Synthesis of novel symmetrical 2-oxo-spiro[indole-3,4'-pyridines] by reaction of oxindoles with 1,2-diaza-1,3-dienes

Orazio A. Attanasi, Linda Campisi, Lucia De Crescentini, Gianfranco Favi and Fabio Mantellini

Department of Biomolecular Sciences, Section of Organic Chemistry and Organic Natural Compounds, University of Urbino "Carlo Bo", Via I Maggetti 24, 61029 Urbino (PU), Italy

e-mail: fabio.mantellini@uniurb.it

SUPPORTING INFORMATION

Table of Contents

Experimental Section

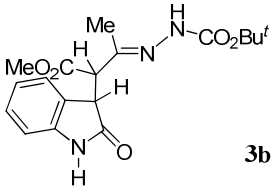
1. General Remarks.

All the commercially available reagents and solvents were used without further purification. 1,2-Diaza-1,3-dienes **2a–i** were synthesized as a mixture of *E/Z* isomers as previously reported.[1,2] Oxindole (**1a**), 1-methyloxindole (**1b**), and 1-phenyloxindole (**1c**) are commercial materials and were used without further purification. Chromatographic purification of compounds was carried out on silica gel (60–200 μm). TLC analysis was performed on pre-loaded (0.25 mm) glass supported silica gel plates (Kieselgel 60); compounds were visualized by exposure to UV light and by dipping the plates in 1% $Ce(SO_4)\cdot 4H_2O$, 2.5% $(NH_4)_6Mo_7O_{24}\cdot 4H_2O$ in 10% sulphuric acid followed by heating on a hot plate. All ^1H NMR and ^{13}C NMR spectra were recorded at 400 and 100.56 MHz, respectively. Proton and carbon spectra were referenced internally to solvent signals, using values of δ = 2.50 ppm for proton (middle peak) and δ = 39.50 ppm for carbon (middle peak) in DMSO-d_6 and δ = 7.27 ppm for proton and δ = 77.00 ppm for carbon (middle peak) in $CDCl_3$. The following abbreviations are used to describe peak patterns where appropriate: s = singlet, d = doublet, t = triplet q = quartet, sex = sextet, m = multiplet and br = broad signal. All coupling constants (*J*) are given in Hz. FT-IR spectra were obtained as Nujol mulls. Mass spectra were recorded in the EI mode (70eV). Melting points were determined in open capillary tubes and are uncorrected.

2. Experimental procedures and spectral data.

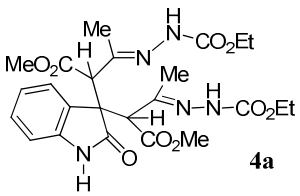
General procedure for the synthesis of bis-hydrazones 4a–m, starting from oxindoles 1a–c and 1,2-diaza-1,3-dienes 2a–i.

A mixture of oxindole **1** (1 mmol), 1,2-diaza-1,3-diene **2** (4 mmol), and DIPEA (2.2 mmol) was stirred at room temperature in CH_2Cl_2 (6 mL) for the appropriate time (14–18 hours), until the disappearance of the reagent **1** (TLC monitoring). The crude mixture was then purified by column chromatography on silica gel to afford the products **4a–m**, that were crystallized from diethyl ether. Also a little amount (4%) of mono-adduct **3** was obtained. ^1H-NMR of **3b**, chosen as an example was described.



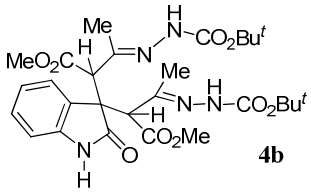
3b

***tert*-Butyl 2-[(3-methoxy-1-methyl-3-oxo-2-(2-oxo-2,3-dihydro-1H-indol-3-yl)propylidene)]hydrazinecarboxylate (3b)** ^1H NMR (400 MHz, $CDCl_3$, 25 °C): δ = 1.48 and 1.50 (2s, 9H), 1.96 (s, 3H), 3.47 (s, 3H), 4.14 (d, *J* = 4.0 Hz, 1H), 4.27 (d, *J* = 4.0 Hz, 1H), 6.83 (d, *J* = 7.6 Hz, 1H), 6.96 (t, *J* = 7.6 Hz, 1H), 7.15–7.26 (m, 2H), 7.67 (s, 1H), 8.12 (s, 1H).



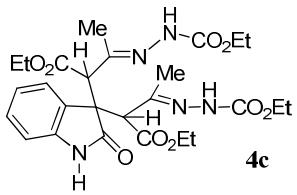
4a

Diethyl 2,2'-[(2-oxo-2,3-dihydro-1*H*-indole-3,3-diyl)bis(4-methoxy-4-oxobutyl-2-ylidene)]dihydrazinecarboxylate (4a): 4a was isolated by column chromatography (acetate/cyclohexane 20:80) in 72% yield. White solid; mp: 114–116 C; ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ = 1.25–1.31 (m, 6H), 1.62 (s, 3H), 1.80 (s, 3H), 3.51 (s, 3H), 3.53 (s, 3H), 4.20–4.26 (m, 5H), 4.93 (br, 1H), 6.78 (d, *J* = 4.0 Hz, 1H), 6.95–6.99 (m, 1H), 7.15 (t, *J* = 7.6 Hz, 1H), 7.69 (s, 1H), 7.69–7.73 (m, 1H), 8.18 (br, 2H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 14.4 (q), 14.5 (q), 16.4 (q), 52.1 (q), 52.4 (q), 55.2 (s), 57.0 (d), 61.7 (t), 61.9 (t), 109.4 (d), 122.3 (d), 128.5 (d), 128.6 (s), 142.0 (s), 146.8 (s), 153.7 (s), 169.5 (s), 170.2 (s), 178.7 (s); IR (nujol): ν_{max} = 3502, 3452, 3306, 3261, 1731, 1712, 1681 cm^{-1}; MS *m/z* (%): 533 (M^+) (1), 430 (39), 398 (20), 342 (34), 332 (60), 300 (38), 228 (64); anal. calcd. for $C_{24}H_{31}N_5O_9$ (533.53): C 54.03, H 5.86, N 13.13; found: C 54.11, H 5.90, N 13.11.



4b

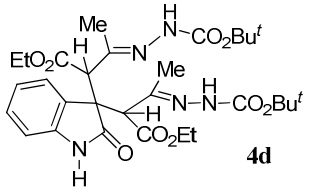
Di-*tert*-butyl 2,2'-[(2-oxo-2,3-dihydro-1*H*-indole-3,3-diyl)bis(4-methoxy-4-oxo-3-butyl-2-ylidene)]dihydrazinecarboxylate (4b): 4b was isolated by column chromatography (acetate/cyclohexane 20:80) in 75% yield. Pale yellow solid; mp: 129–131 C; ^{1}H NMR (400 MHz, DMSO-d_6, 25 °C): δ = 1.30–1.36 (m, 24H), 3.50 (s, 6H), 4.10 (s, 1H), 4.26 and 4.57 (2 br, 1H), 6.71 (d, *J* = 7.6 Hz, 1H), 6.84–6.95 (m, 1H), 7.11–7.19 (m, 1H), 7.77–7.89 (m, 1H), 9.37 and 9.45 (2 br, 1H), 9.56 (s, 1H), 10.44 and 10.52 (2 br, 1H); ^{13}C NMR (100 MHz, DMSO-d_6, 25 °C): δ = 15.0 (q), 15.2 (q), 28.0 (q), 51.9 (q), 54.3 (s), 57.6 (d), 79.2 (s), 109.0 (d), 120.8 (d), 126.3 (d), 128.6 (d), 128.9 (s), 142.9 (s), 146.3 (s), 152.6 (s), 169.4 (s), 176.7 (s), 177.1 (s); IR (nujol): ν_{max} = 3514, 3460, 3294, 1751, 1726, 1685 cm^{-1}; MS *m/z* (%): 589 (M^+) (9), 544 (6), 499 (6), 319 (45), 283 (41), 255 (29), 200 (32), 185 (38), 161 (64), 133 (100); anal. calcd. for $C_{28}H_{39}N_5O_9$ (589.63): C 57.03, H 6.67, N 11.88; found: C 57.01, H 6.71, N 11.85.



4c

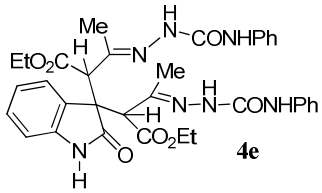
Diethyl 2,2'-[(2-oxo-2,3-dihydro-1*H*-indole-3,3-diyl)bis(4-ethoxy-4-oxobutyl-2-ylidene)]dihydrazinecarboxylate (4c): 4c was isolated by column chromatography (acetate/cyclohexane 20:80) in 65% yield. Yellow solid; mp: 170–171 C; ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ = 0.98–1.03 (m, 6H), 1.25–1.33 (m, 6H), 1.76 (s, 3H), 1.86 (s, 3H), 3.89–3.98 (m, 4H), 4.18–4.30 (m, 5H), 5.02 (br, 1H), 7.27 (d, *J* = 7.6 Hz, 1H), 6.98–7.02 (m, 1H), 7.15 (t, *J* = 7.6 Hz, 1H), 7.73 (s, 1H), 7.82–7.84 (m, 1H), 8.04 (br, 1H), 8.36 (br, 1H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 13.6

(q), 13.7 (q), 14.5 (q), 16.8 (q), 26.9 (q), 55.4 (s), 56.9 (d), 57.5 (d), 61.0 (t), 61.4 (t), 61.7 (t), 61.9 (t), 109.0 (d), 122.4 (d), 128.5 (d), 128.8 (d), 129.2(s), 141.9 (s), 147.2 (s), 154.1 (s), 168.8 (s), 169.5 (s), 178.7 (s); IR (nujol): ν_{max} = 3304, 3232, 1731, 1710 cm^{-1}; MS *m/z* (%): 561 (M^+) (1), 458 (38), 412 (24), 384 (100), 346 (57), 300 (51), 228 (57); anal. calcd. for $C_{26}H_{35}N_5O_9$ (561.55): C 55.61, H 6.28, N 12.47; found: C 55.63, H 6.30, N 12.51.



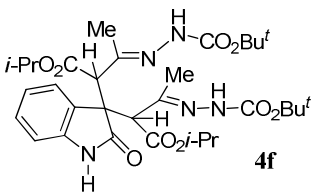
4d

Di-*tert*-butyl 2,2'-[(2-oxo-2,3-dihydro-1*H*-indole-3,3-diyl)bis(4-ethoxy-4-oxo-3-butyl-2-ylidene)]dihydrazinecarboxylate (4d): 4d was isolated by column chromatography (acetate/cyclohexane 20:80) in 71% yield. White solid; mp: 163–164 C; ^{1}H NMR (400 MHz, DMSO-d_6, 25 °C): δ = 0.99–1.03 (m, 6H), 1.43–1.47 (m, 21H), 1.67 (s, 3H), 3.90–3.99 (m, 5H), 4.09 (s, 1H), 6.69 (d, *J* = 7.6 Hz, 1H), 6.84 (t, *J* = 7.6 Hz, 1H), 7.10–7.17 (m, 1H), 7.78–7.89 (m, 1H), 9.37 and 9.45 (2 br, 1H), 9.56 (s, 1H), 10.44 and 10.52 (2 br, 1H); ^{13}C NMR (100 MHz, DMSO-d_6, 25 °C): δ = 13.5 (q), 13.6 (q), 14.9 (q), 15.3 (q), 28.0 (q), 28.1 (q), 54.4 (s), 56.6 (d), 57.6 (d), 60.4 (t), 60.7 (t), 79.1 (s), 79.3 (s), 108.7 (d), 108.9 (d), 120.7 (d), 126.4 (d), 128.2 (d), 128.6 (d), 129.0 (s), 143.0 (s), 143.4 (s), 146.4 (s), 152.5 (s), 152.7 (s), 168.9 (s), 169.4 (s), 176.5 (s), 177.2 (s); IR (nujol): ν_{max} = 3521, 3445, 3253, 3163, 1744, 1723, 1694 cm^{-1}; MS *m/z* (%): 617 (M^+) (1), 560 (6), 544 (5), 516 (11), 469 (8), 297 (41), 199 (44), 161 (57), 133 (79), 111 (100); anal. calcd. for $C_{30}H_{43}N_5O_9$ (617.69): C 58.33, H 7.02, N 11.34; found: C 58.29, H 7.03, N 11.33.



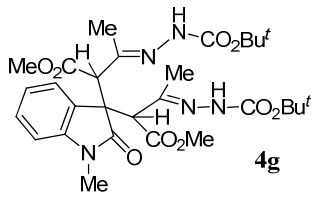
4e

Diethyl 2,2'-[(2-oxo-2,3-dihydro-1*H*-indole-3,3-diyl)bis{[(anilinocarbonyl)hydrazono]butanoate} (4e): 4e was isolated by column chromatography (acetate/cyclohexane 20:80) in 70% yield. White solid; mp: 229–231 C; ^{1}H NMR (400 MHz, DMSO-d_6, 25 °C): δ = 1.08–1.14 (m, 6H), 1.35 (s, 3H), 1.63 (s, 3H), 4.05–4.12 (m, 4H), 4.42 (s, 1H), 4.61 (s, 1H), 6.71 (d, *J* = 8.0 Hz, 1H), 6.92–7.02 (m, 3H), 7.10 (t, *J* = 7.6 Hz, 1H), 7.23–7.31 (m, 4H), 7.51–7.57 (m, 4H), 7.75 (d, *J* = 7.2 Hz, 1H), 8.42 (s, 2H), 9.51 (s, 1H), 9.72 (s, 1H), 10.61 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6, 25 °C): δ = 13.8 (q), 15.6 (q), 17.2 (q), 54.8 (s), 55.3 (d), 57.4 (d), 60.7 (t), 60.8 (t), 109.5 (d), 118.4 (d), 118.7 (d), 121.2 (d), 122.2 (d), 126.6 (d), 128.4 (d), 128.6 (d), 128.7 (s), 138.9 (s), 139.0 (s), 142.0 (s), 142.3 (s), 143.7 (s), 152.9 (s), 153.0 (s), 168.8 (s), 169.6 (s), 177.9 (s); IR (nujol): ν_{max} = 3395, 3209, 3126, 1743, 1706 cm^{-1}; MS *m/z* (%): 655 (M^+) (2), 608 (3), 563 (2), 473 (3), 297 (10), 228 (16), 200 (28), 133 (21), 119 (100); anal. calcd. for $C_{34}H_{37}N_7O_7$ (655.70): C 62.28, H 5.69, N 14.95; found: C 62.29, H 5.71, N 14.92.



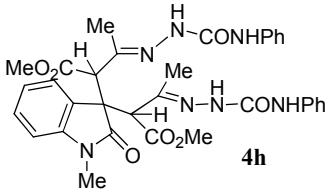
4f

Di-*tert*-butyl 2,2'-[(2-oxo-2,3-dihydro-1*H*-indole-3,3-diyl)bis(4-isopropoxy-4-oxo-3-butyl-2-ylidene)]dihydrazinecarboxylate (4f): 4f was isolated by column chromatography (acetate/cyclohexane 20:80) in 69% yield. Pale yellow solid; mp: 142–143 C; ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ = 0.96–1.00 (m, 12H), 1.50 and 1.56 (2s, 18H), 1.81 (s, 3H), 1.89 (s, 3H), 4.03 (s, 1H), 4.65–4.72 (m, 2H), 5.06 (br, 1H), 6.74 (d, *J* = 7.6 Hz, 1H), 6.96–6.98 (m, 1H), 7.14 (t, *J* = 6.0 Hz, 1H), 7.62 (s, 1H), 8.10–8.14 (m, 1H), 8.12 (s, 1H), 8.45 (br, 1H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 14.5 (q), 21.1 (q), 21.2 (q), 28.2 (q), 28.4 (q), 55.6 (s), 56.7 (d), 57.8 (d), 68.5 (d), 69.0 (d), 80.7 (s), 81.2 (s), 108.8 (d), 122.3 (d), 128.3 (d), 129.1 (d), 129.8 (s), 142.1 (s), 146.4 (s), 146.7 (s), 152.2 (s), 168.4 (s), 169.0 (s), 178.8 (s); IR (nujol): ν_{max} = 3346, 3255, 3155, 3096, 1750, 1718, 1703 cm^{-1}; MS *m/z* (%): 645 (M^+) (1), 546 (3), 514 (19), 458 (23), 413 (25), 398 (37), 370 (85), 311 (100), 269 (79); anal. calcd. for $C_{32}H_{47}N_5O_9$ (645.74): C 59.52, H 7.34, N 10.85; found: C 59.51, H 7.32, N 10.83.



4g

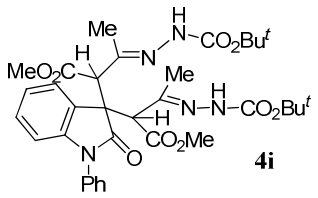
Di-*tert*-butyl 2,2'-[(1-methyl-2-oxo-2,3-dihydro-1*H*-indole-3,3-diyl)bis(4-methoxy-4-oxo-3-butyl-2-ylidene)]dihydrazinecarboxylate (4g): 4g was isolated by column chromatography (acetate/cyclohexane 20:80) in 74% yield. White solid; mp: 151–152 C; ^{1}H NMR (400 MHz, DMSO-d_6, 25 °C): δ = 1.40–1.43 (m, 24H), 3.02 (s, 3H), 3.50 (s, 6H), 4.10 (s, 2H), 6.91 (d, *J* = 7.6 Hz, 1H), 7.00 (t, *J* = 6.8 Hz, 1H), 7.25 (t, *J* = 7.6 Hz, 1H), 7.81 (d, *J* = 7.2 Hz, 1H), 9.52 (br, 2H); ^{13}C NMR (100 MHz, DMSO-d_6, 25 °C): δ = 15.1 (q), 25.9 (q), 28.0 (q), 52.0 (q), 54.0 (s), 57.3 (d), 79.2 (s), 108.0 (d), 121.5 (d), 125.9 (d), 128.1 (d), 128.7 (s), 144.6 (s), 146.3 (s), 152.6 (s), 169.3 (s), 175.0 (s); IR (nujol): ν_{max} = 3297, 3228, 3146, 3117, 1752, 1735, 1719, 1686 cm^{-1}; MS *m/z* (%): 603 (M^+) (1), 472 (15), 384 (12), 340 (5), 311 (14), 297 (100); anal. calcd. for $C_{29}H_{41}N_5O_9$ (603.66): C 57.70, H 6.85, N 11.60; found: C 57.68, H 6.87, N 11.63.



4h

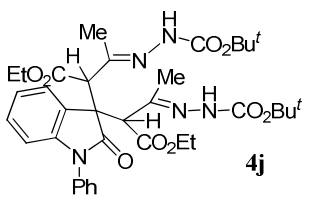
Dimethyl 2,2'-[(2-oxo-2,3-dihydro-1*H*-indole-3,3-diyl)bis{[(anilinocarbonyl)hydrazono]butanoate} (4h): 4h was isolated by column chromatography (acetate/cyclohexane 20:80) in 72% yield. Pale yellow solid; mp: 165–167 C; ^{1}H NMR (400 MHz, DMSO-d_6, 25 °C): δ = 1.65 (s, 6H), 3.05 (s, 3H), 3.51 (s, 6H), 4.36 (s, 2H), 6.96–7.03 (m, 4H), 7.28–7.32 (m, 5H), 7.56 (d, *J* = 8.8 Hz, 4H), 7.82 (d, *J* = 7.2 Hz, 1H), 8.50 (s, 2H), 9.76 (s, 2H); ^{13}C

NMR (100 MHz, DMSO-d_6, 25 °C): δ = 16.0 (q), 26.3 (q), 52.2 (q), 54.5 (s), 57.1 (d), 108.3 (d), 118.6 (d), 122.0 (d), 122.4 (d), 125.5 (d), 128.2 (d), 128.8 (d), 129.0 (s), 138.7 (s), 142.8 (s), 144.0 (s), 152.9 (s), 169.4 (s), 175.9 (s); IR (nujol): ν_{max} = 3332, 3187, 1756, 1718, 1704, 1686 cm^{-1}; MS *m/z* (%): 641 (M^+) (2), 493 (20), 459 (2), 431 (100), 338 (40), 297 (58), 242 (52); anal. calcd. for $C_{33}H_{35}N_7O_7$ (641.67): C 61.77, H 5.50, N 15.28; found: C 61.79, H 5.51, N 15.30.



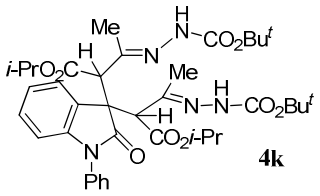
4i

Di-*tert*-butyl 2,2'-[(2-oxo-1-phenyl-2,3-dihydro-1*H*-indole-3,3-diyl)bis(4-methoxy-4-oxo-3-butyl-2-ylidene)]dihydrazinecarboxylate (4i): 4i was isolated by column chromatography (acetate/cyclohexane 20:80) in 71% yield. Pale yellow solid; mp: 101–102 C; ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ = 1.49 and 1.55 (2s, 18H), 1.72 (s, 3H), 1.91 (s, 3H), 3.42 and 3.44 (2s, 6H), 4.21 (br, 1H), 5.16 (br, 1H), 6.66 (d, *J* = 8.0 Hz, 1H), 7.05–7.57 (m, 8H), 7.78 (br, 1H), 8.53 (br, 1H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 14.5 (q), 17.1 (q), 28.2 (q), 28.4 (q), 51.9 (q), 52.3 (q), 55.1 (s), 56.8 (d), 57.8 (d), 81.2 (s), 108.3 (d), 122.9 (d), 126.7 (d), 127.9 (d), 128.3 (d), 129.3 (d), 129.5 (s), 134.8 (s), 144.8 (s), 152.6 (s), 169.4 (s), 170.1 (s), 176.3 (s); IR (nujol): ν_{max} = 3516, 3462, 3251, 3170, 1749, 1730, 1682 cm^{-1}; MS *m/z* (%): 665 (M^+) (1), 534 (85), 502 (13), 478 (72), 446 (51), 433 (60), 418 (100), 402 (34), 380 (100), 359 (100); anal. calcd. for $C_{34}H_{43}N_5O_9$ (665.73): C 61.34, H 6.51, N 10.52; found: C 61.32, H 6.50, N 10.49.



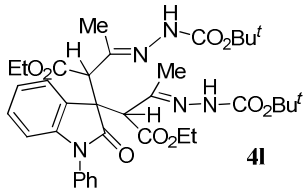
4j

Di-*tert*-butyl 2,2'-[(2-oxo-1-phenyl-2,3-dihydro-1*H*-indole-3,3-diyl)bis(4-ethoxy-4-oxo-3-butyl-2-ylidene)]dihydrazinecarboxylate (4j): 4j was isolated by column chromatography (acetate/cyclohexane 20:80) in 75% yield. White solid; mp: 159–160 C; ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ = 0.92–1.00 (m, 6H), 1.46–1.57 (m, 18H), 1.76 (s, 3H), 1.93 (s, 3H), 3.83–3.95 (m, 4H), 4.17 (br, 1H), 5.18 (br, 1H), 6.67 (d, *J* = 8.4 Hz, 1H), 7.03–7.15 (m, 3H), 7.37–7.51 (m, 5H), 7.74 (br, 1H), 8.56 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 13.7 (q), 13.8 (q), 16.0 (q), 28.2 (q), 28.4 (q), 55.2 (s), 56.9 (d), 58.0 (d), 60.2 (t), 61.3 (t), 81.2 (s), 81.7 (s), 108.2 (d), 108.3 (d), 122.8 (d), 123.4 (d), 126.0 (d), 126.4 (d), 127.9 (d), 128.2 (d), 129.2 (d), 129.6 (s), 135.3 (s), 145.0 (s), 147.1 (s), 154.6 (s), 166.5 (s), 168.9 (s), 169.5 (s), 176.4 (s), 179.2 (s); IR (nujol): ν_{max} = 3297, 3166, 1752, 1723, 1706 cm^{-1}; MS *m/z* (%): 693 (M^+) (3), 562 (10), 506 (14), 460 (40), 388 (25), 373 (100), 345 (64); anal. calcd. for $C_{36}H_{47}N_5O_9$ (693.78): C 62.32, H 6.83, N 10.09; found: C 62.29, H 6.83, N 10.11.



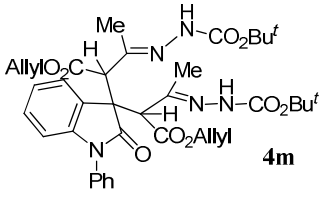
4k

Di-*tert*-butyl 2,2'-[(2-oxo-1-phenyl-2,3-dihydro-1*H*-indole-3,3-diyl)bis(4-isopropoxy-4-oxo-3-butyl-2-ylidene)]dihydrazinecarboxylate (4k): 4k was isolated by column chromatography (acetate/cyclohexane 20:80) in 69% yield. White solid; mp: 103–105 C; ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ = 0.82–0.85 (m, 12H), 1.40 (s, 18H), 1.50 (s, 6H), 4.11 (br, 1H), 4.70–4.75 (m, 2H), 5.12 (br, 1H), 6.66 (d, *J* = 8.0 Hz, 1H), 6.99–7.12 (m, 2H), 7.35–7.38 (m, 1H), 7.46–7.53 (m, 4H), 7.58 (s, 1H), 7.73–7.76 (m, 1H), 8.57 (br, 1H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 14.5 (q), 21.2 (q), 21.3 (q), 28.3 (q), 28.5 (q), 55.2 (s), 56.5 (d), 58.1 (d), 68.3 (d), 68.8 (d), 80.8 (s), 81.1 (s), 108.3 (d), 108.8 (d), 122.6 (d), 122.9 (d), 126.6 (d), 127.7 (d), 128.1 (d), 129.1 (d), 129.7 (s), 134.9 (s), 143.4 (s), 145.0 (s), 146.8 (s), 152.2 (s), 156.2 (s), 166.0 (s), 168.4 (s), 169.0 (s), 176.4 (s); IR (nujol): ν_{max} = 3248, 3146, 1743, 1698 cm^{-1}; MS *m/z* (%): 721 (M^+) (1), 590 (30), 534 (22), 502 (11), 490 (19), 474 (42), 446 (61), 430 (18), 402 (50), 387 (100), 360 (34), 345 (78), 317 (44), 304 (50); anal. calcd. for $C_{38}H_{51}N_5O_9$ (721.83): C 63.23, H 7.21, N 9.70; found: C 63.25, H 7.22, N 9.69.



