Supporting Information

Diastereoselective Synthesis of Bicyclic γ-Lactams via Ring Expansion of Monocylic β-Lactams

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(*E*)-*N*-(2-Methylpropylidene)-3-(trimethylsilyloxy)propylamine 4b

Colorless liquid. Yield 74% (Purity: 96%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 0.11 (9H, s); 1.07 (6H, d, *J*= 6.9 Hz); 1.81 (2H, quint, *J*= 6.6 Hz); 2.34-2.47 (1H, m); 3.41 (2H, t, *J*= 6.6 Hz); 3.60 (2H, t, *J*= 6.6 Hz); 7.53 (1H, d, *J*= 5.2 Hz). ^{13}C NMR (75 MHz, ref = $CDCl_3$): δ -0.4 (CH_3); 19.5 (CH_3); 33.6 and 34.1 (CH_2 and CH); 57.6 (CH_2); 60.2 (CH_2); 170.2 (C). IR (NaCl, cm^{-1}): $\nu_{C=N}$ = 1671; ν_{max} = 2957, 2870, 1250, 1093, 866, 837, 746. MS (70eV): m/z (%) 202 (M^++1, 62); 148 (100).

(*E*)-*N*-(2-Methylpropylidene)-3-[(*tert*-butoxycarbonyl)amino]propylamine 14b

Colorless liquid. Yield 95% (Purity: 95%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.07 (6H, d, *J*= 6.9 Hz); 1.44 (9H, s); 1.76 (2H, quint, *J*= 6.6 Hz); 2.36-2.46 (1H, m); 3.17-3.23 (2H, m); 3.41 (2H, t, *J*= 6.6 Hz); 5.05 (1H, broad s); 7.54 (1H, d, *J*= 4.4 Hz). ^{13}C NMR (75 MHz, ref = $CDCl_3$): δ 19.2 (CH_3); 28.4 (CH_3); 30.8 (CH_2); 33.9 (CH); 39.2 (CH_2); 59.3 (CH_2); 77.6 (C); 156.0 (C); 170.2 (C). IR (NaCl, cm^{-1}): ν_{NH} = 3340; $\nu_{C=O}$ = 1692; $\nu_{C=N}$ = 1672; ν_{max} = 2967, 2871, 1519, 1364, 1271, 1250, 1168. MS (70 eV): m/z (%) 229 (M^++1, 100); 175 (85).

(*E*)-*N*-(2-Chloro-2-methylpropylidene)-3-(trimethylsilyloxy)propylamine 5b

Colorless liquid. Yield 97% (Purity: 92%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 0.11 (9H, s); 1.70 (6H, s); 1.83 (2H, quint, *J*= 6.6 Hz); 3.51 (2H, t x d, *J*= 6.6, 1.3 Hz); 3.61 (2H, t, *J*= 6.6 Hz); 7.70 (1H, t, *J*= 1.3 Hz). ^{13}C NMR (75 MHz, ref = $CDCl_3$): δ -0.4 (CH_3); 29.4 (CH_3); 33.3 (2 x CH_2); 56.6 (CH_2); 59.6 (CH_2); 68.0 (C); 165.4 (C). IR (NaCl, cm^{-1}): $\nu_{C=N}$ = 1669; ν_{max} = 2955, 2866, 1250, 1094, 865, 838, 747. MS (70eV): m/z (%) 236/8 (M^++1, 21); 148 (100).

(*E*)-*N*-(2-Chloro-2-methylpropylidene)-3-[(*tert*-butoxycarbonyl)amino]propylamine 15b

Light-yellow liquid. Yield 95% (Purity: 90%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.43 (9H, s); 1.70 (6H, s); 1.79 (2H, quint, *J*= 6.5 Hz); 3.19-3.25 (2H, m); 3.51 (2H, t, *J*= 6.5 Hz); 5.07 (1H, broad s); 7.69 (1H, s). ^{13}C NMR (75 MHz, ref = $CDCl_3$): δ 28.5 (CH_3); 29.3 (CH_3); 30.7 (CH_2); 39.3 (CH_2); 58.5 (CH_2); 68.0 (C); 79.0 (C); 156.0 (C); 165.4 (C). IR (NaCl, cm^{-1}): ν_{NH} = 3354; $\nu_{C=O}$ and $\nu_{C=N}$ = 1693; ν_{max} = 2976, 1515, 1366, 1271, 1250, 1168, 785. MS (70eV): m/z (%) 263/5 (M^++1, 100).

***cis*-3-Benzyloxy-4-(1-chloro-1-methylethyl)-1-(2-hydroxyethyl)azetidin-2-one 6b**

White crystals. Mp 99.7°C. R_f = 0.16 (hexane/EtOAc 1/1). Yield 65% (crude 87%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.72 and 1.75 (2 x 3H, 2 x s); 3.36-3.44 (1H, m); 3.68-3.76 (1H, m); 3.87-3.90 (2H, m); 4.09 (1H, d, *J*= 5.3 Hz); 4.68 (1H, d, *J*= 11.6 Hz); 4.69 (1H, d, *J*= 5.3 Hz); 4.92 (1H, d, *J*= 11.6 Hz); 7.28-7.39 (5H, m). ^{13}C NMR (75 MHz, ref = $CDCl_3$): δ 27.6 and 29.4 (2 x CH_3); 47.6 (CH_2); 59.9 (CH_2); 67.8 (CH); 71.6 (C); 73.4 (CH_2); 80.6 (CH); 127.9, 128.2 and 128.6 (5 x CH); 136.7 (C); 169.5 (C). IR (KBr, cm^{-1}): ν_{OH} = 3334; $\nu_{C=O}$ = 1717; ν_{max} = 2935, 1432, 1340, 1162, 1066, 748, 697. MS (70eV): m/z (%) 298/300 (M^++1, 100). Anal. Calcd for $C_{15}H_{20}ClNO_3$: C 60.50, H 6.77, N 4.70. Found: C 60.74, H 7.01, N 4.44.

***cis*-4-(1-Chloro-1-methylethyl)-1-(2-hydroxyethyl)-3-methoxyazetidin-2-one 6c**

White crystals. Mp 76.4 °C. R_f = 0.19 (hexane/EtOAc 1/1). Yield 55% (crude 81%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.69 and 1.71 (2 x 3H, 2 x s); 3.36-3.46 (1H, m); 3.56 (3H, s); 3.67-3.75 (1H, m); 3.89 (2H, t, *J*= 5.0 Hz); 4.08 (1H, d, *J*= 5.1 Hz); 4.49 (1H, d, *J*= 5.1 Hz). ^{13}C NMR (75 MHz, ref = $CDCl_3$): δ 27.5 and 29.3 (2 x CH_3); 47.2 (CH_2); 59.7 (CH_2 and CH_3); 67.8 (CH); 71.6 (C); 83.2 (CH); 169.6 (C). IR (KBr, cm^{-1}): ν_{OH} = 3340; $\nu_{C=O}$ = 1717; ν_{max} = 2932, 1424, 1362, 1204, 1124, 1067, 825, 696. MS (70eV): m/z (%) 222/4 (M^++1, 100). Anal. Calcd for $C_9H_{16}ClNO_3$: C 48.76, H 7.27, N 6.32. Found: C 49.03, H 7.51, N 6.17.

***cis*-4-(1-Chloro-1-methylethyl)-1-(3-hydroxypropyl)-3-phenoxyazetidin-2-one 6d**

White crystals. Mp. 54.1°C. R_f = 0.19 (hexane/EtOAc 1/1). Yield 53% (crude 85%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.77 and 1.83 (2 x 3H, 2 x s); 1.88-1.97 (2H, m); 2.56 (1H, broad s); 3.58-3.80 (4H, m); 4.27 (1H, d, *J*= 5.3 Hz); 5.25 (1H, d, *J*= 5.3 Hz); 7.02-7.11 and 7.28-7.34 (3H and 2H, 2 x m). ^{13}C NMR (75 MHz, ref = $CDCl_3$): δ 27.5 and 29.7 (2 x CH_3); 30.2 (CH_2); 39.0 (CH_2); 59.7 (CH_2); 67.9 (CH); 71.3 (Cl); 80.7 (CH); 116.0 (2 x CH); 122.9 (CH); 129.8

(2 x CH); 157.5 (C); 168.1 (C). IR (KBr, cm^{-1}): ν_{OH} = 3325; $\nu_{C=O}$ = 1743; ν_{max} = 2932, 1598, 1588, 1496, 1417, 1234, 1108, 1053, 748, 691. MS (70eV): m/z (%) 298/300 (M^++1, 100). Anal. Calcd for $C_{15}H_{20}ClNO_3$: C 60.50, H 6.77, N 4.70. Found: C 60.64, H 6.92, N 4.62.

***cis*-3-Benzyloxy-4-(1-chloro-1-methylethyl)-1-(3-hydroxypropyl)azetidin-2-one 6e**

Yellow oil. R_f = 0.07 (hexane/EtOAc 3/1). Yield 61% (crude 84%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.71 and 1.74 (2 x 3H, 2 x s); 1.78-1.95 (2H, m); 2.76 (1H, s); 3.50-3.76 (4H, m); 4.08 (1H, d, *J*= 5.2 Hz); 4.67 (2 x 1H, 2 x d, *J*= 11.7, 5.2 Hz); 4.91 (1H, d, *J*= 11.7 Hz); 7.28-7.39 (5H, m). ^{13}C NMR (75 MHz, ref = $CDCl_3$): δ 27.7 and 29.4 (2 x CH_3); 30.2 (CH_2); 38. (CH_2); 59.5 (CH_2); 67.8 (CH); 71.6 (C); 73.4 (CH_2); 81.1 (CH); 127.8, 128.2 and 128.6 (5 x CH); 136.8 (C); 169.7 (C). IR (NaCl, cm^{-1}): ν_{OH} = 3420; $\nu_{C=O}$ = 1738; ν_{max} = 2918, 2850, 1455, 1346, 1215, 1173, 1113, 1057, 738, 698. MS (70eV): m/z (%) 312/4 (M^++1, 100). Anal. Calcd for $C_{16}H_{22}ClNO_3$: C 61.63, H 7.11, N 4.49. Found: C 61.88, H 7.30, N 4.35.

***cis*-4-(1-Chloro-1-methylethyl)-1-(3-hydroxypropyl)-3-methoxyazetidin-2-one 6f**

Light-yellow oil. R_f = 0.12 (hexane/EtOAc 1/1). Yield 51% (crude 86%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.68 and 1.70 (2 x 3H, 2 x s); 1.79-1.93 (2H, m); 2.65 (1H, broad s); 3.48-3.76 (4H, m); 3.56 (3H, s); 4.07 (1H, d, *J*= 5.3 Hz); 4.48 (1H, d, *J*= 5.3 Hz). ^{13}C NMR (75 MHz, ref = $CDCl_3$): δ 27.6 and 29.3 (2 x CH_3); 30.2 (CH_2); 38.4 (CH_2); 59.5 and 59.7 (CH_2 and CH_3); 67.9 (CH); 71.6 (C); 83.7 (CH); 169.8 (C). IR (NaCl, cm^{-1}): ν_{OH} = 3429; $\nu_{C=O}$ = 1738; ν_{max} = 2937, 1448, 1366, 1220, 1114, 1059, 915, 730. MS (70eV): m/z (%) 236/8 (M^++1, 100). Anal. Calcd for $C_{10}H_{18}ClNO_3$: C 50.96, H 7.70, N 5.94. Found: C 51.17, H 7.87, N 5.78.

***cis*-3-Benzyloxy-4-(1-chloro-1-methylethyl)-1-{2-[(*tert*-butoxycarbonyl)amino]ethyl}-azetidin-2-one 16b**

White crystals. Mp 81.2 °C. R_f = 0.09 (hexane/EtOAc 4/1). Yield 71%. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.41 (9H, s); 1.71 and 1.73 (2 x 3H, 2 x s); 3.12-3.17, 3.37-3.43 and 3.56-3.73 (1H, 1H and 2H, 3 x m); 4.29 (1H, d, *J*= 5.5 Hz); 4.59 (1H, d, *J*= 5.5 Hz); 4.65 (1H, s, *J*= 11.6 Hz); 4.89 (1H, s, *J*= 11.6 Hz); 4.93 (1H, broad s); 7.27-7.38 (5H, m). ^{13}C NMR (75 MHz, ref = $CDCl_3$): δ 27.6 and 29.5 (2 x CH_3); 28.5 (CH_3); 37.8 and 42.7 (2 x CH_2); 66.6 (CH); 72.0 (C); 73.4 (CH_2); 79.5 (C); 81.3 (CH); 127.8, 128.1 and 128.6 (5 x CH); 136.9 (C); 156.2 (C); 169.3 (C). IR (KBr, cm^{-1}): ν_{NH} = 3356; $\nu_{NC=O}$ = 1751; $\nu_{NHC=O}$ = 1705; ν_{max} = 2978, 1514, 1365, 1249, 1166, 1056, 737, 697. MS (70eV): m/z (%) no M^+; 297/9 (100). Anal. Calcd for $C_{20}H_{29}ClN_2O_4$: C 60.52, H 7.36, N 7.06. Found: C 60.89, H 7.69, N 7.11.

***cis*-4-(1-Chloro-1-methylethyl)-3-methoxy-1-{2-[(*tert*-butoxycarbonyl)amino]ethyl}-azetidin-2-one 16c**

White crystals. Mp 67.5 °C. R_f = 0.17 (hexane/EtOAc 4/1). Yield 65%. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.45 (9H, s); 1.68 (6H, s); 3.14-3.18, 3.36-3.42 and 3.55-3.72 (1H, 1H and 2H, 3 x m); 3.53 (3H, s); 4.27 (1H, d, *J*= 5.3 Hz); 4.39 (1H, d, *J*= 5.3 Hz); 4.96 (1H, broad s). ^{13}C NMR (75 MHz, ref = $CDCl_3$): δ 27.5 and 29.4 (2 x CH_3); 28.5 (CH_3); 37.9 and 42.7 (2 x CH_2); 59.8 (CH_3); 66.8 (CH); 72.0 (C); 79.5 (C); 83.9 (CH); 156.2 (C); 169.3 (C). IR (KBr, cm^{-1}): ν_{NH} = 3356; $\nu_{NC=O}$ = 1751; $\nu_{NHC=O}$ = 1706; ν_{max} = 2978, 1516, 1365, 1247, 1166, 1062. MS (70eV): m/z (%) no M^+; 221/3 (100). Anal. Calcd for $C_{14}H_{25}ClN_2O_4$: C 52.41, H 7.85, N 8.73. Found: C 52.82, H 8.11, N 8. 61.

***cis*-4-(1-Chloro-1-methylethyl)-3-phenoxy-1-{3-[(*tert*-butoxycarbonyl)amino]propyl}-azetidin-2-one 16d**

Light-yellow oil. R_f = 0.15 (hexane/EtOAc 2/1). Yield 78%. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.44 (9H, s); 1.76 and 1.81 (2 x 3H, 2 x s); 1.84-1.99 (2H, m); 3.09-3.27, 3.44-3.53 and 3.60-3.69 (2H, 1H and 1H, 3 x m); 4.26 (1H, d, *J*= 5.2 Hz); 5.03 (1H, broad s); 5.26 (1H, d, *J*= 5.2 Hz); 7.01-7.10 and 7.27-7.34 (3H and 2H, 2 x m). ^{13}C NMR (75 MHz, ref = $CDCl_3$): δ 27.4 (CH_3); 27.5 (CH_2); 28.5 (CH_3); 29.7 (CH_3); 37.8 and 39.3 (2 x CH_2); 67.4 (CH); 71.4 (C); 79.3 (C); 80.7 (CH); 116.0 (2 x CH); 122.8 (CH); 129.8 (2 x CH); 156.1 (C); 157.6 (C); 167.5 (C). IR (NaCl, cm^{-1}): ν_{NH} = 3361; $\nu_{NC=O}$ = 1755; $\nu_{NHC=O}$ = 1698; ν_{max} = 2977, 1495, 1365, 1233, 1168, 1110, 752, 732, 690. MS (70eV): m/z (%) no M^+; 341/3 (100), 297/9 (45). Anal. Calcd for $C_{20}H_{29}ClN_2O_4$: C 60.52, H 7.36, N 7.06. Found: C 60.74, H 7.57, N 6.91.

***cis*-3-Benzyloxy-4-(1-chloro-1-methylethyl)-1-{3-[(*tert*-butoxycarbonyl)amino]propyl}-azetidin-2-one 16e**

Yellow oil. R_f = 0.24 (hexane/EtOAc 2/1). Yield 62%. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.43 (9H, s); 1.70 and 1.73 (2 x 3H, 2 x s); 1.76-1.91 (2H, m); 3.02-3.27, 3.36-3.45 and 3.54-3.63 (2H, 1H and 1H, 3 x m); 4.07 (1H, d, *J*= 5.2 Hz); 4.66 (1H, d, *J*= 5.2 Hz); 4.67 and 4.91 (2 x 1H, 2 x d, *J*= 11.7 Hz); 4.97 (1H, broad s); 7.28-7.36 (5H, m). ^{13}C NMR (75 MHz, ref = $CDCl_3$): δ 27.6 (CH_3 and CH_2); 28.5 (CH_3); 29.4 (CH_3); 37.8 and 38.9 (2 x CH_2); 67.3 (CH); 71.7 (C); 73.4 (CH_2); 79.3 (C); 80.7 (CH); 127.8, 128.2 and 128.6 (5 x CH); 136.8 (C), 156.0 (C); 169.0 (C). IR (NaCl, cm^{-1}): ν_{NH} = 3358; $\nu_{NC=O}$ = 1752; $\nu_{NHC=O}$ = 1697; ν_{max} = 2923, 1366, 1249, 1165, 1113, 738, 698. MS (70eV): m/z 411/3 (M^++1, 39); 220 (100). Anal. Calcd for $C_{21}H_{31}ClN_2O_4$: C 61.38, H 7.60, N 6.82. Found: C 61.53, H 7.92, N 6.68.

***cis*-4-(1-Chloro-1-methylethyl)-3-methoxy-1-{3-[(*tert*-butoxycarbonyl)amino]propyl}-azetidin-2-one 16f**

Light-yellow oil. R_f = 0.16 (hexane/EtOAc 2/1). Yield 71%. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.44 (9H, s); 1.67 and 1.68 (2 x 3H, 2 x s); 1.74-1.88 (2H, m); 3.03-3.27, 3.31-3.49 and 3.52-3.62 (2H, 1H and 1H, 3 x m); 3.55 (3H, s); 4.06 (1H, d, *J*= 5.0 Hz); 4.47 (1H, d, *J*= 5.0 Hz); 4.99 (1H, broad s). ^{13}C NMR (75 MHz, ref = $CDCl_3$): δ 27.5 (CH_3 and CH_2); 28.5 (CH_3); 29.3 (CH_3); 37.7 and 38.8 (2 x CH_2); 59.7 (CH_3); 67.3 (CH); 71.7 (C); 79.3 (C); 83.7 (CH); 156.0 (C); 169.0 (C). IR (NaCl, cm^{-1}): ν_{NH} = 3358; $\nu_{NC=O}$ = 1750; $\nu_{NHC=O}$ = 1702; ν_{max} = 2934, 1514, 1365, 1249, 1169, 1112. MS (70eV): m/z (%) no M^+; 279/81 (100). Anal. Calcd for $C_{15}H_{27}ClN_2O_4$: C 53.81, H 8.13, N 8.37. Found: C 53.99, H 8.37, N 8.24.

***trans*-1-Aza-4-oxa-7-benzyloxy-6,6-dimethylbicyclo[3.3.0]octan-8-one 7b**

Colorless oil. Yield 46%. R_f = 0.29 (hexane/EtOAc 2/1). ^{1}H NMR (300 MHz, $CDCl_3$): δ 0.94 and 1.24 (2 × 3H, 2 × s); 3.17 (1H, d × d × d, *J*= 10.9 Hz, 7.2 Hz, 6.1 Hz); 3.60 (1H, s); 3.79 (1H, d × d × d, *J*= 10.9 Hz, 7.4 Hz, 6.2 Hz); 3.97-4.11 (2H, m); 4.61 and 4.86 (2 × 1H, 2 × s, *J*= 12.4 Hz); 4.96 (1H, s); 7.27-7.36 (5H, m). ^{13}C NMR (75 MHz, ref = $CDCl_3$): δ 19.8 and 19.8 (2 x CH_3); 41.5 (CH_2); 42.8 (CH_3); 68.2 (CH_2); 72.4 (CH_2); 88.4 (CH); 97.9 (CH); 127.8 and 128.5 (5 × CH); 137.9 (C); 175.1 (C). IR (NaCl, cm^{-1}): $\nu_{C=O}$ = 1708, ν_{max}= 2962, 2888, 1417, 1110, 1069, 736, 698. MS (70eV) m/z (%): 262 (M^++1, 100). Anal. Calcd for $C_{15}H_{19}NO_3$: C 68.94; H 7.33; N 5.36. Found: C 69.07; H 7.54; N 5.21.

***cis*-1-Aza-4-oxa-7-benzyloxy-6,6-dimethylbicyclo[3.3.0]octan-8-one 8b**

Colorless oil. Yield 18%. R_f = 0.19 (hexane/EtOAc 2/1). ^{1}H NMR (300 MHz, $CDCl_3$): δ 0.89 and 1.19 (2 × 3H, 2 × s); 3.04-3.12 and 3.79-3.86 (2 × 1H, 2 × m); 3.91-3.99 (2H, m); 3.96 (1H, s); 4.71 (1H, s); 4.72 and 5.08 (2 × 1H, 2 × s, *J*= 12.4 Hz); 7.27-7.40 (5H, m). ^{13}C NMR

(75 MHz, ref = $CDCl_3$): δ 14.80 and 23.78 (2 x CH_3); 41.0 (CH_2); 46.5 (C); 67.0 (CH_2); 73.0 (CH_2); 84.4 (CH); 94.8 (CH); 127.9, 128.0 and 128.4 (5 × CH); 138.0 (C); 174.0 (C). IR (NaCl, cm^{-1}): $\nu_{C=O}$ = 1715, ν_{max}= 2966, 2877, 1422, 1103, 1065, 736, 699. MS (70eV) m/z (%): 262 (M^++1, 100). Anal. Calcd for $C_{15}H_{19}NO_3$: C 68.94; H 7.33; N 5.36. Found: C 69.16; H 7.62; N 5.11.

***trans*-1-Aza-4-oxa-7-methoxy-6,6-dimethylbicyclo[3.3.0]octan-8-one 7c**

Colorless oil. Yield 45 %. R_f = 0.20 (hexane/EtOAc 2/1). ^1H NMR (300 MHz, $CDCl_3$): δ 0.84 and 1.33 (2 × 3H, 2 × s); 3.08-3.16 (1H, m); 3.65 (3H, s); 3.82 (1H, s); 3.82-3.89 (1H, m); 3.95-4.03 (2H, m); 4.78 (1H, s). ^{13}C NMR (75 MHz, ref = $CDCl_3$): δ 19.5 and 19.9 (2 x CH_3); 41.5 (CH_2); 42.7 (C); 58.9 (CH_3); 68.1 (CH_2); 90.8 (CH); 97.9 (CH); 175.0 (C). IR (NaCl, cm^{-1}): $\nu_{C=O}$ = 1714, ν_{max}= 2963, 1464, 1420, 1134, 1067, 971, 792. MS (70eV) m/z (%): 186 (M^++1, 100). Anal. Calcd for $C_9H_{15}NO_3$: C 58.36; H 8.16; N 7.56. Found: C 58.57; H 8.40; N 7.38.

***cis*-1-Aza-4-oxa-7-methoxy-6,6-dimethylbicyclo[3.3.0]octan-8-one 8c**

Colorless oil. Yield 17%. R_f = 0.12 (hexane/EtOAc 2/1). ^1H NMR (300 MHz, $CDCl_3$): δ 0.98 and 1.19 (2 × 3H, 2 × s); 3.17 (1H, d × d × d, *J*= 10.7 Hz, 7.4 Hz, 6.1 Hz); 3.40 (1H, s); 3.53 (3H, s); 3.79 (1H, d × d × d, *J*= 10.7 Hz, 7.4 Hz, 6.1 Hz); 4.01-4.08 (2H, m); 4.91 (1H, s). ^{13}C NMR (75 MHz, ref = $CDCl_3$): δ 14.5 and 24.2 (2 x CH_3); 41.0 (CH_2); 46.6 (C); 60.2 (CH_3); 67.0 (CH_2); 87.8 (CH); 94.8 (CH); 173.8 (C). IR (NaCl, cm^{-1}): $\nu_{C=O}$ = 1710, ν_{max}= 2918, 1465, 1416, 1101, 1071, 978, 780. MS (70eV) m/z (%): 186 (M^++1, 100). Anal. Calcd for $C_9H_{15}NO_3$: C 58.36; H 8.16; N 7.56. Found: C 58.64; H 8.49; N 7.27.

***trans*-1-Aza-5-oxa-8-benzyloxy-7,7-dimethylbicyclo[4.3.0]nonan-9-one 9b**

Colorless oil. R_f = 0.24 (hexane/EtOAc 2/1). Yield 41%. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.05 and 1.11 (2 x 3H, 2 x s); 1.42-1.50 and 1.67-1.83 (2 x 1H, 2 x m); 2.99 (1H, t x d, *J*= 12.8, 3.9 Hz); 3.64 (1H, t x d, *J*= 12.1, 2.1 Hz); 3.75 (1H, s); 4.07-4.20 (2H, m); 4.42 (1H, s); 4.77 (1H, d, *J*= 12.1 Hz); 5.06 (1H, d, *J*= 12.1 Hz); 7.28-7.40 (5H, m). ^{13}C NMR (75 MHz, ref = $CDCl_3$): δ 20.6 and 20.7 (2 x CH_3); 24.7 (CH_2); 39.1 (CH_2); 40.6 (C); 67.2 (CH_2); 73.0 (CH_2); 82.8 (CH); 92.7 (CH); 127.7, 127.9 and 128.4 (5 x CH); 138.3 (C); 172.7 (C). IR (NaCl, cm^{-1}): $\nu_{C=O}$ = 1702; ν_{max} = 2964, 2870, 1454, 1432, 1263, 1058, 915, 734, 698. MS (70 eV): m/z (%) 276 (M^++1, 100). Anal. Calcd for $C_{16}H_{21}NO_3$: C 69.79; H 7.69; N 5.09. Found: C 69.94; H 7.89; N 4.90.

***cis*-1-Aza-5-oxa-8-benzyloxy-7,7-dimethylbicyclo[4.3.0]nonan-9-one 10b**

Colorless oil. R_f = 0.12 (hexane/EtOAc 2/1). Yield 21%. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.03 and 1.10 (2 x 3H, 2 x s); 1.50-1.57 and 1.77-1.94 (2 x 1H, 2 x m); 2.92 (1H, t x d, *J*= 12.8, 4.0 Hz); 3.57 (1H, d, *J*= 1.1 Hz); 3.63 (1H, t x d, *J*= 12.2, 2.0 Hz); 4.13-4.19 (2H, m); 4.35 (1H, s); 4.82 (1H, d, *J*= 12.1 Hz); 5.08 (1H, d, *J*= 12.1 Hz); 7.28-7.41 (5H, m). ^{13}C NMR (75 MHz, ref = $CDCl_3$): δ 15.9 and 25.1 (2 x CH_3); 24.4 (CH_2); 38.1 (CH_2); 41.4 (C); 67.0 (CH_2); 72.9 (CH_2); 82.0 (CH); 91.6 (CH); 127.7, 128.0 and 128.4 (5 x CH); 138.2 (C); 171.4 (C). IR (NaCl, cm^{-1}): $\nu_{C=O}$ = 1701; ν_{max} = 2961, 2855, 1454, 1444, 1270, 1081, 738, 698. MS (70 eV): m/z (%) 276 (M^++1, 100). Anal. Calcd for $C_{16}H_{21}NO_3$: C 69.79; H 7.69; N 5.09. Found: C 70.00; H 7.91; N 4.87.

***trans*-1-Aza-5-oxa-8-methoxy-7,7-dimethylbicyclo[4.3.0]nonan-9-one 9c**

White crystals. Mp. 68°C. R_f = 0.37 (hexane/EtOAc 1/1). Yield 38%. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.05 and 1.15 (2 x 3H, 2 x s); 1.43-1.49 and 1.67-1.83 (2 x 1H, 2 x m); 2.99 (1H, t x

d, *J*= 12.9, 3.8 Hz); 3.58 (1H, s); 3.61-3.70 (1H, m); 3.64 (3H, s); 4.09-4.20 (2H, m); 4.38 (1H, s). ^{13}C NMR (75 MHz, ref = $CDCl_3$): δ 20.4 and 20.9 (2 x CH_3); 24.8 (CH_2); 39.2 (CH_2); 40.5 (C); 60.1 (CH_3); 67.3 (CH_2); 85.7 (CH); 92.67 (CH); 172.4 (C). IR (KBr, cm^{-1}): $\nu_{C=O}$ = 1693; ν_{max} = 2985, 2856, 1459, 1435, 1264, 1132, 1057, 1005, 913, 759. MS (70 eV): m/z (%) 200 (M^++1, 100). Anal. Calcd for $C_{10}H_{17}NO_3$: C 60.28; H 8.60; N 7.03. Found: C 60.44; H 8.81; N 6.87.

***cis*-1-Aza-5-oxa-8-methoxy-7,7-dimethylbicyclo[4.3.0]nonan-9-one 10c**

Light-yellow oil. R_f = 0.15 (hexane/EtOAc 1/1). Yield 20%. ^{1}H NMR (300 MHz, $CDCl_3$): δ 0.99 and 1.21 (2 x 3H, 2 x s); 1.50-1.56 and 1.72-1.93 (2 x 1H, 2 x m); 2.89-2.99 (1H, m); 3.39 (1H, d, *J*= 1.1 Hz); 3.56-3.68 (1H, m); 3.65 (3H, s); 4.13-4.19 (2H, m); 4.36 (1H, s). ^{13}C NMR (75 MHz, ref = $CDCl_3$): δ 15.5 and 25.6 (2 x CH_3); 24.4 (CH_2); 38.2 (CH_2); 41.3 (C); 60.2 (CH_3); 67.1 (CH_2); 85.5 (CH); 91.8 (CH); 171.1 (C). IR (NaCl, cm^{-1}): $\nu_{C=O}$ = 1694; ν_{max} = 2963, 2857, 1444, 1271, 1211, 1083, 1016, 773. MS (70 eV): m/z (%) 200 (M^++1, 100). Anal. Calcd for $C_{10}H_{17}NO_3$: C 60.28; H 8.60; N 7.03. Found: C 60.43; H 8.78; N 6.93.

***trans*-1,4-Diaza-7-benzyloxy-6,6-dimethyl-4-(*tert*-butoxycarbonyl)-bicyclo[3.3.0]octan-8-one 17b**

Light-yellow oil. Yield 57%. R_f = 0.14 (hexane/EtOAc 4/1). ^{1}H NMR (300 MHz, $CDCl_3$): δ 0.82 and 1.34 (2 × 3H, s and broad s); 1.49 (9H, s); 2.99-3.15 (2H, m); 3.49 (1H, s); 3.98-4.04 (2H, m); 4.62 and 4.81 (2 x 1H, 2 x s, *J*= 11.6 Hz); 5.23 (1H, s); 7.27-7.37 (5H, m). ^{13}C NMR (75 MHz, ref = $CDCl_3$): δ 19.6 and 20.3 (2 x CH_3); 28.5 (CH_3); 40.5 (CH_2); 45.6 and 46.2 (C and CH_2); 72.1 (CH_2); 80.8 (CH); 81.4 (C); 88.3 (CH); 127.8 and 128.4 (5 x CH); 137.8 (C); 153.6 (C); 173.1 (C). IR (NaCl, cm^{-1}): $\nu_{C=O}$= 1695, ν_{max}= 2975, 2931, 1390, 1367, 1165, 1128,

1088. MS (70eV) m/z (%): 361 (M^++1, 100). Anal. Calcd for $C_{20}H_{28}N_2O_4$: C 66.64; H 7.83; N 7.77. Found: C 66.79; H 8.01; N 7.64.

trans-1,4-Diaza-7-methoxy-6,6-dimethyl-4-(_tert_-butoxycarbonyl)-bicyclo[3.3.0]octan-8-one 17c

White crystals. Mp 98.6 °C. Yield 43%. R_f = 0.11 (hexane/EtOAc 3/1). ^{1}H NMR (300 MHz, $CDCl_3$): δ 0.75 and 1.20 (2 × 3H, s and broad s); 1.42 (9H, s); 2.96-3.08 (2H, m); 3.20 (1H, s); 3.42 (3H, s); 3.91-3.97 (2H, m); 5.10 (1H, s). ^{13}C NMR (75 MHz, $CDCl_3$): δ 19.6 and 20.0 (2 x CH_3); 28.4 (CH_3); 40.4 (CH_2); 45.6 (C); 46.1 (CH_2); 58.4 (CH_3); 80.7 (CH); 81.3 (C); 90.6 (CH); 153.6 (C); 173.8 (C). IR (KBr, cm^{-1}): $\nu_{C=O}$= 1711 and 1687, ν_{max}= 2974, 2930, 1378, 1369, 1164, 1098, 1088. MS (70eV) m/z (%): 285 (M^++1, 100). Anal. Calcd for $C_{14}H_{24}N_2O_4$: C 59.13; H 8.51; N 9.85. Found: C 59.24; H 8.63; N 9.49.

trans-1,5-Diaza-8-benzyloxy-7,7-dimethyl-5-(_tert_-butoxycarbonyl)-bicyclo[4.3.0]nonan-9-one 19b

White crystals. Mp 79.4°C. Yield 48%. R_f = 0.21 (hexane/EtOAc 2/1). ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.00 and 1.24 (2 x 3H, 2 x s); 1.49 (9H, s); 1.81-1.90 (2H, m); 2.63-2.72 and 2.87-2.97 (2 x 1H, 2 x m); 3.57 (1H, s); 4.01-4.20 (2H, m); 4.72 (1H, d, *J*= 12.1 Hz); 4.97 (1H, d, *J*= 12.1 Hz); 5.25 (1H, s); 7.25-7.39 (5H, m). ^{13}C NMR (75 MHz, ref = $CDCl_3$): δ 21.1 and 21.4 (2 x CH_3); 22.4 (CH_2); 28.5 (CH_3); 34.4 and 37.9 (2 x CH_2); 43.1 (C); 72.6 (CH_2); 76.2 (CH); 81.0 (C); 83.3 (CH); 127.7, 127.8 and 128.4 (5 x CH); 138.1 (C); 154.9 (C); 171.9 (C). IR (KBr, cm^{-1}): $\nu_{C=O}$= 1691, ν_{max}= 2973, 1382, 1366, 1164, 1111, 1068, 737, 698. MS (70eV) m/z (%): 375 (M^++1, 100). Anal. Calcd for $C_{21}H_{30}N_2O_4$: C 67.35; H 8.07; N 7.48. Found: C 67.02; H 8.47; N 7.34.

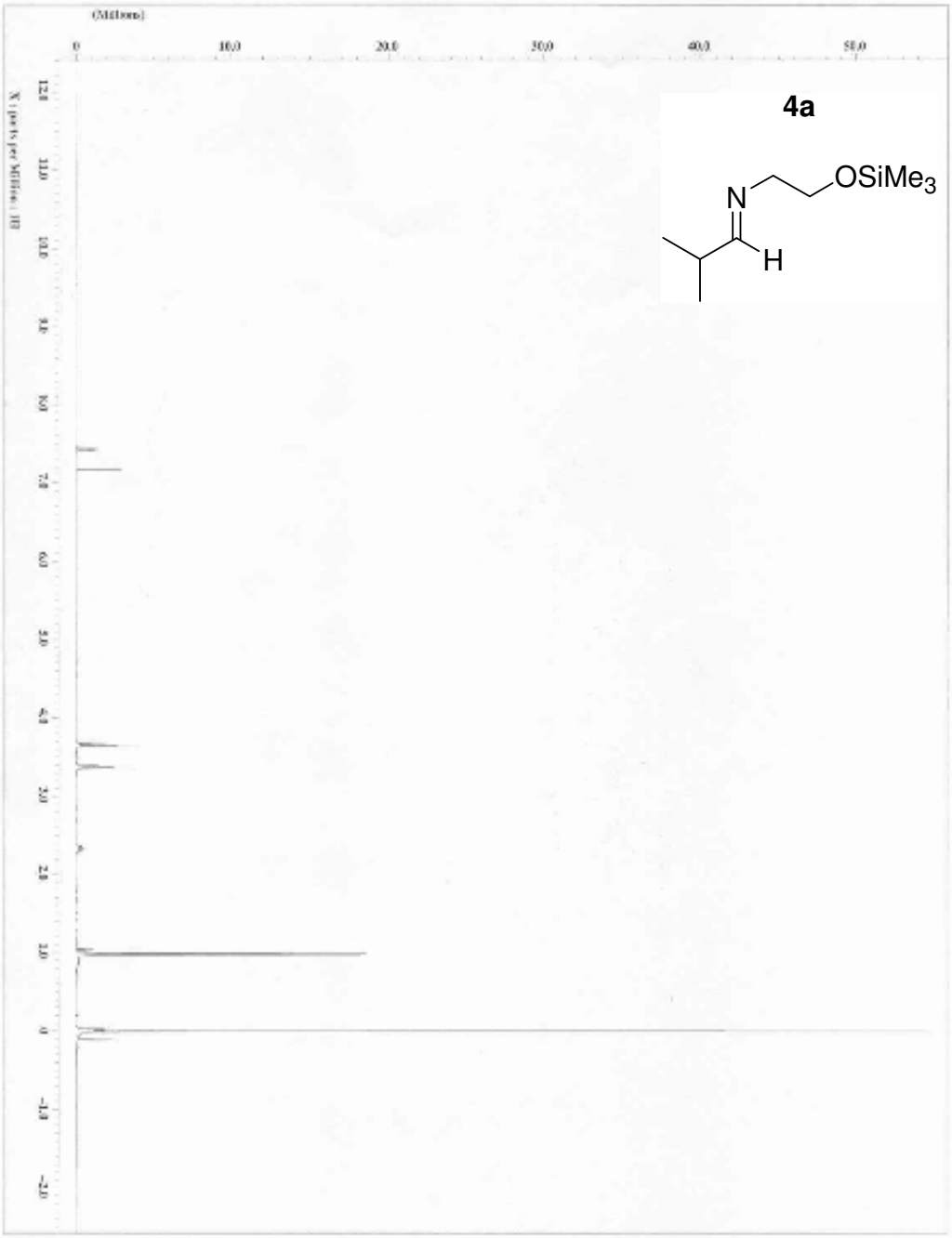
***trans*-1,5-Diaza-8-methoxy-7,7-dimethyl-5-(*tert*-butoxycarbonyl)-bicyclo[4.3.0]nonan-9-one 19c**

White crystals. Mp 75.8 °C. Yield 51%. R_f = 0.17 (hexane/EtOAc 2/1). ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.05 and 1.17 (2 x 3H, 2 x s); 1.49 (9H, s); 1.81-1.90 (2H, m); 2.63-2.73 and 2.86-2.96 (2 x 1H, 2 x m); 3.36 (1H, s); 3.55 (3H, s); 4.02-4.20 (2H, m); 5.19 (1H, s). ^{13}C NMR (75 MHz, ref = $CDCl_3$): δ 21.1 and 21.3 (2 x CH_3); 22.5 (CH_2); 28.5 (CH_3); 34.4 and 37.9 (2 x CH_2); 43.1 (C); 59.5 (CH_3); 76.2 (CH); 81.0 (C); 83.57 (CH); 154.9 (C); 171.7 (C). IR (KBr, cm^{-1}): $\nu_{C=O}$ = 1709 and 1686, ν_{max}= 2970, 1401, 1387, 1363, 1162, 1128, 1098, 1078. MS (70eV) m/z (%): 299 (M^++1, 100). Anal. Calcd for $C_{15}H_{26}N_2O_4$: C 60.38; H 8.78; N 9.39. Found: C 60.65; H 9.10; N 9.19.

