SUPPORTING INFORMATION

^{18}F-Deoxyfluorination of Phenols via Ru π-Complexes

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TABLE OF CONTENTS

MATERIALS AND METHODS

All air- and/or moisture-sensitive reactions were performed under an inert atmosphere of nitrogen or argon with standard Schlenk and glovebox techniques.[1]

Solvents

Tetrahydrofuran was distilled from deep purple sodium benzophenone ketyl. Dry DMF and dry DMSO were purchased from Acros Organics. Other anhydrous solvents (acetonitrile, diethyl ether, dichloromethane, pentane, and toluene) were obtained by filtration through drying columns[2] on an mBraun system.

Chromatography

Thin layer chromatography (TLC) was performed by EMD TLC plates pre-coated with 250 μm thickness silica gel 60 F_{254} plates and visualized by fluorescence quenching under UV light and $KMnO_4$ stain.
Preparative TLC was performed using Analtech Uniplates pre-coated with 1000 μm thickness silica gel GF.
Flash chromatography was performed using silica gel (230-400 mesh) purchased from Silicycle Inc.

Spectroscopy and Instruments

NMR spectra were recorded on either a Varian Unity/Inova 600 spectrometer operating at 600 MHz for ^1H acquisitions, a Bruker 500 spectrometer or a Varian Unity/Inova 500 spectrometer, both operating at 500 MHz, 471 MHz and 126 MHz for ^1H, ^{19}F and ^{13}C acquisitions, respectively, or a Varian Mercury 400 spectrometer operating at 375 MHz for ^{19}F acquisitions. Chemical shifts are reported in ppm with the solvent resonance as the internal standard (^1H: $CDCl_3$, δ 7.26; CD_2Cl_2, δ 5.32; CD_3OD, δ 3.31; CD_3CN, δ 1.94), (^{13}C: $CDCl_3$, δ 77.16; CD_2Cl_2, δ 53.84; CD_3OD, δ 49.00; CD_3CN, δ 1.32). Data is reported as follows: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad; coupling constants in Hz; integration.

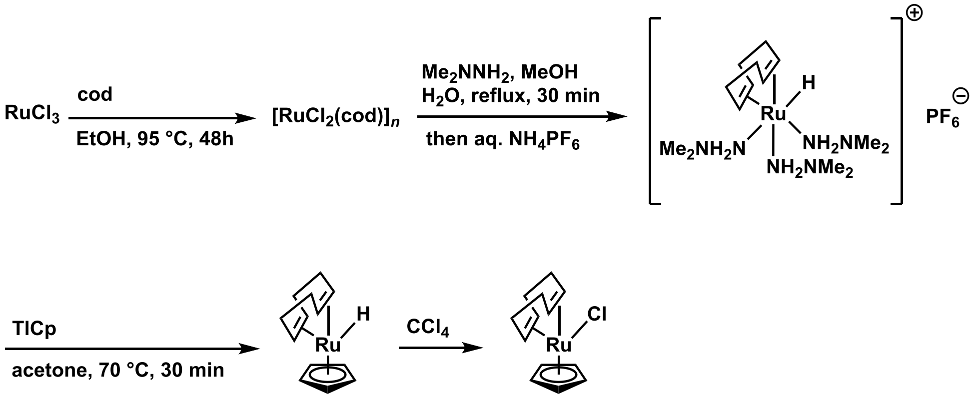
Starting materials

All substrates and reagents were used as received from commercial suppliers unless otherwise stated.

EXPERIMENTAL DATA

Experimental Procedures and Compound Characterization

[CpRu(cod)Cl] (1)



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[RuCl$_2$(cod)]$_n$

A two-neck round bottom flask was flame-dried and purged with N_2. Ruthenium trichloride hydrate ($RuCl_3\cdot\times H_2O$, 7.4 g, 0.03 mol, 1 eq.) was added to the flask. The flask was evacuated and kept under vacuum for 1 h and then was purged with N_2. To the flask were added 1,5-cyclooctadiene (20 mL, 18 g, 0.16 mol, 5 eq.) and ethanol (0.14 L, c = 0.2 M) to give a dark brown solution. The reaction mixture was stirred and heated at reflux for 48 h and subsequently cooled to 23 °C. The resulting brown precipitate was filtered off through a sintered glass funnel under air, and washed thoroughly with ethanol (50 mL). The brown solid was dried under vacuum for 48 h to afford [RuCl$_2$(cod)]$_n$ (8.2 g). The material was used in the subsequent step without further purification.

Note: Commercial $RuCl_3\cdot\times H_2O$ has variable water content, the total ruthenium content is 40–43%.

[(cod)RuH(NH$_2$NMe$_2$)$_3$]PF$_6$

To an oven dried 250 mL two-neck round bottom flask equipped with a magnetic stir bar was added [RuCl$_2$(cod)]$_n$ (5.5 g) under N_2. To the flask were added degassed methanol (55 mL), degassed water (13.8 mL) and freshly distilled degassed *N*,*N*'-dimethyl hydrazine (55 mL, 43 g, 0.72 mol, 4 × 10 eq.). The mixture was heated at 95 °C and stirred at the same temperature for 45 min. The resulting mixture was subsequently cooled to 23 °C over 60 min with stirring.

Under N_2, to the above reaction mixture was added a degassed solution of NH_4PF_6 (5.5 g, 34 mmol, 2 eq.) in H_2O (55 mL). The slurry was kept at –20 °C for 12 h under N_2.
The resulting colorless precipitate was filtered off with a sintered glass funnel under air to furnish a first crop of product. Then the filtrate was concentrated under reduced pressure to half of the volume and was then

kept at –20 °C for 60 min. The resulting colorless precipitate was filtered off with a sintered glass funnel to afford a second crop of product, which was combined with the previous fraction. The combined colorless precipitate was washed thoroughly with ice-cold water (200 mL) and dried under vacuum for 48 h to afford $[(cod)RuH(NH_2NMe_2)_3]PF_6$ (4.9 g). The material was used in subsequent steps without further purification.

[CpRu(cod)Cl] (1)

Caution: This step involves the use of toxic CpTl reagent. Proper care is essential to safely carry out this reaction, and the appropriate disposal of the thallium-contaminated flask, celite, gloves, needles and other materials is of the utmost importance for the safety of the chemist, staff, and other personnel.

Inside a nitrogen-filled glovebox, a 250 mL two necked round bottom flask equipped with a magnetic stir-bar and a rubber septum was charged with $[(cod)RuH(Me_2NNH_2)_3]PF_6$ (5.00 g) and thallium cyclopentadienide (2.78 g, 10.3 mmol). The flask was sealed with a second rubber septum and was brought outside the glovebox. Degassed acetone (88 mL) was added to the flask under N_2. The mixture was heated at 65 °C and stirred at the same temperature for 30 min. The resulting mixture was subsequently cooled to 23 °C over 20 min. The mixture was transferred with a cannula into a Schlenck flask, sealed, and brought inside a glovebox (Note: a rubber septum alone can not withstand the pressure difference inside the antechamber and presents a significant spill hazard). The mixture was filtered through a pad of celite under vacuum. The resulting filtrate was concentrated *in vacuo* to afford a brown solid. Pentane (30 mL) was added to the brown solid and the mixture was shaken vigorously for 10 min. The resulting mixture was drawn into a 40 mL syringe and filtered through a 0.2 nm PTFE syringe filter into a separate 50 mL flask containing CCl_4 (1.93 mL). A yellow precipitate was immediately observed. The above sequence of pentane (30 mL) addition to the brown solid was repeated. The supernatant was filtered again and added to the CCl_4 containing flask, where yellow precipitate formed immediately, and the suspension was stirred inside a glove box for an additional 30 min. Then the suspension was removed from the glove box, and the yellow solid was filtered off with a sintered glass funnel under air. The resulting solid was washed with pentane (30 mL) and dried under vacuum to afford [CpRu(cod)Cl] (1.21 g, 3.27 mmol, 16 ± 1 % yield from $RuCl_3 \cdot \times H_2O$) as a dark yellow solid.

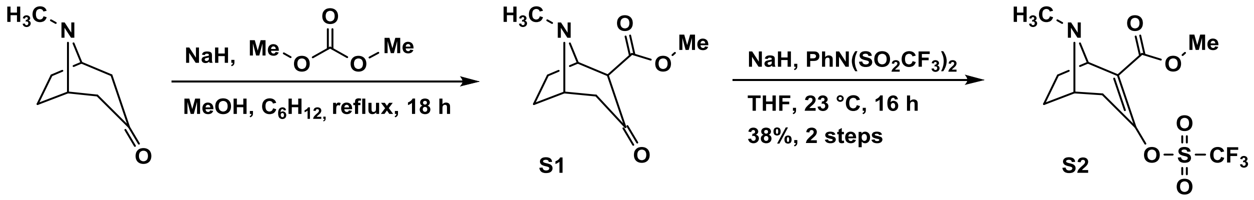
NMR Spectroscopy:

^{1}H NMR (500 MHz, $CDCl_3$, 23 ºC, δ): 5.32–5.29 (m, 2H), 4.95 (s, 5H), 4.41–4.38 (m, 2H), 2.62–2.59 (m, 2H), 2.10–2.03 (m, 4H), 2.00–1.93 (m, 2H).[3]

^{13}C NMR (125 MHz, $CDCl_3$, 23 ºC, δ): 128.8, 87.1, 85.9, 78.7, 32.6, 28.1, 28.0.

HRMS (m/z) calc'd for $C_{13}H_{17}Ru$ $[M-Cl]^+$, 275.0374; found, 275.0367.

Alkenyltriflate S2



Sodium hydride (60% dispersion in mineral oil, 5.2 g, 0.13 mol, 3.0 eq.) was washed with anhydrous cyclohexane (2 × 30 mL) and dried *in vacuo* (0.2 millibar) for 12 h. To the dried sodium hydride were added anhydrous cyclohexane (24 mL) and dimethyl carbonate (20 g, 18 mL, 0.22 mol, 5.0 eq.) at 23 °C. Then, the mixture was heated at reflux. A solution of tropinone (6.0 g, 43 mmol, 1.0 eq.) in cyclohexane (41 mL, 1.0 M) was added dropwise over 20 min with a syringe pump while the solution was heated at reflux. Then MeOH (0.15 mL) was added with a syringe. The mixture was heated at reflux for 2 h until gas evolution ceased and subsequently was cooled to 23 °C. Water (60 mL) was added to the mixture and the layers were separated. The organic layer was washed with water (2 × 30 mL). The combined aqueous layers were saturated with solid ammonium chloride (40 g) and extracted with CH_2Cl_2 (2 × 60 mL). The organic layer was dried over Na_2SO_4 and concentrated under reduced pressure to afford 7.6 g of a brown material (**S1**) that was used without purification in the next step.
To a stirred solution of **S1** (7.6 g, 38 mmol, 1 eq.) in THF (0.20 L, 0.2 M) at 0 °C was added NaH (60% dispersion in mineral oil, 4.6 g, 0.11 mol, 3 eq.). The mixture was warmed from 0 °C to 23 °C over 10 min and stirred for 20 min at 23 °C. Then, the mixture was cooled to 0 °C and $PhN(SO_2CF_3)_2$ (68 g, 0.19 mmol, 5.0 eq.) was added portionwise over 15 min. Then, the reaction mixture was allowed to warm to 23 °C over 10 min. The reaction mixture was stirred at 23 °C for 16 h. The resulting solution was diluted with EtOAc (200 mL) and washed with brine (75 mL). The organic layer was dried over Na_2SO_4 and concentrated under reduced pressure. The residue was purified by chromatography on silica gel eluting with hexanes in EtOAc 2:3 (v/v) to afford 5.40 g (16.4 mmol) of **S2** as a yellow oil (38% yield) over two-steps.

R*f* = 0.32 (EtOAc in hexanes = 60%)

NMR Spectroscopy:

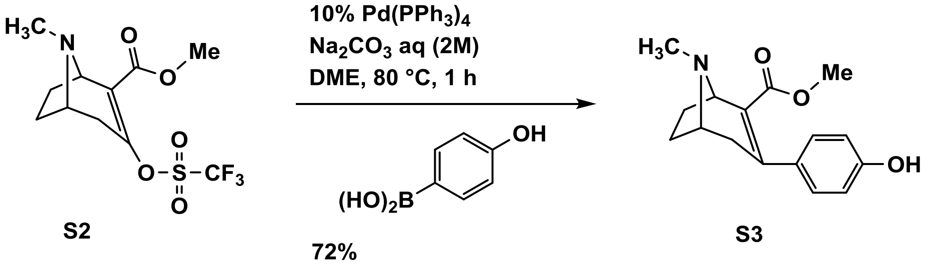
^{1}H NMR (500 MHz, $CDCl_3$, 23 ºC, δ): 3.93 (d, *J* = 5.5 Hz, 1H), 3.81 (s, 3H), 3.43–3.41 (m, 1H), 2.84 (dd, *J* = 18.5, 4.6 Hz, 1H), 2.39 (s, 3H), 2.23–2.12 (m, 2H), 2.01–1.95 (m, 2H), 1.61–1.57 (m, 1H).

^{13}C NMR (125 MHz, $CDCl_3$, 23 ºC, δ):164.0, 149.2, 125.4, 118.4 (q, *J* = 318.8 Hz), 60.3, 57.6, 52.3, 35.1, 34.9, 33.3, 30.2.

HRMS (m/z) calc'd for $C_{11}H_{15}F_3NO_5S$ $[M+H]^+$, 330.0623; found, 330.0663.

The ^{1}H and ^{13}C NMR spectroscopic data correspond to the data reported in the literature.[4]

Styrene S3



To a stirred solution of **S2** (6.3 g, 19 mmol, 1.0 eq.) in DME (0.14 mL, c = 0.14 M) at 23 °C was added (4-hydroxyphenyl)boronic acid (3.2 g, 23 mmol, 1.2 eq.) and then aqueous Na_2CO_3 solution (2.0 M, 17 mL, 34 mmol, 1.8 eq.). The mixture was stirred for 10 min at 23 °C and then $Pd(PPh_3)_4$ (2.2 g, 1.9 mmol, 10. mol%) was added. The resulting mixture was heated at 80 °C and stirred for 1 h. Then, the solution was cooled to 23 °C and partitioned between EtOAc (100 mL) and H_2O (50 mL). The aqueous layer was extracted with EtOAc (2 × 100 mL). The combined organic layers were washed with brine (30 mL), dried over Na_2SO_4 and concentrated under reduced pressure. The resulting brown liquid was purified by chromatography on silica gel eluting with MeOH in CH_2Cl_2 5:95 (v/v) to afford 3.8 g (14 mmol) of **S3** as a light brown solid (72% yield).

R*f* = 0.24 (MeOH in CH_2Cl_2 = 5%).

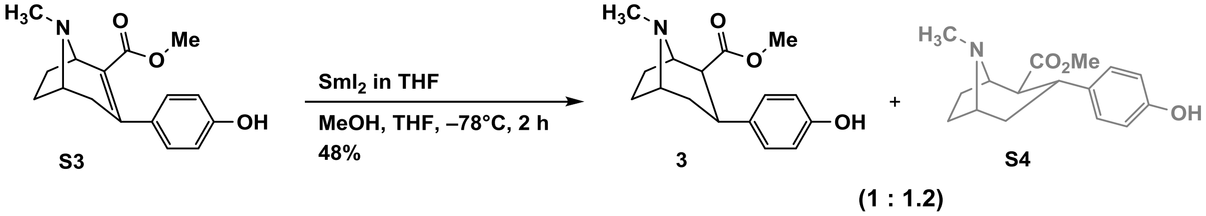
NMR Spectroscopy:

^{1}H NMR (500 MHz, CD_2Cl_2, 23 ºC, δ): 7.11 (dd, *J* = 8.6, 5.3 Hz, 2H), 6.99–7.02 (m, 2H), 3.77 (d, *J* = 5.5 Hz, 1H), 3.46 (s, 3H), 3.46–3.43 (m, 1H), 3.30–3.32 (m, 1H), 2.70–2.75 (m, 1H), 2.39 (s, 3H), 2.21–2.10 (m, 2H), 2.09–2.03 (br s, 1H), 2.01–1.92 (m, 1H), 1.65–1.60 (m, 1H).

^{13}C NMR (125 MHz, CD_2Cl_2, 23 ºC, δ):168.8, 157.0, 143.4, 132.7, 129.7, 128.7, 115.5, 61.3, 58.5, 51.8, 38.1, 36.3, 34.2, 30.1.

HRMS (m/z) calc'd for $C_{16}H_{20}NO_3$ $[M+H]^+$, 274.1443; found, 274.1449.

Phenol 3



To a stirred solution of **S3** (1.00 g, 3.65 mmol, 1.00 eq.) in THF (12 mL) and MeOH (3.0 mL) at –78 °C, SmI_2 in THF (c = 0.1 M, 0.3 L, 0.03 mol, 8 eq.) was added drop-wise with a syringe pump over 60 min. The solution was stirred for 4 h at –78 °C and then water (120 mL) was added at –78 °C. The mixture was warmed to 23 °C over 1 h and then saturated aqueous $NaHCO_3$ solution (60 mL) was added. The resulting suspension was filtered through a celite pad to remove the precipitate and the celite pad was washed with EtOAc (2 × 40 mL). The layers of the filtrate were separated and the aqueous layer was extracted with EtOAc (2 × 70 mL). The combined organic layers were washed with brine (30 mL), dried over Na_2SO_4 and was concentrated under reduced pressure to afford a dark brown liquid. ^{1}H NMR analysis showed a 1:1.2 ratio of the desired compound **3** and the undesired compound **S4**. The product was purified by chromatography on silica gel eluting with MeOH in EtOAc 15:85 (v/v) to afford 0.48 g (1.7 mmol) of a mixture of **3** and **S4** as a yellow solid (48% yield),.

Compound 3

R*f* = 0.25 (MeOH in EtOAc = 15%)

NMR Spectroscopy:

> **^{1}H NMR** (500 MHz, CD_3OD, 23 ºC, δ): 7.05 (d, *J* = 8.2 Hz, 2H), 6.65 (d, *J* = 8.6 Hz, 2H), 3.61–3.59 (m, 1H), 3.46–3.43 (m, 1H), 3.43 (s, 3H), 3.13–3.07 (m, 1H), 2.93–2.92 (m, 1H), 2.56–2.51 (m, 1H), 2.31 (s, 3H), 2.28–2.25 (m, 1H), 2.21–2.14 (m, 1H), 1.92–1.86 (m, 1H), 1.80–1.75 (m, 1H), 1.72–1.67 (m, 1H).

> **^{13}C NMR** (125 MHz, CD_3OD, 23 ºC, δ):174.3, 156.7, 134.1, 129.4, 115.8, 66.3, 63.9, 53.5, 51.6, 41.7, 34.9, 33.9, 26.5, 25.4.

HRMS (m/z) calc'd for $C_{16}H_{22}NO_3$ $[M+H]^+$, 276.1600; found, 276.1631.

Compound S4

R*f* = 0.52 (MeOH in EtOAc = 20%)

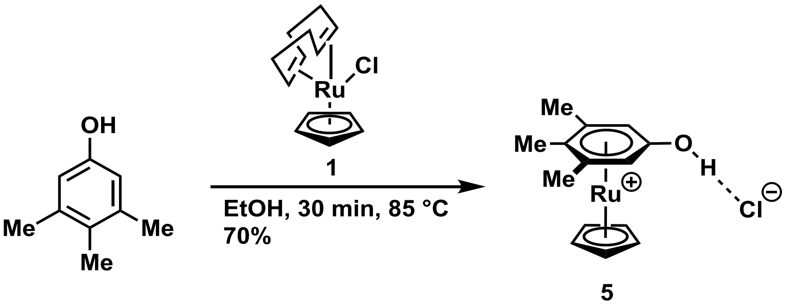
NMR Spectroscopy:

^{1}H NMR (500 MHz, CD_3OD, 23 ºC, δ): 7.01 (d, *J* = 8.5 Hz, 2H), 6.65 (d, *J* = 8.6 Hz, 2H), 3.52 (s, 3H), 3.34 (d, *J* = 6.65 Hz, 1H), 3.24–3.22 (m, 1H), 3.19–3.14 (m, 1H), 2.54–2.52 (m, 1H), 2.36–2.31 (m, 1H), 2.28 (s, 3H), 2.26–2.21 (m, 1H), 2.25–2.09 (m, 1H), 1.67–1.61 (m, 1H), 1.58–1.52 (m, 1H), 1.47–1.42 (m, 1H).

^{13}C NMR (125 MHz, CD_3OD, 23 ºC, δ): 175.4, 155.5, 134.1, 128.1, 114.7, 63.1, 59.6, 55.8, 50.8, 39.6, 38.3, 34.9, 27.9, 27.7.

HRMS (m/z) calc'd for $C_{16}H_{22}NO_3$ $[M+H]^+$, 276.1600; found, 276.1662.

[(η^6-3,4,5-Trimethylphenol)RuCp]Cl (5)



3,4,5-Trimethylphenol (16 mg, 0.12 mmol, 1.0 eq.) and [CpRu(cod)Cl] (**1**) (36 mg, 0.12 mmol, 1.0 eq.) were added to EtOH (50 µL, c = 4.8 M) in a 0.5 dram (1.8 mL) borosilicate glass vial. The vial was capped and the reaction mixture was stirred at an oil bath temperature of 85 °C (heating block temperature) for 30 min, then cooled to 23 °C. EtOH was evaporated under reduced pressure. Then the light red residue was washed with diethyl ether (2 × 200 µL) followed by cold acetonitrile (0 °C, 2 × 100 µL). The remaining solid was dried under vacuum (0.2 millibar) for 2 h, which afforded 29 mg (83 µmol) of **5** as a colorless solid (70%).

Crystal growth of 5: Complex **5** (20 mg, 59 µmol) was dissolved in methylene chloride (200 µL) and then diethyl ether (ca. 200 µL) was slowly added until the solution became cloudy. Then, the mixture was was filtered through a glass microfibre filter and then the eluent was slowly cooled to –15 °C and kept for 12 h at –15 °C. Single crystals of **5** were formed at the bottom and on the wall of the vial. Crystals of **5** were harvested from the wall of the vial with a crystallography needle for single crystal analysis.

NMR Spectroscopy:

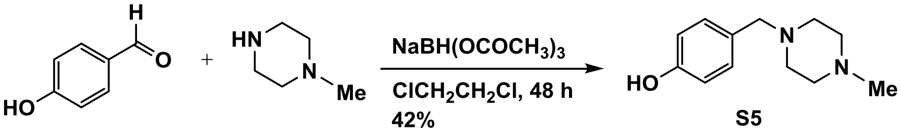
^{1}H NMR (500 MHz, $CDCl_3$, 23 ºC, δ): 6.45 (s, 2H), 5.06 (s, 5H), 2.34 (s, 6H), 2.24 (s, 3H).

^{13}C NMR (126 MHz, $CDCl_3$, 23 ºC, δ): 132.5, 99.0, 96.0, 80.0, 77.7, 20.3, 15.3.

HRMS (m/z) calc'd for $C_{14}H_{17}ORu$ $[M-Cl]^+$, 303.0317; found, 303.0319.

Elemental Analysis calc'd for $C_{14}H_{17}ClORu$: C, 49.78; H, 5.07; found: C, 49.65; H, 5.01.

Methylpiperazin S5



To a stirred solution of 4-hydroxybenzaldehyde (100 mg, 810 µmol, 1.00 eq.) in 1,2-dichloroethane (4.0 mL, c = 0.20 M) at 0 °C was added 1-methylpiperazine (81.1 mg, 90.0 µL, 810 µmol, 1.00 eq.) and $NaBH(OCOCH_3)_3$ (264 mg, 1.24 mmol, 1.50 eq.). The mixture was warmed to 23 °C and stirred at 23 °C for 48 h. The resulting solution was concentrated under reduced pressure and then the residue was taken up in ethyl acetate (20 mL). The solution was washed with water (10 mL) and then with brine (5 mL). The organic layer was dried over Na_2SO_4 and concentrated under reduced pressure, which was purified by chromatography on silica gel eluting with MeOH/EtOAc/Et_3N 9:1:0.5 to afford 71 mg (0.34 mmol) of **S5** as a colorless solid (42% yield).

R*f* = 0.31 (MeOH in EtOAc = 10%, with 5% NEt_3)

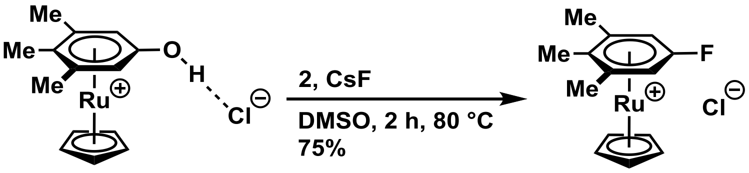
NMR Spectroscopy:

^{1}**H NMR** (500 MHz, CD_3OD, 23 ºC, δ): 7.15–7.13 (m, 2H), 6.76–6.73 (m, 2H), 3.45 (s, 2H), 2.49 (br s, 8H), 2.29 (s, 3H).

^{13}**C NMR** (125 MHz, CD_3OD, 23 ºC, δ): 157.9, 132.0, 128.7, 116.0, 63.3, 55.6, 53.3, 45.9.

HRMS (m/z) calc'd for $C_{12}H_{19}N_2O$ $[M+H]^+$, 207.1497; found, 207.1545.

[(η^6-5-Fluoro-1,2,3-trimethylbenzene)RuCp]Cl (6)



5

6

In an N_2-filled glovebox, an oven-dried vial was charged with Chloroimidazolium chloride **2** (32 mg, 69 µmol, 1.1 eq.), previously dried (200 ºC, 24 h) CsF (19 mg, 0.13 mmol, 2.0 eq.) and complex **5** (20. mg, 60 µmol, 1.0 eq.). Dry DMSO (0.2 mL) was added to the vial and the vial was sealed, then removed from the glovebox. Then the reaction mixture was stirred at 80 °C for 2 h and subsequently cooled to 23 °C. Then, the reaction mixture was filtered through a glass frit. The residue on the glass frit was washed with DMSO (0.3 mL). The filtrate was concentrated *in vacuo* (0.2 millibar) at 40 °C over 6 h and then the residue was washed with diethyl ether (2 × 0.5 mL). The residue was then redissolved in MeCN (0.1 mL) and then diethyl ether (0.5 mL) was slowly added, which resulted in the formation of a suspension. The supernatant was decanted and then the colorless solid was washed with ditheyl ether (0.5 mL) and dried *in vacuo* (0.2 millibar) for 2 h, which afforded 16 mg (45 µmol) of **6** as a colorless solid (75% yield).

Crystal growth of 6: Complex **6** (10 mg, 29 µmol) was dissolved in methylene chloride (200 µL) and then diethyl ether (ca. 100 µL) was slowly added until the solution became cloudy. Then, the mixture was filtered through a glass microfibre filter and the filtrate was slowly cooled to –15 °C and kept over night at –15 °C. Single crystals of **6** formed at the bottom of the vial. Crystals of **6** were harvested with a crystallography needle for single crystal analysis.

NMR Spectroscopy:

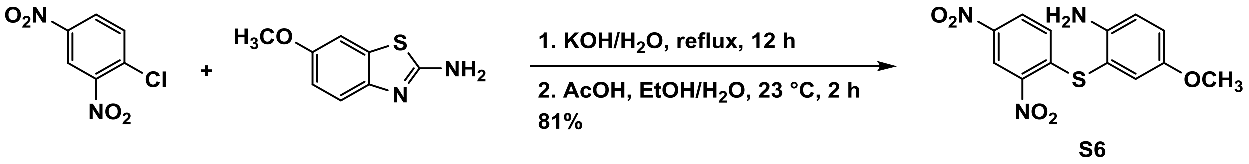
^{1}H NMR (500 MHz, CD_2Cl_2, 23 ºC, δ): 6.6 (d, J = 3.5 Hz, 2H), 5.4 (s, 5H), 2.53 (s, 6H), 2.37 (s, 3H).

^{13}C NMR (126 MHz, CD_2Cl_2, 23 ºC, δ): 135.2 (d, $^1J_{CF}$ = 276.3 Hz), 101.3 (d, $^4J_{CF}$ = 3.4 Hz), 100.7 (d, $^3J_{CF}$ = 6.3 Hz), 82.69, 78.62 (d, $^2J_{CF}$ = 20.3 Hz), 20.2, 15.7.

HRMS (m/z) calc'd for $C_{14}H_{16}FRu$ $[M\text{-}Cl]^+$, 305.0274; found, 305.0274.

Elemental Analysis calc'd for $C_{14}H_{16}ClFRu$: C, 49.49; H, 4.75; found: C, 49.65; H, 4.62.

Methoxyaniline S6



To an aqueous solution of potassium hydroxide (100 mL, 50% w/w) was added 6-methoxybenzo[*d*]-thiazol-2-amine (5.00 g, 27.7 mmol, 1.10 eq.) at 23 °C. The reaction mixture was heated at reflux and stirred for 12 h. Then, the solution was cooled to 23 °C. The solution was added drop-wise over 30 min with syringe to a stirred solution of 1-chloro-2,4-dinitrobenzene (5.10 g, 25.2 mmol, 1.00 eq.) in ethanol (200 mL)/acetic acid (500 mL) at 0 °C. The mixture was warmed to 23 °C and stirred for 2 h The resulting precipitate was filtered off with a Büchner funnel with a fritted disc and washed with water (100 mL) followed by ethanol (100 mL). The product was dried under vacuum to afford 6.55 g (20.4 mmol) of **S6** as a yellow solid (81% yield).

R_f = 0.85 (EtOAc in hexanes = 50%)

NMR Spectroscopy:

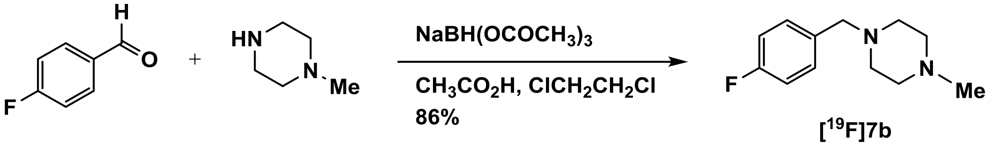
^{1}H NMR (500 MHz, $CDCl_3$, 23 ºC, δ): 9.12 (d, *J* = 2.4 Hz, 1H), 8.18 (dd, *J* = 9.0, 3.0 Hz, 1H), 7.05 (d, *J* = 8.9 Hz, 1H), 7.01 (dd, *J* = 8.8, 3.0 Hz, 1H), 6.97 (d, *J* = 2.8 Hz, 1H), 6.85 (d, *J* = 8.8 Hz, 1H), 4.02 (br s, 2H), 3.76 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$, 23 ºC, δ): 153.1, 146.0, 144.8, 144.6, 143.5, 128.8, 127.3, 121.9, 120.8, 120.6, 117.7, 111.1, 56.0.

HRMS (m/z) calc'd for $C_{13}H_{12}N_3O_5S$ $[M+H]^+$, 322.0498; found, 322.0482.

The ^{1}H NMR spectroscopic data correspond to the data reported in the literature.[5]

1-(4-Fluorobenzyl)-4-methylpiperazine ([^{19}F]7b)



To a stirred solution of 4-fluorobenzaldehyde (86 µL, 0.10 g, 0.80 mmol, 1.1 eq.) in 1,2-dichloroethane (1.2 mL, c = 0.67 M) at 23 °C was added 1-methylpiperazine (0.81 mL, 0.73 g, 0.73 mmol, 1.0 eq.) in one portion. To the solution was added acetic acid (0.46 mL, 0.49 g, 0.80 mmol, 1.0 eq.), and the solution was stirred for 2 h at 23 °C. To the resulting mixture was added $NaBH(OCOCH_3)_3$ (0.26 mg, 1.2 mmol, 1.5 eq.) at 23 °C and the reaction mixture was stirred for 24 h. The reaction was quenched by dropwise addition of saturated aqueous $NaHCO_3$ solution (15 mL). The layers were separated and the aqueous layer was washed with ethyl acetate (3 × 10 mL). The combined organic layers were washed with brine (10 mL) and dried over Na_2SO_4, concentrated to dryness and the product purified by preparative thin-layer chromatography eluting with $MeOH/CH_2Cl_2/NH_4OH$ = 9:1:0.1 (v/v) to afford 130 mg (624 µmol) of **[^{19}F]7b** as a colorless solid (86% yield).

R*f* = 0.61 (MeOH in CH_2Cl_2 = 10% with 1% NH_4OH added)

NMR Spectroscopy:

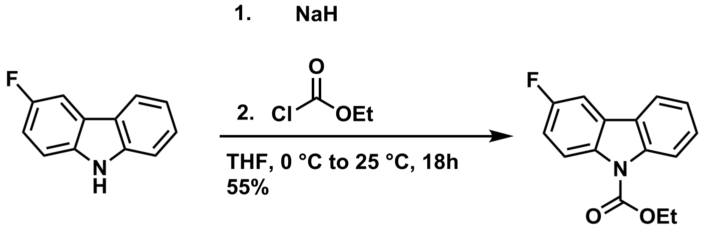
^{1}H NMR (500 MHz, $CDCl_3$, 23 ºC, δ): 7.32 (dd, *J* = 8.4, 5.6 Hz, 2H), 7.04–7.08 (m, 2H), 3.48 (s, 2H), 2.46 (br s, 8H), 2.25 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$, 23 ºC, δ): 163.5 (d, *J* = 291 Hz), 134.5, 132.3, 115.9 (d, *J* = 25 Hz), 62.8, 55.7, 53.4, 46.0.

^{19}F NMR (376 MHz, $CDCl_3$, 23 ºC, δ): –116.0.

HRMS (m/z) calc'd for $C_{12}H_{18}FN_2$ $[M+H]^+$, 209.1454; found, 209.1498.

3-Fluoro-carbazole [^{19}F]7f



S15 **[^{19}F]7f**

To a stirred solution of 3-fluoro-9*H*-carbazole (**S15**) (50 mg, 0.27 mmol, 1.0 eq.) in dry THF (0.70 mL, c = 0.39 M) at 0 °C was added sodium hydride (60% dispersion in mineral oil, 32 mg, 0.80 mmol, 3.0 eq.), and the reaction mixture was stirred for 30 min at 0 °C. Then, ethyl chloroformate (0.13 mL, 0.15 g, 1.4 mmol, 5.2 eq.) was added. The reaction mixture was then allowed to warm to 23 °C and stirred for 18 h at 23 °C. Then, methanol (1 mL) was added, and the reaction mixture was filtered through a pad of celite. The filter cake was washed with methanol (1 mL). The filtrate was concentrated *in vacuo*, and the product was purified by preparative TLC (hexanes/ethyl acetate 85:15 (v/v)) to afford 39 mg (0.15 mmol) of [^{19}F]**7f** as a colorless solid compound (55% yield).

R*f* = 0.66 (EtOAc in hexanes = 15%)

NMR Spectroscopy:

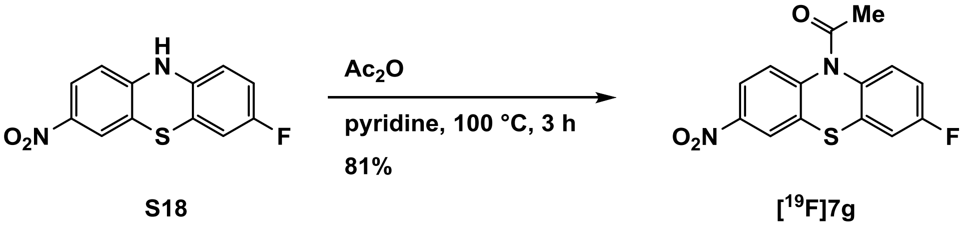
^{1}H NMR (500 MHz, $CDCl_3$, 23 ºC, δ): 8.30–8.25 (m, 2H), 7.91 (ddd, *J* = 7.8, 1.3, 1.0 Hz, 1H), 7.61 (dd, *J* = 8.2, 2.6 Hz, 1H), 7.50 (ddd, *J* = 8.5, 7.3, 1.3 Hz, 1H), 7.36 (td, *J* = 7.5, 1.0 Hz, 1H), 7.18 (td, *J* = 9.0, 2.7 Hz, 1H), 4.60 (q, *J* = 7.1 Hz, 2H), 1.56 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (126 MHz, $CDCl_3$, 23 ºC, δ): 159.5 (d, *J* = 241.0 Hz), 152.2, 139.0, 134.5, 127.8, 127.1 (d, *J* = 9.5 Hz), 125.3 (d, *J* = 3.6 Hz), 123.3, 120.0, 117.4 (d, *J* = 8.7 Hz), 116.5, 114.4 (d, *J* = 24.3 Hz), 105.7 (d, *J* = 24.0 Hz), 63.2, 14.5.

^{19}F NMR (471 MHz, $CDCl_3$, 23 ºC, δ): –119.8.

HRMS (m/z) calc'd for $C_{15}H_{13}FNO_2$ $[M+H]^+$, 258.0930; found, 258.0925.

3- Fluoro-7-nitro-phenothiazin [^{19}F]7g



To a stirred solution of **S18** (0.15 g, 0.57 mmol, 1.0 eq.) in pyridine (0.68 mL, c = 0.83 M) was added acetic anhydride (3.4 mL, 3.6 g, 36 mmol, 63 eq.) at 0 °C. The reaction mixture was heated to 100 °C and stirred at the same temperature for 2 h. The resulting mixture was then poured into 20 mL of ice-cold water. The aqueous and organic layers were separated, the aqueous layer was extracted with ethyl acetate (3 × 10 mL) and the combined organic layers were washed with water (10 mL) and then with brine (10 mL). The organic layer was dried over Na_2SO_4 and concentrated under reduced pressure. The product was purified with chromatography on silica gel eluting with ethyl acetate in hexane 1:4 (v/v) to afford 0.14 g (0.46 mmol) of [^{19}F]**7g** as a brown solid (81%).

R*f* = 0.52 (EtOAc in hexanes = 30%)

NMR Spectroscopy:

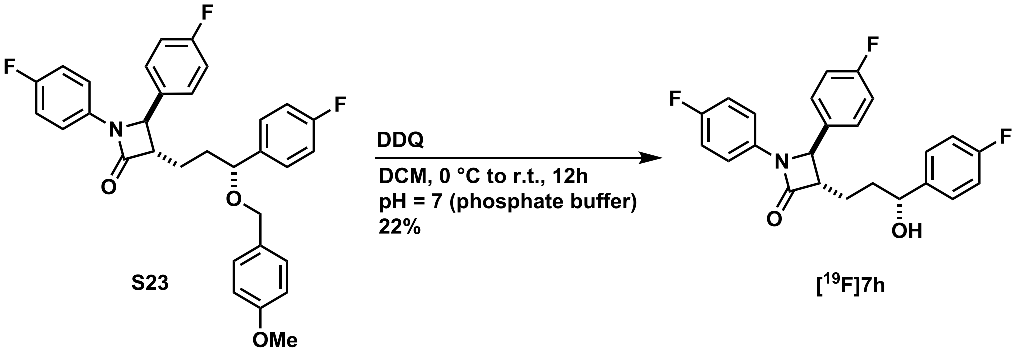
^{1}H NMR (500 MHz, $CDCl_3$, 23 ºC, δ): 8.28 (d, *J* = 2.5 Hz, 1H), 8.18 (dd, *J* = 8.7, 2.5 Hz, 1H), 7.67 (d, *J* = 8.8 Hz, 1H), 7.41 (dd, *J* = 8.7, 5.5 Hz, 1H), 7.24 (dd, *J* = 8.9, 2.5 Hz, 1H), 7.05 (td, *J* = 8.3, 2.6 Hz, 1H), 2.27 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$, 23 ºC, δ): 168.7, 163.2, 161.2, 145.1 (d, *J* = 247.3 Hz), 139.5 (d, *J* = 10.3 Hz), 135.0, 129.2 (d, *J* = 9.3 Hz), 128.0, 127.1 (d, *J* = 3.2 Hz), 123.2, 122.4, 115.2 (d, *J* = 22.5 Hz), 115.0 (d, *J* = 24.8 Hz), 23.2.

^{19}F NMR (376 MHz, $CDCl_3$, 23 ºC, δ): –112.6.

HRMS (m/z) calc'd for $C_{14}H_9FN_2O_3SNa$ $[M+Na]^+$, 327.0216; found, 327.0216.

Hydroxypropylazetidin [^{19}F]7h



An oven-dried 5 mL glass vial was charged with a magnetic stir bar and dichloromethane (1.0 mL) and was cooled to 0 °C. PMB ether **S23** (60 mg, 0.11 mmol, 1.0 eq.) and phosphate buffer solution (0.1 mL, (c = 0.01 M NaH_2PO_4 and c = 6.2 mM Na_2HPO_4) (pH = 7.1 at 0 °C, pH = 7.0 at 25 °C)) were added to the vial. Then, 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (DDQ) (51 mg, 0.23 mmol, 2.1 eq.) was added portionwise to the stirred solution over 10 min. The reaction mixture was then stirred for 12 h at 23 °C. The product was extracted with dichloromethane (10 mL), the organic phase was washed with water (2 × 2 mL) and then was dried with anhydrous Mg_2SO_4, filtered and concentrated under reduced pressure. The resulting residue was purified by preparative TLC (hexanes:ethyl acetate 85:15 (v/v)) to give 11 mg (27 µmol) of [^{19}F]**7h** as a colorless oil (22% yield).

R*f* = 0.25 (EtOAc in hexanes = 15%)

NMR Spectroscopy:

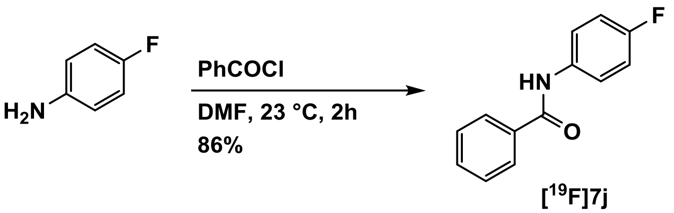
^{1}H NMR (600 MHz, $CDCl_3$, 23 ºC, δ): 7.29 (ddd, *J* = 8.8, 5.3, 3.1 Hz, 4H), 7.21 (dd, *J* = 9.0, 4.6 Hz, 2H), 7.05–7.09 (m, 2H), 7.00–7.04 (m, 2H), 6.91–6.95 (m, 2H), 4.72 (dd, *J* = 7.3, 5.1 Hz, 1H), 4.61 (d, *J* = 2.3 Hz, 1H), 3.07 (d, *J* = 7.5, 2.4 Hz, 1H), 1.99–2.04 (m, 2H), 1.93–1.98 (m, 2H).

^{13}C NMR (126 MHz, $CDCl_3$, 23 ºC, δ): 167.3, 162.7 (d, *J* = 247.8 Hz), 162.2 (d, *J* = 245.7 Hz), 159.1 (d, *J* = 243.7 Hz), 140.0 (d, *J* = 2.9 Hz), 133.7 (d, *J* = 2.8 Hz), 133.3 (d, *J* = 3.1 Hz), 127.6 (d, *J* = 8.2 Hz), 127.4 (d, *J* = 8.1 Hz), 118.3 (d, *J* = 7.7 Hz), 116.3 (d, *J* = 21.6 Hz), 115.9 (d, *J* = 22.6 Hz), 115.4 (d, *J* = 21.5 Hz), 73.1, 60.8, 60.5, 36.6, 25.1.

^{19}F NMR (376 MHz, $CDCl_3$, 23 ºC, δ): –112.8, –114.8, –117.8.

HRMS (m/z) calc'd for $C_{24}H_{21}F_3NO_2$ $[M+H]^+$, 412.1524; found, 412.1519.

N-(4-Fluorophenyl)benzamide ([^{19}F]7j)



To a stirred solution of 4-fluoroaniline (85.3 µL, 100 mg, 890 µmol, 1.00 eq.) in DMF (0.45 mL, c = 1.9 M) at 0 °C was added benzoyl chloride (100 µL, 125 mg, 890 µmol, 1.00 eq.) drop-wise with a syringe over 10 min. The solution was warmed to 23 °C over 30 min and was stirred for 2 h. Then aqueous NaOH solution (1.5 mL, c = 1.0 M) was added to the solution to adjust the pH to 7. The resulting solution was added to ice-cold water (10 mL) dropwise with a syringe over 10 min. The resulting precipitate was filtered off with a Büchner funnel and dried *in vacuo* to afford 0.17 g (0.79 mmol) of [^{19}F]**7j** as an off-white solid (86% yield).

R*f* = 0.65 (EtOAc in hexanes = 30%)

NMR Spectroscopy:

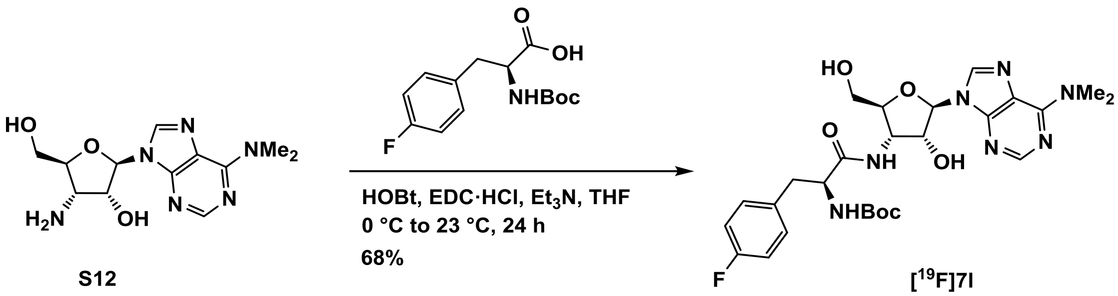
^{1}H NMR (500 MHz, CD_3OD, 23 ºC, δ): 7.90 (d, *J* = 7.1 Hz, 1H), 7.67 (dd, *J* = 9.2, 4.9 Hz, 2H), 7.56 (t, *J* = 7.5 Hz, 2H), 7.49 (t, *J* = 7.5 Hz, 2H), 7.07 (t, *J* = 8.9 Hz, 2H).

^{13}C NMR (125 MHz, CD_3OD, 23 ºC, δ): 168.8, 161.0 (d, *J* = 241 Hz), 136.1, 136.0 (d, *J* = 2.7 Hz), 132.9, 129.6, 128.6, 124.2 (d, *J* = 7.9 Hz), 116.2 (d, *J* = 22.5 Hz).

^{19}F NMR (376 MHz, CD_3OD, 23 ºC, δ): –123.2.

HRMS (m/z) calc'd for $C_{13}H_{10}FNONa$ $[M+Na]^+$, 238.0644; found, 238.0665.

Purin [^{19}F]7l



To a stirred solution of Boc-*L*-3-fluorophenylalanine (17 mg, 60 µmol, 1.0 eq.) in THF (0.70 mL, c = 0.086 M) at 0 °C was added a solution of puromycin aminonucleoside (**S12**) (20 mg, 68 µmol, 1.1 eq.) in THF (0.7 mL, c = 0.1 M) in one-portion. Subsequently, 1-hydroxybenzotriazole (HOBt, 9.2 mg, 68 µmol, 1.1 eq.), 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide hydrochloride (EDC·HCl, 23 mg, 0.12 mmol, 2.0 eq.), and triethyl amine (Et_3N, 40 ml, 29 mg, 0.29 mmol, 4.8 eq.) were added to the solution at 0 °C. The mixture was then stirred for 12 h at 23 °C. The resulting solution was diluted with ethyl acetate (10 mL) and filtered through a celite pad. The filtrate was washed with aqueous HCl solution (2 mL, c = 1.0 M), H_2O (1 mL) and then with brine (1 mL). The organic layer was dried over Na_2SO_4 and concentrated under reduced pressure, which was purified by chromatography on silica gel eluting with MeOH/CH_2Cl_2 5:95 (v/v) to afford 23 mg (41 µmol) of [^{19}F]**7l** as a colorless solid (68% yield).

R*f* = 0.49 (MeOH in CH_2Cl_2 = 5%)

NMR Spectroscopy:

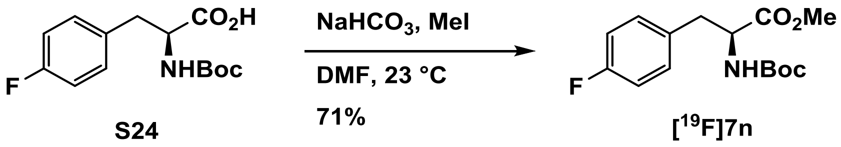
^{1}H NMR (500 MHz, CD_2Cl_2: CD_3OD 1:1, calibrated to CD_2Cl_2 peak, 23 ºC, δ): 8.21 (s, 1H), 8.16 (s, 1H), 7.17 (dd, *J* = 5.4 Hz, *J* = 8.6 Hz, 2H), 6.97 (t, *J* = 8.7 Hz, 2H), 5.82 (d, *J* = 2.2 Hz, 1H), 4.47 (d, *J* = 4.5 Hz, 2H), 4.27–4.25 (m, 1H), 4.02–4.01 (m, 1H), 3.96 (br s, 1H), 3.85 (d, *J* = 12.5 Hz, 1H), 3.57 (d, *J* = 11.9 Hz, 1H), 3.45 (br s, 6H), 3.02–2.98 (m, 1H), 2.86–2.82 (m, 1H), 1.32 (s, 9H).

^{13}C NMR (125 MHz, CD_2Cl_2: CD_3OD 1:1, calibrated to CD_2Cl_2, 23 ºC, δ): 178.8, 168.7, 160.7, 157.4, 154.8, 143.5, 138.7, 136.6 (d, *J* = 7.7 Hz), 126.3, 120.8, 120.6, 96.6, 89.6, 85.6, 79.6, 66.8, 61.9, 56.3, 43.8, 43.1, 33.4.

^{19}F NMR (471 MHz, CD_2Cl_2: CD_3OD 1:1, 23 ºC, δ): –115.5.

HRMS (m/z) calc'd for $C_{26}H_{36}FN_7O_6$ $[M+H]^+$, 560.2633; found, 560.2666.

Fluoro-*L*-tyrosinate [^{19}F]7n



To a stirred solution of **S24** (0.10 g, 0.35 mmol, 1.0 eq.) in DMF (1.4 mL, c = 0.25 M) at 23 °C was added sodium bicarbonate (60 mg, 0.71 mmol, 2.0 eq.). The mixture was stirred for 10 min at 23 °C and subsequently cooled to 0 °C. To the ice-cold solution was added methyl iodide (0.11 mL, 0.25 g, 1.8 mmol, 5.0 eq.) dropwise with a syringe over 10 min. The reaction mixture was stirred for 12 h allowing the temperature to rise to 23 °C. The mixture was poured into water (5 mL) and extracted with ethyl acetate (3 × 10 mL). The organic layer was washed with brine (10 mL) and dried over Na_2SO_4. The organic layer was concentrated and the product was purified by preparative thin-layer chromatography plate eluting with ethyl acetate in hexanes 1:4 (v/v) to give 0.075 g (0.25 mmol) of [^{19}F]**7n** as a colorless solid compound (71% yield).

R*f* = 0.67 (EtOAc in hexanes = 20%)

NMR Spectroscopy:

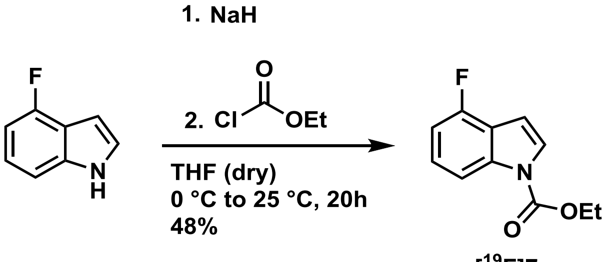
^{1}H NMR (500 MHz, $CDCl_3$, 23 ºC, δ): 7.08–7.06 (m, 2H), 6.96 (t, *J* = 8.5 Hz, 2H), 5.02–5.01 (m, 1H), 4.57–4.53 (m, 1H), 3.69 (s, 3H), 3.10–2.96 (m, 2H), 1.39 (s, 9H).

^{13}C NMR (125 MHz, $CDCl_3$, 23 ºC, δ): 172.2, 162.0 (d, $^1J_{CF}$ = 243 Hz), 154.9, 131.7, 130.8 (d, $^3J_{CF}$ = 7.9 Hz), 115.4 (d, *J* = 21.2 Hz), 79.9, 54.4, 52.2, 37.6, 28.2.

^{19}F NMR (376 MHz, $CDCl_3$, 23 ºC, δ): –115.9.

HRMS (m/z) calc'd for $C_{15}H_{20}FNO_4Na$ [M+Na]$^+$, 320.1274; found, 320.1269.

Ethyl 4-fluoro-1*H*-indole-1-carboxylate ([^{19}F]7o)



[^{19}F]7o

To a stirred solution of 4-fluoro-1*H*-indole (55 mg, 0.41 mmol, 1.0 eq.) in dry THF (0.80 mL, c = 0.51 M) at 0 °C was added sodium hydride (60% dispersion in mineral oil, 20. mg, 0.50 mmol, 1.2 eq.). The reaction mixture was stirred at 0 °C for 30 min. Then, ethyl chloroformate (0.10 mL, 0.11 g, 1.0 mmol, 3.9 eq.) was added to the reaction mixture at 0 °C. The reaction mixture was stirred for 20 h at 23 °C. Then, methanol (1 mL) was added to the reaction mixture, and the reaction mixture was filtered through a pad of celite and the celite was washed with methanol (1 mL). The filtrate was concentrated under reduced pressure, and the product was purified by preparative TLC (hexanes/ethyl acetate 90:10 (v/v)) to give 41 mg (0.20 mmol) of [^{19}F]**7o** as a pale yellow oil (48% yield).

R*f* = 0.76 (EtOAc in hexanes = 10%)

NMR Spectroscopy:

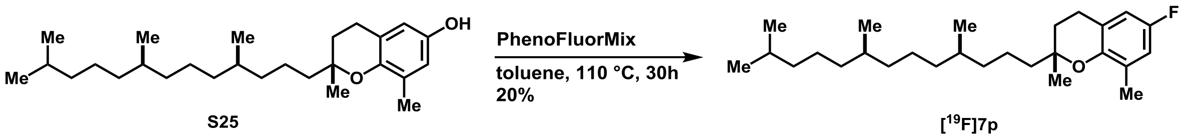
^{1}H NMR (600 MHz, C_6D_6, 23 ºC, δ): 8.18 (br s, 1H), 7.25 (br s, 1H), 7.00–6.97 (m, 1H), 6.80 (dd, *J* = 9.7, 8.0 Hz, 1H), 6.51 (d, *J* = 3.7 Hz, 1H), 3.90 (q, *J* = 7.1 Hz, 2H), 0.85 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (126 MHz, C_6D_6, 23 ºC, δ): 156.0 (d, $^1J_{CF}$ = 247.2 Hz), 150.2, 125.4, 125.2 (d, $^3J_{CF}$ = 7.4 Hz), 111.4 (d, $^4J_{CF}$ = 3.8 Hz), 110.0, 108.2, 108.0, 103.0, 62.7, 13.6.

^{19}F NMR (471 MHz, C_6D_6, 23 ºC, δ): –121.9.

HRMS (m/z) calc'd for $C_{11}H_{10}FNO_2Na$ [M+Na]$^+$, 230.0593; found, 230.0597.

Fluoro-deoxytocopherol [^{19}F]7p



In an N_2-filled glovebox, an oven-dried glass vial was charged with **2** (100. mg, 218 µmol, 1.46 eq.), previously dried (200 ºC, 24 hrs) CsF (231 mg, 1.52 mmol, 10.2 eq.) and (+)-δ-tocopherol (**S25**) (60.0 mg, 149 µmol, 1.00 eq.). Dry toluene (0.5 mL) was added and the vial was sealed, then removed from the glovebox. The reaction mixture in the vial was sonicated for 5 min and subsequently heated and stirred at 110 °C for 30 h and then cooled to 23 °C. Then, methanol (1 mL) was added to the reaction mixture, and the reaction mixture was filtered through celite, and the celite was washed with methanol (1 mL). The filtrate was concentrated under reduced pressure, and the product was purified by preparative TLC (hexanes/ethyl acetate 90:10 (v/v)) to give 12 mg (30 µmol) of [^{19}F]**7p** as a pale brown oil (20% yield).

R*f* = 0.65 (EtOAc in hexanes = 10%)

NMR Spectroscopy:

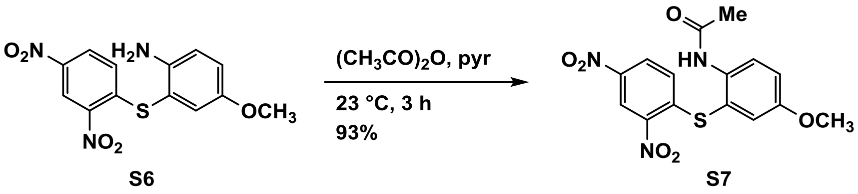
^{1}H NMR (600 MHz, $CDCl_3$, 23 ºC, δ): 6.66 (dd, *J* = 9.0, 3.1 Hz, 1H), 6.58 (dd, *J* = 8.9, 2.8 Hz, 1H), 3.48 (s, 3H), 2.73–2.70 (m, 2H), 2.14 (s, 3H), 1.82–1.70 (m, 2H), 1.60–1.47 (m, 3H), 1.45–1.33 (m, 4H), 1.32–1.25 (m, 5H), 1.25 (s, 3H), 1.18–1.10 (m, 3H), 1.10–1.02 (m, 3H), 0.87–0.83 (m, 12H).

^{13}C NMR (126 MHz, $CDCl_3$, 23 ºC, δ): 155.7 (d, $^1J_{CF}$ = 236.3 Hz), 147.9, 127.7 (d, $^3J_{CF}$ = 7.8 Hz), 121.3 (d, $^3J_{CF}$ = 7.3 Hz), 114.9 (d, $^2J_{CF}$ = 22.6 Hz), 112.2 (d, $^2J_{CF}$ = 22.0 Hz), 75.9, 39.9, 39.4, 37.5, 37.4, 37.3, 32.8, 32.7, 31.1, 29.7, 28.0, 24.8, 24.5, 24.1, 22.7, 22.6, 22.6, 20.9, 19.8, 19.7, 16.1.

^{19}F NMR (471 MHz, $CDCl_3$, 23 ºC, δ): –126.1.

HRMS (m/z) calc'd for $C_{27}H_{45}FO$ [M]$^{\bullet+}$, 404.3449; found, 404.3450.

Acetanilide S7



To a stirred solution of **S6** (2.00 g, 6.20 mmol, 1.00 eq.) in pyridine (7.5 mL, c = 0.83 M) was added acetic anhydride (0.58 mL, 0.63 g, 6.2 mmol, 1.0 eq.) at 0 °C. The reaction mixture was warmed to 23 °C and stirred for 3 h at 23 °C. Then 20 mL of ice-cold water were added. The resulting precipitate was filtered off with a Büchner funnel with a fritted disc and washed with 10 mL of water to obtain 2.21 g (6.08 mmol) of **S7** as a yellow solid (93% yield).

R*f* = 0.45 (EtOAc in hexanes = 50%)

NMR Spectroscopy:

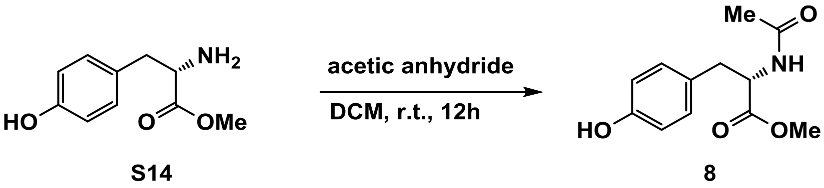
^{1}H NMR (500 MHz, $CDCl_3$, 23 ºC, δ): 9.14 (d, *J* = 2.5 Hz, 1H), 8.34 (d, *J* = 9.2 Hz, 1H), 8.19 (dd, *J* = 9.0, 2.5 Hz, 1H), 7.64 (br s, 1H), 7.16 (dd, *J* = 9.0, 3.0 Hz, 1H), 7.09 (d, *J* = 3.0 Hz, 1H), 6.94 (d, *J* = 9.0 Hz, 1H), 3.81 (s, 3H), 2.05 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$, 23 ºC, δ): 168.5, 157.1, 146.2, 145.1, 145.0, 144.5, 134.1, 128.8, 127.2, 124.8, 121.8, 121.3, 118.9, 118.7, 55.9.

HRMS (m/z) calc'd for $C_{15}H_{14}N_3O_6S$ $[M+H]^+$, 364.0603; found, 364.0596.

The ^{1}H NMR spectroscopic data correspond to the data reported in the literature.[5]

Methyl acetyl-*L*-tyrosinate (8)



To a solution of *L*-tyrosine methyl ester (**S14**) (100 mg, 513 µmol, 1.00 eq.) in dichloromethane (3 mL, c = 0.2 M) at 23 °C was added acetic anhydride (50.9 µL, 54.9 mg, 538 µmol, 1.05 eq). The reaction mixture was stirred at 23 °C for 12 h. Then, the solvent was removed *in vacuo*. The product was purified by chromatography on silica gel with hexanes / EtOAc 20:80 (v/v) as eluents to afford 102 mg (430 µmol) of methyl acetyl-*L*-tyrosinate (**8**) as a colorless solid (84% yield).

R*f* = 0.14 (EtOAc in hexanes = 75%)

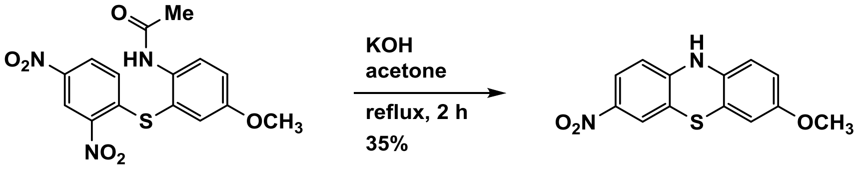
NMR Spectroscopy:

^{1}H NMR (600 MHz, $CDCl_3$, 23 ºC, δ) 6.93 (d, *J* = 8.4 Hz, 2H), 6.73 (d, *J* = 8.4 Hz, 2H), 6.09 (d, *J* = 8.2 Hz, 1H), 4.86 (dt, *J* = 7.9, 6.0 Hz, 1H), 3.74 (s, 3H), 3.08 (dd, *J* = 14.1, 5.6 Hz, 1H), 2.97 (dd, *J* = 14.1, 6.3 Hz, 1H), 1.98 (s, 3H).

^{13}C NMR (126 MHz, $CDCl_3$, 23 ºC, δ) 172.2, 170.21, 155.4, 130.1, 126.9, 115.5, 53.3, 52.3, 37.1, 22.9.

HRMS (m/z) calc'd for $C_{12}H_{16}NO_4$ $[M+H]^+$, calc'd 238.1079, found: 238.1080.

Phenothiazine S8



S7 **S8**

To a stirred solution of **S7** (2.00 g, 5.48 mmol, 1.00 eq.) in acetone (0.13 L, c = 43 mM) was added potassium hydroxide (1.8 g, 33 mmol, 6.0 eq.) portion-wise over 15 min at reflux. The reaction mixture was heated at reflux for 2 h and subsequently cooled to 23 °C. The solution was poured into 20 mL of ice-cold water. The resulting precipitate was filtered off with a Büchner funnel with a fritted disc and washed with 15 mL of water. The solid was dried under vacuum to obtain 0.53 g (1.9 mmol) of **S8** as a violet solid (35% yield).

R*f* = 0.37 (EtOAc in hexanes = 30%)

NMR Spectroscopy:

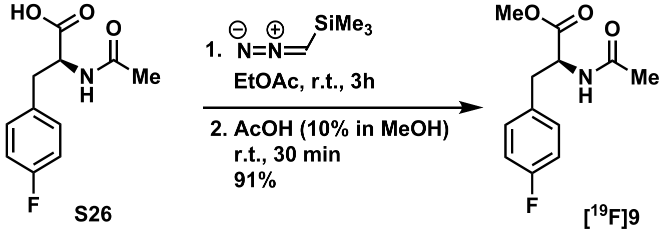
^{1}H NMR (500 MHz, DMSO-*d*$_6$, 23 ºC, δ): 9.38 (s, 1H), 7.81 (dd, *J* = 8.9, 2.5 Hz, 1H), 7.70 (d, *J* = 3.0 Hz, 1H), 6.64–6.60 (m, 3H), 6.57 (d, *J* = 1.9 Hz, 1H), 3.67 (s, 3H).

^{13}C NMR (125 MHz, DMSO-*d*$_6$, 23 ºC, δ): 155.8, 147.9, 140.4, 131.8, 124.7, 121.6, 116.4, 116.2, 115.8, 113.4, 112.9,111.6, 55.4.

HRMS (m/z) calc'd for $C_{13}H_{10}N_2O_3SNa$ $[M+Na]^+$, 297.0310; found, 297.0276.

The ^{1}H NMR spectroscopic data correspond to the data reported in the literature.[5]

Fluoro-acetyl-*L*-tyrosinate [^{19}F]9



To a solution of *N*-acetyl-4-fluoro-*L*-phenylalanine (**S26**) (50. mg, 0.22 mmol, 1.0 eq.) in ethyl acetate (2 mL, c = 0.1 M) was added 0.12 mL trimethylsilyldiazomethane (2.0 M in diethyl ether, 0.24 mmol, 1.1 eq.) and stirred at 23 °C for 3h. Then, 0.5 mL 10% acetic acid in methanol was added and the reaction mixture was stirred for another 30 min and then concentrated in vacuo. *N*-Acetyl-4-fluoro-*L*-phenylalanine methyl ester ([^{19}F]**9**) (48 mg, 0.20 mmol) was obtained as a colorless oil (91% yield).

R$_f$ = 0.22 (EtOAc in hexanes = 75%)

NMR Spectroscopy:

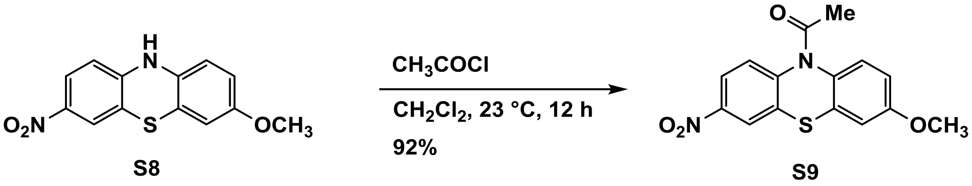
^{1}H NMR (600 MHz, CDCl$_3$, 23 ºC, δ) 7.04 (dd, *J* = 8.6, 5.4 Hz, 2H), 6.94 (t, *J* = 8.7 Hz, 2H), 6.19 (d, *J* = 7.9 Hz, 1H), 4.81 (dt, *J* = 7.8, 5.9 Hz, 1H), 3.68 (s, 3H), 3.09 (dd, *J* = 14.0, 6.0 Hz, 1H), 3.01 (dd, *J* = 14.0, 5.9 Hz, 1H), 1.95 (s, 3H).

^{13}C NMR (126 MHz, CDCl$_3$, 23 ºC, δ) 172.0, 169.8, 162.0 (d, $^1J_{CF}$ = 245.5 Hz), 131.7, 130.7, 115.4 (d, $^2J_{CF}$ = 21.6 Hz), 53.2, 52.3, 37.0, 23.0.

^{19}F NMR (471 MHz, CDCl$_3$, 23 ºC, δ) –115.7.

HRMS (m/z) calc'd for $C_{12}H_{15}FNO_3$ [M+H]$^+$, calc'd: 240.1036, found: 240.1030.

Acetyl-phenothiazin S9



To a stirred solution of **S8** (1.20 g, 4.37 mmol, 1.00 eq.) in CH_2Cl_2 (24 mL, c = 0.18 M) at 0 °C was added acetyl chloride (1.00 mL, 1.10 g, 14.0 mmol, 3.20 eq.) drop-wise over 10 min by a syringe. The solution was warmed to 23 °C and stirred for 12 h. Then the solution was concentrated to dryness under reduced pressure. The resulting residue was dissolved in ethyl acetate (75 mL). The solution was washed with water (15 mL) and then with brine (20 mL). The ethyl acetate layer was dried over Na_2SO_4 and concentrated under reduced pressure to afford a solid, which was purified by chromatography on silica gel eluting with hexanes / EtOAc 3:2 (v/v) to afford 1.27 g (4.01 mmol) of **S9** as an orange solid (92% yield).

R*f* = 0.62 (EtOAc in hexanes = 40%)

NMR Spectroscopy:

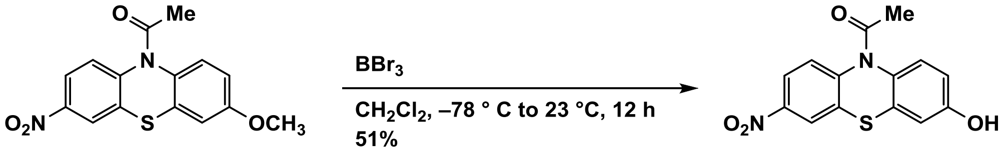
^{1}**H NMR** (500 MHz, $CDCl_3$, 23 ºC, δ): 8.28 (d, *J* = 2.5 Hz, 1H), 8.18 (dd, *J* = 8.8, 2.5 Hz, 1H), 7.72 (d, *J* = 8.8 Hz, 1H), 7.31 (d, *J* = 8.8 Hz, 1H), 6.97 (d, *J* = 2.8 Hz, 1H), 6.89 (dd, *J* = 8.8, 3.0 Hz, 1H), 3.83 (s, 3H), 2.22 (s, 3H).

^{13}**C NMR** (125 MHz, $CDCl_3$, 23 ºC, δ): 169.4, 158.7, 145.7, 144.9, 134.5, 133.3, 130.9, 128.1, 127.6, 123.0, 122.2, 114.1, 112.9, 55.9, 23.1.

HRMS (m/z) calc'd for $C_{15}H_{13}N_2O_4S$ $[M+H]^+$, 317.0596; found, 317.0593.

The ^{1}H NMR spectroscopic data correspond to the data reported in the literature.[5]

Hydroxy-phenothiazin S10



S9 **S10**

To a stirred solution of **S9** (1.05 g, 3.31 mmol, 1.00 eq.) in CH_2Cl_2 (0.13 L, c = 22 mM) at –78 °C was added BBr_3 in CH_2Cl_2, c = 1.0 M (13 mL, 13 mmol, 4.0 eq.) drop-wise over 30 min by a syringe pump. The reaction mixture was stirred for 12 h, allowing the reaction temperature to rise to 23 °C. CH_2Cl_2 was removed under reduced pressure and the resulting residue was dissolved in ethyl acetate (100 mL) and th and water (25 mL). The organic layer was washed with brine (25 mL), dried over Na_2SO_4 and concentrated under reduced pressure. The residue was purified by chromatography on silica gel eluting with hexanes in EtOAc 1:1 (v/v) to afford 0.51 g (1.7 mmol) of **S10** as a yellow solid (51% yield).

R*f* = 0.42 (EtOAc in hexanes = 50%)

NMR Spectroscopy:

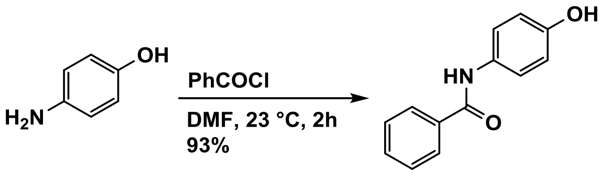
^{1}**H NMR** (500 MHz, DMSO-*d*$_6$, 23 ºC, δ): 9.96 (s, 1H), 8.32 (d, *J* = 2.6 Hz, 1H), 8.14 (dd, *J* = 8.8, 2.6 Hz, 1H), 7.74 (d, *J* = 8.8 Hz, 1H), 7.39 (d, *J* = 8.6 Hz, 1H), 6.86 (d, *J* = 2.6 Hz, 1H), 6.74 (dd, *J* = 8.7, 2.6 Hz, 1H), 2.08 (s, 3H).

^{13}C NMR (125 MHz, DMSO-*d*$_6$, 23 ºC, δ): 168.6, 156.3, 145.2, 144.6, 133.8, 131.9, 128.9, 128.2, 128.1, 122.8, 122.2, 114.9, 113.9, 22.6.

HRMS (m/z) calc'd for $C_{14}H_{11}N_2O_4S$ $[M+H]^+$, 303.0440; found, 303.0420.

The ^{1}H NMR spectroscopic data correspond to the data reported in the literature.[5]

N-(4-Hydroxyphenyl)benzamide (S11)



S11

To a stirred solution of 4-aminophenol (500 mg, 4.58 mmol, 1.00 eq.) in DMF (3.0 mL, c = 1.5 M) at 0 °C was added benzoyl chloride (530 µL, 643 mg, 4.58 mmol, 1.00 eq.) drop-wise by a syringe over 5 min. The mixture was warmed to 23 °C and stirred for 2 h. Then aqueous 1 M NaOH solution (5 mL) was added to the above solution to adjust the pH to 7. The resulting solution was added drop-wise to ice-cold water (10 mL) with a syringe over 10 min. The resulting precipitate was filtered off with a Büchner funnel and dried under vacuum to afford 908 mg (4.26 mmol) of **S11** as an off-white solid (93% yield).

R*f* = 0.47 (EtOAc in hexanes = 50%)

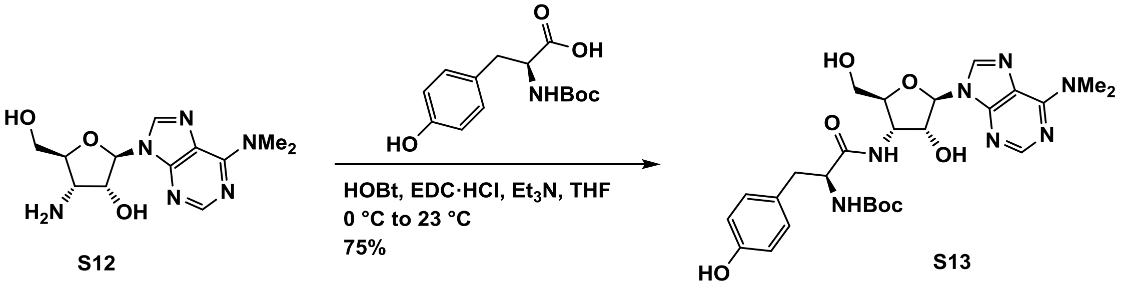
NMR Spectroscopy:

^{1}H NMR (500 MHz, CD_3OD, 23 ºC, δ): 7.92–7.89 (m, 2H), 7.58–7.54 (m, 1H), 7.52–7.47 (m, 2H), 7.45 (d, *J* = 8.9 Hz, 2H), 6.78 (d, *J* = 8.9 Hz, 2H).

^{13}C NMR (125 MHz, CD_3OD, 23 ºC, δ): 168.7, 155.8, 136.4, 132.7, 131.6, 129.6, 128.5, 124.2, 112.3.

HRMS (m/z) calc'd for $C_{13}H_{11}NO_2Na$ $[M+Na]^+$, 236.0687; found, 236.0724.

