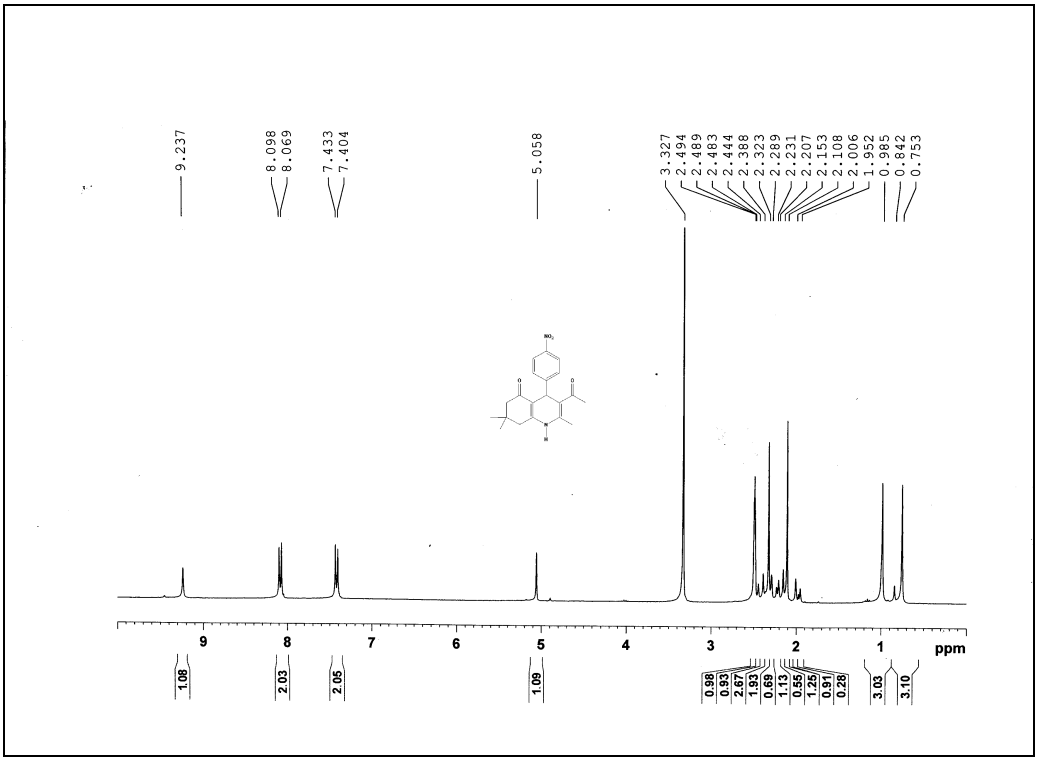
^{13}C NMR of 4w



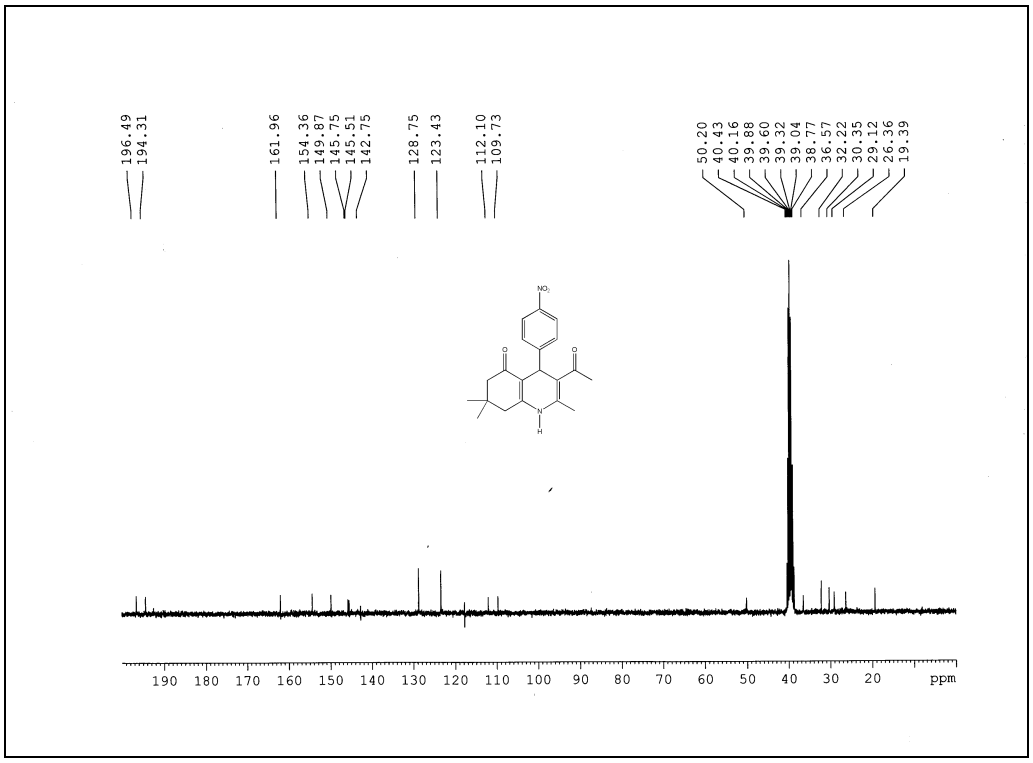
^{1}H NMR of 4x



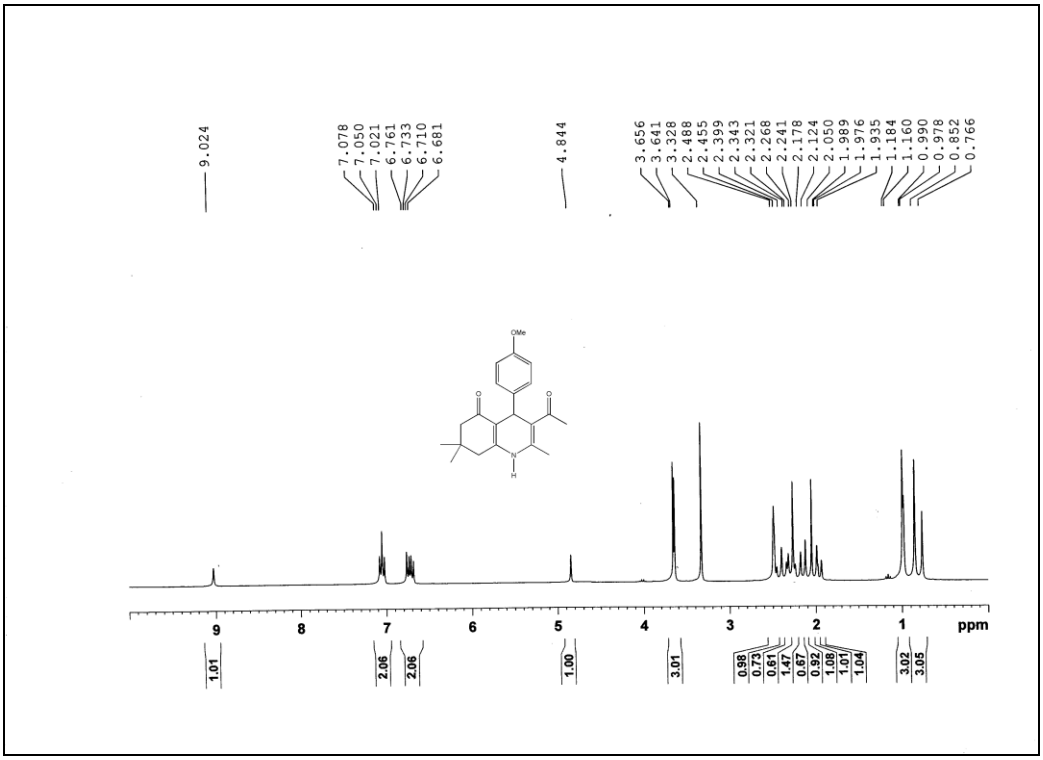