4l

Di-*tert*-butyl 2,2'-[(2-oxo-1-phenyl-2,3-dihydro-1*H*-indole-3,3-diyl)bis(4-methoxy-4-oxo-3-pentyl-2-ylidene)]dihydrazinecarboxylate (4l): 4l was isolated by column chromatography (acetate/cyclohexane 20:80) in 68% yield. Pale yellow solid; mp: 101–103 C; ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ = 0.83 (t, *J* = 7.6 Hz, 3H), 0.98 (t, *J* = 7.6 Hz, 3H), 1.42–1.56 (m, 18H), 2.15–2.32 and 2.40–2.51 (2m, 4H), 3.36 (s, 3H), 3.38 (s, 3H), 4.26 (s, 1H), 5.18 (br, 1H), 6.65 (d, *J* = 8.4 Hz, 1H), 6.97–7.13 (m, 2H), 7.36–7.51 (m, 5H), 7.74 (s, 1H), 7.93 (br, 1H), 8.61 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 8.9 (q), 9.2 (q), 21.4 (t), 23.9 (t), 28.2 (q), 28.3 (q), 51.6 (q), 52.2 (q), 55.1 (s), 55.5 (s), 81.1 (s), 108.2 (d), 108.3 (d), 122.8 (d), 126.7 (d), 127.8 (d), 128.0 (d), 128.3 (d), 129.4 (d), 129.5 (s), 134.8 (s), 144.8 (s), 152.6 (s), 169.7 (s), 170.1 (s), 176.4 (s); IR (nujol): ν_{max} = 3251, 3138, 1739, 1725, 1695 cm^{-1}; MS *m/z* (%): 693 (M^+) (3), 619 (33), 590 (11), 561 (34), 530 (18), 450 (29), 398 (100); anal. calcd. for $C_{36}H_{47}N_5O_9$ (693.78): C 62.32, H 6.83, N 10.09; found: C 62.33, H 6.81, N 10.08.



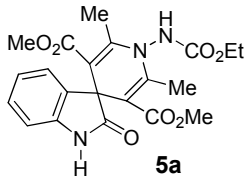
4m

Di-*tert*-butyl 2,2'-{[(2-oxo-1-phenyl-2,3-dihydro-1*H*-indole-3,3-diyl)bis(4-(allyloxy)-4-oxo-3-butyl-2-ylidene]}dihydrazinecarboxylate

(4m): 4m was isolated by column chromatography (acetate/cyclohexane 20:80) in 73% yield. Pale yellow solid; mp: 94–96 C; ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ = 1.38 (s, 18H), 1.48 (3, 3H), 1.47 (s, 3H), 4.21–4.63 (m, 2H), 4.98–5.17 (m, 4H), 5.48–5.78 (m, 1H), 6.61 (d, *J* = 8.0 Hz, 1H), 6.97–7.12 (m, 2H), 7.33–7.35 (m, 1H), 7.40–7.47 (m, 4H), 7.58 (br, 1H), 8.04–8.06 (m, 1H),), 8.52 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 14.1 (q), 14.5 (q), 26.7 (q), 28.0 (q), 28.3 (q), 55.0 (s), 57.3 (d), 57.8 (d), 65.4 (t), 65.7 (t), 80.8 (s), 81.2 (s), 108.3 (d), 108.7 (d), 118.1 (t), 118.4 (t), 122.4 (d), 122.6 (d), 126.5 (d), 126.6 (d), 126.9 (d), 127.6 (d), 127.7 (d), 128.1 (d), 129.2 (d), 129.3 (s), 131.3 (d), 131.7 (d), 134.5 (s), 134.7 (s), 144.5 (s), 144.8 (s), 146.1 (s), 146.4 (s), 152.1 (s), 168.5 (s), 169.1 (s), 175.2 (s), 176.1 (s); IR (nujol): ν_{max} = 3247, 3142, 1742, 1696 cm^{-1}; MS *m/z* (%): 717 (M^+) (1), 587 (12), 530 (20), 428 (8), 385 (100), 357 (24), 333 (48); anal. calcd. for $C_{38}H_{47}N_5O_9$ (717.80): C 63.58, H 6.60, N 9.76; found: C 63.61, H 6.61, N 9.78.

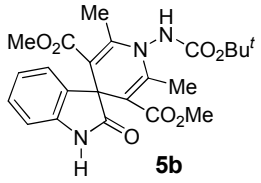
General procedure for the synthesis of 2-oxo-spiro[indole-3,4'-pyridines]5a–m, starting from bis-hydrazones 4a–m.

To magnetically stirred solution of bis-hydrazone **4** (1 mmol) in CH_2Cl_2 (6 mL), four drops of TFA were added. The mixture was stand in these conditions for 3–5 hours, until the disappearance of the **4** (TLC monitoring). The crude mixture was purified by column chromatography on silica gel to afford the products **5**, that were crystallized from diethyl ether-light petroleum (bp 40–60 °C).



5a

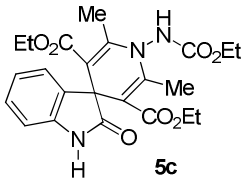
Dimethyl 1'-[(ethoxycarbonyl)amino]-2',6'-dimethyl-2-oxo-1,2-dihydro-1'*H*-spiro[indole-3,4'-pyridine]-3',5'-dicarboxylate (5a): 5a was isolated by column chromatography (acetate/cyclohexane 20:80) in 89% yield. White solid; mp: 228–230 C; ^{1}H NMR (400 MHz, DMSO-d_6, 25 °C): δ = 1.24 (t, *J* = 7.2 Hz, 6H), 2.04 (s, 6H), 3.32 (s, 6H), 4.18 (q, *J* = 7.2 Hz, 2H), 6.68 (d, *J* = 7.2 Hz, 1H), 6.84 (t, *J* = 8.0 Hz, 1H), 7.07 (t, *J* = 7.2 Hz, 1H), 7.42 (d, *J* = 7.2 Hz, 1H), 10.13 (s, 1H), 10.23 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6, 25 °C): δ = 14.4 (q), 15.5 (q), 50.7 (q), 51.1 (s), 61.6 (t), 104.7 (s), 108.3 (d), 121.0 (d), 123.8 (d), 127.9 (d), 136.5 (s), 141.7 (s), 146.5 (s), 155.9 (s), 166.2 (s), 180.3 (s); IR (nujol): ν_{max} = 3274, 1747, 1724, 1669 cm^{-1}; MS *m/z* (%): 429 (M^+) (2), 370 (100), 342 (38), 314 (11), 296 (9), 281 (8), 265 (6), 254 (7); anal. calcd. for $C_{21}H_{23}N_3O_7$ (429.42): C 58.74, H 5.40, N 9.79; found: C 58.71, H 5.39, N 9.81.



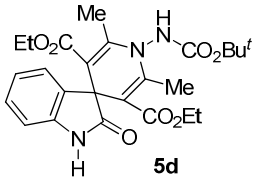
5b

Dimethyl 1'-[(*tert*-butoxycarbonyl)amino]-2',6'-dimethyl-2-oxo-1,2-dihydro-1'*H*-spiro[indole-3,4'-pyridine]-3',5'-dicarboxylate (5b): 5b was isolated by column chromatography (acetate/cyclohexane 20:80) in 91%

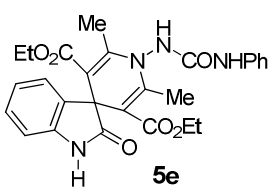
yield. White solid; mp: 205–207 C; ^{1}H NMR (400 MHz, DMSO-d_6, 25 °C): δ = 1.46 (s, 9H), 2.00 (s, 6H), 3.28 (s, 6H), 6.51 (d, *J* = 8.0 Hz, 1H), 6.82 (t, *J* = 7.6 Hz, 1H), 7.06 (t, *J* = 7.2 Hz, 1H), 7.38 (d, *J* = 7.2 Hz, 1H), 9.93 (s, 1H), 10.08 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6, 25 °C): δ = 15.6 (q), 27.9 (q), 50.7 (q), 50.8 (s), 80.8 (s), 104.5 (s), 108.3 (d), 121.1 (d), 123.8 (d), 127.9 (d), 136.6 (s), 141.8 (s), 146.5 (s), 155.0 (s), 166.3 (s), 180.4 (s); IR (nujol): ν_{max} = 3208, 1735, 1720, 1700, 1685 cm^{-1}; MS *m/z* (%): 457 (M^+) (100), 396 (16), 382 (23), 356 (15), 322 (23), 296 (14), 281 (14); anal. calcd. for $C_{23}H_{27}N_3O_7$ (457.47): C 60.38, H 5.95, N 9.19; found: C 60.40, H 5.98, N 9.21.



Diethyl 1'-[(ethoxycarbonyl)amino]-2',6'-dimethyl-2-oxo-1,2-dihydro-1'*H*-spiro[indole-3,4'-pyridine]-3',5'-dicarboxylate (5c): 5c was isolated by column chromatography (acetate/cyclohexane 20:80) in 88% yield. Pale yellow solid; mp: 195–196 C; ^{1}H NMR (400 MHz, DMSO-d_6, 25 °C): δ = 0.89 (t, *J* = 7.2 Hz, 6H), 1.24 (t, *J* = 7.2 Hz, 3H), 2.02 (s, 6H), 3.69–3.80 (m, 4H), 4.17 (q, *J* = 7.2 Hz, 2H), 6.65 (d, *J* = 7.6 Hz, 1H), 6.82 (t, *J* = 7.6 Hz, 1H), 7.06 (t, *J* = 7.6 Hz, 1H), 7.35 (d, *J* = 7.6 Hz, 1H), 10.10 (s, 1H), 10.18 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6, 25 °C): δ = 13.1 (q), 14.4 (q), 15.4 (q), 51.1 (s), 59.6 (t), 61.5 (t), 104.7 (s), 108.3 (d), 121.0 (d), 123.8 (d), 127.8 (d), 136.6 (s), 142.0 (s), 146.0 (s), 156.0 (s), 165.7 (s), 180.1 (s); IR (nujol): ν_{max} = 3243, 1743, 1720, 1704, 1689 cm^{-1}; MS *m/z* (%): 457 (M^+) (1), 384 (100), 356 (48), 328 (13), 310 (8), 296 (4), 267 (8); anal. calcd. for $C_{23}H_{27}N_3O_7$ (457.47): C 60.38, H 5.95, N 9.19; found: C 60.39, H 5.96, N 9.17.

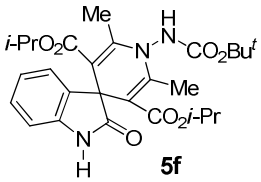


Diethyl 1'-[(*tert*-butoxycarbonyl)amino]-2',6'-dimethyl-2-oxo-1,2-dihydro-1'*H*-spiro[indole-3,4'-pyridine]-3',5'-dicarboxylate (5d): 5d was isolated by column chromatography (acetate/cyclohexane 20:80) in 90% yield. White solid; mp: 193–195 C; ^{1}H NMR (400 MHz, DMSO-d_6, 25 °C): δ = 0.86 (t, *J* = 6.8 Hz, 6H), 1.46 (s, 9H), 2.10 (s, 6H), 3.67–3.79 (m, 4H), 6.64 (d, *J* = 7.6 Hz, 1H), 6.82 (t, *J* = 7.6 Hz, 1H), 7.07 (t, *J* = 7.6 Hz, 1H), 7.27 (d, *J* = 7.6 Hz, 1H), 9.92 (s, 1H), 10.09 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6, 25 °C): δ = 13.1 (q), 15.4 (q), 27.9 (q), 51.2 (s), 59.6 (t), 80.7 (s), 104.4 (s), 108.3 (d), 121.0 (d), 123.8 (d), 127.8 (d), 136.5 (s), 142.2 (s), 146.1 (s), 155.0 (s), 165.8 (s), 180.2 (s); IR (nujol): ν_{max} = 3310, 3227, 1738, 1718, 1703, 1683 cm^{-1}; MS *m/z* (%): 485(M^+) (1), 412 (24), 356 (100), 328 (23), 312 (27), 297 (10), 284 (15), 267 (14); anal. calcd. for $C_{25}H_{31}N_3O_7$ (485.53): C 61.84, H 6.44, N 8.65; found: C 61.82, H 6.45, N 8.63.



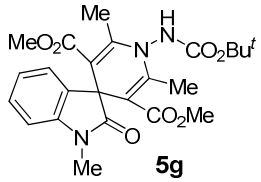
Diethyl 1'-[(anilinocarbonyl)amino]-2',6'-dimethyl-2-oxo-1,2-dihydro-1'*H*-spiro[indole-3,4'-pyridine]-3',5'-dicarboxylate (5e): 5e was isolated by column chromatography (acetate/cyclohexane 20:80) in 52% yield. Pale

yellow solid; mp: 198–200 C; ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ = 0.80 (t, *J* = 7.2 Hz, 6H), 2.22 (s, 6H), 3.64–3.78 (m, 4H), 6.72 (d, *J* = 7.6 Hz, 1H), 6.97 (t, *J* = 7.2 Hz, 1H), 7.14–7.18 (m, 3H), 7.37 (t, *J* = 8.4 Hz, 2H), 7.73 (d, *J* = 7.6 Hz, 2H), 8.43 (s, 1H), 8.68 (s, 1H), 8.82 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 13.3 (q), 15.3 (q), 50.9 (s), 60.6 (t), 107.0 (s), 109.3 (d), 121.3 (d), 122.9 (d), 123.1 (d), 124.2 (d), 128.4 (d), 128.8 (d), 134.5 (s), 137.8 (s), 142.4 (s), 146.0 (s), 157.0 (s), 165.8 (s), 181.8 (s); IR (nujol): ν_{max} = 3318, 3252, 1743, 1723, 1702 cm^{-1}; MS *m/z* (%): 504 (M^+) (1), 431 (100), 403 (21), 338 (41), 310 (29), 297 (8), 268 (13), 251 (14); anal. calcd. for $C_{27}H_{28}N_4O_6$ (504.53): C 64.27, H 5.59, N 11.10; found: C 64.30, H 5.58, N 11.11.



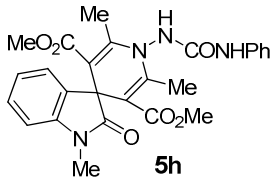
5f

Diisopropyl 1'-[(*tert*-butoxycarbonyl)amino]-2',6'-dimethyl-2-oxo-1,2-dihydro-1'*H*-spiro[indole-3,4'-pyridine]-3',5'-dicarboxylate (5f): 5f was isolated by column chromatography (acetate/cyclohexane 20:80) in 88% yield. White solid; mp: 195–196 C; ^{1}H NMR (400 MHz, DMSO-d_6, 25 °C): δ = 0.73 (d, *J* = 6.4 Hz, 6H), 0.94 (d, *J* = 6.0 Hz, 6H), 1.47 (s, 9H), 2.00 (s, 6H), 4.57 (hept, *J* = 6.4 Hz, 2H), 6.65 (d, *J* = 7.6 Hz, 1H), 6.83 (t, *J* = 7.6 Hz, 1H), 7.08 (t, *J* = 8.0 Hz, 1H), 7.20 (d, *J* = 7.2 Hz, 1H), 9.91 (s, 1H), 10.07 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6, 25 °C): δ = 15.4 (q), 20.5 (q), 20.8 (q), 27.9 (q), 51.2 (s), 67.1 (d), 80.6 (s), 104.6 (s), 108.3 (d), 120.9 (d), 123.9 (d), 127.7 (d), 136.6 (s), 142.5 (s), 145.4 (s), 155.0 (s), 165.3 (s), 180.0 (s); IR (nujol): ν_{max} = 3370, 3196, 1736, 1721, 1701,1682 cm^{-1}; MS *m/z* (%): 513 (M^+) (1), 426 (39), 370 (100), 342 (19), 328 (49), 300 (16), 284 (23), 267 (22), 256 (15), 240 (12); anal. calcd. for $C_{27}H_{35}N_3O_7$ (513.58): C 63.14, H 6.87, N 8.18; found: C 63.11, H 6.90, N 8.21.



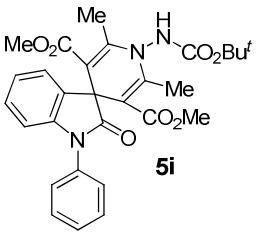
5g

Dimethyl 1'-[(*tert*-butoxycarbonyl)amino]-1,2',6'-trimethyl-2-oxo-1,2-dihydro-1'*H*-spiro[indole-3,4'-pyridine]-3',5'-dicarboxylate (5g): 5g was isolated by column chromatography (acetate/cyclohexane 20:80) in 75% yield. Pale yellow solid; mp: 190–191 C; ^{1}H NMR (400 MHz, DMSO-d_6, 25 °C): δ = 1.48 (s, 9H), 2.05 (s, 6H), 3.08 (s, 3H), 3.28 (s, 6H), 6.86 (d, *J* = 7.6 Hz, 1H), 6.93 (t, *J* = 7.2 Hz, 1H), 7.18 (t, *J* = 7.6 Hz, 1H), 7.42 (d, *J* = 7.6 Hz, 1H), 10.03 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6, 25 °C): δ = 15.6 (q), 27.9 (q), 50.5 (s), 50.9 (q), 80.8 (s), 104.1 (s), 107.1 (d), 121.8 (d), 123.5 (d), 128.1 (d), 135.6 (s), 143.1 (s), 147.1 (s), 154.9 (s), 166.0 (s), 178.7 (s); IR (nujol): ν_{max} = 3197, 1751, 1735, 1704, 1689 cm^{-1}; MS *m/z* (%): 471 (M^+) (6), 412 (25), 356 (100), 328 (9), 312 (58), 297 (40), 284 (11), 269 (12); anal. calcd. for $C_{24}H_{29}N_3O_7$ (471.50): C 61.14, H 6.20, N 8.91; found: C 61.17, H 6.18, N 8.89.



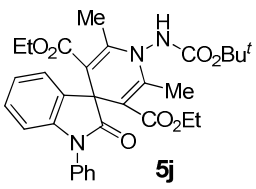
5h

Dimethyl 1'-[(anilinocarbonyl)amino]-1,2',6'-trimethyl-2-oxo-1,2-dihydro-1'*H*-spiro[indole-3,4'-pyridine]-3',5'-dicarboxylate (5h): 5h was isolated by column chromatography (acetate/cyclohexane 20:80) in 92% yield. White solid; mp: 253–255 C; ^{1}H NMR (400 MHz, DMSO-d_6, 25 °C): δ = 2.13 (s, 6H), 3.09 (s, 3H), 3.31 (s, 6H), 6.86 (d, *J* = 8.0 Hz, 1H), 6.95 (t, *J* = 7.2 Hz, 1H), 7.00 (t, *J* = 7.6 Hz, 1H), 7.20 (t, *J* = 7.6 Hz, 1H), 7.28–7.32 (m, 2H), 7.48 (d, *J* = 8.8 Hz, 2H), 7.60 (d, *J* = 7.2 Hz, 1H), 9.05 (s, 1H), 8.27 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6, 25 °C): δ = 15.8 (q), 26.0 (q), 50.8 (q), 50.9 (q), 103.9 (s), 107.0 (d), 118.7 (d), 121.9 (d), 122.3 (d), 123.8 (d), 128.0 (d), 128.7 (d), 135.9 (s), 139.2 (s), 142.9 (s), 148.3 (s), 154.4 (s), 166.2 (s), 179.0 (s); IR (nujol): ν_{max} = 3362, 3217, 1738, 1721, 1704, 1683 cm^{-1}; MS *m/z* (%): 490 (M^+) (6), 431 (100), 403 (9), 328 (79), 310 (18), 297 (52), 268 (27); anal. calcd. for $C_{26}H_{26}N_4O_6$ (490.51): C 63.66, H 5.34, N 11.42; found: C 64.68, H 5.36, N 11.41.



5i

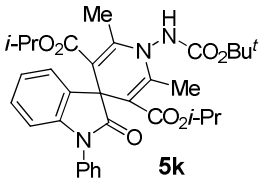
Dimethyl 1'-[(*tert*-butoxycarbonyl)amino]-2',6'-dimethyl-2-oxo-1-phenyl-1,2-dihydro-1'*H*-spiro[indole-3,4'-pyridine]-3',5'-dicarboxylate (5i): 5i was isolated by column chromatography (acetate/cyclohexane 20:80) in 87% yield. White solid; mp: 205–206 C; ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ = 1.49 (s, 9H), 2.23 (s, 6H), 3.42 (s, 6H), 6.80 (d, *J* = 7.6 Hz, 1H), 7.05 (t, *J* = 7.6 Hz, 1H), 7.15 (t, *J* = 7.6 Hz, 1H), 7.38–7.40 (m, 1H), 7.48–7.55 (m, 4H), 7.61 (d, *J* = 7.2 Hz, 1H), 8.05 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 16.0 (q), 28.1 (q), 51.3 (q), 51.7 (s), 81.7 (s), 105.1 (s), 108.1 (d), 123.4 (d), 125.0 (d), 126.0 (d), 127.3 (d), 128.1 (d), 129.3 (d), 135.3 (s), 135.6 (s), 142.8 (s), 148.2 (s), 154.6 (s), 167.0 (s), 179.5 (s); IR (nujol): ν_{max} = 3266, 1738, 1722, 1703 cm^{-1}; MS *m/z* (%): 533 (M^+) (5), 475 (6), 443 (6), 418 (79), 359 (100), 331 (58), 290 (13), 264 (9); anal. calcd. for $C_{29}H_{31}N_3O_7$ (533.57): C 65.28, H 5.86, N 7.88; found: C 65.30, H 5.88, N 7.83.



5j

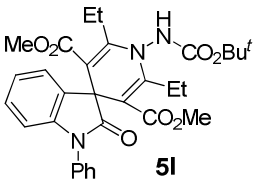
Diethyl 1'-[(*tert*-butoxycarbonyl)amino]-2',6'-dimethyl-2-oxo-1-phenyl-1,2-dihydro-1'*H*-spiro[indole-3,4'-pyridine]-3',5'-dicarboxylate (5j): 5j was isolated by column chromatography (acetate/cyclohexane 20:80) in 73% yield. White solid; mp: 192–194 C; ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ = 0.86 (t, *J* = 7.2 Hz, 6H), 1.44 (s, 9H), 2.21 (s, 6H), 3.86–3.91 (m, 4H), 6.79 (d, *J* = 7.6 Hz, 1H), 7.02 (t, *J* = 7.2 Hz, 1H), 7.11 (t, *J* = 7.6 Hz, 1H), 7.30–7.34 (m, 1H), 7.46–7.55 (m, 4H), 7.60 (d, *J* = 7.2 Hz, 1H), 8.76 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 13.6 (q), 15.8 (q), 28.0 (q),

51.8 (s), 60.1 (t), 80.9 (s), 104.6 (s), 108.0 (d), 123.1 (d), 124.9 (d), 125.7 (d), 127.0 (d), 127.7 (d), 129.0 (d), 135.1 (s), 135.8 (s), 142.6 (s), 147.8 (s), 154.9 (s), 166.5 (s), 179.5 (s); IR (nujol): ν_{max} = 3225, 1733, 1705 cm^{-1}; MS *m/z* (%): 561 (M^+) (3), 488 (41), 432 (100), 388 (100), 373 (90), 360 (34), 345 (44), 327 (10), 317 (18); anal. calcd. for $C_{31}H_{35}N_3O_7$ (561.62): C 66.30, H 6.28, N 7.48; found: C 66.31, H 6.28, N 7.50.



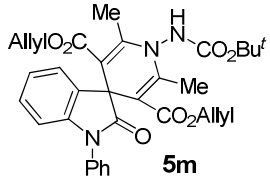
5k

Diisopropyl 1'-[(*tert*-butoxycarbonyl)amino]-2',6'-dimethyl-2-oxo-1-phenyl-1,2-dihydro-1'*H*-spiro[indole-3,4'-pyridine]-3',5'-dicarboxylate (5k): 5k was isolated by column chromatography (acetate/cyclohexane 20:80) in 80% yield. Pale yellow solid; mp: 176–178 C; ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ = 0.83 (d, *J* = 6.0 Hz, 6H), 0.92 (d, *J* = 6.0 Hz, 6H), 1.49 (s, 9H), 2.18 (s, 6H), 4.76 (hept, *J* = 6.4 Hz, 2H), 6.81 (d, *J* = 7.2 Hz, 1H), 7.01 (t, *J* = 7.2 Hz, 1H), 7.12 (t, *J* = 7.6 Hz, 1H), 7.32–7.36 (m, 1H), 7.46–7.52 (m, 3H), 7.60 (d, *J* = 7.6 Hz, 1H), 7.75 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 15.9 (q), 21.0 (q), 21.5 (q), 28.2 (q), 51.6 (s), 67.7 (d), 81.6 (s), 105.5 (s), 108.4 (d), 123.0 (d), 125.0 (d), 126.0 (d), 127.1 (d), 127.8 (d), 129.1 (d), 135.3 (s), 135.4 (s), 143.7 (s), 146.1 (s), 154.8 (s), 166.1 (s), 178.9 (s); IR (nujol): ν_{max} = 3239, 1724, 1704, 1685 cm^{-1}; MS *m/z* (%): 589 (M^+) (1), 502 (52), 446 (100), 402 (54), 387 (68), 360 (56), 345 (47), 332 (15), 317 (24); anal. calcd. for $C_{33}H_{39}N_3O_7$ (589.67): C 67.22, H 6.67, N 7.13; found: C 67.21, H 6.68, N 7.11.



5l

Dimethyl 1'-[(*tert*-butoxycarbonyl)amino]-2',6'-diethyl-2-oxo-1-phenyl-1,2-dihydro-1'*H*-spiro[indole-3,4'-pyridine]-3',5'-dicarboxylate (5l): 5l was isolated by column chromatography (acetate/cyclohexane 20:80) in 64% yield. Pale yellow solid; mp: 191–193 C; ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ = 1.16–1.23 (m, 6H), 1.54 (s, 9H), 2.49–2.54 (m, 2H), 2.74–2.79 (m, 2H), 3.50 (s, 6H), 6.81 (d, *J* = 8.0 Hz, 1H), 6.99–7.17 (m, 3H), 7.34–7.51 (m, 5H), 7.84 and 7.86 (2s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 13.5 (q), 22.8 (t), 28.2 (q), 51.1 (s), 51.4 (q), 82.4 (s), 106.2 (s), 108.1 (d), 123.7 (d), 125.0 (d), 126.0 (d), 127.3 (d), 128.1 (d), 129.1 (d), 135.4 (s), 142.5 (s), 152.8 (s), 154.4 (s), 166.4 (s), 178.9 (s); IR (nujol): ν_{max} = 3238, 1738, 1721, 1700, 1687 cm^{-1}; MS *m/z* (%): 561 (M^+) (3), 503 (10), 446 (100), 402 (40), 387 (100), 359 (86); anal. calcd. for $C_{31}H_{35}N_3O_7$ (561.62): C 66.30, H 6.28, N 7.48; found: C 66.28, H 6.31, N 7.49.

