

Supporting Information Binder, Kirsch

Synthesis of Highly Substituted Pyrroles via a Multimetal-Catalyzed Rearrangement-Condensation-Cyclization Domino Approach

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Supporting Information

Representative experimental procedures for catalytic pyrrole formation, and copies of ^1H and ^{13}C NMR of **3** and **5**.

(35 Pages)

List of Contents

S1–S2	General experimental details
S2	General procedure for the pyrrole formation starting from propargyl vinyl ethers 1
S2–S9	Further characterization data for compounds 3
S10–S31	^1H NMR and ^{13}C NMR spectra for compounds 3
S32–S35	^1H NMR and ^{13}C NMR spectra for compounds 5

General experimental details: All propargyl vinyl ethers **1** were synthesized by the reaction of the corresponding propargylic alcohols with 2-propynoic acid derivatives in the presence of trimethylphosphine or tributylphosphine.¹ 3-Butin-1-ol was purchased from Acros; and ethyl 2-butynoate, methyl 2-octynoate, ethyl phenylpropiolate and 3-pentyn-2-ol were purchased from Aldrich. All commercially available chemicals were used without further purification. All the other propargylic alcohols were prepared from the corresponding alkynes by addition to paraformaldehyde.² AgSbF₆ and (Ph₃P)AuCl were purchased from Aldrich.

¹ Inanaga, J.; Baba, Y.; Hanamoto, T. *Chem. Lett.* **1993**, 241–244.

² Hashmi, A. S. K.; Haufe, P.; Nass, A. R. *Adv. Synth. Catal.* **2003**, 345, 1237–1241.

¹H NMR spectra were obtained on Bruker 500 MHz FT-NMR, 360 MHz FT-NMR and 250 MHz FT-NMR spectrometers. ¹³C NMR spectra were recorded at 90.6 MHz. Chemical shifts are reported in ppm relative to solvent signal. Multiplicity is indicated as follows: s (singlet); d (doublet); t (triplet); q (quartet); m (multiplet); dd (doublet of doublets); sep (septet). High resolution mass spectra and EI were determined on a Finnigan MAT 95S and MAT 8200. Flash chromatography was performed with neutral Al₂O₃ (Aldrich; Brockmann 1).³ The eluent used is reported in parentheses (P = pentanes). Thin-layer chromatography (TLC) was performed on precoated glass-backed plates (Merck Kieselgel 60 F₂₅₄), and components were visualized by observation under UV light or by treating the plates with KMnO₄/H₂SO₄ followed by heating.

General Procedure for the Pyrrole Formation starting from Propargyl Vinyl Ethers 1.

Ethyl 1-(3-chlorophenyl)-4,5-dimethyl-2-phenylpyrrole-3-carboxylate (**3af**)

AgSbF₆ (3.4 mg, 5 mol%) was added to a solution of **1a** (50 mg, 0.20 mmol) in CH₂Cl₂ (0.5 ml), and the reaction vial was sealed protected from light, and stirred at room temperature for 10 min. Then, 3-chloro-aniline (39.2 mg, 0.31 mmol, 1.5 eq) and (Ph₃P)AuCl (5.1 mg, 5 mol%) were added subsequently. The dark reaction mixture was stirred at 38°C for 1 h (until TLC analysis indicated complete conversion). The mixture was concentrated under reduced pressure. Purification of the residue by flash chromatography on neutral Al₂O₃ (P/EtOAc = 98/2) gave pyrrole **3af** as a colorless solid (59.0 mg, 0.17 mmol, 83%). R_f = 0.73 (P/EtOAc = 80/20); ¹H NMR (360 MHz, CDCl₃): δ = 1.04 (t, *J* = 7.2 Hz, 3 H), 2.01 (s, 3 H), 2.31 (s, 3 H), 4.08 (q, *J* = 7.2 Hz, 2 H), 6.88–6.90 (m, 1 H), 7.05–7.06 (m, 1 H), 7.09–7.12 (m, 2 H), 7.15–7.24 (m, 5 H); ¹³C NMR (90.6 MHz, CDCl₃): δ = 10.7, 11.1, 14.1, 59.4, 113.4, 117.2, 127.1, 127.2, 127.5, 127.6, 128.2, 129.1, 129.8, 131.2, 132.5, 134.4, 137.9, 139.6, 165.8; IR (cm⁻¹): 2924 (m), 1700 (vs), 1592 (m), 1481 (s), 1380 (m), 1259 (m), 1147 (s), 1069 (m); LRMS (EI): 353 (100%) [M⁺], 324 (26%), 308 (26%), 280 (8%), 244 (15%), 152 (12%); HRMS 353.1182 [353.1183 calcd for C₂₁H₂₀NO₂Cl (M⁺)].

³ The use of neutral Al₂O₃ for column chromatography was necessary to ensure reproducible yields.

Ethyl 4,5-dimethyl-2-phenyl-1-phenylpyrrole-3-carboxylate (3aa)

Following the general procedure, **3aa** was obtained as a colorless solid (71%) after flash chromatography on neutral Al₂O₃ (P/EtOAc = 95/5). R_f = 0.73 (P/EtOAc = 80/20); ¹H NMR (360 MHz, CDCl₃): δ = 1.07 (t, *J* = 7.2 Hz, 3 H), 2.02 (s, 3 H), 2.02 (s, 3 H), 4.11 (q, *J* = 7.2 Hz, 2 H), 7.02–7.05 (m, 2 H), 7.11–7.17 (m, 5 H), 7.22–7.25 (m, 1 H), 7.28–7.30 (m, 2 H); ¹³C NMR (90.6 MHz, CDCl₃): δ = 10.7, 11.2, 14.1, 59.3, 113.0, 116.8, 127.3, 127.3, 127.3, 127.3, 127.8, 128.8, 131.2, 132.9, 137.9, 138.4, 165.9; IR (cm⁻¹): 2926 (m), 1698 (s), 1498 (m), 1269 (s), 1179 (s), 1080 (m), 763 (m), 697 (s); LRMS (EI): 319 (100%) [M⁺], 290 (26%), 274 (29%), 258 (10%), 244 (13%), 230 (12%), 128 (13%), 118 (18%), 105 (40%), 77 (30%), 71 (17%), 57 (27%), 43 (28%); HRMS 319.1573 [319.1572 calcd for C₂₁H₂₁NO₂ (M⁺)].

Ethyl 4,5-dimethyl-2-phenyl-1-(4-methoxyphenyl)-pyrrole-3-carboxylate (3ab)

Following the general procedure, **3ab** was obtained as a colorless solid (75%) after flash chromatography on neutral Al₂O₃ (P/EtOAc = 95/5). R_f = 0.58 (P/EtOAc = 80/20); ¹H NMR (360 MHz, CDCl₃): δ = 1.04 (t, *J* = 7.0 Hz, 3 H), 1.98 (s, 3 H), 2.31 (s, 3 H), 3.76 (s, 3 H), 4.08 (q, *J* = 7.0 Hz, 2 H), 6.75–6.78 (m, 2 H), 6.91–6.94 (m, 2 H), 7.10–7.16 (m, 5 H); ¹³C NMR (90.6 MHz, CDCl₃): δ = 10.7, 11.2, 14.1, 55.5, 59.2, 112.8, 114.0, 116.6, 127.2, 127.3, 127.6, 129.8, 131.2, 131.2, 133.0, 138.2, 158.9, 166.0; IR (cm⁻¹): 2924 (s), 1693 (s), 1607 (w), 1514 (s), 1480 (m), 1386 (m), 1248 (s), 1148 (m), 1068 (m), 1036 (m), 837 (m); LRMS (EI): 349 (100%) [M⁺], 320 (20%), 304 (20%), 276 (10%), 105 (22%); HRMS 349.1675 [349.1678 calcd for C₂₂H₂₃NO₃ (M⁺)].

Ethyl 4,5-dimethyl-2-phenyl-1-(4-*iso*-propylphenyl)-pyrrole-3-carboxylate (3ac)

Following the general procedure, **3ac** was obtained as a brown solid (73%) after flash chromatography on neutral Al₂O₃ (P/EtOAc = 95/5). R_f = 0.80 (P/EtOAc = 80/20); ¹H NMR (360 MHz, CDCl₃): δ = 1.05 (t, *J* = 7.2 Hz, 3 H), 1.20 (d, *J* = 6.8 Hz, 6 H), 2.00 (s, 3 H), 2.32 (s, 3 H), 2.85 (sep, *J* = 6.8 Hz, 1 H), 4.09 (q, *J* = 7.2 Hz, 2 H), 6.90–6.93 (m, 2 H), 7.08–7.13 (m, 7 H); ¹³C NMR (90.6 MHz, CDCl₃): δ = 10.8, 11.2, 14.1, 23.9, 33.8, 59.2, 112.8, 116.7, 126.7, 127.2, 127.2, 127.5, 128.5, 131.2, 133.0, 135.9, 137.9, 148.5, 166.0; IR (cm⁻¹): 2925 (m), 1698 (s), 1515 (m), 1264 (m), 1030 (s), 740 (m); LRMS (EI): 361 (96%) [M⁺], 332 (16%), 316 (18%), 199 (14%), 105 (100%); HRMS 361.2041 [361.2042 calcd for C₂₄H₂₇NO₂ (M⁺)].

Ethyl 4,5-dimethyl-2-phenyl-1-(4-hydroxyphenyl)-pyrrole-3-carboxylate (3ad)

Following the general procedure, **3ad** was obtained as a yellow solid (41%) after flash chromatography on silica. (P/EtOAc = 90/10). $R_f = 0.25$ (P/EtOAc = 80/20); ^1H NMR (360 MHz, CDCl_3): $\delta = 1.05$ (t, $J = 7.2$ Hz, 3 H), 1.98 (s, 3 H), 2.30 (s, 3 H), 4.08 (q, $J = 7.2$ Hz, 2 H), 5.57 (s, 1 H), 6.64–6.67 (m, 2 H), 6.84–6.86 (m, 2 H), 7.09–7.13 (m, 5 H); ^{13}C NMR (90.6 MHz, CDCl_3): $\delta = 10.7, 11.2, 14.1, 59.4, 112.6, 115.6, 116.6, 127.3, 127.6, 129.9, 131.0, 131.2, 131.3, 133.0, 138.4, 155.3, 166.3$; IR (cm^{-1}): 3357 (m), 2924 (m), 1673 (s), 1517 (s), 1446 (m), 1264 (m); LRMS (EI): 335 (24%) [M^+], 260 (38%), 215 (16%), 141 (32%), 105 (100%), 99 (31%), 71 (34%), 57 (51%), 43 (47%); HRMS 335.1520 [335.1521 calcd for $\text{C}_{21}\text{H}_{21}\text{NO}_3(\text{M}^+)$].

Ethyl 4,5-dimethyl-2-phenyl-1-(4-bromophenyl)-pyrrole-3-carboxylate (3ae)

Following the general procedure, **3af** was obtained as a colorless solid (74%) after flash chromatography on neutral Al_2O_3 (P/EtOAc = 95/5). $R_f = 0.75$ (P/EtOAc = 80/20); ^1H NMR (360 MHz, CDCl_3): $\delta = 1.04$ (t, $J = 7.2$ Hz, 3 H), 2.00 (s, 3 H), 2.31 (s, 3 H), 4.08 (q, $J = 7.2$ Hz, 2 H), 6.88–6.90 (m, 2 H), 7.08–7.18 (m, 5 H), 7.38–7.40 (m, 2 H); ^{13}C NMR (90.6 MHz, CDCl_3): $\delta = 10.7, 11.1, 14.1, 59.3, 113.4, 117.2, 121.7, 127.1, 127.5, 127.5, 130.4, 131.2, 132.1, 132.6, 137.5, 137.8, 165.8$; IR (cm^{-1}): 2925 (m), 1694 (s), 1528 (m), 1492 (m), 1386 (m), 1263 (m); LRMS (EI): 397 (100%) [M^+], 368 (22%), 352 (25%), 324 (7%), 244 (34%), 230 (10%); HRMS 397.0673 [397.0678 calcd for $\text{C}_{21}\text{H}_{20}\text{NO}_2\text{Br}(\text{M}^+)$].

Ethyl 4,5-dimethyl-2-phenyl-1-(2-*iso*-propylphenyl)-pyrrole-3-carboxylate (3ag)

Following the general procedure, **3ag** was obtained as a colorless solid (67%) after flash chromatography on neutral Al_2O_3 (P/EtOAc = 98/2). $R_f = 0.72$ (P/EtOAc = 80/20); ^1H NMR (360 MHz, CDCl_3): $\delta = 0.68$ (d, $J = 7.0$ Hz, 3 H), 0.98 (d, $J = 7.0$ Hz, 3 H), 1.06 (t, $J = 7.2$ Hz, 3 H), 1.90 (s, 3 H), 2.30–2.39 (m, 4 H), 4.04–4.18 (m, 2 H), 7.10–7.23 (m, 8 H), 7.27–7.31 (m, 1 H); ^{13}C NMR (90.6 MHz, CDCl_3): $\delta = 10.6, 11.3, 14.1, 22.7, 24.6, 27.4, 59.3, 112.6, 116.7, 125.9, 126.7, 127.1, 127.3, 127.6, 129.2, 130.1, 131.3, 132.4, 135.7, 138.0, 146.9, 166.2$; IR (cm^{-1}): 2963 (m), 1698 (s), 1493 (m), 1383 (m), 1235 (m); LRMS (EI): 361 (100%) [M^+], 346 (24%), 288 (44%), 258 (20%); HRMS 361.2040 [361.2042 calcd for $\text{C}_{24}\text{H}_{27}\text{NO}_2(\text{M}^+)$].

Ethyl 4,5-dimethyl-2-phenyl-1-(3-nitrophenyl)-pyrrole-3-carboxylate (3ah)

Following the general procedure, **3ah** was obtained as a yellow solid (55%) after flash chromatography on neutral Al₂O₃ (P/EtOAc = 96/4). R_f = 0.48 (P/EtOAc = 80/20); ¹H NMR (360 MHz, CDCl₃): δ = 1.04 (t, *J* = 7.2 Hz, 3 H), 2.04 (s, 3 H), 2.33 (s, 3 H), 4.09 (q, *J* = 7.2 Hz, 2 H), 7.08–7.11 (m, 2 H), 7.16–7.18 (m, 3 H), 7.41–7.46 (m, 2 H), 7.93 (s, 1 H), 8.09–8.12 (m, 1 H); ¹³C NMR (90.6 MHz, CDCl₃): δ = 10.8, 11.1, 14.1, 59.5, 114.1, 117.9, 122.7, 123.9, 127.0, 127.7, 127.8, 129.7, 131.2, 132.2, 134.8, 137.9, 139.6, 148.4, 165.6; IR (cm⁻¹): 2925 (s), 1698 (vs), 1538 (vs), 1483 (m), 1349 (vs), 1238 (m); LRMS (EI): 364 (100%) [M⁺], 335 (21%), 319 (22%), 273 (12%); HRMS 364.1413 [364.1423 calcd for C₂₁H₂₀N₂O₂ (M⁺)].

Ethyl 4,5-dimethyl-2-phenyl-1-(methyl thiophenyl-2-carboxylate-3-yl)-pyrrole-3-carboxylate (3ai)

Following the general procedure, **3ai** was obtained as a colorless solid (52%) after flash chromatography on neutral Al₂O₃ (P/EtOAc = 95/5). R_f = 0.42 (P/EtOAc = 80/20); ¹H NMR (360 MHz, CDCl₃): δ = 1.04 (t, *J* = 7.0 Hz, 3 H), 1.96 (s, 3 H), 2.32 (s, 3 H), 3.75 (s, 3 H), 4.10 (q, *J* = 7.0 Hz, 2 H), 6.76–6.80 (m, 1 H), 7.08–7.17 (m, 5 H), 7.36–7.37 (m, 1 H); ¹³C NMR (90.6 MHz, CDCl₃): δ = 10.2, 11.3, 14.1, 52.4, 59.2, 113.3, 117.1, 127.1, 127.2, 127.5, 128.1, 128.1, 128.6, 129.7, 130.7, 132.8, 138.1, 140.8, 160.8, 165.8; IR (cm⁻¹): 2924 (m), 1698 (s), 1437 (m), 1259 (s), 1071 (m); LRMS (EI): 383 (65%) [M⁺], 310 (25%), 258 (26%), 213 (14%), 105 (100%); HRMS 383.1193 [383.1191 calcd for C₂₁H₂₁NO₄S (M⁺)].

Ethyl 4,5-dimethyl-2-phenyl-1-naphtylpyrrole-3-carboxylate (3aj)

Following the general procedure, **3aj** was obtained as a yellow solid (72%) after flash chromatography on neutral Al₂O₃ (P/EtOAc = 90/10). R_f = 0.67 (P/EtOAc = 80/20); ¹H NMR (360 MHz, CDCl₃): δ = 1.05 (t, *J* = 7.2 Hz, 3 H), 1.82 (s, 3 H), 2.39 (s, 3 H), 4.11 (q, *J* = 7.2 Hz, 2 H), 6.95–7.01 (m, 3 H), 7.06–7.09 (m, 2 H), 7.20–7.22 (m, 1 H), 7.31–7.37 (m, 2 H), 7.44–7.50 (m, 2 H), 7.76–7.83 (m, 2 H); ¹³C NMR (90.6 MHz, CDCl₃): δ = 10.2, 11.3, 14.1, 59.3, 113.0, 116.7, 123.3, 125.1, 126.6, 127.0, 127.2, 127.3, 127.4, 128.2, 128.4, 128.9, 130.7, 131.8, 132.9, 133.9, 135.1, 139.2, 166.1; IR (cm⁻¹): 2977 (w), 1696 (s), 1598 (w), 1508 (w), 1379 (w), 1254 (m), 1150 (m), 1069 (m); LRMS (EI): 369 (100%) [M⁺], 340 (20%), 324 (18%), 167 (12%), 149 (16%), 127 (23%), 105 (24%); HRMS 369.1720 [369.1729 calcd for C₂₅H₂₃NO₂ (M⁺)].

Ethyl 4,5-dimethyl-2-phenyl-1-(4-[Ethyl 4,5-dimethyl-2-phenyl-pyrrole-3-carboxylate-1-yl]-phenyl)-pyrrole-3-carboxylate (3ak)

Following the general procedure, **3ak** was obtained as a yellow solid (31%) after flash chromatography on neutral Al₂O₃ (P/EtOAc = 95/5). R_f = 0.33 (P/EtOAc = 80/20); ¹H NMR (360 MHz, CDCl₃): δ = 1.04 (t, *J* = 7.0 Hz, 6 H), 1.93 (s, 6 H), 2.29 (s, 6 H), 4.08 (q, *J* = 7.0 Hz, 4 H), 6.89 (s, 4 H), 7.00–7.02 (m, 4 H), 7.09–7.14 (m, 6 H); ¹³C NMR (90.6 MHz, CDCl₃): δ = 10.6, 11.1, 14.1, 59.4, 113.3, 117.2, 127.1, 127.4, 127.4, 129.1, 131.1, 132.5, 137.7, 137.8, 165.8; IR (cm⁻¹): 2924 (s), 2851 (w), 1694 (s), 1519 (m), 1480 (m), 1381 (m), 1255 (m), 1154 (m), 1069 (m); LRMS (EI): 560 (16%) [M⁺], 233 (6%), 105 (100%); HRMS 560.2683 [560.2675 calcd for C₃₆H₃₆N₂O₄ (M⁺)].

Ethyl 2,5-dimethyl-4-phenyl-1-phenyl-pyrrole-3-carboxylate (3ba)⁴

Following the general procedure, **3ba** was obtained as a yellow oil (75%) after flash chromatography on neutral Al₂O₃ (P/EtOAc = 96/4). R_f = 0.73 (P/EtOAc = 80/20); ¹H NMR (500 MHz, CDCl₃): δ = 1.03 (t, *J* = 7.2 Hz, 3 H), 1.89 (s, 3 H), 2.32 (s, 3 H), 4.09 (q, *J* = 7.2 Hz, 2 H), 7.24–7.24 (m, 1 H), 7.27–7.39 (m, 6 H), 7.43–7.56 (m, 3 H); ¹³C NMR (90.6 MHz, CDCl₃): δ = 11.4, 12.7, 14.1, 59.3, 111.2, 122.4, 126.0, 126.9, 127.5, 128.4, 128.7, 129.6, 130.6, 135.9, 136.6, 138.0, 166.1; IR (cm⁻¹): 2923 (m), 1694 (s), 1598 (w), 1497 (m).

Ethyl 2,5-dimethyl-4-phenyl-1-[4-methoxyphenyl]-pyrrole-3-carboxylate (3bb)

Following the general procedure, **3bb** was obtained as a yellow oil (75%) from after flash chromatography on neutral Al₂O₃ (P/EtOAc = 95/5). R_f = 0.53 (P/EtOAc = 80/20); ¹H NMR (500 MHz, CDCl₃): δ = 1.03 (t, *J* = 7.1 Hz, 3 H), 1.88 (s, 3 H), 2.31 (s, 3 H), 3.88 (s, 3 H), 4.08 (q, *J* = 7.1 Hz, 2 H), 7.00–7.02 (m, 2 H), 7.16–7.17 (m, 2 H), 7.23–7.25 (m, 1 H), 7.29–7.30 (m, 2 H), 7.33–7.36 (m, 2 H); ¹³C NMR (90.6 MHz, CDCl₃): δ = 11.3, 12.7, 14.1, 55.7, 59.2, 111.0, 114.7, 122.2, 126.0, 127.2, 127.5, 129.4, 130.6, 130.7, 136.2, 136.7, 159.7, 166.1; IR (cm⁻¹): 2922 (m), 1690 (s), 1606 (m), 1514 (s), 1442 (w), 1250 (m), 1179 (m), 1082 (m); LRMS (EI): 349 (100%) [M⁺], 320 (52%), 304 (14%), 105 (18%); HRMS 349.1681 [349.1678 calcd for C₂₂H₂₃NO₃ (M⁺)].

Ethyl 2,5-dimethyl-4-[2-methoxyphenyl]-1-phenylpyrrole-3-carboxylate (3ca)

Following the general procedure, **3ca** was obtained as a yellow solid (83%) after flash chromatography on neutral Al₂O₃ (P/EtOAc = 95/5). R_f = 0.45 (P/EtOAc = 80/20); ¹H NMR

⁴ Huisgen, R.; Gotthardt, H.; Bayer, H. O. *Angew. Chem.* **1964**, *76*, 185.

(360 MHz, CDCl₃): δ = 0.98 (t, J = 7.0 Hz, 3 H), 1.87 (s, 3 H), 2.31 (s, 3 H), 3.79 (s, 3 H), 4.05 (q, J = 7.0 Hz, 2 H), 6.91–6.99 (m, 2 H), 7.19–7.24 (m, 2 H), 7.29–7.33 (m, 2 H), 7.42–7.52 (m, 3 H); ¹³C NMR (90.6 MHz, CDCl₃): δ = 11.5, 12.7, 14.1, 55.6, 59.1, 110.4, 112.1, 117.9, 120.1, 125.7, 127.1, 127.7, 128.5, 128.5, 129.4, 131.9, 135.3, 138.2, 157.7, 166.3; IR (cm⁻¹): 2925 (m), 1694 (s), 1597 (w), 1538 (m), 1494 (m); LRMS (EI): 349 (100%) [M⁺], 320 (34%), 287 (19%), 276 (53%); HRMS 349.1680 [349.1678 calcd for C₂₂H₂₃NO₃ (M⁺)].

Methyl 4,5-dimethyl-2-(*n*-pentyl)-1-phenylpyrrole-3-carboxylate (3da)

Following the general procedure, **3da** was obtained as a colorless liquid (68%) after flash chromatography on neutral Al₂O₃ (P/EtOAc = 98/2). R_f = 0.77 (P/EtOAc = 80/20); ¹H NMR (360 MHz, CDCl₃): δ = 0.76 (t, J = 6.9 Hz, 3 H), 1.05–1.18 (m, 4 H), 1.33–1.41 (m, 2 H), 1.85 (s, 3 H), 2.23 (s, 3 H), 2.62–2.66 (m, 2 H), 3.81 (s, 3 H), 7.16–7.19 (m, 2 H), 7.44–7.50 (m, 3 H); ¹³C NMR (90.6 MHz, CDCl₃): δ = 10.4, 11.4, 14.0, 22.2, 26.2, 30.0, 31.8, 50.5, 110.4, 115.9, 125.8, 128.6, 128.8, 129.3, 128.3, 141.0, 166.8; IR (cm⁻¹): 2928 (s), 2851 (m), 1718 (s), 1503 (m), 1438 (m), 1252 (m), 1140 (m); LRMS (EI): 299 (30%) [M⁺], 268 (4%), 242 (100%), 182 (8%); HRMS 299.1885 [299.1885 calcd for C₁₉H₂₅NO₂ (M⁺)].

Ethyl 2,4-diphenyl-1-phenylpyrrole-3-carboxylate (3ea)

Following the general procedure, **3ea** was obtained as a yellow solid (65% [72% starting from 1.3 mmol of **1k**]) after flash chromatography on neutral Al₂O₃ (P/EtOAc = 95/5). R_f = 0.63 (P/EtOAc = 80/20); ¹H NMR (360 MHz, CDCl₃): δ = 0.86 (t, J = 7.0 Hz, 3 H), 2.04 (s, 3 H), 3.96 (q, J = 7.0 Hz, 2 H), 7.12–7.15 (m, 2 H), 7.18–7.20 (m, 3 H), 7.23–7.26 (m, 2 H), 7.29–7.35 (m, 4 H), 7.39–7.43 (m, 4 H); ¹³C NMR (90.6 MHz, CDCl₃): δ = 11.7, 13.7, 59.6, 113.3, 123.2, 126.3, 127.4, 127.5, 127.8, 128.0, 128.2, 128.8, 129.0, 130.5, 131.2, 132.2, 136.1, 137.7, 138.2, 165.5; IR (cm⁻¹): 2921 (m), 1698 (s), 1597 (w), 1495 (m), 1440 (m), 1381 (m), 1273 (m), 1184 (m), 1129 (m); LRMS (EI): 381 (100%) [M⁺], 336 (26%), 309 (10%); HRMS 381.1732 [381.1729 calcd for C₂₆H₂₃NO₂ (M⁺)].