Purin S13



To a stirred solution of Boc-Tyr-OH (19 mg, 68 µmol, 1.0 eq.) in THF (1.0 mL, c = 0.068 M) at 0 °C was added a solution of puromycin aminonucleoside **S12** (20 mg, 68 µmol, 1.0 eq.) in THF (0.35 mL, c = 0.20 M) in one portion. Subsequently, 1-hydroxybenzotriazole (HOBt, 9.2 mg, 68 µmol, 1.0 eq.), 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide hydrochloride (EDC·HCl, 23 mg, 0.12 mmol, 1.7 eq.), and triethyl amine (33 µl, 24 mg, 0.24 mmol, 3.5 eq.) were added to the above solution at 0 °C. The reaction mixture was allowed to warm to 23 °C and stirred for 12 h. The resulting solution was diluted with ethyl acetate (10 mL) and filtered through a celite pad. The filtrate was washed with 1 M aqueous HCl solution (2 mL), H_2O (1 mL) and then brine (1 mL). The organic layer was dried over Na_2SO_4 and concentrated under reduced pressure. The product was purified by chromatography on silica gel eluting with MeOH / CH_2Cl_2 5:95 (v/v) to afford 28 mg (51 µmol) of **S13** as a colorless solid (75% yield).

R*f* = 0.32 (MeOH in CH_2Cl_2 = 5%)

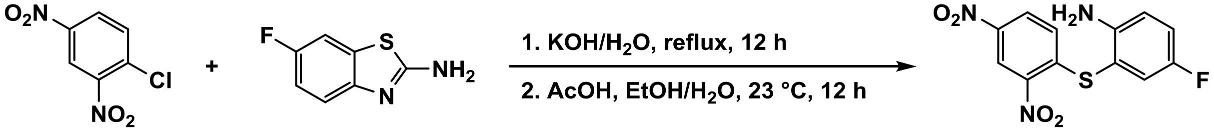
NMR Spectroscopy:

^{1}H NMR (500 MHz, CD_2Cl_2:CD_3OD 1:1, calibrated to CD_2Cl_2 peak, 23 ºC, δ): 8.18 (s, 1H), 8.14 (s, 1H), 7.01 (d, *J* = 8.6 Hz, 2H), 6.69 (d, *J* = 8.5 Hz, 2H), 5.76 (d, *J* = 3.1 Hz, 1H), 4.50 (br s, 2H), 4.45–4.42 (m, 1H), 4.21–4.18 (m, 1H), 3.94–3.92 (m, 1H), 3.81 (d, *J* = 12.2 Hz, 1H), 3.56 (d, *J* = 12.8 Hz, 1H), 3.42 (br s, 6H), 3.24–3.27 (m, 1H), 2.89–2.77 (m, 3H), 1.34 (s, 9H).

^{13}C NMR (125 MHz, CD_2Cl_2:CD_3OD 1:1, calibrated to CD_2Cl_2 peak 23 ºC, δ): 156.8, 155.7, 154.7, 152.4, 149.7, 138.6, 130.9, 128.4, 121.4, 116.1, 112.9, 110.9, 91.7, 84.7, 80.7, 74.4, 61.9, 57.2, 51.3, 38.2, 38.06, 28.5.

HRMS (m/z) calc'd for $C_{26}H_{36}N_7O_7$ $[M+H]^+$, 558.2676; found, 558.2635.

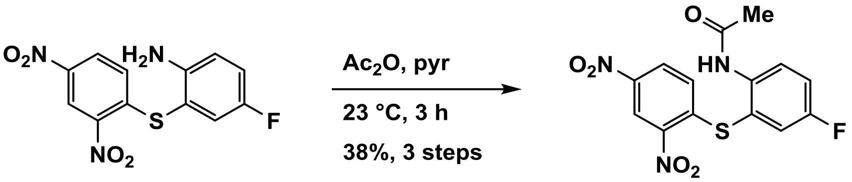
4-Fluoroaniline S16



S14 **S15** **S16**

To an aqueous solution of potassium hydroxide (20 mL, 50% w/w) was added 6-fluorobenzo[*d*]thiazol-2-amine (0.94 g, 5.6 mmol, 1.1 eq.) at 23 °C. The reaction mixture was heated at reflux and stirred for 12 h. Then the resulting solution was cooled to 23 °C. The solution was then added drop-wise over 10 min with a syringe to a stirred solution of 1-chloro-2,4-dinitrobenzene (1.0 g, 5.0 mmol, 1.0 eq.) in ethanol (40 mL)/acetic acid (100 mL) at 0 °C. The mixture was warmed to 23 °C and stirred for 2 h. The resulting precipitate was filtered off with a Büchner funnel with a fritted disc and washed with water (15 mL) and ethanol (10 mL) to afford **S16**, which was used in the next step without purification.

2,4-Dinitrophenylthio-acetamide S17



S16 **S17**

To a stirred solution of **S16** (1.40 g, 4.52 mmol, 1.00 eq.) in pyridine (5.5 mL, c = 0.83 M) was added acetic anhydride (430 µL, 460 mg, 4.52 mmol, 1.00 eq.) at 0 °C. The solution was warmed to 23 °C and stirred for 3 h. Then, the reaction mixture was poured into 20 mL of ice-cold water. The resulting precipitate was filtered off with a Büchner funnel with fritted glass and was washed with 10 mL of water. The solid was dried under vacuum to afford 0.76 g (2.1 mmol) of **S17** as a pale yellow solid (38% yield over three steps).

R*f* = 0.51 (EtOAc in hexanes = 20%)

NMR Spectroscopy:

^{1}H NMR (500 MHz, $CDCl_3$, 23 ºC, δ): 9.12 (d, *J* = 2.5 Hz, 1H), 8.44 (dd, *J* = 2.7, 2.2 Hz, 1H), 8.21 (dd, *J* = 9.0, 2.5 Hz, 1H), 8.05 (s, 1H), 7.55 (dd, *J* = 6.8, 6.2 Hz, 1H), 6.97 (td, *J* = 8.1, 2.8 Hz, 1H), 6.87 (d, *J* = 8.9 Hz, 1H), 2.12 (s, 3H).

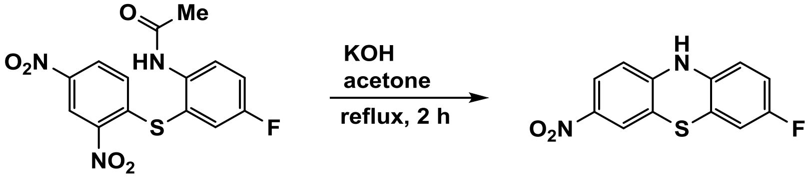
^{13}C NMR (125 MHz, $CDCl_3$, 23 ºC, δ): 168.7, 165.5 (d, *J* = 251.1 Hz), 144.7, 145.3, 144.8 (d, *J* = 1.7 Hz), 142.9 (d, *J* = 12.7 Hz), 138.8 (d, *J* = 9.9 Hz), 128.3, 127.8, 121.9, 112.9 (d, *J* = 22.4 Hz), 110.9 (d, *J* =

3.2 Hz), 109.5 (d, *J* = 28.0 Hz), 25.1.

^{19}F NMR (376 MHz, $CDCl_3$, 23 ºC, δ): –102.5.

HRMS (m/z) calc'd for $C_{14}H_{10}FN_3O_5SNa$ $[M+Na]^+$, 374.0223; found, 374.0235.

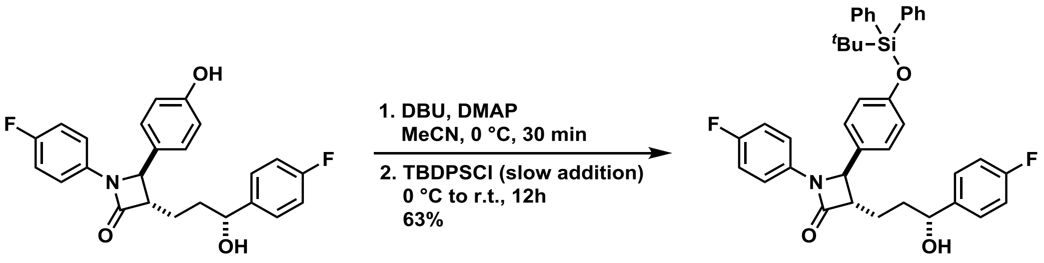
3-Fluoro-7-nitro-10*H*-phenothiazine (S18)



S17 **S18**

To a stirred solution of **S17** (0.50 g, 1.4 mmol, 1.0 eq.) in acetone (33 mL, c = 0.043 M) was added potassium hydroxide (0.48 g, 8.5 mmol, 6.0 eq.) portionwise over 15 min at reflux. The reaction mixture was stirred for another 2 h and subsequently cooled to 23 °C. The solution was poured into ice-cold water (10 mL). The resulting precipitate was filtered off with a Büchner funnel with a fritted glass and washed with 5 mL of water and dried under vacuum to afford 0.15 g of **S18** as a violet solid, which was used for the next step without further purification.

tert-Butyldiphenylsilyloxy-phenylazetidin S20



S19 **S20**

An oven-dried 5 mL glass vial was charged with magnetic stirring bar, dry acetonitrile (MeCN) (2.0 mL) and was cooled to 0 °C. Under N_2 atmosphere, ezetimibe (**S19**) (0.16 g, 0.39 mmol, 1.0 eq.), 4-(dimethylamino)-pyridine (DMAP) (16 mg, 0.13 mmol, 0.34 eq.) and 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) (0.15 g, 0.15 mL, 0.98 mmol, 2.5 eq.) were added to the vial. Then, *tert*-butyl(chloro)diphenylsilane (TBDPSCl) (0.27 g, 0.26 mL, 0.98 mmol, 2.5 eq.) was added dropwise to the stirring solution with syringe over 5 min. Then the ice bath was removed and the reaction mixture was stirred for 12 h at 23 °C. Then, the reaction mixture was concentrated under reduced pressure and the residue was purified by preparative TLC (hexanes/ethyl acetate 85:15 (v/v)) to give 160 mg (257 μmol) of **S20** as a pale yellow oil (63% yield).

R*f* = 0.45 (EtOAc in hexanes = 15%)

NMR Spectroscopy:

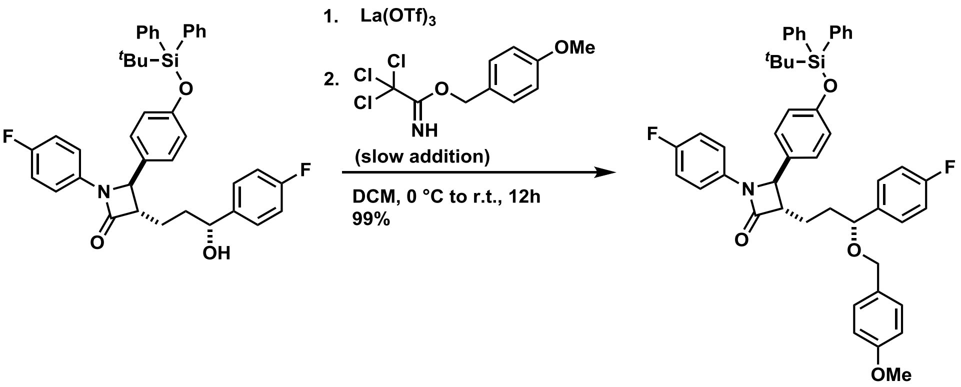
^{1}H NMR (600 MHz, $CDCl_3$, 23 ºC, δ): 7.68–7.70 (m, 4H), 7.40–7.44 (m, 2H), 7.35 (td, *J* = 7.1, 1.1 Hz, 4H), 7.24–7.27 (m, 2H), 7.17 (dd, *J* = 9.1, 4.5 Hz, 2H), 7.04 (d, *J* = 8.6 Hz, 2H), 6.98 (t, *J* = 8.7 Hz, 2H), 6.89 (dd, *J* = 9.1, 8.3 Hz, 2H), 6.75 (d, *J* = 8.6 Hz, 2H), 4.66 (dd, *J* = 7.2, 5.2 Hz, 1H), 4.48 (d, *J* = 2.4 Hz, 1H), 3.03 (dt, *J* = 7.5, 2.5 Hz, 1H), 1.82–1.99 (m, 4H), 1.10 (s, 9H).

^{13}C NMR (126 MHz, $CDCl_3$, 23 ºC, δ): 171.2, 167.7, 162.1 (d, *J* = 245.3 Hz), 158.9 (d, *J* = 243.2 Hz), 155.9, 140.1, 135.52, 135.50, 133.9, 132.61, 132.62, 130.0, 129.7, 127.8, 127.7, 127.4 (d, *J* = 7.9 Hz), 126.9, 120.5, 118.4 (d, *J* = 7.7 Hz), 115.7 (d, $^2J_{CF}$ = 22.5 Hz), 115.3 (d, J = 21.4 Hz), 72.9, 61.1, 60.1, 36.6, 26.5, 25.0, 19.4.

^{19}F NMR (471 MHz, $CDCl_3$, 23 ºC, δ): –115.0, –118.2.

HRMS (m/z) calc'd for $C_{40}H_{40}F_2NO_3Si$ $[M+H]^+$, 648.2746; found, 648.2798.

PMB-ether S21



S20 **S21**

An oven-dried glass dram vial was charged with magnetic stir bar, dry dichloromethane (2.0 mL) and was cooled to 0 °C. Under N_2 atmosphere, **S20** (120 mg, 185 µmol, 1.00 eq.) and lanthanum(III) trifluoromethanesulfonate ($La(OTf)_3$) (20.0 mg, 34.1 µmol, 18.4 mol%) were added to the vial. Then, 4-methoxybenzyl-2,2,2-trichloroacetimidate (136 mg, 100 µL, 481 µmol, 2.60 eq.) was slowly added to the stirred solution over 5 min. Then, the vial, which contained the reaction mixture was taken out of the ice bath and allowed to warm to 23 °C. The reaction mixture was stirred overnight for 12 h at 23 °C. Then, the reaction mixture was concentrated under reduced pressure, and the product was purified by preparative TLC (hexanes/ethyl acetate 95:5 (v/v)) to give 0.14 g (0.18 mmol) of **S21** as a pale yellow oil (99% yield).

R*f* = 0.60 (EtOAc in hexanes = 5%)

NMR Spectroscopy:

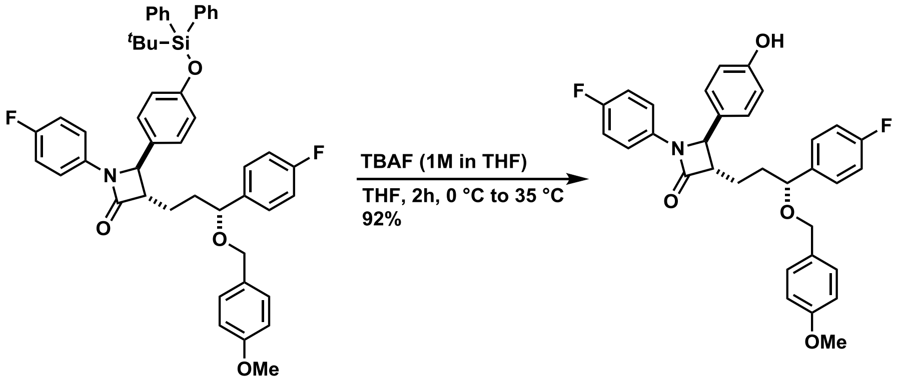
^{1}H NMR (600 MHz, CDCl$_3$, 23 ºC, δ): 7.67–7.70 (m, 4H), 7.42 (td, *J* = 7.2, 2.2 Hz, 2H), 7.35 (td, *J* = 7.3, 1.3 Hz, 4H), 7.21 (dd, *J* = 8.5, 5.5 Hz, 2H), 7.15 (dd, *J* = 8.8, 3.5 Hz, 4H), 7.02 (d, *J* = 8.6 Hz, 2H), 6.99 (d, *J* = 8.6 Hz, 2H), 6.87–6.91 (m, 2H), 6.83 (d, *J* = 8.7 Hz, 2H), 6.72 (d, *J* = 8.7 Hz, 2H), 4.44 (d, *J* = 2.4 Hz, 1H), 4.33 (d, *J* = 11.3 Hz, 1H), 4.20 (dd, *J* = 7.7, 4.8 Hz, 1H), 4.10 (d, *J* = 11.3 Hz, 1H), 3.78 (s, 3H), 2.91 (ddd, *J* = 8.9, 6.2, 2.4 Hz, 1H), 1.82–1.97 (m, 4H), 1.09 (s, 9H).

^{13}C NMR (126 MHz, CDCl$_3$, 23 ºC, δ): 167.6, 162.4 (d, *J* = 245.4 Hz), 159.3, 158.9 (d, *J* = 243.0 Hz), 155.9, 137.9, 135.6 (d, *J* = 3.7 Hz), 134.1, 132.7, 130.2 (d, *J* = 9.7 Hz), 130.1, 130.0, 129.6, 129.4 (d, *J* = 21.5 Hz), 128.3 (d, *J* = 7.9 Hz), 127.9 (d, *J* = 2.5 Hz), 127.0, 120.5, 118.4 (d, *J* = 7.7 Hz), 115.7 (d, *J* = 22.7 Hz), 115.5 (d, *J* = 21.3 Hz), 114.4, 114.1, 113.9, 113.9, 79.5, 70.1, 61.0, 60.2, 55.3, 35.9, 26.6, 25.2, 19.5.

^{19}F NMR (471 MHz, CDCl$_3$, 23 ºC, δ): –114.7, –118.3.

HRMS (m/z) calc'd for $C_{48}H_{48}F_2NO_4Si$ [M+H]$^+$, 768.3321; found, 768.3322.

4-Hydroxyphenylazetidin S22



S21 S22

An oven-dried 5 mL glass vial was charged with magnetic stir bar, dry THF (2.0 mL) and was cooled to 0 °C. Under N_2 atmosphere, PMB ether **S21** (110 mg, 143 µmol, 1.00 eq.) was added to the vial. Then, tetrabutylammonium fluoride solution in THF (c = 1.0 M) (215 µL, 194 mg, 215 µmol, 1.50 eq.) was slowly added to the stired solution over 10 min at 0 °C. Then the ice bath was removed and the reaction mixture was stirred for 2 h at 23 °C. The reaction mixture was concentrated under reduced pressure, and the product was purified by preparative TLC (hexanes/ethyl acetate 85:15 (v/v)) to give 70 mg (0.13 mmol) of **S22** as a pale yellow oil (92% yield).

R*f* = 0.45 (EtOAc in hexanes = 15%)

NMR Spectroscopy:

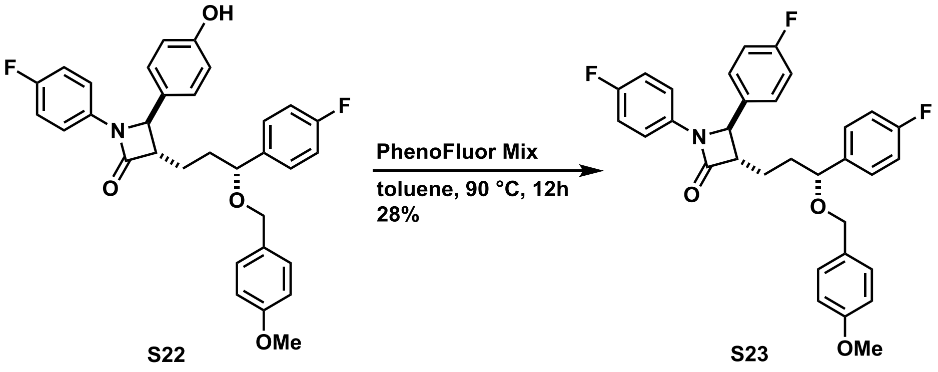
^{1}H NMR (600 MHz, CDCl$_3$, 23 ºC, δ): 7.19–7.24 (m, 4H), 7.16 (d, *J* = 8.6 Hz, 2H), 7.11 (d, *J* = 8.6 Hz, 2H), 7.04–7.00 (m, 2H), 6.89 (dd, *J* = 9.1, 8.3 Hz, 2H), 6.84 (d, *J* = 8.6 Hz, 2H), 6.80 (d, *J* = 5.6 Hz, 2H), 4.53 (d, *J* = 2.3 Hz, 1H), 4.34 (d, *J* = 11.3 Hz, 1H), 4.24 (dd, *J* = 7.6, 4.9 Hz, 1H), 4.12 (d, *J* = 11.3 Hz, 1H), 3.78 (s, 3H), 2.95 (ddd, *J* = 8.8, 6.1, 2.3 Hz, 1H), 1.86-1.98 (m, 4H).

^{13}C NMR (126 MHz, CDCl$_3$, 23 ºC, δ): 170.1, 164.6 (d, *J* = 245.7 Hz), 161.5, 161.3 (d, *J* = 243.9 Hz), 158.9, 140.0, 136.2, 132.4, 131.8, 131.2, 130.6 (d, *J* = 7.9 Hz), 129.6, 120.7 (d, *J* = 7.3 Hz), 118.4, 118.1 (d, *J* = 22.4 Hz), 117.8 (d, *J* = 21.3 Hz), 116.2, 82.0, 72.4, 69.7, 62.5, 57.6, 35.5, 25.7.

^{19}F NMR (471 MHz, CDCl$_3$, 23 ºC, δ): –114.7, –118.1.

HRMS (m/z) calc'd for $C_{32}H_{30}F_2NO_4$ $[M+H]^+$, 530.2143; found, 530.2157.

Fluorophenylazetidin S23



In an N$_2$-filled glovebox, an oven-dried vial was charged with **2** (74.0 mg, 161 µmol, 1.31 eq.), previously dried (200 ºC, 24 h) CsF (185 mg, 1.22 mmol, 9.92 eq.) and PMB ether **S22** (65.0 mg, 123 µmol, 1.00 eq.). Dry toluene (0.5 mL) was added to the vial and the vial was sealed, sonicated for 5 min and then the reaction mixture was stirred at 90 °C for 12 h. Then the reaction mixture was allowed to cool to 23 °C. Then, methanol (1 mL) was added to the reaction mixture, and then the reaction mixture was filtered through celite and the celite was washed with methanol (1 mL). The filtrate was concentrated under reduced pressure, and the product was purified by preparative TLC (hexanes/ethyl acetate 90:10 (v/v)) to give 18 mg (34 µmol) of **S23** as a pale yellow oil (28% yield).

R*f* = 0.78 (EtOAc in hexanes = 10%)

NMR Spectroscopy:

^{1}H NMR (600 MHz, $CDCl_3$, 23 ºC, δ): 7.23 (ddd, *J* = 7.7, 6.0, 2.3 Hz, 4H), 7.17 (dd, *J* = 9.1, 4.8 Hz, 2H), 7.15 (d, *J* = 8.6 Hz, 2H), 7.02 (td, *J* = 8.6, 1.7 Hz, 4H), 6.92–6.88 (m, 2H), 6.83 (d, *J* = 8.6 Hz, 2H), 4.57 (d, *J* = 2.3 Hz, 1H), 4.33 (d, *J* = 11.4 Hz, 1H), 4.23 (dd, *J* = 7.7, 4.8 Hz, 1H), 4.11 (d, *J* = 11.3 Hz, 1H), 3.77 (s, 3H), 2.95 (ddd, *J* = 10.4, 5.0, 1.9 Hz, 1H), 1.93–1.85 (m, 2H), 1.80–1.75 (m, 2H).

^{13}C NMR (126 MHz, $CDCl_3$, 23 ºC, δ): 167.1, 162.7 (d, $^1J_{CF}$ = 247.66 Hz), 162.3 (d, $^1J_{CF}$ = 245.81 Hz), 159.0 (d, $^1J_{CF}$ = 243.45 Hz), 159.3, 147.4, 137.7 (d, $^4J_{CF}$ = 3.2 Hz), 133.8 (d, $^4J_{CF}$ = 2.7 Hz), 133.4 (d, $^4J_{CF}$ = 3.3 Hz), 130.1, 129.5, 128.2 (d, $^3J_{CF}$ = 8.0 Hz), 127.5 (d, $^3J_{CF}$ = 8.2 Hz), 118.3 (d, $^3J_{CF}$ = 7.7 Hz), 116.3 (d, $^2J_{CF}$ = 21.7 Hz), 115.9 (d, $^2J_{CF}$ = 22.8 Hz), 115.5 (d, $^2J_{CF}$ = 21.5 Hz), 113.8, 79.6, 70.1, 60.6, 55.3, 35.9, 25.3.

^{19}F NMR (471 MHz, $CDCl_3$, 23 ºC, δ): –113.0, –114.7, –118.0.

HRMS (m/z) calc'd for $C_{32}H_{29}F_3NO_3$ $[M+H]^+$, 532.2100; found, 532.2107.

Radiochemistry general methods

No-carrier-added ^{18}F-fluoride was produced from water 97% enriched in ^{18}O (Sigma-Aldrich®) by the nuclear reaction ^{18}O(p,n)^{18}F with a Siemens Eclipse HP cyclotron and a silver-bodied target at MGH Athinoula A. Martinos Center for Biomedical Imaging. The produced ^{18}F-fluoride in water was transferred from the cyclotron target by helium push. Liquid chromatographic analysis (LC) was performed with Agilent 1100 series HPLCs connected to a Carol and Ramsey Associates Model 105-S radioactivity detector. An Agilent Eclipse XDB-C18, 5 µm, 4.6 × 150 mm HPLC column was used for analytical analysis and an Agilent Eclipse XDB-C18, 5 µm, 9.4 × 250 mm HPLC column was used for preparative HPLC. Analytical and preparative HPLC used the following mobile phases: 0.1% CF_3CO_2H in water (A), 0.1% CF_3CO_2H in acetonitrile (B). Unless otherwise mentioned, the HPLC was programmed: 20% (B) for 1 min then a gradient 20–95% (B) over 13 min followed by 3 min of 95% (B). In the analysis of the ^{18}F-labeled compounds, isotopically unmodified reference substances were used for identification. Radioactivity was measured in a Capintec, Inc. CRC-25PET ion chamber.

Solvents and reagents for radiochemical experiments: Acetonitrile (ACS reagent, >99.0%), ethanol (absolute, >99.8%), DMSO (ACS reagent >99.9%) were purchased from SigmaAldrich® and used as received. Water was obtained from a Millipore Milli-Q Integral Water Purification System. Potassium bicarbonate (≥99%) was purchased from SigmaAldrich® and used as received.

All ^{18}F-labeled molecules were characterized by comparing the radioactivity HPLC trace of the reaction mixture to the HPLC UV trace of an authentic reference sample, which was either synthesized as a new or known compound or purchased from a commercial source. The synthetic procedures of all the new reference standards are described in this work. Note: radioactivity chromatographs are offset by 0.15 min on account of the delay introduced by the spatial separation between the diode array detector and the radioactivity detector. Unless otherwised stated, the radiochemical yields (RCYs, percentage of ^{18}F transformed into desired product, corrected for decay) are estimated from an aliquot of the reaction mixtures by radio-HPLC and radio-TLC.

Elution Efficiency (EE) was calculated as following:

$$\mathrm{EE} = \frac{\text{total activity of the reaction mixture after elution of } {}^{18}F\text{−fluoride into a vial}}{\text{activity of cartridge after loading of } {}^{18}F \text{ from cyclotron onto the cartridge}}$$

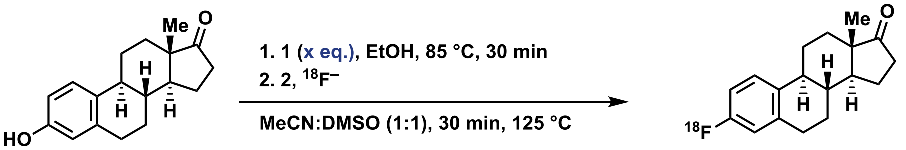
Optimization studies for deoxy[^{18}F]fluorination of phenols

Estrone was chosen as a model phenol because of commercial availability and the high boiling point of the corresponding fluorinated product.

Optimization of [CpRu(cod)Cl] (**1**) **stoichiometry:** We found that 3 equivalents of **1** is an optimal compromise between radiochemical yield and elution efficiency, which increased with higher amounts, and practicality with respect to solubility of the complex. (Scheme S1)

Estrone (2.3 mg, 8.7 μmol, 1.0 eq.) and [CpRu(cod)Cl] (**1**) (a: 2.7 mg, 8.7 μmol, 1 eq.; b: 5.3 mg, 17 μmol, 2.0 eq. and c: 8.0 mg, 26 μmol, 3.0 eq.) were added to EtOH (50 μL, c = a: 0.27 M, b: 0.53 M and c: 0.80 M) in a 0.5 dram (1.8 mL) borosilicate glass vial. The vial was capped, and the reaction mixture was stirred at 85 °C (heating block temperature) for 30 min. Then, the mixture was allowed to stand for 3 min at 23 °C. To the vial, imidazolium chloride **2** (14 mg, 26 μmol, 3.0 eq.) and 150 μL of MeCN were added, and the resulting solution was drawn into a 1.0 mL polypropylene syringe for elution of fluoride.

^{18}F-Fluoride solution from the cyclotron was loaded with a syringe onto a QMA anion exchange cartridge (Chromafix 30-PS-HCO_3), and the trapped radioactivity was measured (a: 10.2 mCi, 377 MBq; b: 9.25 mCi, 342 MBq; c: 16.2 mCi, 599 MBq). The cartridge was washed with MeCN (1.0 mL, inverted and fitted with a female × female Luer adapter. With the solution of estrone-ruthenium complex and **2**, the ^{18}F-fluoride was eluted into a 1 dram (3.7 mL) borosilicate vial. The cartridge was washed with DMSO (150 μL), followed by DMSO:MeCN (50 μL, 1:1 (v/v)) and the radioactivity of the eluted solution was measured (a: 6.3 mCi, 0.23 GBq; b: 6.0 mCi, 0.22 GBq; c: 10.6 mCi, 392 MBq). The reaction vial, which contained 400 μL of the reaction mixture was sealed with teflon-lined caps and heated at 125 °C for 30 min. Then the mixture was allowed to stand for 3 min at 23 °C. The reaction mixtures were analyzed by radio-HPLC and radio-TLC. The product **7d** was characterized by comparing the radio-HPLC traces of the reaction mixture with the HPLC UV trace of the authentic reference sample.



7d

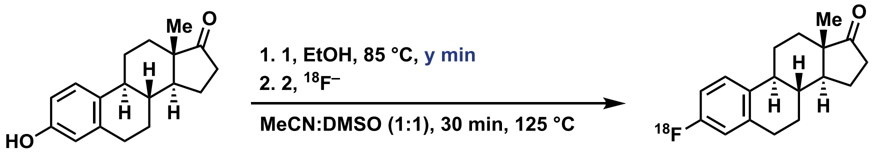
a. x = 1.0 eq., EE = 62%, RCY = 52%
b. x = 2.0 eq., EE = 65%, RCY = 53%
c. x = 3.0 eq., EE = 65%, RCY = 67%

Scheme S1. The effect of [CpRu(cod)Cl] (**1**) stoichiometry on the [^{18}F]deoxyfluorination of estrone. EE = elution efficiency, RCY estimated by TLC.

Optimization of complexation time: The radiochemical yield as a function of complexation time of [CpRu(cod)Cl] (**1**) with estrone as a phenol was shown to reach a plateau around 30 min. (Figure S1) The complexation time of estrone and **1** from 5 min to 30 min did not affect the elution efficiency, and elution efficiency remained relatively unchanged. (EE = ca. 65%)

Estrone (2.3 mg, 8.7 µmol, 1.0 eq.) and [CpRu(cod)Cl] (**1**) (8.0 mg, 26 µmol, 3.0 eq.) were added to an EtOH (50 µL, c = 0.80 M) in a 0.5 dram (1.8 mL) borosilicate glass vial. The vial was capped, and the reaction mixture was stirred at 85 °C (heating block temperature) for 5, 10, 15, 20 and 30 min, respectively. The vial was allowed to stand for 3 min at 23 °C. To the vial, imidazolium chloride **2** (14 mg, 26 µmol, 3.0 eq.) and 150 µL of MeCN were added, and the resulting mixture was drawn into a 1.0 mL polypropylene syringe for elution of fluoride.

^{18}F-Fluoride solution from the cyclotron was loaded with a syringe onto a QMA anion exchange cartridge (Chromafix 30-PS-HCO_3), and the trapped activity was measured (a: 6.4 mCi, 0.24 GBq; b: 8.4 mCi, 0.31 GBq; c: 7.9 mCi, 0.29 GBq, d: 6.4 mCi, 0.24 GBq; e: 16.2 mCi, 599 MBq). The cartridge was washed with MeCN (1.0 mL). The cartridge was inverted and fitted with a female × female Luer adapter. With the solution of estrone-ruthenium complex and **2**, the ^{18}F-fluoride was eluted into a dram (3.7 mL) borosilicate vial. The cartridge was washed with DMSO (150 µL), followed by DMSO:MeCN (50 µL, 1:1 (v/v)) and the radioactivity of the eluted solution was measured (a: 4.1 mCi, 0.15 GBq; b: 5.5 mCi, 0.20 GBq; c: 4.9 mCi, 0.18 GBq, d: 3.9 mCi, 0.14 GBq; e: 10.6 mCi, 392 MBq). The reaction vial, which contained 400 µL of the reaction mixture, was sealed with a teflon-lined cap and heated at 125 °C for 30 min. The vials were allowed to stand for 3 min at 23 °C. The reaction mixture was analyzed by radio-HPLC and radio-TLC. The product **7d** was characterized by comparing the radio-HPLC traces of the reaction mixtures with the HPLC UV trace of the authentic reference sample.



7d

a. y = 05 min, EE = 64%, RCY = 51%
b. y = 10 min, EE = 65%, RCY = 50%
c. y = 15 min, EE = 62%, RCY = 55%
d. y = 20 min, EE = 61%, RCY = 57%
e. y = 30 min, EE = 65%, RCY = 67%

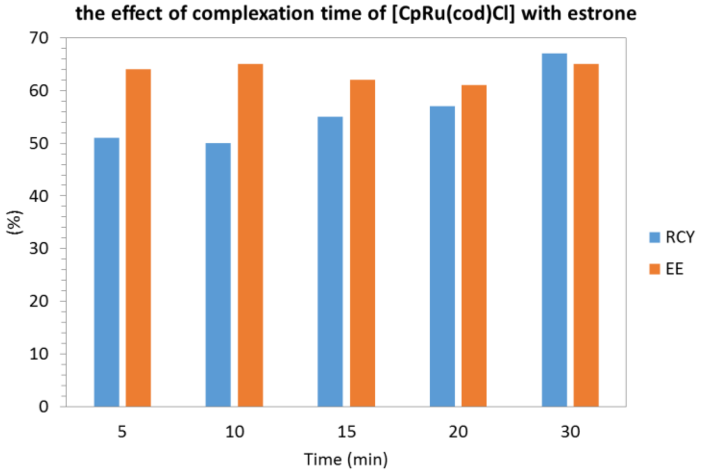
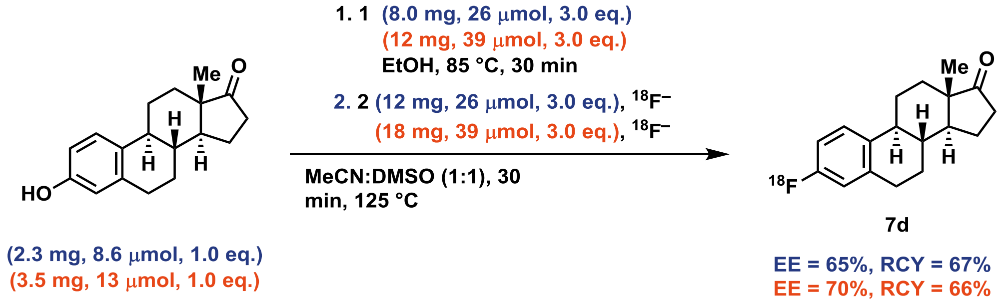


Figure S1. The effect of time on the complexation of [CpRu(cod)Cl] (**1**) complex with estrone on the [^{18}F]deoxyfluorination, RCY estimated by TLC.

Optimization of concentration: The influence of concentration was studied by increasing the mass of estrone, [CpRu(cod)Cl] (**1**) and imidazolium chloride **2** by a factor of 1.5 and keeping the amount of solvent constant. No significant changes were observed within the chosen range (Scheme S2).

Estrone (a: 2.3 mg, 8.7 μmol, 1.0 eq. or b: 3.5 mg, 13 μmol, 1.0 eq.) and [CpRu(cod)Cl] (**1**) (a: 8.0 mg, 2.6 μmol, 3.0 eq. or b: 12 mg, 39 μmol, 3.0 eq.) were added to EtOH (50 μL, a: c = 0.80 M and b: c = 1.2 M) in a 0.5 dram (1.8 mL) borosilicate glass vials. The vial was capped with a Teflon lined cap and the reaction mixture stirred at 85 °C (heating block temperature) for 30 min. The vial was allowed to stand for 3 min at 23 °C, then imidazolium chloride **2** (a: 14 mg, 26 μmol, 3.0 eq. and b: 18 mg, 39 μmol, 3.0 eq.) and 150 μL of MeCN were added, and the resulting solution was drawn into a 1.0 mL polypropylene syringe for elution of fluoride.

^{18}F-Fluoride solution from the cyclotron (approximately 7 mCi, 0.3 GBq) was loaded onto a QMA anion exchange cartridge (Chromafix 30-PS-HCO$_3$), and the trapped radioactivity was measured (a: 16.2 mCi, 599 MBq; b: 4.5 mCi, 0.17 GBq). The cartridge was washed with MeCN (1.0 mL), inverted and fitted with two female × female Luer adapters. With the solution of estrone-ruthenium complex and **2**, the ^{18}F-fluoride was eluted into a dram (3.7 mL) borosilicate vial. The cartridge was washed with DMSO (150 µL), followed by DMSO:MeCN (50 µL, 1:1 (v/v)) and the radioactivity of the eluted solution was measured (a: 10.6 mCi, 392 MBq; b: 3.1 mCi, 0.12 GBq). The reaction vial, which contained 400 µL of the reaction mixture, was sealed with a teflon-lined cap and heated at 125 °C for 30 min, and then allowed to stand for 3 min at 23 °C. The reaction mixture was analyzed by radio-HPLC and radio-TLC. The product **7d** was characterized by comparing the radio-HPLC trace of the reaction mixture with the HPLC UV trace of the authentic reference sample.



7d

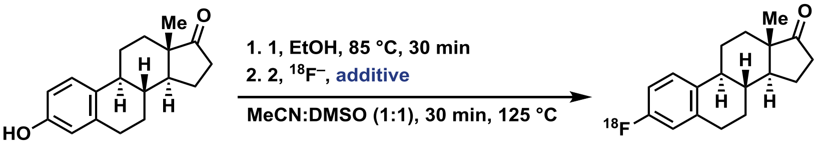
Scheme S2. The effect of increasing mass by a factor of 1.5 at constant volume on the [^{18}F]deoxyfluorination of estrone as a phenol. RCY estimated by TLC.

Effect of additives: The additives were separately added prior to ^{18}F-flouride elution from the cartridge. We found that Bu_4NHSO_4, Bu_4NOTf, Bu_4NNO_3 and NEt_4HCO_3 increase the elution officiency. However, the gain was offset by a decrease in radiochemical yield. (Scheme S3)

Estrone (2.3 mg, 8.7 µmol, 1.0 eq.) and [CpRu(cod)Cl] (**1**) (8.0 mg, 26 µmol, 3.0 eq.) were added to EtOH (50 µL, c = 0.80 M) in a 0.5 dram (1.8 mL) borosilicate glass vial. The vial was capped, and the reaction mixture was stirred at 85 °C (heating block temperature) for 30 min and then allowed to stand for 3 min at 23 °C. To the vial, imidazolium chloride **2** (14 mg, 26 µmol, 3.0 eq.), additives (a: no additive; b: Bu_4NHSO_4 (14 mg, 42 µmol, 5.0 eq.); c: Bu_4NOTf (16 mg, 42 µmol, 5.0 eq.); d: Bu_4NNO_3 (13 mg, 42 µmol, 5.0 eq.) and e: Et_4NHCO_3 (10 mg, 42 µmol, 5.0 eq.)) and 150 µL of MeCN were added, and the resulting solution was drawn into a 1.0 mL polypropylene syringe for elution of fluoride.

^{18}F-fluoride solution from the cyclotron was loaded onto a QMA anion exchange cartridge (Chromafix 30-PS-HCO_3), and the trapped radioactivity was measured (a: 5.1 mCi, 0.19 GBq; b: 7.4 mCi, 0.27 GBq; c: 7.3 mCi, 0.27 GBq; d: 5.8 mCi, 0.22 GBq; e: 7.8 mCi, 0.29 GBq). The cartridge was washed with MeCN (1.0 mL). The cartridge was inverted and fitted with a female × female Luer adapter. With the syringes containing the solution of estrone-ruthenium complex, additives and 2, the ^{18}F-fluoride was eluted into a 1 dram (3.7 mL) borosilicate vials. The cartridge was washed with DMSO (150 µL), followed by DMSO:MeCN (50 µL, 1:1

(v/v)) and the radioactivity of the eluted solution was measured (a: 3.5 mCi, 0.13 GBq; b: 5.0 mCi, 0.19 GBq; c: 5.9 mCi, 0.22 GBq; d: 4.6 mCi, 0.17 GBq; e: 7.0 mCi, 0.26 GBq). The reaction vial, which contained 400 μL of the reaction mixture, was sealed with a teflon-lined cap and heated at 125 °C for 30 min, then allowed to stand for 3 min at 23 °C. The reaction mixture was analyzed by radio-HPLC and radio-TLC. The product **7d** was characterized by comparing the radio-HPLC trace of the reaction mixture with the HPLC UV trace of the authentic reference sample.



7d

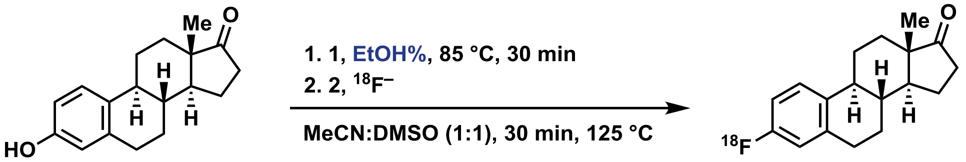
additive:
a: no additive (EE = 70%), RCY = 74%, EE × RCY = 52%
b: Bu_4NHSO_4 (EE = 70%), RCY = 52%, EE × RCY = 36%
c: Bu_4NOTf (EE = 80%), RCY = 47%, EE × RCY = 38%
d: Bu_4NNO_3 (EE = 79%), RCY = 44%, EE × RCY = 35%
e: Et_4NHCO_3 (EE = 90%), RCY = <5%, EE × RCY = 05%

Scheme S3. The effect of additive salts on the efficiency of [^{18}F]deoxyfluorination of estrone as a phenol. RCY estimated by TLC.

Optimization of ethanol content: Ruthenium-phenol complex formation with [CpRu(cod)Cl] (**1**) was carried out in EtOH. We found the presence of EtOH also significantly increases the elution efficiency of ^{18}F-fluoride. Therefore, we decided to investigate the effect of EtOH content in the reaction mixture on the radiochemical yield.

The overall TLC yields for EtOH = 0–30% are in the same range (EE × RCY = 20–30%) and above EtOH% = 30%, EtOH dramatically lowers the overall yield. (Figure S2)

For all reactions except 0% EtOH, the elution was performed with only EtOH (but different volumes depending on EtOH percentage), and the remaining solvent (DMSO:MeCN 1:1) added after the elution; For the first entry in the chart (0% EtOH), after the complexation step, EtOH was evaporated and exchanged with MeCN:DMSO (1:1).



7d

see the following chart for EE and RCY

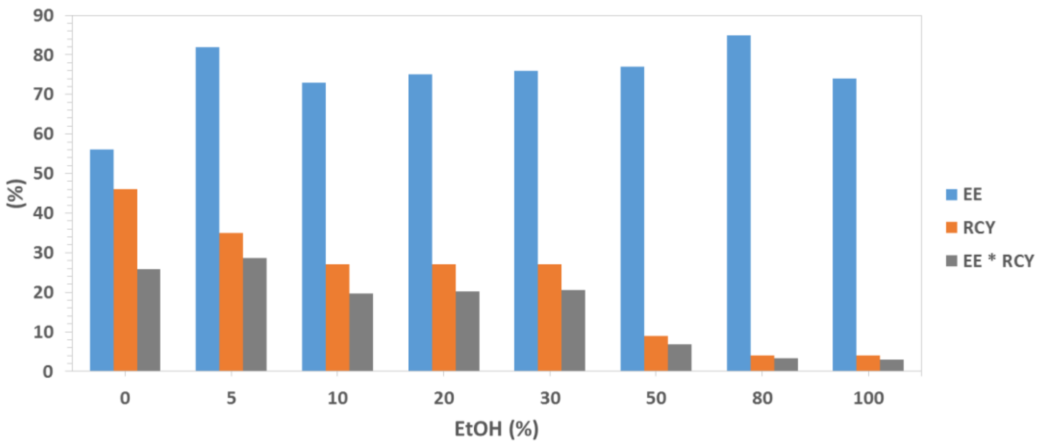


Figure S2. Effect of EtOH on the EE, RCY and the estimated overall yield (EE × RCY) on the [^{18}F]deoxyfluorination of estrone as a phenol.

For comparability, the volume of the reaction mixtures mentioned in Figure S2 were kept all constant (2 ml) to optimize the ethanol content. However, a reduction of volume from 2 mL to 400 µL, the overall yield from ca. 25% was increased to ca. 45% for the reaction without ethanol. (Figure S3) As extremely low amounts (<50 µL) of ethanol make the elution practically challenging, we reduced our overall volume to 400 µL with 12.5% EtOH.

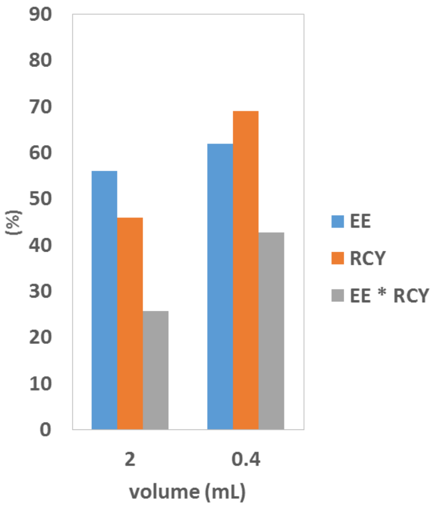
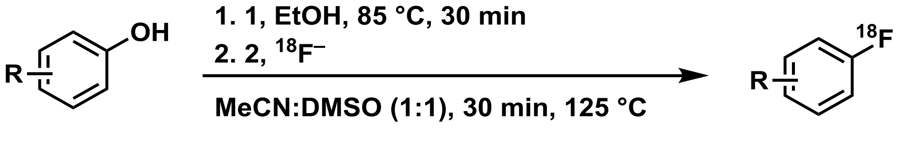


Figure S3. The effect of reaction volume on the reactions occurring in MeCN:DMSO (1:1) (0% EtOH) on the [^{18}F]deoxyfluorination of estrone as a phenol. The left is for the reaction in a total volume of 2 mL and the right is the reaction for a total volume of 400 µL.

General procedure for [^{18}F]deoxyfluorination of phenols



4, 7a–7p

A phenol (8.7 µmol, 1.0 eq.) and [CpRu(cod)Cl] (**1**) (8.0 mg, 26 µmol, 3.0 eq.) were added to EtOH (50 µL, c = 0.80 M) in a 0.5 dram (1.8 mL) borosilicate glass vial. The vial was capped, and the reaction mixture was stirred at 85 °C for 30 min. The vial was removed from the heating block and allowed to stand for 3 min at 23 °C. To the vial, imidazolium chloride **2** (12 mg, 26 µmol, 3.0 eq.) and 150 µL of MeCN were added, and the resulting solution was drawn into a 1.0 mL polypropylene syringe.

Target water from the cyclotron containing ^{18}F-fluoride (typically 50 uL) was loaded with a syringe onto a QMA anion exchange cartridge (Chromafix 30-PS-HCO$_3$) and the radioactivity of the trapped ^{18}F-fluoride was measured (Table S1). The cartridge was washed with MeCN (1.0 mL). The cartridge was inverted and fitted with a female × female Luer adapter. With the syringe, which contained the corresponding solution of phenol-ruthenium complex and **2**, the ^{18}F-fluoride was eluted into a 1 dram (3.7 mL) borosilicate vial. The cartridge was washed with DMSO (150 µL), followed by DMSO:MeCN (50 µL, 1:1 (v/v)) and the radioactivity of the eluted solution was measured (Table S1). The reaction vial, which contained 400 µL of the reaction mixture was sealed with a teflon-lined cap and was heated at 125 °C for 30 min. The vial, which contained the reaction mixture was removed from the heat and was allowed to stand for 3 min at 23 °C. The reaction mixture was analyzed by radio-HPLC and radio-TLC. The products were characterized by comparing the radio-HPLC trace of the reaction mixtures with the HPLC UV traces of the authentic reference samples, respectively.

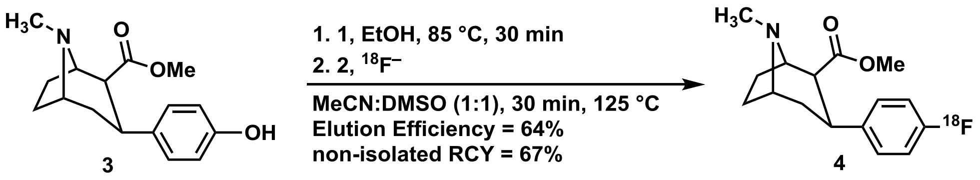
All ^{18}F-labeled molecules were characterized by comparing the retention time of the product (γ-trace) to the retention time of an authentic reference sample. Note: radioactivity chromatographs are offset by 0.15 min on account of the delay introduced by the spatial separation between the diode array detector and the radioactivity detector.

Table S1. The amounts of initial radioactivity trapped, the amount eluted, and the RCYs of [^{18}F]deoxyfluorination of phenols, estimated by TLC.

Entry	Product	Initial radioactivity (mCi, GBq)	Eluted radioavtivity (mCi, GBq)	Elution efficiency (%)	RCY (%)
1	**4**	8.0, 0.30	5.1, 0.19	64	67

2	**7a**	7.5, 0.28	4.9, 0.18	66	89
3	**7b**	5.9, 0.22	4.4, 0.16	75	85
4	**7c**	5.2, 0.19	3.3, 0.12	63	99
5	**7d**	6.2, 0.23	4.6, 0.17	73	88
6	**7e**	4.2, 0.16	3.0, 0.11	71	30
7	**7f**	4.3, 0.16	2.7, 0.10	64	82
8	**7g**	6.9, 0.26	4.0, 0.15	58	10
9	**7h**	5.9, 0.22	3.9, 0.14	66	98
10	**7i**	5.6, 0.21	3.1, 0.12	55	99
11	**7j**	7.2, 0.27	4.8, 0.18	67	99
12	**7k**	6.0, 0.22	4.6, 0.17	77	85
13	**7l**	6.5, 0.24	3.5, 0.13	54	80
14	**7m**	5.1, 0.20	3.5, 0.13	67	43
15	**7n**	7.3, 0.27	4.6, 0.17	62	99
16	**7o**	10.7, 0.40	6.8, 0.25	64	88
17	**7p**	6.0, 0.22	3.0, 0.11	49	62

$[^{18}F]$-β-CFT (4)



Phenol **3** (3.9 mg, 8.7 µmol, 1.0 eq.) and [CpRu(cod)Cl] (**1**) (8.0 mg, 26 µmol, 3.0 eq.) were added to EtOH (50 µL, c = 0.80 M) in a 0.5 dram (1.8 mL) borosilicate glass vial. The vial was capped, and the reaction mixture was stirred at 85 °C (heating block temperature) for 30 min. The vial was removed from the heating block and allowed to stand for 3 min at 23 °C. To the vial, imidazolium chloride **2** (14 mg, 26 µmol, 3.0 eq.) and 150 µL of MeCN were added, and the resulting solution was drawn into a 1.0 mL polypropylene syringe.

Target water from the cyclotron containing ^{18}F-fluoride was loaded with a syringe onto a QMA anion exchange cartridge (Chromafix 30-PS-HCO_3) and the radioactivity of the trapped ^{18}F-fluoride was measured (8.0 mCi, 0.30 GBq). The cartridge was washed with MeCN (1.0 mL). The cartridge was inverted and fitted with a female × female Luer adapter. With the syringe, which contained the corresponding solution of **3**-ruthenium complex and **2**, the ^{18}F-fluoride was eluted into a 1 dram (3.7 mL) borosilicate vial. The cartridge was washed with DMSO (150 µL), followed by DMSO:MeCN (50 µL, 1:1 (v/v)) and the radioactivity of the eluted solution was measured (5.1 mCi, 0.19 GBq). The reaction vial, which contained 400 µL of the reaction mixture was sealed with a teflon-lined cap and was heated at 125 °C for 30 min. The vial, which contained the reaction mixture was removed from the heat and was allowed to stand for 3 min at 23 °C. The reaction mixture was analyzed by radio-HPLC and radio-TLC. The product [^{18}F]-β-CFT (**4**) was characterized by comparing the radio-HPLC trace of the reaction mixture with the HPLC UV traces of the authentic reference sample. The authentic reference (β-CFT) (5 mg) was purchased from Sigma-Aldrich as β-CFT naphthalenedisulfonate monohydrate and then the naphthalenedisulfonate was removed from the sample using 5 coupled Sep-Pak Plus C18 Environmental Cartriges (WAT036800) from Waters connected in series. The sample was loaded onto the C18 cartridges, and a HPLC pump was used for elution with the following mobile phases: 0.1% formic acid in water (A), 0.1% formic acid in acetonitrile (B). Program: starting from 5% (B) to 95% (B) as a gradient over 12 min with flow rate 4.0 mL/min.

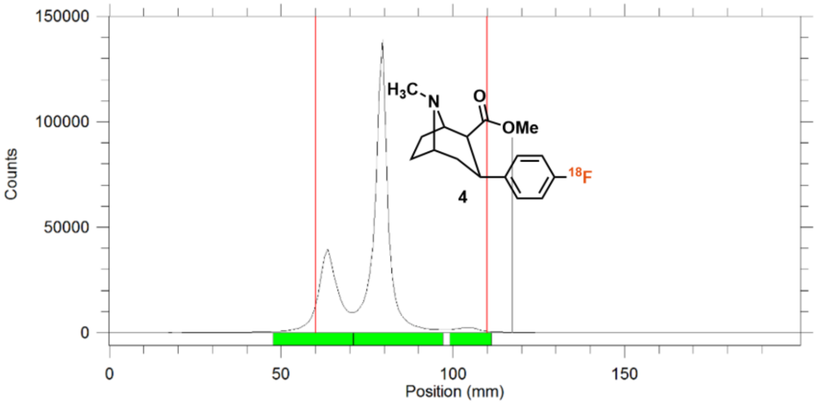


Figure S4. Radio-TLC trace of the [^{18}F]deoxyfluorination reaction of **3** yielding **4**.

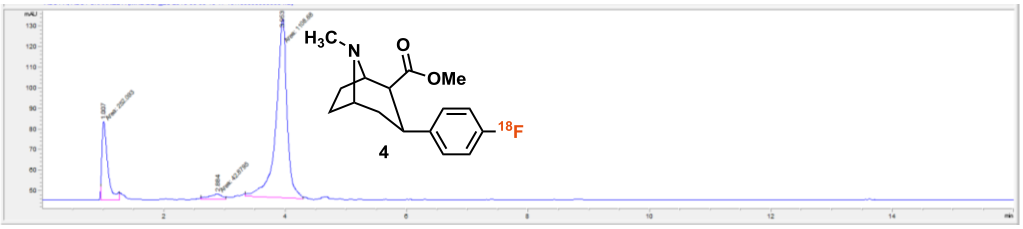


Figure S5. Radio-HPLC trace of the [^{18}F]deoxyfluorination reaction of **3** yielding **4**.

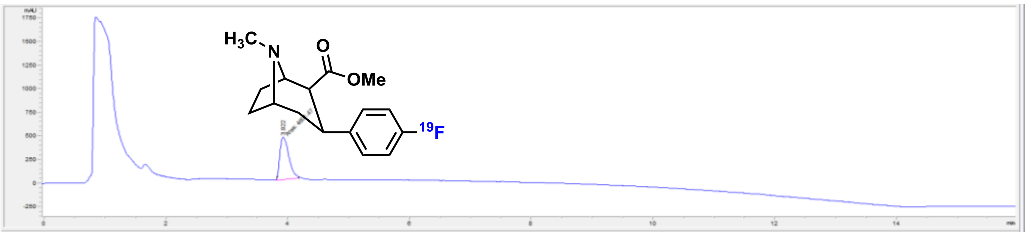
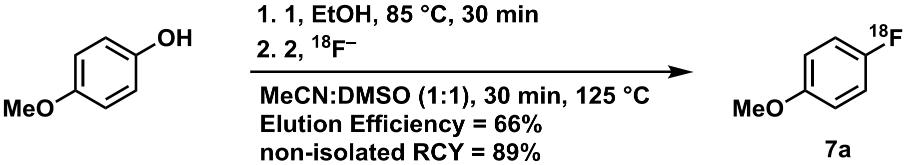


Figure S6. UV-HPLC trace of β-CFT as the reference.

[^{18}F]1-(Fluoro)-4-methoxybenzene (7a)



4-Methoxyphenol (1.1 mg, 8.7 µmol, 1.0 eq.) and [CpRu(cod)Cl] (**1**) (8.0 mg, 26 µmol, 3.0 eq.) were added to EtOH (50 µL, c = 0.80 M) in a 0.5 dram (1.8 mL) borosilicate glass vial. The vial was capped, and the reaction mixture was stirred at 85 °C (heating block temperature) for 30 min. The vial was removed from the heating block and allowed to stand for 3 min at 23 °C. To the vial, imidazolium chloride **2** (14 mg, 26 µmol, 3.0 eq.) and 150 µL of MeCN were added, and the resulting solution was drawn into a 1.0 mL polypropylene syringe.

Target water from the cyclotron containing ^{18}F-fluoride was loaded with a syringe onto a QMA anion exchange cartridge (Chromafix 30-PS-HCO_3) and the radioactivity of the trapped ^{18}F-fluoride was measured (7.5 mCi, 0.28 GBq). The cartridge was washed with MeCN (1.0 mL). The cartridge was inverted and fitted with a female × female Luer adapter. With the syringe, which contained the corresponding solution of 4-methoxyphenol-ruthenium complex and **2**, the ^{18}F-fluoride was eluted into a 1 dram (3.7 mL) borosilicate vial. The cartridge was washed with DMSO (150 µL), followed by DMSO:MeCN (50 µL, 1:1 (v/v)) and the radioactivity of the eluted solution was measured (4.9 mCi, 0.18 GBq). The reaction vial, which contained 400 µL of the reaction mixture was sealed with a teflon-lined cap and was heated at 125 °C for 30 min. The vial, which contained the reaction mixture was removed from the heat and was allowed to stand for 3 min at 23 °C. The reaction mixture was analyzed by radio-HPLC and radio-TLC. The product **7a** was characterized by comparing the radio-HPLC trace of the reaction mixture with the HPLC UV traces of the authentic reference sample.

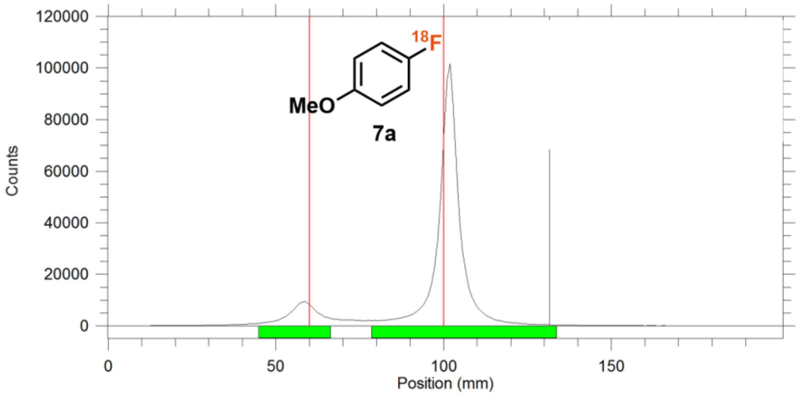


Figure S7. Radio-TLC trace of the [^{18}F]deoxyfluorination reaction of 4-methoxyphenol yielding **7a**.

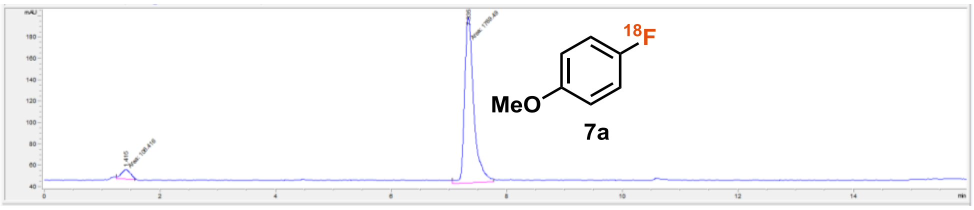


Figure S8. Radio-HPLC trace of the [^{18}F]deoxyfluorination reaction of 4-methoxyphenol yielding **7a**.

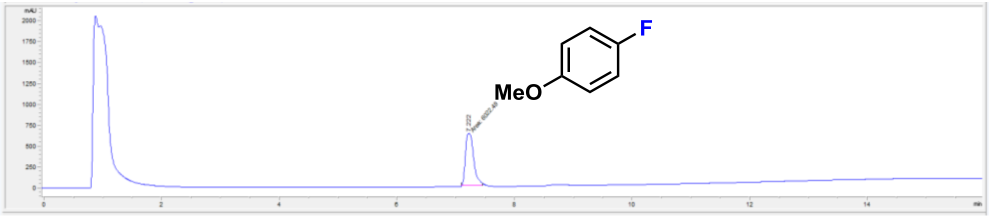
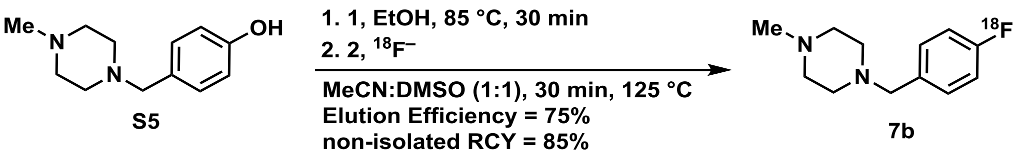


Figure S9. UV-HPLC trace of 1-fluoro-4-methoxybenzene as the reference.

[^{18}F]Benzylpiperazin 7b



Phenol **S5** (1.7 mg, 8.7 µmol, 1.0 eq.) and [CpRu(cod)Cl] (**1**) (8.0 mg, 26 µmol, 3.0 eq.) were added to EtOH (50 µL, c = 0.80 M) in a 0.5 dram (1.8 mL) borosilicate glass vial. The vial was capped, and the reaction mixture was stirred at 85 °C (heating block temperature) for 30 min. The vial was removed from the heating block and allowed to stand for 3 min at 23 °C. To the vial, imidazolium chloride **2** (14 mg, 26 μmol, 3.0 eq.) and 150 μL of MeCN were added, and the resulting solution was drawn into a 1.0 mL polypropylene syringe.

Target water from the cyclotron containing ^{18}F-fluoride was loaded with a syringe onto a QMA anion exchange cartridge (Chromafix 30-PS-HCO$_3$) and the radioactivity of the trapped ^{18}F-fluoride was measured (5.9 mCi, 0.22 GBq). The cartridge was washed with MeCN (1.0 mL). The cartridge was inverted and fitted with a female × female Luer adapter. With the syringe, which contained the corresponding solution of **S5**-ruthenium complex and **2**, the ^{18}F-fluoride was eluted into a 1 dram (3.7 mL) borosilicate vial. The cartridge was washed with DMSO (150 μL), followed by DMSO:MeCN (50 μL, 1:1 (v/v)) and the radioactivity of the eluted solution was measured (4.4 mCi, 0.16 GBq). The reaction vial, which contained 400 μL of the reaction mixture was sealed with a teflon-lined cap and was heated at 125 °C for 30 min. The vial, which contained the reaction mixture was removed from the heat and was allowed to stand for 3 min at 23 °C. The reaction mixture was analyzed by radio-HPLC and radio-TLC. The product **7b** was characterized by comparing the radio-HPLC trace of the reaction mixture with the HPLC UV traces of the authentic reference sample.

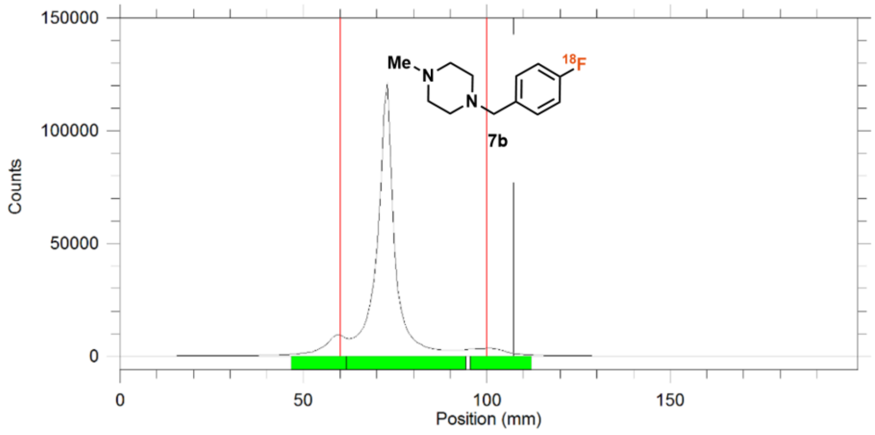


Figure S10. Radio-TLC trace of the [^{18}F]deoxyfluorination reaction of **S5** yielding **7b**.

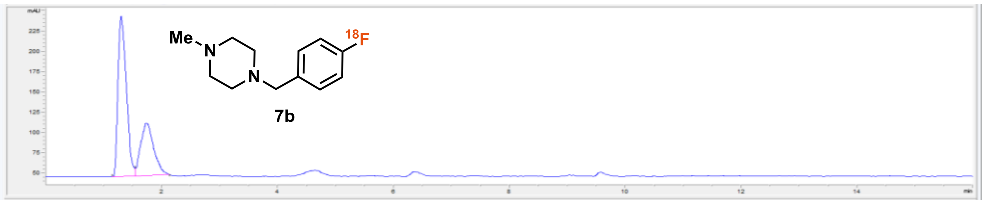


Figure S11. Radio-HPLC trace of the [^{18}F]deoxyfluorination reaction of **S5** yielding **7b**.

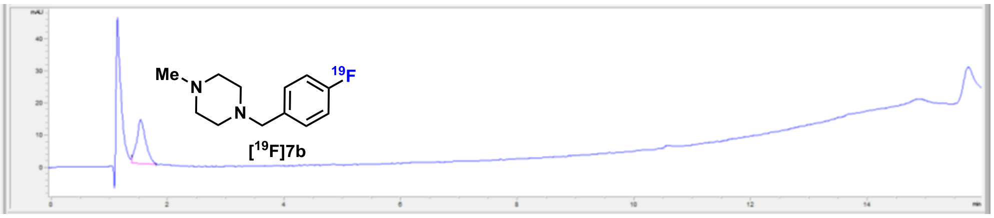
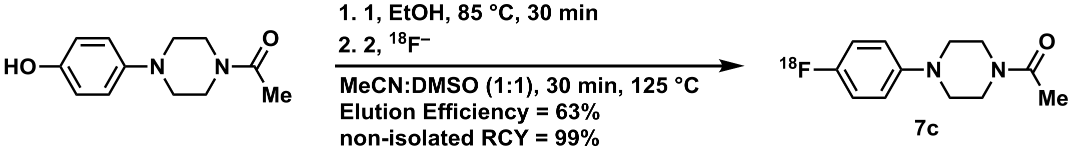


Figure S12. UV-HPLC trace of **[^{19}F]7b** as the reference.

[^{18}F]Piperazin 7c



1-(4-(4-Hydroxyphenyl)piperazin-1-yl)ethan-1-one (1.9 mg, 8.7 µmol, 1.0 eq.) and [CpRu(cod)Cl] (**1**) (8.0 mg, 26 µmol, 3.0 eq.) were added to EtOH (50 µL, c = 0.80 M) in a 0.5 dram (1.8 mL) borosilicate glass vial. The vial was capped, and the reaction mixture was stirred at 85 °C (heating block temperature) for 30 min. The vial was removed from the heating block and allowed to stand for 3 min at 23 °C. To the vial, imidazolium chloride **2** (14 mg, 26 µmol, 3.0 eq.) and 150 µL of MeCN were added, and the resulting solution was drawn into a 1.0 mL polypropylene syringe.

Target water from the cyclotron containing ^{18}F-fluoride was loaded with a syringe onto a QMA anion exchange cartridge (Chromafix 30-PS-HCO$_3$) and the radioactivity of the trapped ^{18}F-fluoride was measured (5.2 mCi, 0.19 GBq). The cartridge was washed with MeCN (1.0 mL). The cartridge was inverted and fitted with a female × female Luer adapter. With the syringe, which contained the corresponding solution of 1-(4-(4-hydroxyphenyl)piperazin-1-yl)ethan-1-one-ruthenium complex and **2**, the ^{18}F-fluoride was eluted into a 1 dram (3.7 mL) borosilicate vial. The cartridge was washed with DMSO (150 µL), followed by DMSO:MeCN (50 µL, 1:1 (v/v)) and the radioactivity of the eluted solution was measured (3.3 mCi, 0.12 GBq). The reaction vial, which contained 400 µL of the reaction mixture was sealed with a teflon-lined cap and was heated at 125 °C for 30 min. The vial, which contained the reaction mixture was removed from the heat and was allowed to stand for 3 min at 23 °C. The reaction mixture was analyzed by radio-HPLC and radio-TLC. The product **7c** was characterized by comparing the radio-HPLC trace of the reaction mixture with the HPLC UV traces of the authentic reference sample.

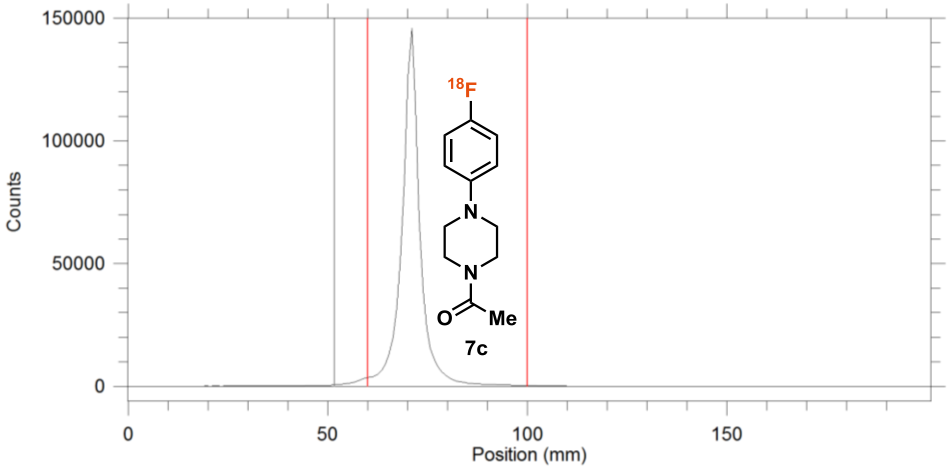


Figure S13. Radio-TLC trace of the [^{18}F]deoxyfluorination reaction of 1-(4-(4-hydroxyphenyl)piperazin-1-yl)ethan-1-one yielding **7c**.

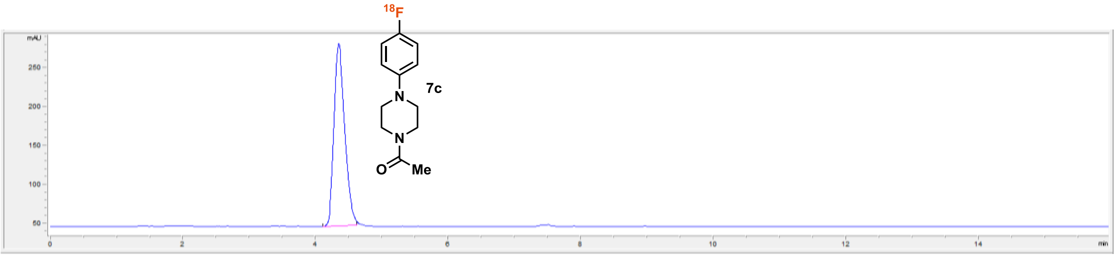


Figure S14. Radio-HPLC trace of the [^{18}F]deoxyfluorination reaction of 1-(4-(4-hydroxyphenyl)piperazin-1-yl)ethan-1-one yielding **7c**.

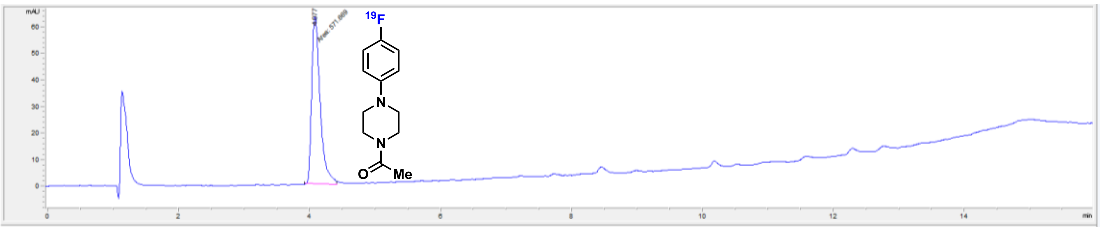
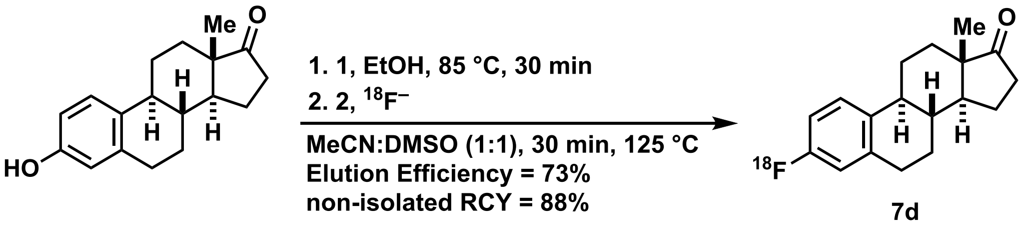


Figure S15. UV-HPLC trace of 1-(4-(4-fluorophenyl)piperazin-1-yl)ethan-1-one as the reference.

[^{18}F]Estrone 7d



Estrone (2.3 mg, 8.7 µmol, 1.0 eq.) and [CpRu(cod)Cl] (**1**) (8.0 mg, 26 µmol, 3.0 eq.) were added to EtOH (50 µL, c = 0.80 M) in a 0.5 dram (1.8 mL) borosilicate glass vial. The vial was capped, and the reaction mixture was stirred at 85 °C (heating block temperature) for 30 min. The vial was removed from the heating block and allowed to stand for 3 min at 23 °C. To the vial, imidazolium chloride **2** (14 mg, 26 µmol, 3.0 eq.) and 150 µL of MeCN were added, and the resulting solution was drawn into a 1.0 mL polypropylene syringe.

