

Nano CoFe₂O₄ supported antimony(III) as an efficient and recyclable catalyst for one-pot three-component synthesis of multisubstituted pyrroles

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Supporting Information

General Information. All solvents and chemicals were obtained commercially and were used as received. X-ray diffraction analysis was carried out using a PANalytical X'Pert Pro X-ray diffractometer. Surface morphology and particle size were studied using a Hitachi S-4800 SEM instrument. Transmission electron microscope (TEM) observation was performed using Hitachi H-7650 microscope at 80 KV. Elemental compositions were determined with a Hitachi S-4800 scanning electron microscope equipped with an INCA 350 energy dispersive spectrometer (SEM-EDS) presenting a 133 eV resolution at 5.9 keV. The ICP-MS analyses were carried out with an X Series 2 spectrometer. Melting points were measured on an X-4 digital melting point apparatus are uncorrected. IR spectra were obtained as KBr pellets or as liquid films on KBr pellets with a Bruker-TENSOR 27 spectrometer. ¹H NMR (500 MHz) and ¹³C NMR (125 MHz) spectra were recorded on Bruker DRX-500 spectrometer using CDCl₃ as the solvent and TMS as an internal standard. Elemental analyses were determined on a Vario EL III CHNOS elemental analyzer.

Chemical structure of 1-phenyl-2-methyl-3-phenyl-4-acetylpyrrole:

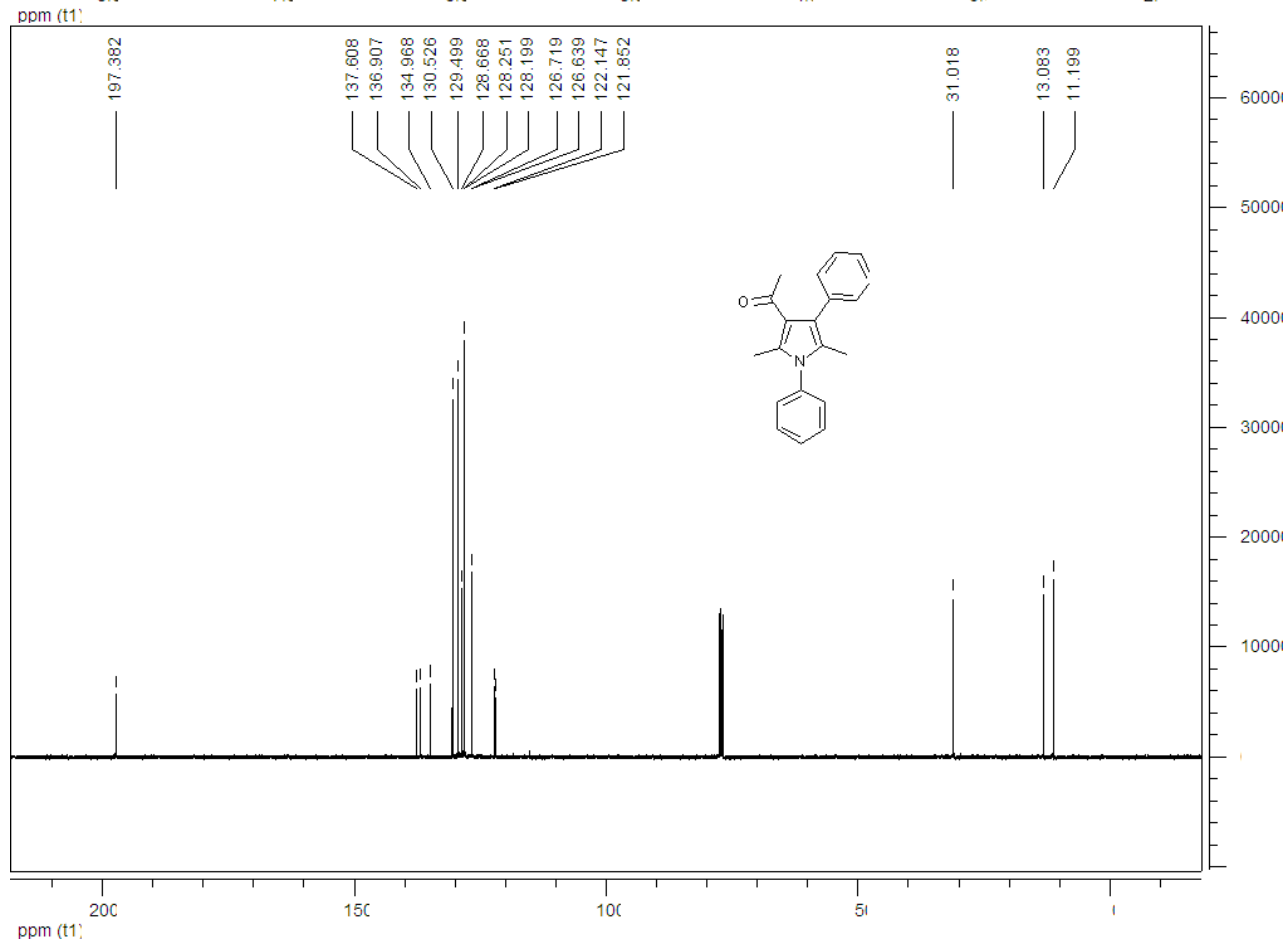
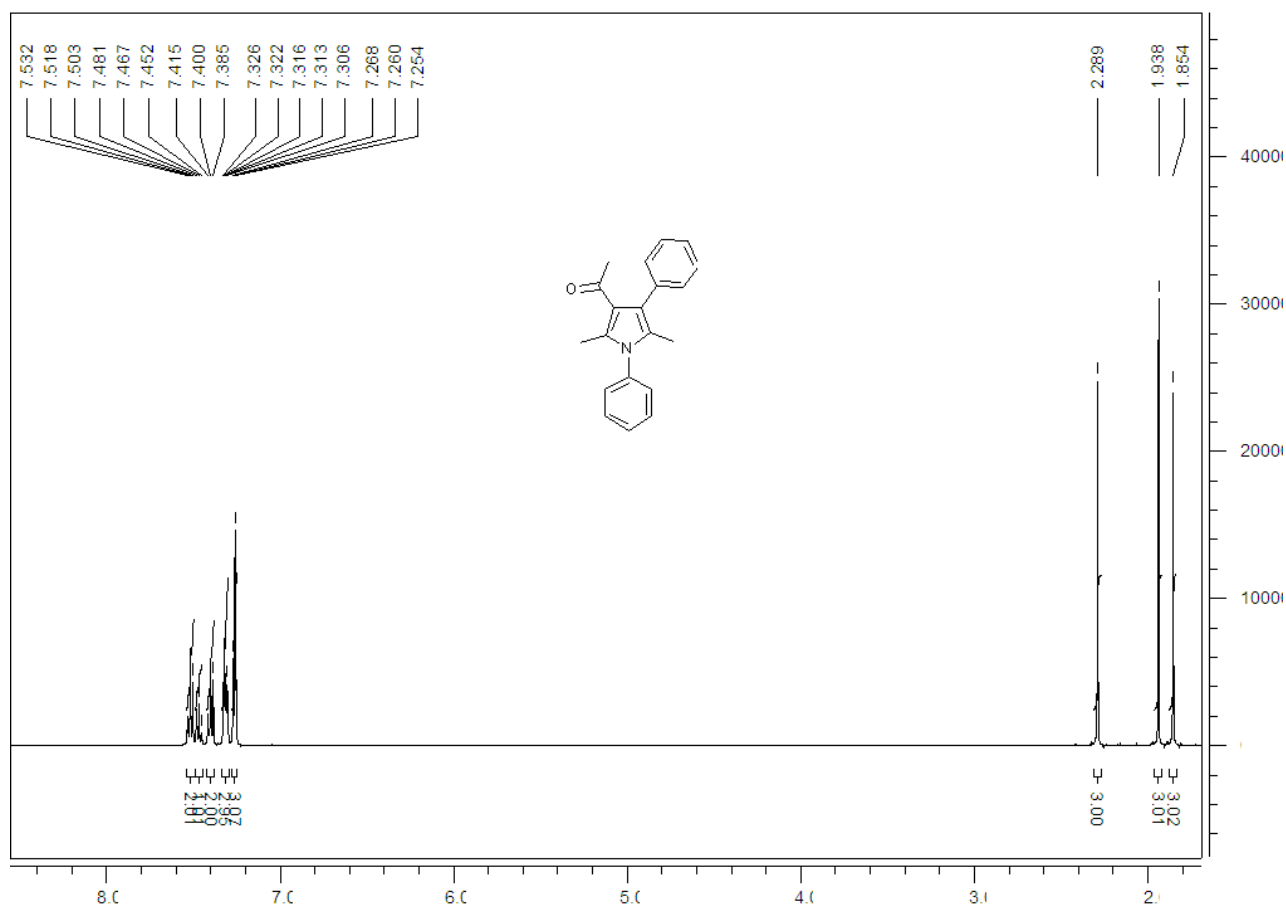
CC(=O)c1cc(Cc2ccccc2)c(C)c1C3=CC=CC=C3

¹H NMR spectrum (CDCl₃) showing peaks in the aromatic region (6.7-7.5 ppm), a methyl singlet (2.4 ppm), and an acetyl singlet (2.1 ppm). Integration values are provided for each group of peaks.

Chemical Shift (ppm)	Integration
7.507, 7.493, 7.477, 7.441, 7.426, 7.412, 7.392, 7.384, 7.345, 7.331, 7.325, 7.316, 7.308, 7.260, 6.679	1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00
2.417	3.00
2.085	3.01



^1H NMR and ^{13}C NMR of compound **4b**

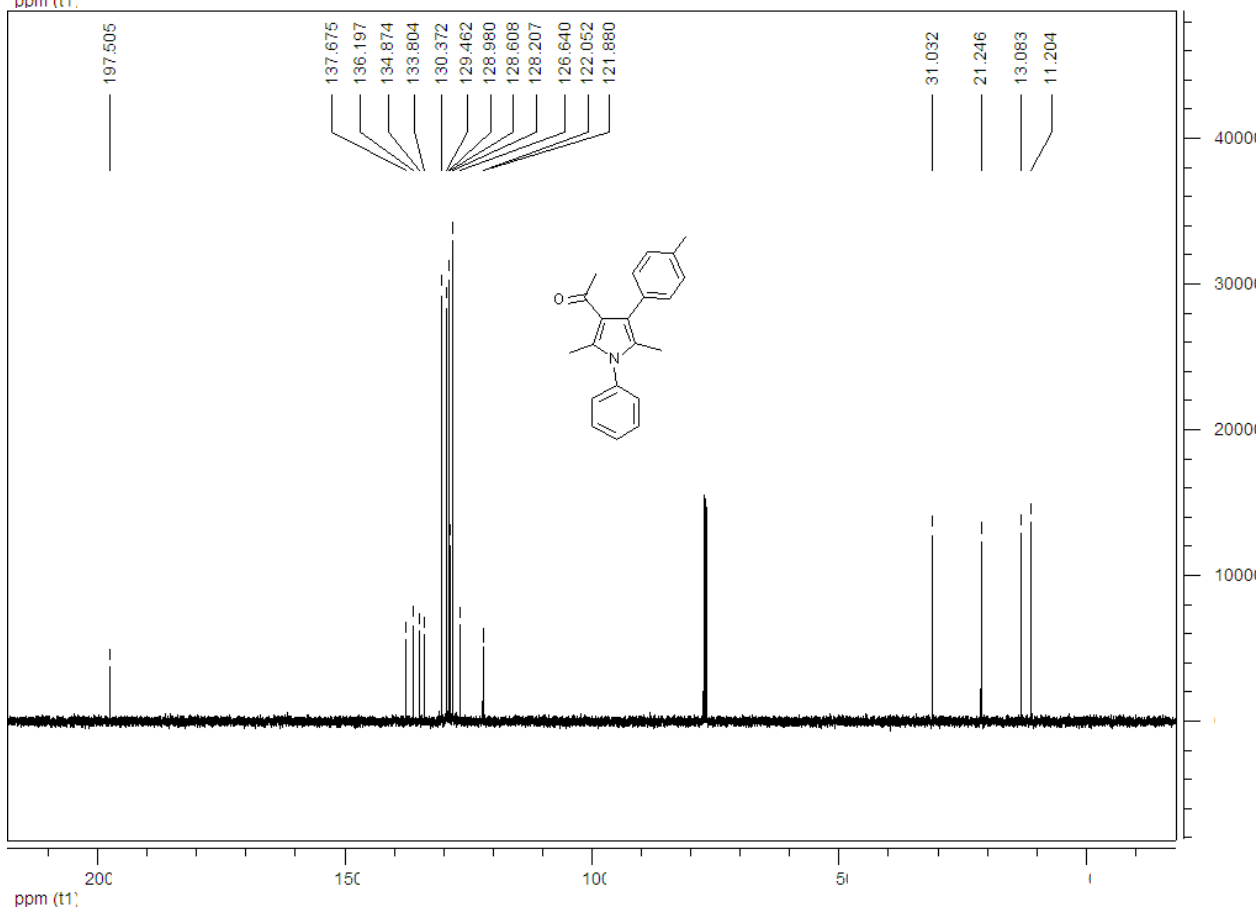


CC(=O)c1c(C)c(C2=CC=CC=C2)n(c3ccccc3)c1C4=CC=C(C)C=C4

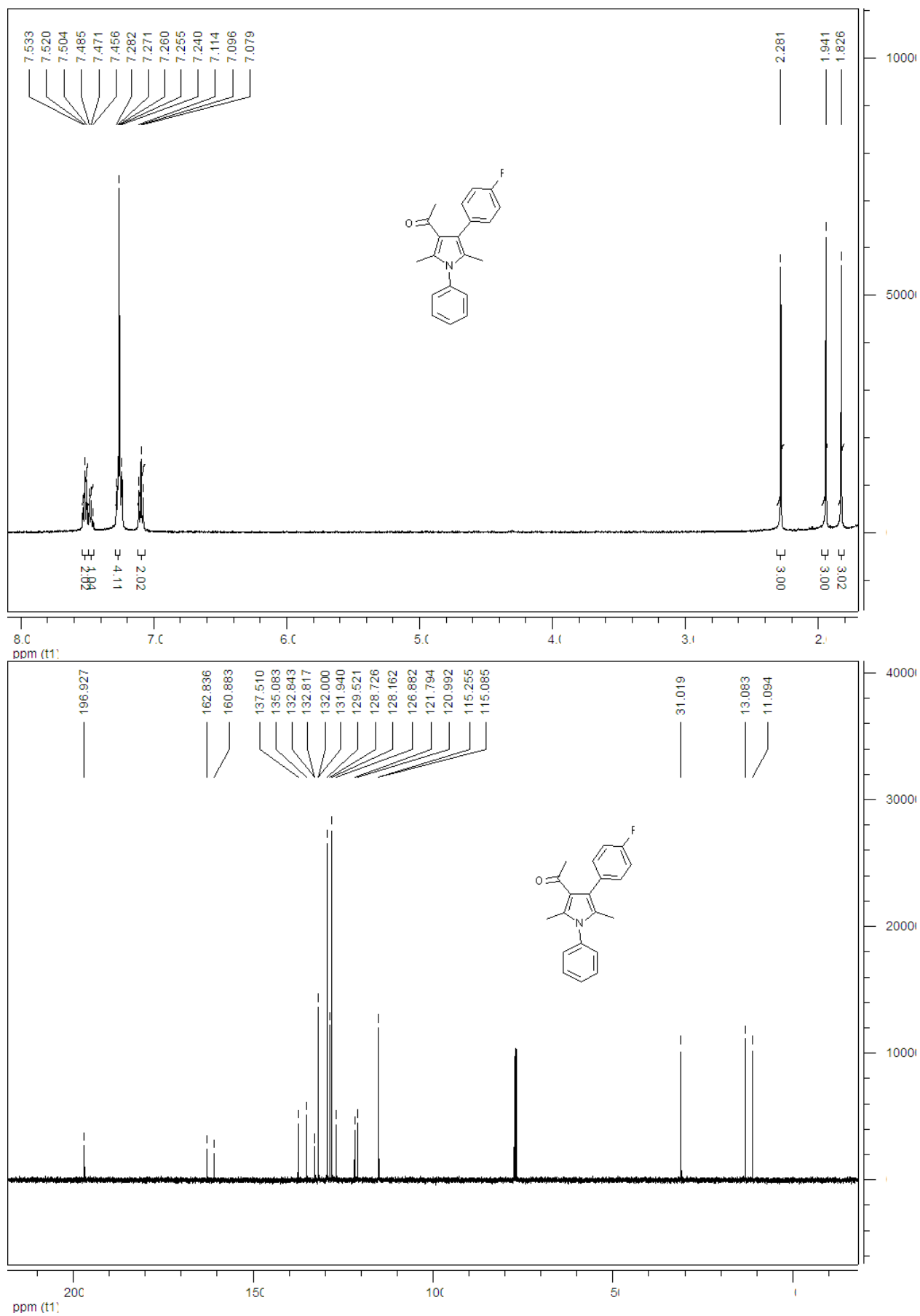
Chemical structure of 1-phenyl-2-methyl-3-(4-methylphenyl)-4-oxo-1H-indole-5-carboxamide is shown above the spectrum.

The spectrum displays peaks in the aromatic region (7.183-7.524 ppm) and aliphatic region (1.847-2.392 ppm). Integration values are provided for the main signals.

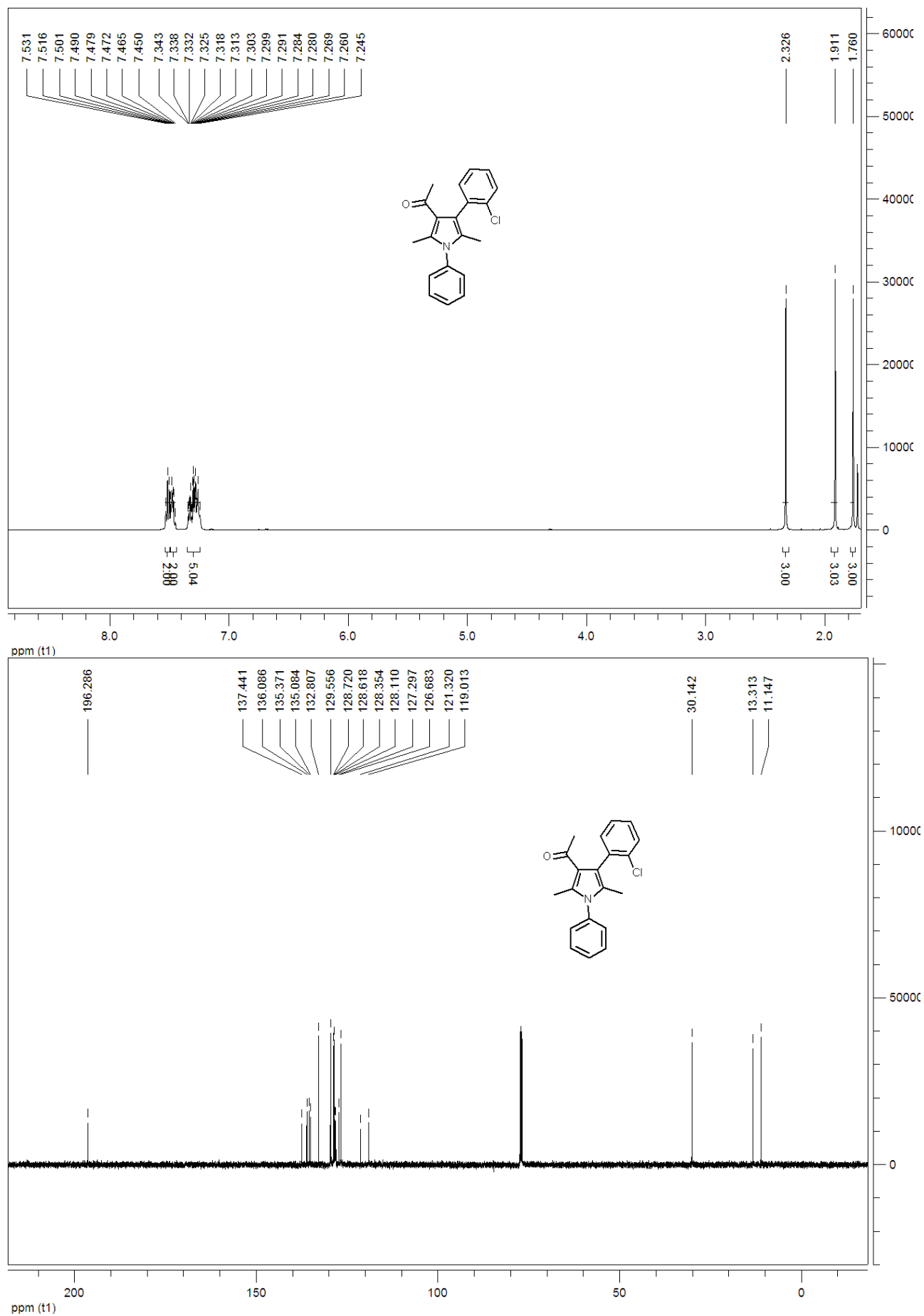
Chemical Shift (ppm)	Integration
7.524	1.09
7.509	1.06
7.494	1.06
7.471	1.06
7.457	1.06
7.442	1.06
7.260	1.06
7.245	1.06
7.218	1.06
7.200	1.06
7.183	1.06
2.392	3.02
2.285	3.00
1.952	3.01
1.847	3.02



