SUPPORTING INFORMATION

Copper-Catalyzed Arylation and Alkenylation of Polyfluoroarene C-H Bonds

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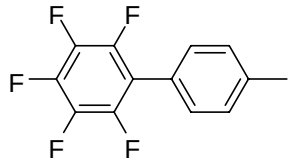
Experimental Section

General considerations. Reactions were performed in 1-dram vials with PTFE/Liner caps. Flash chromatography was performed on 60Å silica gel (Sorbent Technologies). Purification by preparative HPLC was performed on a Shimadzu Prominence LC (LC-20AB) equipped with a SPD-20A UV-Vis detector and a Varian Dynamax (250 mm x 21.4 mm) column. GC-MS analyses were performed on a Shimadzu GCMS-QP5000 chromatograph equipped with a Restek column (Rtx-XLB, 30 m x 0.25 mm I.D.). The ^{1}H, ^{19}F and ^{13}C NMR were recorded on a GE QE-300 spectrometer using residual solvent peak as a reference. Hexafluorobenzene (1% in C_6D_6, δ = -164.9) was employed as an external standard in ^{19}F NMR spectra. Elemental analyses were performed by Atlantic Microlab Inc. of Norcross, GA. IR spectra were obtained using ThermoNicolet Avatar 370 FT-IR instrument.

Materials. The following starting materials were obtained from commercial sources and were used without further purification: 4-bromotoluene, 4-iodotoluene, 4-bromobenzotrifluoride, 4-bromobenzonitrile, 2-bromothiophene, 3-fluoropyridine, 1,4-difluorobenzene, 1,3,5-trifluorobenzene and 1,2,3,4-tetrafluorobenzene were bought from Oakwood. 1,10-Phenanthroline, copper(I) iodide, DMF, lithium t-butoxide, 1-bromonaphthalene and beta-bromostyrene (mixture of *cis* and *trans* isomers) were obtained from Acros. Potassium phosphate, *m*-xylene, 4-bromoanisole, 1-bromo-4-fluorobenzene, ethyl 4-bromobenzoate, 2-bromopyridine, 3-bromopyridine, 2-bromonaphthalene, 2-bromo-1,3,5-trimethylbenzene, fluorobenzene, 1,2,4,5-tetrafluorobenzene, 1,3,4,5-tetrafluorobenzene and 2,3,5,6-tetrafluoropyridine were purchased from Aldrich. 2-Bromotoluene, 1,3-difluorobenzene and pentafluorobenzene were from Alfa Aesar. 2-Iodo-1,3,5-trimethylbenzene was bought from Maybridge. *t*-Butanol (OD) was from Cambridge Isotope Laboratories, Inc.

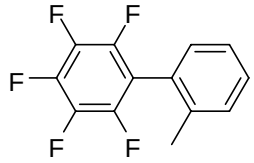
General procedure for coupling of haloarenes with polyfluorobenzenes. Outside the glovebox a 1-dram vial equipped with a magnetic stir bar was charged with the haloarene (1.0 mmol), phenanthroline (0.1 mmol), polyfluorobenzene (1.5-3 equiv) and commercial, non-anhydrous DMF or a mixture (1/1) of DMF and xylene (0.6 mL). The vial was flushed with argon, capped and placed inside a glovebox. To this mixture was added CuI (10 mol %) and K_3PO_4 (2.0-2.5 equiv). The sealed vial was taken out of the glovebox, stirred at room temperature for 5 min and placed in a preheated oil bath (130 ^{o}C) for 24 hours. The reaction

mixture was allowed to cool to room temperature and diluted with ethyl acetate (50 mL). The resulting solution was washed with brine (3 x 15 mL), dried over anhydrous $MgSO_4$, and concentrated under vacuum to a volume of about 1 mL. The mixture containing the product was subjected to flash chromatography on silica gel (hexanes followed by appropriate solvent to elute the products). After concentrating the fractions containing the product, the residue was dried under reduced pressure to yield pure arylation product.

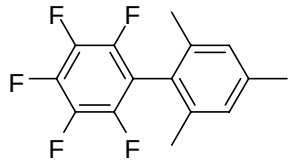


2,3,4,5,6-Pentafluoro-4'-methylbiphenyl (Entry 1, Table 1): Copper(I) iodide (19.1 mg, 0.1 mmol), 4-bromotoluene (171 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), pentafluorobenzene (252 mg, 1.5 mmol), K_3PO_4 (424 mg, 2.0 mmol), and DMF/xylene (0.6 mL), 140 ^oC. After column chromatography (hexanes) 235 mg (91%) of a white solid was obtained. R_f = 0.60 (SiO_2, hexanes). This compound is known.[1] ^1H NMR (300 MHz, $CDCl_3$) δ 2.42 (s, 3H), 7.31 (s, 4H). ^{19}F NMR (282 MHz, $CDCl_3$) δ -164.6- -164.3 (m, 2F), -158.1 (t, J_F = 21.0 Hz, 1F), -145.4 (dd, J_F = 7.6, 23.0 Hz, 2F).

Large scale reaction: Copper(I) iodide (191 mg, 1 mmol), 4-bromotoluene (1710 mg, 10 mmol), 1,10-phenanthroline (180 mg, 1 mmol), pentafluorobenzene (2520 mg, 15 mmol), K_3PO_4 (4240 mg, 20 mmol), and DMF/xylene (6 mL), 140 ^oC. The reaction was carried out in a 25 mL Schlenk flask instead of a 1-dram vial. After column chromatography (hexanes) 2.3 g (88%) of 2,3,4,5,6-pentafluoro-4'-methylbiphenyl was obtained.



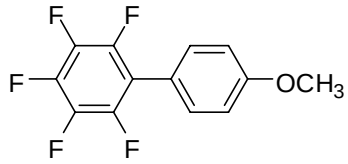
2,3,4,5,6-Pentafluoro-2'-methylbiphenyl (Entry 2, Table 1): Copper(I) iodide (19.1 mg, 0.1 mmol), 2-bromotoluene (171 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), pentafluorobenzene (252 mg, 1.5 mmol), K_3PO_4 (424 mg, 2.0 mmol), and DMF/xylene (0.6 mL), 140 ^oC. After column chromatography (hexanes) 225 mg (87%) of a colorless oil was obtained. R_f = 0.60 (SiO_2, hexanes). This compound is known.[1] ^1H NMR (300 MHz, $CDCl_3$) δ 2.18 (s, 3H), 7.16-7.43 (m, 4H). ^{19}F NMR (282 MHz, $CDCl_3$) δ -164.4- -164.1 (m, 2F), -157.4 (t, J_F = 23.0 Hz, 1F), -142.5 (dd, J_F = 7.6, 23.0 Hz, 2F).



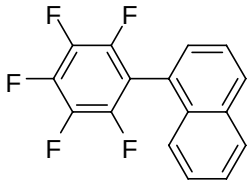
2,3,4,5,6-Pentafluoro-2',4',6'-trimethylbiphenyl (Entry 3, Table 1)

Arylation by aryl bromide: Copper(I) iodide (19.1 mg, 0.1 mmol), 2-bromo-1,3,5-trimethylbenzene (199 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), pentafluorobenzene (252 mg, 1.5 mmol), K_3PO_4 (424 mg, 2.0 mmol), and DMF/xylene (0.6 mL), 140 ^oC. After column chromatography (hexanes) and preparative HPLC (hexanes) 60 mg (20%) of a white solid was obtained.

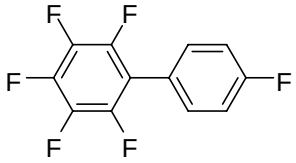
Arylation by aryl iodide: Copper(I) iodide (19.1 mg, 0.1 mmol), 2-iodo-1,3,5-trimethylbenzene (246 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), pentafluorobenzene (252 mg, 1.5 mmol), K_3PO_4 (424 mg, 2.0 mmol), and DMF (0.6 mL). After column chromatography (hexanes) 250 mg (87%) of a white solid was obtained. R_f = 0.64 (SiO_2, hexanes). This compound is known.[2] ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.05 (s, 6H), 2.34 (s, 3H), 7.00 (s, 2H). ^{19}F NMR (282 MHz, $CDCl_3$) δ -164.1- -163.8 (m, 2F), -157.4 (t, J_F = 23.0 Hz, 1F), -145.3 (dd, J_F = 7.6, 23.0 Hz, 2F).



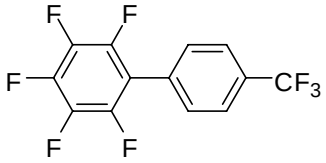
2,3,4,5,6-Pentafluoro-4'-methoxybiphenyl (Entry 4, Table 1): Copper(I) iodide (19.1 mg, 0.1 mmol), 4-bromoanisole (187 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), pentafluorobenzene (252 mg, 1.5 mmol), K_3PO_4 (424 mg, 2.0 mmol), and DMF/xylene (0.6 mL), 140 ^oC. After column chromatography (10% ethyl acetate in hexanes) 240 mg (88%) of a white solid was obtained. R_f = 0.33 (SiO_2, hexanes). This compound is known.[1] ^{1}H NMR (300 MHz, $CDCl_3$) δ 3.86 (s, 3H), 6.98-7.04 (m, 2H), 7.33-7.38 (m, 2H). ^{19}F NMR (282 MHz, $CDCl_3$) δ -164.7- -164.3 (m, 2F), -158.5 (t, J_F = 21.0 Hz, 1F), -145.7 (dd, J_F = 7.6, 23.0 Hz, 2F).



1-(Pentafluorophenyl)naphthalene (Entry 5, Table 1): Copper(I) iodide (19.1 mg, 0.1 mmol), 1-bromonaphthalene (207 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), pentafluorobenzene (252 mg, 1.5 mmol), K_3PO_4 (424 mg, 2.0 mmol), and DMF/xylene (0.6 mL), 140 ^oC. After column chromatography (hexanes) and preparative HPLC (hexanes) 200 mg (68%) of a white solid was obtained. R_f = 0.40 (SiO_2, hexanes). This compound is known.[3] ^1H NMR (300 MHz, $CDCl_3$) δ 7.45-7.63 (m, 5H), 7.94-8.04 (m, 2H). ^{19}F NMR (282 MHz, $CDCl_3$) δ -164.0- -163.7 (m, 2F), -156.6 (t, J_F = 21.0 Hz, 1F), -141.4 (dd, J_F = 7.6, 23.0 Hz, 2F).

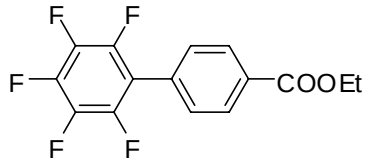


2,3,4,4',5,6-Hexafluorobiphenyl (Entry 6, Table 1): Copper(I) iodide (19.1 mg, 0.1 mmol), 1-bromo-4-fluorobenzene (175 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), pentafluorobenzene (252 mg, 1.5 mmol), K_3PO_4 (424 mg, 2.0 mmol), and DMF/xylene (0.6 mL), 140 ^oC. After column chromatography (hexanes) 240 mg (92%) of a white solid was obtained. R_f = 0.55 (SiO_2, hexanes). This compound is known.[1] ^1H NMR (300 MHz, $CDCl_3$) δ 7.14-7.24 (m, 2H), 7.36-7.45 (m, 2H). ^{19}F NMR (282 MHz, $CDCl_3$) δ -164.1- -163.8 (m, 2F), -157.2 (t, J_F = 21.0 Hz, 1F), -142.1 (dd, J_F = 7.6, 23.0 Hz, 2F), -113.3 (s, 1F).

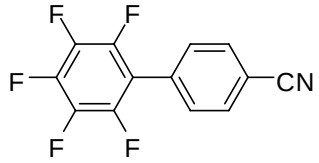


2,3,4,5,6-Pentafluoro-4'-(trifluoromethyl)biphenyl (Entry 7, Table 1): Copper(I) iodide (19.1 mg, 0.1 mmol), 4-bromobenzotrifluoride (225 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), pentafluorobenzene (252 mg, 1.5 mmol), K_3PO_4 (424 mg, 2.0 mmol), and DMF/xylene (0.6 mL), 140 ^oC. After column chromatography (hexanes) 275 mg (88%) of a white solid was obtained. R_f = 0.55 (SiO_2, hexanes). This compound is known.[1] ^1H NMR (300 MHz, $CDCl_3$) δ 7.56 (d, J = 8.0 Hz, 2H), 7.76 (d, J = 8.0 Hz, 2H). ^{19}F NMR (282 MHz,

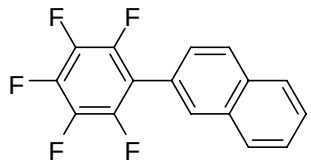
$CDCl_3$) δ -163.4- -163.2 (m, 2F), -155.7 (t, J_F = 21.0 Hz, 1F), -144.9 (dd, J_F = 7.6, 23.0 Hz, 2F), -64.9 (s, 3F).



Ethyl 2',3',4',5',6'-pentafluorobiphenyl-4-carboxylate (Entry 8, Table 1): Copper(I) iodide (19.1 mg, 0.1 mmol), ethyl 4-bromobenzoate (229 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), pentafluorobenzene (252 mg, 1.5 mmol), K_3PO_4 (424 mg, 2.0 mmol), and DMF/xylene (0.6 mL). After column chromatography (10% ethyl acetate in hexanes) 285 mg (90%) of a white solid was obtained. R_f = 0.20 (SiO_2, hexanes). This compound is known.[1] ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.41 (t, J = 7.0 Hz, 3H), 4.41 (q, J = 7.0 Hz, 2H), 7.50 (d, J = 8.0 Hz, 2H), 8.16 (d, J = 8.0 Hz, 2H). ^{19}F NMR (282 MHz, $CDCl_3$) δ -163.7- -163.5 (m, 2F), -156.2 (t, J_F = 21.0 Hz, 1F), -144.8 (dd, J_F = 7.6, 23.0 Hz, 2F).

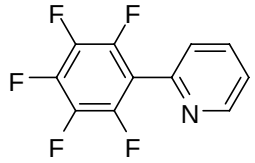


2',3',4',5',6'-Pentafluorobiphenyl-4-carbonitrile (Entry 9, Table 1): Copper(I) iodide (19.1 mg, 0.1 mmol), 4-bromobenzonitrile (182 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), pentafluorobenzene (252 mg, 1.5 mmol), K_3PO_4 (424 mg, 2.0 mmol), and DMF/xylene (0.6 mL). After column chromatography (10% ethyl acetate in hexanes) 255 mg (95%) of a white solid was obtained. R_f = 0.64 (SiO_2, 4/6 AcOEt/hexanes). This compound is known.[3] ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.53-7.59 (m, 2H), 7.77-7.84 (m, 2H). ^{19}F NMR (282 MHz, $CDCl_3$) δ -163.0- -162.7 (m, 2F), -154.8 (t, J_F = 21.0 Hz, 1F), -144.8 (dd, J_F = 7.6, 21.0 Hz, 2F).

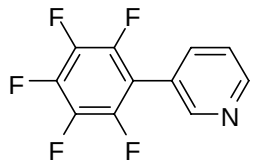


2-(Pentafluorophenyl)naphthalene: Copper(I) iodide (19.1 mg, 0.1 mmol), 2-bromonaphthalene (207 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), pentafluorobenzene (252 mg, 1.5 mmol), K_3PO_4 (424 mg, 2.0 mmol), and DMF/xylene (0.6

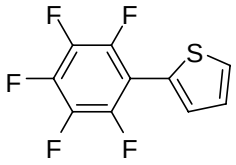
mL). After column chromatography (10% ethyl acetate in hexanes) 265 mg (90%) of a white solid was obtained. R_f = 0.55 (SiO_2, hexanes). This compound is known.[1] ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.45-7.62 (m, 3H), 7.85-8.00 (m, 4H). ^{19}F NMR (282 MHz, $CDCl_3$) δ -164.2- -163.9 (m, 2F), -157.4 (t, J_F = 21.0 Hz, 1F), -145.0 (dd, J_F = 7.6, 23.0 Hz, 2F).



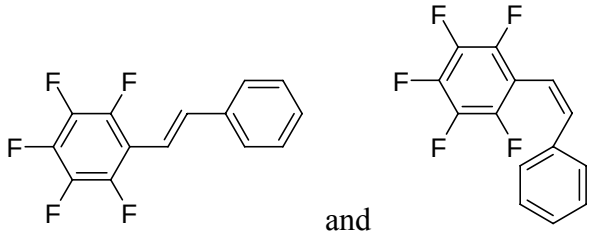
2-(Pentafluorophenyl)pyridine (Entry 10, Table 1): Copper(I) iodide (19.1 mg, 0.1 mmol), 2-bromopyridine (158 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), pentafluorobenzene (252 mg, 1.5 mmol), K_3PO_4 (424 mg, 2.0 mmol), and DMF/xylene (0.6 mL), 120 ^{o}C, 12 hours. After column chromatography (20% ethyl acetate in hexanes) 220 mg (90%) of a white solid was obtained. R_f = 0.55 (SiO_2, 2/3 AcOEt/hexanes). This compound is known.[4] ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.38 (ddd, J = 8.0 Hz, 5.0 Hz, 1.0 Hz, 1H), 7.45-7.50 (m, 1H), 7.80-7.88 (m, 1H), 8.75-8.78 (m, 1H). ^{19}F NMR (282 MHz, $CDCl_3$) δ -163.9- -163.6 (m, 2F), -155.7 (t, J_F = 21.0 Hz, 1F), -145.2 (dd, J_F = 7.6, 23.0 Hz, 2F).



