Supplementary Information

Remote N-Substituent-Tuned Dichotomous Diradical Scission Enables Photocatalytic Divergent Rearrangement of Allylic Aminophosphines

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1 General information

All reagents were purchased from commercial suppliers and used without further purification. Flash chromatography was carried out with silica gel (200-300 mesh). Analytical TLC was performed with silica gel GF254 plates, and the products were visualized by UV detection. ^{1}H, ^{13}C, ^{11}B, ^{19}F and ^{31}P NMR spectra were detected in $CDCl_3$ or CD_3CN on a Bruker AM 400 MHz spectrometer. Chemical shifts in ^{1}H NMR spectra were reported in parts per million (ppm) on the δ scale from an internal standard of residual TMS (0 ppm) or CD_3CN (1.96 ppm). Data for ^{1}H NMR were reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), and coupling constant in Hertz (Hz) and integration. Data for ^{13}C NMR spectra were reported in terms of chemical shift in ppm from the central peak of $CDCl_3$ (77.0 ppm) or CD_3CN (1.32 ppm). Data for ^{13}C NMR were reported as follows: chemical shift, multiplicity (d = doublet), coupling constant in Hertz (Hz). Data for ^{11}B NMR, ^{19}F NMR and ^{31}P NMR were reported in terms of chemical shift in ppm. The high-resolution mass spectra (HRMS) were measured on a Thermo Scientific Orbitrap Exploris 120 by ESI. UV-Vis absorption spectra were recorded on a Lambda 950+Refle UV/Vis spectrometer. Photochemical reactions were carried with 4×(2×3 W) blue LEDs obtained from Suzhou Youjing photoelectric Technology Co., Ltd, respectively.

2 Reaction set-up for dichotomous rearrangement of aminophosphines

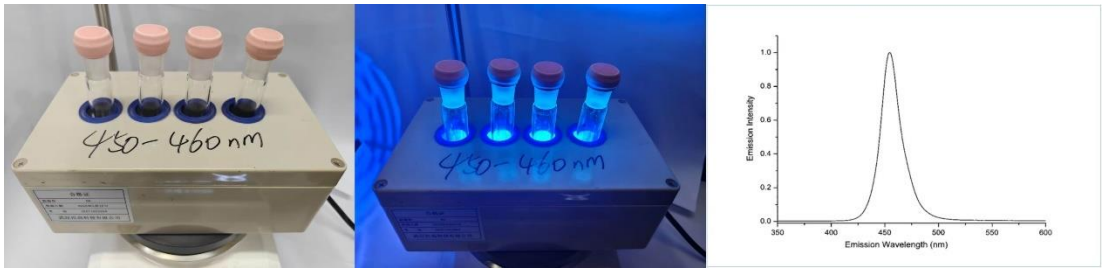


Figure S1. General setup for the reaction. 4×(2×3 W) blue LEDs (λmax = 455 nm) were used as the light source.

3 Preparation of substrates

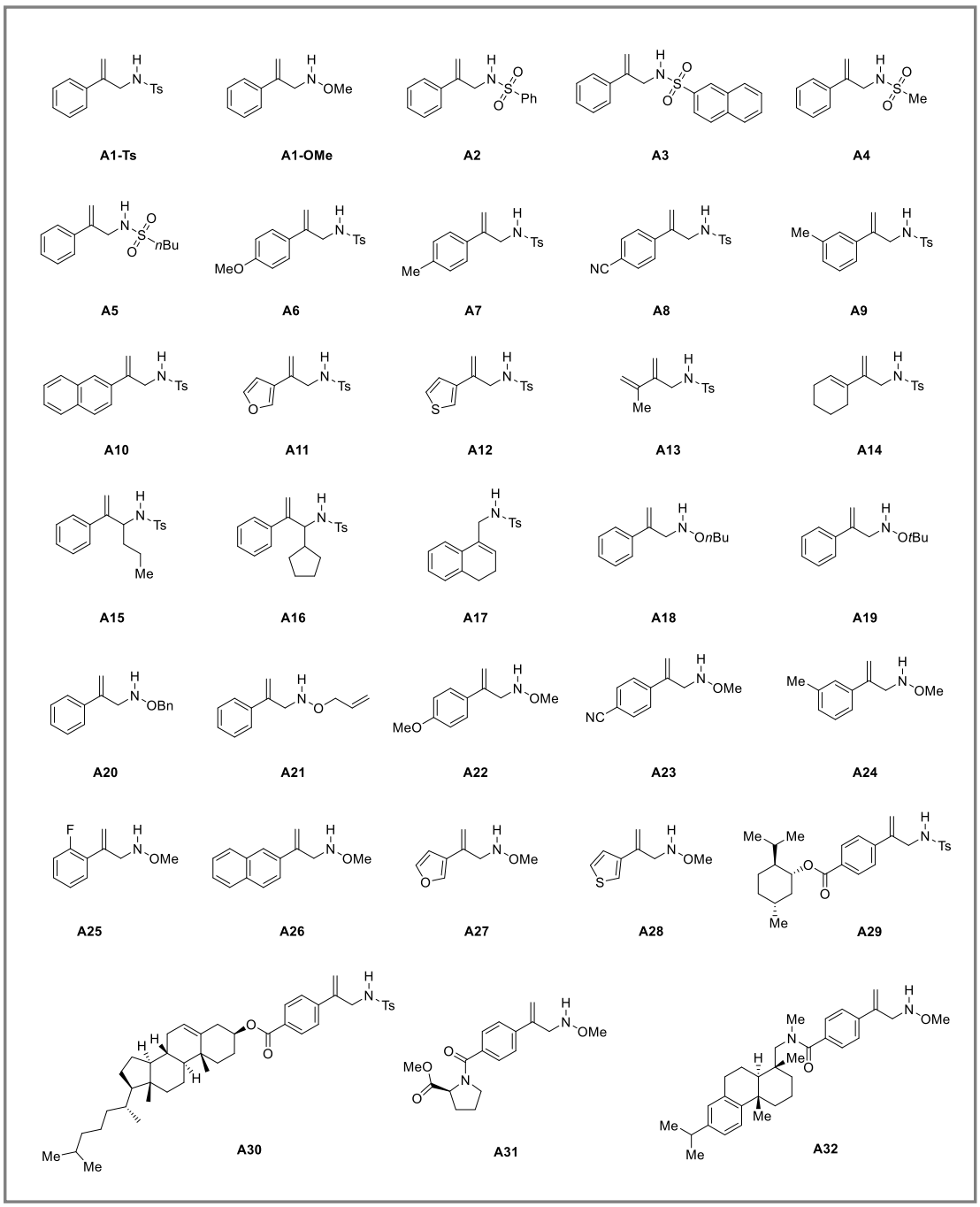
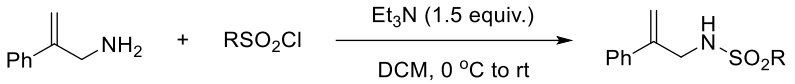


Figure S2. Preparation of substrates

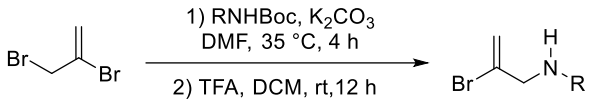
3.1 General Procedure A (GPA) for substrates



S1 **A1-Ts**, **A2–A5**

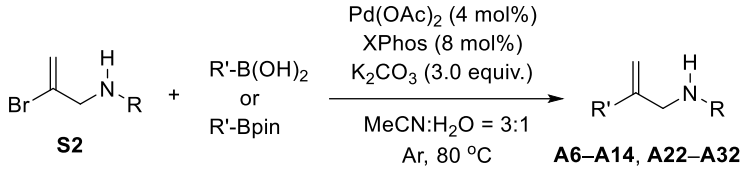
To a solution of the amine (5 mmol, 1.0 equiv.) in DCM (10 mL) at 0 °C were added triethylamine (7.5 mmol, 1.5 equiv.) and R-sulfonyl chloride (6 mmol, 1.2 equiv.). The mixture was maintained at 0 °C for 30 minutes, then allowed to warm gradually to room temperature and was stirred for 2 hours. The resulting mixture was diluted with DCM (3×10 mL) and washed successively with saturated aqueous $NaHCO_3$ solution (3×15 mL) and 1 M hydrochloric acid (3×15 mL). The aqueous layer was extracted with DCM (3×10 mL). The combined organic layers were dried over anhydrous sodium sulfate, filtered, and concentrated under reduced pressure to afford the products **A1-Ts** and **A2**–**A5**. The identity and purity of the products were confirmed by ^{1}H and ^{13}C NMR spectroscopy.

3.2 General Procedure B (GPB) for substrates



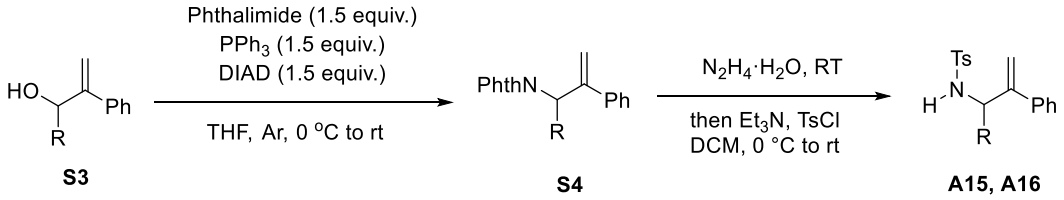
S2

RNHBoc (20 mmol, 1.0 equiv.) and K_2CO_3 (32 mmol, 1.6 equiv.) were added to DMF (20 mL). To this mixture was added 2,3-dibromo-1-propene (40 mmol, 2.0 equiv.). The resulting mixture was stirred at 35 °C for 4 h. Water (100 mL) was then added to the mixture, followed by extraction with diethyl ether (3×30 mL). Removal of ether gave a crude mixture, which was dissolved in DCM (12 mL). Trifluoroacetic acid (18 mL) was slowly added to this solution, which was stirred at room temperature for 12 h. The resulting mixture was concentrated under reduced pressure. The residue was dissolved in DCM (20 mL) and washed with saturated aqueous sodium bicarbonate solution (3×20 mL). The organic layer was dried over anhydrous Na_2SO_4, filtered, and concentrated. Purification by silica gel column chromatography afforded **S2**.



A 60 mL Schlenk tube was charged with **S2** (5 mmol, 1.0 equiv.), R'-$B(OH)_2$ or R'-Bpin (7.5 mmol, 1.5 equiv.), K_2CO_3 (15 mmol, 3.0 equiv), $Pd(OAc)_2$ (4 mol%), XPhos (8 mol%), and MeCN/H_2O (3:1, v/v, 10 mL). The reaction mixture was stirred at 80 °C in an oil bath under an argon atmosphere for 12 h. After completion of the reaction, the mixture was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel to afford products **A6**–**A14** and **A22**–**A32**. The identity and purity of the products were confirmed by ^{1}H, ^{13}C and ^{19}F NMR spectroscopy.

3.3 General Procedure C (GPC) for substrates



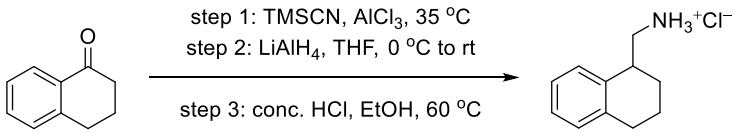
Step 1: To a solution of the allylic alcohols **S3** (20 mmol, 1.0 equiv.) in THF (0.1 M, 200 mL) were added PPh_3 (22 mmol, 1.1 equiv.) and Phthalimide (22 mmol, 1.1 equiv.). The resulting mixture was cooled to 0 °C before DIAD (diisopropyl azodicarboxylate) (22 mmol, 1.1 equiv.) was added dropwise under argon. After stirring for 30 minutes at 0 °C, the reaction mixture was allowed to reach room temperature. The solution was stirred at room temperature, and the conversion was monitored by TLC. Then, the resulting mixture was concentrated in vacuo. The residue was purified by flash chromatography on silica gel to afford the desired N-alkoxyphthalimides **S4**.

Step 2: Hydrazine hydrate (30 mmol, 5 equiv.) was added to a suspension of **S4** (6 mmol, 1 equiv.) in ethanol (80 mL). The resulting mixture was heated under reflux for 1 h. Then HCl (aq, 2.0 M, 10 mL) was added and the reaction was heated for another 1 h. The reaction mixture was then cooled to 4 °C and the phthalyl hydrazide removed by filtration. The ethanol was removed in vacuum and the solid residue was redissolved in 15 mL NaOH aq. (2.0 M). The solution was extracted with diethyl ether (3×30 mL) and the organic extract

was dried over Na_2SO_4, filtered and concentrated to give the crude product, which was used directly in the next step without further purification.

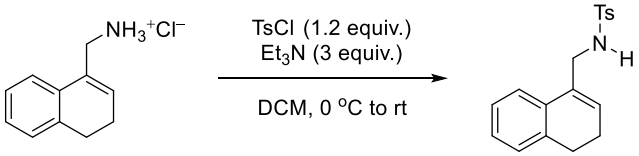
Step 3: The crude products (5 mmol, 1.0 equiv.) were dissolved in DCM (10 mL), and the resulting solution was treated with Et_3N (7.5 mmol, 1.5 equiv.) and TsCl (6 mmol, 1.2 equiv.) at 0 °C. The mixture was then warmed to room temperature and stirred for 4 h. After removal of the solvent in vacuo, the residue was purified by flash chromatography on silica gel to afford **A15** and **A16**. The identity and purity of the products were confirmed by ^1H and ^{13}C NMR spectroscopy.

3.4 General Procedure D (GPD) for substrates



S5

In a 100 mL two-neck flask with a stirring bar under N_2 atmosphere, the mixture of ketone (16.2 mmol), $AlCl_3$ (0.003 g, 0.0225 mmol) and trimethylsilyl cyanide (TMSCN, 2.5 mL, 20 mmol) was stirred for 20 h at 35 °C. Anhydrous THF (30 mL) was poured into the mixture, and lithium aluminum hydride ($LiAlH_4$) (0.740 g, 19.4 mmol) was slowly added at 0 °C. The mixture was stirred for 3 h at room temperature. The reaction was quenched by careful addition of $Na_2SO_4 \cdot 10H_2O$ at 0 °C. After stirring for 1 h at room temperature, the reaction mixture was filtered through a glass filter and washed with Et_2O. The filtrate was concentrated with a rotary evaporator, and EtOH (100 mL) and concentrated HCl solution (10.0 mL) were added to the residue. The mixture was stirred for 16 h at 60 °C. The volatile components were removed in vacuo, and the resulting solid was washed with Et_2O and CH_2Cl_2 and dried in vacuo to afford **S5**.

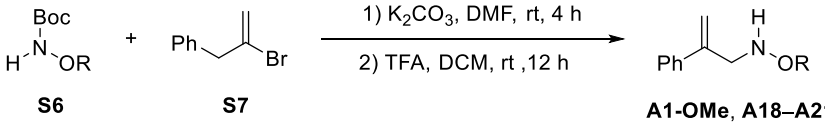


S5 **A17**

Add triethylamine (15 mmol, 3 equiv.) and TsCl (6 mmol, 1.2 equiv.) to a solution of amine **S5** (5 mmol, 1 equiv.) in DCM (10 mL) at 0°C. Allow the reaction mixture to stir at 0 °C for

1 hour. Warm up the reaction mixture gradually to room temperature over 1 hour. Dilute the resulting mixture with DCM (30 mL). Wash the resulting mixture with saturated aqueous sodium bicarbonate solution (25 mL). Extract the aqueous layer with DCM (3×10 mL). The combined organic layers were dried over anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (petroleum ether/ethyl acetate) to afford product **A17**. The identity and purity of the products were confirmed by ^1H and ^{13}C NMR spectroscopy.

3.5 General Procedure E (GPE) for substrates



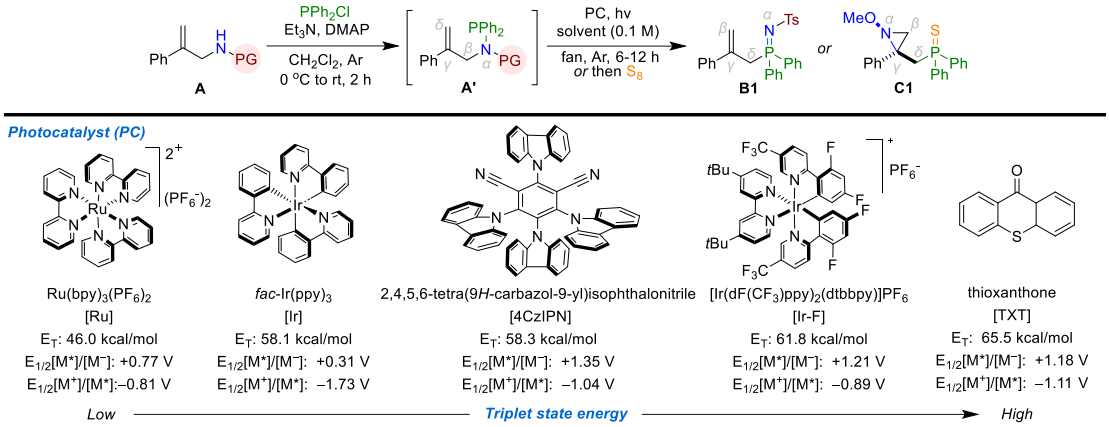
S6 **S7** **A1-OMe**, **A18–A21**

Step 1: To a 40 mL vial were added **S6** (20 mmol, 1.0 equiv.), K_2CO_3 (30 mmol, 1.5 equiv.), DMF (1 M, 20 mL), and **S7** (32 mmol, 1.6 equiv.). The mixture was stirred at room temperature for 12 h before being diluted with H_2O (50 mL) and extracted with Et_2O (3×50 mL). The combined organic phase was washed with H_2O (50 mL) and brine (50 mL), dried over anhydrous Na_2SO_4, filtered and concentrated under vacuum. The residue was purified by flash column chromatography on silica gel to give *tert*-butyl alkoxy(2-phenylallyl)carbamate.

Step 2: Then, to a 100 mL egg-shaped flask were added tert-butyl alkoxy(2-phenylallyl)carbamate (5 mmol, 1.0 equiv.) and DCM (5 mL). The mixture was cooled to 0 °C before CF_3CO_2H (5 mL) was added. After being stirred for 12 h at room temperature, the solvent was removed under vacuum. The residue was redissolved in DCM (10 mL), and K_2CO_3 was added portionwise until no gas evolution was observed. The mixture was diluted with H_2O (25 mL) and extracted with DCM (2×25 mL). The combined organic phase was washed with H_2O (25 mL) and brine (25 mL), dried over anhydrous Na_2SO_4, filtered, and concentrated under vacuum. The residue was purified by flash column chromatography on silica gel (petroleum ether/ethyl acetate) to afford products **A1-OMe** and **A18**–**A21**. The identity and purity of the products were confirmed by ^1H and ^{13}C NMR spectroscopy.

4 Optimization of reaction conditions

Table S1. Optimization of reaction conditions

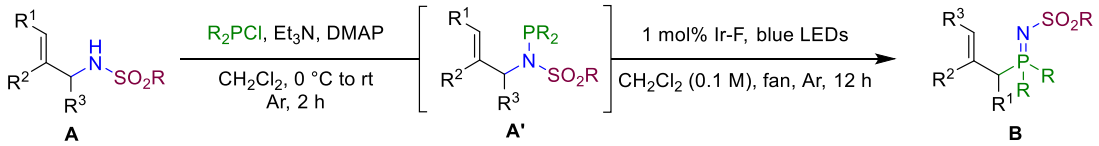


entry	PG	photocatalyst	solvent	yield (%)	
				B	**C**
1	Ac	Ir-F	CH_2Cl_2	NR	NR
2	Bz	Ir-F	CH_2Cl_2	NR	NR
3	Ts	Ir-F	CH_2Cl_2	**B1**, 81	0
4	Ts	TXT	CH_2Cl_2	**B1**, 73	0
5	Ts	4CzIPN	CH_2Cl_2	**B1**, 64	0
6	Ts	*fac*-Ir(ppy)$_3$	CH_2Cl_2	**B1**, 43	**0**
7	Ts	Ru(bpy)$_3$(PF$_6$)$_2$	CH_2Cl_2	NR	NR
8	Ts	Ir-F	AcOEt	**B1,** 68	0
9	Ts	Ir-F	MeCN	**B1,** 66	0
10	MeO	Ir-F	CH_2Cl_2	0	**C1**, 52, dr 2.3:1
11	MeO	Ir-F	EtOAc	0	**C1**, 78, dr 2.5:1
12	MeO	Ir-F	MeCN	0	**C1**, 67, dr 2.0:1
13	*n*Bu	Ir-F	CH_2Cl_2	NR	NR
14	Ph	Ir-F	CH_2Cl_2	NR	NR

All reactions performed on 0.2 mmol scale following general procedure. Isolated yields.

5 General procedure for *β*- and *α*-scission products

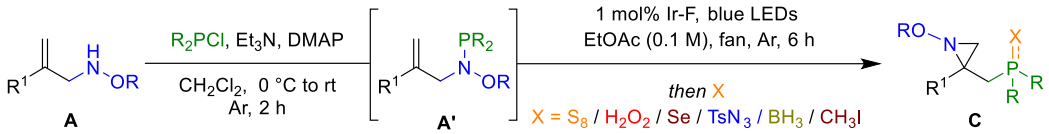
5.1 General procedure for *β*-scission products



To a glass tube equipped with a magnetic stir bar were added allyl sulfonamides **A1-Ts**, **A2**–**A17**, or **A29**–**A30** (0.2 mmol, 1.0 equiv.), anhydrous DCM (2 mL, 0.1 M), 4-dimethylaminopyridine (DMAP, 20.0 mol%), and Et_3N (0.24 mmol, 1.2 equiv.). The mixture

was stirred under an argon atmosphere, followed by the dropwise addition of R_2PCl (0.22 mmol, 1.2 equiv.) using a microsyringe at 0 °C. The mixture was stirred at room temperature for 2 hours. After the reaction was complete, Ir-F was added to the reaction solution in a glovebox. The reaction mixture was allowed to stir for 12 h under irradiation from 6 W blue LEDs (λ_{max} = 455 nm) with fan cooling. Then the solution was concentrated under reduced pressure and the crude product was purified by flash column chromatography (gradient eluent of ethyl acetate and petroleum ether) to give the corresponding product. The identity and purity of the products were confirmed by ^{1}H, ^{13}C and ^{31}P NMR spectroscopy.

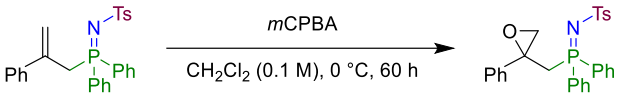
5.2 General procedure for *α*-scission products



To a glass tube equipped with a magnetic stir bar were added O-alkyl-N-(allyl)hydroxylamine **A1-OMe**, **A18**–**A28**, or **A31**–**A32** (0.2 mmol, 1.0 equiv.), anhydrous DCM (2 mL, 0.1 M), 4-dimethylaminopyridine (DMAP, 20.0 mol%), and Et_3N (0.24 mmol, 1.2 equiv.). The mixture was stirred under an argon atmosphere, followed by the dropwise addition of R_2PCl (0.22 mmol, 1.2 equiv.) using a microsyringe at 0 °C. The mixture was stirred at room temperature for 2 hours. After the reaction was complete, the solvent was concentrated under vacuum, and Ir–F was added. The tube was then evacuated and backfilled with argon three times. Subsequently, EtOAc (2 mL, 0.1 M) was added via syringe under an argon atmosphere. The reaction mixture was allowed to stir for 6 h under irradiation from 6 W blue LEDs (λ_{max} = 455 nm) with fan cooling. After the reaction was complete, S_8 (13 mg, 0.4 mmol, 2 equiv., for **C1**–**C17**, **C23**, and **C24**), H_2O_2 (45 μL, 0.4 mmol, 30% w/w in H_2O, 2 equiv., for **C18**), Se powder (32 mg, 0.4 mmol, 2 equiv. for **C19**), TsN_3 (234 μL, 0.8 mmol, 75% w/w in ethyl acetate, for **C20**), $Me_2S{\bullet}BH_3$ (200 μL, 0.4 mmol, 2 equiv., 2 M in Me_2S, for **C21**) or MeI (50 μL, 0.8 mmol, for **C22**) was added respectively. The mixture was stirred for 2 h (**C1**–**C19** and **C21**–**C24**) or 8 h (**C20**) at room temperature. Then the solution was concentrated under reduced pressure and the crude product was

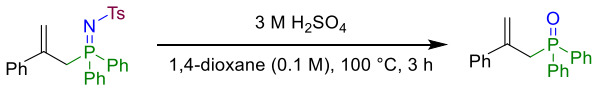
purified by flash column chromatography (gradient eluent of ethyl acetate and petroleum ether) to give the corresponding product. The identity and purity of the products were confirmed by ^{1}H, ^{13}C, ^{11}B, ^{19}F and ^{31}P NMR spectroscopy.

6 Follow-up transformation



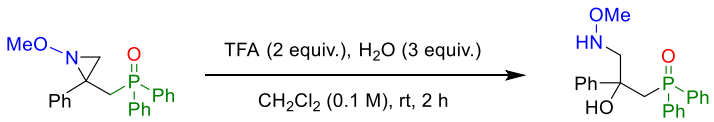
B1 **D1**

To a solution of **B1** (0.2 mmol, 1 equiv.) in CH_2Cl_2 (2 mL, 0.1 M) was added *m*CPBA (0.22 mmol, 1.1 equiv.) at 0 °C. The reaction mixture was stirred at that temperature for 60 h. The reaction was quenched with sat. aq. $NaHCO_3$, and the product was extracted with CH_2Cl_2 for three times. The combined organic layer was washed with brine, dried over Na_2SO_4 and evaporated. Then the solution was concentrated under reduced pressure and the crude product was purified by flash column chromatography (gradient eluent of ethyl acetate and petroleum ether) to give the corresponding product **D1**. The identity and purity of the products were confirmed by ^{1}H, ^{13}C and ^{31}P NMR spectroscopy.



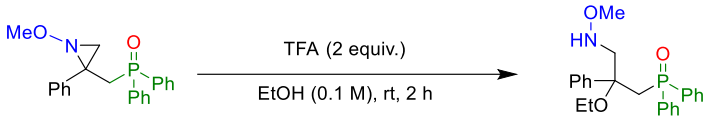
B1 **E1**

To a solution of **B1** (0.2 mmol, 1 equiv.) in 1,4-dioxane (2 mL, 0.1 M) was added 3 M H_2SO_4 (0.84 mL) at room temperature. The reaction mixture was stirred at 100 °C for 3 h. The reaction was quenched with sat. aq. $NaHCO_3$, and the product was extracted with CH_2Cl_2 for three times. The combined organic layer was washed with brine, dried over Na_2SO_4 and evaporated. Then the solution was concentrated under reduced pressure and the crude product was purified by flash column chromatography (gradient eluent of ethyl acetate and petroleum ether) to give the corresponding product **E1**. The identity and purity of the products were confirmed by ^{1}H, ^{13}C and ^{31}P NMR spectroscopy.



C18 **F1**

To a solution of **C18** (0.2 mmol, 1 equiv.) in CH_2Cl_2 (2 mL, 0.1 M) was added Trifluoroacetic acid (TFA, 0.4 mmol, 2 equiv.) and H_2O (0.6 mmol, 3 equiv.) at 0 °C. Subsequently, the reaction mixture was allowed to warm to room temperature and stirred for 2 h. The reaction was quenched with sat. aq. $NaHCO_3$, and the product was extracted with CH_2Cl_2 for three times. The combined organic layer was washed with brine, dried over Na_2SO_4 and evaporated. Then the solution was concentrated under reduced pressure and the crude product was purified by flash column chromatography (gradient eluent of ethyl acetate and petroleum ether) to give the corresponding product **F1**. The identity and purity of the products were confirmed by ^1H, ^{13}C and ^{31}P NMR spectroscopy.

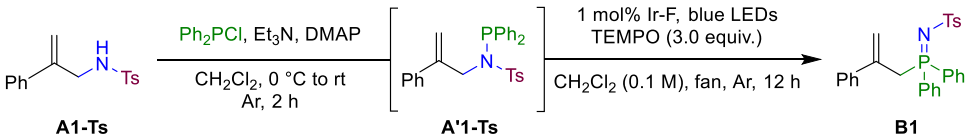


C18 **G1**

To a solution of **C18** (0.2 mmol, 1 equiv.) in EtOH (2 mL, 0.1 M) was added Trifluoroacetic acid (TFA, 0.4 mmol, 2 equiv.) at 0 °C. Subsequently, the reaction mixture was allowed to warm to room temperature and stirred for 2 h. The reaction was quenched with sat. aq. $NaHCO_3$, and the product was extracted with CH_2Cl_2 for three times. The combined organic layer was washed with brine, dried over Na_2SO_4 and evaporated. Then the solution was concentrated under reduced pressure and the crude product was purified by flash column chromatography (gradient eluent of ethyl acetate and petroleum ether) to give the corresponding product **G1**. The identity and purity of the products were confirmed by ^1H, ^{13}C and ^{31}P NMR spectroscopy.

7 Mechanism investigations

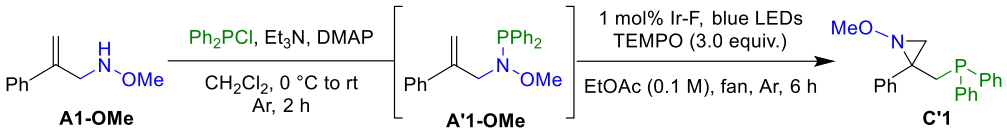
7.1 Control experiments



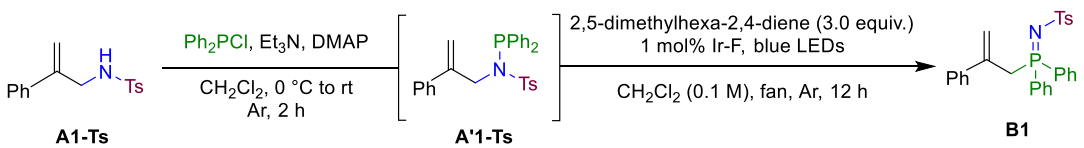
A1-Ts **A'1-Ts** **B1**

To a glass tube equipped with a magnetic stir bar were added 2-phenylallyl sulfonamides **A1-Ts** (0.2 mmol, 1.0 equiv.), anhydrous DCM (2 mL, 0.1 M), 4-dimethylaminopyridine (DMAP, 20.0 mol%), and Et_3N (0.24 mmol, 1.2 equiv.). The mixture was stirred under an

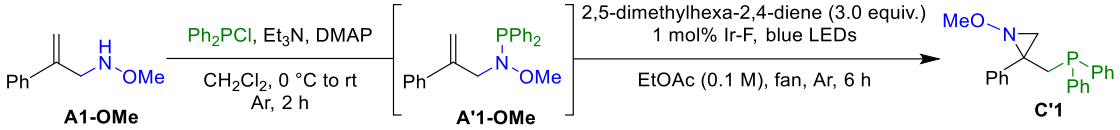
argon atmosphere, followed by the dropwise addition of Ph_2PCl (0.22 mmol, 1.2 equiv.) using a microsyringe at 0 °C. The mixture was stirred at room temperature for 2 hours. After the reaction was complete, Ir-F and TEMPO (2,2,6,6-tetramethyl-piperidine-*N*-oxyl, 0.6 mmol, 3.0 equiv.) were added to the reaction solution in a glovebox. The reaction mixture was allowed to stir for 12 h under irradiation from 6 W blue LEDs (λ_{max} = 455 nm) with fan cooling. Then the solution was concentrated under reduced pressure and the crude product was purified by flash column chromatography (gradient eluent of ethyl acetate and petroleum ether) to give the corresponding product. The identity and purity of the products were confirmed by ^{1}H NMR spectroscopic analyses.



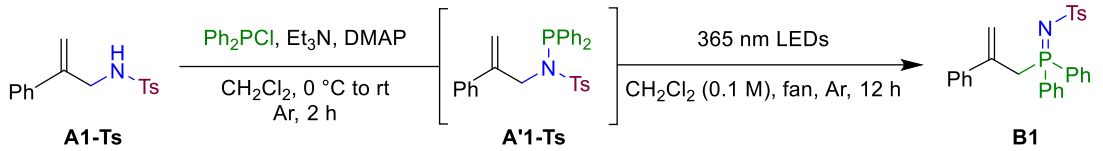
To a glass tube equipped with a magnetic stir bar were added O-methyl-N-(2-phenylallyl)hydroxylamine **A1-OMe** (0.2 mmol, 1.0 equiv.), anhydrous DCM (2 mL, 0.1 M), 4-dimethylaminopyridine (DMAP, 20.0 mol%), and Et_3N (0.24 mmol, 1.2 equiv.). The mixture was stirred under an argon atmosphere, followed by the dropwise addition of Ph_2PCl (0.22 mmol, 1.2 equiv.) using a microsyringe at 0 °C. The mixture was stirred at room temperature for 2 hours. After the reaction was complete, the solvent was concentrated under vacuum, and Ir–F and TEMPO (2,2,6,6-tetramethyl-piperidine-*N*-oxyl, 0.6 mmol, 3.0 equiv.) were added. The tube was then evacuated and backfilled with argon three times. Subsequently, EtOAc (2 mL, 0.1 M) was added via syringe under an argon atmosphere. The reaction mixture was allowed to stir at room temperature for 6 h under irradiation from 6 W blue LEDs (λ_{max} = 455 nm). Then the solution was concentrated under reduced pressure and the crude product was purified by flash column chromatography (gradient eluent of ethyl acetate and petroleum ether) to give the corresponding product. The identity and purity of the products were confirmed by ^{1}H spectroscopy.



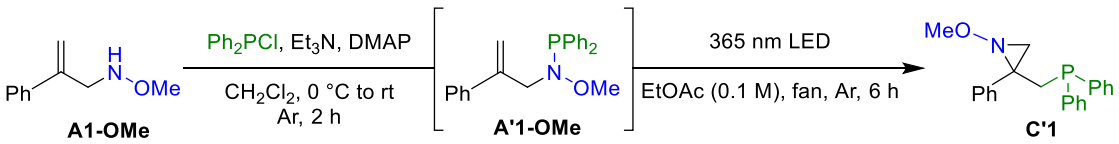
To a glass tube equipped with a magnetic stir bar were added 2-phenylallyl sulfonamides **A1-Ts** (0.2 mmol, 1.0 equiv.), anhydrous DCM (2 mL, 0.1 M), 4-dimethylaminopyridine (DMAP, 20.0 mol%), and Et_3N (0.24 mmol, 1.2 equiv.). The mixture was stirred under an argon atmosphere, followed by the dropwise addition of Ph_2PCl (0.22 mmol, 1.2 equiv.) using a microsyringe at 0 °C. The mixture was stirred at room temperature for 2 hours. After the reaction was complete, Ir-F and 2,5-dimethylhexa-2,4-diene (0.6 mmol, 3.0 equiv.) were added to the reaction solution in a glovebox. The reaction mixture was allowed to stir for 12 h under irradiation from 6 W blue LEDs (λ_{max} = 455 nm) with fan cooling. Then the solution was concentrated under reduced pressure and the crude product was purified by flash column chromatography (gradient eluent of ethyl acetate and petroleum ether) to give the corresponding product. The identity and purity of the products were confirmed by ^1H NMR spectroscopic analyses.



To a glass tube equipped with a magnetic stir bar were added O-methyl-N-(2-phenylallyl)hydroxylamine **A1-OMe** (0.2 mmol, 1.0 equiv.), anhydrous DCM (2 mL, 0.1 M), 4-dimethylaminopyridine (DMAP, 20.0 mol%), and Et_3N (0.24 mmol, 1.2 equiv.). The mixture was stirred under an argon atmosphere, followed by the dropwise addition of Ph_2PCl (0.22 mmol, 1.2 equiv.) using a microsyringe at 0 °C. The mixture was stirred at room temperature for 2 hours. After the reaction was complete, the solvent was concentrated under vacuum, and Ir–F and 2,5-dimethylhexa-2,4-diene (0.6 mmol, 3.0 equiv.) were added. The tube was then evacuated and backfilled with argon three times. Subsequently, EtOAc (2 mL, 0.1 M) was added via syringe under an argon atmosphere. The reaction mixture was allowed to stir for 6 h under irradiation from 6 W blue LEDs (λ_{max} = 455 nm) with fan cooling. Then the solution was concentrated under reduced pressure and the crude product was purified by flash column chromatography (gradient eluent of ethyl acetate and petroleum ether) to give the corresponding product. The identity and purity of the products were confirmed by ^1H spectroscopy.



To a glass tube equipped with a magnetic stir bar were added 2-phenylallyl sulfonamides **A1-Ts** (0.2 mmol, 1.0 equiv.), anhydrous DCM (2 mL, 0.1 M), 4-dimethylaminopyridine (DMAP, 20.0 mol%), and Et_3N (0.24 mmol, 1.2 equiv.). The mixture was stirred under an argon atmosphere, followed by the dropwise addition of Ph_2PCl (0.22 mmol, 1.2 equiv.) using a microsyringe at 0 °C. The mixture was stirred at room temperature for 2 hours. After the reaction was complete, the reaction mixture was allowed to stir for 12 h under irradiation from 6 W blue LEDs (λ_{max} = 365 nm) with fan cooling. Then the solution was concentrated under reduced pressure and the crude product was purified by flash column chromatography (gradient eluent of ethyl acetate and petroleum ether) to give the corresponding product in 26% yield. The identity and purity of the products were confirmed by ^1H NMR spectroscopy.



To a glass tube equipped with a magnetic stir bar were added O-methyl-N-(2-phenylallyl)hydroxylamine **A1-OMe** (0.2 mmol, 1.0 equiv.), anhydrous DCM (2 mL, 0.1 M), 4-dimethylaminopyridine (DMAP, 20.0 mol%), and Et_3N (0.24 mmol, 1.2 equiv.). The mixture was stirred under an argon atmosphere, followed by the dropwise addition of Ph_2PCl (0.22 mmol, 1.2 equiv.) using a microsyringe at 0 °C. The mixture was stirred at room temperature for 2 hours. After the reaction was complete, the solvent was concentrated under vacuum, and the tube was then evacuated and backfilled with argon three times. Subsequently, EtOAc (2 mL, 0.1 M) was added via syringe under an argon atmosphere. The reaction mixture was allowed to stir for 6 h under irradiation from 6 W blue LEDs (λ_{max} = 365 nm) with fan cooling. After the reaction was complete, the solution was concentrated under reduced pressure and the crude product was purified by flash column chromatography (gradient eluent of ethyl acetate and petroleum ether) to give the

corresponding product. The identity and purity of the products were confirmed by ^{1}H spectroscopy.

7.2 UV-Vis absorption spectroscopy

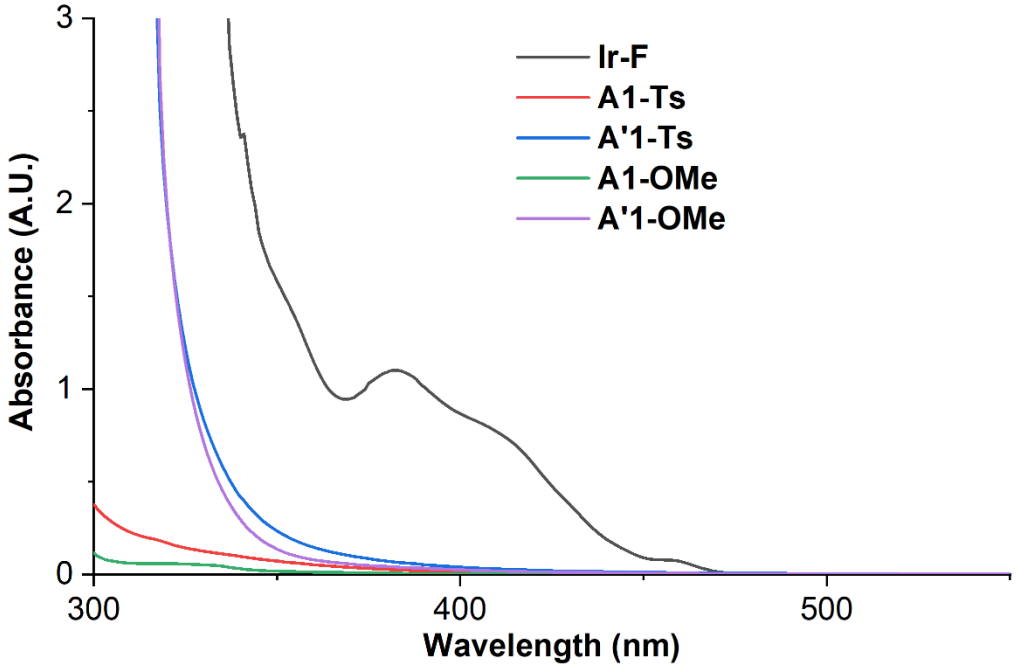


Figure S3. UV-Vis absorption spectra of photocatalyst Ir-F (0.1 mM), **A1-Ts** (10 mM), **A1-OMe** (10 mM), **A'1-Ts** (10 mM), **A'1-OMe** (10 mM), in deoxygenated CH_2Cl_2.

7.3 DFT calculations

Computational details

All the Density functional theory (DFT) calculations were performed with the GAUSSIAN 16 series of programs[1]. Geometry optimizations were performed using (U)B3LYP[2] functional with a basis set of 6-31+G(d,p)[3]. Frequency calculations were performed at the same levels as that used for geometry optimizations.

All stationary points were characterized by frequency calculations to confirm their identities as either local minima (zero imaginary frequencies) or first-order saddle points (one imaginary frequency). IRC calculations were used to confirm that the transition states found from the optimization calculations connect the related reactants and products. The electronic energy of the previously optimized geometries was then refined through an additional single point calculation on the (U)B3LYP-D3[4] functional and 6-311+G(d,p)

basis set, with the SMD[5] solvation model for ethyl acetate. The reported Gibbs free energies at 298 K were obtained as the sum of the electronic energies and the corresponding free energy corrections (ZPVE, thermal corrections, enthalpy correction, entropic corrections), as obtained from the frequency calculations. The minimum energy crossing point (MECP) in this work was located with the code sobMECP[6-8] at B3LYP(D3)/6-311+G(d,p) level with the SMD solvation model for ethyl acetate. All structural figures were generated with CYLview.[9]

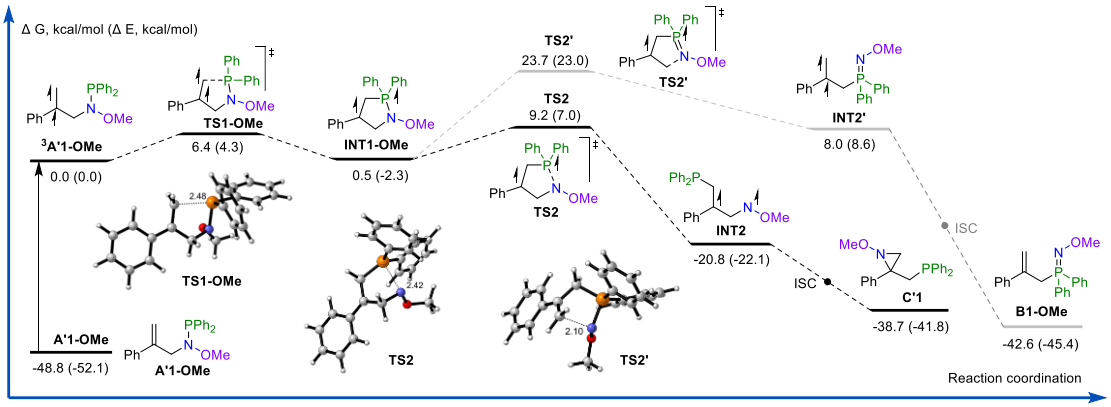


Figure S5. DFT calculations on the N-substituent-tuned α-scission rearrangement of phosphanamine

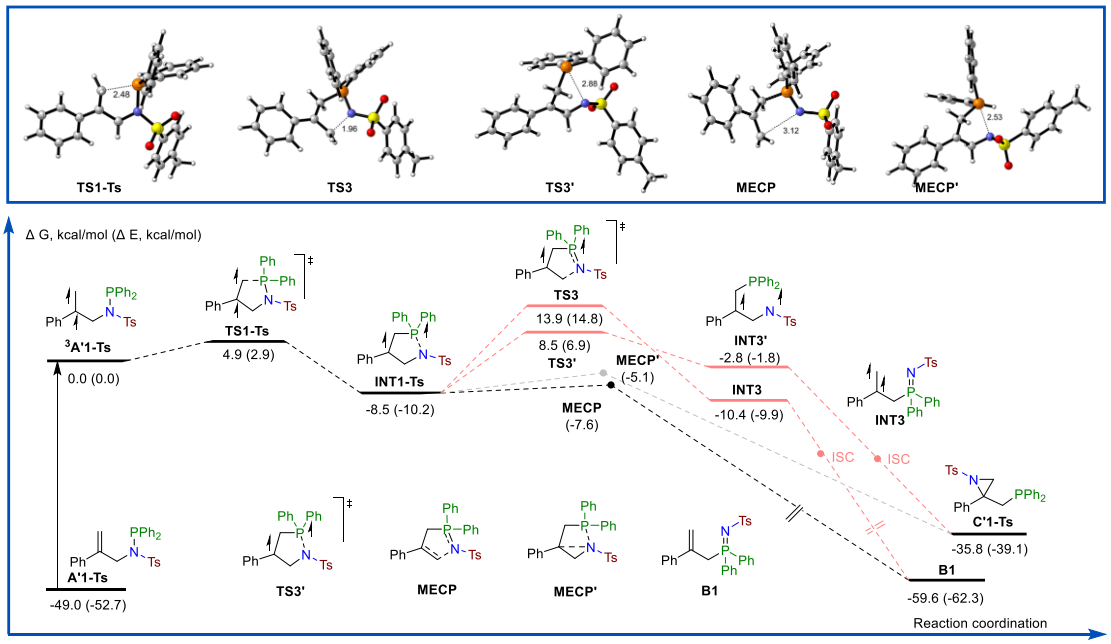


Figure S4. DFT calculations on the N-substituent-tuned β-scission rearrangement of phosphanamine

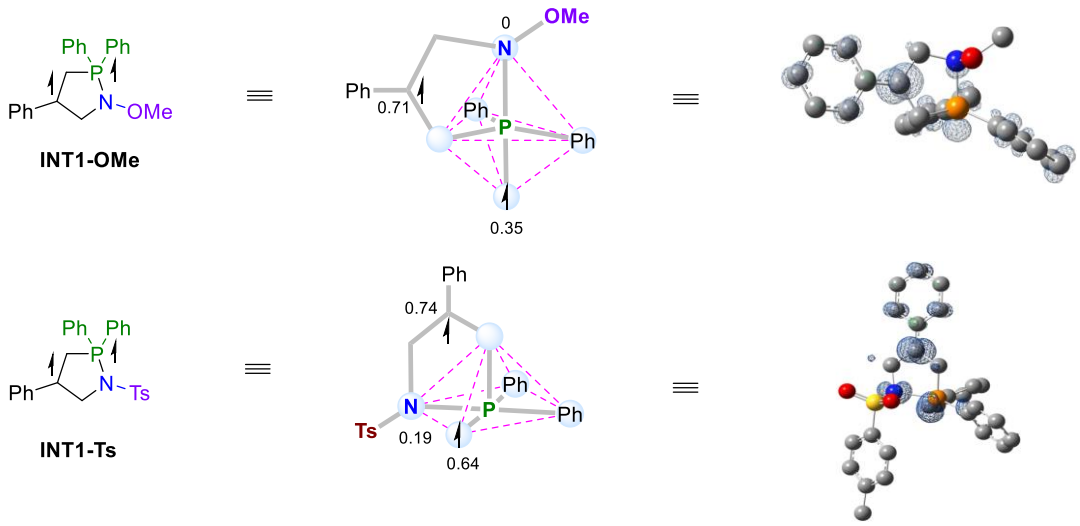


Figure S7. Atomic spin population analysis and spin density visualization. (hydrogen atoms are omitted for clarity and isovalue = 0.01).

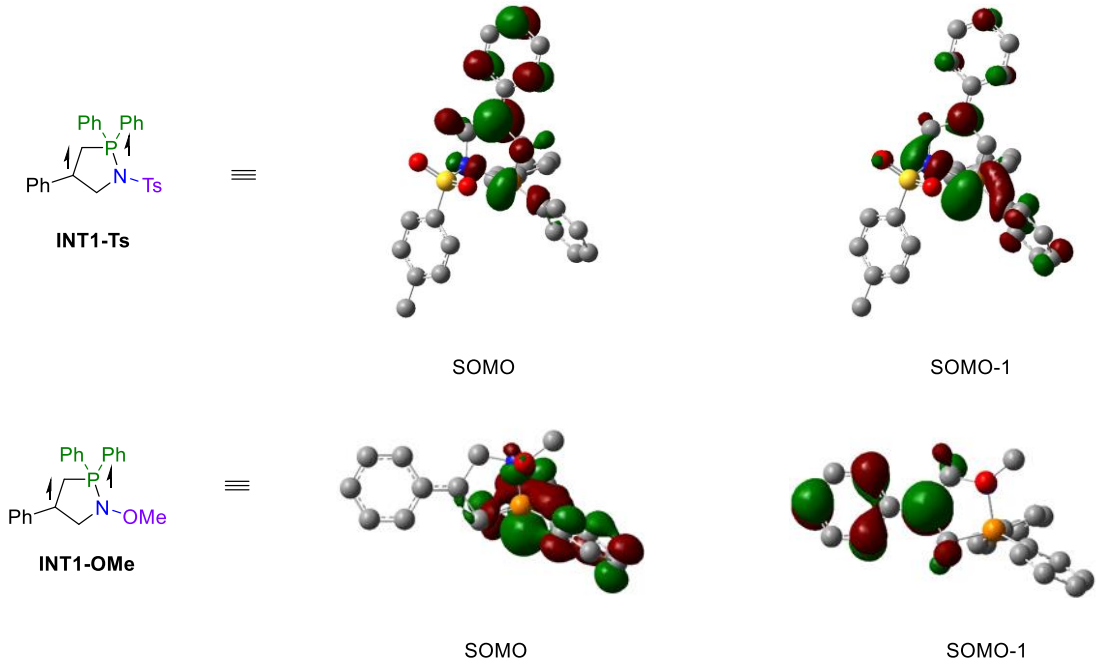


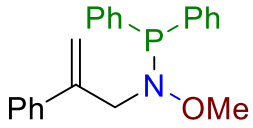
Figure S7. FMO analysis of **INT1-Ts and INT1-OMe**. (hydrogen atoms are omitted for clarity and isovalue = 0.04).

Table S2 Summary of energies.

	G (hartree)	G_ corrections (hartree)	E_ SinglePoint (hartree)	G_total (hartree)	IF
A'1-OMe	-1322.572537	0.325325	-1323.24306	-1322.917735	
^{3}A'1-OMe	-1322.494165	0.32013	-1323.160114	-1322.839984	
TS1-OMe	-1322.482347	0.323455	-1323.153247	-1322.829792	-87.41
INT1-OMe	-1322.487301	0.32465	-1323.163793	-1322.839143	
TS2'	-1322.448632	0.321182	-1323.123405	-1322.802223	-510.07
TS2	-1322.474061	0.323538	-1323.148898	-1322.82536	-232.34
INT2'	-1322.474292	0.319194	-1323.146458	-1322.827264	
INT2	-1322.527463	0.322188	-1323.19535	-1322.873162	
C'1	-1322.556436	0.324963	-1323.226667	-1322.901704	
B1-OMe	-1322.551262	0.324593	-1323.232538	-1322.907945	
A'1-Ts	-2026.980359	0.401735	-2027.871412	-2027.469677	
^{3}A'1-Ts	-2026.900966	0.395783	-2027.787432	-2027.391649	
TS1-Ts	-2026.892647	0.398883	-2027.782748	-2027.383865	-88.27
INT1-Ts	-2026.913007	0.398485	-2027.803658	-2027.405173	
TS-3	-2026.88429	0.398256	-2027.776371	-2027.378115	-711.81
TS-3'	-2026.876034	0.394425	-2027.763891	-2027.369466	-183.12
MECP			-2027.799617		
MECP'			-2027.795517		
INT3	-2026.910772	0.394981	-2027.803200	-2027.408219	
INT3'	-2026.915252	0.394183	-2027.790308	-2027.396125	
B1	-2026.988308	0.400138	-2027.886741	-2027.486603	
C'1-Ts	-2026.964765	0.401073	-2027.849716	-2027.448643	

Coordinates of stationary points

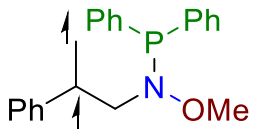
A'1-OMe



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C	4.80558600	-1.47180000	0.05436800
C	6.10368500	-0.96625800	-0.03612300
C	6.31371100	0.38515500	-0.32322900
H	5.36434100	2.27529400	-0.74930300
H	3.07528100	1.38311400	-0.60243000
H	4.64828100	-2.51850400	0.29724800
H	6.95061900	-1.62699900	0.12688600
H	7.32302600	0.78065900	-0.39103000
C	2.30868200	-1.20375900	-0.07159800
C	1.98610000	-2.34712500	-0.69317200
H	2.70892500	-2.87403400	-1.30807700
H	0.98647700	-2.75946600	-0.61803700
P	-0.91242200	-0.05685800	-0.72581300
C	1.32841000	-0.43702300	0.80518300
H	1.48078100	0.64519300	0.68695000
H	1.56713700	-0.65188300	1.85301600
C	-1.24029300	1.70517700	-0.24003400
C	-1.42079300	2.60704100	-1.30456800
C	-1.25738000	2.20719500	1.07426700
C	-1.64294100	3.96551800	-1.06773800
H	-1.38274900	2.24267200	-2.32877700
C	-1.45785900	3.57101700	1.30887900

H	-1.11733900	1.53024900	1.90888100
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H	-1.81897400	5.50963300	0.43047600
C	-2.57254500	-0.85772600	-0.57836600
C	-2.74533500	-2.08577200	-1.24071400
C	-3.66427900	-0.30163800	0.10482400
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H	-6.00567100	-2.70851600	-0.48151700
N	-0.08295500	-0.82208100	0.61892000
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^{3}A'1-OMe

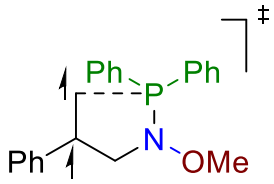


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C	5.55315900	0.20384200	-0.94058700
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H	-4.46763700	-3.26103300	-1.10967100
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C	-1.84921900	-1.71027300	2.71525600
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TS1-OMe

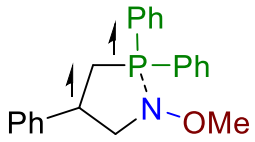


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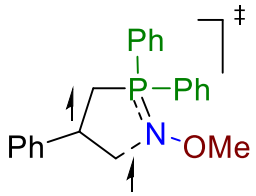
INT1-OMe



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C	-0.73949800	-0.45628700	-0.90812200
H	-0.60627100	-1.49531600	-1.24253700
H	-0.90255200	0.14340700	-1.80921300
P	0.84195500	0.03406000	-0.06655400
N	0.17080000	-0.39526500	1.58660200
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C	2.28954300	3.75230700	0.73694700
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C	0.42567300	4.03241800	-0.78039500
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H	3.08260800	4.17486000	1.34812300
H	-0.23012400	4.67366600	-1.36268000
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H	1.01143600	-3.30183400	2.83889200
H	2.09784500	-1.90314100	2.58703100
H	0.71145400	-1.76526400	3.71413000
C	2.28621500	-0.93370900	-0.39713700
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H	3.68998600	0.73398000	-0.47972100
C	4.50676100	-2.47863000	-1.26592900
H	3.13716400	-4.14781300	-1.22911000
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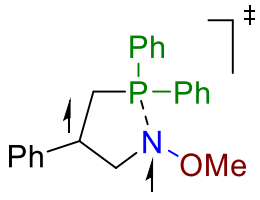
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C	3.44222500	-0.25513700	-1.56384800
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C	5.68138900	-0.25646200	-0.63613200
H	5.87599500	-1.21290400	1.29054900
H	3.51649100	-1.81786500	1.46308900
H	2.78546900	0.00648200	-2.38644400
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H	6.73210400	0.00682400	-0.70996700
C	1.52041700	-1.31819400	-0.35747600
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H	0.85522200	0.24977700	-1.73818600
H	0.06043800	-1.29353900	-2.00695400
P	-0.89367100	-0.08111900	-0.10726600
N	-0.15344500	-0.53391800	1.53051900
C	0.96576300	-2.08212500	0.66537300
H	1.57420700	-2.52121200	1.44835700
H	0.01859900	-2.58864200	0.51087900
C	-2.34928300	-1.05374600	-0.24775800
C	-3.42080800	-0.84213300	0.67807600
C	-2.51002300	-2.09105500	-1.21559900
C	-4.59325900	-1.58102700	0.58577500
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C	-3.68333900	-2.82601900	-1.27986000
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H	-3.77739100	-3.60364200	-2.03309700
H	-5.66454100	-3.15323000	-0.45341900
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C	1.05973100	0.30348700	3.31419600
H	1.64056200	1.18653400	3.58965800
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C	0.00262400	2.54563000	-0.21075600
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H	1.00291400	2.13913700	-0.10586200
C	-2.56432800	3.64342800	-0.40001300
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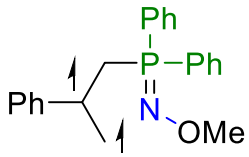


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C	-4.23163500	-2.79162000	-0.98638200
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H	-4.30764600	0.41145300	1.19492700
H	-2.15823000	-2.40524700	-1.30221900
H	-4.21274800	-3.68939800	-1.59834600
H	-6.33998200	-2.95359700	-0.52258400
C	-1.83181300	-0.12068600	0.15159500
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H	-0.35443300	-1.65367700	-0.32996100
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P	0.99394800	0.22526200	0.24771900
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C	-1.72460400	1.21045100	0.85594700
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H	-1.56626300	2.00783400	0.11148400
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C	1.72055700	2.92757500	0.57550500
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INT2'

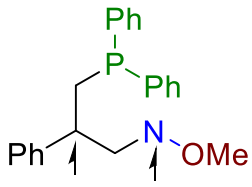


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H	2.59940254	3.69005905	1.40659615
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H	0.96781646	-4.44620109	2.37894117
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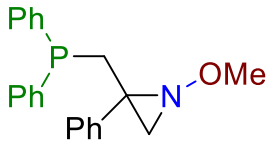
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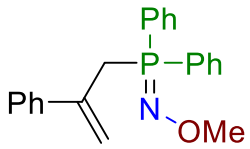
C'1



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C	-2.32442623	1.02615098	-0.43239820
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C	-5.34481408	2.47182465	1.44624692
H	-4.89108025	1.96552727	-0.59019871
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H	-3.20153109	2.09190005	4.05374689
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B1-OMe

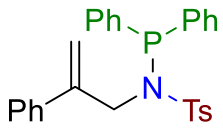


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C	0.08463500	2.74810500	-1.08392400
C	1.22064200	3.80348900	1.24188500
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H	0.48392100	4.66729800	-1.96670600
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O	2.18034501	-0.44394638	-0.00443096
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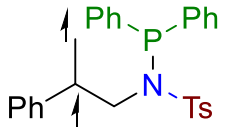


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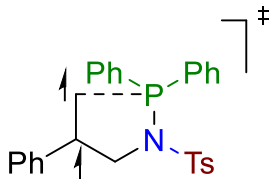


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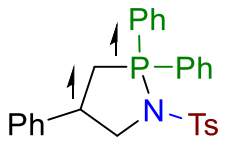


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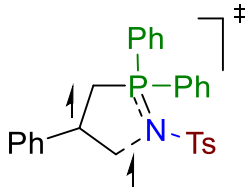


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TS3

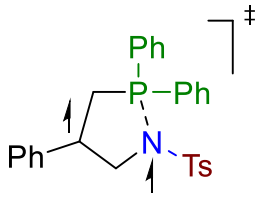


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TS3’

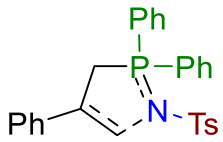


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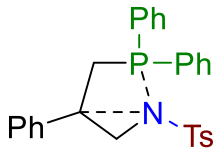


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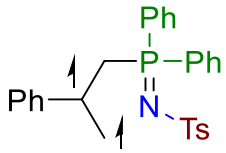


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INT3

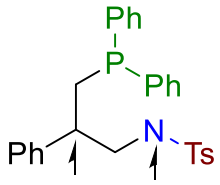


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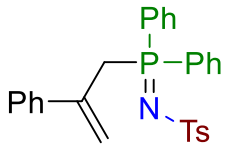


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B1

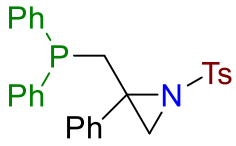


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C	1.48526400	-1.12434400	2.12227500
C	3.60495200	0.68167400	2.40927300
H	2.72966900	1.75119300	0.76384800
C	2.44811300	-1.32350000	3.11488000
H	0.65616500	-1.81841700	2.02411400
C	3.50647000	-0.42437100	3.25933100
H	4.42603900	1.38397200	2.51959600
H	2.36220700	-2.17918100	3.77766900
H	4.25169600	-0.58081400	4.03401000
C	-0.16733800	1.95176000	-0.06700300
C	-0.75656200	2.48787500	-1.22427700
C	-0.08512300	2.74682800	1.08584600
C	-1.22168000	3.80339200	-1.23916000
H	-0.87167000	1.88131200	-2.11724300
C	-0.55107200	4.06285000	1.06895000
H	0.32109800	2.33617900	2.00292100
C	-1.11365400	4.59582900	-0.09287000
H	-1.67139100	4.20540000	-2.14228600

H	-0.48471900	4.66538800	1.96986300
H	-1.47636700	5.61958100	-0.10298700
S	-2.00348500	-0.95041500	1.23079800
O	-1.87547800	-2.24519000	1.92786400
O	-2.00864800	0.28339400	2.05257400
C	-3.55867200	-1.00346600	0.32358100
C	-4.28294600	0.17163000	0.12676400
C	-4.02549600	-2.22181200	-0.17358100
C	-5.48265100	0.12292100	-0.58675400
H	-3.91523200	1.10498800	0.53964200
C	-5.22343900	-2.25308100	-0.88677800
H	-3.45933800	-3.12922800	0.00707700
C	-5.97186600	-1.08500900	-1.10414400
H	-6.04991300	1.03835900	-0.73633100
H	-5.58691100	-3.20171200	-1.27460800
C	-7.28756800	-1.13855500	-1.84541800
H	-7.24649500	-1.84287700	-2.68268300
H	-8.09814500	-1.46758500	-1.18300000
H	-7.56449600	-0.15659000	-2.24044500

C'1-Ts

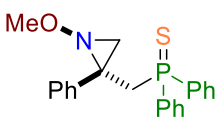


C	-0.75418200	0.26985100	1.33480000
H	-1.11956800	0.80947100	2.20458200
H	-0.41967100	-0.74937400	1.51437000
N	-1.52865200	0.51505900	0.10875400
C	-0.11334700	0.99666800	0.19309400
C	-0.03742000	2.50362800	0.20756000
C	-0.37834400	3.22409000	-0.94580400

C	0.38668000	3.19935900	1.34488800
C	-0.29202700	4.61661900	-0.96036100
H	-0.72610700	2.68984900	-1.82589300
C	0.47460800	4.59463400	1.33150900
H	0.65543100	2.65088000	2.24327800
C	0.13665600	5.30622900	0.17871800
H	-0.56296900	5.16398300	-1.85870800
H	0.80781100	5.12245100	2.22054400
H	0.20355000	6.39030500	0.16730200
C	0.97372300	0.28212600	-0.60932600
H	0.75772700	-0.78784400	-0.65561400
H	0.96538500	0.67091600	-1.63326700
P	2.71231100	0.56930500	0.06030500
C	2.71251200	-0.57760500	1.52817500
C	2.51628300	-1.96599300	1.43630200
C	2.92144600	-0.01241700	2.79596100
C	2.51573700	-2.76320600	2.58219100
H	2.36900600	-2.43096500	0.46545100
C	2.91952100	-0.80850700	3.94675400
H	3.09315900	1.05775200	2.88088300
C	2.71475900	-2.18556400	3.84133300
H	2.36224100	-3.83509100	2.49281300
H	3.08348100	-0.35338300	4.91968400
H	2.71622800	-2.80767500	4.73193700
C	3.71645100	-0.40173800	-1.16251100
C	5.11460600	-0.29810900	-1.03998900
C	3.19741500	-1.17948500	-2.21028200
C	5.96650000	-0.96915600	-1.91751900
H	5.53896800	0.31702300	-0.24993000
C	4.05119300	-1.84097800	-3.09998700

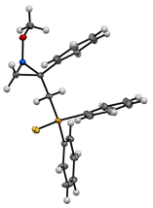
H	2.12635200	-1.28177500	-2.34896000
C	5.43590200	-1.74309800	-2.95459400
H	7.04270200	-0.87878200	-1.79900200
H	3.62748300	-2.43552400	-3.90466100
H	6.09640800	-2.25884700	-3.64569600
C	-3.73606500	-0.88470000	-0.51529800
C	-4.61508200	0.06567300	-1.04331700
C	-4.19619100	-1.92521000	0.28980400
C	-5.97117100	-0.03110800	-0.74531000
H	-4.23924300	0.86058600	-1.67816100
C	-5.56116700	-2.00549300	0.57758600
H	-3.49823100	-2.66230600	0.67148100
C	-6.46678900	-1.06564400	0.06815500
H	-6.65870300	0.70533300	-1.15345100
H	-5.92457600	-2.81620900	1.20324800
C	-7.94388000	-1.16181500	0.36741300
H	-8.51345200	-1.39741900	-0.53946400
H	-8.15293700	-1.94136900	1.10491100
H	-8.33202800	-0.21398800	0.75623400
S	-1.99108800	-0.78014700	-0.90926000
O	-1.83225900	-0.28191500	-2.28289700
O	-1.36212800	-2.05370200	-0.50726000

8 X-Ray single-crystal diffraction study for C1 (minor)



C1 (minor)

≡



X-ray for **C1 (minor)**

Table S3. The crystal data and refinement results of compound **C1 (minor**)

Compound number	**C1 (minor)**
Formula	$C_{22}H_{22}NOPS$
Formula weight	379.43
Temperature/K	149.99(10)
Crystal system	monoclinic
Space group	I2/a
a/Å	22.6241(6)
b/Å	6.5676(3)
c/Å	27.9941(11)
α/°	90
β/°	103.876(4)
γ/°	90
Volume/$Å^3$	4038.1(3)
Z	8
ρcalcg/cm^3	1.248
μ/mm^{-1}	2.242
F(000)	1600.0
Crystal size/mm^3	0.25 × 0.14 × 0.11
Radiation	Cu Kα (λ = 1.54184)
2Θ range for data collection/°	6.504 to 151.824
Index ranges	-20 ≤ h ≤ 27, -7 ≤ k ≤ 8, -34 ≤ l ≤ 32
Goodness-of-fit on F^2	1.038
CCDC number	2588516

Sigle crystal Preparation: Crystallization of **C1 (minor)** was performed in a 5 mL glass vial dissolving 40 mg of compound in 2 mL CH_2Cl_2 and kept the vial in dark room for slow evaporation covered with cotton. After two days crystal was formed as colorless cubic shape.

Data collections and solution method: Data collections for crystal structure were performed at 149.99 K using MoKα radiation on a Bruker APEXII diffractometer. Integration of the frames and data reduction was carried out using SAINT. The structure was solved by direct methods using SHELXS-97.

9 Reference

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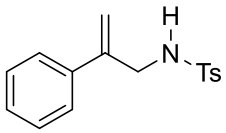
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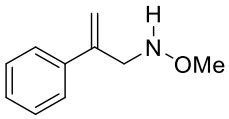
10 Analytical data for substrates

4-methyl-N-(2-phenylallyl)benzenesulfonamide (A1-Ts)



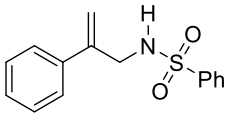
White solid; 0.920 g, 64%; R_f = 0.4 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): *δ* 7.15 (d, *J* = 8.4 Hz, 2H), 7.29–7.22 (m, 7H), 5.37 (s, 1H), 5.20 (s, 1H), 4.66 (t, *J* = 6.0 Hz, 1H), 3.99 (d, *J* = 6.0 Hz, 2H), 2.43 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): *δ* 143.5, 142.8, 137.8, 136.7, 129.6, 128.5, 128.1, 127.2, 126.0, 115.1, 47.0, 21.5; ESI-HRMS: Calcd for $C_{16}H_{18}NO_2S^+$ $[M+H]^+$ 288.1053, found 288.1052.

O-methyl-N-(2-phenylallyl)hydroxylamine (A1-OMe)



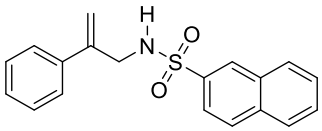
Colorless oil; 0.555 g, 68%; R_f = 0.4 (10:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.47–7.44 (m, 2H), 7.36–7.24 (m, 3H), 5.63 (m, 1H), 5.46 (d, J = 0.8 Hz, 1H), 5.29 (d, J = 1.2 Hz, 1H), 3.95 (d, J = 0.4 Hz, 2H), 3.51 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 144.0, 139.4, 128.5, 127.8, 126.2, 115.4, 61.7, 55.8; ESI-HRMS: Calcd for $C_{10}H_{14}NO^+$ $[M+H]^+$ 164.1070, found 164.1073.

N-(2-phenylallyl)benzenesulfonamide (A2)



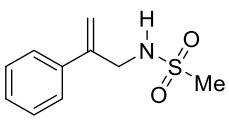
White solid; 0.997 g, 73%; R_f = 0.4 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.84–7.82 (m, 2H), 7.61–7.57 (m, 1H), 7.52–7.48 (m, 2H), 7.29–7.26 (m, 3H), 7.24–7.21 (m, 2H), 5.36 (d, J = 0.4 Hz, 1H), 5.20 (d, J = 0.4 Hz, 1H), 4.64 (m, 1H), 4.03 (dd, J = 6.0, 0.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 142.8, 139.8, 137.7, 132.7, 129.1, 128.6, 128.2, 127.2, 126.0, 115.3, 47.1; ESI-HRMS: Calcd for $C_{15}H_{16}NO_2S^+$ $[M+H]^+$ 274.0897, found 274.0893.

N-(2-phenylallyl)naphthalene-2-sulfonamide (A3)



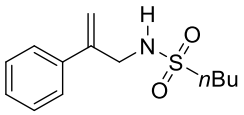
White solid; (0.906 g, 56%); R_f = 0.4 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.41 (d, J = 1.2 Hz, 1H), 7.96–7.91 (m, 3H), 7.77 (dd, J = 8.8, 2.0 Hz, 1H), 7.69–7.60 (m, 2H), 7.26–7.16 (m, 5H), 5.33 (s, 1H), 5.19 (s, 1H), 4.63 (t, J = 5.6 Hz, 1H), 4.06 (dd, J = 6.0, 0.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 142.8, 137.7, 136.5, 134.8, 132.1, 129.4, 129.2, 128.8, 128.6, 128.5, 128.2, 127.9, 127.5, 126.0, 122.4, 115.3, 47.1; ESI-HRMS: Calcd for $C_{19}H_{18}NO_2S^+$ $[M+H]^+$ 324.1053, found 324.1049.

N-(2-phenylallyl)methanesulfonamide (A4)



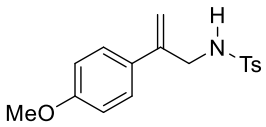
Colorless oil; 0.792 g, 75%; R_f = 0.4 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.42–7.31 (m, 5H), 5.50 (s, 1H), 5.36 (d, J = 0.8 Hz, 1H), 4.56 (m, 1H), 4.21 (d, J = 6.4 Hz, 2H), 2.88 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.7, 137.9, 128.8, 128.4, 126.2, 115.2, 47.0, 41.0; ESI-HRMS: Calcd for $C_{10}H_{14}NO_2S^+$ $[M+H]^+$ 212.0740, found 212.0741.

N-(2-phenylallyl)butane-1-sulfonamide (A5)



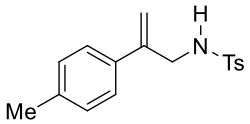
Colorless oil; 0.836 g, 66%; R_f = 0.4 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.42–7.30 (m, 5H), 5.48 (s, 1H), 5.35 (d, J = 0.8 Hz, 1H), 4.57 (t, J = 2.0 Hz, 1H), 4.18 (d, J = 6.4 Hz, 2H), 2.94–2.90 (m, 2H), 1.67–1.58 (m, 2H), 1.39–1.30 (m, 2H), 0.87 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.9, 138.0, 128.7, 128.3, 126.1, 115.0, 53.1, 46.9, 25.5, 21.4, 13.5; ESI-HRMS: Calcd for $C_{13}H_{20}NO_2S^+$ $[M+H]^+$ 254.1210, found 254.1205.

N-(2-(4-methoxyphenyl)allyl)-4-methylbenzenesulfonamide (A6)



White solid; 0.857 g, 54%; R_f = 0.2 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.72 (d, J = 8.4 Hz, 2H), 7.30 (d, J = 8.4 Hz, 2H), 7.20–7.18 (m, 2H), 6.82–6.80 (m, 2H), 5.29 (s, 1H), 5.10 (d, J = 0.4 Hz, 1H), 4.45–4.44 (m, 1H), 3.96 (d, J = 6.0 Hz, 2H), 3.81 (s, 3H), 2.44 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 159.6, 143.5, 142.1, 136.7, 130.1, 129.7, 127.2, 113.9, 113.6, 55.3, 47.2, 21.5; ESI-HRMS: Calcd for $C_{17}H_{20}NO_3S^+$ $[M+H]^+$ 318.1159, found 318.1163.

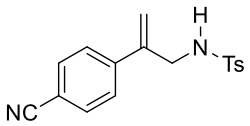
4-methyl-N-(2-(p-tolyl)allyl)benzenesulfonamide (A7)



White solid; 0.919 g, 61%; R_f = 0.4 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.71 (d, J = 8.0 Hz, 2H), 7.29 (d, J = 8.0 Hz, 2H), 7.14–7.07 (m, 4H), 5.33 (s,

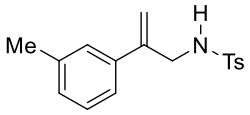
1H), 5.14 (d, *J* = 0.8 Hz, 1H), 4.58 (t, *J* = 6.4 Hz, 1H), 3.97 (d, *J* = 6.0 Hz, 2H), 2.44 (s, 3H), 2.33 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): *δ* 143.4, 142.6, 138.0, 136.7, 134.9, 129.6, 129.2, 127.2, 125.9, 114.3, 47.0, 21.5, 21.1; ESI-HRMS: Calcd for $C_{17}H_{20}NO_2S^+$ $[M+H]^+$ 302.1210, found 302.1207.

N-(2-(4-cyanophenyl)allyl)-4-methylbenzenesulfonamide (A8)



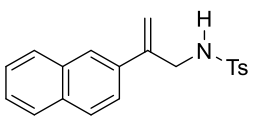
White solid; 0.625 g, 40%; R_f = 0.2 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): *δ* 7.69 (d, *J* = 8.0 Hz, 2H), 7.54 (d, *J* = 8.4 Hz, 2H), 7.38 (d, *J* = 8.4 Hz, 2H), 7.28 (d, *J* = 8.0 Hz, 2H), 5.49 (s, 1H), 5.37 (s, 1H), 5.03 (t, *J* = 6.0 Hz, 1H), 3.97 (d, *J* = 6.4 Hz, 2H), 2.45 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): *δ* 143.7, 142.4, 141.6, 136.5, 132.2, 129.7, 127.0, 126.8, 118.6, 118.2, 111.5, 46.6, 21.5; ESI-HRMS: Calcd for $C_{17}H_{17}N_2O_2S^+$ $[M+H]^+$ 313.1006, found 313.1009.

4-methyl-N-(2-(m-tolyl)allyl)benzenesulfonamide (A9)



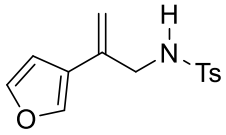
Colorless oil; 0.754 g, 50%; R_f = 0.4 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): *δ* 7.71 (d, *J* = 8.4 Hz, 2H), 7.28 (d, *J* = 8.4 Hz, 2H), 7.17 (t, *J* = 7.6 Hz, 1H), 7.08 (d, *J* = 7.6 Hz, 1H), 7.01 (d, *J* = 11.6 Hz, 2H), 5.33 (s, 1H), 5.18 (s, 1H), 4.61 (t, *J* = 6.0 Hz, 1H), 3.98 (d *J* = 6.4 Hz, 2H), 2.43 (s, 3H), 2.29 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): *δ* 143.4, 142.9, 138.1, 137.8, 136.8, 129.6, 128.9, 128.4, 127.2, 126.8, 123.1, 114.9, 47.0, 21.5, 21.4; ESI-HRMS: Calcd for $C_{17}H_{20}NO_2S^+$ $[M+H]^+$ 302.1210, found 302.1207.

4-methyl-N-(2-(naphthalen-2-yl)allyl)benzenesulfonamide (A10)



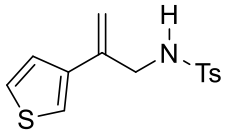
White solid; 0.641 g, 38%; R_f = 0.4 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.80–7.69 (m, 5H), 7.60 (s, 1H), 7.48–7.45 (m, 2H), 7.39 (dd, *J* = 8.4, 2.0 Hz, 1H), 7.23 (d, *J* = 8.0 Hz, 2H), 5.51 (s, 1H), 5.31 (s, 1H), 4.71 (m, 1H), 4.11 (d *J* = 6.0 Hz, 2H), 2.42 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.5, 142.7, 136.8, 135.0, 133.1, 133.0, 129.6, 128.2, 127.5, 127.2, 126.33, 126.28, 125.0, 124.1, 115.8, 47.1, 21.5; ESI-HRMS: Calcd for $C_{20}H_{20}NO_2S^+$ $[M+H]^+$ 338.1210, found 338.1207.

N-(2-(furan-3-yl)allyl)-4-methylbenzenesulfonamide (A11)



Colorless oil; 0.887 g, 64%; R_f = 0.4 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.75 (d, *J* = 8.4 Hz, 2H), 7.45 (s, 1H), 7.34–7.29 (m, 3H), 6.44 (d, *J* = 0.8 Hz, 1H), 5.28 (s, 1H), 5.07 (s, 1H), 4.97 (t, *J* = 6.0 Hz, 1H), 3.79 (d, *J* = 6.0 Hz, 2H), 2.43 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.5, 143.2, 139.3, 136.6, 134.4, 129.7, 127.1, 123.9, 113.0, 107.9, 46.9, 21.5; ESI-HRMS: Calcd for $C_{14}H_{16}NO_3S^+$ $[M+H]^+$ 278.0846, found 278.0846.

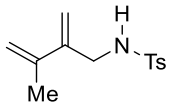
4-methyl-N-(2-(thiophen-3-yl)allyl)benzenesulfonamide (A12)



Colorless oil; 0.778 g, 53%; R_f = 0.4 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.74 (d, *J* = 8.0 Hz, 2H), 7.29 (d, *J* = 8.0 Hz, 2H), 7.25–7.23 (m, 1H), 7.19–7.18 (m, 1H), 7.13–7.12 (m, 1H), 5.40 (s, 1H), 5.14 (s, 1H), 4.89 (m, 1H), 3.91 (d, *J* = 6.4 Hz, 2H), 2.43 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.5, 139.2, 137.5, 136.6, 129.7, 127.1,

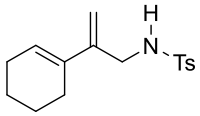
125.8, 125.5, 121.3, 113.9, 47.2, 21.5; ESI-HRMS: Calcd for $C_{14}H_{16}NO_2S_2^+$ $[M+H]^+$ 294.0617, found 294.0612.

4-methyl-N-(3-methyl-2-methylenebut-3-en-1-yl)benzenesulfonamide (A13)



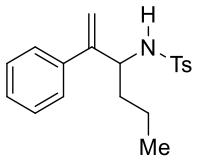
White solid; 0.351 g, 28%; R_f = 0.4 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.76 (d, J = 8.4 Hz, 2H), 7.30 (d, J = 8.4 Hz, 2H), 5.16 (s, 1H), 5.11 (s, 1H), 4.98 (s, 1H), 4.94 (s, 1H), 4.86 (m,1H), 3.77 (d, J = 6.0 Hz, 2H), 2.43 (s, 3H), 1.82 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.3, 142.2, 140.4, 136.7, 129.6, 127.1, 115.2, 113.6, 45.7, 21.5, 20.9; ESI-HRMS: Calcd for $C_{13}H_{18}NO_2S^+$ $[M+H]^+$ 252.1053, found 252.1051.

N-(2-(cyclohex-1-en-1-yl)allyl)-4-methylbenzenesulfonamide (A14)



White solid; 0.510 g, 35%; R_f = 0.4 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.75 (d, J = 8.0 Hz, 2H), 7.31 (d, J = 8.4 Hz, 2H), 5.71 (t, J = 4.0 Hz, 1H), 5.01 (s, 1H), 4.92 (s, 1H), 4.44 (t, J = 5.2 Hz, 1H), 3.75 (d, J = 6.0 Hz, 2H), 2.43 (s, 3H), 2.07–2.02 (m, 4H), 1.65–1.51 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.4, 142.8, 136.8, 133.7, 129.6, 127.2, 125.9, 112.2, 46.1, 25.73, 25.70, 22.6, 21.9, 21.5; ESI-HRMS: Calcd for $C_{16}H_{22}NO_2S^+$ $[M+H]^+$292.1366, found 292.1369.

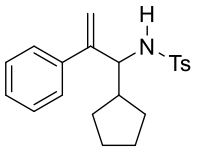
4-methyl-N-(2-phenylhex-1-en-3-yl)benzenesulfonamide (A15)



White solid; 0.873 g, 53%; R_f = 0.4 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.71 (d, J = 8.4 Hz, 2H), 7.26–7.25 (m, 3H), 7.22 (d, J = 8.4 Hz, 2H), 7.14–7.12

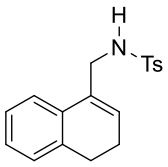
(m, 2H), 5.09–5.06 (m, 2H), 4.83 (m, 1H), 4.29–4.24 (m, 1H), 2.39 (s, 3H), 1.65–1.43 (m, 2H), 1.40–1.17 (m, 2H), 0.79 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 149.0, 143.1, 139.9, 137.9, 129.4, 128.3, 127.6, 127.1, 126.8, 114.1, 57.3, 37.8, 21.5, 18.8, 13.5; ESI-HRMS: Calcd for $C_{19}H_{24}NO_2S^+$ $[M+H]^+$ 330.1523, found 330.1526.

N-(1-cyclopentyl-2-phenylallyl)-4-methylbenzenesulfonamide (A16)



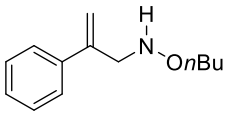
White solid; 0.853 g, 48%; R_f = 0.4 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.71 (d, J = 8.4 Hz, 2H), 7.26–7.24 (m, 3H), 7.20 (d, J = 8.4 Hz, 2H), 7.14–7.11 (m, 2H), 5.03–5.01 (m, 2H), 4.86 (m, 1H), 4.12 (t, J = 8.0 Hz, 1H), 2.38 (s, 3H), 2.00–1.90 (m, 1H), 1.70–1.40 (m, 6H), 1.28–1.18 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 148.8, 143.0, 140.2, 138.0, 129.4, 128.2, 127.5, 127.2, 114.9, 61.9, 44.1, 29.7, 28.8, 25.4, 25.0, 21.5; ESI-HRMS: Calcd for $C_{21}H_{26}NO_2S^+$ $[M+H]^+$ 356.1679, found 356.1678.

N-((3,4-dihydronaphthalen-1-yl)methyl)-4-methylbenzenesulfonamide (A17)



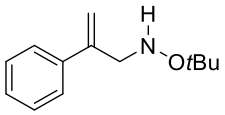
White solid; 0.784 g, 50%; R_f = 0.4 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.74 (d, J = 8.4 Hz, 2H), 7.28 (d, J = 8.0 Hz, 2H), 7.14–7.06 (m, 4H), 5.93 (t, J = 4.4 Hz, 1H), 4.61 (t, J = 6.0 Hz, 1H), 3.93 (dd, J = 6.0, 0.8 Hz, 2H), 2.63 (t, J = 8.0 Hz, 2H), 2.43 (s, 3H), 2.21–2.16 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.4, 136.7, 136.4, 132.4, 131.4, 129.6, 129.0, 127.7, 127.3, 127.2, 126.5, 122.5, 45.5, 27.6, 22.9, 21.5; ESI-HRMS: Calcd for $C_{18}H_{20}NO_2S^+$ $[M+H]^+$ 314.1210, found 314.1207.

O-butyl-N-(2-phenylallyl)hydroxylamine (A18)



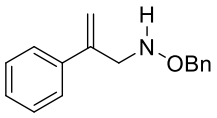
Colorless oil; 0.667 g, 65%; R_f = 0.4 (10:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.47–7.45 (m, 2H), 7.35–7.24 (m, 3H), 5.48–5.45 (m, 2H), 5.28 (d, J = 1.2 Hz, 1H), 3.94 (d, J = 0.8 Hz, 2H), 3.66 (t, J = 6.8 Hz, 2H), 1.55–1.48 (m, 2H), 1.38–1.28 (m, 2H), 0.90 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 144.0, 139.5, 128.4, 127.7, 126.1, 115.3, 73.7, 56.1, 30.8, 19.2, 13.9; ESI-HRMS: Calcd for $C_{13}H_{20}NO^+$ $[M+H]^+$ 206.1540, found 206.1542.

O-(tert-butyl)-N-(2-phenylallyl)hydroxylamine (A19)



Colorless oil; 0.544 g, 53%; R_f = 0.3 (50:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.51–7.49 (m, 2H), 7.36–7.24 (m, 3H), 5.47 (d, J = 1.2 Hz, 1H), 5.27 (d, J = 0.8 Hz, 1H), 4.92 (m, 1H), 3.88 (s, 2H), 1.18 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.9, 139.7, 128.3, 127.6, 126.1, 115.5, 77.1, 57.4, 26.8; ESI-HRMS: Calcd for $C_{13}H_{20}NO^+$ $[M+H]^+$ 206.1540, found 206.1537.

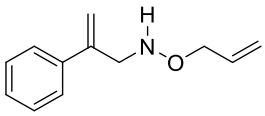
O-benzyl-N-(2-phenylallyl)hydroxylamine (A20)



Colorless oil; 0.850 g, 71%; R_f = 0.4 (10:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.43–7.40 (m, 2H), 7.33–7.24 (m, 8H), 5.46 (d, J = 1.2 Hz, 1H), 5.28 (d, J = 1.2 Hz, 1H), 4.67 (s, 2H), 3.93 (d, J = 0.8 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.9,

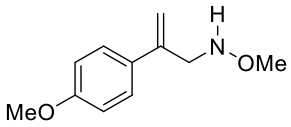
139.4, 137.9, 128.39, 128.36, 128.3, 127.70, 127.66, 126.2, 115.5, 76.1, 56.2; ESI-HRMS: Calcd for $C_{16}H_{18}NO^+$ $[M+H]^+$ 240.1383, found 240.1384.

O-allyl-N-(2-phenylallyl)hydroxylamine (A21)



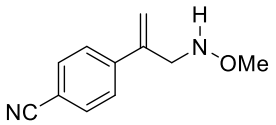
Colorless oil; 0.691 g, 73%; R_f = 0.4 (10:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.48–7.45 (m, 2H), 7.36–7.24 (m, 3H), 5.96–5.86 (m, 1H), 5.47 (d, J = 1.2 Hz, 1H), 5.30 (d, J = 1.2 Hz, 1H), 5.26–5.21 (m, 1H), 5.18–5.15 (m, 1H), 4.17 (dt, J = 6.0, 1.6 Hz, 2H), 3.97 (d, J = 0.8 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.9, 139.4, 134.5, 128.4, 127.7, 126.2, 117.6, 115.5, 75.0, 56.2; ESI-HRMS: Calcd for $C_{12}H_{16}NO^+$ $[M+H]^+$ 190.1227, found 190.1223.

N-(2-(4-methoxyphenyl)allyl)-O-methylhydroxylamine (A22)



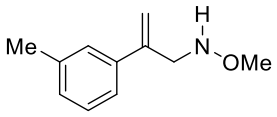
Colorless oil; 0.435 g, 45%; R_f = 0.4 (10:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.41 (d, J = 8.8 Hz, 2H), 6.88 (d, J = 8.4 Hz, 2H), 5.62–5.39 (m, 2H), 5.21 (s, 1H), 3.93 (s, 2H), 3.81 (s, 3H), 3.52 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 159.3, 143.2, 131.8, 127.3, 113.82, 113.79, 61.7, 55.9, 55.2; ESI-HRMS: Calcd for $C_{11}H_{16}NO_2^+$ $[M+H]^+$ 194.1176, found 194.1171.

4-(3-(methoxyamino)prop-1-en-2-yl)benzonitrile (A23)



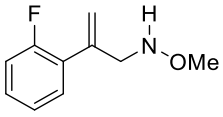
Colorless oil; 0.395 g, 42%; R_f = 0.2 (10:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.65–7.63 (m, 2H), 7.61–7.57 (m, 2H), 5.81 (s, 1H), 5.46 (d, J = 0.4 Hz, 1H), 3.94 (s, 2H), 3.49 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 144.2, 142.8, 132.2, 126.9, 118.8, 118.5, 111.3, 61.9, 55.6; ESI-HRMS: Calcd for $C_{11}H_{13}N_2O^+$ $[M+H]^+$ 189.1023, found 189.1021.

O-methyl-N-(2-(m-tolyl)allyl)hydroxylamine (A24)



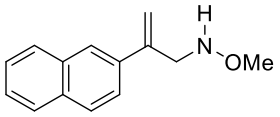
Colorless oil; 0.301 g, 34%; R_f = 0.4 (10:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.25–7.20 (m, 3H), 7.10–7.09 (m, 1H), 5.63 (m, 1H), 5.43 (d, J = 0.8 Hz, 1H), 5.26 (d, J = 0.8 Hz, 1H), 3.93 (s, 2H), 3.51 (s, 3H), 2.35 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 144.1, 139.4, 137.9, 128.5, 128.3, 126.9, 123.2, 115.0, 61.6, 55.7, 21.4; ESI-HRMS: Calcd for $C_{11}H_{16}NO^+$ $[M+H]^+$ 178.1227, found 178.1225.

N-(2-(2-fluorophenyl)allyl)-O-methylhydroxylamine (A25)



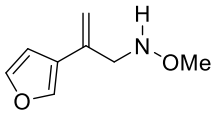
Colorless oil; 0.399 g, 44%; R_f = 0.4 (10:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.35 (td, J = 7.6, 1.6 Hz, 1H), 7.30–7.24 (m, 1H), 7.12 (td, J = 7.6, 1.2 Hz, 1H), 7.07–7.03 (m, 1H), 5.64 (m, 1H), 5.45 (d, J = 1.2 Hz, 1H), 5.37 (s, 1H), 3.92 (s, 2H), 3.47 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 159.9 (d, $J_{C\text{-}F}$ = 245.9 Hz), 141.3, 130.3 (d, $J_{C\text{-}F}$ = 4.3 Hz), 129.2 (d, $J_{C\text{-}F}$ = 8.2 Hz), 127.9 (d, $J_{C\text{-}F}$ = 14.1 Hz), 124.2 (d, $J_{C\text{-}F}$ = 3.5 Hz), 118.5 (d, $J_{C\text{-}F}$ = 2.5 Hz), 115.7 (d, $J_{C\text{-}F}$ = 22.7 Hz), 61.6, 56.4 (d, $J_{C\text{-}F}$ = 3.7 Hz); ^{19}F NMR (376 MHz, $CDCl_3$): δ -114.8; ESI-HRMS: Calcd for $C_{10}H_{13}FNO^+$ $[M+H]^+$ 182.0976, found 182.0977.