Ethyl 5-methyl-2-phenyl-4-(thiophen-3-yl)-1-phenylpyrrole-3-carboxylate (3fa)

Following the general procedure, **3fa** was obtained as a colorless solid (74%) after flash chromatography on neutral Al₂O₃ (P/EtOAc = 95/5). R_f = 0.69 (P/EtOAc = 80/20); ¹H NMR (360 MHz, CDCl₃): δ = 0.90 (t, J = 7.2 Hz, 3 H), 2.05 (s, 3 H), 3.98 (q, J = 7.2 Hz, 2 H), 7.11 (d, 2 H), 7.16–7.21 (m, 6 H), 7.22–7.24 (m, 1 H), 7.27–7.34 (m, 4 H); ¹³C NMR (90.6 MHz,

CDCl₃; one C_{Ar} missing): δ = 11.9, 13.8, 59.6, 113.4, 117.7, 122.6, 123.8, 127.4, 127.5, 128.1, 128.8, 129.0, 130.5, 131.1, 132.2, 135.7, 137.7, 138.1, 165.5; IR (cm⁻¹): 2923 (m), 1703 (vs), 1598 (w), 1498 (m), 1400 (m), 1263 (m), 1210 (m), 1132 (s); LRMS (EI): 387 (100%) [M⁺], 342 (26%), 312 (12%), 277 (9%); HRMS 387.1292 [387.1293 calcd for C₂₄H₂₁NO₂S (M⁺)].

Ethyl 4-cyclohexylmethyl-5-methyl-2-phenyl-1-phenylpyrrole-3-carboxylate (3ga)

Following the general procedure, **3ga** was obtained as a colorless solid (90%) after flash chromatography on neutral Al₂O₃ (P/EtOAc = 95/5). R_f = 0.84 (P/EtOAc = 80/20); ¹H NMR (360 MHz, CDCl₃): δ = 0.97–1.00 (m, 2 H), 1.06 (t, *J* = 7.2 Hz, 3 H), 1.15–1.22 (m, 3 H), 1.60–1.73 (m, 4 H), 1.77–1.81 (m, 2 H), 1.98 (s, 3 H), 2.63 (d, *J* = 6.8 Hz, 2 H), 4.09 (q, *J* = 7.2 Hz, 2 H), 7.00–7.03 (m, 2 H), 7.11–7.17 (m, 5 H), 7.24–7.27 (m, 3 H); ¹³C NMR (90.6 MHz, CDCl₃): δ = 11.3, 14.1, 26.7, 26.9, 33.3, 33.6, 40.0, 59.3, 112.8, 120.5, 127.2, 127.3, 127.8, 127.9, 128.8, 128.9, 131.2, 133.1, 138.1, 138.5, 166.0; IR (cm⁻¹): 2922 (s), 2848 (w), 1698 (s), 1498 (m), 1384 (m), 1234 (m), 1111 (s); LRMS (EI): 401 (25%) [M⁺], 326 (99%), 267 (28%), 244 (100%), 215 (26%); HRMS 401.2350 [401.2355 calcd for C₂₇H₃₁NO₂ (M⁺)].

Ethyl 4-cyclohexylmethyl-5-methyl-2-phenyl-1-naphtylpyrrole-3-carboxylate (3gj)

Following the general procedure, **3gj** was obtained as a yellow solid (79%) after flash chromatography on neutral Al₂O₃ (P/EtOAc = 95/5). R_f = 0.72 (P/EtOAc = 80/20); ¹H NMR (360 MHz, CDCl₃): δ = 0.99–1.10 (m, 5 H), 1.18–1.24 (m, 2 H), 1.30–1.37 (m, 1 H), 1.68–1.77 (m, 4 H), 1.82–1.87 (m, 5 H), 2.66 (dd, *J* = 13.4 Hz, *J* = 7.3 Hz, 1 H), 2.76 (dd, *J* = 13.4 Hz, *J* = 6.6 Hz, 1 H), 4.12 (q, *J* = 7.2 Hz, 2 H), 6.96–7.01 (m, 3 H), 7.06–7.08 (m, 2 H), 7.22–7.34 (m, 1 H), 7.28–7.37 (m, 2 H), 7.46–7.49 (m, 2 H), 7.75–7.83 (m, 2 H); ¹³C NMR (90.6 MHz, CDCl₃): δ = 10.7, 14.1, 26.7, 27.0, 33.5, 33.8, 39.9, 59.3, 112.7, 120.3, 123.2, 125.0, 126.6, 127.0, 127.2, 127.2, 127.4, 128.2, 128.8, 129.1, 130.6, 131.9, 133.0, 133.9, 135.2, 139.4, 166.0; IR (cm⁻¹): 2922 (s), 2850 (m), 1698 (s), 1598 (w), 1479 (m), 1258 (m), 1149 (m), 1113 (s); LRMS (EI): 451 (70%) [M⁺], 368 (100%), 105 (15%). HRMS 451.2520 [451.2511 calcd for C₃₁H₃₃NO₂ (M⁺)].

Ethyl 4-(3-[[tetrahydropyran-2-yl]-oxy]-propyl)-5-methyl-2-phenyl-1-phenylpyrrole-3-carboxylate (3ha)

Following the general procedure, **3ha** was obtained as a colorless solid (70%) after flash chromatography on neutral Al₂O₃ (P/EtOAc = 95/5). R_f = 0.47 (P/EtOAc = 80/20); ¹H NMR (360 MHz, CDCl₃): δ = 1.05 (t, *J* = 7.2 Hz, 3 H), 1.56–1.64 (m, 3 H), 1.71–1.77 (m, 1 H),

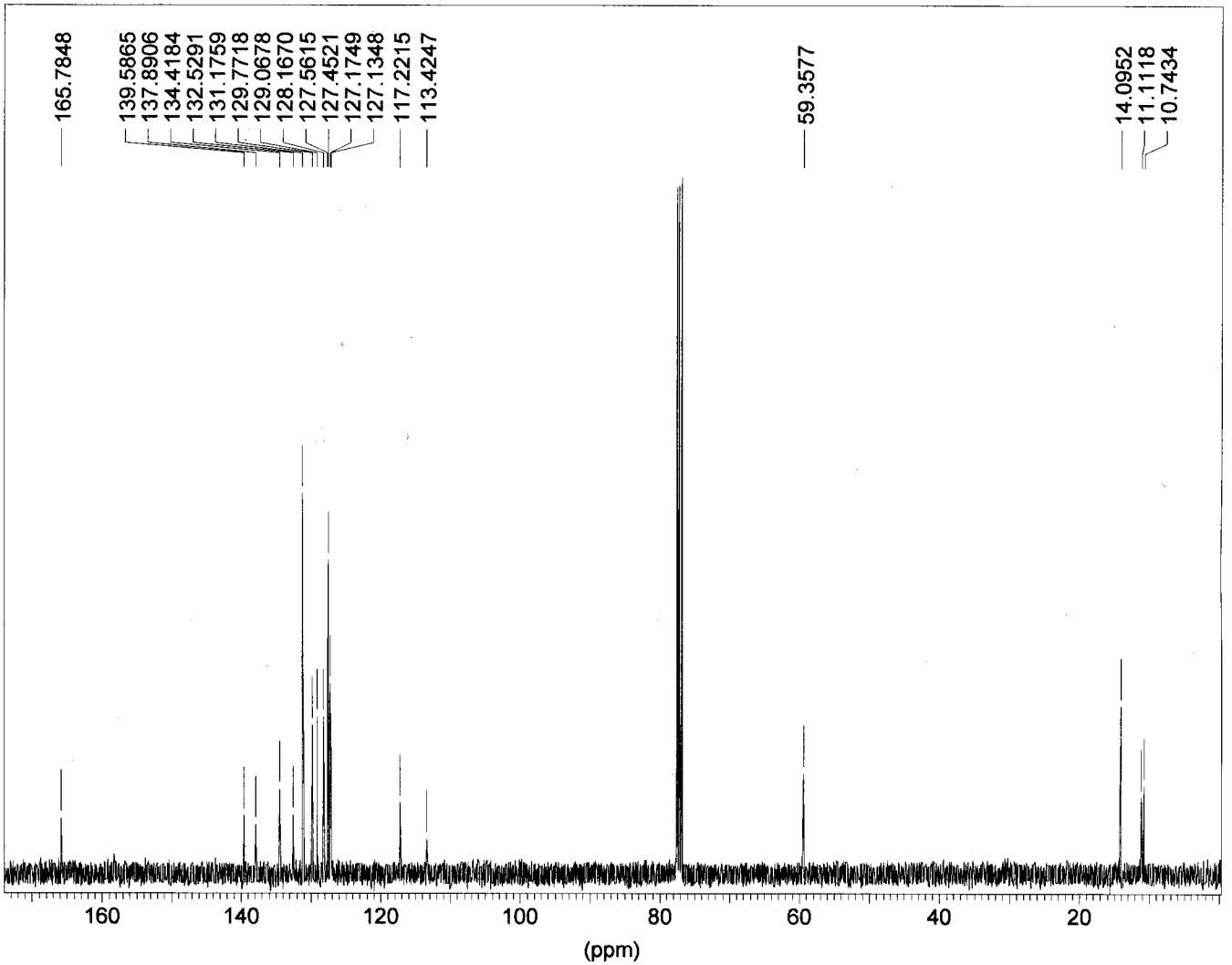
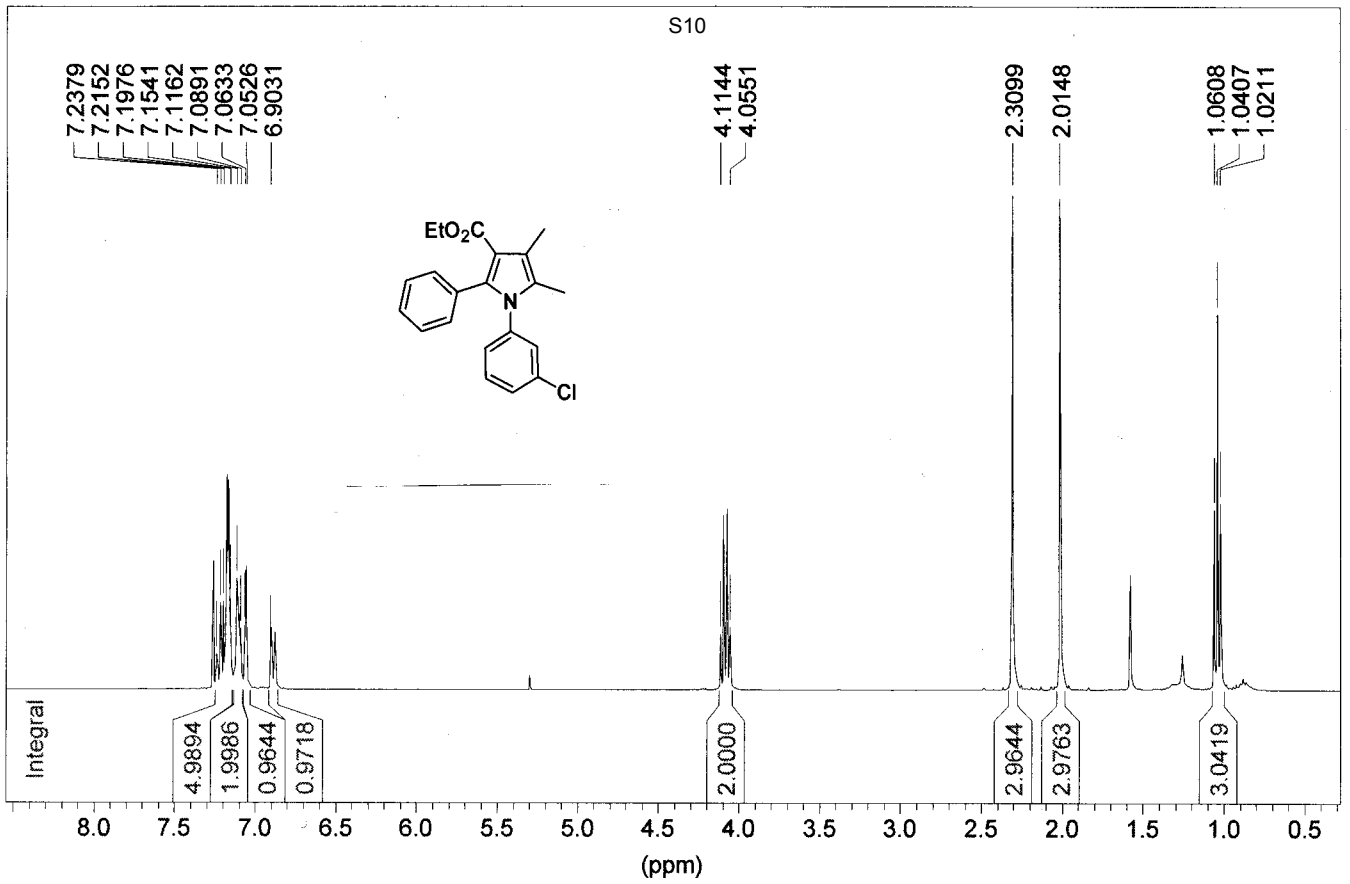
1.82–1.97 (m, 4 H), 2.00 (s, 3 H), 2.83–2.87 (m, 2 H), 3.46–3.55 (m, 2 H), 3.81–3.95 (m, 2 H), 4.08 (q, $J = 7.2$ Hz, 2 H), 4.60–4.64 (m, 1 H), 7.00–7.03 (m, 2 H), 7.12–7.15 (m, 5 H), 7.22–7.25 (m, 3 H); ^{13}C NMR (90.6 MHz, CDCl_3 ; one C_{Ar} missing): $\delta = 10.8, 14.1, 19.9, 22.2, 25.7, 31.0, 31.4, 59.3, 62.5, 67.5, 99.0, 112.3, 121.1, 127.2, 127.5, 127.8, 128.8, 128.8, 131.2, 132.9, 138.2, 138.3, 165.7$; IR (cm^{-1}): 2940 (s), 1698 (vs), 1598 (m), 1498 (m), 1384 (m), 1234 (m), 1138 (s); LRMS (EI): 447 (100%) [M^+], 362 (37%), 344 (56%), 318 (68%), 290 (31%), 274 (23%); HRMS 447.2401 [447.2410 calcd for $\text{C}_{28}\text{H}_{33}\text{NO}_4(\text{M}^+)$].

Ethyl 5-methyl-2-phenyl-1-phenylpyrrole-3-carboxylate (3ia)

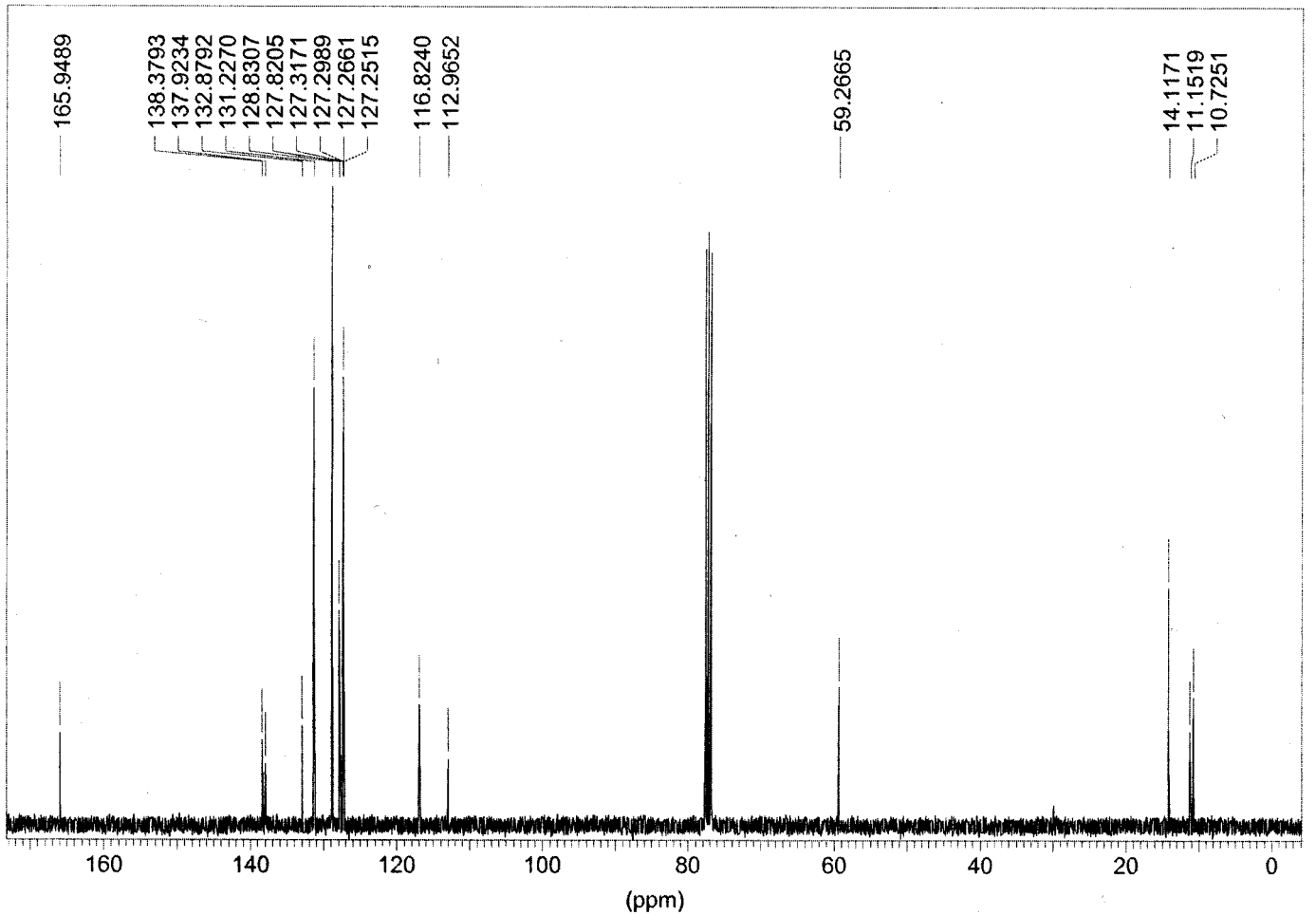
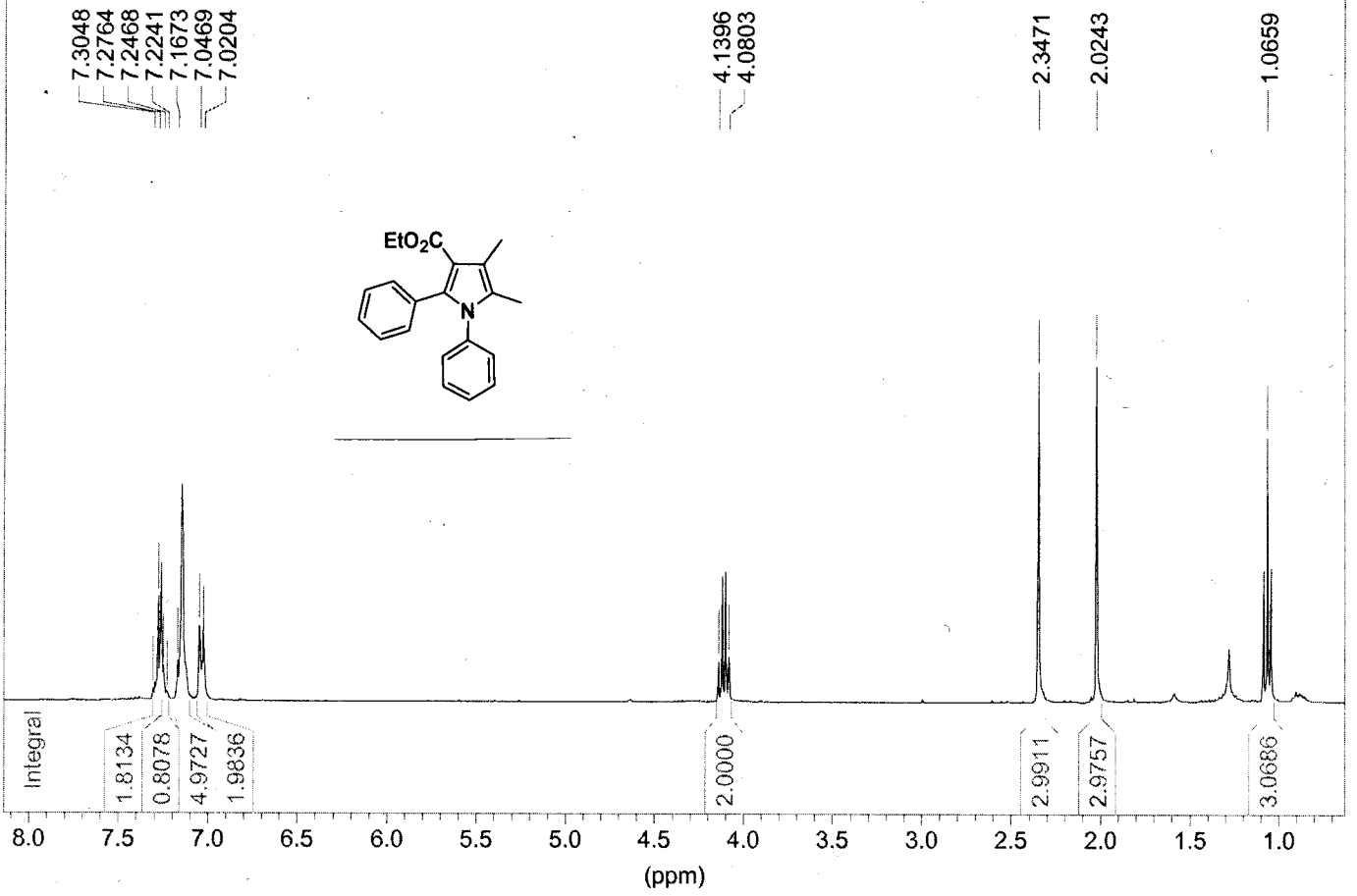
Following the general procedure, **3ia** was obtained as a yellow solid (52%) after flash chromatography on neutral Al_2O_3 (P/EtOAc = 95/5). $R_f = 0.60$ (P/EtOAc = 80/20); ^1H NMR (360 MHz, CDCl_3): $\delta = 1.16$ (t, $J = 7.2$ Hz, 3 H), 2.08 (s, 3 H), 4.15 (q, $J = 7.2$ Hz, 2 H), 6.55 (s, 1 H), 7.02–7.04 (m, 2 H), 7.15–7.18 (m, 6 H), 7.26–7.28 (m, 2 H); ^{13}C NMR (90.6 MHz, CDCl_3): $\delta = 13.1, 14.4, 59.5, 108.9, 113.2, 127.3, 127.5, 128.0, 128.6, 128.9, 130.3, 131.2, 132.0, 138.1, 138.6, 165.0$; IR (cm^{-1}): 2923 (m), 1698 (s), 1496 (m), 1422 (m), 1225 (vs), 1112 (s); LRMS (EI): 305 (100%) [M^+], 277 (14%), 260 (61%), 217 (12%), 105 (24%); HRMS 305.1418 [305.1416 calcd for $\text{C}_{20}\text{H}_{19}\text{NO}_2(\text{M}^+)$].