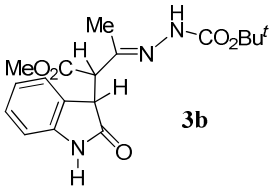


5m

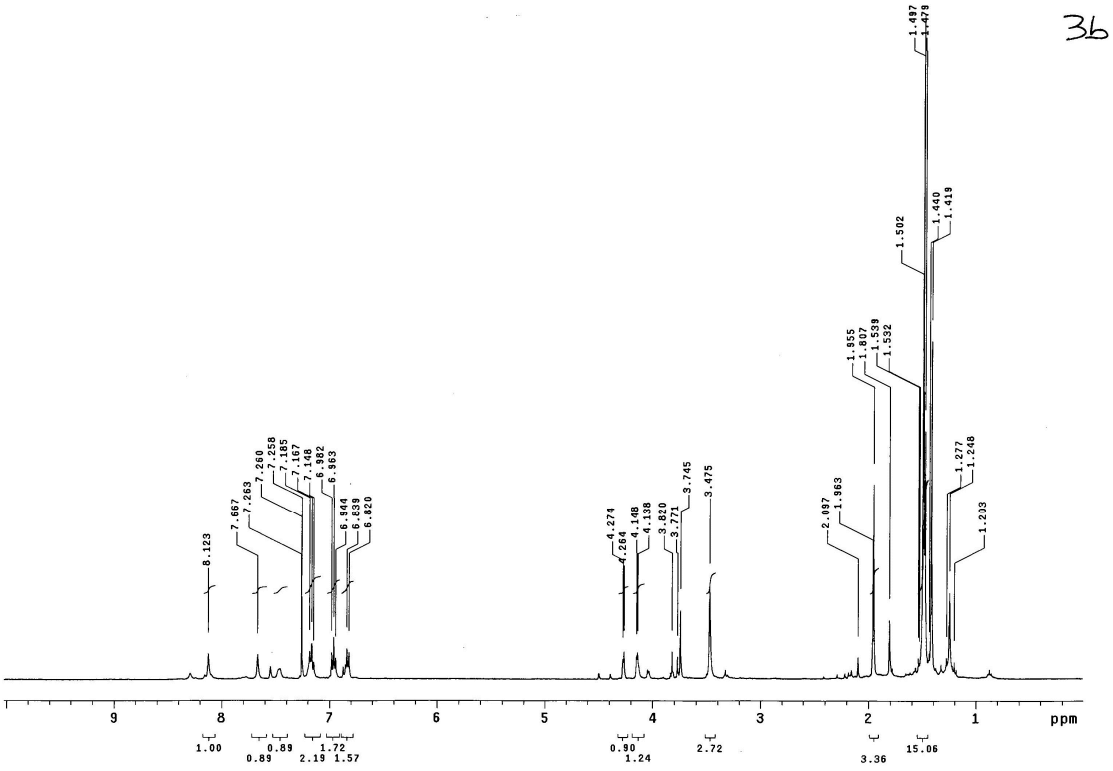
Diallyl 1'-[(*tert*-butoxycarbonyl)amino]-2',6'-dimethyl-2-oxo-1-phenyl-1,2-dihydro-1'*H*-spiro[indole-3,4'-pyridine]-3',5'-dicarboxylate (5m): 5m was isolated by column chromatography (acetate/cyclohexane 20:80) in

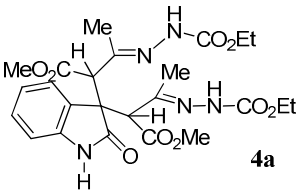
88% yield. Pale yellow solid; mp: 181–183 C; ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ = 1.49 (s, 9H), 2.21 (s, 6H), 4.28–4.37 (m, 2H), 4.94–4.99 (m, 2H), 5.43–5.51 (m, 1H), 6.74 (d, *J* = 7.6 Hz, 1H), 7.06 (t, *J* = 7.6 Hz, 1H), 7.10–7.12 (m, 1H), 7.35–7.37 (m, 1H), 7.46–7.50 (m, 5H), 7.77 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 16.2 (q), 28.2 (q), 52.0 (s), 65.1 (t), 81.9 (s), 105.2 (s), 108.5 (d), 118.1 (t), 123.3 (d), 125.0 (d), 126.2 (d), 127.4 (d), 128.0 (d), 129.1 (d), 131.9 (d), 135.9 (s), 143.3 (s), 147.6 (s), 154.6 (s), 166.1 (s), 179.8 (s); IR (nujol): ν_{max} = 3219, 1743, 1719, 1702 cm^{-1}; MS *m/z* (%): 585 (M^+) (1), 500 (53), 444 (100), 416 (10), 400 (100), 385 (65), 372 (25), 357 (19); anal. calcd. for $C_{33}H_{35}N_3O_7$ (585.64): C 67.68, H 6.02, N 7.18; found: C 67.68, H 6.01, N 7.19.

3. ^{1}H and ^{13}C NMR spectra of products.