O-methyl-N-(2-(naphthalen-2-yl)allyl)hydroxylamine (A26)



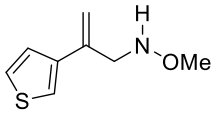
Colorless oil; 0.373 g, 35%; R_f = 0.4 (10:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.90 (s, 1H), 7.84–7.80 (m, 3H), 7.61 (dd, J = 8.8, 1.6 Hz, 1H), 7.49–7.43 (m, 2H), 5.61 (s, 1H), 5.40 (d, J = 0.8 Hz, 1H), 4.07 (s, 2H), 3.54 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.8, 136.6, 133.3, 132.9, 128.2, 128.1, 127.5, 126.2, 126.0 124.9, 124.5, 115.9, 61.8, 55.8; ESI-HRMS: Calcd for $C_{14}H_{16}NO^+$ $[M+H]^+$ 214.1227, found 214.1226.

N-(2-(furan-3-yl)allyl)-O-methylhydroxylamine (A27)



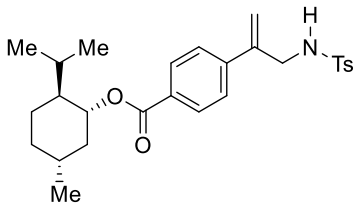
Colorless oil; 0.391 g, 51%; R_f = 0.4 (10:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.59 (s, 1H), 7.39–7.38 (m, 1H), 6.55 (m, 1H), 5.38 (s, 1H), 5.18 (d, J = 1.2 Hz, 1H), 3.79 (s, 2H), 3.54 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.2, 139.3, 135.5, 125.2, 113.2, 108.2, 61.8, 55.9; ESI-HRMS: Calcd for $C_8H_{12}NO_2^+$ $[M+H]^+$ 154.0863, found 154.0861.

O-methyl-N-(2-(thiophen-3-yl)allyl)hydroxylamine (A28)



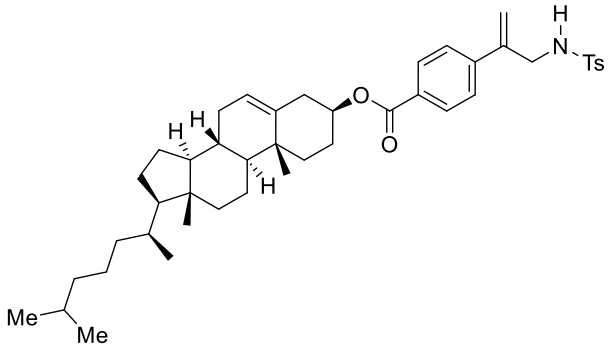
Colorless oil; 0.457 g, 54%; R_f = 0.4 (10:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.34–7.33 (m, 1H), 7.29–7.25 (m, 2H), 5.50 (d, J = 0.4 Hz, 1H), 5.24 (d, J = 0.8 Hz, 1H), 3.89 (d, J = 0.8 Hz, 2H), 3.54 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 140.8, 138.5, 125.7, 125.6, 120.9, 114.0, 61.7, 56.1; ESI-HRMS: Calcd for $C_8H_{12}NOS^+$ $[M+H]^+$ 170.0635, found 170.0634.

(1R,2S,5R)-2-isopropyl-5-methylcyclohexyl 4-(3-((4-methylphenyl)sulfonamido)pro p-1-en-2-yl)benzoate (A29)



White solid; 1.033 g, 44%; R_f = 0.2 (3:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.95–7.93 (m, 2H), 7.72–7.69 (m, 2H), 7.32–7.30 (m, 4H), 5.46 (s, 1H), 5.32 (s, 1H), 4.93 (td, *J* = 10.8, 4.4 Hz, 1H), 4.79–4.66 (m, 1H), 4.01 (d, *J* = 5.6 Hz, 2H), 2.44 (s, 3H), 2.12 (d, *J* = 12.0 Hz, 1H), 1.99–1.91 (m, 1H), 1.74 (d, *J* = 11.2 Hz, 2H), 1.58–1.53 (m, 2H), 1.18–1.06 (m, 2H), 0.94–0.91 (m, 7H), 0.80 (d, *J* = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 165.6, 143.6, 142.3, 142.1, 136.6, 130.3, 129.73, 129.68, 127.2, 126.0, 117.0, 74.9, 47.2, 46.8, 40.9, 34.3, 31.4, 26.5, 23.6, 22.0, 21.5, 20.7, 16.5; ESI-HRMS: Calcd for $C_{27}H_{36}NO_4S^+$ $[M+H]^+$ 470.2360, found 470.2356.

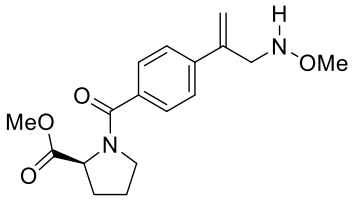
(3S,8S,9S,10R,13R,14S,17R)-10,13-dimethyl-17-((R)-6-methylheptan-2-yl)-2,3,4,7,8,9, 10,11,12,13,14,15,16,17-tetradecahydro-1H-cyclopenta[a]phenanthren-3-yl 4-(3-((4-methylphenyl)sulfonamido)prop-1-en-2-yl)benzoate (A30)



White solid; 2.170 g, 62 %; R_f = 0.4 (3:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.92 (d, *J* = 8.4 Hz, 2H), 7.70 (d, *J* = 8.0 Hz, 2H), 7.31–7.26 (m, 4H), 5.46 (s, 1H), 5.42–5.41 (m, 1H), 5.31 (s, 1H), 4.88–4.80 (m, 2H), 3.99 (d, *J* = 6.0 Hz, 2H), 2.47–

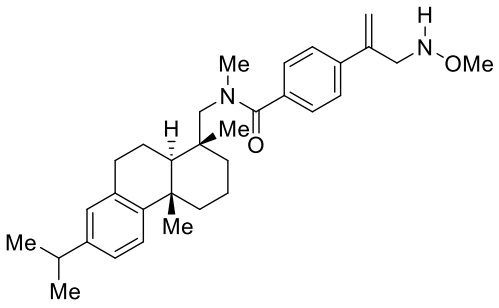
2.43 (m, 5H), 2.04–1.68 (m, 6H), 1.60–1.45 (m, 6H), 1.39–0.97 (m, 17H), 0.93 (d, *J* = 6.8 Hz, 3H), 0.88 (d, *J* = 2.0 Hz, 6H), 0.86 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): *δ* 165.5, 143.5, 142.22, 142.15, 139.5, 136.6, 130.2, 129.68, 129.65, 127.1, 125.9, 122.8, 117.0, 74.6, 56.6, 56.1, 50.0, 46.8, 42.3, 39.7, 39.5, 38.2, 37.0, 36.6, 36.1, 35.8, 31.9, 31.8, 28.2, 28.0, 27.8, 24.2, 23.8, 22.8, 22.5, 21.5, 21.0, 19.3, 18.7, 11.8; ESI-HRMS: Calcd for $C_{44}H_{62}NO_4S^+$ $[M+H]^+$ 700.4395, found 700.4397.

methyl (4-(3-(methoxyamino)prop-1-en-2-yl)benzoyl)-L-prolinate (A31)



White solid; 0.573 g, 36 %; R_f = 0.2 (1:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): *δ* 7.59–7.57 (m, 2H), 7.52–7.50 (m, 2H), 5.52 (s, 1H), 5.36 (s, 1H), 4.69–4.65 (m, 1H), 3.95 (s, 2H), 3.78 (s, 3H), 3.71–3.65 (m, 1H), 3.60–3.55 (m, 1H), 3.50 (s, 3H), 2.36–2.30 (m, 1H), 2.07–1.99 (m, 2H), 1.94–1.88 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): *δ* 172.6, 169.1, 143.2, 141.3, 135.1, 127.5, 125.9, 116.4, 61.6, 59.0, 55.5, 52.1, 49.8, 29.2, 25.2; ESI-HRMS: Calcd for $C_{17}H_{23}N_2O_4^+$ $[M+H]^+$ 319.1653, found 319.1655.

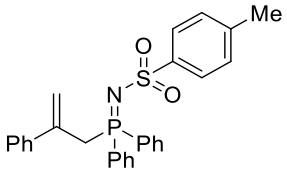
N-(((1R,4aS,10aR)-7-isopropyl-1,4a-dimethyl-1,2,3,4,4a,9,10,10a-octahydrophenanth-ren-1-yl)methyl)-4-(3-(methoxyamino)prop-1-en-2-yl)-N-methylbenzamide (A32)



White solid; 0.904 g, 37 %; R_f = 0.4 (1:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.48 (d, J = 8.4 Hz, 2H), 7.40 (d, J = 8.0 Hz, 2H), 7.19 (d, J = 8.4 Hz, 1H), 7.00 (d, J = 8.0 Hz, 1H), 6.89 (s, 1H), 5.62 (m, 1H), 5.50 (s, 1H), 5.34 (s, 1H), 3.94 (s, 2H), 3.76 (d, J = 13.6 Hz, 1H), 3.50 (s, 3H), 3.29 (d, J = 14.0 Hz, 1H), 3.05 (s, 2H), 2.93–2.79 (m, 3H), 2.32 (d, J = 12.8 Hz, 1H), 2.09–2.04 (m, 1H), 1.84–1.40 (m, 8H), 1.25–1.21 (m, 9H), 1.05 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.9, 147.3, 145.5, 143.4, 140.7, 136.3, 134.7, 127.4, 126.9, 126.1, 124.0, 123.8, 116.3, 61.8, 59.2, 55.7, 46.2, 42.5, 40.2, 38.3, 37.7, 37.6, 33.4, 30.3, 25.8, 24.0, 23.9, 19.4, 19.0, 18.7; ESI-HRMS: Calcd for $C_{32}H_{45}N_2O_2^+$ $[M+H]^+$ 489.3476, found 489.3472.

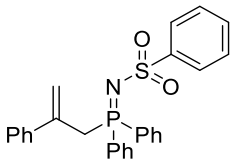
11 Analytical data for *β*- and *α*-scission products

N-(diphenyl(2-phenylallyl)-λ^5-phosphaneylidene)-4-methylbenzenesulfonamide (B1)



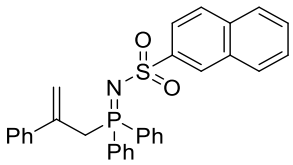
Colorless oil; 76 mg, 81% yield; R_f = 0.3 (2:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.58–7.48 (m, 6H), 7.45–7.41 (m, 2H), 7.29–7.24 (m, 4H), 7.08–7.02 (m, 3H), 7.01–6.98 (m, 4H), 5.49 (d, J = 4.8 Hz, 1H), 5.40 (d, J = 5.2 Hz, 1H), 4.06 (d, J = 15.2 Hz, 2H), 2.30 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.2 (d, $J_{C\text{-}P}$ = 2.5 Hz), 140.6 (d, $J_{C\text{-}P}$ = 3.1 Hz), 140.4, 137.0 (d, $J_{C\text{-}P}$ = 8.9 Hz), 132.4 (d, $J_{C\text{-}P}$ = 2.8 Hz), 132.2 (d, $J_{C\text{-}P}$ = 10.2 Hz), 128.4 (d, $J_{C\text{-}P}$ = 8.8 Hz), 128.3, 128.0, 127.3, 126.3 (d, $J_{C\text{-}P}$ = 101.1 Hz), 126.2, 125.6, 120.5 (d, $J_{C\text{-}P}$ = 9.6 Hz), 34.0 (d, $J_{C\text{-}P}$ = 60.1 Hz), 21.2; ^{31}P NMR (162 MHz, $CDCl_3$): δ 17.3; ESI-HRMS: Calcd for $C_{28}H_{26}NNaO_2PS^+$ $[M+Na]^+$ 494.1315, found 494.1305.

N-(diphenyl(2-phenylallyl)-λ^5-phosphaneylidene)benzenesulfonamide (B2)



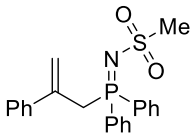
Colorless oil; 70 mg, 76% yield; R_f = 0.3 (2:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.62–7.52 (m, 6H), 7.44–7.40 (m, 2H), 7.30–7.23 (m, 5H), 7.21–7.17 (m, 2H), 7.10–6.98 (m, 5H), 5.49 (d, J = 5.2 Hz, 1H), 5.40 (d, J = 5.2 Hz, 1H), 4.07 (d, J = 15.2 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 145.8 (d, $J_{C\text{-}P}$ = 2.5 Hz), 140.6 (d, $J_{C\text{-}P}$ = 3.2 Hz), 137.0 (d, $J_{C\text{-}P}$ = 9.0 Hz), 132.5 (d, $J_{C\text{-}P}$ = 2.9 Hz), 132.2 (d, $J_{C\text{-}P}$ = 10.1 Hz), 130.1, 128.3 (d, $J_{C\text{-}P}$ = 12.4 Hz), 127.9 (d, $J_{C\text{-}P}$ = 8.6 Hz), 127.3, 126.18, 126.17, 126.1 (d, $J_{C\text{-}P}$ = 100.8 Hz), 125.6, 120.5 (d, $J_{C\text{-}P}$ = 9.8 Hz), 34.0 (d, $J_{C\text{-}P}$ = 60.4 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 17.6; ESI-HRMS: Calcd for $C_{27}H_{25}NO_2PS^+$ $[M+H]^+$ 458.1339, found 458.1327.

N-(diphenyl(2-phenylallyl)-λ^5-phosphaneylidene)naphthalene-2-sulfonamide (B3)



Colorless oil; 62 mg, 61% yield; R_f = 0.3 (2:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.93 (s, 1H), 7.77–7.63 (m, 4H), 7.54–7.43 (m, 6H), 7.36–7.32 (m, 2H), 7.20–7.16 (m, 4H), 7.06–6.98 (m, 5H), 5.52 (d, J = 5.2 Hz, 1H), 5.41 (d, J = 5.2 Hz, 1H), 4.08 (d, J = 15.2 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 142.7 (d, $J_{C\text{-}P}$ = 2.2 Hz), 140.6 (d, $J_{C\text{-}P}$ = 3.4 Hz), 137.0 (d, $J_{C\text{-}P}$ = 8.9 Hz), 133.7, 132.5 (d, $J_{C\text{-}P}$ = 2.9 Hz), 132.2 (d, $J_{C\text{-}P}$ = 10.1 Hz), 131.9, 128.9, 128.3 (d, $J_{C\text{-}P}$ = 12.5 Hz), 128.1, 128.0, 127.5, 127.4, 127.3, 126.4, 126.2, 125.8 (d, $J_{C\text{-}P}$ = 100.9 Hz), 125.5, 122.7, 120.6 (d, $J_{C\text{-}P}$ = 9.8 Hz), 34.1 (d, $J_{C\text{-}P}$ = 60.6 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 17.6; ESI-HRMS: Calcd for $C_{31}H_{27}NO_2PS^+$ $[M+H]^+$ 508.1495, found 508.1471.

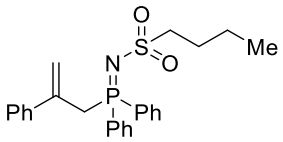
N-(diphenyl(2-phenylallyl)-λ^5-phosphaneylidene)methanesulfonamide (B4)



Colorless oil; 59 mg, 75% yield; R_f = 0.2 (2:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.70–7.65 (m, 4H), 7.52–7.48 (m, 2H), 7.40–7.35 (m, 4H), 7.11–7.03 (m, 5H), 5.46 (dd, J = 5.2, 0.4 Hz, 1H), 5.42 (dd, J = 5.2, 0.4 Hz, 1H), 4.07 (dd, J = 15.2, 0.8 Hz, 2H), 2.66 (d, J = 1.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 140.7 (d, $J_{C\text{-}P}$ = 3.3 Hz), 137.5 (d, $J_{C\text{-}P}$ = 8.8 Hz), 132.7 (d, $J_{C\text{-}P}$ = 2.8 Hz), 132.1 (d, $J_{C\text{-}P}$ = 10.1 Hz), 128.6 (d, $J_{C\text{-}P}$ =

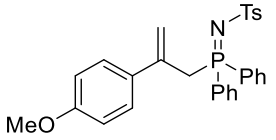
12.7 Hz), 128.1, 127.5, 126.8 (d, $J_{C\text{-}P}$ = 101.5 Hz), 126.3, 120.4 (d, $J_{C\text{-}P}$ = 9.7 Hz), 44.0 (d, $J_{C\text{-}P}$ = 3.5 Hz), 34.0 (d, $J_{C\text{-}P}$ = 59.3 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 17.4; ESI-HRMS: Calcd for $C_{22}H_{23}NO_2PS^+$ $[M+H]^+$ 396.1182, found 396.1171.

N-(diphenyl(2-phenylallyl)-λ^5-phosphaneylidene)butane-1-sulfonamide (B5)



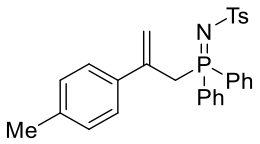
White solid; 69 mg, 79% yield; R_f = 0.4 (1:1 petroleum ether/ethyl acetate);^{1}H NMR (400 MHz, $CDCl_3$): δ 7.70–7.65 (m, 4H), 7.52–7.48 (m, 2H), 7.40–7.35 (m, 4H), 7.12–7.03 (m, 5H), 5.45 (d, J = 5.2 Hz, 1H), 5.41 (d, J = 5.2 Hz, 1H), 4.07 (d, J = 15.2 Hz, 2H), 2.69–2.64 (m, 2H), 1.73–1.65 (m, 2H), 1.33–1.24 (m, 2H), 0.82 (t, J = 7.6 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 140.8 (d, $J_{C\text{-}P}$ = 3.4 Hz), 137.6 (d, $J_{C\text{-}P}$ = 9.1 Hz), 132.6 (d, $J_{C\text{-}P}$ = 2.8 Hz), 132.2 (d, $J_{C\text{-}P}$ = 10.1 Hz), 128.5 (d, $J_{C\text{-}P}$ = 12.4 Hz), 128.1,127.4, 127.1 (d, $J_{C\text{-}P}$ = 101.4 Hz), 126.3, 120.4 (d, $J_{C\text{-}P}$ = 9.7 Hz), 55.7 (d, $J_{C\text{-}P}$ = 3.4 Hz), 34.3 (d, $J_{C\text{-}P}$ = 59.4 Hz), 26.3, 21.6, 13.6; ^{31}P NMR (162 MHz, $CDCl_3$): δ 17.4; ESI-HRMS: Calcd for $C_{25}H_{29}NO_2PS^+$ $[M+H]^+$ 438.1652, found 438.1650.

N-((2-(4-methoxyphenyl)allyl)diphenyl-λ^5-phosphaneylidene)-4-methylbenzenesulfo -namide (B6)



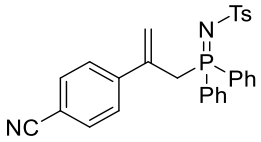
Colorless oil; 61 mg, 61% yield; R_f = 0.4 (1:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.59–7.54 (m, 4H), 7.50–7.42 (m, 4H), 7.31–7.26 (m, 4H), 7.01–6.93 (m, 4H), 6.59–6.57 (m, 2H), 5.35–5.31 (m,2H), 4.03 (d, J = 15.2 Hz, 2H), 3.72 (s, 3H), 2.30 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 158.9, 143.2 (d, $J_{C\text{-}P}$ =2.6 Hz), 140.4, 136.5 (d, $J_{C\text{-}P}$ = 8.9 Hz), 133.0 (d, $J_{C\text{-}P}$ = 3.4 Hz), 132.4 (d, $J_{C\text{-}P}$ = 2.8 Hz), 132.3 (d, $J_{C\text{-}P}$ = 10.1 Hz), 128.5, 128.3 (d, $J_{C\text{-}P}$ = 12.5 Hz), 127.4, 126.4 (d, $J_{C\text{-}P}$ = 101.1 Hz), 125.6, 118.9 (d, $J_{C\text{-}P}$ = 9.8 Hz), 113.4, 55.2, 34.2 (d, $J_{C\text{-}P}$ = 60.0 Hz), 21.2; ^{31}P NMR (162 MHz, $CDCl_3$): δ 17.5; ESI-HRMS: Calcd for $C_{29}H_{29}NO_3PS^+$ $[M+H]^+$ 502.1601, found 502.1595.

N-(diphenyl(2-(p-tolyl)allyl)-λ^5-phosphaneylidene)-4-methylbenzenesulfonamide (B7)



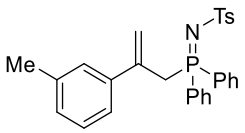
Colorless oil; 75 mg, 77% yield; R_f = 0.4 (1:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.59–7.49 (m, 6H), 7.45–7.41 (m, 2H), 7.29–7.25 (m, 4H), 6.99 (d, J = 8.0 Hz, 2H), 6.91–6.84 (m, 4H), 5.40–5.35 (m, 2H), 4.03 (d, J = 15.2 Hz, 2H), 2.29 (s, 3H), 2.22 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.2 (d, $J_{C\text{-}P}$ = 2.7 Hz), 140.3, 137.7 (d, $J_{C\text{-}P}$ = 3.5 Hz), 137.1, 137.0 (d, $J_{C\text{-}P}$ = 9.1 Hz), 132.3 (d, $J_{C\text{-}P}$ = 2.8 Hz), 132.2 (d, $J_{C\text{-}P}$ = 10.1 Hz), 128.6, 128.4, 128.3 (d, $J_{C\text{-}P}$ = 12.4 Hz), 126.4 (d, $J_{C\text{-}P}$ = 101.0 Hz), 126.1, 125.6, 119.6 (d, $J_{C\text{-}P}$ = 9.7 Hz), 34.1 (d, $J_{C\text{-}P}$ = 60.2 Hz), 21.2, 20.9; ^{31}P NMR (162 MHz, $CDCl_3$): δ 17.5; ESI-HRMS: Calcd for $C_{29}H_{29}NO_2PS^+$ $[M+H]^+$ 486.1652, found 486.1643.

N-((2-(4-cyanophenyl)allyl)diphenyl-λ^5-phosphaneylidene)-4-methylbenzenesulfona -mide (B8)



Colorless oil; 64 mg, 65% yield; R_f = 0.4 (1:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.57–7.52 (m, 4H), 7.49–7.43 (m, 4H), 7.33–7.30 (m, 6H), 7.12–7.10 (m, 2H), 7.01–6.99 (m, 2H), 5.64 (d, J = 5.2 Hz, 1H), 5.50 (d, J = 5.2 Hz, 1H), 4.07 (d, J = 14.8 Hz, 2H), 2.31 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 144.9 (d, $J_{C\text{-}P}$ = 3.0 Hz), 142.9 (d, $J_{C\text{-}P}$ = 3.0 Hz), 140.6, 135.9 (d, $J_{C\text{-}P}$ = 9.0 Hz), 132.7 (d, $J_{C\text{-}P}$ = 3.0 Hz), 132.1 (d, $J_{C\text{-}P}$ = 10.0 Hz), 131.7, 128.49 (d, $J_{C\text{-}P}$ = 12.5 Hz), 128.47, 127.0, 126.0 (d, $J_{C\text{-}P}$ = 101.5 Hz), 125.4, 123.3 (d, $J_{C\text{-}P}$ = 9.5 Hz), 118.5, 110.7, 33.8 (d, $J_{C\text{-}P}$ = 60.0 Hz), 21.2; ^{31}P NMR (162 MHz, $CDCl_3$): δ 16.5; ESI-HRMS: Calcd for $C_{29}H_{26}N_2O_2PS^+$ $[M+H]^+$ 497.1448, found 497.1439.

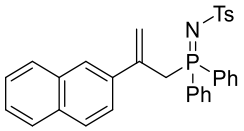
N-(diphenyl(2-(m-tolyl)allyl)-λ^5-phosphaneylidene)-4-methylbenzenesulfonamide (B9)



Colorless oil; 47 mg, 49% yield; R_f = 0.4 (1:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.58–7.49 (m, 6H), 7.45–7.41 (m, 2H), 7.30–7.25 (m, 4H), 7.01–6.99 (m,

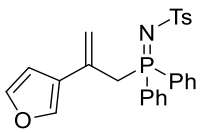
2H), 6.97–6.93 (m, 1H), 6.89–6.87 (m, 1H), 6.83–6.81 (m, 1H), 6.70 (s, 1H), 5.47 (d, *J* = 5.2 Hz, 1H), 5.38 (d, *J* = 5.2 Hz, 1H), 4.04 (d, *J* = 15.2 Hz, 2H), 2.30 (s, 3H), 2.14 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): *δ* 143.3 (d, J_{C-P} = 2.7 Hz), 140.7 (d, J_{C-P} = 3.2 Hz), 140.4, 137.5, 137.2 (d, J_{C-P} = 8.8 Hz), 132.4 (d, J_{C-P} = 2.9 Hz), 132.3 (d, J_{C-P} = 10.1 Hz), 128.5, 128.3 (d, J_{C-P} = 12.5 Hz), 128.1, 127.9, 127.1 (d, J_{C-P} = 1.4 Hz), 126.4 (d, J_{C-P} = 101.0 Hz), 125.7, 123.3, 120.3 (d, J_{C-P} = 9.6 Hz), 34.3 (d, J_{C-P} = 60.1 Hz), 21.3, 21.2; ^{31}P NMR (162 MHz, $CDCl_3$): *δ* 17.2; ESI-HRMS: Calcd for $C_{29}H_{29}NO_2PS^+$ $[M+H]^+$ 486.1652, found 486.1646.

4-methyl-N-((2-(naphthalen-2-yl)allyl)diphenyl-λ^5-phosphaneylidene)benzenesulfonamide (B10)



Colorless oil; 53 mg, 51% yield; R_f = 0.4 (1:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): *δ* 7.70–7.68 (m, 1H), 7.60–7.47 (m, 8H), 7.41–7.32 (m, 5H), 7.23–7.16 (m, 5H), 6.98–6.96 (m, 2H), 5.58–5.54 (m, 2H), 4.18–4.15 (m, 2H), 2.29 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): *δ* 143.2 (d, J_{C-P} = 2.6 Hz), 140.4, 137.8 (d, J_{C-P} = 3.1 Hz), 137.1 (d, J_{C-P} = 8.9 Hz), 132.8, 132.5, 132.4 (d, J_{C-P} = 2.9 Hz), 132.3 (d, J_{C-P} = 10.0 Hz), 128.5, 128.3 (d, J_{C-P} = 12.6 Hz), 128.0, 127.7, 127.3, 126.4 (d, J_{C-P} = 100.0 Hz), 126.03, 125.95, 125.6, 125.4,124.3, 121.0 (d, J_{C-P} = 9.5 Hz), 34.3 (d, J_{C-P} = 60.4 Hz), 21.3; ^{31}P NMR (162 MHz, $CDCl_3$): *δ* 17.3; ESI-HRMS: Calcd for $C_{32}H_{29}NO_2PS^+$ $[M+H]^+$ 522.1652, found 522.1643.

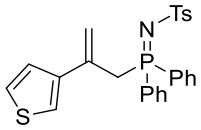
N-((2-(furan-3-yl)allyl)diphenyl-λ^5-phosphaneylidene)-4-methylbenzenesulfonamide (B11)



Colorless oil; 44 mg, 48% yield; R_f = 0.4 (1:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): *δ* 7.66–7.61 (m, 4H), 7.52–7.46 (m, 4H), 7.37–7.33 (m, 4H), 7.14 (m, 2H), 7.00–6.98 (m, 2H), 6.23 (t, *J* = 1.2 Hz, 1H), 5.36 (d, *J* = 5.2 Hz, 1H), 5.17 (d, *J* = 5.2 Hz, 1H), 3.83 (d, *J* = 15.2 Hz, 2H), 2.30 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): *δ* 143.1, 143.0,

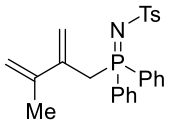
140.4, 139.7 (d, $J_{C\text{-}P}$ = 1.7 Hz), 132.6 (d, $J_{C\text{-}P}$ = 2.8 Hz), 132.3 (d, $J_{C\text{-}P}$ = 10.0 Hz), 128.5, 128.3, 128.0 (d, $J_{C\text{-}P}$ = 9.2 Hz), 126.4 (d, $J_{C\text{-}P}$ = 3.5 Hz), 126.2 (d, $J_{C\text{-}P}$ = 101.2 Hz), 125.5, 117.6 (d, $J_{C\text{-}P}$ = 9.1 Hz), 107.8, 34.0 (d, $J_{C\text{-}P}$ = 61.2 Hz), 21.2; ^{31}P NMR (162 MHz, $CDCl_3$): δ 17.6; ESI-HRMS: Calcd for $C_{26}H_{25}NO_3PS^+$ $[M+H]^+$ 462.1288, found 462.1270.

N-(diphenyl(2-(thiophen-3-yl)allyl)-λ^5-phosphaneylidene)-4-methylbenzenesulfonam -ide (B12)



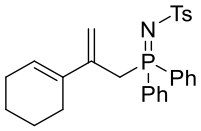
White solid; 52 mg, 55% yield; R_f = 0.4 (1:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.63–7.57 (m, 4H), 7.50–7.45 (m, 4H), 7.33–7.29 (m, 4H), 7.03–6.99 (m, 3H), 6.89–6.85 (m, 2H), 5.46 (d, J = 5.2 Hz, 1H), 5.33 (d, J = 4.8 Hz, 1H), 3.98 (d, J = 15.2 Hz, 2H), 2.30 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.1 (d, $J_{C\text{-}P}$ = 2.6 Hz), 141.6 (d, $J_{C\text{-}P}$ = 3.4 Hz), 140.4, 132.5 (d, $J_{C\text{-}P}$ = 2.9 Hz), 132.3 (d, $J_{C\text{-}P}$ = 10.0 Hz), 131.6 (d, $J_{C\text{-}P}$ = 9.2 Hz), 128.5, 128.3 (d, $J_{C\text{-}P}$ = 12.6 Hz), 126.2 (d, $J_{C\text{-}P}$ = 100.9 Hz), 125.6, 125.49, 125.45, 121.7 (d, $J_{C\text{-}P}$ = 1.5 Hz), 118.6 (d, $J_{C\text{-}P}$ = 9.5 Hz), 34.4 (d, $J_{C\text{-}P}$ = 60.5 Hz), 21.2; ^{31}P NMR (162 MHz, $CDCl_3$): δ 17.5; ESI-HRMS: Calcd for $C_{26}H_{25}NO_2PS_2^+$ $[M+H]^+$ 478.1059, found 478.1048.

4-methyl-N-((3-methyl-2-methylenebut-3-en-1-yl)diphenyl-λ^5-phosphaneylidene)ben zene-sulfonamide (B13)



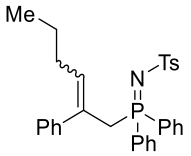
Colorless oil; 40 mg, 46% yield; R_f = 0.4 (1:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.67–7.62 (m, 4H), 7.55–7.48 (m, 4H), 7.41–7.36 (m, 4H), 7.01–6.99 (m, 2H),5.34 (d, J = 4.8 Hz, 1H), 5.29–5.27 (m, 2H), 4.80 (s, 1H), 4.71 (s, 1H), 3.83 (d, J = 15.2 Hz, 2H), 2.30 (s, 3H), 1.64 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.3 (d, $J_{C\text{-}P}$ = 2.2 Hz), 141.8 (d, $J_{C\text{-}P}$ = 3.7 Hz), 140.4, 136.4 (d, $J_{C\text{-}P}$ = 8.4 Hz), 132.6, 132.5 (d, $J_{C\text{-}P}$ = 10.0 Hz), 128.5, 128.4(d, $J_{C\text{-}P}$ = 12.5 Hz), 126.6 (d, $J_{C\text{-}P}$ = 100.9 Hz), 125.7, 119.3 (d, $J_{C\text{-}P}$ = 8.9 Hz), 114.3 (d, $J_{C\text{-}P}$ = 1.9 Hz), 31.7 (d, $J_{C\text{-}P}$ = 61.6 Hz), 21.3, 20.7; ^{31}P NMR (162 MHz, $CDCl_3$): δ 17.9; ESI-HRMS: Calcd for $C_{25}H_{27}NO_2PS^+$ $[M+H]^+$ 436.1495, found 436.1487.

N-((2-(cyclohex-1-en-1-yl)allyl)diphenyl-λ^5-phosphaneylidene)-4-methylbenzenesulf-onamide (B14)



Colorless oil; 51 mg, 53% yield; R_f = 0.4 (1:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.67–7.62 (m, 4H), 7.54–7.49 (m, 4H), 7.40–7.35 (m, 4H), 7.01–6.99 (m, 2H), 5.53 (t, J = 3.6 Hz, 1H), 5.20–5.15 (m, 2H), 3.83 (d, J = 15.2 Hz, 2H), 2.30 (s, 3H), 1.84–1.82 (m, 2H), 1.74 (s, 2H), 1.38–1.32 (m, 2H), 1.29–1.24 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.3 (d, $J_{C\text{-}P}$ = 2.5 Hz), 140.3, 137.0 (d, $J_{C\text{-}P}$ = 8.6 Hz), 134.8 (d, $J_{C\text{-}P}$ = 3.6 Hz), 132.5, 132.4, 128.5, 128.3 (d, $J_{C\text{-}P}$ = 12.5 Hz), 126.74 (d, $J_{C\text{-}P}$ = 2.1 Hz), 126.72 (d, $J_{C\text{-}P}$ = 100.8 Hz), 125.6, 116.0 (d, $J_{C\text{-}P}$ = 9.1 Hz), 31.7 (d, $J_{C\text{-}P}$ = 60.6 Hz), 25.8, 25.4, 22.3, 21.5, 21.2; ^{31}P NMR (162 MHz, $CDCl_3$): δ 17.9; ESI-HRMS: Calcd for $C_{28}H_{31}NO_2PS^+$ $[M+H]^+$ 476.1808, found 476.1793.

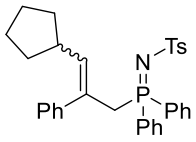
(E)-N-(diphenyl(2-phenylhex-2-en-1-yl)-λ^5-phosphaneylidene)-4-methylbenzenesulf-onamide (B15)



Colorless oil; 77 mg, 75% yield; R_f = 0.4 (1:1 petroleum ether/ethyl acetate); The product was isolated as a mixture of E/Z isomers in a 1:1 ratio, as determined by ^{1}H NMR integration; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.54–7.48 (m, 11H), 7.44–7.40 (m, 6.4H), 7.27–7.23 (m, 8.8H), 7.06–6.95 (m, 13.2H), 6.75–6.73 (m, 2.4H), 5.85–5.60 (m, 1.2H), 5.67–5.62 (m, 1H), 4.05 (d, J = 16.4 Hz, 2H), 3.93 (d, J = 14.8 Hz, 2.4H), 2.29–2.28 (m, 6.6H), 1.96–1.89 (m, 2.4H), 1.83–1.76 (m, 2H), 1.32–1.16 (m, 4.4H), 0.83 (t, J = 7.2 Hz, 3H), 0.72 (t, J = 7.2 Hz, 3.6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.4 (d, $J_{C\text{-}P}$ = 2.6 Hz), 143.3 (d, $J_{C\text{-}P}$ = 2.3 Hz), 142.2 (d, $J_{C\text{-}P}$ =2.0 Hz), 140.2, 140.1, 139.5 (d, $J_{C\text{-}P}$ = 2.9 Hz), 136.8 (d, $J_{C\text{-}P}$ = 10.8 Hz), 136.3 (d, $J_{C\text{-}P}$ = 10.2 Hz), 132.4 (d, $J_{C\text{-}P}$ = 10.2 Hz), 132.3 (d, $J_{C\text{-}P}$ = 2.8 Hz), 132.2 (d, $J_{C\text{-}P}$ = 2.7 Hz), 132.0 (d, $J_{C\text{-}P}$ = 10.1 Hz), 131.7 (d, $J_{C\text{-}P}$ = 10.2 Hz), 129.2 (d, $J_{C\text{-}P}$ = 9.1 Hz), 128.38, 128.35, 128.31 (d, $J_{C\text{-}P}$ = 1.8 Hz), 128.2 (d, $J_{C\text{-}P}$ = 12.4 Hz), 128.0 (d, $J_{C\text{-}P}$ =

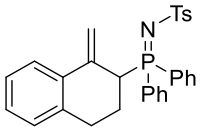
12.5 Hz), 127.8, 127.7, 126.68 (d, $J_{C\text{-}P}$ = 100.0 Hz), 126.67 (d, $J_{C\text{-}P}$ = 1.5 Hz), 126.6, 126.4, 126.0 (d, $J_{C\text{-}P}$ = 99.3 Hz), 125.50, 125.47, 36.9 (d, $J_{C\text{-}P}$ = 59.6 Hz), 31.3 (d, $J_{C\text{-}P}$ = 63.9 Hz), 31.2, 31.1, 22.5 (d, $J_{C\text{-}P}$ = 3.5 Hz), 22.2 (d, $J_{C\text{-}P}$ = 2.6 Hz), 21.1, 13.60, 13.58; ^{31}P NMR (162 MHz, $CDCl_3$): δ 17.8, 17.3; ESI-HRMS: Calcd for $C_{31}H_{33}NO_2PS^+$ $[M+H]^+$ 514.1965, found 514.1952.

N-((3-cyclopentyl-2-phenylallyl)diphenyl-λ^5-phosphaneylidene)-4-methylbenzenesul-fonamide (B16)



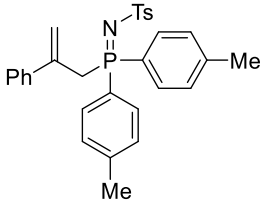
Colorless oil; 77 mg, 71% yield; R_f = 0.4 (1:1 petroleum ether/ethyl acetate); 1D NOE irradiation of the major olefinic proton at δ 5.65–5.60 ppm (integral –7.974) gave a significant enhancement of the P–CH_2 protons at δ 3.92 ppm (+0.31), confirming the *E*-configuration for the major isomer. The product was isolated as a mixture of *E/Z* isomers in a 5:1 ratio, as determined by 1D selective NOE and ^{1}H NMR integration; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.54–7.49 (m, 6.6H), 7.46–7.41 (m, 3H), 7.30–7.22 (m, 4.8H), 7.06–6.96 (m, 6.4H), 6.78–6.76 (m, 2H), 5.63–5.55 (m, 1.2H), 4.07 (d, *J* = 16.4 Hz, 0.4H), 3.90 (d, *J* = 14.8 Hz, 2H), 3.00–2.21 (m, 4.8H), 1.58–1.51 (m, 4.8H), 1.40–1.34 (m, 2.4H), 1.13–1.08 (m, 2.4H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.41 (d, $J_{C\text{-}P}$ = 2.9 Hz), 143.35, 142.0 (d, $J_{C\text{-}P}$ = 9.1 Hz), 141.4 (d, $J_{C\text{-}P}$ = 10.1 Hz), 140.3, 140.2, 139.9 (d, $J_{C\text{-}P}$ = 2.8 Hz), 132.6 (d, $J_{C\text{-}P}$ = 10.1 Hz), 132.26, 132.25 (d, $J_{C\text{-}P}$ = 9.9 Hz), 128.5, 128.43, 128.39 (d, $J_{C\text{-}P}$ = 1.9 Hz), 128.3 (d, $J_{C\text{-}P}$ = 12.5 Hz), 128.1, 128.0, 127.8, 126.8, 126.7 (d, $J_{C\text{-}P}$ = 99.9 Hz), 126.5, 126.3, 126.23, 126.18 (d, $J_{C\text{-}P}$ = 99.9 Hz), 125.61, 125.57, 40.0 (d, $J_{C\text{-}P}$ = 2.5 Hz), 39.7 (d, $J_{C\text{-}P}$ = 2.7 Hz), 37.0 (d, $J_{C\text{-}P}$ = 59.7 Hz), 33.5 (d, $J_{C\text{-}P}$ = 3.5 Hz), 33.2 (d, $J_{C\text{-}P}$ = 2.9 Hz), 31.3 (d, $J_{C\text{-}P}$ = 63.9 Hz), 29.6, 25.4, 25.3, 21.2; ^{31}P NMR (162 MHz, $CDCl_3$): δ 17.7, 17.6; ESI-HRMS: Calcd for $C_{33}H_{35}NO_2PS^+$ $[M+H]^+$ 540.2121, found 540.2114.

4-methyl-N-((1-methylene-1,2,3,4-tetrahydronaphthalen-2-yl)diphenyl-λ^5-phosphane-ylidene)benzenesulfonamide (B17)



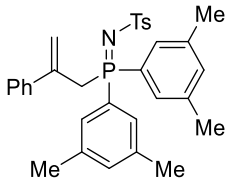
Colorless oil; 52 mg, 52% yield; R_f = 0.4 (1:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.74–7.66 (m, 4H), 7.54–7.48 (m, 1H), 7.38–7.33 (m, 5H), 7.22–7.16 (m, 3H), 6.99–6.94 (m, 4H), 6.78–6.75 (m, 1H), 5.58 (d, J = 5.2 Hz, 1H), 5.13 (d, J = 4.8 Hz, 1H), 4.53–4.46 (m, 1H), 2.75–2.39 (m, 4H), 2.28 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.3 (d, $J_{C\text{-}P}$ = 2.8 Hz), 140.3, 137.5 (d, $J_{C\text{-}P}$ = 5.4 Hz), 136.7 (d, $J_{C\text{-}P}$ = 1.6 Hz), 134.5 (d, $J_{C\text{-}P}$ = 2.3 Hz), 133.7 (d, $J_{C\text{-}P}$ = 9.4 Hz), 133.2 (d, $J_{C\text{-}P}$ = 9.7 Hz), 132.52 (d, $J_{C\text{-}P}$ = 2.9 Hz), 132.49 (d, $J_{C\text{-}P}$ = 2.7 Hz), 128.5, 128.3 (d, $J_{C\text{-}P}$ = 11.9 Hz), 128.1, 127.83,127.81 (d, $J_{C\text{-}P}$ = 12.3 Hz), 126.1, 125.7 (d, $J_{C\text{-}P}$ = 91.1 Hz), 125.5, 124.7, 124.0 (d, $J_{C\text{-}P}$ = 100.9 Hz), 116.7 (d, $J_{C\text{-}P}$ = 9.7 Hz), 40.6 (d, $J_{C\text{-}P}$ = 62.1 Hz), 27.4 (d, $J_{C\text{-}P}$ = 6.7 Hz), 24.0 (d, $J_{C\text{-}P}$ = 2.7 Hz) 21.3; ^{31}P NMR (162 MHz, $CDCl_3$): δ 21.0; ESI-HRMS: Calcd for $C_{30}H_{29}NO_2PS^+$ $[M+H]^+$ 498.1652, found 498.1631.

4-methyl-N-((2-phenylallyl)di-p-tolyl-λ^5-phosphaneylidene)benzenesulfonamide (B18)



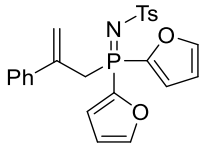
Colorless oil; 63 mg, 63% yield; R_f = 0.4 (1:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.50–7.48 (m, 2H), 7.45–7.40 (m, 4H), 7.09–7.03 (m, 7H), 7.00–6.97 (m, 4H), 5.44 (d, J = 5.2 Hz, 1H), 5.38 (d, J = 5.2 Hz, 1H), 4.00 (d, J = 15.2 Hz, 2H), 2.32–2.31 (m, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.4, 143.2 (d, $J_{C\text{-}P}$ = 2.9 Hz), 140.9 (d, $J_{C\text{-}P}$ = 3.4 Hz), 140.3, 137.4 (d, $J_{C\text{-}P}$ = 8.8 Hz), 132.3 (d, $J_{C\text{-}P}$ = 10.5 Hz), 129.1 (d, $J_{C\text{-}P}$ = 12.8 Hz), 128.4, 127.9, 127.1, 126.3, 125.7, 123.1 (d, $J_{C\text{-}P}$ = 103.2 Hz), 120.4 (d, $J_{C\text{-}P}$ = 9.5 Hz), 34.4 (d, $J_{C\text{-}P}$ = 60.8 Hz), 21.5, 21.3; ^{31}P NMR (162 MHz, $CDCl_3$): δ 17.5; ESI-HRMS: Calcd for $C_{30}H_{31}NO_2PS^+$ $[M+H]^+$ 500.1808, found 500.1793.

N-(bis(3,5-dimethylphenyl)(2-phenylallyl)-λ^5-phosphaneylidene)-4-methylbenzenes u-lfonamide (B19)



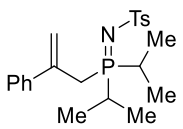
Colorless oil; 64 mg, 61% yield; R_f = 0.4 (1:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.45–7.43 (m, 2H), 7.08–7.06 (m, 5H), 7.02–6.95 (m, 8H), 5.58 (d, J = 5.2 Hz, 1H), 5.43 (d, J = 5.6 Hz, 1H), 4.02 (d, J = 15.2 Hz, 2H), 2.29 (s, 3H), 2.15 (s, 12H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.2, 141.1 (d, J_{C-P} = 3.0 Hz), 140.1, 138.1 (d, J_{C-P} = 13.2 Hz), 137.1 (d, J_{C-P} = 9.0 Hz), 134.1 (d, J_{C-P} = 3.0 Hz), 129.7 (d, J_{C-P} = 10.1 Hz), 128.3, 127.7, 127.2, 126.3, 125.78, 125.76 (d, J_{C-P} = 100.0 Hz), 120.7 (d, J_{C-P} = 9.7 Hz), 33.9 (d, J_{C-P} = 59.0 Hz), 21.2, 21.0; ^{31}P NMR (162 MHz, $CDCl_3$): δ 17.7; ESI-HRMS: Calcd for $C_{32}H_{35}NO_2PS^+$ $[M+H]^+$ 528.2121, found 528.2107.

N-(di(furan-2-yl)(2-phenylallyl)-λ^5-phosphaneylidene)-4-methylbenzenesulfonamide (B20)



Colorless oil; 40 mg, 44% yield; R_f = 0.4 (1:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.64–7.62 (m, 2H), 7.52–7.51 (m, 2H), 7.18–7.11 (m, 9H), 6.40–6.39 (m, 2H), 5.45 (d, J = 6.0 Hz, 1H), 5.29 (d, J = 5.6 Hz, 1H), 3.91 (d, J = 17.2 Hz, 2H), 2.34 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 149.1 (d, J_{C-P} = 8.3 Hz), 142.7 (d, J_{C-P} = 3.4 Hz), 140.86, 140.80 (d, J_{C-P} = 145.1 Hz), 139.6 (d, J_{C-P} = 3.4 Hz), 136.3 (d, J_{C-P} = 9.9 Hz), 128.7, 128.0, 127.5, 126.0 (d, J_{C-P} = 1.4 Hz), 125.9, 125.7, 119.9 (d, J_{C-P} = 11.1 Hz), 111.4 (d, J_{C-P} = 9.1 Hz), 34.7 (d, J_{C-P} = 74.0 Hz), 21.3; ^{31}P NMR (162 MHz, $CDCl_3$): δ -6.6; ESI-HRMS: Calcd for $C_{24}H_{23}NO_4PS^+$ $[M+H]^+$ 452.1080, found 452.1071.

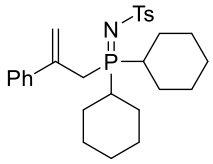
N-(diisopropyl(2-phenylallyl)-λ^5-phosphaneylidene)-4-methylbenzenesulfonamide (B21)



Colorless oil; 33 mg, 41% yield; R_f = 0.4 (1:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.79–7.77 (m, 2H), 7.39–7.30 (m, 5H), 7.20–7.18 (m, 2H), 5.47–5.45 (m,

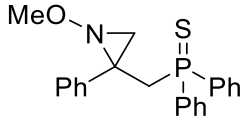
2H), 3.49 (d, J = 15.6 Hz, 2H), 2.38 (s, 3H), 2.28–2.18 (m, 2H), 1.22–1.14 (m, 12H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.9 (d, $J_{C\text{-}P}$ = 5.5 Hz), 140.6 (d, $J_{C\text{-}P}$ = 2.5 Hz), 140.5, 138.7 (d, $J_{C\text{-}P}$ = 7.8 Hz), 128.8, 128.6, 128.2, 126.4, 125.6, 119.9 (d, $J_{C\text{-}P}$ = 8.9 Hz), 29.9 (d, $J_{C\text{-}P}$ = 51.3 Hz), 25.3 (d, $J_{C\text{-}P}$ = 60.3 Hz), 21.3, 16.2 (d, $J_{C\text{-}P}$ = 2.7 Hz), 15.8 (d, $J_{C\text{-}P}$ = 3.0 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 43.2; ESI-HRMS: Calcd for $C_{22}H_{30}NNaO_2PS^+$ $[M+Na]^+$ 426.1628, found 426.1621.

N-(dicyclohexyl(2-phenylallyl)-λ^5-phosphaneylidene)-4-methylbenzenesulfonamide (B22)



Colorless oil; 35 mg, 36% yield; R_f = 0.4 (1:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.81–7.78 (m, 2H), 7.39–7.30 (m, 5H), 7.20–7.18 (m, 2H), 5.49 (d, J = 4.4 Hz, 1H), 5.45 (d, J = 4.4 Hz, 1H), 3.46 (d, J = 15.6 Hz, 2H), 2.38 (s, 3H), 1.94–1.59 (m, 12H), 1.46–1.40 (m, 4H), 1.10–0.98 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 144.1 (d, $J_{C\text{-}P}$ = 5.0 Hz), 140.9 (d, $J_{C\text{-}P}$ = 2.6 Hz), 140.4, 138.8 (d, $J_{C\text{-}P}$ = 7.8 Hz), 128.7, 128.6, 128.1, 126.5, 125.6, 120.0 (d, $J_{C\text{-}P}$ = 9.0 Hz), 35.3 (d, $J_{C\text{-}P}$ = 59.8 Hz), 28.9 (d, $J_{C\text{-}P}$ = 50.3 Hz), 26.4, 26.3 (d, $J_{C\text{-}P}$ = 2.5 Hz), 26.2, 25.9 (d, $J_{C\text{-}P}$ = 3.8 Hz), 25.6 (d, $J_{C\text{-}P}$ = 3.2 Hz), 25.54, 25.52, 21.3; ^{31}P NMR (162 MHz, $CDCl_3$): δ 36.9; ESI-HRMS: Calcd for $C_{28}H_{39}NO_2PS^+$ $[M+H]^+$ 484.2434, found 484.2426.

((1-methoxy-2-phenylaziridin-2-yl)methyl)diphenylphosphine sulfide (C1)



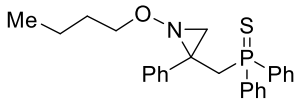
Total mass: 59 mg; 78% total yield (**Major**: 56% yield, **Minor**: 22% yield); a mixture of diastereoisomers, dr = 2.5:1 (the ratio was determined by ^{1}H NMR analysis).

Major: White solid; R_f = 0.5 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.77–7.72 (m, 2H), 7.57–7.52 (m, 2H), 7.44–7.39 (m, 3H), 7.26–7.23 (m, 1H), 7.16–7.10 (m, 4H), 6.96–6.95 (m, 3H), 3.66 (s, 3H), 3.46 (ddd, J = 14.4, 8.4, 1.6 Hz, 1H), 3.18 (t, J = 14.4 Hz, 1H), 2.76 (d, J = 4.0 Hz, 1H), 2.60–2.59 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 139.5, 134.8 (d, $J_{C\text{-}P}$ = 81.1 Hz), 131.3 (d, $J_{C\text{-}P}$ = 10.5 Hz), 131.2 (d, $J_{C\text{-}P}$ = 3.0 Hz), 130.74

(d, $J_{C\text{-}P}$ = 3.0 Hz), 130.65 (d, $J_{C\text{-}P}$ = 79.7 Hz), 130.5 (d, $J_{C\text{-}P}$ = 9.9 Hz), 128.8, 128.5 (d, $J_{C\text{-}P}$ = 12.0 Hz), 128.9, 127.8 (d, $J_{C\text{-}P}$ = 12.3 Hz), 127.3, 60.1, 46.7, 42.3 (d, $J_{C\text{-}P}$ = 2.0 Hz), 34.0 (d, $J_{C\text{-}P}$ = 58.2 Hz). ^{31}P NMR (162 MHz, $CDCl_3$): δ 40.3; ESI-HRMS: Calcd for $C_{22}H_{23}NOPS^+$ $[M+H]^+$ 380.1233, found 380.1227.

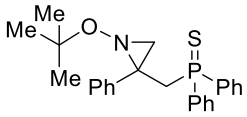
Minor: White solid; R_f = 0.4 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.72–7.67 (m, 2H), 7.50–7.39 (m, 5H), 7.23–7.19 (m, 3H), 7.14–7.09 (m, 2H), 7.03–7.01 (m, 3H), 3.73–3.68 (m, 1H), 3.39 (s, 3H), 2.91 (d, J = 4.0 Hz, 1H), 2.54 (d, J = 3.2 Hz, 1H), 2.46 (t, J = 14.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 134.84, 134.80 (d, $J_{C\text{-}P}$ = 80.7 Hz), 131.30 (d, $J_{C\text{-}P}$ = 4.0 Hz), 131.27 (d, $J_{C\text{-}P}$ = 10.0 Hz), 130.72 (d, $J_{C\text{-}P}$ = 3.0 Hz), 130.70 (d, $J_{C\text{-}P}$ = 79.1 Hz), 130.4, 130.3 (d, $J_{C\text{-}P}$ = 10.0 Hz), 128.6 (d, $J_{C\text{-}P}$ = 12.0 Hz), 127.9, 127.7 (d, $J_{C\text{-}P}$ = 2.4 Hz), 59.7, 48.1, 42.1 (d, $J_{C\text{-}P}$ = 2.8 Hz), 40.8 (d, $J_{C\text{-}P}$ = 56.1 Hz). ^{31}P NMR (162 MHz, $CDCl_3$): δ 36.8; ESI-HRMS: Calcd for $C_{22}H_{23}NOPS^+$ $[M+H]^+$ 380.1233, found 380.1226.

((1-butoxy-2-phenylaziridin-2-yl)methyl)diphenylphosphine sulfide (C2)



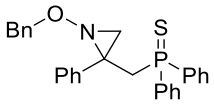
White solid; 63 mg, 75% yield; R_f = 0.5 (5:1 petroleum ether/ethyl acetate); a mixture of diastereoisomers, dr = 1.7:1 (the ratio was determined by ^{1}H NMR analysis); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.77–7.68 (m, 5.4H), 7.57–7.38 (m, 13.5H), 7.26–7.09 (m, 13.5H), 7.02–6.95 (m, 8.1H), 3.91–3.79 (m, 3.4H), 3.71–3.63 (m, 2H), 3.53–3.49 (m, 1H), 3.44–3.38 (m, 1.7H), 3.28–3.20 (m, 1.7H), 2.88 (d, J = 4.0 Hz, 1H), 2.73 (d, J = 3.6 Hz, 1.7H), 2.60–2.56 (m, 2.7H), 2.47 (t, J = 14.0 Hz, 1H), 1.69–1.60 (m, 3.7H), 1.42–1.37 (m, 3.4H), 1.26–1.20 (m, 2.7H), 1.02–0.93 (m, 6.1H), 0.71 (t, J = 7.6 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 139.7, 135.0 (d, $J_{C\text{-}P}$ = 80.9 Hz), 134.9, 134.8 (d, $J_{C\text{-}P}$ = 81.2 Hz), 131.3 (d, $J_{C\text{-}P}$ = 13.0 Hz), 131.25 (d, $J_{C\text{-}P}$ = 13.5 Hz), 131.23, 130.73 (d, $J_{C\text{-}P}$ = 2.9 Hz), 130.68 (d, $J_{C\text{-}P}$ = 3.1 Hz), 130.48, 130.46 (d, $J_{C\text{-}P}$ = 9.8 Hz), 130.45, 130.3 (d, $J_{C\text{-}P}$ = 10.0 Hz), 128.77, 128.5 (d, $J_{C\text{-}P}$ = 12.0 Hz), 127.9, 127.8 (d, $J_{C\text{-}P}$ = 12.3 Hz), 127.5, 127.3, 72.5, 71.9, 47.7, 46.3, 42.3 (d, $J_{C\text{-}P}$ = 2.5 Hz), 42.0 (d, $J_{C\text{-}P}$ = 2.9 Hz), 40.8 (d, $J_{C\text{-}P}$ = 56.0 Hz), 34.2 (d, $J_{C\text{-}P}$ = 58.2 Hz), 30.7, 30.4, 19.4, 19.0, 13.9, 13.8; ^{31}P NMR (162 MHz, $CDCl_3$): δ 40.3, 36.9; ESI-HRMS: Calcd for $C_{25}H_{29}NOPS^+$ $[M+H]^+$ 422.1702, found 422.1694.

((1-(tert-butoxy)-2-phenylaziridin-2-yl)methyl)diphenylphosphine sulfide (C3)



White solid; 50 mg, 59% yield; R_f = 0.3 (20:1 petroleum ether/ethyl acetate); a mixture of diastereoisomers, dr = 9:1 (the ratio was determined by ^{1}H NMR analysis); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.81–7.75 (m, 2.2H), 7.58–7.53 (m, 2.2H), 7.51–7.38 (m, 3.4H), 7.27–7.22 (m, 1.1H), 7.20–7.09 (m, 4.4H), 6.98–6.95 (m, 3.3H), 3.67–3.61 (m, 0.1H), 3.39–3.27 (m, 2.1H), 2.84 (d, J = 3.2 Hz, 0.1H), 2.58–2.57 (m, 1H), 2.54–2.53 (m, 1H), 2.45–2.42 (m, 0.2H), 1.30 (s, 9H), 1.08 (s, 0.9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 140.7, 134.9 (d, $J_{C\text{-}P}$ = 80.5 Hz), 131.5 (d, $J_{C\text{-}P}$ = 79.4 Hz), 131.3 (d, $J_{C\text{-}P}$ = 10.3 Hz), 131.2 (d, $J_{C\text{-}P}$ = 3.0 Hz), 130.70 (d, $J_{C\text{-}P}$ = 9.8 Hz), 130.67 (d, $J_{C\text{-}P}$ = 3.1 Hz), 128.52 (d, $J_{C\text{-}P}$ = 11.9 Hz), 128.51, 127.86 (d, $J_{C\text{-}P}$ = 12.2 Hz), 127.85, 127.1, 77.5, 44.2, 42.3 (d, $J_{C\text{-}P}$ = 2.8 Hz), 34.2 (d, $J_{C\text{-}P}$ = 58.3 Hz), 27.6; ^{31}P NMR (162 MHz, $CDCl_3$): δ 40.3, 37.1; ESI-HRMS: Calcd for $C_{25}H_{29}NOPS^+$ $[M+H]^+$ 422.1702, found 422.1684.

((1-(benzyloxy)-2-phenylaziridin-2-yl)methyl)diphenylphosphine sulfide (C4)



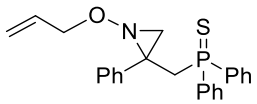
Total mass: 71 mg; 78% total yield (**Major**: 50% yield, **Minor**: 28% yield); a mixture of diastereoisomers, dr = 1.8:1 (the ratio was determined by ^{1}H NMR analysis).

Major: White solid; R_f = 0.5 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.73–7.67 (m, 2H), 7.49–7.36 (m, 10H), 7.23–7.19 (m, 1H), 7.11–7.07 (m, 2H), 6.95–6.87 (m, 5H), 4.94–4.83 (m, 2H), 3.22–3.19 (m, 2H), 2.77–2.76 (m, 1H), 2.63–2.62 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 139.4, 137.5, 134.8 (d, $J_{C\text{-}P}$ = 81.0 Hz), 131.19 (d, $J_{C\text{-}P}$ = 10.3 Hz), 131.18 (d, $J_{C\text{-}P}$ = 2.9 Hz), 130.9 (d, $J_{C\text{-}P}$ = 78.7 Hz), 130.7 (d, $J_{C\text{-}P}$ = 3.0 Hz), 130.5 (d, $J_{C\text{-}P}$ = 9.7 Hz), 128.9, 128.7, 128.5 (d, $J_{C\text{-}P}$ = 11.9 Hz), 128.4, 128.1, 127.81, 127.79 (d, $J_{C\text{-}P}$ = 12.3 Hz), 127.3, 75.2, 46.4, 42.4 (d, $J_{C\text{-}P}$ = 2.6 Hz), 34.5 (d, $J_{C\text{-}P}$ = 57.9 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 39.9; ESI-HRMS: Calcd for $C_{28}H_{27}NOPS^+$ $[M+H]^+$ 456.1546, found 456.1536.

Minor: White solid; R_f = 0.4 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.73–7.68 (m, 2H), 7.50–7.37 (m, 5H), 7.25–7.17 (m, 6H), 7.14–7.09 (m, 2H), 7.06–7.00

(m, 3H), 6.92–6.89 (m, 2H), 4.65–4.55 (m, 2H), 3.75–3.69 (m, 1H), 2.91 (d, J = 4.0 Hz, 1H), 2.65 (dd, J = 4.0 Hz, J = 1.2 Hz, 1H), 2.50 (t, J = 14.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 137.0, 134.74, 134.73 (d, $J_{C\text{-}P}$ = 81.2 Hz), 131.32 (d, $J_{C\text{-}P}$ = 10.6 Hz), 131.31 (d, $J_{C\text{-}P}$ = 3.1 Hz), 130.8 (d, $J_{C\text{-}P}$ = 80.1 Hz), 130.7 (d, $J_{C\text{-}P}$ = 3.0 Hz), 130.6, 130.4 (d, $J_{C\text{-}P}$ = 10.0 Hz), 128.6 (d, $J_{C\text{-}P}$ = 11.9 Hz), 128.3, 128.1, 127.8 (d, $J_{C\text{-}P}$ = 12.4 Hz), 127.7, 127.6, 74.3, 48.1, 42.2 (d, $J_{C\text{-}P}$ = 3.0 Hz), 40.6 (d, $J_{C\text{-}P}$ = 55.8 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 36.9; ESI-HRMS: Calcd for $C_{28}H_{27}NOPS^+$ $[M+H]^+$ 456.1546, found 456.1539.

((1-(allyloxy)-2-phenylaziridin-2-yl)methyl)diphenylphosphine sulfide (C5)



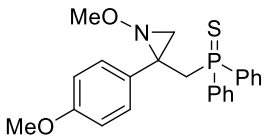
Total mass: 61 mg; 75% total yield (**Major**: 50% yield, **Minor**: 25% yield); a mixture of diastereoisomers, dr = 2:1 (the ratio was determined by ^{1}H NMR analysis).

Major: White solid; R_f = 0.5 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.77–7.72 (m, 2H), 7.57–7.51 (m, 2H), 7.46–7.37 (m, 3H), 7.27–7.22 (m, 1H), 7.17–7.10 (m, 4H), 6.96–6.94 (m, 3H), 6.08–5.98 (m, 1H), 5.37–5.24 (m, 2H), 4.42–4.34 (m, 2H), 3.45–3.39 (m, 1H), 3.27–3.20 (m, 1H), 2.78–2.77 (m, 1H), 2.62–2.61 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 139.6, 134.9 (d, $J_{C\text{-}P}$ = 80.9 Hz), 134.0, 131.27 (d, $J_{C\text{-}P}$ = 10.4 Hz), 131.2 (d, $J_{C\text{-}P}$ = 3.2 Hz), 130.9 (d, $J_{C\text{-}P}$ = 80.5 Hz), 130.7 (d, $J_{C\text{-}P}$ = 3.0 Hz), 130.5 (d, $J_{C\text{-}P}$ = 9.9 Hz), 128.8, 128.5 (d, $J_{C\text{-}P}$ = 12.0 Hz), 127.9, 127.8 (d, $J_{C\text{-}P}$ = 12.3 Hz), 127.3, 118.1, 73.8, 46.5, 42.5 (d, $J_{C\text{-}P}$ = 2.5 Hz), 34.4 (d, $J_{C\text{-}P}$ = 58.1 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 40.2; ESI-HRMS: Calcd for $C_{24}H_{25}NOPS^+$ $[M+H]^+$ 406.1389, found 406.1372.

Minor: White solid; R_f = 0.4 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.72–7.67 (m, 2H), 7.50–7.36 (m, 5H), 7.24–7.18 (m, 3H), 7.14–7.09 (m, 2H), 7.02–6.99 (m, 3H), 5.71–5.62 (m, 1H), 5.05–5.00 (m, 2H), 4.18–4.13 (m, 1H), 4.06–4.01 (m, 1H), 3.69 (dd, J = 15.6 Hz, J = 8.4 Hz, 1H), 2.92 (d, J = 4.0 Hz, 1H), 2.60 (dd, J = 4.0 Hz, J = 1.2 Hz, 1H), 2.48 (t, J = 14.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 134.9, 132.3 (d, $J_{C\text{-}P}$ = 81.0 Hz), 133.9, 131.31 (d, $J_{C\text{-}P}$ = 10.3 Hz), 131.27 (d, $J_{C\text{-}P}$ = 3.6 Hz), 130.8 (d, $J_{C\text{-}P}$ = 79.3 Hz), 130.7 (d, $J_{C\text{-}P}$ = 3.1 Hz), 130.5, 130.3 (d, $J_{C\text{-}P}$ = 9.8 Hz), 128.6 (d, $J_{C\text{-}P}$ = 11.9 Hz), 127.9, 127.6 (d, $J_{C\text{-}P}$ = 12.3 Hz), 117.4, 73.2, 48.0, 42.3 (d, $J_{C\text{-}P}$ = 2.7 Hz), 40.8 (d, $J_{C\text{-}P}$ = 55.9 Hz);

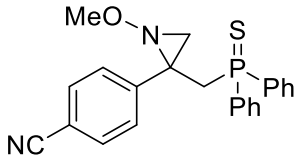
^{31}P NMR (162 MHz, $CDCl_3$): δ 36.9; ESI-HRMS: Calcd for $C_{24}H_{25}NOPS^+$ $[M+H]^+$ 406.1389, found 406.1377.

((1-methoxy-2-(4-methoxyphenyl)aziridin-2-yl)methyl)diphenylphosphine sulfide (C6)



White solid; 43 mg, 53% yield; R_f = 0.4 (5:1 petroleum ether/ethyl acetate); a mixture of diastereoisomers, dr = 3.1:1 (the ratio was determined by ^{1}H NMR analysis); ^{1}H NMR (400 MHz, CD_3CN): δ 7.84–7.74 (m, 8.2H), 7.63–7.55 (m, 4.1H), 7.52–7.44 (m, 16.4H), 7.38–7.29 (m, 4.1H), 7.23–7.19 (m, 8.2H), 7.16–7.14 (m, 2H), 7.09–7.06 (m, 6.2H), 6.55–6.50 (m, 8.2H), 3.90–3.86 (m, 1H), 3.76–3.68 (m, 6.1H), 3.67 (s, 9.3H), 3.63 (s, 9.3H), 3.31 (s, 3H), 3.03 (t, J = 14.4 Hz, 3.1H), 2.68 (d, J = 3.6 Hz, 1H), 2.56–2.54 (m, 3.1H), 2.53–2.51 (m, 3.1H), 2.45 (dd, J = 4.0, 1.6 Hz, 1H), 2.41–2.34 (m, 1H); ^{13}C NMR (100 MHz, CD_3CN): δ 160.0, 159.7, 136.3 (d, $J_{C\text{-}P}$ = 80.8 Hz), 136.2 (d, $J_{C\text{-}P}$ = 81.0 Hz), 133.0, 132.9, 132.6, 132.4, 132.3, 132.2 (d, $J_{C\text{-}P}$ = 10.3 Hz), 132.15 (d, $J_{C\text{-}P}$ = 10.4 Hz), 132.14, 132.10, 131.7 (d, $J_{C\text{-}P}$ = 2.9 Hz), 131.6 (d, $J_{C\text{-}P}$ = 3.0 Hz), 131.4, 131.3, 131.2, 129.3, 129.1, 128.9 (d, $J_{C\text{-}P}$ = 12.2 Hz), 128.8 (d, $J_{C\text{-}P}$ = 12.2 Hz), 128.0, 127.8, 114.1, 113.9, 60.6, 59.7, 55.80, 55.76, 48.5, 47.0, 42.9 (d, $J_{C\text{-}P}$ = 2.3 Hz), 42.8 (d, $J_{C\text{-}P}$ = 2.3 Hz), 40.9 (d, $J_{C\text{-}P}$ = 56.9 Hz), 34.5 (d, $J_{C\text{-}P}$ = 59.0 Hz); ^{31}P NMR (162 MHz, CD_3CN): δ 40.2, 36.7; ESI-HRMS: Calcd for $C_{23}H_{25}NO_2PS^+$ $[M+H]^+$ 410.1339, found 410.1332.

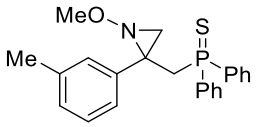
4-(2-((diphenylphosphorothioyl)methyl)-1-methoxyaziridin-2-yl)benzonitrile (C7)



White solid; 59 mg, 73% yield; R_f = 0.3 (5:1 petroleum ether/ethyl acetate); a mixture of diastereoisomers, dr = 2:1 (the ratio was determined by ^{1}H NMR analysis); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.77–7.66 (m, 6H), 7.60–7.55 (m, 4H), 7.52–7.38 (m, 11H), 7.36–7.14 (m, 21H), 3.69–3.63 (m, 7H), 3.42–3.36 (m, 5H), 3.20 (t, J = 14.4 Hz, 2H), 2.88 (d, J = 4.0 Hz, 1H), 2.72 (d, J = 4.0 Hz, 2H), 2.57–2.56 (m, 2H), 2.52–2.51 (m, 1H), 2.49–2.42 (m, 1H);

^{13}C NMR (100 MHz, $CDCl_3$): δ 140.7, 140.3, 134.2 (d, $J_{C\text{-}P}$ = 81.8 Hz), 134.1 (d, $J_{C\text{-}P}$ = 81.6 Hz), 131.6, 131.51, 131.46, 131.4, 131.3 (d, $J_{C\text{-}P}$ = 10.2 Hz), 131.2 (d, $J_{C\text{-}P}$ = 10.3 Hz), 131.1 (d, $J_{C\text{-}P}$ = 3.1 Hz), 131.00 (d, $J_{C\text{-}P}$ = 2.9 Hz), 130.6 (d, $J_{C\text{-}P}$ = 79.5 Hz), 130.44 (d, $J_{C\text{-}P}$ = 10.0 Hz), 130.36 (d, $J_{C\text{-}P}$ = 78.8 Hz), 130.1 (d, $J_{C\text{-}P}$ = 10.1 Hz), 129.8, 128.7 (d, $J_{C\text{-}P}$ = 12.1 Hz), 128.6 (d, $J_{C\text{-}P}$ = 12.0 Hz), 128.03 (d, $J_{C\text{-}P}$ = 12.1 Hz), 127.96 (d, $J_{C\text{-}P}$ = 12.3 Hz), 118.4, 111.4, 111.0, 60.3, 59.7, 47.7, 46.3, 42.8 (d, $J_{C\text{-}P}$ = 2.4 Hz), 42.6 (d, $J_{C\text{-}P}$ = 2.5 Hz), 40.4 (d, $J_{C\text{-}P}$ = 55.8 Hz), 33.7 (d, $J_{C\text{-}P}$ = 57.8 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): 39.3, 35.9; ESI-HRMS: Calcd for $C_{23}H_{22}N_2OPS^+$ $[M+H]^+$ 405.1185, found 405.1172.

((1-methoxy-2-(m-tolyl)aziridin-2-yl)methyl)diphenylphosphine sulfide (C8)



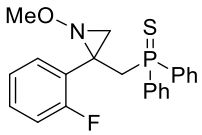
Total mass: 47 mg; 60% total yield (**Major**: 37% yield, **Minor**: 23% yield); a mixture of diastereoisomers, dr = 1.6:1 (the ratio was determined by ^{1}H NMR analysis).

Major: White solid; R_f = 0.4 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.75–7.72 (m, 2H), 7.58–7.53 (m, 2H), 7.44–7.37 (m, 3H), 7.27–7.22 (m, 1H), 7.16–7.11 (m, 2H), 7.00–6.98 (m, 1H), 6.90–6.85 (m, 2H), 6.76–6.74 (m, 1H), 3.66 (s, 3H), 3.46–3.40 (m, 1H), 3.19–3.12 (m, 1H), 2.77 (m, 1H), 2.59–2.57 (m, 1H), 2.06 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 139.3, 137.5, 135.1 (d, $J_{C\text{-}P}$ = 81.0 Hz), 131.3 (d, $J_{C\text{-}P}$ = 10.4 Hz), 131.2 (d, $J_{C\text{-}P}$ = 3.0 Hz), 130.73 (d, $J_{C\text{-}P}$ = 3.1 Hz), 130.66 (d, $J_{C\text{-}P}$ = 79.6 Hz), 130.5 (d, $J_{C\text{-}P}$ = 10.0 Hz), 129.5, 128.6 (d, $J_{C\text{-}P}$ = 11.9 Hz), 128.1 ,128.0, 127.6 (d, $J_{C\text{-}P}$ = 12.2 Hz), 125.9, 60.1, 46.7, 42.2 (d, $J_{C\text{-}P}$ = 2.4 Hz), 34.1 (d, $J_{C\text{-}P}$ = 58.2 Hz), 21.1; ^{31}P NMR (162 MHz, $CDCl_3$): δ 40.3; ESI-HRMS: Calcd for $C_{23}H_{25}NOPS^+$ $[M+H]^+$ 394.1389, found 394.1371.

Minor: White solid; R_f = 0.4 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.72–7.66 (m, 2H), 7.50–7.36 (m, 5H), 7.24–7.20 (m, 1H), 7.14–7.10 (m, 2H), 7.06–7.04 (m, 1H), 6.96–6.90 (m, 2H), 6.81–6.79 (m, 1H), 3.72–3.66 (m, 1H), 3.39 (s, 3H), 2.94 (d, J = 3.6 Hz, 1H), 2.52–7.51 (m, 1H), 2.43 (t, J = 14.4 Hz, 1H), 2.10 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 137.2, 135.0 (d, $J_{C\text{-}P}$ = 81.3 Hz), 134.7, 131.4, 131.3, 130.7 (d, $J_{C\text{-}P}$ = 3.1 Hz), 130.6 (d, $J_{C\text{-}P}$ = 79.1 Hz), 130.3 (d, $J_{C\text{-}P}$ = 9.8 Hz), 128.60, 128.59 (d, $J_{C\text{-}P}$ = 12.0 Hz), 127.7, 127.6, 127.5, 127.4, 59.7, 48.1, 42.1 (d, $J_{C\text{-}P}$ = 2.9 Hz), 40.9 (d, $J_{C\text{-}P}$ = 56.2 Hz), 21.2;

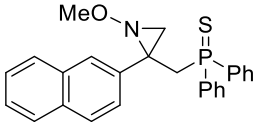
^{31}P NMR (162 MHz, $CDCl_3$): δ 36.8; ESI-HRMS: Calcd for $C_{23}H_{25}NOPS^+$ $[M+H]^+$ 394.1389, found 394.1375.

((2-(2-fluorophenyl)-1-methoxyaziridin-2-yl)methyl)diphenylphosphine sulfide (C9)



White solid; 59 mg, 73% yield; R_f = 0.5 (5:1 petroleum ether/ethyl acetate); a mixture of diastereoisomers, dr = 3.3:1 (the ratio was determined by ^{1}H NMR analysis); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.78–7.67 (m, 8.6H), 7.64–7.53 (m, 8.6H), 7.45–7.39 (m, 12.9H), 7.26–7.22 (m, 6.3H), 7.17–7.13 (m, 8.6H), 7.02–6.91 (m, 7.6H), 6.82 (td, J = 7.6, 0.8 Hz, 1.0H), 6.71–6.61 (m, 6.6H), 3.92–3.87 (m, 1.1H), 3.71 (s, 9.9H), 3.64 (ddd, J = 14.4, 8.4, 1.6 Hz, 3.3H), 3.47 (s, 3.1H), 3.08 (t, J = 14.4 Hz, 3.3H), 2.87 (d, J = 4.0 Hz, 1.0H), 2.72 (d, J = 4.0 Hz, 3.3H), 2.61 (d, J = 3.2 Hz, 3.3H), 2.48 (dd, J = 4.0, 1.2 Hz, 1.0H), 2.34 (t, J = 14.4 Hz, 1.0H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 162.0 (d, $J_{C\text{-}F}$ = 246.0 Hz), 161.8 (d, $J_{C\text{-}F}$ = 246.4 Hz), 134.85 (d, $J_{C\text{-}P}$ = 81.4 Hz), 134.81 (d, $J_{C\text{-}P}$ = 81.6 Hz), 133.4 (d, $J_{C\text{-}P}$ = 4.4 Hz), 131.33, 131.30, 131.27, 131.24, 131.13, 131.04, 130.9 (d, $J_{C\text{-}P}$ = 3.1 Hz), 130.80, 130.77, 130.4 (d, $J_{C\text{-}P}$ = 9.9 Hz), 130.2 (d, $J_{C\text{-}P}$ = 9.9 Hz), 130.01, 129.94, 130.7 (d, $J_{C\text{-}P}$ = 8.5 Hz), 128.6 (d, $J_{C\text{-}P}$ = 12.0 Hz), 127.9 (d, $J_{C\text{-}P}$ = 12.1 Hz), 127.8 (d, $J_{C\text{-}P}$ = 12.2 Hz), 126.2 (d, $J_{C\text{-}P}$ = 12.4 Hz), 123.6 (d, $J_{C\text{-}P}$ = 3.1 Hz), 123.5 (d, $J_{C\text{-}P}$ = 3.4 Hz), 115.0 (d, $J_{C\text{-}F}$ = 20.8 Hz), 114.6 (d, $J_{C\text{-}F}$ = 21.7 Hz), 60.34 (d, $J_{C\text{-}P}$ = 2.8 Hz), 60.29 (d, $J_{C\text{-}P}$ = 1.6 Hz), 44.7, 42.8, 42.5 (d, $J_{C\text{-}P}$ = 2.5 Hz), 42.2 (d, $J_{C\text{-}P}$ = 1.9 Hz), 38.4 (d, $J_{C\text{-}P}$ = 55.8 Hz), 32.53 (d, $J_{C\text{-}P}$ = 61.0 Hz); ^{19}F NMR (376 MHz, $CDCl_3$): δ -113.0, -115.2; ^{31}P NMR (162 MHz, $CDCl_3$): δ 39.8, 36.4; ESI-HRMS: Calcd for $C_{22}H_{22}FNOPS^+$ $[M+H]^+$ 398.1139, found 398.1135.

((1-methoxy-2-(naphthalen-2-yl)aziridin-2-yl)methyl)diphenylphosphine sulfide (C10)

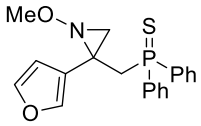


Total mass: 49 mg; 57% total yield (**Major**: 37% yield, **Minor**: 20% yield); a mixture of diastereoisomers, dr = 1.8:1 (the ratio was determined by ^{1}H NMR analysis).

Major: White solid; R_f = 0.3 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.75–7.71 (m, 2H), 7.62–7.59 (m, 1H), 7.52–7.31 (m, 11H), 6.83–6.76 (m, 3H), 3.71 (s, 3H), 3.50 (ddd, J = 14.4, 8.8, 1.6 Hz, 1H), 3.23 (t, J = 14.4 Hz, 1H), 2.87 (d, J = 3.6 Hz, 1H), 2.73–2.72 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 136.5, 134.9 (d, $J_{C\text{-}P}$ = 81.3 Hz), 132.5 (d, $J_{C\text{-}P}$ = 7.9 Hz), 131.21, 131.18, 131.1, 130.42 (d, $J_{C\text{-}P}$ = 9.8 Hz), 130.24 (d, $J_{C\text{-}P}$ = 3.0 Hz), 130.15 (d, $J_{C\text{-}P}$ = 79.8 Hz), 128.6, 128.5, 128.0, 127.8, 127.4, 127.2 (d, $J_{C\text{-}P}$ = 12.4 Hz), 126.1, 125.9, 125.6, 60.2, 46.9, 42.6 (d, $J_{C\text{-}P}$ = 2.3 Hz), 34.1 (d, $J_{C\text{-}P}$ = 58.3 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 40.2; ESI-HRMS: Calcd for $C_{26}H_{25}NOPS^+$ $[M+H]^+$ 430.1389, found 430.1371.

Minor: White solid; R_f = 0.2 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.71–7.58 (m, 5H), 7.47 (d, J = 8.8 Hz, 1H), 7.42–7.25 (m, 8H), 6.82–6.72 (m, 3H), 3.77 (ddd, J = 14.4, 8.4, 1.2 Hz, 1H), 3.42 (s, 3H), 3.03 (d, J = 3.6 Hz, 1H), 2.67 (dd, J = 3.6, 1.2 Hz, 1H), 2.50 (t, J = 14.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 134.9 (d, $J_{C\text{-}P}$ = 81.3 Hz), 132.8, 132.6, 132.2, 131.3 (d, $J_{C\text{-}P}$ = 2.9 Hz), 131.1 (d, $J_{C\text{-}P}$ = 10.5 Hz), 130.6, 130.3, 130.2, 130.1,130.0 (d, $J_{C\text{-}P}$ = 79.2 Hz), 128.6 (d, $J_{C\text{-}P}$ = 12.0 Hz), 127.9, 127.5, 127.3 (d, $J_{C\text{-}P}$ = 11.8 Hz), 127.2 (d, $J_{C\text{-}P}$ = 4.1 Hz), 126.0, 125.7, 59.8, 48.4, 42.5 (d, $J_{C\text{-}P}$ = 2.8 Hz), 40.9 (d, $J_{C\text{-}P}$ = 56.5 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 36.8; ESI-HRMS: Calcd for $C_{26}H_{25}NOPS^+$ $[M+H]^+$ 430.1389, found 430.1378.

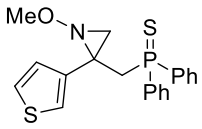
((2-(furan-3-yl)-1-methoxyaziridin-2-yl)methyl)diphenylphosphine sulfide (C11)



White solid; 49 mg, 66% yield; R_f = 0.3 (5:1 petroleum ether/ethyl acetate); a mixture of diastereoisomers, dr = 1.7:1 (the ratio was determined by ^{1}H NMR analysis); ^{1}H NMR (400 MHz, CD_3CN): δ 7.97–7.68 (m, 10.8H), 7.57–7.44 (m, 10.8H), 7.39–7.34 (m, 5.4H), 7.20 (m, 1.0H), 7.11–7.10 (m, 2.7H), 7.03 (m, 1.7H), 6.27 (dd, J = 2.0, 0.8 Hz, 1.0H), 6.24 (dd, J = 2.0, 0.8 Hz, 1.7H), 3.77–3.71 (m, 1.1H), 3.61–3.58 (m, 1.7H), 3.57–3.56 (m, 5.1H), 3.27 (s, 3.1H), 3.09 (t, J = 14.4 Hz, 1.7H), 2.62 (d, J = 4.0 Hz, 1.0H), 2.48–2.45 (m, 2.7H), 2.40–2.39 (m, 1.7H), 2.34–2.33 (m, 1.1H); ^{13}C NMR (100 MHz, CD_3CN): δ 144.4, 143.7, 143.2, 142.5, 135.7 (d, $J_{C\text{-}P}$ = 80.8 Hz), 135.6 (d, $J_{C\text{-}P}$ = 80.6 Hz), 133.4 (d, $J_{C\text{-}P}$ = 79.7 Hz), 133.3

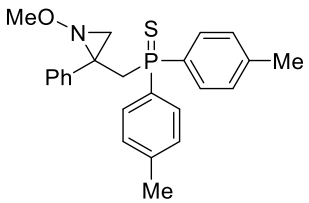
(d, $J_{C\text{-}P}$ = 79.1 Hz), 132.5 (d, $J_{C\text{-}P}$ = 2.9 Hz), 132.4 (d, $J_{C\text{-}P}$ = 2.9 Hz), 132.31 (d, $J_{C\text{-}P}$ = 10.5 Hz), 132.24 (d, $J_{C\text{-}P}$ = 10.7 Hz), 132.22, 132.1 (d, $J_{C\text{-}P}$ = 3.0 Hz), 131.7 (d, $J_{C\text{-}P}$ = 10.0 Hz), 131.5 (d, $J_{C\text{-}P}$ = 9.9 Hz), 129.7 (d, $J_{C\text{-}P}$ = 11.8 Hz), 129.6 (d, $J_{C\text{-}P}$ = 11.8 Hz), 129.1 (d, $J_{C\text{-}P}$ = 12.2 Hz), 129.0 (d, $J_{C\text{-}P}$ = 12.1 Hz), 127.1, 121.8, 112.3, 110.8, 60.5, 59.8, 42.9 (d, $J_{C\text{-}P}$ = 2.9 Hz), 42.6 (d, $J_{C\text{-}P}$ = 3.2 Hz), 41.0, 39.8, 39.3, 32.4 (d, $J_{C\text{-}P}$ = 58.7 Hz); ^{31}P NMR (162 MHz, CD_3CN): δ 40.2, 36.9; ESI-HRMS: Calcd for $C_{20}H_{21}NO_2PS^+$ $[M+H]^+$ 370.1026, found 370.1013.

((1-methoxy-2-(thiophen-3-yl)aziridin-2-yl)methyl)diphenylphosphine sulfide (C12)



White solid; 58 mg, 75% yield; R_f = 0.3 (5:1 petroleum ether/ethyl acetate); a mixture of diastereoisomers, dr = 1.3:1 (the ratio was determined by ^{1}H NMR analysis); ^{1}H NMR (400 MHz, CD_3CN): δ 7.89–7.77 (m, 4.6H), 7.71–7.59 (m, 4.6H), 7.54–7.40 (m, 6.9H), 7.37–7.31 (m, 2.3H), 7.29–7.25 (m, 4.6H), 7.13–7.12 (m, 1.0H), 7.04–6.99 (m, 2.3H), 6.96–6.92 (m, 3.6H), 3.89 (ddd, J = 14.4, 8.8, 1.2 Hz, 1.0H), 3.77–3.71 (m, 1.3H), 3.60 (s, 3.9H), 3.28 (s, 3.0H), 3.10 (t, J = 14.4 Hz, 1.3H), 2.71 (d, J = 3.6 Hz, 1.0H), 2.56 (s, 1.3H), 2.51–2.50 (m, 1.0H), 2.43 (t, J = 14.4 Hz, 1.0H), 2.27–2.23 (m, 1.3H); ^{13}C NMR (100 MHz, CD_3CN): δ 142.3, 137.2, 135.84 (d, $J_{C\text{-}P}$ = 80.9Hz), 135.79 (d, $J_{C\text{-}P}$ = 80.7 Hz), 133.3, 133.2, 132.5, 132.42, 132.39, 132.3 (d, $J_{C\text{-}P}$ = 3.0 Hz), 132.1, 131.98, 131.96, 131.92, 131.88, 131.8 (d, $J_{C\text{-}P}$ = 3.1 Hz), 131.5 (d, $J_{C\text{-}P}$ = 9.9 Hz), 131.3 (d, $J_{C\text{-}P}$ = 9.8 Hz), 129.7, 129.62 (d, $J_{C\text{-}P}$ = 11.9 Hz), 129.57 (d, $J_{C\text{-}P}$ = 11.8 Hz), 129.5 (d, $J_{C\text{-}P}$ = 12.0 Hz), 128.9 (d, $J_{C\text{-}P}$ = 12.1 Hz), 128.4, 127.3, 126.4, 125.7, 125.2, 60.6, 59.9, 44.42, 43.3 (d, $J_{C\text{-}P}$ = 2.6 Hz), 43.2, 43.1 (d, $J_{C\text{-}P}$ = 2.9 Hz), 40.1 (d, $J_{C\text{-}P}$ = 56.8 Hz), 33.1 (d, $J_{C\text{-}P}$ = 58.7 Hz); ^{31}P NMR (162 MHz, CD_3CN): δ 40.3, 36.9; ESI-HRMS: Calcd for $C_{20}H_{21}NOPS_2^+$ $[M+H]^+$ 386.0797, found 386.0781.

((1-methoxy-2-phenylaziridin-2-yl)methyl)di-p-tolylphosphine sulfide (C13)

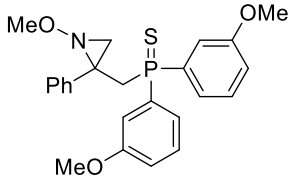


Total mass: 51 mg; 62% total yield (**Major**: 46% yield, **Minor**: 16% yield); a mixture of diastereoisomers, dr = 2.8:1 (the ratio was determined by ^{1}H NMR analysis).

Major: White solid; R_f = 0.3 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.63 (dd, J = 12.8, 8.4 Hz, 2H), 7.41 (dd, J = 12.8, 8.0 Hz, 2H), 7.21–7.19 (m, 2H), 7.14–7.12 (m, 2H), 6.99–6.91 (m, 5H), 3.65 (s, 3H), 3.37 (ddd, J = 14.4, 8.8, 2.0 Hz, 1H), 3.15 (t, J = 14.4 Hz, 1H), 2.74 (d, J = 4.0 Hz, 1H), 2.57–2.56 (m, 1H), 2.35 (s, 3H), 2.26 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 141.7 (d, $J_{C\text{-}P}$ = 3.0 Hz), 141.1 (d, $J_{C\text{-}P}$ = 3.1 Hz), 139.8, 131.8 (d, $J_{C\text{-}P}$ = 83.7 Hz), 131.4 (d, $J_{C\text{-}P}$ = 10.6 Hz), 130.6 (d, $J_{C\text{-}P}$ = 10.3 Hz), 129.3 (d, $J_{C\text{-}P}$ = 12.4 Hz), 128.9, 128.6 (d, $J_{C\text{-}P}$ = 12.6 Hz), 127.9, 127.7 (d, $J_{C\text{-}P}$ = 82.1 Hz), 127.0, 60.1, 46.8, 42.2 (d, $J_{C\text{-}P}$ = 2.6 Hz), 34.49 (d, $J_{C\text{-}P}$ = 58.3 Hz), 21.3 (d, $J_{C\text{-}P}$ = 1.5 Hz), 21.2 (d, $J_{C\text{-}P}$ = 1.6 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 39.7; ESI-HRMS: Calcd for $C_{24}H_{27}NOPS^+$ $[M+H]^+$ 408.1546, found 408.1536.

Minor: White solid; R_f = 0.2 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.57 (dd, J = 12.4, 8.0 Hz, 2H), 7.34 (dd, J = 13.2, 8.4 Hz, 2H), 7.20–7.16 (m, 4H), 7.05–6.99 (m, 3H), 6.90 (dd, J = 8.0, 2.4 Hz, 2H), 3.64 (ddd, J = 14.4, 8.4, 1.2 Hz, 1H), 3.38 (s, 3H), 2.90 (d, J = 4.0 Hz, 1H), 2.51 (dd, J = 3.6, 1.2 Hz, 1H), 2.43 (t, J = 14.4 Hz, 1H), 2.35 (s, 3H), 2,26 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 141.7 (d, $J_{C\text{-}P}$ = 3.1 Hz), 141.0 (d, $J_{C\text{-}P}$ = 2.9 Hz), 135.15, 131.7 (d, $J_{C\text{-}P}$ = 83.3 Hz), 131.4 (d, $J_{C\text{-}P}$ = 11.0 Hz), 130.5, 130.3 (d, $J_{C\text{-}P}$ = 10.3 Hz), 129.3 (d, $J_{C\text{-}P}$ = 12.3 Hz), 128.6 (d, $J_{C\text{-}P}$ = 12.7 Hz), 127.7, 127.6 (d, $J_{C\text{-}P}$ = 81.7 Hz), 127.4, 59.7, 48.3, 42.0 (d, $J_{C\text{-}P}$ = 2.9 Hz), 27.7 (d, $J_{C\text{-}P}$ = 56.2 Hz), 21.4, 21.2;^{31}P NMR (162 MHz, $CDCl_3$): δ 36.3; ESI-HRMS: Calcd for $C_{24}H_{27}NOPS^+$ $[M+H]^+$ 408.1546, found 408.1539.

((1-methoxy-2-phenylaziridin-2-yl)methyl)bis(3-methoxyphenyl)phosphine sulfide (C14)

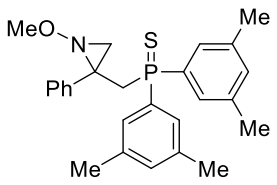


Total mass: 68.4 mg; 55% total yield (**Major**: 44% yield, **Minor**: 11% yield); a mixture of diastereoisomers, dr = 4.1:1 (the ratio was determined by ^{1}H NMR analysis).