^{13}C NMR of 4x



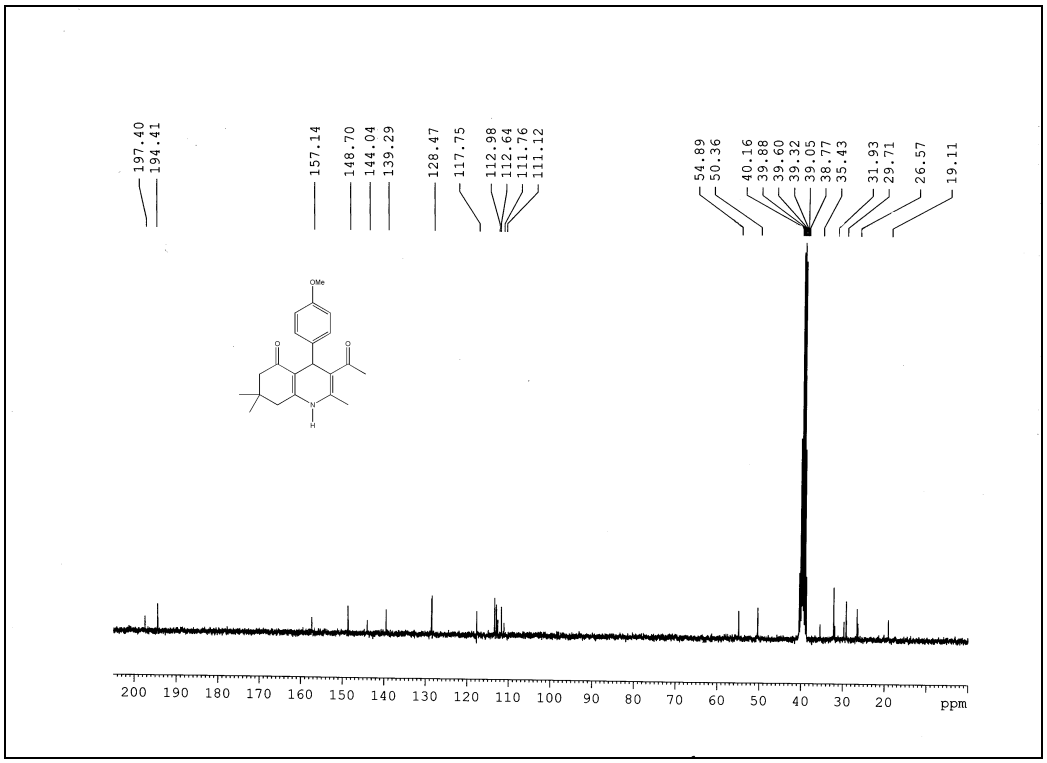
^{1}H NMR of 4y



^{13}C NMR of 4y



^{1}H NMR of 4z



^{13}C NMR of 4z