

Visible Light Mediated Cyclization of Tertiary Anilines with Maleimides Using Supported Iridium Complex Catalyst

Feng Peng,^a Peng Zhi,^a HengJi,^{a,b} HuanZhao,^a Fen-ying Kong,^b
Xue-Zheng Liang*^a and Yong-Miao Shen*^a

^aKey Laboratory of Clean Dyeing and Finishing Technology of Zhejiang Province,
School of Chemistry and Chemical Engineering, Shaoxing University, Shaoxing
312000, China

^bSchool of Chemistry and Chemical Engineering, Yancheng Institute of Technology,
224051, China

Corresponding authors: liangxuezheng@126.com, shenyongmiao@usx.edu.cn

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1. General information

All reagents were commercially available and used without further purification. All solvents were dried according to standard procedures. Melting points were measured on a Taike X-4 microscopic melting point apparatus and are uncorrected. ^1H and ^{13}C NMR spectra were measured on a Bruker ACF-400 spectrometer and recorded at 400 and 100 MHz, respectively, using CDCl_3 as solvent. IR spectra were taken with a Nicolet FT-IR 5DX spectrometer. UV-vis absorption spectroscopy was measured on a Shimadzu 2550 spectrometer. Mass spectra were recorded with a VG ZAB-HS spectrometer using ESI techniques. HRMS were taken with a AB TripleTOF 5600 plus System (AB SCIEX, Framingham, USA). The exact mass calibration was performed automatically before each analysis employing the Automated Calibration Delivery System. Elemental analyses were obtained using a Heraeus CHN-O-Rapid analyzer. XRD were measured with PANalytical Empyrean. TEM were measured with a JEM-1011. TEM-EDS were measured with a JSM-6360LV, ICP-AES were recorded at a Leeman Prodigy xp. The Brunauer-Emmett-Teller (BET) surface area was measured using a Micromeritics Empyrean instrument.

2. Photoreaction setup

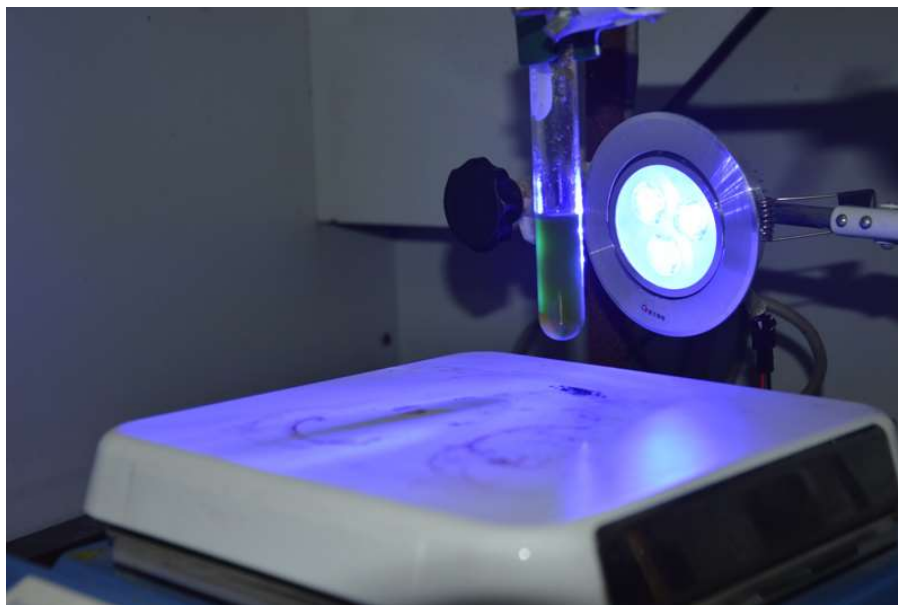


Fig. 1s Photoreaction setup for the cyclization reactions.

3. Centrifugal separation of the P4photocatalyst

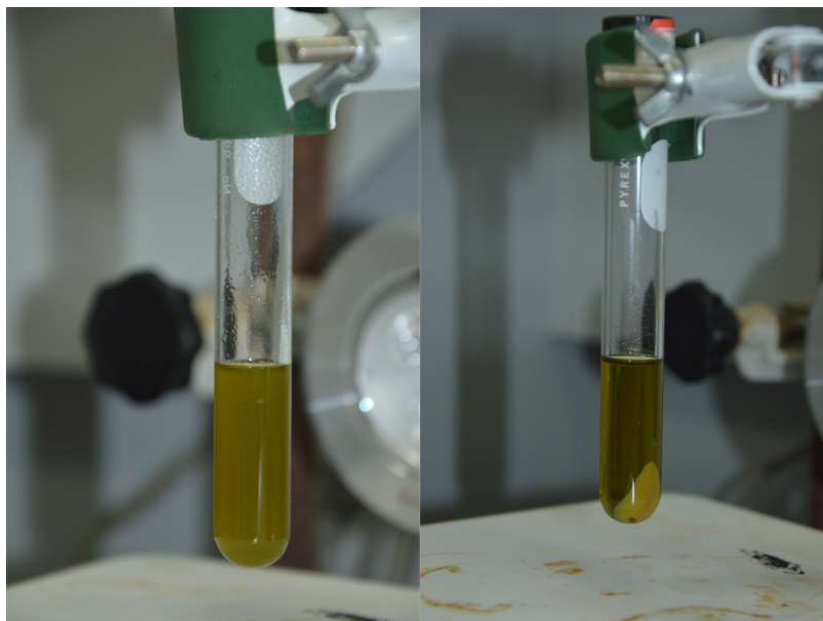
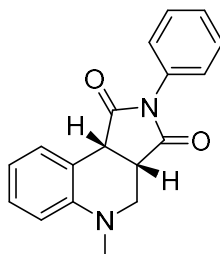
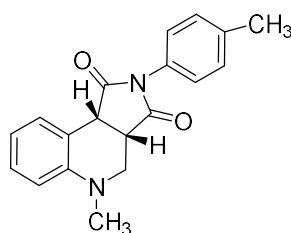


Fig. 2s Centrifugal separation of the P4 photocatalyst (Left) Before the centrifugal (Right) After the centrifugal.

4. Analytical data for the synthesized compounds

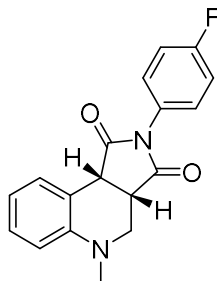


(3a*S**,9b*R**)-5-methyl-2-phenyl-3a,4,5,9b-tetrahydro-1*H*-pyrrolo[3,4-*c*]quinoline-1,3(2*H*)-dione (**3a**) 105.3 mg. White solid: $R_f = 0.45$ (petroleum ether/ethyl acetate 30:8); m.p. 202-204 °C^[1]; ¹H NMR (400 MHz, CDCl₃) δ 2.84 (s, 3H), 3.13 (dd, 1H, $J = 11.6, 4.4$ Hz), 3.55 (ddd, 1H, $J = 9.6, 4.3, 2.7$ Hz), 3.62 (dd, 1H, $J = 11.6, 2.8$ Hz), 4.17 (d, 1H, $J = 9.6$ Hz), 6.75 (d, 1H, $J = 8.0$ Hz), 6.91 (td, 1H, $J = 8.4, 1.0$ Hz), 7.22 – 7.28 (m, 3H), 7.36–7.44 (m, 3H), 7.53 (d, 1H, $J = 7.6$ Hz).

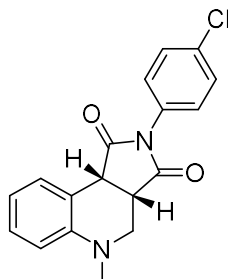


(3a*S**,9b*R**)-5-methyl-2-(*p*-tolyl)-3a,4,5,9b-tetrahydro-1*H*-pyrrolo[3,4-*c*]quinoline-1,

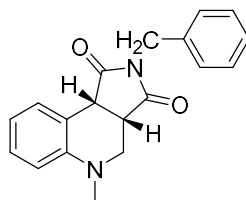
3(2H)-dione(3b) 133.7 mg. White solid: $R_f = 0.47$ (petroleum ether/ethyl acetate 30:8); m.p. 212-214 °C; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 2.36 (s, 3H), 2.85 (s, 3H), 3.15 (dt, 1H, $J = 11.5, 4.1$ Hz), 3.55 (ddd, 1H, $J = 9.6, 4.5, 2.8$ Hz), 3.60 – 3.64 (m, 1H), 4.16 (d, 1H, $J = 9.5$ Hz), 6.76 – 6.82 (m, 1H), 6.93 (td, 1H, $J = 7.5, 2.5$ Hz), 7.12–7.16 (m, 2H), 7.20–7.25 (m, 3H), 7.52 (d, 1H, $J = 7.6$ Hz).



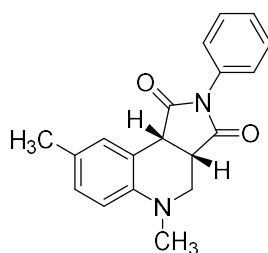
(3aS,9bR*)-2-(4-fluorophenyl)-5-methyl-3a,4,5,9b-tetrahydro-1H-pyrrolo[3,4-c]quinoline-1,3(2H)-dione(3c)* 77.1 mg. White solid: $R_f = 0.42$ (petroleum ether/ethyl acetate 30:8); m.p. 172-174 °C; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 2.84 (s, 3H), 3.13 (dd, 1H, $J = 11.5, 4.4$ Hz), 3.54 (ddd, 1H, $J = 9.6, 4.3, 2.7$ Hz), 3.60 (dd, 1H, $J = 11.5, 2.7$ Hz), 4.15 (d, 1H, $J = 9.6$ Hz), 6.75 (d, 1H, $J = 7.6$ Hz), 6.91 (td, 1H, $J = 7.5, 1.1$ Hz), 7.07-7.15 (m, 2H), 7.21-7.28 (m, 3H), 7.52 (d, 1H, $J = 7.5$ Hz).