Major: White solid; R_f = 0.3 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.37–7.28 (m, 3H), 7.17–7.02 (m, 5H), 6.99–6.96 (m, 4H), 6.79–6.76 (m, 1H), 3.78 (s, 3H), 3.70 (s, 3H), 3.66 (s, 3H), 3.41 (ddd, J = 14.8, 8.8, 2.0 Hz, 1H), 3.16 (t, J = 14.4 Hz, 1H), 2.75 (d, J = 4.0 Hz, 1H), 2.61–2.60 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 159.5 (d, $J_{C\text{-}P}$ = 15.2 Hz), 158.9 (d, $J_{C\text{-}P}$ = 15.3 Hz), 139.51, 136.1 (d, $J_{C\text{-}P}$ = 80.4 Hz), 132.2 (d, $J_{C\text{-}P}$ = 78.0 Hz), 129.7 (d, $J_{C\text{-}P}$ = 13.9 Hz), 129.0 (d, $J_{C\text{-}P}$ = 14.3 Hz), 127.9, 127.3, 123.4 (d, $J_{C\text{-}P}$ = 9.8 Hz), 122.4 (d, $J_{C\text{-}P}$ = 9.4 Hz), 117.03 (d, $J_{C\text{-}P}$ = 2.7 Hz), 116.98 (d, $J_{C\text{-}P}$ = 2.7 Hz), 116.6 (d, $J_{C\text{-}P}$ = 12.2 Hz), 116.1 (d, $J_{C\text{-}P}$ = 11.4 Hz), 60.2, 55.4, 55.2, 46.7, 42.3 (d, $J_{C\text{-}P}$ = 2.4 Hz), 34.1 (d, $J_{C\text{-}P}$ = 58.3 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 40.8; ESI-HRMS: Calcd for $C_{24}H_{27}NO_3PS^+$ $[M+H]^+$ 440.1444, found 440.1435.

Minor: White solid; R_f = 0.2 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.34–7.29 (m, 2H), 7.24–7.20 (m, 3H), 7.08–6.95 (m, 7H), 6.77–6.75 (m, 1H), 3.78 (s, 3H), 3.71–3.66 (m, 4H), 3.39 (s, 3H), 2.90 (d, J = 4.0 Hz, 1H), 2.55 (dd, J = 4.0, 1.2 Hz, 1H), 2.44 (t, J = 14.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 159.6 (d, $J_{C\text{-}P}$ = 15.0 Hz), 158.8 (d, $J_{C\text{-}P}$ = 15.6 Hz), 136.1 (d, $J_{C\text{-}P}$ = 80.6 Hz), 134.78, 132.2 (d, $J_{C\text{-}P}$ = 78.5 Hz), 130.5, 129.7 (d, $J_{C\text{-}P}$ = 13.9 Hz), 128.9 (d, $J_{C\text{-}P}$ = 14.3 Hz), 127.7, 127.6, 122.27 (d, $J_{C\text{-}P}$ = 10.1 Hz), 122.25 (d, $J_{C\text{-}P}$ = 9.4 Hz), 117.3 (d, $J_{C\text{-}P}$ = 2.7 Hz), 117.1 (d, $J_{C\text{-}P}$ = 2.9 Hz), 116.6 (d, $J_{C\text{-}P}$ = 12.6 Hz), 115.7 (d, $J_{C\text{-}P}$ = 11.8 Hz), 59.7, 55.4, 55.2, 48.2, 42.2 (d, $J_{C\text{-}P}$ = 2.7 Hz), 40.9 (d, $J_{C\text{-}P}$ = 56.2 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 37.2; ESI-HRMS: Calcd for $C_{24}H_{27}NO_3PS^+$ $[M+H]^+$ 440.1444, found 440.1438.

bis(3,5-dimethylphenyl)((1-methoxy-2-phenylaziridin-2-yl)methyl)phosphine sulfide (C15)



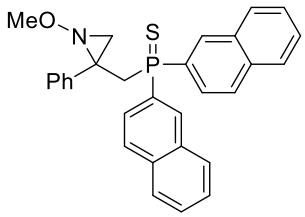
Total mass: 58 mg; 66% total yield (**Major**: 41% yield, **Minor**: 25% yield); a mixture of diastereoisomers, dr = 1.6:1 (the ratio was determined by ^{1}H NMR analysis).

Major: White solid; R_f = 0.3 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.32 (d, J = 13.2 Hz, 2H), 7.17–7.14 (m, 2H), 7.11–7.06 (m, 3H), 7.01–6.97 (m, 3H), 6.85

(s, 1H), 3.67 (s, 3H), 3.39 (ddd, *J* = 14.8, 8.8, 2.0 Hz, 1H), 3.10 (t, *J* = 14.8 Hz, 1H), 2.81 (d, *J* = 3.6 Hz, 1H), 2.59–2.58 (m, 1H), 2.30 (s, 6H), 2.14 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): *δ* 139.8, 138.2 (d, J_{C-P} = 12.4 Hz), 137.4 (d, J_{C-P} = 12.8 Hz), 134.8 (d, J_{C-P} = 80.21 Hz), 133.0 (d, J_{C-P} = 3.0 Hz), 132.7 (d, J_{C-P} = 3.1 Hz), 130.4 (d, J_{C-P} = 78.9 Hz), 129.1 (d, J_{C-P} = 10.2 Hz), 128.8, 128.0 (d, J_{C-P} = 8.5 Hz), 127.7, 127.3, 60.1, 46.9, 42.2 (d, J_{C-P} = 2.4 Hz), 33.9 (d, J_{C-P} = 57.7 Hz), 21.3, 21.1; ^{31}P NMR (162 MHz, $CDCl_3$): *δ* 40.6; ESI-HRMS: Calcd for $C_{26}H_{31}NOPS^+$ $[M+H]^+$ 436.1859, found 436.1840.

Minor: White solid; R_f = 0.2 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): *δ* 7.28 (m, 1H), 7.24 (m, 1H), 7.21–7.19 (m, 2H), 7.05–7.01 (m, 6H), 6.83 (s, 1H), 3.66 (ddd, *J* = 14.4, 8.4, 1.2 Hz, 1H), 3.40 (s, 3H), 2.96 (d, *J* = 4.0 Hz, 1H), 2.53 (dd, *J* = 4.0, 1.2 Hz, 1H), 2.45–2.34 (m, 1H), 2.29 (s, 6H), 2.14 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): *δ* 138.3 (d, J_{C-P} = 12.5 Hz), 137.3 (d, J_{C-P} = 12.9 Hz), 135.0, 134.8 (d, J_{C-P} = 80.6 Hz), 133.0 (d, J_{C-P} = 3.0 Hz), 132.7 (d, J_{C-P} = 3.1 Hz), 130.4, 130.3 (d, J_{C-P} = 78.4 Hz), 129.1 (d, J_{C-P} = 10.6 Hz), 127.8 (d, J_{C-P} = 9.9 Hz), 127.7, 127.4, 59.7, 48.3, 42.2 (d, J_{C-P} = 2.8 Hz), 40.8 (d, J_{C-P} = 55.8 Hz), 21.3, 21.1; ^{31}P NMR (162 MHz, $CDCl_3$): *δ* 36.9; ESI-HRMS: Calcd for $C_{26}H_{31}NOPS^+$ $[M+H]^+$ 436.1859, found 436.1845.

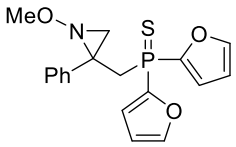
((1-methoxy-2-phenylaziridin-2-yl)methyl)di(naphthalen-2-yl)phosphine sulfide (C16)



White solid; 55 mg, 57% yield; R_f = 0.3 (5:1 petroleum ether/ethyl acetate); a mixture of diastereoisomers, dr = 3:1 (the ratio was determined by ^{1}H NMR analysis); ^{1}H NMR (400 MHz, $CDCl_3$): *δ* 8.26–8.18 (m, 8H), 7.86–7.81 (m, 12H), 7.77–7.67 (m, 12H), 7.57–7.47 (m, 20H), 7.43–7.38 (m, 3H), 7.33–7.30 (m, 1H), 7.20–7.15 (m, 8H), 6.81–6.76 (m, 8H), 6.71–6.67 (m, 4H), 3.91–3.85 (m, 1H), 3.69 (s, 9H), 3.61 (ddd, *J* = 14.4, 8.4, 1.6 Hz, 3H), 3.40–3.33 (m, 6H), 2.99 (d, *J* = 3.6 Hz, 1H), 2.83 (d, *J* = 4.0 Hz, 3H), 2.69–2.62 (m, 4H), 2.57 (dd, *J* = 3.6, 0.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): *δ* 139.5, 134.4, 134.33 (d, J_{C-P} = 74.2 Hz), 134.30 (d, J_{C-P} = 2.5 Hz), 134.28 (d, J_{C-P} = 2.6 Hz), 134.1 (d, J_{C-P} = 10.5 Hz),

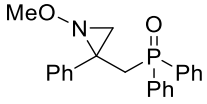
134.0 (d, $J_{C\text{-}P}$ = 2.3 Hz), 132.4 (d, $J_{C\text{-}P}$ = 13.4 Hz), 132.3, 132.23, 132.19, 132.11, 132.05, 132.0, 131.6, 131.54, 131.47, 131.4, 130.4, 128.9, 128.8, 128.7, 128.6 (d, $J_{C\text{-}P}$ = 11.6 Hz), 128.4, 128.1 (d, $J_{C\text{-}P}$ = 13.6 Hz), 127.8, 127.71, 127.67, 127.60, 127.57, 127.5, 127.4, 127.3, 127.01, 126.96, 126.6, 126.5, 125.8 (d, $J_{C\text{-}P}$ = 3.6 Hz), 125.7 (d, $J_{C\text{-}P}$ = 3.8 Hz), 125.6, 60.2, 59.7, 48.2, 46.8, 42.3 (d, $J_{C\text{-}P}$ = 2.5 Hz), 42.2 (d, $J_{C\text{-}P}$ = 3.0 Hz), 40.6 (d, $J_{C\text{-}P}$ = 56.4 Hz), 34.0 (d, $J_{C\text{-}P}$ = 58.2 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 40.8, 37.1; ESI-HRMS: Calcd for $C_{30}H_{27}NOPS^+$ $[M+H]^+$ 480.1546, found 480.1524.

di(furan-2-yl)((1-methoxy-2-phenylaziridin-2-yl)methyl)phosphine sulfide (C17)



White solid; 35 mg, 49% yield; R_f = 0.4 (5:1 petroleum ether/ethyl acetate); a mixture of diastereoisomers, dr = 1.6:1 (the ratio was determined by ^{1}H NMR analysis); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.63–7.62 (m, 2.6H), 7.32–7.27 (m, 4.6H),7.24–7.22 (m, 3.2H), 7.19–7.04 (m, 7.8H), 7.02–7.00 (m, 1.6H), 6.98–6.96 (m, 1H), 6.95–6.93 (m, 1.6H), 6.87–6.85 (m, 1H), 6.45–6.44 (m, 2.6H), 6.21–6.19 (m, 1.6H), 6.17–6.16 (m, 1H), 3.74 (ddd, J = 14.8 Hz, 1.1H), 3.66 (s, 4.8H), 3.52–3.45 (m, 1.6H), 3.37 (m, 3.1H), 3.07 (t, J = 14.8 Hz, 1.6H), 2.74 (d, J = 3.6 Hz, 1.1H), 2.61 (s, 3.2H), 3.55 (dd, J = 4.0, 1.2 Hz, 1H), 2.33 (t, J = 14.8, 10.8, 1.2 Hz, 1.1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 148.5 (d, $J_{C\text{-}P}$ = 81.8 Hz), 148.21, 148.16, 148.1 (d, $J_{C\text{-}P}$ = 2.4 Hz), 148.04, 148.00 (d, $J_{C\text{-}P}$ = 2.8 Hz), 147.9 (d, $J_{C\text{-}P}$ = 118.3 Hz), 147.6 (d, $J_{C\text{-}P}$ = 118.1 Hz), 145.9 (d, $J_{C\text{-}P}$ = 117.6 Hz), 145.6 (d, $J_{C\text{-}P}$ = 117.5 Hz), 139.1, 134.5, 130.2, 128.5, 128.0, 127.73, 127.67, 127.2, 123.40, 123.36, 123.19, 123.15, 121.4, 121.2, 121.1, 120.9, 111.04 (d, $J_{C\text{-}P}$ = 9.4 Hz), 111.01 (d, $J_{C\text{-}P}$ = 9.4 Hz), 110.9 (d, $J_{C\text{-}P}$ = 9.6 Hz), 60.2, 59.7, 47.3, 45.8, 41.8 (d, $J_{C\text{-}P}$ = 3.1 Hz), 41.5 (d, $J_{C\text{-}P}$ = 3.5 Hz), 40.5 (d, $J_{C\text{-}P}$ = 62.7 Hz), 33.7 (d, $J_{C\text{-}P}$ = 64.9 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 12.2, 8.7; ESI-HRMS: Calcd for $C_{18}H_{19}NO_3PS^+$ $[M+H]^+$ 360.0818, found 360.0811.

((1-methoxy-2-phenylaziridin-2-yl)methyl)diphenylphosphine oxide (C18)

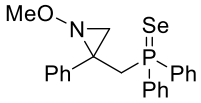


Total mass: 61 mg; 84% total yield (**Major**: 59% yield, **Minor**: 25% yield); a mixture of diastereoisomers, dr = 2.3:1 (the ratio was determined by ^{1}H NMR analysis).

Major: White solid; R_f = 0.2 (0:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.73–7.68 (m, 2H), 7.52–7.40 (m, 5H), 7.36–7.32 (m, 1H), 7.24–7.20 (m, 2H), 7.16–7.14 (m, 2H), 7.06–7.04 (m, 3H), 3.66 (s, 3H), 3.21–3.14 (m, 1H), 3.04–2.98 (m, 1H), 2.46–2.45 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 140.4, 134.2 (d, $J_{C\text{-}P}$ = 98.8 Hz), 132.4 (d, $J_{C\text{-}P}$ = 98.8 Hz), 131.6 (d, $J_{C\text{-}P}$ = 2.9 Hz), 131.2 (d, $J_{C\text{-}P}$ = 2.8 Hz), 130.8 (d, $J_{C\text{-}P}$ = 9.3 Hz), 130.6 (d, $J_{C\text{-}P}$ = 9.2 Hz), 128.6 (d, $J_{C\text{-}P}$ = 11.6 Hz), 128.4, 128.13 (d, $J_{C\text{-}P}$ = 11.8 Hz), 128.12, 127.3, 60.1, 45.8 (d, $J_{C\text{-}P}$ = 2.9 Hz), 41.8 (d, $J_{C\text{-}P}$ = 3.2 Hz), 31.1 (d, $J_{C\text{-}P}$ = 72.2 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 28.5; ESI-HRMS: Calcd for $C_{22}H_{23}NO_2P^+$ $[M+H]^+$ 364.1461, found 364.1450.

Minor: White solid; R_f = 0.1 (0:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.67–7.62 (m, 2H), 7.49–7.39 (m, 5H), 7.32–7.28 (m, 1H), 7.21–7.15 (m, 4H), 7.10–7.08 (m, 3H), 3.36 (m, 3H), 3.34–3.28 (m, 1H), 2.71–2.70 (m, 1H), 2.45 (t, J = 15.2 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 135.8, 134.3 (d, $J_{C\text{-}P}$ = 98.7 Hz), 131.9 (d, $J_{C\text{-}P}$ = 98.9 Hz), 131.6 (d, $J_{C\text{-}P}$ = 2.7 Hz), 131.0 (d, $J_{C\text{-}P}$ = 2.9 Hz), 130.7 (d, $J_{C\text{-}P}$ = 9.4 Hz), 130.2 (d, $J_{C\text{-}P}$ = 9.2 Hz), 130.0, 128.5 (d, $J_{C\text{-}P}$ = 11.7 Hz), 128.0 (d, $J_{C\text{-}P}$ = 11.8 Hz), 127.5, 127.7, 59.6, 47.3 (d, $J_{C\text{-}P}$ = 2.5 Hz), 41.1 (d, $J_{C\text{-}P}$ = 3.1 Hz), 39.2 (d, $J_{C\text{-}P}$ = 69.8 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 27.7; ESI-HRMS: Calcd for $C_{22}H_{23}NO_2P^+$ $[M+H]^+$ 364.1461, found 364.1452.

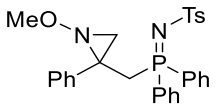
((1-methoxy-2-phenylaziridin-2-yl)methyl)diphenylphosphine selenide (C19)



White solid; 55 mg; 64% yield; R_f = 0.4 (5:1 petroleum ether/ethyl acetate); a mixture of diastereoisomers, dr = 2:1 (the ratio was determined by ^{1}H NMR analysis), ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.75–7.64 (m, 6H), 7.58–7.45 (m, 6H), 7.42–7.36 (m, 9H), 7.24–7.19 (m, 5H), 7.17–7.09 (m, 10H), 7.03–7.00 (m, 3H), 6.96–6.94 (m, 6H), 3.92–3.86 (m, 1H), 3.66–3.59 (m, 8H), 3.38 (s, 3H), 3.26 (t, J = 14.0 Hz, 2H), 3.01–3.00 (m, 1H) , 2.87–2.86 (m, 2H) , 2.63–2.62 (m, 2H) , 2.57–2.51 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 139.2, 134.6, 133.9 (d, $J_{C\text{-}P}$ = 73.3 Hz), 133.7 (d, $J_{C\text{-}P}$ = 73.6 Hz), 132.02 (d, $J_{C\text{-}P}$ = 10.5 Hz), 131.96 (d, $J_{C\text{-}P}$ = 10.8 Hz), 131.3 (d, $J_{C\text{-}P}$ = 2.9 Hz), 131.2 (d, $J_{C\text{-}P}$ = 3.1 Hz), 130.81 (d, $J_{C\text{-}P}$ = 2.9 Hz), 130.80

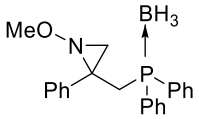
(d, $J_{C\text{-}P}$ = 10.2 Hz), 130.6 (d, $J_{C\text{-}P}$ = 9.9 Hz), 130.5, 129.0 (d, $J_{C\text{-}P}$ = 70.2 Hz), 128.91 (d, $J_{C\text{-}P}$ = 65.7 Hz), 128.88, 128.6 (d, $J_{C\text{-}P}$ = 11.9 Hz), 128.5 (d, $J_{C\text{-}P}$ = 11.9 Hz), 127.94, 127.87, 127.8, 127.74 (d, $J_{C\text{-}P}$ = 4.5 Hz), 127.72 (d, $J_{C\text{-}P}$ = 6.3 Hz), 127.68, 127.4, 60.1, 59.6, 48.5, 47.1, 42.5 (d, $J_{C\text{-}P}$ = 2.4 Hz), 42.3 (d, $J_{C\text{-}P}$ = 2.8 Hz), 40.2 (d, $J_{C\text{-}P}$ = 49.2 Hz), 33.7 (d, $J_{C\text{-}P}$ = 51.1 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 31.5, 26.1; ESI-HRMS: Calcd for $C_{22}H_{23}NOPSe^+$ $[M+H]^+$ 428.0677, found 428.0663.

N-(((1-methoxy-2-phenylaziridin-2-yl)methyl)diphenyl-l5-phosphaneylidene)-4-meth-ylbenzenesulfonamide (C20)



White solid; 73 mg, 71% yield; R_f = 0.3 (1:1 petroleum ether/ethyl acetate); a mixture of diastereoisomers, dr = 2:1 (the ratio was determined by ^{1}H NMR analysis); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.48–7.28 (m, 30H), 7.18–7.07 (m, 8H), 7.03–6.93 (m, 19H), 3.90–3.82 (m, 2H), 3.69 (s, 6H), 3.36 (s, 3H), 3.54–3.49 (m, 1H), 3.26–3.20 (m, 2H), 3.12–3.04 (m, 2H), 2.80–2.79 (m, 2H), 2.55–2.54 (m, 2H), 2.48–2.47 (m, 1H), 2.29–2.28 (m, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.2 (d, $J_{C\text{-}P}$ = 2.2 Hz), 143.0 (d, $J_{C\text{-}P}$ = 2.0 Hz), 140.3, 139.0, 134.7, 132.4 (d, $J_{C\text{-}P}$ = 2.9 Hz), 132.12, 132.05, 132.02, 131.98, 131.9, 131.8 (d, $J_{C\text{-}P}$ = 10.0 Hz), 131.7 (d, $J_{C\text{-}P}$ = 9.9 Hz), 130.1, 128.61, 128.56, 128.48, 128.45, 128.22 (d, $J_{C\text{-}P}$ = 13.2 Hz), 128.19 (d, $J_{C\text{-}P}$ = 15.0 Hz), 128.1, 127.82, 127.75, 127.6, 127.5, 127.4, 125.58 (d, $J_{C\text{-}P}$ = 110.9 Hz), 125.56, 125.53, 125.49 (d, $J_{C\text{-}P}$ = 111.0 Hz), 60.2, 59.6, 46.83, 46.81, 42.0 (d, $J_{C\text{-}P}$ = 2.2 Hz), 41.6 (d, $J_{C\text{-}P}$ = 2.8 Hz), 36.5 (d, $J_{C\text{-}P}$ = 65.7 Hz), 29.8 (d, $J_{C\text{-}P}$ = 69.4 Hz), 21.2; ^{31}P NMR (162 MHz, $CDCl_3$): δ 16.5, 14.2; ESI-HRMS: Calcd for $C_{29}H_{30}N_2O_3PS^+$ $[M+H]^+$ 517.1710, found 517.1697.

2-((diphenylphosphaneyl)methyl)-1-methoxy-2-phenylaziridine borane (C21)



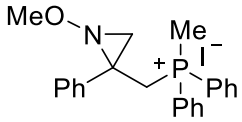
Total mass: 46 mg; 59% total yield (**Major**: 35% yield, **Minor**: 24% yield); a mixture of diastereoisomers, dr = 1.5:1 (the ratio was determined by ^{1}H NMR analysis).

Major: White solid; R_f = 0.5 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.60–7.55 (m, 2H), 7.44–7.36 (m, 5H), 7.27–7.23 (m, 1H), 7.14–7.09 (m, 4H), 6.98–6.95

(m, 3H), 3.67 (s, 3H), 3.19–3.12 (m, 1H), 3.00–2.94 (m, 1H), 2.59–2.58 (m, 1H), 2.52–2.51 (m, 1H), 1.44–0.72 (br, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 139.5, 132.5 (d, $J_{C\text{-}P}$ = 9.5 Hz), 131.5 (d, $J_{C\text{-}P}$ = 8.8 Hz), 131.0 (d, $J_{C\text{-}P}$ = 55.8 Hz), 130.9 (d, $J_{C\text{-}P}$ = 2.4 Hz), 130.8 (d, $J_{C\text{-}P}$ = 2.5 Hz), 128.8, 127.7, 128.2 (d, $J_{C\text{-}P}$ = 10.1 Hz), 128.1, 127.4, 127.2 (d, $J_{C\text{-}P}$ = 54.0 Hz), 60.3, 47.0 (d, $J_{C\text{-}P}$ = 3.6 Hz), 42.7, 28.1 (d, $J_{C\text{-}P}$ = 36.9 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 16.0–16.4, br; ^{11}B NMR (128 MHz, $CDCl_3$): δ 39.8, br; ESI-HRMS: Calcd for $C_{22}H_{25}BNNaOP^+$ $[M+Na]^+$ 384.1659, found 384.1652.

Minor: White solid; R_f = 0.4 (5:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.55–7.50 (m, 2H), 7.43–7.31 (m, 5H), 7.24–7.21 (m, 1H), 7.19–7.17 (m, 2H), 7.12–7.08 (m, 2H), 7.04–7.00 (m, 3H), 3.52–3.44 (m, 1H), 3.38 (s, 3H), 2.65–2.64 (m, 1H), 2.51–2.50 (m, 1H), 2.18–2.12 (m, 1H), 1.15–0.68 (br, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 134.8, 132.5 (d, $J_{C\text{-}P}$ = 9.6 Hz), 131.3 (d, $J_{C\text{-}P}$ = 8.8 Hz), 130.7 (d, $J_{C\text{-}P}$ = 2.0 Hz), 130.7 (d, $J_{C\text{-}P}$ = 2.5 Hz), 130.6 (d, $J_{C\text{-}P}$ = 55.9 Hz), 130.2, 128.7 (d, $J_{C\text{-}P}$ = 9.8 Hz), 128.10 (d, $J_{C\text{-}P}$ = 10.1 Hz), 128.06, 127.82, 127.79, 127.4 (d, $J_{C\text{-}P}$ = 53.8 Hz), 59.7, 48.3 (d, $J_{C\text{-}P}$ = 4.4 Hz), 42.4 (d, $J_{C\text{-}P}$ = 1.8 Hz), 35.6 (d, $J_{C\text{-}P}$ = 34.5 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 13.1–13.5, br; ^{11}B NMR (128 MHz, $CDCl_3$): δ 39.7, br; ESI-HRMS: Calcd for $C_{22}H_{25}BNNaOP^+$ $[M+Na]^+$ 384.1659, found 384.1652.

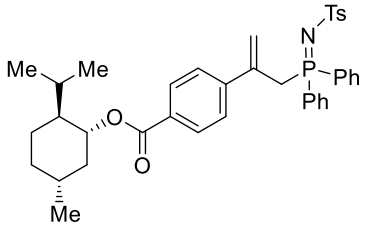
((1-methoxy-2-phenylaziridin-2-yl)methyl)(methyl)diphenylphosphonium iodide (C 22)



White solid; 58 mg; 59% yield; R_f = 0.4 (10:1 CH_2Cl_2/MeOH); a mixture of diastereoisomers, dr = 1.5:1 (the ratio was determined by ^{1}H NMR analysis); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.87–7.78 (m, 7.5H), 7.76–7.65 (m, 10H), 7.59–7.57 (m, 7.5H), 7.35–7.27 (m, 8.5H), 7.15 (m, 4H), 4.62 (m, 1H), 4.49–4.42 (m, 1.5H), 4.24–4.17 (m, 1.5H), 3.71 (s, 4.5H), 2.67–2.66 (m, 1H), 2.57 (d, J = 13.6 Hz, 3H), 2.41–2.32 (m, 7H , 2.26 (s, 1.5H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 136.6, 134.7 (d, $J_{C\text{-}P}$ = 2.7 Hz), 134.42 (d, $J_{C\text{-}P}$ = 7.0 Hz), 134.38 (d, $J_{C\text{-}P}$ = 7.9 Hz), 133.9 (d, $J_{C\text{-}P}$ = 3.2 Hz), 132.54 (d, $J_{C\text{-}P}$ = 4.7 Hz), 132.46, 132.4 (d, $J_{C\text{-}P}$ = 3.2 Hz), 132.3, 131.2 (d, $J_{C\text{-}P}$ = 3.1 Hz), 130.3, 130.1, 129.88 (d, $J_{C\text{-}P}$ = 12.3 Hz), 129.85 (d, $J_{C\text{-}P}$ = 12.6 Hz), 129.8 (d, $J_{C\text{-}P}$ = 12.4 Hz), 128.8, 128.7, 128.6, 128.5, 128.2, 119.7 (d, $J_{C\text{-}P}$ = 85.2

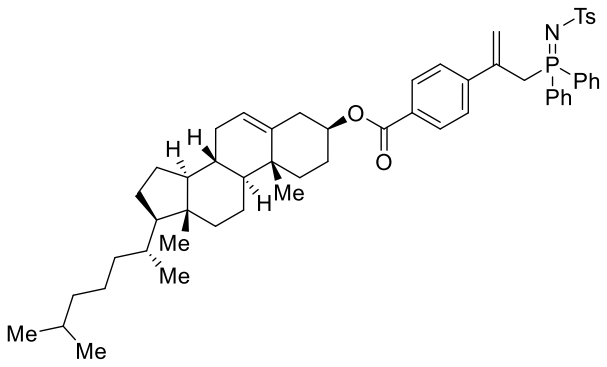
Hz), 119.5 (d, $J_{C\text{-}P}$ = 84.8 Hz), 119.2 (d, $J_{C\text{-}P}$ = 84.9 Hz), 119.1(d, $J_{C\text{-}P}$ = 85.3 Hz), 60.2, 59.7, 46.1(d, $J_{C\text{-}P}$ = 3.2 Hz), 45.1(d, $J_{C\text{-}P}$ = 2.7 Hz), 44.3 (d, $J_{C\text{-}P}$ = 7.4 Hz), 41.5, 32.4 (d, $J_{C\text{-}P}$ = 50.9 Hz), 27.7 (d, $J_{C\text{-}P}$ = 53.6 Hz), 9.0 (d, $J_{C\text{-}P}$ = 54.3 Hz), 8.6 (d, $J_{C\text{-}P}$ = 54.1 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 22.4, 21.0; ESI-HRMS: Calcd for $C_{23}H_{25}NOP^+$ $[M\text{-}I]^+$ 362.1669, found 362.1653.

(1R,2S,5R)-2-isopropyl-5-methylcyclohexyl 4-(3-(P,P-diphenyl-N-tosylphosphorimid -oyl)prop-1-en-2-yl)benzoate (B23)



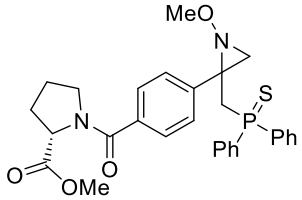
Colorless oil; 72 mg, 55% yield; R_f = 0.2 (1:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.72–7.70 (m, 2H), 7.57–7.52 (m, 4H), 7.49–7.41 (m, 4H), 7.29–7.24 (m, 4H), 7.06–6.99 (m, 4H), 5.61 (d, J = 5.2 Hz, 1H), 5.49 (d, J = 5.2 Hz, 1H), 4.89 (td, J = 10.8 Hz, J = 4.4 Hz, 2H), 4.08 (d, J = 14.8 Hz, 2H), 2.30 (s, 3H), 2.12–2.09 (m, 1H), 1.94–1.88 (m, 1H), 1.74–1.72 (m, 2H), 1.57–1.51 (m, 2H), 1.18–1.05 (m, 2H), 1.18–1.05 (m, 2H), 0.94–0.92 (m, 7H), 0.81–0.79 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 165.6, 144.9 (d, $J_{C\text{-}P}$ = 3.1 Hz), 143.0 (d, $J_{C\text{-}P}$ = 2.4 Hz), 140.5, 136.4 (d, $J_{C\text{-}P}$ = 9.2 Hz), 132.5, 132.2 (d, $J_{C\text{-}P}$ = 10.1 Hz), 129.5, 129.2, 128.4 (d, $J_{C\text{-}P}$ = 12.5 Hz), 126.21 (d, $J_{C\text{-}P}$ = 101.1 Hz), 126.19, 126.1 (d, $J_{C\text{-}P}$ = 101.6 Hz), 125.6, 122.2 (d, $J_{C\text{-}P}$ = 9.5 Hz), 74.8, 47.2, 40.9, 34.3, 34.2, 33.7,31.3, 26.6, 23.7, 22.0, 20.9 (d, $J_{C\text{-}P}$ = 59.9 Hz), 16.6; ^{31}P NMR (162 MHz, $CDCl_3$): δ 16.9; ESI-HRMS: Calcd for $C_{39}H_{45}NO_4PS^+$ $[M+H]^+$ 654.2802, found 654.2798.

(3S,8S,9S,10R,13R,14S,17R)-10,13-dimethyl-17-((R)-6-methylheptan-2-yl)-2,3,4,7,8,9, 10,11,12,13,14,15,16,17-tetradecahydro-1H-cyclopenta[a]phenanthren-3-yl 4-(3-(P,P -diphenyl-N-tosylphosphorimidoyl)prop-1-en-2-yl)benzoate (B24)



White solid; 106 mg, 60% yield; R_f = 0.2 (1:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.72–7.70 (m, 2H), 7.58–7.53 (m, 4H), 7.48–7.42 (m, 4H), 7.29–7.25 (m, 4H), 7.06–7.04 (m, 2H), 7.00–6.98 (m, 2H), 5.59 (d, J = 4.8 Hz, 1H), 5.47 (d, J = 5.2 Hz, 1H), 5.42–5.41 (m, 1H), 4.86–4.78 (m, 1H), 4.08 (d, J = 14.8 Hz, 2H), 2.45–2.43 (m, 2H), 2.29 (s, 3H), 2.04–1.73 (m, 6H), 1.60–0.97 (m, 23H), 0.93–0.92 (m, 3H), 0.88–0.86 (m, 6H), 0.69 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 165.4, 144.8 (d, $J_{C\text{-}P}$ = 3.1 Hz), 143.0 (d, $J_{C\text{-}P}$ = 2.6 Hz), 140.4, 139.5, 136.4 (d, $J_{C\text{-}P}$ = 9.0 Hz), 132.53, 132.51, 132.1 (d, $J_{C\text{-}P}$ = 10.0 Hz), 129.2, 128.9 (d, $J_{C\text{-}P}$ = 103.0 Hz), 128.4, 128.3, 126.10 (d, $J_{C\text{-}P}$ = 101.3 Hz), 126.06, 125.5, 122.7, 122.2 (d, $J_{C\text{-}P}$ = 9.2 Hz), 74.4, 56.6, 56.0, 49.9, 42.2, 39.6, 39.4, 38.1, 36.9, 36.5, 36.1, 35.7, 33.8 (d, $J_{C\text{-}P}$ = 60.1 Hz), 31.8, 31.7, 28.1, 27.9, 27.7, 24.2, 23.7, 22.7, 22.5, 21.2, 20.9, 19.3 ,18.6, 11.8; ^{31}P NMR (162 MHz, $CDCl_3$): δ 17.0; ESI-HRMS: Calcd for $C_{56}H_{71}NO_4PS^+$ $[M+H]^+$ 884.4836, found 884.4817.

***methyl (4-(2-((diphenylphosphorothioyl)methyl)-1-methoxyaziridin-2-yl)benzoyl)-L-prolinate* (C23)**



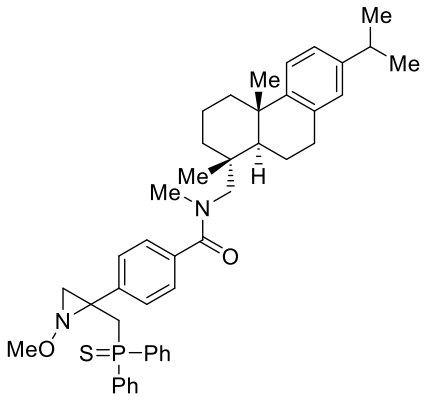
Total mass: 86mg; 80% total yield (**Major**: 52% yield; **Minor**: 28% yield); a mixture of diastereoisomers, dr = 13:4:9:1 (the ratio was determined by ^{1}H NMR analysis).

Major: **isomer 1 and 2**, a mixture of diastereoisomers, dr = 3.2:1 (the ratio was determined by ^{31}P NMR analysis); White solid; R_f = 0.3 (1:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.72–7.67 (m, 2H), 7.54–7.49 (m, 2H), 7.45–7.38 (m, 3H), 7.28 (m, 1H), 7.25 (m, 3.5H), 7.19–7.13 (m, 2.3H), 7.06–7.02 (m, 0.3H), 4.65–4.62 (m, 0.9H), 3.78–

3.70 (m, 4H), 3.58–3.49 (m, 1H), 3.43–3.32 (m, 4H), 2.89–2.88 (m, 1H), 2.54–2.42 (m, 2H), 2.34–2.28 (m, 0.9H), 2.04–1.97 (m, 2H), 1.88–1.85 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.61, 172.60, 168.8, 137.21, 137.16, 135.2, 135.1, 134.5 ($J_{C\text{-}P}$ = 81.3 Hz), 131.4, 131.3, 131.2 ($J_{C\text{-}P}$ = 10.4 Hz), 131.0 ($J_{C\text{-}P}$ = 9.4 Hz), 130.27, 130.2 ($J_{C\text{-}P}$ = 10.4 Hz), 128.6 ($J_{C\text{-}P}$ = 12.1 Hz), 128.0 ($J_{C\text{-}P}$ = 2.5 Hz), 127.9 ($J_{C\text{-}P}$ = 2.5 Hz), 126.8, 126.0, 125.9, 59.75, 59.6, 59.0, 52.2, 49.9, 47.8, 42.2, 40.6 ($J_{C\text{-}P}$ = 56.1 Hz), 29.3, 25.3; ^{31}P NMR (162 MHz, $CDCl_3$): δ 36.43, 39.42; ESI-HRMS: Calcd for $C_{29}H_{32}N_2O_4PS^+$ $[M+H]^+$ 535.1815, found 535.1796.

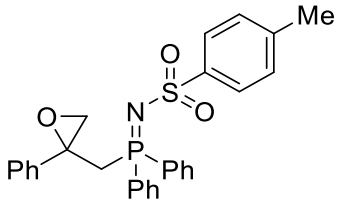
Minor: **isomer 3 and 4**, a mixture of diastereoisomers, dr = 9:1 (the ratio was determined by ^{31}P NMR analysis); White solid; R_f = 0.2 (1:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.78–7.73 (m, 2H), 7.59–7.55 (m, 2H), 7.46–7.41 (m, 3H), 7.32–7.29 (m, 1H), 7.22–7.16 (m, 5.7H), 6.97–6.95 (m, 0.3H), 4.62–4.59 (m, 0.8H), 3.78–3.77 (m, 2.7H), 3.67 (s, 3H), 3.62–3.60 (m, 0.5H), 3.47–3.29 (m, 2.8H), 3.24–3.16 (m, 1H), 2.78 (m, 0.9H), 2.77 (m, 0.1H), 2.59–2.55 (m, 1H), 2.32–2.26 (m, 0.9H), 2.09–2.02 (m, 0.1H), 2.00–1.96 (m, 2H), 1.91–1.82 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.73, 172. 70, 141.9, 141.8, 135.2, 135.1, 134.3, 134.7 ($J_{C\text{-}P}$ = 84.7 Hz), 133.7, 133.6, 131.4 ($J_{C\text{-}P}$ = 10.2 Hz), 131. 2 ($J_{C\text{-}P}$ = 2.5 Hz), 130.6 ($J_{C\text{-}P}$ = 79.6 Hz), 130.5 ($J_{C\text{-}P}$ = 10.0 Hz), 128.7 ($J_{C\text{-}P}$ = 12.1 Hz), 128.1 ($J_{C\text{-}P}$ = 12.3 Hz), 127.1 ($J_{C\text{-}P}$ = 9.7 Hz), 126.4, 126.2, 60.3, 59.0, 58.99, 52.26, 49.88, 46.50, 42.53, 42.41, 33.9 ($J_{C\text{-}P}$ = 58.1 Hz) , 29.36, 25.29, 25.15; ^{31}P NMR (162 MHz, $CDCl_3$): δ 39.93, 39.90; ESI-HRMS: Calcd for $C_{29}H_{32}N_2O_4PS^+$ $[M+H]^+$ 535.1815, found 535.1799.

4-(2-((diphenylphosphorothioyl)methyl)-1-methoxyaziridin-2-yl)-N-(((1R,4aS,10aR)-7-isopropyl-1,4a-dimethyl-1,2,3,4,4a,9,10,10a-octahydrophenanthren-1-yl)methyl)-N-methylbenzamide (C24)



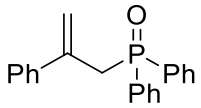
White solid; 103 mg, 73% yield; R_f = 0.3 (1:1 petroleum ether/ethyl acetate); **Isomer 1, 2, 3 and 4:** a mixture of diastereoisomers, dr = 1.9:1.5:1:1 (the ratio was determined by ^{31}P NMR analysis). ^1H NMR (400 MHz, $CDCl_3$): δ 7.75–7.65 (m, 2H), 7.56–7.48 (m, 2H), 7.42–7.40 (m, 3.1H), 7.22–7.07 (m, 6.9H), 7.02–6.99 (m, 2.1H), 6.90 (m, 0.9H), 3.73–3.61 (m, 2.8H), 3.44–3.13 (m, 4H), 2.93–2.76 (m, 6.4H), 2.56–2.41 (m, 1.4H), 2.35–2.32 (m, 0.9H), 2.08–2.08 (m, 1H), 1.82–1.38 (m, 7.5H), 1.24–1.18 (m, 9.3H), 1.02 (m, 2.7H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.52, 172.45, 147.3, 145.5, 141.1, 141.0, 136.5 (J_{C-P} = 8.2 Hz), 136.1 (J_{C-P} = 5.0 Hz) , 135.91, 135.0 (J_{C-P} = 12.0 Hz), 134.68, 134. 61, 134.3 (J_{C-P} = 4.1 Hz), 131.29, 131.25, 131.2,131.13,131.06, 131.0, 130.93, 130.85, 130.48, 130.46, 130.4, 130.3, 130.2 (J_{C-P} = 9.4 Hz), 128.8, 128.6 (J_{C-P} = 11.9 Hz), 128.03, 128.00, 127.95, 127.91, 127.88, 127.8, 126.88, 126.84, 126.7 (J_{C-P} = 2.2 Hz), 123.91, 123.88, 123.7, 60.2, 59.6,, 59.0, 47.7, 46.4, 46.0, 45.9, 45.8, 42.6, 42.5, 42.40, 42.35, 42.22, 42.15, 40.6 (J_{C-P} = 56.1 Hz), 40.1, 38.3, 37.6, 34.0 (J_{C-P} =58.5 Hz), 33.3, 30.2, 25.8, 23.92, 23.86, 19.4, 19.1,19.0, 18.9, 18.7; ^{31}P NMR (162 MHz, $CDCl_3$): δ 40.0, 39.9, 36.42, 36.38; ESI-HRMS: Calcd for $C_{44}H_{53}N_2NaO_2PS^+$ $[M+Na]^+$ 727.3458, found 727.3429.

N-(diphenyl((2-phenyloxiran-2-yl)methyl)-l5-phosphaneylidene)-4-methylbenzenesu-lfonamide（D1)



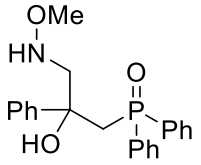
White solid; 63 mg, 65% yield; R_f = 0.3 (1:1 petroleum ether/ethyl acetate); ^1H NMR (400 MHz, $CDCl_3$): δ 7.71–7.66 (m, 2H), 7.55–7.39 (m, 7H), 7.34–7.26 (m, 2H), 7.13 (m, 1H), 7.06–7.04 (m, 2H), 7.01–6.94 (m, 3H), 6.87–6.83 (m, 2H), 4.00 (s, 2H), 3.20 (dd, J = 14.8, 8.0 Hz, 1H), 3.03 (t, J = 14.4 Hz, 1H), 2.30 (s, 3H); ^{13}C NMR (400 MHz, $CDCl_3$): δ 142.81, 139.0, 138.4, 138.3, 133.5 (J_{C-P} = 101.6 Hz), 132.0 (J_{C-P} = 2.7 Hz), 132.6 (J_{C-P} = 3.0 Hz), 131.3 (J_{C-P} = 100.2 Hz), 130.9 (J_{C-P} = 9.8 Hz), 130.3 (J_{C-P} = 9.3 Hz), 129.2, 128.7 (J_{C-P} = 11.8 Hz), 128.5 (J_{C-P} = 12.1 Hz), 127.7, 127.4, 126.9 (J_{C-P} = 12.6 Hz), 69.3 (J_{C-P} = 8.5 Hz), 65.1 (J_{C-P} = 5.1 Hz), 37.8 (J_{C-P} = 69.2 Hz), 21.40; ^{31}P NMR (162 MHz, $CDCl_3$): δ 31.8; ESI-HRMS: Calcd for $C_{28}H_{27}NO_3PS^+$ $[M+H]^+$ 488.1444, found 488.1440.

diphenyl(2-phenylallyl)phosphine oxide (E1)



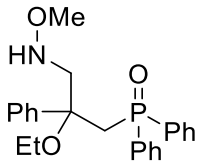
White solid; 55mg, 87% yield; R_f = 0.1 (1:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.72–7.68 (m, 4H), 7.48–7.44 (m, 2H), 7.41–7.36 (m, 4H), 7.28–7.26 (m, 2H), 7.22–7.17 (m, 3H), 5.40 (d, J = 4.8 Hz, 1H), 5.25 (d, J = 4.4 Hz, 1H), 3.56 (d, J = 14.0, 2H); ^{13}C NMR (400 MHz, $CDCl_3$): δ 141.4 ($J_{C\text{-}P}$ = 3.9 Hz), 138.6 ($J_{C\text{-}P}$ = 8.7 Hz), 132.5 ($J_{C\text{-}P}$ = 98.8 Hz), 131.6 ($J_{C\text{-}P}$ = 2.6 Hz), 131.1 ($J_{C\text{-}P}$ = 9.3 Hz), 128.4 ($J_{C\text{-}P}$ = 11.6 Hz), 128.1, 127.4, 126.3, 118.1 ($J_{C\text{-}P}$ = 8.8 Hz), 37.0 ($J_{C\text{-}P}$ = 66.7 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 29.3; ESI-HRMS: Calcd for $C_{21}H_{20}OP^+$ $[M+H]^+$ 319.1247, found 319.1234.

(2-hydroxy-3-(methoxyamino)-2-phenylpropyl)diphenylphosphine oxide (F1)



White solid; 66 mg, 86% yield; R_f = 0.2 (1:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.71–7.66 (m, 2H), 7.52–7.43 (m, 3H), 7.31–7.25 (m, 5H), 7.17–7.14 (m, 2H), 7.03–6.98 (m, 3H), 6.20 (s, 1H), 6.08 (br, 1H), 3.45 (s, 3H), 3.40 – 3.30 (m, 2H), 3.14 (dd, J = 13.2, 3.2 Hz, 1H), 2.90 (dd, J = 15.2, 6.8 Hz, 1H); ^{13}C NMR (400 MHz, $CDCl_3$): δ 143.5 ($J_{C\text{-}P}$ = 4.2 Hz), 134.1 ($J_{C\text{-}P}$ = 99.2 Hz), 132.3 ($J_{C\text{-}P}$ = 2.7 Hz), 132.0 ($J_{C\text{-}P}$ = 99.5 Hz), 130.9 ($J_{C\text{-}P}$ = 2.8 Hz), 130.3 ($J_{C\text{-}P}$ = 9.9 Hz), 130.1 ($J_{C\text{-}P}$ = 9.4 Hz), 128.7 ($J_{C\text{-}P}$ = 11.6 Hz), 128.0 ($J_{C\text{-}P}$ = 12.0 Hz), 127.8, 126.9, 125.2, 75.8 ($J_{C\text{-}P}$ = 5.5 Hz), 62.6 ($J_{C\text{-}P}$ = 9.7 Hz), 61.3, 38.3 ($J_{C\text{-}P}$ = 70.0 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 33.3; ESI-HRMS: Calcd for $C_{22}H_{25}NO_3P^+$ $[M+H]^+$ 382.1567, found 382.1551.

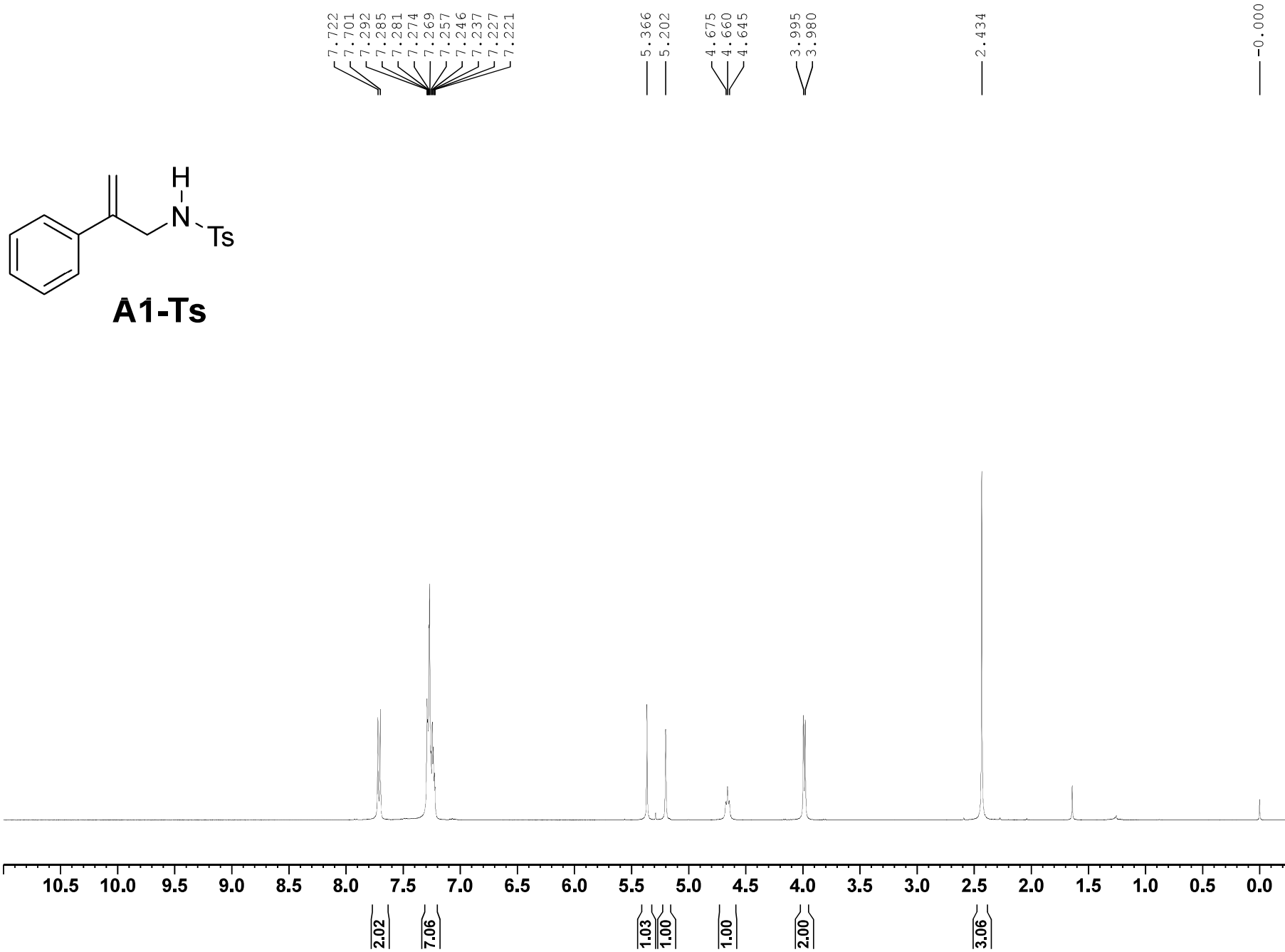
(2-ethoxy-3-(methoxyamino)-2-phenylpropyl)diphenylphosphine oxide (G1)



White solid; 66 mg, 81% yield; R_f = 0.3 (1:1 petroleum ether/ethyl acetate); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.74–7.69 (m, 2H), 7.46–7.38 (m, 5H), 7.32–7.27 (m, 3H), 7.22–7.18 (m, 2H), 7.11–7.02 (m, 3H), 6.24 (s, 1H), 4.19 (d, J = 12.4 Hz, 1H), 3.69 (d, J = 12.8 Hz, 1H),

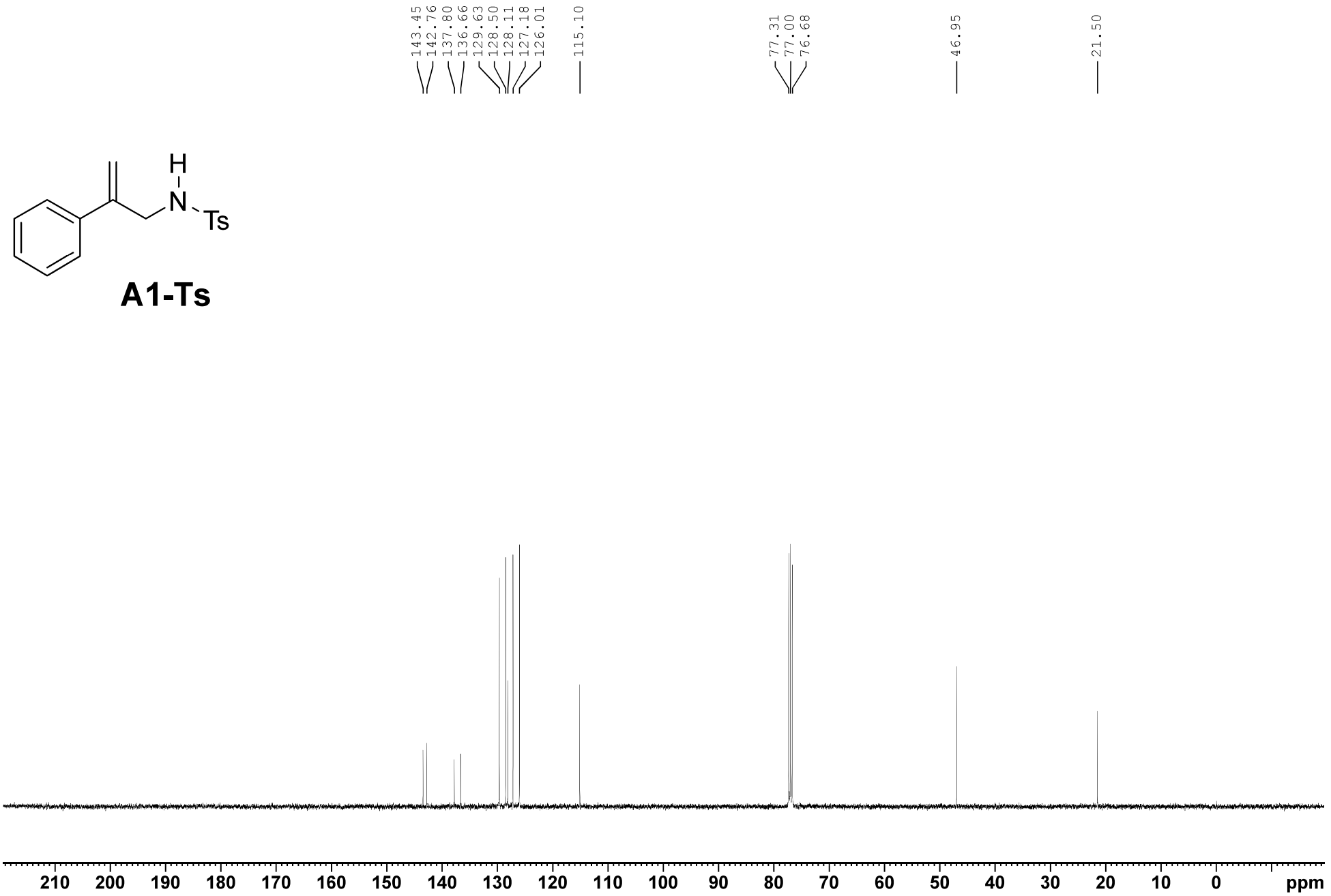
3.57 (s, 3H), 3.33 (dd, J = 14.8, 12.4 Hz, 1H), 3.25–3.18 (m, 1H), 3.00–2.92 (m, 1H), 2.81 (dd, J = 14.8, 10.0 Hz, 1H), 0.94 (t, J = 6.8 Hz, 3H); ^{13}C NMR (400 MHz, $CDCl_3$): δ 141.5 ($J_{C\text{-}P}$ = 4.4 Hz), 135.0 ($J_{C\text{-}P}$ = 100.6 Hz), 133.2 ($J_{C\text{-}P}$ = 99.4 Hz), 131.2 ($J_{C\text{-}P}$ = 2.7 Hz), 130.6 ($J_{C\text{-}P}$ = 2.7 Hz), 130.54 ($J_{C\text{-}P}$ = 9.1 Hz), 130.49 ($J_{C\text{-}P}$ = 9.3 Hz), 128.2 ($J_{C\text{-}P}$ = 11.7 Hz), 128.1, 127.9 ($J_{C\text{-}P}$ = 11.7 Hz), 127.5, 126.4, 78.8, 61.5, 57.2, 53.7, 39.7 ($J_{C\text{-}P}$ = 70.3Hz), 15.0; ^{31}P NMR (162 MHz, $CDCl_3$): δ 26.0; ESI-HRMS: Calcd for $C_{24}H_{29}NO_3P^+$ $[M+H]^+$ 410.1880, found 410.1863.

^{1}H NMR ($CDCl_3$, 400 MHz)



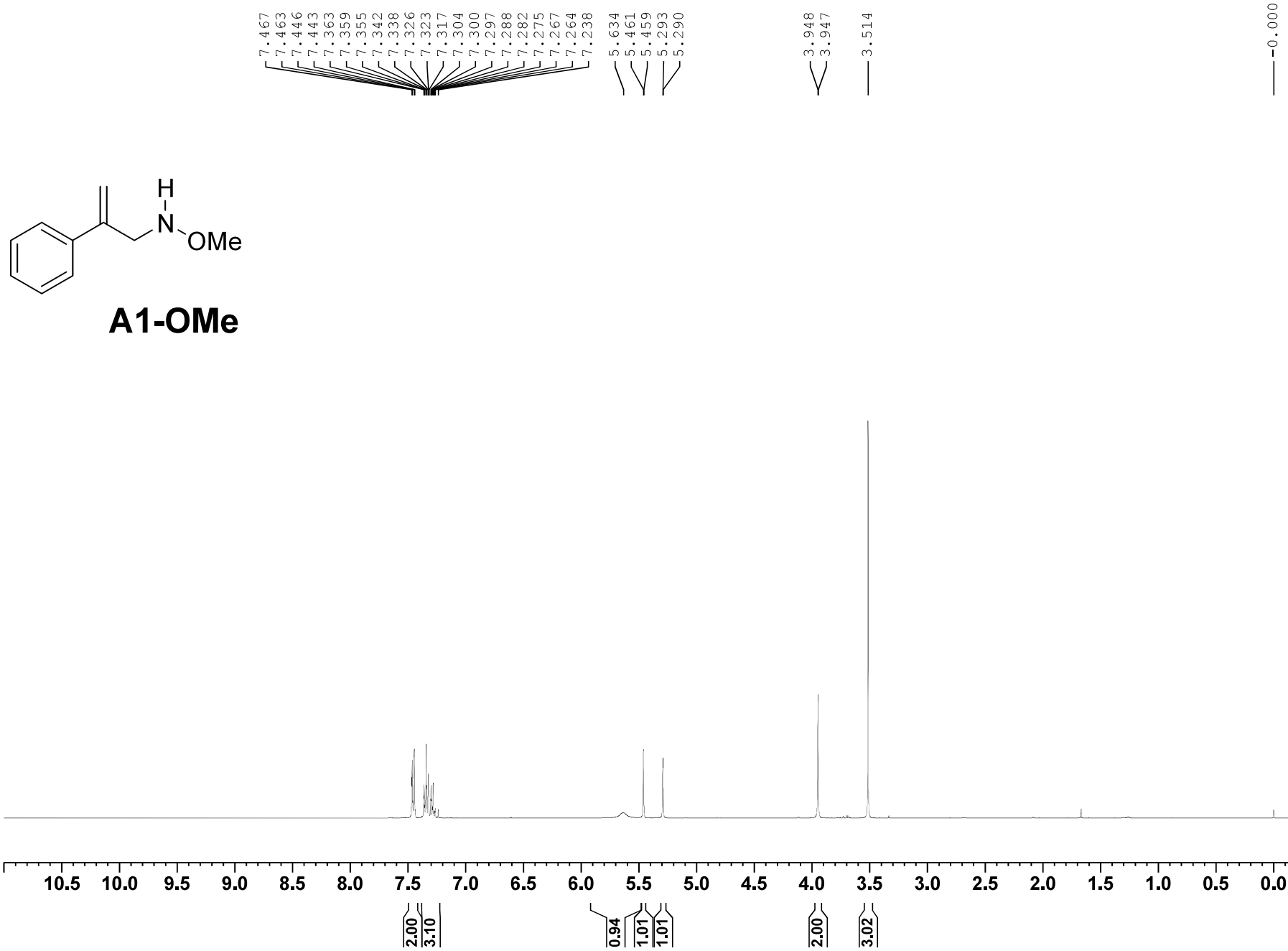
A1-Ts

^{13}C NMR (100 MHz, $CDCl_3$)



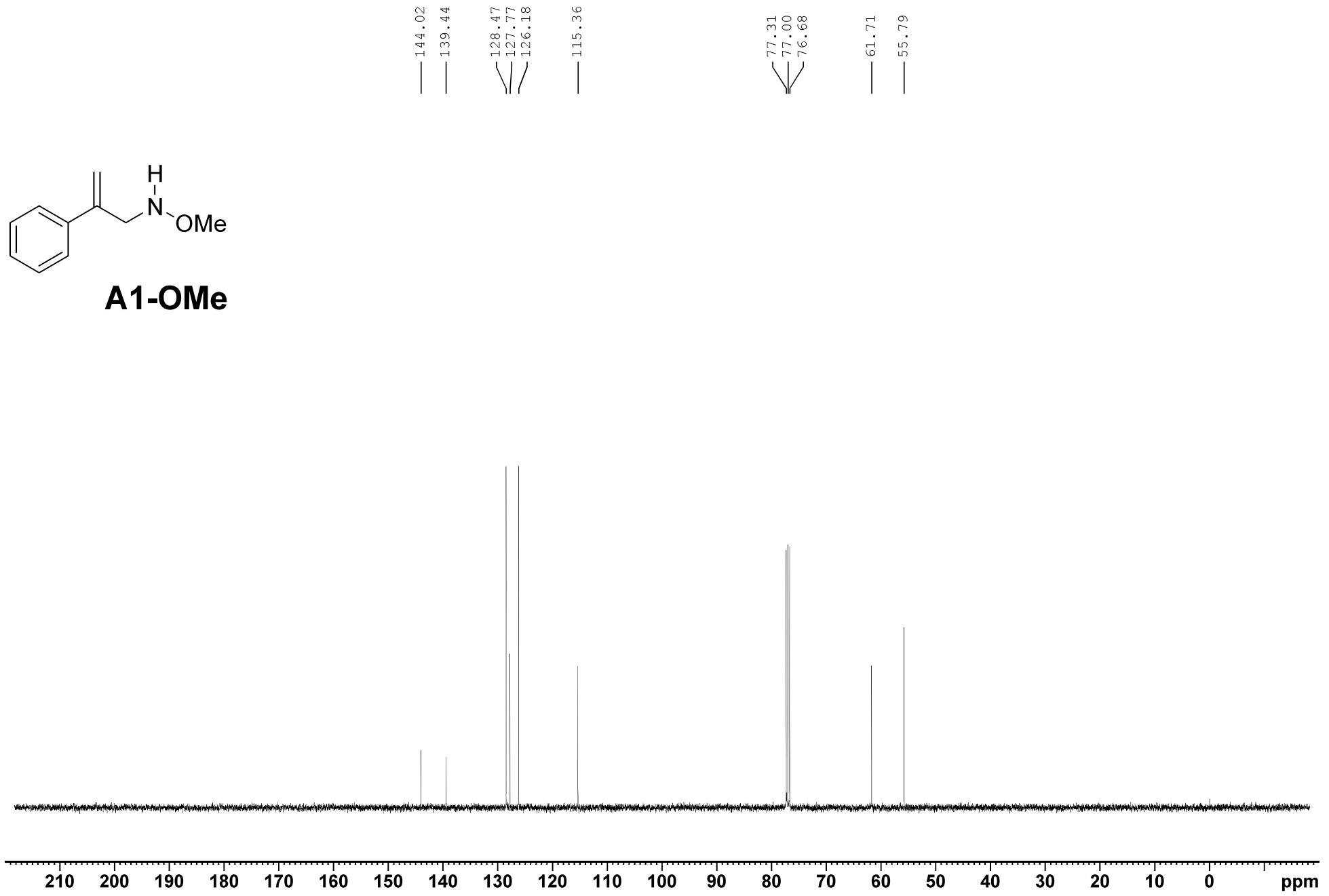
A1-Ts

^{1}H NMR ($CDCl_3$, 400 MHz)



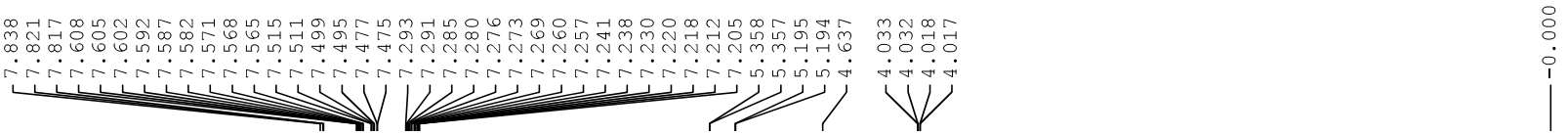
A1-OMe

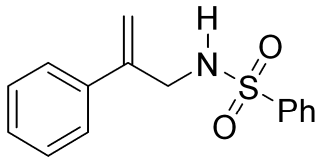
^{13}C NMR (100 MHz, $CDCl_3$)



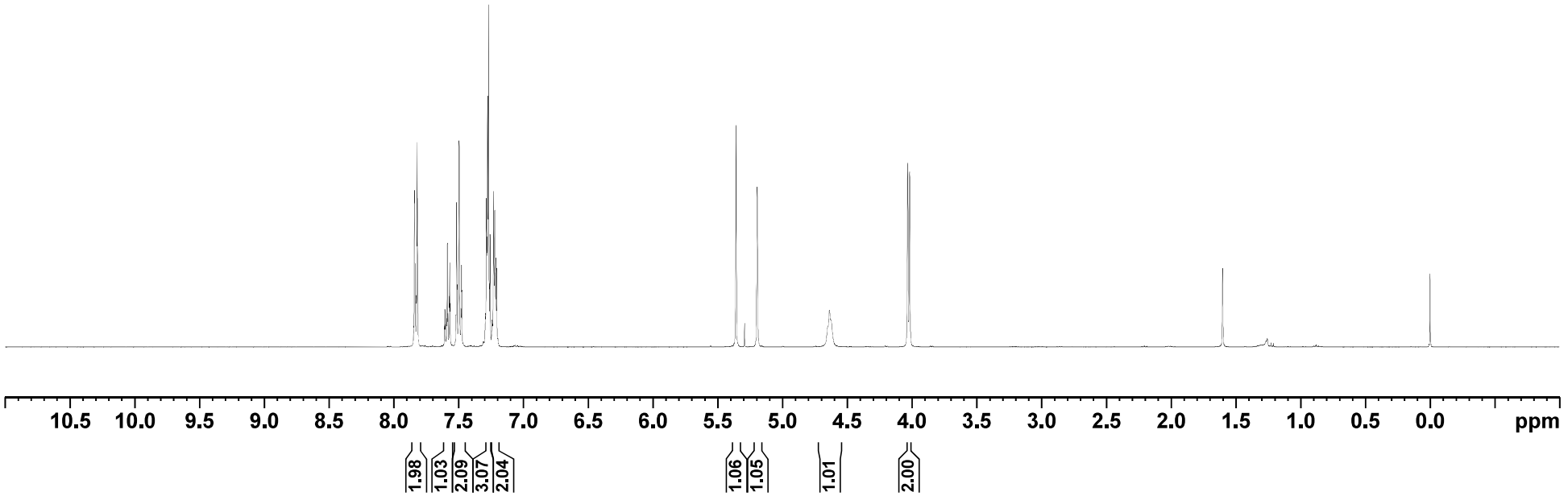
A1-OMe

^{1}H NMR ($CDCl_3$, 400 MHz)

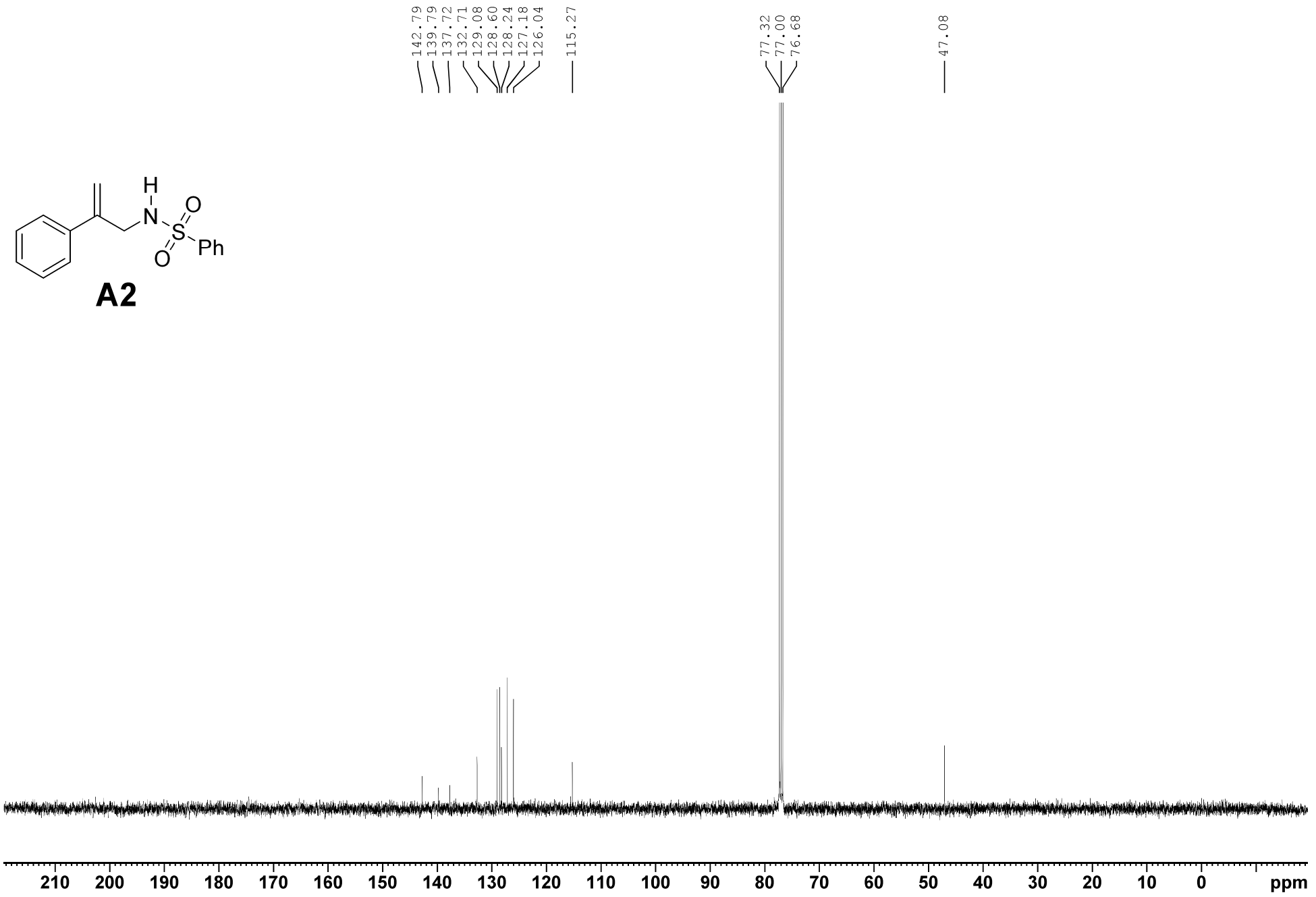




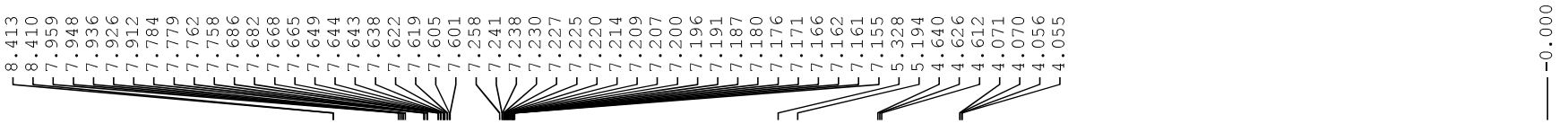
A2

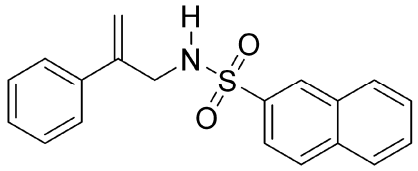


^{13}C NMR (100 MHz, $CDCl_3$)

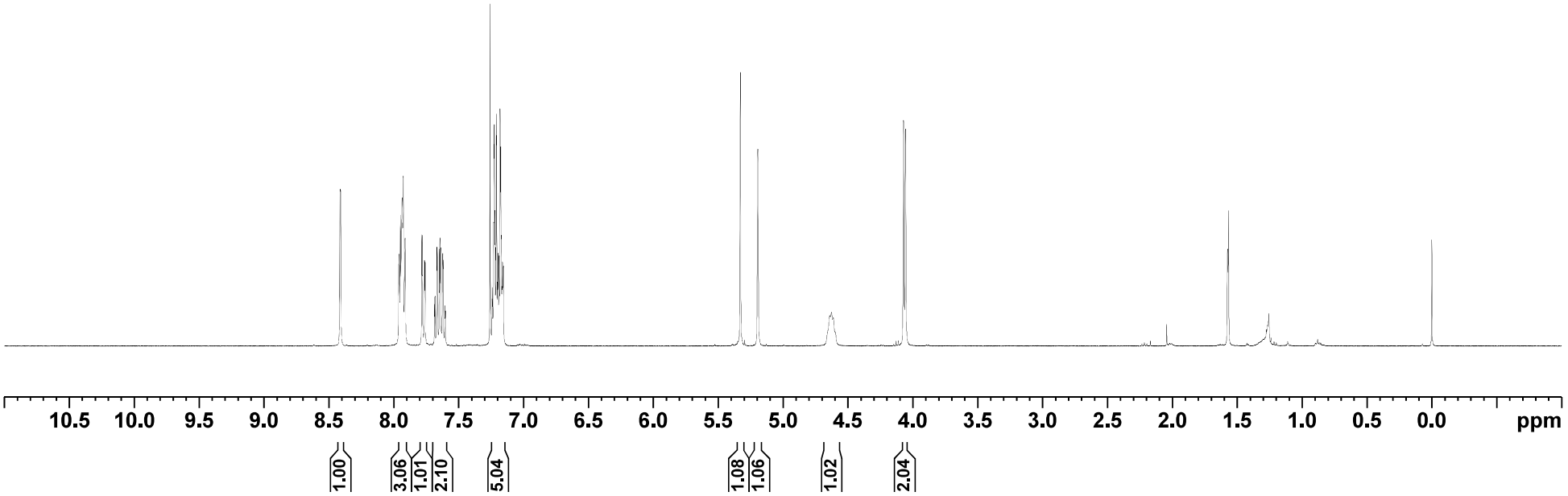


^{1}H NMR ($CDCl_3$, 400 MHz)

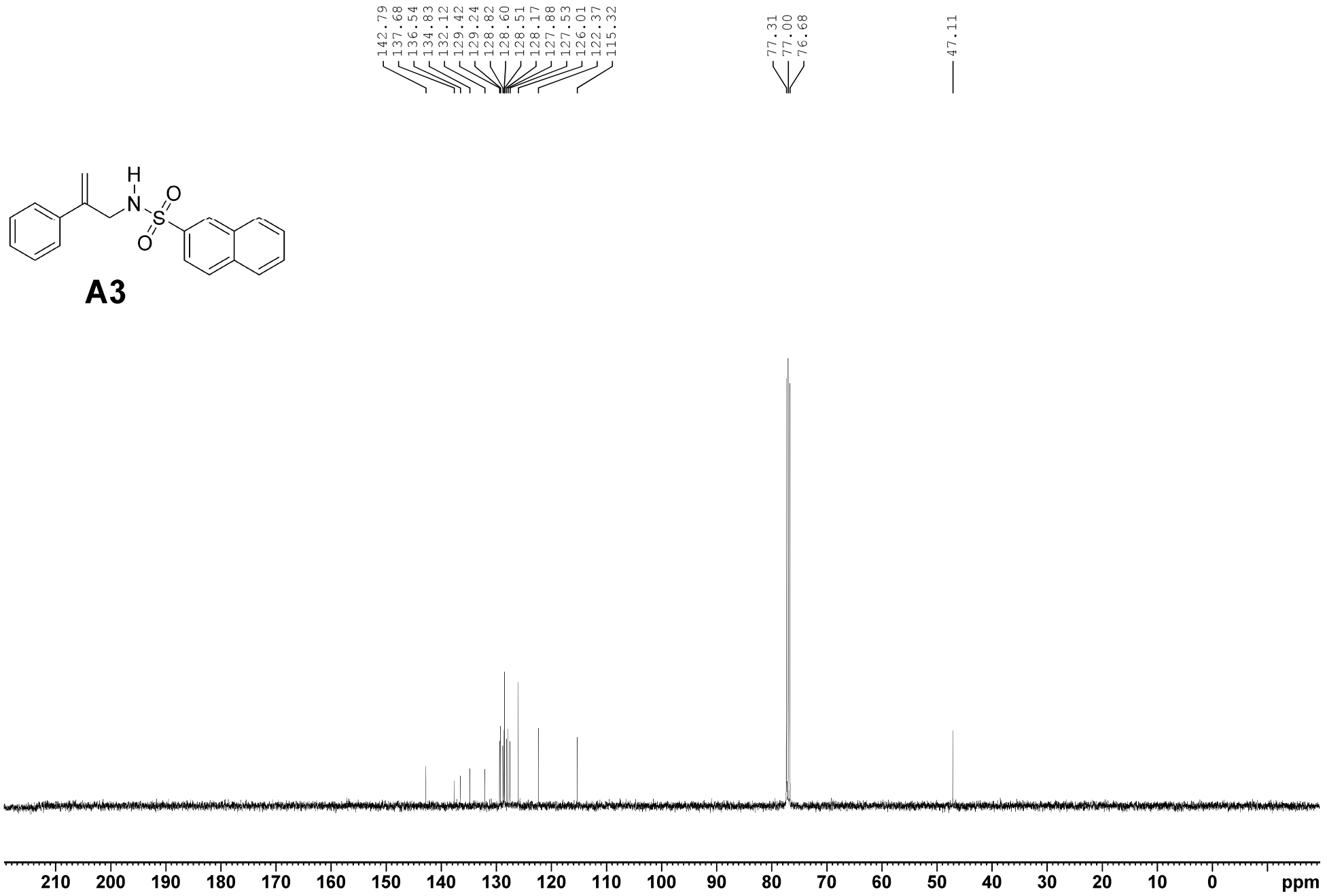




A3

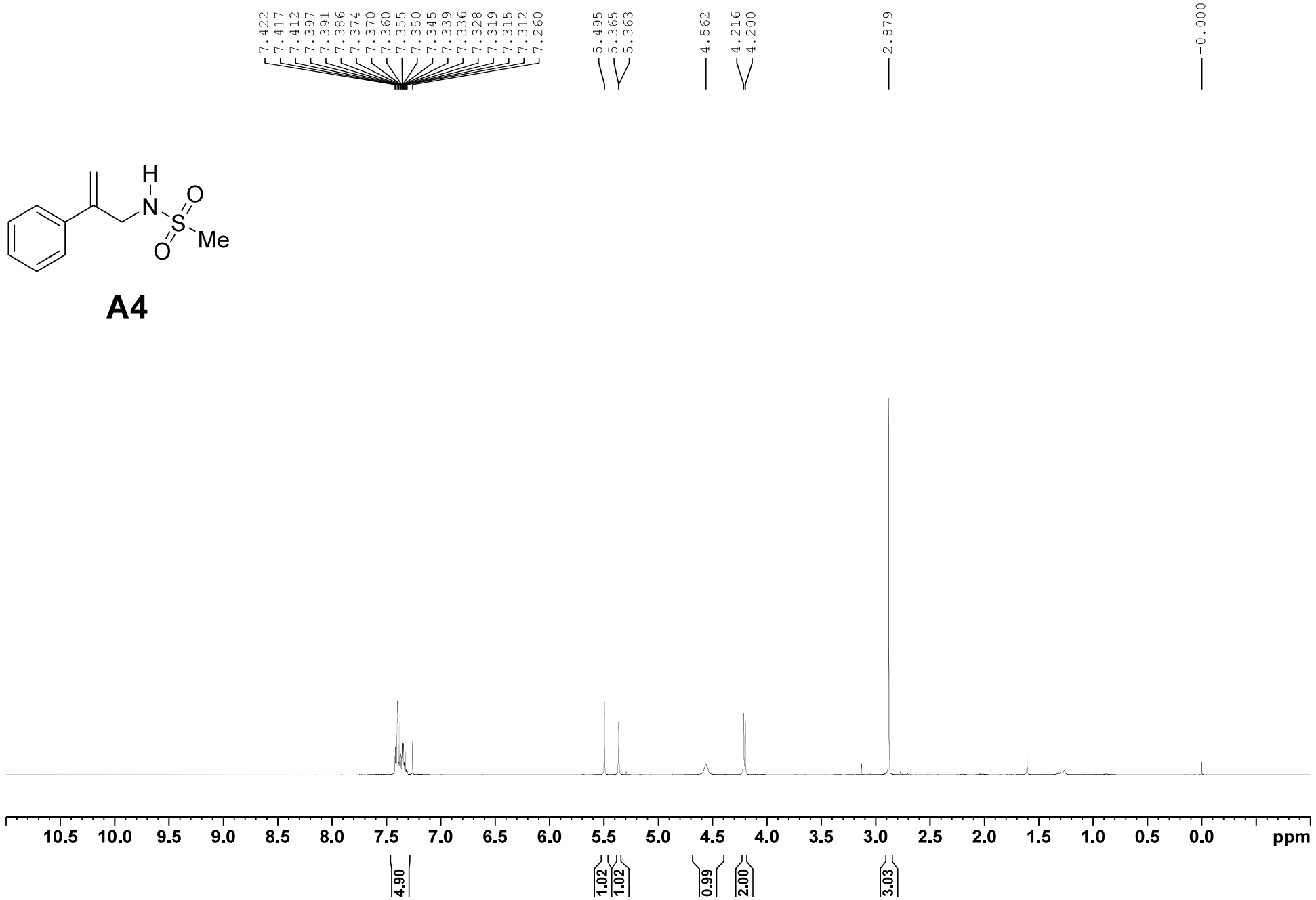


^{13}C NMR (100 MHz, $CDCl_3$)



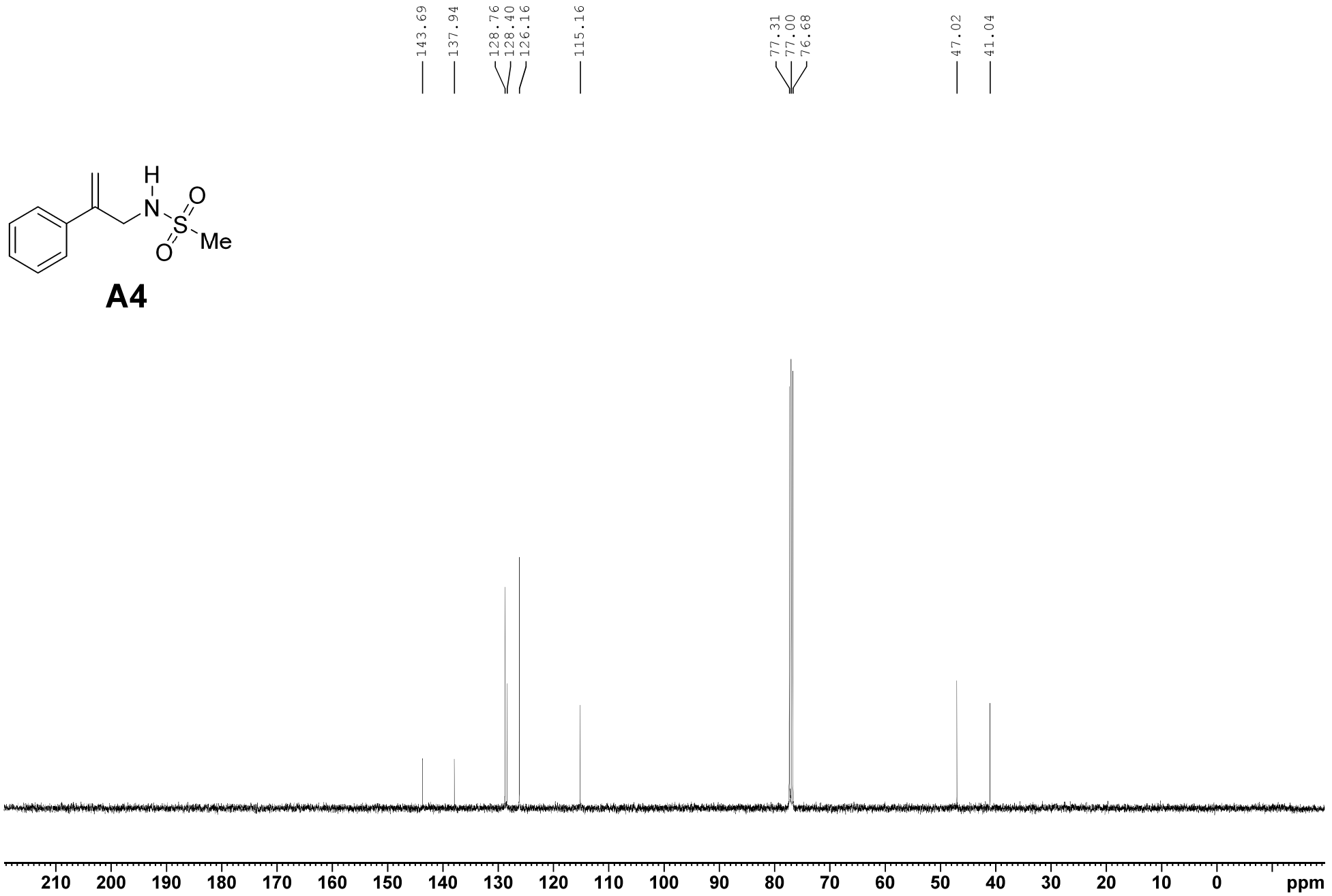
A3

^{1}H NMR ($CDCl_3$, 400 MHz)



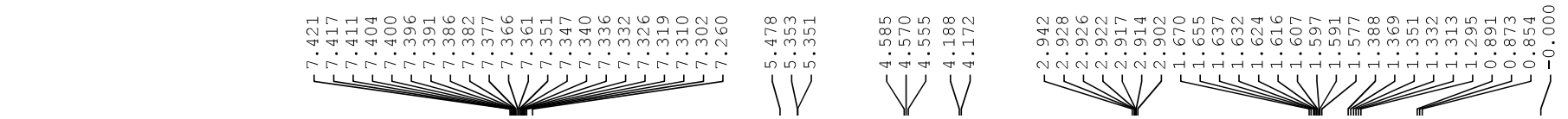
A4

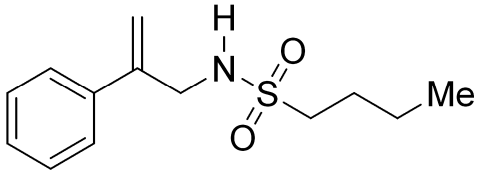
^{13}C NMR (100 MHz, $CDCl_3$)



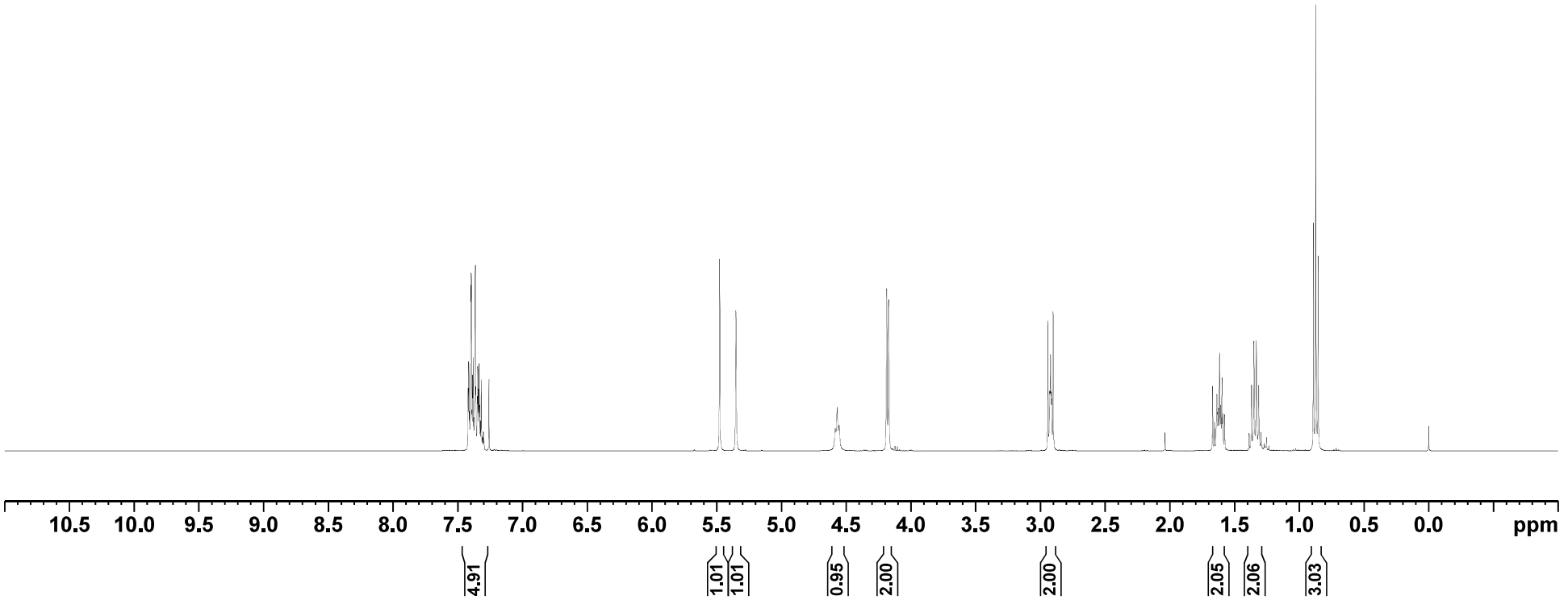
A4

^{1}H NMR ($CDCl_3$, 400 MHz)



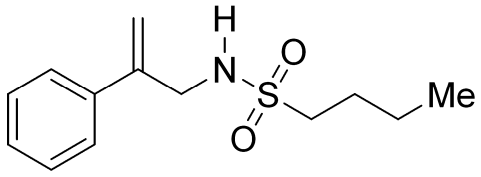


A5

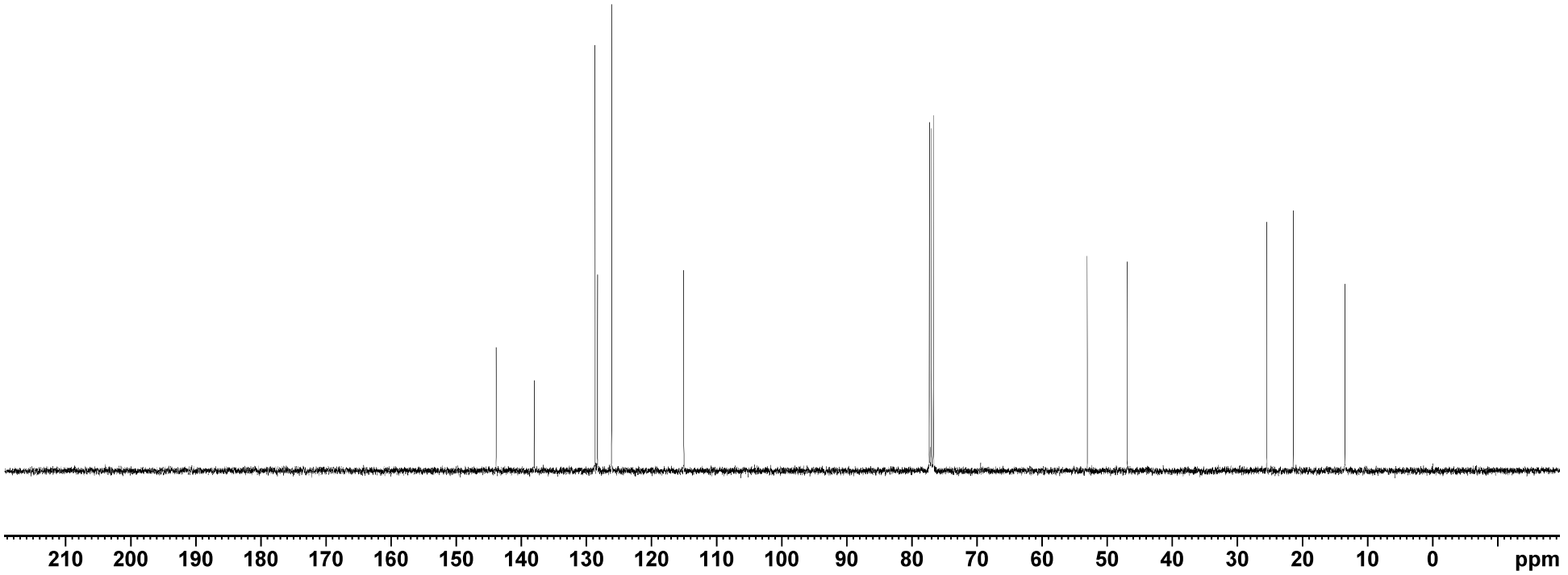


^{13}C NMR (100 MHz, $CDCl_3$)

