

# Palladium-Catalyzed Negishi Cross-Coupling Reactions of Unactivated Alkyl Iodides, Bromides, Chlorides, and Tosylates

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## Supporting Information

### I. General

The following reagents were purchased: *N*-methylpyrrolidinone (NMP; anhydrous in a Sure-Seal bottle; Fluka), Pd<sub>2</sub>(dba)<sub>3</sub> (Johnson Matthey), *N*-methylimidazole (NMI; stored over 4 Å molecular sieves; Avocado), PCyp<sub>3</sub> (Strem), PCy<sub>3</sub> (Strem), P(*i*-Pr)<sub>3</sub> (Strem), P(*t*-Bu)<sub>2</sub>Me (Strem), P(*t*-Bu)<sub>3</sub> (Alfa-Aesar), P(*n*-Bu)<sub>3</sub> (Sigma), PPh<sub>3</sub> (Alfa-Aesar), P(*o*-Tol)<sub>3</sub> (Strem), P(2,4,6-trimethoxyphenyl)<sub>3</sub> (Strem), P(2-furyl)<sub>3</sub> (Strem), Cy<sub>2</sub>P(CH<sub>2</sub>)<sub>2</sub>PCy<sub>2</sub> (dcpe; Strem), 1,3-bis(mesityl)-4,5-dihydroimidazolium tetrafluoroborate (Strem), P(OPh)<sub>3</sub> (Aldrich), *n*-BuZnBr (0.5 M in THF in a Sure-Seal bottle; Aldrich), 2-ethylhexylzinc bromide (0.5 M in THF in a Sure-Seal bottle; Aldrich), cyclohexylmethylzinc bromide (0.5 M in THF in a Sure-Seal bottle; Aldrich), 4-pentenylzinc bromide (0.5 M in THF in a Sure-Seal bottle; Aldrich), 5-cyano-5-methylhexylzinc bromide (0.5 M in THF in a Sure-Seal bottle; Aldrich), 6-ethoxy-6-oxohexylzinc bromide (0.5 M in THF in a Sure-Seal bottle; Aldrich), 1-phenylvinylzinc bromide (0.5 M in THF in a Sure-Seal bottle; Aldrich), PhZnBr (0.5 M in THF in a Sure-Seal bottle; Aldrich), 1-methylvinylmagnesium bromide (0.5 M in THF in a Sure-Seal bottle; Aldrich), 2-methyl-1-propenylmagnesium bromide (0.5 M in THF in a Sure-Seal bottle; Aldrich), *p*-methoxyphenylmagnesium bromide (0.5 M in THF in a Sure-Seal bottle; Aldrich), lithium hydride (powder; stored in a glove box; Aldrich), titanocene dichloride (stored in a glove box; Strem), zinc chloride (anhydrous; Strem), zinc bromide (anhydrous; Strem; dried at 150 °C overnight under vacuum and stored in a glove box), 2-butyne (Avocado), 1-phenyl-1-propyne (Aldrich), 1-bromo-3-benzyloxypropane (Aldrich), *n*-decyl bromide (Alfa-Aesar), 2-cyclohexylethyl bromide (Aldrich), 1-bromo-3-phenylpropane (Aldrich), 1-bromo-3-(*t*-butyldimethylsiloxy)propane (Aldrich), 7-bromoheptanenitrile (Aldrich), *n*-decyl iodide (Avocado), *n*-dodecyl *p*-toluenesulfonate (Acros), *n*-decyl chloride (Aldrich), 1-bromo-6-chlorohexane (Avocado), 2-(3-bromopropoxy)-tetrahydro-2*H*-pyran (Aldrich), 4-chlorobutyraldehyde diethyl acetal

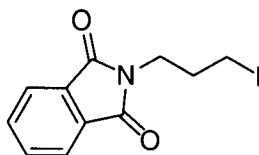
(Alfa-Aesar), ethyl 6-bromohexanoate (Avocado), 2-(3-bromopropyl)-1*H*-isoindole-1,3(2*H*)-dione (Avocado), 6-bromohexanoyl chloride (Avocado), 2-picoline (stored over KOH pellets; Aldrich), diethylamine (Avocado), 3-cyclohexenylmethanol (Aldrich), 11-undecenyl alcohol (Alfa-Aesar), tetrafluoroboric acid (48 wt% in water; Aldrich).

THF was dried by passage through a neutral alumina column. 6-Bromohexyl pivalate was prepared according to a literature procedure.<sup>1</sup> The liquid alkyl halides/tosylates were purged with argon before use.

All reactions were conducted in oven-dried glassware under an inert atmosphere with magnetic stirring.

## II. Preparation of Substrates and [HPCyp<sub>3</sub>]BF<sub>4</sub>

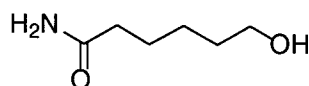
These procedures have not been optimized.



**2-(3-Iodopropyl)-1H-isoindole-1,3(2H)-dione [5457-29-4]<sup>2</sup>** (Table 4, entry 2). A solution of 2-(3-bromopropyl)-1H-isoindole-1,3(2H)-dione (3.00 g, 11.2 mmol) and NaI (8.40 g, 55.8 mmol) in acetone (anhydrous; 25 mL) was refluxed for 14 h. The solvent was then removed, and the resulting residue was extracted (CH<sub>2</sub>Cl<sub>2</sub>/10% Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> solution). The CH<sub>2</sub>Cl<sub>2</sub> layer was dried over anhydrous MgSO<sub>4</sub>, and the solvent was removed to give 3.52 g (100%) of the product as a yellow solid. The product was stored in the dark at 0 °C.

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz):  $\delta$  7.87-7.84 (m, 2H), 7.76-7.72 (m, 2H), 3.78 (t,  $J$  = 6.8 Hz, 2H), 3.18 (t,  $J$  = 7.2 Hz, 2H), 2.26 (tt,  $J$  = 7.2, 6.8 Hz, 2H).

<sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz):  $\delta$  168.7, 134.5, 132.4, 123.8, 39.0, 33.0, 1.7.

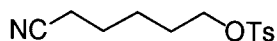


**6-Hydroxyhexanoamide [4547-52-8].<sup>3</sup>** A suspension of  $\epsilon$ -caprolactone (10.0 g, 87.7 mmol) in a conc. aq NH<sub>3</sub> solution (100 mL) was vigorously stirred at r.t. for 12 h. Then, the water was removed at 80 °C on a rotary evaporator, and the resulting solid was dissolved in CH<sub>2</sub>Cl<sub>2</sub> (20 mL) and precipitated with Et<sub>2</sub>O (20 mL). After vigorously stirring the mixture for 5 min and then letting it stand for 4 h, the white solids were collected by filtration and washed sequentially with EtOH and Et<sub>2</sub>O. Concentration of the filtrate furnished additional crystals. Total yield: 8.30 g, 72%.

<sup>1</sup>H NMR (CD<sub>3</sub>CN, 400 MHz):  $\delta$  6.28 (br s, 1H), 5.85 (br s, 1H), 3.50 (t,  $J$  = 6.6 Hz, 2H), 2.87 (br s, 1H), 2.16 (t,  $J$  = 7.4 Hz, 2H), 1.61-1.47 (m, 4H), 1.39-1.33 (m, 2H).

<sup>13</sup>C NMR (CD<sub>3</sub>CN, 100 MHz):  $\delta$  176.0, 61.8, 35.6, 32.7, 25.7, 25.6.

HRMS (ESI): Calcd for C<sub>6</sub>H<sub>14</sub>NO<sub>2</sub> (M+H)<sup>+</sup>: 132.1019. Found: 132.1020.



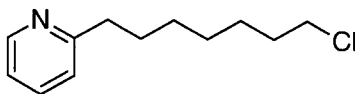
**6-(*p*-Toluenesulfonyloxy)hexanenitrile** (Table 4, entry 4). THF (20 mL) and Et<sub>3</sub>N (2.90 mL, 20.8 mmol) were added to a flask containing 6-hydroxyhexanoamide (2.48 g, 18.9 mmol) and *p*-toluenesulfonyl chloride (4.31 g, 22.6 mmol). The suspension was stirred at 50 °C for 14 h. Then, the solvent was evaporated, and the resulting residue was purified by flash chromatography (pentane/EtOAc 10:1), which afforded 0.70 g (14%) of the product.

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz): δ 7.78 (d, *J* = 8.3 Hz, 2H), 7.37 (d, *J* = 8.0 Hz, 2H), 4.03 (t, *J* = 6.2 Hz, 2H), 2.46 (s, 3H), 2.34 (t, *J* = 7.1 Hz, 2H), 1.73-1.59 (m, 4H), 1.52-1.46 (m, 2H).

<sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz): δ 145.4, 133.2, 130.4, 128.3, 119.8, 70.3, 28.5, 25.2, 25.1, 22.1, 17.4.

IR (thin film): 2943, 2871, 2245, 1598, 1357, 1176 cm<sup>-1</sup>.

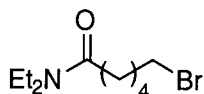
HRMS (ESI): Calcd for C<sub>13</sub>H<sub>17</sub>NNaO<sub>3</sub>S (M+Na)<sup>+</sup>: 290.0827. Found: 290.0815.



**2-(7-Chloroheptyl)pyridine** [237763-54-1]<sup>4</sup> (Table 4, entry 6). *n*-BuLi (2.65 M in hexane; 5.7 mL, 15 mmol) was added dropwise to a solution of 2-picoline (1.46 mL, 15 mmol) in THF (8 mL) at -78 °C. The resulting red solution was warmed to r.t. over 20 min, and then it was transferred to a Schlenk tube that contained a solution of 1-bromo-6-chlorohexane (2.24 mL, 3.00 g, 15 mmol) in THF (8 mL) at -78 °C. The mixture was then warmed to r.t. and stirred for 12 h. The reaction was quenched with MeOH (2 mL), and the solvents were removed under partial vacuum. The resulting oil was distilled (0.2 Torr, 93-95 °C) to give 2.01 g (64%) of the product as a yellow oil.

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz): δ 8.53 (d, *J* = 4.1 Hz, 1H), 7.59 (td, *J* = 1.8, 7.7 Hz, 1H), 7.14 (d, *J* = 7.8 Hz, 1H), 7.10 (dd, *J* = 4.9, 5.9 Hz, 1H), 3.53 (t, *J* = 6.8 Hz, 2H), 2.79 (t, *J* = 7.7 Hz, 2H), 1.80-1.71 (m, 4H), 1.47-1.37 (m, 6H).

<sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz): δ 162.7, 149.6, 136.7, 123.1, 121.3, 45.6, 38.8, 33.0, 30.2, 29.6, 29.1, 27.2.

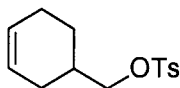


***N,N*-Diethyl 6-bromohexanamide [150514-56-0] (Table 5, entry 5).** 6-Bromohexanoyl chloride (3.93 mL, 25.0 mmol) was added dropwise over 10 minutes to a 0 °C solution of DMAP (54 mg, 0.25 mmol), Et<sub>3</sub>N (5.20 mL, 37.5 mmol), and Et<sub>2</sub>NH (2.61 mL, 25 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (50 mL). The resulting mixture was stirred at 0 °C for 1.0 h, and then the yellow suspension was passed through a pad of silica gel (washing with Et<sub>2</sub>O). The filtrate was concentrated, and the residue was distilled under partial vacuum (150 mTorr, 95 °C) to give 6.06 g (99%) of the desired product as a colorless oil.

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz): δ 3.44-3.28 (m, 6H), 2.31 (t, *J* = 7.3 Hz, 2H), 1.89 (dd, *J* = 7.1, 6.9 Hz, 2H), 1.68 (dd, *J* = 7.6, 6.7 Hz, 2H), 1.49 (dd, *J* = 7.9, 7.3 Hz, 2H), 1.17 (t, *J* = 7.1 Hz, 3H), 1.11 (t, *J* = 7.1 Hz, 3H).

<sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz): δ 172.2, 42.3, 40.5, 34.2, 33.2, 33.0, 28.4, 24.9, 14.8, 13.5.

HRMS (ESI): Calcd for C<sub>10</sub>H<sub>20</sub>NNaOBr (M+Na)<sup>+</sup>: 272.0620. Found: 272.0628.

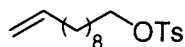


**3-Cyclohexene-1-methanol *p*-toluenesulfonate [92864-78-3] (Table 5, entry 9).** 3-Cyclohexenylmethanol (2.08 mL, 2.00 g, 17.8 mmol) and Et<sub>3</sub>N (2.60 mL, 18.7 mmol) were added to a solution of *p*-toluenesulfonyl chloride (3.38 g, 17.8 mmol) in THF (20 mL). The initially clear solution became cloudy within a few minutes. After 12 h of stirring at r.t., a white suspension had formed. Pentane (20 mL) was added, and then the suspension was passed through Celite, which was washed with pentane. The filtrate was concentrated, and the residue was purified by flash chromatography (pentane/Et<sub>2</sub>O 100:3), which furnished 2.15 g (45%) of the desired product as a colorless oil.

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz): δ 7.80 (d, *J* = 8.4 Hz, 2H), 7.36 (d, *J* = 8.0 Hz, 2H), 5.67-5.57 (m, 2H), 3.91 (d, *J* = 6.6 Hz, 2H), 2.46 (s, 3H), 2.11-1.94 (m, 4H), 1.76-1.66 (m, 2H), 1.32-1.22 (m, 1H).

<sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz): δ 145.1, 133.4, 130.3, 128.3, 127.4, 125.4, 74.8, 33.5, 28.0, 25.1, 24.4, 22.1.

HRMS (ESI): Calcd for C<sub>14</sub>H<sub>18</sub>NaO<sub>3</sub>S (M+Na)<sup>+</sup>: 289.0869. Found: 289.0864.



**10-Undecen-1-ol *p*-toluenesulfonate [51148-67-5] (Table 6, entry 5).** 11-Undecenyl alcohol (5.89 mL, 5.00 g, 29.4 mmol) and Et<sub>3</sub>N (4.09 mL, 29.4 mmol) were added to a solution of *p*-toluenesulfonyl chloride (5.60 g, 29.4 mmol) in THF (20 mL). The mixture was stirred at 70 °C (white solids appeared within the first 10 min). After 8 h, the resulting suspension was mixed with pentane (20 mL) and passed through a pad of silica gel (Et<sub>2</sub>O washings). The filtrate was concentrated, and the residue was purified by flash chromatography (pentane/Et<sub>2</sub>O 100:2) to give 5.27 g (58%) of the desired product as a colorless oil.

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz): δ 7.81 (d, *J* = 8.3 Hz, 2H), 7.36 (d, *J* = 8.0 Hz, 2H), 5.86-5.77 (m, 1H), 5.03-4.93 (m, 2H), 4.04 (t, *J* = 6.5 Hz, 2H), 2.47 (s, 3H), 2.07-2.02 (m, 2H), 1.68-1.61 (m, 2H), 1.39-1.24 (m, 12H).

<sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz): δ 145.0, 139.6, 133.6, 130.2, 128.3, 114.6, 71.1, 34.2, 29.7 (two overlapping resonances), 29.4, 29.3 (two overlapping resonances), 29.2, 25.7, 22.0.

**[HPCyp<sub>3</sub>]BF<sub>4</sub>.<sup>5</sup>** Under an argon atmosphere in a scintillation vial, HBF<sub>4</sub> (48 wt% in water; 1.64 mL, 12.6 mmol) was added dropwise to a solution of PCyp<sub>3</sub> (1.06 g, 4.45 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (10 mL). The reaction mixture was stirred vigorously at r.t. for 10 min, and then water (5 mL) was added and the organic layer was removed by pipet. The aqueous layer was shaken with CH<sub>2</sub>Cl<sub>2</sub> (10 mL), and the organic layer was again removed by pipet. The combined organic extracts were dried over anhydrous MgSO<sub>4</sub>, filtered, and concentrated to give a white solid, which was re-dissolved in hot acetone (10 mL) and then precipitated with hexane (20 mL) to give a fine white powder (1.44 g, 99%).

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz): δ 6.17 (dd, *J* = 474.3, 5.2 Hz, 1H), 2.70-2.62 (m, 3H), 2.26-2.19 (m, 6H), 1.86-1.75 (m, 18H).

<sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz): δ 29.5, 28.7 (d, *J* = 45.9 Hz), 26.3 (d, *J* = 11.3 Hz).

<sup>31</sup>P NMR (CDCl<sub>3</sub>, 100 MHz): δ 32.0.

IR (KBr pellet): 3421, 2984, 2923, 2361, 2336, 2017, 1236 cm<sup>-1</sup>.

HRMS (EI): Calcd for C<sub>15</sub>H<sub>28</sub>P (M)<sup>+</sup>: 239.1923. Found: 239.1930.

mp: 252 °C (decomposition).

### III. Negishi Cross-Coupling Reactions

**Representative Procedure for the Optimization Studies (Tables 1 and 2).** In a glove box, Pd<sub>2</sub>(dba)<sub>3</sub> (4.6 mg, 0.0050 mmol), PCyp<sub>3</sub> (5.0  $\mu$ L, 4.8 mg, 0.020 mmol), THF (0.15 mL), and dry NMP (0.4 mL) were added sequentially to a vial. The resulting mixture was stirred at r.t. for 3 min, resulting in a yellow-green solution. *n*-BuZnBr (0.5 M in THF; 0.65 mL, 0.32 mmol), NMI (25  $\mu$ L, 0.30 mmol), *n*-hexadecane (GC internal standard; 29  $\mu$ L, 0.10 mmol), and 1-bromo-3-benzyloxypropane (46  $\mu$ L, 58 mg, 0.25 mmol) were added, and then the vial was closed with a Teflon-coated screw cap, sealed with electrical tape, taken out of the glove box, and stirred in an 80 °C oil bath. After 14 h, an aliquot was passed through silica gel and analyzed by gas chromatography.

**Benzyl *n*-heptyl ether [16519-20-3].** <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz):  $\delta$  7.38-7.28 (m, 5H), 4.54 (s, 2H), 3.50 (t, *J* = 6.6 Hz, 2H), 1.67-1.62 (m, 2H), 1.41-1.29 (m, 8H), 0.92 (t, *J* = 7.0 Hz, 3H).

<sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz):  $\delta$  139.1, 128.8, 128.1, 127.9, 73.3, 71.0, 32.3, 30.2, 29.6, 26.6, 23.1, 14.5.

**Procedure for Tables 3 and 4 (no glove box).** Pd<sub>2</sub>(dba)<sub>3</sub> (9.2 mg, 0.010 mmol) was added to a Schlenk tube equipped with a stir bar. The air was removed by evacuating/refilling with argon (three times), and then PCyp<sub>3</sub> (10  $\mu$ L, 9.6 mg, 0.040 mmol), THF (0.3 mL), and dry NMP (0.8 mL) were added. After stirring for 3 min at r.t., the yellow-green solution was treated with the alkylzinc bromide solution (0.5 M in THF; 1.3 mL, 0.65 mmol), NMI (50  $\mu$ L, 0.60 mmol), and the alkyl halide/tosylate (0.50 mmol). The reaction mixture was stirred in an oil bath for 14 h at 80 °C, and then it was diluted with pentane (2 mL) and passed through a short pad of silica gel (to remove inorganic salts and NMP). The filtrate was then concentrated, and the residue was purified by flash chromatography.

***n*-Tetradecane [629-59-4] (Table 3, entry 1).** *n*-BuZnBr (0.5 M in THF; 1.3 mL, 0.65 mmol) and *n*-decyl bromide (111 mg, 0.50 mmol) were used. Solvent for chromatography: pentane. Colorless oil (89 mg, 90%).

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz):  $\delta$  1.33-1.29 (m, 24H), 0.91 (t, *J* = 7.0 Hz, 6H).

<sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz):  $\delta$  32.4, 30.2 (two overlapping resonances), 30.1, 29.8, 23.1, 14.5.

The NMR spectra and the GC retention time were identical to those of an authentic sample (Aldrich).

**5-Ethylhexadecane [125182-41-4] (Table 3, entry 2).** 2-Ethylhexylzinc bromide (0.5 M

in THF; 1.3 mL, 0.65 mmol) and *n*-decyl bromide (111 mg, 0.50 mmol) were used. Solvent for chromatography: pentane. Colorless oil (113 mg, 89%).

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz): δ 1.28-1.24 (m, 29H), 0.93-0.83 (m, 9H).

<sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz): δ 39.2, 33.6, 33.3, 32.4, 30.6, 30.2, 30.15 (two overlapping resonances), 30.10, 29.8, 29.4, 27.2, 26.3, 23.6, 23.1, 14.61, 14.55, 11.3.

**(4-Ethyl-octyl)cyclohexane (Table 3, entry 3).** 2-Ethylhexylzinc bromide (0.5 M in THF; 1.3 mL, 0.65 mmol) and 2-cyclohexylethyl bromide (98 mg, 0.50 mmol) were used. Solvent for chromatography: pentane. Colorless oil (85 mg, 76%).

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz): δ 1.73-1.69 (m, 4H), 1.31-1.15 (m, 22H), 0.93-0.83 (m, 6H).

<sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz): δ 39.3, 38.5, 38.2, 33.9 (two overlapping resonances), 33.3, 29.4, 27.2, 26.9, 26.3, 24.3, 23.6, 14.6, 11.3.

IR (thin film): 2923, 2853, 1449 cm<sup>-1</sup>.

HRMS (EI): Calcd for C<sub>16</sub>H<sub>32</sub> (M)<sup>+</sup>: 224.2504. Found: 224.2503.

**(4-Cyclohexylbutyl)benzene [6199-25-3] (Table 3, entry 4).** Cyclohexylmethylzinc bromide (0.5 M in THF; 1.3 mL, 0.65 mmol) and 1-bromo-3-phenylpropane (102 mg, 0.50 mmol) were used. Solvent for chromatography: pentane. Colorless oil (90 mg, 83%).

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz): δ 7.34-7.28 (m, 2H), 7.23-7.19 (m, 3H), 2.64 (t, *J* = 7.7 Hz, 2H), 1.74-1.57 (m, 7H), 1.41-1.14 (m, 8H), 0.93-0.90 (m, 2H).

<sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz): δ 143.4, 128.8, 128.6, 126.0, 38.1, 37.8, 36.5, 33.9, 32.3, 27.2, 27.0, 26.9.

HRMS (EI): Calcd for C<sub>16</sub>H<sub>24</sub> (M)<sup>+</sup>: 216.1873. Found: 216.1881.

**1-Pentadecene [13360-61-7] (Table 3, entry 5).** 4-Pentenylzinc bromide (0.5 M in THF; 1.3 mL, 0.65 mmol) and *n*-decyl bromide (111 mg, 0.50 mmol) were used. Solvent for chromatography: pentane. Colorless oil (55 mg, 52%).

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz): δ 5.89-5.79 (m, 1H), 5.05-4.94 (m, 2H), 2.07 (dd, *J* = 6.8, 6.7 Hz, 2H), 1.42-1.29 (m, 22H), 0.91 (t, *J* = 7.0 Hz, 3H).

<sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz): δ 139.7, 114.5, 34.3, 32.4, 32.3, 30.12, 30.10, 30.06, 30.0, 29.9, 29.8, 29.6, 29.4, 23.1, 14.5.

**9-Benzyloxy-2,2-dimethylnonanenitrile (Table 3, entry 6).** 5-Cyano-5-methylhexylzinc bromide (0.5 M in THF; 1.3 mL, 0.65 mmol) and 1-bromo-3-benzyloxypropane (116 mg, 0.50 mmol) were used. Solvent for chromatography: pentane/EtOAc 100:3 → 100:4. Yellow oil (80 mg, 68%).

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz): δ 7.38 (m, 5H), 4.53 (s, 2H), 3.49 (t, *J* = 6.6 Hz, 2H), 1.66-1.63 (m, 2H), 1.51 (br s, 4H), 1.42-1.35 (m, 12H).

<sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz): δ 139.1, 128.8, 128.1, 127.9, 125.7, 70.8, 41.5, 32.8, 30.1, 30.0, 29.7, 27.1 (two overlapping resonances), 26.5, 25.6.



IR (thin film): 2935, 2859, 2233, 1719, 1275  $\text{cm}^{-1}$ .

HRMS (ESI): Calcd for  $\text{C}_{18}\text{H}_{27}\text{NNaO}$  ( $\text{M}+\text{Na}$ ) $^{+}$ : 296.1990. Found: 296.1971.

**9-*t*-Butyldimethylsiloxy-2,2-dimethylnonanenitrile** (Table 3, entry 7). 5-Cyano-5-methylhexylzinc bromide (0.5 M in THF; 1.3 mL, 0.65 mmol) and 1-bromo-3-(*t*-butyldimethylsiloxy)propane (106 mg, 0.50 mmol) were used. Solvent for chromatography: pentane/ $\text{CH}_2\text{Cl}_2$  100:30  $\rightarrow$  100:50  $\rightarrow$  100:100. Colorless oil (100 mg, 67%).

$^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz):  $\delta$  3.62 (t,  $J$  = 6.6 Hz, 2H), 1.53-1.51 (br, 6H), 1.35 (br, 12H), 0.92 (s, 9H), 0.07 (s, 6H).

$^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz):  $\delta$  125.7, 63.6, 41.5, 33.2, 32.8, 30.0, 29.6, 27.1, 26.4, 26.1, 25.6, 18.8, -4.8.

IR (thin film): 2935, 2858, 2235, 1472, 1101  $\text{cm}^{-1}$ .

HRMS (ESI): Calcd for  $\text{C}_{17}\text{H}_{35}\text{NNaOSi}$  ( $\text{M}+\text{Na}$ ) $^{+}$ : 320.2380. Found: 320.2370.

**Ethyl 12-cyanododecanoate [133310-02-8]** (Table 3, entry 8). 6-Ethoxy-6-oxohexylzinc bromide (0.5 M in THF; 1.3 mL, 0.65 mmol) and 7-bromoheptanenitrile (96 mg, 0.50 mmol) were used. Solvent for chromatography: pentane/EtOAc 100:5  $\rightarrow$  100:7.5. Yellow oil (82 mg, 65%).

$^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz):  $\delta$  4.13 (q,  $J$  = 7.1 Hz, 2H), 2.36-2.27 (m, 4H), 1.68-1.60 (m, 4H), 1.46-1.43 (m, 2H), 1.29-1.24 (m, 15H).

$^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz):  $\delta$  174.3, 120.3, 60.6, 34.8, 29.8, 29.7 (two overlapping resonances), 29.6, 29.5, 29.2, 29.1, 25.8, 25.4, 17.5, 14.7.

***n*-Tetradecane [629-59-4]** (Table 4, entry 1). *n*-BuZnBr solution (0.5 M in THF; 1.3 mL, 0.65 mmol) and *n*-decyl iodide (134 mg, 0.50 mmol) were used. Solvent for chromatography: pentane. Colorless oil (86 mg, 87%).

The NMR ( $^1\text{H}$  and  $^{13}\text{C}$ ) spectra and the GC retention time were identical to those of an authentic sample (Aldrich).

**2-Heptyl-1*H*-isoindole-1,3(2*H*)-dione [71510-40-2]** (Table 4, entry 2). *n*-BuZnBr solution (0.5 M in THF; 1.3 mL, 0.65 mmol) and a solution of 2-(3-iodopropyl)-1*H*-isoindole-1,3(2*H*)-dione (158 mg, 0.50 mmol) in NMP (0.8 mL) were used. Solvent for chromatography: pentane/EtOAc 100:3  $\rightarrow$  100:4. Yellow oil (59 mg, 48%).

$^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz):  $\delta$  7.86-7.82 (m, 2H), 7.74-7.70 (m, 2H), 3.68 (t,  $J$  = 7.3 Hz, 2H), 1.69-1.64 (m, 2H), 1.35-1.26 (m, 8H), 0.87 (t,  $J$  = 6.8 Hz, 3H).

$^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz):  $\delta$  168.9, 134.2, 132.6, 123.5, 38.5, 32.1, 29.3, 29.0, 27.2, 23.0, 14.5.

***n*-Hexadecane [544-76-3]** (Table 4, entry 3). *n*-BuZnBr solution (0.5 M in THF; 1.3 mL, 0.65 mmol) and *n*-dodecyl *p*-toluenesulfonate (157 mg, 0.50 mmol) were used. 80  $^{\circ}\text{C}$ , 40 h.

Solvent for chromatography: pentane. Colorless oil (93 mg, 86%).

The NMR ( $^1\text{H}$  and  $^{13}\text{C}$ ) spectra and the GC retention time were identical to those of an authentic sample (Aldrich).

**11-Cyano-2,2-dimethylundecanenitrile (Table 4, entry 4).** 5-Cyano-5-methylhexylzinc bromide (0.5 M in THF; 1.3 mL, 0.65 mmol) and 6-*p*-toluenesulfonyloxyhexanenitrile (134 mg, 0.50 mmol) were used. 80 °C, 40 h. Solvent for chromatography: pentane/Et<sub>2</sub>O 3:1. Colorless oil (70 mg, 64%).

$^1\text{H}$  NMR (CDCl<sub>3</sub>, 400 MHz):  $\delta$  2.34 (t,  $J$  = 7.1 Hz, 2H), 1.67-1.62 (m, 2H), 1.49-1.42 (m, 6H), 1.33-1.31 (m, 14H).

$^{13}\text{C}$  NMR (CDCl<sub>3</sub>, 100 MHz):  $\delta$  125.7, 120.3, 41.4, 32.8, 29.9, 29.63, 29.56, 29.1, 29.0, 27.1, 25.7, 25.6, 17.5.

IR (thin film): 2933, 2234, 1470 cm<sup>-1</sup>.

HRMS (ESI): Calcd for C<sub>14</sub>H<sub>24</sub>N<sub>2</sub>Na (M+Na)<sup>+</sup>: 243.1831. Found: 243.1837.

***n*-Tetradecane [629-59-4] (Table 4, entry 5).** *n*-BuZnBr solution (0.5 M in THF; 1.3 mL, 0.65 mmol) and *n*-decyl chloride (90 mg, 0.50 mmol) were used. 80 °C, 40 h. Solvent for chromatography: pentane. Colorless oil (96 mg, 97%).

The NMR ( $^1\text{H}$  and  $^{13}\text{C}$ ) spectra and the GC retention time were identical to those of an authentic sample (Aldrich).

**2-Undecylpyridine [80401-50-9] (Table 4, entry 6).** *n*-BuZnBr solution (0.5 M in THF; 1.3 mL, 0.65 mmol) and 2-(7-chloroheptyl)pyridine (106 mg, 0.50 mmol) were used. 80 °C, 40 h. Solvent for chromatography: pentane/EtOAc 100:3 → 100:4. Yellow oil (90 mg, 77%).

$^1\text{H}$  NMR (CDCl<sub>3</sub>, 400 MHz):  $\delta$  8.53 (d,  $J$  = 4.8 Hz, 1H), 7.59 (td,  $J$  = 7.6, 1.8 Hz, 1H), 7.15 (d,  $J$  = 7.8 Hz, 1H), 7.10 (dd,  $J$  = 7.4, 4.9 Hz, 1H), 2.79 (t,  $J$  = 7.7 Hz, 2H), 1.73 (tt,  $J$  = 7.7, 7.0 Hz, 2H), 1.36-1.26 (m, 16H), 0.89 (t,  $J$  = 6.6 Hz, 3H).

$^{13}\text{C}$  NMR (CDCl<sub>3</sub>, 100 MHz):  $\delta$  163.0, 149.6, 136.6, 123.1, 121.2, 38.9, 32.3, 30.4, 30.1, 30.04, 29.98, 29.9, 29.84, 29.76, 23.1, 14.6.

***n*-Tetradecane [629-59-4] (Table 4, entry 7).** *n*-BuZnBr solution (0.5 M in THF; 1.3 mL, 0.65 mmol) and 1-bromo-6-chlorohexane (51 mg, 0.25 mmol) were used. 80 °C, 40 h. Solvent for chromatography: pentane. Colorless oil (dialkylated product; 35 mg, 70%).

**Procedure A for Table 5 (with PCyp<sub>3</sub> and a commercially available organozinc reagent).** In a glove box, Pd<sub>2</sub>(dba)<sub>3</sub> (9.2 mg, 0.010 mmol), PCyp<sub>3</sub> (10  $\mu\text{L}$ , 9.6 mg, 0.040 mmol), and dry NMP (0.8 mL) were added to a vial. The reaction mixture was stirred for 3 min at r.t., and then the resulting yellow-green solution was treated with the organozinc bromide (0.5 M in THF; 1.60 mL, 0.80 mmol), NMI (50  $\mu\text{L}$ , 0.60 mmol), and the alkyl

halide/tosylate (0.50 mmol). The vial was closed with a Teflon-coated screw cap, sealed with electrical tape, and taken out of the glove box. The reaction mixture was stirred in an 80 °C oil bath for 12 h, and then pentane (2 mL) was added. The reaction mixture was passed through a short pad of silica gel (to remove inorganic salts and NMP), the filtrate was concentrated, and the residue was purified by flash chromatography.

**Procedure B for Table 5 (with [HPCyp<sub>3</sub>]BF<sub>4</sub> and a commercially available organozinc reagent; no glove box).** In air, Pd<sub>2</sub>(dba)<sub>3</sub> (9.2 mg, 0.010 mmol) and [HPCyp<sub>3</sub>]BF<sub>4</sub> (13 mg, 0.040 mmol) were added to a Schlenk tube. The air was removed by evacuating/refilling with argon (three times), and then dry NMP (0.8 mL) was added. The reaction mixture was stirred for 3 min at r.t., and then the resulting yellow-green solution was treated with the organozinc bromide (0.5 M in THF; 1.60 mL, 0.80 mmol), NMI (50 µL, 0.60 mmol), and the alkyl halide/tosylate (0.50 mmol). The reaction mixture was stirred in an 80 °C oil bath for 12 h, and then pentane (2 mL) was added. The reaction mixture was passed through a short pad of silica gel (to remove inorganic salts and NMP), the filtrate was concentrated, and the residue was purified by flash chromatography.

**1-Methyleneundecylbenzene [115146-99-1] (Table 5, entry 1).** 1-Phenylvinylzinc bromide (0.5 M in THF; 1.6 mL, 0.80 mmol) and *n*-decyl bromide (111 mg, 0.50 mmol) were used. Solvent for chromatography: pentane. Colorless solid (Procedure A: 114 mg, 93%; Procedure B: 114 mg, 93%).

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz): δ 7.47-7.44 (m, 2H), 7.39-7.35 (m, 2H), 7.33-7.28 (m, 1H), 5.31 (d, *J* = 1.5 Hz, 1H), 5.10 (d, *J* = 1.4 Hz, 1H), 2.55 (t, *J* = 7.6 Hz, 2H), 1.52-1.46 (m, 2H), 1.39-1.30 (m, 14H), 0.93 (t, *J* = 6.7 Hz, 3H).

<sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz): δ 149.2, 141.9, 128.6, 127.7, 126.5, 112.4, 35.8, 32.4, 30.1 (two overlapping resonances), 29.9, 29.8 (two overlapping resonances), 28.7, 23.2, 14.6.

IR (thin film): 2926, 2854, 1628, 1466 cm<sup>-1</sup>.

HRMS (EI): Calcd for C<sub>18</sub>H<sub>28</sub> (M)<sup>+</sup>: 244.2186. Found: 244.2185.

**1-Methyleneundecylbenzene [115146-99-1] (Table 5, entry 7).** 1-Phenylvinylzinc bromide (0.5 M in THF; 1.6 mL, 0.80 mmol) and *n*-decyl iodide (134 mg, 0.50 mmol) were used. Solvent for chromatography: pentane. Colorless solid (Procedure A: 114 mg, 93%; Procedure B: 113 mg, 93%).

**2-(4-Phenyl-4-pentenyl)-1H-isoindole-1,3(2H)-dione (Table 5, entry 8).** 1-Phenylvinylzinc bromide (0.5 M in THF; 1.6 mL, 0.80 mmol) and 2-(3-iodopropyl)-1H-isoindole-1,3(2H)-dione (158 mg, 0.50 mmol) were used in Procedure A; in Procedure B, the iodide was introduced as a solution in NMP (0.8 mL). Solvent for chromatography: pentane/EtOAc 100:7. White solid (Procedure A: 107 mg, 74%; Procedure B: 111 mg, 76%).

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz): δ 7.84-7.82 (m, 2H), 7.74-7.71 (m, 2H), 7.41-7.39 (m, 2H),

7.35-7.31 (m, 2H), 7.30-7.26 (m, 1H), 5.31 (s, 1H), 5.13 (d,  $J = 1.2$  Hz, 1H), 3.76 (t,  $J = 7.2$  Hz, 2H), 2.59 (t,  $J = 7.7$  Hz, 2H), 1.89 (dd,  $J = 7.7, 7.2$  Hz, 2H).

$^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz):  $\delta$  168.8, 147.6, 141.4, 134.3, 132.5, 128.8, 127.9, 126.5, 123.6, 113.2, 38.1, 33.0, 27.5.

IR (KBr pellet): 3083, 3024, 2943, 1699, 1401, 1030  $\text{cm}^{-1}$ .

HRMS (ESI): Calcd for  $\text{C}_{19}\text{H}_{17}\text{NNaO}_2$  ( $\text{M}+\text{Na}$ ) $^+$ : 314.1151. Found: 314.1155.

**4-(2-Phenyl-2-propenyl)cyclohexene (Table 5, entry 9).** 1-Phenylvinylzinc bromide (0.5 M in THF; 1.6 mL, 0.80 mmol) and 3-cyclohexene-1-methanol *p*-toluenesulfonate (133 mg, 0.50 mmol) were used. Solvent for chromatography: pentane. Colorless oil (Procedure A: 56 mg, 58%; Procedure B: 52 mg, 53%).

$^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz):  $\delta$  7.45-7.42 (m, 2H), 7.37-7.33 (m, 2H), 7.31-7.29 (m, 1H), 5.67-5.61 (m, 2H), 5.31 (d,  $J = 1.8$  Hz, 1H), 5.07 (d,  $J = 1.5$  Hz, 1H), 2.55-2.45 (m, 2H), 2.10-1.93 (m, 3H), 1.81-1.65 (m, 3H), 1.31-1.21 (m, 1H).

$^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz):  $\delta$  147.4, 141.7, 128.7, 127.7, 127.4, 126.8, 126.7, 114.1, 43.1, 32.00, 31.99, 29.0, 25.4.

IR (thin film): 3022, 2917, 2837, 1626, 1436  $\text{cm}^{-1}$ .

HRMS (EI): Calcd for  $\text{C}_{15}\text{H}_{18}$  ( $\text{M}$ ) $^+$ : 198.1403. Found: 198.1406.

**6,6-Diethoxy-2-phenyl-1-hexene (Table 5, entry 10).** 1-Phenylvinylzinc bromide (0.5 M in THF; 1.6 mL, 0.80 mmol) and 4-chlorobutyraldehyde diethyl acetal (91 mg, 0.50 mmol) were used. Solvent for chromatography: pentane/EtOAc 100:2. Yellow oil (Procedure A: 91 mg, 73%; Procedure B: 97 mg, 78%).

$^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz):  $\delta$  7.43-7.42 (m, 2H), 7.37-7.33 (m, 2H), 7.31-7.28 (m, 1H), 5.30 (s, 1H), 5.09 (s, 1H), 4.50 (t,  $J = 5.6$  Hz, 1H), 3.64-3.58 (m, 2H), 3.52-3.44 (m, 2H), 2.56 (t,  $J = 7.3$  Hz, 2H), 1.70-1.65 (m, 2H), 1.59-1.52 (m, 2H), 1.20 (t,  $J = 7.1$  Hz, 6H).

$^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz):  $\delta$  148.6, 141.6, 128.7, 127.7, 126.6, 112.9, 103.1, 61.2, 35.4, 33.4, 23.7, 15.7.

IR (thin film): 2975, 2930, 2876, 1444, 1374, 1129, 1063  $\text{cm}^{-1}$ .

HRMS (ESI): Calcd for  $\text{C}_{16}\text{H}_{24}\text{NaO}_2$  ( $\text{M}+\text{Na}$ ) $^+$ : 271.1669. Found: 271.1674.

**Decylbenzene [104-72-3] (Table 5, entry 12).**  $\text{PhZnBr}$  (0.5 M in THF; 1.6 mL, 0.80 mmol) and *n*-decyl iodide (134 mg, 0.50 mmol) were used. Solvent for chromatography: pentane. Colorless oil (Procedure A: 70 mg, 65%; Procedure B: 68 mg, 62%).

$^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz):  $\delta$  7.36-7.32 (m, 2H), 7.26-7.22 (m, 3H), 2.67 (t,  $J = 7.7$  Hz, 2H), 1.68 (q,  $J = 7.7$  Hz, 2H), 1.38-1.30 (m, 14H), 0.96 (t,  $J = 7.1$  Hz, 3H).

$^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz):  $\delta$  143.4, 128.8, 128.7, 126.0, 36.5, 32.4, 32.0, 30.11, 30.09, 30.01, 29.8 (two overlapping resonances), 23.2, 14.6.

Both spectra were identical to those of an authentic sample (Aldrich).

**Procedure C for Table 5 (with PCyp<sub>3</sub> and a Grignard reagent/ZnCl<sub>2</sub>).** In a glove box, anhydrous ZnCl<sub>2</sub> granules (109 mg, 0.80 mmol) and 1.6 mL of a solution of the Grignard reagent (0.5 M in THF; 0.80 mmol) were vigorously stirred for 20 min. To the resulting suspension was added sequentially dry NMP (0.8 mL), PCyp<sub>3</sub> (10  $\mu$ L, 9.6 mg, 0.040 mmol), NMI (50  $\mu$ L, 0.60 mmol), the alkyl halide/tosylate (0.50 mmol), and then Pd<sub>2</sub>(dba)<sub>3</sub> (9.2 mg, 0.010 mmol). The vial was closed with a Teflon-coated screw cap, sealed with electrical tape, and taken out of the glove box. The reaction mixture was stirred in an 80 °C oil bath for 12 h, and then pentane (2 mL) was added. The reaction mixture was passed through a short pad of silica gel (to remove inorganic salts and NMP), the filtrate was concentrated, and the residue was purified by flash chromatography.

**Procedure D for Table 5 (with [HPCyp<sub>3</sub>]BF<sub>4</sub> and a Grignard reagent/ZnCl<sub>2</sub>; no glove box).** In air, Pd<sub>2</sub>(dba)<sub>3</sub> (9.2 mg, 0.010 mmol) and [HPCyp<sub>3</sub>]BF<sub>4</sub> (13 mg, 0.040 mmol) were added to a Schlenk tube. The air was removed by evacuating/refilling with argon (three times), and then a ZnCl<sub>2</sub> solution (0.5 M in THF; 1.6 mL, 0.80 mmol) was added. A solution of the Grignard reagent (0.5 M in THF; 0.80 mmol) was introduced dropwise over 30 seconds, and the resulting mixture was stirred for 1 min. To this brown suspension was added the alkyl halide/tosylate (0.50 mmol), NMI (50  $\mu$ L, 0.60 mmol), and then dry NMP (1.6 mL) (*The addition sequence is important*). The reaction mixture was stirred in an 80 °C oil bath for 12 h, and then pentane (2 mL) was added. The reaction mixture was passed through a short pad of silica gel (to remove inorganic salts and NMP), the filtrate was concentrated, and the residue was purified by flash chromatography.

**7-Methyl-7-octenyl pivalate (Table 5, entry 2).** 1-Methylvinylmagnesium bromide (0.5 M in THF; 1.6 mL, 0.80 mmol) and 6-bromohexyl pivalate (133 mg, 0.50 mmol) were used. Solvent for chromatography: pentane/Et<sub>2</sub>O 100:1. After concentration under reduced pressure, the yellow residue was treated with dry MeOH (2 mL). The resulting mixture was allowed to stand overnight, and then the small amount of phosphine-containing yellow solid was removed by filtration through a short plug of Celite in a Pasteur pipet (MeOH washings). The filtrate was concentrated to give a yellow oil that was pure according to <sup>1</sup>H and <sup>13</sup>C NMR spectroscopy (Procedure C: 77 mg, 68%; Procedure D: 80 mg, 71%).

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz):  $\delta$  4.70 (s, 1H), 4.67 (s, 1H), 4.06 (t, *J* = 6.6 Hz, 2H), 2.01 (t, *J* = 7.3 Hz, 2H), 1.72 (s, 3H), 1.67-1.60 (m, 2H), 1.47-1.32 (m, 6H), 1.21 (s, 9H).

<sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz):  $\delta$  179.0, 146.4, 110.1, 64.8, 39.1, 38.1, 29.2, 29.0, 27.8, 27.6, 26.2, 22.7.

IR (thin film): 2970, 2934, 2859, 1731, 1285, 1156 cm<sup>-1</sup>.

HRMS (ESI): Calcd for  $C_{14}H_{26}NaO_2$  ( $M+Na$ )<sup>+</sup>: 249.1825. Found: 249.1831.

**2-(4-Methyl-4-pentenyl-oxo)-tetrahydro-2H-pyran** (Table 5, entry 3). 1-Methylvinylmagnesium bromide (0.5 M in THF; 1.6 mL, 0.80 mmol) and 2-(3-bromopropoxy)tetrahydro-2H-pyran (112 mg, 0.50 mmol) were used. Solvent for chromatography: pentane/Et<sub>2</sub>O 100:2. Colorless oil (Procedure C: 70 mg, 76%; Procedure D: 71 mg, 77%).

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz):  $\delta$  4.72 (s, 1H), 4.70 (s, 1H), 4.59 (t,  $J$  = 4.2 Hz, 1H), 3.91-3.85 (m, 1H), 3.78-3.72 (m, 1H), 3.54-3.48 (m, 1H), 3.43-3.37 (m, 1H), 2.14-2.04 (m, 2H), 1.88-1.80 (m, 1H), 1.79-1.69 (m, 6H), 1.62-1.51 (m, 4H).

<sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz):  $\delta$  145.8, 110.3, 99.3, 67.6, 62.7, 34.7, 31.1, 28.1, 25.9, 22.8, 20.1.

IR (thin film): 2942, 2871, 1651, 1442, 1034 cm<sup>-1</sup>.

HRMS (ESI): Calcd for  $C_{11}H_{20}NaO_2$  ( $M+Na$ )<sup>+</sup>: 207.1356. Found: 207.1356.

**Benzyl 5-methyl-4-hexenyl ether** [131721-93-2] (Table 5, entry 4). 2-Methyl-1-propenylmagnesium bromide (0.5 M in THF; 1.6 mL, 0.80 mmol) and benzyl 3-bromopropyl ether (116 mg, 0.50 mmol) were used. The reaction mixture was passed through a short silica-gel column with pentane/Et<sub>2</sub>O 100:2. The yellow fractions were combined and concentrated under partial vacuum to give a yellow oil, which was treated with dry MeOH (2 mL). The resulting mixture was allowed to stand overnight, and then the small amount of phosphine-containing yellow solid was removed by filtration through a short plug of Celite in a Pasteur pipet (MeOH washings). The filtrate was concentrated, and the residue was purified by flash chromatography (pentane/Et<sub>2</sub>O 100:1). Yellow oil (Procedure C: 84 mg, 83%; Procedure D: 76 mg, 75%).

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz):  $\delta$  7.38-7.28 (m, 5H), 5.14 (t,  $J$  = 7.2 Hz, 1H), 4.53 (s, 2H), 3.50 (d,  $J$  = 6.6 Hz, 2H), 2.10 (m, 2H), 1.72-1.59 (m, 8H).

<sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz):  $\delta$  139.1, 132.3, 128.8, 128.0, 127.9, 124.4, 73.3, 70.4, 30.3, 26.1, 25.0, 18.1.

IR (thin film): 2965, 2927, 2855, 1453, 1102 cm<sup>-1</sup>.

HRMS (ESI): Calcd for  $C_{14}H_{20}NaO$  ( $M+Na$ )<sup>+</sup>: 227.1406. Found: 227.1407.

***N,N*-Diethyl 8-methyl-8-nonenamide** (Table 5, entry 5). 2-Methyl-1-propenylmagnesium bromide (0.5 M in THF; 1.6 mL, 0.80 mmol) and *N,N*-diethyl 6-bromohexanamide (123 mg, 0.50 mmol) were used. Solvent for chromatography: pentane/EtOAc 6:1. Colorless oil (Procedure C: 91 mg, 81%; Procedure D: 81 mg, 72%).

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz):  $\delta$  5.11 (t,  $J$  = 7.1 Hz, 1H), 3.37 (q,  $J$  = 7.1 Hz, 2H), 3.30 (q,  $J$  = 7.1 Hz, 2H), 2.28 (t,  $J$  = 7.5 Hz, 2H), 1.97 (d,  $J$  = 6.6 Hz, 2H), 1.68-1.61 (m, 5H), 1.59 (s, 3H), 1.34 (t,  $J$  = 3.5 Hz, 4H), 1.17 (t,  $J$  = 7.1 Hz, 3H), 1.11 (t,  $J$  = 7.1 Hz, 3H).

$^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz):  $\delta$  172.7, 131.7, 125.1, 42.3, 40.4, 33.6, 30.1, 29.6, 28.3, 26.1, 25.9, 18.1, 14.8, 13.5.

IR (thin film): 2932, 1644, 1430  $\text{cm}^{-1}$ .

HRMS (ESI): Calcd for  $\text{C}_{14}\text{H}_{27}\text{NNaO}$  ( $\text{M}+\text{Na}$ ) $^{+}$ : 248.1985. Found: 248.1986.

**2-Methyl-1-dodecene [16435-49-7] (Table 5, entry 6).** 1-Methylvinylmagnesium bromide (0.5 M in THF; 1.6 mL, 0.8 mmol) and *n*-decyl iodide (134 mg, 0.50 mmol) were used. Solvent for chromatography: pentane. Colorless oil (Procedure C: 82 mg, 98%; Procedure D: 78 mg, 93%).

$^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz):  $\delta$  4.71 (s, 1H), 4.69 (s, 1H), 2.03 (t,  $J$  = 7.4 Hz, 2H), 1.74 (s, 3H), 1.48-1.40 (m, 2H), 1.30 (br s, 14H), 0.91 (t,  $J$  = 7.0 Hz, 3H).

$^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz):  $\delta$  146.8, 109.9, 38.3, 32.3, 30.05 (two overlapping resonances), 29.98, 29.8 (two overlapping resonances), 28.1, 23.1, 22.8, 14.5.

**Ethyl 6-(4-methoxyphenyl)hexanoate [59339-35-4] (Table 5, entry 11).** *p*-Methoxyphenylmagnesium bromide (0.5 M in THF; 1.6 mL, 0.80 mmol) and ethyl 6-bromohexanoate (112 mg, 0.50 mmol) were used. Solvent for chromatography: pentane/EtOAc 100:3. Colorless oil (Procedure C: 92 mg, 74%; Procedure D: 86 mg, 69%).

$^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz):  $\delta$  7.13-7.10 (m, 2H), 6.87-6.83 (m, 2H), 4.14 (q,  $J$  = 7.2 Hz, 2H), 3.81 (s, 3H), 2.58 (t,  $J$  = 7.6 Hz, 2H), 2.31 (t,  $J$  = 7.6 Hz, 2H), 1.71-1.69 (m, 4H), 1.41-1.36 (m, 2H), 1.27 (t,  $J$  = 7.2 Hz, 3H).

$^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz):  $\delta$  174.2, 158.1, 135.0, 129.7, 114.1, 60.6, 55.7, 35.2, 34.7, 31.8, 29.1, 25.3, 14.7.

IR (thin film): 2934, 2857, 1733, 1513, 1246  $\text{cm}^{-1}$ .

HRMS (ESI): Calcd for  $\text{C}_{15}\text{H}_{22}\text{NaO}_3$  ( $\text{M}+\text{Na}$ ) $^{+}$ : 273.1461. Found: 273.1464.

**Procedure E (Table 6).** Anhydrous  $\text{ZnBr}_2$  (180 mg, 0.80 mmol) and LiH (15 mg, 18 mmol) were added to a Schlenk tube in a glove box. The flask was removed from the glove box and placed under an argon atmosphere. THF (1 mL) was added, and the resulting gray suspension was vigorously stirred at r.t. for 3 h. The flask was then chilled to  $-78\text{ }^{\circ}\text{C}$ , and the alkyne (freshly purged with argon, 0.80 mmol) and  $\text{Cp}_2\text{TiCl}_2$  (20 mg, 0.080 mmol) were added. The reaction mixture was allowed to warm to r.t. over 1 h, during which time the stirred suspension turned from orange to yellow to brown/black. The reaction mixture was vigorously stirred for 2 additional hours, and then the flask was taken into a glove box, and the dark suspension was passed through an Acrodisc (CR PTFE 0.45  $\mu\text{m}$  membrane) with the aid of THF (0.6 mL). The resulting dark filtrate was treated with dry NMP (0.8 mL),  $\text{PCyp}_3$  (9.6 mg, 0.040 mmol) or  $[\text{HPCyp}_3]\text{BF}_4$  (13 mg, 0.040 mmol), NMI (50  $\mu\text{L}$ , 0.60 mmol), the alkyl halide/tosylate (0.50 mmol), and then

$\text{Pd}_2(\text{dba})_3$  (9.2 mg, 0.010 mmol). The vessel was sealed, removed from the glove box, and heated in an 80 °C oil bath with stirring for 12 h. Pentane (2 mL) was then added, and the dark reaction mixture was passed through a short pad of silica gel (to remove inorganic salts and NMP), the filtrate was concentrated, and the residue was purified by flash chromatography.

**(E)-4-Methyl-4-hexenylbenzene (Table 6, entry 1).** 2-Butyne (43 mg, 0.80 mmol) and 1-bromo-3-phenylpropane (102 mg, 0.50 mmol) were used. Solvent for chromatography: pentane. Colorless oil (PCyp<sub>3</sub>: 55 mg, 63%; [HPCyp<sub>3</sub>]BF<sub>4</sub>: 42 mg, 48%).

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz):  $\delta$  7.35-7.32 (m, 2H), 7.25-7.21 (m, 3H), 5.31-5.26 (qd,  $J$  = 6.6, 1.2 Hz, 1H), 2.63 (t,  $J$  = 7.7 Hz, 2H), 2.09 (t,  $J$  = 7.8 Hz, 2H), 1.82-1.74 (m, 2H), 1.66-1.63 (m, 6H).

<sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz):  $\delta$  143.2, 136.0, 128.9, 128.7, 126.0, 119.0, 39.7, 36.0, 30.2, 16.0, 13.8.

IR (thin film): 2934, 2859, 1496, 1453 cm<sup>-1</sup>.

HRMS (EI): Calcd for C<sub>13</sub>H<sub>18</sub> (M)<sup>+</sup>: 174.1403. Found: 174.1399.

**(E)-4-Methyl-4-hexenyl phenyl ether (Table 6, entry 2).** 2-Butyne (43 mg, 0.80 mmol) and 3-bromopropyl phenyl ether (113 mg, 0.50 mmol) were used. The crude mixture was passed through a short silica-gel column (pentane/Et<sub>2</sub>O 100:2). The yellow fractions were combined and concentrated under partial vacuum to give a yellow oil, which was treated with dry MeOH (2 mL). The resulting mixture was allowed to stand overnight, and then the small amount of phosphine-containing yellow solid was removed by filtration through a short plug of Celite in a Pasteur pipet (MeOH washings). The filtrate was concentrated, and the residue was purified by flash chromatography (pentane/Et<sub>2</sub>O 200:1). Yellow oil (PCyp<sub>3</sub>: 50 mg, 53%; [HPCyp<sub>3</sub>]BF<sub>4</sub>: 49 mg, 51%).

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz):  $\delta$  7.33-7.29 (m, 2H), 6.98-6.92 (m, 3H), 5.28 (qd,  $J$  = 6.7, 1.3 Hz, 1H), 3.96 (t,  $J$  = 6.6 Hz, 2H), 2.18 (t,  $J$  = 6.6 Hz, 2H), 1.95-1.88 (m, 2H), 1.66 (s, 3H), 1.61 (dd,  $J$  = 6.7, 1.0 Hz, 3H).

<sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz):  $\delta$  159.5, 135.2, 129.8, 120.9, 119.4, 114.9, 67.8, 36.3, 27.9, 16.0, 13.8.

IR (thin film): 2921, 1601, 1498, 1246 cm<sup>-1</sup>.

HRMS (EI): Calcd for C<sub>13</sub>H<sub>18</sub>O (M)<sup>+</sup>: 190.1352. Found: 190.1355.

**(Z)-5-Cyclohexyl-3-phenyl-2-pentene (Table 6, entry 3).** 1-Phenyl-1-propyne (93 mg, 0.80 mmol) and 1-bromo-2-cyclohexylethane (98 mg, 0.50 mmol) were used. Solvent for chromatography: pentane. Colorless oil (PCyp<sub>3</sub>: 70 mg, 61%, regioselectivity 94:6; [HPCyp<sub>3</sub>]BF<sub>4</sub>: 72 mg, 63%, regioselectivity 94:6).

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz):  $\delta$  7.39-7.35 (m, 2H), 7.29-7.25 (m, 1H), 7.20-7.18 (m, 2H),



5.57 (q,  $J = 6.8$  Hz, 1H), 2.38 (t,  $J = 7.0$  Hz, 2H), 1.72-1.65 (m, 5H), 1.59 (d,  $J = 6.8$  Hz, 3H), 1.25-1.19 (m, 6H), 0.91-0.83 (m, 2H).

$^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz):  $\delta$  142.7, 141.7, 128.9, 128.4, 126.6, 121.0, 37.8, 37.0, 36.5, 33.7, 27.2, 26.8, 15.1.

IR (thin film): 2922, 2851, 1494, 1448  $\text{cm}^{-1}$ .

HRMS (EI): Calcd for  $\text{C}_{17}\text{H}_{24}$  ( $\text{M}^+$ ): 228.1873. Found: 228.1882.

**2-[(*E*)-4-Methyl-4-hexenyl]-1*H*-isoindole-1,3(2*H*)-dione (Table 6, entry 4).** 2-Butyne (43 mg, 0.80 mmol) and 2-(3-iodopropyl)-1*H*-isoindole-1,3(2*H*)-dione (158 mg, 0.50 mmol) were used. Solvent for chromatography: pentane/EtOAc 100:4. Yellow solid (PCyp<sub>3</sub>: 84 mg, 69%; [HPCyp<sub>3</sub>]BF<sub>4</sub>: 87 mg, 72%).

$^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz):  $\delta$  7.90-7.85 (m, 2H), 7.77-7.72 (m, 2H), 5.27 (qd,  $J = 6.7$ , 1.2 Hz, 1H), 3.69 (t,  $J = 7.4$  Hz, 2H), 2.09 (t,  $J = 7.6$  Hz, 2H), 1.82 (dd,  $J = 7.6$ , 7.4 Hz, 2H), 1.64 (s, 3H), 1.58 (dd,  $J = 6.7$ , 0.9 Hz, 3H).

$^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz):  $\delta$  168.9, 134.8, 134.3, 132.6, 123.6, 119.6, 38.3, 37.3, 27.0, 15.9, 13.8.

IR (KBr pellet): 2940, 2880, 1702, 1356, 1040  $\text{cm}^{-1}$ .

HRMS (ESI): Calcd for  $\text{C}_{15}\text{H}_{17}\text{NNaO}_2$  ( $\text{M}+\text{Na}^+$ ): 266.1151. Found: 266.1156.

**(*Z*)-12-Phenyl-1,12-tetradecadiene (Table 6, entry 5).** 1-Phenyl-1-propyne (93 mg, 0.80 mmol) and 10-undecen-1-ol *p*-toluenesulfonate (155 mg, 0.50 mmol) were used. Solvent for chromatography: pentane. Colorless oil (PCyp<sub>3</sub>: 80 mg, 59%, regioselectivity 95:5; [HPCyp<sub>3</sub>]BF<sub>4</sub>: 84 mg, 62%, regioselectivity 94:6).

$^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz):  $\delta$  7.39-7.35 (m, 2H), 7.29-7.25 (m, 1H), 7.20-7.18 (m, 2H), 5.90-5.80 (m, 1H), 5.56 (q,  $J = 6.9$  Hz, 1H), 5.05-4.95 (m, 2H), 2.36 (t,  $J = 7.0$  Hz, 2H), 2.24 (m, 2H), 1.59 (d,  $J = 6.8$  Hz, 3H), 1.42-1.27 (m, 14H).

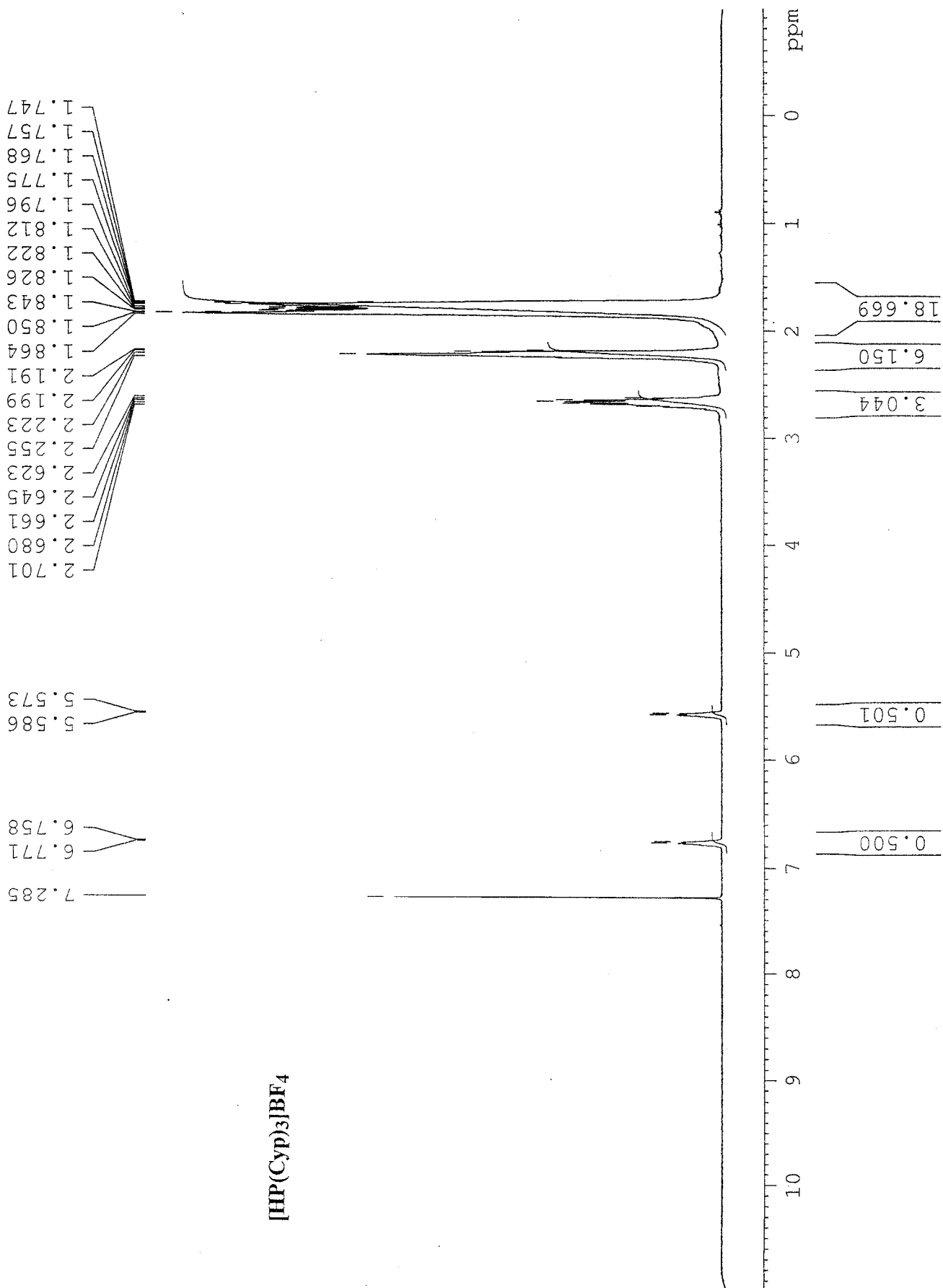
$^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz):  $\delta$  142.4, 141.6, 139.7, 128.9, 128.4, 126.7, 121.3, 114.5, 39.6, 34.3, 30.0, 29.90, 29.86, 29.63, 29.56, 29.4, 28.6, 15.1.

IR (thin film): 2926, 2855, 1641, 1441  $\text{cm}^{-1}$ .

HRMS (EI): Calcd for  $\text{C}_{20}\text{H}_{30}$  ( $\text{M}^+$ ): 270.2342. Found: 270.2355.

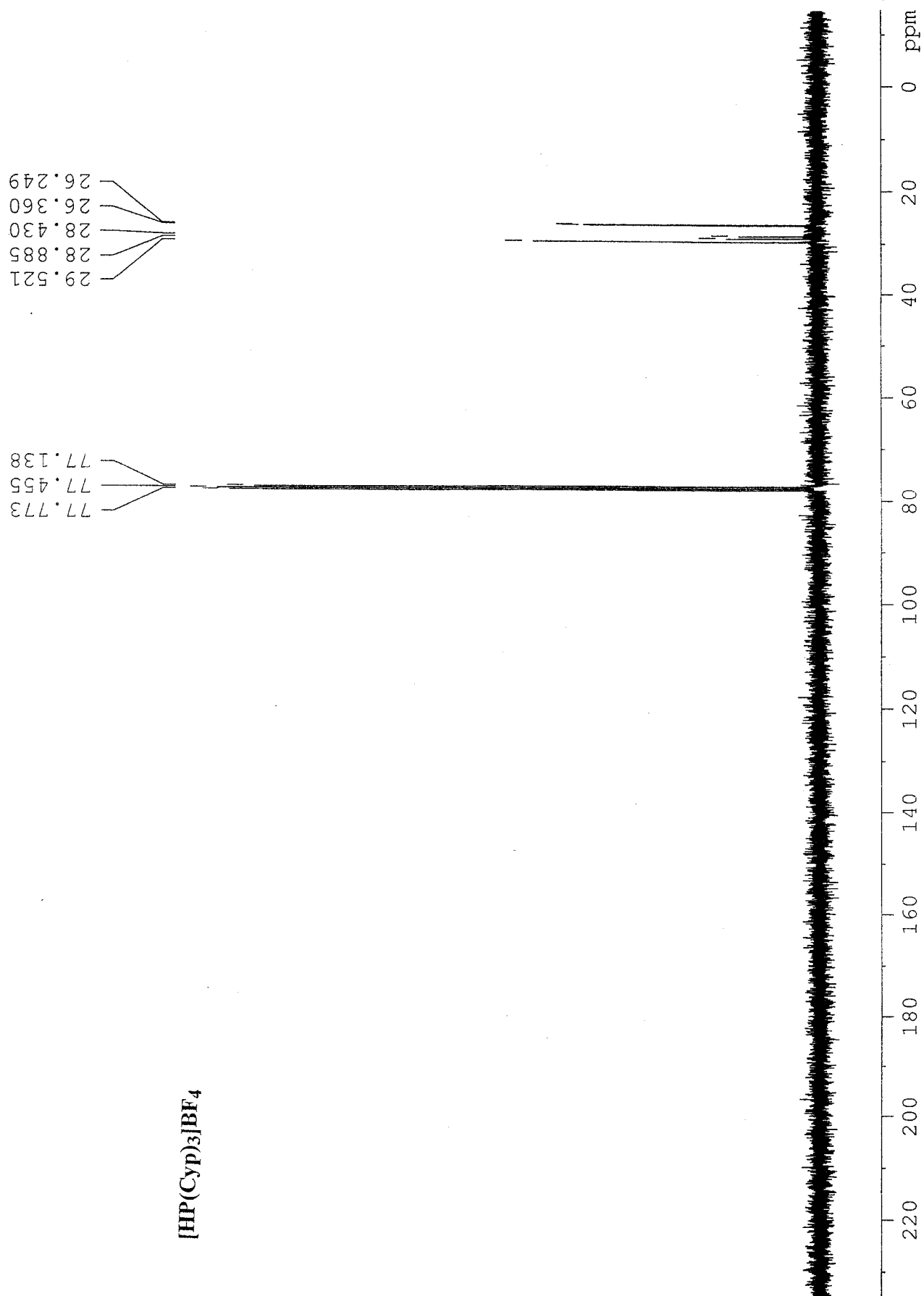
## References

- (1) Kirchhoff, J. H.; Netherton, M. R.; Hills, I. D.; Fu, G. C. *J. Am. Chem. Soc.* **2002**, *124*, 13662-13663.
- (2) Yeh, M. C. P.; Chen, H. G.; Knochel, P. *Org. Synth.* **1992**, *70*, 195-203.
- (3) Zürn, L. *Justus Liebigs Ann. Chem.* **1960**, *631*, 56-60.
- (4) Jansen, A.; Pitter, S. *Monatsh. Chem.* **1999**, *130*, 783-794.
- (5) Netherton, M. R.; Fu, G. C. *Org. Lett.* **2001**, *3*, 4295-4298.