Target water from the cyclotron containing ^{18}F-fluoride was loaded with a syringe onto a QMA anion exchange cartridge (Chromafix 30-PS-HCO$_3$) and the radioactivity of the trapped ^{18}F-fluoride was measured (6.2 mCi, 0.23 GBq). The cartridge was washed with MeCN (1.0 mL). The cartridge was inverted and fitted with a female × female Luer adapter. With the syringe, which contained the corresponding solution of estrone-ruthenium complex and **2**, the ^{18}F-fluoride was eluted into a 1 dram (3.7 mL) borosilicate vial. The cartridge was washed with DMSO (150 µL), followed by DMSO:MeCN (50 µL, 1:1 (v/v)) and the radioactivity of the eluted solution was measured (4.6 mCi, 0.17 GBq). The reaction vial, which contained 400 µL of the reaction mixture was sealed with a teflon-lined cap and was heated at 125 °C for 30 min. The vial, which contained the reaction mixture was removed from the heat and was allowed to stand for 3 min at 23 °C. The reaction mixture was analyzed by radio-HPLC and radio-TLC. The product **7d** was characterized by comparing the radio-HPLC trace of the reaction mixture with the HPLC UV traces of the authentic reference sample.

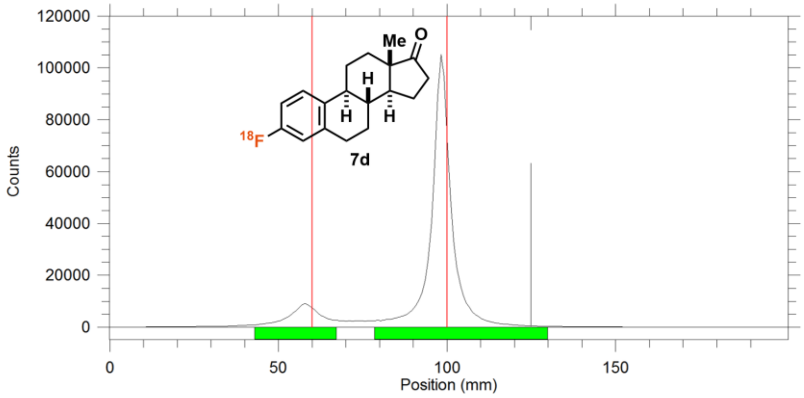


Figure S16. Radio-TLC trace of the [^{18}F]deoxyfluorination reaction of estrone yielding **7d**.

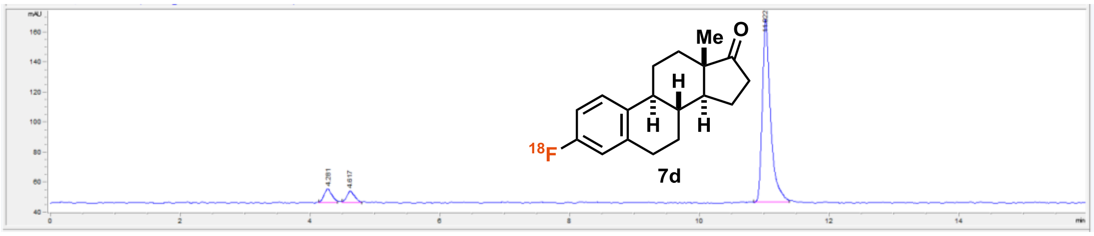


Figure S17. Radio-HPLC trace of the [^{18}F]deoxyfluorination reaction of estrone yielding **7d**.

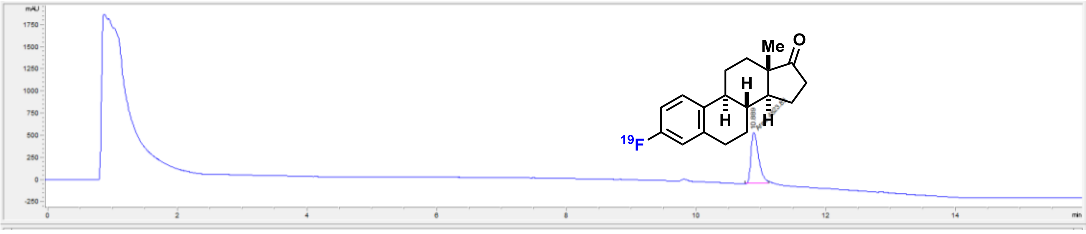
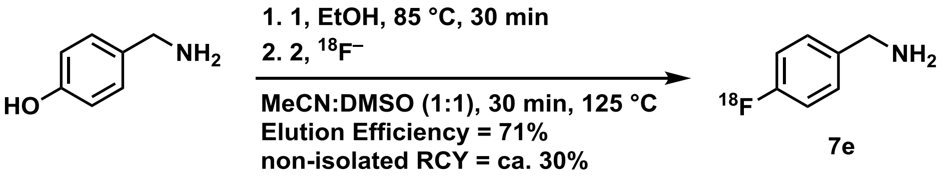


Figure S18. UV-HPLC trace of deoxyfluorinated estrone as the reference.

[^{18}F](4-(Fluoro)phenyl)methanamine (7e)



7e

4-(Aminomethyl)phenol (1.1 mg, 8.7 µmol, 1.0 eq.) and [CpRu(cod)Cl] (**1**) (8.0 mg, 26 µmol, 3.0 eq.) were added to EtOH (50 µL, c = 0.80 M) in a 0.5 dram (1.8 mL) borosilicate glass vial. The vial was capped, and the reaction mixture was stirred at 85 °C (heating block temperature) for 30 min. The vial was removed from the heating block and allowed to stand for 3 min at 23 °C. To the vial, imidazolium chloride **2** (14 mg, 26 µmol, 3.0 eq.) and 150 µL of MeCN were added, and the resulting solution was drawn into a 1.0 mL polypropylene syringe.

Target water from the cyclotron containing ^{18}F-fluoride was loaded with a syringe onto a QMA anion exchange cartridge (Chromafix 30-PS-HCO$_3$) and the radioactivity of the trapped ^{18}F-fluoride was measured (4.2 mCi, 0.16 GBq). The cartridge was washed with MeCN (1.0 mL). The cartridge was inverted and fitted with a female × female Luer adapter. With the syringe, which contained the corresponding solution of 4-(aminomethyl)phenol-ruthenium complex and **2**, the ^{18}F-fluoride was eluted into a 1 dram (3.7 mL) borosilicate vial. The cartridge was washed with DMSO (150 µL), followed by DMSO:MeCN (50 µL, 1:1 (v/v)) and the radioactivity of the eluted solution was measured (3.0 mCi, 0.11 GBq). The reaction vial, which contained 400 µL of the reaction mixture was sealed with a teflon-lined cap and was heated at 125 °C for 30 min. The vial, which contained the reaction mixture was removed from the heat and was allowed to stand for 3 min at 23 °C. The reaction mixture was analyzed by radio-HPLC and radio-TLC. The product **7e** was characterized by comparing the radio-HPLC trace of the reaction mixture with the HPLC UV traces of the authentic reference sample.

Note: Lewis basic compounds, such as amines, can form unproductive ruthenium coordination compounds. These are typically visible by HPLC as broad peaks within the first minutes after the solvent front. We attribute the relatively low yield of **7e** to the formation of such compounds and consequently suggest protection of primary amines, despite fundamental compatibility with the reaction

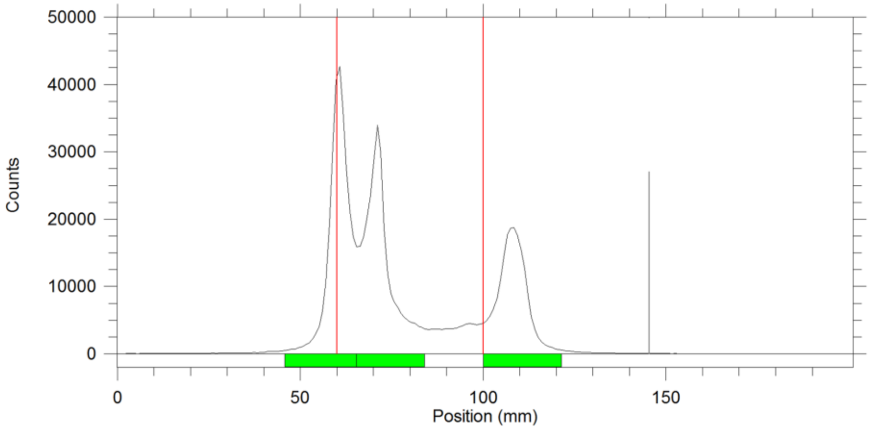


Figure S19. Radio-TLC trace of the [^{18}F]deoxyfluorination reaction of 4-(aminomethyl)phenol yielding **7e**.

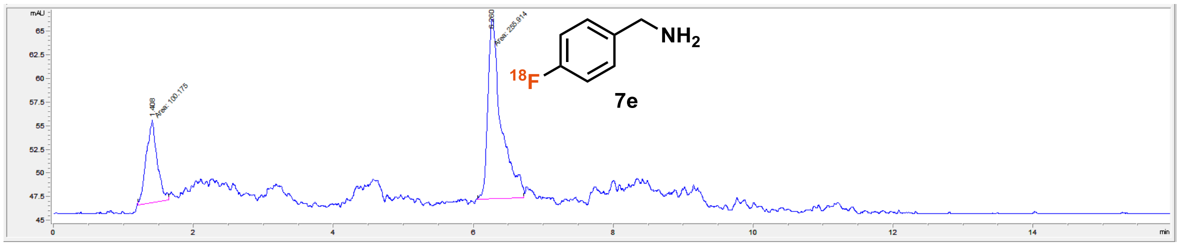


Figure S20. Radio-HPLC trace of the [^{18}F]deoxyfluorination reaction of 4-(aminomethyl)phenol yielding **7e**.

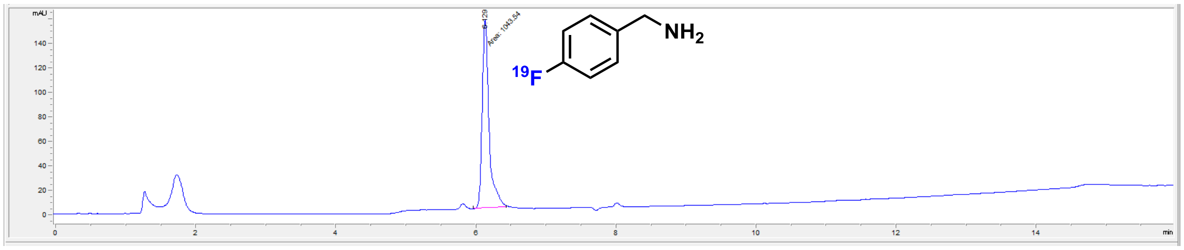
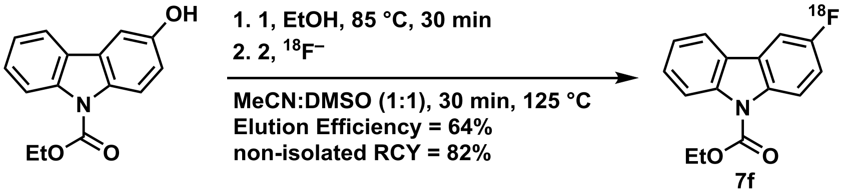


Figure S21. UV-HPLC trace of (4-fluorophenyl)methanamine as the reference.

[^{18}F]Ethyl 3-(fluoro)-9*H*-carbazole-9-carboxylate (7f)



Ethyl 3-hydroxy-9*H*-carbazole-9-carboxylate (2.2 mg, 8.7 µmol, 1.0 eq.) and [CpRu(cod)Cl] (**1**) (8.0 mg, 26 µmol, 3.0 eq.) were added to EtOH (50 µL, c = 0.80 M) in a 0.5 dram (1.8 mL) borosilicate glass vial. The vial was capped, and the reaction mixture was stirred at 85 °C (heating block temperature) for 30 min. The vial was removed from the heating block and allowed to stand for 3 min at 23 °C. To the vial, imidazolium chloride **2** (14 mg, 26 µmol, 3.0 eq.) and 150 µL of MeCN were added, and the resulting solution was drawn into a 1.0 mL polypropylene syringe.

Target water from the cyclotron containing ^{18}F-fluoride was loaded with a syringe onto a QMA anion exchange cartridge (Chromafix 30-PS-HCO_3) and the radioactivity of the trapped ^{18}F-fluoride was measured (4.3 mCi, 0.16 GBq). The cartridge was washed with MeCN (1.0 mL). The cartridge was inverted and fitted with a female × female Luer adapter. With the syringe, which contained the corresponding solution of ethyl 3-hydroxy-9*H*-carbazole-9-carboxylate-ruthenium complex and **2**, the ^{18}F-fluoride was eluted into a 1 dram (3.7 mL) borosilicate vial. The cartridge was washed with DMSO (150 µL), followed by DMSO:MeCN (50 µL, 1:1 (v/v)) and the radioactivity of the eluted solution was measured (2.7 mCi, 0.10 GBq). The reaction vial, which contained 400 µL of the reaction mixture was sealed with a teflon-lined cap and was heated at 125 °C for 30 min. The vial, which contained the reaction mixture was removed from the heat and was allowed to stand for 3 min at 23 °C. The reaction mixture was analyzed by radio-HPLC and radio-TLC. The product **7f** was characterized by comparing the radio-HPLC trace of the reaction mixture with the HPLC UV traces of the authentic reference sample.

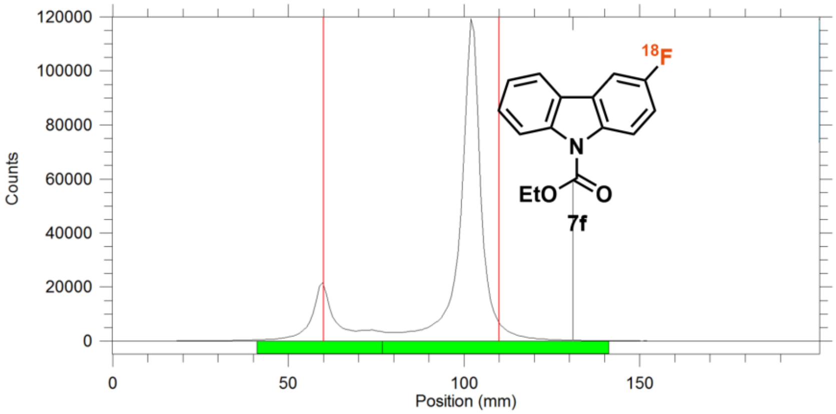


Figure S22. Radio-TLC trace of the [^{18}F]deoxyfluorination reaction of ethyl 3-hydroxy-9*H*-carbazole-9-carboxylate yielding **7f**.

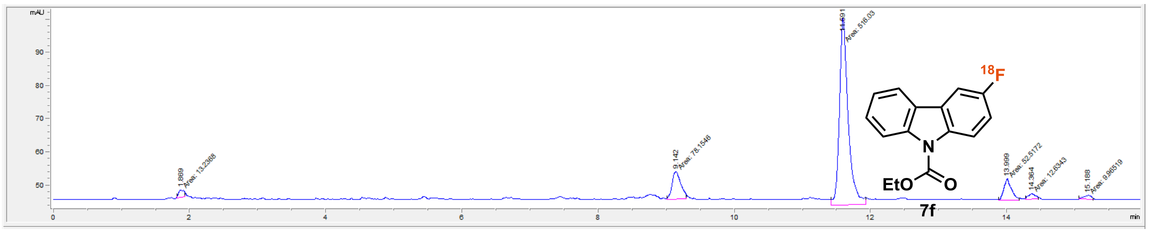


Figure S23. Radio-HPLC trace of the [^{18}F]deoxyfluorination reaction of ethyl 3-hydroxy-9*H*-carbazole-9-carboxylate yielding **7f**.

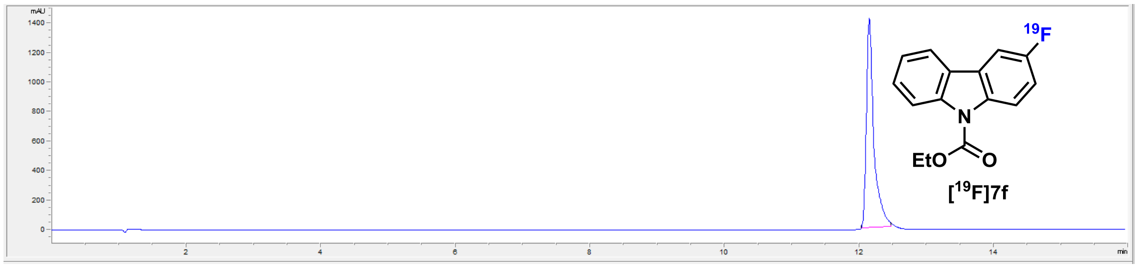
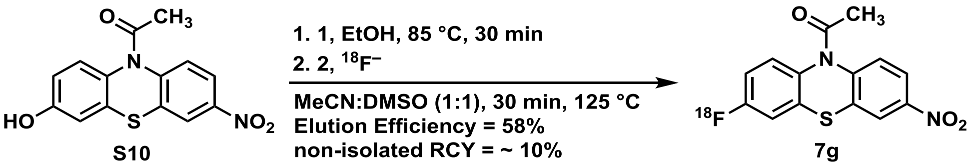


Figure S24. UV-HPLC trace of **[^{19}F]7f** as the reference.

[^{18}F]Phenothiazin 7g



Phenol **S10** (2.6 mg, 8.7 µmol, 1.0 eq.) and [CpRu(cod)Cl] (**1**) (8.0 mg, 26 µmol, 3.0 eq.) were added to EtOH (50 µL, c = 0.80 M) in a 0.5 dram (1.8 mL) borosilicate glass vial. The vial was capped, and the reaction mixture was stirred at 85 °C (heating block temperature) for 30 min. The vial was removed from the heating block and allowed to stand for 3 min at 23 °C. To the vial, imidazolium chloride **2** (14 mg, 26 µmol, 3.0 eq.) and 150 µL of MeCN were added, and the resulting solution was drawn into a 1.0 mL polypropylene syringe.

Target water from the cyclotron containing ^{18}F-fluoride was loaded with a syringe onto a QMA anion exchange cartridge (Chromafix 30-PS-HCO$_3$) and the radioactivity of the trapped ^{18}F-fluoride was measured (6.9 mCi, 0.26 GBq). The cartridge was washed with MeCN (1.0 mL). The cartridge was inverted and fitted with a female × female Luer adapter. With the syringe, which contained the corresponding solution of **S10**-ruthenium complex and **2**, the ^{18}F-fluoride was eluted into a 1 dram (3.7 mL) borosilicate vial. The cartridge was washed with DMSO (150 µL), followed by DMSO:MeCN (50 µL, 1:1 (v/v)) and the radioactivity of the eluted solution was measured (4.0 mCi, 0.15 GBq). The reaction vial, which contained 400 µL of the reaction mixture was sealed with a teflon-lined cap and was heated at 125 °C for 30 min. The vial, which contained the reaction mixture was removed from the heat and was allowed to stand for 3 min at 23 °C. The reaction mixture was analyzed by radio-HPLC and radio-TLC. The product **7g** was characterized by comparing the radio-HPLC trace of the reaction mixture with the HPLC UV traces of the authentic reference sample.

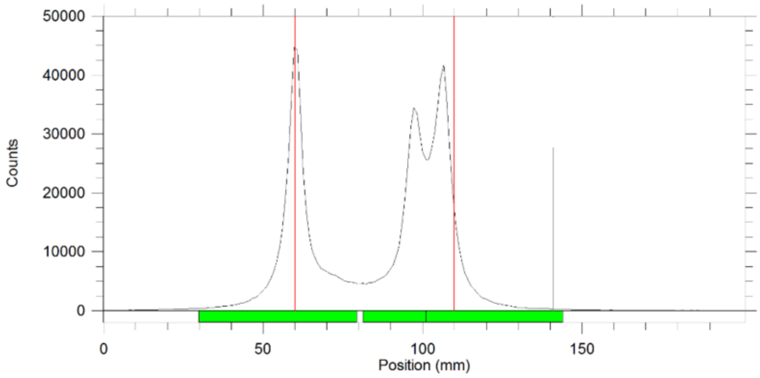


Figure S25. Radio-TLC trace of the [^{18}F]deoxyfluorination reaction of **S10** yielding **7g**.

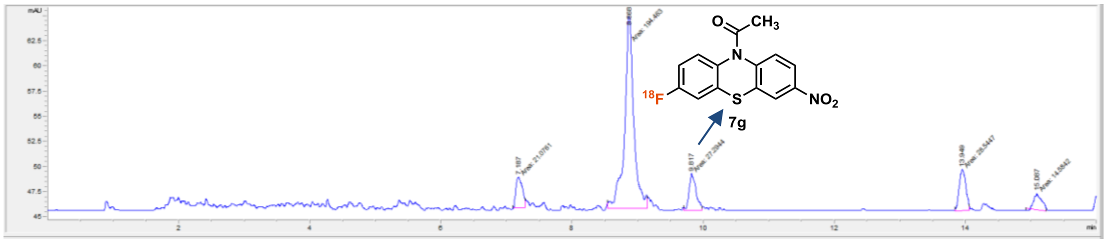


Figure S26. Radio-HPLC trace of the [^{18}F]deoxyfluorination reaction of **S10** yielding **7g**.

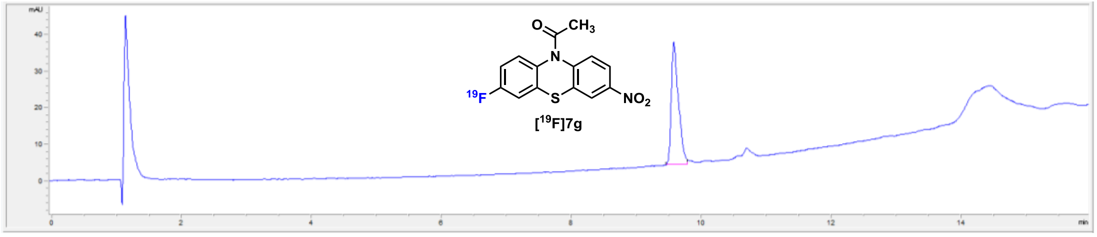
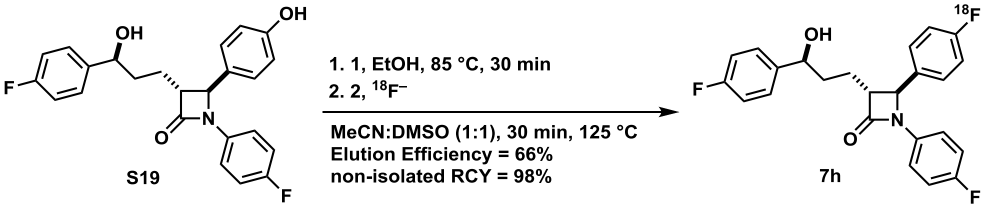


Figure S27. UV-HPLC trace of **[^{19}F]7g** as the reference.

[^{18}F]Fluorodeoxyezetimibe (7h)



Ezetimibe (**S19**) (3.5 mg, 8.7 µmol, 1.0 eq.) and [CpRu(cod)Cl] (**1**) (8.0 mg, 26 µmol, 3.0 eq.) were added to EtOH (50 µL, c = 0.80 M) in a 0.5 dram (1.8 mL) borosilicate glass vial. The vial was capped, and the reaction mixture was stirred at 85 °C (heating block temperature) for 30 min. The vial was removed from the heating block and allowed to stand for 3 min at 23 °C. To the vial, imidazolium chloride **2** (14 mg, 26 µmol, 3.0 eq.) and 150 µL of MeCN were added, and the resulting solution was drawn into a 1.0 mL polypropylene syringe.

Target water from the cyclotron containing ^{18}F-fluoride was loaded with a syringe onto a QMA anion exchange cartridge (Chromafix 30-PS-HCO_3) and the radioactivity of the trapped ^{18}F-fluoride was measured (5.9 mCi, 0.22 GBq). The cartridge was washed with MeCN (1.0 mL). The cartridge was inverted and fitted with a female × female Luer adapter. With the syringe, which contained the corresponding solution of **S19**-ruthenium complex and **2**, the ^{18}F-fluoride was eluted into a 1 dram (3.7 mL) borosilicate vial. The cartridge was washed with DMSO (150 µL), followed by DMSO:MeCN (50 µL, 1:1 (v/v)) and the radioactivity of the eluted solution was measured (3.9 mCi, 0.14 GBq). The reaction vial, which contained 400 µL of the reaction mixture was sealed with a teflon-lined cap and was heated at 125 °C for 30 min. The vial, which contained the reaction mixture was removed from the heat and was allowed to stand for 3 min at 23 °C. The reaction mixture was analyzed by radio-HPLC and radio-TLC. The product **7h** was characterized by comparing the radio-HPLC trace of the reaction mixture with the HPLC UV traces of the authentic reference sample.

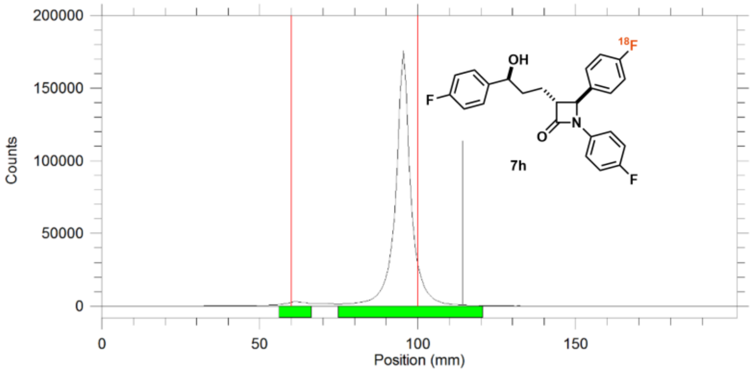


Figure S28. Radio-TLC trace of the [^{18}F]deoxyfluorination reaction of **S19** yielding **7h**.

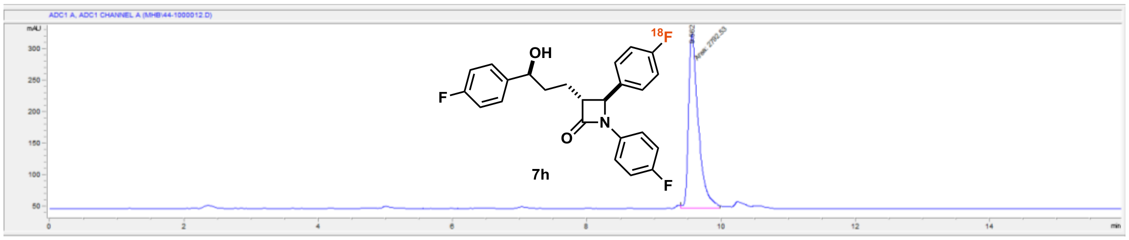


Figure S29. Radio-HPLC trace of the [^{18}F]deoxyfluorination reaction of **S19** yielding **7h**.

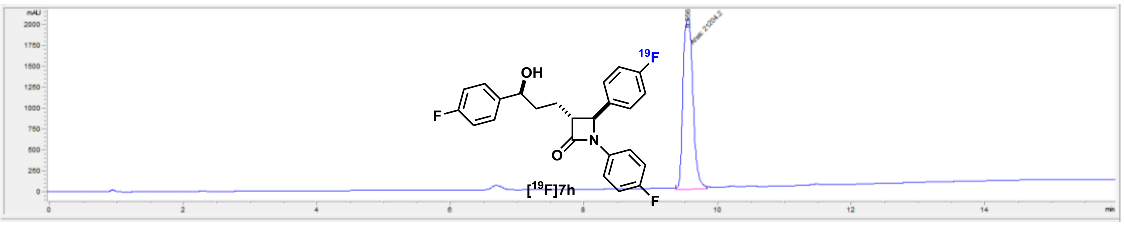
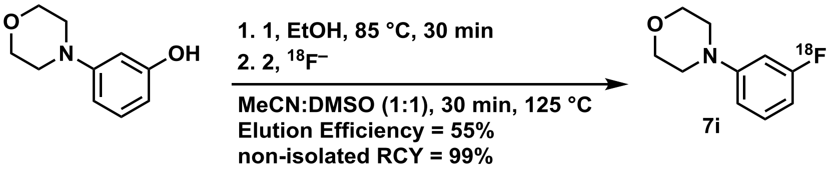


Figure S30. UV-HPLC trace of **[^{19}F]7h** as the reference.

[^{18}F](4-(3-(Fluoro)phenyl)morpholine) (7i)



3-Morpholinophenol (1.5 mg, 8.7 µmol, 1.0 eq.) and [CpRu(cod)Cl] (**1**) (8.0 mg, 26 µmol, 3.0 eq.) were added to EtOH (50 µL, c = 0.80 M) in a 0.5 dram (1.8 mL) borosilicate glass vial. The vial was capped, and the reaction mixture was stirred at 85 °C (heating block temperature) for 30 min. The vial was removed from the heating block and allowed to stand for 3 min at 23 °C. To the vial, imidazolium chloride **2** (14 mg, 26 µmol, 3.0 eq.) and 150 µL of MeCN were added, and the resulting solution was drawn into a 1.0 mL polypropylene syringe.

Target water from the cyclotron containing ^{18}F-fluoride was loaded with a syringe onto a QMA anion exchange cartridge (Chromafix 30-PS-HCO_3) and the radioactivity of the trapped ^{18}F-fluoride was measured (5.6 mCi, 0.21 GBq). The cartridge was washed with MeCN (1.0 mL). The cartridge was inverted and fitted with a female × female Luer adapter. With the syringe, which contained the corresponding solution of 3-morpholinophenol-ruthenium complex and **2**, the ^{18}F-fluoride was eluted into a 1 dram (3.7 mL) borosilicate vial. The cartridge was washed with DMSO (150 µL), followed by DMSO:MeCN (50 µL, 1:1 (v/v)) and the radioactivity of the eluted solution was measured (3.1 mCi, 0.12 GBq). The reaction vial, which contained 400 µL of the reaction mixture was sealed with a teflon-lined cap and was heated at 125 °C for 30 min. The vial, which contained the reaction mixture was removed from the heat and was allowed to stand for 3 min at 23 °C. The reaction mixture was analyzed by radio-HPLC and radio-TLC. The product **7i** was characterized by comparing the radio-HPLC trace of the reaction mixture with the HPLC UV traces of the authentic reference sample.

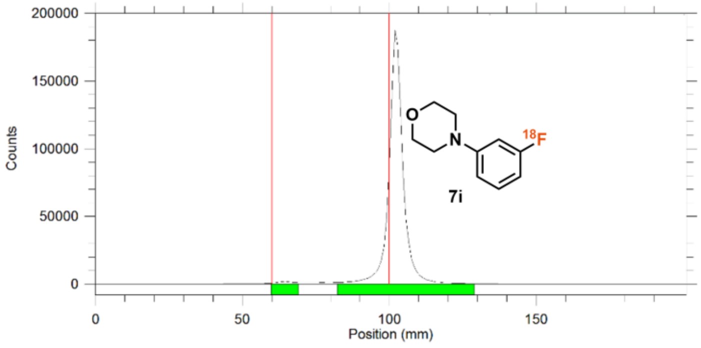


Figure S31. Radio-TLC trace of the [^{18}F]deoxyfluorination reaction of 3-morpholinophenol yielding **7i**.

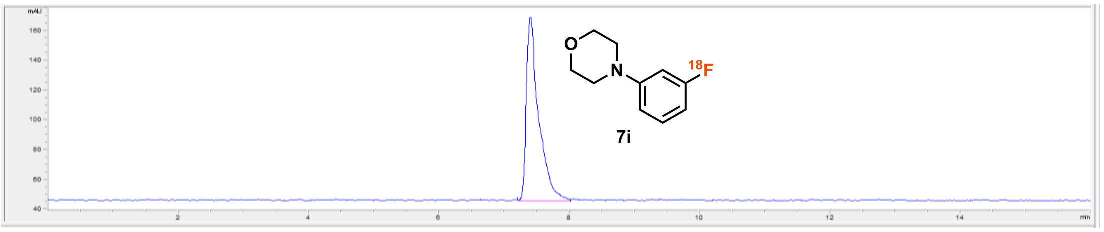


Figure S32. Radio-HPLC trace of the [^{18}F]deoxyfluorination reaction of 3-morpholinophenol yielding **7i**.

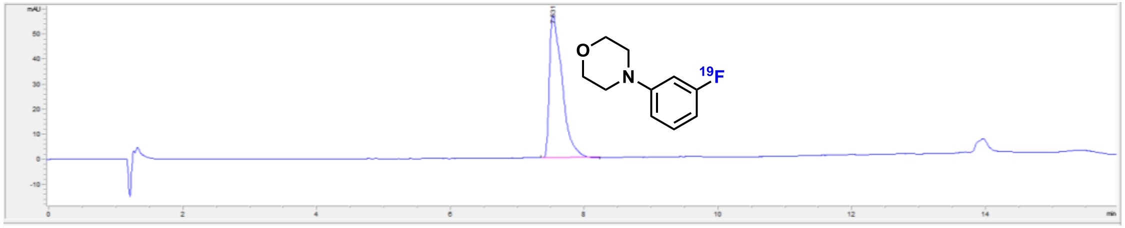
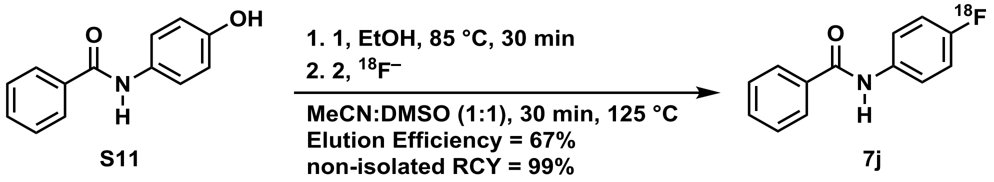


Figure S33. UV-HPLC trace of 4-(3-fluorophenyl)morpholine as the reference.

[^{18}F]4-Fluorobenzanilide (7j)



N-(4-Hydroxyphenyl)benzamide (**S11**) (1.8 mg, 8.7 µmol, 1.0 eq.) and [CpRu(cod)Cl] (**1**) (8.0 mg, 26 µmol, 3.0 eq.) were added to EtOH (50 µL, c = 0.80 M) in a 0.5 dram (1.8 mL) borosilicate glass vial. The vial was capped, and the reaction mixture was stirred at 85 °C (heating block temperature) for 30 min. The vial was removed from the heating block and allowed to stand for 3 min at 23 °C. To the vial, imidazolium chloride **2**

(14 mg, 26 µmol, 3.0 eq.) and 150 µL of MeCN were added, and the resulting solution was drawn into a 1.0 mL polypropylene syringe.

Target water from the cyclotron containing ^{18}F-fluoride was loaded with a syringe onto a QMA anion exchange cartridge (Chromafix 30-PS-HCO_3) and the radioactivity of the trapped ^{18}F-fluoride was measured (7.2 mCi, 0.27 GBq). The cartridge was washed with MeCN (1.0 mL). The cartridge was inverted and fitted with a female × female Luer adapter. With the syringe, which contained the corresponding solution of **S11**-ruthenium complex and **2**, the ^{18}F-fluoride was eluted into a 1 dram (3.7 mL) borosilicate vial. The cartridge was washed with DMSO (150 µL), followed by DMSO:MeCN (50 µL, 1:1 (v/v)) and the radioactivity of the eluted solution was measured (4.8 mCi, 0.18 GBq). The reaction vial, which contained 400 µL of the reaction mixture was sealed with a teflon-lined cap and was heated at 125 °C for 30 min. The vial, which contained the reaction mixture was removed from the heat and was allowed to stand for 3 min at 23 °C. The reaction mixture was analyzed by radio-HPLC and radio-TLC. The product **7j** was characterized by comparing the radio-HPLC trace of the reaction mixture with the HPLC UV traces of the authentic reference sample.

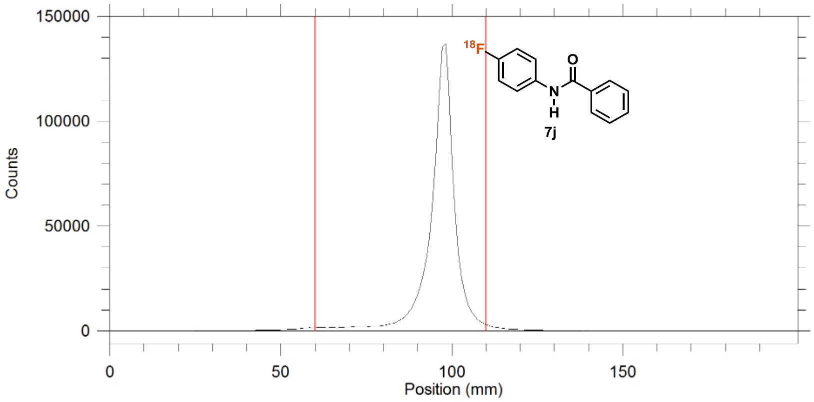


Figure S34. Radio-TLC trace of the [^{18}F]deoxyfluorination reaction of **S11** yielding **7j**.

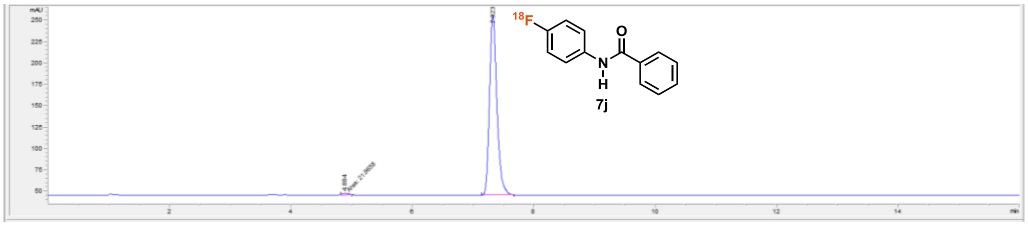


Figure S35. Radio-HPLC trace of the [^{18}F]deoxyfluorination reaction of **S11** yielding **7j**.

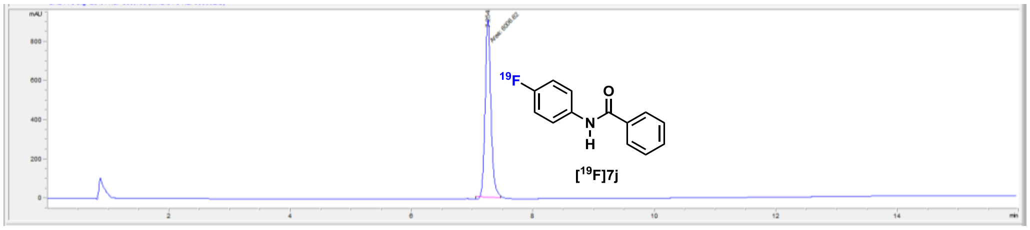
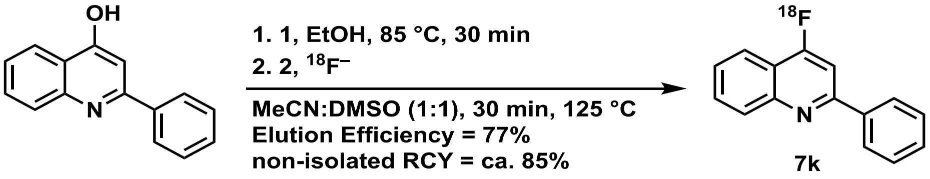


Figure S36. UV-HPLC trace of **[^{19}F]7j** as the reference.

[^{18}F]4-(Fluoro)-2-phenylquinoline (7k)



2-Phenylquinolin-4-ol (1.9 mg, 8.7 µmol, 1.0 eq.) and [CpRu(cod)Cl] (**1**) (8.0 mg, 26 µmol, 3.0 eq.) were added to EtOH (50 µL, c = 0.80 M) in a 0.5 dram (1.8 mL) borosilicate glass vial. The vial was capped, and the reaction mixture was stirred at 85 °C (heating block temperature) for 30 min. The vial was removed from the heating block and allowed to stand for 3 min at 23 °C. To the vial, imidazolium chloride **2** (14 mg, 26 µmol, 3.0 eq.) and 150 µL of MeCN were added, and the resulting solution was drawn into a 1.0 mL polypropylene syringe.

Target water from the cyclotron containing ^{18}F-fluoride was loaded with a syringe onto a QMA anion exchange cartridge (Chromafix 30-PS-HCO$_3$) and the radioactivity of the trapped ^{18}F-fluoride was measured (6.0 mCi, 0.22 GBq). The cartridge was washed with MeCN (1.0 mL). The cartridge was inverted and fitted with a female × female Luer adapter. With the syringe, which contained the corresponding solution of 2-phenylquinolin-4-ol-ruthenium complex and **2**, the ^{18}F-fluoride was eluted into a 1 dram (3.7 mL) borosilicate vial. The cartridge was washed with DMSO (150 µL), followed by DMSO:MeCN (50 µL, 1:1 (v/v)) and the radioactivity of the eluted solution was measured (4.6 mCi, 0.170 Bq). The reaction vial, which contained 400 µL of the reaction mixture was sealed with a teflon-lined cap and was heated at 125 °C for 30 min. The vial, which contained the reaction mixture was removed from the heat and was allowed to stand for 3 min at 23 °C. The reaction mixture was analyzed by radio-HPLC and radio-TLC. The product **7k** was characterized by comparing the radio-HPLC trace of the reaction mixture with the HPLC UV traces of the authentic reference sample.

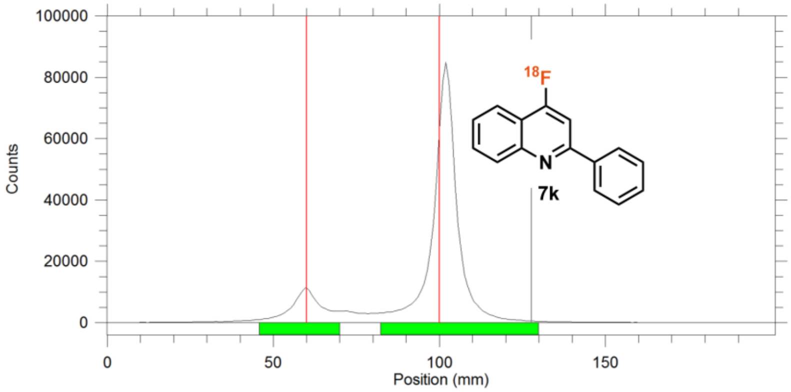


Figure S37. Radio-TLC trace of the [^{18}F]deoxyfluorination reaction of 2-phenylquinolin-4-ol yielding **7k**.

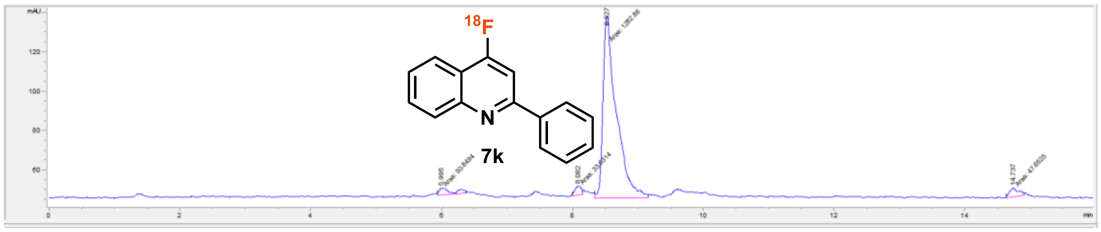


Figure S38. Radio-HPLC trace of the [^{18}F]deoxyfluorination reaction of 2-phenylquinolin-4-ol yielding **7k**.

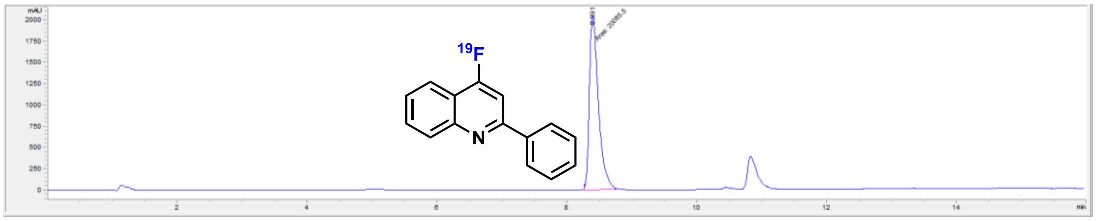
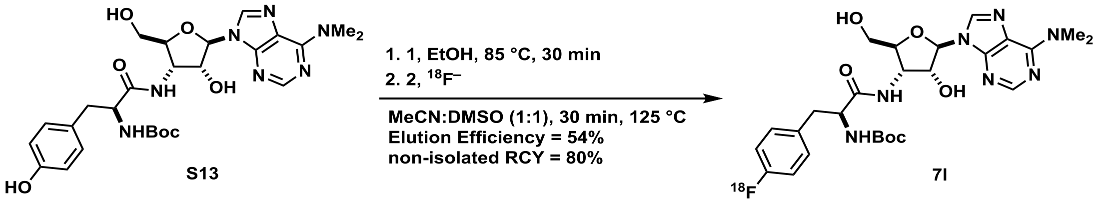


Figure S39. UV-HPLC trace of 4-fluoro-2-phenylquinoline as the reference.

[^{18}F]Purin 7l



Purin **S13** (3.9 mg, 8.7 µmol, 1.0 eq.) and [CpRu(cod)Cl] (**1**) (8.0 mg, 26 µmol, 3.0 eq.) were added to EtOH (50 µL, c = 0.80 M) in a 0.5 dram (1.8 mL) borosilicate glass vial. The vial was capped, and the reaction mixture was stirred at 85 °C (heating block temperature) for 30 min. The vial was removed from the heating block and allowed to stand for 3 min at 23 °C. To the vial, imidazolium chloride **2** (14 mg, 26 µmol, 3.0 eq.) and 150 µL of MeCN were added, and the resulting solution was drawn into a 1.0 mL polypropylene syringe.

Target water from the cyclotron containing ^{18}F-fluoride was loaded with a syringe onto a QMA anion exchange cartridge (Chromafix 30-PS-HCO_3) and the radioactivity of the trapped ^{18}F-fluoride was measured (6.5 mCi, 0.24 GBq). The cartridge was washed with MeCN (1.0 mL). The cartridge was inverted and fitted with a female × female Luer adapter. With the syringe, which contained the corresponding solution of **S13**-ruthenium complex and **2**, the ^{18}F-fluoride was eluted into a 1 dram (3.7 mL) borosilicate vial. The cartridge was washed with DMSO (150 µL), followed by DMSO:MeCN (50 µL, 1:1 (v/v)) and the radioactivity of the eluted solution was measured (3.5 mCi, 0.13 GBq). The reaction vial, which contained 400 µL of the reaction mixture was sealed with a teflon-lined cap and was heated at 125 °C for 30 min. The vial, which contained the reaction mixture was removed from the heat and was allowed to stand for 3 min at 23 °C. The reaction mixture was analyzed by radio-HPLC and radio-TLC. The product **7l** was characterized by comparing the radio-HPLC trace of the reaction mixture with the HPLC UV traces of the authentic reference sample.

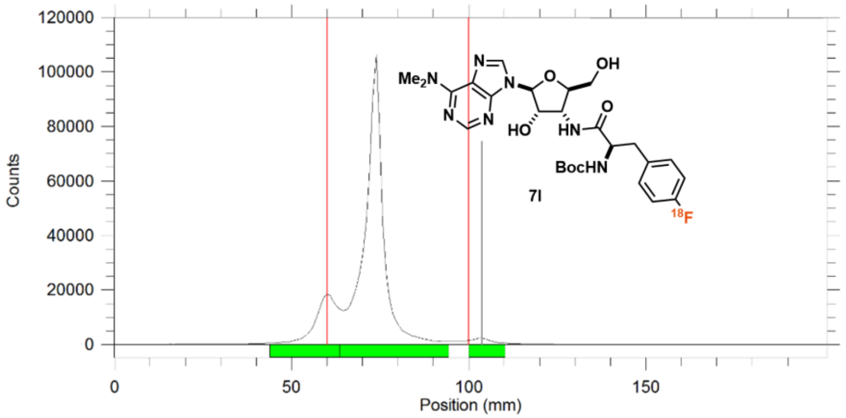


Figure S40. Radio-TLC trace of the [^{18}F]deoxyfluorination reaction of **S13** yielding **7l**.

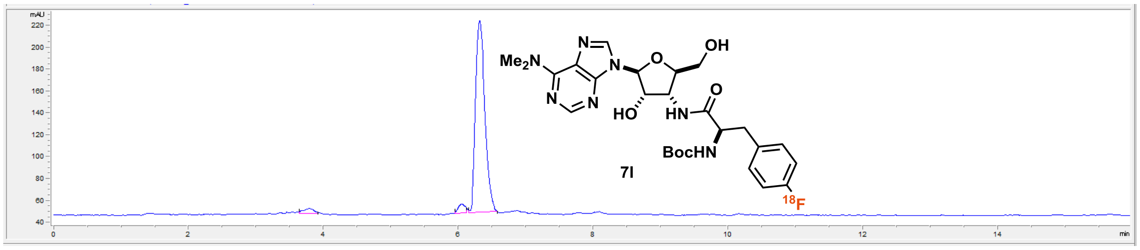


Figure S41. Radio-HPLC trace of the [^{18}F]deoxyfluorination reaction of **S13** yielding **7l**.

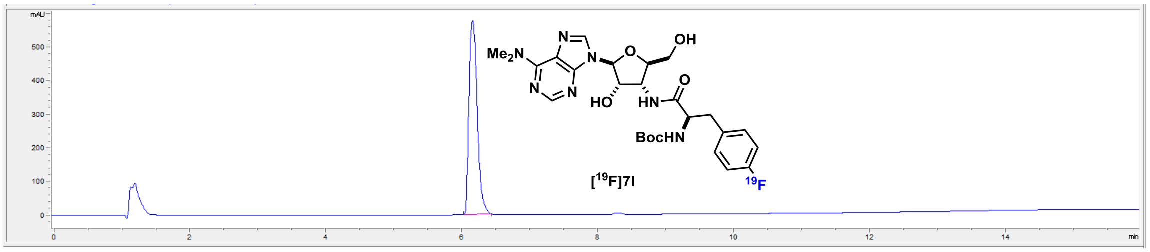
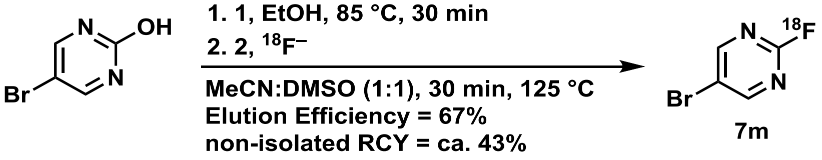


Figure S42. UV-HPLC trace of **[^{19}F]7l** as the reference.

[^{18}F]5-Bromo-2-(fluoro)pyrimidine (7m)



5-Bromopyrimidin-2-ol (1.5 mg, 8.7 μmol, 1.0 eq.) and [CpRu(cod)Cl] (**1**) (8.0 mg, 26 μmol, 3.0 eq.) were added to EtOH (50 μL, c = 0.80 M) in a 0.5 dram (1.8 mL) borosilicate glass vial. The vial was capped, and the reaction mixture was stirred at 85 °C (heating block temperature) for 30 min. The vial was removed from the heating block and allowed to stand for 3 min at 23 °C. To the vial, imidazolium chloride **2** (14 mg, 26 μmol, 3.0 eq.) and 150 μL of MeCN were added, and the resulting solution was drawn into a 1.0 mL polypropylene syringe.

Target water from the cyclotron containing ^{18}F-fluoride was loaded with a syringe onto a QMA anion exchange cartridge (Chromafix 30-PS-HCO$_3$) and the radioactivity of the trapped ^{18}F-fluoride was measured (5.1 mCi, 0.19 GBq). The cartridge was washed with MeCN (1.0 mL). The cartridge was inverted and fitted with a female × female Luer adapter. With the syringe, which contained the corresponding solution of 5-bromopyrimidin-2-ol-ruthenium complex and **2**, the ^{18}F-fluoride was eluted into a 1 dram (3.7 mL) borosilicate vial. The cartridge was washed with DMSO (150 μL), followed by DMSO:MeCN (50 μL, 1:1 (v/v)) and the radioactivity of the eluted solution was measured (3.5 mCi, 0.13 GBq). The reaction vial, which contained 400 μL of the reaction mixture was sealed with a teflon-lined cap and was heated at 125 °C for 30 min. The vial, which contained the reaction mixture was removed from the heat and was allowed to stand for 3 min at 23 °C. The reaction mixture was analyzed by radio-HPLC and radio-TLC. The product **7m** was characterized by comparing the radio-HPLC trace of the reaction mixture with the HPLC UV traces of the authentic reference sample.

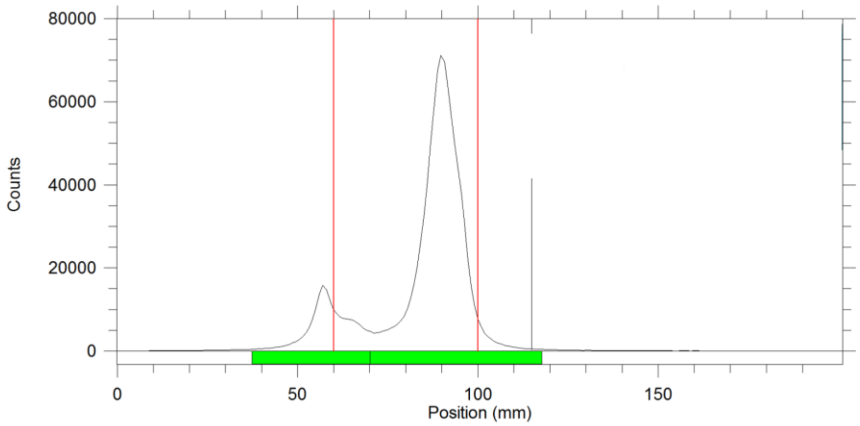


Figure S43. Radio-TLC trace of the [^{18}F]deoxyfluorination reaction of 5-bromopyrimidin-2-ol yielding **7m**.

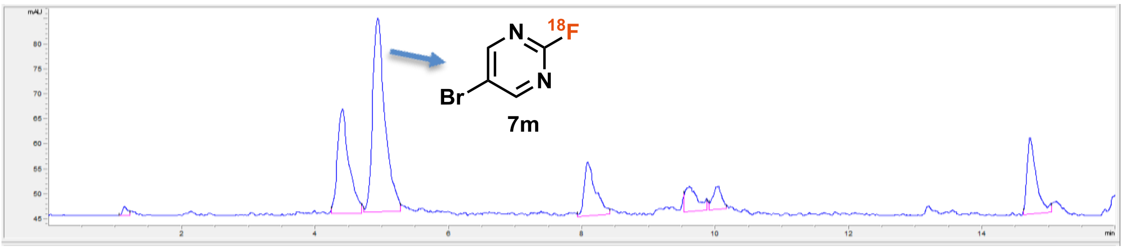


Figure S44. Radio-HPLC trace of the [^{18}F]deoxyfluorination reaction of 5-bromopyrimidin-2-ol yielding **7m**.

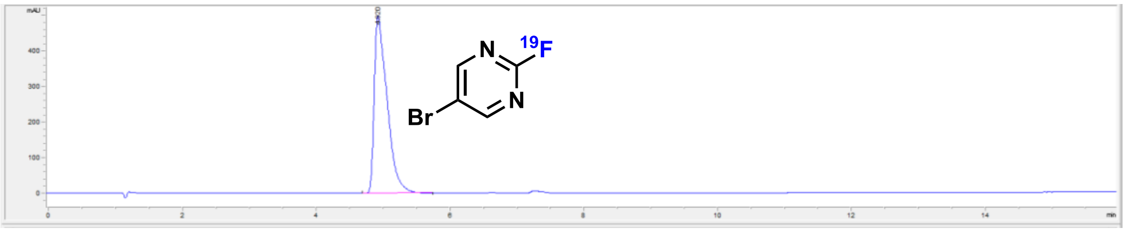
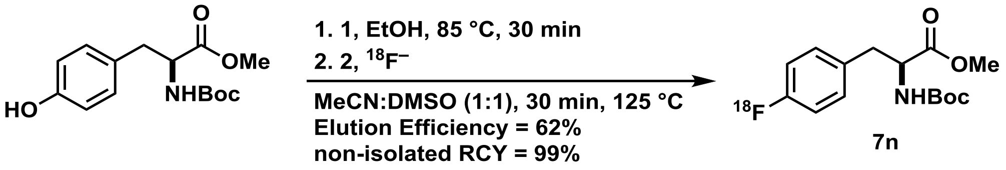


Figure S45. UV-HPLC trace of 5-bromo-2-fluoropyrimidine as the reference.

[^{18}F]*L*-tyrosinate 7n



Methyl (*tert*-butoxycarbonyl)-*L*-tyrosinate (2.5 mg, 8.7 µmol, 1.0 eq.) and [CpRu(cod)Cl] (**1**) (8.0 mg, 26 µmol, 3.0 eq.) were added to EtOH (50 µL, c = 0.80 M) in a 0.5 dram (1.8 mL) borosilicate glass vial. The vial was capped, and the reaction mixture was stirred at 85 °C (heating block temperature) for 30 min. The vial was removed from the heating block and allowed to stand for 3 min at 23 °C. To the vial, imidazolium chloride **2** (14 mg, 26 µmol, 3.0 eq.) and 150 µL of MeCN were added, and the resulting solution was drawn into a 1.0 mL polypropylene syringe.

Target water from the cyclotron containing ^{18}F-fluoride was loaded with a syringe onto a QMA anion exchange cartridge (Chromafix 30-PS-HCO_3) and the radioactivity of the trapped ^{18}F-fluoride was measured (7.3 mCi, 0.27 GBq). The cartridge was washed with MeCN (1.0 mL). The cartridge was inverted and fitted with a female × female Luer adapter. With the syringe, which contained the corresponding solution of methyl (*tert*-butoxycarbonyl)-*L*-tyrosinate-ruthenium complex and **2**, the ^{18}F-fluoride was eluted into a 1 dram (3.7 mL) borosilicate vial. The cartridge was washed with DMSO (150 µL), followed by DMSO:MeCN (50 µL, 1:1 (v/v)) and the radioactivity of the eluted solution was measured (4.6 mCi, 0.17 GBq). The reaction vial, which contained 400 µL of the reaction mixture was sealed with a teflon-lined cap and was heated at 125 °C for 30 min. The vial, which contained the reaction mixture was removed from the heat and was allowed to stand for 3 min at 23 °C. The reaction mixture was analyzed by radio-HPLC and radio-TLC. The product **7n** was characterized by comparing the radio-HPLC trace of the reaction mixture with the HPLC UV traces of the authentic reference sample.

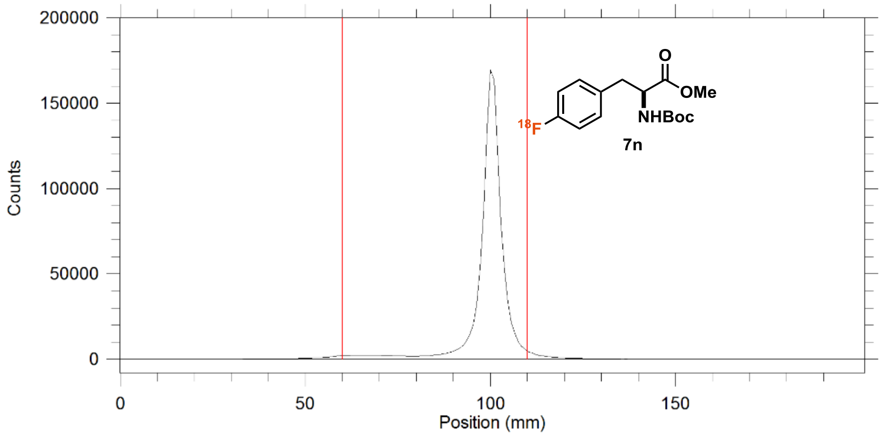


Figure S46. Radio-TLC trace of the [^{18}F]deoxyfluorination reaction of methyl (*tert*-butoxycarbonyl)-*L*-tyrosinate yielding **7n**.

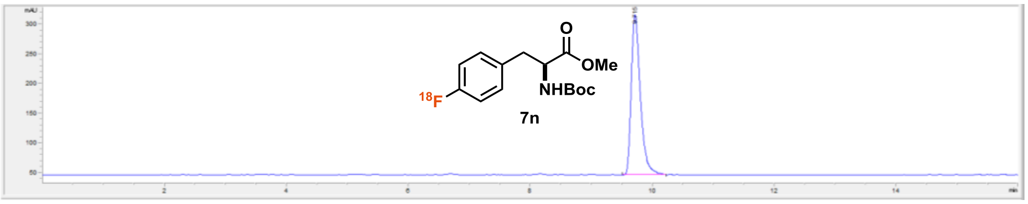


Figure S47. Radio-HPLC trace of the [^{18}F]deoxyfluorination reaction of methyl (*tert*-butoxycarbonyl)-*L*-tyrosinate yielding **7n**.

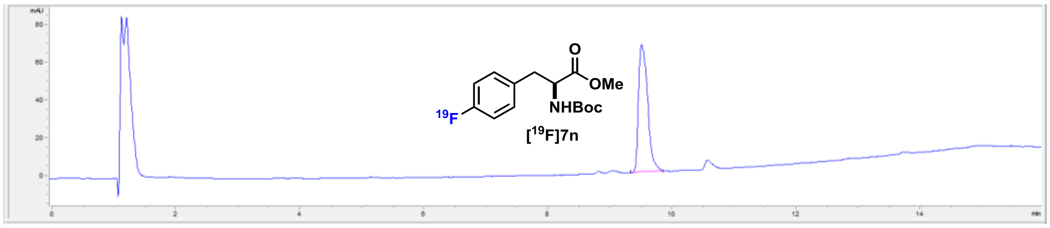
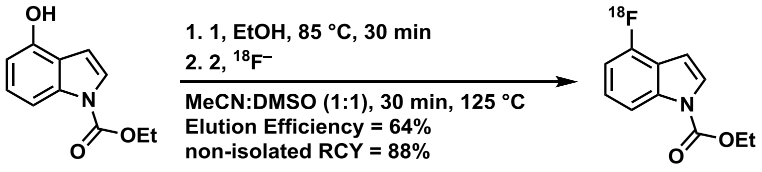


Figure S48. UV-HPLC trace of **[^{19}F]7n** as the reference.

[^{18}F]Ethyl 4-(fluoro)-1*H*-indole-1-carboxylate (7o)



7o

Ethyl 4-hydroxy-1*H*-indole-1-carboxylate (1.7 mg, 8.7 µmol, 1.0 eq.) and [CpRu(cod)Cl] (**1**) (8.0 mg, 26 µmol, 3.0 eq.) were added to EtOH (50 µL, c = 0.80 M) in a 0.5 dram (1.8 mL) borosilicate glass vial. The vial was capped, and the reaction mixture was stirred at 85 °C (heating block temperature) for 30 min. The vial was removed from the heating block and allowed to stand for 3 min at 23 °C. To the vial, imidazolium chloride **2** (14 mg, 26 µmol, 3.0 eq.) and 150 µL of MeCN were added, and the resulting solution was drawn into a 1.0 mL polypropylene syringe.

Target water from the cyclotron containing ^{18}F-fluoride was loaded with a syringe onto a QMA anion exchange cartridge (Chromafix 30-PS-HCO$_3$) and the radioactivity of the trapped ^{18}F-fluoride was measured (10.7 mCi, 0.40 GBq). The cartridge was washed with MeCN (1.0 mL). The cartridge was inverted and fitted with a female × female Luer adapter. With the syringe, which contained the corresponding solution of ethyl 4-hydroxy-1*H*-indole-1-carboxylate-ruthenium complex and **2**, the ^{18}F-fluoride was eluted into a 1 dram (3.7 mL) borosilicate vial. The cartridge was washed with DMSO (150 µL), followed by DMSO:MeCN (50 µL, 1:1 (v/v)) and the radioactivity of the eluted solution was measured (6.8 mCi, 0.25 GBq). The reaction vial, which contained 400 µL of the reaction mixture was sealed with a teflon-lined cap and was heated at 125 °C for 30 min. The vial, which contained the reaction mixture was removed from the heat and was allowed to stand for 3 min at 23 °C. The reaction mixture was analyzed by radio-HPLC and radio-TLC. The product **7o** was characterized by comparing the radio-HPLC trace of the reaction mixture with the HPLC UV traces of the authentic reference sample.

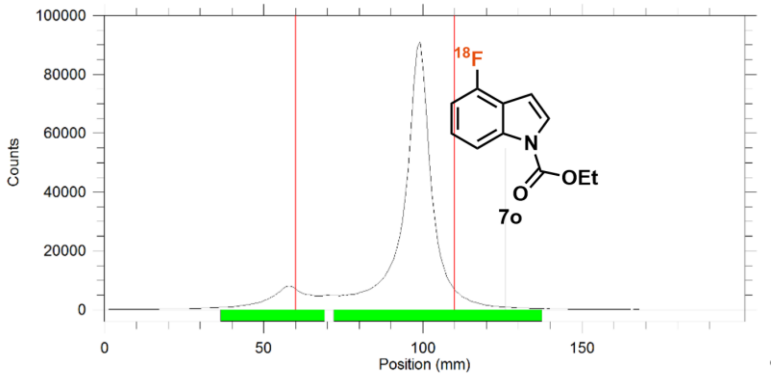


Figure S49. Radio-TLC trace of the [^{18}F]deoxyfluorination reaction of ethyl 4-hydroxy-1*H*-indole-1-carboxylate yielding **7o**.

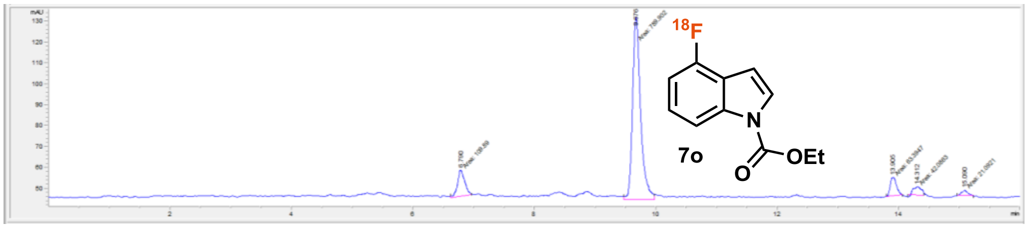


Figure S50. Radio-HPLC trace of the [^{18}F]deoxyfluorination reaction of ethyl 4-hydroxy-1*H*-indole-1-carboxylate yielding **7o**.

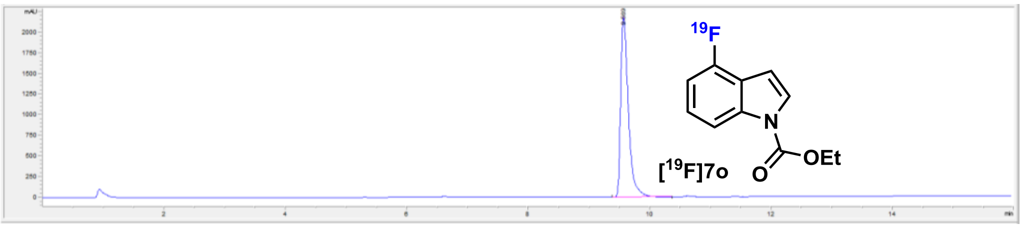
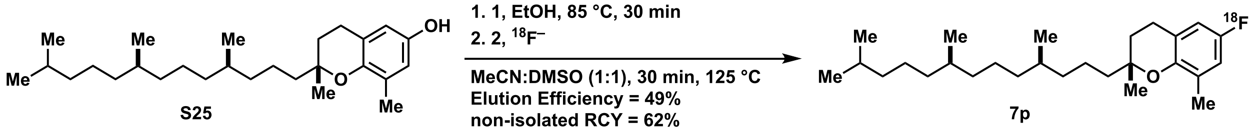


Figure S51. UV-HPLC trace of **[^{19}F]7o** as the reference.

[^{18}F]Chromane 7p



1. 1, EtOH, 85 °C, 30 min
2. 2, ^{18}F^{-}

MeCN:DMSO (1:1), 30 min, 125 °C
Elution Efficiency = 49%
non-isolated RCY = 62%

(+)-δ-Tocopherol (**S25**) (3.4 mg, 8.7 µmol, 1.0 eq.) and [CpRu(cod)Cl] (**1**) (8.0 mg, 26 µmol, 3.0 eq.) were added to EtOH (50 µL, c = 0.80 M) in a 0.5 dram (1.8 mL) borosilicate glass vial. The vial was capped, and the reaction mixture was stirred at 85 °C (heating block temperature) for 30 min. The vial was removed from the heating block and allowed to stand for 3 min at 23 °C. To the vial, imidazolium chloride **2** (14 mg, 26 µmol, 3.0 eq.) and 150 µL of MeCN were added, and the resulting solution was drawn into a 1.0 mL polypropylene syringe.

Target water from the cyclotron containing ^{18}F-fluoride was loaded with a syringe onto a QMA anion exchange cartridge (Chromafix 30-PS-HCO$_3$) and the radioactivity of the trapped ^{18}F-fluoride was measured (6.0 mCi, 0.22 GBq). The cartridge was washed with MeCN (1.0 mL). The cartridge was inverted and fitted with a female × female Luer adapter. With the syringe, which contained the corresponding solution of **S25**-ruthenium complex and **2**, the ^{18}F-fluoride was eluted into a 1 dram (3.7 mL) borosilicate vial. The cartridge was washed with DMSO (150 µL), followed by DMSO:MeCN (50 µL, 1:1 (v/v)) and the radioactivity of the eluted solution was measured (3.0 mCi, 0.11 GBq). The reaction vial, which contained 400 µL of the reaction mixture was sealed with a teflon-lined cap and was heated at 125 °C for 30 min. The vial, which contained the reaction mixture was removed from the heat and was allowed to stand for 3 min at 23 °C. The reaction mixture was analyzed by radio-HPLC and radio-TLC. The product **7p** was characterized by comparing the radio-HPLC trace of the reaction mixture with the HPLC UV traces of the authentic reference sample.

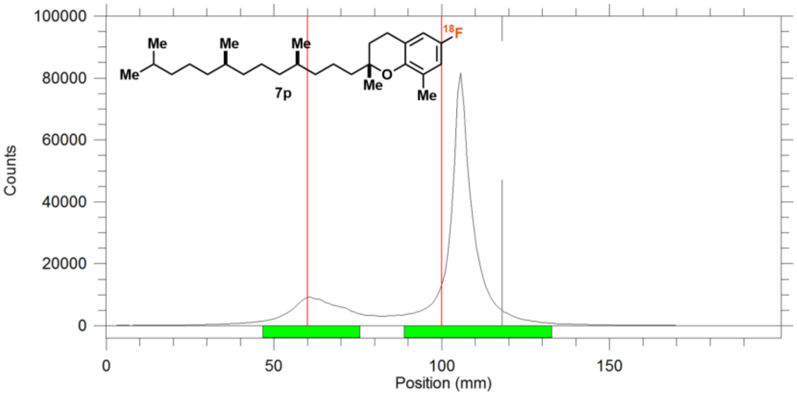


Figure S52. Radio-TLC trace of the [^{18}F]deoxyfluorination reaction of **S25** yielding **7p**.

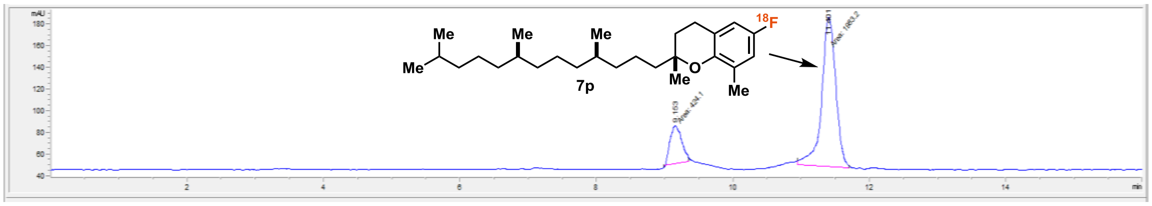


Figure S53. Radio-HPLC trace of the [^{18}F]deoxyfluorination reaction of **S25** yielding **7p**. (Pentafluorophenyl (PFP) HPLC column was used).

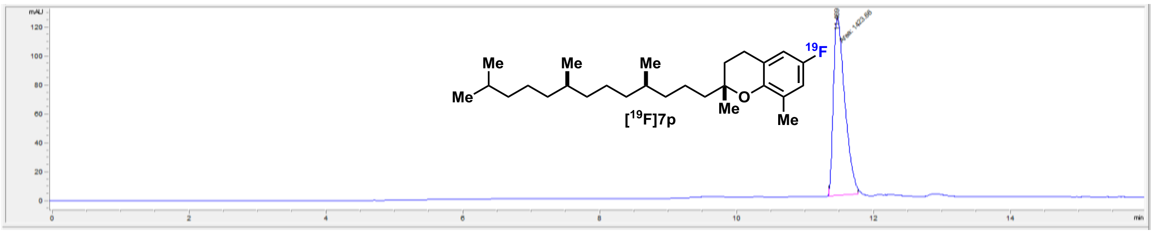


Figure S54. UV-HPLC trace of **[^{19}F]7p** as the reference. (Pentafluorophenyl (PFP) HPLC column was used).

Automated radiosynthesis

For reactions performed on the Elixys, an adapter was needed to accommodate Wheaton 3 mL v-vials. A cylinder of solid aluminum (diameter 0.60 in, height 0.52 inches) was manufactured for that purpose.

Automated radiosynthesis of 9

Influence of vial size and type: In ethanol (200 µL), methyl acetyl-*L*-tyrosinate (**8**) (5.0 mg, 21 µmol, 1.0 eq), [CpRu(cod)Cl] complex **1** (10 mg, 27 µmol, 1.3 eq) and *N*,*N*'-bis(2,6-diisopropylphenyl)-2-chloroimidazolium chloride (**2**) (15 mg, 33 µmol, 1.6 eq) were mixed in a dram vial and heated at 85 °C (heating block temperature) for 30 min to constitute the *eluent.* ^{18}F-Fluoride was loaded onto QMA anion exchange cartridge (Chromafix 30-PS-HCO$_3$), and the cartridge was washed with 1 mL of ethanol to remove water from ^{18}F-fluoride. The cartridge was inverted and fitted with a female × female Luer adapter. ^{18}F-Fluoride was eluted with the *eluent* into a dram vial (3 mL Wheaton v-vial, 8 mL Wheaton v-vial). Then, acetonitrile (300 µL) followed by DMSO (300 µL) were passed through the cartridge and collected into the same vial. The reaction vial was sealed with a teflon-lined cap and heated at 130 °C for 30 min. The reaction was subsequently cooled to 23 °C and the radiochemical yield was estimated by radio-TLC. The results are summarized in Figure S55.

