

Supporting Information

One-pot Preparation of Piperazines by Regioselective Ring-Opening of Non-Activated Arylaziridines

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General

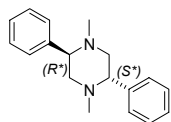
Dry acetonitrile was commercially available and used without further purification. For the ^1H and ^{13}C NMR spectra (^1H NMR 400, 500, 600 MHz, ^{13}C NMR 100, 125, 150 MHz), CDCl_3 , CD_3OD and CD_3CN were used as the solvents. MS-ESI analyses were performed on Agilent 110 LC/MSD trap system VL. GC-MS spectrometry analyses were carried out on a gas chromatograph (dimethylsilicon capillary column, 30 m, 0.25 mm i.d.) equipped with a mass selective detector operating at 70 eV (EI). Melting points are uncorrected. Infra-red spectra of the compounds were recorded as a film or as KBr disc as indicated, by a Perkin-Elmer 283 spectrometer. Analytical thin layer chromatography (TLC) was carried out on aluminium backed plates pre-coated (0.25 mm) with Silica Gel 60 F254. Detection was accomplished by UV light (254 nm), by spraying a 5% solution of $(\text{NH}_4)_2\text{Mo}_7\text{O}_{24} \cdot 4 \text{H}_2\text{O}$ (phosphomolibdic acid) in EtOH, or in a 5% solution (w/v) of ammonium molybdate and 0.2% (w/v) of cerium(III)sulfate in 17.6% (w/v) aqueous sulfuric acid followed by heating until dark spots appear, or in a iodine chamber. For flash chromatography silica Gel 60, 0.040–0.063 mm particle size was used. CHN analyses were performed on a EuroEA 3000 analyzer. Optical rotation $[\alpha]^{20}$ values were measured by using a polarimeter with a cell of 1 dm path length; the concentration (c) is expressed in g/100mL. All air- and water-sensitive reactions were carried out in oven-dried glassware under argon or nitrogen atmosphere using syringe-septum cap techniques. Aziridines **1a-r** were prepared according to reported procedures.¹

General Procedure for the Dimerization of Aziridines 1a-r.

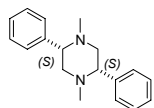
In a sealed glass tube, to a pre-warmed solution of aziridine (1.0 mmol) in 10.0 ml of acetonitrile at 70 °C, MgBr_2 (0.05 mol %) was added. The resulting suspension was stirred at 70 °C until consumption of the starting aziridine (TLC, GC, GC-MS monitoring). The reaction mixture was then poured in 20 mL of water and extracted with EtOAc (3×10 mL). The combined organic layers were dried (Na_2SO_4) and the solvent evaporated *in vacuo*. The crude was purified by flash chromatography on silica gel (EtOAc/Hexane) or by crystallization. Piperazines **2a**, *meso*-**2b**, and **2m** have been already reported.²

¹ a) Capriati, V.; Florio, S.; Luisi, R.; Musio, B. *Org. Lett.* **2005**, *7*, 17, 3749-3752. b) Sawamura, M.; Hamashima, H; Ito, Y. *J. Org. Chem.* **1990**, *55*, 5935. c) Huszthy, P; Oue, M; Bradshaw, J. S.; Zhu, C. Y.; Wang, T.; Dalley, N. K.; Curtis, J. C.; Izatt, R. M. *J. Org. Chem.* **1992**, *57*, 5383-5394. d) Anderson, W. K.; Milowsky, A. S. *J. Med. Chem.* **1986**, *29*, 2241 – 2249. e) Fujita, S.; Imamura, K.; Nozaki, H. *Bull. Chem. Soc. Jpn.* **1971**, *44*, 1975-1977.

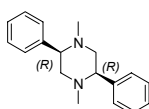
² a) Takasu, K.; Miyamoto, H.; Tanaka, K.; Taga, T.; Bando, M.; Fuji, K. *Chemical & Pharmaceutical Bulletin* **2000**, *48*, 12, 2014-2016. b) Yang, Z. -Z., ; He, L. -N.; Peng, S. -Y.; Liu, A. -H. *Green Chemistry* **2010**, *12*, 10, 1850-1854. c) Bretschneider, H. *Monatshefte fuer Chemie* **1948**, *78*, 82-116.



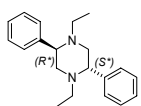
(2R*,5S*)-2,5-diphenyl-1,4-dimethylpiperazine (meso-2a). white solid, Mp = 180 °C, R_f [Hexane/EtOAc (8:2)] = 0.6. ¹H NMR (CDCl₃, 600 MHz) δ 7.42 (m, 2H), 7.36 (t, *J* = 7.6 Hz, 2H), 7.29-7.31 (m, 1H), 3.27 (dd, *J* = 2.8, 10.6 Hz, 1H), 2.97 (dd, *J* = 3.0, 11.8 Hz, 1H), 2.38 (dd, *J* = 11.1, 11.5 Hz, 1H), 2.07 (s, 3H). ¹³C NMR (CDCl₃, 100 MHz) δ 141.1, 128.5, 127.9, 127.6, 69.4, 64.1, 43.2. GC-MS *m/z* (%) 266 [M⁺, 35], 223 (41), 222 (28), 119 (36), 118 (86), 104 (100). FT-IR (KBr, cm⁻¹): 2950, 2835, 2786, 1635, 1451, 1144, 1098, 753, 699. Anal. Calcd for C₁₈H₂₂N₂: C, 81.16%; H, 8.32%; N, 10.52%. Found: C, 80.93%; H, 8.12%; N, 10.29%.



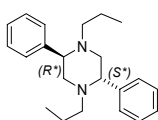
(S,S)-1,4-dimethyl-2,5-diphenylpiperazine (S,S-2a). [α]₅₈₉²⁰ = +56.4 (c=0.5, CHCl₃). Enantiomeric purity (er = 3:97) was determined by HPLC analysis (Daicel Chiralpak AD, Hexane/ Isopropanol= 97:3 + 0.2% Et₂NH, Flow rate=0.50 mL/min, λ= 254 nm): for racemic piperazine t₁ = 7.79 min, t₂ = 8.68 min; for enantioenriched piperazine resulted t = 8.68 min. See er determination section.



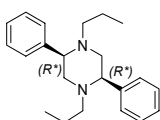
(R,R)-1,4-dimethyl-2,5-diphenylpiperazine (R,R-2a). [α]₅₈₉²⁰ = -56.4 (c=0.5, CHCl₃). Enantiomeric purity (er = 97:3) was determined by HPLC analysis (Daicel Chiralpak AD, Hexane/ Isopropanol= 97:3 + 0.2% Et₂NH, Flow rate=0.50 mL/min, λ= 254 nm): for racemic piperazine t₁ = 7.79 min, t₂ = 8.68 min; for enantioenriched piperazine resulted t = 7.79 min. See er determination section.



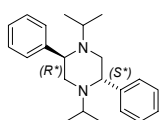
(2R*,5R*)-2,5-diphenyl-1,4-diethylpiperazine (2b). yellow oil, R_f [Hexane/EtOAc (8:2)] = 0.2. ¹H NMR (CDCl₃, 400 MHz) δ 7.70 (d, *J* = 7.1 Hz, 2H), 7.35-7.39 (m, 2H), 7.27-7.31 (m, 1H), 3.72 (dd, *J* = 3.9, 6.1 Hz, 1H), 2.97 (dd, *J* = 6.3, 11.8 Hz, 1H), 2.67 (dd, *J* = 3.8, 11.8 Hz, 1H), 2.34-2.42 (m, 1H), 2.18-2.27 (m, 1H), 1.01 (t, *J* = 7.2 Hz, 3H). ¹³C NMR (CDCl₃, 100 MHz) δ 129.3, 128.0, 127.2, 63.8, 54.1, 48.3, 11.9. GC-MS *m/z* (%) 294 [M⁺, 16], 236 (35), 207 (31), 146 (18), 134 (44), 133 (87), 132 (95), 118 (71), 104 (100), 91 (50), 77(15). FT-IR (film, cm⁻¹): 3027, 2969, 2814, 1661, 1452, 1386, 1312, 1155, 760, 703.



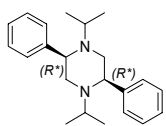
(2R*,5S*)-2,5-diphenyl-1,4-dipropylpiperazine (meso-2c). white solid, Mp = 110 °C, R_f [Hexane/EtOAc (9:1)] = 0.6. ¹H NMR (CDCl₃, 400 MHz) δ 7.40 (d, *J* = 7.2 Hz, 2H), 7.32 (t, *J* = 7.2 Hz, 2H), 7.24-7.27 (m, 1H), 3.39 (dd, *J* = 2.8, 10.5 Hz, 1H), 3.05 (dd, *J* = 2.9, 11.6 Hz, 1H), 2.36-2.43 (m, 1H), 2.24 (t, *J* = 11.1 Hz, 1H), 1.83-1.90 (m, 1H), 1.28-1.42 (m, 2H), 0.69 (t, *J* = 7.3 Hz, 3H). ¹³C NMR (CDCl₃, 100 MHz) δ 142.0, 128.3, 128.0, 127.3, 67.7, 60.8, 56.5, 19.1, 11.7. GC-MS *m/z* (%) 322 [M⁺, 23], 293 (41), 250 (44), 222 (19), 189 (22), 146 (90), 118 (100), 104 (68), 91 (64), 77 (11), 70 (16). FT-IR (KBr, cm⁻¹): 2957, 2870, 2791, 1451, 1388, 1142, 1115, 1012, 744, 699. Anal. Calcd for C₂₂H₃₀N₂: C, 81.94%; H, 9.38%; N, 8.69%. Found: C, 81.88%; H, 9.36%; N, 8.74%.



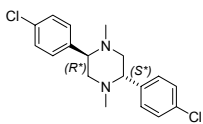
(2R*,5R*)-2,5-diphenyl-1,4-dipropylpiperazine (2c). yellow oil, R_f [Hexane/EtOAc (9:1)] = 0.2. ¹H NMR (CDCl₃, 400 MHz) δ 7.67 (d, *J* = 7.5 Hz, 2H), 7.34 (t, *J* = 7.5 Hz, 2H), 7.24-7.28 (m, 1H), 3.66 (dd, *J* = 3.9, 5.9 Hz, 1H), 2.97 (dd, *J* = 6.3, 11.9 Hz, 1H), 2.60 (dd, *J* = 3.8, 11.9 Hz, 1H), 2.21-2.28 (m, 1H), 2.06-2.13 (m, 1H), 1.39-1.48 (m, 2H), 0.79 (t, *J* = 7.3 Hz, 3H). ¹³C NMR (CDCl₃, 100 MHz) δ 141.0, 129.3, 128.0, 127.1, 64.4, 56.5, 54.8, 20.0, 11.8. GC-MS *m/z* (%) 322 [M⁺, 23], 293 (35), 250 (40), 222 (18), 189 (20), 146 (89), 118 (100), 104 (67), 91 (62), 77 (11), 70 (17). FT-IR (film, cm⁻¹): 2960, 2809, 1653, 1451, 1260, 1107, 1018, 800, 759, 702.



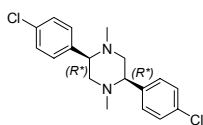
(2R*,5S*)-1,4-diisopropyl-2,5-diphenylpiperazine (meso-2d): white solid, Mp = 222 °C, R_f [Hexane/EtOAc (8:2)] = 0.6. ¹H NMR (CDCl₃, 600 MHz) δ 7.43 (m, 2H), 7.35 (t, *J* = 7.2 Hz, 2H), 7.28-7.30 (m, 1H), 3.66 (dd, *J* = 2.7, 10.2 Hz, 1H), 2.81-2.86 (m, 2H), 2.44 (t, *J* = 10.7 Hz, 1H), 0.97 (d, *J* = 6.8 Hz, 3H), 0.76 (d, *J* = 6.5 Hz, 3H). ¹³C NMR (CDCl₃, 150 MHz) δ 142.2, 128.4, 127.3, 64.7, 52.6, 48.0, 21.0, 12.3. GC-MS *m/z* (%) 322 [M⁺, 3], 307 (9), 279 (8), 250 (14), 161 (26), 147 (86), 132 (100), 104 (39), 91 (25). FT-IR (KBr, cm⁻¹): 2966, 2818, 1639, 1454, 1173, 1119, 1030, 746, 699. Anal. Calcd for C₂₂H₃₀N₂: C, 81.94%; H, 9.38%; N, 8.69%. Found: C, 81.64%; H, 9.12%; N, 8.52%.



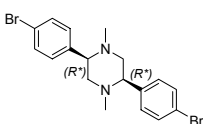
(2R*,5R*)-1,4-diisopropyl-2,5-diphenylpiperazine (2d): yellow oil, R_f [Hexane/EtOAc (8:2)] = 0.2. $^1\text{H NMR}$ (CDCl_3 , 400 MHz) δ 7.67 (d, J = 8.0 Hz, 2H), 7.32-7.36 (m, 2H), 7.25-7.28 (m, 1H), 3.90 (m, 1H), 2.91 (dd, J = 6.3, 11.8 Hz, 1H), 2.78-2.84 (m, 2H), 0.91 (d, J = 6.3 Hz, 3H), 0.83 (d, J = 6.6 Hz, 3H). $^{13}\text{C NMR}$ (CDCl_3 , 150 MHz) δ 142.5, 129.0, 128.0, 126.9, 61.9, 49.3, 48.9, 20.5, 16.4. GC-MS m/z (%) 322 [M^+ , 3], 307 (8), 279 (7), 250 (13), 161 (23), 147 (80), 132 (100), 104 (39), 91 (26). FT-IR (film, cm^{-1}): 2965, 1600, 1452, 1183, 1113, 1030, 761, 702.



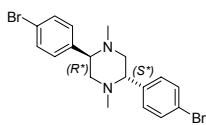
(2R*,5S*)-2,5-bis(4-chlorophenyl)-1,4-dimethylpiperazine (meso-2f): white solid, Mp = 221 $^\circ\text{C}$, R_f [Hexane/EtOAc (8:2)] = 0.6. $^1\text{H NMR}$ (CDCl_3 , 600 MHz) δ 7.32 (m, 4H), 3.20 (dd, J = 2.8, 10.6 Hz, 1H), 2.88 (dd, J = 2.8, 11.8 Hz, 1H), 2.28 (t, J = 11.2 Hz, 1H), 2.01 (s, 3H). $^{13}\text{C NMR}$ (CDCl_3 , 100 MHz) δ 139.7, 133.2, 129.2, 128.7, 68.6, 63.9, 43.1. GC-MS m/z (%) 334 [M^+ , 16], 291 (15), 152 (27), 138 (100). FT-IR (KBr, cm^{-1}): 2946, 2789, 1635, 1488, 1451, 1145, 1099, 838, 815, 522; Anal. Calcd for $\text{C}_{18}\text{H}_{20}\text{Cl}_2\text{N}_2$: C, 64.48%; H, 6.01%; N, 8.36%. Found: C, 64.20%; H, 6.12%; N, 8.29%.



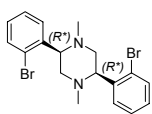
(2R*,5R*)-2,5-bis(4-chlorophenyl)-1,4-dimethylpiperazine (2f): white solid, Mp = 139 $^\circ\text{C}$, R_f [Hexane/EtOAc (8:2)] = 0.2. $^1\text{H NMR}$ (CDCl_3 , 600 MHz) δ 7.56 (d, J = 8.1 Hz, 2H), 7.33 (d, J = 8.3 Hz, 2H), 3.50 (m, 1H), 2.81 (dd, J = 6.2, 11.9 Hz, 1H), 2.60 (dd, J = 3.6, 12.0 Hz, 1H), 2.10 (s, 3H). $^{13}\text{C NMR}$ (CDCl_3 , 100 MHz) δ 138.4, 133.1, 130.5, 128.2, 65.0, 57.4, 43.1. GC-MS m/z (%) 334 [M^+ , 13], 291 (14), 152 (27), 138 (100). FT-IR (KBr, cm^{-1}): 2937, 2796, 1641, 1488, 1157, 1084, 840, 816, 526; Anal. Calcd for $\text{C}_{18}\text{H}_{20}\text{Cl}_2\text{N}_2$: C, 64.48%; H, 6.01%; N, 8.36%. Found: C, 64.51%; H, 5.95%; N, 8.23%.



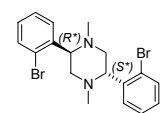
(2R*,5S*)-2,5-bis(4-bromophenyl)-1,4-dimethylpiperazine (meso-2g): white solid, Mp = 227 $^\circ\text{C}$, R_f [Hexane/EtOAc (8:2)] = 0.6. $^1\text{H NMR}$ (CDCl_3 , 600 MHz) δ 7.49 (d, J = 8.4 Hz, 2H), 7.29 (d, J = 7.7 Hz, 2H), 3.21 (dd, J = 2.4, 10.6 Hz, 1H), 2.90 (dd, J = 2.8, 11.8 Hz, 1H), 2.29 (t, J = 11.2 Hz, 1H), 2.04 (s, 3H). $^{13}\text{C NMR}$ (CDCl_3 , 150 MHz) δ 140.2, 131.7, 129.5, 121.3, 68.6, 63.8, 43.2. GC-MS m/z (%) 424 [M^+ , 20], 381 (23), 302 (5), 300 (6), 198 (25), 196 (22), 184 (99), 182 (100). FT-IR (KBr, cm^{-1}): 2926, 2795, 1485, 1144, 1095, 1069, 840, 803, 517. Anal. Calcd for $\text{C}_{18}\text{H}_{20}\text{Br}_2\text{N}_2$: C, 50.97%; H, 4.75%; N, 6.60%. Found: C, 50.56%; H, 4.89%; N, 6.39%.



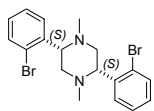
(2R*,5R*)-2,5-bis(4-bromophenyl)-1,4-dimethylpiperazine (2g): yellow oil, R_f [Hexane/EtOAc (8:2)] = 0.2. $^1\text{H NMR}$ (CDCl_3 , 400 MHz) δ 7.47-7.53 (m, 4H), 3.48-3.50 (m, 1H), 2.81 (dd, J = 6.3, 12.2 Hz, 1H), 2.60 (dd, J = 3.7, 11.8 Hz, 1H), 2.10 (s, 3H). $^{13}\text{C NMR}$ (CDCl_3 , 150 MHz) δ 138.8, 131.2, 130.9, 121.3, 65.0, 57.4, 43.1. GC-MS m/z (%) 424 [M^+ , 19], 381 (24), 302 (6), 300 (6), 198 (25), 196 (22), 184 (100), 182 (100). FT-IR (film, cm^{-1}): 2927, 2794, 1762, 1485, 1156, 1093, 1072, 1011, 816.



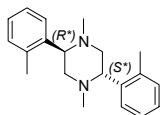
(2R*,5S*)-2,5-bis(2-bromophenyl)-1,4-dimethylpiperazine (meso-2h): Purification by crystallizing from EtOAc, white solid, Mp = dec, R_f [Hexane/EtOAc (8:2)] = 0.6. $^1\text{H NMR}$ (CDCl_3 , 400 MHz) δ 7.64 (dd, J = 1.5, 7.8 Hz, 1H), 7.52 (dd, J = 0.9, 8.0 Hz, 1H), 7.33 (t, J = 7.6 Hz, 1H), 7.10 (dt, J = 1.6, 8.0 Hz, 1H), 3.77 (dd, J = 2.9, 11.5 Hz, 1H), 2.97 (dd, J = 3.0, 11.6 Hz, 1H), 2.20 (t, J = 10.9 Hz, 1H), 2.02 (s, 3H). $^{13}\text{C NMR}$ (CDCl_3 , 150 MHz) δ 139.9, 132.8, 129.7, 128.6, 127.6, 124.2, 66.8, 62.3, 43.0. GC-MS m/z (%) 424 [M^+ , 22], 381 (23), 345 (53), 343 (54), 302 (98), 300 (100), 199 (89), 198 (93), 197 (90), 196 (80), 184 (51), 182 (51), 103 (40), 77 (28), 42 (36). FT-IR (KBr, cm^{-1}): 3061, 1692, 1457, 1098, 849, 606. Anal. Calcd for $\text{C}_{18}\text{H}_{20}\text{Br}_2\text{N}_2$: C, 50.97%; H, 4.75%; N, 6.60%. Found: C, 51.02%; H, 4.69%; N, 6.58%.



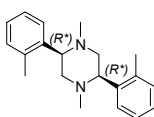
(2R*,5R*)-2,5-bis(2-bromophenyl)-1,4-dimethylpiperazine (2h): yellow oil, R_f [Hexane/EtOAc (8:2)] = 0.6. $^1\text{H NMR}$ (CDCl_3 , 400 MHz) δ 8.17 (dd, J = 1.4, 7.8 Hz, 1H), 7.57 (dd, J = 1.2, 8.0 Hz, 1H), 7.37 (dt, J = 0.9, 7.4 Hz, 1H), 7.13 (dt, J = 1.7, 7.9 Hz, 1H), 4.16 (dd, J = 4.1, 5.3 Hz, 1H), 2.87 (dd, J = 6.0, 12.4 Hz, 1H), 2.78 (dd, J = 4.0, 12.2 Hz, 1H), 2.26 (s, 3H). $^{13}\text{C NMR}$ (CDCl_3 , 150 MHz) δ 139.8, 133.0, 130.3, 128.5, 127.2, 125.1, 62.2, 55.6, 42.5. GC-MS m/z (%) 424 [M^+ , 22], 381 (25), 345 (52), 343 (53), 302 (97), 300 (100), 199 (90), 198 (95), 197 (92), 196 (80), 184 (53), 182 (53), 103 (39), 77 (27), 42 (37). FT-IR (film, cm^{-1}): 3060, 2938, 2845, 2795, 1677, 1465, 1159, 1094, 1019, 754.



(S,S-2h): $[\alpha]_{589}^{20} = +14$ ($c=0.2$, CHCl_3). Enantiomeric purity ($er = 5:95$) was determined by HPLC analysis (Daicel Chiralpak ODH, Hexane/ Isopropanol= 90:10, Flow rate=0.50 mL/min, $\lambda = 254$ nm): for racemic piperazine $t_1 = 7.80$ min, $t_2 = 8.86$ min; for enantioenriched piperazine resulted $t = 8.86$ min). See *er* determination section.

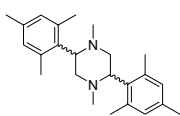


(2R*,5S*)-1,4-Dimethyl-2,5-di(2-methylphenyl)piperazine (meso-2i): white solid, $M_p = 173$ °C, R_f [Hexane/EtOAc (8:2)] = 0.6. $^1\text{H NMR}$ (CDCl_3 , 400 MHz) δ 7.54 (d, $J = 7.5$ Hz, 1H), 7.19-7.23 (m, 1H), 7.13-7.16 (m, 2H), 3.53 (dd, $J = 2.5, 10.4$ Hz, 1H), 2.89 (dd, $J = 2.9, 11.8$ Hz, 1H), 2.42 (s, 3H), 2.31 (t, $J = 11.1$ Hz, 1H), 2.01 (s, 3H). $^{13}\text{C NMR}$ (CDCl_3 , 100 MHz) δ 138.9, 136.0, 130.4, 127.4, 126.9, 126.3, 64.1, 63.0, 42.8, 19.8. GC-MS m/z (%) 294 [M^+ , 24], 251 (20), 236 (15), 132 (27), 118 (100). FT-IR (KBr, cm^{-1}): 2935, 2847, 2794, 1638, 1449, 1258, 1143, 1098, 768. Anal. Calcd for $\text{C}_{20}\text{H}_{26}\text{N}_2$: C, 81.59%; H, 8.90%; N, 9.51%. Found: C, 81.71%; H, 9.03%; N, 9.19%.

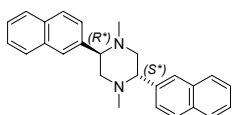


(2R*,5R*)-1,4-Dimethyl-2,5-di(2-methylphenyl)piperazine (2i): yellow oil, R_f [Hexane/EtOAc (8:2)] = 0.2. $^1\text{H NMR}$ (CDCl_3 , 400 MHz) δ 8.09 (d, $J = 7.7$ Hz, 1H), 7.23-7.27 (m, 1H), 7.13-7.18 (m, 2H), 3.84 (dd, $J = 4.0, 6.1$ Hz, 1H), 2.95 (dd, $J = 6.2, 12.4$ Hz, 1H), 2.64 (dd, $J = 4.0, 12.4$ Hz, 1H), 2.38 (s, 3H), 2.20 (s, 3H). $^{13}\text{C NMR}$ (CDCl_3 , 100 MHz) δ 139.4, 136.4, 130.3, 128.8, 126.7, 125.8, 59.3, 55.9, 42.6, 19.8. GC-MS m/z (%) 294 [M^+ , 20], 251 (22), 236 (13), 132 (28), 118 (100). FT-IR (film, cm^{-1}): 2939, 2786, 1459, 1353, 1157, 1024, 752.

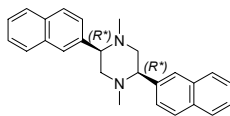
(R,R)-1,4-Dimethyl-2,5-di(2-methylphenyl)piperazine. $[\alpha]_{589}^{20} = -25.43$ ($c=0.7$, CHCl_3). Enantiomeric purity ($er = 30:70$) was determined by HPLC analysis (Cellulose – Lux2, Hexane/ Isopropanol= 99:0.1, Flow rate=0.50 mL/min, $\lambda = 254$ nm): for racemic piperazine $t_1 = 7.27$ min, $t_2 = 8.23$ min; for enantioenriched piperazine resulted $t = 8.23$ min. See *er* determination section.



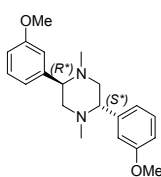
Unseparable diastereomeric mixture, $dr = 1:1$, 75%. **2,5-dimesityl-1,4-dimethylpiperazine (meso-2j + 2j).** R_f [Hexane/EtOAc (8:2)] = 0.6. $^1\text{H NMR}$ (CDCl_3 , 400 MHz): δ 6.86 (s, 4H), 4.01 (dd, $J = 5.9, 9.5$ Hz, 1H), 3.75 (dd, $J = 3.0, 10.8$ Hz, 1H), 3.50 (dd, $J = 9.5, 12.9$ Hz, 1H), 2.79 (dd, $J = 3.0, 11.5$ Hz, 1H), 2.73 (s, 3H), 2.53 (m, 7H), 2.39-2.44 (m, 4H), 2.29 (s, 6H), 2.18 (s, 3H), 2.02 (s, 3H). The attached protonic spectrum refers to a chromatographic fraction containing a 60:40 diastereomeric mixture. $^{13}\text{C NMR}$ (CDCl_3 , 100 MHz) δ 137.7, 137.2, 136.8, 135.9₄, 135.9, 135.8, 133.6, 131.1, 129.9, 129.1, 64.8, 59.2, 59.1, 56.3, 42.7, 42.3, 21.7, 21.2, 20.8, 20.8, 20.7. GC-MS m/z (%) 350 [M^+ , 4], 306 (21), 162 (44), 146 (100). FT-IR (film, cm^{-1}): 2939, 2762, 1611, 1446, 1370, 1096, 849, 808.



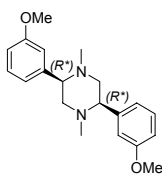
(2R*,5S*)-1,4-Dimethyl-2,5-di(naphthalen-2-yl)piperazine (meso-2k): white solid, $M_p = \text{dec}$. R_f [Hexane/EtOAc (8:2)] = 0.6. $^1\text{H NMR}$ (CDCl_3 , 500 MHz) δ 7.84-7.89 (m, 4H), 7.60 (d, $J = 7.6$ Hz, 1H), 7.46-7.52 (m, 2H), 3.51 (d, $J = 9.3$ Hz, 1H), 3.08 (dd, $J = 2.4, 11.9$ Hz, 1H), 2.55 (t, $J = 11.3$ Hz, 1H), 2.12 (s, 3H). $^{13}\text{C NMR}$ (CDCl_3 , 125 MHz) δ 138.6, 133.5, 133.1, 128.3, 127.8, 127.7, 126.9, 126.1, 125.8, 69.5, 64.0, 43.3. GC-MS m/z (%) 366 [M^+ , 20], 323 (6), 168 (19), 154 (100). FT-IR (KBr, cm^{-1}): 2936, 2835, 2784, 1506, 1446, 1323, 1093, 822, 749, 480. Anal. Calcd for $\text{C}_{26}\text{H}_{26}\text{N}_2$: C, 85.21%; H, 7.15%; N, 7.64%. Found: C, 85.10%; H, 7.06%; N, 7.59%.



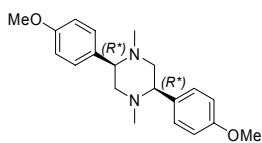
(2R*,5R*)-1,4-Dimethyl-2,5-di(naphthalen-2-yl)piperazine (2k): yellow oil; R_f [Hexane/EtOAc (8:2)] = 0.2. $^1\text{H NMR}$ (CDCl_3 , 400 MHz) δ 8.16 (s, 1H), 7.84-7.91 (m, 4H), 7.44-7.51 (m, 2H), 3.74 (dd, $J = 4.0, 5.8$ Hz, 1H), 3.05 (dd, $J = 6.2, 11.9$ Hz, 1H), 2.73 (dd, $J = 3.8, 11.9$ Hz, 1H), 2.18 (s, 3H). $^{13}\text{C NMR}$ (CDCl_3 , 100 MHz) δ 137.7, 133.2, 132.8, 128.2, 128.0, 127.6, 127.5, 127.4, 125.9, 125.7, 65.8, 57.7, 43.4. GC-MS m/z (%) 366 [M^+ , 16], 323 (6), 168 (18), 154 (100). FT-IR (film, cm^{-1}): 3054, 2934, 2793, 1599, 1506, 1452, 1372, 1121, 1093, 820, 746.



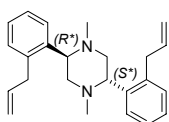
(2R*,5S*)-2,5-bis(3-methoxyphenyl)-1,4-dimethylpiperazine (meso-2l): white solid, $M_p = 124$ °C, R_f [Hexane/EtOAc (7:3)] = 0.6. $^1\text{H NMR}$ (CDCl_3 , 600 MHz) δ 7.27-7.28 (m, 1H), 6.99-7.03 (m, 2H), 6.84 (dd, $J = 1.8, 8.2$ Hz, 1H), 3.84 (s, 3H), 3.24 (d, $J = 9.2$ Hz, 1H), 2.97 (dd, $J = 2.6, 11.7$ Hz, 1H), 2.37 (t, $J = 11.2$ Hz, 1H), 2.08 (s, 3H). $^{13}\text{C NMR}$ (CDCl_3 , 150 MHz) δ 159.8, 142.9, 129.4, 120.2, 113.2, 69.4, 64.0, 55.3, 43.2. GC-MS m/z (%) 326 [M^+ , 25], 283 (9), 149 (16), 148 (26), 134 (100); FT-IR (KBr, cm^{-1}): 2926, 2789, 1597, 1483, 1459, 1266, 1239, 1040, 786, 698; Anal. Calcd for $\text{C}_{20}\text{H}_{26}\text{N}_2\text{O}_2$: C, 73.59%; H, 8.03%; N, 8.58%. Found: C, 73.49%; H, 7.99%; N, 8.61%.



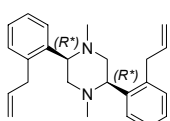
(2R*,5R*)-2,5-bis(3-methoxyphenyl)-1,4-dimethylpiperazine (2l): yellow oil. R_f [Hexane/EtOAc (7:3)] = 0.2. $^1\text{H NMR}$ (CDCl_3 , 600 MHz) δ 7.35 (s, 1H), 7.27-7.30 (m, 1H), 7.21 (d, $J = 7.5$ Hz, 1H), 6.85 (dd, $J = 2.0, 8.1$ Hz, 1H), 3.87 (s, 3H), 3.53 (m, 1H), 2.93 (dd, $J = 5.7, 11.6$ Hz, 1H), 2.66 (dd, $J = 3.6, 11.9$ Hz, 1H), 2.14 (s, 3H). $^{13}\text{C NMR}$ (CDCl_3 , 150 MHz): δ 159.4, 132.1, 132.0, 131.9₂, 131.9, 128.9, 128.5, 128.4, 121.8, 115.1, 112.6, 65.6, 57.6, 55.2, 43.1. GC-MS m/z (%) 326 [M^+ , 26], 283 (10), 149 (16), 148 (26), 134 (100). FT-IR (film, cm^{-1}): 2931, 2836, 2791, 1759, 1599, 1485, 1453, 1266, 1167, 1044, 786, 459.