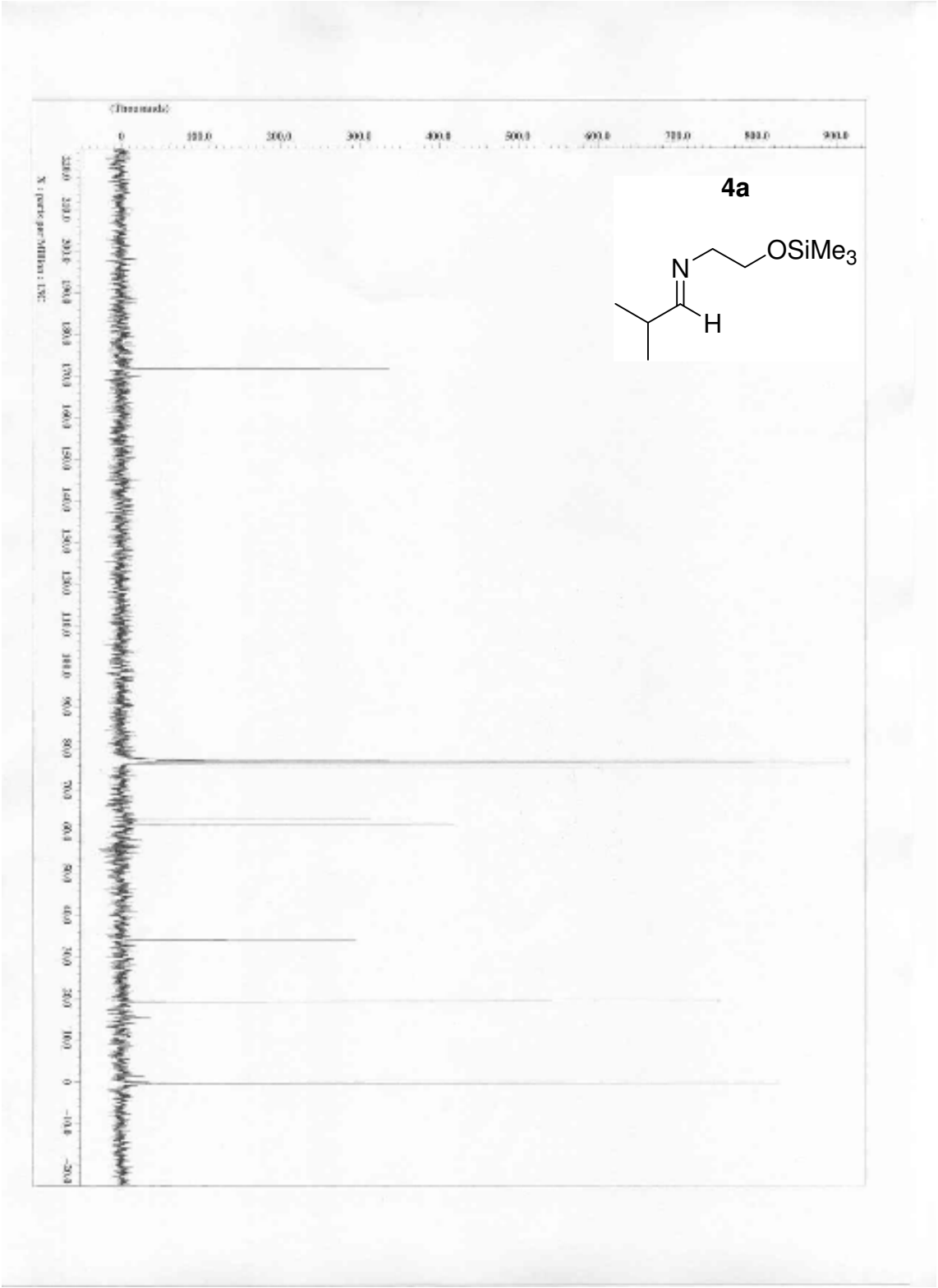
***cis*-1,5-Diaza-8-methoxy-7,7-dimethyl-5-(*tert*-butoxycarbonyl)-bicyclo[4.3.0]nonan-9-one 20c**

Colorless oil. Yield 12%. R_f = 0.10 (hexane/EtOAc 2/1). ^{1}H NMR (300 MHz, $CDCl_3$): δ 0.95 and 1.34 (2 x 3H, 2 x s); 1.49 (9H, s); 1.82-1.91 (2H, m); 2.80-2.90 (2H, m); 3.47 (1H, d, *J*= 1.1 Hz); 3.67 (3H, s); 3.97-4.09 and 4.12-4.19 (2 x 1H, 2 x m); 5.10 (1H, s). ^{13}C NMR (75 MHz, ref = $CDCl_3$): δ 15.9 and 26.5 (2 x CH_3); 22.5 (CH_2); 28.5 (CH_3); 34.1 and 37.6 (2 x CH_2); 44.9 (C); 60.4 (CH_3); 74.9 (CH); 80.9 (C); 85.5 (CH); 154.8 (C); 171.9 (C). IR (NaCl, cm^{-1}): $\nu_{C=O}$ = 1712 and 1687, ν_{max}= 2968, 1400, 1383, 1164, 1129, 1096, 1075. MS (70eV) m/z (%): 299 (M^++1, 100). Anal. Calcd for $C_{15}H_{26}N_2O_4$: C 60.38; H 8.78; N 9.39. Found: C 60.67; H 9.13; N 9.08.

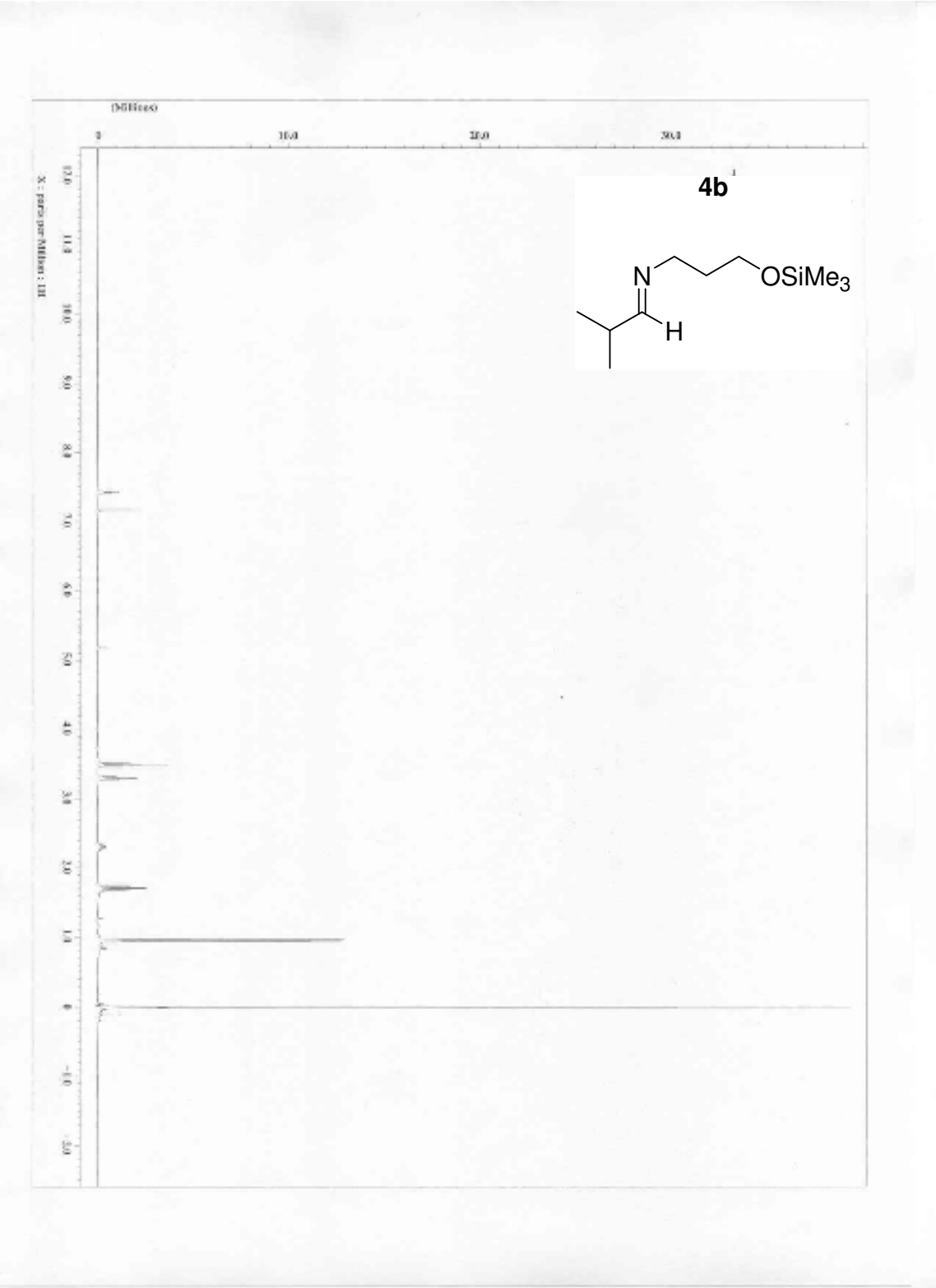
^{1}H NMR **4a**



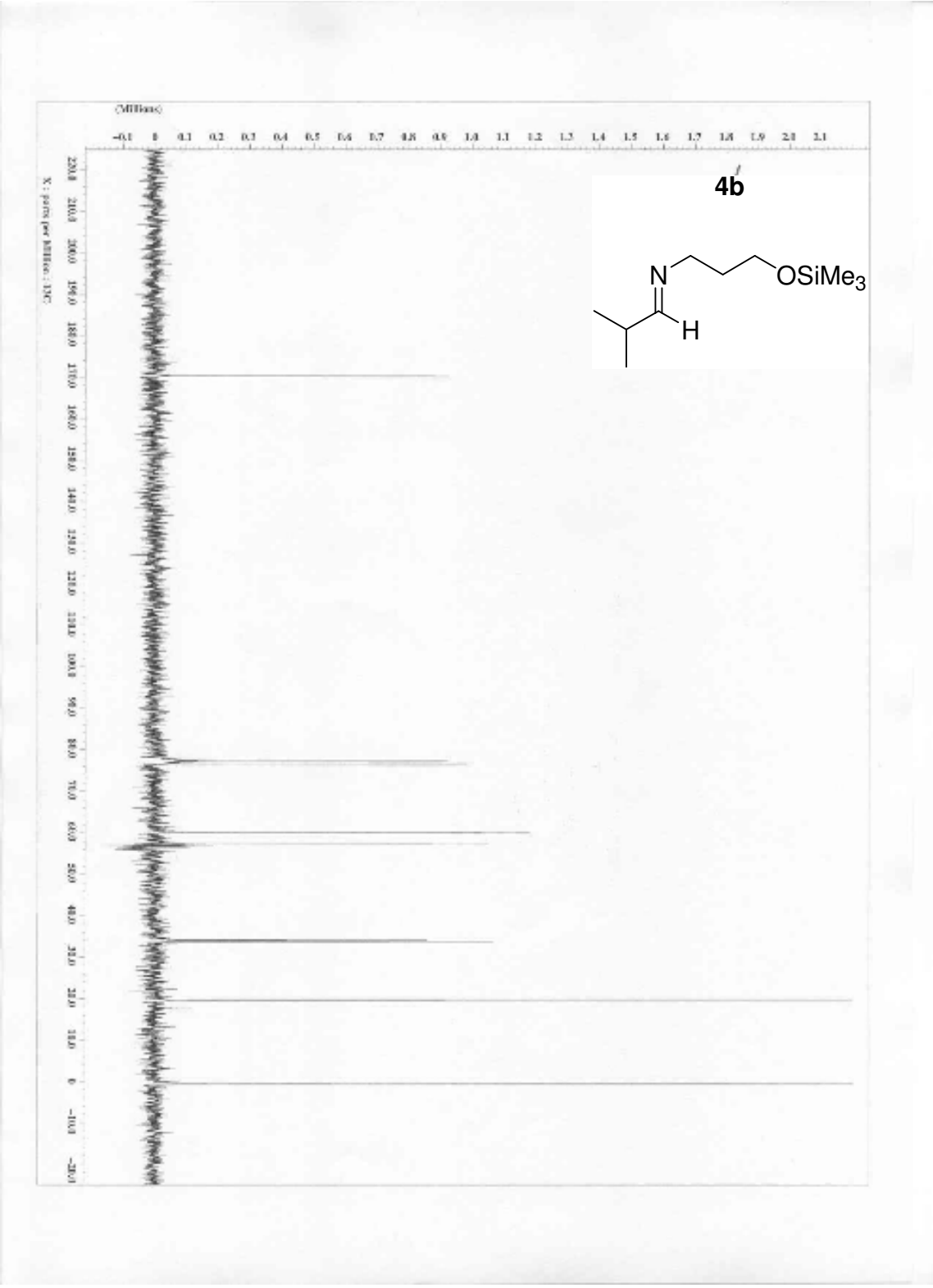
^{13}C NMR **4a**



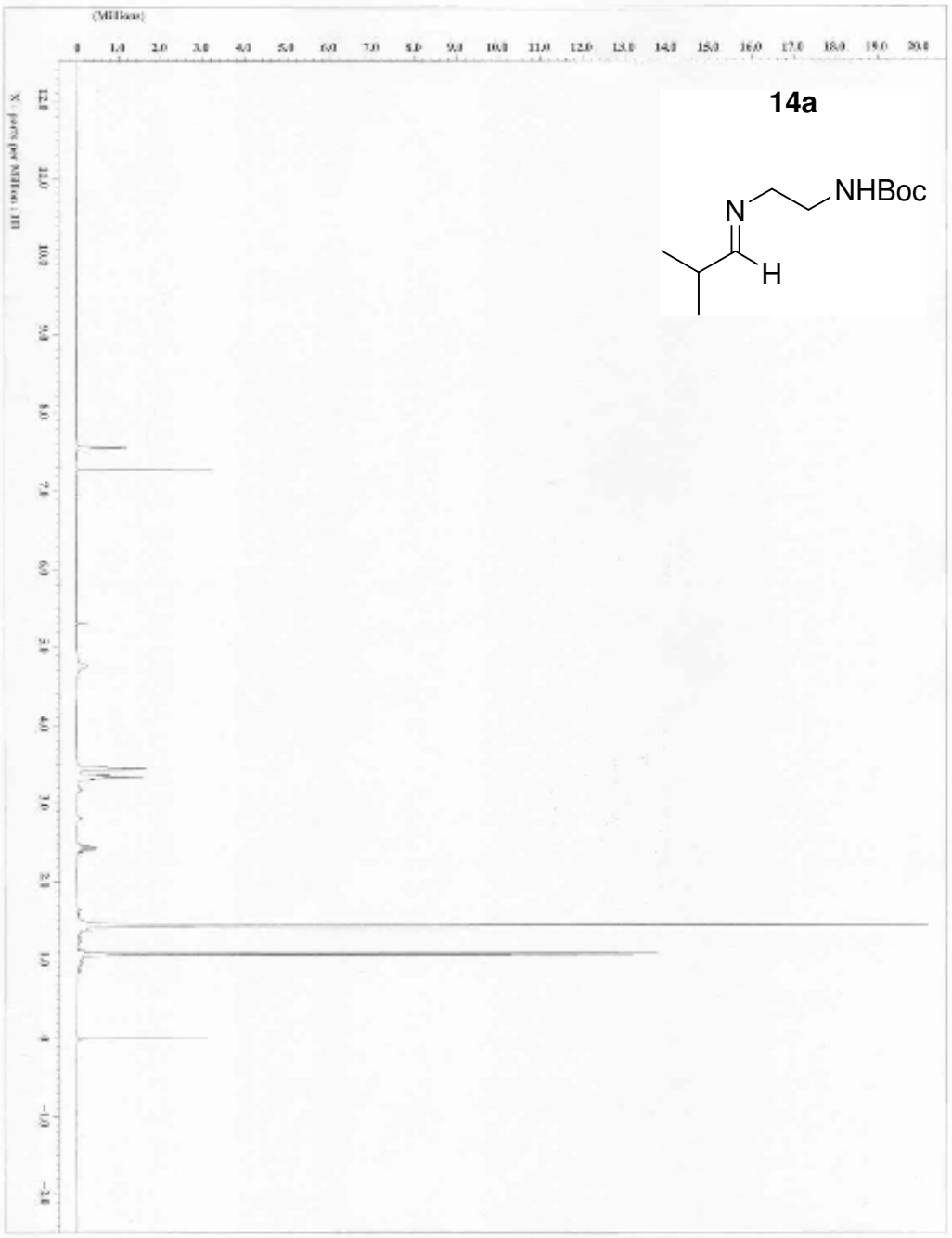
^{1}H NMR **4b**



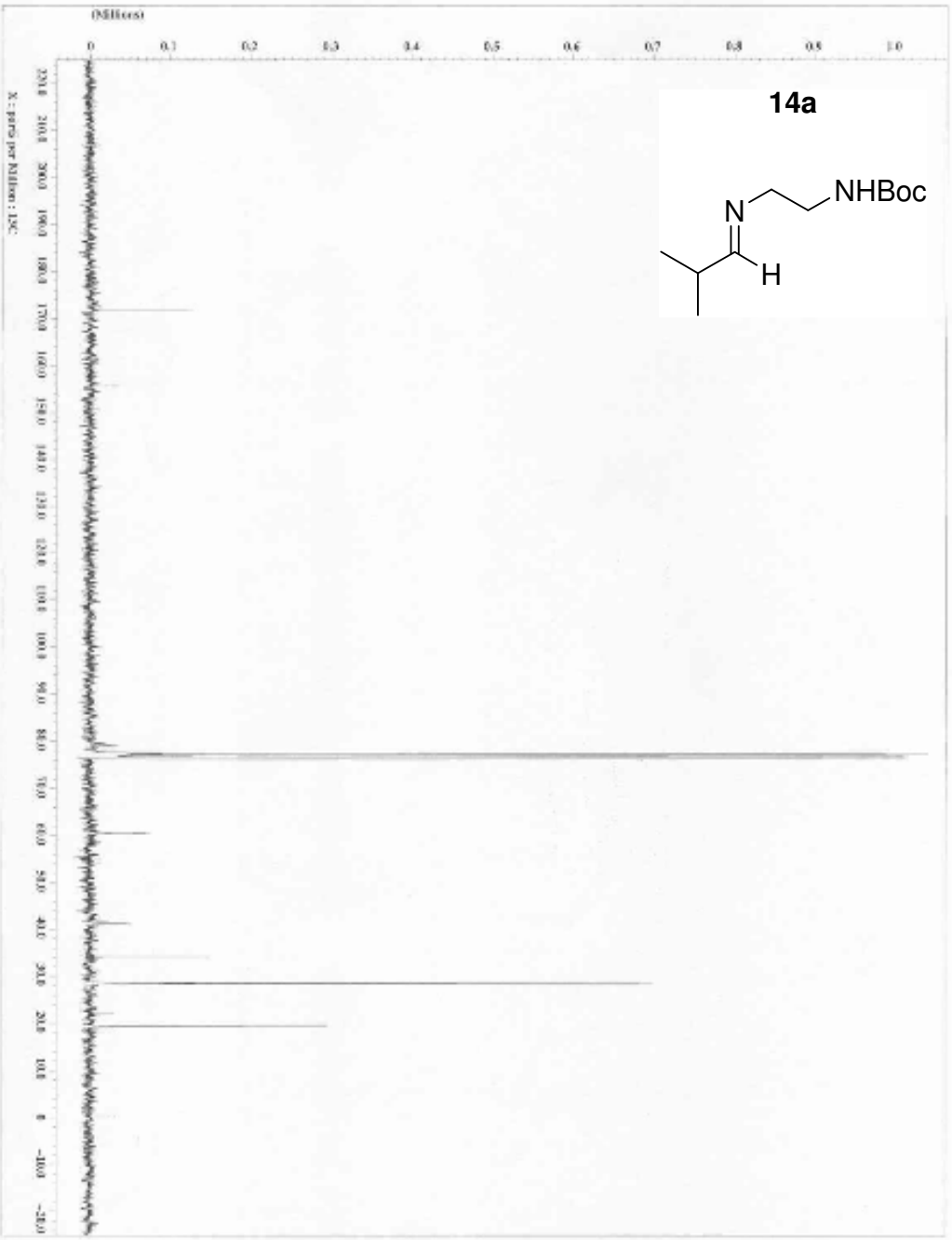
^{13}C NMR **4b**



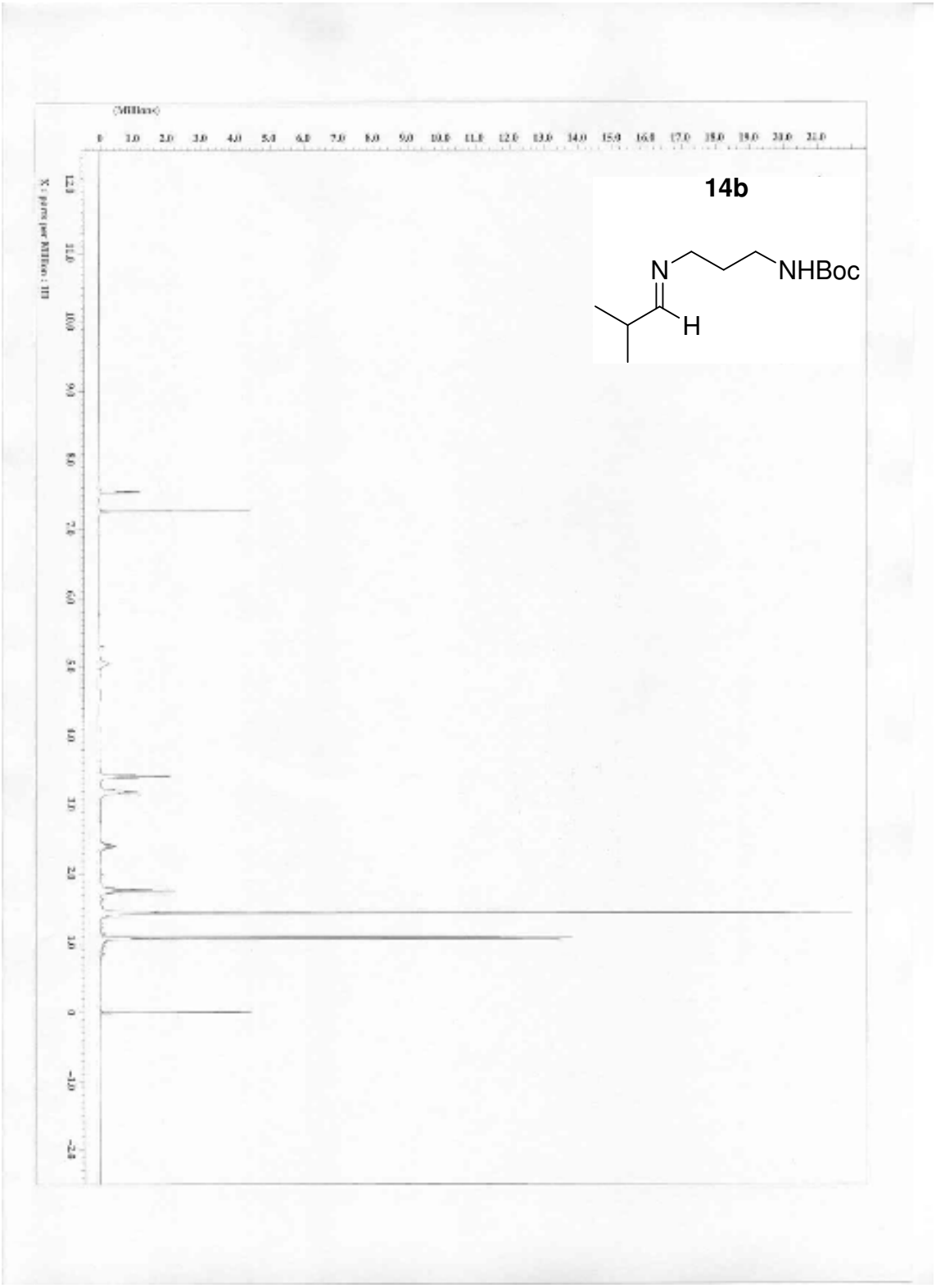
^{1}H NMR **14a**



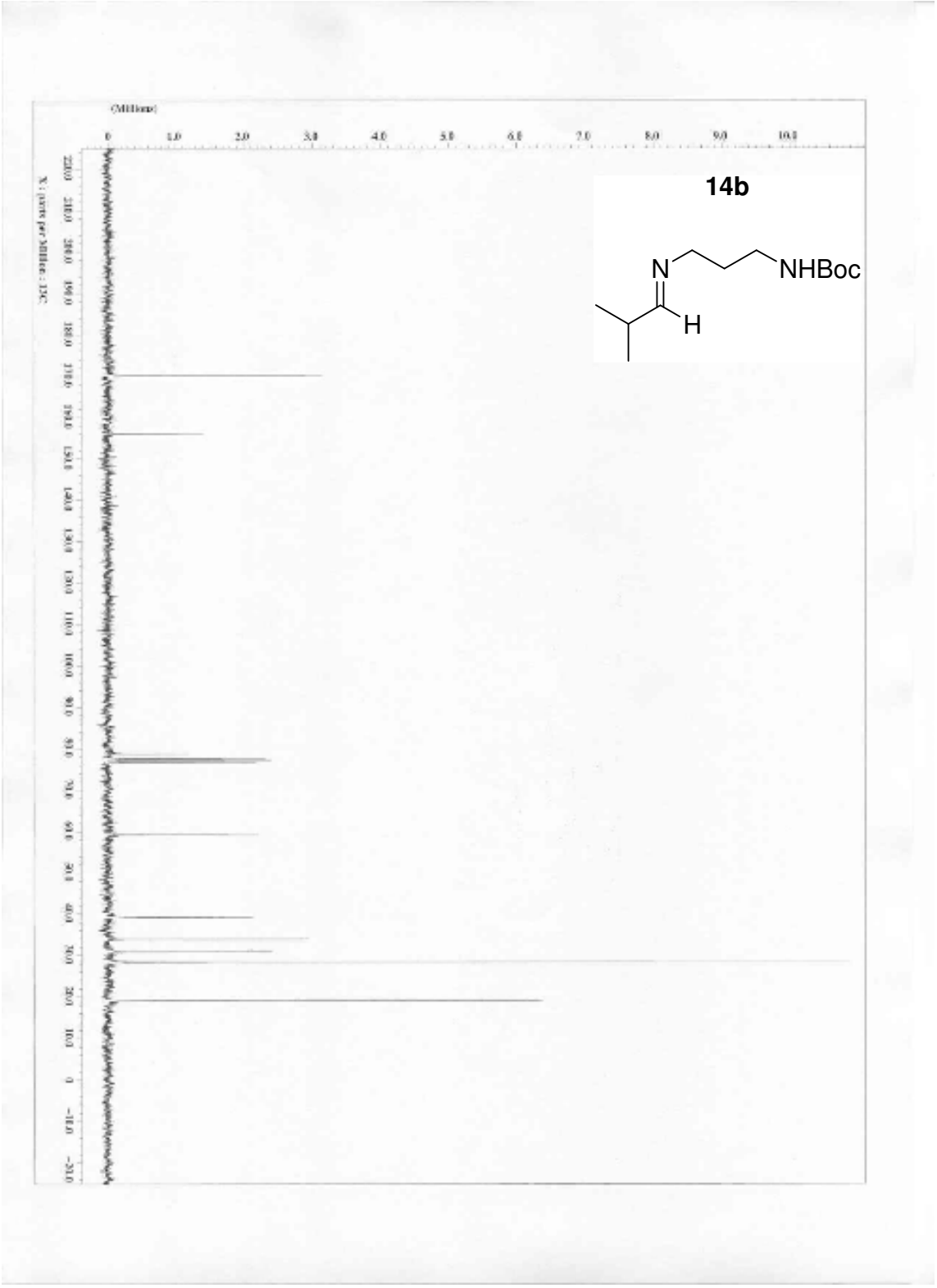
^{13}C NMR **14a**



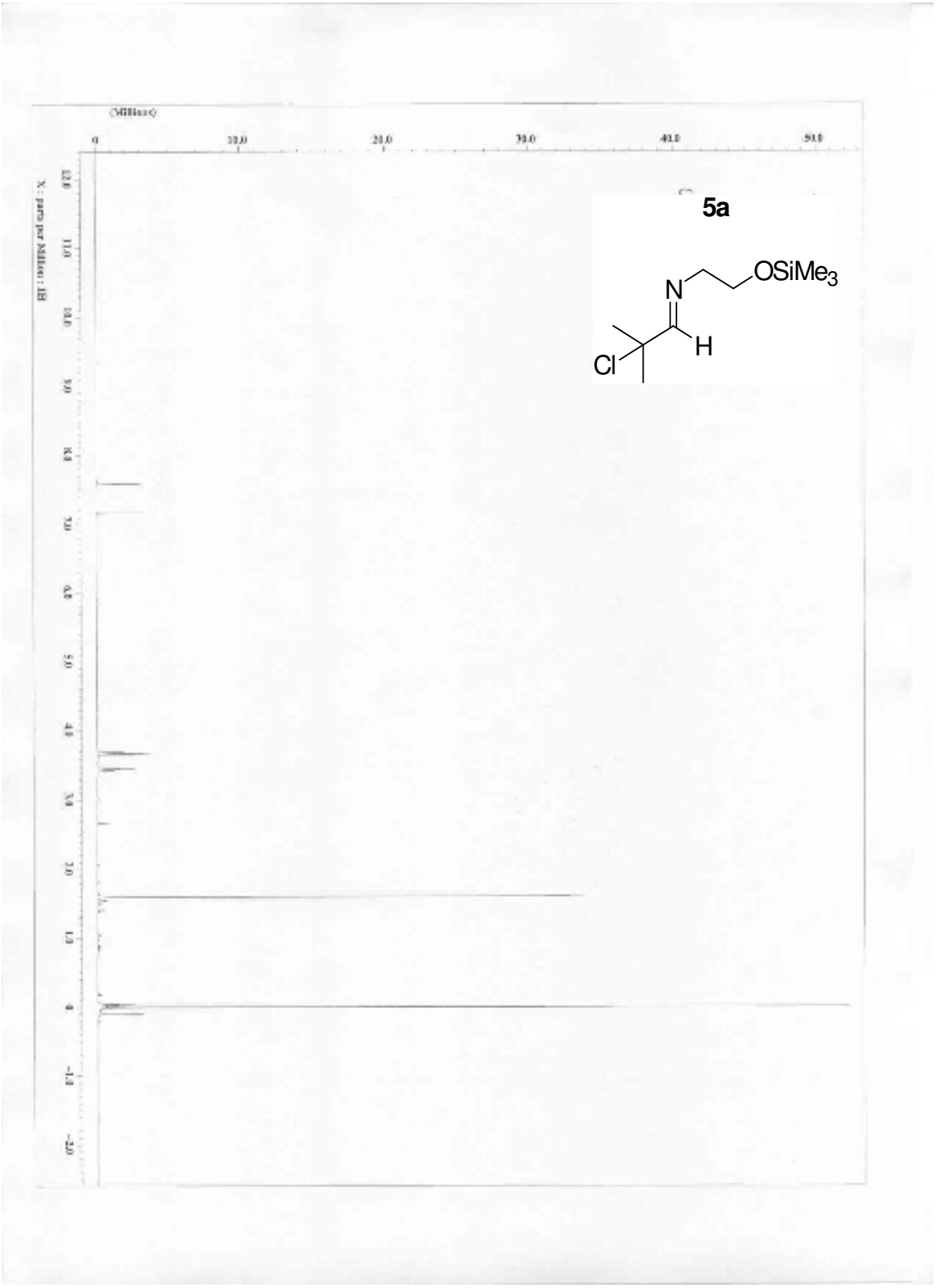
^{1}H NMR **14b**



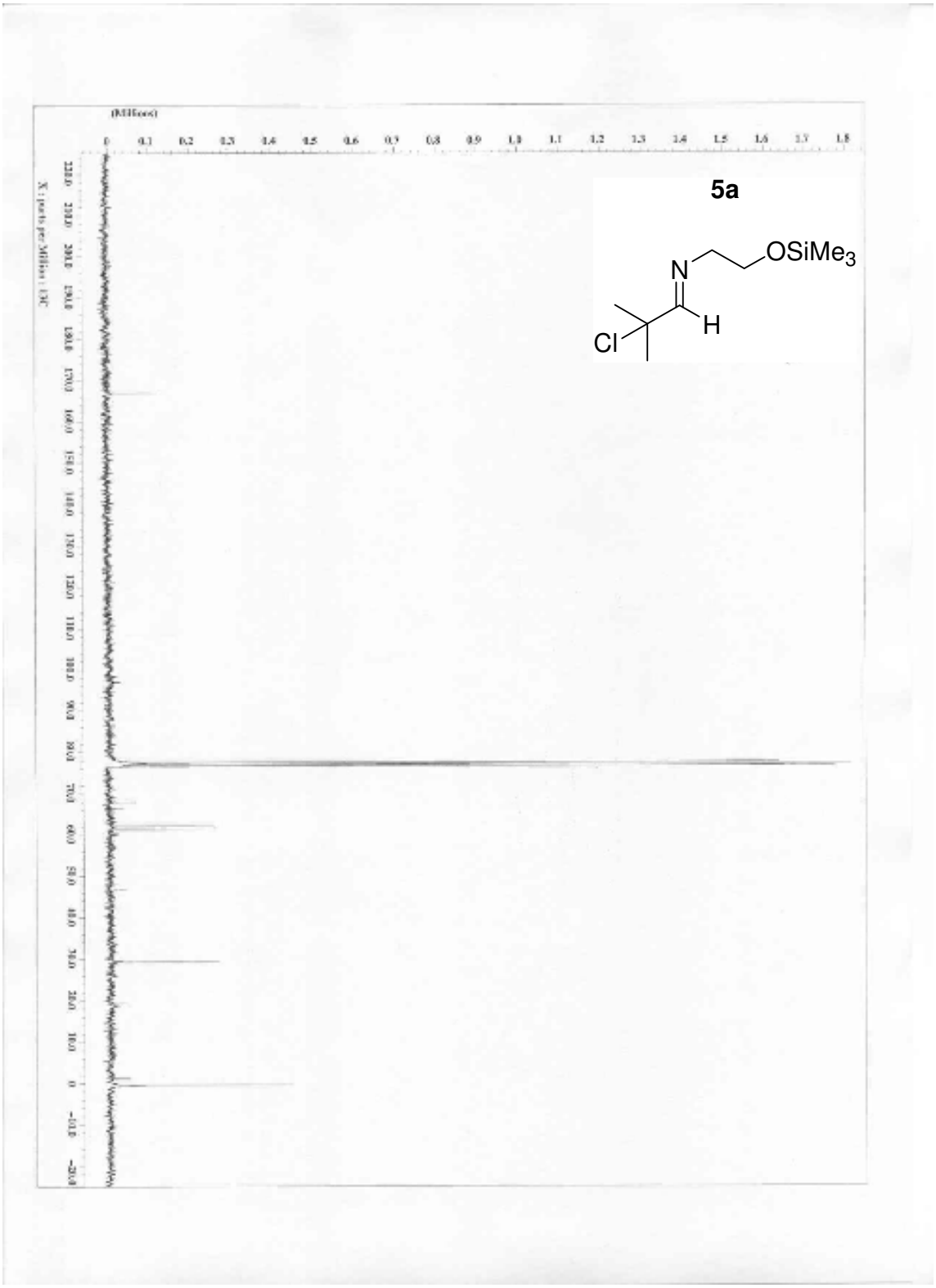
^{13}C NMR **14b**



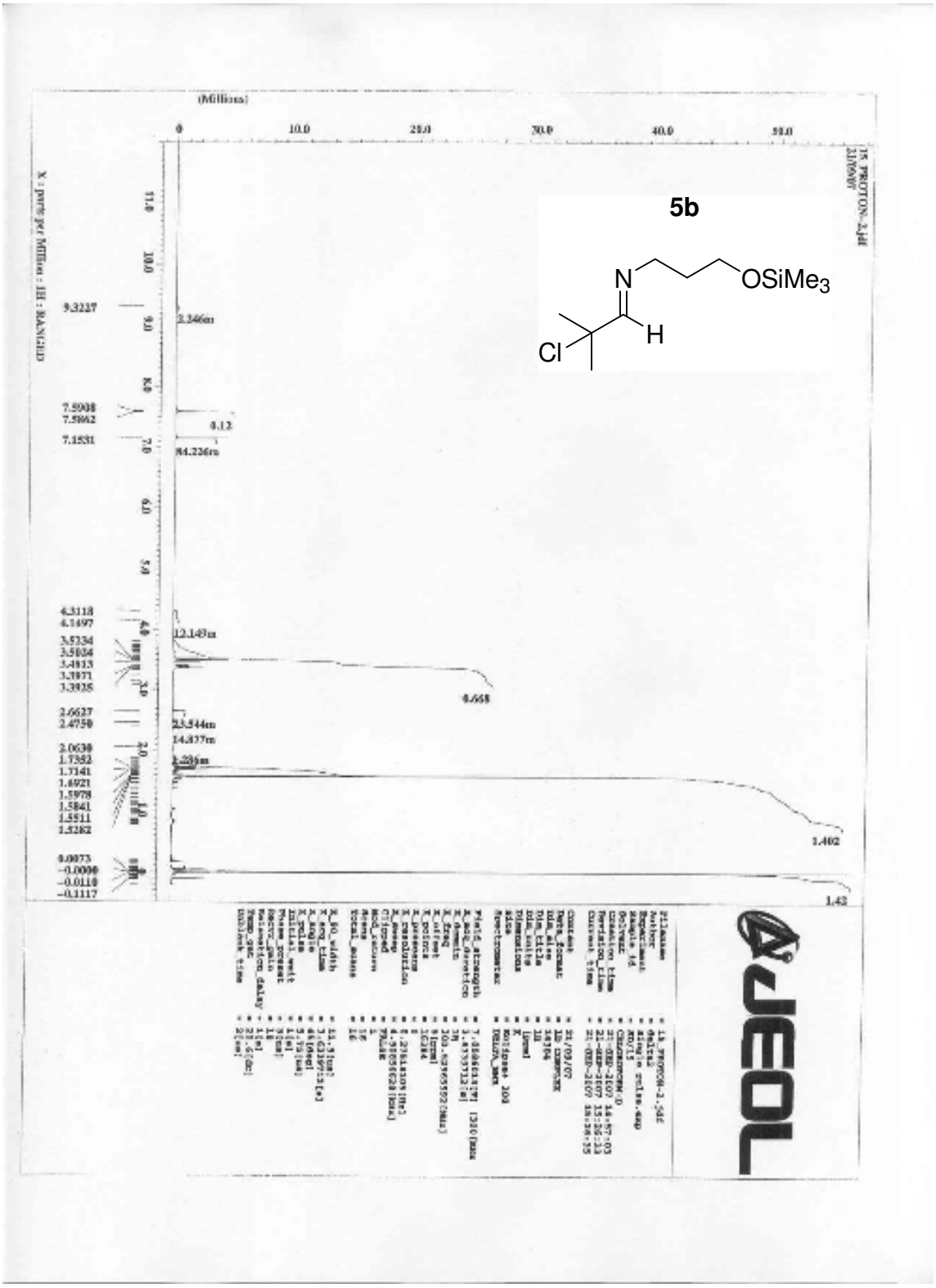
^{1}H NMR **5a**



^{13}C NMR **5a**



^{1}H NMR **5b**


5b
N
OSiMe3
H
Cl
(Millions)
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10.0
20.0
30.0
40.0
50.0
X : parts per Million : 1H : RANGED
9.3227
7.5908
7.5862
7.1531
4.3118
4.1497
3.5234
3.5024
3.4813
3.3971
3.3925
2.6627
2.4750
2.0630
1.7352
1.7141
1.6921
1.5978
1.5841
1.5511
1.5282
0.0073
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-0.1117
3.346m
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12.143m
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1.402
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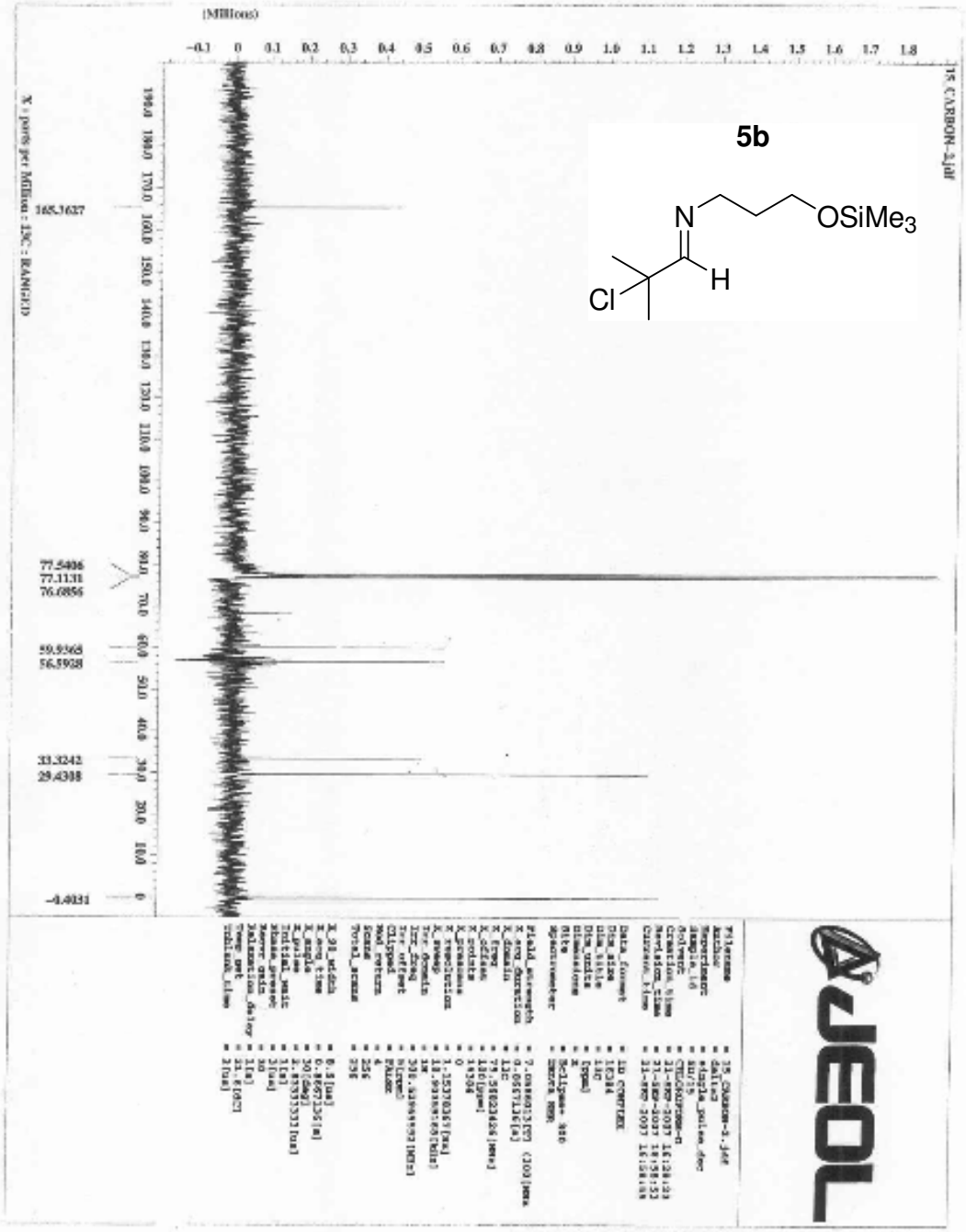
JEOL

