Electronic Supplementary Material (ESI) for Chemical Communications

Supporting Information

Ruthenium Catalyzed Hydroaminoalkylation of Isoprene *via* Transfer Hydrogenation: Byproduct-free Prenylation of Hydantoins

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General detailed information

All reactions were run under an atmosphere of argon, unless otherwise indicated. Reaction tubes were oven-dried and cooled under a stream of argon. Reactions tubes were purchased from Fischer Scientific (catalog number 14-959-35C). $Ru_3(CO)_{12}$ and phosphine ligands were used as received from commercial suppliers. THF was dried over sodium/benzophenone, distilled immediately prior to use, and transferred via an oven-dried syringe. Isoprene was distilled in a Hickman still immediately prior to use. Analytical Thin-layer chromatography (TLC) was carried out using 0.25 mm commercial silica gel plates. Visualization was accomplished with UV light followed by dipping in $KMnO_4$ and/or p-anisaldehyde solution and heating. Column chromatography was carried out with Silacycle silica gel (40-60 μm). Infrared spectra were recorded on a Perkin-Elmer 1600 spectrometer. Mass spectra were obtained on a Karatos MS9 and a TSQ Quantum GC and are reported as m/z (relative intensity). Accurate masses are reported for the molecular ion $[M+H]^+$ or a suitable fragment ion. Melting points were obtained on a Thomas-Hoover Unimelt apparatus and are uncorrected. Proton and deuteron nuclear magnetic resonance (^{1}H NMR) spectra were recorded with a Varian Gemini 400 MHz spectrometer. Chemical shifts are reported in delta (δ) units, parts per million (ppm) downfield from tetramethylsilane or ppm relative to the center of the singlet at 7.26 ppm for deuteriochloroform and 2.50 ppm for DMSO-d6. Coupling constants *J* values are reported in Hertz (Hz). Carbon-13 nuclear magnetic resonance (^{13}C NMR) spectra were recorded with a Varian Gemini 400 spectrometer (100 MHz). Chemical shifts are reported in delta (δ) units, ppm relative to the center of the triplet at 77.0 ppm for deuteriochloroform. ^{13}C NMR spectra were routinely run with broadband decoupling.

Experimental Procedures and Spectroscopic Data for the hydantoins (1a - 1f)

Experimental Procedure[1,2,3,4]

Preparation of hydantoins (1a, 1d, 1e, or 1f)

To a one neck round bottom flask equipped with a reflux condenser was added a aldehyde (100 mol%), KCN (120 mol%), $(NH_4)_2CO_3$ (500 mol%) in a solution of 50% EtOH. The reaction mixture was allowed to stir vigorously at 60 - 70 °C for 12 - 18 h, at which point the reflux condenser was removed and the reaction was concentrated by evaporating the water for 1-2 hours. Then the reaction mixture was cooled to 0 °C, at which point concentrated HCl was added until pH 6-7, and a solid precipitated which was collected upon filtration and washed with ice-water. The crude hydantoin (100 mol%) was dissolved in DMF in a round bottom flask. To the stirring solution was added K_2CO_3 (400 mol%) at 0 °C. The solution was allowed to stir at 0 °C for 10-15 min, at which point BnCl (100 mol%) was added dropwise. The reaction mixture was allowed to stir at ambient temperature for 18 h. The reaction mixture was diluted with EtOAc and then transferred to a separatory funnel. The organic layer was washed with water (4 times). The organic layer was then dried over Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by silica gel flash column chromatography to provide n-benzyl protected hydantoins (**1a**, **1d**, **1e**, or **1f**).

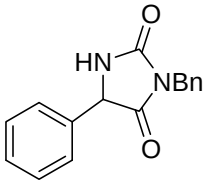
Preparation of hydantoins (1b or 1c)

To a three neck round bottom flask equipped with a reflux condenser was added a aldehyde (100 mol%), KCN (200 mol%), $(NH_4)_2CO_3$ (400 mol%) in a solution of 50% EtOH. The reaction mixture was allowed to stir vigorously at 70 °C for 24 h, at which point the reflux condenser was removed and the reaction was concentrated by evaporating the water for 1-2 hours. Then the reaction mixture was cooled to 0 °C, at which point concentrated HCl was added until pH 6-7, and a solid precipitated which was collected upon filtration. The crude hydantoin (100 mol%) was dissolved in DMF in a round bottom flask. To the stirring solution was added K_2CO_3 (400 mol%) at 0 °C. The solution was allowed to stir at 0 °C for 10-15 min, at which point BnCl (100 mol%) was added dropwise. The reaction mixture was allowed to stir at ambient temperature for 24 h. The reaction mixture was diluted with CH_2Cl_2 and then transferred to a separatory funnel. The organic layer was washed with 1M HCl solution. The organic layer was then dried over

[1] Henze, H. R.; Speer, R. *J. Am. Chem. Soc*. 1942, *64*, 522.
[2] Jordan, T. E.; Grinsburg, S. J. *J. Am. Chem. Soc*. 1949, *71*, 2258
[3] Pinnal, G.; Gavinil, E.; Cignarellaz, G.; Scolastico, S.; Fadda, P. *Eur. J. Med. Chem*. 1995, *30*, 515
[4] Ahmed, S. K.; Etoga, J. G.; Patel, S. A.; Bridges, R. J.; Thompson, C. M. *Bioorg. Med. Chem. Lett*. 2011, 21, 4358

$MgSO_4$ and concentrated under reduced pressure. The crude product was then recrystallized in EtOAc / CH_2Cl_2 / hexanes to provide hydantoins (**1b** or **1c**).

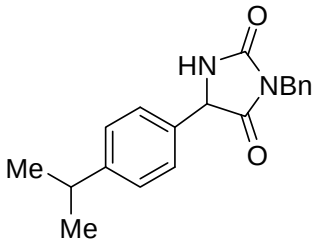
N- Benzyl protected phenyl hydantoin (1a)



General Procedure : To KCN (15.6 g, 0.24 mol, 120 mol%) and $(NH_4)_2CO_3$ (19.6 g, 1.00 mol, 500 mol%) in a solution of 50% EtOH (600 mL) was added benzaldehyde (20.4 mL, 0.2 mol, 100 mol%) and the resulting solution was heated to 65 ^oC for 18 h. The crude product was obtained as a white solid (24 g, 68 %). After the protection of the hydantoin, the crude product was purified by silica gel flash column chromatography (elution with EtOAc : Toluene = 1 : 2 to 2 : 1) to produce the hydantoin **1a** (14.5 g, 40 %) as a white solid.

^{1}H NMR (400 MHz, DMSO-d6) : δ 8.82 (s, 1H), 7.42 - 7.30 (m, 7H), 7.28 - 7.23 (m, 3H), 5.32 (s, 1H), 4.59 (d, J = 15.6, 1H), 4.54 (d, J = 15.2, 1H). The ^{1}H NMR data were consistent with the reported values.[5,6]

N- Benzyl protected isopropyl phenyl hydantoin (1b)



General Procedure : To KCN (13.0 g, 0.20 mol, 200 mol%) and $(NH_4)_2CO_3$ (38.4 g, 0.40 mol, 400 mol%) in a solution of 50% EtOH (300 mL) was added 4-isopropylbenzaldehyde (14.8 g, 0.10 mol, 100 mol%) and the resulting solution was heated to 70 ^oC for 24 h. The crude hydantoin was obtained as a white solid (21 g, 95 %). After the protection of the hydantoin, the crude product was purified by recrystallized in EtOAc / CH_2Cl_2 / hexane to provide the hydantoin **1b** (16 g, 55 %) as a white solid.

[5] Cortes, S.; Kohn, H., *J. Org. Chem.* 1983, *48*, 2246
[6] Tiran, A. L.; Stables, J. P.; Kohnc, H. *Bioorg. Med. Chem*. 2001, *9*, 2693

^{1}H NMR (400 MHz, $CDCl_3$) : δ 7.40 - 7.37 (m, 2H), 7.34 - 7.28 (m, 3H), 7.24 (s, 4H), 5.98 (s, 1H), 5.02 (d, *J* = 1.2 Hz, 1H), 4.71 (d, *J* = 14.4 Hz, 1H), 4.64 (d, *J* = 14.4 Hz, 1H), 2.90 (Oct, *J* = 7.2 Hz, 1H), 1.24 (s, 3H), 1.23 (s, 3H).

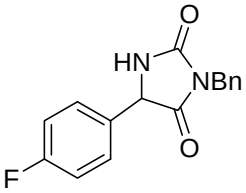
^{13}C NMR (100 MHz, $CDCl_3$) : δ 171.9, 157.2, 150.0, 128.7, 128.5, 127.9, 127.3, 126.5, 60.7, 42.4, 33.9, 23.9, 23.8.

FTIR (neat) ν_{max} 3299, 2961, 1773, 1702, 1455, 1438, 1362, 1340, 1147 cm^{-1}.

LRMS[ES+] calcd for $C_{19}H_{20}N_2O_2$ $[M+Na]^+$ 331.1, found 331.1.

Melting Point : 162 - 163 ^oC.

N- Benzyl protected 4-fluorophenyl hydantoin (1c)



General Procedure : To KCN (13.0 g, 0.20 mol, 200 mol%) and $(NH_4)_2CO_3$ (38.4 g, 0.40 mol, 400 mol%) in a solution of 50% EtOH (300 mL) was added 4-fluorobenzaldehyde (12.4 g, 0.10 mol, 100 mol%) and the resulting solution was heated to 70 ^oC for 24 h. The crude hydantoin[7] was obtained as a white solid (17 g, 87 %). After the protection of the hydantoin, the crude product was purified by recrystallized in EtOAc/ CH_2Cl_2 / hexanes to provide the hydantoin **1c** (8 g, 34 %) as a white solid.

^{1}H NMR (400 MHz, $CDCl_3$) : δ 7.37 - 7.28 (m, 7H), 7.10 - 7.05 (m, 2H), 6.32 (s, 1H), 5.04 (s, 1H), 4.70 (d, *J* = 14.8 Hz, 1H), 4.63 (d, *J* = 14.8 Hz, 1H).

^{13}C NMR (100 MHz, $CDCl_3$) : δ 171.6, 164.3, 161.8, 157.2, 135.7, 129.9, 128.7, 128.5, 128.3, 128.2, 128.0, 116.3, 116.0, 60.1, 42.5.

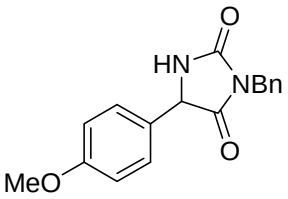
FTIR (neat) ν_{max} 2977, 2860, 1773, 1706, 1603, 1513, 1451, 1350, 1233, 1119 cm^{-1}.

LRMS[ES+] calcd for $C_{16}H_{13}FN_2O_2$ $[M+Na]^+$ 307.1, found 307.1.

Melting Point : 165 - 166 ^oC.

[7] Arcuri, M. B.; Sabino, S. J.; Antunes, O. A. C.; Oestreicher, E. G. *J. Fluorine. Chem.* 2003, *121*, 55

N- Benzyl protected 4-methoxyphenyl hydantoin (1d)



General Procedure : To KCN (3.1 g, 48 mmol, 120 mol%) and $(NH_4)_2CO_3$ (19.2 g, 200 mmol, 500 mol%) in a solution of 50% EtOH (120 mL) was added 4-methoxy-benzaldehyde (5.4 g, 40 mmol, 100 mol%) and the resulting solution was heated to 60 ^oC for 18 h. The crude hydantoin[8] was obtained as a white solid (6.1 g, 74 %). After the protection of the hydantoin, the crude product was purified by silica gel flash column chromatography (elution with EtOAc : hexane = 1 : 2 to 1 : 1) produce the hydantoin **1d** (3.4 g, 56 %) as a white solid.

^{1}H NMR (400 MHz, $CDCl_3$) : δ 7.39 - 7.38 (m, 2H), 7.33 - 7.27 (m, 3H), 7.21 (dt, *J* = 6.8, 2.0 Hz, 2H), 6.90 (dt, *J* = 6.8, 2.0 Hz, 2H), 6.07 (s, 1H), 4.99 (s, 1H), 4.70 (d, *J* = 14.4 Hz, 1H), 4.63 (d, *J* = 14.4 Hz, 1H), 3.80 (s, 3H).

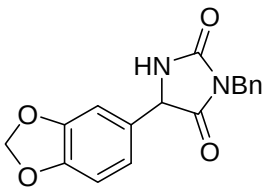
^{13}C NMR (100 MHz, $CDCl_3$) : δ 172.1, 160.2, 157.2, 135.9, 128.7, 128.5, 127.9, 127.7, 126.1, 114.5, 60.3, 55.3, 42.4.

FTIR (neat) ν_{max} 3294, 1770, 1702, 1611, 1514, 1457, 1440, 1251, 1180 cm^{-1}.

LRMS[ES+] calcd for $C_{17}H_{16}N_2O_3$ $[M+Na]^+$ 319.1, found 319.1.

Melting point : 157 - 158 ^oC.

N- Benzyl protected piperonyl hydantoin (1e)



General Procedure : To KCN (3.1 g, 48 mmol, 120 mol%) and $(NH_4)_2CO_3$ (19.2 g, 200 mmol, 500 mol%) in a solution of 50% EtOH (120 mL) was added piperonal (6.0 g, 40 mmol, 100 mol%) and the resulting solution was heated to 60 ^oC for 18 h. The crude hydantoin[9] was

[8] Payen, O. et al. *J. Med. Chem*. 2008, *51*, 1791
[9] Henze, H. R.; Speer, R. J. *J. Am. Chem. Soc*. 1942, *64*, 522

obtained as a white solid (6.6 g, 75 %). After the protection of the hydantoin, the crude product was purified by silica gel flash column chromatography (elution with CH_2Cl_2 to EtOAc : hexane = 1 : 2) produce the hydantoin **1e** (3.3 g, 36 %) as a white solid.

^{1}H NMR (400 MHz, $CDCl_3$) : δ 7.35 - 7.23 (m, 5H), 6.76 (s, 2H), 6.72 (s, 1H), 6.13 (s, 1H), 5.94 (s, 2H), 4.92 (s, 1H), 4.66 (d, *J* = 14.4 Hz, 1H), 4.60 (d, *J* = 14.4 Hz, 1H).

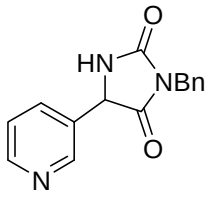
^{13}C NMR (100 MHz, $CDCl_3$) : δ 171.8, 157.2, 148.4, 135.8, 128.7, 128.4, 128.0, 127.7, 120.2, 108.6, 106.7, 101.4, 60.6, 42.4.

FTIR (neat) ν_{max} 3297, 1769, 1702, 1489, 1443, 1418, 1361, 1249, 1187, 1135 cm^{-1}.

LRMS[ES+] calcd for $C_{17}H_{14}N_2O_4$ $[M+Na]^+$ 333.1, found 333.1.

Melting Point : 141 - 143 ^oC.

N- Benzyl protected 3-pyridinyl hydantoin (1f)



General Procedure : To KCN (6.3 g, 96 mmol, 120 mol%) and $(NH_4)_2CO_3$ (30.7 g, 320 mmol, 500 mol%) in a solution of 50% MeOH (120 mL) was added 3-pyridinecarboxaldehyde (7.5 mL, 80 mmol, 100 mol%) and the resulting solution was heated to 60 ^oC for 12 h. The crude hydantoin[10] was obtained as a yellow solid (6.8 g, 48 %). After the protection of the hydantoin, the crude product was purified by silica gel flash column chromatography (elution with EtOAc : hexane = 3 : 1 to EtOAc : Toluene 1 : 5) produce the hydantoin **1f** (5.6 g, 55 %) as a white solid.

^{1}H NMR (400 MHz, $CDCl_3$) : δ 8.61 - 8.59 (m, 2H), 7.65 (d, *J* = 8.0 Hz, 1H), 7.37 - 7.27 (m, 6H), 6.92 (s, 1H), 5.08 (d, *J* = 0.8 Hz, 1H), 4.70 (d, *J* = 14.8 Hz, 1H), 4.63 (d, *J* = 14.8 Hz, 1H).

^{13}C NMR (100 MHz, $CDCl_3$) : δ 171.1, 157.3, 150.2, 147.9, 135.5, 134.2, 130.2, 128.7, 128.5, 128.1, 123.9, 58.5, 42.6.

