Design, Synthesis and Evaluation of Novel Auxin Mimic Herbicides

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Supporting Information

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Synthetic Procedures

General Procedure A: Esterification of Aromatic Carboxylic Acids

Concentrated sulfuric acid (1 mL) was added to a solution of the carboxylic acid (10 mmol) in methanol (20 mL). The reaction mixture was stirred at 65 °C overnight, after which a saturated aqueous sodium bicarbonate solution was added to adjust the pH to about 8. The mixture was then extracted twice with dichloromethane, and the combined organic layers were dried with magnesium sulfate, filtered, and concentrated to give the product.

General Procedure B: Palladium-Catalyzed Coupling of Aryl Bromides with 4-Chlorophenylboronic Acid

The procedure described by Miyaura, Yanagi, and Suzuki[1] was modified in the following manner. To a suspension of the aryl bromide (10 mmol), bis(triphenylphosphine)palladium(II) chloride (0.5 mmol), and 4-chlorophenylboronic acid (15 mmol) in methanol (30 mL) and toluene (30 mL) was added a 2 M aqueous sodium carbonate solution (20 mmol). The reaction mixture was stirred at 80 °C overnight and then filtered through Celite. The filtrate was extracted twice with diethyl ether from water, and the combined organic layers were dried over magnesium sulfate, filtered, and concentrated. Column chromatography over silica gel afforded the pure product. Compounds were eluted using varying percentages of ethyl acetate in hexanes as eluant.

General Procedure C: Ester Hydrolysis

A 2 M aqueous sodium hydroxide solution (15 mmol) was added to a suspension of the ester (5 mmol) in methanol (50 mL). The reaction mixture was stirred at 65 °C for 3 h and then extracted twice with dichloromethane from 1 M hydrochloric acid. The combined organic layers were dried over magnesium sulfate, filtered, and concentrated. When necessary, column chromatography over silica gel afforded the pure product.

methyl 5-bromo-2-chlorobenzoate (9a)

This compound was prepared, following General Procedure A, from 5-bromo-2-chlorobenzoic acid (**8a**, 2.09 g, 8.89 mmol) and was obtained as a white solid (2.08 g, 94%).

Characterizations matched those reported in the literature.[2,3]

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.96 (d, *J* = 2.5 Hz, 1H), 7.53 (dd, *J* = 8.5, 2.5 Hz, 1H), 7.32 (d, *J* = 8.5 Hz, 1H), 3.94 (s, 3H).

methyl 2-chloro-5-(4-chlorophenyl)benzoate (10a)

This compound was prepared, following General Procedure B, from **9a** (1.99 g, 7.96 mmol). Column chromatography over silica gel with gradient elution from 5 to 15% ethyl acetate/hexanes gave the product as a white solid (1.66 g, 74%).

^{1}H NMR (250 MHz, $CDCl_3$) δ 8.00 (d, *J* = 2.2 Hz, 1H), 7.63–7.36 (m, 6H), 3.96 (s, 3H).

2-chloro-5-(4-chlorophenyl)benzoic acid (1a)

This compound was prepared, following General Procedure C, from **10a** (1.34 g, 4.75 mmol). Column chromatography over silica gel with gradient elution from 5 to 30% methanol/dichloromethane gave the product as a pale yellow solid (1.25 g, 99%).

^{1}H NMR (300 MHz, CD_3OD) δ 8.05 (d, *J* = 2.4 Hz, 1H), 7.72 (dd, *J* = 8.4, 2.4 Hz, 1H), 7.62 (d, *J* = 8.8 Hz, 2H), 7.56 (d, *J* = 8.4 Hz, 1H), 7.46 (d, *J* = 8.8 Hz, 2H).

methyl 5-bromo-2-fluorobenzoate (9b)

This compound was prepared, following General Procedure A, from 5-bromo-2-fluorobenzoic acid (**8b**, 2.00 g, 9.14 mmol) and was obtained as a colorless liquid (1.98 g, 93%).

Characterizations matched those reported in the literature.[4]

^{1}H NMR (300 MHz, $CDCl_3$) δ 8.06 (dd, *J* = 6.3, 2.6 Hz, 1H), 7.62 (ddd, *J* = 8.8, 4.2, 2.6 Hz, 1H), 7.05 (dd, *J* = 10.1, 8.8 Hz, 1H), 3.94 (s, 3H).

methyl 5-(4-chlorophenyl)-2-fluorobenzoate (10b)

This compound was prepared, following General Procedure B, from **9b** (1.95 g, 8.37 mmol). Column chromatography over silica gel with gradient elution from 5 to 15% ethyl acetate/hexanes gave the product as a white solid (1.48 g, 67%).

^{1}H NMR (300 MHz, $CDCl_3$) δ 8.12 (dd, *J* = 6.8, 2.5 Hz, 1H), 7.69 (ddd, *J* = 8.6, 4.5, 2.5 Hz, 1H), 7.50 (d, *J* = 8.8 Hz, 2H), 7.42 (d, *J* = 8.8 Hz, 2H), 7.22 (dd, *J* = 10.3, 8.6 Hz, 1H), 3.97 (s, 3H).

5-(4-chlorophenyl)-2-fluorobenzoic acid (1b)

This compound was prepared, following General Procedure C, from **10b** (1.47 g, 5.54 mmol). Column chromatography over silica gel with gradient elution from 5 to 30% methanol/dichloromethane gave the product as a white solid (1.01 g, 73%).

^{1}H NMR (300 MHz, CD_3OD) δ 8.12 (dd, *J* = 6.9, 2.5 Hz, 1H), 7.80 (ddd, *J* = 8.6, 4.5, 2.5 Hz, 1H), 7.59 (d, *J* = 8.8 Hz, 2H), 7.44 (d, *J* = 8.8 Hz, 2H), 7.27 (dd, *J* = 10.5, 8.6 Hz, 1H).

methyl 5-bromonicotinate (12a)

This compound was prepared, following General Procedure A, from 5-bromonicotinic acid (**11a**, 2.03 g, 10.04 mmol) as a white solid (1.91 g, 88%).

Characterizations matched those reported in the literature.[5,6]

^{1}H NMR (300 MHz, $CDCl_3$) δ 9.13 (d, *J* = 1.8 Hz, 1H), 8.84 (d, *J* = 2.3 Hz, 1H), 8.44 (t, *J* = 2.1 Hz, 1H), 3.97 (s, 3H).

methyl 5-(4-chlorophenyl)nicotinate (13a)

This compound was prepared, following General Procedure B, from **12a** (1.75 g, 8.11 mmol). Column chromatography over silica gel with gradient elution from 10 to 50% ethyl acetate/hexanes gave the product as a light yellow solid (1.67 g, 83%).

Characterizations matched those reported in the literature.[7]

^{1}H NMR (250 MHz, $CDCl_3$) δ 9.20 (d, *J* = 1.7 Hz, 1H), 8.98 (d, *J* = 2.2 Hz, 1H), 8.46 (t, *J* = 2.2 Hz, 1H), 7.56 (d, *J* = 8.8 Hz, 2H), 7.48 (d, *J* = 8.8 Hz, 2H), 3.99 (s, 3H).

5-(4-chlorophenyl)nicotinic acid (2a)

This compound was prepared, following General Procedure C, from **13a** (1.63 g, 6.59 mmol). Column chromatography over silica gel with gradient elution from 10 to 50% methanol/dichloromethane gave the product as a white solid (1.34 g, 87%).

^{1}H NMR (300 MHz, CD_3OD) δ 9.10 (s, 1H), 8.97 (s, 1H), 8.58 (t, *J* = 2.1 Hz, 1H), 7.71 (d, *J* = 8.8 Hz, 2H), 7.53 (d, *J* = 8.8 Hz, 2H).

methyl 6-bromopicolinate (12b)

This compound was prepared, following General Procedure A, from 6-bromopicolinic acid (**11b**, 0.33 g, 1.58 mmol) as a white solid (0.33 g, 95%).

Characterizations matched those reported in the literature.[8-10]

^{1}H NMR (300 MHz, $CDCl_3$) δ 8.11 (dd, *J* = 7.3, 0.8 Hz, 1H), 7.81–7.68 (m, 2H), 4.01 (s, 3H).

methyl 6-(4-chlorophenyl)picolinate (13b)

This compound was prepared, following General Procedure B, from **12b** (0.17 g, 0.78 mmol). Column chromatography over silica gel with gradient elution from 5 to 20% ethyl acetate/hexanes gave the product as a white solid (0.084 g, 44%).

^{1}H NMR (300 MHz, $CDCl_3$) δ 8.06 (d, *J* = 7.0 Hz, 1H), 8.00 (d, *J* = 8.7 Hz, 2H), 7.93–7.83 (m, 2H), 7.45 (d, *J* = 8.7 Hz, 2H), 4.02 (s, 3H).

6-(4-chlorophenyl)picolinic acid (2b)

This compound was prepared, following General Procedure C, from **13b** (0.084 g, 0.34 mmol). Column chromatography over silica gel with gradient elution from 5 to 20% methanol/dichloromethane gave the product as a white solid (0.072 g, 91%).

Characterizations matched those reported in the literature.[11]

^{1}H NMR (300 MHz, CD_3OD) δ 8.16–7.91 (m, 5H), 7.45 (d, *J* = 7.9 Hz, 2H).

methyl 5-bromo-6-chloronicotinate (15a)

This compound was prepared according to a literature procedure.[12] A solution of 5-bromo-6-chloronicotinic acid (**14a**, 0.16 g, 0.67 mmol) in thionyl chloride (5 mL) was stirred at 70 °C for 1 h and then concentrated by rotary evaporation. Benzene (10 mL) and anhydrous methanol (5 mL) were added to the residue, followed by stirring at 65 °C for 1 h. The reaction mixture was then concentrated and extracted with dichloromethane (2 × 20 mL) from saturated aqueous sodium bicarbonate (20 mL). The combined organic layers were dried over magnesium sulfate, filtered, and concentrated to give the product as a light yellow solid (0.16 g, 98%).

Characterizations matched those reported in the literature.[12]

^{1}H NMR (300 MHz, $CDCl_3$) δ 8.92 (d, *J* = 2.0 Hz, 1H), 8.52 (d, *J* = 2.0 Hz, 1H), 3.98 (s, 3H).

methyl 6-chloro-5-(4-chlorophenyl)nicotinate (16a)

This compound was prepared, following General Procedure B, from **15a** (0.083 g, 0.32 mmol). Column chromatography over silica gel with gradient elution from 10 to 30% ethyl acetate/hexanes gave the product as a white solid (0.027 g, 29%).

^{1}H NMR (300 MHz, $CDCl_3$) δ 8.99 (d, *J* = 2.3 Hz, 1H), 8.25 (d, *J* = 2.3 Hz, 1H), 7.47 (d, *J* = 8.8 Hz, 2H), 7.41 (d, *J* = 8.8 Hz, 2H), 3.98 (s, 3H).

6-chloro-5-(4-chlorophenyl)nicotinic acid (3a)

This compound was prepared, following General Procedure C, from **16a** (0.061 g, 0.22 mmol). Column chromatography over silica gel with gradient elution from 3 to 20% methanol/dichloromethane gave the product as a white solid (0.049 g, 85%).

^{1}H NMR (300 MHz, CD_3OD) δ 8.88 (s, 1H), 8.28 (s, 1H), 7.49–7.39 (m, 4H).

methyl 5-bromo-2-chloronicotinate (15b)

This compound was prepared, in the same manner as **15a** described above, from 5-bromo-2-chloronicotinic acid (0.20 g, 0.84 mmol) as a light yellow solid (0.20 g, 95%).

Characterizations matched those reported in the literature.[12]

^{1}H NMR (300 MHz, $CDCl_3$) δ 8.58 (d, *J* = 2.5 Hz, 1H), 8.30 (d, *J* = 2.5 Hz, 1H), 3.98 (s, 3H).

methyl 2-chloro-5-(4-chlorophenyl)nicotinate (16b)

This compound was prepared, following General Procedure B, from **15b** (0.097 g, 0.39 mmol). Column chromatography over silica gel with gradient elution from 10 to 30% ethyl acetate/hexanes gave the product as a white solid (0.031 g, 28%).

^{1}H NMR (300 MHz, $CDCl_3$) δ 8.69 (d, *J* = 2.6 Hz, 1H), 8.32 (d, *J* = 2.6 Hz, 1H), 7.53 (d, *J* = 8.9 Hz, 2H), 7.48 (d, *J* = 8.9 Hz, 2H), 4.00 (s, 3H).

2-chloro-5-(4-chlorophenyl)nicotinic acid (3b)

This compound was prepared, following General Procedure C, from **16b** (0.11 g, 0.39 mmol). Column chromatography over silica gel with gradient elution from 5 to 15% methanol/dichloromethane gave the product as a white solid (0.074 g, 70%).

^{1}H NMR (300 MHz, CD_3OD) δ 8.63 (s, 1H), 8.31 (s, 1H), 7.65 (d, *J* = 8.2 Hz, 2H), 7.48 (d, *J* = 8.2 Hz, 2H).

methyl 3-bromo-5-hydroxybenzoate (18)

This compound was prepared, following General Procedure A, from 3-bromo-5-hydroxybenzoic acid (**17**, 0.10 g, 0.45 mmol) as a light yellow solid (0.10 g, 100%).

Characterizations matched those reported in the literature.[13,14]

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.74 (t, *J* = 1.5 Hz, 1H), 7.54 (dd, *J* = 2.4, 1.5 Hz, 1H), 7.25 (dd, *J* = 2.4, 1.8 Hz, 1H), 6.07 (bs, 1H), 3.93 (s, 3H).

methyl 3-bromo-5-(4-methoxybenzyloxy)benzoate (19)

To a solution of **18** (0.10 g, 0.44 mmol) and potassium carbonate (0.090 g, 0.65 mmol) in *N,N*-dimethylformamide (10 mL) was added 4-methoxybenzyl chloride (0.092 mL, 0.65 mmol) dropwise. The reaction mixture was stirred at 100 °C overnight and then extracted with ethyl acetate (2 × 30 mL) from water (30 mL). The combined organic layers were dried over magnesium sulfate, filtered, and concentrated. Column chromatography over silica gel with gradient elution from 3 to 15% ethyl acetate/hexanes gave the product as a colorless oil (0.14 g, 94%).

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.77–7.73 (m, 1H), 7.56 (dd, *J* = 2.4, 1.3 Hz, 1H), 7.33 (d, *J* = 8.7 Hz, 2H), 7.29 (dd, *J* = 2.4, 1.8 Hz, 1H), 6.91 (d, *J* = 8.7 Hz, 2H), 4.98 (s, 2H), 3.89 (s, 3H), 3.80 (s, 3H).

methyl 3-(4-chlorophenyl)-5-(4-methoxybenzyloxy)benzoate (20)

This compound was prepared, following General Procedure B, from **19** (2.71 g, 7.72 mmol). Column chromatography over silica gel with gradient elution from 5 to 25% ethyl acetate/hexanes gave the product as a dark yellow solid (2.17 g, 74%).

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.83 (t, *J* = 1.5 Hz, 1H), 7.62 (dd, *J* = 2.5, 1.5 Hz, 1H), 7.49 (d, *J* = 8.7 Hz, 2H), 7.41–7.34 (m, 4H), 7.32 (dd, *J* = 2.5, 1.7 Hz, 1H), 6.92 (d, *J* = 8.7 Hz, 2H), 5.04 (s, 2H), 3.93 (s, 3H), 3.80 (s, 3H).

methyl 3-(4-chlorophenyl)-5-hydroxybenzoate (21)

Trifluoroacetic acid (5 mL) was added dropwise to a solution of **20** (0.12 g, 0.30 mmol) in dichloromethane (5 mL) at rt. The reaction mixture was stirred at rt for 3 h, followed by extraction with dichloromethane (2 × 20 mL) from water (20 mL). The combined organic layers were dried over magnesium sulfate, filtered, and concentrated. Column chromatography over silica gel with gradient elution from 20 to 40% ethyl acetate/hexanes yielded the product as a white solid (0.078 g, 98%).

^{1}H NMR (300 MHz, 1:1 $CDCl_3$: CD_3OD) δ 7.72 (t, *J* = 1.6 Hz, 1H), 7.54 (d, *J* = 8.7 Hz, 2H), 7.45 (dd, *J* = 2.4, 1.4 Hz, 1H), 7.41 (d, *J* = 8.7 Hz, 2H), 7.24 (dd, *J* = 2.4, 1.7 Hz, 1H), 3.93 (s, 3H).

3-(4-chlorophenyl)-5-hydroxybenzoic acid (4)

This compound was prepared, following General Procedure C, from **21** (1.12 g, 4.28 mmol). Column chromatography over silica gel with gradient elution from 3 to 25% methanol/dichloromethane gave the product as a white solid (0.83 g, 78%).

^{1}H NMR (300 MHz, CD_3OD) δ 7.72 (t, *J* = 1.5 Hz, 1H), 7.55 (d, *J* = 8.7 Hz, 2H), 7.44 (dd, *J* = 2.4, 1.4 Hz, 1H), 7.40 (d, *J* = 8.7 Hz, 2H), 7.21 (dd, *J* = 2.4, 1.7 Hz, 1H).

methyl 5-bromo-2-chloro-3-nitrobenzoate (23)

5-bromo-2-chlorobenzoic acid (**22**, 3.01 g, 12.77 mmol) was added to concentrated sulfuric acid (29 mL) at 0 °C. A cooled mixture of concentrated sulfuric acid (1 mL) and concentrated nitric acid (1 mL) was added dropwise, and the reaction mixture was stirred at rt overnight. The reaction crude was then poured into ice, and the resulting precipitate was filtered and washed with cold water. The precipitate was extracted with ethyl acetate (2 × 50 mL) from water (50 mL), and the combined organic layers were dried over magnesium sulfate, filtered, and concentrated to give a mixture of mostly 5-bromo-2-chloro-3-nitrobenzoic acid and some 3-bromo-6-chloro-2-nitrobenzoic acid. Methanol (20 mL) and concentrated sulfuric acid (1 mL) were added to the mixture which was then stirred at 65 °C overnight. A saturated aqueous sodium bicarbonate solution (15 mL) was then added to adjust the pH to about 8, and the mixture was extracted with dichloromethane (2 × 30 mL). The combined organic layers were dried over magnesium sulfate, filtered, and concentrated. Column chromatography over silica gel with gradient elution from 10 to 20% ethyl acetate/hexanes then yielded the pure product as a light yellow solid (1.17 g, 31% over 2 steps).

^{1}H NMR (300 MHz, $CDCl_3$) δ 8.09 (d, *J* = 2.4 Hz, 1H), 7.97 (d, *J* = 2.3 Hz, 1H), 3.99 (s, 3H).

methyl 3-amino-5-bromo-2-chlorobenzoate (24)

Iron powder (0.48 g, 8.55 mmol) and saturated aqueous ammonium chloride (1.22 mL) were added to a solution of **23** (0.50 g, 1.71 mmol) in ethanol (20 mL). The reaction mixture was stirred at 80 °C for 2 h and then filtered through Celite. The filtrate was concentrated, and the residue was extracted with ethyl acetate (2 × 30 mL) from saturated aqueous sodium bicarbonate (30 mL). The combined organic layers were dried over magnesium sulfate, filtered, and concentrated. Column chromatography over silica gel with gradient elution from 5 to 20% ethyl acetate/hexanes gave the product as a white solid (0.38 g, 84%).