3-(Pentafluorophenyl)pyridine (Entry 11, Table 1): Copper(I) iodide (19.1 mg, 0.1 mmol), 3-bromopyridine (158 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), pentafluorobenzene (252 mg, 1.5 mmol), K_3PO_4 (424 mg, 2.0 mmol), and DMF/xylene (0.6 mL). After column chromatography (1/1 ethyl acetate/hexanes) 210 mg (86%) of a light tan solid was obtained. R_f = 0.43 (SiO_2, 2/3 AcOEt/hexanes). This compound is known.[5] ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.40-7.48 (m, 1H), 7.72-7.80 (m, 1H), 8.65-8.73 (m, 2H). ^{19}F NMR (282 MHz, $CDCl_3$) δ -163.3- -163.0 (m, 2F), -155.4 (t, J_F = 21.0 Hz, 1F), -144.9 (dd, J_F = 7.6, 23.0 Hz, 2F).



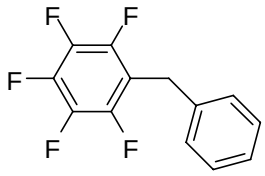
2-(Pentafluorophenyl)thiophene (Entry 12, Table 1): Copper(I) iodide (19.1 mg, 0.1 mmol), 2-bromothiophene (163 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), pentafluorobenzene (252 mg, 1.5 mmol), K_3PO_4 (424 mg, 2.0 mmol), and DMF/xylene (0.6 mL), 120 ^oC, 12 hours. After column chromatography (hexanes) 230 mg (92%) of a white solid was obtained. R_f = 0.54 (SiO_2, hexanes). This compound is known.[3] ^1H NMR (300 MHz, $CDCl_3$) δ 7.16-7.21 (m, 1H), 7.50-7.57 (m, 2H). ^{19}F NMR (282 MHz, $CDCl_3$) δ -164.3- -164.0 (m, 2F), -157.9 (t, J_F = 21.0 Hz, 1F), -141.9 (dd, J_F = 7.6, 21.0 Hz, 2F).


and

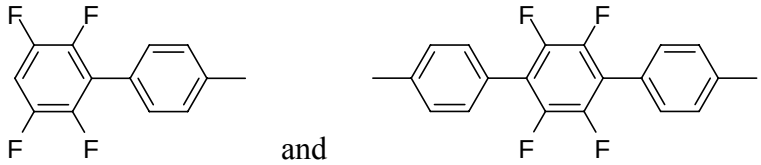
(*E*)-1,2,3,4,5-Pentafluorostilbene and (*Z*)-1,2,3,4,5-pentafluorostilbene (Entry 13, Table 1): Copper(I) iodide (19.1 mg, 0.1 mmol), beta-bromostyrene (5.7/1 E/Z mixture; 183 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), pentafluorobenzene (252 mg, 1.5 mmol), K_3PO_4 (424 mg, 2.0 mmol), and DMF/xylene (0.6 mL). After column chromatography (hexanes) and preparative HPLC (hexanes) 33 mg (12%) of a colorless oil ((*Z*)-1,2,3,4,5-pentafluorostilbene), R_f = 0.50 (SiO_2, hexanes), and 207 mg (77%) of a white solid ((*E*)-1,2,3,4,5-pentafluorostilbene), R_f = 0.54 (SiO_2, hexanes), were obtained. These compounds are known.[6,7]

- (*E*)-1,2,3,4,5-Pentafluorostilbene: ^1H NMR (300 MHz, $CDCl_3$) δ 6.98 (d, J = 16.6 Hz, 1H), 7.30-7.48 (m, 4H), 7.50-7.56 (m, 2H). ^{19}F NMR (282 MHz, $CDCl_3$) δ -165.0- -164.8 (m, 2F), -158.5 (t, J_F = 21.0 Hz, 1F), -144.7 (dd, J_F = 7.6, 23.0 Hz, 2F).

- (*Z*)-1,2,3,4,5-Pentafluorostilbene: ^1H NMR (300 MHz, $CDCl_3$) δ 6.24 (dd, J = 1.5, 11.6 Hz, 1H), 6.97 (d, J = 11.6 Hz, 1H), 7.09-7.14 (m, 2H), 7.22-7.28 (m, 3H). ^{19}F NMR (282 MHz, $CDCl_3$) δ -164.4- -164.1 (m, 2F), -157.8 (t, J_F = 21.0 Hz, 1F), -140.6 (dd, J_F = 7.6, 23.0 Hz, 2F).



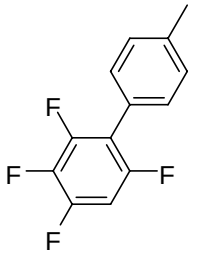
1-Benzyl-2,3,4,5,6-pentafluorobenzene (Entry 14, Table 1): Copper(I) iodide (19.1 mg, 0.1 mmol), benzyl bromide (171 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), pentafluorobenzene (252 mg, 1.5 mmol), K_3PO_4 (424 mg, 2.0 mmol), and DMF/xylene (0.6 mL), 120 ^oC. After column chromatography (hexanes) and preparative HPLC (hexanes) 80 mg (31%) of a white solid was obtained. R_f = 0.46 (SiO_2, hexanes). This compound is known.[8] ^1H NMR (300 MHz, $CDCl_3$) δ 4.01 (s, 2H), 7.19-7.34 (m, 5H). ^{19}F NMR (282 MHz, $CDCl_3$) δ -164.4- -164.2 (m, 2F), -159.0 (t, J_F = 21.0 Hz, 1F), -145.3 (dd, J_F = 7.6, 23.0 Hz, 2F).



2,3,5,6-Tetrafluoro-4'-methylbiphenyl and 1,4-di-(p-tolyl)-2,3,5,6-tetrafluorobenzene (Entry 1, Table 2): Copper(I) iodide (19.1 mg, 0.1 mmol), 4-iodotoluene (218 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), 1,2,4,5-tetrafluorobenzene (300 mg, 2.0 mmol), K_3PO_4 (488 mg, 2.3 mmol), and DMF (0.6 mL). After column chromatography (hexanes) and preparative HPLC (hexanes) 185 mg (77%) of 2,3,5,6-tetrafluoro-4'-methylbiphenyl, R_f = 0.50 (SiO_2, hexanes), and 50 mg (15%) of 1,4-di-(p-tolyl)-2,3,5,6-tetrafluorobenzene, R_f = 0.52 (SiO_2, hexanes), were obtained as white solids. These compounds are known.[5]

- 2,3,5,6-Tetrafluoro-4'-methylbiphenyl: ^1H NMR (300 MHz, $CDCl_3$) δ 2.42 (s, 3H), 6.97-7.12 (m, 1H), 7.30 (d, J = 8.3 Hz, 2H), 7.36 (d, J = 8.3 Hz, 2H). ^{19}F NMR (282 MHz, $CDCl_3$) δ -146.2- -145.9 (m, 2F), -141.5- -141.2 (m, 2F).

- 1,4-Di-(p-tolyl)-2,3,5,6-tetrafluorobenzene: ^1H NMR (300 MHz, $CDCl_3$) δ 2.43 (s, 6H), 7.32 (d, J = 8.0 Hz, 4H), 7.41 (d, J = 8.0 Hz, 4H). ^{19}F NMR (282 MHz, $CDCl_3$) δ -146.7 (s, 4F).



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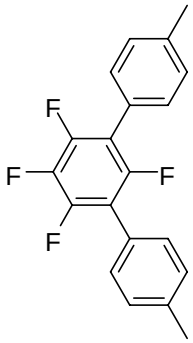
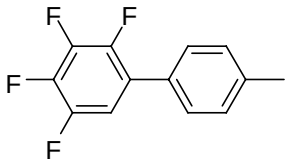


2,3,4,6-Tetrafluoro-4'-methylbiphenyl and 1,3-di-(p-tolyl)-2,4,5,6-tetrafluorobenzene (Entry 2, Table 2): Copper(I) iodide (19.1 mg, 0.1 mmol), 4-iodotoluene (218 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), 1,3,4,5-tetrafluorobenzene (300 mg, 2.0 mmol), K_3PO_4 (488 mg, 2.3 mmol), and DMF (0.6 mL). After column chromatography (hexanes) and preparative HPLC (hexanes) 175 mg (73%) 2,3,4,6-tetrafluoro-4'-methylbiphenyl, R_f = 0.51 (SiO_2, hexanes), and 55 mg (17%) of 1,3-di-(p-tolyl)-2,4,5,6-tetrafluorobenzene, R_f = 0.42 (SiO_2, hexanes), were obtained as white solids. These compounds are known.[5]

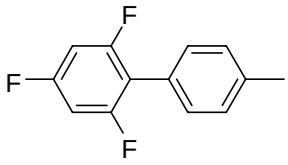
- 2,3,4,6-Tetrafluoro-4'-methylbiphenyl: ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.42 (s, 3H), 6.80-6.92 (m, 1H), 7.29 (d, J = 8.2 Hz, 2H), 7.33 (d, J = 8.2 Hz, 2H). ^{19}F NMR (282 MHz, $CDCl_3$) δ -167.1- -166.8 (m, 1F), -137.6 (d, J_F = 21.0 Hz, 1F), -136.0- -135.8 (m, 1F), -120.3- -120.2 (m, 1F).

- 1,3-Di-(p-tolyl)-2,4,5,6-tetrafluorobenzene: ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.41 (s, 6H), 7.28 (d, J = 7.8 Hz, 4H), 7.35 (d, J = 7.8 Hz, 4H). ^{19}F NMR (282 MHz, $CDCl_3$) δ -166.9- -166.7 (m, 1F), -139.9 (d, J_F = 23.0 Hz, 2F), -124.7 (d, J_F = 11.4 Hz, 1F).

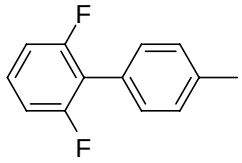


2,3,4,5-Tetrafluoro-4'-methylbiphenyl (Entry 3, Table 2): Copper(I) iodide (19.1 mg, 0.1 mmol), 4-iodotoluene (218 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), 1,2,3,4-tetrafluorobenzene (300 mg, 2.0 mmol), K_3PO_4 (488 mg, 2.3 mmol), and DMF (0.6 mL), 140 ^{o}C. After column chromatography (hexanes) and preparative HPLC (hexanes) 25 mg (10%) of a white solid was obtained. R_f = 0.60 (SiO_2, hexanes). This compound is known.[5] ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.41 (s, 3H), 6.98-7.09 (m, 1H), 7.27 (d, J = 7.8 Hz, 2H), 7.37 (d, J =

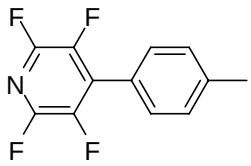
7.8 Hz, 2H). ^{19}F NMR (282 MHz, $CDCl_3$) δ -159.8- -159.5 (m, 1F), -157.4 (t, J_F = 21.0 Hz, 1F), -146.0- -145.8 (m, 1F), -142.0- -141.7 (m, 1F).



2,4,6-Trifluoro-4'-methylbiphenyl (Entry 4, Table 2): Copper(I) iodide (19.1 mg, 0.1 mmol), 4-iodotoluene (218 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), 1,3,5-trifluorobenzene (396 mg, 3.0 mmol), K_3PO_4 (530 mg, 2.5 mmol), DMF (0.6 mL) and diglime (0.1 mL), 140 ^oC. After column chromatography (hexanes) 150 mg (68%) of a white solid was obtained. R_f = 0.64 (SiO_2, hexanes). This compound is known.[5] ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.41 (s, 3H), 6.68-6.82 (m, 2H), 7.27 (d, J = 8.2 Hz, 2H), 7.33 (d, J = 8.2 Hz, 2H). ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.9, 100.4-101.6 (m), 115.0-115.9 (m), 125.8, 129.7, 130.7, 138.8, 159.0-160.6 (m), 162.2-164.0 (m). ^{19}F NMR (282 MHz, $CDCl_3$) δ -113.4 (t, J_F = 5.7 Hz, 2F), -111.6- -111.5 (m, 1F).

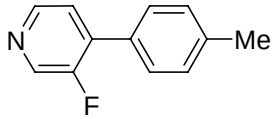


2,6-Difluoro-4'-methylbiphenyl (Entry 5, Table 2): Copper(I) iodide (19.1 mg, 0.1 mmol), 4-iodotoluene (218 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), 1,3-difluorobenzene (342 mg, 3.0 mmol), t-BuOLi (160 mg, 2.0 mmol), and DMF (1.0 mL), 15 hours. After column chromatography (hexanes) and preparative HPLC (hexanes) 165 mg (81%) of a white solid was obtained. R_f = 0.52 (SiO_2, hexanes). This compound is known.[5] ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.41 (s, 3H), 6.91-7.04 (m, 2H), 7.20-7.32 (m, 3H), 7.34-7.40 (m, 2H). ^{19}F NMR (282 MHz, $CDCl_3$) δ -116.6 (s, 2F).



2,3,5,6-Tetrafluoro-4-p-tolylpyridine (Entry 6, Table 2): Copper(I) iodide (19.1 mg, 0.1 mmol), 4-iodotoluene (218 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), 2,3,5,6-tetrafluoropyridine (227 mg, 1.5 mmol), K_3PO_4 (424 mg, 2.0 mmol), and DMF (0.6 mL), 36

hours. After column chromatography (10% ethyl acetate in hexanes) 220 mg (91%) of a white solid was obtained. R_f = 0.42 (SiO_2, hexanes). This compound is known.[5] ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.44 (s, 3H), 7.35 (d, *J* = 8.0 Hz, 2H), 7.43 (d, *J* = 8.0 Hz, 2H). ^{19}F NMR (282 MHz, $CDCl_3$) δ -147.5- -147.2 (m, 2F), -93.2- -92.8 (m, 2F).



3-Fluoro-4-p-tolylpyridine (Entry 7, Table 2): Copper(I) iodide (19.1 mg, 0.1 mmol), 4-iodotoluene (218 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), 3-fluoropyridine (291 mg, 3.0 mmol), t-BuOLi (160 mg, 2.0 mmol), and DMF (1.0 mL), 140 ^{o}C, 12 hours. After column chromatography (40% ethyl acetate in hexanes) and preparative HPLC (40% ethyl acetate in hexanes) 70 mg (40%) of a light tan oil was obtained. R_f = 0.40 (SiO_2, 2/3 AcOEt/hexanes). ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.41 (s, 3H), 7.29 (d, *J* = 8.0 Hz, 2H), 7.38 (dd, *J* = 6.6 Hz, 5.0 Hz, 1H), 7.38 (dd, *J* = 8.0 Hz, 1.5 Hz, 2H), 8.43 (d, *J* = 5.0 Hz, 1H), 8.51 (d, *J* = 2.8 Hz, 1H). ^{19}F NMR (282 MHz, $CDCl_3$) δ -135.0 (s). ^{13}C NMR (75 MHz, $CDCl_3$; list of peaks, ^{13}C-^{19}F couplings not assigned) δ 21.8, 124.6, 129.3, 130.1, 130.6, 136.4, 136.6, 139.3, 139.7, 139.9, 146.5, 155.5, 159.0. FT-IR (neat, cm^{-1}) υ 3036, 1605, 1519, 1481, 1264, 1208. Anal calcd for $C_{12}H_{10}NF$ (187.217 g/mol): C, 76.99; H, 5.38; N, 7.48; Found. C, 77.05; H, 5.38; N, 7.51.

Attempted reaction with fluorobenzene: Copper(I) iodide (19.1 mg, 0.1 mmol), 4-iodotoluene (218 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), fluorobenzene (288 mg, 3.0 mmol), t-BuOLi (160 mg, 2.0 mmol), and DMF (0.6 mL). No product was detected.

Control reaction (without phenanthroline): Copper(I) iodide (19.1 mg, 0.1 mmol), 4-bromotoluene (171 mg, 1.0 mmol), pentafluorobenzene (252 mg, 1.5 mmol), K_3PO_4 (424 mg, 2.0 mmol), and DMF/xylene (0.6 mL). No product was detected.

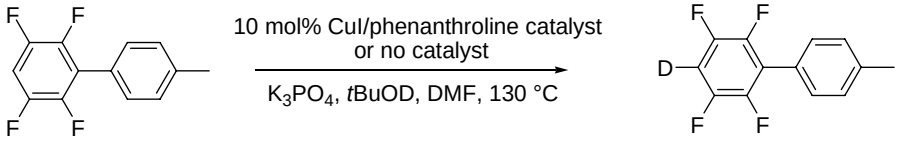
Using 4-chlorotoluene as coupling partner: Copper(I) iodide (19.1 mg, 0.1 mmol), 4-chlorotoluene (126.5 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol),

pentafluorobenzene (252 mg, 1.5 mmol), K_3PO_4 (424 mg, 2.0 mmol), and DMF (0.6 mL). No product was detected.