$[\text{HP}(\text{Cyp})_3]\text{BF}_4$ 

3203

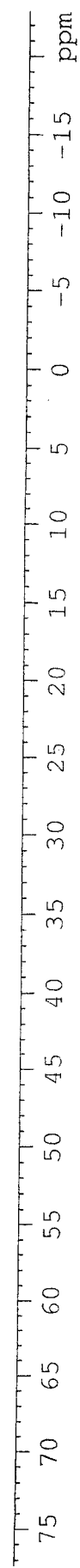
[HP(Cyp)<sub>3</sub>]BF<sub>4</sub>

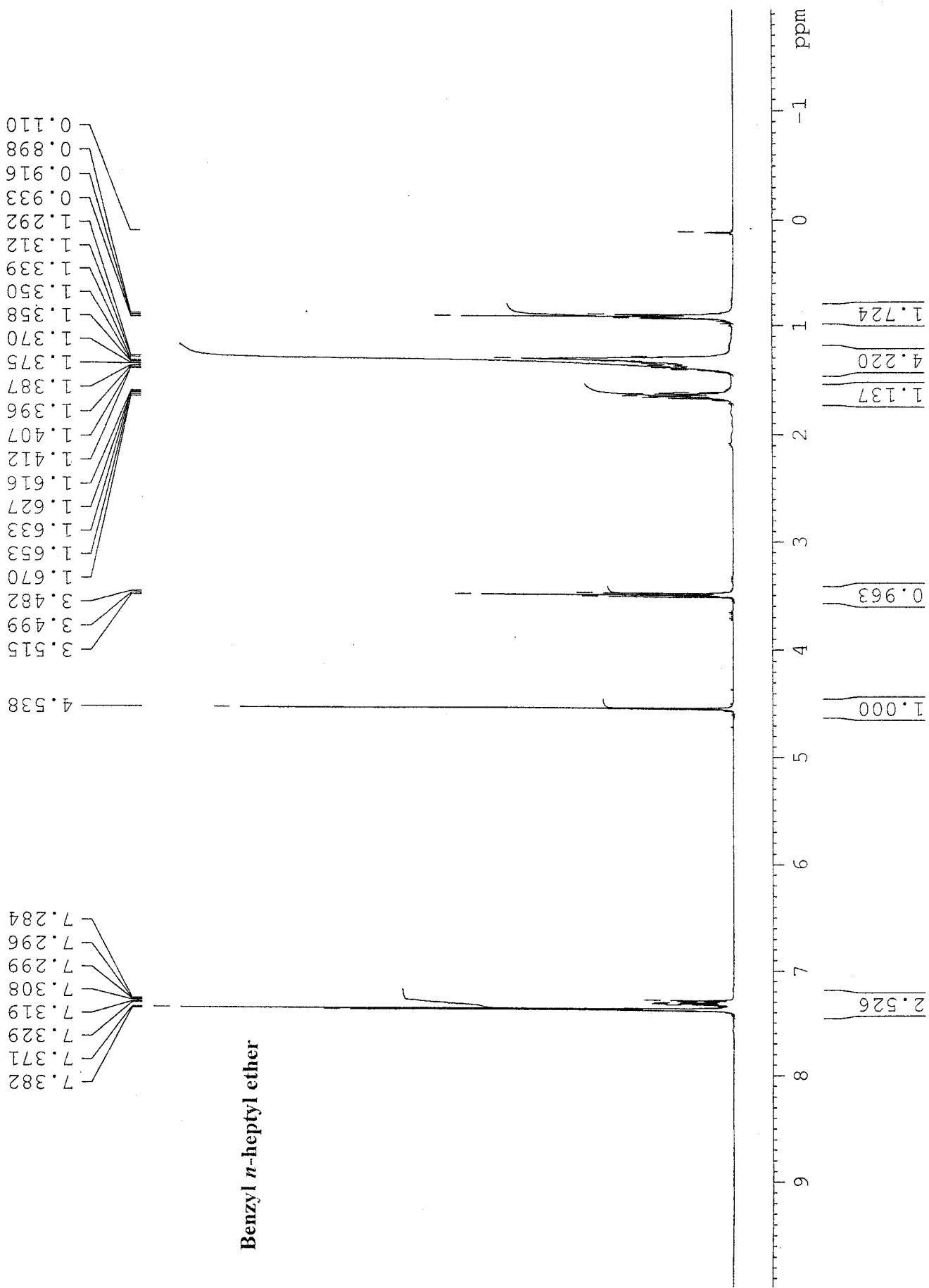


3203

$[\text{HP}(\text{Cyp})_3]\text{BF}_4$

32.022





3035c

Table 3, entry 1

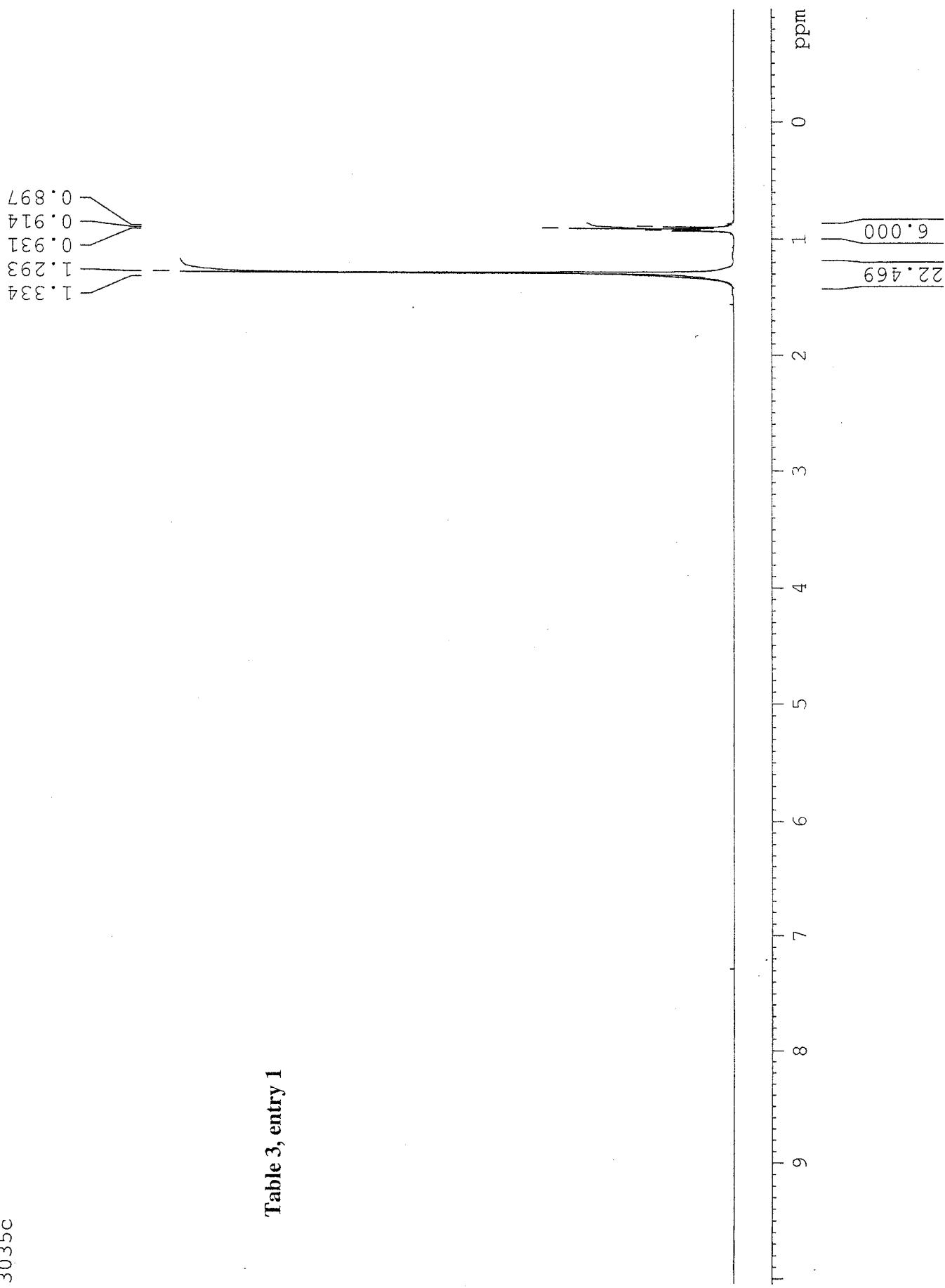
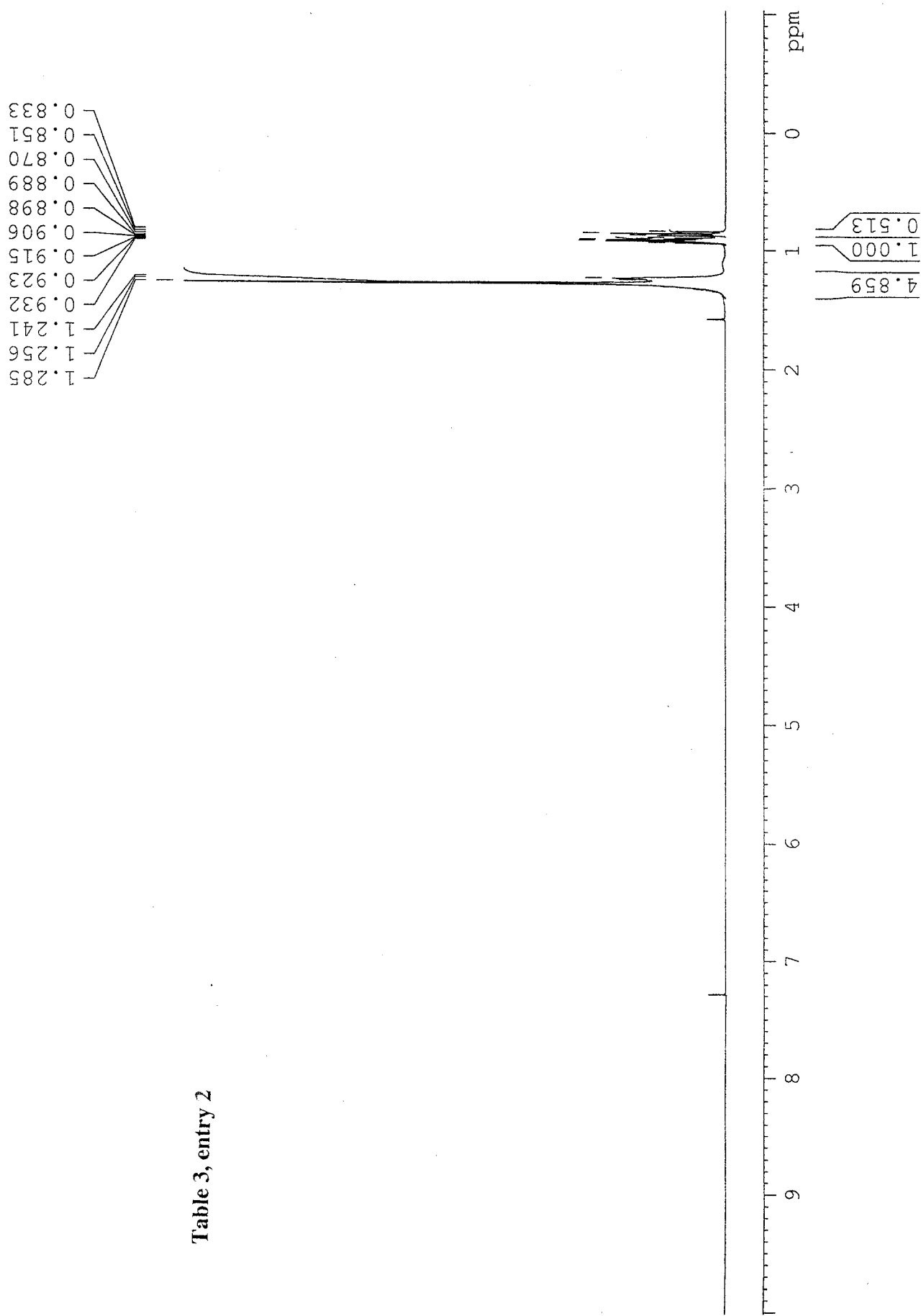


Table 3, entry 2





3071c

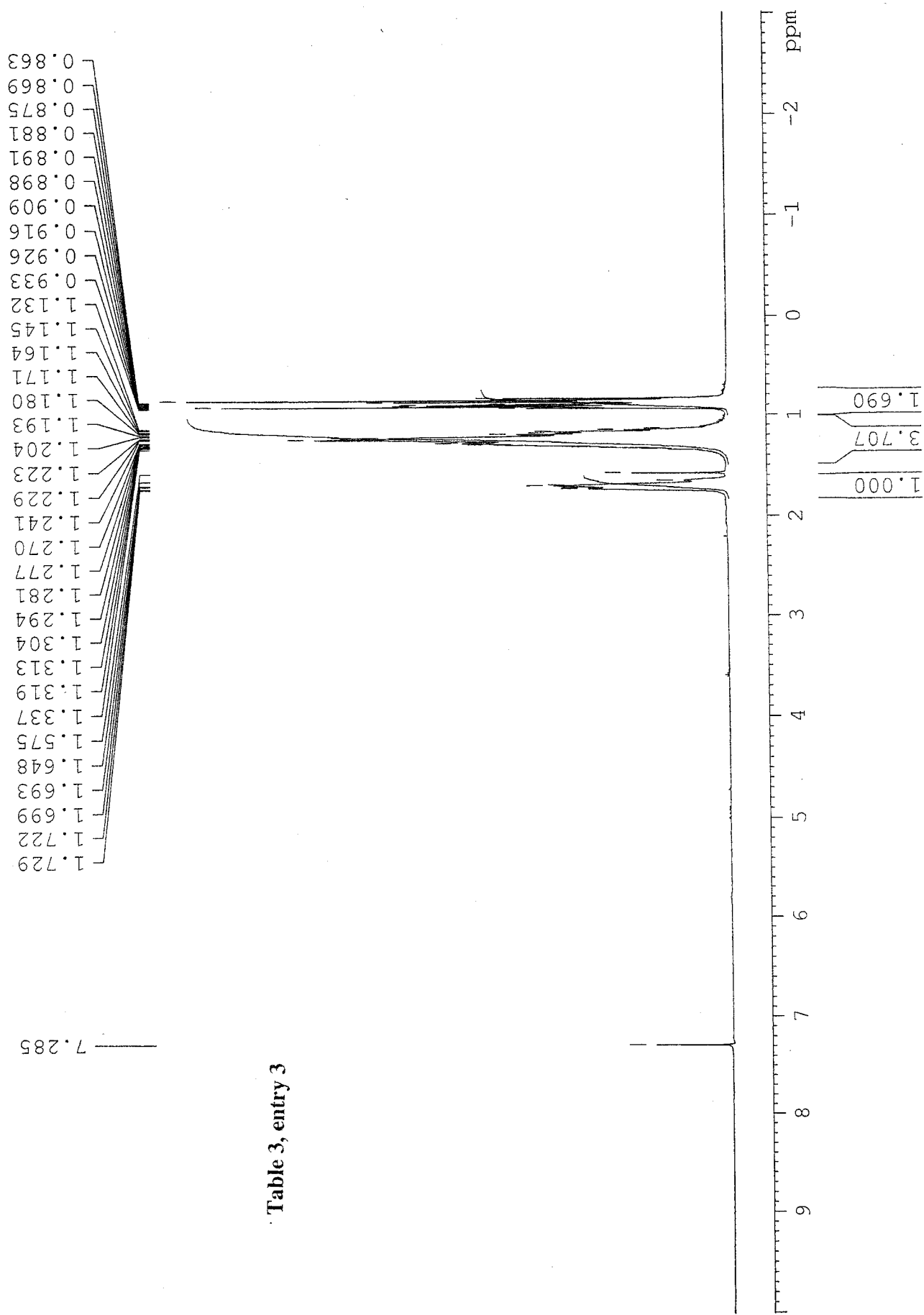
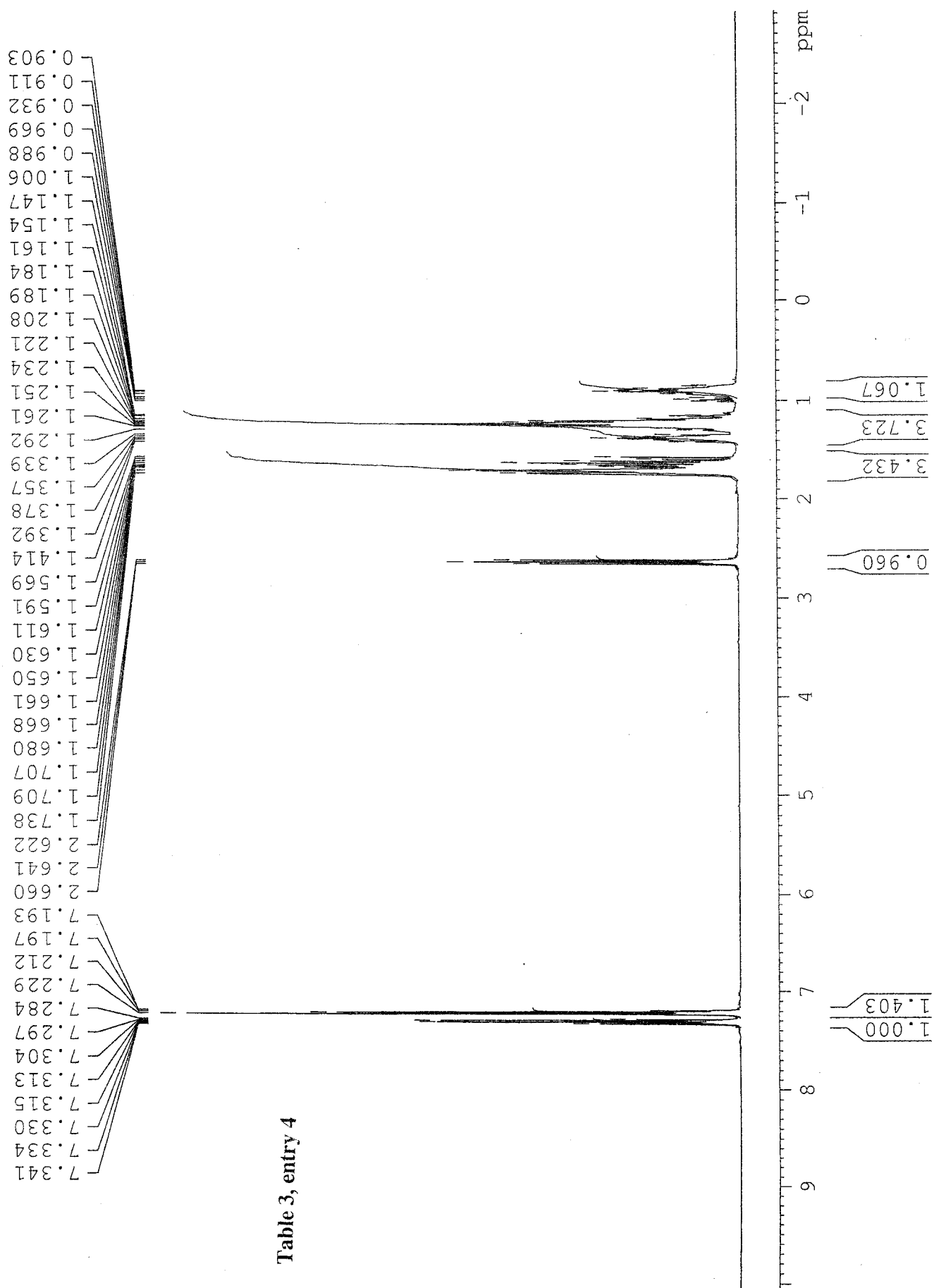
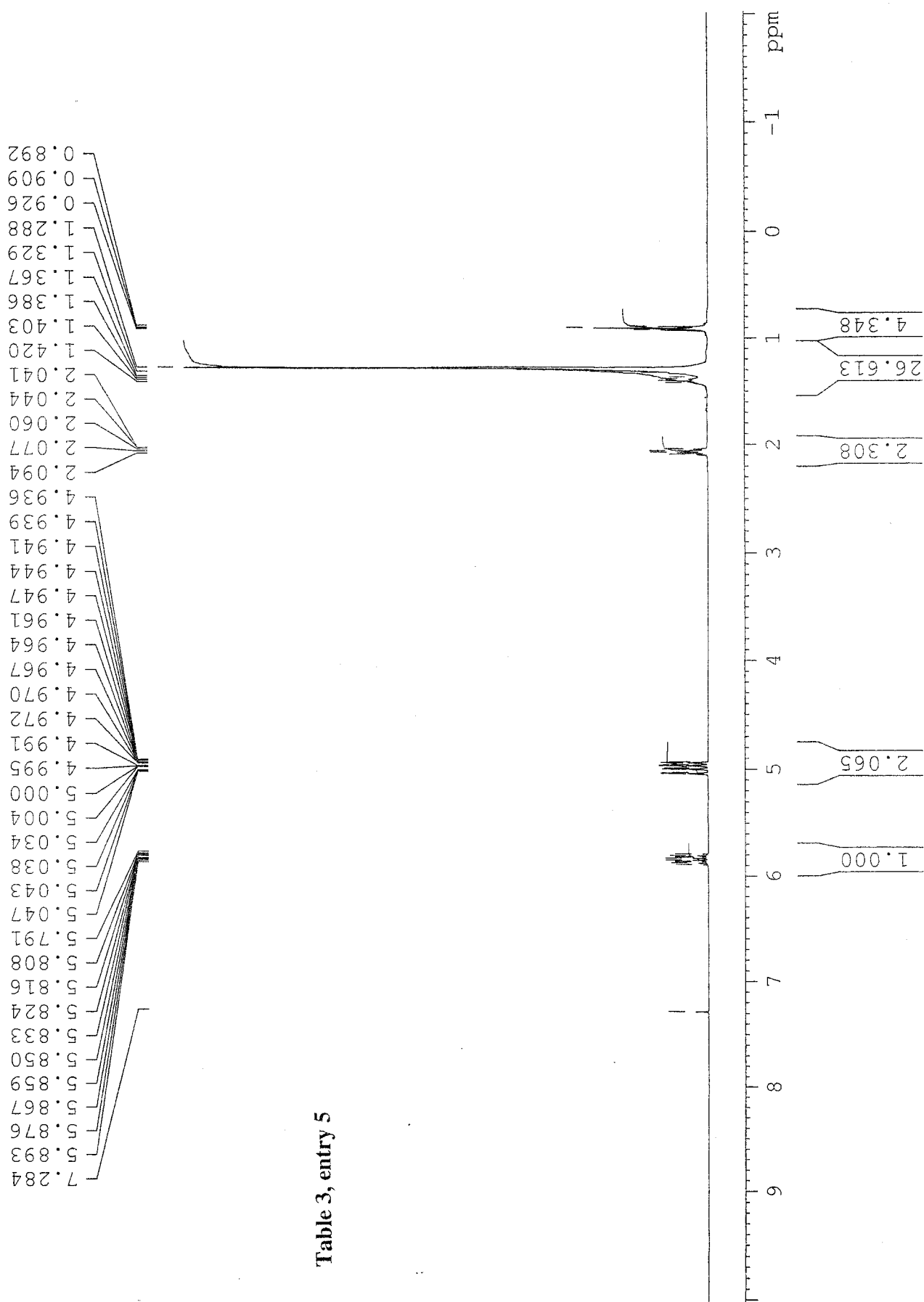