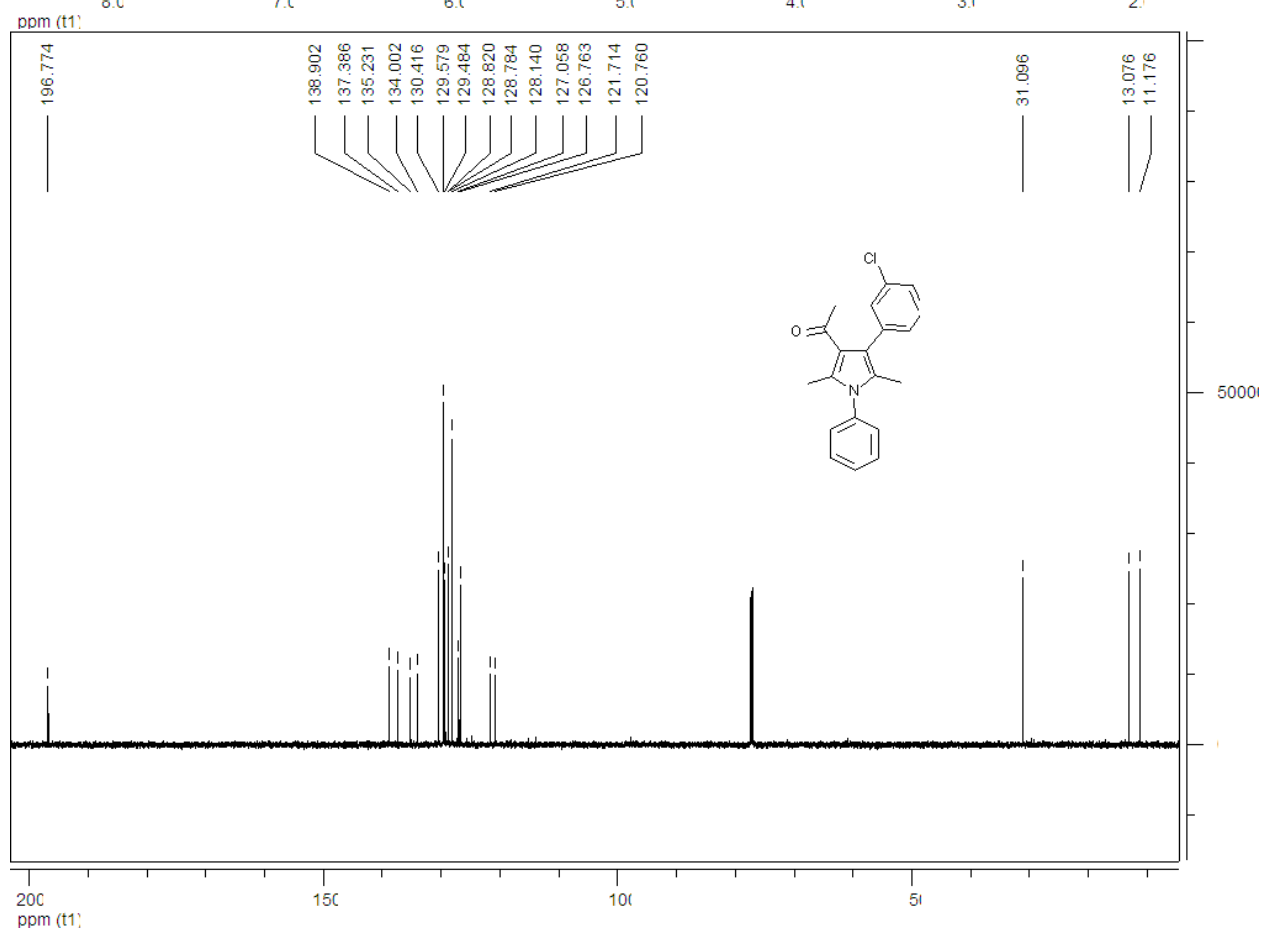
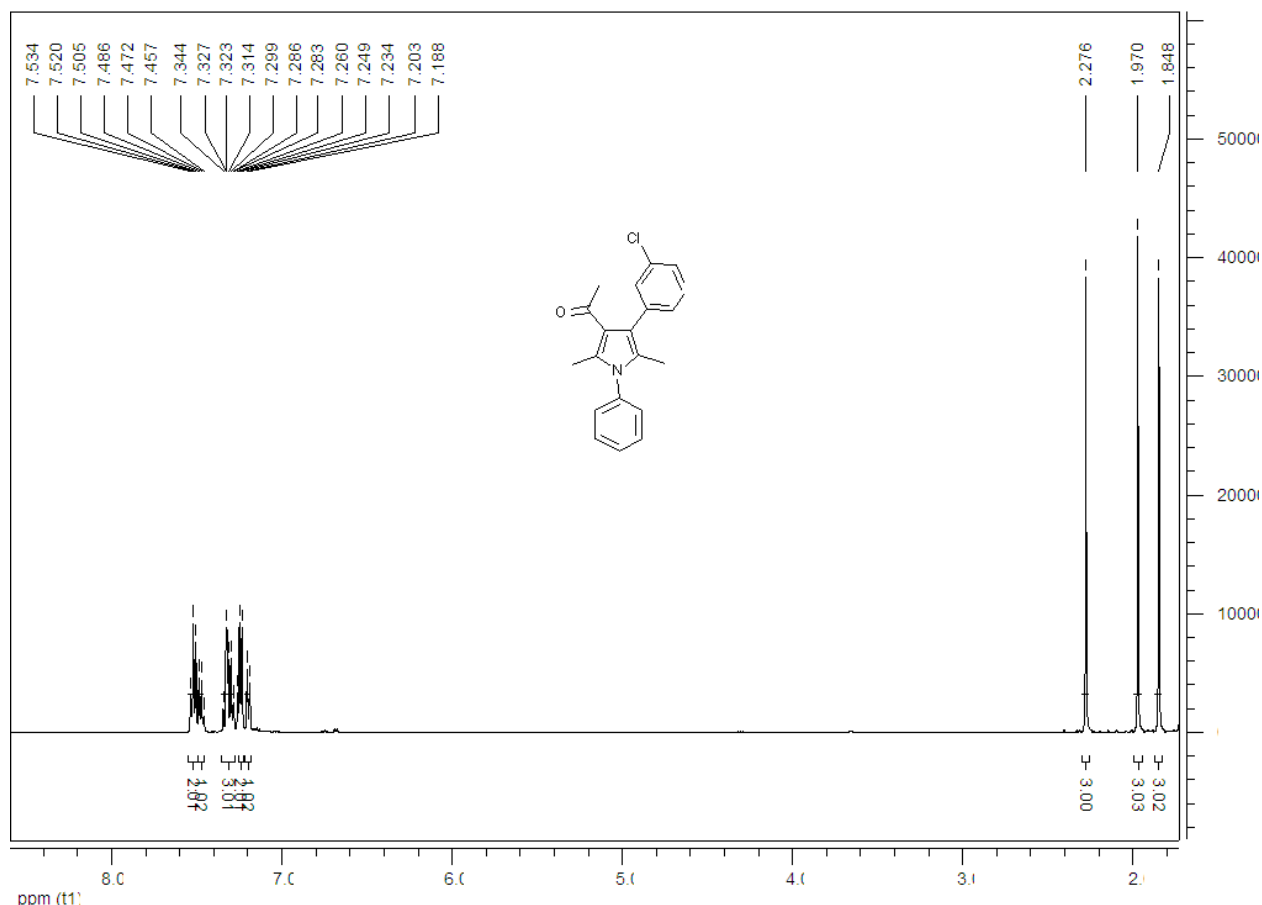
^1H NMR and ^{13}C NMR of compound **4d**



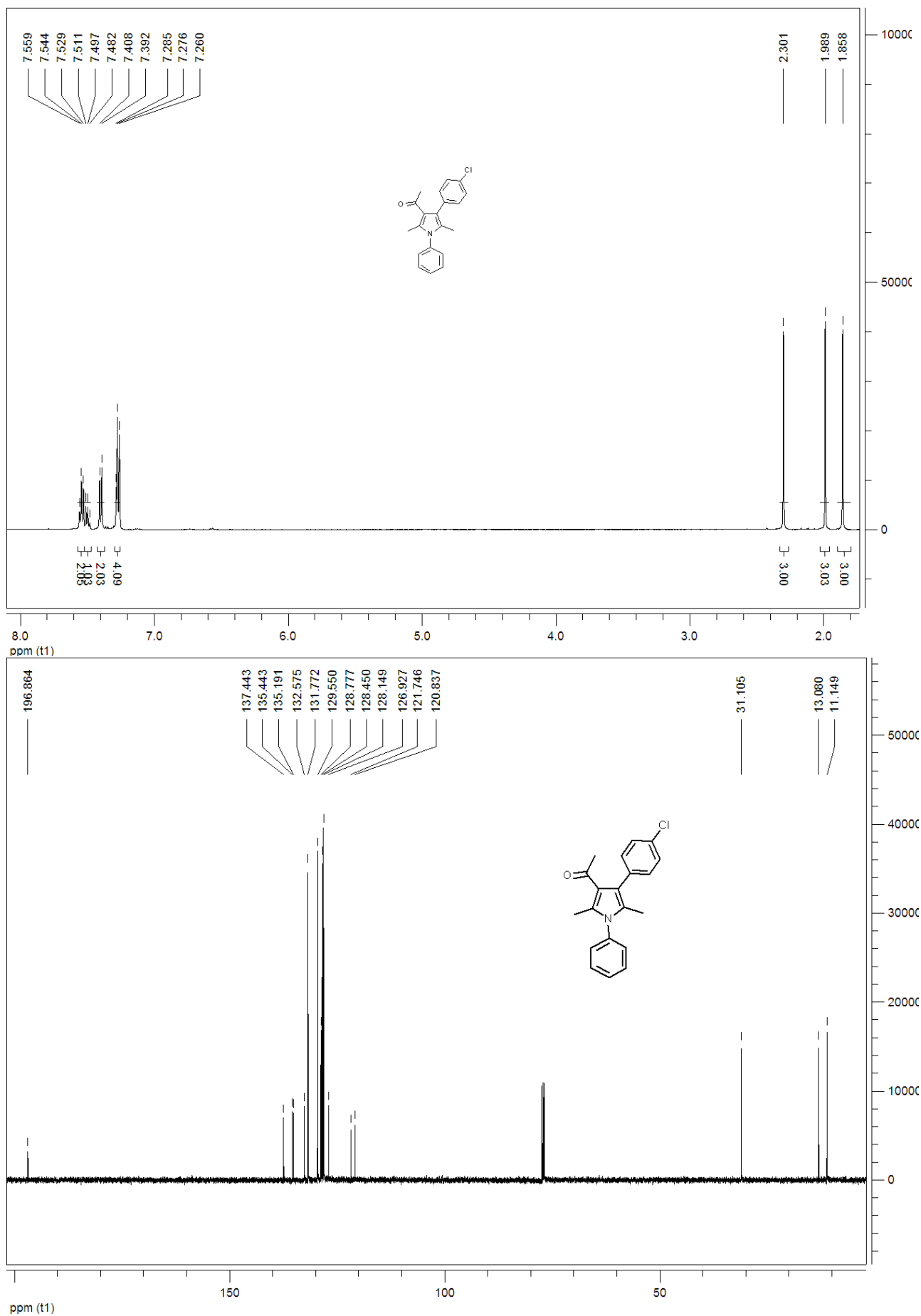
^1H NMR and ^{13}C NMR of compound **4e**



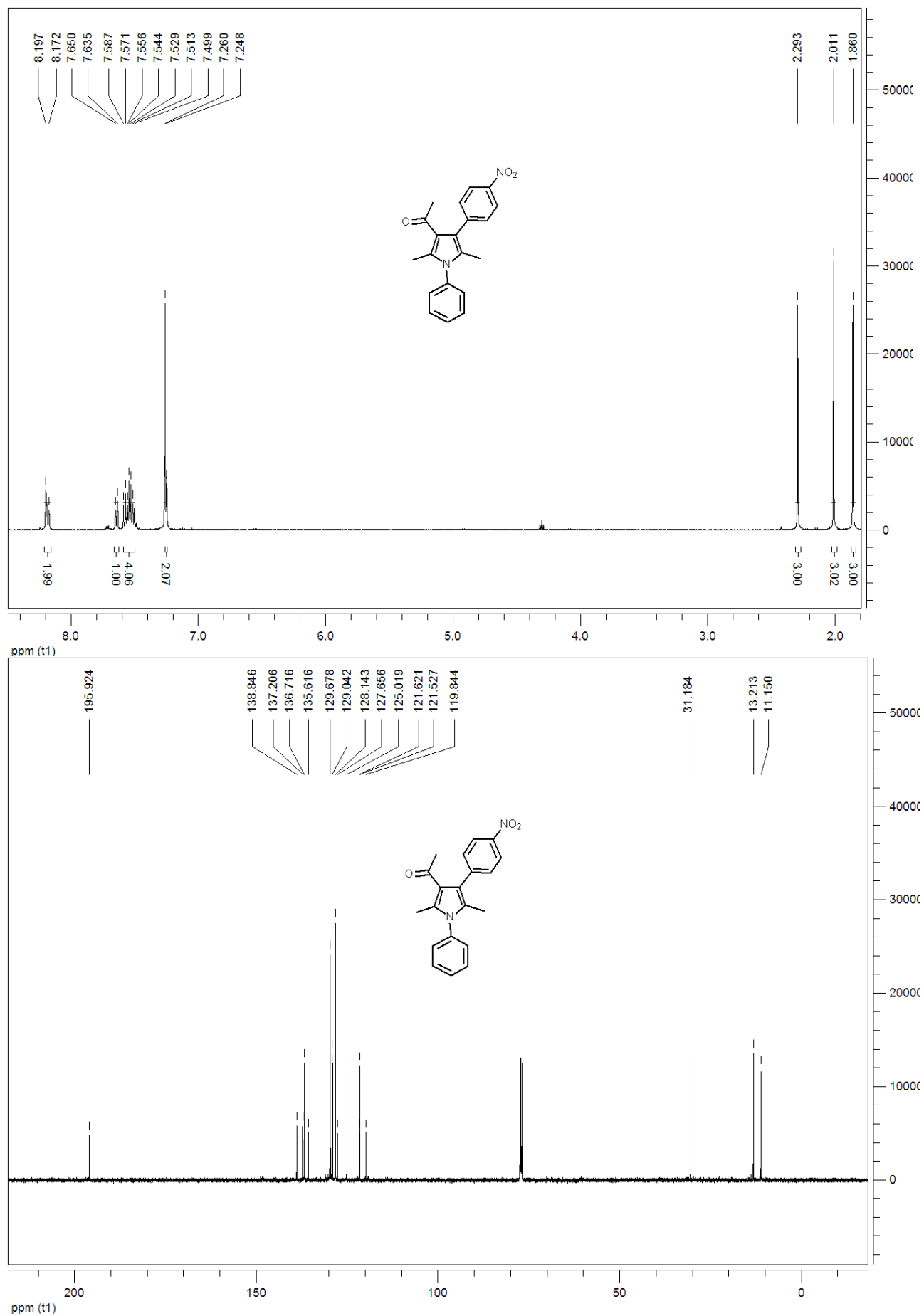
^1H NMR and ^{13}C NMR of compound **4f**



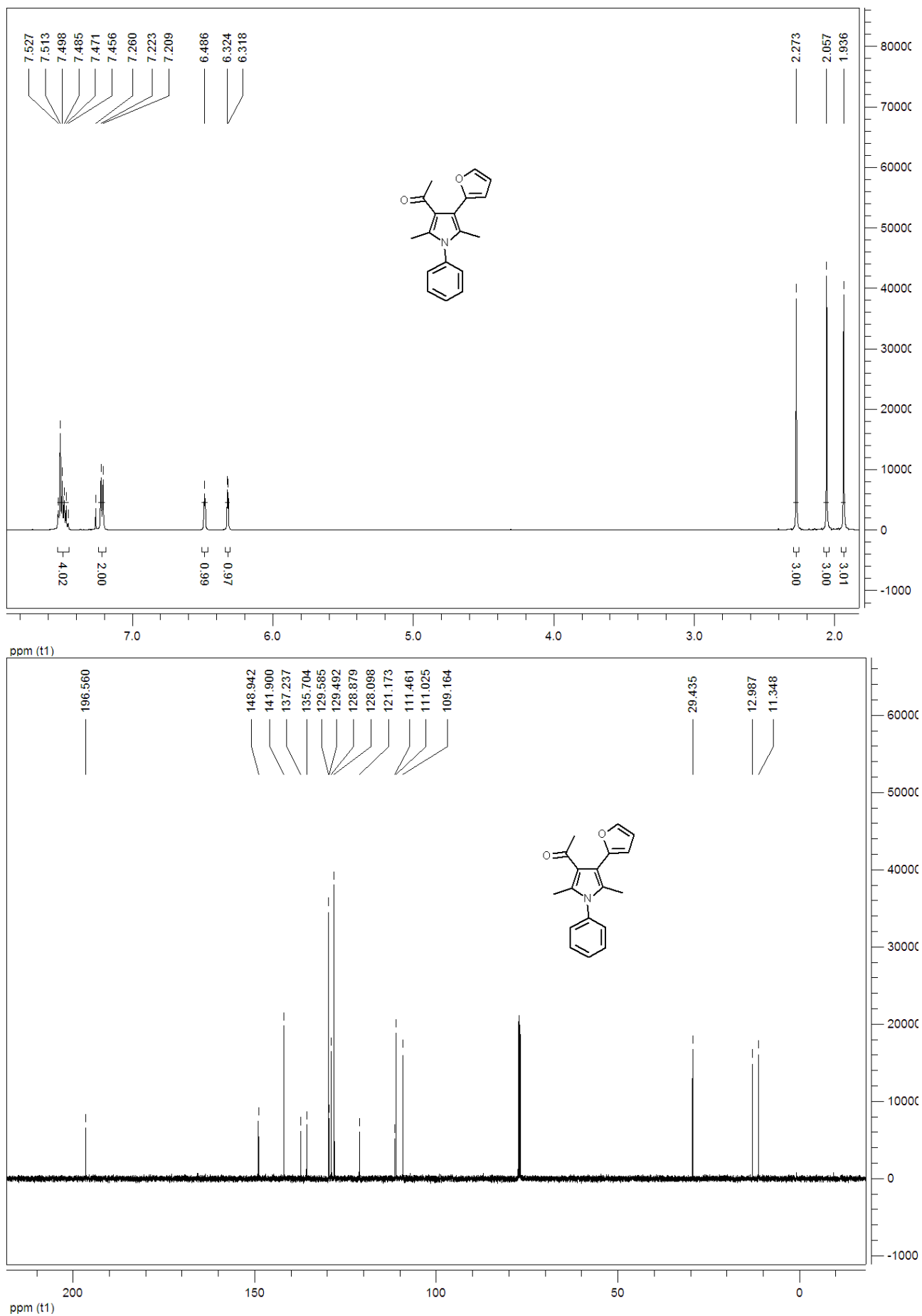
^1H NMR and ^{13}C NMR of compound **4g**



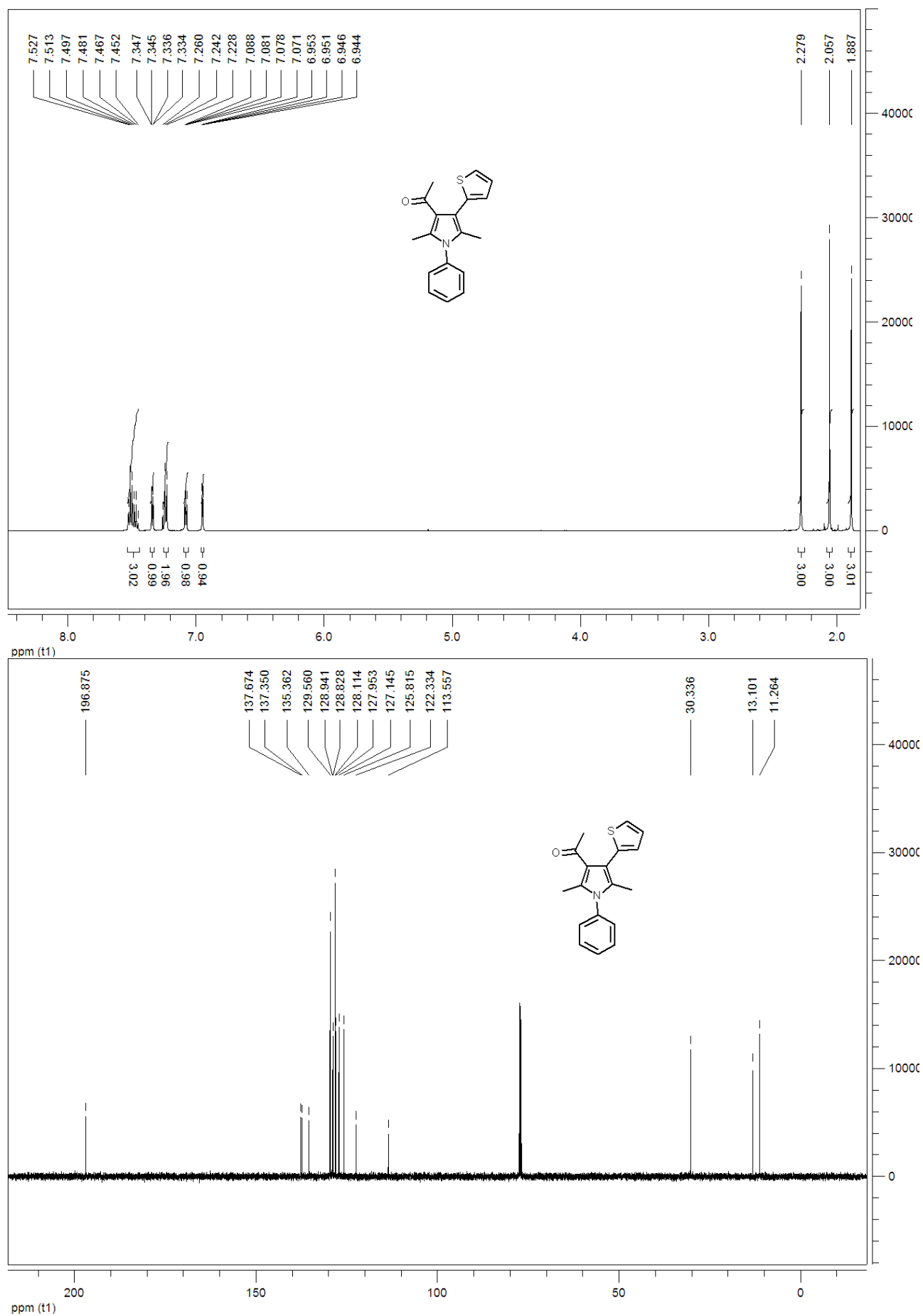
^1H NMR and ^{13}C NMR of compound **4h**



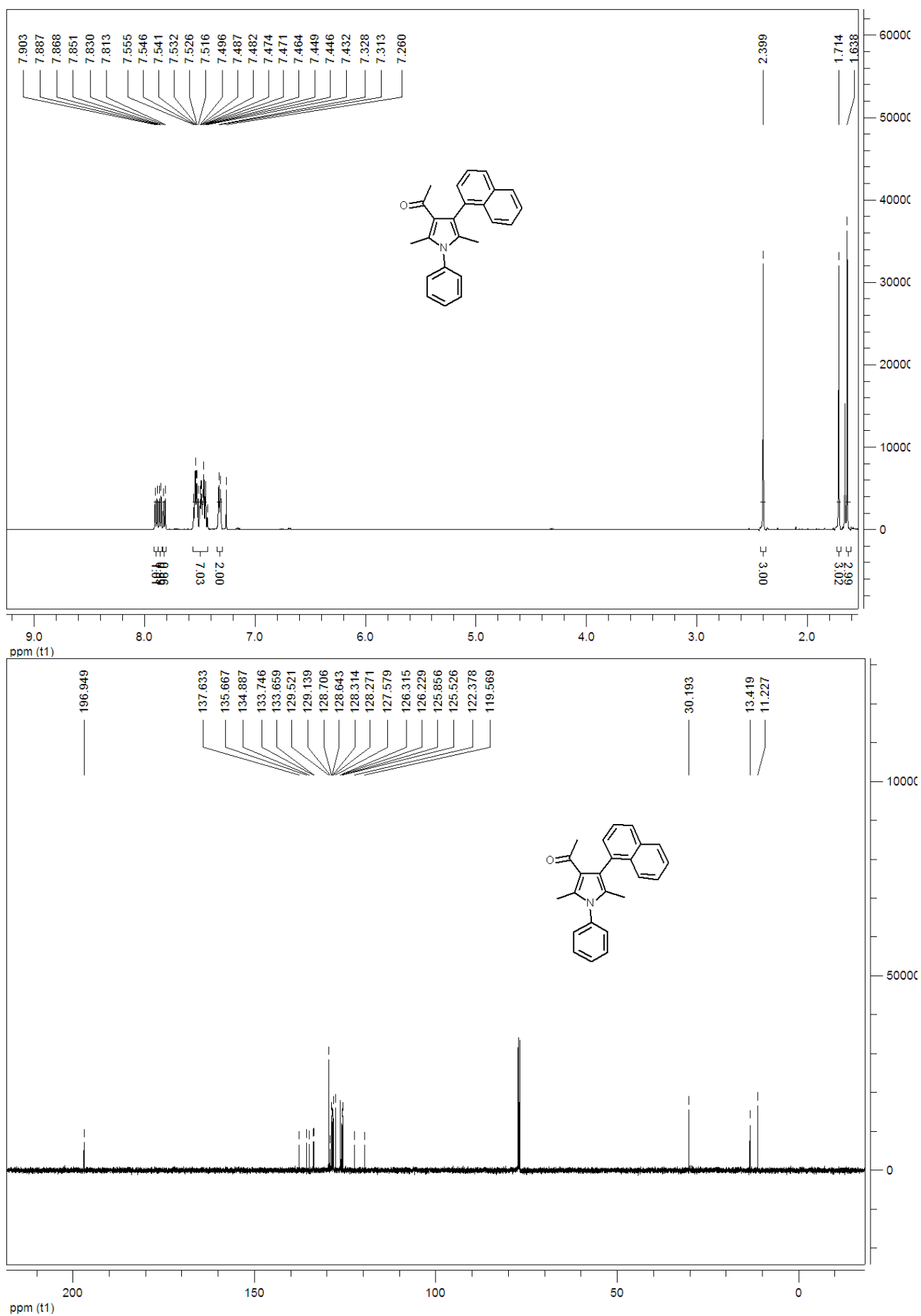
^1H NMR and ^{13}C NMR of compound **4i**