FTIR (neat) ν_{max} 3389, 1773, 1712, 1444, 1340, 1253, 1188 cm^{-1}.

LRMS[ES+] calcd for $C_{15}H_{13}N_3O_2$ $[M+H]^+$ 268.1, found 268.1. **Melting Point** : 147 - 149 ^oC.

[10] Ahmed, S. Kaleem et al. *Bioorg. Med. Chem. Lett*, 2011, *21*(14), 4358

Experimental Procedures and Spectroscopic Data for the hydroaminoalkylation of isoprene with hydantoins (1a - 1f) to form the prenylated adducts (3a - 3f)

General Experimental Procedures for the hydroaminoalkylation of isoprene with hydantoins (1a - 1e)

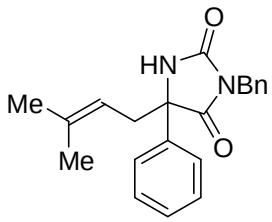
A pressure tube equipped with magnetic stir bar was added $Ru_3(CO)_{12}$ (3.8 mg, 0.006 mmol, 3 mol%), $[PhP(CH_2CH_2PPh_2)_2]$ (12.8 mg, 0.024 mmol, 12 mol%), and hydantoins (0.200 mmol, 100 mol%) was sealed with a rubber septum, purged with argon. To the tube was added an isoprene solution (0.22 mL, 600 mol%, 1.2 M in THF) (the isoprene solution was prepared by mixing with isoprene (0.36 mL, 3.600 mmol) and THF (0.3 mL), and then it was dried over molecular sieves prior to use). The rubber septum was replaced with a screw cap. The resulting mixture was immersed to a pre-heated oil bath (140^{o}C). After 48 h, the reaction mixture was slowly cooled to room temperature and concentrated under reduced pressure. To the residue was added 1,3,5-trimethoxybenzene (33.6 mg, 0.200 mmol, 100 mol%) as an internal standard to determine NMR yields. The mixture was concentrated under reduced pressure again and purified by short packed silica gel column chromatography (elution with EtOAc : Toluene = 1 : 20) to give prenylated products (**3a - 3f**) as white solids.

General Experimental Procedures for the hydroaminoalkylation of isoprene with a hydantoin (1f)

The general procedure is the same as other hydantoins (**1a - 1e**) above. The crude product was purified by short packed silica gel column chromatography (elution with EtOAc : hexane = 1 : 1 to CH_2Cl_2) to give a prenylated product (**3f**) as a white solid.

Spectroscopic Data of Prenylated adducts (3a - 3f)

5-(3-Methylbut-2-enyl)-5-phenyl-3-phenylmethyl-2,4-imidazolidinedione (3a)



1H NMR (400 MHz, $CDCl_3$) : δ 7.52 - 7.48 (m, 2H), δ 7.33 - 7.18 (m, 8H), 6.63 (s, 1H), 4.78 (m, 1H), 4.55 (s, 2H), 2.85 (dd, J = 14.4, 8.0 Hz, 1H), 2.63 (dd, J = 14.4, 7.2 Hz, 1H), 1.48 (s, 3H), 1.45 (s, 3H).

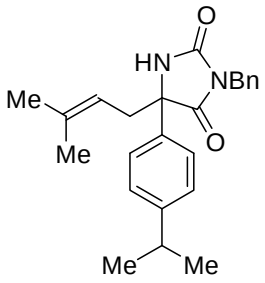
^{13}C NMR (100 MHz, $CDCl_3$) : 174.4, 157.0, 149.0, 138.1, 136.0, 135.2, 128.5, 128.3, 127.7, 126.8, 125.4, 115.8, 67.1, 42.3, 37.6, 33.7, 25.8, 23.9, 23.8, 18.1.

FTIR (neat) ν_{max} 2975, 2928, 2855, 1776, 1715, 1441, 1382, 1350, 1118 cm^{-1}.

LRMS[CI] calcd for $C_{21}H_{22}N_2O_2$ $[M+H]^+$ 335, found 335.

Melting Point : 172 - 174 ^oC.

5-(3-Methylbut-2-enyl)-5-[4-(1-methylethy)phenyl]-3-phenylmethyl-2,4-imidazolidinedione (3b)



^{1}H NMR (400 MHz, $CDCl_3$) : δ 7.49 - 7.46 (m, 2H), 7.36 - 7.22 (m, 9H), 6.58 (s, 1H), 4.90 - 4.86 (m, 1H), 4.61 (s, 2H), 2.95 - 2.87 (m, 2H), 2.66 (dd, J = 14.0, 6.8 Hz, 1H), 1.55 (s, 3H), 1.52 (s, 3H), 1.25 (s, 3H), 1.24 (s, 3H).

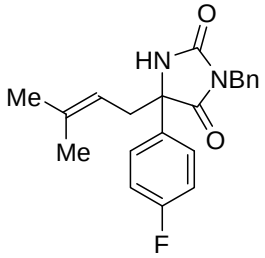
^{13}C NMR (100 MHz, $CDCl_3$) : 174.4, 157.0, 149.0, 138.1, 136.0, 135.2, 128.5, 128.3, 127.7, 126.8, 125.4, 115.8, 67.1, 42.3, 37.6, 33.7, 25.8, 23.9, 23.8, 18.1.

FTIR (neat) ν_{max} 2974, 2928, 2859, 1774, 1712, 1441, 1415, 1382, 1350, 1118 cm^{-1}.

LRMS[CI] calcd for $C_{24}H_{28}N_2O_2$ $[M+H]^+$ 377, found 377.

Melting Point : 133 - 135 ^oC.

5-(4-Fluorophenyl)-5-(3-methylbut-2-enyl)-3-phenylmethyl-2,4-imidazolidinedione (3c)



^{1}H NMR (400 MHz, $CDCl_3$) : 7.56 - 7.52 (m, 2H), 7.34 - 7.26 (m, 5H), 7.07 - 7.03 (m, 2H), 6.87 (s, 1H), 4.85 - 4.81 (m, 1H), 4.62 (d, *J* = 1.2 Hz, 2H), 2.87 (dd, *J* = 14.4, 8.0 Hz, 1H), 2.66 (dd, *J* = 14.4, 7.2 Hz, 1H), 1.53 (s, 3H), 1.52 (s, 3H).

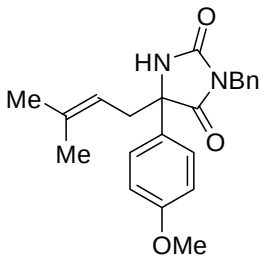
^{13}C NMR (100 MHz, $CDCl_3$) : 174.2, 163.8, 161.4, 157.1, 138.6, 135.9, 133.6, 128.6, 128.3, 127.8, 127.4, 127.3, 115.7, 115.5, 115.4, 66.8, 42.3, 38.0, 25.8, 18.1.

FTIR (neat) ν_{max} 3265, 2924, 1774, 1711, 1509, 1444, 1417, 1234, 1163 cm^{-1}.

LRMS[CI] calcd for $C_{21}H_{21}FN_2O_2$ $[M+H]^+$ 353, found 353.

Melting Point : 150 - 152 ^oC.

5-(4-methoxyphenyl)-5-(3-methylbut-2-enyl)-3-phenylmethyl-2,4-imidazolidinedione (3d)



^{1}H NMR (400 MHz, $CDCl_3$) : δ 7.46 (d, *J* = 8.8 Hz, 2H), 7.38 - 7.20 (m, 5H), 6.89 (d, J = 9.2 Hz, 2H), 6.59 (s, 1H), 4.87 - 4.83 (m, 1H), 4.62 (s, 2H), 3.80 (s, 3H), 2.88 (dd, *J* = 14.4, 8.0 Hz, 1H), 2.67 (dd, *J* = 14.4, 6.8 Hz, 1H), 1.55 (s, 3H), 1.53 (s, 3H)

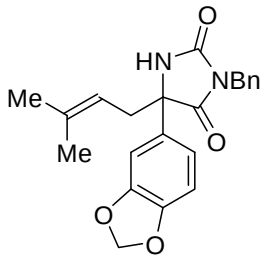
^{13}C NMR (100 MHz, $CDCl_3$): 174.6, 159.5, 156.9, 138.2, 136.0, 129.8, 128.6, 128.3, 127.7, 126.7, 115.8, 114.1, 66.8, 52.3, 42.2, 37.6, 25.8, 18.1.

FTIR (neat) ν_{max} 3282, 2921, 1772, 1700, 1513, 1441, 1346, 1315, 1258, 1180 cm^{-1}.

LRMS[CI] calcd for $C_{22}H_{24}N_2O_3$ $[M+H]^+$ 365, found 365.

Melting Point : 147 - 149 ^oC.

5-(1,3-Benzodioxol-5-yl)-5-(3-methylbut-2-enyl)-3-phenylmethyl-2,4-imidazolidinedione (3e)



^{1}H NMR (400 MHz, $CDCl_3$) : δ 7.35 - 7.25 (m, 4H), 7.08 (dd, *J* = 2.0, 0.4 Hz, 1H), 6.98 (dd, *J* = 6.4, 2.0 Hz, 1H), 6.78 (dd, J = 8.4, 0.4, 1H), 6.46 (s, 1H), 5.96 (q, *J* = 1.6 Hz, 2H), 4.84 (tm, *J* = 7.4 Hz, 1H), 4.62 (d, *J* = 2.4 Hz, 2H), 2.85 (dd, *J* = 14.4, 8.0 Hz, 1H), 2.65 (dd, *J* = 14.4, 6.8 Hz, 1H), 1.55 (s, 3H), 1.53 (s, 3H).

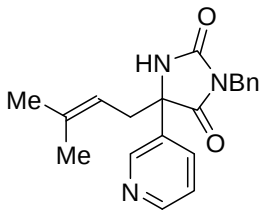
^{13}C NMR (100 MHz, $CDCl_3$) : 174.3, 156.8, 148.1, 147.6, 138.3, 135.9, 131.6, 128.6, 128.3, 127.7, 118.9, 115.6, 108.1, 106.4, 101.4, 66.9, 42.3, 37.7, 25.8, 18.1

FTIR (neat) ν_{max} 3245, 2974, 2926, 1772, 1711, 1490, 1441, 1249, 1116 cm^{-1}.

LRMS[CI] calcd for $C_{22}H_{22}N_2O_4$ $[M+H]^+$ 379, found 379.

Melting Point : 153 - 155 ^oC.

5-(3-Methylbut-2-enyl)-3-phenylmethyl-5-(3-pyridinyl)-2,4-imidazolidinedione (3f)



^{1}H NMR (400 MHz, $CDCl_3$) : δ 8.88 (d, *J* = 6.0 Hz, 1H), 8.60 (dd, *J* = 4.8, 1.2 Hz, 1H), 7.93 (ddd, *J* = 8.0, 4.0, 1.6 Hz, 1H), 7.35 - 7.26 (m, 6H), 6.83 (s, 1H), 4.85 - 4.82 (m, 1H), 4.63 (d, J = 2.8 Hz, 2H), 2.89 (dd, *J* = 14.8, 8.4 Hz, 1H), 2.70 (dd, *J* = 14.8, 7.6 Hz, 1H), 1.54 (s, 3H), 1.52 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$) : δ 173.7, 156.7, 149.6, 147.0, 139.2, 135.7, 133.6, 133.5, 128.7, 128.4, 127.9, 123.4, 114.9, 65.8, 42.5, 38.0, 25.8, 18.1.

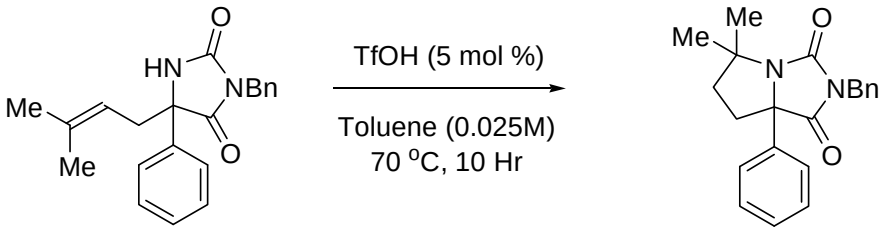
FTIR (neat) ν_{max} 3268, 2924, 1774, 1713, 1444, 1414, 1344, 1261, 1102 cm^{-1}.

LRMS[CI] calcd for $C_{20}H_{21}N_3O_2$ $[M+H]^+$ 336, found 336.

Melting Point : 186 - 188 ^{o}C.

Experimental Procedures and Spectroscopic Data for hydroamination of prenylated adduct 3a

The triflic acid-catalyzed hydroamination procedures were used.[11, 12] To prenylated adduct **3a** (14.1 mg, 0.042 mmol, 100 mol%) solution in toluene (1.7 mL) was added TfOH (0.2 μL, 0.002 mmol, 5 mol%) under argon. The resulting mixture was heated to 70 ^{o}C and stirred for 10 h. After cooling to room temperature, the resulting solution was quenched with saturated aq. $NaHCO_3$ and extracted with CH_2Cl_2 (1 mL x 2). The combined organic layer was dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (elution with EtOAc : n-hexane = 1 : 4) to obtain **4a** (10.9 mg, 77 %) as a colorless oil.



3a **4a**, 77% Yield

^{1}H NMR (400 MHz, $CDCl_3$) : δ 7.61 - 7.59 (m, 2H), 7.37 - 7.32 (m, 3H), 7.25 - 7.21 (m, 4H), 4.61 (d, *J* = 14.8 Hz, 1H), 4.47 (d, *J* = 14.8 Hz, 1H), 2.45 - 2.41 (m,1H), 2.26 (sext, *J* = 6.4 Hz, 1H), 1.95 - 1.90 (m, 1H), 1.87 - 1.80 (m, 1H), 1.52 (s, 3H), 1.50 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$) : δ 174.3, 157.1, 138.7, 136.2, 128.6, 128.5, 128.3, 127.9, 127.6, 125.8, 75.8, 62.5, 42.4, 41.9, 33.3, 29.3, 24.4.

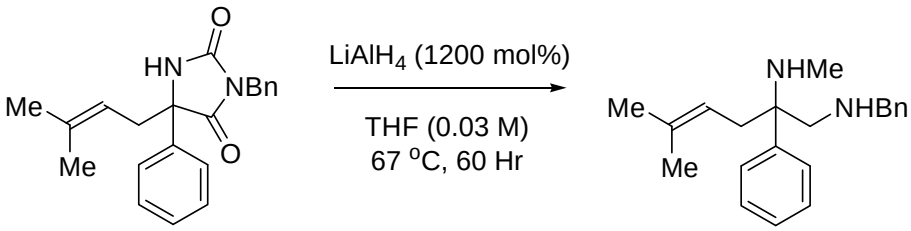
FTIR (neat) ν_{max} 2967, 2926, 2854, 1767, 1711, 1447, 1404, 1339, 1151, 1071 cm^{-1}.

LRMS[ES+] calcd for $C_{21}H_{22}N_2O_2$ $[M+Na]^+$ 357.2, found 357.2.

[11] Schlummer, B.; Hartwig, J. F. *Org. Lett*. 2002, *4*, 1471
[12] Hartwig, J. F. et al. *Org. Lett*. 2006, *8*, 4179

Experimental Procedures and Spectroscopic Data for reduction of prenylated adduct 3a

The reduction procedure of Kohn et al. was used.[5] To a pressure tube equipped with magnetic stir bar was added prenylated adduct **3a** (19.2 mg, 0.0574 mmol, 100 mol%). The tube was sealed with a rubber septum, purged argon. To the tube was added THF (1.9 mL) and then LAH (0.689 mmol, 26.1 mg, 1200 mol%) was quickly added to the tube. The rubber septum was replaced with a screw cap. The reaction mixture was stirred at 67 ^{o}C. After 60 h, the resulting mixture was cooled to room temperature and added 10% NaOH solution (2 mL). The mixture was diluted with EtOAc (10 mL) and filtered throughout Celite. The resulting mixture was separated and the aqueous layer was extracted with EtOAc. The combined organic layer was concentrated under reduced pressure and purified by silica gel column flash column chromatography (elution with CH_2Cl_2 : MeOH = 7 : 1) to afford the vicinal diamine **5a** (15.5 mg, 87 %) as a colorless oil.