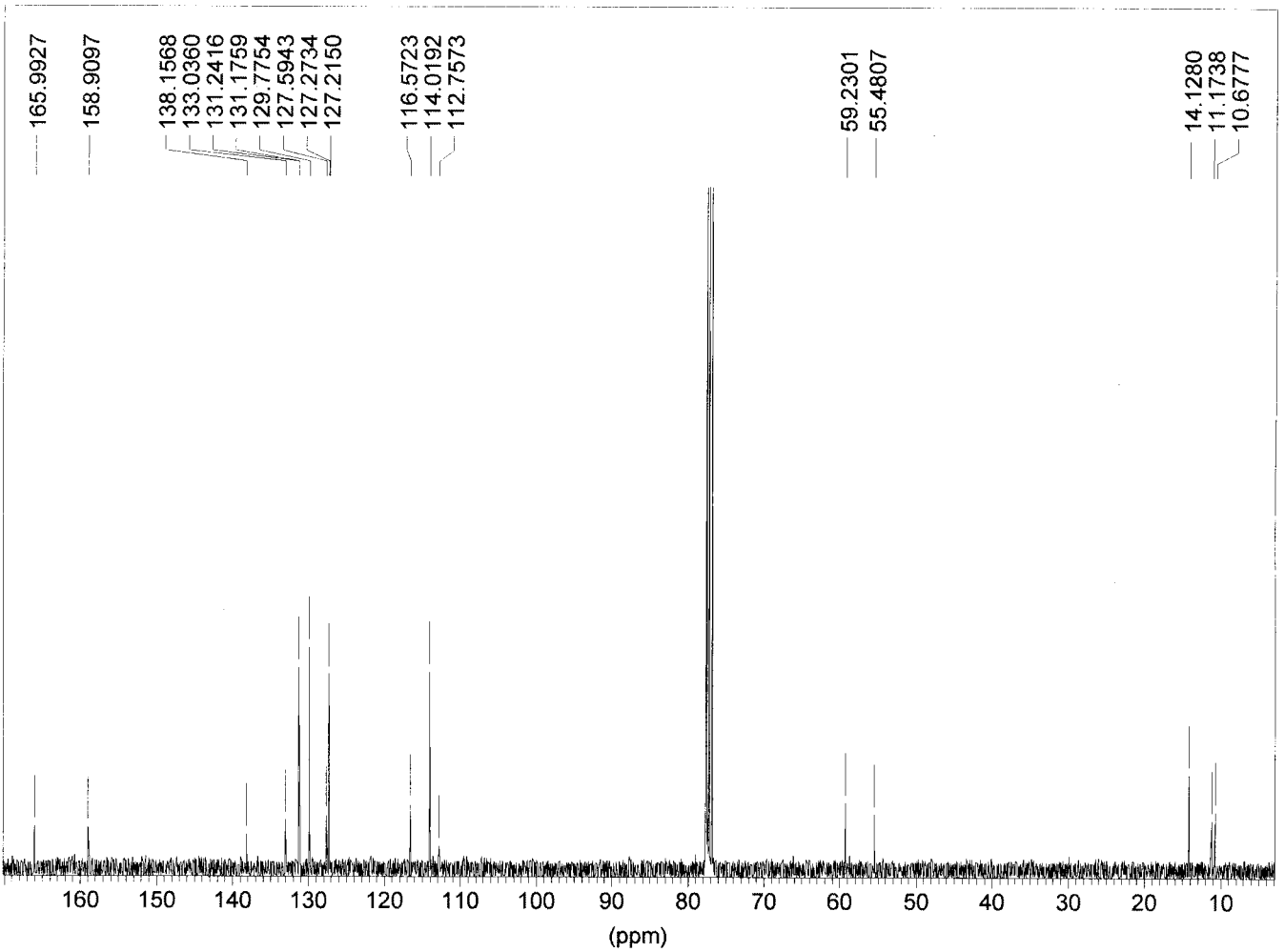
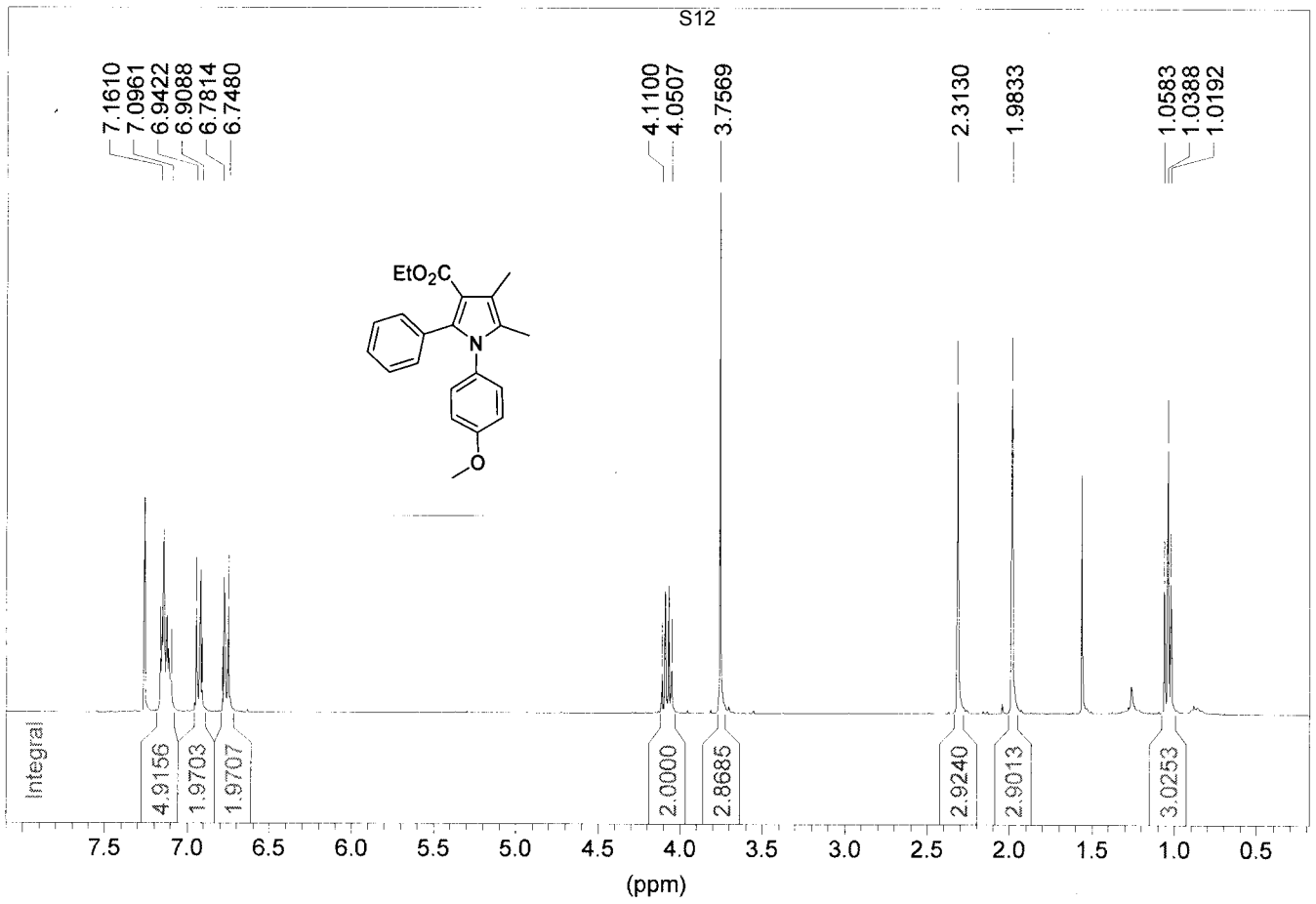
Ethyl 4-(tert-butyldimethylsilyl)-5-methyl-2-phenyl-1-phenylpyrrole-3-carboxylate (3ja)

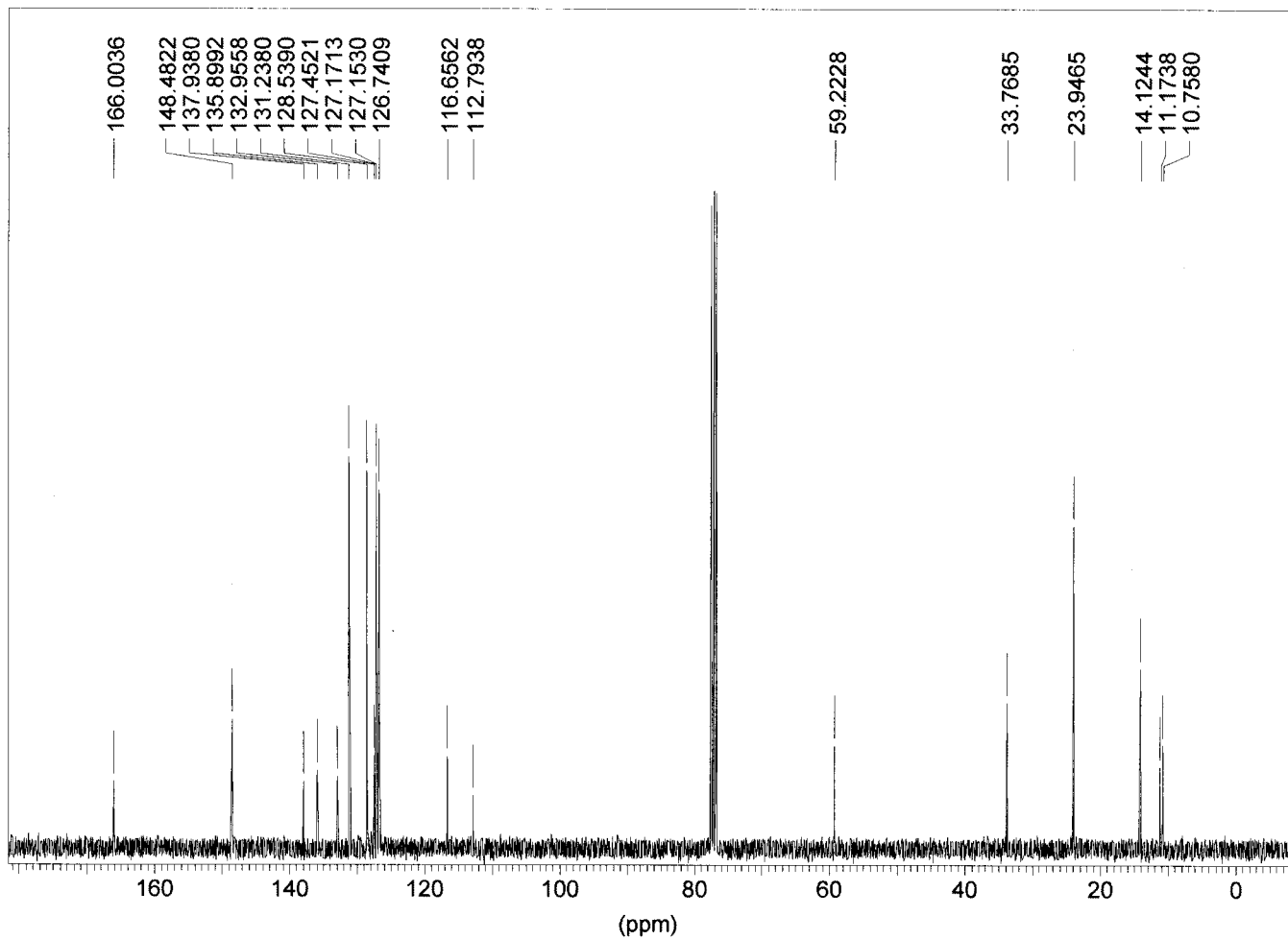
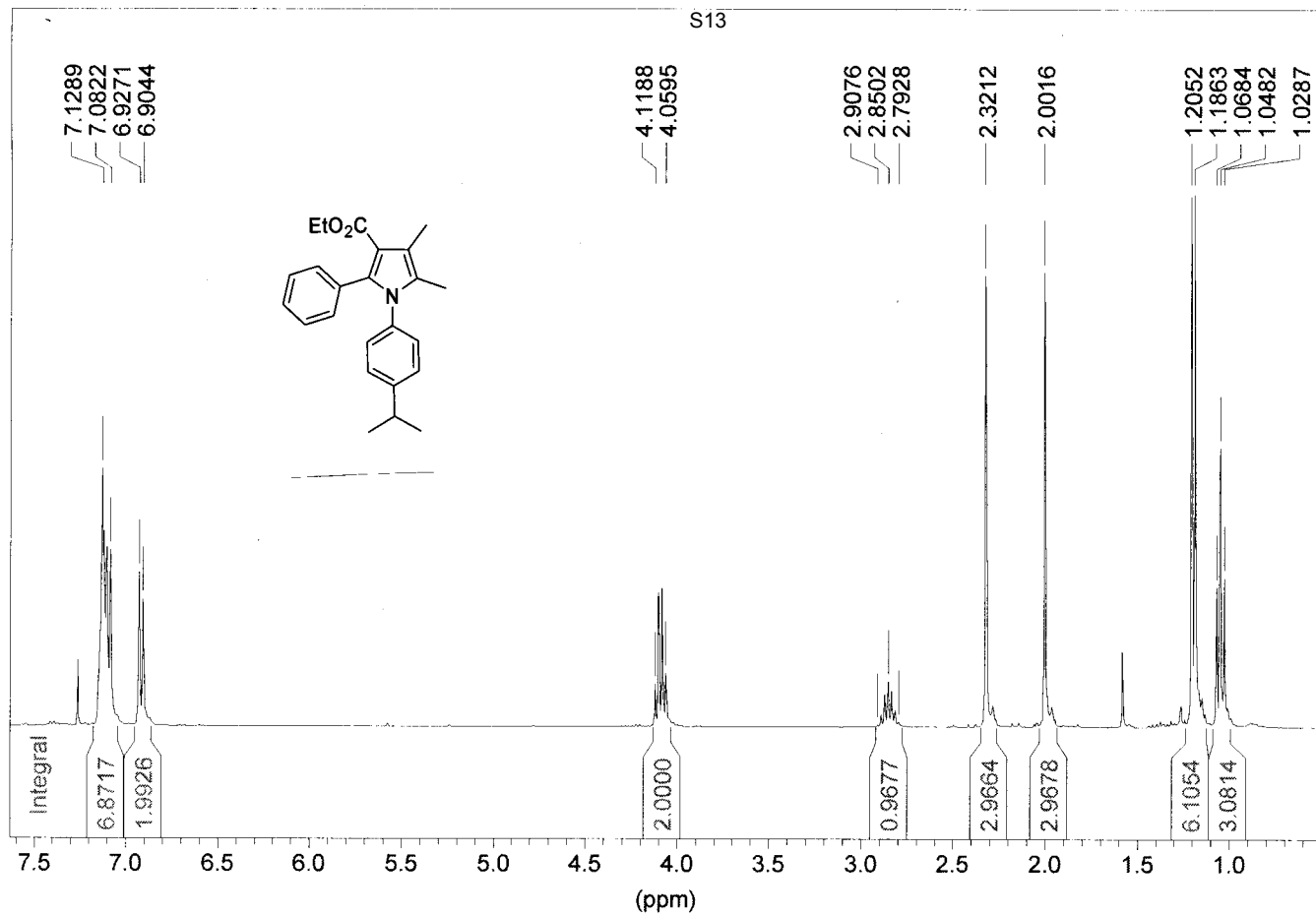
Following the general procedure, **3ja** was obtained as a colorless solid (77%) after flash chromatography on neutral Al_2O_3 (P/EtOAc = 98/2). $R_f = 0.82$ (P/EtOAc = 80/20); ^1H NMR (360 MHz, CDCl_3): $\delta = 0.03$ (s, 6 H), 0.95 (t, $J = 7.2$ Hz, 3 H), 1.03 (s, 9 H), 2.13 (s, 3 H), 4.01 (q, $J = 7.2$ Hz, 2 H), 7.04–7.13 (m, 7 H), 7.27–7.29 (m, 3 H); ^{13}C NMR (90.6 MHz, CDCl_3): $\delta = -2.5, 13.9, 14.9, 18.9, 27.5, 60.1, 111.1, 121.3, 127.0, 127.5, 127.9, 128.9, 129.0, 130.4, 132.7, 136.9, 137.5, 138.5, 167.9$; IR (cm^{-1}): 3416 (s), 2951 (s), 1712 (vs), 1499 (s), 1398 (m), 1205 (s), 1132 (s), 1068 (m); LRMS (EI): 419 (5%) [M^+], 362 (100%), 334 (69%), 287 (13%), 131 (17%); HRMS 419.2281 [418.2281 calcd for $\text{C}_{26}\text{H}_{33}\text{NO}_2\text{Si}(\text{M}^+)$].

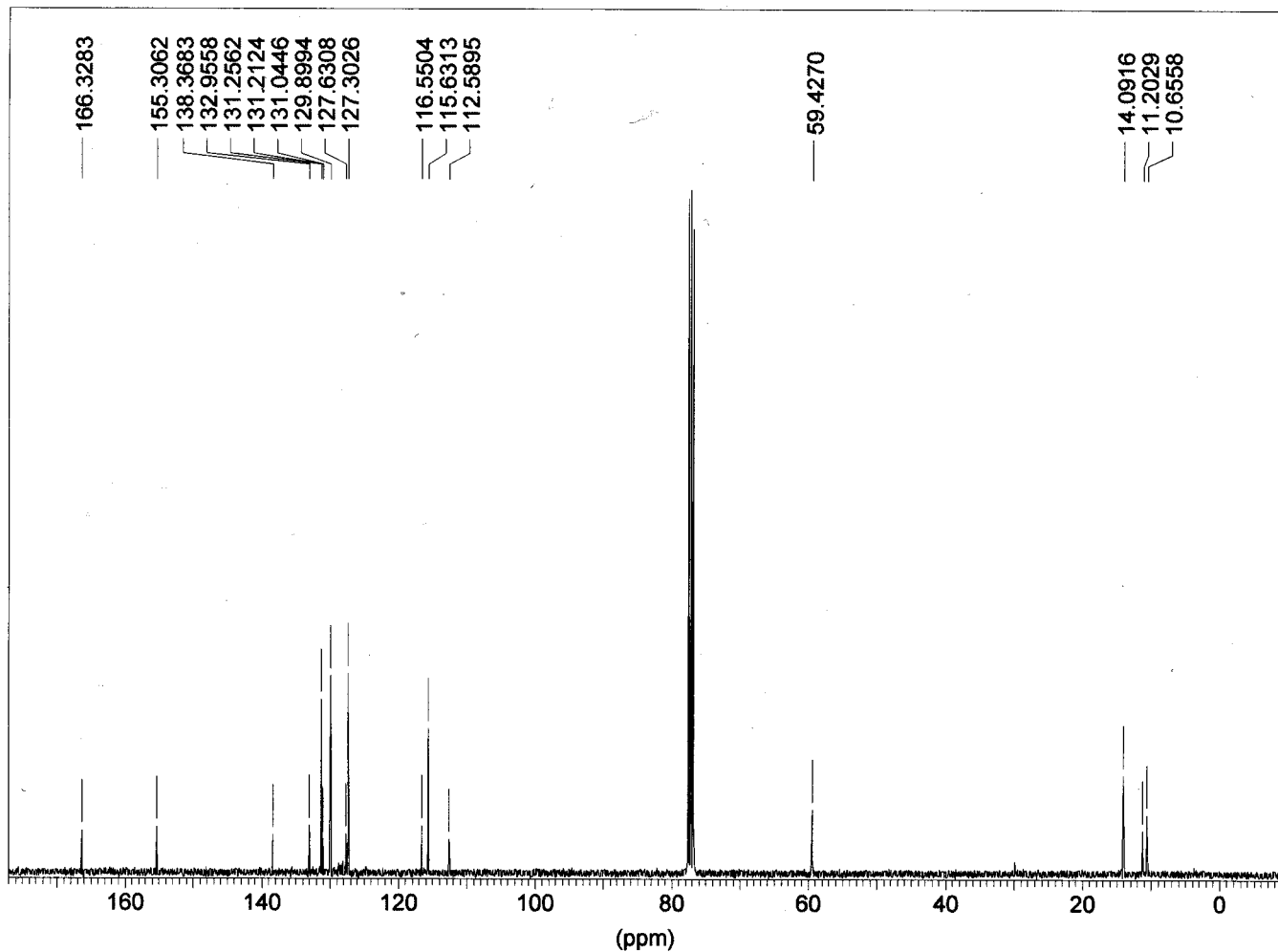
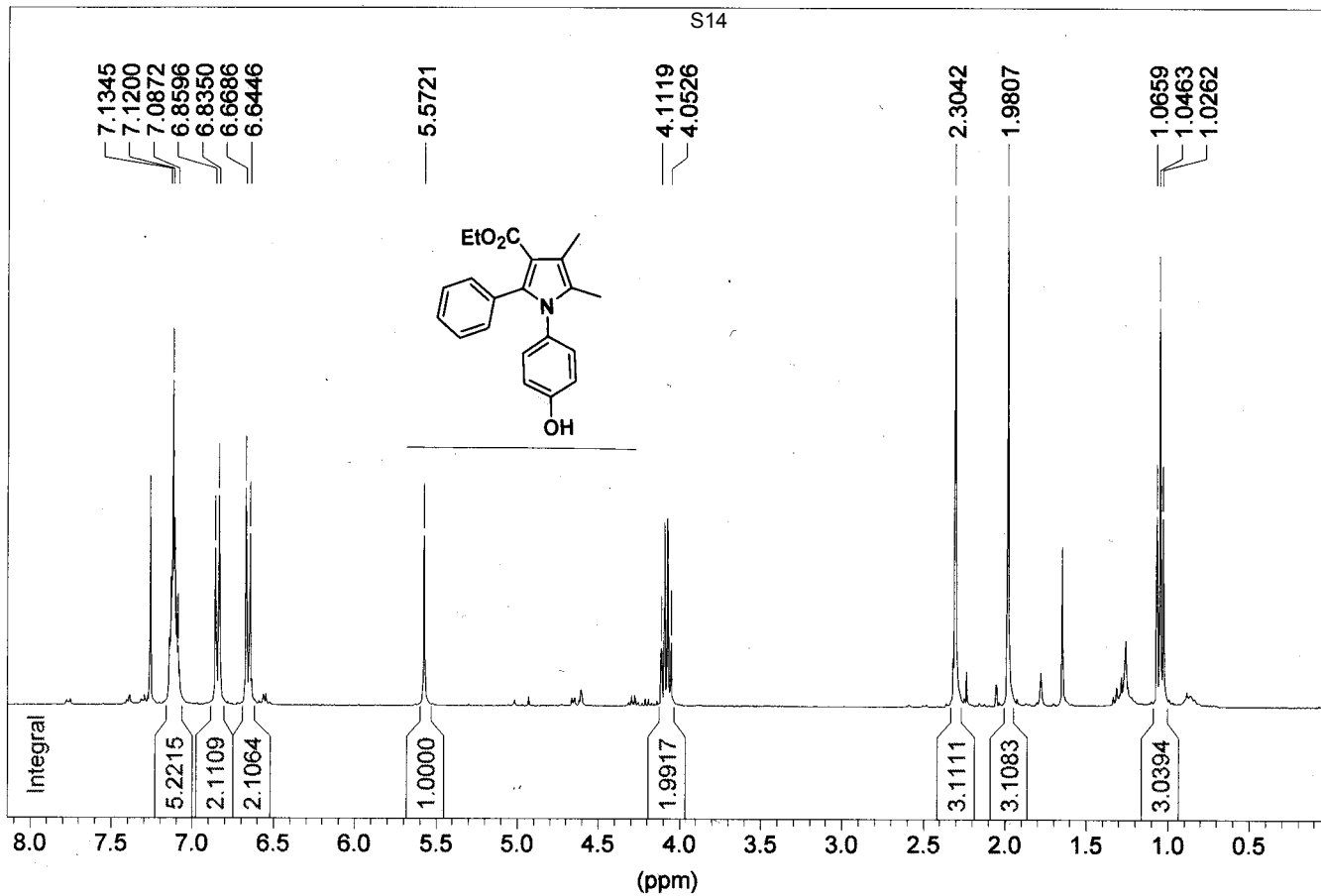