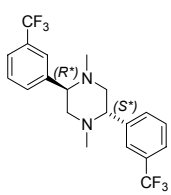
(2R*,5S*)-2,5-bis(4-methoxyphenyl)-1,4-dimethylpiperazine (meso-2m): yellow solid, $\text{Mp} = 161$ °C, R_f [Hexane/EtOAc (7:3)] = 0.6. $^1\text{H NMR}$ (CDCl_3 , 400 MHz) δ 7.26 (d, $J = 8.0$ Hz, 2H), 6.83 (d, $J = 8.8$ Hz, 2H), 3.75 (s, 3H), 3.14 (dd, $J = 2.6, 10.7$ Hz, 1H), 2.87 (dd, $J = 2.9, 11.7$ Hz, 1H), 2.29 (t, $J = 11.2$ Hz, 1H), 1.98 (s, 3H). $^{13}\text{C NMR}$ (CDCl_3 , 100 MHz) δ 159.0, 128.8, 126.6, 113.8, 68.6, 64.1, 55.2, 43.0. GC-MS m/z (%) 326 [M^+ , 14], 283 (7), 134 (100). FT-IR (KBr, cm^{-1}): 2944, 2786, 1610, 1513, 1441, 1249, 1031, 842. Anal. Calcd for $\text{C}_{20}\text{H}_{26}\text{N}_2\text{O}_2$: C, 73.59%; H, 8.03%; N, 8.58%. Found: C, 73.22%; H, 7.96%; N, 8.21%.



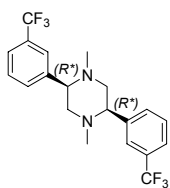
(2R*,5S*)-2,5-di(2-Allylphenyl)-1,4-dimethylpiperazine (meso-2n): white solid, $\text{Mp} = 124$ °C, R_f [Hexane/EtOAc (8.5:1.5)] = 0.6. $^1\text{H NMR}$ (CDCl_3 , 600 MHz) δ 7.52 (br s, 1H), 7.06-7.17 (m, 3H), 5.91 (ddt, $J = 6.2, 10.2, 6.2$ Hz, 1H), 4.96 (ddt, $J = 1.6, 10.1, 17.06$ Hz, 2H), 3.42-3.51 (m, 3H), 2.81 (dd, $J = 2.8, 11.8$ Hz, 1H), 2.20 (t, $J = 11.1$ Hz, 1H), 1.89 (s, 3H). $^{13}\text{C NMR}$ (CDCl_3 , 125 MHz) δ 139.2, 137.8, 137.4, 129.9, 127.8, 127.1, 126.7, 116.0, 63.8, 43.0, 31.6, 14.1. GC-MS m/z (%) 346 [M^+ , 24], 302 (45), 158 (32), 144 (33), 129 (100), 116 (32), 44 (15). FT-IR (KBr, cm^{-1}): 2940, 2842, 2792, 1636, 1449, 1095, 900, 764. Anal. Calcd for $\text{C}_{24}\text{H}_{30}\text{N}_2$: C, 83.19%; H, 8.73%; N, 8.08%. Found: C, 83.21%; H, 8.70%; N, 8.00%.



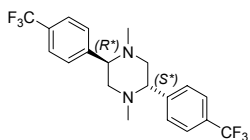
(2R*,5R*)-2,5-di(2-Allylphenyl)-1,4-dimethylpiperazine (2n): yellow oil. R_f [Hexane/EtOAc (8.5:1.5)] = 0.2. $^1\text{H NMR}$ (CDCl_3 , 400 MHz) δ 8.11 (dd, $J = 1.2, 7.8$ Hz), 7.29 (dt, $J = 1.6, 7.5$ Hz, 1H), 7.22 (dt, $J = 1.5, 7.3$ Hz, 1H), 7.16 (dd, $J = 1.6, 7.5$ Hz, 1H), 5.98 (ddt, $J = 6.2, 10.2, 16.8$ Hz, 1H), 5.02 (ddq, $J = 1.7, 17.1, 33.3$ Hz, 2H), 3.86 (dd, $J = 4.1, 6.1$ Hz, 1H), 3.56 (ddt, $J = 1.6, 6.6, 15.8$ Hz, 1H), 3.43 (ddt, $J = 1.9, 6.0, 16.1$ Hz, 1H), 2.95 (dd, $J = 6.2, 12.6$ Hz, 1H), 2.67 (dd, $J = 4.1, 12.6$ Hz, 1H), 2.21 (s, 3H). $^{13}\text{C NMR}$ (CDCl_3 , 125 MHz) δ 139.7, 138.2, 137.6, 129.9, 129.1, 126.9, 126.3, 115.6, 58.6, 55.9, 42.6, 37.2. GC-MS m/z (%): 346 [M^+ , 26], 302 (43), 172 (21), 158 (33), 144 (33), 129 (100), 116 (32). FT-IR (film, cm^{-1}): 2925, 2852, 2790, 1637, 1450, 1025, 913, 754.



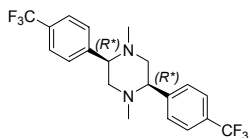
(2R*,5S*)-1,4-Dimethyl-2,5-di(3-trifluoromethylphenyl)piperazine (meso-2o): white solid, $\text{Mp} = 127$ °C, R_f [Hexane/EtOAc (8:2)] = 0.6. $^1\text{H NMR}$ (CDCl_3 , 400 MHz) δ 7.68 (s, 1H), 7.55-7.60 (m, 2H), 7.45-7.49 (m, 1H), 3.33 (dd, $J = 2.4, 10.3$ Hz, 1H), 2.94 (dd, $J = 2.9, 11.7$ Hz, 1H), 2.33 (t, $J = 10.9$ Hz, 1H), 2.04 (s, 3H). $^{13}\text{C NMR}$ (CDCl_3 , 125 MHz) δ 142.2, 131.3, 131.0 (q, $J = 32.5$ Hz), 129.0, 124.6, 124.5, 124.1 (q, $J = 272.4$ Hz), 68.8, 63.9, 43.2. GC-MS m/z (%) 402 [M^+ , 26], 359 (34), 186 (100), 172 (63). FT-IR (KBr, cm^{-1}): 2919, 2849, 1446, 1328, 1253, 1157, 1128, 1098, 1070, 800. Anal. Calcd for $\text{C}_{20}\text{H}_{20}\text{F}_6\text{N}_2$: C, 59.70%; H, 5.01%; N, 6.96%. Found: C, 59.57%; H, 4.98%; N, 6.94%.



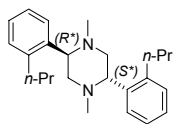
(2R*,5R*)-1,4-Dimethyl-2,5-di(3-trifluoromethylphenyl)piperazine (2o): yellow oil. R_f [Hexane/EtOAc (8:2)] = 0.2. $^1\text{H NMR}$ (CDCl_3 , 400 MHz) δ 8.05 (s, 1H), 7.75 (d, $J = 7.5$ Hz, 1H), 7.56-7.58 (m, 1H), 7.47-7.50 (m, 1H), 3.62 (dd, $J = 4.1, 5.8$ Hz, 1H), 2.85 (dd, $J = 6.2, 12.1$ Hz, 1H), 2.68 (dd, $J = 3.8, 12.0$ Hz, 1H), 2.13 (s, 3H). $^{13}\text{C NMR}$ (CDCl_3 , 100 MHz) δ 140.6, 132.5, 130.4 (q, $J = 32.1$), 128.5, 125.8, 124.3, 124.2 (q, $J = 272.1$ Hz), 65.1, 57.2, 43.1. GC-MS m/z (%): 402 [M^+ , 23], 359 (33), 186 (100), 172 (60). FT-IR (film, cm^{-1}): 2936, 2800, 1667, 1449, 1328, 1164, 1125, 1074, 804, 704.



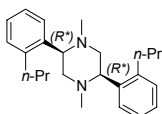
(2R*,5S*)-1,4-Dimethyl-2,5-di(4-trifluoromethylphenyl)piperazine (meso-2p): white solid, Mp = 202 °C, R_f [Hexane/EtOAc (8:2)] = 0.6. ¹H NMR (CDCl₃, 400 MHz) δ 7.62 (d, *J* = 8.3 Hz, 2H), 7.53 (d, *J* = 7.8 Hz, 2H), 3.32 (dd, *J* = 2.9, 10.6 Hz, 1H), 2.93 (dd, *J* = 3.0, 11.7 Hz, 1H), 2.32 (dd, *J* = 10.8, 11.5 Hz, 1H), 2.04 (s, 3H). ¹³C NMR (CDCl₃, 125 MHz) δ 145.2, 130.0 (q, *J* = 32.4 Hz), 128.2, 125.5, 124.2 (q, *J* = 272.0 Hz), 68.8, 63.8, 43.2. GC-MS *m/z* (%) 402 [M⁺, 26], 359 (33), 186 (100), 172 (66). FT-IR (KBr, cm⁻¹): 2955, 2801, 1619, 1322, 1168, 1136, 1064, 848. Anal. Calcd for C₂₀H₂₀F₆N₂: C, 59.70%; H, 5.01%; N, 6.96%. Found: C, 59.35%; H, 5.15%; N, 6.65%.



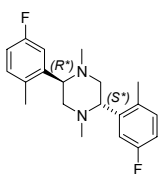
(2R*,5R*)-1,4-Dimethyl-2,5-di(4-trifluoromethylphenyl)piperazine (2p): white solid, Mp = 109 °C, R_f [Hexane/EtOAc (8:2)] = 0.2. ¹H NMR (CDCl₃, 400 MHz) δ 7.74 (d, *J* = 8.1 Hz, 2H), 7.60 (d, *J* = 8.2 Hz, 2H), 3.58 (dd, *J* = 4.0, 6.0 Hz, 1H), 2.83 (dd, *J* = 6.2, 12.1 Hz, 1H), 2.64 (dd, *J* = 3.9, 12.1 Hz, 1H), 2.11 (s, 3H). ¹³C NMR (CDCl₃, 125 MHz) δ 143.9, 129.8 (q, *J* = 32.4 Hz), 129.5, 125.1, 124.2 (q, *J* = 272.0 Hz), 65.2, 57.2, 43.2. GC-MS *m/z* (%) 402 [M⁺, 31], 359 (43), 186 (100), 172 (62). FT-IR (film, cm⁻¹): 2932, 2804, 1619, 1327, 1163, 1120, 1067, 853. Anal. Calcd for C₂₀H₂₀F₆N₂: C, 59.70%; H, 5.01%; N, 6.96%. Found: C, 59.90%; H, 5.13%; N, 6.85%.



(2R*,5S*)-1,4-Dimethyl-2,5-di(2-propylphenyl)piperazine (Meso-2q): white solid, Mp = 157 °C, R_f [Hexane/EtOAc (9:1)] = 0.6. ¹H NMR (CDCl₃, 500 MHz) δ 7.52 (d, *J* = 7.0 Hz, 1H), 7.05-7.15 (m, 3H), 3.47 (dd, *J* = 2.4, 10.3 Hz, 1H), 2.83 (dd, *J* = 2.9, 11.8 Hz, 1H), 2.67-2.73 (m, 1H), 2.53-2.59 (m, 1H), 2.25 (t, *J* = 11.1 Hz, 1H), 1.92 (s, 3H), 1.53-1.61 (m, 2H), 0.93 (t, *J* = 7.3 Hz, 3H). ¹³C NMR (CDCl₃, 100 MHz) δ 140.6, 138.9, 129.5, 127.7, 126.8, 126.1, 64.1, 63.7, 43.0, 34.8, 24.7, 14.2. GC-MS *m/z* (%) 350 [M⁺, 19], 306 (37), 264 (30), 146 (100), 131 (76). FT-IR (KBr, cm⁻¹): 2948, 2866, 1456, 1095, 760. Anal. Calcd for C₂₄H₃₄N₂: C, 82.23%; H, 9.78%; N, 7.99%. Found: C, 82.10%; H, 9.67%; N, 8.03%.

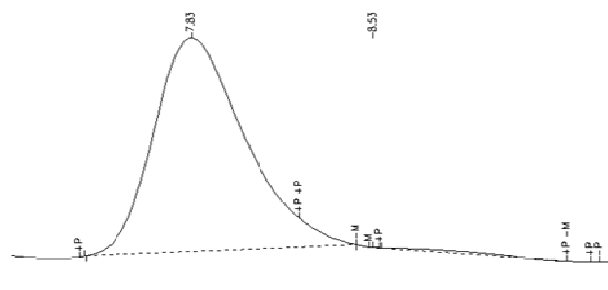
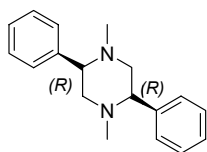
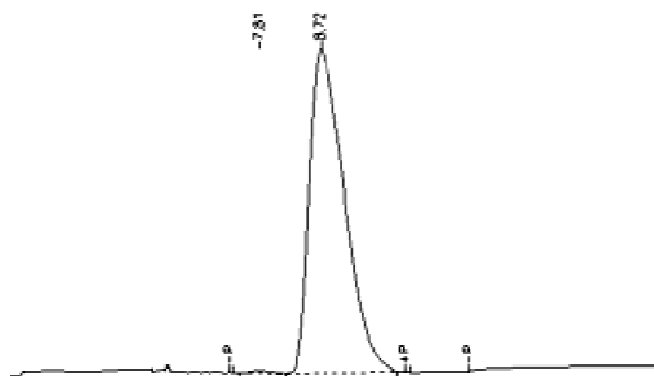
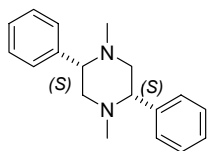
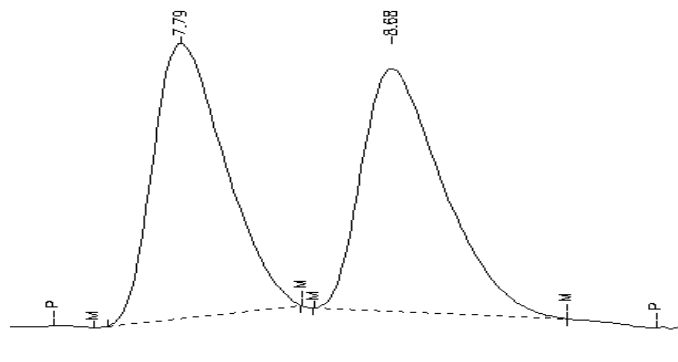
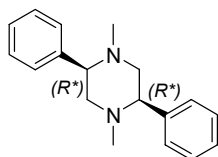


(2R*,5R*)-1,4-Dimethyl-2,5-di(2-propylphenyl)piperazine (2q): yellow oil, R_f [Hexane/EtOAc (9:1)] = 0.2. ¹H NMR (CDCl₃, 400 MHz) δ 8.10 (d, *J* = 6.9 Hz, 1H), 7.22-7.26 (m, 1H), 7.13-7.20 (m, 2H), 3.89 (m, 1H), 2.97 (dd, *J* = 6.2, 12.3 Hz, 1H), 2.58-2.77 (m, 3H), 2.16 (s, 3H), 1.54-1.64 (m, 2H), 0.97 (t, *J* = 7.3 Hz, 3H). ¹³C NMR (CDCl₃, 100 MHz) δ 141.2, 139.0, 129.6, 129.0, 126.8, 125.8, 58.9, 56.8, 42.5, 35.2, 25.0, 14.2. GC-MS *m/z* (%) 350 [M⁺, 19], 306 (39), 264 (30), 174 (26), 162 (30), 146 (100), 131 (77). FT-IR (film, cm⁻¹): 2957, 2870, 1455, 1024, 753.

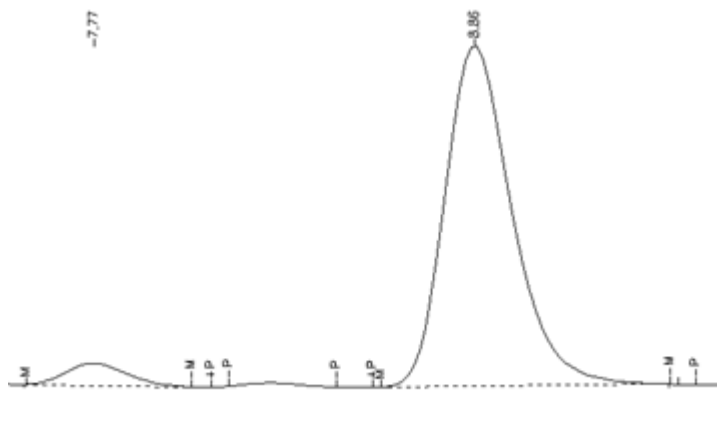
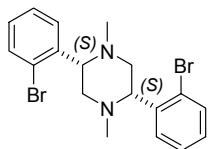
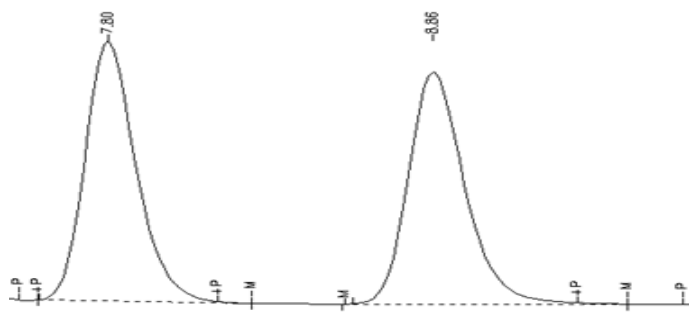
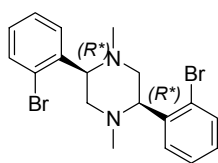


(2R*,5S*)-2,5-di(5-Fluoro-2-methylphenyl)1,4-dimethylpiperazine (meso-2r): white solid, Mp = 168 °C, R_f [Hexane/EtOAc (9:1)] = 0.6. ¹H NMR (CDCl₃, 500 MHz) δ 7.23 (d, *J* = 8.4 Hz, 1H), 7.03 (dd, *J* = 6.0, 8.2 Hz, 1H), 6.78 (dt, *J* = 2.8, 8.2 Hz, 1H), 3.41 (d, *J* = 10.3 Hz, 1H), 2.80 (dd, *J* = 2.8, 11.8 Hz, 1H), 2.31 (s, 3H), 2.17 (t, *J* = 10.9 Hz, 1H), 1.95 (s, 3H). ¹³C NMR (CDCl₃, 125 MHz) δ 161.7 (d, *J* = 243.1 Hz), 141.3 (d, *J* = 6.6 Hz), 131.5 (d, *J* = 7.7 Hz), 131.3, 114.1 (d, *J* = 19.3 Hz), 113.7 (d, *J* = 21.0 Hz), 64.1, 62.8, 42.9, 18.9. GC-MS *m/z* (%) 330 [M⁺, 22], 287 (17), 152 (34), 136 (100). FT-IR (KBr, cm⁻¹): 2977, 2948, 2796, 1611, 1589, 1492, 1260, 1091, 805. Anal. Calcd for C₂₀H₂₄F₂N₂: C, 72.70%; H, 7.32%; N, 8.48%. Found: C, 72.61%; H, 7.34%; N, 8.43%.

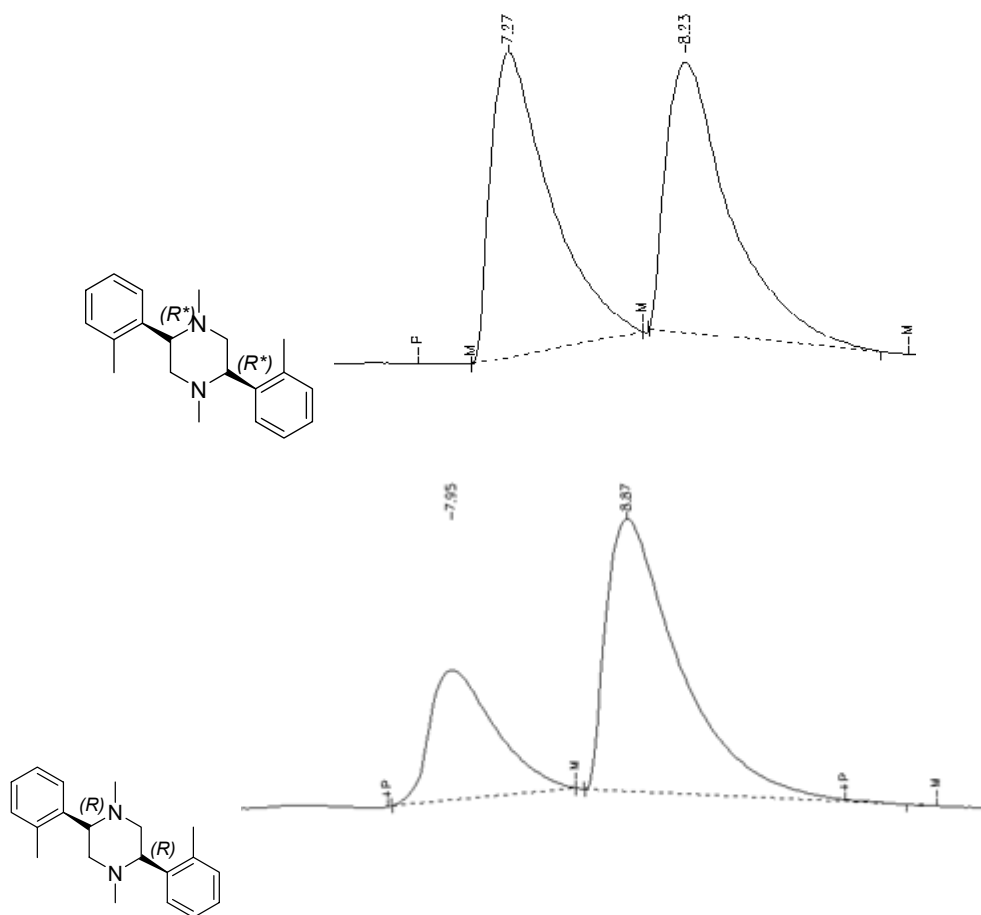
HPLC analysis (Daicel Chiralpak AD, Hexane/ Isopropanol= 97:3 + 0.2% Et₂NH, Flow rate=0.50 mL/min, λ= 254 nm):
for racemic piperazine $t_1 = 7.79$ min, $t_2 = 8.68$ min; for enantioenriched piperazine (**S,S**-**2a**) $t = 8.72$ min). For enantioenriched piperazine (**R,R**-**2a**) $t = 7.83$ min)



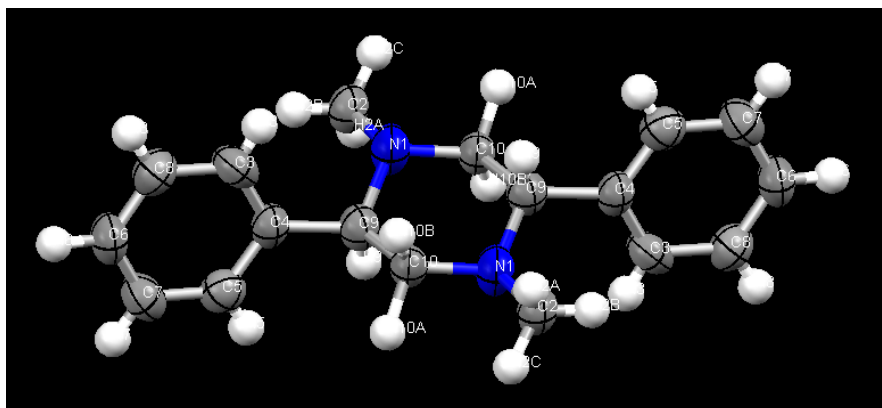
HPLC analysis (Daicel Chiralpak ODH, Hexane/ Isopropanol= 90:10, Flow rate=0.50 mL/min, λ = 254 nm): for racemic piperazine $t_1 = 7.80$ min, $t_2 = 8.86$ min; for enantioenriched piperazine (**S,S**)-**2h** $t = 8.86$ min).



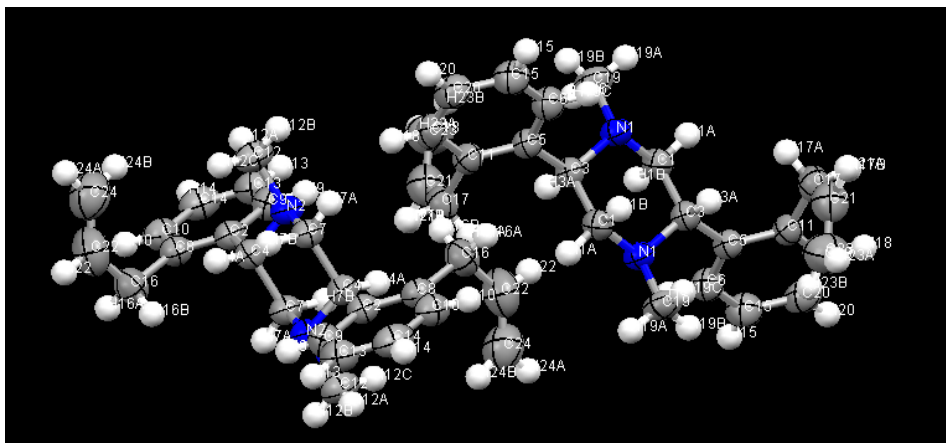
HPLC analysis (Cellulose – Lux2, Hexane/ Isopropanol= 99:0.1, Flow rate=0.50 mL/min, $\lambda = 254$ nm): for racemic piperazine $t_1 = 7.95$ min, $t_2 = 8.87$ min; for enantioenriched piperazine (***R,R***-**2i**) $t = 8.87$ min.



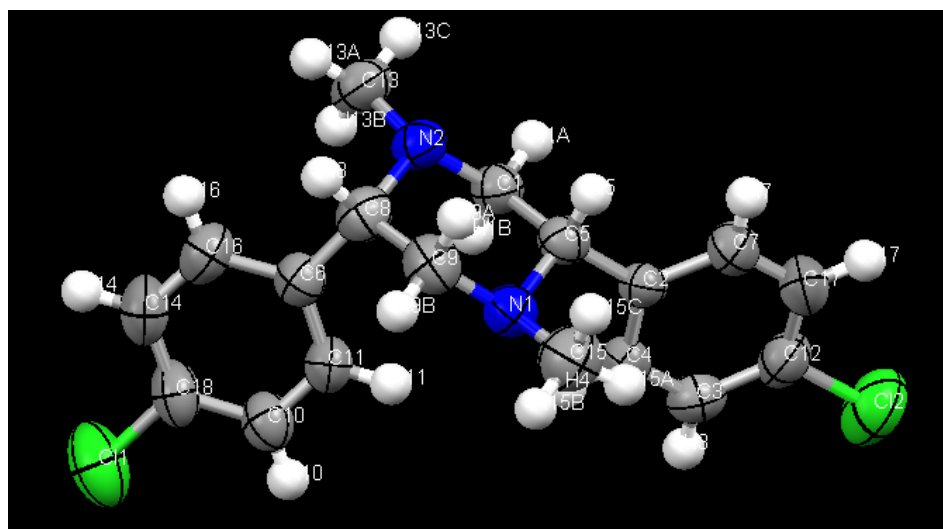
X-Ray structure of *meso*-2a



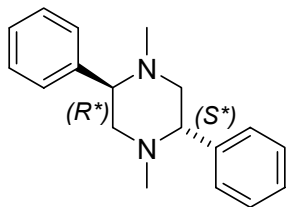
X-Ray structure of *meso*-2n



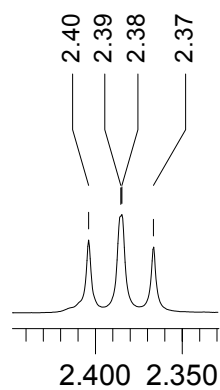
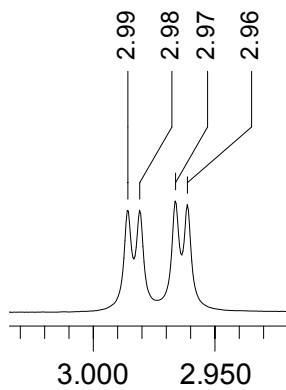
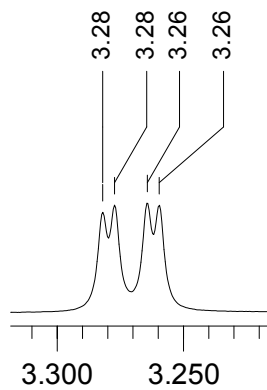
X-Ray structure of 2f



7.43
7.42
7.38
7.36
7.35
7.31
7.30
7.29



3.28
3.28
3.26
3.26
2.99
2.98
2.97
2.96
2.40
2.39
2.38
2.37
2.40
2.39
2.38
2.37
2.07



1.00

1.00

1.02

3.07

1.03
1.04

7.0

6.0

5.0

4.0

3.0

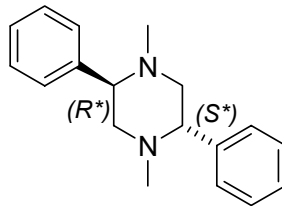
2.0

141.1

128.5

127.9

127.6



77.3

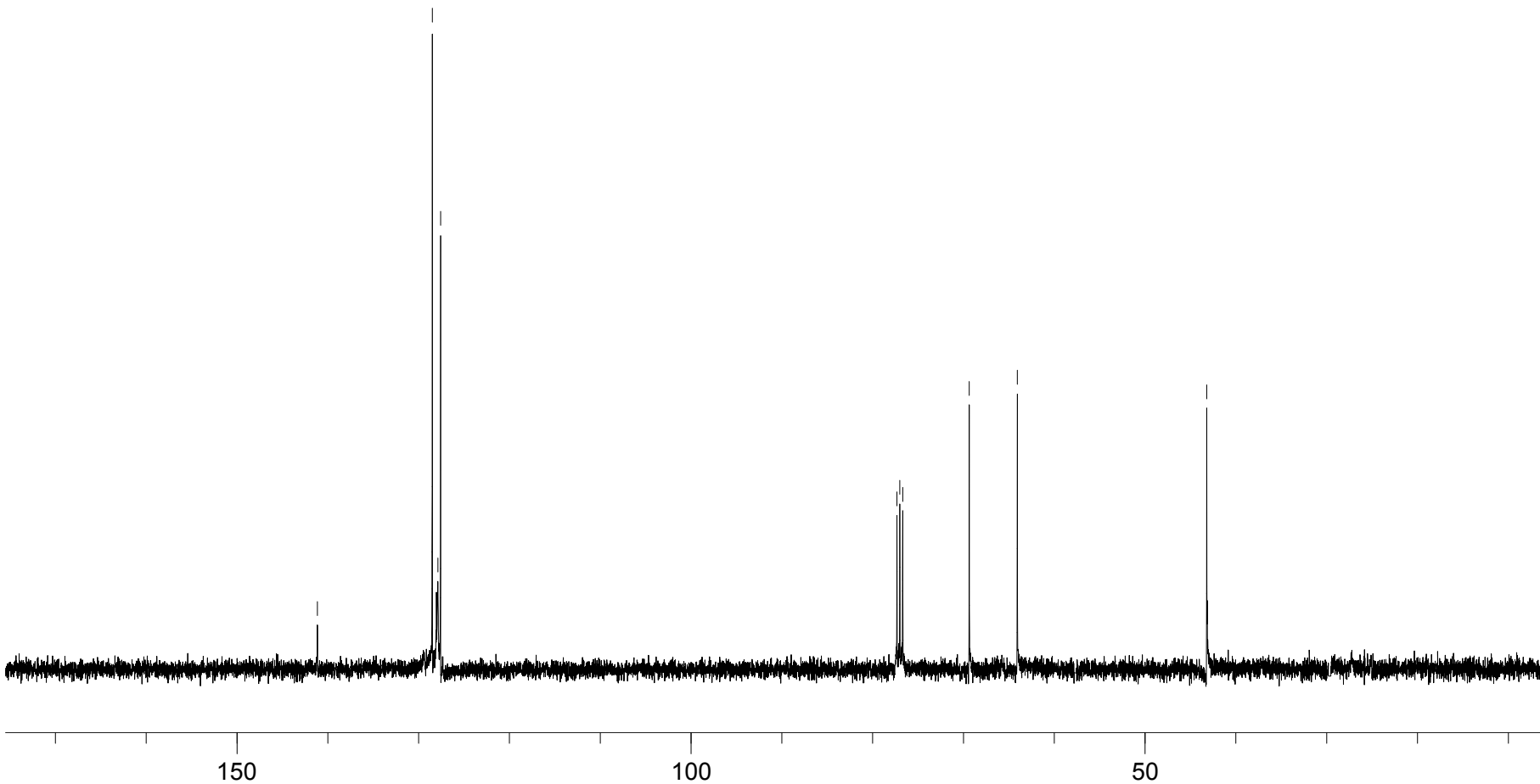
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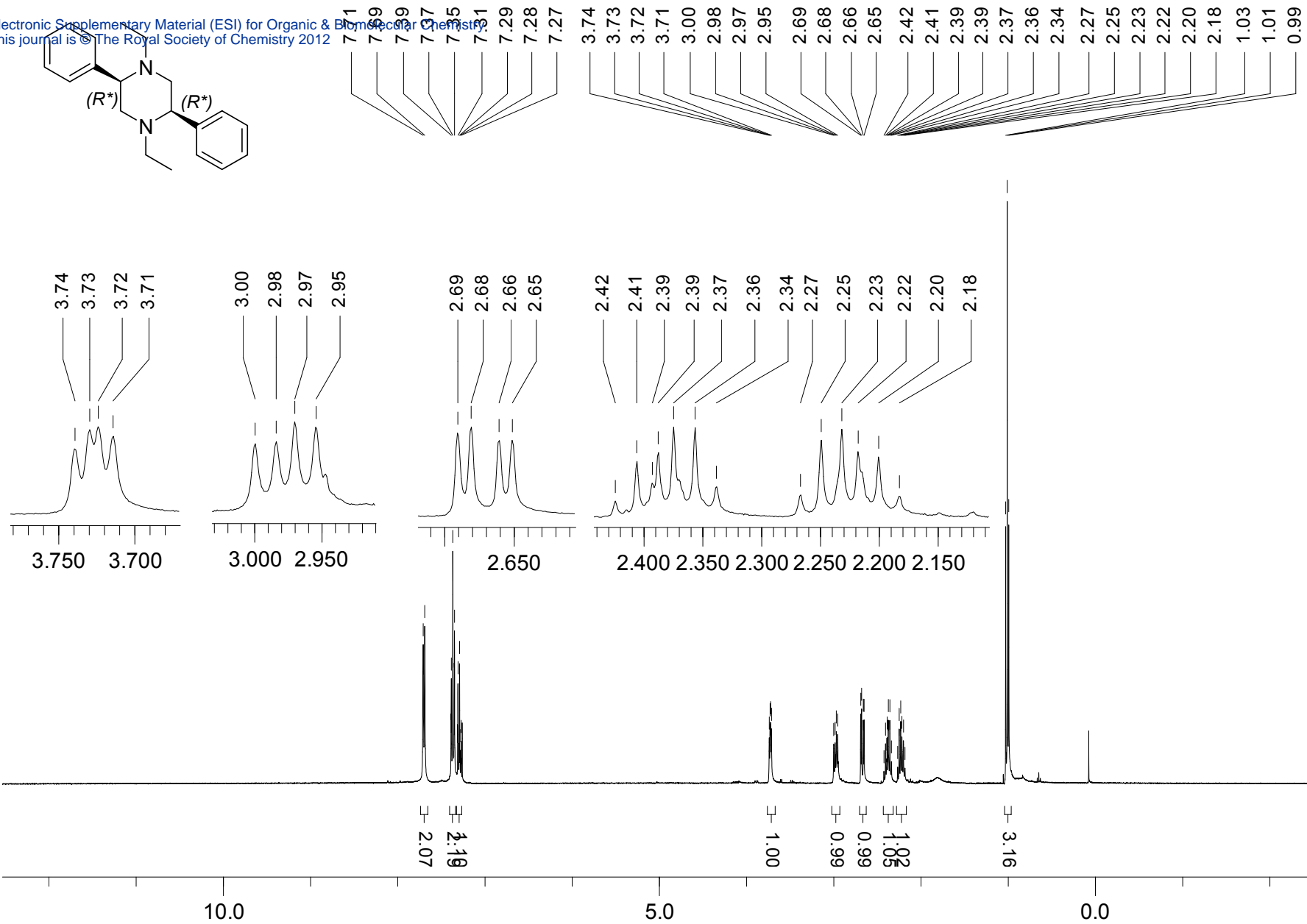
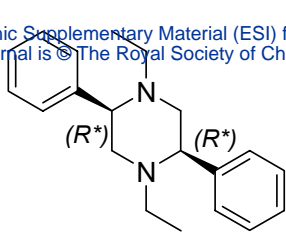
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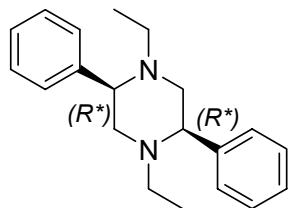
69.4