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.28 (d, *J* = 2.2 Hz, 1H), 7.03 (d, *J* = 2.3 Hz, 1H), 4.32 (bs, 2H), 3.91 (s, 3H).

methyl 3-amino-2-chloro-5-(4-chlorophenyl)benzoate (25)

This compound was prepared, following General Procedure B, from **24** (0.26 g, 0.97 mmol). Column chromatography over silica gel with gradient elution from 5 to 20% ethyl acetate/hexanes gave the product as a light yellow solid (0.17 g, 58%).

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.41 (d, *J* = 8.8 Hz, 2H), 7.35 (d, *J* = 8.8 Hz, 2H), 7.31 (d, *J* = 2.2 Hz, 1H), 7.01 (d, *J* = 2.2 Hz, 1H), 4.36 (bs, 2H), 3.93 (s, 3H).

3-amino-2-chloro-5-(4-chlorophenyl)benzoic acid (5)

This compound was prepared, following General Procedure C, from **25** (0.25 g, 0.83 mmol) as a tan solid (0.21 g, 90%).

^{1}H NMR (300 MHz, CD_3OD) δ 7.56 (d, *J* = 8.8 Hz, 2H), 7.43 (d, *J* = 8.8 Hz, 2H), 7.26 (d, *J* = 2.2 Hz, 1H), 7.19 (d, *J* = 2.2 Hz, 1H).

methyl 5-bromoindole-2-carboxylate (27)

This compound was prepared, following General Procedure A, from 5-bromoindole-2-carboxylic acid (**26**, 0.32 g, 1.35 mmol) as a light yellow solid (0.33 g, 96%).

Characterizations matched those reported in the literature.[15,16]

^{1}H NMR (300 MHz, $CDCl_3$) δ 8.99 (bs, 1H), 7.85–7.82 (m, 1H), 7.41 (dd, *J* = 8.8, 1.9 Hz, 1H), 7.31 (d, *J* = 8.8 Hz, 1H), 7.16–7.13 (m, 1H), 3.96 (s, 3H).

methyl 5-(4-chlorophenyl)indole-2-carboxylate (28)

This compound was prepared, following General Procedure B, from **27** (0.33 g, 1.29 mmol). Column chromatography over silica gel with gradient elution from 5 to 25% ethyl acetate/hexanes gave the product as a white solid (0.15 g, 40%).

^{1}H NMR (300 MHz, $CDCl_3$) δ 8.99 (bs, 1H), 7.85 (s, 1H), 7.59–7.46 (m, 4H), 7.41 (d, *J* = 8.6 Hz, 2H), 7.27–7.26 (m, 1H), 3.97 (s, 3H).

5-(4-chlorophenyl)indole-2-carboxylic acid (6)

This compound was prepared, following General Procedure C, from **28** (0.065 g, 0.23 mmol). Column chromatography over silica gel with gradient elution from 3 to 30% methanol/dichloromethane gave the product as a light yellow solid (0.062 g, 100%).

^{1}H NMR (300 MHz, CD_3OD) δ 7.83 (s, 1H), 7.59 (d, *J* = 8.4 Hz, 2H), 7.50 (s, 2H), 7.39 (d, *J* = 8.4 Hz, 2H), 7.18 (s, 1H).

methyl 2-(5-bromoindol-3-yl)acetate (30)

This compound was prepared according to a known procedure.[17] A solution of chlorotrimethylsilane (1 mL) in anhydrous methanol (10 mL) was cooled to −20 °C and then added to a solution of 5-bromoindole-3-acetic acid (**29**, 0.31 g, 1.20 mmol) in anhydrous methanol (10 mL). The reaction mixture was stirred at rt overnight and then concentrated by rotary evaporation. The residue was dissolved with dichloromethane, filtered through a pad of silica gel, and washed with 50% ethyl acetate/hexanes (50 mL). The filtrate was then concentrated to provide the product as a light brown solid (0.29 g, 90%).

Characterizations matched those reported in the literature.[17,18]

^{1}H NMR (300 MHz, $CDCl_3$) δ 8.30 (bs, 1H), 7.70 (d, *J* = 1.9 Hz, 1H), 7.23 (dd, *J* = 8.6, 1.9 Hz, 1H), 7.11 (d, *J* = 8.6 Hz, 1H), 7.02 (d, *J* = 2.4 Hz, 1H), 3.72–3.71 (m, 5H).

methyl 2-[5-(4-chlorophenyl)indol-3-yl]acetate (31)

This compound was prepared, following General Procedure B, from **30** (0.25 g, 0.93 mmol). Column chromatography over silica gel with gradient elution from 20 to 40% ethyl acetate/hexanes gave the product as a light yellow oil (0.17 g, 60%).

^{1}H NMR (300 MHz, $CDCl_3$) δ 8.19 (bs, 1H), 7.76 (s, 1H), 7.56 (d, *J* = 8.6 Hz, 2H), 7.43–7.35 (m, 4H), 7.17 (d, *J* = 2.4 Hz, 1H), 3.81 (s, 2H), 3.71 (s, 3H).

2-[5-(4-chlorophenyl)indol-3-yl]acetic acid (7)

This compound was prepared, following General Procedure C, from **31** (0.17 g, 0.57 mmol). Column chromatography over silica gel with gradient elution from 5 to 20% methanol/dichloromethane gave the product as a white solid (0.072 g, 45%).

Characterizations matched those reported in the literature.[19]

^{1}H NMR (300 MHz, CD_3OD) δ 10.42 (bs, 1H), 7.77–7.74 (m, 1H), 7.57 (d, *J* = 8.3 Hz, 2H), 7.42–7.31 (m, 4H), 7.19 (s, 1H), 3.76 (s, 2H).