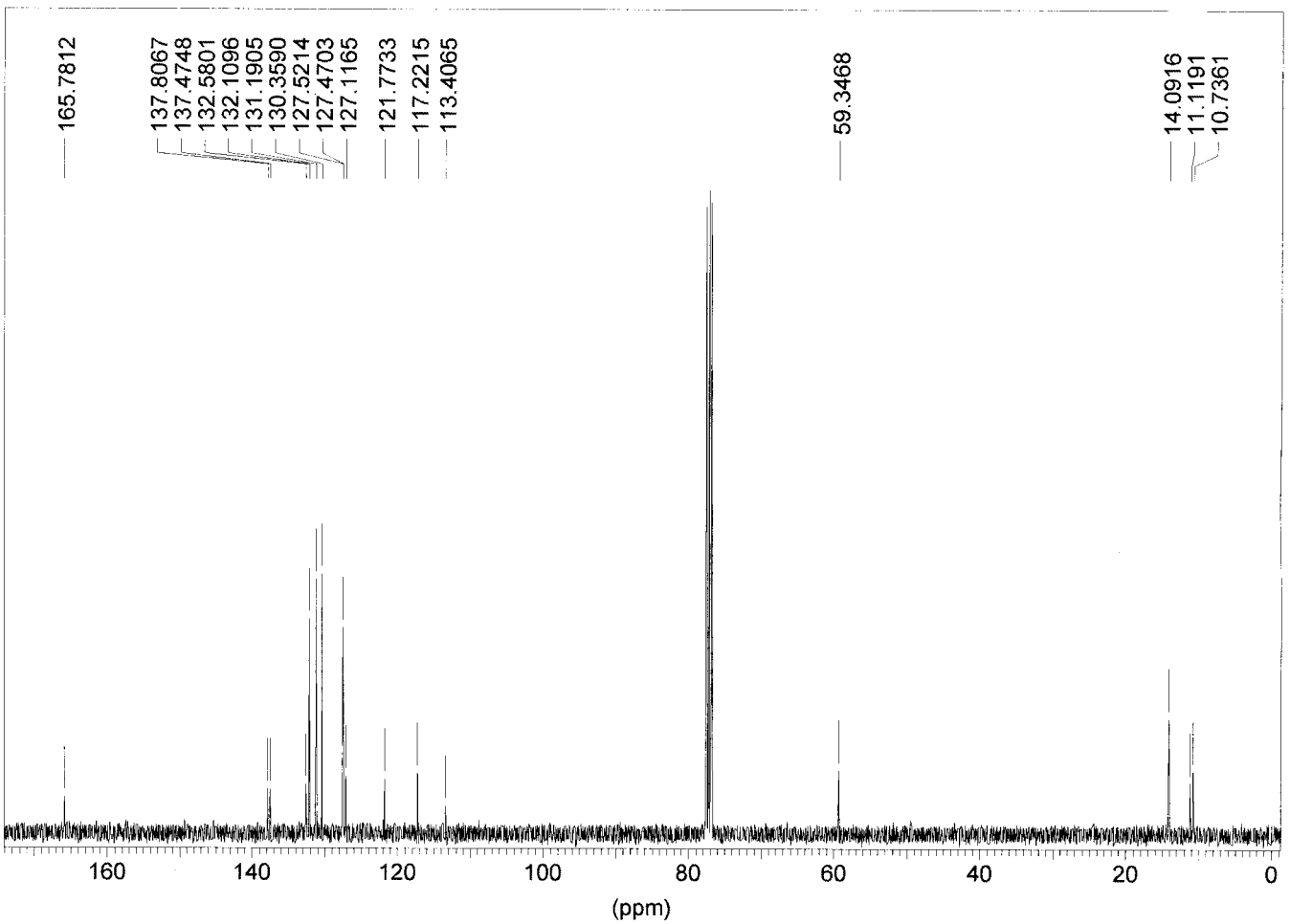
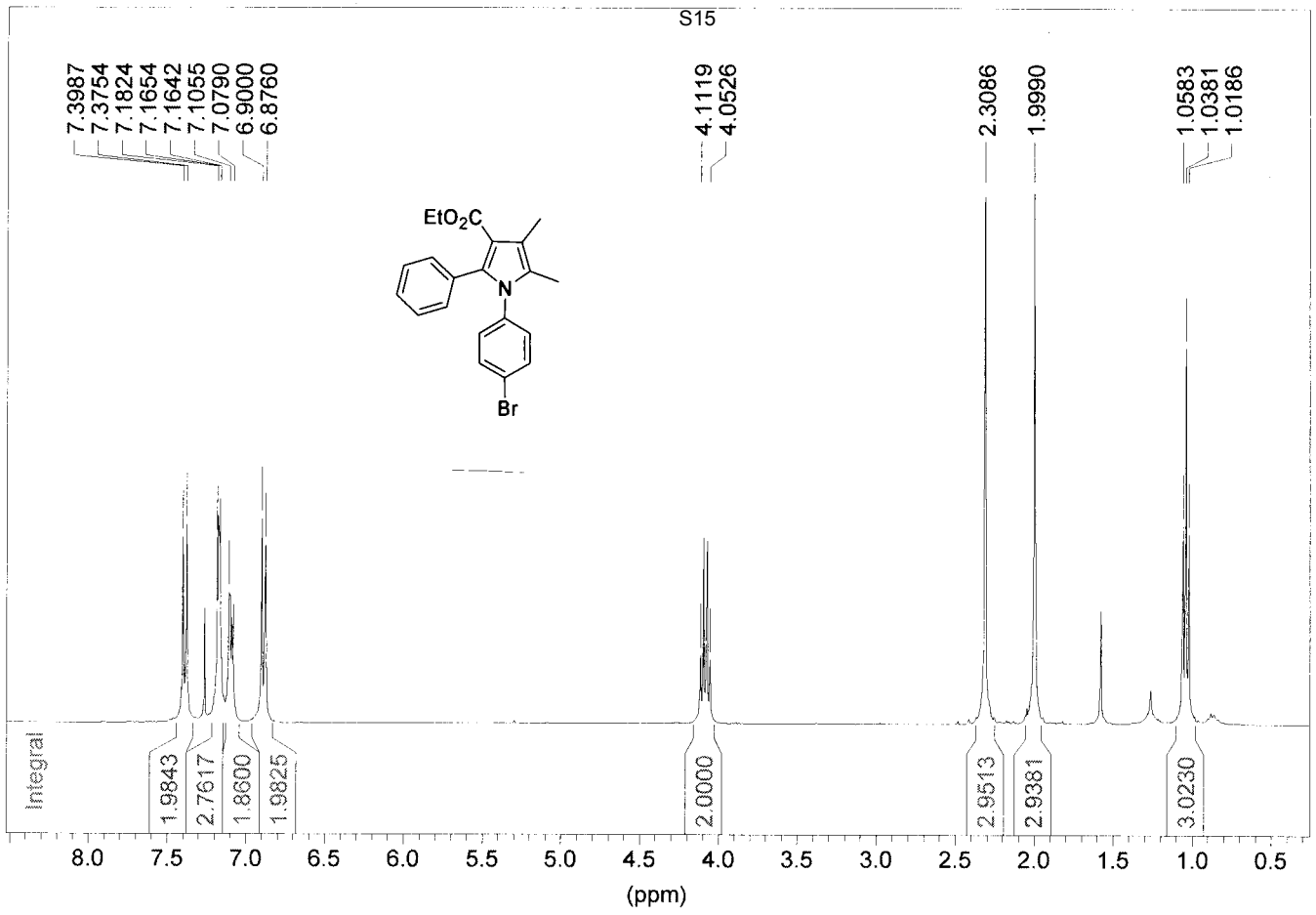
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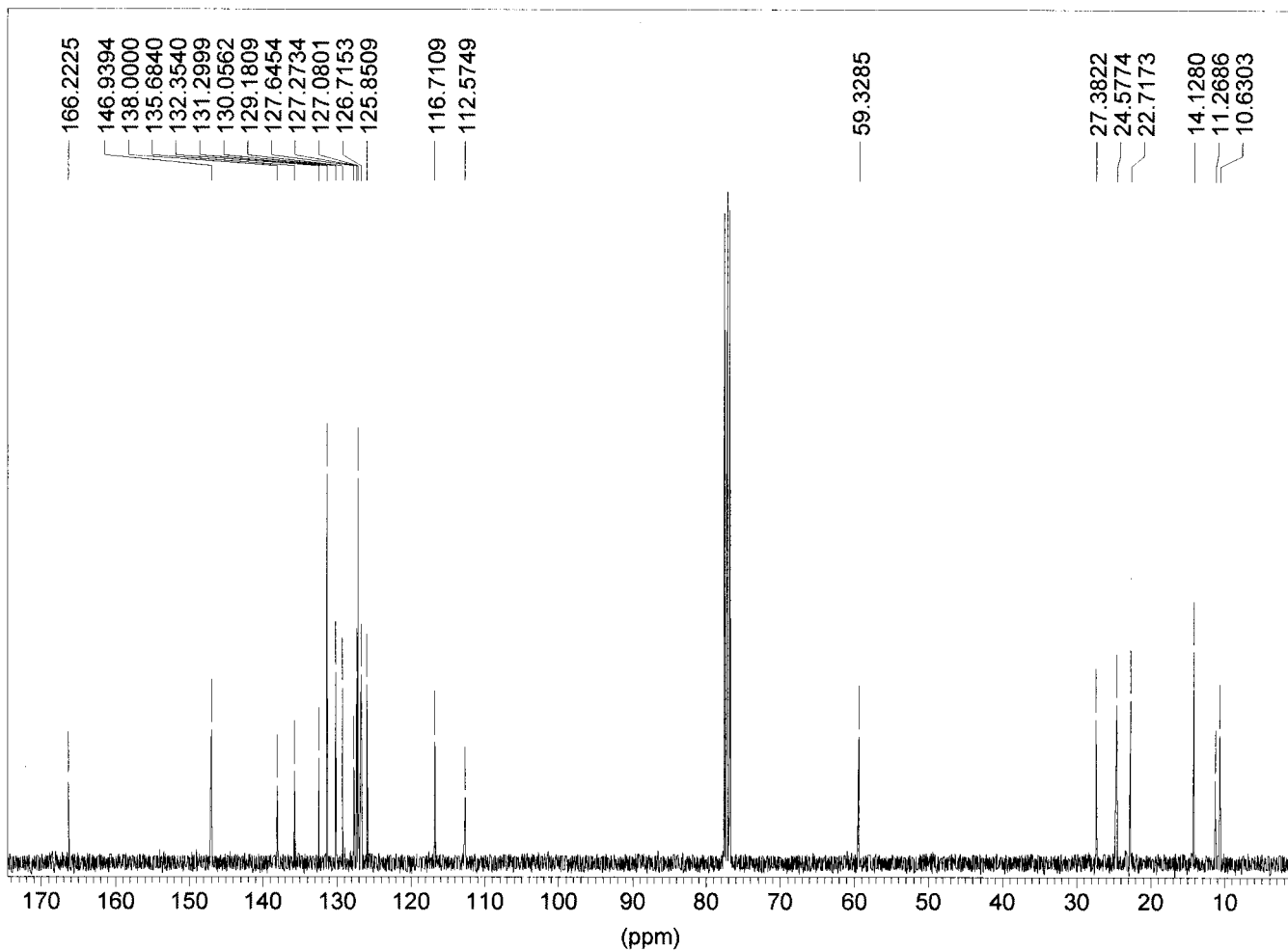
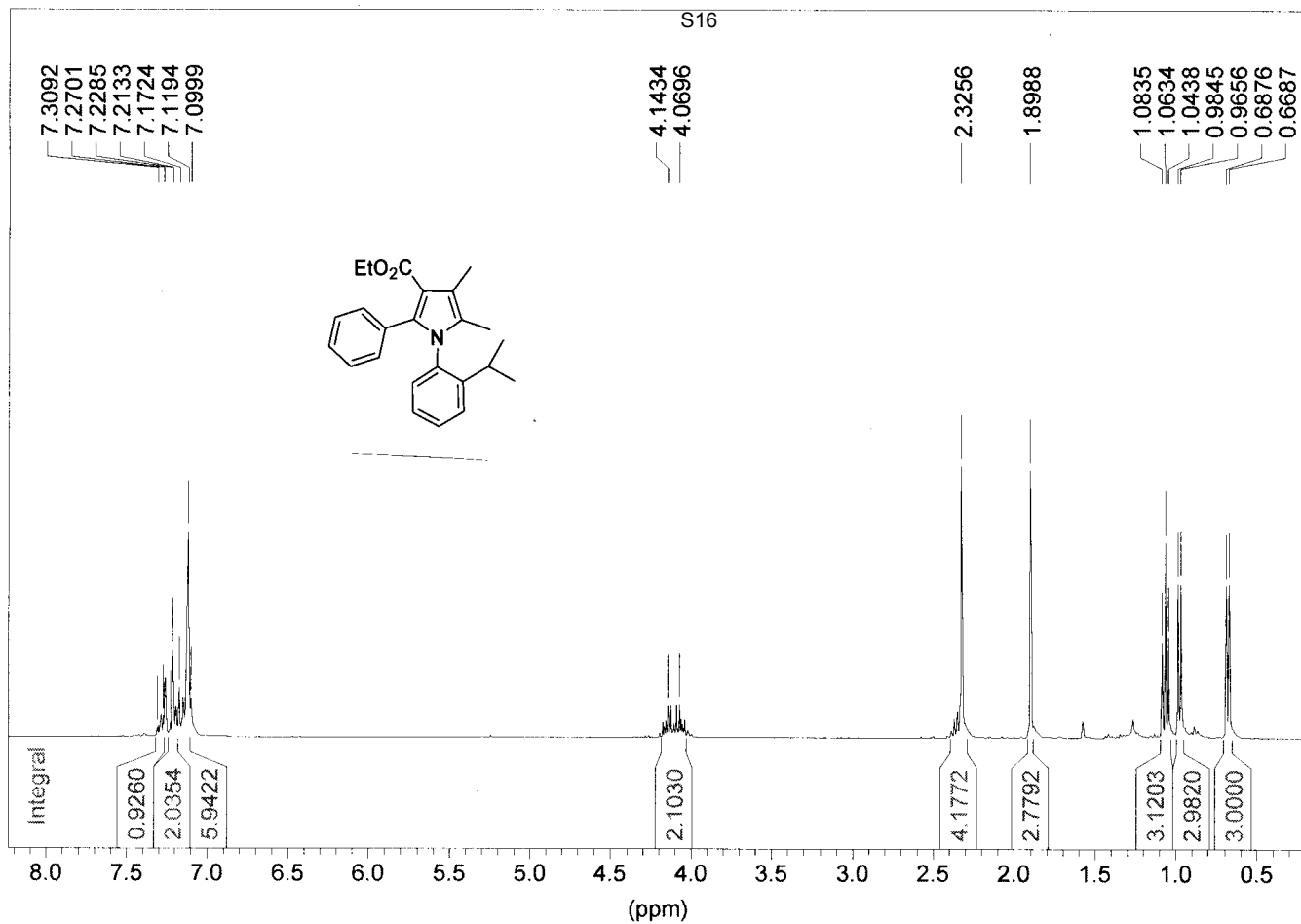


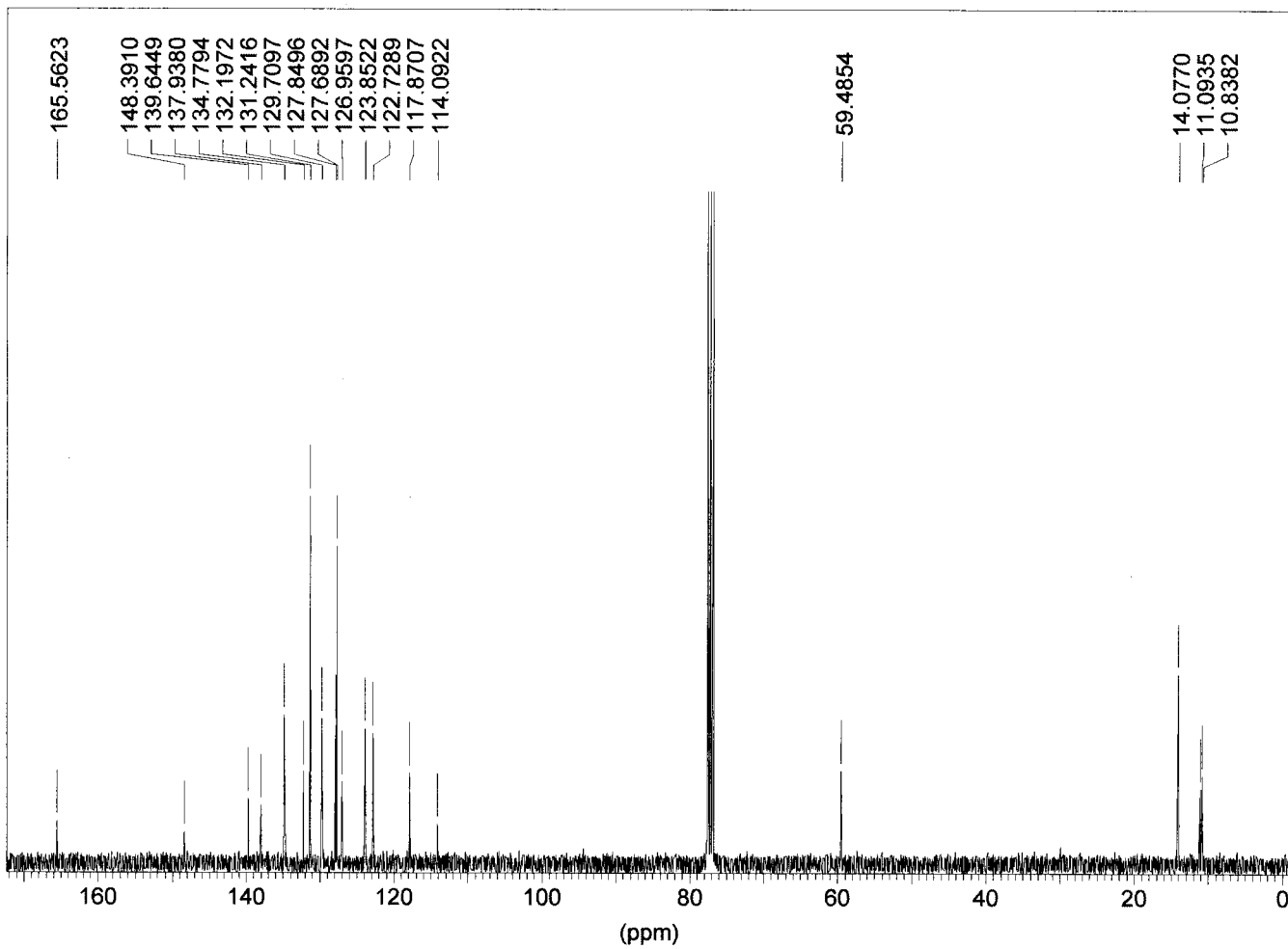
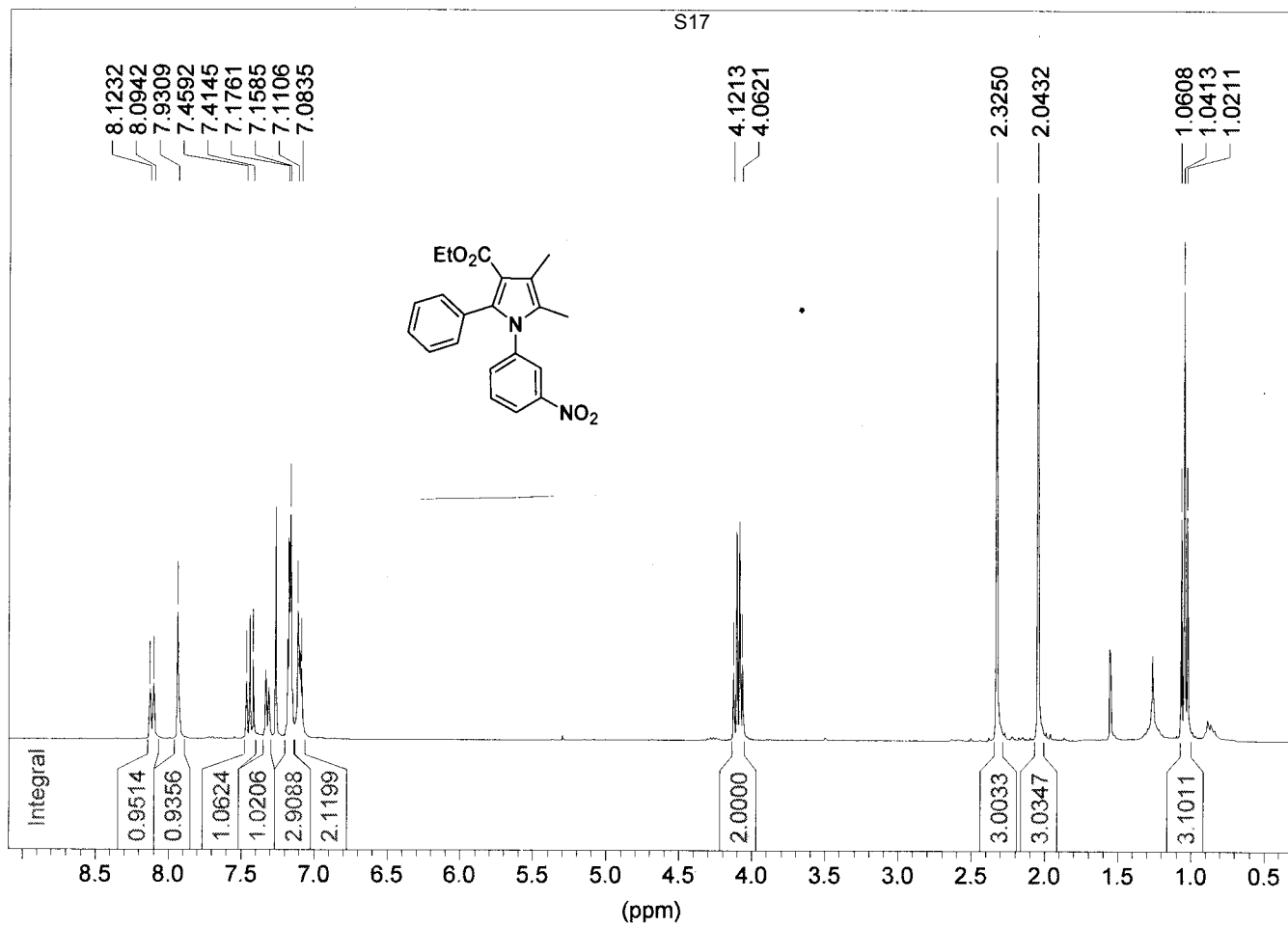


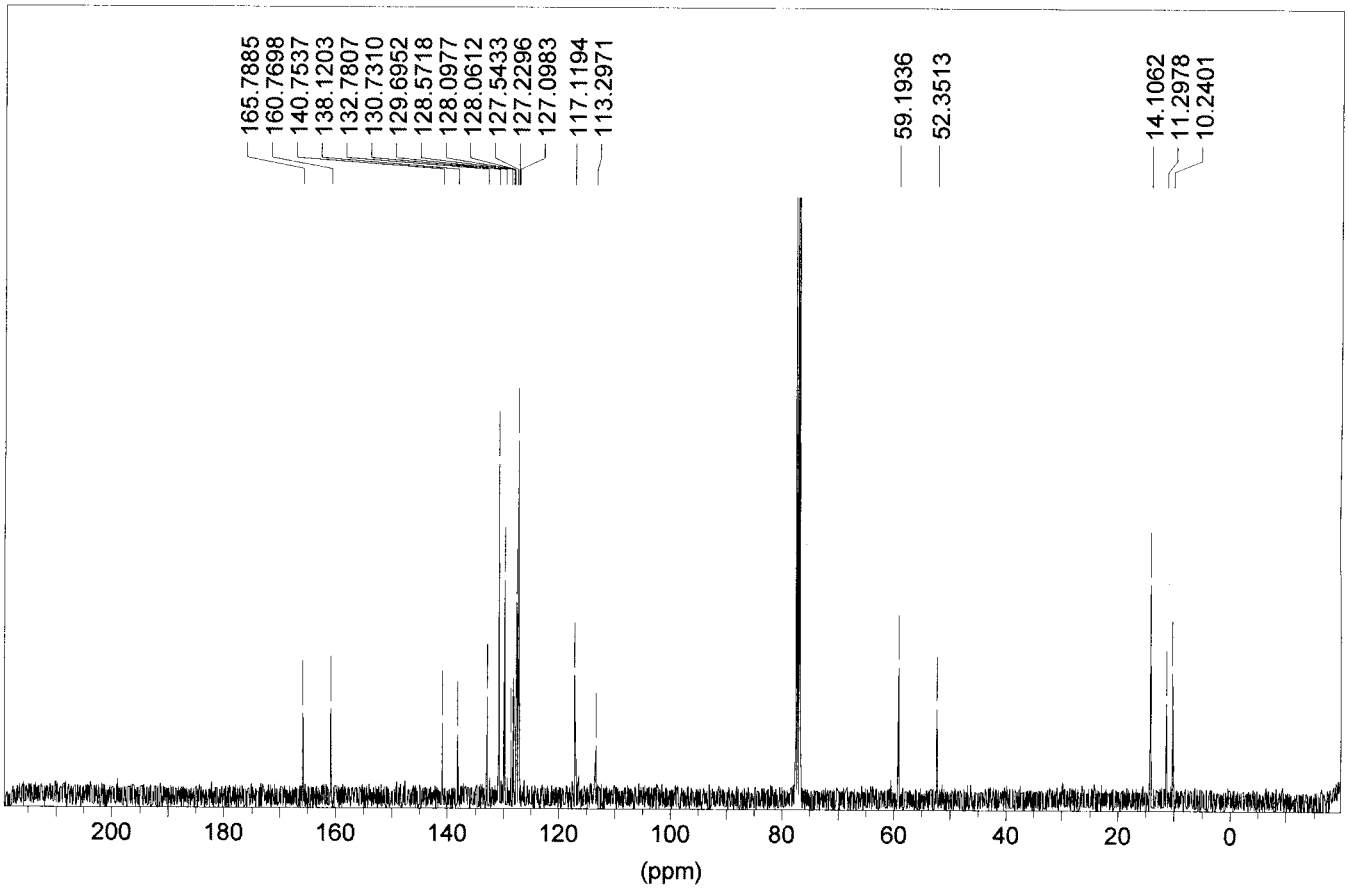
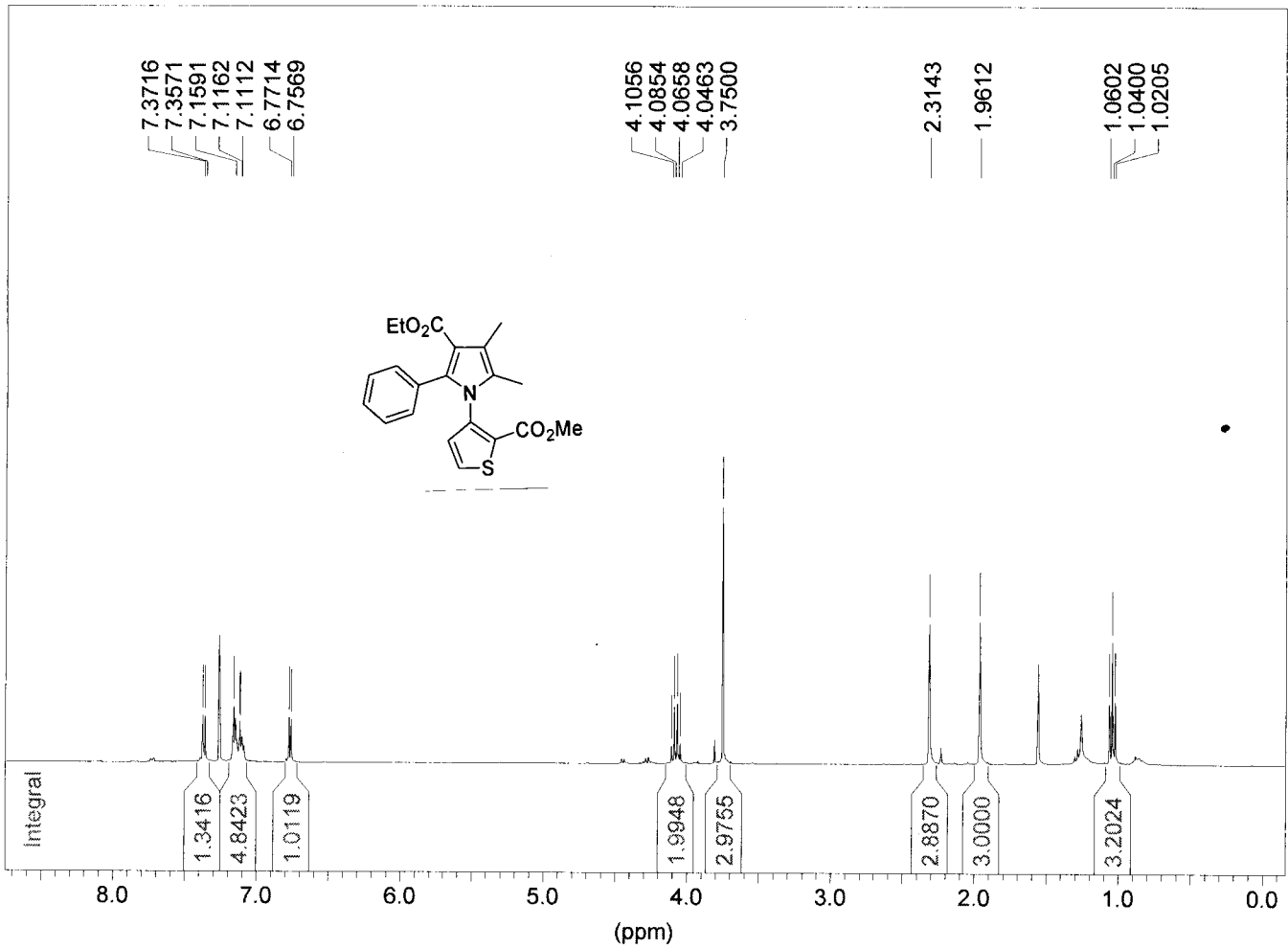