64.1

43.2







129.3
128.1
127.2

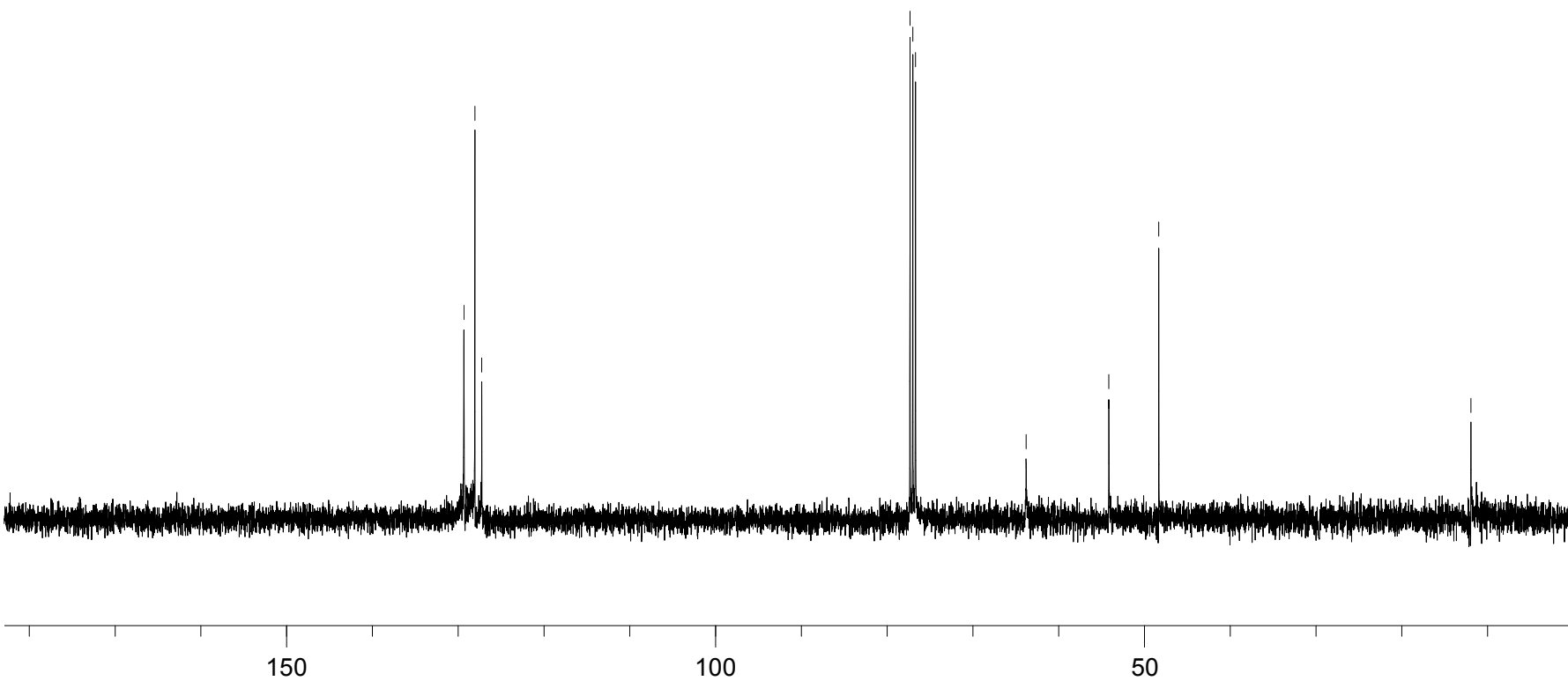
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77.0
76.7

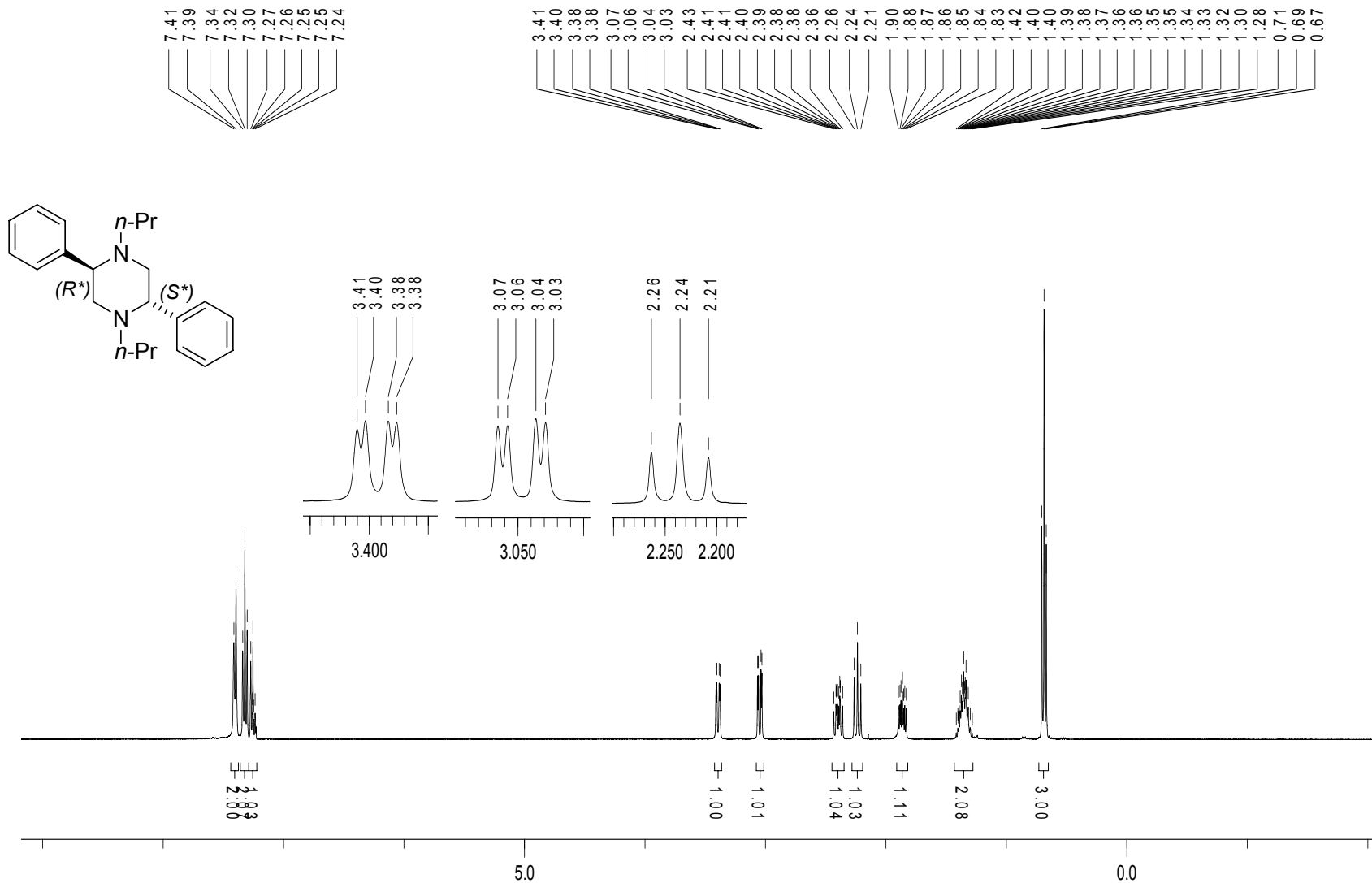
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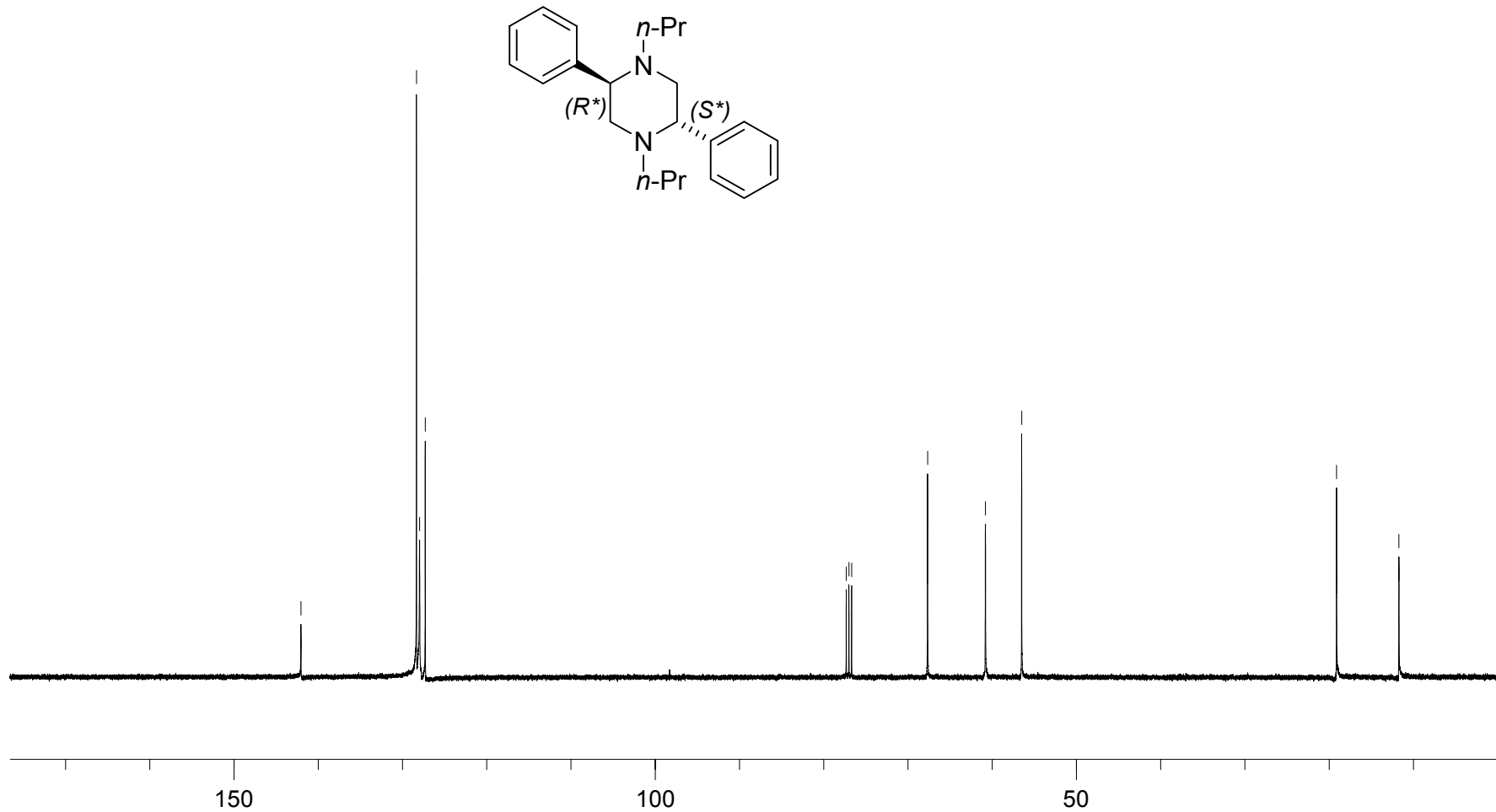
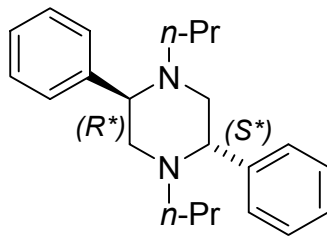
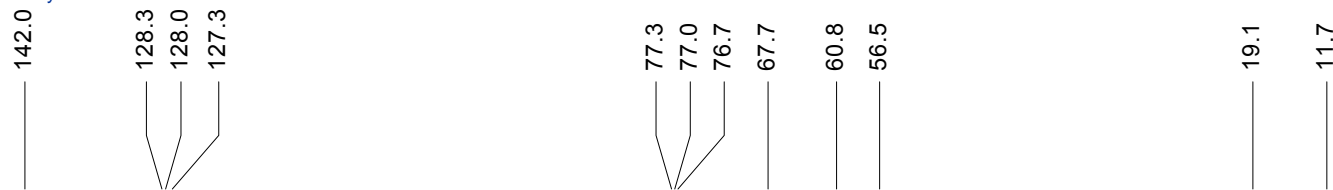
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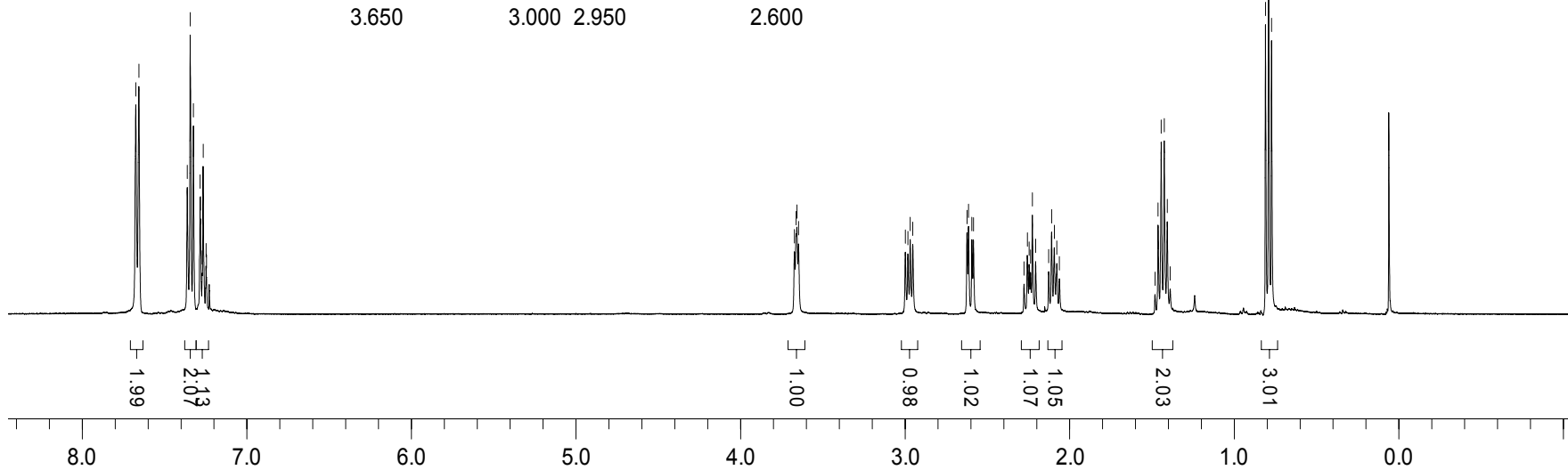
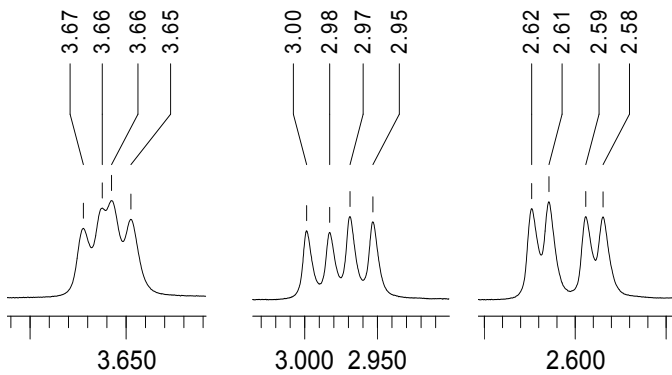
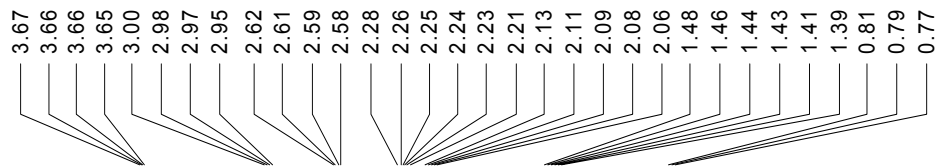
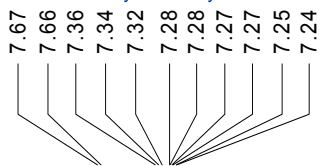
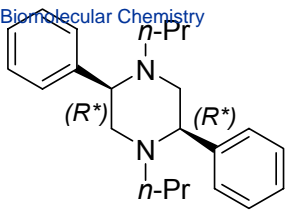
48.3

11.9









141.0
129.3
128.0
127.1

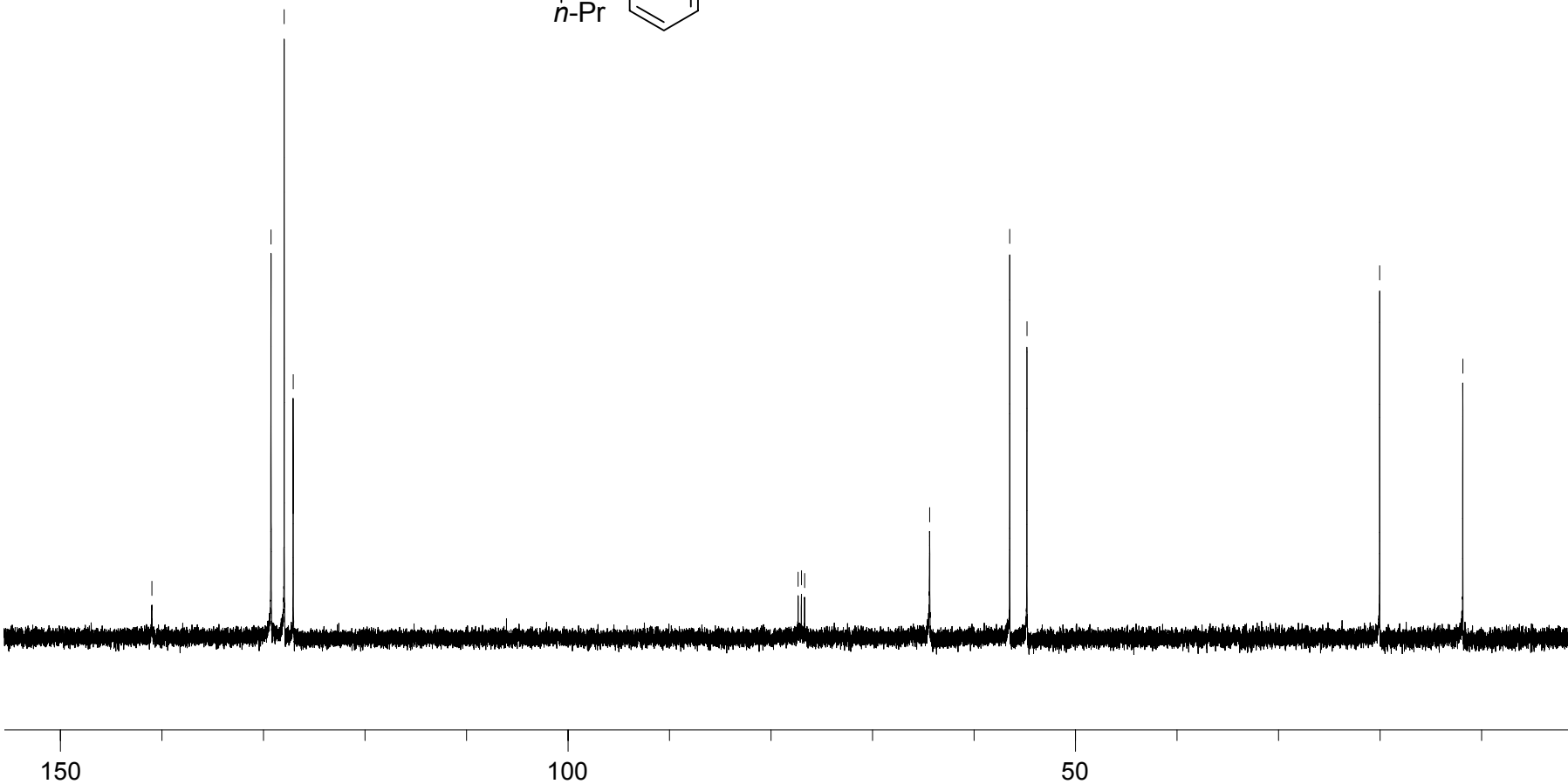
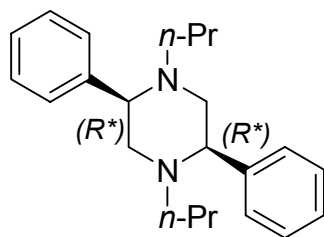
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77.0
76.7