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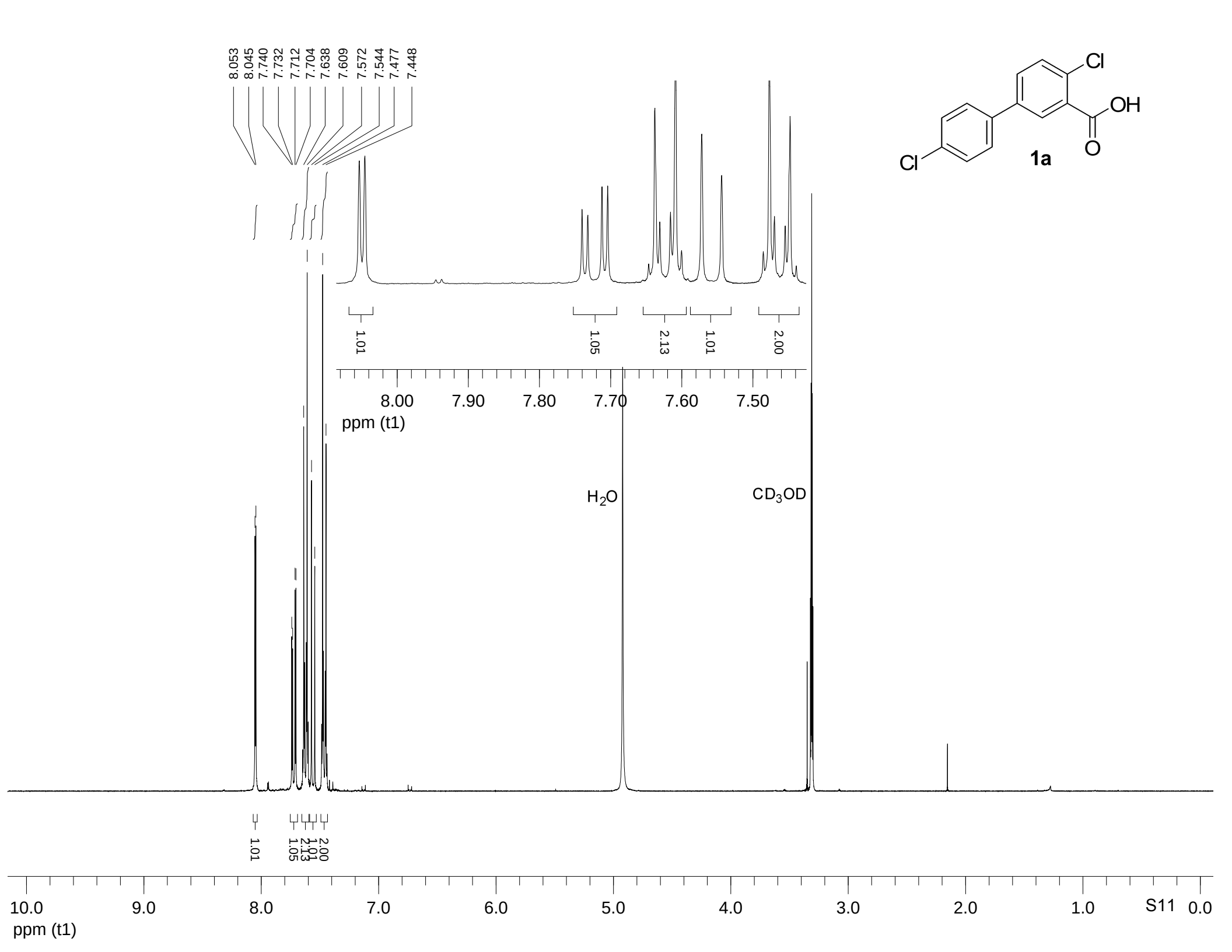
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7.609
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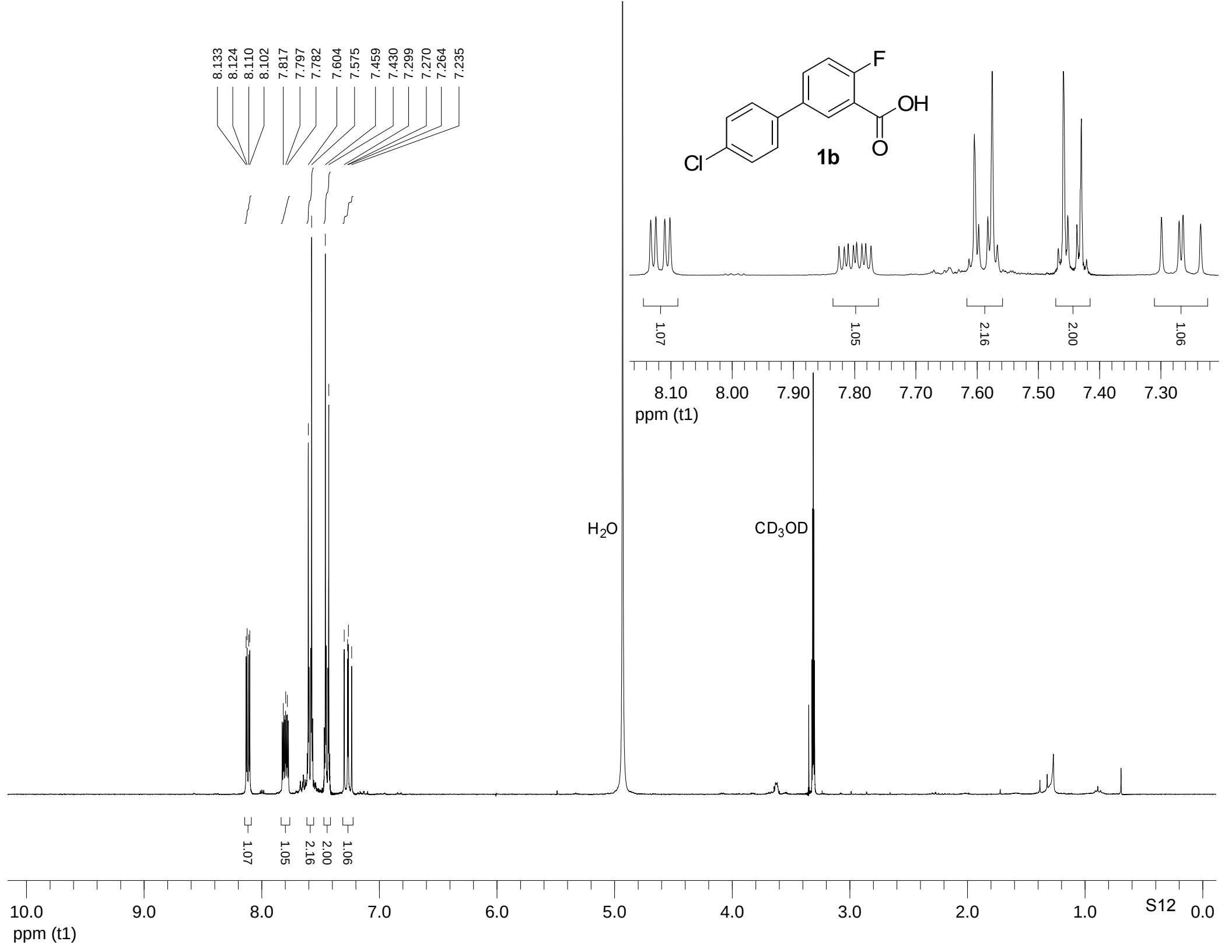
7.544
7.477
7.448
1.01
1.05
2.13
1.01
2.00
8.00
7.90
7.80
7.70
7.60
7.50
ppm (t1)
H2O
CD3OD
Cl
OH
O
Cl
1a
1.01
1.05
2.13
1.01
2.00
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ppm (t1)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7.270
7.264
7.235
F
OH
O
Cl
1b
1.07
1.05
2.16
2.00
1.06
8.10
8.00
7.90
7.80
7.70
7.60
7.50
7.40
7.30
ppm (t1)
H2O
CD3OD
1.07
1.05
2.16
2.00
1.06
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9.0
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6.0
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4.0
3.0
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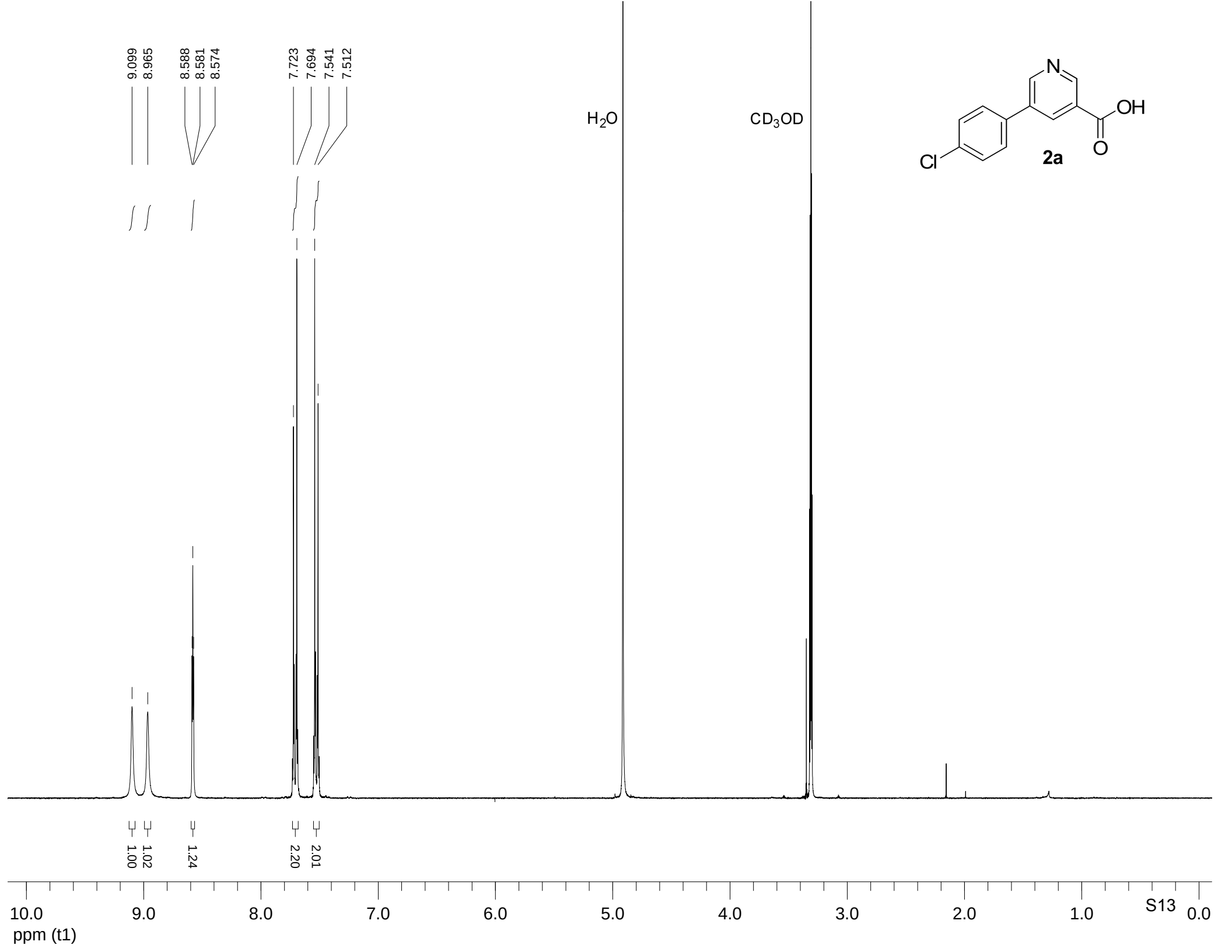
ppm (t1)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N
OH
O
Cl
2a
1.00
1.02
1.24
2.20
2.01
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8.0
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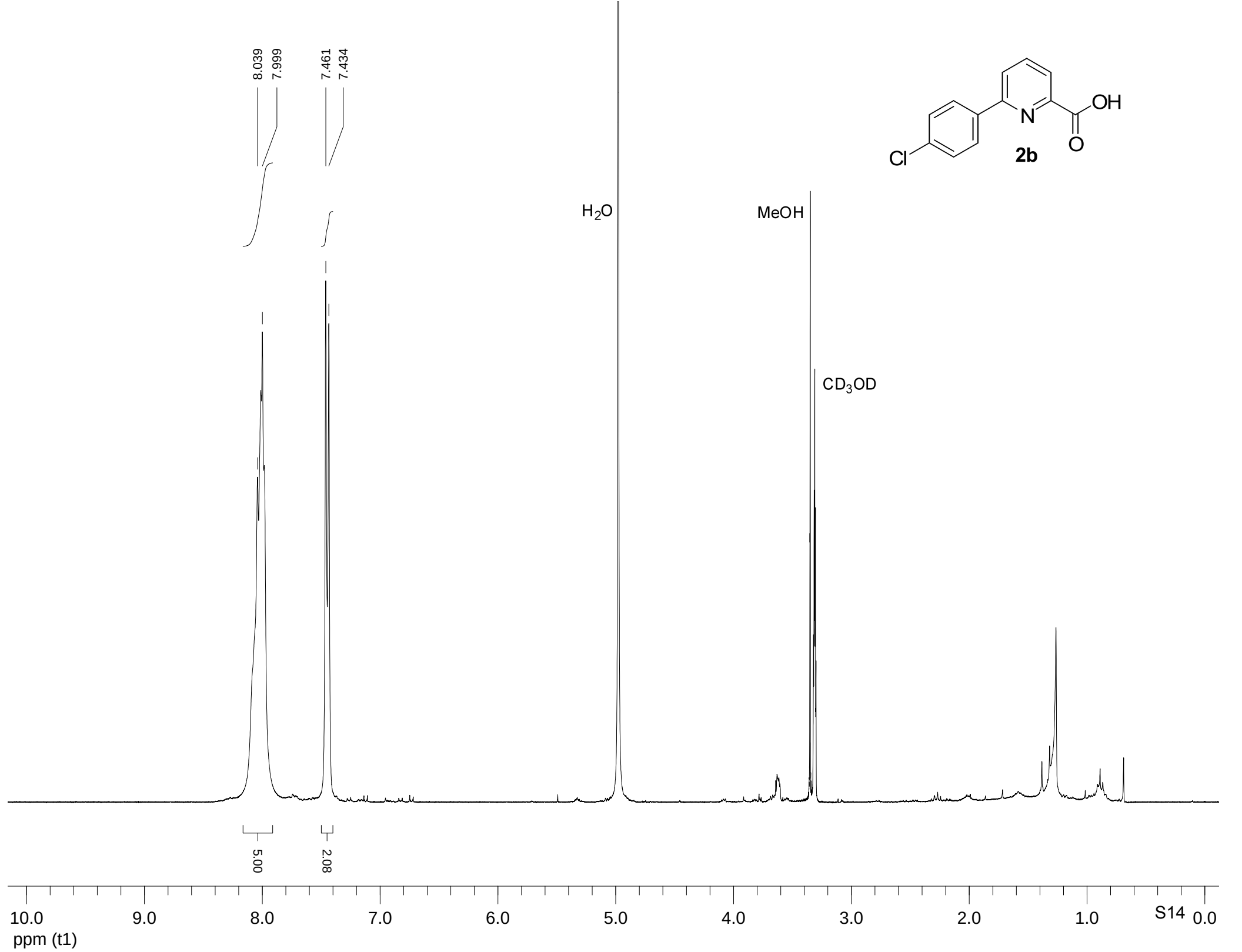
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ppm (t1)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CD3OD
Cl
N
OH
O
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7.0
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5.0
4.0
3.0
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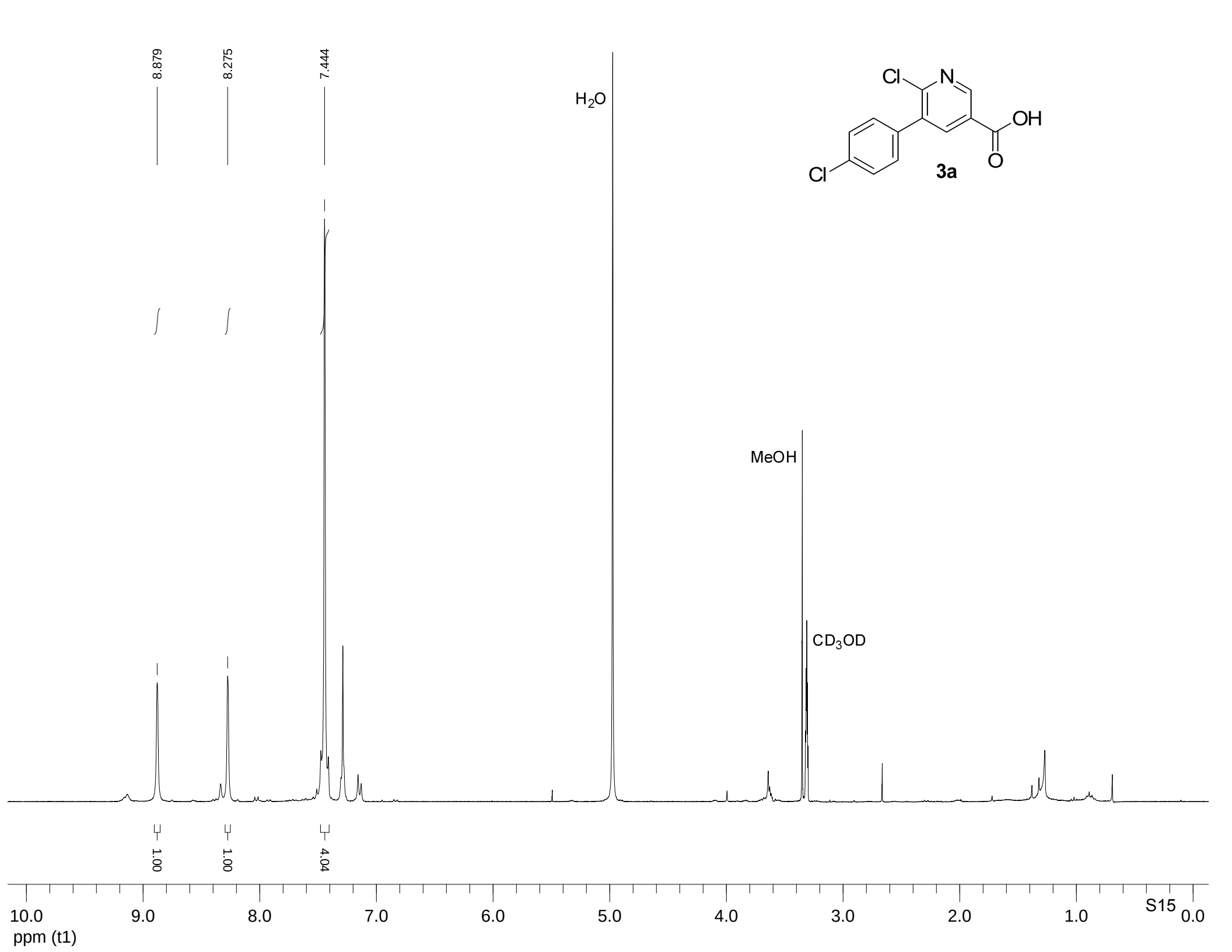
0.0
ppm (t1)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OH