Table 3, entry 3

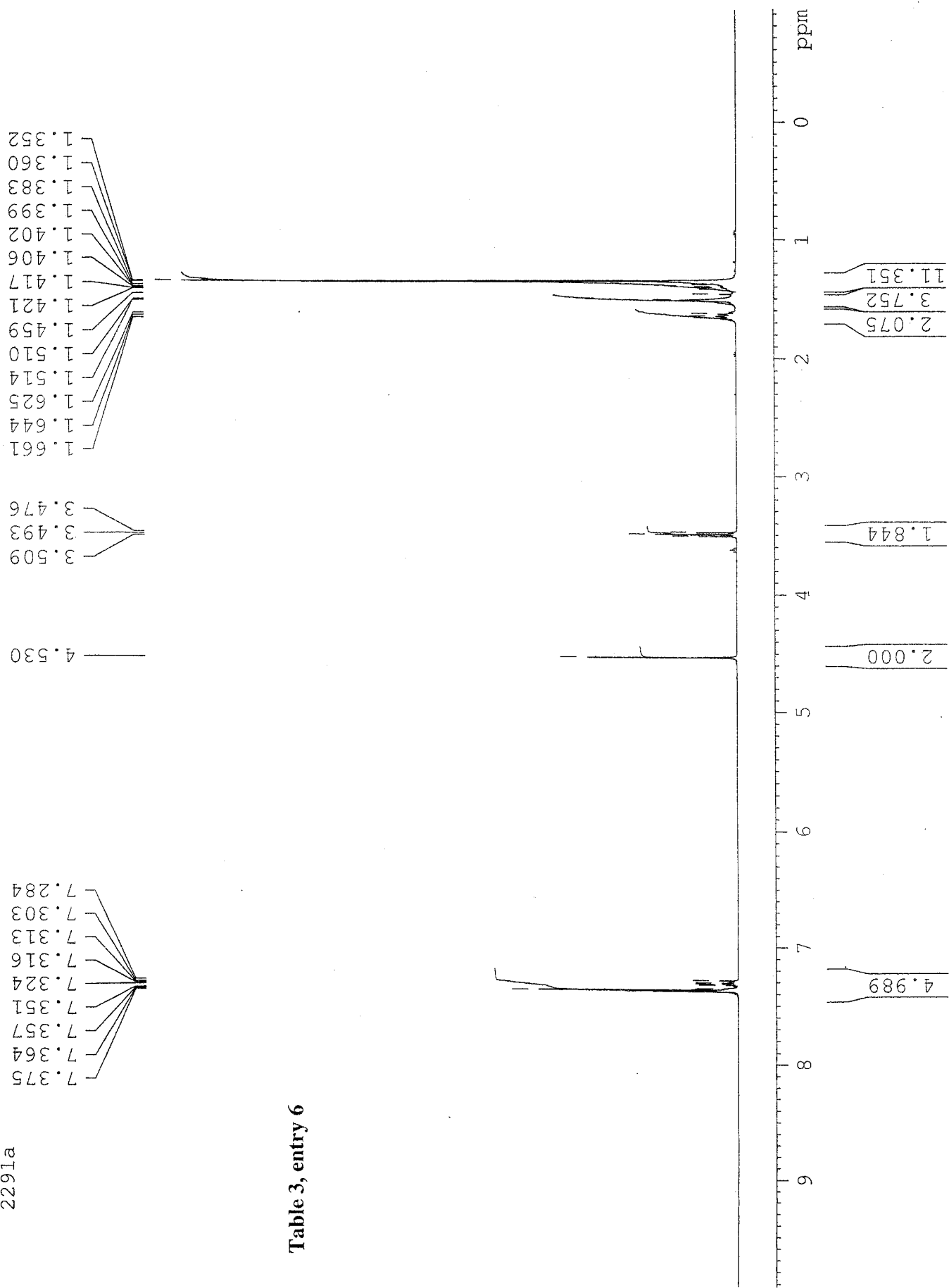
Table 3, entry 4





2291a

Table 3, entry 6



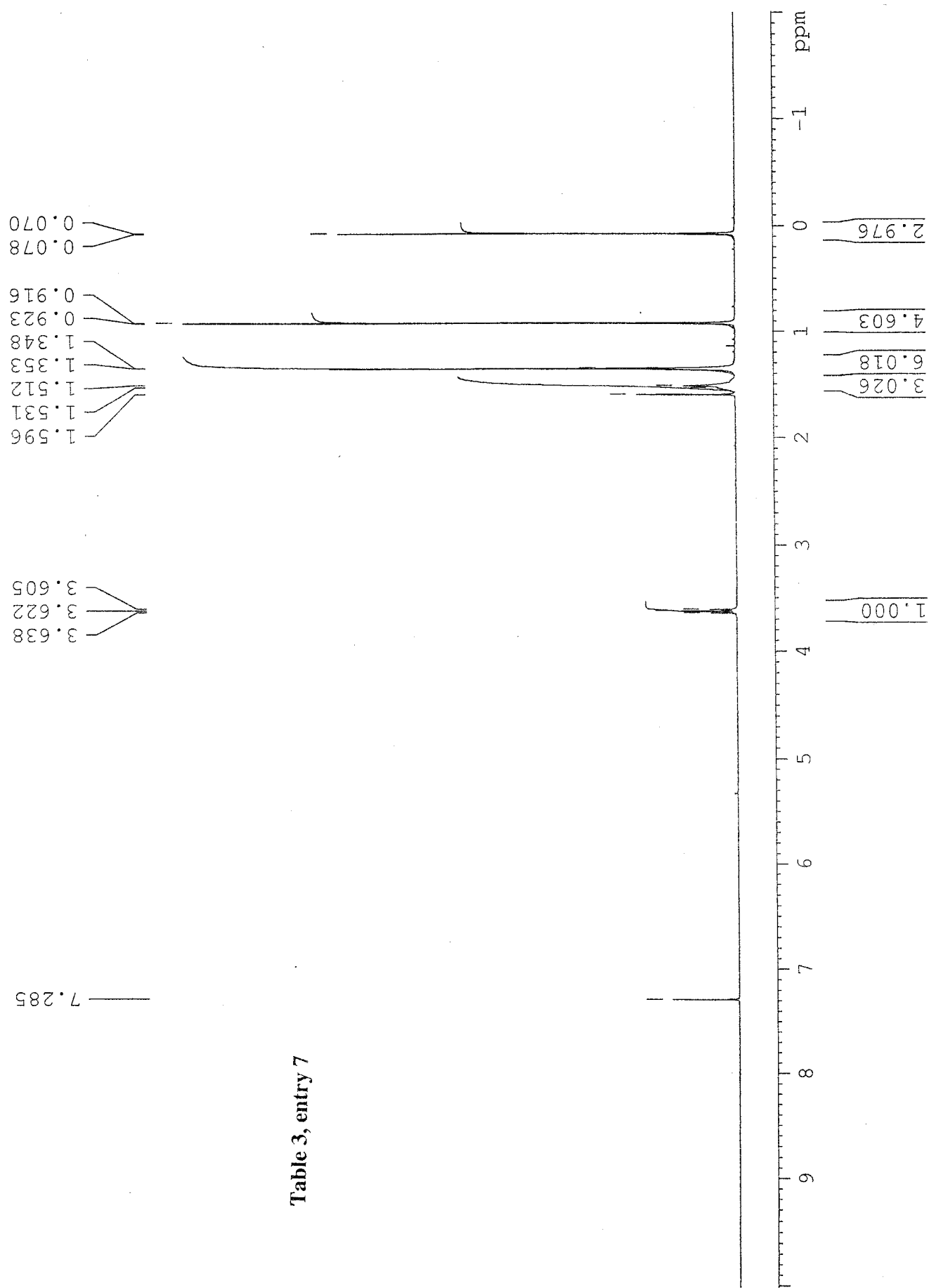


Table 3, entry 7

3063g

Table 3, entry 8

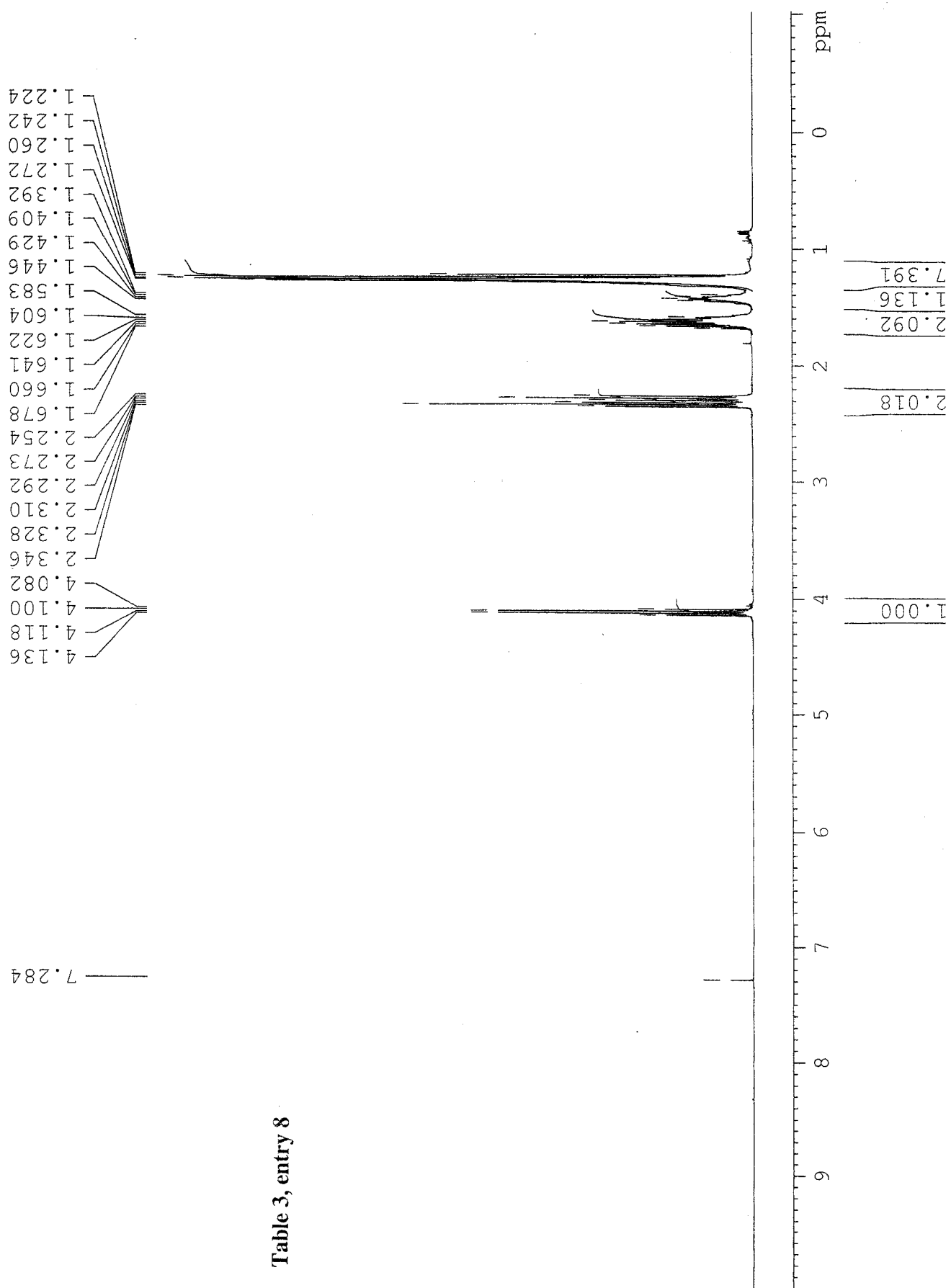
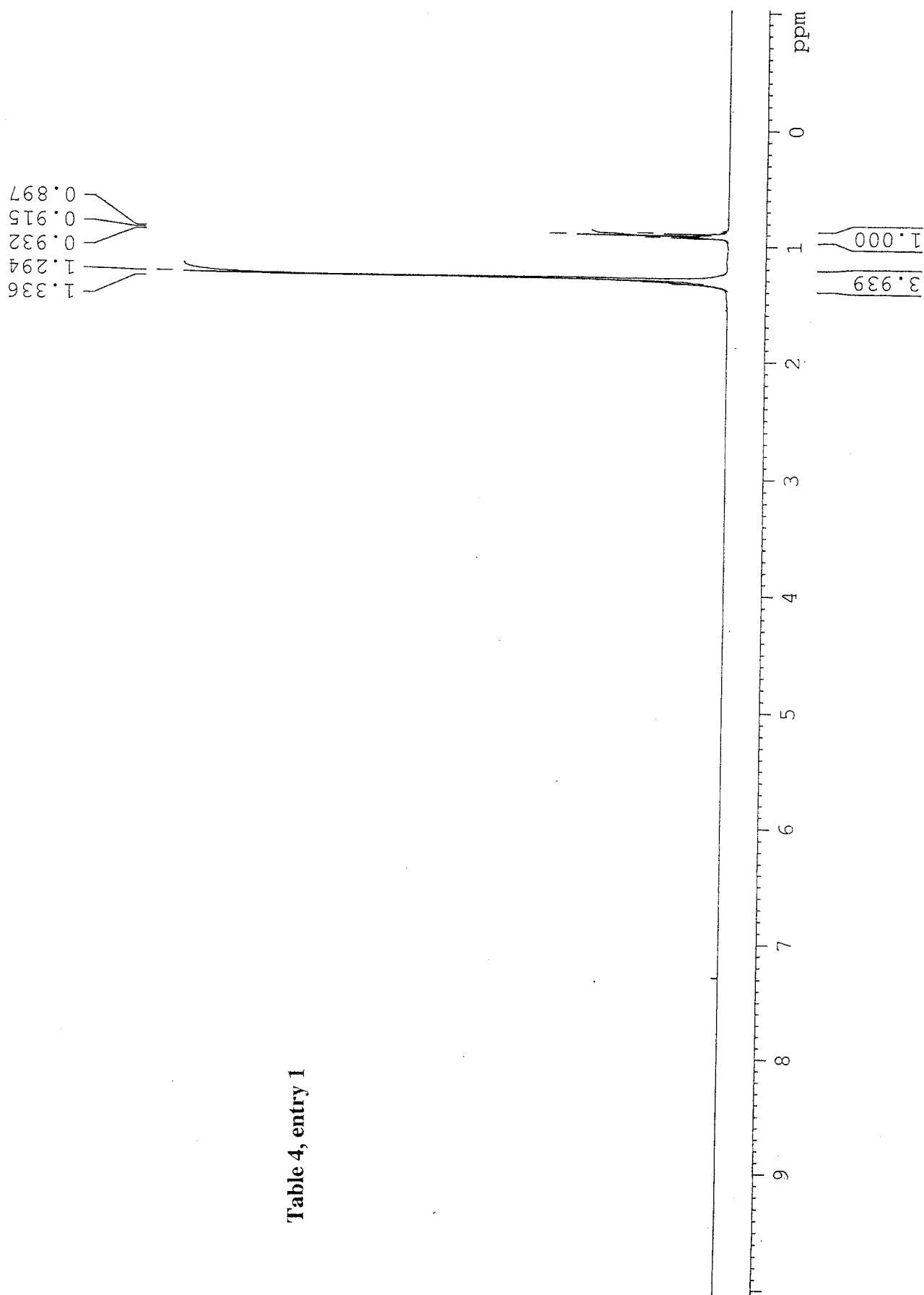


Table 4, entry 1

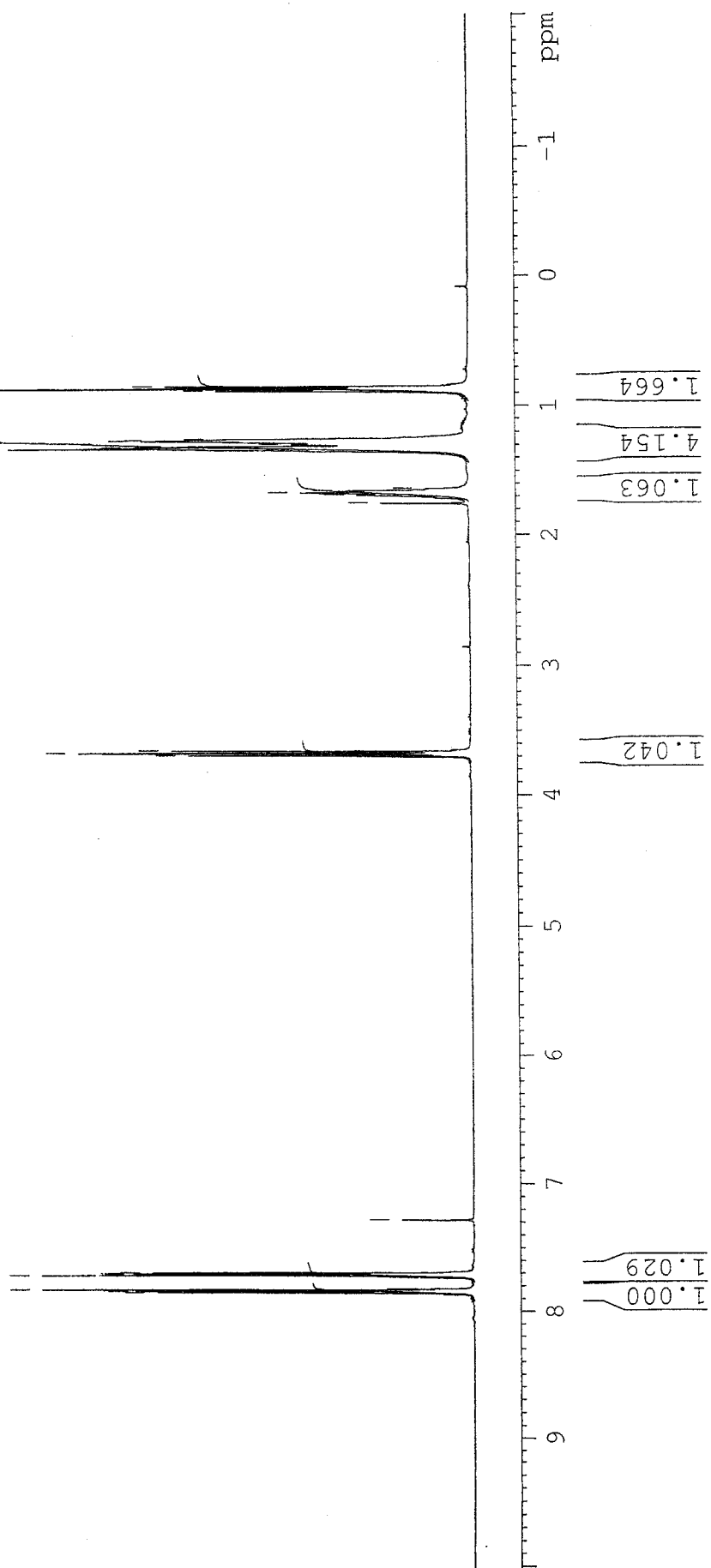


3039d

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7.717  
7.711  
7.704  
7.284

3.699  
3.681  
3.663  
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1.692  
1.675  
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1.638  
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1.333  
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Table 4, entry 2





