Supporting Information for:
Palladium-Catalyzed Mono-α-Arylation of Acetone with Aryl Halides and Tosylates

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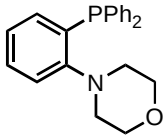
Contents

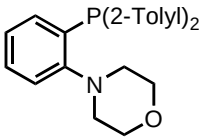
General Considerations

Unless noted, all catalytic reactions were set up inside an inert atmosphere (N_2) glovebox, and worked up outside of the glovebox under air. Acetone was distilled prior to use and stored in air over activated 4 Å molecular sieves. 1,4-Dioxane was dried over Na/benzophenone followed by distillation under an atmosphere of N_2. All solvents used within the glovebox were stored over activated 4 Å molecular sieves. Pd starting materials, ligands, bases and solid substrates were evacuated under reduced pressure prior to use and stored in an inert atmosphere glove box. N-(2-bromophenyl)morpholine[S1] and $[Pd(cinnamyl)Cl]_2$[S2] were prepared by literature procedures. Ligands were obtained from commercial sources, or prepared via established methods.[S3,S4] Aryl tosylates were prepared via literature methods.[S5,S6] Flash column chromatography was performed on silica gel (SiliaFlash P60). GC data were obtained on a Shimadzu GC-2014 equipped with a SGE BP-5 30 m, 0.25 mm I.D. column. ^1H, ^{13}C and ^{31}P NMR characterization data were collected at 300 K on a Bruker AV-500 spectrometer operating at 500.1, 125.8 and 202.5 MHz (respectively) or a Bruker/Tecmag AC-250 spectrometer operating at 250.1, 62.9, and 101.3 MHz (respectively), with chemical shifts reported in parts per million downfield of $SiMe_4$ (for ^1H and ^{13}C) as referenced to residual NMR solvent signals, or to 85% H_3PO_4 in D_2O for ^{31}P. NMR data were acquired at the NMR3 (Dalhousie) with the assistance of Dr. M. Lumsden. HRMS was acquired at the Maritime Mass Spectrometry Laboratories (Dalhousie) by Mr. X. Feng. Mor-DalPhos (**L1**) is commercially available from Strem Chemicals.

Ligand Synthesis and Characterization



Ph-MorDalPhos (L12). In an inert atmosphere glovebox, to a solution of *N*-(2-bromophenyl)morpholine (363 mg, 1.5 mmol) cooled to -35 °C in Et_2O (5 mL) was added 550 μL of a 2.9 M nBuLi solution (1.6 mmol). The solution was stirred at room temperature for 15 minutes then cooled again to -35 °C before a solution of $ClPPh_2$ in 2 mL Et_2O (275 μL, 1.5 mmol) was added dropwise. The resulting solution was stirred at room temperature for 10 minutes, after which time all the $ClPPh_2$ had been consumed as evidenced by ^{31}P NMR. The reaction mixture was evaporated to dryness, and the residue was taken up in CH_2Cl_2 and filtered through a short plug of Celite. The solvent was removed from the filtrate and the resulting solid was washed with pentane (2 x 4 mL) to yield the product as a beige powder in 66% yield (342 mg, 0.99 mmol). ^1H NMR ($CDCl_3$): δ 7.38-7.33 (m, 11H), 7.22 (ddd, J = 1.1, 4.4, 7.9 Hz, 1H), 7.09 (tt, J = 1.1, 7.5 Hz, 1H), 6.77 (ddd, J = 1.5, 3.6, 7.6 Hz, 1H), 3.53 (br s, 4H), 2.85 (t, J = 4.5 Hz, 4H). $^{13}C\{^1H\}$ NMR ($CDCl_3$): δ155.4 (d, J_{PC} = 17 Hz), 138.0 (d, J_{PC} = 10 Hz), 137.0 (d, J_{PC} = 8 Hz), 134.2 (d, J_{PC} = 20 Hz), 133.3, 129.9, 128.7, 128.5 (d, J_{PC} = 7 Hz), 125.6, 121.9, 67.3, 52.9. $^{31}P\{^1H\}$ NMR ($CDCl_3$): δ -11.1. HRMS (ESI/$[M+H]^+$) calcd. for $C_{22}H_{23}N_1O_1P_1$: 348.1512 Found 348.1505.

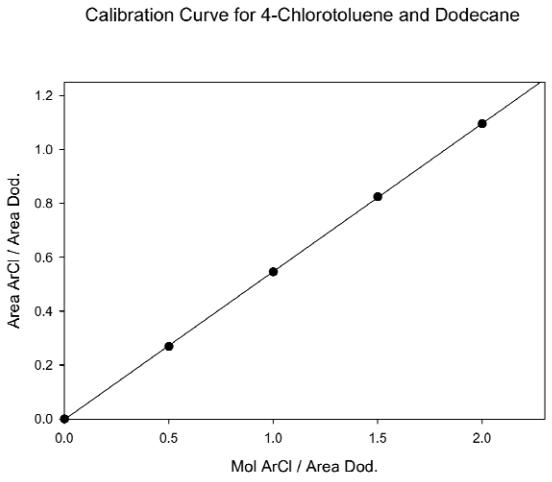


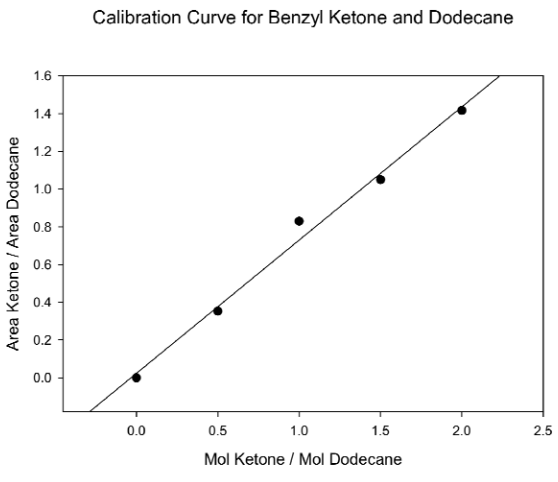
2-Tolyl-MorDalPhos (L13). In an inert atmosphere glovebox, a solution of $Pd(OAc)_2$ (18 mg, 0.08 mmol) and DiPPF (1,1'-bis(diisopropylphosphino)ferrocene; 40 mg, 0.096 mmol) in 2 mL toluene was added to a vial containing *N*-(2-bromophenyl)morpholine (484 mg, 2.0 mmol) and NaOtBu (230 mg, 2.4 mmol), followed by di(2-tolyl)phosphine (449 mg, 2.1 mmol) and an additional 2 mL of toluene. The vial was sealed with a PTFE lined cap, removed from the glovebox and stirred at 110 °C for 18 h. The reaction mixture was then filtered through a plug of silica. The filtrate was concentrated and the product was isolated by column chromatography

(10:1 Hex:EtOAc) as a white solid with a slight purple tinge in 80% yield (600 mg, 1.6 mmol). ^{1}H NMR ($CDCl_3$): δ 7.38 (m, 1H), 7.29-7.25 (m, 4H), 7.21 (m, 1H), 7.07 (m, 3H), 6.74 (m, 3H), 3.53 (br s, 4H), 2.87 (br s, 4H), 2.50 (s, 6H). $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ 155.9 (d, J_{PC} = 18 Hz), 142.7, (d, J_{PC} = 27 Hz), 136.3 (d, J_{PC} = 12 Hz), 135.4 (d, J_{PC} = 8 Hz), 133.5, 133.4, 130.0 (d, J_{PC} = 5 Hz), 129.8, 128.6, 126.1, 125.7, 121.8, 67.6, 52.8, 21.4 (d, J_{PC} = 23 Hz). $^{31}P\{^{1}H\}$ NMR ($CDCl_3$): δ -29.1. HRMS (ESI/$[M+H]^+$) calcd. for $C_{24}H_{27}N_1O_1P_1$: 376.1825. Found: 376.1834.

General Procedure for Optimization of the Pd-Catalyzed Cross-Coupling of 4-Chlorotoluene and Acetone

A vial was charged with 4-chlorotoluene (119μL, 1.0 mmol), dodecane (91μL, 0.40 mmol), acetone (725 μL, 10 mmol) and 1,4-dioxane (2.000 mL) to afford the substrate stock solution. To separate vials containing Cs_2CO_3 (163 mg, 0.5 mmol), $[Pd(cinnamyl)Cl]_2$ (1.3 mg, 0.005 mmol Pd), and 0.01 mmol of the appropriate ligand was added 730 μL of the substrate stock solution. Reaction mixtures were then heated at the desired temperature for the indicated time, after which time the reaction mixtures were cooled and an aliquot of the reaction mixture was passed through a silica plug and subjected to GC-analysis employing dodecance as the internal standard. Conversions were determined by comparison of the 4-chlorotoluene GC signal relative to dodecane, and yields were determined by comparison of the (4-tolyl)-2-propanone GC signal relative to dodecane. In both cases, the GC data were calibrated by using data obtained from a calibration curve developed using authentic samples, as shown below.



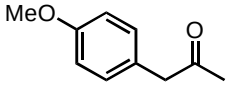


General Procedure for the Pd-catalyzed α-Arylation of Acetone

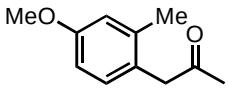
In a N_2-filled glovebox, $[Pd(cinnamyl)Cl]_2$ (2.6 mg, 0.005 mmol), **L1** (Mor-DalPhos, 9.3 mg, 0.02 mmol), Cs_2CO_3 (326 mg, 1 mmol), and a stir-bar were added to a screw-capped vial (solid aryl (psuedo)halides were also added at this time). The vial was sealed with a cap containing a PTFE septum and was removed from the glovebox. Using a microsyringe, the corresponding aryl halides (0.5 mmol) were added to the reaction vessel (if liquid) followed by addition of acetone (1 mL) as the reaction solvent. The reaction vial was placed in a temperature-controlled aluminum-heating block set at 90 ^oC. After 16 h of stirring, the vial was removed from the heating block and was left to cool to ambient temperature. The crude reaction mixture was dissolved in CH_2Cl_2 (10 mL) and was quantitatively transferred to a separatory funnel where it was washed with brine (2 x 20 mL). For products containing acidic protons or alternative enolizable groups, the crude reaction mixture was washed with a 1M HCl (aq.) solution (20 mL) followed by brine (2 x 20 mL). The organic fractions were combined, dried over Na_2SO_4, and concentrated under reduced pressure. After removal of the solvent, the crude product residue was purified by flash column chromatography on silica gel.

Reactions could be performed without the use of a glovebox. For example, when the solid materials (Pd, ligand, base) were weighed out into a vial in air, sealed and placed under N_2 (evacuating and backfilling 5 times), followed by delivery of the liquid reagents/solvent (no special handling) to the vial, the test substrate (**1a**) gave a 88% calibrated GC yield (94% conversion) after 18 h at 60 ^oC using 2 mol% Pd.

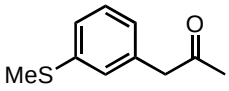
Product Characterization



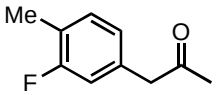
2b. From the corresponding aryl chloride, the indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (20:1) in a 80% isolated yield (66 mg, 0.40 mmol) as a colorless oil, employing 3 mol% Pd. Yield from the corresponding aryl iodide employing 2 mol% Pd: 98%. ^1H NMR ($CDCl_3$): δ 7.15-7.07 (m, 2H), 6.89-6.84 (m, 2H), 3.79 (s, 3H), 3.63 (s, 2H), 2.14 (s, 3H); $^{13}C\{^1H\}$ NMR ($CDCl_3$): δ 207.2, 159.0, 130.7, 126.6, 114.5, 55.6, 50.4, 29.4. HRMS (ESI/$[M+H]^+$) calcd. for $C_{10}H_{13}O_2$: 165.0910. Found: 165.0904.



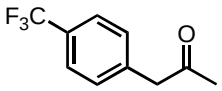
2c. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (20:1) in a 98% isolated yield (86 mg, 0.49 mmol) as a colorless oil, employing 2 mol% Pd. ^{1}H NMR ($CDCl_3$): δ 7.01-6.96 (m, 2H), 6.80-6.77 (m, 1H), 3.81 (s, 3H), 3.61 (s, 2H), 2.21 (s, 3H), 2.14 (s, 3H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ 207.4, 157.1, 131.9, 127.9, 127.2, 126.1, 110.4, 55.6, 50.5, 29.2, 16.5. HRMS (ESI/$[M+Na]^+$) calcd. for $C_{11}H_{14}Na_1O_2$: 201.0886. Found: 201.0887.



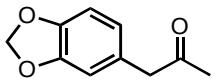
2d. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (20:1) in a 80% isolated yield (72 mg, 0.40 mmol) as a yellow oil, employing 2 mol% Pd. ^{1}H NMR ($CDCl_3$): δ7.24 (m, 1H), 7.15 (m, 1H), 7.08 (m, 1H), 6.97 (m, 1H), 3.66 (s, 2H), 2.47 (s, 3H), 2.15 (s, 3H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ206.4, 139.4, 135.2, 129.4, 127.6, 126.4, 125.4, 51.1, 29.6, 16.0. HRMS (ESI/$[M+H]^+$) calcd. for $C_{10}H_{13}O_1S_1$: 181.0682. Found: 181.0685.



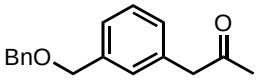
2e. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (20:1) in a 78% isolated yield (64 mg, 0.39 mmol) as a yellow oil, employing 2 mol% Pd. ^{1}H NMR ($CDCl_3$): δ7.16-7.11 (m, 1H), 6.88-6.83 (m, 2H), 3.65 (s, 2H), 2.25 (d, J = 1.6 Hz, 3H), 2.16 (s, 3H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ206.2, 161.3 (d, J = 245.4 Hz), 133.9 (d, J = 8.3 Hz), 131.6 (d, J = 6.1 Hz), 125.1 (d, J = 3.0 Hz), 123.4 (d, J = 17.4 Hz), 116.3 (d, J = 23.4), 50.5, 29.6, 14.5 (d, J = 3.7 Hz). HRMS (ESI/$[M+H]^+$) calcd. for $C_{10}H_{12}F_1O_1$: 167.0867. Found: 167.0861.



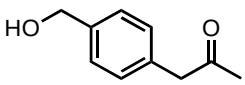
2f. Employing the corresponding aryl chloride, the indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (20:1) in a 70% isolated yield (71 mg, 0.35 mmol) as a white solid, employing 2 mol% Pd. Yield from the corresponding aryl iodide employing 2 mol% Pd: 67%. ^{1}H NMR ($CDCl_3$): δ 7.63-7.55 (m, 2H), 7.35-7.28 (m, 2H), 3.78 (s, 2H), 2.20 (s, 3H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ205.4, 138.4, 130.2, 129.7 (q, J_{CF} = 33 Hz), 125.9 (q, J_{CF} = 4 Hz), 124.4 (q, J = 259 Hz), 50.7, 30.0. HRMS (ESI/$[M+H]^+$) calcd. for $C_{10}H_{10}F_3O_1$: 203.0678. Found: 203.0683.



2g. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (20:1) in a 72% isolated yield (65 mg, 0.36 mmol) as a colorless oil, employing 2 mol% Pd. ^{1}H NMR ($CDCl_3$): δ 6.76 (m, 1H), 6.67 (m, 1H), 6.63 (m, 1H), 5.93 (s, 2H), 3.59 (s, 2H), 2.14 (s, 3H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ 206.9, 148.2, 147.0, 128.1, 122.8, 110.0, 108.8, 101.4, 50.8, 29.4. HRMS (ESI/$[M+H]^+$) calcd. for $C_{10}H_{11}O_3$: 179.0703. Found: 179.0698.

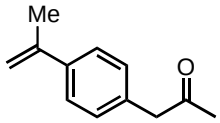


2h. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (20:1 to 10:1) in a 86% isolated yield (109 mg, 0.43 mmol) as a colorless oil, employing 2 mol% Pd. ^{1}H NMR ($CDCl_3$): δ 7.40-7.28 (m, 7H), 7.23 (m, 1H), 7.15 (m, 1H), 4.58 (s, 2H), 4.56 (s, 2H), 3.71 (s, 2H), 2.17 (s, 3H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ 206.6, 139.2, 138.4, 134.7, 129.1, 129.0, 128.9, 128.7, 128.1, 128.0, 126.8, 72.5, 72.2, 51.2, 29.6. HRMS (ESI/$[M+Na]^+$) calcd. for $C_{17}H_{18}Na_1O_2$: 277.1199. Found: 277.1214.

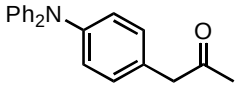


2i. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (2:1) in a 72% isolated yield (59 mg, 0.36 mmol) as a colorless oil, employing 3 mol% Pd. ^{1}H NMR ($CDCl_3$): δ 7.34-7.29 (m, 2H), 7.19-7.17 (m, 2H), 4.65 (s, 2H), 3.68 (s, 2H),

2.18 (br s, 1H), 2.14 (s, 3H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ 206.9, 140.1, 133.8, 129.9, 127.7, 65.2, 50.9, 29.6. HRMS (ESI/$[M+Na]^+$) calcd. for $C_{10}H_{12}Na_1O_2$: 187.0730. Found: 187.0730.



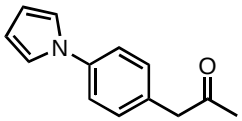
2j. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (20:1) in a 96% isolated yield (84 mg, 0.48 mol) as a colorless oil, employing 2 mol% Pd. ^{1}H NMR ($CDCl_3$): δ7.50-7.40 (m, 2H), 7.22-7.14 (m, 2H), 5.37 (m, 1H), 5.08 (m, 1H), 3.69 (s, 2H), 2.15 (s, 3H), 2.14 (m, 3H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ206.7, 143.1, 140.3, 133.6, 129.6, 126.2, 112.7, 51.0, 29.6, 22.1. HRMS (ESI/$[M+H]^+$) calcd. for $C_{12}H_{15}O_1$: 175.1117. Found: 175.1119.



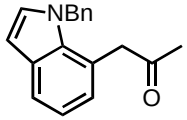
2k. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (10:1) in a 80% isolated yield (120 mg, 0.40 mmol) as a thick brown oil that solidifies over time, employing 2 mol% Pd. ^{1}H NMR ($CDCl_3$): δ 7.30-7.27 (m, 4H), 7.14-7.03 (m, 10H), 3.69 (s, 2H), 2.23 (s, 3H). $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ206.8, 147.8, 147.0, 130.3, 129.4, 128.3, 124.4, 124.2, 123.0, 50.4, 29.5. HRMS (ESI/$[M+Na]^+$) calcd. for $C_{21}H_{19}N_1Na_1O_1$: 324.1359. Found: 324.1356.

2l. The indicated compound was purified by flash column chromatography on silica gel using CH_2Cl_2:MeOH:NH_4OH (500:10:1) in a 85% isolated yield (97 mg, 0.43 mmol) as a white solid, employing 3 mol% Pd. ^{1}H NMR ($CDCl_3$): δ 8.81 (m, 1H), 8.61 (d, J = 3.7 Hz, 1H), 7.85 (ddd, J = 1.6, 2.4, 7.9, 1H), 7.38 (ddd, J = 0.8, 4.3, 7.9 Hz, 1H), 7.21-7.18 (m, 2H), 6.97 (m, 1H), 3.79 (s, 2H), 2.23 (s, 3H). $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ205.2, 163.4 (d, J_{CF} = 257 Hz), 149.3, 148.4 140.4 (d, J_{CF} = 8 Hz) 137.3 (d, J_{CF} = 8 Hz), 135.4, 134.6, 124.2, 123.8, 116.3 (d, J_{CF} = 22 Hz), 113.1

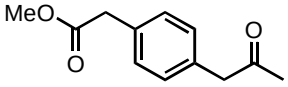
(d, J_{CF} = 22 Hz), 50.5, 29.8. HRMS (ESI/$[M+H]^+$) calcd. for $C_{14}H_{13}F_1N_1O_1$: 230.0976. Found: 230.0979.



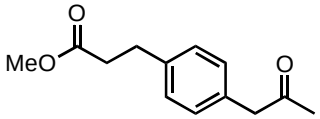
2m. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (10:1) in a 96% isolated yield (95 mg, 0.48 mmol) as an off-white solid, employing 2 mol% Pd. ^{1}H NMR ($CDCl_3$): δ 7.39-7.35 (m, 2H), 7.27-7.24 (m, 2H), 7.09-7.07 (m, 2H), 6.36-6.34 (m, 2H), 3.74 (s, 2H), 2.20 (s, 3H); $^{13}C\{^1H\}$ NMR ($CDCl_3$): δ 206.4, 140.1, 131.8, 130.9, 121.1, 119.6, 110.8, 50.5, 29.8. HRMS (ESI/$[M+H]^+$) calcd. for $C_{13}H_{14}N_1O_1$: 200.1070. Found: 200.1066.



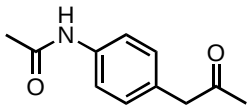
2n. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (10:1) in a 72% isolated yield (81 mg, 0.31 mmol) as a thick colourless oil employing 3 mol% Pd. ^{1}H NMR ($CDCl_3$): δ7̃67 (m, 1H), 7.34-7.37 (m, 3H), 7.15 (m, 2H), 7.00 (d, J = 6.9 Hz, 1H), 6.92 (d, J = 6.9 Hz, 2H), 6.65 (d, J = 3.2 Hz, 1H), 5.56 (s, 2H), 3.80 (s, 2H), 2.09 (s, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$): δ208.1, 139.5, 134.6, 131.3, 131.0, 129.1, 127.6, 125.9, 125.5, 120.8, 120.1, 117.8, 102.4, 52.1, 48.6, 29.1. HRMS (ESI/$[M+Na]^+$) calcd. for $C_{18}H_{17}N_1Na_1O_1$: 286.1202. Found: 286.1202.



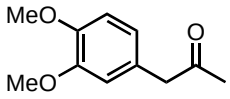
2o. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (5:1) in a 80% isolated yield (83 mg, 0.40 mmol) as a colorless oil, employing 2 mol% Pd. ^{1}H NMR ($CDCl_3$): δ 7.26-7.22 (m, 2H), 7.17-7.14 (m, 2H), 3.68 (s, 3H), 3.67 (s, 2H), 3.60 (s, 2H), 2.14 (s, 3H); $^{13}C\{^1H\}$ NMR ($CDCl_3$): δ 206.6, 172.2, 133.3, 133.1, 129.9, 129.8, 52.3, 50.8, 41.0, 29.6. HRMS (ESI/$[M+Na]^+$) calcd. for $C_{12}H_{14}Na_1O_3$: 229.0835. Found: 229.0835.



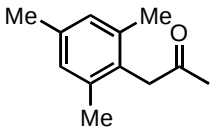
2p. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (10:1) in a 84% isolated yield (93 mg, 0.42 mmol) as a colorless oil, employing 2 mol% Pd. ^{1}H NMR ($CDCl_3$): δ 7.18-7.14 (m, 2H), 7.13-7.09 (m, 2H), 3.68-3.63 (m, 5H), 2.93 (t, J = 8.1 Hz, 2H), 2.61 (t, J = 7.9 Hz, 2H), 2.14 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$): δ 206.9, 173.7, 139.7, 132.5, 129.9, 129.1, 52.0, 50.9, 35.9, 30.8, 29.8. HRMS (ESI/[M+Na]$^{+}$) calcd. for $C_{13}H_{16}Na_1O_3$: 243.0992. Found: 243.1001.



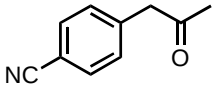
2q. The indicated compound was observed in a 66% ^{1}H NMR yield relative to 1,4-bis(trifluoromethyl)benzene, employing 3 mol% Pd. ^{1}H NMR ($CDCl_3$): δ 8.79 (br s, 1H), 7.49-7.42 (m, 2H), 7.05-6.98 (m, 2H), 3.57 (s, 2H), 2.09 (s, 3H), 2.06 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$): δ 207.2, 169.5, 137.8, 129.8, 126.3, 124.5, 50.7, 29.4, 27.7.



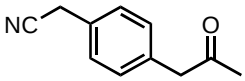
2r. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (10:1 to 5:1) in a 88% isolated yield (86 mg, 0.44 mmol) as a yellow oil, employing 2 mol% Pd. ^{1}H NMR ($CDCl_3$): δ 6.82 (m, 1H), 6.74 (m, 1H), 6.69 (m, 1H), 3.88-3.82 (m, 6H), 3.62 (s, 2H), 2.14 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$): δ 207.2, 149.4, 148.4, 127.0, 121.9, 112.6, 111.6, 56.2, 56.1, 50.9, 29.4. HRMS (ESI/[M+Na]$^{+}$) calcd. for $C_{11}H_{14}Na_1O_3$: 217.0835. Found: 217.0841.