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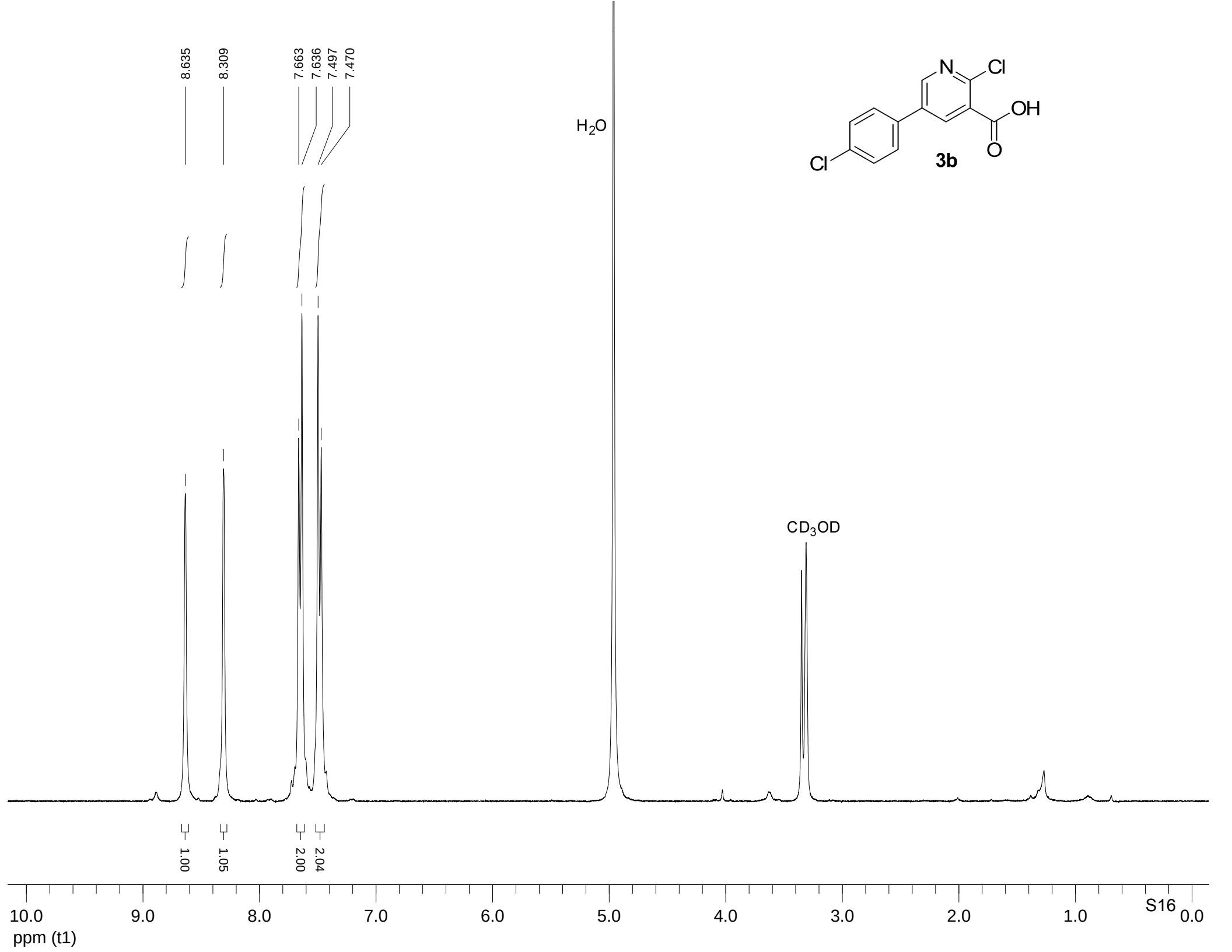
ppm (t1)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OH
O
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3b
1.00
1.05
2.00
2.04
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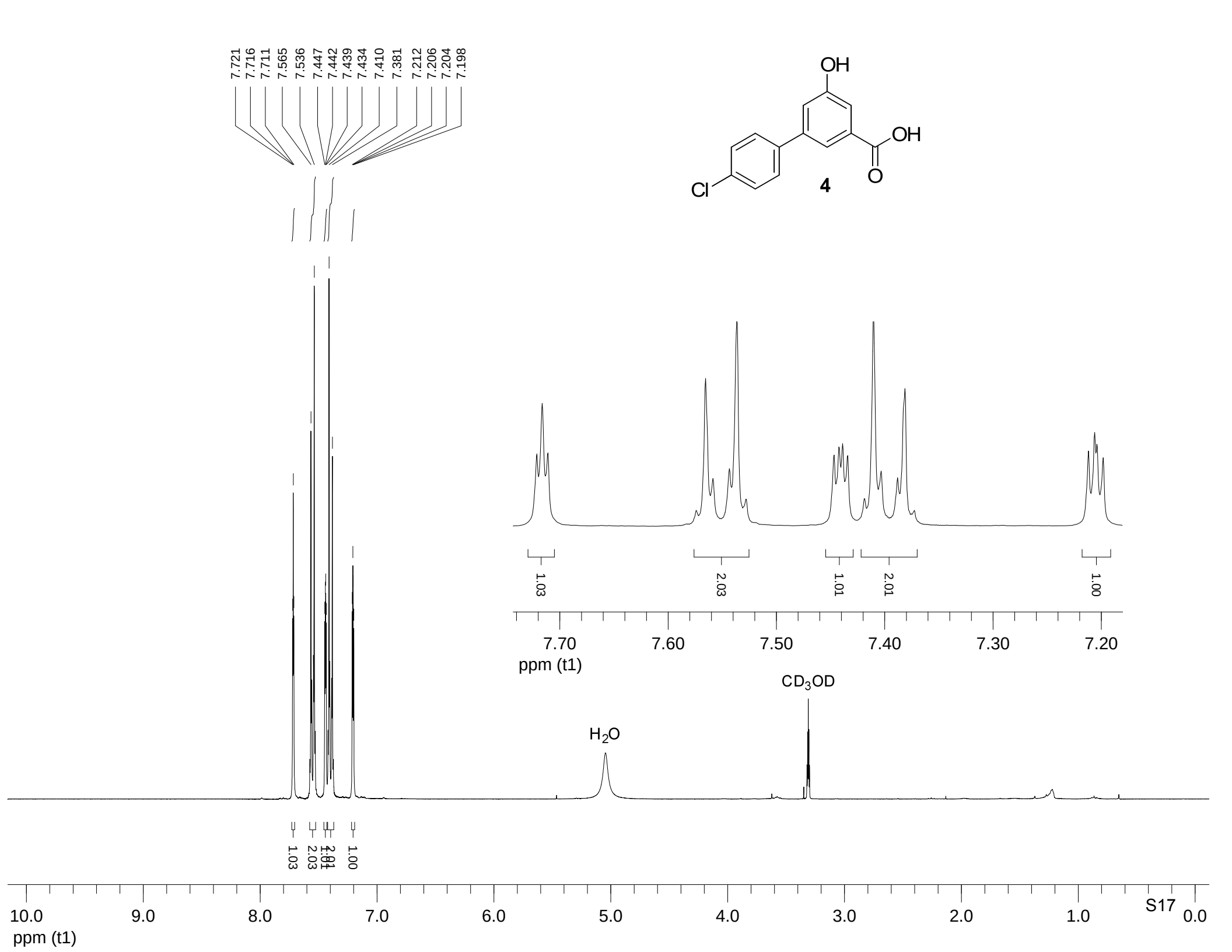
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ppm (t1)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7.206
7.204
7.198
OH
OH
O
Cl
4
1.03
2.03
1.01
2.01
1.00
7.70
7.60
7.50
7.40
7.30
7.20
ppm (t1)
CD3OD
H2O
1.03
2.03
1.01
2.01
1.00
10.0
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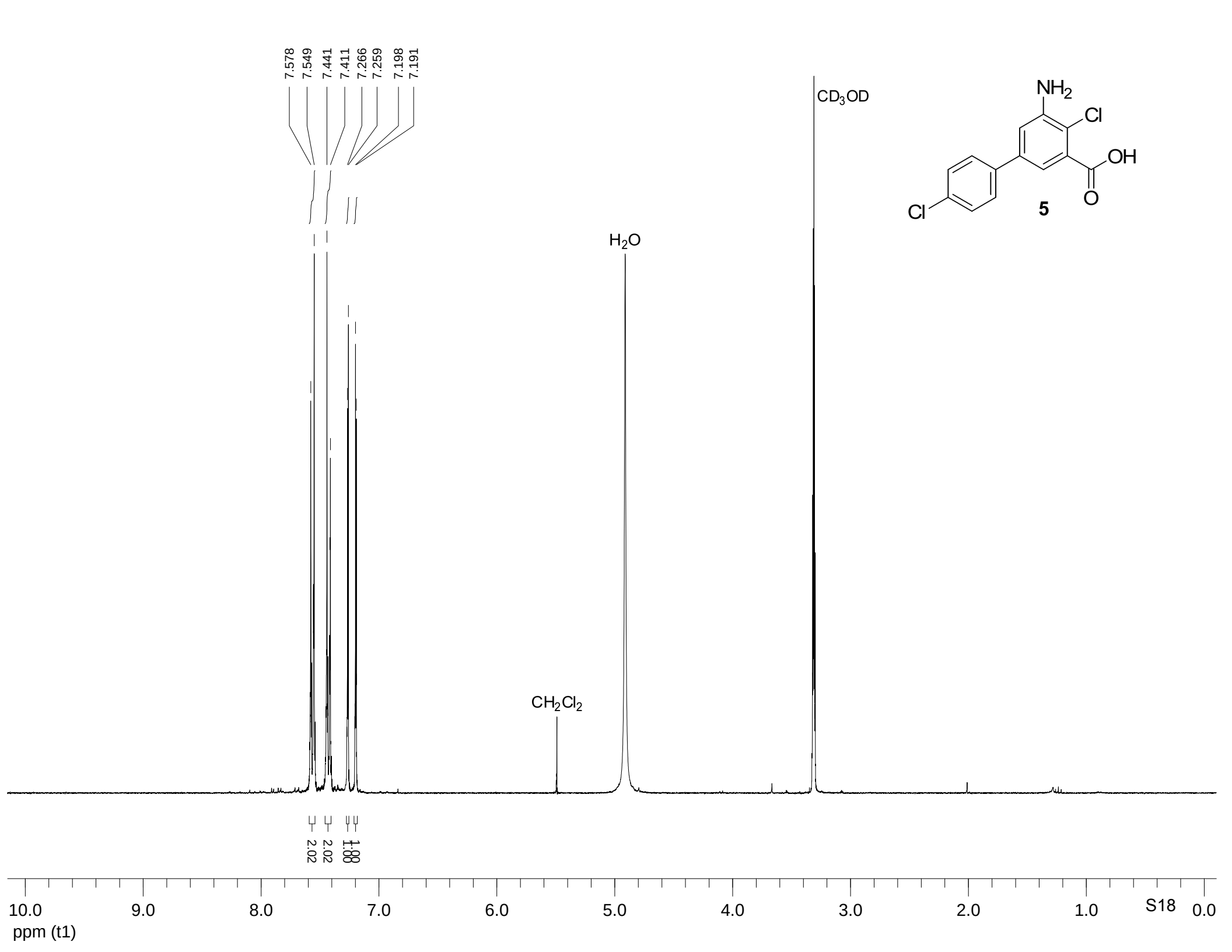
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ppm (t1)
S17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7.198
7.191
CD3OD
H2O
CH2Cl2
NH2
Cl
OH
O
Cl
5
2.02
2.02
1.00
1.00
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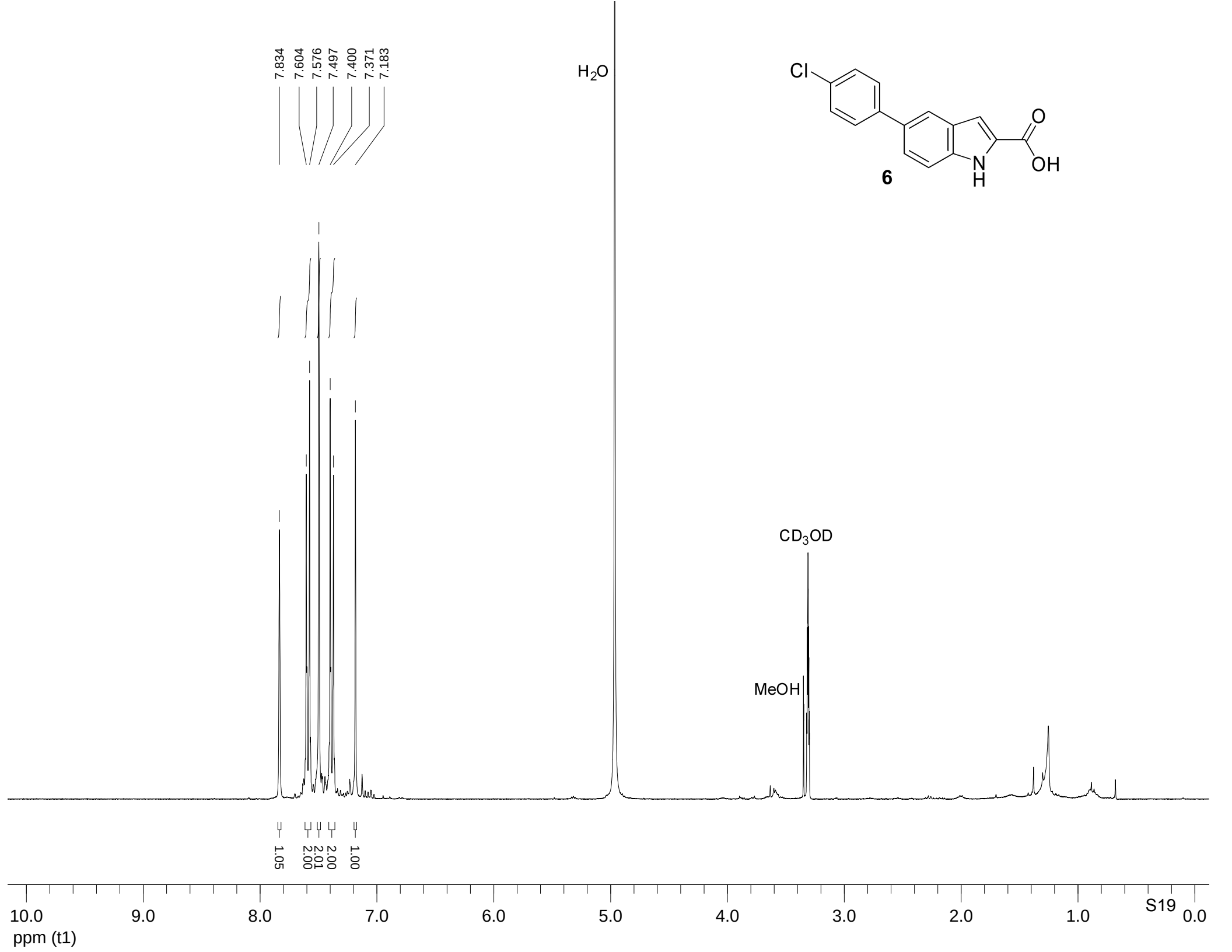
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ppm (t1)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H2O
Cl
O
OH
N
H
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CD3OD
MeOH
1.05
2.00
2.01
2.00
1.00
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6.0
5.0
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2.0
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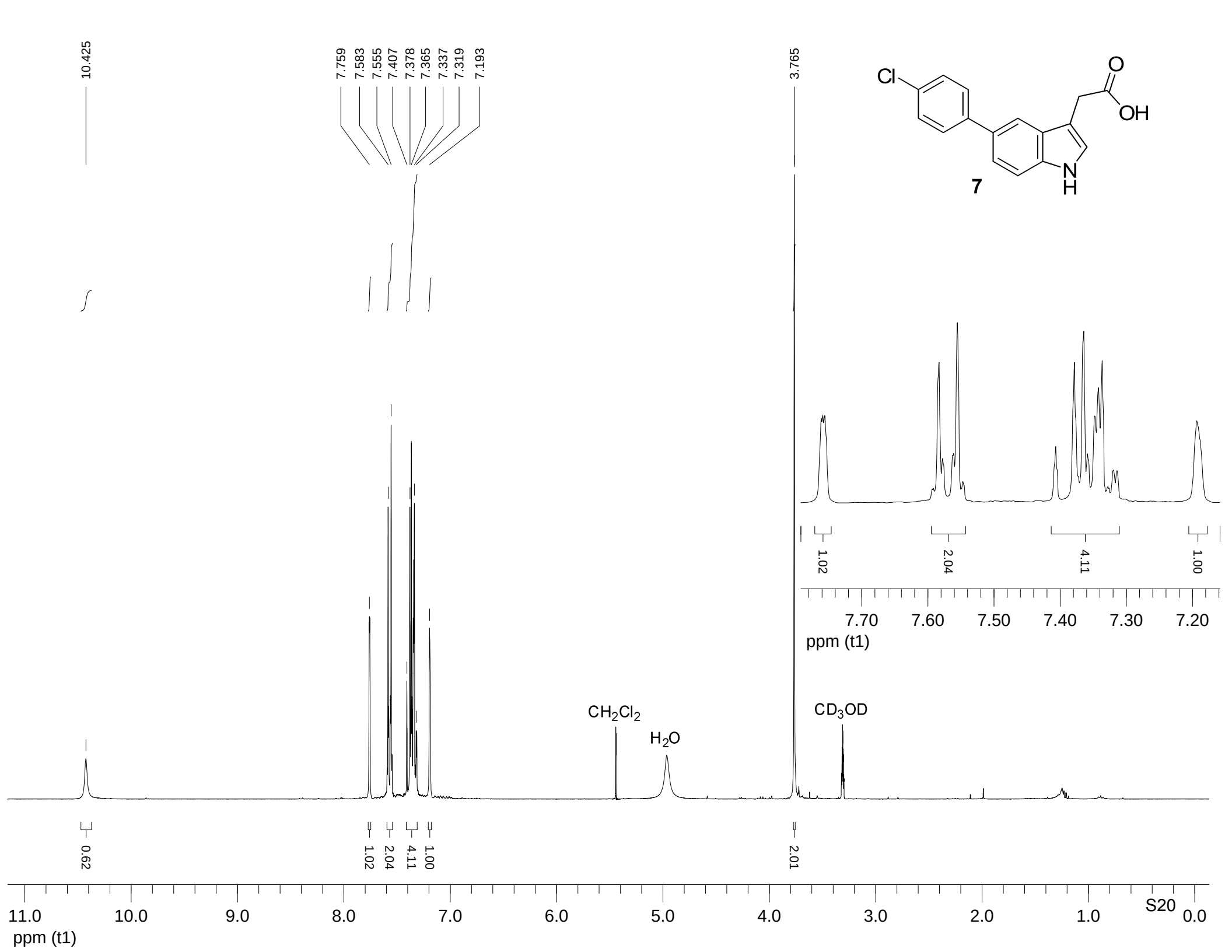
0.0
ppm (t1)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OH
N
H
7
1.02
2.04
4.11
1.00
7.70
7.60
7.50
7.40
7.30
7.20