^{13}C NMR **5b**


5b
N
OSiMe3
H
Cl
(Millions)
X : parts per Million : 13C : RANGED
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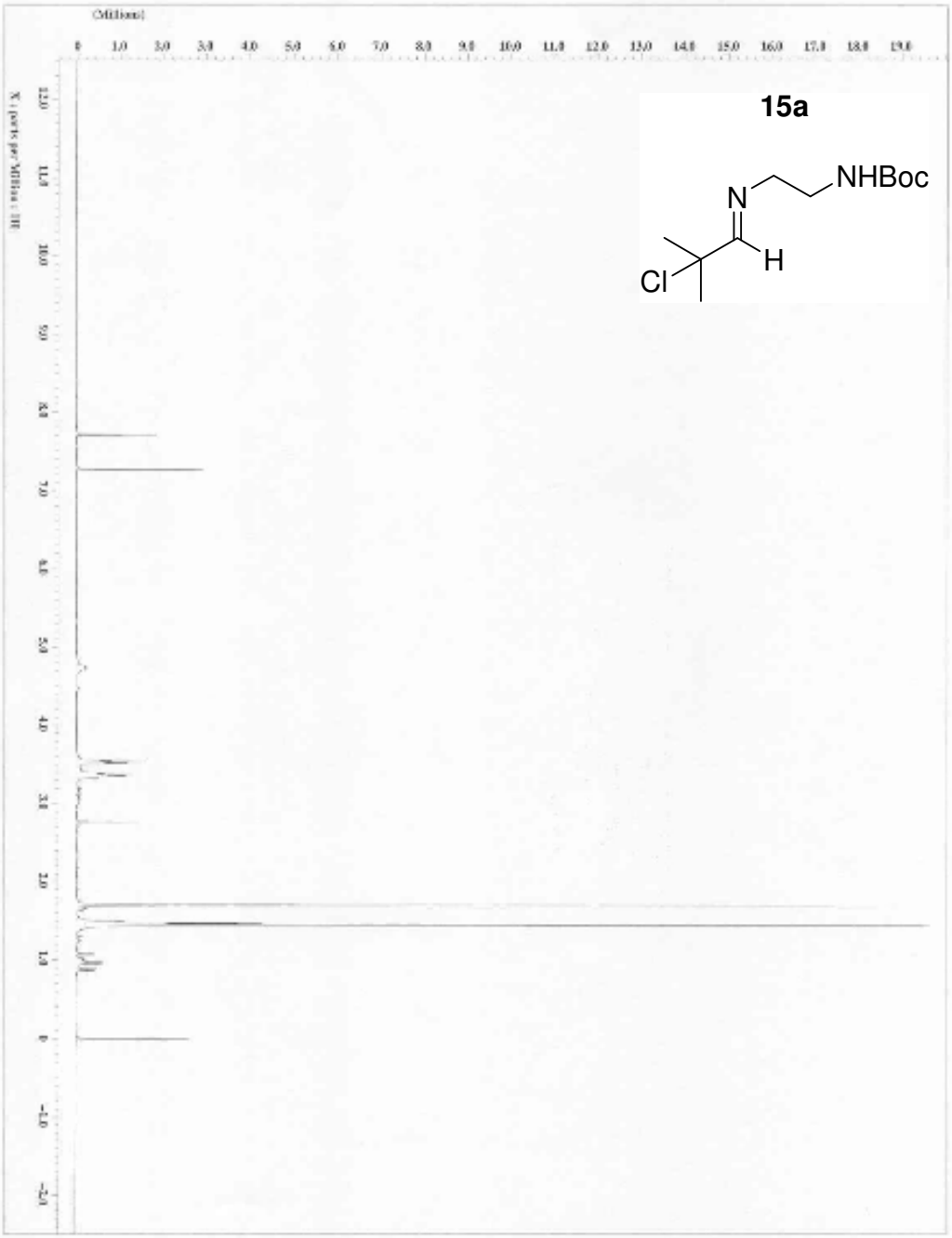
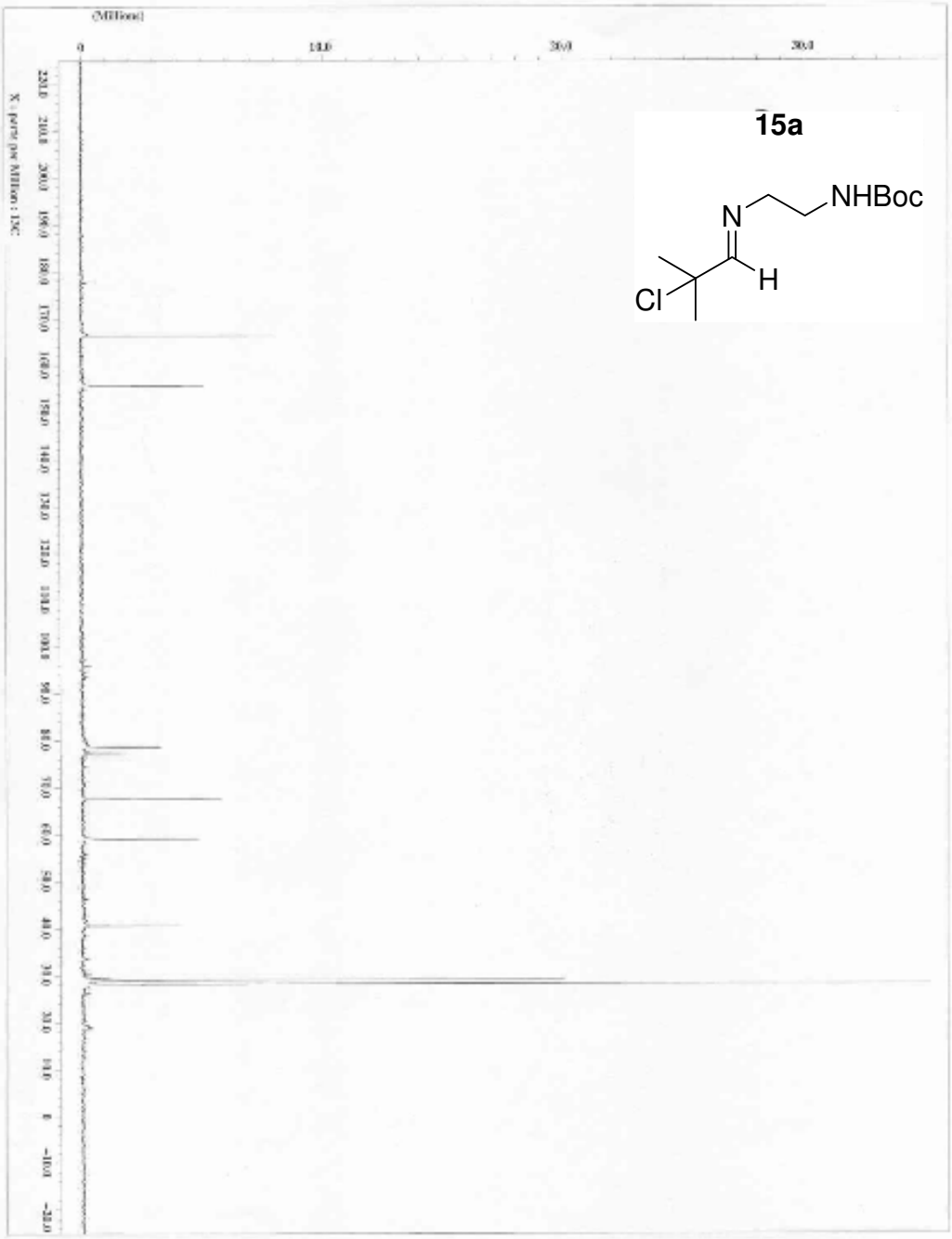
56.5928
33.3242
29.4318
-4.0031
JEOL