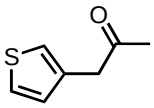
2s. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (20:1) in a 72% isolated yield (63 mg, 0.36 mmol) as a white solid, employing 2 mol% Pd. ^{1}H NMR ($CDCl_3$): δ 6.88 (s, 2H), 3.73 (s, 2H), 2.27 (s, 3H), 2.22 (s, 6H), 2.15 (s, 3H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ 207.0, 137.0, 136.8, 129.4, 129.3, 45.2, 29.7, 21.2, 20.6. HRMS (ESI/$[M+Na]^+$) calcd. for $C_{12}H_{16}Na_1O_1$: 199.1093. Found: 199.1106.



2t. From the corresponding aryl bromide, the indicated compound was purified by flash column chromatography on silica gel using CH_2Cl_2 in a 33% isolated yield (39 mg, 0.25 mmol) as a white solid, employing 4 mol% Pd. ^{1}H NMR ($CDCl_3$): δ 7.63 (m, 2H), 7.30 (m, 2H), 3.80 (s, 2H), 2.22 (s, 3H). $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ204.5, 139.6, 132.5, 130.5, 118.9, 111.2, 50.5, 30.0. HRMS (ESI/$[M+Na]^+$) calcd. for $C_{10}H_9N_1Na_1O_1$: 182.0576. Found: 182.0589.

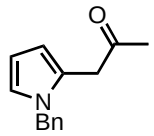


2u. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (5:1) in a 58% isolated yield (51 mg, 0.29 mmol) as a colorless oil, employing 2 mol% Pd. ^{1}H NMR ($CDCl_3$): δ 7.31-7.27 (m, 2H), 7.22-7.18 (m, 2H), 3.73 (s, 2H), 3.71 (s, 2H), 2.16 (s, 3H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ 206.1, 134.4, 130.5, 129.0, 128.6, 118.1, 50.6, 29.8, 23.6. HRMS (ESI/$[M+Na]^+$) calcd. for $C_{11}H_{11}N_1Na_1O_1$: 196.0733. Found: 196.0741.

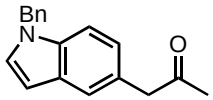


2v. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (20:1→10:1) as an inseparable mixture of the alpha arylated product and the alpha arylated product which had undergone subsequent direct arylation with 3-bromothiophene in a 70% combined isolated yield (4.6:1; 49% of the desired product, 81 mg, 0.31 mmol) as a

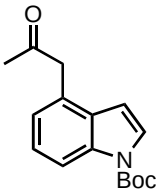
thick light orange oil employing 4 mol% Pd. ^{1}H NMR ($CDCl_3$): δMajor product: 7.31 (dd, *J* = 3.0, 5.0 Hz, 1H), 7.11 (m, 1H), 6.97 (dd, *J* = 1.3, 5.0 Hz, 1H), 3.97 (s, 2H), 2.18 (s, 3H). Minor product: 7.39 (m, 1H), 7.34 (m, 1H), 7.26 (d, *J* = 5.0 Hz, 1H), 7.18 (dd, *J* = 1.4, 5.0 Hz, 1H), 6.97 (m, 1H), 3.78 (s, 2H), 2.16 (s, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 206.4 (minor), 206.1 (major), 134.1, 130.0, 128.7 (major), 126.4, 126.2 (major), 124.1, 123.2 (major), 45.4 (major), 44.3 (minor), 29.7 (minor), 29.4 (major).



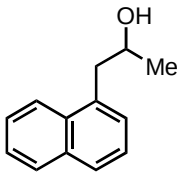
2w. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (10:1) in a 69% isolated yield (59 mg, 0.28 mmol) as a yellow oil employing 3 mol% Pd. ^{1}H NMR ($CDCl_3$): δ7.33-7.30 (m, 2H), 7.28-7.26 (m, 1H), 7.00 (m, 2H), 6.71 (m, 1H), 6.18 (t, *J* = 3.3 Hz, 1H), 6.10 (m, 1H), 5.03 (s, 2H), 3.56 (s, 2H), 2.06 (s, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ206.1, 138.0, 128.9, 127.7, 126.7, 125.5, 122.8, 109.8, 107.9, 50.9, 42.4, 28.9. HRMS (ESI/$[M+Na]^+$) calcd. for $C_{14}H_{15}N_1Na_1O_1$: 236.1046. Found: 236.1053.



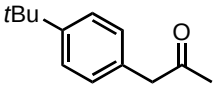
2x. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (10:1→3:1) in a 98% isolated yield (93 mg, 0.34 mmol) as a pale yellow solid, employing 3 mol% Pd. ^{1}H NMR ($CDCl_3$): δ 7.50 (m, 1H), 7.33-7.24 (m, 4H), 7.15-7.12 (m, 3H), 7.02 (dd, *J* = 1.6, 8.6 Hz, 1H), 6.52 (d, *J* = 3.1 Hz, 1H), 5.32 (s, 2H), 3.77 (s, 2H), 2.15 (s, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ207.9, 137.6, 135.7, 129.3, 129.0, 128.9, 127.8, 127.0, 125.6, 123.3, 121.8, 116.2, 110.7, 101.7, 51.5, 50.4, 29.2. HRMS (ESI/$[M+Na]^+$) calcd. for $C_{18}H_{17}N_1Na_1O_1$: 286.1202. Found: 286.1205.



2y. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (10:1) in a 91% isolated yield (118 mg, 0.36 mmol) as a thick colourless oil employing 3 mol% Pd. ^{1}H NMR ($CDCl_3$): δ8.11 (d, *J* = 8.0 Hz, 1H), 7.63 (d, *J* = 3.7 Hz, 1H), 7.30 (m, 1H), 7.10 (m, 1H), 6.58 (dd, *J* = 0.8, 3.8 Hz, 1H), 3.92 (s, 2H), 2.11 (s, 3H), 1.68 (s, 9H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ206.6, 149.8, 135.5, 130.3, 126.8, 126.4, 124.7, 124.0, 114.5, 105.4, 84.0, 49.1, 29.1, 28.4. HRMS (ESI/[M+Na]$^{+}$) calcd. for $C_{16}H_{19}N_1Na_1O_3$: 296.1297. Found: 296.1251.

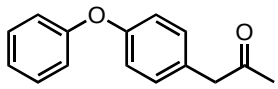


2z. (10 mmol scale reaction) To a vial inside a controlled atmosphere glovebox was added [Pd(cinnamyl)Cl]$_2$ (52 mg, 0.10 mmol), **L1** (185 mg, 0.40 mmol) and 10 mL acetone. 6.50 g of Cs_2CO_3 was added to the vial which was then sealed with a PTFE line screwcap and removed from the glovebox. 1-Bromonaphthlene (2.04 g, 10 mmol) was then added by syringe to the vial which was then stirred at 90 ^{o}C for 16 h, after which time ~95% conversion was observed by GC. The reaction mixture was allowed to cool, dissolved in 150 mL EtOAc and washed with 100 mL water. The organic layer was dried with Na_2SO_4, concentrated, and purified by column chromatography to yield 1.70 g (92%) of the product ketone that contained ~10% of an impurity (by ^{1}H NMR). The mixture was then reduced with $NaBH_4$ (1.1 equiv. in CH_2Cl_2/MeOH), and the pure alcohol was obtained after column chromatography (5:1 hexanes:EtOAc) in 67% yield (1.24 g, 6.67 mmol) as a thick colourless oil. ^{1}H NMR ($CDCl_3$): δ8.06 (dd, *J* = 8.3 Hz, 1H), 7.88 (m, 1H), 7.78 (d, *J* = 8.2 Hz, 1H), 7.56-7.49 (m, 2H), 7.44 (t, *J* = 8.1 Hz, 1H), 7.38 (m, 1H), 4.22 (m, 1H), 3.31 (dd, *J* = 4.7, 13.9 Hz, 1H), 3.14 (dd, *J* = 8.3, 13.9 Hz, 1H), 1.53 (d, *J* = 3.0 Hz, 1H), 1.35 (d, *J* = 6.2 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ134.9, 134.2, 132.4, 129.0, 127.8, 127.6, 126.6, 125.9, 125.7, 124.1, 68.4, 43.1, 23.4. HRMS (ESI/[M+Na]$^{+}$) calcd. for $C_{13}H_{14}Na_1O_1$: 209.0937. Found: 209.0936.

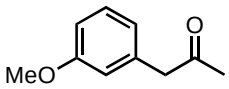


2aa. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (20:1) in a 92% isolated yield (87 mg, 0.46 mmol) as a colorless oil, employing 2

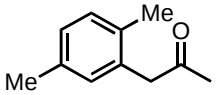
mol% Pd. ^{1}H NMR ($CDCl_3$): δ7.39-7.34 (m, 2H), 7.17-7.12 (m, 2H), 3.67 (s, 2H), 2.16 (s, 3H), 1.32 (s, 9H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ 207.1, 150.2, 131.4, 129.4, 126.0, 50.8, 34.8, 31.6, 29.6. HRMS (ESI/$[M+Na]^+$) calcd. for $C_{13}H_{18}Na_1O_1$: 213.1250. Found: 213.1245.



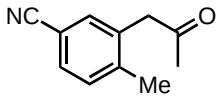
2bb. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (20:1) in a 96% isolated yield (108 mg, 0.48 mmol) as a yellow oil, employing 2 mol% Pd. ^{1}H NMR ($CDCl_3$): δ 7.36-7.32 (m, 2H), 7.18-7.14 (m, 2H), 7.13-7.09 (m, 1H), 7.03-7.00 (m, 2H), 6.99-6.96 (m, 2H), 3.68 (s, 2H), 2.18 (s, 3H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ 206.8, 157.4, 156.7, 131.0, 130.1, 129.2, 123.7, 119.3, 119.2, 50.4, 29.6. HRMS (ESI/$[M+Na]^+$) calcd. for $C_{15}H_{14}Na_1O_2$: 249.0886. Found: 249.0883.



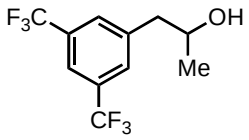
2cc. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (20:1) in a 74% isolated yield (60 mg, 0.37 mmol) as a yellow oil, employing 3 mol% Pd. ^{1}H NMR ($CDCl_3$): δ 7.25 (m, 1H), 6.83-6.78 (m, 2H), 6.75 (m, 1H), 3.80 (s, 3H), 3.67 (s, 2H), 2.15 (s, 3H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ 206.7, 160.2, 136.0, 130.8, 122.1, 115.3, 112.8, 55.5, 51.4, 29.5. HRMS (ESI/$[M+H]^+$) calcd. for $C_{10}H_{13}O_2$: 165.0910. Found: 165.0904.



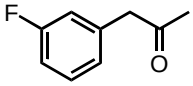
2dd. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (20:1) in a 92% isolated yield (75 mg, 0.46 mmol) as a faint yellow oil, employing 2 mol% Pd. ^{1}H NMR ($CDCl_3$): δ 7.08 (m, 1H), 7.01 (m, 1H), 6.96 (m, 1H), 3.68 (s, 2H), 2.32 (s, 3H), 2.21 (s, 3H), 2.15 (s, 3H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ 206.9, 136.0, 133.9, 133.2, 131.4, 130.7, 128.4, 49.4, 29.6, 21.2, 19.4. HRMS (ESI/$[M+Na]^+$) calcd. for $C_{11}H_{14}Na_1O_1$: 185.0937. Found: 185.0939.



2ee. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (10:1→5:1) followed by CH_2Cl_2 in a 73% isolated yield (63 mg, 0.36 mmol) as a white solid employing 4 mol% Pd and 8 mol% 2-Tolyl-MorDalPhos (**L13**). ^{1}H NMR ($CDCl_3$): δ7.49 (dd, *J* = 1.8, 7.9 Hz, 1H), 7.41 (d, *J* = 1.7 Hz, 1H), 7.30 (d, *J* = 7.9 Hz, 1H), 3.78 (s, 2H), 2.29 (s, 3H), 2.24 (s, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ204.6, 143.1, 134.2, 134.0, 131.4, 131.2, 119.0, 110.3, 48.5, 29.9, 20.2. HRMS (ESI/$[M+Na]^+$) calcd. for $C_{11}H_{11}N_1Na_1O_1$: 196.0733. Found: 196.0740.

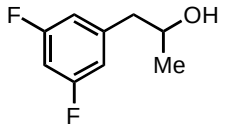


2ff. After cross-coupling using the standard protocol (5 mol% Pd) and 2-Tolyl-MorDalPhos (**L13**) (7.5 mol%) as the ligand, the reaction mixture was filtered through a short plug of silica, which was washed with CH_2Cl_2 and concentrated. The crude reaction mixture was taken up in MeOH and 1.2 equivalents of $NaBH_4$ was added. After 10 minutes the reaction was concentrated, quenched with water (5 mL) and extracted with CH_2Cl_2 (3 X 5mL). The organic layer was dried with Na_2SO_4 and concentrated. The product was then isolated as a white solid in 64% yield (84 mg, 31 mmol) by column chromatography (10:1→5:1 hexanes:EtOAc). ^{1}H NMR ($CDCl_3$): δ7.76 (s, 1H), 7.70 (s, 2H), 4.10 (m, 1H), 2.89 (m, 2H), 1.53 (br s, 1H), 1.29 (d, *J* = 6.2 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 141.4, 131.7 (q, J_{CF} = 33 Hz), 129.8, 123.6 (q, J_{CF} = 273 Hz), 120.6 (m), 68.5, 45.1, 23.6.

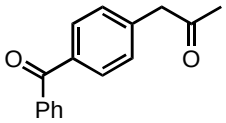


2gg. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (10:1→5:1) in a 67% isolated yield (53 mg, 0.35 mmol) as a colourless oil employing 3 mol% Pd and 6 mol% 2-Tolyl-MorDalPhos (**L13**). ^{1}H NMR ($CDCl_3$): δ7.30 (m, 1H), 7.00-6.92 (m, 3H), 3.71 (s, 2H), 2.19 (s, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ205.7, 163.0 (d, J_{CF} = 246 Hz), 136.6 (d, J_{CF} = 8 Hz), 130.3 (d, J_{CF} = 8 Hz), 125.3 (d, J_{CF} = 2 Hz), 116.6 (d, J_{CF} = 21

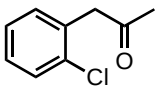
Hz), 114.2 (d, J_{CF} = 21 Hz), 50.6, 29.6. HRMS (ESI/[M+Na]$^+$) calcd. for $C_9H_9F_1Na_1O_1$: 175.0530. Found: 175.0527.



2hh. After cross-coupling using the standard protocol (5 mol% Pd) and 2-Tolyl-MorDalPhos (**L13**) (7.5 mol%) as the ligand, the reaction mixture was filtered through a short plug of silica, which was washed with CH_2Cl_2 and concentrated. The crude reaction mixture was taken up in MeOH and 1.2 equivalents of $NaBH_4$ was added. After 10 minutes the reaction was concentrated, quenched with water (5 mL) and extracted with CH_2Cl_2 (3 X 5mL). The organic layer was dried with Na_2SO_4 and concentrated. The product was then isolated as a thick colourless oil in 71% yield (61 mg, 35 mmol) by column chromatography (hexanes:EtOAc 10:1→5:1). ^{1}H NMR ($CDCl_3$): δ6.78-6.73 (m, 2H), 6.69 (tt, J = 2.3, 9.0 Hz, 1H), 4.04 (m, 1H), 2.72 (m, 2H), 1.61 (br s, 1H), 1.25 (d, J = 6.2 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 163.2 (dd, J_{CF} = 13, 248 Hz), 142.7 (t, J_{CF} = 9 Hz), 112.3 (dd, J_{CF} = 6, 19 Hz), 102.1 (t, J_{CF} = 25 Hz), 68.6, 45.5, 23.2.



2ii. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (5:1→2:1) in a 74% isolated yield (88 mg, 0.37 mmol) as a thick yellow oil employing 4 mol% Pd and 8 mol% 2-Tolyl-MorDalPhos (**L13**). ^{1}H NMR ($CDCl_3$): δ7.82-7.79 (m, 4H), 7.60 (m, 1H), 7.49 (m, 2H), 7.33 (m, 2H), 3.82 (s, 2H), 2.23 (s, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 205.4, 196.5, 139.0, 137.7, 136.5, 132.6, 130.7, 130.2, 129.6, 128.5, 50.9, 29.9. HRMS (ESI/[M+Na]$^+$) calcd. for $C_{16}H_{14}Na_1O_2$: 261.0886. Found: 261.0889.



2jj. The indicated compound was purified by flash column chromatography on silica gel using hexanes:EtOAc (10:1) in a 76% isolated yield (64 mg, 0.38 mmol) as a colourless oil employing

3 mol% Pd and 6 mol% 2-Tolyl-MorDalPhos (**L13**). ^{1}H NMR ($CDCl_3$): δ7.43 (m, 1H), 7.30-7.24 (m, 3H), 3.89 (s, 2H), 2.26 (s, 3H). $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ205.2, 134.6, 133.1, 131.8, 129.8, 128.9, 127.2, 48.6, 29.8. HRMS (ESI/$[M+Na]^+$) calcd. for $C_9H_9Cl_1Na_1O_1$: 191.0234. Found: 191.0235.

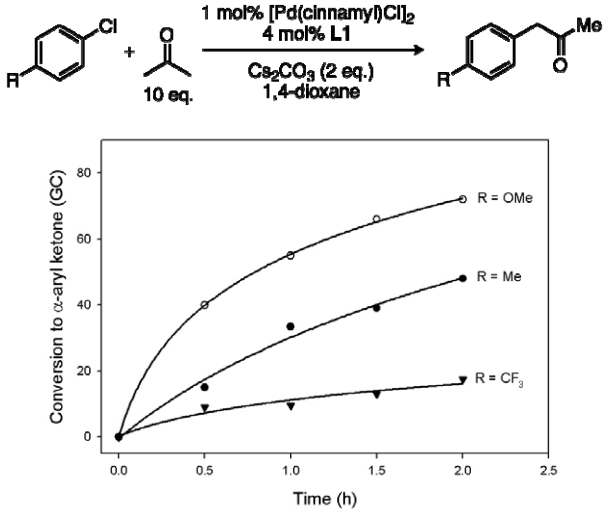


Figure S1. Conversion versus time data for the palladium-catalyzed α-arylation of acetone with 4-chloroanisole, 4-chlorotoluene, and 4-chlorobenzotrifluoride.

References

S1. J. P. Wolfe, S. L. Buchwald, *J. Org. Chem.* **1997**, *62*, 6066.

S2. P. R. Auburn, P. B. Mackenzie, B. Bosnich, *J. Am. Chem. Soc.* **1985**, 107, 2033.

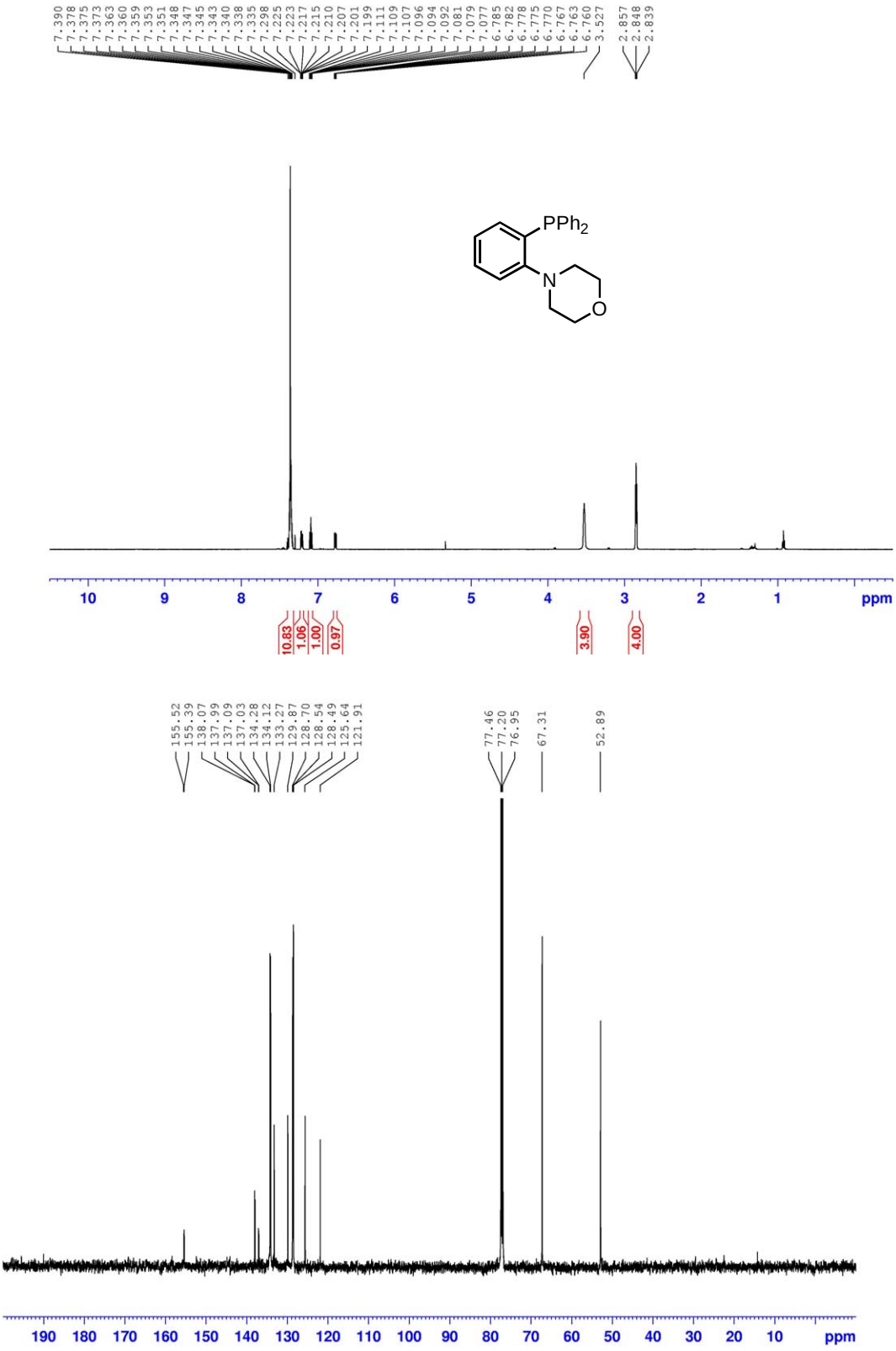
S3. R. J. Lundgren, A. Sappong-Kumankumah, M. Stradiotto, *Chem. Eur. J.* **2010**, *16*, 1983.

S4. R. J. Lundgren, B. D. Peters, P. G. Alsabeh, M. Stradiotto, *Angew. Chem. Int. Ed.* **2010**, *49*,

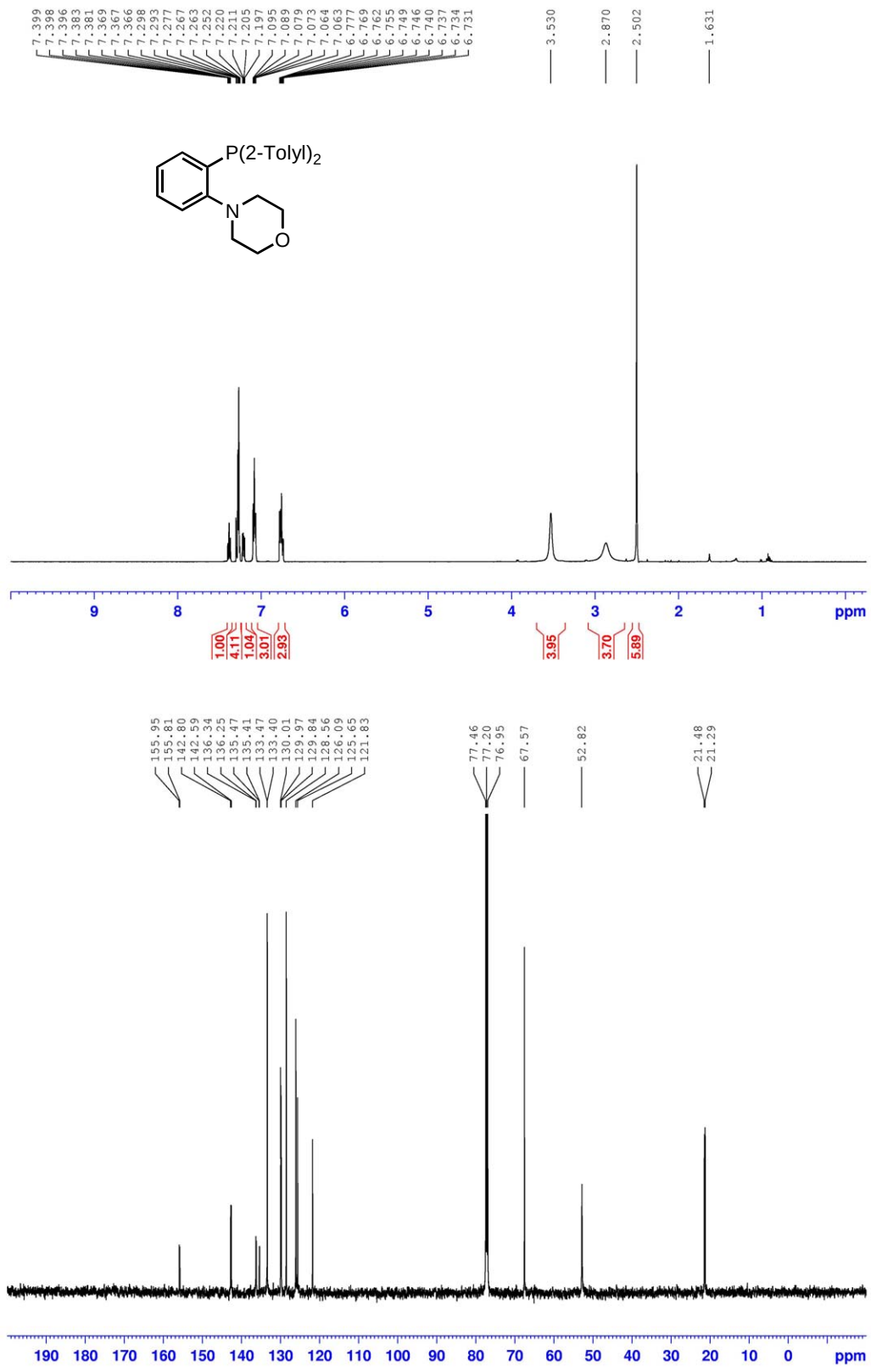
S5. T. Ogata, J. F. Hartwig, *J. Am. Chem. Soc.* **2008**, *130*, 13848.