3035d

Table 4, entry 3

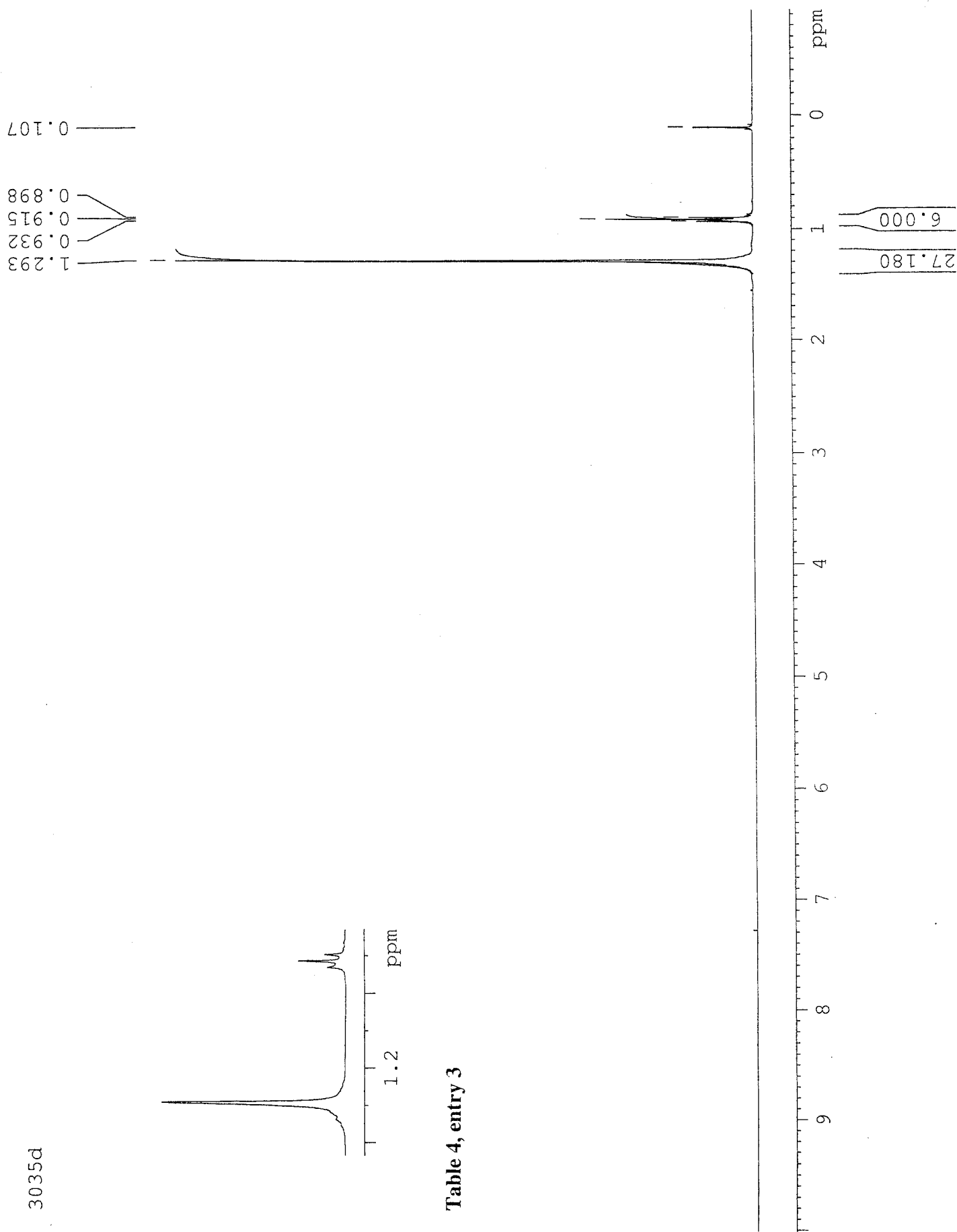


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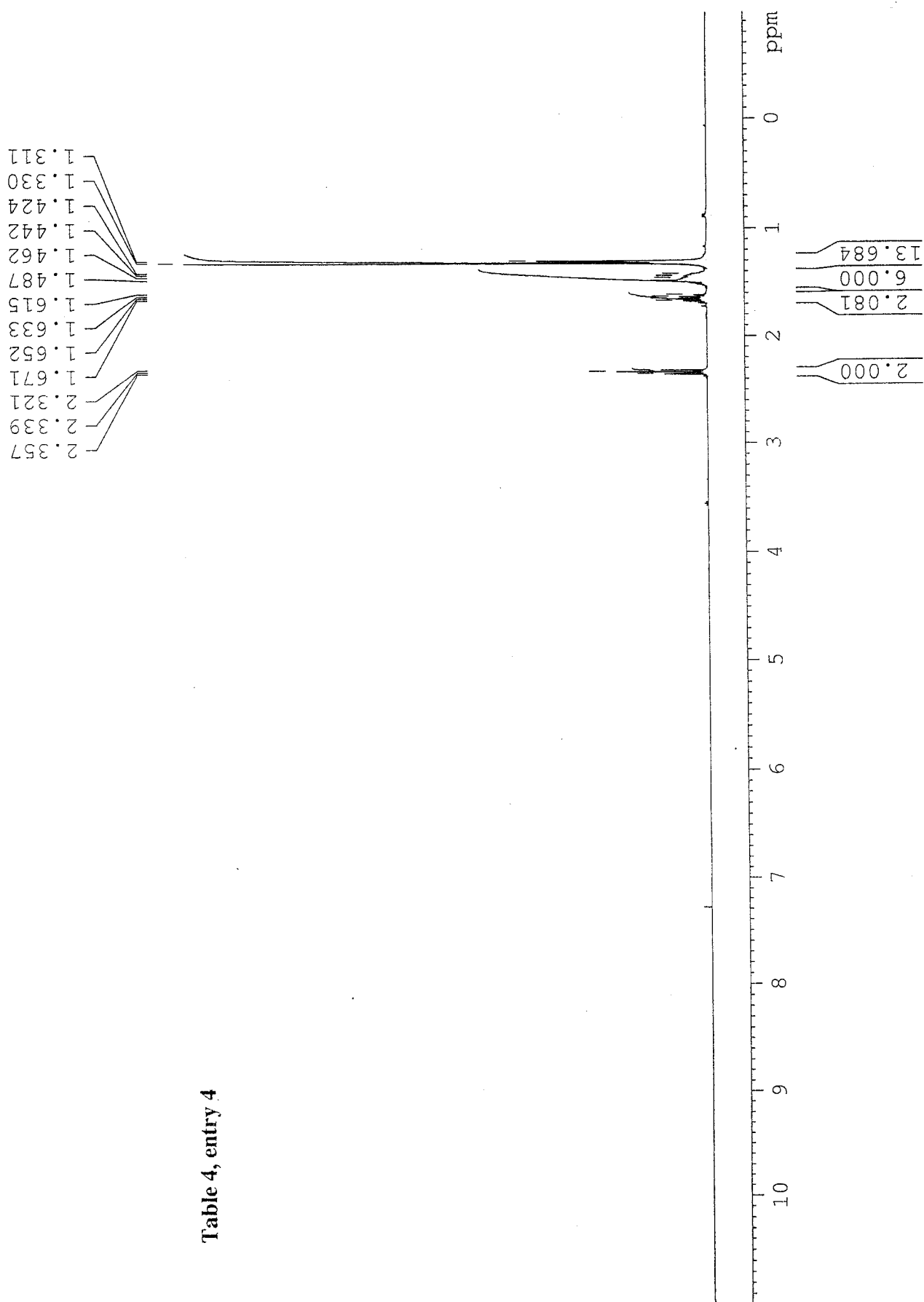
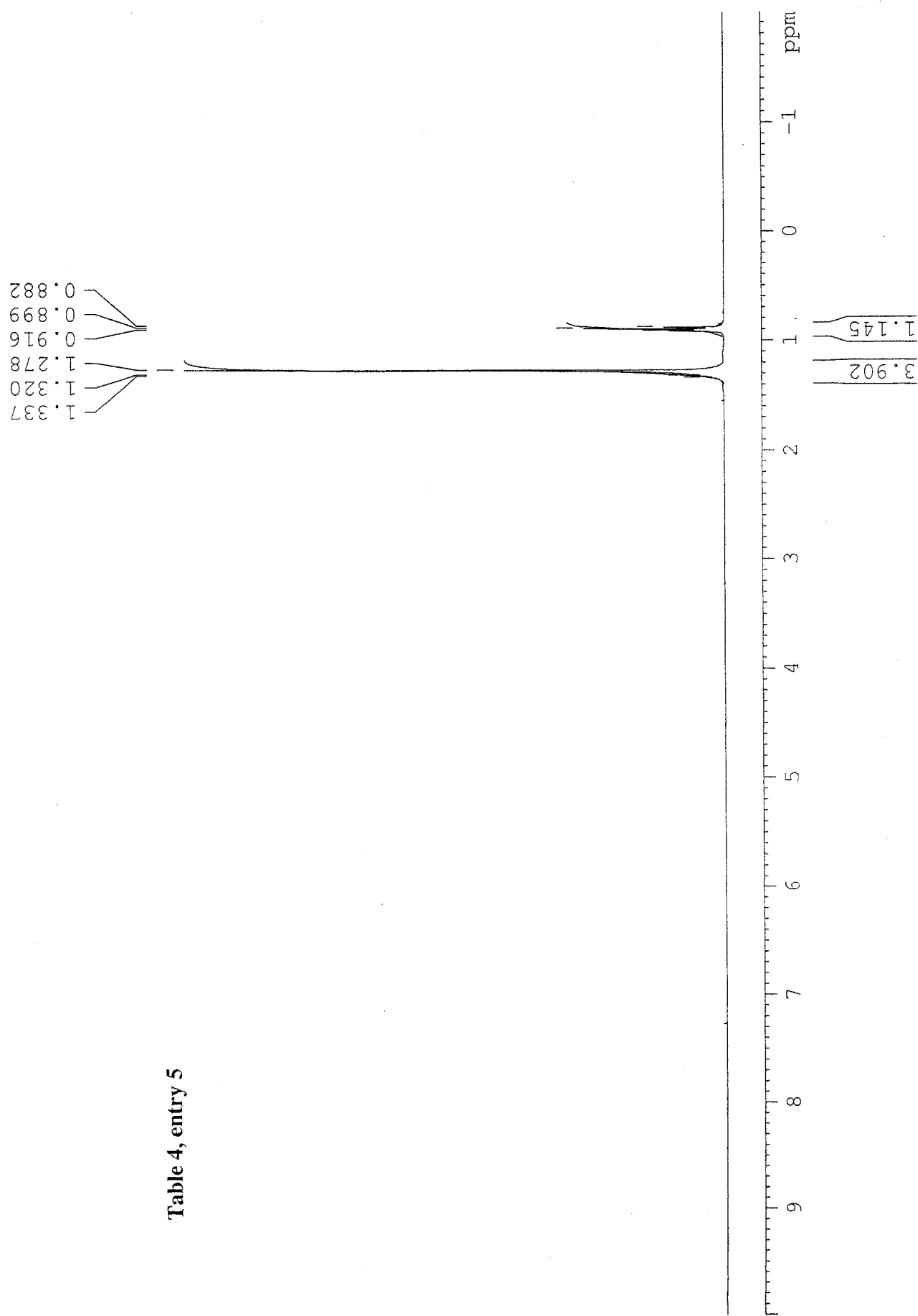


Table 4, entry 5



3067g

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7.140  
7.115  
7.103  
7.101  
7.097  
7.085

2.809  
2.789  
2.769  
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Table 4, entry 6

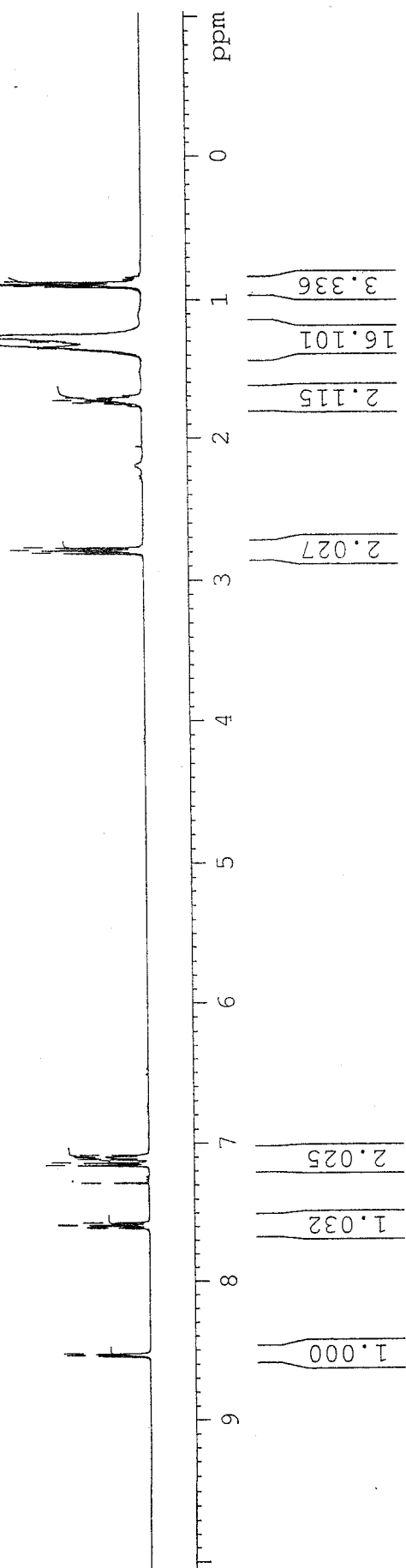
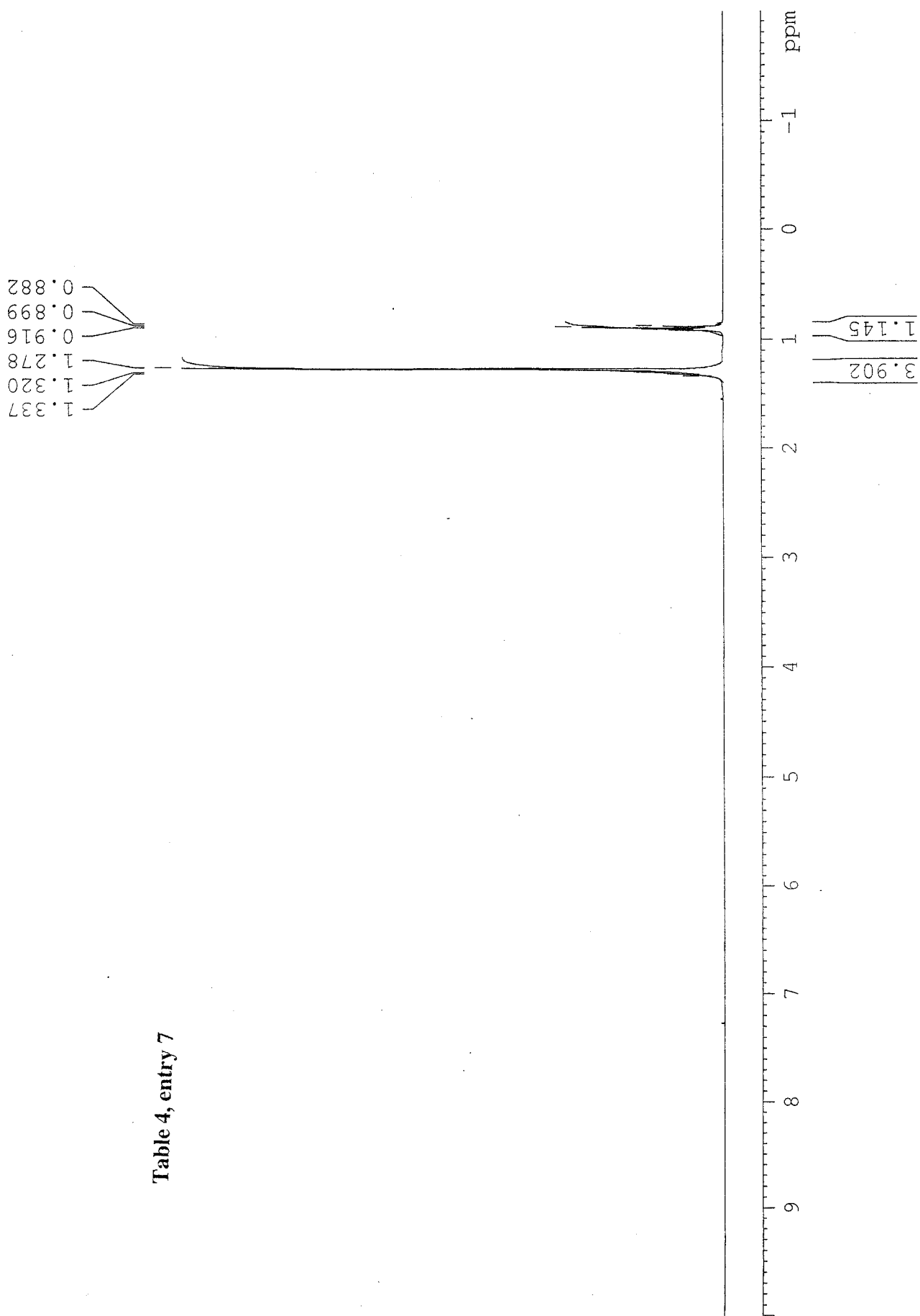


Table 4, entry 7



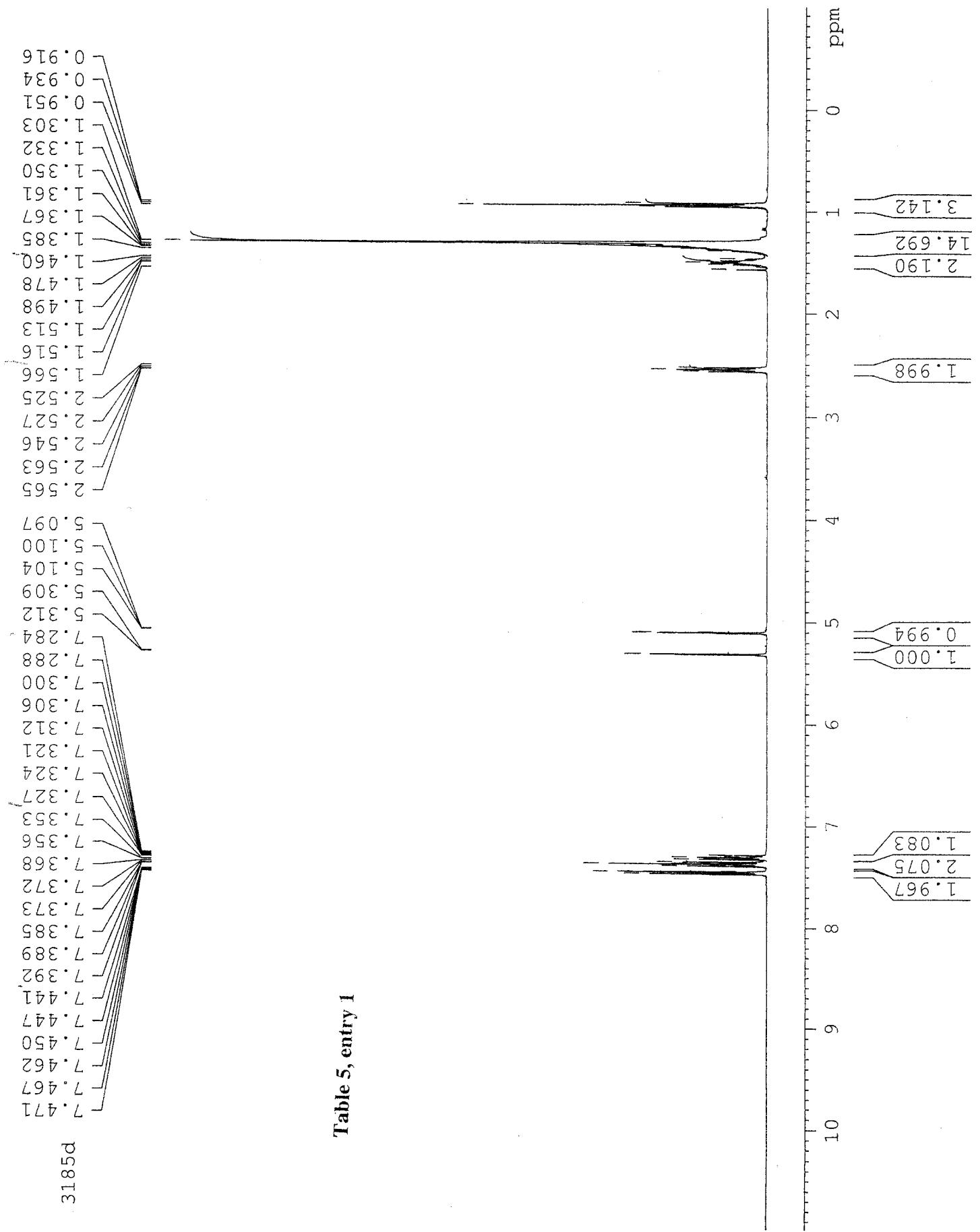


Table 5, entry 1

3269a

Table 5, entry 2

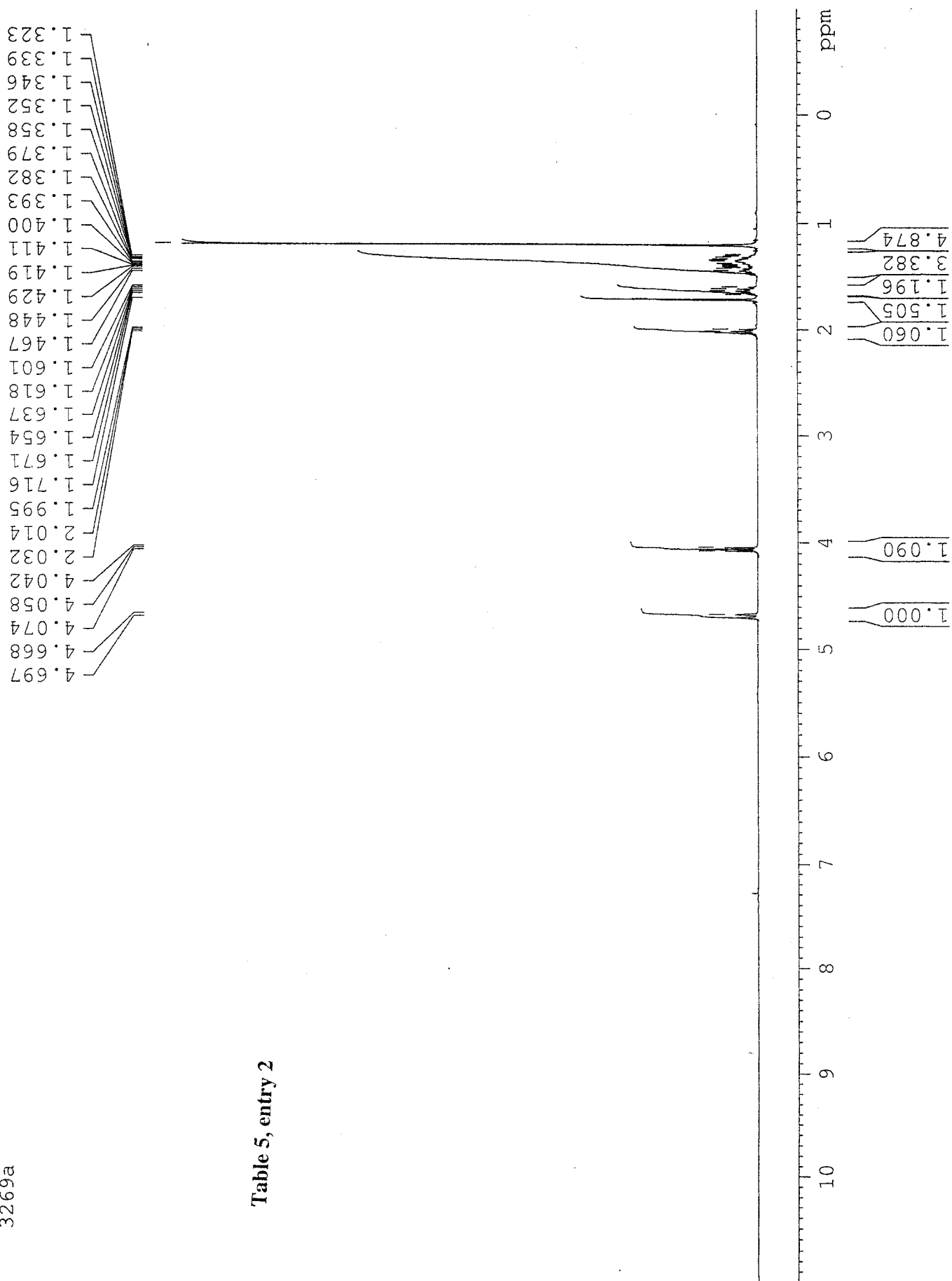


Table 5, entry 3

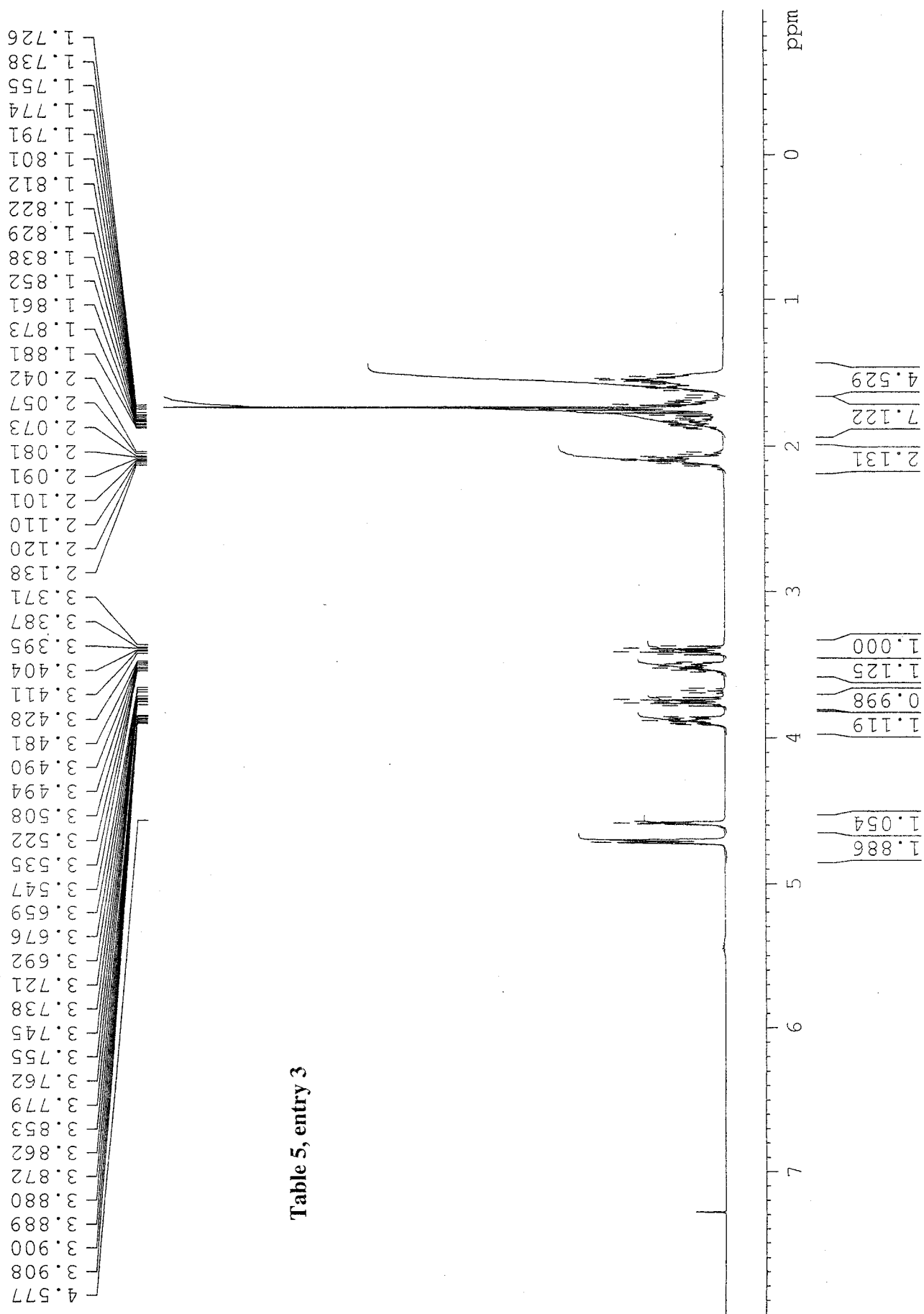




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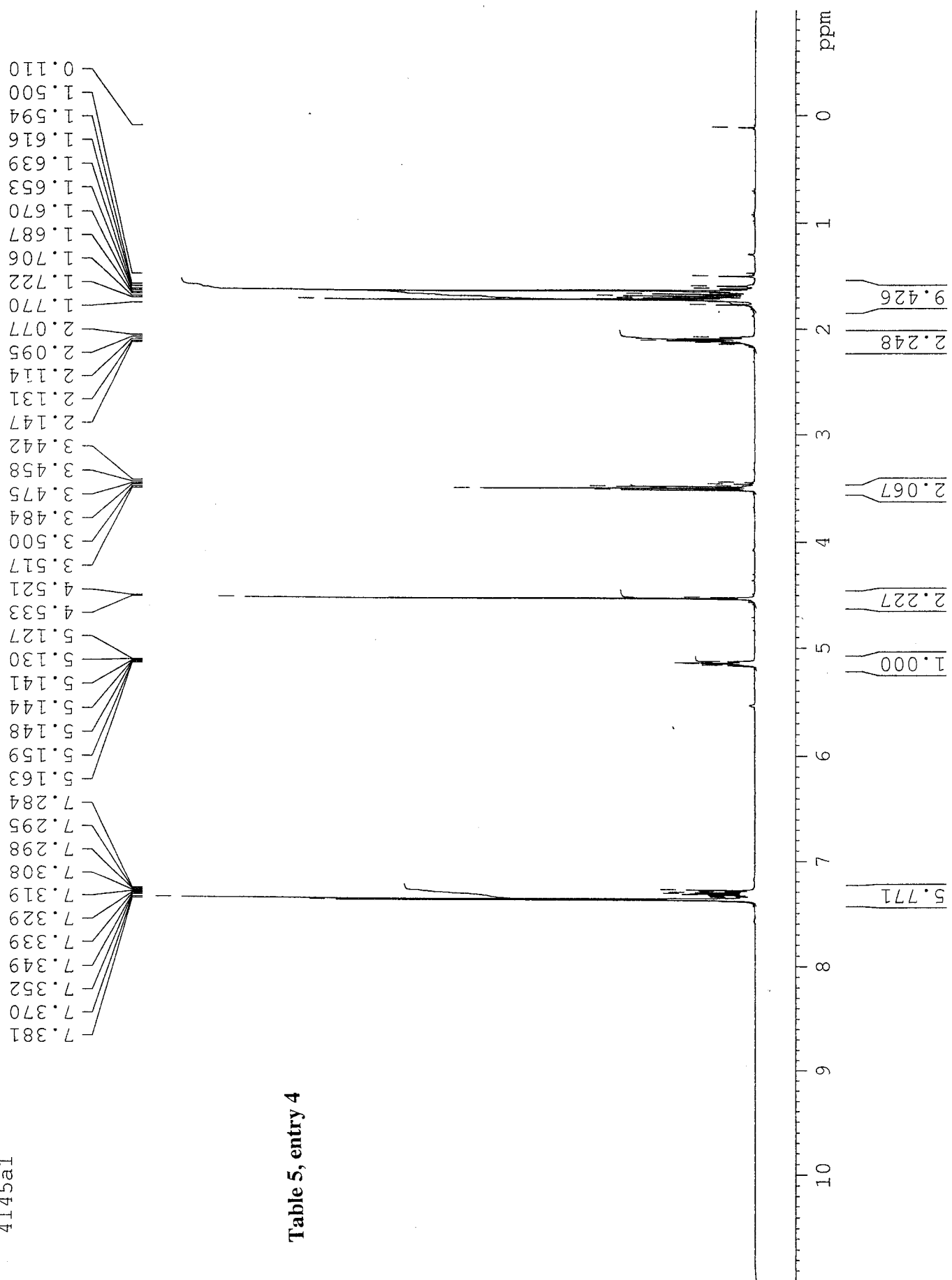