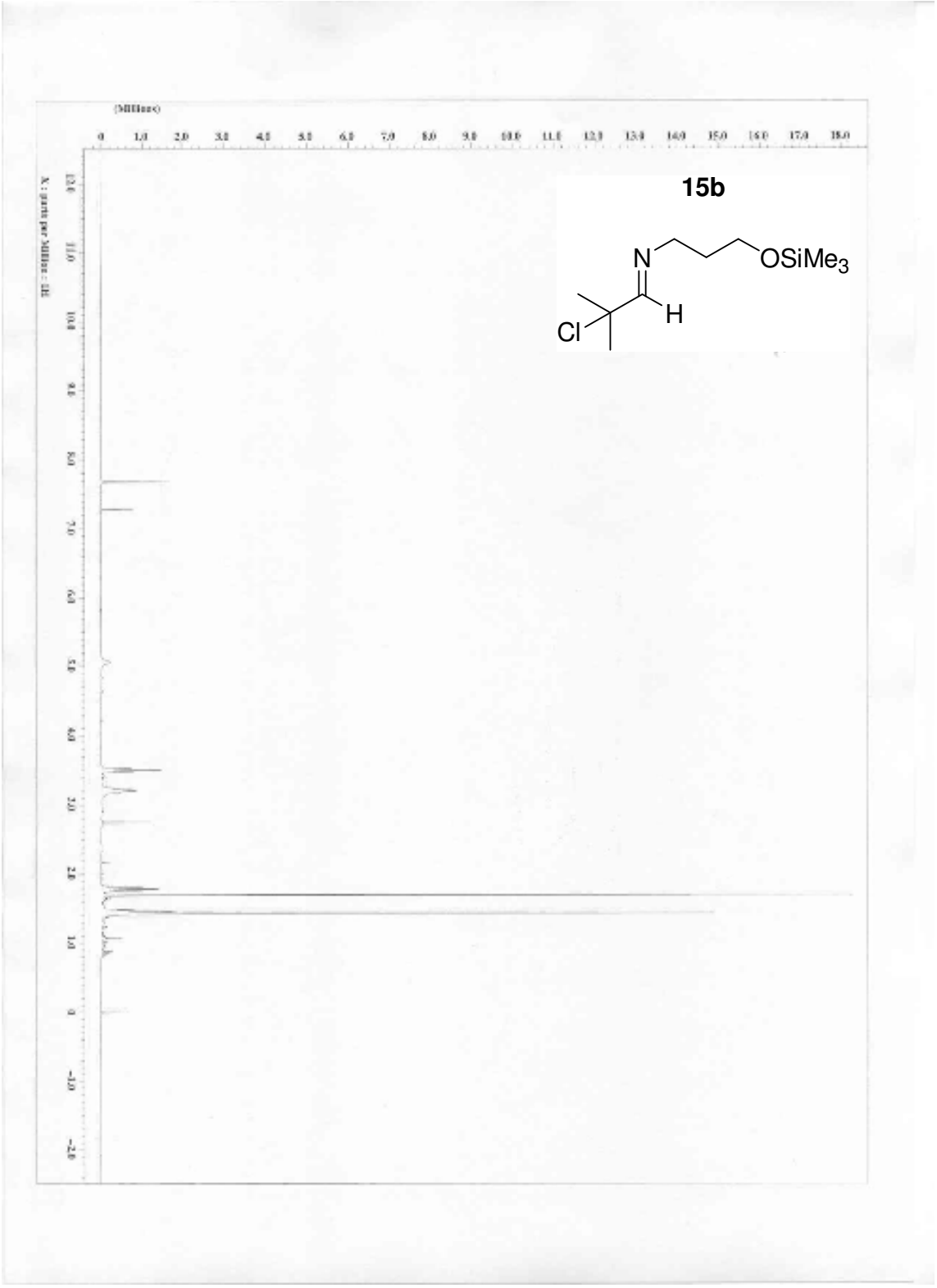
^{1}H NMR **15a**



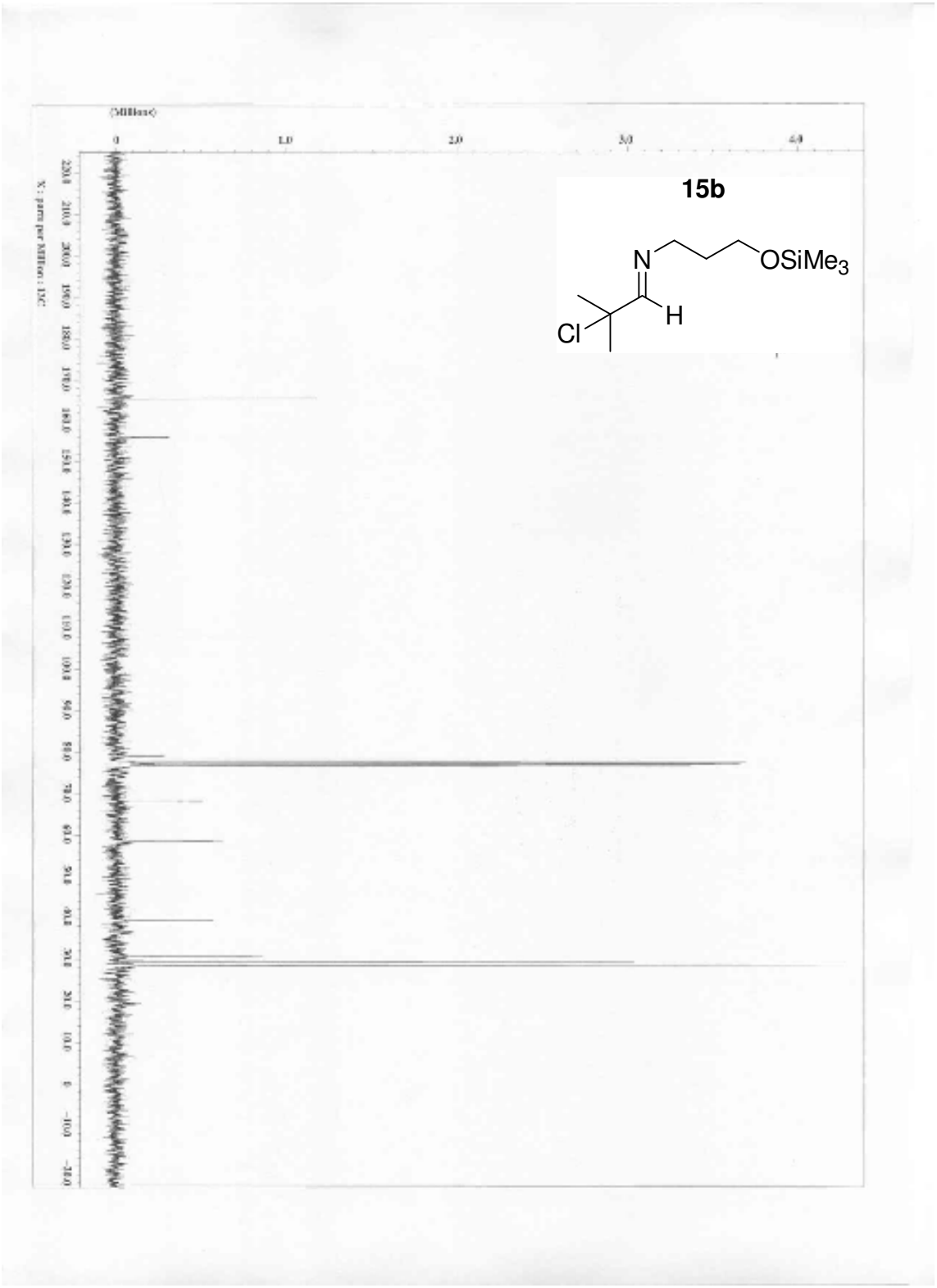
^{13}C NMR **15a**



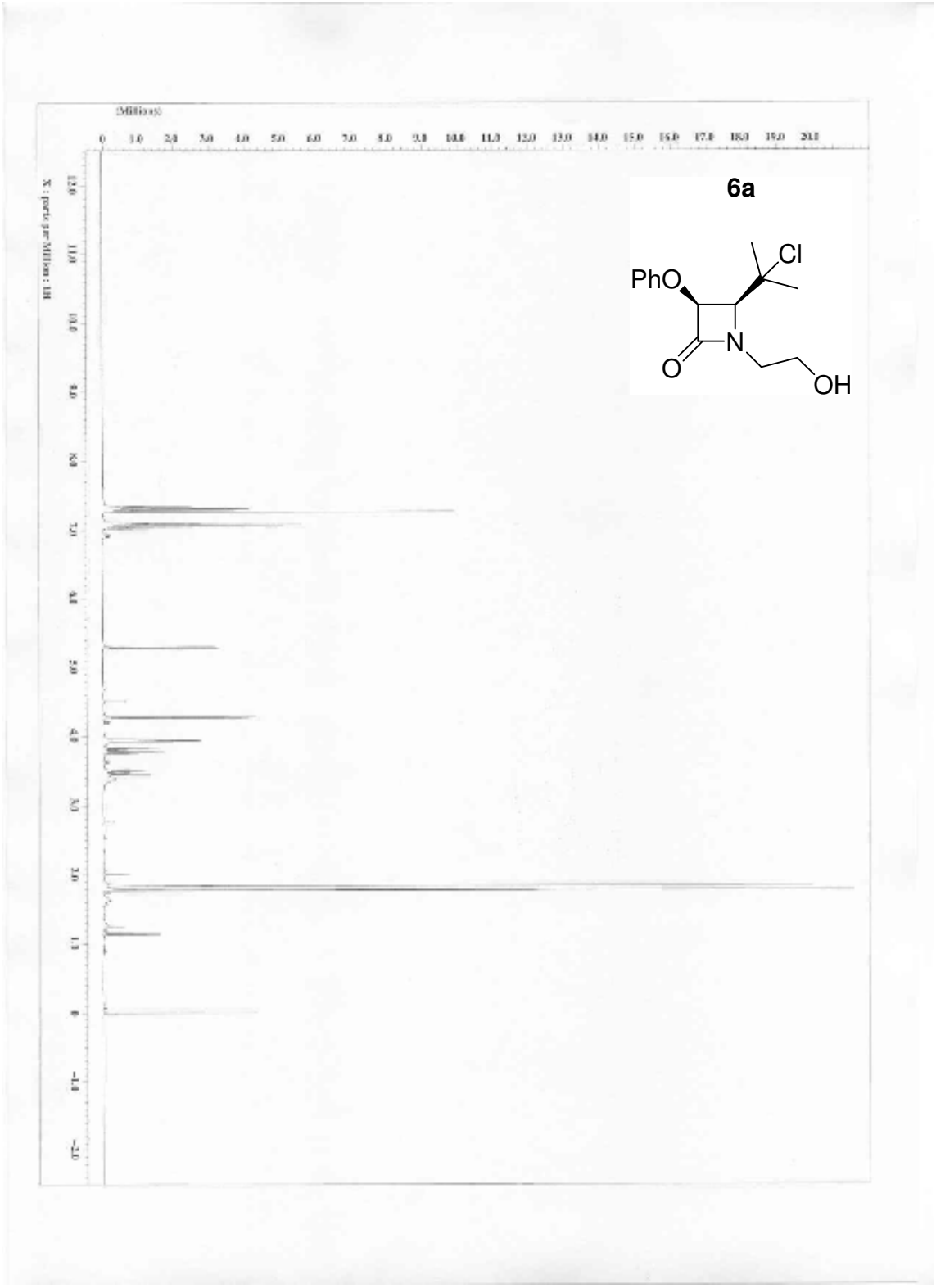
^{1}H NMR **15b**



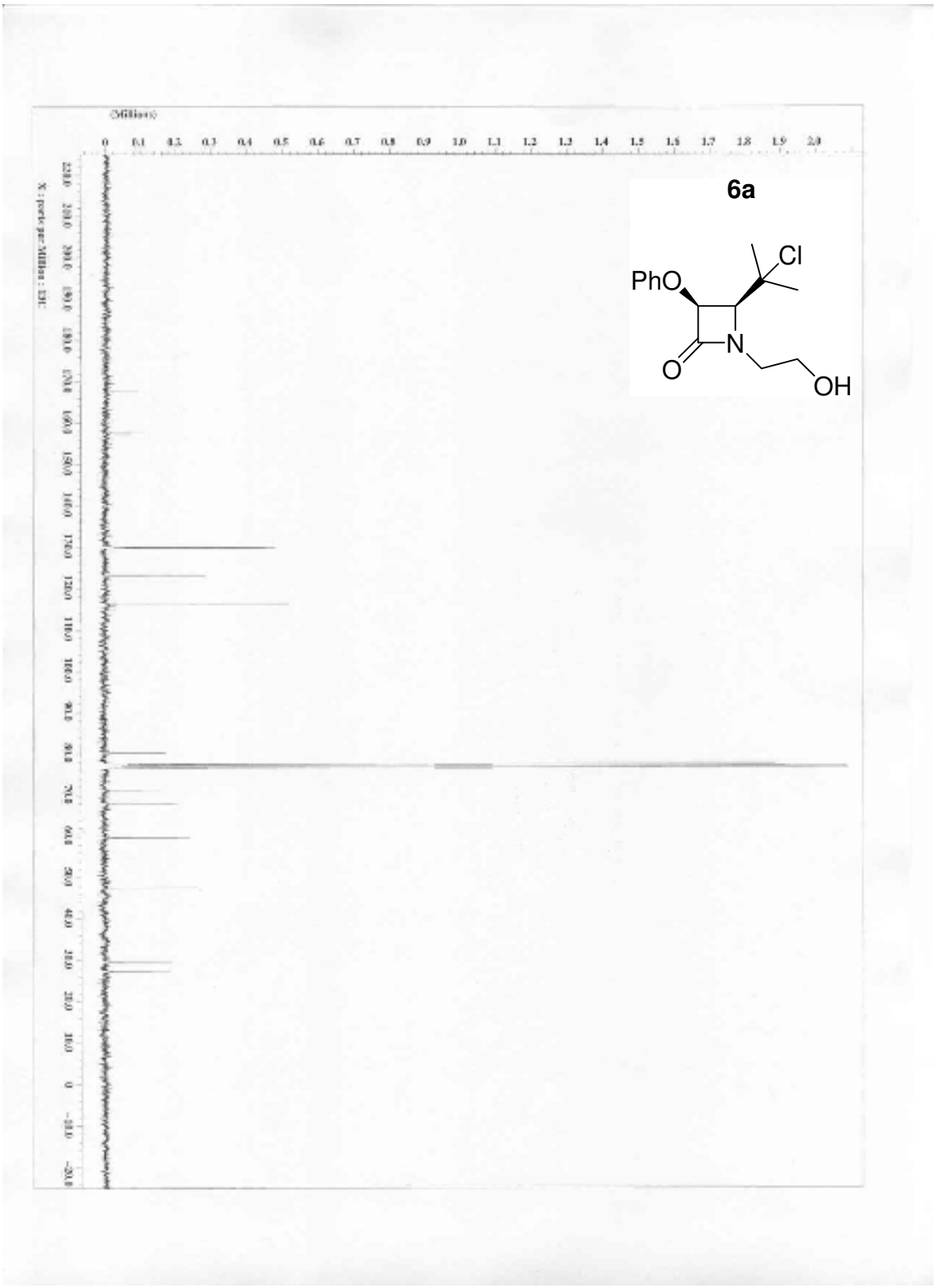
^{13}C NMR **15b**



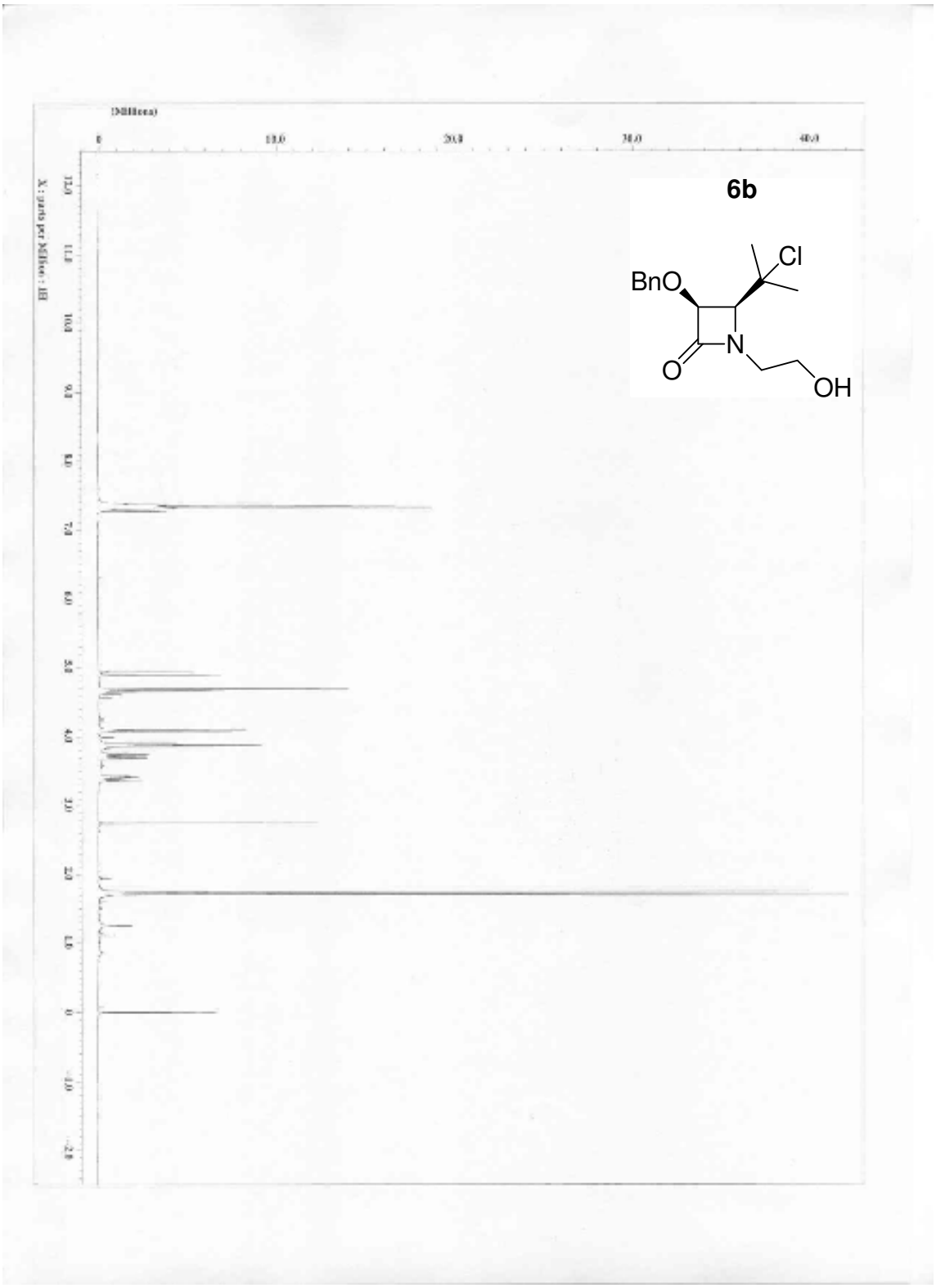
^{1}H NMR **6a**



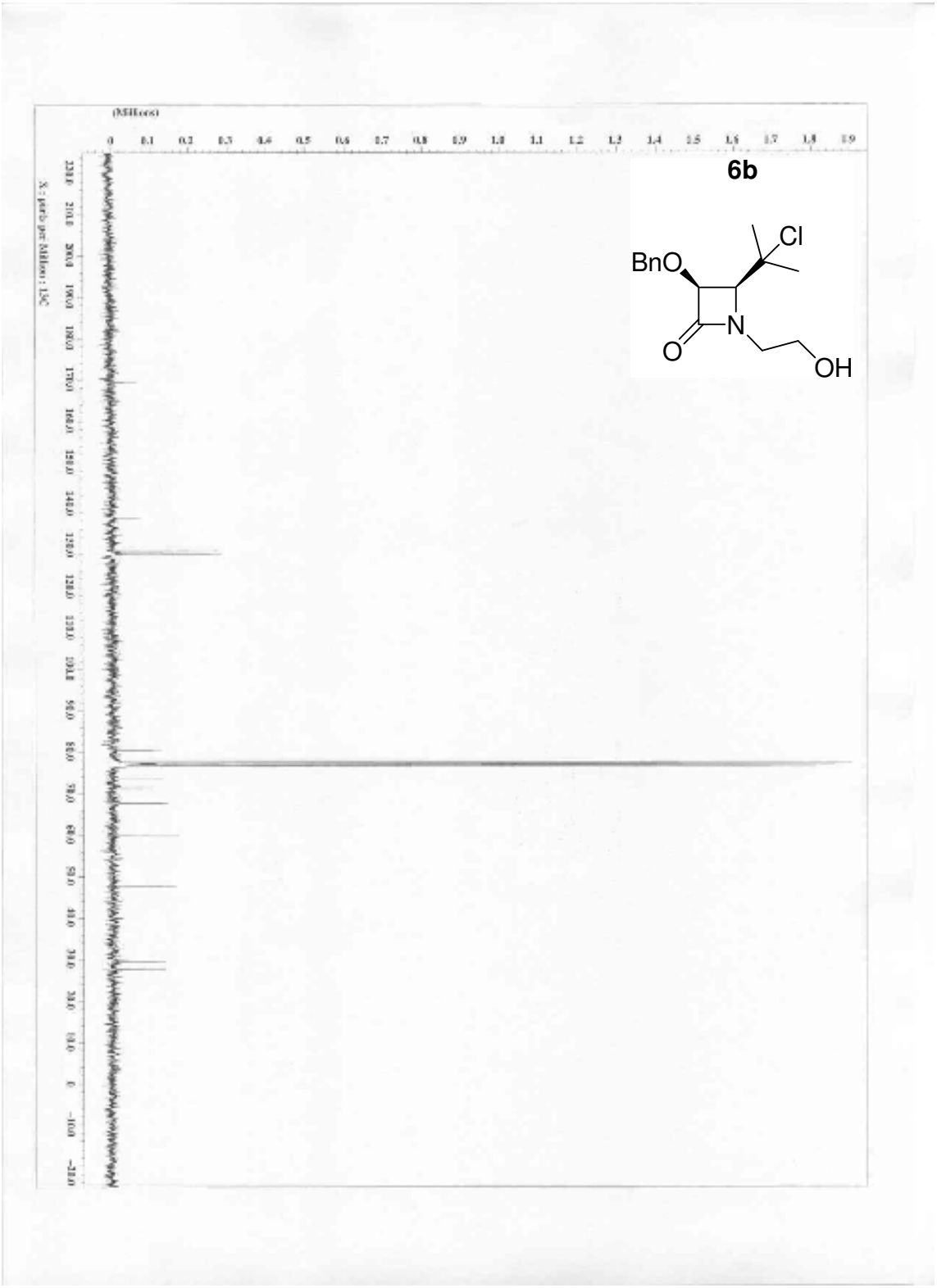
^{13}C NMR **6a**



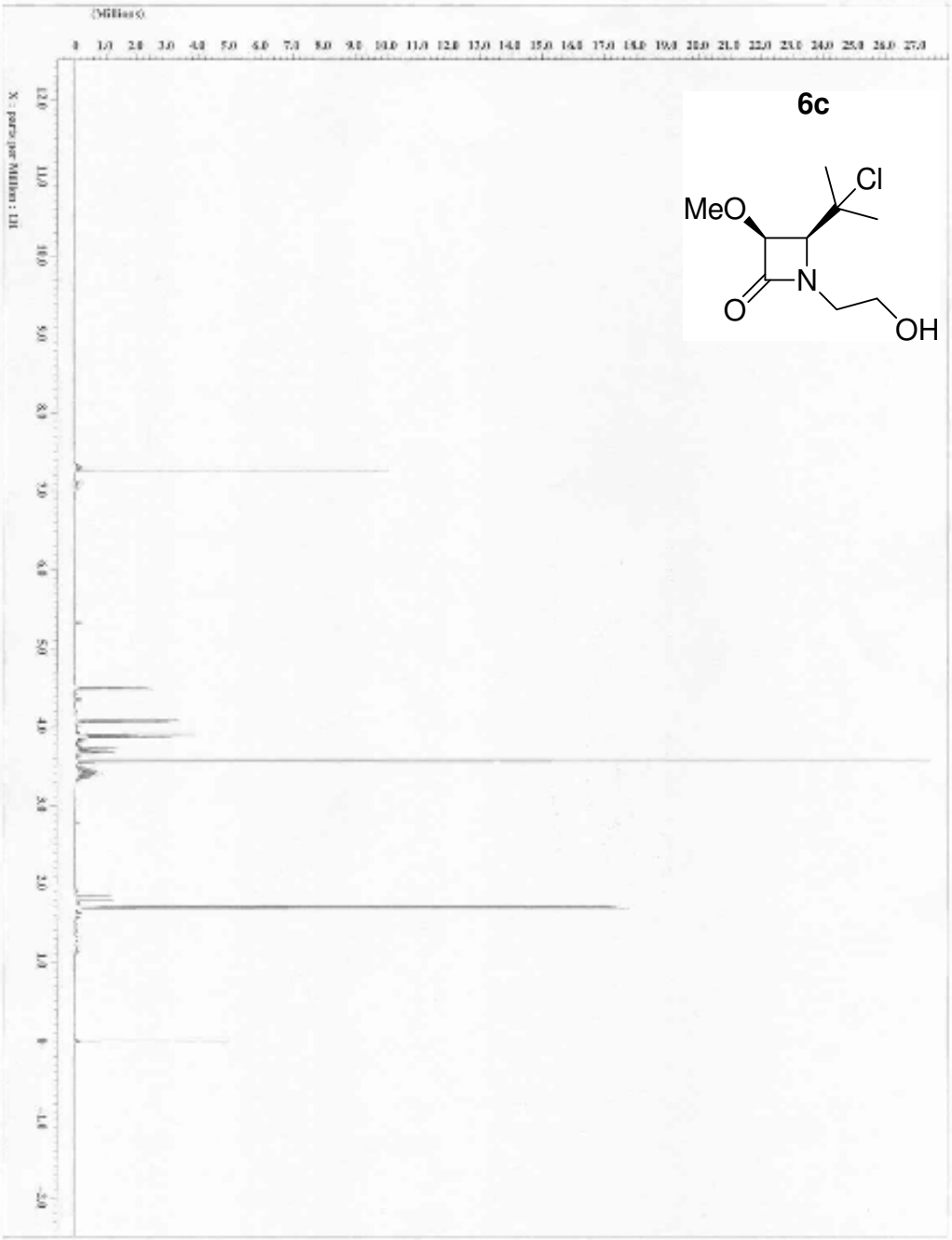
^{1}H NMR **6b**



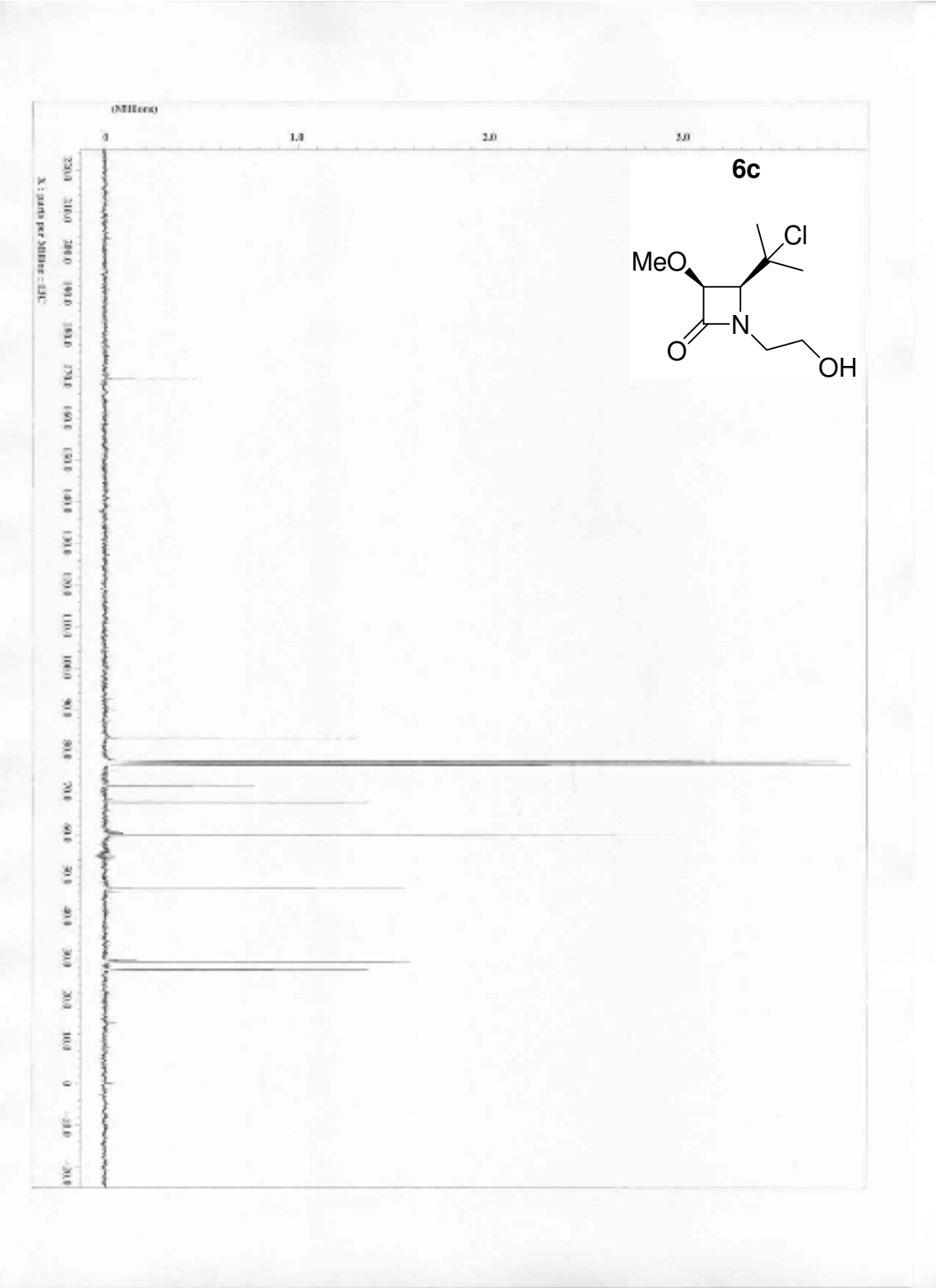
^{13}C NMR **6b**



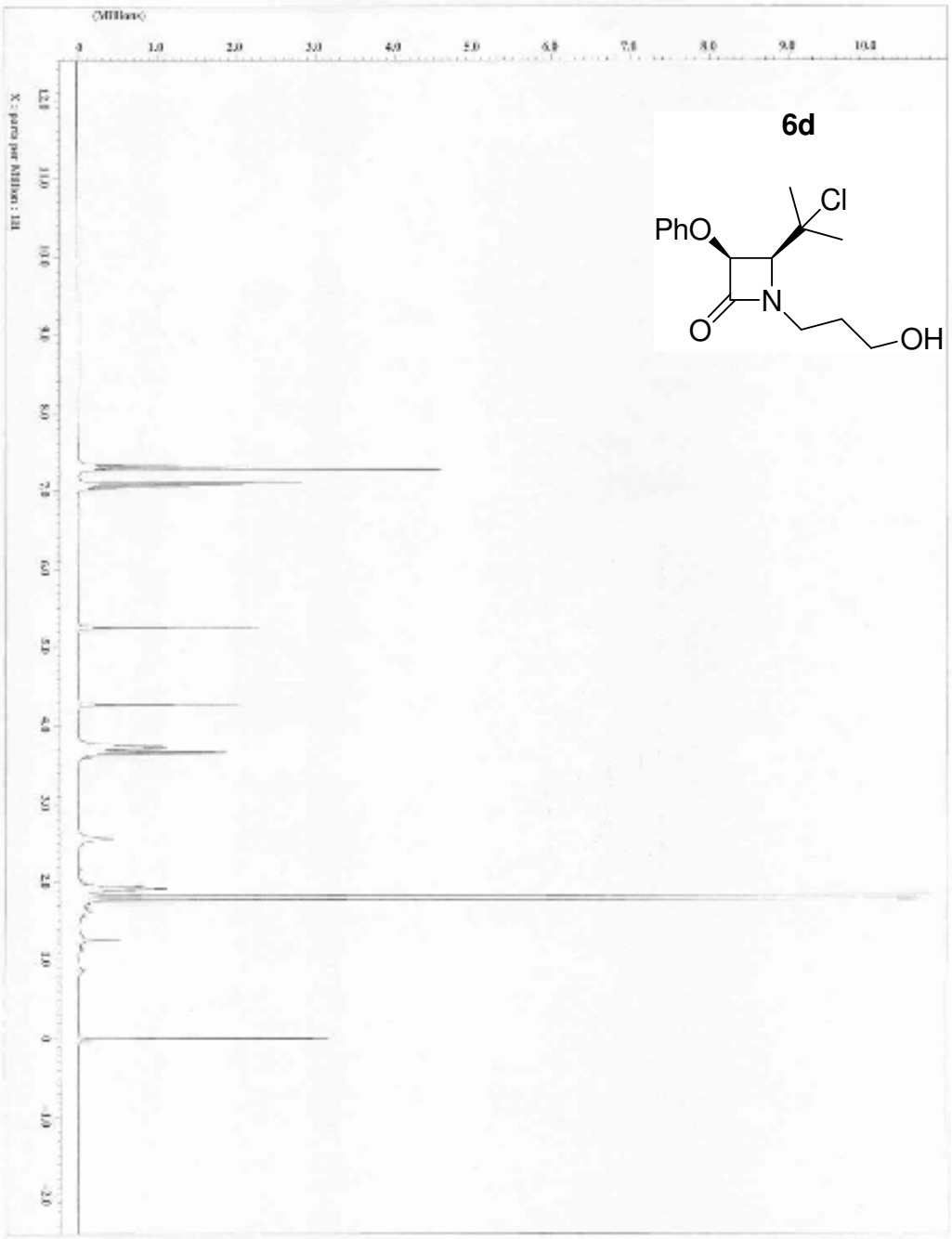
^{1}H NMR **6c**



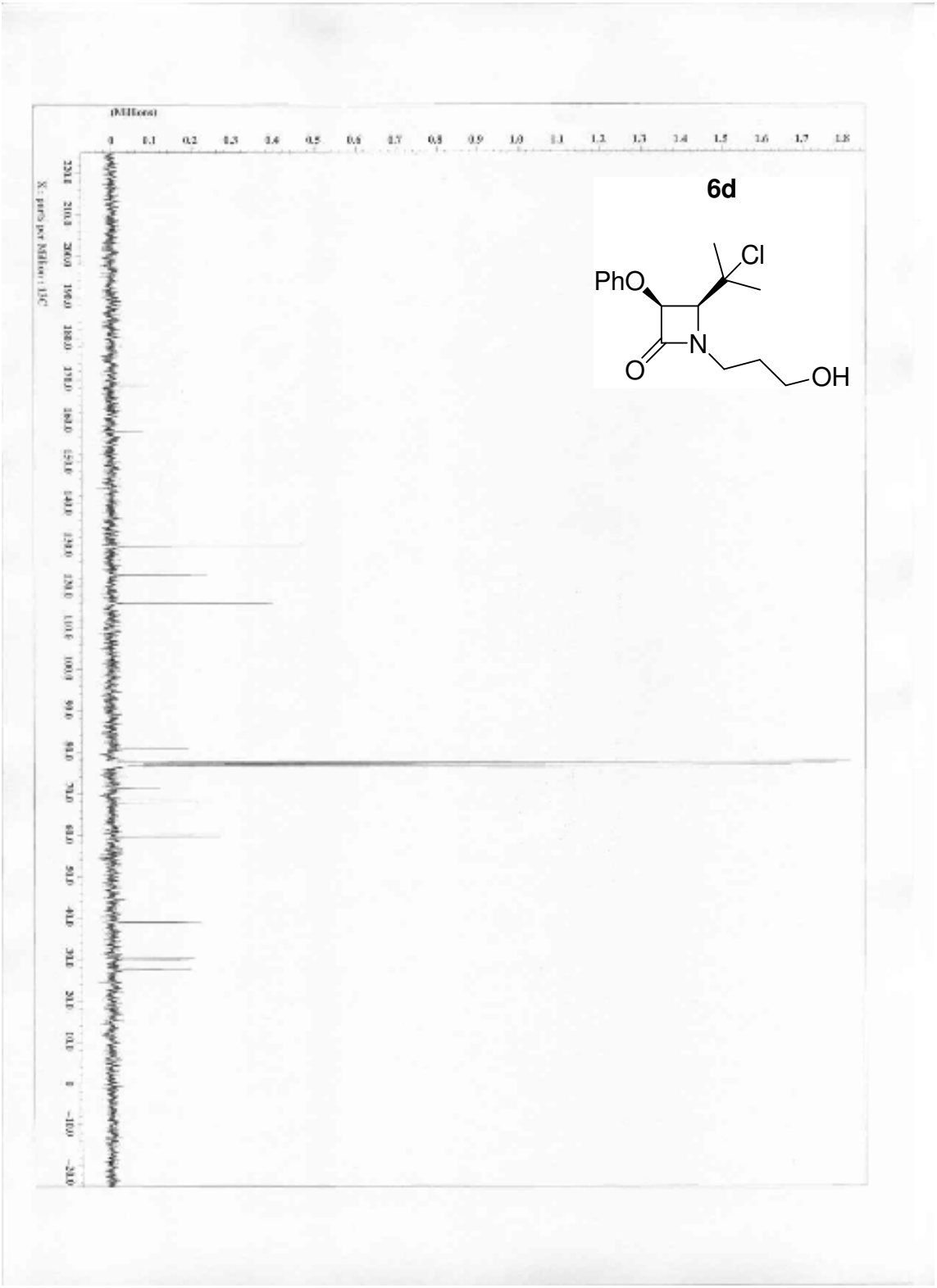
^{13}C NMR **6c**



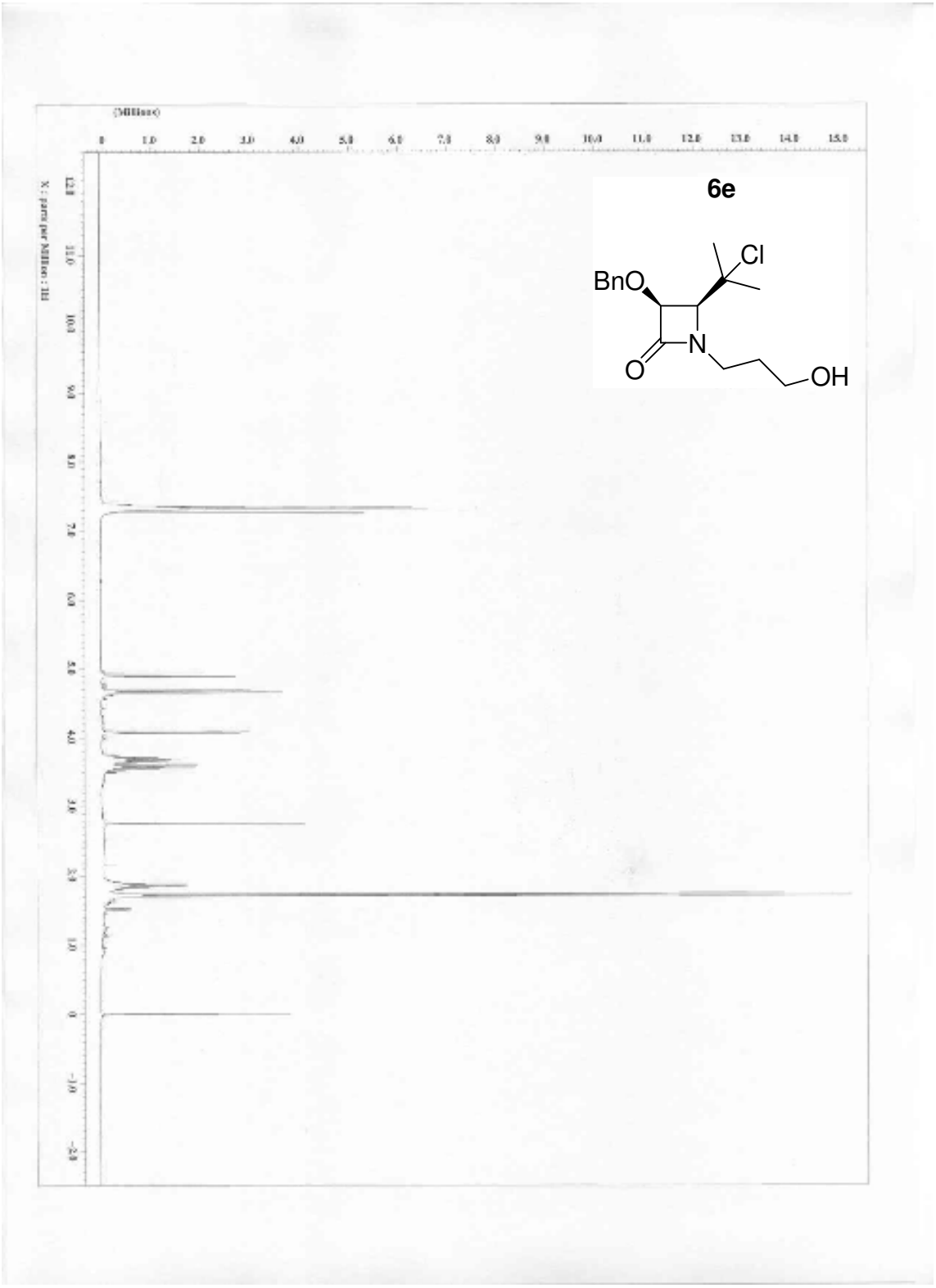
^{1}H NMR **6d**



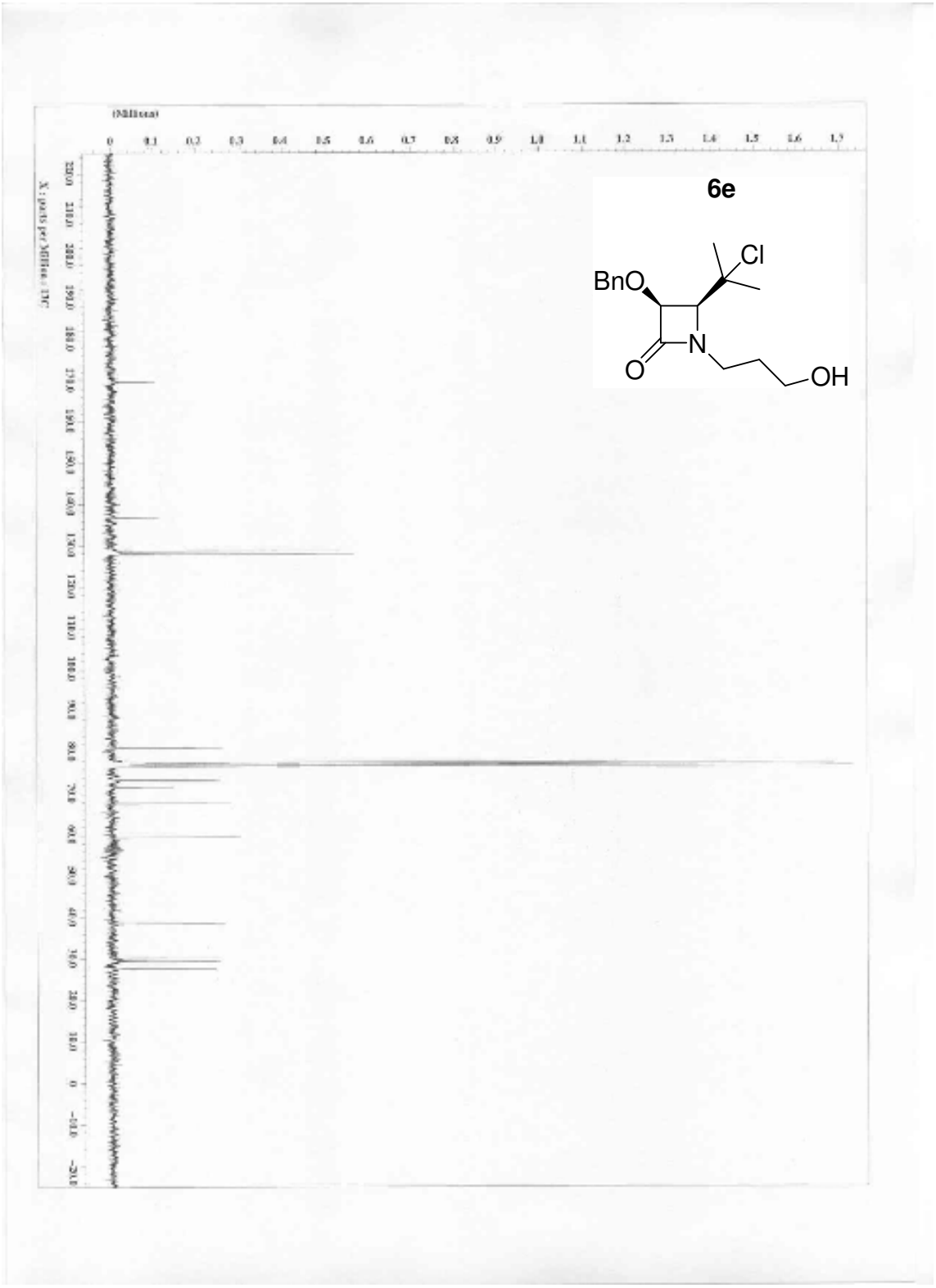
^{13}C NMR **6d**



^{1}H NMR **6e**



^{13}C NMR **6e**



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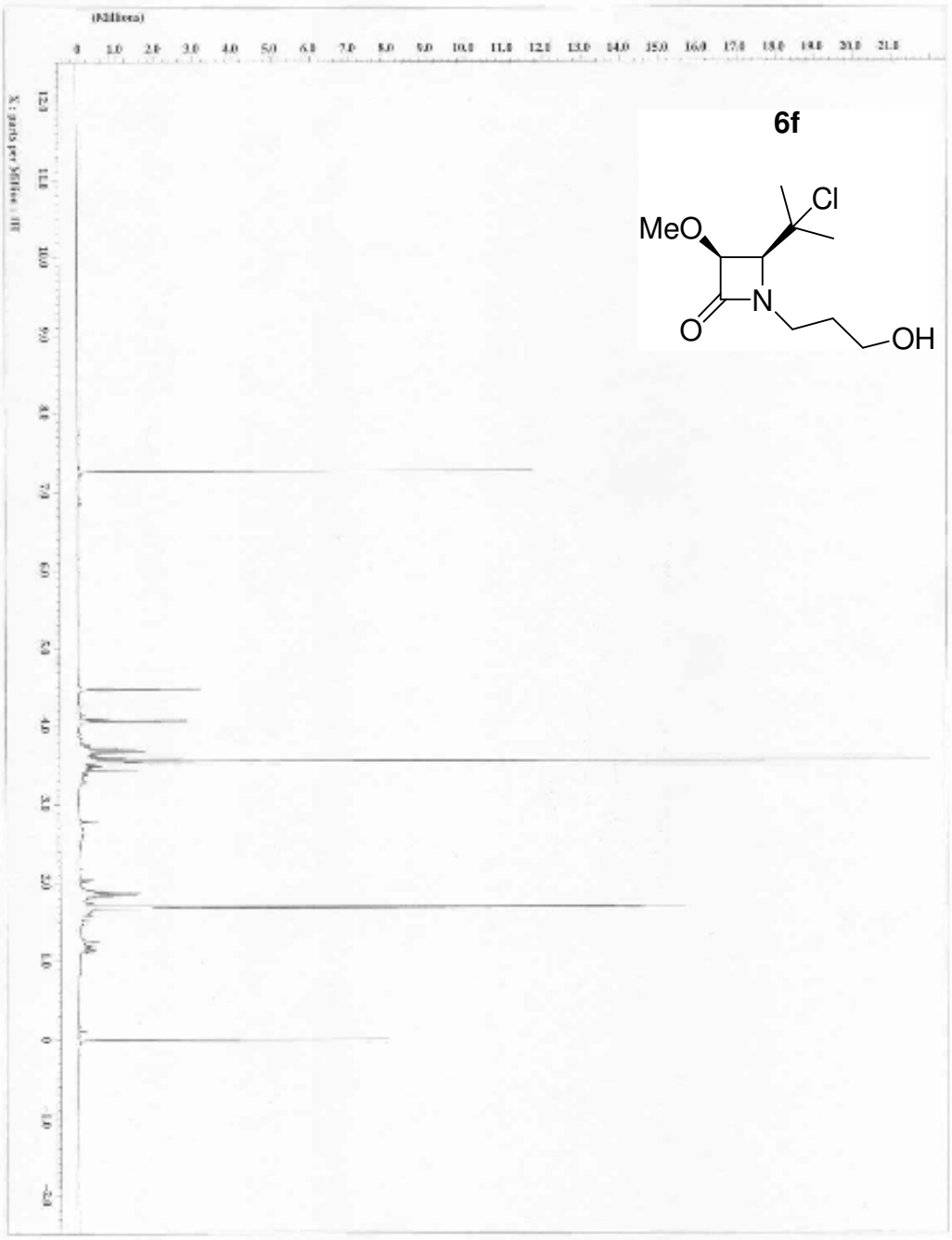
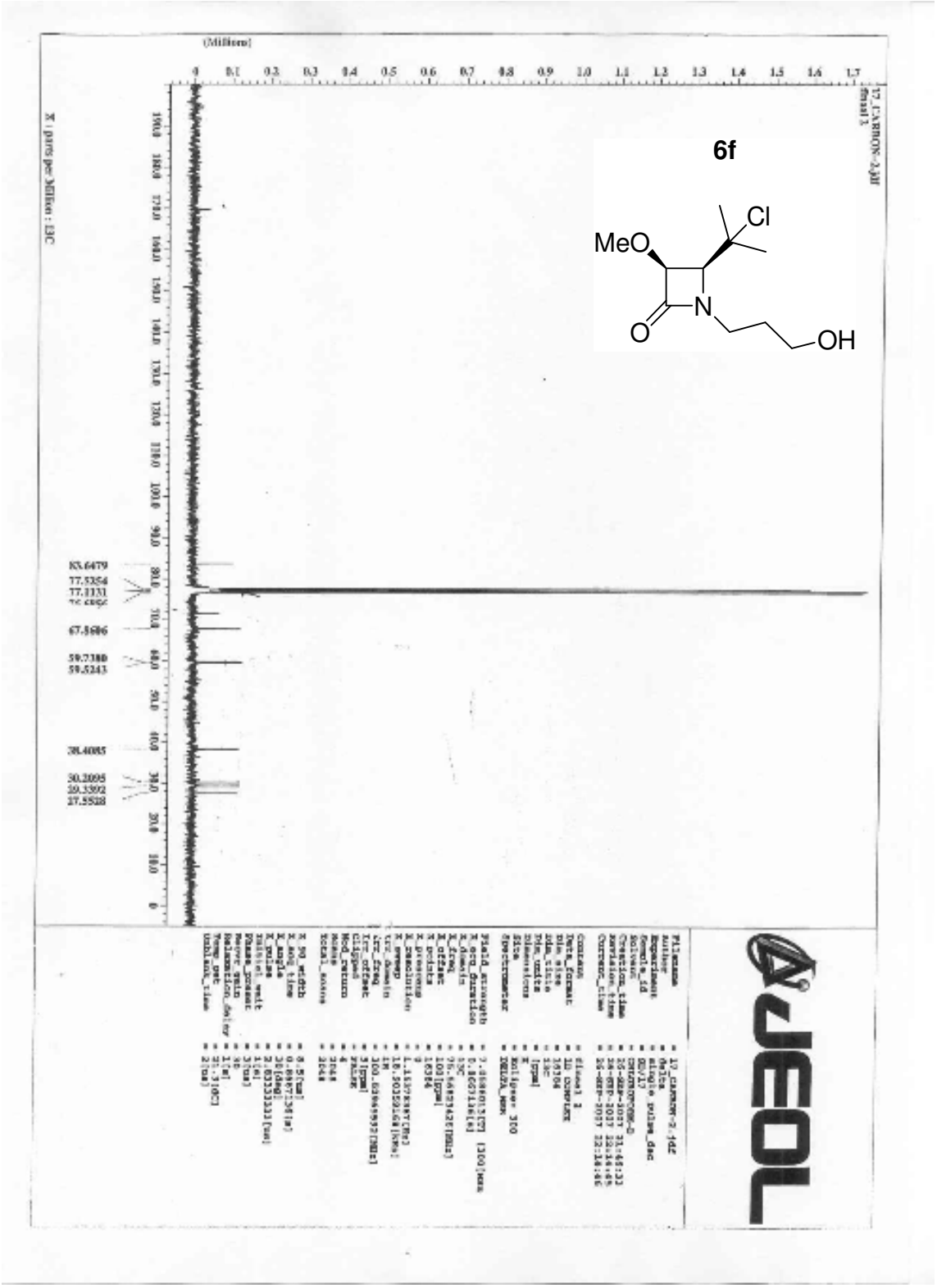
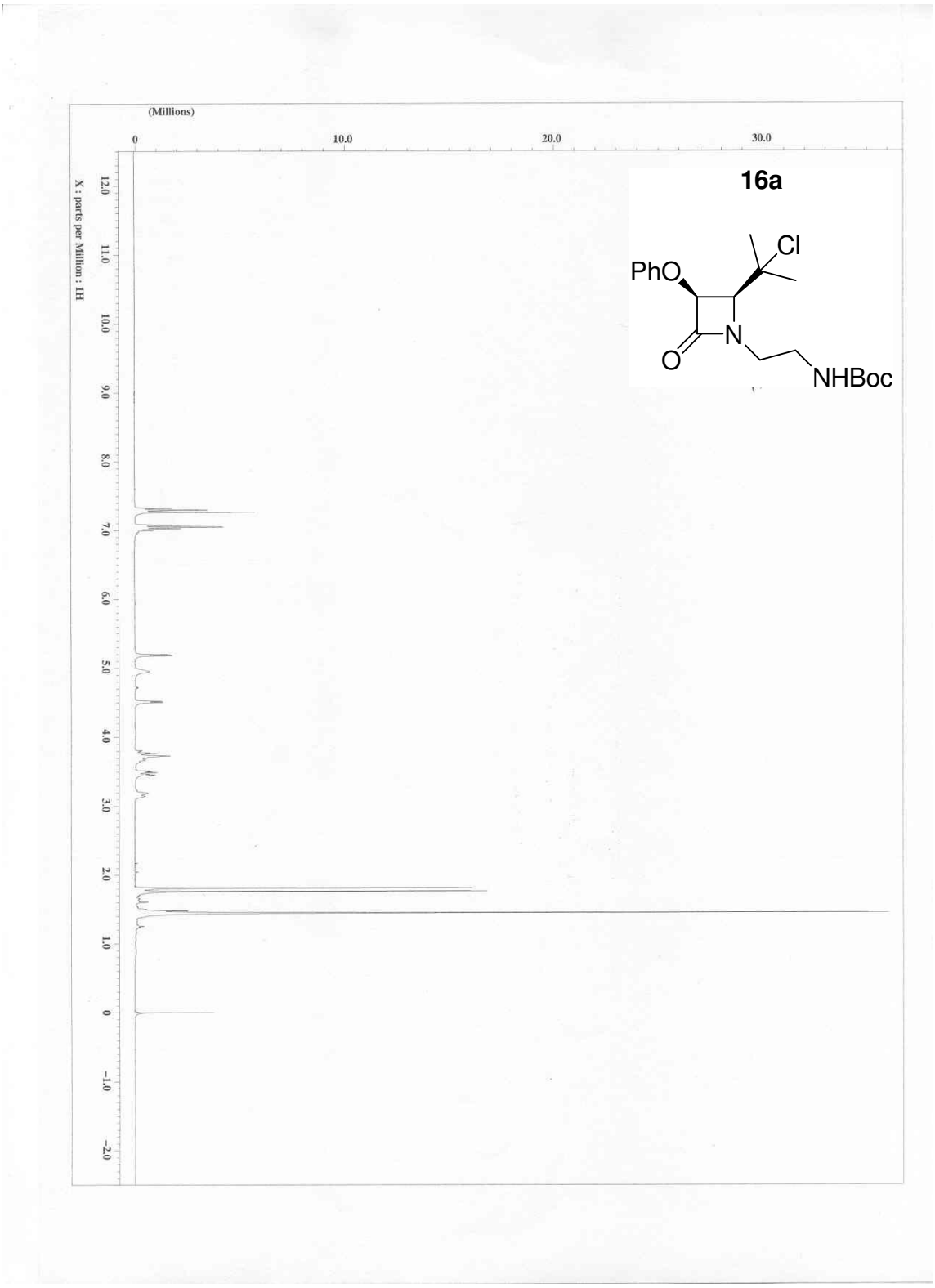


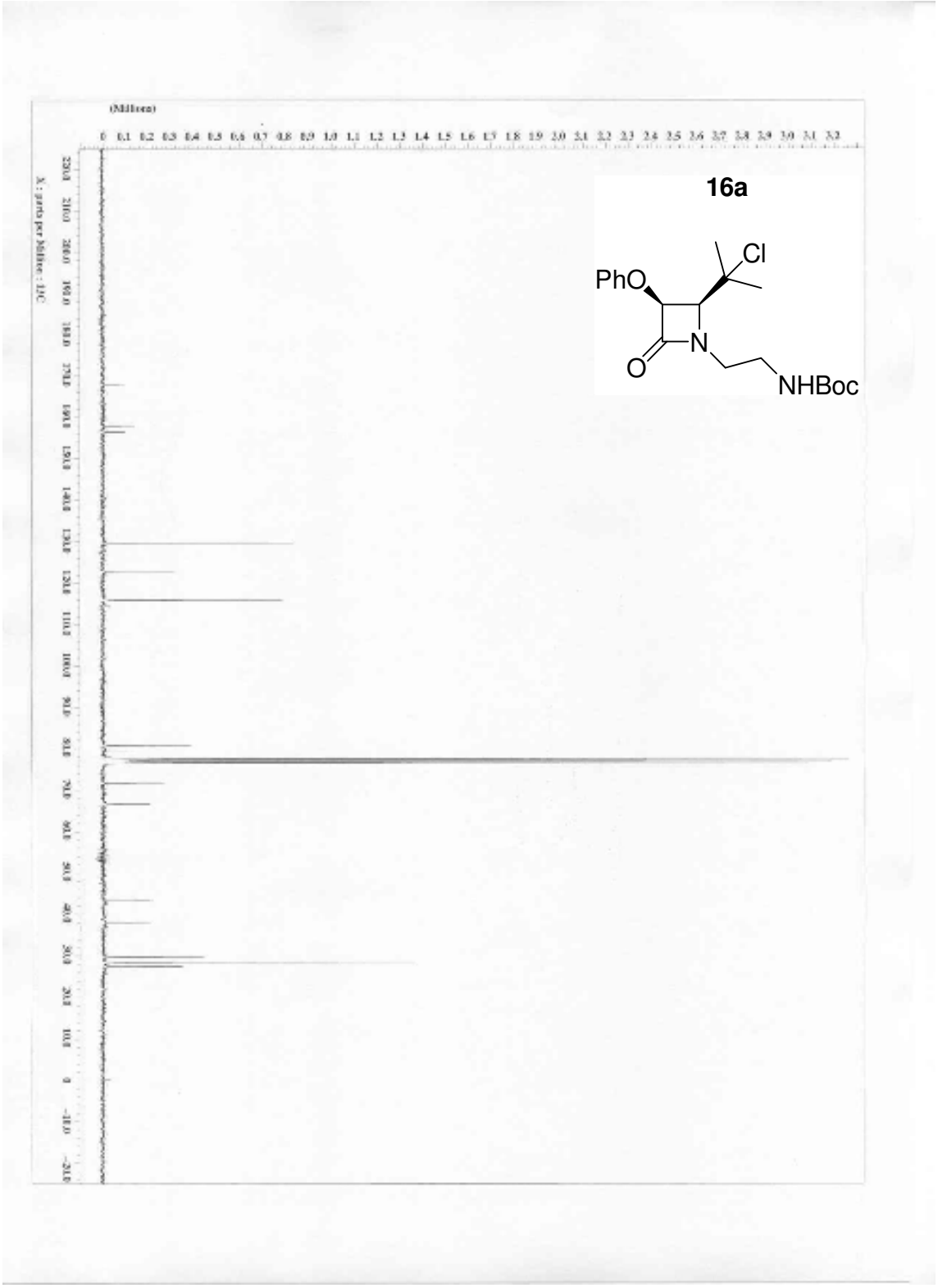
^{13}C NMR **6f**



^{1}H NMR **16a**


(Millions)
0
10.0
20.0
30.0
X : parts per Million : 1H
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
−1.0
−2.0
16a
PhO
Cl
N
O
NHBoc

^{13}C NMR **16a**



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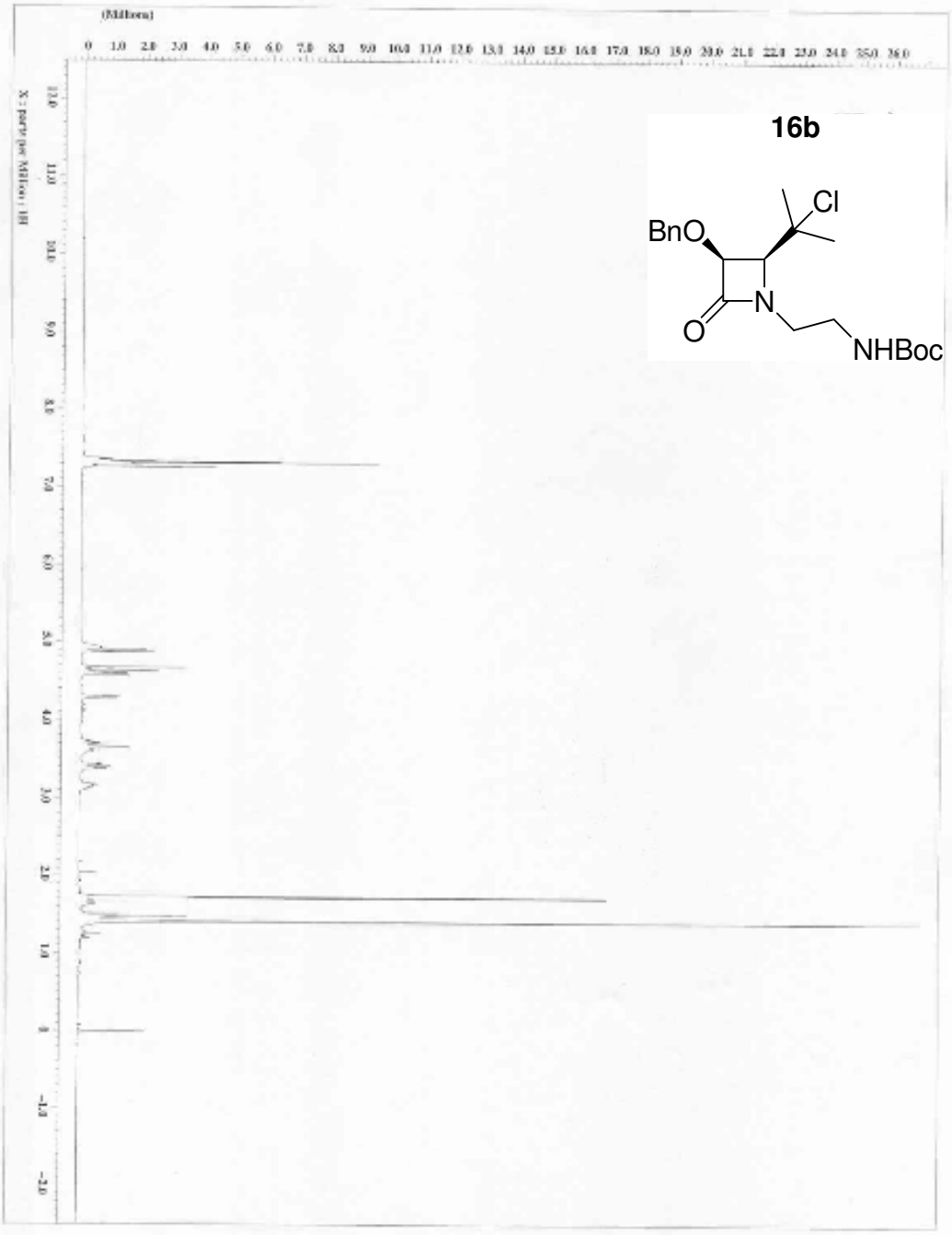
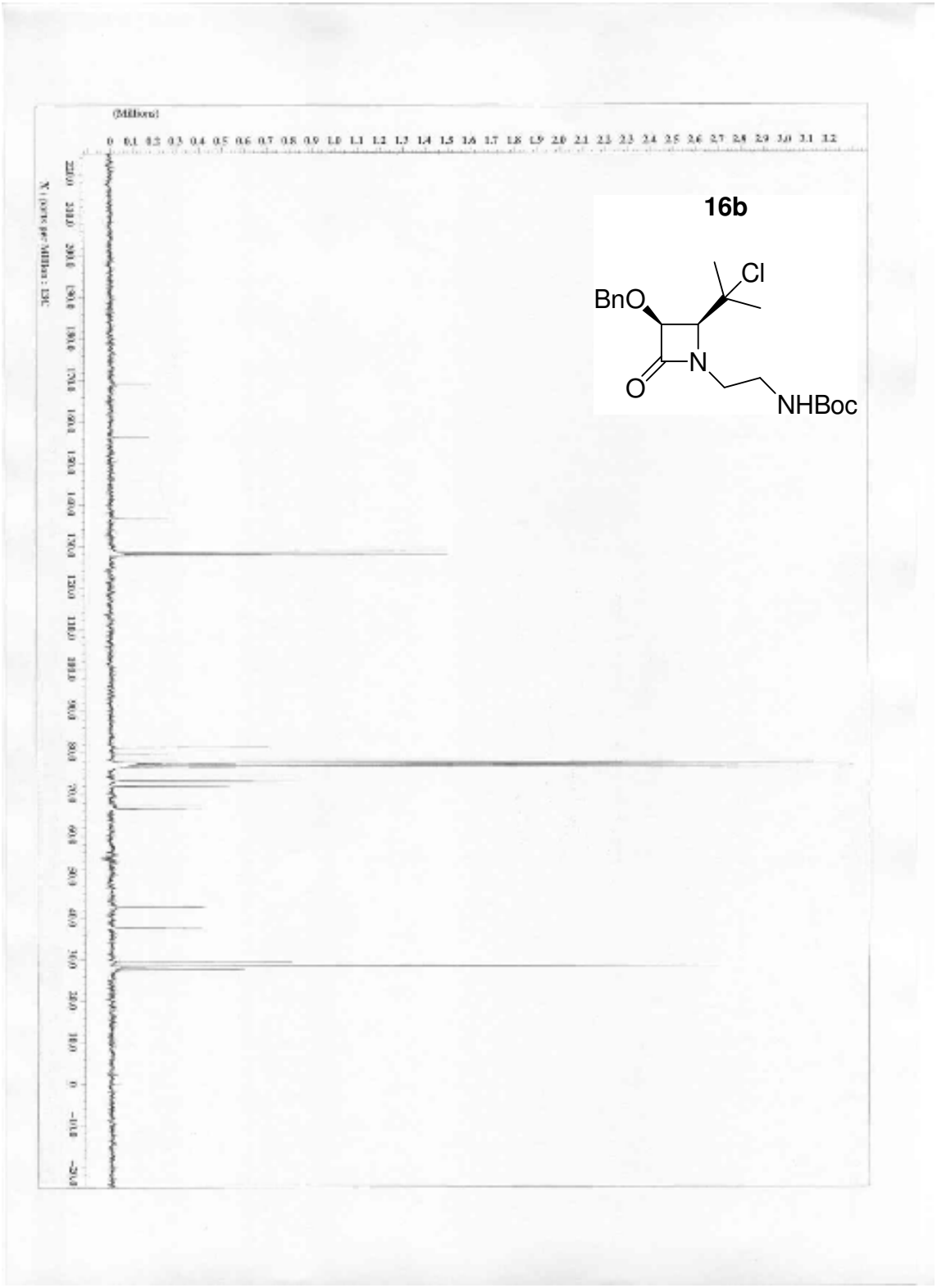


^{13}C NMR **16b**



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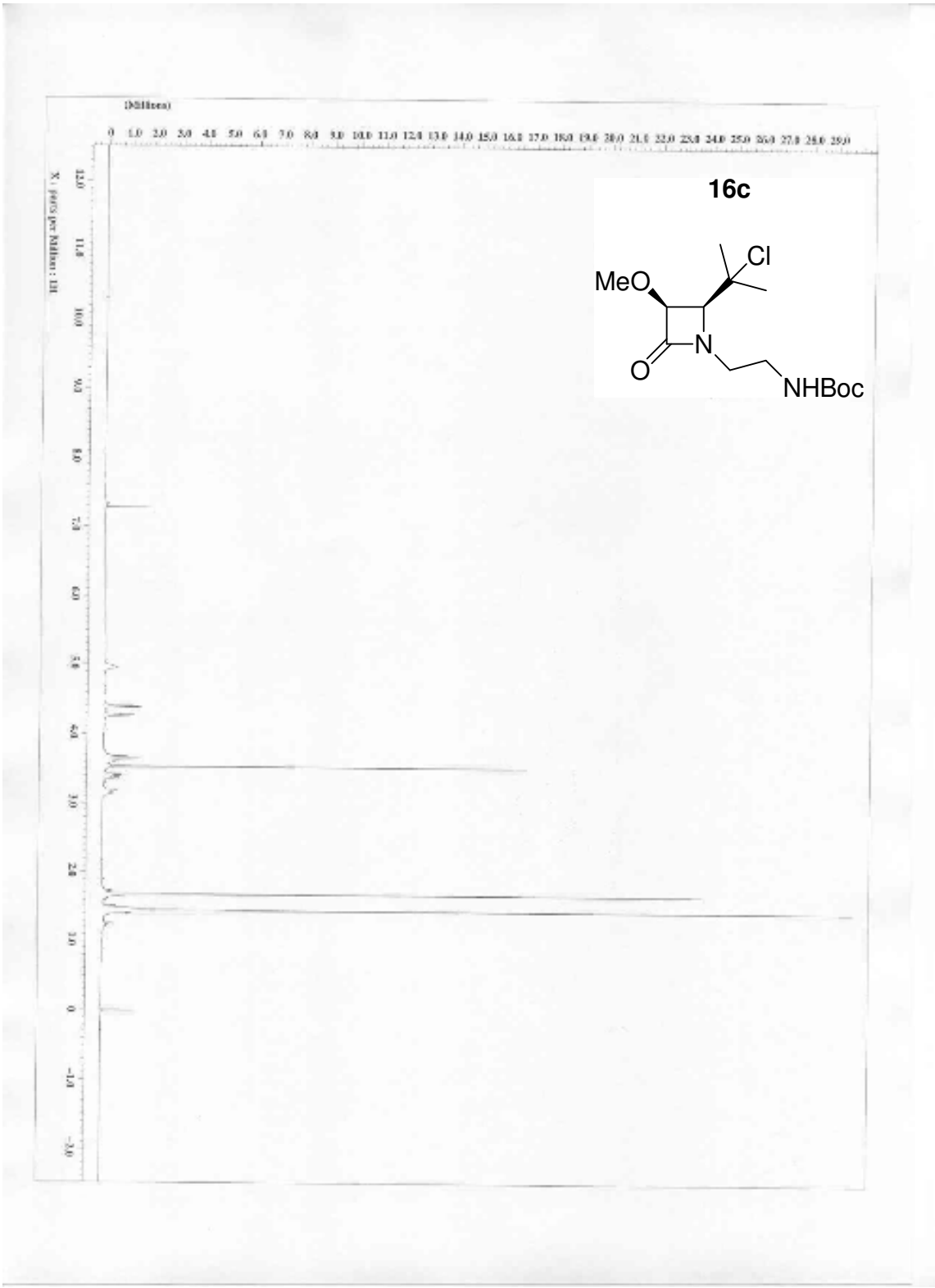