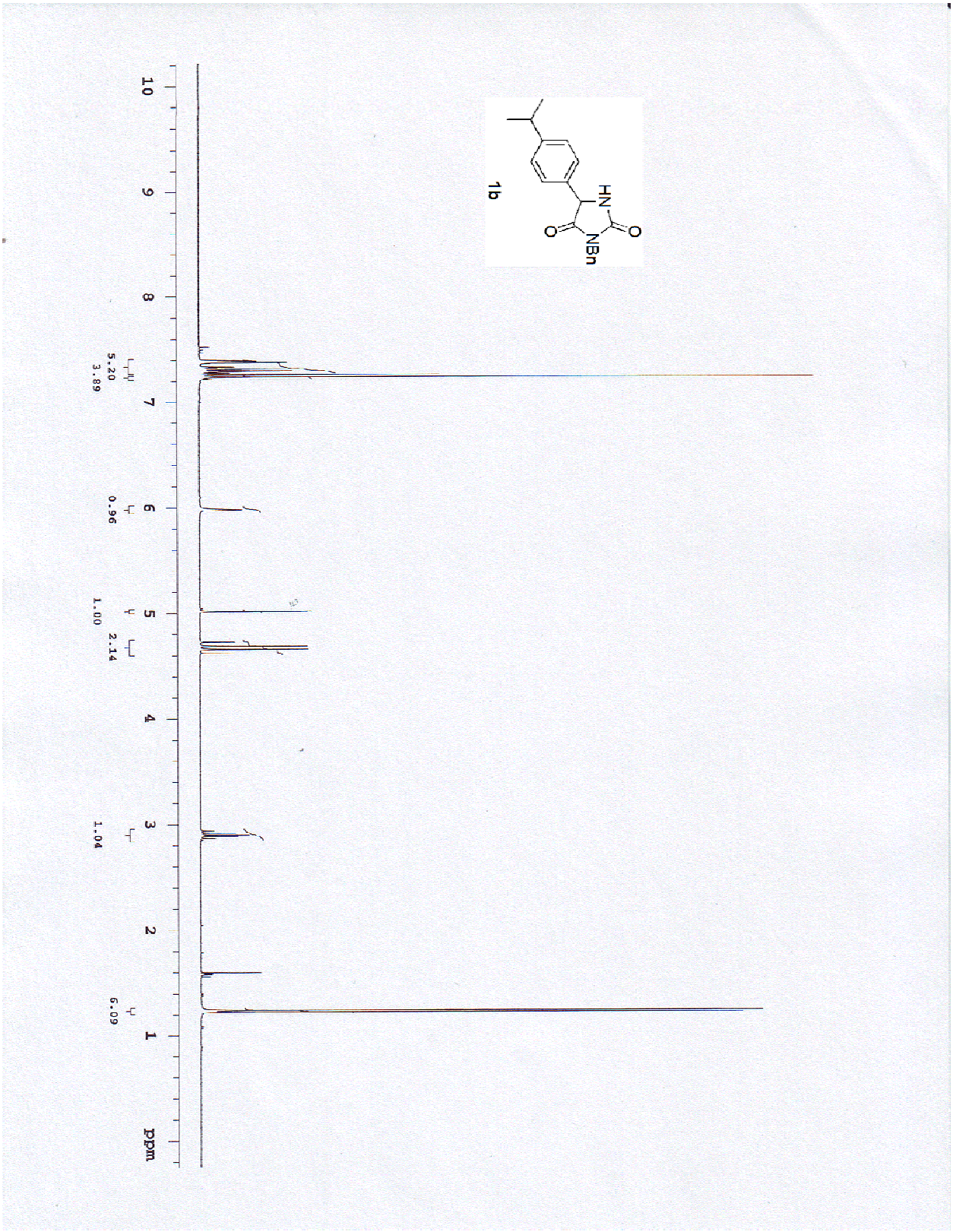
3a **5a**, 87% Yield

^{1}H NMR (400 MHz, $CDCl_3$) : δ 7.41 - 7.21 (m, 9H), 4.93 (m, 1H), 3.74 (d, J = 3.2 Hz, 2H), 2.92 (d, *J* = 11.6 Hz, 1H), 2.79 (d, *J* = 12.0 Hz, 1H), 2.61 (m, 1H), 2.46 (m, 1H), 2.12 (s, 3H), 1.64 (s, 3H), 1.54 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$) : δ140.5, 134.4, 128.3, 128.2, 128.0, 126.8, 126.7, 126.5, 119.0, 62.1, 54.2, 53.7, 34.9, 28.6, 26.0.

FTIR (neat) ν_{max} 3059, 3025, 2966, 2913, 2854, 2798, 1713, 1495, 1451, 1376, 1119 cm^{-1}.

LRMS[ES+] calcd for $C_{21}H_{28}N_2$ $[M+H]^+$ 309.2, found 309.2.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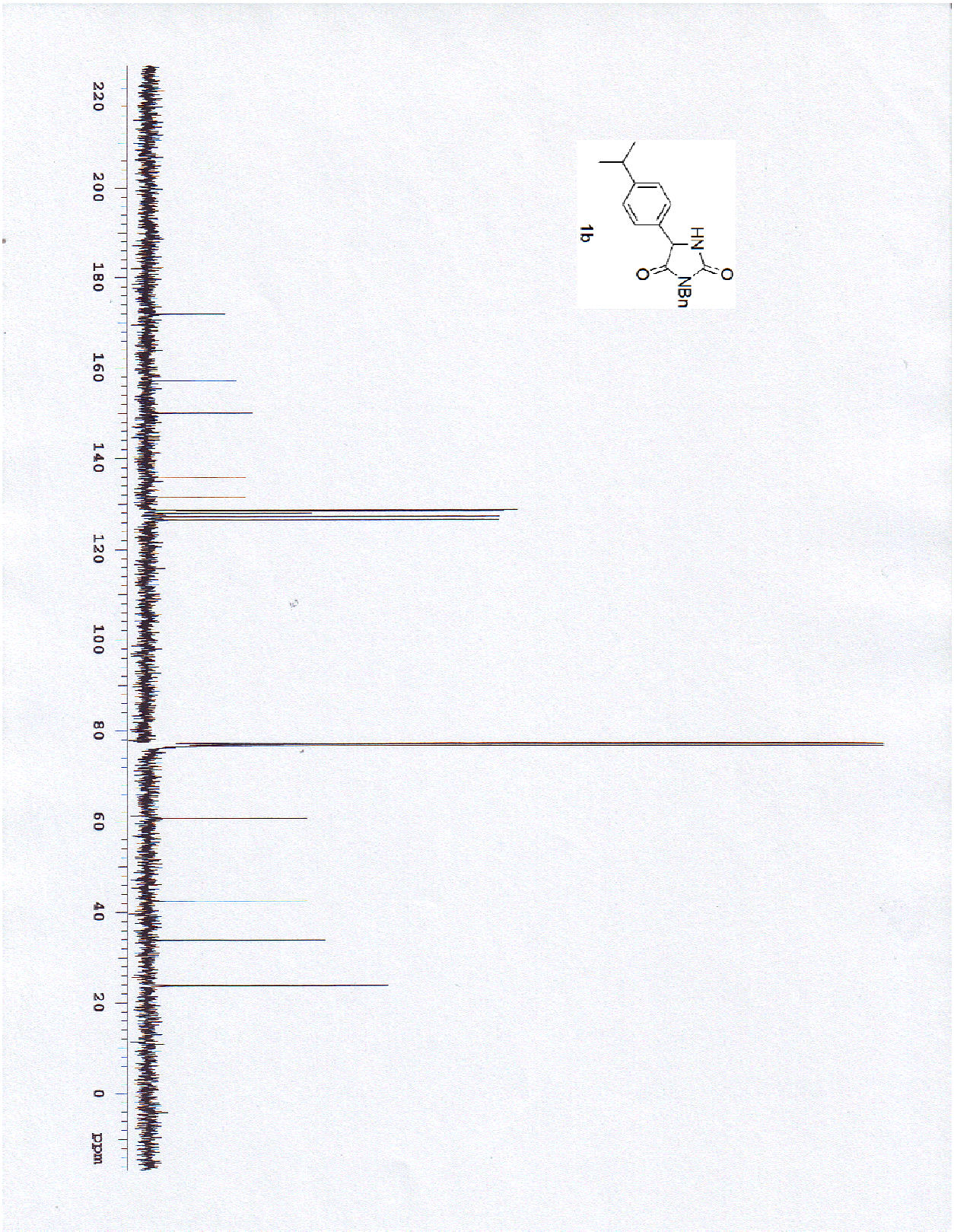
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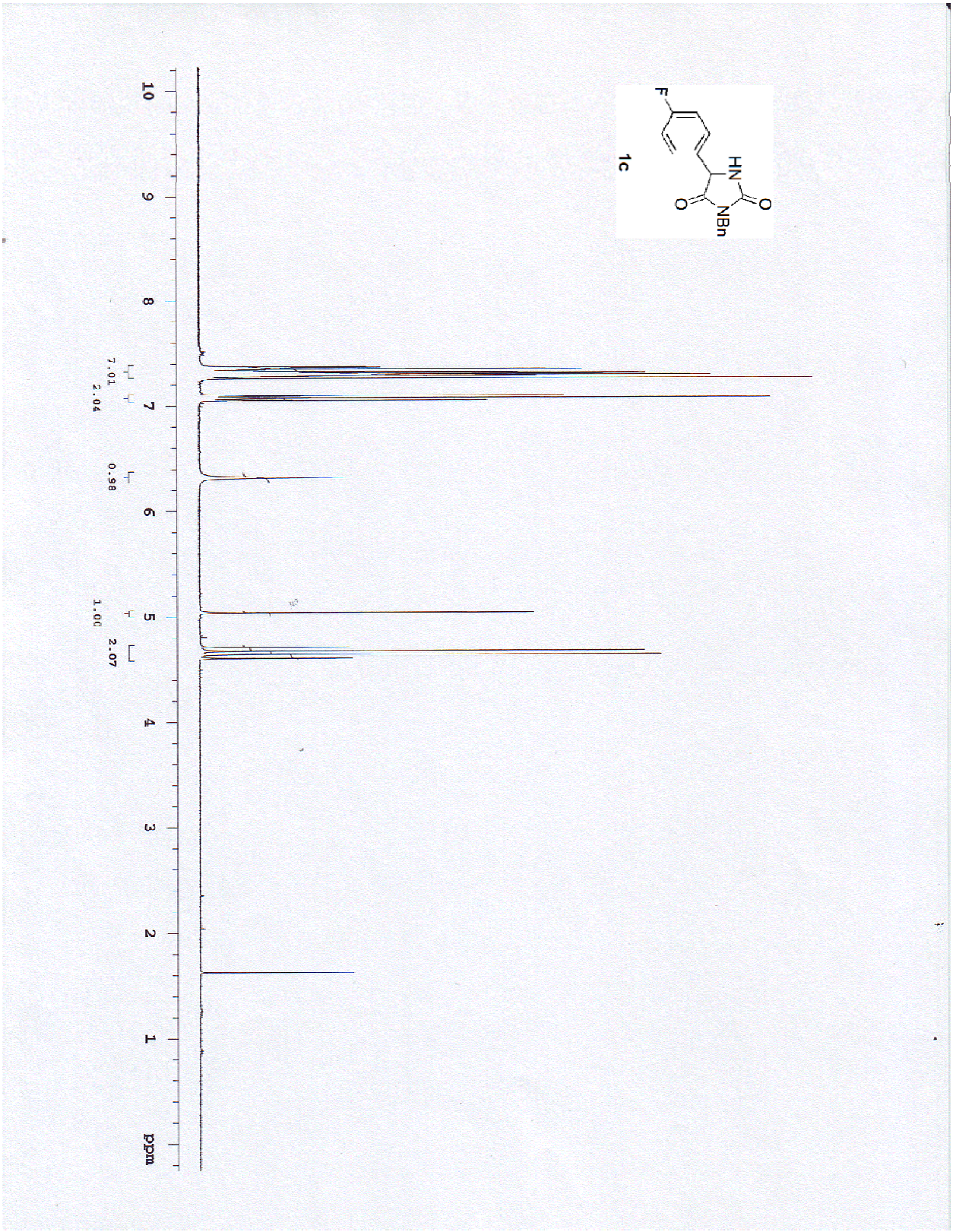