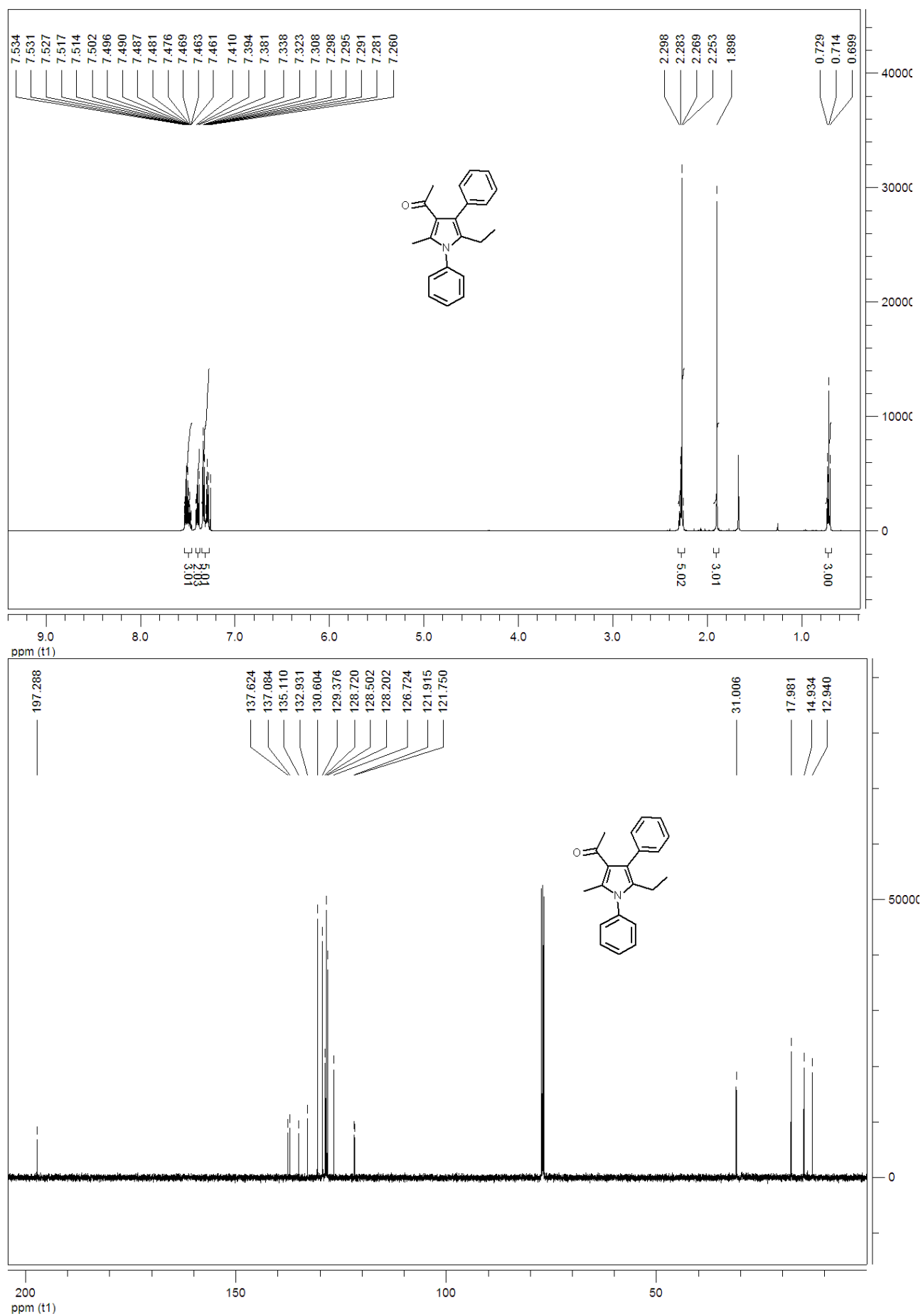
^1H NMR and ^{13}C NMR of compound **4j**



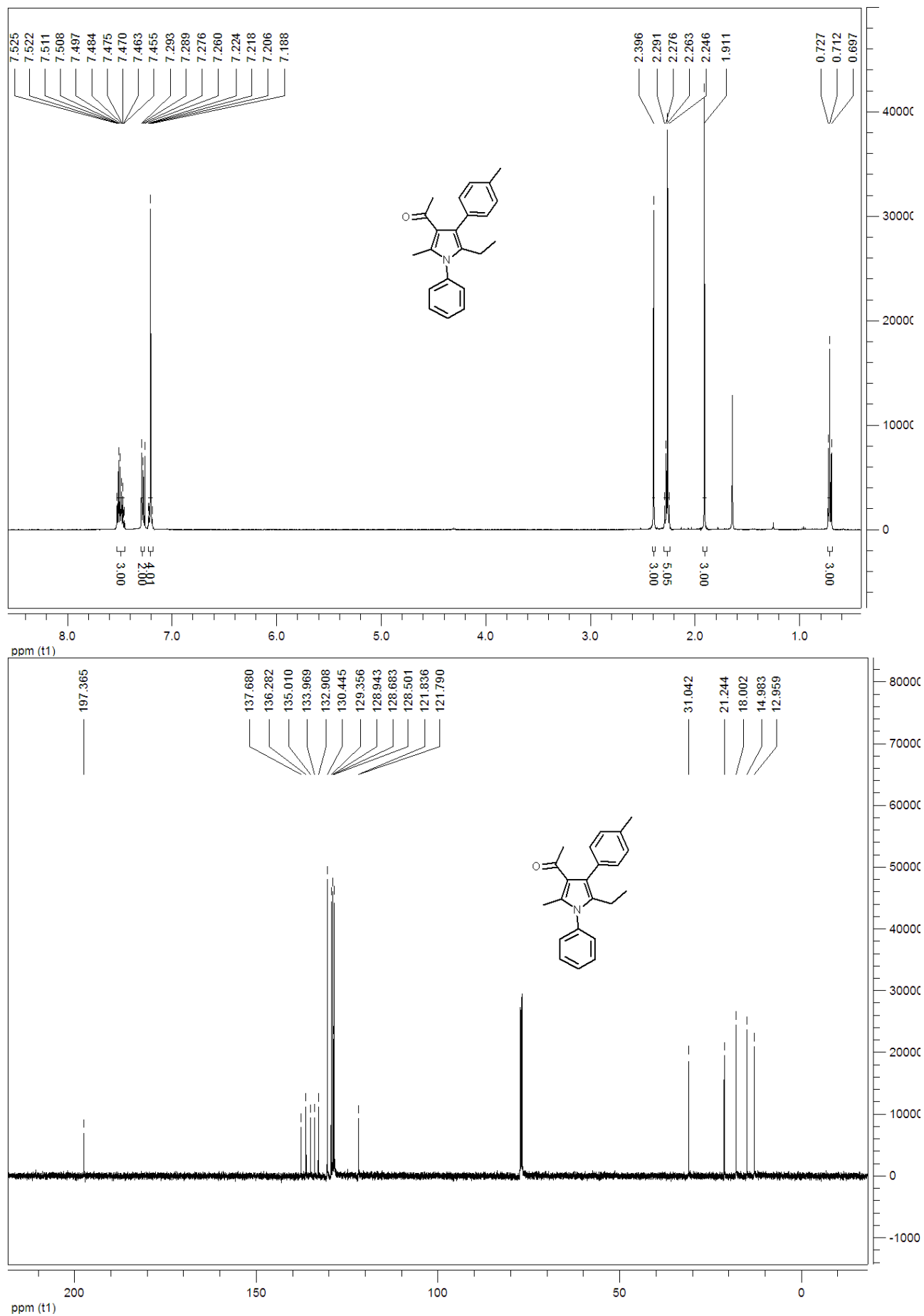
^1H NMR and ^{13}C NMR of compound **4k**



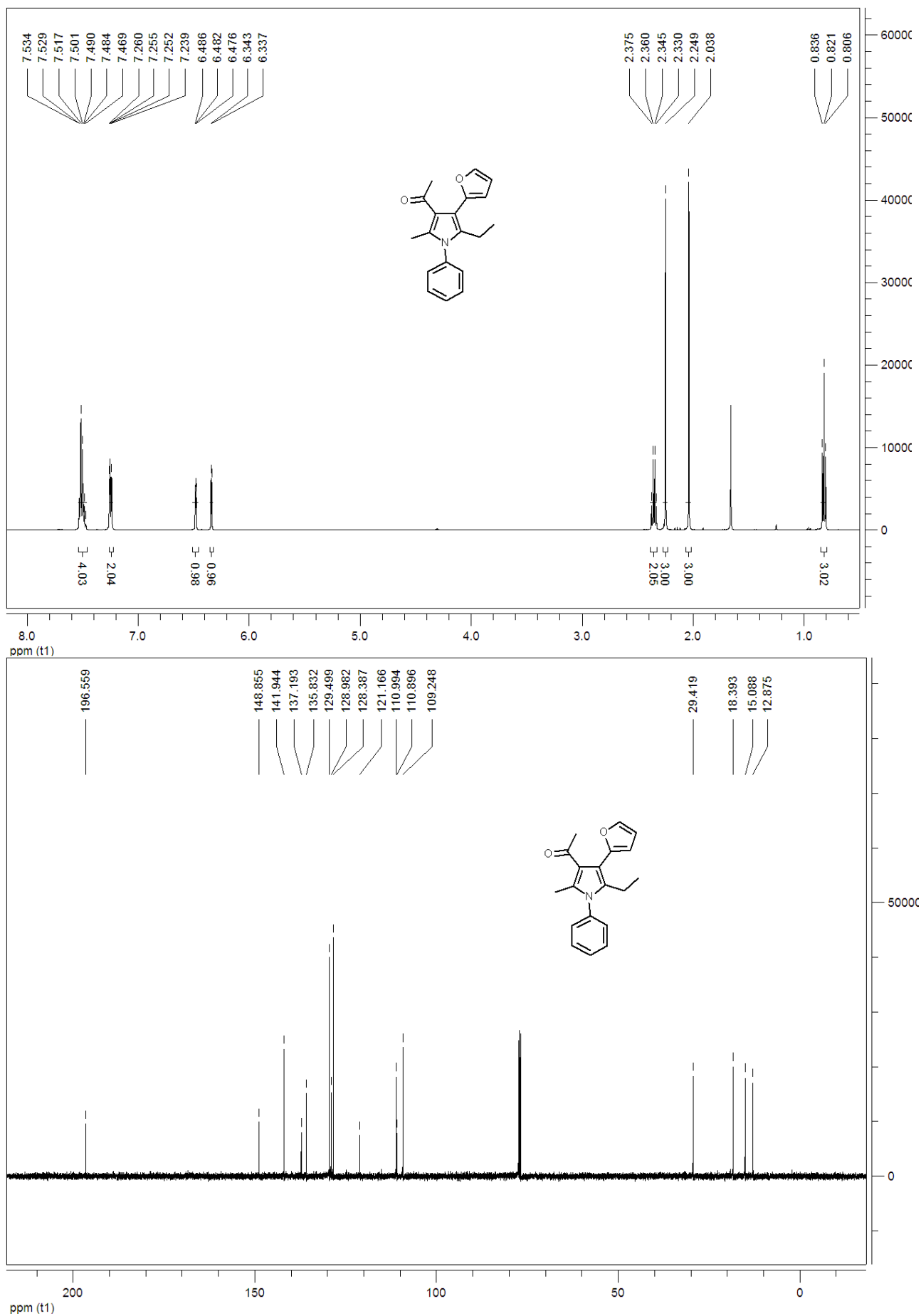
^1H NMR and ^{13}C NMR of compound **4l**



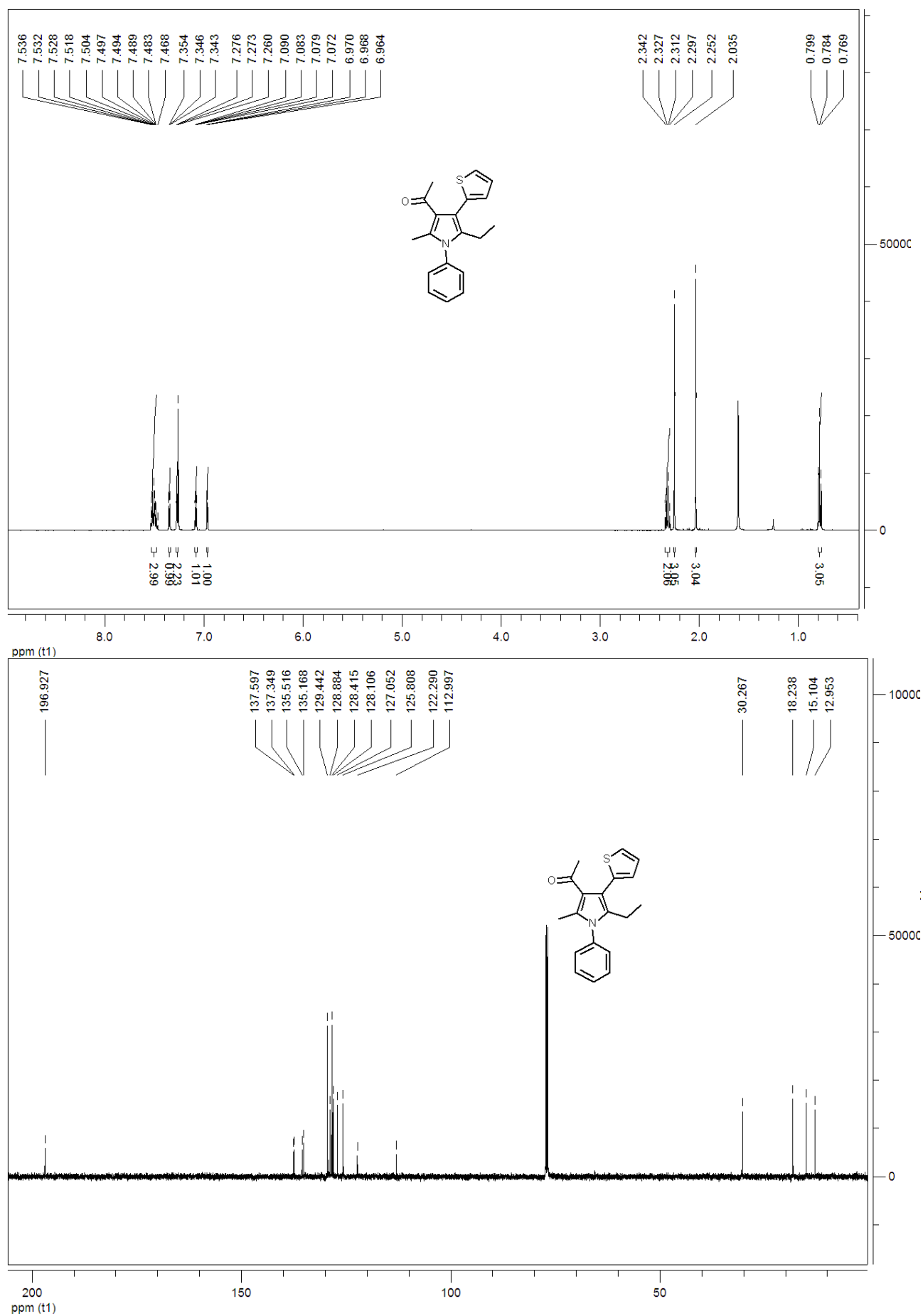
^1H NMR and ^{13}C NMR of compound **4m**



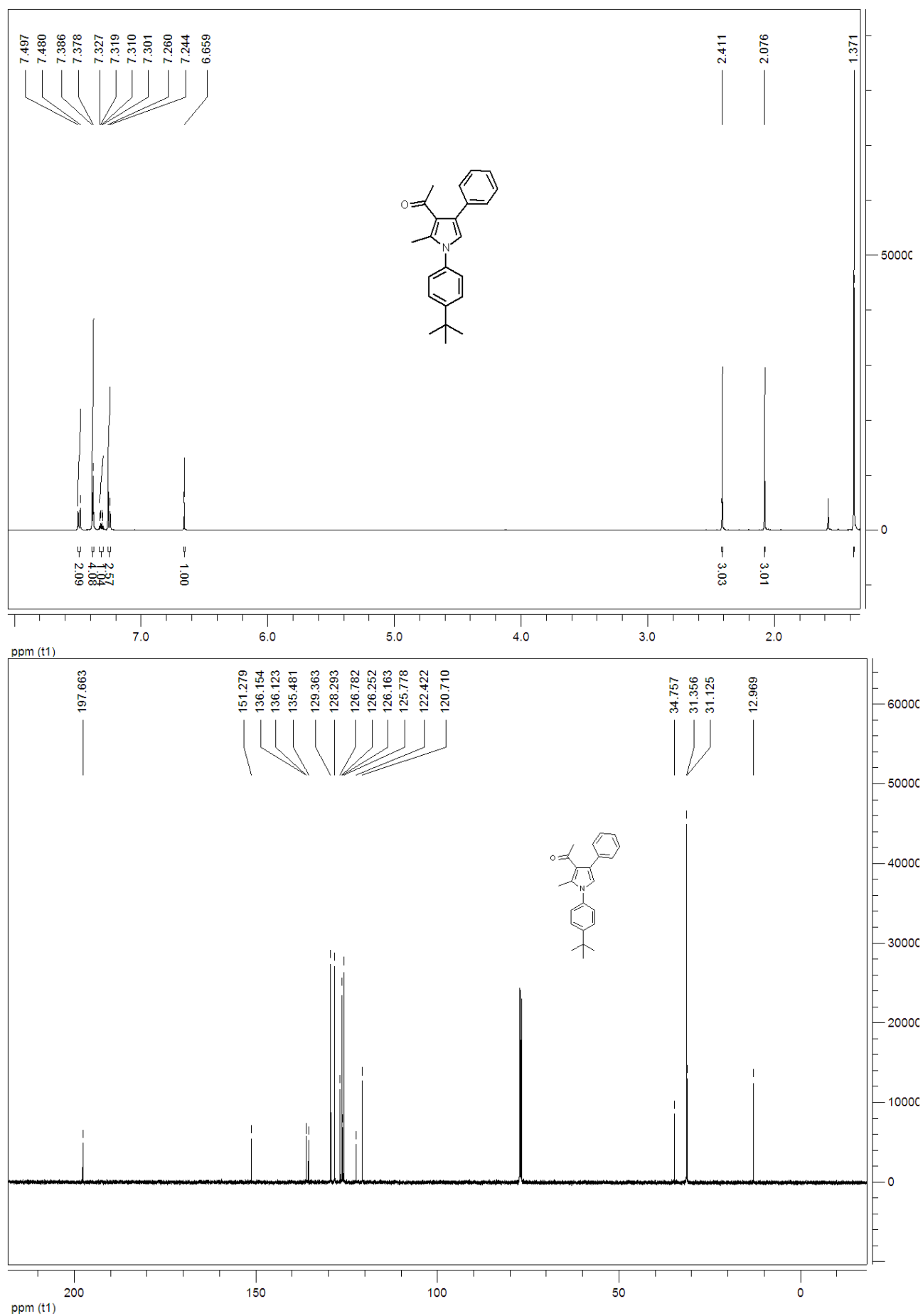
^1H NMR and ^{13}C NMR of compound **4n**



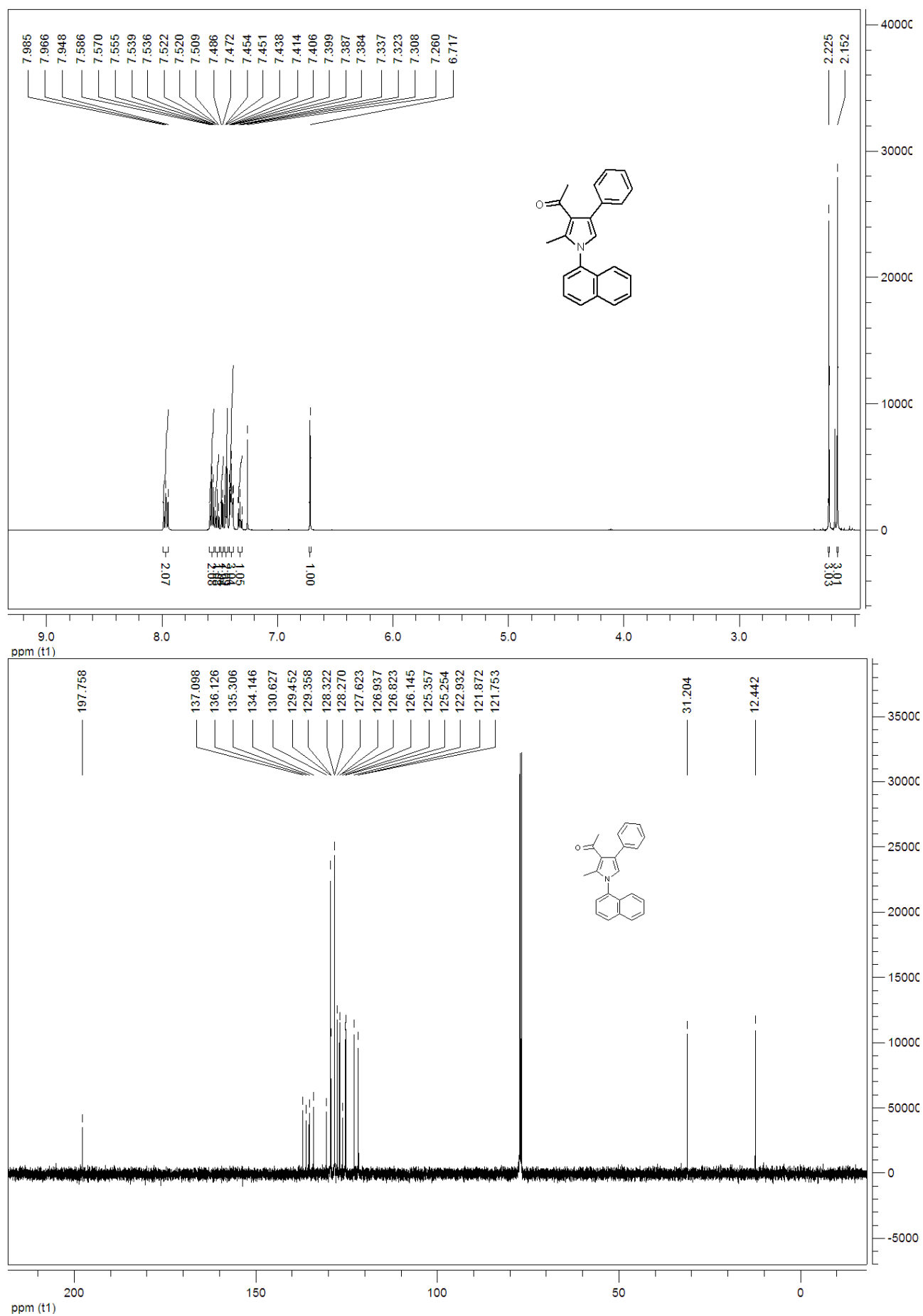
^1H NMR and ^{13}C NMR of compound **4o**