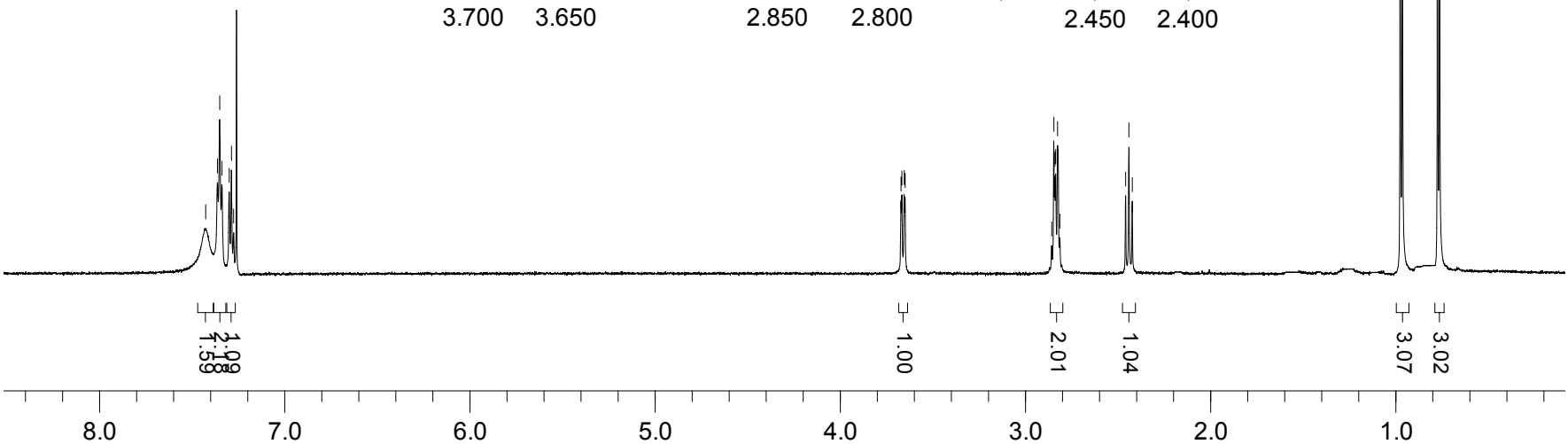
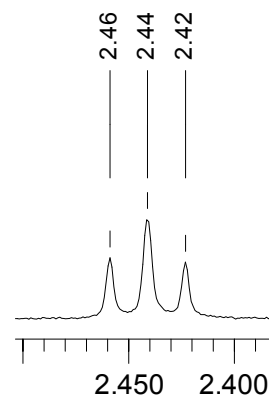
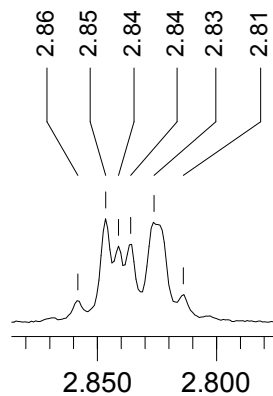
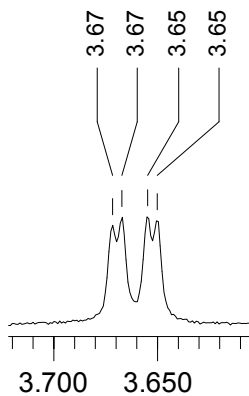
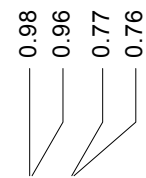
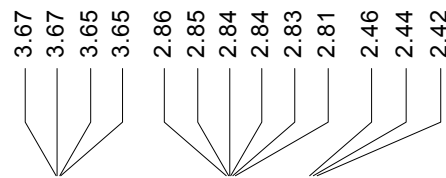
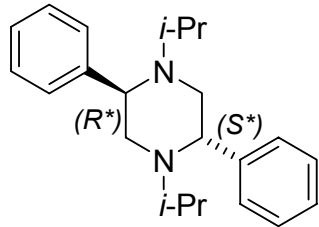
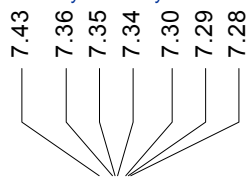
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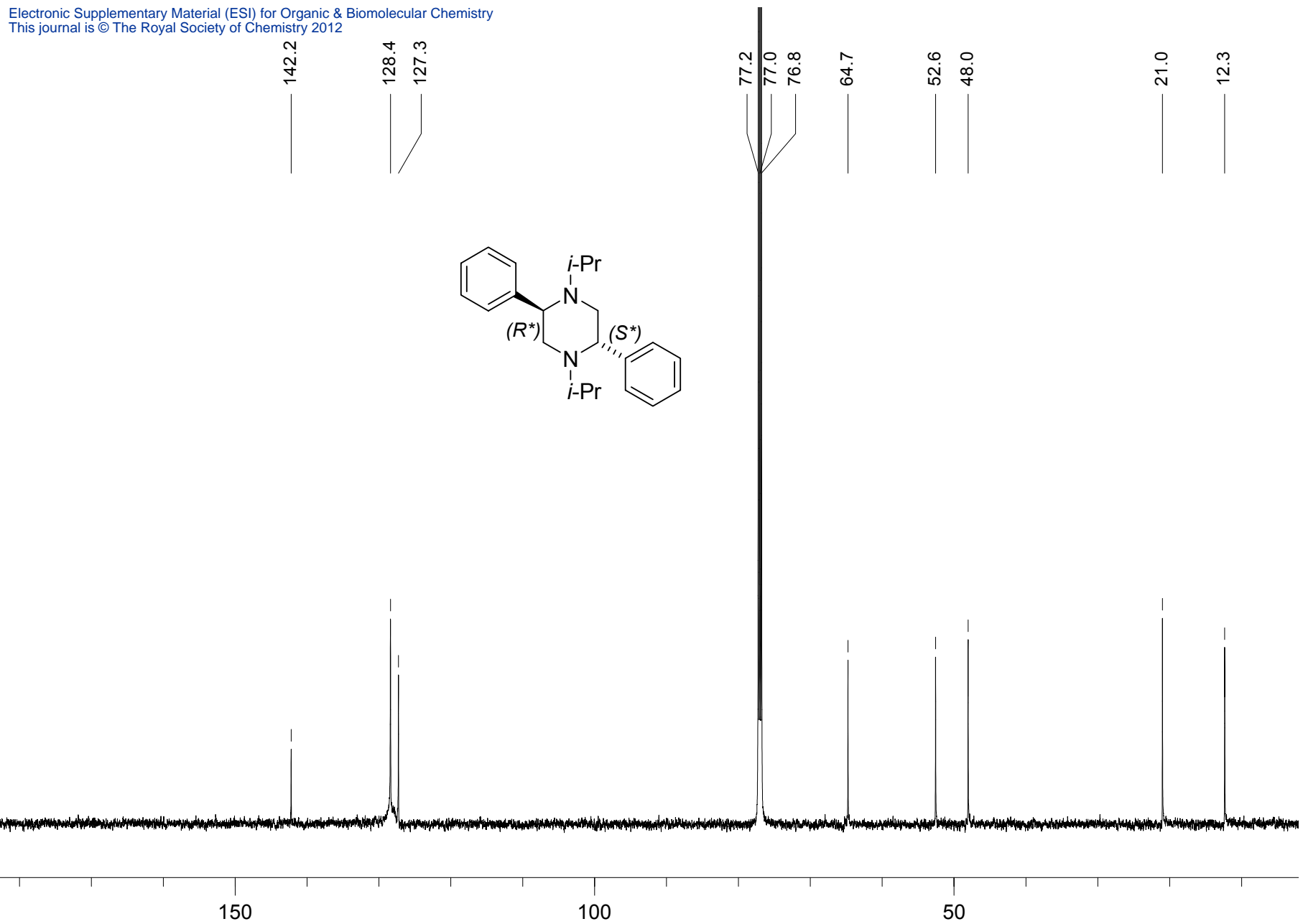
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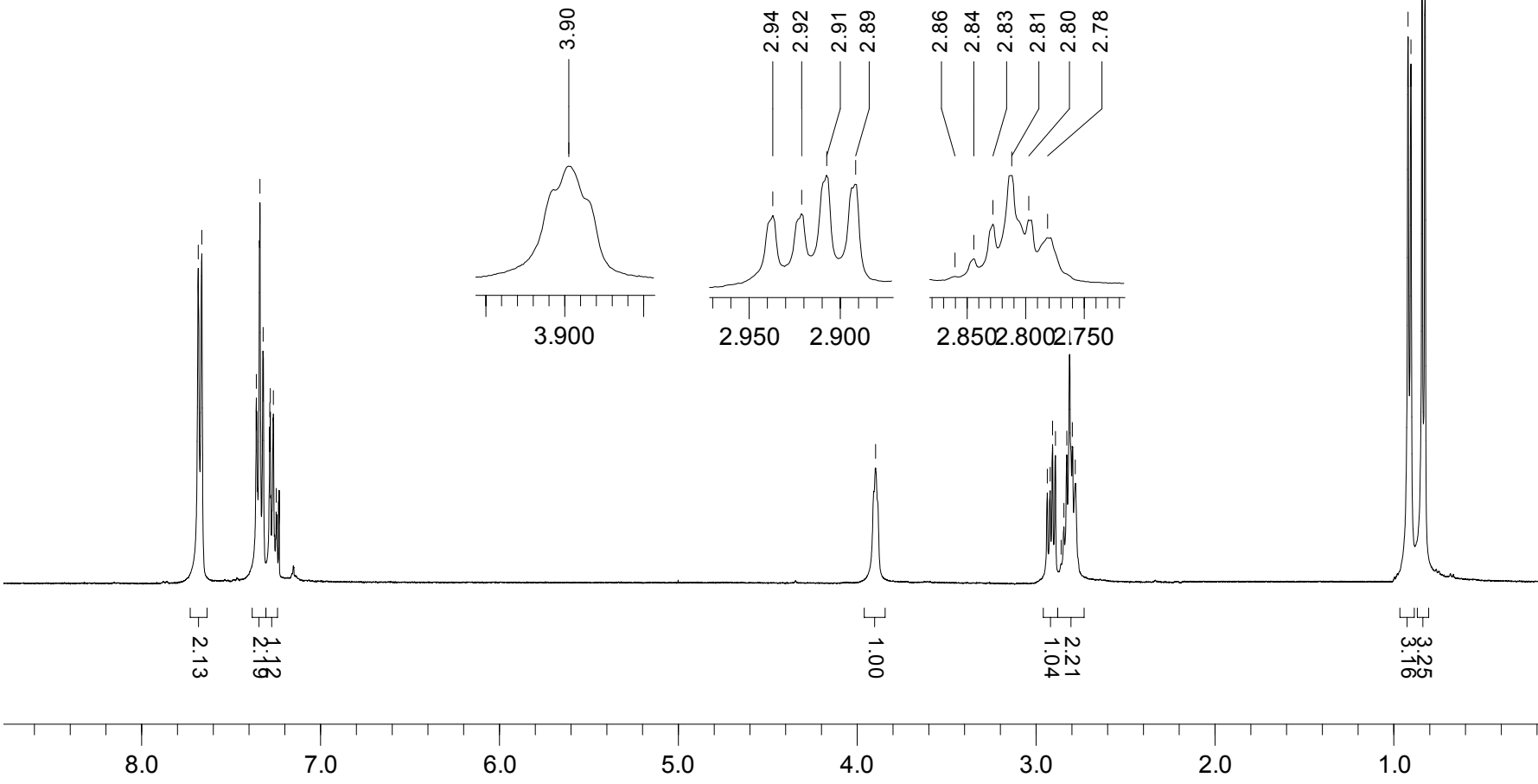
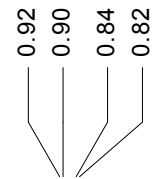
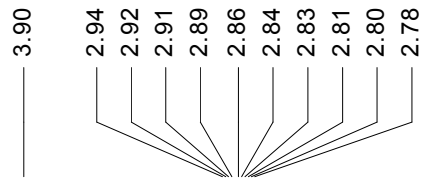
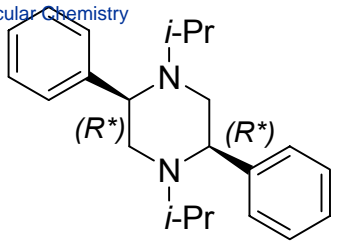
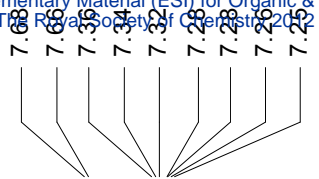
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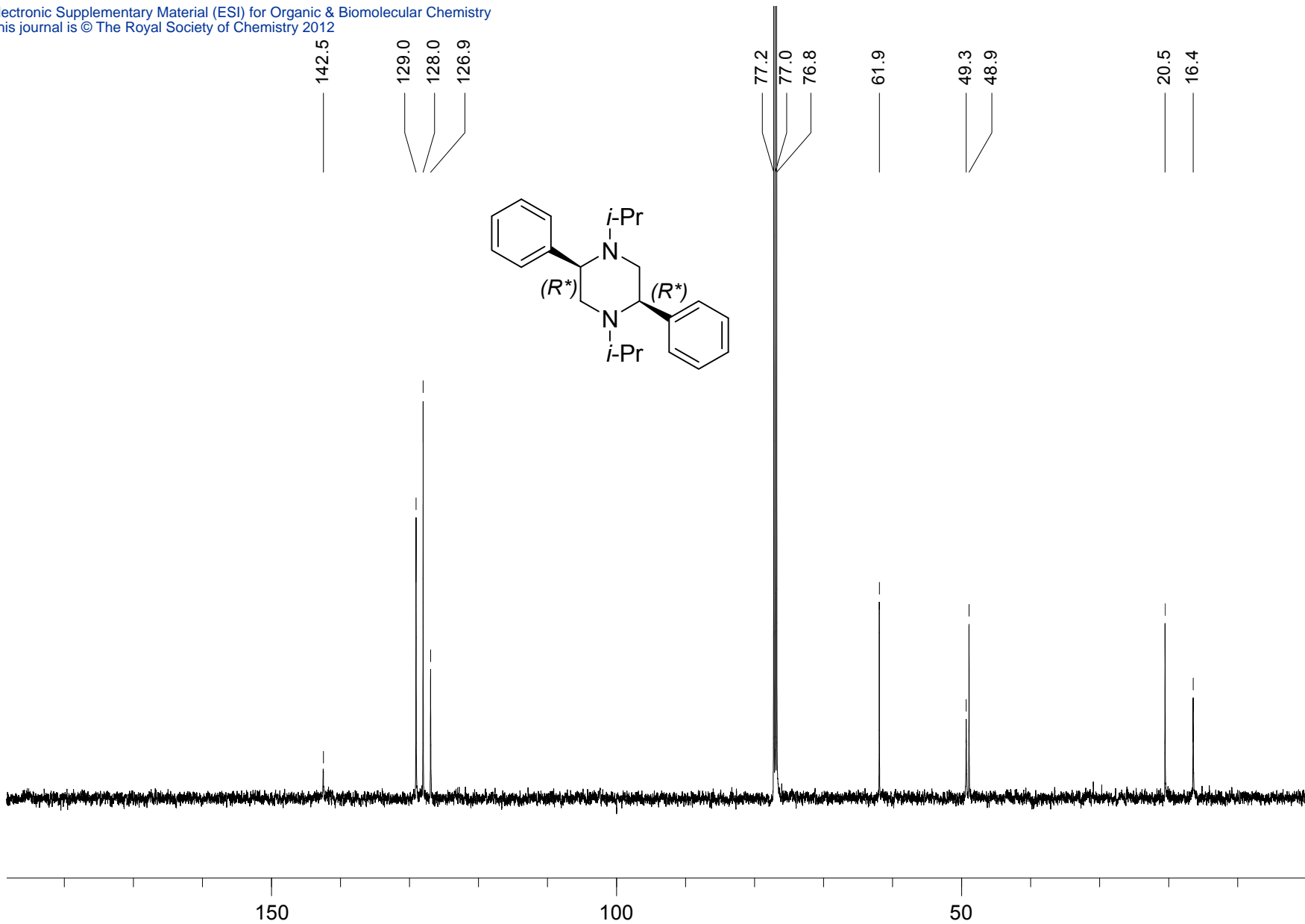
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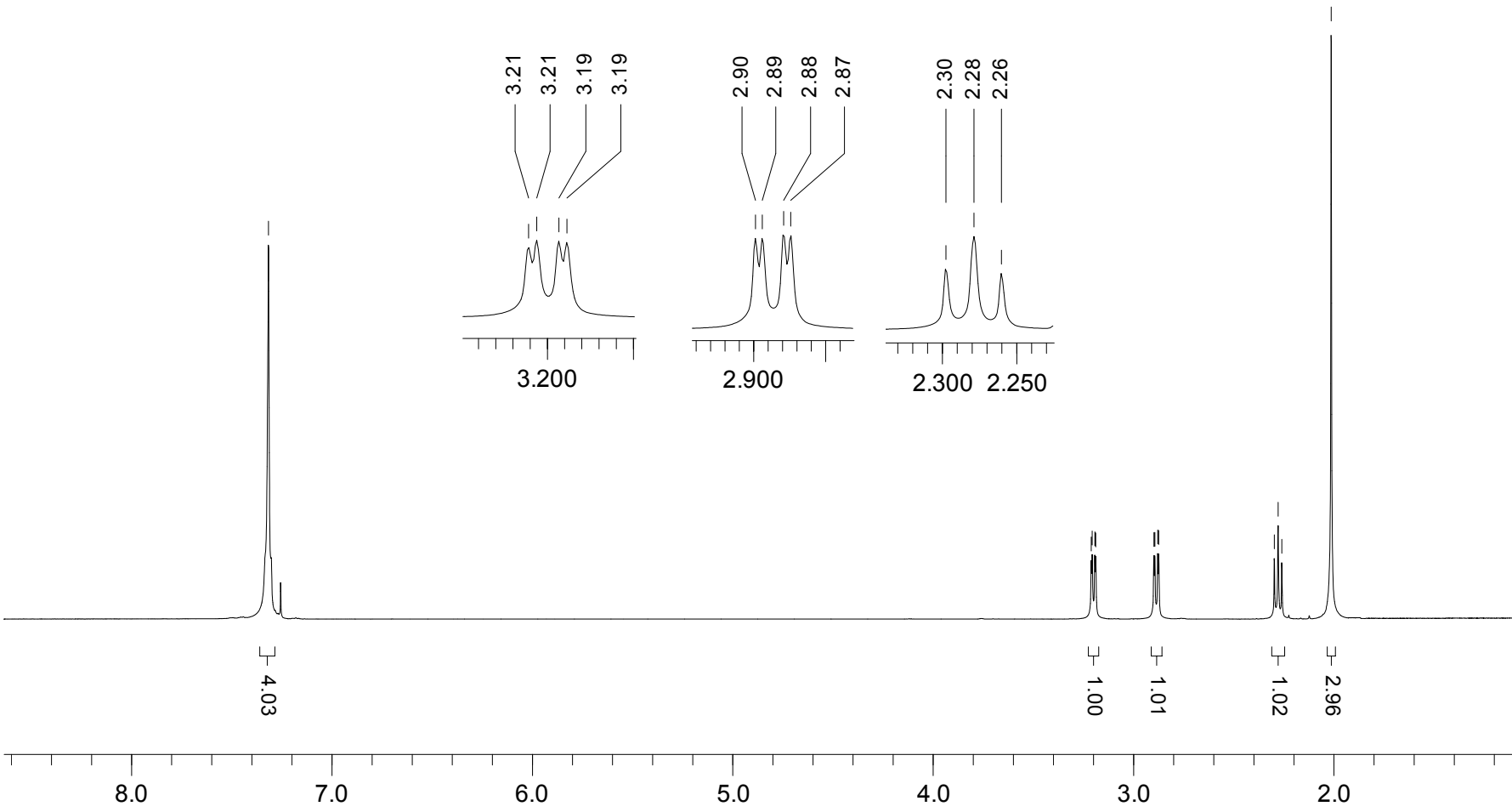
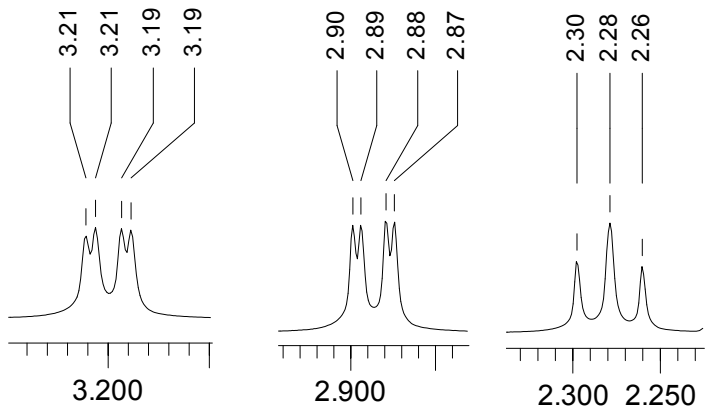
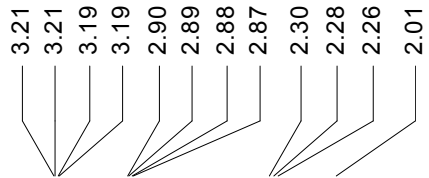
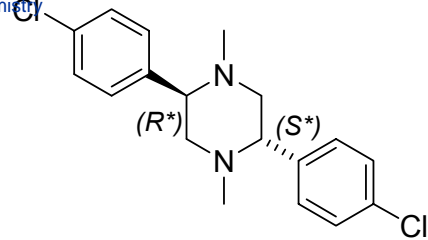








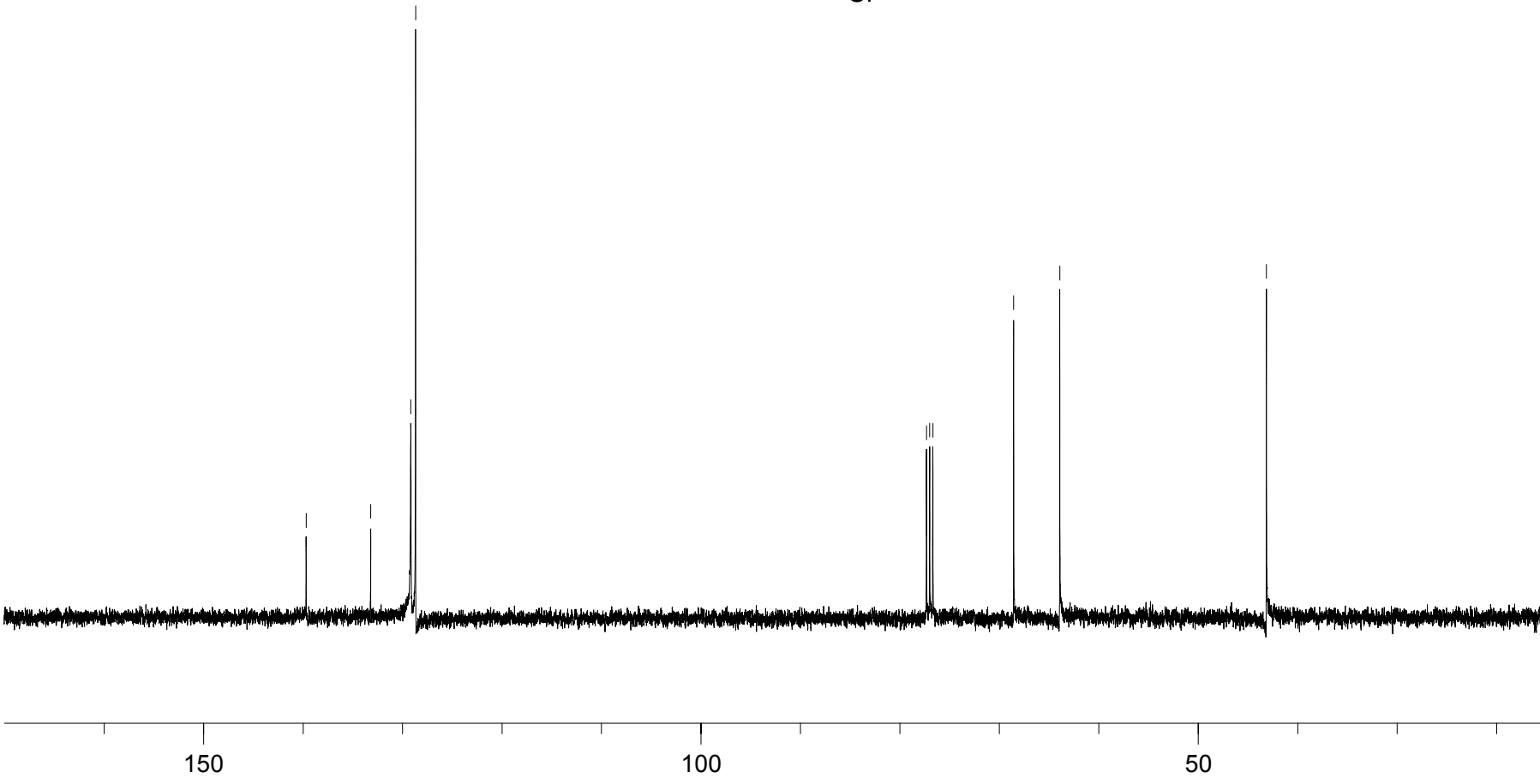
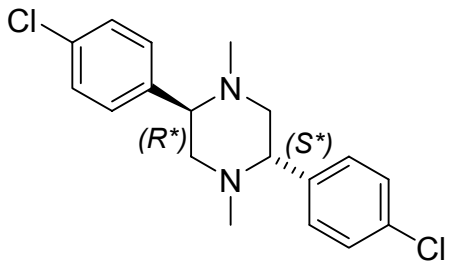


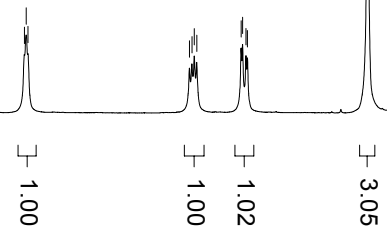
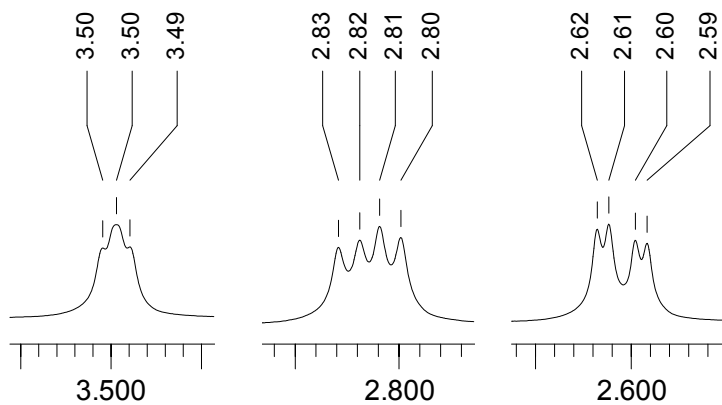
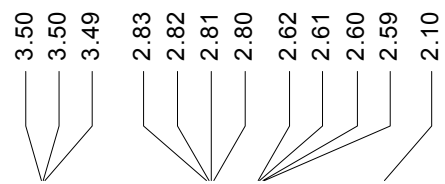
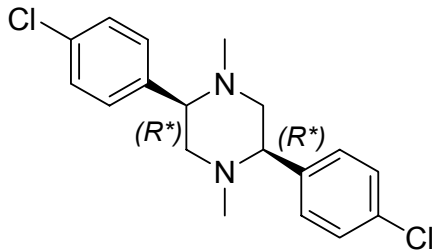
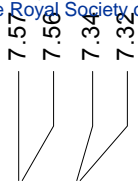


139.7
133.2
129.2
128.7

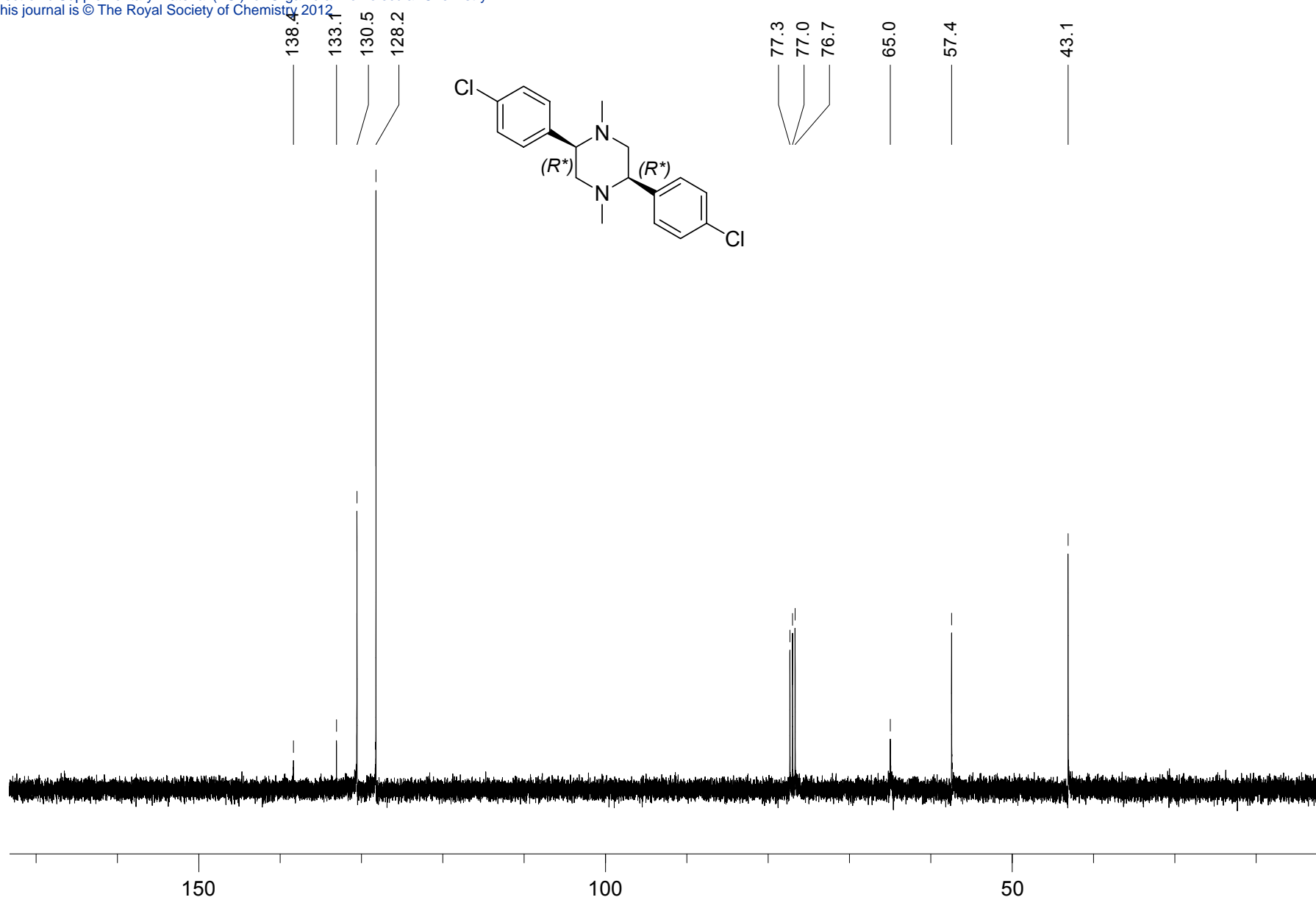
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63.9

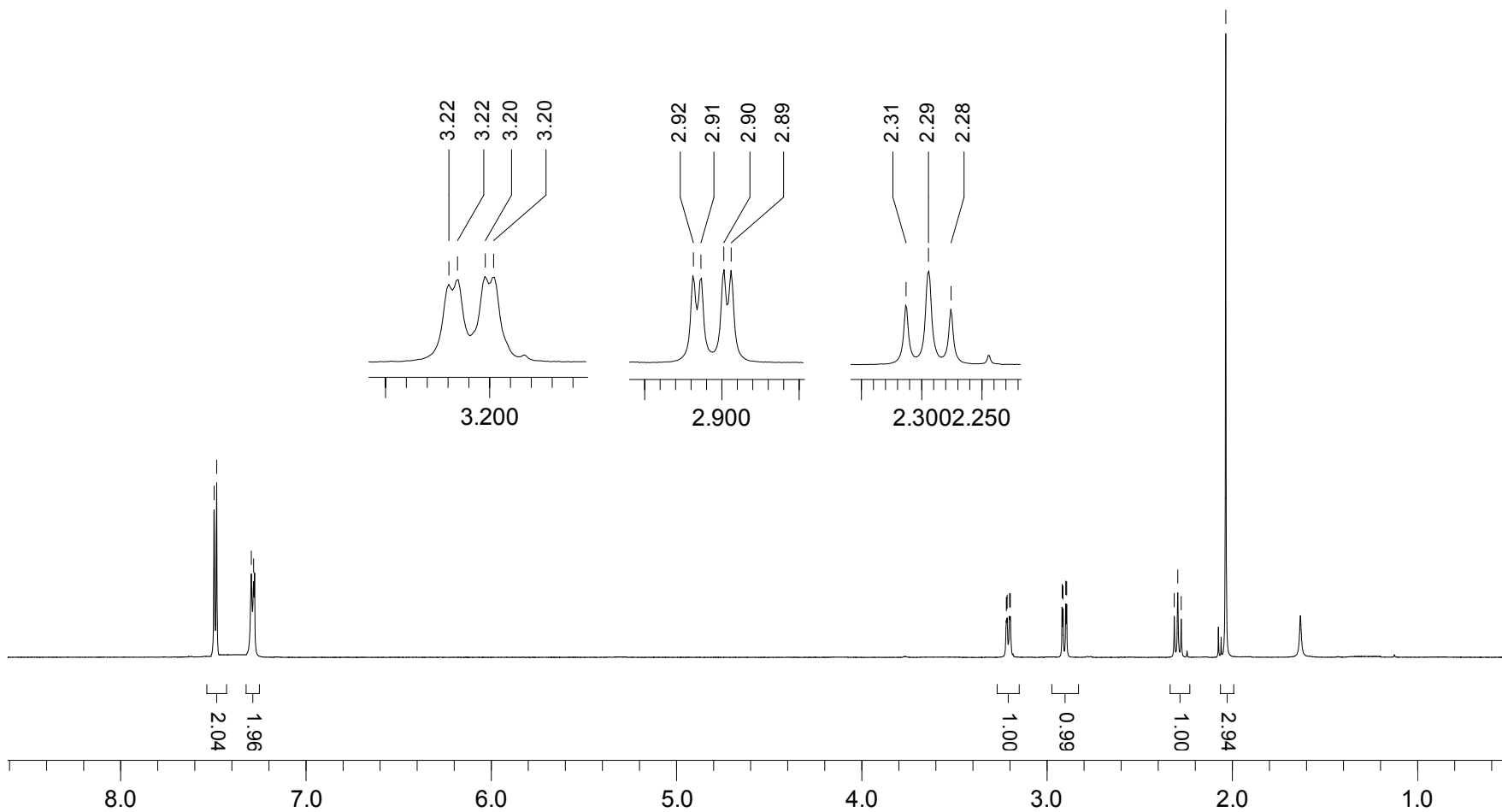
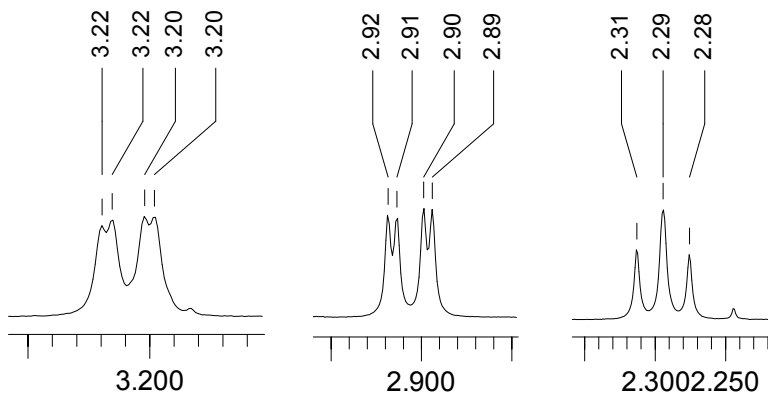
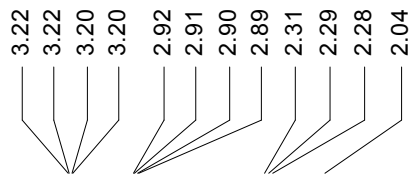
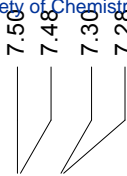
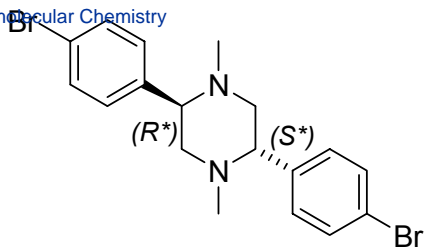
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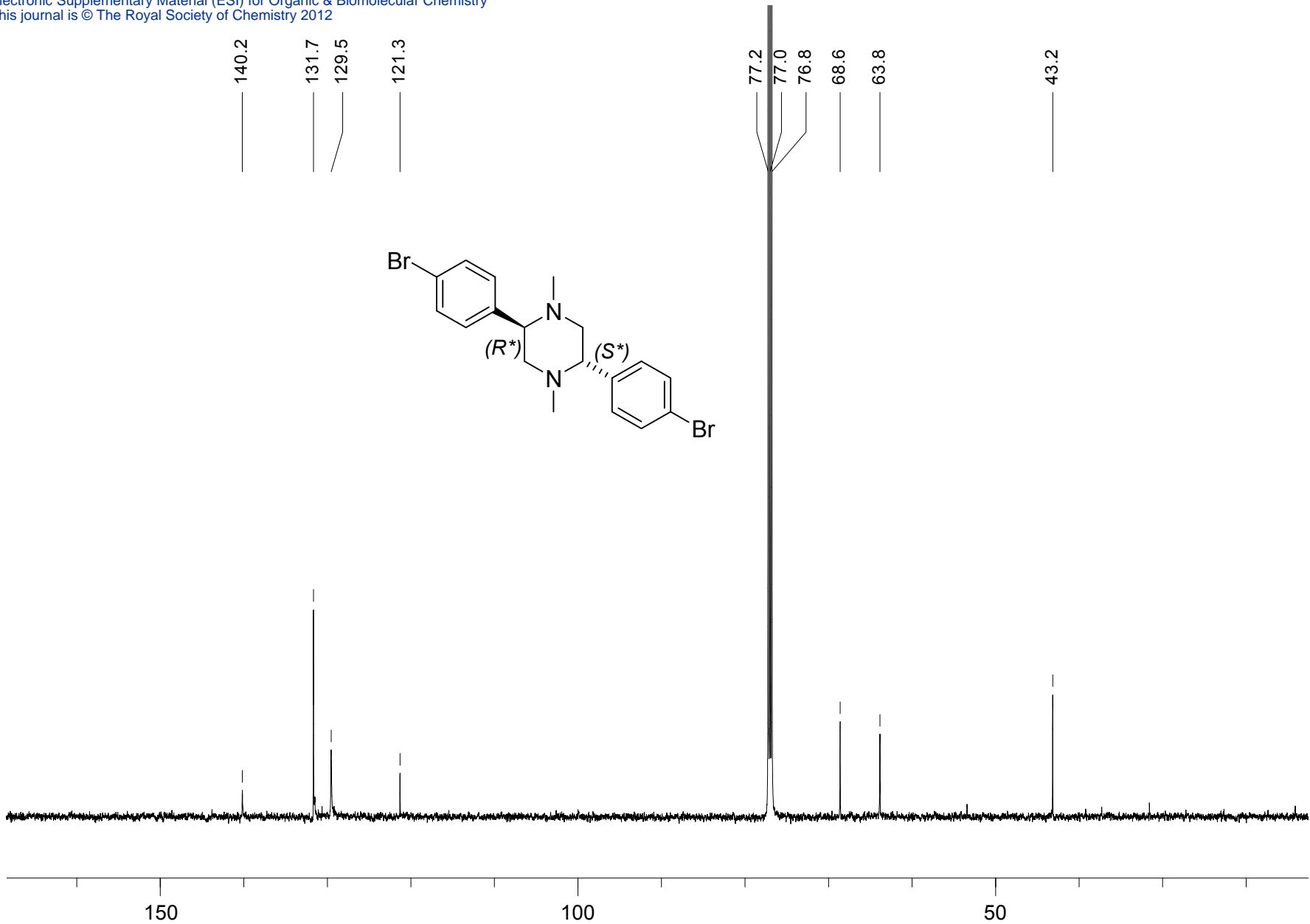
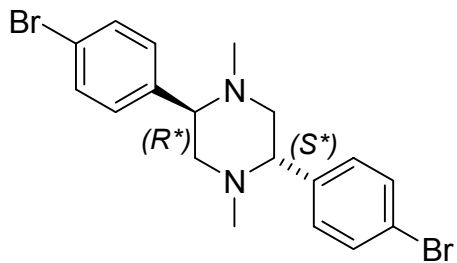