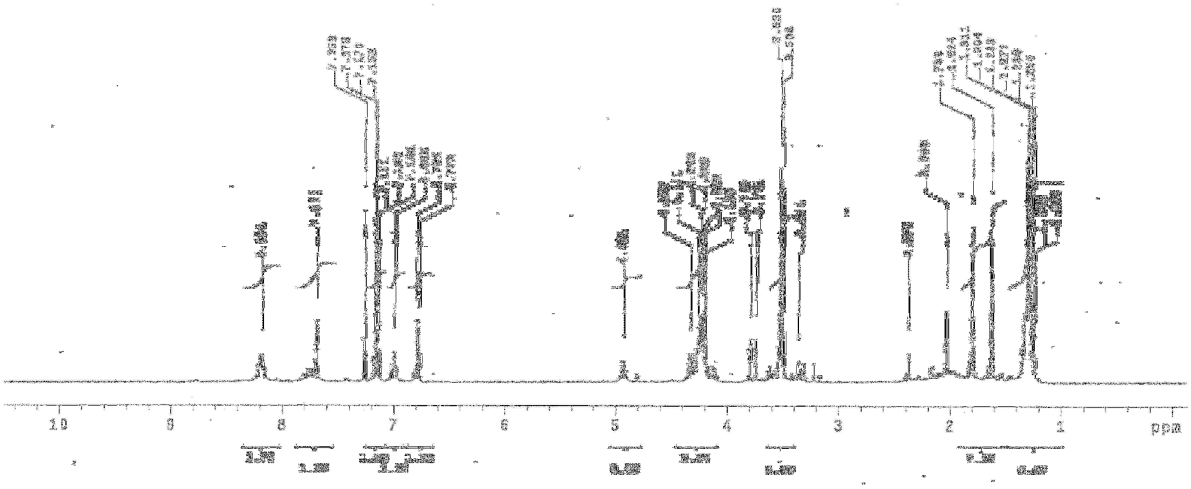


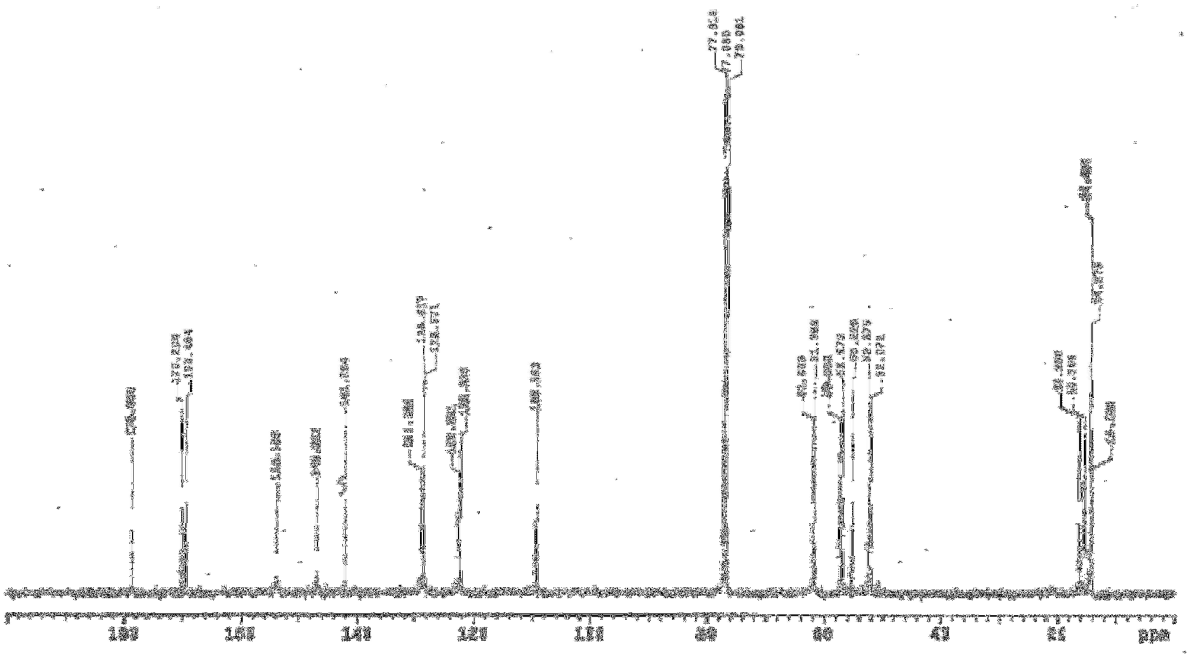
3b

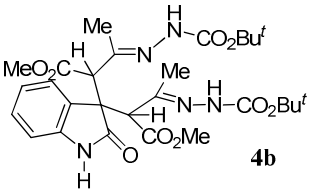




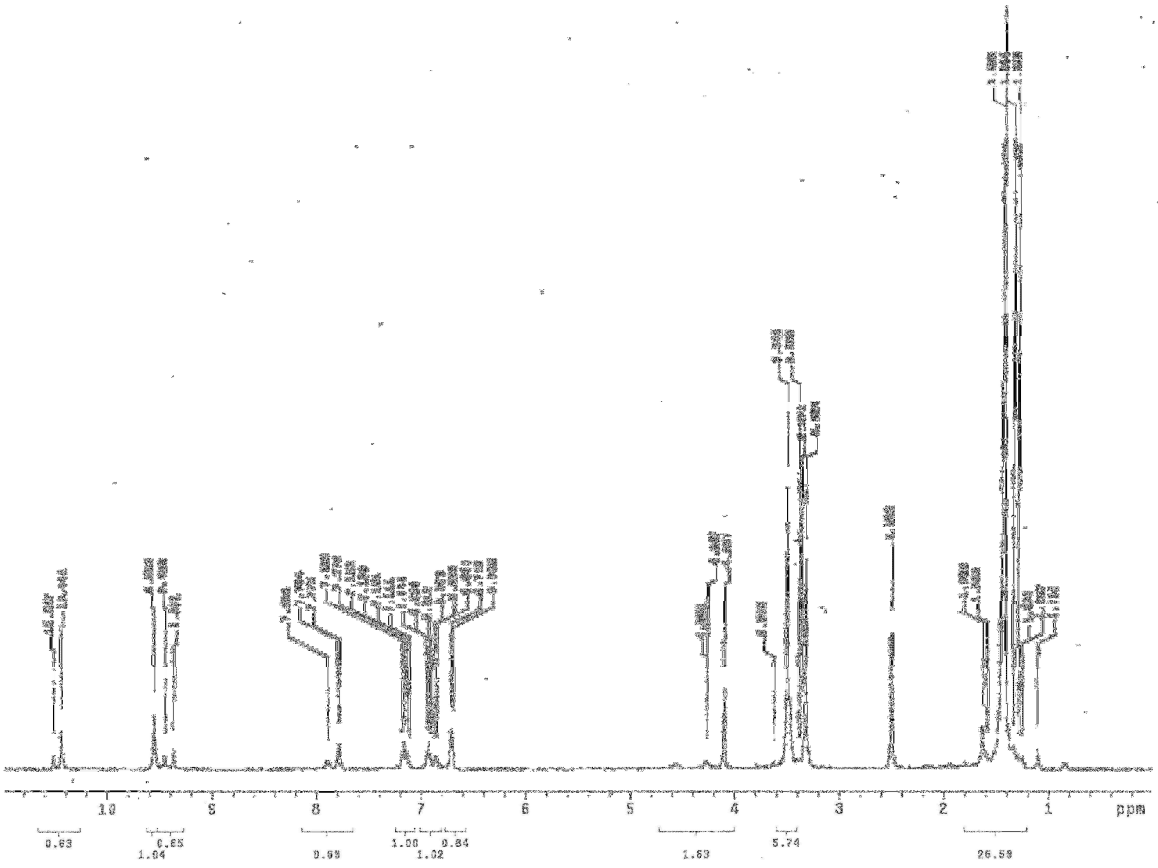
4a

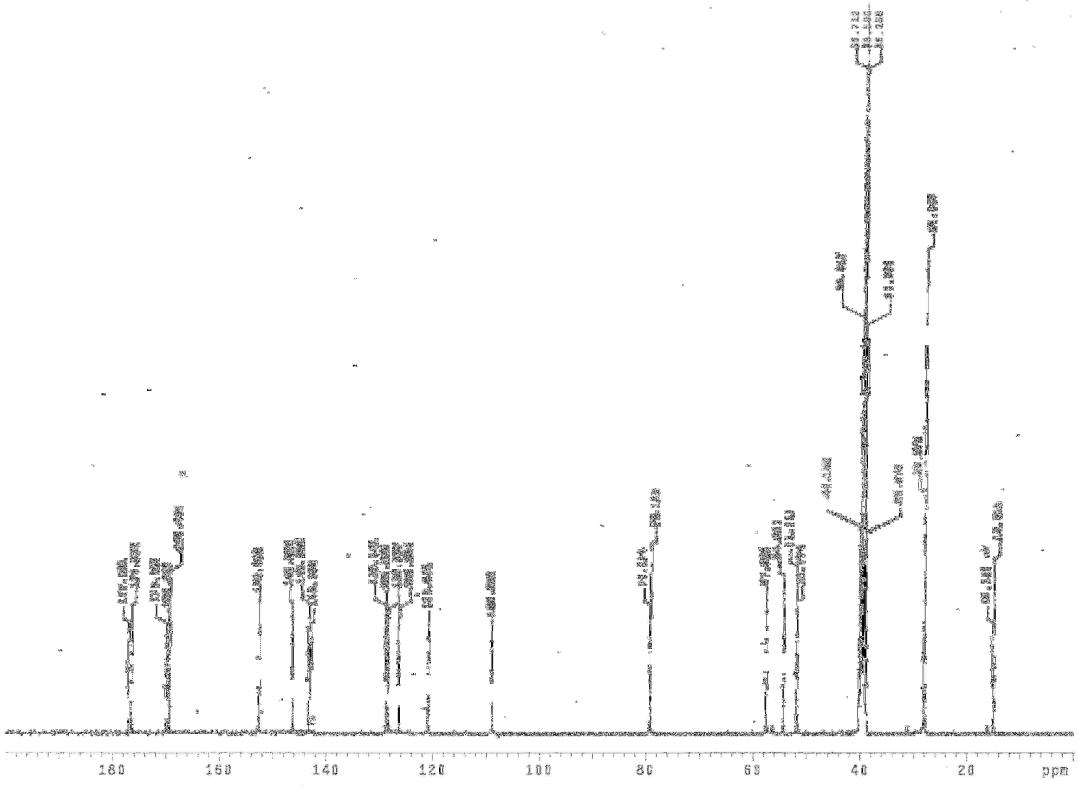


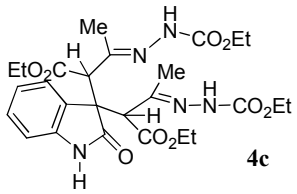



Me
H
N
N
CO2But
MeO2C
Me
N
N
CO2But
H
H
CO2Me
N
H
O

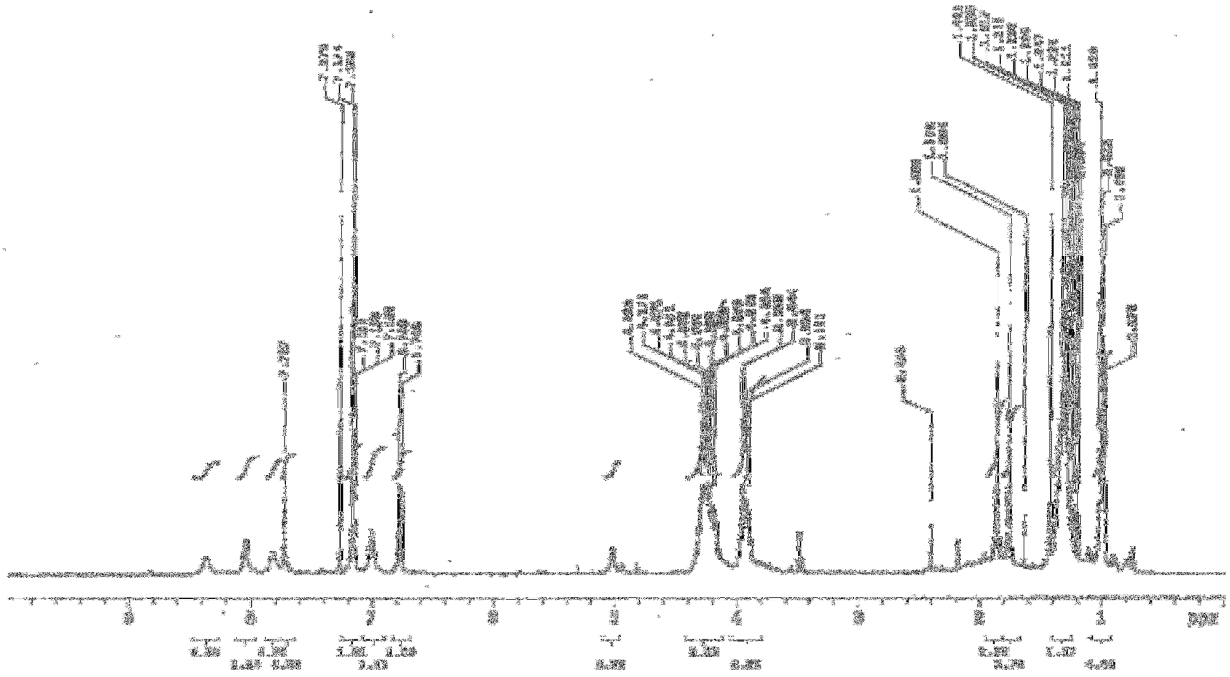
4b

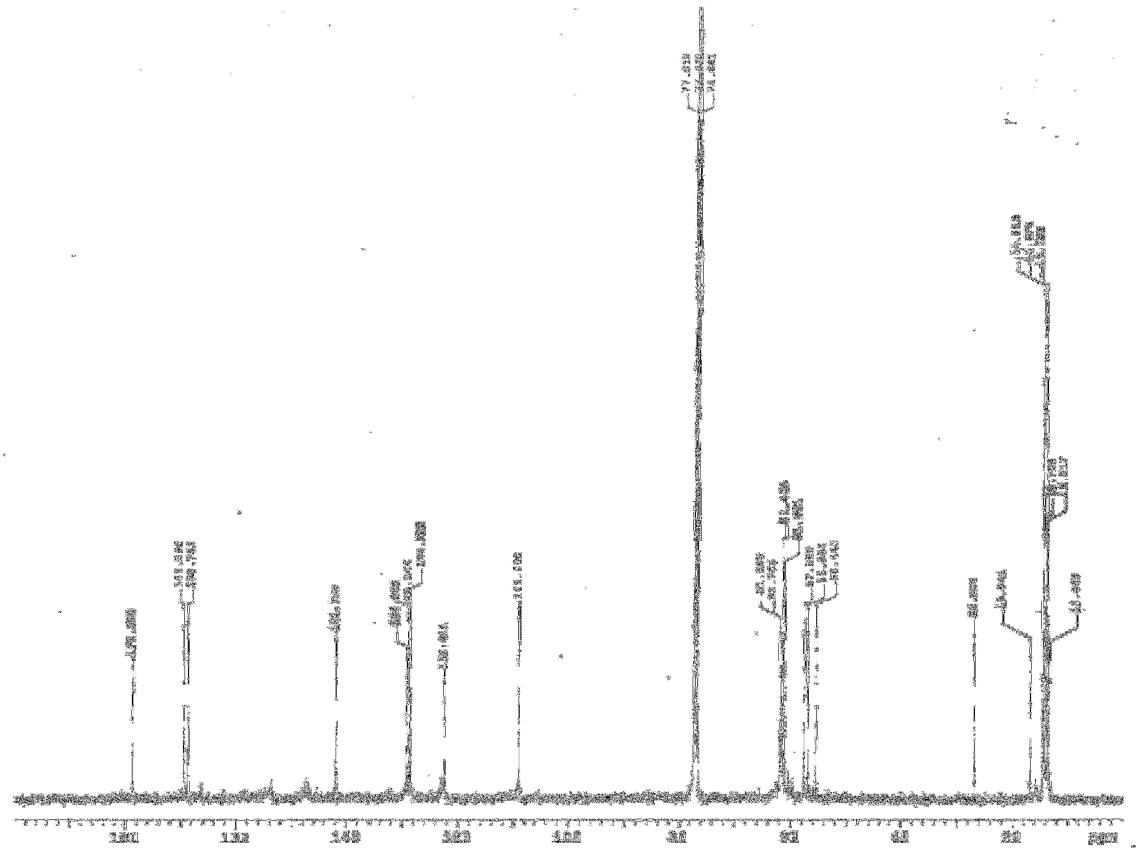

10
9
8
7
6
5
4
3
2
1
ppm
0.83
0.85
1.84
0.98
1.00
0.84
1.02
1.69
5.74
26.59

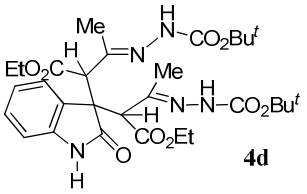

180
160
140
120
100
80
60
40
20
ppm



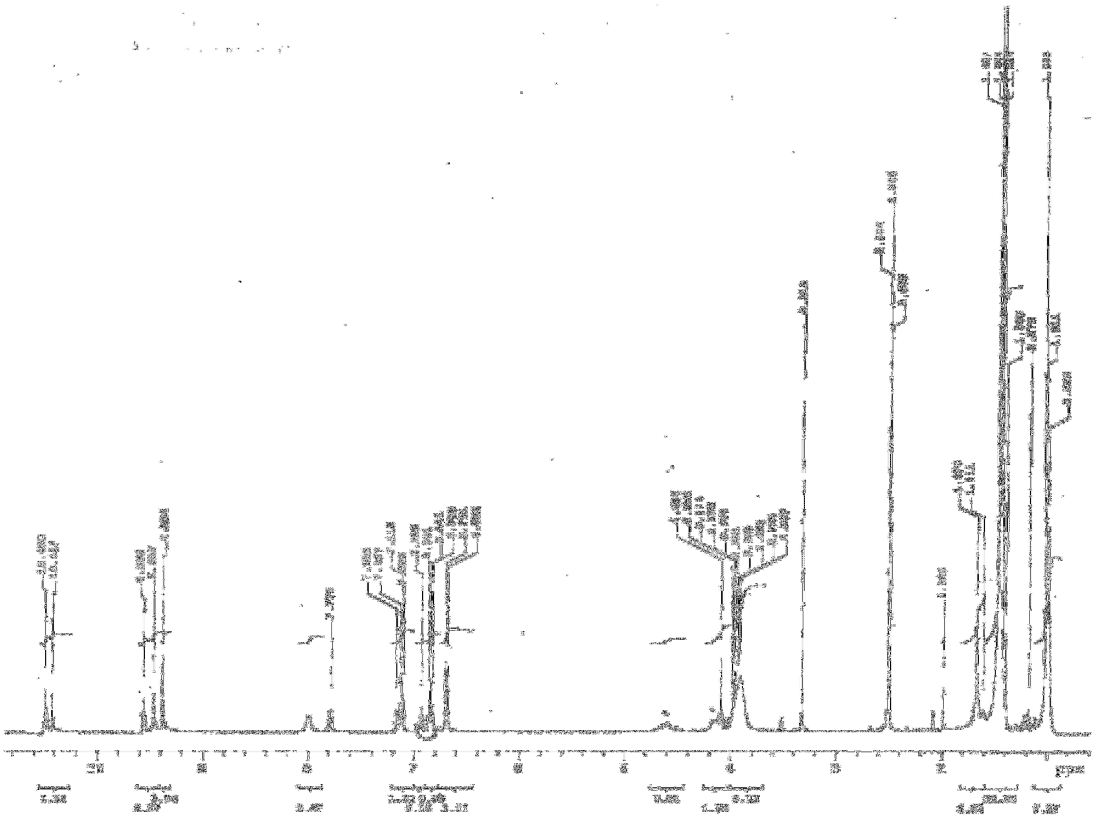
4c

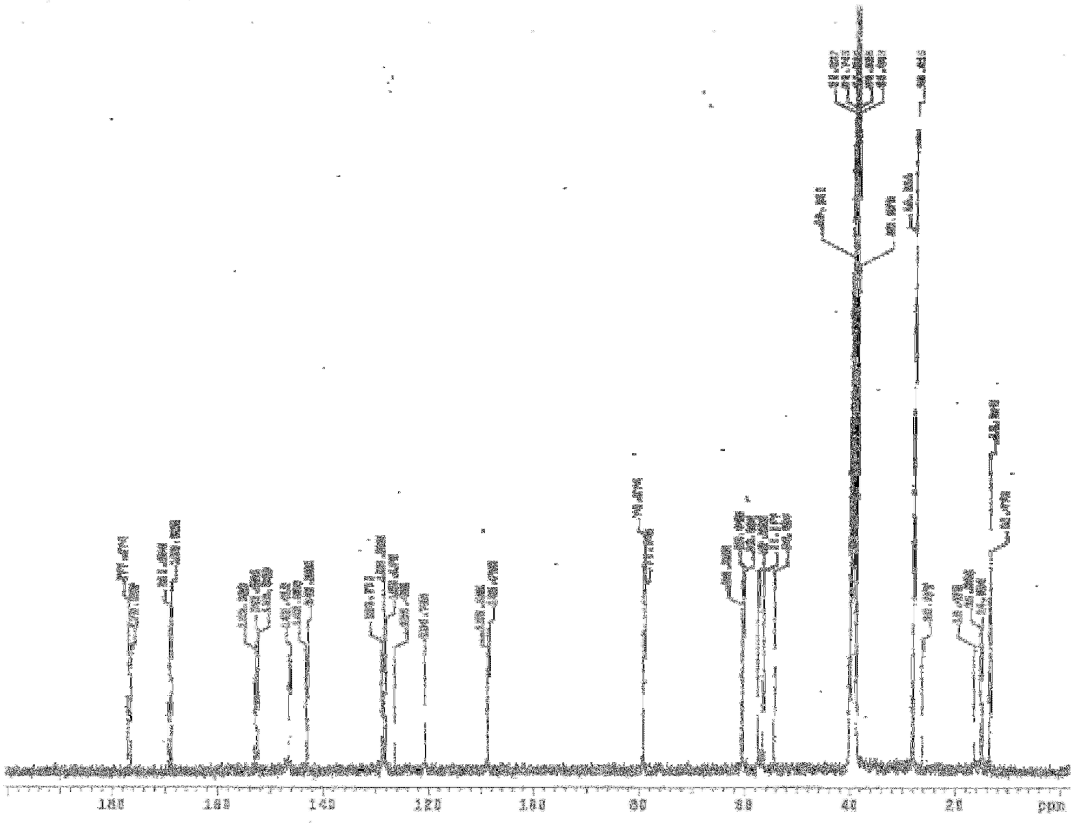


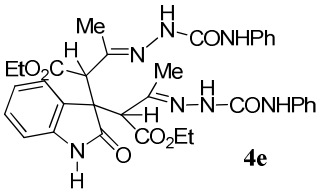



Me
H
N
CO2But
EtO2C
Me
H
N–N–CO2But
H
CO2Et
N
H
O

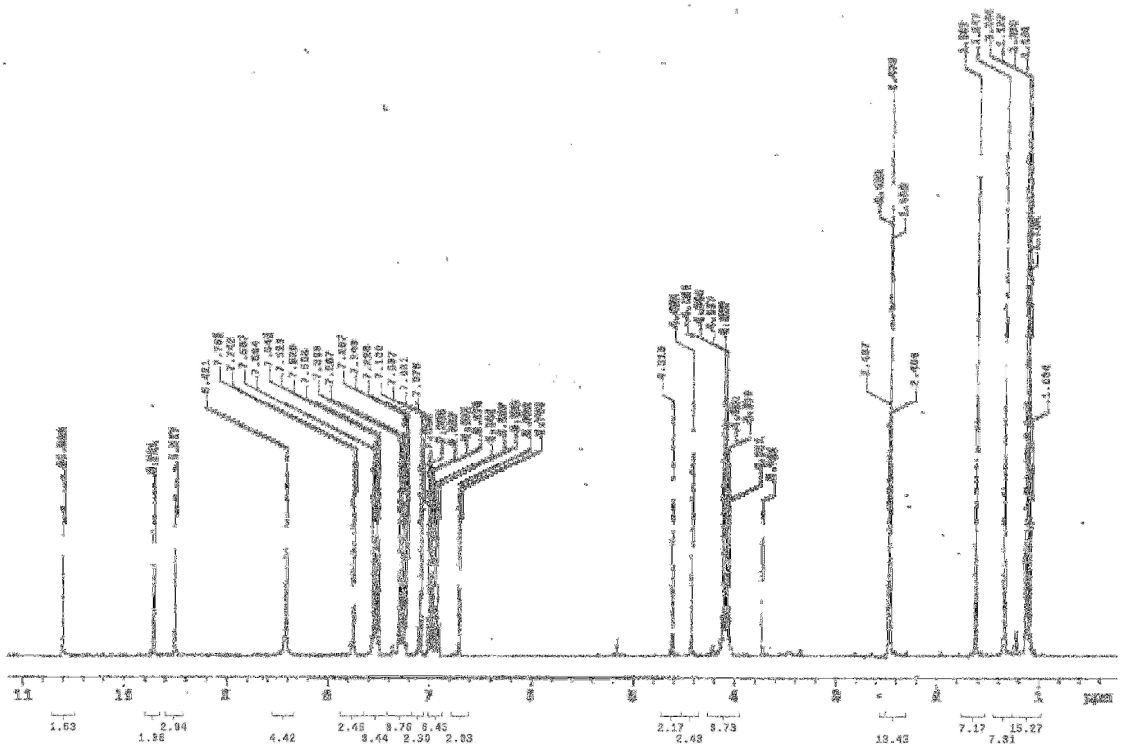
4d

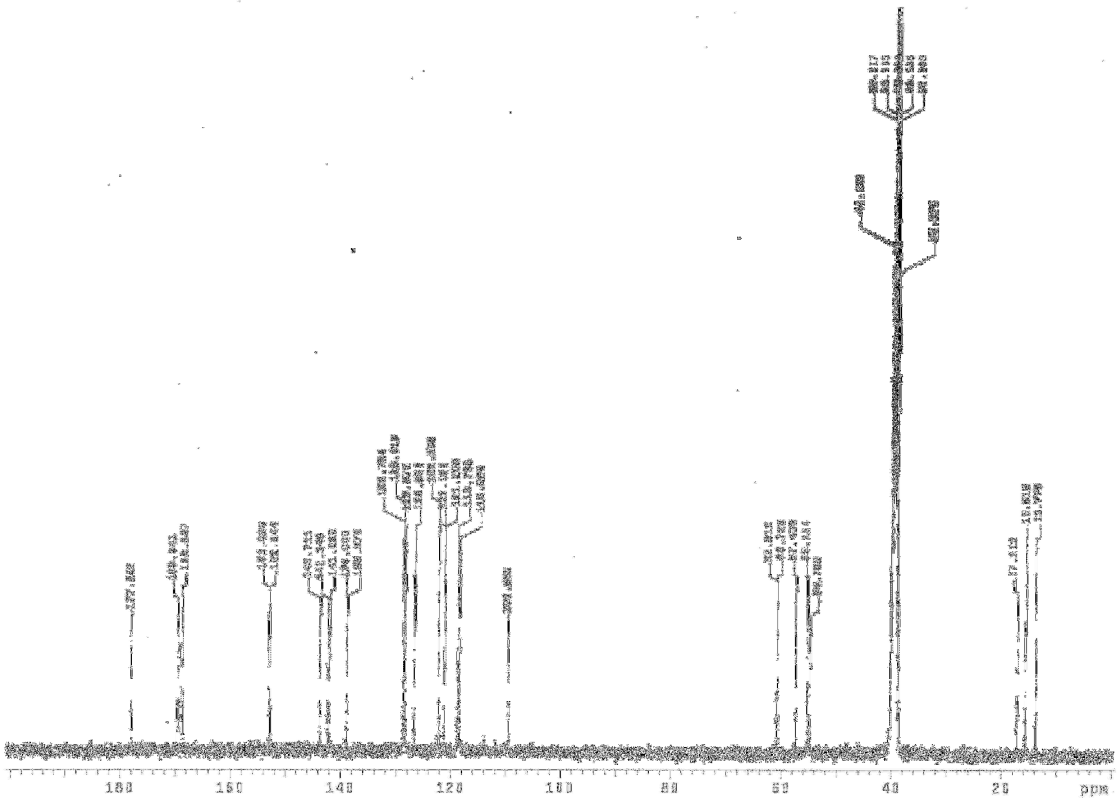


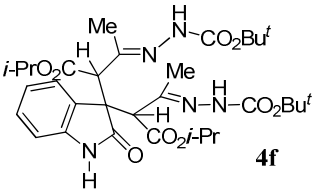

160
140
120
100
80
60
40
20
ppm