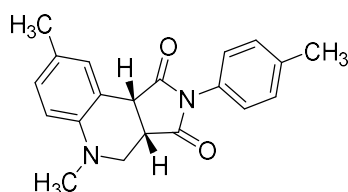
(3aS,9bR*)-2-(4-chlorophenyl)-5-methyl-3a,4,5,9b-tetrahydro-1H-pyrrolo[3,4-c]quinoline-1,3(2H)-dione(3d)* 96.4 mg. White solid: $R_f = 0.41$ (petroleum ether/ethyl acetate 30:8); m.p. 188-190 °C; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 2.84 (s, 3H), 3.12 (dd, 1H, $J = 11.5, 4.3$ Hz), 3.55 (ddd, 1H, $J = 9.6, 4.3, 2.6$ Hz), 3.62 (dd, 1H, $J = 11.5, 2.6$ Hz), 4.17 (d, 1H, $J = 9.6$ Hz), 6.75 (d, 1H, $J = 8.2$ Hz), 6.92 (td, 1H, $J = 7.5, 1.1$ Hz), 7.22-7.26 (m, 3H), 7.37-7.41 (m, 2H), 7.52 (d, 1H, $J = 7.4$ Hz).



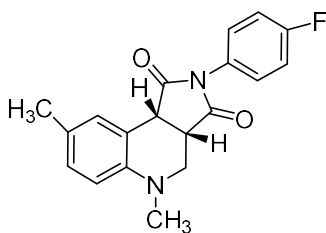
(3aS,9bR*)-2-benzyl-5-methyl-3a,4,5,9b-tetrahydro-1H-pyrrolo[3,4-c]quinoline-1,3(2H)-dione (3e)* 79.6 mg. White solid: $R_f = 0.45$ (petroleum ether/ethyl acetate 30:8); m.p. 126-128 °C; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 2.72 (s, 3H), 2.97 (dd, 1H, $J = 11.5, 4.5$ Hz), 3.25 – 3.32 (m, 1H), 3.42 (dd, 1H, $J = 11.5, 2.7$ Hz), 3.92 (d, 1H, $J = 9.4$ Hz), 4.58 (q, 2H, $J = 14.3$ Hz), 6.64 (d, 1H, $J = 8.1$ Hz), 6.82 (td, 1H, $J = 7.5, 0.9$ Hz), 7.12-7.24 (m, 6H), 7.39 (d, 1H, $J = 7.3$ Hz).



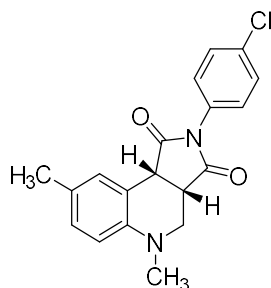
(3aS*,9bR*)-5,8-dimethyl-2-phenyl-3a,4,5,9b-tetrahydro-1H-pyrrolo[3,4-c]quinoline-1,3(2H)-dione(**3f**) 132.4 mg. White solid: $R_f = 0.50$ (petroleum ether/ethyl acetate 30:8); m.p. 193-195 °C; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 2.30 (s, 3H), 2.80 (s, 3H), 3.06 (dd, 1H, $J = 11.4, 4.3$ Hz), 3.52 (ddd, 1H, $J = 9.5, 4.3, 2.7$ Hz), 3.59 (dd, 1H, $J = 11.4, 2.7$ Hz), 4.12 (d, 1H, $J = 9.6$ Hz), 6.65 (d, 1H, $J = 8.3$ Hz), 7.04 (dd, 1H, $J = 8.3, 1.7$ Hz), 7.26-7.28 (m, 2H), 7.33-7.37 (m, 2H), 7.41-7.45 (m, 2H).



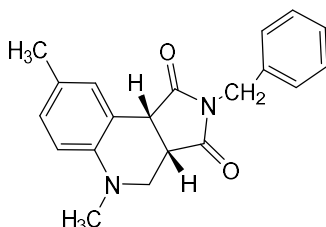
(3aS*,9bR*)-5,8-dimethyl-2-(p-tolyl)-3a,4,5,9b-tetrahydro-1H-pyrrolo[3,4-c]quinoline-1,3(2H)-dione(**3g**) 143.1 mg. White solid: $R_f = 0.47$ (petroleum ether/ethyl acetate 6:1); m.p. 207-208 °C; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 2.32 (s, 3H), 2.36 (s, 3H), 2.84 (s, 3H), 3.14 (dd, 1H, $J = 11.6, 4.4$ Hz), 3.53 – 3.58 (m, 1H), 3.62 (dd, 1H, $J = 11.6, 2.8$ Hz), 4.14 (d, 1H, $J = 9.6$ Hz), 6.77 (d, 1H, $J = 8.0$ Hz), 7.06 (dd, 1H, $J = 8.0, 2.0$ Hz), 7.13 (dd, 2H, $J = 8.4, 2.0$ Hz), 7.23 (d, 2H, $J = 8.2$ Hz), 7.39 (d, 1H, $J = 0.8$ Hz).



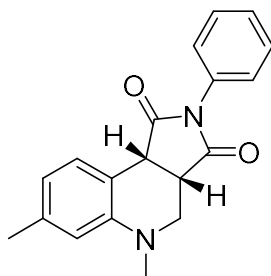
(3aS*,9bR*)-2-(4-fluorophenyl)-5,8-dimethyl-3a,4,5,9b-tetrahydro-1H-pyrrolo[3,4-c]quinoline-1,3(2H)-dione(**3h**) 100.2 mg. White solid: $R_f = 0.42$ (petroleum ether/ethyl acetate 5:1); m.p. 157-159 °C; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 2.30 (s, 3H), 2.80 (s, 3H), 3.06 (dd, 1H, $J = 11.4, 4.3$ Hz), 3.49 – 3.56 (m, 1H), 3.59 (dd, 1H, $J = 11.4, 2.6$ Hz), 4.13 (d, 1H, $J = 9.6$ Hz), 6.66 (d, 1H, $J = 8.3$ Hz), 7.04 (dd, 1H, $J = 8.4, 1.6$ Hz), 7.09-7.13 (m, 2H), 7.254-7.27 (m, 2H), 7.32 (s, 1H).



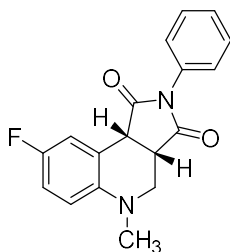
(3aS*,9bR*)-2-(4-chlorophenyl)-5,8-dimethyl-3a,4,5,9b-tetrahydro-1H-pyrrolo[3,4-c]quinoline-1,3(2H)-dione(**3i**) 129.5 mg. White solid: $R_f = 0.40$ (petroleum ether/ethyl acetate 30:8); m.p. 178-180 °C; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 2.31 (s, 3H), 2.81 (s, 3H), 3.07 (dd, 1H, $J = 11.4, 4.3$ Hz), 3.53 (ddd, 1H, $J = 9.6, 4.3, 2.6$ Hz), 3.59 (dd, 1H, $J = 11.4, 2.6$ Hz), 4.13 (d, 1H, $J = 9.6$ Hz), 6.67 (d, 1H, $J = 9.6$ Hz), 7.05 (dd, 1H, $J = 8.3, 2.0$ Hz), 7.24-7.26 (m, 2H), 7.34 (d, 1H, $J = 1.6$ Hz), 7.38-7.41 (m, 2H).



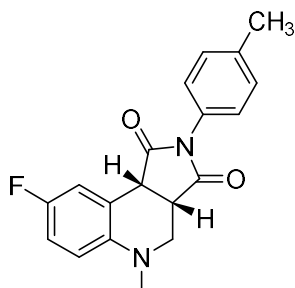
(3aS*,9bR*)-2-benzyl-5,8-dimethyl-3a,4,5,9b-tetrahydro-1H-pyrrolo[3,4-c]quinoline-1,3(2H)-dione(**3j**) 105.5 mg. White solid: $R_f = 0.45$ (petroleum ether/ethyl acetate 30:7); m.p. 131-136 °C; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 2.30 (s, 3H), 2.77 (s, 3H), 3.00 (dd, 1H, $J = 11.5, 4.0$ Hz), 3.35 (ddd, 1H, $J = 9.3, 4.3, 2.6$ Hz), 3.48 (dd, 1H, $J = 11.4, 2.7$ Hz), 3.96 (d, 1H, $J = 9.4$ Hz), 4.65 (q, 2H, $J = 14.3$ Hz), 6.64 (dd, 1H, $J = 8.2, 4.0$ Hz), 7.03 (d, 1H, $J = 6.8$ Hz), 7.21-7.34 (m, 6H).



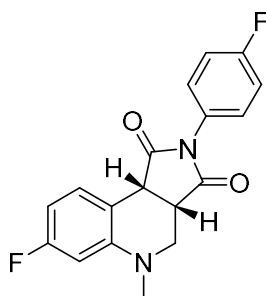
(3aS*,9bR*)-5,7-dimethyl-2-phenyl-3a,4,5,9b-tetrahydro-1H-pyrrolo[3,4-c]quinoline-1,3(2H)-dione(**3k**) 99.6 mg. White solid: $R_f = 0.40$ (petroleum ether/ethyl acetate 6:1); m.p. 193-195 °C; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 2.59 (s, 3H), 2.79 (s, 3H), 2.96 (dd, 1H, $J = 11.2, 4.8$ Hz), 3.51 – 3.55 (m, 1H), 3.59 (ddd, 1H, $J = 11.3, 4.9, 2.2$ Hz), 4.52 (d, 1H, $J = 9.8$ Hz), 6.64 (d, 1H, $J = 8.2$ Hz), 6.82 (d, 1H, $J = 7.5$ Hz), 7.13 (t, 1H, $J = 7.9$ Hz), 7.23-7.31 (m, 1H), 7.32 – 7.39 (m, 1H), 7.40-7.46 (m, 3H).



(3aS*,9bR*)-8-fluoro-5-methyl-2-phenyl-4,5-dihydro-2H-pyrrolo[3,4-c]quinoline-1,3(3aH,9bH)-dione(**3l**) 107.3 mg. White solid: $R_f = 0.46$ (petroleum ether/ethyl acetate 30:8); m.p. 172-174 °C; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 2.82 (s, 3H), 3.09 (dd, 1H, $J = 11.4, 4.4$ Hz), 3.55 (ddd, 1H, $J = 9.6, 4.3, 2.8$ Hz), 3.60 (dd, 1H, $J = 11.4, 2.8$ Hz), 4.13 (d, 1H, $J = 9.5$ Hz), 6.69 (dd, 1H, $J = 9.0, 4.7$ Hz), 6.86 (s, 1H), 6.95 (td, 1H, $J = 8.6, 3.0$ Hz), 7.25-7.29 (m, 2H), 7.42-7.49 (m, 3H).