S6. Y. Kubota, S. Nakada, Y. Sugi, *Synlett,* **1998**, 183.

<u>NMR Spectra</u> – Ph-MorDalPhos (**L12**)



(2-Tolyl)Mor-DalPhos (**L13**)



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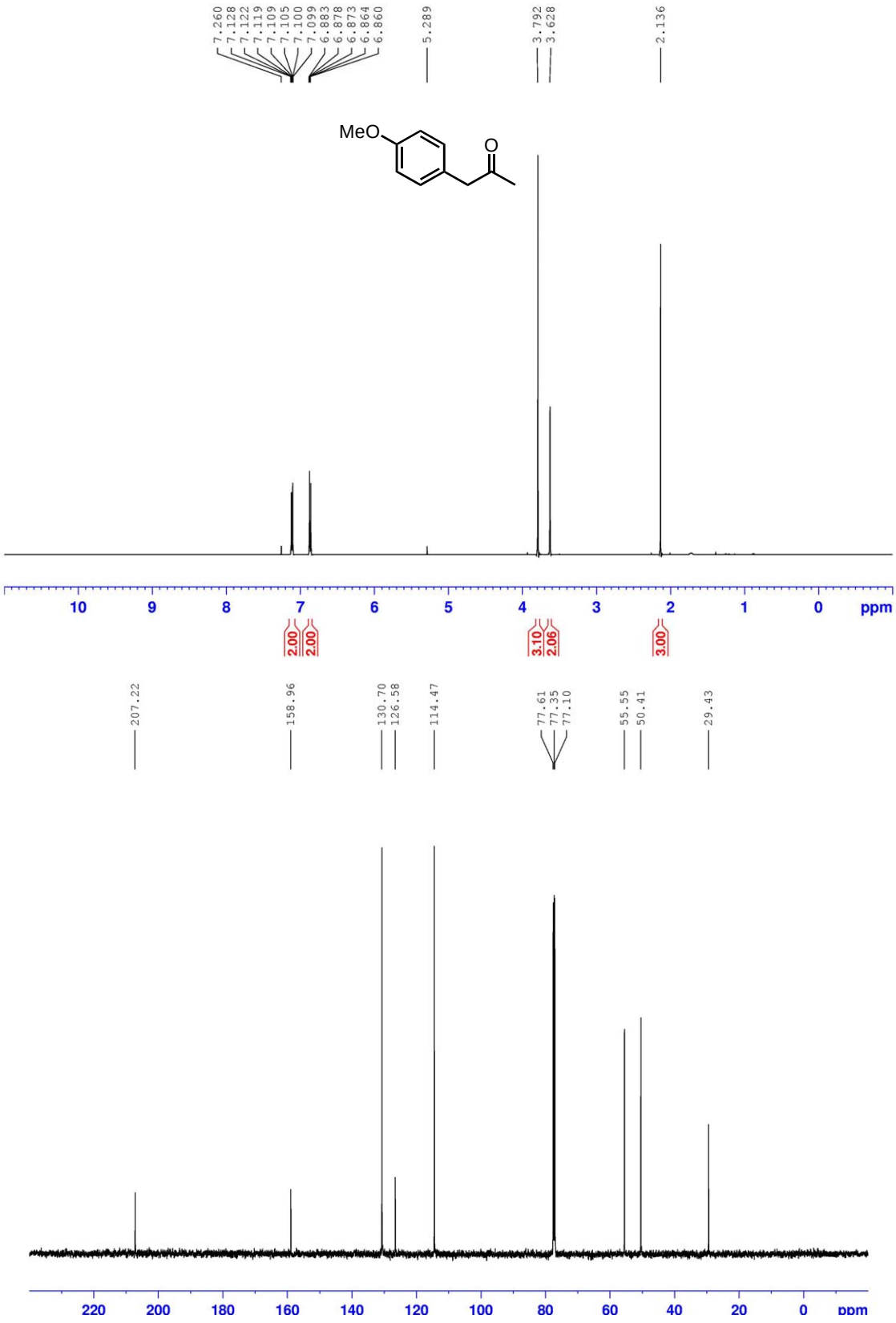
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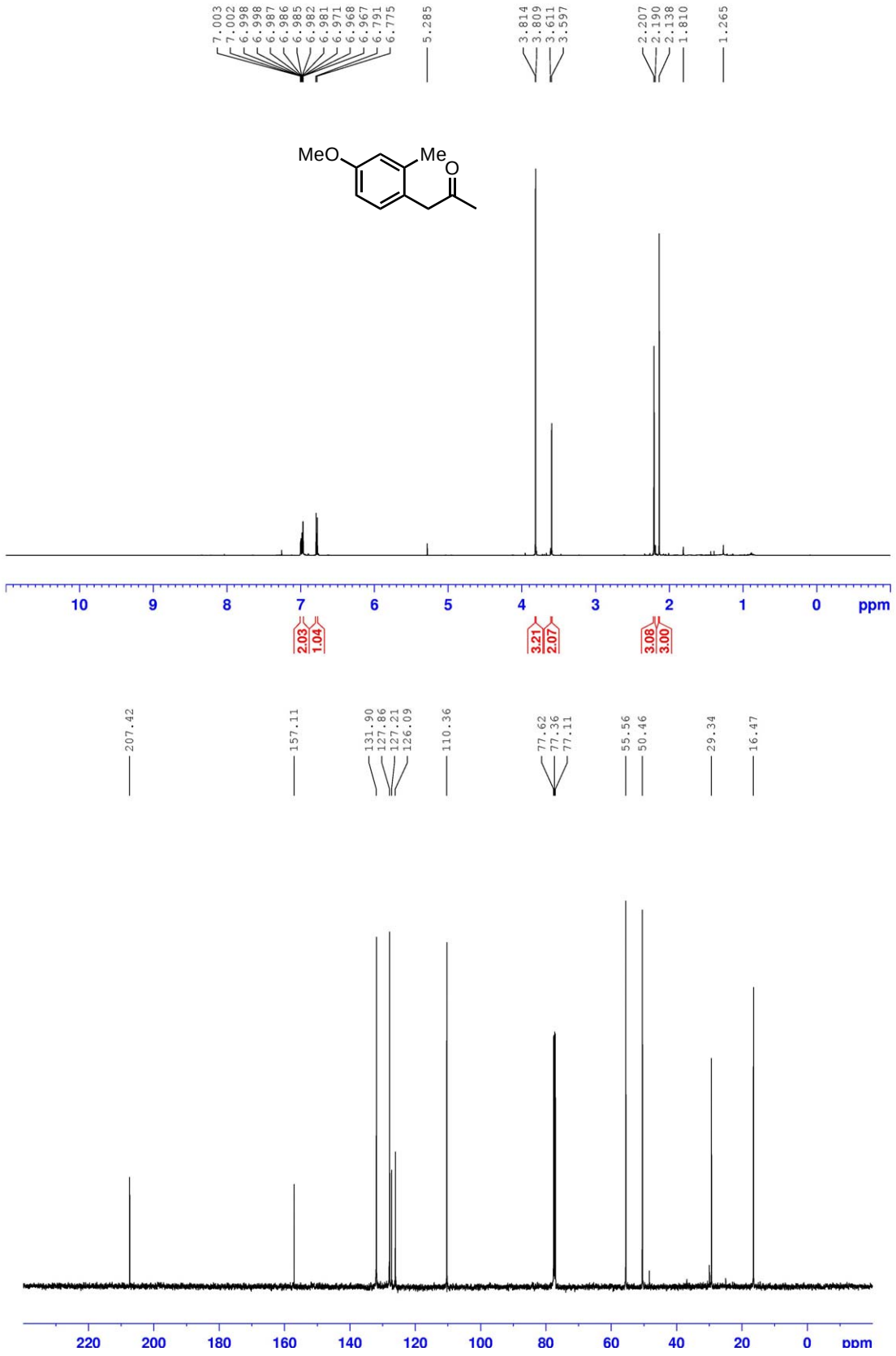
7.128
7.122
7.119
7.109
7.105
7.100
7.099
6.883
6.878
6.873
6.864
6.860
5.289
3.792
3.628
2.136
MeO
O
10
9
8
7
6
5
4
3
2
1
0
ppm
2.00
2.00
3.10
2.06
3.00
207.22
158.96
130.70
126.58
114.47
77.61
77.35
77.10
55.55
50.41
29.43
220
200
180
160
140
120
100
80
60
40
20
0
ppm

Table 2, 2c: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7.002
6.998
6.998
6.987
6.986
6.985
6.982
6.981
6.971
6.968
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6.775
5.285
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3.809
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2.190
2.138
1.810
1.265
MeO
Me
O
10
9
8
7
6
5
4
3
2
1
0
ppm
2.03
1.04
3.21
2.07
3.08
3.00
207.42
157.11
131.90
127.86
127.21
126.09
110.36
77.62
77.36
77.11
55.56
50.46
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180
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140
120
100
80
60
40
20
0
ppm

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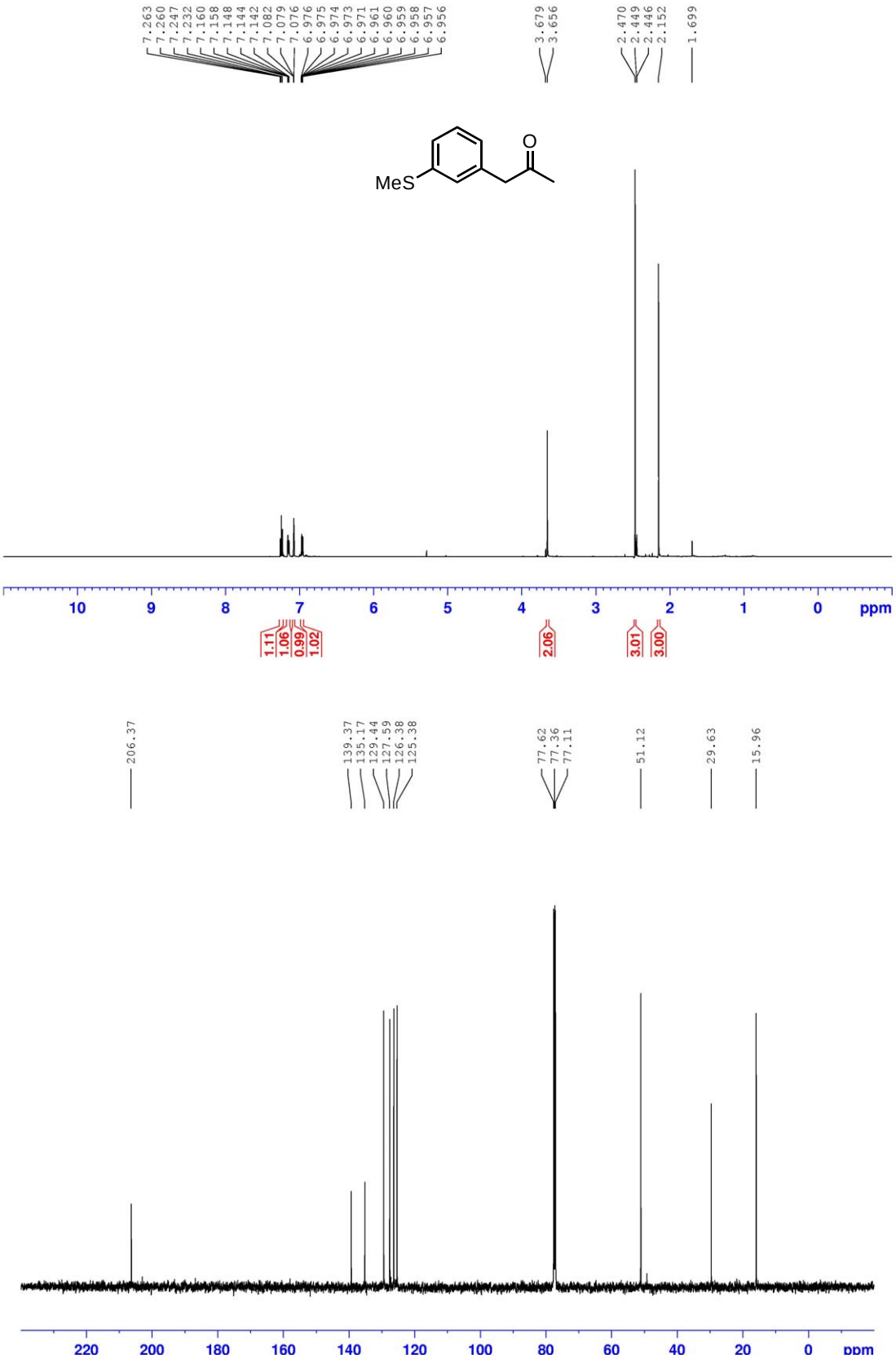
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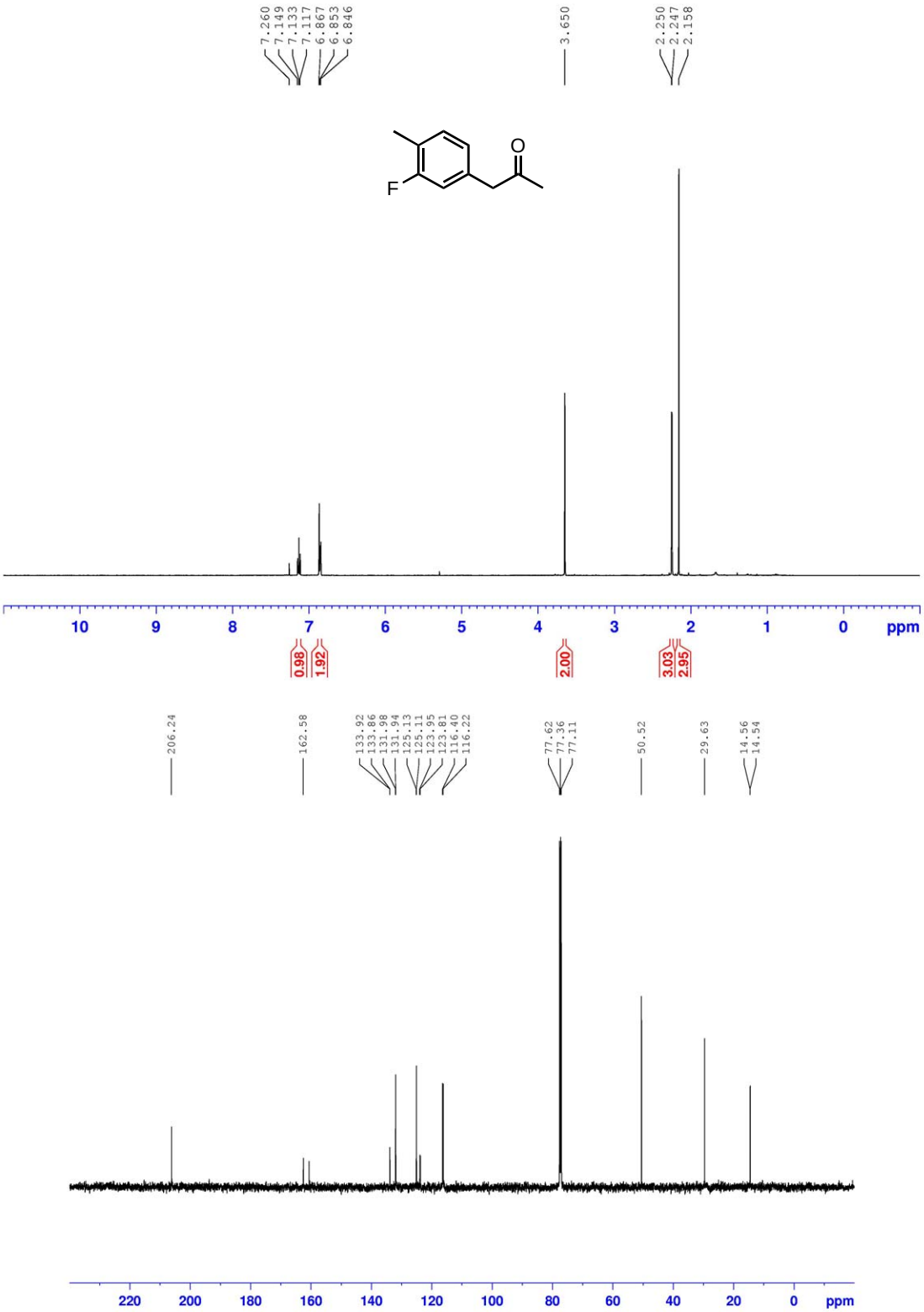
7.260
7.247
7.232
7.160
7.158
7.148
7.144
7.142
7.082
7.079
7.076
6.976
6.975
6.974
6.973
6.971
6.961
6.960
6.959
6.958
6.957
6.956
3.679
3.656
2.470
2.449
2.446
2.152
1.699
MeS
O
10
9
8
7
6
5
4
3
2
1
0
ppm
1.11
1.06
0.99
1.02
2.06
3.01
3.00
206.37
139.37
135.17
129.44
127.59
126.38
125.38
77.62
77.36
77.11
51.12
29.63
15.96
220
200
180
160
140
120
100
80
60
40
20
0
ppm

Table 2, 2e:


7.260
7.149
7.133
7.117
6.867
6.853
6.846
3.650
2.250
2.247
2.158
F
O
10
9
8
7
6
5
4
3
2
1
0
ppm
0.98
1.92
2.00
3.03
2.95
206.24
162.58
133.92
133.86
131.98
131.94
125.13
125.11
123.95
123.81
116.40
116.22
77.62
77.36
77.11
50.52
29.63
14.56
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220
200
180
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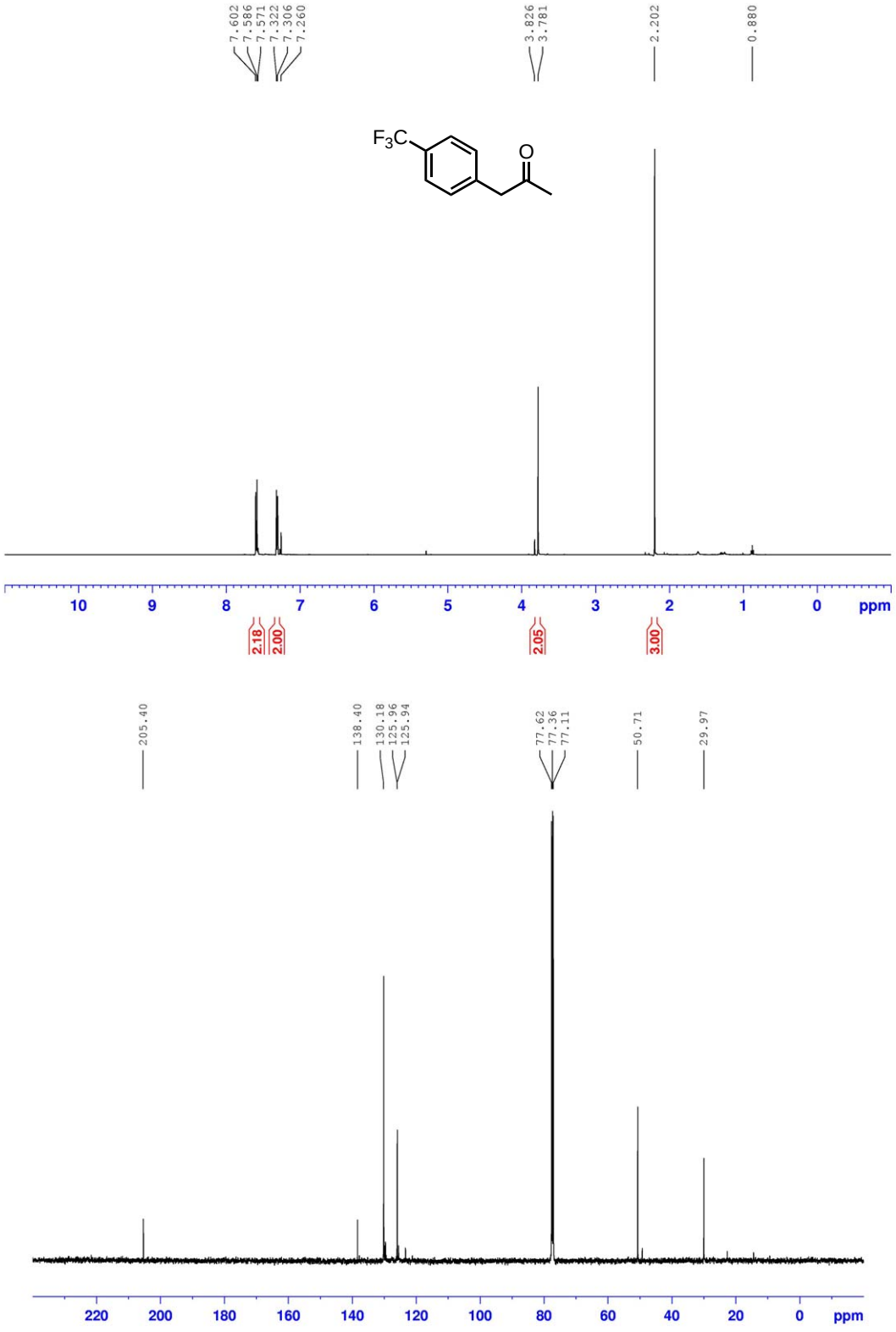
140
120
100
80
60
40
20
0
ppm

Table 2, 2f: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7.260
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F3C
O
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9
8
7
6
5
4
3
2
1
0
ppm
2.18
2.00
2.05
3.00
205.40
138.40
130.18
125.96
125.94
77.62
77.36
77.11
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200
180
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120
100
80
60
40
20
0
ppm