ppm (t1)
CH2Cl2
H2O
CD3OD
0.62
1.02
2.04
4.11
1.00
2.01
11.0
10.0
9.0
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6.0
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4.0
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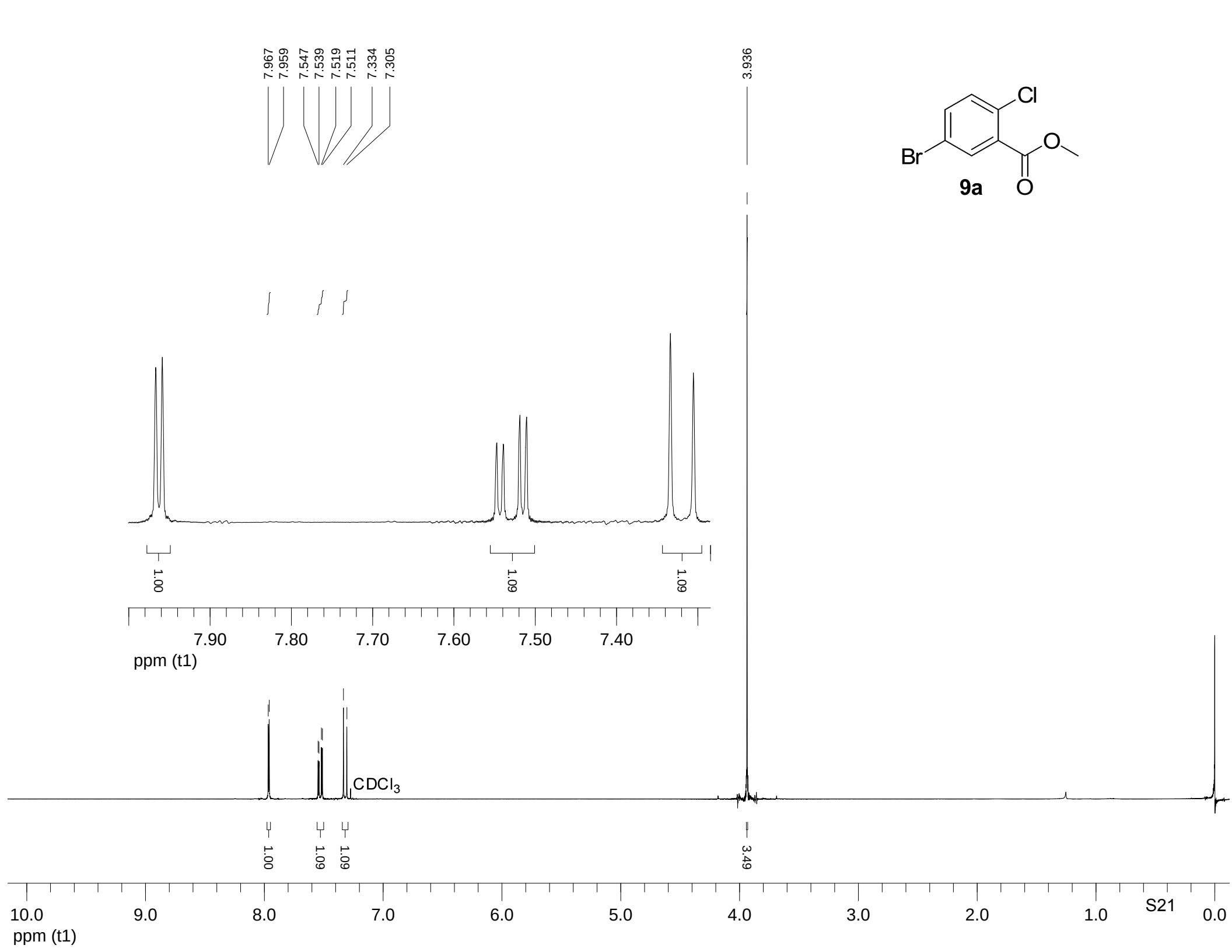
2.0
1.0
0.0
ppm (t1)
S20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7.305
3.936
Cl
Br
O
O
9a
1.00
1.09
1.09
7.90
7.80
7.70
7.60
7.50
7.40
ppm (t1)
CDCl3
1.00
1.09
1.09
3.49
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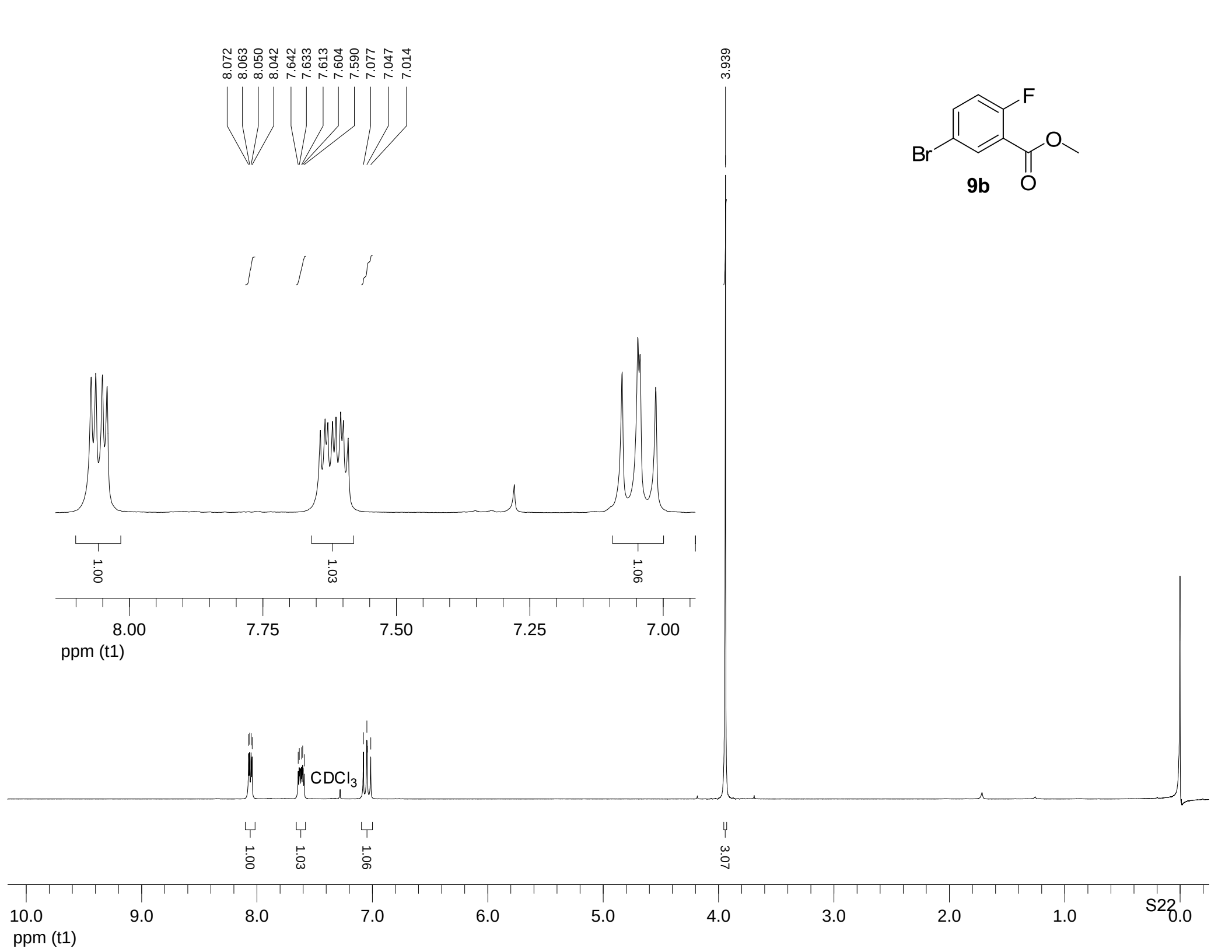
0.0
ppm (t1)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Br
O
O
9b
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1.03
1.06
8.00
7.75
7.50
7.25
7.00
ppm (t1)
CDCl3
1.00
1.03
1.06
3.07
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7.0
6.0
5.0
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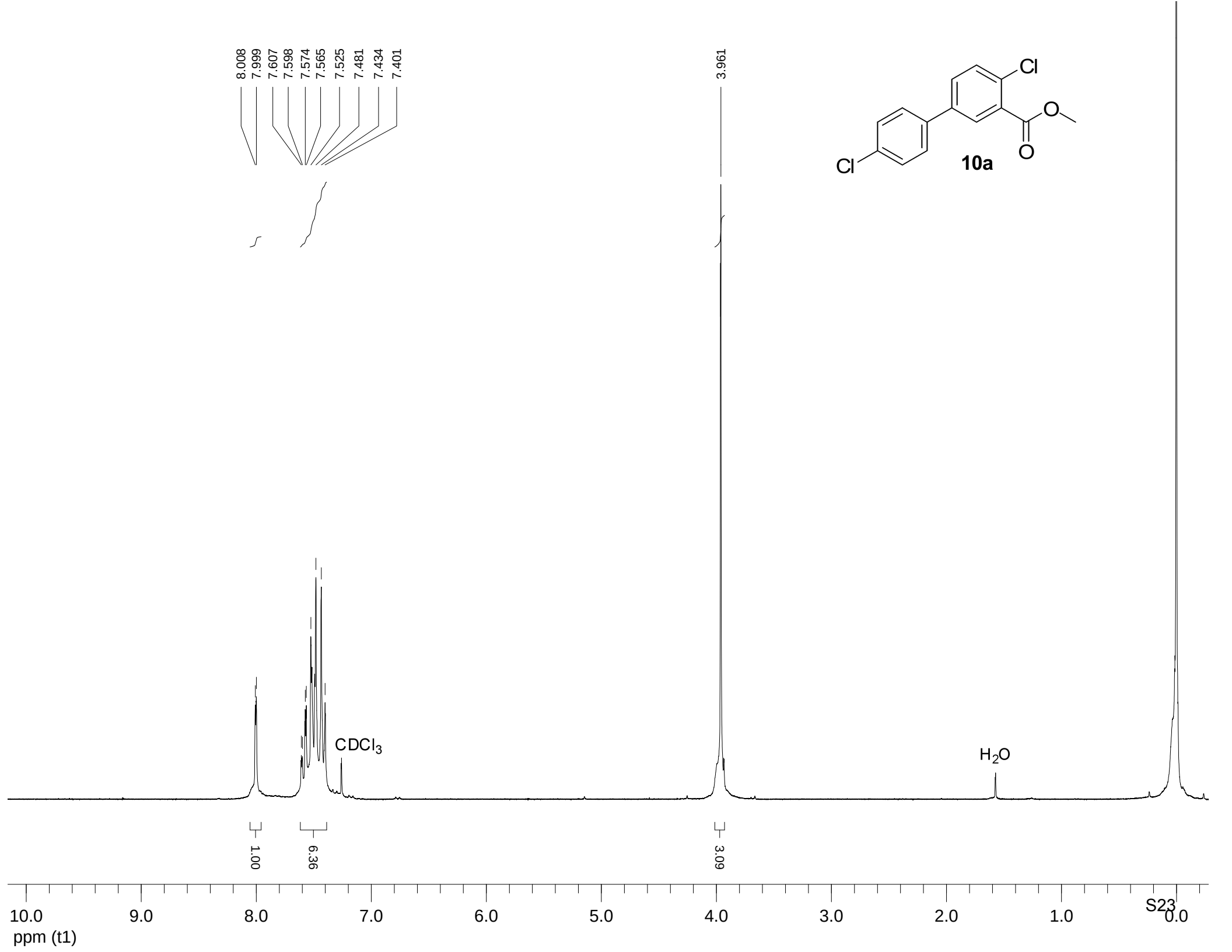
2.0
1.0
0.0
ppm (t1)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7.401
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O
O
Cl
10a
CDCl3
H2O
1.00
6.39
3.09
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7.0
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5.0
4.0
3.0
2.0
1.0
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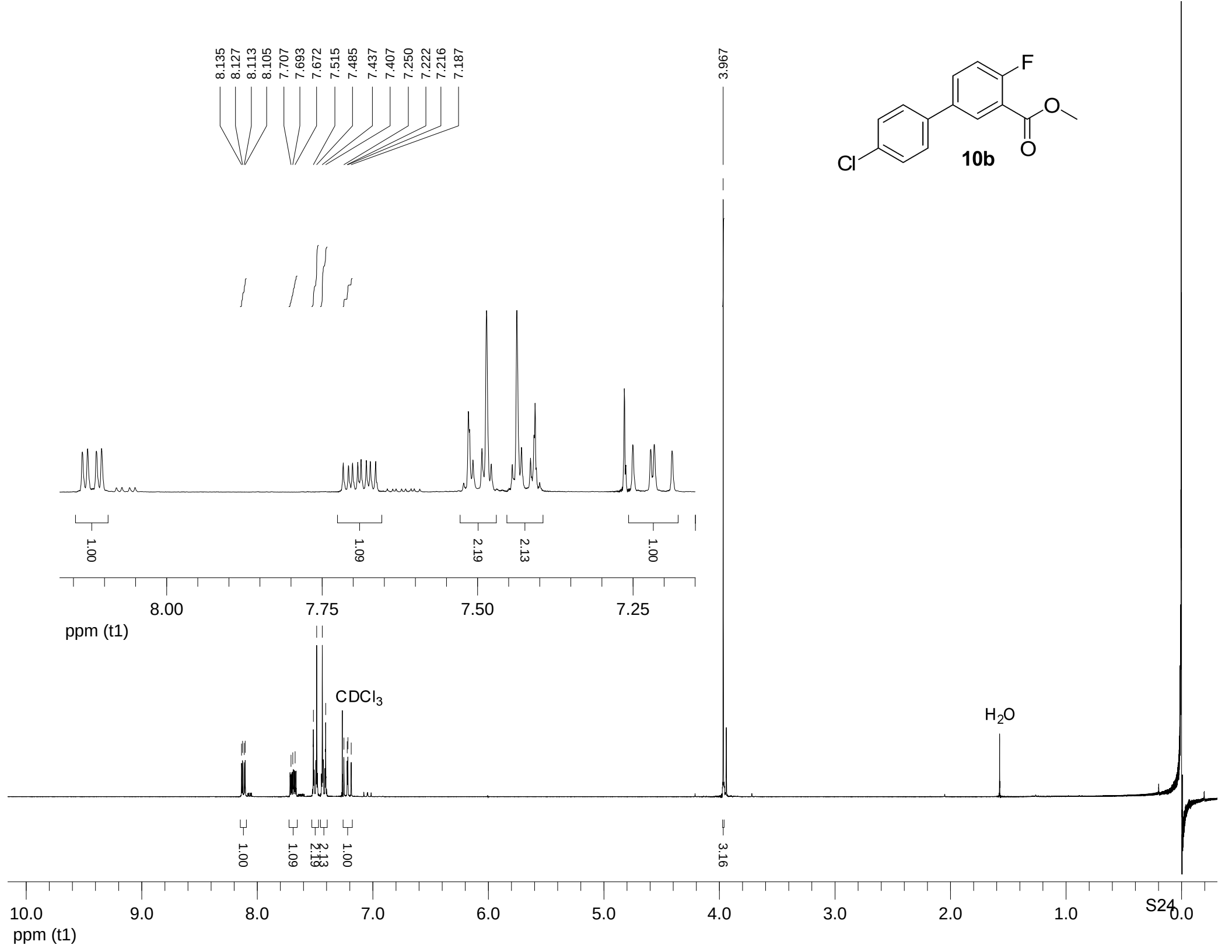
ppm (t1)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7.216
7.187
3.967
F
O
O
Cl
10b
1.00
1.09
2.19
2.13
1.00
8.00
7.75
7.50
7.25
ppm (t1)
CDCl3
H2O
1.00
1.09
2.13
2.19
1.00
3.16
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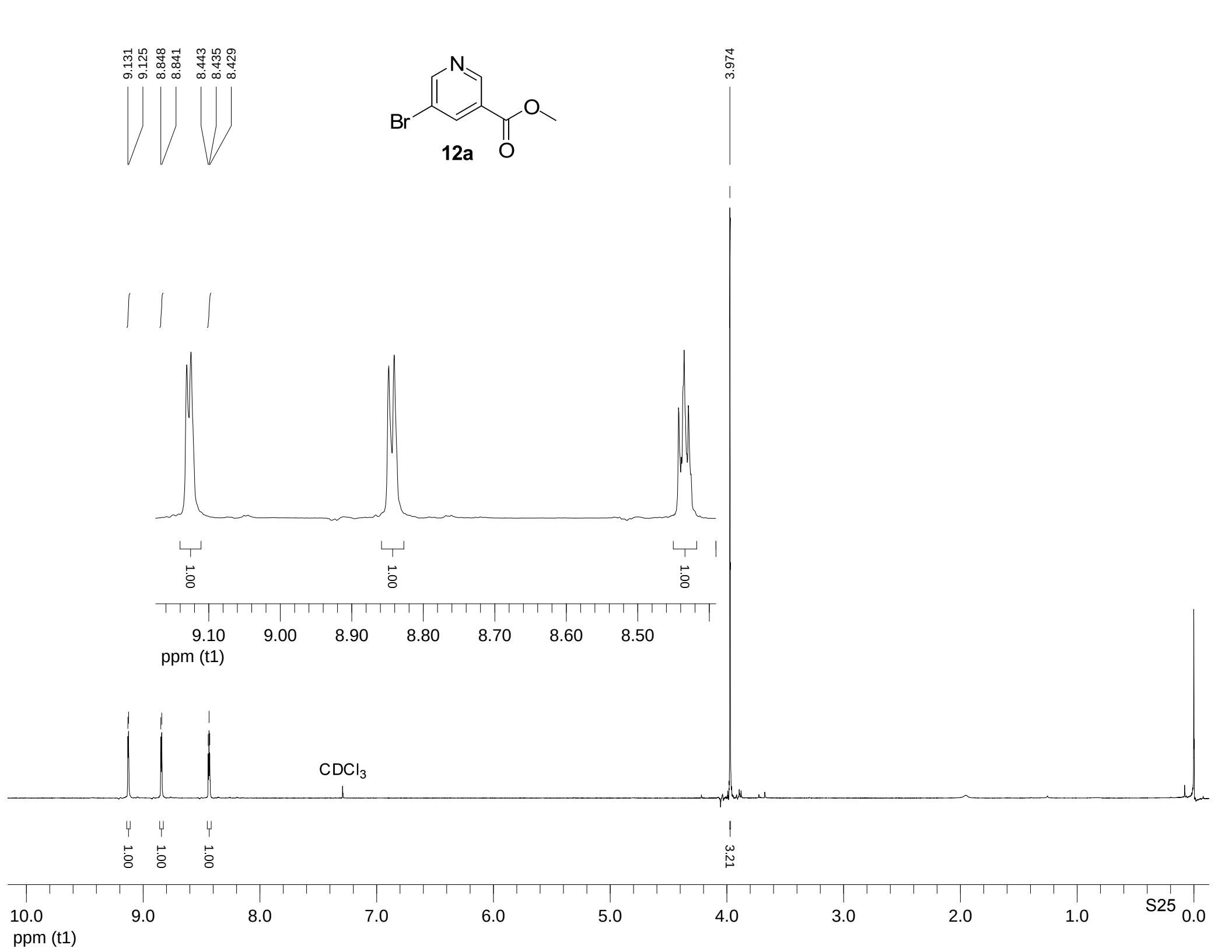