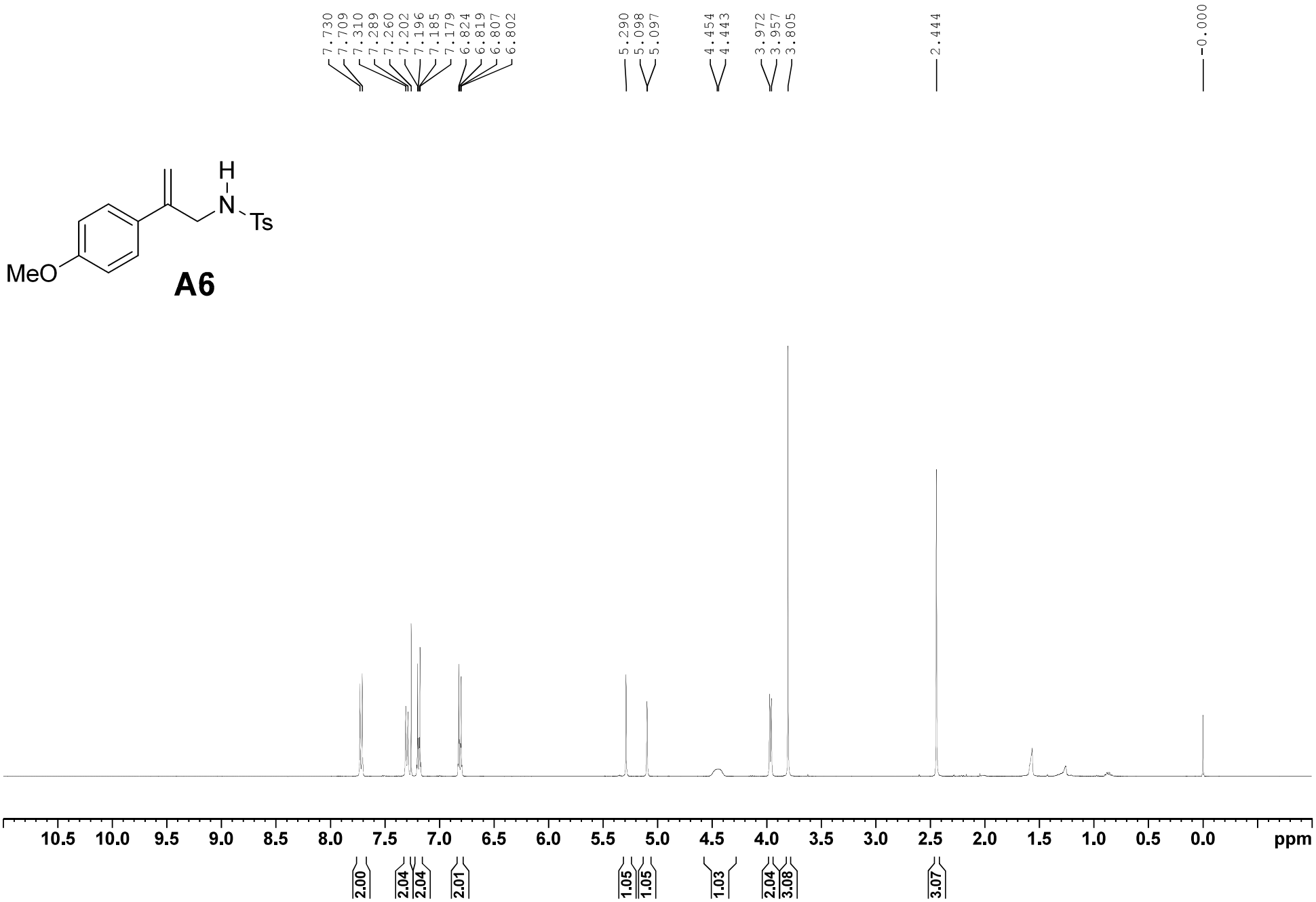
143.87
138.01
128.66
128.29
126.13
115.04
77.31
76.99
76.68
53.05
46.90
25.48
21.41
13.47



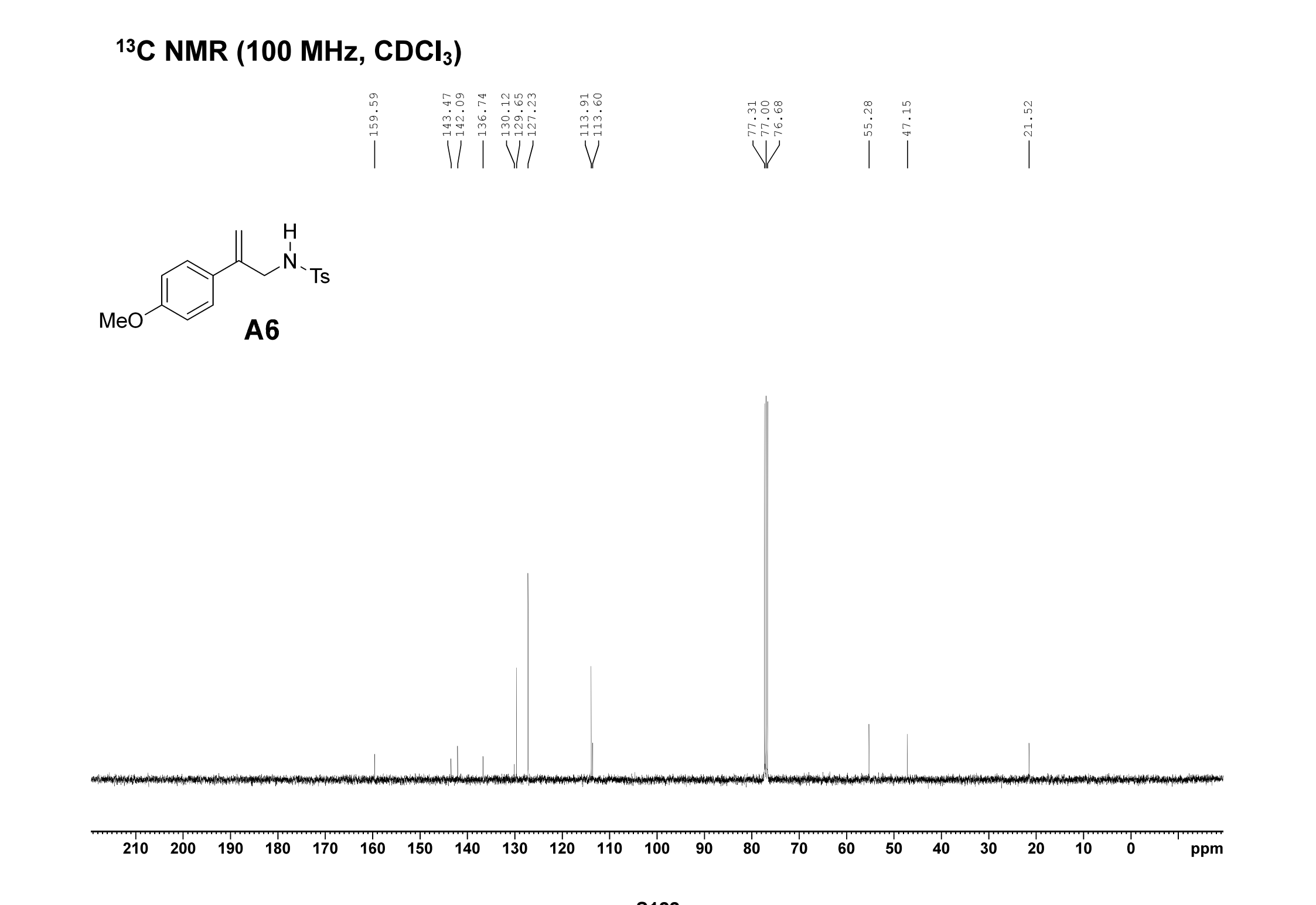
A5



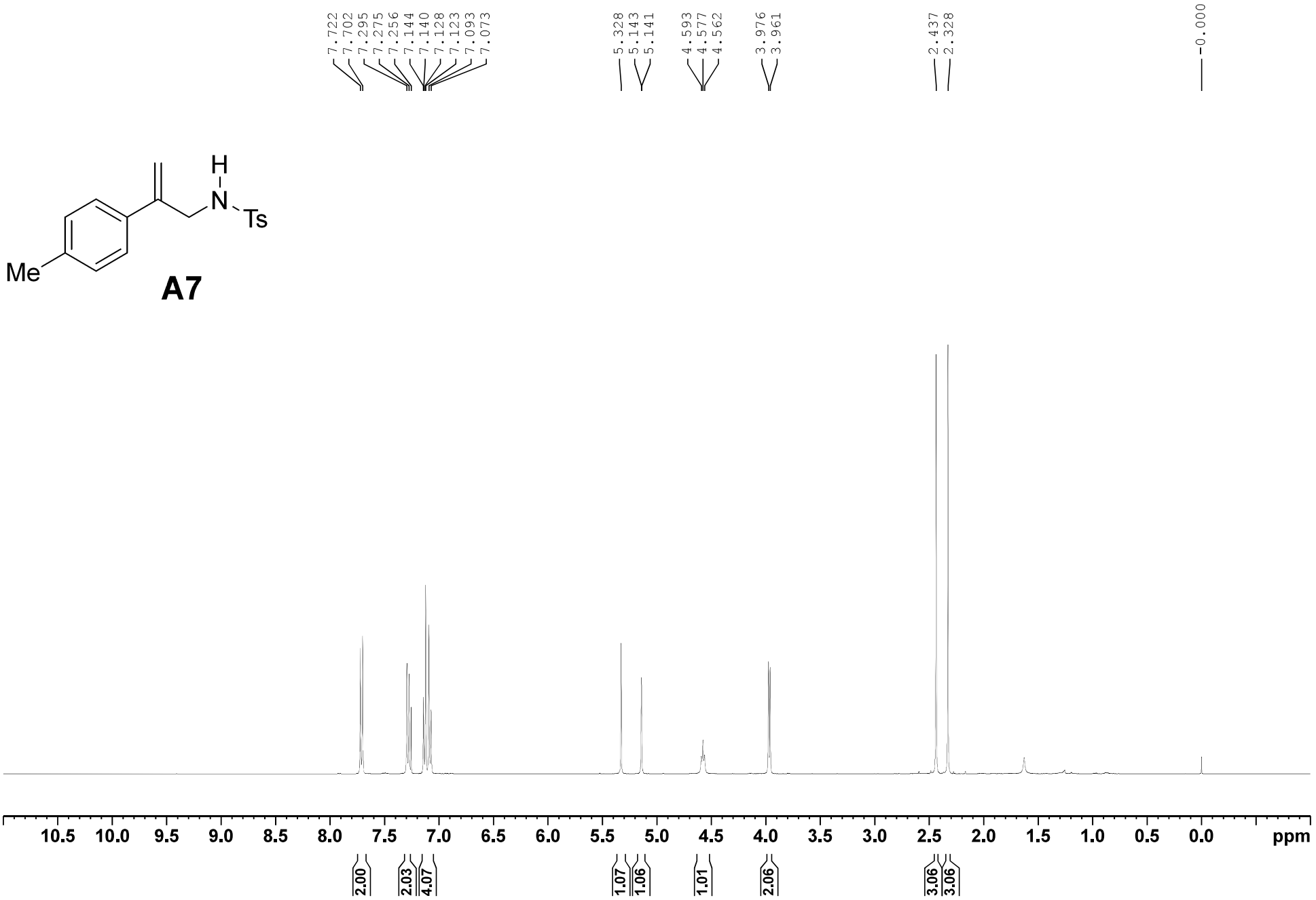
^{1}H NMR ($CDCl_3$, 400 MHz)



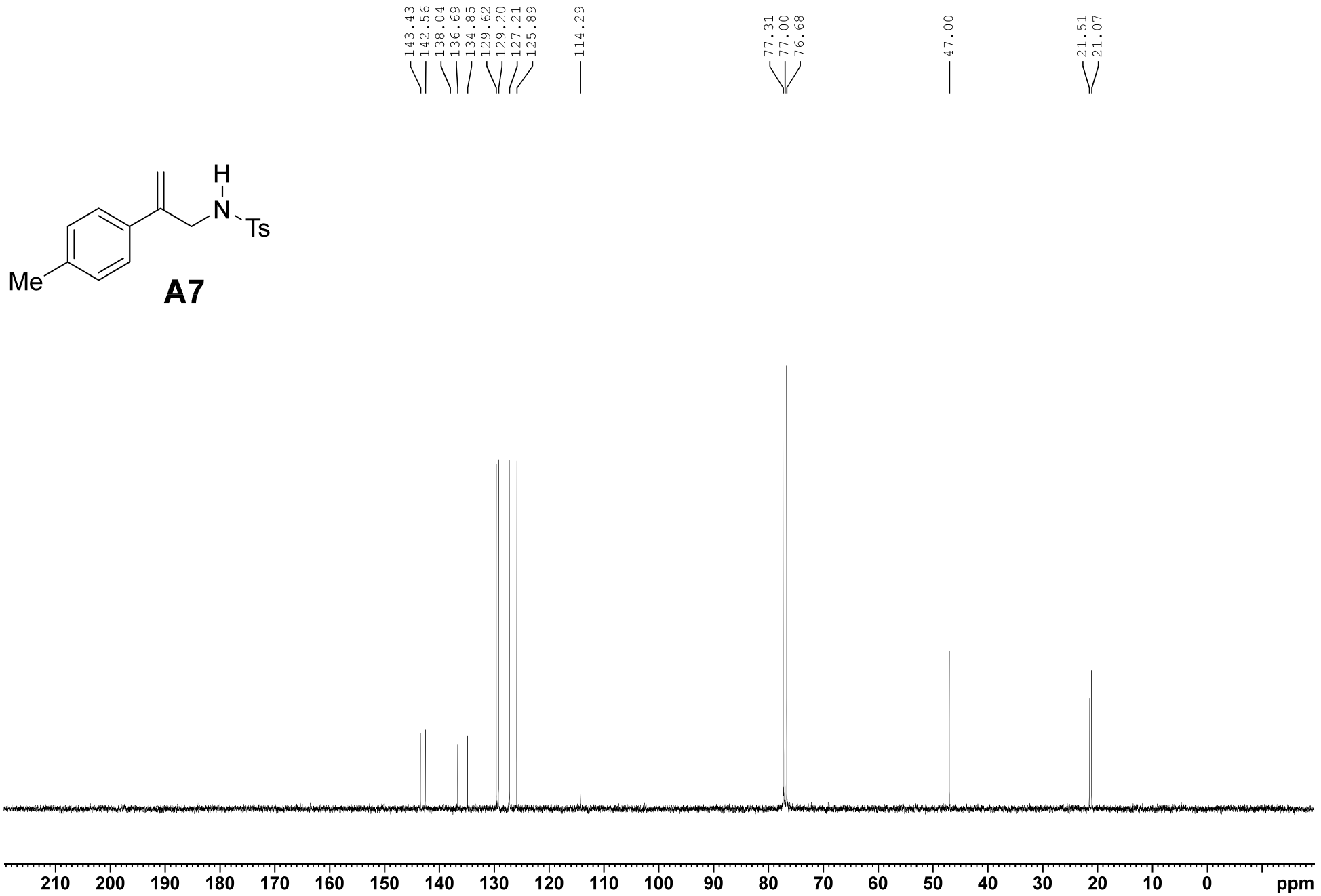
^{13}C NMR (100 MHz, $CDCl_3$)



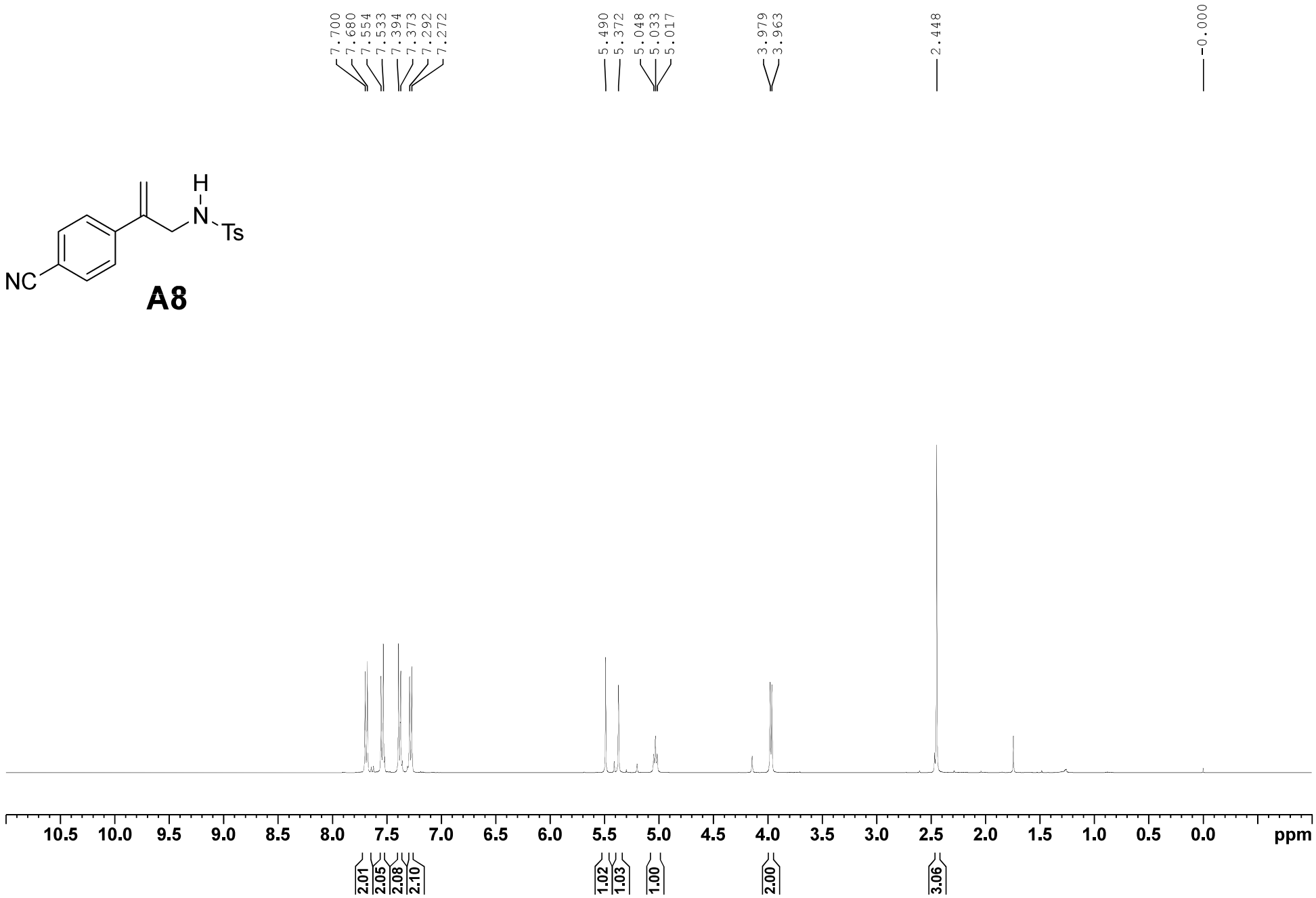
^{1}H NMR ($CDCl_3$, 400 MHz)



^{13}C NMR (100 MHz, $CDCl_3$)



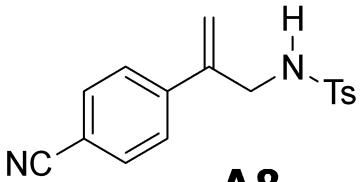
^{1}H NMR ($CDCl_3$, 400 MHz)



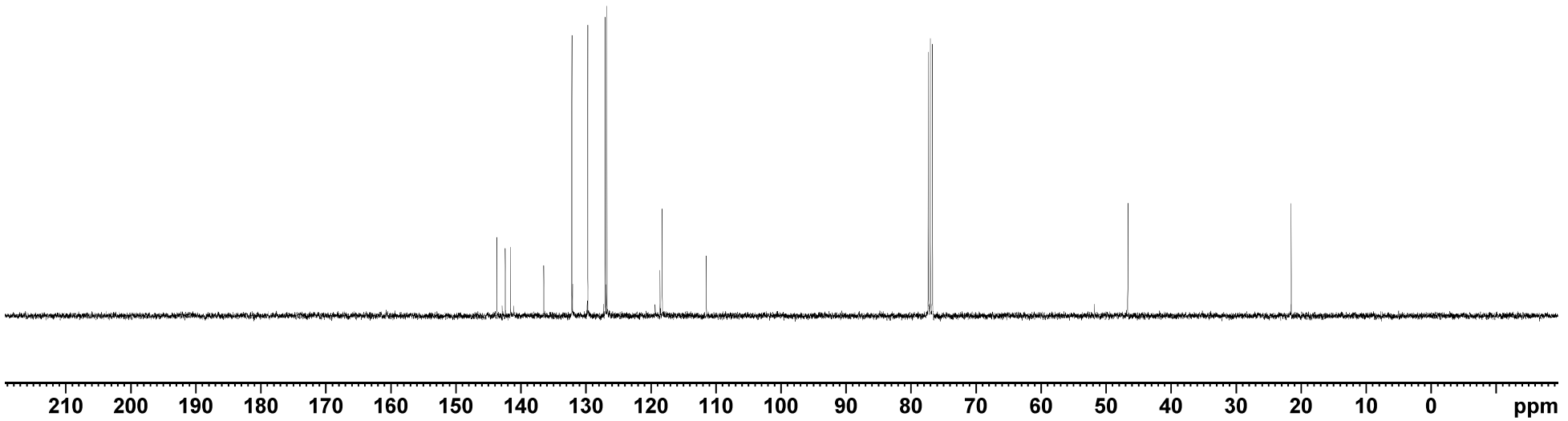
A8

^{13}C NMR (100 MHz, $CDCl_3$)

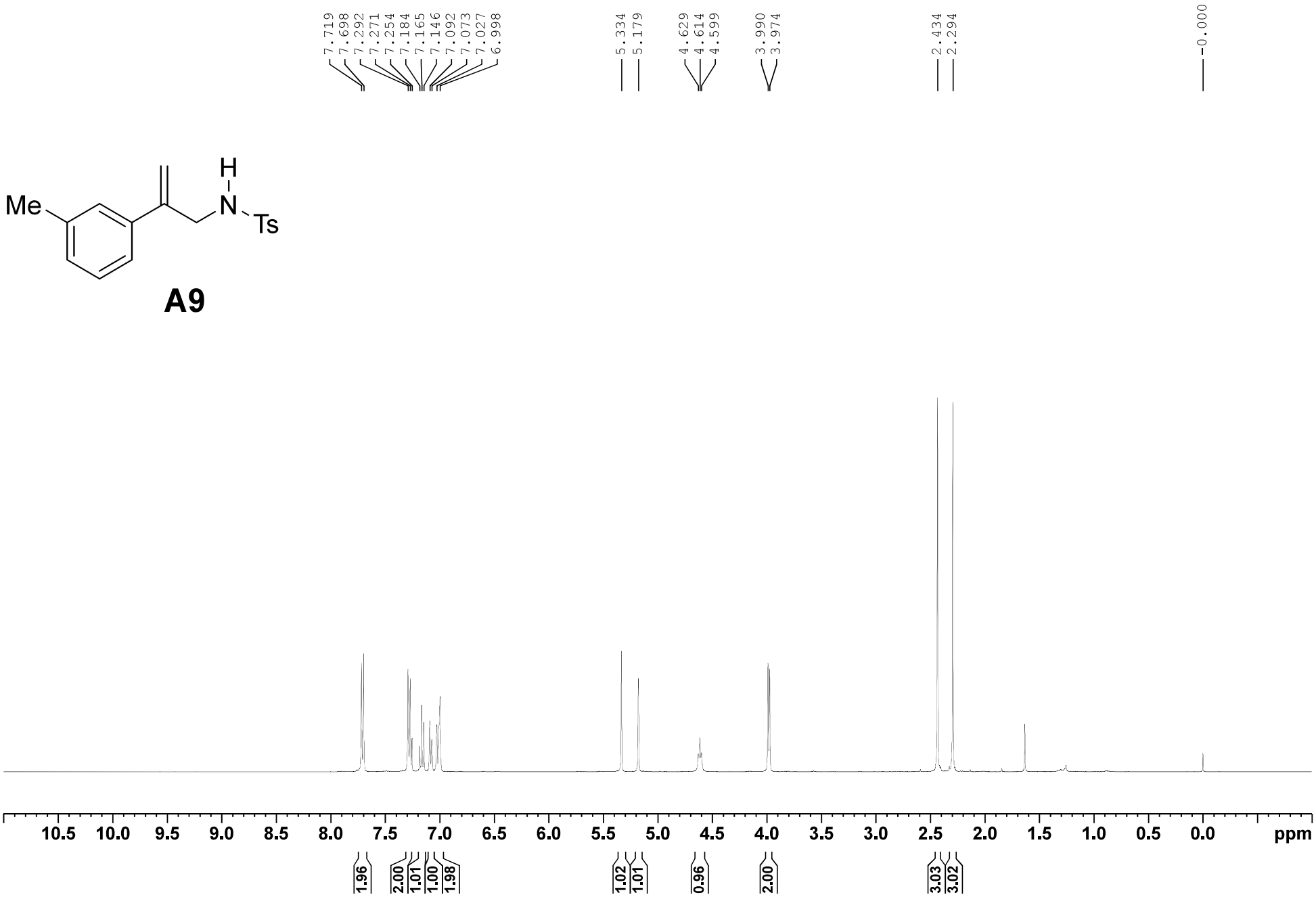
143.70
142.38
141.58
136.47
132.15
129.69
127.04
126.75
118.59
118.24
111.45
77.31
77.00
76.68
46.62
21.48



A8

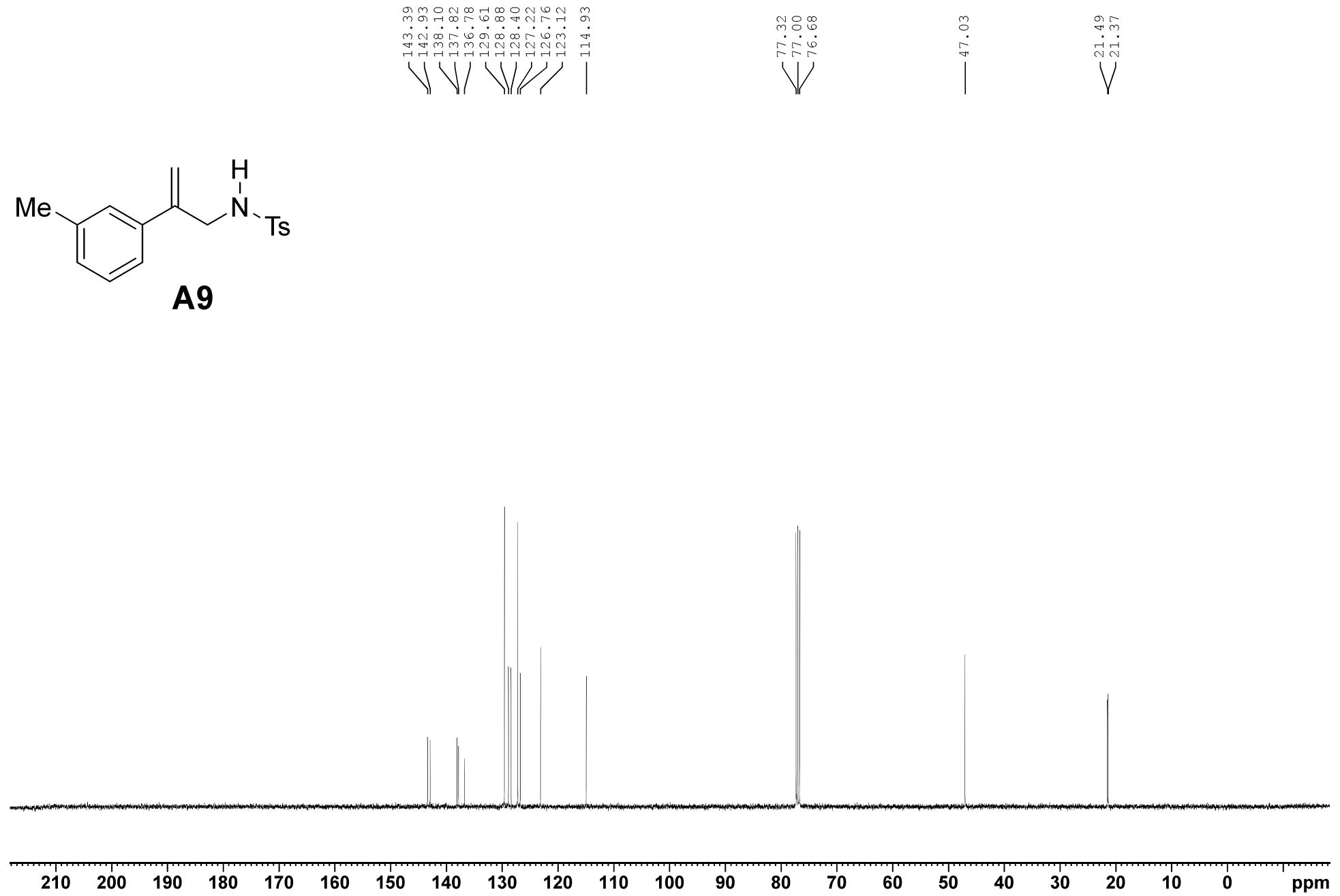


^{1}H NMR ($CDCl_3$, 400 MHz)



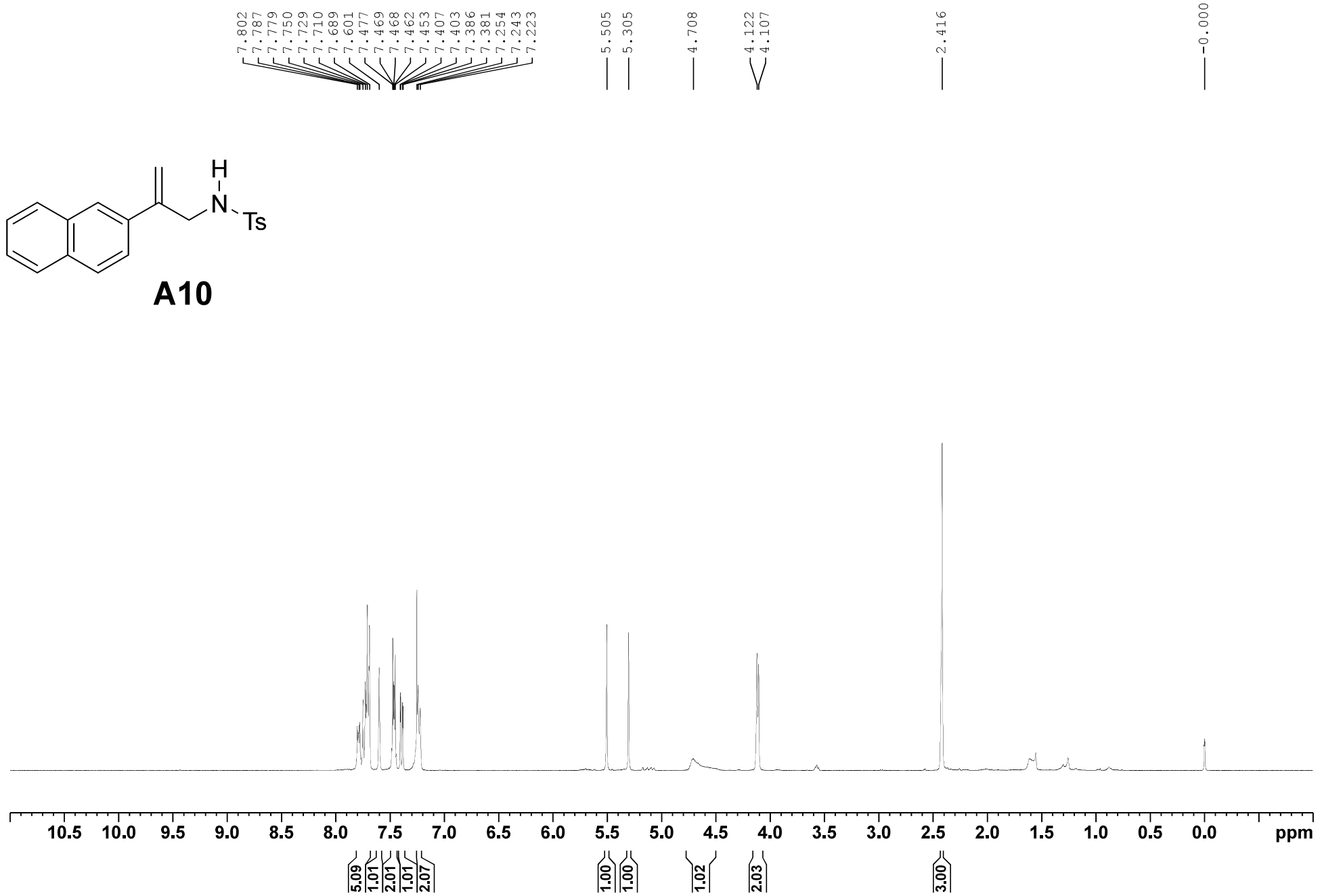
A9

^{13}C NMR (100 MHz, $CDCl_3$)



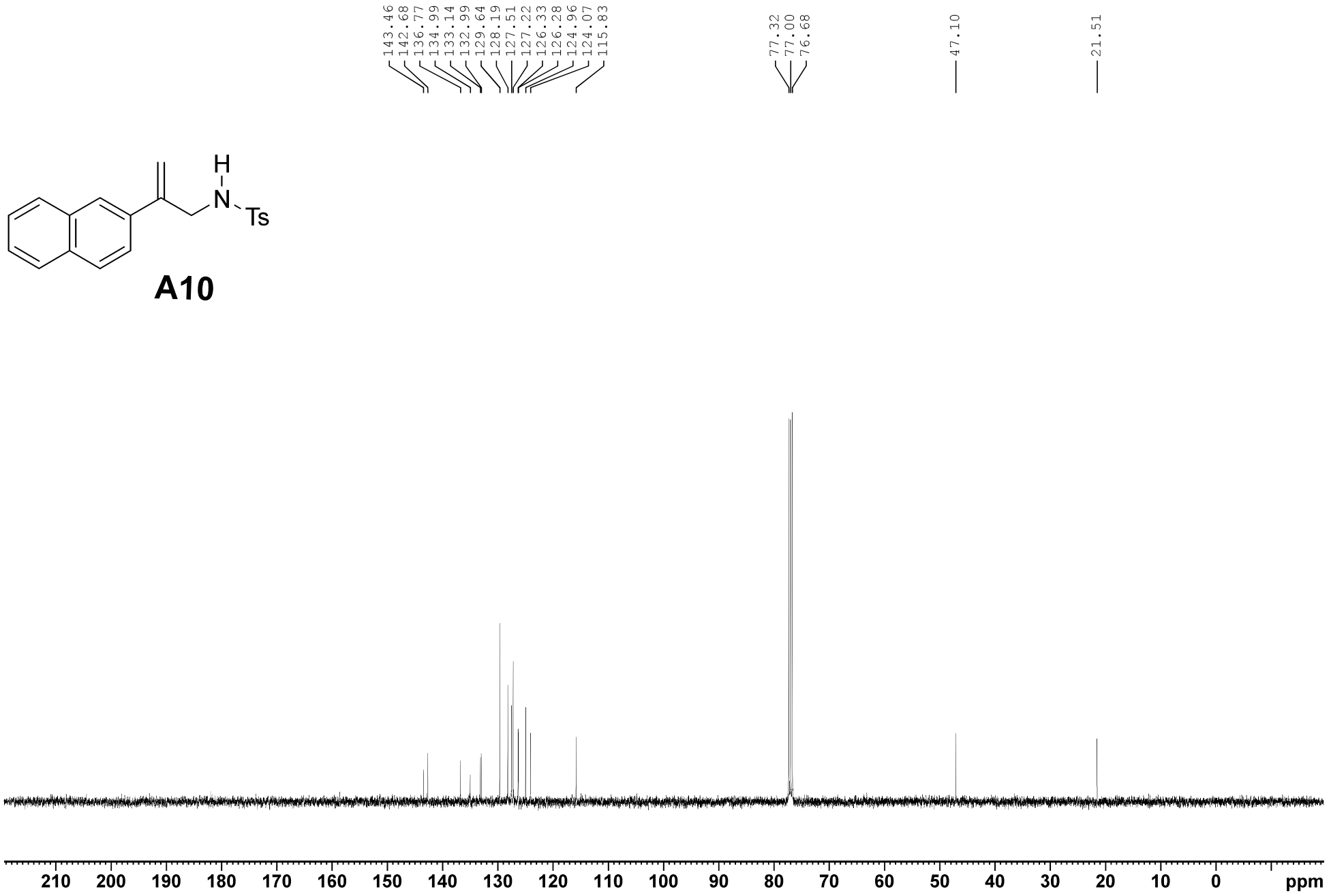
A9

^{1}H NMR ($CDCl_3$, 400 MHz)



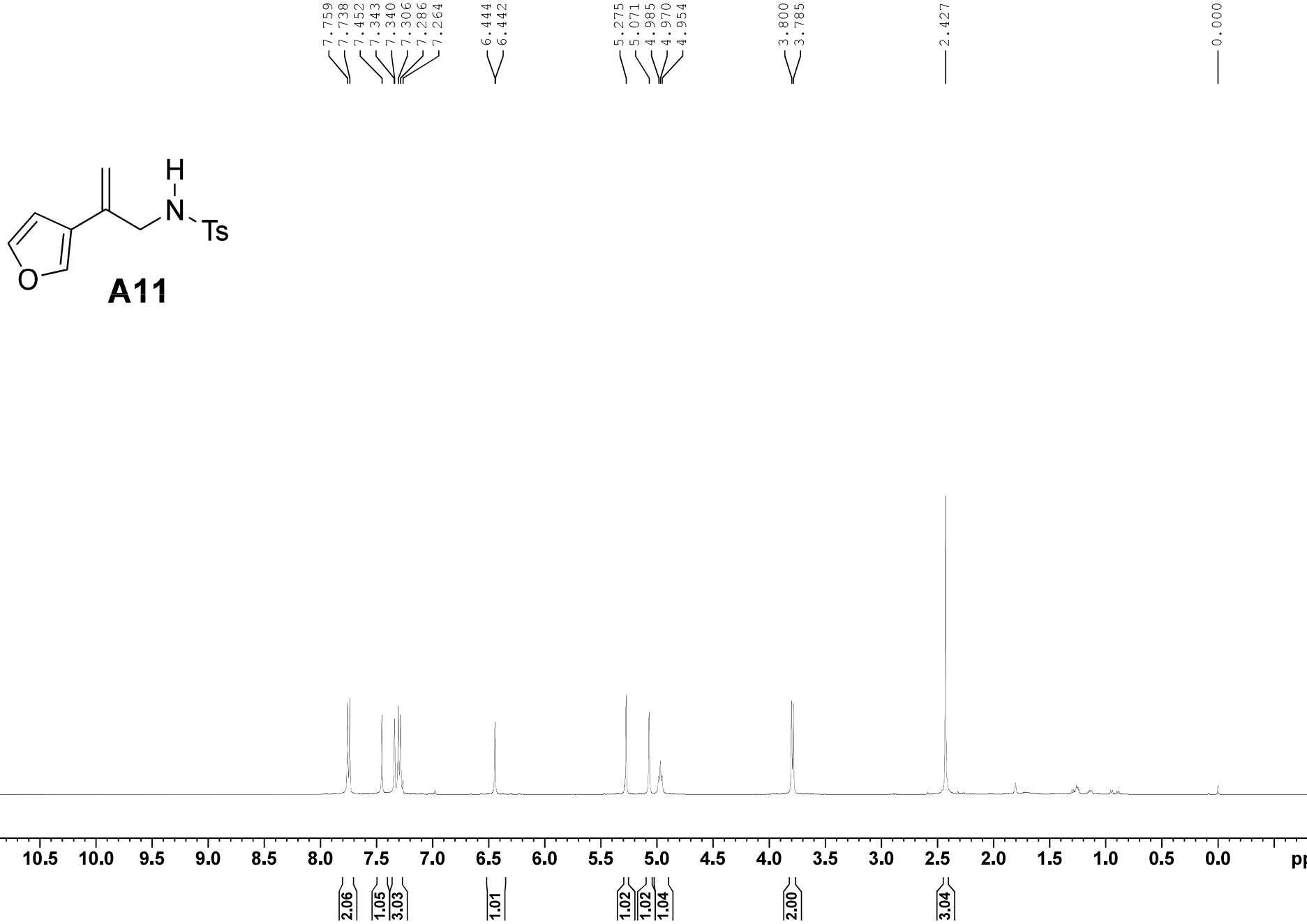
A10

^{13}C NMR (100 MHz, $CDCl_3$)

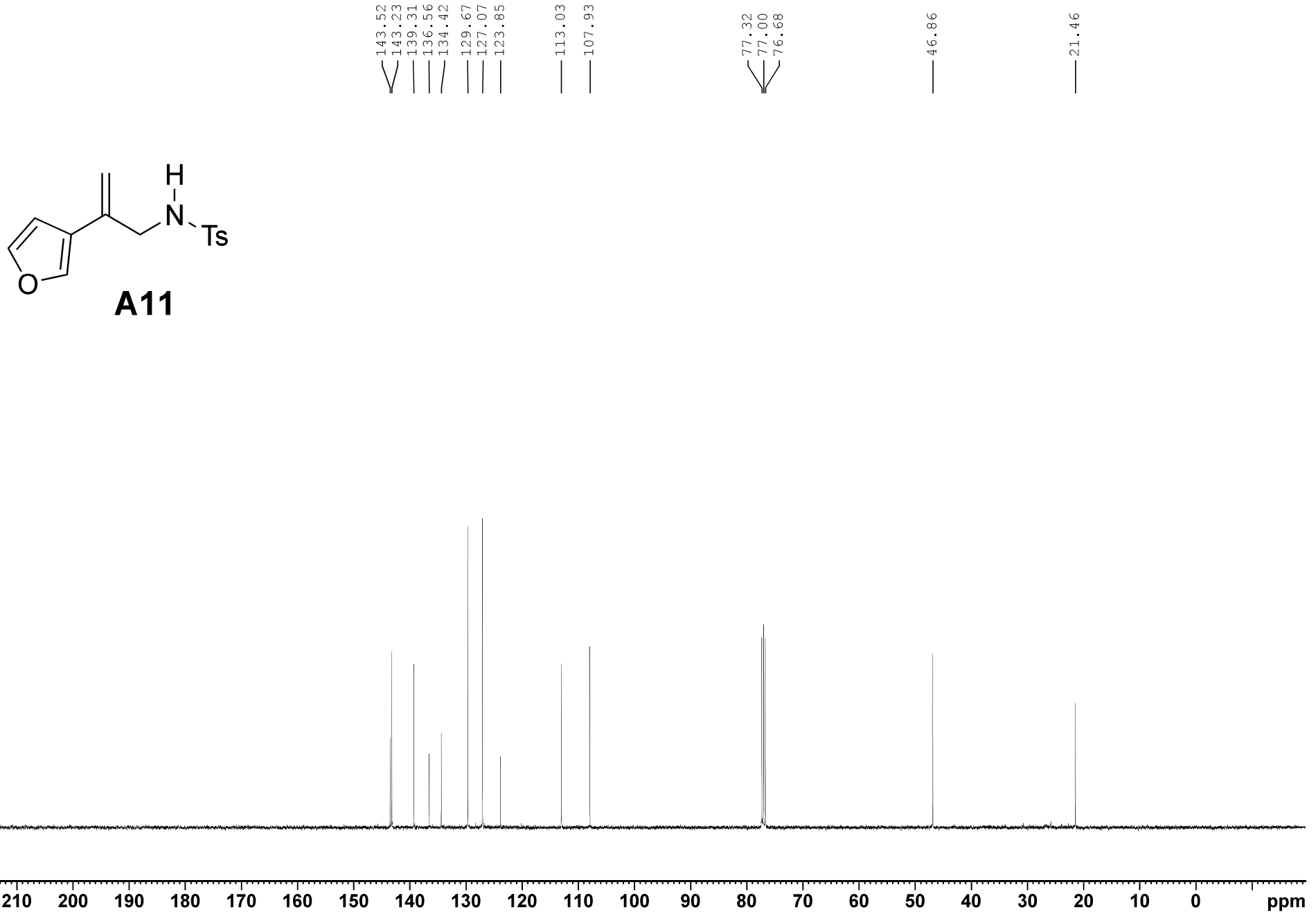


A10

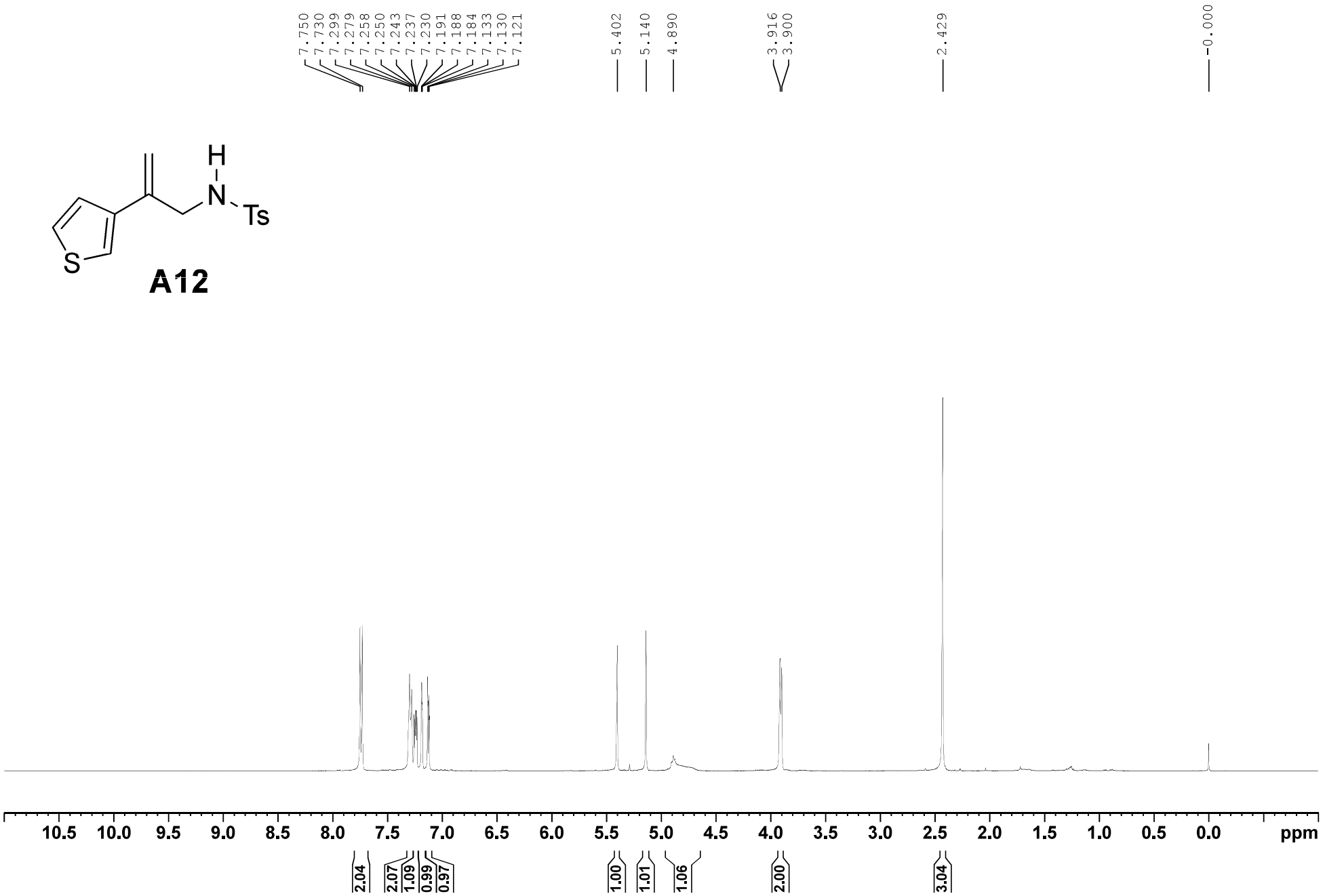
^{1}H NMR ($CDCl_3$, 400 MHz)



^{13}C NMR (100 MHz, $CDCl_3$)

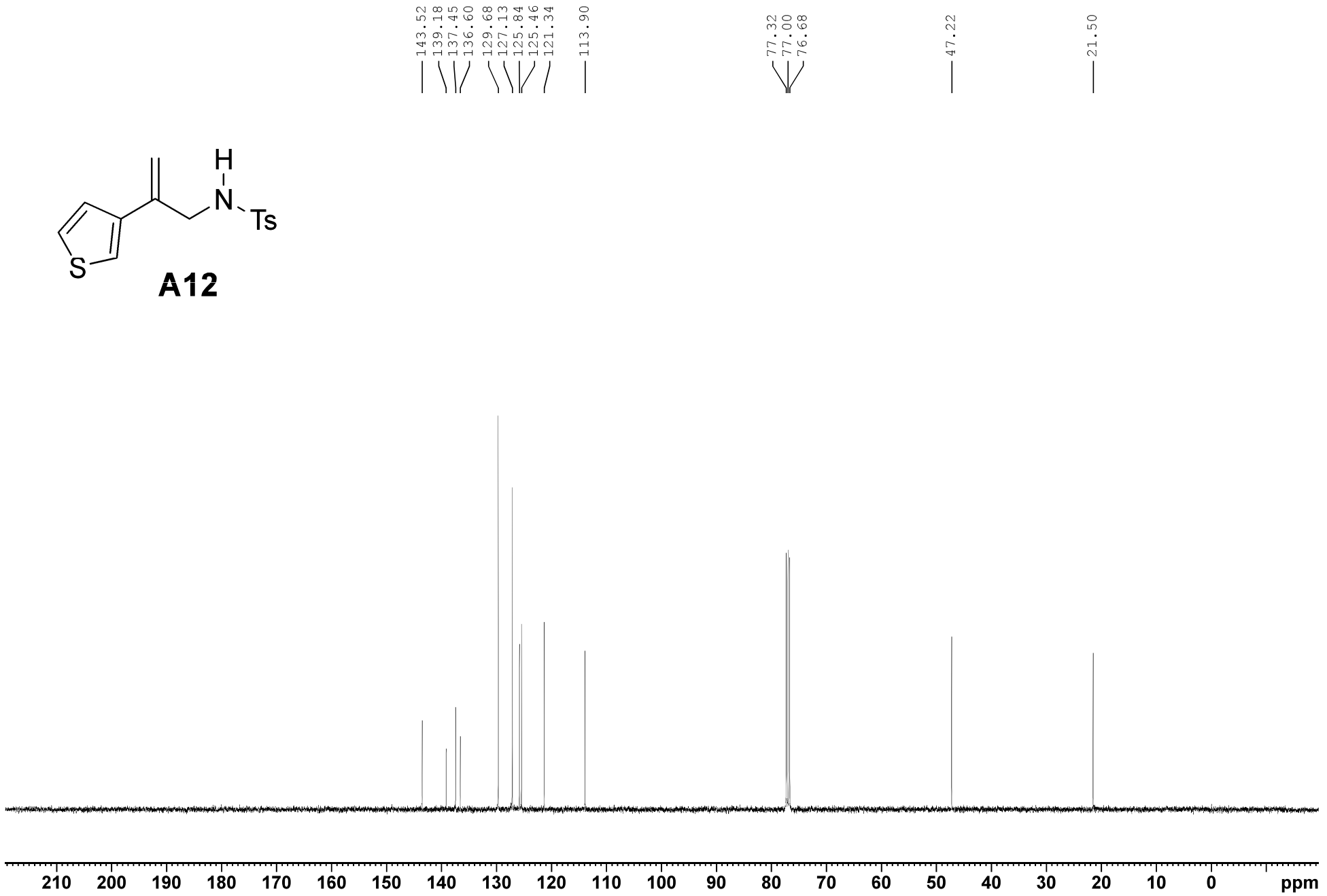


^{1}H NMR ($CDCl_3$, 400 MHz)



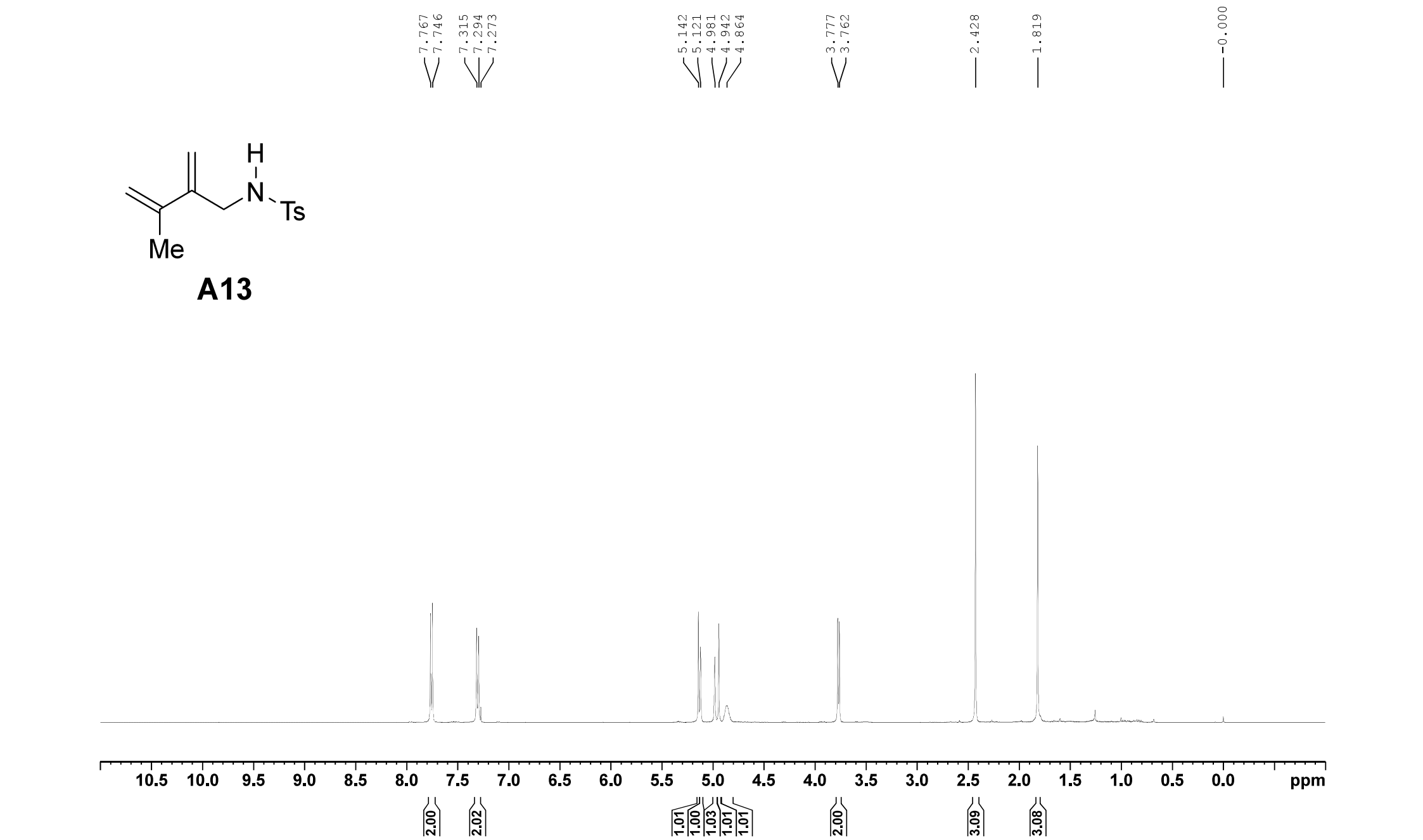
A12

^{13}C NMR (100 MHz, $CDCl_3$)



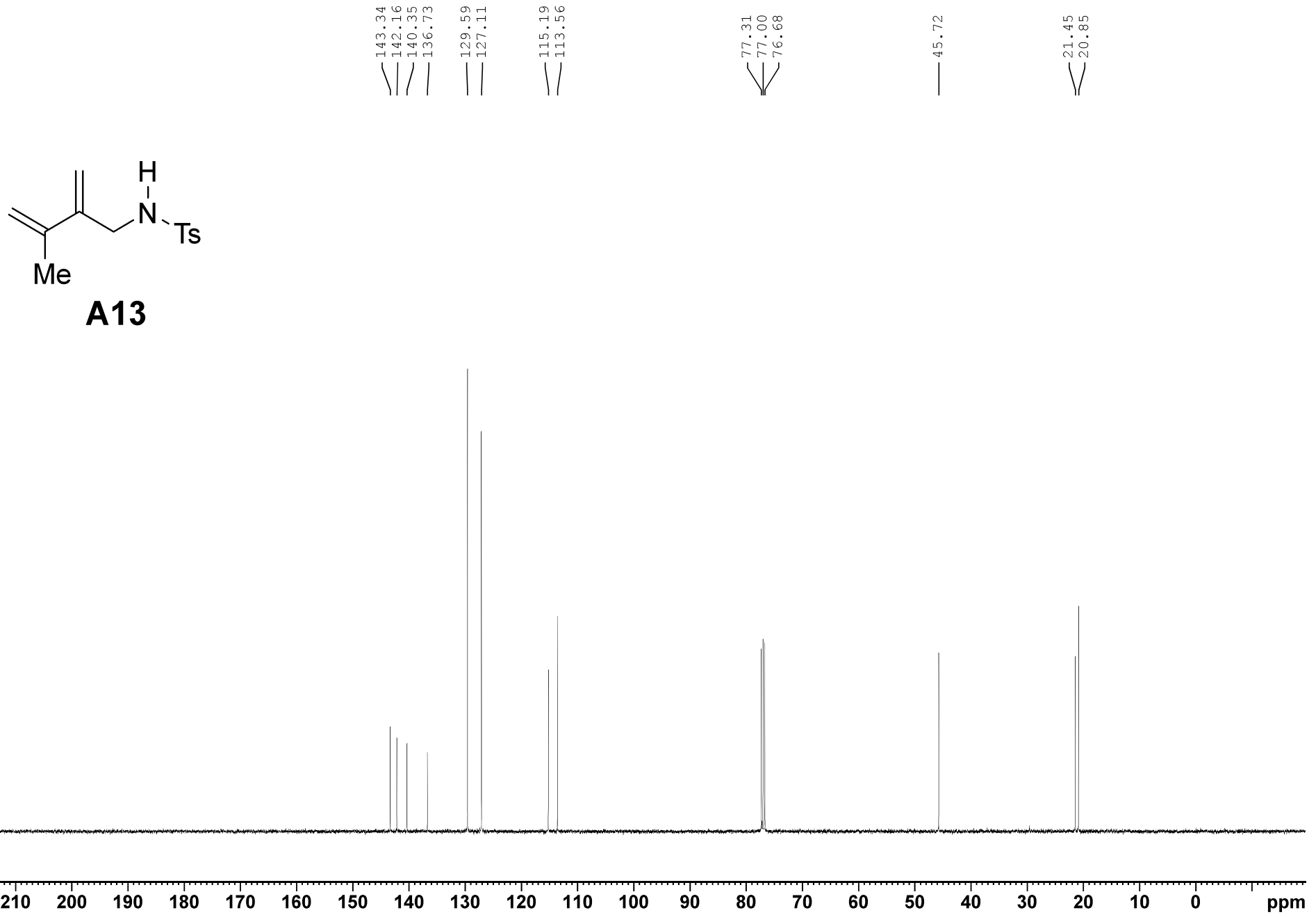
A12

^{1}H NMR ($CDCl_3$, 400 MHz)



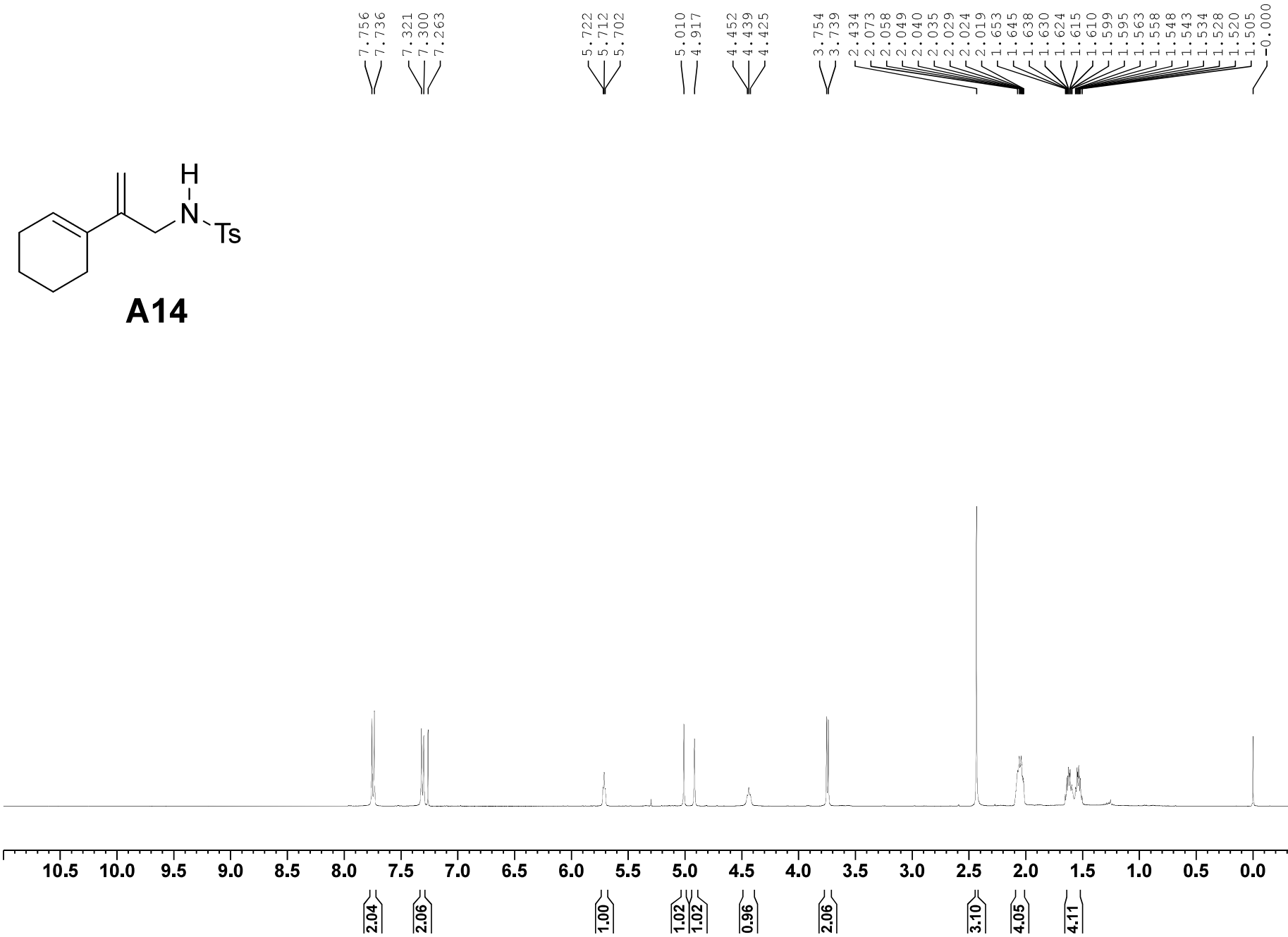
A13

^{13}C NMR (100 MHz, $CDCl_3$)



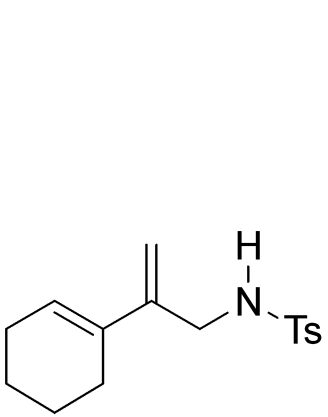
A13

^{1}H NMR ($CDCl_3$, 400 MHz)



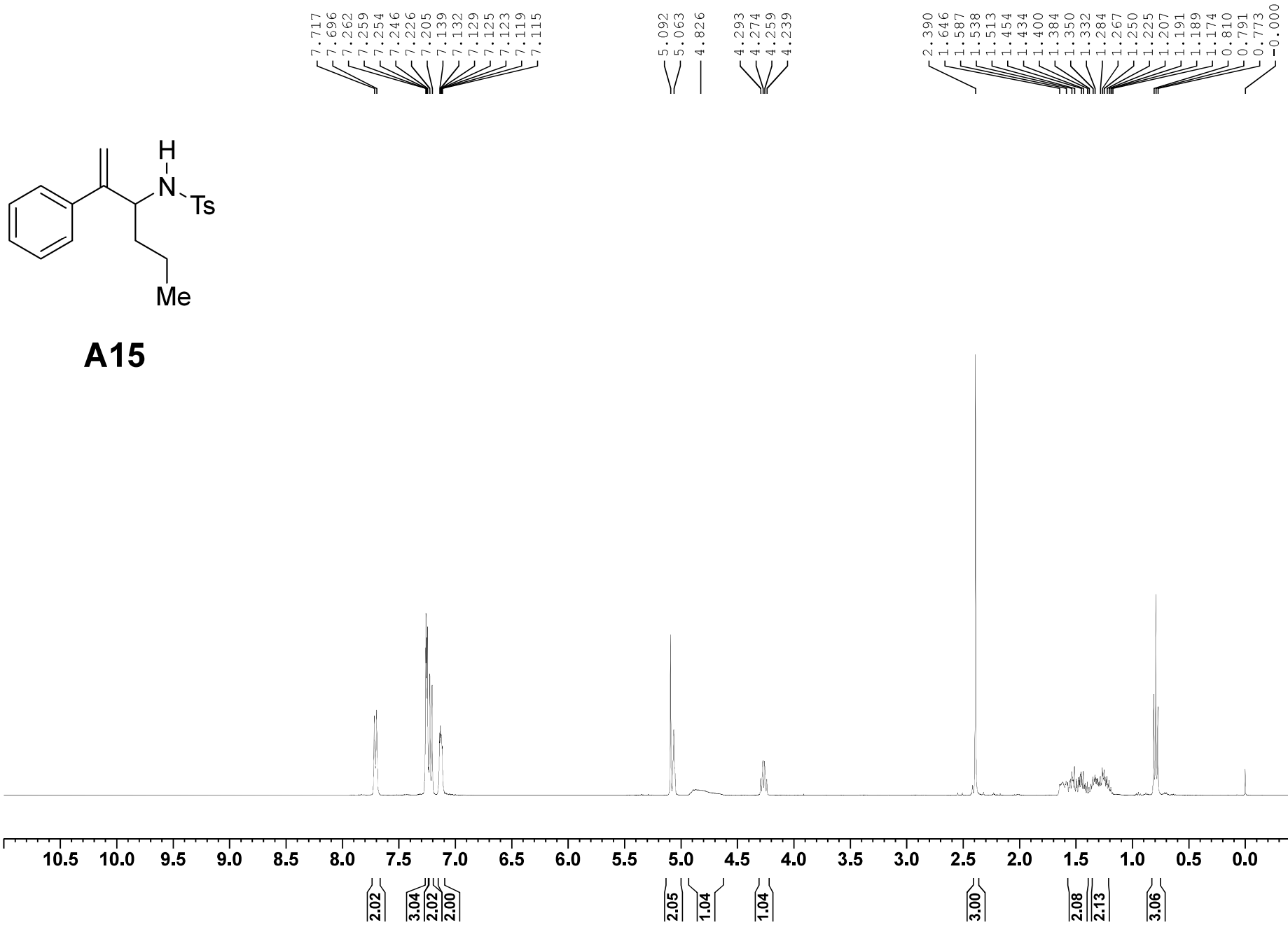
A14

^{13}C NMR (100 MHz, $CDCl_3$)

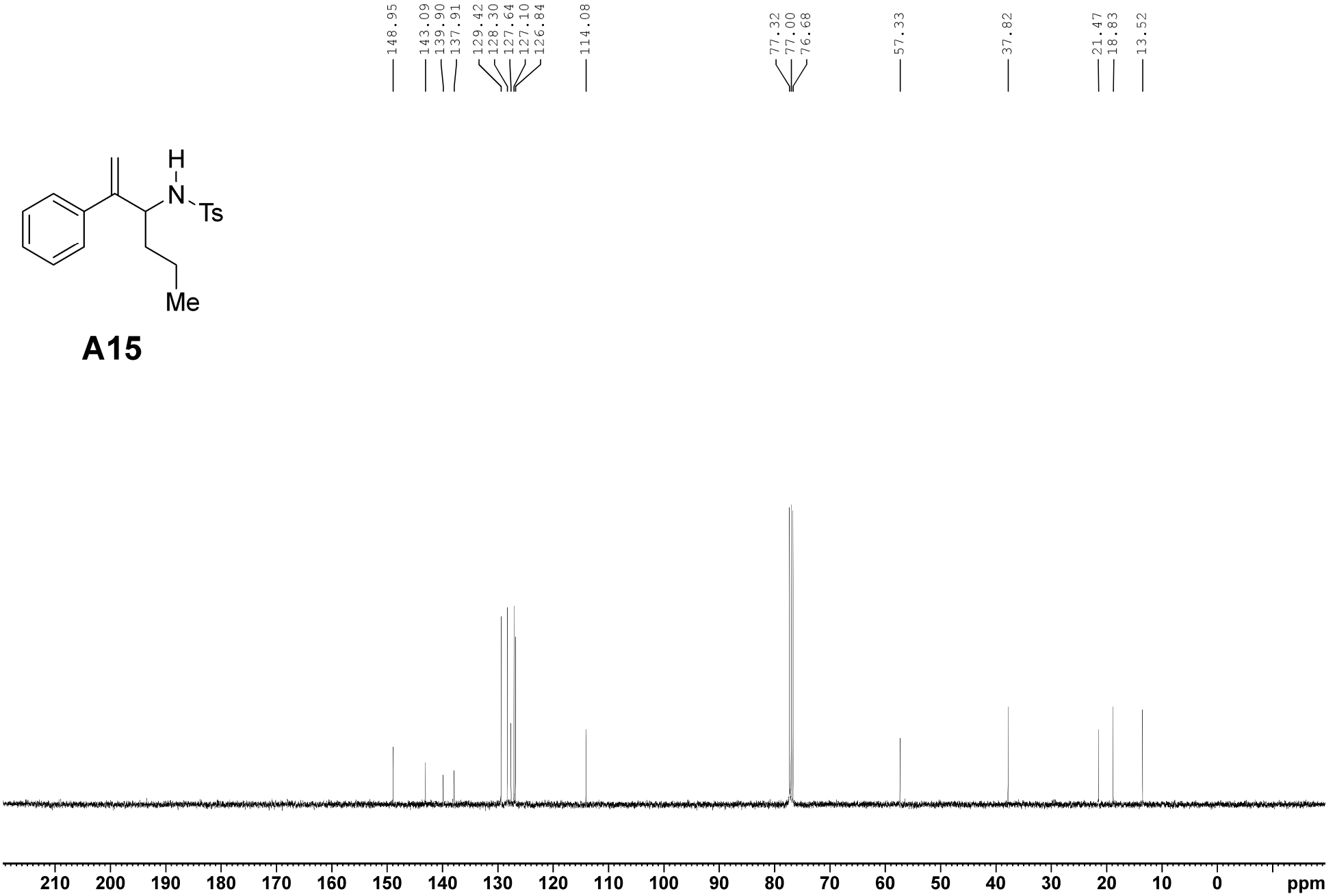


A14

^{1}H NMR ($CDCl_3$, 400 MHz)

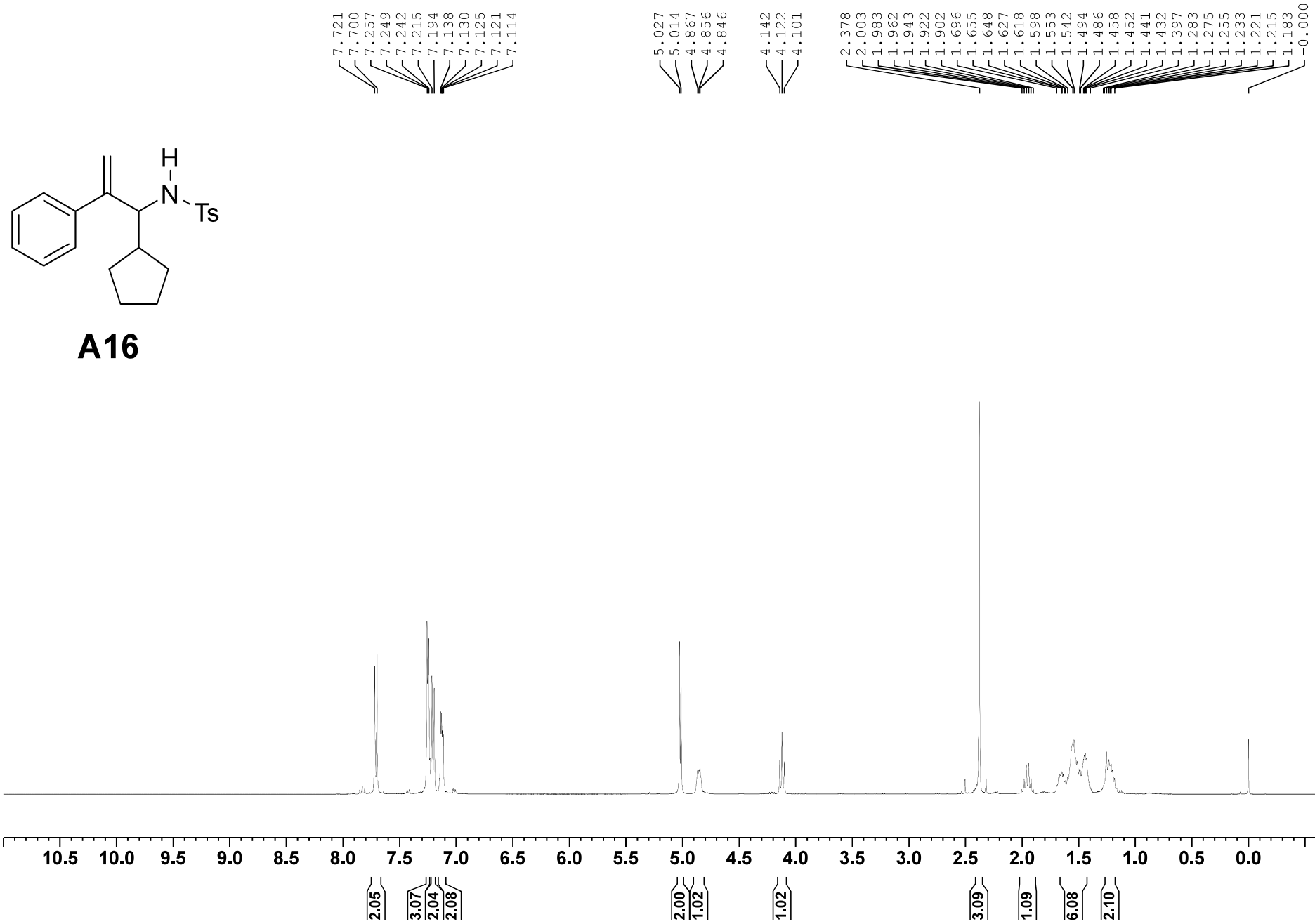


^{13}C NMR (100 MHz, $CDCl_3$)



A15

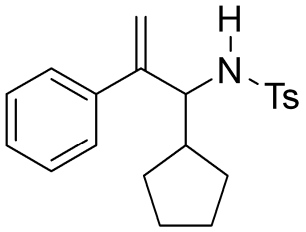
^{1}H NMR ($CDCl_3$, 400 MHz)



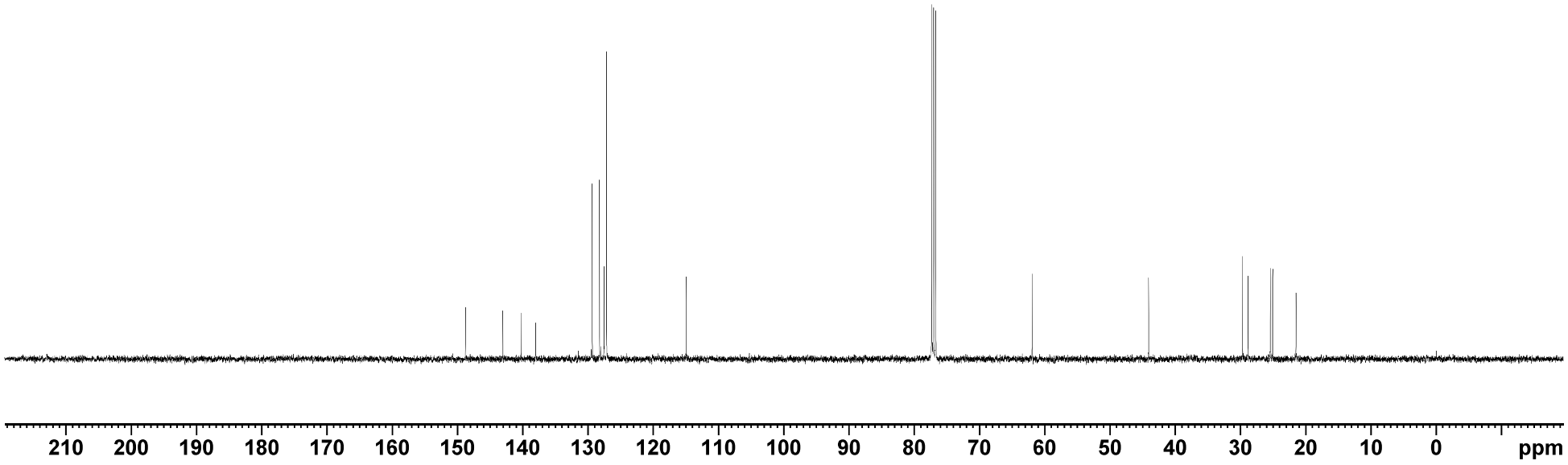
A16

^{13}C NMR (100 MHz, $CDCl_3$)

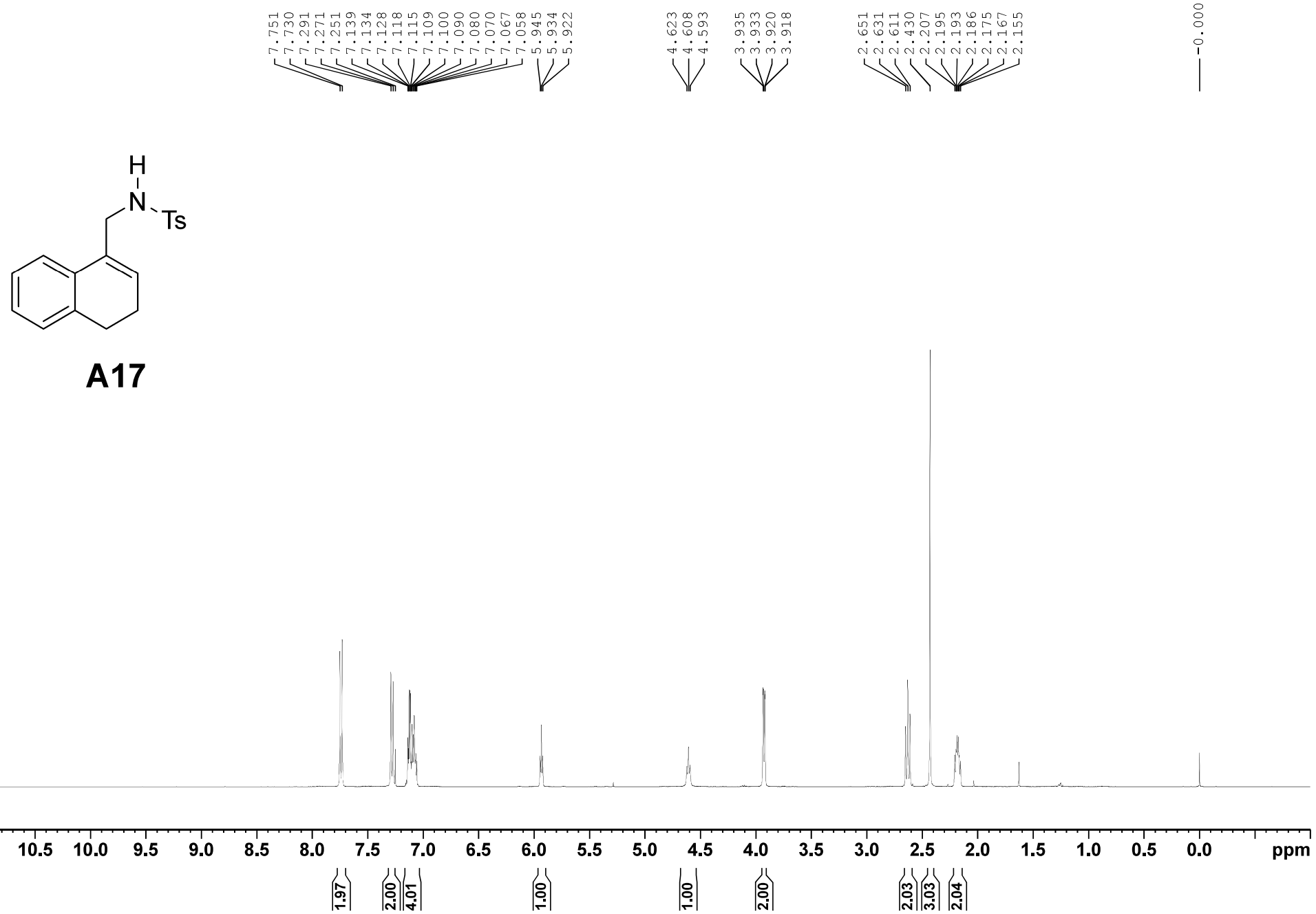
148.77
143.03
140.24
138.02
129.35
128.23
127.54
127.16
114.94
77.32
77.00
76.68
61.91
44.05
29.65
28.81
25.39
25.04
21.47



A16

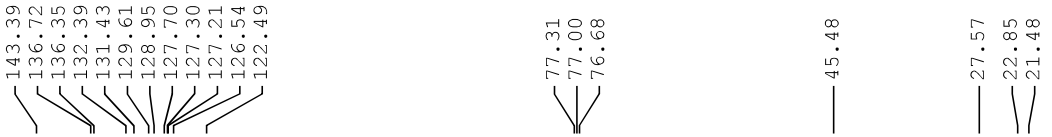


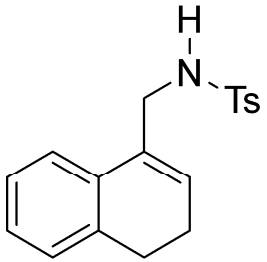
^{1}H NMR ($CDCl_3$, 400 MHz)



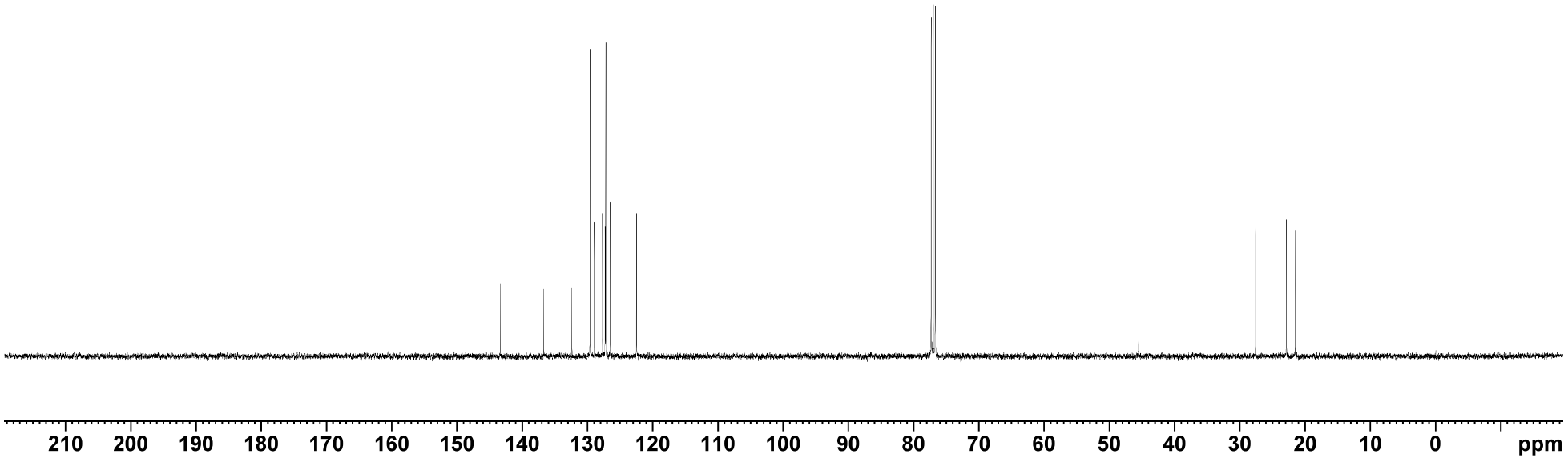
A17

^{13}C NMR (100 MHz, $CDCl_3$)

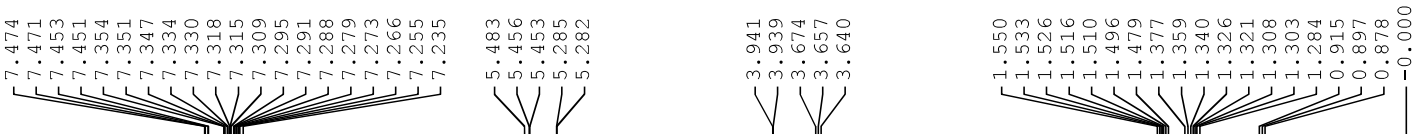


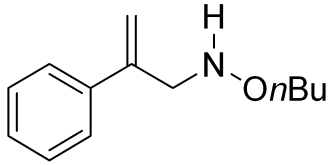


A17

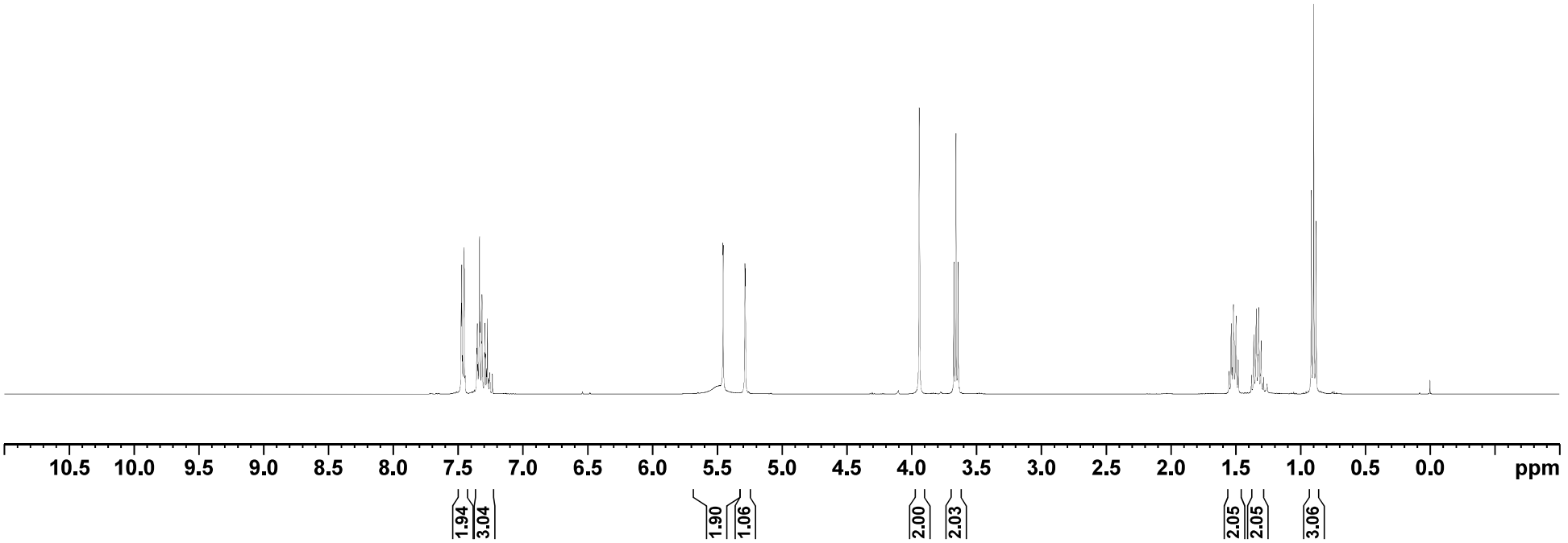


^{1}H NMR ($CDCl_3$, 400 MHz)