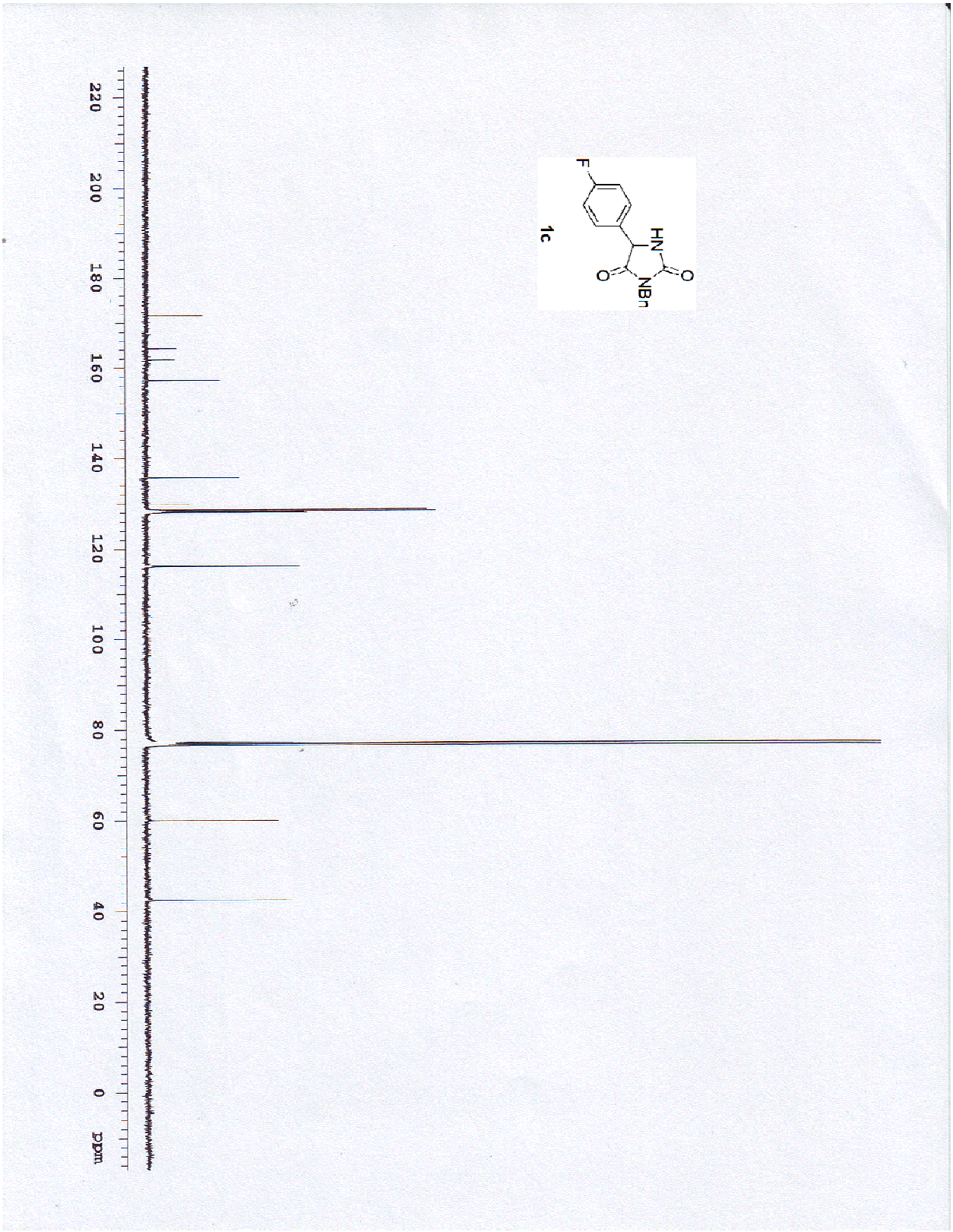
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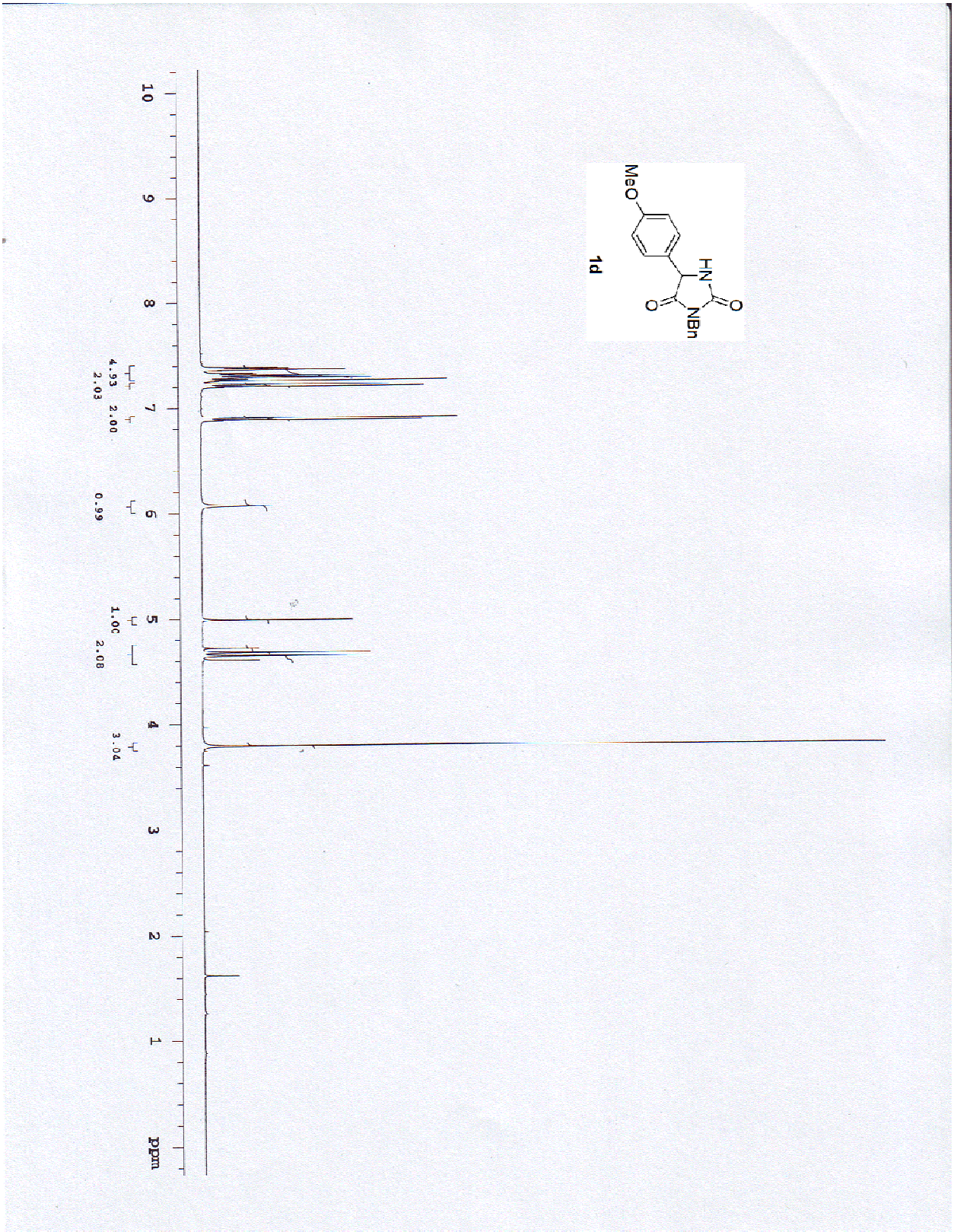
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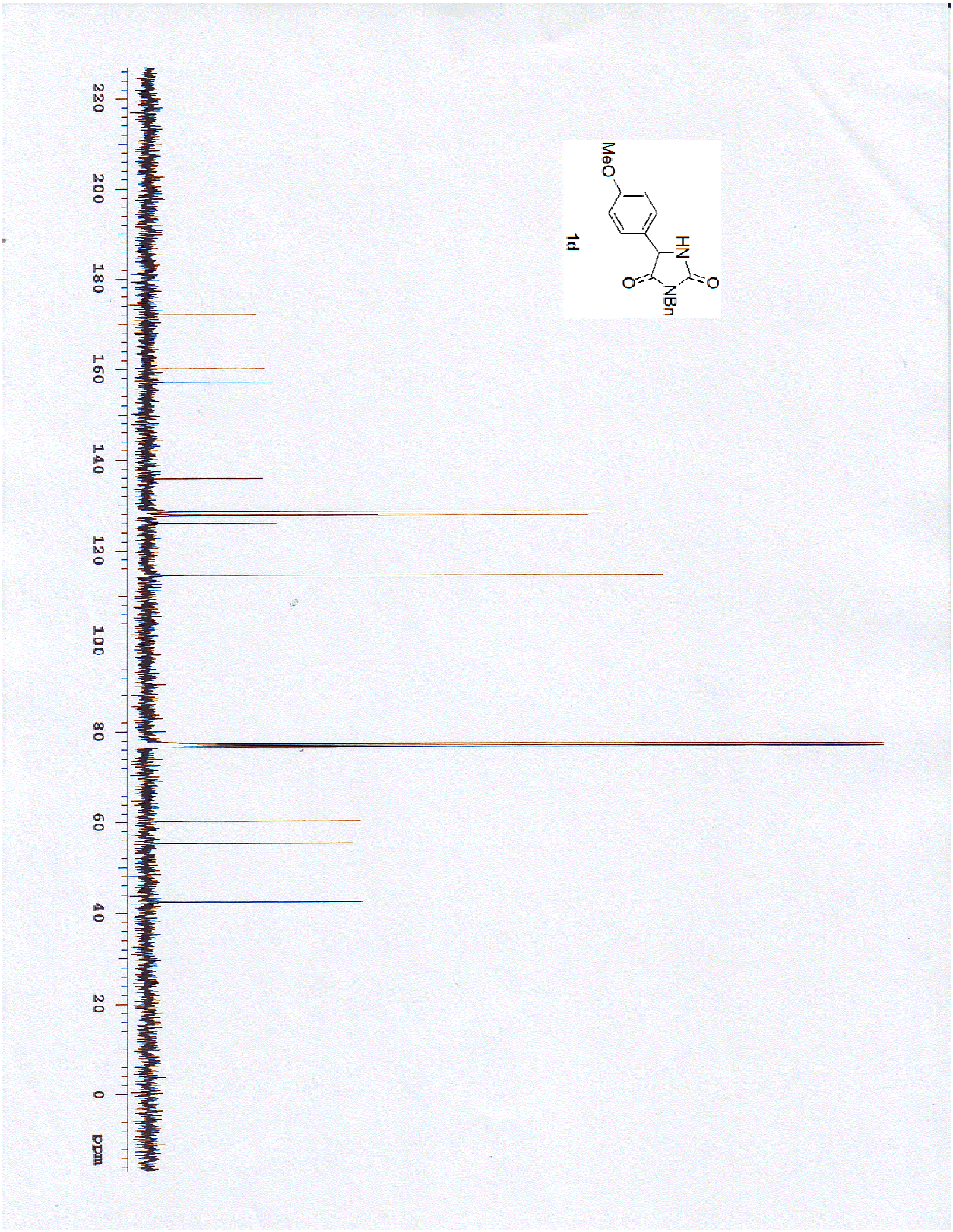
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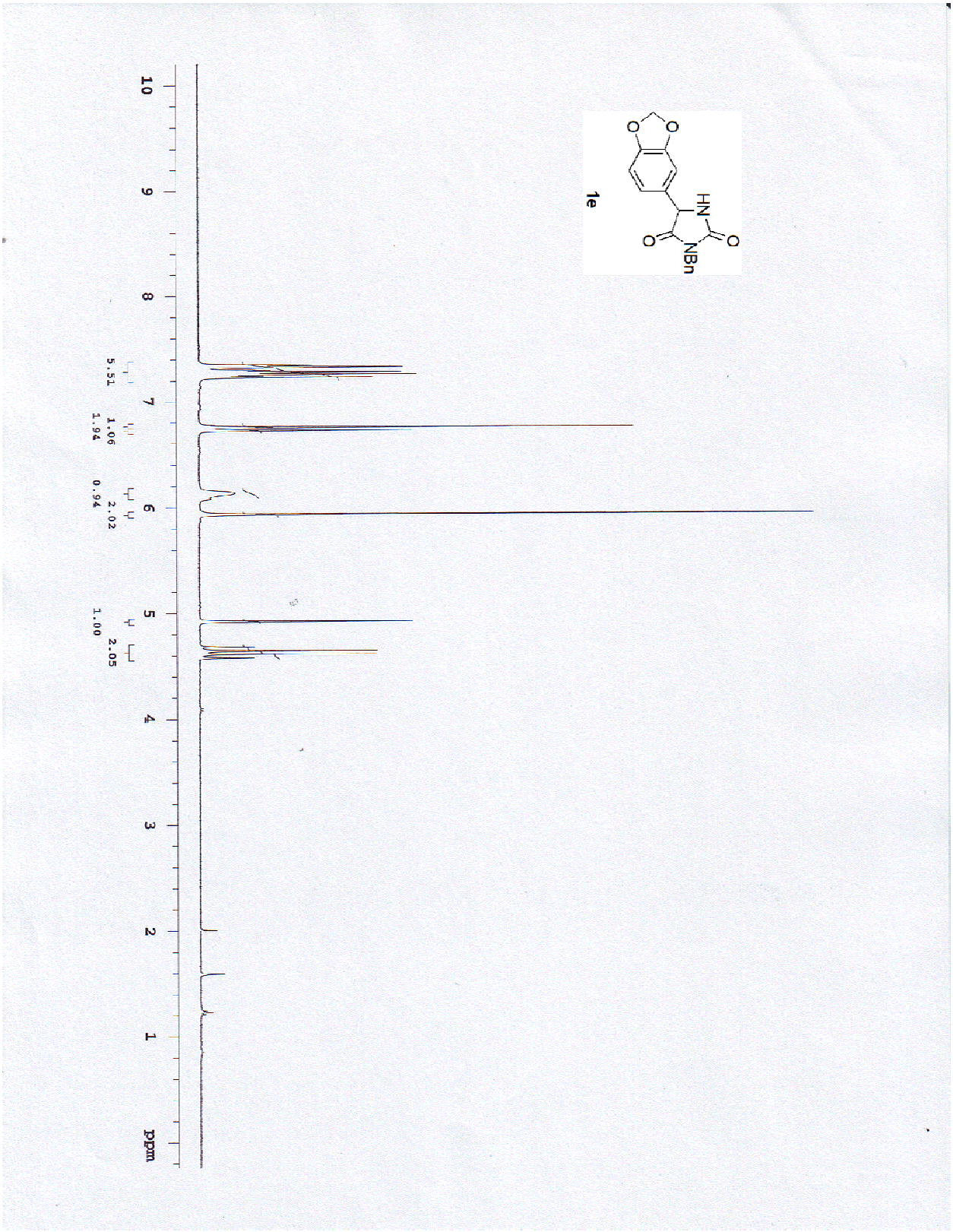