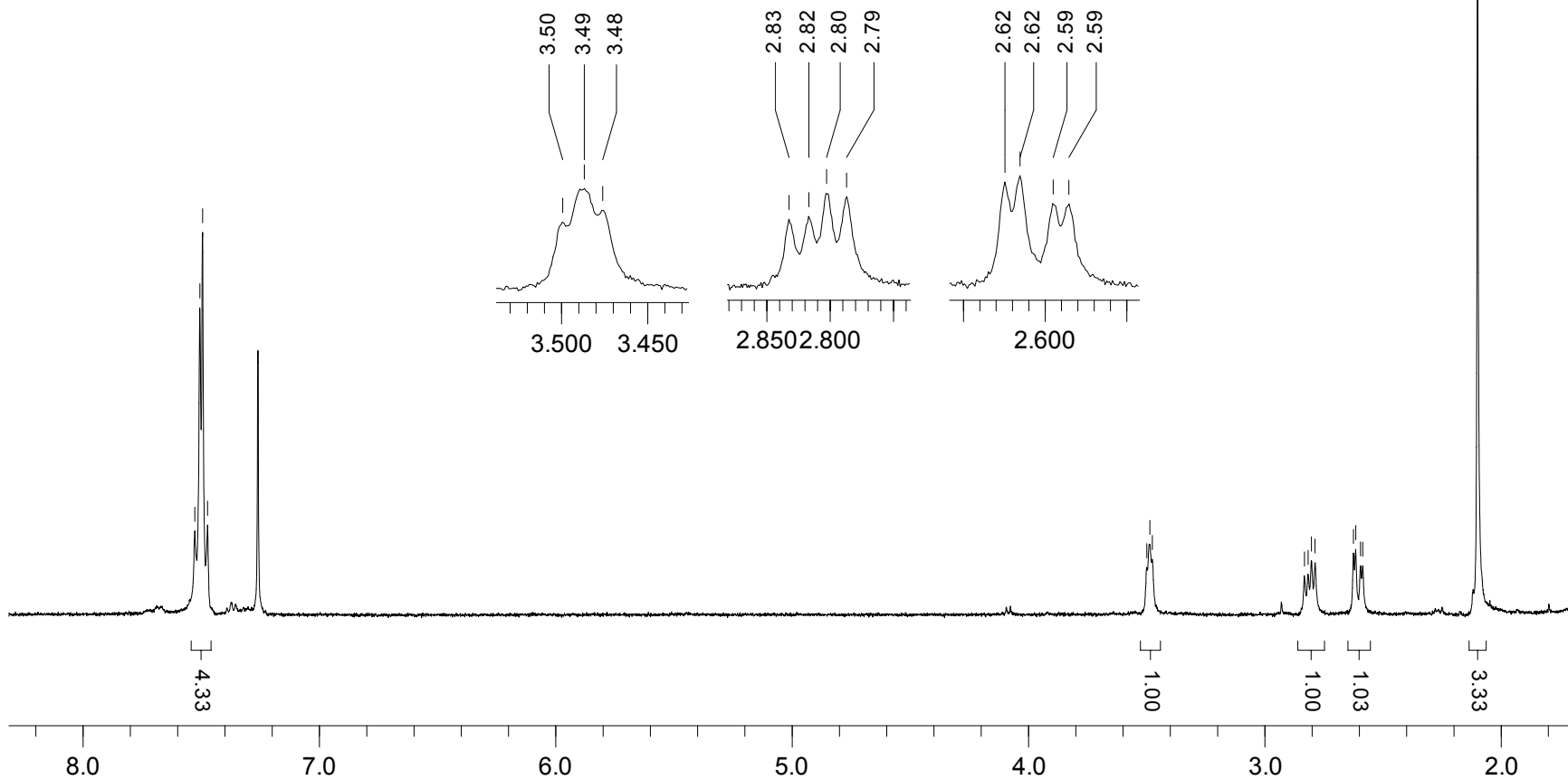
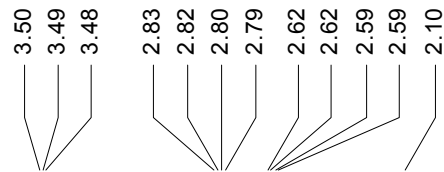
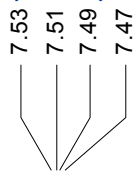
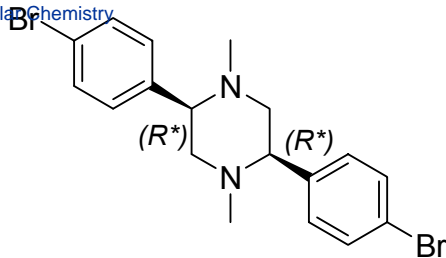


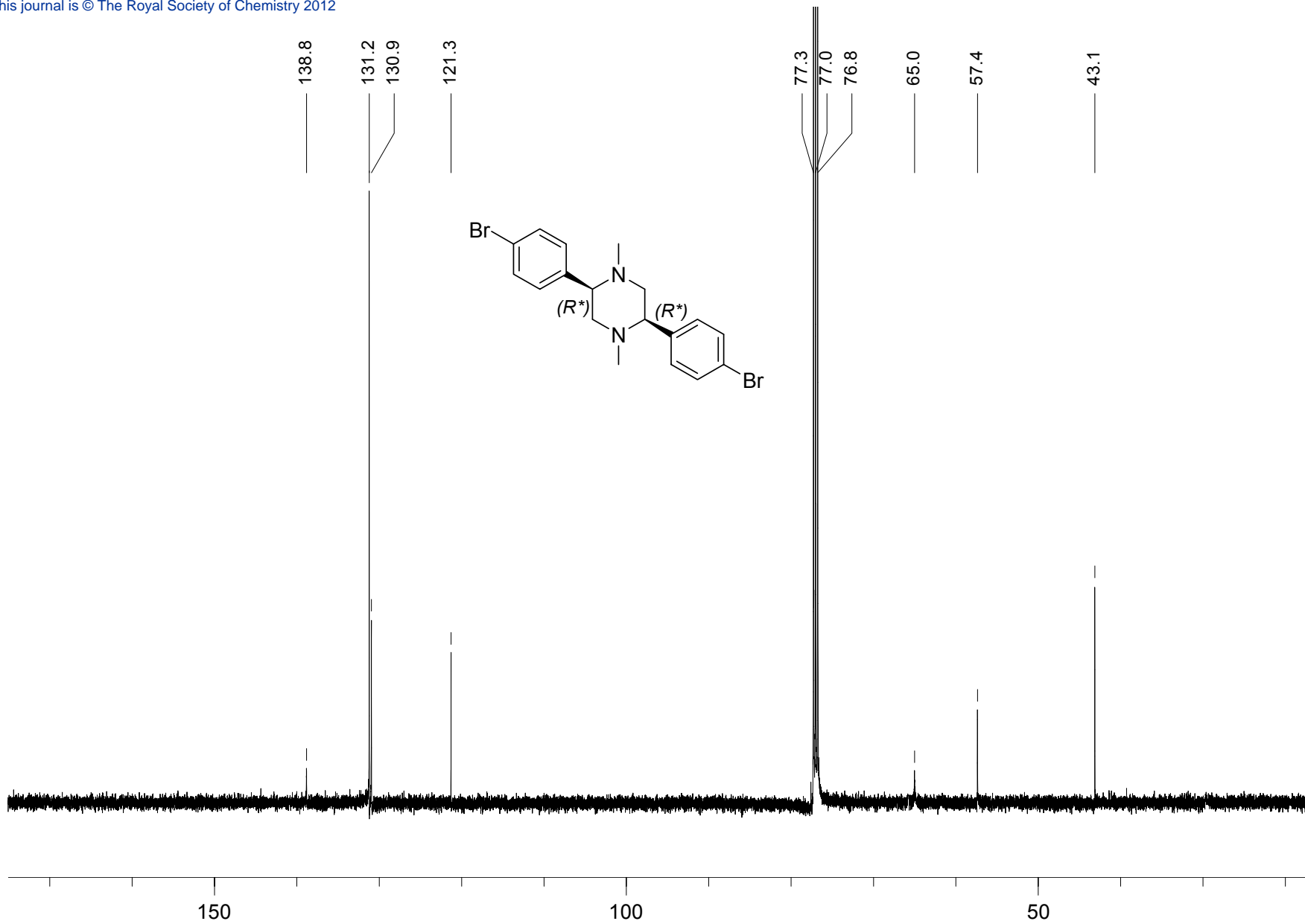
8.0 7.0 6.0 5.0 4.0 3.0 2.0

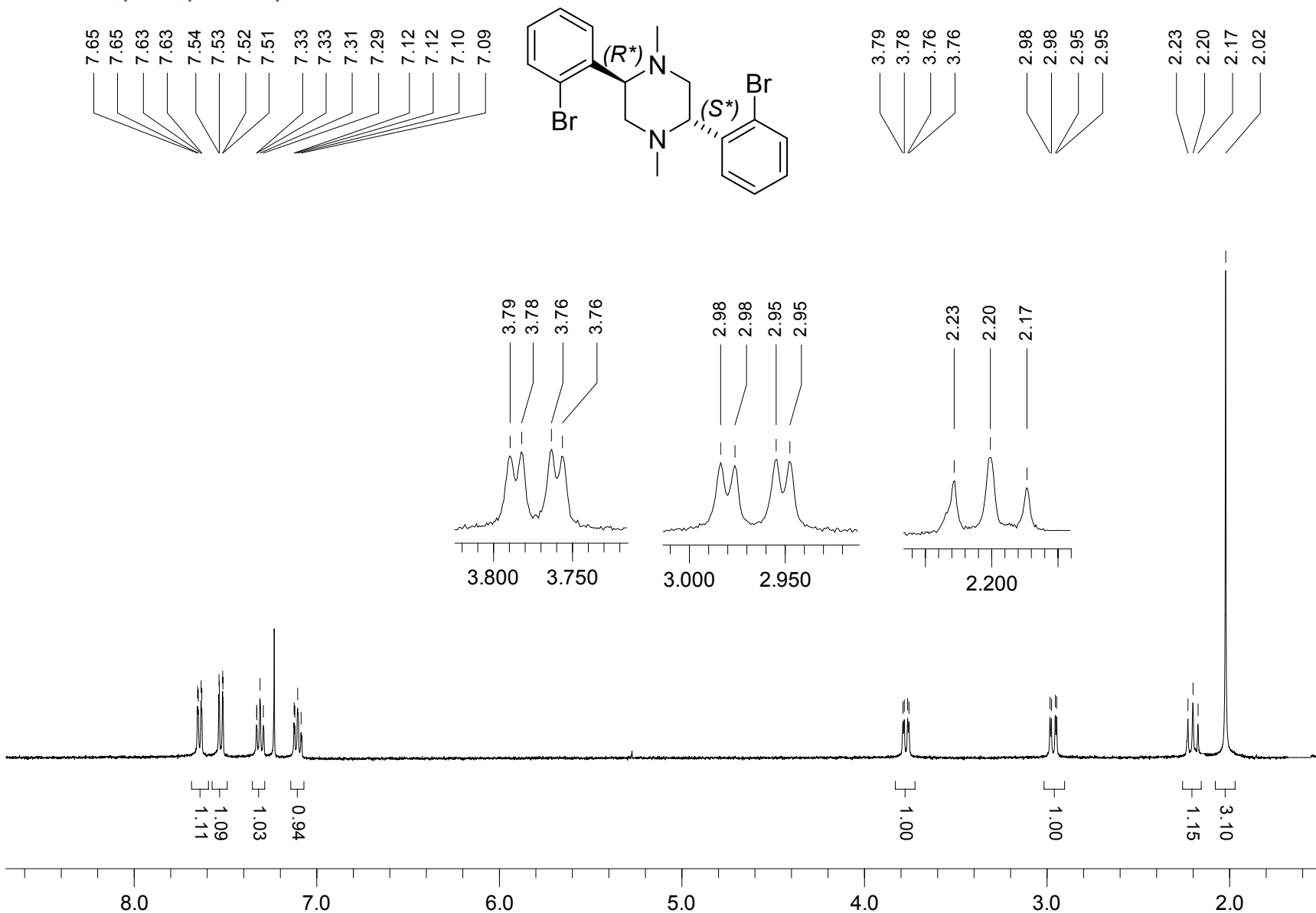




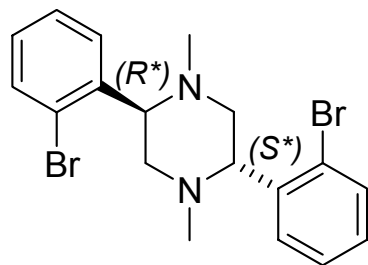






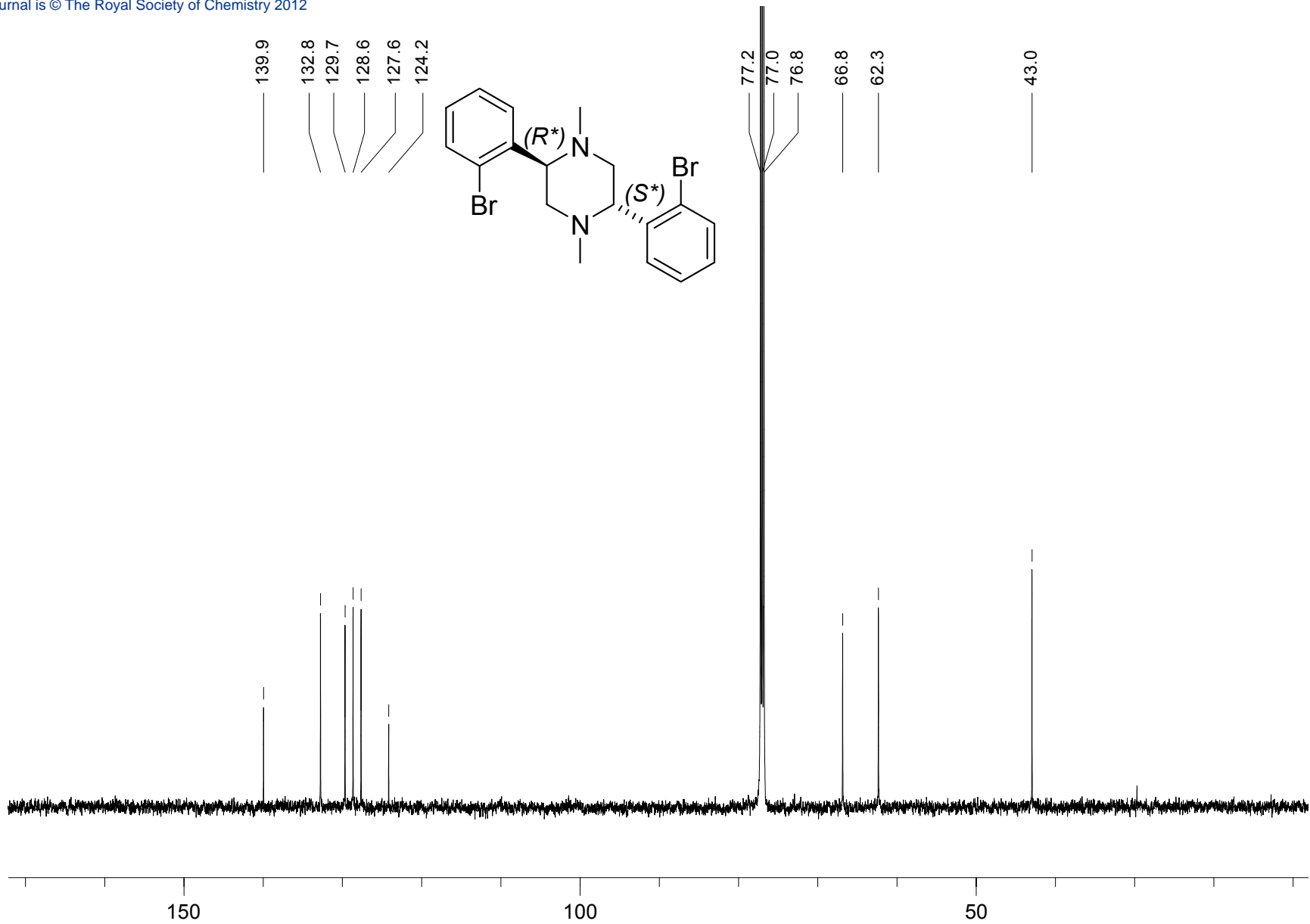


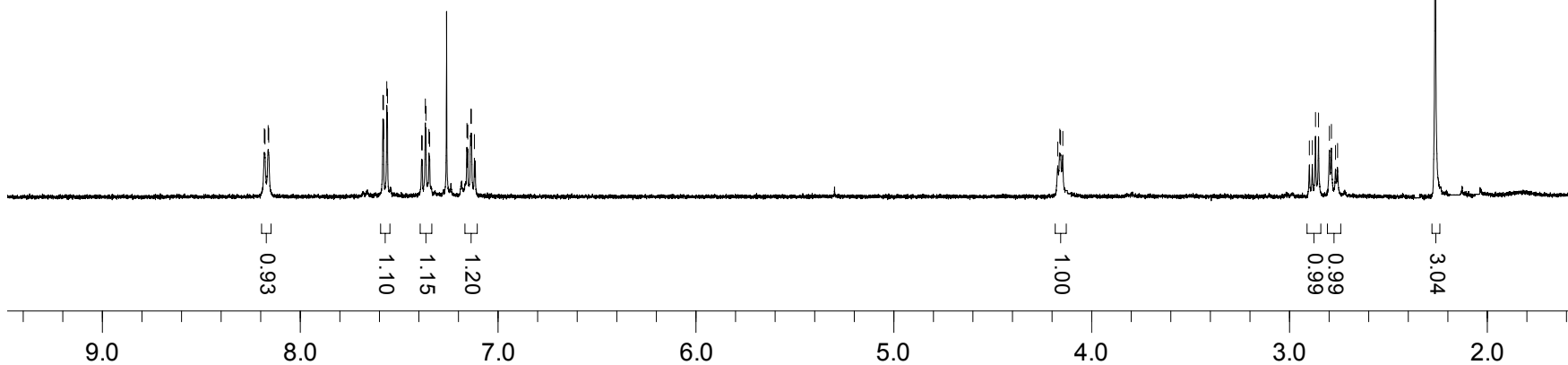
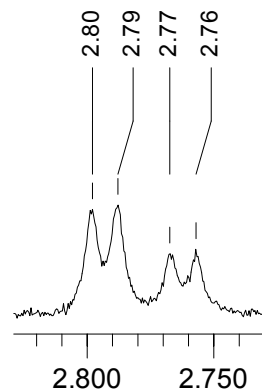
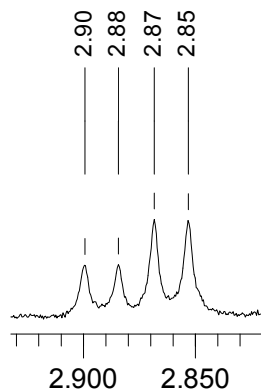
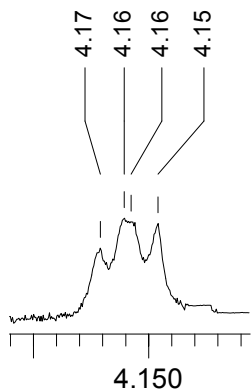
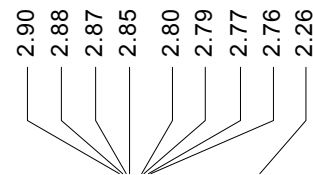
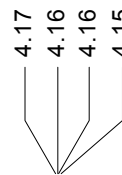
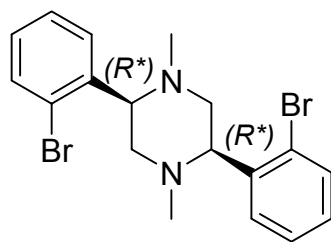
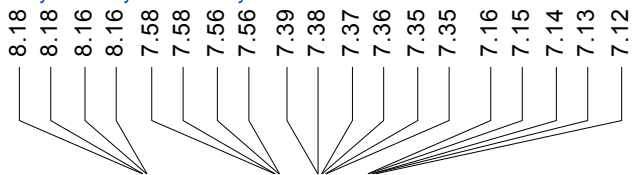
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129.7
128.6
127.6
124.2



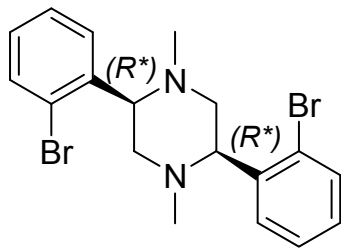
77.2
77.0
76.8
66.8
62.3

43.0





139.8
133.0
130.3
128.5
127.2
125.1



77.2
77.0
76.8

62.2

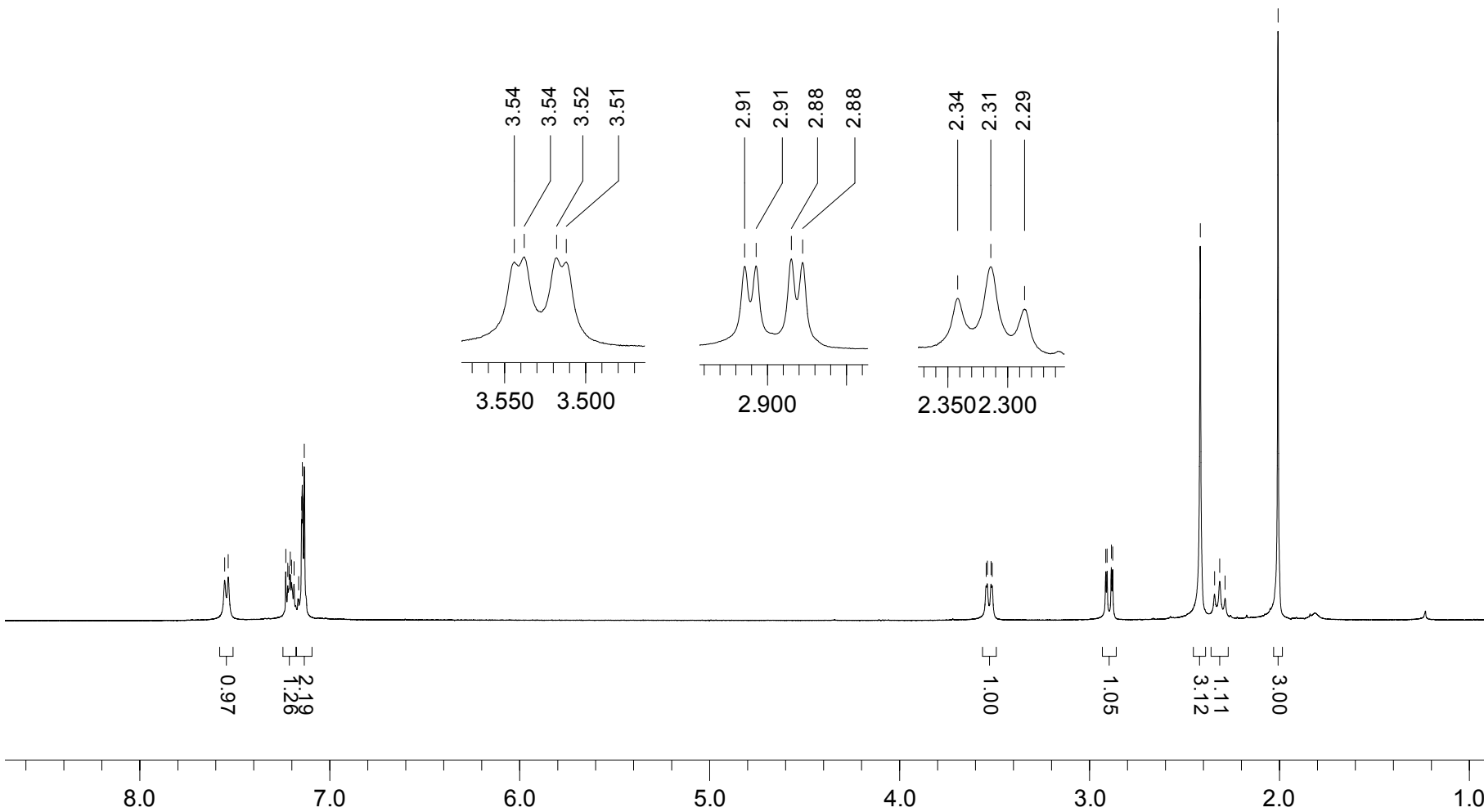
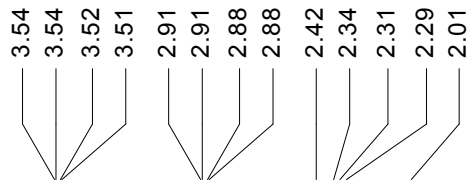
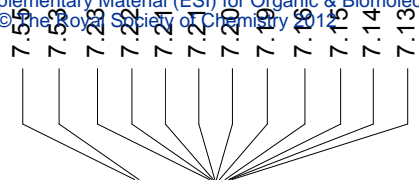
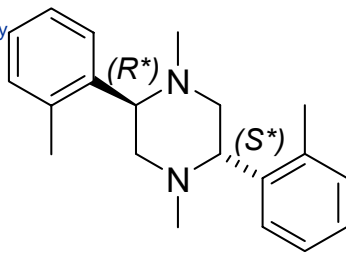
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42.5

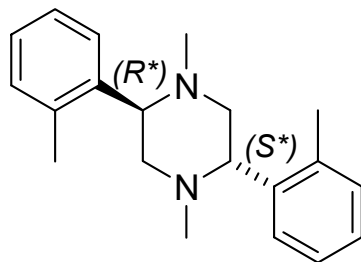
150

100

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138.9
136.0
130.4
127.4
126.9
126.3



77.2

77.0

76.8

64.1

63.0

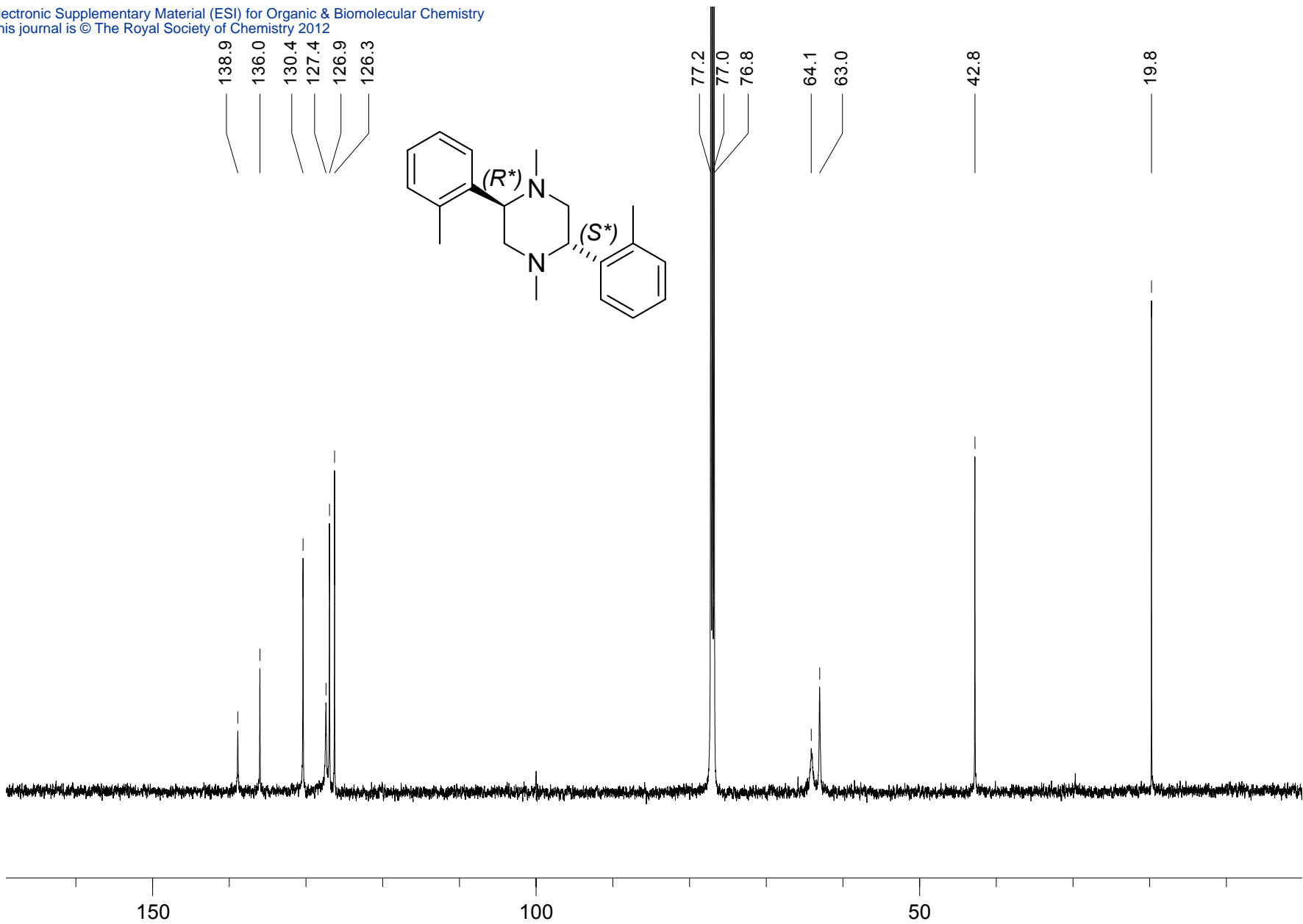
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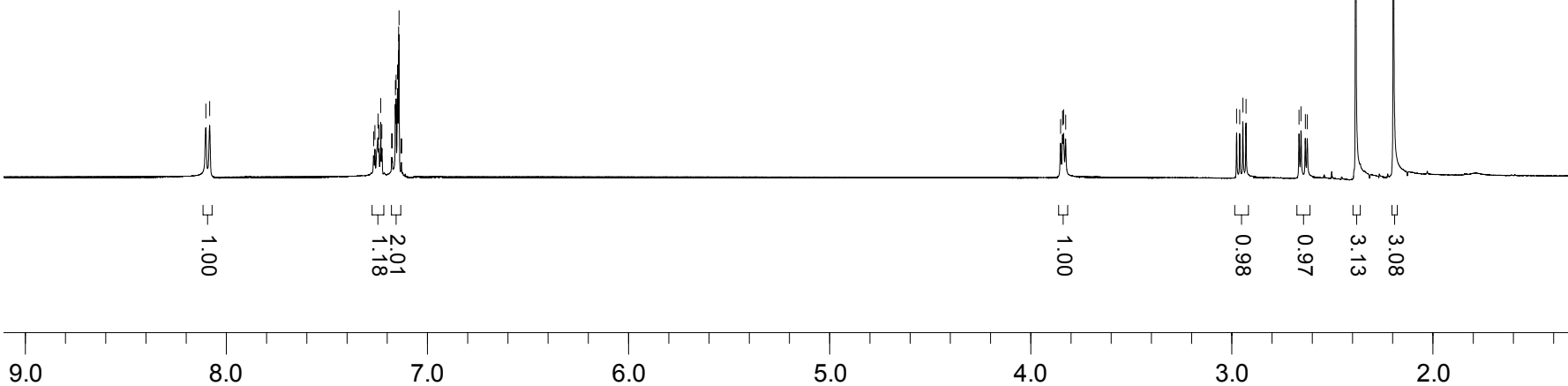
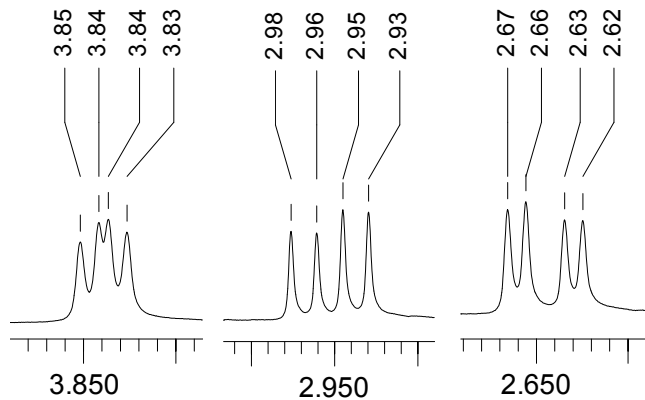
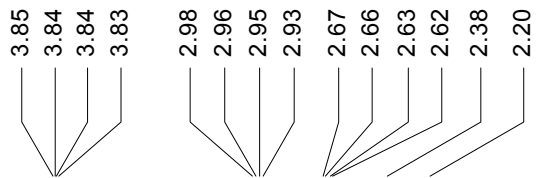
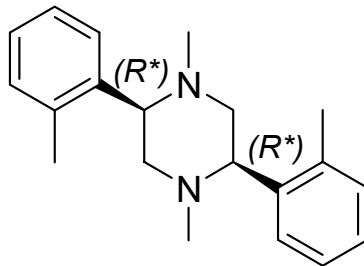
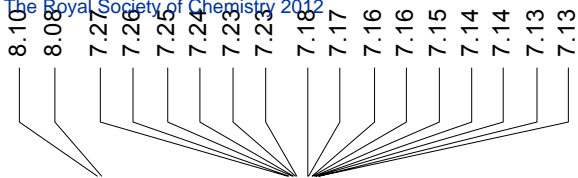
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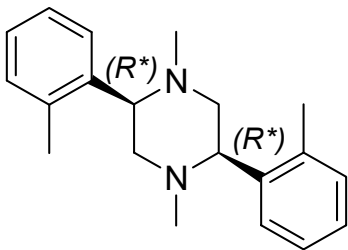
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136.4
130.3
128.8
126.7
125.8