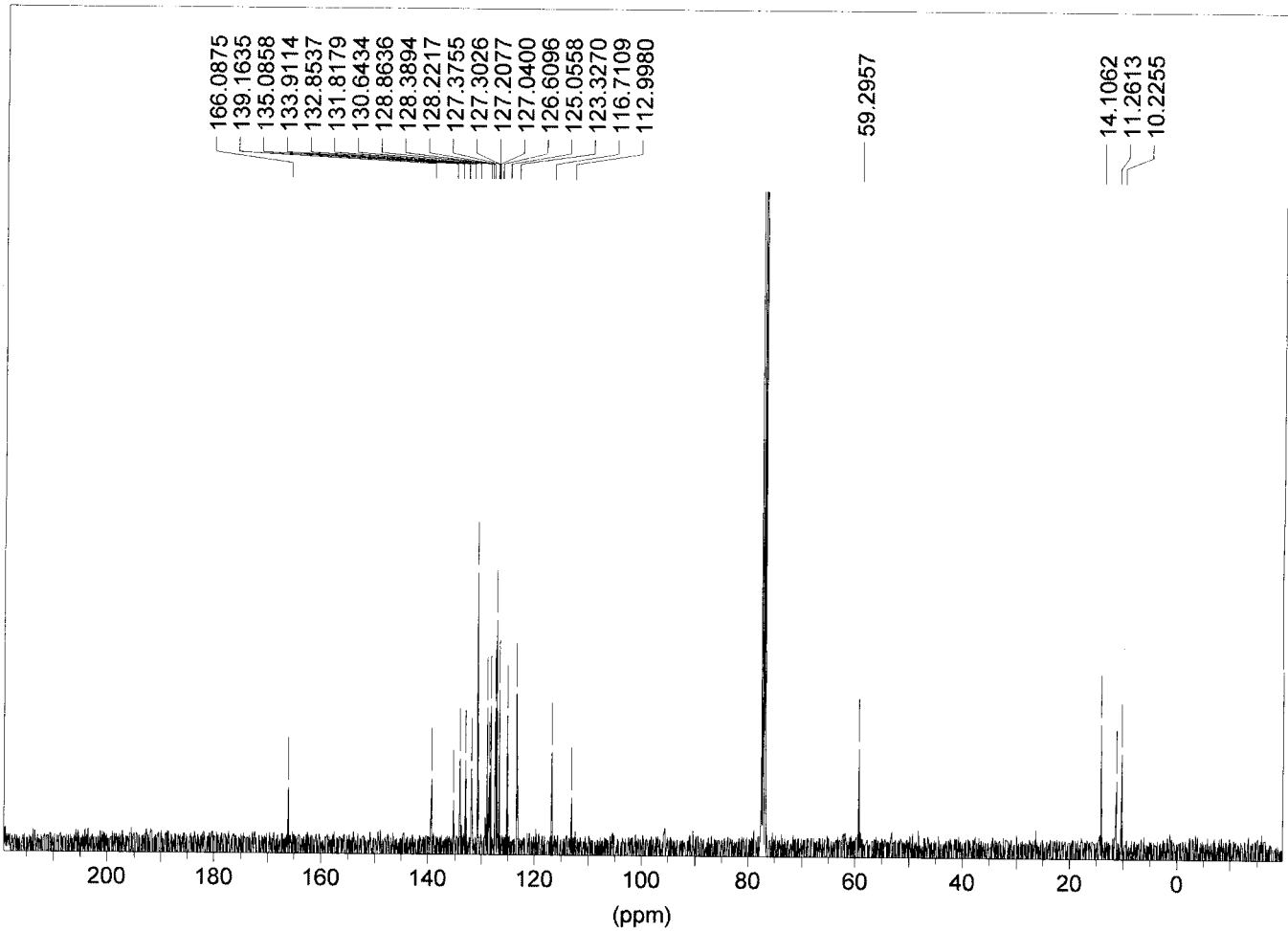
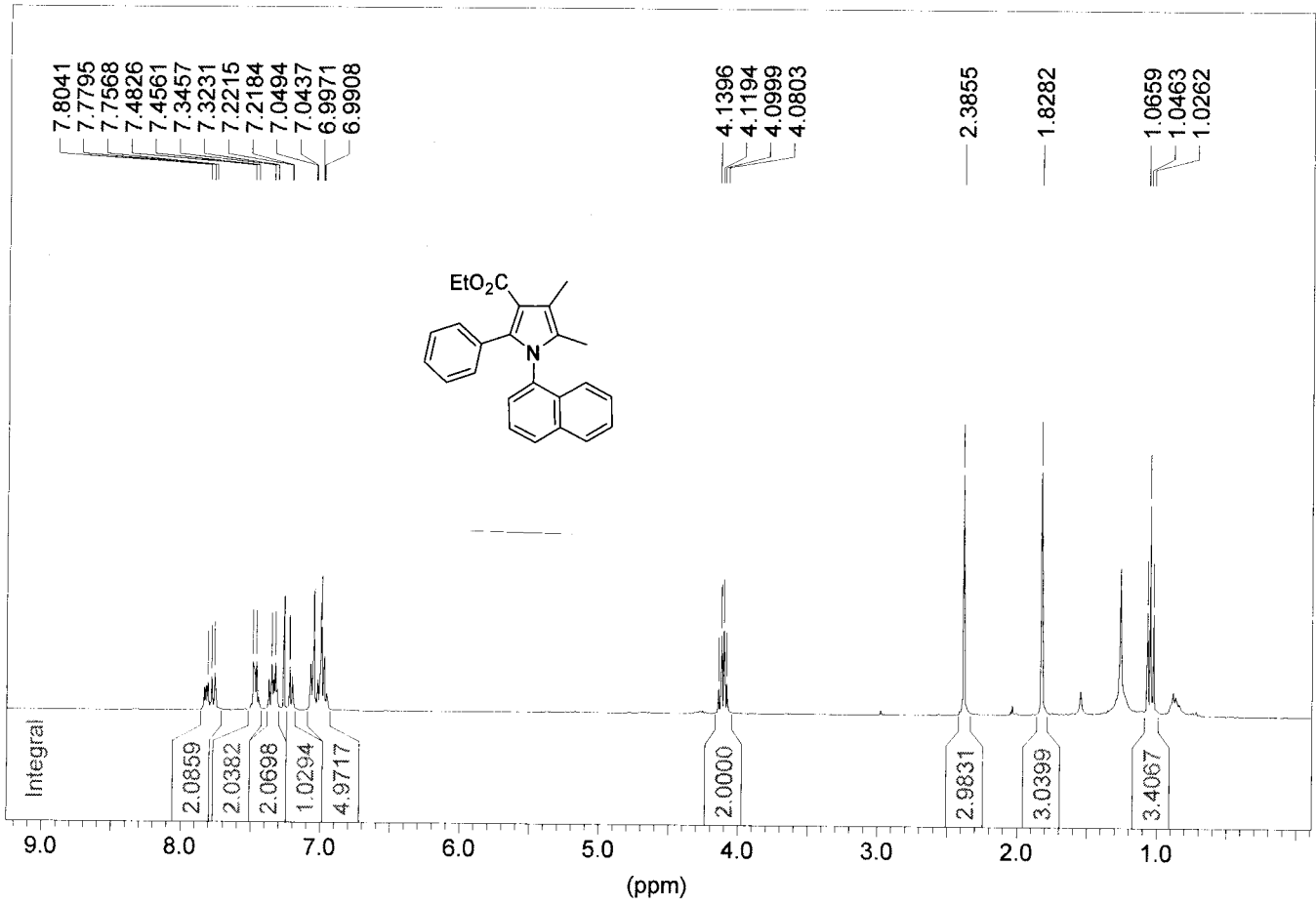


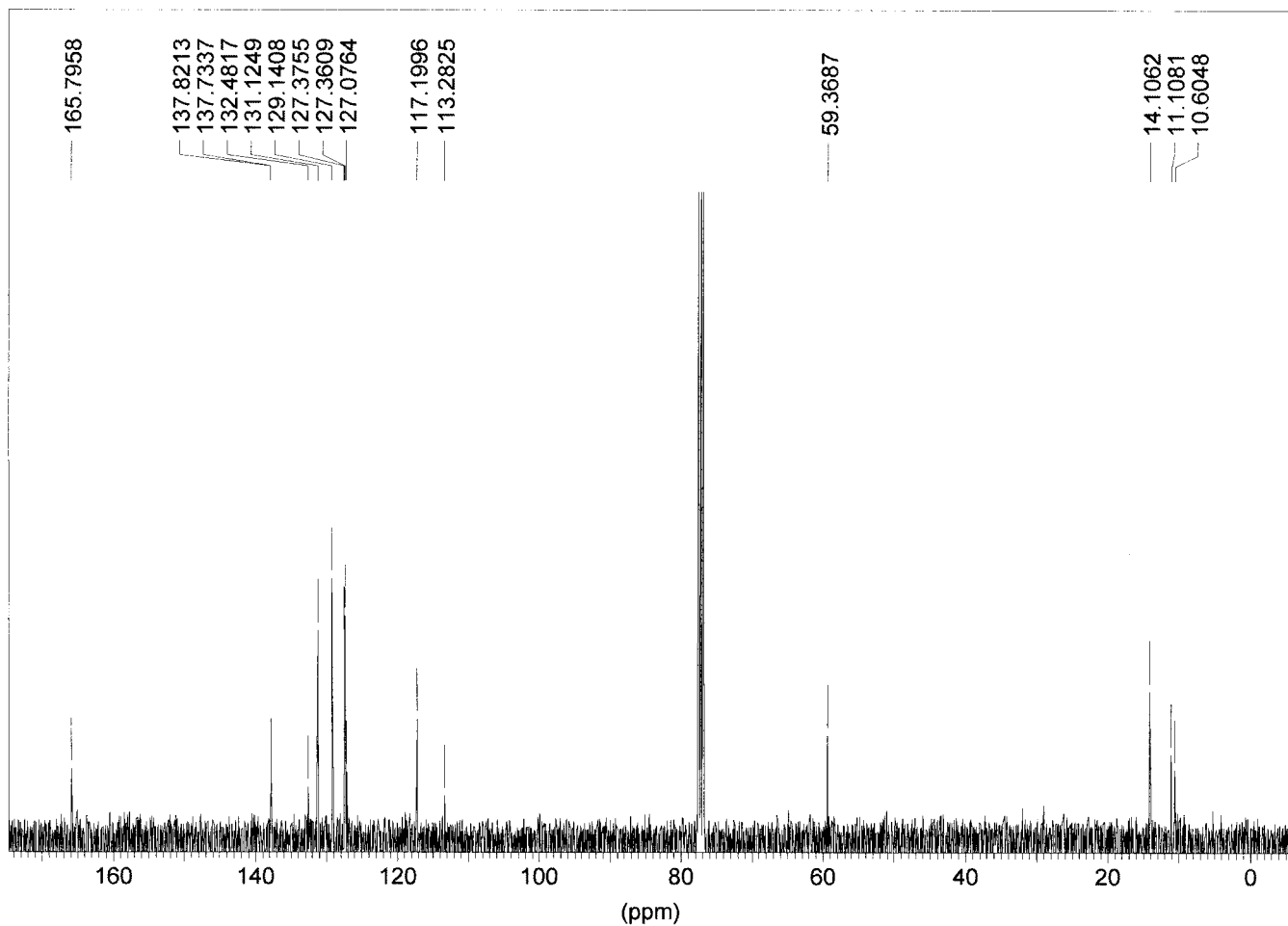
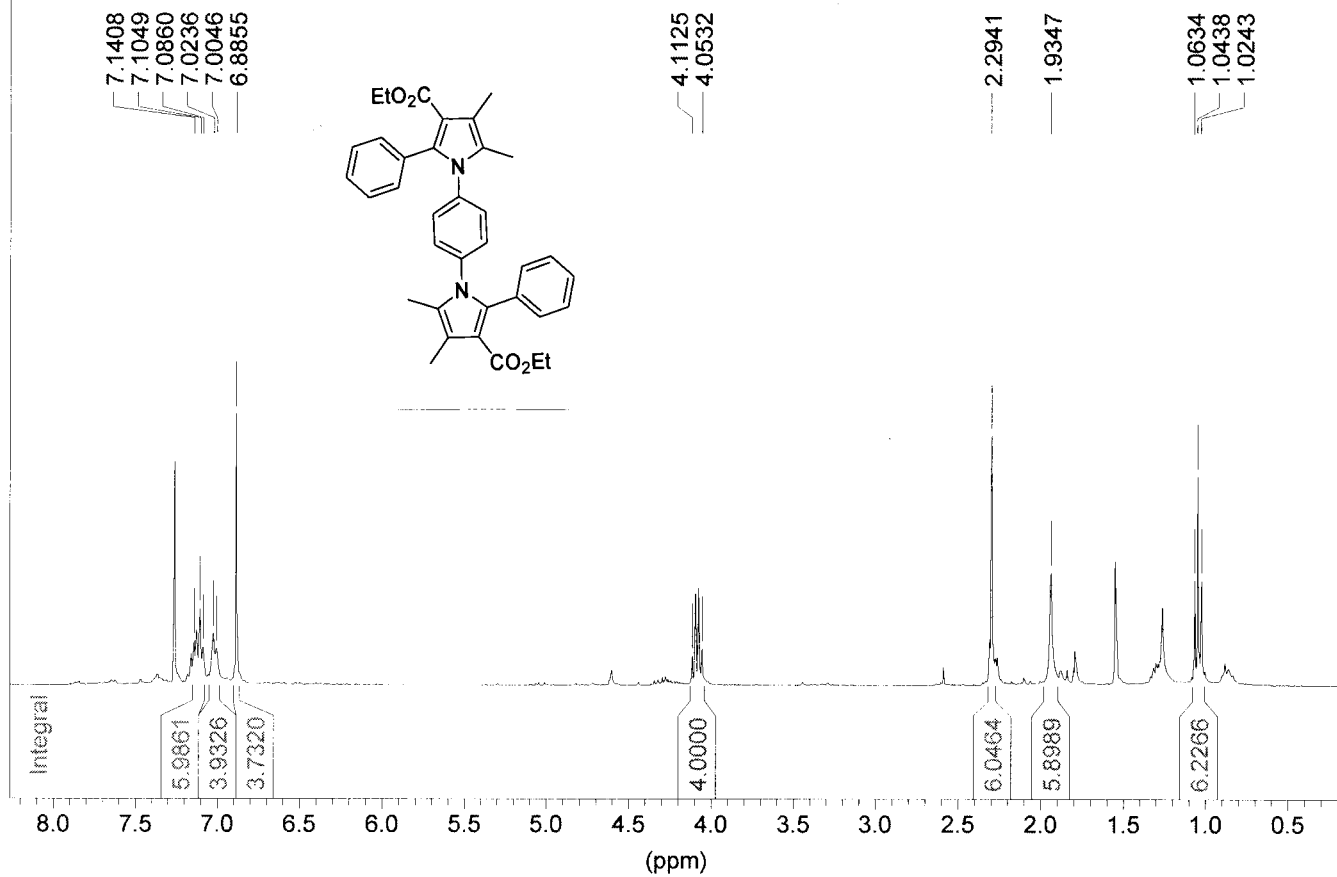




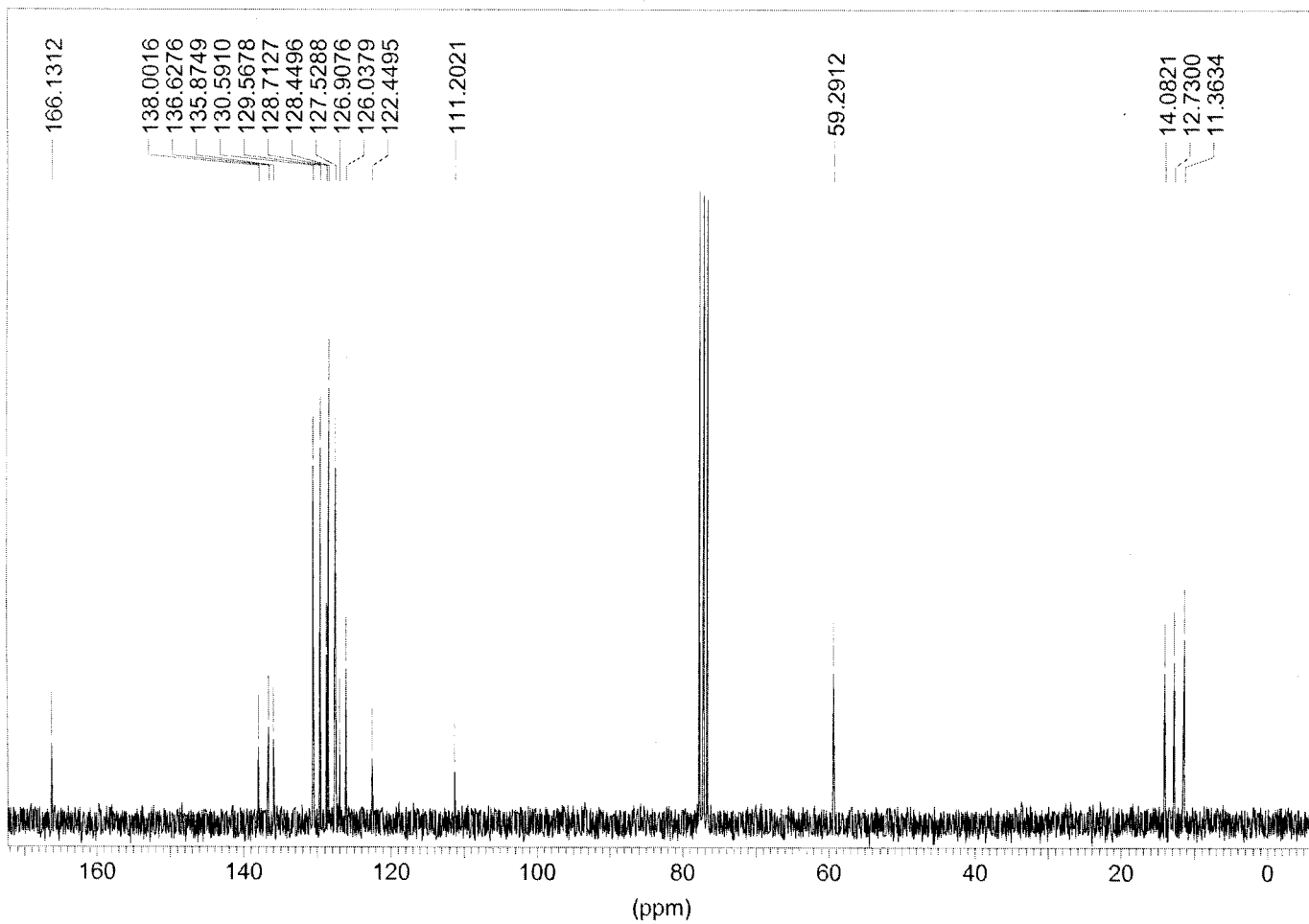
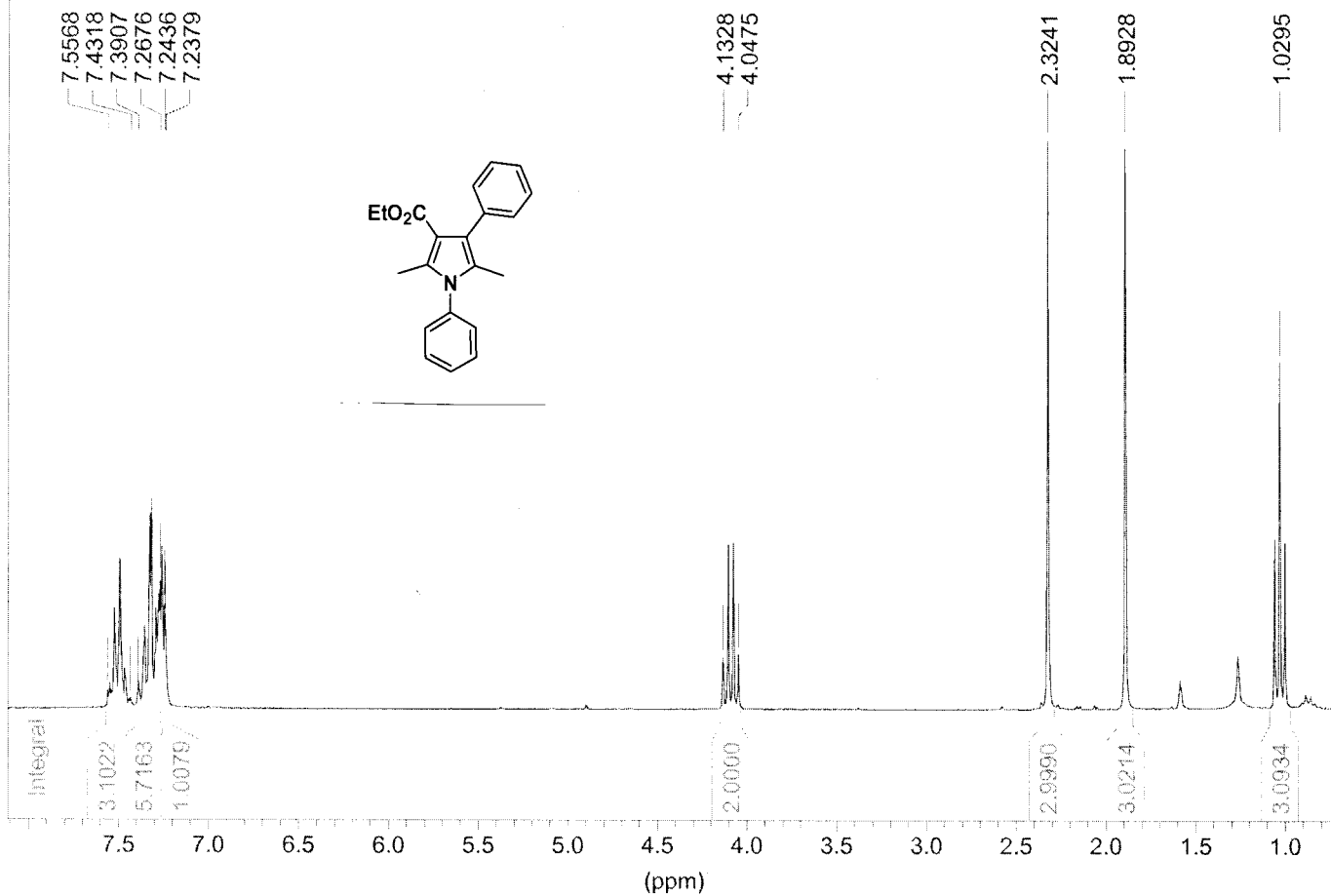




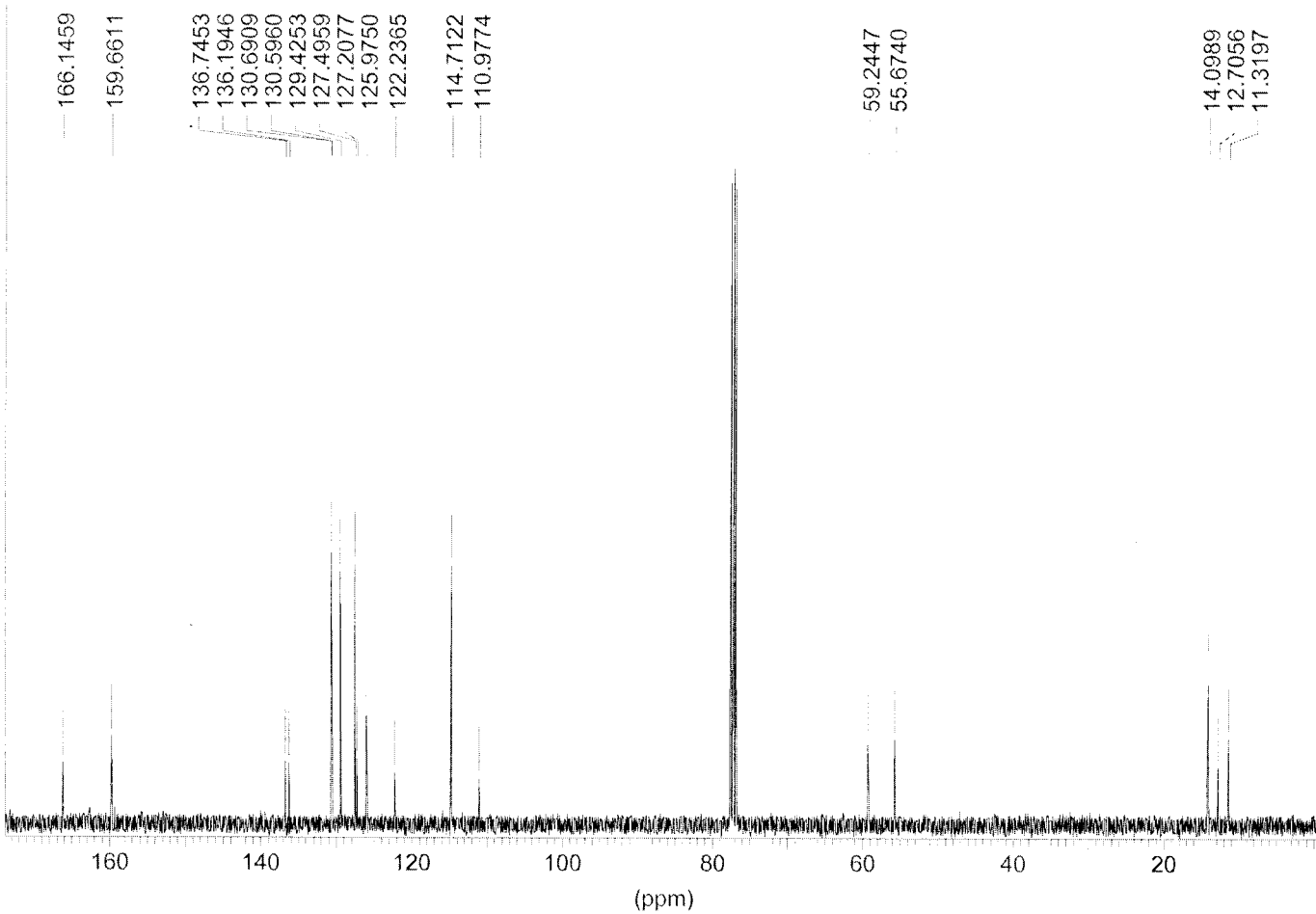
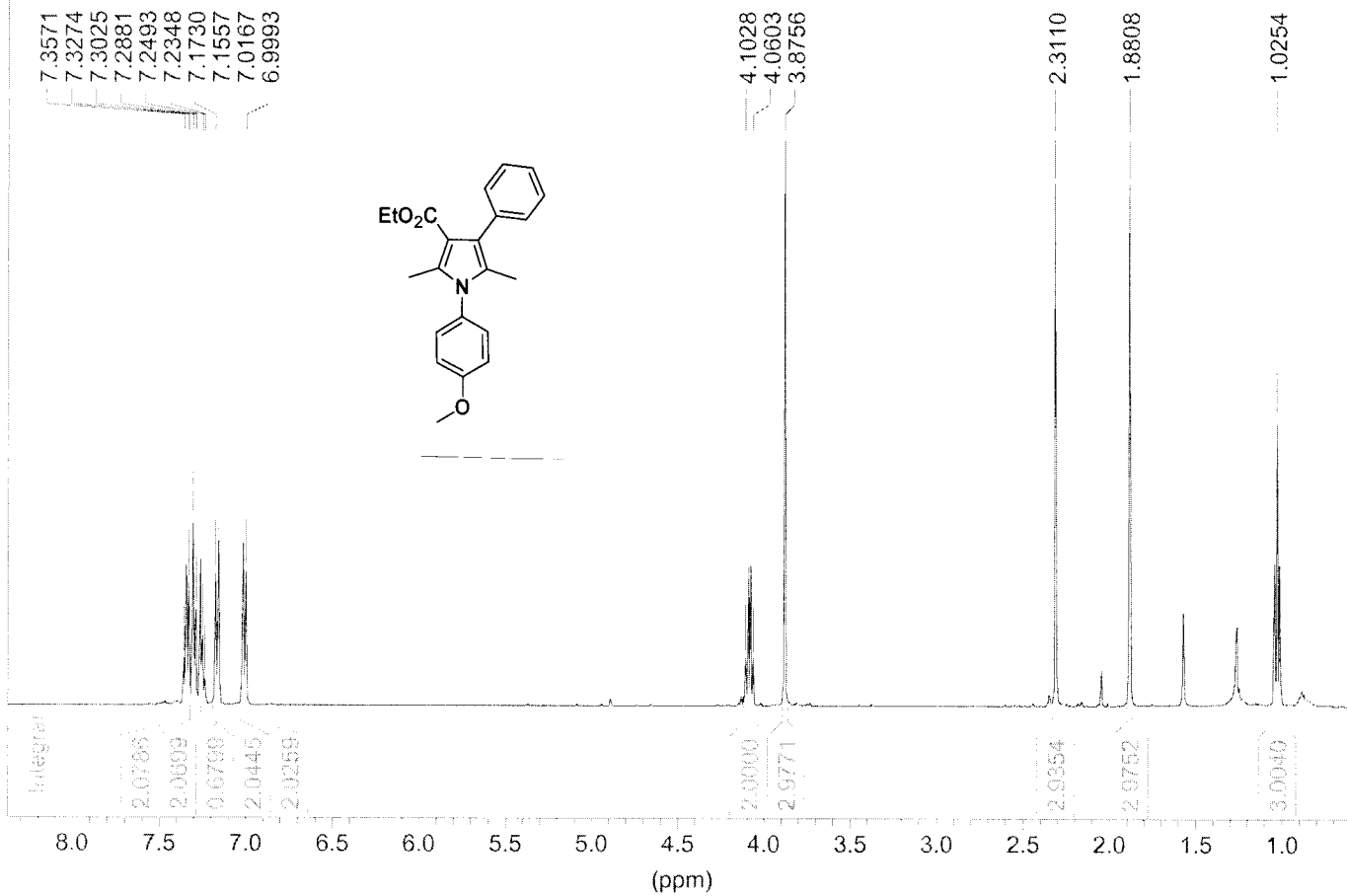