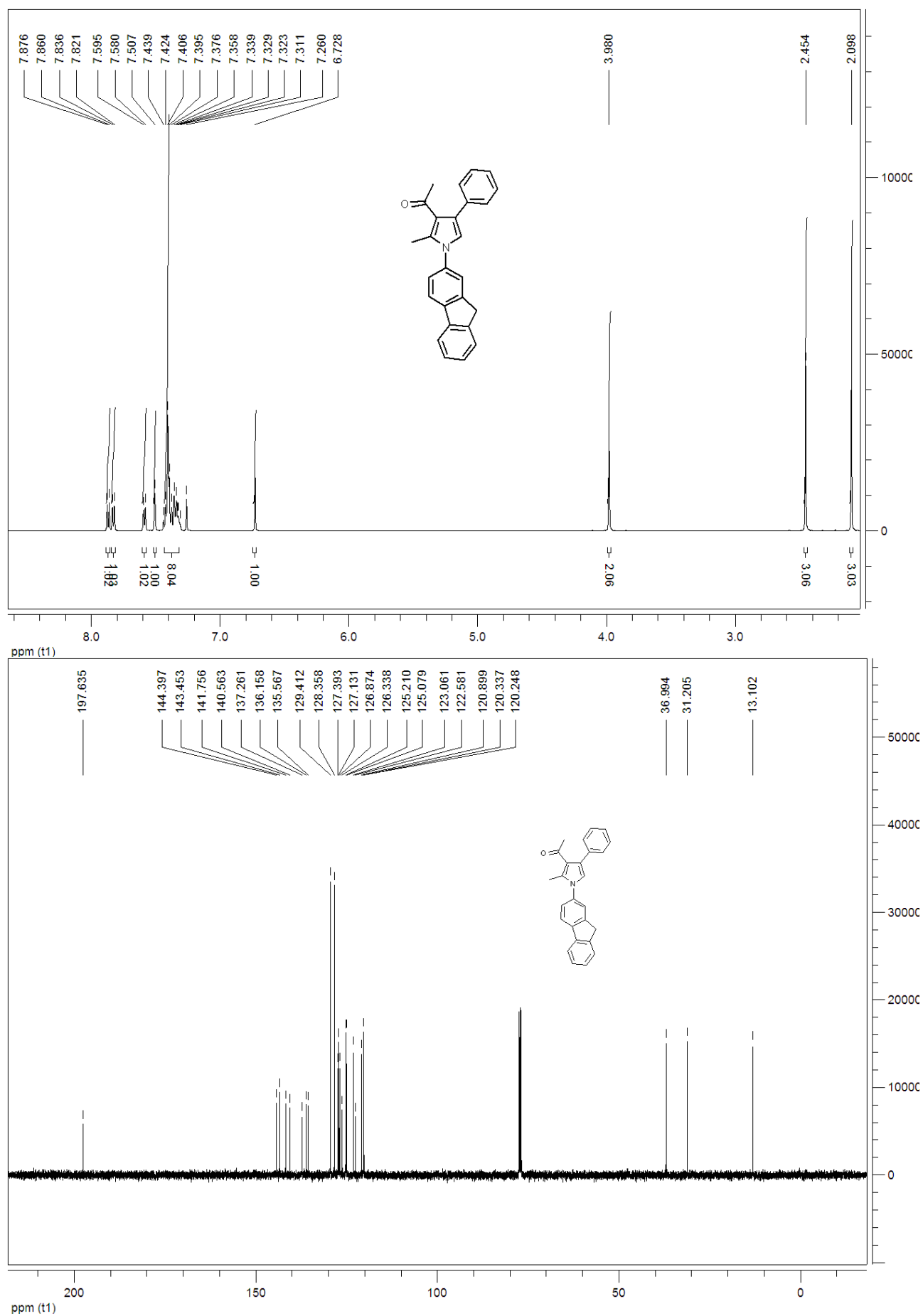
^1H NMR and ^{13}C NMR of compound **4p**



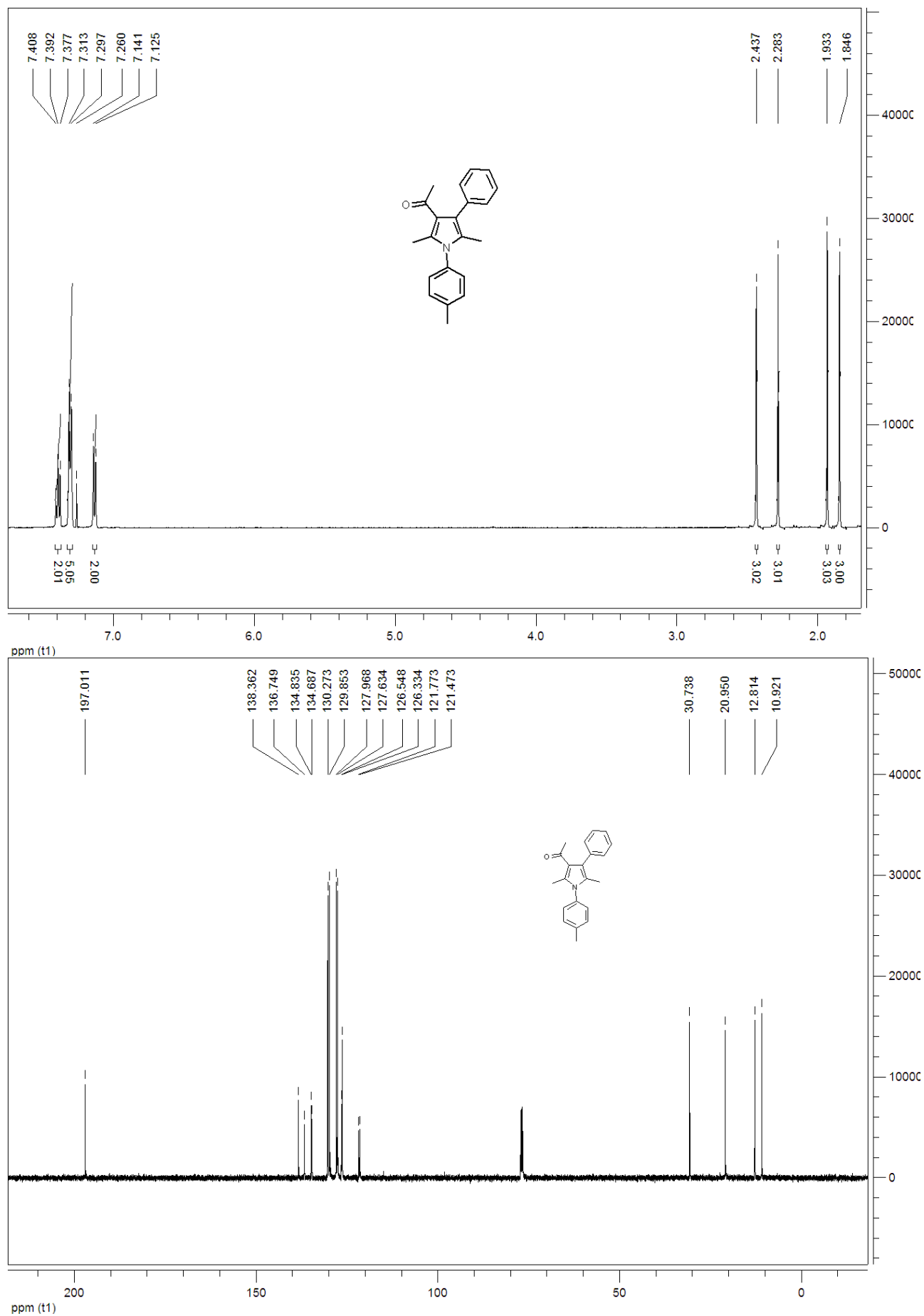
^1H NMR and ^{13}C NMR of compound **4q**



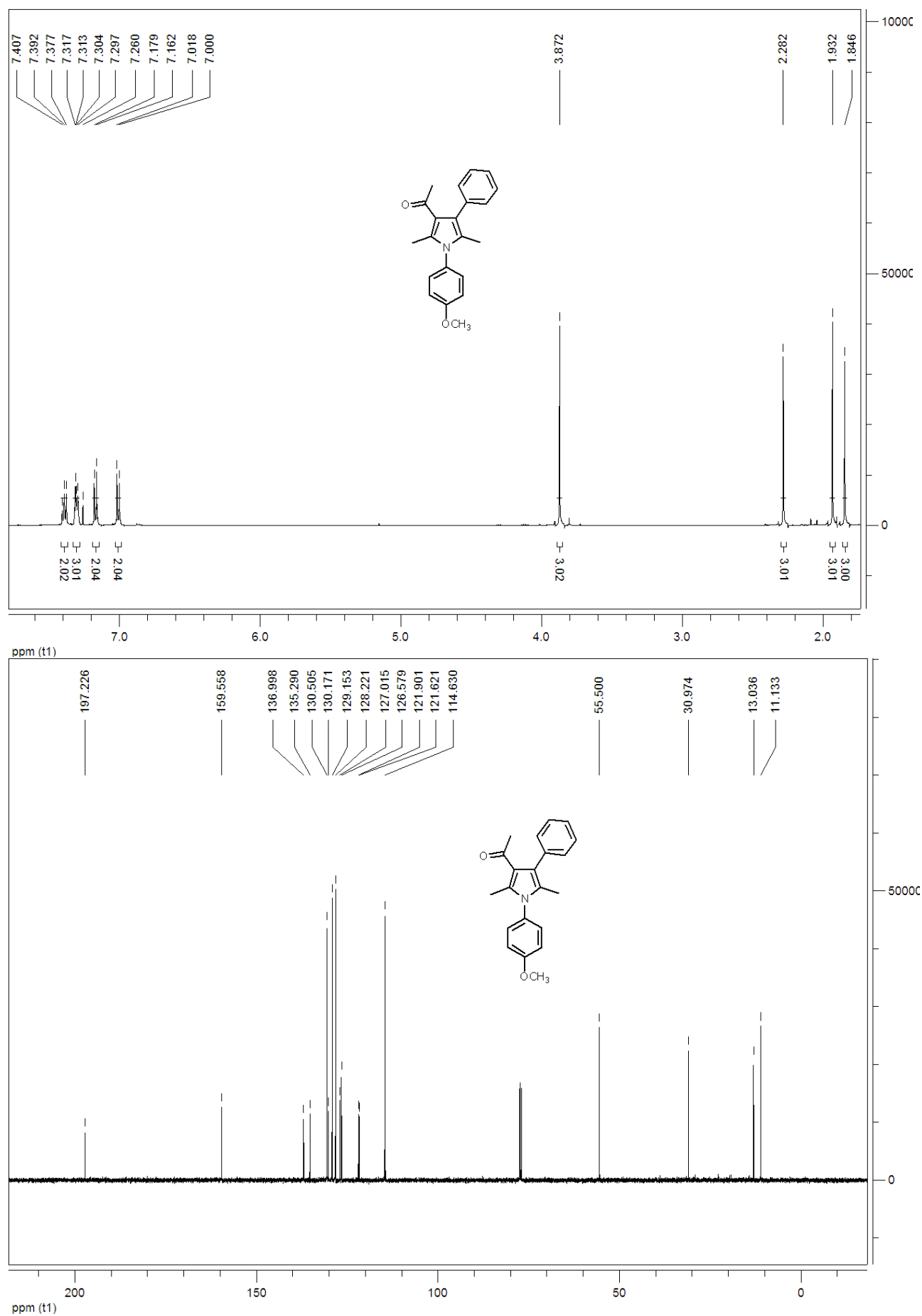
^1H NMR and ^{13}C NMR of compound **4r**



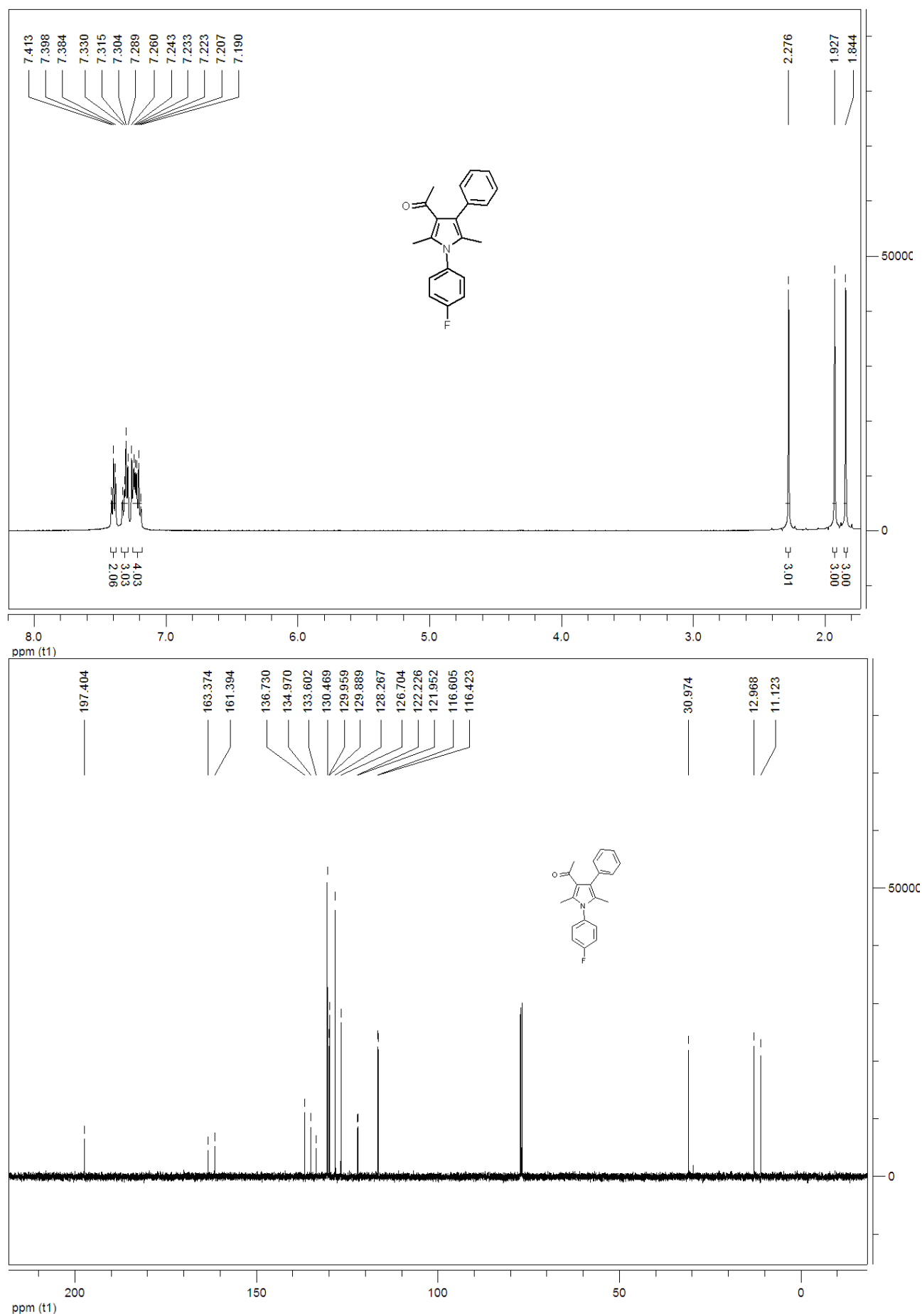
^1H NMR and ^{13}C NMR of compound **4s**



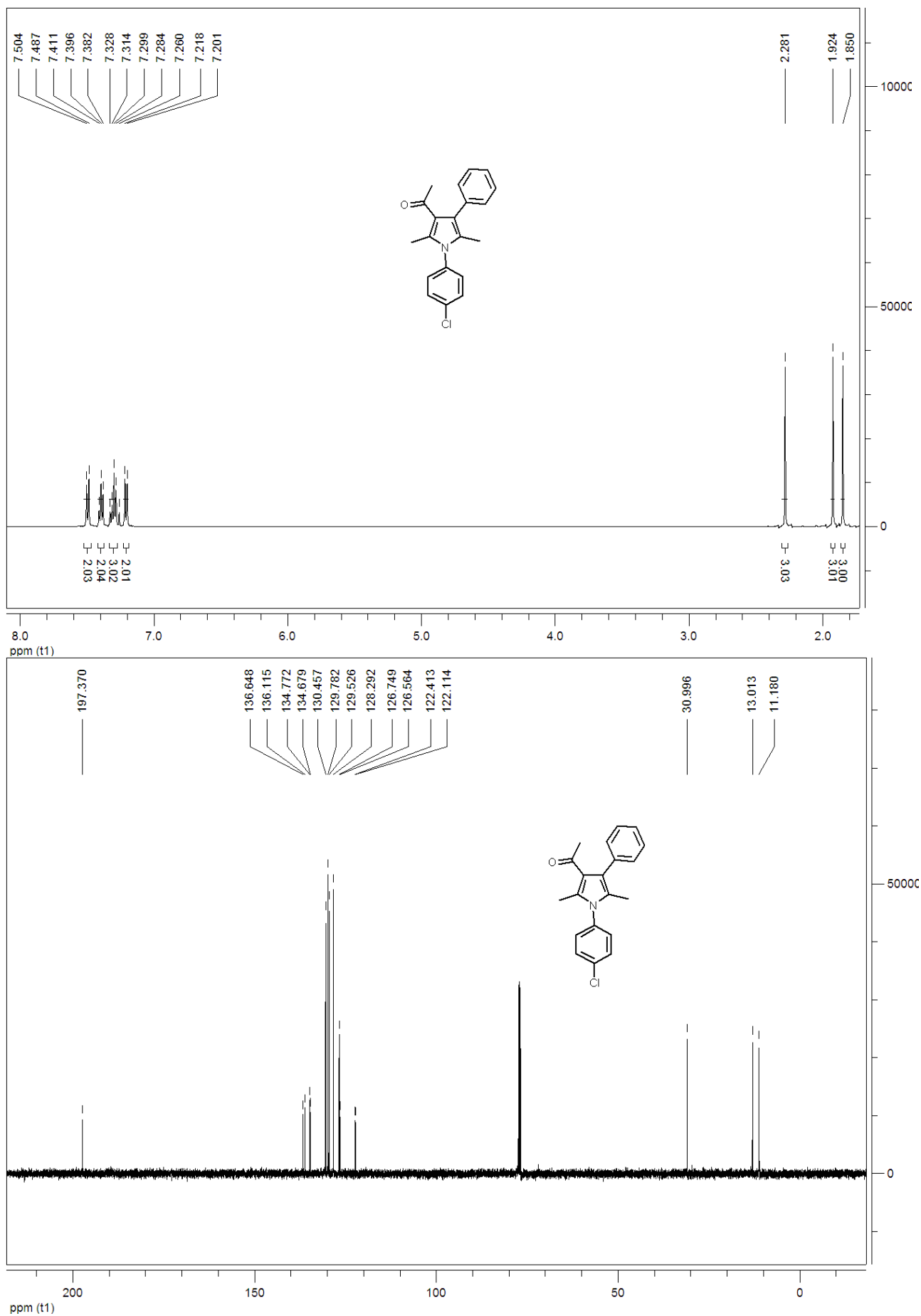
¹H NMR and ¹³C NMR of compound **4t**



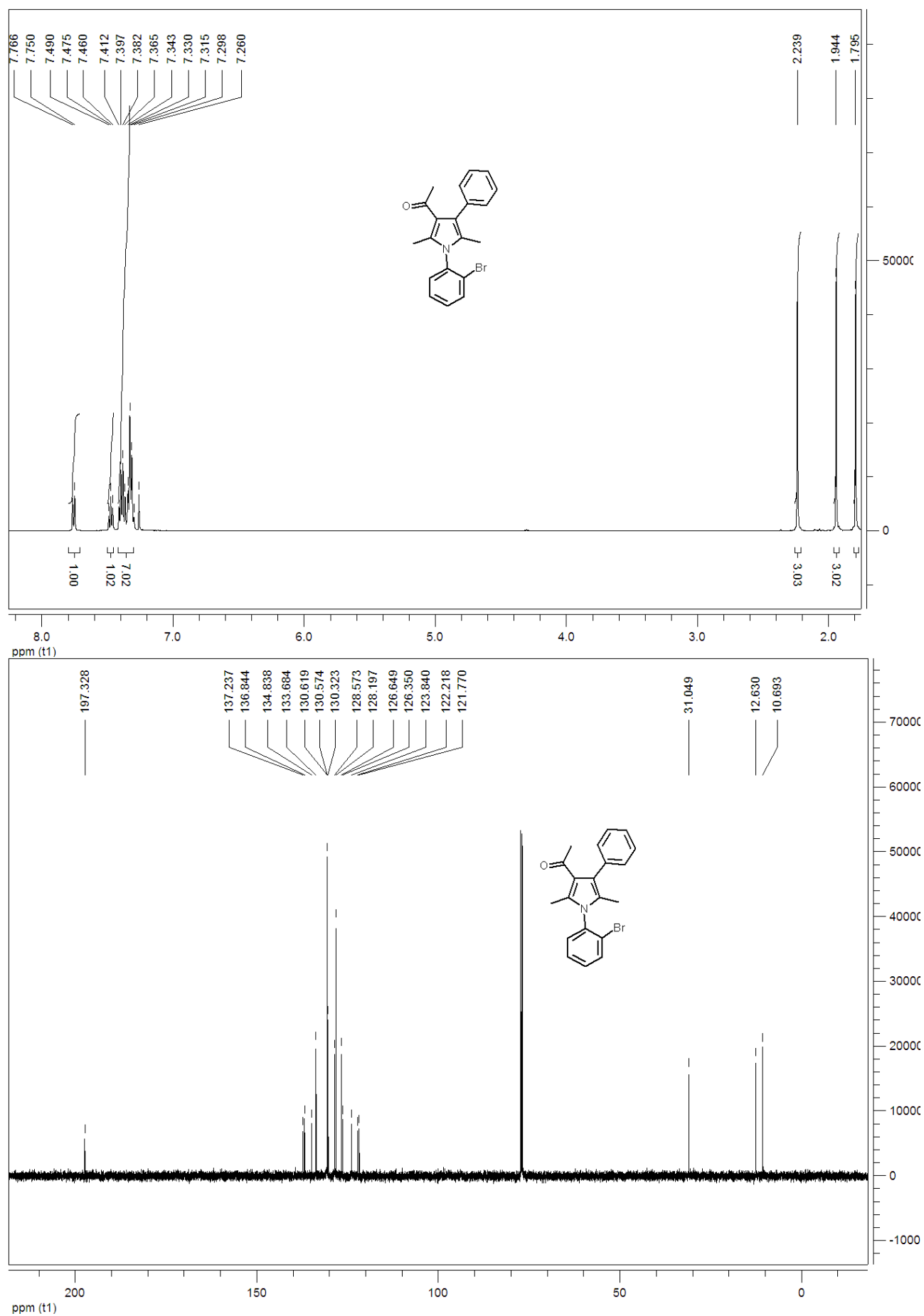
^1H NMR and ^{13}C NMR of compound **4u**