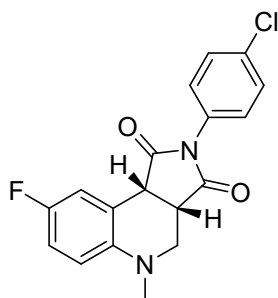


(3aS*,9bR*)-8-fluoro-5-methyl-2-(p-tolyl)-3a,4,5,9b-tetrahydro-1H-pyrrolo[3,4-c]quinoline-1,3(2H)-dione(**3m**) 147.4 mg. White solid: $R_f = 0.46$ (petroleum ether/ethyl acetate 6:1); m.p. 178-181 °C; IR (KBr) ν 2964, 2867, 1710, 1577, 1504, 1194, 618 cm^{-1} ; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 2.36 (s, 3H), 2.82 (s, 3H), 3.09 (dd, 1H, $J = 11.4, 4.4$ Hz), 3.53 (ddd, 1H, $J = 9.6, 4.4, 2.9$ Hz), 3.58 (dd, 1H, $J = 11.4, 2.9$ Hz), 4.11 (d, 1H, $J = 9.6$ Hz), 6.68 (dd, 1H, $J = 9.0, 4.7$ Hz), 6.94 (td, 1H, $J = 8.6, 3.0$ Hz), 7.12-7.15 (m, 2H), 7.24 (d, 2H, $J = 8.1$ Hz), 7.28 (dd, 1H, $J = 9.0, 2.7$ Hz); $^{13}\text{C NMR}$ (100 MHz, CDCl_3) δ 28.2, 39.8, 42.4, 43.5, 55.7, 113.4, 114.4, 115.7, 119.8, 126.1, 129.3, 129.7, 138.6, 142.8, 153.2, 175.7, 177.3, 177.9; HRMS (ESI) Calcd for $\text{C}_{19}\text{H}_{18}\text{FN}_2\text{O}_2$ $[\text{M}+\text{H}]^+$: 325.1352, found 325.1350.

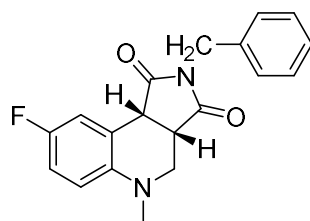


(3aS*,9bR*)-8-fluoro-2-(4-fluorophenyl)-5-methyl-3a,4,5,9b-tetrahydro-1H-pyrrolo[3,4-c]quinoline-1,3(2H)-dione(**3n**) 86.9 mg. White solid: $R_f = 0.34$ (petroleum ether/ethyl acetate 5:1); m.p. 150-152 °C; IR (KBr) ν 2924, 1709, 1577, 1508, 1425,

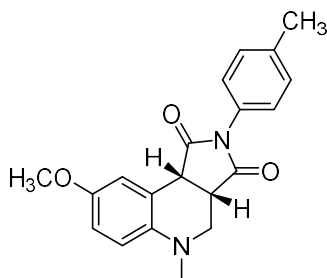
1151, 679 cm^{-1} ; ^1H NMR (400 MHz, CDCl_3) δ 2.81 (s, 3H), 3.07 (dd, 1H, $J = 11.4, 4.4$ Hz), 3.53 (ddd, 1H, $J = 9.6, 4.3, 2.7$ Hz), 3.59 (dd, 1H, $J = 11.4, 2.7$ Hz), 4.12 (d, 1H, $J = 9.6$ Hz), 6.67 (dd, 1H, $J = 9.0, 4.6$ Hz), 6.94 (td, 1H, $J = 8.6, 3.0$ Hz), 7.09-7.15 (m, 2H), 7.24-7.31 (m, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 39.8, 42.1, 43.4, 51.0, 113.4 (d, $J = 8.0$ Hz), 115.1 (d, $J = 21.0$ Hz), 116.1 (d, $J = 22.0$ Hz), 116.9 (d, $J = 23.0$ Hz), 119.8 (d, $J = 7.0$ Hz), 128.2 (d, $J = 9.0$ Hz), 145.0, 155.5, 157.9, 160.9, 163.4, 175.1, 177.4; HRMS (ESI) Calcd for $\text{C}_{18}\text{H}_{15}\text{F}_2\text{N}_2\text{O}_2$ $[\text{M}+\text{H}]^+$: 329.1102, found 329.1096.



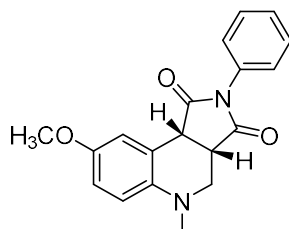
(3a*S**,9b*R**)-2-(4-chlorophenyl)-8-fluoro-5-methyl-3a,4,5,9b-tetrahydro-1H-pyrrolo[3,4-c]quinoline-1,3(2H)-dione (**3o**) 123.8 mg. White solid: $R_f = 0.31$ (petroleum ether/ethyl acetate 30:7); m.p. 156-158 $^{\circ}\text{C}$; IR (KBr) ν 2925, 2854, 1718, 1577, 1438, 1133, 619 cm^{-1} ; ^1H NMR (400 MHz, CDCl_3) δ 2.81 (s, 3H), 3.08 (ddd, 1H, $J = 11.4, 4.3, 1.7$ Hz), 3.50-3.56 (m, 1H), 3.59 (dd, 1H, $J = 11.5, 2.6$ Hz), 4.12 (d, 1H, $J = 9.4$ Hz), 6.68 (dd, 1H, $J = 9.0, 4.6$ Hz), 6.95 (td, 1H, $J = 8.6, 3.0$ Hz), 7.23-7.28 (m, 3H), 7.39-7.43 (m, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ 39.6, 42.1, 43.3, 50.9, 113.3 (d, $J = 7.6$ Hz), 114.9 (d, $J = 21.8$ Hz), 116.7 (d, $J = 23.1$ Hz), 119.9 (d, $J = 7.7$ Hz), 127.5, 129.0, 130.3, 134.1, 144.9, 155.2, 157.6, 160.1, 177.2, 177.3; HRMS (ESI) Calcd for $\text{C}_{18}\text{H}_{15}\text{ClFN}_2\text{O}_2$ $[\text{M}+\text{H}]^+$: 345.0806, found 345.0806.



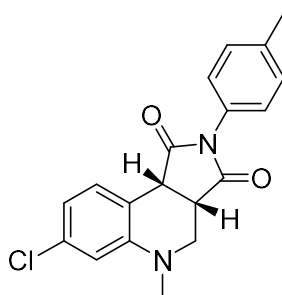
(3a*S**,9b*R**)-2-benzyl-8-fluoro-5-methyl-3a,4,5,9b-tetrahydro-1H-pyrrolo[3,4-c]quinoline-1,3(2H)-dione (**3p**) 87.4 mg. White solid: $R_f = 0.38$ (petroleum ether/ethyl acetate 30:7); m.p. 130-132 $^{\circ}\text{C}$; IR (KBr) ν 2925, 1701, 1577, 1495, 1438, 1130, 619 cm^{-1} ; ^1H NMR (400 MHz, CDCl_3) δ 2.77 (s, 3H), 2.99 (dd, 1H, $J = 11.4, 4.8$ Hz), 3.35 (ddd, 1H, $J = 9.4, 4.5, 2.8$ Hz), 3.47 (dd, 1H, $J = 11.5, 2.8$ Hz), 3.94 (d, 1H, $J = 9.4$ Hz), 4.66 (q, 2H, $J = 14.3$ Hz), 6.62 (dd, 1H, $J = 9.0, 4.6$ Hz), 6.91 (td, 1H, $J = 8.6, 3.0$ Hz), 7.20 - 7.22 (m, 1H), 7.23 - 7.26 (m, 1H), 7.31 - 7.23 (m, 4H); ^{13}C NMR (100 MHz, CDCl_3) δ 39.6, 42.2, 42.9, 43.5, 51.1, 113.3 (d, $J = 8.0$ Hz), 114.9 (d, $J = 22.0$ Hz), 116.9 (d, $J = 23.0$ Hz), 120.3 (d, $J = 8.0$ Hz), 127.9, 128.3, 128.6, 135.4, 144.93, 144.95, 155.45, 157.82, 175.8, 178.1; HRMS (ESI) Calcd for $\text{C}_{19}\text{H}_{18}\text{FN}_2\text{O}_2$ $[\text{M}+\text{H}]^+$: 325.1352, found 325.1352.



(3a*S**,9b*R**)-8-methoxy-5-methyl-2-(*p*-tolyl)-3a,4,5,9b-tetrahydro-1*H*-pyrrolo[3,4-*c*]quinoline-1,3(2*H*)-dione(**3q**) 128.7 mg. White solid: $R_f = 0.37$ (petroleum ether/ethyl acetate 30:8); m.p. 212–214 °C; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 2.38 (s, 3H), 2.81 (s, 3H), 3.07(dd, 1H, $J = 11.2, 4.4$ Hz), 3.38 (s, 3H), 3.53 (ddd, 1H, $J = 9.4, 4.2, 2.8$ Hz), 3.58 (dd, 1H, $J = 11.6, 2.8$ Hz), 4.11 (d, 1H, $J = 9.6$ Hz), 6.66 (dd, 1H, $J = 8.8, 4.8$ Hz), 6.93 (td, 1H, $J = 8.4, 2.9$ Hz), 7.12 – 7.15 (m, 2H), 7.23-7.29 (m, 3H).



(3a*S**,9b*R**)-8-methoxy-5-methyl-2-phenyl-3a,4,5,9b-tetrahydro-1*H*-pyrrolo[3,4-*c*]quinoline-1,3(2*H*)-dione(**3r**) 95.1 mg. White solid: $R_f = 0.41$ (petroleum ether/ethyl acetate 30:8); m.p. 164-166 °C; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 2.79 (s, 3H), 3.03 (dd, 1H, $J = 11.3, 4.3$ Hz), 3.52 (ddd, 1H, $J = 9.5, 4.3, 2.8$ Hz), 3.56 (dd, 1H, $J = 11.2, 2.8$ Hz), 3.79 (s, 3H), 4.13 (d, 1H, $J = 9.5$ Hz), 6.68 (d, 1H, $J = 8.9$ Hz), 6.81 (dd, 1H, $J = 8.9, 2.9$ Hz), 7.13 (d, 1H, $J = 2.8$ Hz), 7.26-7.28 (m, 2H), 7.34 – 7.38 (m, 1H), 7.40-7.45 (m, 2H).