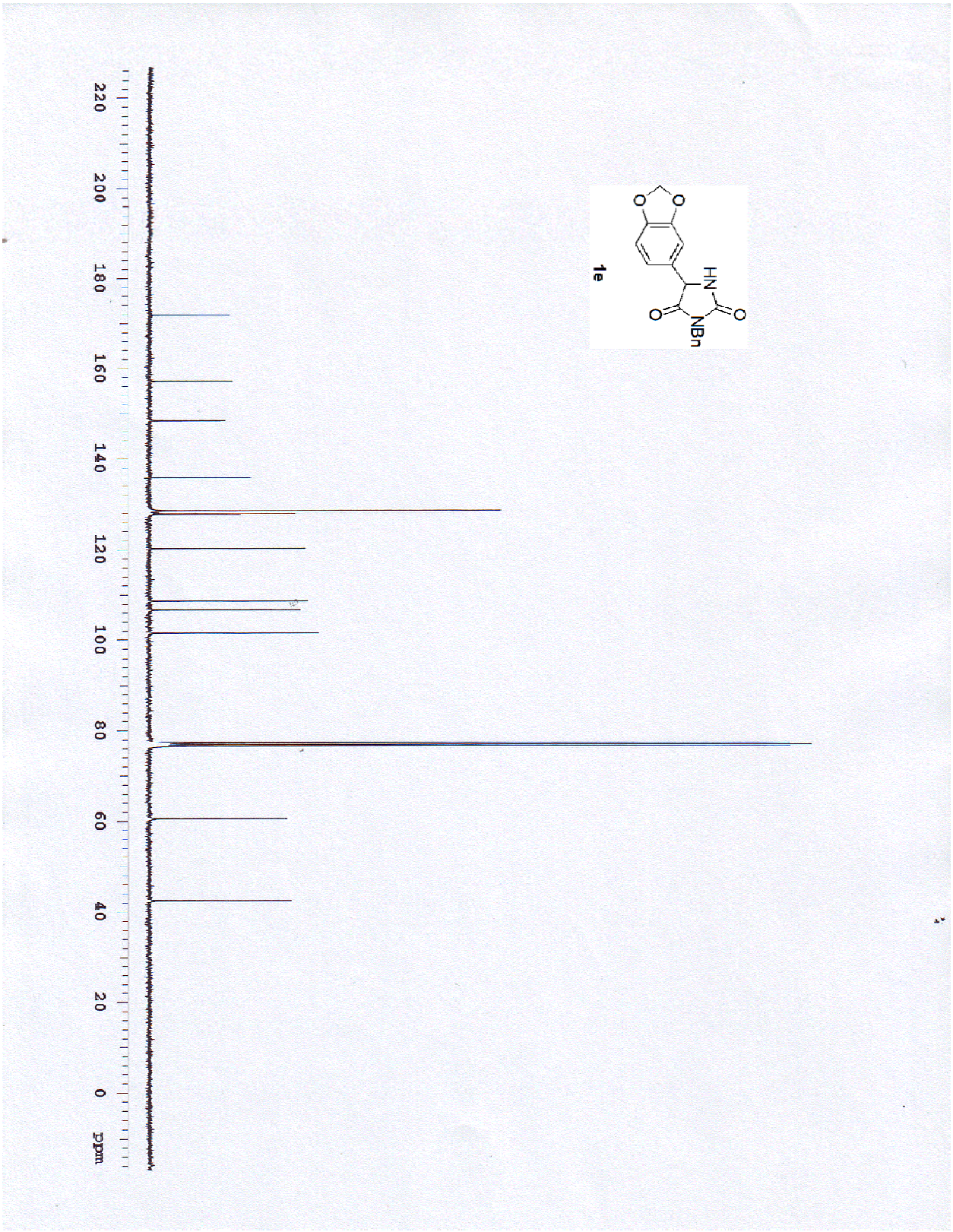
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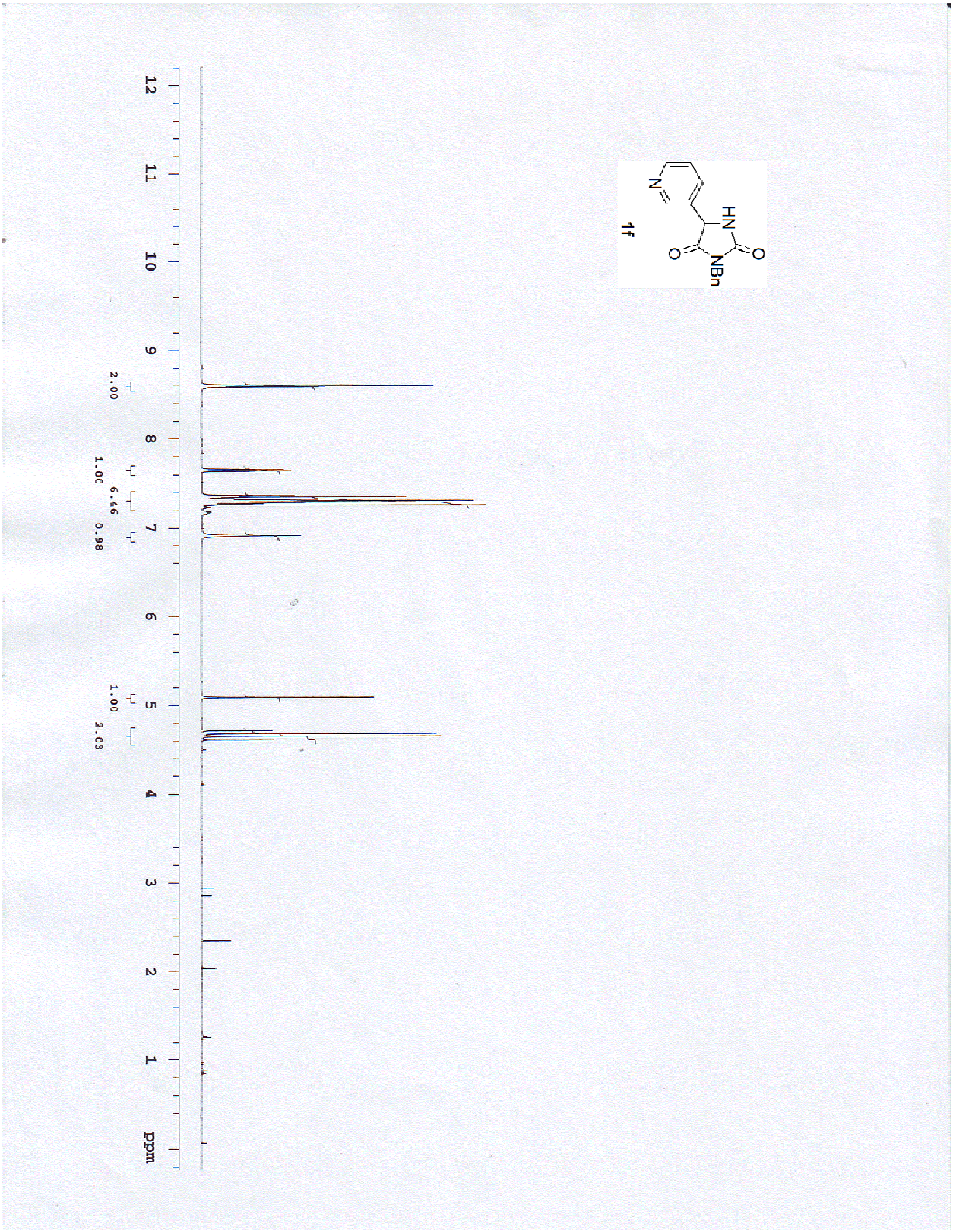
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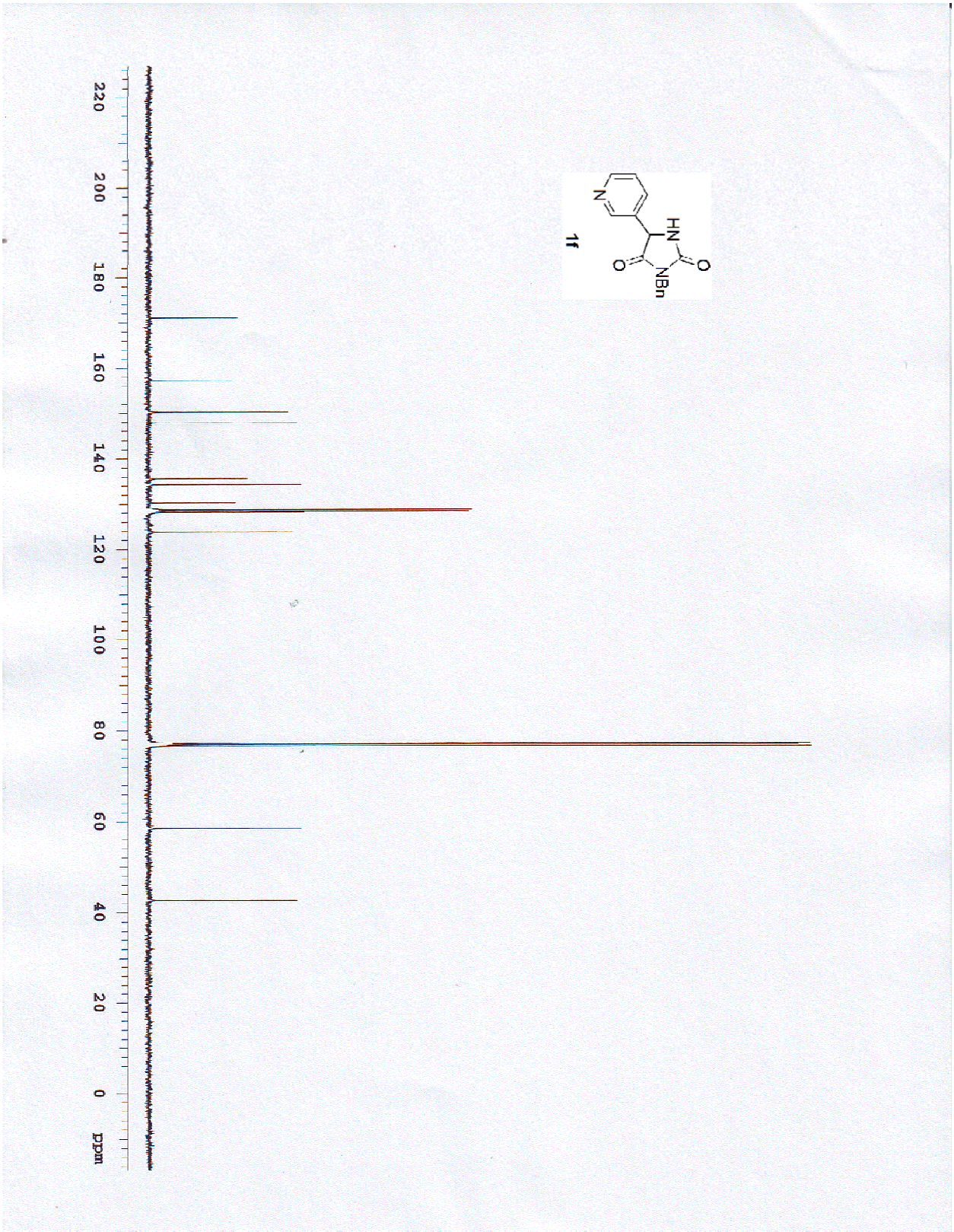
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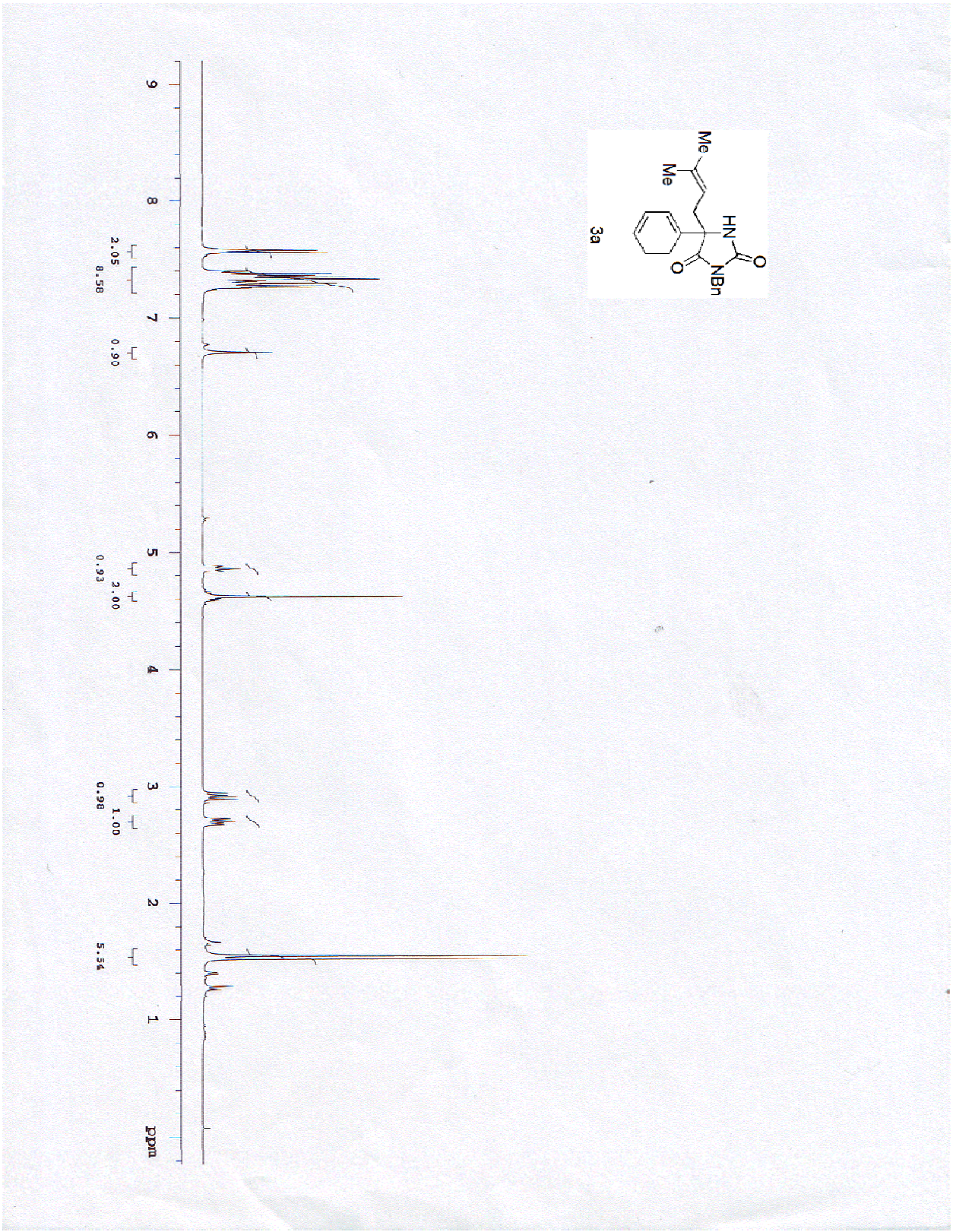
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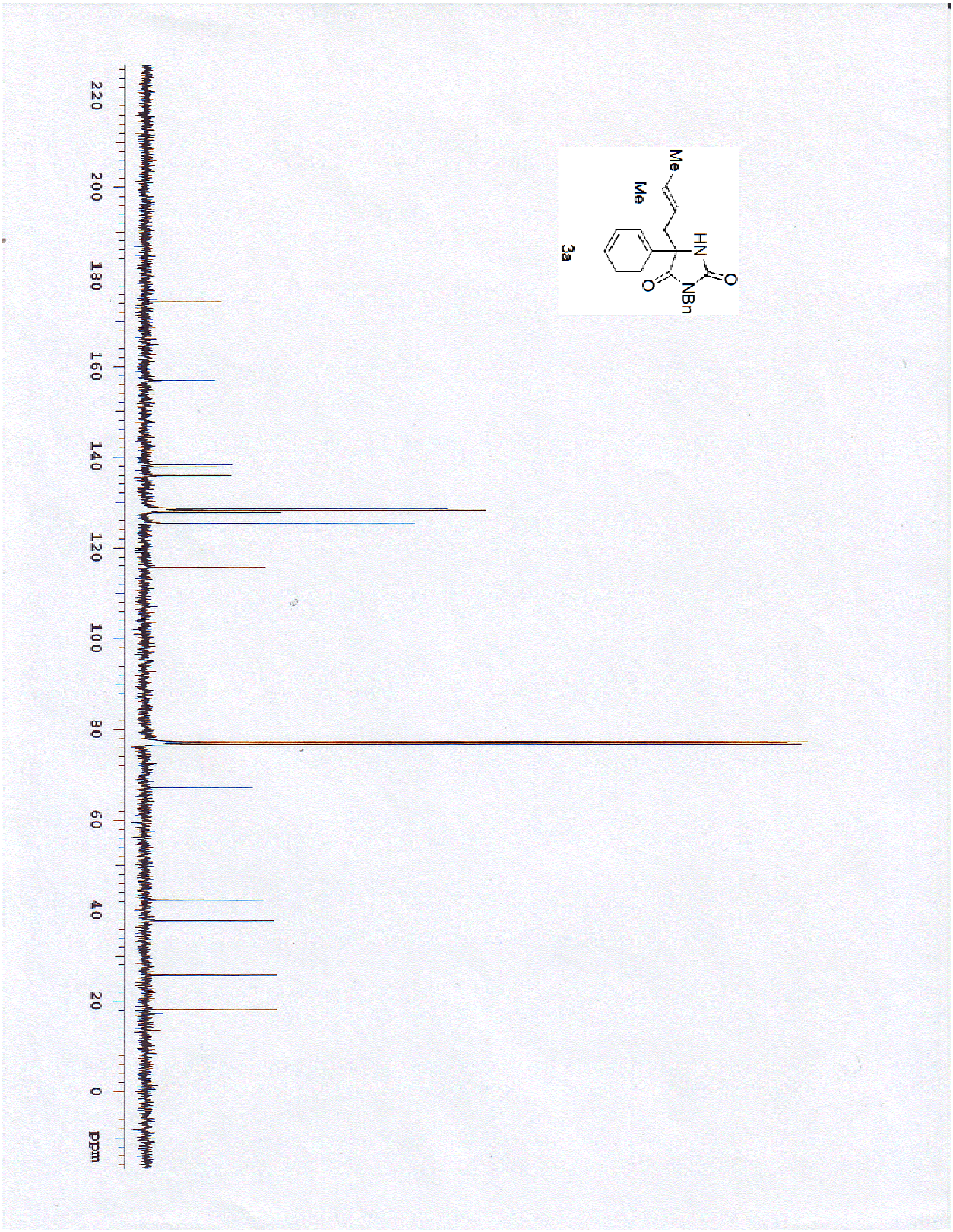