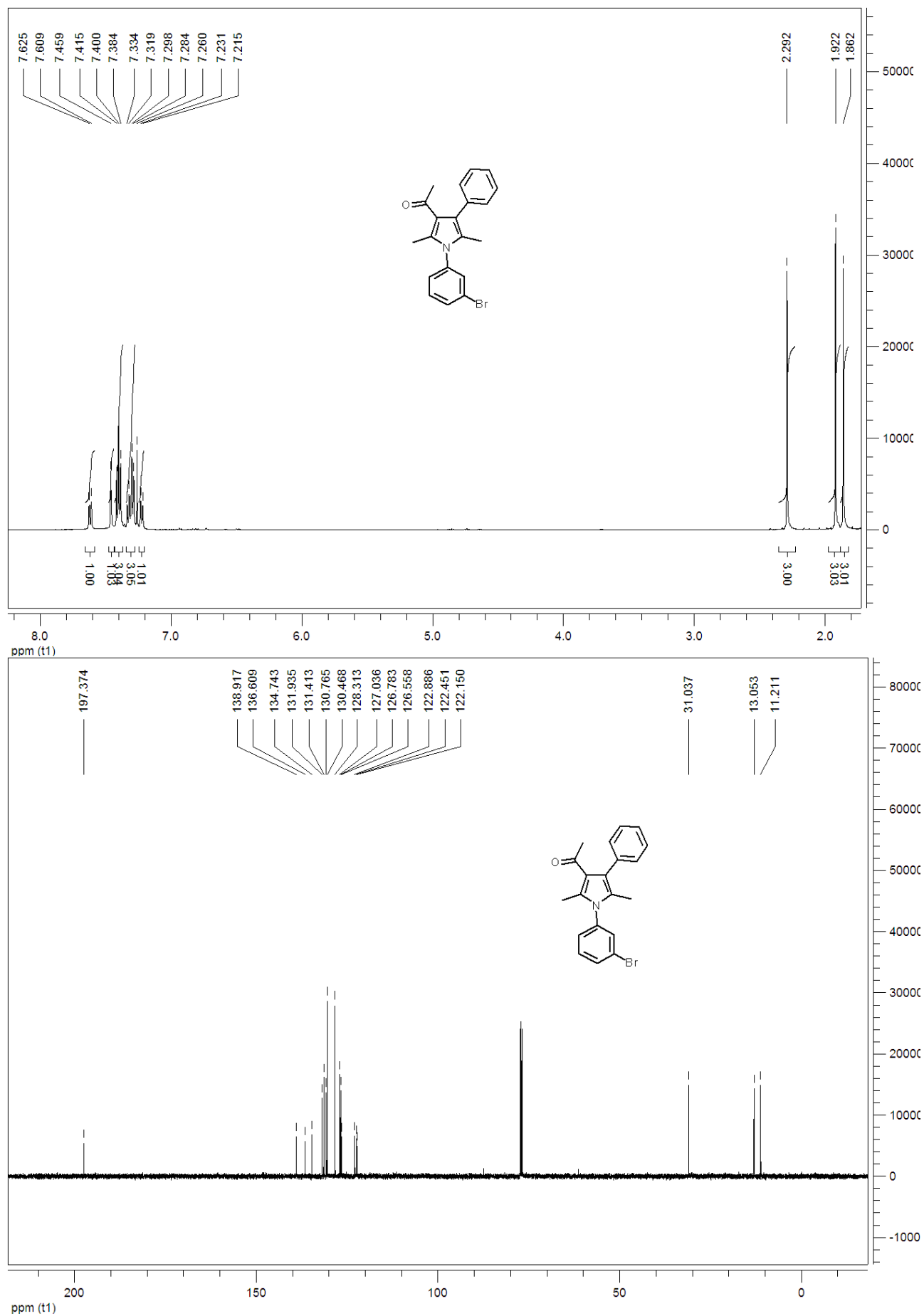
^1H NMR and ^{13}C NMR of compound **4v**



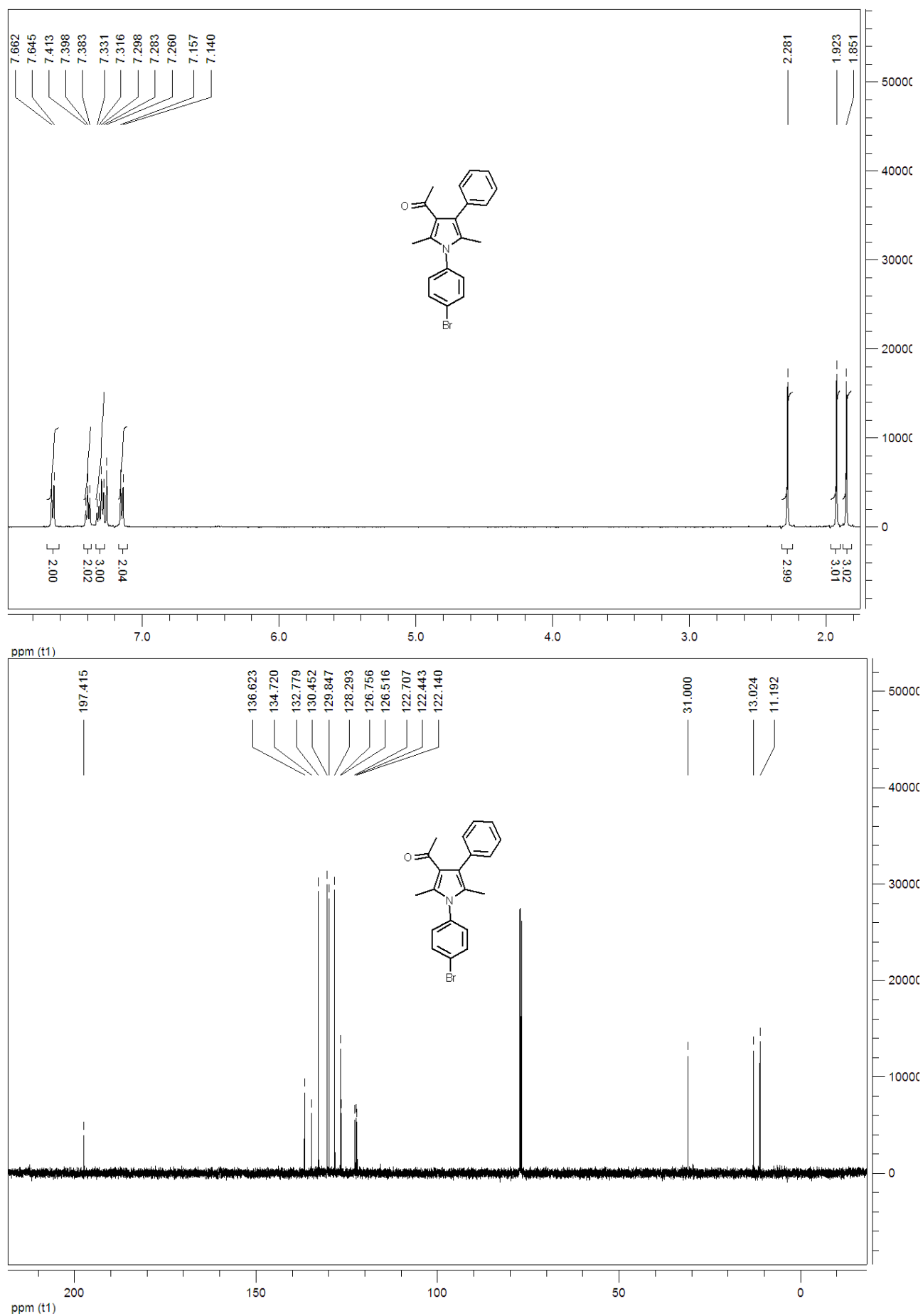
^1H NMR and ^{13}C NMR of compound **4w**



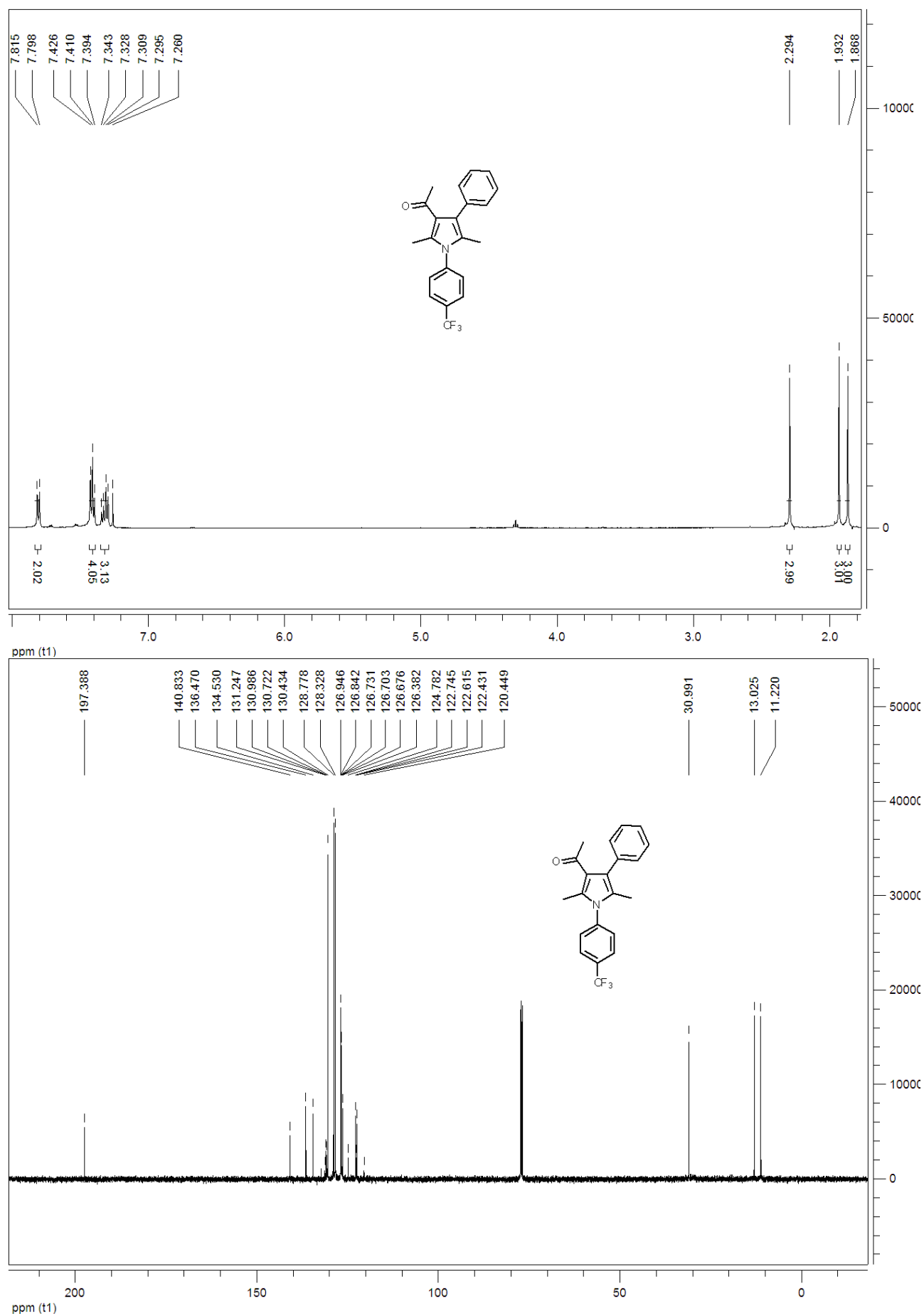
^1H NMR and ^{13}C NMR of compound **4x**



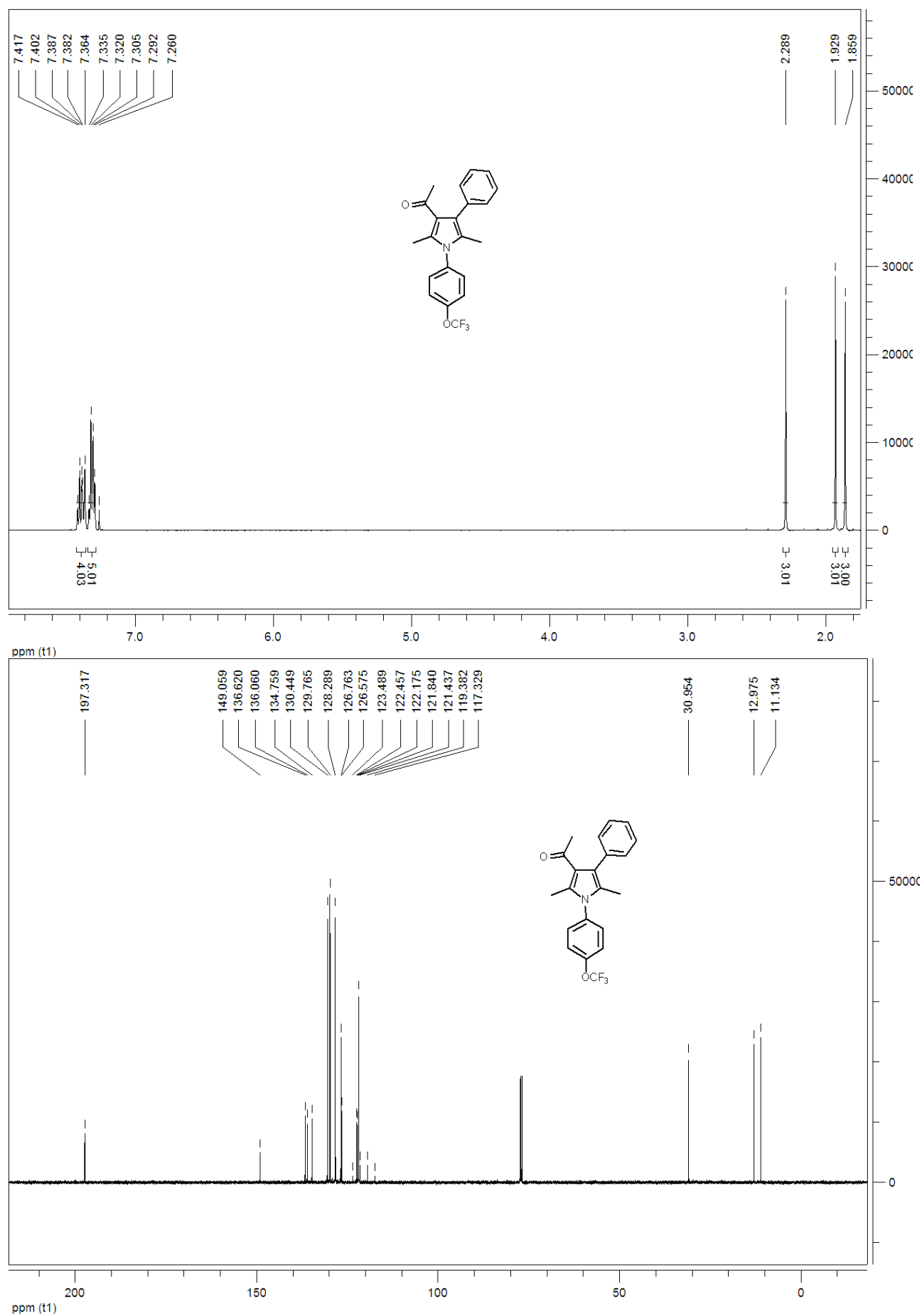
^1H NMR and ^{13}C NMR of compound **4y**



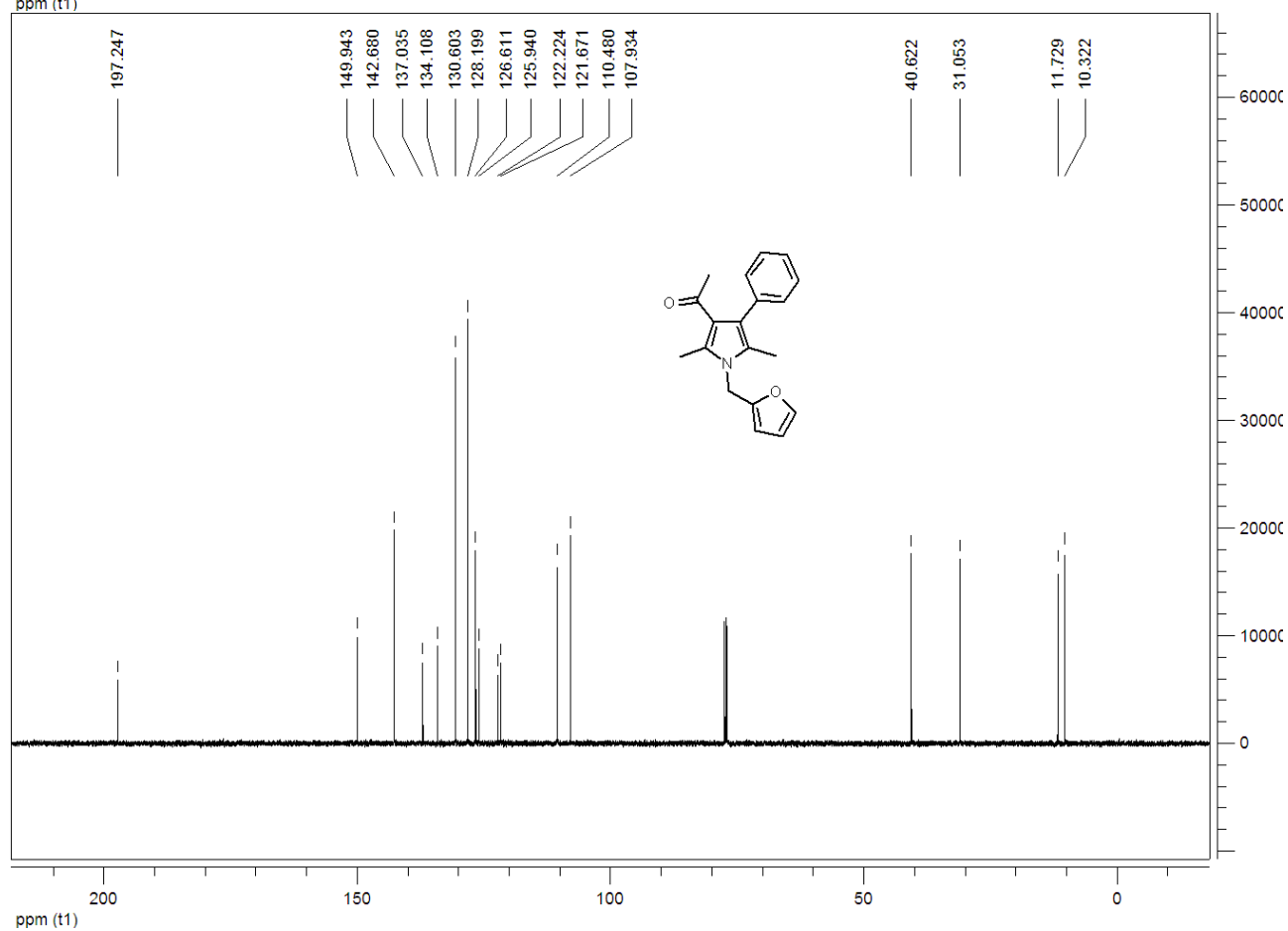
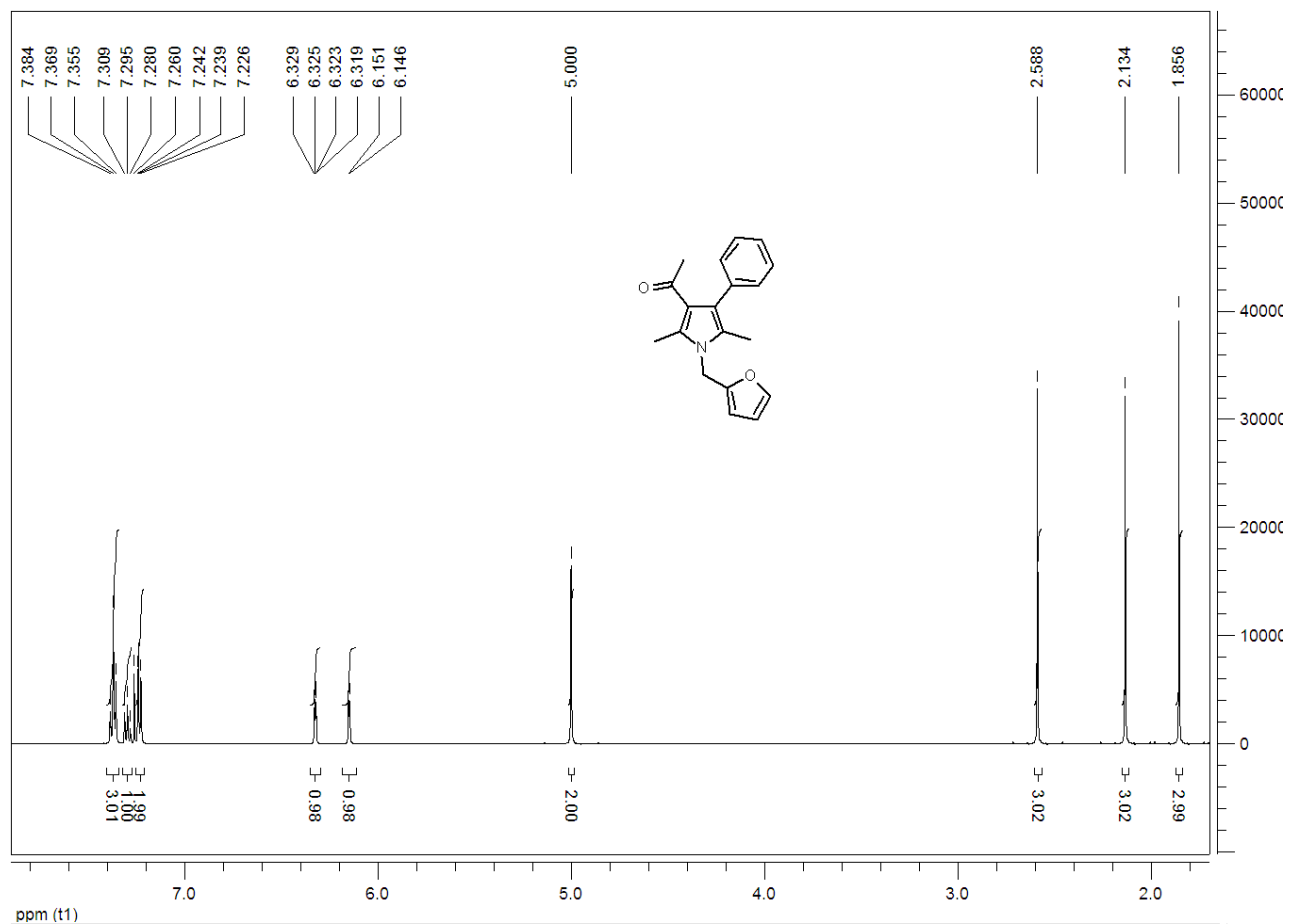
¹H NMR and ¹³C NMR of compound **4z**