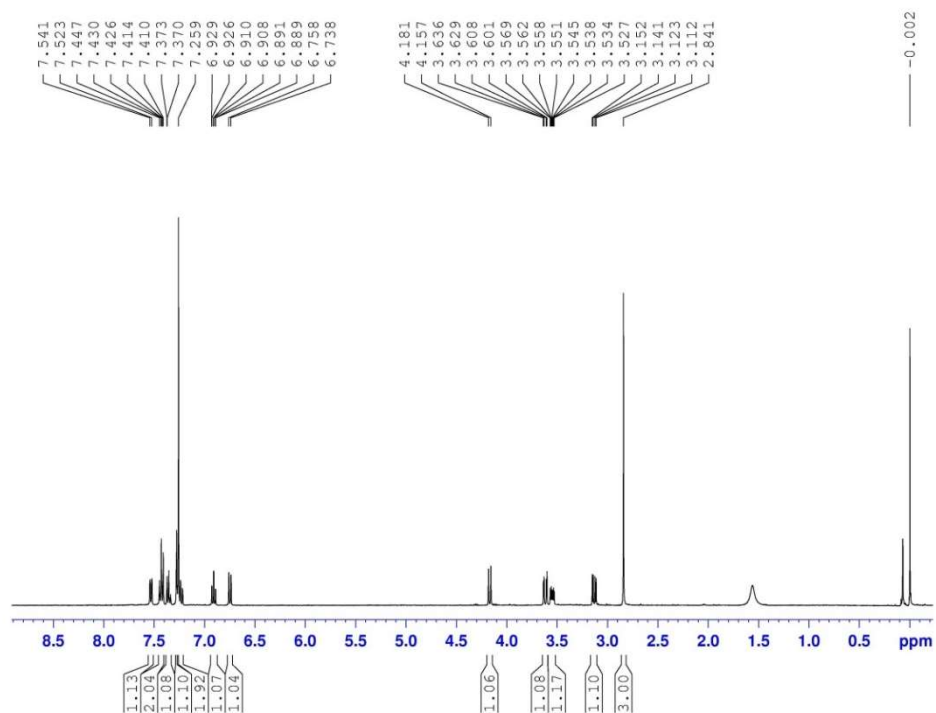


(3a*S**,9b*R**)-8-chloro-5-methyl-2-(*p*-tolyl)-3a,4,5,9b-tetrahydro-1*H*-pyrrolo[3,4-*c*]quinoline-1,3(2*H*)-dione(**3s**) 161.3 mg. White solid: $R_f = 0.37$ (petroleum ether/ethyl acetate 30:8); m.p. 189-191 °C; IR (KBr) ν 2958, 1707, 1577, 1512, 1497, 1395, 648 cm^{-1} ; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 2.36 (s, 3H), 2.82 (s, 3H), 3.10 (dd, 1H, $J = 11.5, 4.4$ Hz), 3.52 (ddd, 1H, $J = 9.6, 4.4, 2.8$ Hz), 3.60 (dd, 1H, $J = 11.5, 2.8$ Hz), 4.10 (d, 1H, $J = 9.6$ Hz), 6.60 (d, 1H, $J = 8.8$ Hz), 7.11-7.15 (m, 2H), 7.18 (dd, 1H, $J = 8.7, 2.5$ Hz), 7.24 (d, 2H, $J = 8.2$ Hz), 7.51 (d, 1H, $J = 2.0$ Hz); $^{13}\text{C NMR}$ (100 MHz, CDCl_3) δ 21.2, 39.5, 41.8, 43.2, 50.5, 113.8, 120.0, 124.5, 126.1, 128.5, 129.2, 129.7,

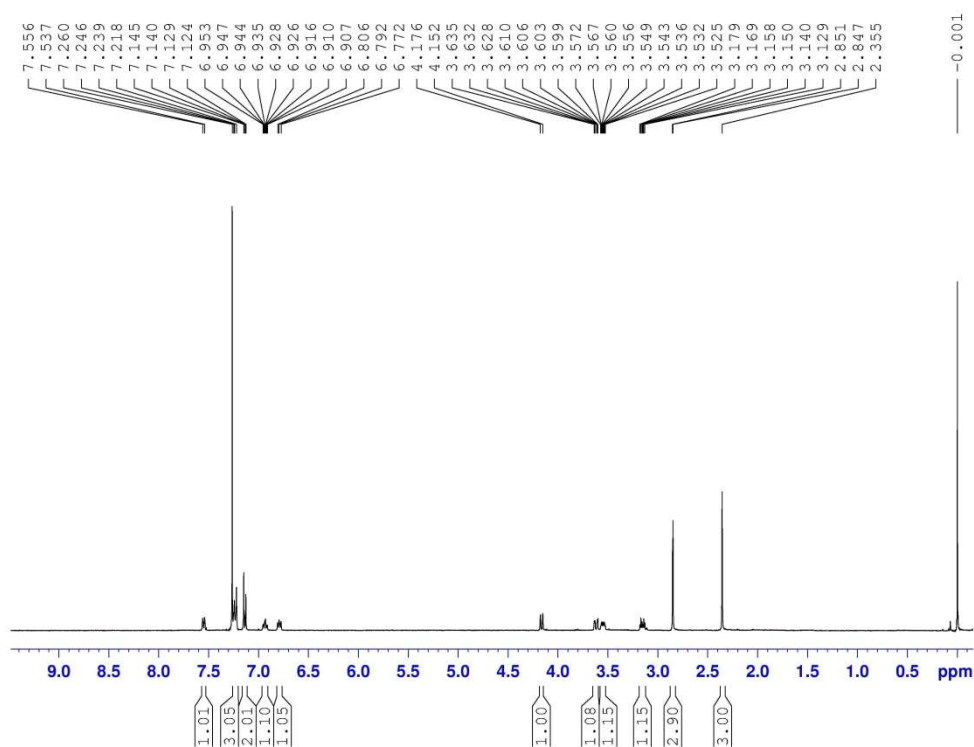
130.0, 138.7, 147.0, 175.2, 177.4; HRMS (ESI) Calcd for C₁₉H₁₈ClN₂O₂ [M+H]⁺: 341.1057, found 341.1058.