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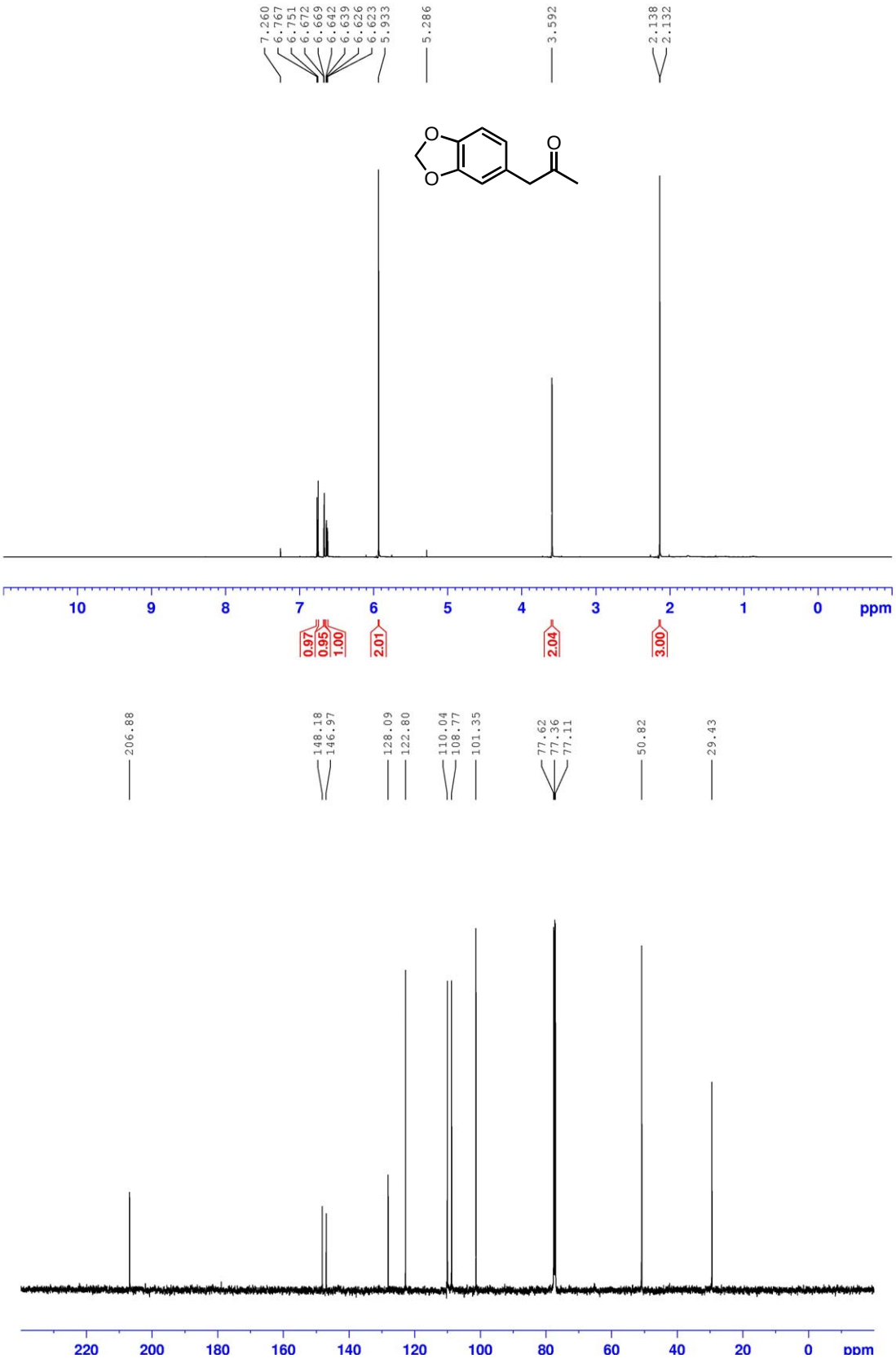
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6.672
6.669
6.642
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6.626
6.623
5.933
5.286
3.592
2.138
2.132
O
O
O
10
9
8
7
6
5
4
3
2
1
0
ppm
0.97
0.95
1.00
2.01
2.04
3.00
206.88
148.18
146.97
128.09
122.80
110.04
108.77
101.35
77.62
77.36
77.11
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220
200
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60
40
20
0
ppm

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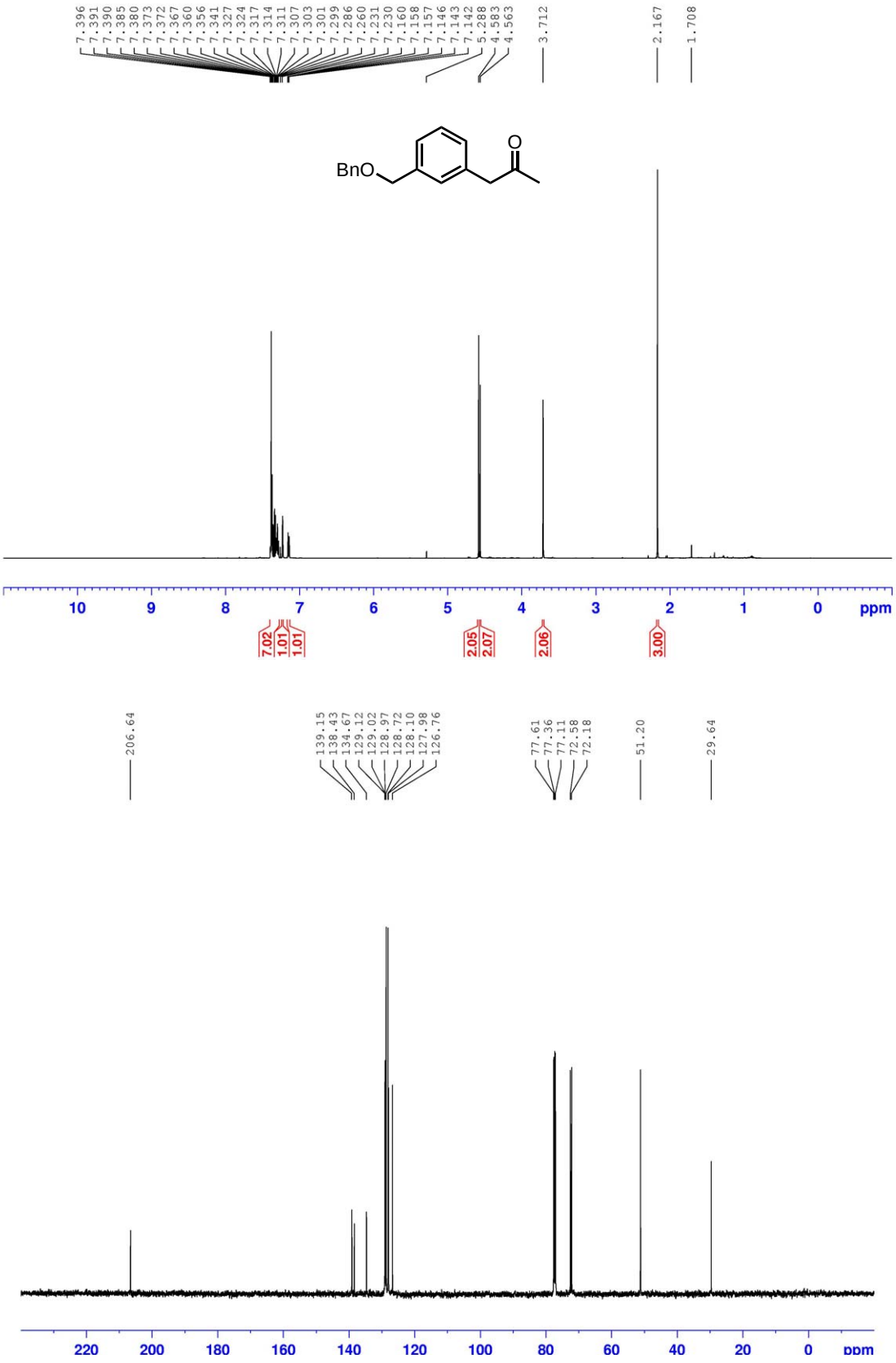
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7.390
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7.373
7.372
7.367
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7.341
7.327
7.324
7.317
7.314
7.311
7.307
7.303
7.301
7.299
7.286
7.260
7.231
7.230
7.160
7.158
7.157
7.146
7.143
7.142
5.288
4.583
4.563
3.712
2.167
1.708
BnO
O
10
9
8
7
6
5
4
3
2
1
0
ppm
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1.01
2.05
2.07
2.06
3.00
206.64
139.15
138.43
134.67
129.12
129.02
128.97
128.72
128.10
127.98
126.76
77.61
77.36
77.11
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200
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160
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80
60
40
20
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ppm

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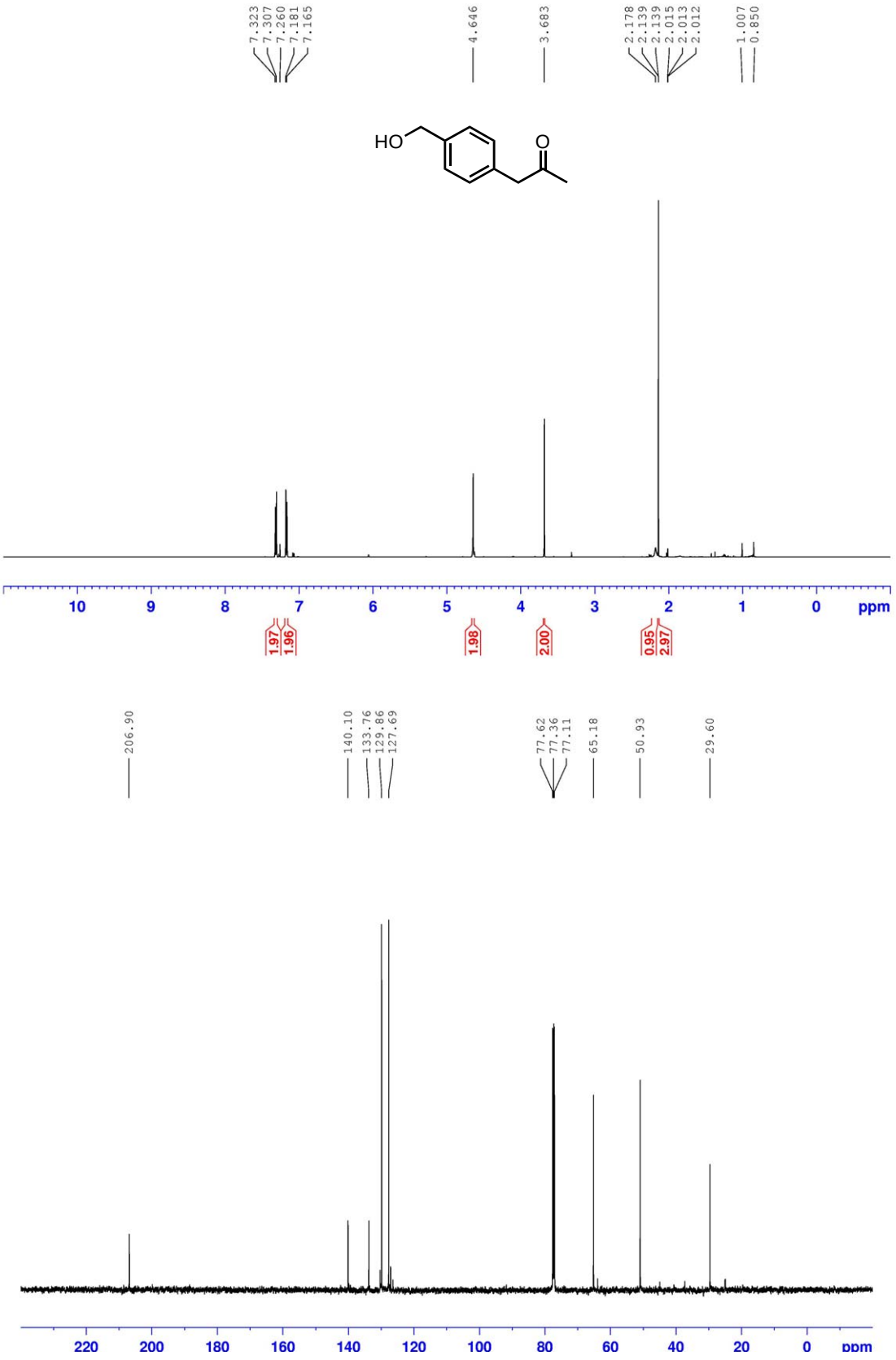
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2.012
1.007
0.850
HO
O
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9
8
7
6
5
4
3
2
1
0
ppm
1.97
1.96
1.98
2.00
0.95
2.97
206.90
140.10
133.76
129.86
127.69
77.62
77.36
77.11
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120
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ppm

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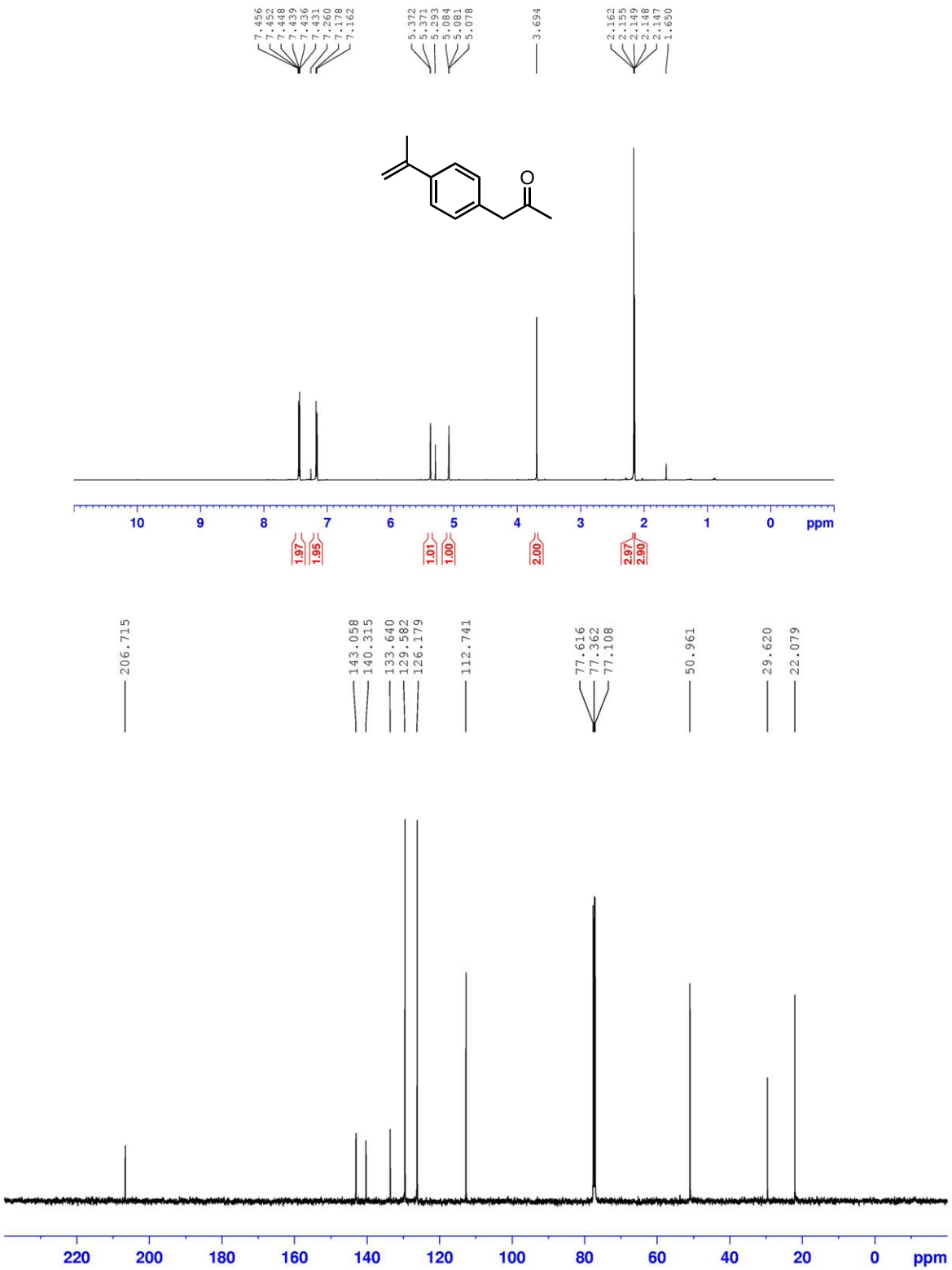
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5.293
5.084
5.081
5.078
3.694
2.162
2.155
2.149
2.148
2.147
1.650
O
10 9 8 7 6 5 4 3 2 1 0 ppm
1.97
1.95
1.01
1.00
2.00
2.97
2.90
206.715
143.058
140.315
133.640
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126.179
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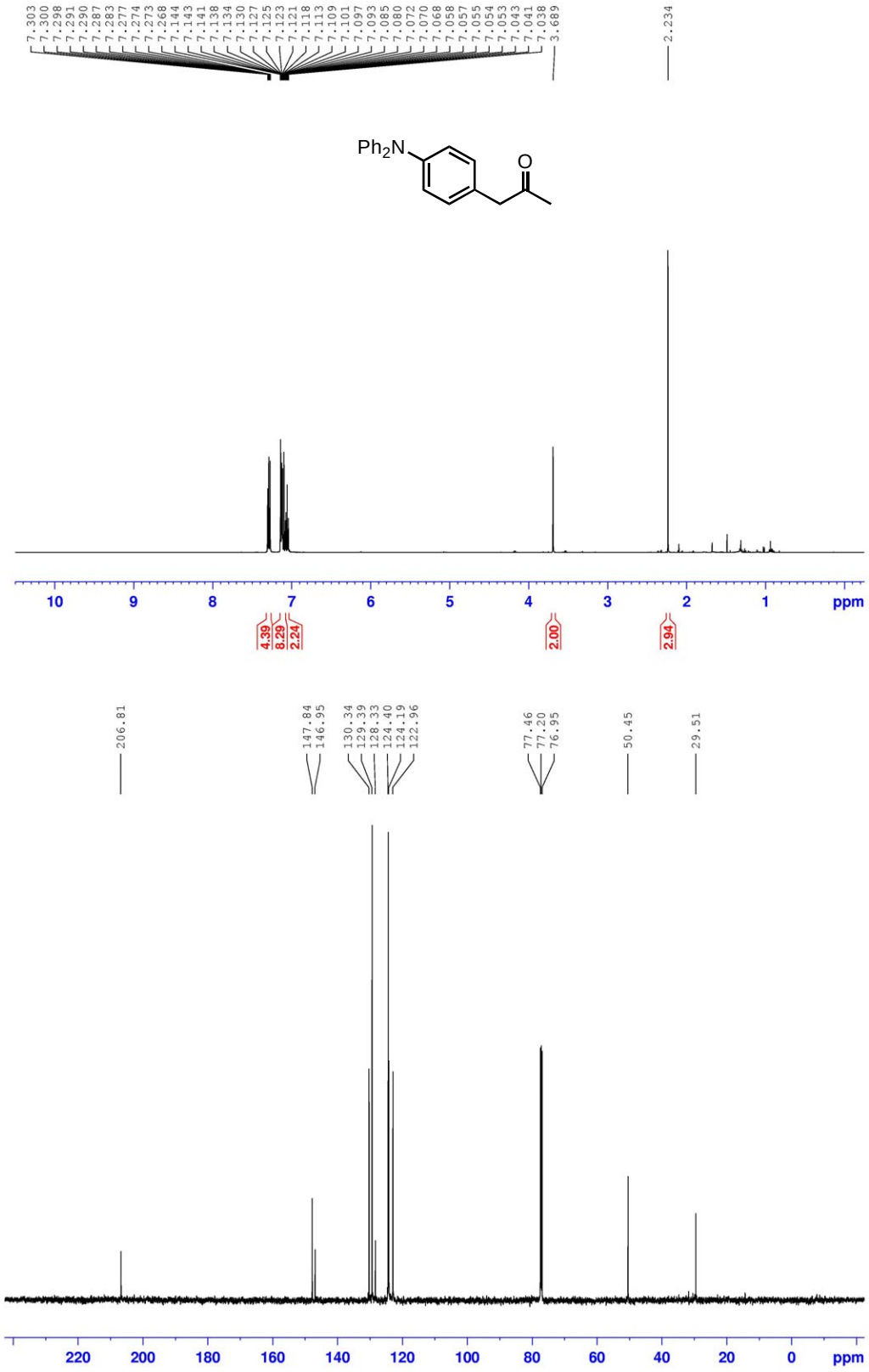
Table 2, 2k: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7.143
7.141
7.138
7.134
7.130
7.127
7.125
7.123
7.121
7.118
7.113
7.109
7.101
7.097
7.093
7.085
7.080
7.072
7.070
7.068
7.058
7.057
7.055
7.054
7.053
7.043
7.041
7.038
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2.234
Ph2N
O
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9
8
7
6
5
4
3
2
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129.39
128.33
124.40
124.19
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77.46
77.20
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80
60
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ppm

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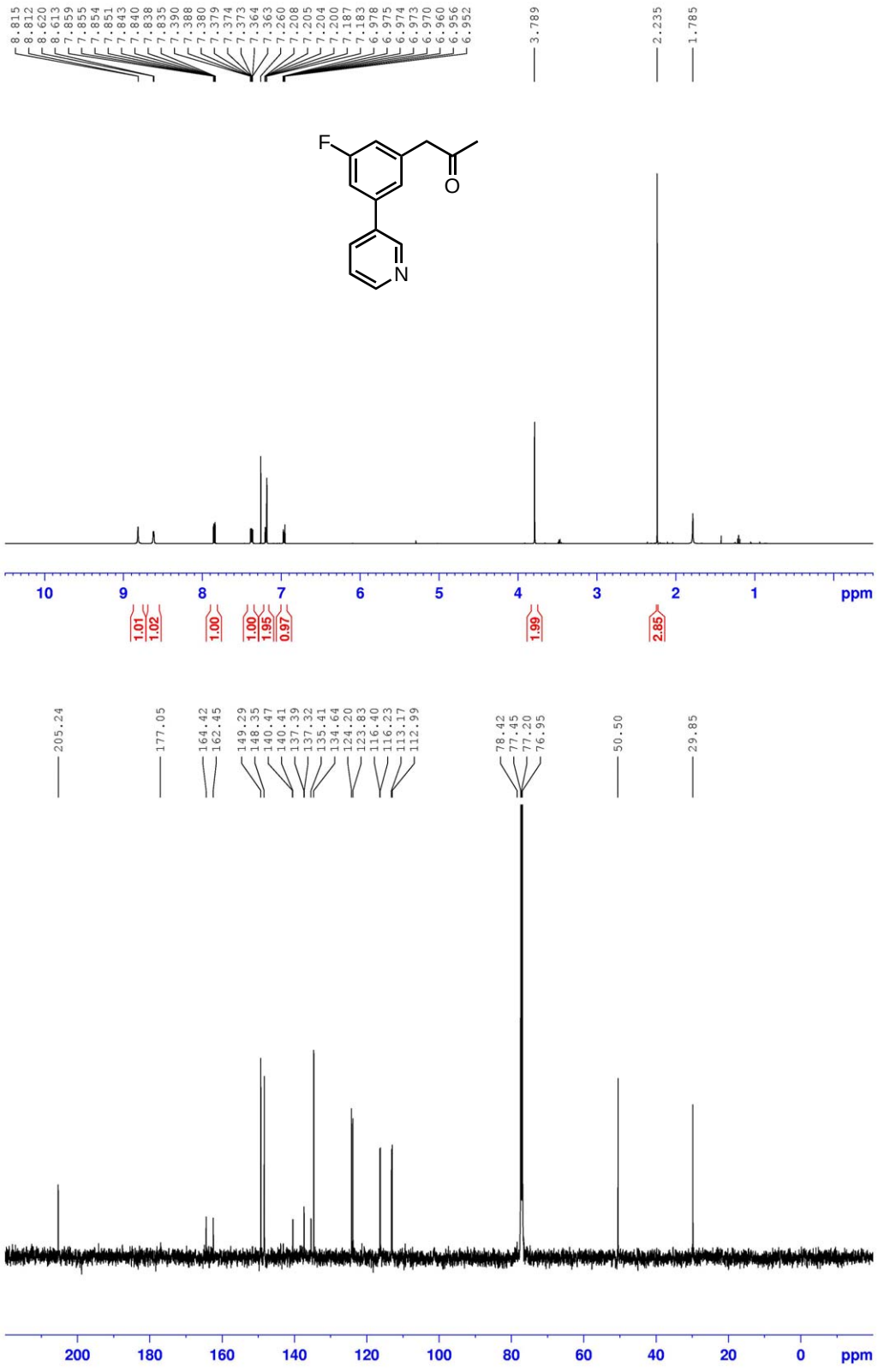
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7.840
7.838
7.835
7.390
7.388
7.380
7.379
7.374
7.373
7.364
7.363
7.260
7.208
7.205
7.204
7.200
7.187
7.183
6.978
6.975
6.974
6.973
6.970
6.960
6.956
6.952
3.789
2.235
1.785
F
O
N
10
9
8
7
6
5
4
3
2
1
ppm
1.01
1.02
1.00
1.00
1.95
0.97
1.99
2.85
205.24
177.05
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162.45
149.29
148.35
140.47
140.41
137.39
137.32
135.41
134.64
124.20
123.83
116.40
116.23
113.17
112.99
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77.20
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60
40
20
0
ppm