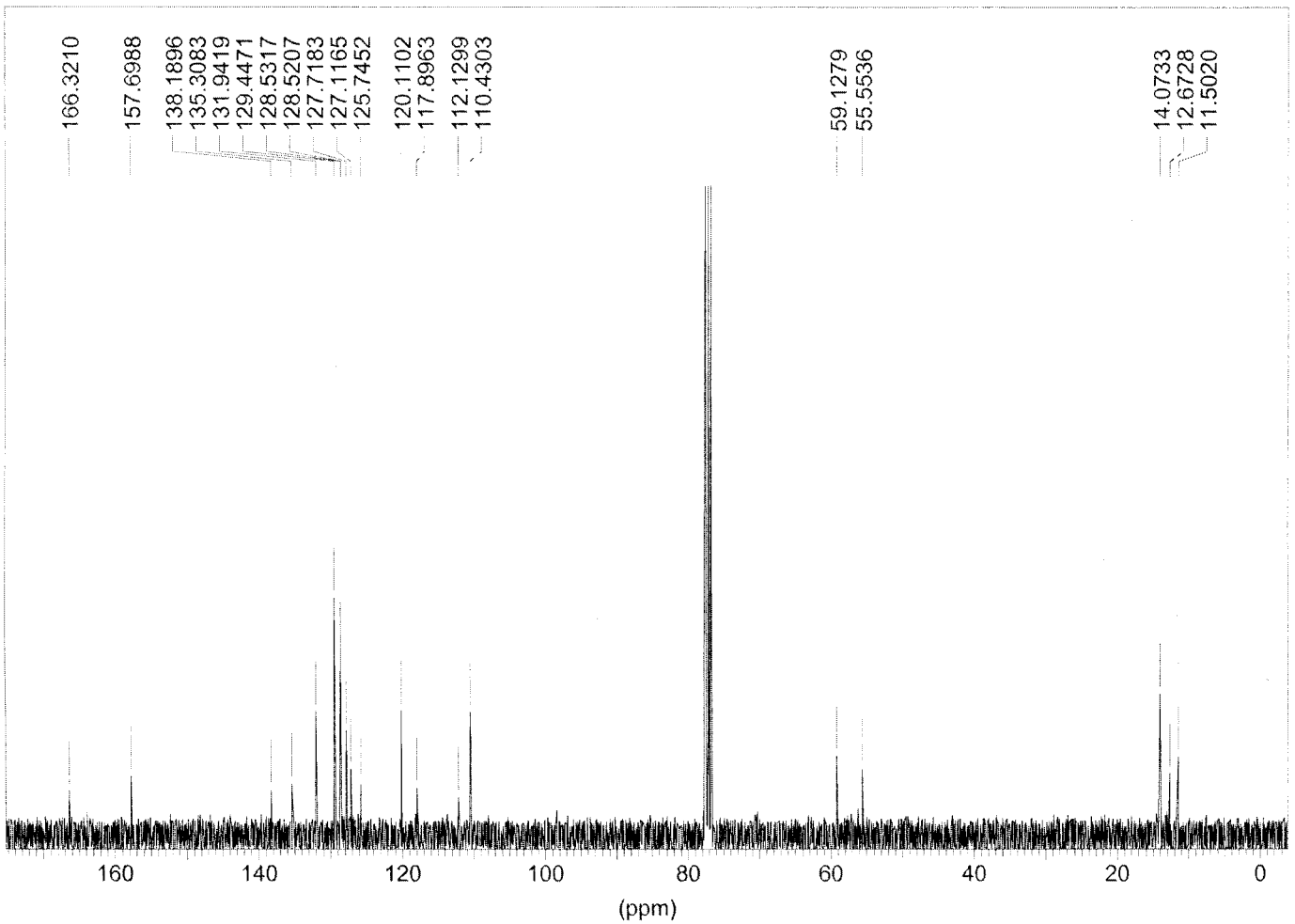
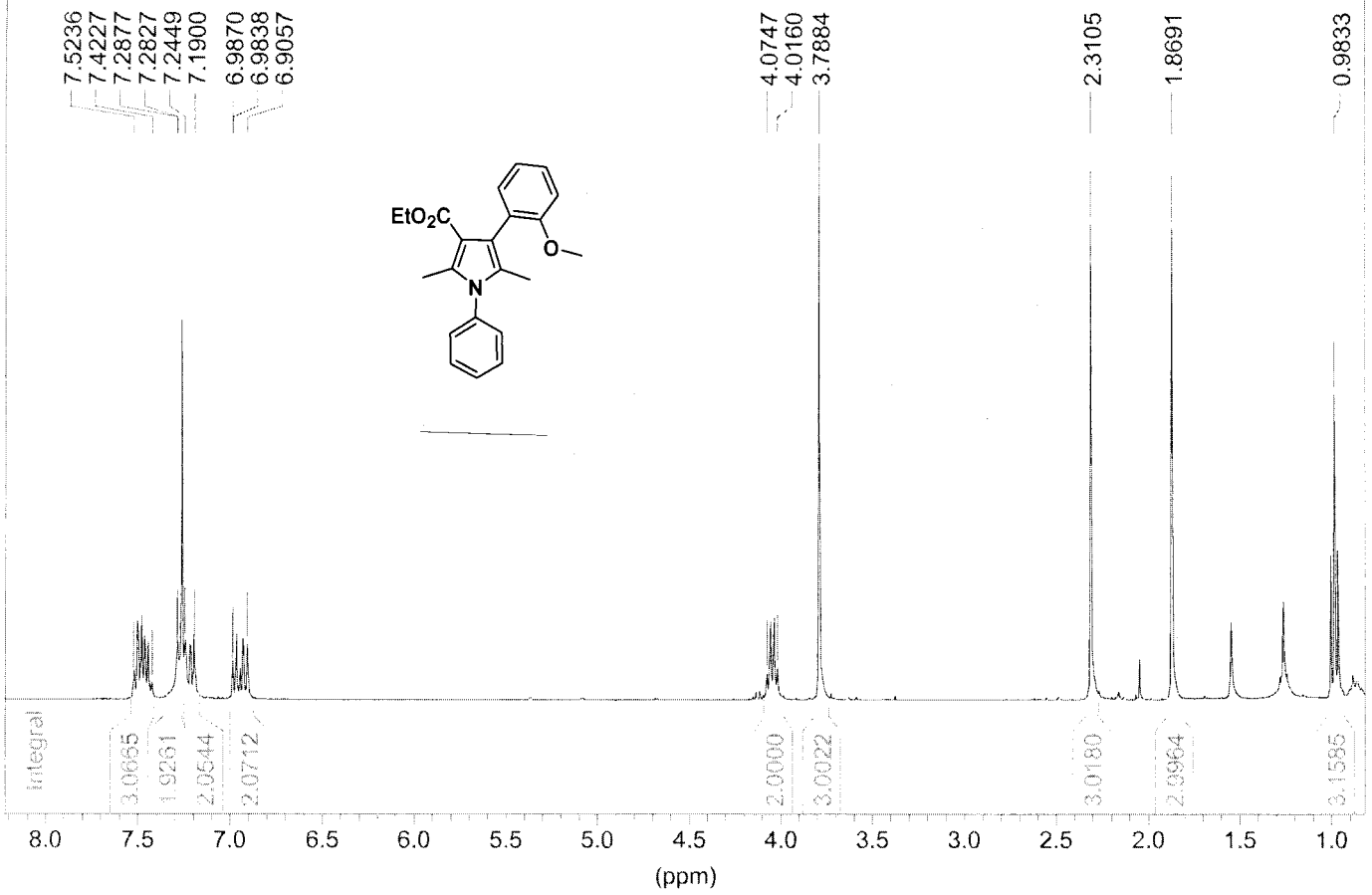
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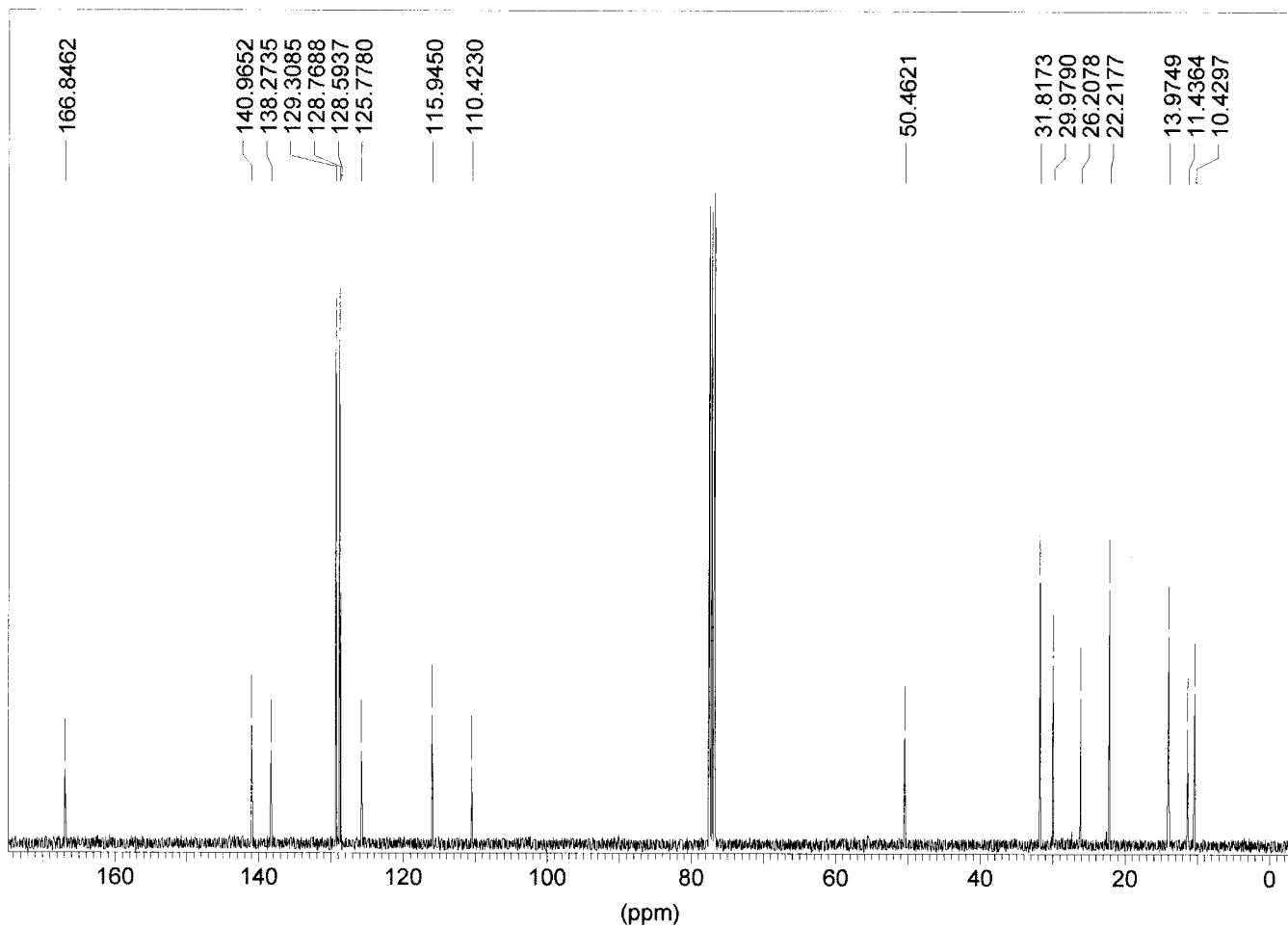
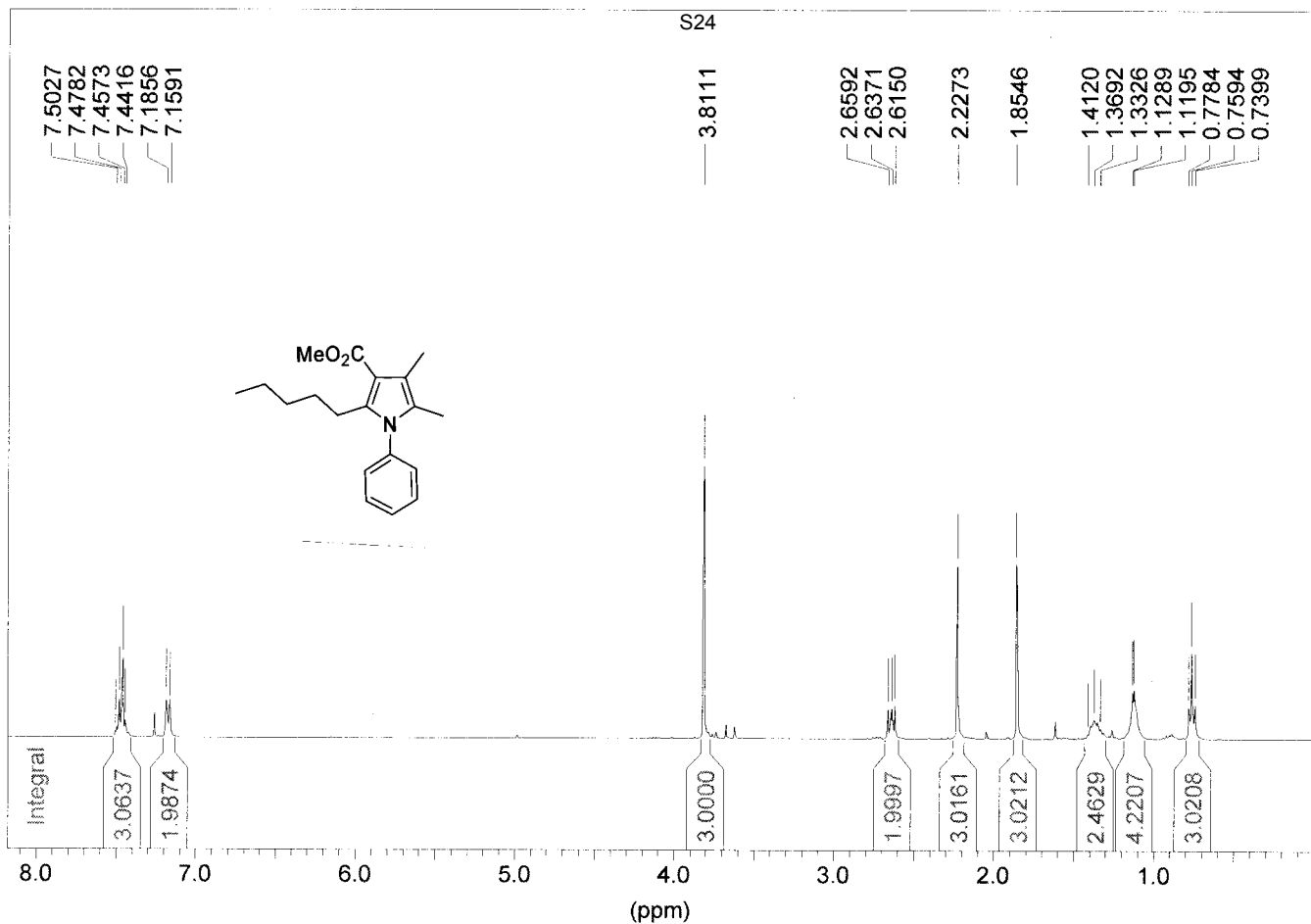