5. ¹H NMR (400MHz, CDCl₃) and ¹³C NMR (100MHz, CDCl₃) of compounds 3a-3s

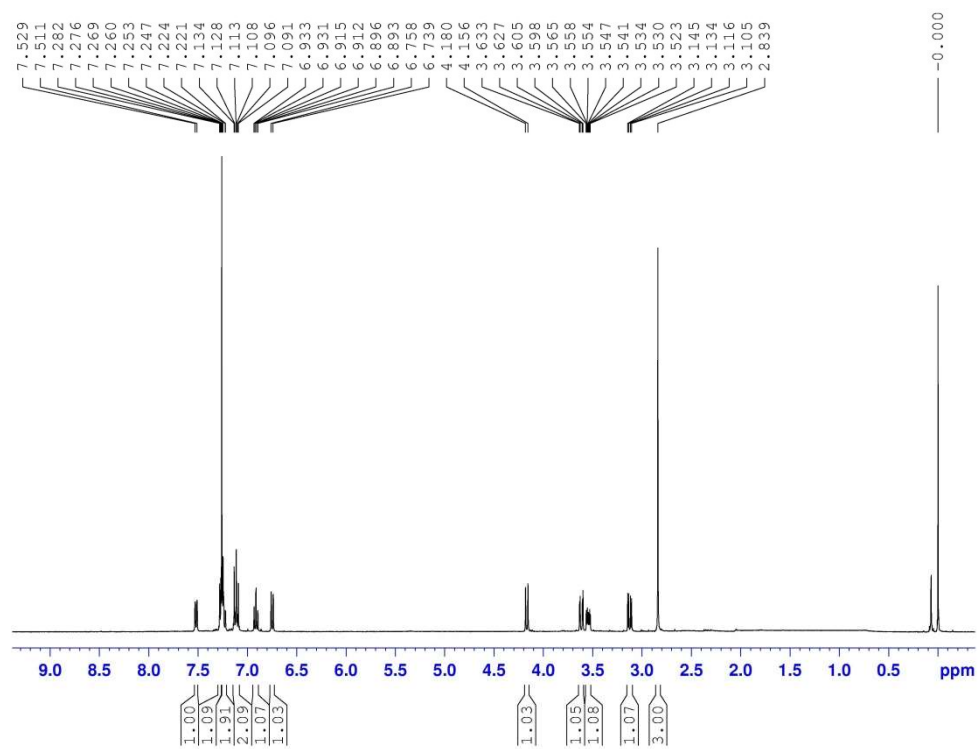
3a



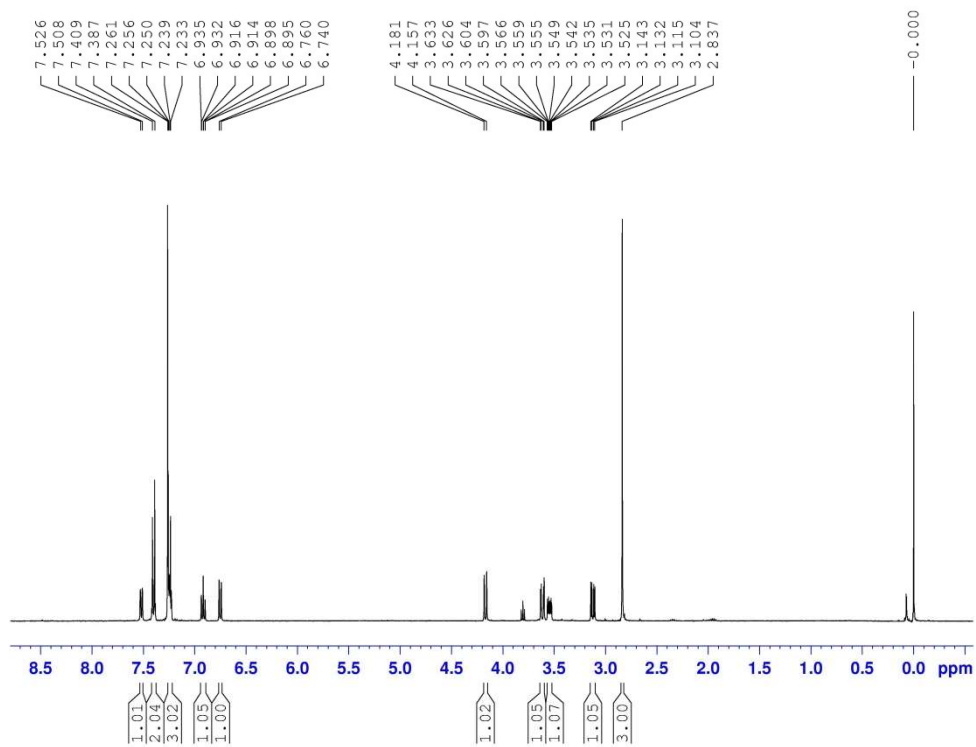
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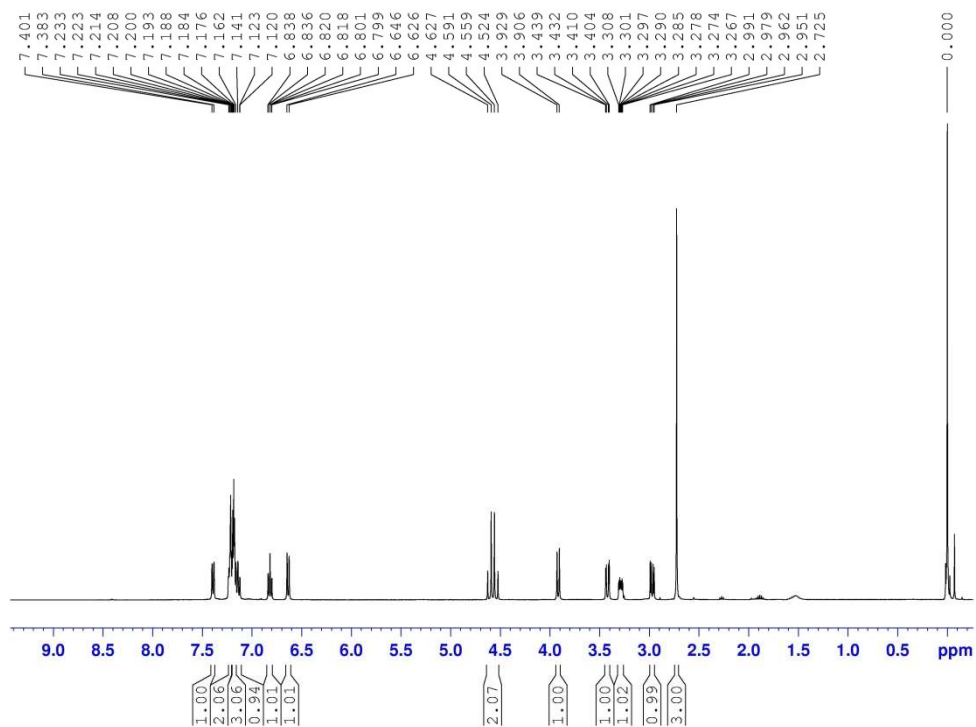
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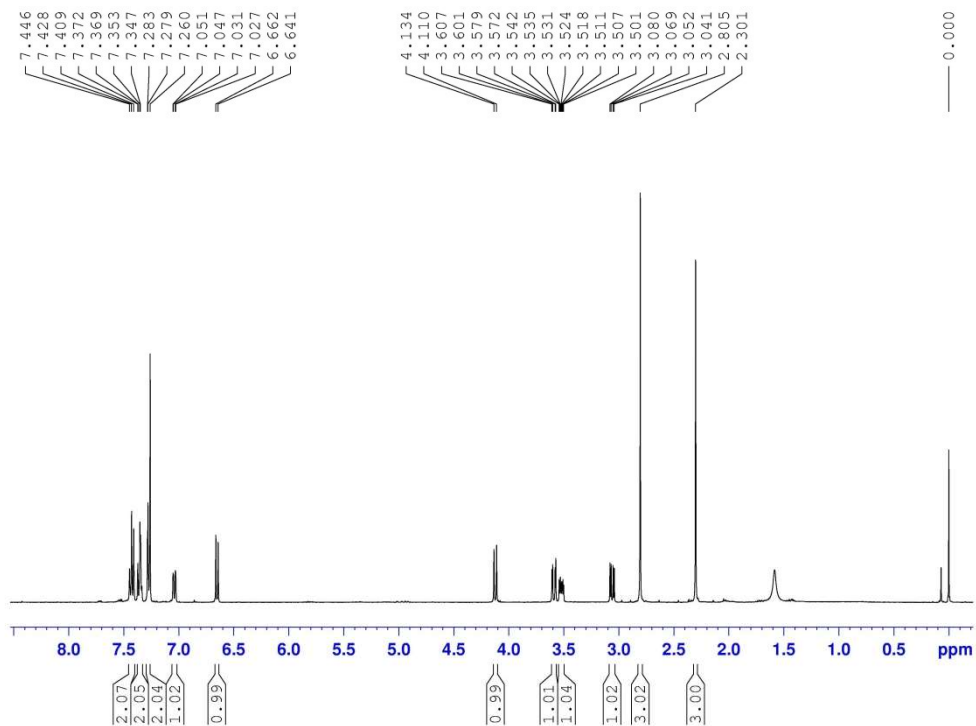
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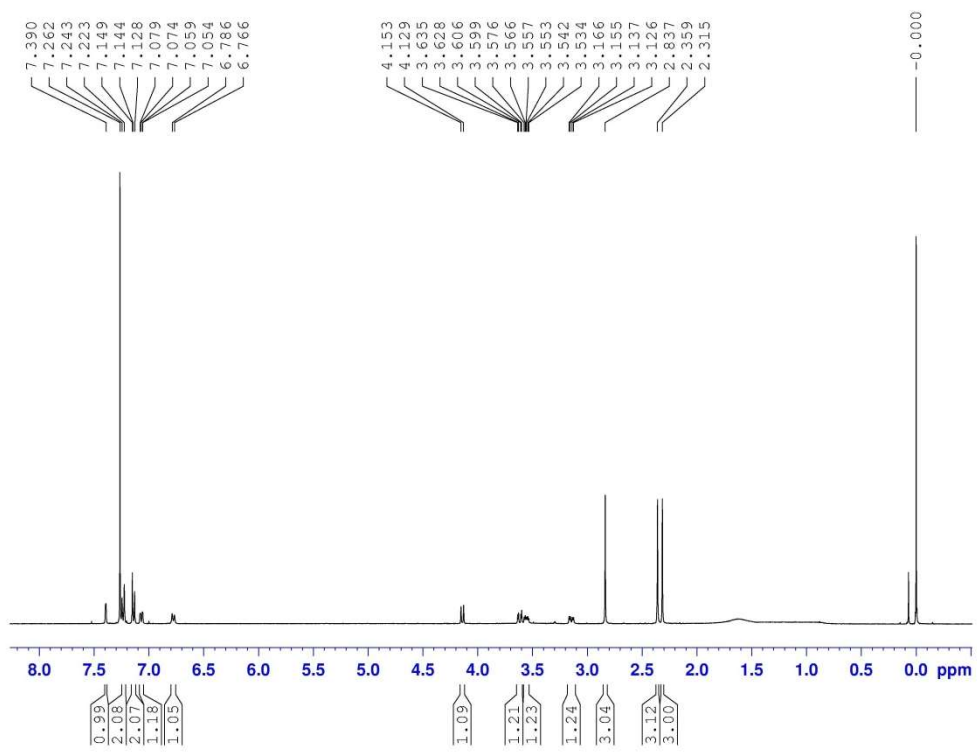