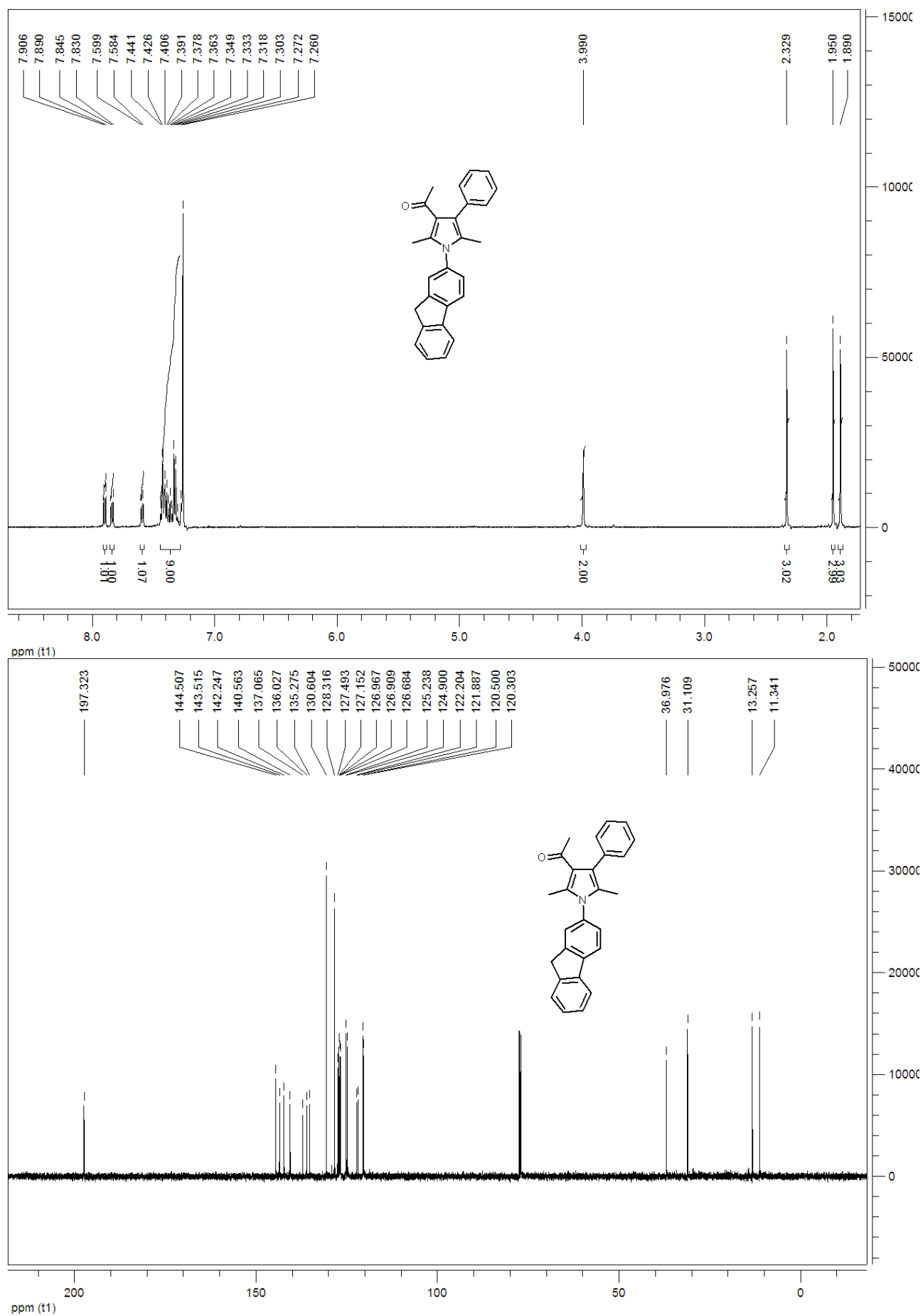
¹H NMR and ¹³C NMR of compound **4aa**



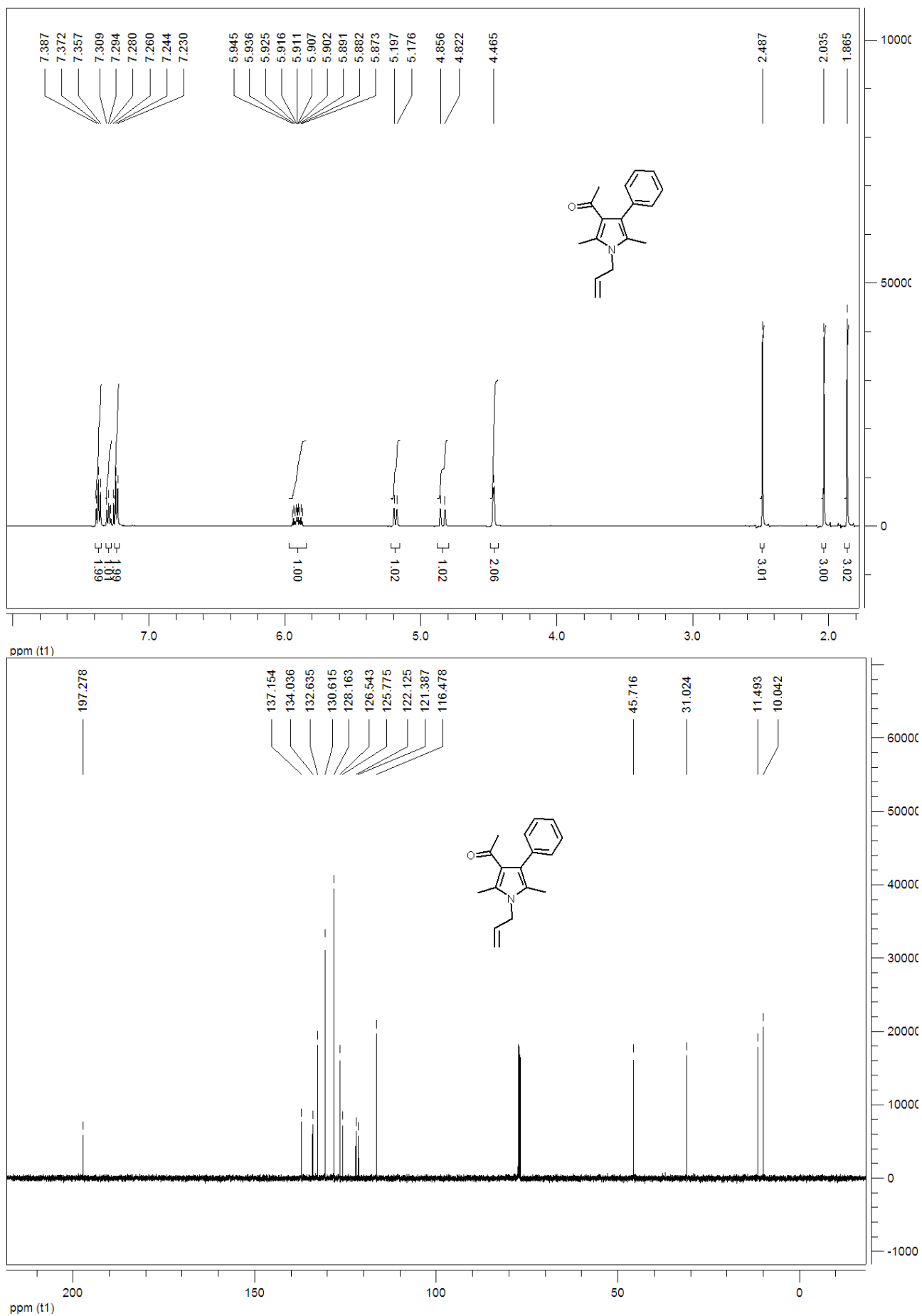
^1H NMR and ^{13}C NMR of compound **4ab**



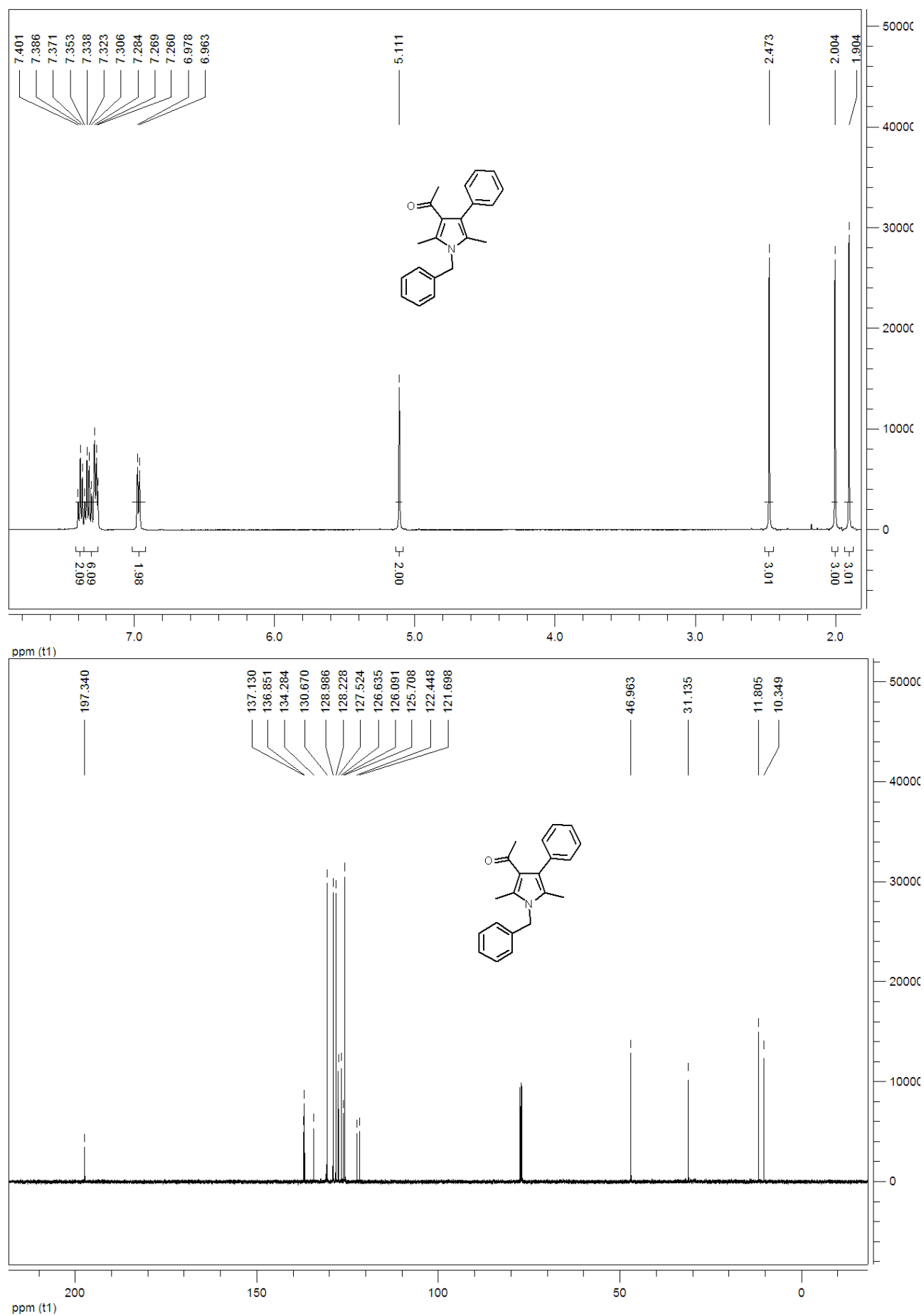
^1H NMR and ^{13}C NMR of compound **4ac**



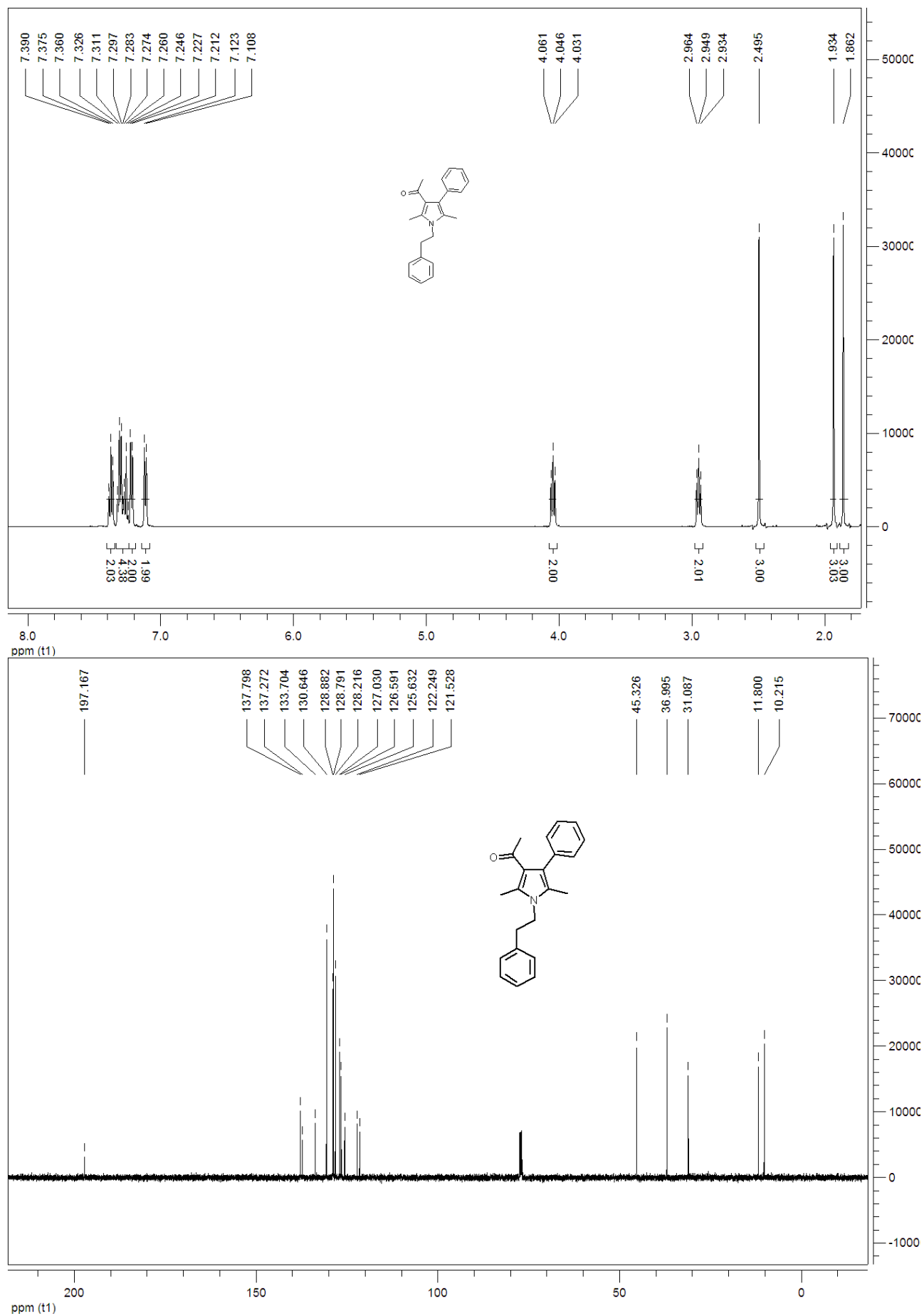
^1H NMR and ^{13}C NMR of compound **4ad**



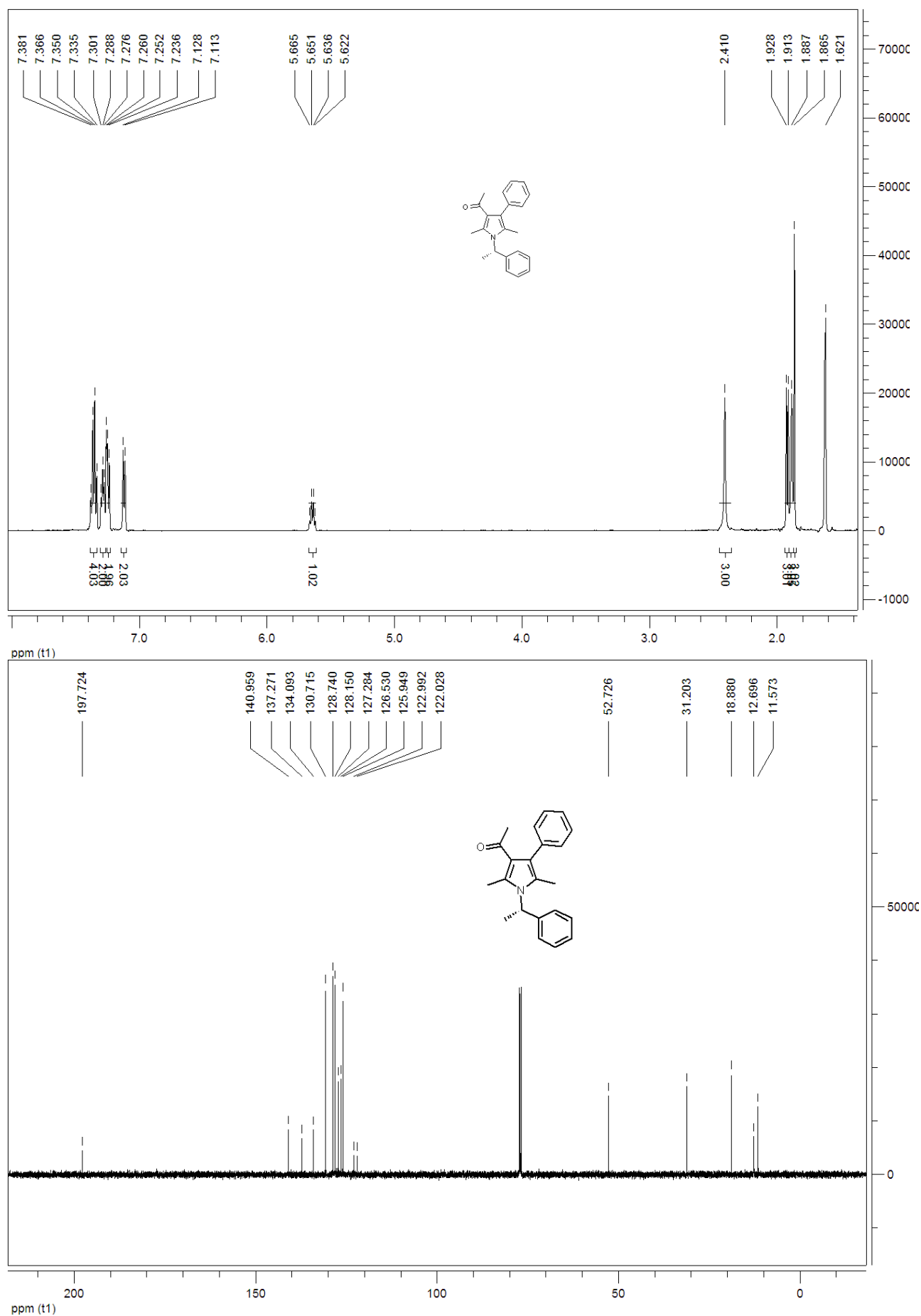
^1H NMR and ^{13}C NMR of compound **4ae**



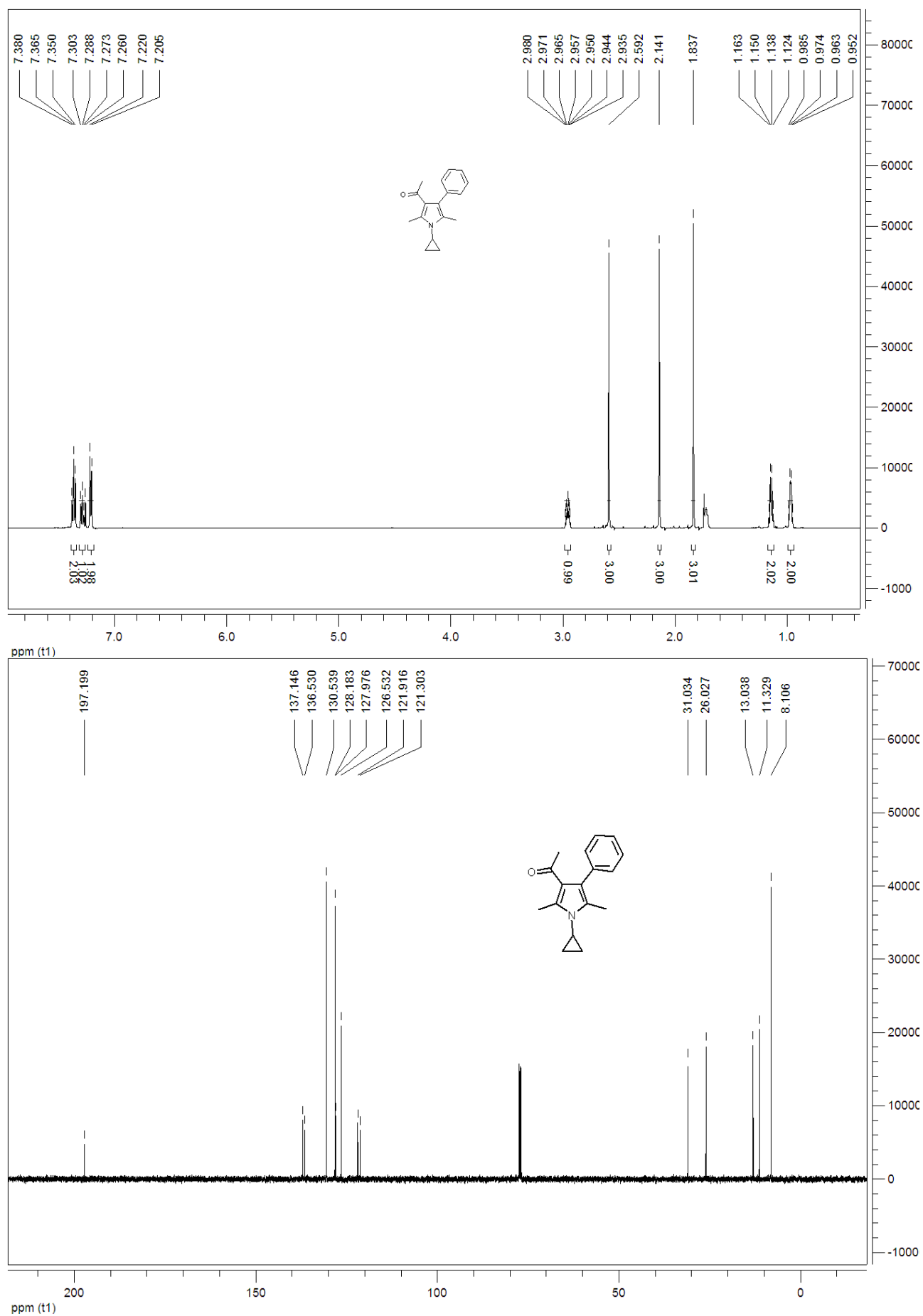
^1H NMR and ^{13}C NMR of compound **4af**