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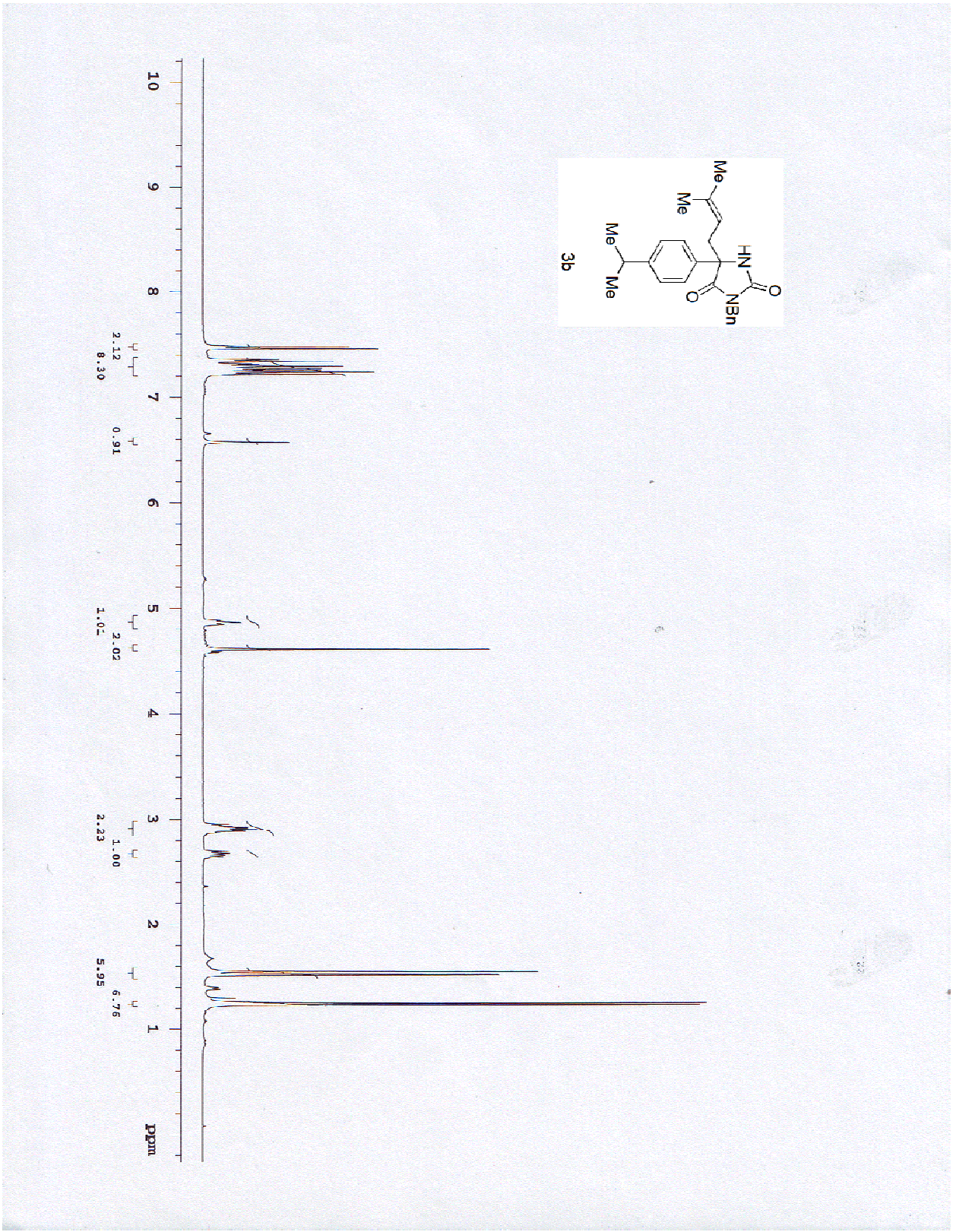
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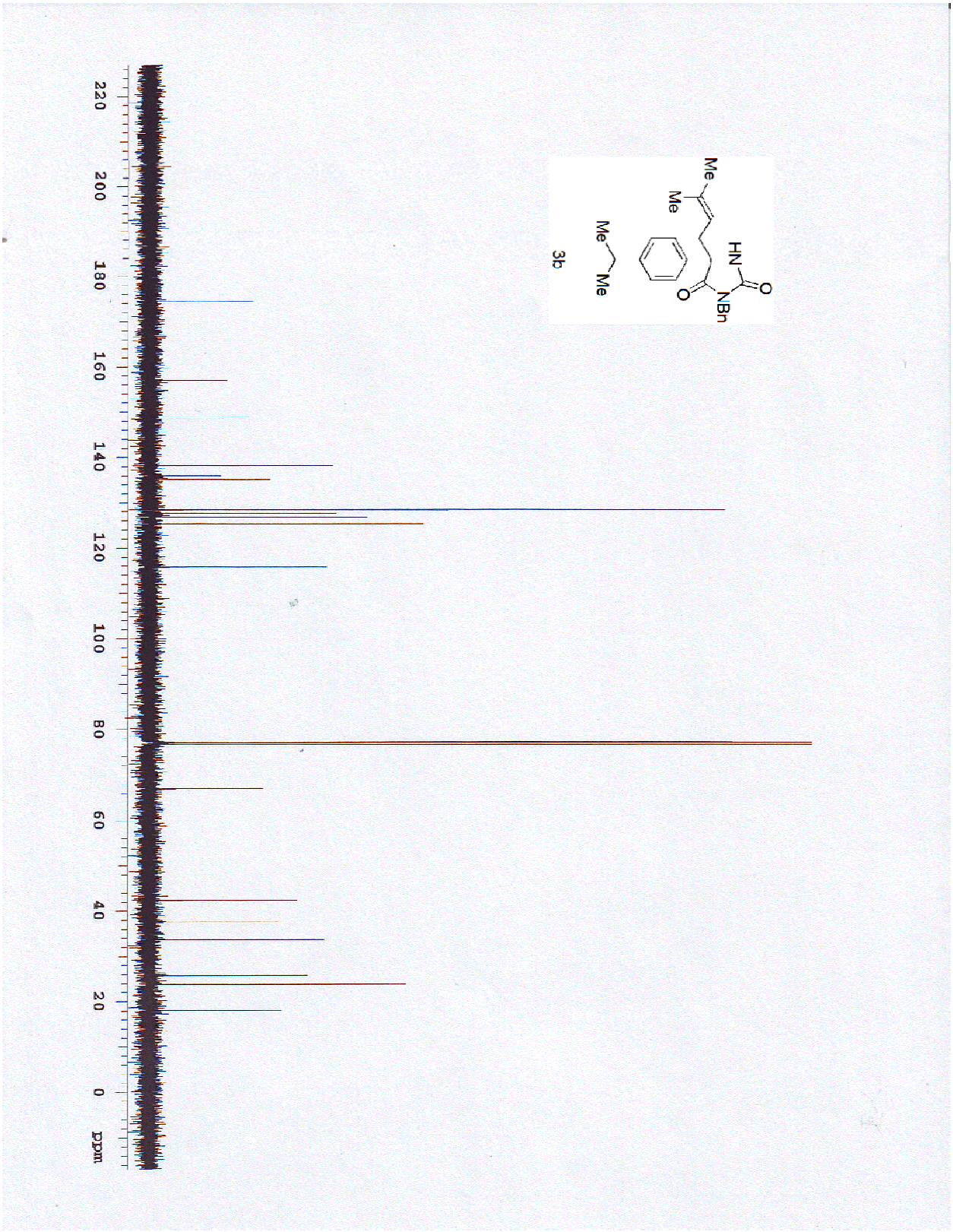
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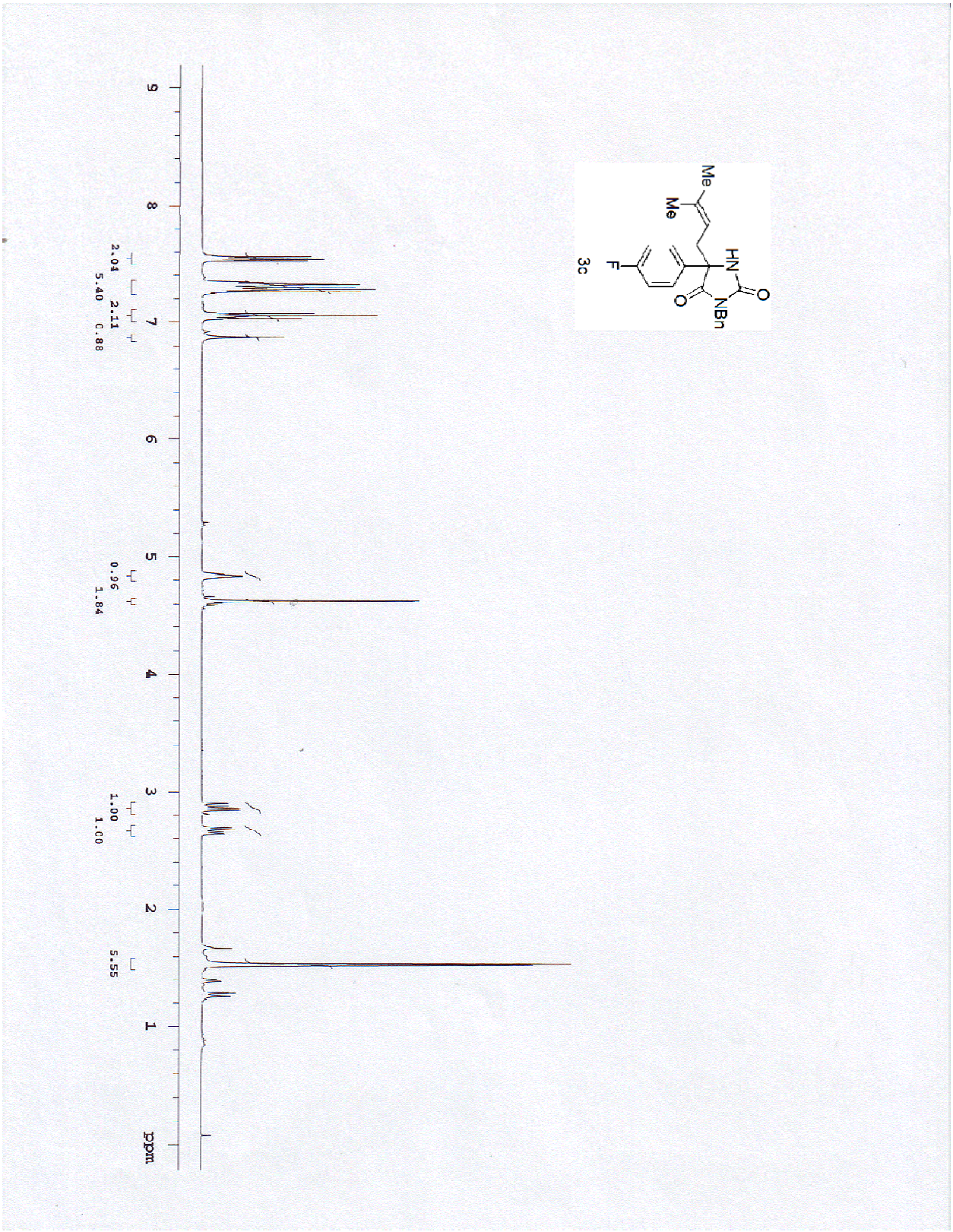
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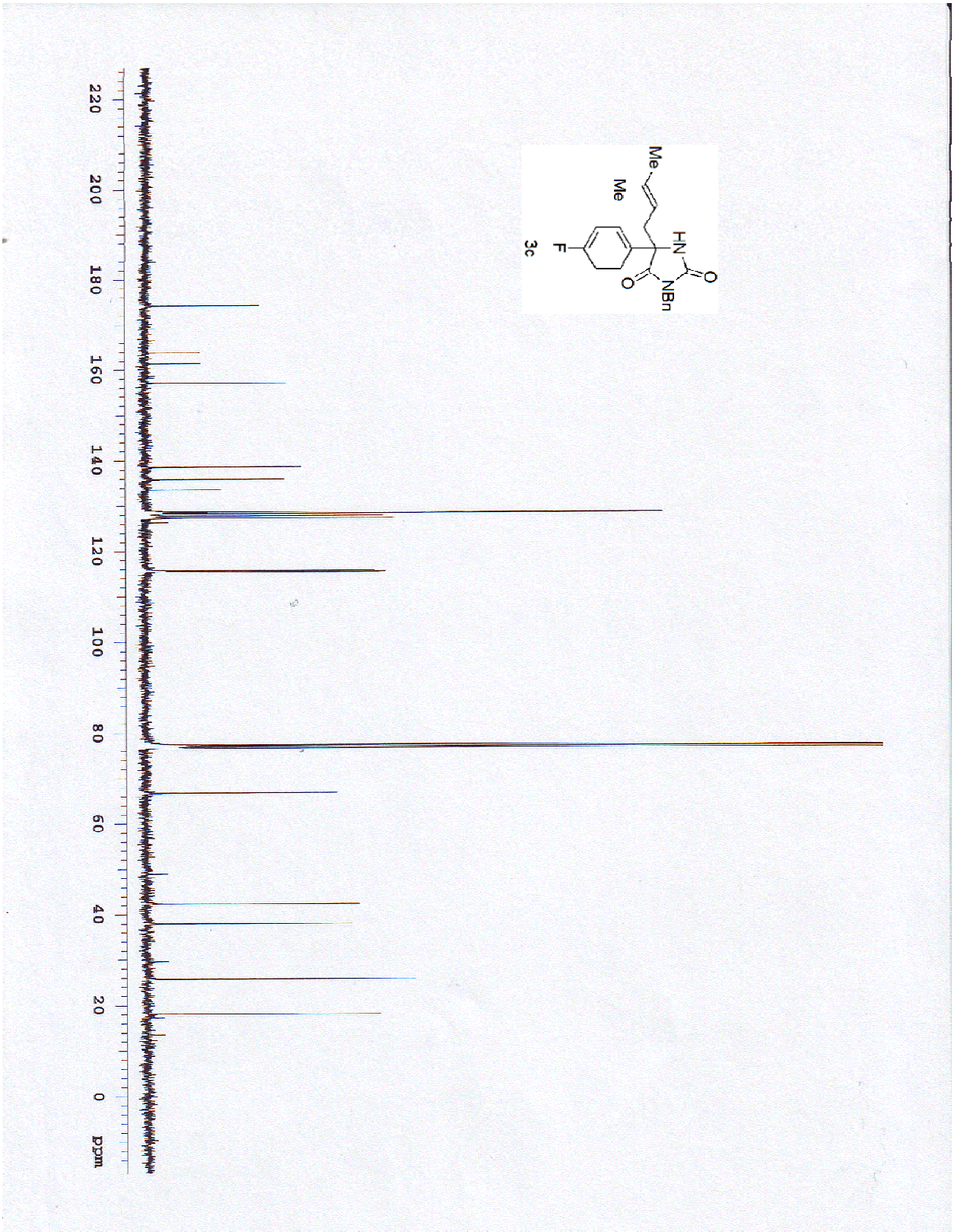
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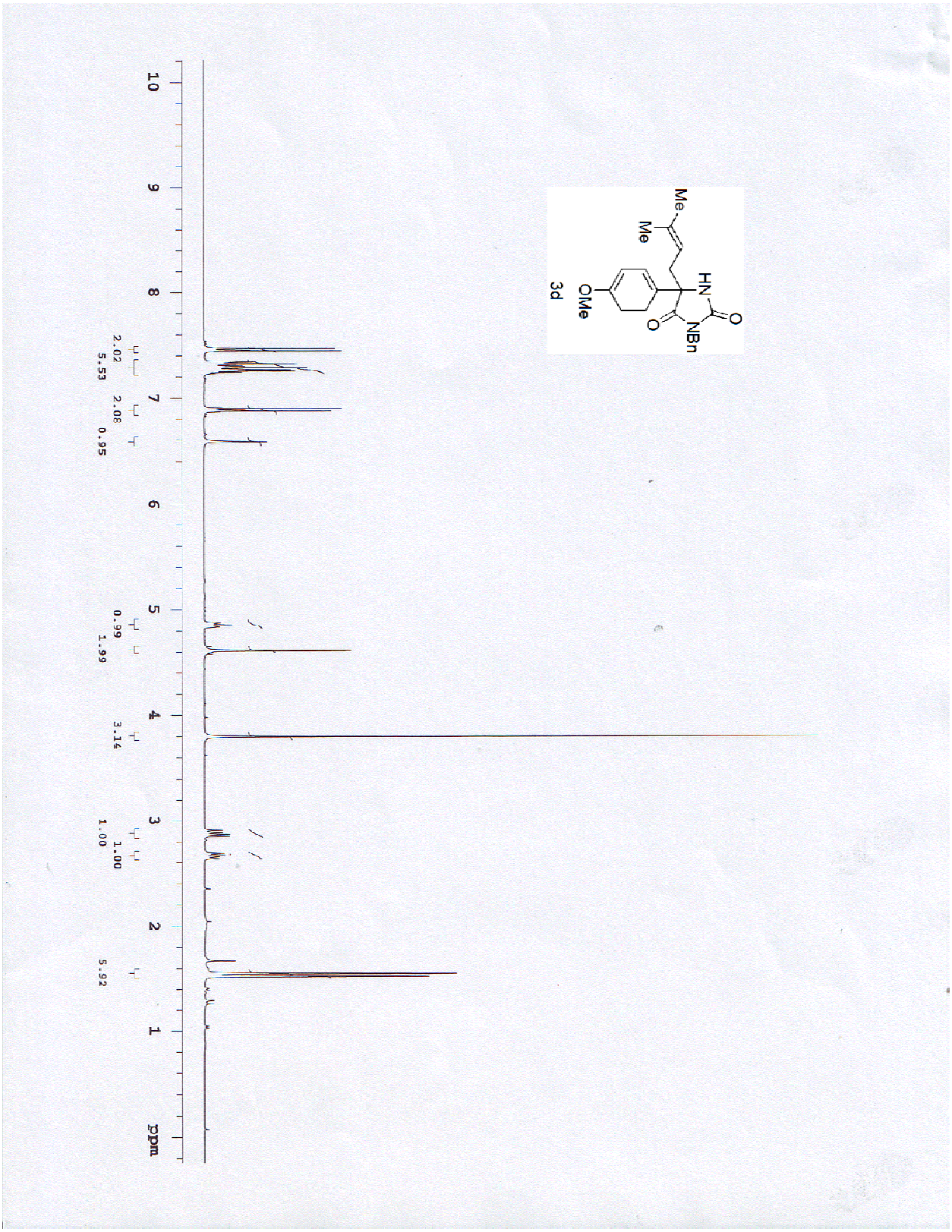