Table 5, entry 5

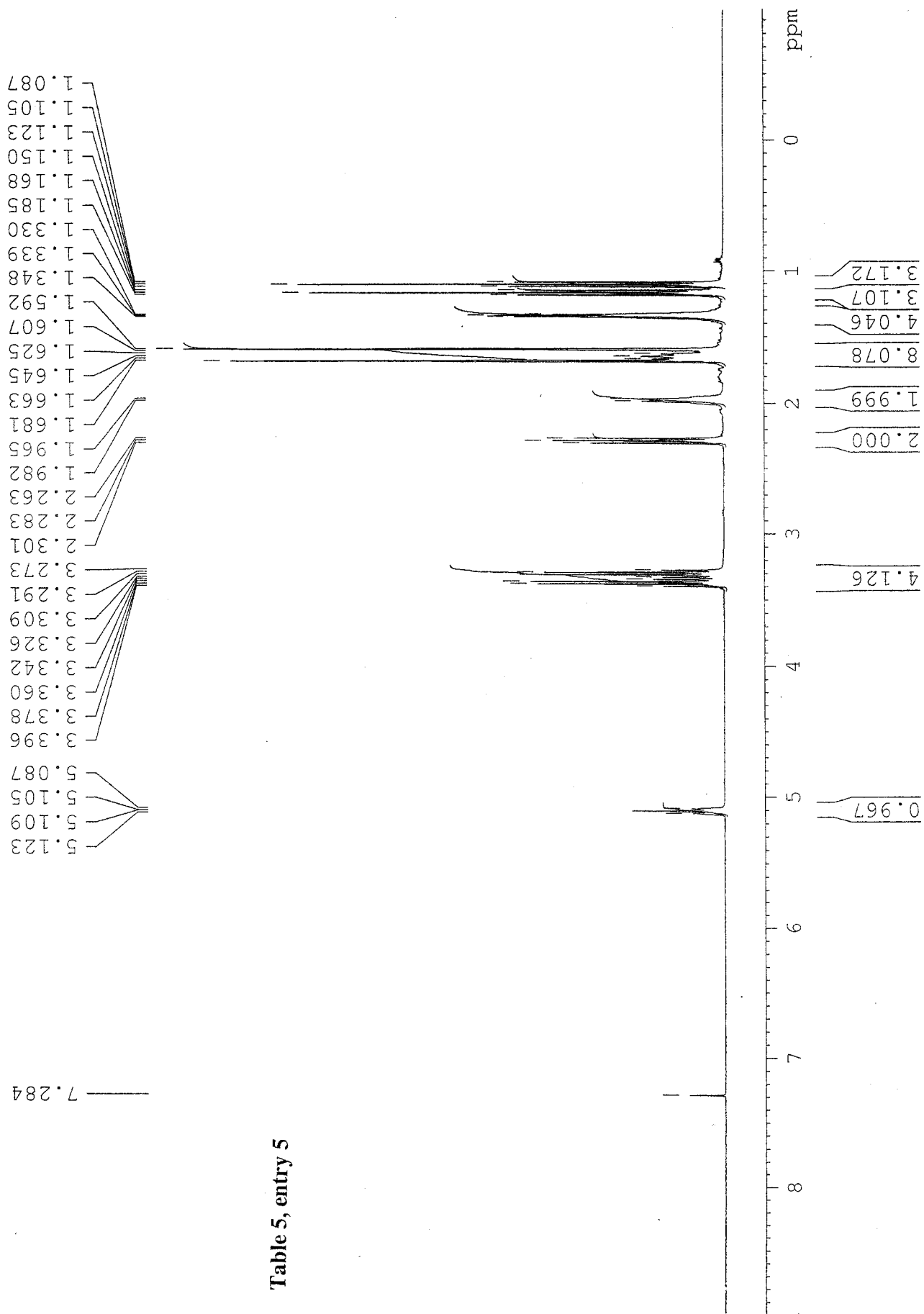
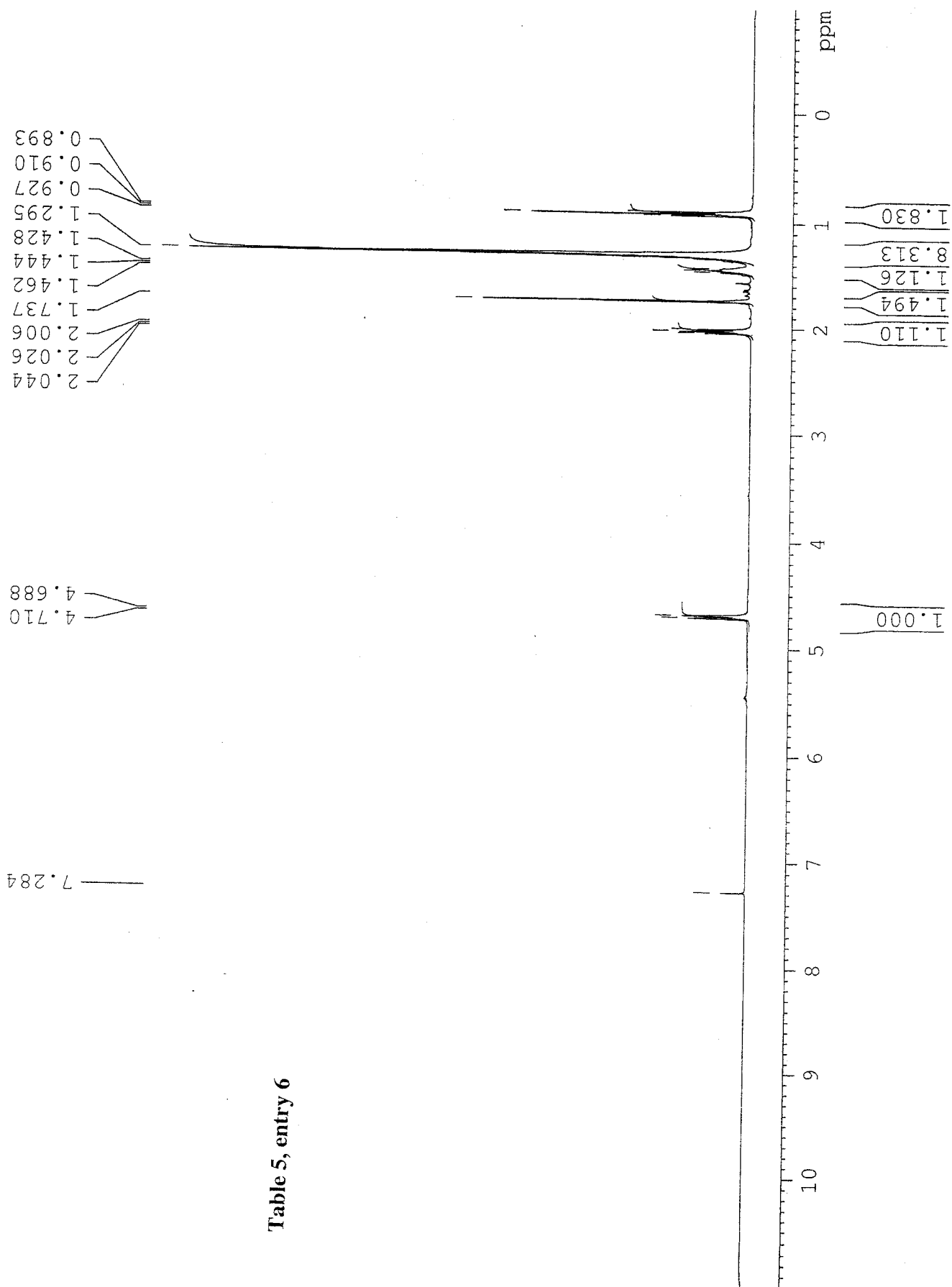
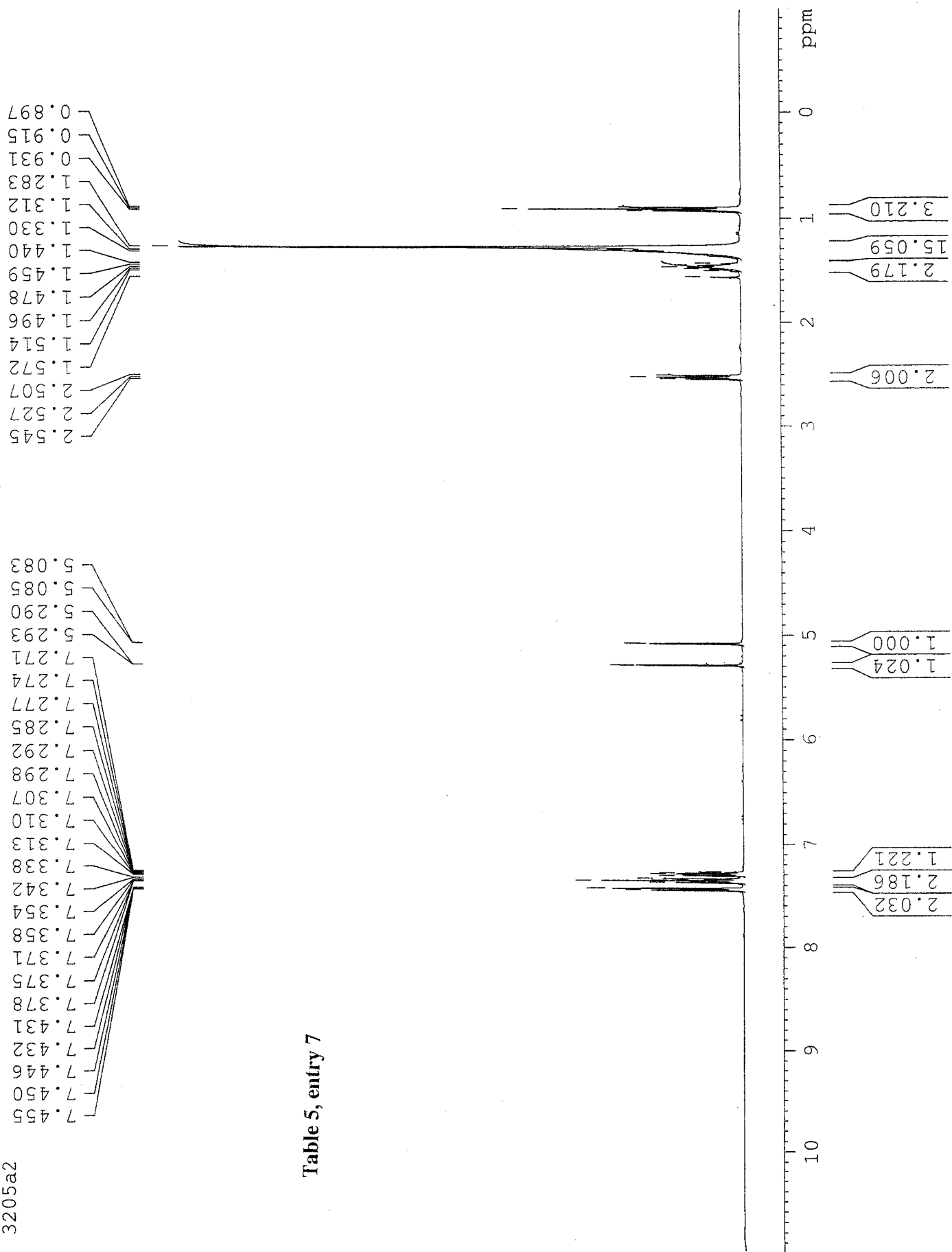


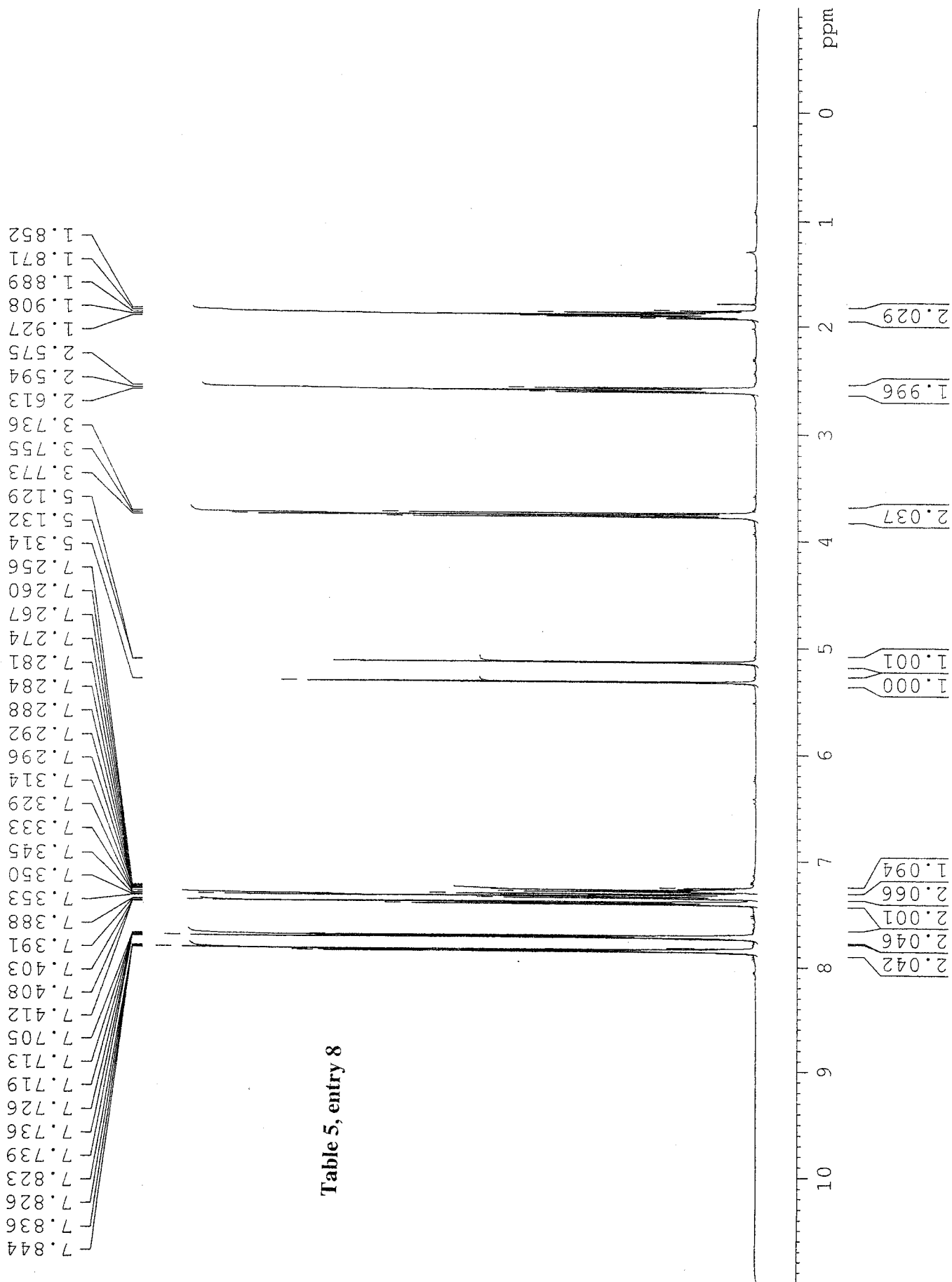
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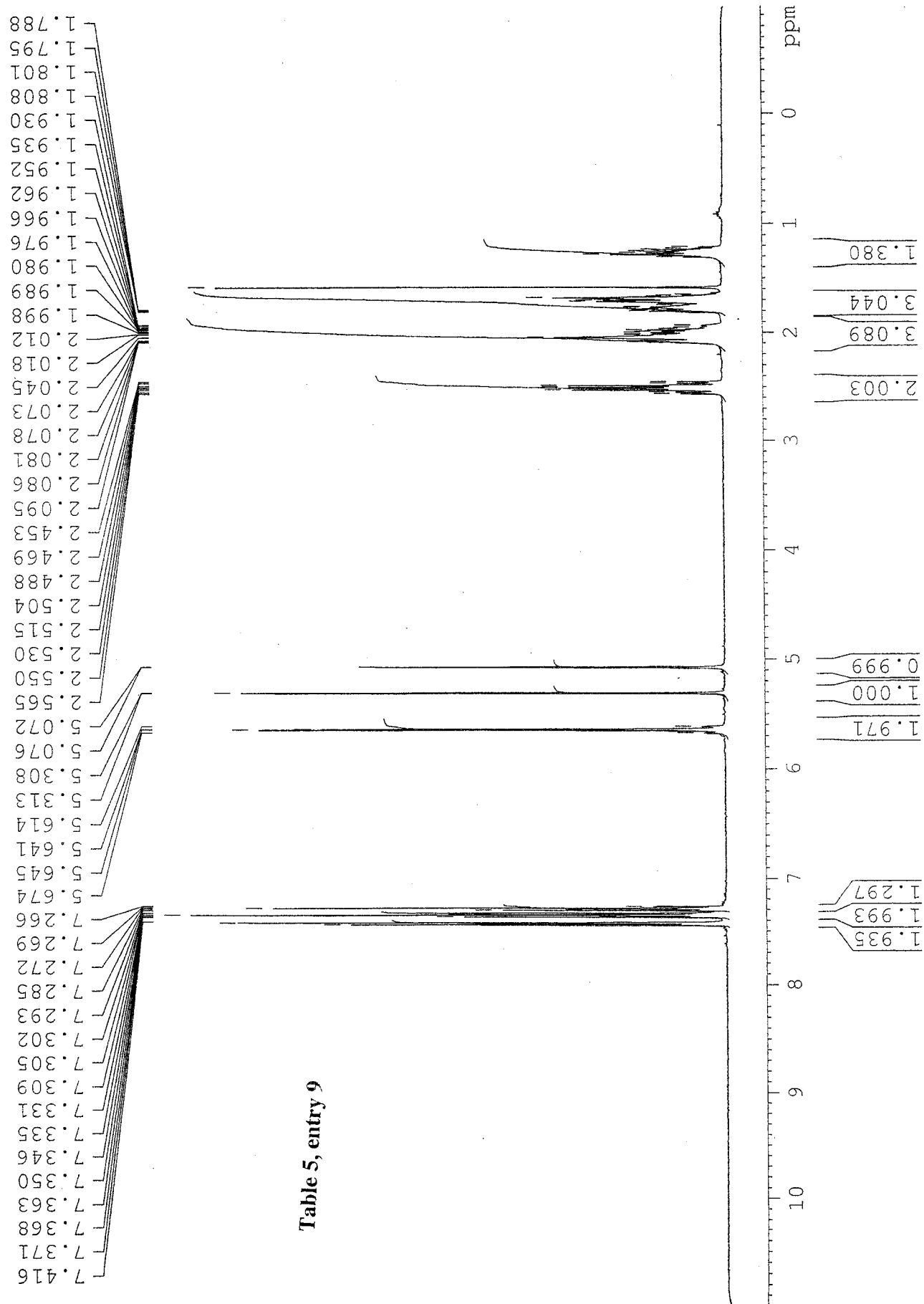