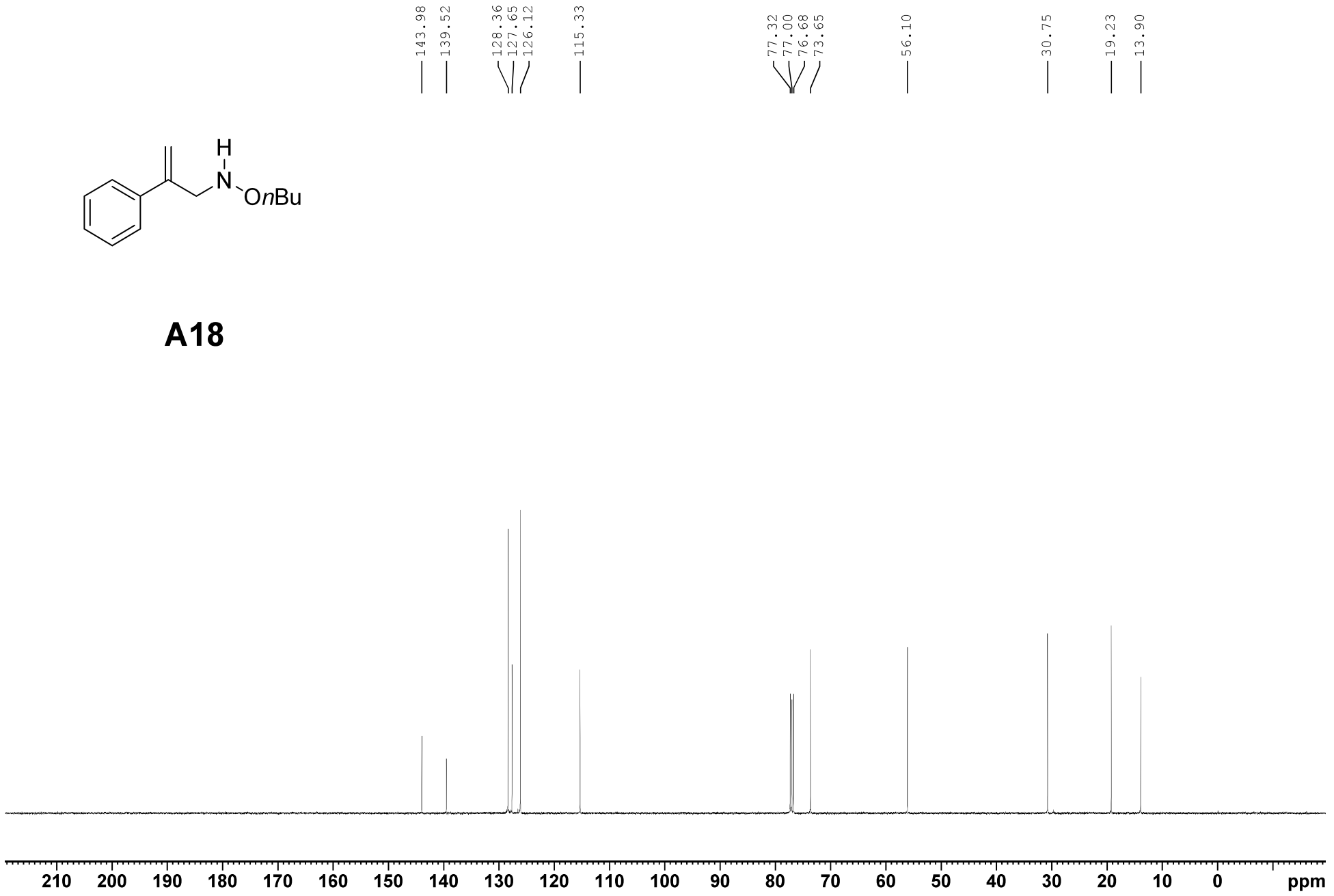




A18

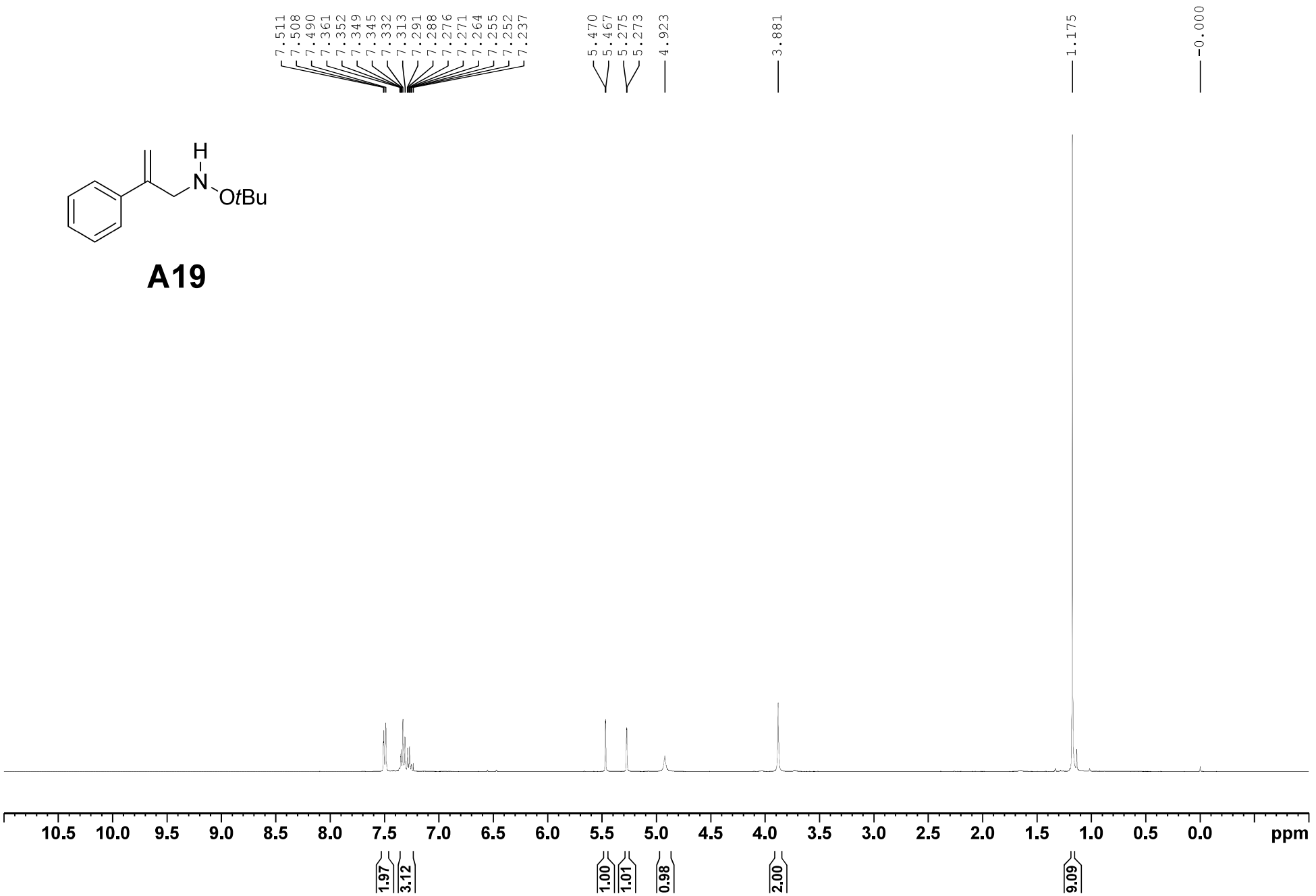


^{13}C NMR (100 MHz, $CDCl_3$)



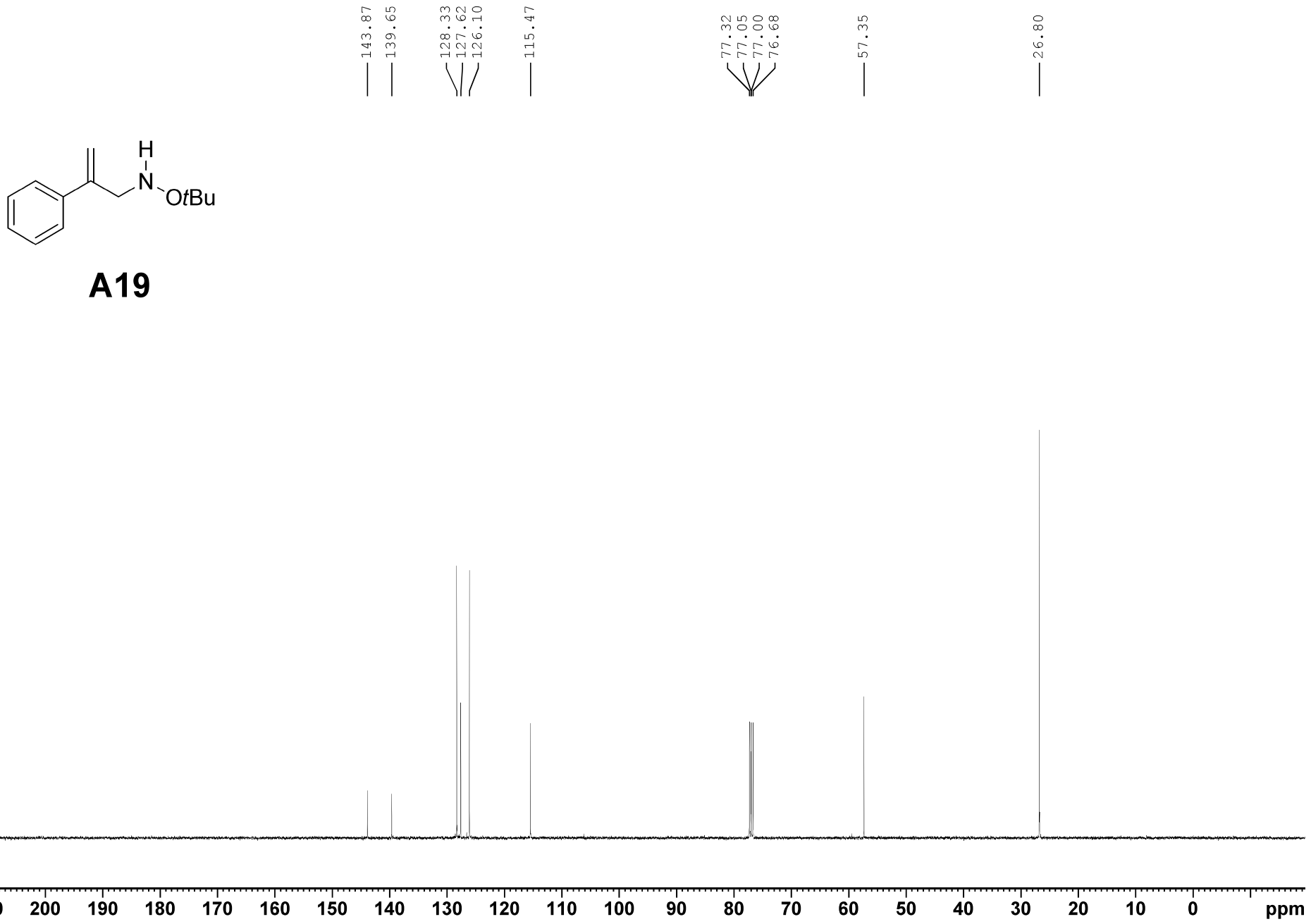
A18

^{1}H NMR ($CDCl_3$, 400 MHz)



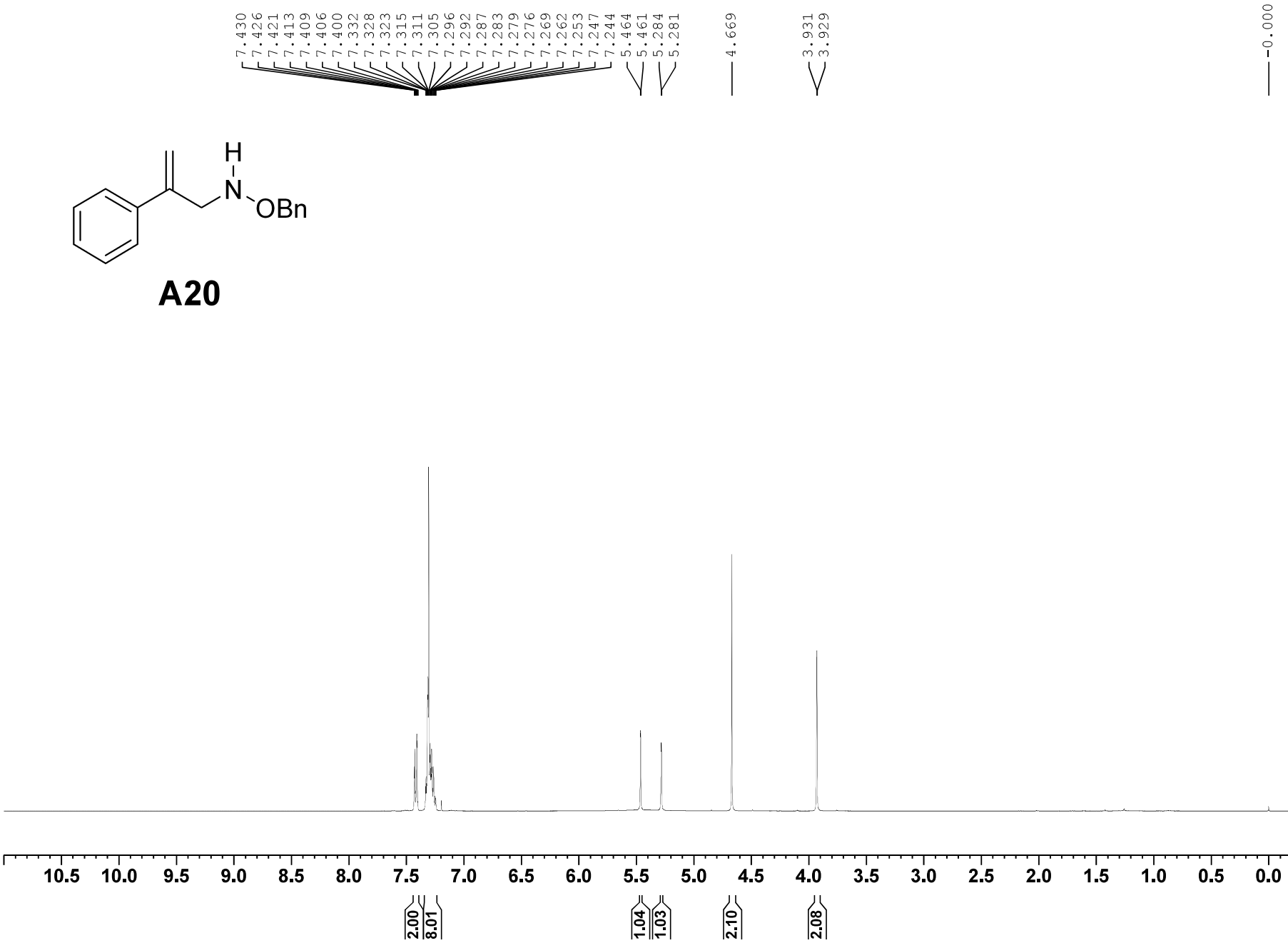
A19

^{13}C NMR (100 MHz, $CDCl_3$)



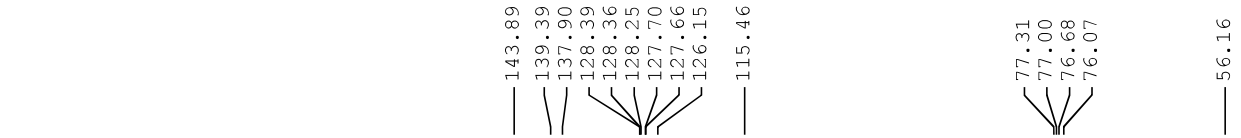
A19

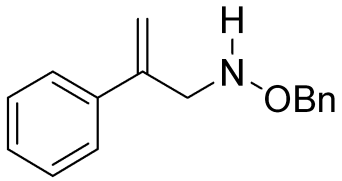
^{1}H NMR ($CDCl_3$, 400 MHz)



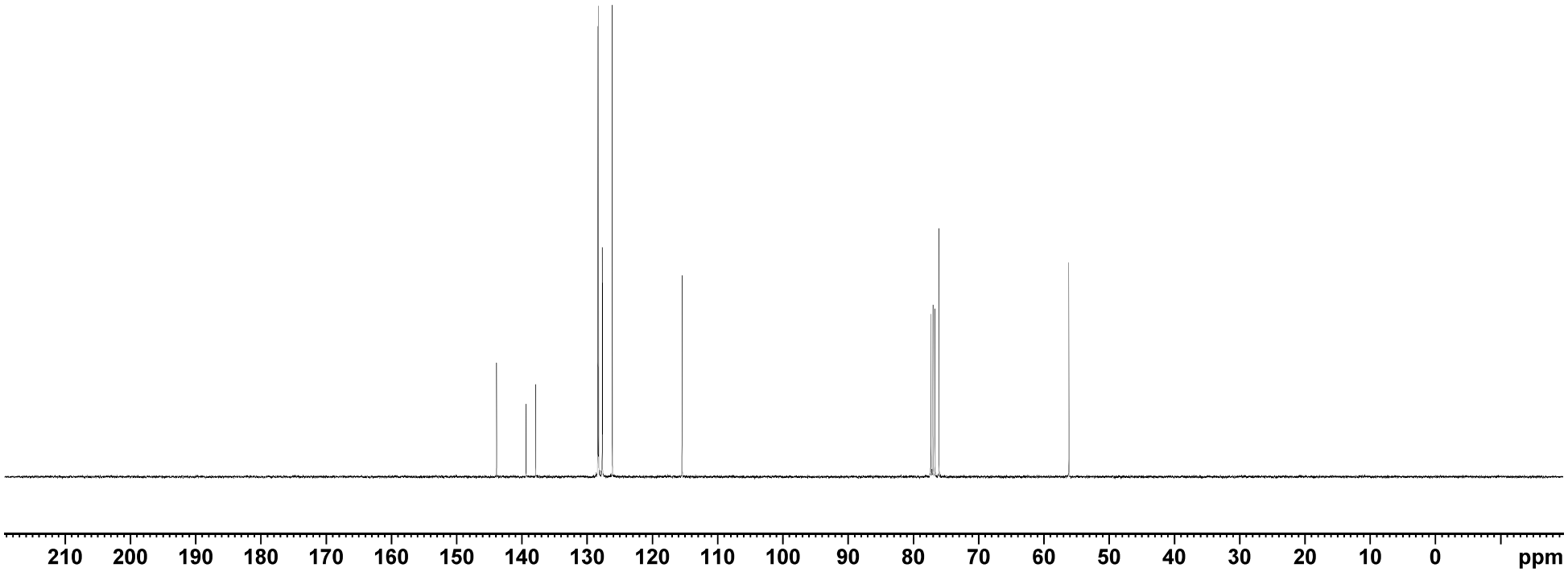
A20

^{13}C NMR (100 MHz, $CDCl_3$)

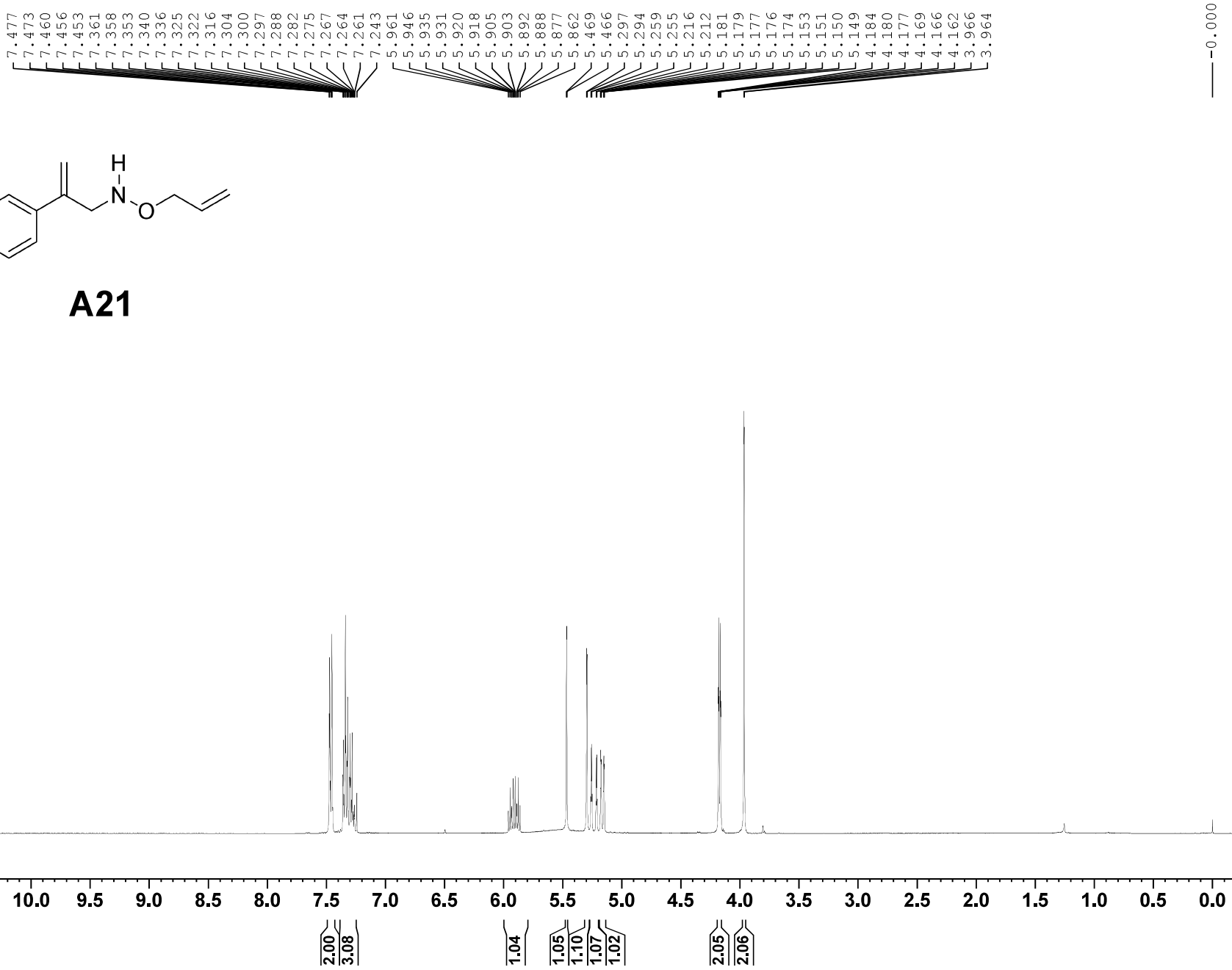




A20

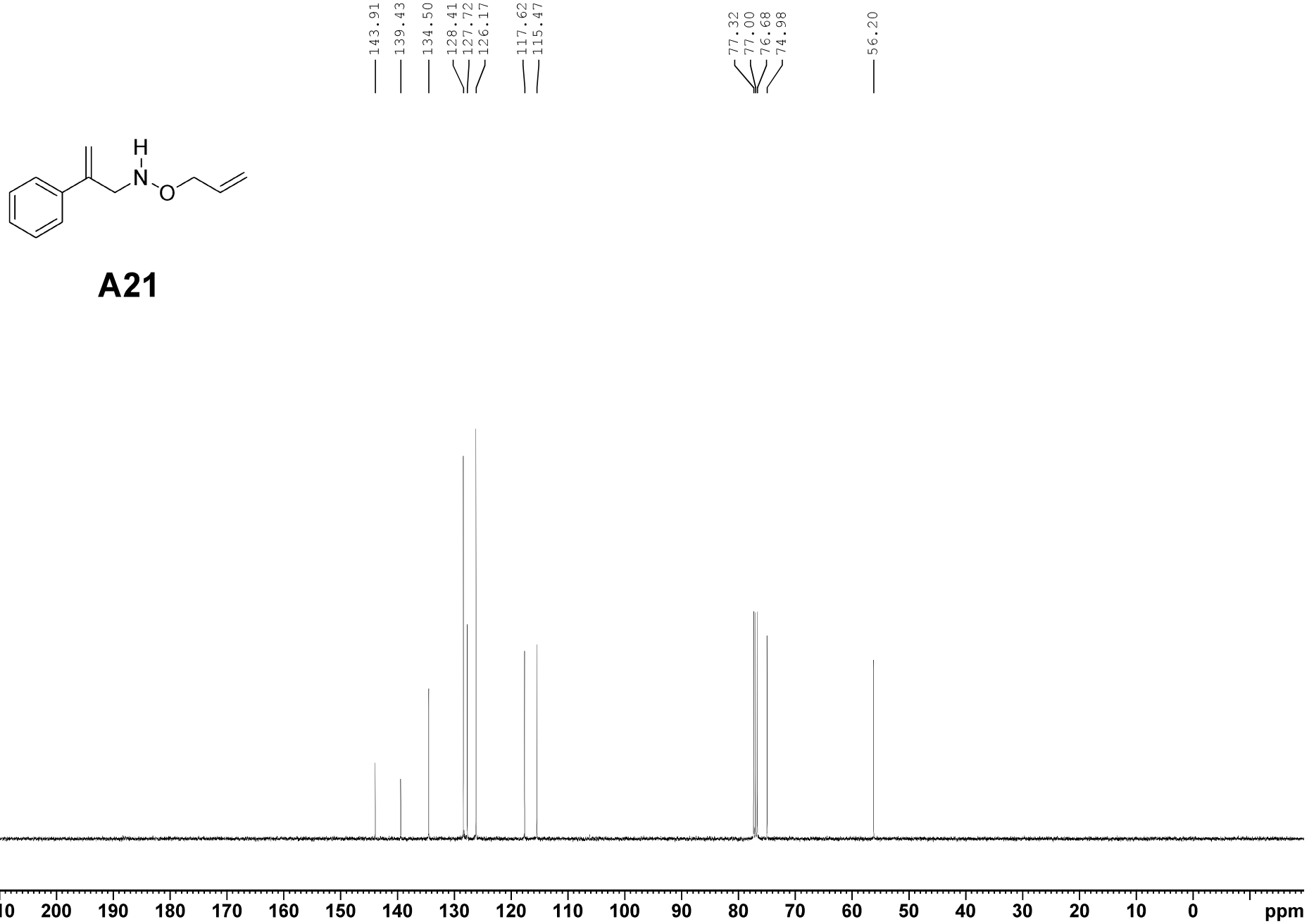


^{1}H NMR ($CDCl_3$, 400 MHz)



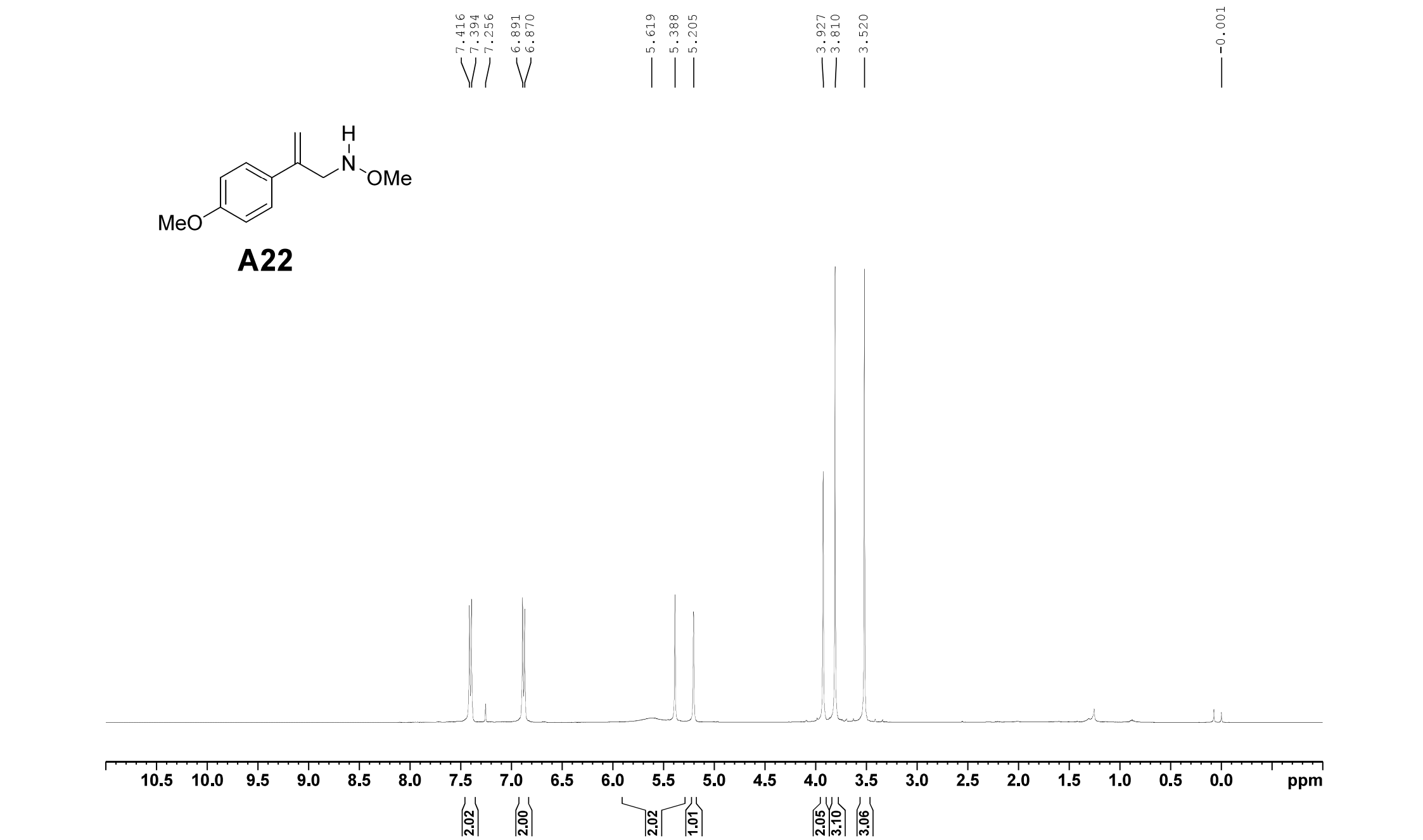
A21

^{13}C NMR (100 MHz, $CDCl_3$)



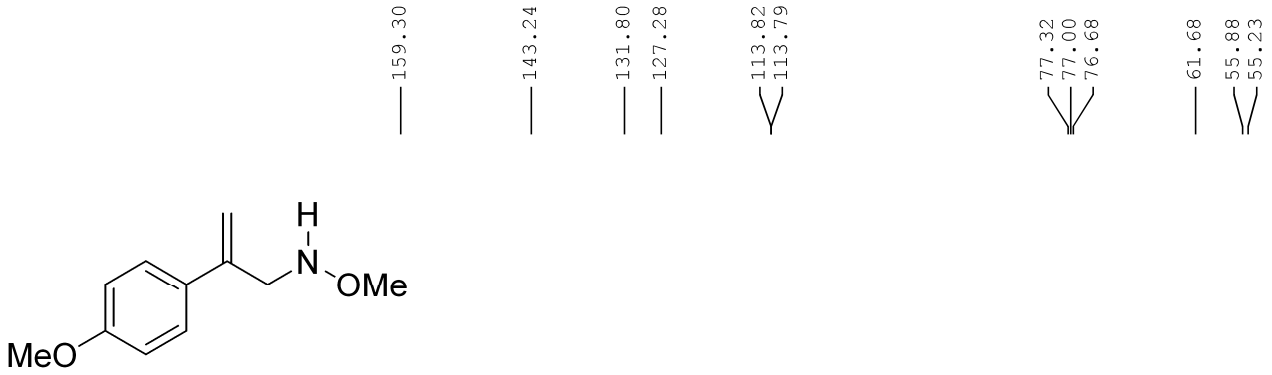
A21

^{1}H NMR ($CDCl_3$, 400 MHz)

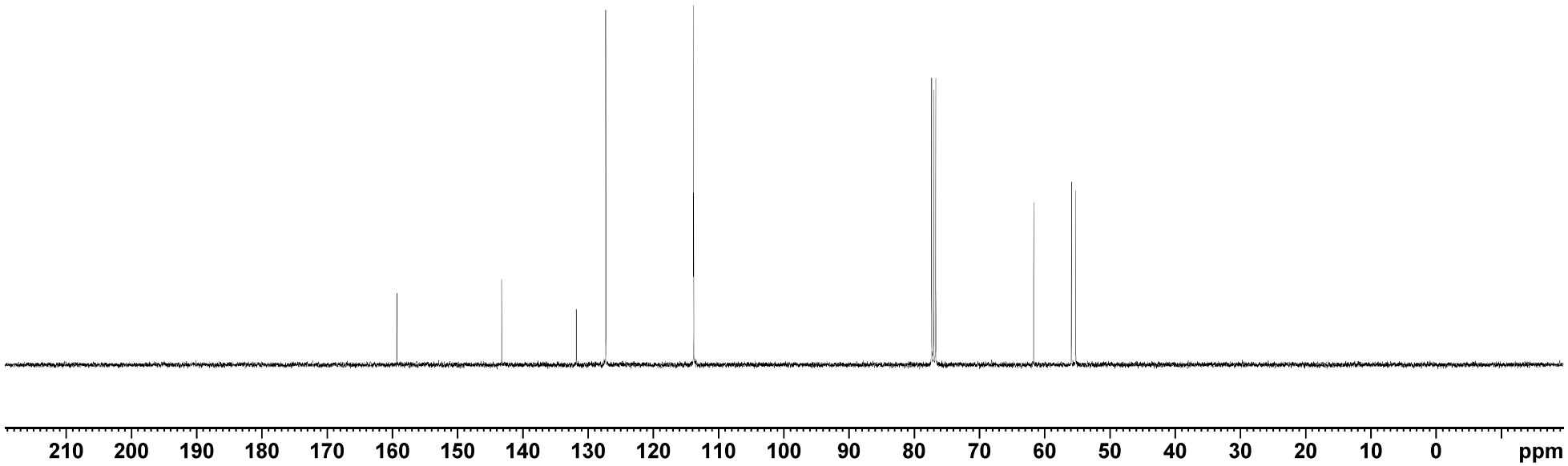


A22

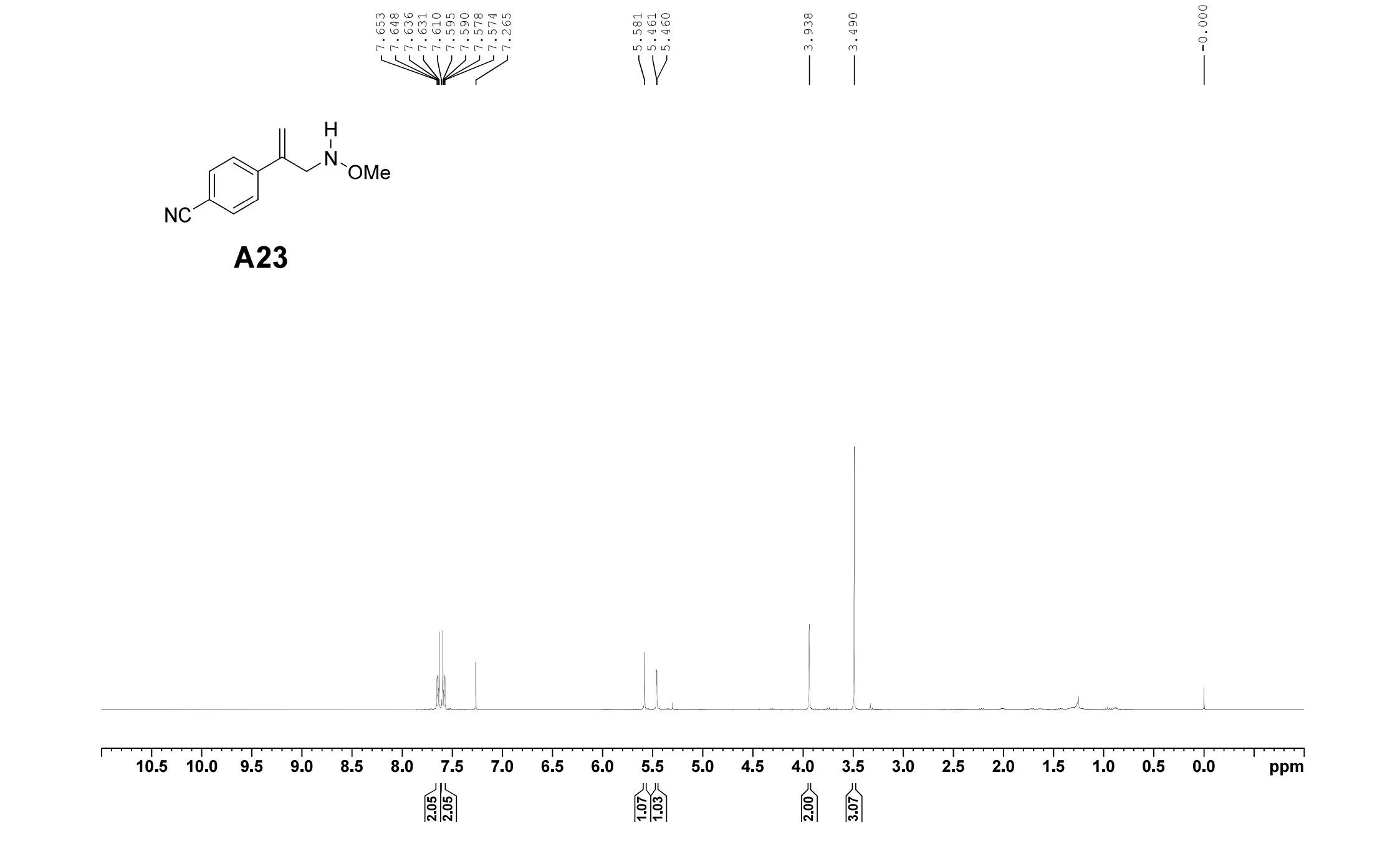
^{13}C NMR (100 MHz, $CDCl_3$)



A22

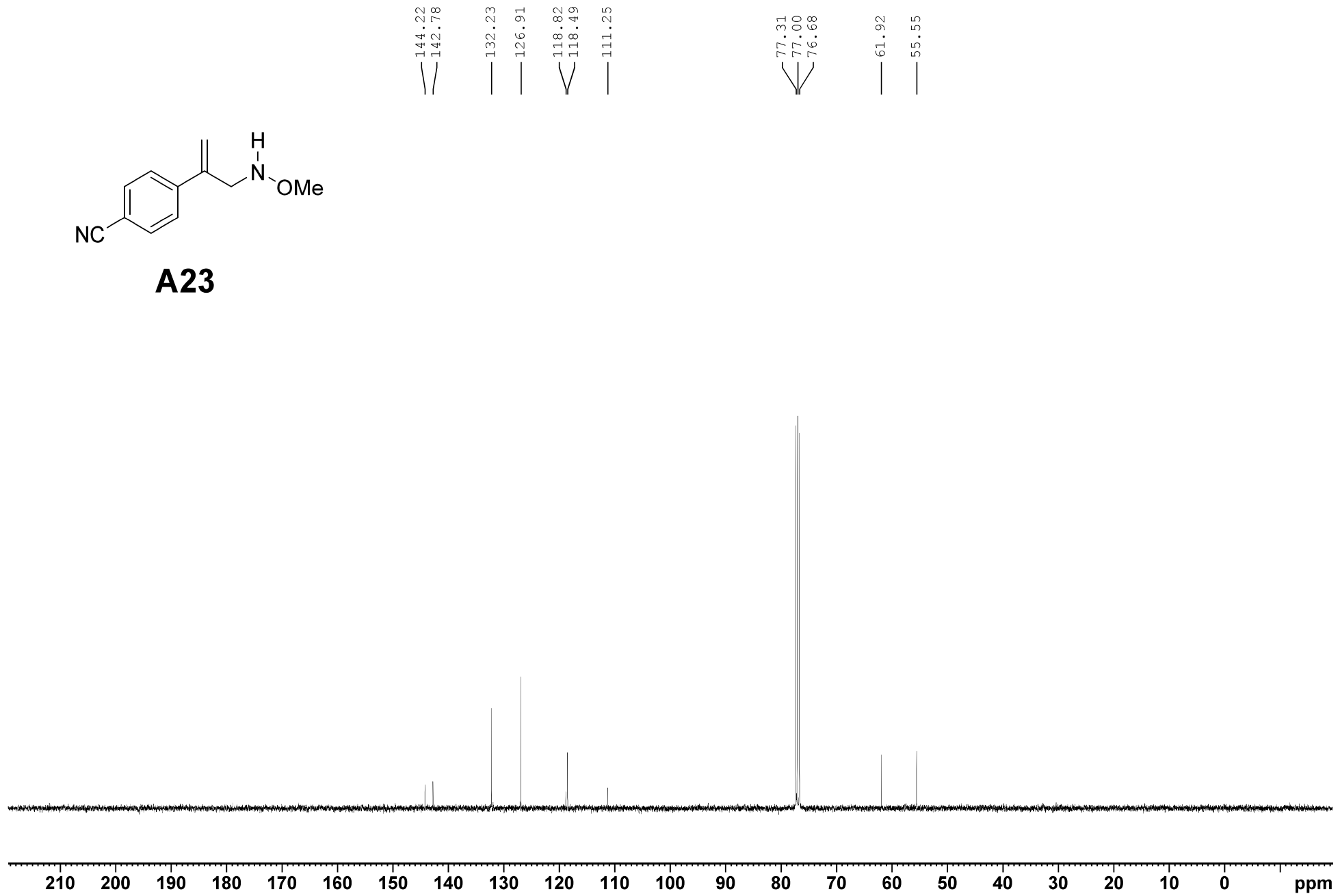


^{1}H NMR ($CDCl_3$, 400 MHz)



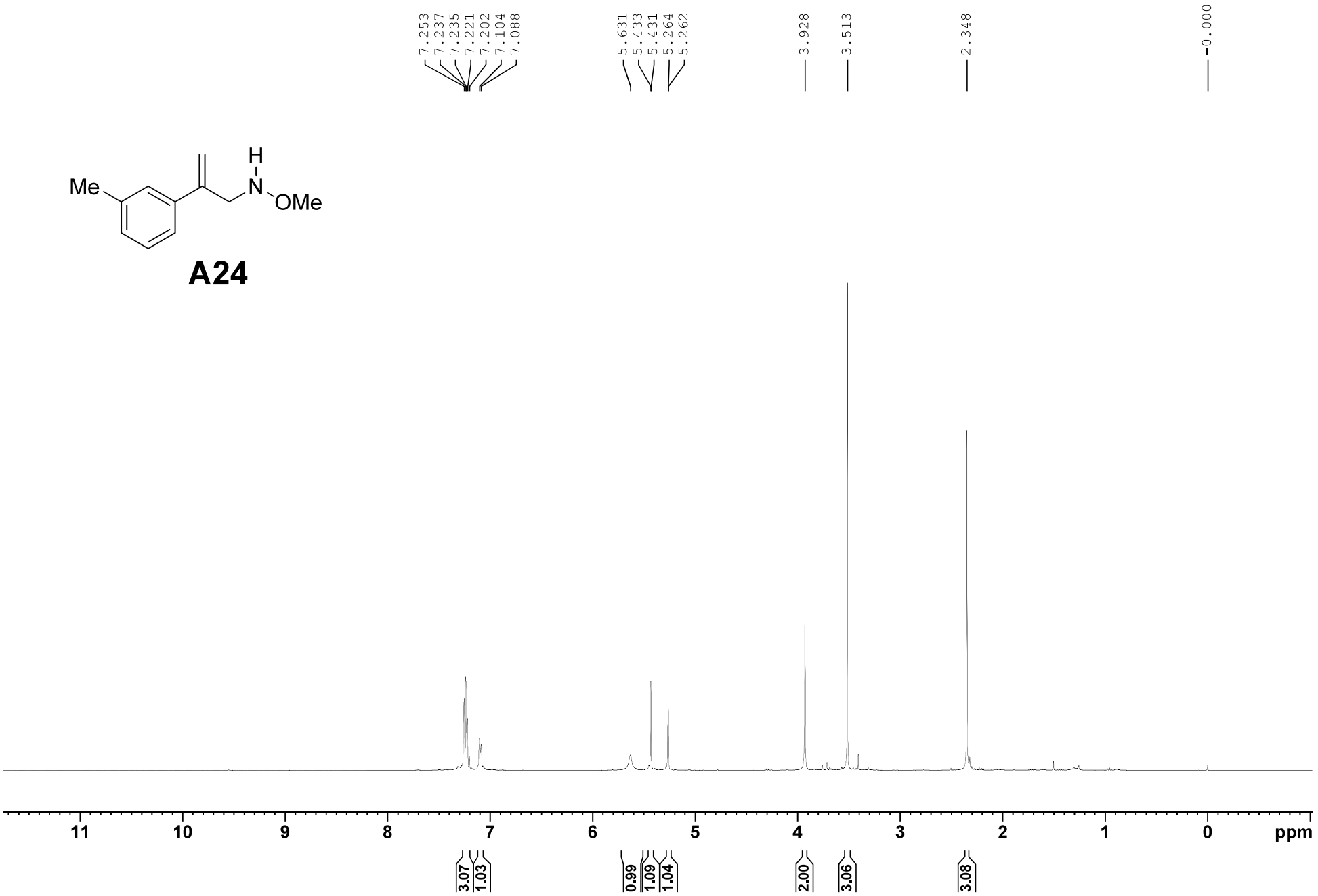
A23

^{13}C NMR (100 MHz, $CDCl_3$)



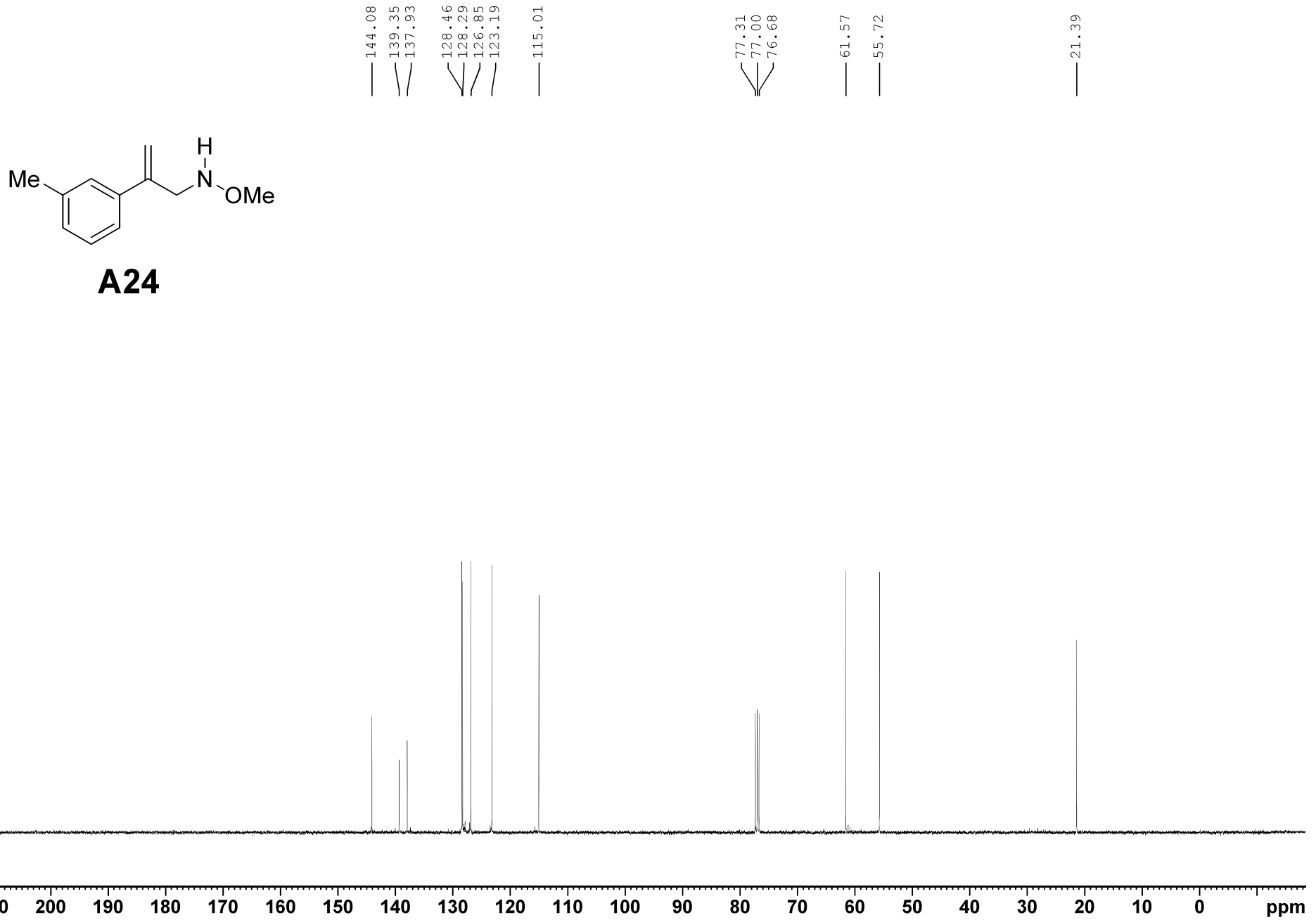
A23

^{1}H NMR ($CDCl_3$, 400 MHz)



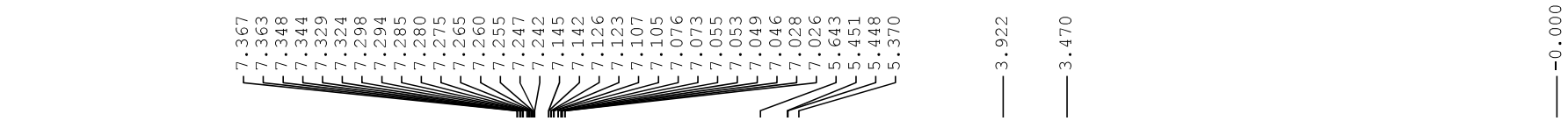
A24

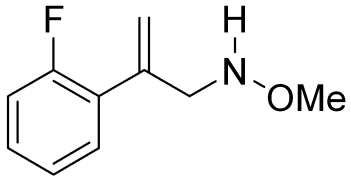
^{13}C NMR (100 MHz, $CDCl_3$)



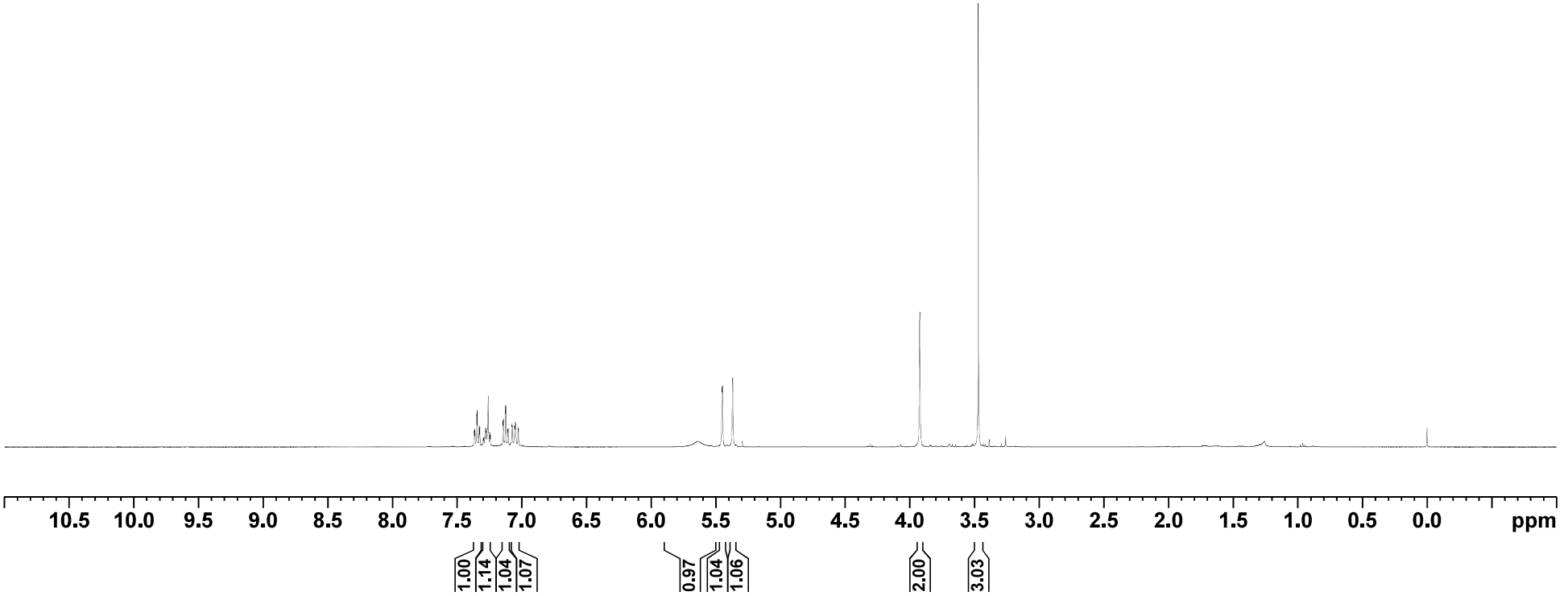
A24

^{1}H NMR ($CDCl_3$, 400 MHz)



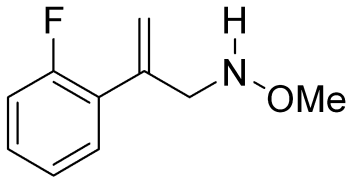


A25

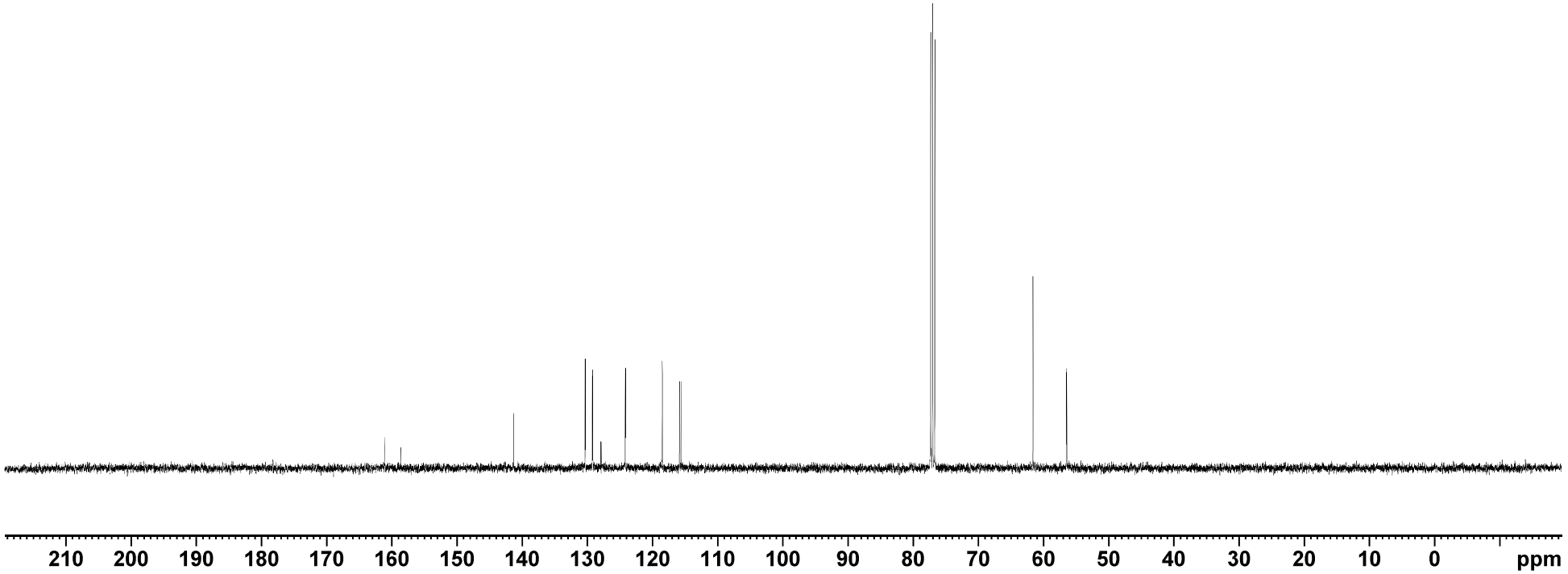


^{13}C NMR (100 MHz, $CDCl_3$)

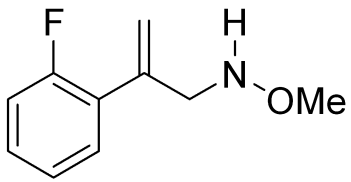
161.11
158.66
141.33
130.35
130.30
129.24
129.16
127.95
127.81
124.18
124.14
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118.49
115.85
115.62
77.31
77.00
76.68
61.62
56.46
56.42



A25

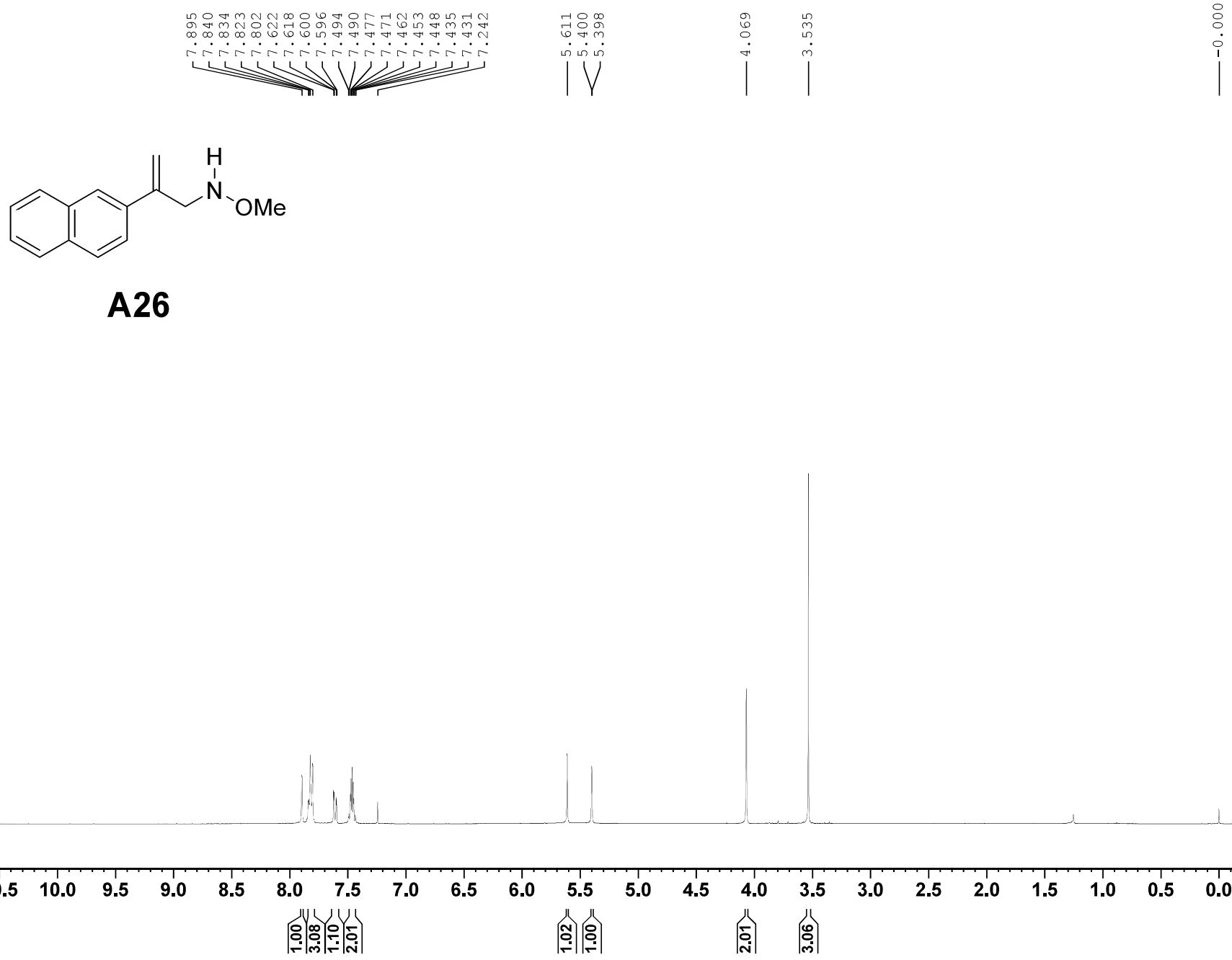


^{19}F NMR (376 MHz, $CDCl_3$)



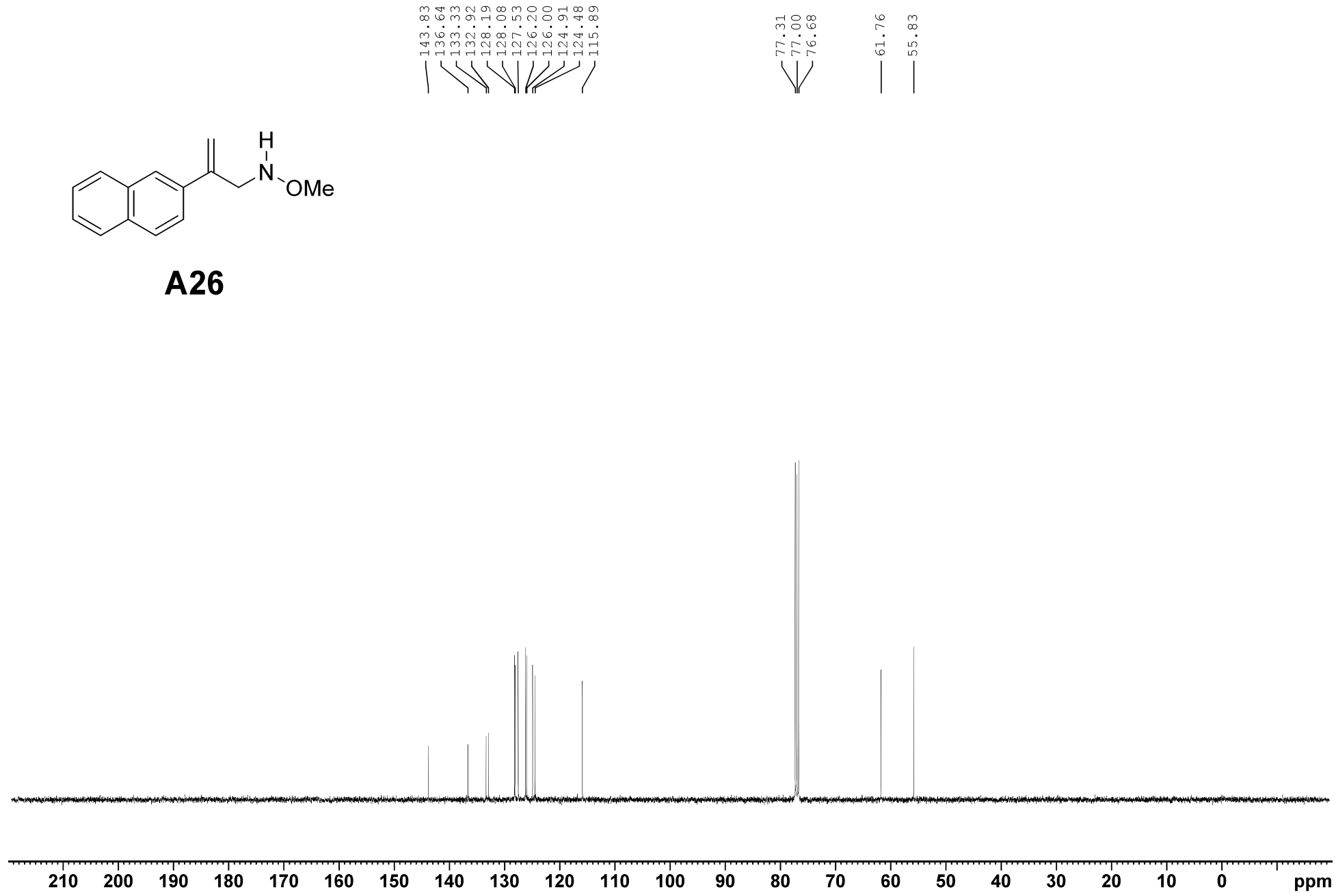
A25

^{1}H NMR ($CDCl_3$, 400 MHz)



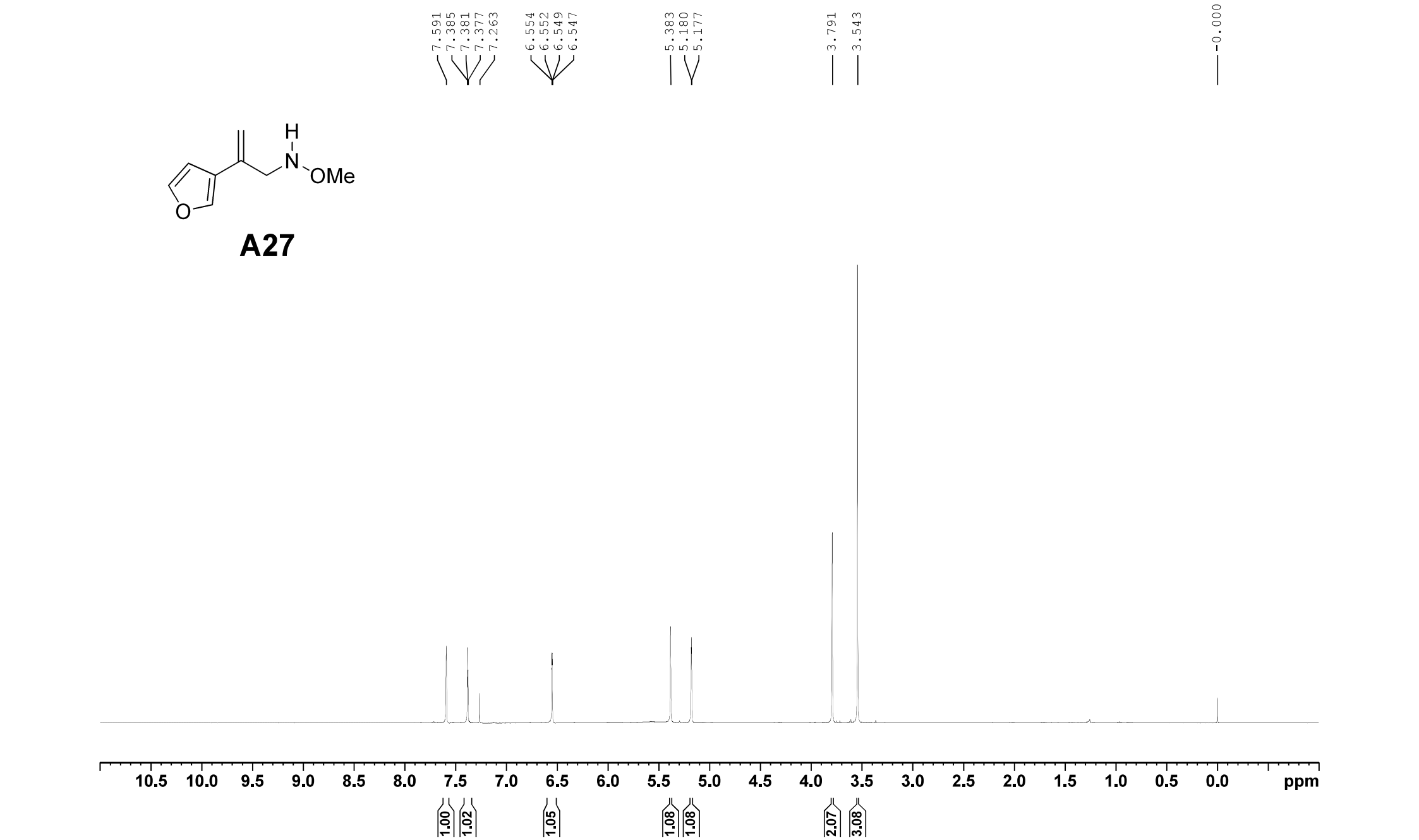
A26

^{13}C NMR (100 MHz, $CDCl_3$)



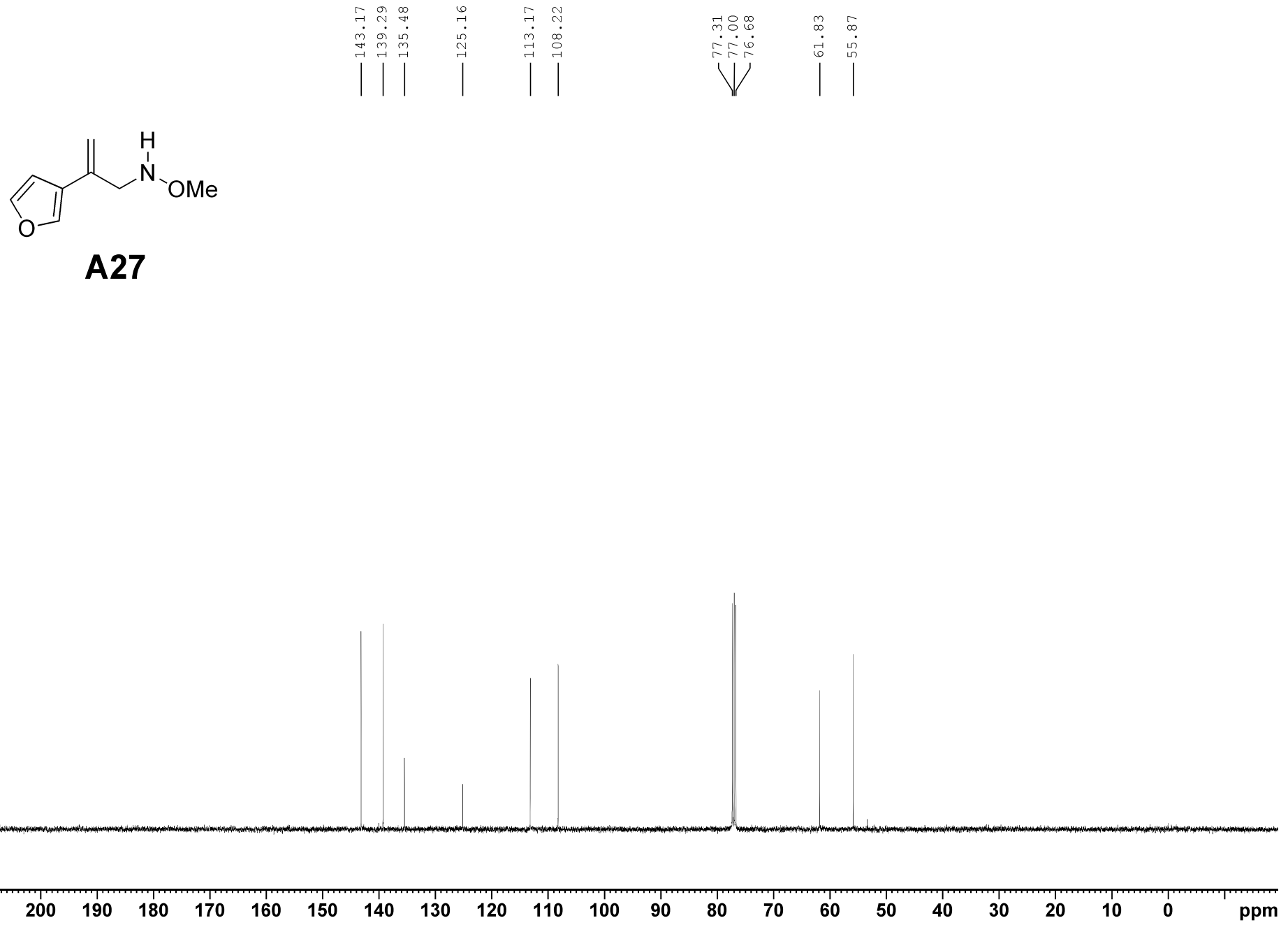
A26

^{1}H NMR ($CDCl_3$, 400 MHz)



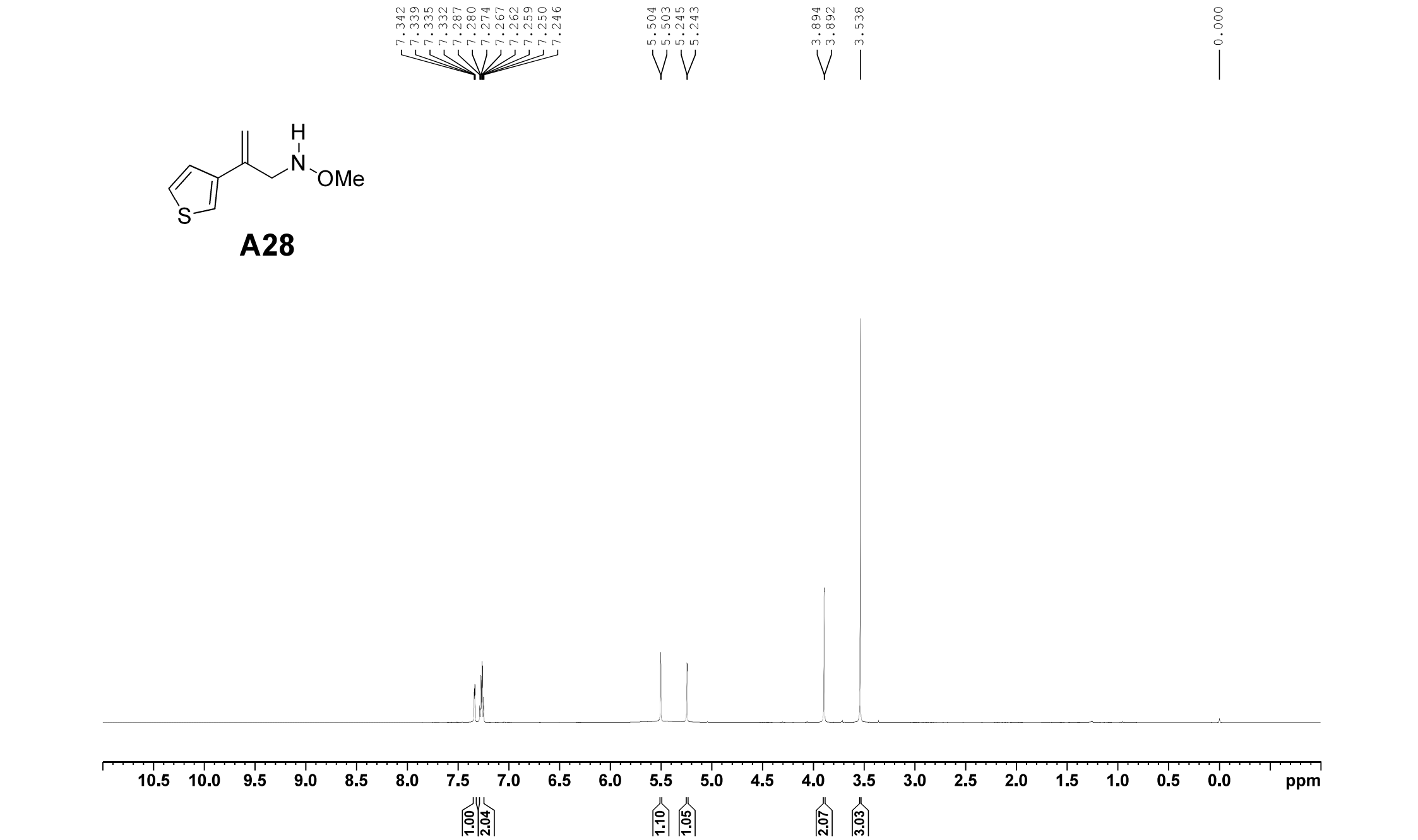
A27

^{13}C NMR (100 MHz, $CDCl_3$)



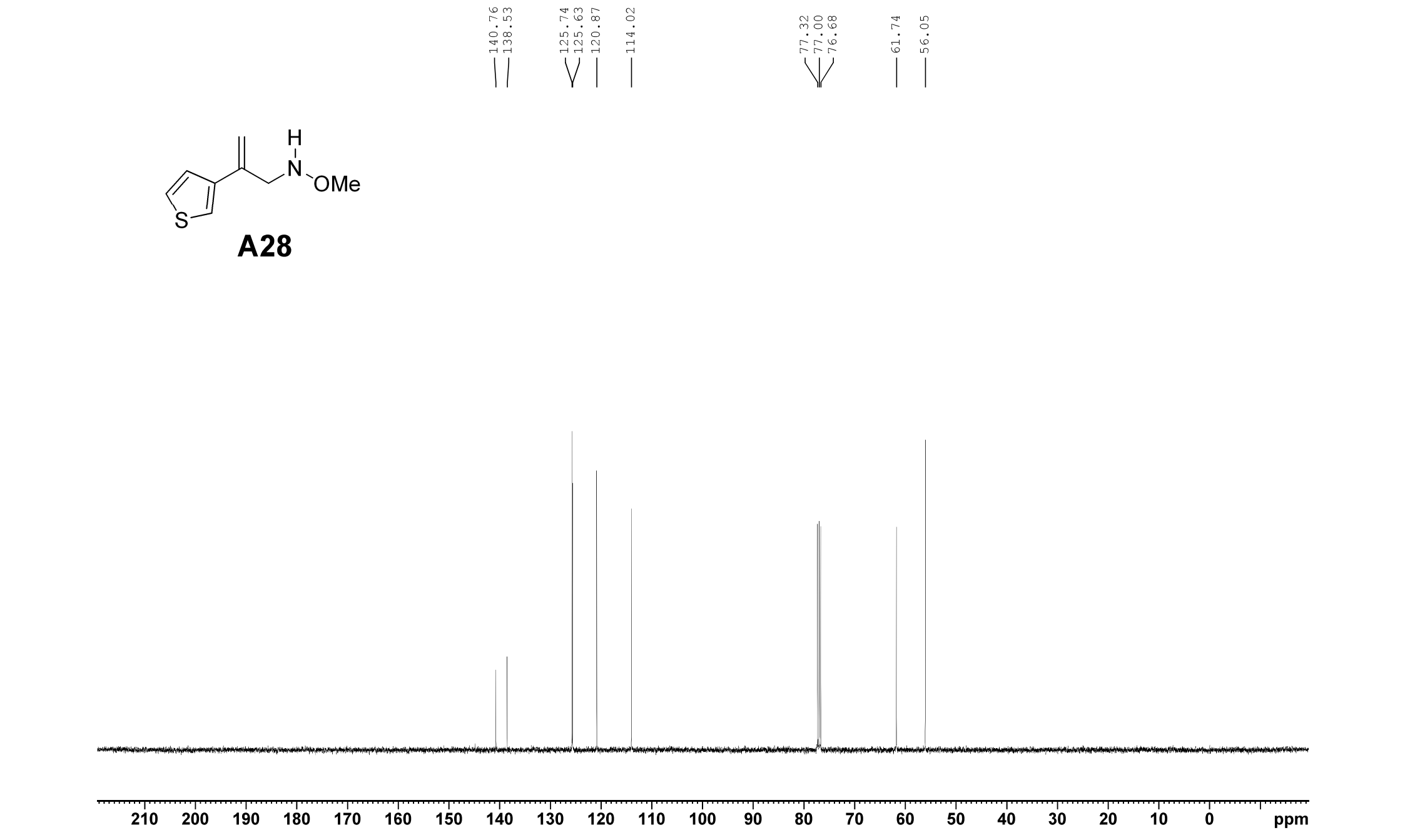
A27

^{1}H NMR ($CDCl_3$, 400 MHz)



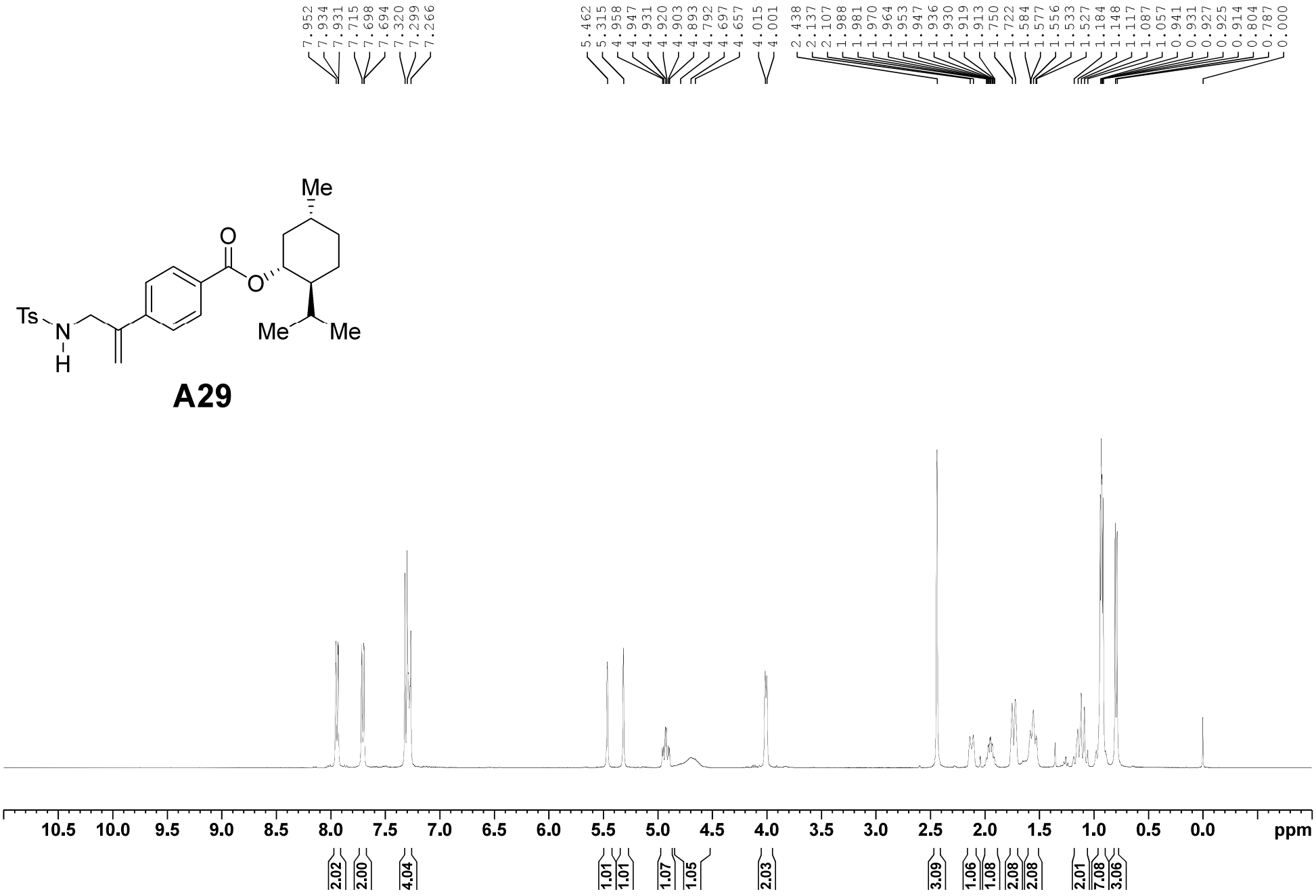
A28

^{13}C NMR (100 MHz, $CDCl_3$)



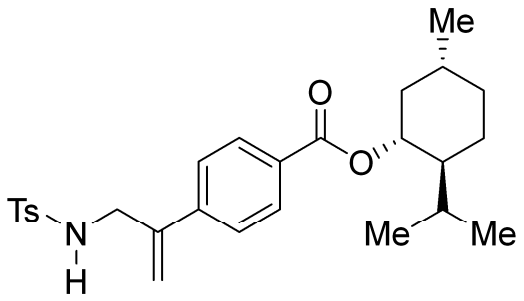
A28

^{1}H NMR ($CDCl_3$, 400 MHz)

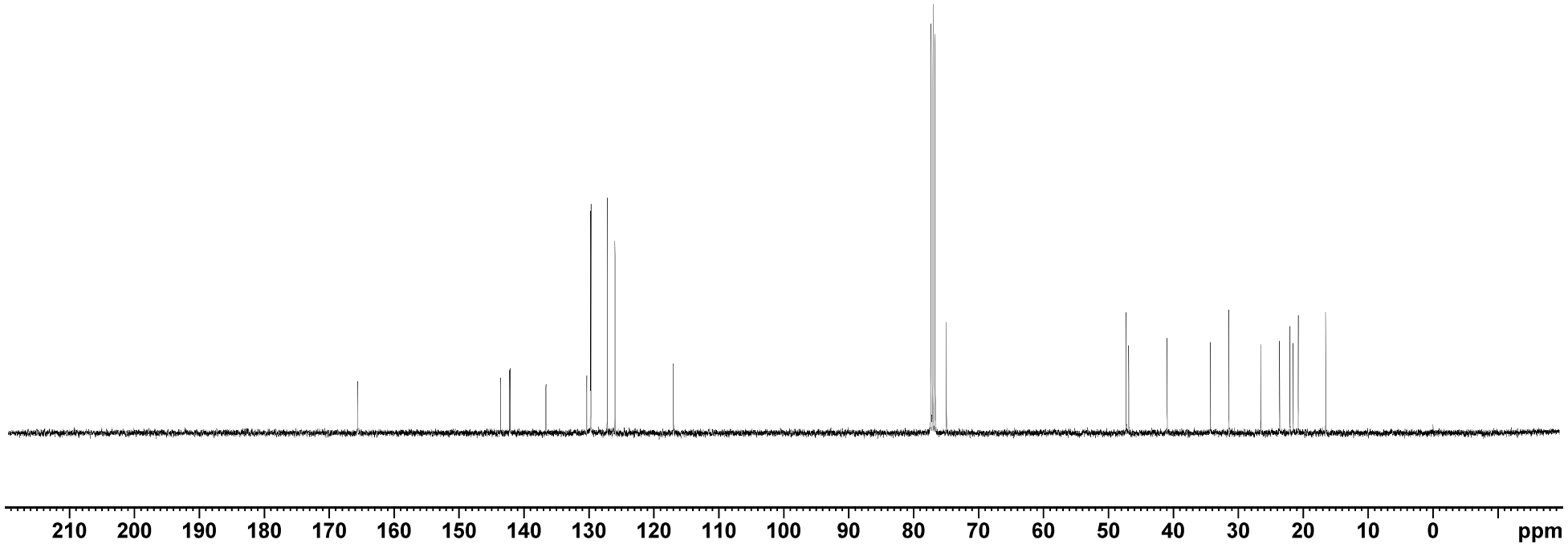


^{13}C NMR (100 MHz, $CDCl_3$)

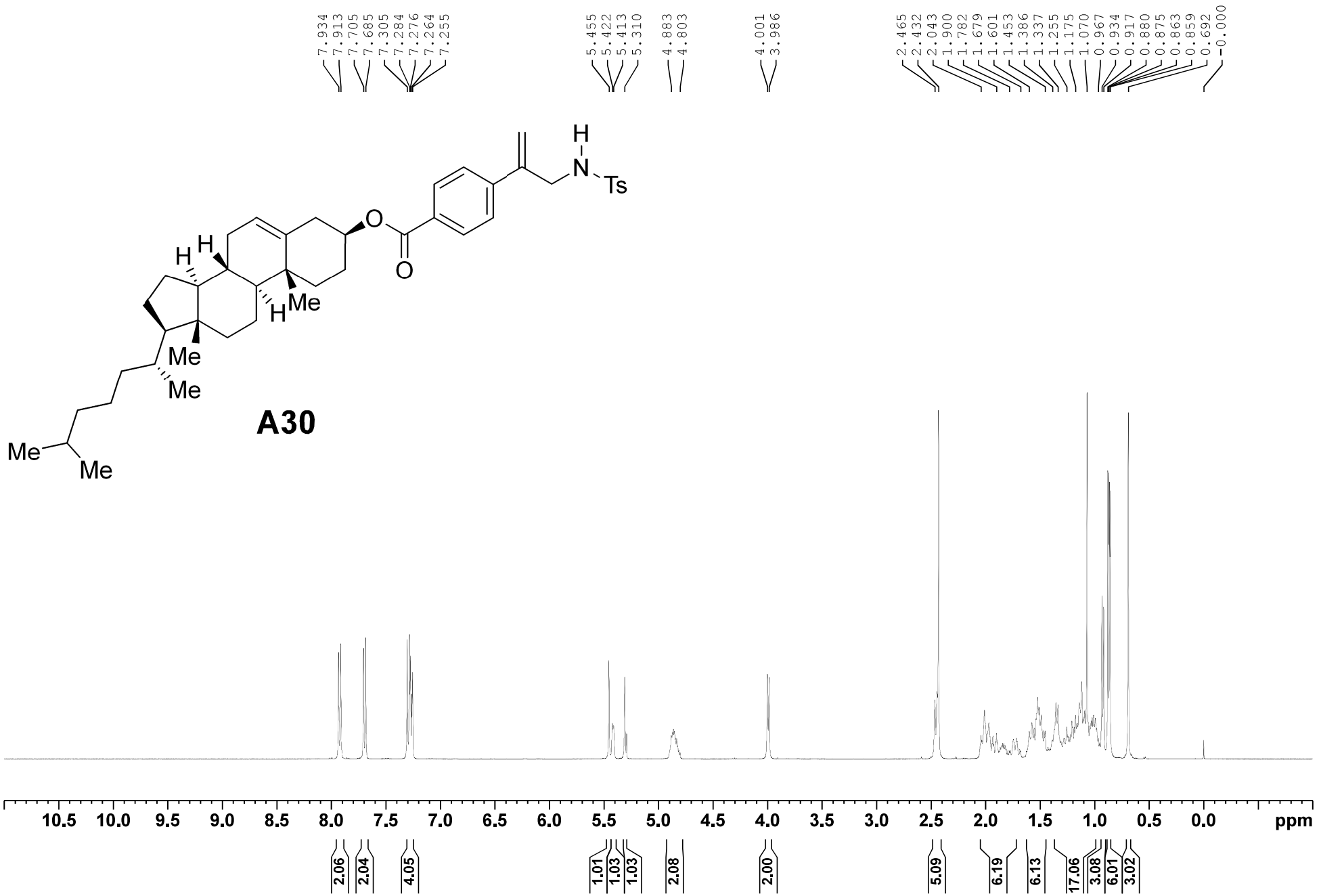
165.63
143.58
142.25
142.12
136.62
130.32
129.73
129.68
127.15
125.97
116.98
77.32
77.00
76.68
74.92
47.23
46.84
40.92
34.26
31.40
26.49
23.61
22.01
21.51
20.72
16.51



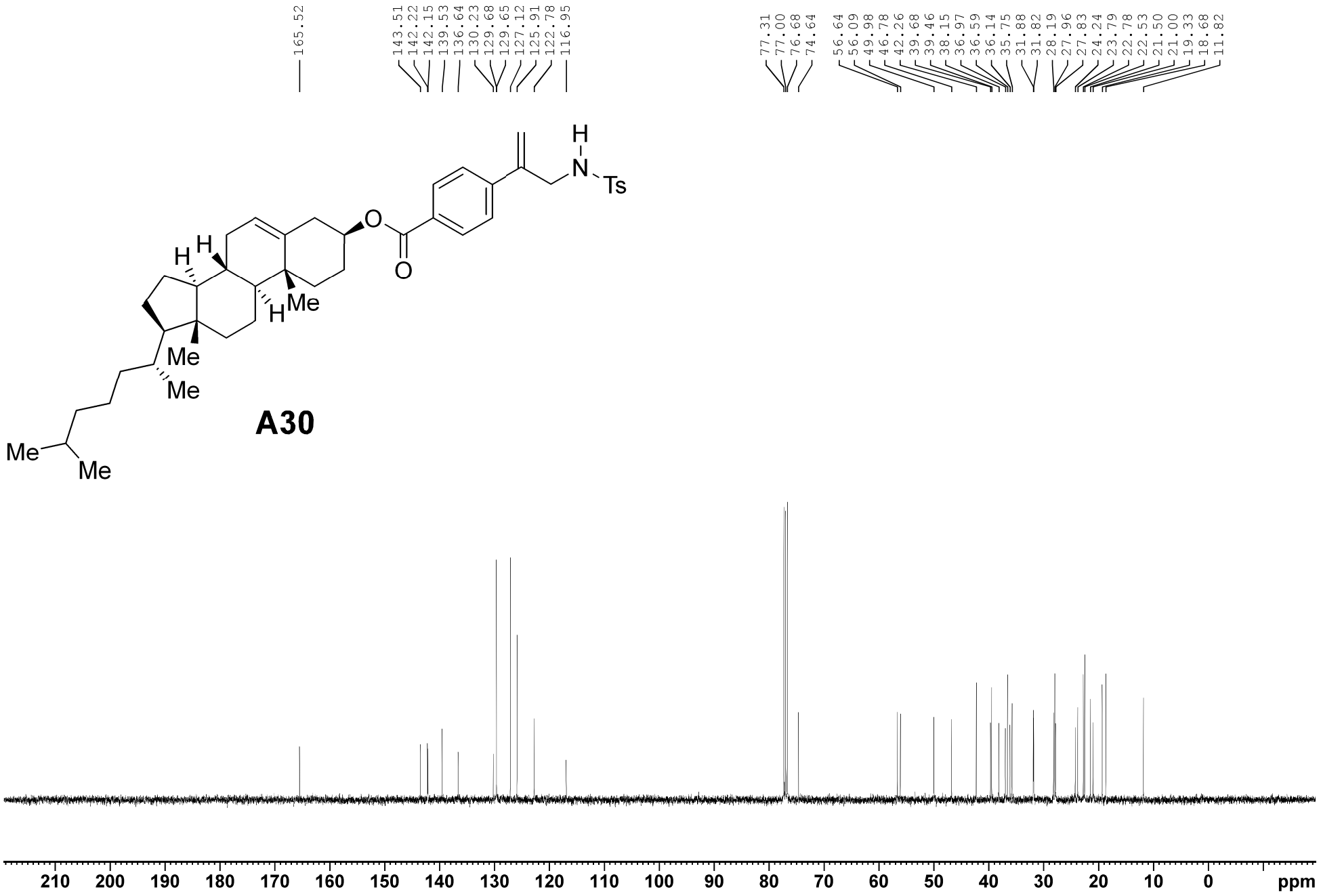
A29



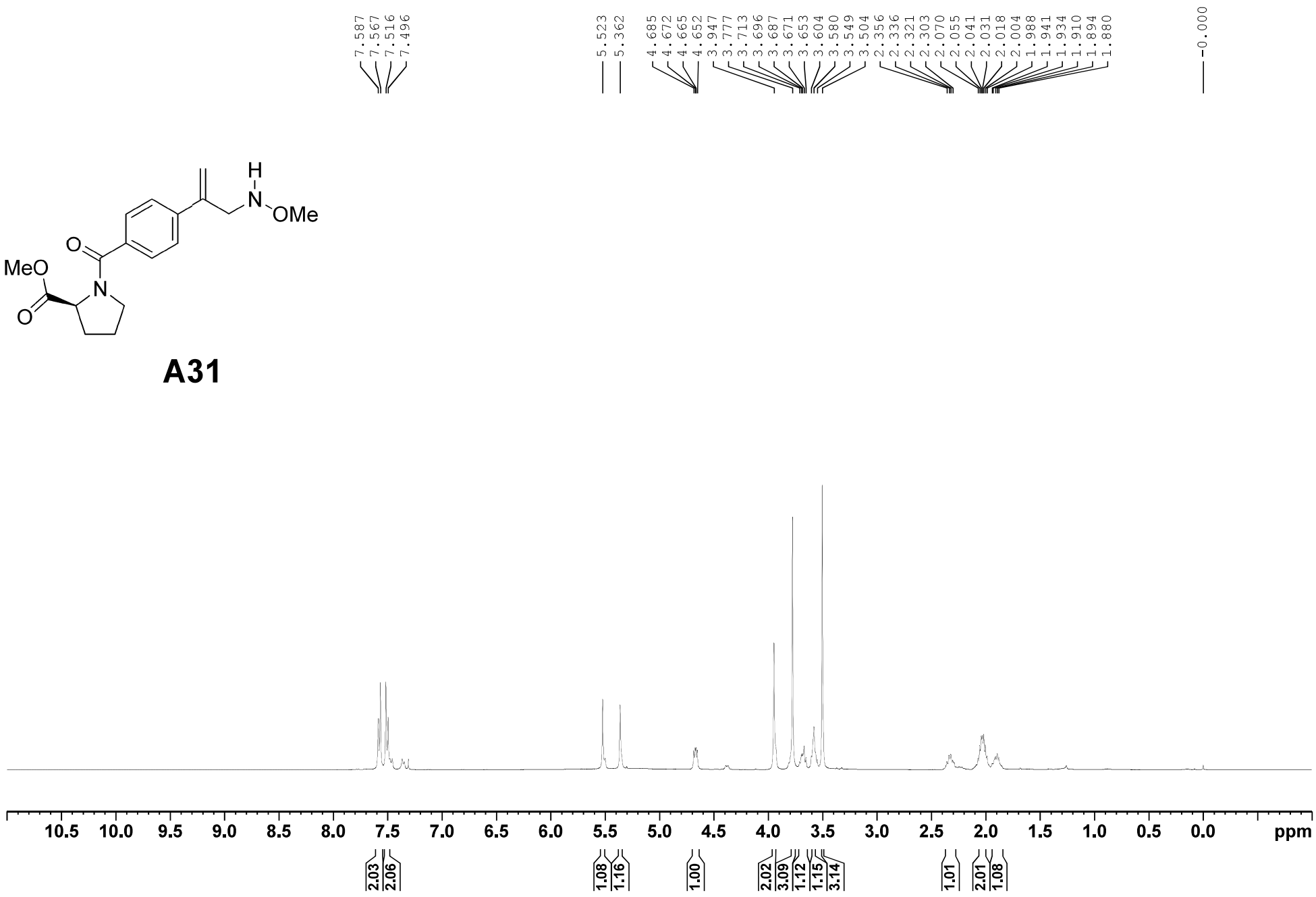
^{1}H NMR ($CDCl_3$, 400 MHz)