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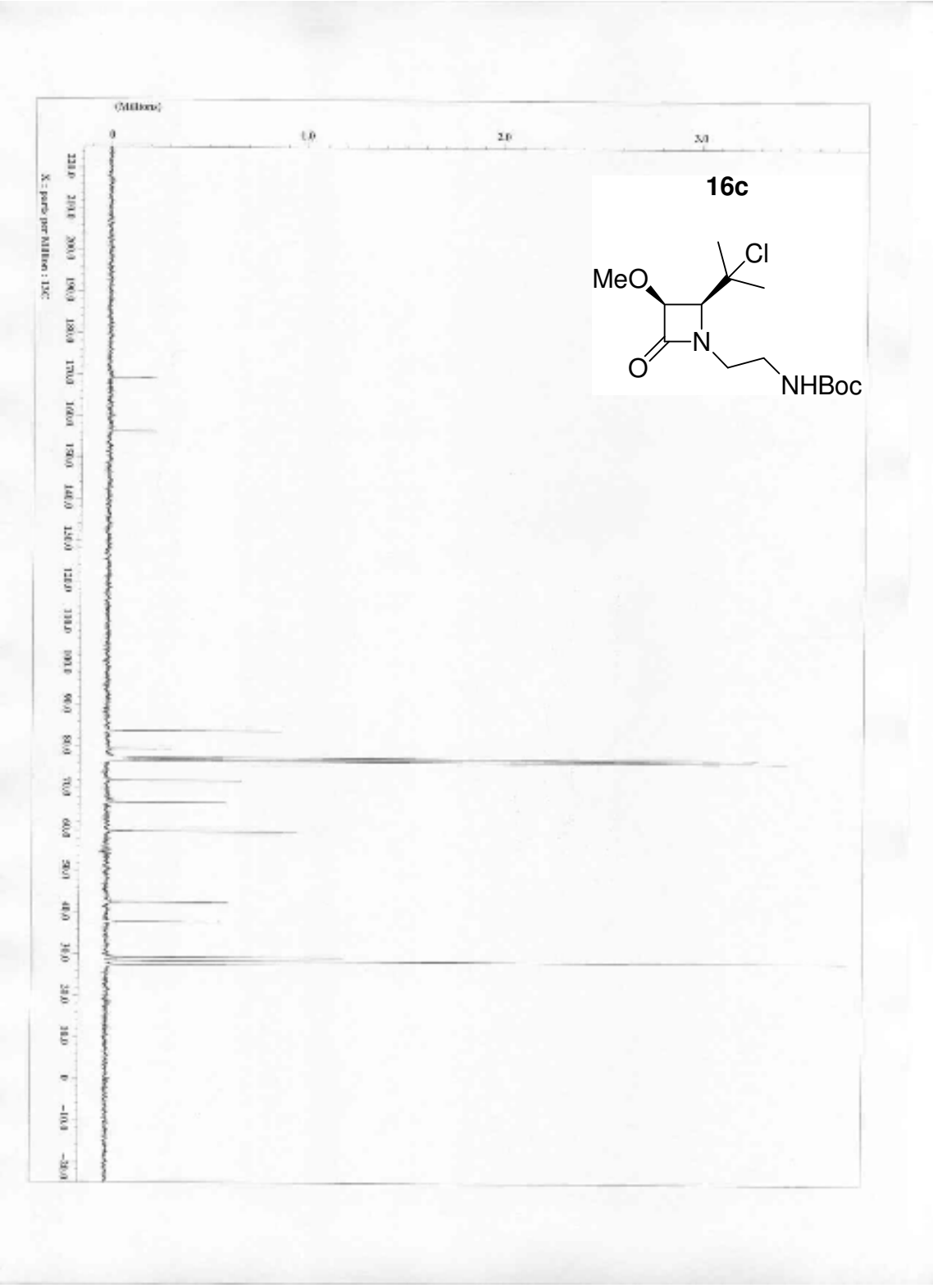

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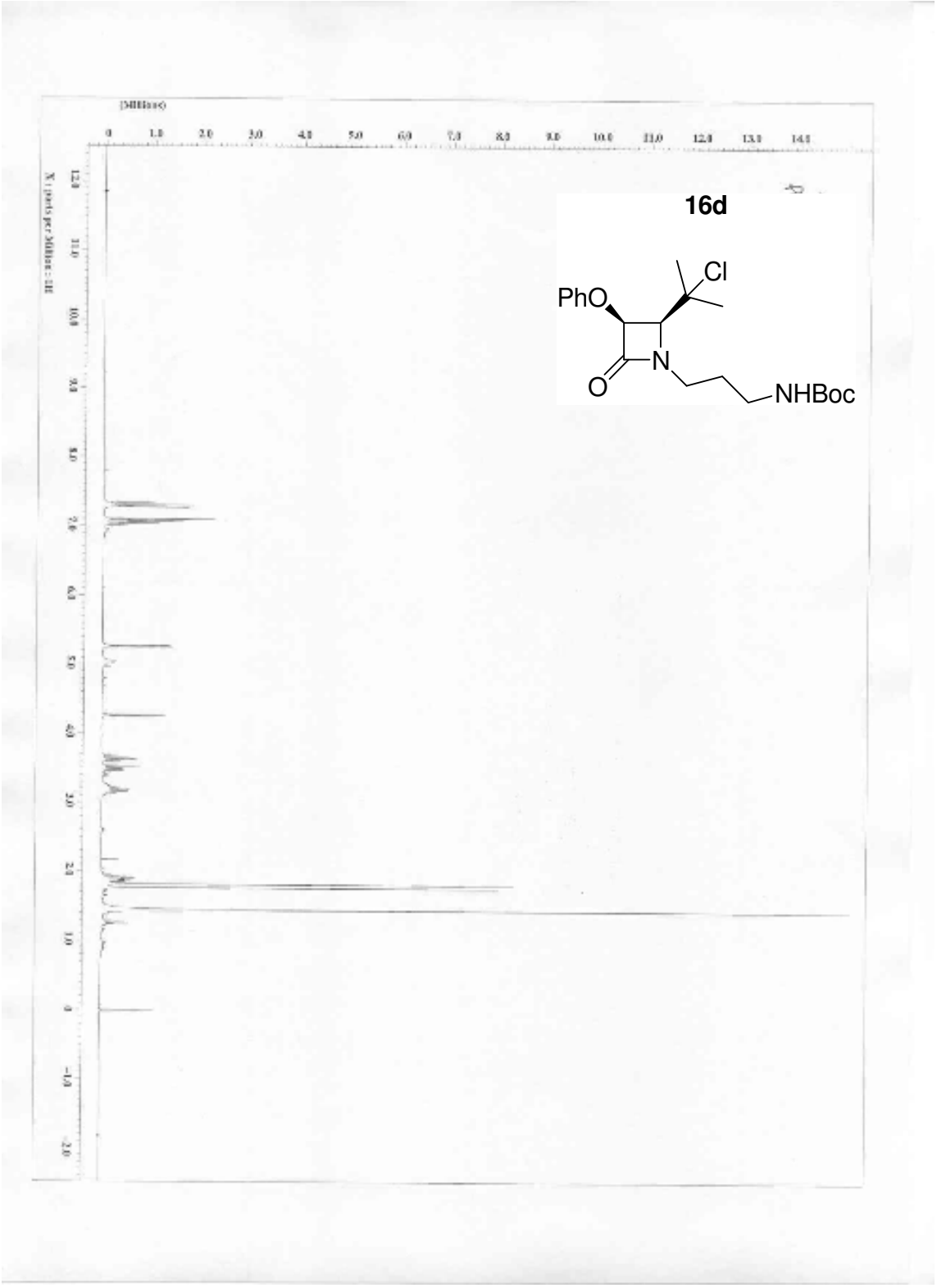

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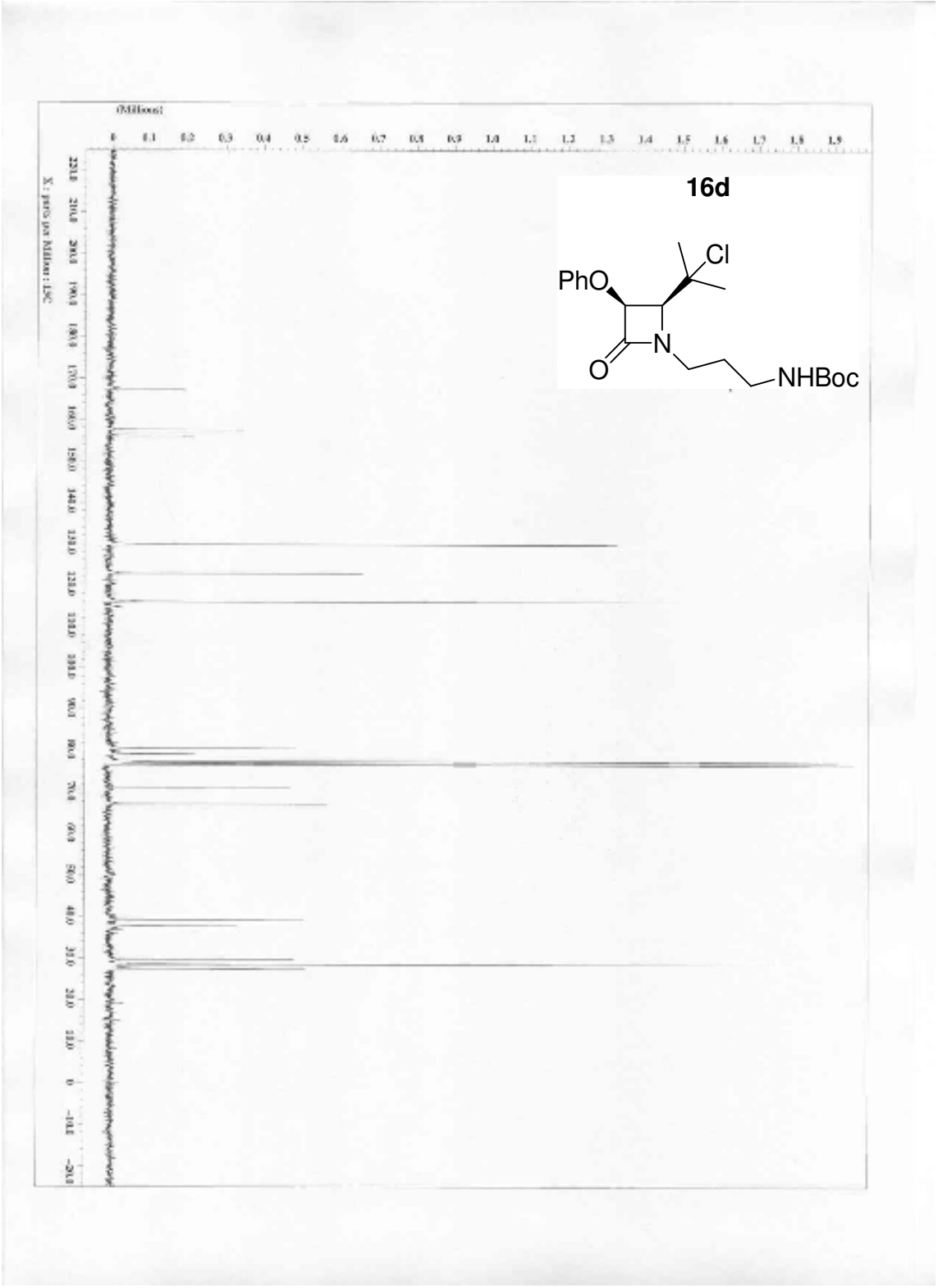
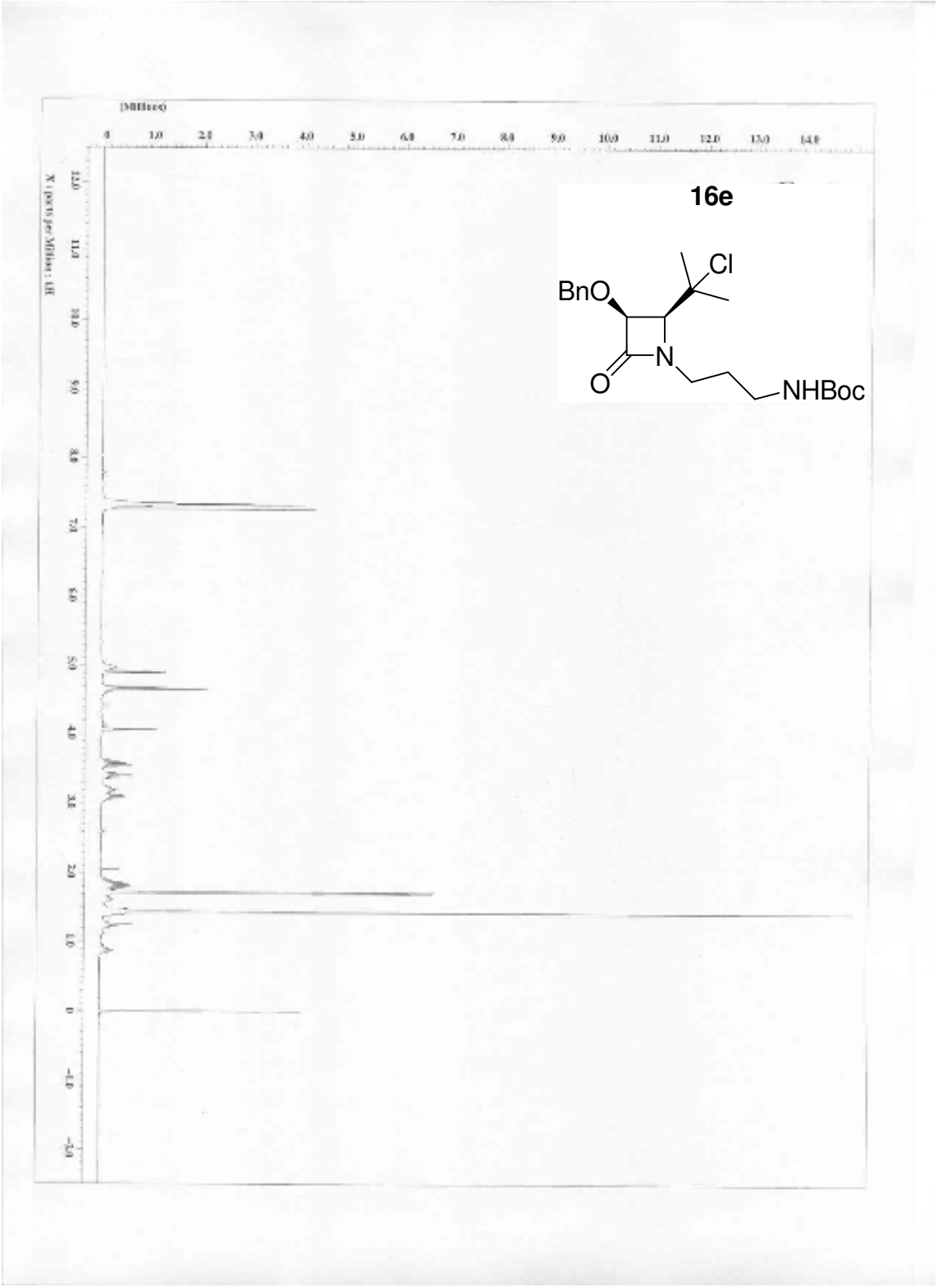


^{1}H NMR **16e**



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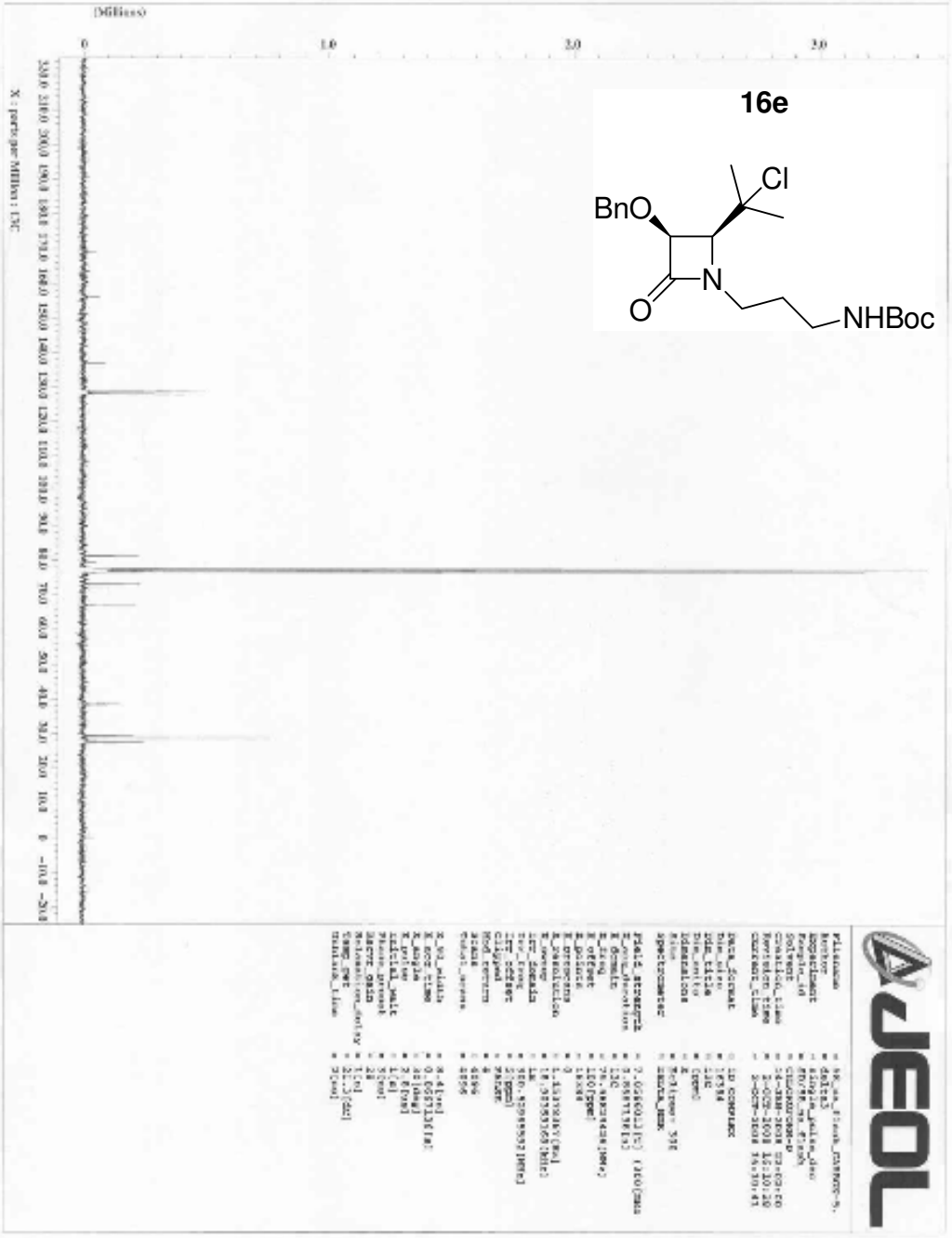
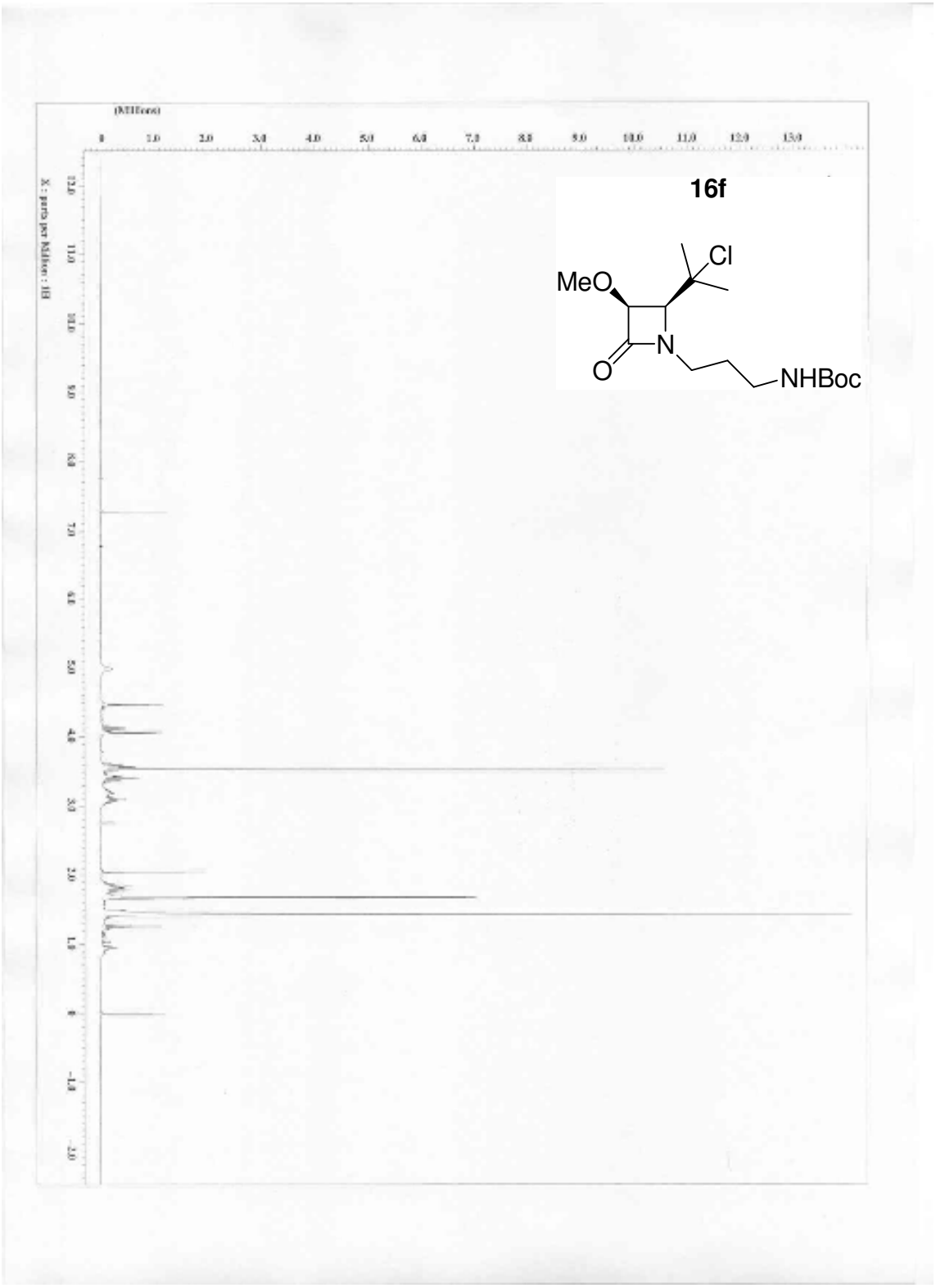
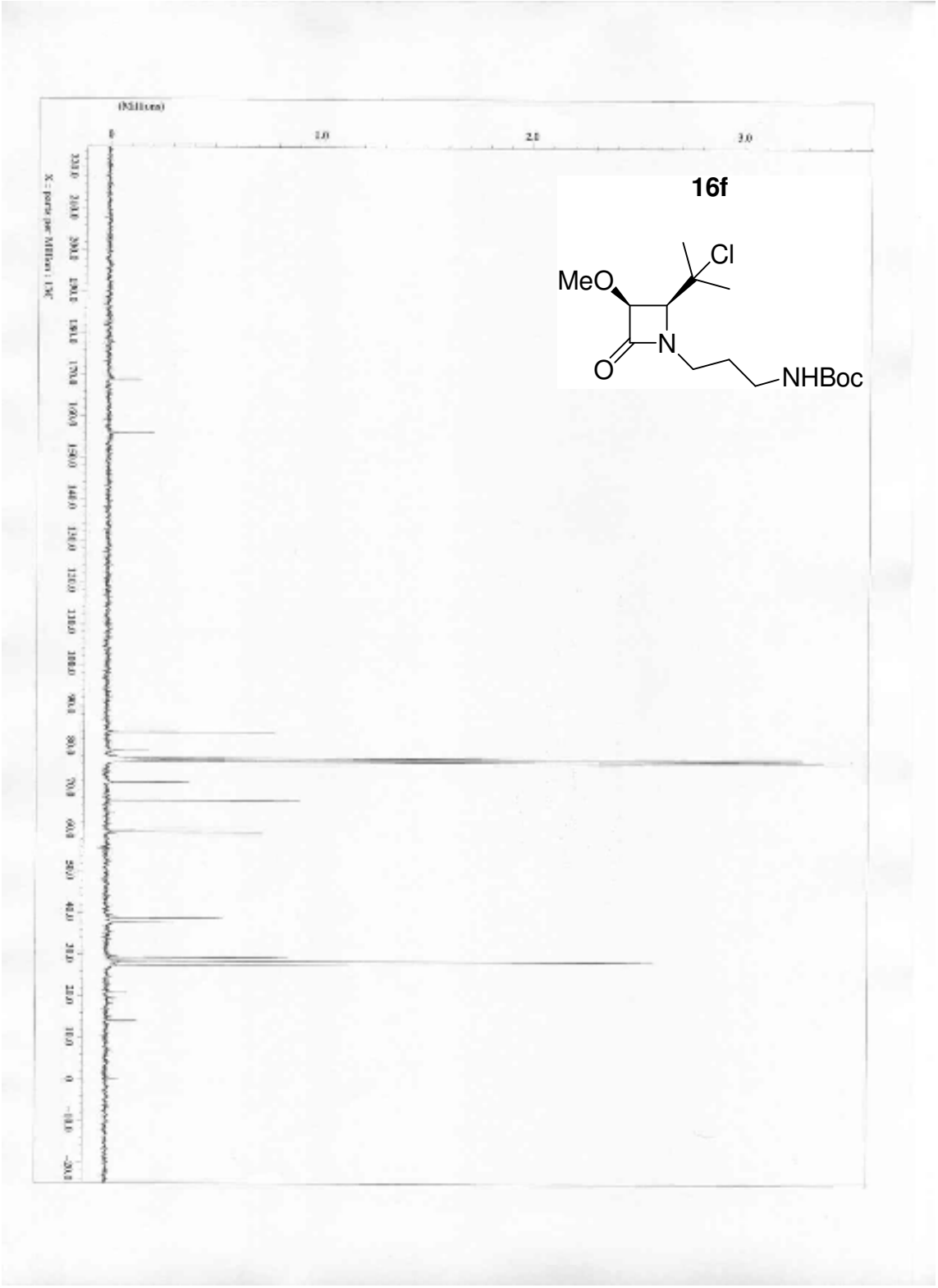