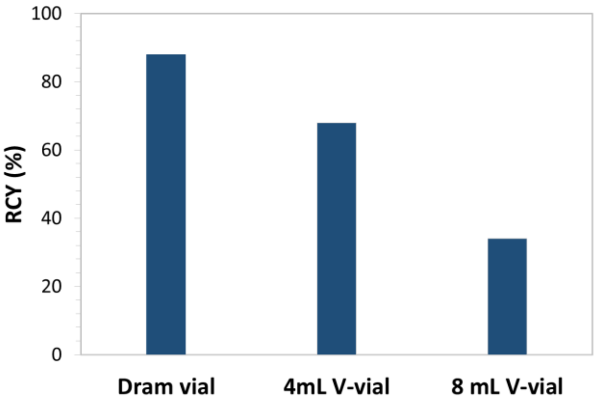


Figure S55. Influence of vial size and type on [^{18}F]deoxyfluorination of **8** yielding **9**.

Influence of pressure: The *precursor solution* was prepared by heating methyl acetyl-*L*-tyrosinate (**8**) (5.0 mg, 21 µmol, 1.0 eq), [CpRu(COD)Cl] (**1**) (10 mg, 27 µmol, 1.3 eq), *N*,*N*'-bis(2,6-diisopropylphenyl)-2-chloroimidazolium chloride (**2**) (15 mg, 33 µmol, 1.6 eq)) in ethanol (250 µL, 200 proof) at 85 °C (heating block temperature) for 30 min and diluting with DMSO (0.4 mL) and acetonitrile (0.4 mL).

In a Siemens Explora FDG4, fluoride was captured on a QMA previously conditioned (with 1 mg K_2CO_3 in 1 mL water an subsequently washed with 10 mL water), eluted with Kryptofix solution (2 mL water, 8 mL acetonitrile, 10 mg K_2CO_3, 50 mg $K_{2.2.2}$) and dried azeotropically with acetonitrile (1 mL) three times. The *precursor solution* was added and heated at a defined pressure (30 kPa or 205 kPa) for 30 min. A sample was taken to estimate the radiochemical yield by HPLC. At 30 kPa 4.1% RCY and at 205 kPa 21% RCY were observed.

Radiosynthesis: Methyl acetyl-*L*-tyrosinate (**8**) (5.0 mg, 21 µmol, 1.0 eq), [CpRu(COD)Cl] (**1**) (7.0 mg, 27 µmol, 1.3 eq), 30 mg *N*,*N*'-bis(2,6-diisopropylphenyl)-2-chloroimidazolium chloride (**2**) (65 µmol, 3.1 eq) were heated in 250 µL ethanol (200 proof) at 85 °C (heating block temperature) for 30 min to constitute the *eluent*.

On an automated synthesis platform (Elixys, Sofie Biosciences), aqueous ^{18}F-fluoride was trapped on a QMA cartridge and ethanol (1 mL 200 proof) was passed through the cartridge to remove residual water. 461 mCi (17.1 GBq) of ^{18}F-fluoride were measured at t = 0. The *eluent* was used to elute fluoride off the QMA into a 3 mL Wheaton V-vial . 0.8 mL 1:1 DMSO/MeCN were used to flush the piping and collected in the V-vial as well. Remaining on Cartridge: 66.4 mCi (2.46 GBq) (t = 22 min), in reactor (after reaction): 236 mCi (8.84 GBq) (t = 45 min). Elution efficiency: 69.0%.

Elution losses not accounted for in the EE can occur during transfer from QMA to reactor and during the reaction, where HF can be absorbed into the sealant of Elixys cassettes.

The mixture was stirred at elevated temperature (set-point at 150 °C) for 30 min and subsequently cooled to 23 °C. A sample was used to estimate the radiochemical yield by analytical HPLC (69% estimated radiochemical yield, Figure S56, analytical HPLC on an Eclipse XDB-C18 column (10 × 4.6 mm, 5 µM), by a gradient from 5% MeCN/H_2O/0.1% TFA to 95% MeCN/H_2O/0.1%TFA within 10 min at a flow rate of 2 mL/min. The solution was diluted to 2mL with water and loaded onto a semipreparative HPLC and purified with a Gemini NX-C18 (250 × 10 mm, 5 µm) column with a gradient from 5% MeCN/Water/0.1% TFA to 60% MeCN/Water/0.1% TFA within 45 min, at a flow rate of 3 mL/min (Figure S57). 111 mCi (4.11 GBq) were isolated (t = 80 min).

Isolated activity yield: 24.1 % (t = 80 min), 40.0 % isolated radiochemical yield.

The isolated fraction was diluted with 200 mL water and loaded onto a C-18 SepPak. The cartridge was washed with 5 mL of water and the product eluted with 1 mL of ethanol. 78 % of the loaded activity were recovered after elution. When instead an OASIS WAX cartridge was used, the same reformulation procedure allowed 62% recovery of initial activity.

In the dose reformulated via a C-18 solid phase extraction, the ruthenium content by ICP was determined to be 101 ppb, which is almost tenfold below the US pharmacopoeia specified limit of 1 ppm for safe injections into human subjects. When the dose was reformulated with an OASIS WAX cartridge instead, that level dropped to 33 ppb. If for different molecules those levels cannot be reached by HPLC and reformulation, commercial chelator cartridges are available for removal of ruthenium impurities by filtration.

The reformulated dose was passed through a sterile filter unit (Millex GP, 0.22 µm), which led to a loss of 5 % activity. The total activity yield including reformulation with a C-18 SPE and filtration is 18 %.

The radiochemical identity was confirmed by analytical HPLC on an Eclipse XDB-C18 column (10 × 4.6 mm, 5 µM), by a gradient from 5% MeCN/H_2O/0.1% TFA to 95% MeCN/H_2O/0.1%TFA within 10 min at a flow rate of 2 mL/min. (Figure S58)

Specific activity was determined to be 2.5 mCi/nmol (92 MBq/nmol) (7.84 nmol/mL molar concentration in sample by calibration curve, 19.6 mCi/mL (726 MBq/mL) activity concentration at end of synthesis) (Figure S59) via a calibration curve (Figure S60) acquired with an authentic standard for *N*-acetyl-4-fluoro-*L*-phenylalanine methyl ester, with the same analytical HPLC method as for the confirmation of radiochemical identity and a 30 µL injection per sample. We determined the total impurity concentration in the formulated dose to be 3.6 µg/mL. Further optimization is needed for human injection grade purity, but unoptimized impurity levels are within an order of magnitude of acceptable levels.

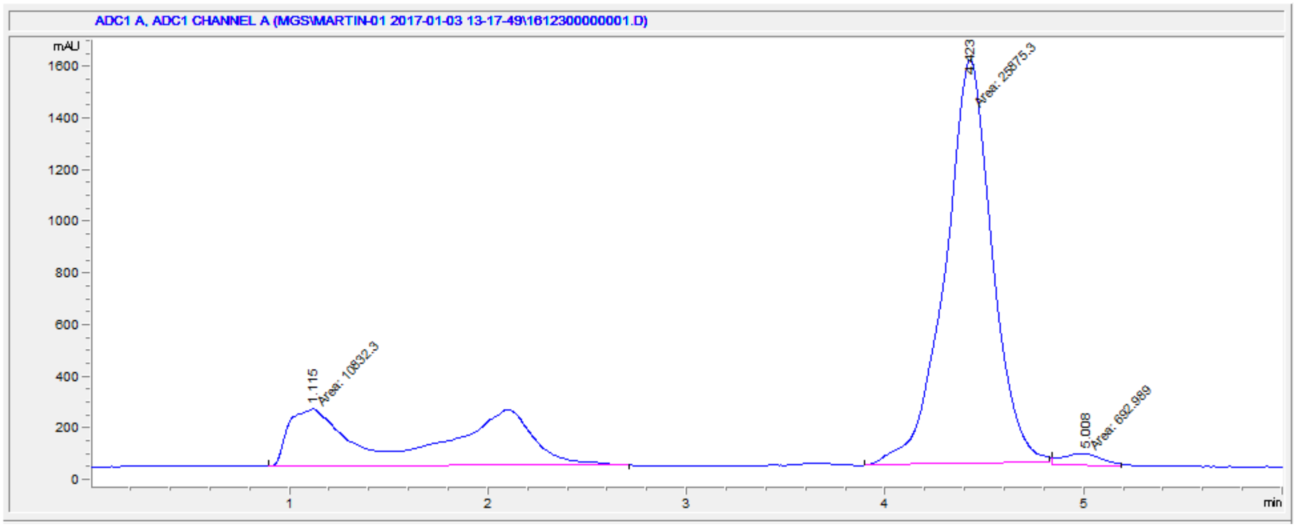


Figure S56. Estimate of radiochemical yield; reaction mixture γ-trace, RCY = 69%.

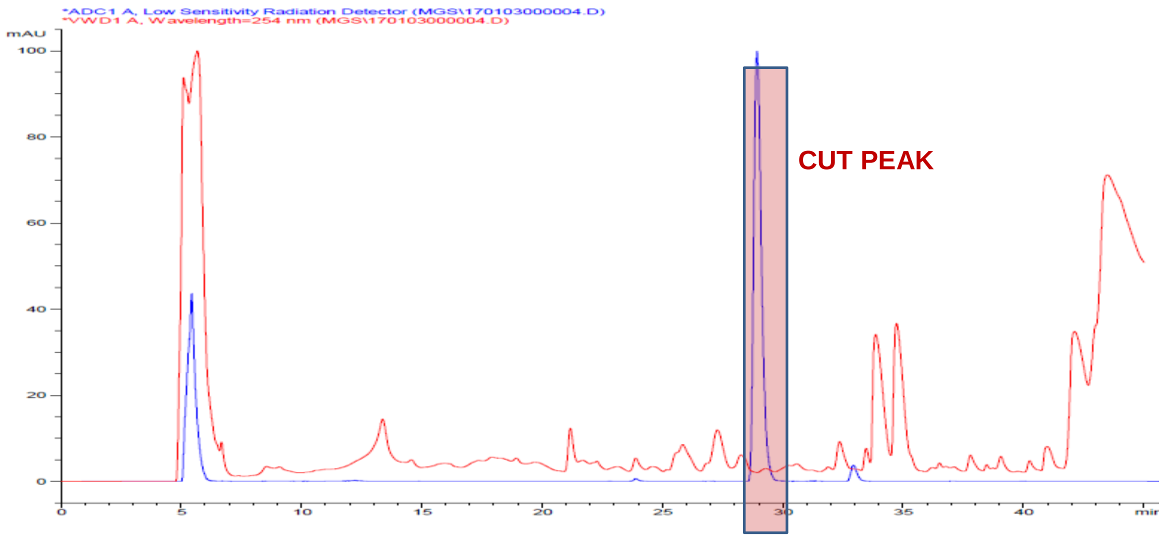


Figure S57. Semipreparative HPLC purification, overlay of γ-trace (blue) and UV(254nm) trace (red).

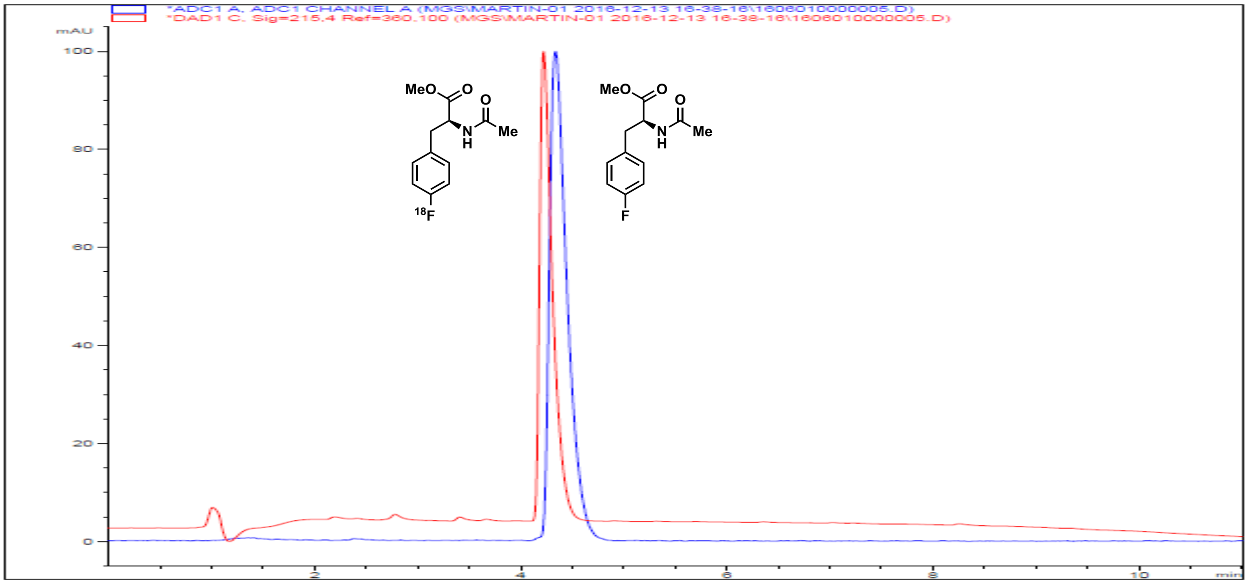


Figure S58. Confirmation of radiochemical identity; overlay of γ-trace (blue) and UV (254nm) trace (red).

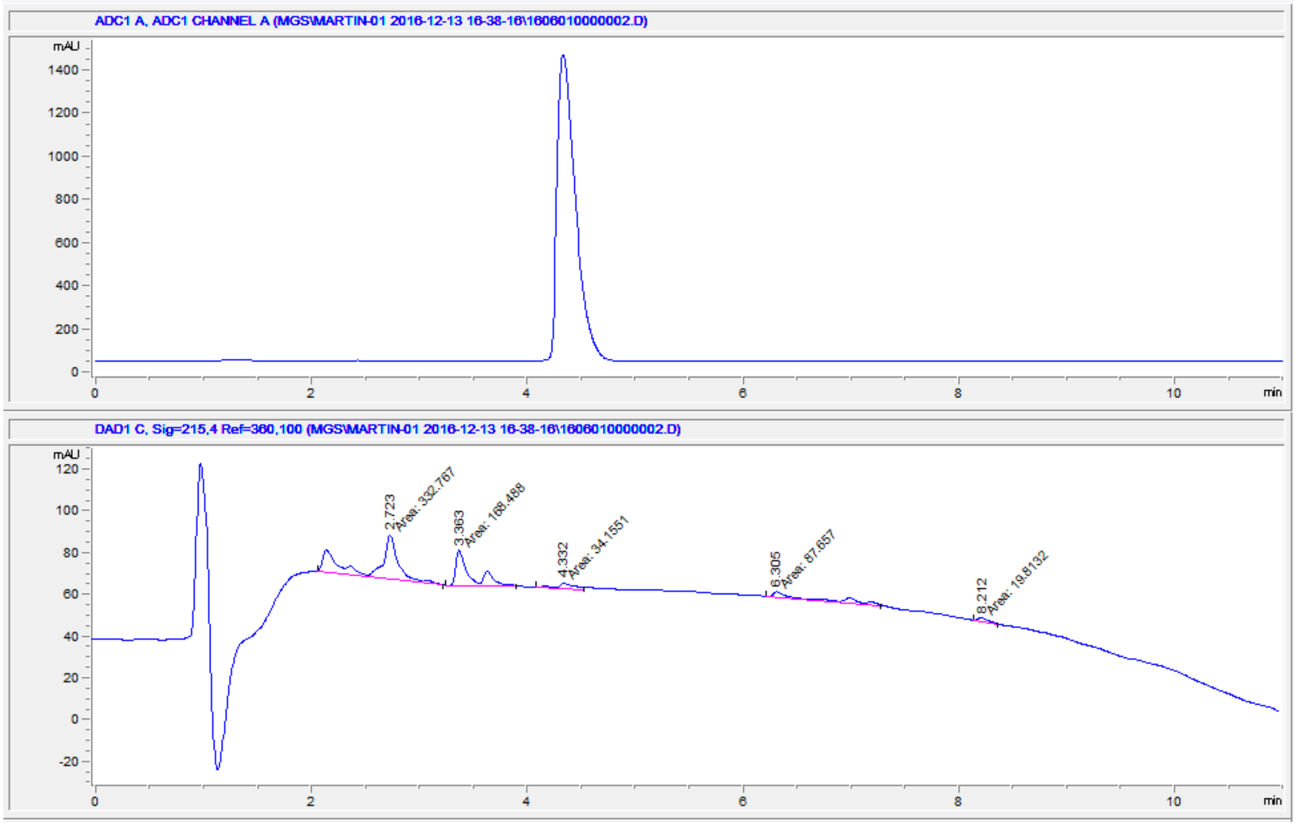


Figure S59. Determination of Specific Activity; γ-trace (top) and UV(215nm) trace (bottom) of 10x concentrated purified fraction; AUC = 36.05.

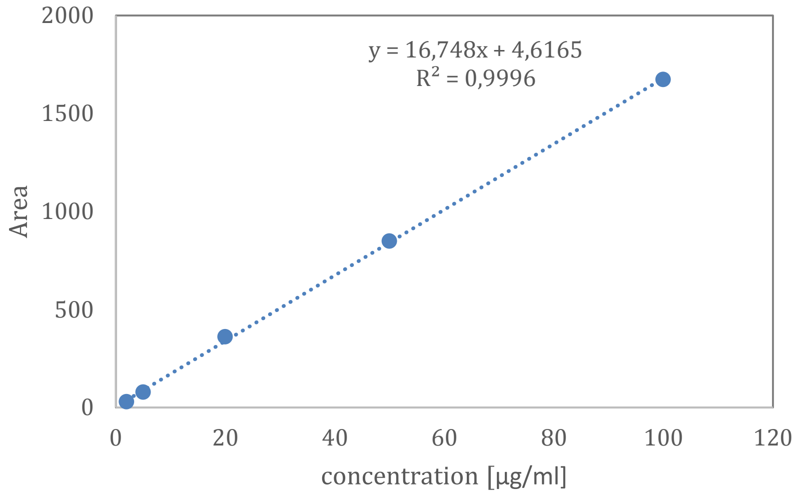


Figure S60. Calibration curve acquired with authentic standard at 215 nm (averaged triplicate) for determination of specific activity.

Determination of enantiopurity: A racemic standard was analyzed on a Chiralcel AD column (250 × 4.6 mm, 10 µm) with 10% isopropanol in hexanes at a flow rate of 1 ml/min and monitored at 254 nm. (*R*)- and (*L*)-N-acetyl-4-fluoro-phenylalanine methyl ester separated well under these conditions. Coinjection with a sample of the reaction mixture showed the retention of stereochemical information through the labeling procedure. (Figure S61)

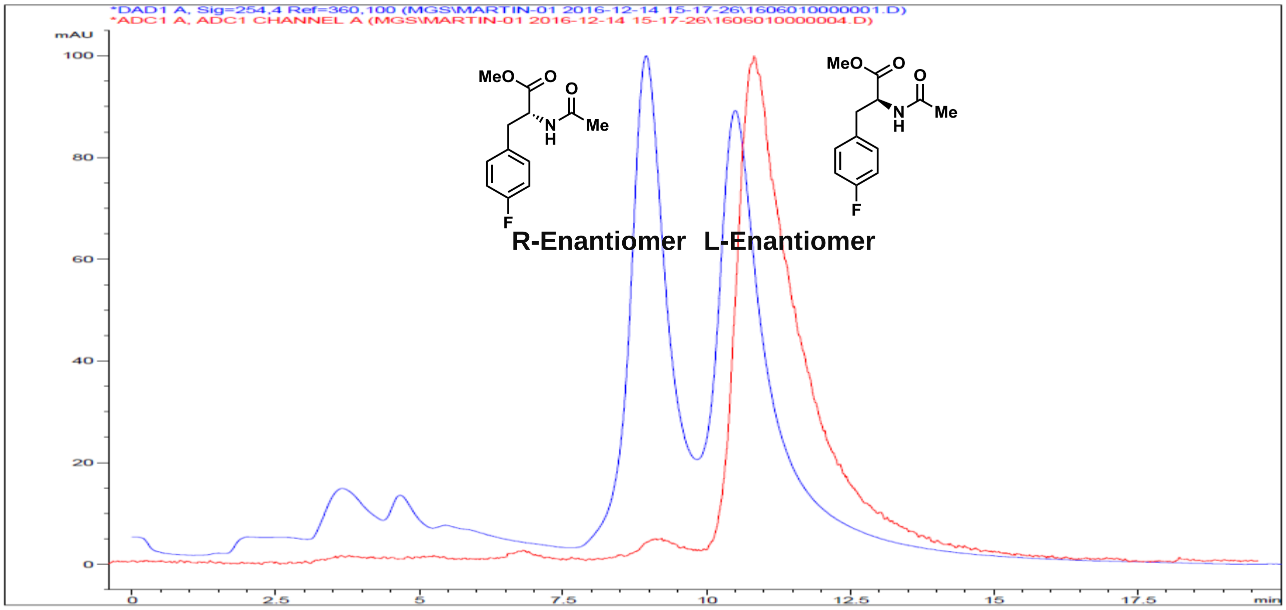


Figure S61. Coinjection of racemic *N*-acetyl-4-fluoro-phenylalanine methyl ester with reaction mixture, enantiomeric excess (*e.e.*) of labeling product determined >97%; UV(254nm) trace in blue, γ-trace in red.

Automated radiosynthesis of [^{18}F]-β-CFT (4)

Radiosynthesis: 3 (5.0 mg, 18 µM, 1.0 eq), [CpRu(COD)Cl] (**1**) (10 mg, 27 µmol, 1.5 eq) and **2** (30 mg, 65 µmol, 3.6 eq) were heated in 250 µL ethanol (200 proof) at 85 °C (heating block temperature) for 30 min to constitute the eluent.

On an automated synthesis platform (Elixys, Sofie Biosciences), aqueous ^{18}F-fluoride was trapped on a QMA cartridge and 1 mL 200 proof ethanol was passed through the cartridge to remove residual water. 409 mCi (15.1 GBq) were measured at t = 0. The eluent was used to elute fluoride off the QMA into a 3 mL Wheaton V-vial (adapter as specified). In order to flush the pipe, 0.8 mL 1:1 DMSO/MeCN were used and collected in the V-vial as well.

Remaining on Cartridge: 28.9 mCi (1.07 GBq) (t = 42 min), in reactor (after reaction): 200 mCi (7.4 GBq) (t = 46 min)

Elution efficiency: 65.5%

The mixture was stirred at elevated temperature (set-point at 160 °C) for 30 min and subsequently cooled to 23 °C. A sample was used to estimate the radiochemical yield by analytical HPLC (73% RCY, determined by analytical HPLC on an Eclipse XDB-C18 column (10x4.6 mm, 5µM) by a gradient from 5% MeCN/H_2O/0.1% TFA to 95% MeCN/H_2O/0.1%TFA within 10 min at a flow of 2 mL/min, Figure S62). An analytical sample was obtained by diluting the reaction mixture with water to 2 mL and subsequent purification via semipreparative HPLC on a Gemini NX-C18 column (250 × 10 mm, 5 µm) with a gradient from 5% MeCN/Water/0.1% TFA to 60% MeCN/Water/0.1% TFA within 45 min at 3 mL/min. The pure sample was used to confirm the radiochemical identity of the product (Figures S63 and S64) and for determination of the specific activity with the same analytical HPLC conditions used for the estimation of radiochemical yield. The product has very low UV absorption and the amount of β-CFT in the purified sample was below the detection limit. At the measured radioactivity concentration, the specific activity was determined to be greater than 1.5 mCi/nmol (56 GBq/µmol). The majority of the product was not retained on the column and an isolated yield could not be determined. Based on the content of product in the solvent front as determined by HPLC, we estimate that under appropriate purification conditions an isolated activity yield of ca. 30 % can be achieved. Based on our experience, we recommend to investigate SPE protocols and subsequent HILIC or normal phase chromatography.

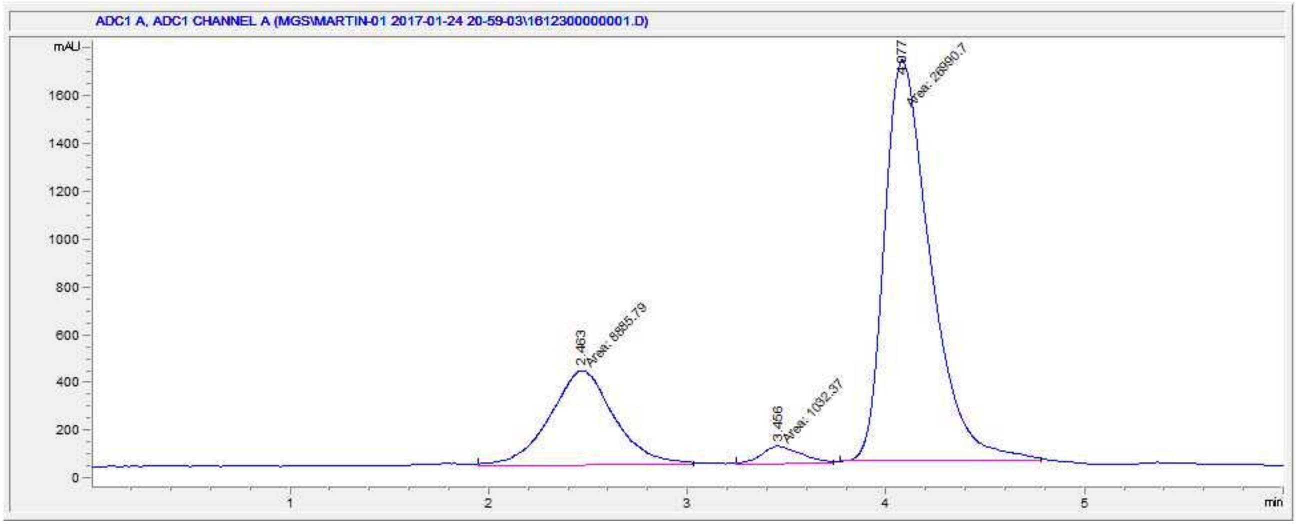


Figure S62. Analytical HPLC of reacton mixture to estimate radiochemical yield, γ-trace.

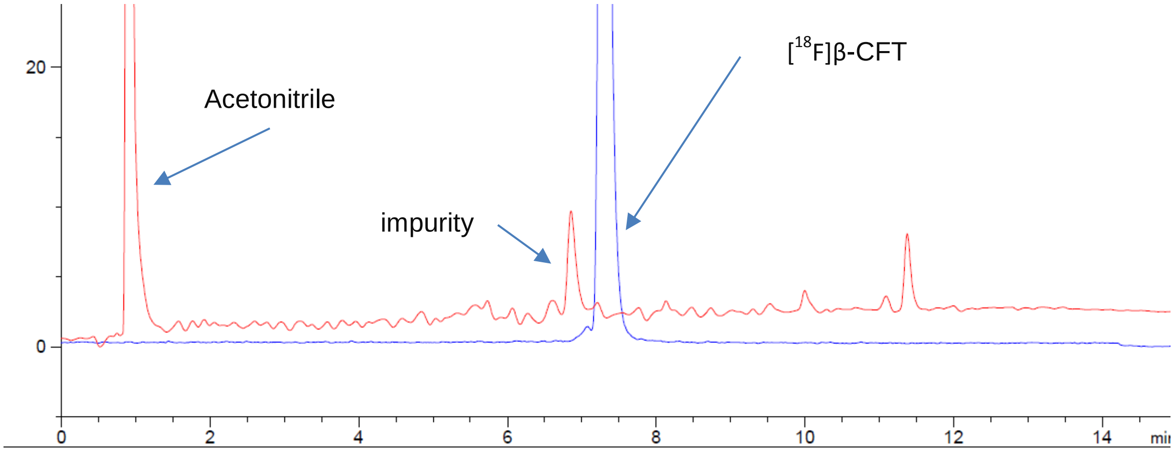


Figure S63. HPLC trace of purified analytical sample, UV(210nm)-trace in red, γ-trace in blue.

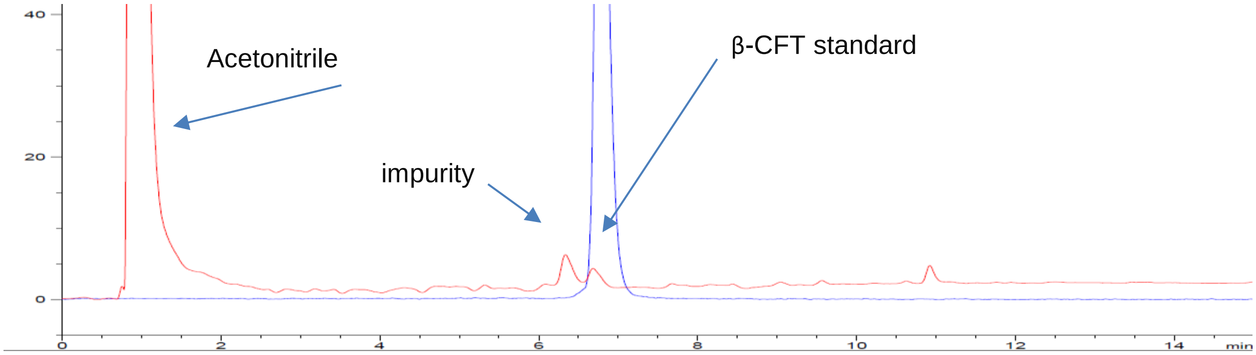


Figure S64. HPLC trace of analytical sample of β-CFT with added authentic standard of β-CFT, UV(210nm)-trace in red, γ-trace in blue.

DFT Calculations Supporting the Proposed Mechanism

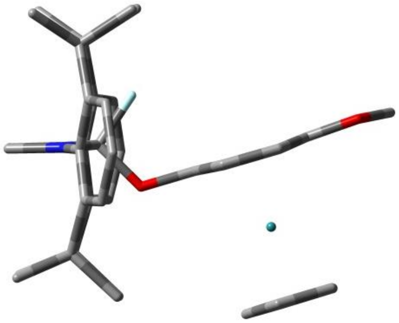
Methods for DFT calculations

Density functional theory (DFT) calculations were performed by Gaussian09[6] at the Odyssey cluster at Harvard University. Geometry optimizations were carried out with the atomic coordinates of molecular structures created with Avogadro[7] or GaussView5[8] as starting points. Geometry optimizations were performed with the B3LYP functional[9–11] with a 6-31G(d) basis set for atoms other than ruthenium and a LANL2DZ effective core potential for ruthenium.[12] Frequency calculations were performed for all structures to characterize the stationary points as ground or transition states. Single point energies were obtained for ground and transition states by the B3LYP functional with a 6-311++G(d,p) basis set for atoms other than ruthenium and the LANL2DZ effective core potential for ruthenium. The polarized continuum model (PCM) is used to simulate solvent effects (toluene) as the energy values obtained are more realistic than for gas phase calculations.[13,14] Images were generated by GaussView 5.0.

Tetrahedral adduct RuCp 4-methoxyphenol

Spin Multiplicity = 1

Charge = 1



N	2.44637	-0.94132	0.45698
C	3.58774	-0.42996	1.11296
C	3.45922	0.90385	1.19221
N	2.23453	1.26129	0.58690
C	1.69351	2.58967	0.50897
C	2.18022	-2.33026	0.20165
C	0.94902	3.08862	1.60467
C	0.41676	4.38049	1.50225

C	0.62018	5.15528	0.36202
C	1.38357	4.65849	-0.69044
C	1.94600	3.37542	-0.63870
C	2.58147	-2.89923	-1.02878
C	2.29298	-4.25321	-1.24892
C	1.65356	-5.02232	-0.28098
C	1.30147	-4.45297	0.94096
C	1.55827	-3.10267	1.21148
C	2.57090	-2.04726	-3.42209
C	4.75557	-2.70587	-2.30443
C	1.22056	-2.53030	2.58518
C	2.19134	-3.07282	3.65439
C	-0.23999	-2.79489	2.99289
C	2.83143	2.90207	-1.78749
C	2.05734	2.83214	-3.11722
C	4.08499	3.79036	-1.91997
C	0.77060	2.29790	2.89773
C	1.65284	2.88641	4.01849
C	-0.69937	2.21759	3.34758
H	4.36987	-1.09142	1.44853
H	4.10317	1.65853	1.61385
H	-0.15182	4.79197	2.33120
H	0.19910	6.15545	0.30326
H	1.55909	5.28181	-1.56262
H	2.58714	-4.71388	-2.18762
H	1.44538	-6.07191	-0.47091

H	0.83185	-5.07055	1.70116
H	1.59785	-1.56661	-3.28070
H	2.40416	-3.04361	-3.84809
H	3.13456	-1.46240	-4.15814
H	5.32300	-2.72761	-1.36743
H	4.71372	-3.72957	-2.69428
H	5.31405	-2.09776	-3.02550
H	1.35194	-1.44668	2.53723
H	3.23212	-2.84214	3.40276
H	2.10447	-4.16123	3.75344
H	1.97187	-2.62709	4.63166
H	-0.93386	-2.39860	2.24354
H	-0.44555	-3.86434	3.11616
H	-0.45595	-2.30898	3.95175
H	3.17078	1.89038	-1.55749
H	2.70951	2.46041	-3.91597
H	1.68676	3.81739	-3.42379
H	1.20318	2.15289	-3.03308
H	4.73898	3.40512	-2.71085
H	3.82549	4.82400	-2.17661
H	4.65802	3.81151	-0.98629
H	1.10906	1.27514	2.71470
H	1.55225	2.29360	4.93518
H	1.36485	3.91839	4.25096
H	2.71019	2.89088	3.73245
H	-0.78387	1.58793	4.24110

H	-1.10730	3.20205	3.60370
H	-1.32655	1.78245	2.56180
C	1.61004	0.11589	0.07604
F	1.43142	0.18296	-1.35739
O	0.22065	-0.04342	0.52298
C	-0.77577	-0.06520	-0.41271
C	-1.21742	-1.29852	-0.96515
C	-1.45471	1.13068	-0.76686
C	-2.25885	-1.31987	-1.92468
H	-0.75390	-2.21991	-0.63324
C	-2.49462	1.11184	-1.73561
H	-1.17039	2.05958	-0.28670
C	-2.84753	-0.10576	-2.38835
H	-2.60533	-2.25646	-2.34609
H	-2.99892	2.03698	-1.98360
O	-3.76194	-0.22442	-3.35711
C	3.34611	-2.11726	-2.09285
H	3.46949	-1.09325	-1.73546
C	-4.50345	0.93407	-3.76860
H	-5.16399	0.58647	-4.56161
H	-3.83466	1.70792	-4.15852
H	-5.09799	1.32602	-2.93609
Ru	-3.05592	-0.31085	-0.04379
C	-4.18896	0.61207	1.63514
C	-3.45750	-0.51321	2.13286
C	-3.94100	-1.6839	1.46516

C	-4.97440	-1.2821	0.55912
C	-5.12702	0.13489	0.66416
H	-3.58952	-2.69511	1.61914
H	-5.53457	-1.93529	-0.09652
H	-2.67163	-0.48336	2.87490
H	-4.06021	1.64119	1.94216
H	-5.82472	0.74243	0.10344

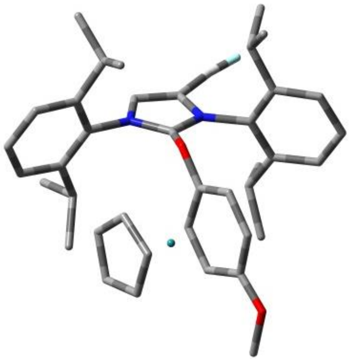
E = – 1969.07130881 a.u. (basis set: Ru: LANL2DZ, other atoms: 6-311++G(d,p))

No imaginary frequencies.

Uronium fluoride RuCp 4-methoxyphenol

Spin Multiplicity = 1

Charge = 1



N	-1.14779	1.93042	0.68088
C	-2.37504	2.14403	1.32395
C	-3.20151	1.06006	1.16034
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C	-2.84468	-1.12154	-0.10779
C	-0.03193	2.84956	0.61753

C	-2.78064	-2.23360	0.75609
C	-3.12211	-3.48075	0.21652
C	-3.52819	-3.60622	-1.10969
C	-3.64849	-2.47693	-1.91618
C	-3.32560	-1.20426	-1.42932
C	0.15035	3.61315	-0.55360
C	1.23196	4.50387	-0.57594
C	2.07327	4.64642	0.52454
C	1.84840	3.89907	1.67944
C	0.79186	2.98187	1.75621
C	-0.05136	3.07963	-3.02885
C	-1.50862	4.88048	-1.97960
C	0.54714	2.21155	3.05189
C	-0.06040	3.13302	4.13087
C	1.82282	1.53091	3.58501
C	-3.63489	0.04183	-2.25124
C	-3.22826	-0.06964	-3.72943
C	-5.13732	0.37218	-2.09159
C	-2.49562	-2.09352	2.24797
C	-3.83983	-2.06390	3.01239
C	-1.57075	-3.18727	2.80945
H	-2.53999	3.07770	1.83965
H	-4.60568	0.63930	1.34346
H	-3.09112	-4.36197	0.84926
H	-3.78728	-4.58423	-1.50601
H	-4.02330	-2.58248	-2.92921

H	1.40374	5.10797	-1.46163
H	2.89690	5.35391	0.48929
H	2.49701	4.03860	2.53857
H	0.42636	2.10424	-2.88251
H	0.72156	3.79766	-3.32638
H	-0.75822	2.99055	-3.86117
H	-2.06223	5.18821	-1.08642
H	-0.80199	5.67904	-2.23188
H	-2.22123	4.79023	-2.80681
H	-0.18921	1.42464	2.85195
H	-0.99861	3.58320	3.79207
H	0.62966	3.94502	4.38669
H	-0.26783	2.56370	5.04362
H	2.29672	0.90059	2.82281
H	2.56581	2.26384	3.91731
H	1.57862	0.90267	4.44881
H	-3.07704	0.88338	-1.82732
H	-3.41913	0.88063	-4.24061
H	-3.80076	-0.83986	-4.25767
H	-2.16254	-0.30545	-3.83991
H	-5.36681	1.33587	-2.56203
H	-5.75103	-0.39581	-2.57815
H	-5.41972	0.41120	-1.03394
H	-2.00665	-1.12703	2.41644
H	-4.51849	-1.31826	2.58766
H	-4.32965	-3.04372	2.95221

H	-3.66868	-1.83697	4.07177
H	-1.3443	-2.97785	3.86112
H	-2.03916	-4.17676	2.77319
H	-0.62313	-3.24679	2.26067
C	-1.21647	0.71332	0.11998
O	-0.31382	0.25584	-0.78315
C	0.46246	-0.85200	-0.52305
C	0.84663	-1.62746	-1.64514
C	0.97625	-1.15866	0.75939
C	1.67527	-2.76103	-1.46543
H	0.50447	-1.33973	-2.63225
C	1.79807	-2.30711	0.93879
H	0.7431	-0.52666	1.60759
C	2.08235	-3.17049	-0.15996
H	1.97572	-3.36238	-2.31539
C	-0.78752	3.53602	-1.75426
H	-1.56292	2.79433	-1.54124
F	-5.56133	0.17424	1.30232
H	2.17850	-2.52494	1.92834
O	2.77345	-4.30921	-0.08785
C	3.31324	-4.73064	1.17622
H	3.79225	-5.68817	0.97841
H	2.51592	-4.86120	1.91432
H	4.05714	-4.01153	1.53555
C	4.49649	-0.50763	-1.95557
C	3.70467	0.67905	-1.83509

C	4.98931	-0.84464	-0.65566
C	3.70637	1.07760	-0.46209
C	4.49699	0.13435	0.26867
Ru	2.77020	-0.94339	-0.62059
H	4.68413	-1.05707	-2.86846
H	3.18786	1.18239	-2.64113
H	3.19002	1.93305	-0.04684
H	4.69562	0.16126	1.33160
H	5.62325	-1.68749	-0.41576

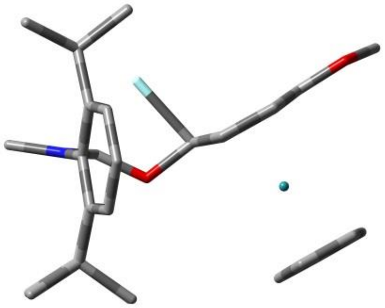
E = – 1969.04088433 a.u. (basis set: Ru: LANL2DZ, other atoms: 6-311++G(d,p))

No imaginary frequencies.

TS1 RuCp 4-methoxyphenol

Spin Multiplicity = 1

Charge = 1



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C	1.73859	2.59019	0.32663
C	2.15893	-2.32325	0.01333

C	1.33876	3.05848	1.59564
C	0.78695	4.34432	1.66202
C	0.65743	5.13013	0.51928
C	1.08959	4.64969	-0.71443
C	1.64478	3.36959	-0.84612
C	2.19511	-2.95299	-1.24921
C	1.87578	-4.31713	-1.28751
C	1.54249	-5.01707	-0.13065
C	1.53618	-4.37000	1.10268
C	1.85202	-3.00929	1.20698
C	1.52301	-2.33033	-3.62240
C	3.96005	-2.77165	-3.04051
C	1.88499	-2.34559	2.58035
C	3.00644	-2.94041	3.45560
C	0.52105	-2.43123	3.29077
C	2.16191	2.90449	-2.20474
C	1.07153	2.95378	-3.29004
C	3.40259	3.72282	-2.61582
C	1.51660	2.24565	2.87463
C	2.53601	2.91653	3.81732
C	0.17561	1.99997	3.59079
H	4.64990	-1.02414	0.05767
H	4.41233	1.73808	0.22976
H	0.46856	4.73958	2.62218
H	0.23173	6.12707	0.59333
H	1.00300	5.28181	-1.59308

H	1.89593	-4.83888	-2.23940
H	1.29958	-6.07450	-0.18832
H	1.29677	-4.93255	2.00019
H	0.61743	-1.81690	-3.29087
H	1.28010	-3.36737	-3.88129
H	1.87405	-1.83499	-4.53501
H	4.74458	-2.67846	-2.28065
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H	2.11225	-1.28395	2.44414
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H	2.83758	-4.00506	3.65250
H	3.04852	-2.42392	4.42130
H	-0.26754	-1.98910	2.67297
H	0.24379	-3.46876	3.50932
H	0.55598	-1.89103	4.24396
H	2.44930	1.85604	-2.11997
H	1.49541	2.64604	-4.25289
H	0.65489	3.95954	-3.41852
H	0.26896	2.25586	-3.03977
H	3.80408	3.34860	-3.56450
H	3.15941	4.78329	-2.75046
H	4.19697	3.65807	-1.86313
H	1.92367	1.26614	2.60541
H	2.68821	2.30111	4.71125
H	2.18885	3.90296	4.14450

H	3.50574	3.04937	3.32532
H	0.32957	1.37256	4.47633
H	-0.28234	2.93764	3.92529
H	-0.53150	1.49186	2.92681
C	1.60689	0.10883	0.09688
F	0.84273	0.17316	-1.77240
O	0.32681	-0.02981	0.51038
C	-0.66565	-0.04037	-0.48396
C	-1.25492	-1.29033	-0.82460
C	-1.47250	1.12232	-0.61904
C	-2.39900	-1.32440	-1.66233
H	-0.75674	-2.20800	-0.53999
C	-2.61934	1.10209	-1.46237
H	-1.13757	2.05329	-0.17964
C	-3.03972	-0.11719	-2.06793
H	-2.79980	-2.26739	-2.01577
H	-3.16086	2.02309	-1.63586
O	-4.06344	-0.24673	-2.92596
C	2.60616	-2.23576	-2.53255
H	2.71260	-1.17320	-2.31062
C	-4.85498	0.90455	-3.24478
H	-5.59360	0.55746	-3.96647
H	-4.24107	1.69018	-3.69735
H	-5.36297	1.28587	-2.35139
Ru	-2.98254	-0.31035	0.26878
C	-4.05797	0.64060	1.96491

C	-3.14533	-0.33212	2.48800
C	-3.53865	-1.61573	1.99132
C	-4.69719	-1.43904	1.17122
C	-5.01861	-0.04675	1.15432
H	-3.04367	-2.55519	2.19682
H	-2.31147	-0.13406	3.14679
H	-5.22747	-2.22039	0.64332
H	-5.84132	0.40775	0.61876
H	-4.03657	1.70408	2.16140

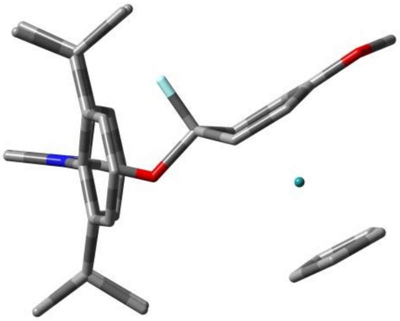
E = – 1969.06291917 a. u. (basis set: Ru: LANL2DZ, other atoms: 6-311++G(d,p))

Imaginary frequency: – 283.6 cm^{-1}

Meisenheimer intermediate RuCp 4-methoxyphenol

Spin multiplicity = 1

Charge = 1



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C	3.60769	1.30767	0.05876
N	2.22873	1.47014	0.12945
C	1.52941	2.74163	0.18956
C	2.45419	-2.12326	0.09178

C	1.12206	3.21910	1.45127
C	0.45709	4.45139	1.47830
C	0.22961	5.17345	0.30966
C	0.66341	4.67917	-0.91798
C	1.32319	3.44719	-1.01409
C	2.54243	-2.80968	-1.13725
C	2.40192	-4.20257	-1.09314
C	2.18252	-4.86985	0.10922
C	2.10718	-4.15888	1.30417
C	2.24831	-2.76568	1.32894
C	1.78351	-2.49967	-3.54935
C	4.24947	-2.40479	-2.95440
C	2.19903	-2.02406	2.66158
C	3.39301	-2.41176	3.55693
C	0.85851	-2.24622	3.38751
C	1.81013	2.94957	-2.37320
C	0.68402	2.91776	-3.42377
C	3.00007	3.79757	-2.86839
C	1.38483	2.47319	2.75575
C	2.28965	3.29481	3.69557
C	0.06977	2.07305	3.45273
H	4.78427	-0.57592	-0.01269
H	4.27137	2.15680	0.03873
H	0.12170	4.85386	2.42916
H	-0.28208	6.13049	0.35670
H	0.48881	5.26004	-1.81810

H	2.46782	-4.77159	-2.01502
H	2.07665	-5.95083	0.11579
H	1.94588	-4.69351	2.23498
H	0.76611	-2.27023	-3.22150
H	1.83554	-3.56331	-3.80595
H	1.98071	-1.93162	-4.46536
H	4.99946	-2.07766	-2.22535
H	4.40015	-3.47629	-3.12785
H	4.44357	-1.88102	-3.89715
H	2.28322	-0.94993	2.46644
H	4.34757	-2.20508	3.06051
H	3.37189	-3.47671	3.81319
H	3.36472	-1.84195	4.49250
H	0.01620	-1.94662	2.75528
H	0.71962	-3.29675	3.66603
H	0.82770	-1.65310	4.30858
H	2.16028	1.91970	-2.25991
H	1.07295	2.52336	-4.36901
H	0.28267	3.91698	-3.62496
H	-0.13692	2.27150	-3.10101
H	3.37135	3.40820	-3.82294
H	2.70426	4.84125	-3.02369
H	3.83017	3.79063	-2.15304
H	1.92343	1.54819	2.52454
H	2.51542	2.71904	4.60005
H	1.80520	4.22700	4.00632

H	3.23698	3.55471	3.21070
H	0.28368	1.49617	4.35980
H	-0.50980	2.95484	3.74986
H	-0.55380	1.46089	2.79336
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F	0.32958	-0.07550	-1.90725
O	0.37742	0.00704	0.36649
C	-0.54545	-0.17459	-0.77529
C	-1.23629	-1.47635	-0.64388
C	-1.60174	0.85970	-0.73646
C	-2.38634	-1.72124	-1.44740
H	-0.69320	-2.31271	-0.21931
C	-2.75764	0.68591	-1.55959
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C	-3.11712	-0.62470	-1.99249
H	-2.74906	-2.72779	-1.62348
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O	-4.15677	-0.92872	-2.80173
C	2.81340	-2.11565	-2.46995
H	2.72360	-1.03630	-2.32081
C	-5.09975	0.09821	-3.11078
H	-5.85762	-0.37556	-3.73487
H	-4.62942	0.91591	-3.66888
H	-5.56572	0.48743	-2.19729
R	-3.00534	-0.50459	0.29743
C	-3.75841	0.56904	2.12707

C	-2.99312	-0.57091	2.52857
C	-3.66848	-1.73914	2.03749
C	-4.85437	-1.31662	1.35947
C	-4.90597	0.10787	1.41025
H	-3.35384	-2.76387	2.18455
H	-5.57818	-1.96304	0.88089
H	-5.67528	0.73242	0.97554
H	-2.09202	-0.55714	3.12466
H	-3.51792	1.60253	2.33814

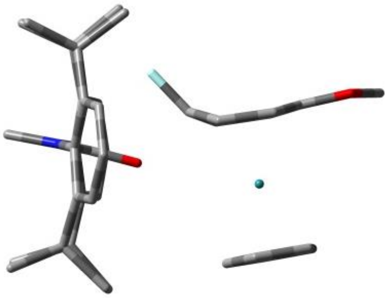
E = – 1969.07312641 a.u. (basis set: Ru: LANL2DZ, other atoms: 6-311++G(d,p))

No imaginary frequencies.

TS2 RuCp 4-methoxyphenol

Spin Muliplicity = 1

Charge = 1



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C	1.42015	2.73589	0.2694
C	2.41654	-2.10638	-0.0618

C	0.97248	3.15858	1.53963
C	0.32445	4.39748	1.61069
C	0.14170	5.18233	0.47391
C	0.60869	4.74578	-0.76206
C	1.26012	3.51185	-0.89785
C	2.46507	-2.72836	-1.32804
C	2.34248	-4.12370	-1.36013
C	2.18689	-4.86249	-0.19000
C	2.16404	-4.22099	1.04566
C	2.28415	-2.82891	1.14175
C	1.69642	-2.31199	-3.73026
C	4.15144	-2.17861	-3.11985
C	2.32459	-2.16528	2.51509
C	3.65551	-2.47719	3.23085
C	1.12219	-2.55876	3.39207
C	1.80595	3.09008	-2.26046
C	0.75602	3.19687	-3.38237
C	3.06275	3.91164	-2.61749
C	1.23683	2.35014	2.80711
C	2.53921	2.82622	3.48604
C	0.06457	2.38353	3.80273
H	4.71670	-0.51390	-0.07486
H	4.15784	2.19248	0.11659
H	-0.03283	4.76034	2.56870
H	-0.35888	6.14314	0.55520
H	0.47198	5.37409	-1.63666

H	2.38076	-4.63935	-2.31457
H	2.09676	-5.94391	-0.24069
H	2.06398	-4.81122	1.95135
H	0.66674	-2.13869	-3.40374
H	1.78479	-3.35693	-4.04697
H	1.87891	-1.68724	-4.61174
H	4.88914	-1.88979	-2.36307
H	4.32494	-3.23206	-3.36802
H	4.33978	-1.58469	-4.02144
H	2.27944	-1.08072	2.37528
H	4.51589	-2.15098	2.63618
H	3.76398	-3.55212	3.41495
H	3.69616	-1.96433	4.19848
H	0.17733	-2.32969	2.88902
H	1.12578	-3.62692	3.63558
H	1.15036	-2.00775	4.33904
H	2.10074	2.03873	-2.20087
H	1.18259	2.83142	-4.32314
H	0.43694	4.23149	-3.54882
H	-0.13004	2.59542	-3.15900
H	3.47730	3.57521	-3.57449
H	2.82314	4.97719	-2.70966
H	3.84390	3.81260	-1.85564
H	1.37813	1.30336	2.51971
H	2.74722	2.22535	4.37887
H	2.45582	3.87445	3.79537

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C	-3.14988	0.78422	-1.41793
H	-1.44788	1.94827	-0.72732
C	-3.61097	-0.49180	-1.84755
H	-3.11077	-2.60127	-1.82514
H	-3.80701	1.64445	-1.41079
O	-4.83522	-0.76262	-2.34544
C	2.70673	-1.95702	-2.62353
H	2.58845	-0.89045	-2.41386
C	-5.80551	0.28714	-2.37850
H	-6.70332	-0.15690	-2.80787
H	-5.46959	1.11602	-3.01164
H	-6.02233	0.65088	-1.36714
Ru	-2.85936	-0.57390	0.32493
C	-3.40615	0.32643	2.28716

C	-2.32563	-0.59360	2.48822
C	-2.79019	-1.89674	2.12266
C	-4.15417	-1.78614	1.70915
C	-4.53605	-0.41255	1.81290
H	-2.21043	-2.80946	2.14825
H	-4.78324	-2.59717	1.36716
H	-5.50867	-0.00381	1.57341
H	-1.33662	-0.34847	2.84603
H	-3.38134	1.39085	2.47872

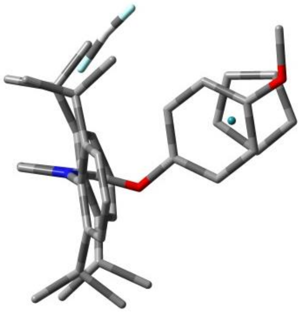
E = – 1969.06194725 a.u. (basis set: Ru: LANL2DZ, other atoms: 6-311++G(d,p))

Imaginary frequency: – 295.5 cm^{-1}

Uronium bifluoride RuCp 4-methoxyphenol

Spin Multiplicity = 1

Charge = 1



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C	-3.05019	-1.06896	0.09744
C	-0.10233	2.90985	0.57166

C	-2.95479	-2.27037	0.83208
C	-3.59944	-3.39143	0.29053
C	-4.30710	-3.31844	-0.90492
C	-4.40746	-2.10784	-1.58521
C	-3.79345	-0.94827	-1.09713
C	-0.09461	3.60378	-0.65899
C	0.92781	4.54000	-0.85840
C	1.87628	4.79622	0.12764
C	1.81045	4.12801	1.34650
C	0.82076	3.16940	1.60967
C	-0.56495	3.07296	-3.10507
C	-2.02135	4.72650	-1.83750
C	0.76341	2.52550	2.99202
C	0.34045	3.56816	4.04807
C	2.09420	1.85747	3.38384
C	-4.01444	0.37278	-1.82839
C	-3.59299	0.30200	-3.30777
C	-5.48229	0.82796	-1.68952
C	-2.23845	-2.38796	2.17084
C	-3.25421	-2.37300	3.33401
C	-1.35516	-3.65193	2.26100
H	-2.28193	2.93198	2.33709
H	-3.87807	0.67363	2.12383
H	-3.54427	-4.33493	0.82398
H	-4.79610	-4.20394	-1.30110
H	-4.98659	-2.05610	-2.50185

H	0.96644	5.09279	-1.79182
H	2.65513	5.53315	-0.04696
H	2.53640	4.35803	2.1199
H	0.04033	2.16299	-3.03677
H	0.06862	3.87355	-3.50192
H	-1.36611	2.89780	-3.83126
H	-2.48146	4.97452	-0.87498
H	-1.41976	5.58601	-2.15266
H	-2.82137	4.58868	-2.57374
H	0.04100	1.70922	2.98652
H	-0.62146	4.03490	3.80299
H	1.07908	4.37312	4.14253
H	0.24115	3.08734	5.02745
H	2.32935	1.04048	2.69604
H	2.93333	2.56266	3.40496
H	1.99905	1.41930	4.38253
H	-3.40105	1.14495	-1.35449
H	-3.72028	1.28091	-3.78332
H	-4.20061	-0.41674	-3.86793
H	-2.54305	0.00752	-3.41009
H	-5.62478	1.80262	-2.16967
H	-6.16574	0.11556	-2.16440
H	-5.77200	0.91979	-0.63692
H	-1.57523	-1.53048	2.31250
H	-3.84610	-1.45065	3.35430
H	-3.95253	-3.21598	3.26537

H	-2.72282	-2.44828	4.28909
H	-0.59011	-3.50057	3.02708
H	-1.93746	-4.54760	2.50851
H	-0.83452	-3.84461	1.31600
C	-1.30519	0.74133	0.17941
O	-0.58377	0.37255	-0.88681
C	0.22483	-0.76634	-0.86339
C	0.60008	-1.29790	-2.12092
C	0.70439	-1.31646	0.33921
C	1.40710	-2.46427	-2.15400
H	0.28104	-0.81750	-3.03802
C	1.50444	-2.48843	0.29715
H	0.46065	-0.85492	1.31031
C	1.79149	-3.12249	-0.94503
H	1.71144	-2.89408	-3.10096
C	-1.16411	3.44752	-1.73644
H	-1.84031	2.63847	-1.44963
F	1.32706	-2.11856	3.24258
H	1.83990	-2.86517	1.25643
O	2.47489	-4.26251	-1.08651
C	3.01577	-4.89283	0.08786
H	3.52038	-5.78779	-0.27321
H	2.21763	-5.16940	0.78306
H	3.73472	-4.23090	0.58155
C	4.46067	-0.45882	-1.99995
C	3.67637	0.73809	-1.99983

C	4.71884	-0.81849	-0.64024
C	3.45131	1.12176	-0.63932
C	4.09356	0.15856	0.20236
Ru	2.52437	-0.87414	-0.97242
H	4.78918	-1.00450	-2.87431
H	3.31617	1.25985	-2.87630
H	2.88699	1.98118	-0.30362
H	4.10259	0.16409	1.28363
H	5.28482	-1.67788	-0.30643
F	-0.08479	-0.30450	2.80380
H	0.69919	-1.29927	3.14733

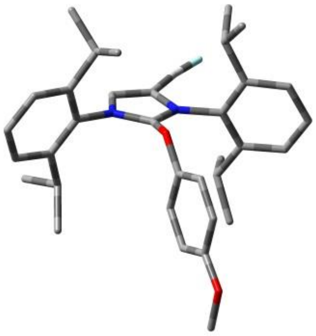
E = – 2069.58422372 a.u. (basis set: Ru: LANL2DZ, other atoms: 6-311++G(d,p))

No imaginary frequencies.

Uronium fluoride 4-methoxyphenol

Spin Multiplicity = 1

Charge = 0



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C	0.22640	-1.90675	1.80215

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C	2.08534	-1.16248	0.23215
C	-2.76240	-0.34089	0.35959
C	3.01356	-0.31797	0.87050
C	4.30800	-0.27026	0.33774
C	4.66405	-1.04427	-0.76255
C	3.74361	-1.92375	-1.32613
C	2.43758	-2.01528	-0.83183
C	-3.44035	-1.01434	-0.67668
C	-4.72731	-0.56732	-1.00005
C	-5.32058	0.48482	-0.30923
C	-4.63601	1.11396	0.72664
C	-3.34112	0.72039	1.08571
C	-2.64527	-1.88030	-2.92323
C	-3.69889	-3.46982	-1.23971
C	-2.63342	1.41618	2.24519
C	-3.27698	1.03285	3.59352
C	-2.59808	2.94676	2.07296
C	1.49751	-3.10947	-1.32349
C	1.52356	-3.32050	-2.84532
C	1.82482	-4.41216	-0.55679
C	2.69086	0.41665	2.16684
C	3.21424	-0.41974	3.35731
C	3.23351	1.85483	2.21765
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H	1.15404	-2.75754	2.39935

H	5.05100	0.37150	0.80072
H	5.67276	-0.98536	-1.16296
H	4.05008	-2.56275	-2.14825
H	-5.27467	-1.05813	-1.79942
H	-6.32260	0.81128	-0.57381
H	-5.11461	1.92519	1.26692
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H	-3.60093	-1.68007	-3.42143
H	-2.17520	-2.72951	-3.43247
H	-3.81128	-3.71849	-0.17897
H	-4.70146	-3.35060	-1.66627
H	-3.22303	-4.32112	-1.73956
H	-1.59678	1.06487	2.27344
H	-3.25930	-0.05039	3.75301
H	-4.32154	1.36257	3.64044
H	-2.73623	1.50580	4.42121
H	-2.14556	3.23250	1.11783
H	-3.60211	3.38331	2.11327
H	-2.01181	3.40041	2.88051
H	0.47292	-2.82901	-1.05899
H	0.76924	-4.06298	-3.13046
H	2.49243	-3.69692	-3.19252
H	1.30765	-2.39119	-3.38483
H	1.07639	-5.18387	-0.77649
H	2.80540	-4.79636	-0.86525
H	1.85698	-4.23529	0.52438

H	1.60135	0.47124	2.26592
H	2.86514	-1.45543	3.29341
H	4.31176	-0.42942	3.35930
H	2.88076	0.01963	4.30601
H	2.89004	2.34791	3.13479
H	4.32910	1.87674	2.23328
H	2.89634	2.44815	1.36101
C	-0.29485	-0.52937	0.07258
O	-0.24284	0.08058	-1.11764
C	0.22592	1.40063	-1.26209
C	0.51287	1.79185	-2.56970
C	0.35912	2.28660	-0.20470
C	0.93587	3.09046	-2.81472
H	0.40327	1.07692	-3.37850
C	0.78944	3.59673	-0.45181
H	0.13757	1.97721	0.81095
C	1.07780	4.00527	-1.75814
H	1.16606	3.41866	-3.82309
C	-2.84530	-2.20043	-1.42929
H	-1.86012	-2.41881	-1.00667
F	2.03693	-3.39716	2.65575
H	0.89057	4.27837	0.38414
O	1.49851	5.25399	-2.10822
C	1.66595	6.22031	-1.07808
H	2.00653	7.12998	-1.57481
H	2.41992	5.90099	-0.34750

H	0.71996	6.42193	-0.55947

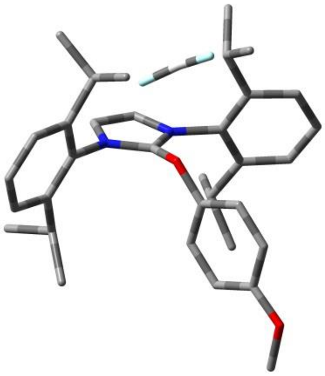
E = – 1681.72247367 a.u. (basis set: 6-311++G(d,p))

No imaginary frequencies.

Uronium bifluoride 4-methoxyphenol

Spin Multiplicity = 1

Charge = 0



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C	1.95682	-1.04169	0.02927
C	-2.90934	-0.24545	0.33226
C	2.91539	-0.33610	0.77972
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C	4.53067	-0.89083	-0.95265
C	3.56654	-1.61648	-1.64458
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C	-3.62492	-0.83473	-0.72859

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C	-5.47524	0.64656	-0.18129
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C	-3.44630	0.76514	1.15572
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C	-3.90841	-3.24437	-1.45233
C	-2.69140	1.36860	2.33679
C	-3.29511	0.89787	3.67595
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C	1.26927	-2.64470	-1.87141
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C	3.16169	-0.64247	3.26721
C	3.18825	1.70196	2.29576
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H	-5.49852	-0.78145	-1.78272
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H	-5.19921	1.96740	1.48649
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H	0.28391	-2.51821	-1.41109
H	0.36834	-2.98377	-3.82093
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H	2.93995	-0.19782	4.24615
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H	4.28382	1.70510	2.31012
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H	2.24899	-3.62802	2.24844

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C	0.18814	1.58296	-1.20551
C	0.59409	1.99541	-2.47296
C	0.31930	2.40948	-0.10122
C	1.14429	3.25976	-2.62922
H	0.47678	1.32862	-3.32058
C	0.87965	3.68289	-0.25865
H	-0.00097	2.08264	0.88226
C	1.29299	4.11456	-1.52417
H	1.47131	3.60629	-3.60398
H	0.98073	4.31980	0.61165
O	1.84369	5.33109	-1.78808
C	-3.06602	-1.96100	-1.59171
H	-2.06031	-2.20475	-1.23627
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C	2.03151	6.23655	-0.70600
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H	1.07597	6.50544	-0.23835

E = – 1782.25002457 a. u. (basis set: 6-311++G(d,p))

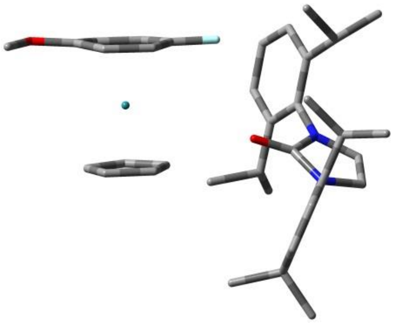
No imaginary frequencies.

Product complex RuCp 4-fluroanisole PhenoFluor-urea

PhenoFluor-urea = 1,3-bis(2,6-diisopropylphenyl)-1,3-dihydro-2H-imidazol-2-one

Spin Multiplicity = 1

Charge = 1



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H	-4.92319	1.86854	0.78018
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H	-2.86622	-4.41803	-2.83518
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H	-1.73705	3.55602	4.53463
H	-3.35166	3.13731	3.93934
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H	-3.49726	4.99757	-2.51112
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C	3.89876	-0.25893	1.84615
C	4.21364	-2.12087	-0.26703
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C	5.13374	-0.33481	1.14406
H	3.74867	0.47154	2.63243

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H	4.33685	-2.80105	-1.10151
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H	4.34172	0.58680	-3.12192
H	4.68060	2.55559	-1.30095
H	0.66033	0.88931	-0.76097
H	2.40516	2.75772	0.14379

E = – 1969.12098190 a.u. (basis set: Ru: LANL2DZ, other atoms: 6-311++G(d,p))

No imaginary frequencies

Intrinsic reaction coordinates

We were able to localize two transition states by DFT (**TS1** and **TS2**) for the ruthenium-mediated deoxyfluorination reaction. Intrinsic reaction coordinates (IRCs) were generated for both transition states and

TS1 was shown to interconnect the tetrahedral adduct with the Meisenheimer intermediate while **TS2** interconnects the Meisenheimer intermediate with the reaction products.

Activation barriers for ruthenium-mediated deoxyfluorination

The following activation barriers were obtained from the single point energies of the tetrahedral adduct and **TS1** (first barrier) and the Meisenheimer intermediate and **TS2** (second barrier), respectively. The values quoted below differ from, and are more accurate than, those quoted in Figure S65 because the values quoted below were obtained with a larger (LANL2DZ (ruthenium), 6-311+G(d,p) (other atoms)) basis set. The energy diagram was obtained by combining the intrinsic reaction coordinates obtained from **TS1** and **TS2.** IRC points were calculated using B3LYP with a split basis set (LANL2DZ for ruthenium and 6-31G(d) for other atoms) and a toluene continuous solvent model.

First barrier: 5.3 kcal·mol^{-1}

Second barrier: 7.0 kcal·mol^{-1}

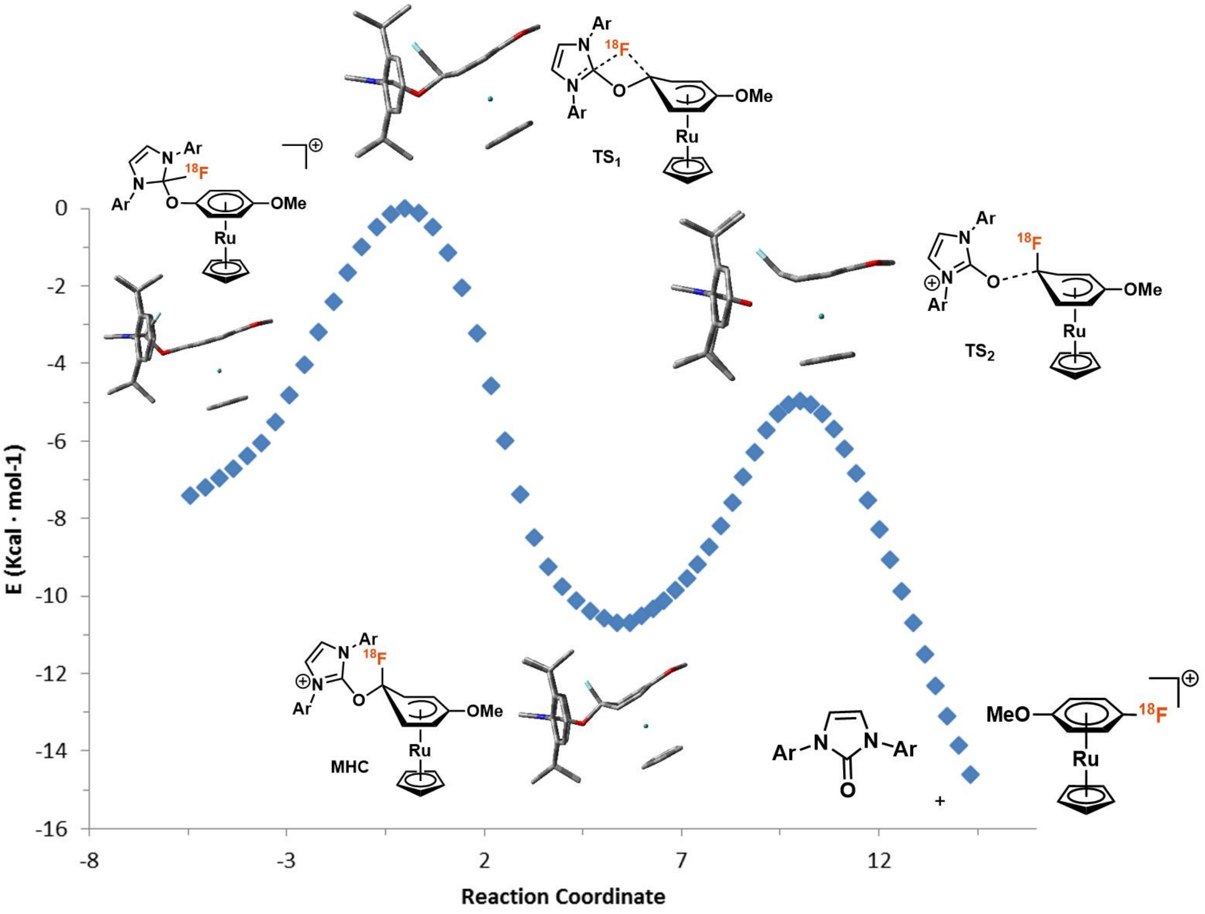
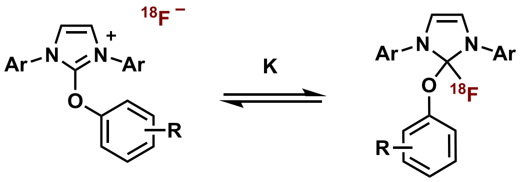


Figure S65. Calculated enery diagram for ruthenium-mediated deoxyfluorination.

Tetrahedral adduct stabilization through ruthenium incorporation

We have established in our earlier work[15] on uronium-mediated deoxyfluorination that an equilibrium exists between a tetrahedral adduct structure and an uronium fluoride structure. ^{18}F-Deoxyfluorination of electron-rich phenols had not been possible prior to this work because ^{18}F^{-} undergoes unproductive side reactions in the absence of added fluoride salt. Electron-rich phenol substrates decrease the equilibrium constant K and lead to a build-up of uronium fluoride **a**. The basic fluoride is liable to undergo undesirable side reactions and decrease the radiochemical yield.



^{18}F-a **^{18}F-b**

The dynamic equilibrium, which exists between **^{18}F-a** and **^{18}F-b** is affected by the phenol substituent R as well as by complexation of the phenol to RuCp.

In the present work, the presence of RuCp increases the equilibrium constant substantially and ensures the stability of the tetrahedral adduct structure even in the case of highly electron-rich substrates. We have calculated ground state structures for the uronium fluoride and tetrahedral adduct structures in the presence and absence of RuCp to showcase the effect of the introduction of RuCp on the equilibrium position. (Figure S66)

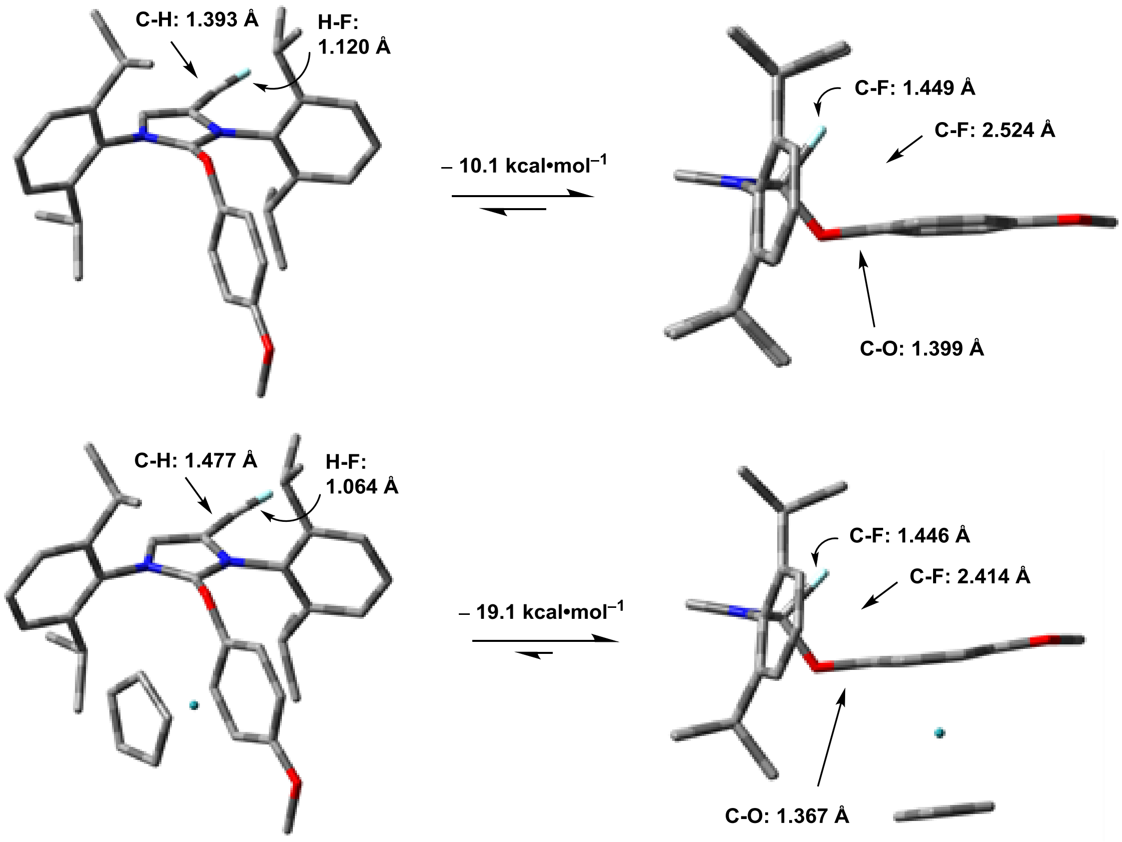


Figure S66. Uronium fluoride and tetrahedral adduct optimized structures.

Uronium fluoride and tetrahedral adduct structures were optimized with B3LYP/(LANL2DZ, 6-31G(d)) and a toluene solvent model and single point energies were calculated at B3LYP/(LANL2DZ, 6-311++G(d,p)). A relative stabilization of the tetrahedral adduct over the uronium fluoride structure occurs upon introduction of the RuCp fragment.