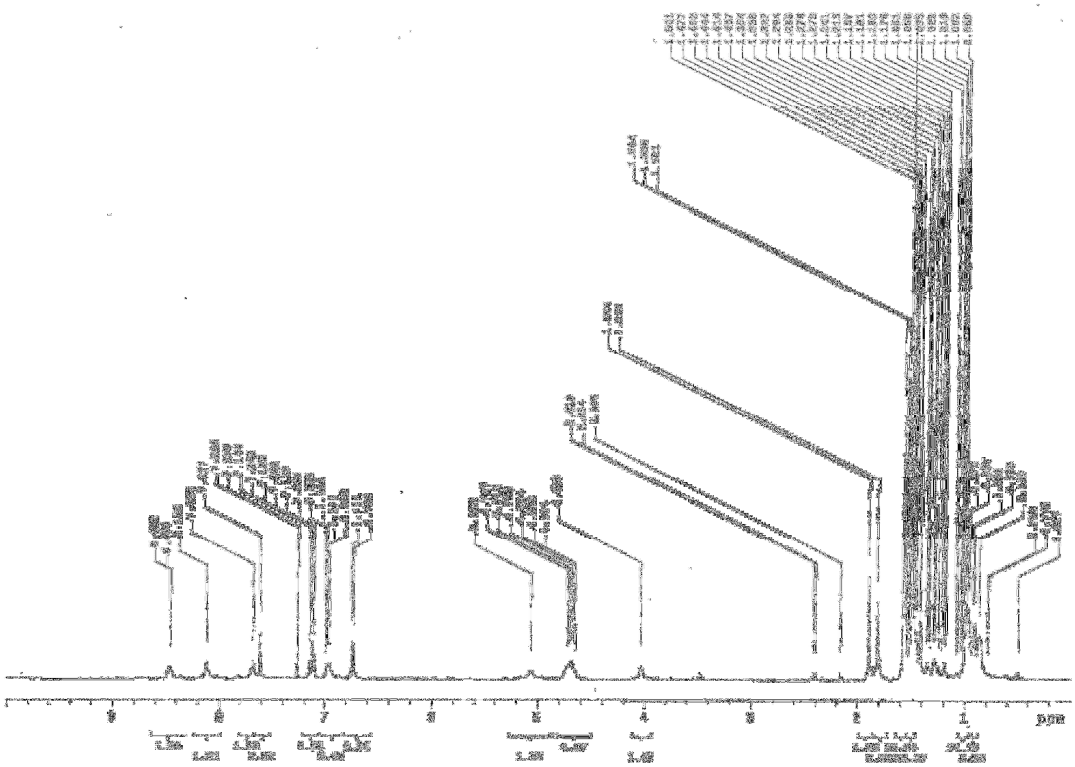
4e

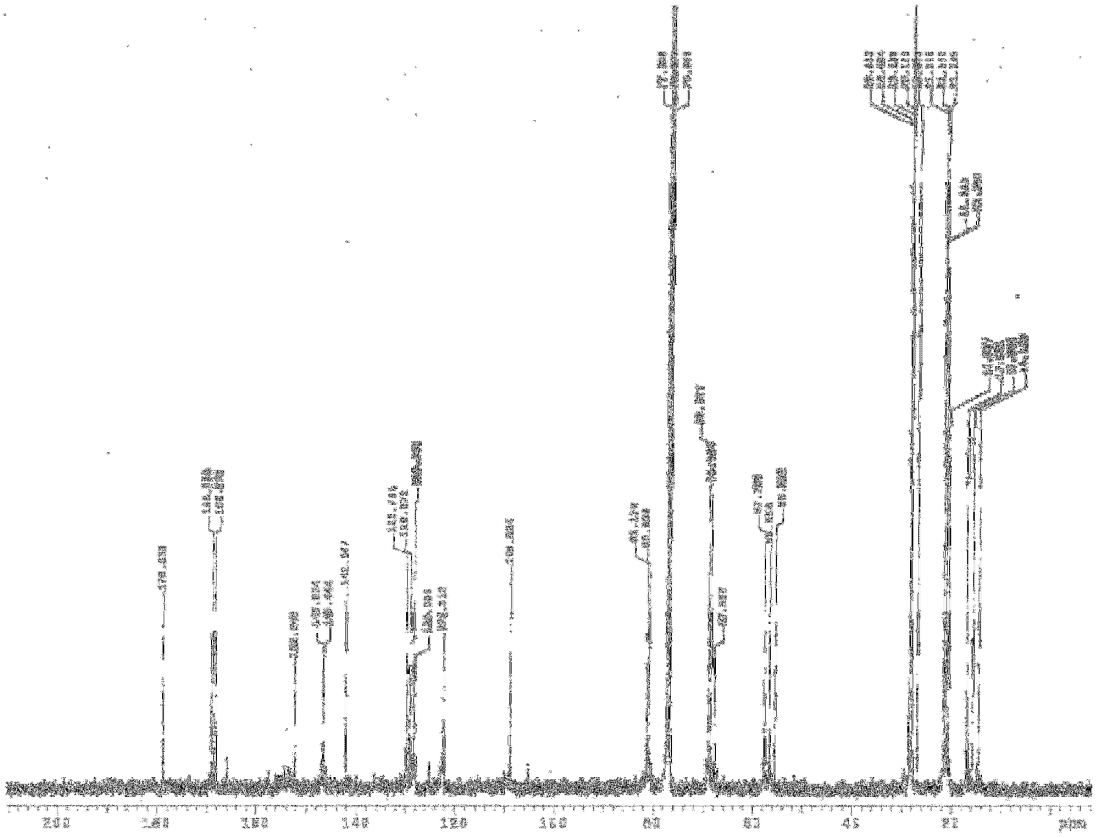


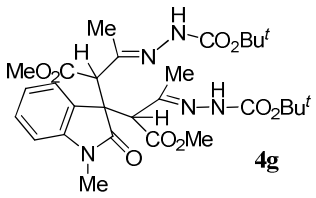




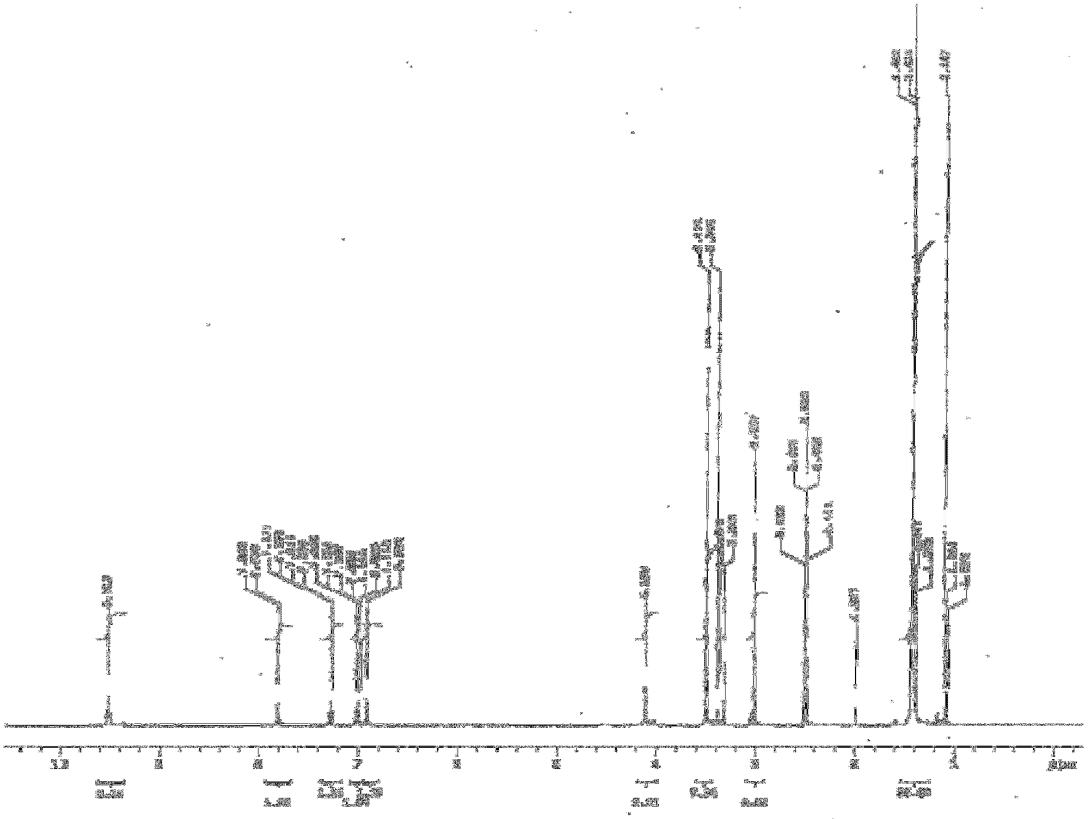
4f

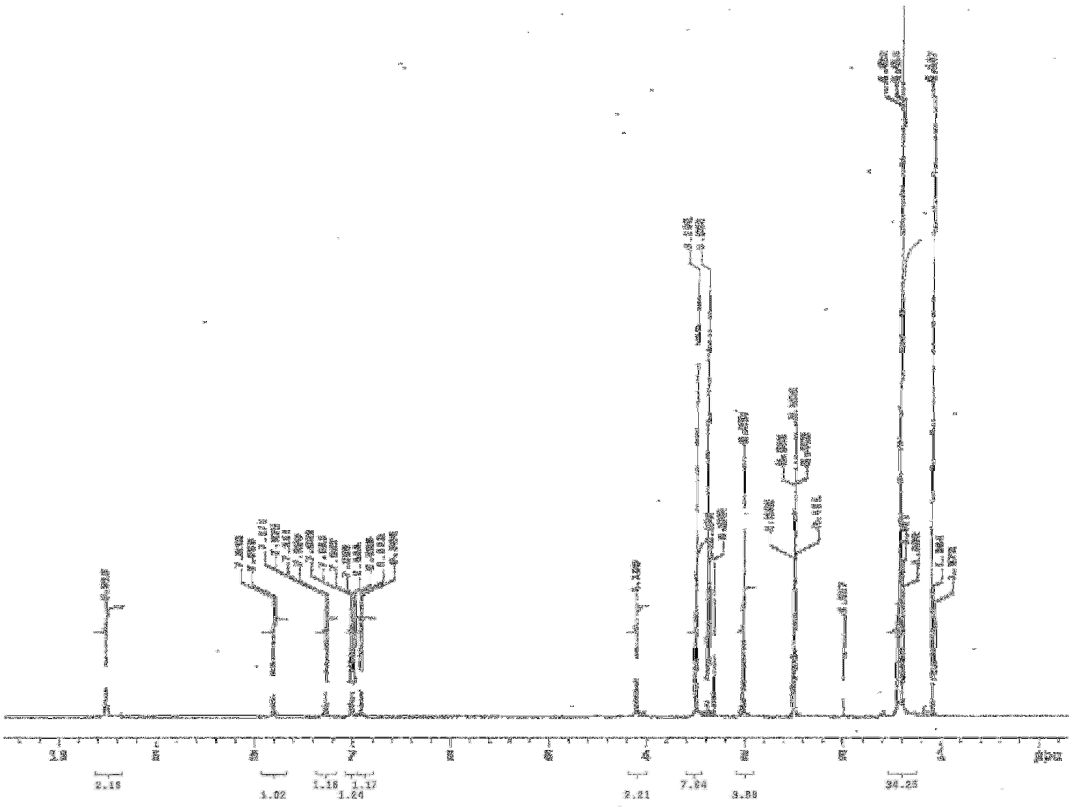


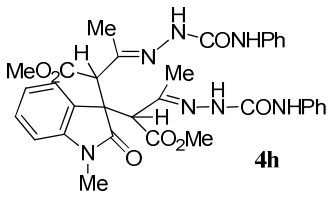




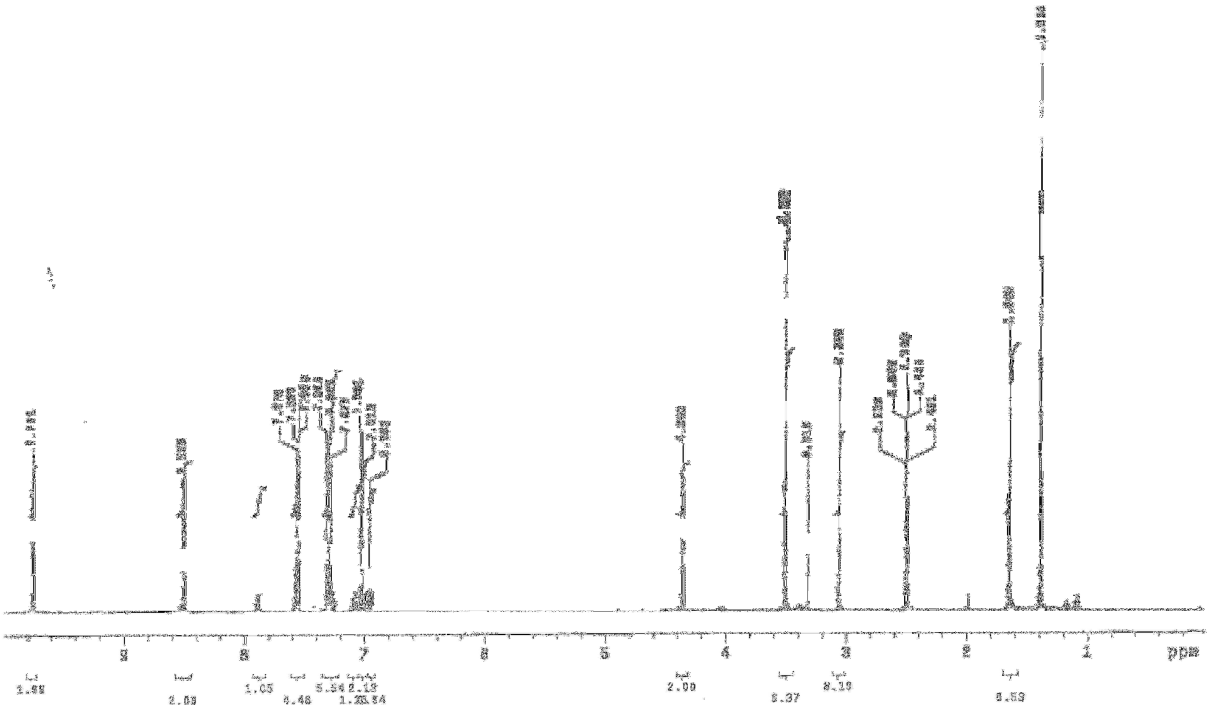
4g

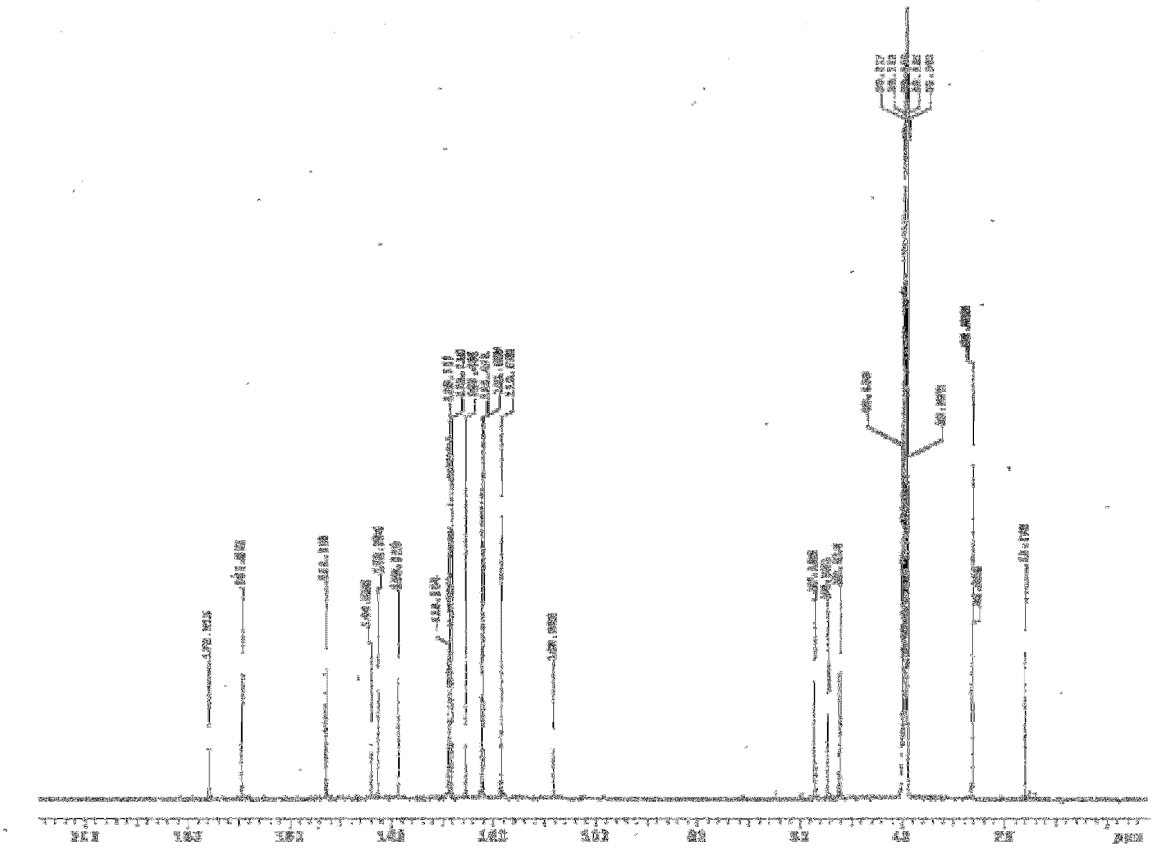


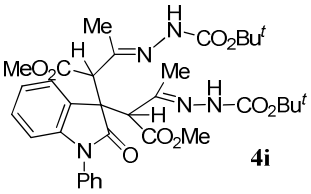




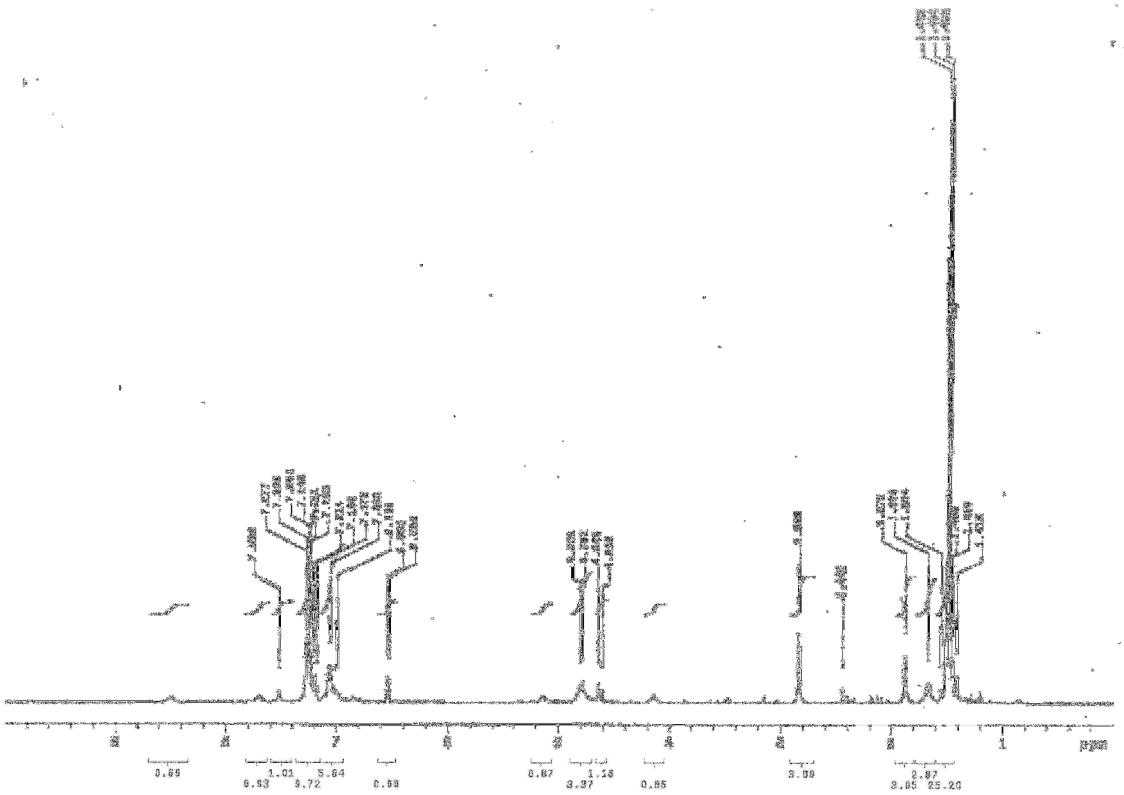
4h

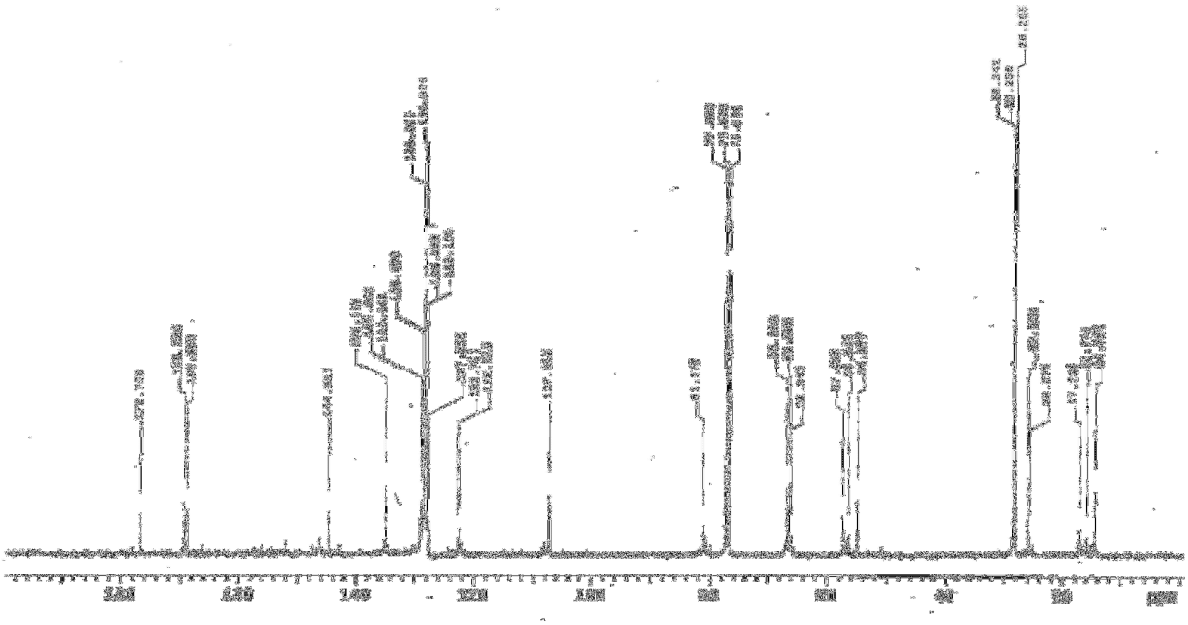


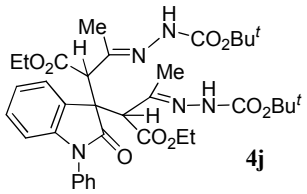




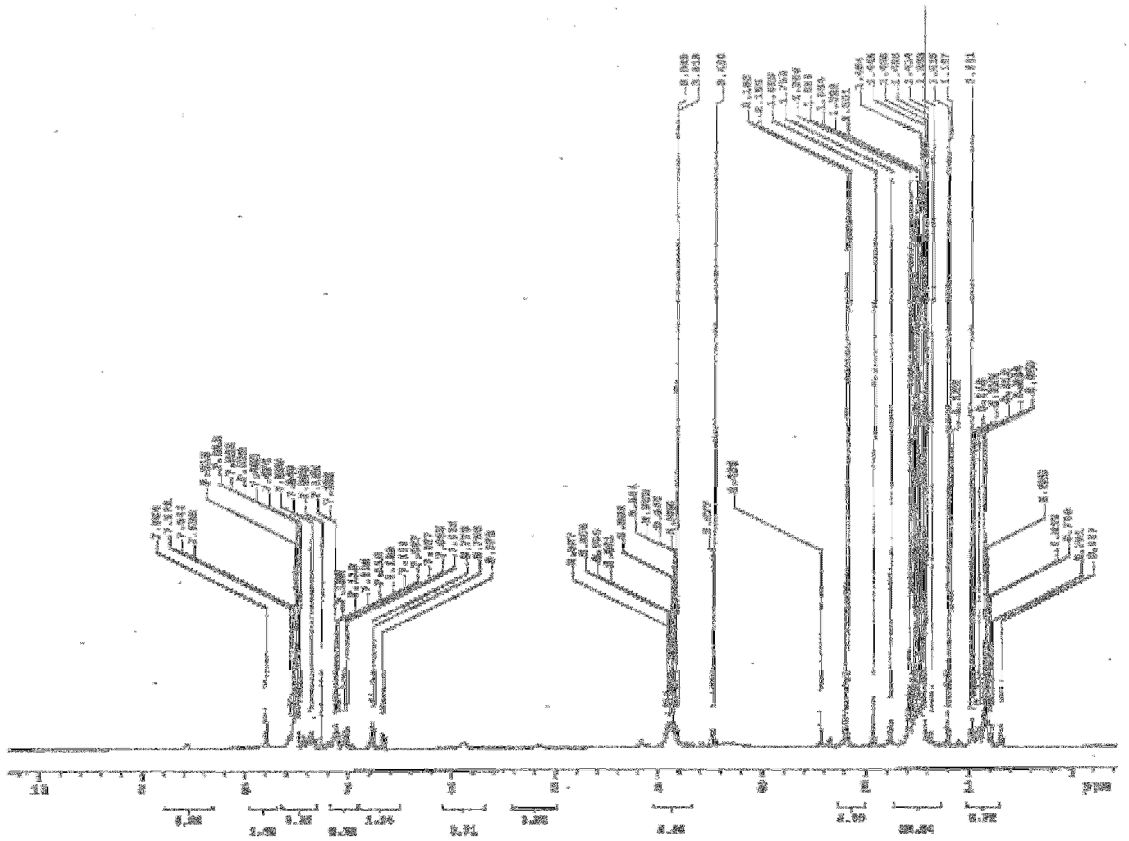
4i

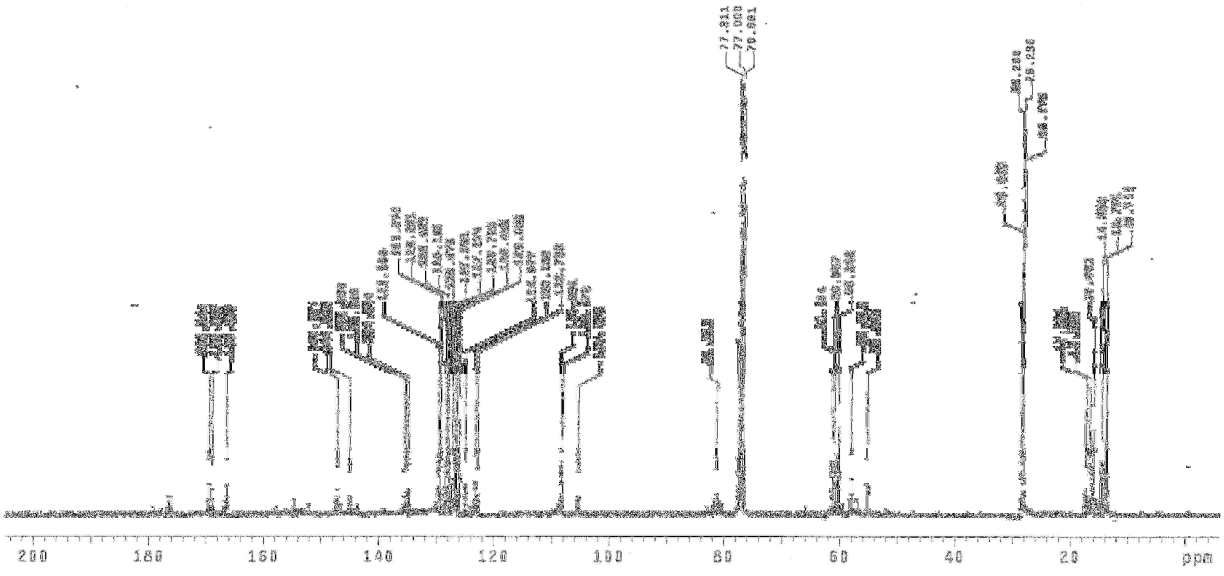


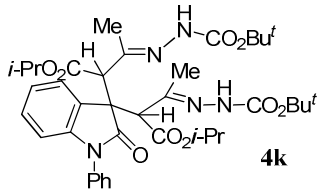



Me
H
N
CO2But
EtO2C
N
Me
H
N
N
CO2But
H
CO2Et
N
O
Ph

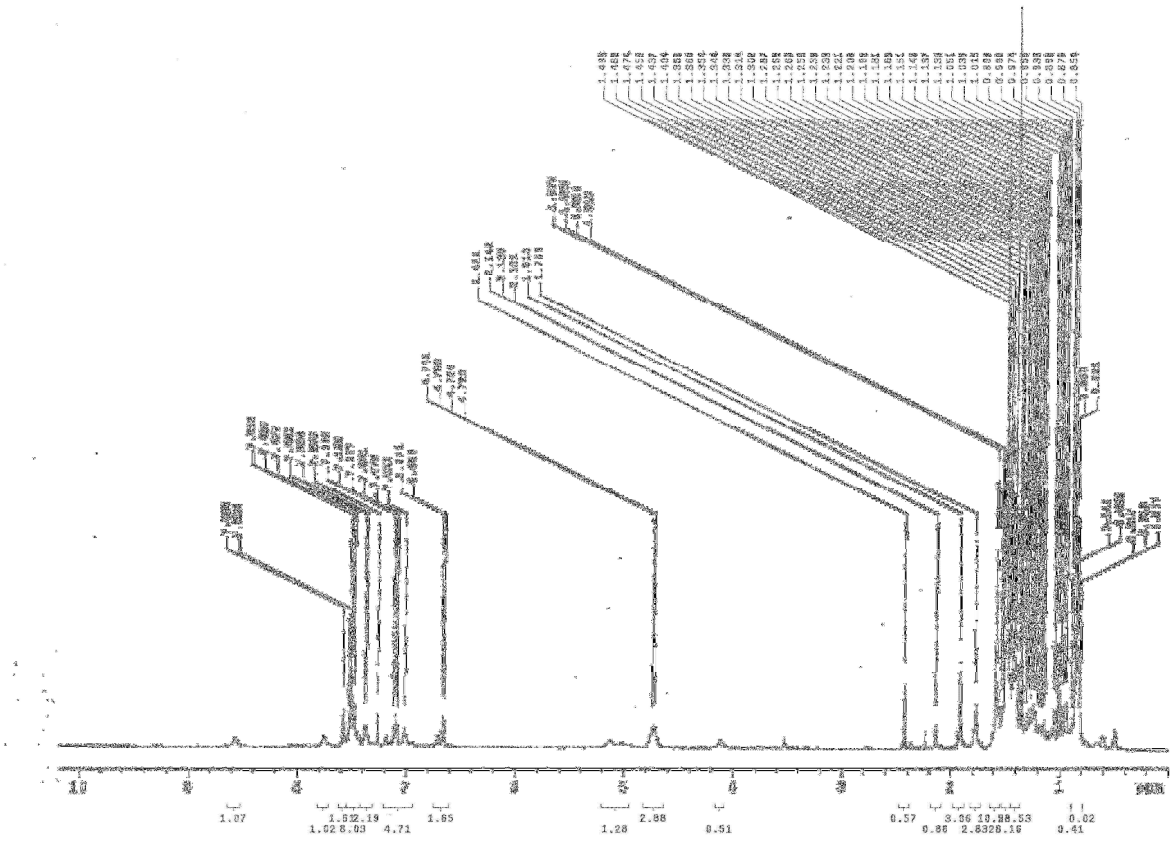
4j

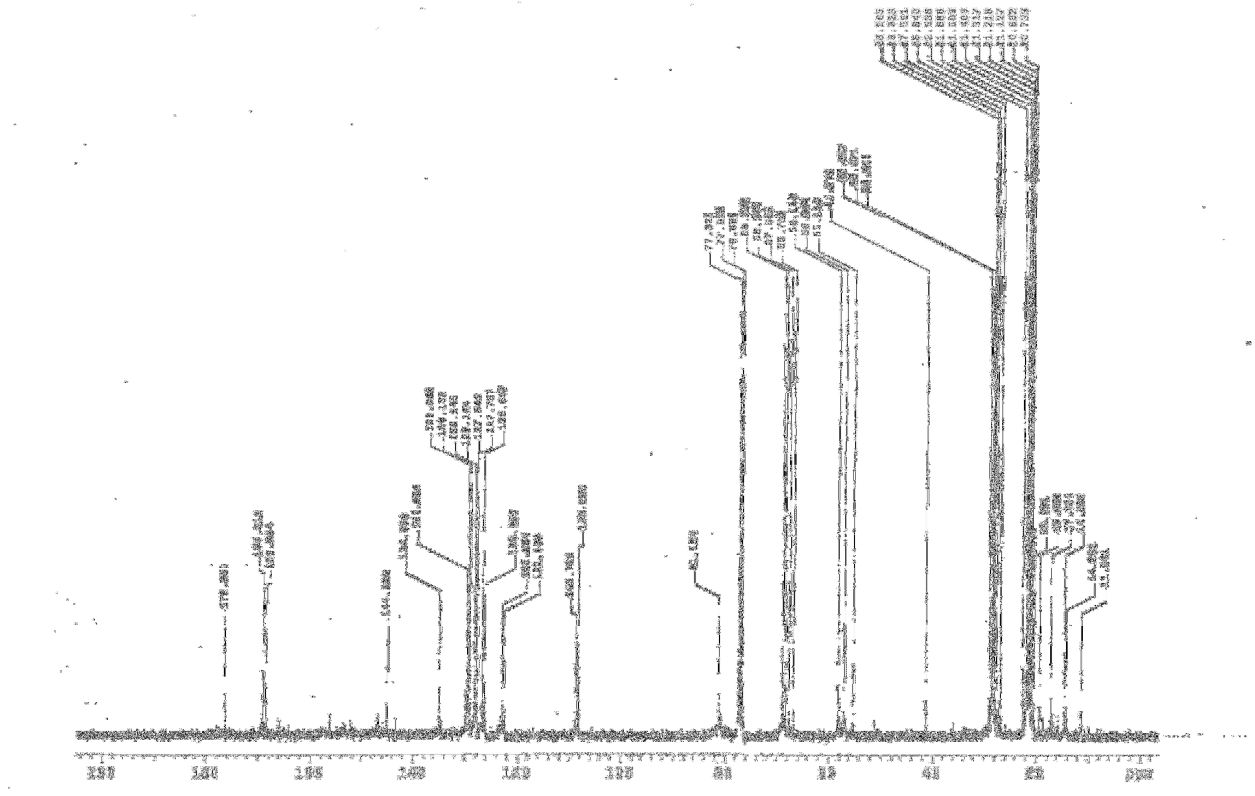


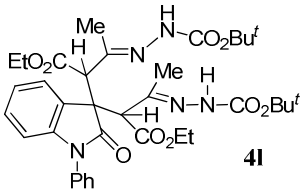

200
180
160
140
120
100
80
60
40
20
ppm



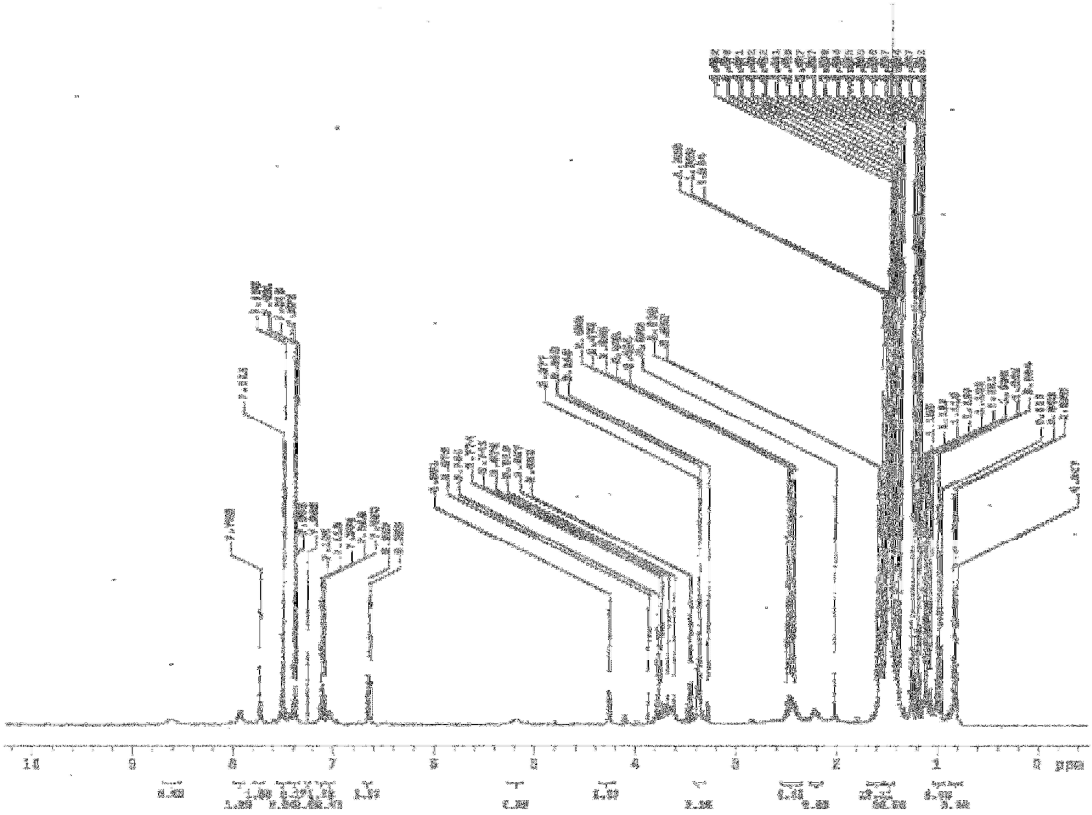