^{13}C NMR (100 MHz, $CDCl_3$)



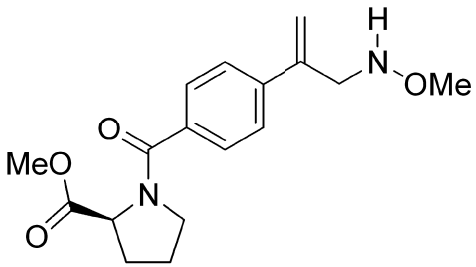
^{1}H NMR ($CDCl_3$, 400 MHz)



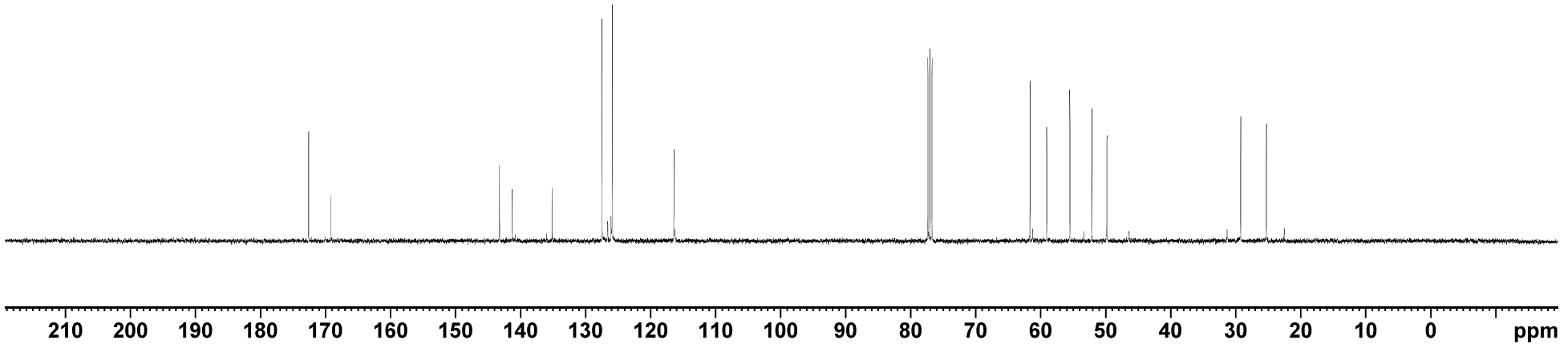
A31

^{13}C NMR (100 MHz, $CDCl_3$)

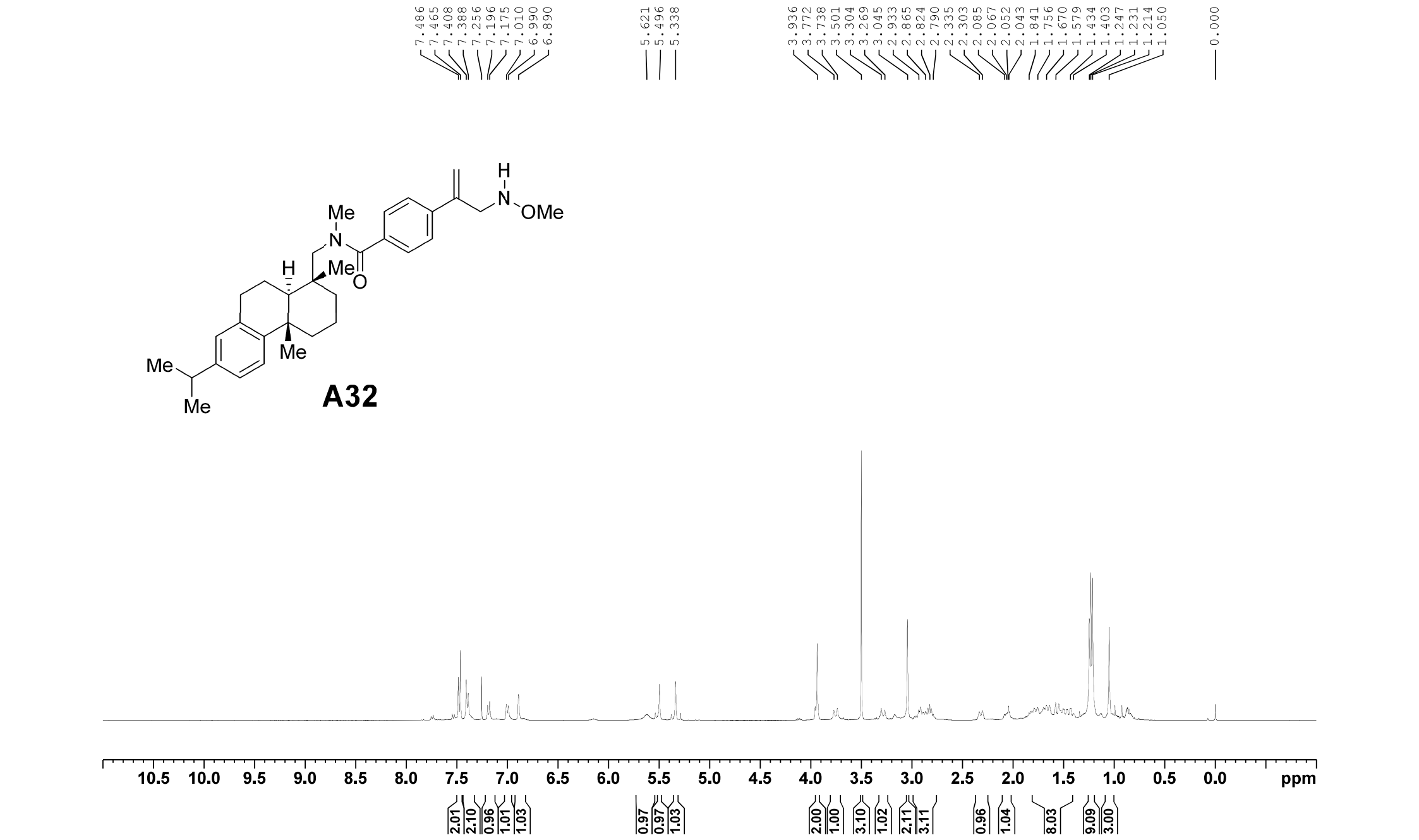
172.58
169.10
143.22
141.29
135.13
127.45
125.87
116.38
77.32
77.00
76.68
61.61
59.03
55.47
52.09
49.78
29.19
25.24



A31

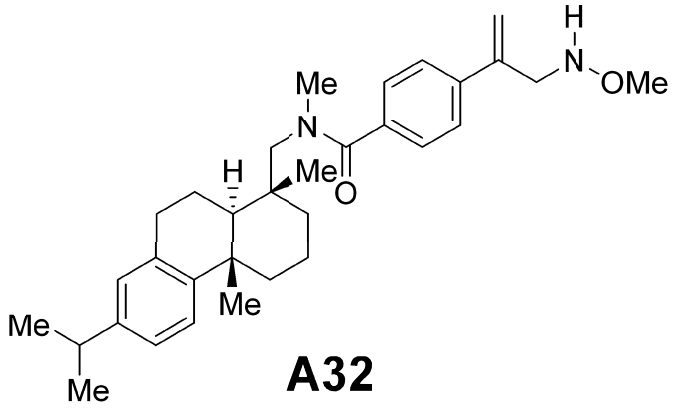


^{1}H NMR ($CDCl_3$, 400 MHz)

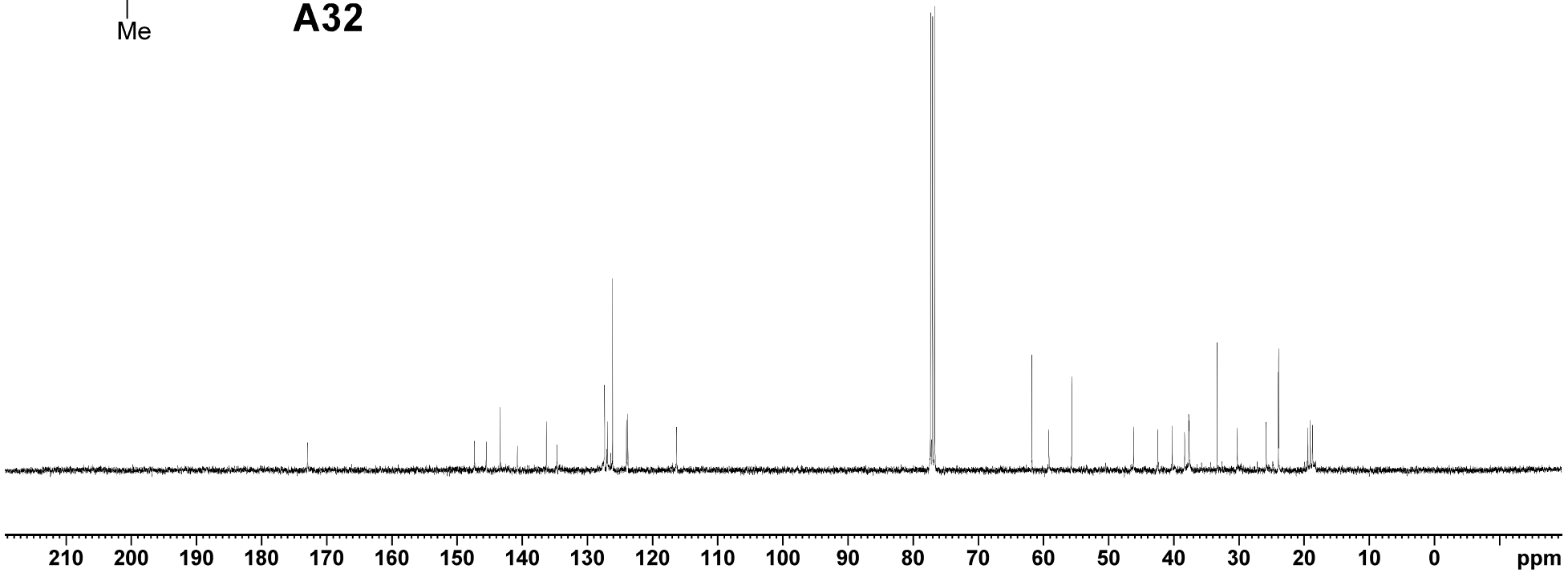


^{13}C NMR (100 MHz, $CDCl_3$)

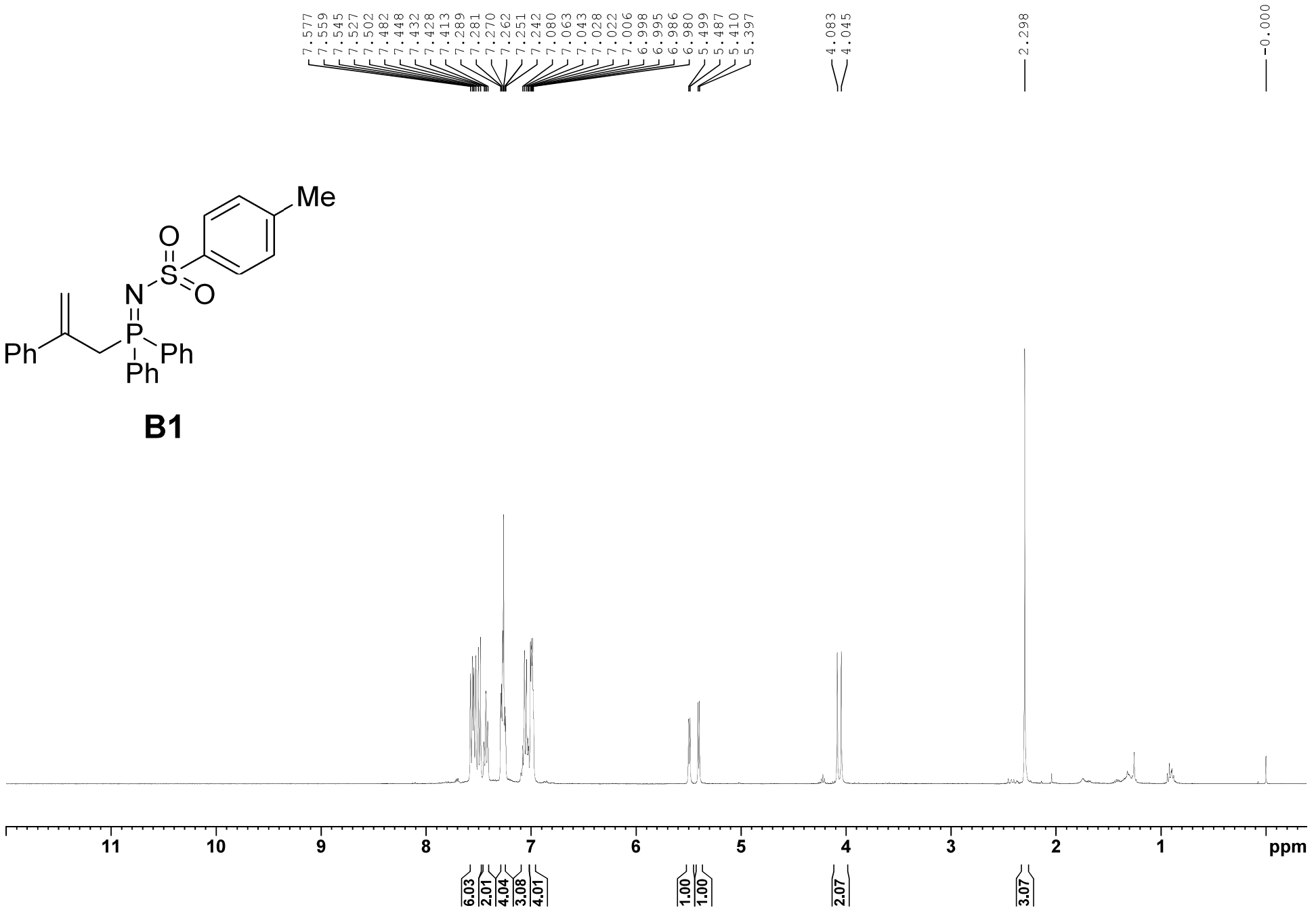
172.93
147.32
145.50
143.37
140.72
136.28
134.66
127.35
126.91
126.12
123.97
123.77
116.31
77.31
77.00
76.68
61.75
59.16
55.65
46.15
42.45
40.23
38.32
37.68
37.64
33.36
30.25
25.82
23.95
23.89
19.42
19.04
18.69



A32

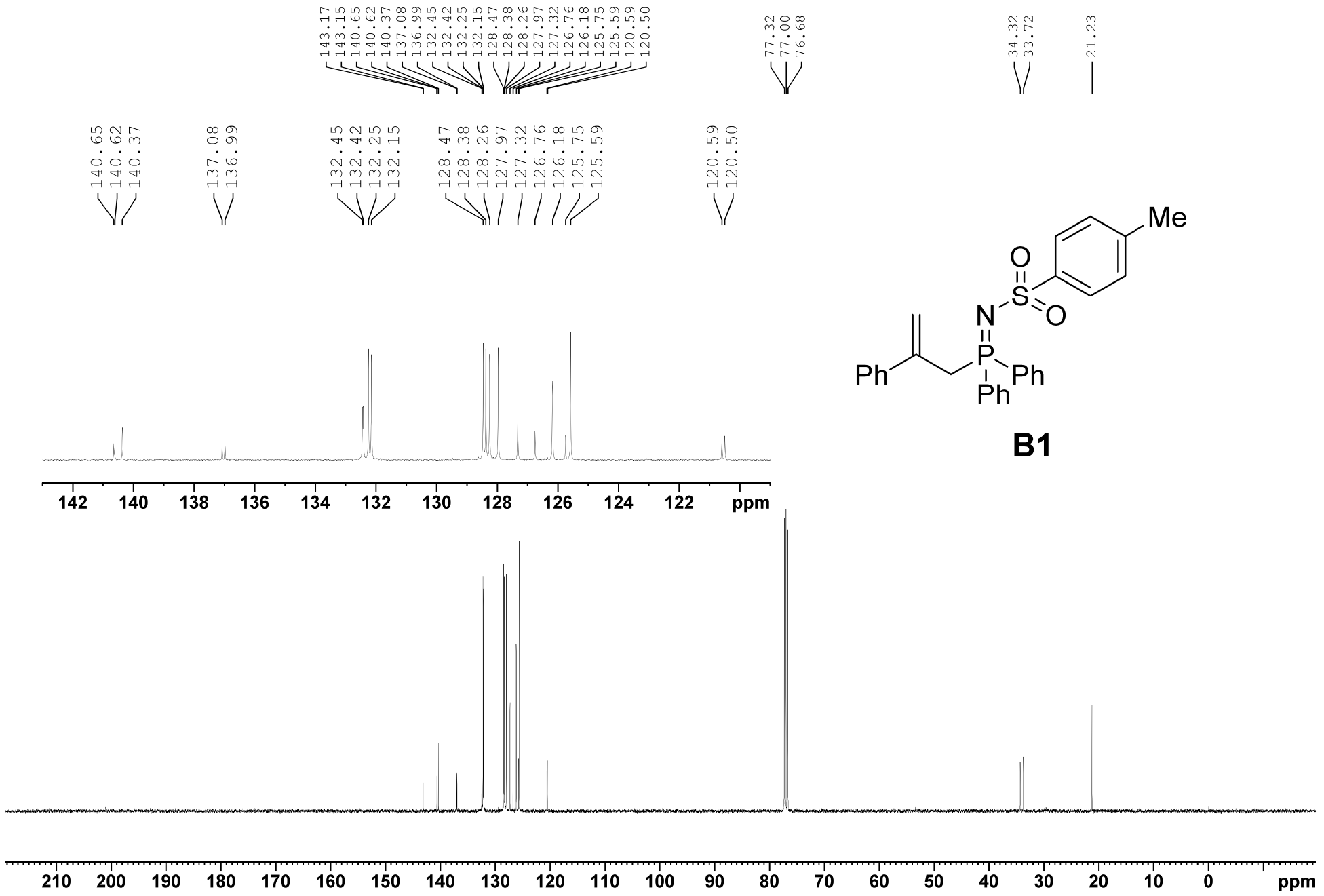


^{1}H NMR ($CDCl_3$, 400 MHz)

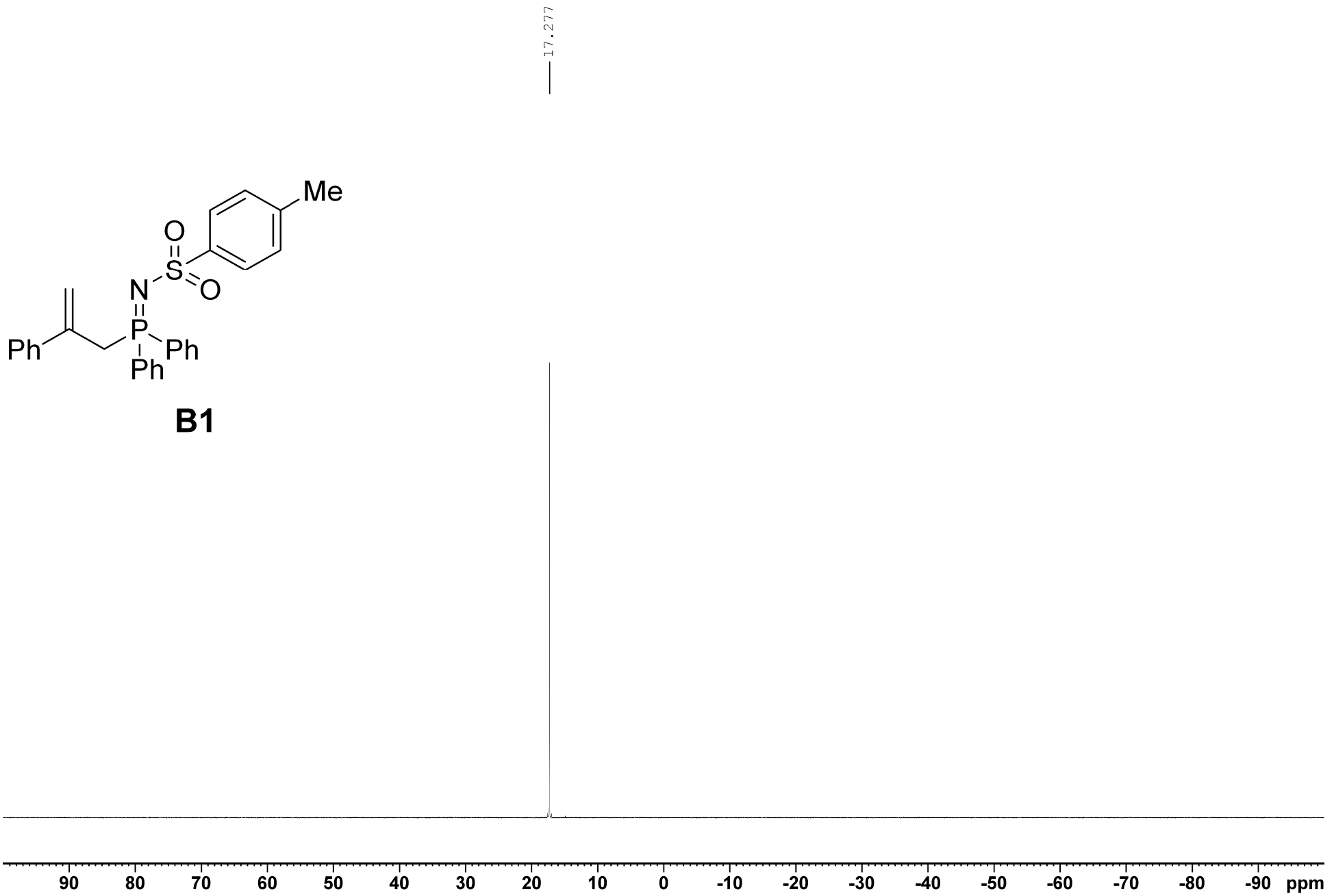


B1

^{13}C NMR (100 MHz, $CDCl_3$)

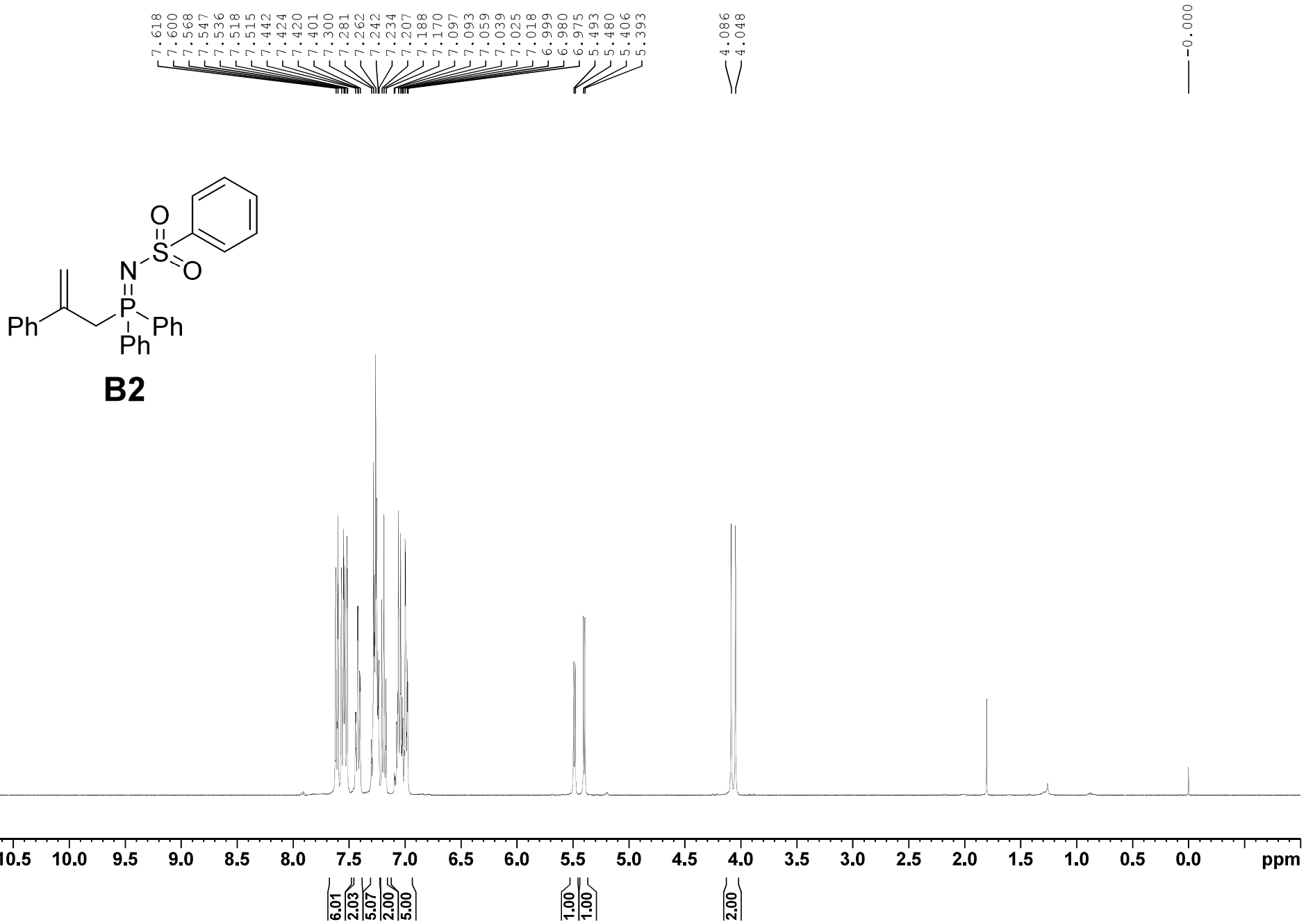


^{31}P NMR (162 MHz, $CDCl_3$)



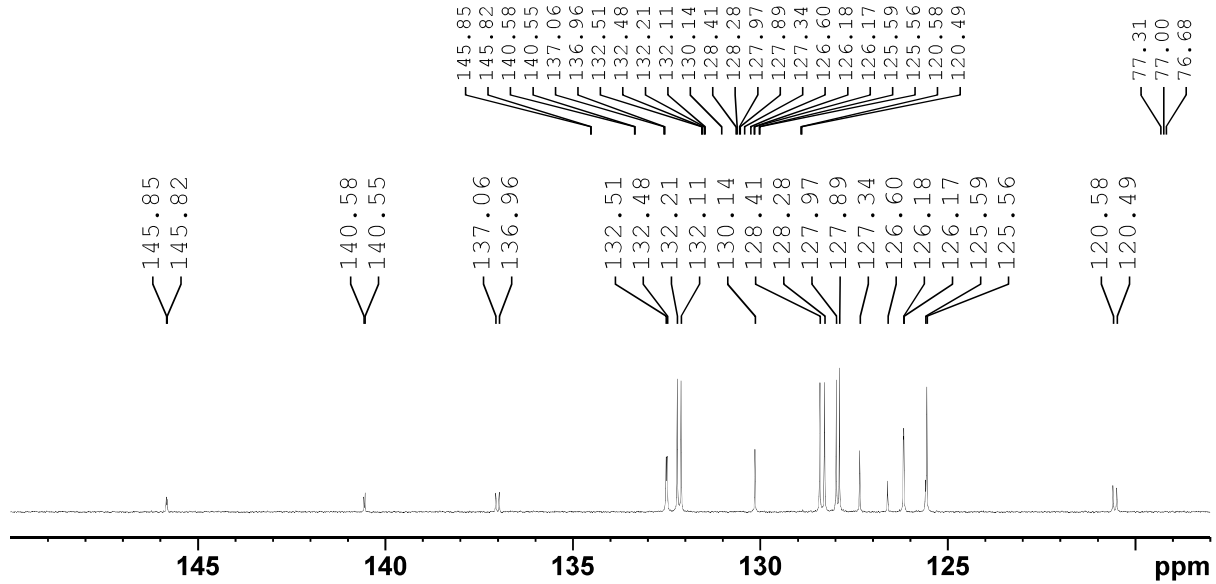
B1

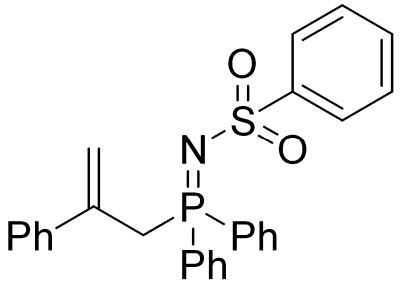
^{1}H NMR ($CDCl_3$, 400 MHz)



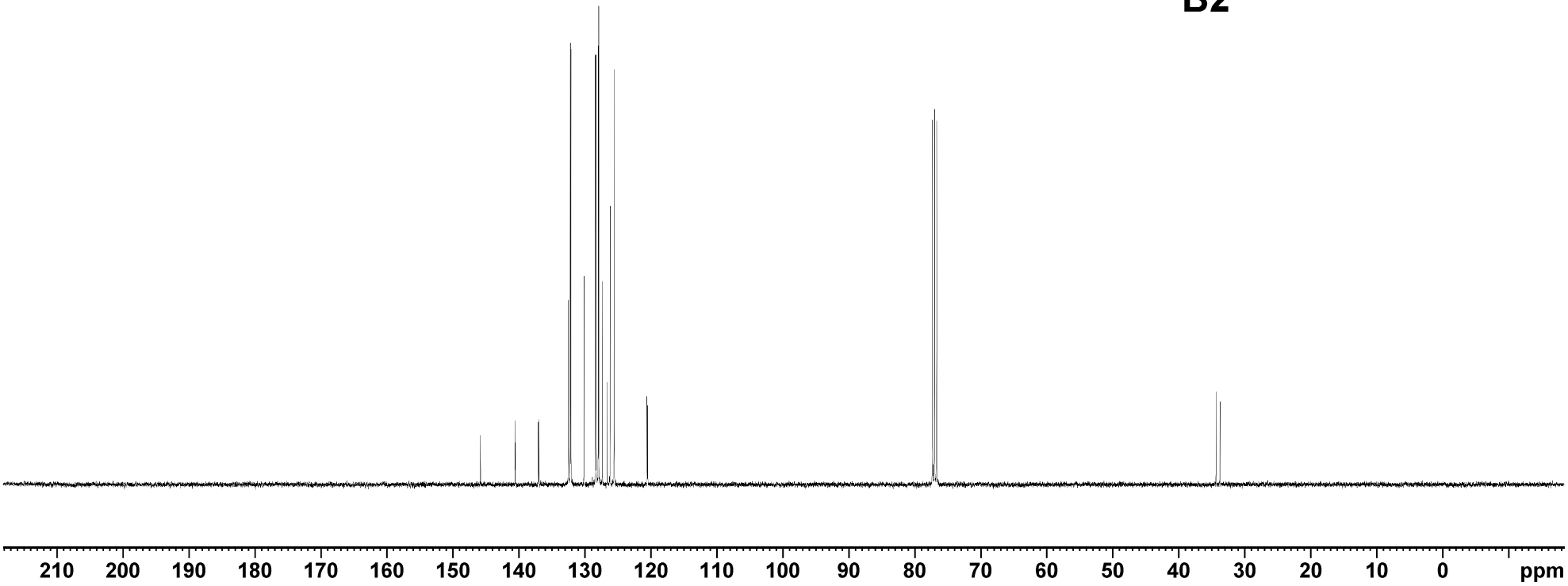
B2

^{13}C NMR (100 MHz, $CDCl_3$)

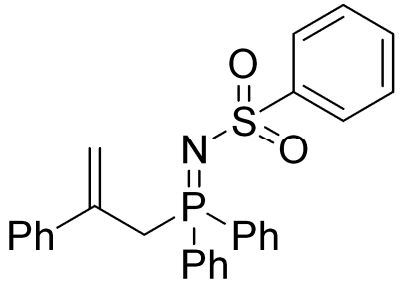




B2

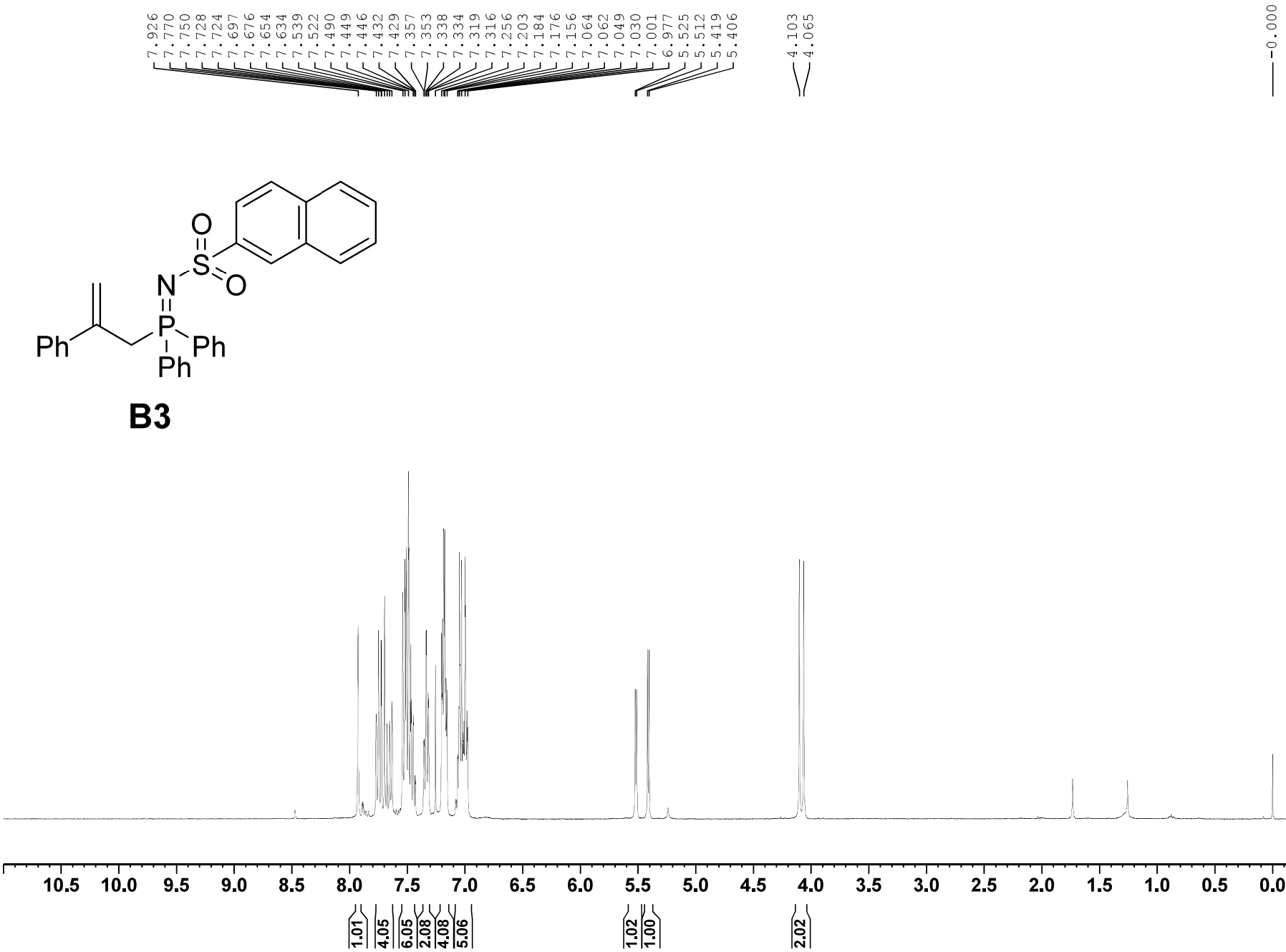


^{31}P NMR (162 MHz, $CDCl_3$)



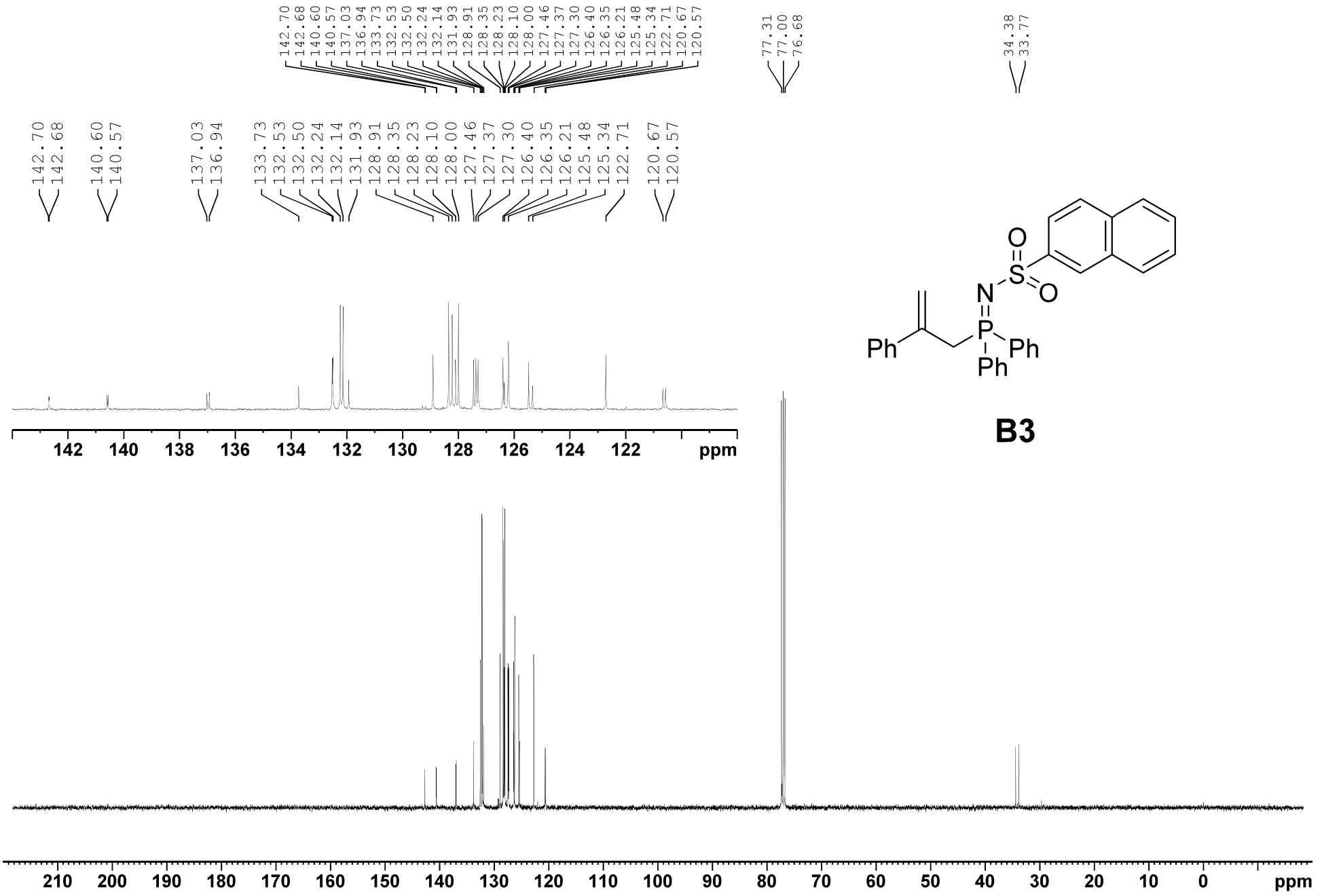
B2

^{1}H NMR ($CDCl_3$, 400 MHz)



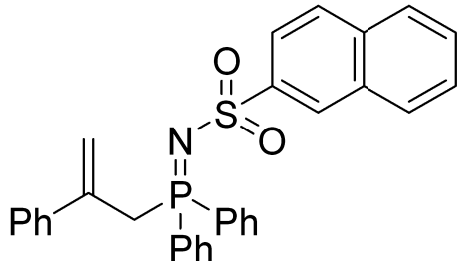
B3

^{13}C NMR (100 MHz, $CDCl_3$)



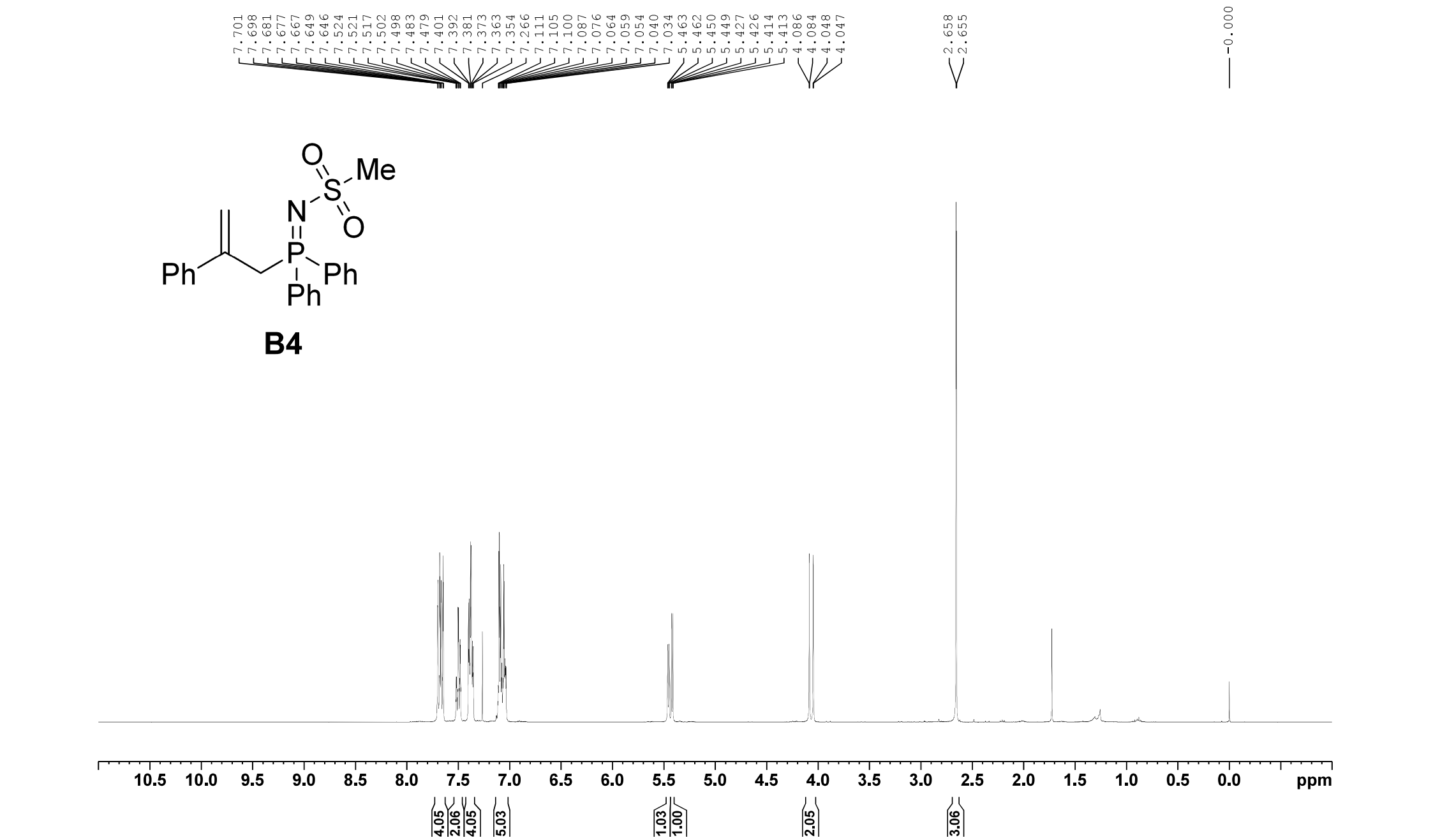
B3

^{31}P NMR (162 MHz, $CDCl_3$)

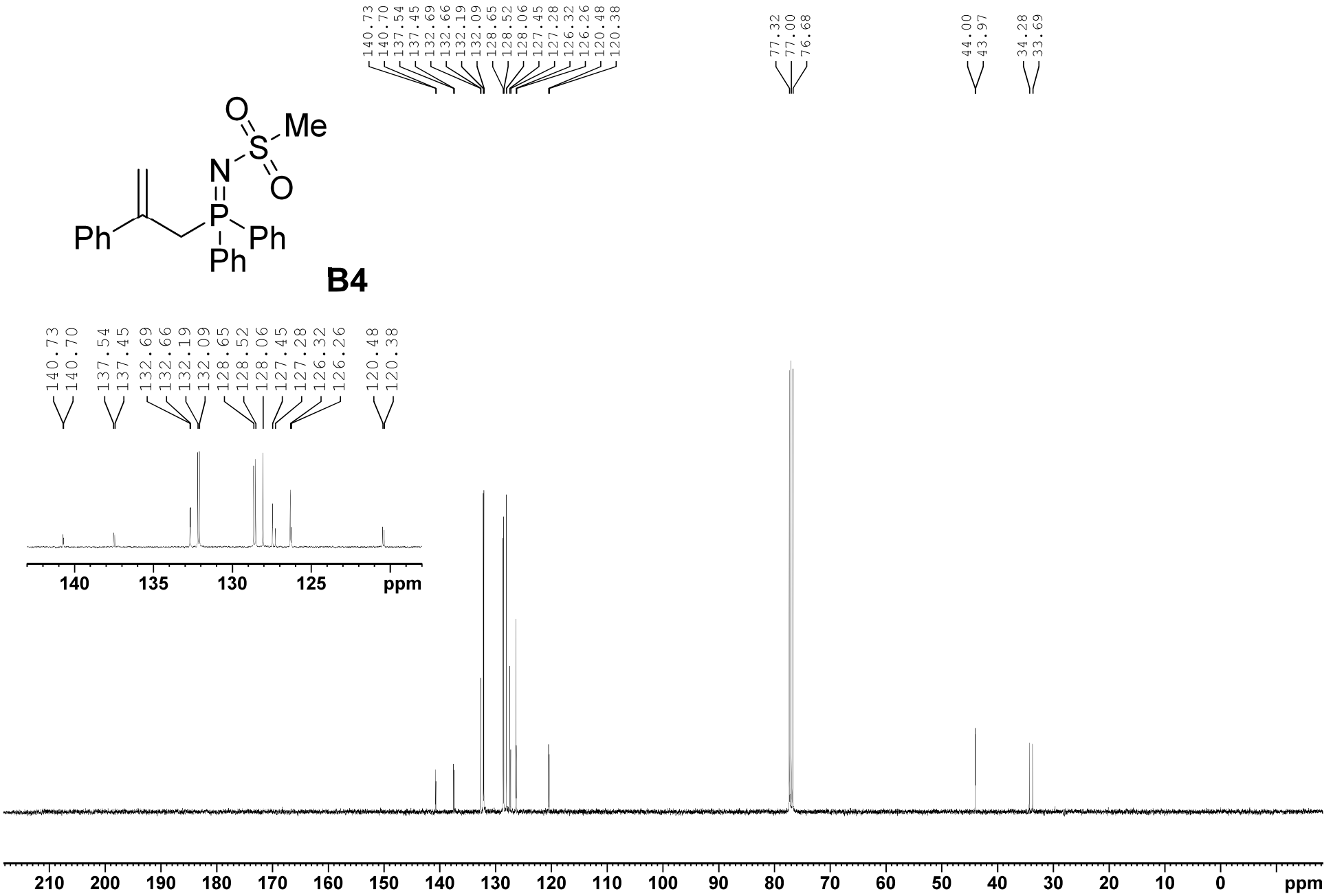


B3

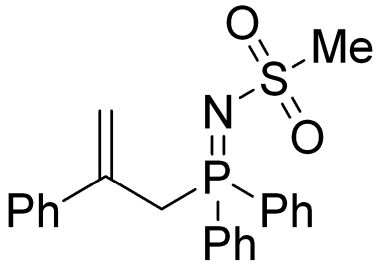
^{1}H NMR ($CDCl_3$, 400 MHz)



^{13}C NMR (100 MHz, $CDCl_3$)

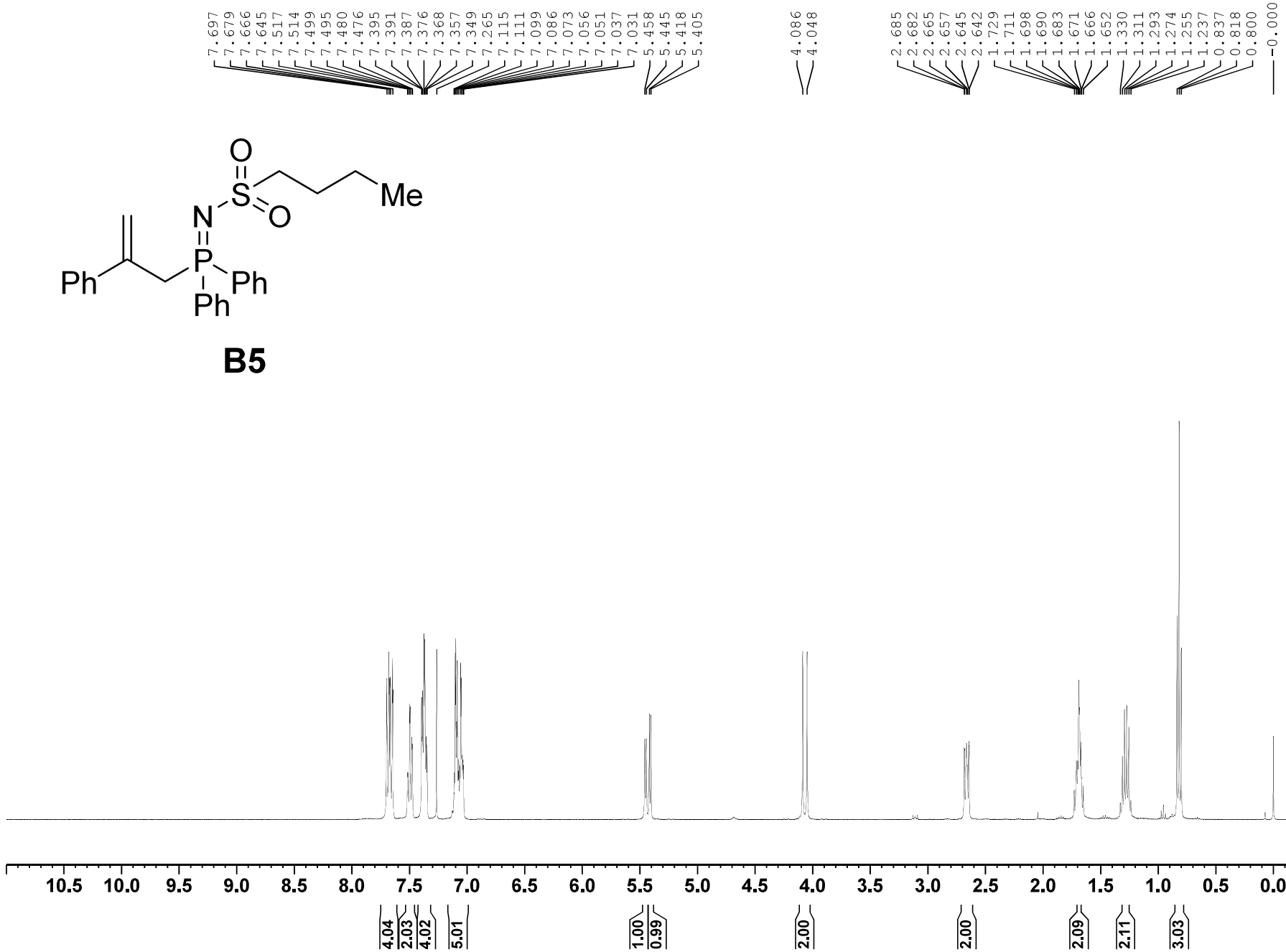


^{31}P NMR (162 MHz, $CDCl_3$)



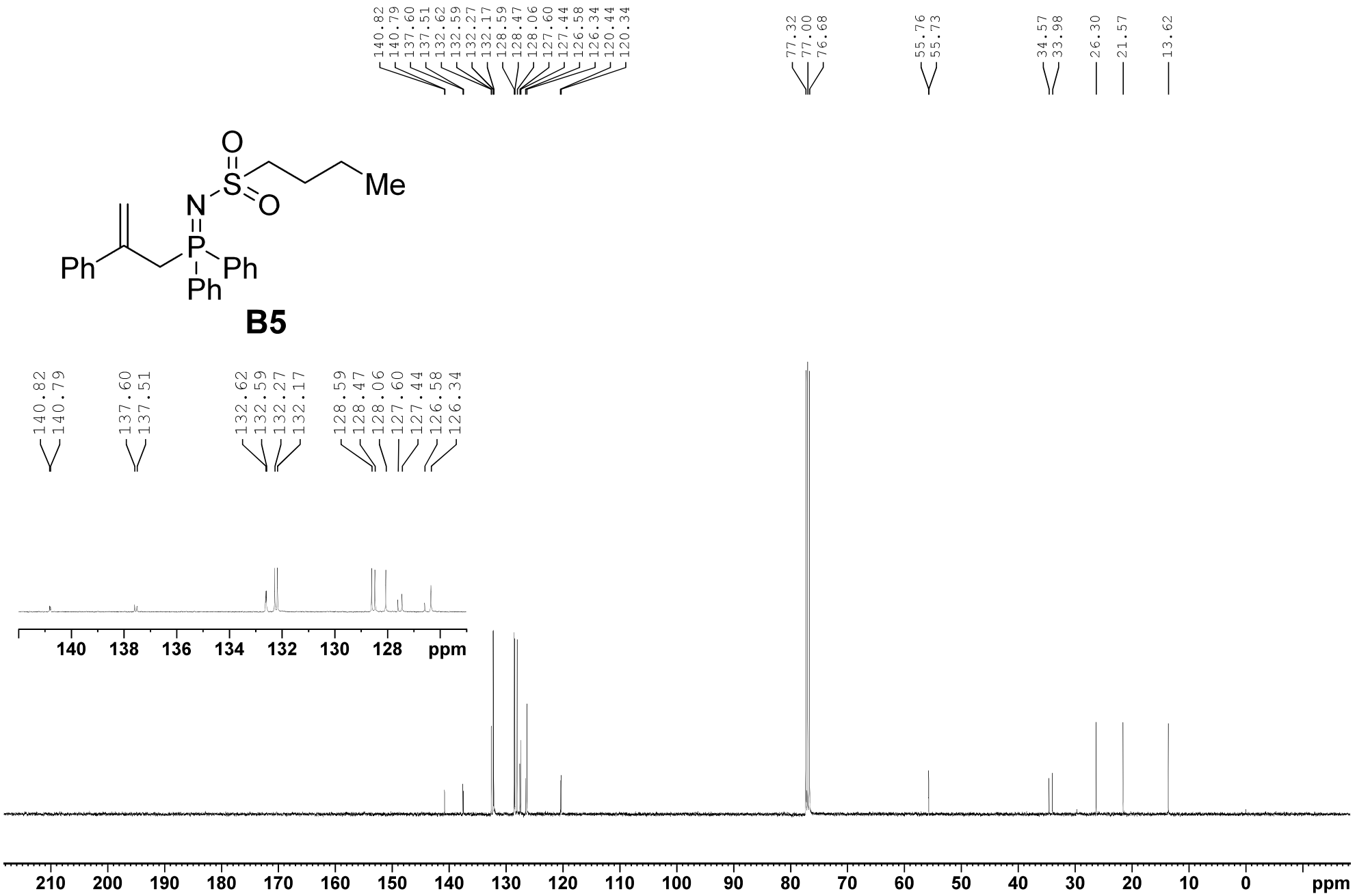
B4

^{1}H NMR ($CDCl_3$, 400 MHz)

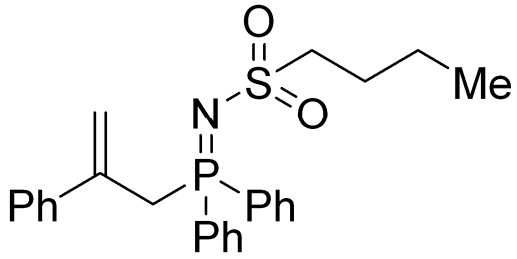


B5

^{13}C NMR (100 MHz, $CDCl_3$)

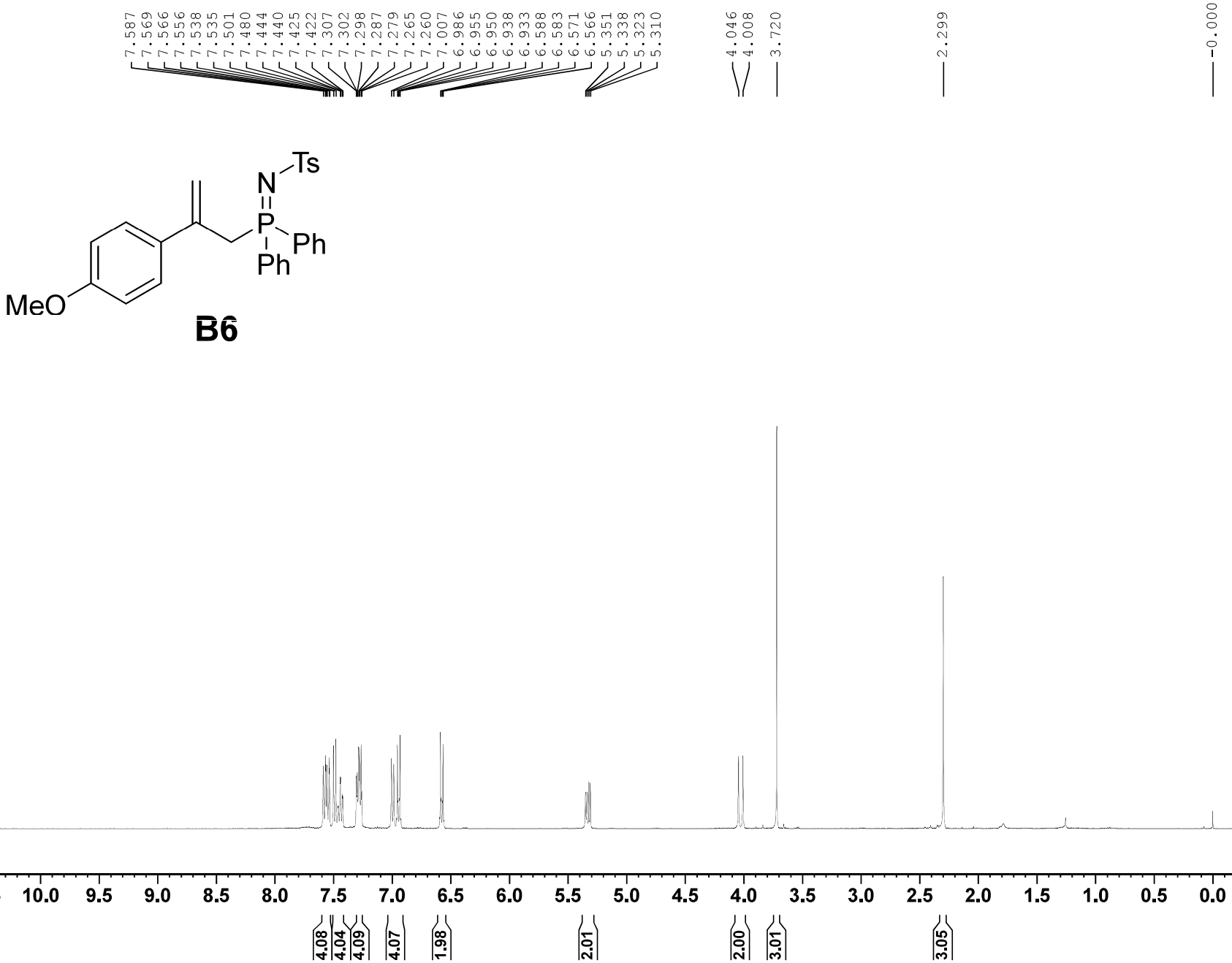


^{31}P NMR (162 MHz, $CDCl_3$)



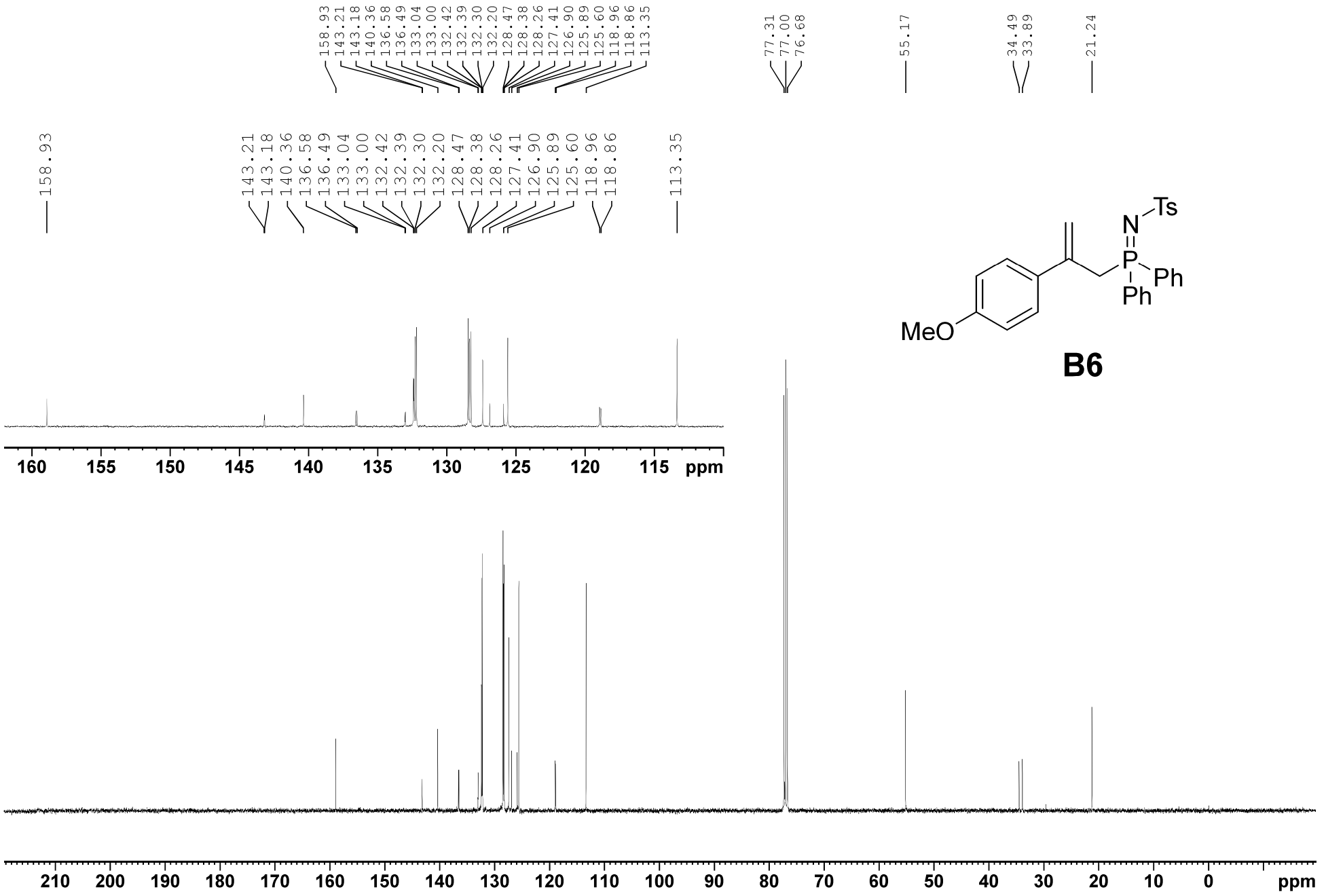
B5

^{1}H NMR ($CDCl_3$, 400 MHz)



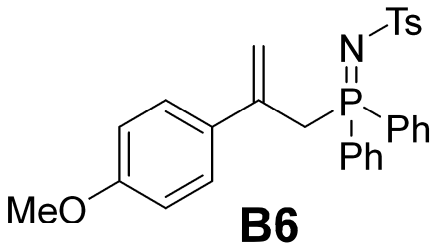
B6

^{13}C NMR (100 MHz, $CDCl_3$)



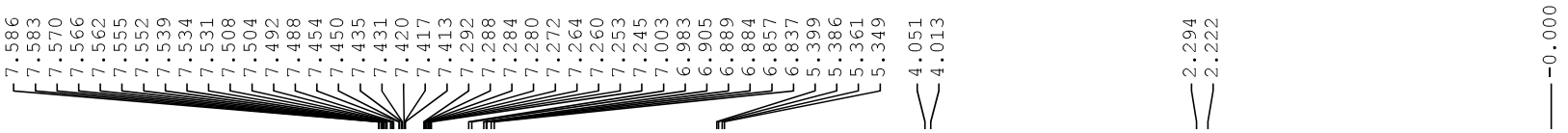
B6

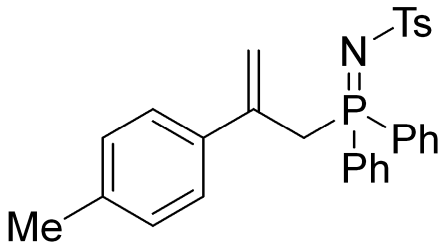
^{31}P NMR (162 MHz, $CDCl_3$)



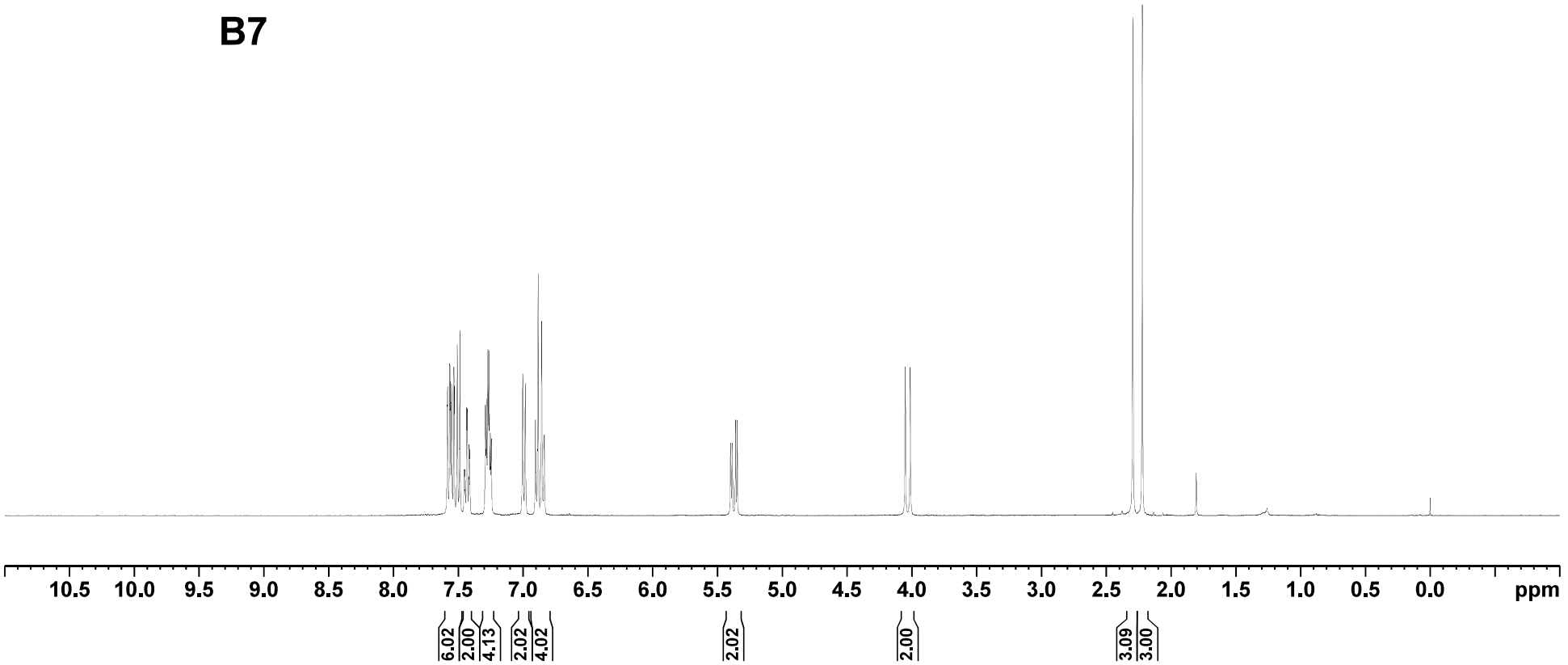
B6

^{1}H NMR ($CDCl_3$, 400 MHz)

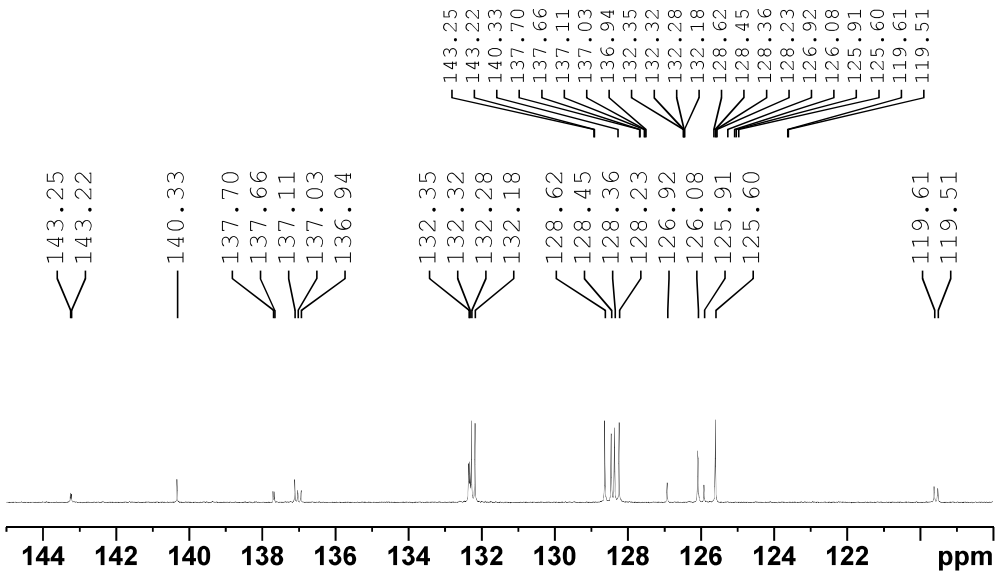


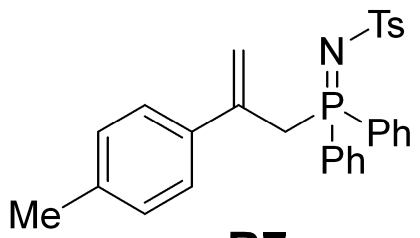


B7



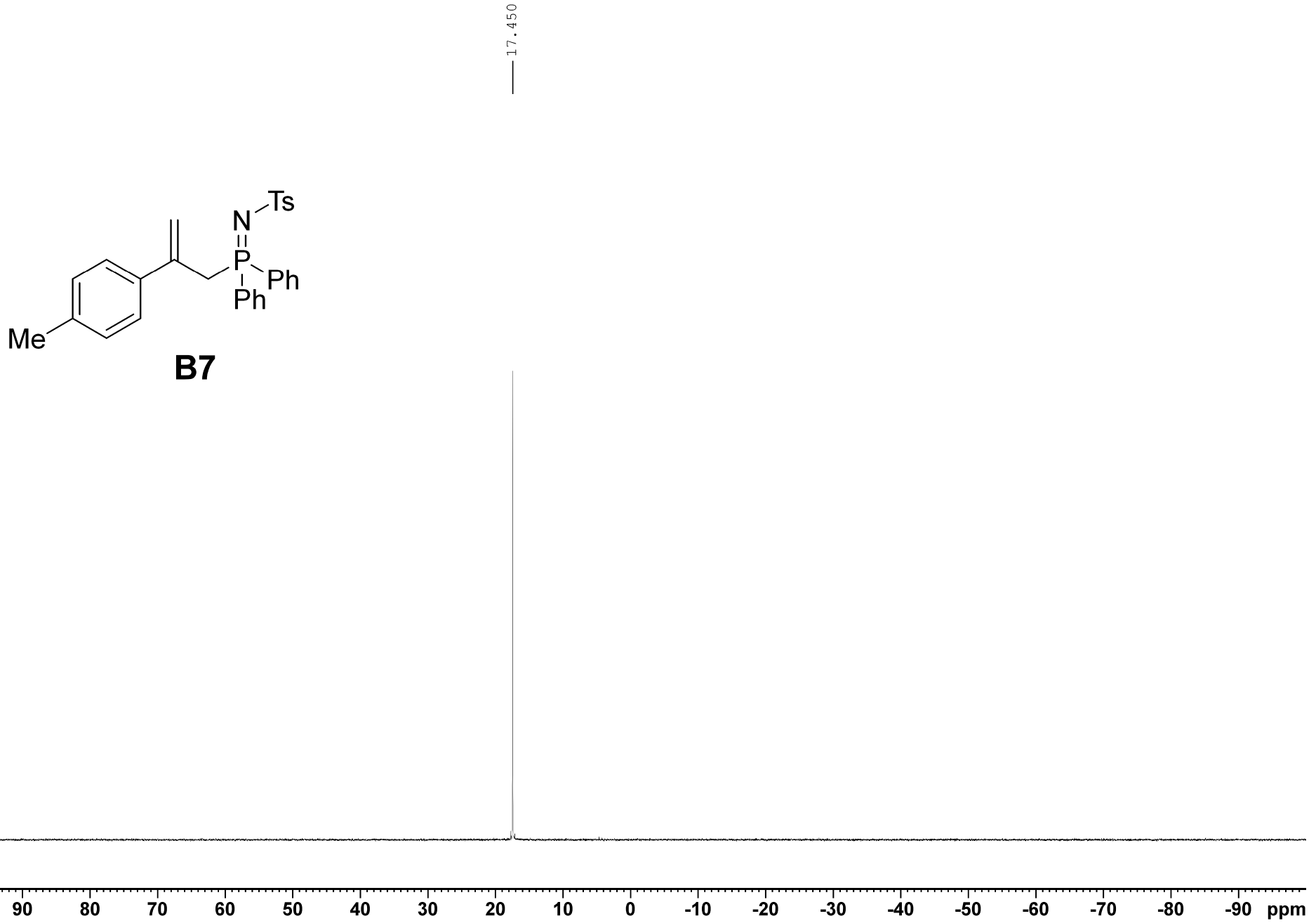
^{13}C NMR (100 MHz, $CDCl_3$)





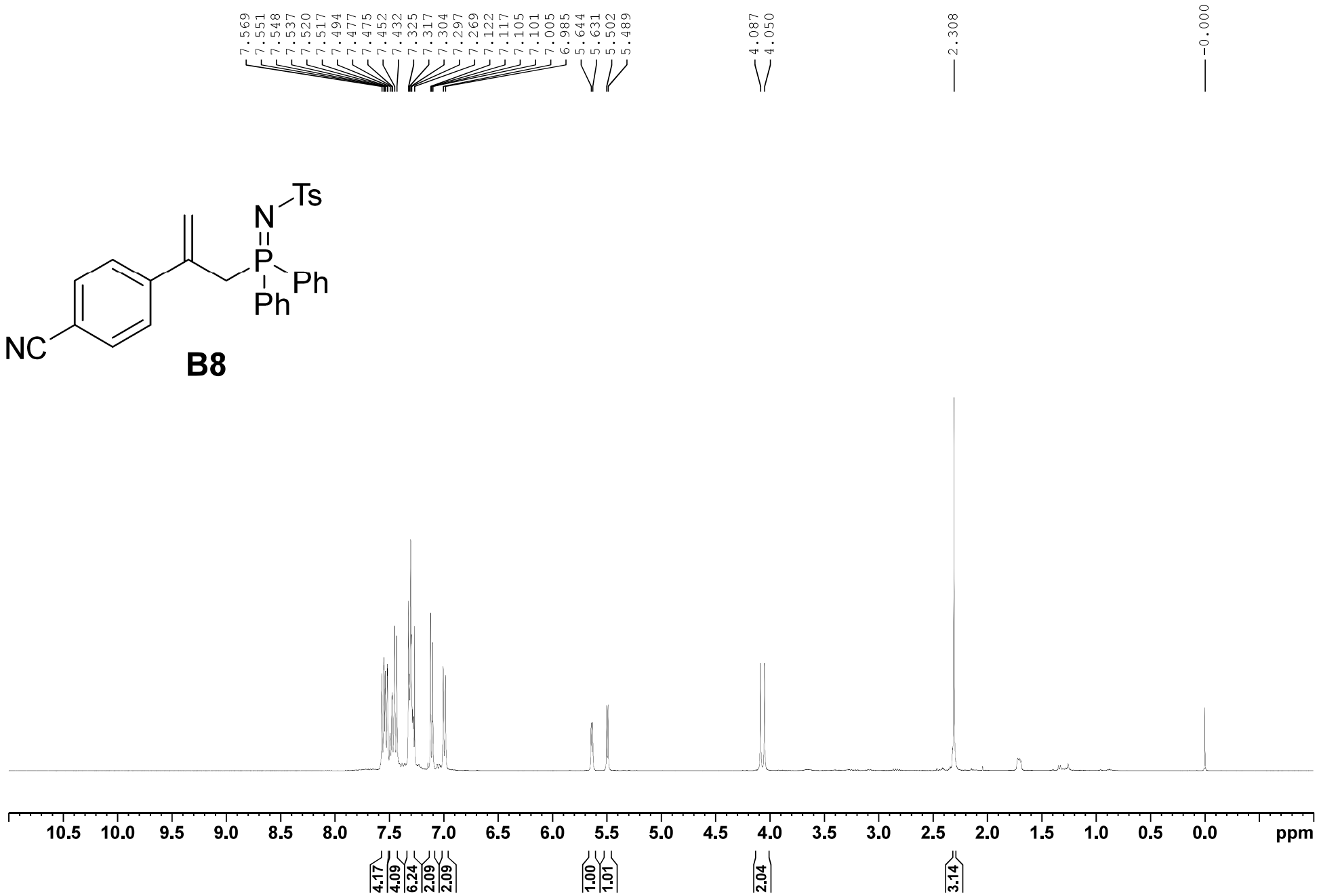
B7

^{31}P NMR (162 MHz, $CDCl_3$)

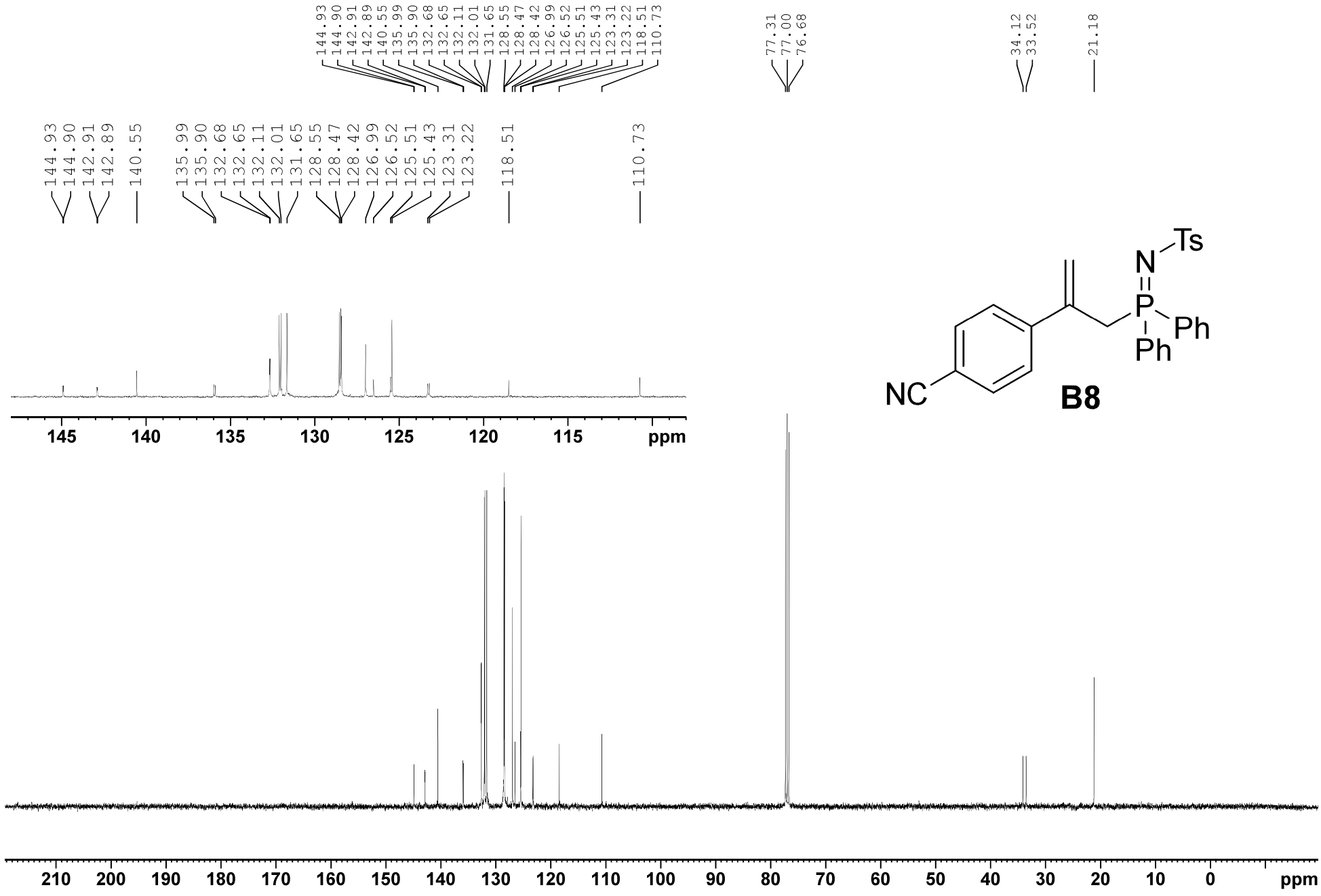


B7

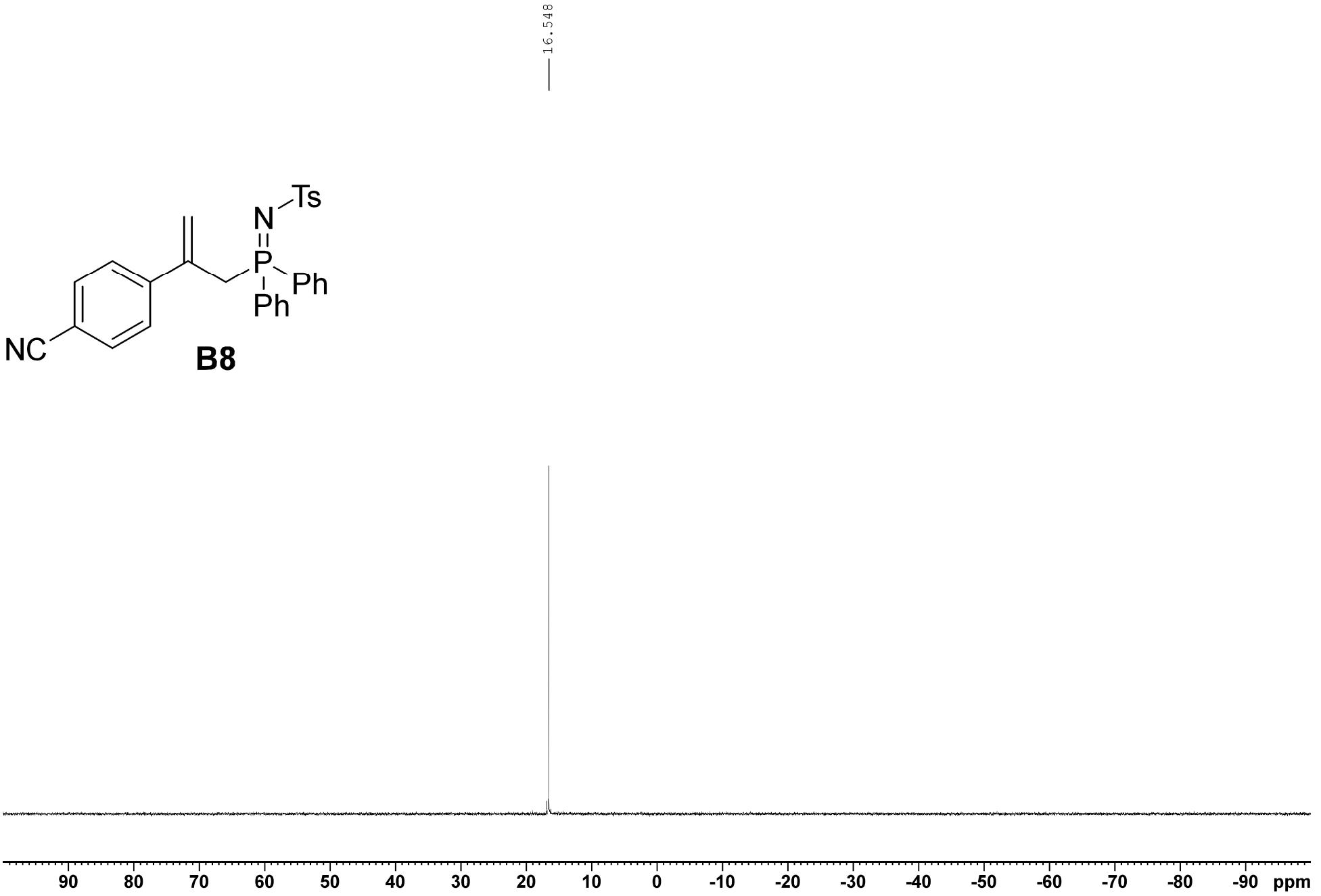
^{1}H NMR ($CDCl_3$, 400 MHz)



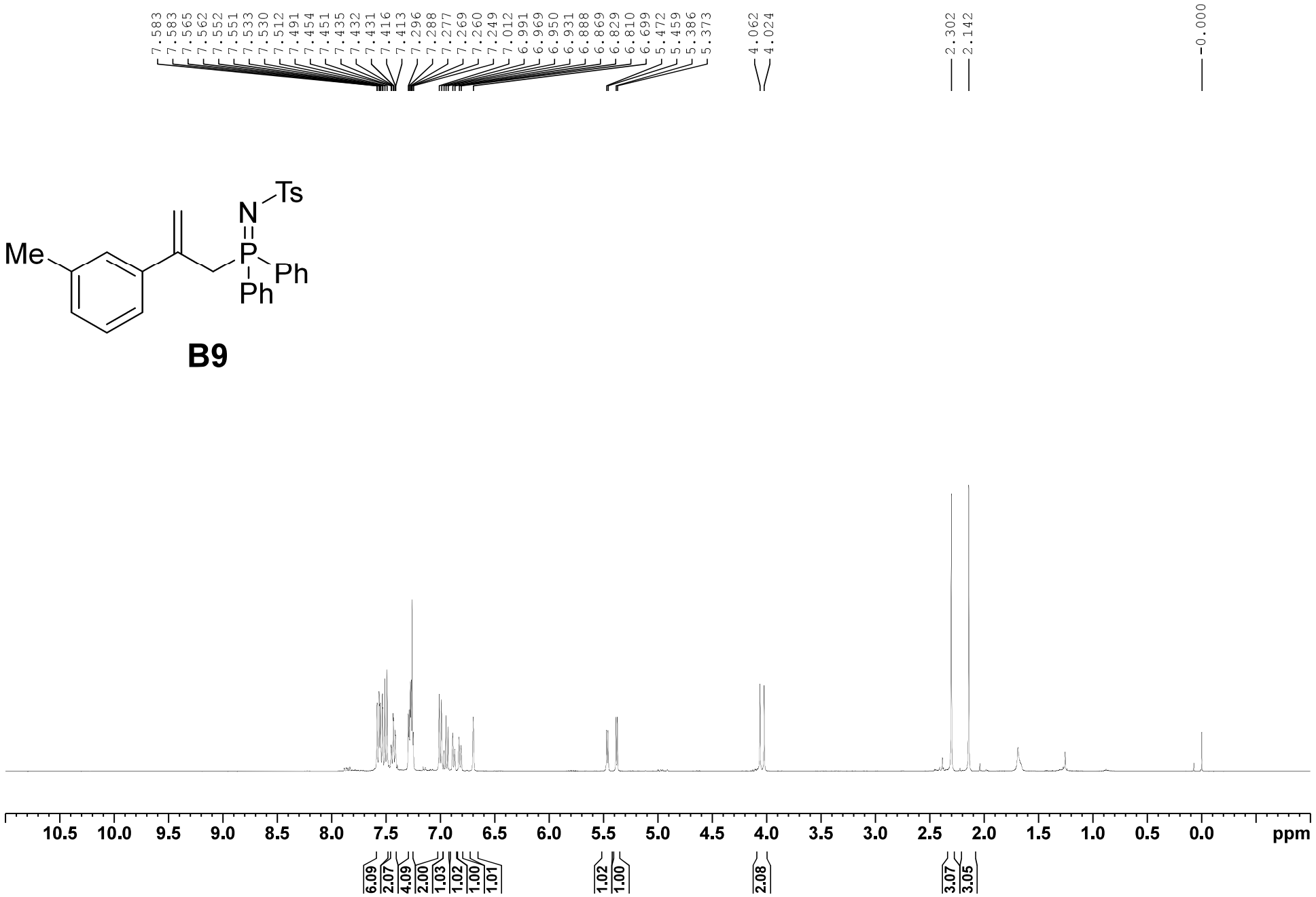
^{13}C NMR (100 MHz, $CDCl_3$)



^{31}P NMR (162 MHz, $CDCl_3$)