Using phenyl triflate as coupling partner: Copper(I) iodide (19.1 mg, 0.1 mmol), phenyl triflate (226 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), pentafluorobenzene (252 mg, 1.5 mmol), K_3PO_4 (424 mg, 2.0 mmol), and DMF (0.6 mL). No product was detected.

Competition reaction of pentafluorobenzene and 1,2,4,5-tetrafluorobenzene: Copper(I) iodide (19.1 mg, 0.1 mmol), 4-iodotoluene (218 mg, 1.0 mmol), 1,10-phenanthroline (18 mg, 0.1 mmol), pentafluorobenzene (252 mg, 1.5 mmol), 1,2,4,5-tetrafluorobenzene (225 mg, 1.5 mmol), K_3PO_4 (488 mg, 2.3 mmol), and DMF (0.6 mL) at 130° C, 24 h. The molar ratio of arylation products 2,3,4,5,6-pentafluoro-4'-methylbiphenyl/2,3,5,6-tetrafluoro-4'-methyl-biphenyl was determined to be 2.0 by GC analysis of crude reaction mixture.

H/D exchange reactions :



62-65% D incorporation

With copper(I) catalyst: Copper(I) iodide (9.6 mg, 0.05 mmol), 1,10-phenanthroline (9 mg, 0.05 mmol), 2,3,5,6-tetrafluoro-4'-methylbiphenyl (120 mg, 0.5 mmol), $(CH_3)_3COD$ (375 mg, 5 mmol), K_3PO_4 (212 mg, 1.0 mmol), and DMF (0.4 mL) at 130° C for 24 h. The unreacted starting material was recovered by column chromatography (hexanes). NMR integration showed 65% of D incorporation in starting material.

Without copper(I) catalyst: 2,3,5,6-Tetrafluoro-4'-methylbiphenyl (120 mg, 0.5 mmol), $(CH_3)_3COD$ (375 mg, 5 mmol), K_3PO_4 (212 mg, 1.0 mmol), and DMF (0.4 mL) at 130° C for 24 h. The unreacted starting material was recovered by column chromatography (hexanes). NMR integration showed 62% of D incorporation in starting material.