4k

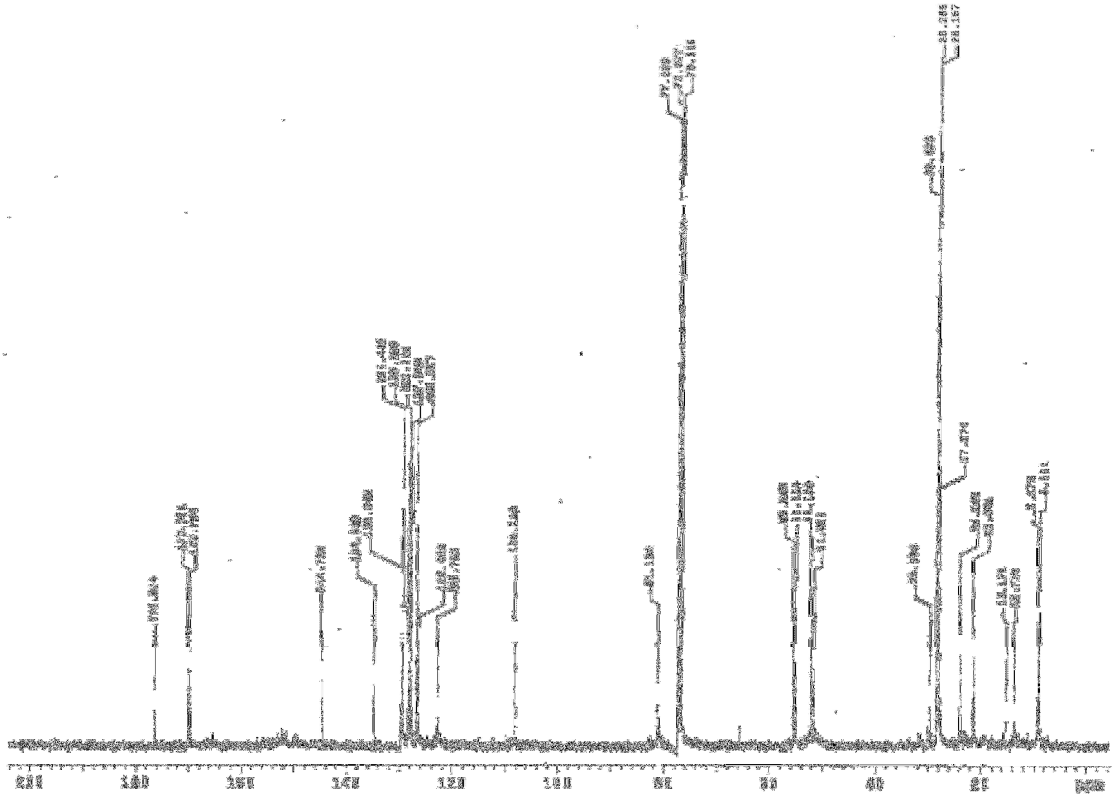


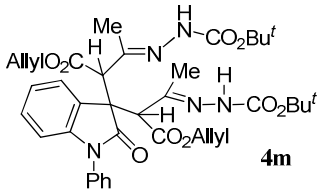




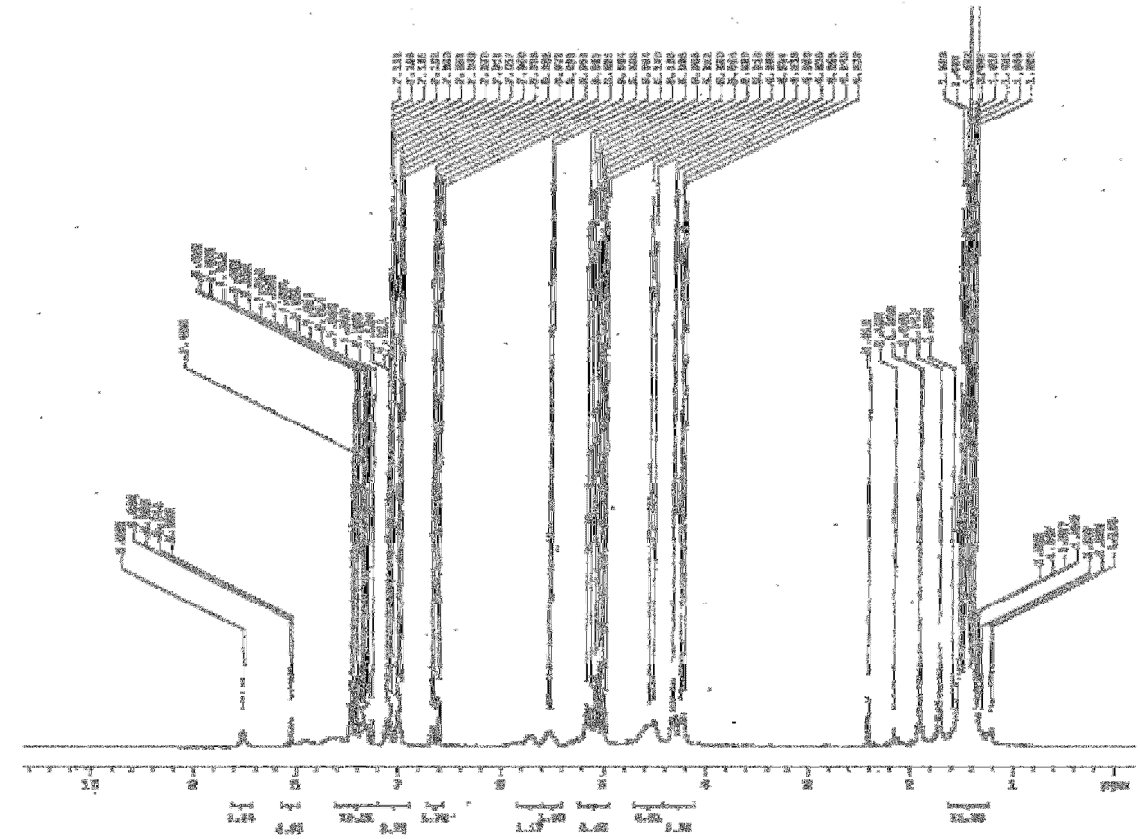
4l

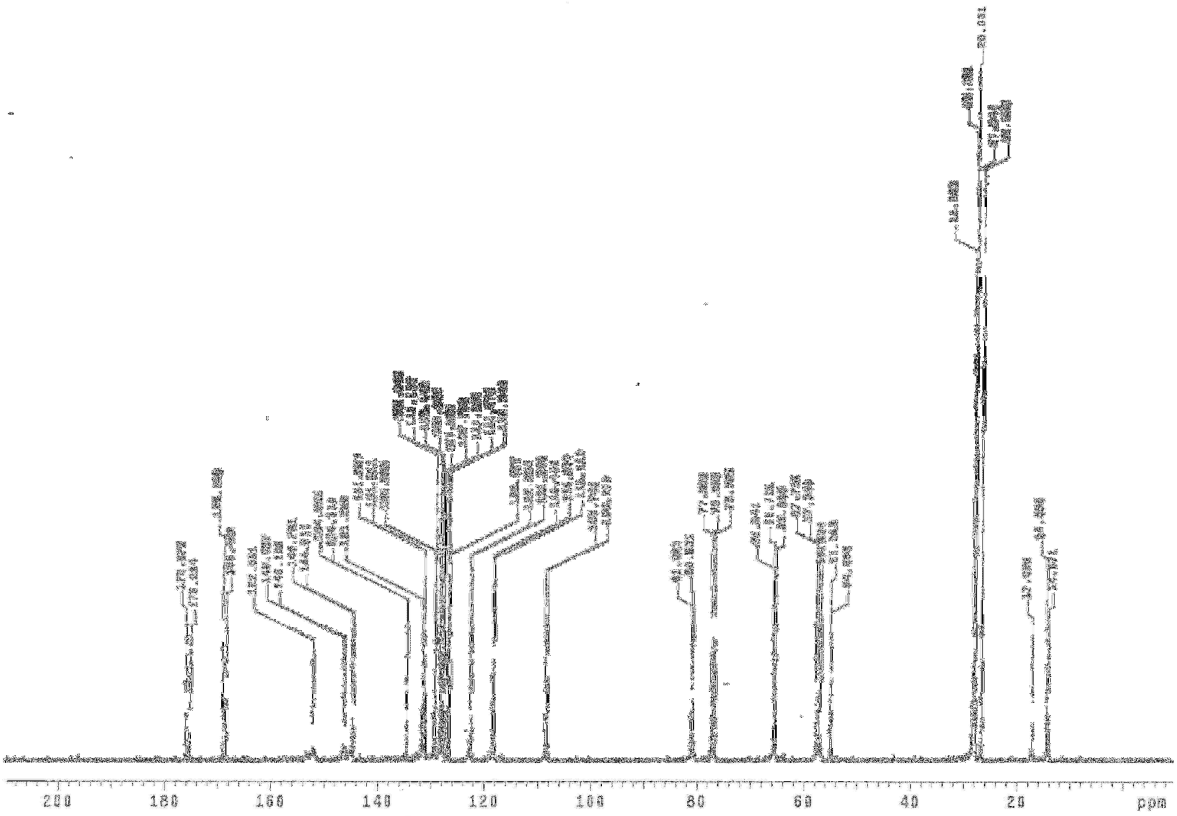


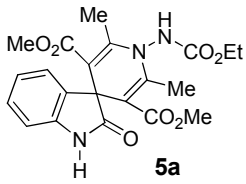



Me
H
N
CO2But
AllylO2C
Me
H
N
N
CO2But
H
CO2Allyl
O
N
Ph

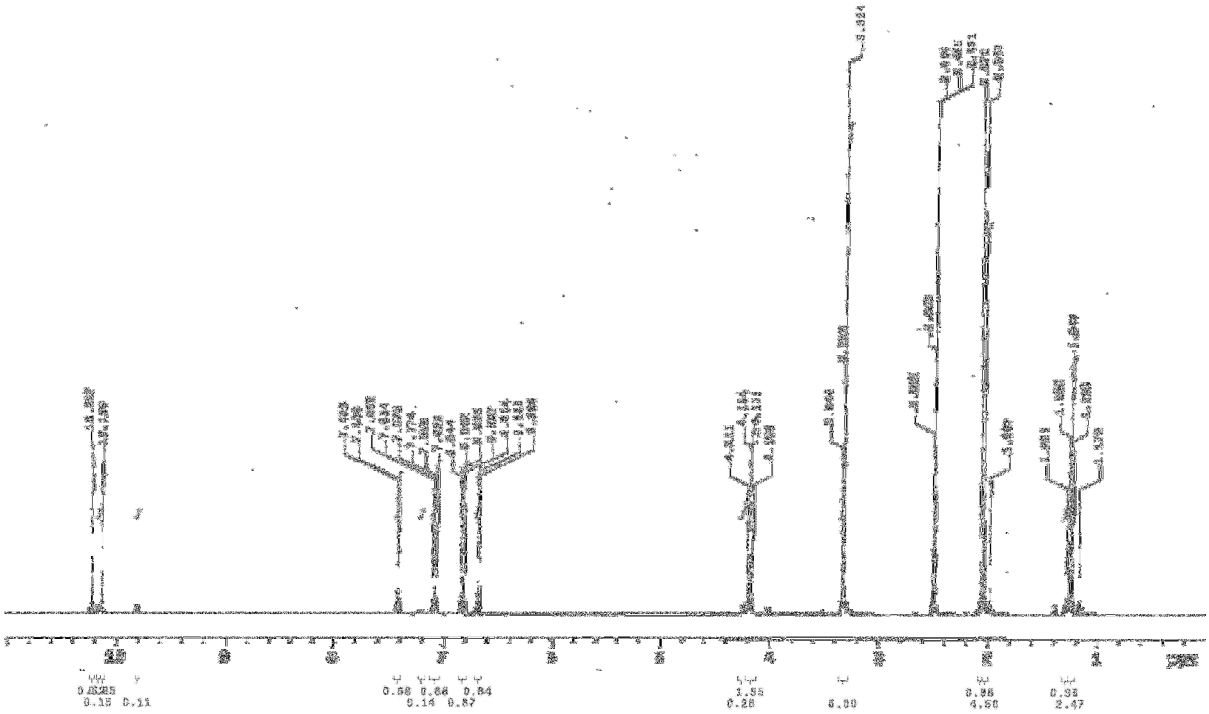
4m

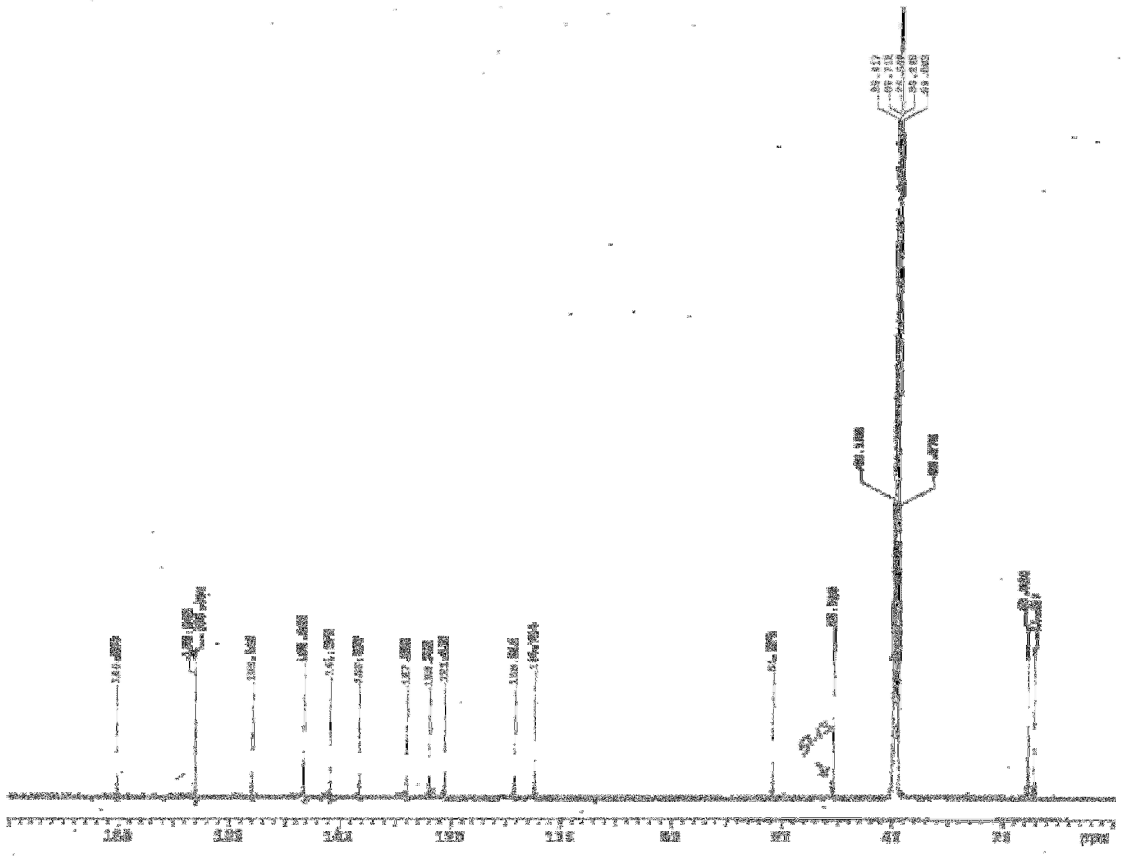


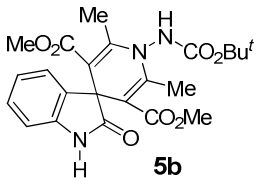

200
180
160
140
120
100
80
60
40
20
ppm



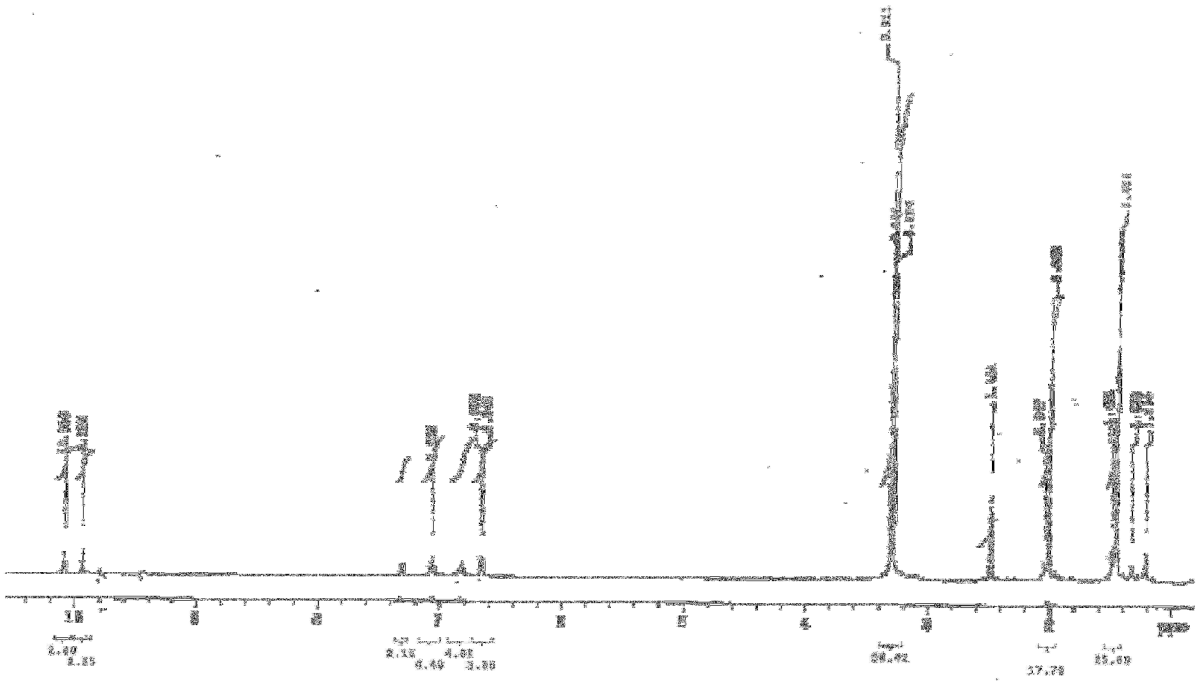
5a

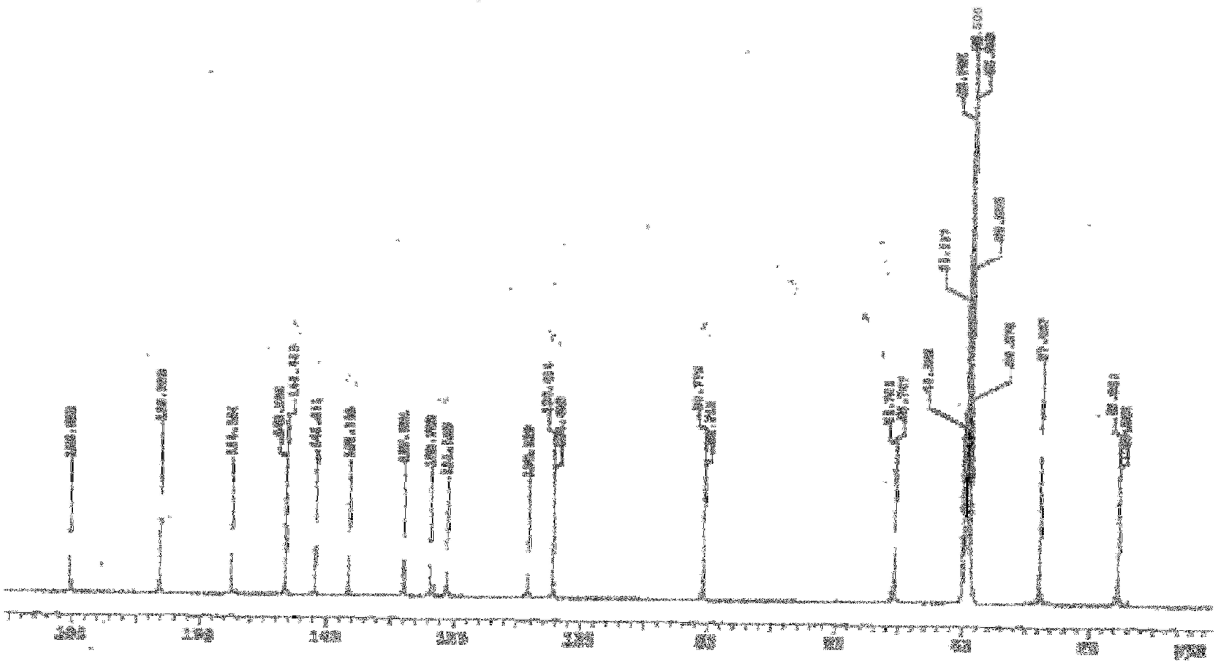


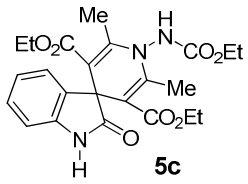




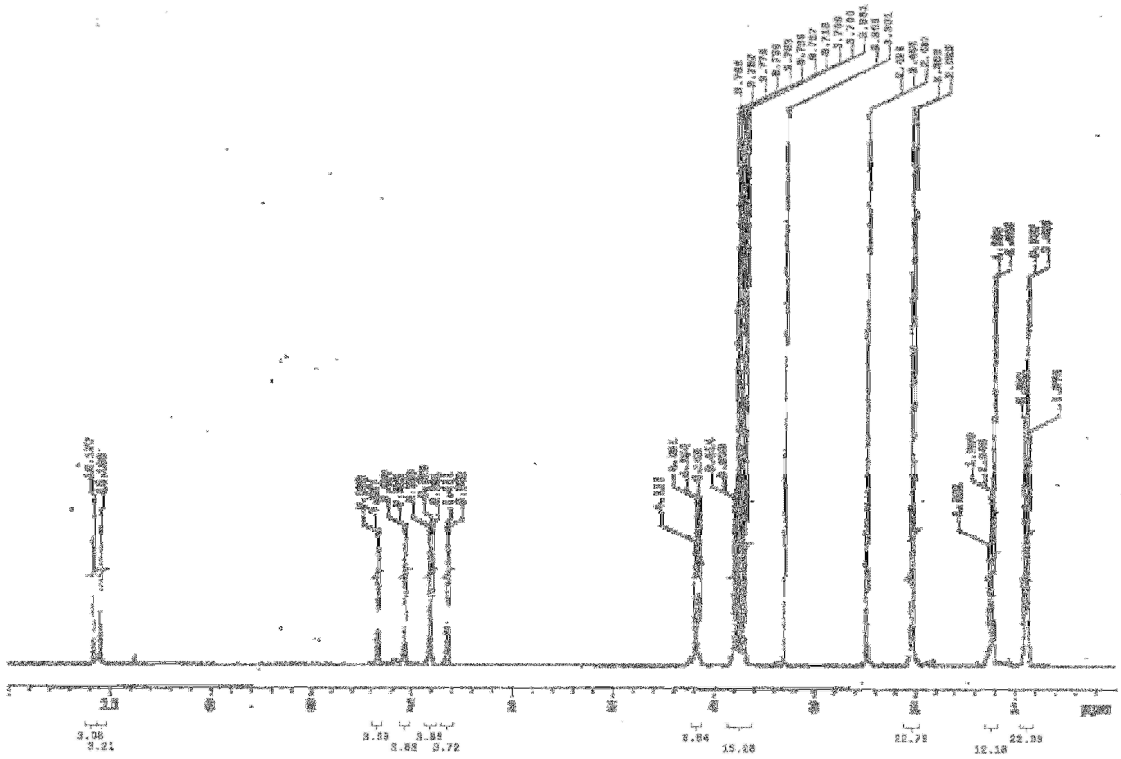
5b

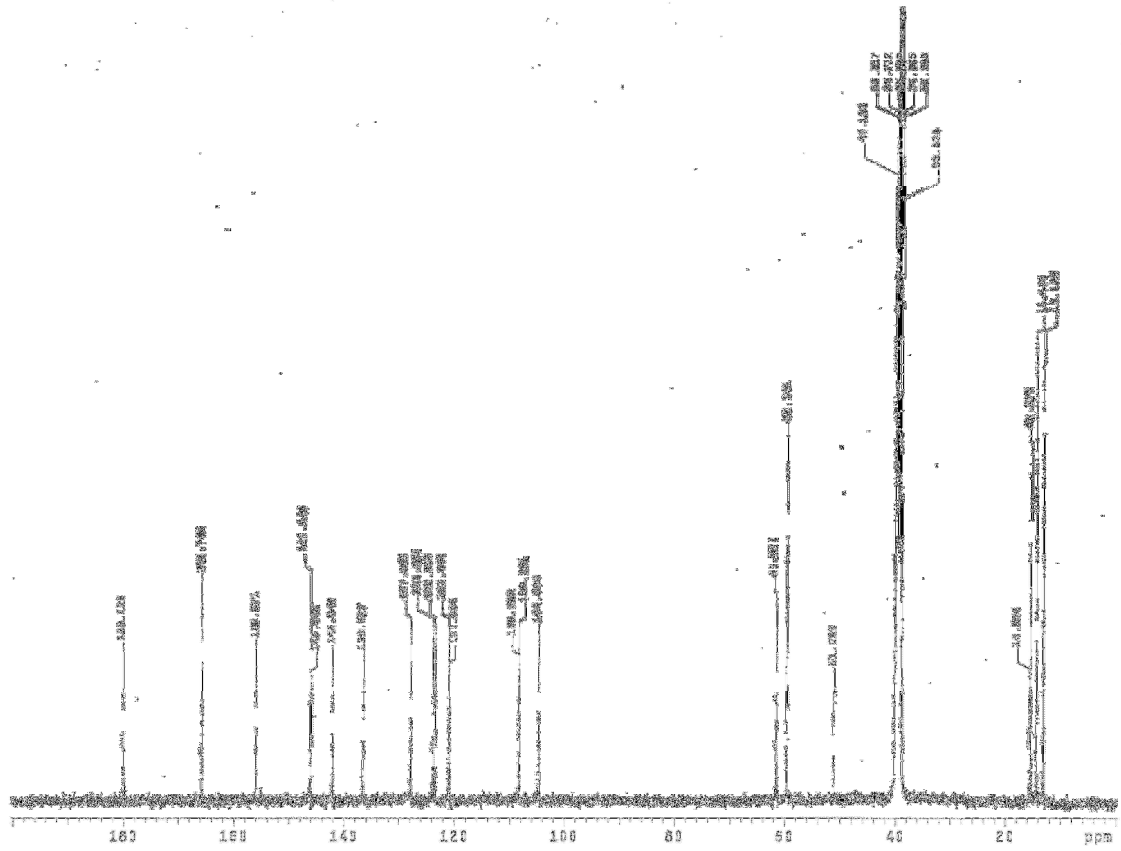


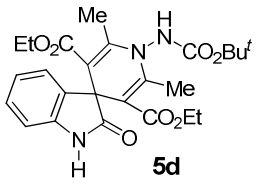




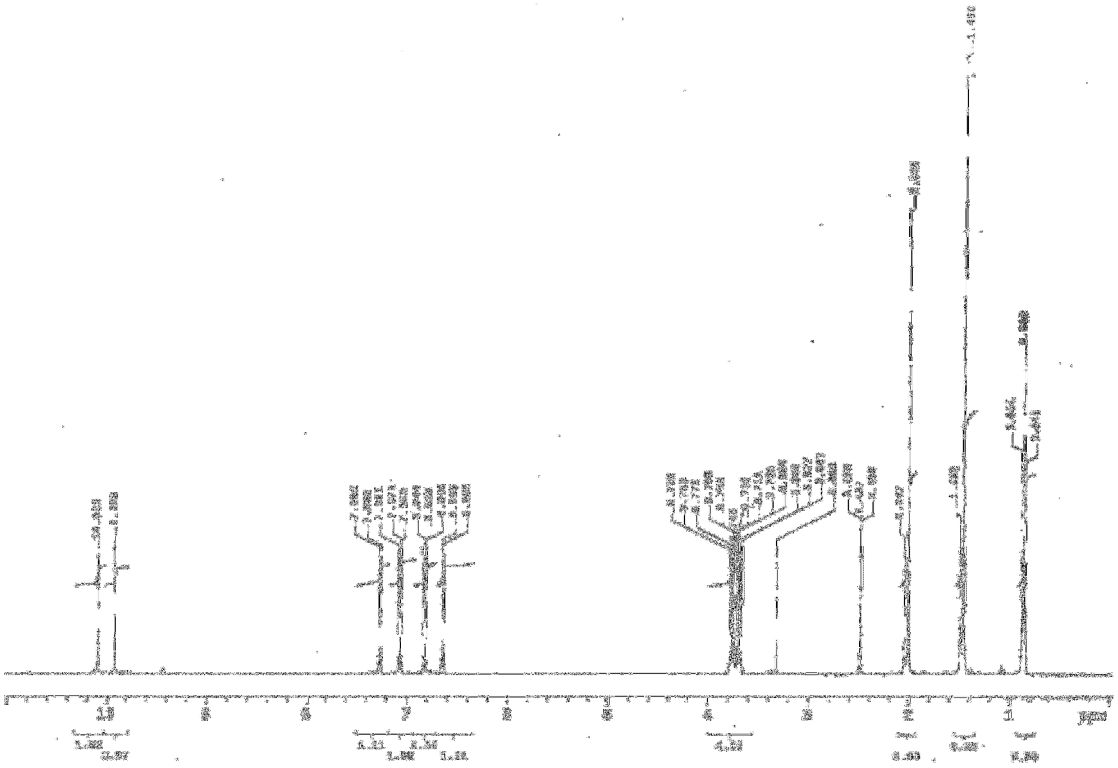
5c

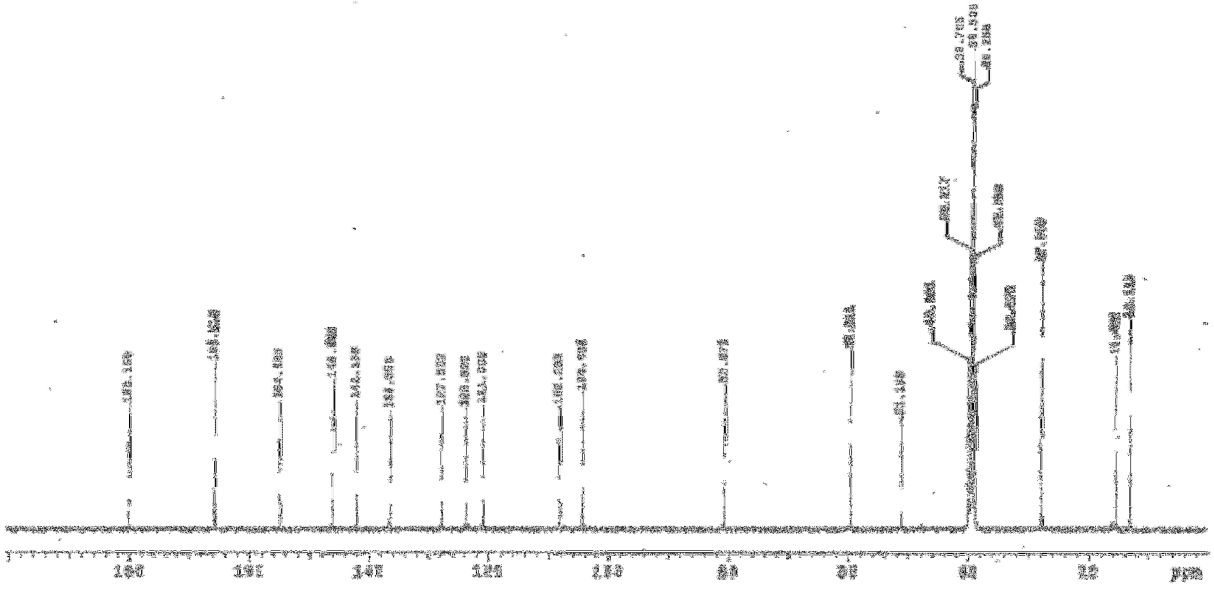


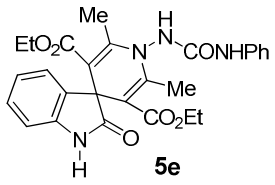




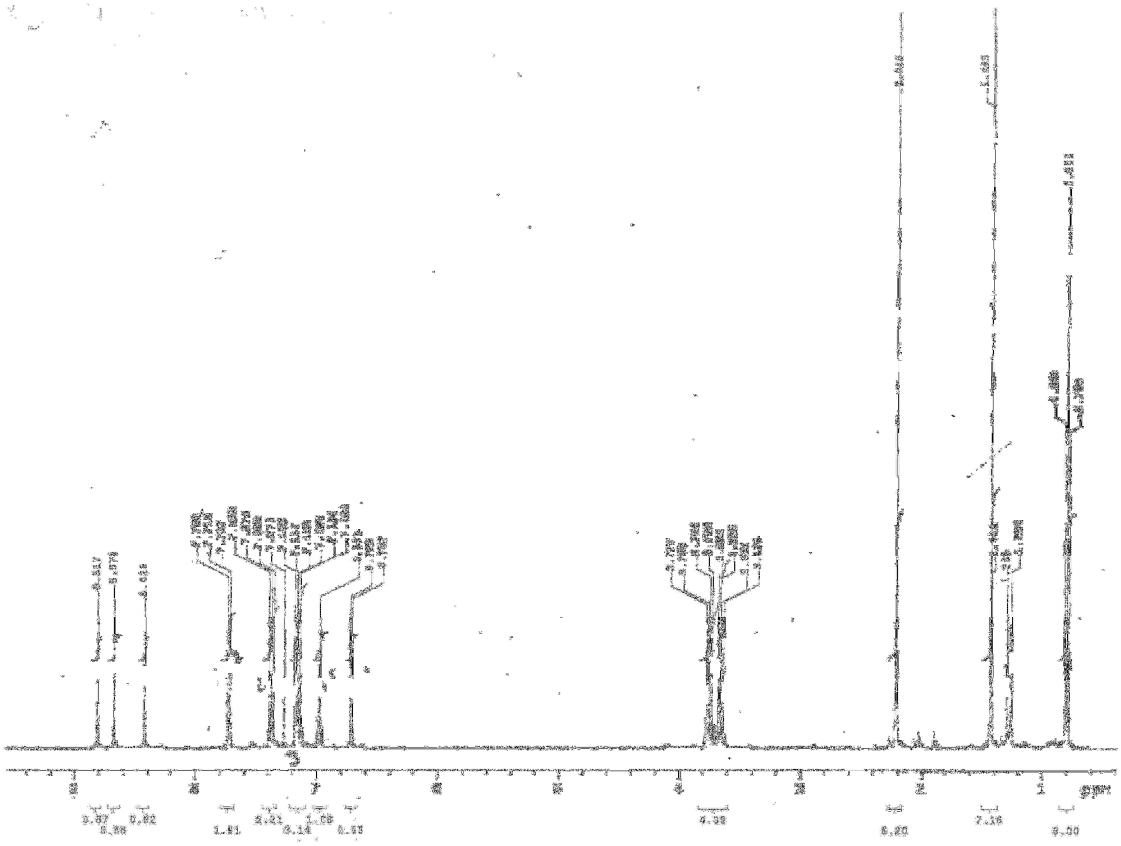
5d