ppm (t1)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Br
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O
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1.00
1.00
1.00
9.10
9.00
8.90
8.80
8.70
8.60
8.50
ppm (t1)
CDCl3
1.00
1.00
1.00
3.21
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5.0
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1.0
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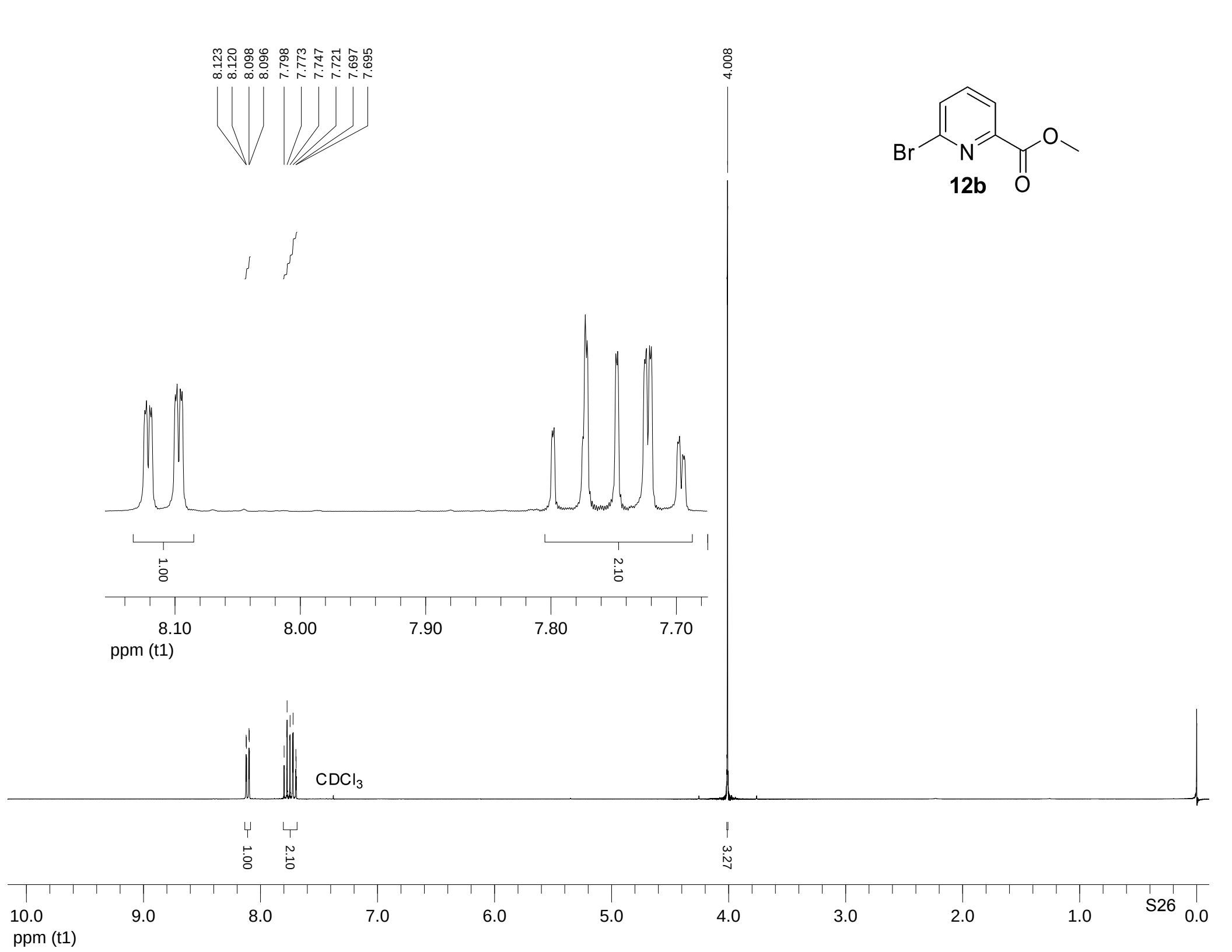
ppm (t1)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7.721
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7.695
4.008
Br
N
O
O
12b
1.00
2.10
8.10
8.00
7.90
7.80
7.70
ppm (t1)
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2.10
3.27
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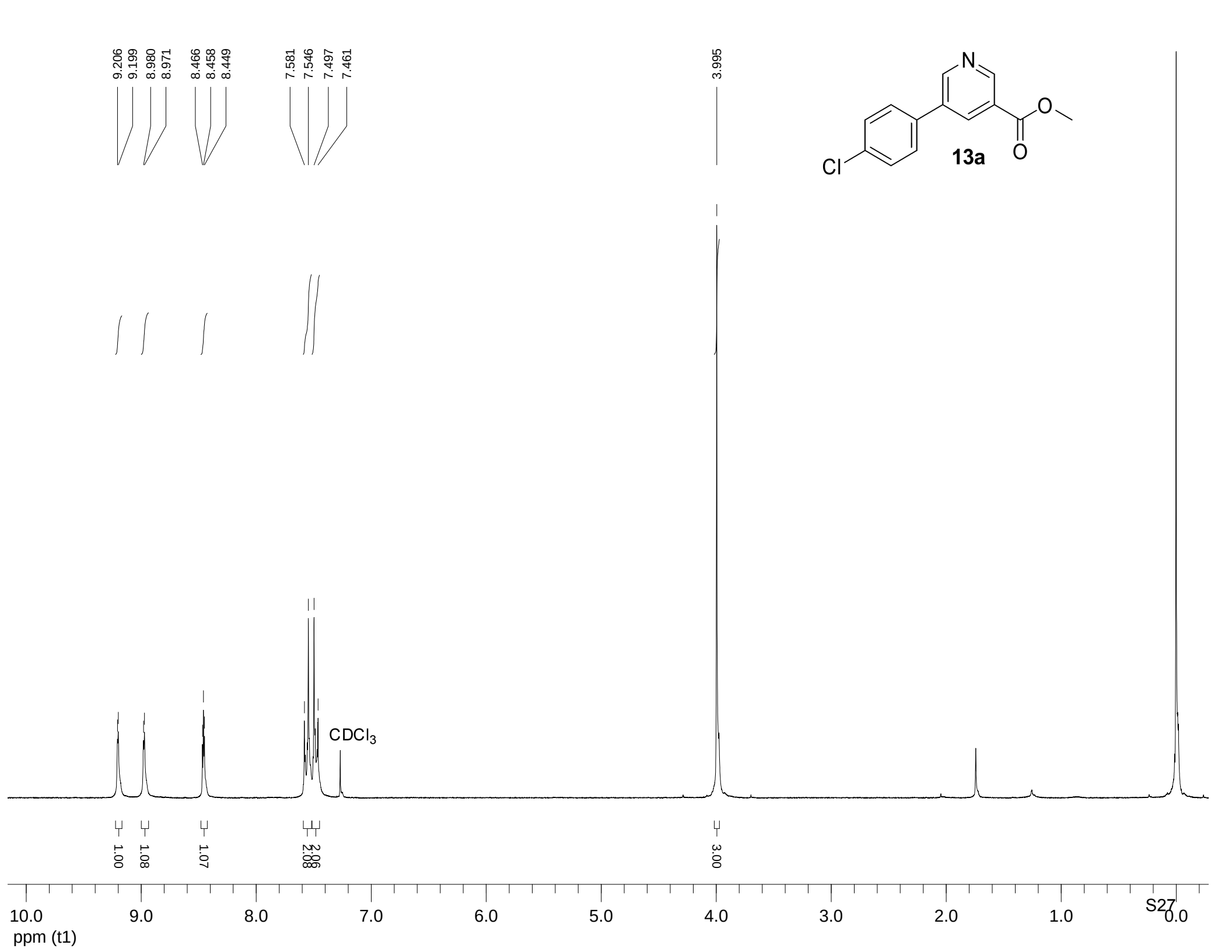
ppm (t1)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7.497
7.461
3.995
N
O
O
Cl
13a
CDCl3
1.00
1.08
1.07
2.08
2.06
3.00
10.0
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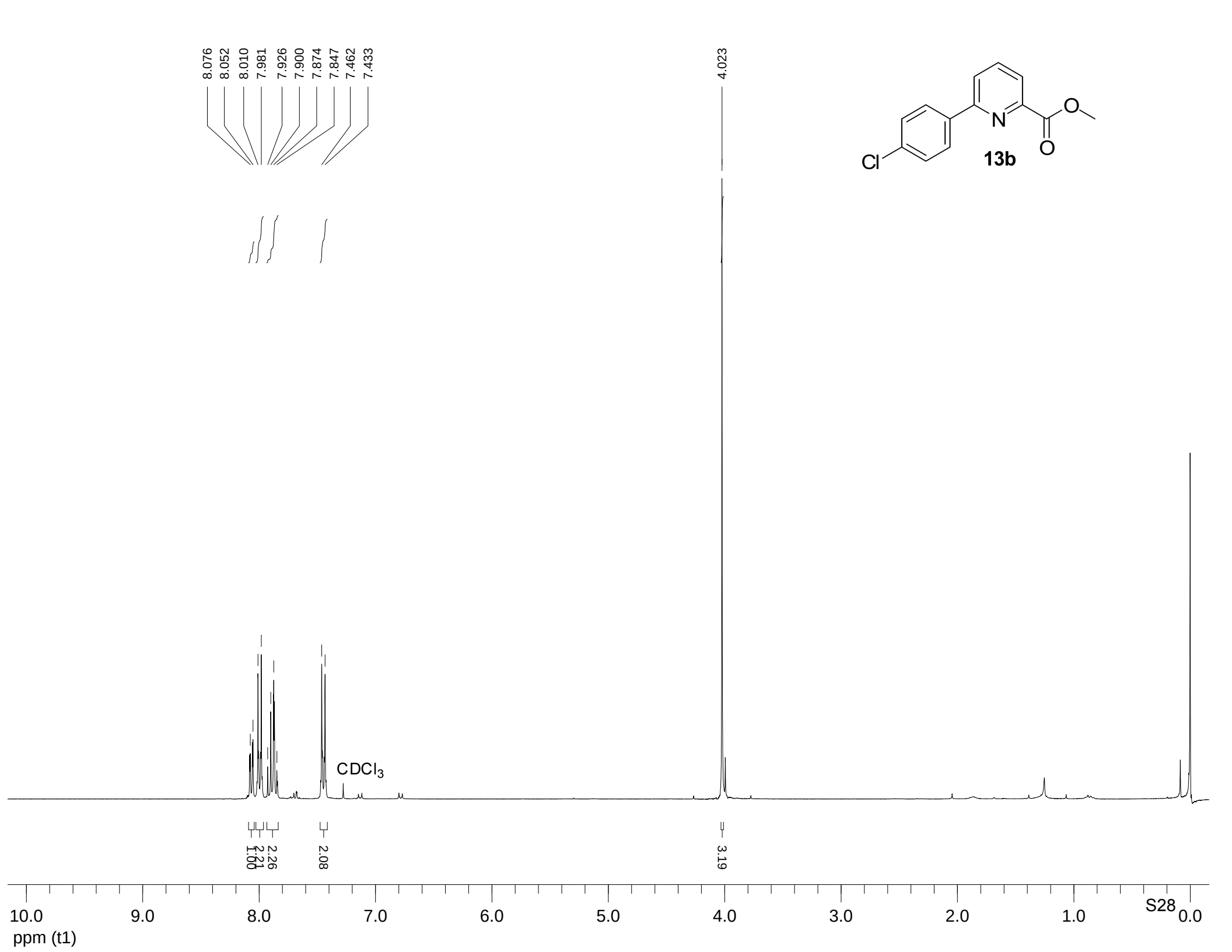
ppm (t1)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O
O
13b
CDCl3
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2.26
2.08
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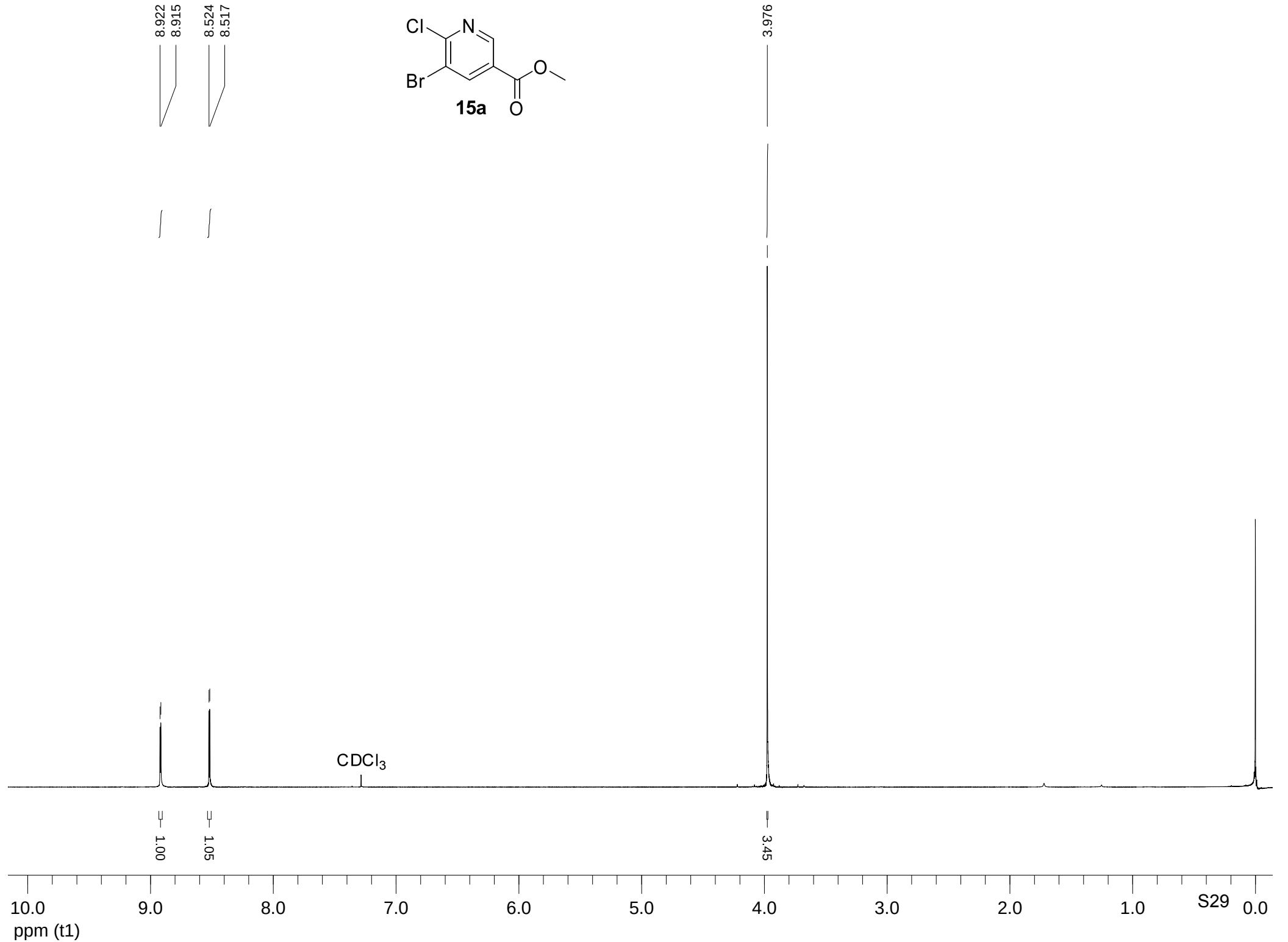
ppm (t1)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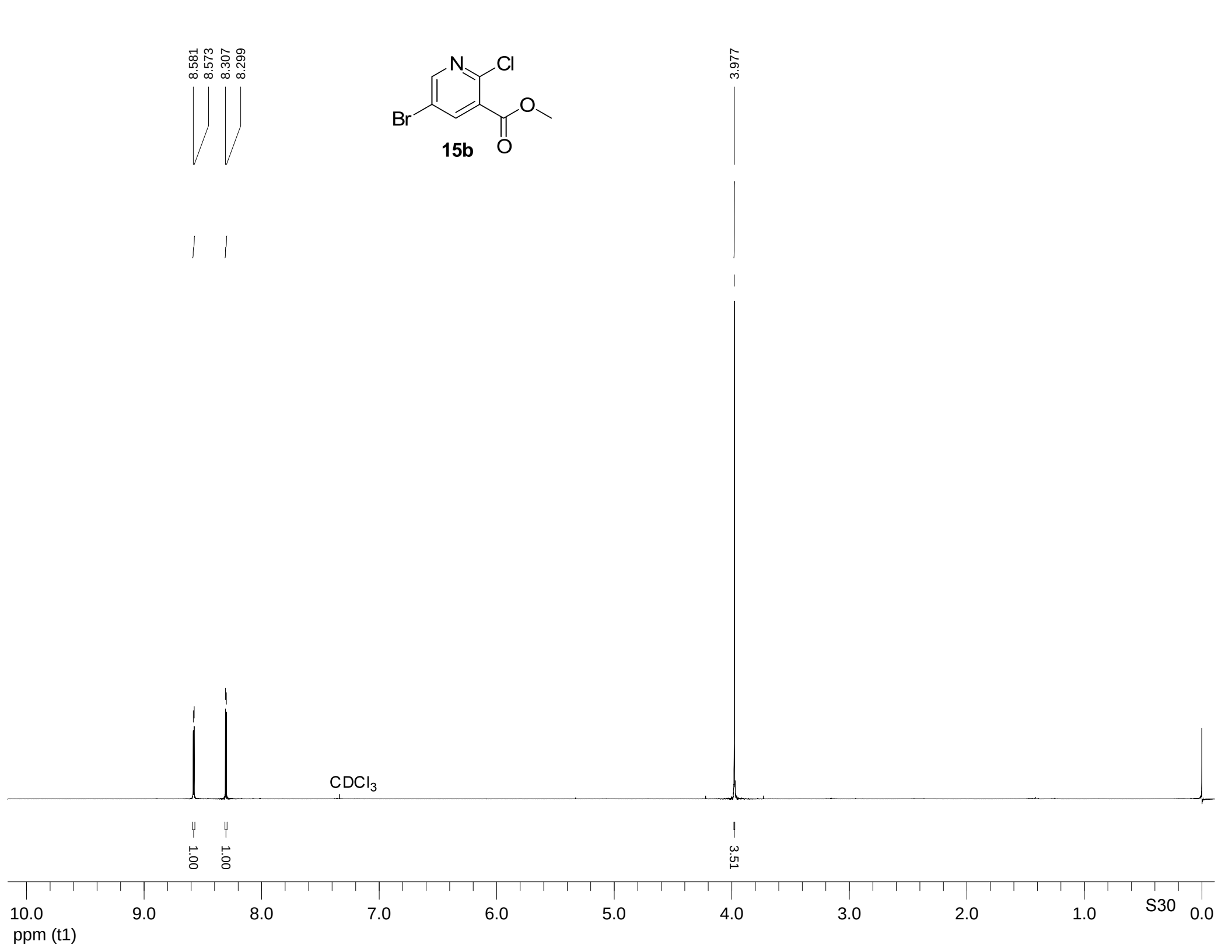
ppm (t1)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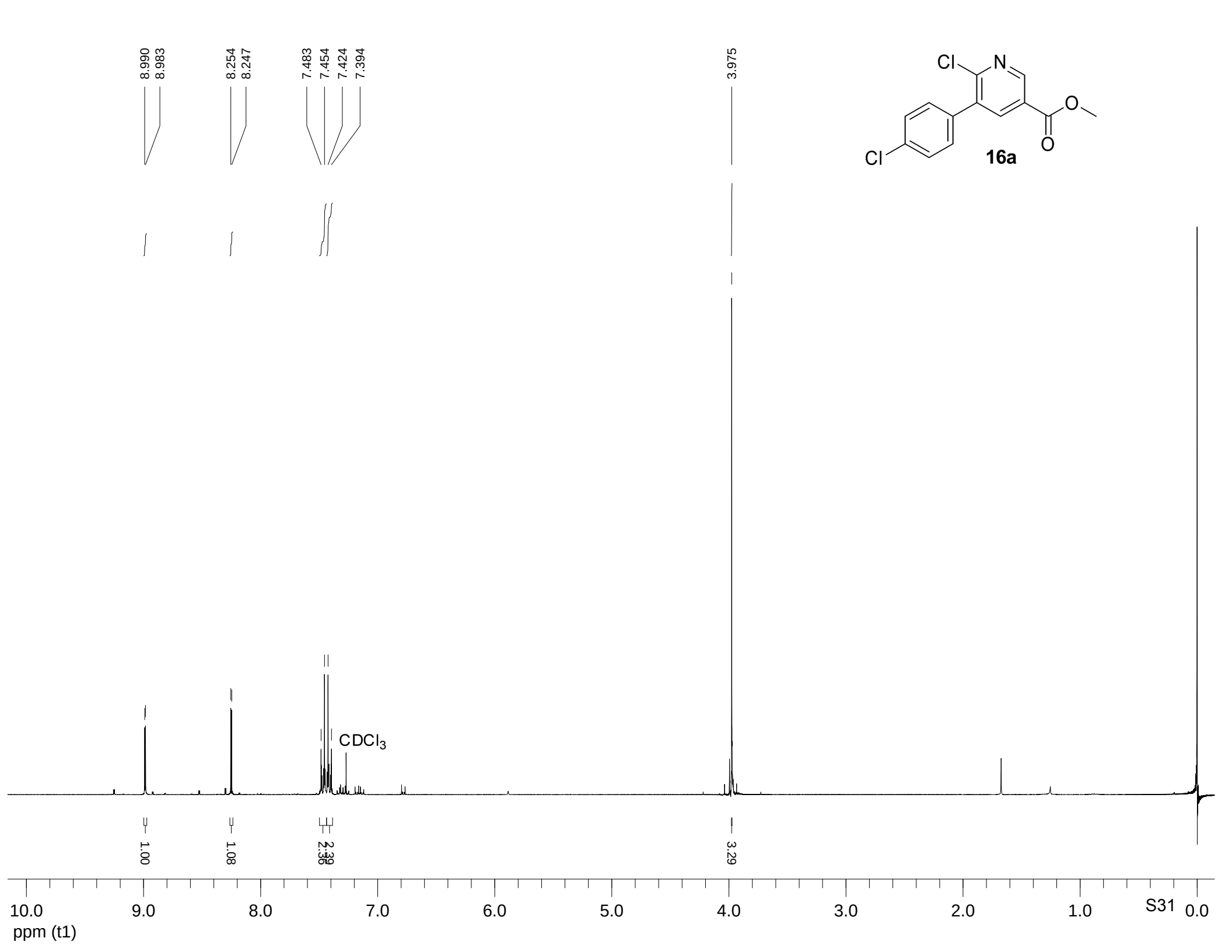