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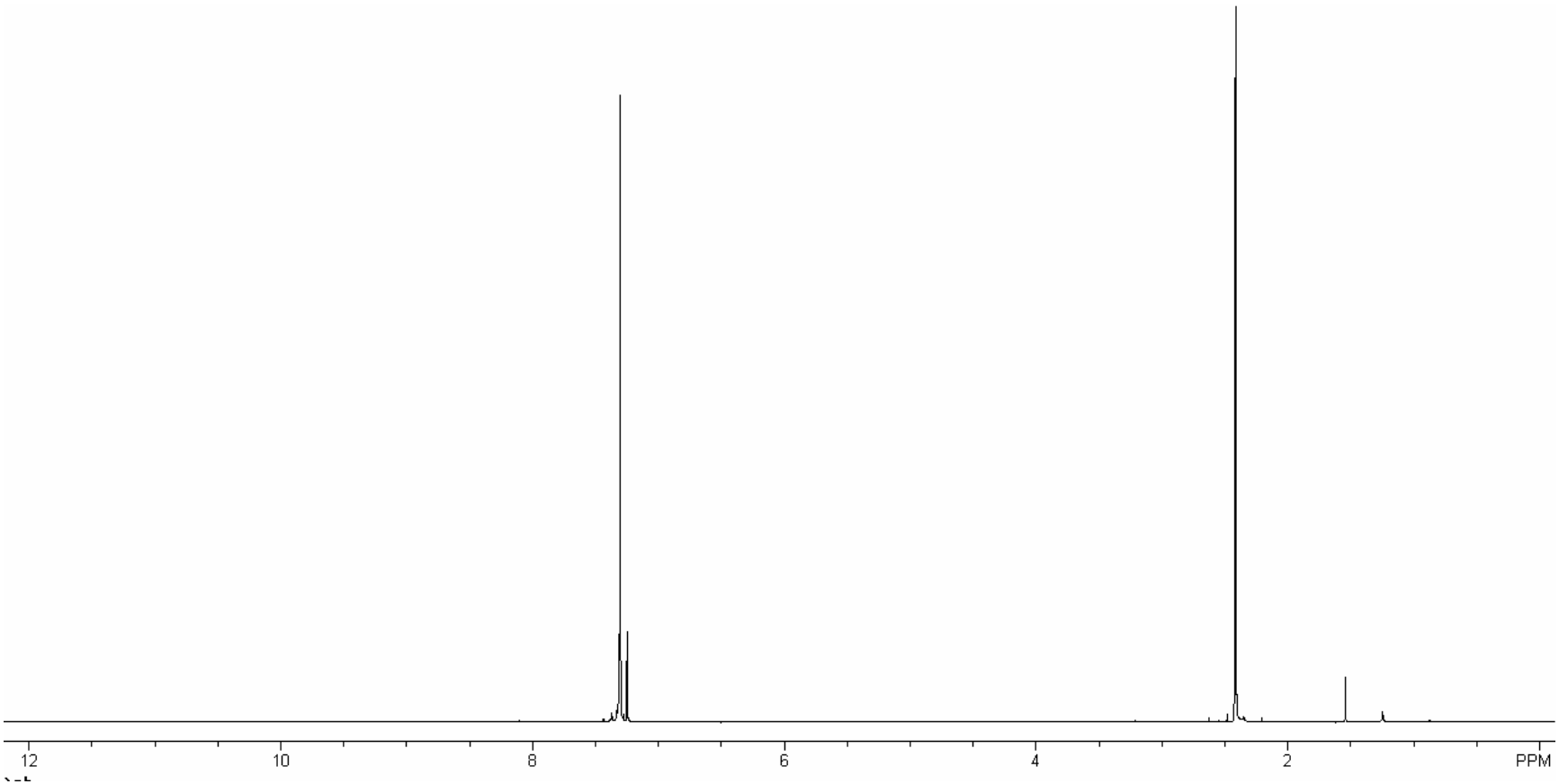
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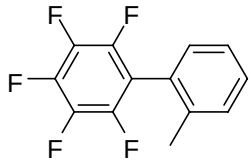
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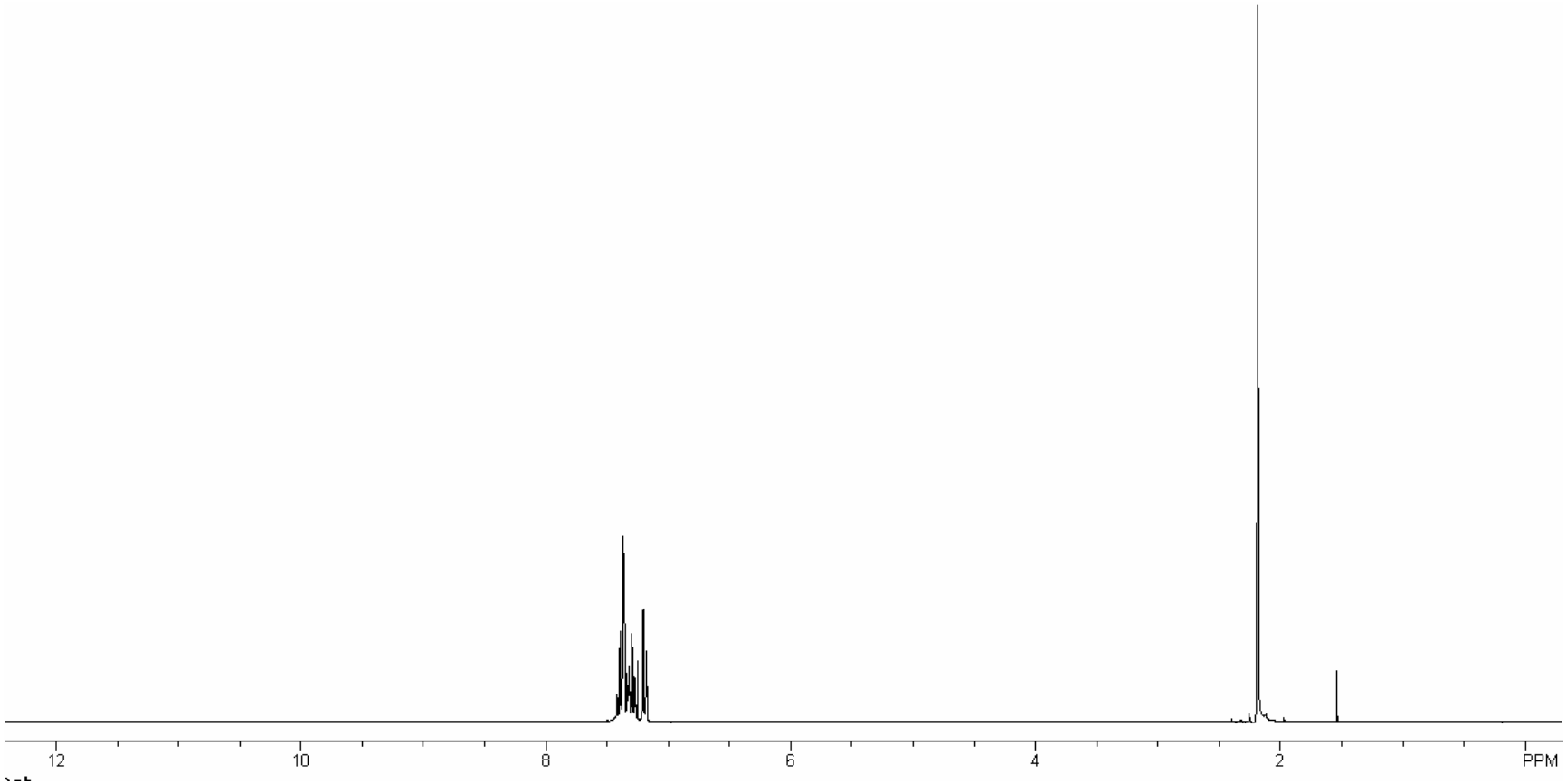
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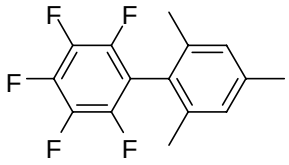
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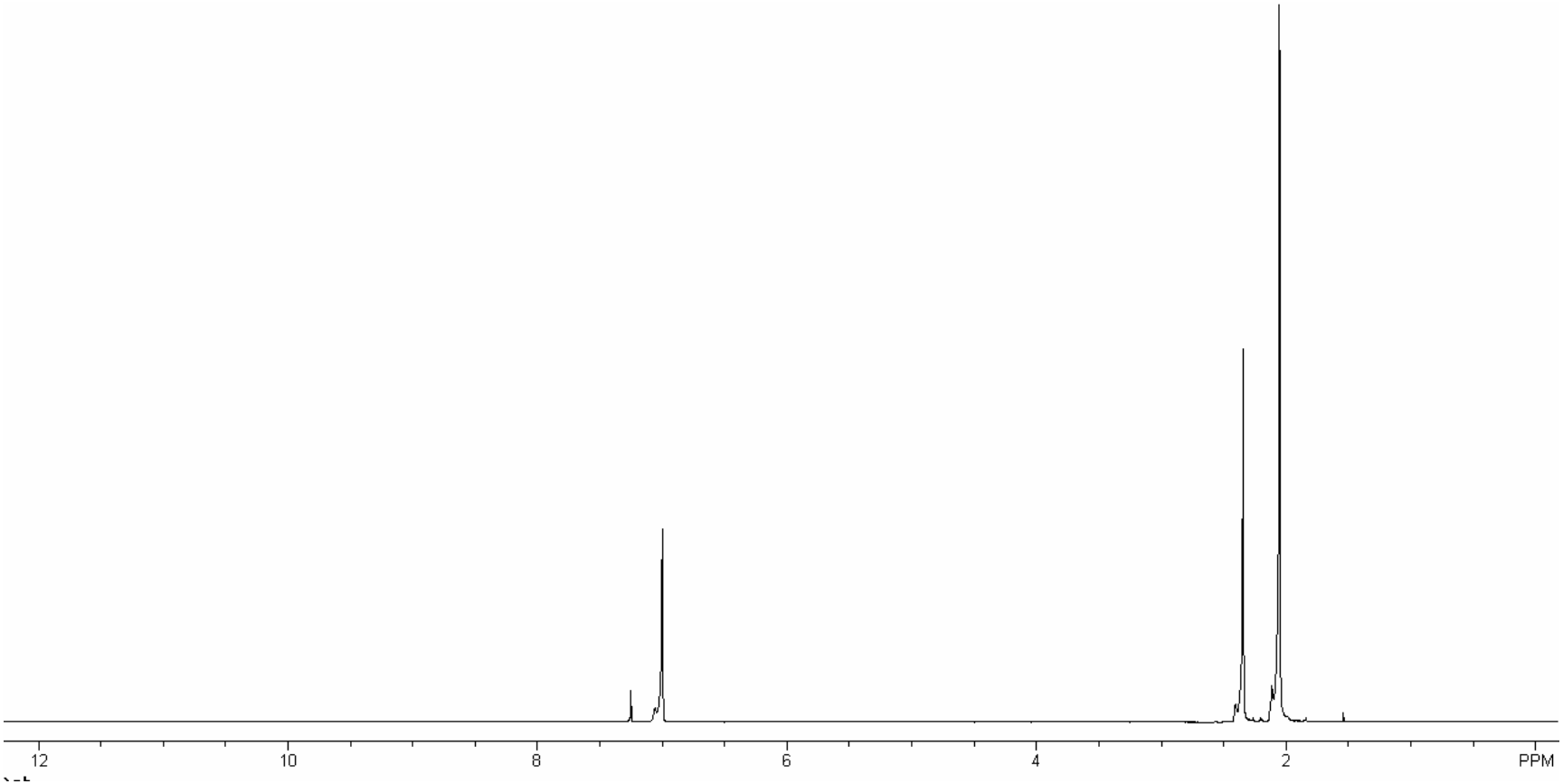
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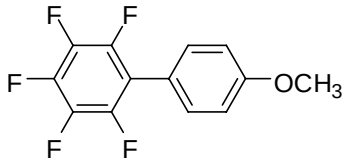
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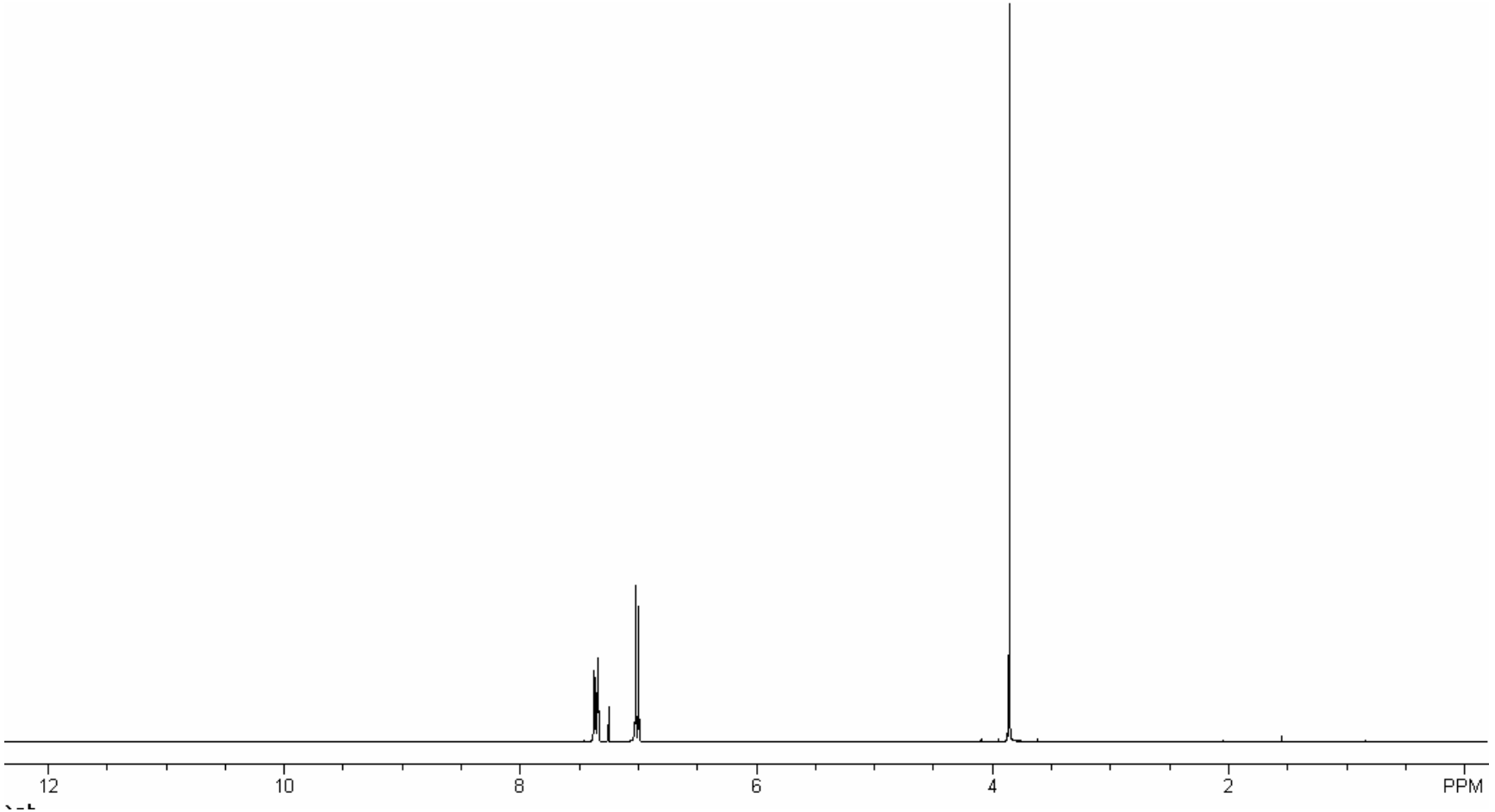
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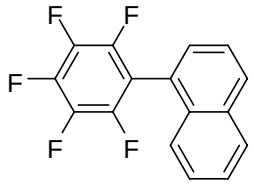
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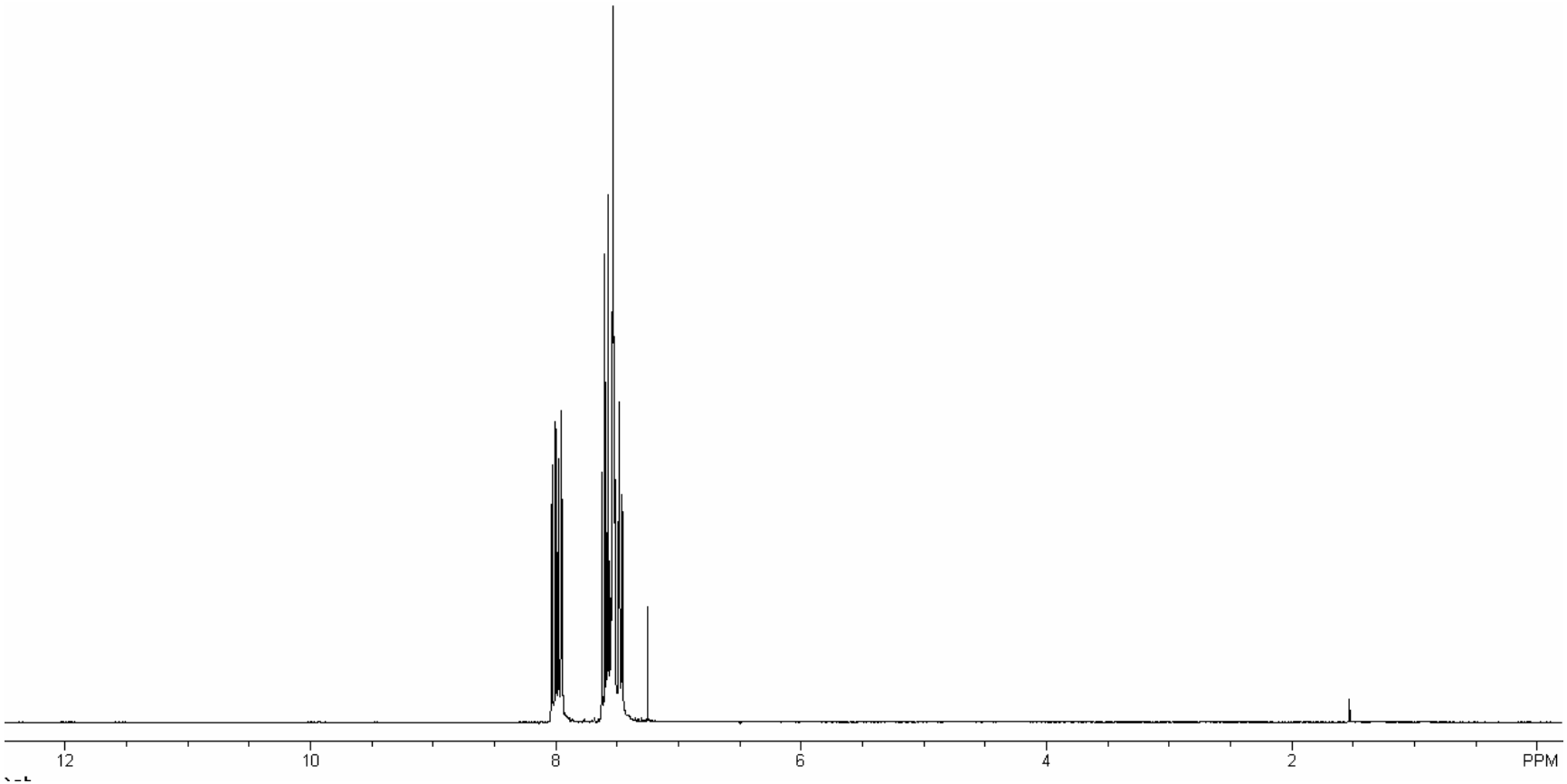