77.3
77.0
76.7

59.3
55.9

42.6

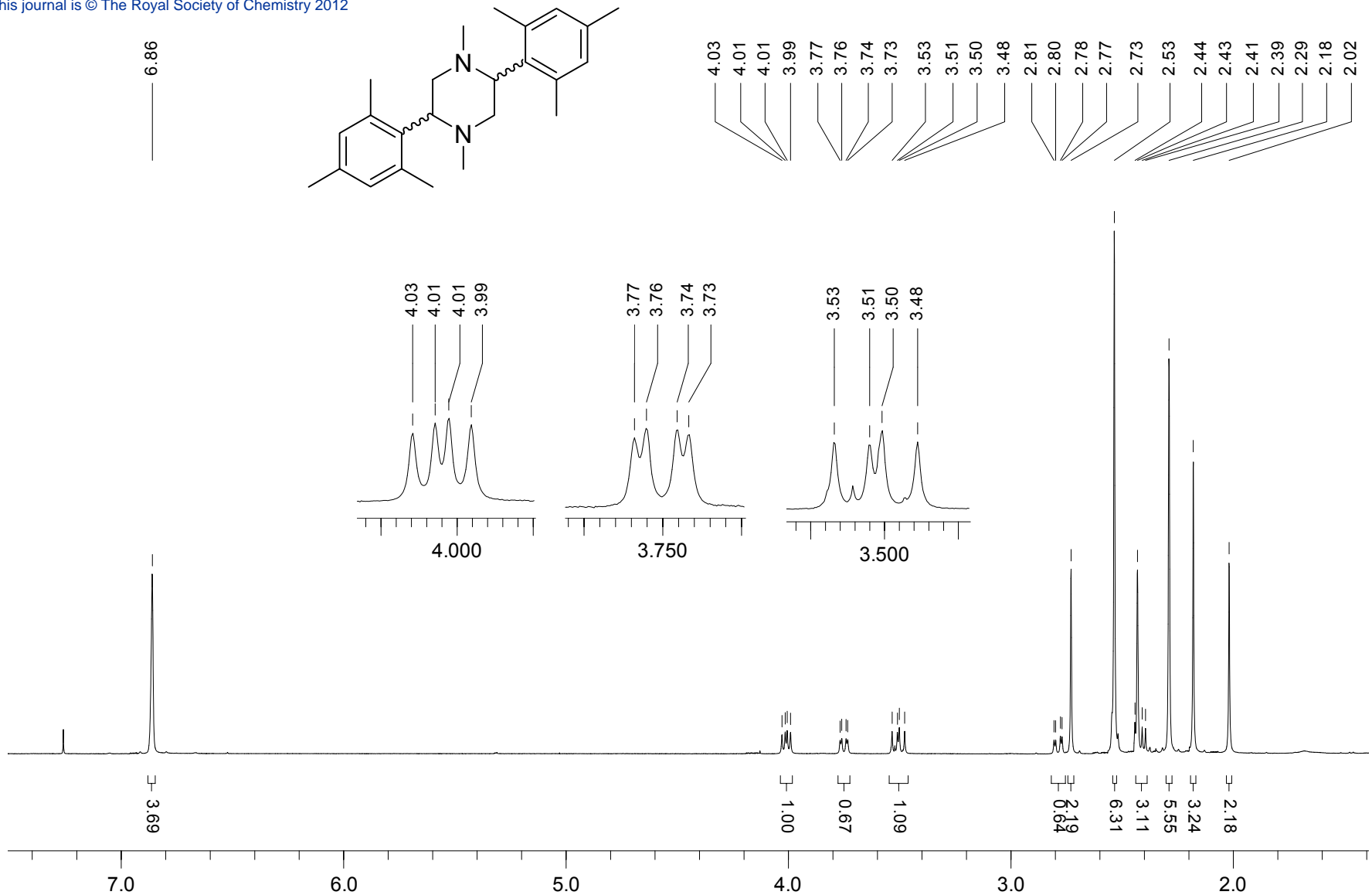
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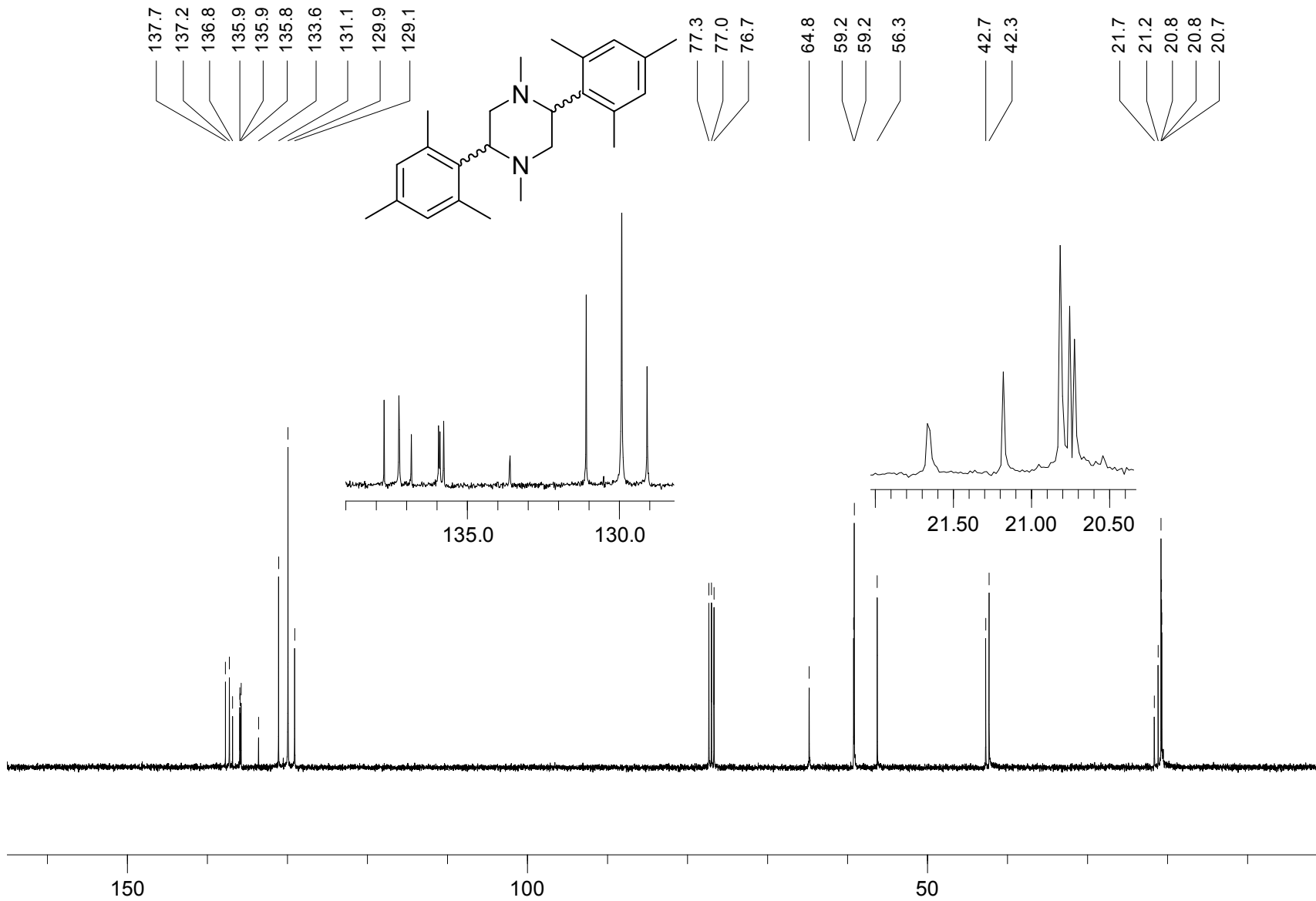


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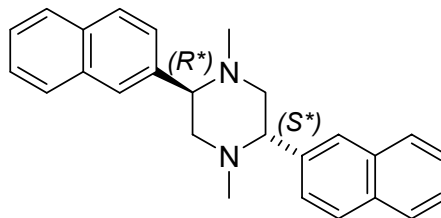
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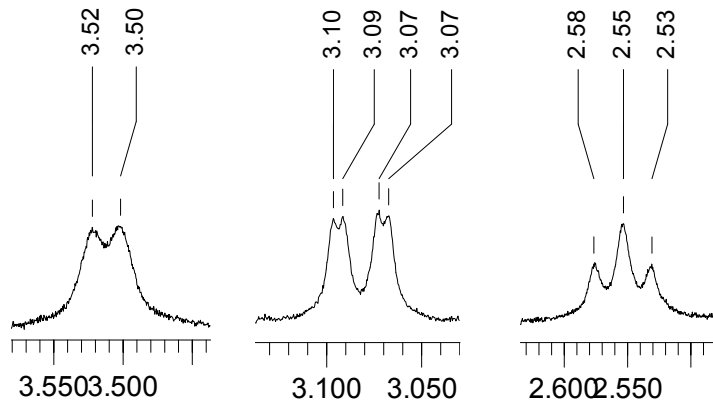




7.89
7.87
7.87
7.86
7.85
7.84
7.61
7.59
7.52
7.51
7.50
7.50
7.49
7.49
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7.48
7.47
7.46
7.46



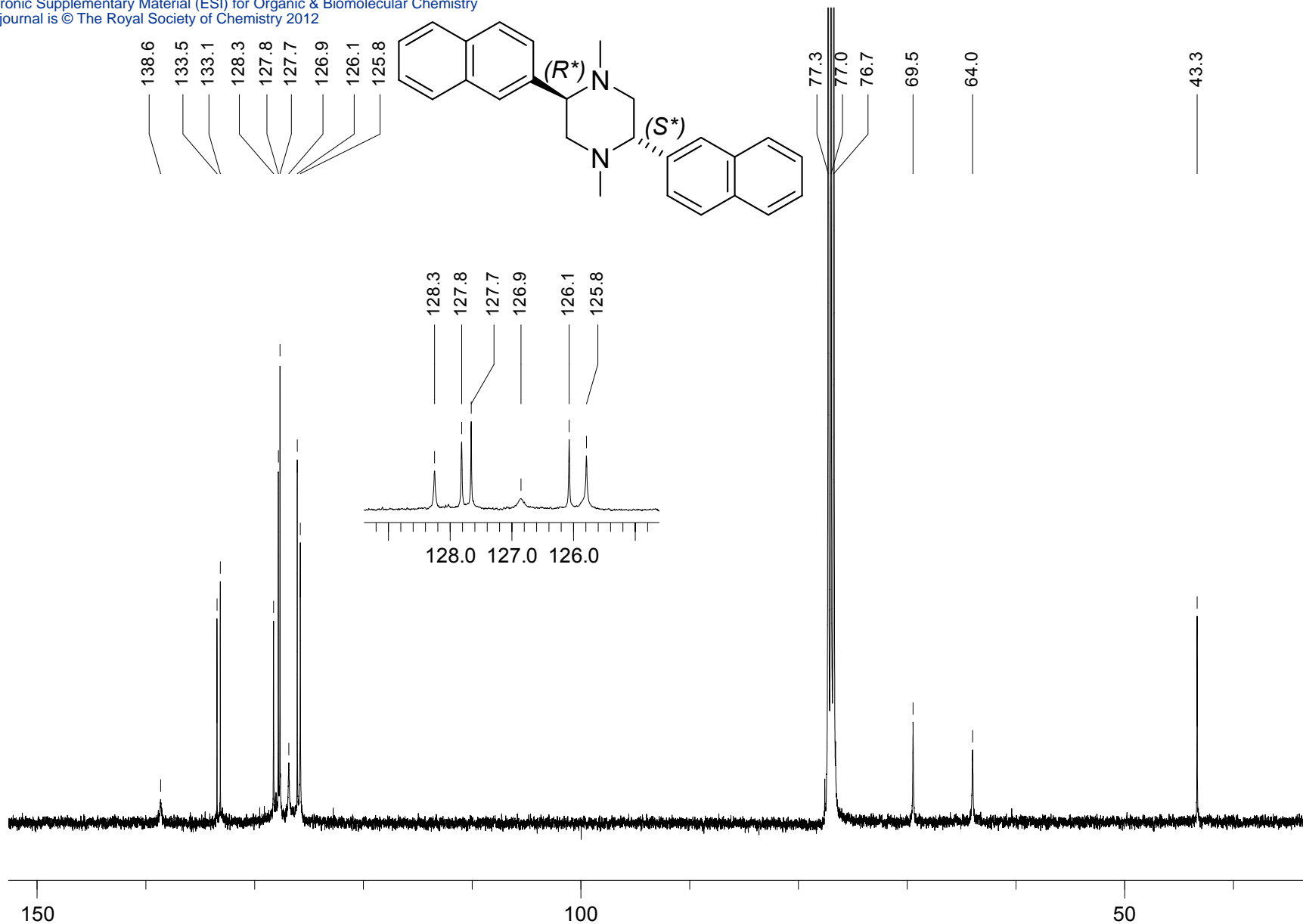
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3.09
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3.07
2.58
2.55
2.53
2.12

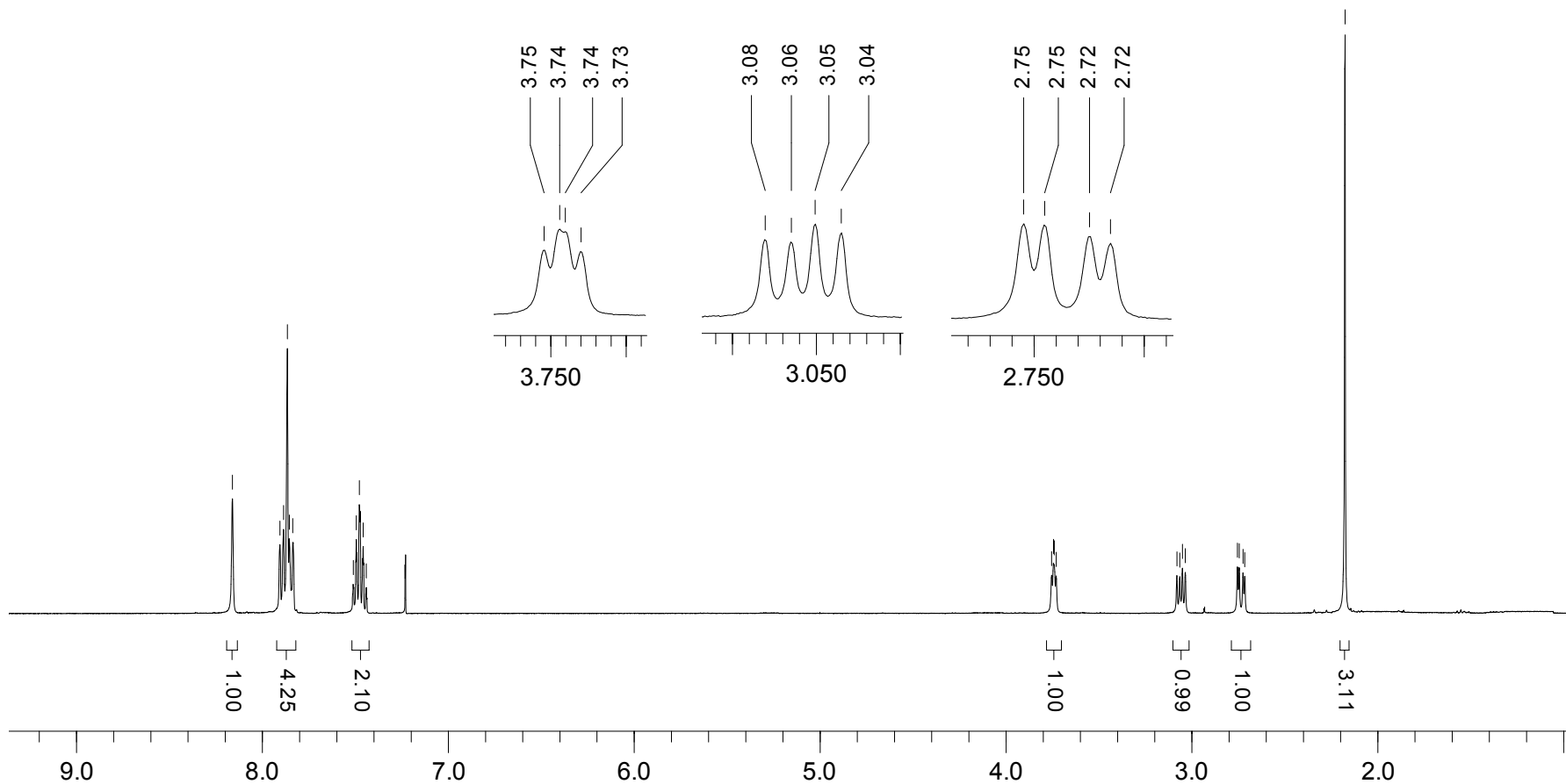
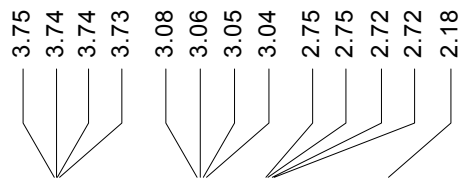
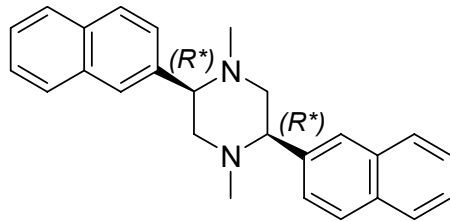
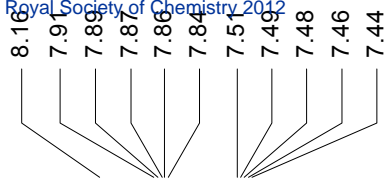


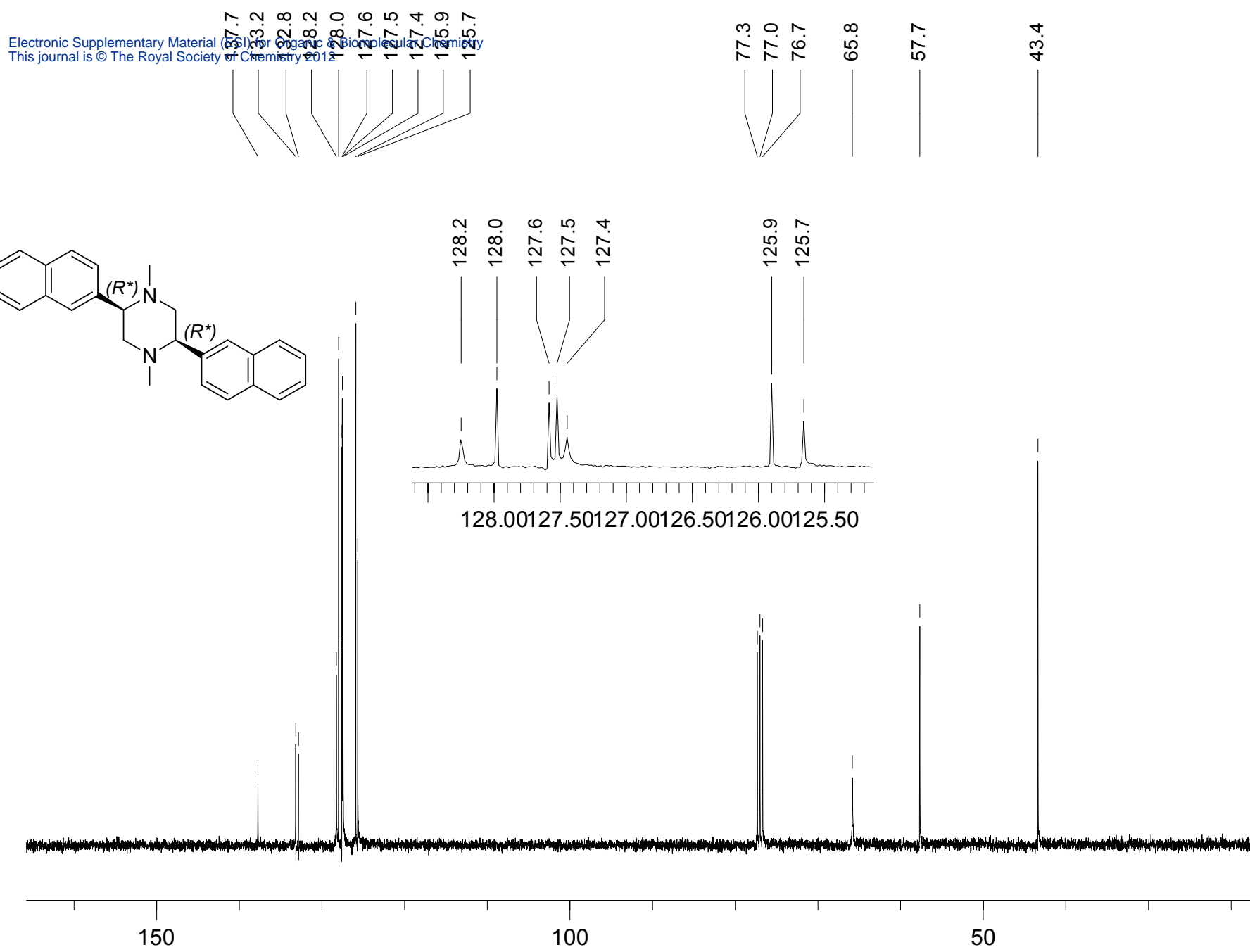
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0.96

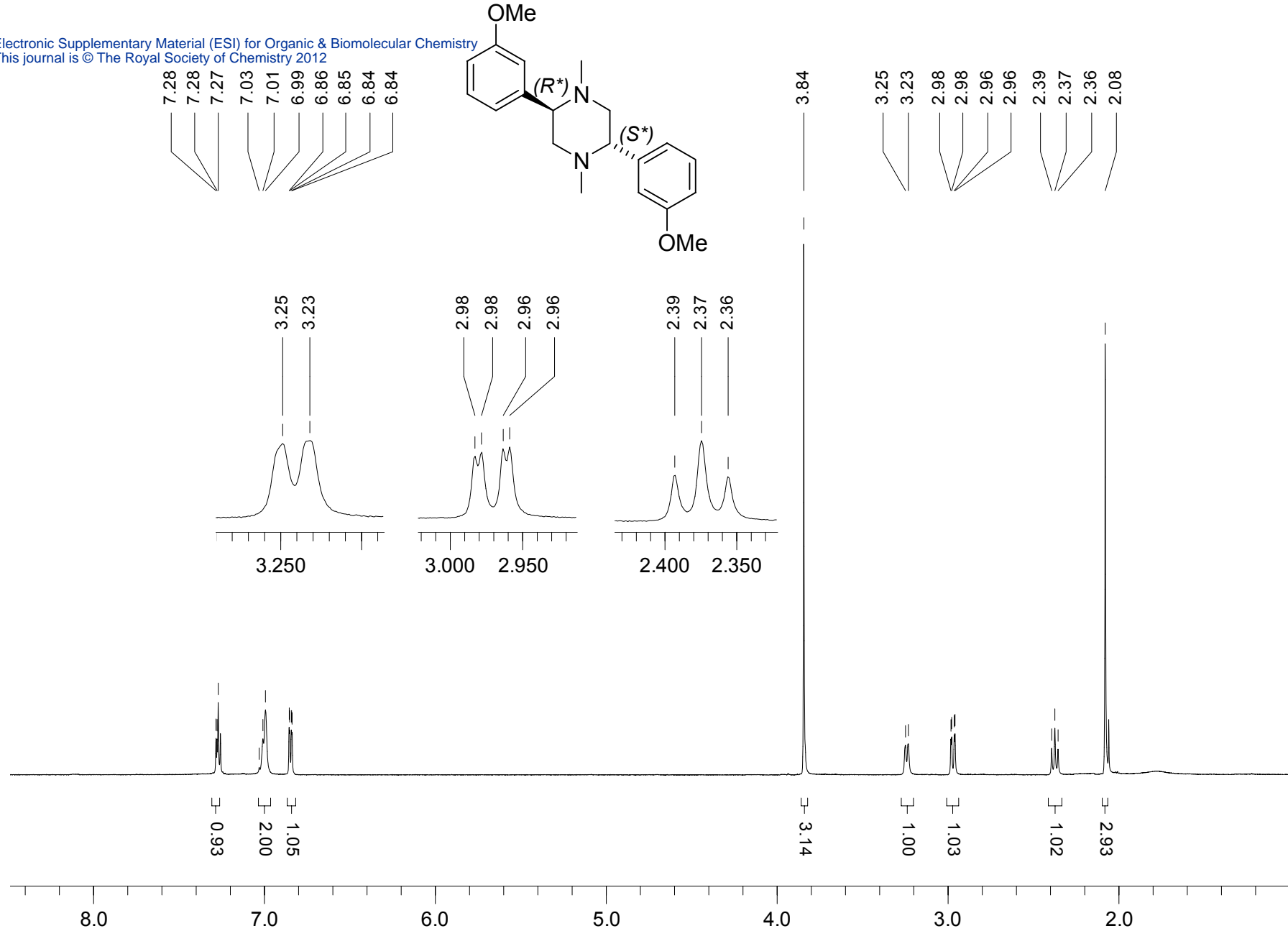
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1.00
1.00
2.95

9.0 8.0 7.0 6.0 5.0 4.0 3.0 2.0

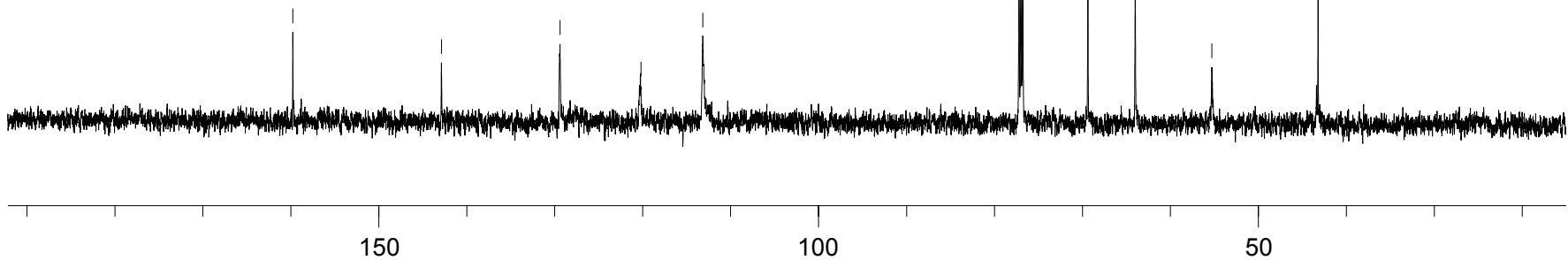
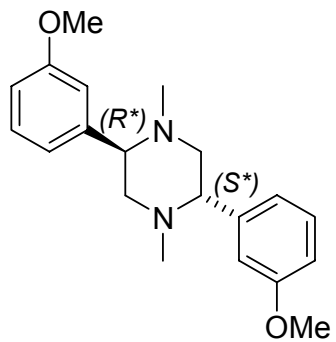