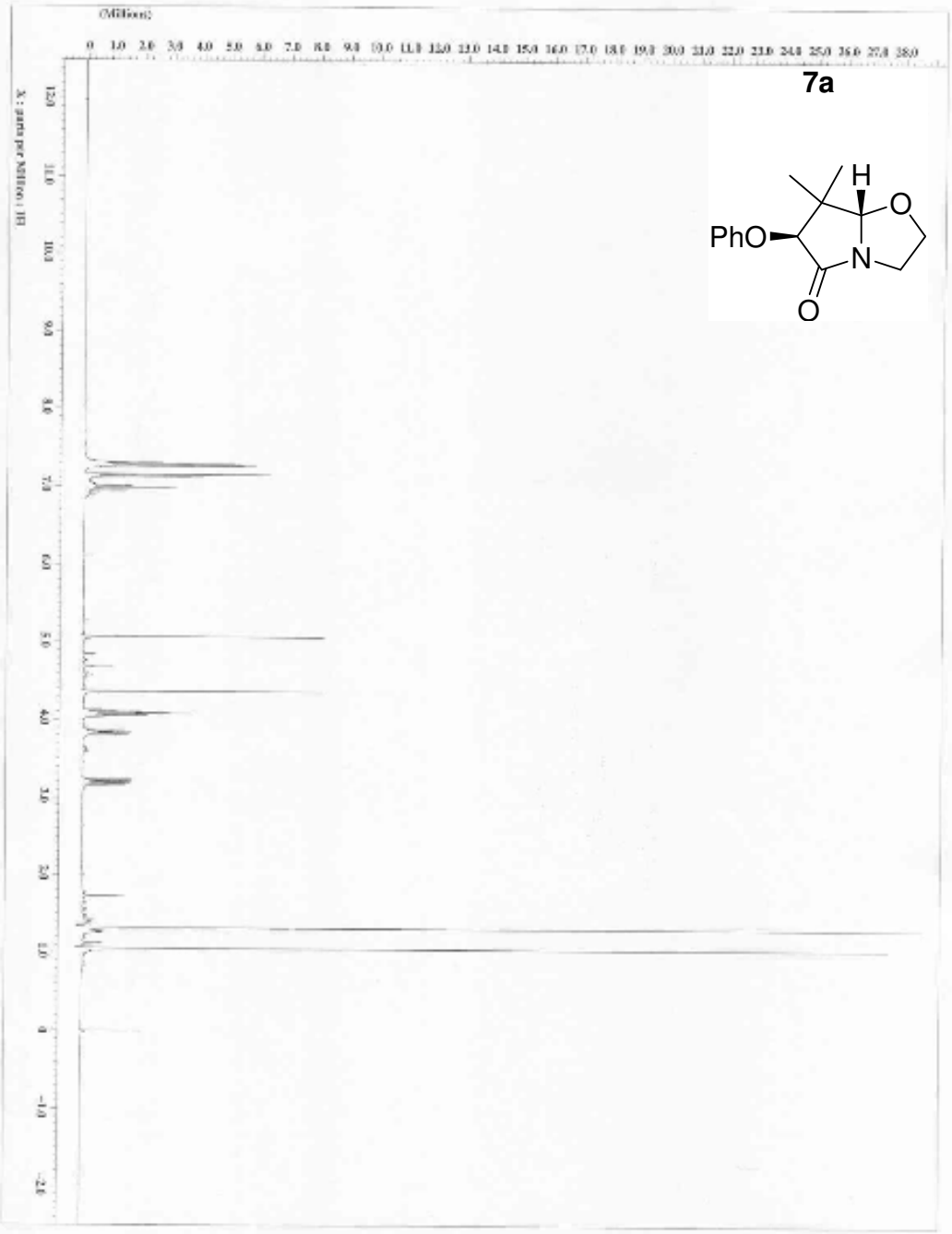
^{1}H NMR **16f**



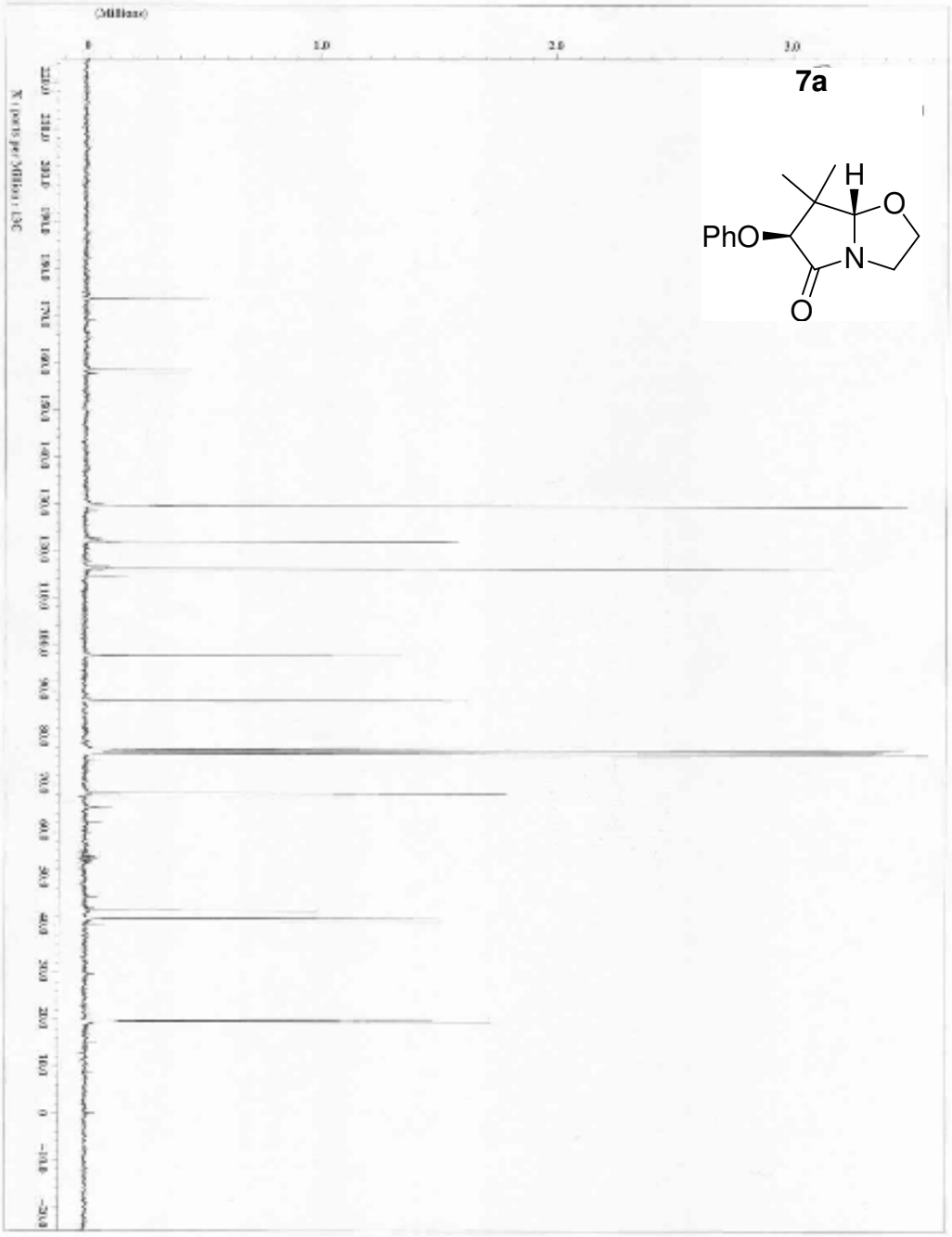
^{13}C NMR **16f**



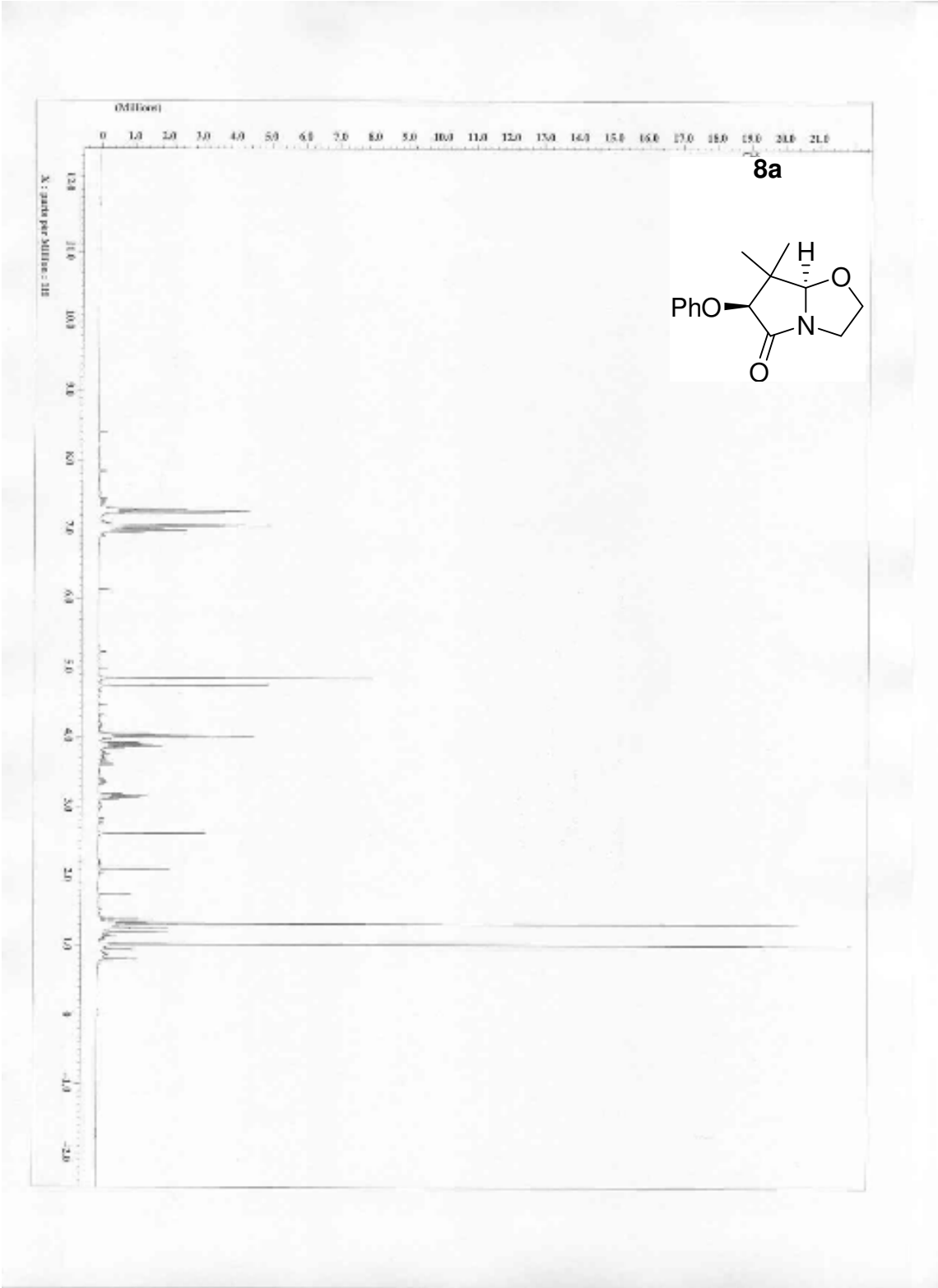
^{1}H NMR **7a**



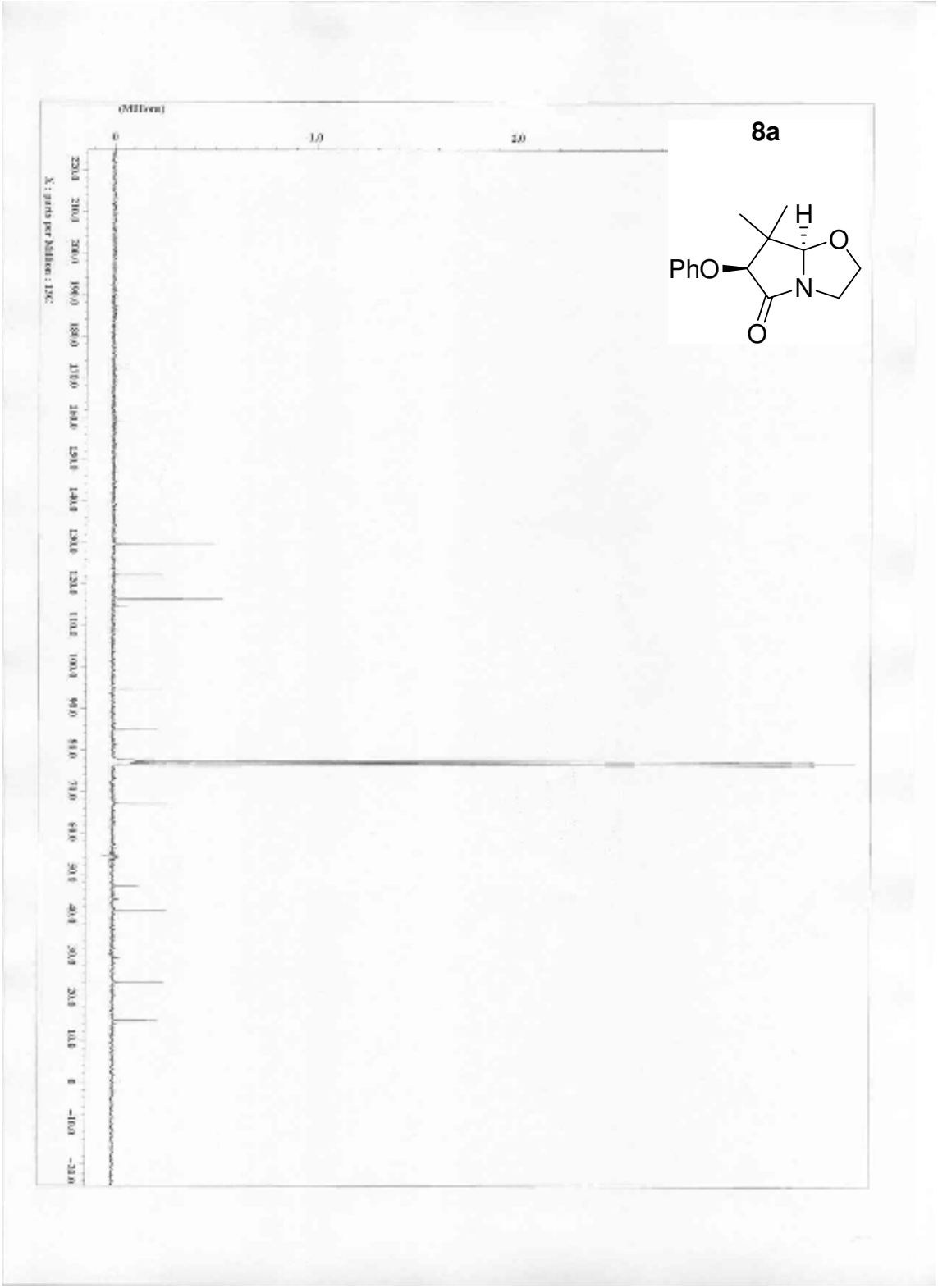
^{13}C NMR **7a**



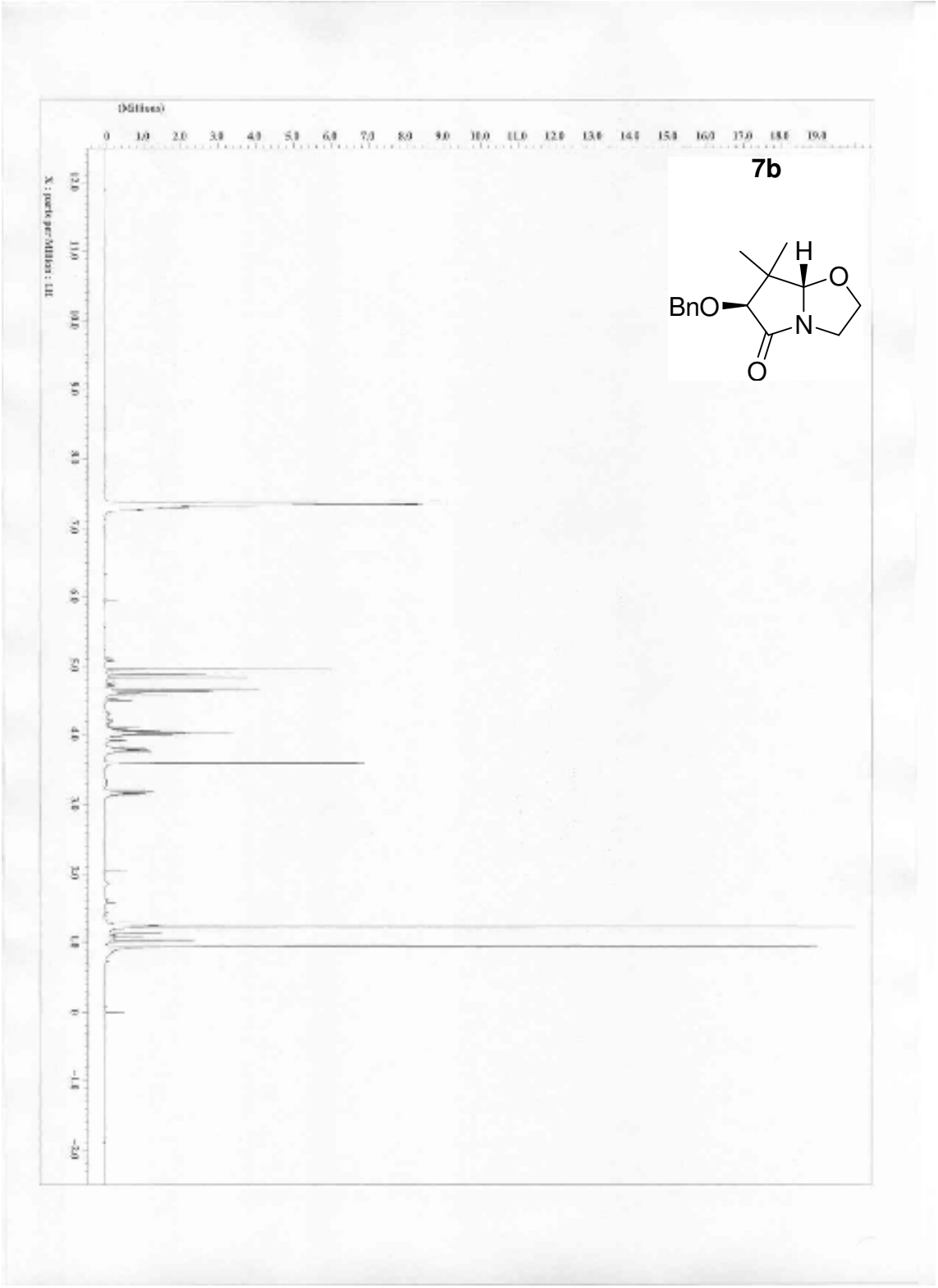
^{1}H NMR **8a**



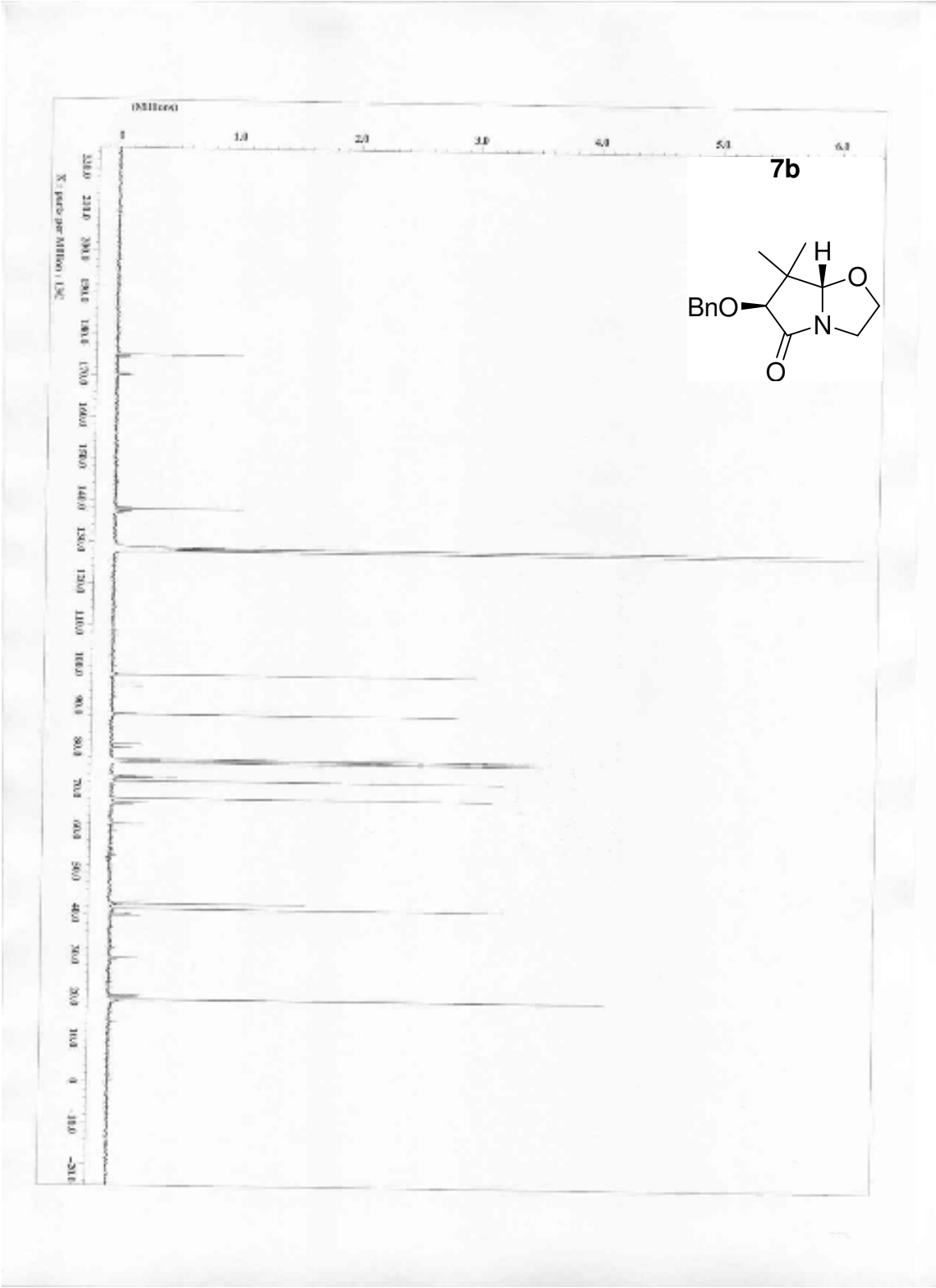
^{13}C NMR **8a**



^{1}H NMR **7b**



^{13}C NMR **7b**



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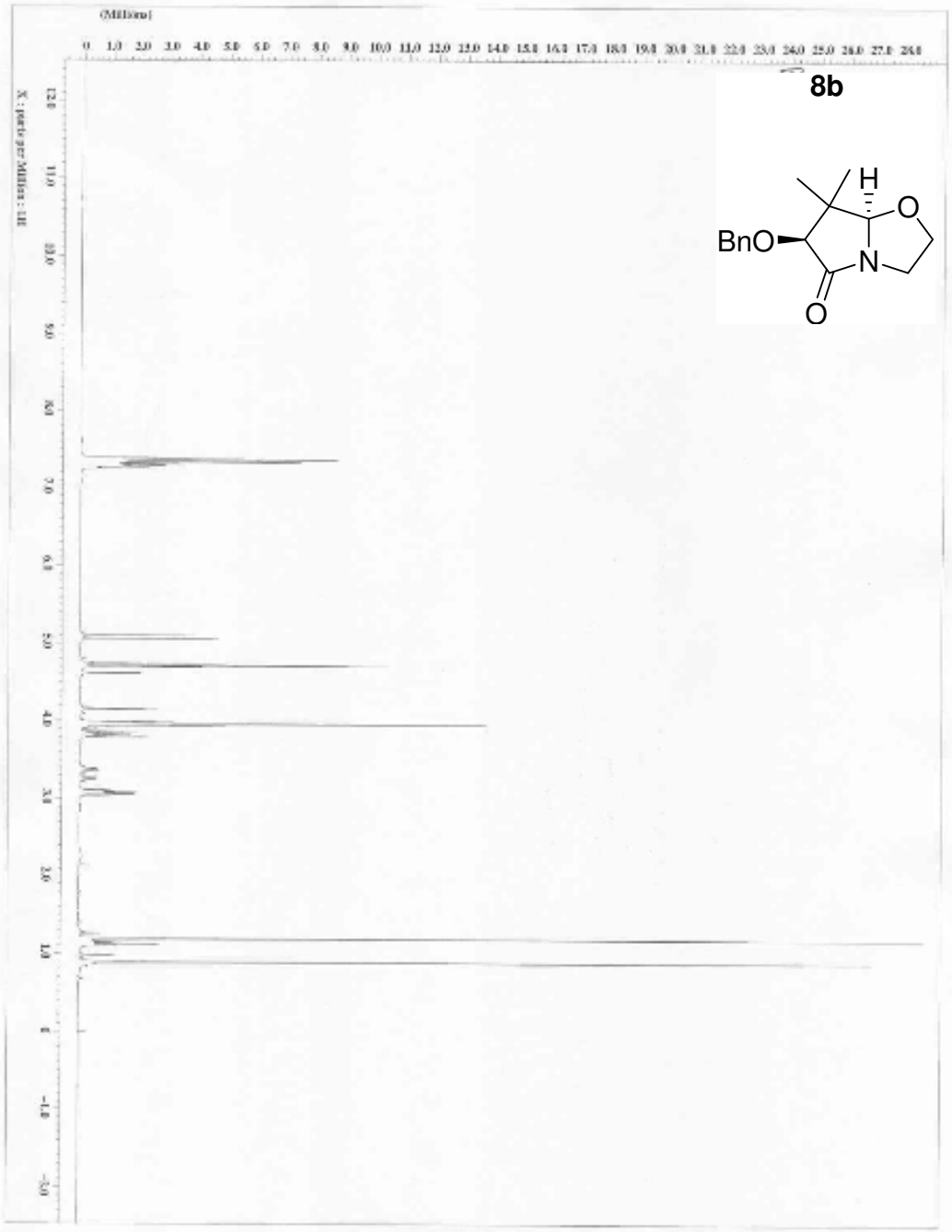
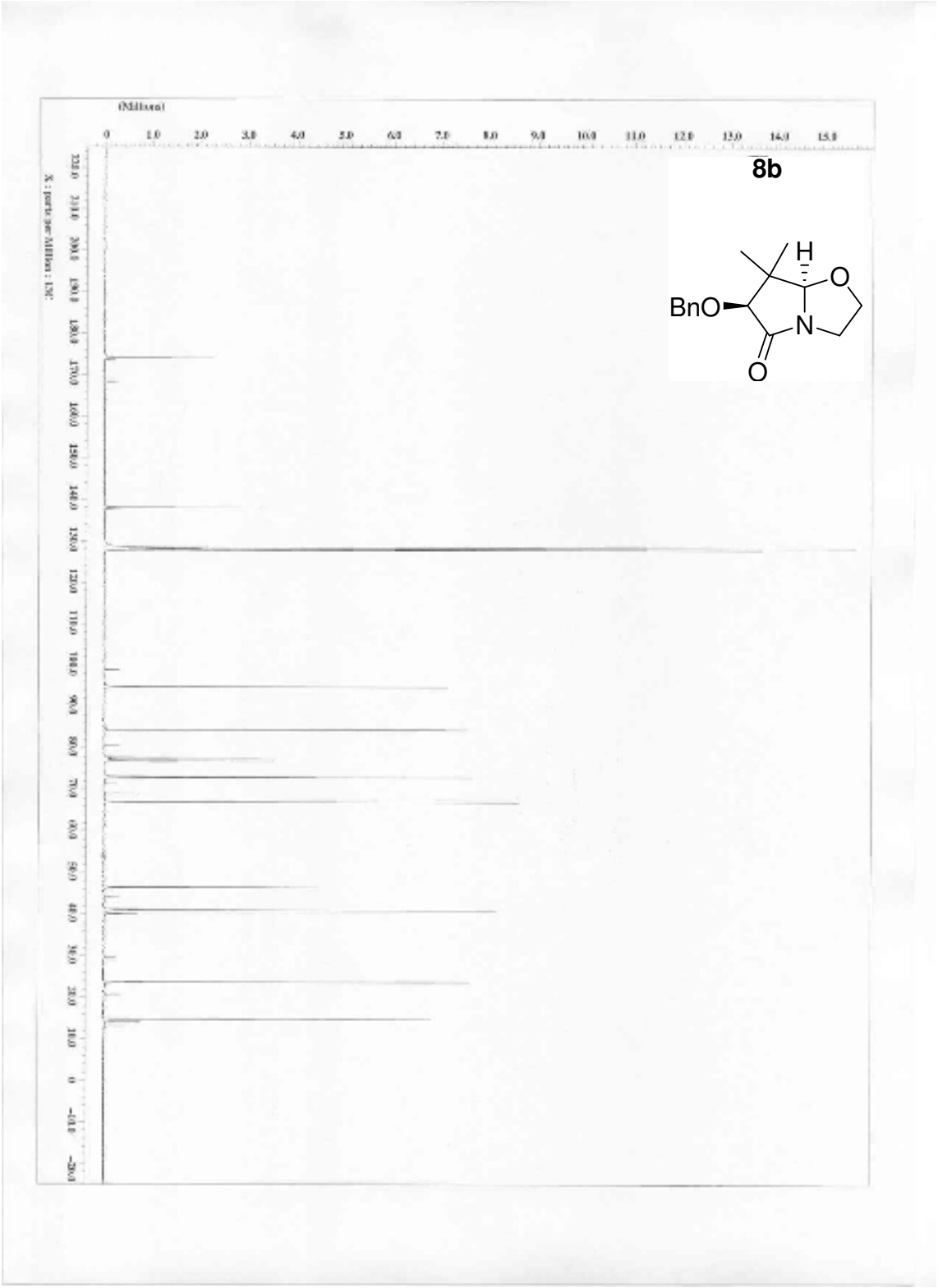
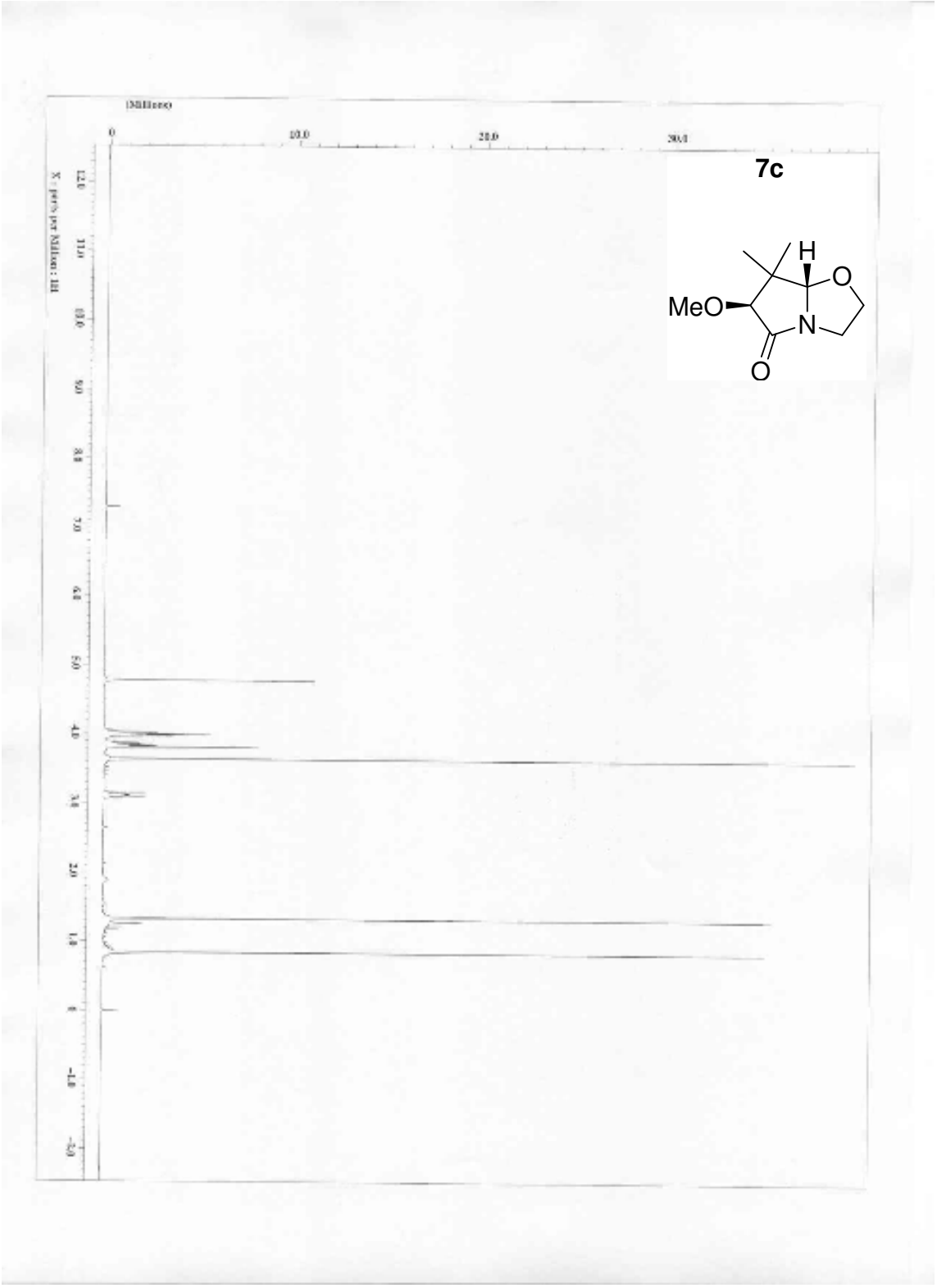