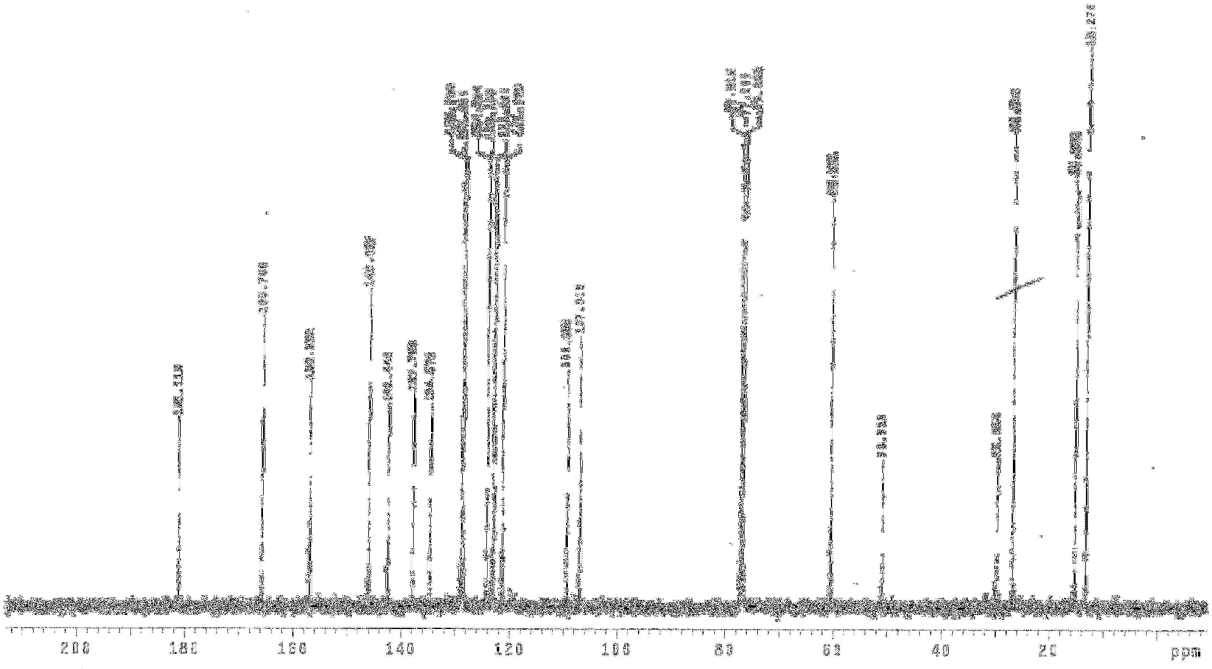


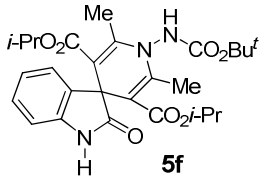



Me
H
N
EtO2C
N
CONHPh
Me
CO2Et
N
O
H

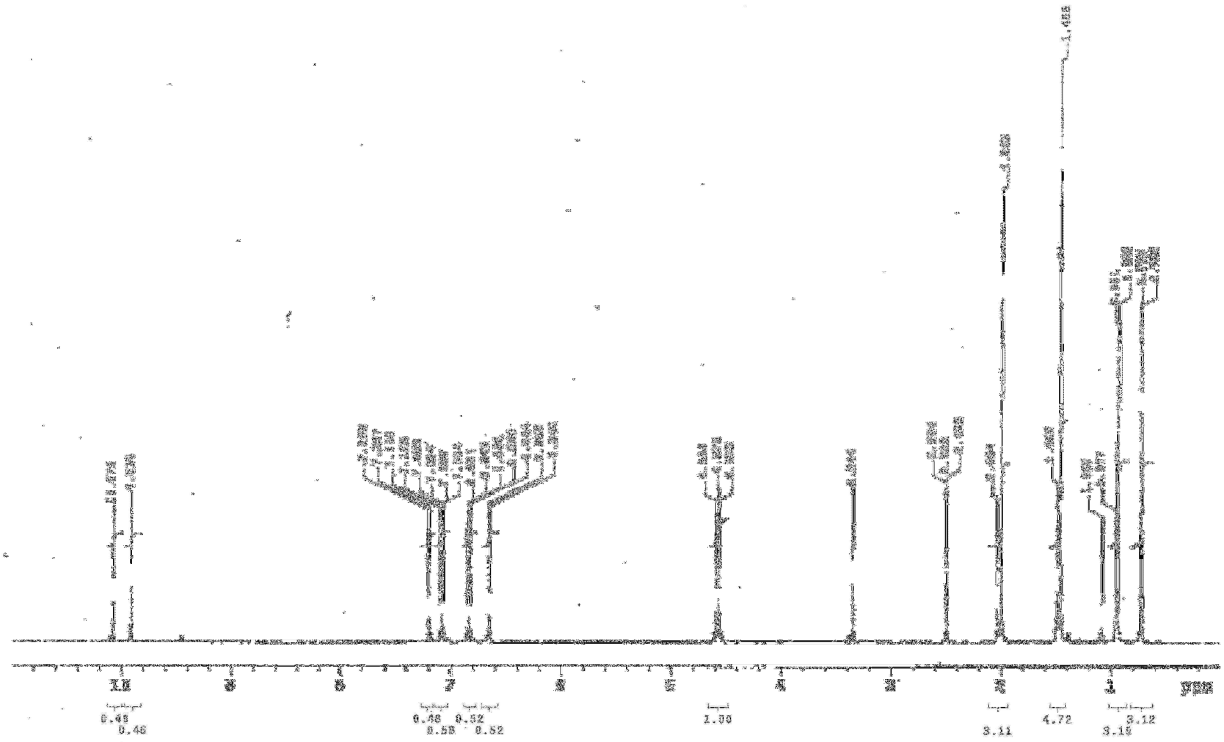
5e

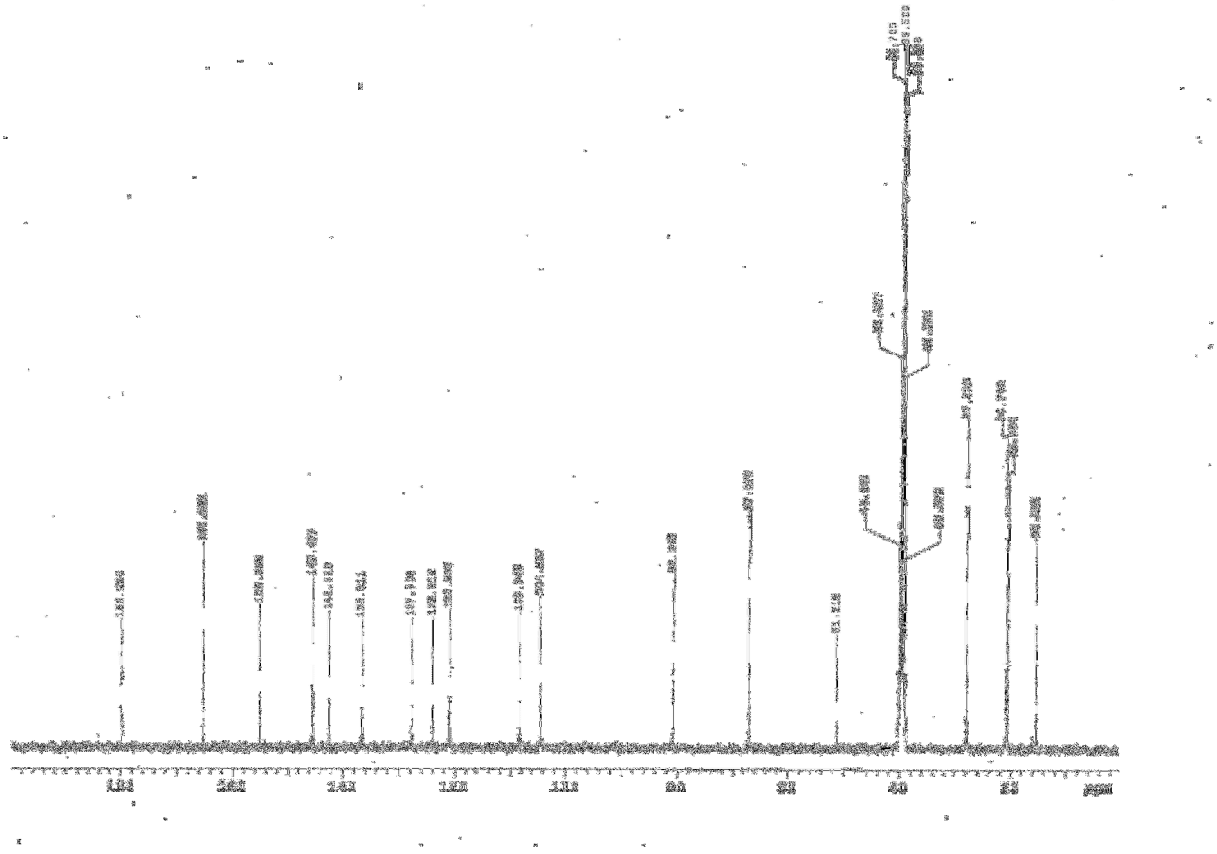


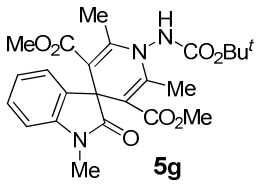

200
180
160
140
120
100
80
60
40
20
ppm



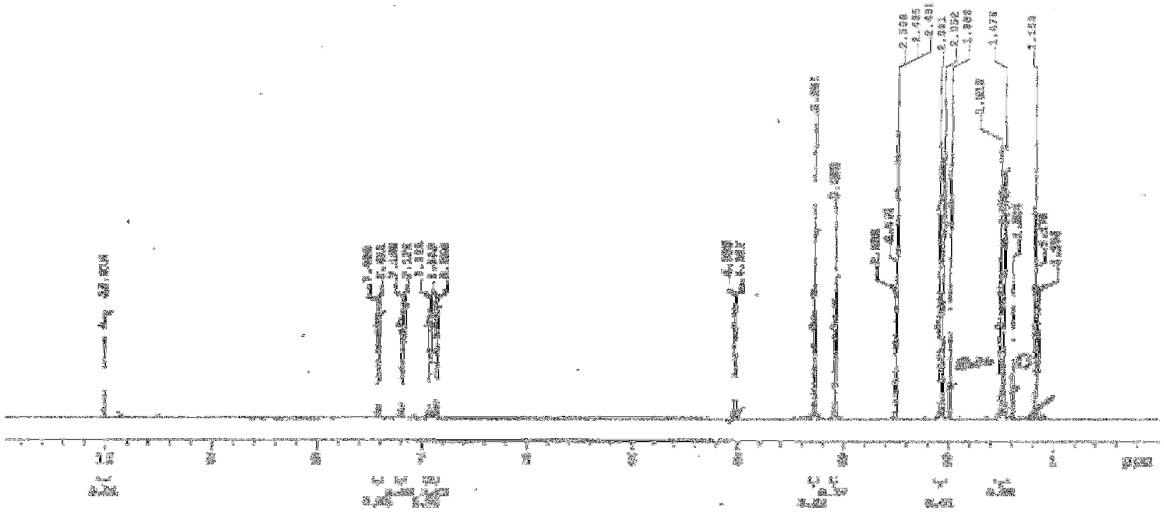
5f

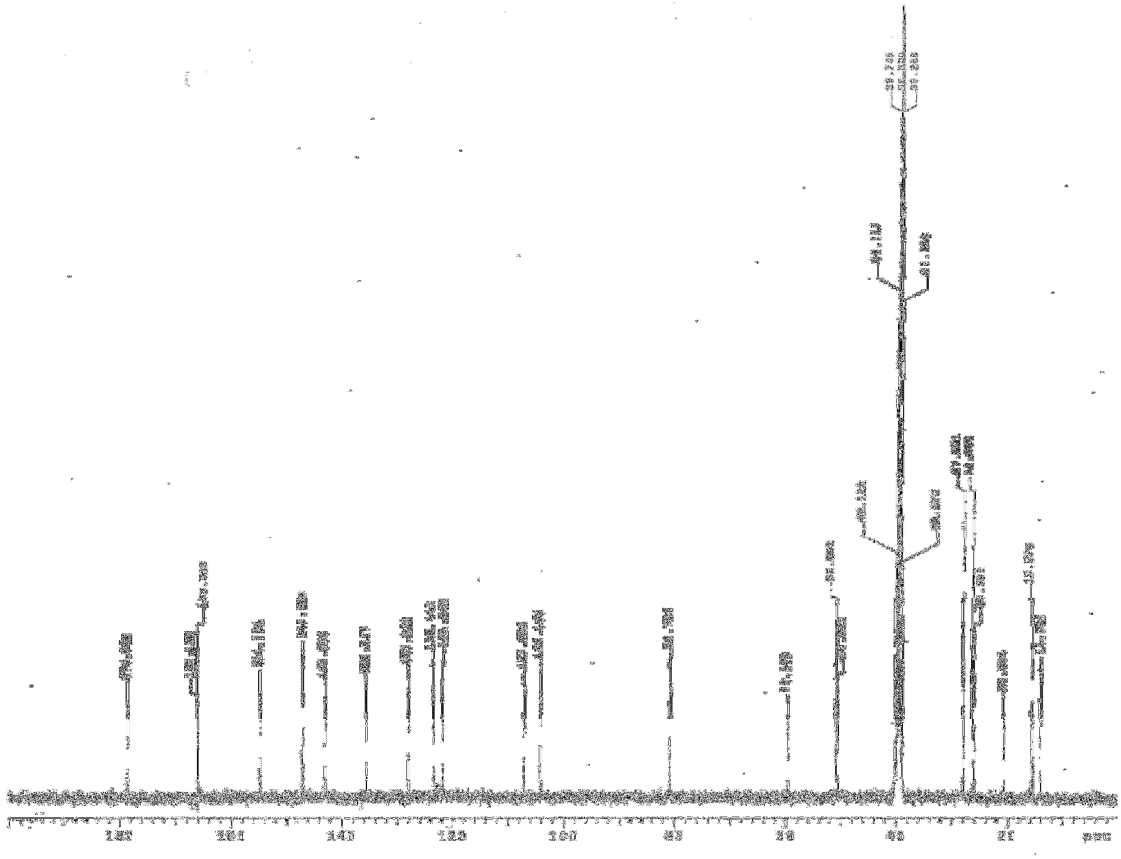


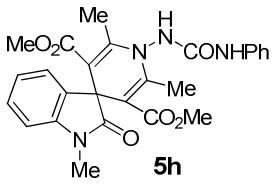




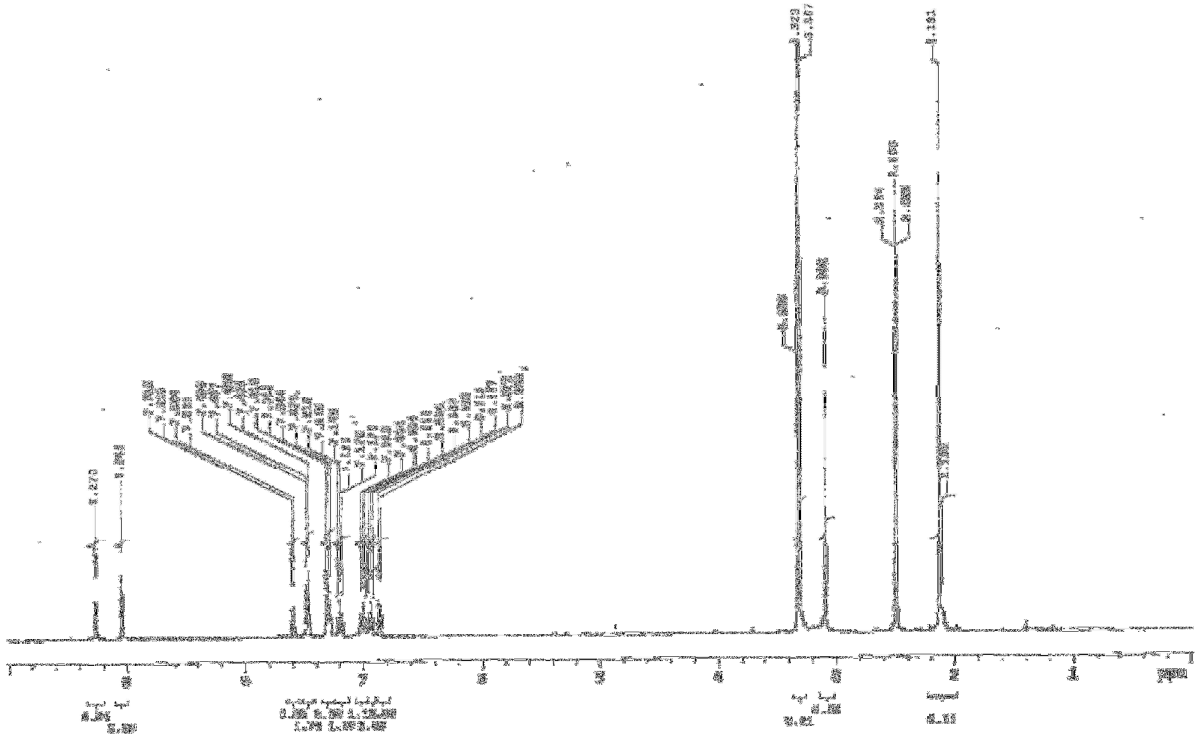
5g

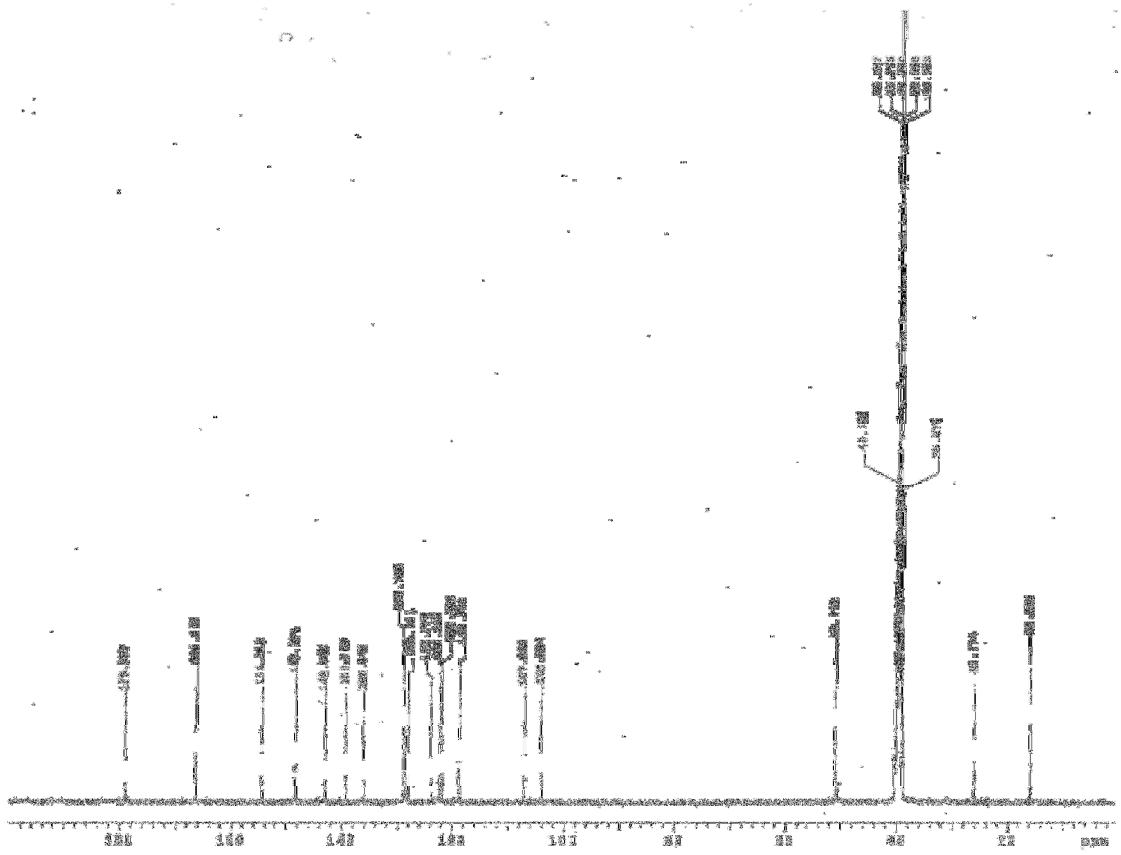


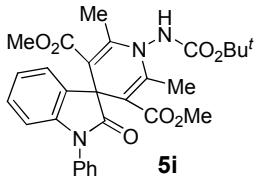




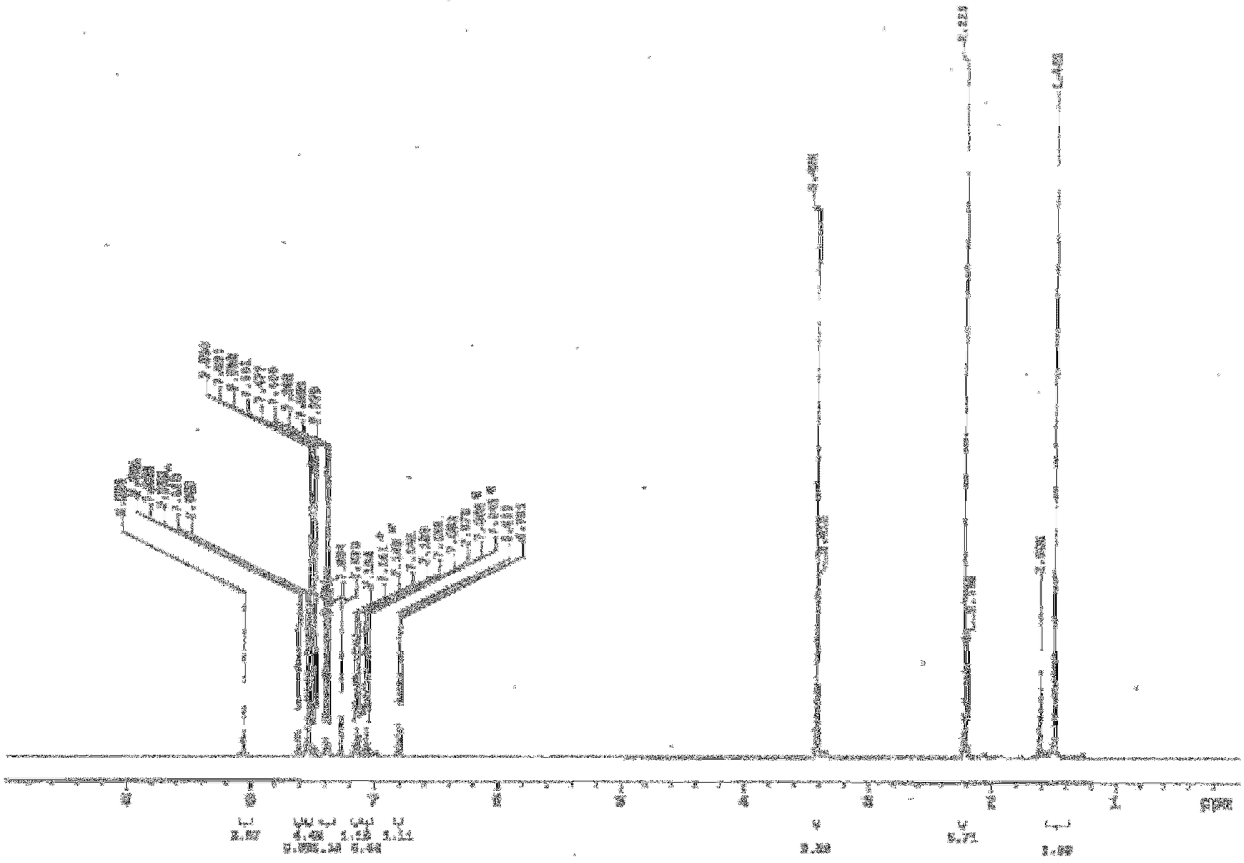
5h

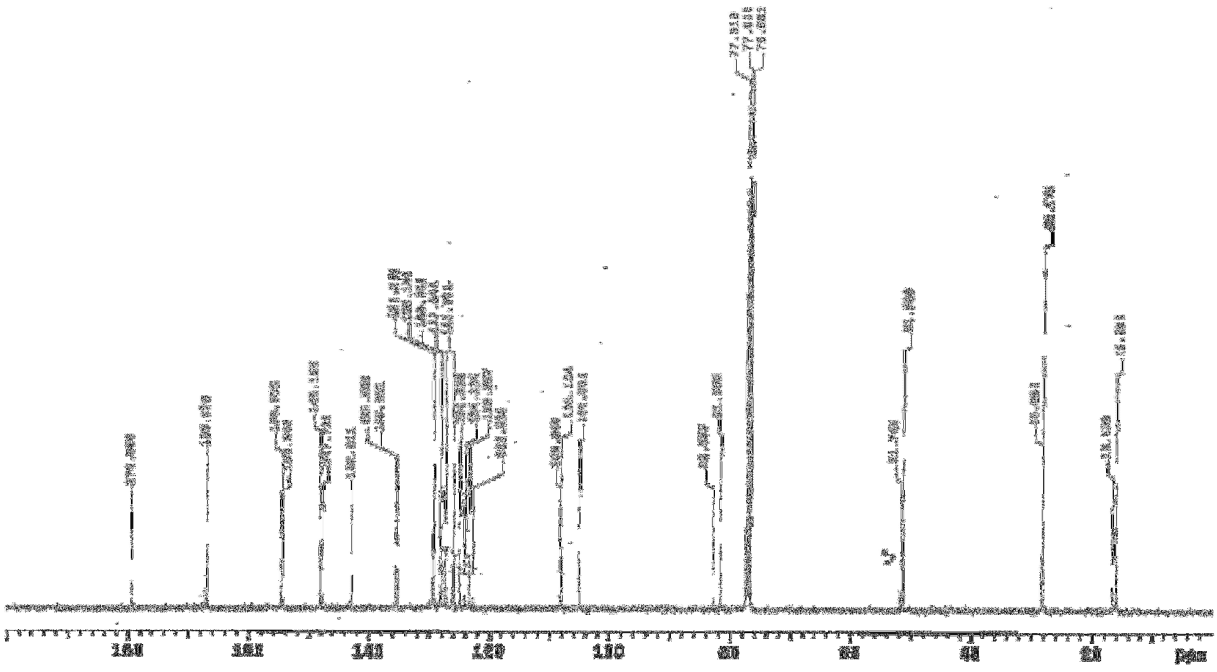


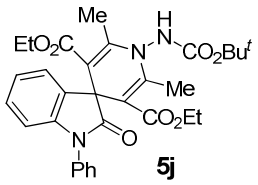




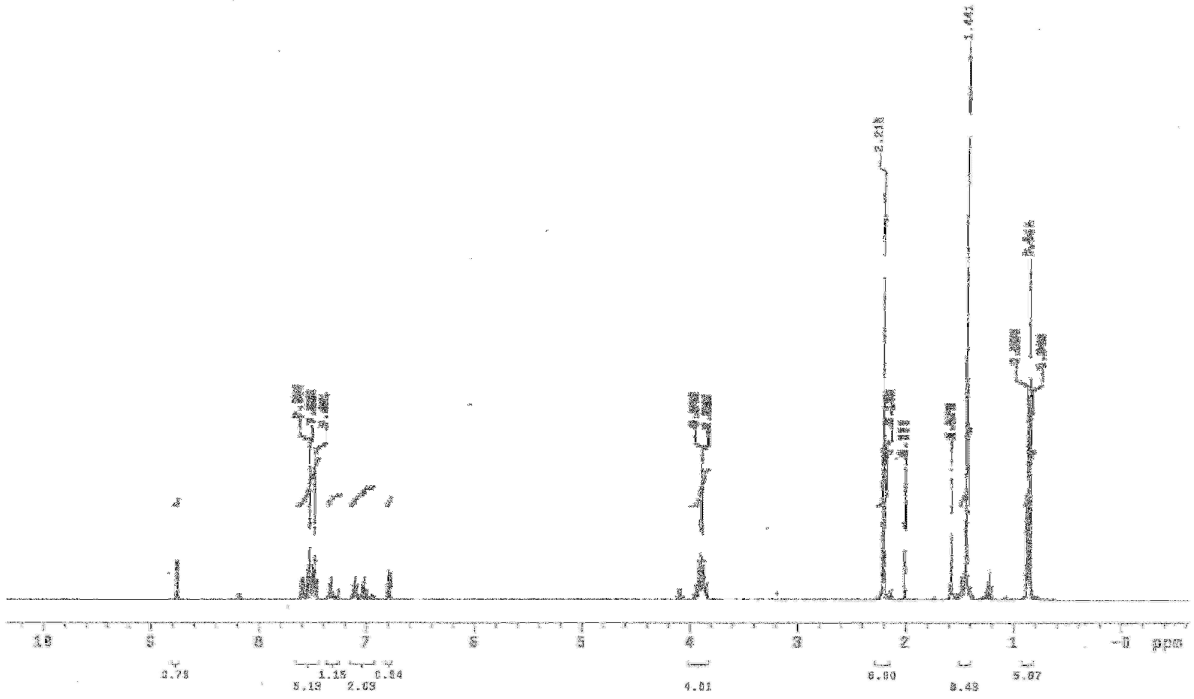
5i

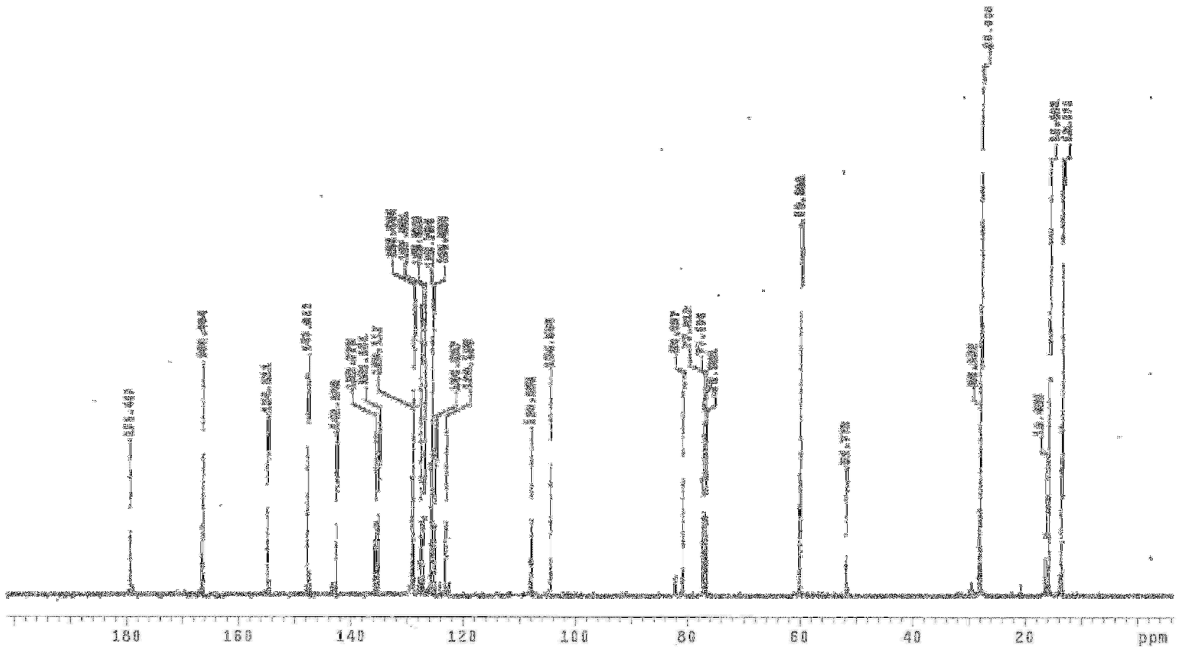


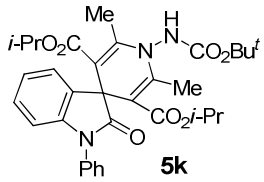



Me
H
N
EtO2C
N
CO2Bu^t
Me
CO2Et
N
O
Ph

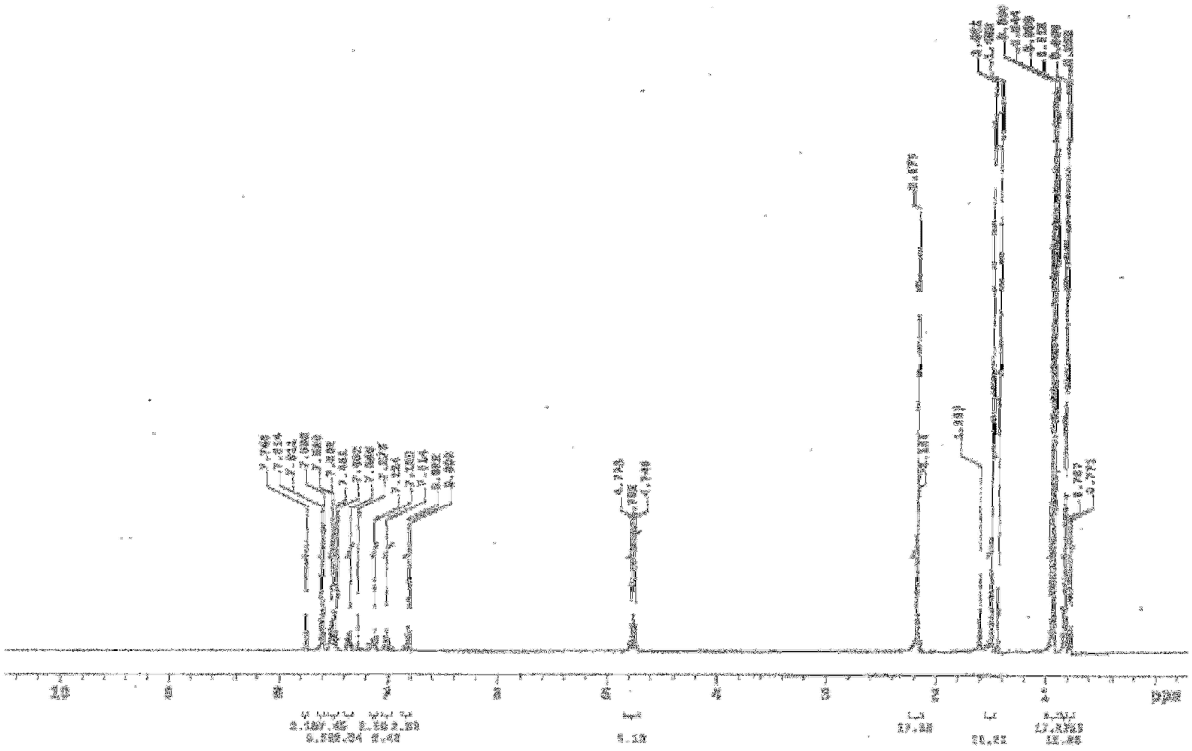
5j