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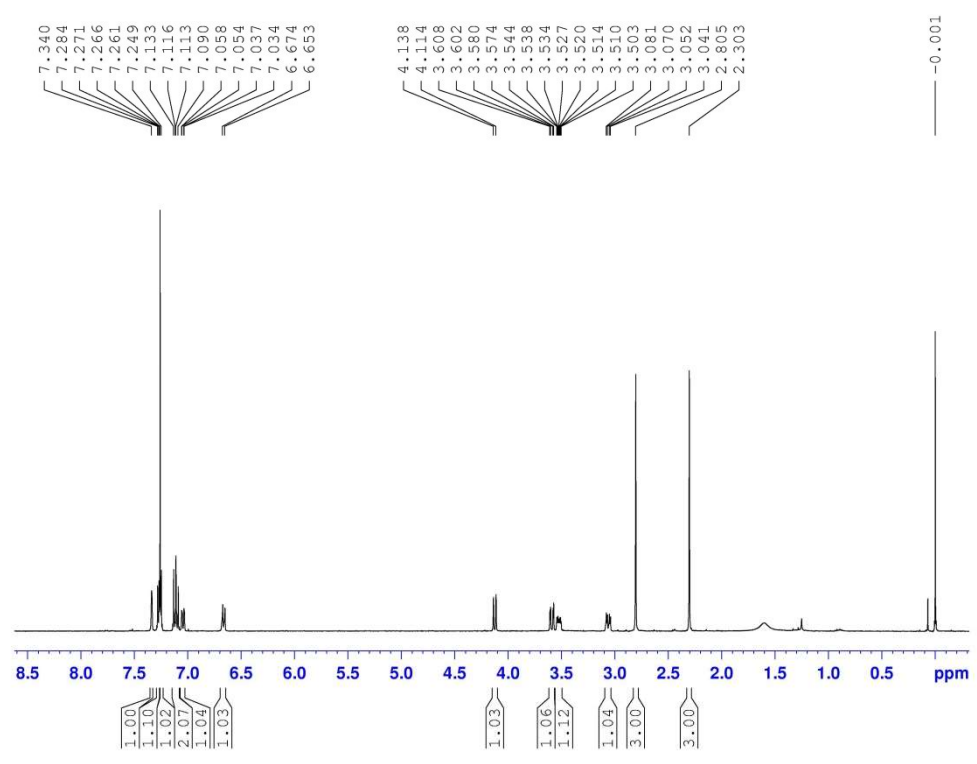
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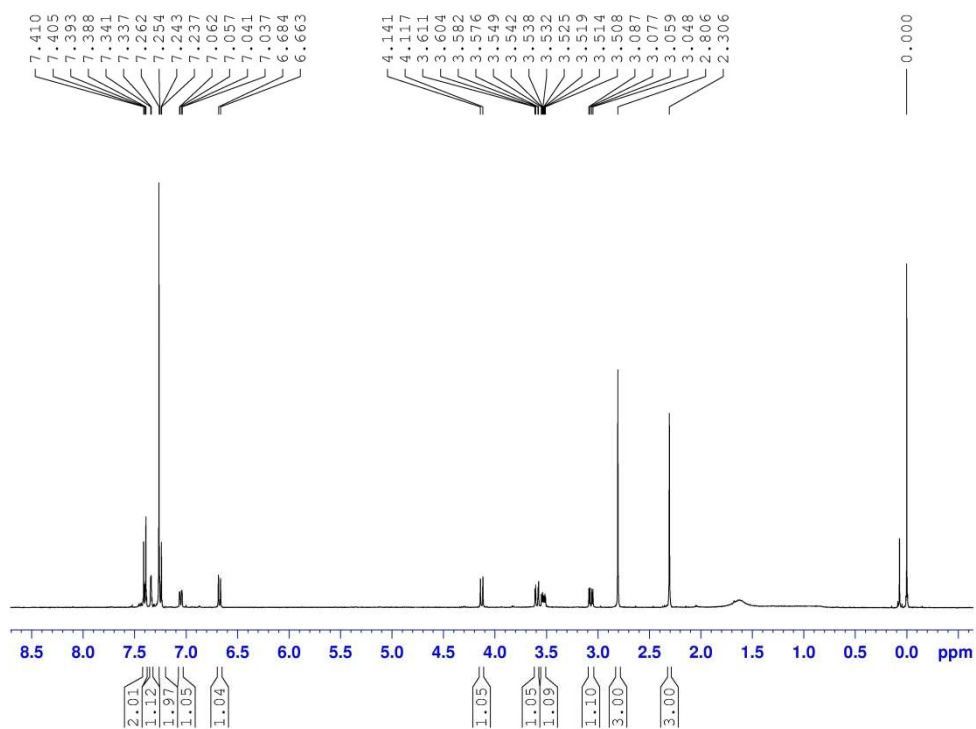
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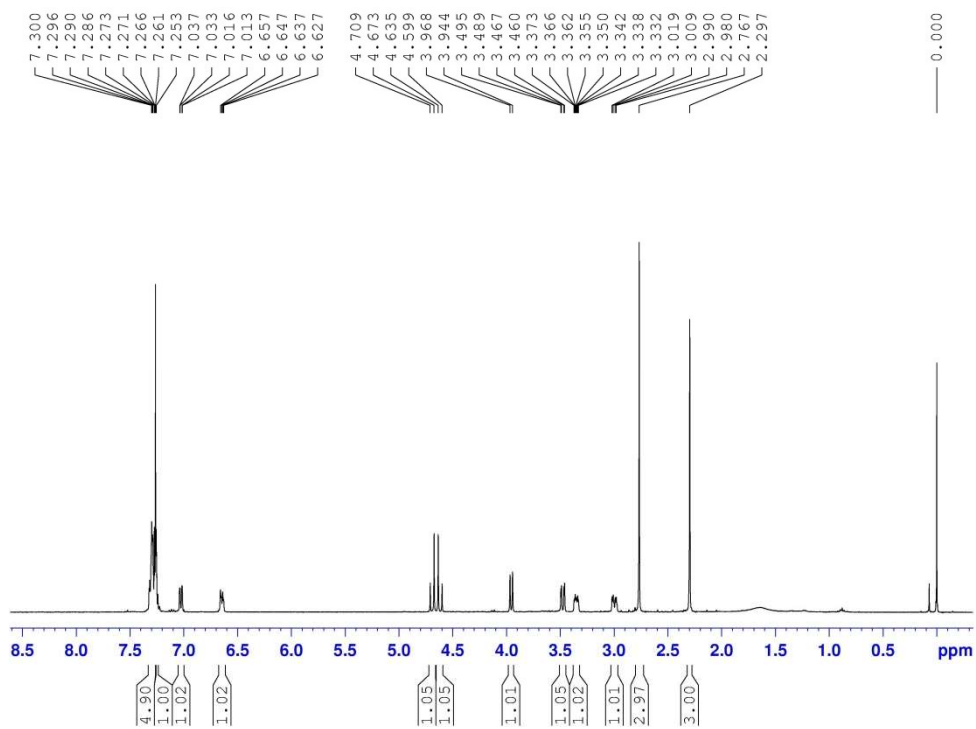
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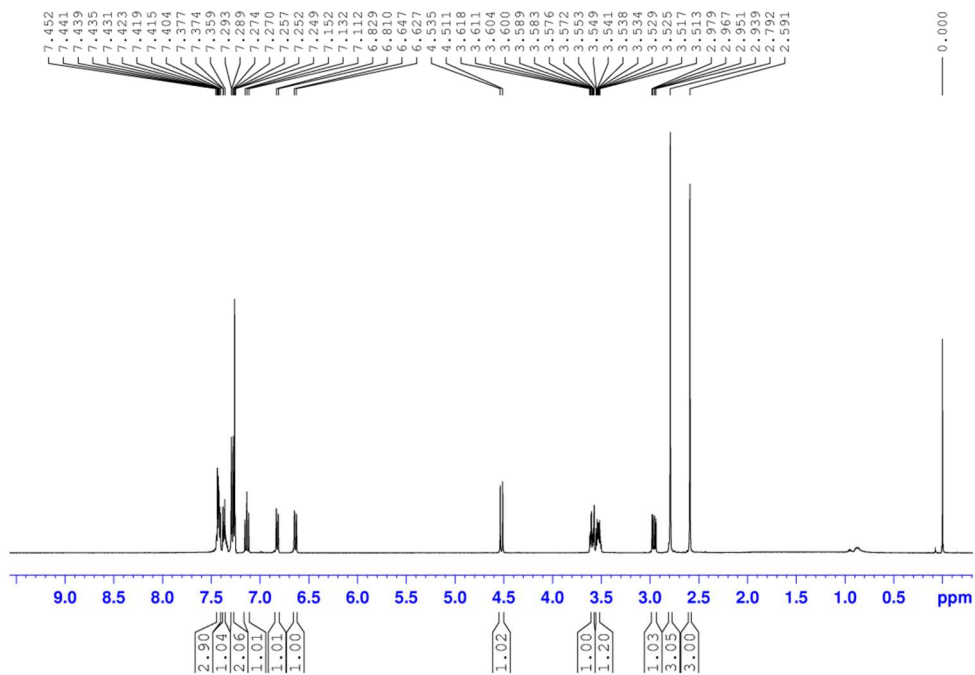