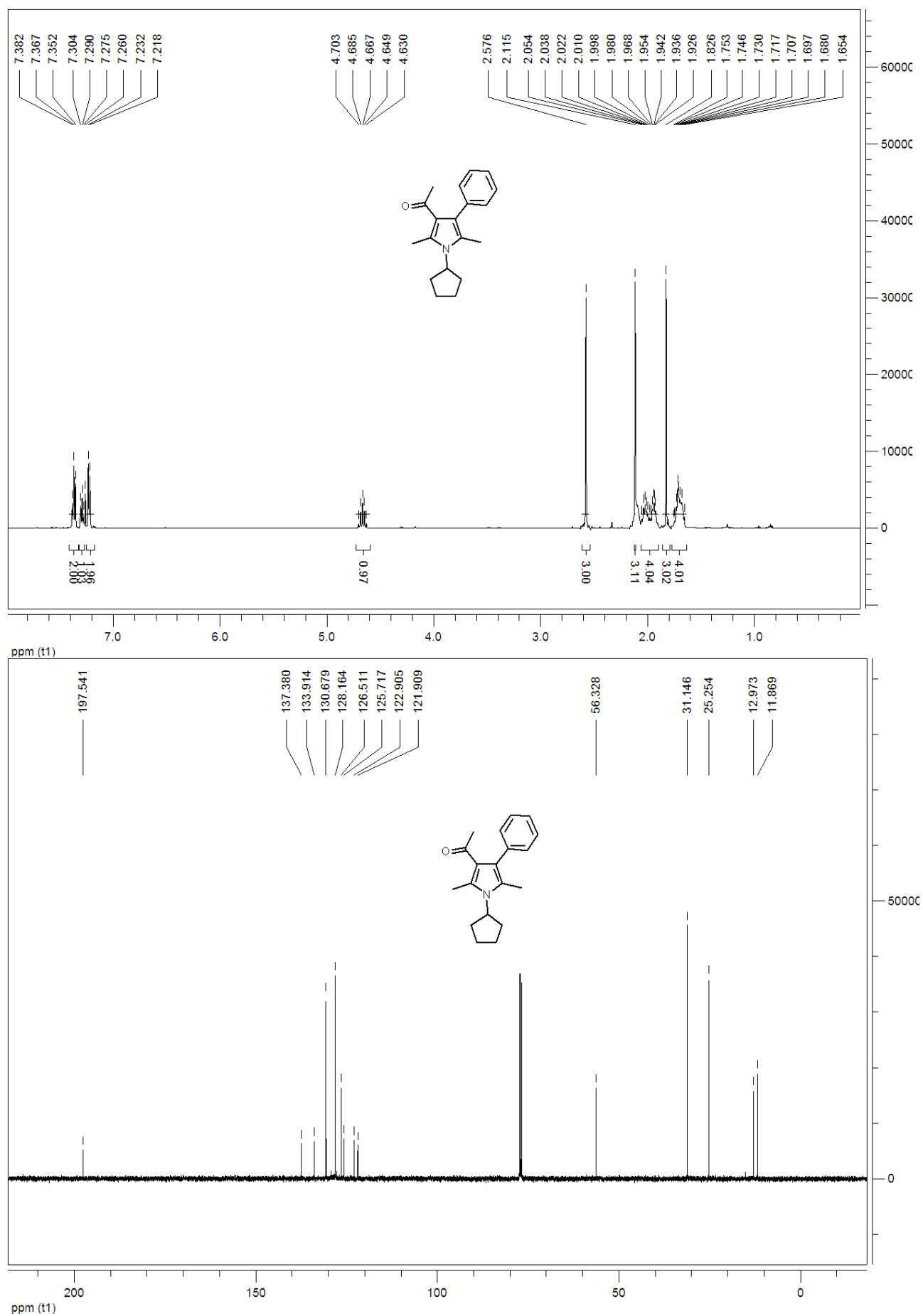
^1H NMR and ^{13}C NMR of compound **4ag**



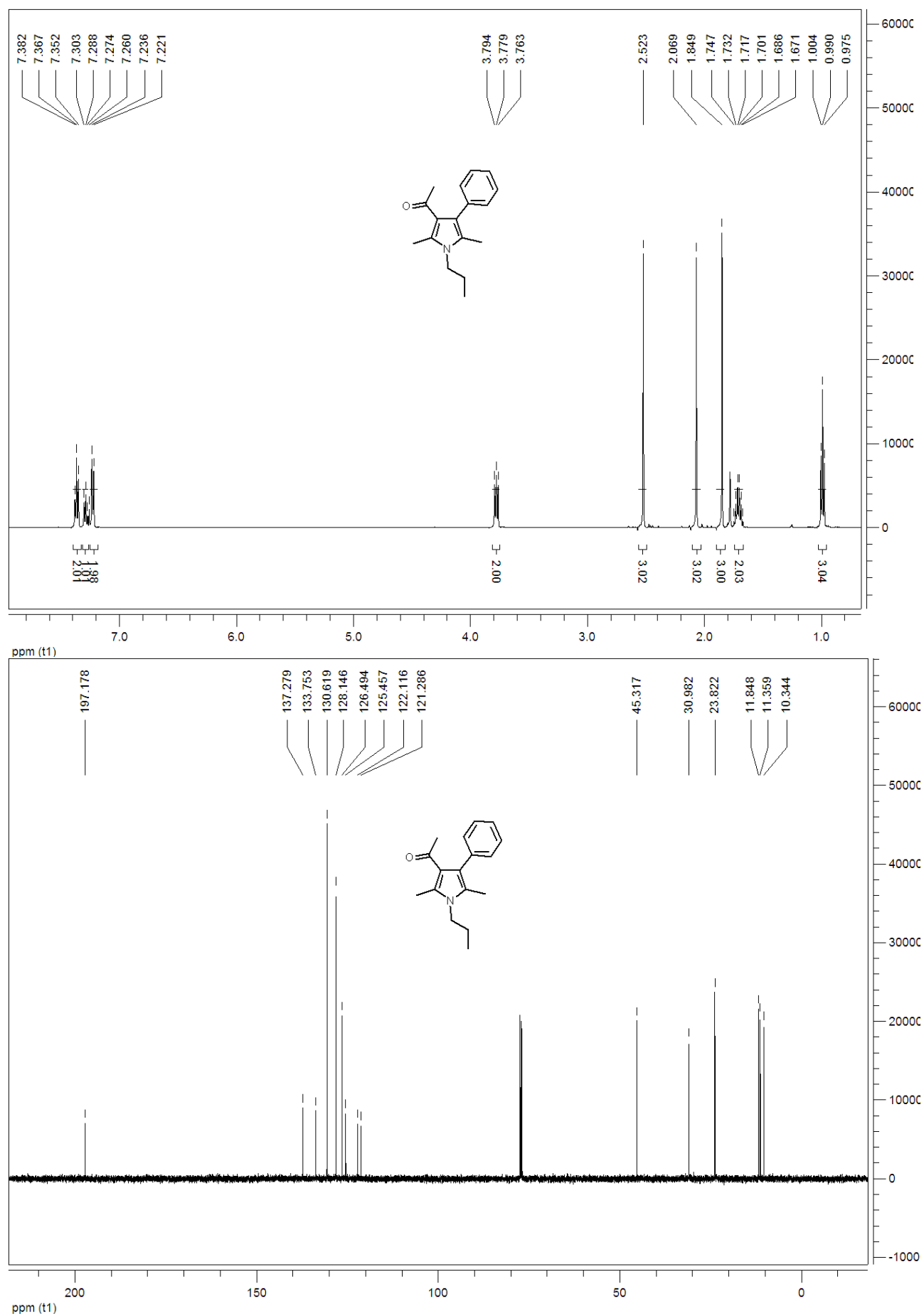
^1H NMR and ^{13}C NMR of compound **4ah**



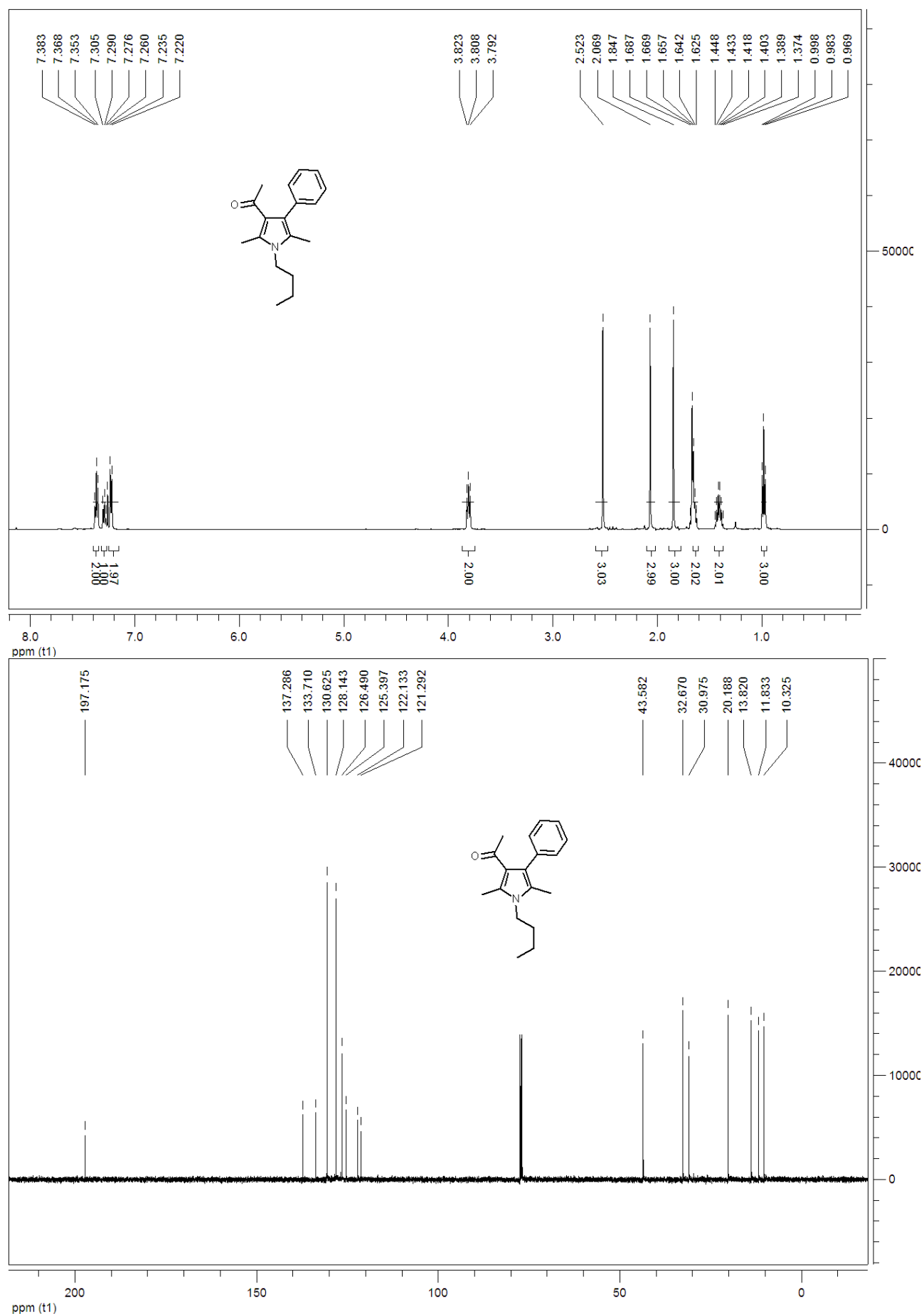
^1H NMR and ^{13}C NMR of compound **4ai**



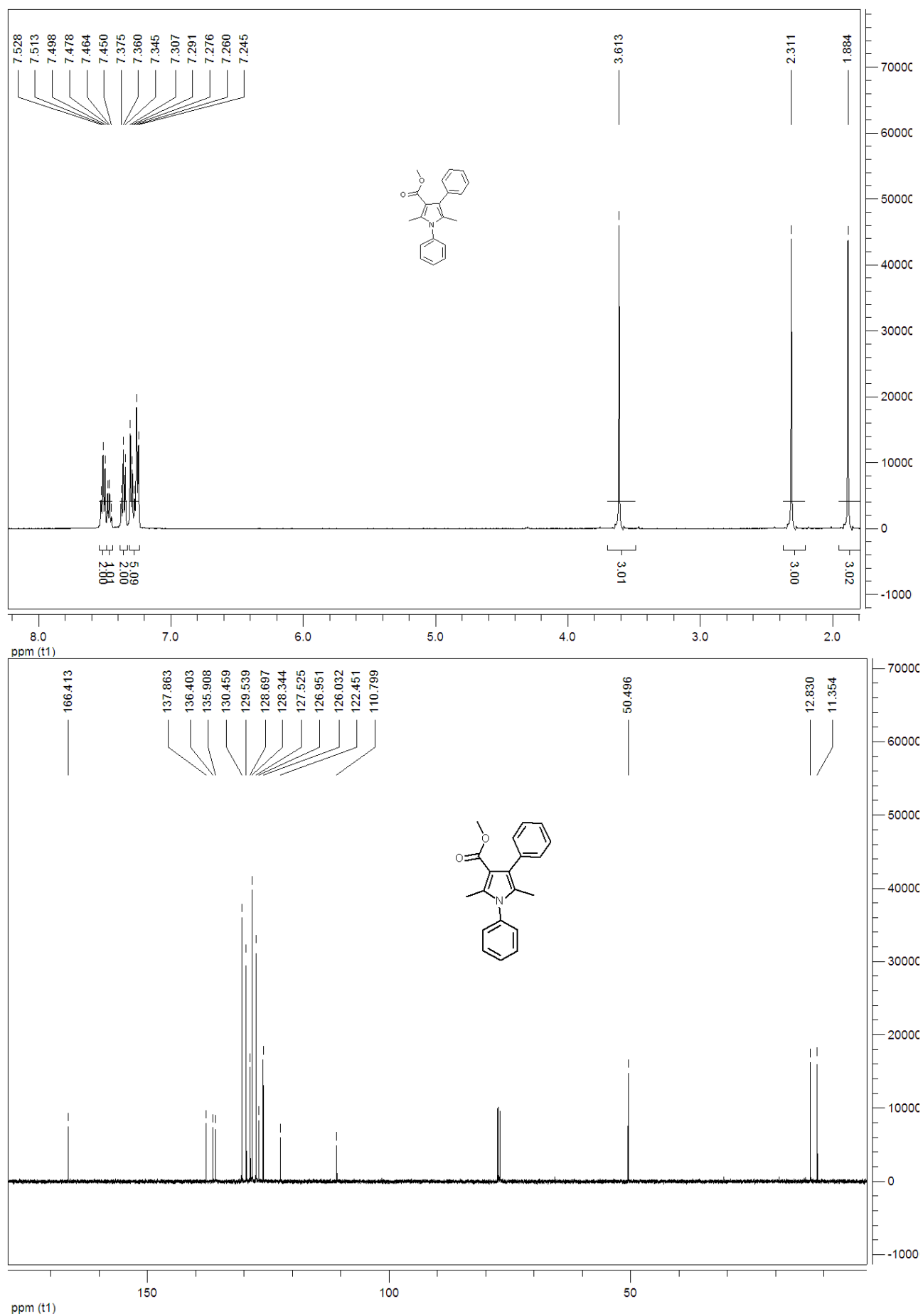
^1H NMR and ^{13}C NMR of compound **4aj**



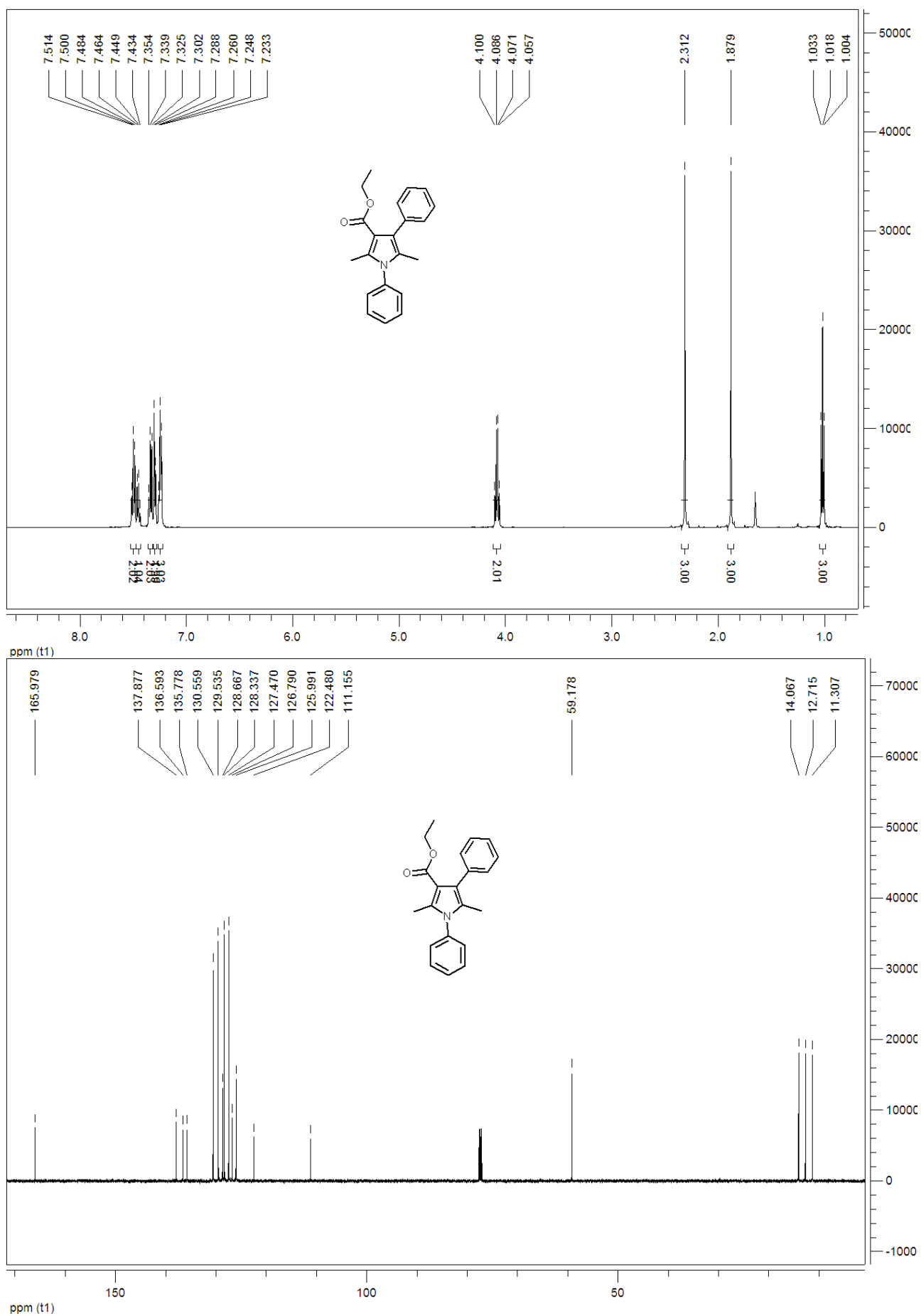
^1H NMR and ^{13}C NMR of compound **4ak**



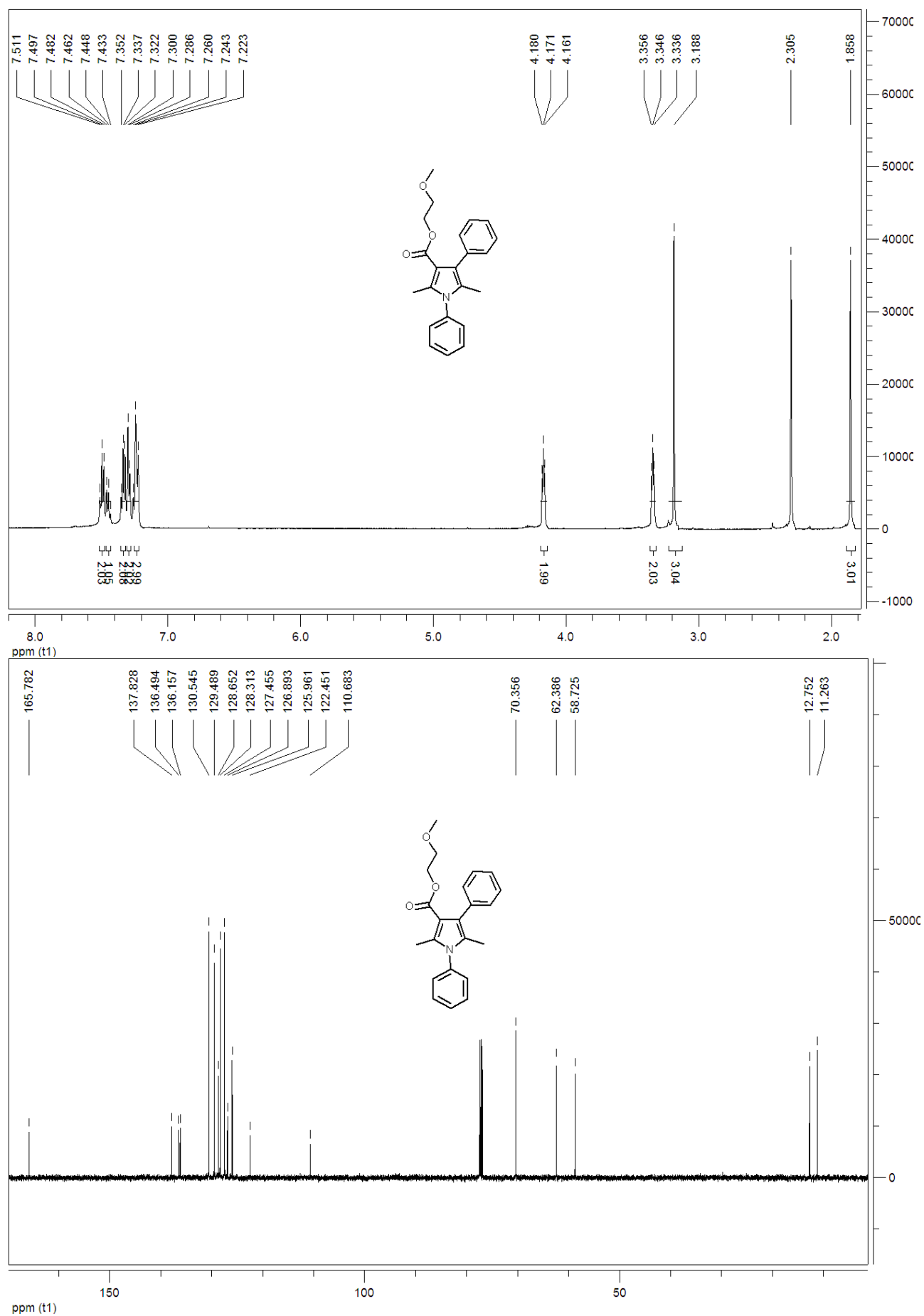
^1H NMR and ^{13}C NMR of compound **4al**



^1H NMR and ^{13}C NMR of compound **4am**



^1H NMR and ^{13}C NMR of compound **4an**



The figure displays two NMR spectra for compound 10, which is 2-(2-allyloxy-4-methyl-5-phenyl-1H-imidazol-1-yl)-1-phenylethane-1-one. The chemical structure is shown in the center of each spectrum.