Further evidence of the power of the RuCp fragment to ‘localize’ the fluoride (containing) anion close to the imidazolium core comes from the uronium bifluoride structures in the presence and absence of RuCp. We have previously studied the uronium bifluoride structure in detail, both in solution and in the solid state and we have collected a wealth of data supporting that the bifluoride anion is attached *via* a hydrogen bond to the uronium backbone. Complexation to the RuCp fragment leads to a uronium bifluoride structure where bifluoride is located above the imidazolium core, close to its central carbon atom. This arrangement positions the counteranion favorably for formation of the tetrahedral adduct, which corresponds the energy minimum immediately proceeding the C–F bond forming transition state. (Figure S67)

Figure S67. The structures of uronium bifluoride (left) and RuCp uronium bifluoride (right) differ in the location of the bifluoride counteranion.

X-Ray Crystallography

X-ray crystallographic data have been deposited in the Cambridge Crystallographic Data Centre database with accession numbers CCDC 1544015 (**5**) and CCDC 1544723 (**6**).

A crystal mounted on a diffractometer was collected data at 100 K. The intensities of the reflections were collected by means of a Bruker APEX II CCD diffractometer ($Mo_{K\alpha}$ radiation, λ=0.71073 Å), and equipped with an Oxford Cryosystems nitrogen flow apparatus. The collection method involved 0.5° scans in ω at 28° in 2θ. Data integration down to 0.78 Å resolution was carried out by SAINT V8.37A (Bruker AXS APEX3, Bruker AXS, Madison, Wisconsin, 2016) with reflection spot size optimization. Absorption corrections were made with the program SADABS (Bruker AXS APEX3, Bruker AXS, Madison, Wisconsin, 2016). The structure was solved by the Intrinsic Phasing methods and refined by least-squares methods again F^2 with SHELXT-2014[16] and SHELXL-2014[16] with OLEX 2 interface.[17] Non-hydrogen atoms were refined anisotropically, and hydrogen atoms were allowed to ride on the respective atoms. Crystal data as well as details of data collection and refinement are summarized in Tables S2 and S5 (for compounds **5** and **6** respectively), geometric parameters are shown in Tables S3 and S6 (for compounds **5** and **6** respectively) and hydrogen-bond parameters are listed in Tables S4 and S7 (for compounds **5** and **6** respectively). The Ortep plots produced with SHELXL-2014 program, and the other drawings were produced with Accelrys DS Visualizer 2.0.[18]

Table S2. Experimental details.

Compound Number	**5**
CCDC Number	1544015
Crystal data	
Chemical formula	$C_{16}H_{19}Cl_7ORu$
M_r	576.53
Crystal system, space group	Monoclinic, $P2_1/n$
Temperature (K)	100
a, *b*, *c* (Å)	16.0893 (8), 8.7477 (4), 16.6789 (8)
β (°)	110.0404 (7)
V (Å^3)	2205.32 (18)
Z	4
Radiation type	Mo $K\alpha$

μ (mm^{-1})	1.56
Crystal size (mm)	0.14 × 0.12 × 0.10
Data collection	
Diffractometer	Bruker D8 goniometer with CCD area detector
Absorption correction	Multi-scan *SADABS*
$T_{\min}$, $T_{\max}$	0.441, 0.491
No. of measured, independent and observed [$I > 2\sigma(I)$] reflections	34295, 4883, 4168
R_{int}	0.032
$(\sin \theta/\lambda)_{\max}$ (Å^{-1})	0.642
Refinement	
$R[F^2 > 2\sigma(F^2)]$, $wR(F^2)$, S	0.041, 0.093, 1.02
No. of reflections	4883
No. of parameters	289
No. of restraints	271
H-atom treatment	H atoms treated by a mixture of independent and constrained refinement
$\Delta\rho_{\max}$, $\Delta\rho_{\min}$ (e Å^{-3})	1.45, -1.05

Computer programs: *APEX3* v2016.1-0 (Bruker-AXS, 2016), *SAINT* 8.35A (Bruker-AXS, 2015), *SHELXT2014* (Sheldrick, 2015), *SHELXL2014* (Sheldrick, 2015), Bruker *SHELXTL* (Sheldrick, 2015).

Table S3. Geometric parameters (Å, º).

Ru1—C12A	2.15 (3)	C12—H12	0.9500
Ru1—C14A	2.16 (3)	C13—C14	1.426 (10)
Ru1—C11	2.166 (5)	C13—H13	0.9500
Ru1—C13A	2.17 (4)	C14—C15	1.411 (9)
Ru1—C15	2.171 (5)	C14—H14	0.9500

Ru1—C12	2.173 (5)	C15—H15	0.9500
Ru1—C14	2.174 (5)	C11A—C15A	1.34 (5)
Ru1—C13	2.182 (5)	C11A—C12A	1.35 (5)
Ru1—C15A	2.18 (3)	C11A—H11A	0.9500
Ru1—C11A	2.18 (3)	C12A—C13A	1.32 (6)
Ru1—C3	2.203 (3)	C12A—H12A	0.9500
Ru1—C2	2.206 (3)	C13A—C14A	1.36 (5)
O1—C1	1.345 (4)	C13A—H13A	0.9500
O1—H1	0.80 (5)	C14A—C15A	1.35 (5)
C1—C6	1.411 (5)	C14A—H14A	0.9500
C1—C2	1.414 (5)	C15A—H15A	0.9500
C2—C3	1.415 (5)	C21—Cl4	1.738 (5)
C2—H2	0.9500	C21—Cl3	1.749 (5)
C3—C4	1.426 (5)	C21—Cl2	1.754 (5)
C3—C7	1.510 (5)	C21—H21	1.0000
C4—C5	1.429 (5)	C21A—Cl3A	1.750 (16)
C4—C8	1.503 (5)	C21A—Cl2A	1.757 (15)
C5—C6	1.418 (5)	C21A—Cl4A	1.763 (16)
C5—C9	1.496 (5)	C21A—H21A	1.0000
C6—H6	0.9500	Cl3A—Cl7A^{i}	2.378 (16)
C7—H7A	0.9800	C22—Cl5	1.754 (6)
C7—H7B	0.9800	C22—Cl6	1.758 (7)
C7—H7C	0.9800	C22—Cl7	1.787 (7)
C8—H8A	0.9800	C22—H22	1.0000
C8—H8B	0.9800	C22A—Cl6A	1.761 (15)
C8—H8C	0.9800	C22A—Cl5A	1.764 (15)
C9—H9A	0.9800	C22A—Cl7A	1.772 (15)

C9—H9B	0.9800	C22A—H22A	1.0000
C9—H9C	0.9800	Cl7A—Cl3A^{i}	2.378 (16)
C11—C15	1.418 (9)	C22B—Cl7B	1.751 (16)
C11—C12	1.424 (8)	C22B—Cl6B	1.751 (16)
C11—H11	0.9500	C22B—Cl5B	1.761 (15)
C12—C13	1.422 (9)	C22B—H22B	1.0000
C12A—Ru1—C14A	60.4 (15)	H9A—C9—H9C	109.5
C12A—Ru1—C13A	35.7 (15)	H9B—C9—H9C	109.5
C14A—Ru1—C13A	36.5 (14)	C15—C11—C12	107.8 (5)
C11—Ru1—C15	38.2 (2)	C15—C11—Ru1	71.1 (3)
C11—Ru1—C12	38.3 (2)	C12—C11—Ru1	71.1 (3)
C15—Ru1—C12	63.8 (2)	C15—C11—H11	126.1
C11—Ru1—C14	63.8 (2)	C12—C11—H11	126.1
C15—Ru1—C14	37.9 (2)	Ru1—C11—H11	123.3
C12—Ru1—C14	63.8 (2)	C13—C12—C11	108.1 (5)
C11—Ru1—C13	64.0 (2)	C13—C12—Ru1	71.3 (3)
C15—Ru1—C13	63.8 (2)	C11—C12—Ru1	70.6 (3)
C12—Ru1—C13	38.1 (2)	C13—C12—H12	126.0
C14—Ru1—C13	38.2 (3)	C11—C12—H12	126.0
C12A—Ru1—C15A	59.6 (15)	Ru1—C12—H12	123.8
C14A—Ru1—C15A	36.1 (13)	C12—C13—C14	107.5 (5)
C13A—Ru1—C15A	59.8 (14)	C12—C13—Ru1	70.6 (3)
C12A—Ru1—C11A	36.3 (13)	C14—C13—Ru1	70.6 (3)
C14A—Ru1—C11A	60.7 (13)	C12—C13—H13	126.2
C13A—Ru1—C11A	60.3 (15)	C14—C13—H13	126.2
C15A—Ru1—C11A	35.8 (13)	Ru1—C13—H13	124.2
C12A—Ru1—C3	150.4 (17)	C15—C14—C13	108.3 (5)

C14A—Ru1—C3	108.6 (10)	C15—C14—Ru1	71.0 (3)
C11—Ru1—C3	145.5 (3)	C13—C14—Ru1	71.2 (3)
C13A—Ru1—C3	118.5 (16)	C15—C14—H14	125.9
C15—Ru1—C3	114.2 (2)	C13—C14—H14	125.9
C12—Ru1—C3	169.9 (3)	Ru1—C14—H14	123.6
C14—Ru1—C3	108.2 (2)	C14—C15—C11	108.3 (5)
C13—Ru1—C3	131.8 (3)	C14—C15—Ru1	71.1 (3)
C15A—Ru1—C3	129.3 (13)	C11—C15—Ru1	70.7 (3)
C11A—Ru1—C3	164.9 (16)	C14—C15—H15	125.9
C12A—Ru1—C2	169.3 (15)	C11—C15—H15	125.9
C14A—Ru1—C2	113.4 (14)	Ru1—C15—H15	123.9
C11—Ru1—C2	117.5 (3)	C15A—C11A—C12A	106 (3)
C13A—Ru1—C2	143.7 (18)	C15A—C11A—Ru1	72 (2)
C15—Ru1—C2	106.42 (18)	C12A—C11A—Ru1	70.5 (18)
C12—Ru1—C2	152.0 (3)	C15A—C11A—H11A	126.9
C14—Ru1—C2	125.9 (3)	C12A—C11A—H11A	126.9
C13—Ru1—C2	163.4 (4)	Ru1—C11A—H11A	122.2
C15A—Ru1—C2	110.1 (9)	C13A—C12A—C11A	110 (3)
C11A—Ru1—C2	133.7 (13)	C13A—C12A—Ru1	73 (2)
C3—Ru1—C2	37.45 (13)	C11A—C12A—Ru1	73 (2)
C1—O1—H1	113 (3)	C13A—C12A—H12A	125.2
O1—C1—C6	118.4 (3)	C11A—C12A—H12A	125.2
O1—C1—C2	122.5 (3)	Ru1—C12A—H12A	120.4
C6—C1—C2	118.9 (3)	C12A—C13A—C14A	108 (3)
O1—C1—Ru1	131.2 (2)	C12A—C13A—Ru1	71 (2)
C6—C1—Ru1	69.51 (19)	C14A—C13A—Ru1	72 (2)
C2—C1—Ru1	69.18 (19)	C12A—C13A—H13A	126.0

C1—C2—C3	120.9 (3)	C14A—C13A—H13A	126.0
C1—C2—Ru1	73.99 (19)	Ru1—C13A—H13A	122.7
C3—C2—Ru1	71.18 (19)	C15A—C14A—C13A	107 (3)
C1—C2—H2	119.6	C15A—C14A—Ru1	73 (2)
C3—C2—H2	119.6	C13A—C14A—Ru1	72 (2)
Ru1—C2—H2	127.3	C15A—C14A—H14A	126.7
C2—C3—C4	120.0 (3)	C13A—C14A—H14A	126.7
C2—C3—C7	118.3 (3)	Ru1—C14A—H14A	120.6
C4—C3—C7	121.7 (3)	C11A—C15A—C14A	110 (3)
C2—C3—Ru1	71.37 (19)	C11A—C15A—Ru1	72.1 (19)
C4—C3—Ru1	72.59 (19)	C14A—C15A—Ru1	71 (2)
C7—C3—Ru1	128.3 (3)	C11A—C15A—H15A	125.2
C3—C4—C5	119.2 (3)	C14A—C15A—H15A	125.2
C3—C4—C8	121.7 (3)	Ru1—C15A—H15A	123.0
C5—C4—C8	119.2 (3)	Cl4—C21—Cl3	110.2 (3)
C3—C4—Ru1	69.96 (19)	Cl4—C21—Cl2	110.7 (3)
C5—C4—Ru1	70.90 (19)	Cl3—C21—Cl2	110.6 (3)
C8—C4—Ru1	131.5 (2)	Cl4—C21—H21	108.4
C6—C5—C4	119.7 (3)	Cl3—C21—H21	108.4
C6—C5—C9	119.5 (3)	Cl2—C21—H21	108.4
C4—C5—C9	120.8 (3)	Cl3A—C21A—Cl2A	107.7 (11)
C6—C5—Ru1	70.85 (19)	Cl3A—C21A—Cl4A	110.4 (11)
C4—C5—Ru1	71.76 (19)	Cl2A—C21A—Cl4A	110.6 (11)
C9—C5—Ru1	130.3 (2)	Cl3A—C21A—H21A	109.4
C1—C6—C5	121.0 (3)	Cl2A—C21A—H21A	109.4
C1—C6—Ru1	73.79 (19)	Cl4A—C21A—H21A	109.4
C5—C6—Ru1	71.90 (19)	C21A—Cl3A—Cl7A^{i}	170.3 (8)

C1—C6—H6	119.5	Cl5—C22—Cl6	111.3 (4)
C5—C6—H6	119.5	Cl5—C22—Cl7	108.3 (4)
Ru1—C6—H6	126.8	Cl6—C22—Cl7	110.7 (4)
C3—C7—H7A	109.5	Cl5—C22—H22	108.8
C3—C7—H7B	109.5	Cl6—C22—H22	108.8
H7A—C7—H7B	109.5	Cl7—C22—H22	108.8
C3—C7—H7C	109.5	Cl6A—C22A—Cl5A	107.8 (11)
H7A—C7—H7C	109.5	Cl6A—C22A—Cl7A	105.9 (10)
H7B—C7—H7C	109.5	Cl5A—C22A—Cl7A	110.9 (12)
C4—C8—H8A	109.5	Cl6A—C22A—H22A	110.7
C4—C8—H8B	109.5	Cl5A—C22A—H22A	110.7
H8A—C8—H8B	109.5	Cl7A—C22A—H22A	110.7
C4—C8—H8C	109.5	C22A—Cl7A—Cl3A^{i}	168.9 (9)
H8A—C8—H8C	109.5	Cl7B—C22B—Cl6B	112.6 (13)
H8B—C8—H8C	109.5	Cl7B—C22B—Cl5B	111.2 (12)
C5—C9—H9A	109.5	Cl6B—C22B—Cl5B	108.6 (11)
C5—C9—H9B	109.5	Cl7B—C22B—H22B	108.1
H9A—C9—H9B	109.5	Cl6B—C22B—H22B	108.1
C5—C9—H9C	109.5	Cl5B—C22B—H22B	108.1
O1—C1—C2—C3	177.9 (3)	C4—C5—C6—Ru1	54.6 (3)
C6—C1—C2—C3	-5.4 (5)	C9—C5—C6—Ru1	-126.2 (3)
Ru1—C1—C2—C3	-55.8 (3)	C15—C11—C12—C13	0.3 (5)
O1—C1—C2—Ru1	-126.3 (3)	Ru1—C11—C12—C13	-61.7 (3)
C6—C1—C2—Ru1	50.3 (3)	C15—C11—C12—Ru1	62.0 (3)
C1—C2—C3—C4	1.1 (5)	C11—C12—C13—C14	0.0 (5)
Ru1—C2—C3—C4	-56.0 (3)	Ru1—C12—C13—C14	-61.3 (3)
C1—C2—C3—C7	-178.7 (3)	C11—C12—C13—Ru1	61.3 (3)

Ru1—C2—C3—C7	124.2 (3)	C12—C13—C14—C15	-0.3 (6)
C1—C2—C3—Ru1	57.1 (3)	Ru1—C13—C14—C15	-61.6 (4)
C2—C3—C4—C5	2.5 (5)	C12—C13—C14—Ru1	61.3 (3)
C7—C3—C4—C5	-177.7 (3)	C13—C14—C15—C11	0.5 (6)
Ru1—C3—C4—C5	-53.0 (3)	Ru1—C14—C15—C11	-61.3 (4)
C2—C3—C4—C8	-177.4 (3)	C13—C14—C15—Ru1	61.8 (4)
C7—C3—C4—C8	2.4 (5)	C12—C11—C15—C14	-0.4 (6)
Ru1—C3—C4—C8	127.1 (3)	Ru1—C11—C15—C14	61.6 (4)
C2—C3—C4—Ru1	55.4 (3)	C12—C11—C15—Ru1	-62.0 (3)
C7—C3—C4—Ru1	-124.8 (3)	C15A—C11A—C12A—C13A	-1 (4)
C3—C4—C5—C6	-1.6 (5)	Ru1—C11A—C12A—C13A	-64 (3)
C8—C4—C5—C6	178.3 (3)	C15A—C11A—C12A—Ru1	64 (2)
Ru1—C4—C5—C6	-54.2 (3)	C11A—C12A—C13A—C14A	2 (4)
C3—C4—C5—C9	179.2 (3)	Ru1—C12A—C13A—C14A	-63 (3)
C8—C4—C5—C9	-1.0 (5)	C11A—C12A—C13A—Ru1	65 (2)
Ru1—C4—C5—C9	126.6 (3)	C12A—C13A—C14A—C15A	-2 (4)
C3—C4—C5—Ru1	52.5 (3)	Ru1—C13A—C14A—C15A	-65 (3)
C8—C4—C5—Ru1	-127.6 (3)	C12A—C13A—C14A—Ru1	62 (3)
O1—C1—C6—C5	-176.9 (3)	C12A—C11A—C15A—C14A	-1 (4)
C2—C1—C6—C5	6.3 (5)	Ru1—C11A—C15A—C14A	62 (3)
Ru1—C1—C6—C5	56.5 (3)	C12A—C11A—C15A—Ru1	-63 (2)
O1—C1—C6—Ru1	126.6 (3)	C13A—C14A—C15A—C11A	2 (4)
C2—C1—C6—Ru1	-50.2 (3)	Ru1—C14A—C15A—C11A	-62 (3)
C4—C5—C6—C1	-2.8 (5)	C13A—C14A—C15A—Ru1	64 (3)

C9—C5—C6—C1	176.5 (3)	Cl6A—C22A—Cl7A—Cl3A^{i}	128 (4)
Ru1—C5—C6—C1	-57.4 (3)	Cl5A—C22A—Cl7A—Cl3A^{i}	-115 (4)

Symmetry code(s): (i) -*x*+1, -*y*+1, -*z*+2.

Table S4. Hydrogen-bond parameters.

D—H···*A*	*D*—H (Å)	H···*A* (Å)	*D*···*A* (Å)	*D*—H···*A* (°)
O1—H1···Cl1	0.80 (5)	2.20 (5)	3.003 (3)	175 (5)

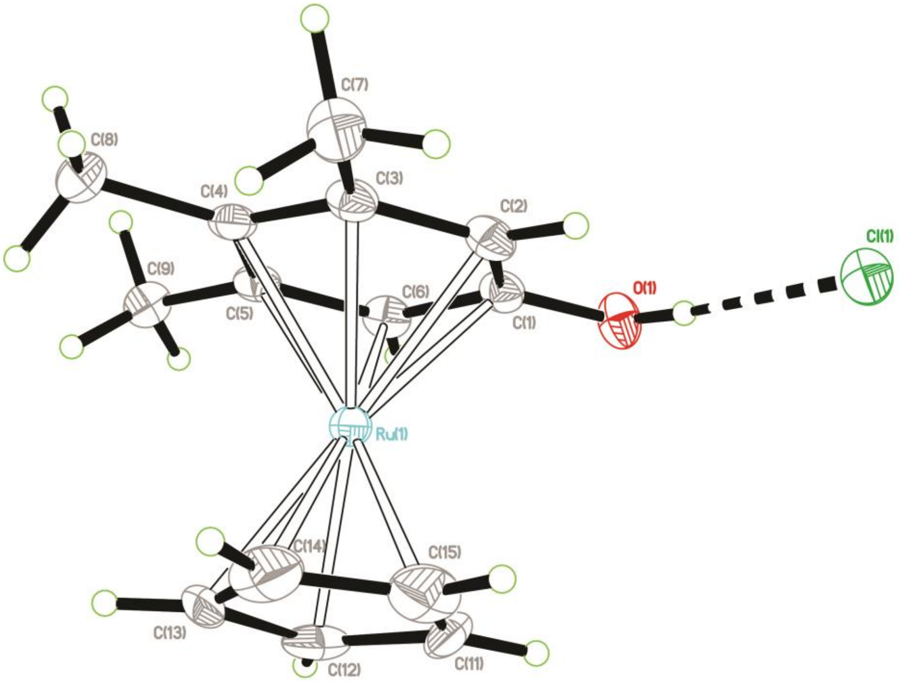


Figure S68. Perspective view of **5** showing 50% probability displacement.

Table S5. Experimental details

Compound Number	**6**
CCDC Number	1544723
Crystal data	
Chemical formula	$C_{28}H_{36}Cl_2F_2O_2Ru_2$
M_r	715.61
Crystal system, space group	Tetragonal, $P4_12_12$

Temperature (K)	100
a, c (Å)	14.7499 (9), 25.5756 (16)
V (Å^3)	5564.2 (8)
Z	8
Radiation type	Mo $K\alpha$
μ (mm^{-1})	1.32
Crystal size (mm)	0.12 × 0.10 × 0.06
Data collection	
Diffractometer	Bruker D8 goniometer with CCD area detector
Absorption correction	Multi-scan *SADABS*
$T_{\min}$, $T_{\max}$	0.698, 0.746
No. of measured, independent and observed [$I > 2\sigma(I)$] reflections	88879, 6650, 6357
R_{int}	0.039
$(\sin \theta/\lambda)_{\max}$ (Å^{-1})	0.658
Refinement	
$R[F^2 > 2\sigma(F^2)]$, $wR(F^2)$, S	0.017, 0.041, 1.04
No. of reflections	6650
No. of parameters	349
H-atom treatment	H atoms treated by a mixture of independent and constrained refinement
$\Delta\rho_{\max}$, $\Delta\rho_{\min}$ (e Å^{-3})	0.76, -0.30
Absolute structure	Refined as an inversion twin.
Absolute structure parameter	0.44 (3)

Computer programs: *APEX3* v2016.9-0 (Bruker-AXS, 2016), *SAINT* 8.37A (Bruker-AXS, 2015), *SHELXT2014* (Sheldrick, 2015), *SHELXL2014* (Sheldrick, 2015), Bruker *SHELXTL* (Sheldrick, 2015).

Table S6. Geometric parameters (Å, º)

Ru1—C4	2.168 (3)	Ru2—C22	2.176 (3)
Ru1—C3	2.170 (3)	Ru2—C25	2.176 (3)
Ru1—C1	2.176 (3)	Ru2—C23	2.179 (3)
Ru1—C2	2.179 (3)	Ru2—C26	2.185 (3)
Ru1—C5	2.182 (3)	Ru2—C29	2.206 (3)
Ru1—C6	2.193 (2)	Ru2—C31	2.209 (3)
Ru1—C7	2.210 (3)	Ru2—C27	2.210 (3)
Ru1—C8	2.213 (3)	Ru2—C30	2.218 (3)
Ru1—C9	2.216 (2)	Ru2—C28	2.219 (3)
Ru1—C11	2.222 (3)	F2—C26	1.351 (3)
Ru1—C10	2.223 (3)	C21—C22	1.416 (5)
F1—C6	1.354 (3)	C21—C25	1.420 (5)
C1—C2	1.418 (4)	C21—H21	0.9500
C1—C5	1.419 (4)	C22—C23	1.411 (5)
C1—H1	0.9500	C22—H22	0.9500
C2—C3	1.422 (4)	C23—C24	1.418 (4)
C2—H2	0.9500	C23—H23	0.9500
C3—C4	1.426 (4)	C24—C25	1.407 (4)
C3—H3	0.9500	C24—H24	0.9500
C4—C5	1.414 (5)	C25—H25	0.9500
C4—H4	0.9500	C26—C31	1.394 (4)
C5—H5	0.9500	C26—C27	1.403 (4)
C6—C11	1.397 (4)	C27—C28	1.420 (4)
C6—C7	1.399 (4)	C27—H27	0.9500
C7—C8	1.426 (4)	C28—C29	1.429 (4)
C7—H7	0.9500	C28—C32	1.499 (4)
C8—C9	1.430 (4)	C29—C30	1.437 (4)

C8—C12	1.497 (4)	C29—C33	1.513 (4)
C9—C10	1.427 (4)	C30—C31	1.421 (4)
C9—C13	1.509 (3)	C30—C34	1.504 (4)
C10—C11	1.421 (4)	C31—H31	0.9500
C10—C14	1.501 (4)	C32—H32A	0.9800
C11—H11	0.9500	C32—H32B	0.9800
C12—H12A	0.9800	C32—H32C	0.9800
C12—H12B	0.9800	C33—H33A	0.9800
C12—H12C	0.9800	C33—H33B	0.9800
C13—H13A	0.9800	C33—H33C	0.9800
C13—H13B	0.9800	C34—H34A	0.9800
C13—H13C	0.9800	C34—H34B	0.9800
C14—H14A	0.9800	C34—H34C	0.9800
C14—H14B	0.9800	O1W—H1WA	0.85 (4)
C14—H14C	0.9800	O1W—H1WB	0.77 (4)
Ru2—C21	2.172 (3)	O2W—H2WA	0.78 (5)
Ru2—C24	2.173 (3)	O2W—H2WB	0.83 (5)
C4—Ru1—C3	38.38 (12)	C21—Ru2—C22	38.01 (13)
C4—Ru1—C1	63.77 (11)	C24—Ru2—C22	63.41 (12)
C3—Ru1—C1	63.83 (11)	C21—Ru2—C25	38.11 (12)
C4—Ru1—C2	63.90 (11)	C24—Ru2—C25	37.75 (12)
C3—Ru1—C2	38.18 (11)	C22—Ru2—C25	63.68 (12)
C1—Ru1—C2	38.01 (11)	C21—Ru2—C23	63.41 (12)
C4—Ru1—C5	37.93 (12)	C24—Ru2—C23	38.04 (11)
C3—Ru1—C5	63.72 (12)	C22—Ru2—C23	37.81 (13)
C1—Ru1—C5	37.99 (11)	C25—Ru2—C23	63.55 (12)
C2—Ru1—C5	63.54 (11)	C21—Ru2—C26	108.82 (11)

C4—Ru1—C6	165.45 (12)	C24—Ru2—C26	159.59 (11)
C3—Ru1—C6	152.93 (11)	C22—Ru2—C26	123.24 (12)
C1—Ru1—C6	109.95 (10)	C25—Ru2—C26	124.30 (12)
C2—Ru1—C6	120.17 (10)	C23—Ru2—C26	158.06 (12)
C5—Ru1—C6	129.05 (11)	C21—Ru2—C29	171.51 (11)
C4—Ru1—C7	157.51 (12)	C24—Ru2—C29	108.31 (11)
C3—Ru1—C7	121.62 (11)	C22—Ru2—C29	138.40 (12)
C1—Ru1—C7	122.80 (11)	C25—Ru2—C29	135.83 (12)
C2—Ru1—C7	106.90 (11)	C23—Ru2—C29	109.33 (11)
C5—Ru1—C7	158.82 (11)	C26—Ru2—C29	79.55 (10)
C6—Ru1—C7	37.04 (10)	C21—Ru2—C31	117.72 (11)
C4—Ru1—C8	125.38 (11)	C24—Ru2—C31	127.40 (11)
C3—Ru1—C8	104.86 (11)	C22—Ru2—C31	151.32 (12)
C1—Ru1—C8	150.60 (10)	C25—Ru2—C31	107.28 (11)
C2—Ru1—C8	116.16 (10)	C23—Ru2—C31	164.85 (11)
C5—Ru1—C8	163.01 (11)	C26—Ru2—C31	36.99 (10)
C6—Ru1—C8	66.93 (10)	C29—Ru2—C31	67.99 (10)
C7—Ru1—C8	37.60 (10)	C21—Ru2—C27	119.64 (12)
C4—Ru1—C9	106.24 (10)	C24—Ru2—C27	163.17 (11)
C3—Ru1—C9	111.00 (11)	C22—Ru2—C27	107.82 (11)
C1—Ru1—C9	169.42 (10)	C25—Ru2—C27	153.79 (12)
C2—Ru1—C9	142.64 (11)	C23—Ru2—C27	126.26 (11)
C5—Ru1—C9	131.82 (10)	C26—Ru2—C27	37.22 (10)
C6—Ru1—C9	78.90 (9)	C29—Ru2—C27	67.84 (10)
C7—Ru1—C9	67.74 (10)	C31—Ru2—C27	67.50 (10)
C8—Ru1—C9	37.66 (10)	C21—Ru2—C30	143.44 (12)
C4—Ru1—C11	131.91 (11)	C24—Ru2—C30	107.25 (11)

C3—Ru1—C11	170.13 (11)	C22—Ru2—C30	169.79 (12)
C1—Ru1—C11	115.98 (11)	C25—Ru2—C30	112.01 (11)
C2—Ru1—C11	147.21 (11)	C23—Ru2—C30	132.18 (12)
C5—Ru1—C11	109.57 (11)	C26—Ru2—C30	66.96 (10)
C6—Ru1—C11	36.90 (10)	C29—Ru2—C30	37.91 (10)
C7—Ru1—C11	67.38 (10)	C31—Ru2—C30	37.45 (10)
C8—Ru1—C11	79.89 (10)	C27—Ru2—C30	80.06 (10)
C9—Ru1—C11	67.37 (10)	C21—Ru2—C28	146.41 (12)
C4—Ru1—C10	108.86 (11)	C24—Ru2—C28	130.51 (11)
C3—Ru1—C10	136.17 (11)	C22—Ru2—C28	114.21 (11)
C1—Ru1—C10	139.76 (10)	C25—Ru2—C28	168.25 (11)
C2—Ru1—C10	172.75 (10)	C23—Ru2—C28	107.25 (11)
C5—Ru1—C10	110.73 (10)	C26—Ru2—C28	67.03 (10)
C6—Ru1—C10	66.69 (10)	C29—Ru2—C28	37.68 (10)
C7—Ru1—C10	79.99 (10)	C31—Ru2—C28	79.99 (10)
C8—Ru1—C10	67.86 (9)	C27—Ru2—C28	37.40 (10)
C9—Ru1—C10	37.50 (10)	C30—Ru2—C28	67.95 (10)
C11—Ru1—C10	37.29 (9)	C22—C21—C25	108.1 (3)
C2—C1—C5	108.1 (3)	C22—C21—Ru2	71.15 (17)
C2—C1—Ru1	71.10 (16)	C25—C21—Ru2	71.10 (16)
C5—C1—Ru1	71.23 (16)	C22—C21—H21	125.9
C2—C1—H1	126.0	C25—C21—H21	125.9
C5—C1—H1	126.0	Ru2—C21—H21	123.5
Ru1—C1—H1	123.3	C23—C22—C21	108.0 (3)
C1—C2—C3	108.0 (3)	C23—C22—Ru2	71.21 (17)
C1—C2—Ru1	70.89 (16)	C21—C22—Ru2	70.85 (17)
C3—C2—Ru1	70.58 (17)	C23—C22—H22	126.0

C1—C2—H2	126.0	C21—C22—H22	126.0
C3—C2—H2	126.0	Ru2—C22—H22	123.6
Ru1—C2—H2	124.1	C22—C23—C24	107.8 (3)
C2—C3—C4	107.7 (3)	C22—C23—Ru2	70.97 (18)
C2—C3—Ru1	71.24 (17)	C24—C23—Ru2	70.74 (18)
C4—C3—Ru1	70.73 (18)	C22—C23—H23	126.1
C2—C3—H3	126.1	C24—C23—H23	126.1
C4—C3—H3	126.1	Ru2—C23—H23	123.8
Ru1—C3—H3	123.5	C25—C24—C23	108.5 (3)
C5—C4—C3	108.0 (3)	C25—C24—Ru2	71.25 (17)
C5—C4—Ru1	71.58 (17)	C23—C24—Ru2	71.23 (18)
C3—C4—Ru1	70.90 (17)	C25—C24—H24	125.7
C5—C4—H4	126.0	C23—C24—H24	125.7
C3—C4—H4	126.0	Ru2—C24—H24	123.4
Ru1—C4—H4	123.2	C24—C25—C21	107.6 (3)
C4—C5—C1	108.2 (3)	C24—C25—Ru2	71.00 (17)
C4—C5—Ru1	70.49 (17)	C21—C25—Ru2	70.80 (17)
C1—C5—Ru1	70.77 (16)	C24—C25—H25	126.2
C4—C5—H5	125.9	C21—C25—H25	126.2
C1—C5—H5	125.9	Ru2—C25—H25	123.6
Ru1—C5—H5	124.4	F2—C26—C31	118.4 (2)
F1—C6—C11	118.3 (2)	F2—C26—C27	118.8 (2)
F1—C6—C7	118.6 (2)	C31—C26—C27	122.8 (2)
C11—C6—C7	123.1 (2)	F2—C26—Ru2	127.91 (18)
F1—C6—Ru1	127.80 (18)	C31—C26—Ru2	72.45 (15)
C11—C6—Ru1	72.69 (15)	C27—C26—Ru2	72.38 (15)
C7—C6—Ru1	72.16 (15)	C26—C27—C28	119.0 (2)

C6—C7—C8	118.7 (2)	C26—C27—Ru2	70.40 (15)
C6—C7—Ru1	70.80 (15)	C28—C27—Ru2	71.63 (15)
C8—C7—Ru1	71.32 (15)	C26—C27—H27	120.5
C6—C7—H7	120.7	C28—C27—H27	120.5
C8—C7—H7	120.7	Ru2—C27—H27	129.8
Ru1—C7—H7	129.5	C27—C28—C29	119.8 (2)
C7—C8—C9	119.5 (2)	C27—C28—C32	118.3 (2)
C7—C8—C12	118.0 (2)	C29—C28—C32	121.9 (3)
C9—C8—C12	122.5 (2)	C27—C28—Ru2	70.98 (15)
C7—C8—Ru1	71.07 (15)	C29—C28—Ru2	70.66 (14)
C9—C8—Ru1	71.25 (14)	C32—C28—Ru2	130.30 (19)
C12—C8—Ru1	129.35 (19)	C28—C29—C30	119.8 (2)
C10—C9—C8	120.2 (2)	C28—C29—C33	120.1 (3)
C10—C9—C13	120.2 (3)	C30—C29—C33	120.1 (2)
C8—C9—C13	119.6 (3)	C28—C29—Ru2	71.66 (15)
C10—C9—Ru1	71.53 (14)	C30—C29—Ru2	71.50 (14)
C8—C9—Ru1	71.09 (14)	C33—C29—Ru2	126.40 (18)
C13—C9—Ru1	129.53 (17)	C31—C30—C29	119.4 (2)
C11—C10—C9	119.6 (2)	C31—C30—C34	118.5 (2)
C11—C10—C14	118.0 (2)	C29—C30—C34	122.0 (2)
C9—C10—C14	122.4 (2)	C31—C30—Ru2	70.94 (15)
C11—C10—Ru1	71.32 (15)	C29—C30—Ru2	70.58 (14)
C9—C10—Ru1	70.97 (14)	C34—C30—Ru2	129.70 (19)
C14—C10—Ru1	130.39 (19)	C26—C31—C30	119.2 (2)
C6—C11—C10	118.9 (2)	C26—C31—Ru2	70.56 (15)
C6—C11—Ru1	70.41 (15)	C30—C31—Ru2	71.61 (15)
C10—C11—Ru1	71.39 (15)	C26—C31—H31	120.4

C6—C11—H11	120.6	C30—C31—H31	120.4
C10—C11—H11	120.6	Ru2—C31—H31	129.9
Ru1—C11—H11	130.1	C28—C32—H32A	109.5
C8—C12—H12A	109.5	C28—C32—H32B	109.5
C8—C12—H12B	109.5	H32A—C32—H32B	109.5
H12A—C12—H12B	109.5	C28—C32—H32C	109.5
C8—C12—H12C	109.5	H32A—C32—H32C	109.5
H12A—C12—H12C	109.5	H32B—C32—H32C	109.5
H12B—C12—H12C	109.5	C29—C33—H33A	109.5
C9—C13—H13A	109.5	C29—C33—H33B	109.5
C9—C13—H13B	109.5	H33A—C33—H33B	109.5
H13A—C13—H13B	109.5	C29—C33—H33C	109.5
C9—C13—H13C	109.5	H33A—C33—H33C	109.5
H13A—C13—H13C	109.5	H33B—C33—H33C	109.5
H13B—C13—H13C	109.5	C30—C34—H34A	109.5
C10—C14—H14A	109.5	C30—C34—H34B	109.5
C10—C14—H14B	109.5	H34A—C34—H34B	109.5
H14A—C14—H14B	109.5	C30—C34—H34C	109.5
C10—C14—H14C	109.5	H34A—C34—H34C	109.5
H14A—C14—H14C	109.5	H34B—C34—H34C	109.5
H14B—C14—H14C	109.5	H1WA—O1W—H1WB	107 (3)
C21—Ru2—C24	63.33 (12)	H2WA—O2W—H2WB	106 (4)
C5—C1—C2—C3	0.9 (3)	C25—C21—C22—C23	-0.1 (3)
Ru1—C1—C2—C3	-61.2 (2)	Ru2—C21—C22—C23	-61.9 (2)
C5—C1—C2—Ru1	62.0 (2)	C25—C21—C22—Ru2	61.8 (2)

C1—C2—C3—C4	-0.3 (3)	C21—C22—C23—C24	0.1 (3)
Ru1—C2—C3—C4	-61.7 (2)	Ru2—C22—C23—C24	-61.5 (2)
C1—C2—C3—Ru1	61.4 (2)	C21—C22—C23—Ru2	61.7 (2)
C2—C3—C4—C5	-0.3 (3)	C22—C23—C24—C25	-0.2 (4)
Ru1—C3—C4—C5	-62.3 (2)	Ru2—C23—C24—C25	-61.8 (2)
C2—C3—C4—Ru1	62.0 (2)	C22—C23—C24—Ru2	61.7 (2)
C3—C4—C5—C1	0.9 (3)	C23—C24—C25—C21	0.1 (3)
Ru1—C4—C5—C1	-61.0 (2)	Ru2—C24—C25—C21	-61.7 (2)
C3—C4—C5—Ru1	61.9 (2)	C23—C24—C25—Ru2	61.8 (2)
C2—C1—C5—C4	-1.1 (3)	C22—C21—C25—C24	0.0 (3)
Ru1—C1—C5—C4	60.9 (2)	Ru2—C21—C25—C24	61.8 (2)
C2—C1—C5—Ru1	-61.9 (2)	C22—C21—C25—Ru2	-61.9 (2)
F1—C6—C7—C8	178.7 (2)	F2—C26—C27—C28	178.7 (2)
C11—C6—C7—C8	0.4 (4)	C31—C26—C27—C28	0.1 (4)
Ru1—C6—C7—C8	54.8 (2)	Ru2—C26—C27—C28	54.6 (2)
F1—C6—C7—Ru1	123.9 (2)	F2—C26—C27—Ru2	124.1 (2)
C11—C6—C7—Ru1	-54.3 (2)	C31—C26—C27—	-54.5 (2)

		Ru2	
C6—C7—C8—C9	-0.3 (4)	C26—C27—C28—C29	-0.9 (4)
Ru1—C7—C8—C9	54.2 (2)	Ru2—C27—C28—C29	53.1 (2)
C6—C7—C8—C12	-179.7 (2)	C26—C27—C28—C32	179.7 (2)
Ru1—C7—C8—C12	-125.2 (2)	Ru2—C27—C28—C32	-126.3 (2)
C6—C7—C8—Ru1	-54.5 (2)	C26—C27—C28—Ru2	-54.0 (2)
C7—C8—C9—C10	-0.1 (4)	C27—C28—C29—C30	1.7 (4)
C12—C8—C9—C10	179.3 (3)	C32—C28—C29—C30	-179.0 (2)
Ru1—C8—C9—C10	54.1 (2)	Ru2—C28—C29—C30	54.9 (2)
C7—C8—C9—C13	-179.5 (2)	C27—C28—C29—C33	-175.2 (2)
C12—C8—C9—C13	-0.1 (4)	C32—C28—C29—C33	4.0 (4)
Ru1—C8—C9—C13	-125.4 (2)	Ru2—C28—C29—C33	-122.0 (2)
C7—C8—C9—Ru1	-54.2 (2)	C27—C28—C29—Ru2	-53.2 (2)
C12—C8—C9—Ru1	125.3 (2)	C32—C28—C29—Ru2	126.1 (3)
C8—C9—C10—C11	0.3 (4)	C28—C29—C30—C31	-1.6 (4)
C13—C9—C10—C11	179.8 (2)	C33—C29—C30—C31	175.3 (2)

Ru1—C9—C10—C11	54.2 (2)	Ru2—C29—C30—C31	53.4 (2)
C8—C9—C10—C14	179.8 (3)	C28—C29—C30—C34	179.7 (2)
C13—C9—C10—C14	-0.8 (4)	C33—C29—C30—C34	-3.4 (4)
Ru1—C9—C10—C14	-126.4 (2)	Ru2—C29—C30—C34	-125.3 (2)
C8—C9—C10—Ru1	-53.9 (2)	C28—C29—C30—Ru2	-55.0 (2)
C13—C9—C10—Ru1	125.6 (2)	C33—C29—C30—Ru2	122.0 (2)
F1—C6—C11—C10	-178.5 (2)	F2—C26—C31—C30	-178.6 (2)
C7—C6—C11—C10	-0.2 (4)	C27—C26—C31—C30	0.0 (4)
Ru1—C6—C11—C10	-54.3 (2)	Ru2—C26—C31—C30	-54.5 (2)
F1—C6—C11—Ru1	-124.1 (2)	F2—C26—C31—Ru2	-124.2 (2)
C7—C6—C11—Ru1	54.1 (2)	C27—C26—C31—Ru2	54.5 (2)
C9—C10—C11—C6	-0.1 (4)	C29—C30—C31—C26	0.8 (4)
C14—C10—C11—C6	-179.6 (2)	C34—C30—C31—C26	179.5 (2)
Ru1—C10—C11—C6	53.8 (2)	Ru2—C30—C31—C26	54.0 (2)
C9—C10—C11—Ru1	-54.0 (2)	C29—C30—C31—Ru2	-53.2 (2)
C14—C10—C11—Ru1	126.5 (2)	C34—C30—C31—Ru2	125.5 (2)

Table S7. Hydrogen-bond parameters

D—H···*A*	*D*—H (Å)	H···*A* (Å)	*D*···*A* (Å)	*D*—H···*A* (°)
O1W—H1WB···Cl1	0.77 (4)	2.46 (4)	3.220 (2)	170 (4)
O1W—H1WA···Cl2	0.85 (4)	2.38 (4)	3.215 (2)	167 (3)
O2W—H2WA···Cl2	0.78 (5)	2.51 (5)	3.260 (3)	160 (4)
O2W—H2WB···Cl3	0.83 (5)	2.43 (5)	3.254 (3)	170 (4)

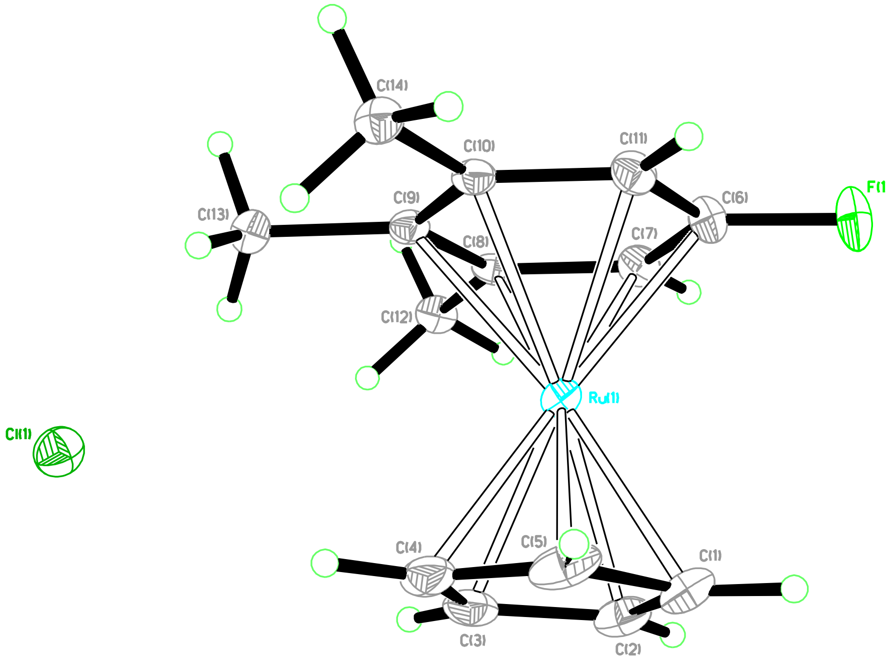


Figure 69. Perspective view of **6** showing 50% probability displacement.

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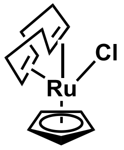
SPECTROSCOPIC DATA

NMR Data

^{1}H NMR of [CpRu(cod)Cl] (**1**):



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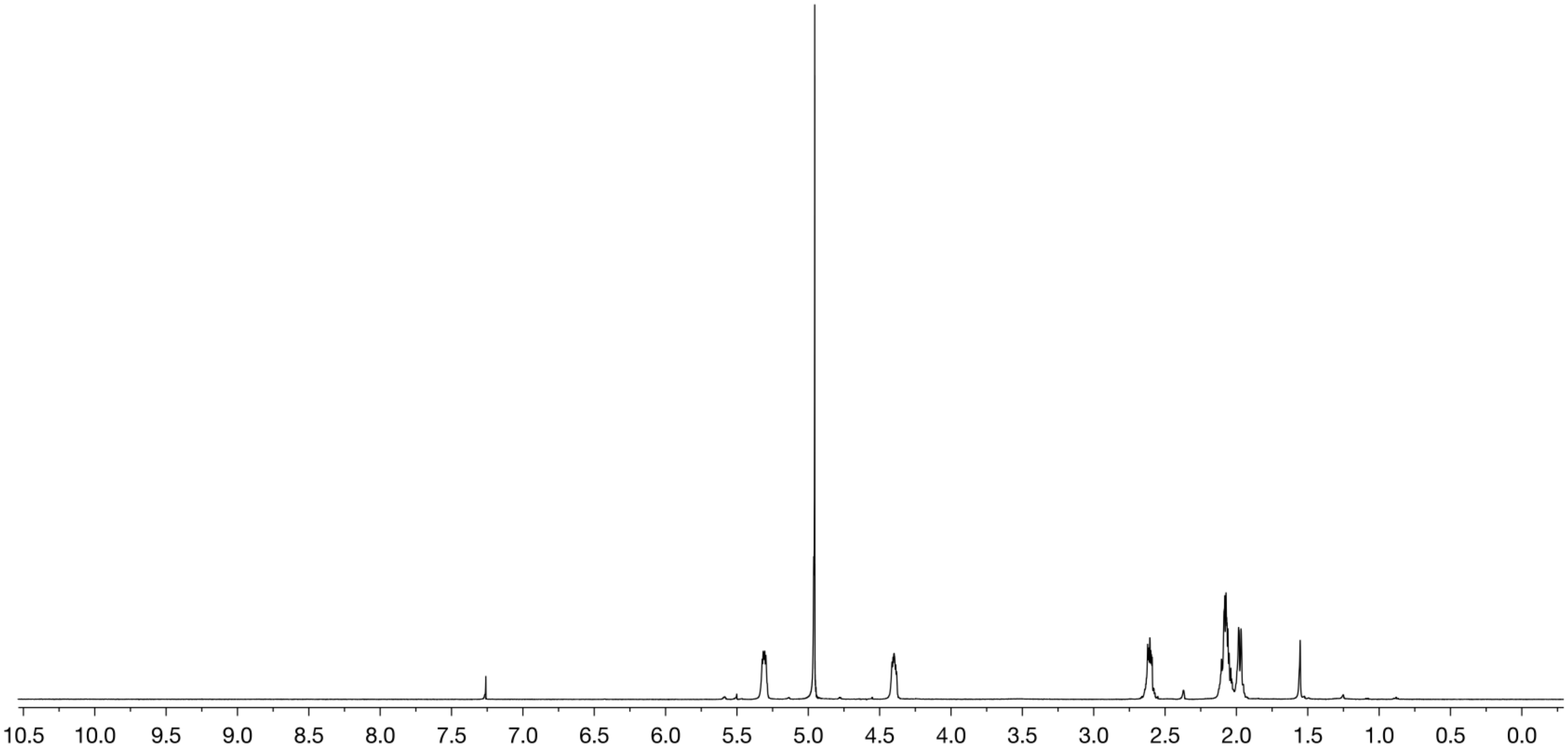
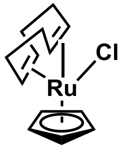
500 MHz, $CDCl_3$, 23 ºC



^{13}C NMR of [CpRu(cod)Cl] (**1**):

125 MHz, $CDCl_3$, 23 ºC



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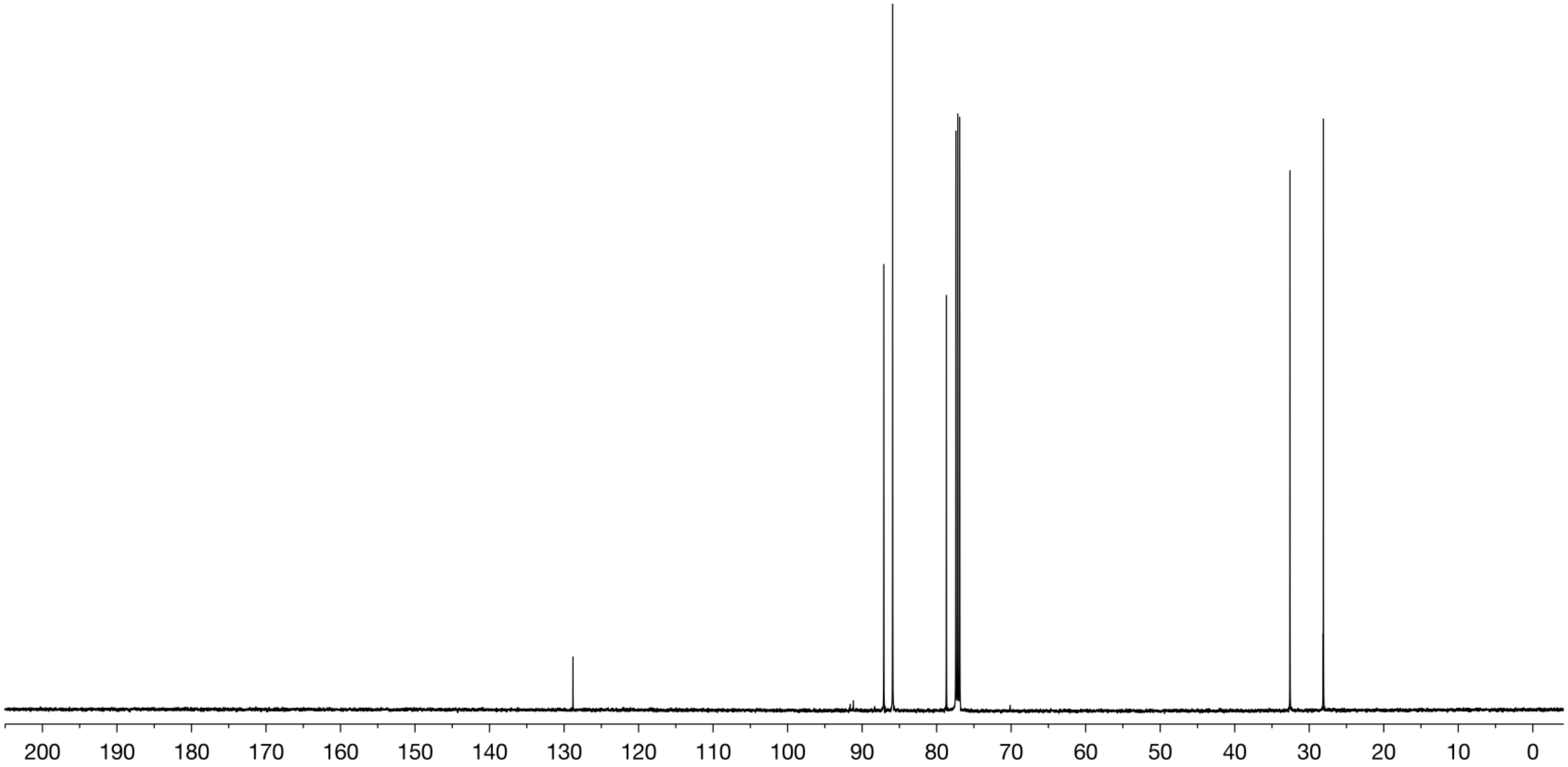
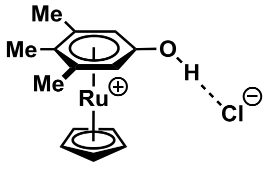


^{1}H NMR of [(η^6-3,4,5-trimethylphenol)RuCp]Cl (**5**):

600 MHz, $CDCl_3$, 23 ºC



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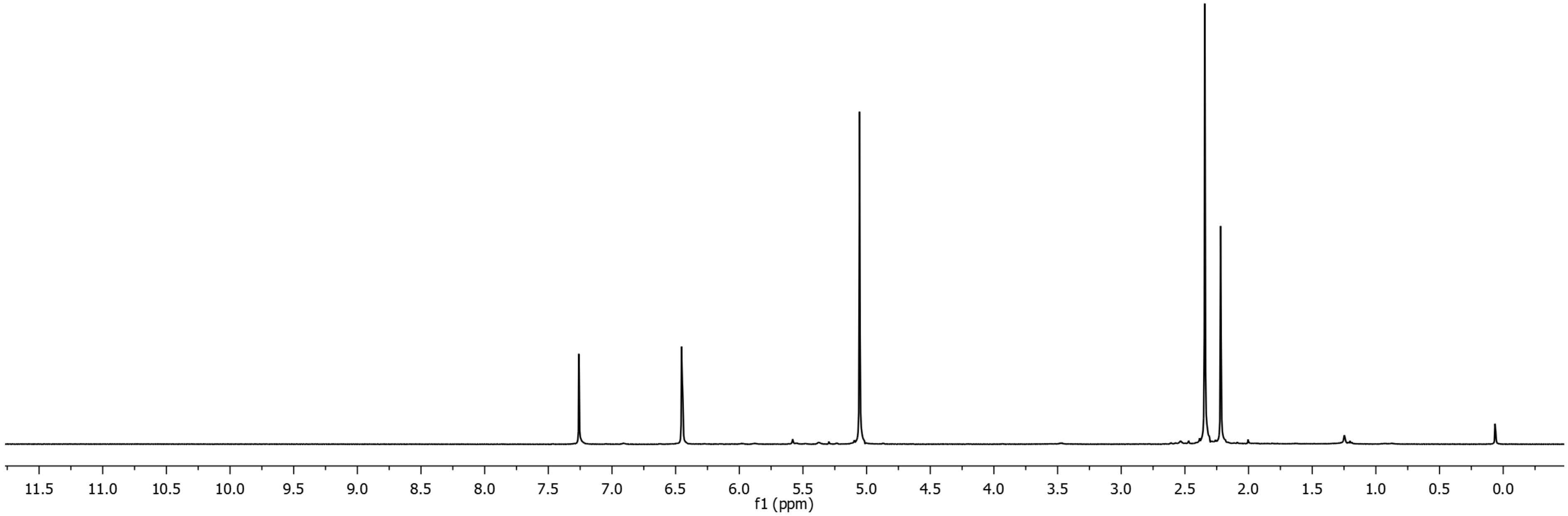
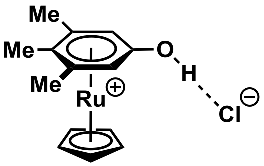


^{13}C NMR of [(η^6-3,4,5-trimethylphenol)RuCp]Cl (**5**):

126 MHz, $CDCl_3$, 23 ºC



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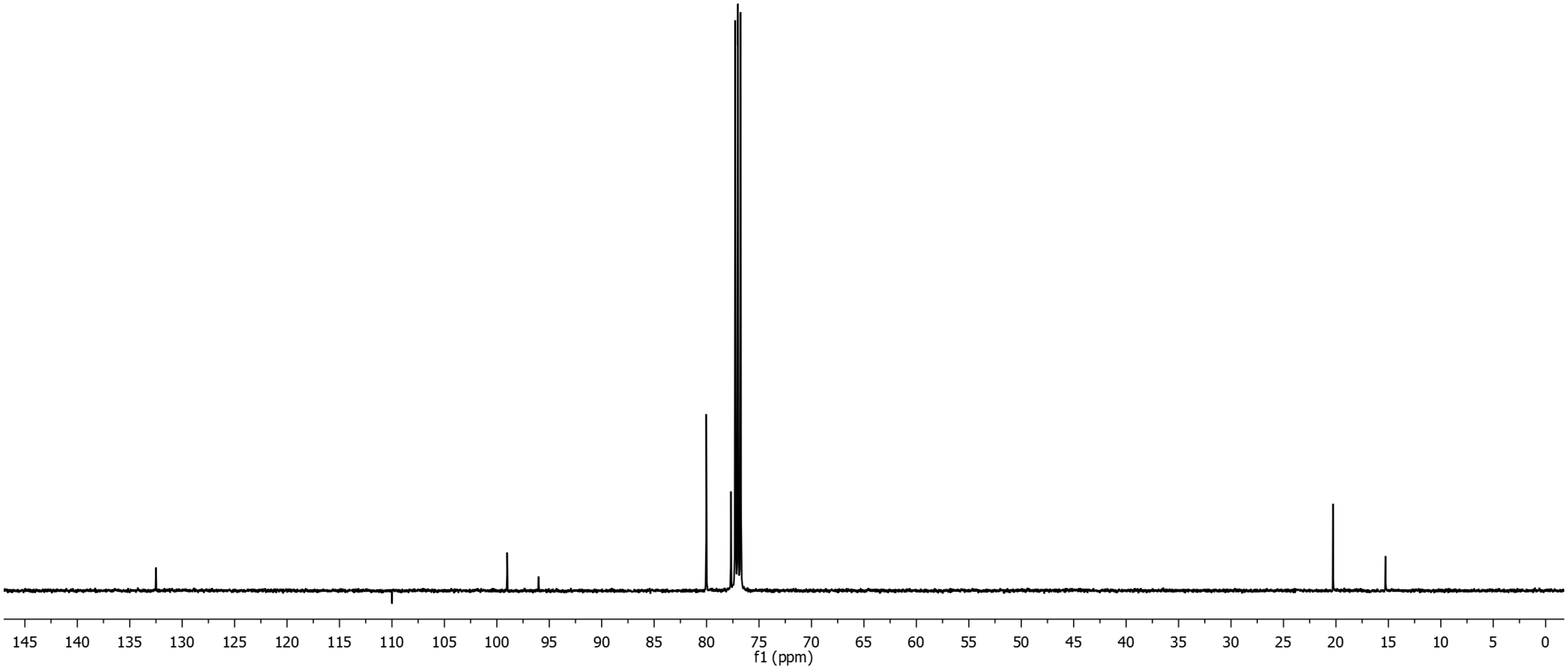
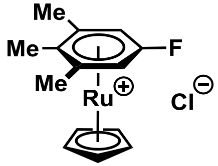


^{1}H NMR of [(η^6-5-fluoro-1,2,3-trimethylbenzene)RuCp]Cl (**6**):

600 MHz, CD_2Cl_3, 23 ºC



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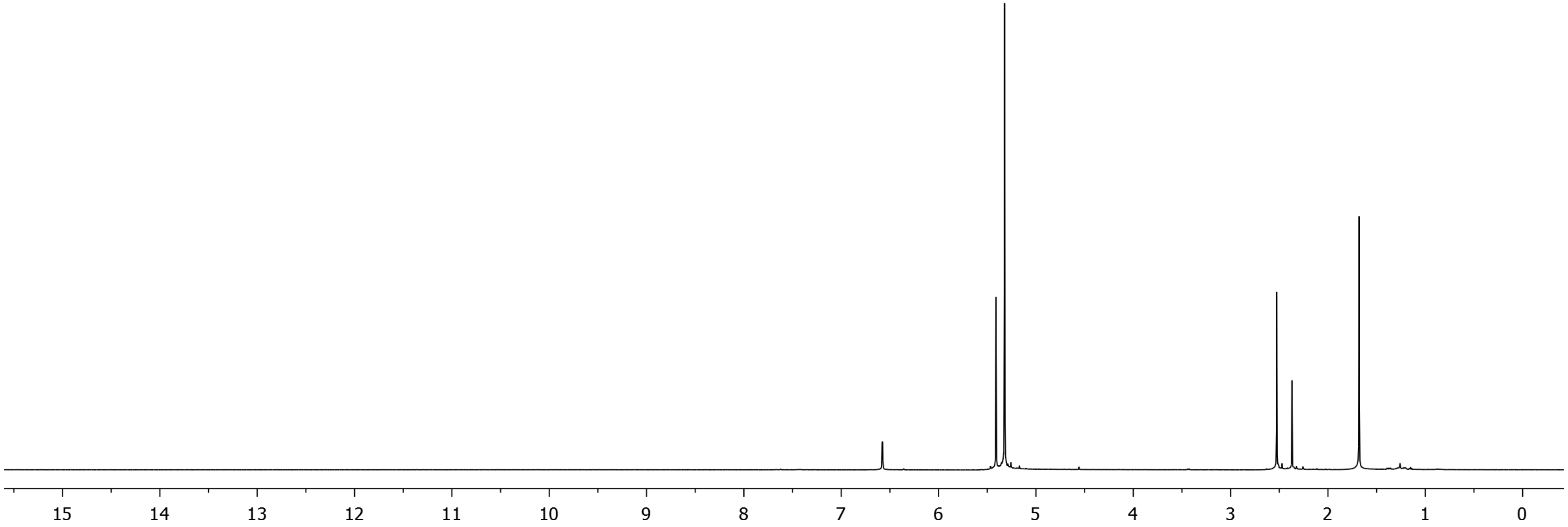

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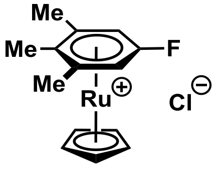
126 MHz, CD_2Cl_2, 23 ºC



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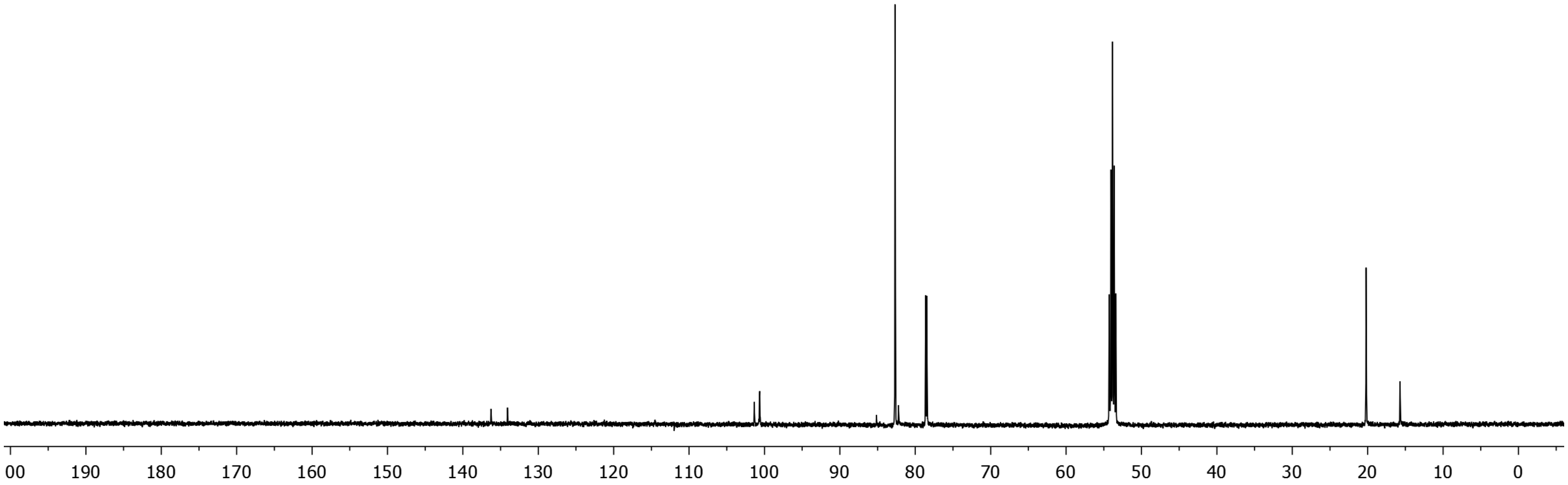
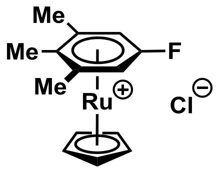


^{19}F NMR of [(η^6-5-fluoro-1,2,3-trimethylbenzene)RuCp]Cl (**6**):

471 MHz, CD_2Cl_2, 23 ºC



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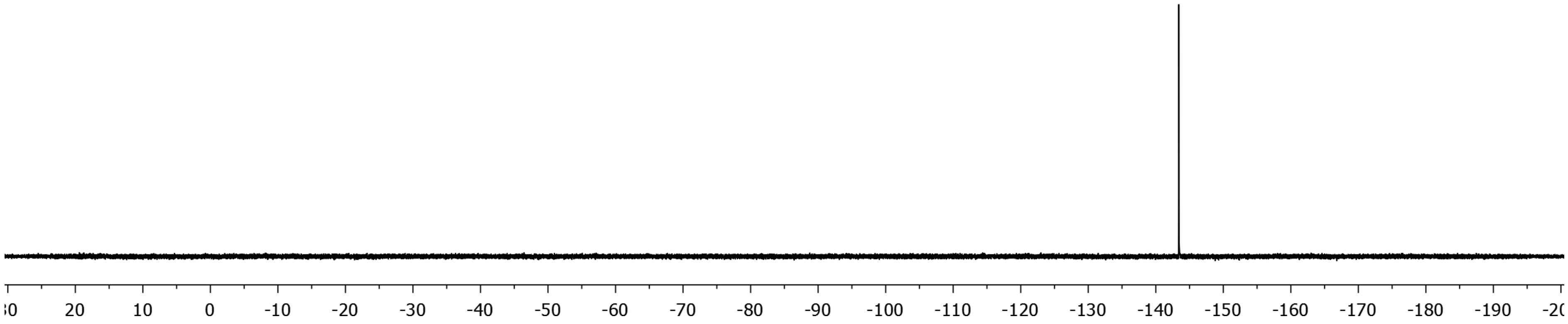
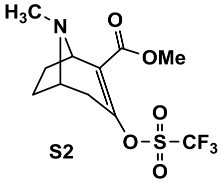
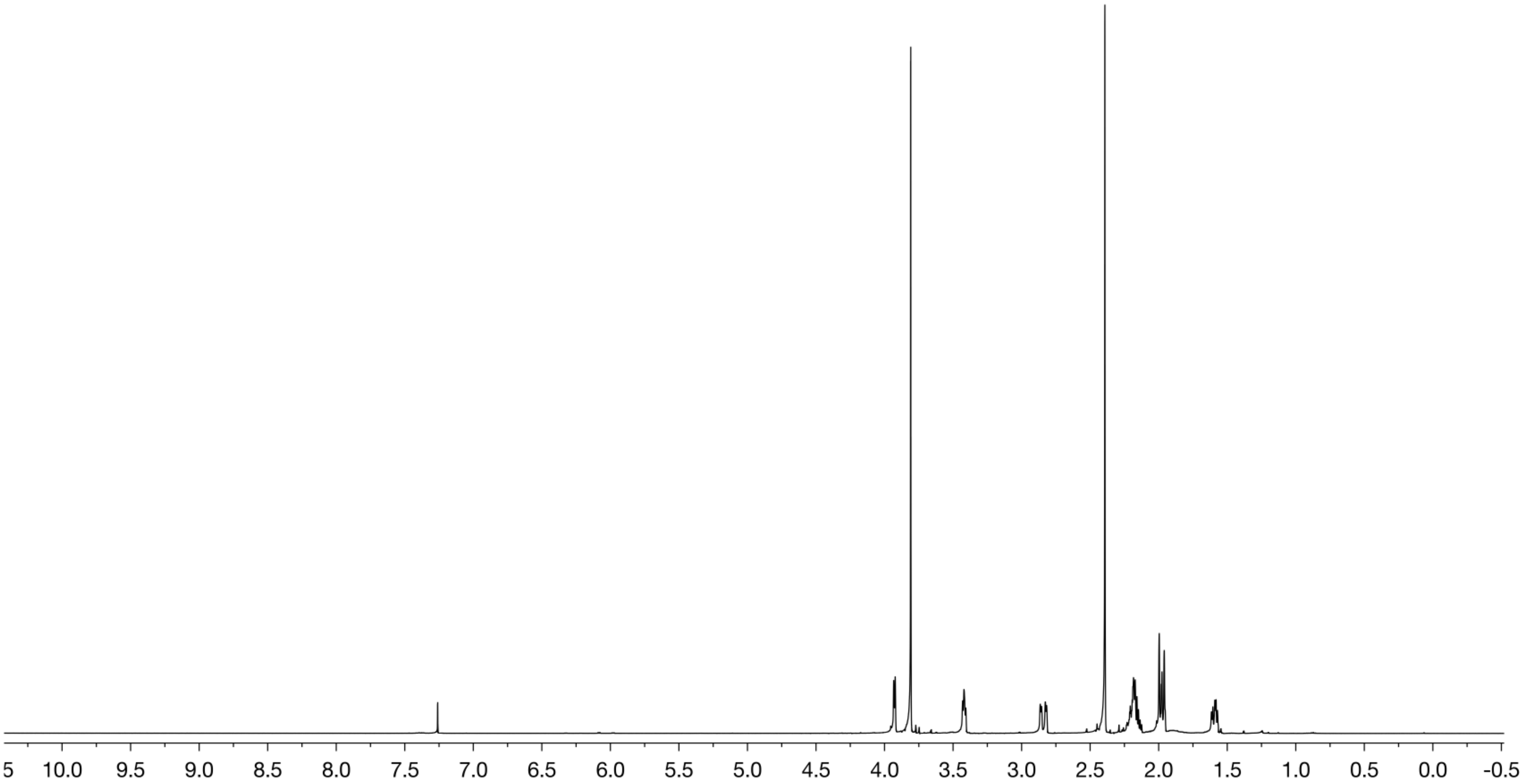


^{1}H NMR of Methyl (1*R*,5*S*)-8-methyl-3-(((trifluoromethyl)sulfonyl)oxy)-8-azabicyclo[3.2.1]oct-2-ene-2-carboxylate (**S2**):

500 MHz, $CDCl_3$, 23 ºC

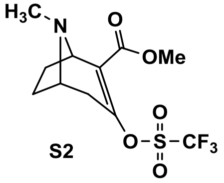


S2



^{13}C NMR of Methyl (1*R*,5*S*)-8-methyl-3-(((trifluoromethyl)sulfonyl)oxy)-8-azabicyclo[3.2.1]oct-2-ene-2-carboxylate (**S2**):

125 MHz, $CDCl_3$, 23 ºC



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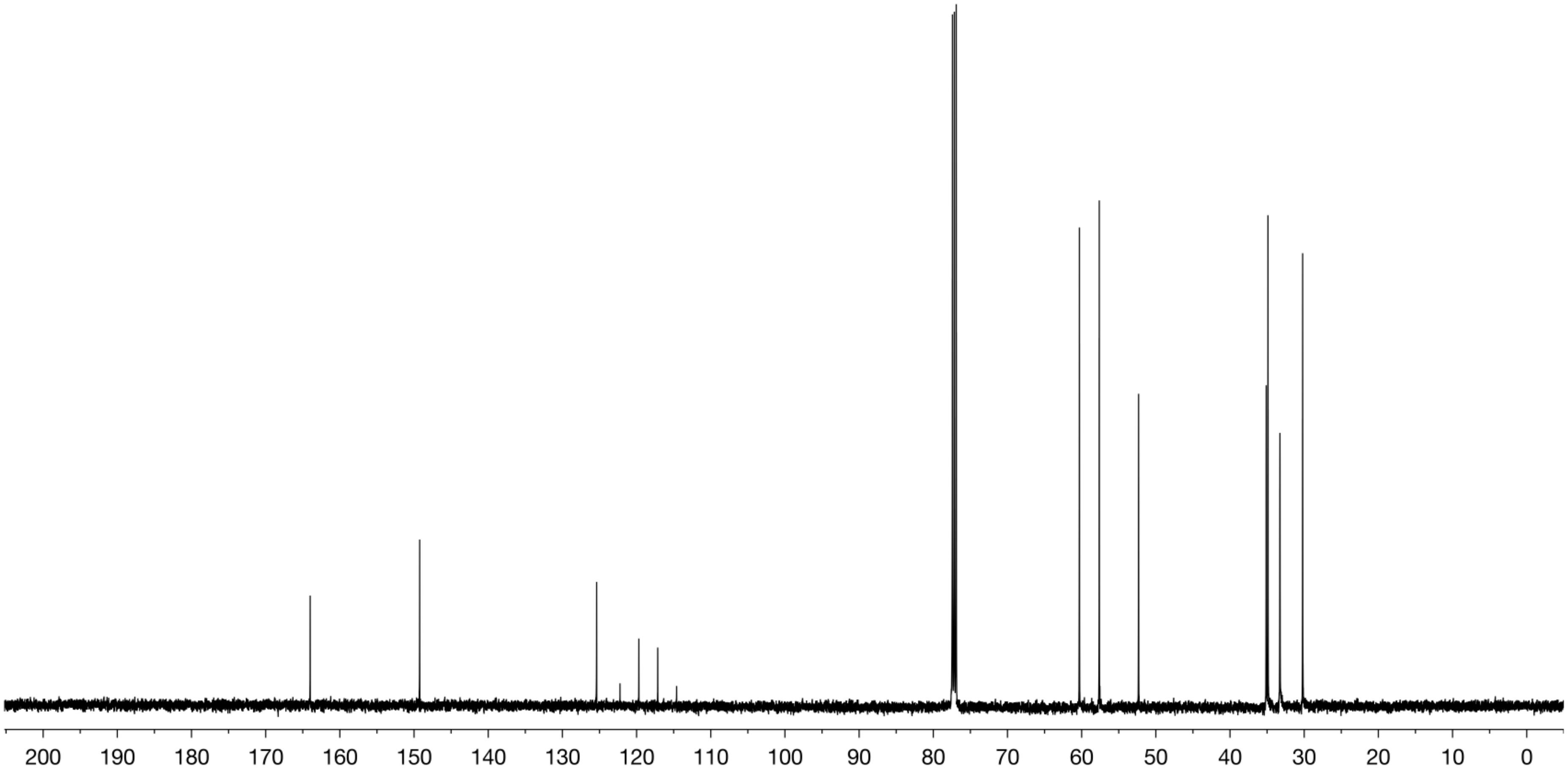
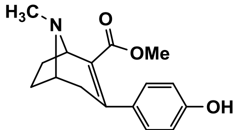
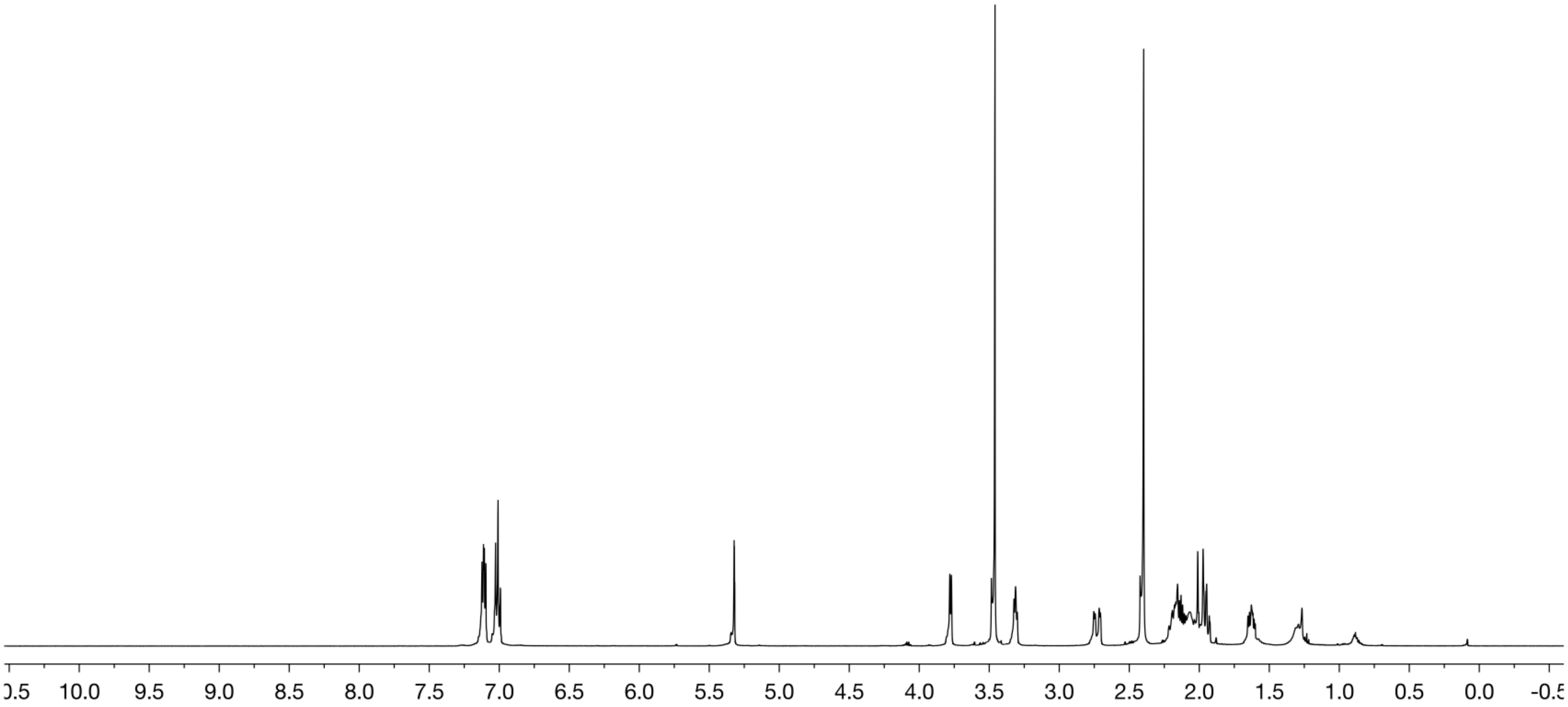