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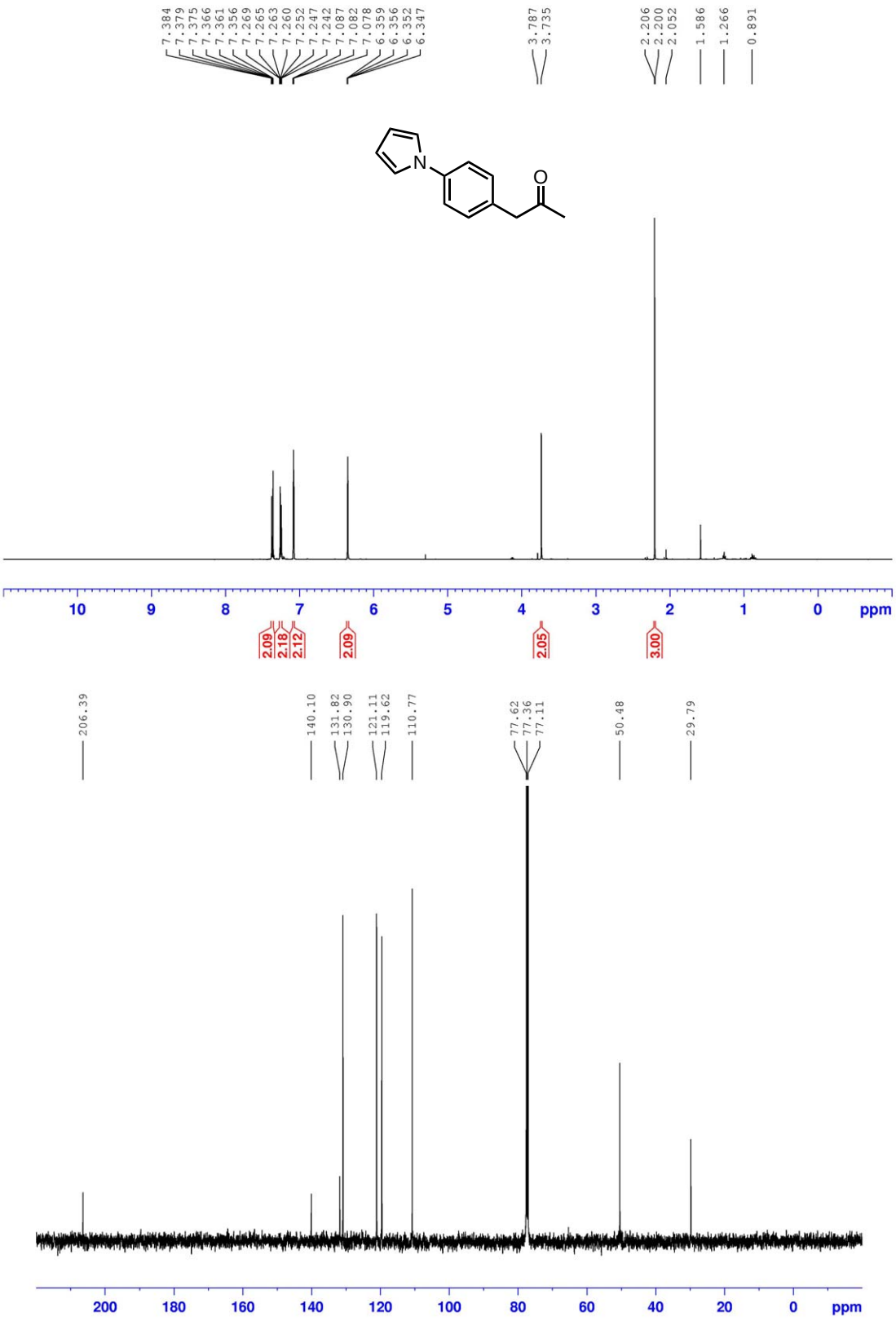
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7.265
7.263
7.260
7.252
7.247
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7.087
7.082
7.078
6.359
6.356
6.352
6.347
3.787
3.735
2.206
2.200
2.052
1.586
1.266
0.891
N
O
10 9 8 7 6 5 4 3 2 1 0 ppm
2.09
2.18
2.12
2.09
2.05
3.00
206.39
140.10
131.82
130.90
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77.11
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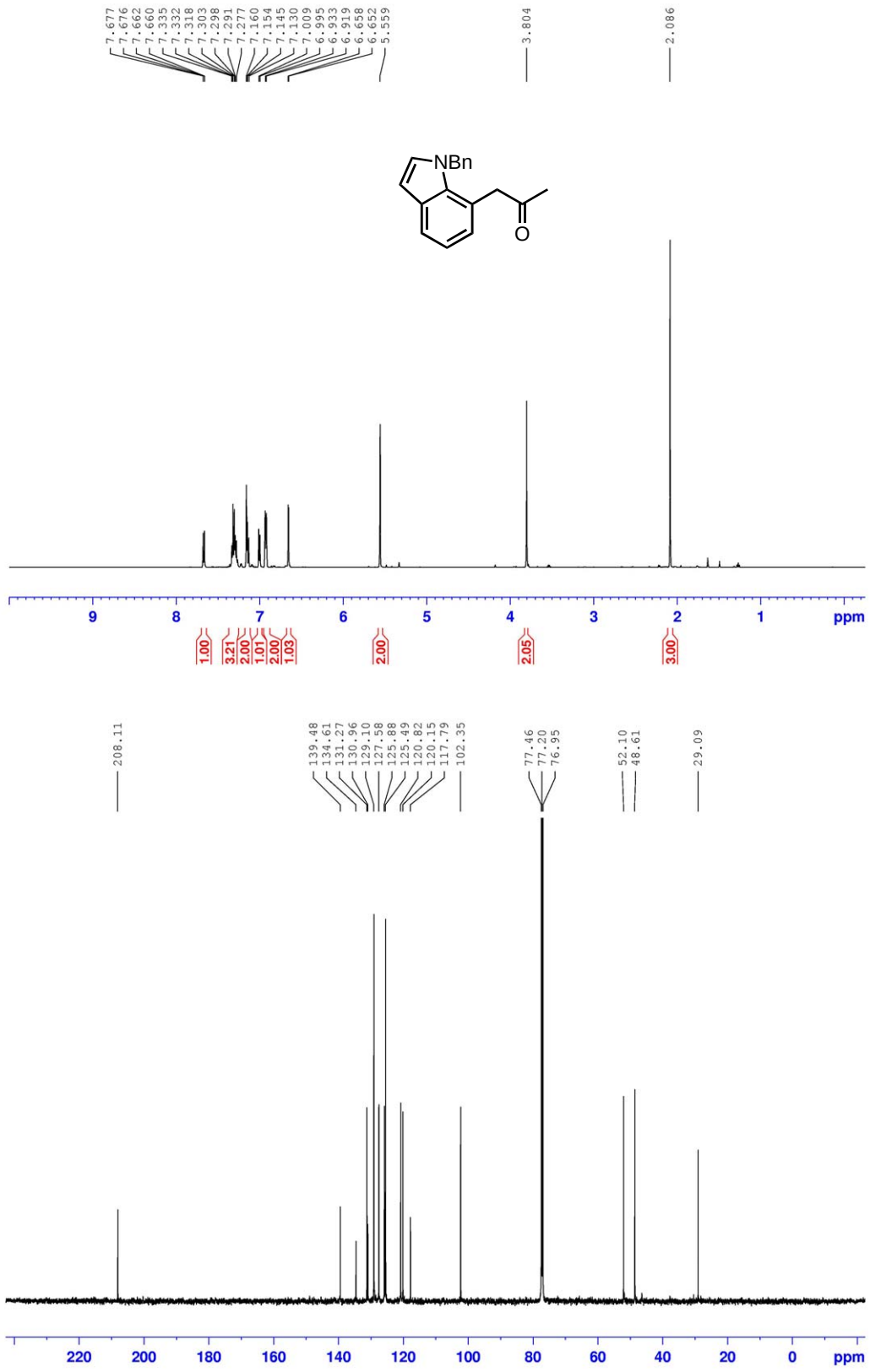
Table 2, 2n: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7.298
7.291
7.277
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7.154
7.145
7.130
7.009
6.995
6.933
6.919
6.658
6.652
5.559
3.804
2.086
NBn
O
9
8
7
6
5
4
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1.00
3.21
2.00
1.01
2.00
1.03
2.00
2.05
3.00
208.11
139.48
134.61
131.27
130.96
129.10
127.58
125.88
125.49
120.82
120.15
117.79
102.35
77.46
77.20
76.95
52.10
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200
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120
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60
40
20
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ppm

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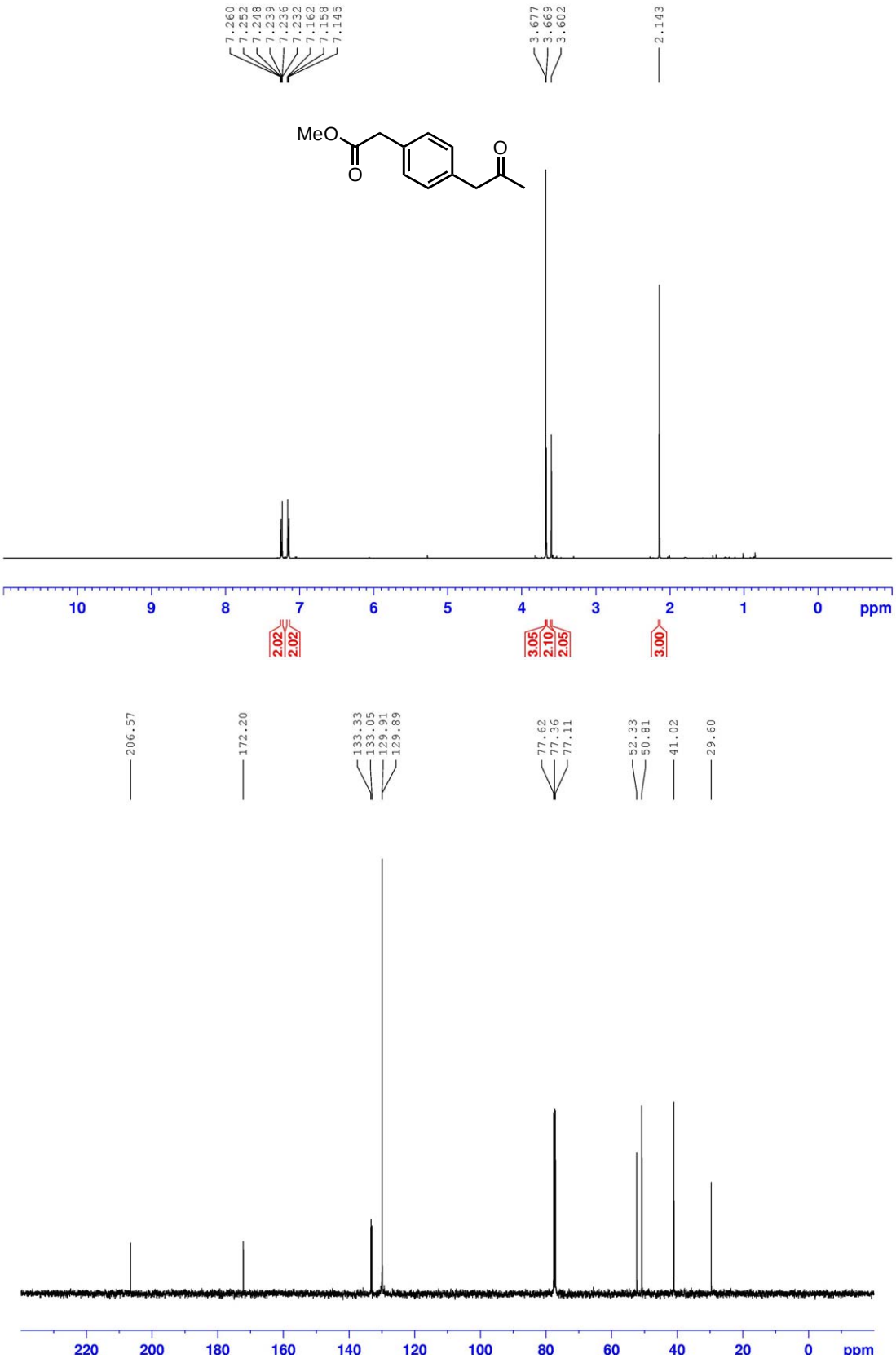
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3.669
3.602
2.143
MeO
O
O
10
9
8
7
6
5
4
3
2
1
0
ppm
2.02
2.02
3.05
2.10
2.05
3.00
206.57
172.20
133.33
133.05
129.91
129.89
77.62
77.36
77.11
52.33
50.81
41.02
29.60
220
200
180
160
140
120
100
80
60
40
20
0
ppm

Table 2, 2p:

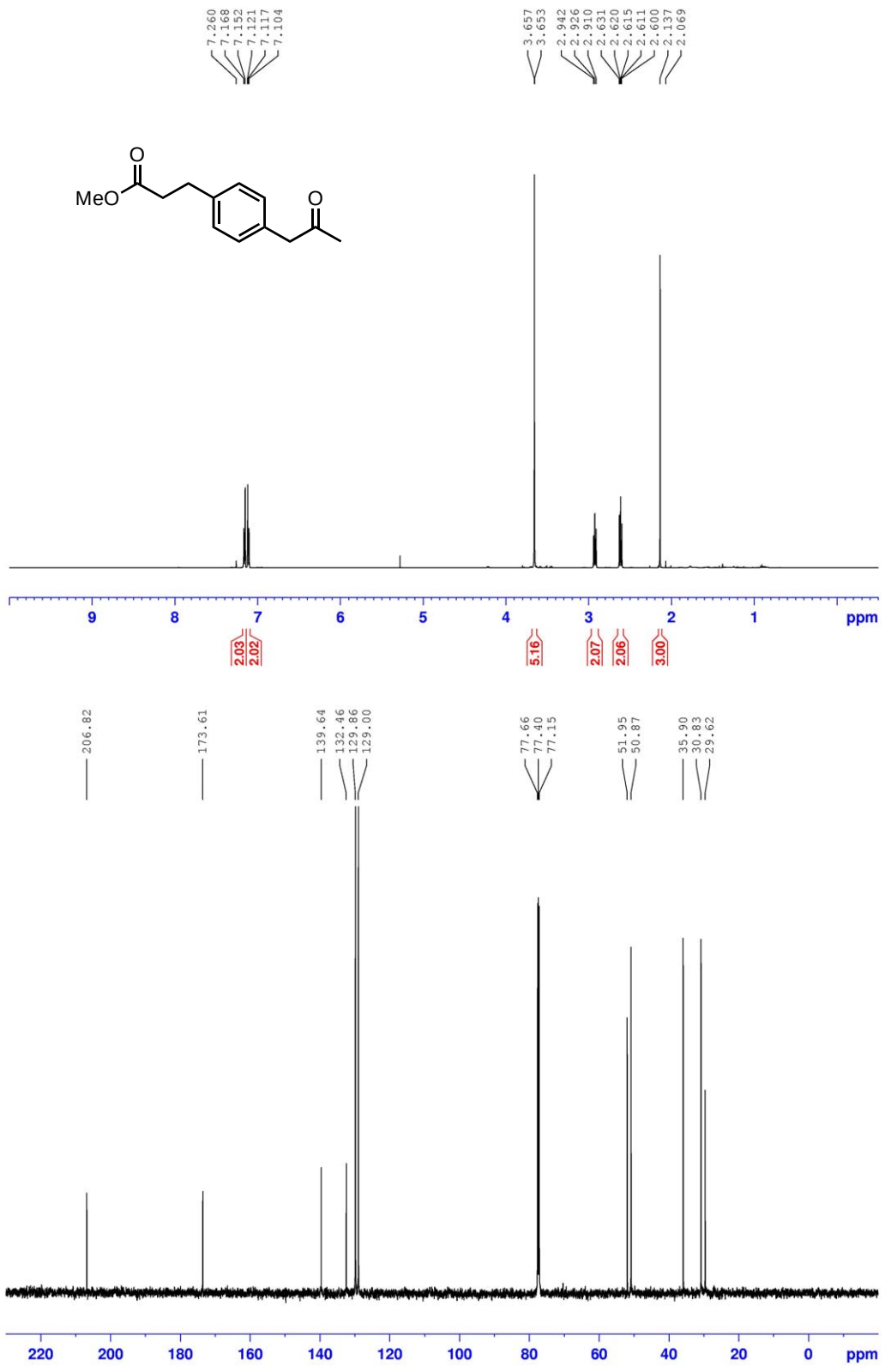

7.260
7.168
7.152
7.121
7.117
7.104
3.657
3.653
2.942
2.926
2.910
2.631
2.620
2.615
2.611
2.600
2.137
2.069
O
MeO
O
9
8
7
6
5
4
3
2
1
ppm
2.03
2.02
5.16
2.07
2.06
3.00
206.82
173.61
139.64
132.46
129.86
129.00
77.66
77.40
77.15
51.95
50.87
35.90
30.83
29.62
220
200
180
160
140
120
100
80
60
40
20
0
ppm

Table 2, 2r:

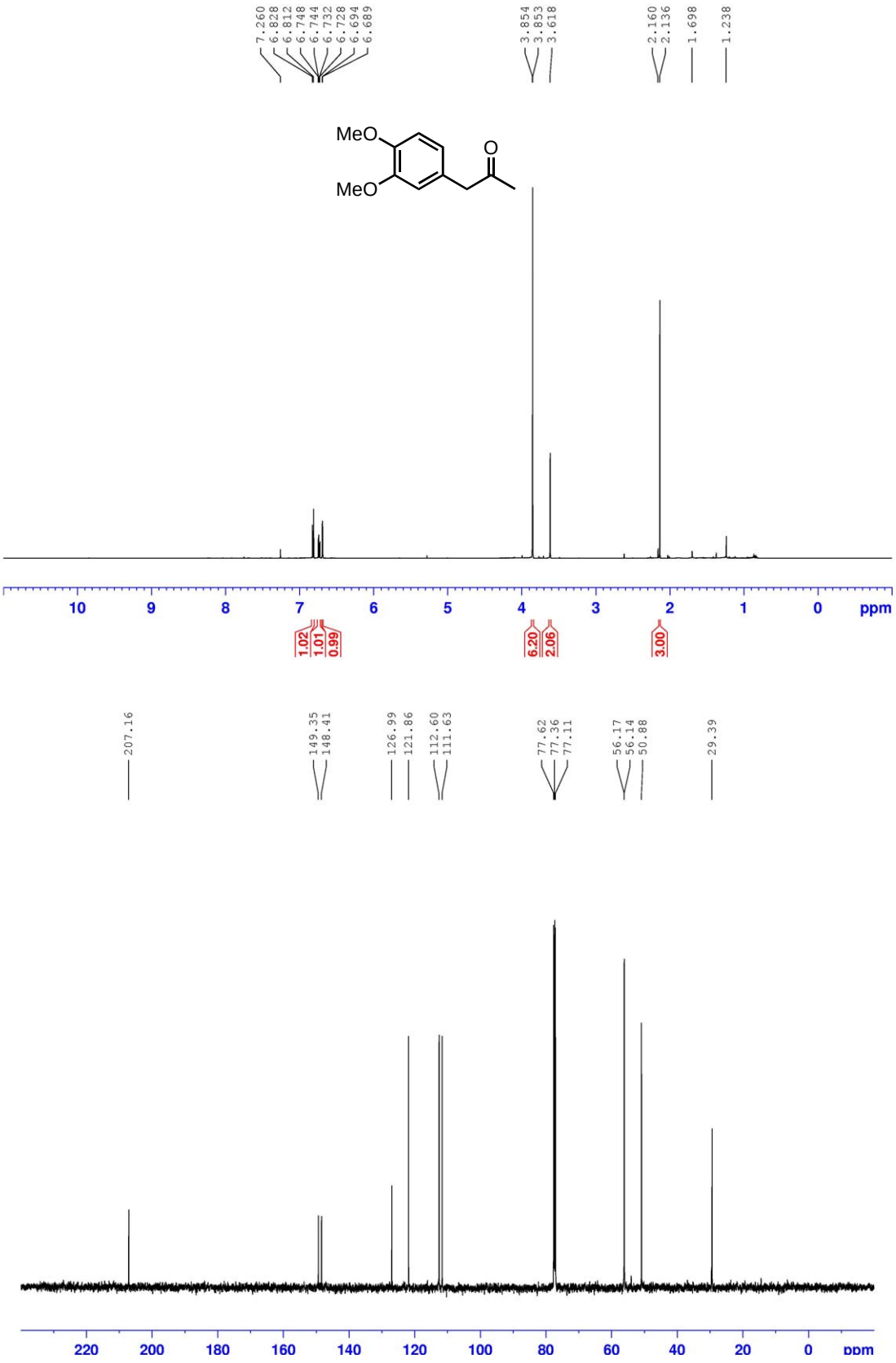

7.260
6.828
6.812
6.748
6.744
6.732
6.728
6.694
6.689
3.854
3.853
3.618
2.160
2.136
1.698
1.238
MeO
MeO
O
10
9
8
7
6
5
4
3
2
1
0
ppm
1.02
1.01
0.99
6.20
2.06
3.00
207.16
149.35
148.41
126.99
121.86
112.60
111.63
77.62
77.36
77.11
56.17
56.14
50.88
29.39
220
200
180
160
140
120
100
80
60
40
20
0
ppm

Table 2, 2s:

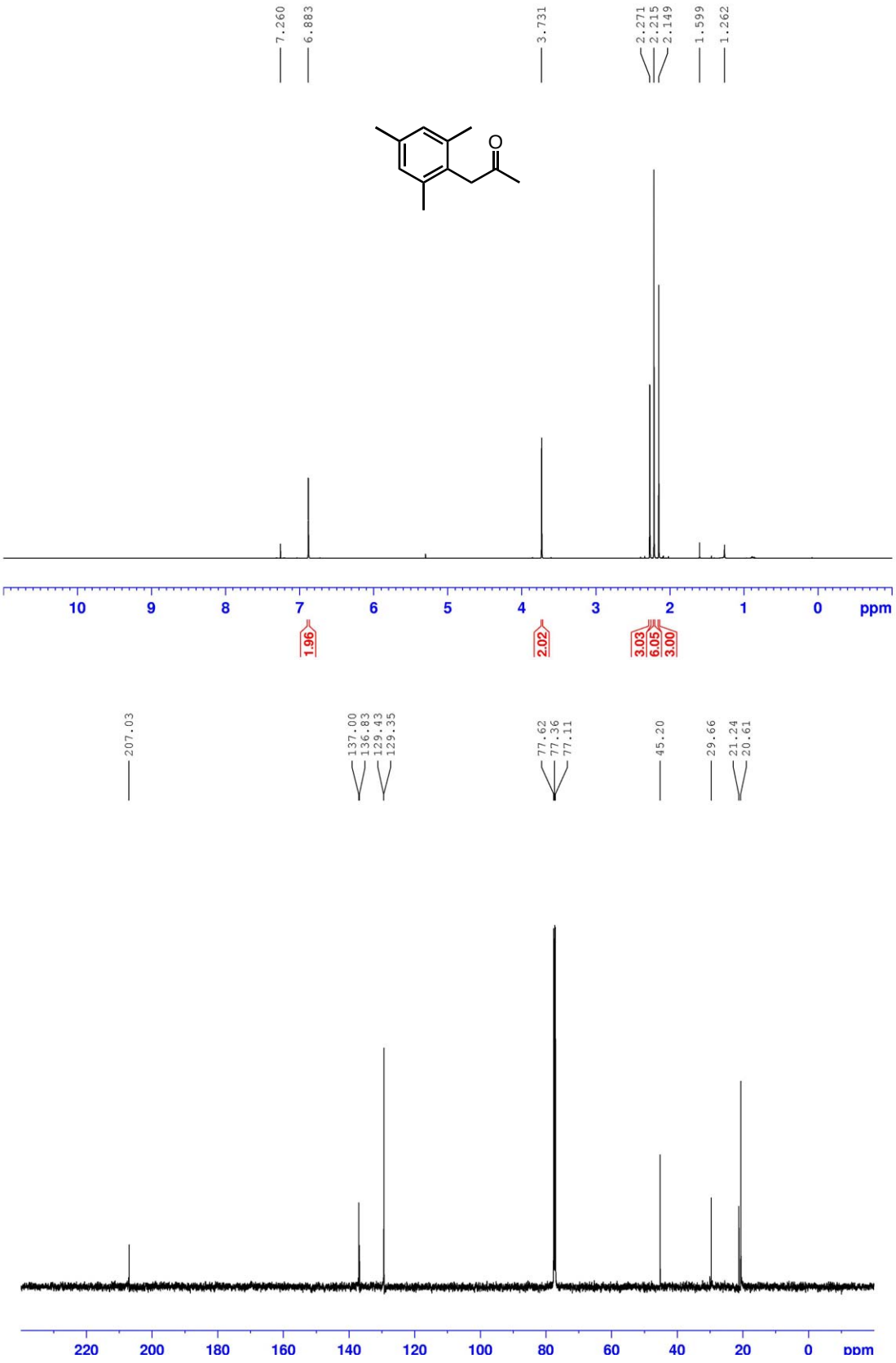

7.260
6.883
3.731
2.271
2.215
2.149
1.599
1.262
O
10
9
8
7
6
5
4
3
2
1
0
ppm
1.96
2.02
3.03
6.05
3.00
207.03
137.00
136.83
129.43
129.35
77.62
77.36
77.11
45.20
29.66
21.24
20.61
220
200
180
160
140
120
100
80
60
40
20
0
ppm