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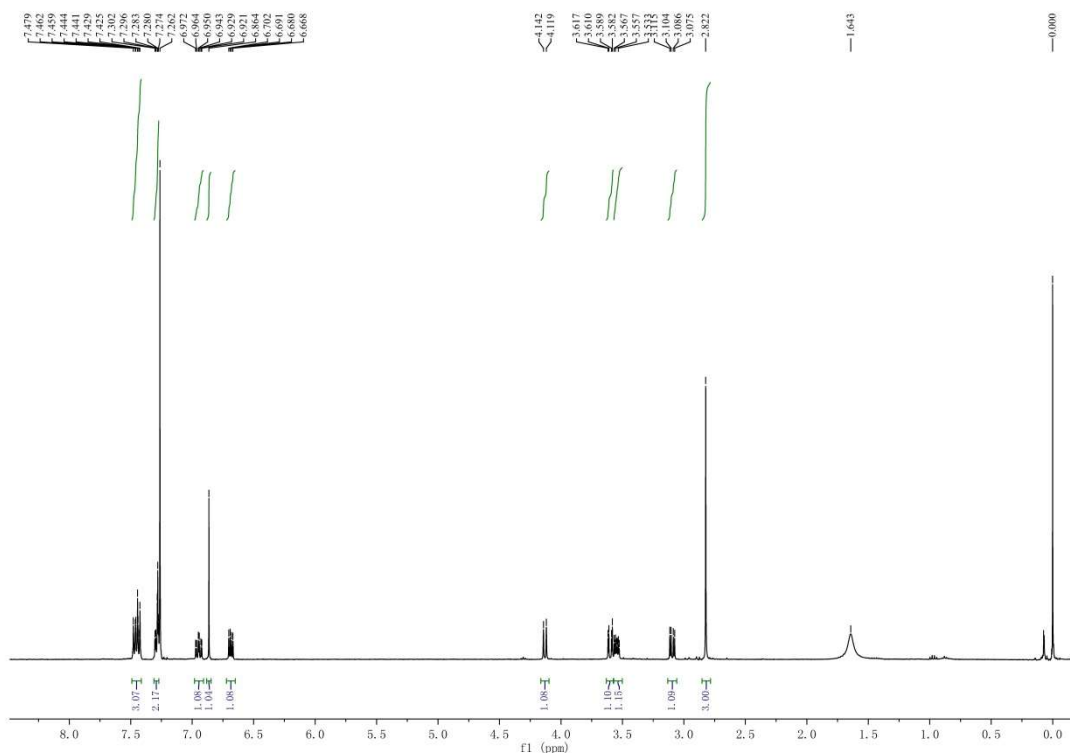
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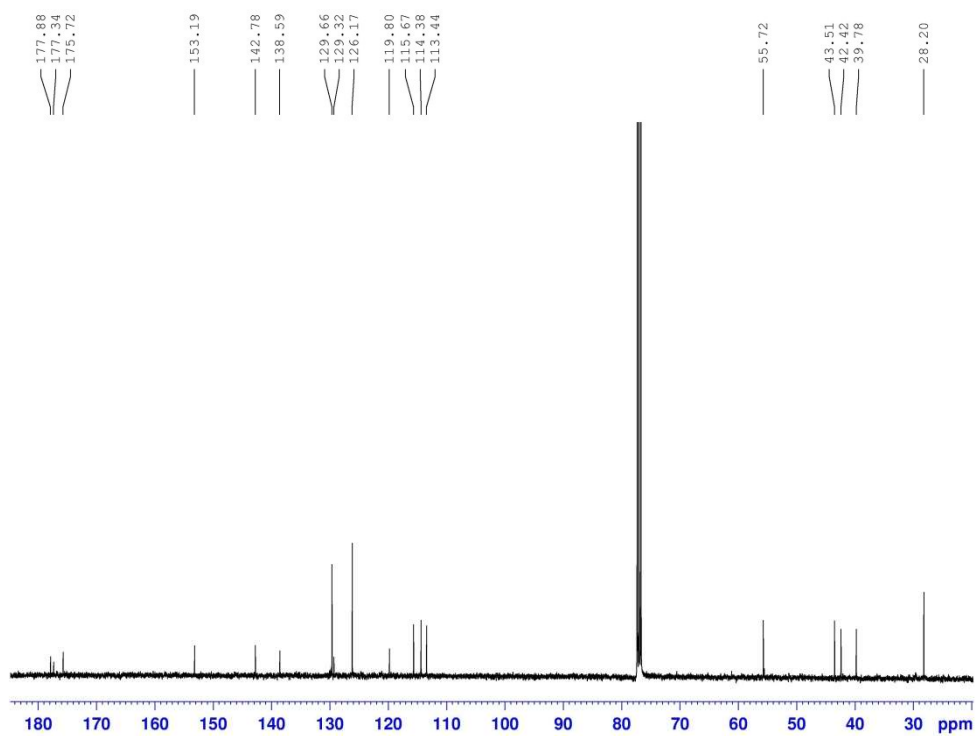
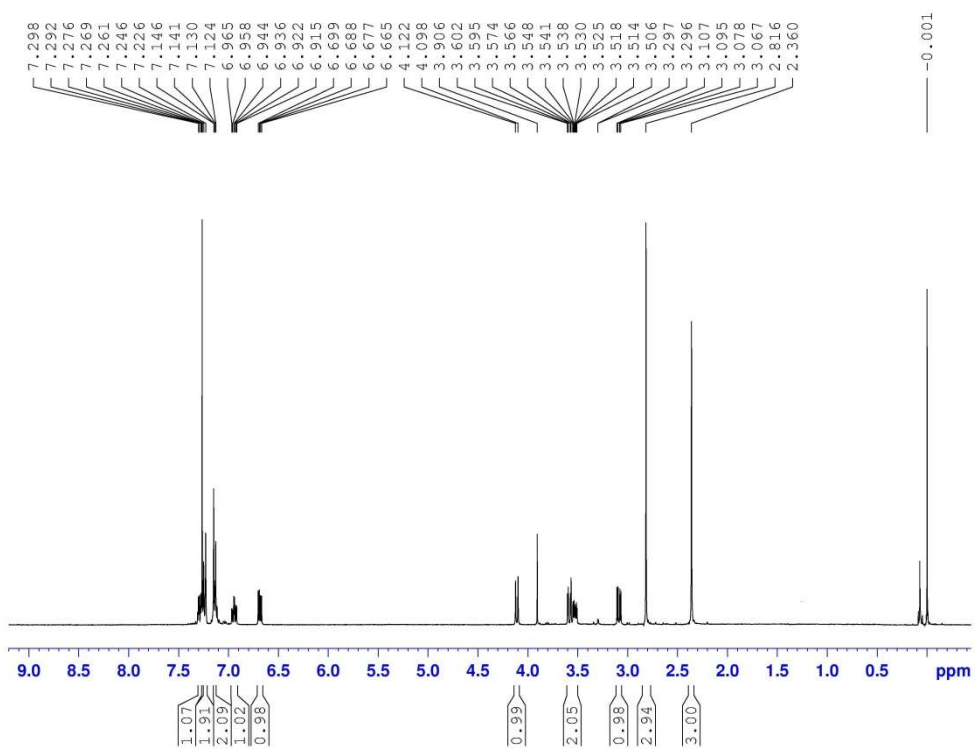
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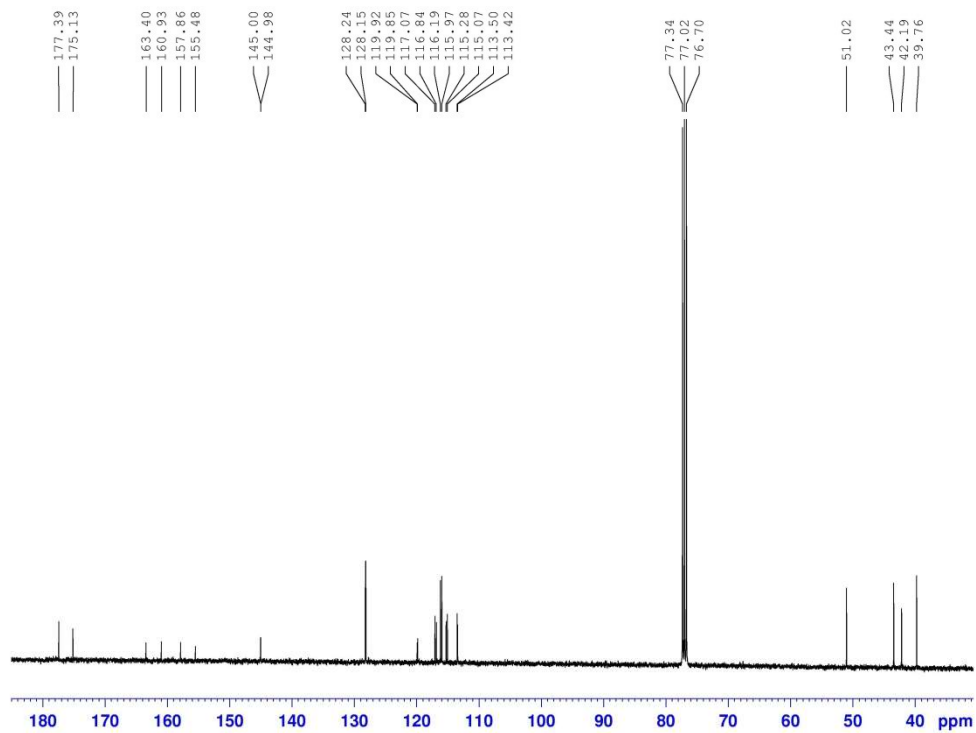
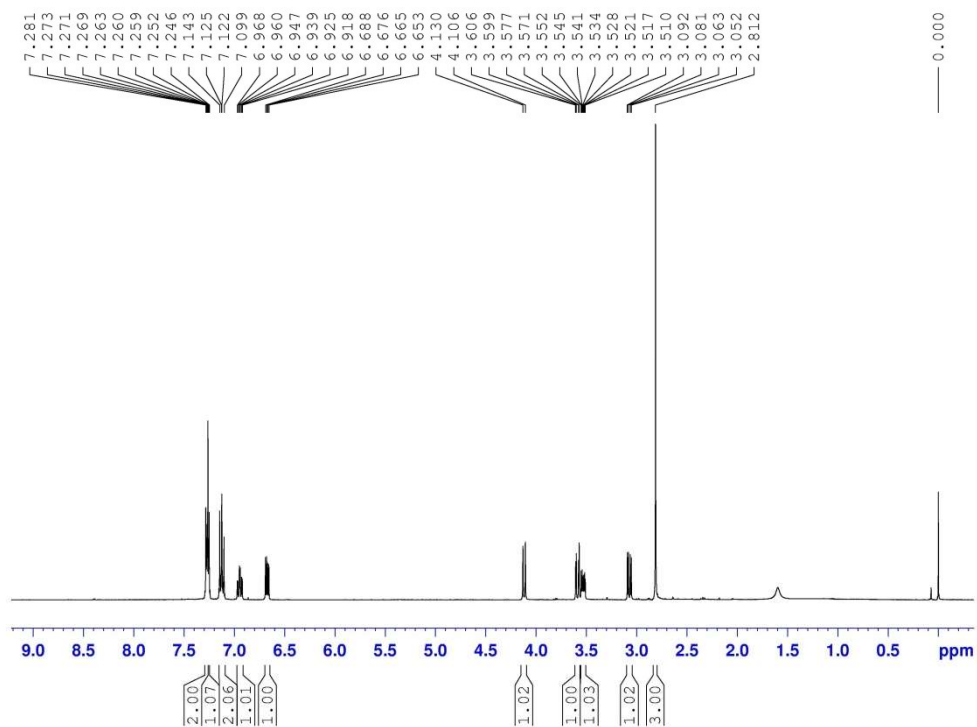