^{1}H NMR of methyl (1*R*,5*S*)-3-(4-hydroxyphenyl)-8-methyl-8-azabicyclo[3.2.1]oct-2-ene-2-carboxylate (**S3**):

500 MHz, CD_2Cl_2, 23 ºC

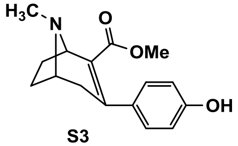


S3



^{13}C NMR of methyl (1*R*,5*S*)-3-(4-hydroxyphenyl)-8-methyl-8-azabicyclo[3.2.1]oct-2-ene-2-carboxylate (**S3**):

125 MHz, CD_2Cl_2, 23 ºC



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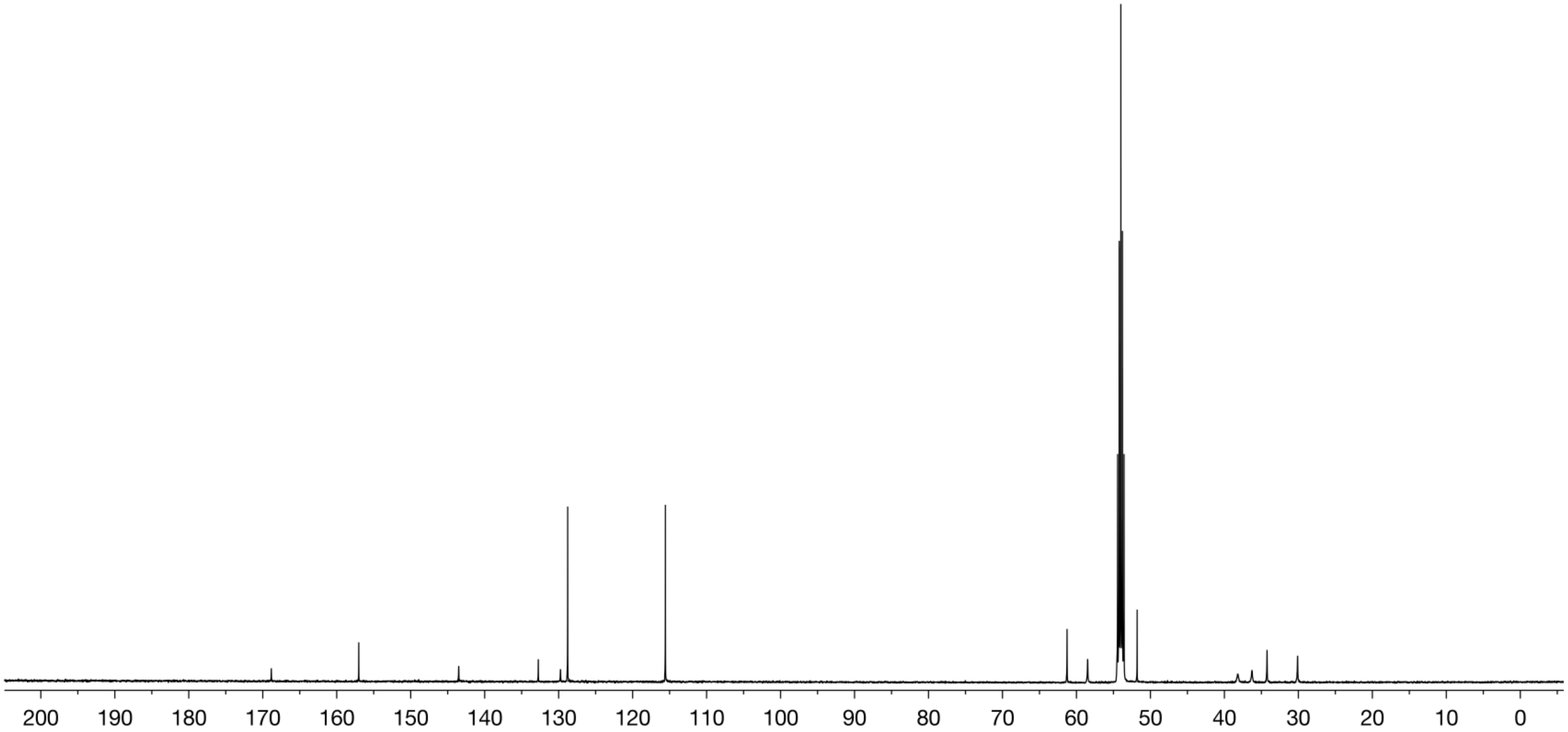
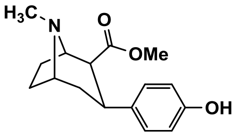


^{1}H NMR of Methyl (1*R*,2*S*,3*S*,5*S*)-3-(4-hydroxyphenyl)-8-methyl-8-azabicyclo[3.2.1]octane-2-carboxylate (**3**):

500 MHz, CD_3OD, 23 ºC



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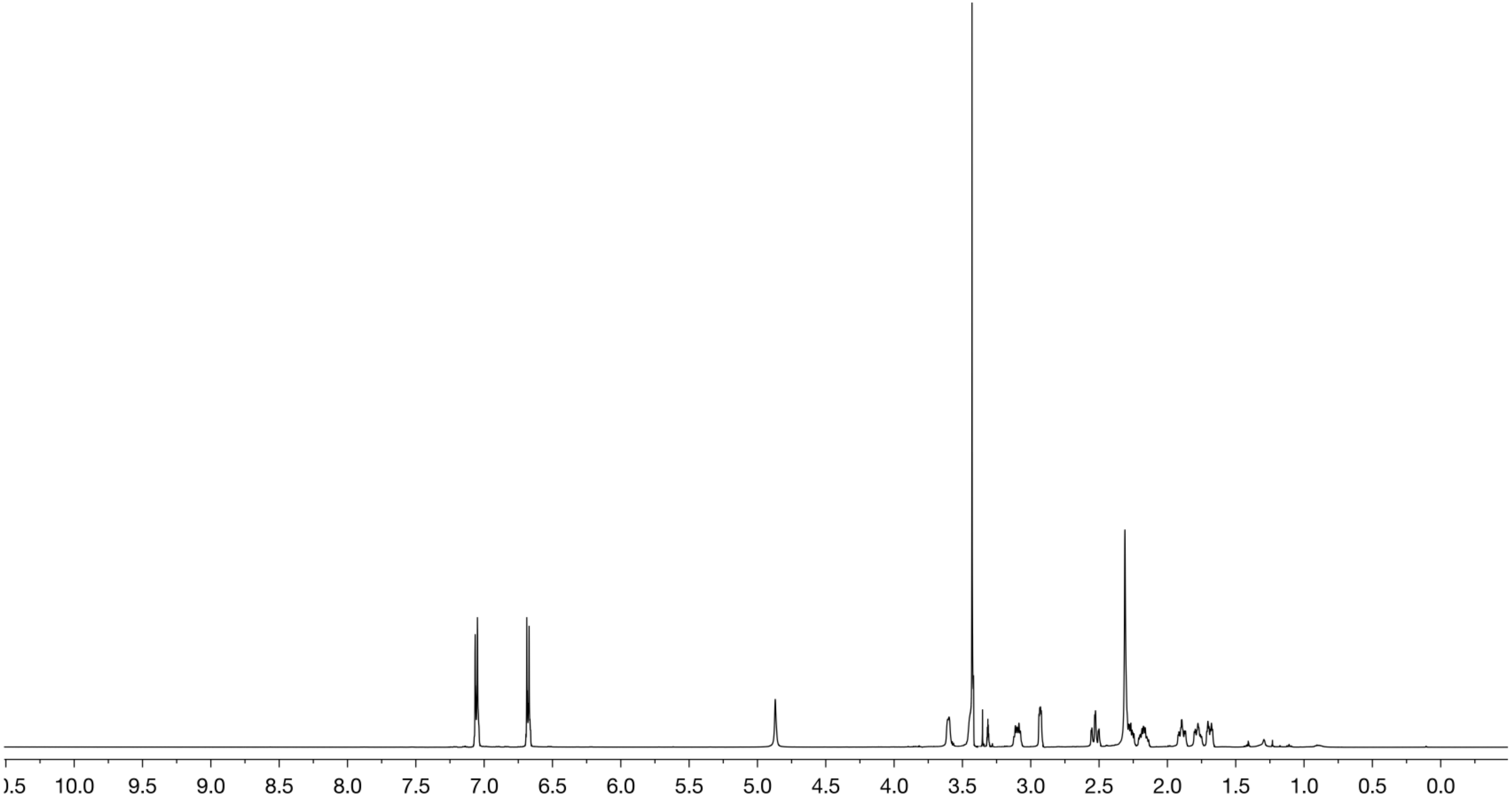
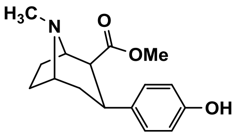


^{13}C NMR of Methyl (1*R*,2*S*,3*S*,5*S*)-3-(4-hydroxyphenyl)-8-methyl-8-azabicyclo[3.2.1]octane-2-carboxylate (**3**):

125 MHz, CD_3OD, 23 ºC



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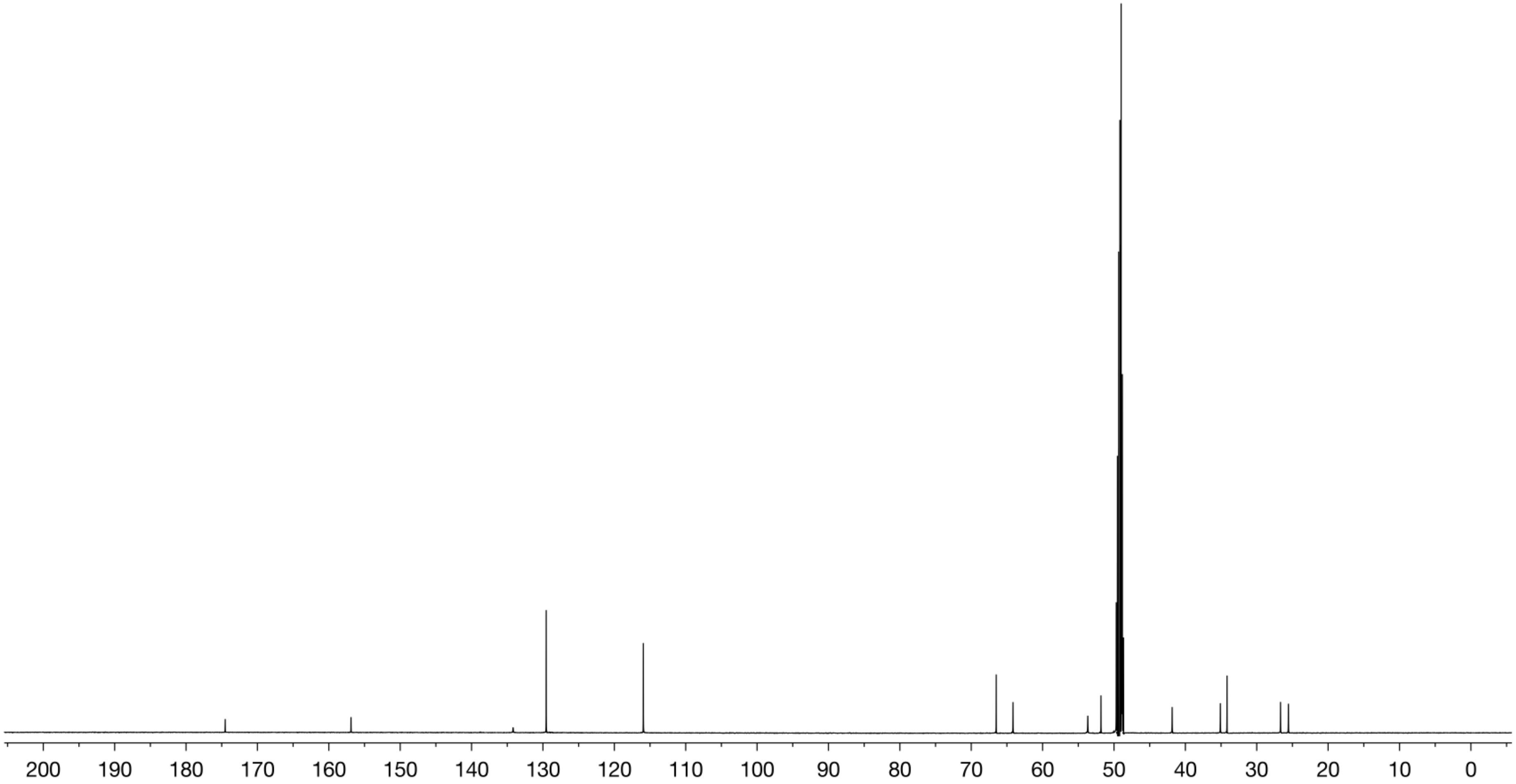
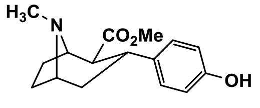


^{1}H NMR of Methyl (1*R*,2*S*,3*R*,5*S*)-3-(4-hydroxyphenyl)-8-methyl-8-azabicyclo[3.2.1]octane-2-carboxylate (**S4**):

500 MHz, CD_3OD, 23 ºC



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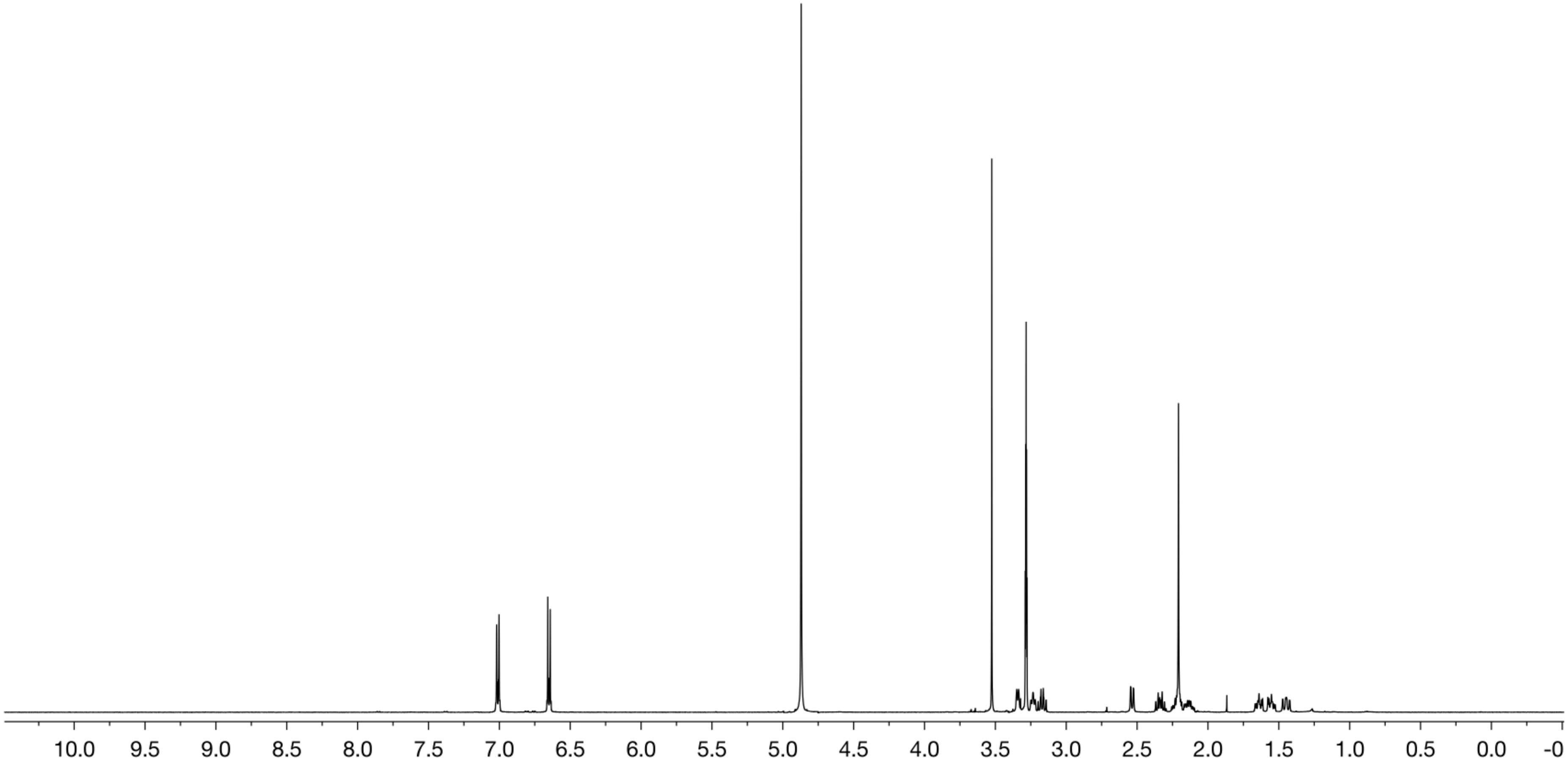
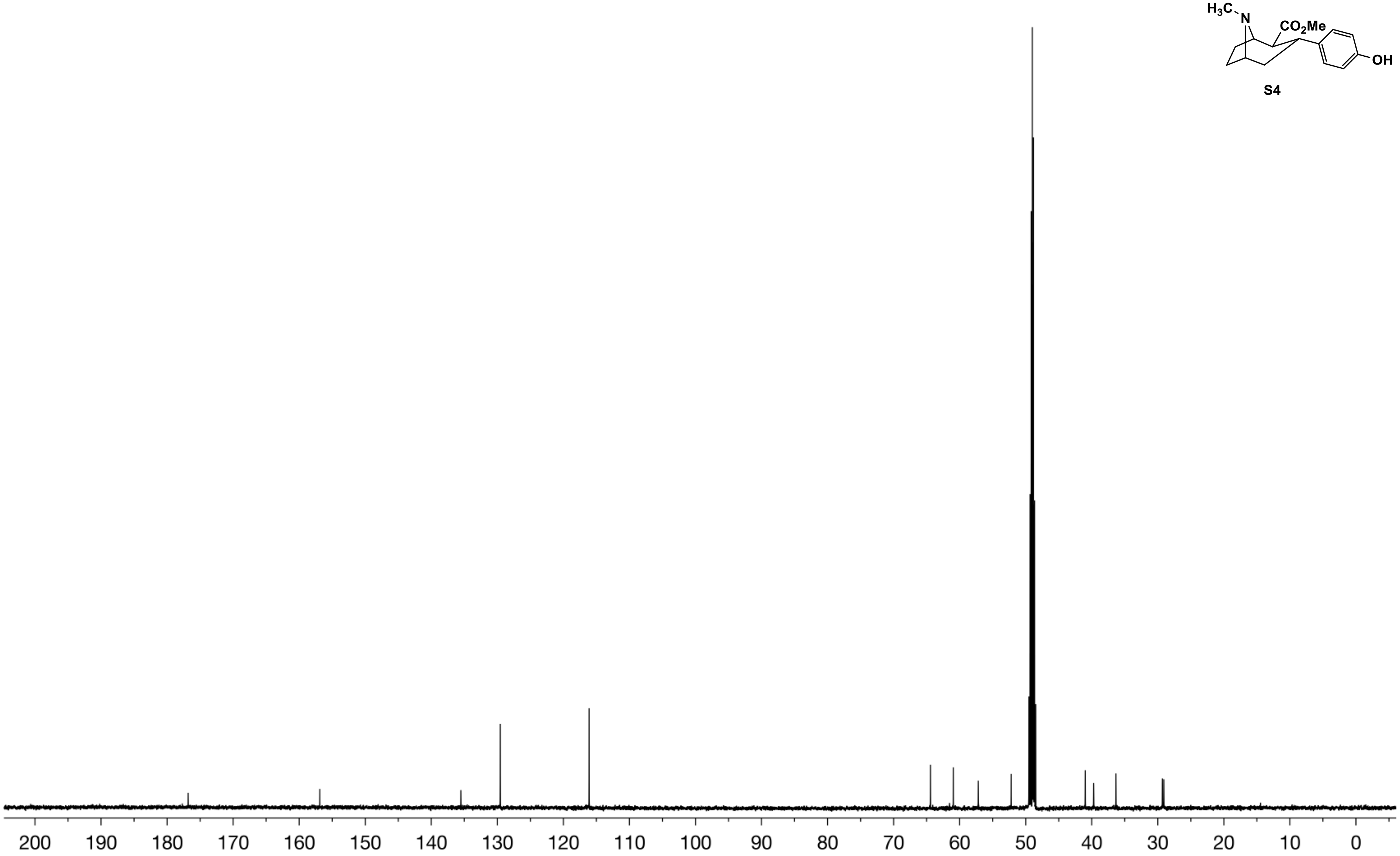


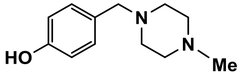
^{13}C NMR of Methyl (1*R*,2*S*,3*R*,5*S*)-3-(4-hydroxyphenyl)-8-methyl-8-azabicyclo[3.2.1]octane-2-carboxylate (**S4**):

125 MHz, CD$_3$OD, 23 ºC

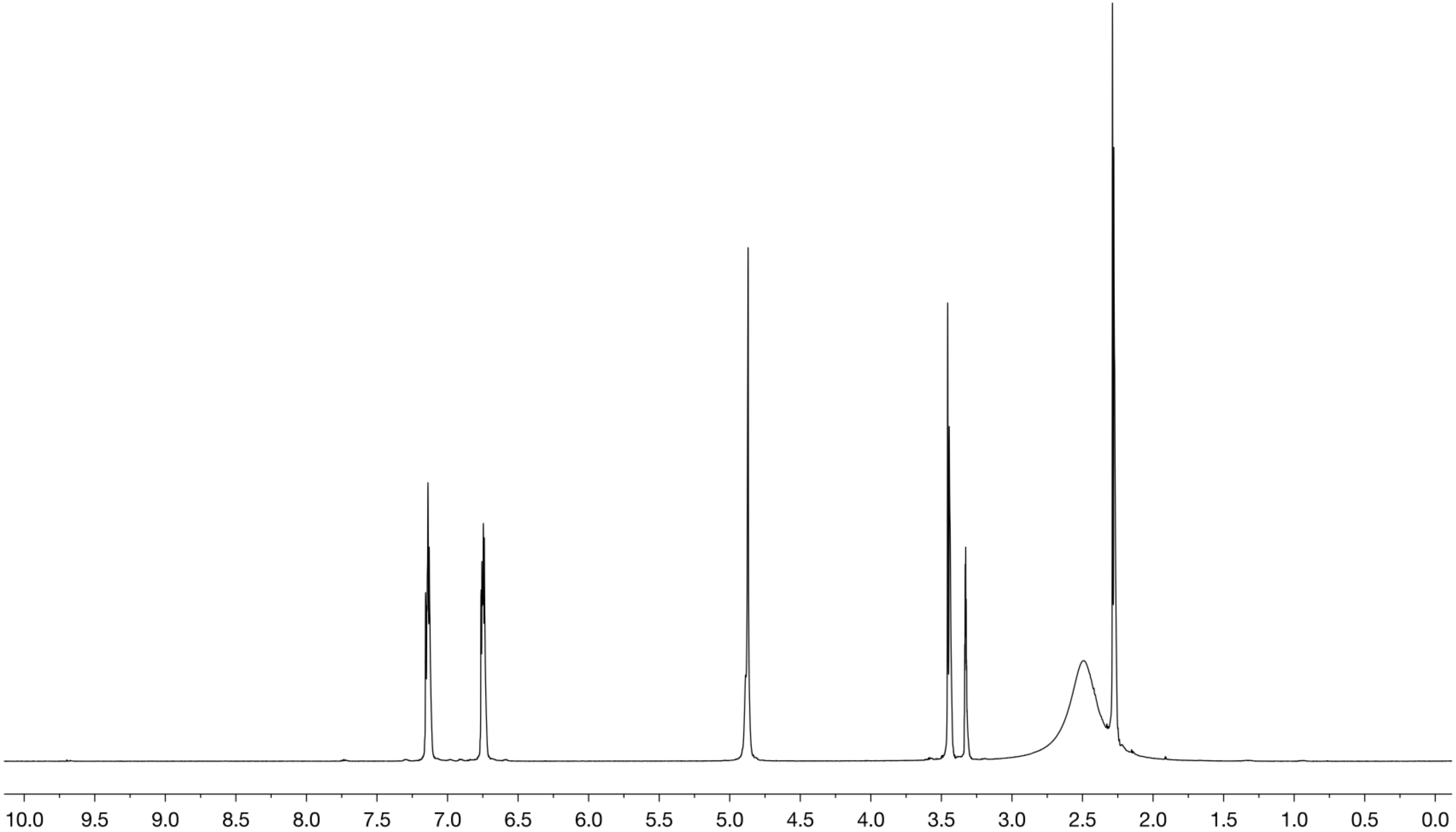


^{1}H NMR *N*-(4-Hydroxyphenyl)benzamide (**S5**)

500 MHz, CD_3OD, 23 ºC

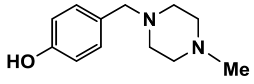


S5

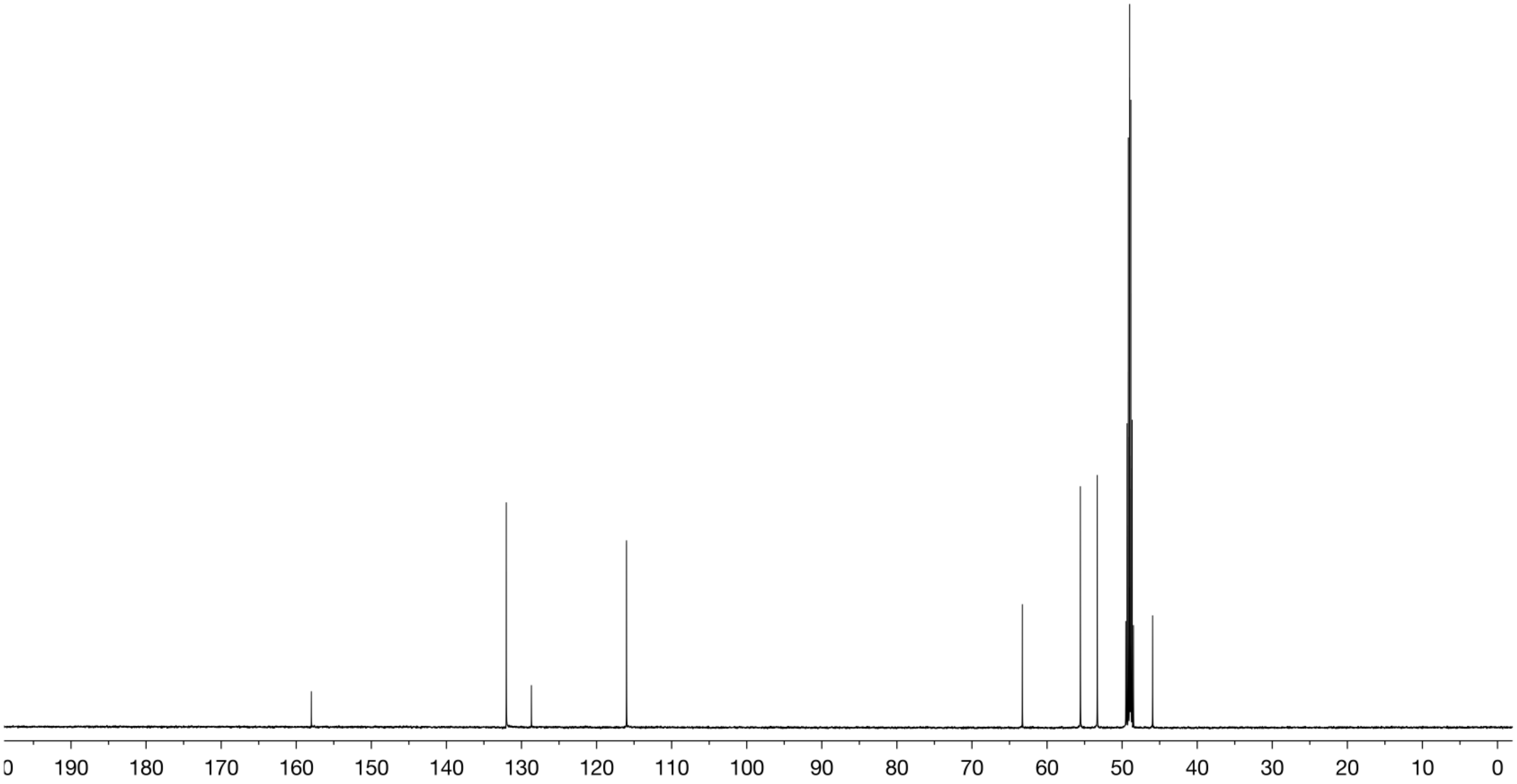


^{13}C NMR *N*-(4-Hydroxyphenyl)benzamide (**S5**):

125 MHz, CD_3OD, 23 ºC

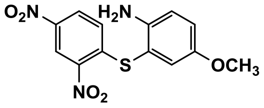


S5

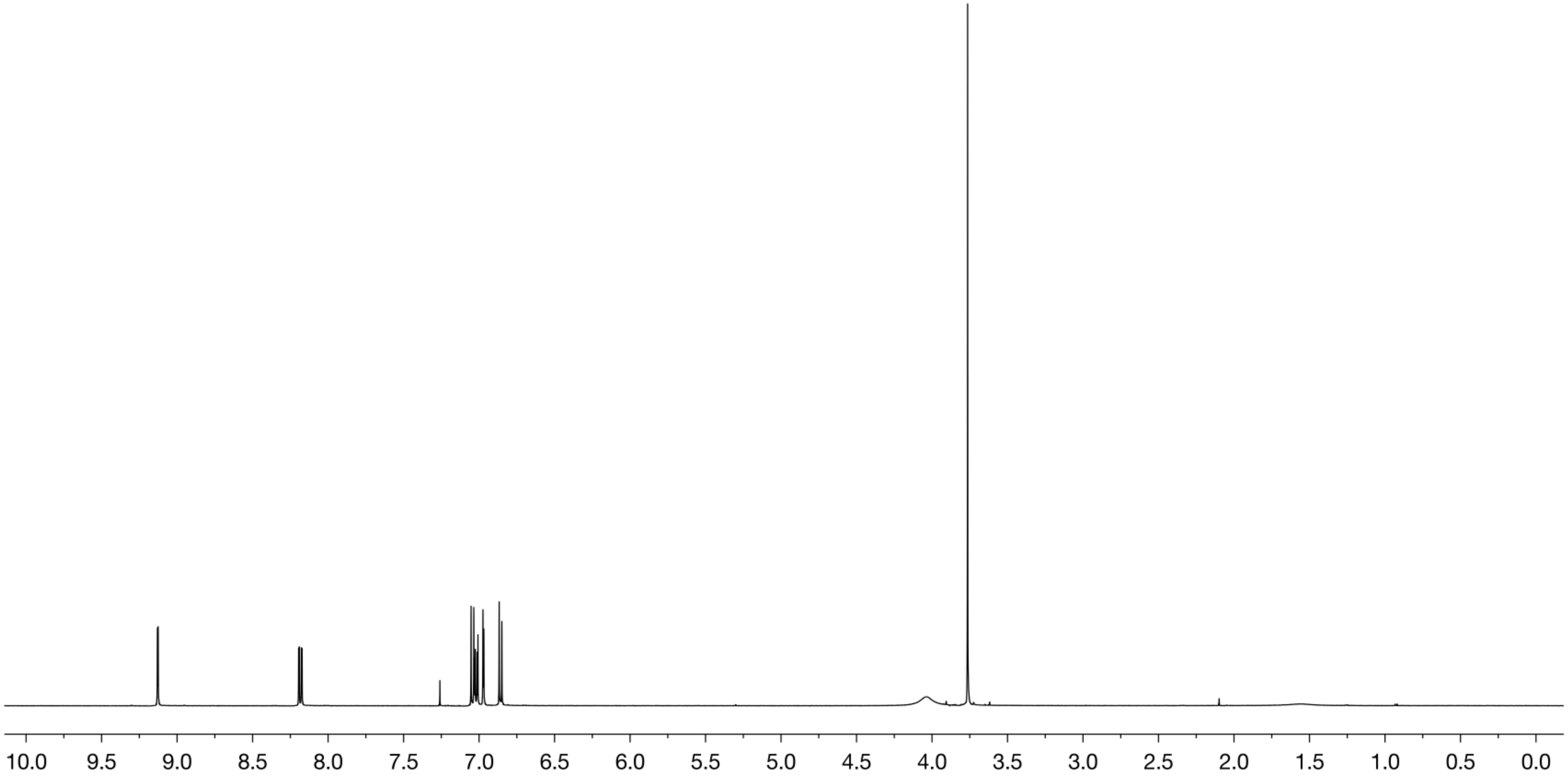


^{1}H NMR of 2-((2,4-dinitrophenyl)thio)-4-methoxyaniline (**S6**):

500 MHz, $CDCl_3$, 23 ºC

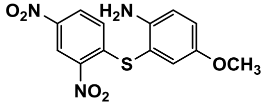


S6

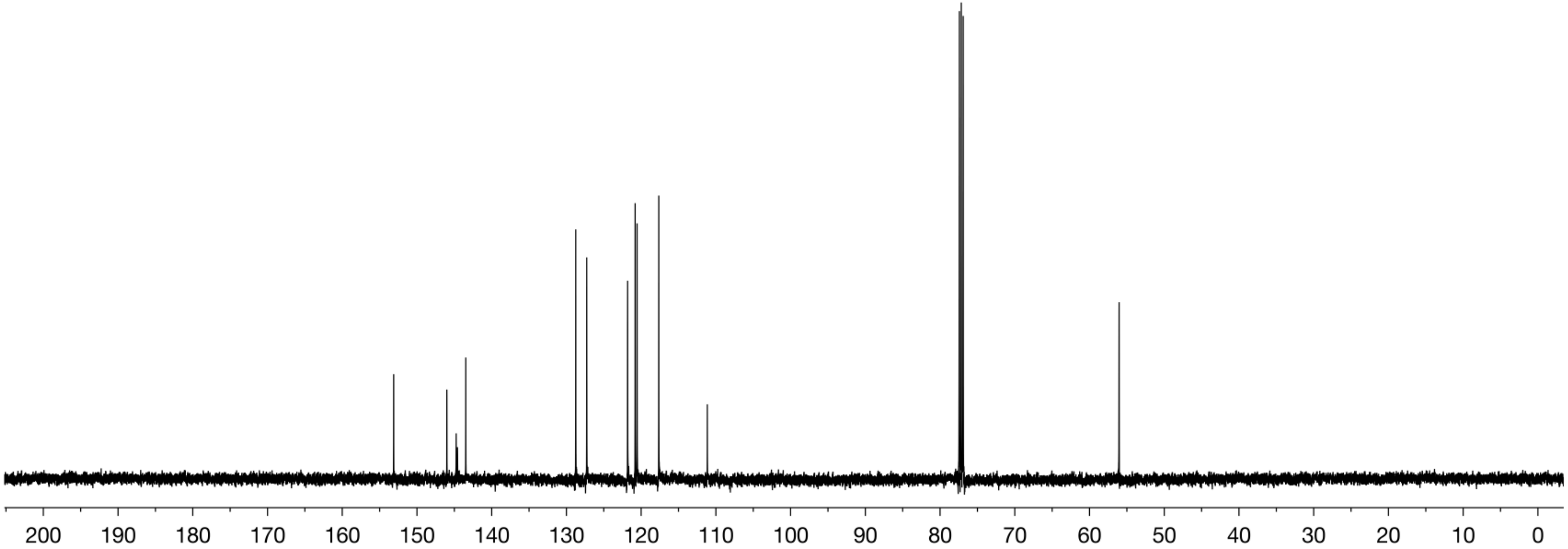


^{13}C NMR of 2-((2,4-dinitrophenyl)thio)-4-methoxyaniline (**S6**):

125 MHz, $CDCl_3$,23 ºC

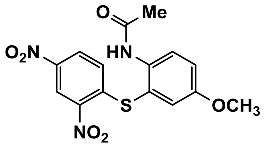


S6



^{1}H NMR of *N*-(2-((2,4-dinitrophenyl)thio)-4-methoxyphenyl)acetamide (**S7**):

500 MHz, $CDCl_3$, 23 ºC



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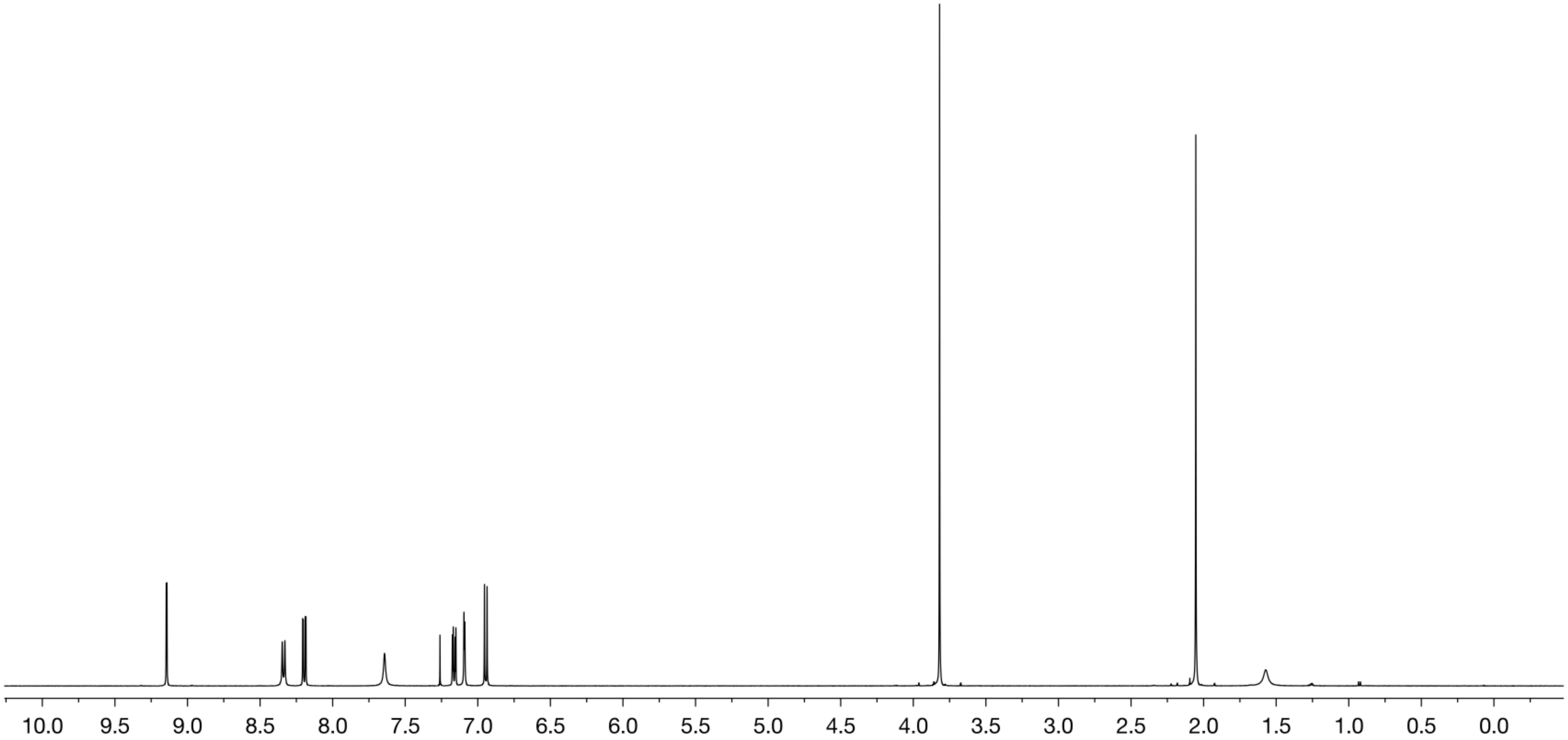
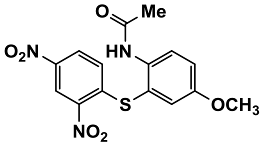
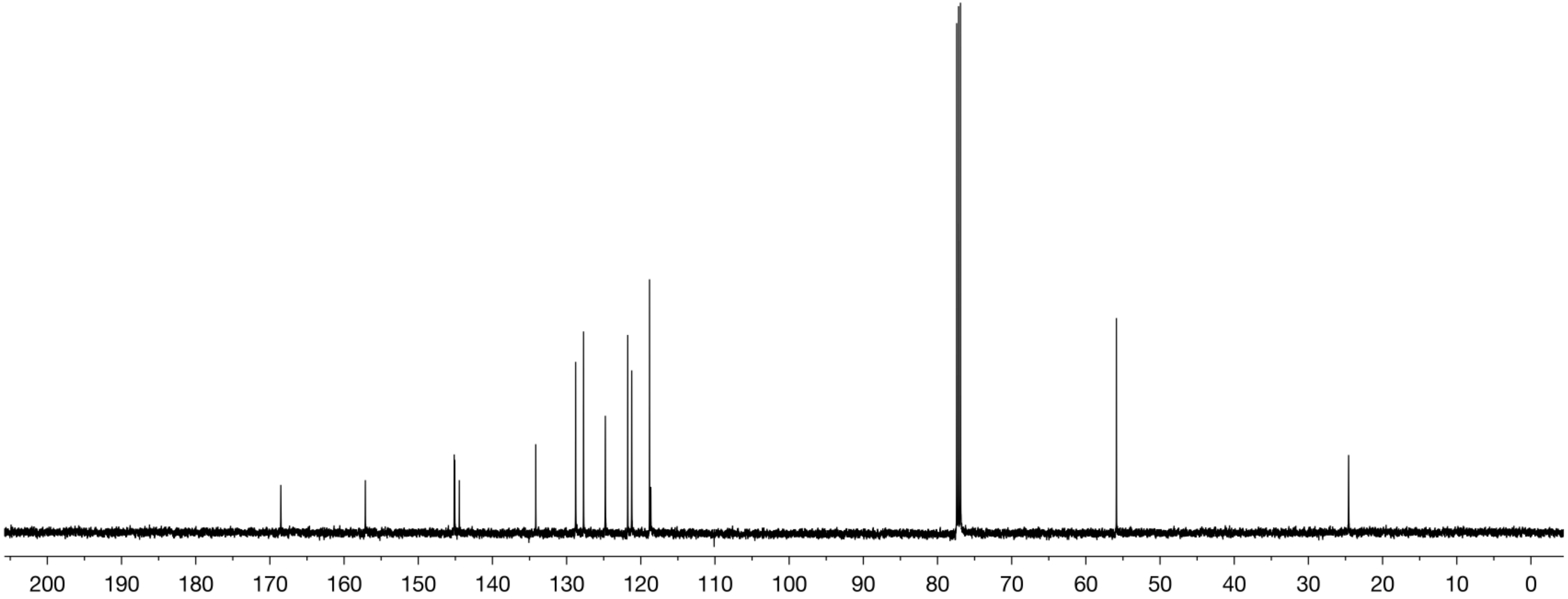


^{13}C NMR of *N*-(2-((2,4-dinitrophenyl)thio)-4-methoxyphenyl)acetamide (**S7**):

125 MHz, $CDCl_3$,23 ºC

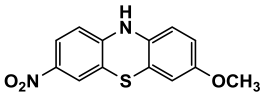


S7

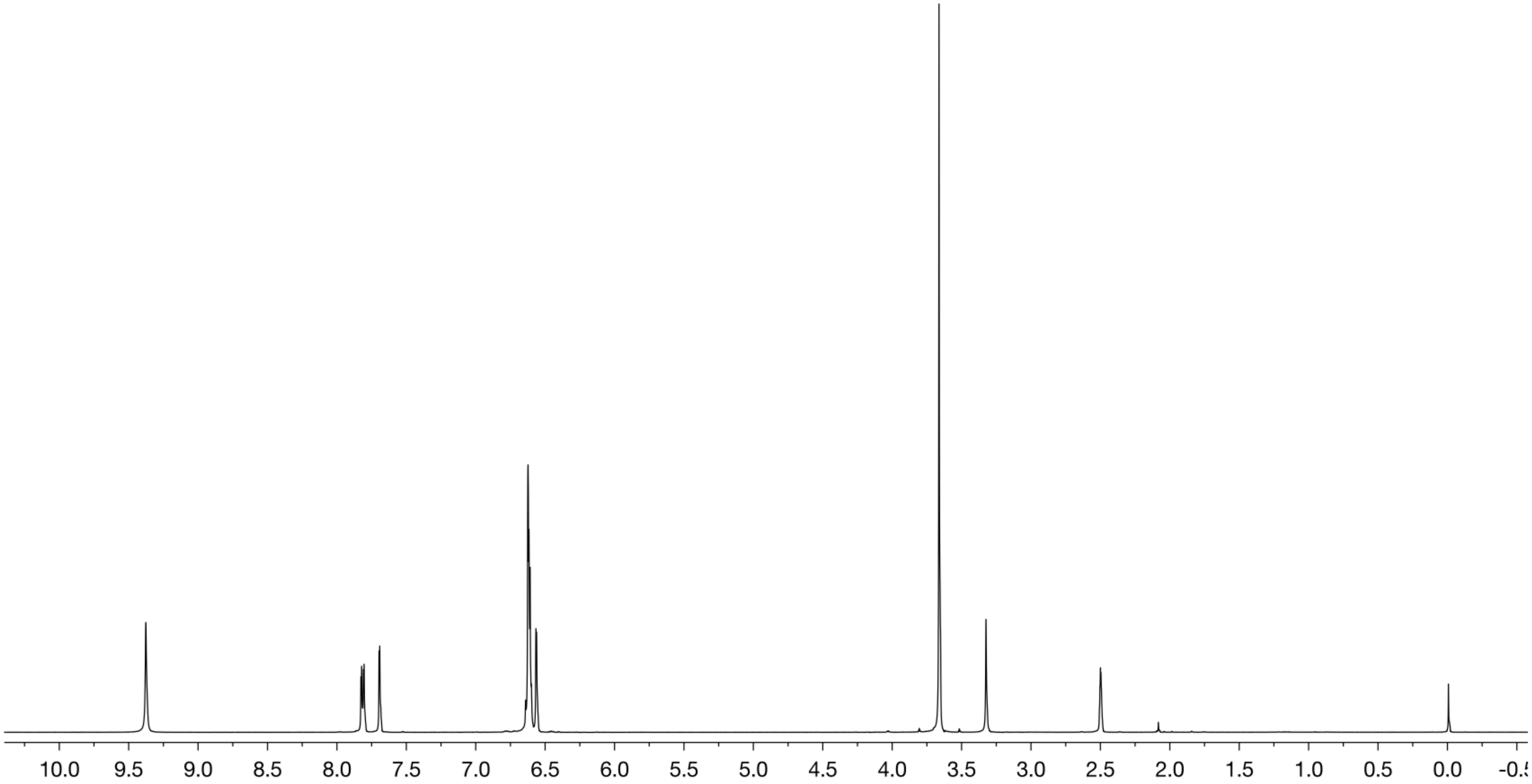


^{1}H NMR of 3-methoxy-7-nitro-10*H*-phenothiazine (**S8**):

500 MHz, DMSO-d_6,23 ºC

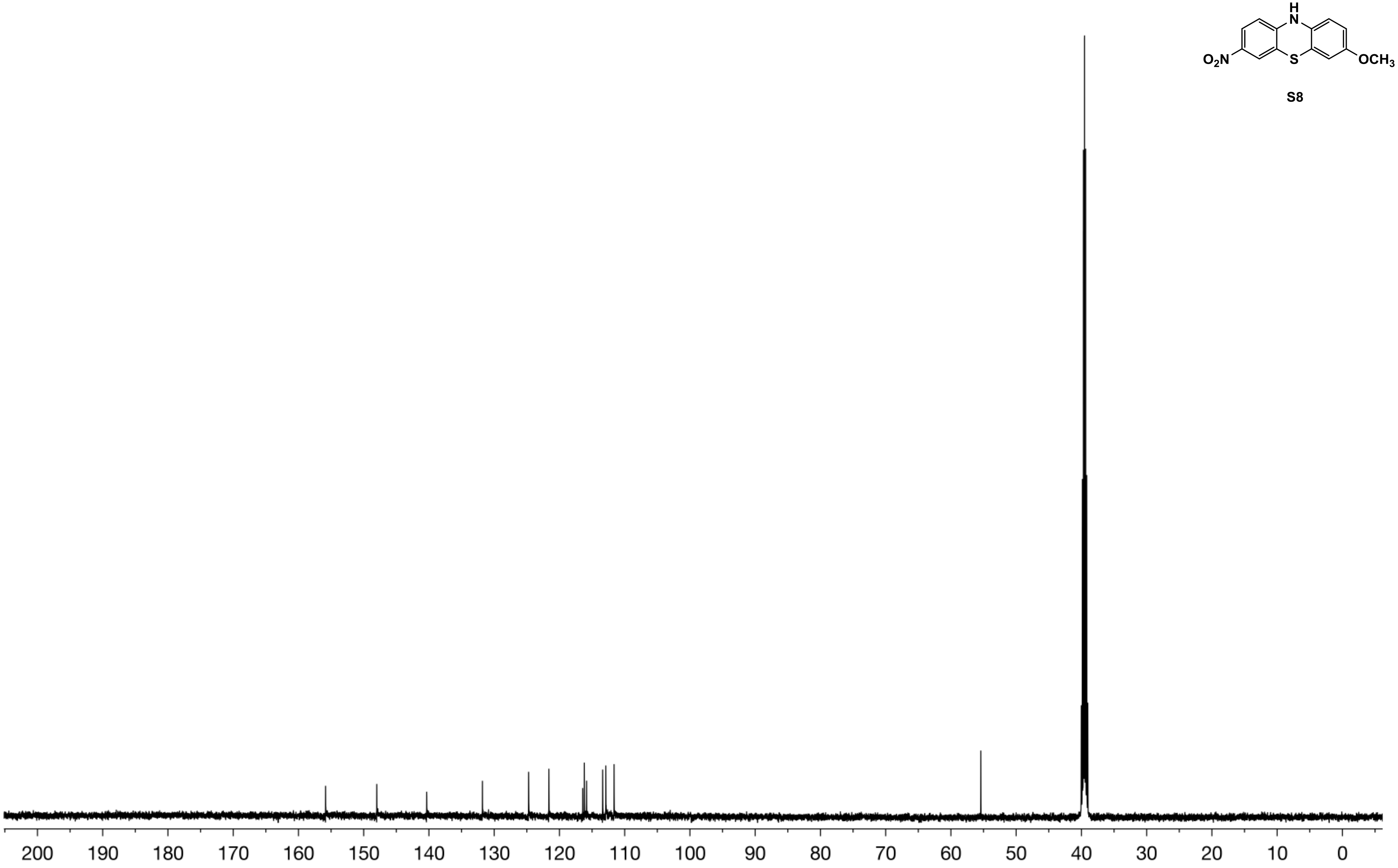


S8



^{13}C NMR of 3-methoxy-7-nitro-10*H*-phenothiazine (**S8**):

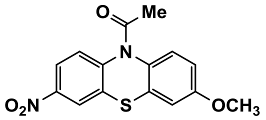
125 MHz, DMSO-d_6, 23 ºC



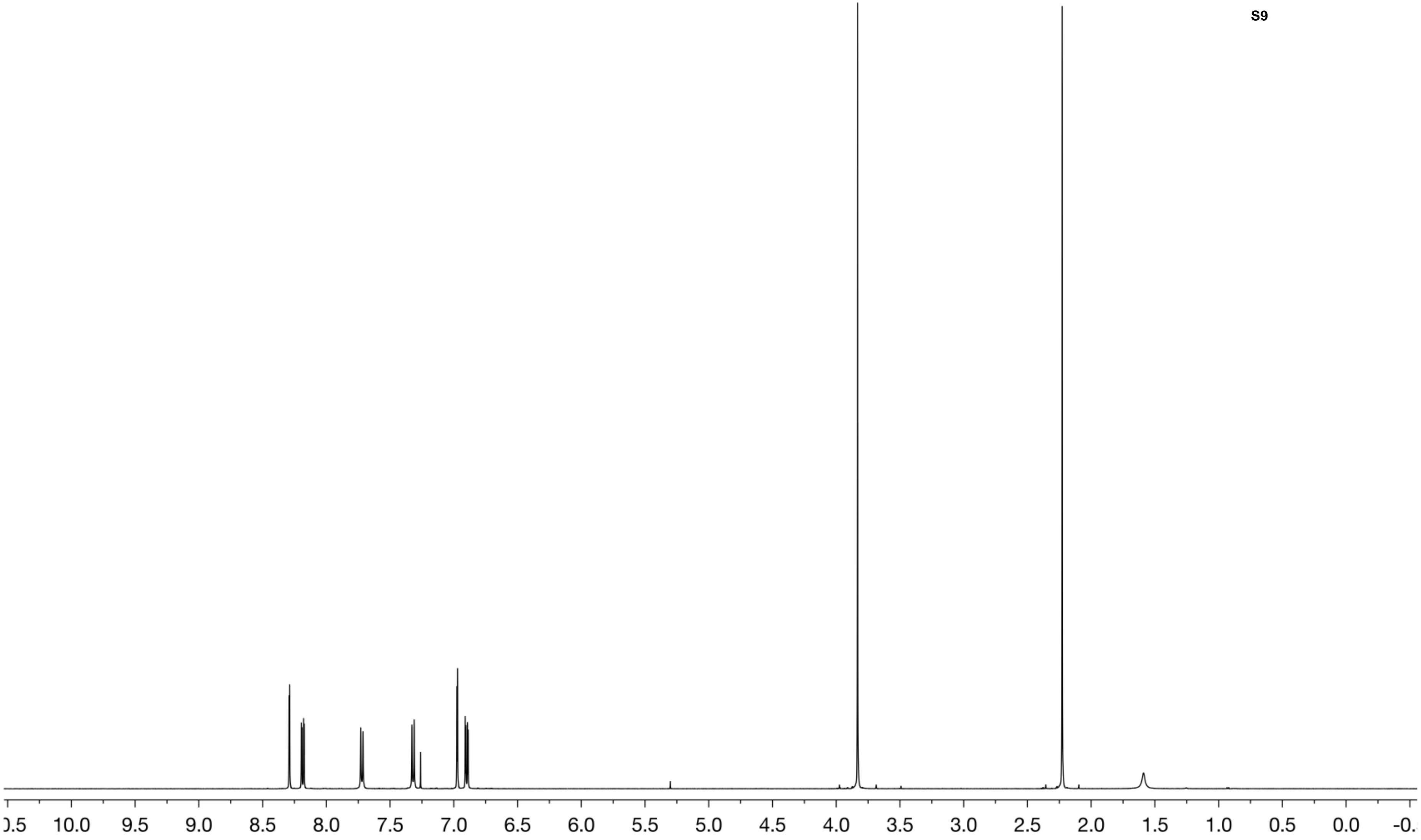
S8

^{1}H NMR of 1-(3-methoxy-7-nitro-10*H*-phenothiazin-10-yl)ethan-1-one (**S9**):

500 MHz, $CDCl_3$, 23 ºC

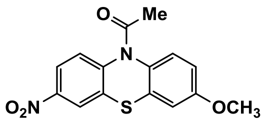


S9

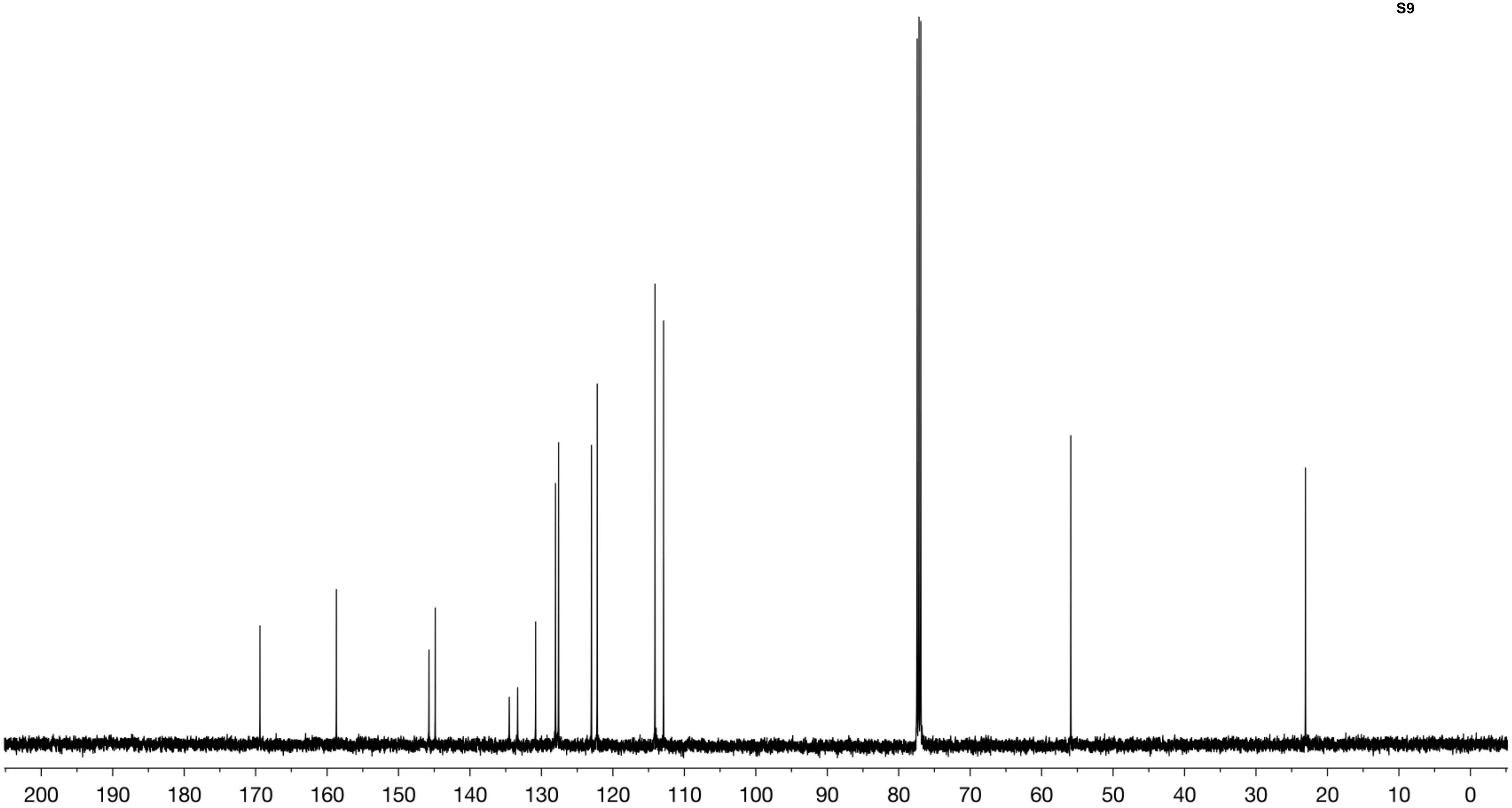


^{13}C NMR of 1-(3-hydroxy-7-nitro-10*H*-phenothiazin-10-yl)ethan-1-one (**S9**):

125 MHz, DMSO-d_6, 23 ºC

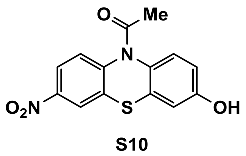


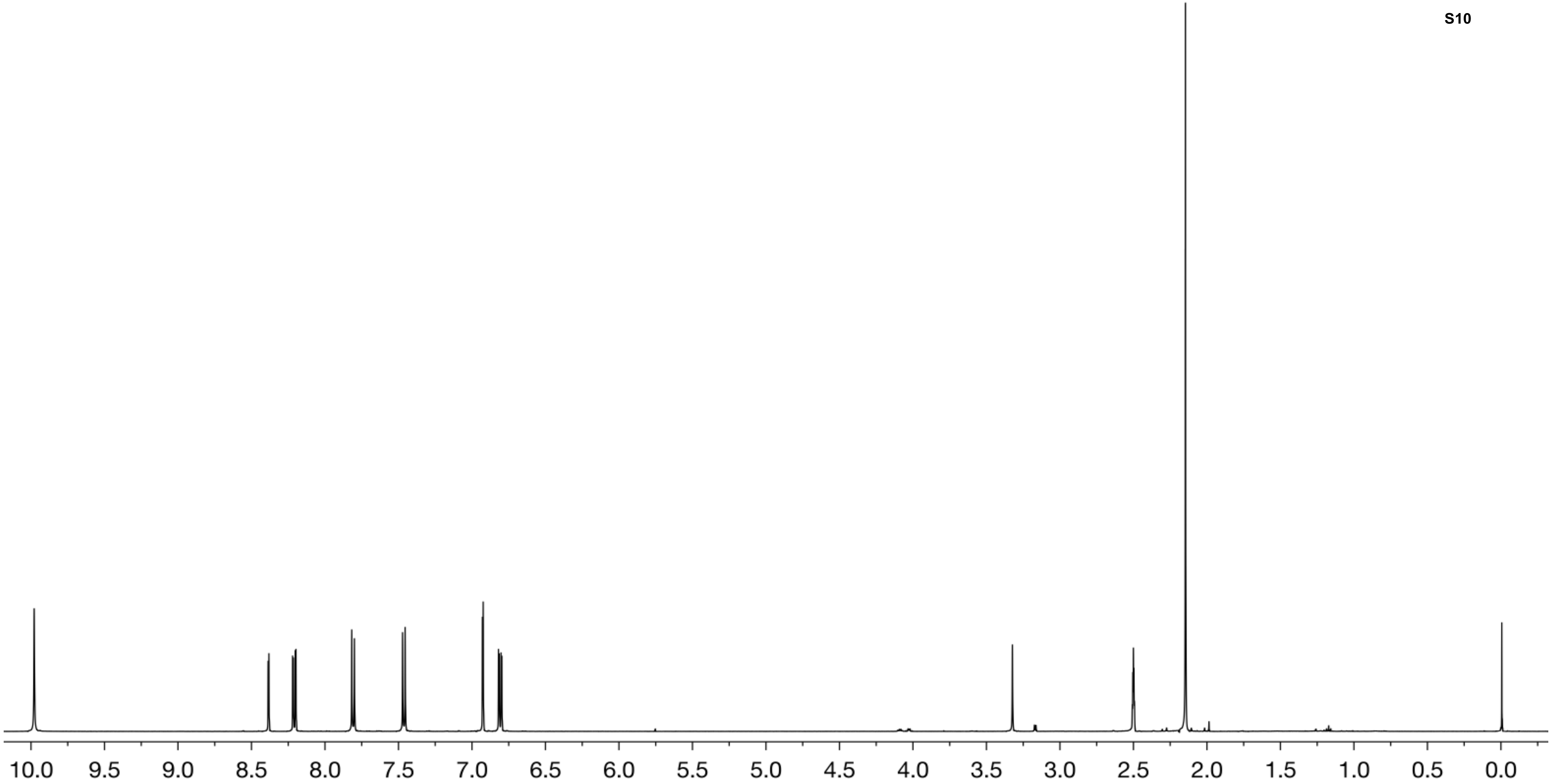
S9



^{1}H NMR of 1-(3-hydroxy-7-nitro-10*H*-phenothiazin-10-yl)ethan-1-one (**S10**):

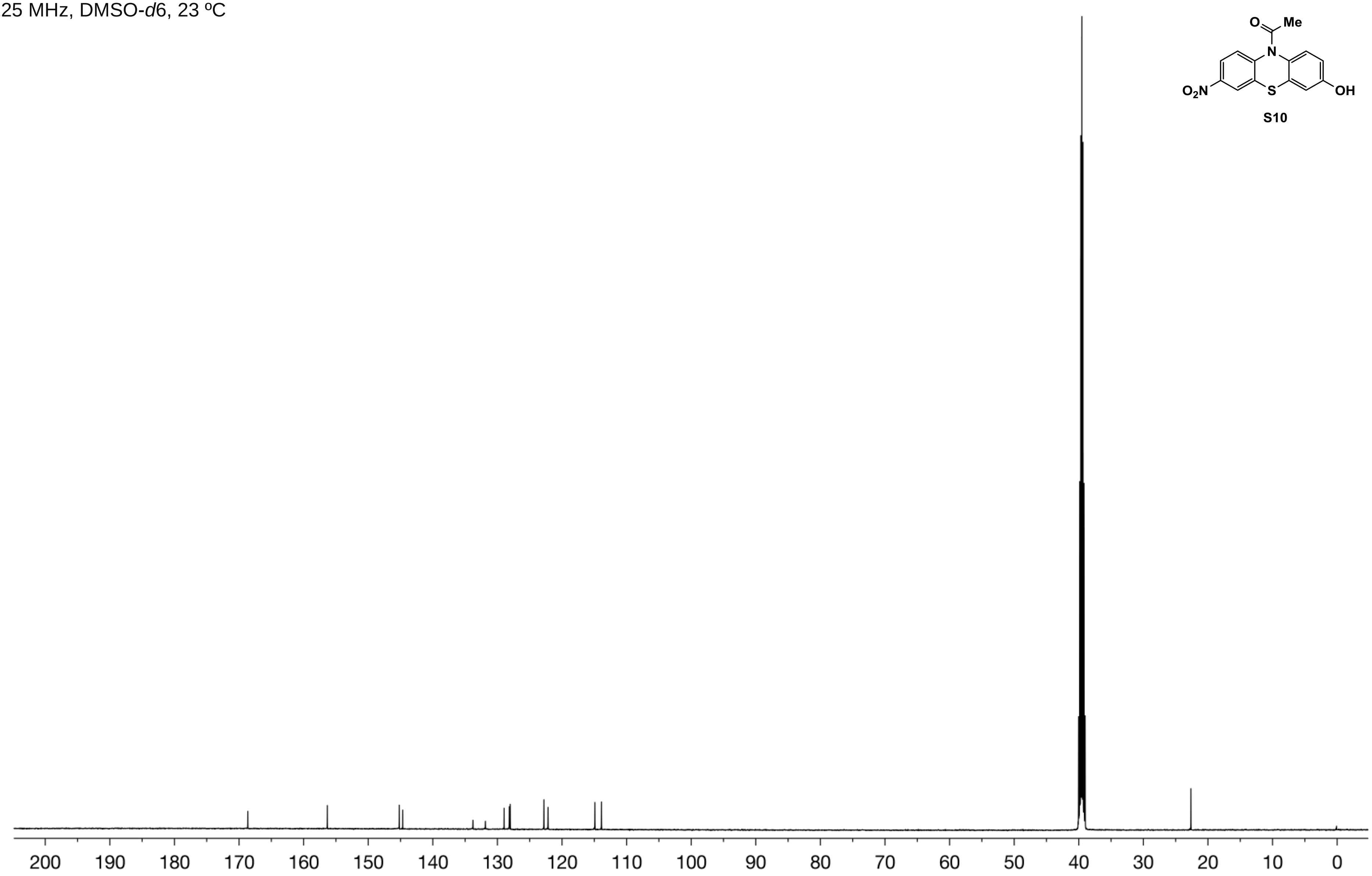
500 MHz, DMSO-d_6, 23 ºC





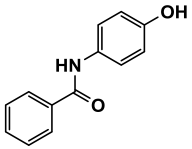
^{13}C NMR of 1-(3-hydroxy-7-nitro-10*H*-phenothiazin-10-yl)ethan-1-one (**S10**):

125 MHz, DMSO-*d*6, 23 ºC

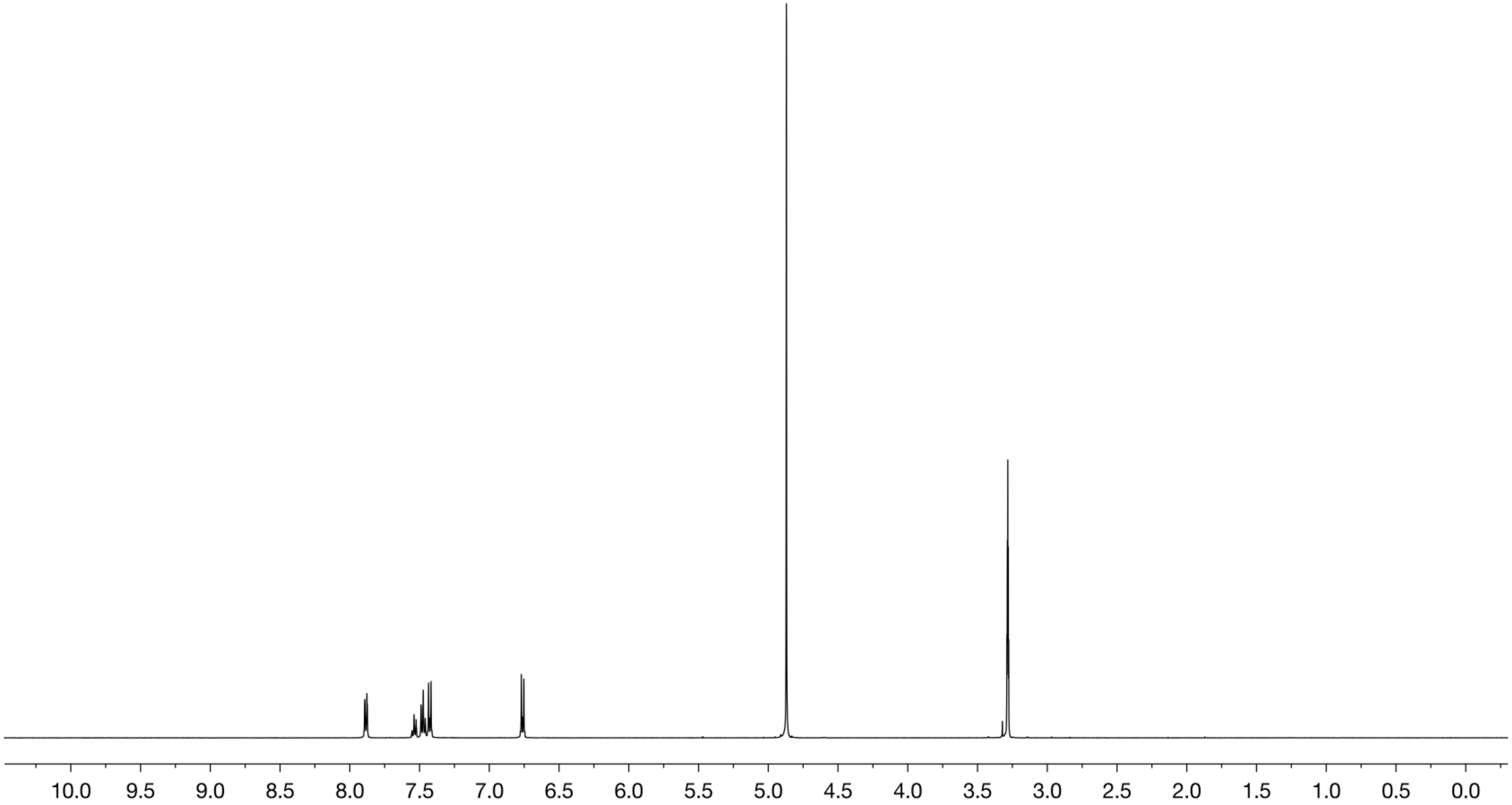


^{1}H NMR *N*-(4-Hydroxyphenyl)benzamide (**S11**):