Table 2, 2t:

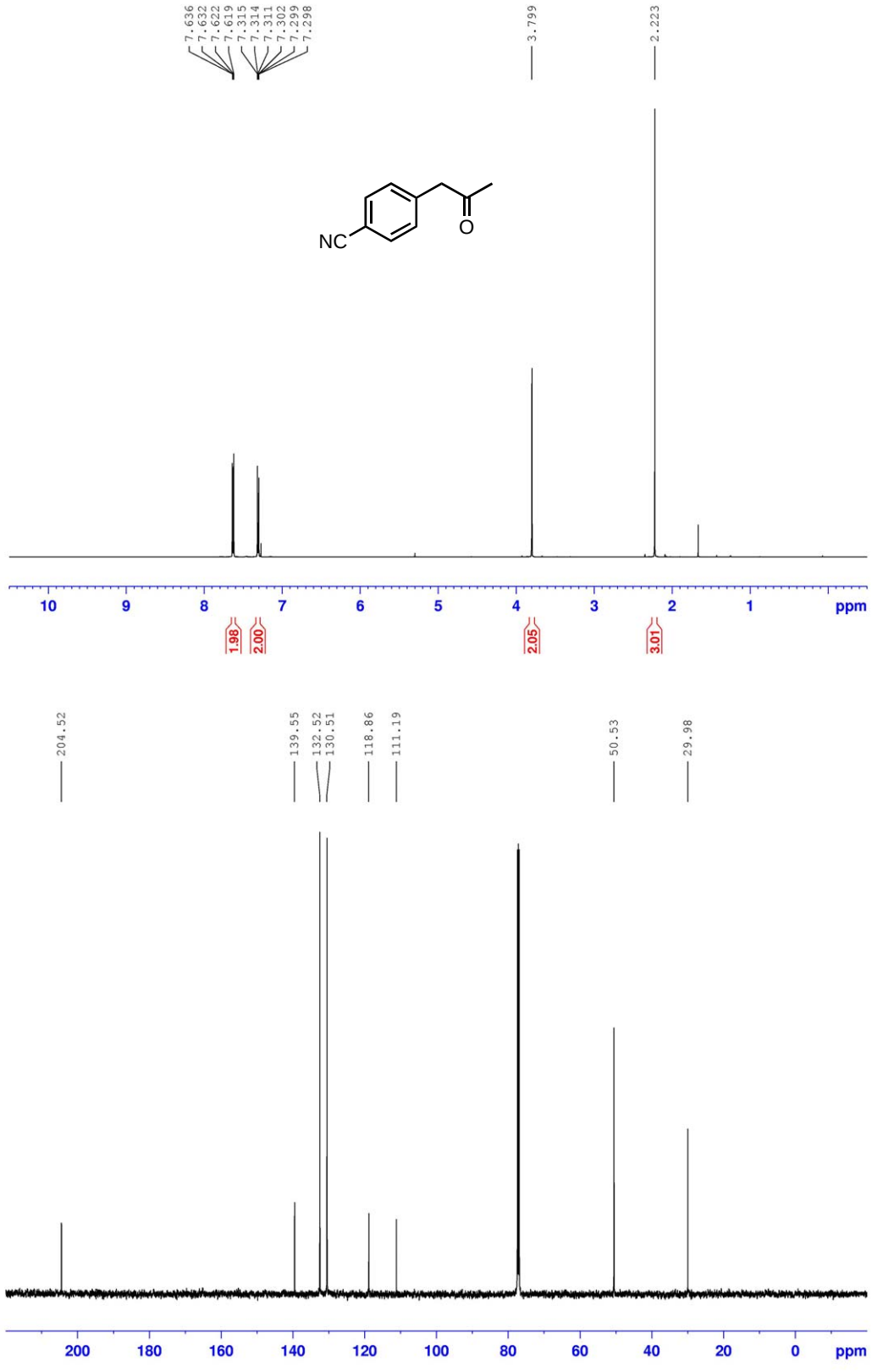

7.636
7.632
7.622
7.619
7.315
7.314
7.311
7.302
7.299
7.298
3.799
2.223
NC
O
10
9
8
7
6
5
4
3
2
1
ppm
1.98
2.00
2.05
3.01
204.52
139.55
132.52
130.51
118.86
111.19
50.53
29.98
200
180
160
140
120
100
80
60
40
20
0
ppm

Table 2, 2u:

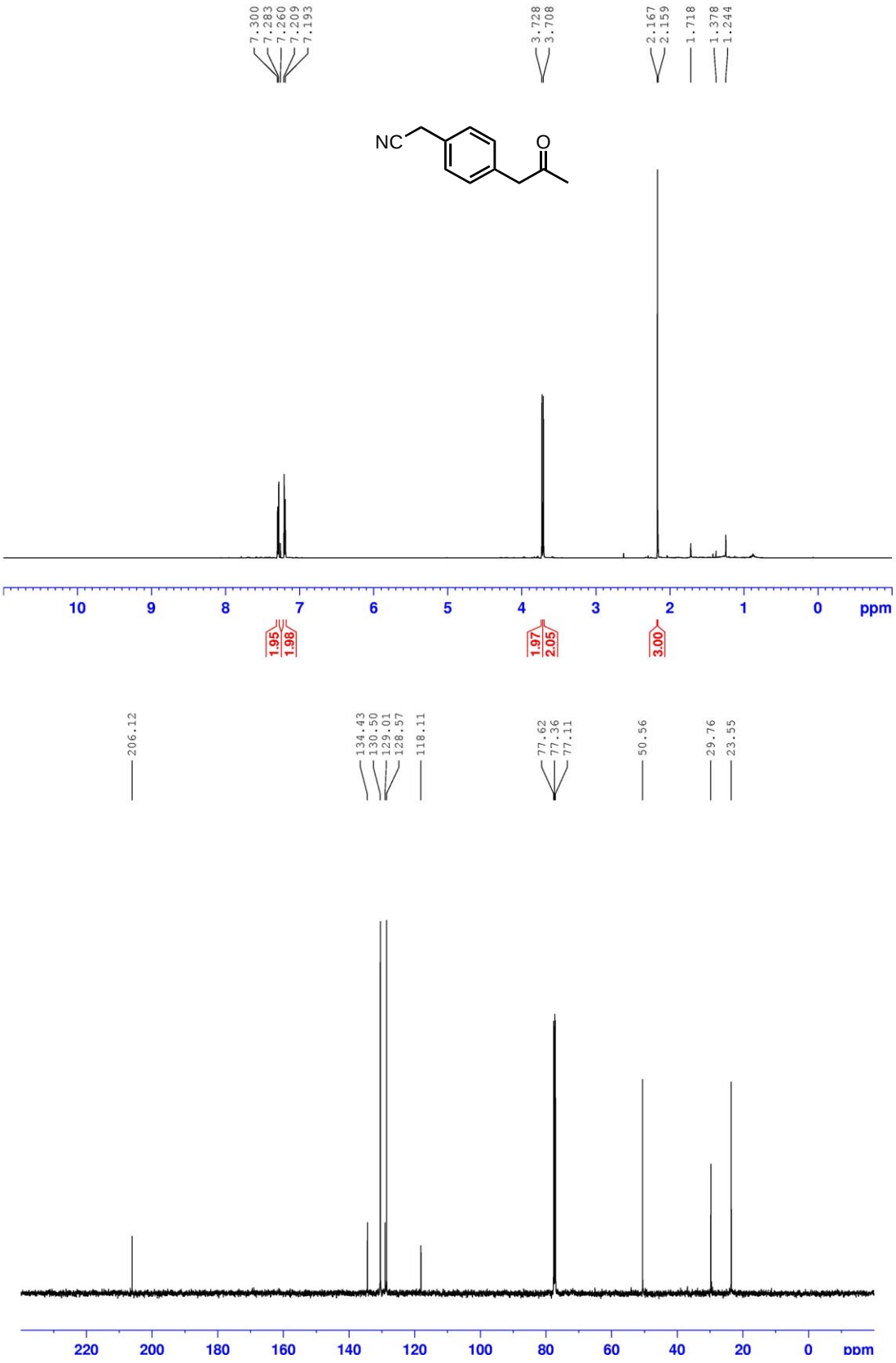

7.300
7.283
7.260
7.209
7.193
3.728
3.708
2.167
2.159
1.718
1.378
1.244
NC
O
10
9
8
7
6
5
4
3
2
1
0
ppm
1.95
1.98
1.97
2.05
3.00
206.12
134.43
130.50
129.01
128.57
118.11
77.62
77.36
77.11
50.56
29.76
23.55
220
200
180
160
140
120
100
80
60
40
20
0
ppm

Table 2, 2v:

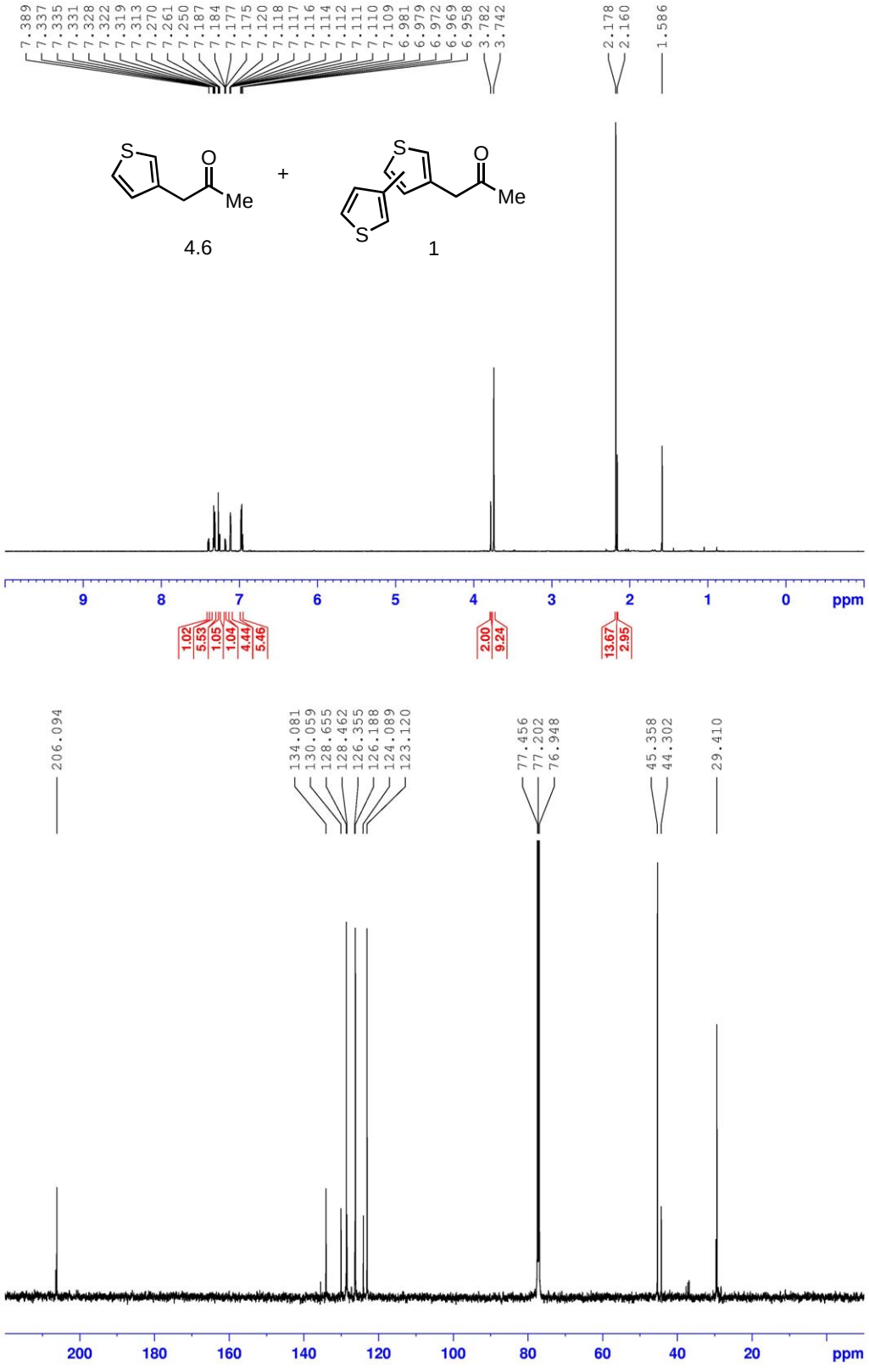

7.389
7.337
7.335
7.331
7.328
7.322
7.319
7.313
7.270
7.261
7.250
7.187
7.184
7.177
7.175
7.120
7.118
7.117
7.116
7.114
7.112
7.111
7.110
7.109
6.981
6.979
6.972
6.969
6.958
3.782
3.742
2.178
2.160
1.586
S
O
Me
+
S
O
Me
S
4.6
1
9
8
7
6
5
4
3
2
1
0
ppm
1.02
5.53
1.05
1.04
4.44
5.46
2.00
9.24
13.67
2.95
206.094
134.081
130.059
128.655
128.462
126.355
126.188
124.089
123.120
77.456
77.202
76.948
45.358
44.302
29.410
200
180
160
140
120
100
80
60
40
20
ppm

Table 2, 2w:

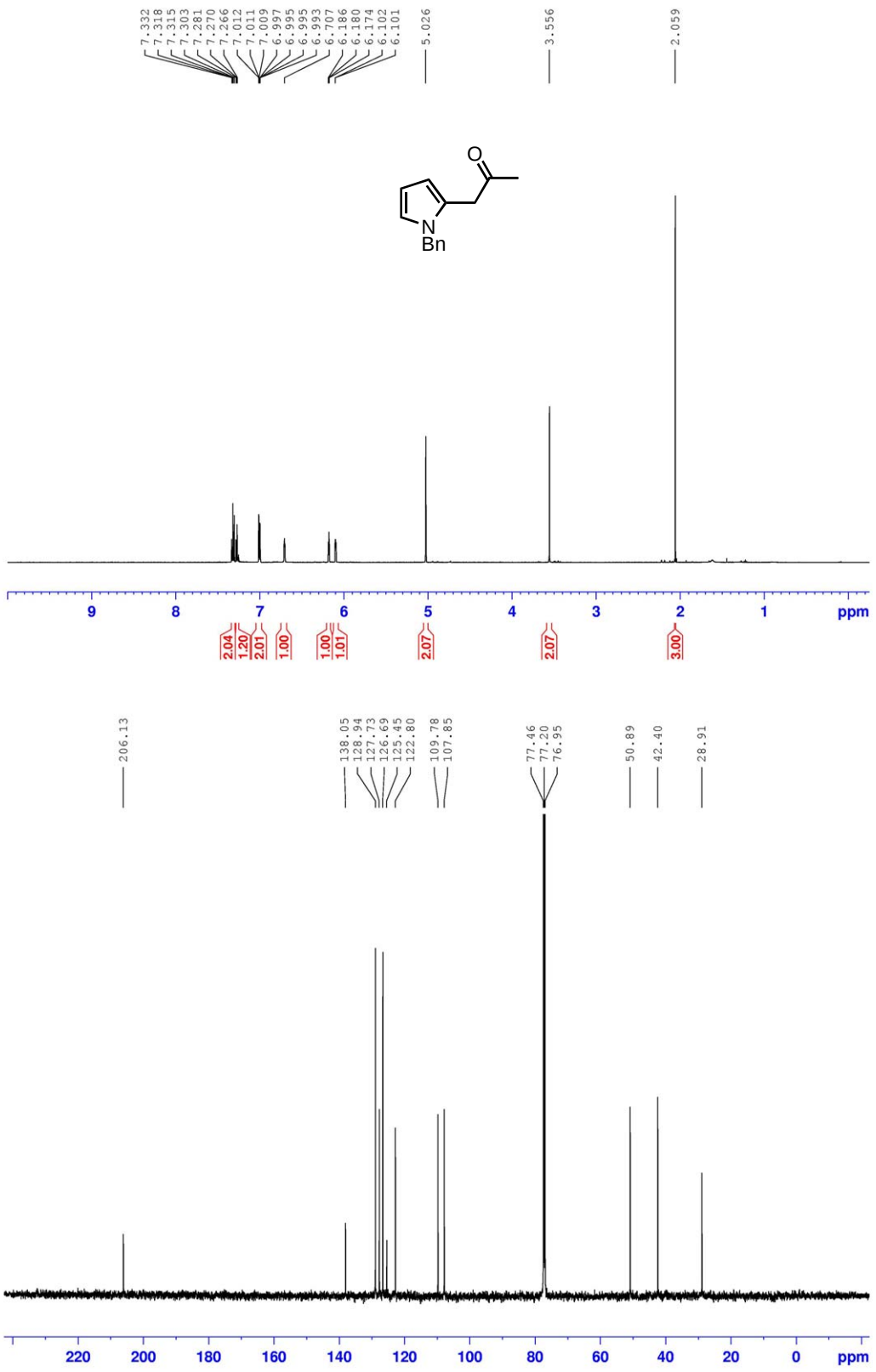

7.332
7.318
7.315
7.303
7.281
7.270
7.266
7.012
7.011
7.009
6.997
6.995
6.995
6.993
6.707
6.186
6.180
6.174
6.102
6.101
5.026
3.556
2.059
O
N
Bn
9
8
7
6
5
4
3
2
1
ppm
2.04
1.20
2.01
1.00
1.00
1.01
2.07
2.07
3.00
206.13
138.05
128.94
127.73
126.69
125.45
122.80
109.78
107.85
77.46
77.20
76.95
50.89
42.40
28.91
220
200
180
160
140
120
100
80
60
40
20
0
ppm

Table 2, 2x:

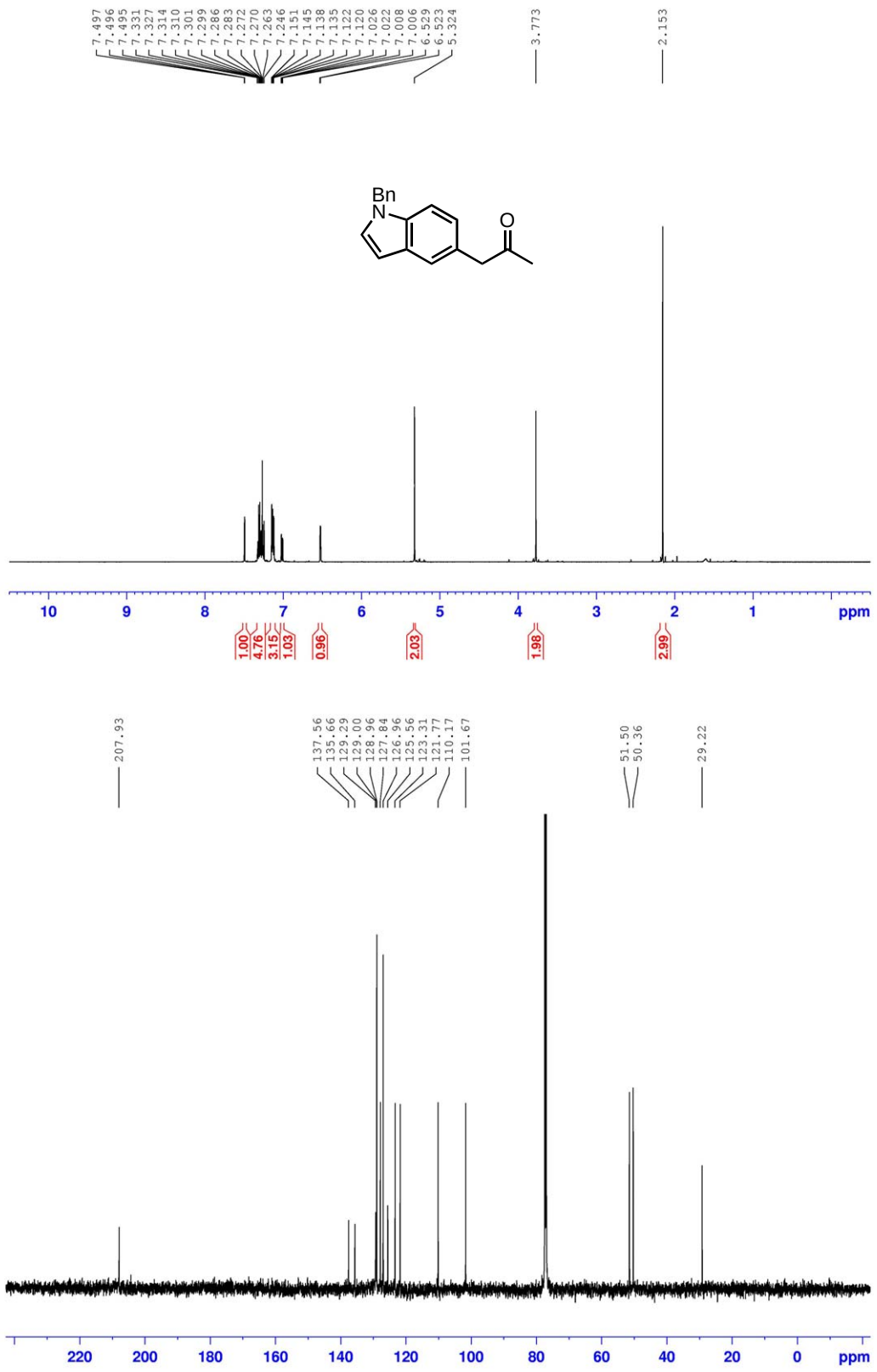

7.497
7.496
7.495
7.331
7.327
7.314
7.310
7.301
7.299
7.286
7.283
7.272
7.270
7.263
7.246
7.151
7.145
7.138
7.135
7.122
7.120
7.026
7.022
7.008
7.006
6.529
6.523
5.324
3.773
2.153
Bn
N
O
10
9
8
7
6
5
4
3
2
1
ppm
1.00
4.76
3.15
1.03
0.96
2.03
1.98
2.99
207.93
137.56
135.66
129.29
129.00
128.96
127.84
126.96
125.56
123.31
121.77
110.17
101.67
51.50
50.36
29.22
220
200
180
160
140
120
100
80
60
40
20
0
ppm

Table 2, 2y:

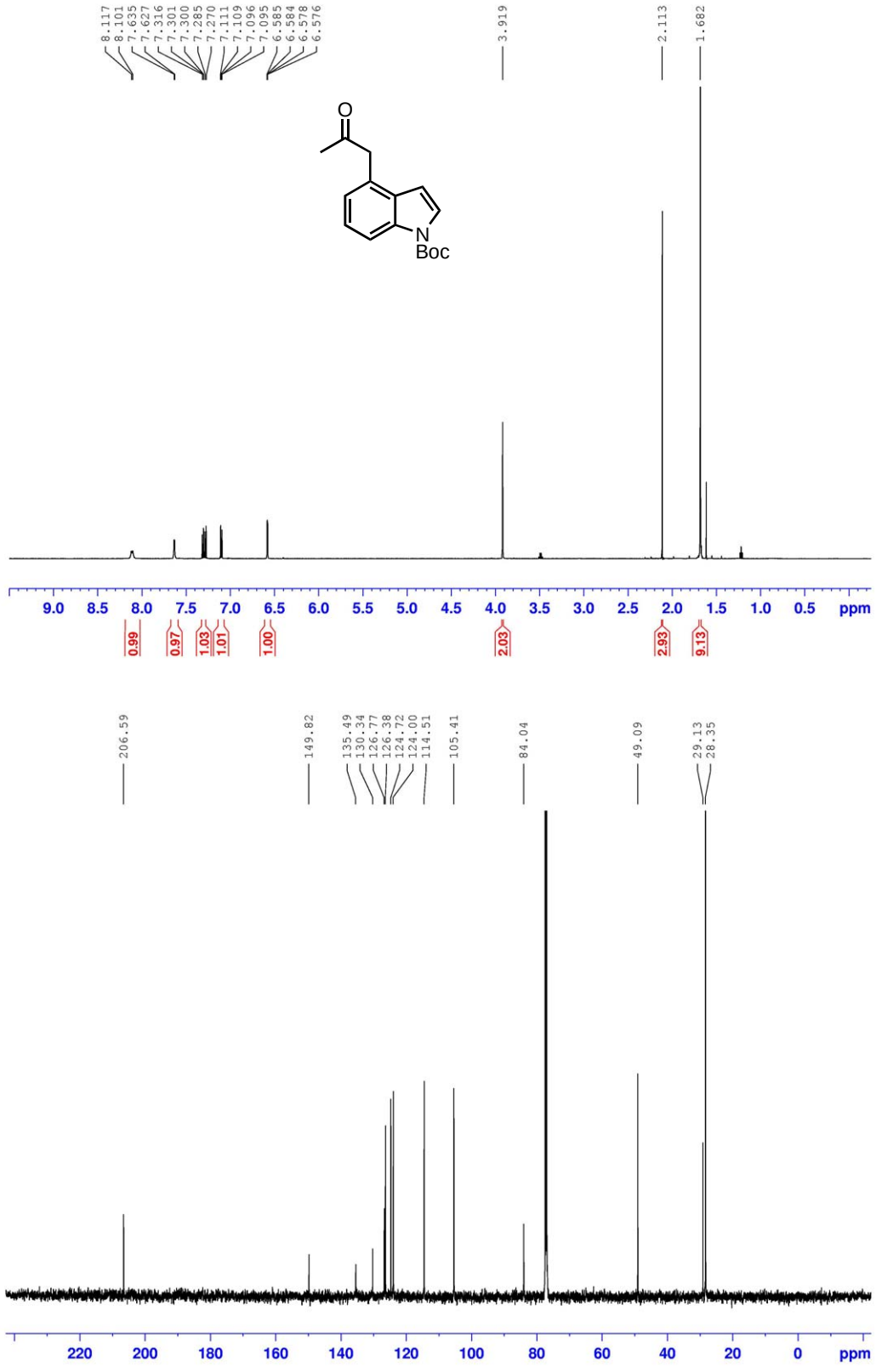

8.117
8.101
7.635
7.627
7.316
7.301
7.300
7.285
7.270
7.111
7.109
7.096
7.095
6.585
6.584
6.578
6.576
3.919
2.113
1.682
O
N
Boc
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
0.99
0.97
1.03
1.01
1.00
2.03
2.93
9.13
206.59
149.82
135.49
130.34
126.77
126.38
124.72
124.00
114.51
105.41
84.04
49.09
29.13
28.35
220 200 180 160 140 120 100 80 60 40 20 0 ppm