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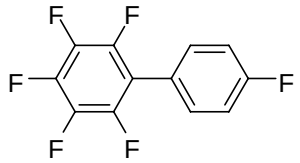
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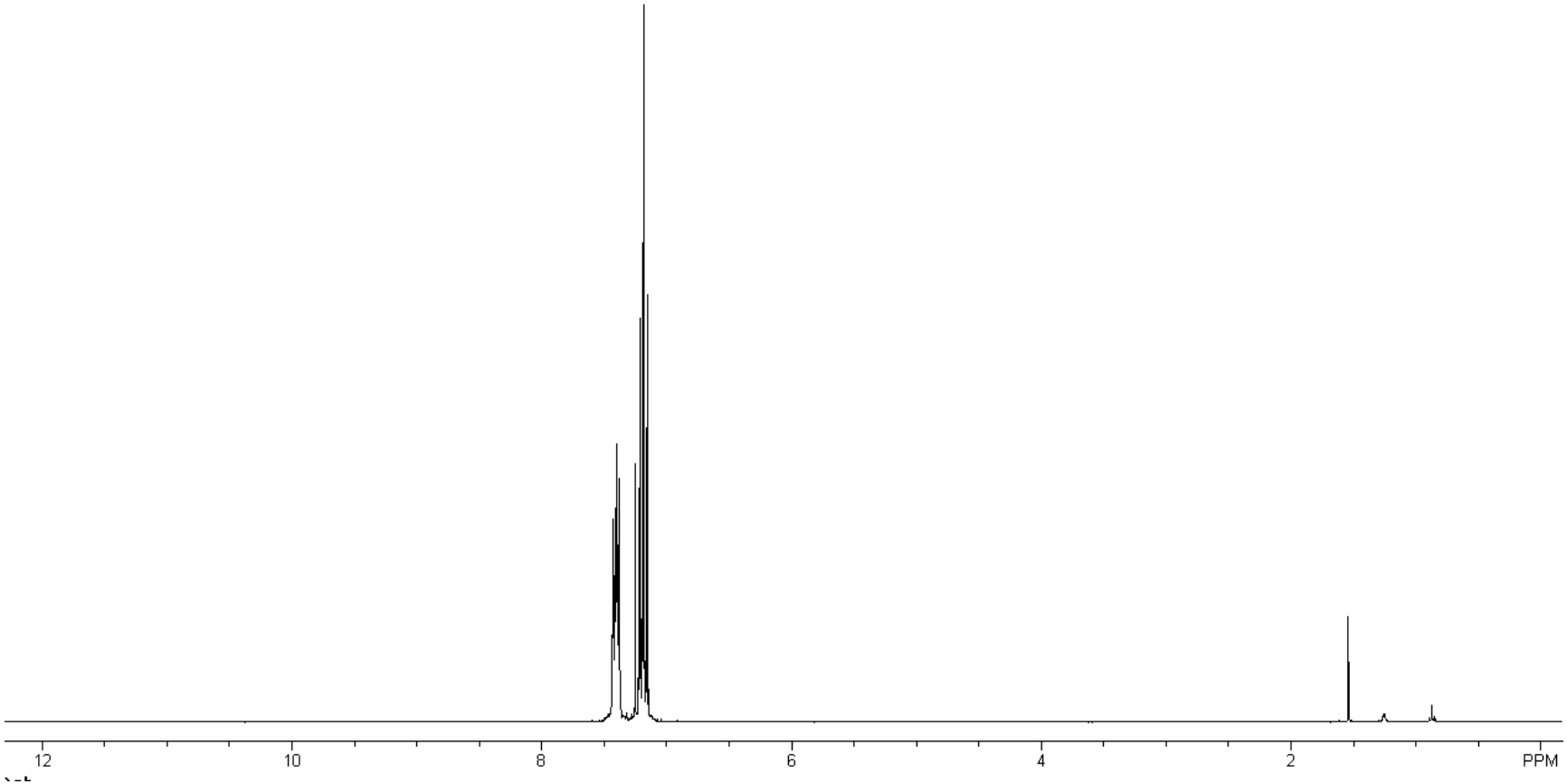
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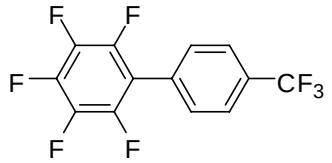
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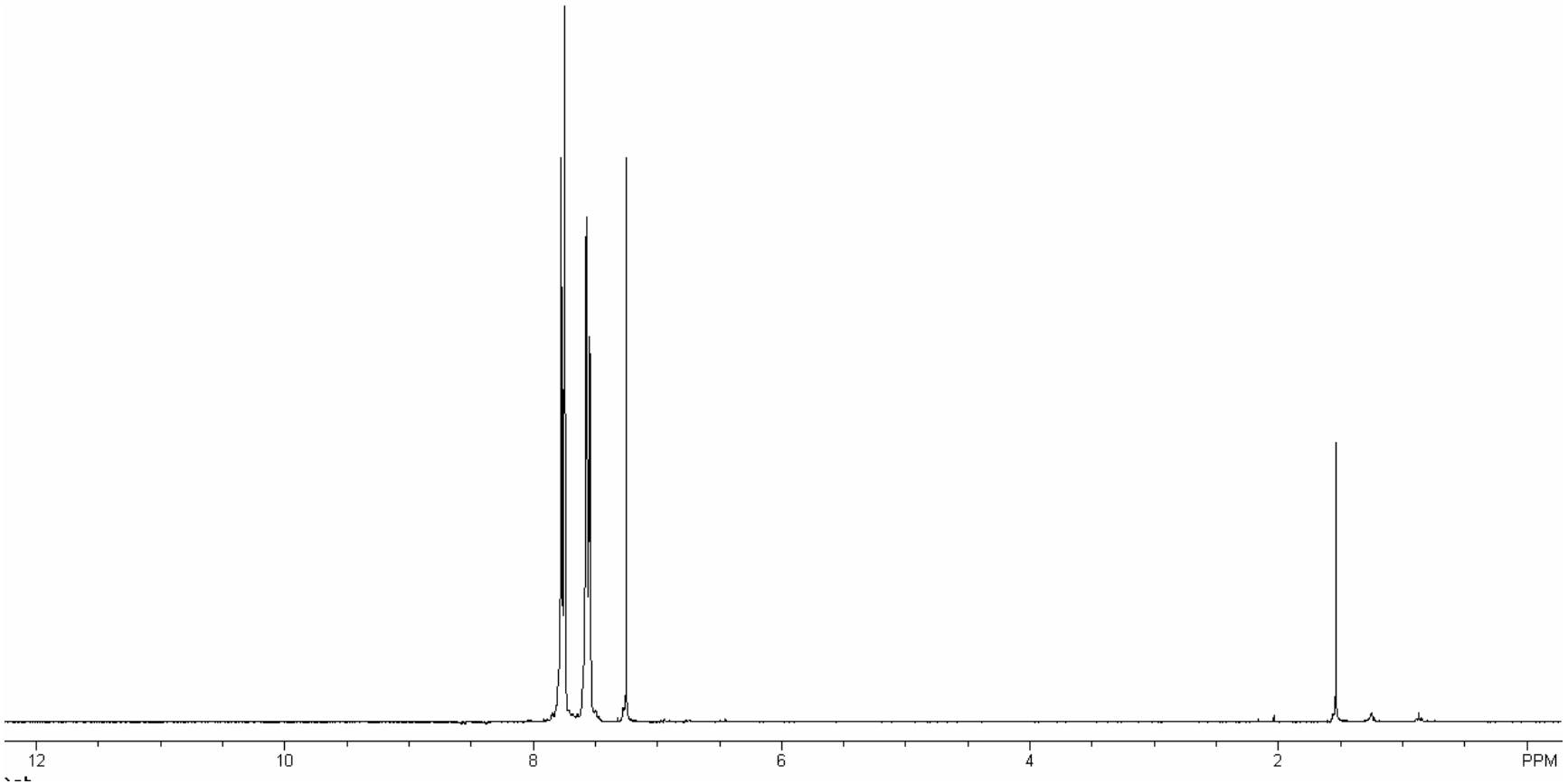
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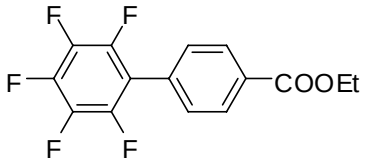
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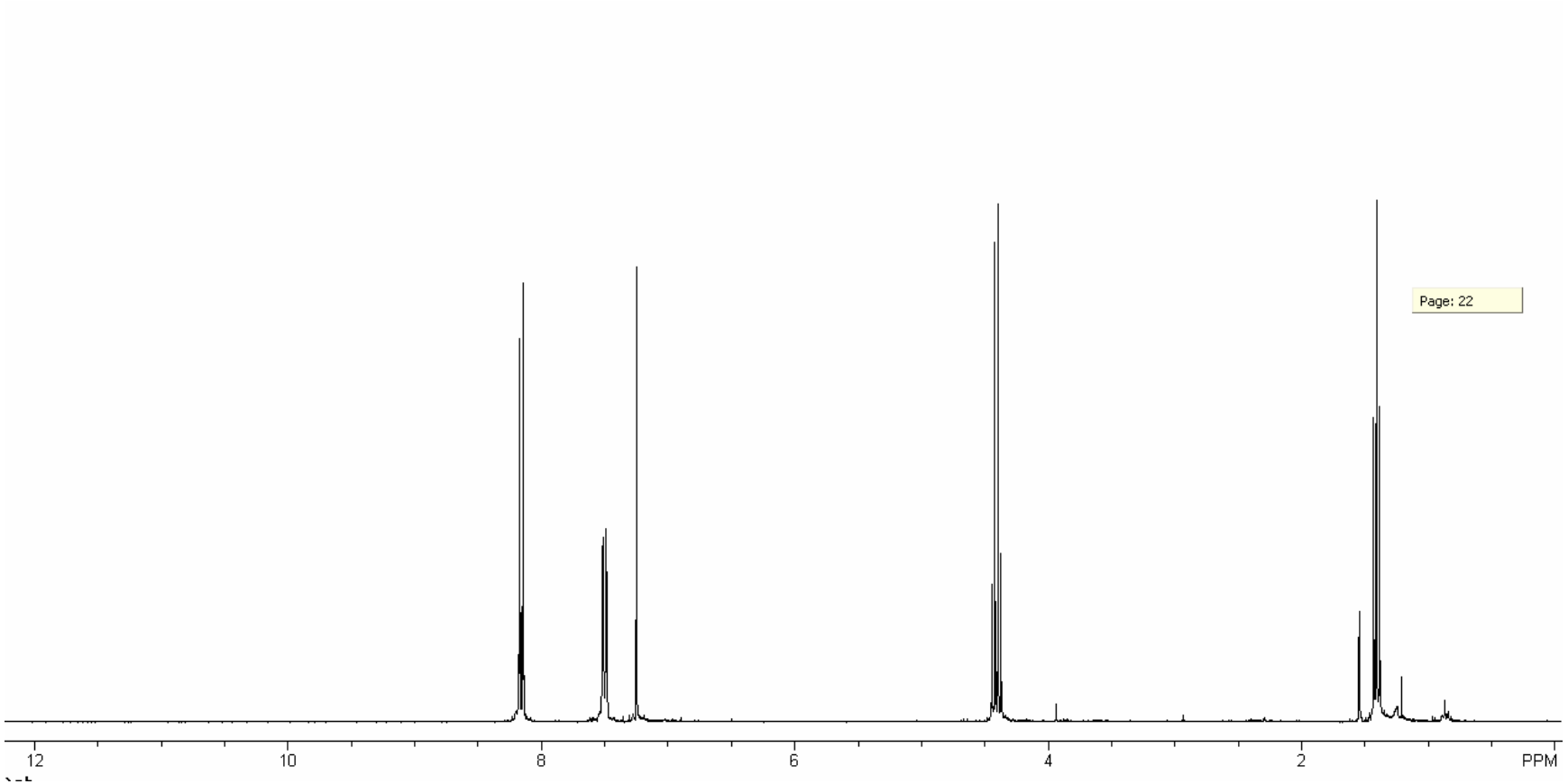
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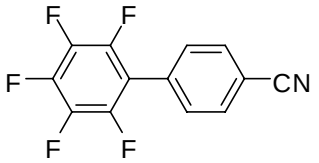
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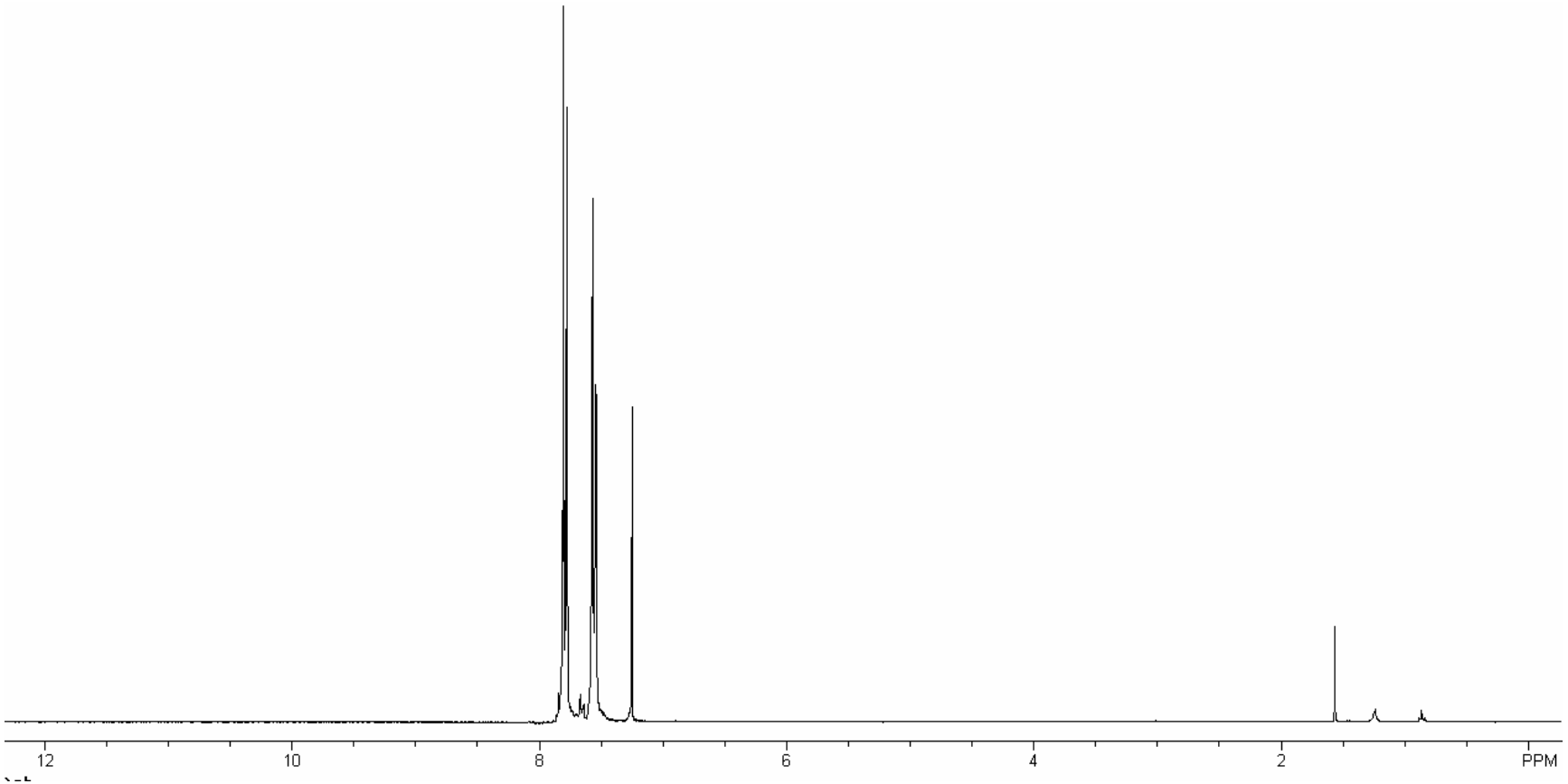
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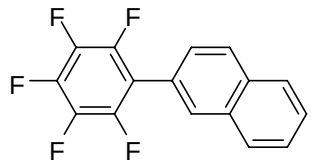