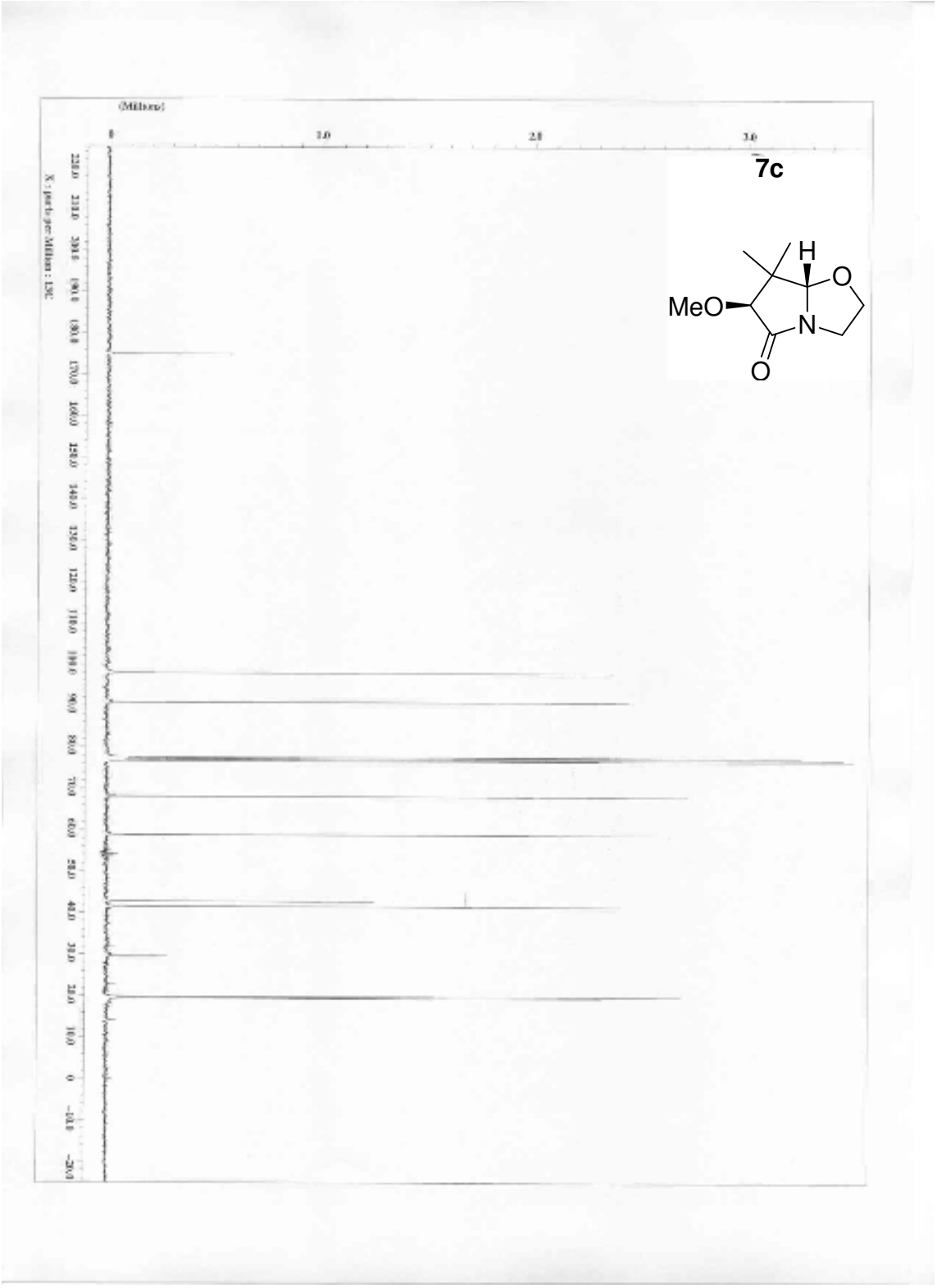
^{13}C NMR **8b**



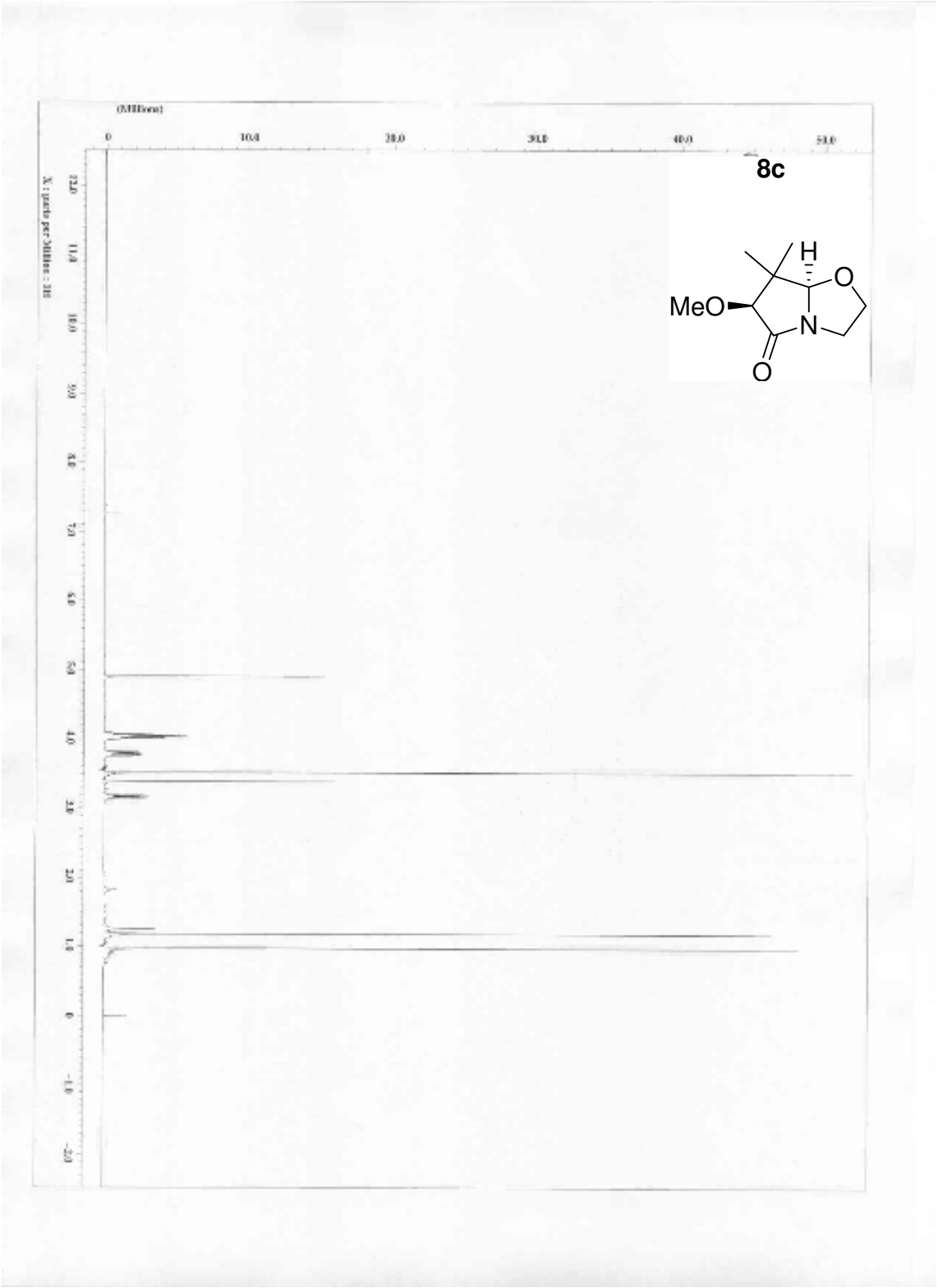
^{1}H NMR **7c**



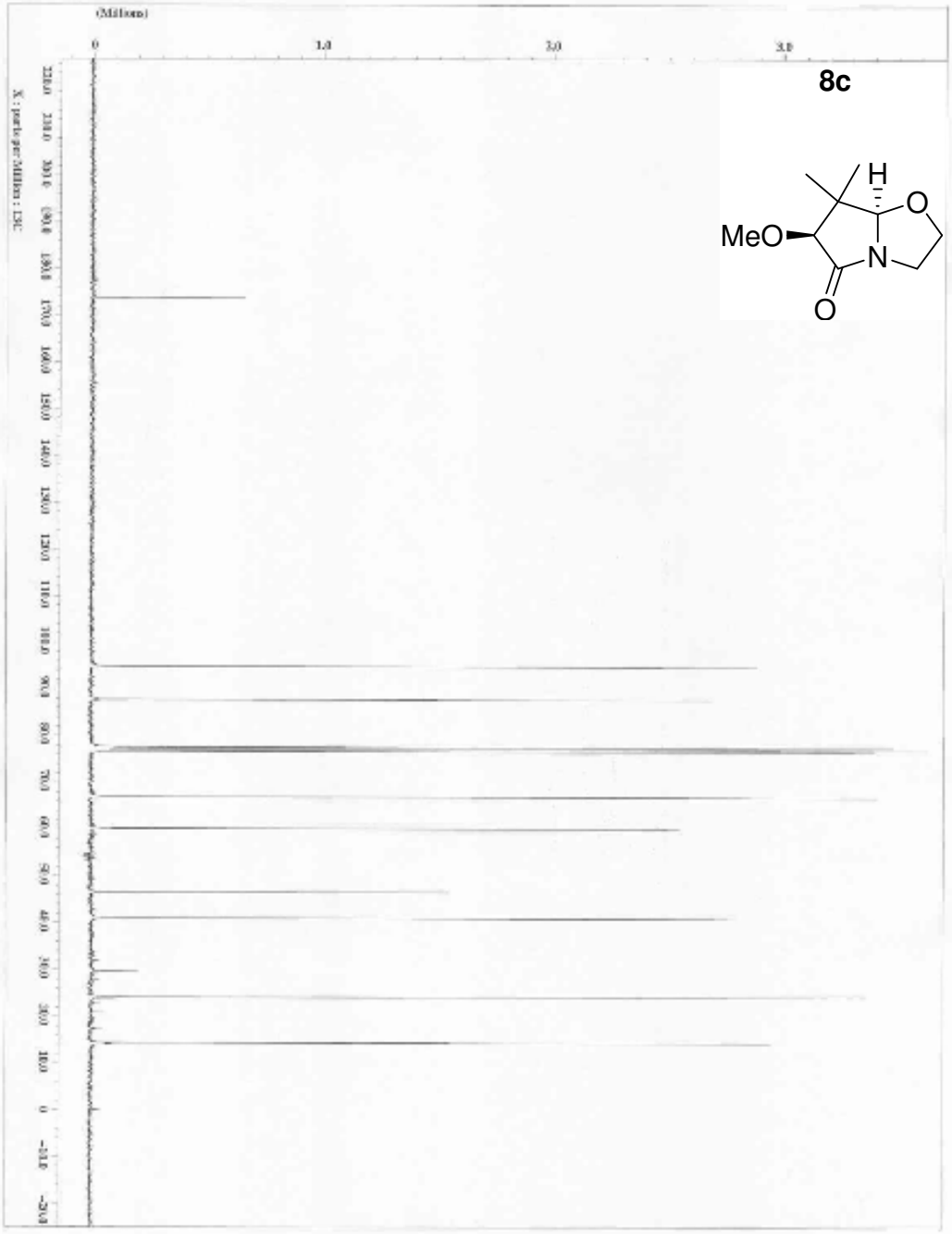
^{13}C NMR **7c**



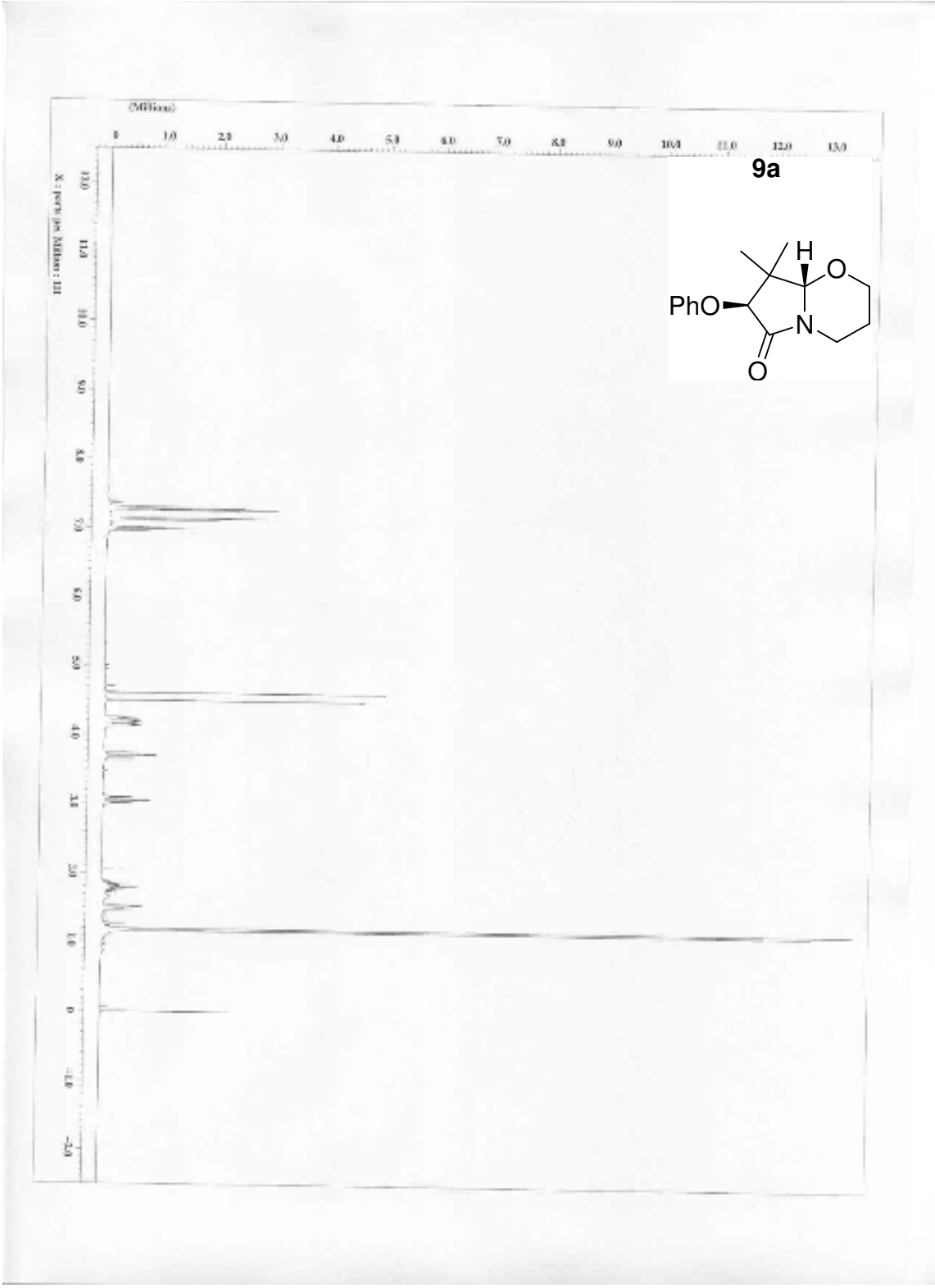
^{1}H NMR **8c**



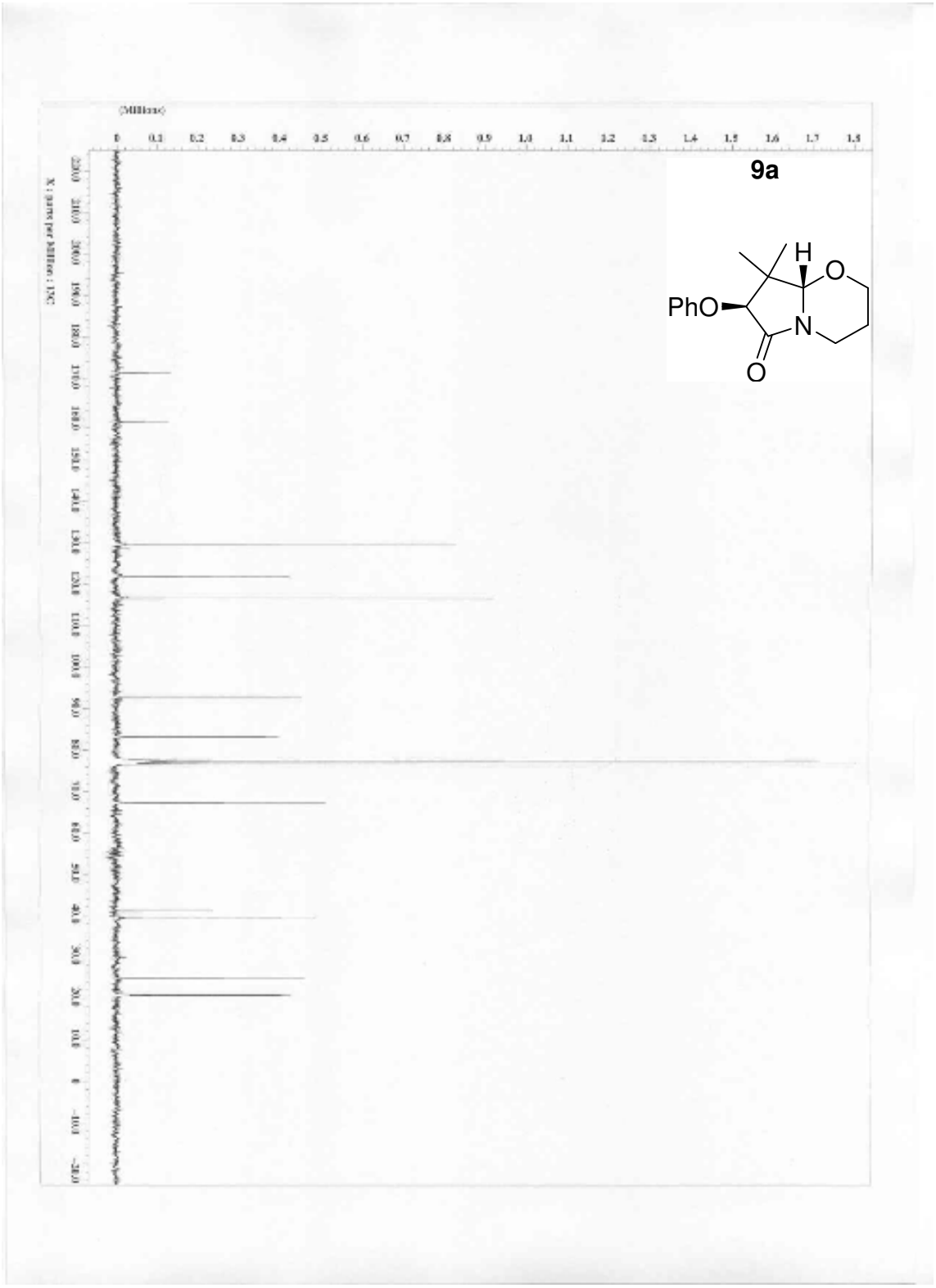
^{13}C NMR **8c**



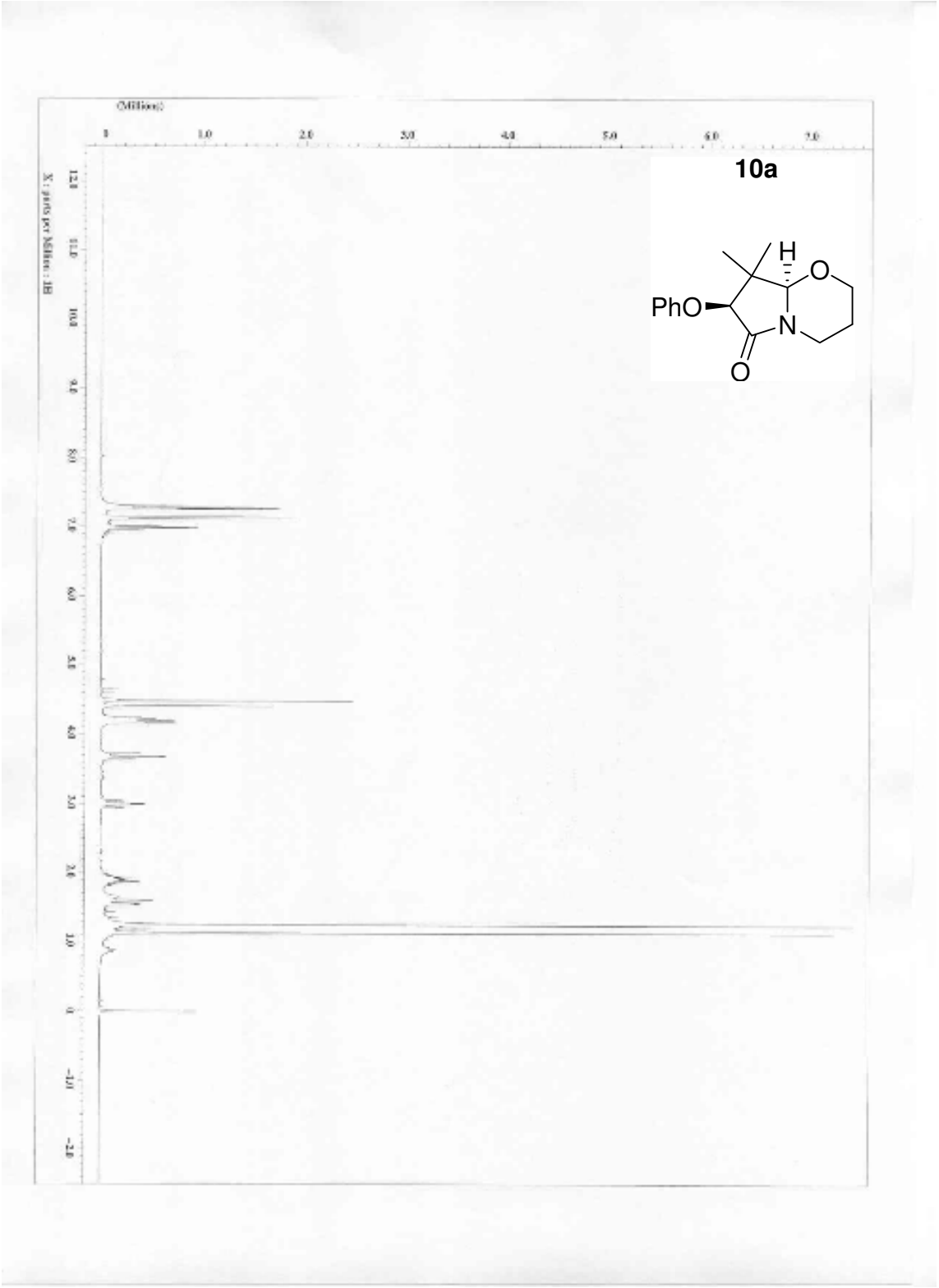
^{1}H NMR **9a**



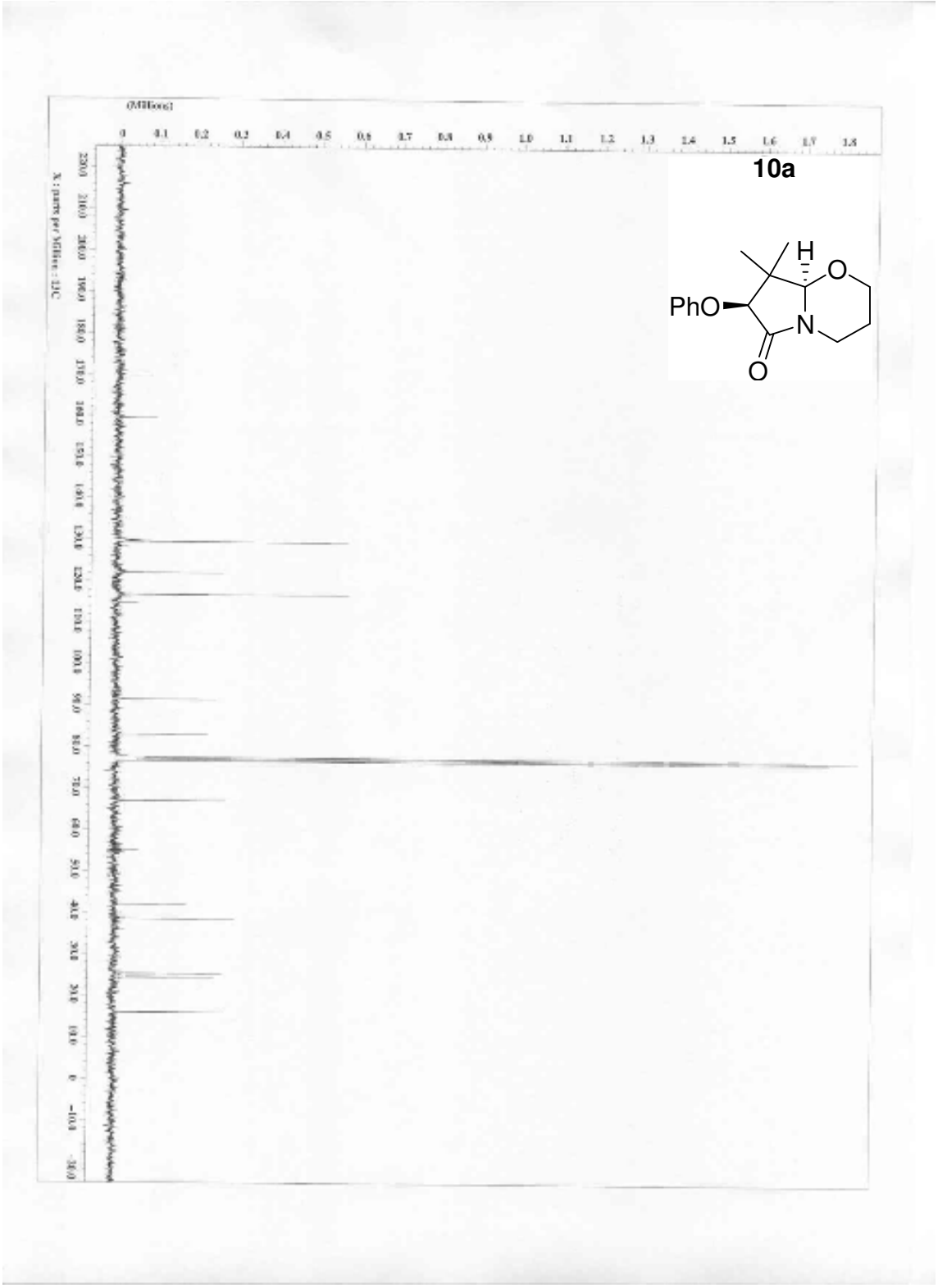
^{13}C NMR **9a**



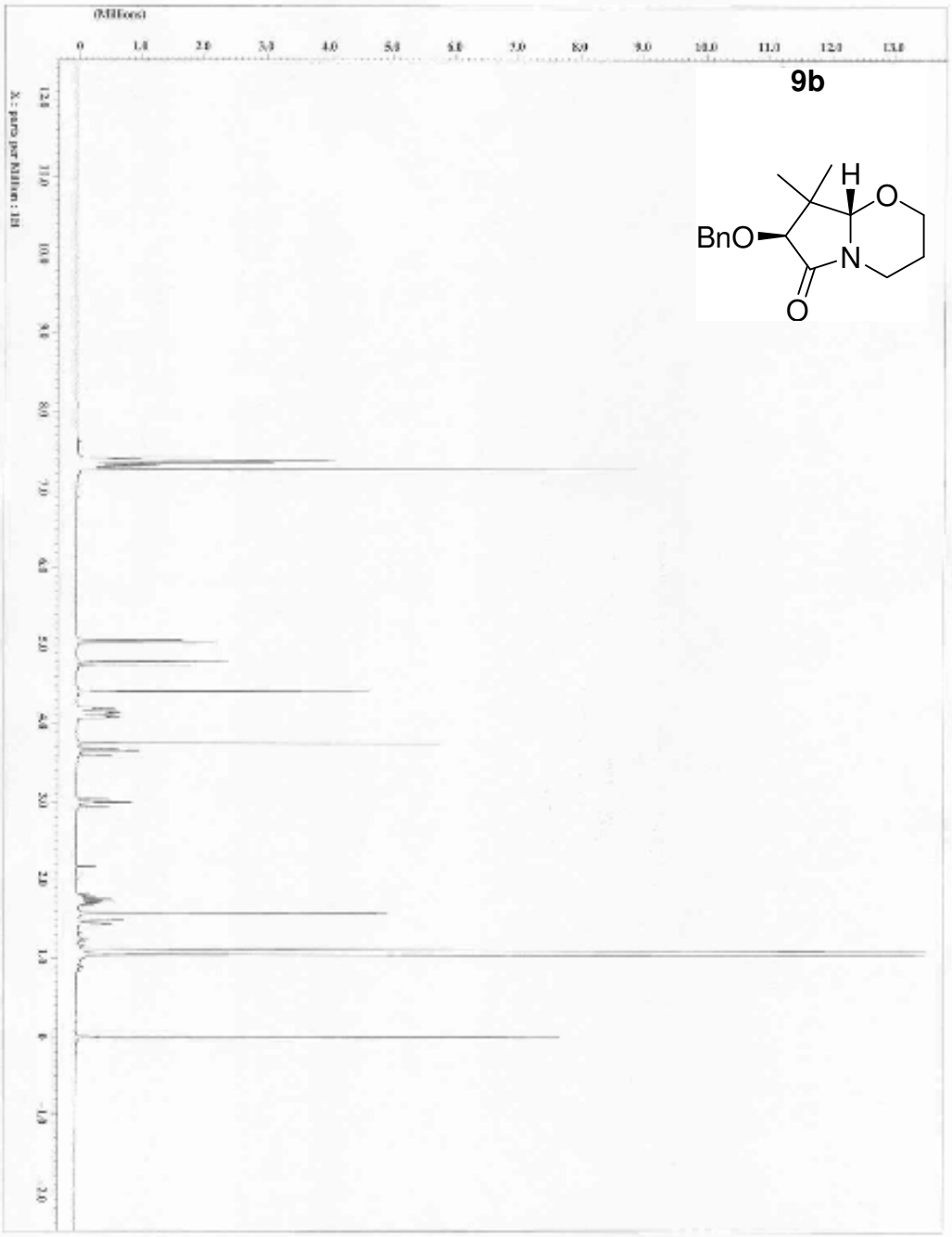
^{1}H NMR **10a**



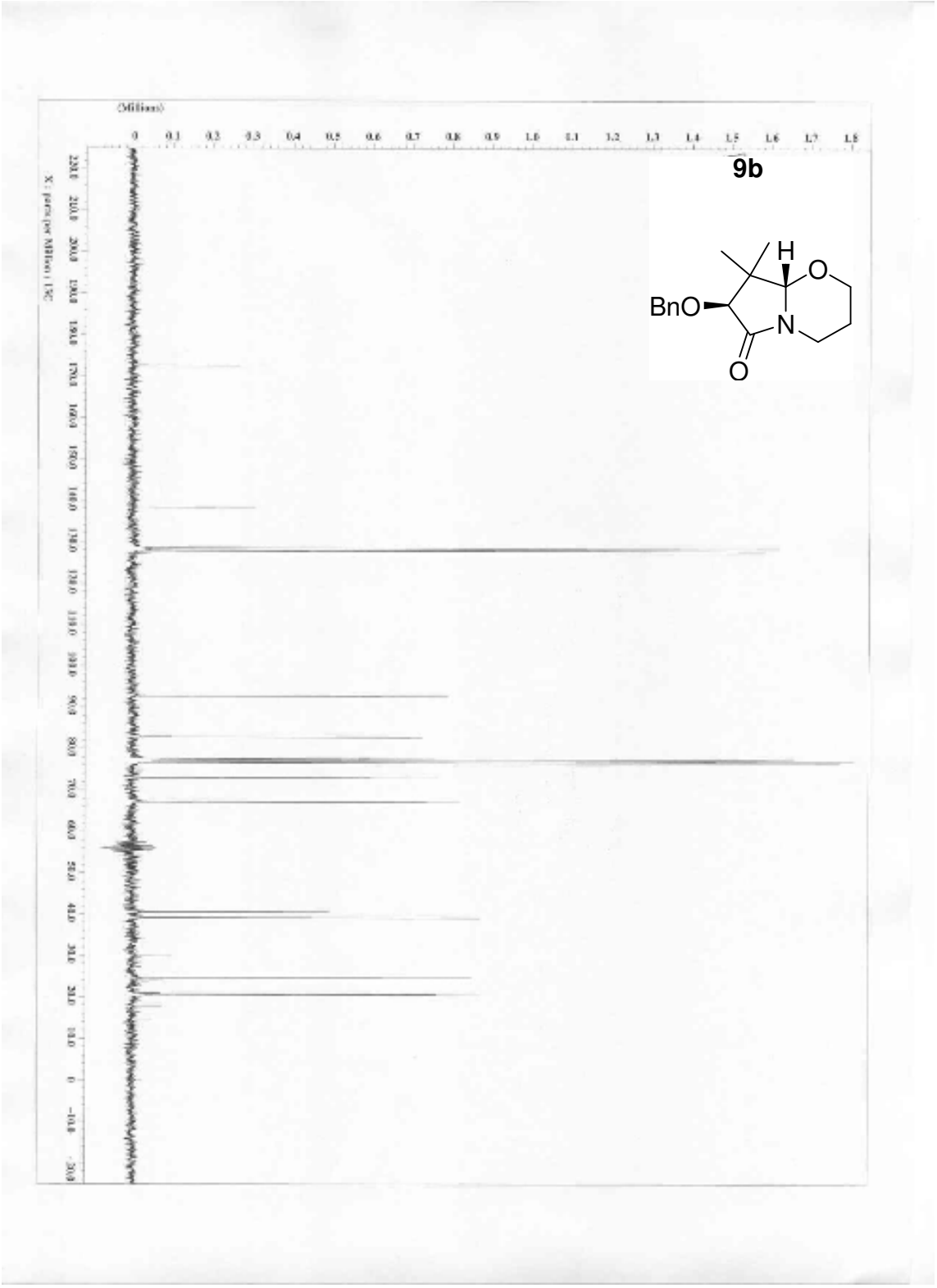
^{13}C NMR **10a**



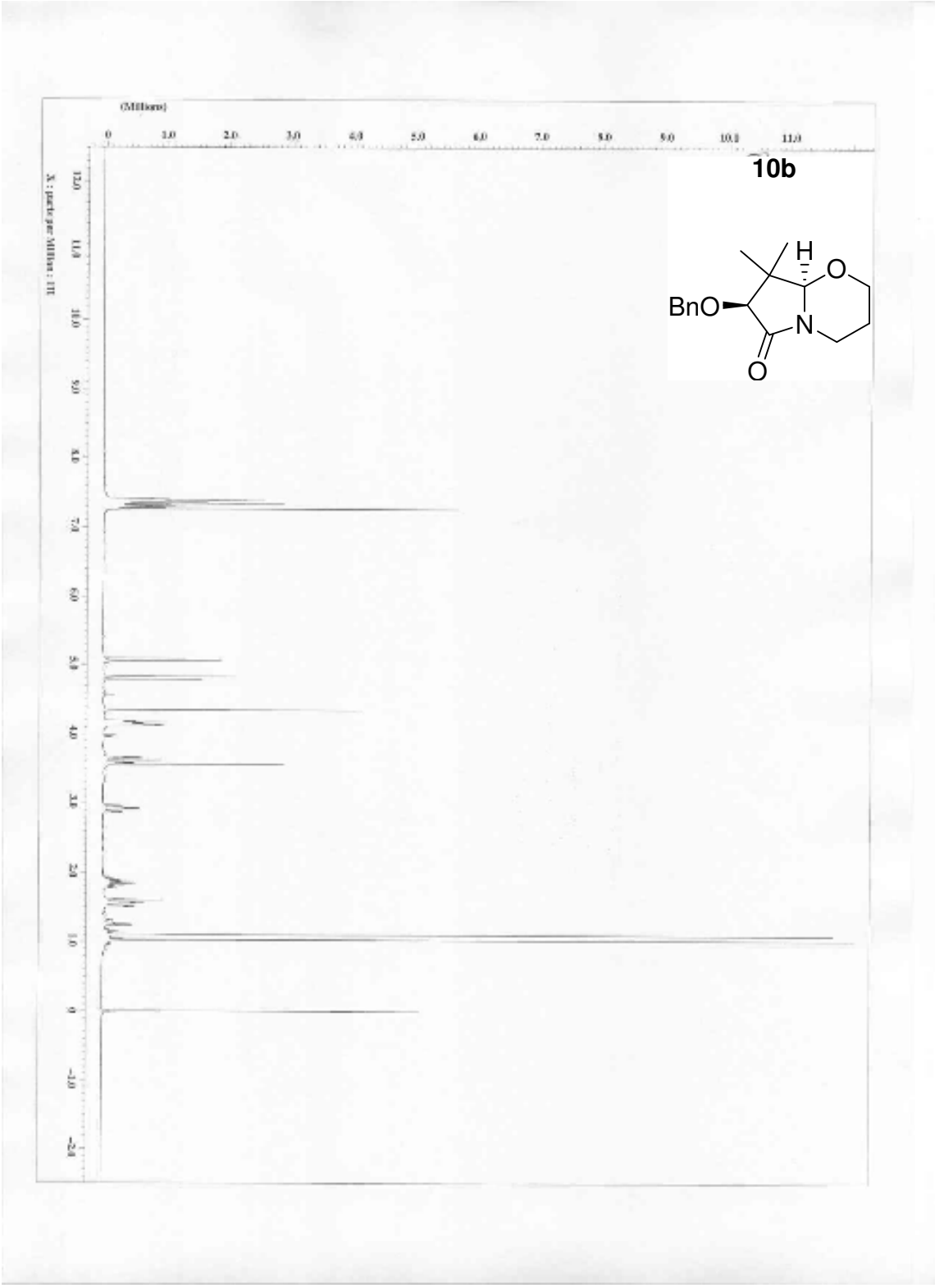
^{1}H NMR **9b**



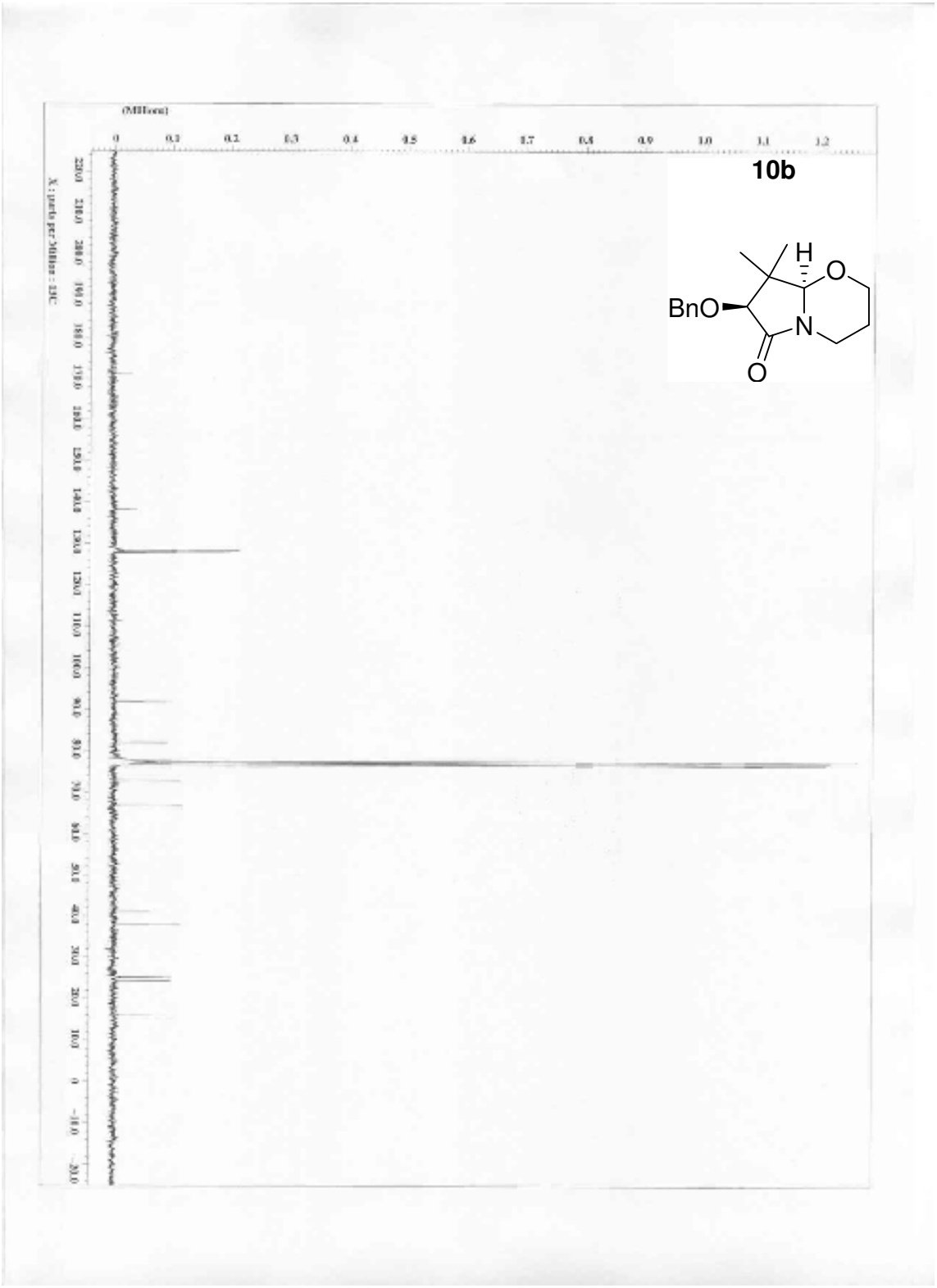
^{13}C NMR **9b**



^{1}H NMR **10b**



^{13}C NMR **10b**



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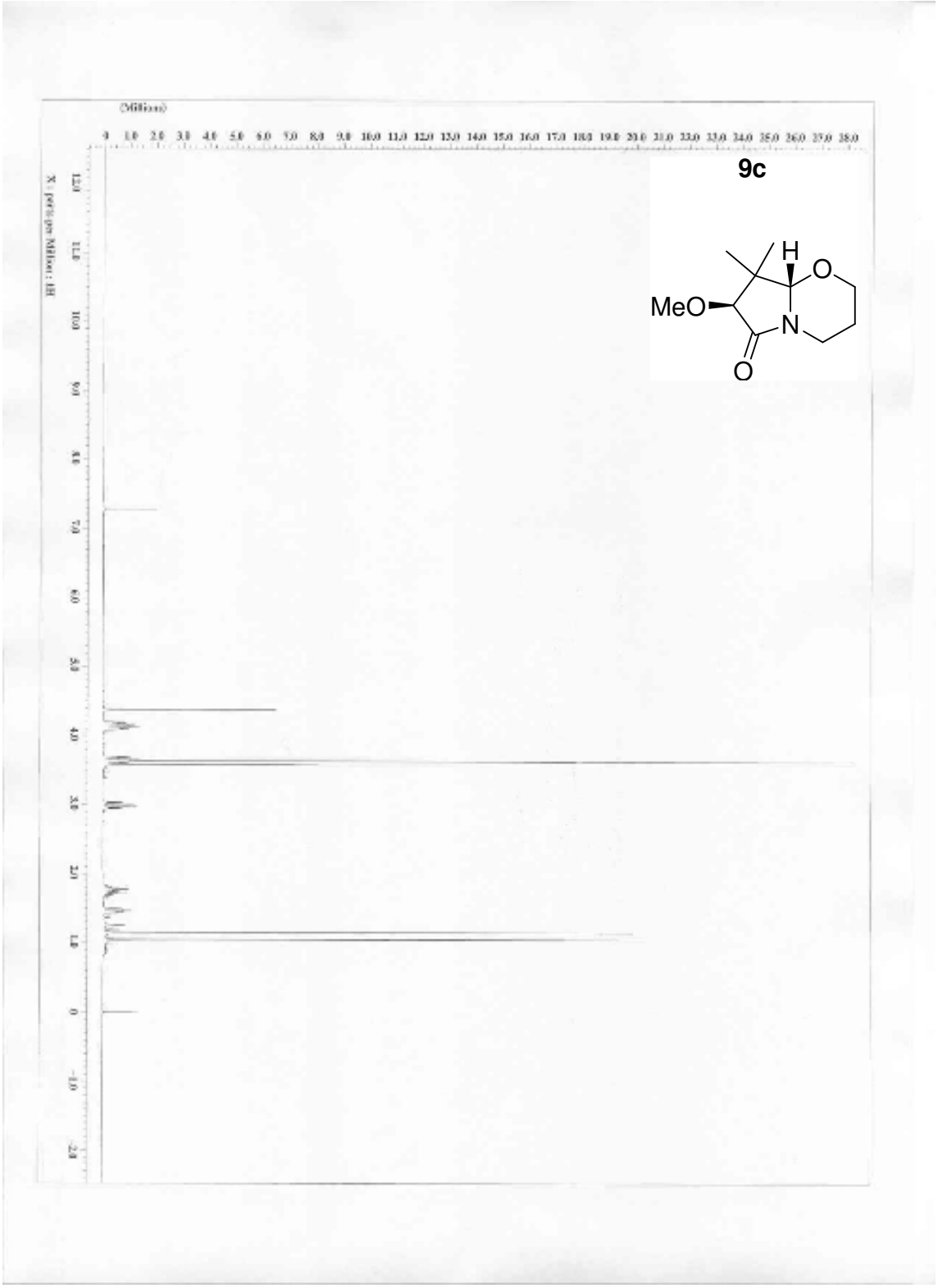
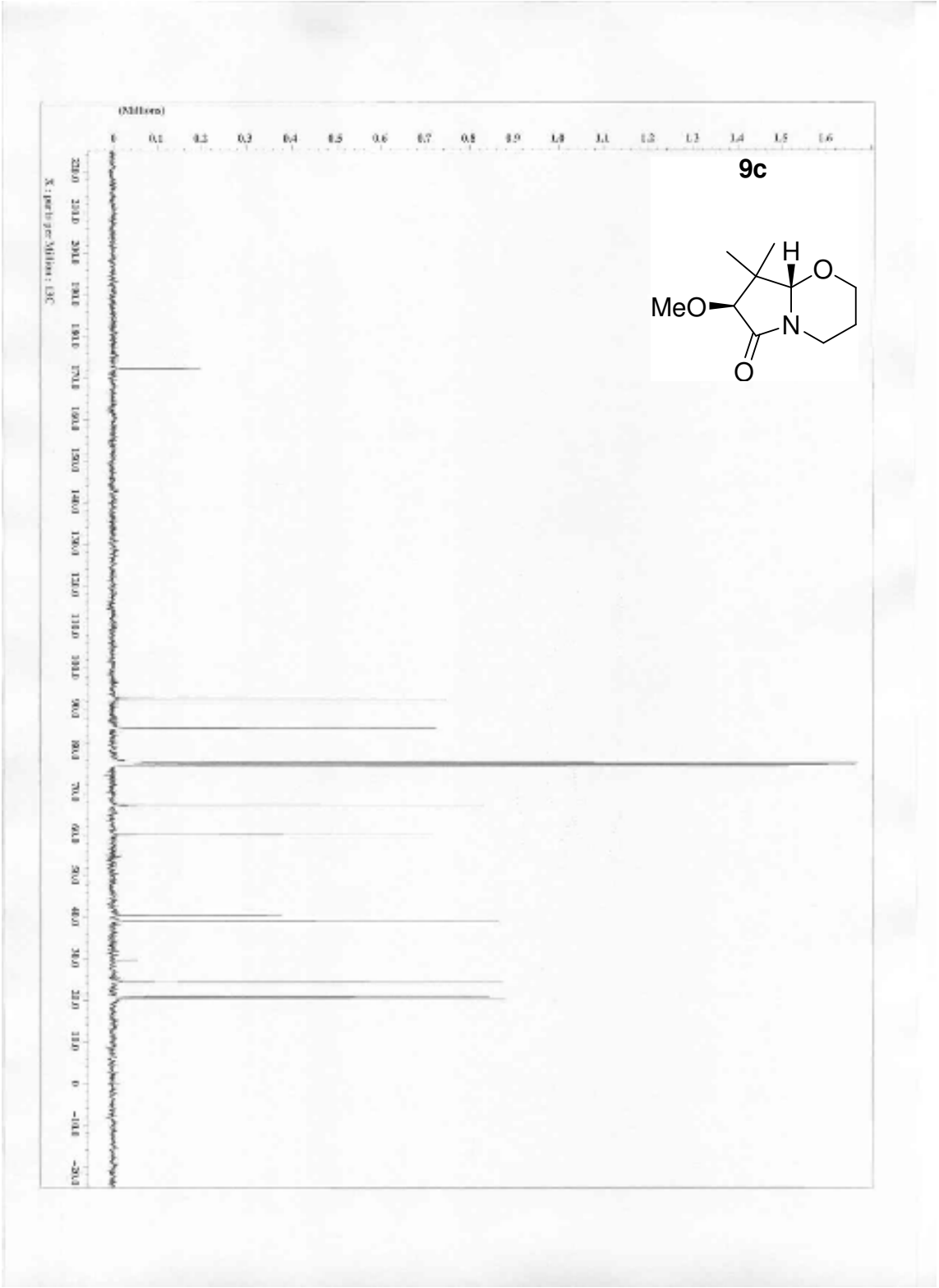
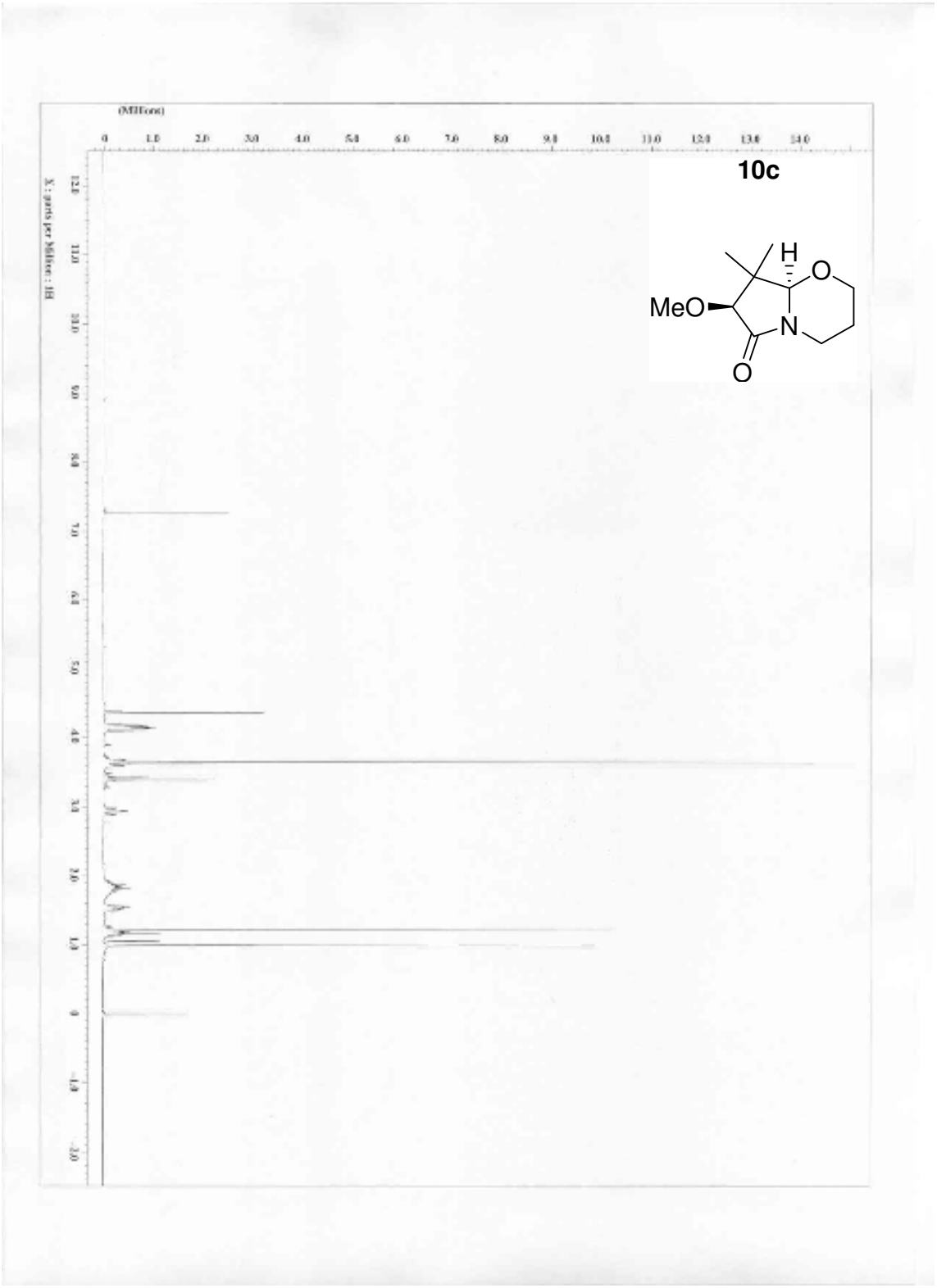