Table 2, alcohol derivative of 2z:

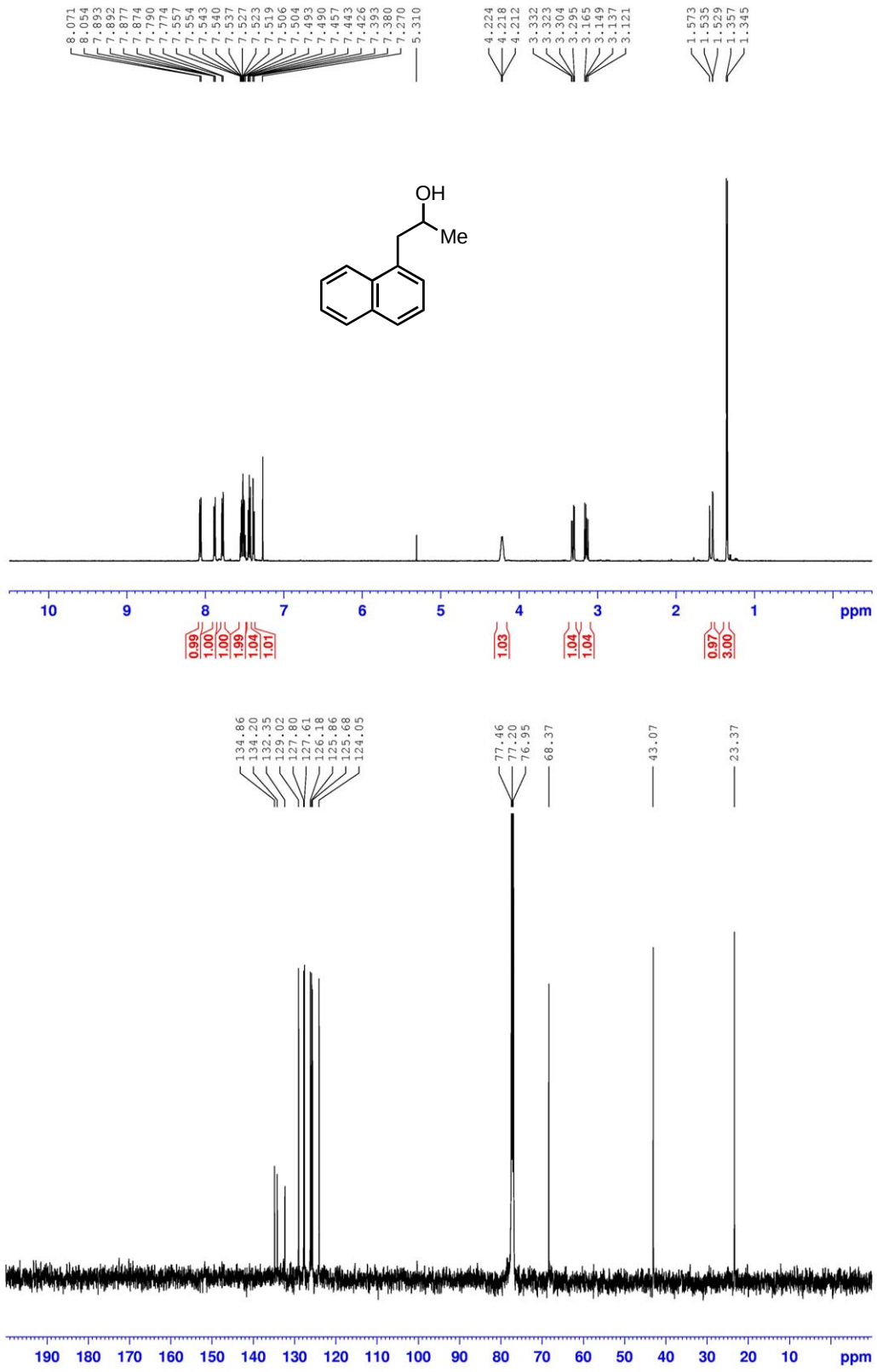


Table 2, 2aa:

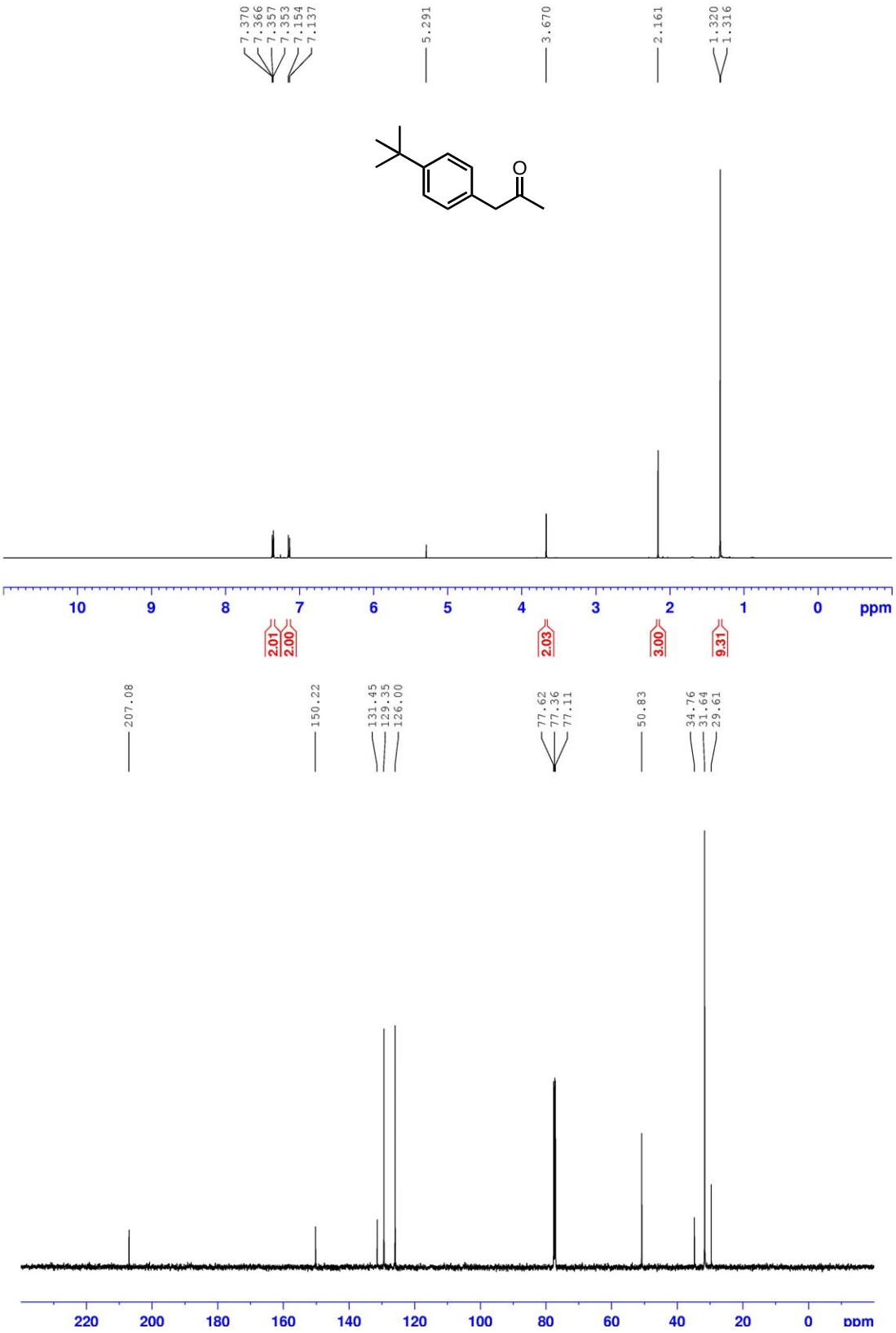

7.370
7.366
7.357
7.353
7.154
7.137
5.291
3.670
2.161
1.320
1.316
O
10 9 8 7 6 5 4 3 2 1 0 ppm
2.01
2.00
2.03
3.00
9.31
207.08
150.22
131.45
129.35
126.00
77.62
77.36
77.11
50.83
34.76
31.64
29.61
220 200 180 160 140 120 100 80 60 40 20 0 ppm

Table 2, 2bb:

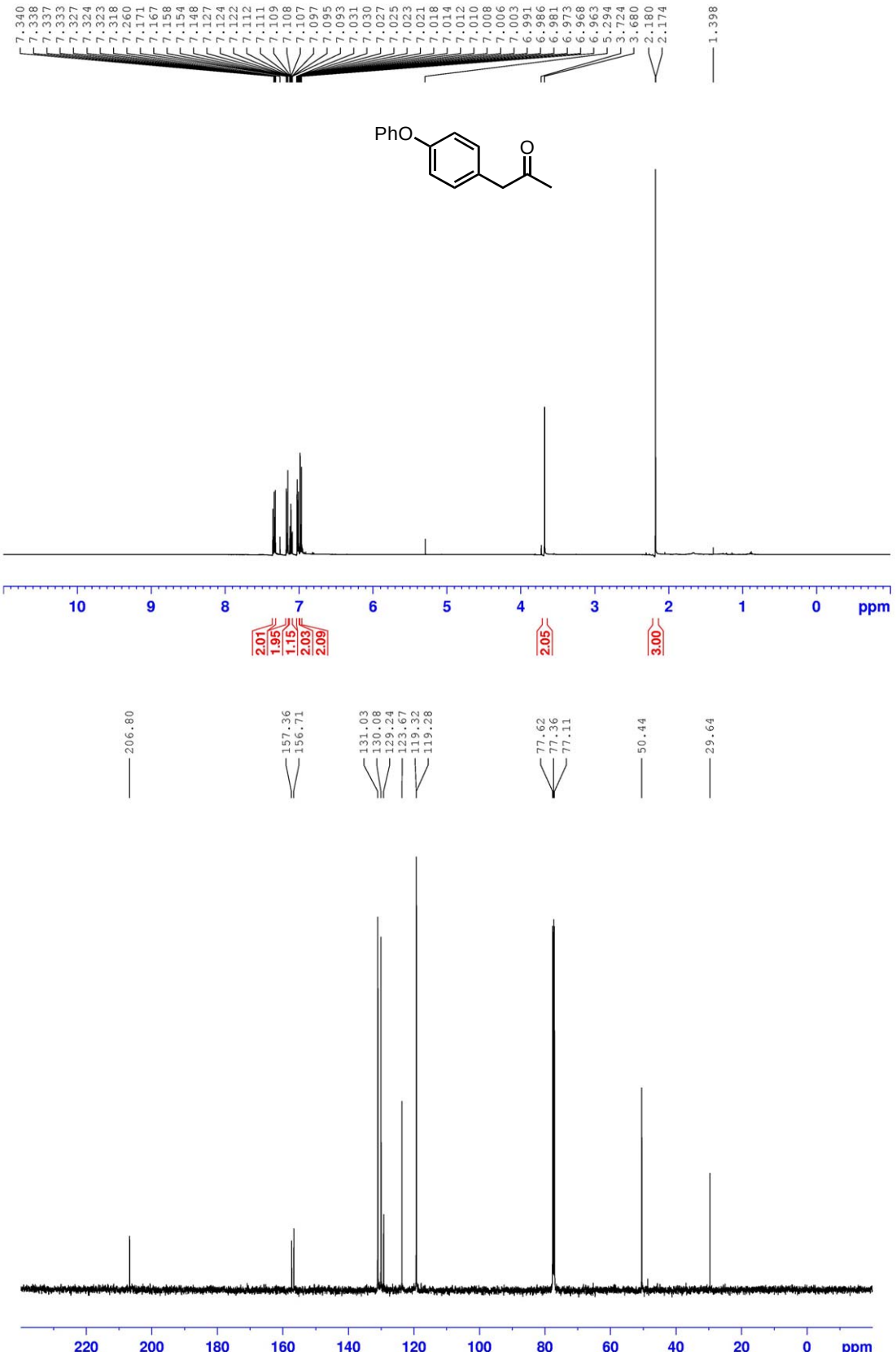

7.340
7.338
7.337
7.333
7.327
7.324
7.323
7.318
7.260
7.171
7.167
7.158
7.154
7.148
7.127
7.124
7.122
7.112
7.111
7.109
7.108
7.107
7.097
7.095
7.093
7.031
7.030
7.027
7.025
7.023
7.021
7.018
7.014
7.012
7.010
7.008
7.006
7.003
6.991
6.986
6.981
6.973
6.968
6.963
5.294
3.724
3.680
2.180
2.174
1.398
PhO
O
10
9
8
7
6
5
4
3
2
1
0
ppm
2.01
1.95
1.15
2.03
2.09
2.05
3.00
206.80
157.36
156.71
131.03
130.08
129.24
123.67
119.32
119.28
77.62
77.36
77.11
50.44
29.64
220
200
180
160
140
120
100
80
60
40
20
0
ppm

Table 2, 2cc:

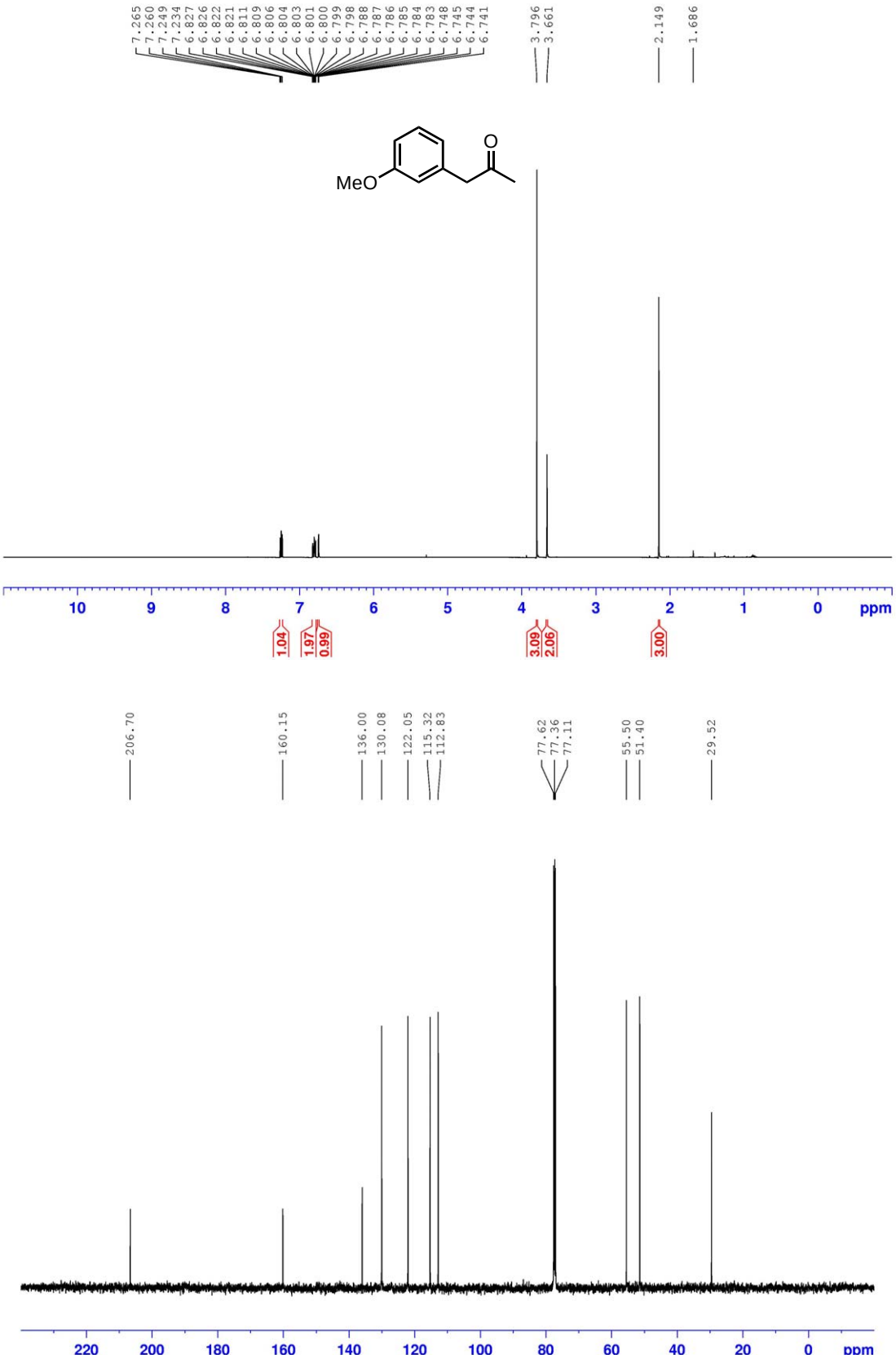

7.265
7.260
7.249
7.234
6.827
6.826
6.822
6.821
6.811
6.809
6.806
6.804
6.803
6.801
6.800
6.799
6.798
6.788
6.787
6.786
6.785
6.784
6.783
6.748
6.745
6.744
6.741
3.796
3.661
2.149
1.686
MeO
O
10 9 8 7 6 5 4 3 2 1 0 ppm
1.04
1.97
0.99
3.09
2.06
3.00
206.70
160.15
136.00
130.08
122.05
115.32
112.83
77.62
77.36
77.11
55.50
51.40
29.52
220 200 180 160 140 120 100 80 60 40 20 0 ppm

Table 2, 2dd:

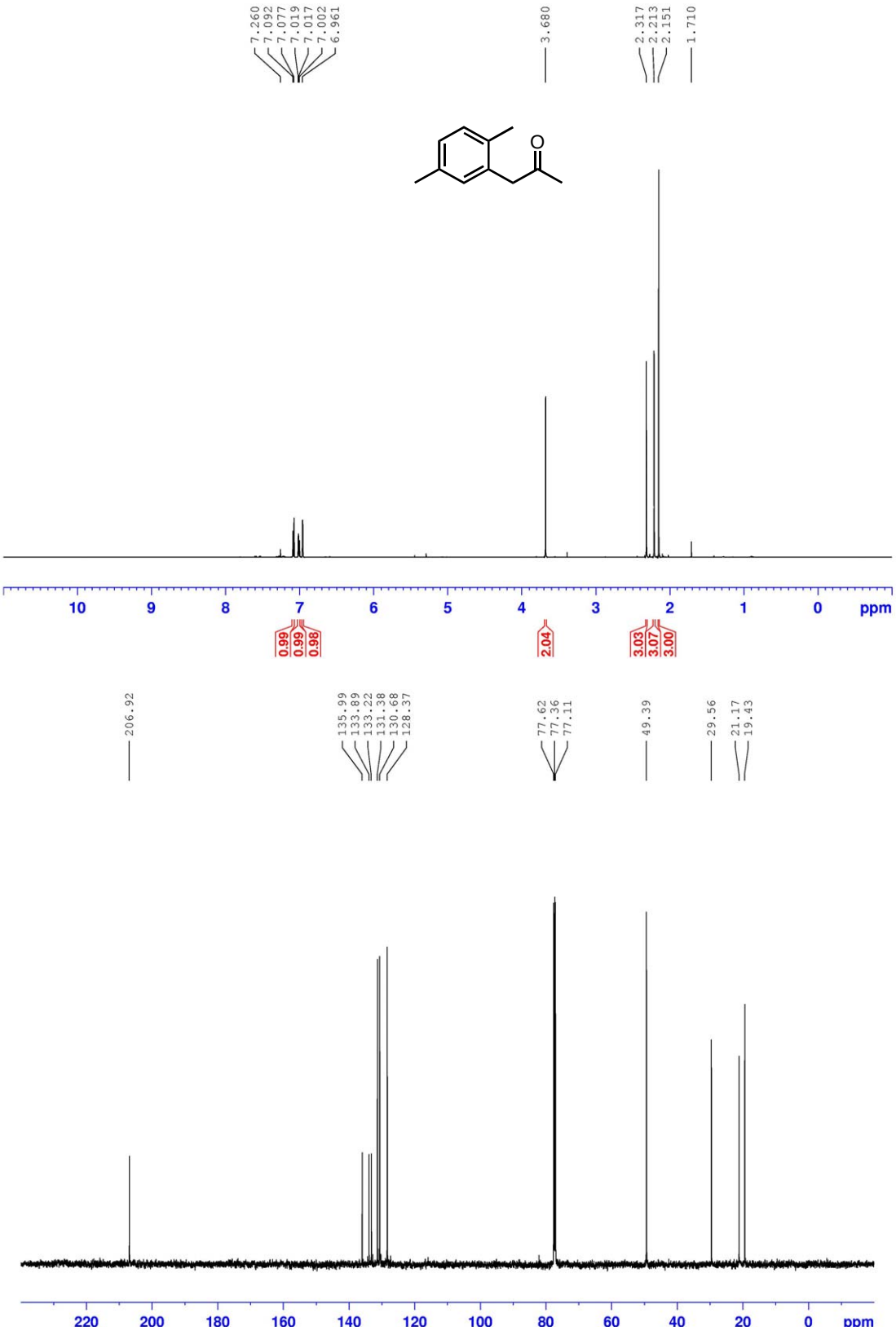

7.260
7.092
7.077
7.019
7.017
7.002
6.961
3.680
2.317
2.213
2.151
1.710
O
10 9 8 7 6 5 4 3 2 1 0 ppm
0.99
0.99
0.98
2.04
3.03
3.07
3.00
206.92
135.99
133.89
133.22
131.38
130.68
128.37
77.62
77.36
77.11
49.39
29.56
21.17
19.43
220 200 180 160 140 120 100 80 60 40 20 0 ppm

Figure 2, 2ee:

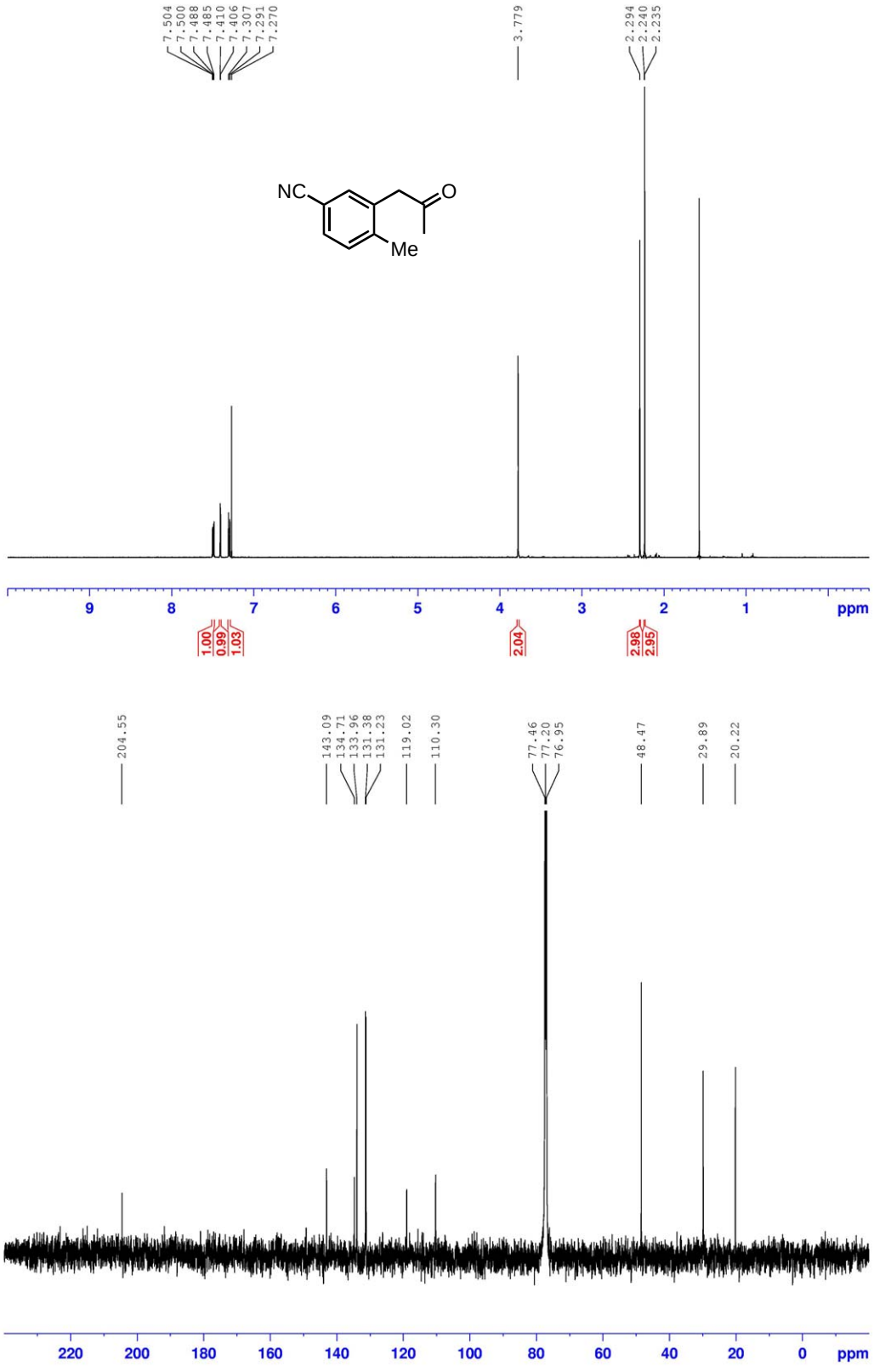

7.504
7.500
7.488
7.485
7.410
7.406
7.307
7.291
7.270
3.779
2.294
2.240
2.235
NC
O
Me
9
8
7
6
5
4
3
2
1
ppm
1.00
0.99
1.03
2.04
2.98
2.95
204.55
143.09
134.71
133.96
131.38
131.23
119.02
110.30
77.46
77.20
76.95
48.47
29.89
20.22
220
200
180
160
140
120
100
80
60
40
20
0
ppm

Figure 2, alcohol derivative of 2ff:

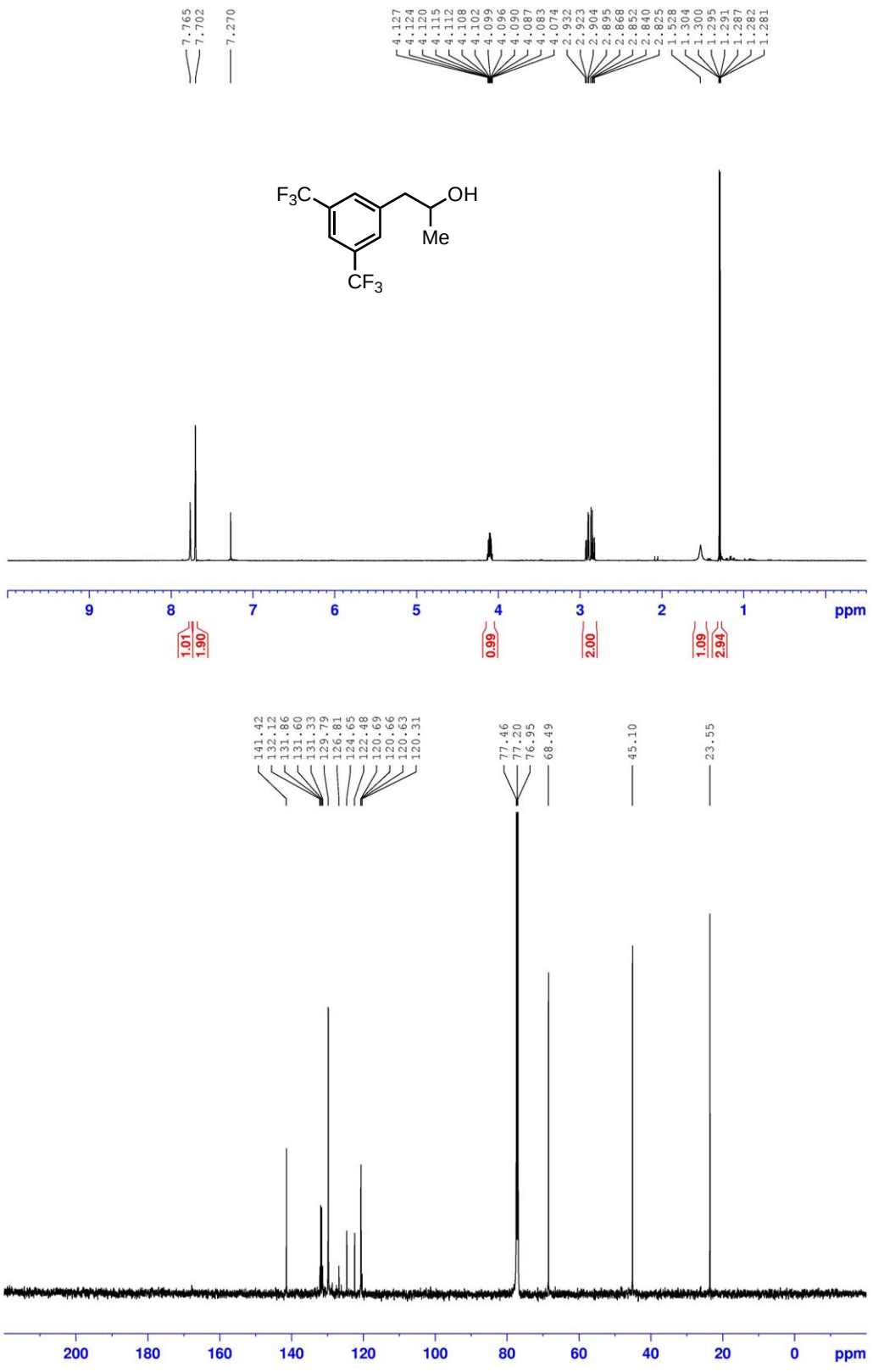


Figure 2, 2gg:

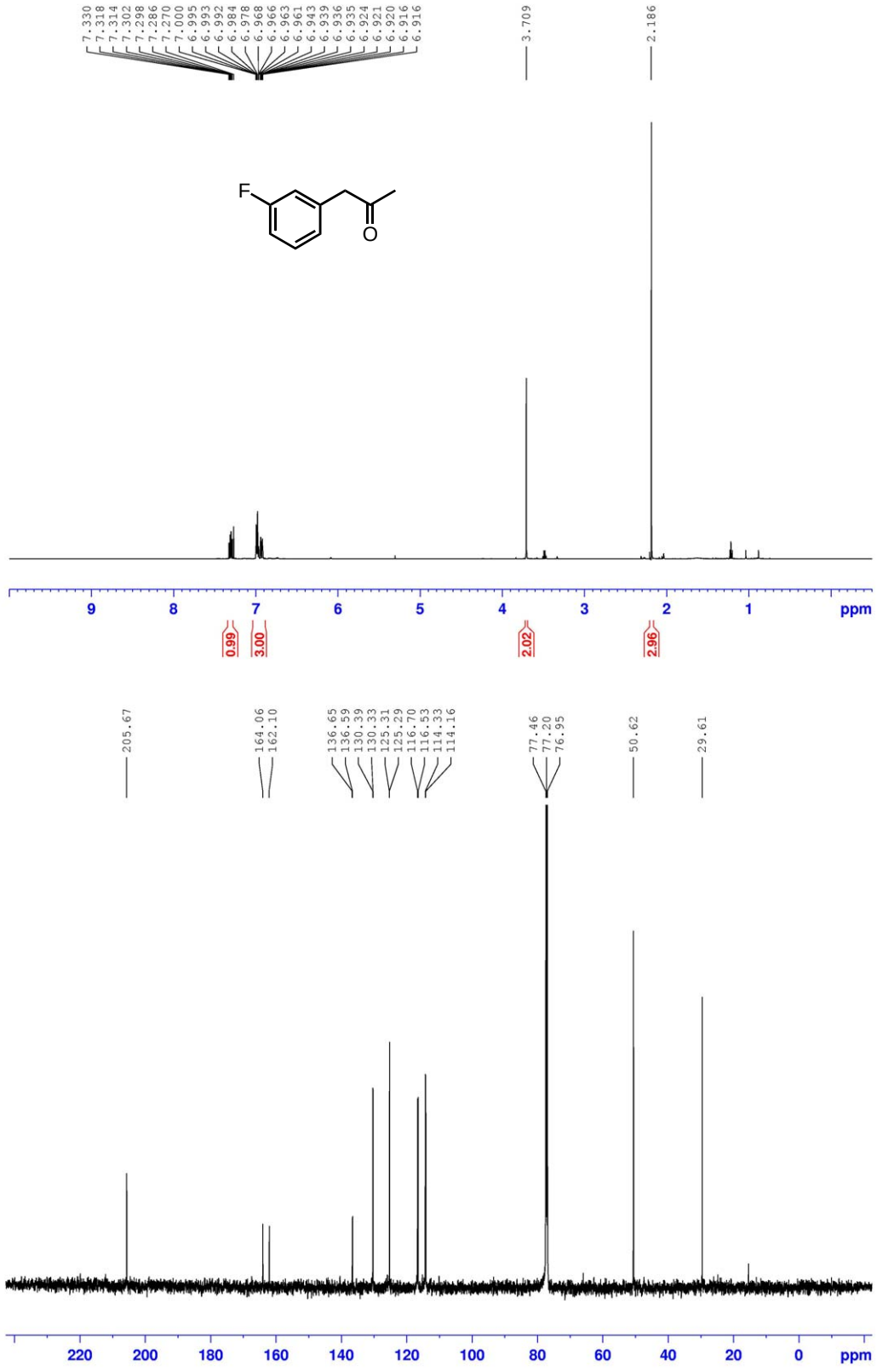

7.330
7.318
7.314
7.302
7.298
7.286
7.270
7.000
6.995
6.993
6.992
6.984
6.978
6.968
6.966
6.963
6.961
6.943
6.939
6.936
6.935
6.924
6.921
6.920
6.916
6.916
3.709
2.186
F
O
9
8
7
6
5
4
3
2
1
ppm
0.99
3.00
2.02
2.96
205.67
164.06
162.10
136.65
136.59
130.39
130.33
125.31
125.29
116.70
116.53
114.33
114.16
77.46
77.20
76.95
50.62
29.61
220
200
180
160
140
120
100
80
60
40
20
0
ppm

Figure 2, 2hh:

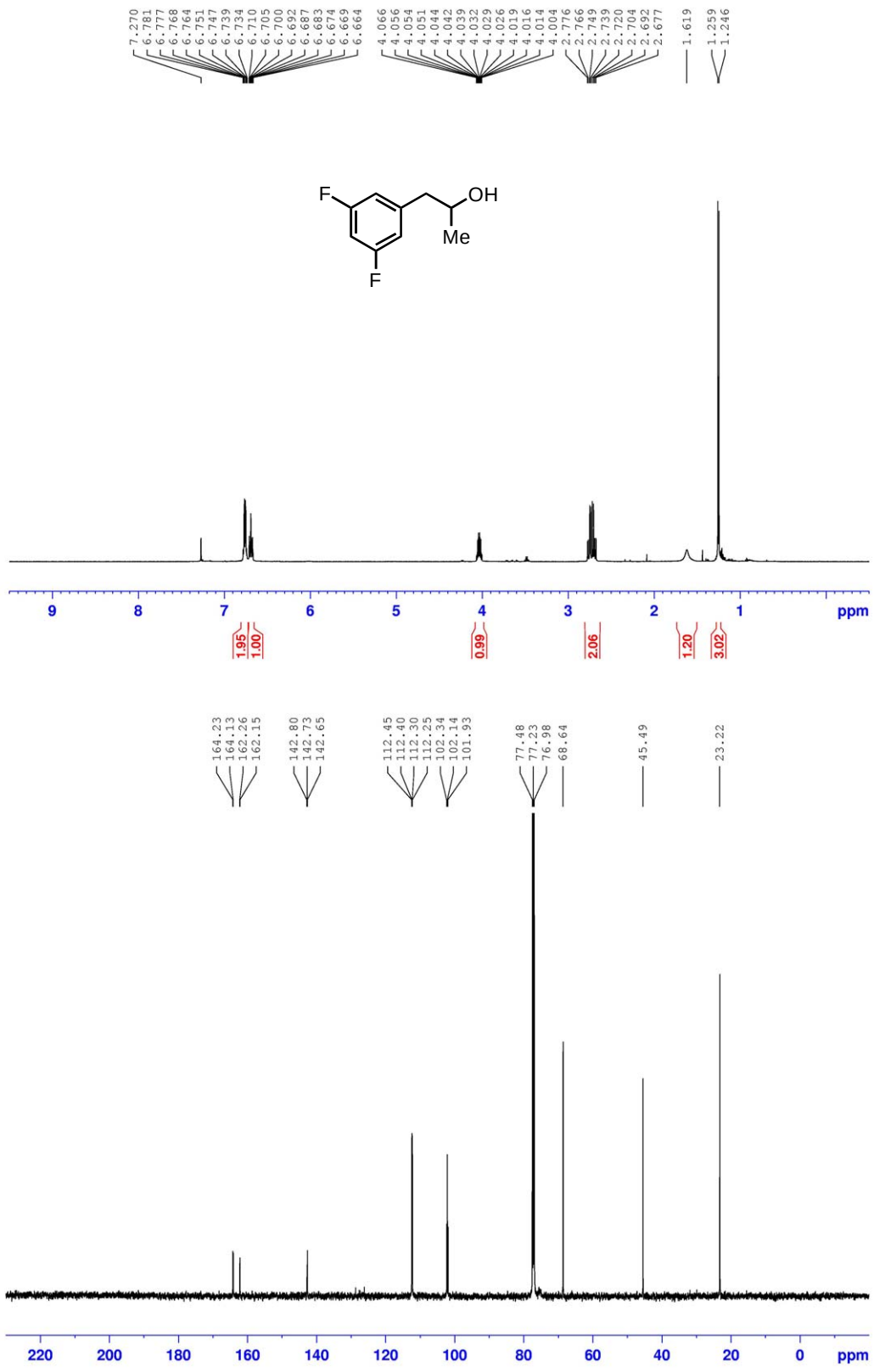

7.270
6.781
6.777
6.768
6.764
6.751
6.747
6.739
6.734
6.710
6.705
6.700
6.692
6.687
6.683
6.674
6.669
6.664
4.066
4.056
4.054
4.051
4.044
4.042
4.039
4.032
4.029
4.026
4.019
4.016
4.014
4.004
2.776
2.766
2.749
2.739
2.720
2.704
2.692
2.677
1.619
1.259
1.246
F
OH
Me
F
9
8
7
6
5
4
3
2
1
ppm
1.95
1.00
0.99
2.06
1.20
3.02
164.23
164.13
162.26
162.15
142.80
142.73
142.65
112.45
112.40
112.30
112.25
102.34
102.14
101.93
77.48
77.23
76.98
68.64
45.49
23.22
220
200
180
160
140
120
100
80
60
40
20
0
ppm

Figure 2, 2ii:

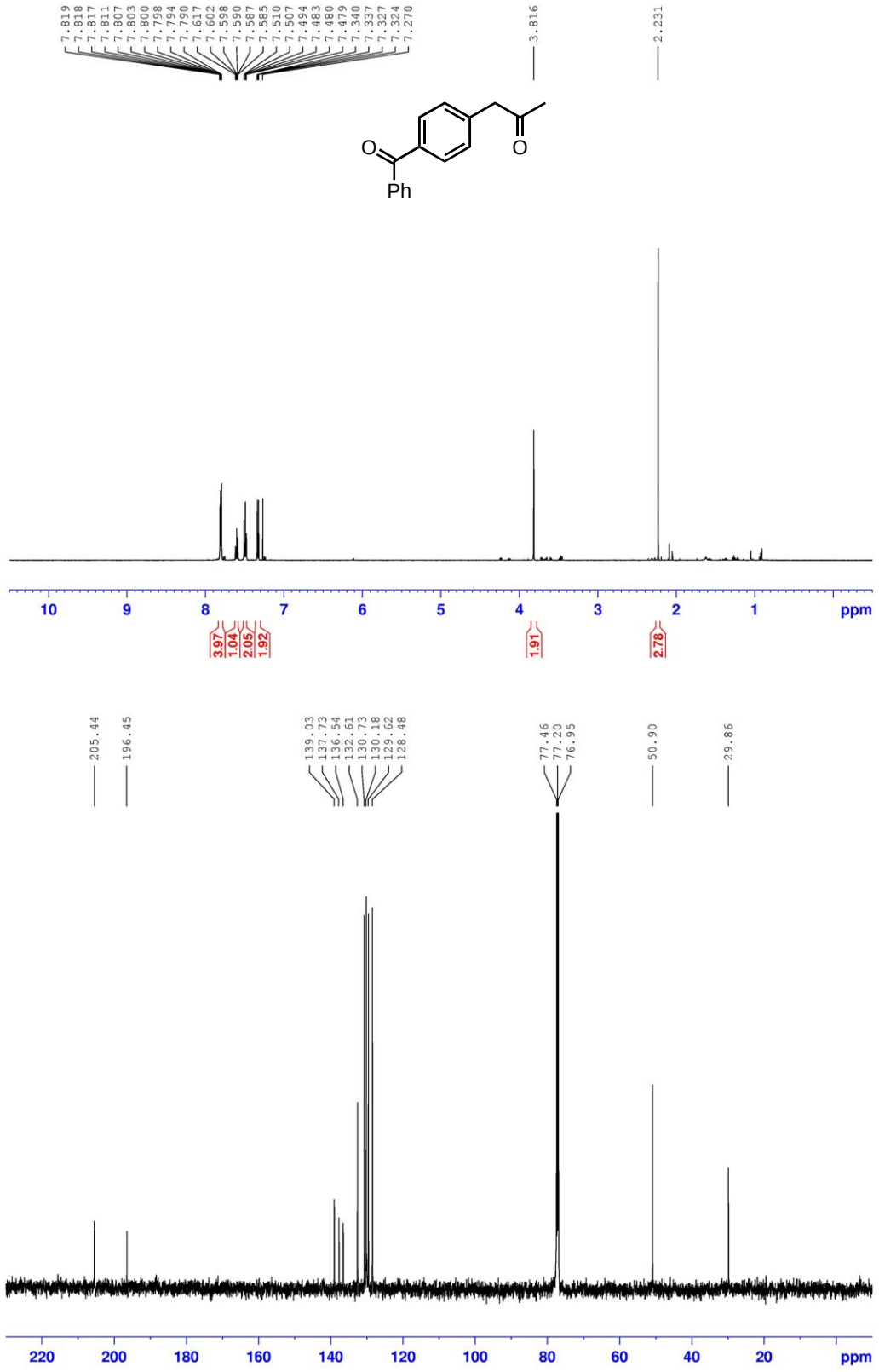
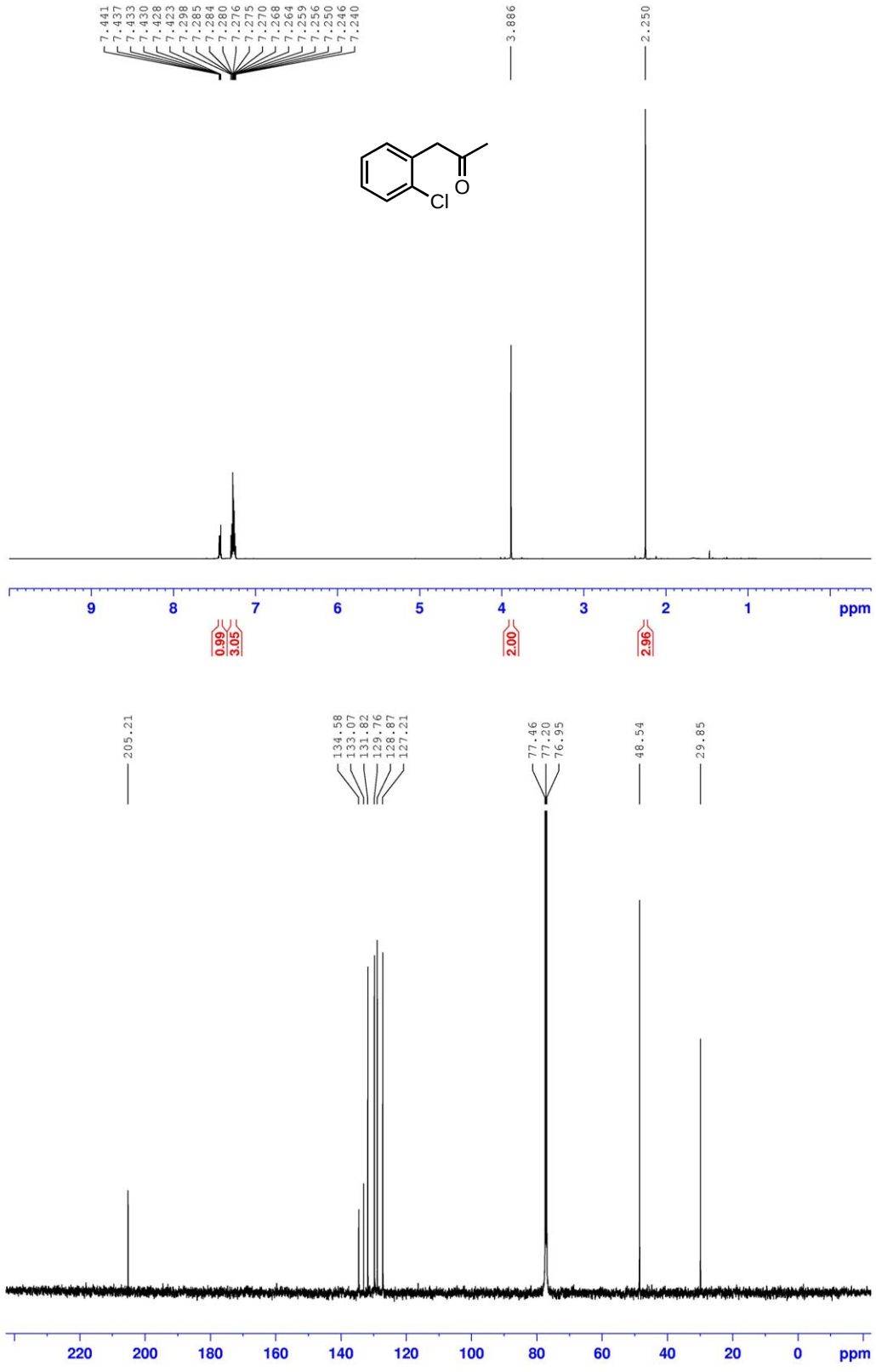

7.819
7.818
7.817
7.811
7.807
7.803
7.800
7.798
7.794
7.790
7.617
7.602
7.598
7.590
7.587
7.585
7.510
7.507
7.494
7.483
7.480
7.479
7.340
7.337
7.327
7.324
7.270
3.816
2.231
O
O
Ph
10
9
8
7
6
5
4
3
2
1
ppm
3.97
1.04
2.05
1.92
1.91
2.78
205.44
196.45
139.03
137.73
136.54
132.61
130.73
130.18
129.62
128.48
77.46
77.20
76.95
50.90
29.86
220
200
180
160
140
120
100
80
60
40
20
ppm

Figure 2, 2jj:


7.441
7.437
7.433
7.430
7.428
7.423
7.298
7.285
7.284
7.280
7.276
7.275
7.270
7.268
7.264
7.259
7.256
7.250
7.246
7.240
3.886
2.250
Cl
O
9
8
7
6
5
4
3
2
1
ppm
0.99
3.05
2.00
2.96
205.21
134.58
133.07
131.82
129.76
128.87
127.21
77.46
77.20
76.95
48.54
29.85
220
200
180
160
140
120
100
80
60
40
20
0
ppm