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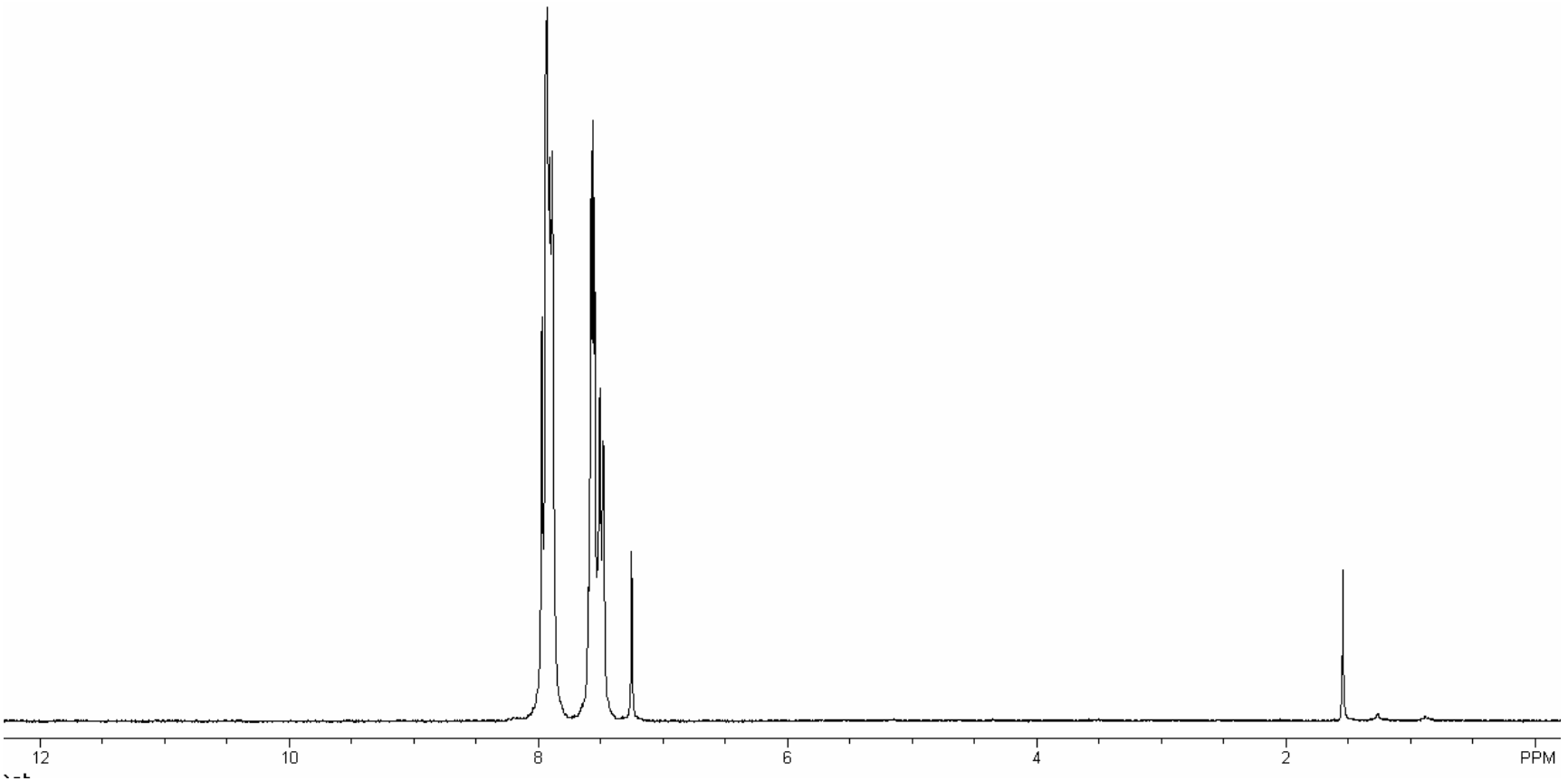
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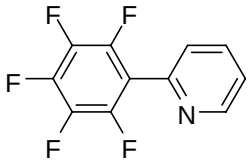
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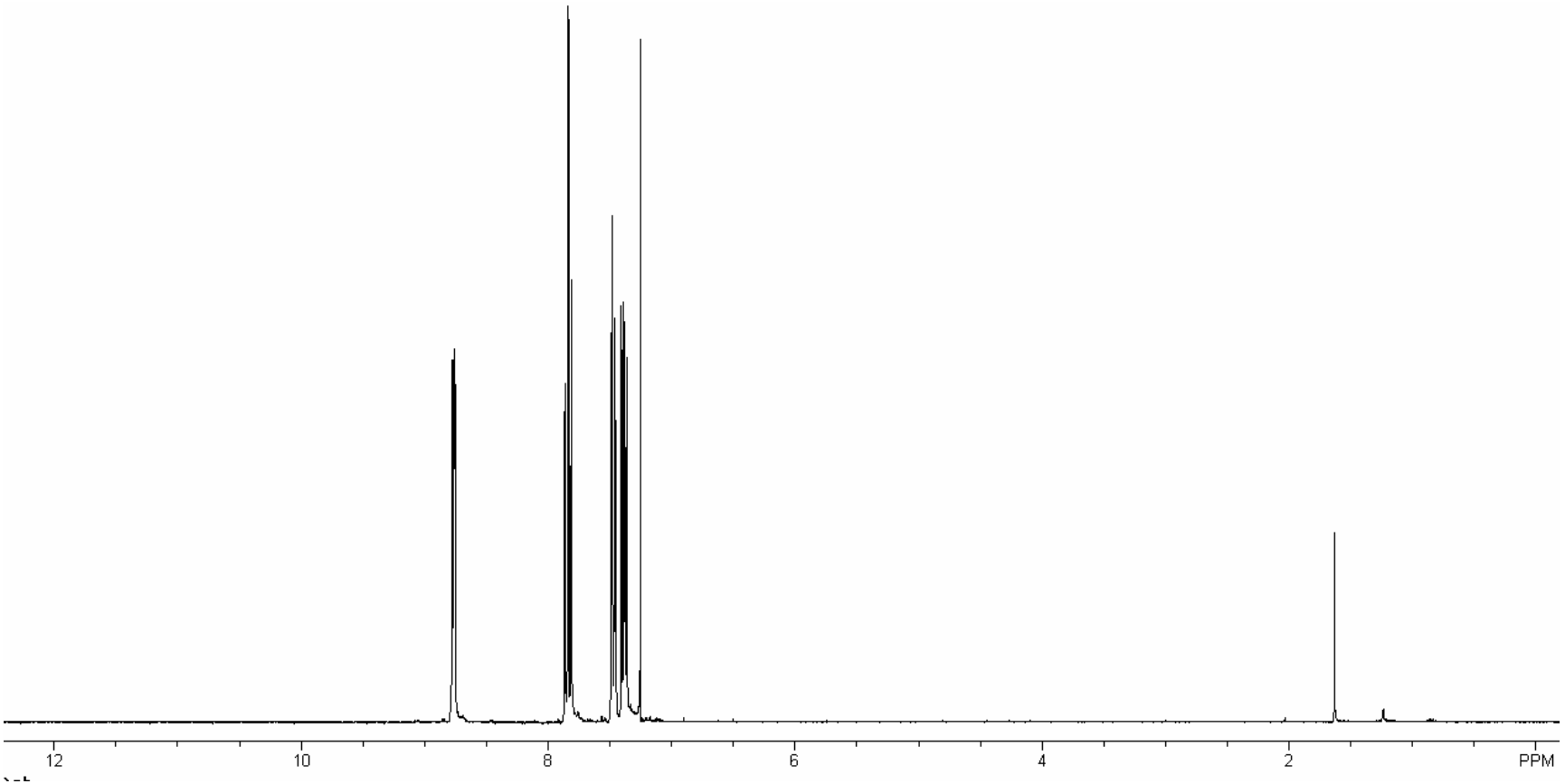
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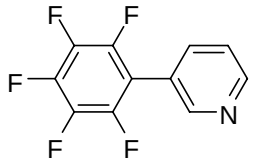
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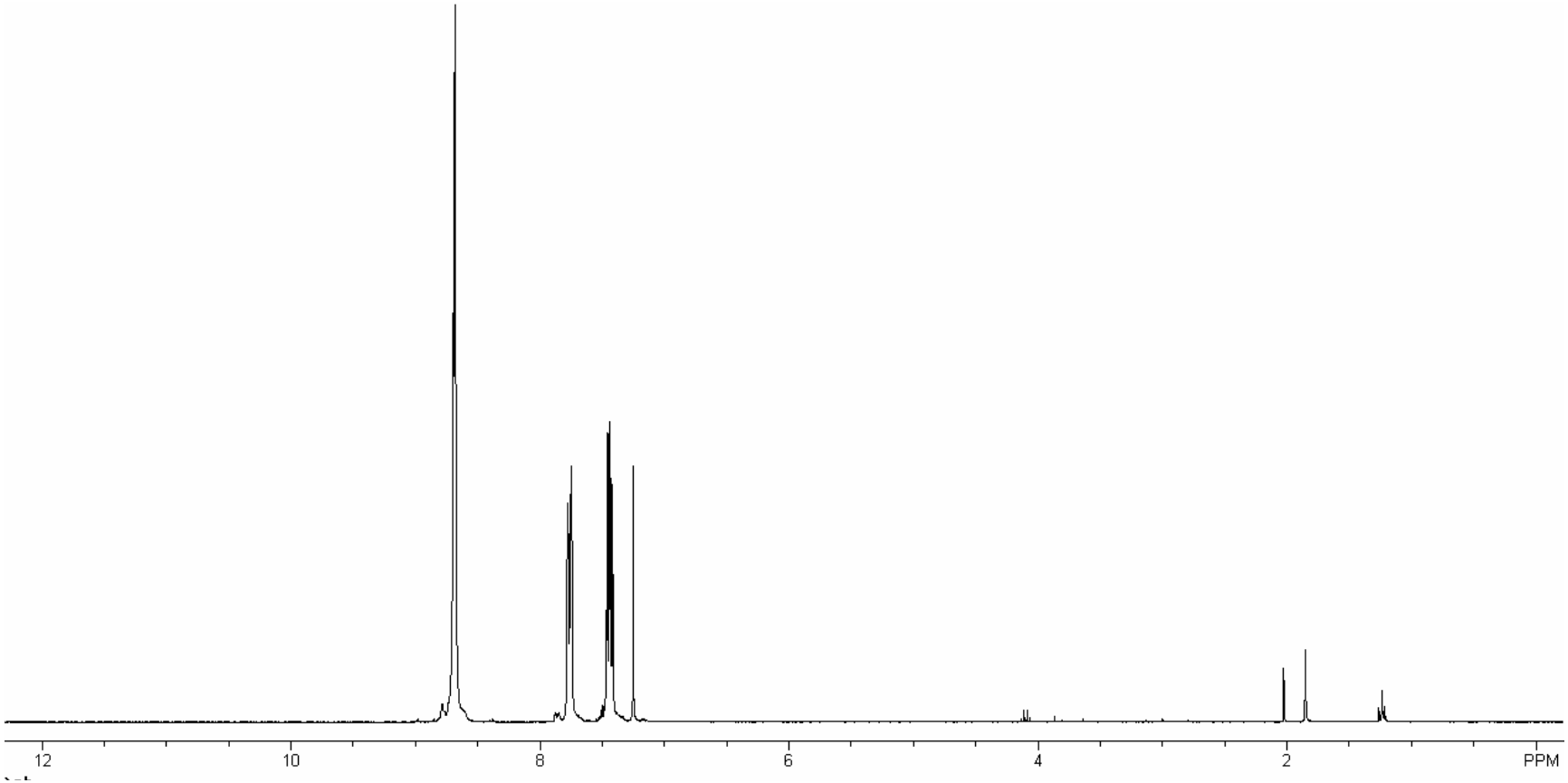
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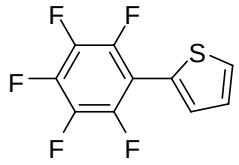
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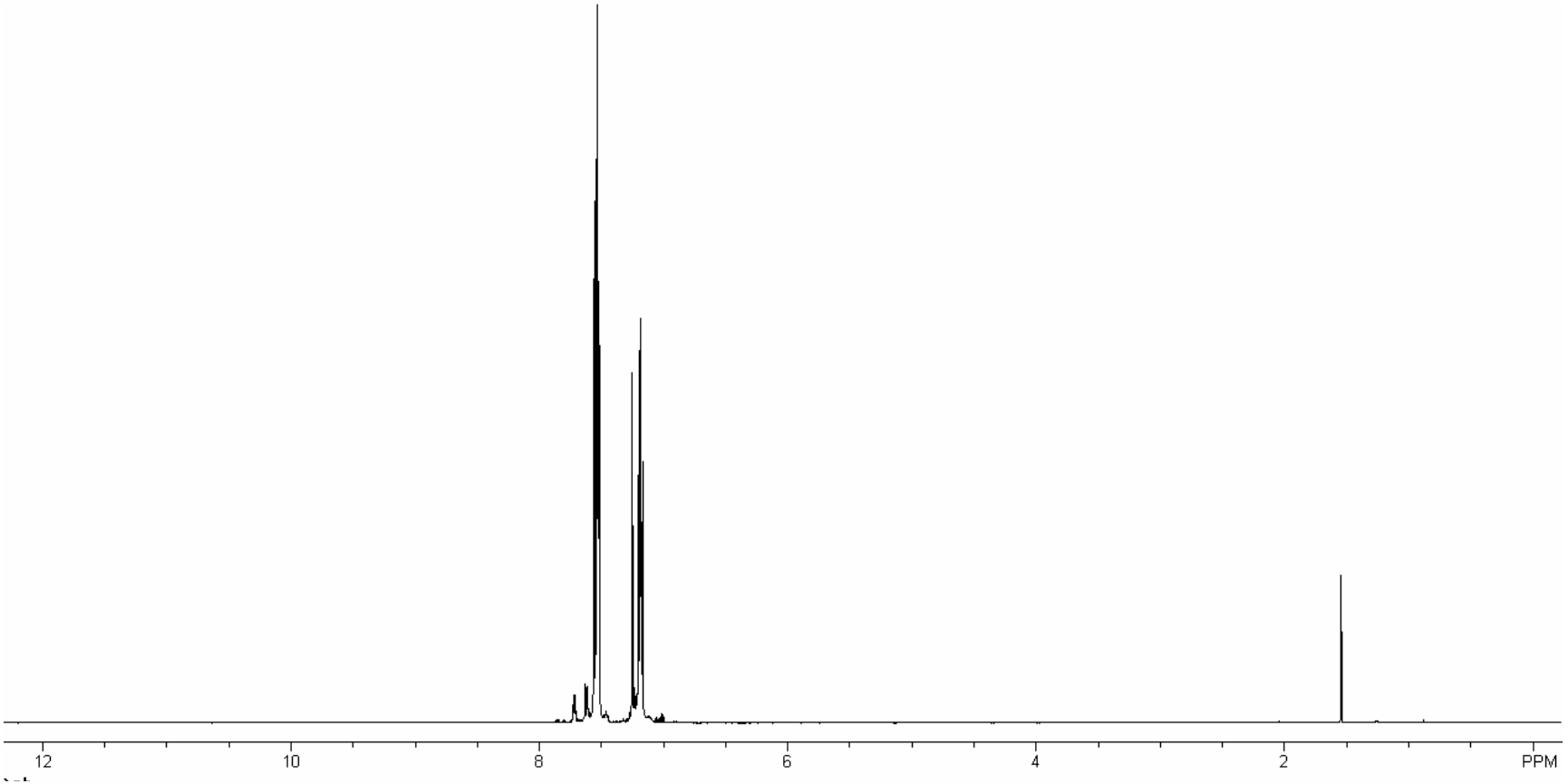
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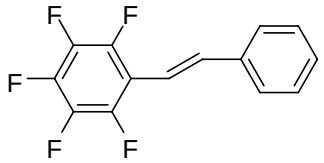
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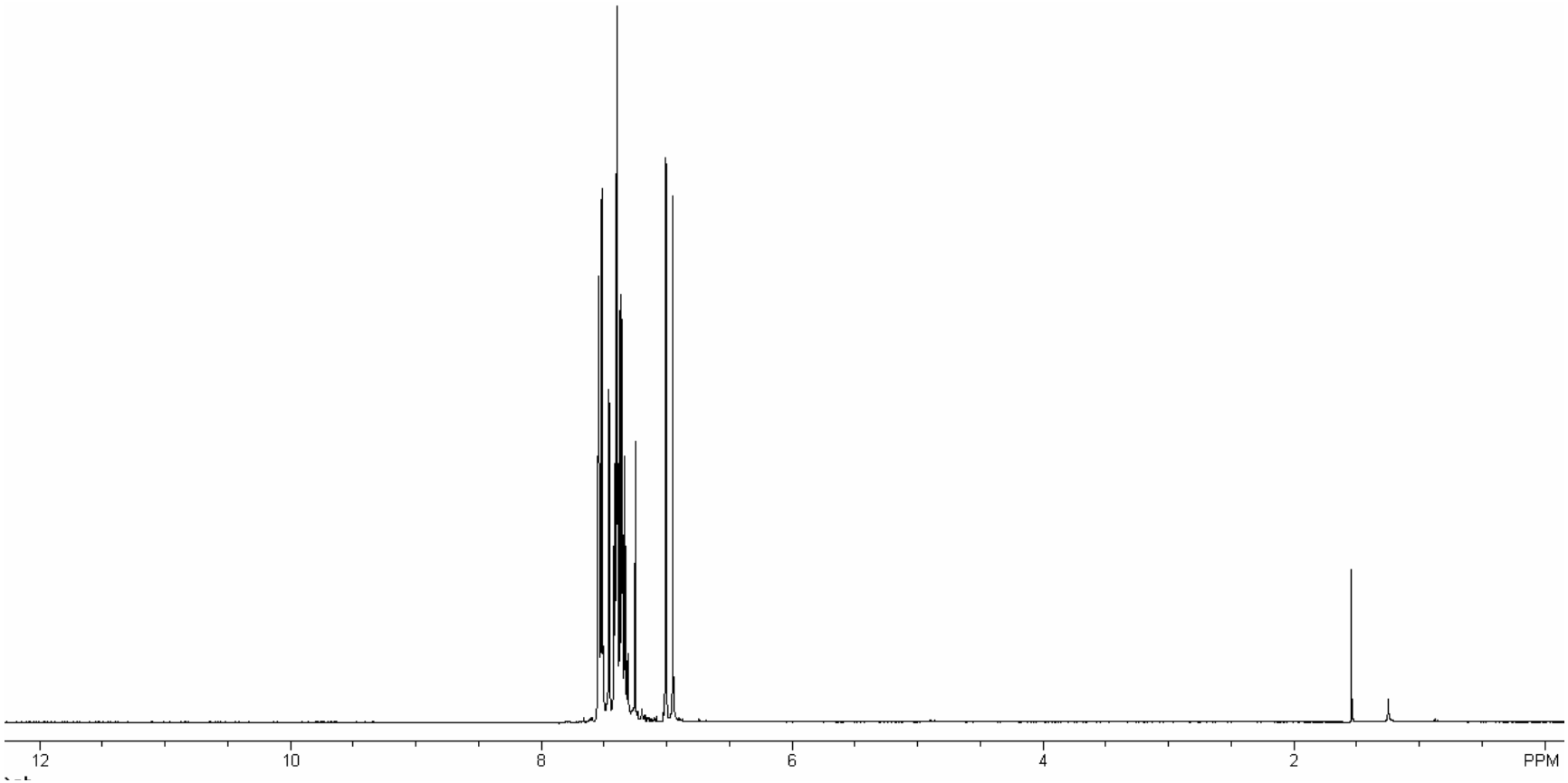