500 MHz, CD_3OD, 23 ºC

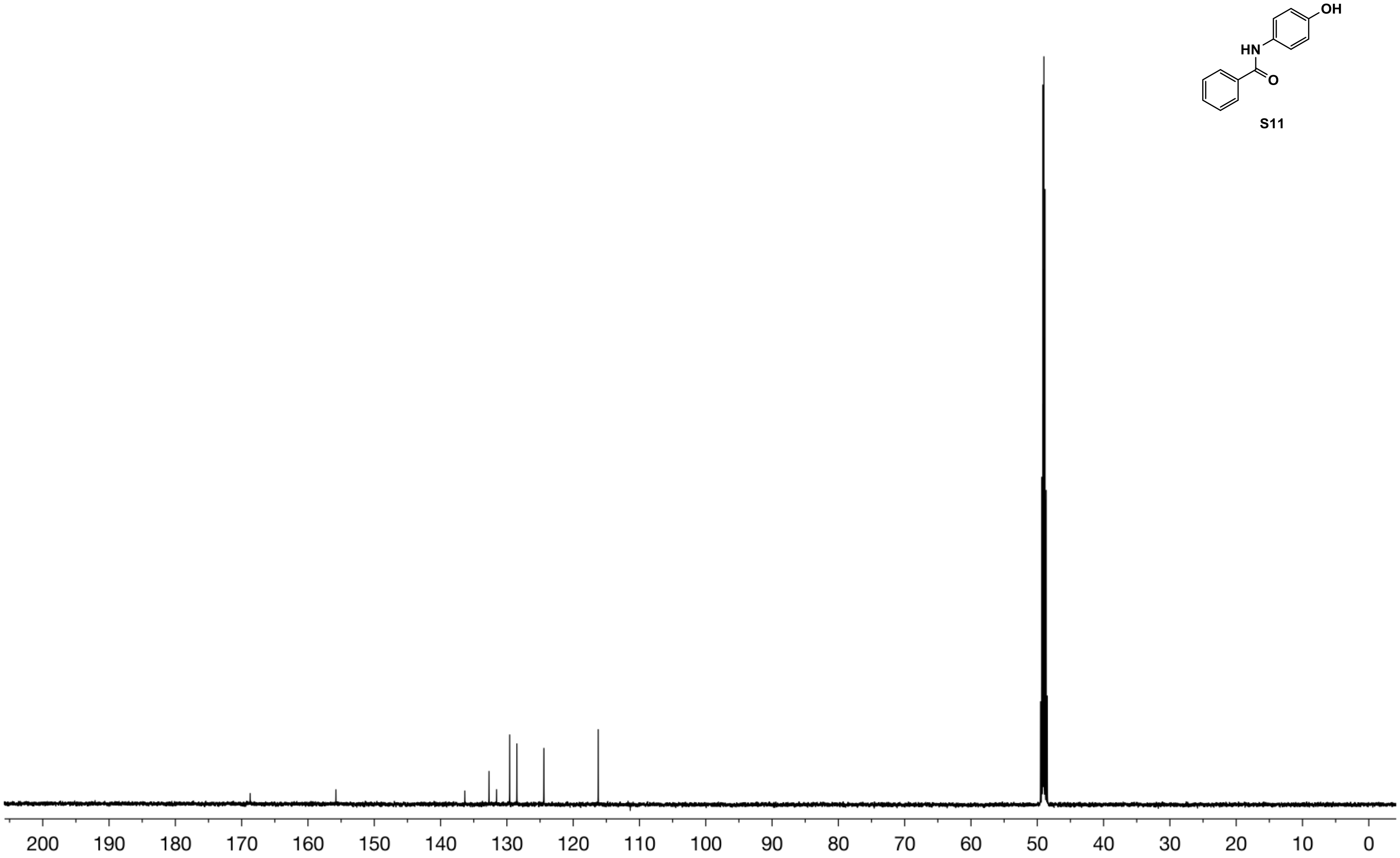


S11



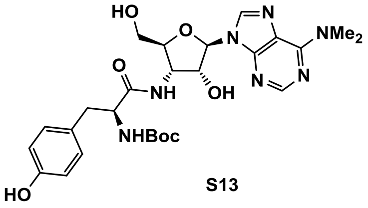
^{13}C NMR *N*-(4-Hydroxyphenyl)benzamide (**S11**):

125 MHz, CD_3OD, 23 ºC

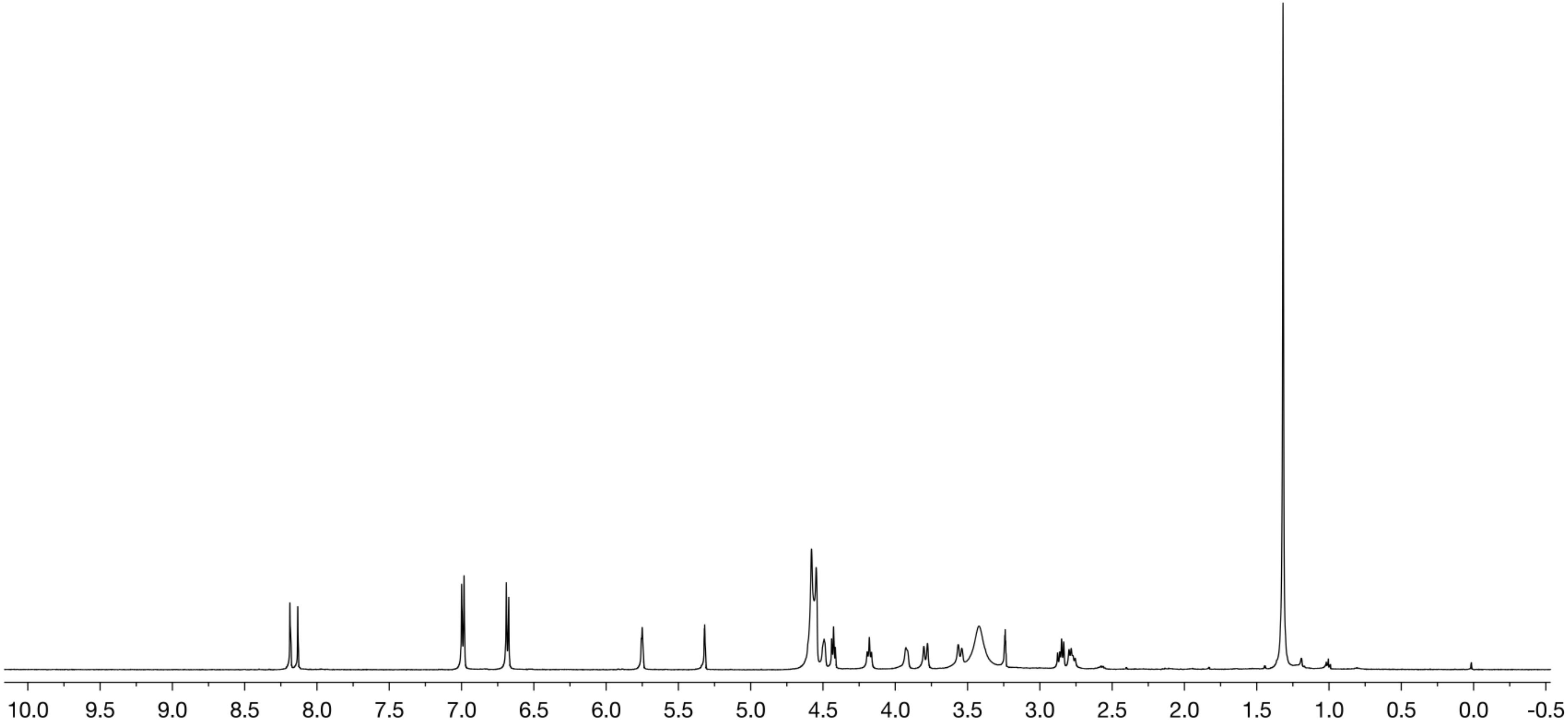


^{1}H NMR of *tert*-butyl ((*S*)-1-(((2*S*,3*S*,4*R*,5*R*)-5-(6-(dimethylamino)-9*H*-purin-9-yl)-4-hydroxy-2-(hydroxymethyl)tetrahydrofuran-3-yl)amino)-3-(4-hydroxyphenyl)-1-oxopropan-2-yl)carbamate (**S13**):

500 MHz, CD_2Cl_2:CD_3OD (1:1), 23 ºC

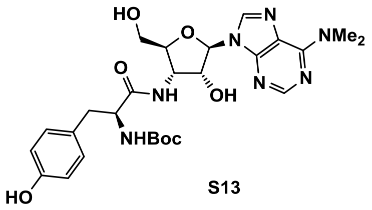


S13

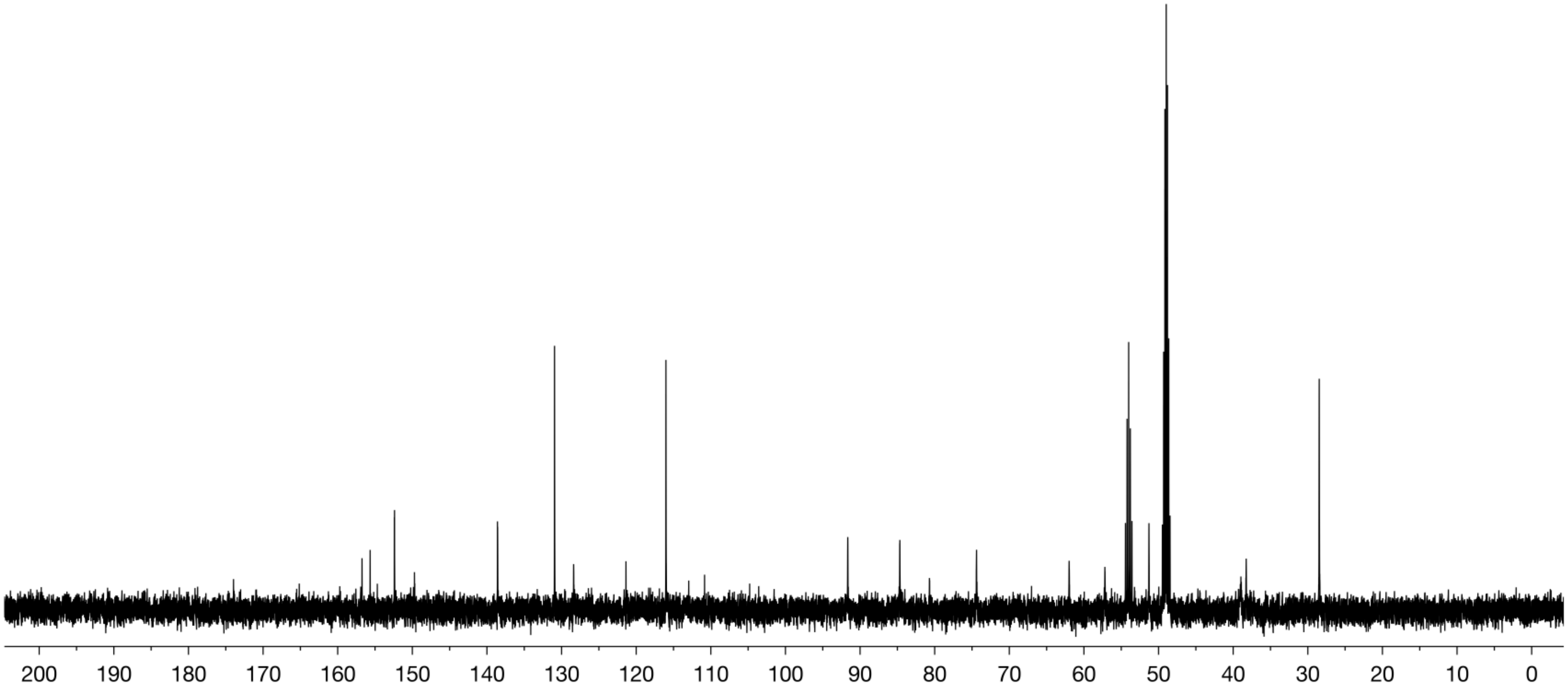


^{13}C NMR of *tert*-butyl ((*S*)-1-(((2*S*,3*S*,4*R*,5*R*)-5-(6-(dimethylamino)-9*H*-purin-9-yl)-4-hydroxy-2-(hydroxymethyl)tetrahydrofuran-3-yl)amino)-3-(4-hydroxyphenyl)-1-oxopropan-2-yl)carbamate (**S13**):

125 MHz, CD_2Cl_2:CD_3OD (1:1), 23 ºC

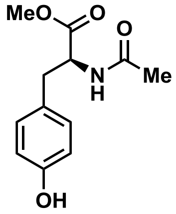


S13



^{1}H NMR of methyl acetyl-*L*-tyrosinate (**8**):

600 MHz, CDCl$_3$, 23 ºC



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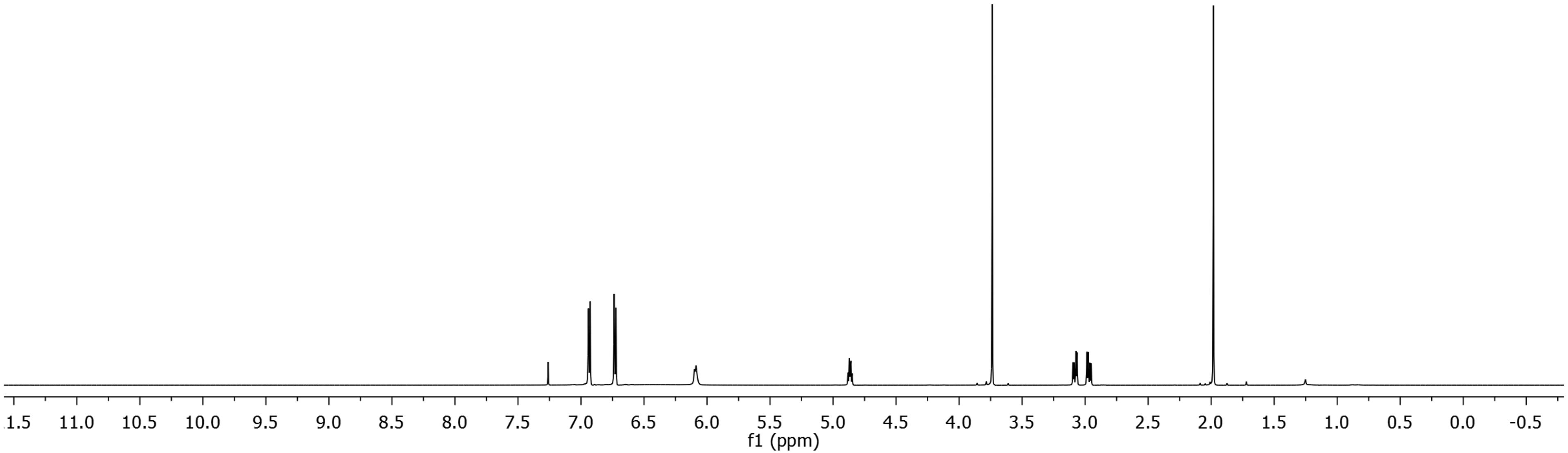
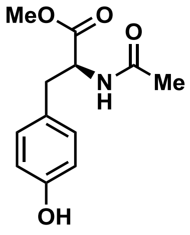


^{13}C NMR of methyl acetyl-*L*-tyrosinate (**8**):

126 MHz, CDCl$_3$, 23 ºC



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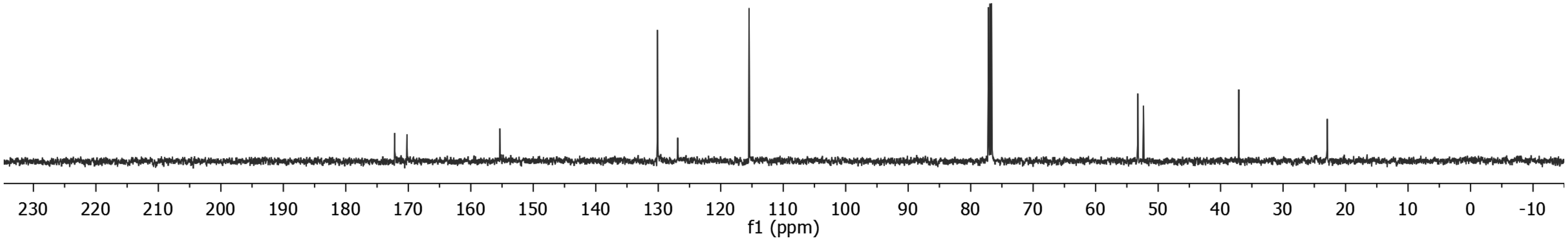
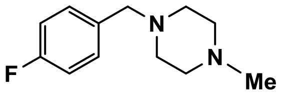
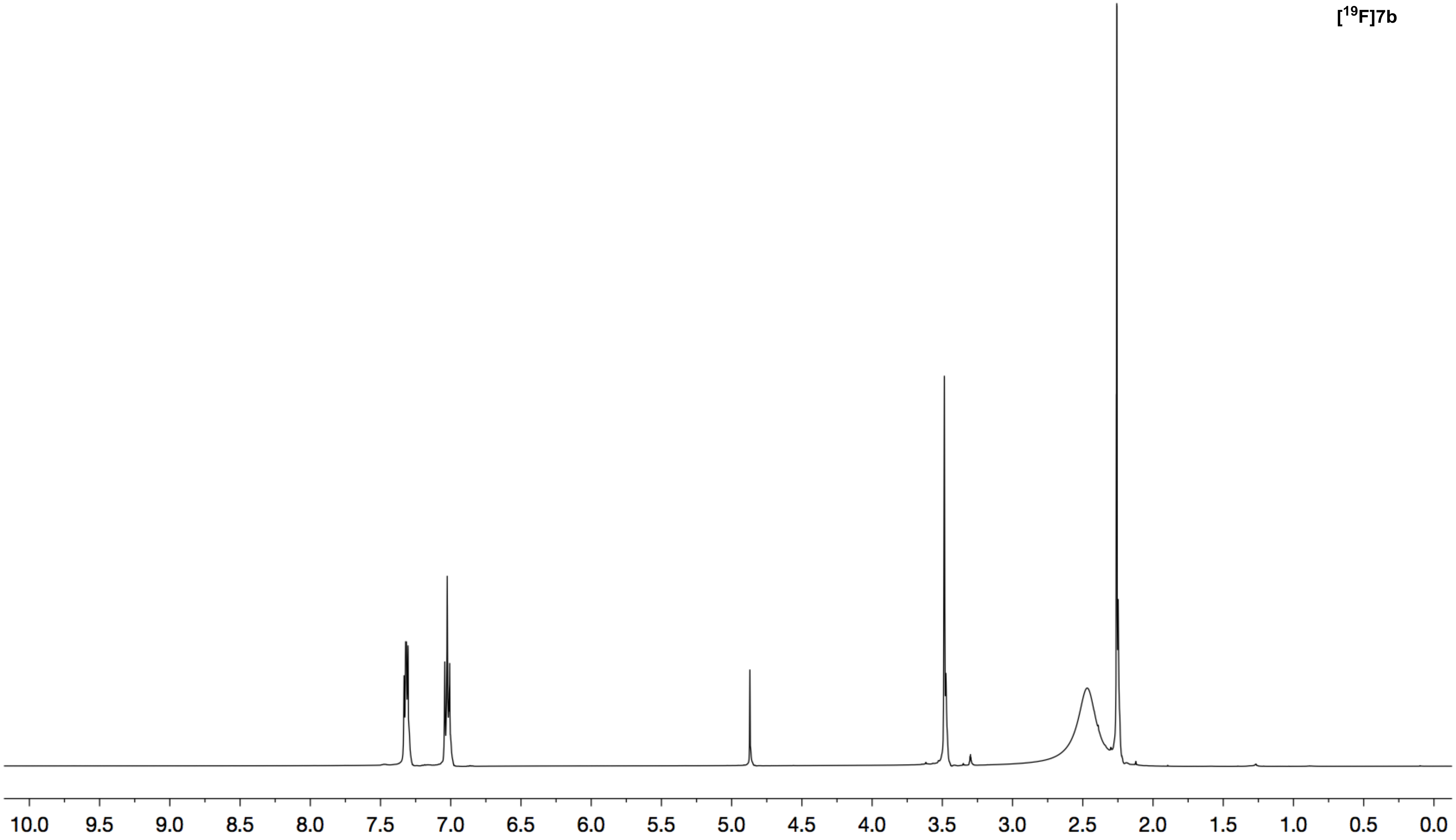


^{1}H NMR of 1-(4-fluorobenzyl)-4-methylpiperazine (**[^{19}F]7b**):

500 MHz, CD_3OD, 23 ºC

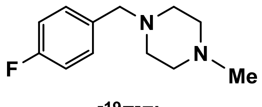


[^{19}F]7b

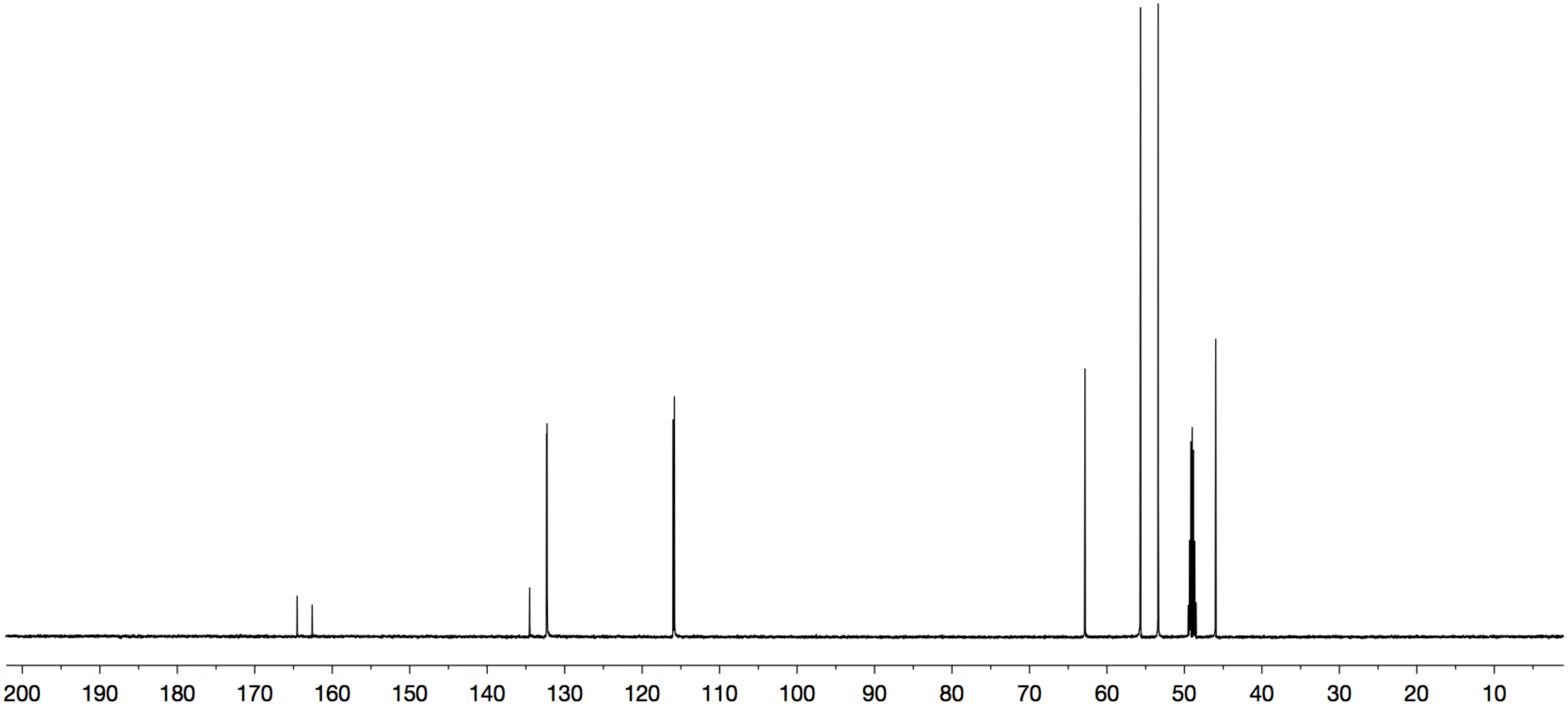


^{13}C NMR of 1-(4-fluorobenzyl)-4-methylpiperazine (**[^{19}F]7b**):

125 MHz, CD$_3$OD, 23 ºC

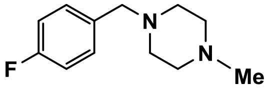


[^{19}F]7b

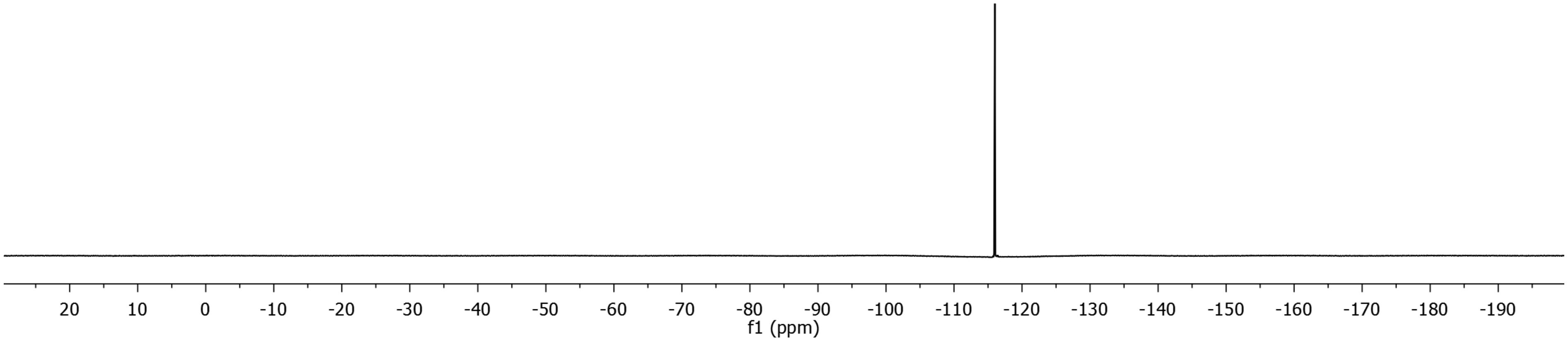


^{19}F NMR of 1-(4-fluorobenzyl)-4-methylpiperazine (**[^{19}F]7b**):

376 MHz, $CDCl_3$, 23 ºC

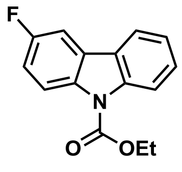


[^{19}F]7b

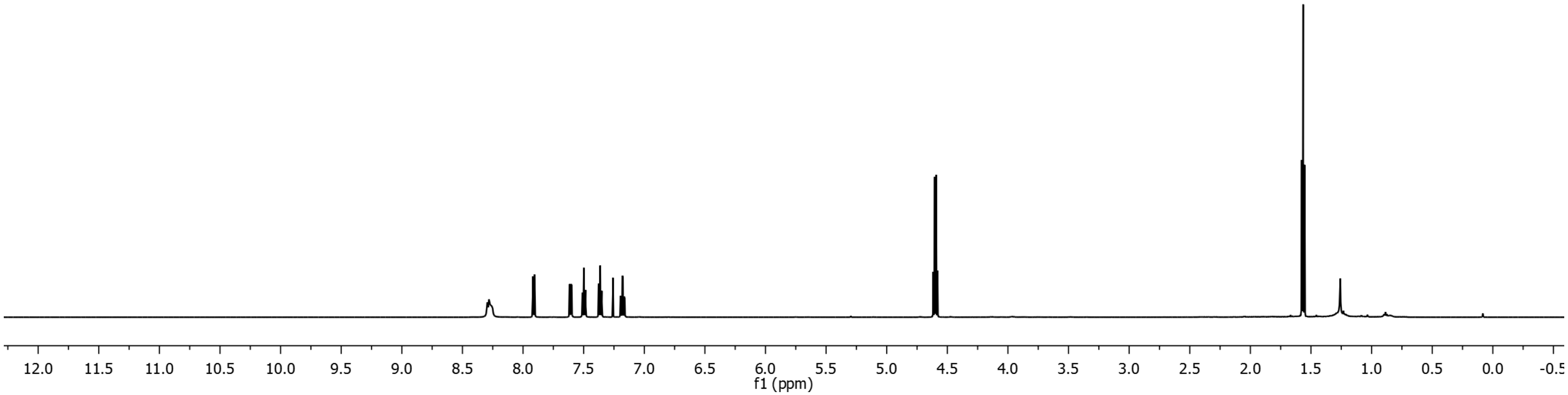


^{1}H NMR of ethyl 3-fluoro-9*H*-carbazole-9-carboxylate (**[^{19}F]7f**):

600 MHz, CDCl$_3$, 23 ºC

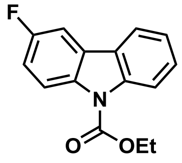


[^{19}F]7f

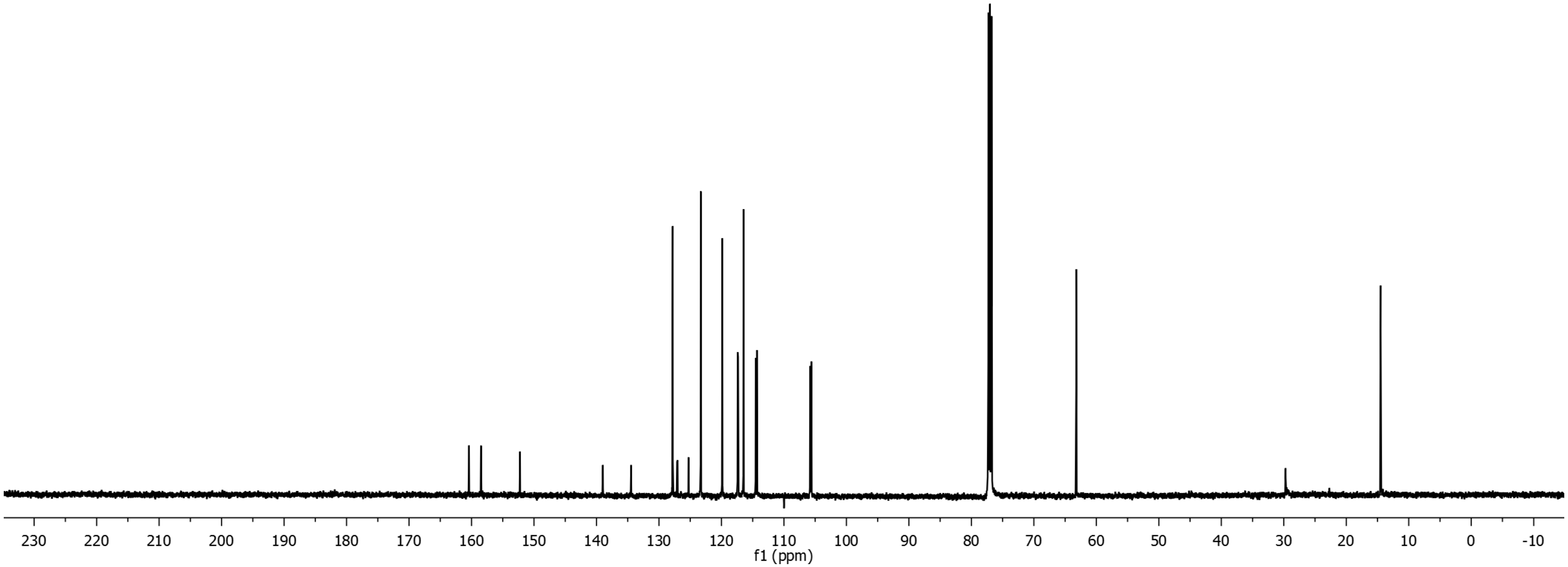


^{13}C NMR of ethyl 3-fluoro-9*H*-carbazole-9-carboxylate (**[^{19}F]7f**):

126 MHz, CDCl$_3$, 23 ºC

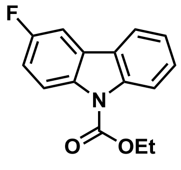


[^{19}F]7f

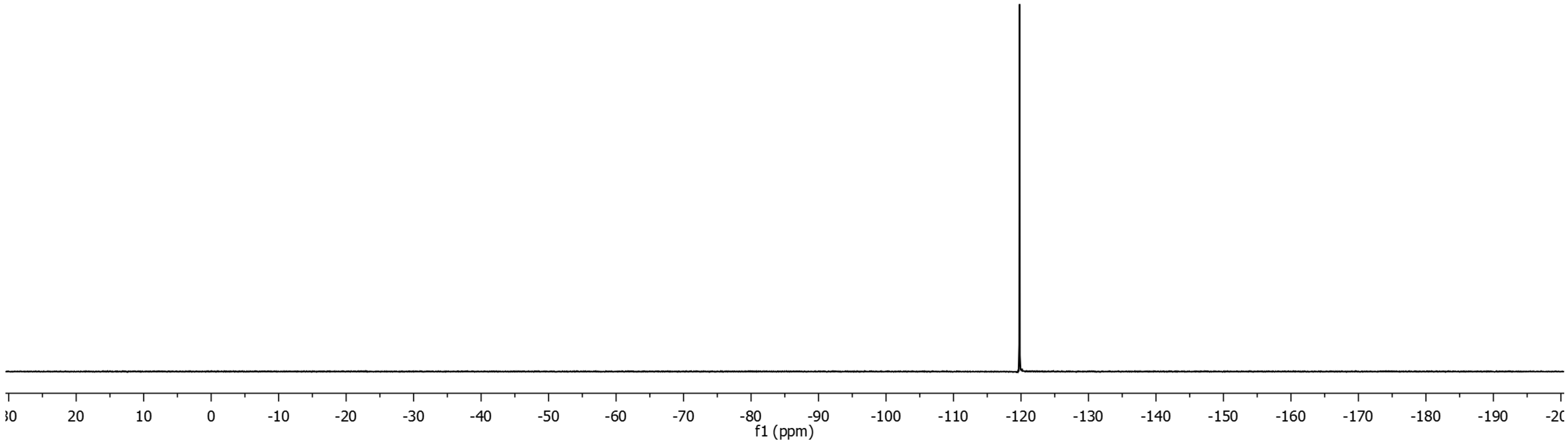


^{19}F NMR of ethyl 3-fluoro-9*H*-carbazole-9-carboxylate (**[^{19}F]7f**):

471 MHz, CDCl$_3$, 23 ºC

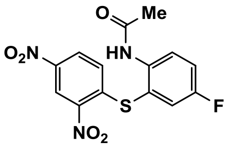


[^{19}F]7f

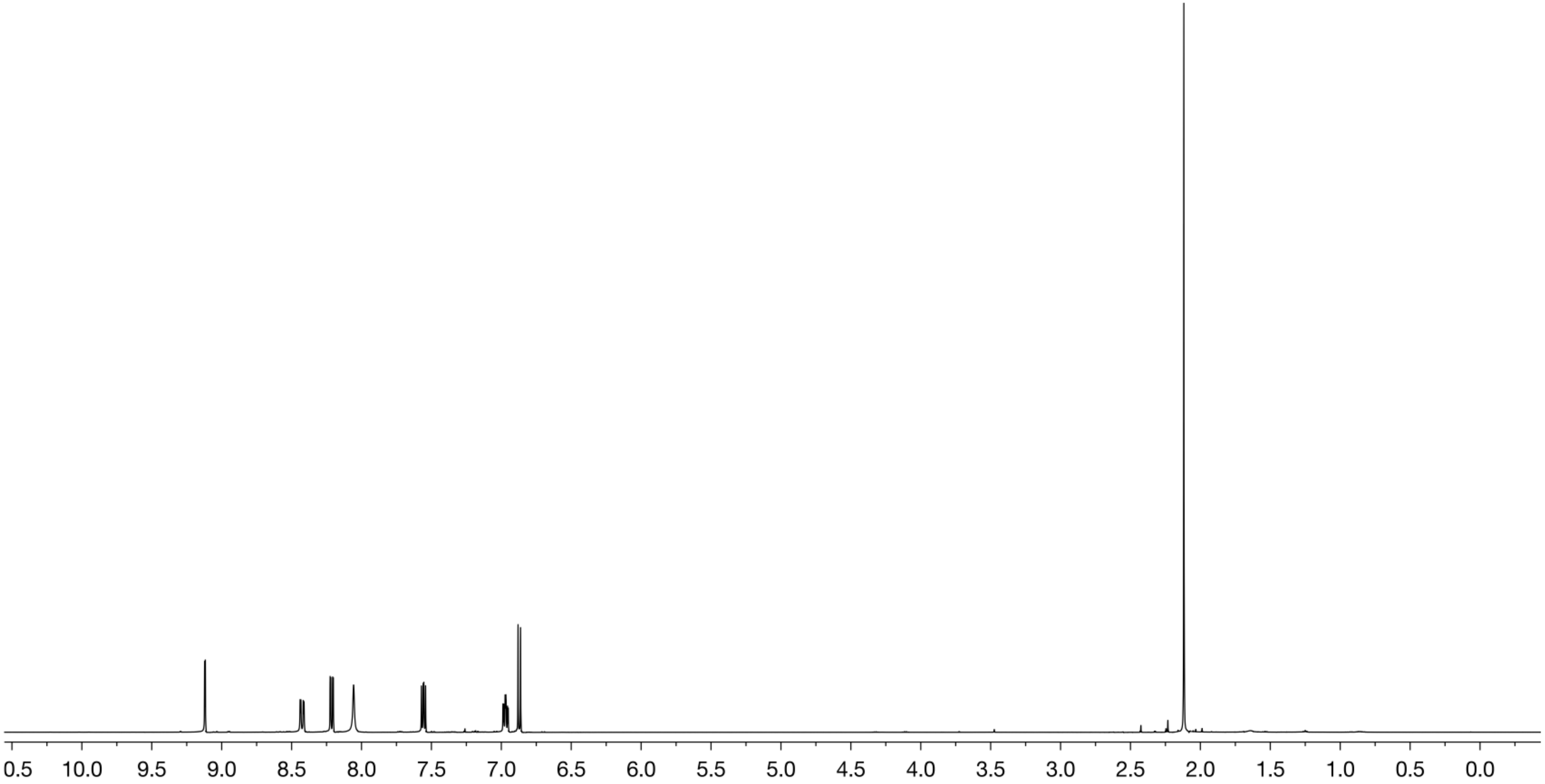


^{1}H NMR of *N*-(2-((2,4-dinitrophenyl)thio)-4-fluorophenyl)acetamide (**S17**):

500 MHz, $CDCl_3$, 23 ºC

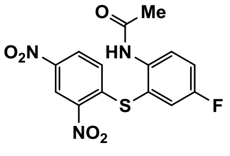


S17

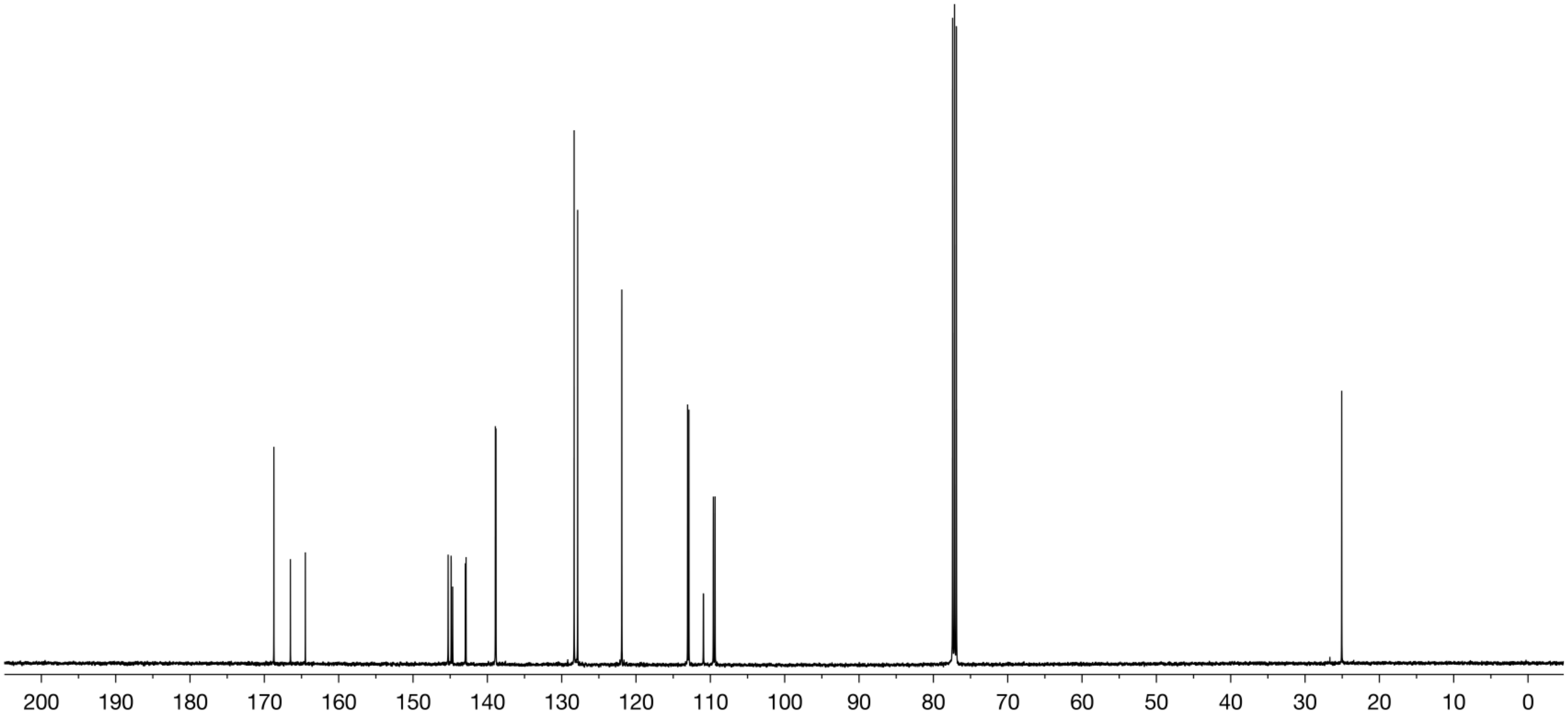


^{13}C NMR of *N*-(2-((2,4-dinitrophenyl)thio)-4-fluorophenyl)acetamide (**S17**):

125 MHz, $CDCl_3$, 23 ºC

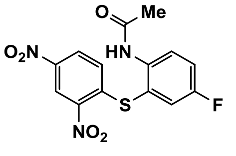


S17



^{19}F NMR of *N*-(2-((2,4-dinitrophenyl)thio)-4-fluorophenyl)acetamide (**S17**):

376 MHz, $CDCl_3$, 23 ºC



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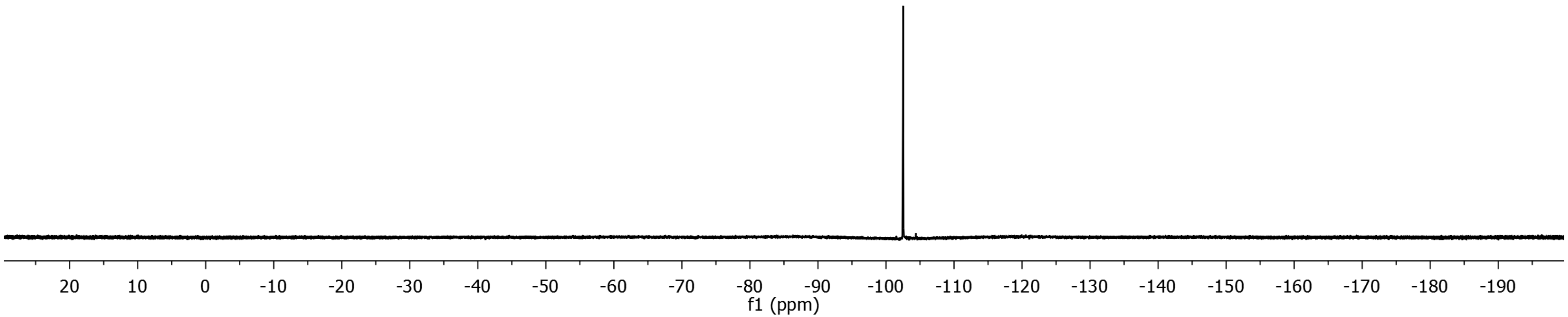
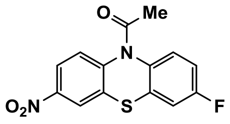
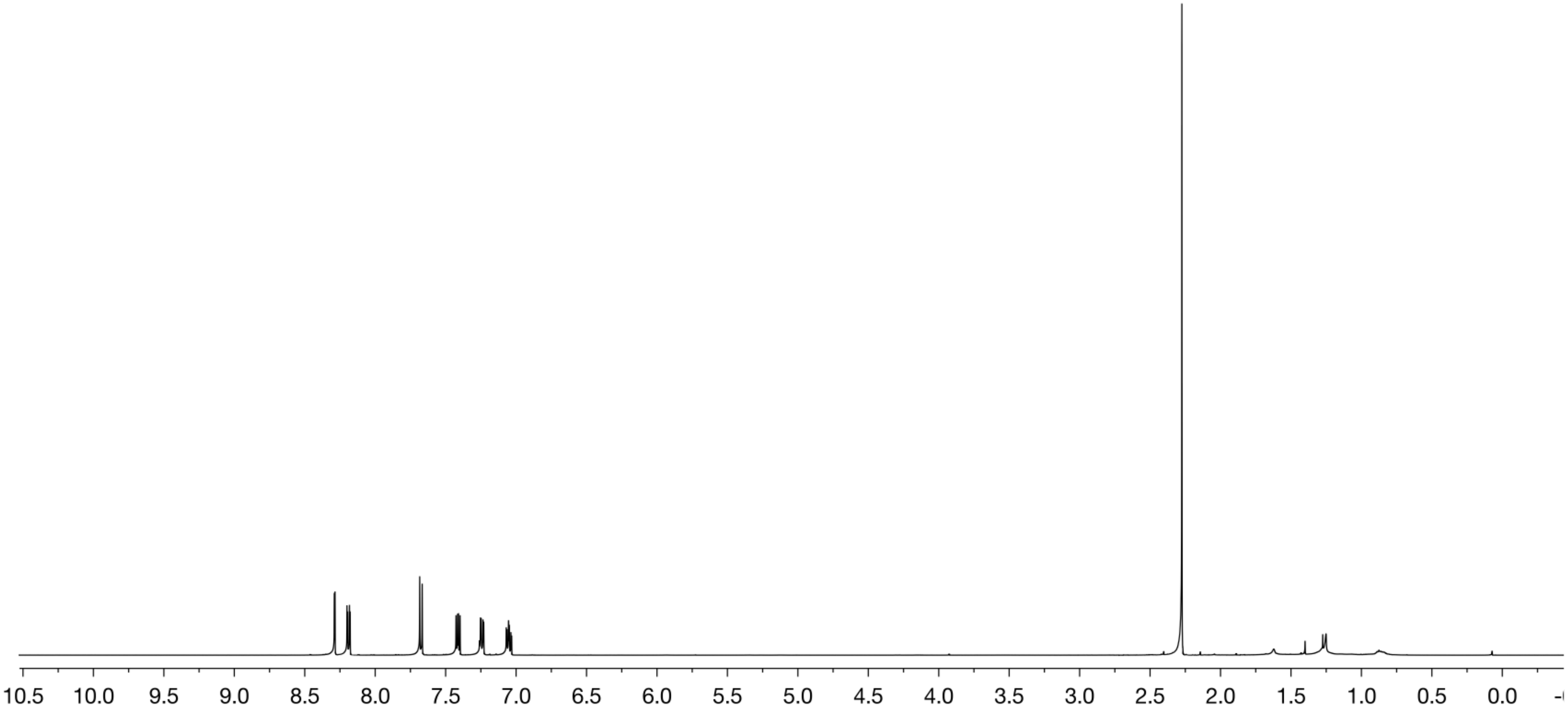


^{1}H NMR of 1-(3-fluoro-7-nitro-10*H*-phenothiazin-10-yl)ethan-1-one (**[^{19}F]7g**):

500 MHz, $CDCl_3$, 23 ºC

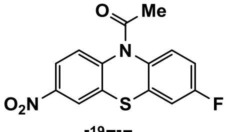


[^{19}F]7g

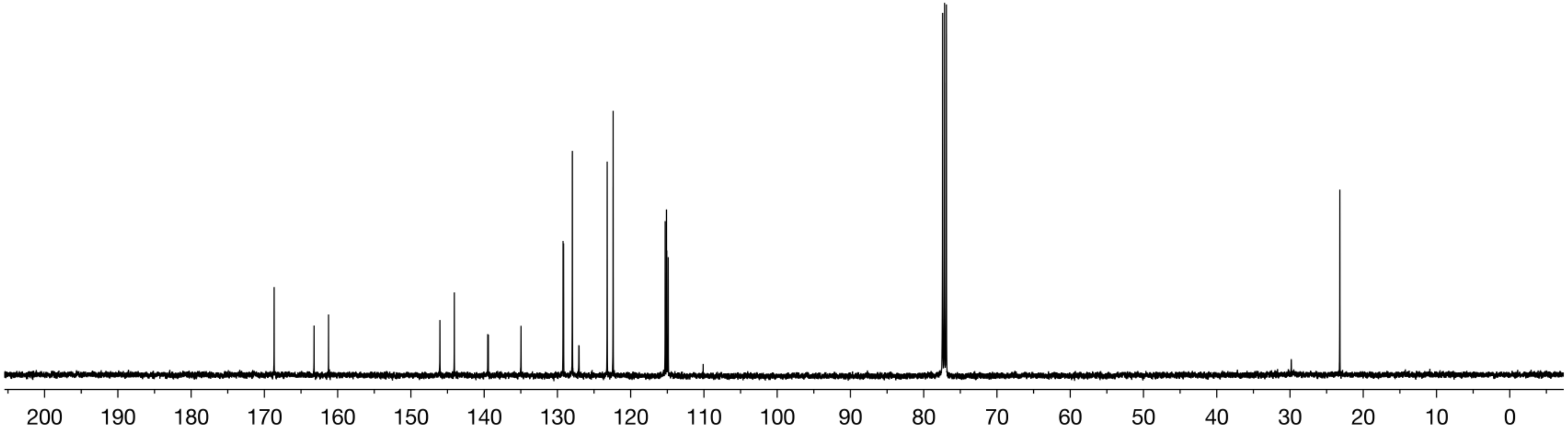


^{13}C NMR of 1-(3-fluoro-7-nitro-10*H*-phenothiazin-10-yl)ethan-1-one (**[^{19}F]7g**):

125 MHz, CDCl$_3$, 23 ºC

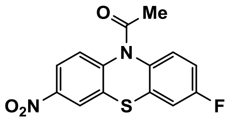


[^{19}F]7g

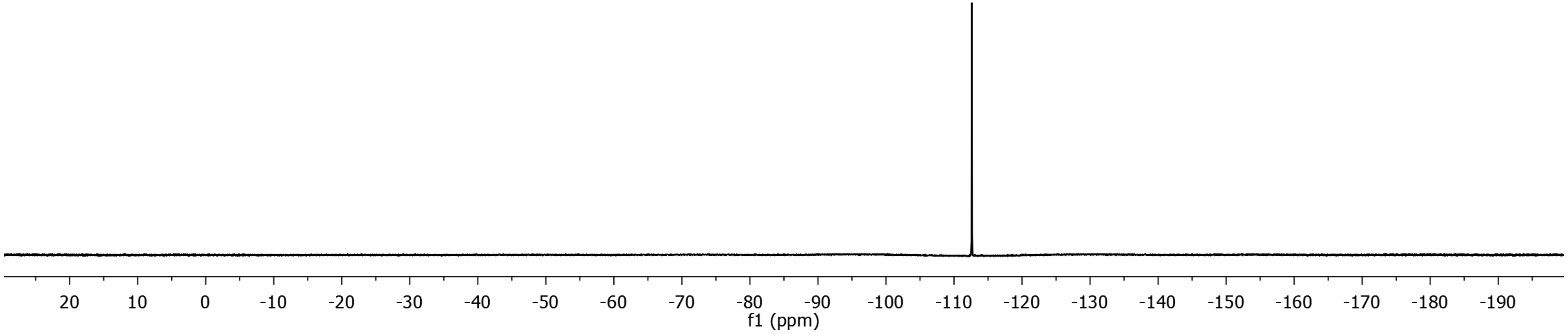


^{19}F NMR of 1-(3-fluoro-7-nitro-10*H*-phenothiazin-10-yl)ethan-1-one (**[^{19}F]7g**):

376 MHz, $CDCl_3$, 23 ºC

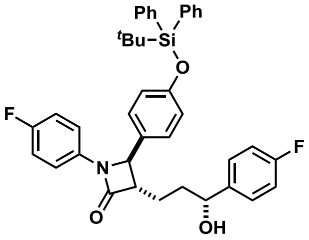


[^{19}F]7g

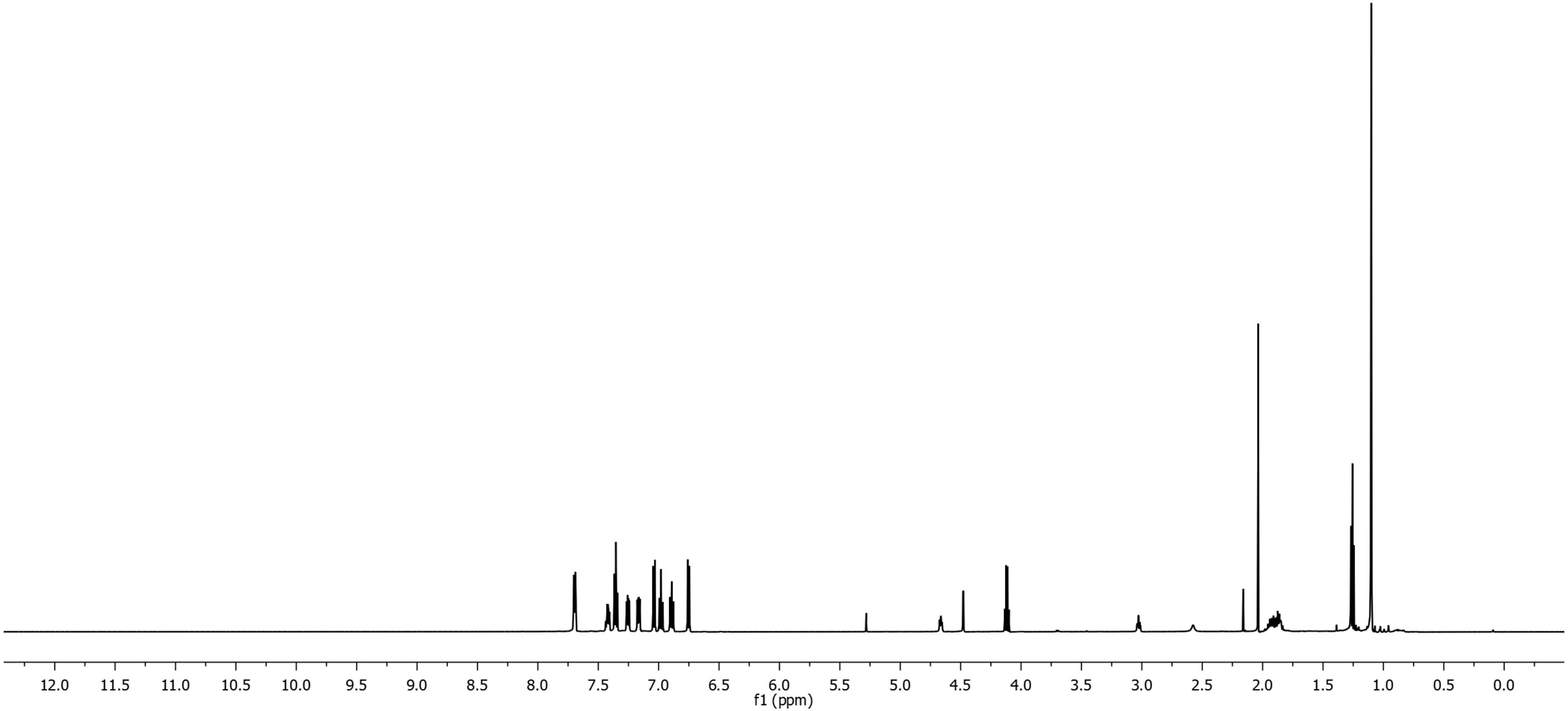


^{1}H NMR of (3*S*,4*R*)-4-(4-((tert-butyldiphenylsilyl)oxy)phenyl)-1-(4-fluorophenyl)-3-((*R*)-3-(4-fluorophenyl)-3-hydroxypropyl)-azetidin-2-one (**S20**):

600 MHz, $CDCl_3$, 23 ºC

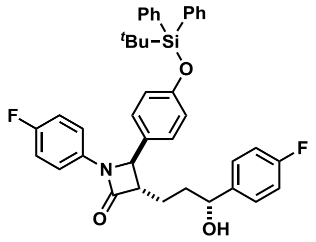


S20

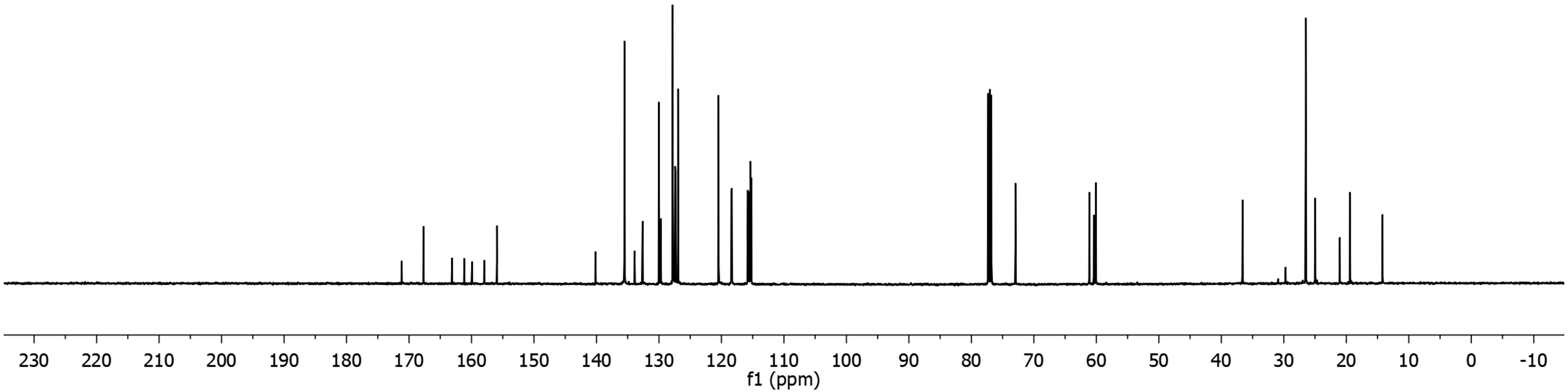


^{13}C NMR of (3*S*,4*R*)-4-(4-((*tert*-butyldiphenylsilyl)oxy)phenyl)-1-(4-fluorophenyl)-3-((*R*)-3-(4-fluorophenyl)-3-hydroxypropyl)-azetidin-2-one (**S20**):

126 MHz, $CDCl_3$, 23 ºC

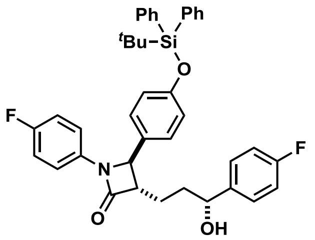


S20

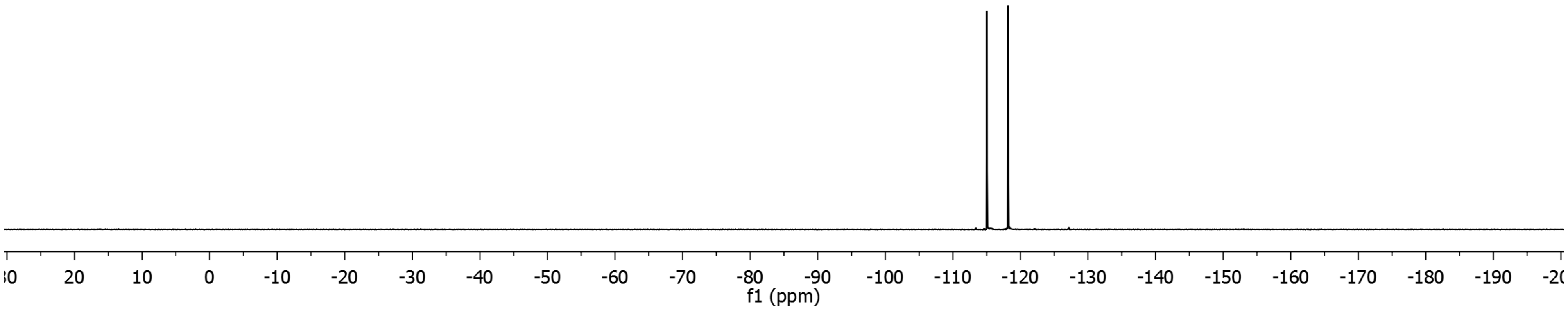


^{19}F NMR of (3*S*,4*R*)-4-(4-((*tert*-butyldiphenylsilyl)oxy)phenyl)-1-(4-fluorophenyl)-3-((*R*)-3-(4-fluorophenyl)-3-hydroxypropyl)-azetidin-2-one (**S20**):

471 MHz, $CDCl_3$, 23 ºC

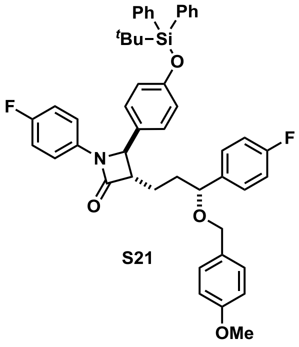


S20

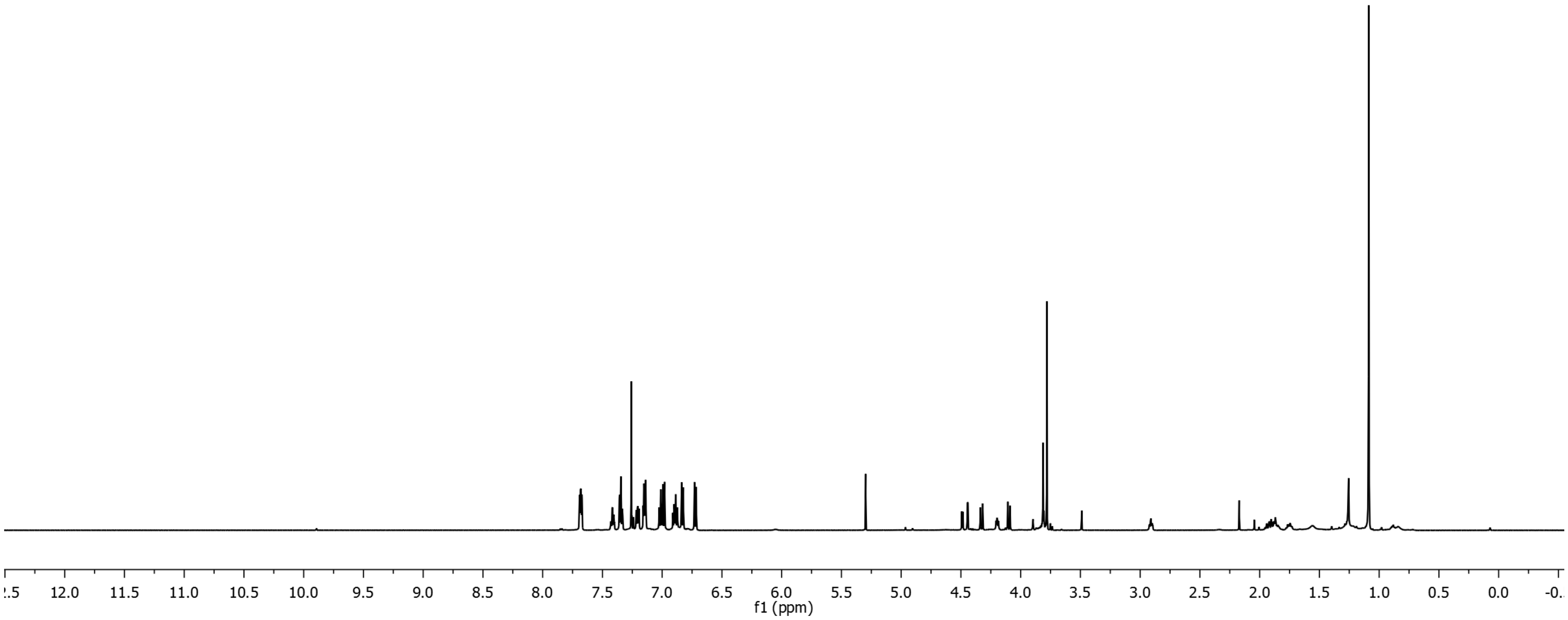


^{1}H NMR of (3*S*,4*R*)-4-(4-((tert-butyldiphenylsilyl)oxy)phenyl)-1-(4-fluorophenyl)-3-((*R*)-3-(4-fluorophenyl)-3-((4-methoxybenzyl)oxy)propyl)azetidin-2-one (**S21**):

600 MHz, $CDCl_3$, 23 ºC

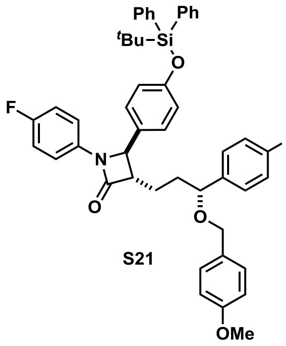


S21

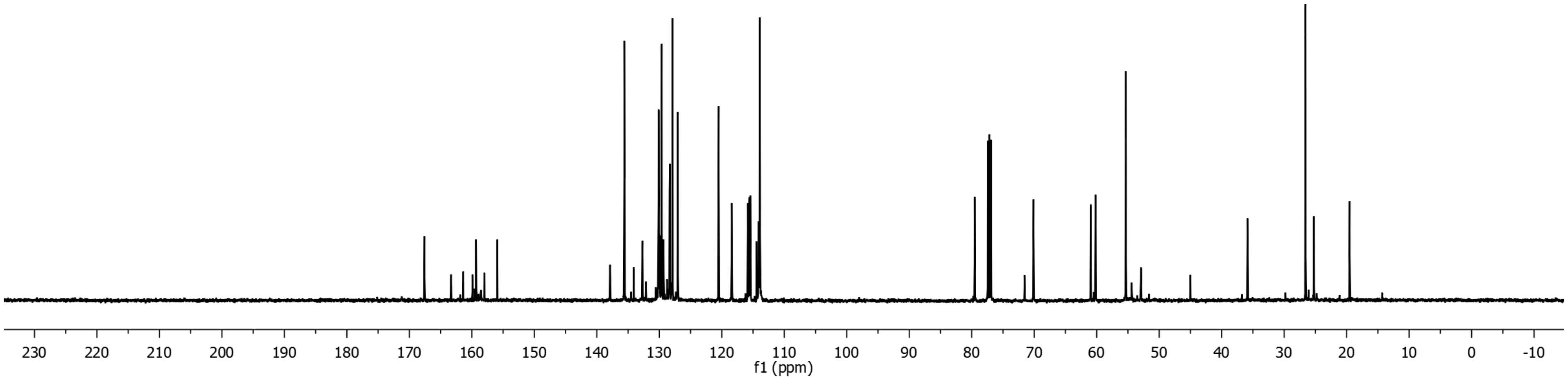


^{13}C NMR of (3*S*,4*R*)-4-(4-((tert-butyldiphenylsilyl)oxy)phenyl)-1-(4-fluorophenyl)-3-((*R*)-3-(4-fluorophenyl)-3-((4-methoxybenzyl)oxy)propyl)azetidin-2-one (**S21**):

126 MHz, $CDCl_3$, 23 ºC

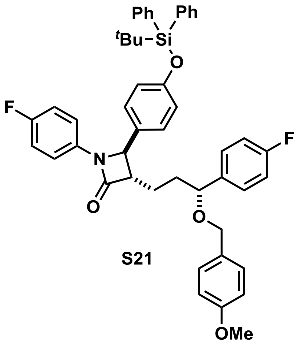


S21

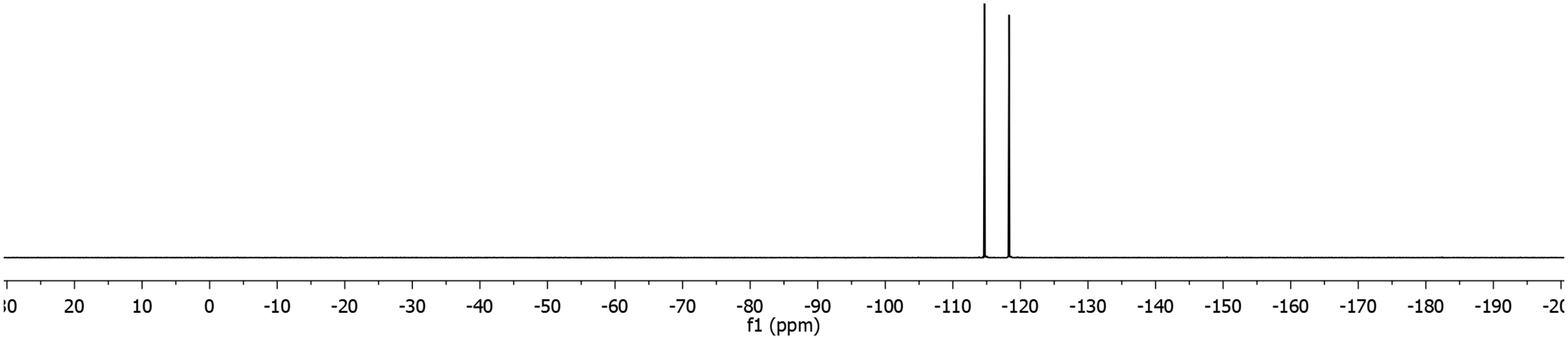


^{19}F NMR of (3S,4R)-4-(4-((tert-butyldiphenylsilyl)oxy)phenyl)-1-(4-fluorophenyl)-3-((R)-3-(4-fluorophenyl)-3-((4-methoxybenzyl)oxy)propyl)azetidin-2-one (**S21**):

471 MHz, CDCl$_3$, 23 ºC

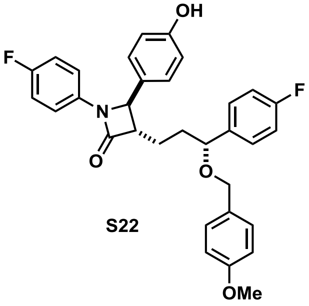


S21

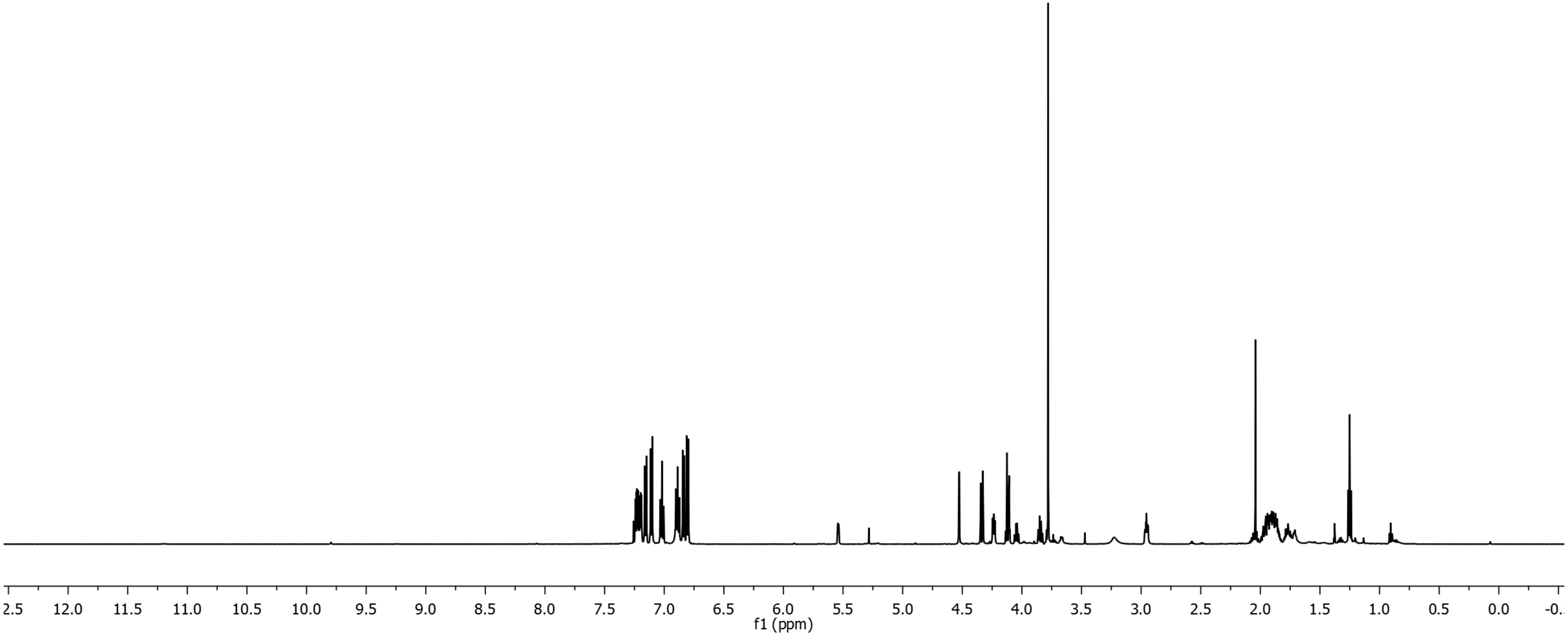


^{1}H NMR of (3*S*,4*R*)-1-(4-fluorophenyl)-3-((*R*)-3-(4-fluorophenyl)-3-((4-methoxybenzyl)oxy)propyl)-4-(4-hydroxyphenyl)azetidin-2-one (**S22**):