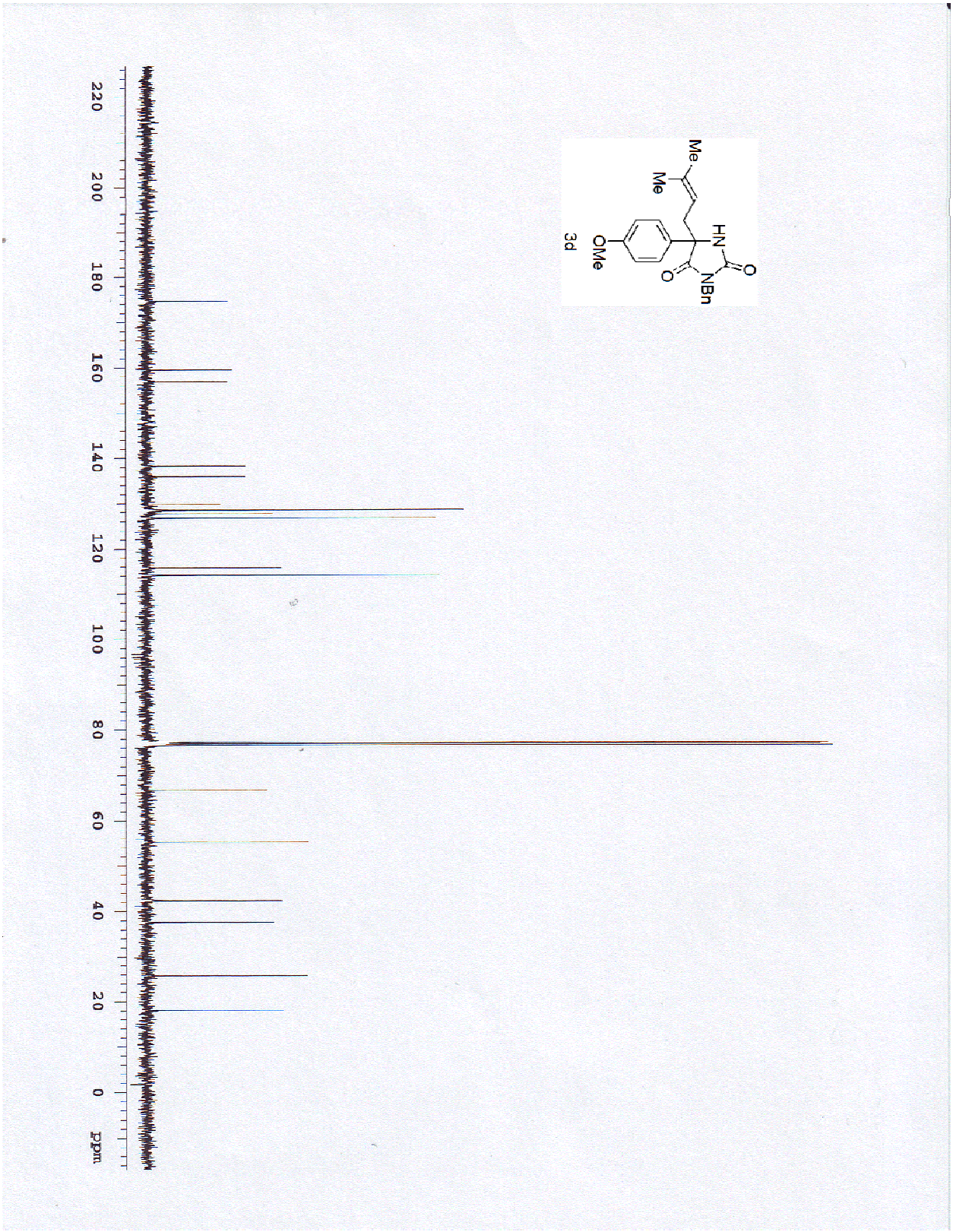
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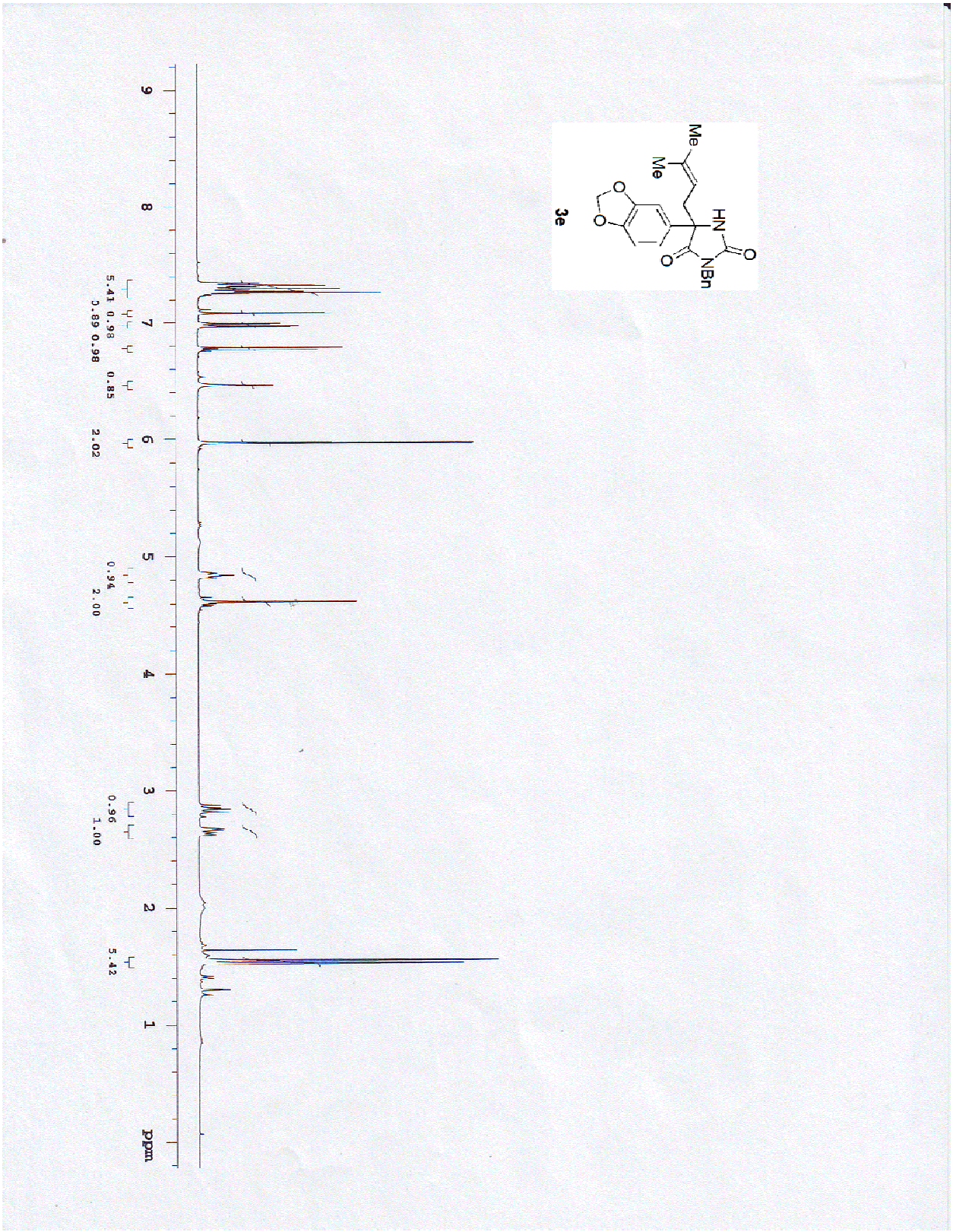
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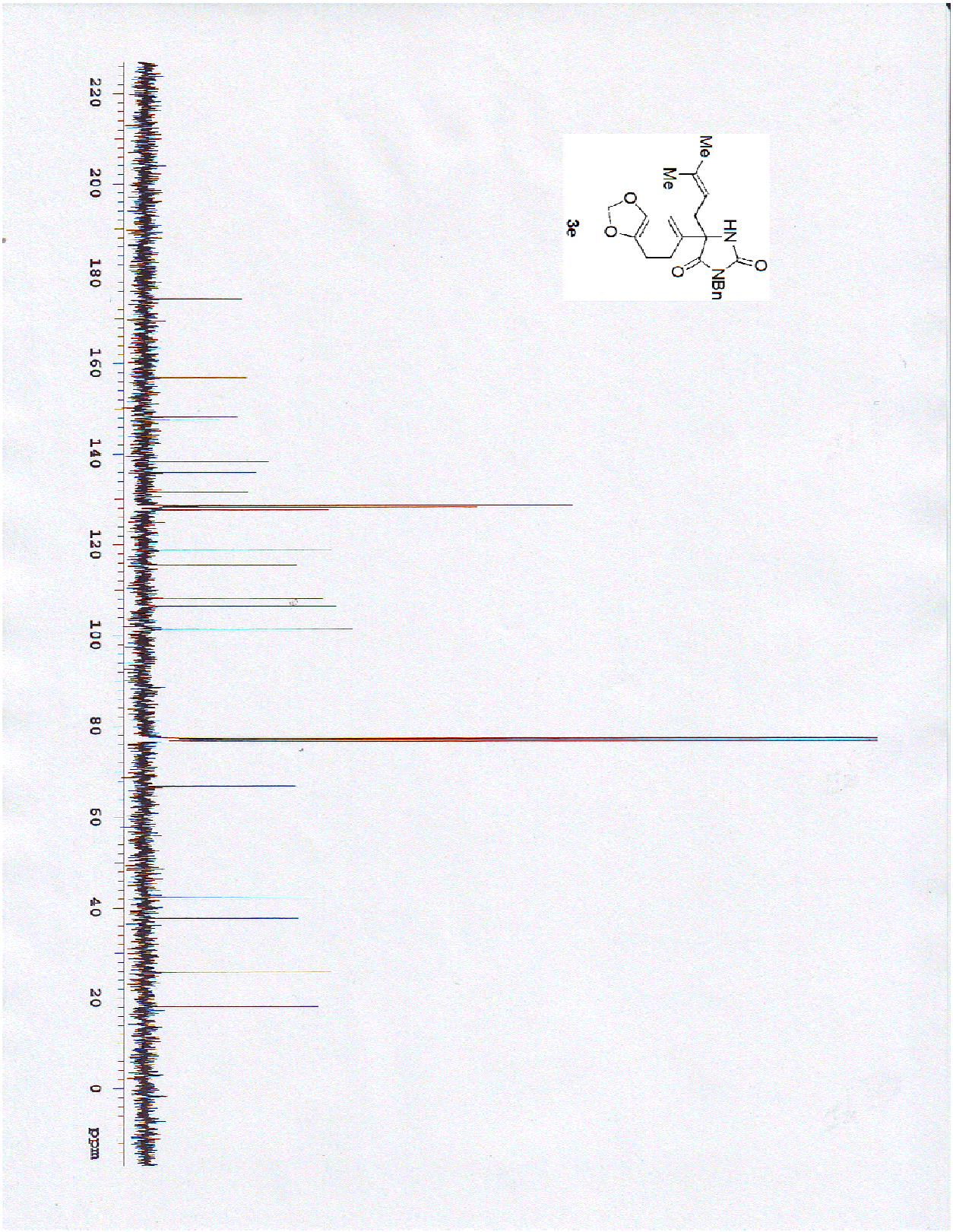
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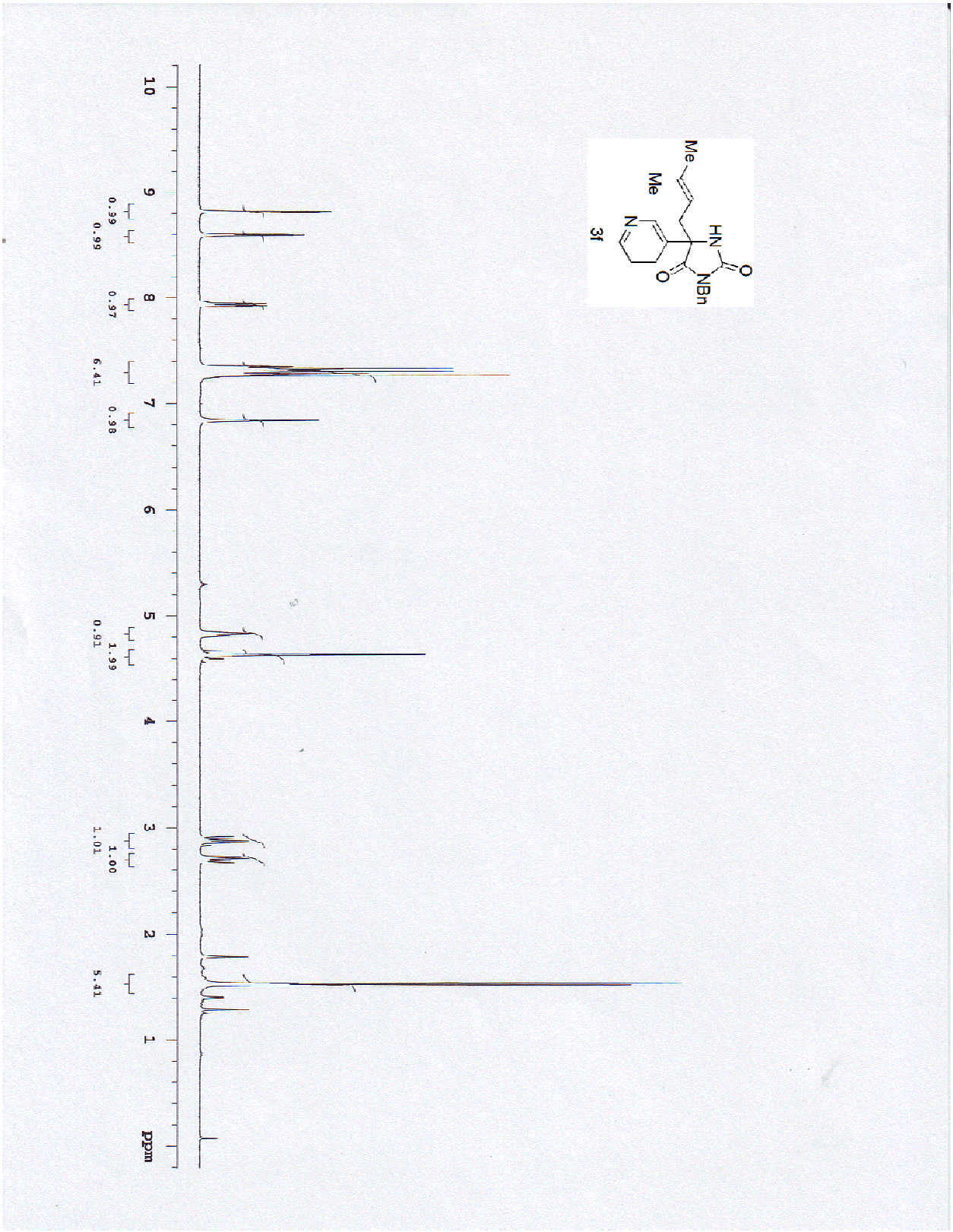
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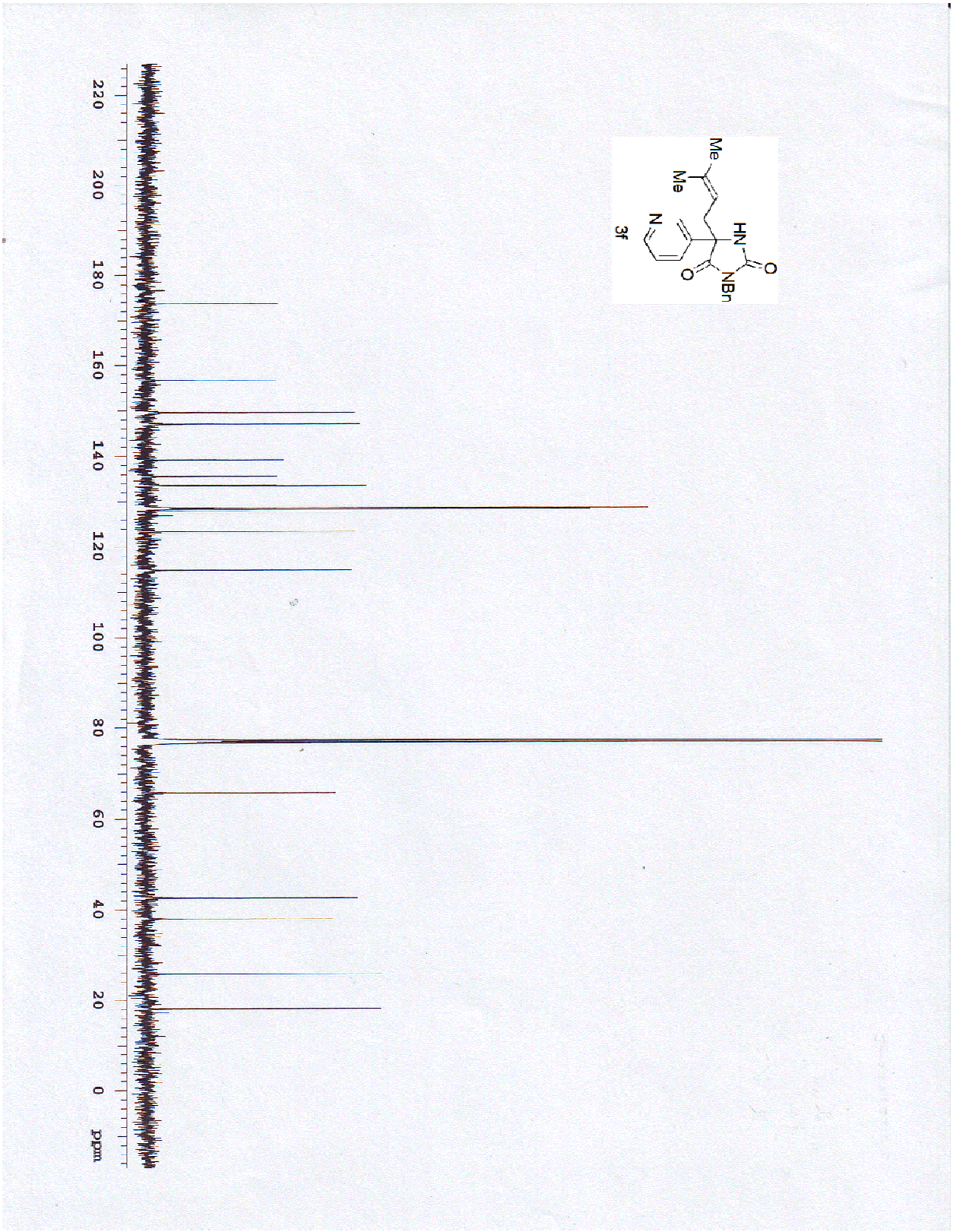