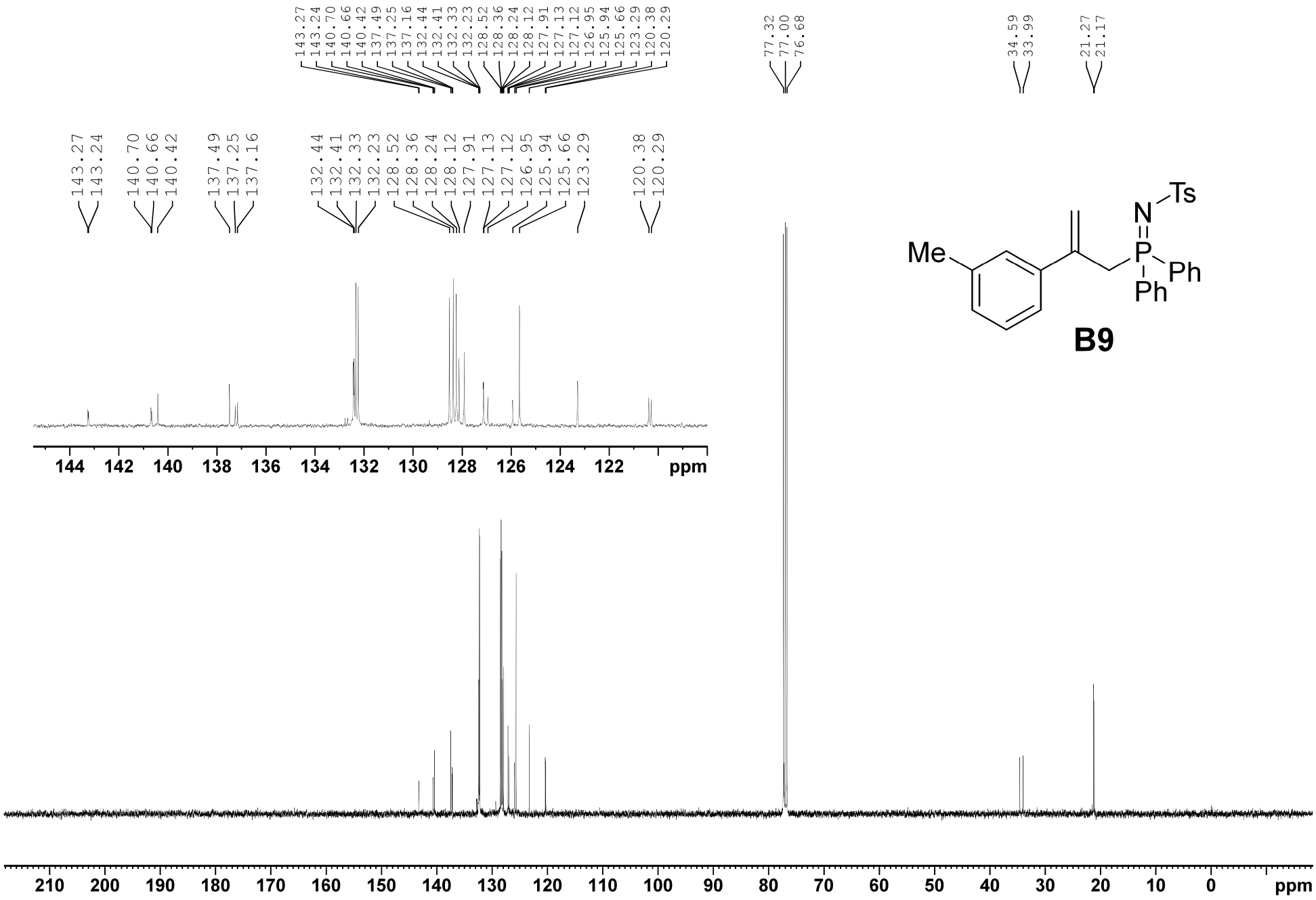


^{1}H NMR ($CDCl_3$, 400 MHz)



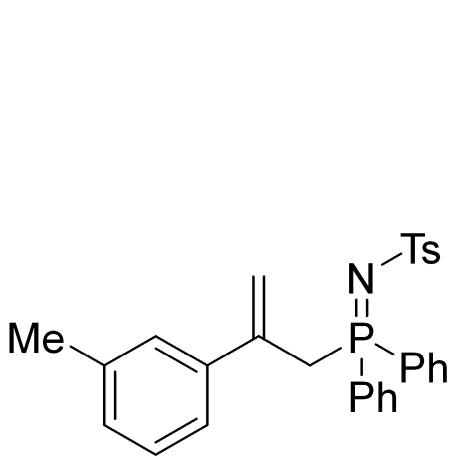
B9

^{13}C NMR (100 MHz, $CDCl_3$)



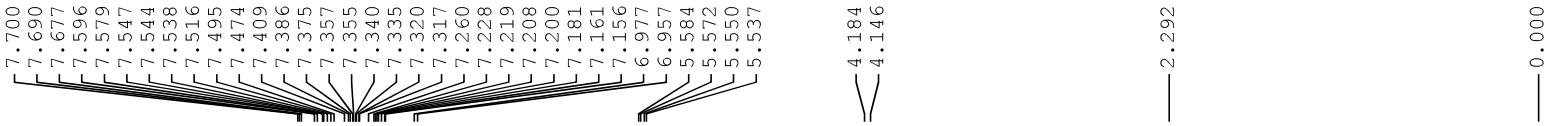
B9

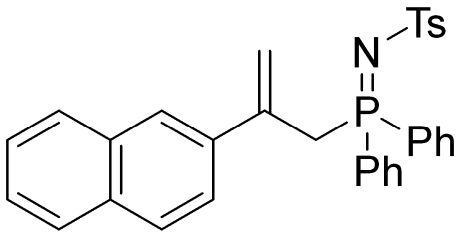
^{31}P NMR (162 MHz, $CDCl_3$)



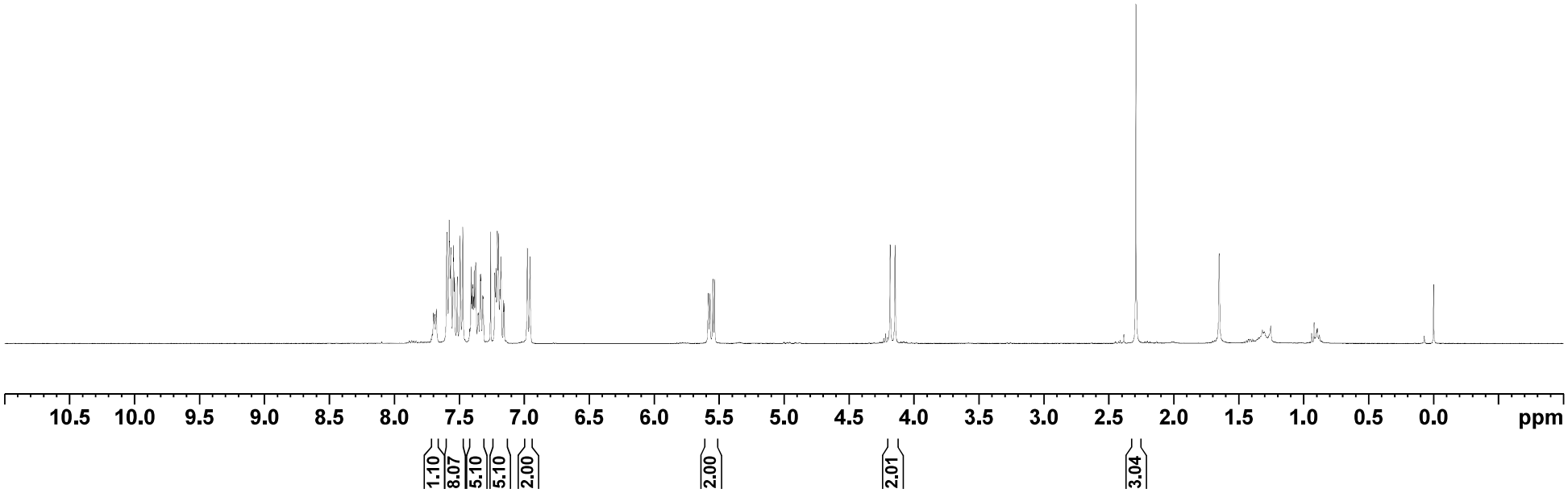
B9

^{1}H NMR ($CDCl_3$, 400 MHz)

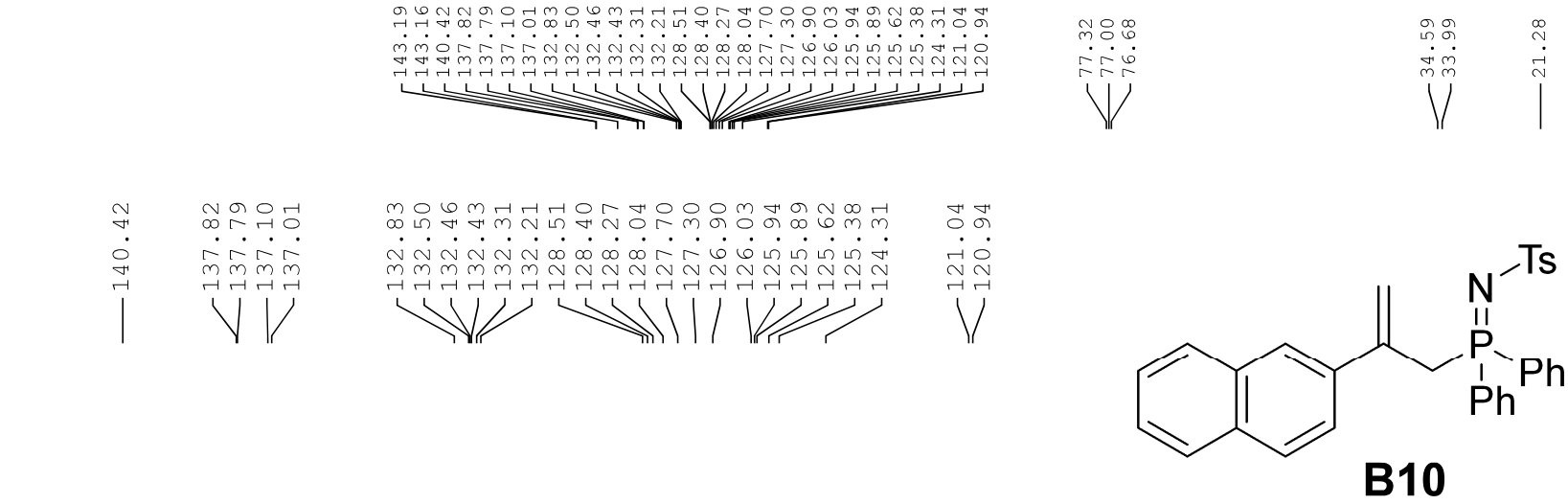




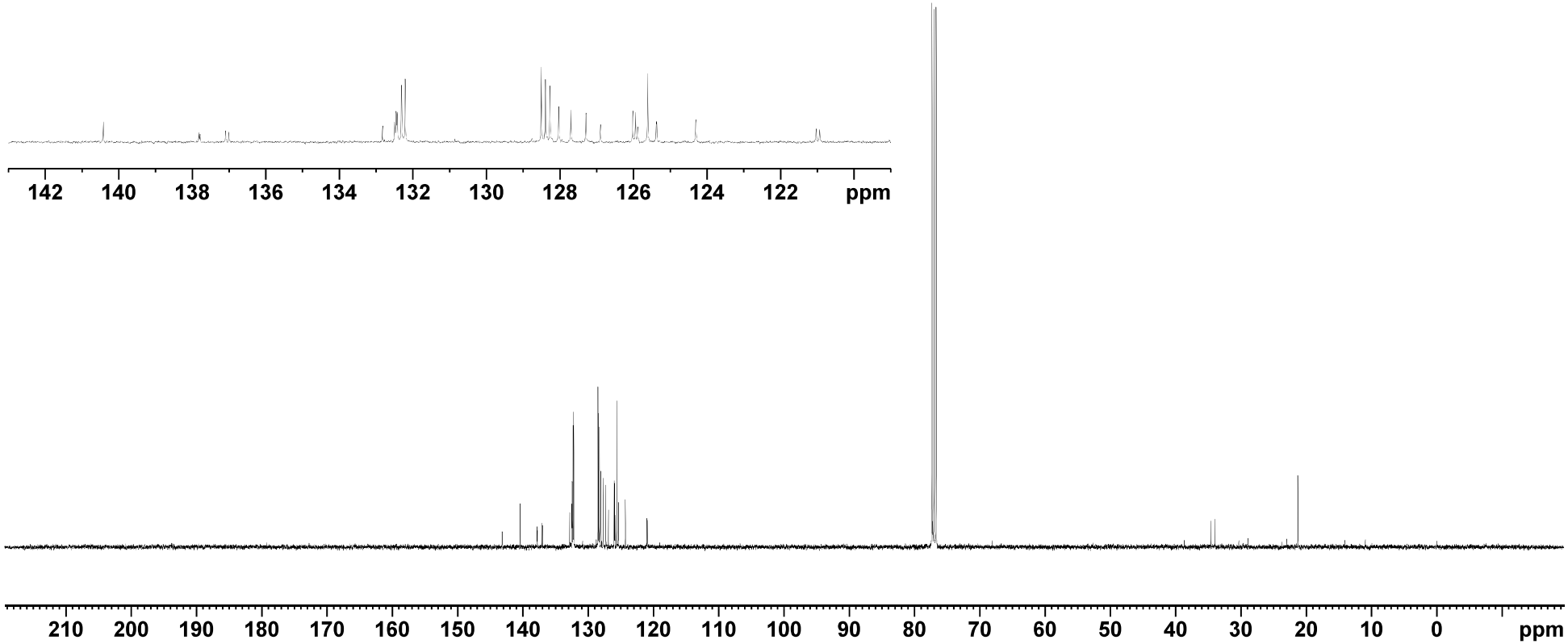
B10



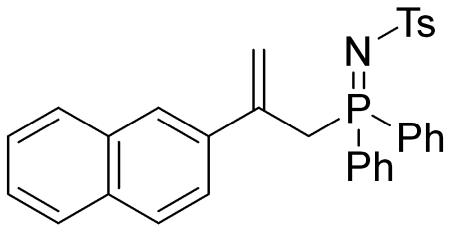
^{13}C NMR (100 MHz, $CDCl_3$)



B10

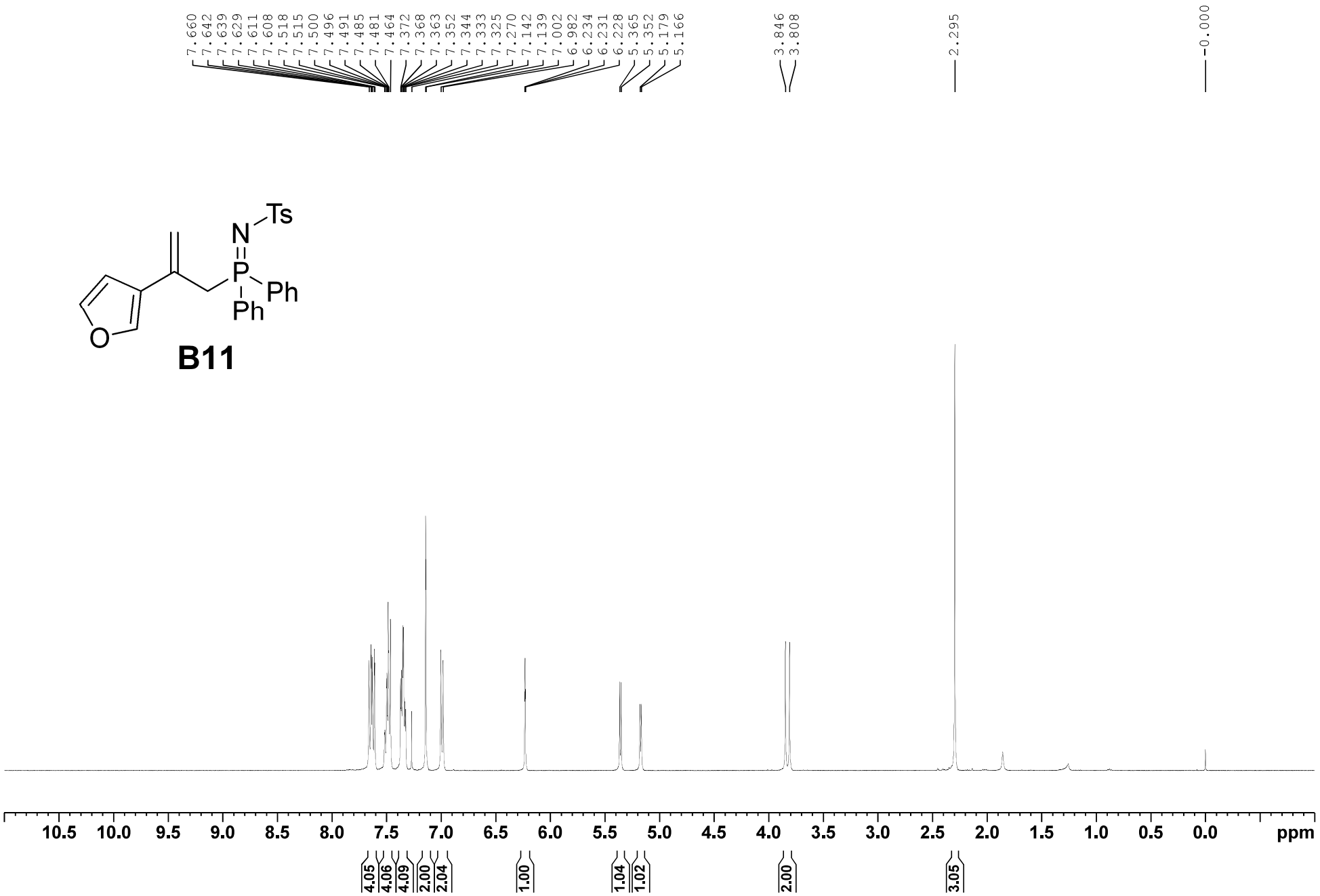


^{31}P NMR (162 MHz, $CDCl_3$)

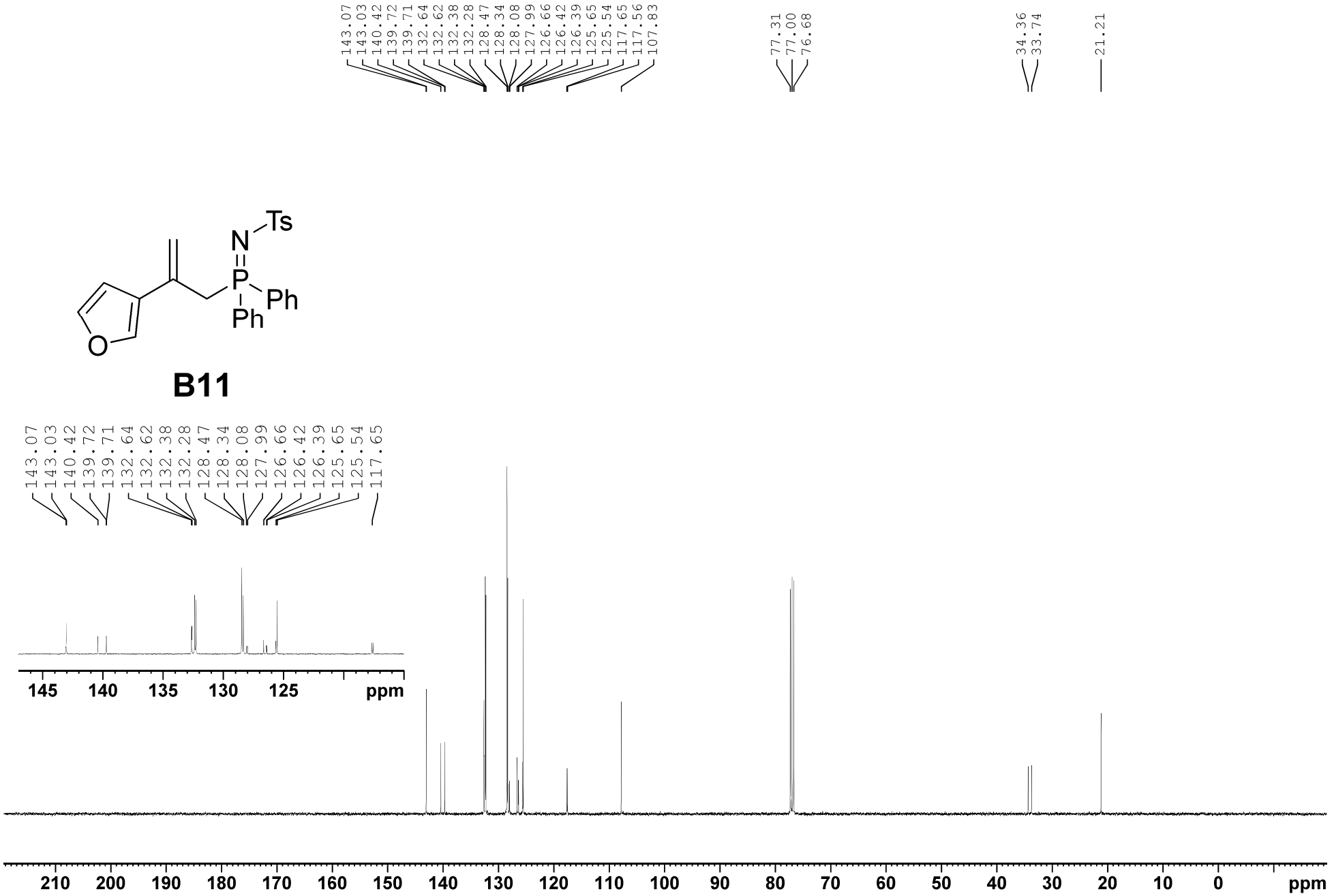


B10

^{1}H NMR ($CDCl_3$, 400 MHz)

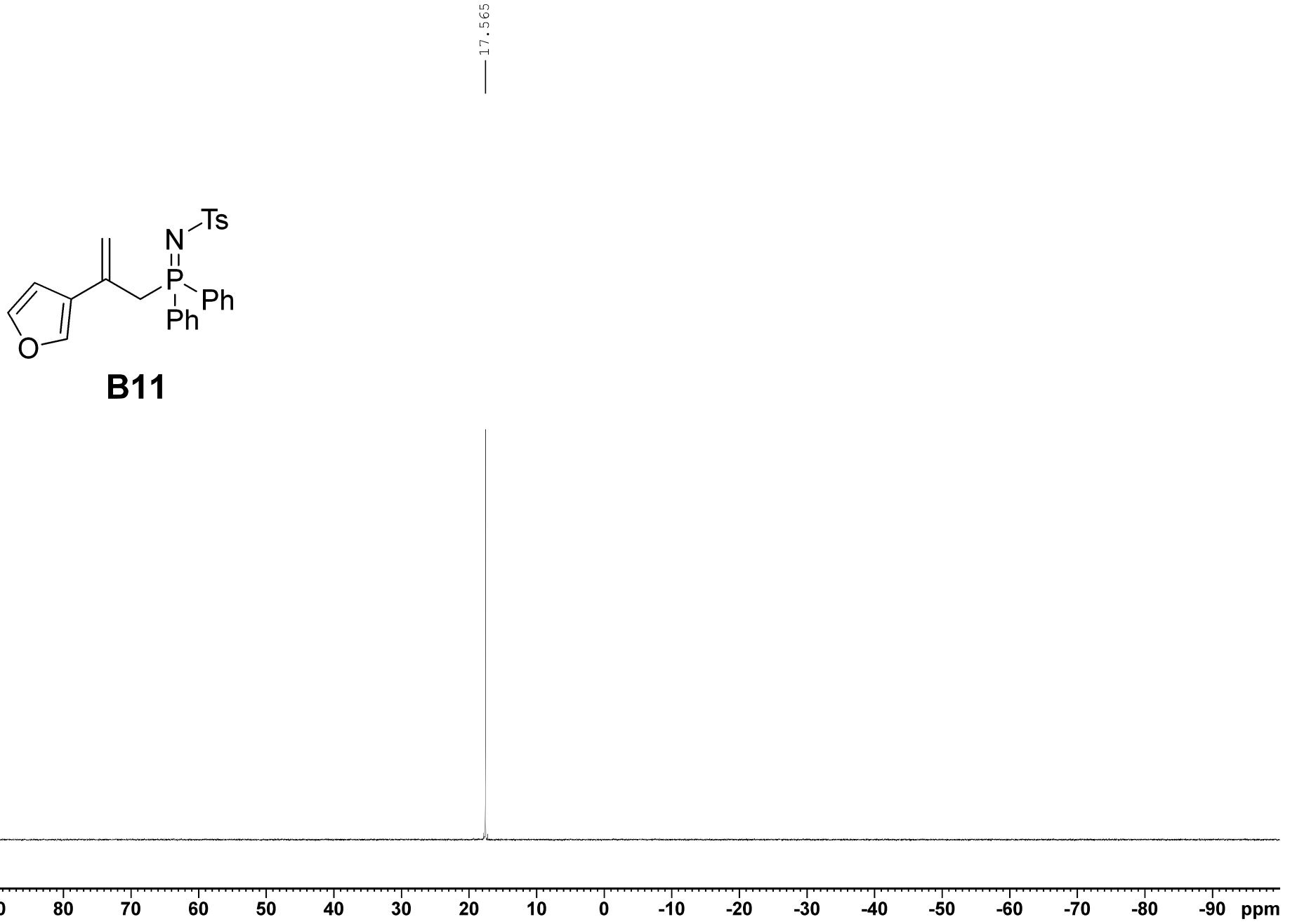


^{13}C NMR (100 MHz, $CDCl_3$)



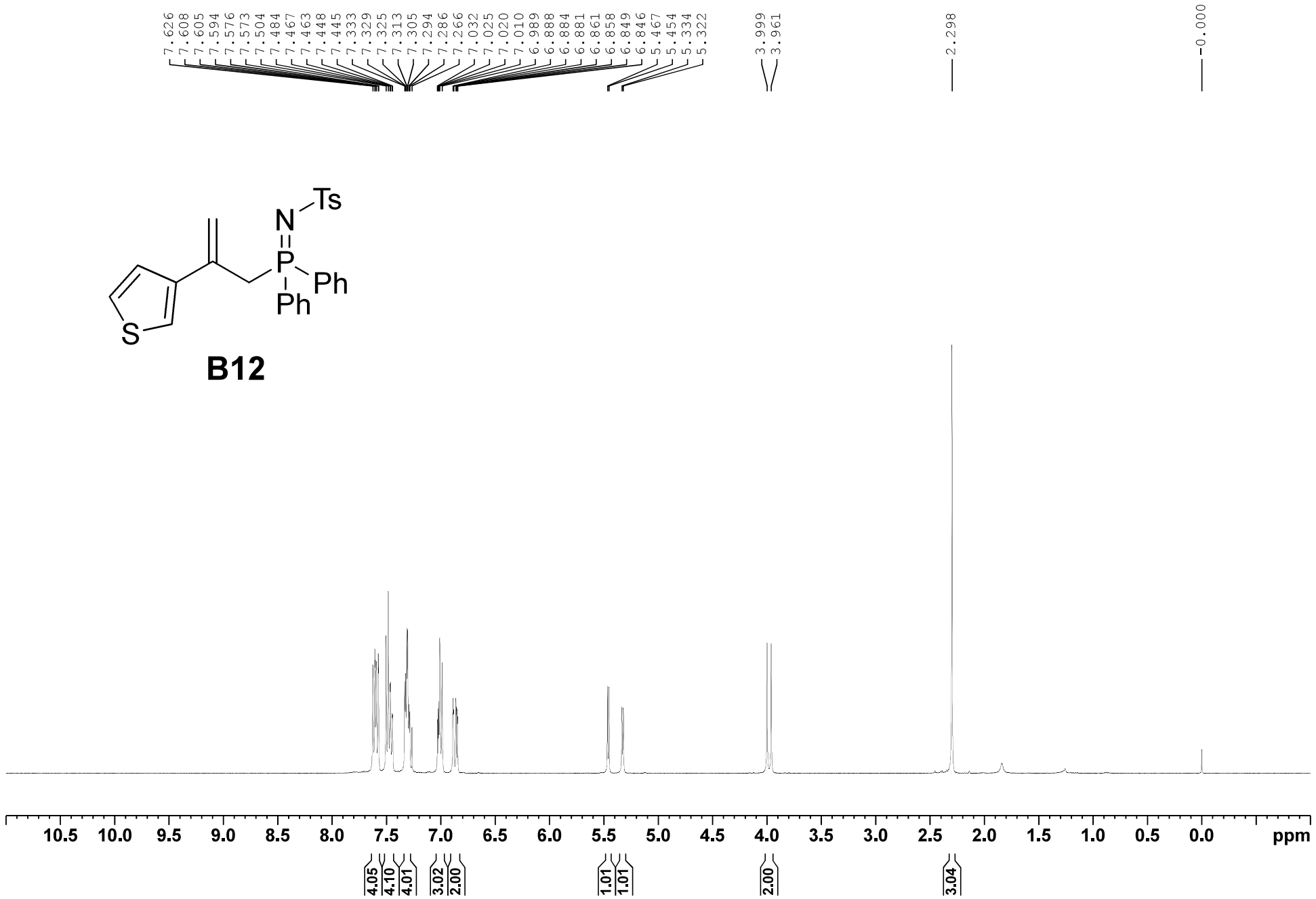
B11

^{31}P NMR (162 MHz, $CDCl_3$)



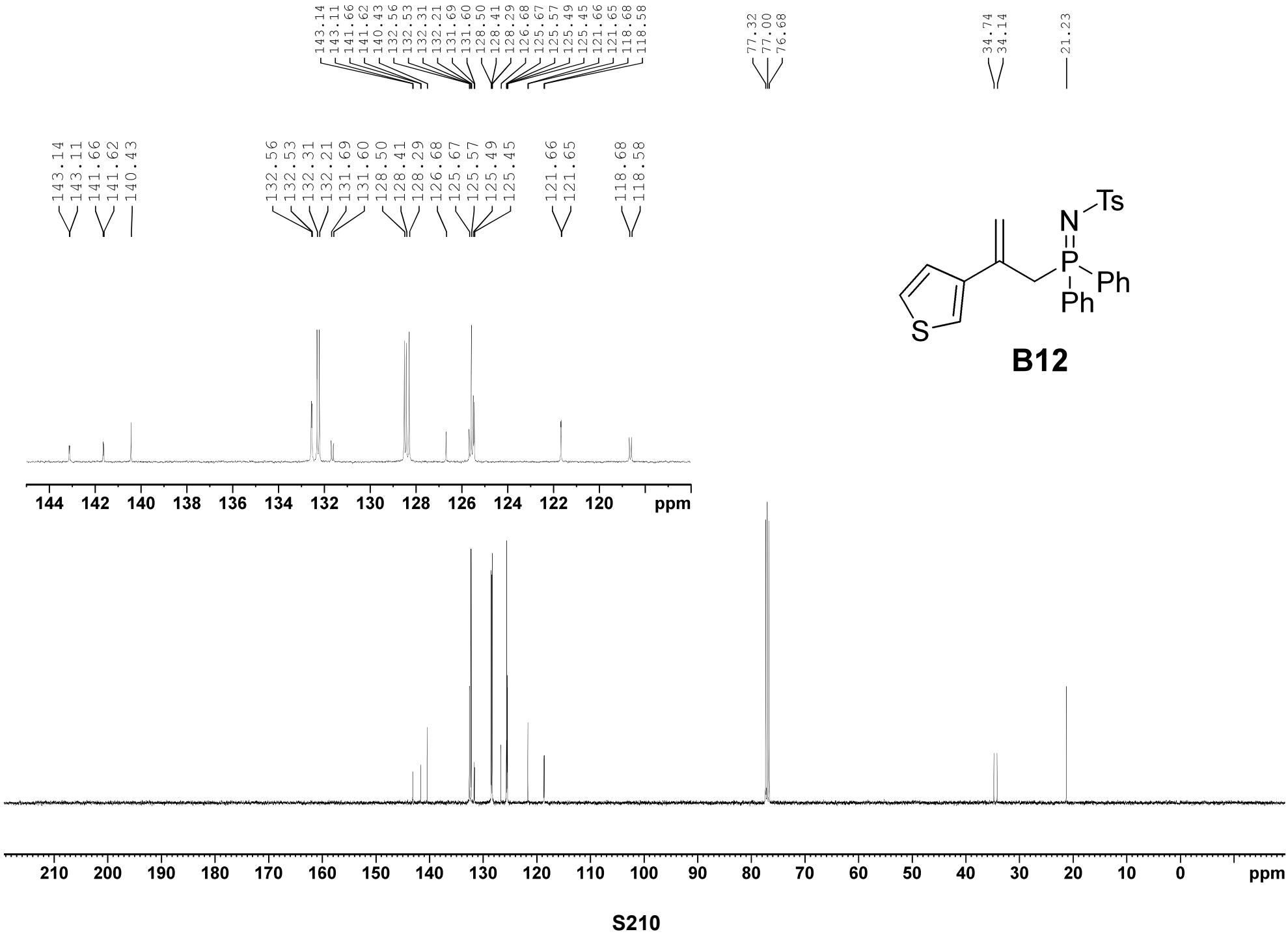
B11

^{1}H NMR ($CDCl_3$, 400 MHz)



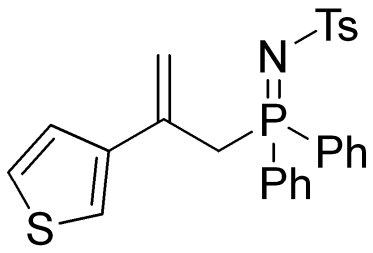
B12

^{13}C NMR (100 MHz, $CDCl_3$)



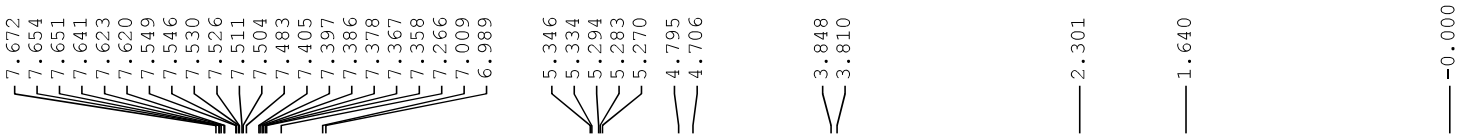
B12

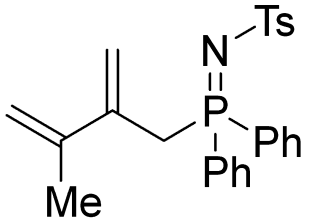
^{31}P NMR (162 MHz, $CDCl_3$)



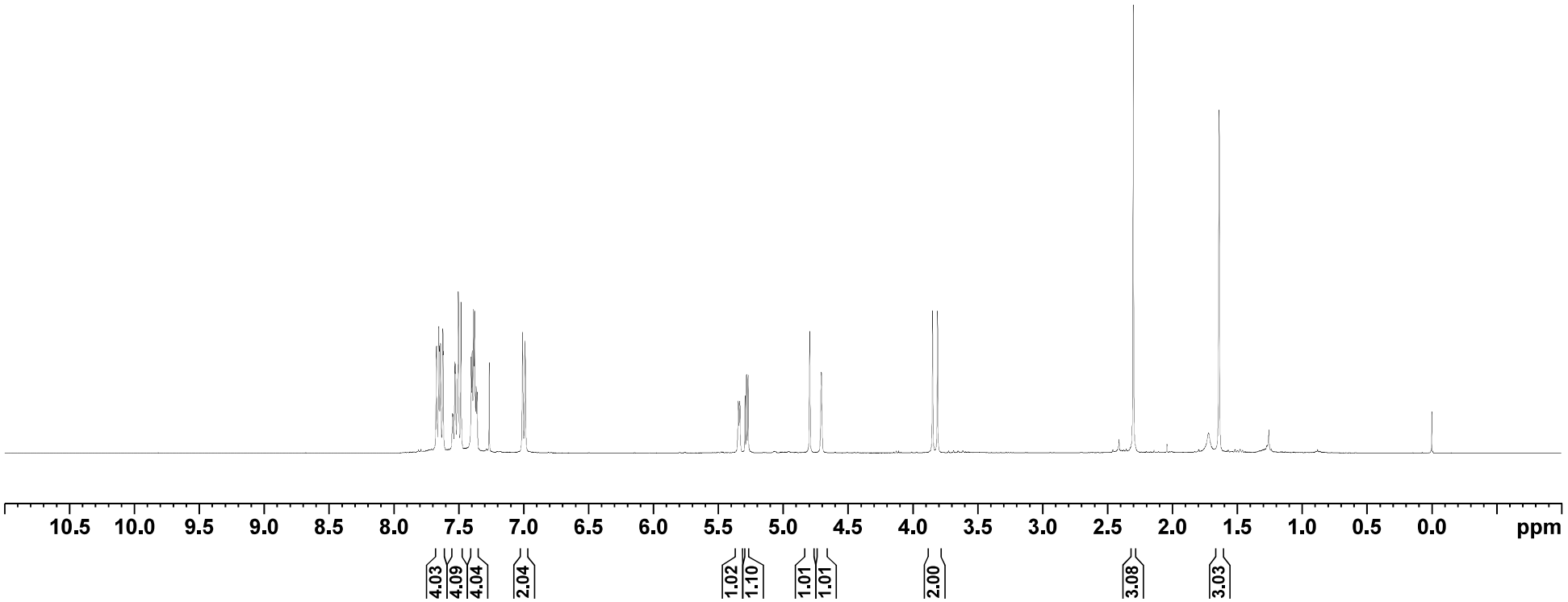
B12

^{1}H NMR ($CDCl_3$, 400 MHz)

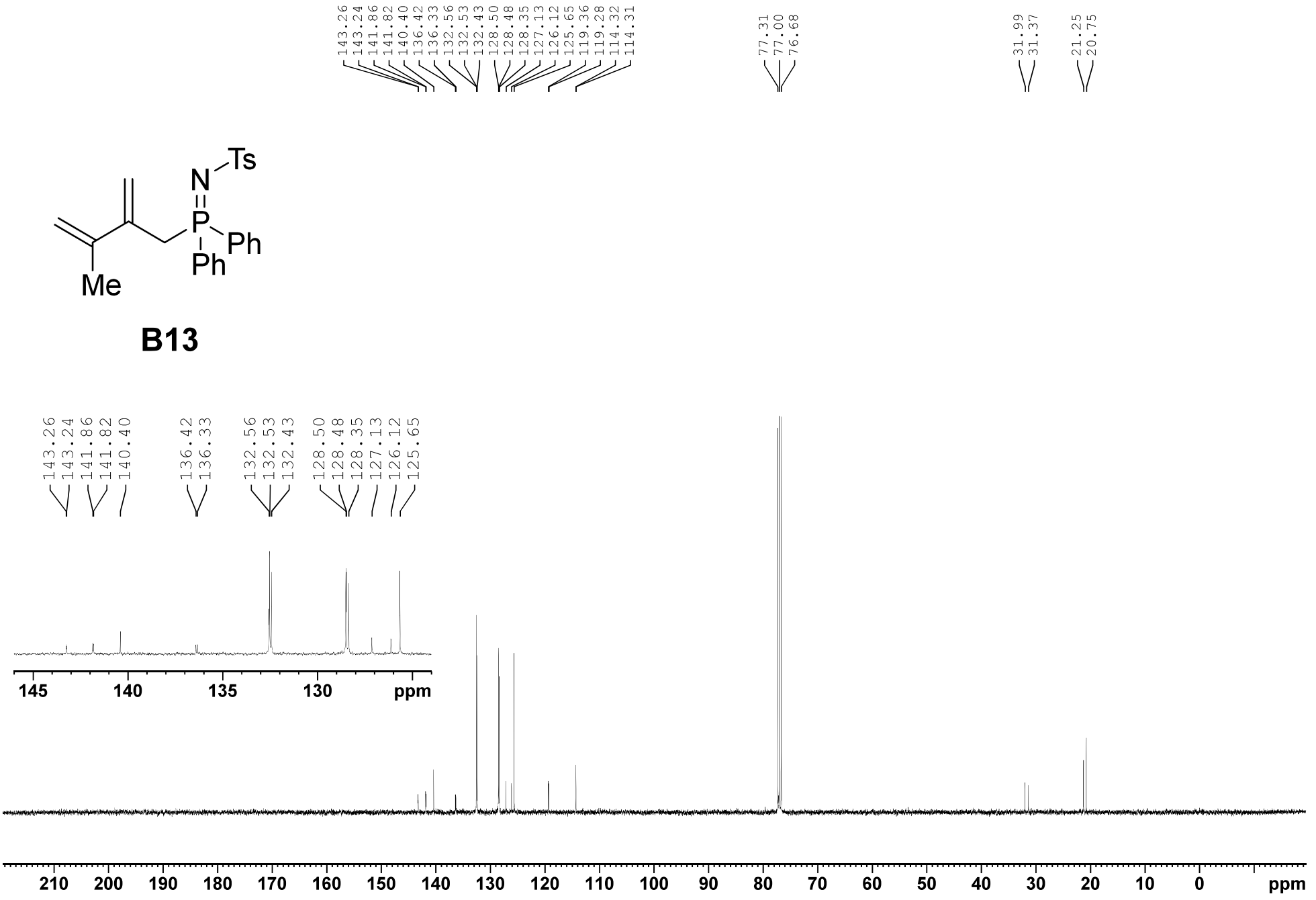




B13

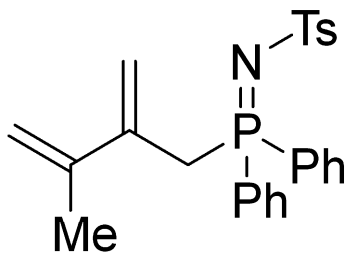


^{13}C NMR (100 MHz, $CDCl_3$)



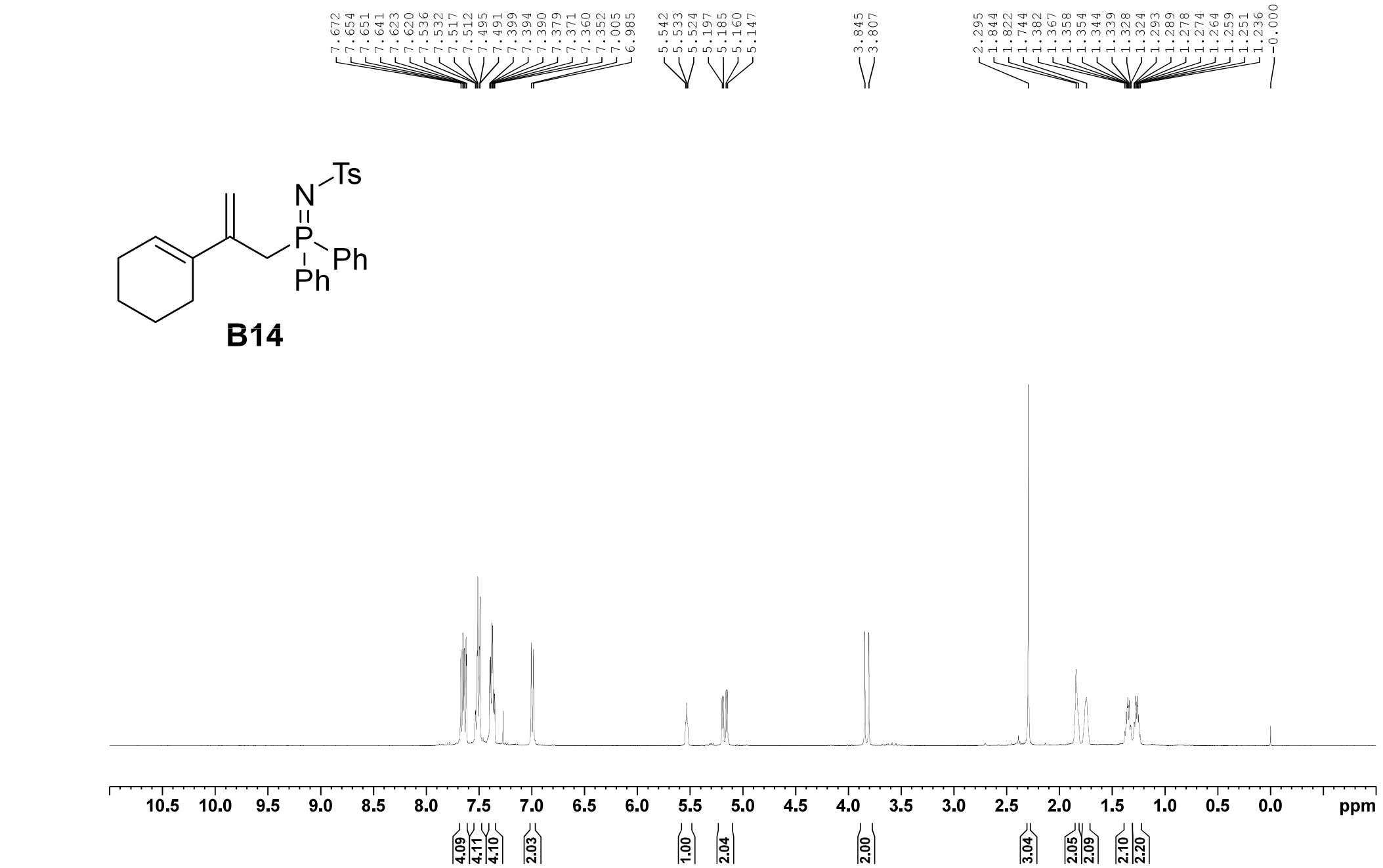
B13

^{31}P NMR (162 MHz, $CDCl_3$)

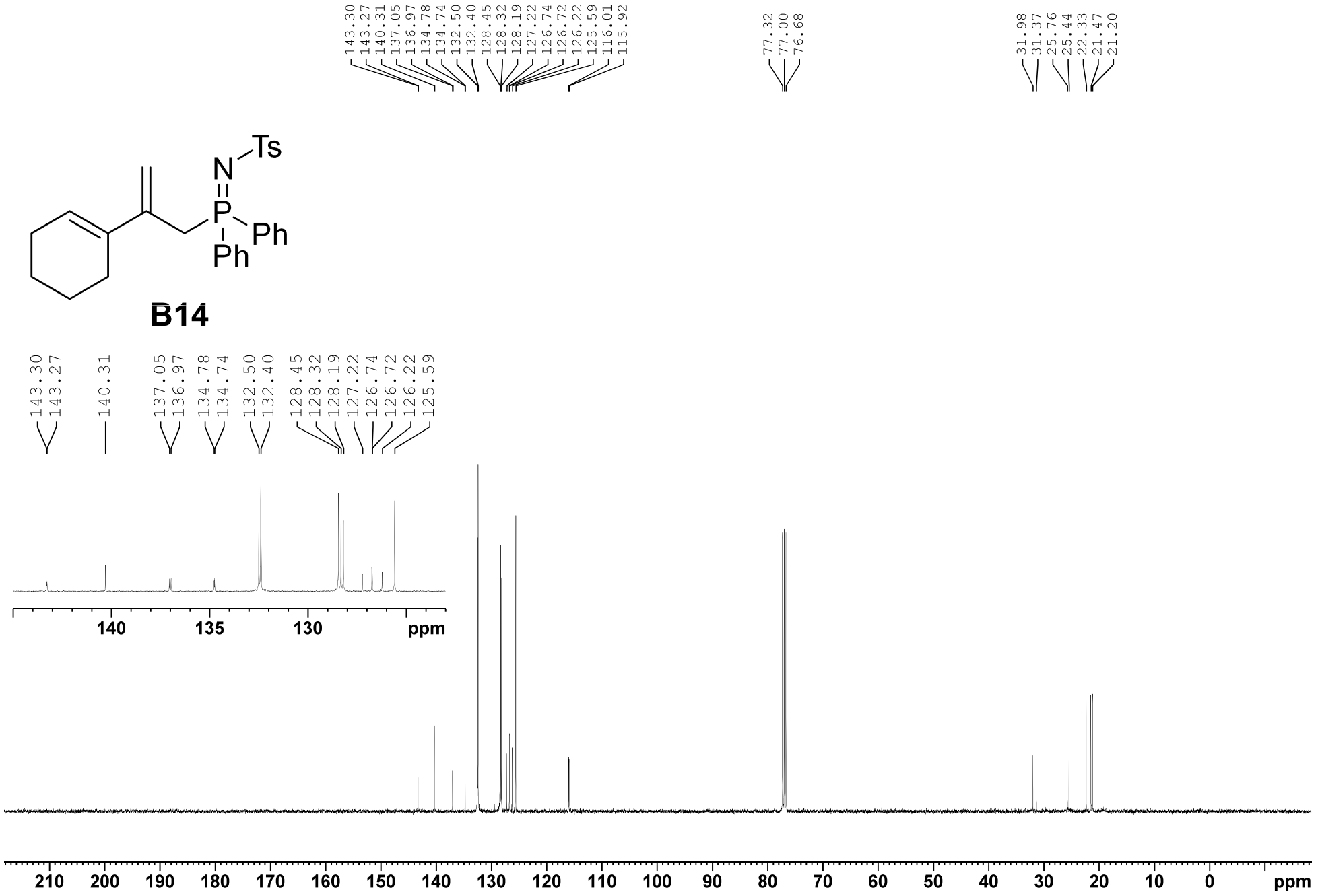


B13

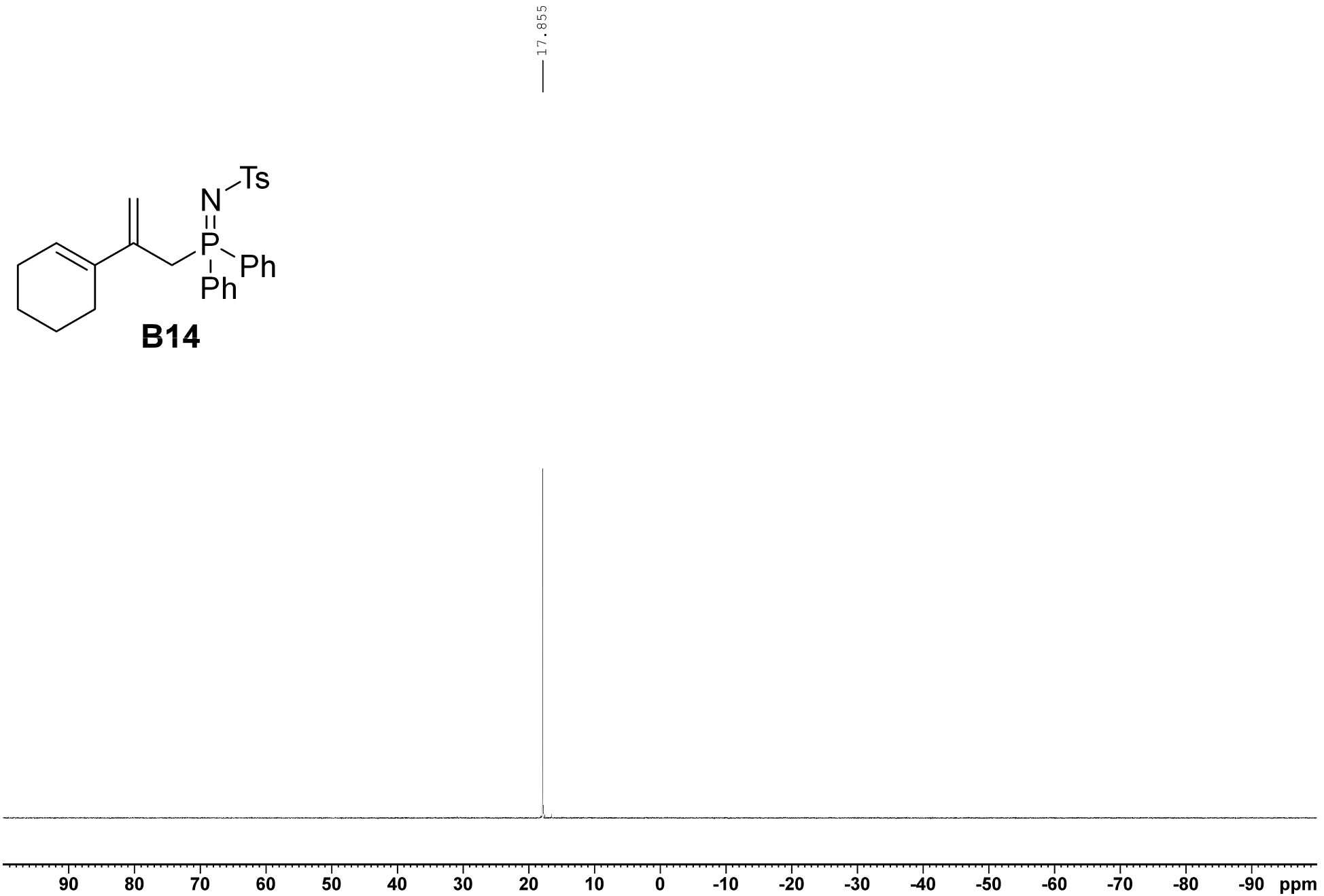
^{1}H NMR ($CDCl_3$, 400 MHz)



^{13}C NMR (100 MHz, $CDCl_3$)

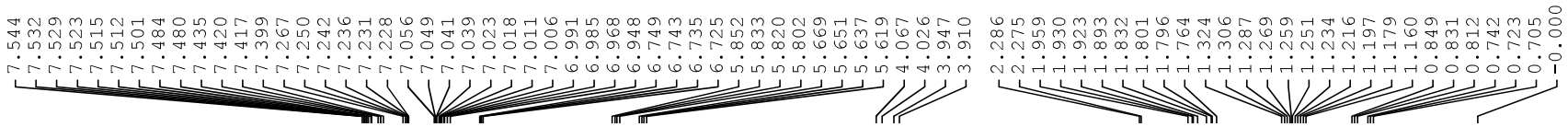


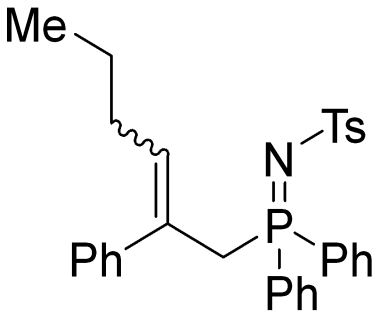
^{31}P NMR (162 MHz, $CDCl_3$)



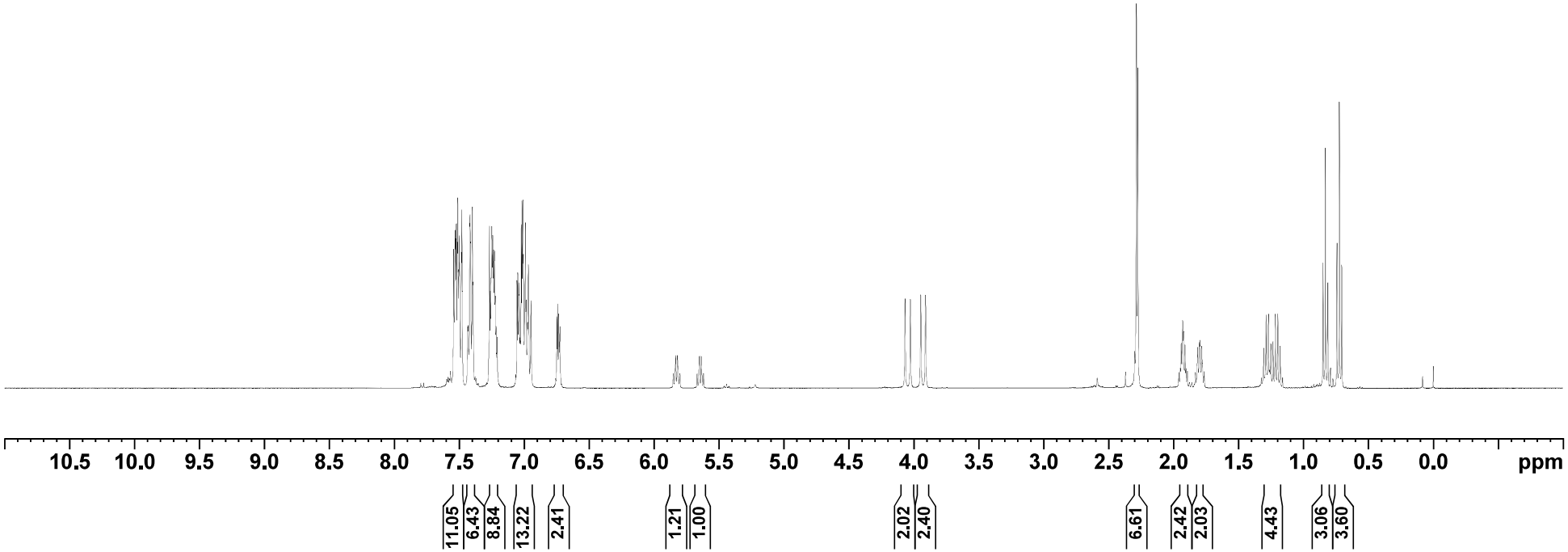
B14

^{1}H NMR ($CDCl_3$, 400 MHz)

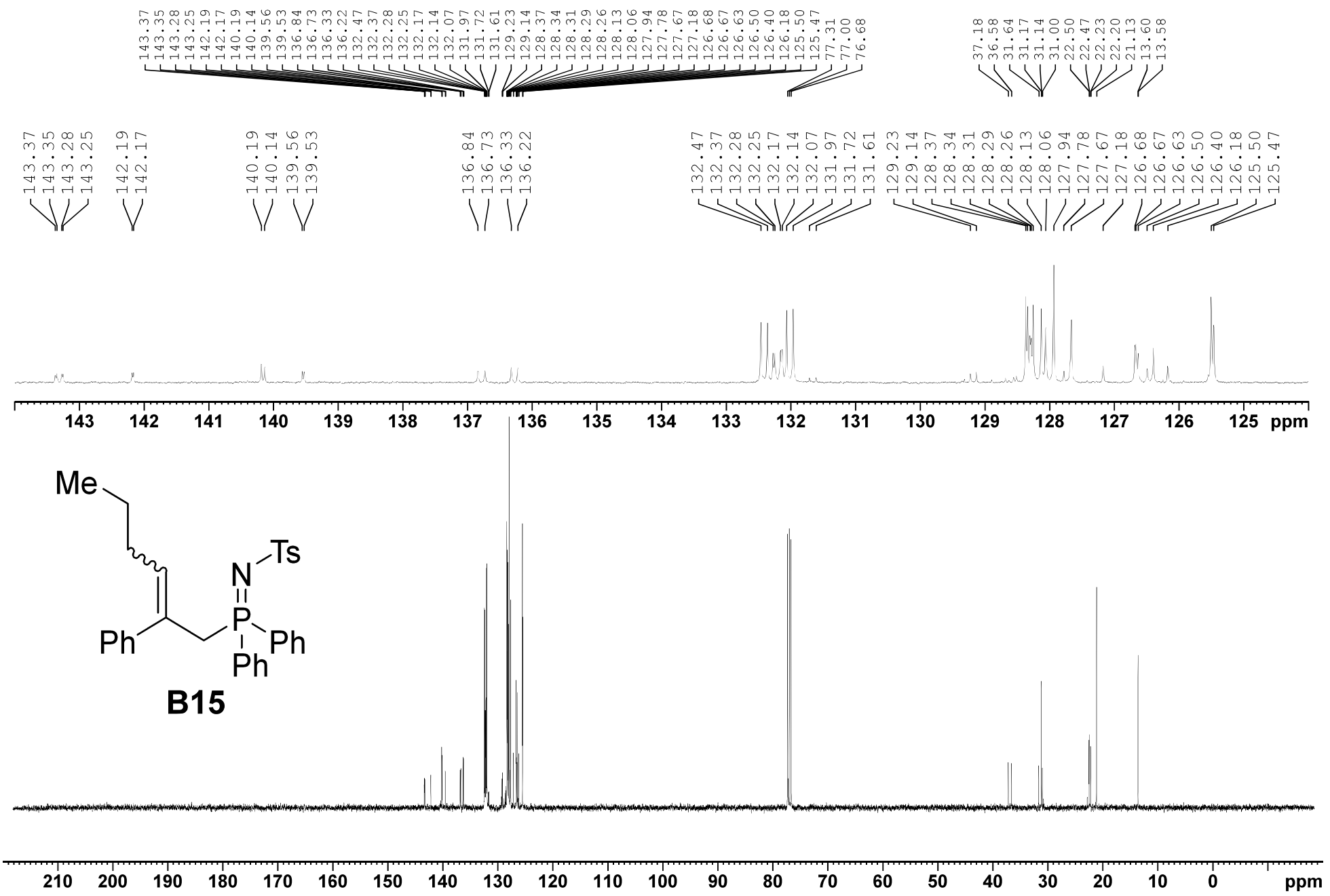




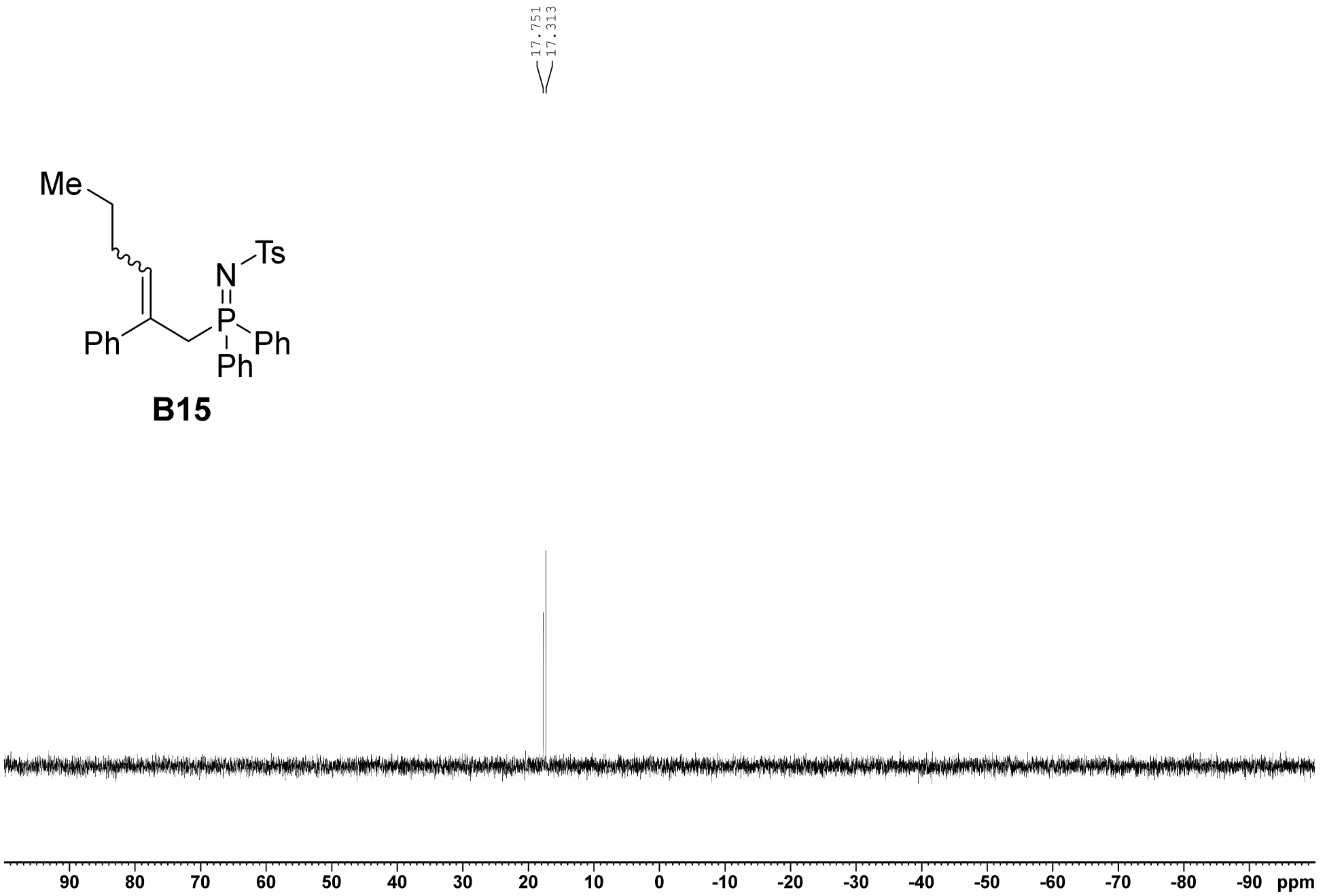
B15



^{13}C NMR (100 MHz, $CDCl_3$)

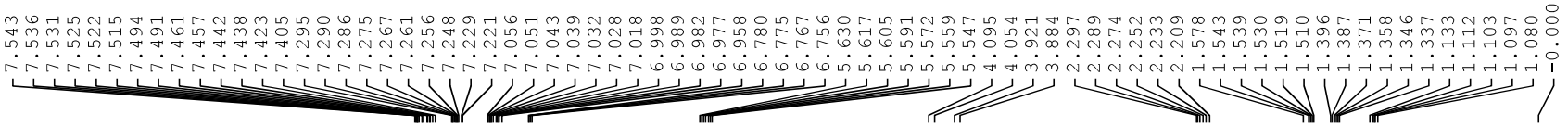


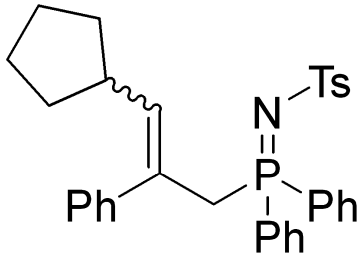
^{31}P NMR (162 MHz, $CDCl_3$)



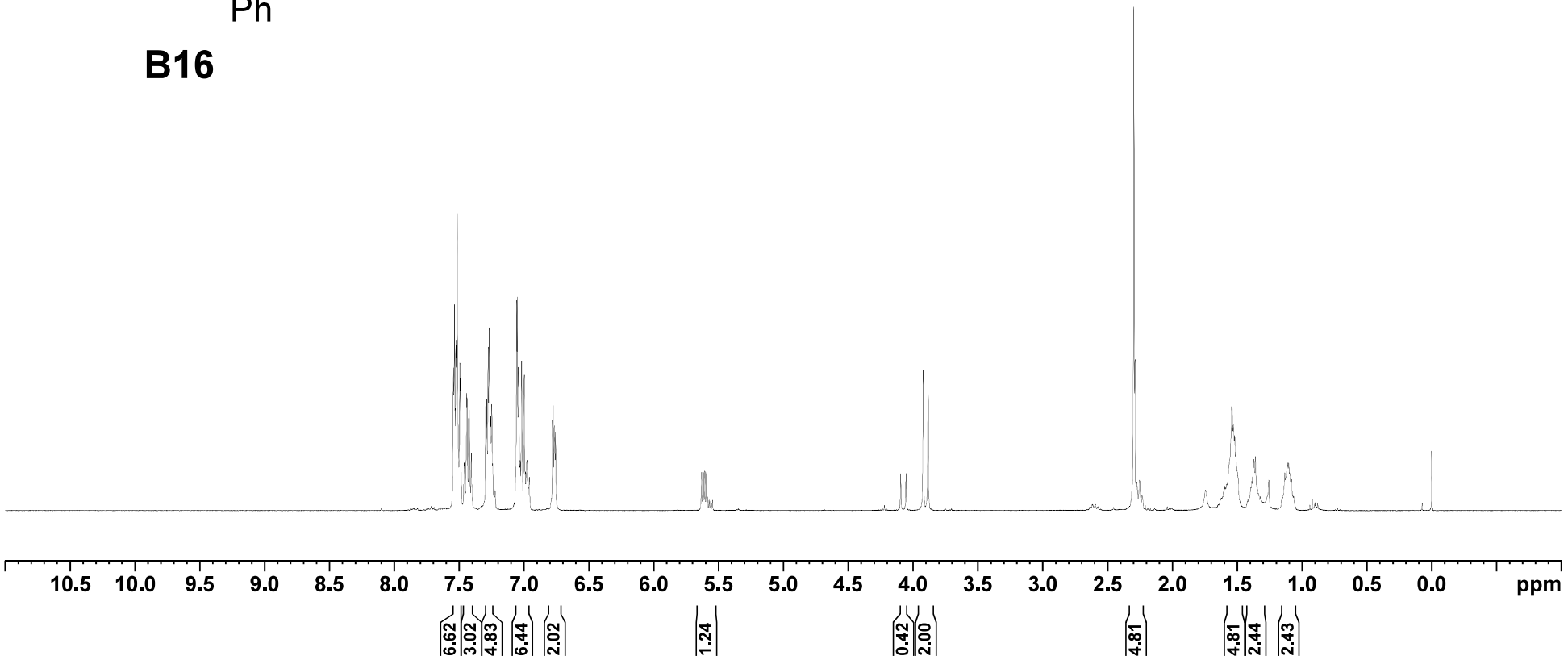
B15

^{1}H NMR ($CDCl_3$, 400 MHz)



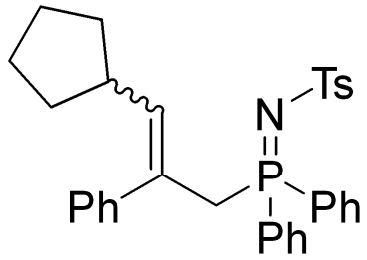


B16

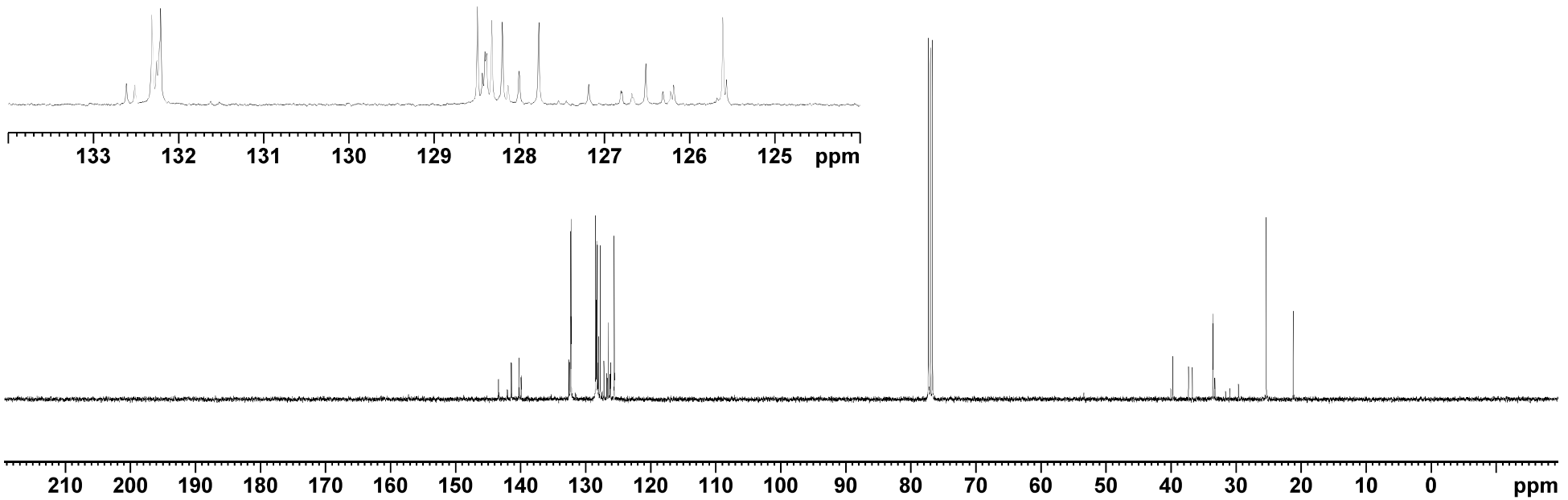


^{13}C NMR (100 MHz, $CDCl_3$)

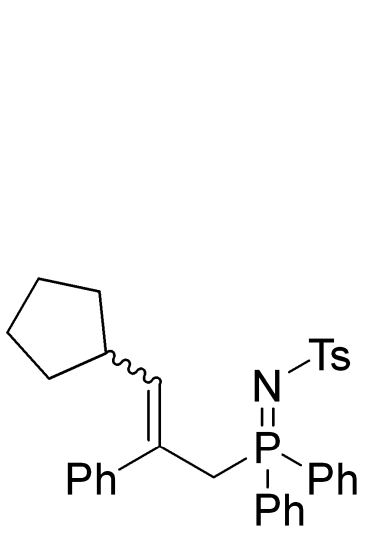
143.43
143.40
143.35
142.05
141.98
141.47
141.37
140.28
140.21
139.93
139.91
132.61
132.51
132.31
132.26
132.21
128.49
128.43
128.40
128.39
128.33
128.20
128.13
128.00
127.77
127.19
126.81
126.68
126.52
126.32
126.22
126.19
125.61
125.57
77.32
77.00
76.68
40.04
40.01
39.73
39.70
37.32
36.72
33.56
33.52
33.26
33.23
31.61
30.98
29.62
25.35
25.33
21.22



B16

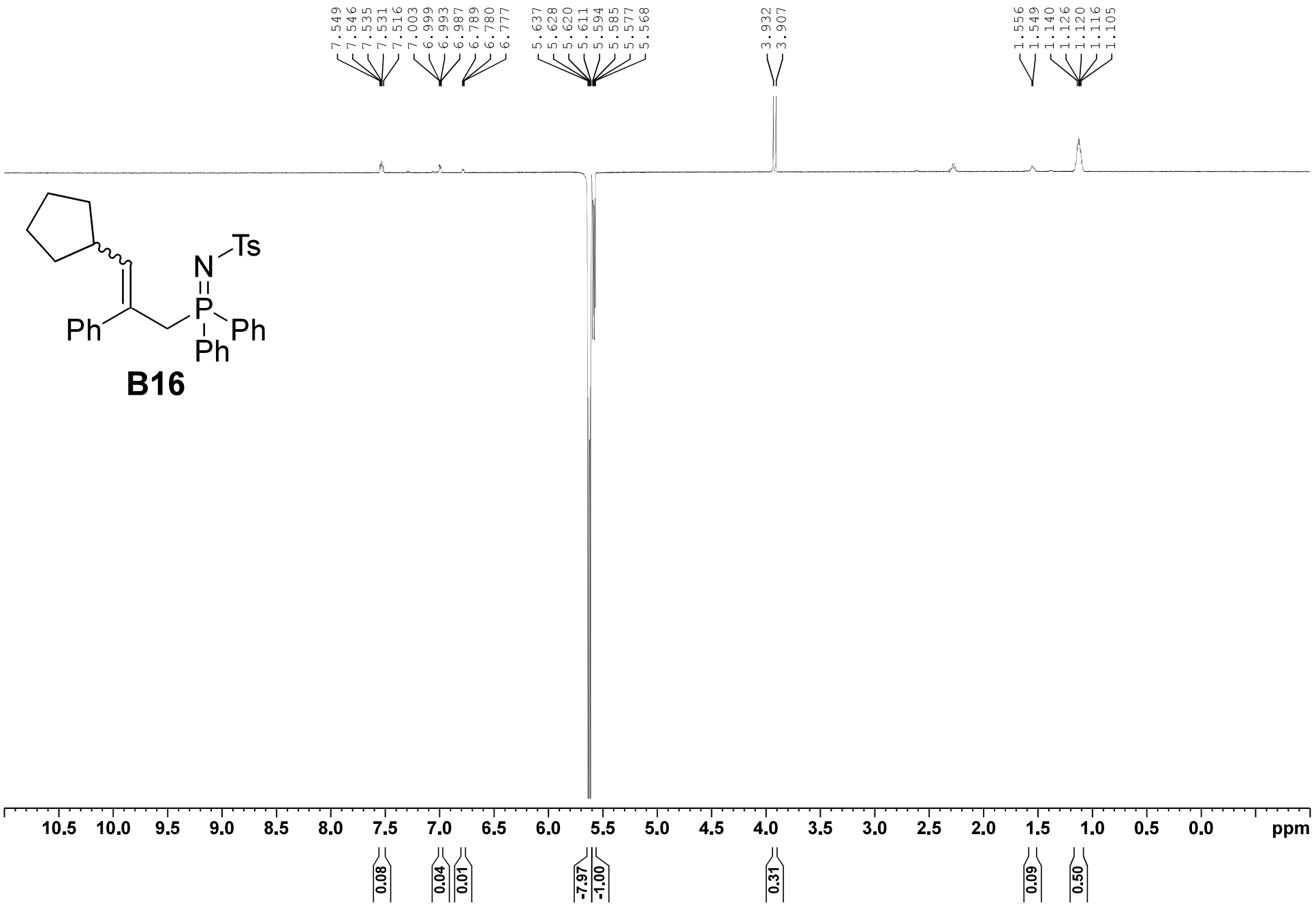


^{31}P NMR (162 MHz, $CDCl_3$)



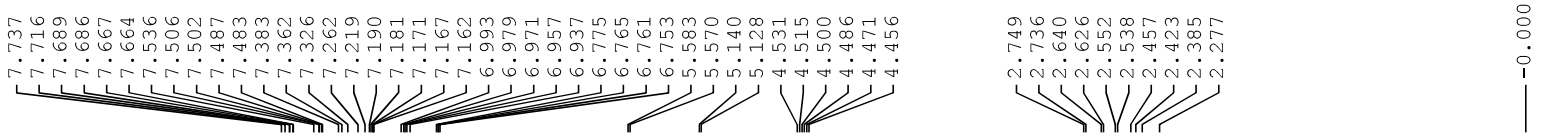
B16

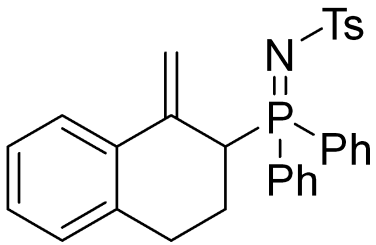
1D NOE ($CDCl_3$, 400 MHz)



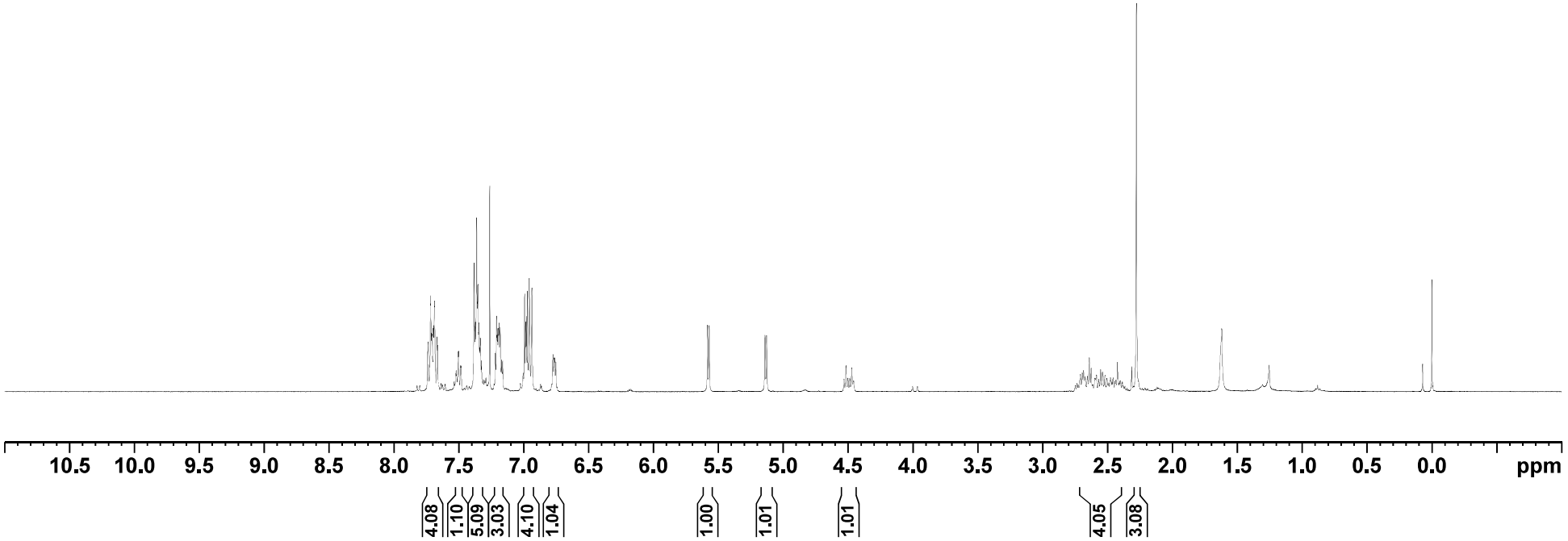
B16

^{1}H NMR ($CDCl_3$, 400 MHz)

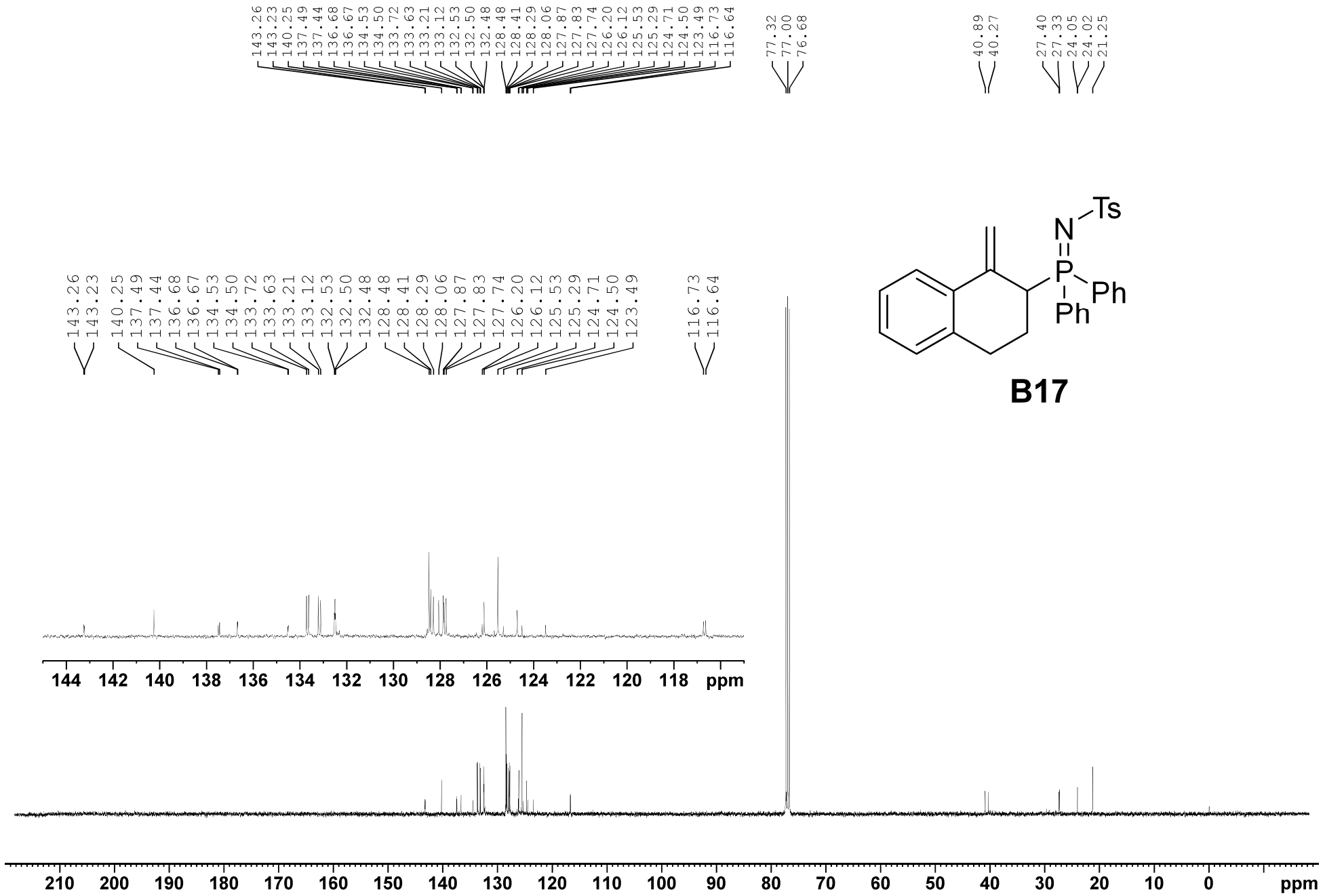




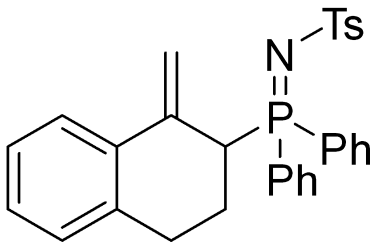
B17



^{13}C NMR (100 MHz, $CDCl_3$)

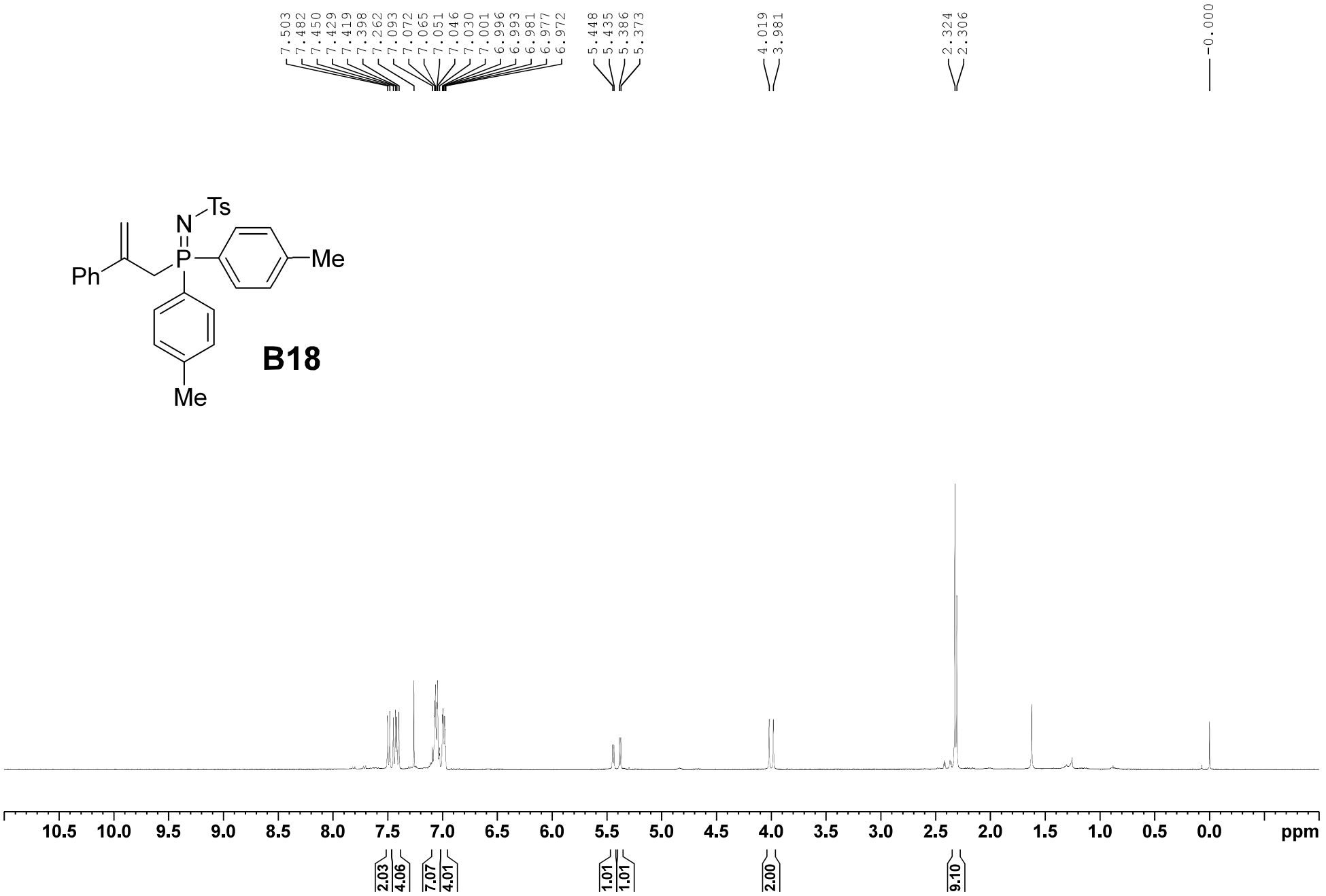


^{31}P NMR (162 MHz, $CDCl_3$)

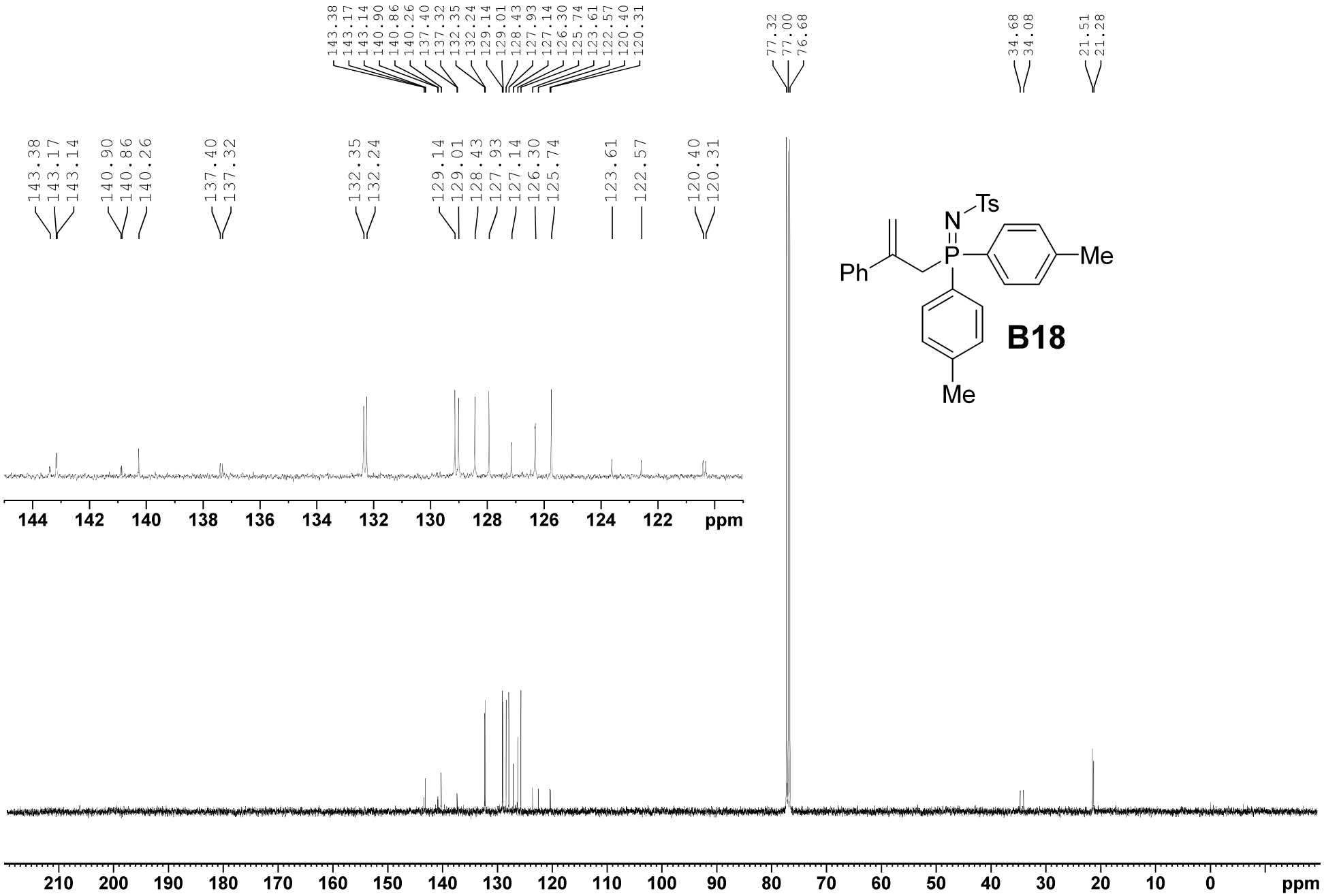


B17

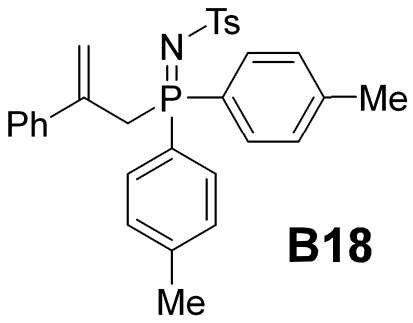
^{1}H NMR ($CDCl_3$, 400 MHz)



^{13}C NMR (100 MHz, $CDCl_3$)