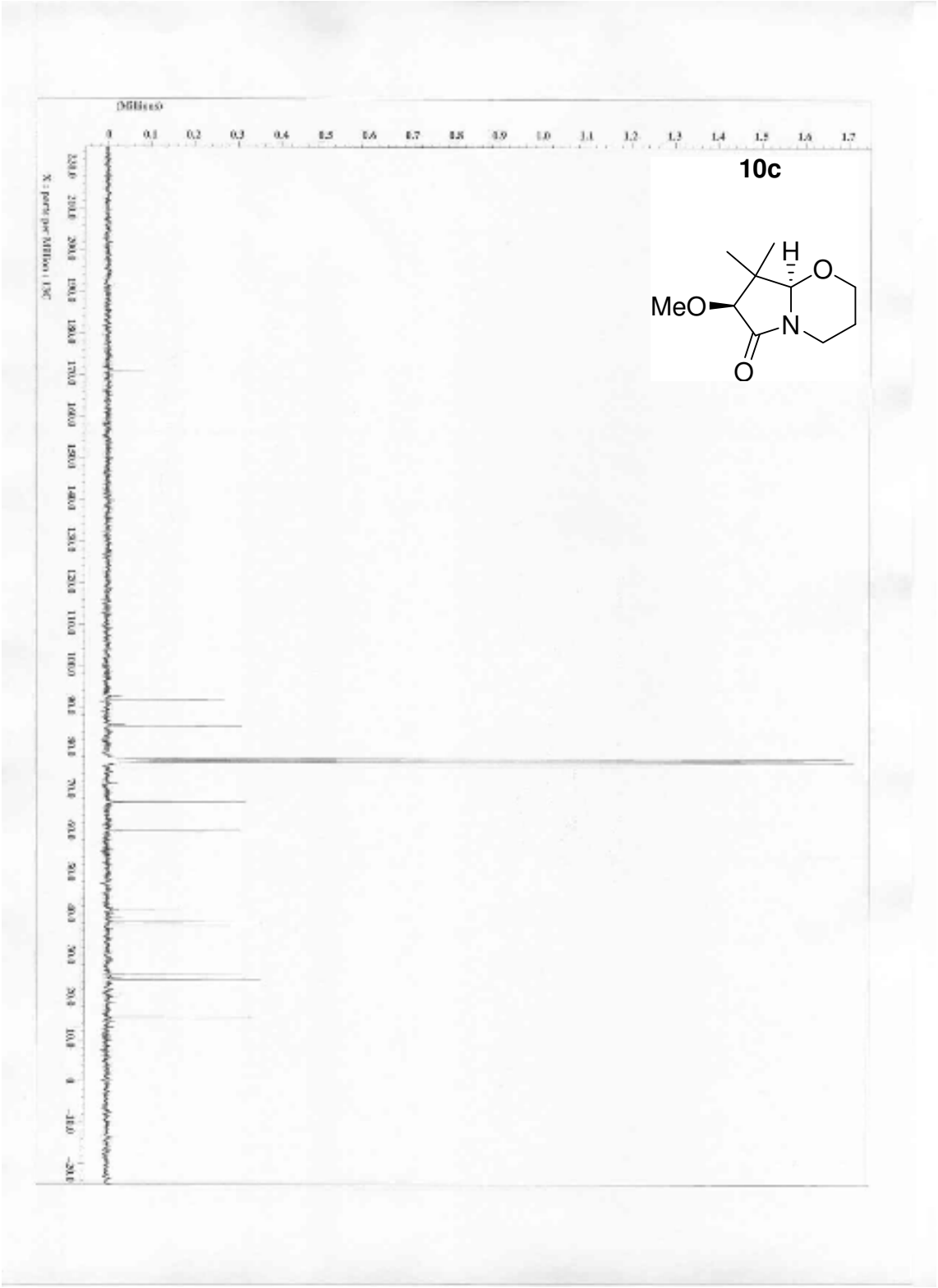
^{13}C NMR **9c**



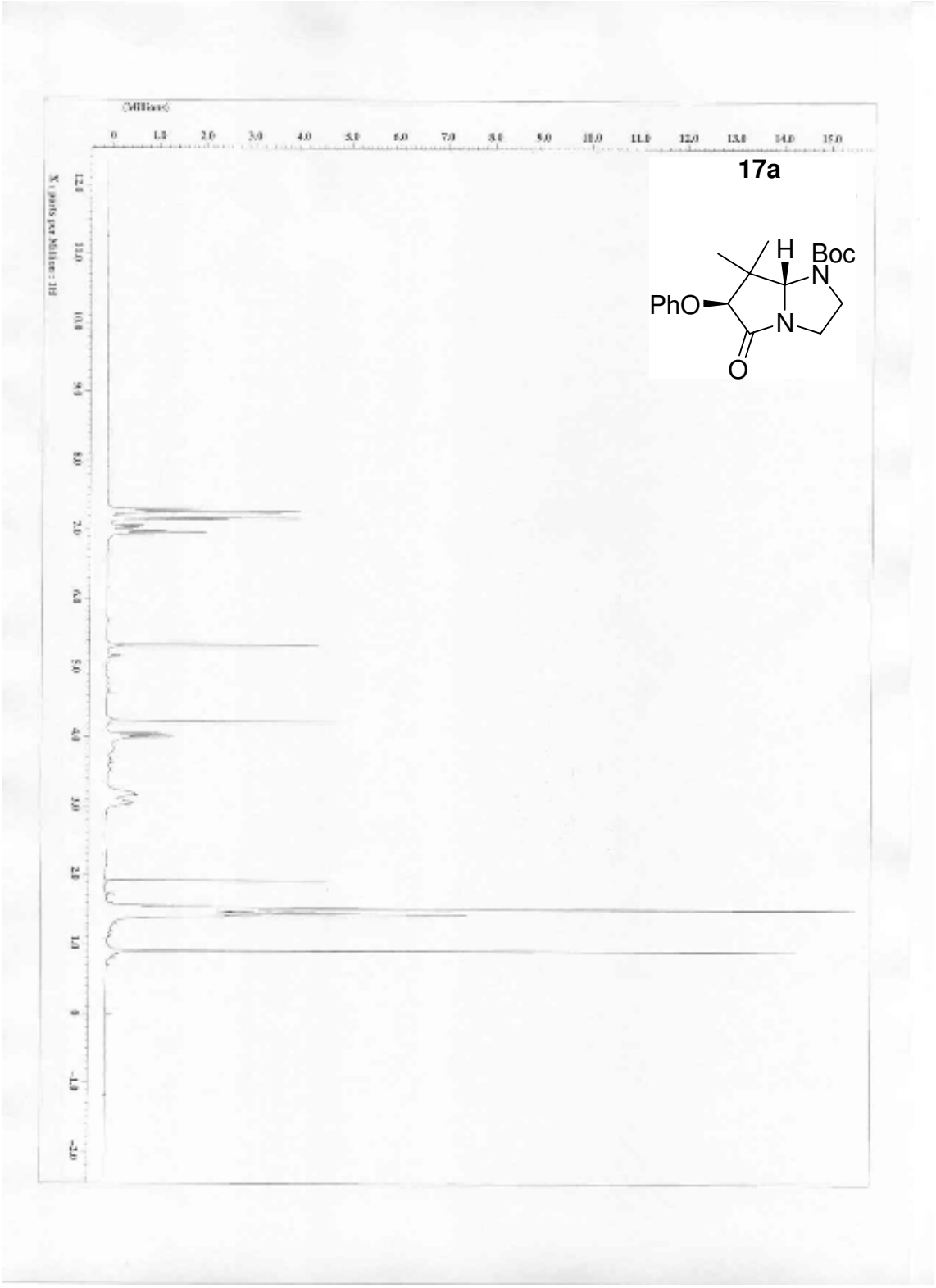
^{1}H NMR **10c**



^{13}C NMR **10c**



^{1}H NMR **17a**



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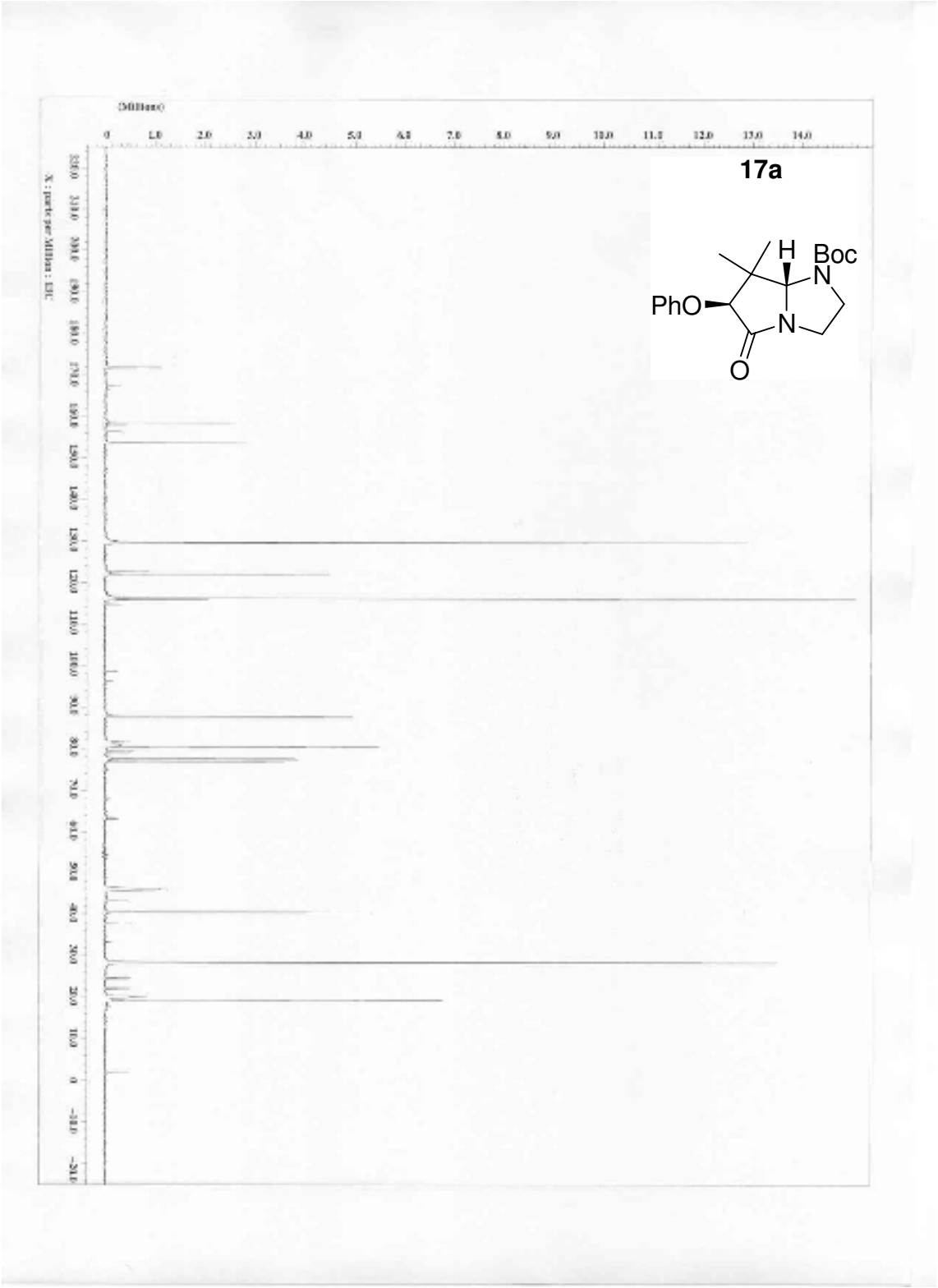
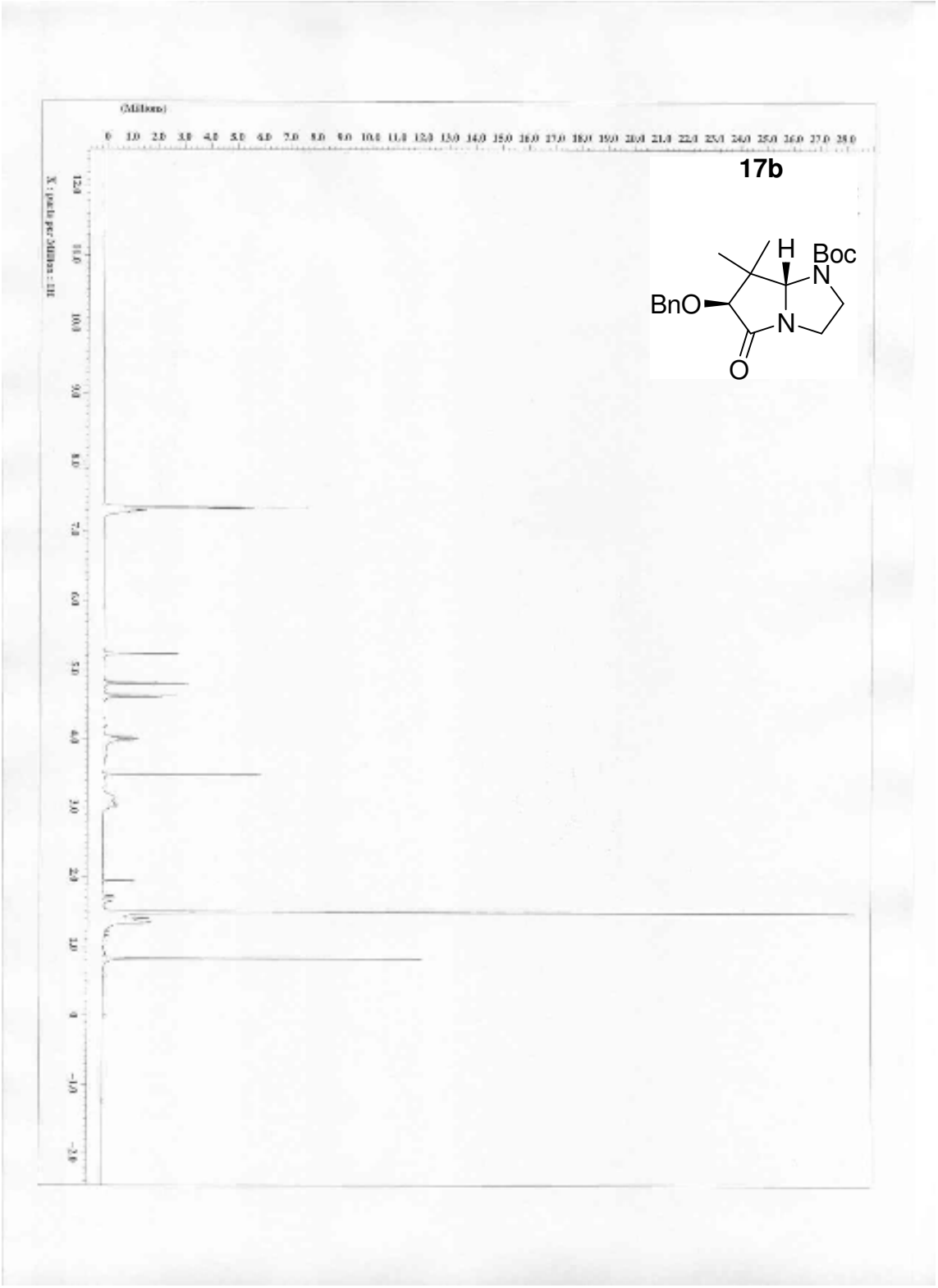
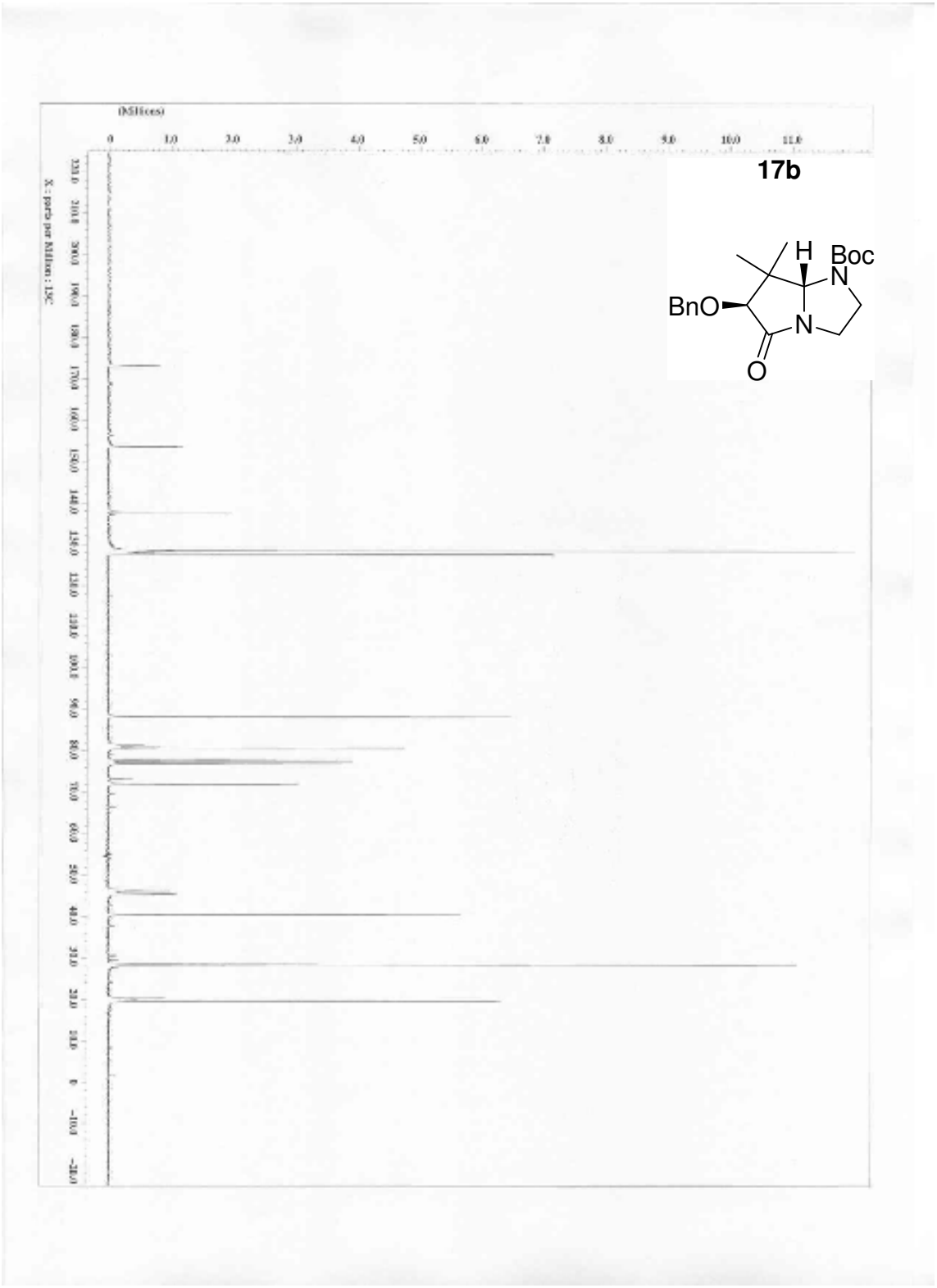


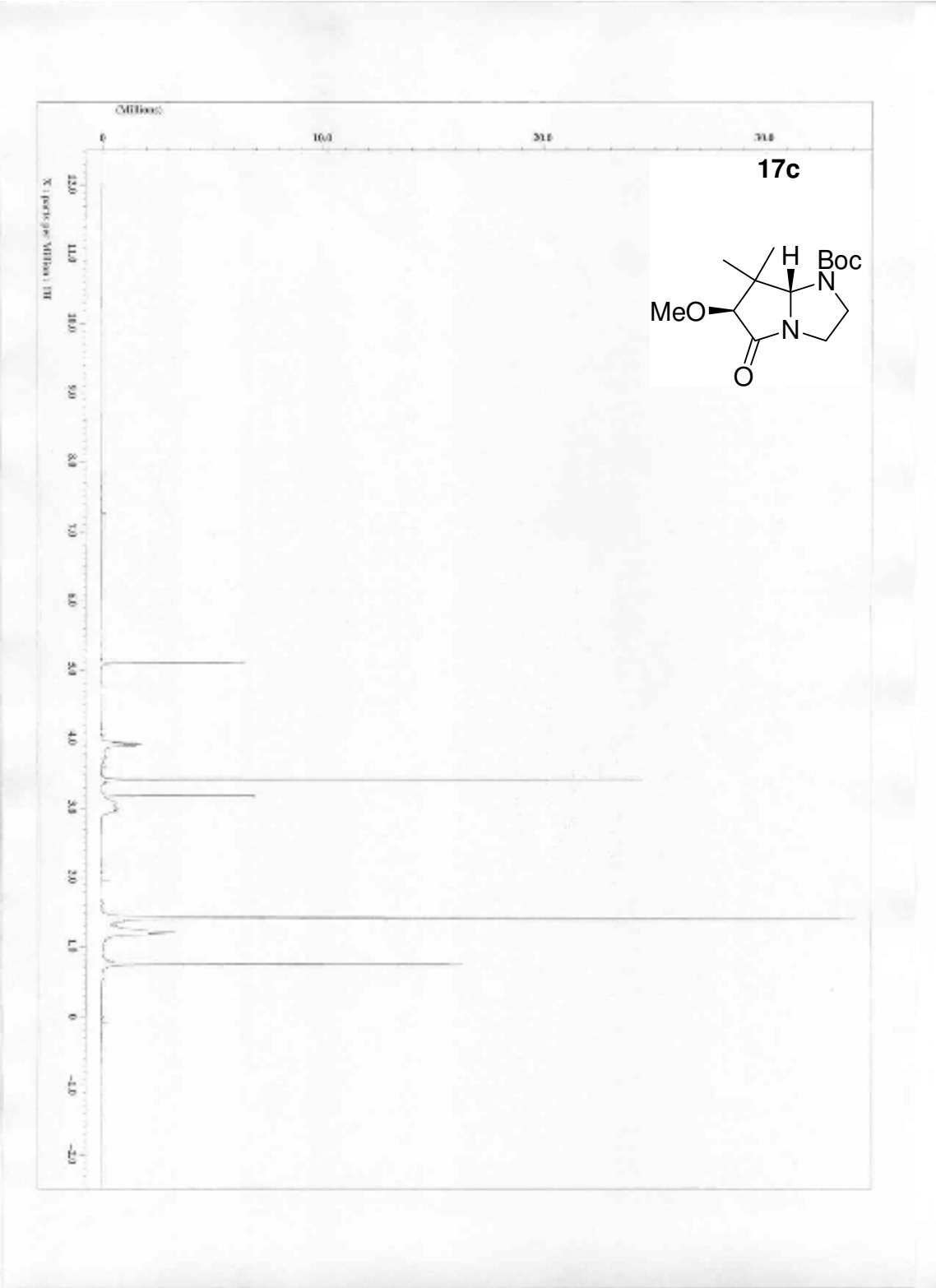
^{1}H NMR **17b**



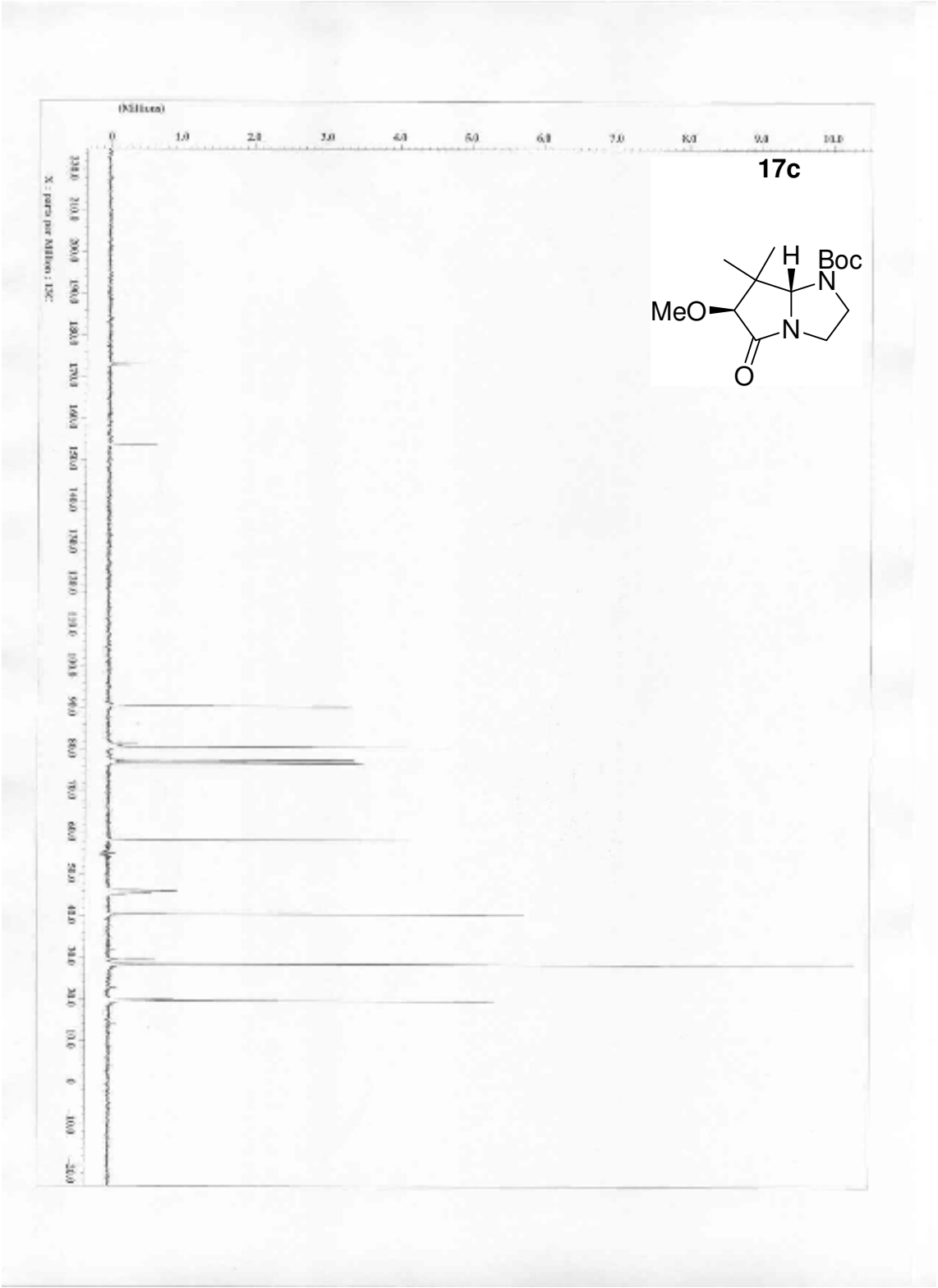
^{13}C NMR **17b**



^{1}H NMR **17c**



^{13}C NMR **17c**



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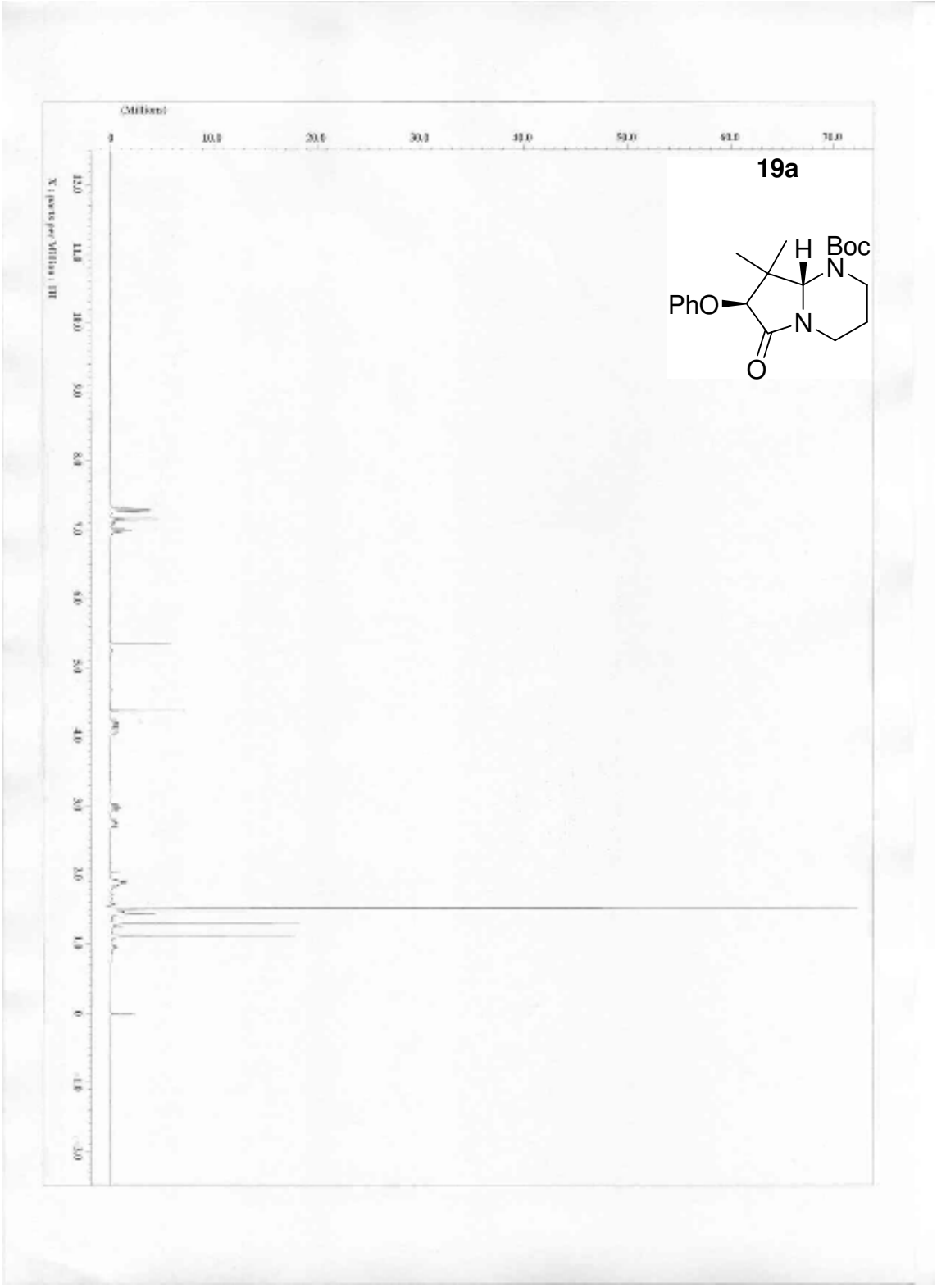
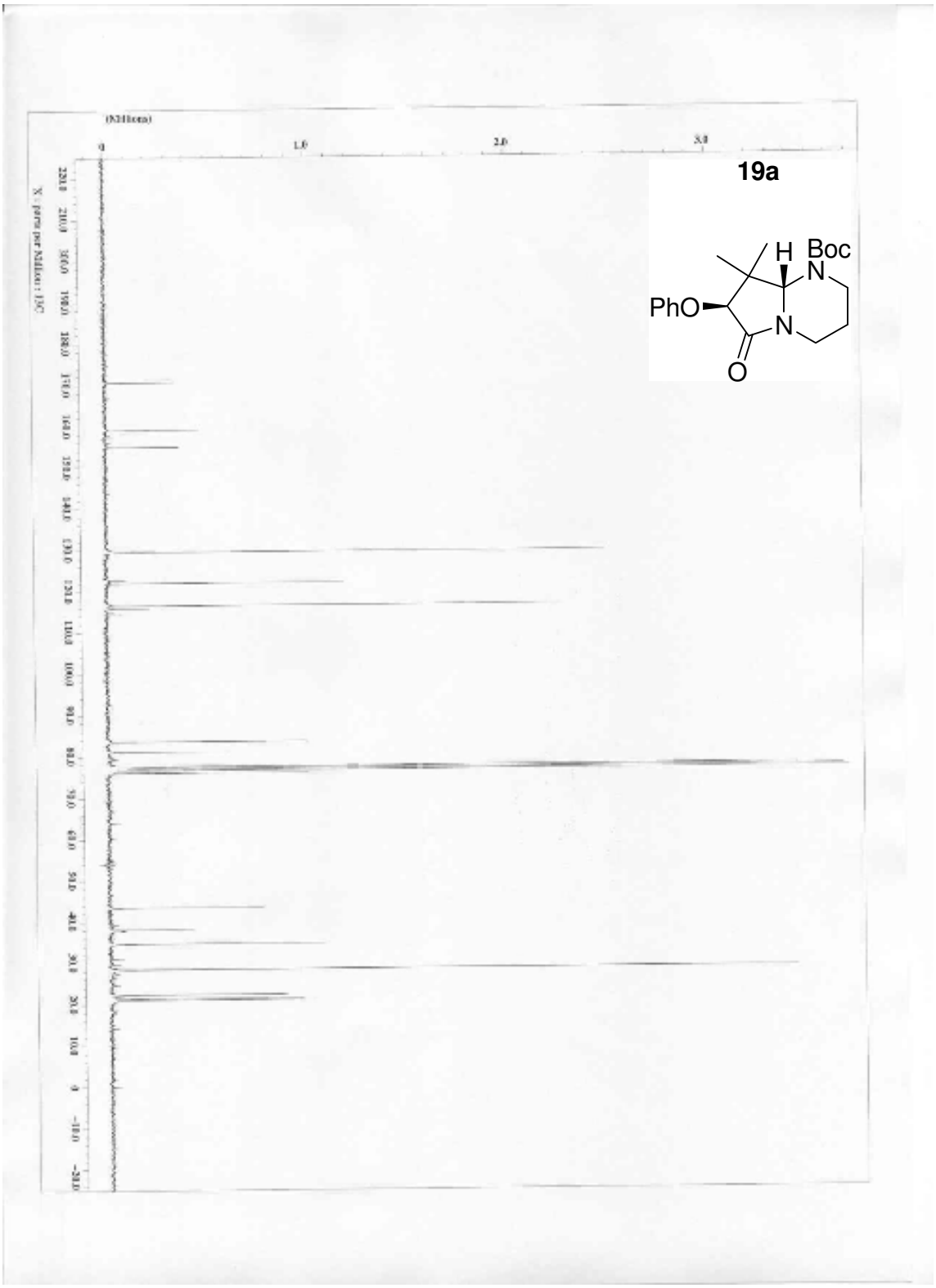
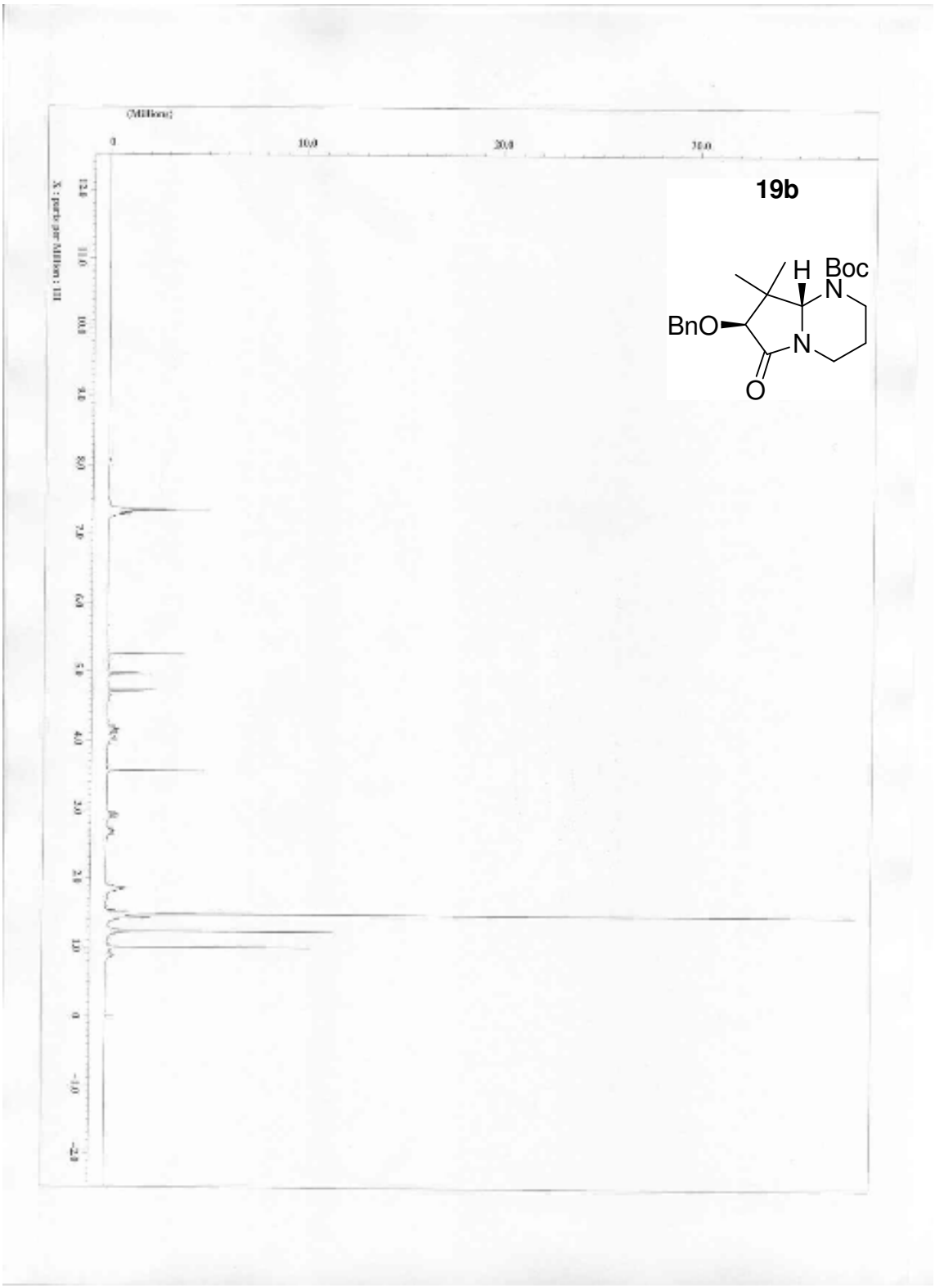


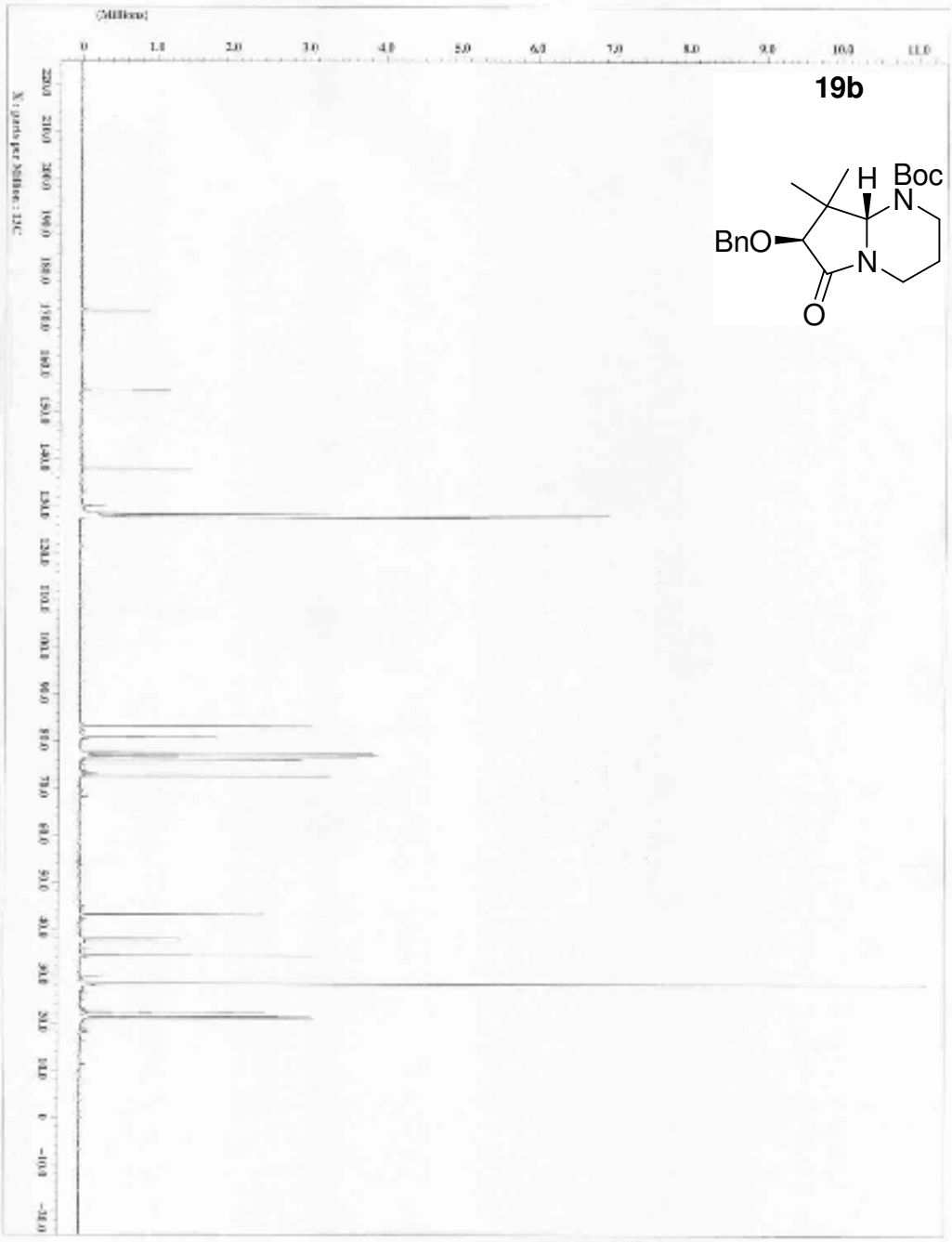
^{13}C NMR **19a**



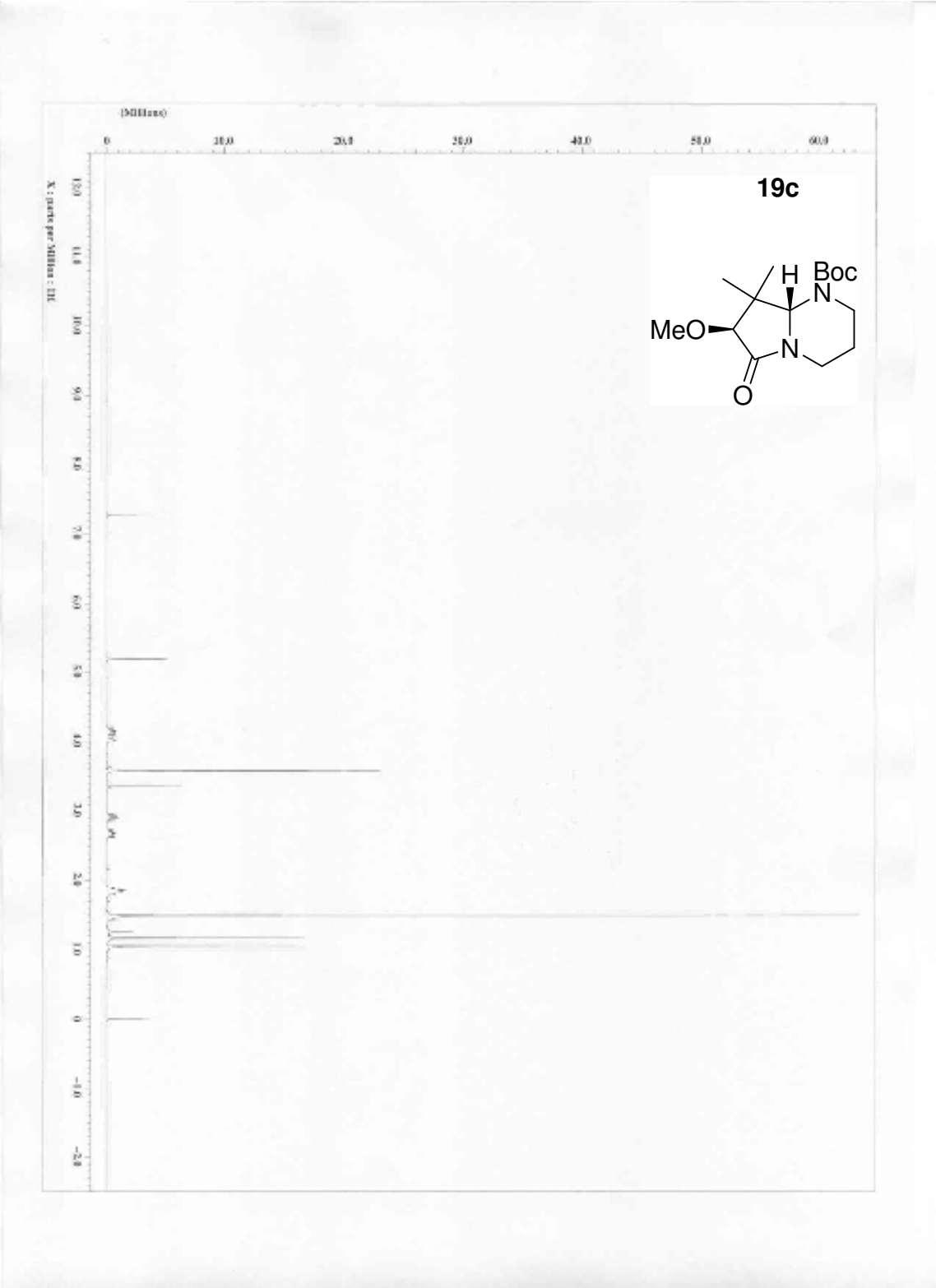
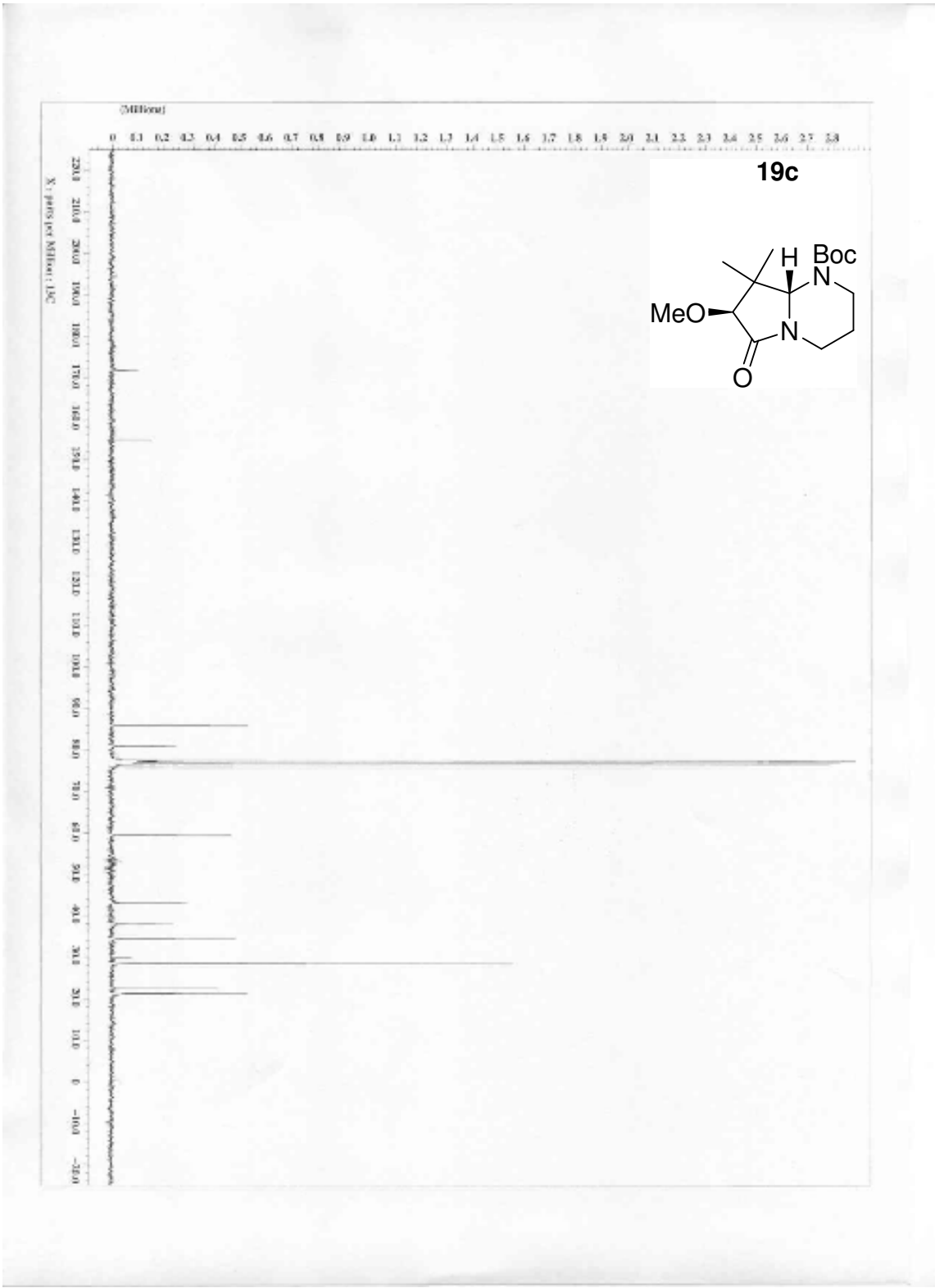
^{1}H NMR **19b**



^{13}C NMR **19b**



^{1}H NMR **19c**



^{13}C NMR **19c**