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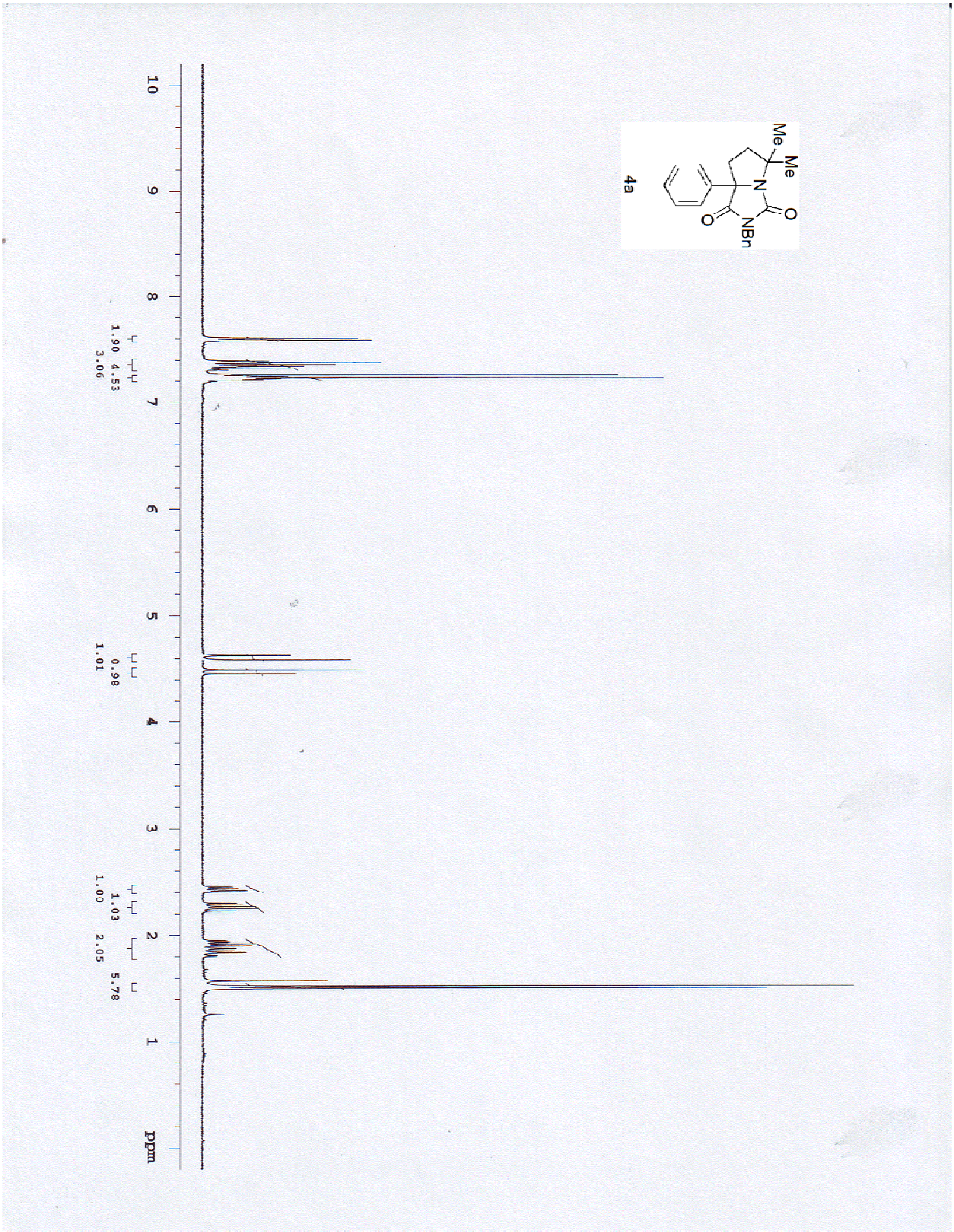
3f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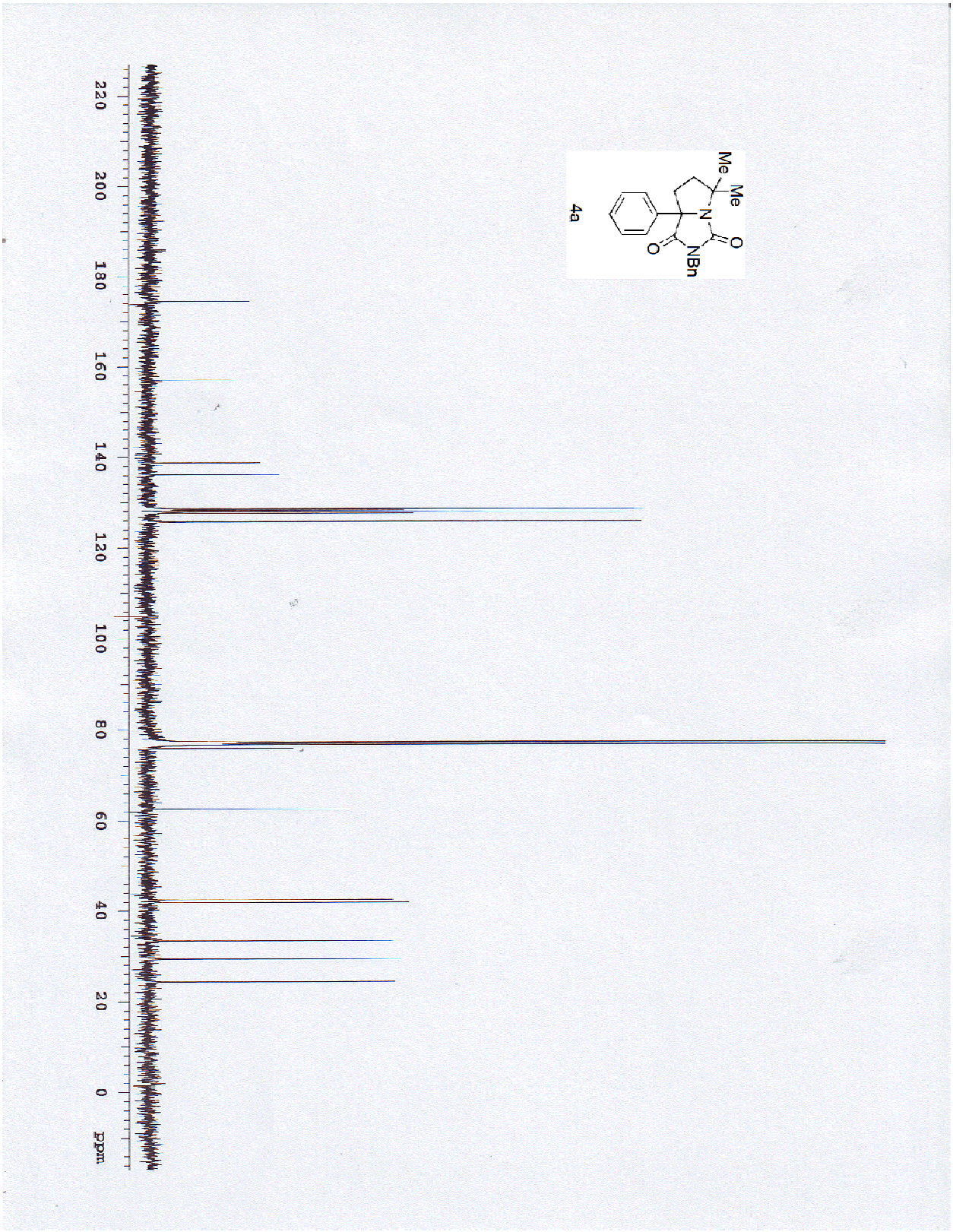
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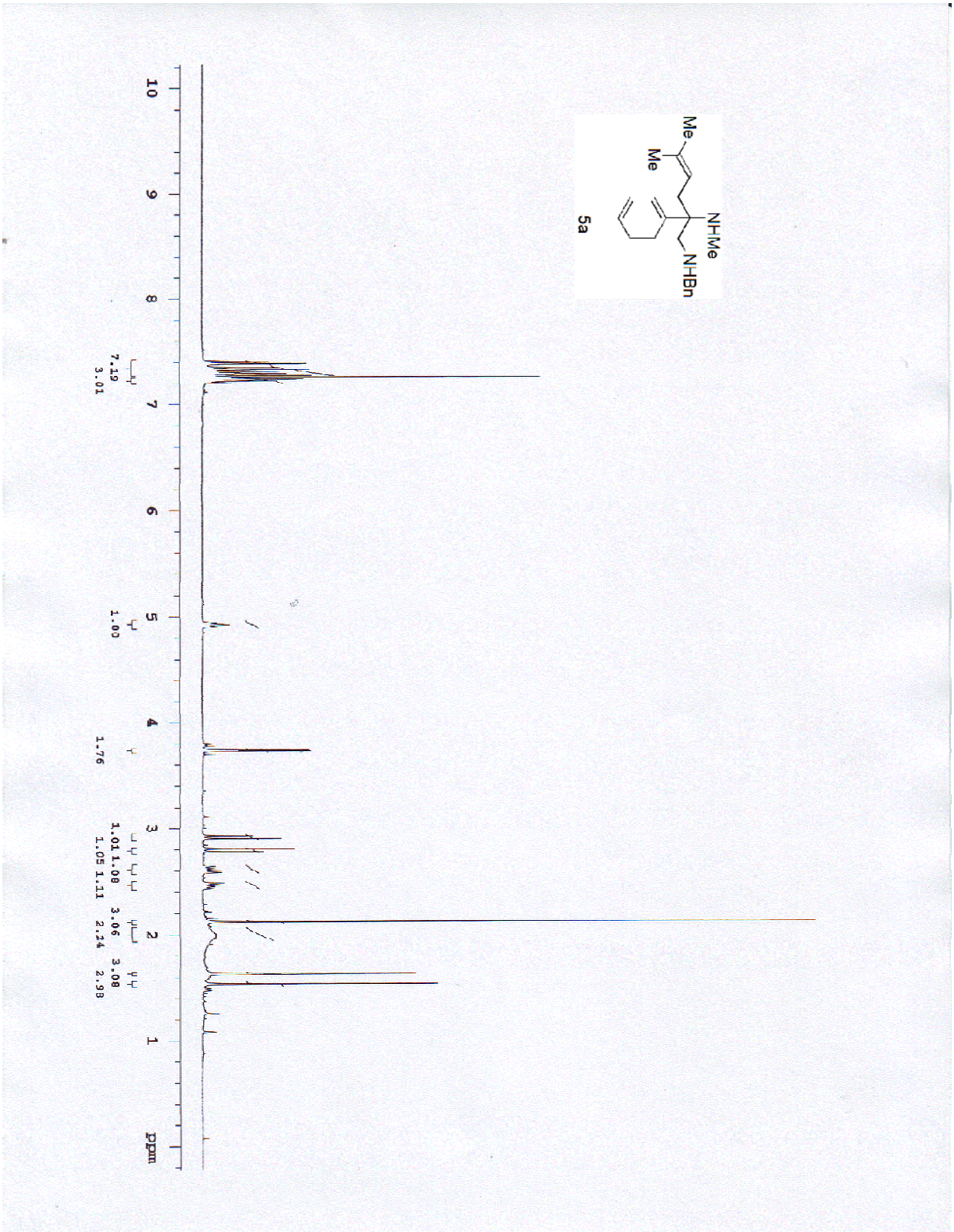
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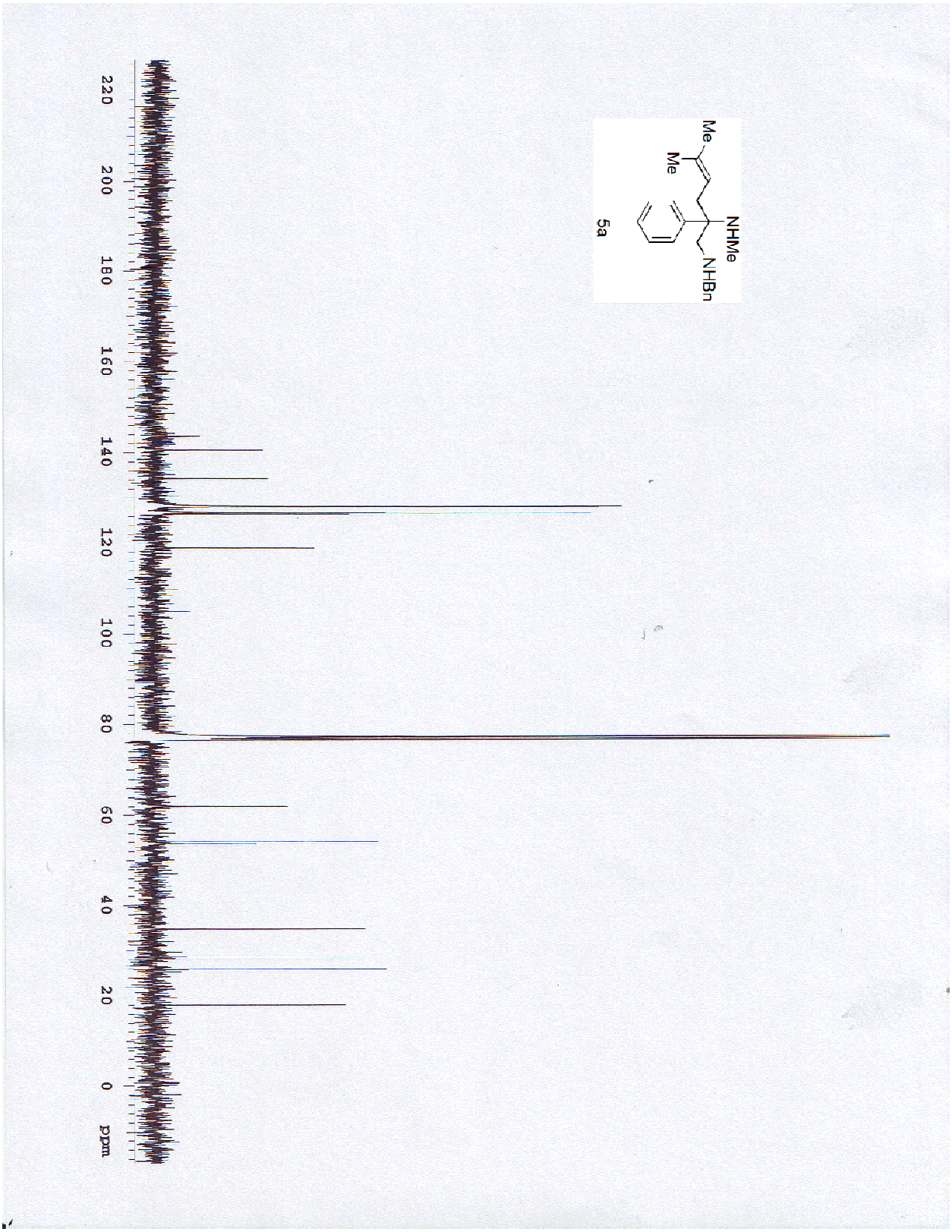
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