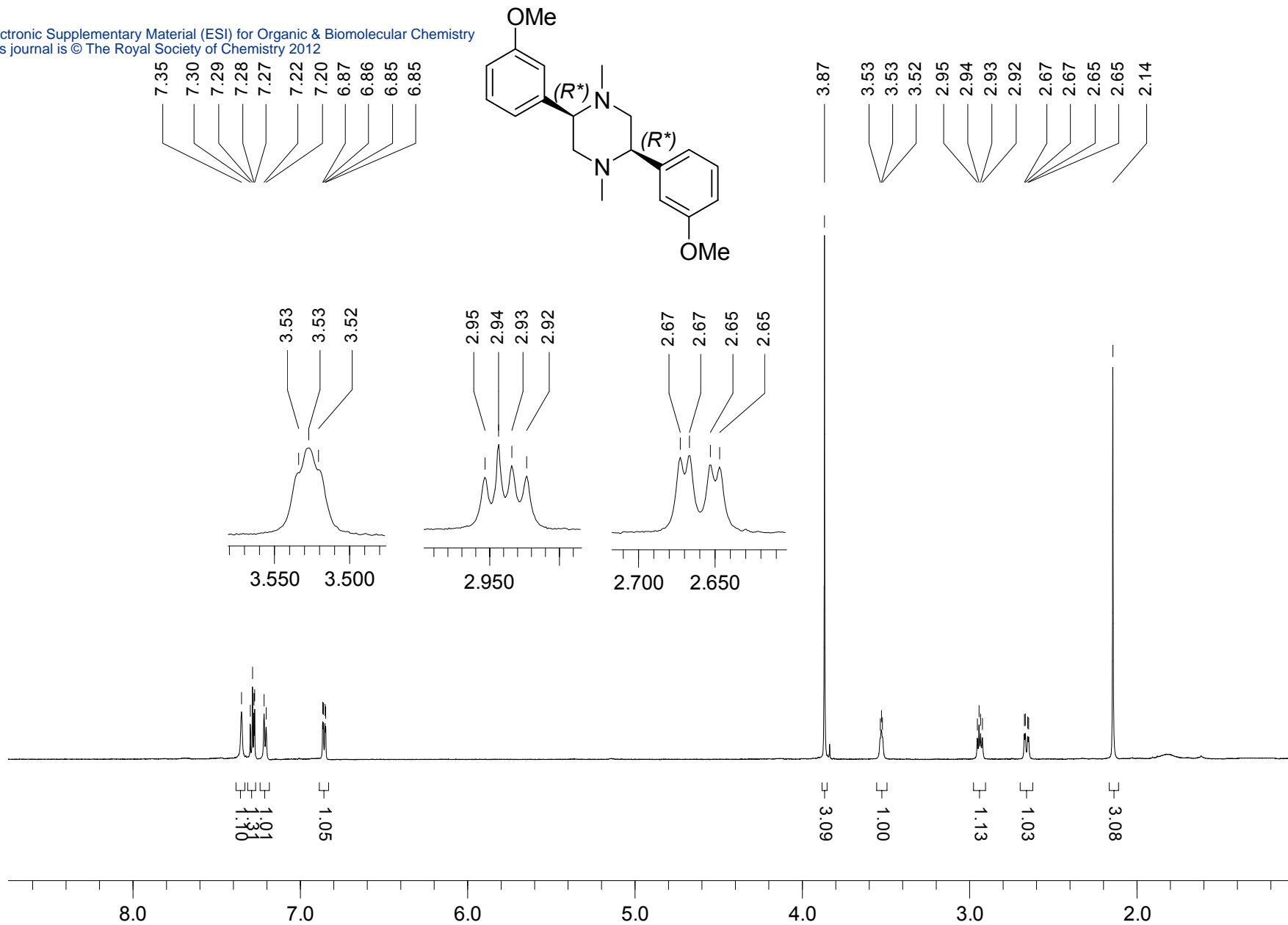


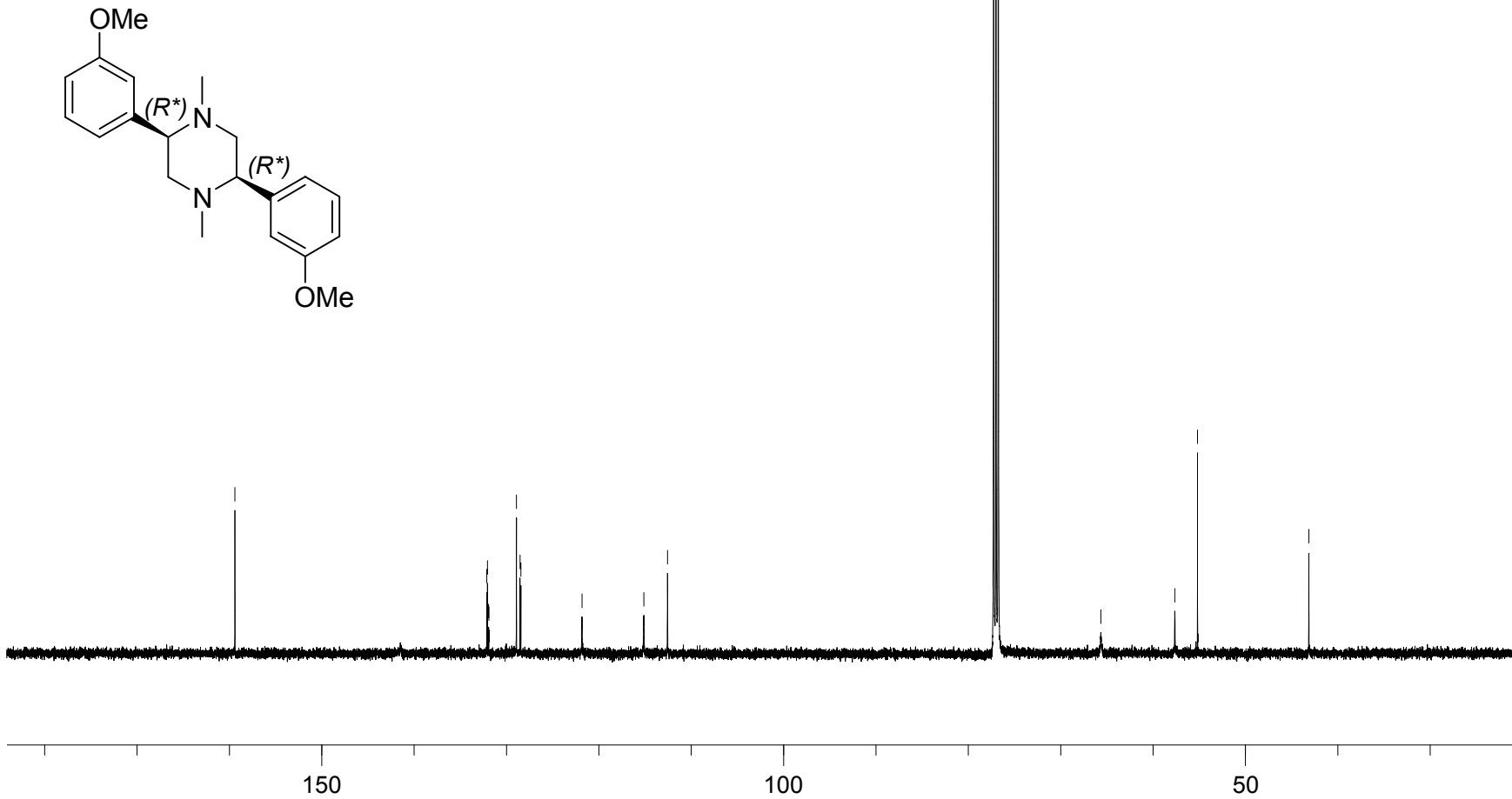


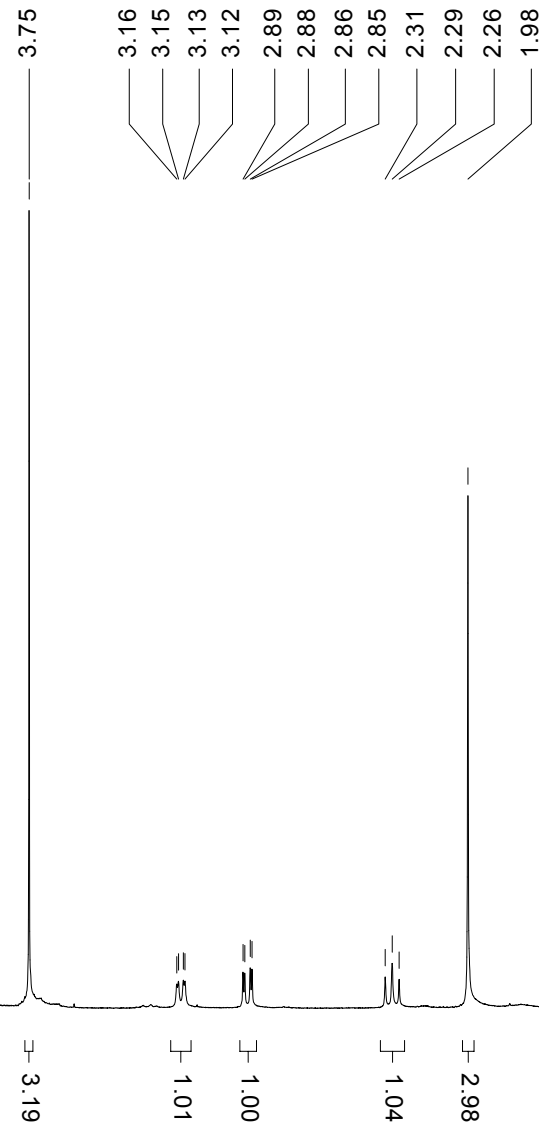
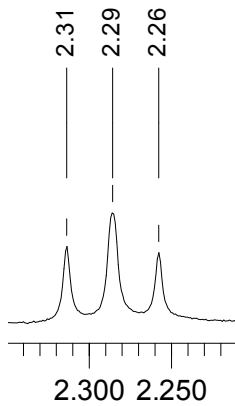
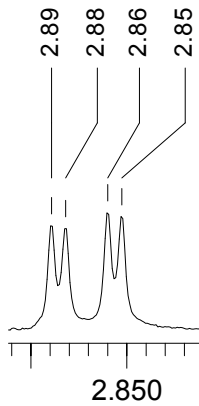
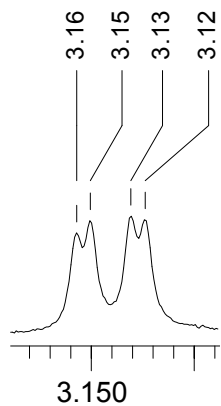
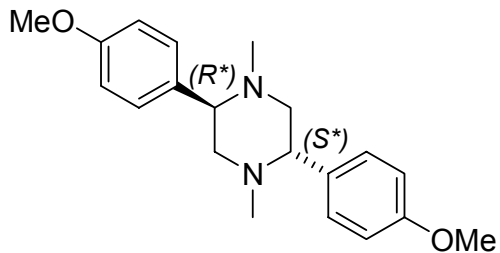


159.8
142.9
129.4
120.2
113.2
77.2
77.0
76.8
69.4
64.0
55.3
43.2









8.0

7.0

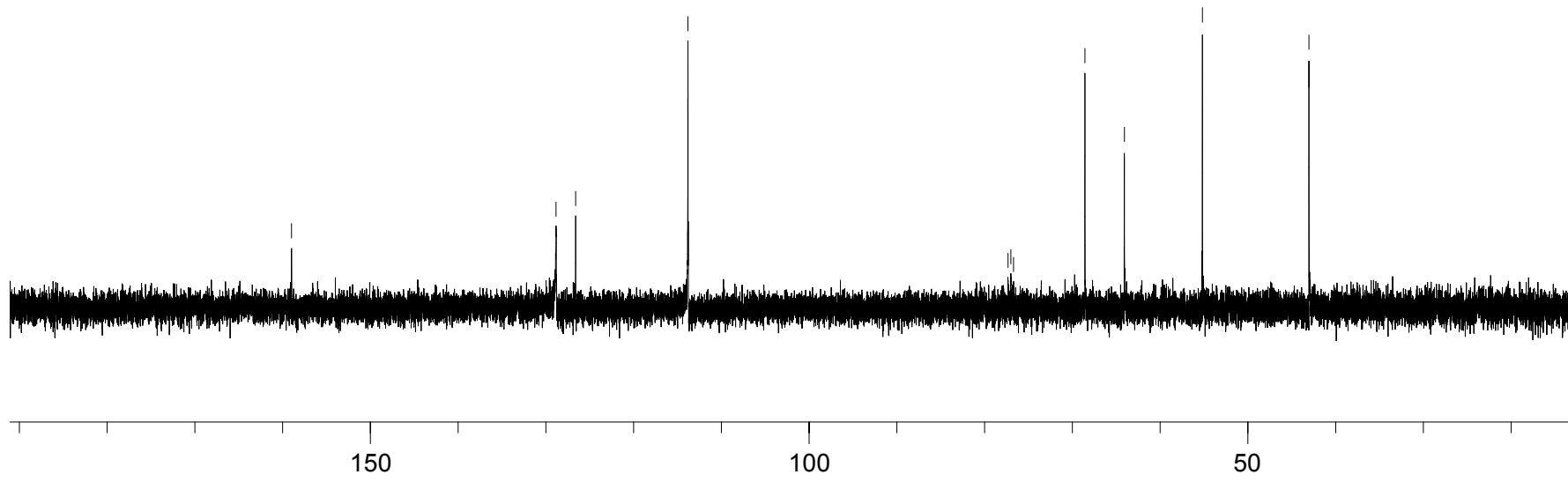
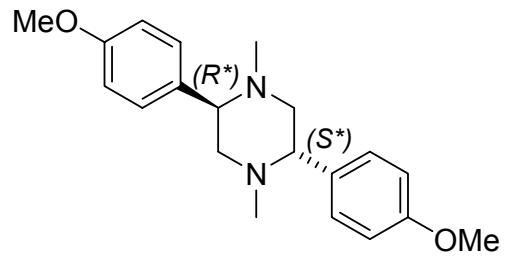
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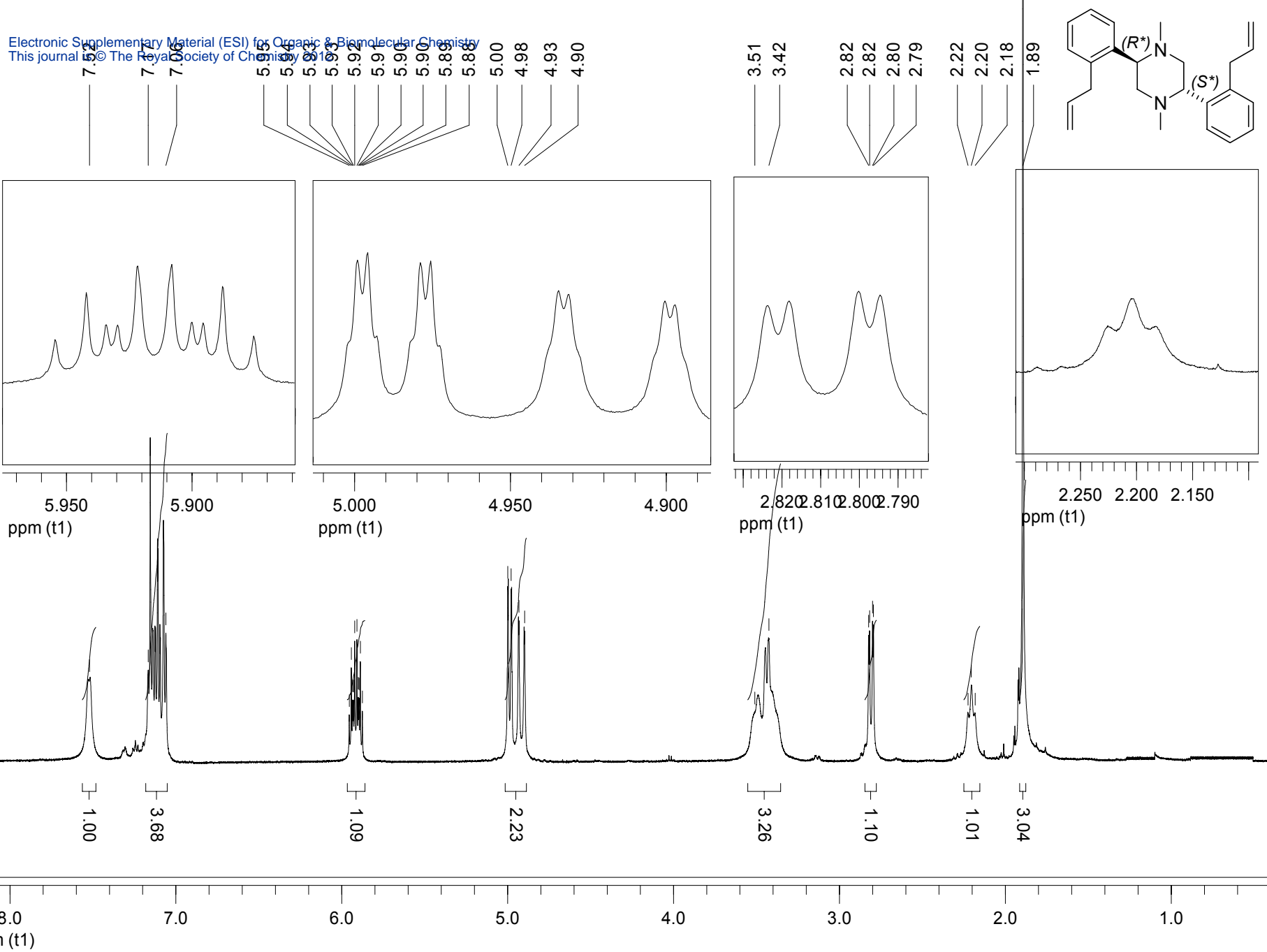
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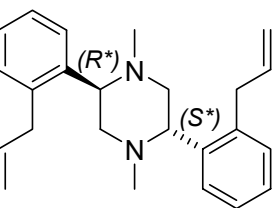
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3.0

2.0







139.6
137.6
137.4
129.9
127.6
127.1
126.7
116.0

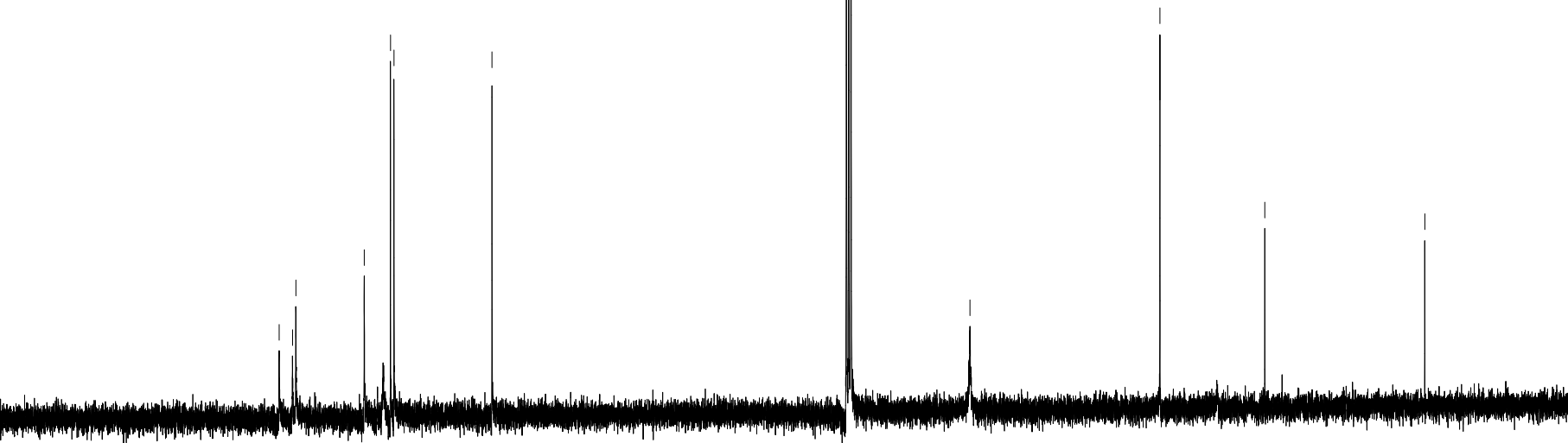
77.3
77.0
76.8

63.8

43.0

31.6

14.1

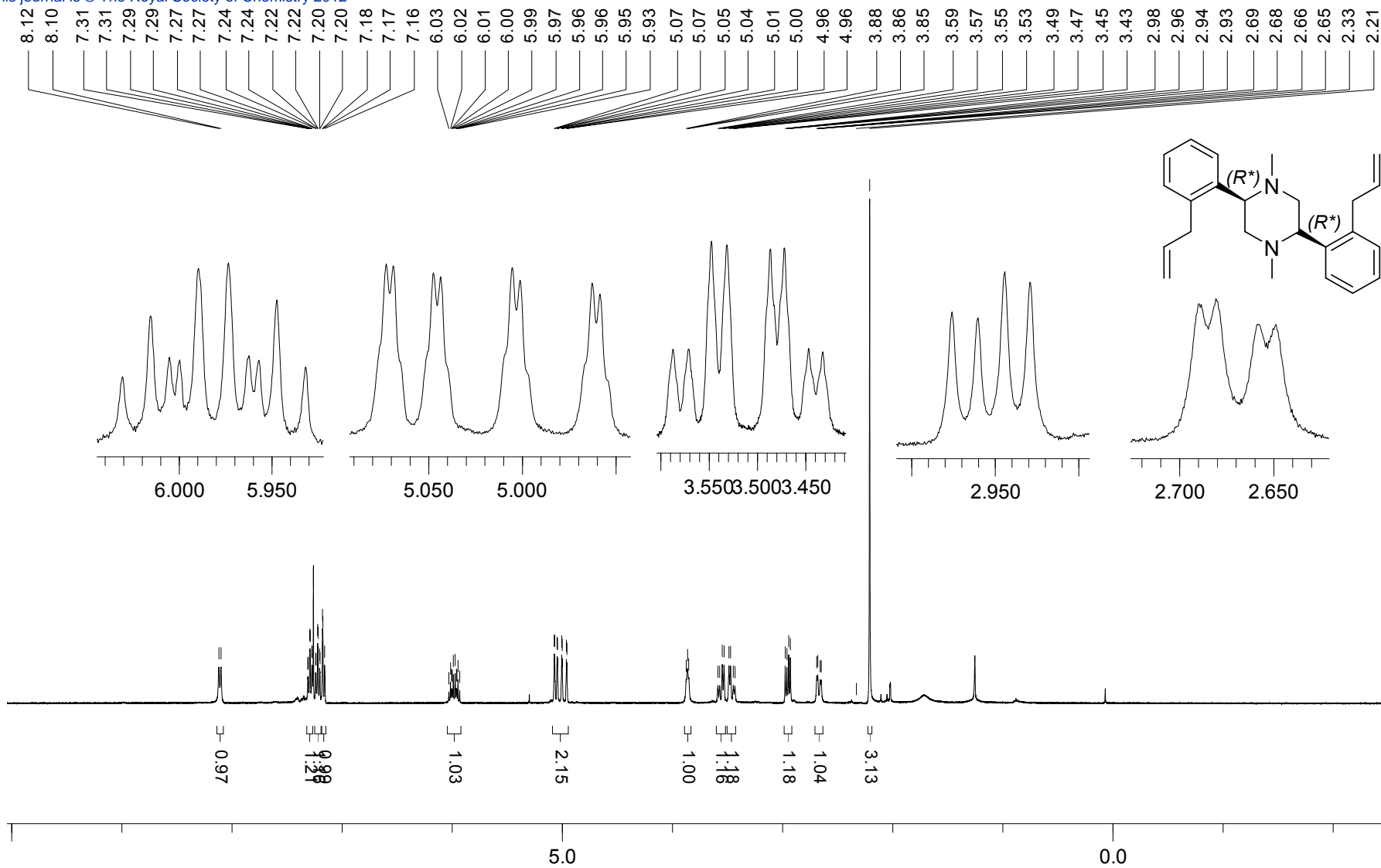


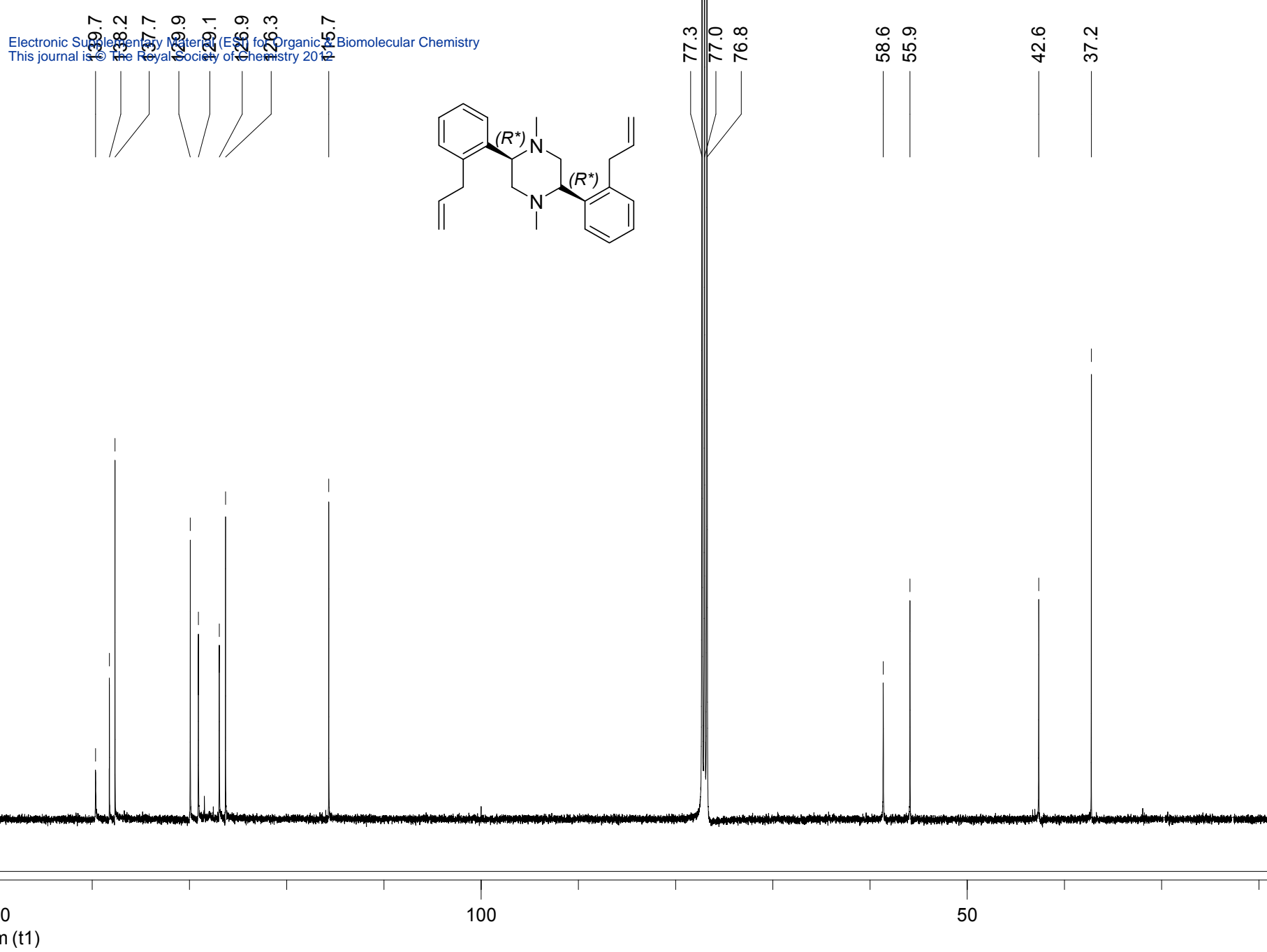
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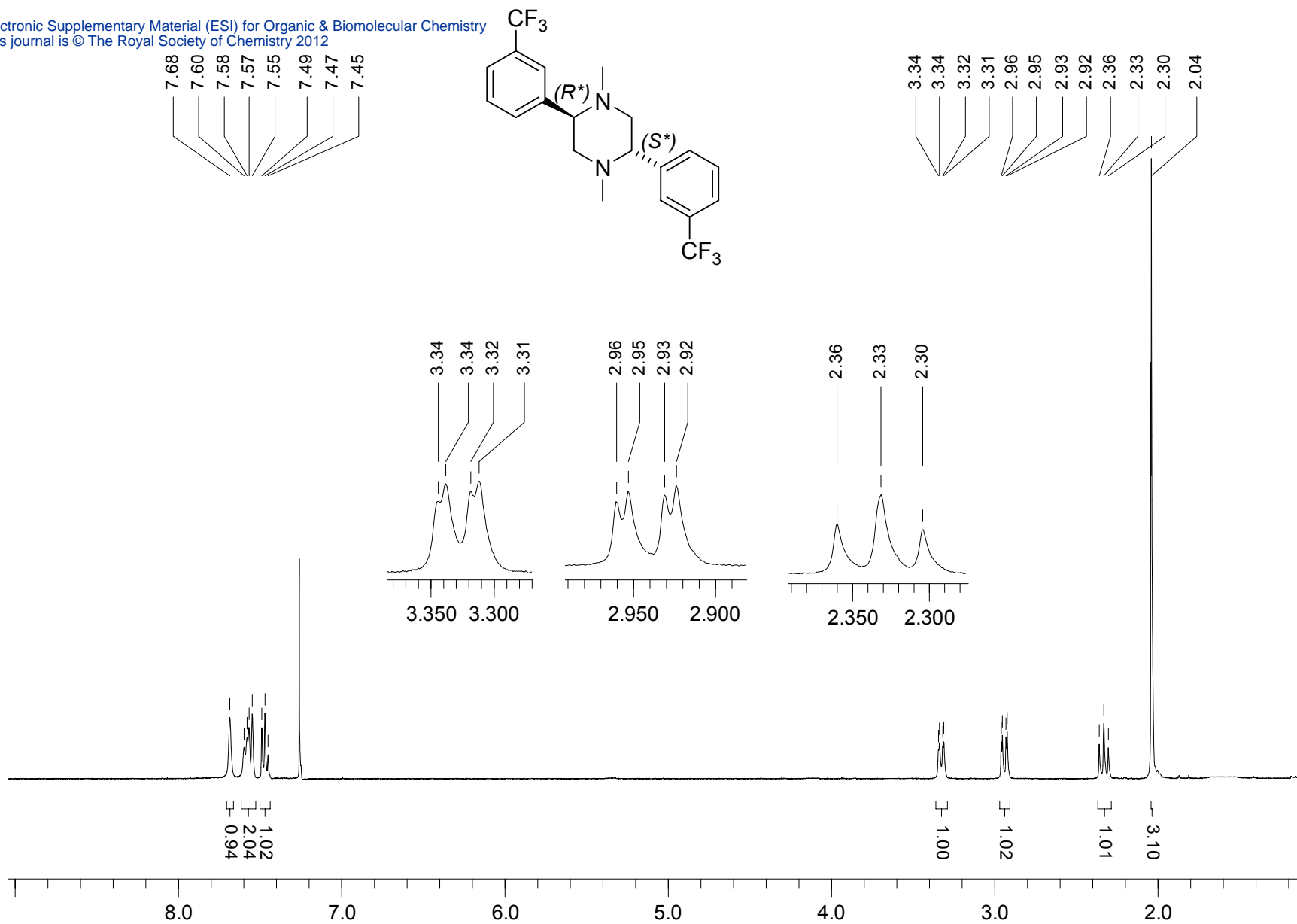
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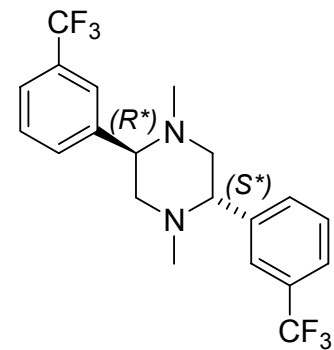
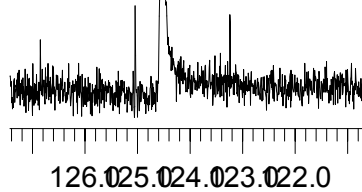
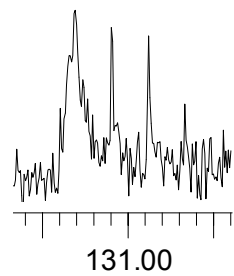




142.7
131.3
131.0
130.9
130.7
129.0
126.8
125.0
124.6
124.5
123.2
121.4

77.2
77.0
76.8
68.8
63.9

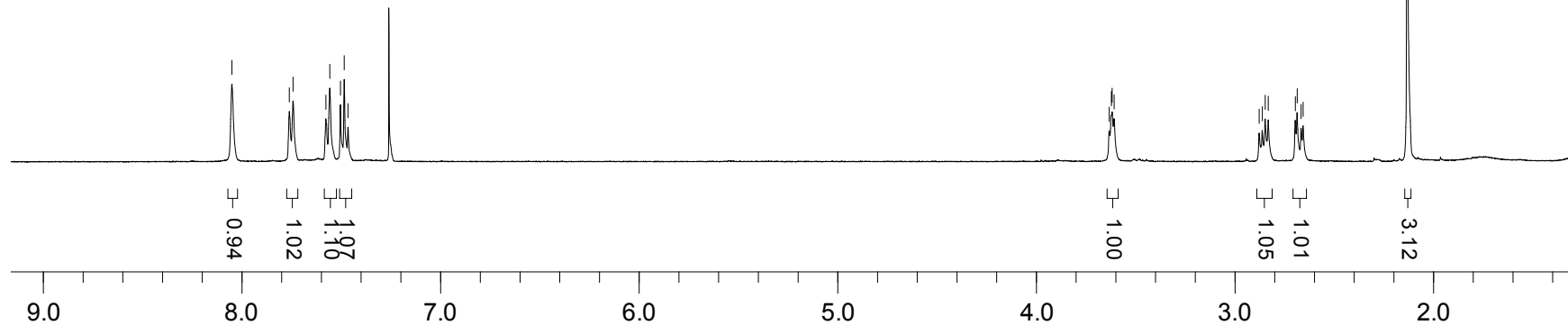
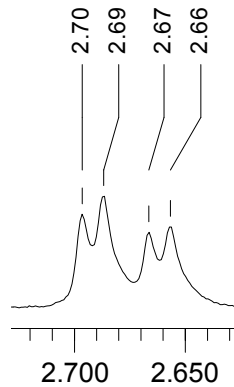
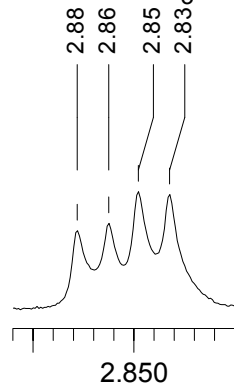
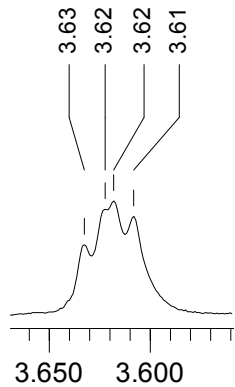
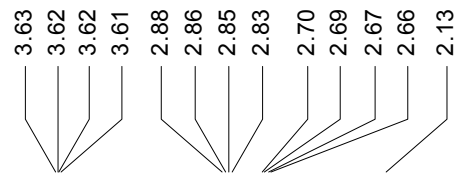
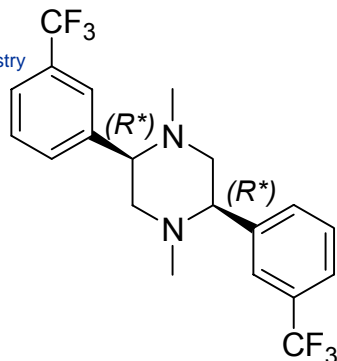
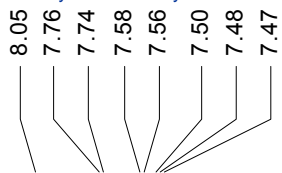
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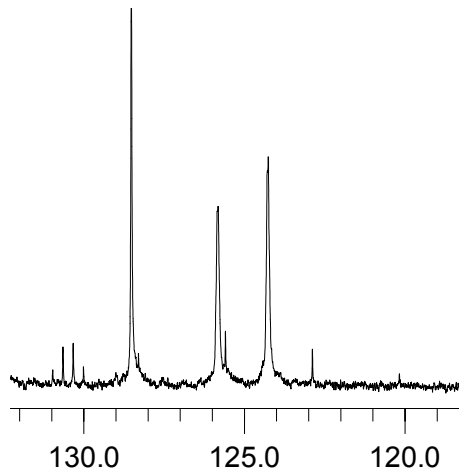
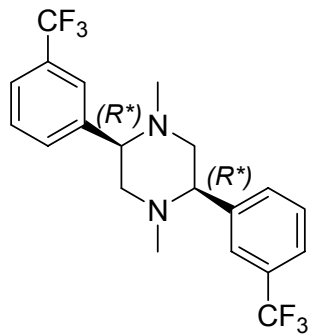
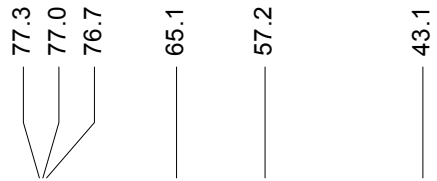
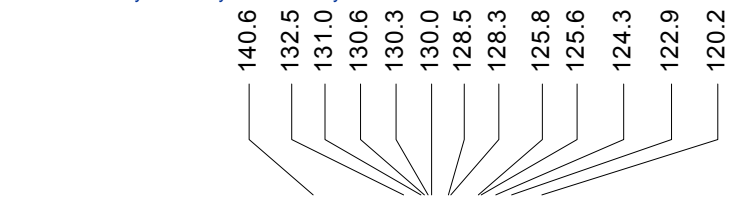