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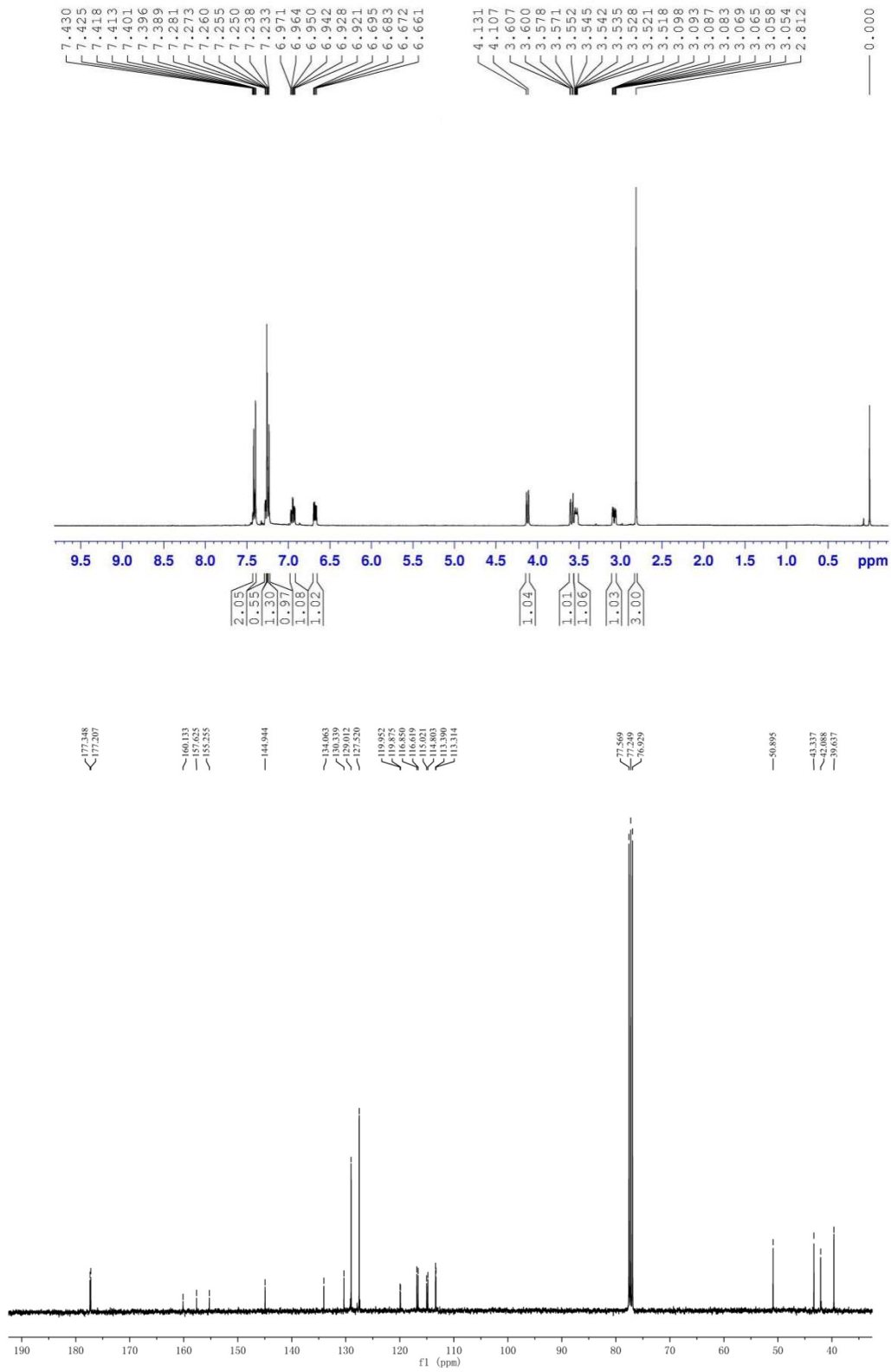
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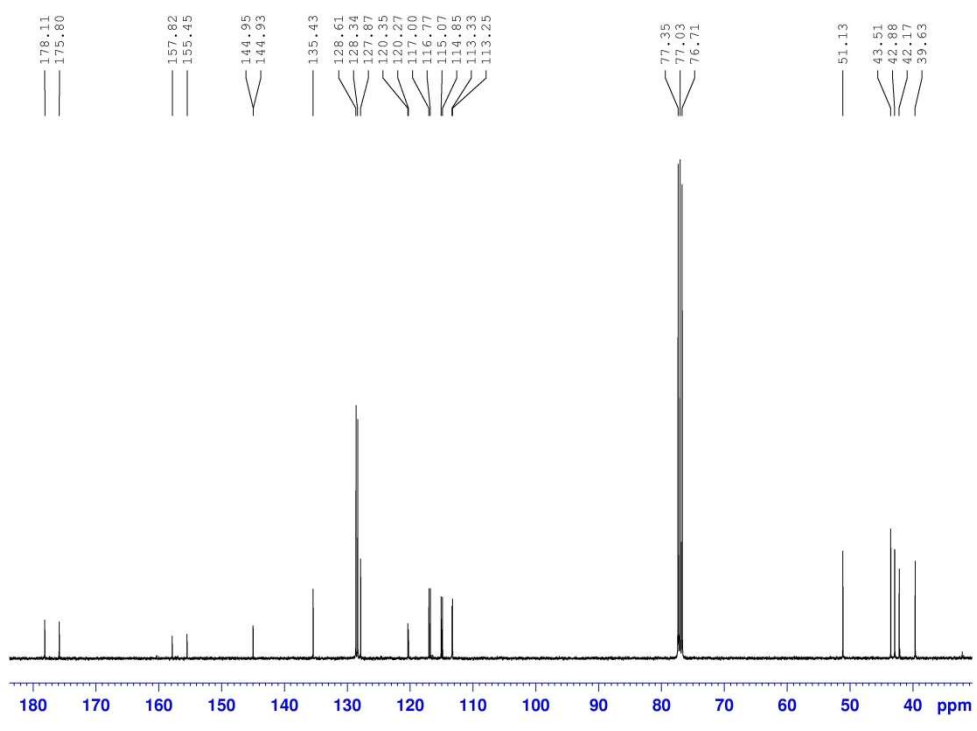
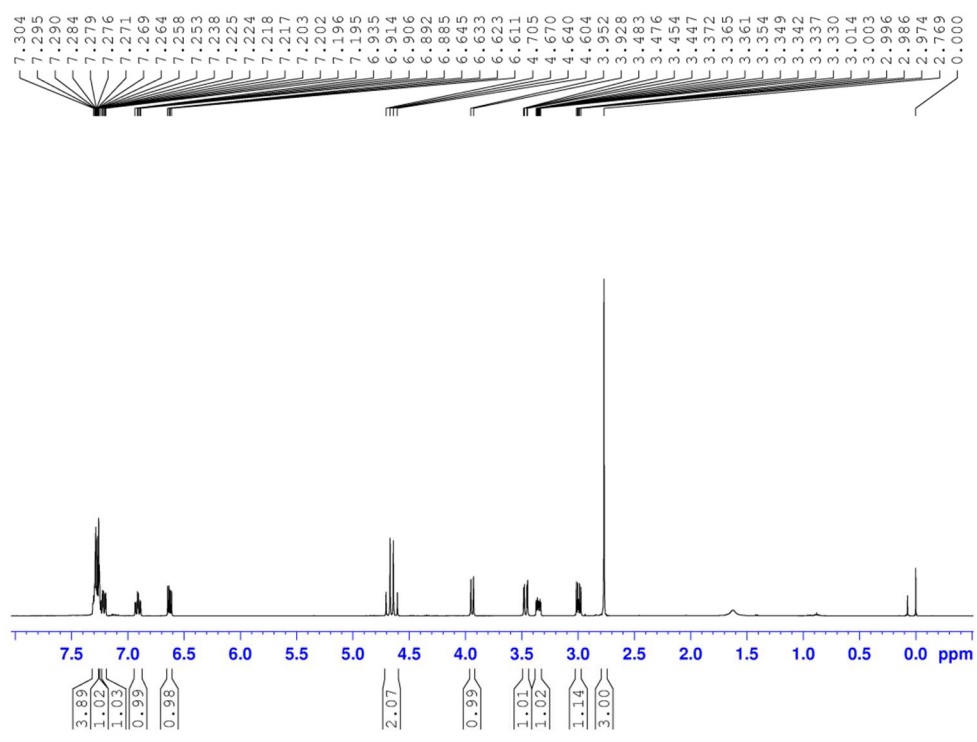
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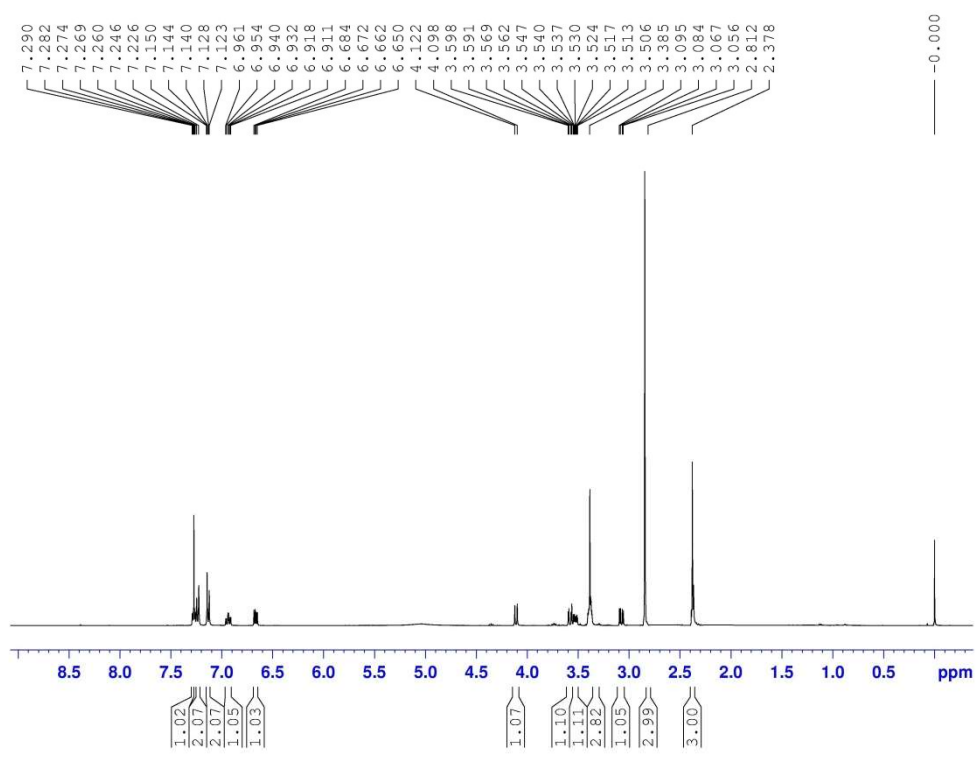
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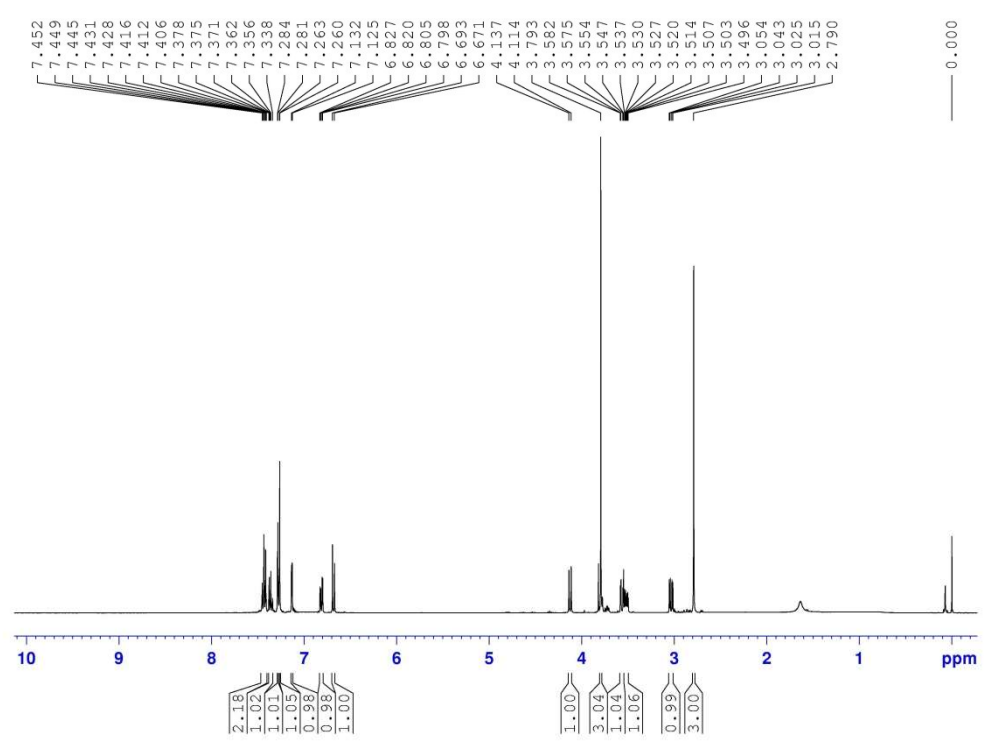
3p



3q



3r



3s