ppm (t1)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O
O
Cl
16a
CDCl3
1.00
1.08
2.39
3.29
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2.0
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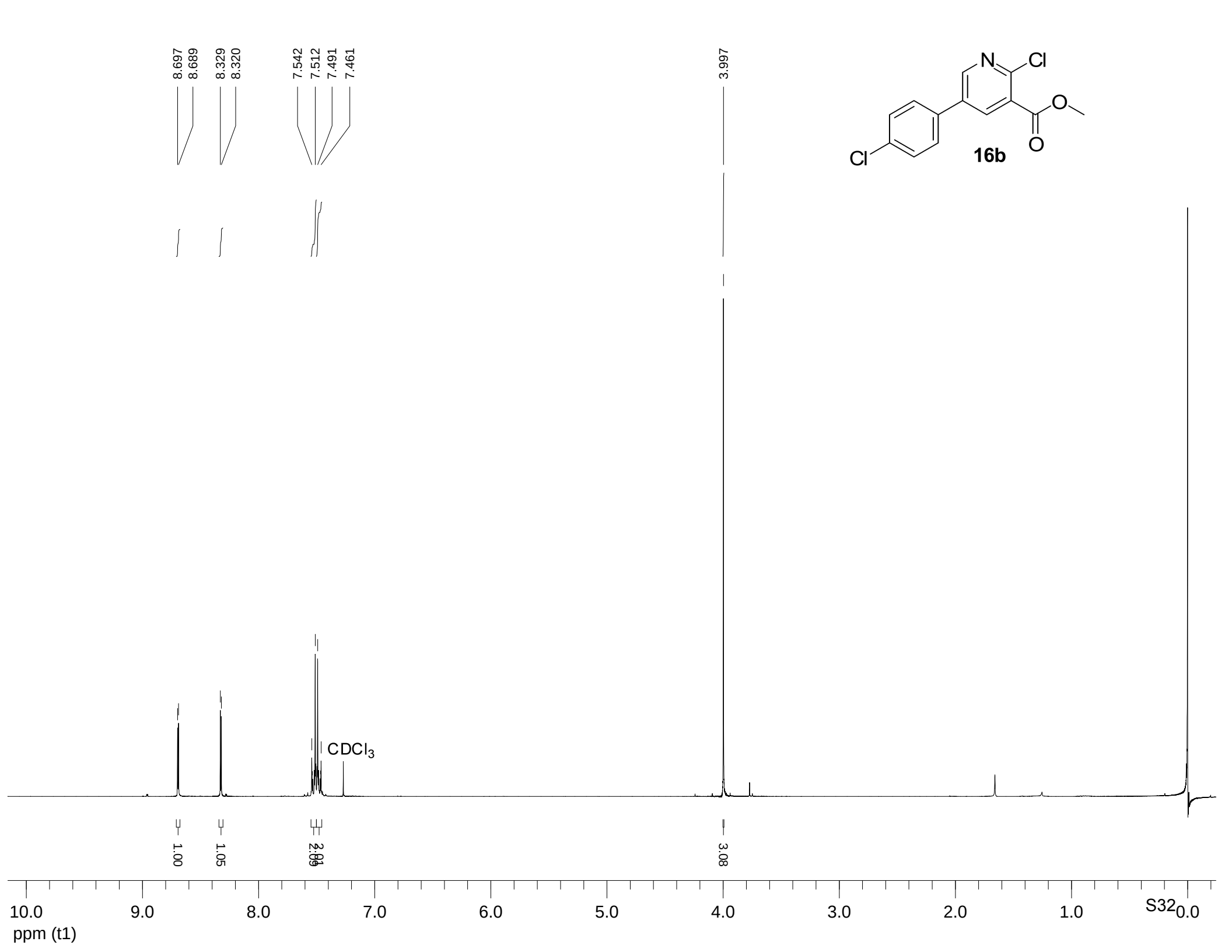
ppm (t1)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Cl
16b
CDCl3
1.00
1.05
2.09
3.08
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2.0
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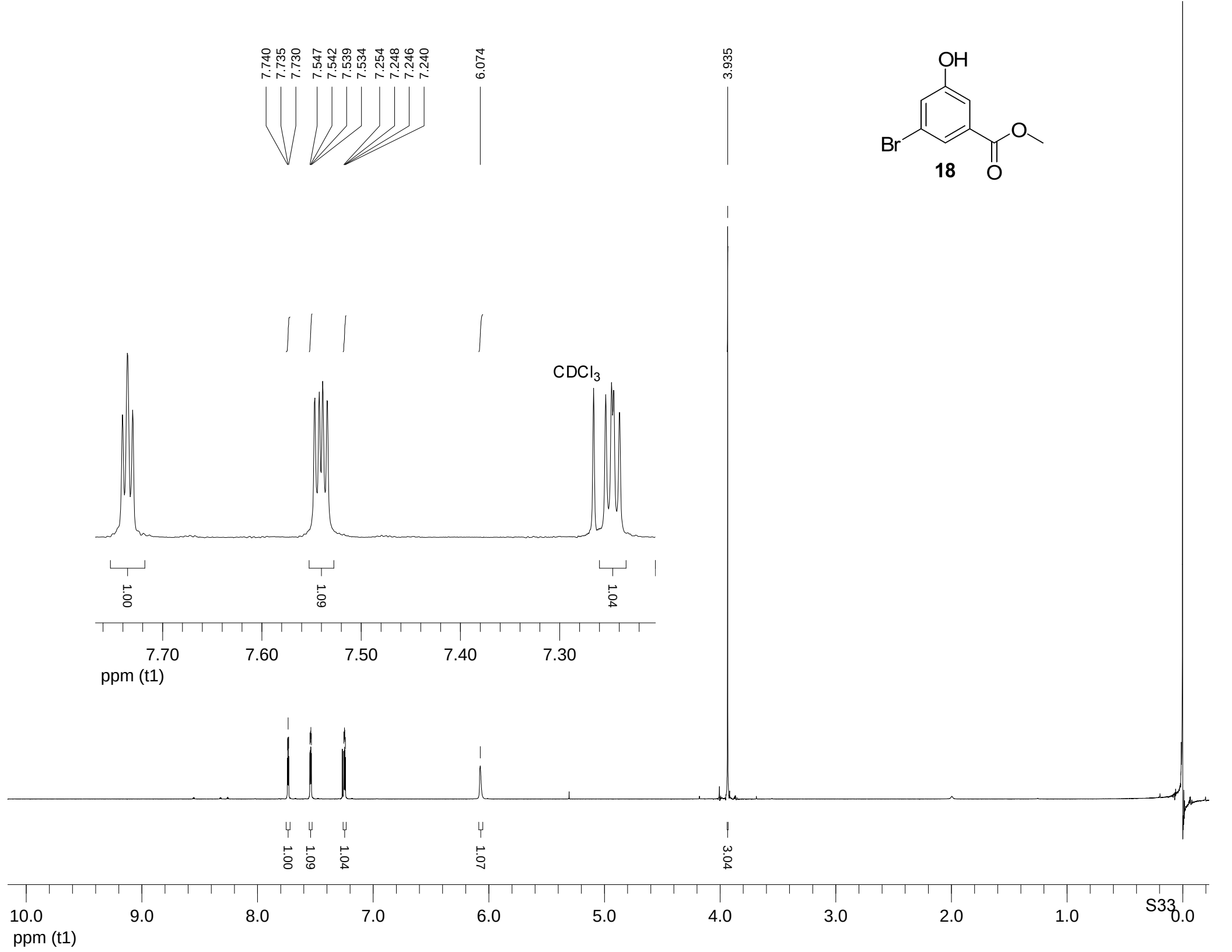
0.0
ppm (t1)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7.246
7.240
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3.935
OH
Br
O
O
18
CDCl3
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1.09
1.04
7.70
7.60
7.50
7.40
7.30
ppm (t1)
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1.07
3.04
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5.0
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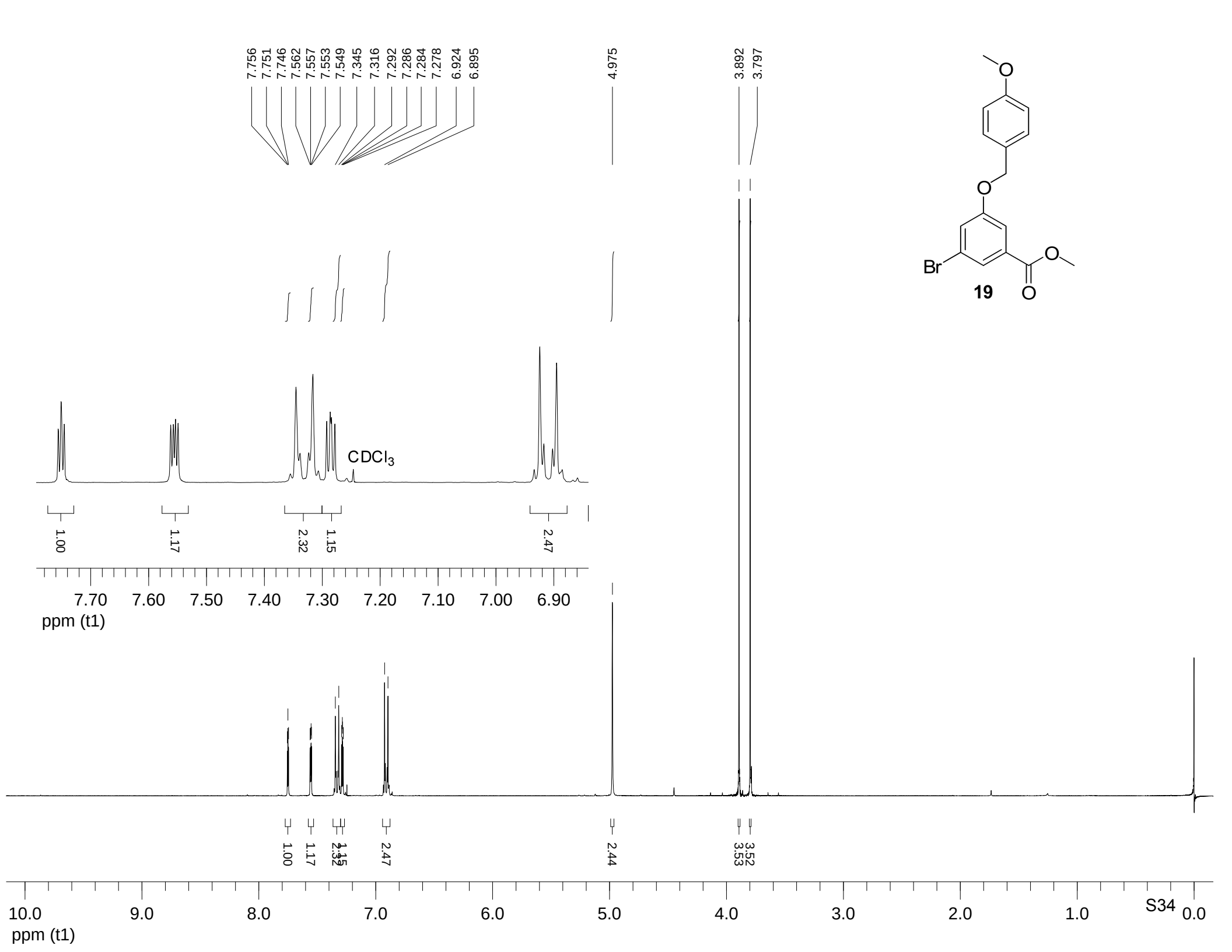
ppm (t1)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7.292
7.286
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7.278
6.924
6.895
4.975
3.892
3.797
CDCl3
1.00
1.17
2.32
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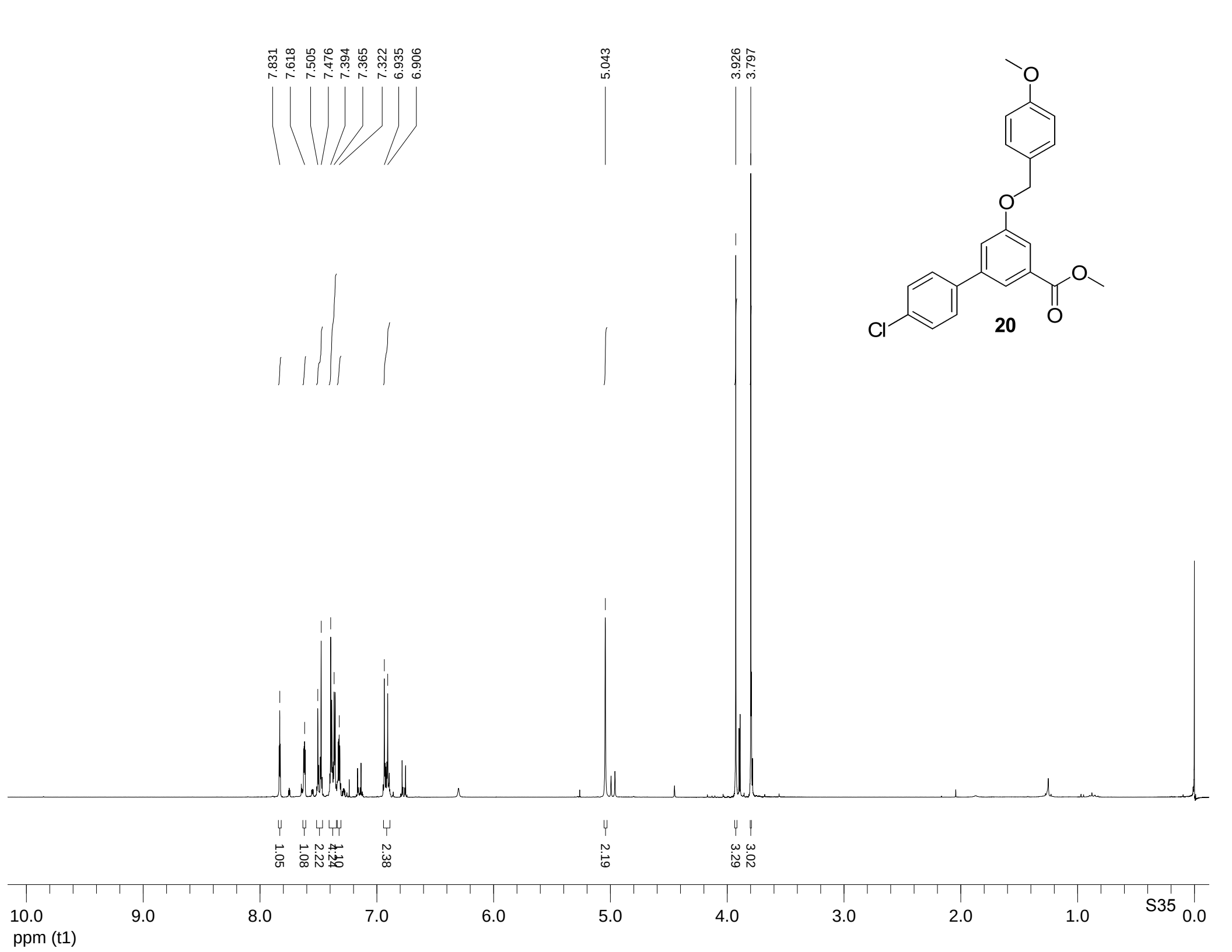
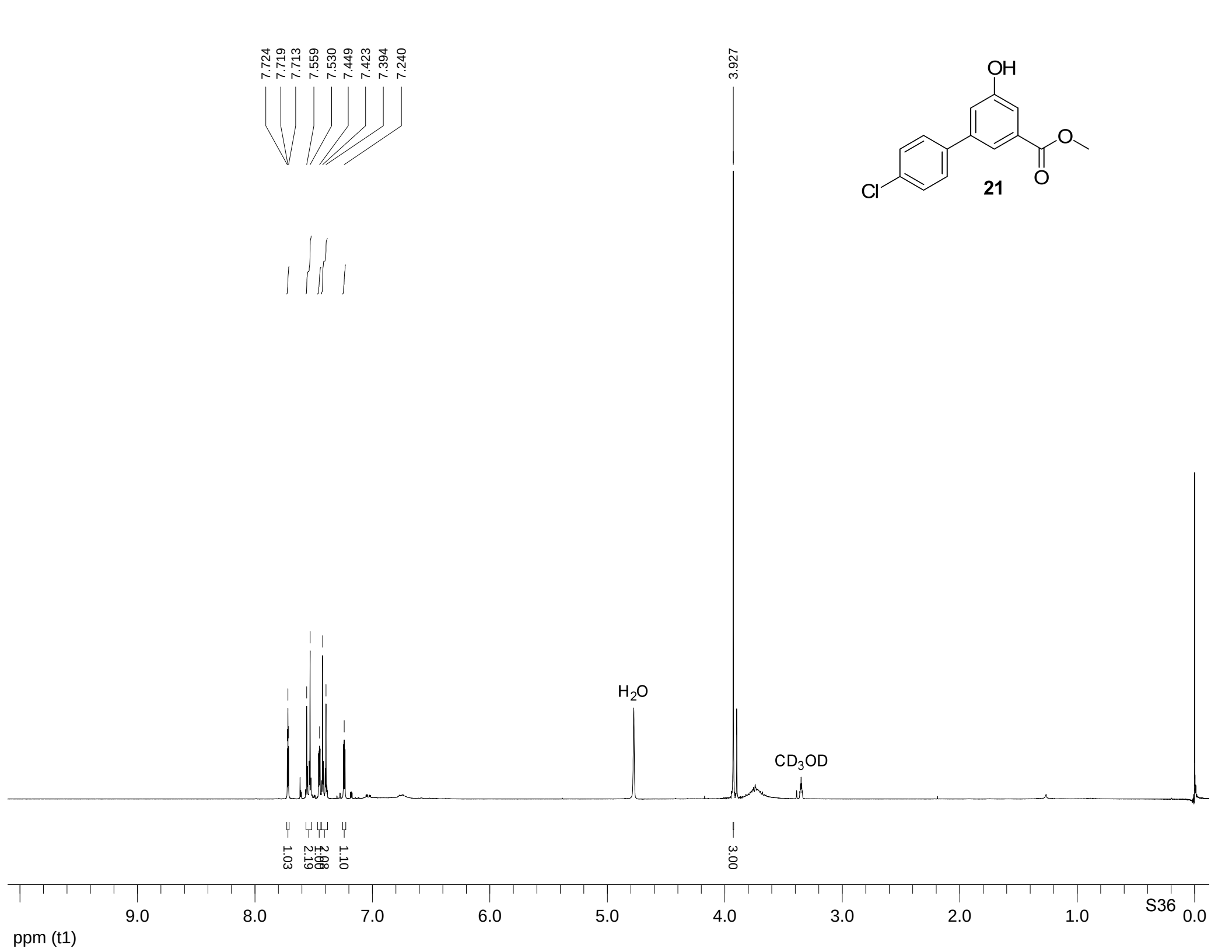
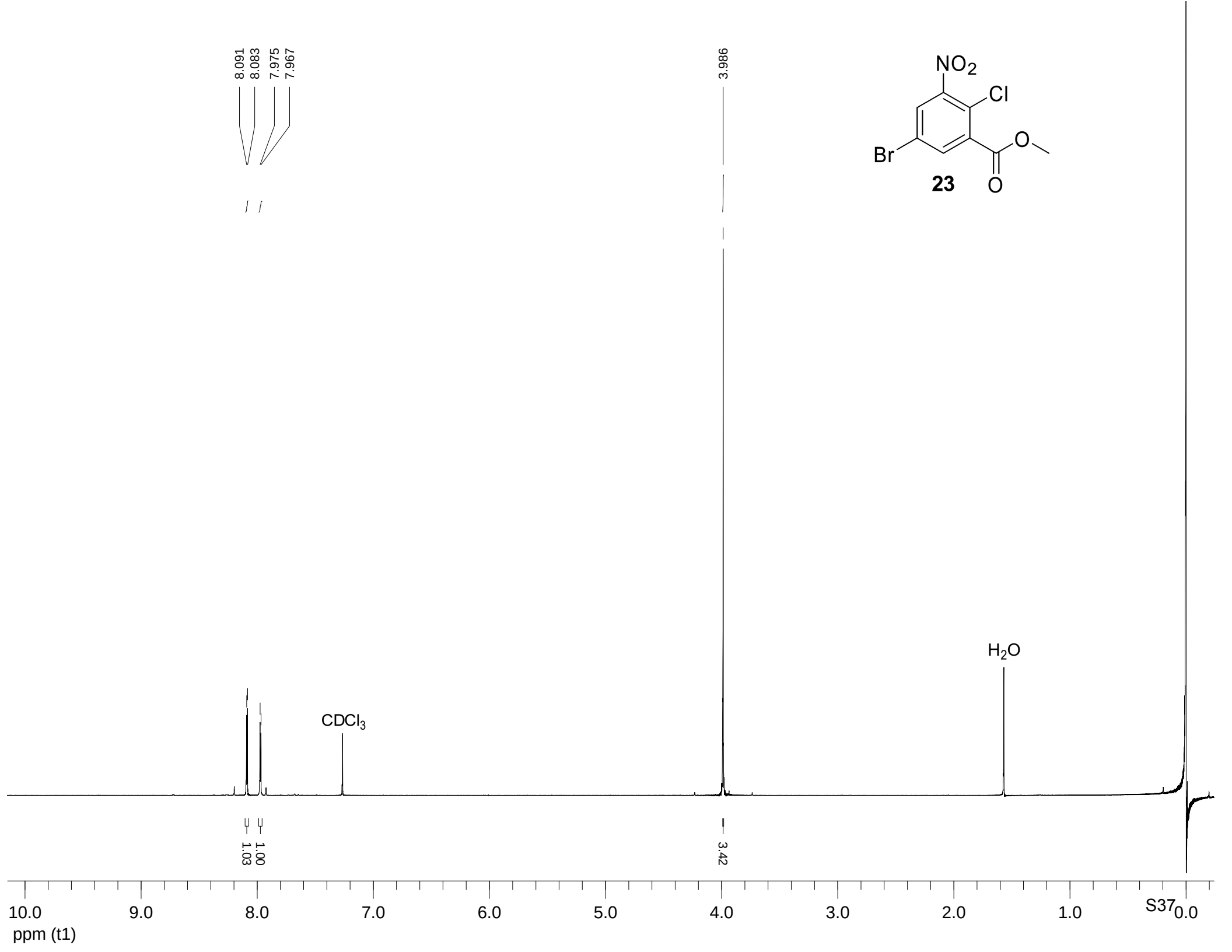
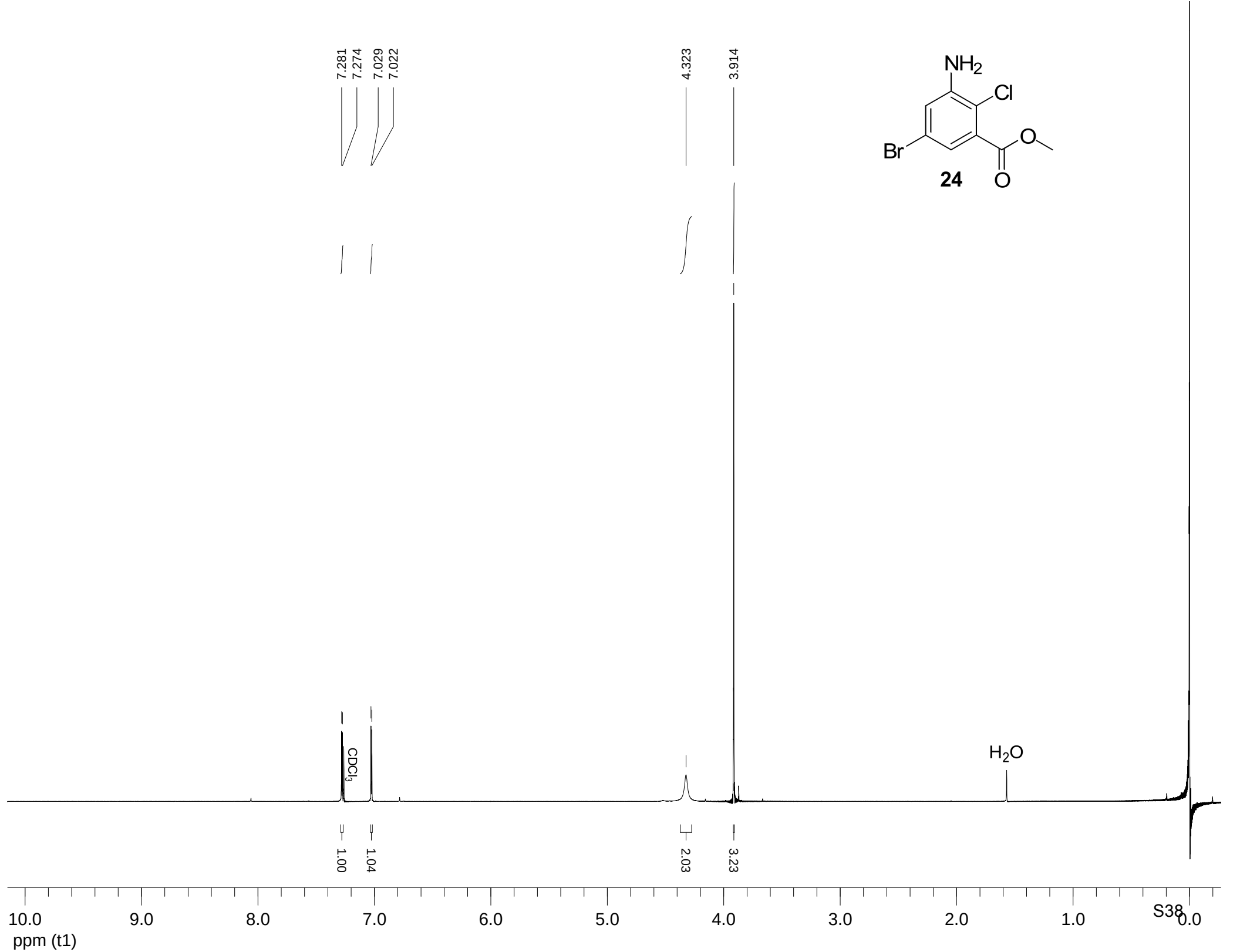
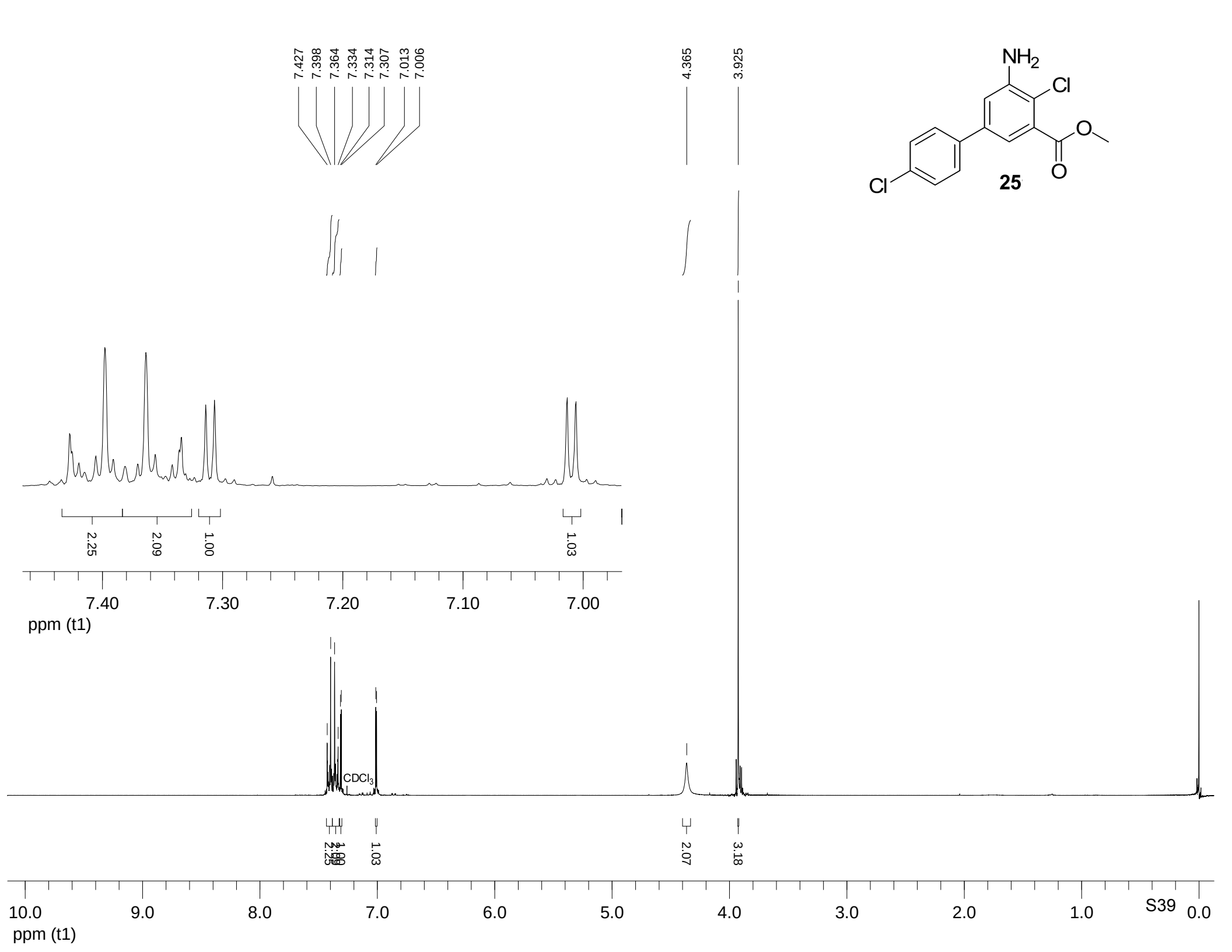
7.70
7.60
7.50
7.40
7.30
7.20
7.10
7.00
6.90
ppm (t1)
Br
O
O
O
O
19
1.00
1.17
2.47
2.44
3.52
3.53
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ppm (t1)
S34