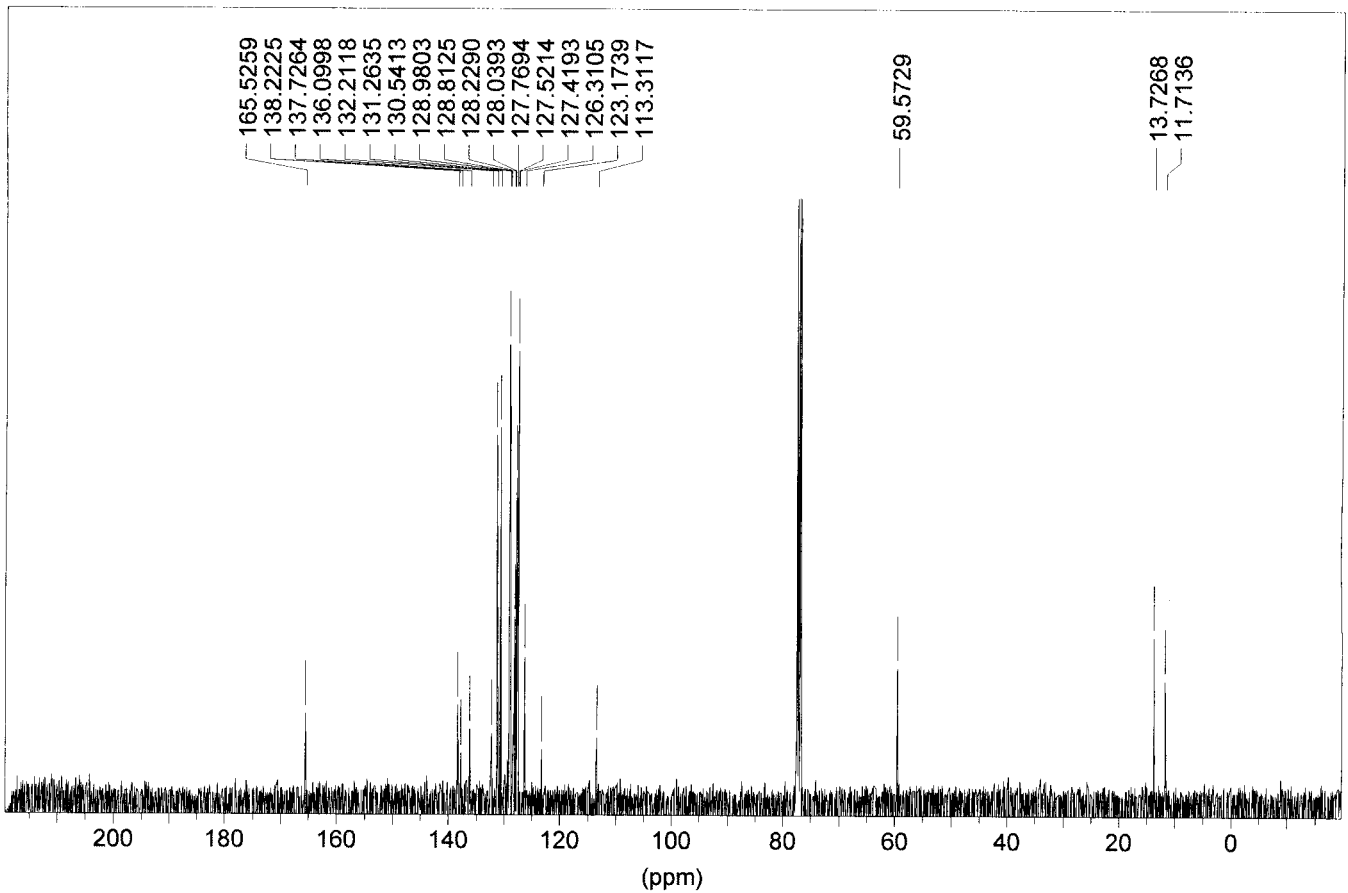
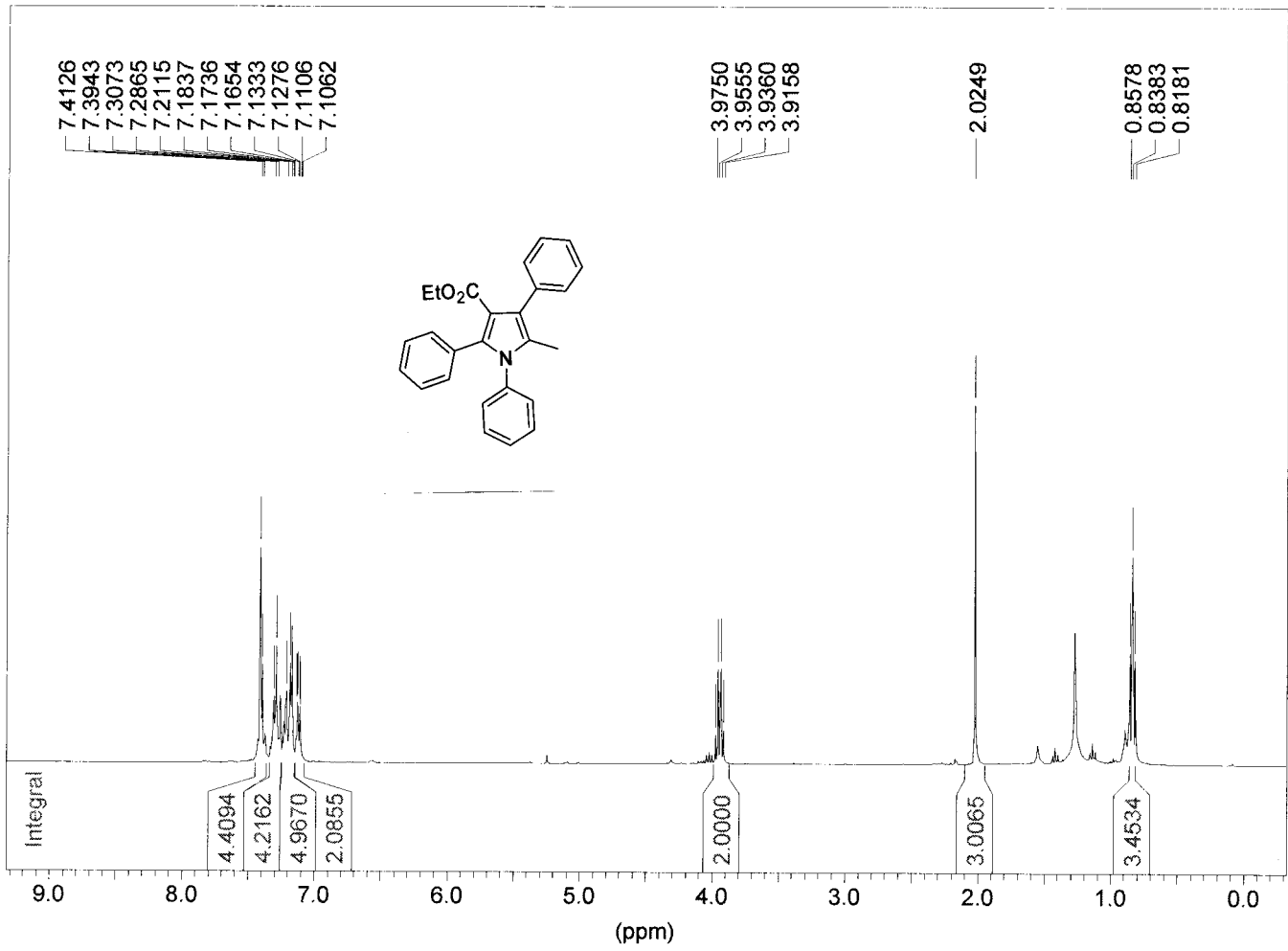
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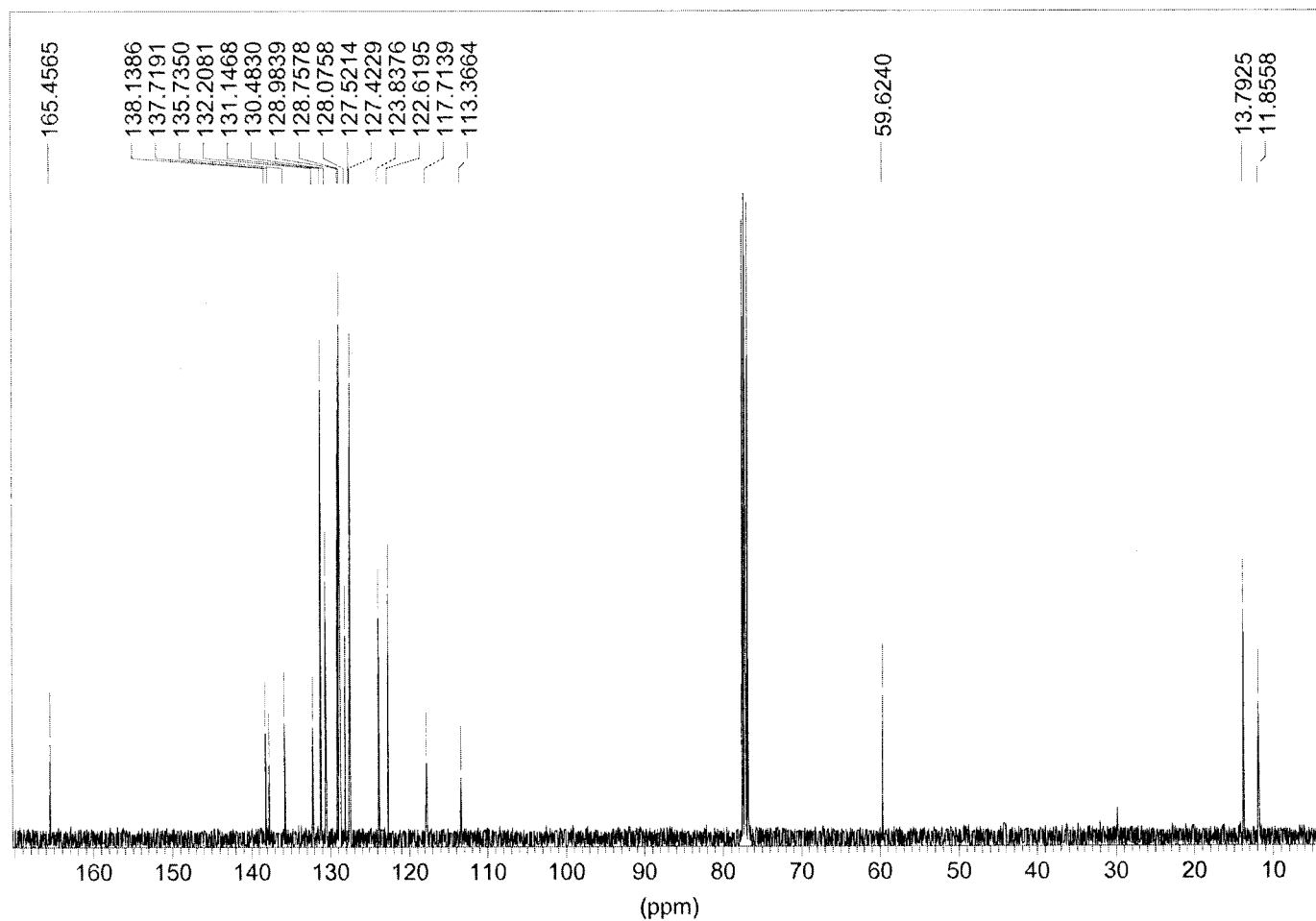
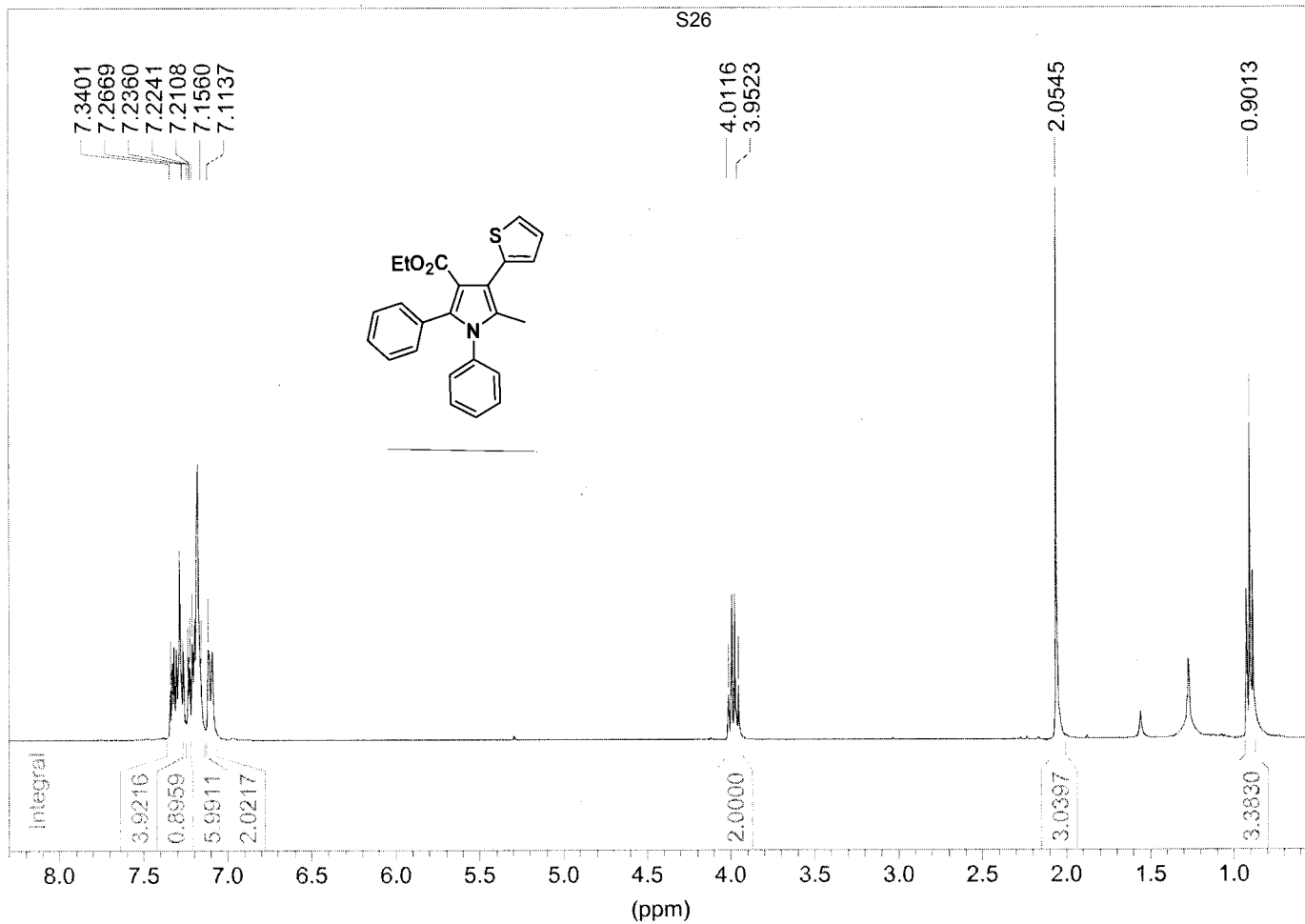
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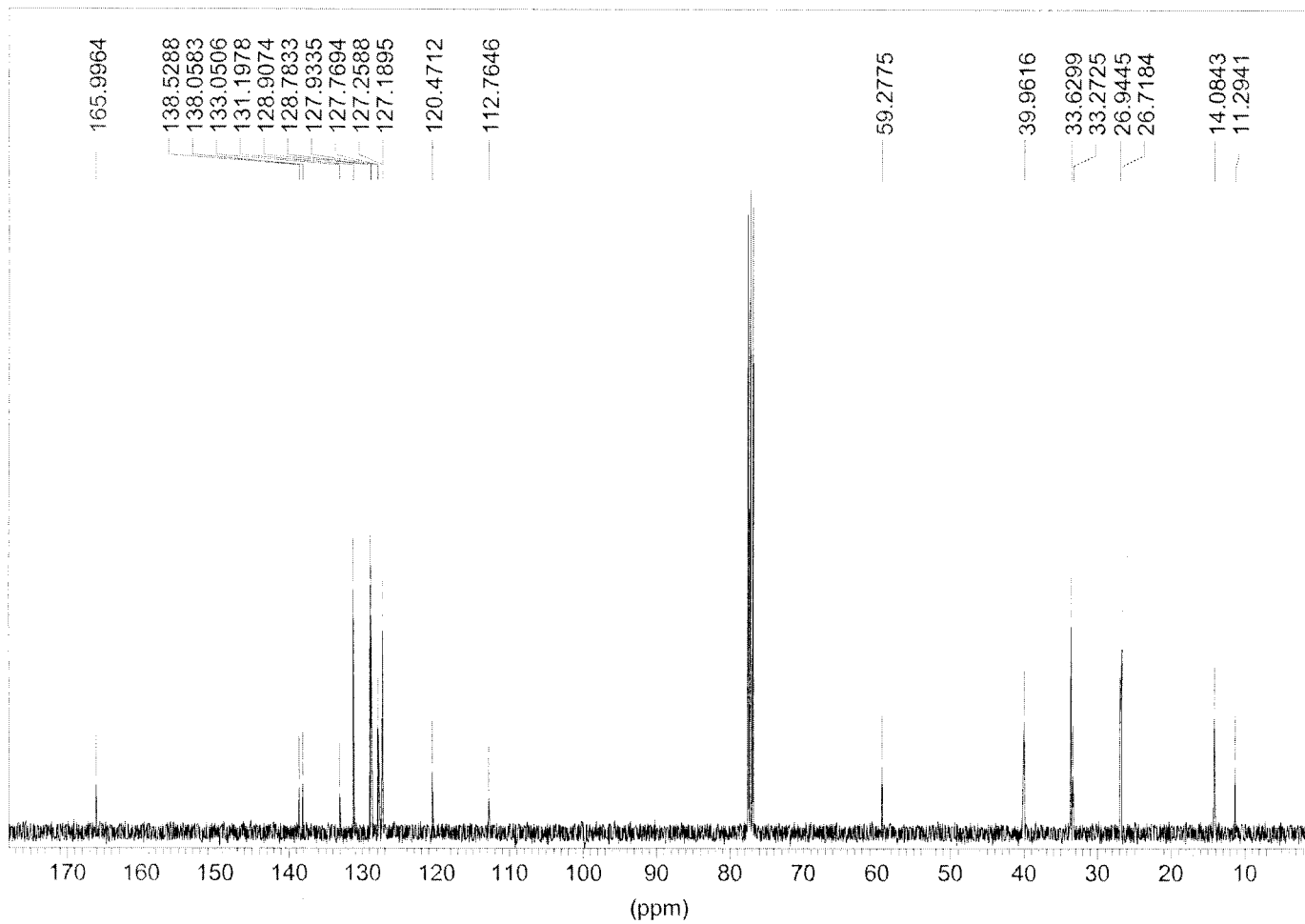
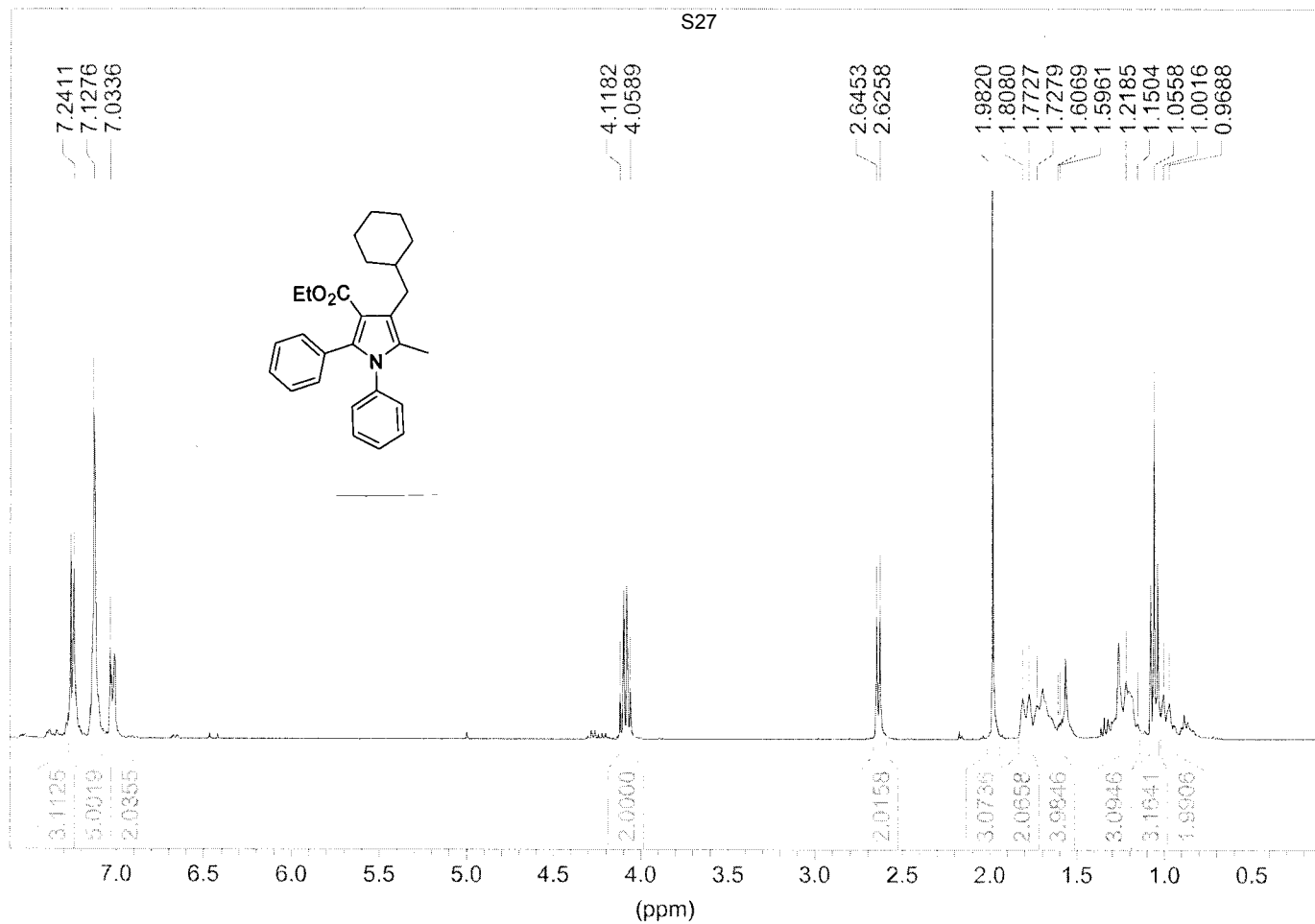




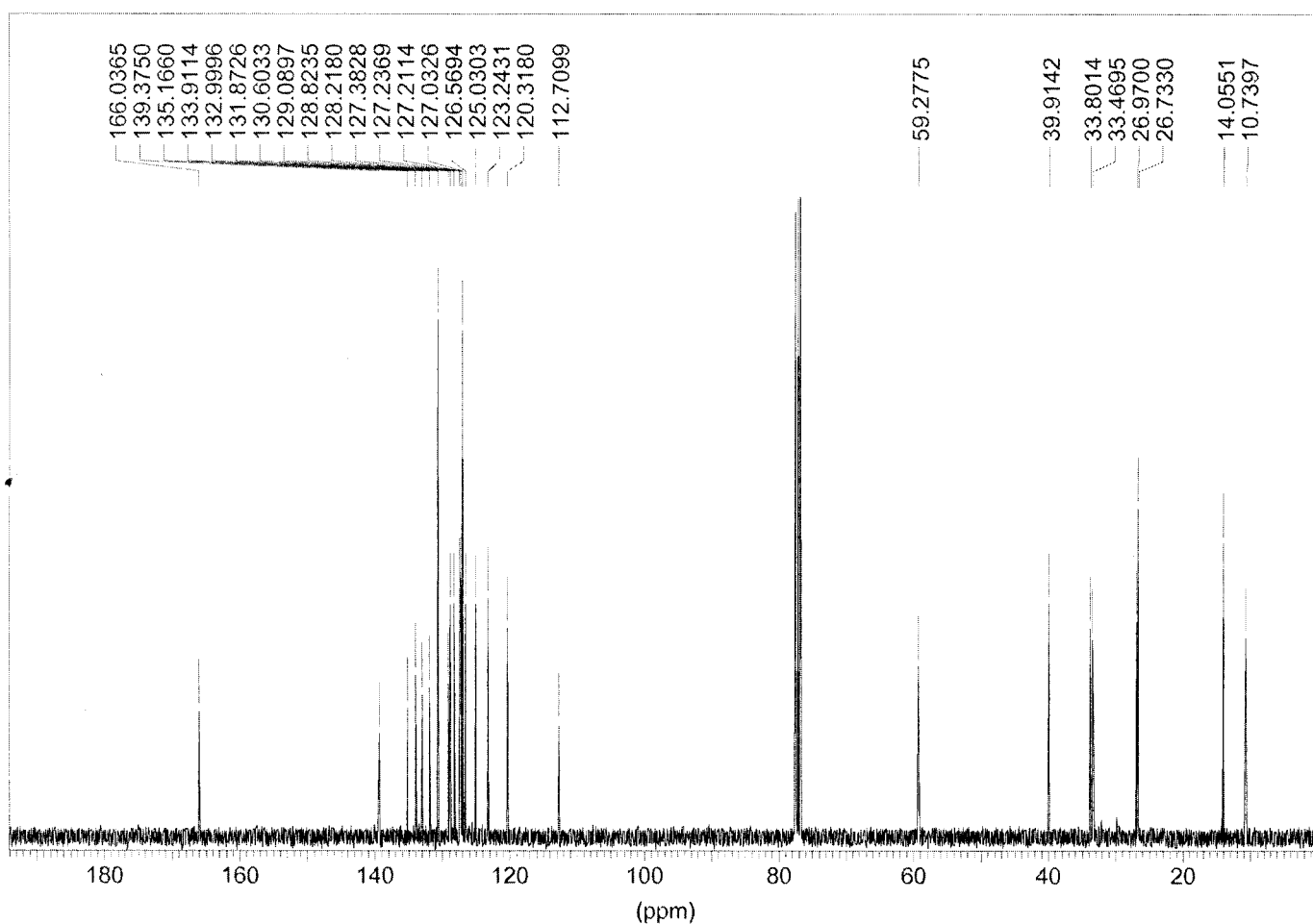
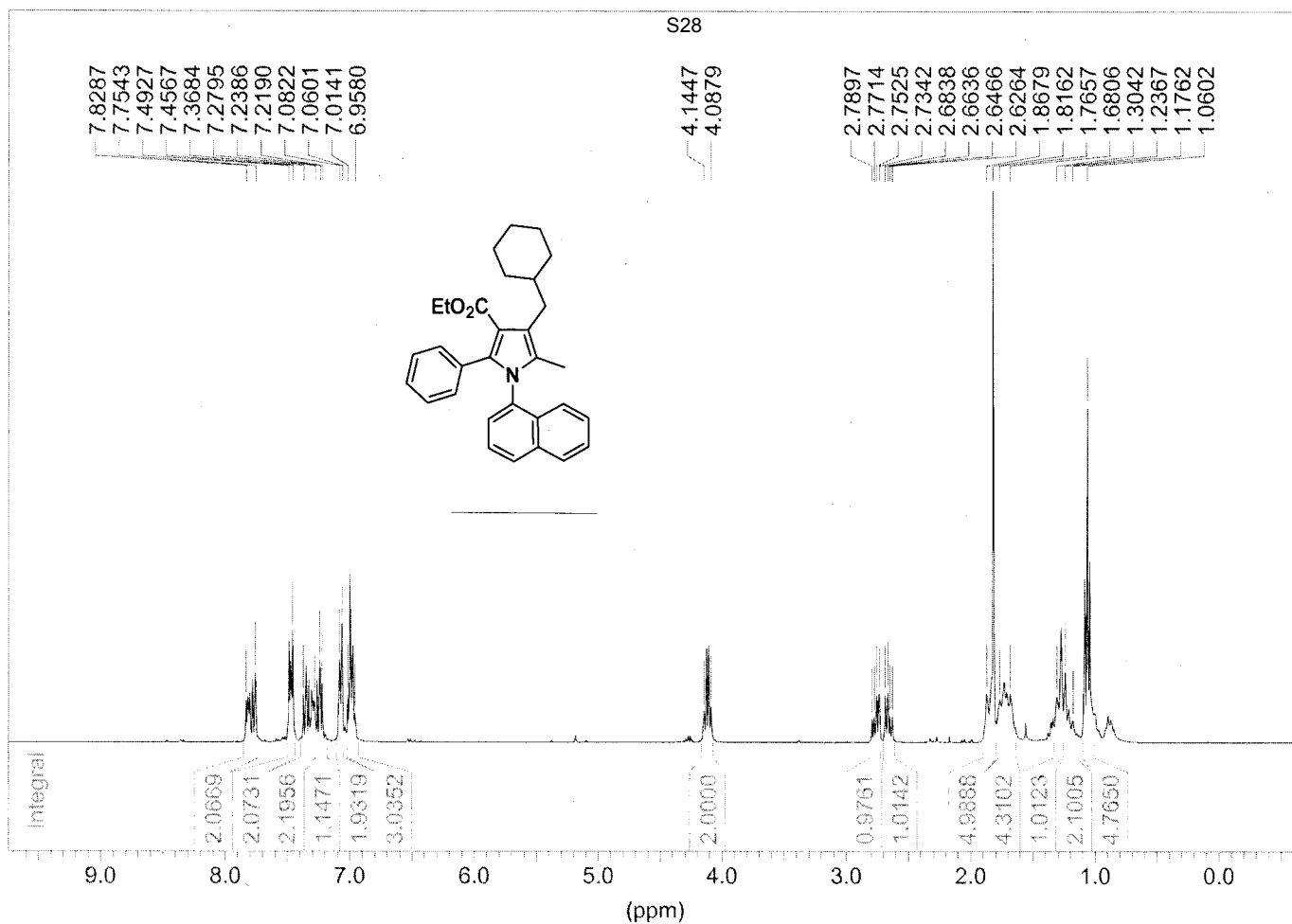