600 MHz, CDCl$_3$, 23 ºC

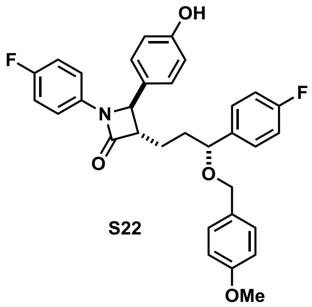


S22

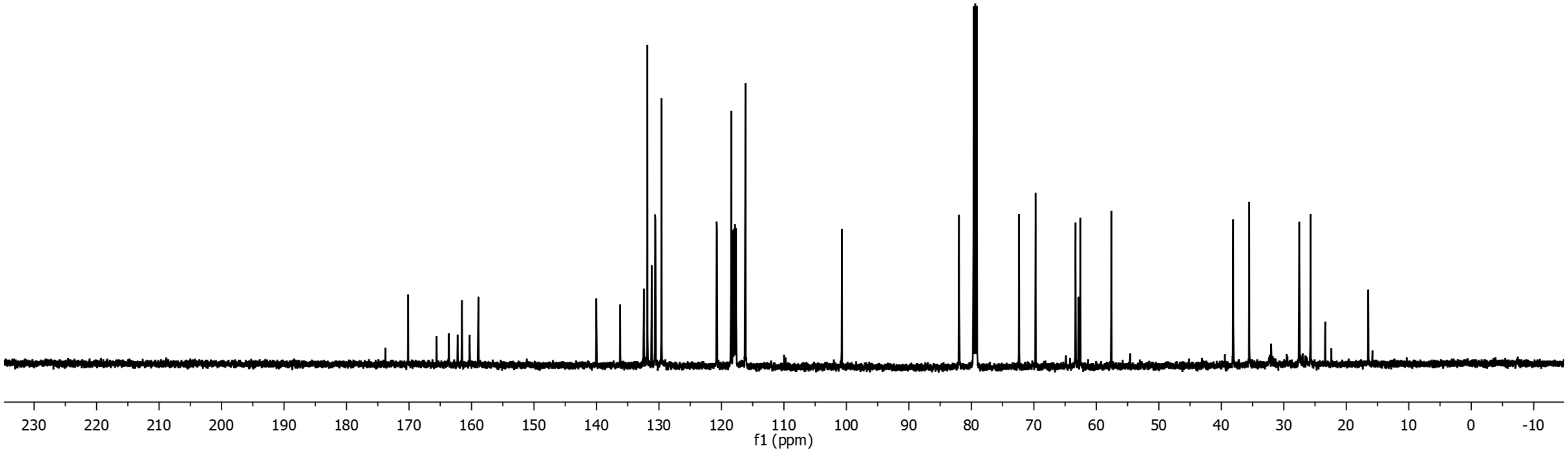


^{13}C NMR of (3*S*,4*R*)-1-(4-fluorophenyl)-3-((*R*)-3-(4-fluorophenyl)-3-((4-methoxybenzyl)oxy)propyl)-4-(4-hydroxyphenyl)azetidin-2-one (**S22**):

126 MHz, CDCl$_3$, 23 ºC

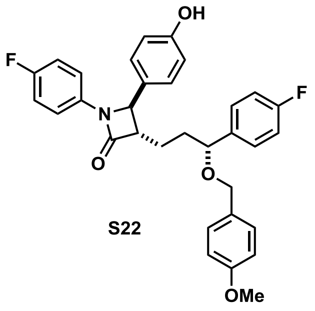


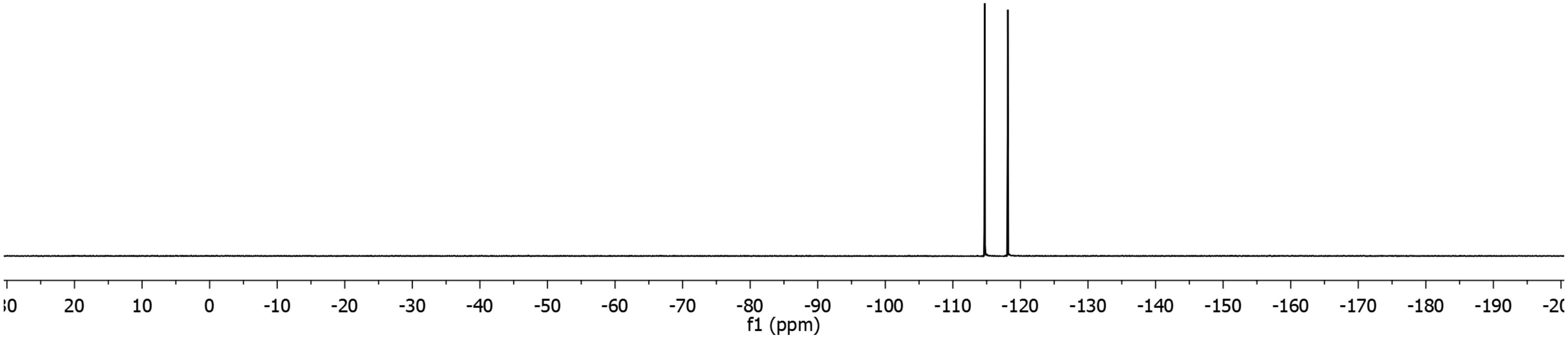
S22



^{19}F NMR of (3*S*,4*R*)-1-(4-fluorophenyl)-3-((*R*)-3-(4-fluorophenyl)-3-((4-methoxybenzyl)oxy)propyl)-4-(4-hydroxyphenyl)azetidin-2-one (**S22**):

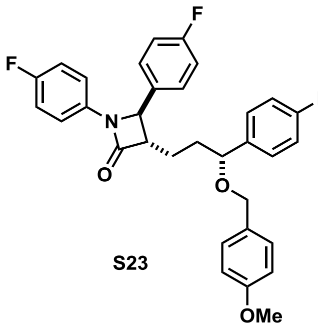
471 MHz, $CDCl_3$, 23 ºC



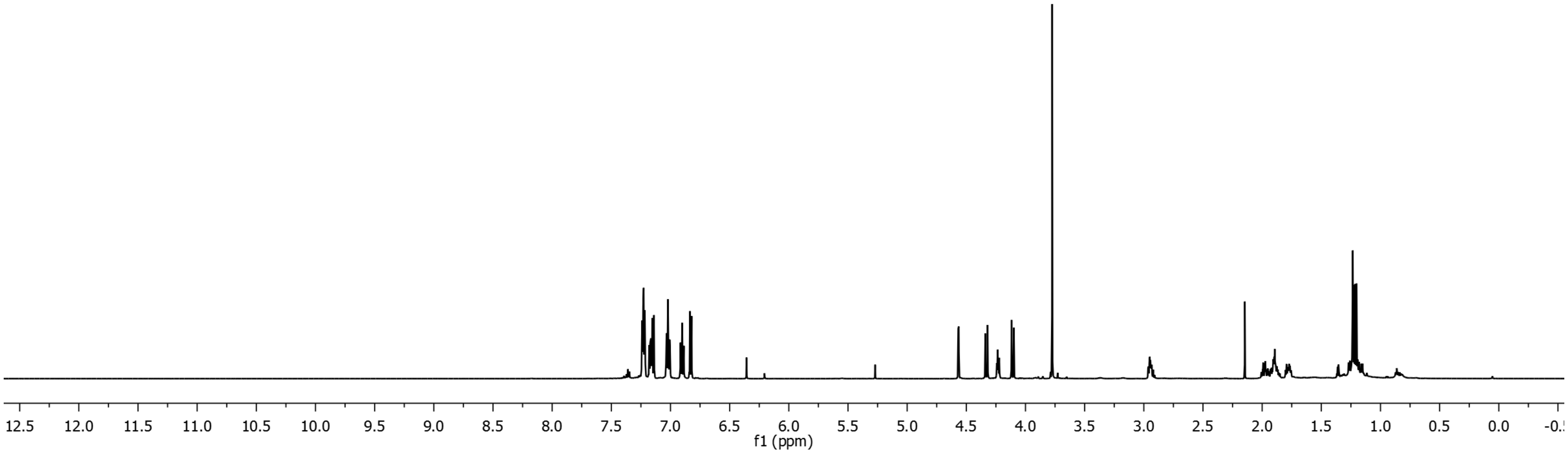


^{1}H NMR of (3*S*,4*R*)-1,4-bis(4-fluorophenyl)-3-((*R*)-3-(4-fluorophenyl)-3-((4-methoxybenzyl)oxy)propyl)azetidin-2-one (**S23**):

600 MHz, $CDCl_3$, 23 ºC

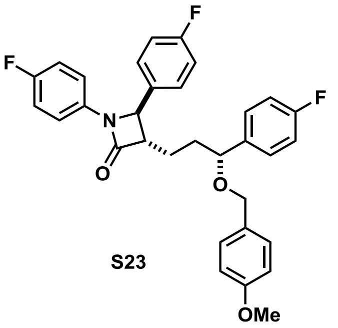


S23

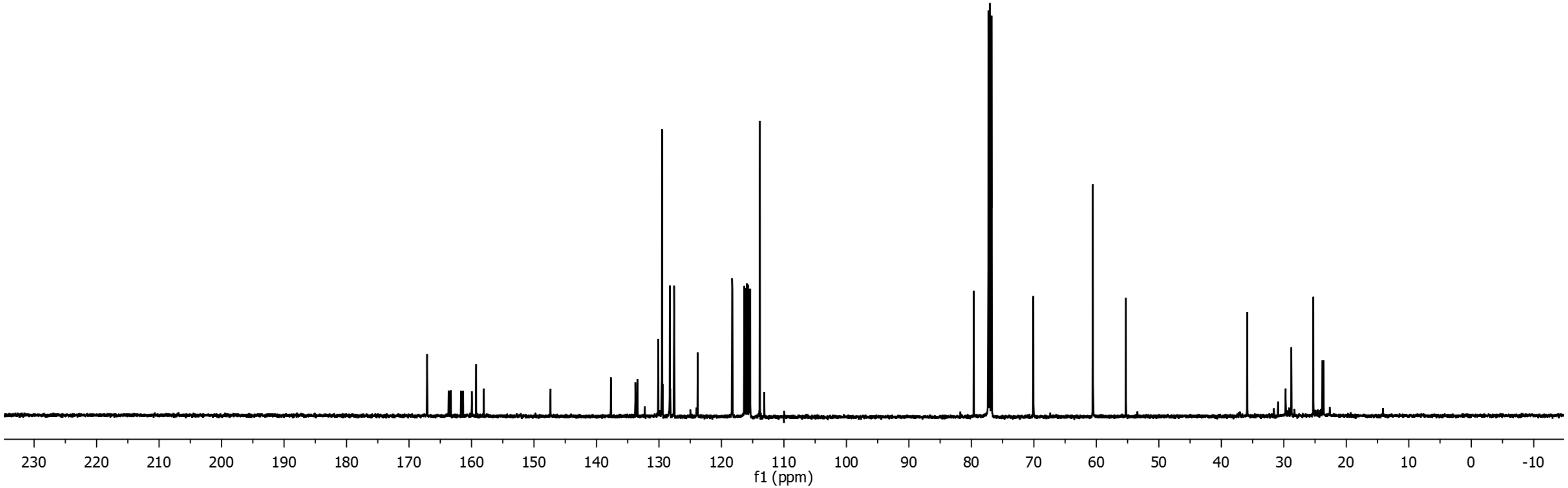


^{13}C NMR of (3*S*,4*R*)-1,4-bis(4-fluorophenyl)-3-((*R*)-3-(4-fluorophenyl)-3-((4-methoxybenzyl)oxy)propyl)azetidin-2-one (**S23**):

126 MHz, $CDCl_3$, 23 ºC

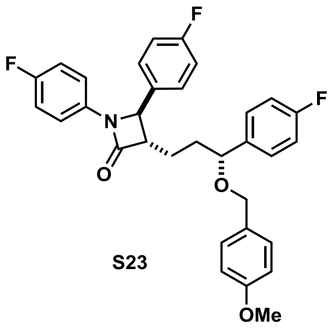


S23

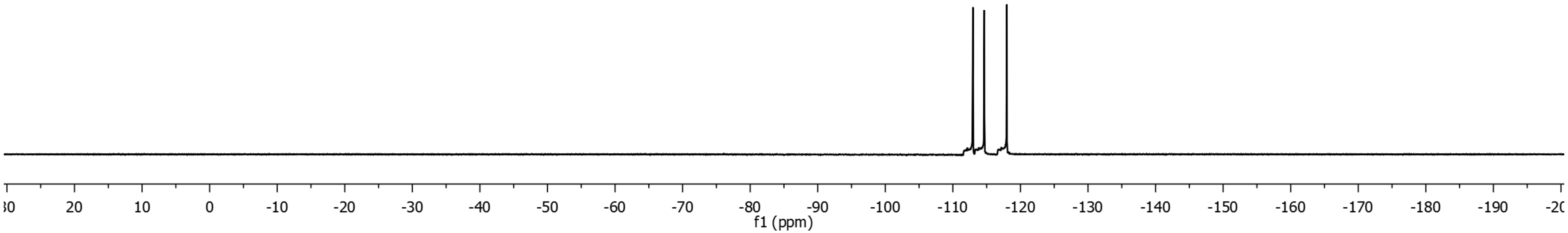


^{19}F NMR of (3*S*,4*R*)-1,4-bis(4-fluorophenyl)-3-((*R*)-3-(4-fluorophenyl)-3-((4-methoxybenzyl)oxy)propyl)azetidin-2-one (**S23**):

471 MHz, $CDCl_3$, 23 ºC

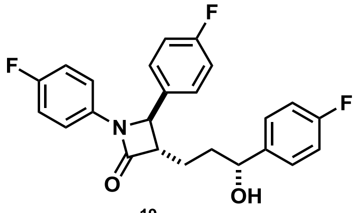


S23

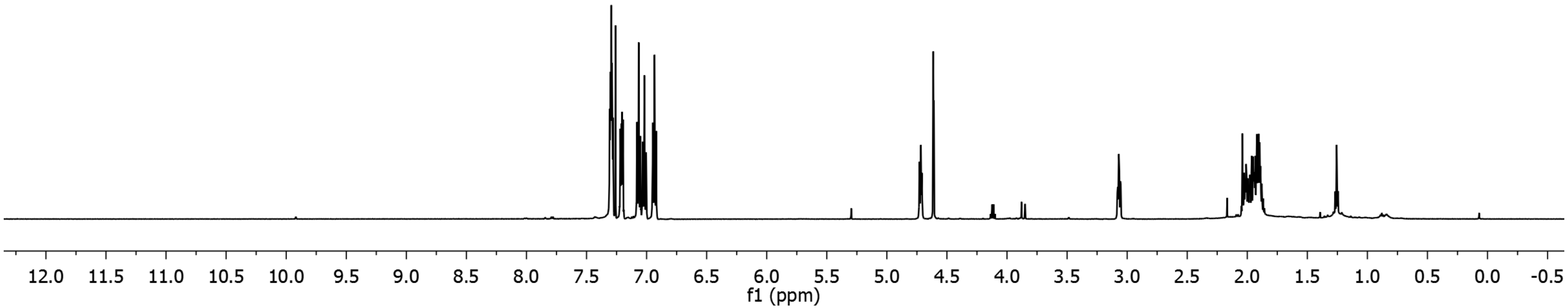


^{1}H NMR of (3*S*,4*R*)-1,4-bis(4-fluorophenyl)-3-((*R*)-3-(4-fluorophenyl)-3-hydroxypropyl)azetidin-2-one (**[^{19}F]7h**):

600 MHz, $CDCl_3$, 23 ºC

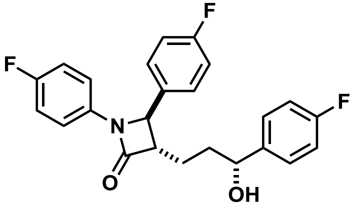


[^{19}F]7h

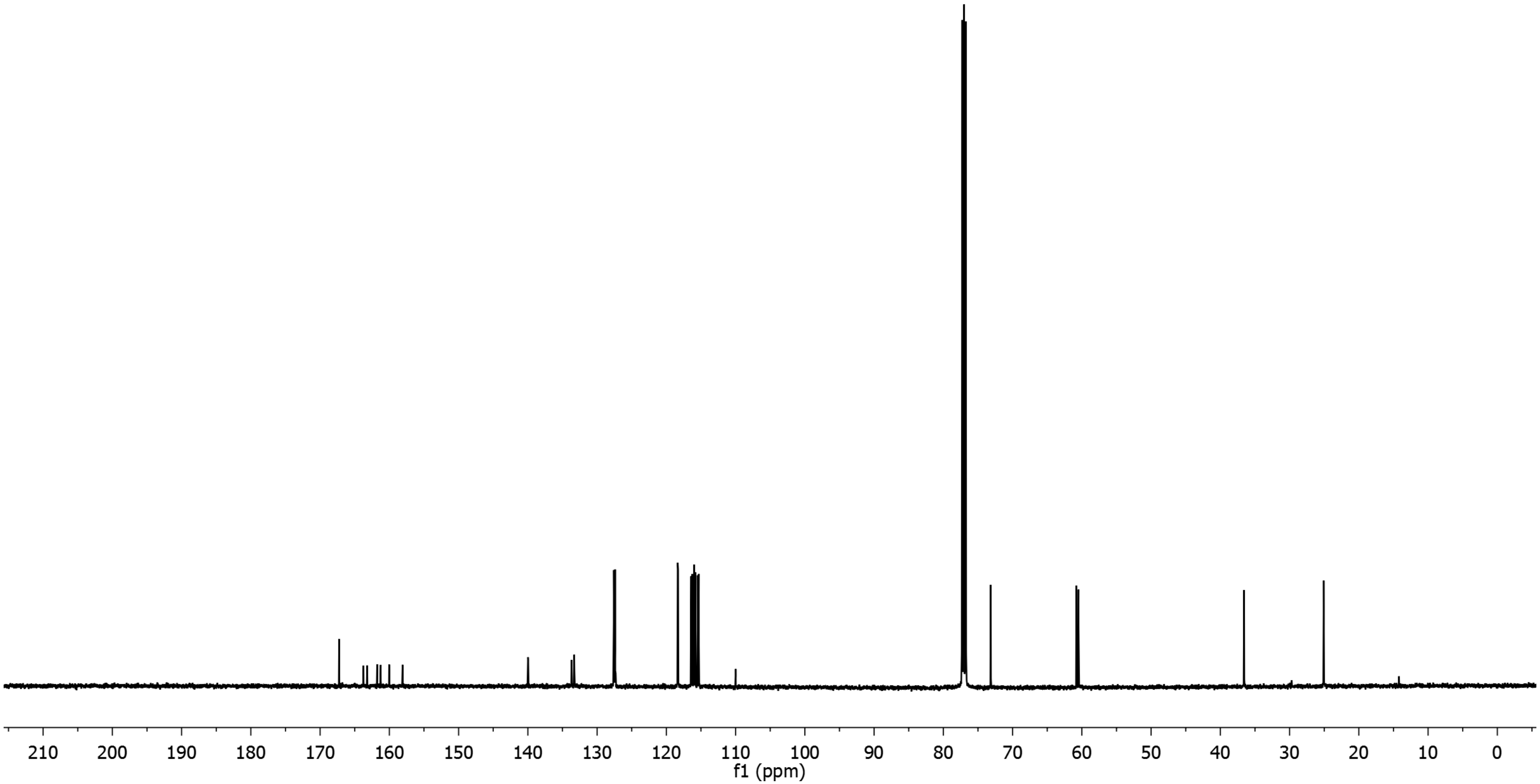


^{13}C NMR of (3*S*,4*R*)-1,4-bis(4-fluorophenyl)-3-((*R*)-3-(4-fluorophenyl)-3-hydroxypropyl)azetidin-2-one (**[^{19}F]7h**):

126 MHz,CDCl$_3$, 23 ºC

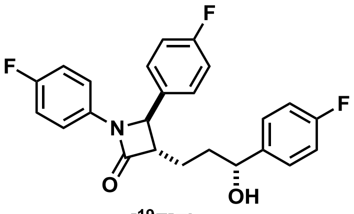


[^{19}F]7h

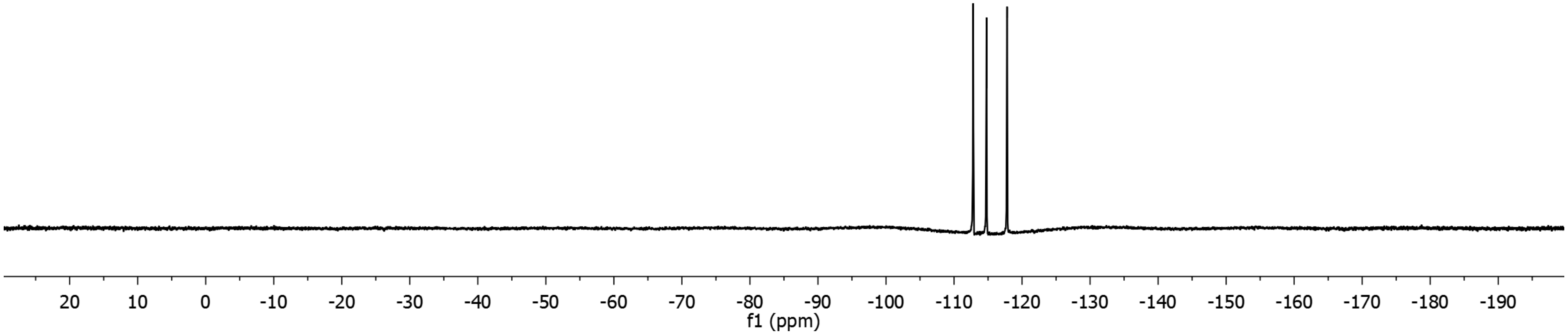


^{19}F NMR of (3*S*,4*R*)-1,4-bis(4-fluorophenyl)-3-((*R*)-3-(4-fluorophenyl)-3-hydroxypropyl)azetidin-2-one (**[^{19}F]7h**):

376 MHz, $CDCl_3$, 23 ºC

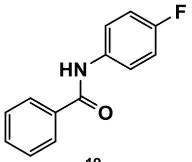


[^{19}F]7h

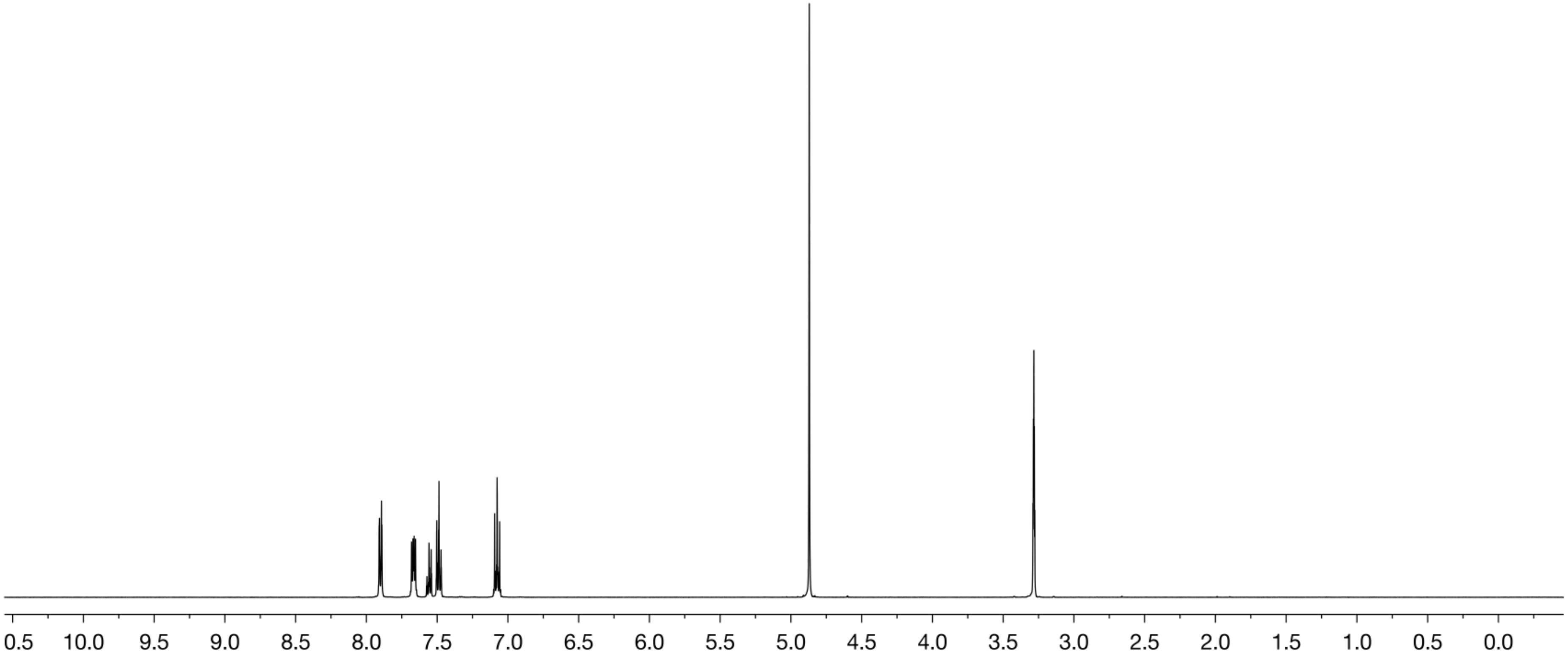


^{1}H NMR of *N*-(4-fluorophenyl)benzamide (**[^{19}F]7j**):

500 MHz, CD_3OD, 23 ºC

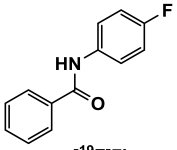


[^{19}F]7j

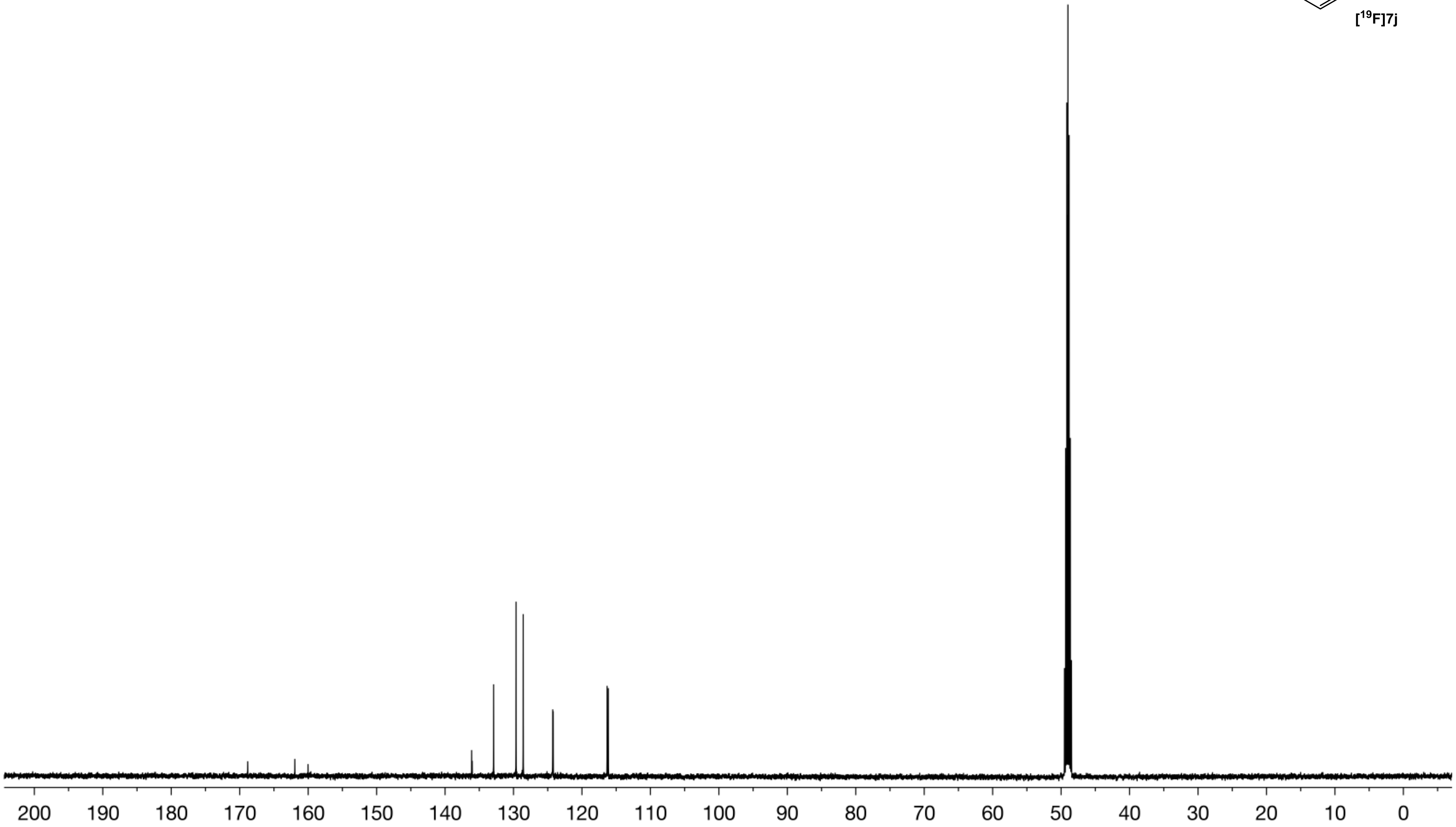


^{13}C NMR of *N*-(4-fluorophenyl)benzamide (**[^{19}F]7j**):

125 MHz, CD$_3$OD, 23 ºC

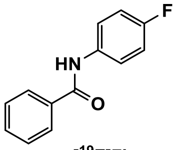


[^{19}F]7j

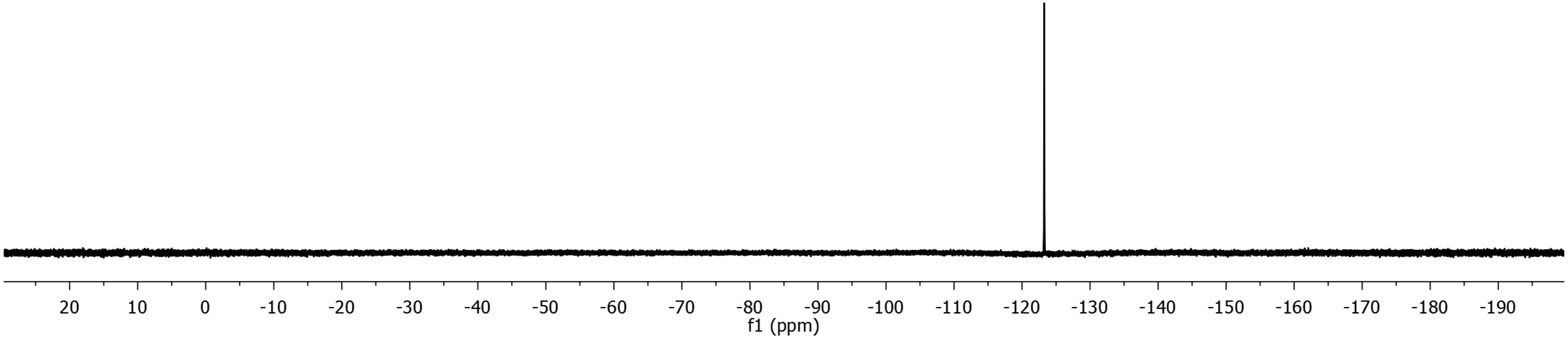


^{19}F NMR of *N*-(4-fluorophenyl)benzamide (**[^{19}F]7j**):

376 MHz, CD$_3$OD, 23 ºC

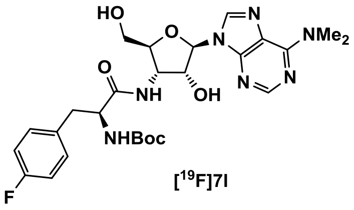


[^{19}F]7j

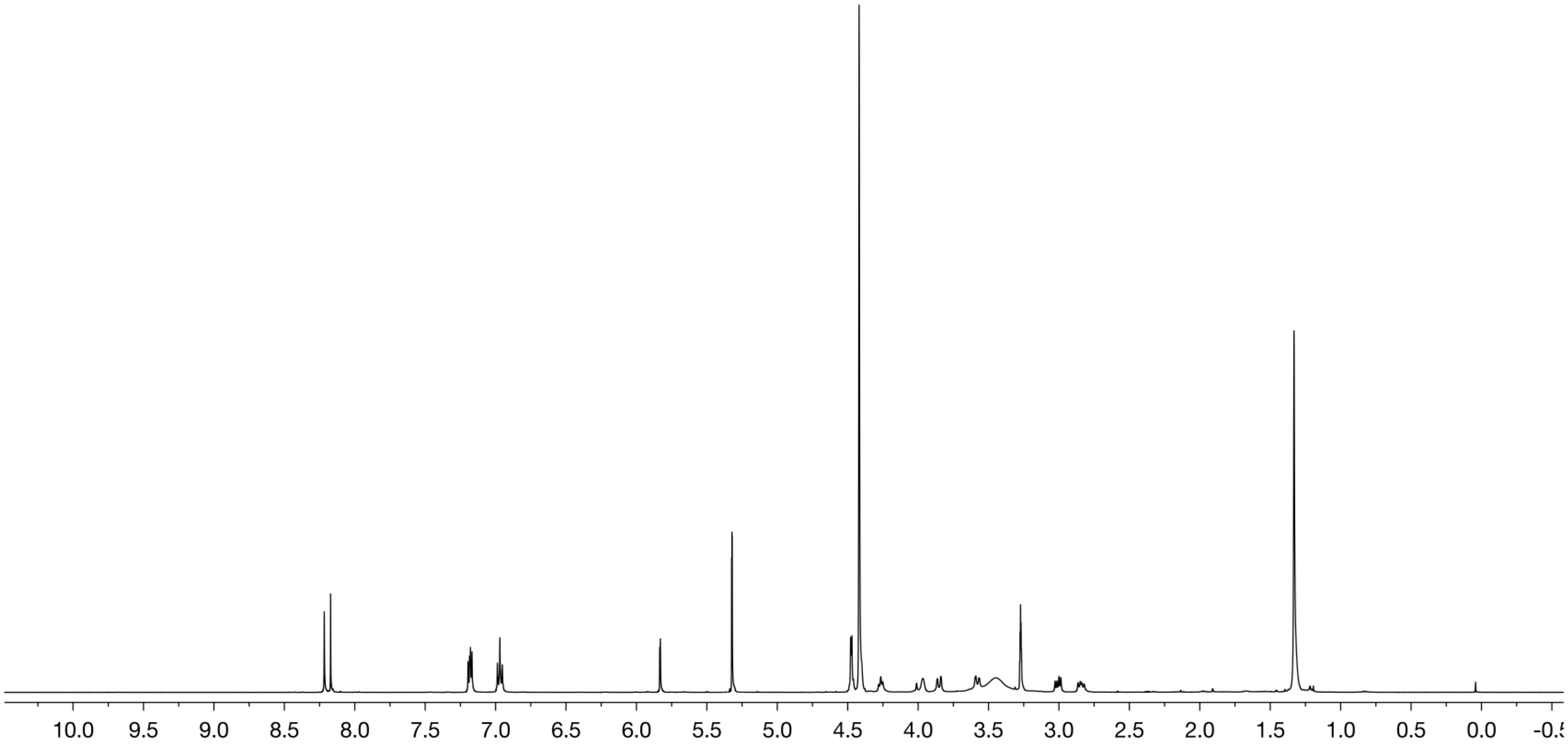


^{1}H NMR of *tert*-butyl ((*S*)-1-(((2*S*,3*S*,4*R*,5*R*)-5-(6-(dimethylamino)-9*H*-purin-9-yl)-4-hydroxy-2-(hydroxymethyl)tetrahydrofuran-3-yl)amino)-3-(4-fluorophenyl)-1-oxopropan-2-yl)carbamate (**[^{19}F]7l**):

500 MHz, CD_2Cl_2:CD_3OD (1:1), 23 ºC

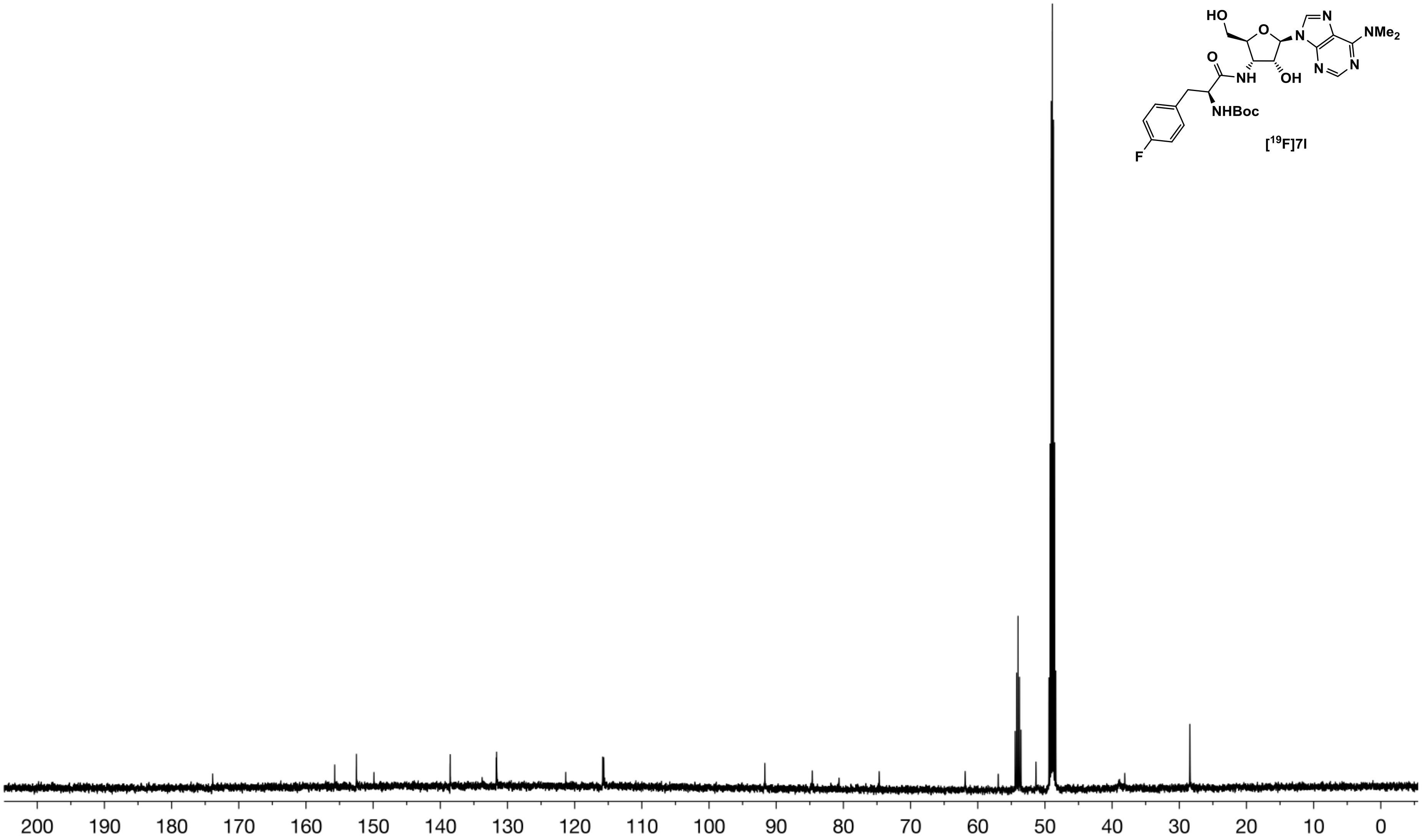


[^{19}F]7l



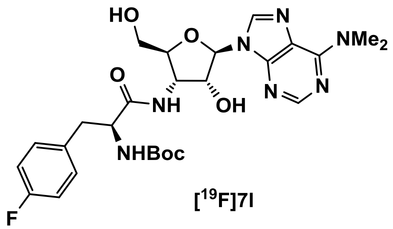
^{13}C NMR of *tert*-butyl ((*S*)-1-(((2*S*,3*S*,4*R*,5*R*)-5-(6-(dimethylamino)-9*H*-purin-9-yl)-4-hydroxy-2-(hydroxymethyl)tetrahydrofuran-3-yl)amino)-3-(4-fluorophenyl)-1-oxopropan-2-yl)carbamate (**[^{19}F]7l**):

125 MHz, CD_2Cl_2:CD_3OD (1:1), 23 ºC

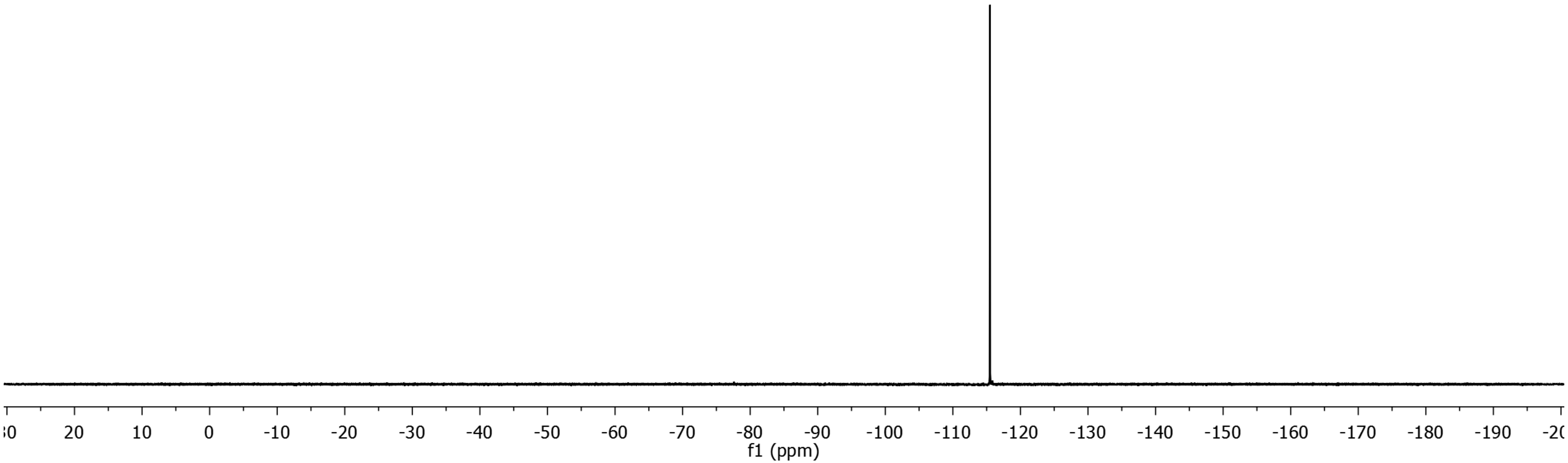


^{19}F NMR of *tert*-butyl ((*S*)-1-(((2*S*,3*S*,4*R*,5*R*)-5-(6-(dimethylamino)-9*H*-purin-9-yl)-4-hydroxy-2-(hydroxymethyl)tetrahydrofuran-3-yl)amino)-3-(4-fluorophenyl)-1-oxopropan-2-yl)carbamate (**[^{19}F]7l**):

471 MHz, CD_2Cl_2:CD_3OD (1:1), 23 ºC

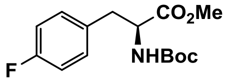


[^{19}F]7l

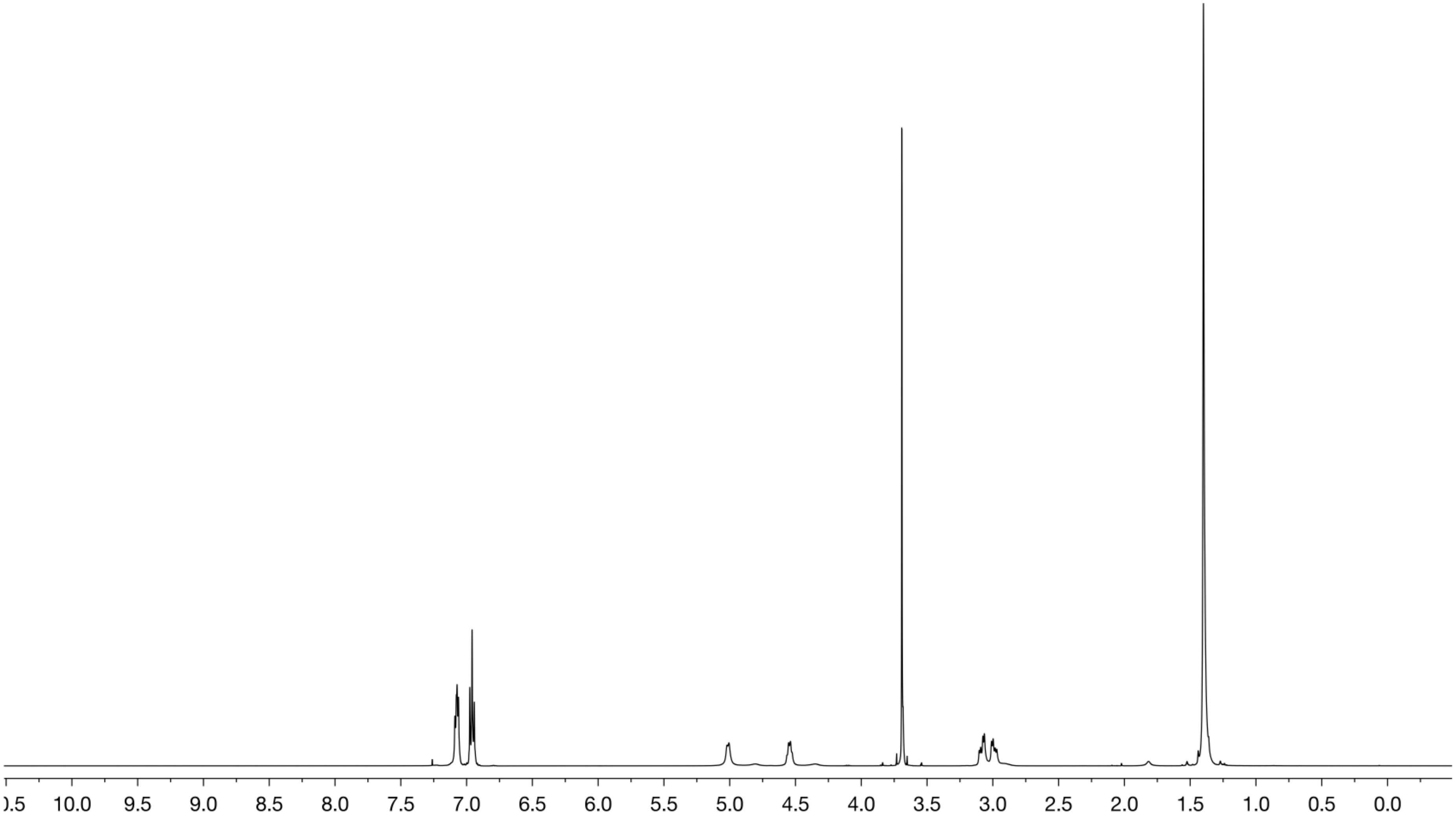


^{1}H NMR of Methyl (*S*)-2-((*tert*-butoxycarbonyl)amino)-3-(4-fluorophenyl)propanoate (**[^{19}F]7n**):

500 MHz, $CDCl_3$, 23 ºC

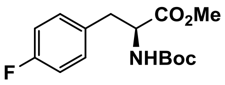


[^{19}F]7n

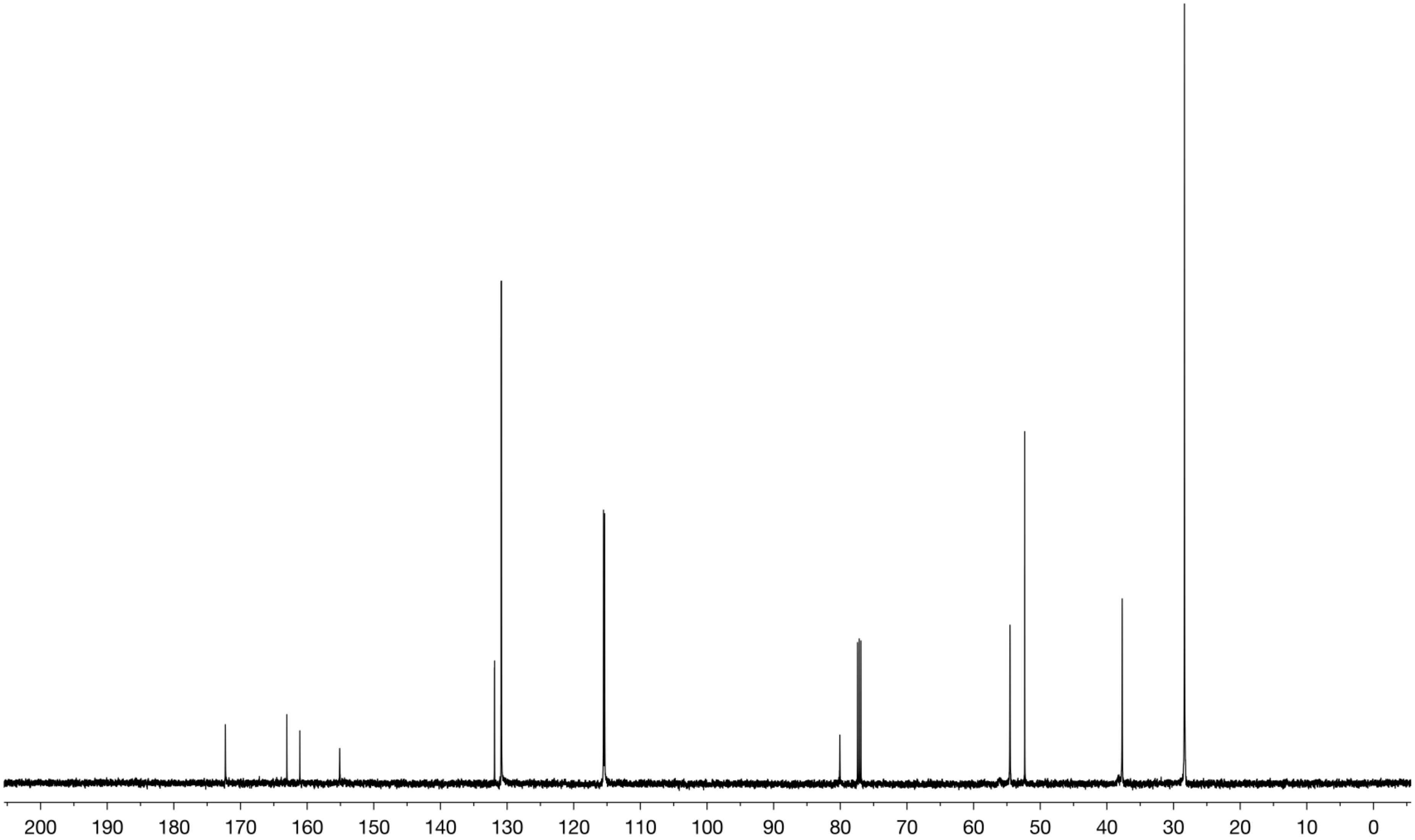


^{13}C NMR of Methyl (*S*)-2-((*tert*-butoxycarbonyl)amino)-3-(4-fluorophenyl)propanoate (**[^{19}F]7n**):

125 MHz, $CDCl_3$, 23 ºC

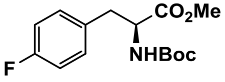


[^{19}F]7n

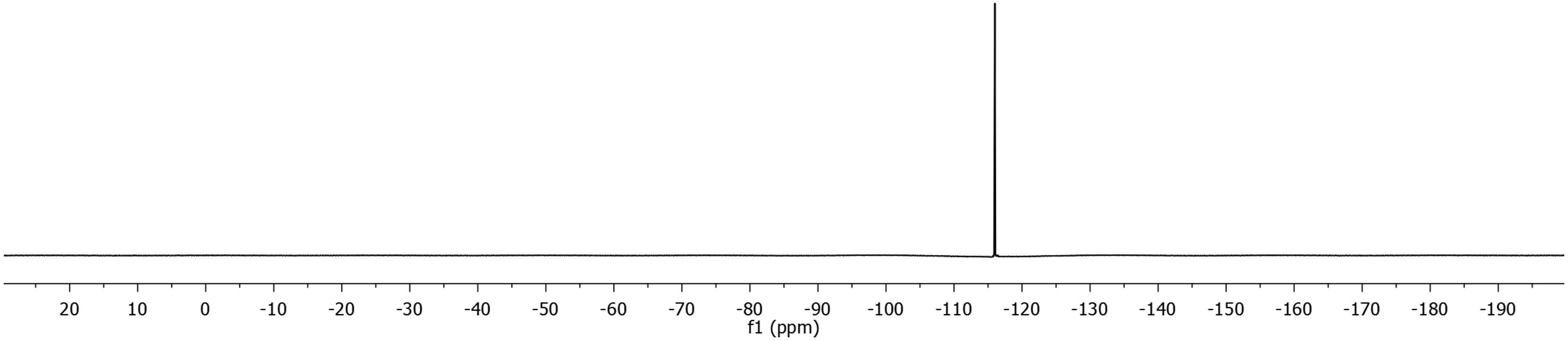


^{19}F NMR of Methyl (*S*)-2-((*tert*-butoxycarbonyl)amino)-3-(4-fluorophenyl)propanoate (**[^{19}F]7n**):

376 MHz, $CDCl_3$, 23 ºC

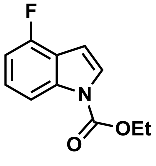


[^{19}F]7n

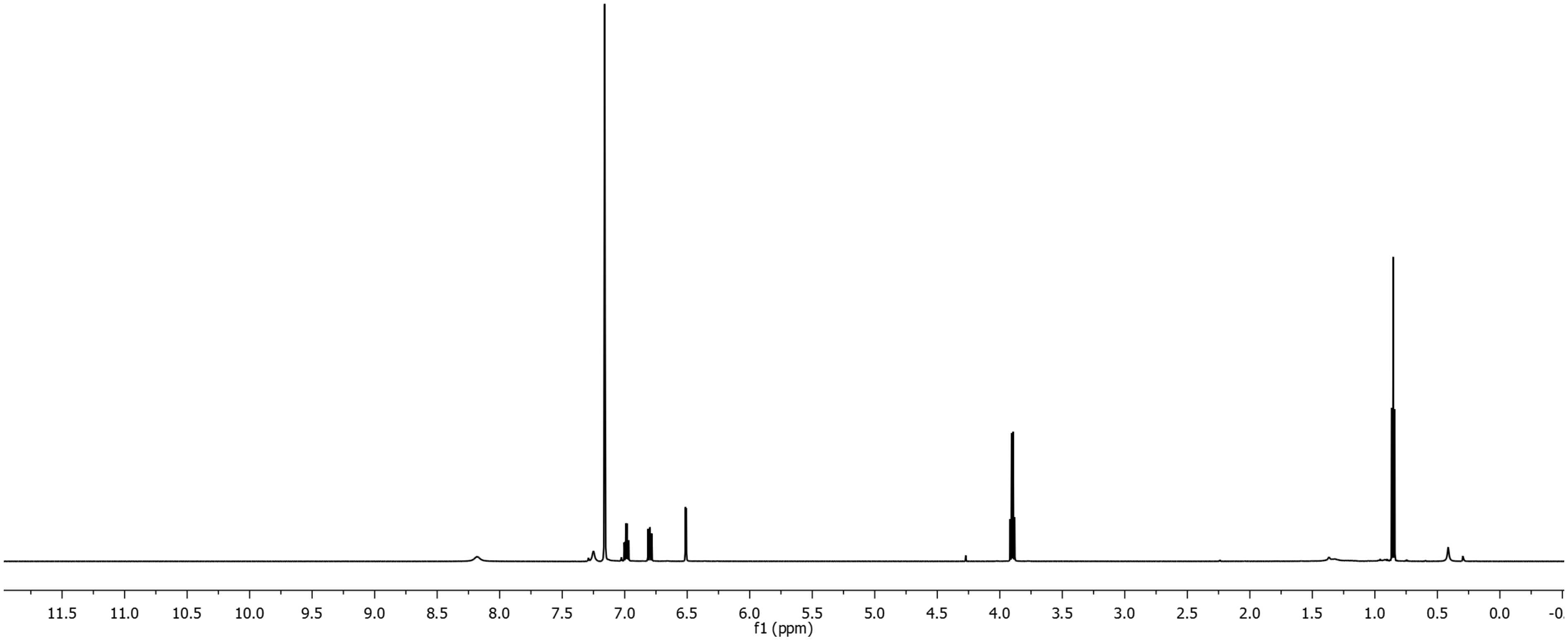


^{1}H NMR of ethyl 4-fluoro-1*H*-indole-1-carboxylate (**[^{19}F]7o**):

600 MHz, C_6D_6, 23 ºC

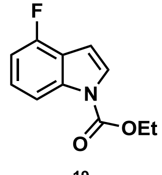


[^{19}F]7o

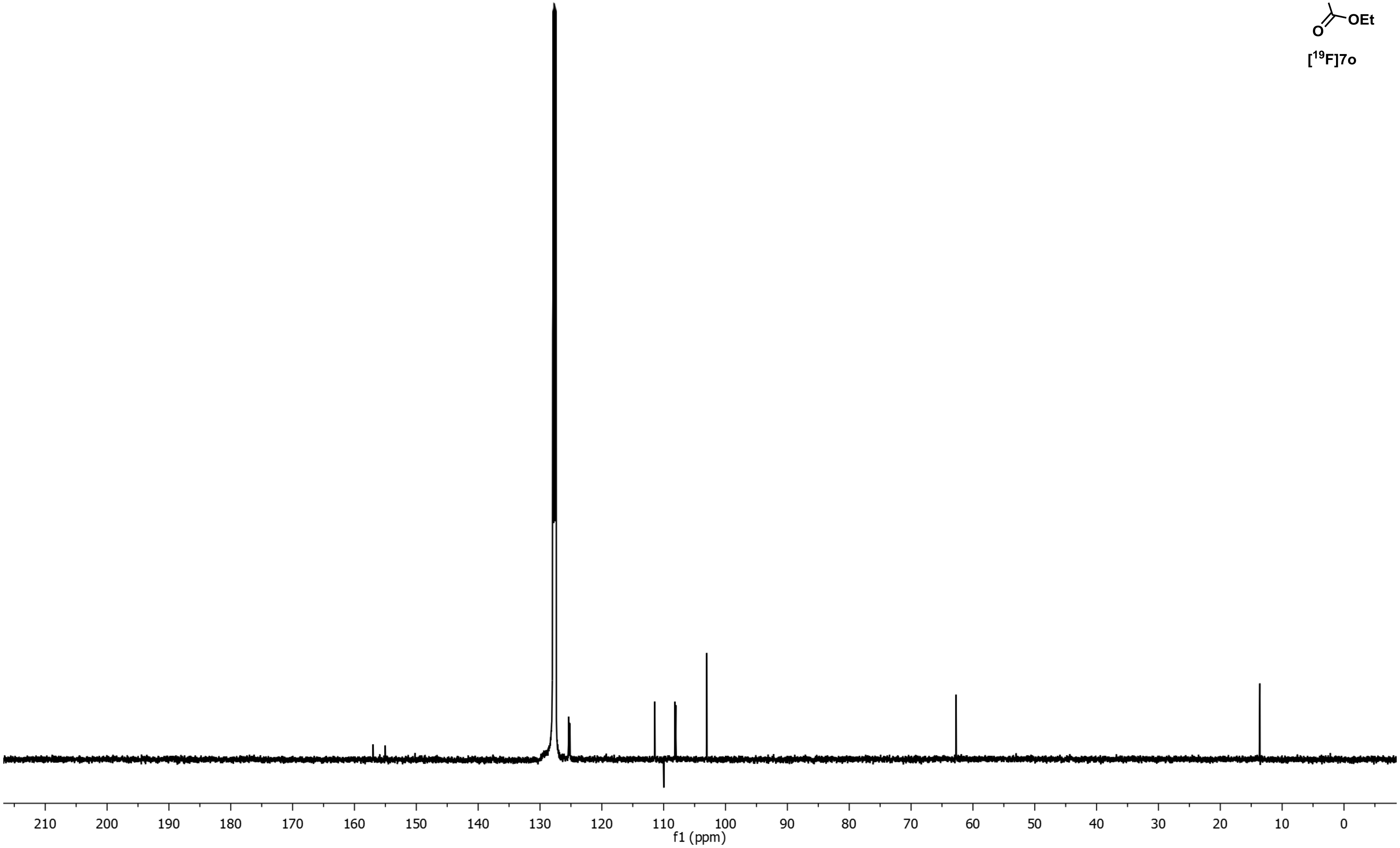


^{13}C NMR of ethyl 4-fluoro-1*H*-indole-1-carboxylate (**[^{19}F]7o**):

126 MHz, C_6D_6, 23 ºC

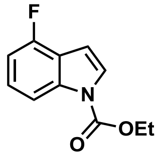


[^{19}F]7o

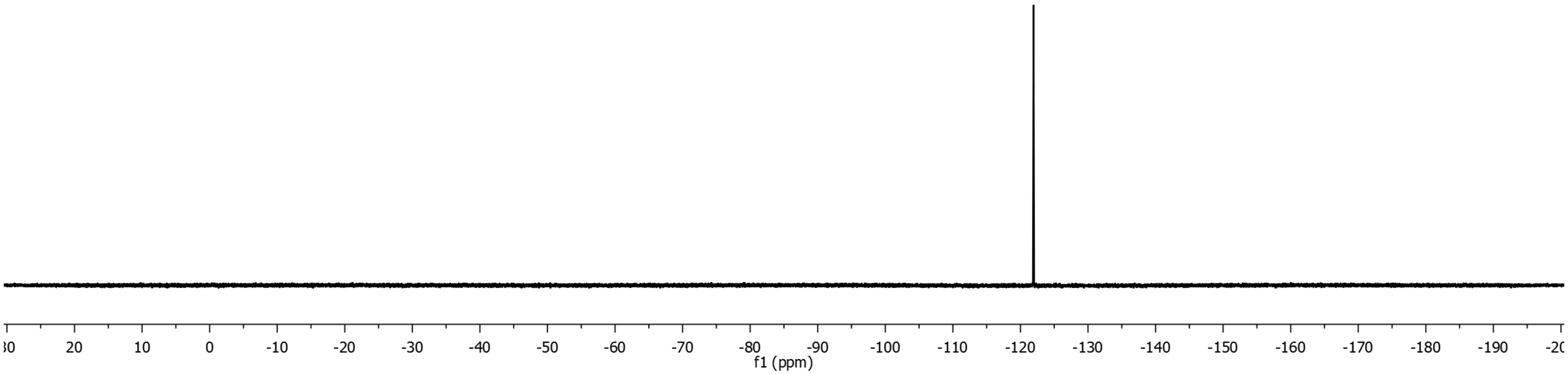


^{19}F NMR of ethyl 4-fluoro-1*H*-indole-1-carboxylate (**[^{19}F]7o**):

471 MHz, C_6D_6, 23 ºC

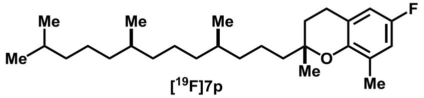


[^{19}F]7o

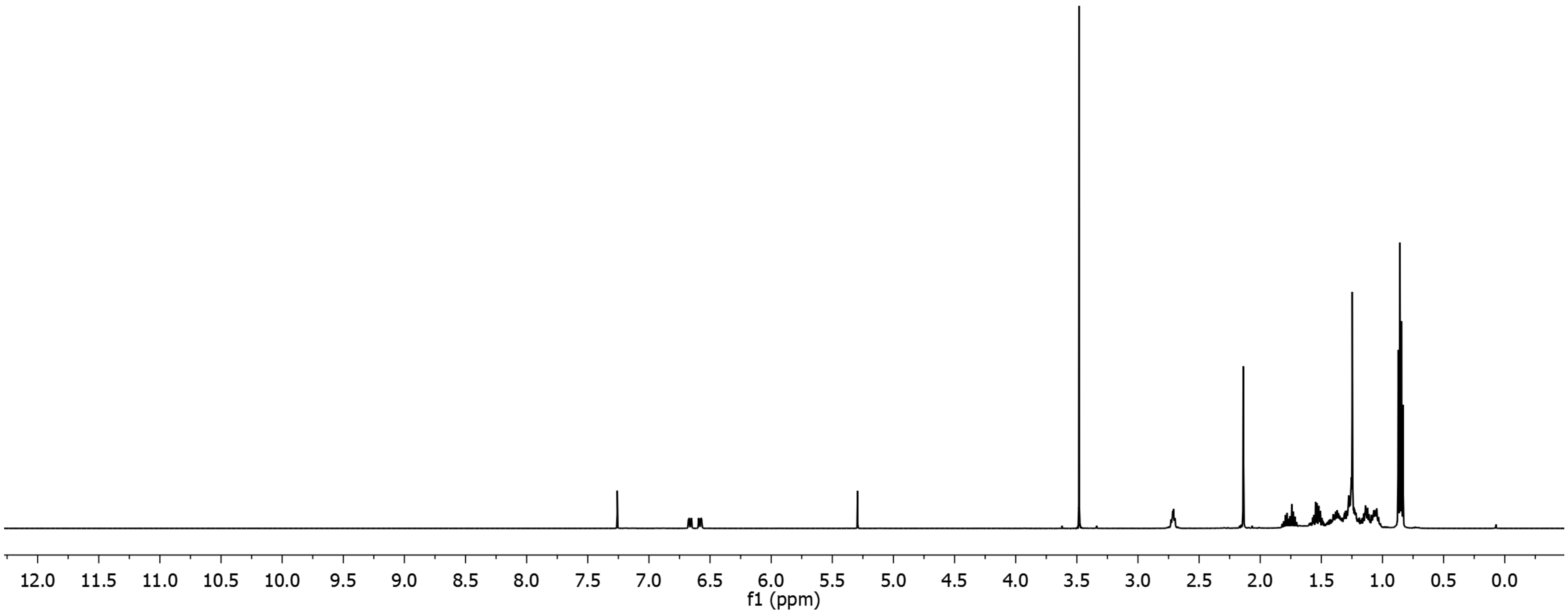


^{1}H NMR of (R)-6-fluoro-2,8-dimethyl-2-((4R,8R)-4,8,12-trimethyltridecyl)chromane (**[^{19}F]7p**):

600 MHz, CDCl$_3$, 23 ºC

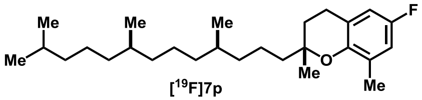


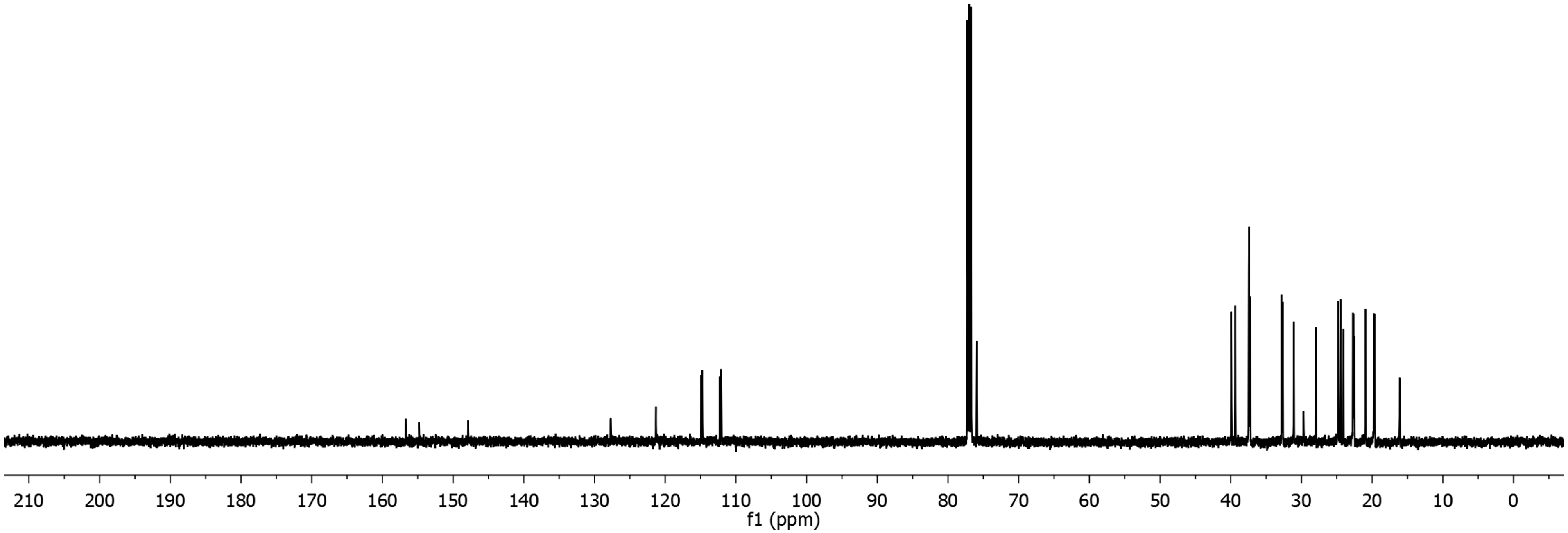
[^{19}F]7p



^{13}C NMR of (*R*)-6-fluoro-2,8-dimethyl-2-((4*R*,8*R*)-4,8,12-trimethyltridecyl)chromane (**[^{19}F]7p**):

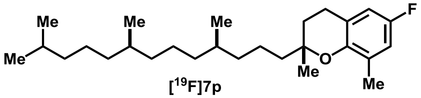
126 MHz, $CDCl_3$, 23 ºC

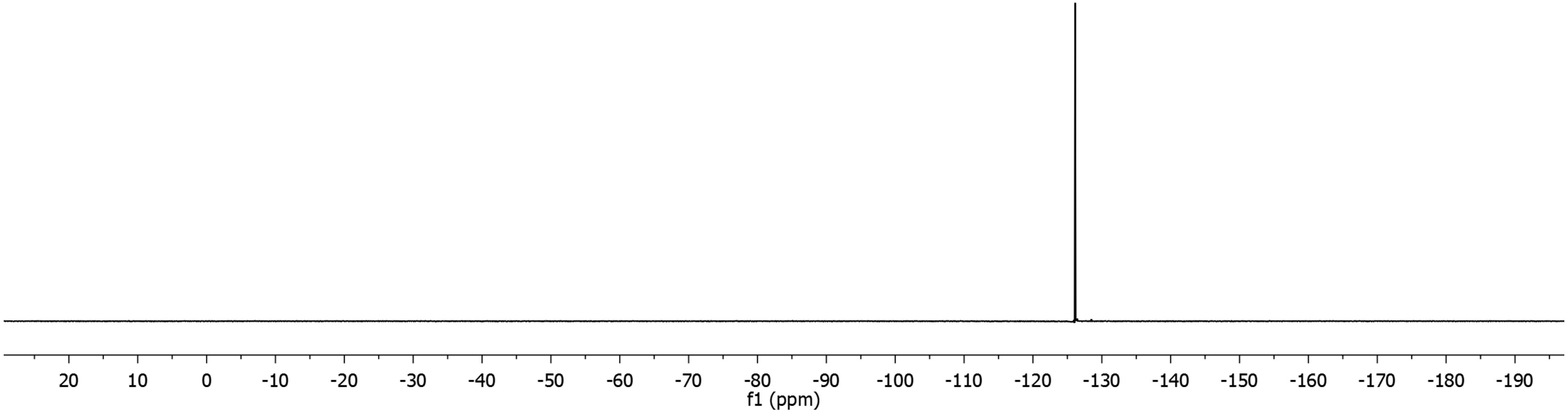




^{19}F NMR of (*R*)-6-fluoro-2,8-dimethyl-2-((4*R*,8*R*)-4,8,12-trimethyltridecyl)chromane (**[^{19}F]7p**):

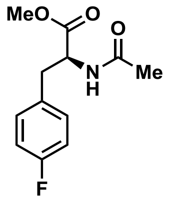
471 MHz, $CDCl_3$, 23 ºC



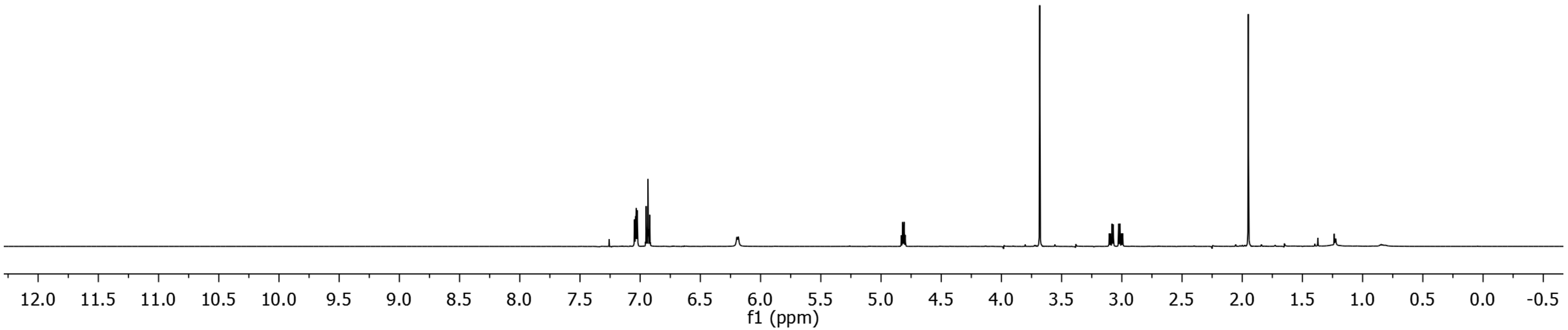


^{1}H NMR of methyl (*S*)-2-acetamido-3-(4-fluorophenyl)propanoate (**[^{19}F]9**):

600 MHz, $CDCl_3$, 23 ºC

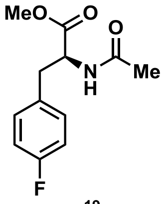


[^{19}F]9

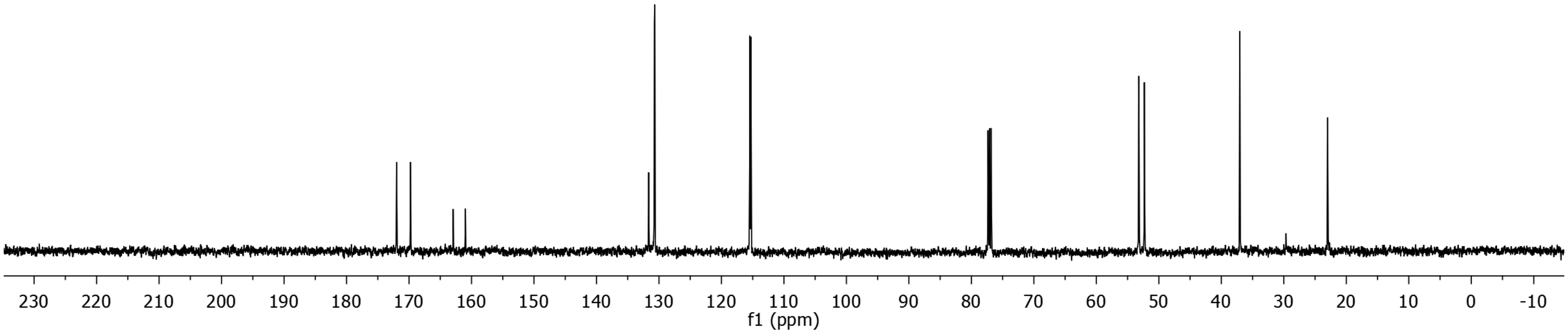


^{13}C NMR of methyl (*S*)-2-acetamido-3-(4-fluorophenyl)propanoate (**[^{19}F]9**):

126 MHz, $CDCl_3$, 23 ºC

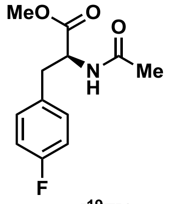


[^{19}F]9



^{19}F NMR of (methyl (*S*)-2-acetamido-3-(4-fluorophenyl)propanoate (**[^{19}F]9**):

471 MHz, CDCl$_3$, 23 ºC



[^{19}F]9