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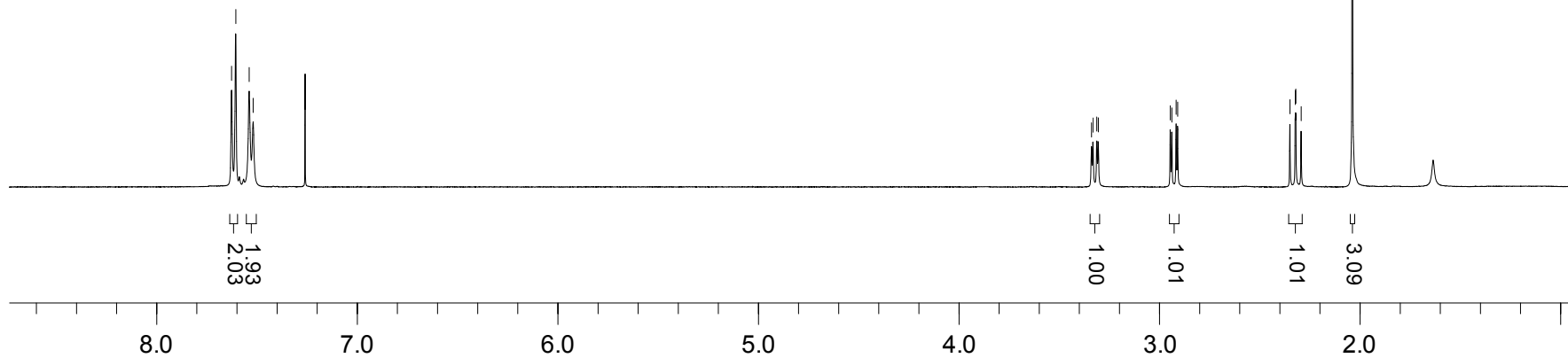
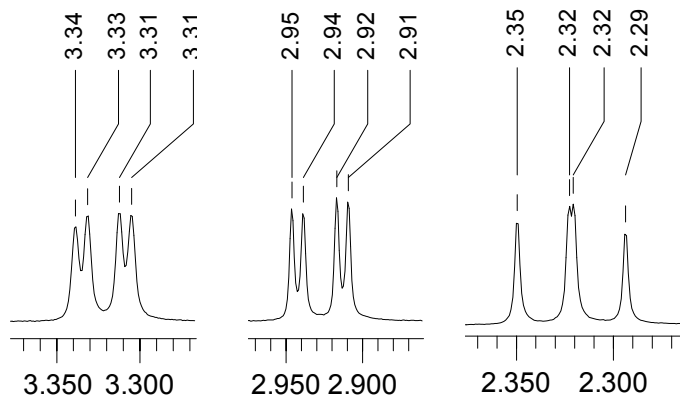
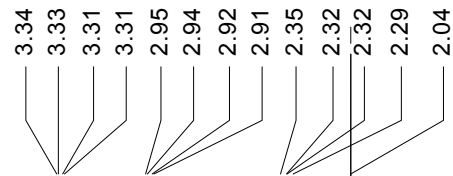
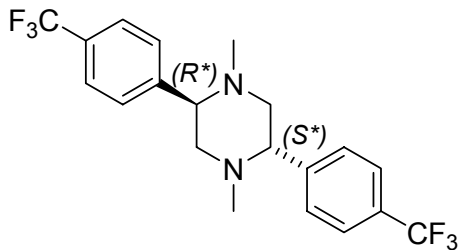
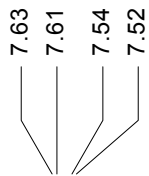


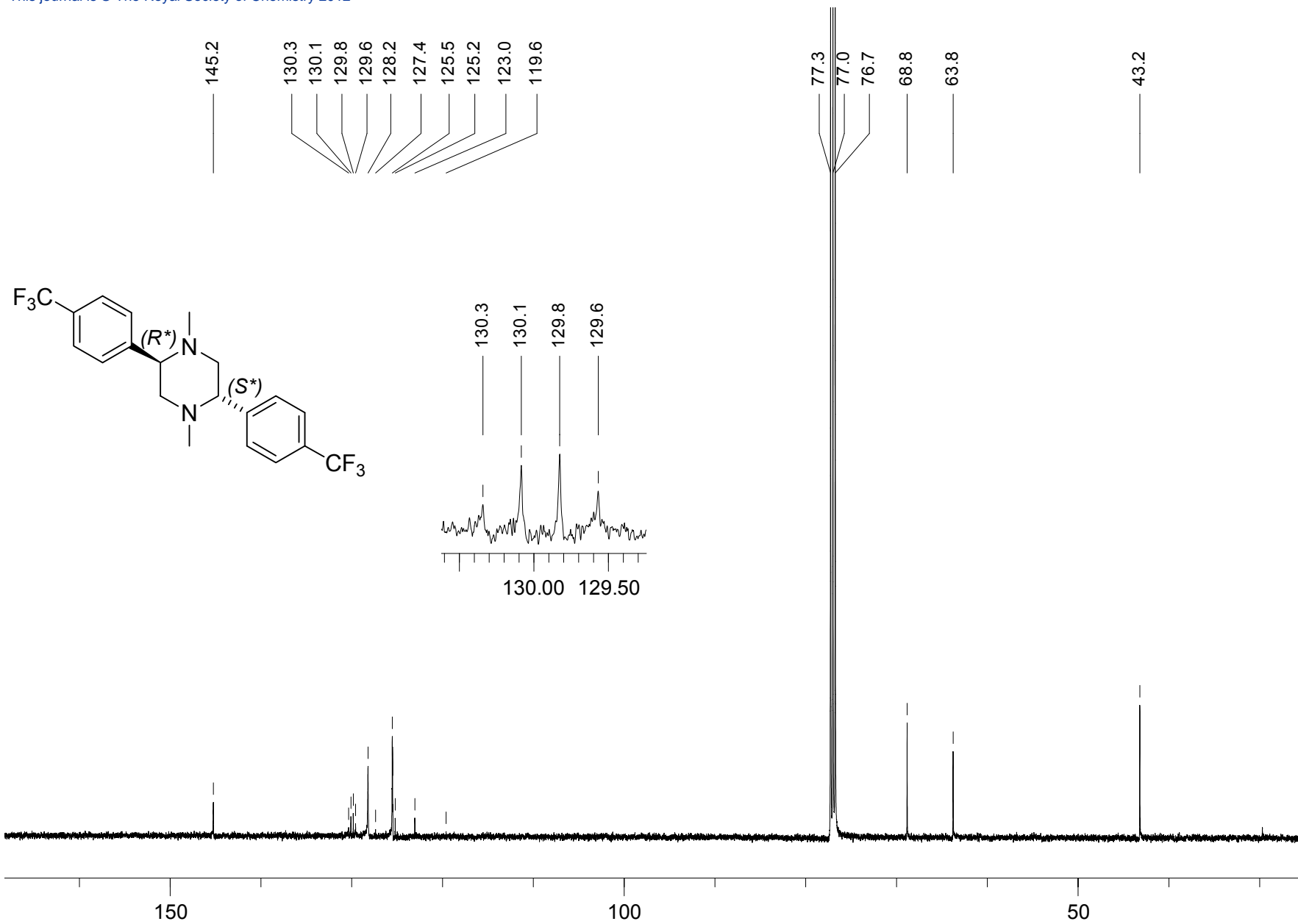


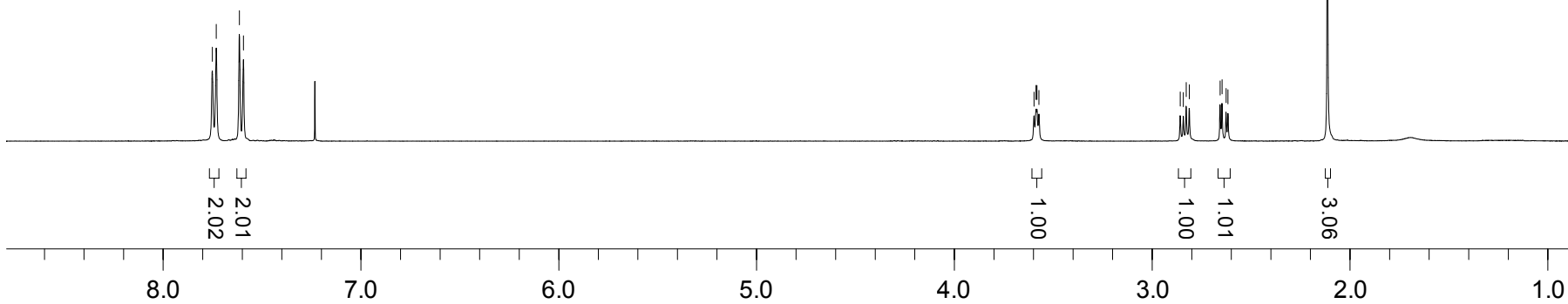
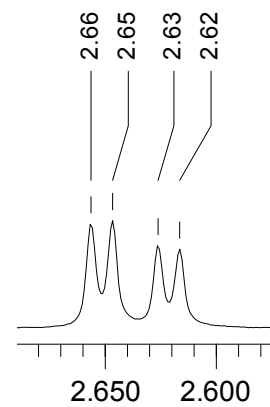
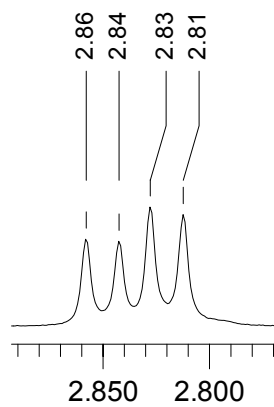
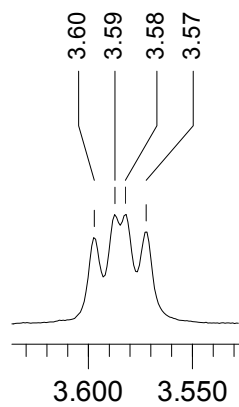
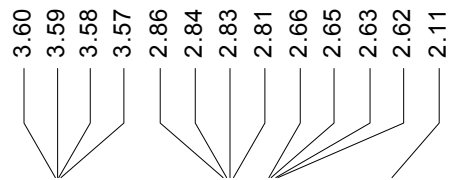
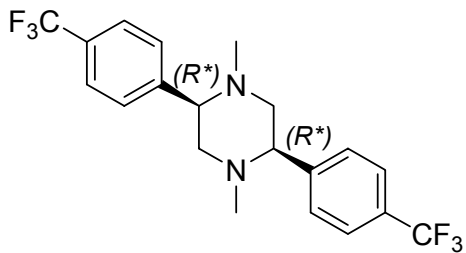
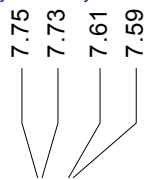
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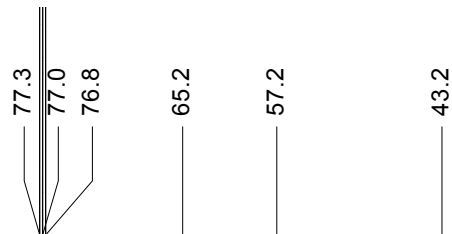
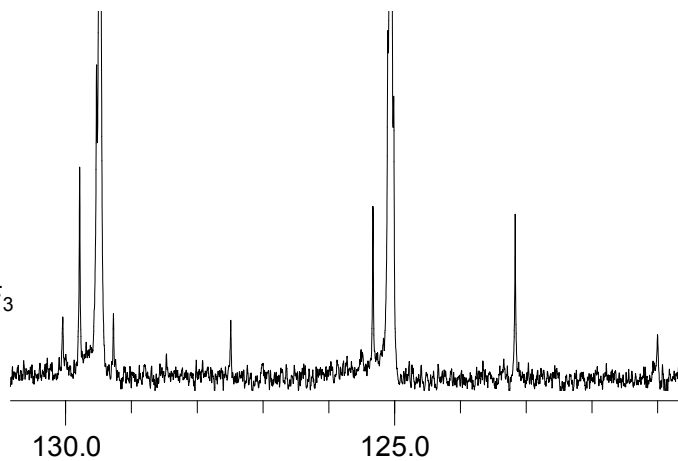
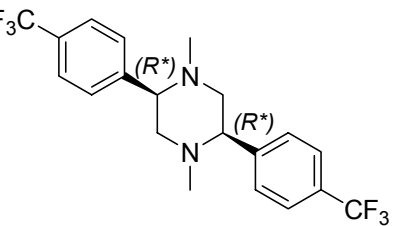
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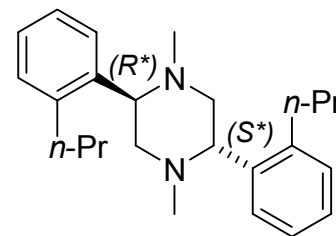
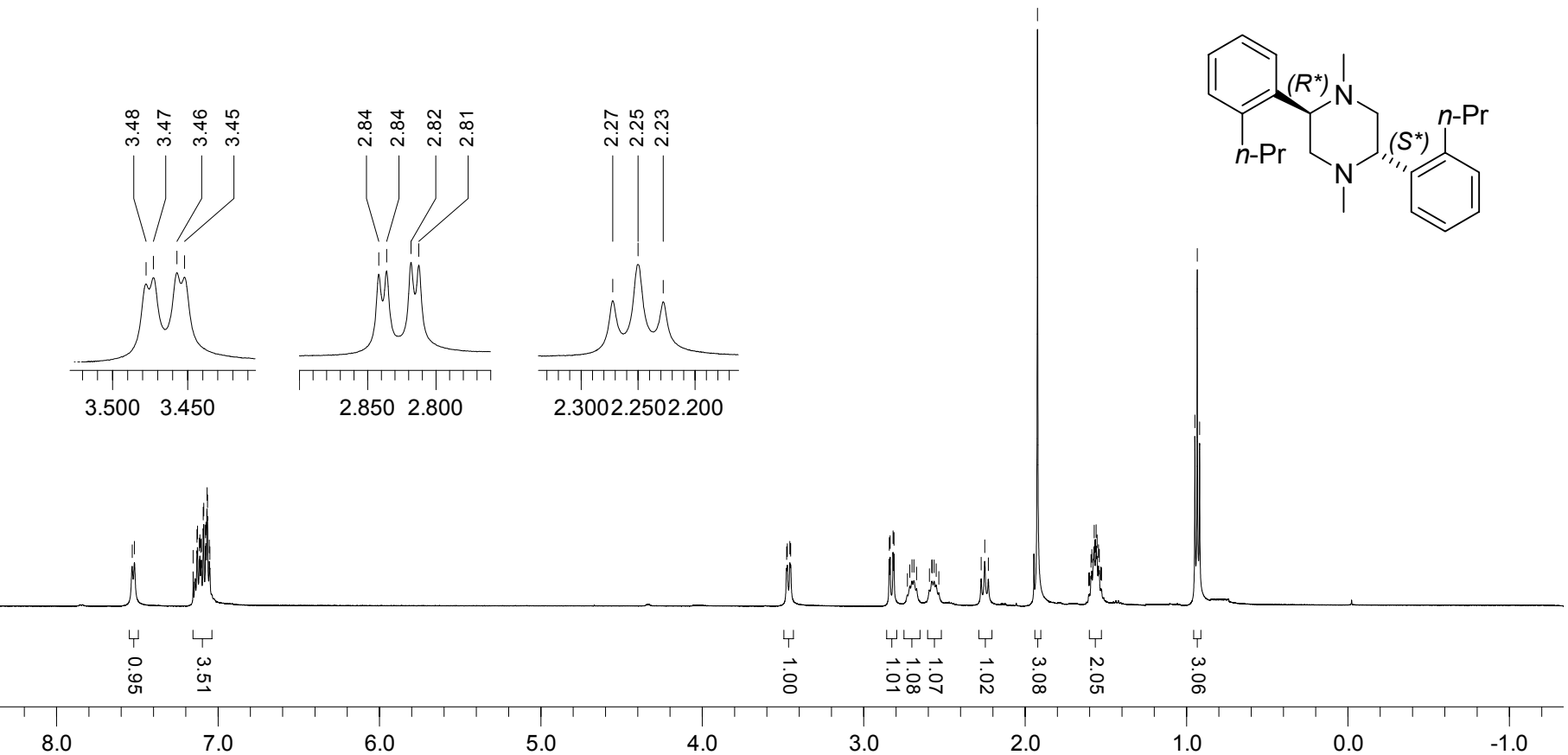
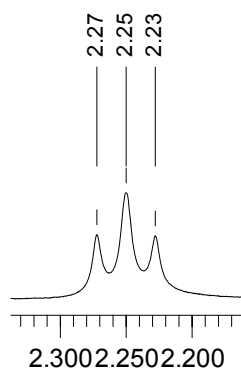
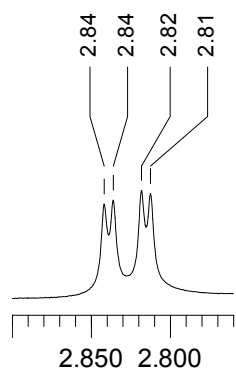
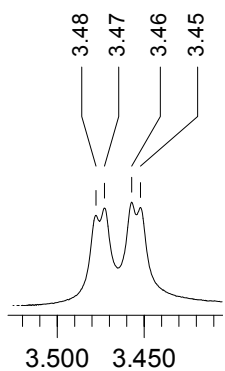
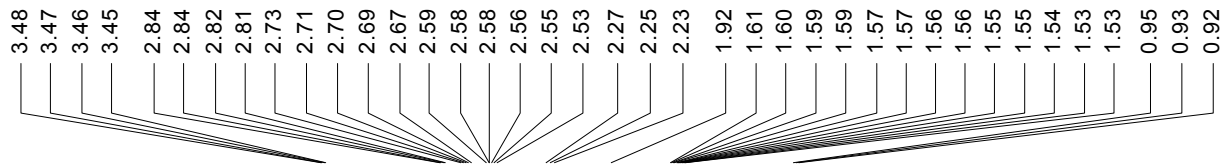
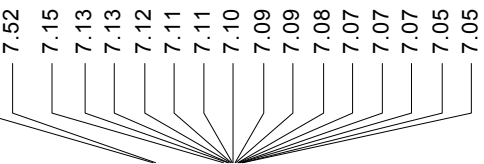


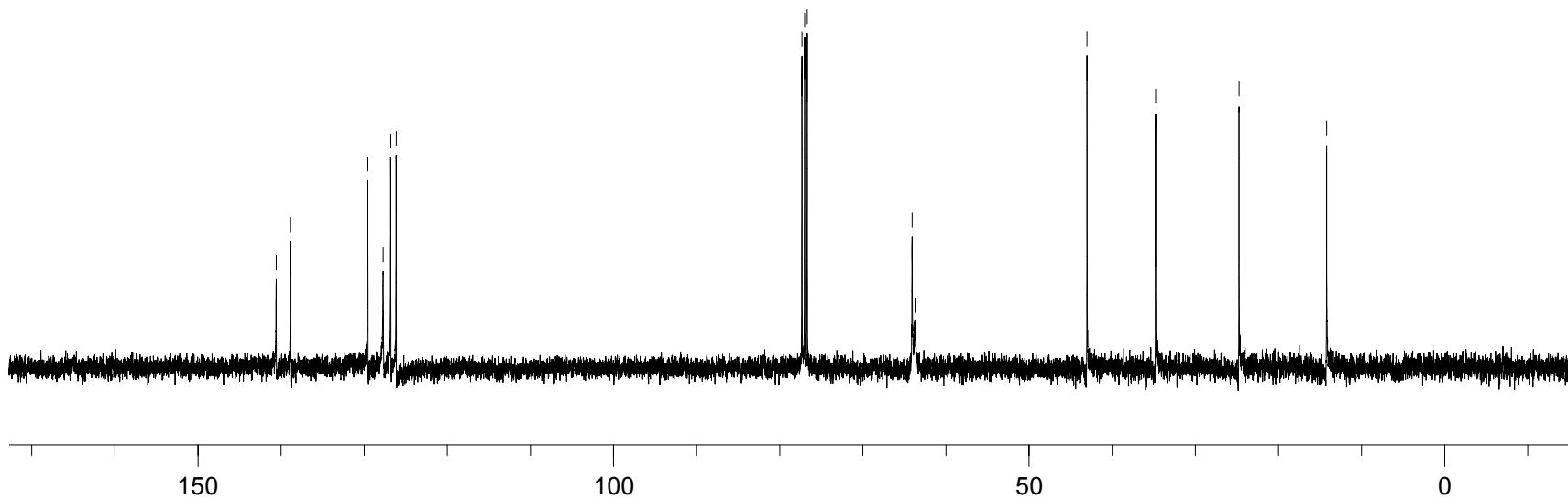
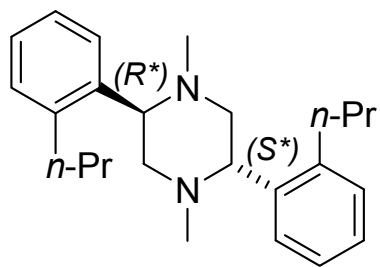
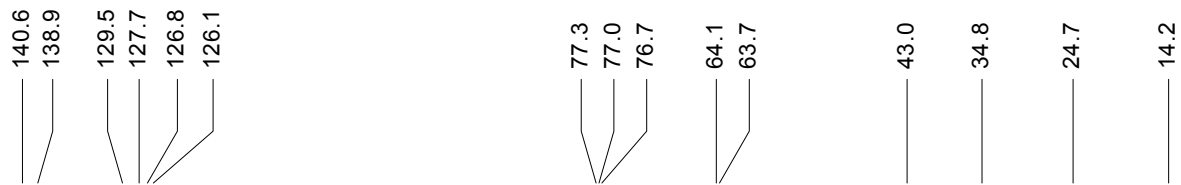


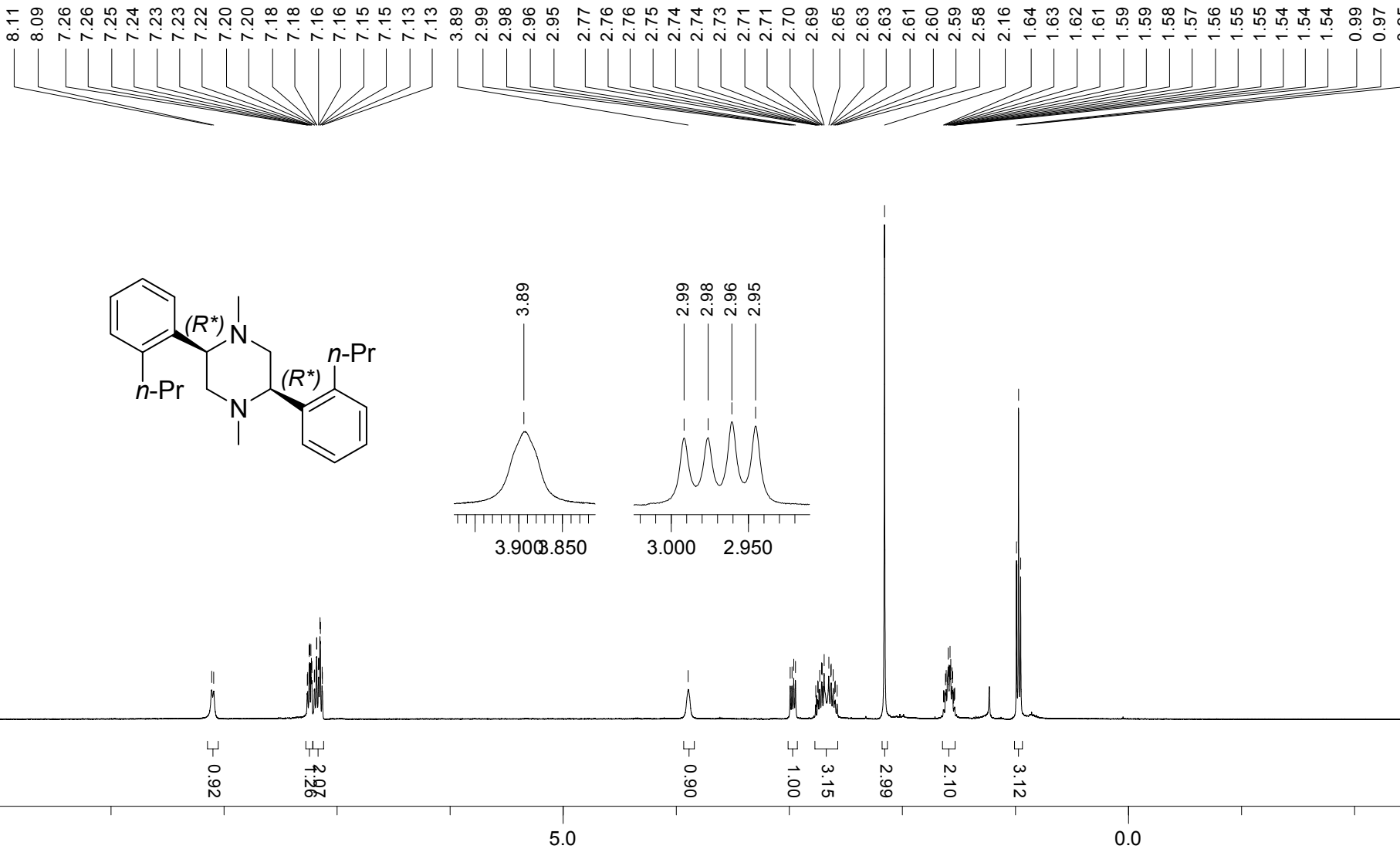
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100

50

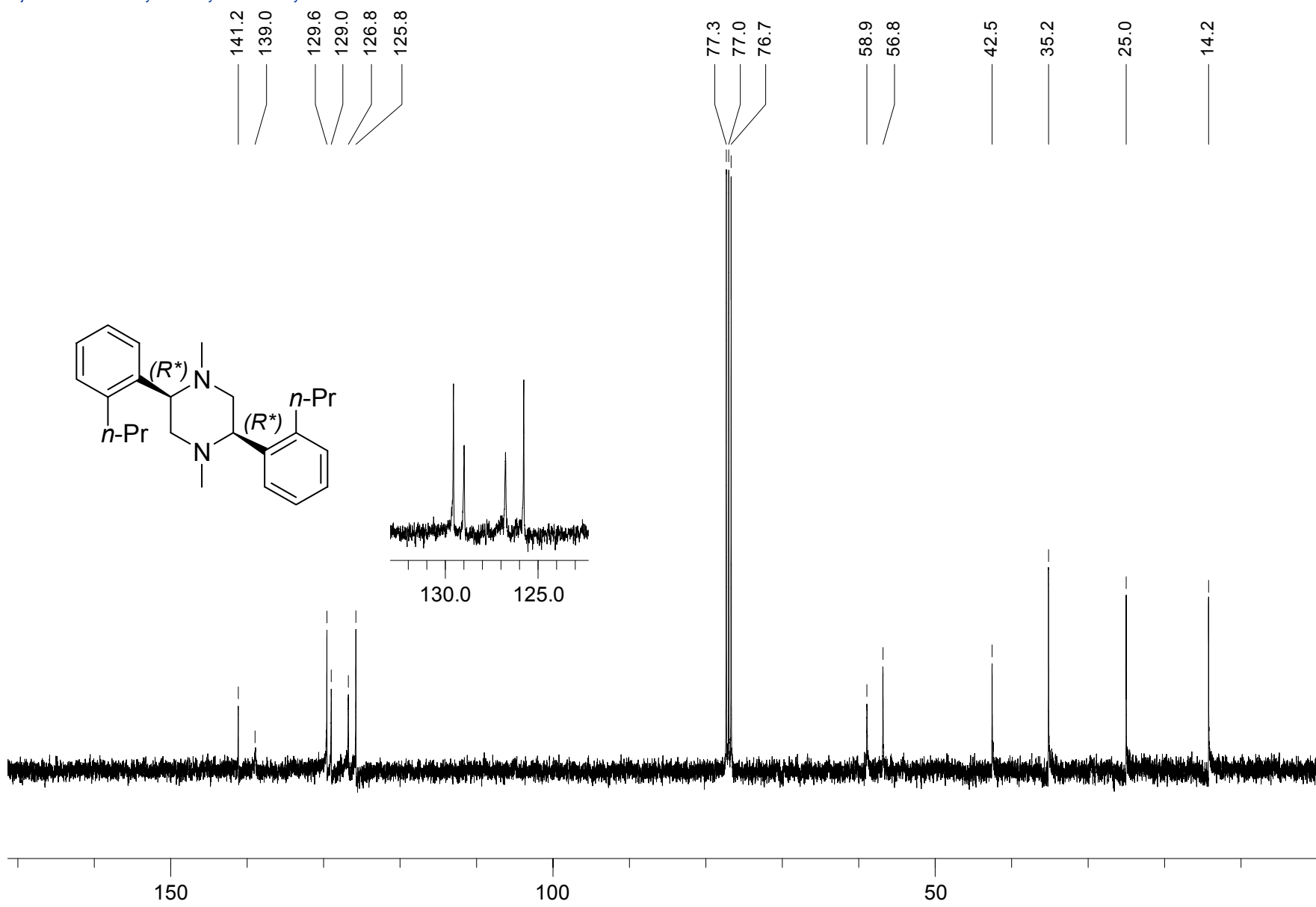
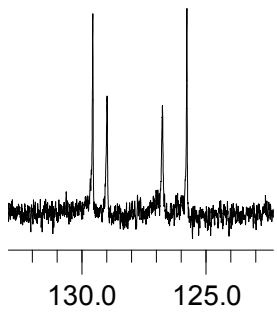
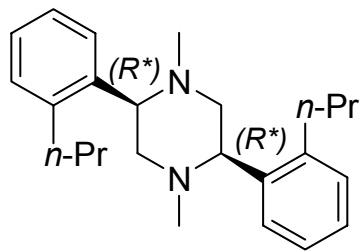






141.2
139.0
129.6
129.0
126.8
125.8

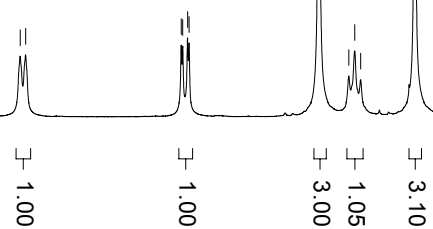
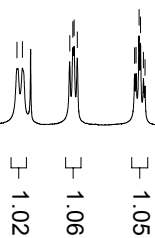
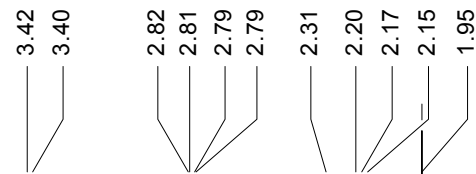
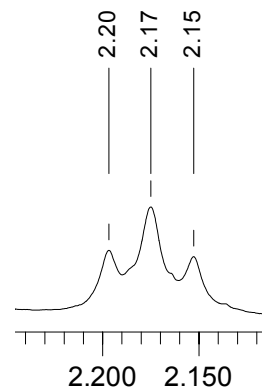
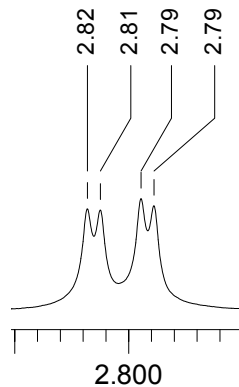
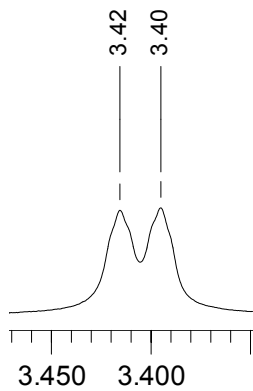
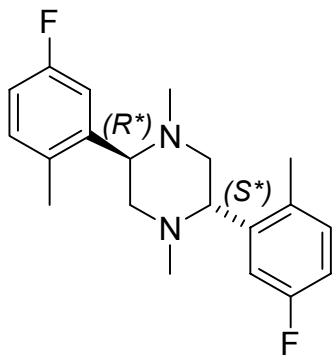
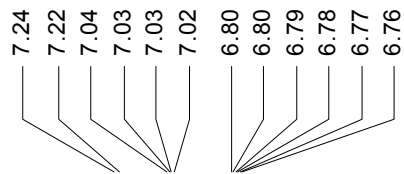
77.3
77.0
76.7
58.9
56.8
42.5
35.2
25.0
14.2



150

100

50



7.0

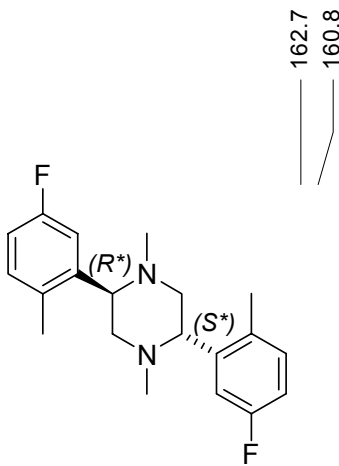
6.0

5.0

4.0

3.0

2.0



162.7
160.8

141.3
141.3

131.5
131.5
131.3

114.2
114.0
113.7
113.6

77.3
77.0
76.7

64.1
62.8

42.9

18.9