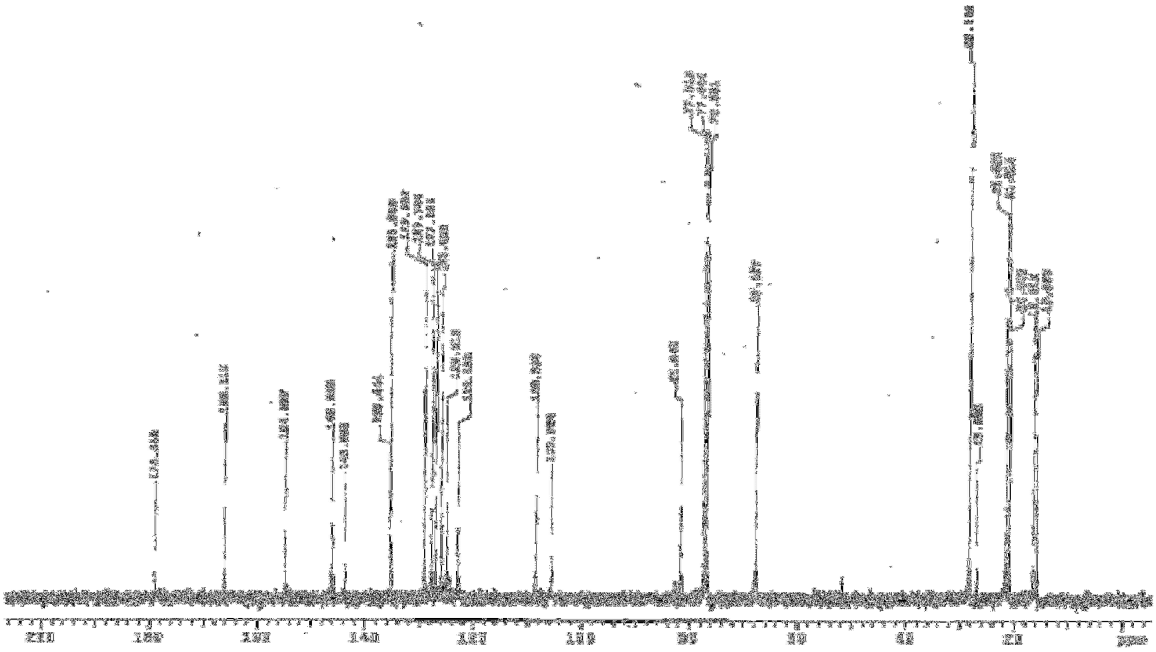

10
9
8
7
6
5
4
3
2
1
0
ppm
3.79
5.19
1.15
2.03
0.84
4.01
6.80
8.43
5.07

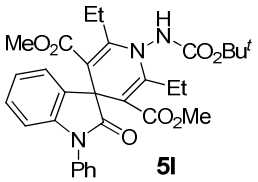

180
160
140
120
100
80
60
40
20
ppm



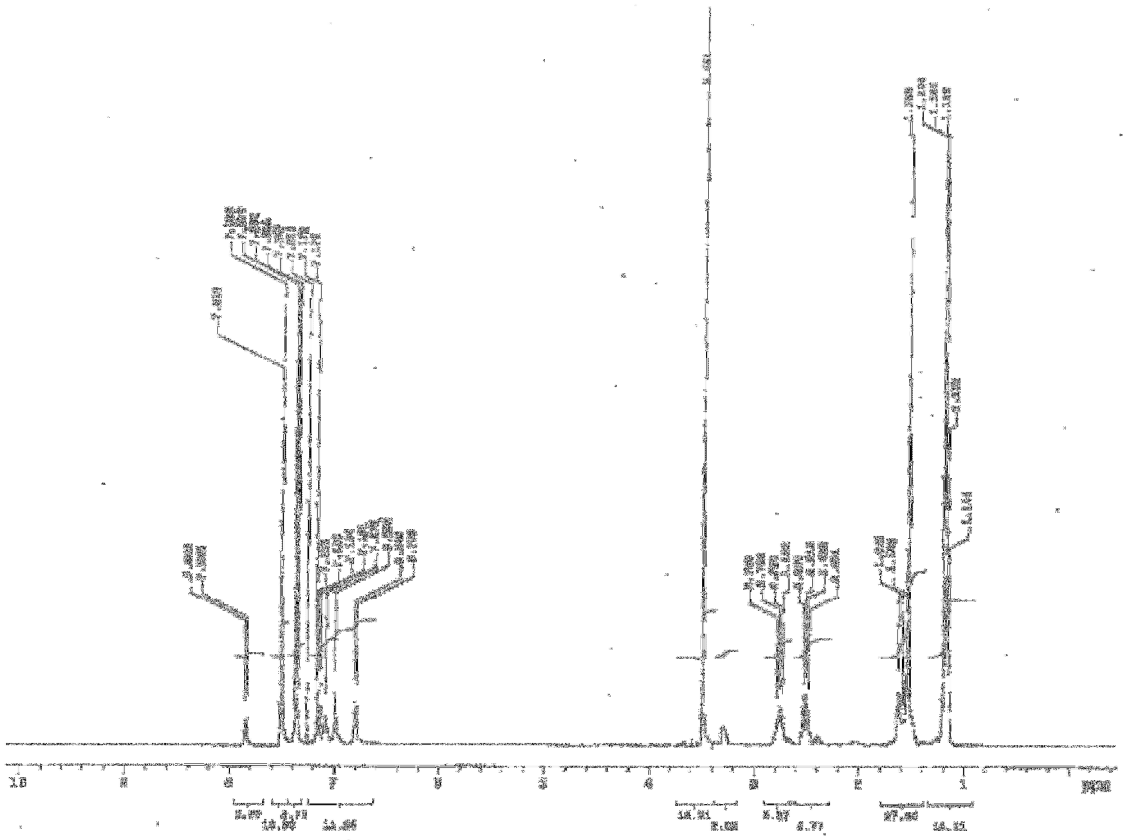
5k

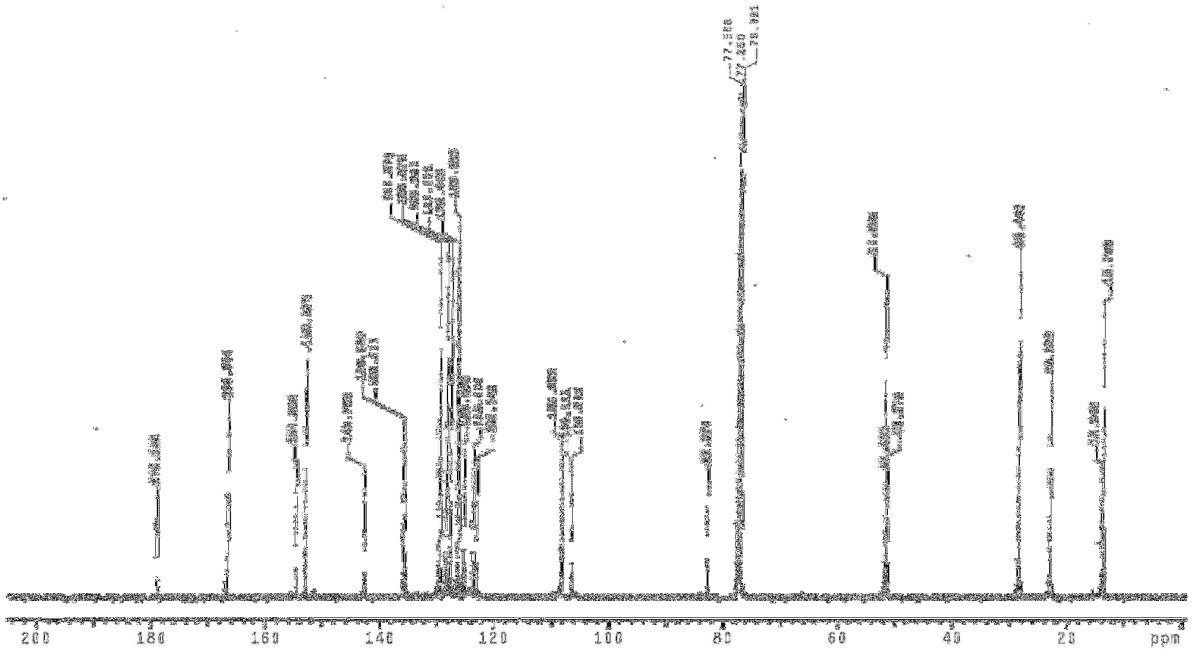


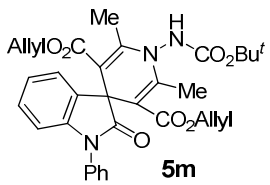



Et
MeO2C
H
N
CO2But
N
Et
CO2Me
O
N
Ph

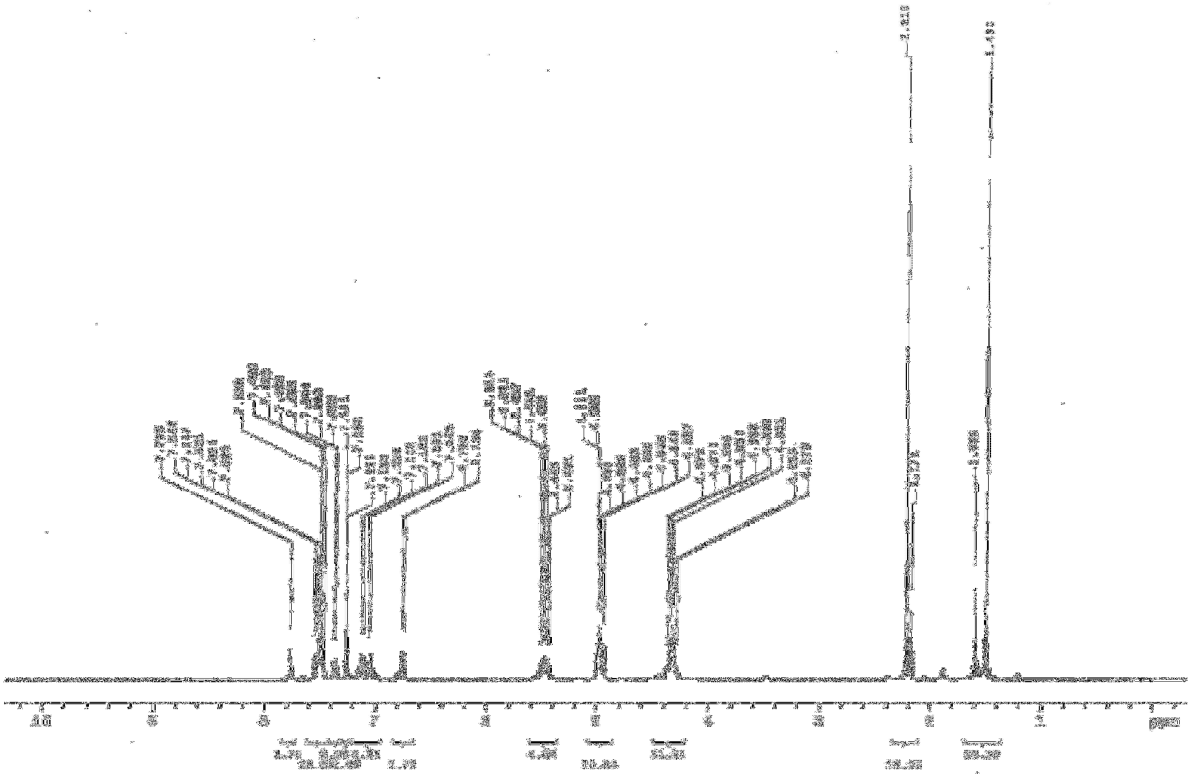
5l

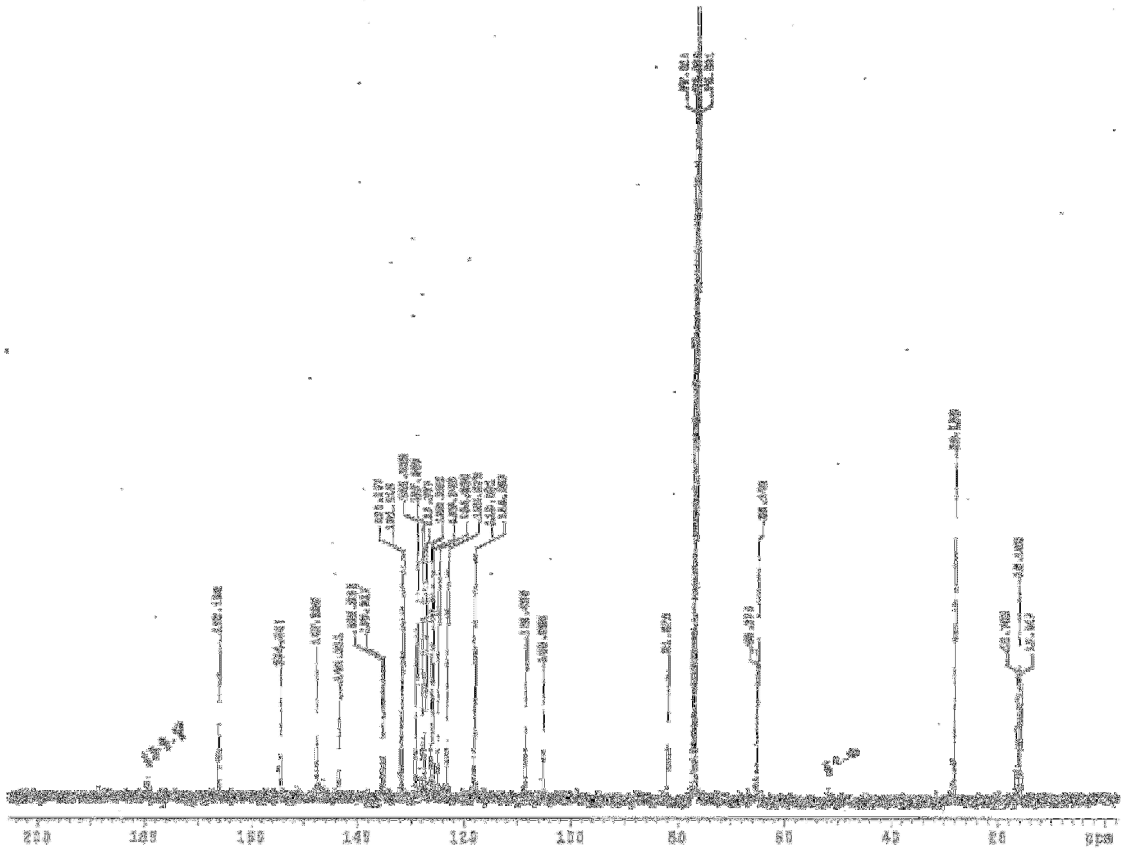



200
180
160
140
120
100
80
60
40
20
ppm



5m





4. References.

(1) Sommer, S. *Tetrahedron Lett.* **1977**, *18*, 117–120.

(2) (a) Attanasi, O. A.; Filippone, P.; Mei, A.; Santeusanio, S. *Synthesis* **1984**, 671–672.

(b) Attanasi, O. A.; Filippone, P.; Mei, A.; Santeusanio, S. *Synthesis* **1984**, 873–874. (c) Preti, L.; Attanasi, O. A.; Caselli, E.; Favi, G.; Ori, C.; Davoli, P.; Felluga, F.; Prati, F. *Eur. J. Org. Chem.* **2010**, 4312–4320.