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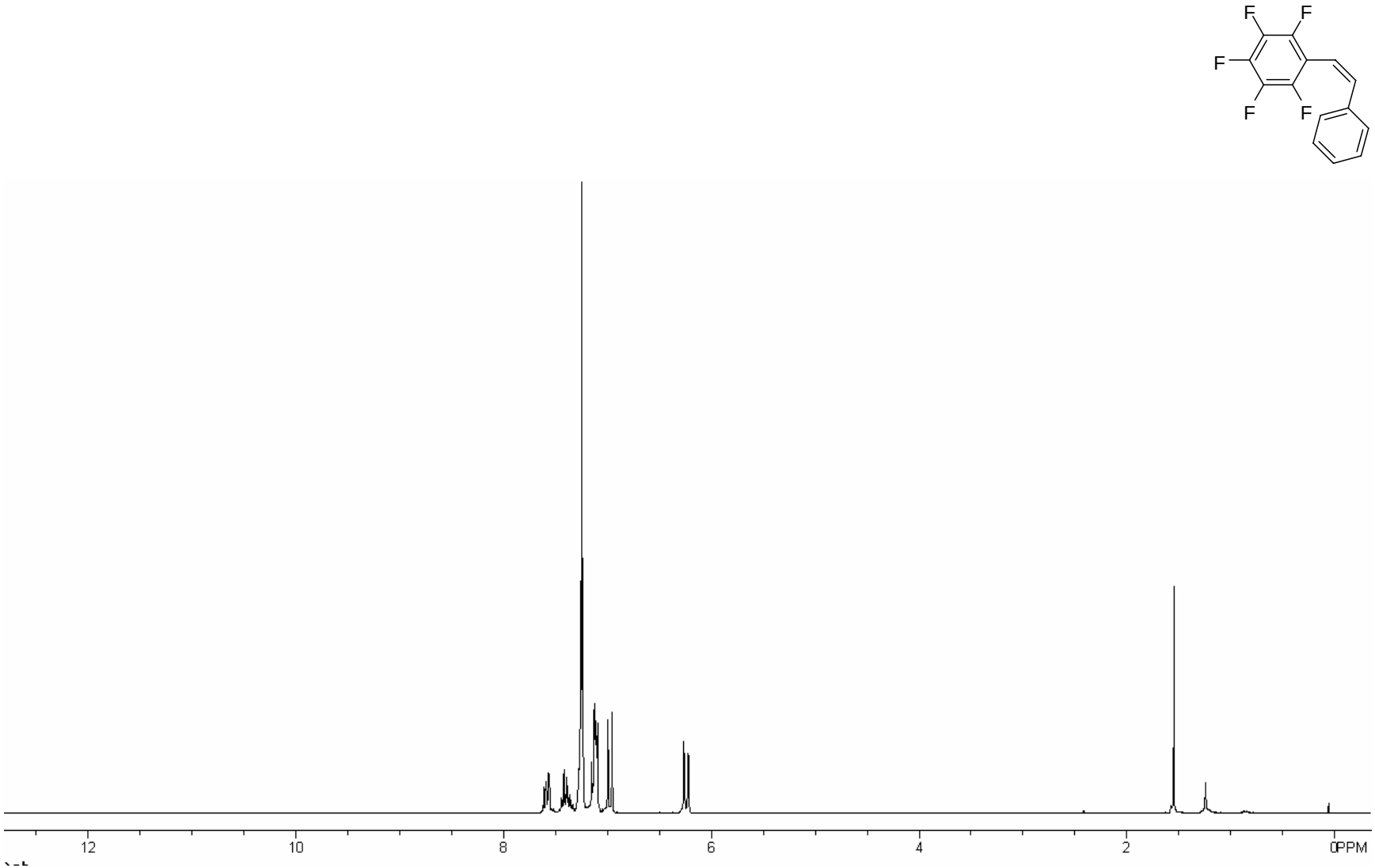
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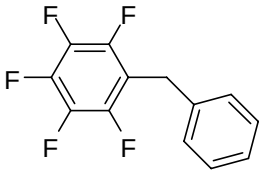
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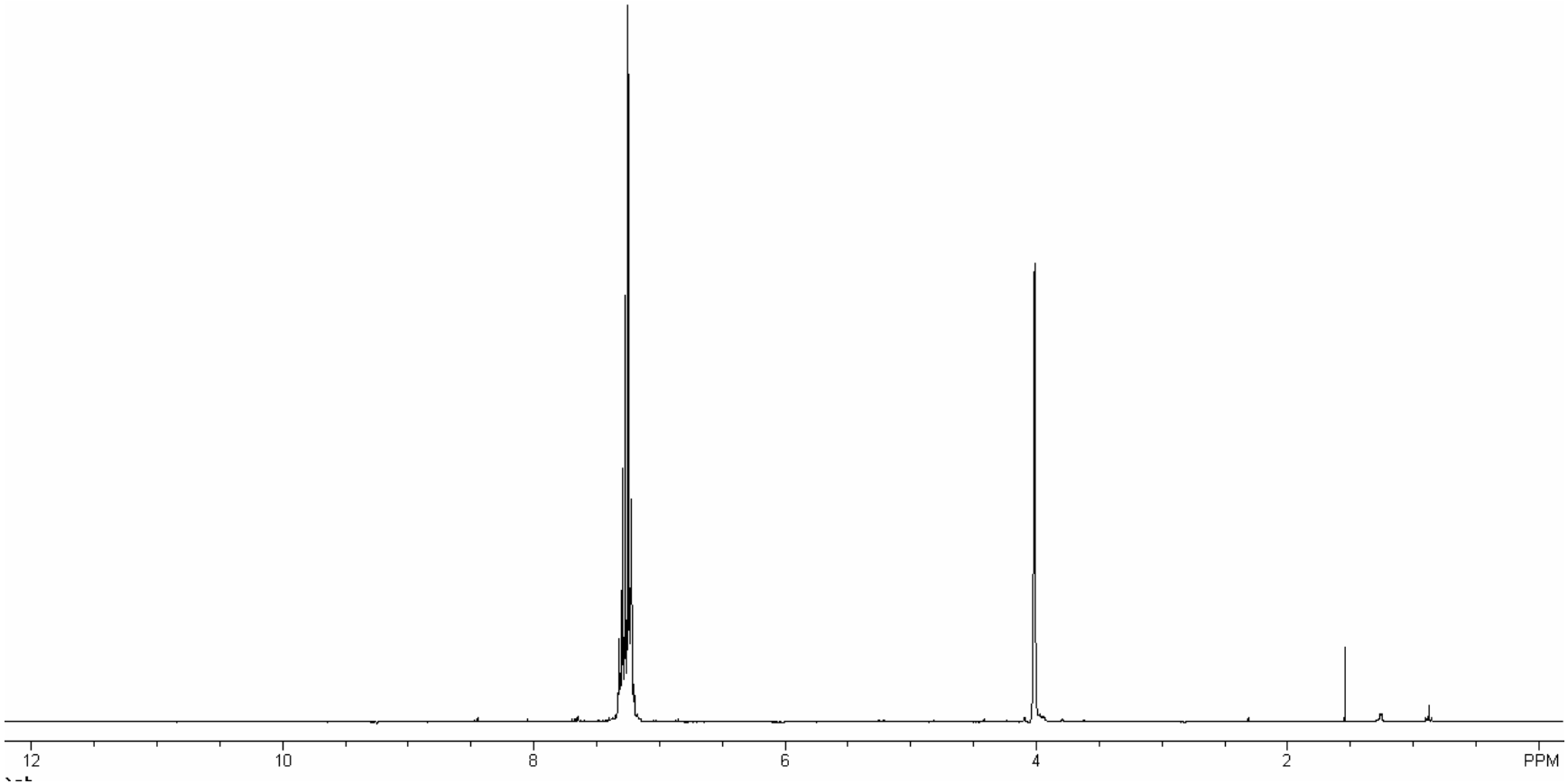
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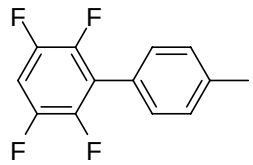
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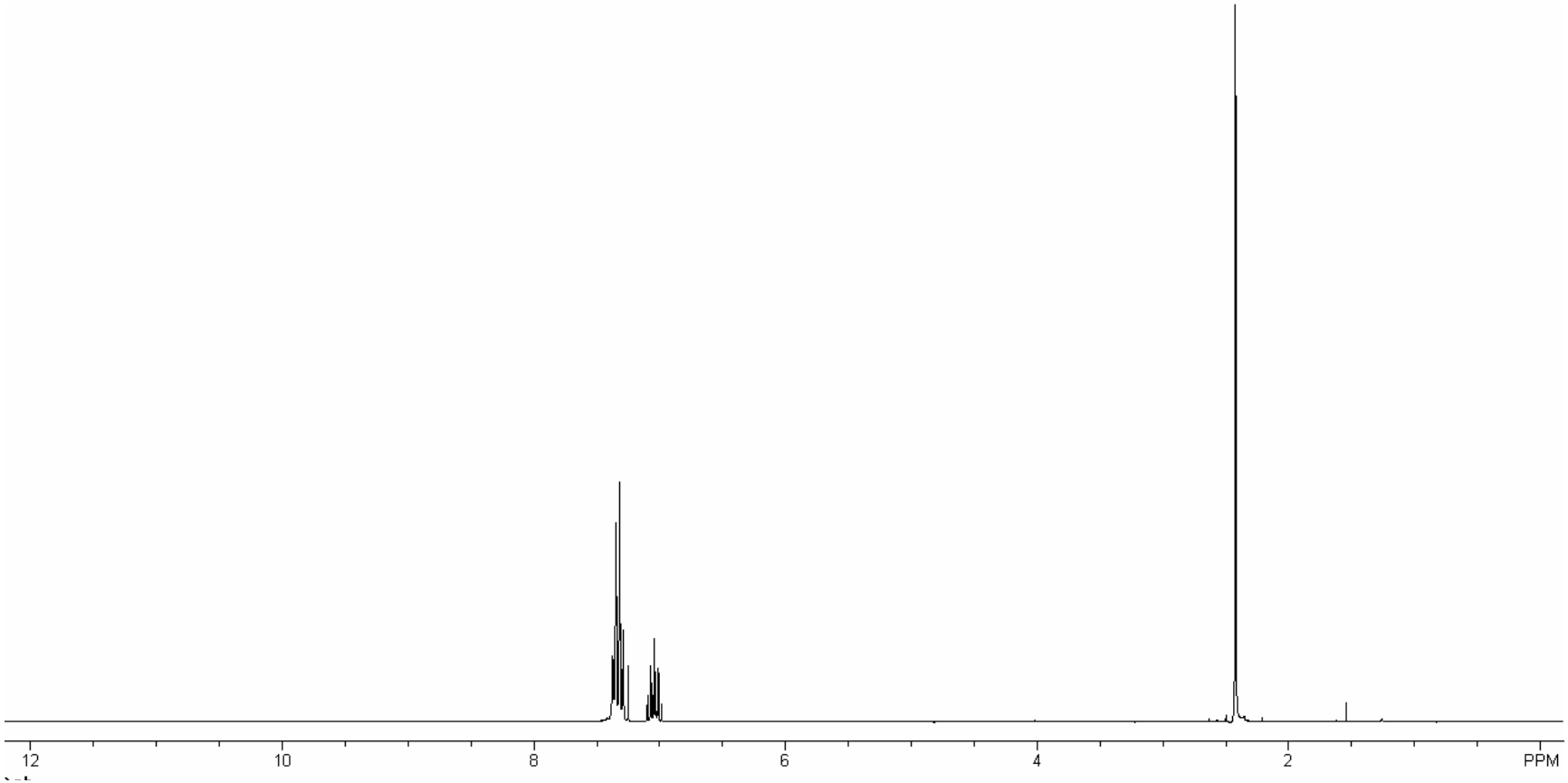
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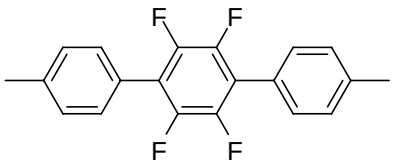
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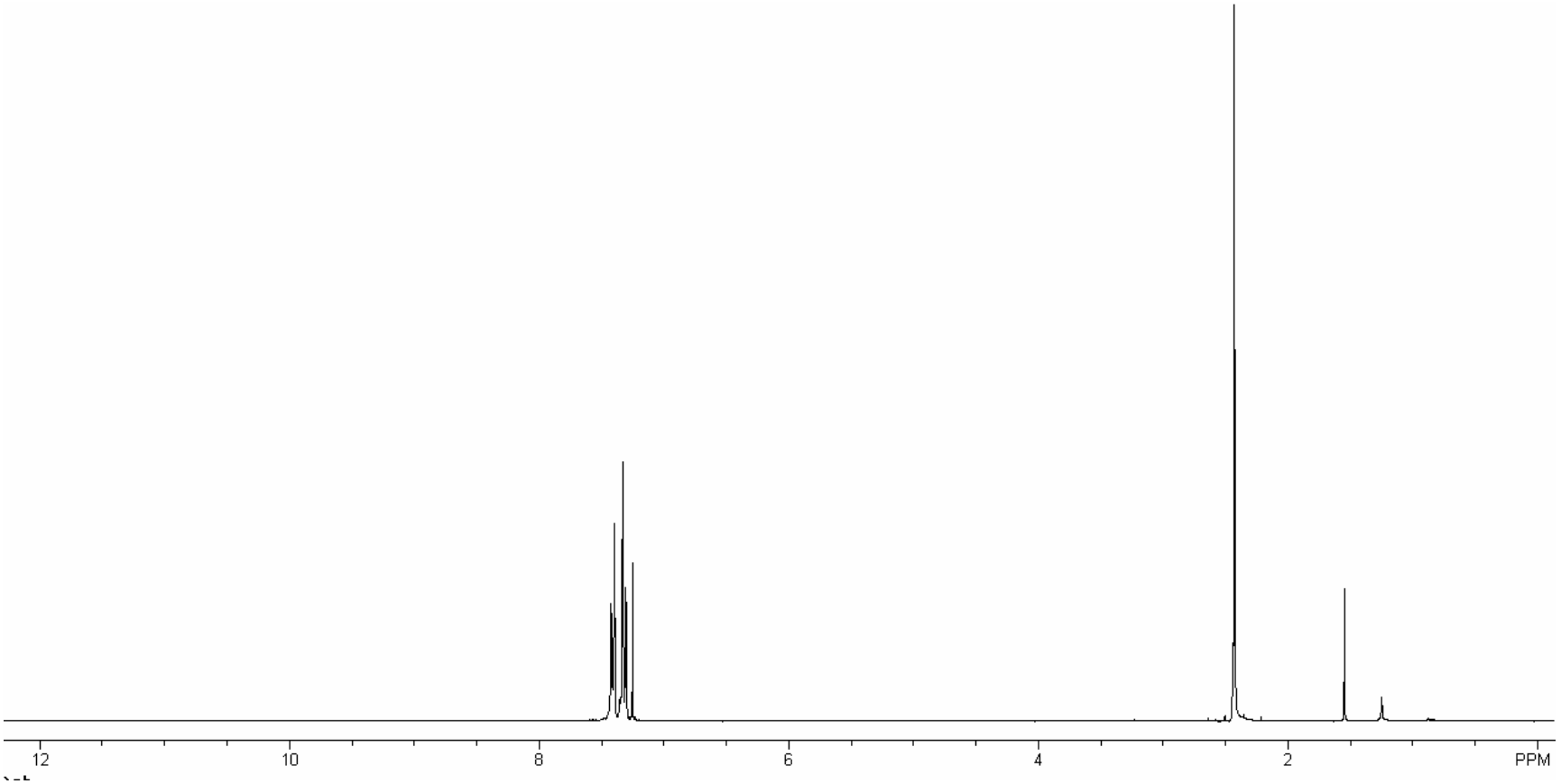
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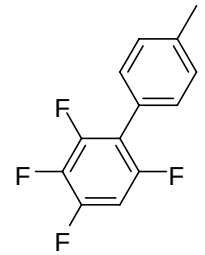
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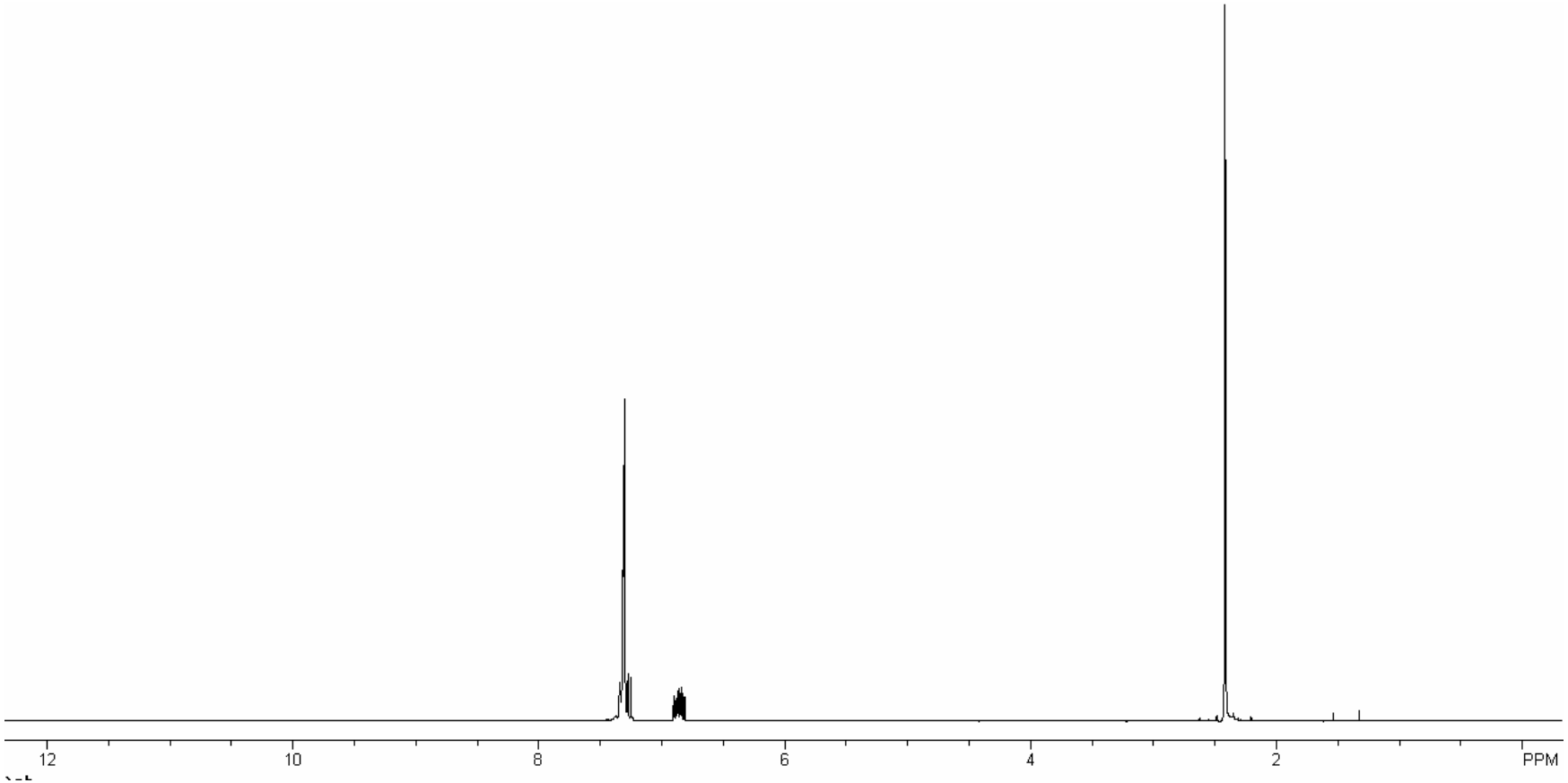