4075ar1

Table 5, entry 8





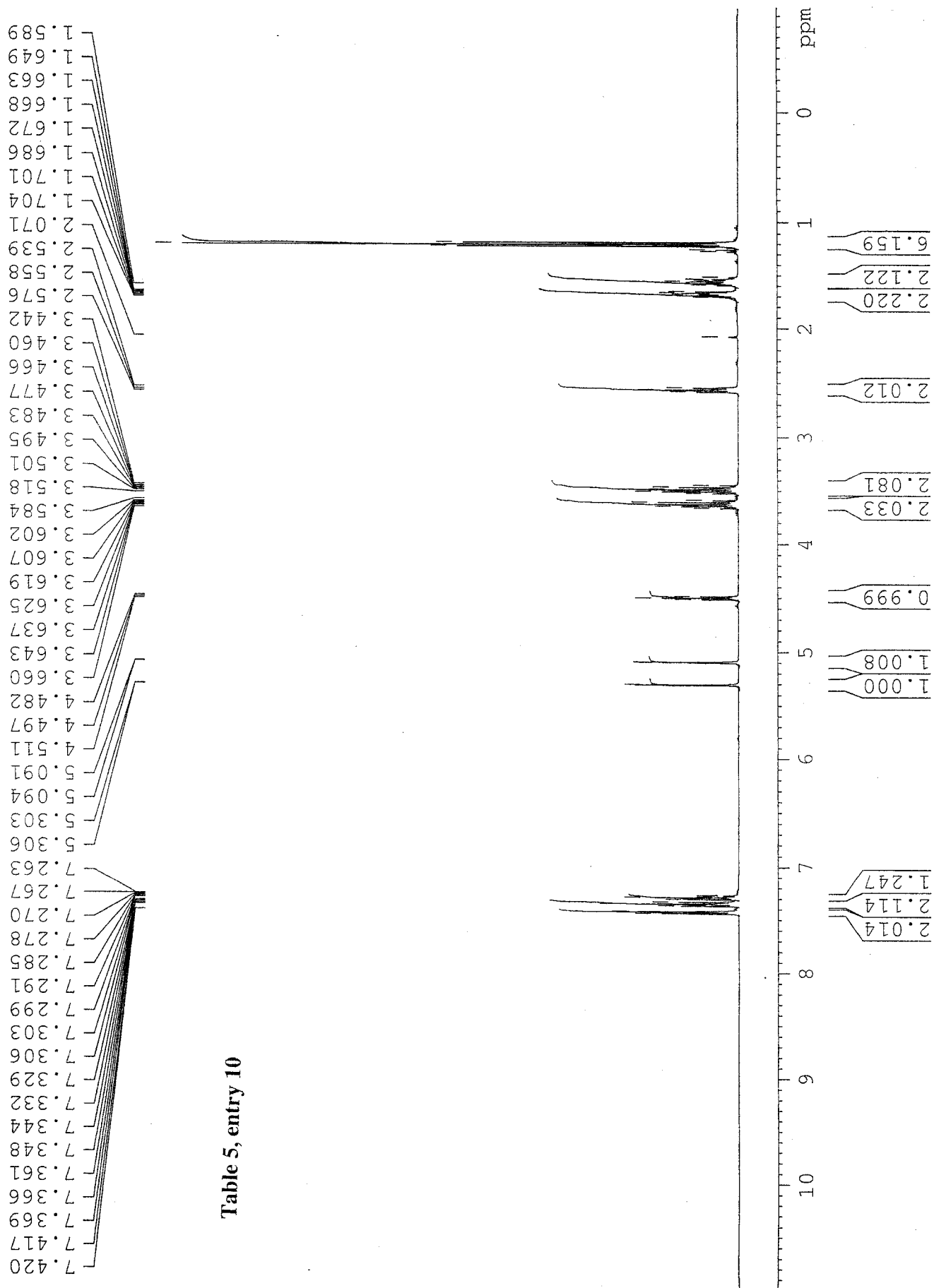
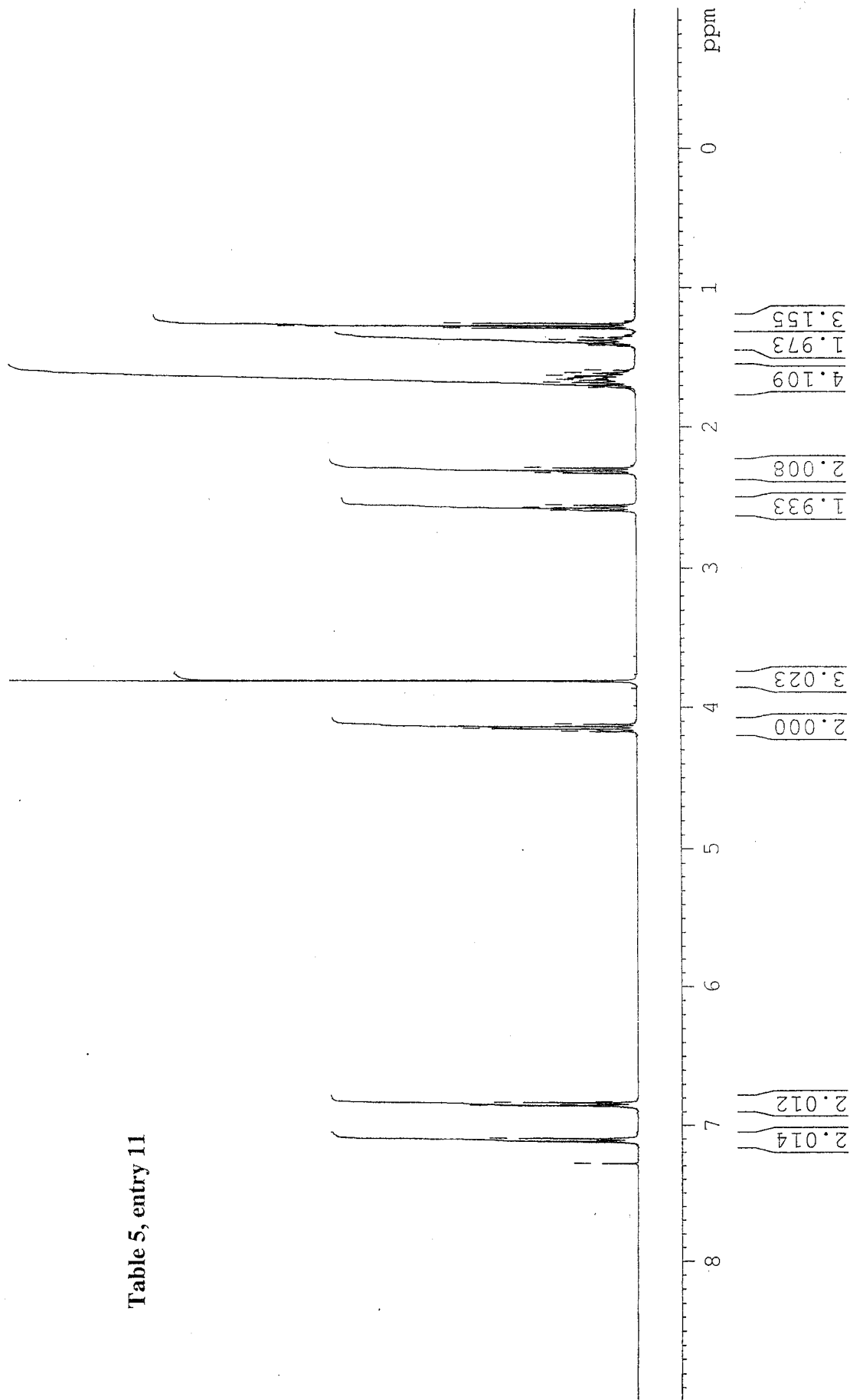


Table 5, entry 10

40931

7.284	7.128	7.121	7.099	6.865	6.858	6.852	6.841	6.836	6.829
4.171	4.153	4.135	4.117	3.810	2.596	2.577	2.557	2.331	2.313
2.293	1.714	1.696	1.677	1.665	1.657	1.646	1.639	1.627	1.608
1.589	1.414	1.400	1.394	1.384	1.376	1.362	1.356	1.290	1.272
1.261	1.254								

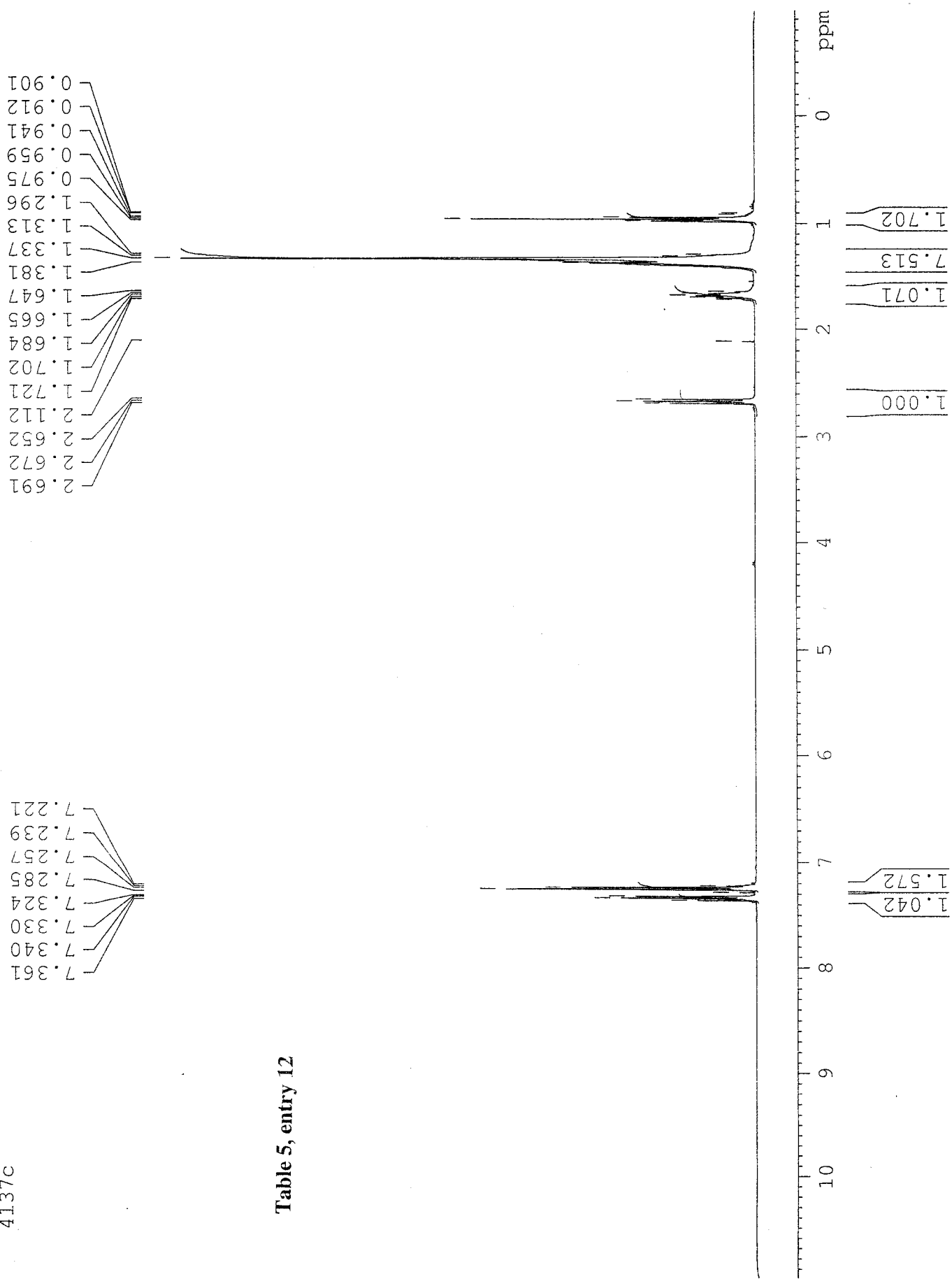
Table 5, entry 11





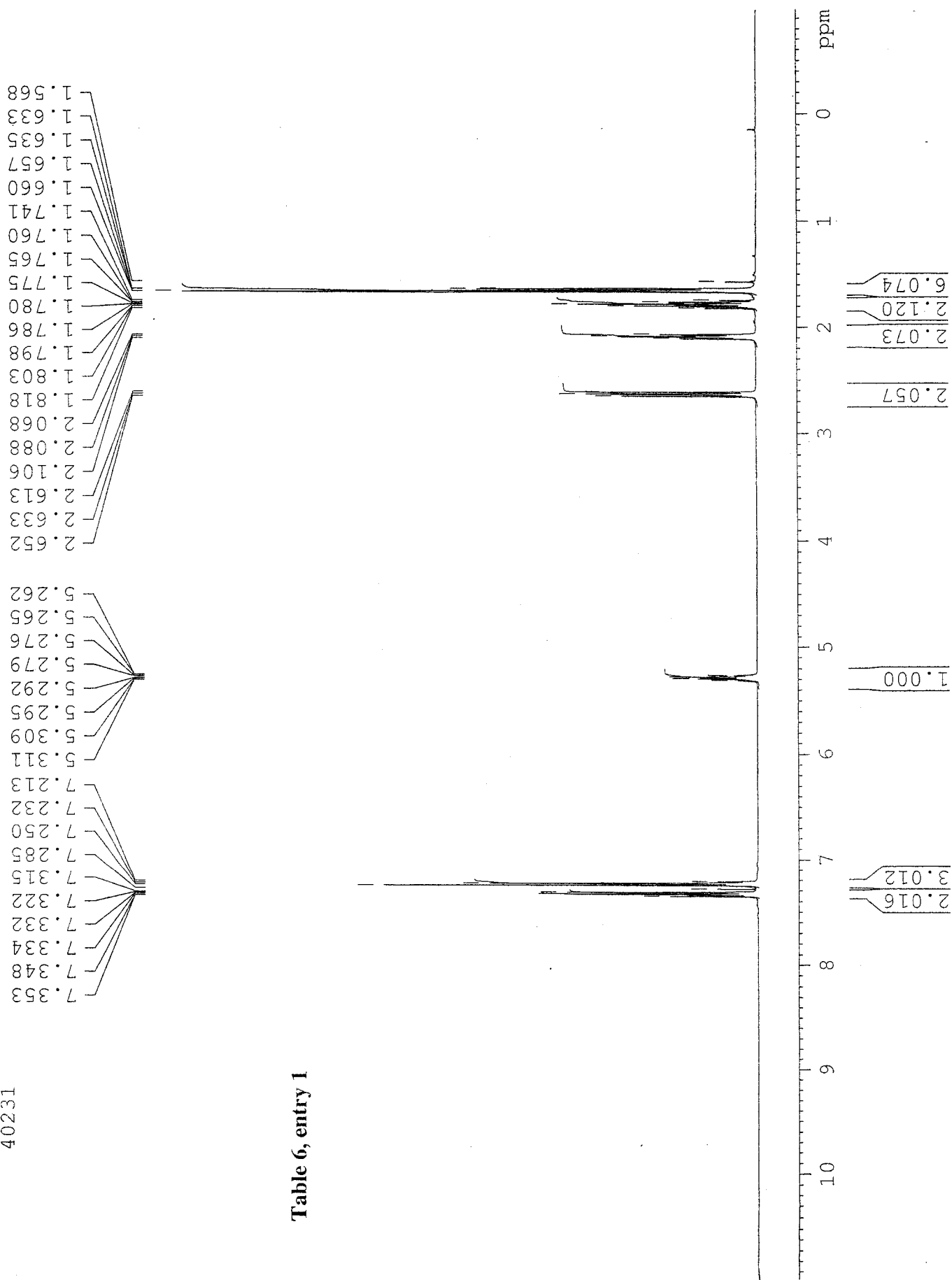
4137c

Table 5, entry 12



40231

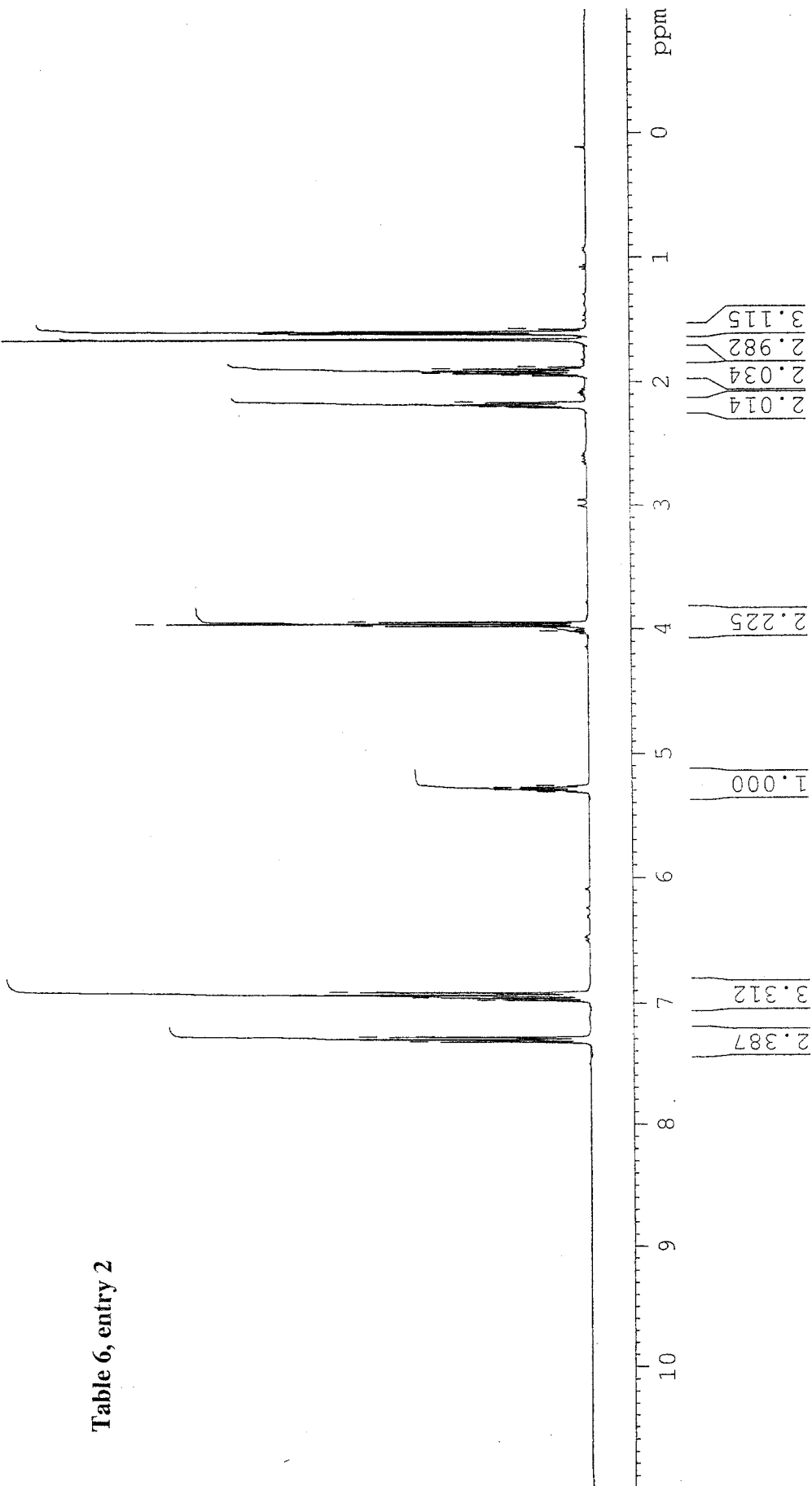
Table 6, entry 1

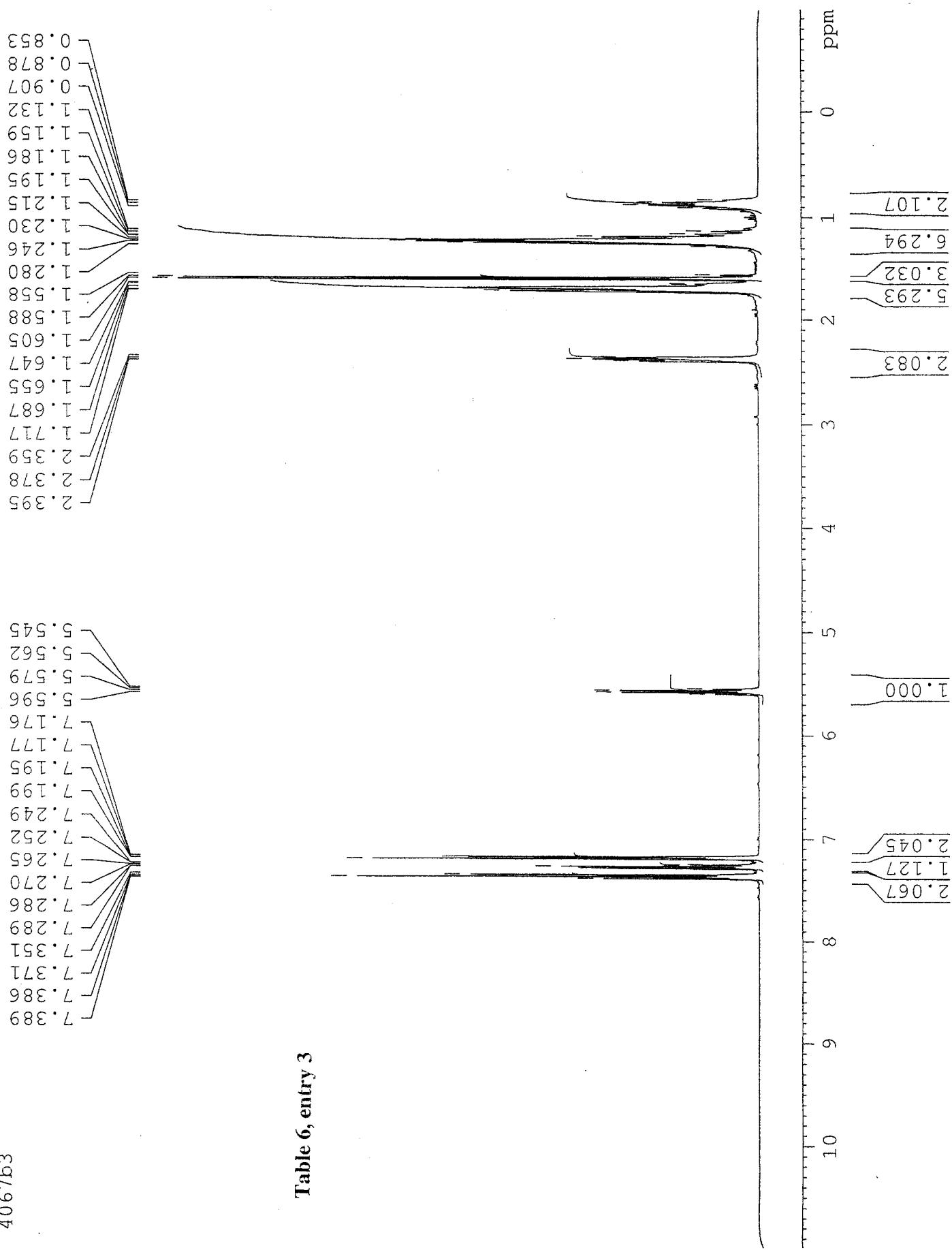


4071a1

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7.322  
7.309  
7.306  
7.300  
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7.288  
7.285  
6.979  
6.976  
6.960  
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6.938  
6.918  
6.916  
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5.309  
5.298  
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1.579

Table 6, entry 2





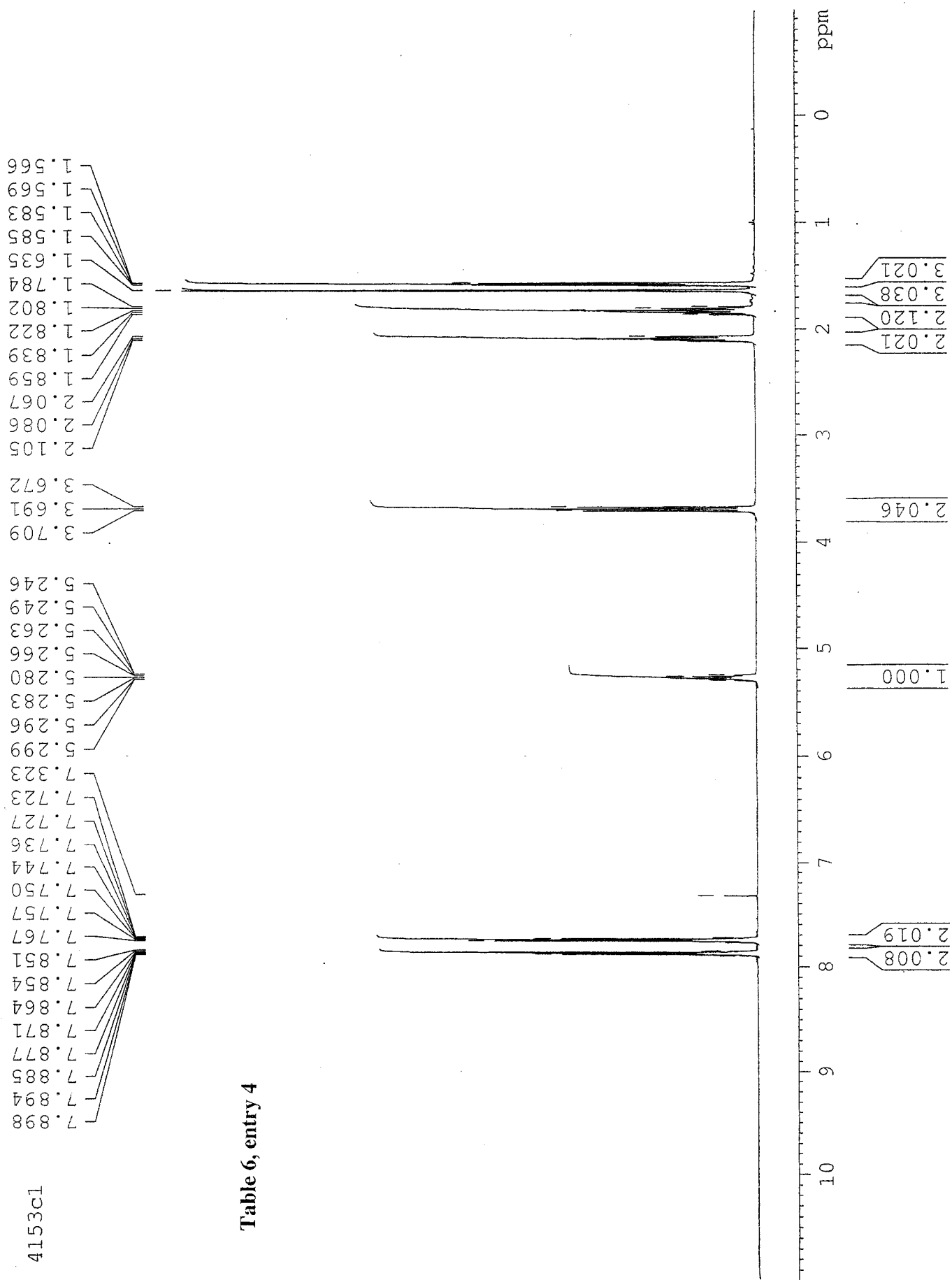


Table 6, entry 4

Table 6, entry 5