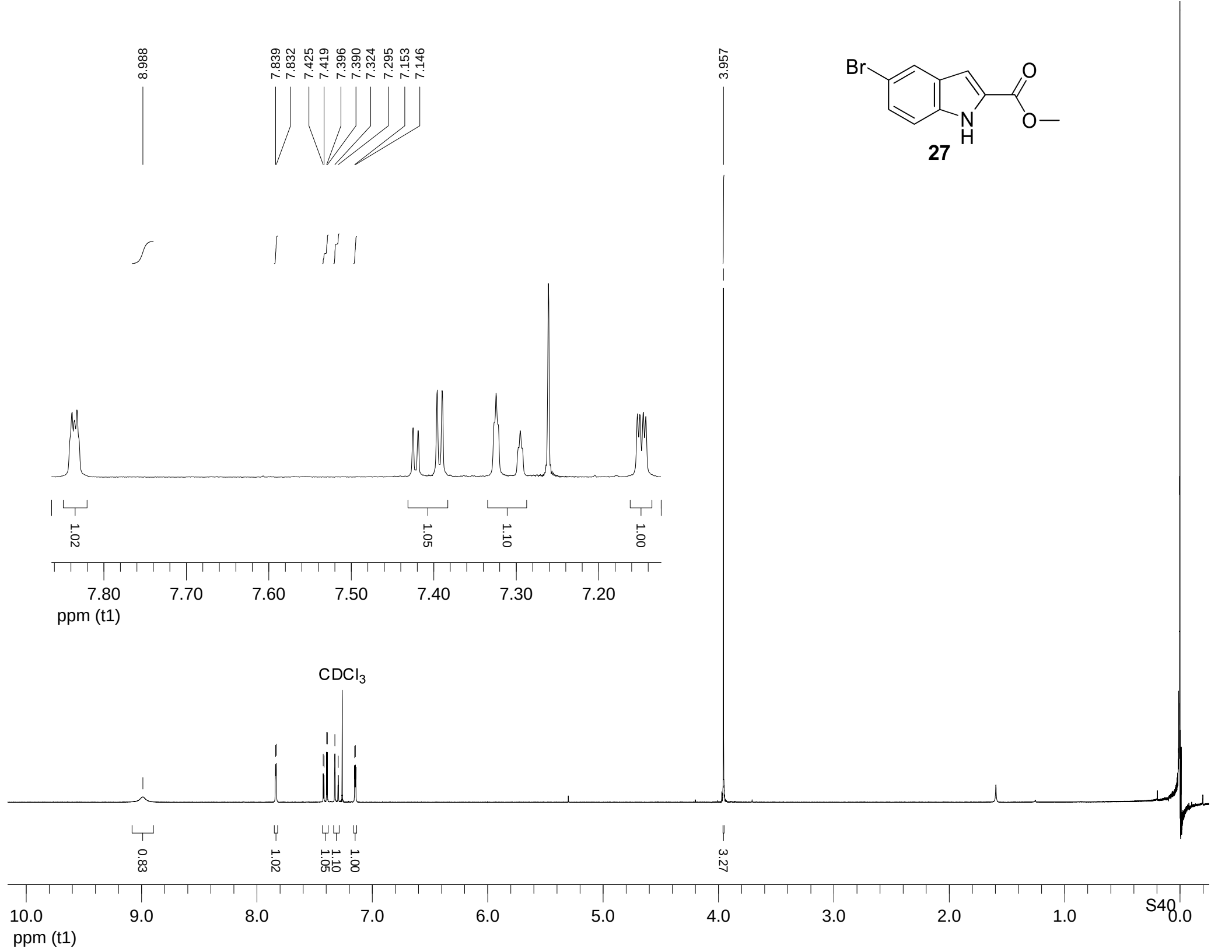

7.831
7.618
7.505
7.476
7.394
7.365
7.322
6.935
6.906
5.043
3.926
3.797
1.05
1.08
2.22
1.10
1.24
2.38
2.19
3.29
3.02
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ppm (t1)
O
O
O
O
Cl
20

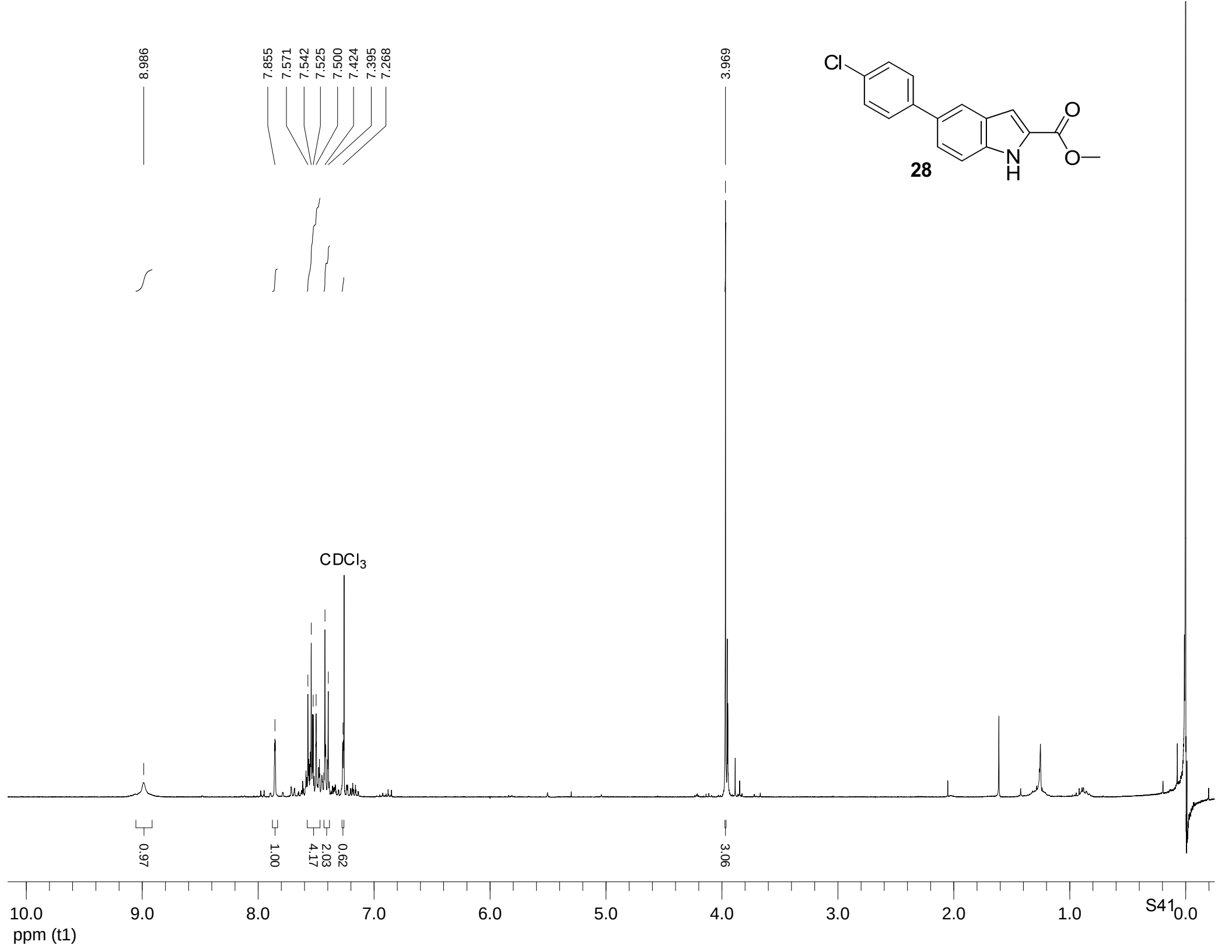

7.724
7.719
7.713
7.559
7.530
7.449
7.423
7.394
7.240
3.927
OH
O
O
Cl
21
H2O
CD3OD
1.03
2.13
2.08
2.08
1.10
3.00
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ppm (t1)

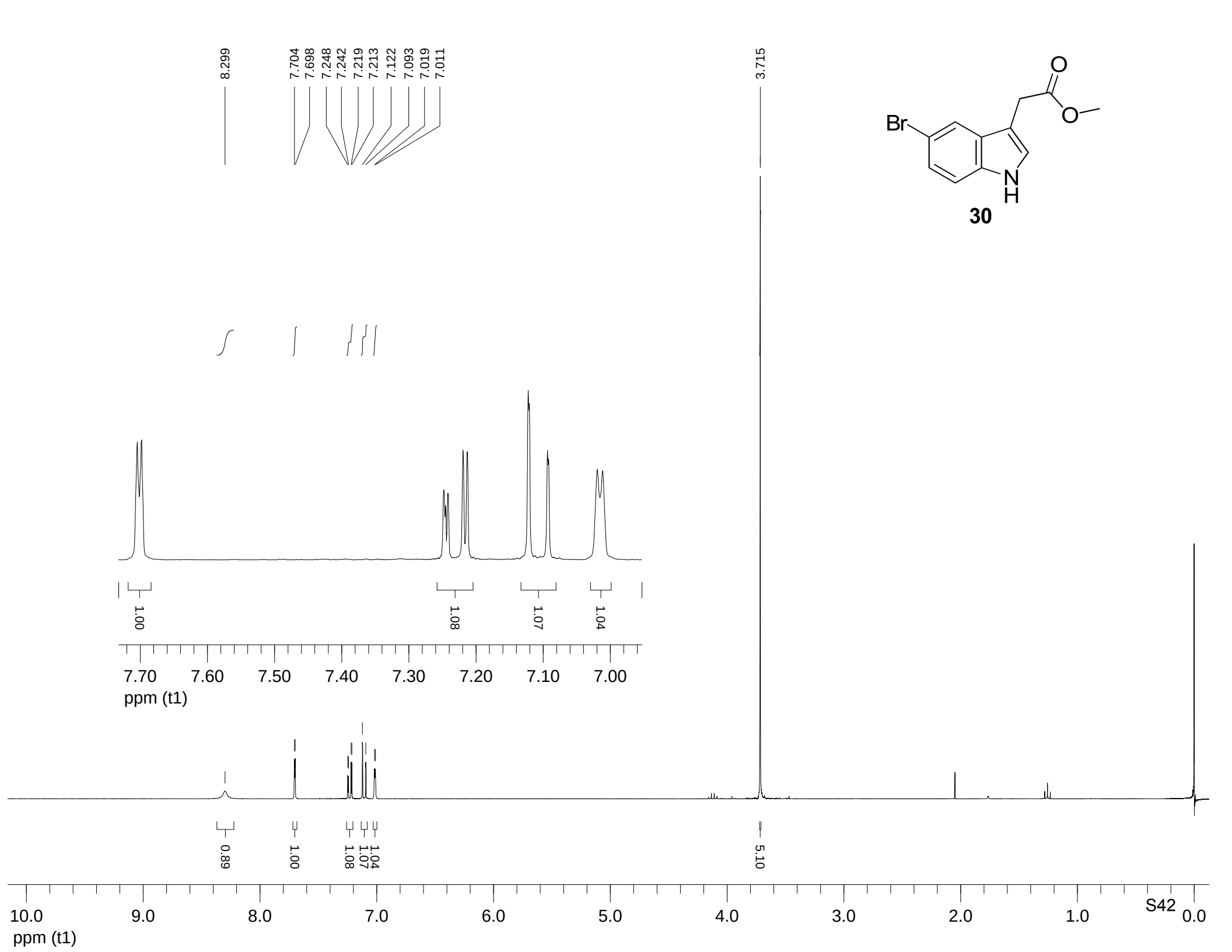

8.091
8.083
7.975
7.967
3.986
NO2
Cl
Br
O
O
23
CDCl3
H2O
1.03
1.00
3.42
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ppm (t1)

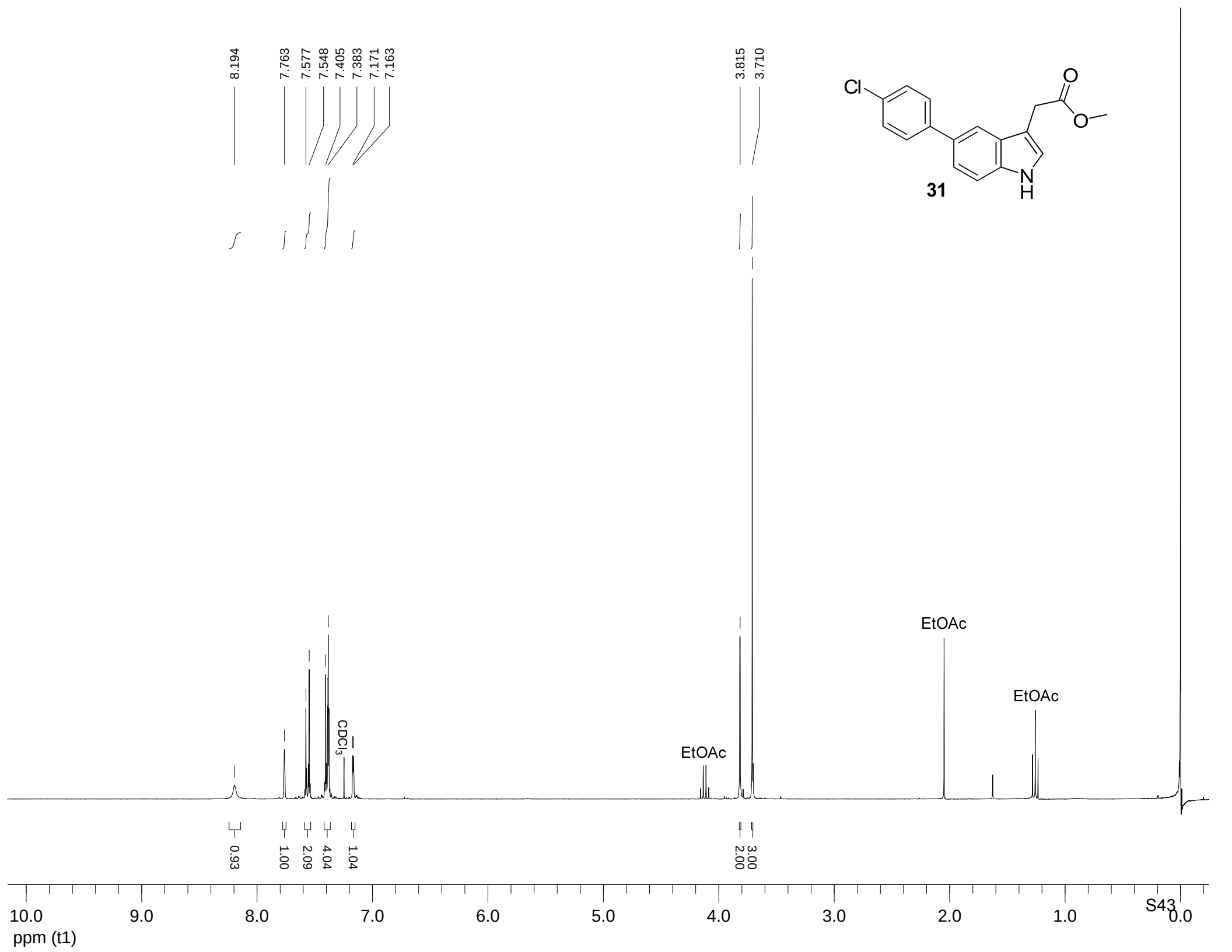

7.281
7.274
7.029
7.022
4.323
3.914
NH2
Cl
Br
O
O
24
CDCl3
H2O
1.00
1.04
2.03
3.23
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ppm (t1)


7.427
7.398
7.364
7.334
7.314
7.307
7.013
7.006
4.365
3.925
NH2
Cl
O
O
Cl
25
2.25
2.09
1.00
1.03
7.40
7.30
7.20
7.10
7.00
ppm (t1)
CDCl3
2.25
1.03
2.07
3.18
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ppm (t1)


8.988
7.839
7.832
7.425
7.419
7.396
7.390
7.324
7.295
7.153
7.146
3.957
Br
O
O
N
H
27
1.02
1.05
1.10
1.00
7.80
7.70
7.60
7.50
7.40
7.30
7.20
ppm (t1)
CDCl3
0.83
1.02
1.05
1.10
1.00
3.27
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ppm (t1)


8.986
7.855
7.571
7.542
7.525
7.500
7.424
7.395
7.268
3.969
Cl
O
O
N
H
28
CDCl3
0.97
1.00
4.17
2.03
0.62
3.06
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ppm (t1)


8.299
7.704
7.698
7.248
7.242
7.219
7.213
7.122
7.093
7.019
7.011
3.715
Br
O
O
N
H
30
1.00
1.08
1.07
1.04
7.70
7.60
7.50
7.40
7.30
7.20
7.10
7.00
ppm (t1)
0.89
1.00
1.08
1.07
1.04
5.10
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ppm (t1)


8.194
7.763
7.577
7.548
7.405
7.383
7.171
7.163
3.815
3.710
Cl
O
O
N
H
31
EtOAc
EtOAc
EtOAc
CDCl3
0.93
1.00
2.09
4.04
1.04
2.00
3.00
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ppm (t1)