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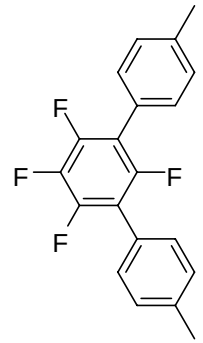
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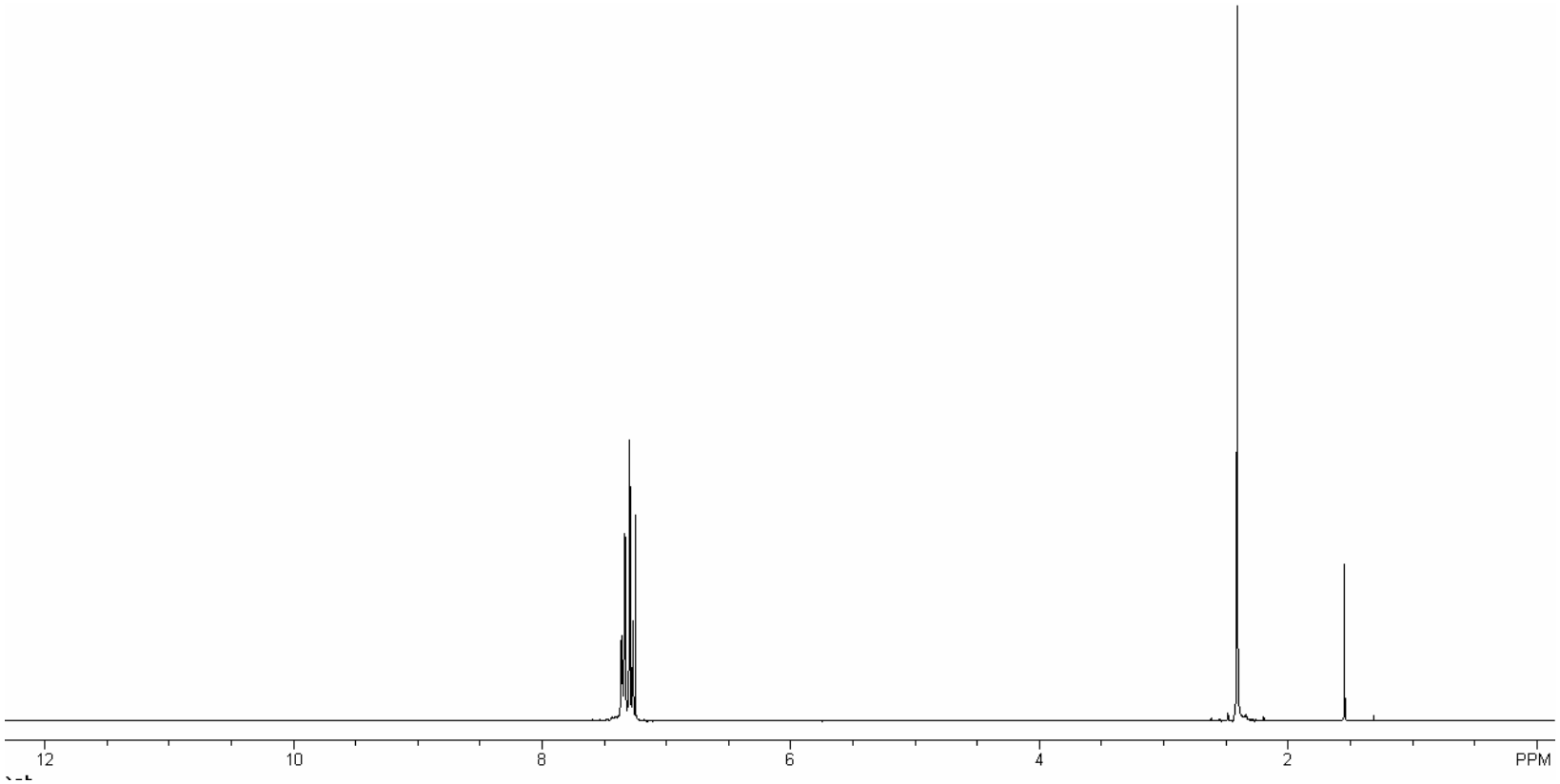
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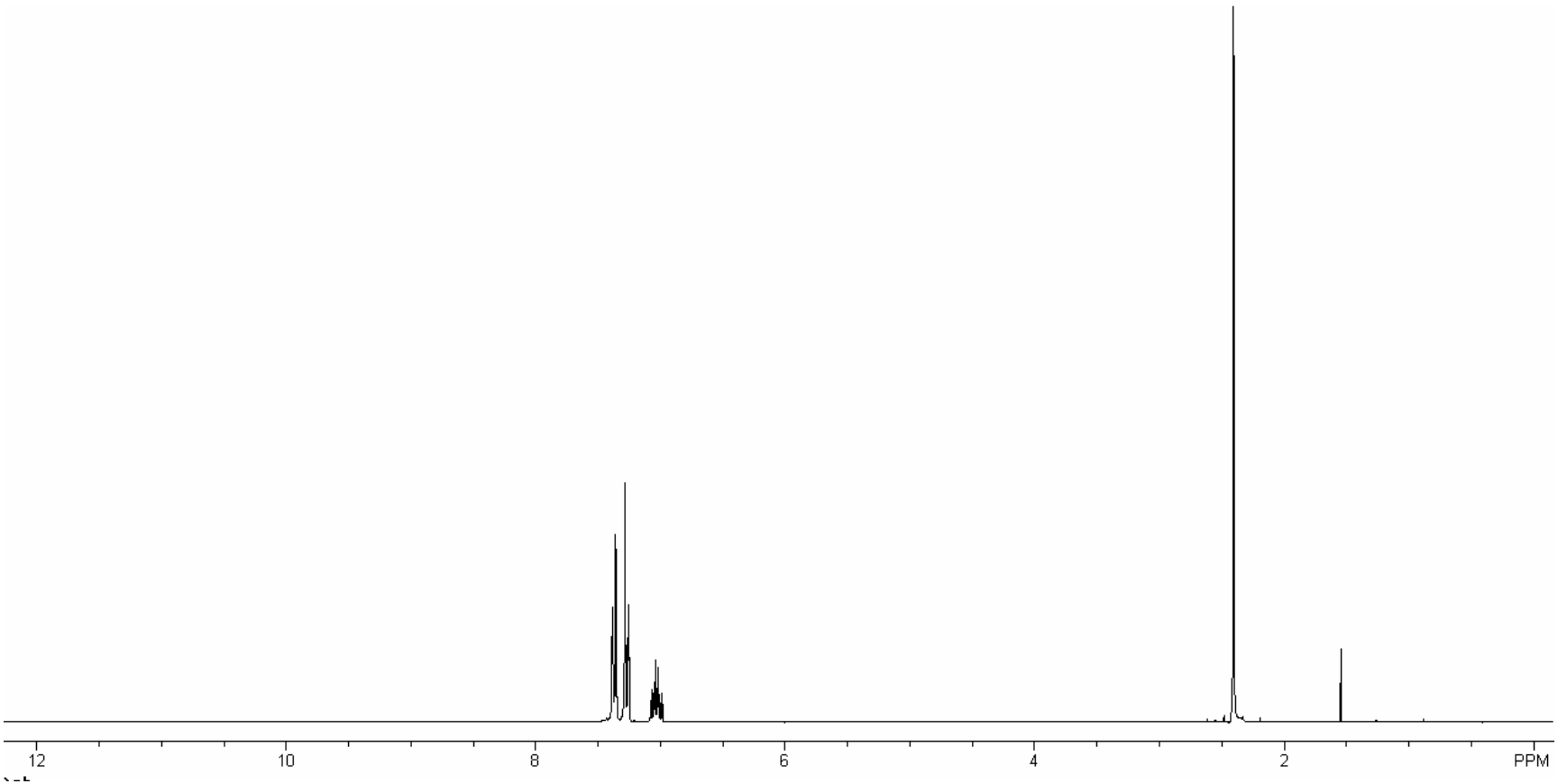
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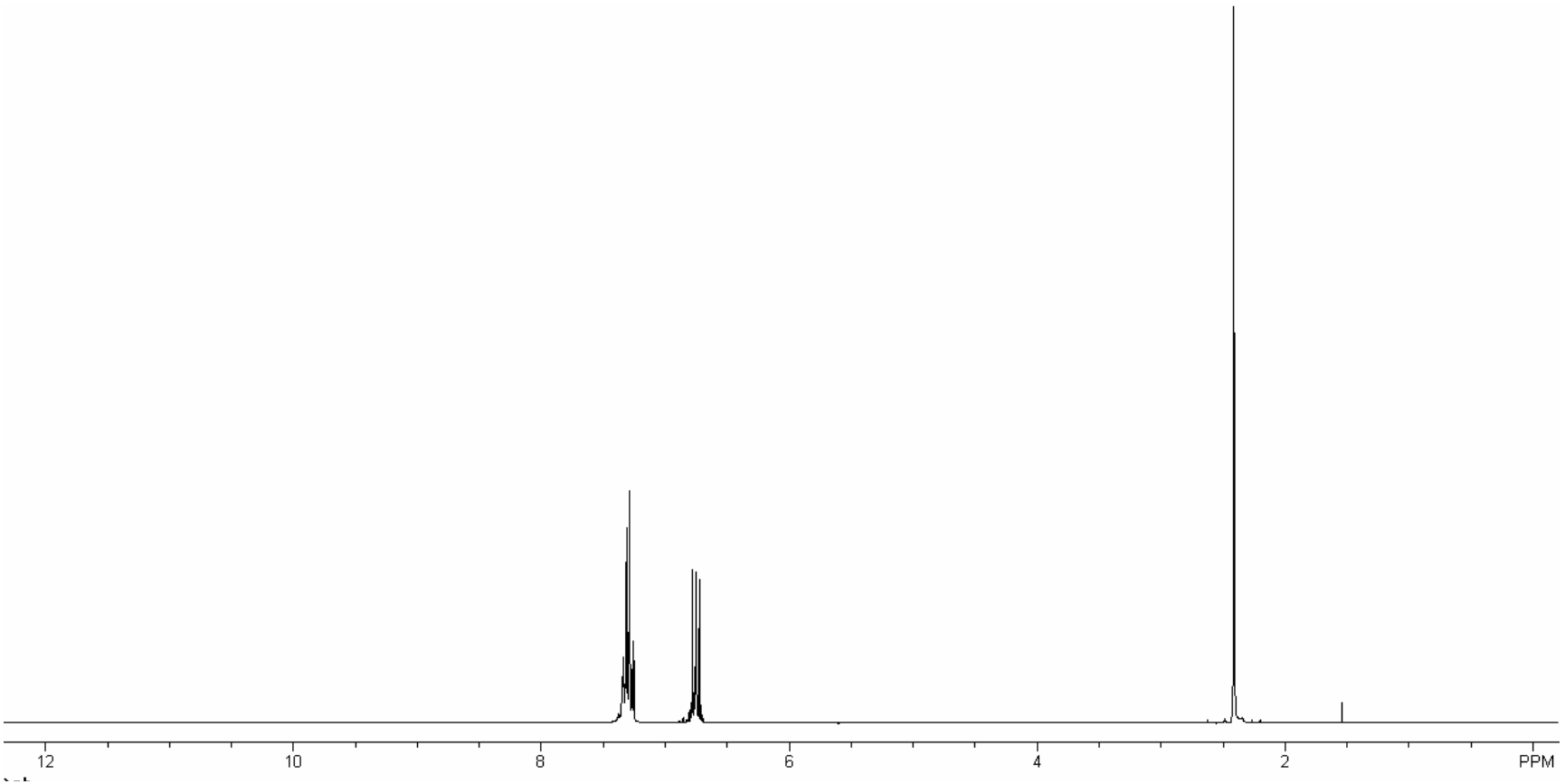
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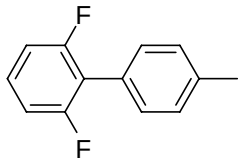
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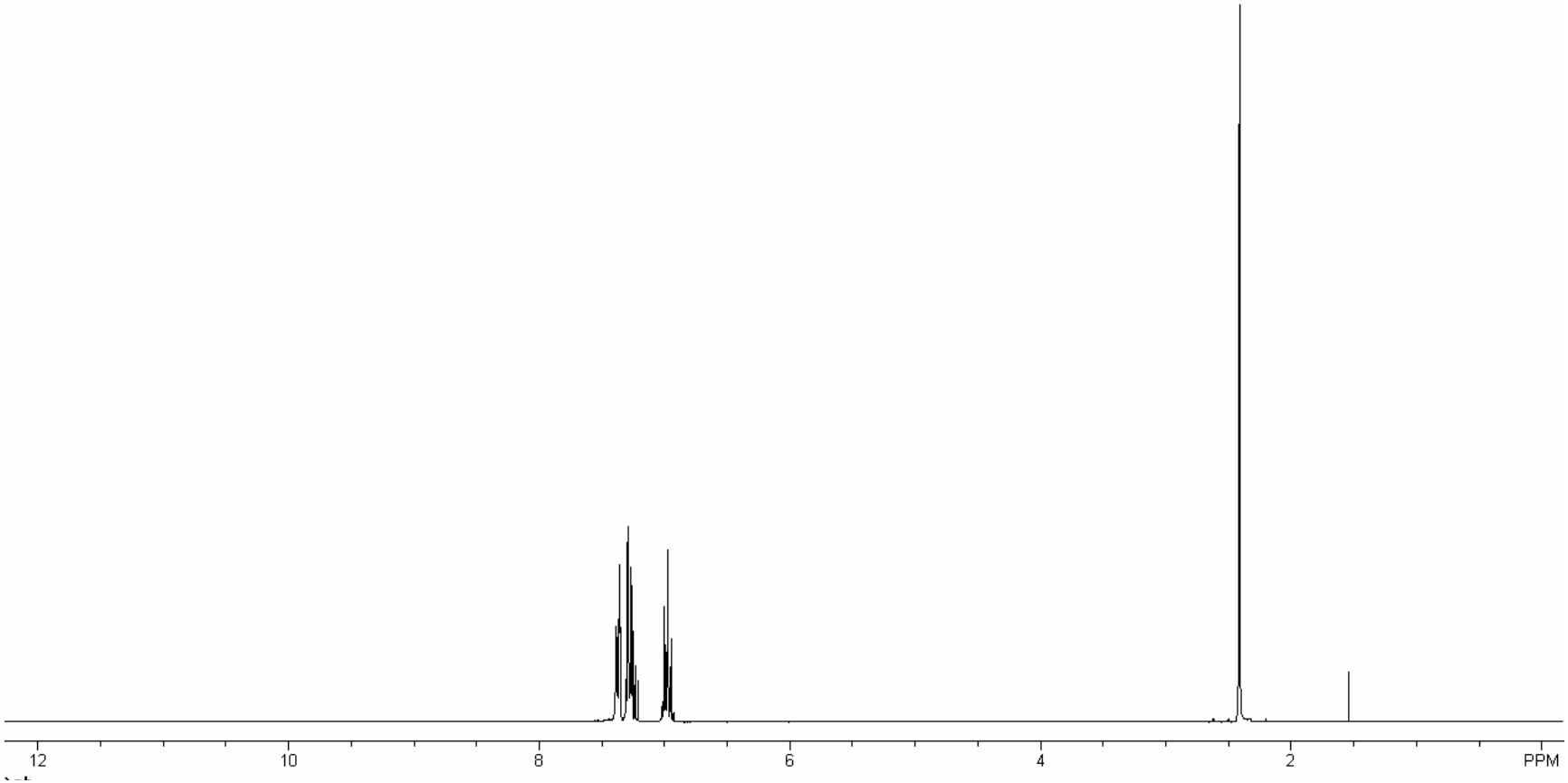
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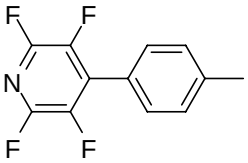
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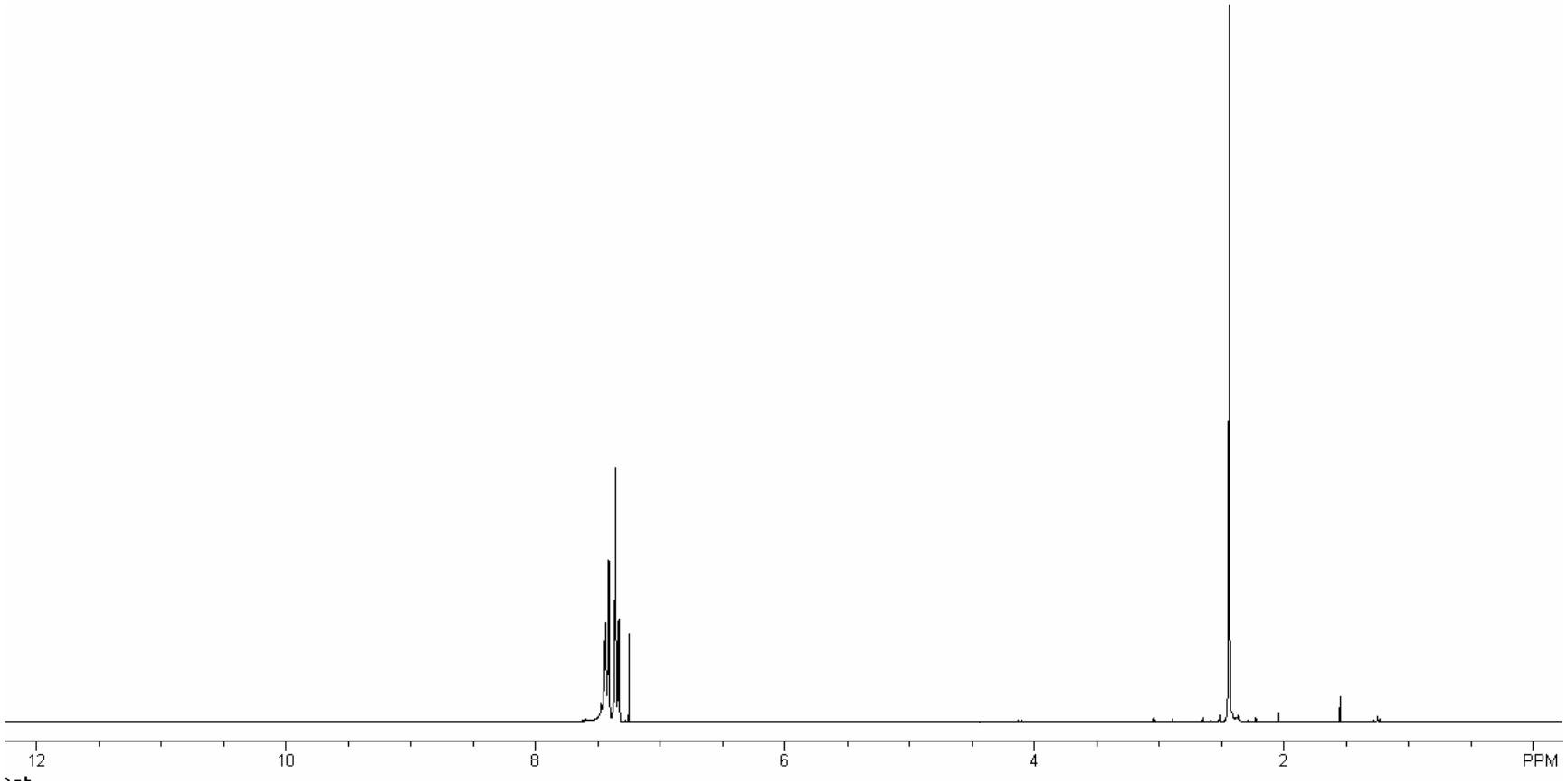
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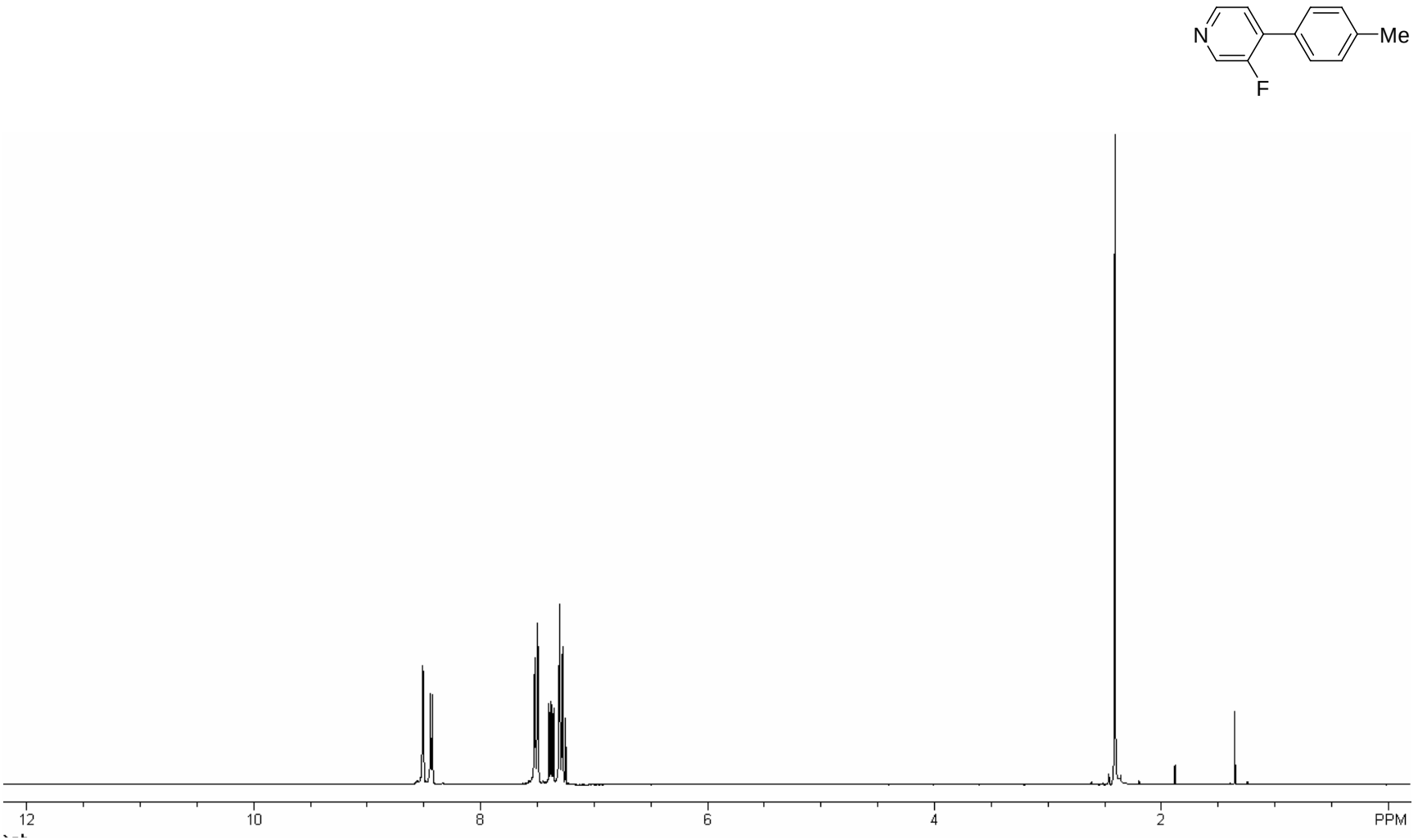
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