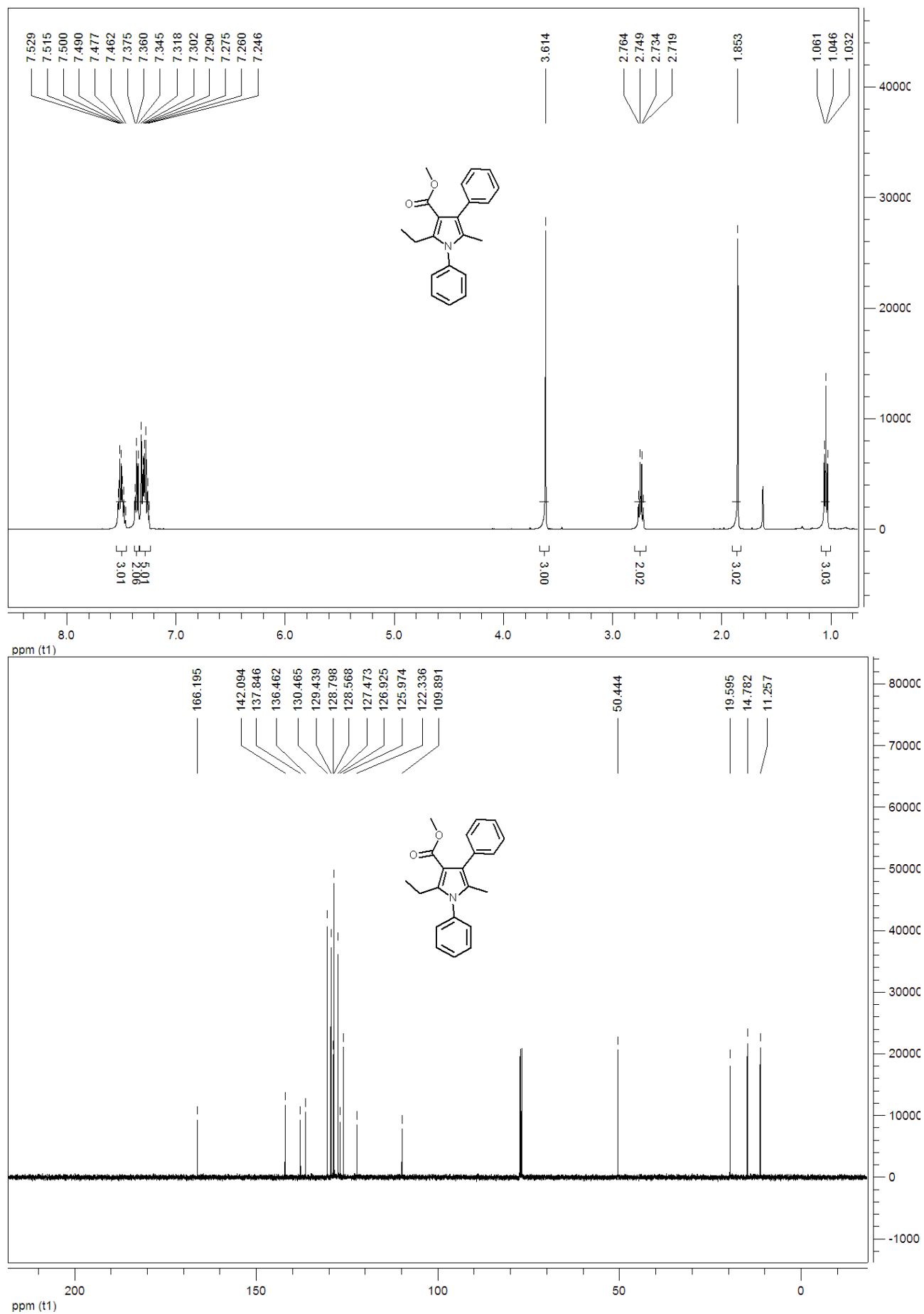
¹H NMR Spectrum (Top): The x-axis represents the chemical shift in ppm (t1), ranging from 8.0 to 1.5. The y-axis represents intensity, ranging from -1000 to 7000. The spectrum shows several multiplets in the aromatic region (6.8-7.6 ppm) and two singlets in the aliphatic region (2.3 and 1.9 ppm). Integration values are provided below the peaks.

Chemical Shift (ppm)	Integration
7.528, 7.514, 7.498, 7.478, 7.464, 7.449	1.83
7.363, 7.348, 7.333, 7.312, 7.298, 7.260, 7.254, 7.245	3.81
5.762, 5.752, 5.741, 5.730, 5.717, 5.707, 5.696, 5.685	0.96
5.028, 5.007, 4.992, 4.989	0.92
4.958, 4.955, 4.954, 4.554	2.01
2.326	3.00
1.881	3.02

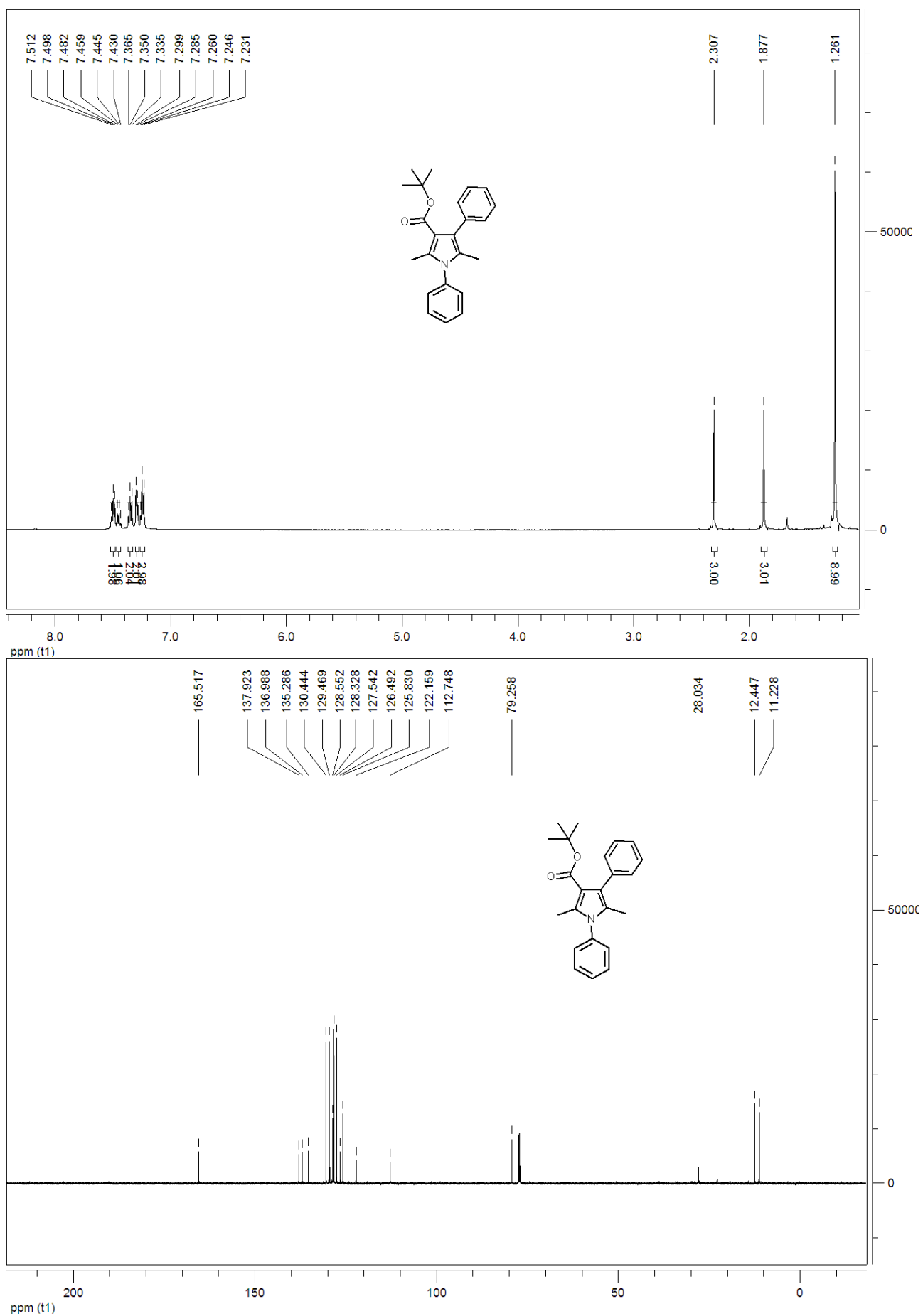
¹³C NMR Spectrum (Bottom): The x-axis represents the chemical shift in ppm (t1), ranging from 150 to 10. The y-axis represents intensity, ranging from -1000 to 6000. The spectrum shows a large cluster of peaks in the aromatic region (110-138 ppm), a single peak at 64.105 ppm, and two peaks in the aliphatic region (12.8 and 11.3 ppm).

Chemical Shift (ppm)
165.615
137.841, 136.476, 136.121, 132.663, 130.512, 129.520, 128.683, 128.328, 127.560, 126.957, 126.041, 122.465, 116.897, 110.777
64.105
12.819, 11.293

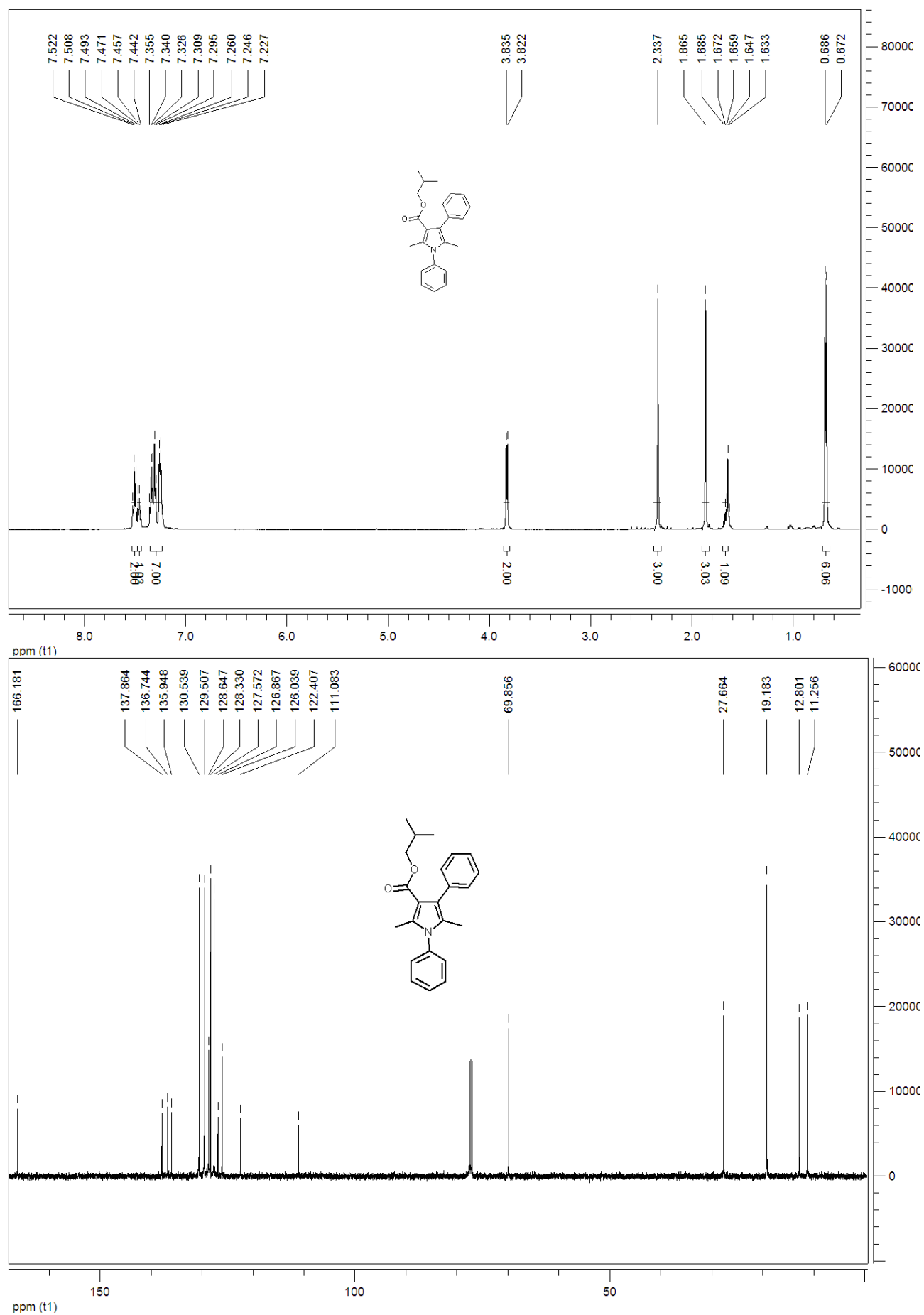
^1H NMR and ^{13}C NMR of compound **4ap**



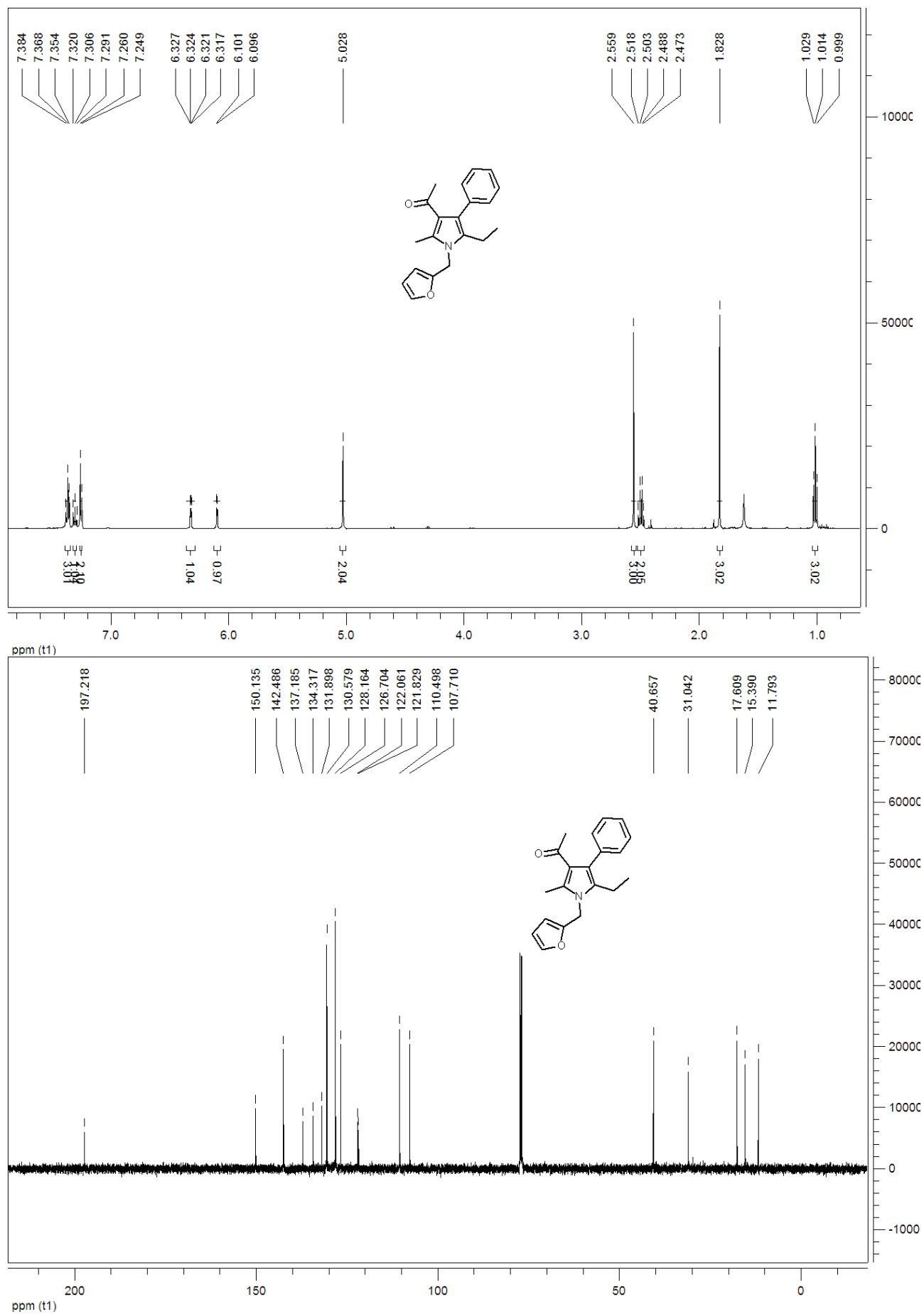
^1H NMR and ^{13}C NMR of compound **4aq**



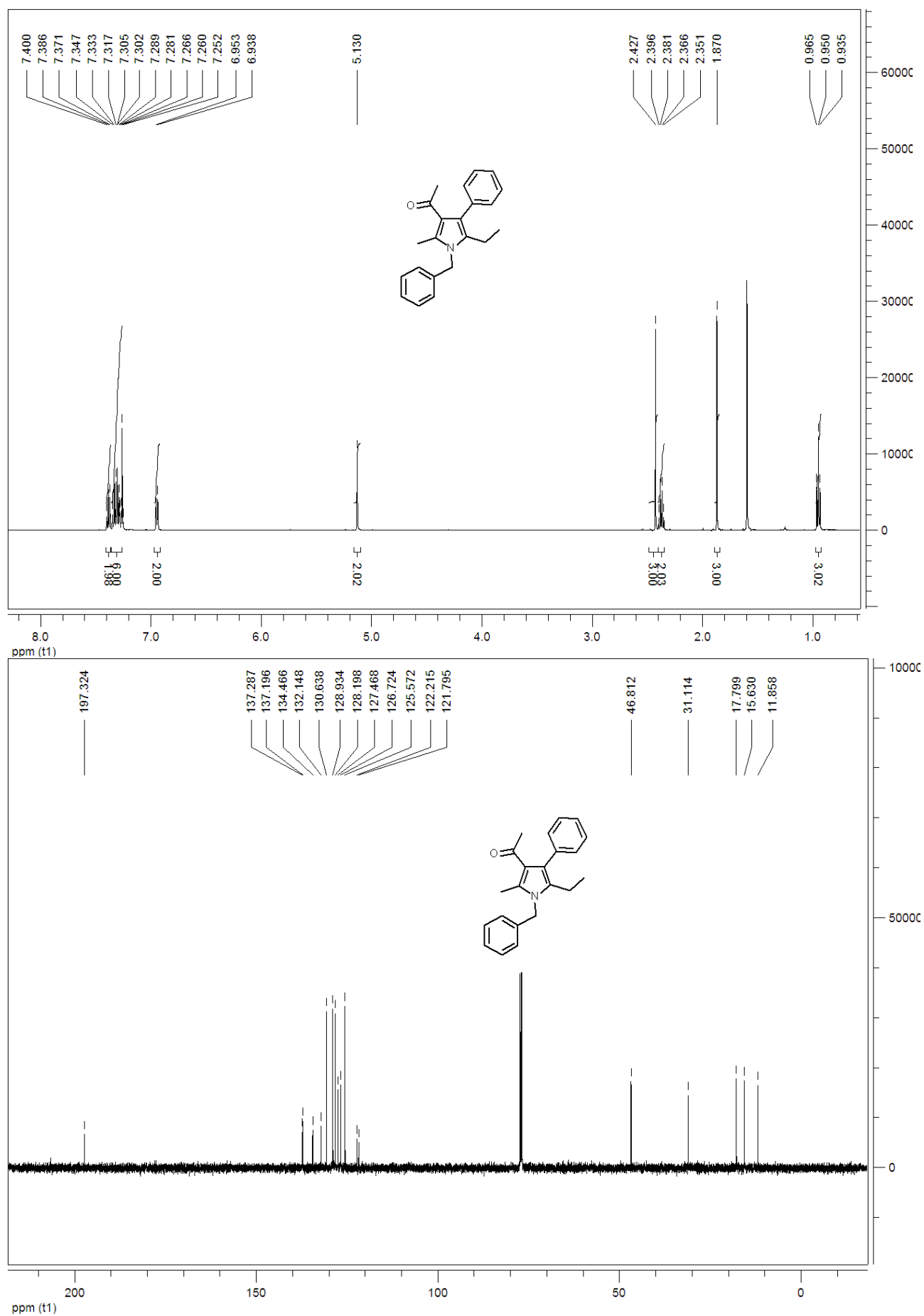
^1H NMR and ^{13}C NMR of compound **4ar**



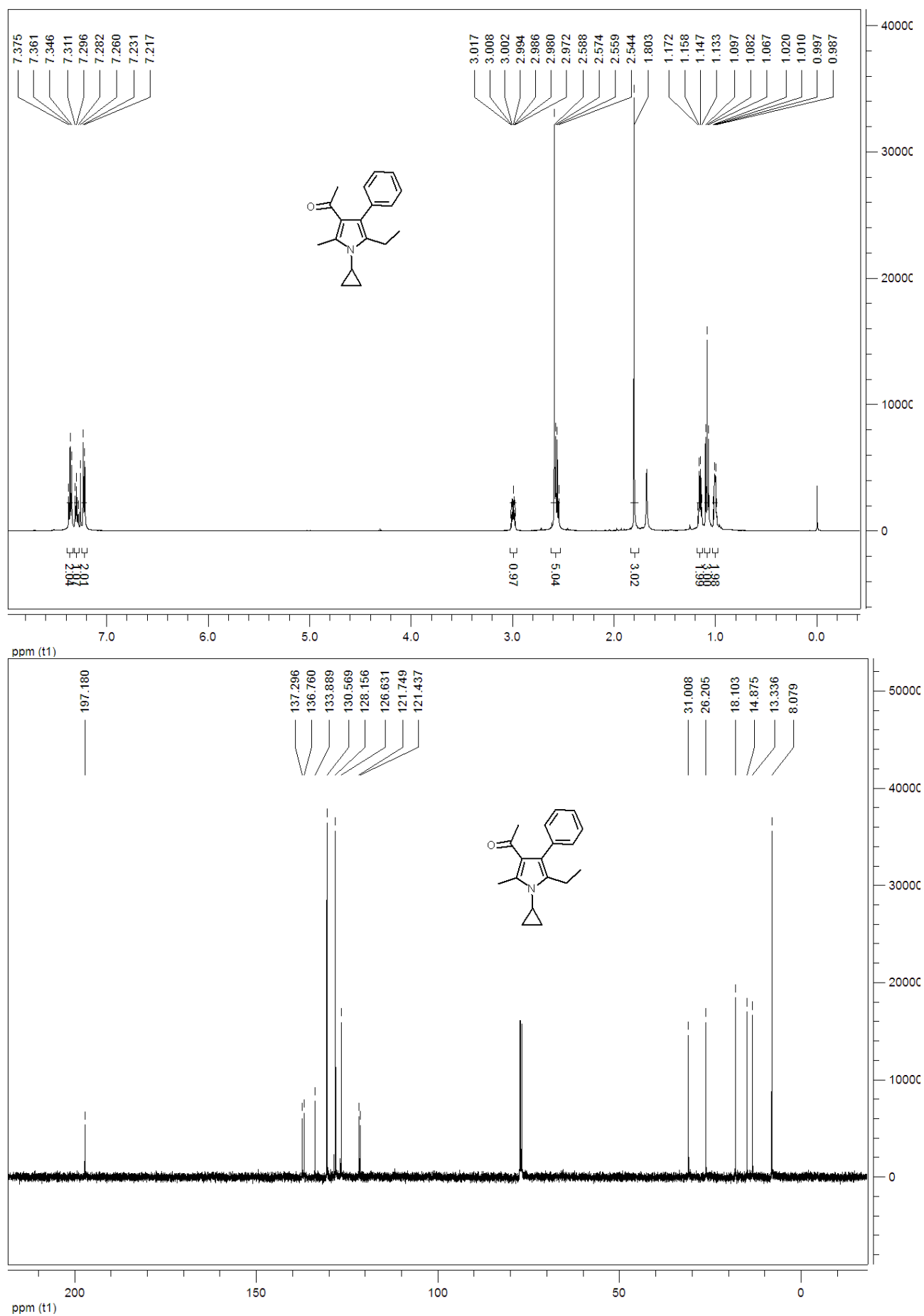
^1H NMR and ^{13}C NMR of compound **4as**



^1H NMR and ^{13}C NMR of compound **4at**



^1H NMR and ^{13}C NMR of compound **4au**



^1H NMR and ^{13}C NMR of compound **4av**