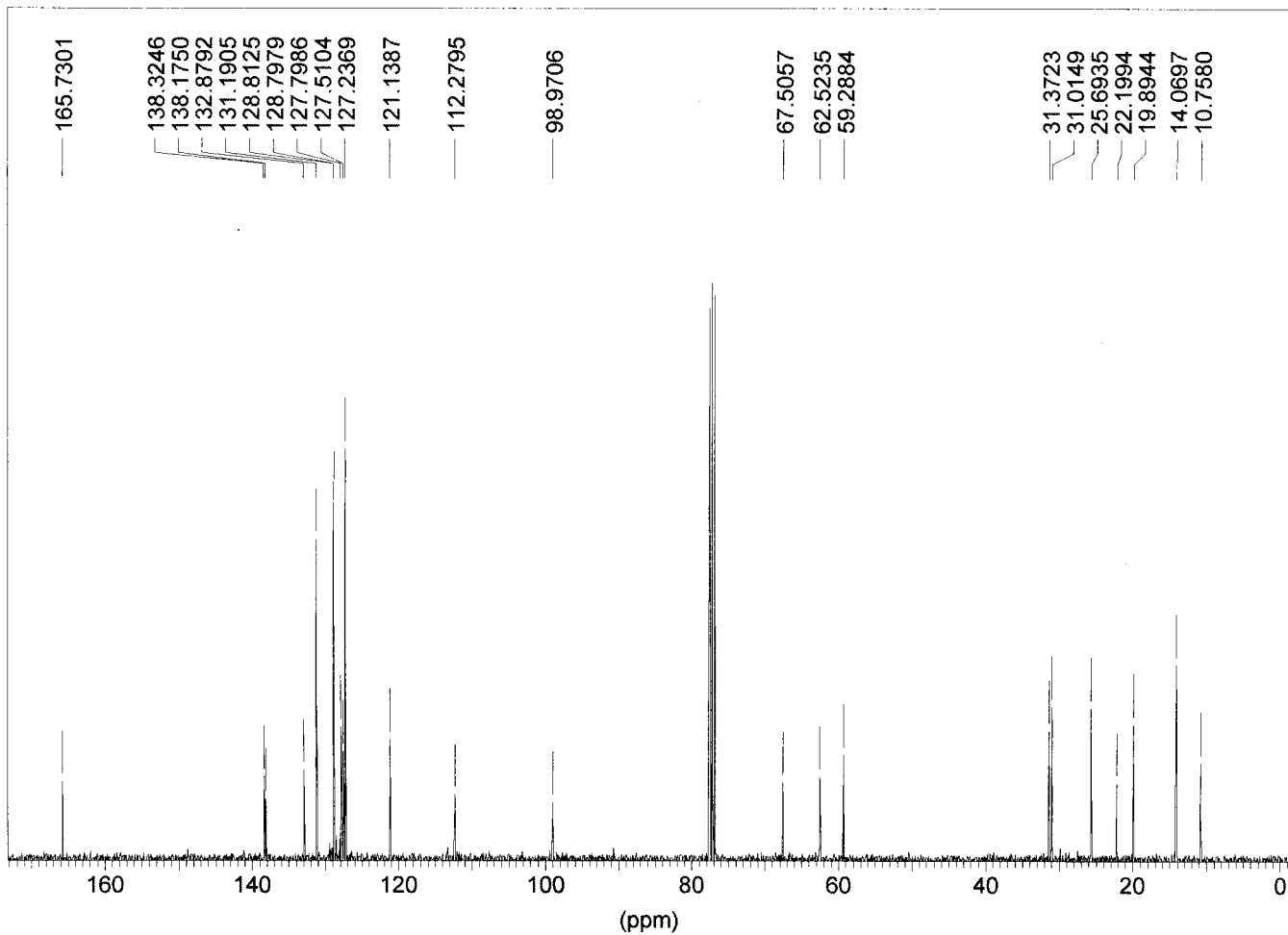
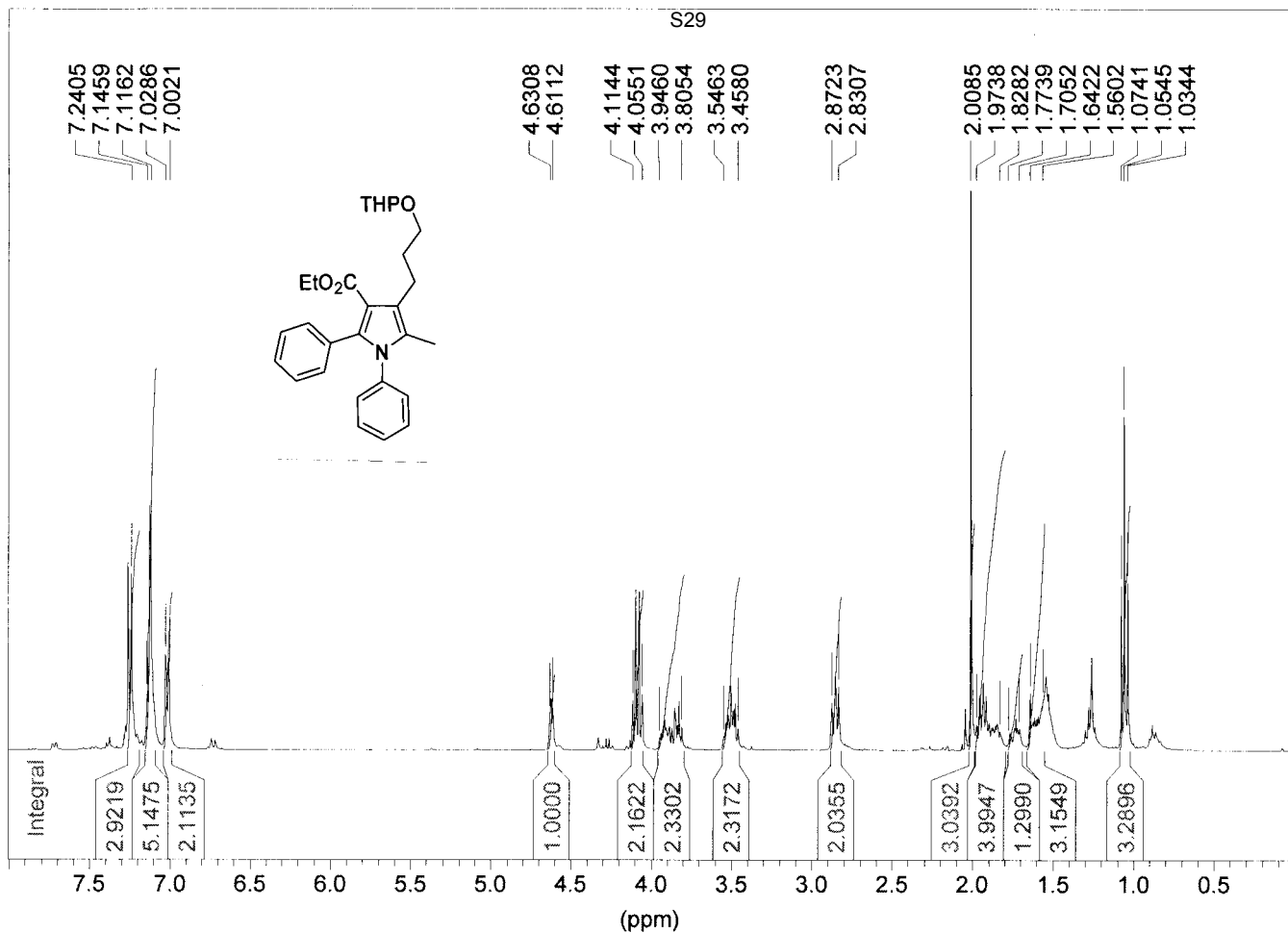
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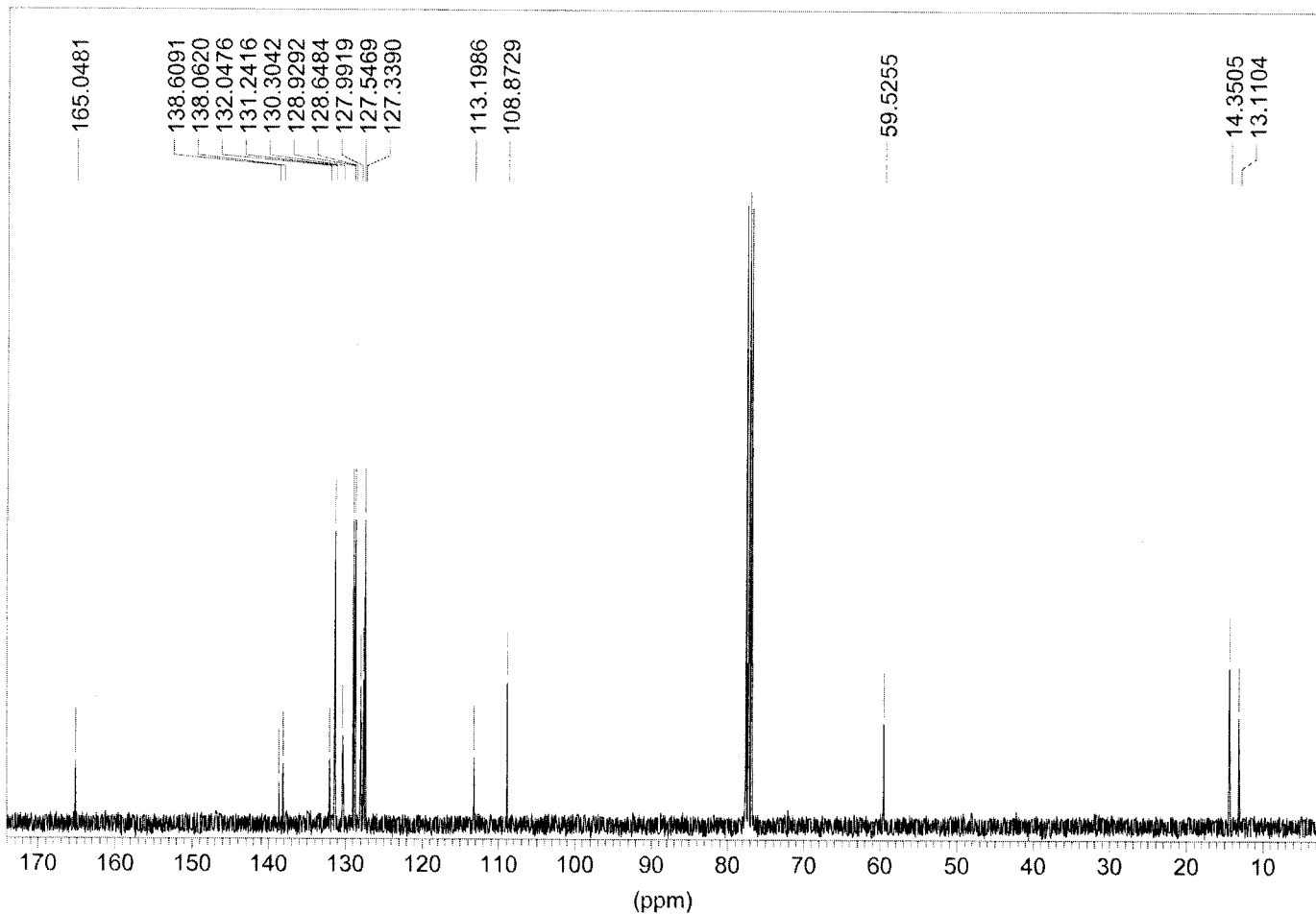
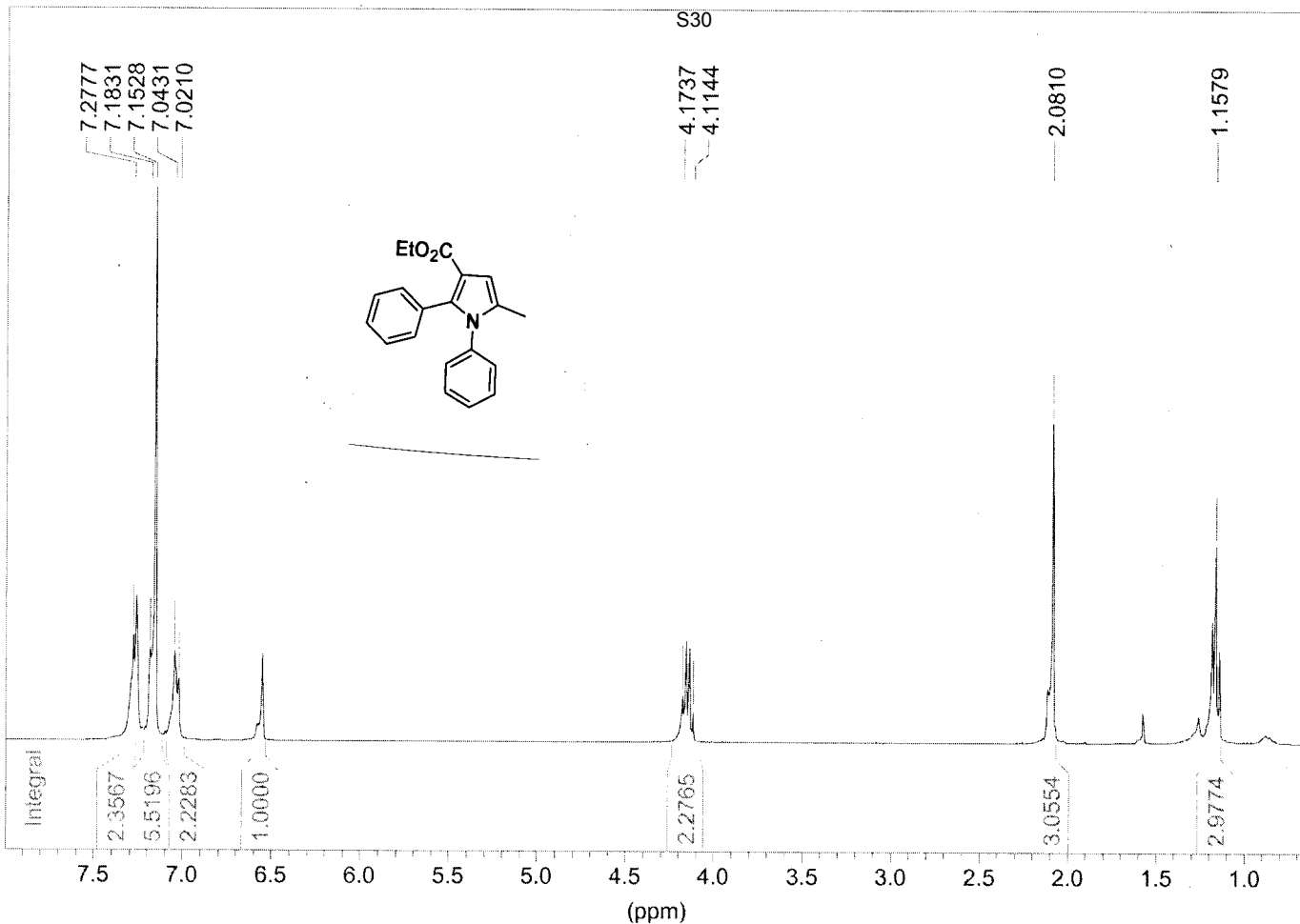


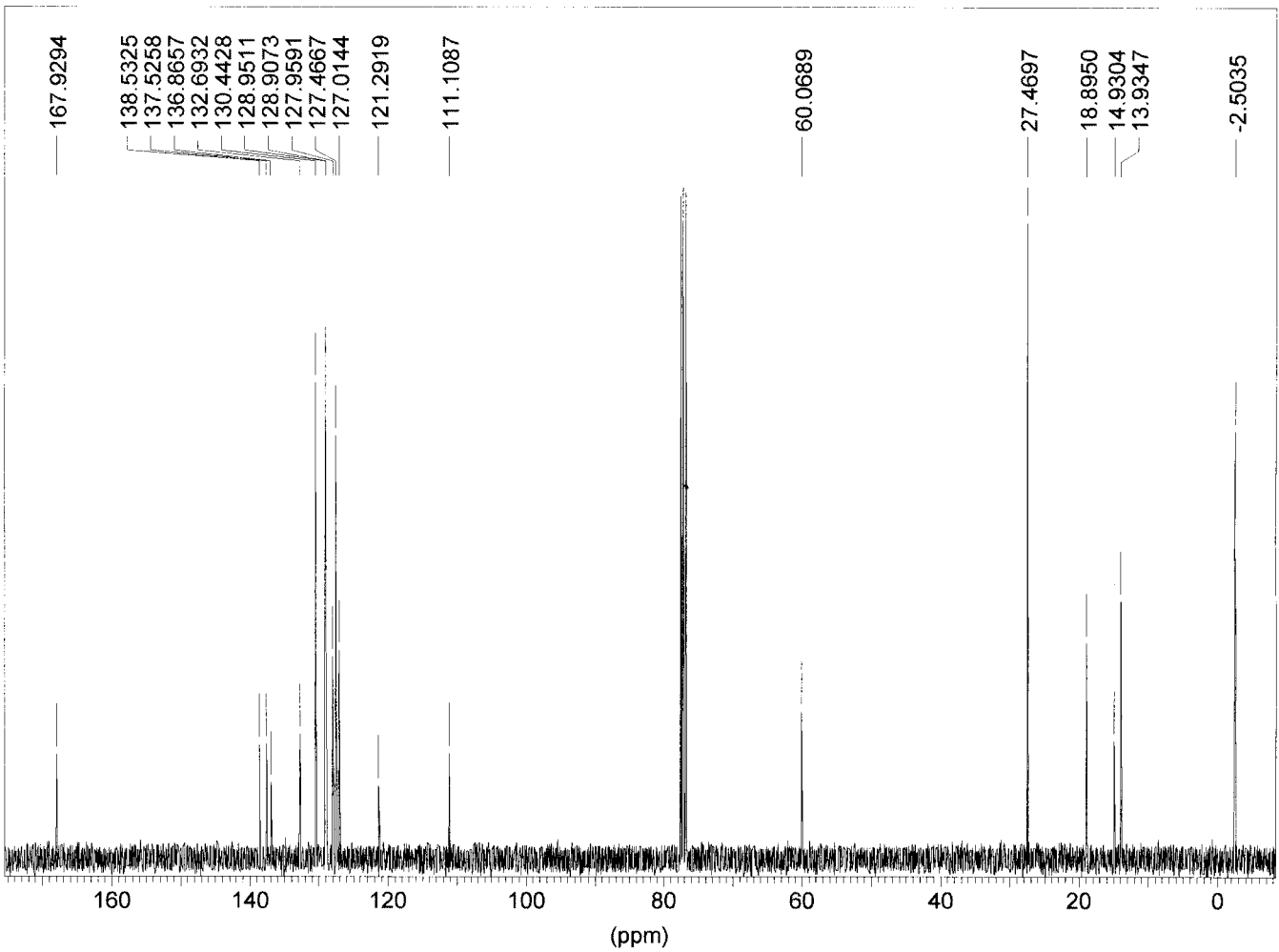
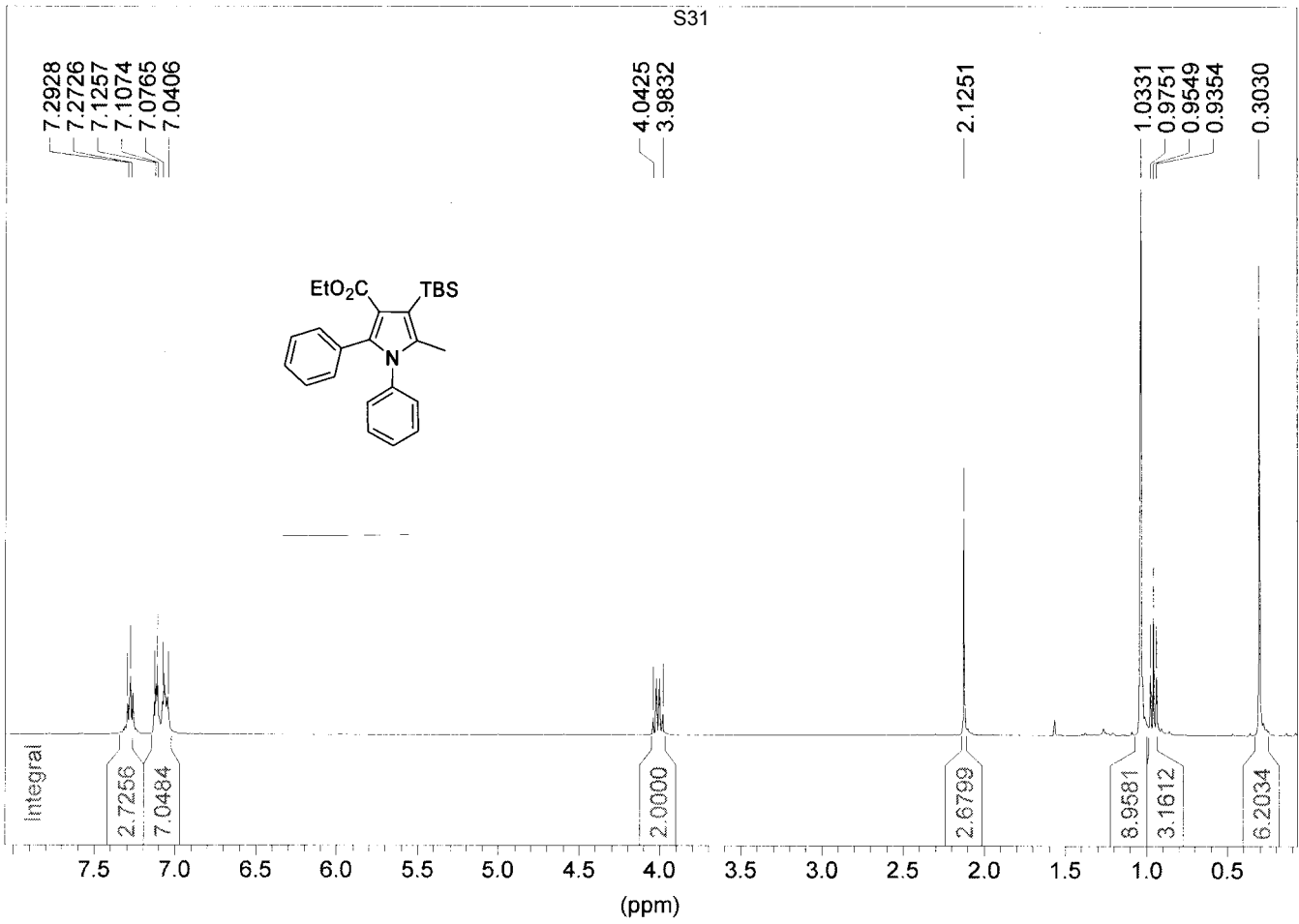
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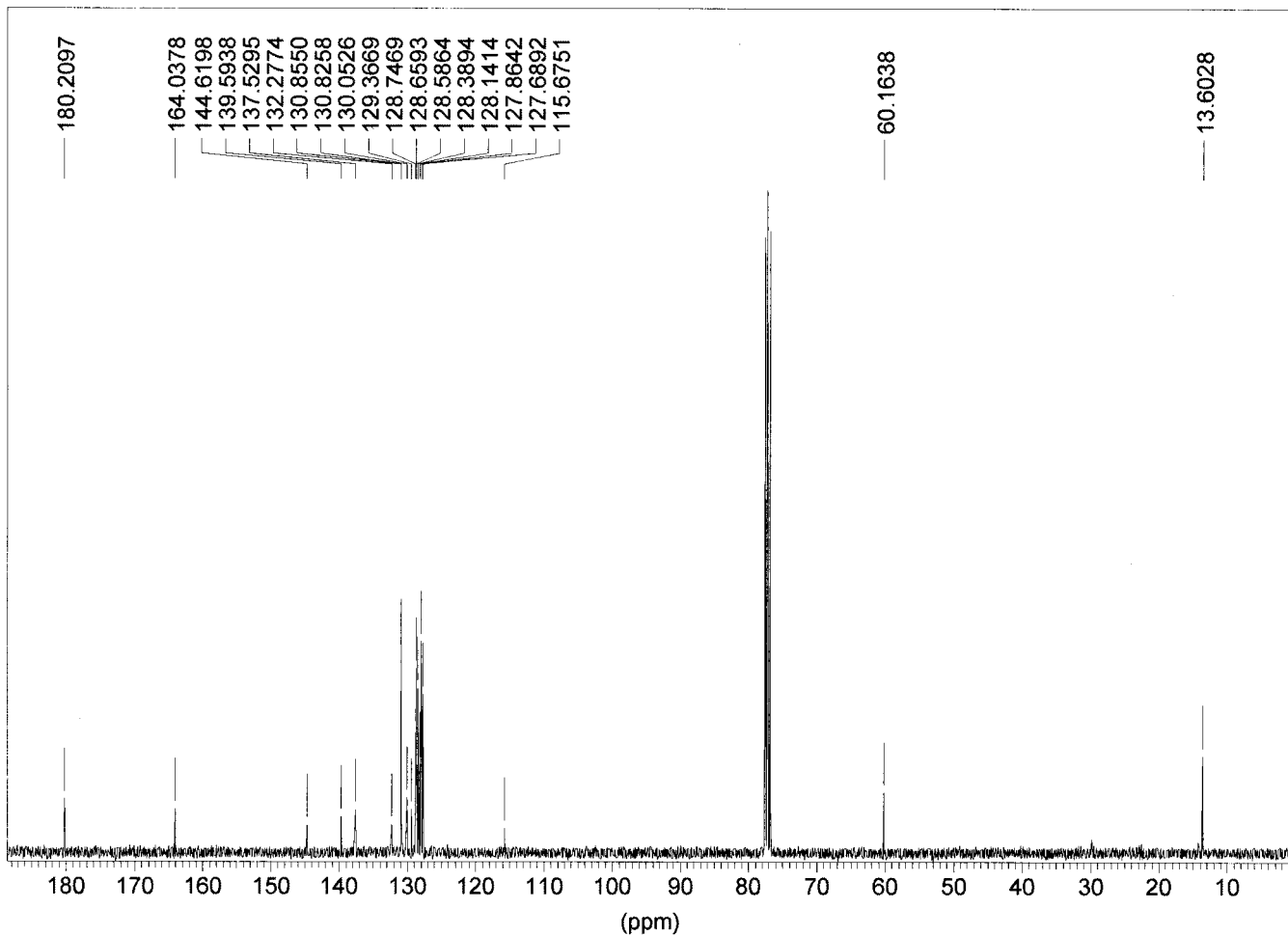
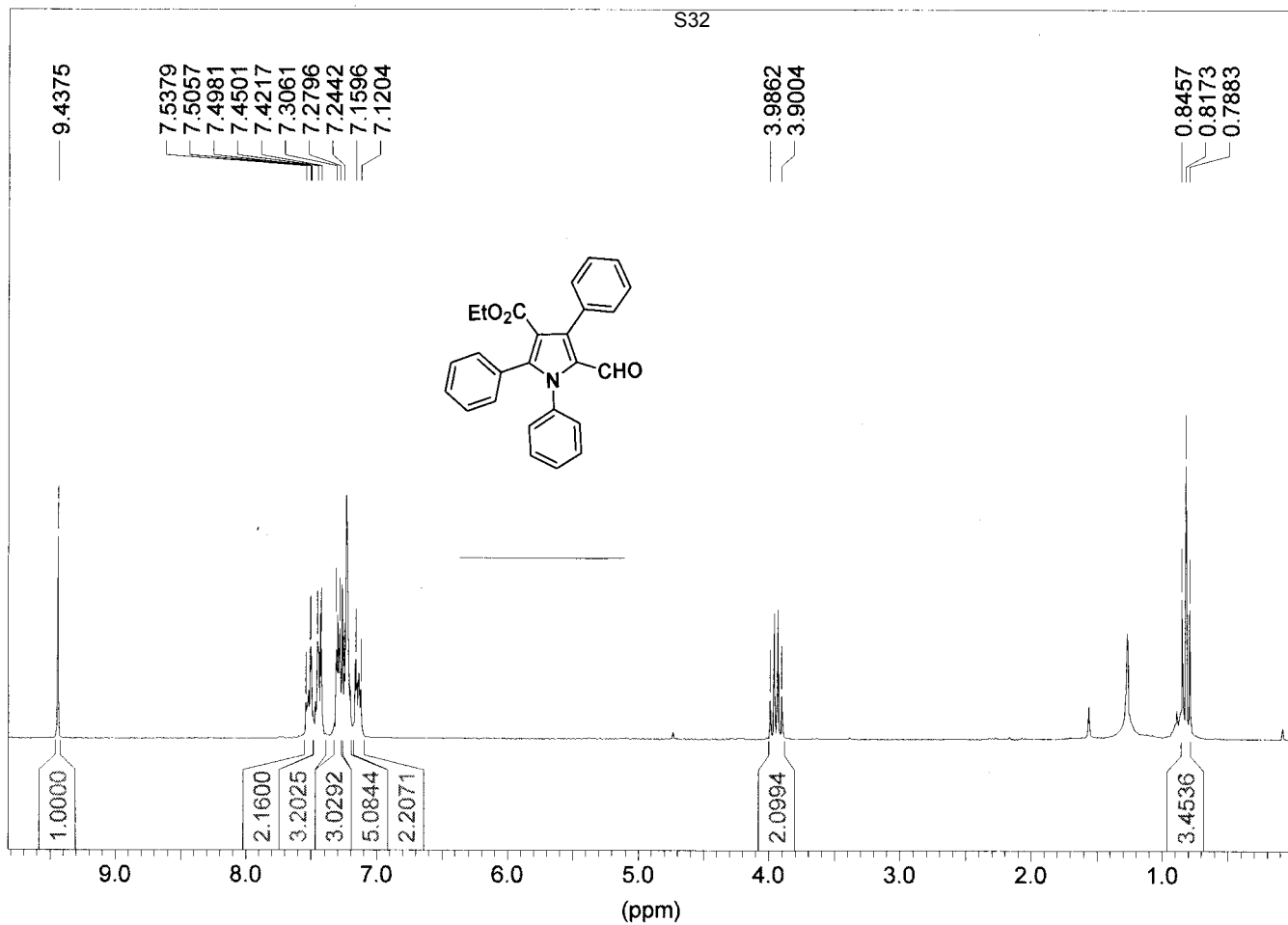




S30







S33