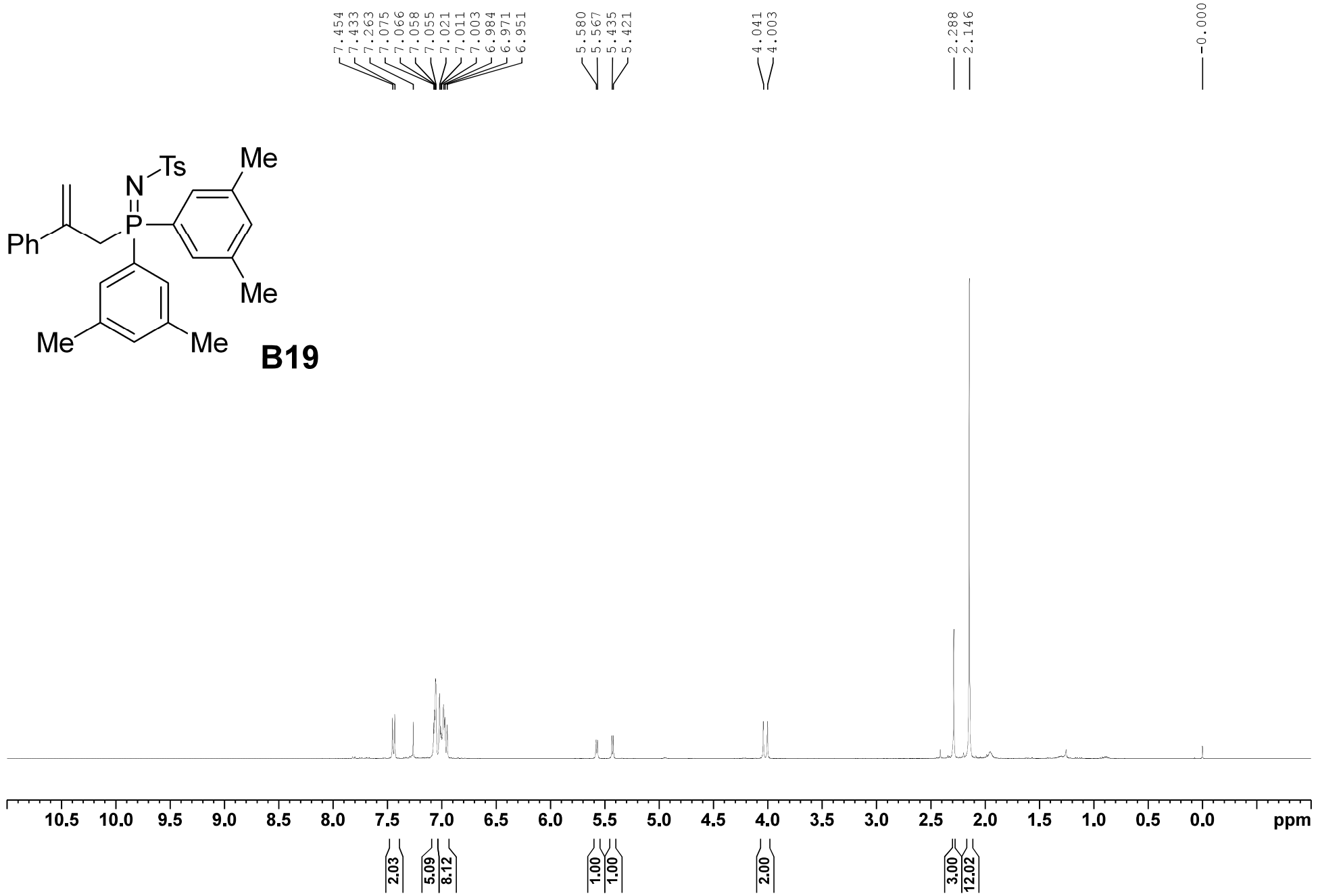


^{31}P NMR (162 MHz, $CDCl_3$)

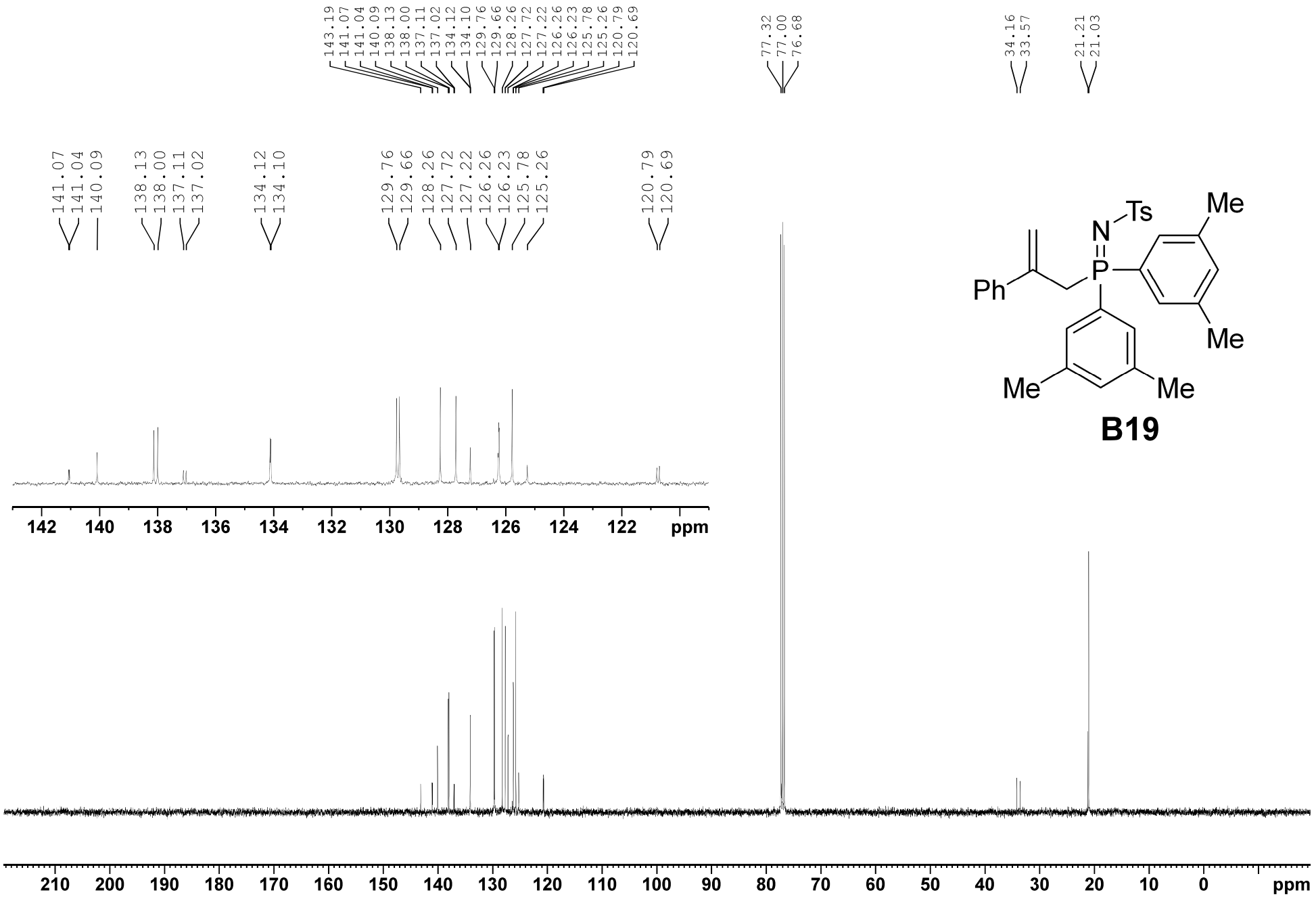


B18

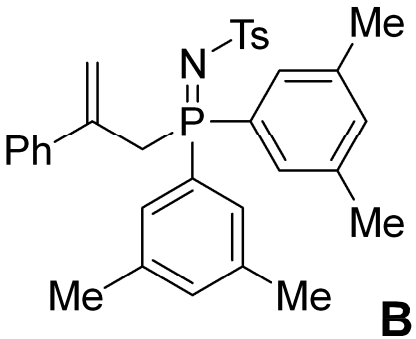
^{1}H NMR ($CDCl_3$, 400 MHz)



^{13}C NMR (100 MHz, $CDCl_3$)

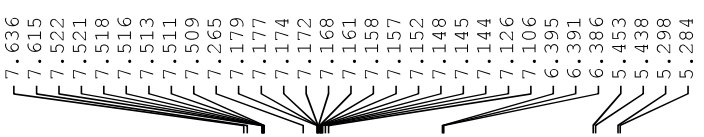


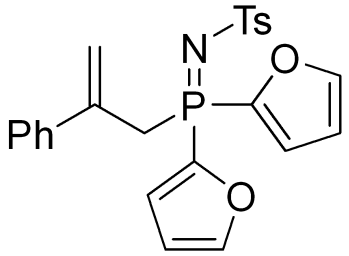
^{31}P NMR (162 MHz, $CDCl_3$)



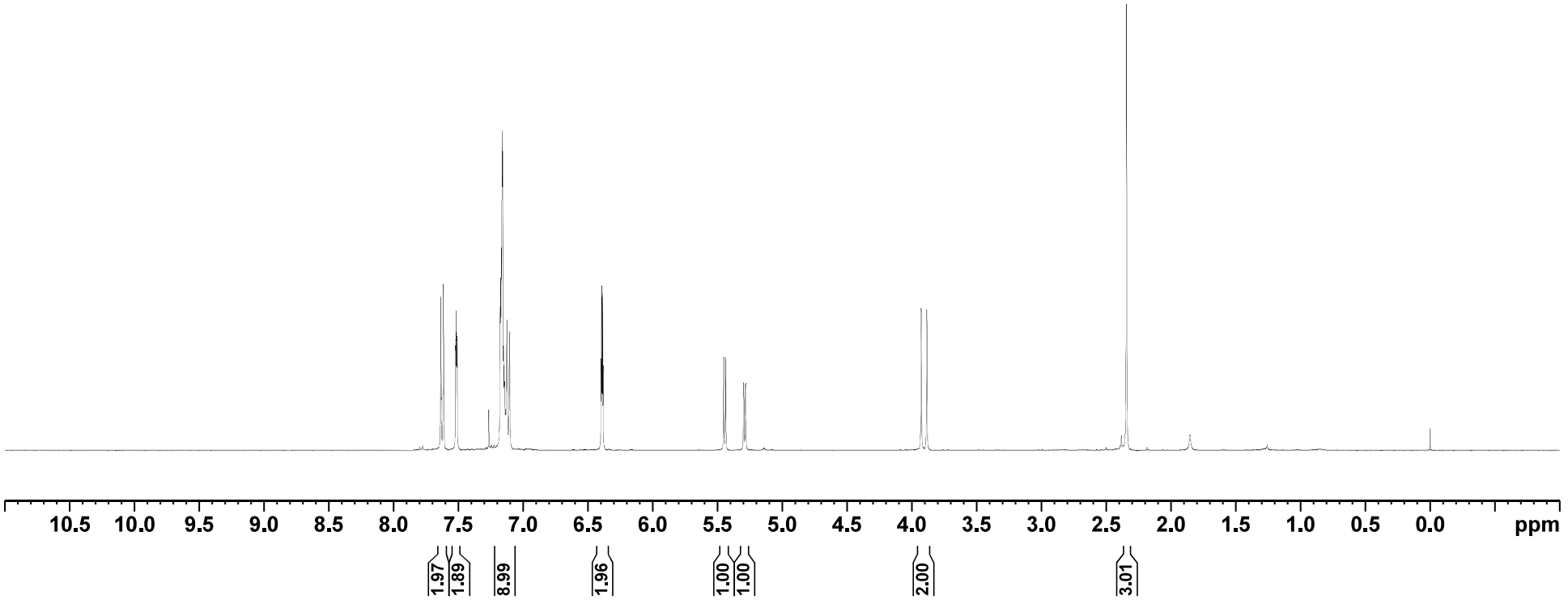
B19

^{1}H NMR ($CDCl_3$, 400 MHz)

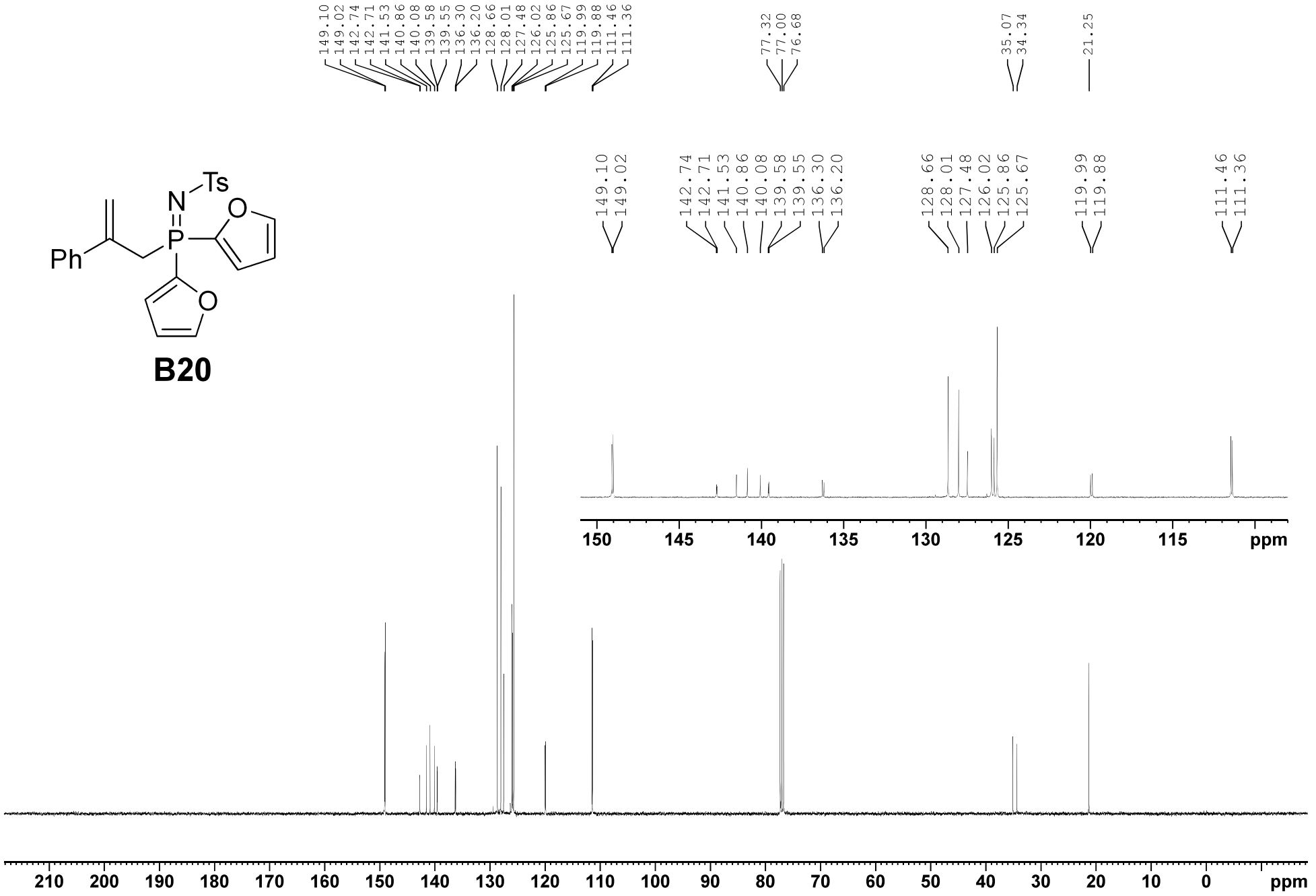




B20

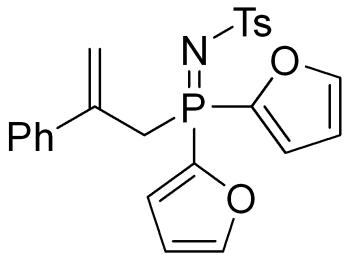


^{13}C NMR (100 MHz, $CDCl_3$)



B20

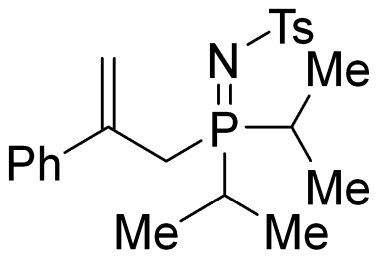
^{31}P NMR (162 MHz, $CDCl_3$)



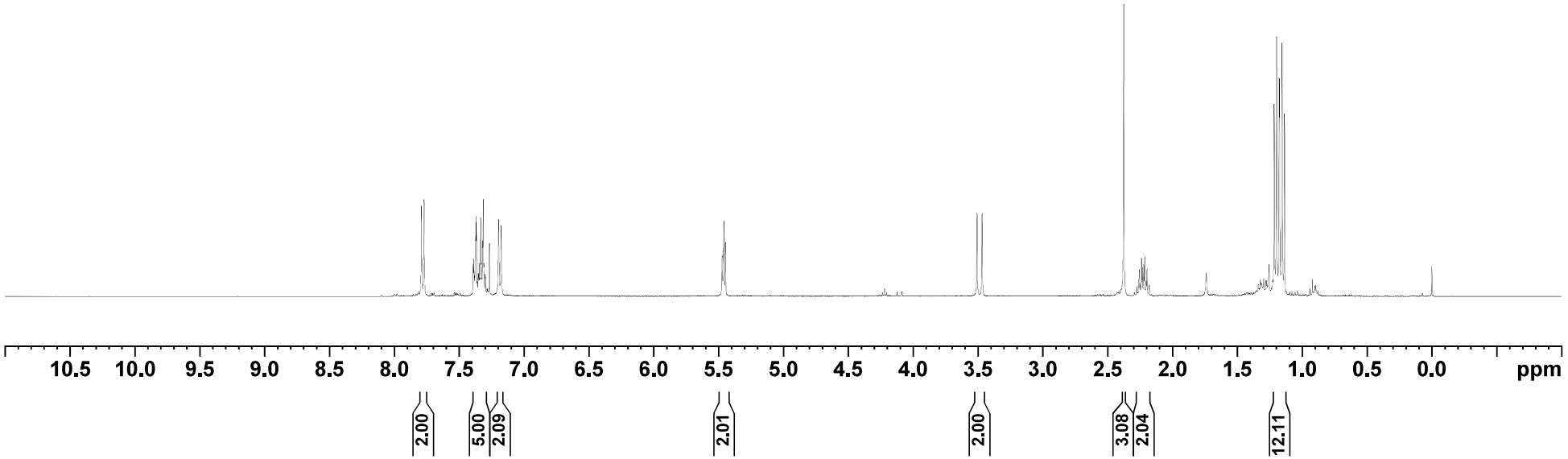
B20

^{1}H NMR ($CDCl_3$, 400 MHz)

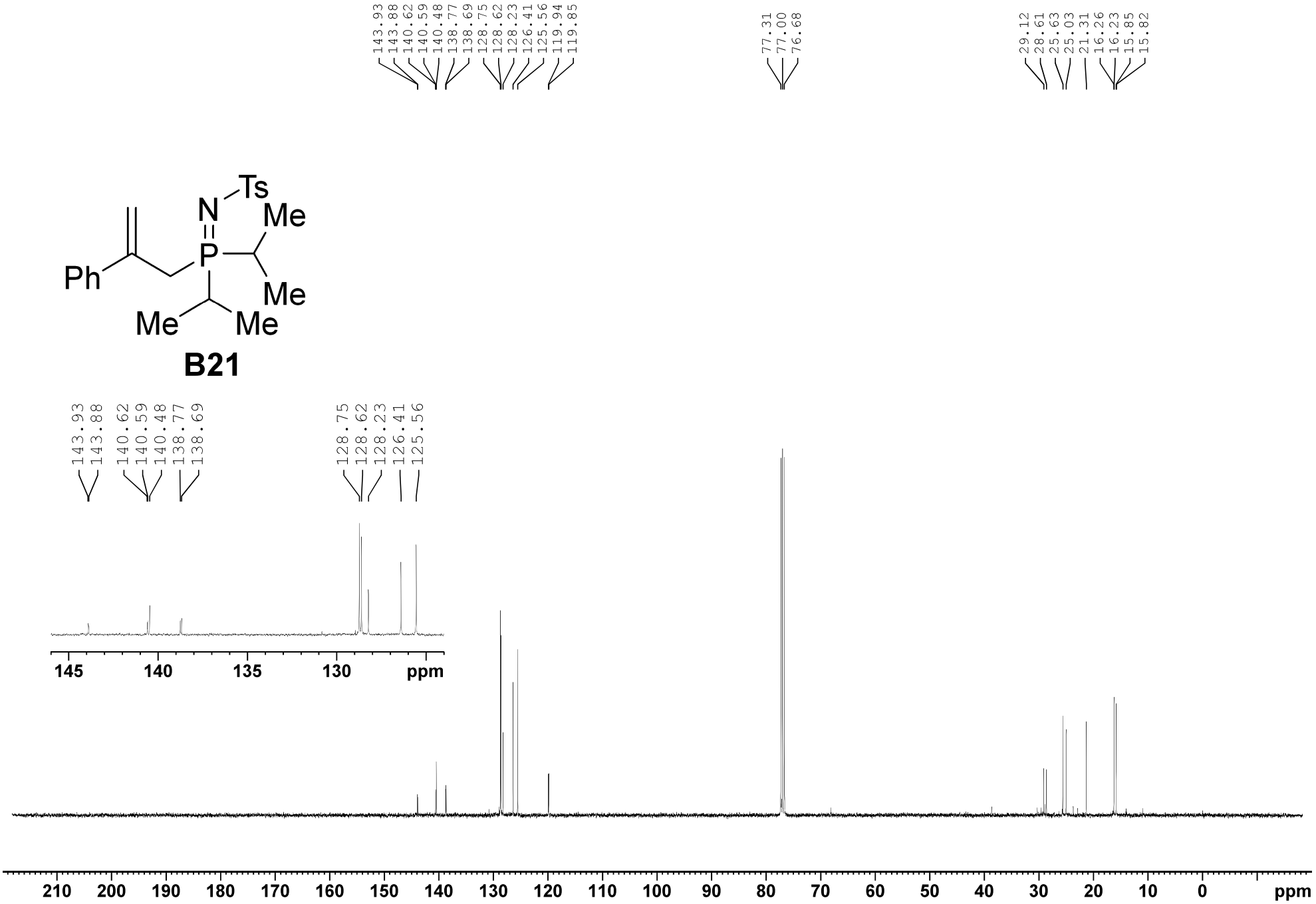




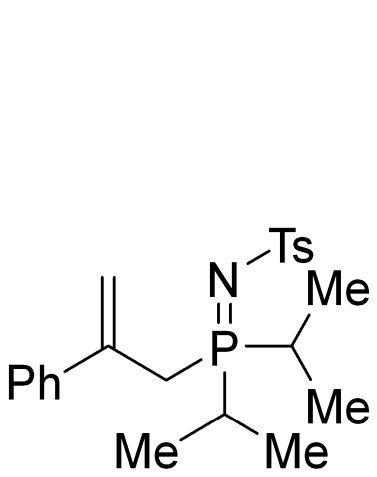
B21



^{13}C NMR (100 MHz, $CDCl_3$)

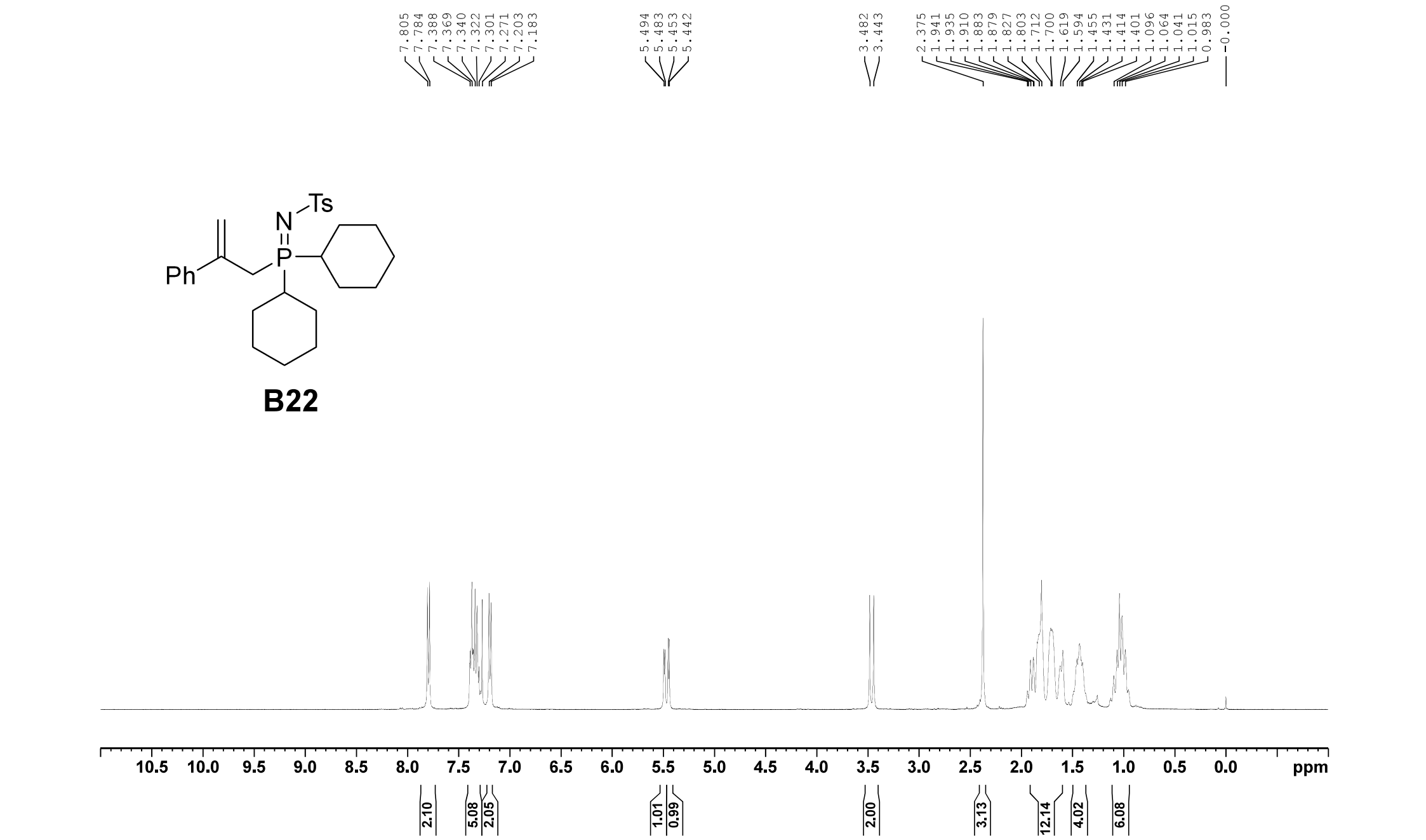


^{31}P NMR (162 MHz, $CDCl_3$)



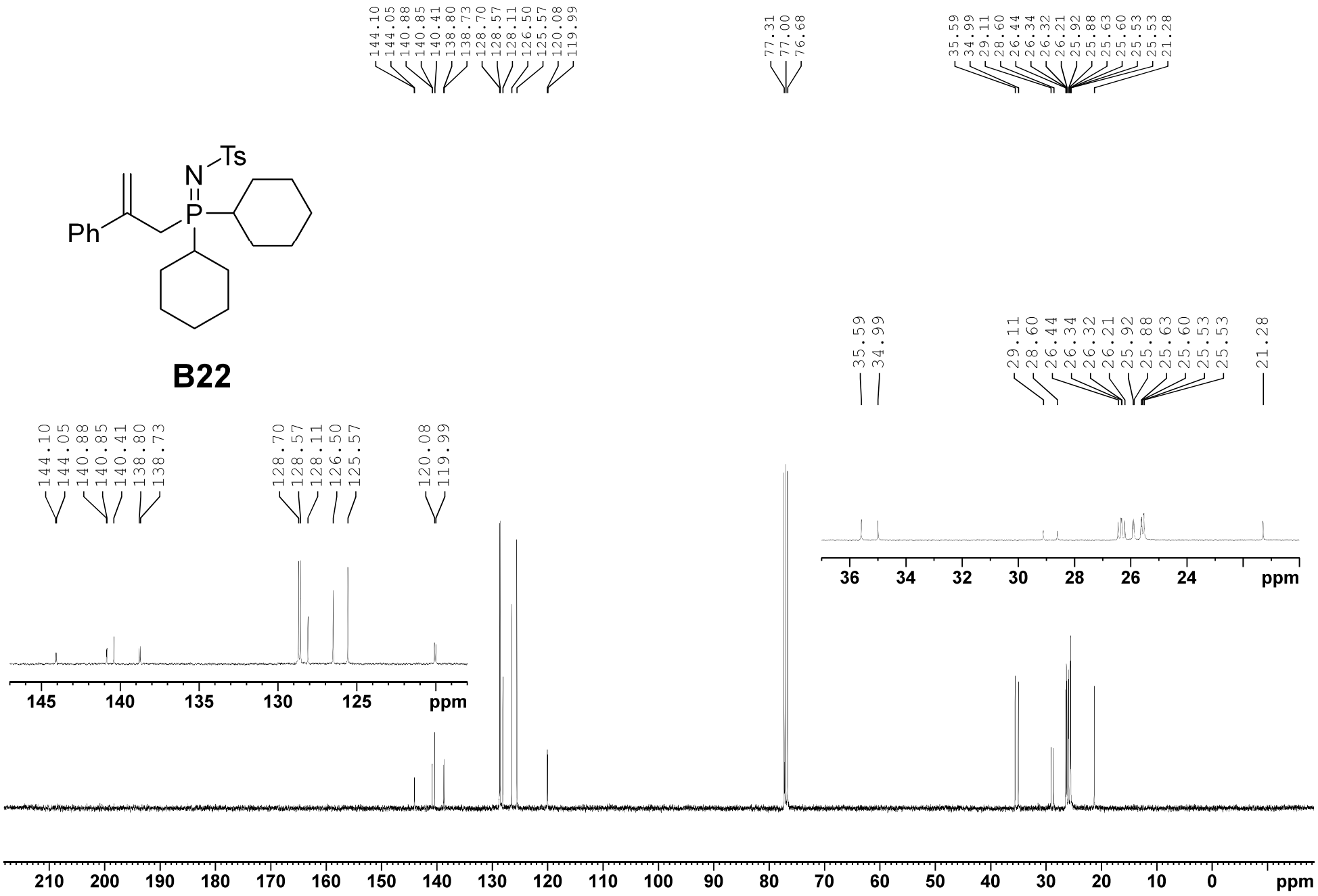
B21

^{1}H NMR ($CDCl_3$, 400 MHz)

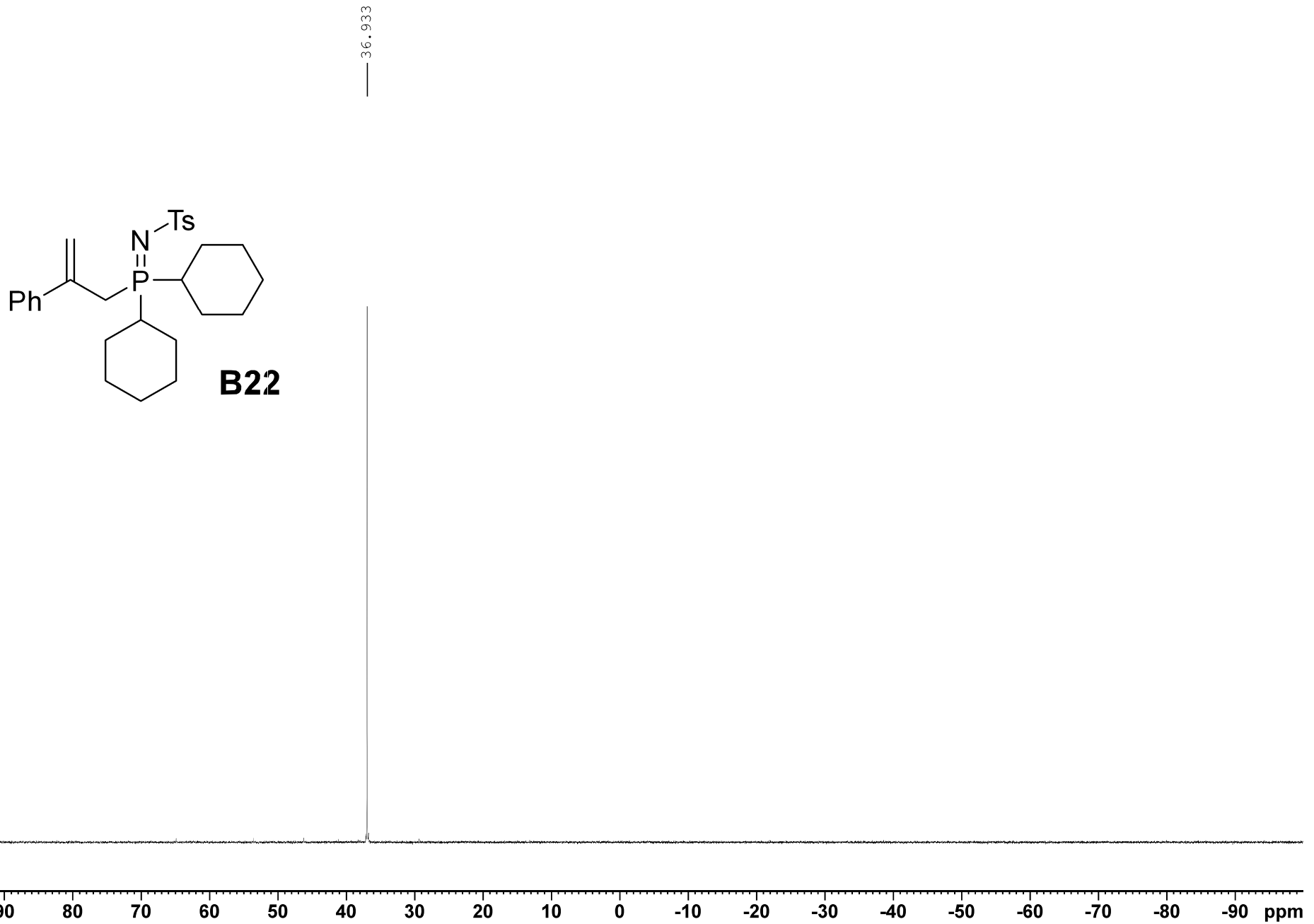


B22

^{13}C NMR (100 MHz, $CDCl_3$)

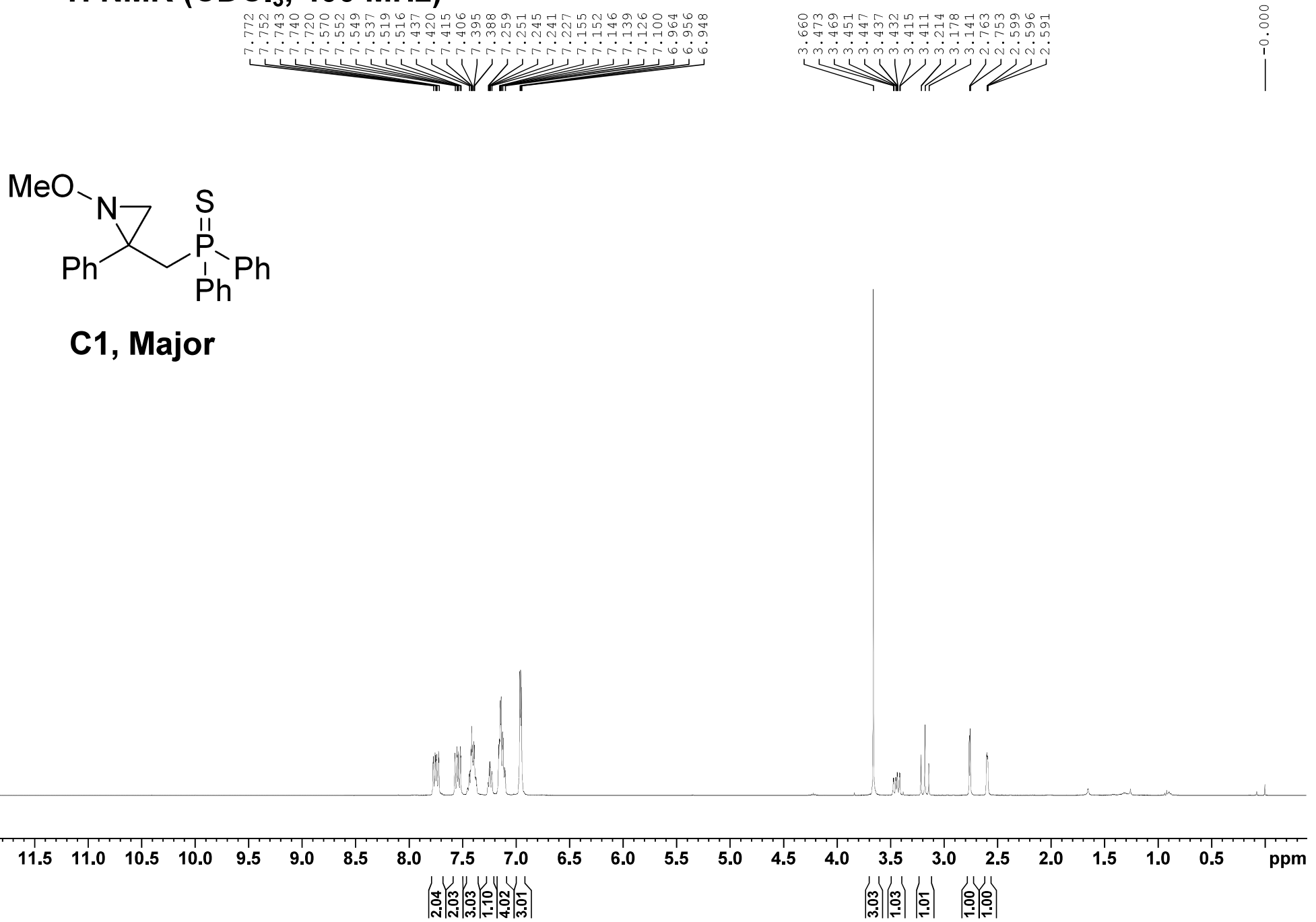


^{31}P NMR (162 MHz, $CDCl_3$)



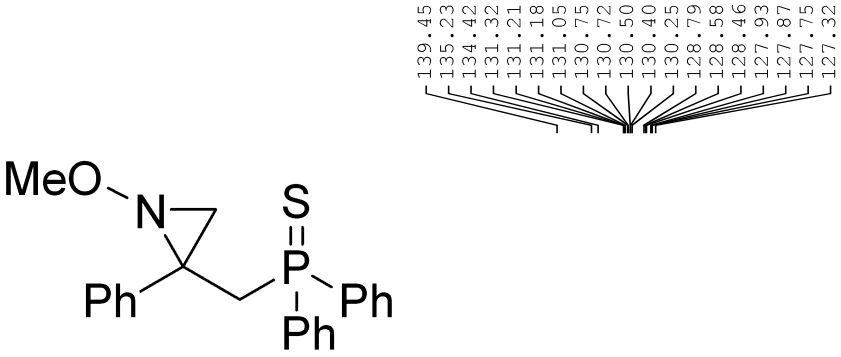
B22

^{1}H NMR ($CDCl_3$, 400 MHz)



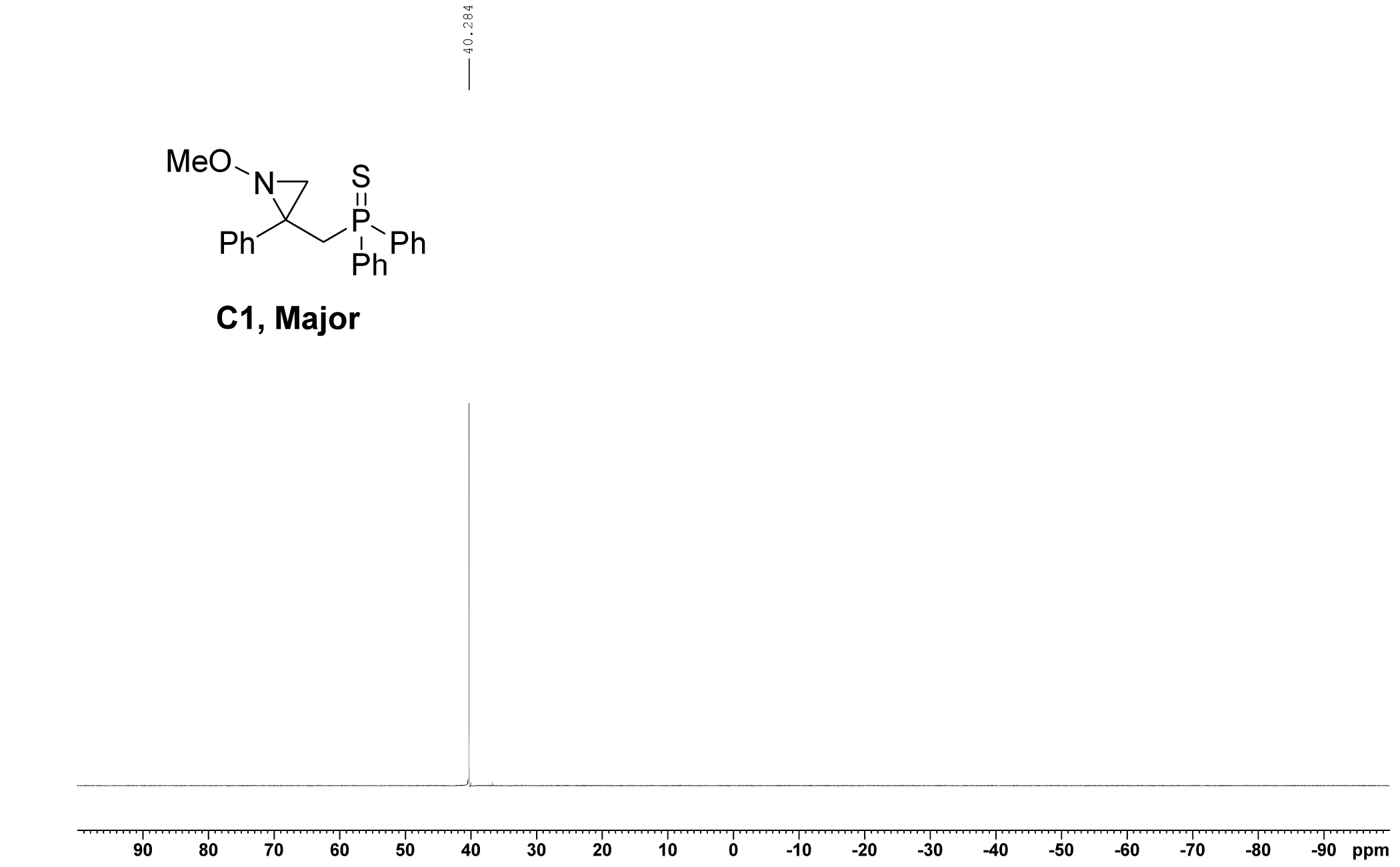
C1, Major

^{13}C NMR (100 MHz, $CDCl_3$)



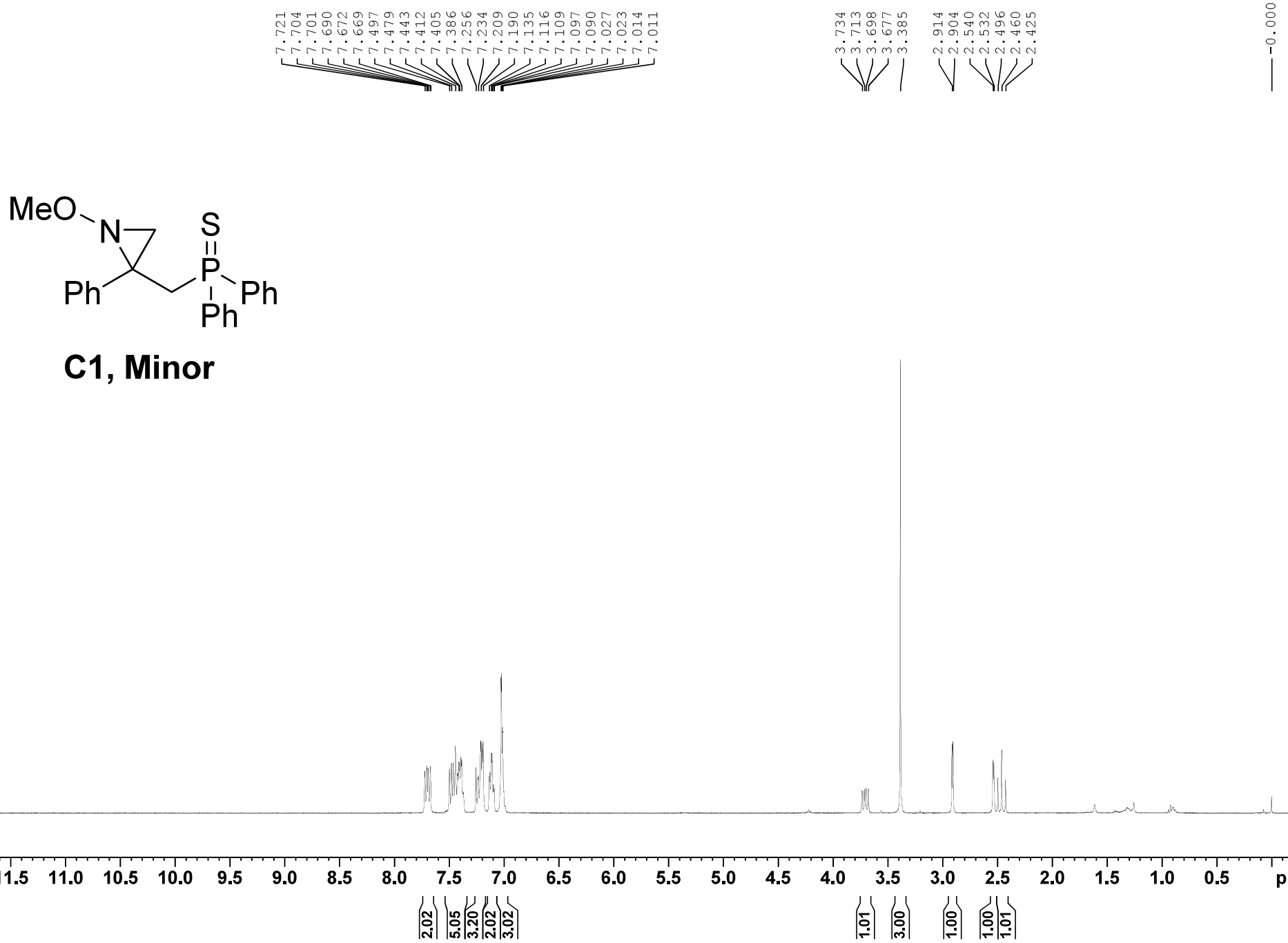
C1, Major

^{31}P NMR (162 MHz, $CDCl_3$)



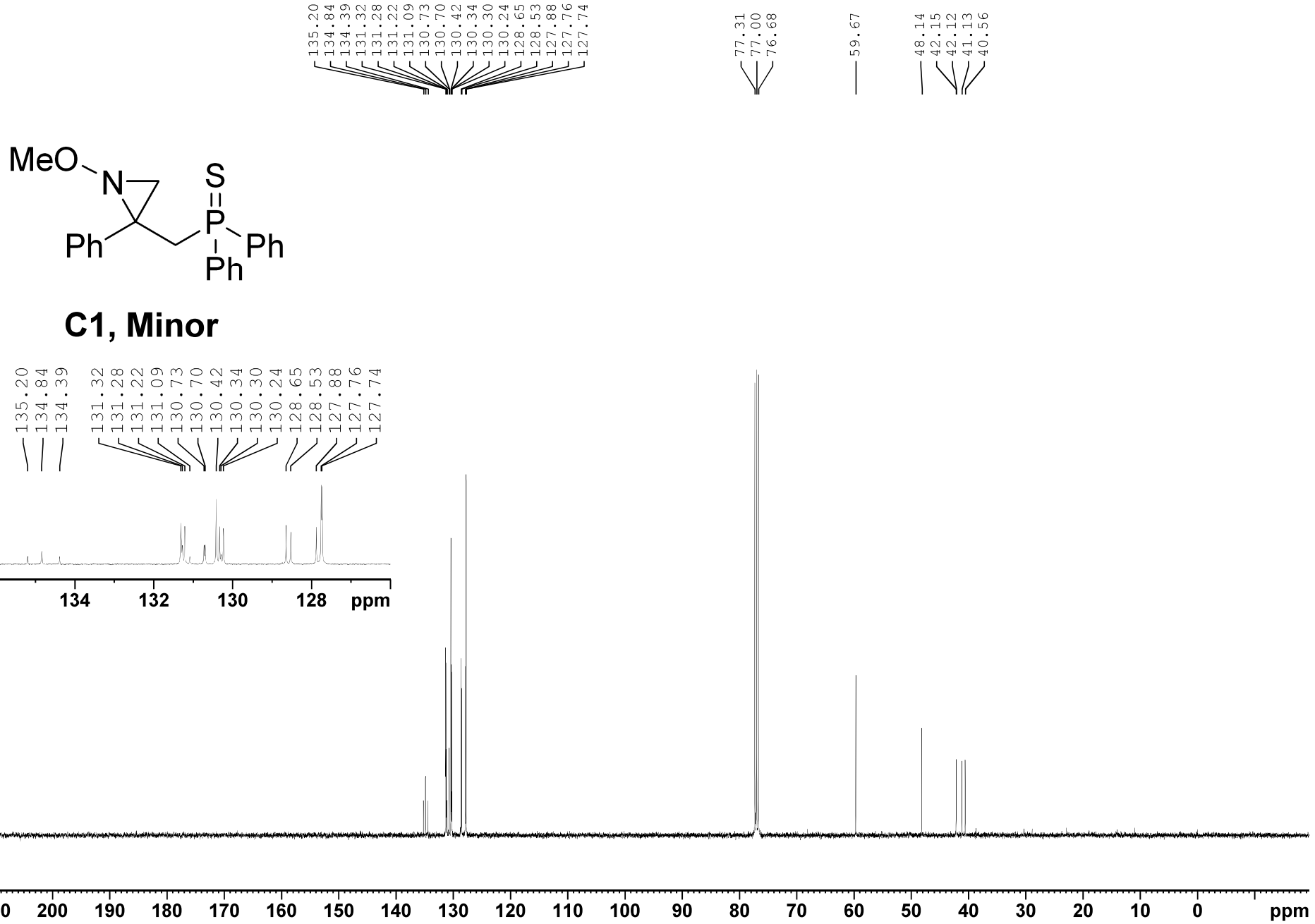
C1, Major

^{1}H NMR ($CDCl_3$, 400 MHz)

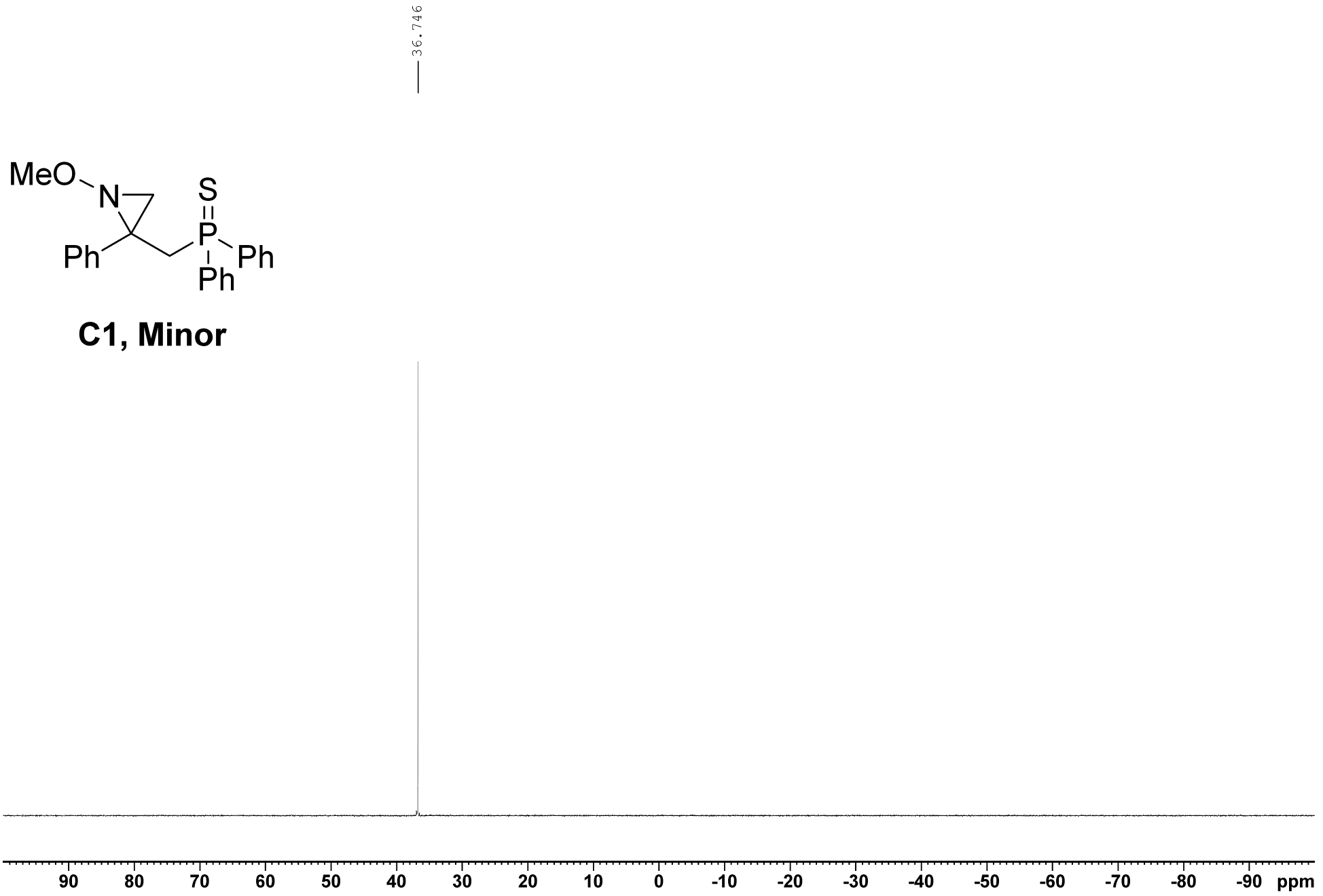


C1, Minor

^{13}C NMR (100 MHz, $CDCl_3$)

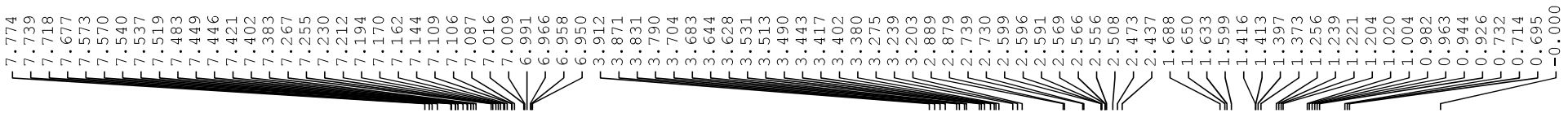


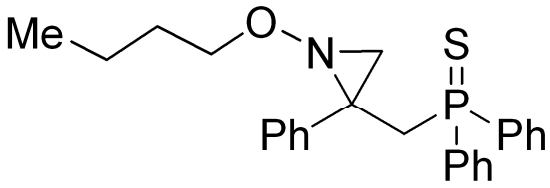
^{31}P NMR (162 MHz, $CDCl_3$)



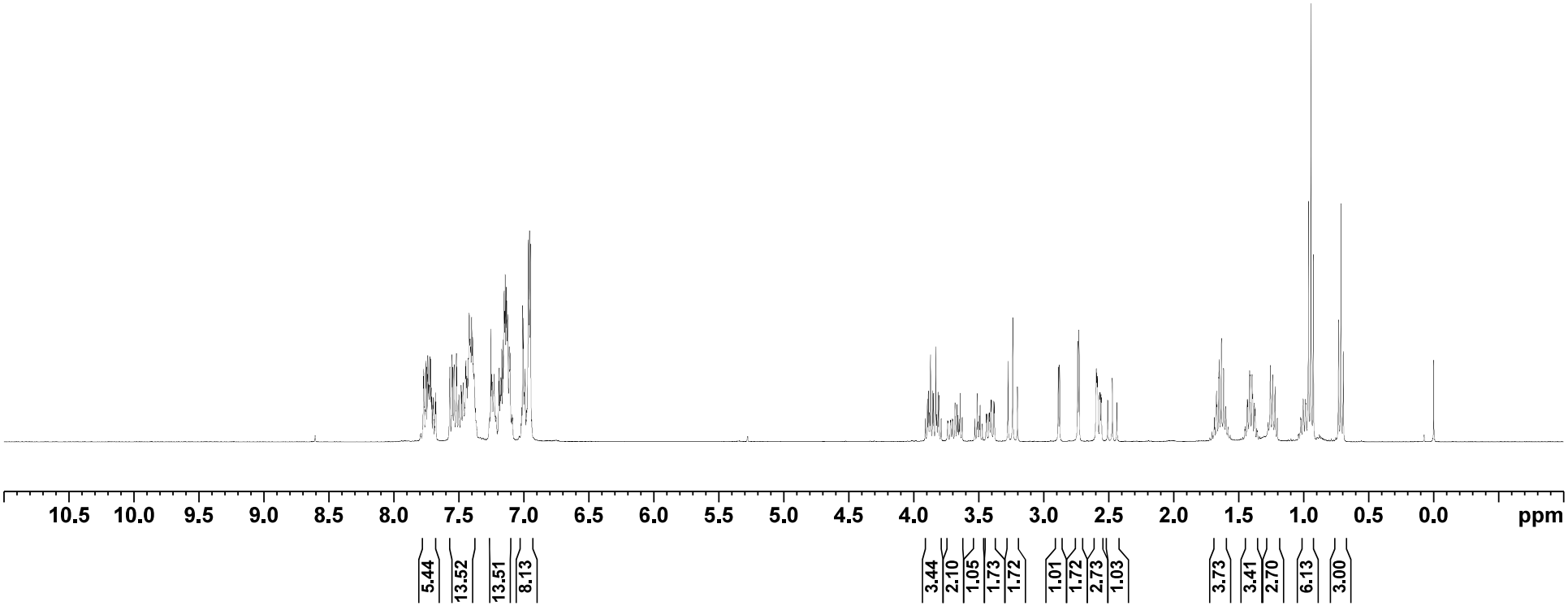
C1, Minor

^{1}H NMR ($CDCl_3$, 400 MHz)

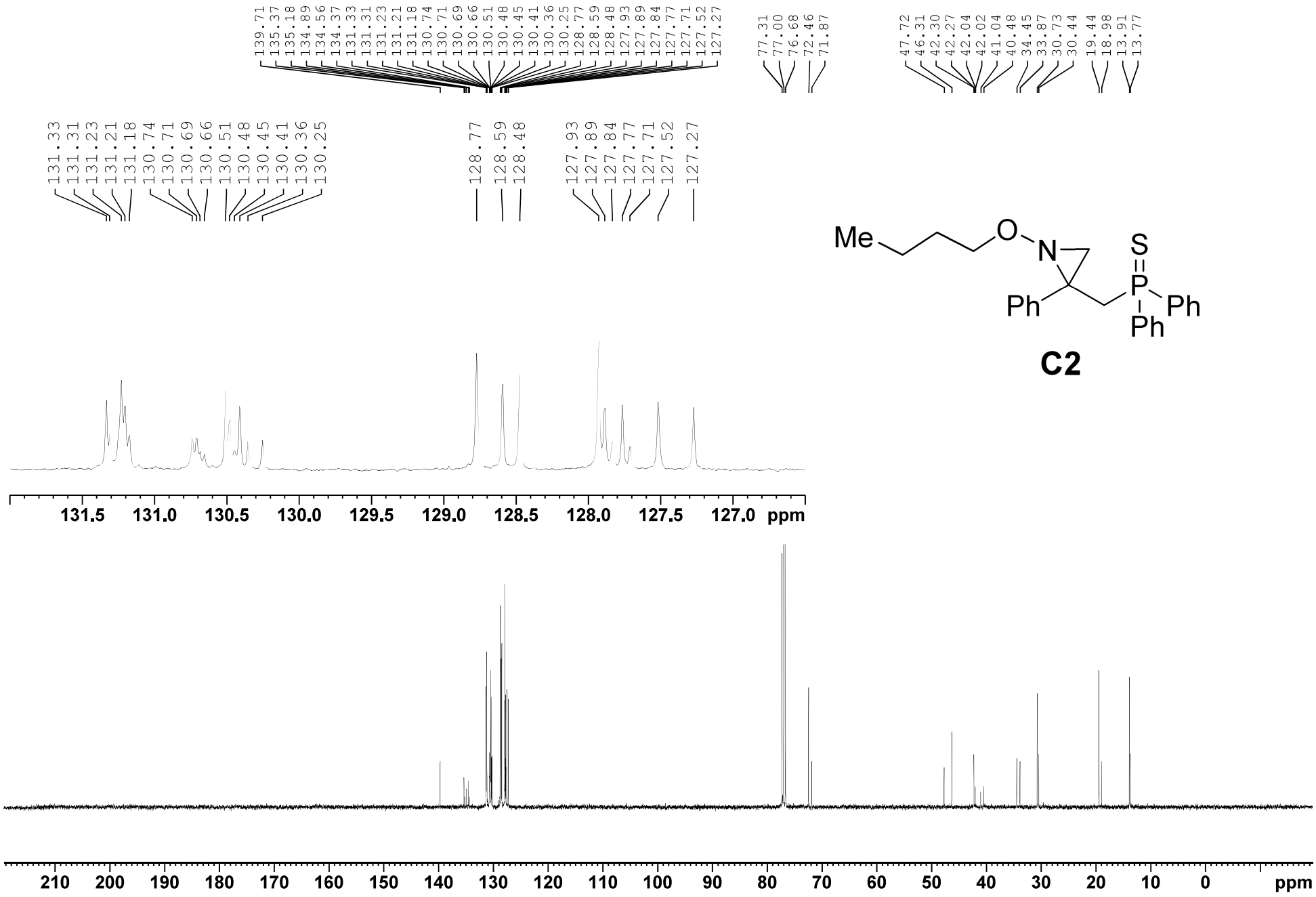




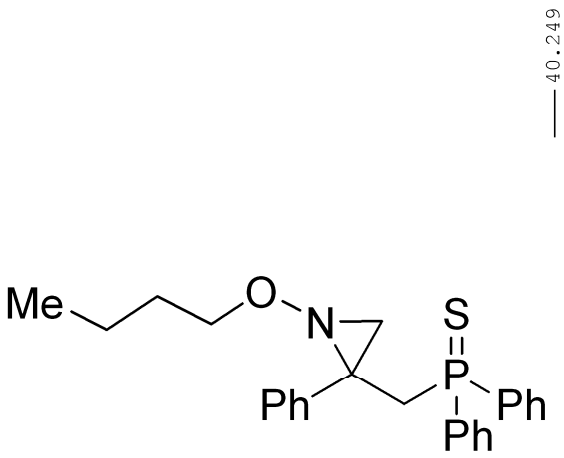
C2



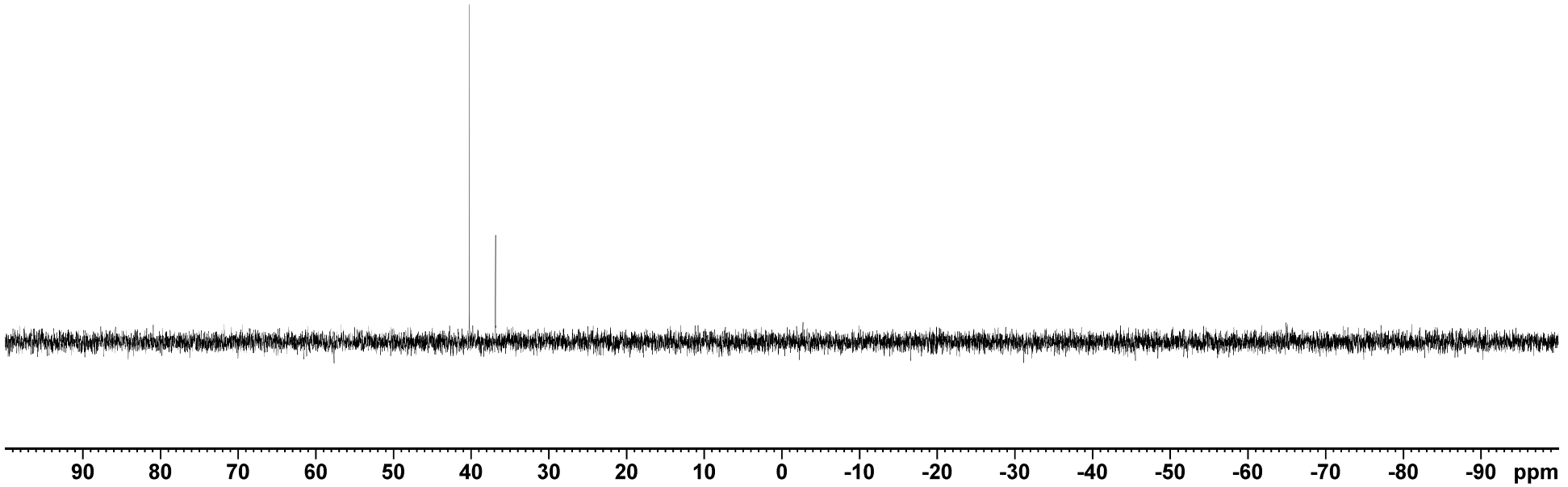
^{13}C NMR (100 MHz, $CDCl_3$)



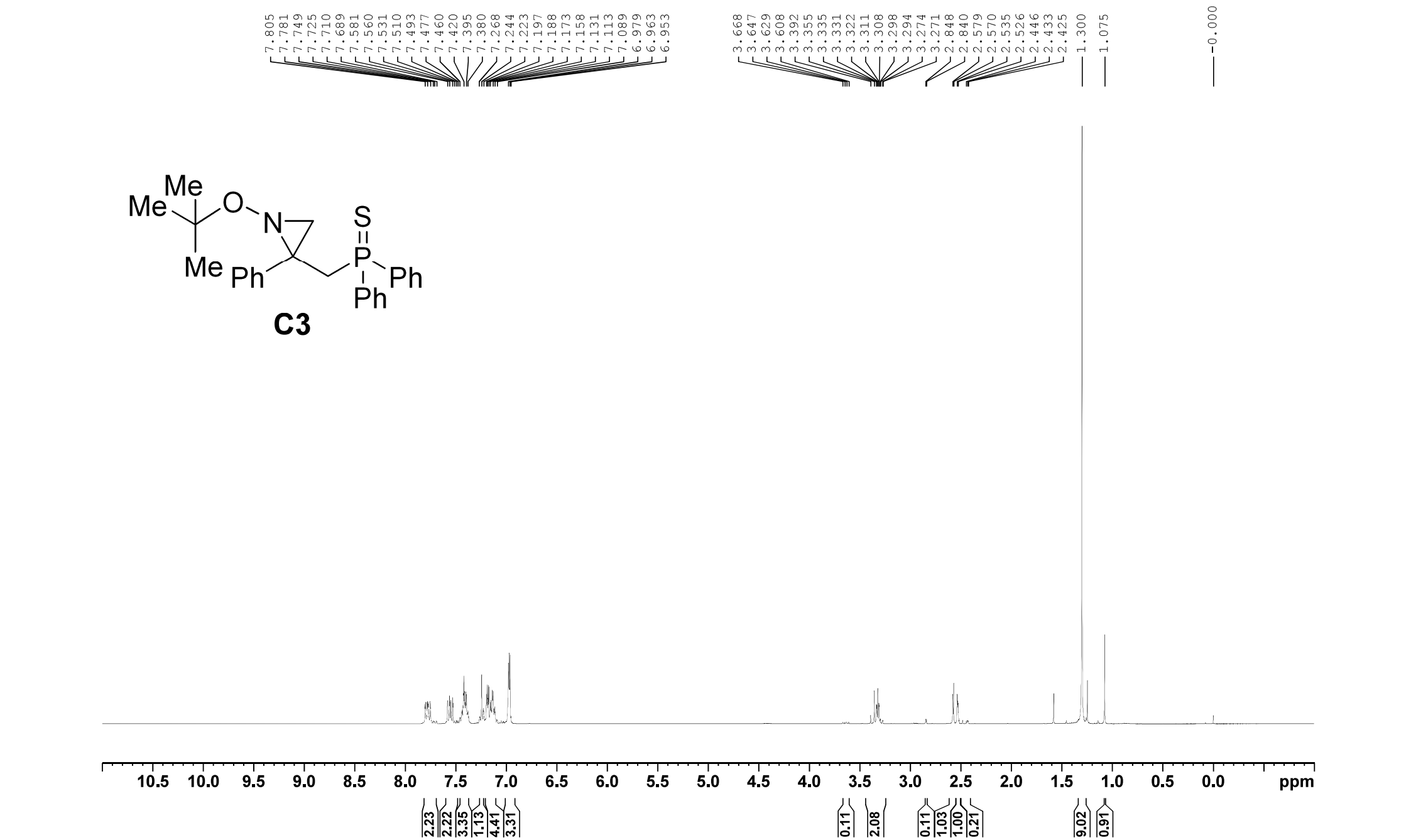
^{31}P NMR (162 MHz, $CDCl_3$)



C2

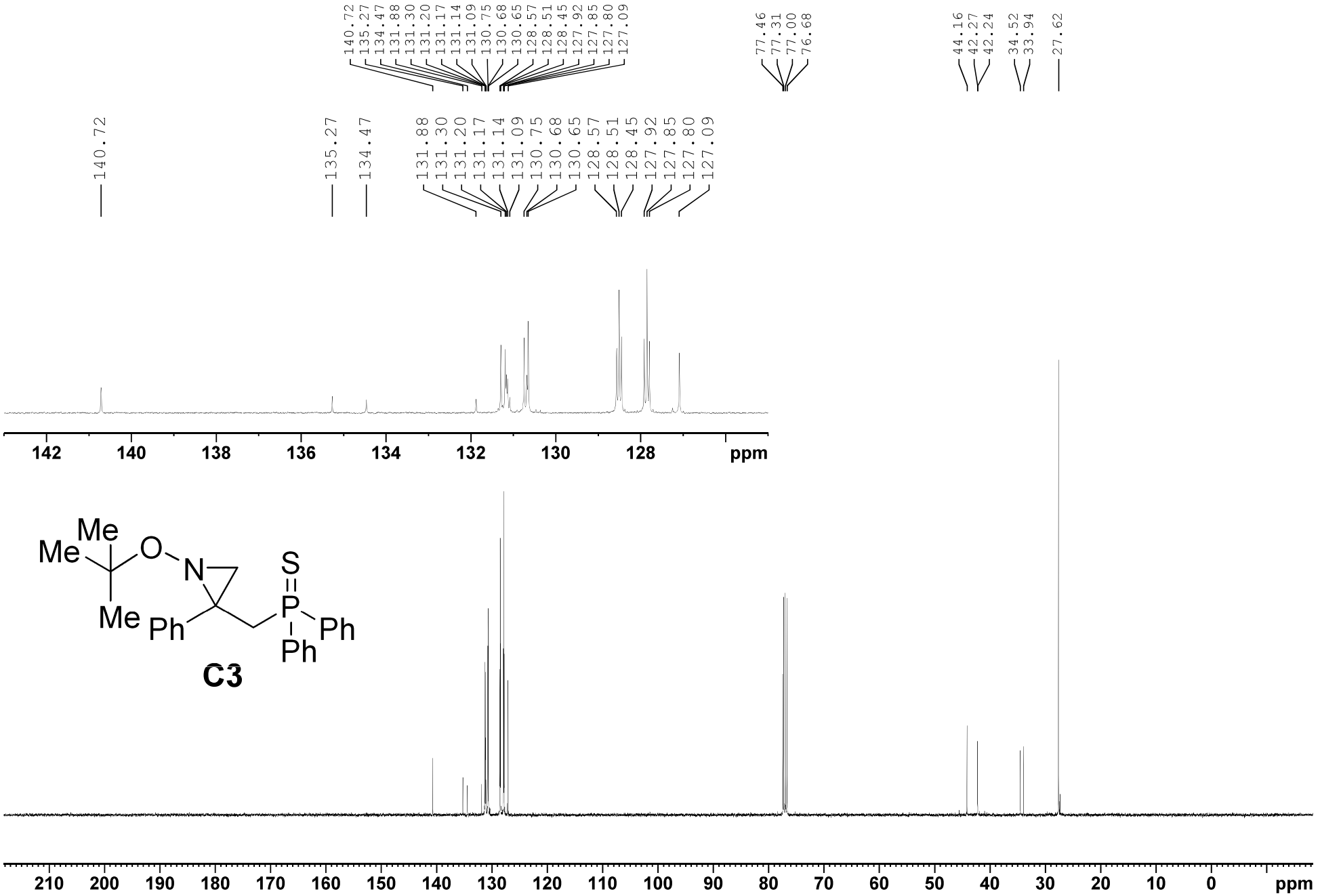


^{1}H NMR ($CDCl_3$, 400 MHz)

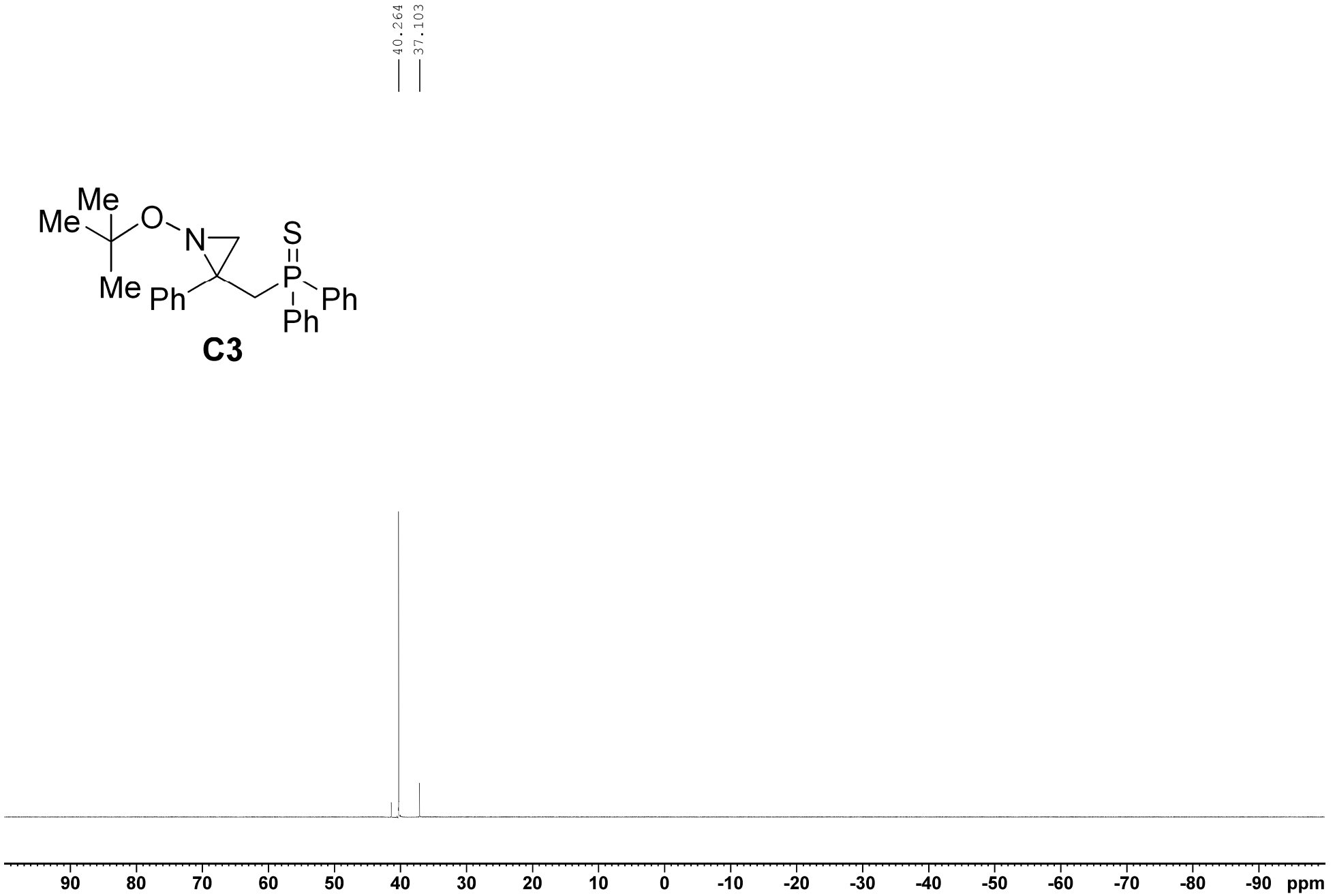


C3

^{13}C NMR (100 MHz, $CDCl_3$)

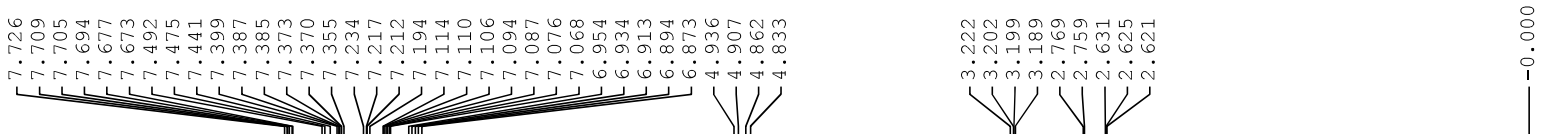


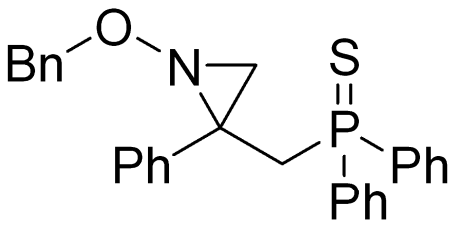
^{31}P NMR (162 MHz, $CDCl_3$)



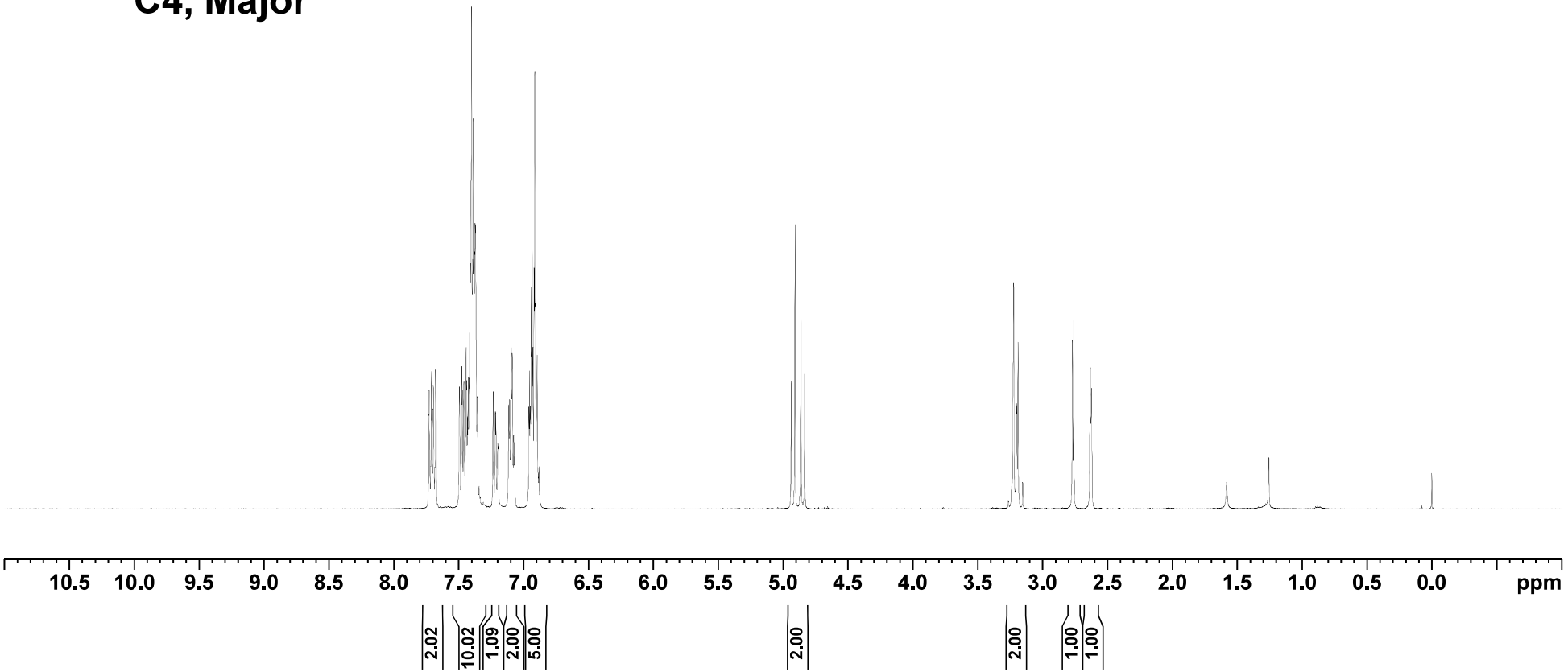
C3

^{1}H NMR ($CDCl_3$, 400 MHz)

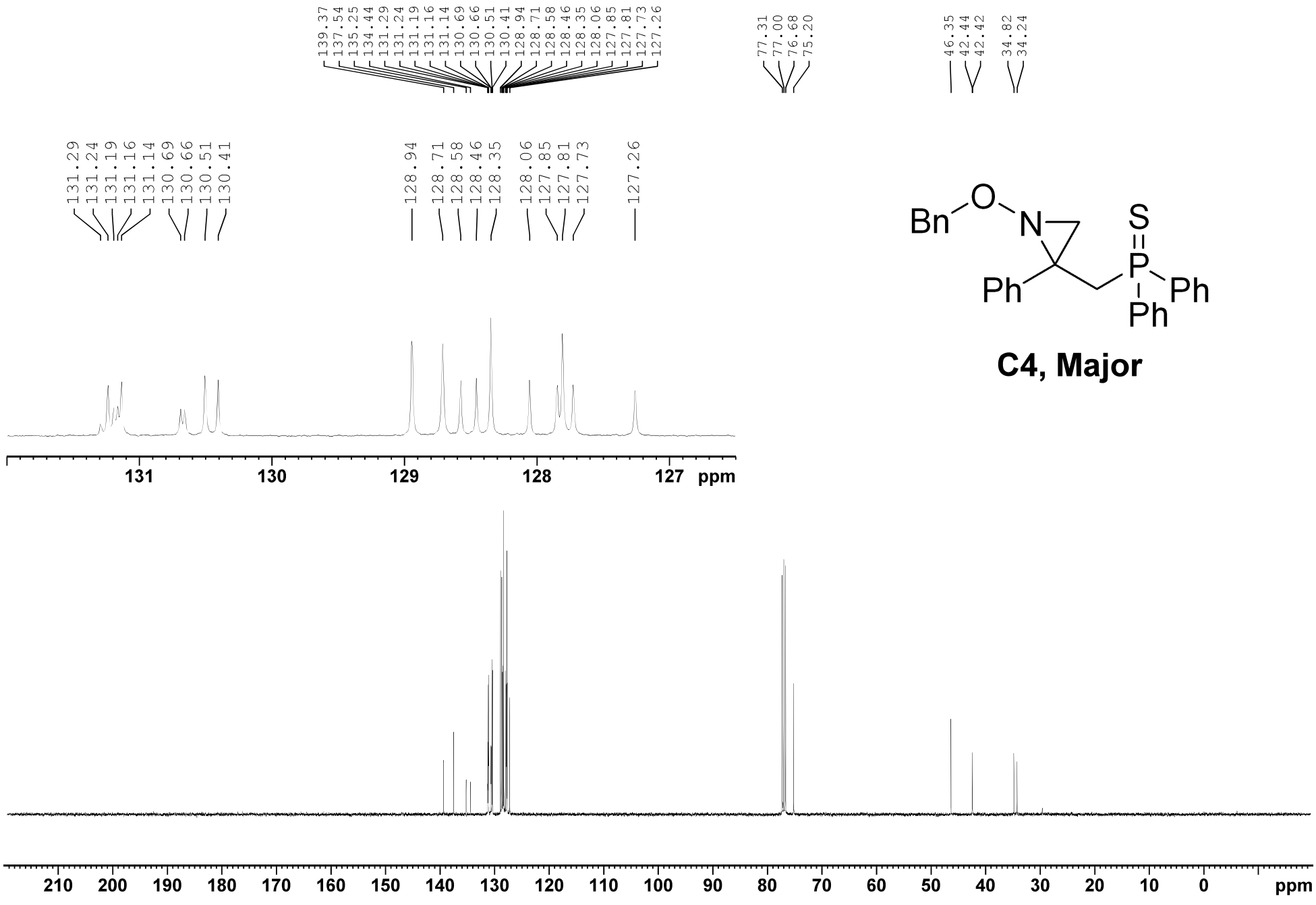




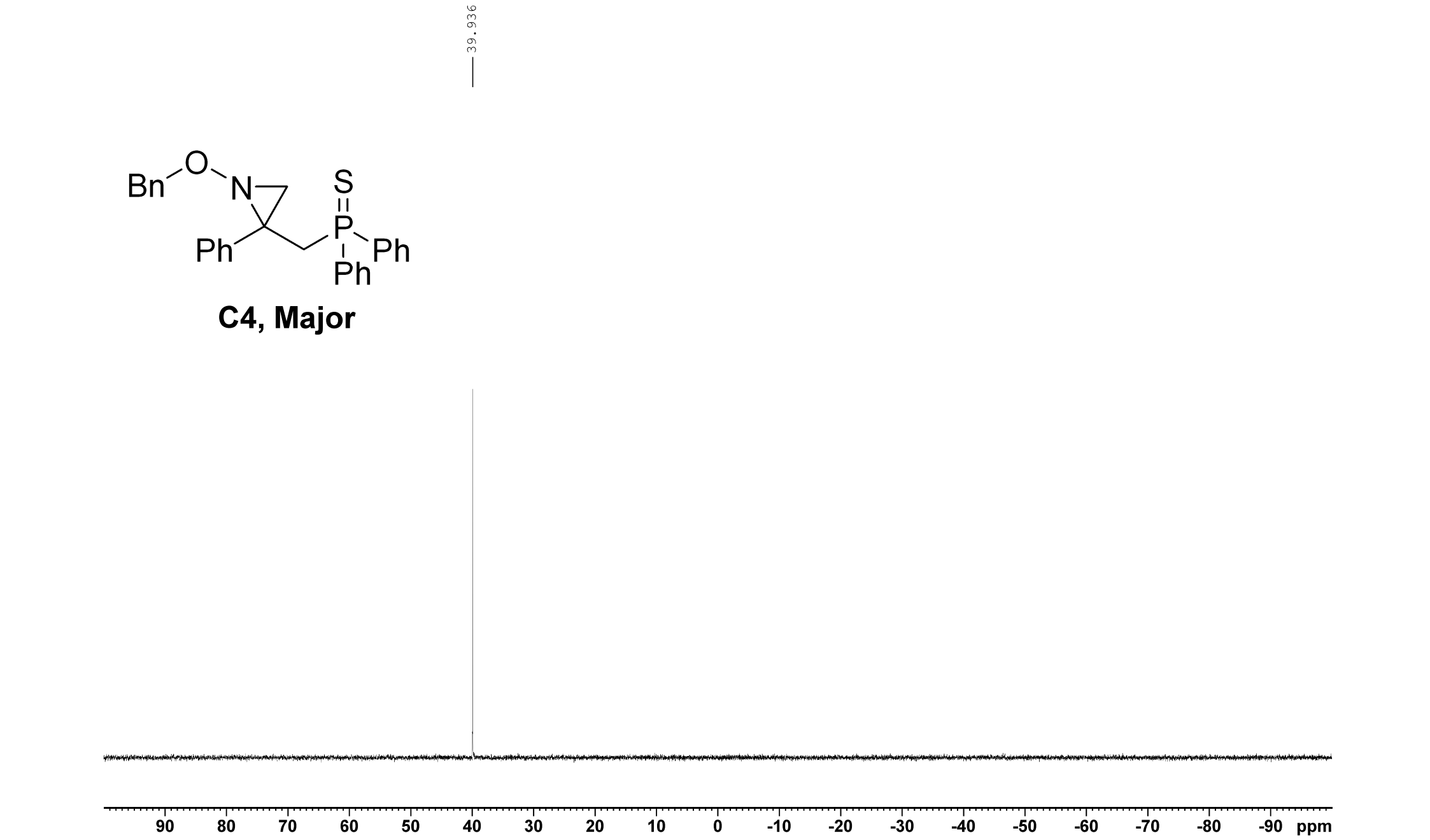
C4, Major



^{13}C NMR (100 MHz, $CDCl_3$)

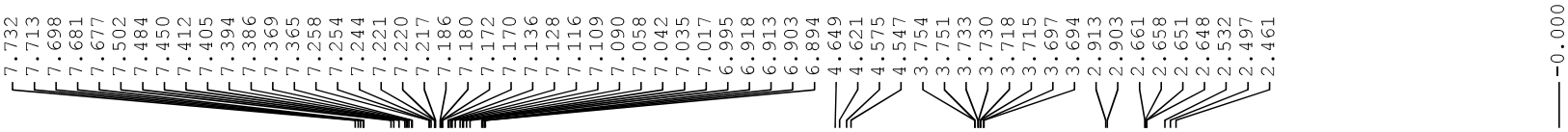


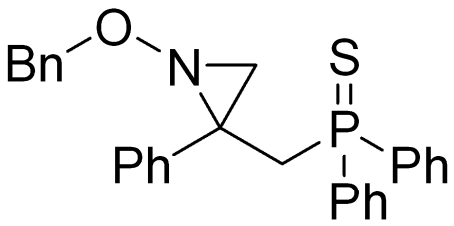
^{31}P NMR (162 MHz, $CDCl_3$)



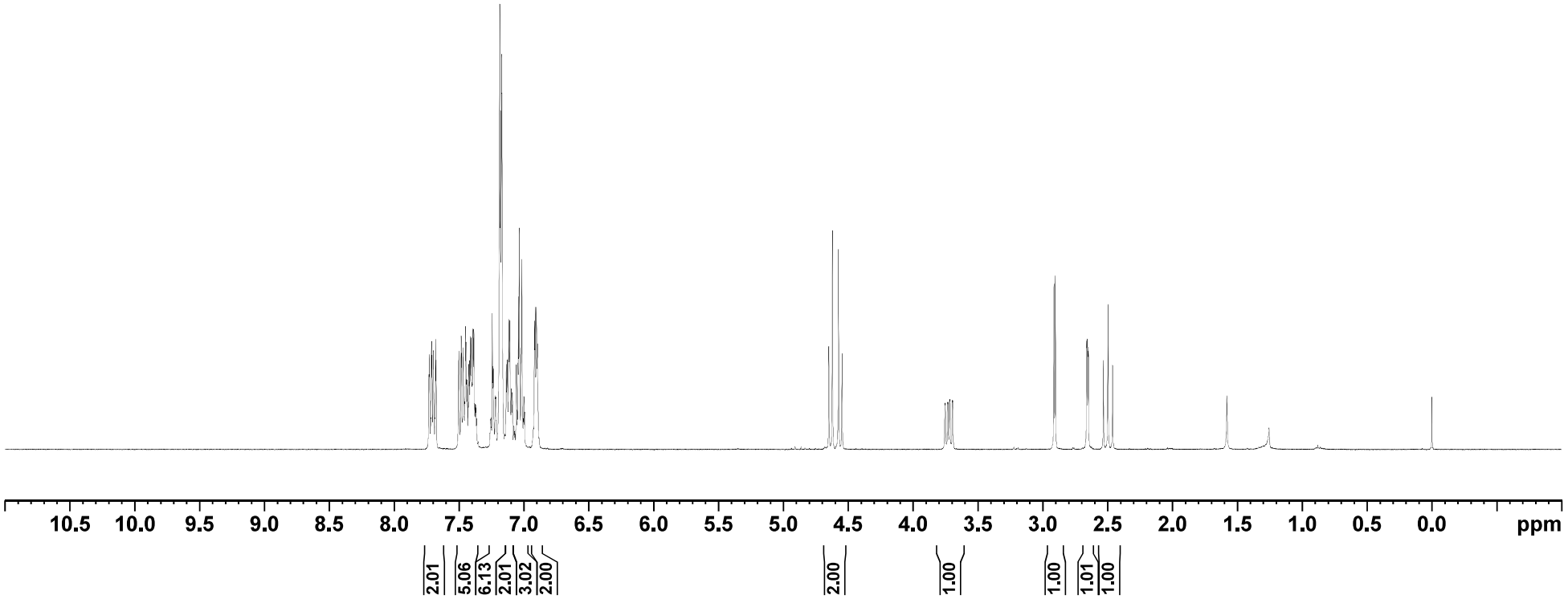
C4, Major

^{1}H NMR ($CDCl_3$, 400 MHz)

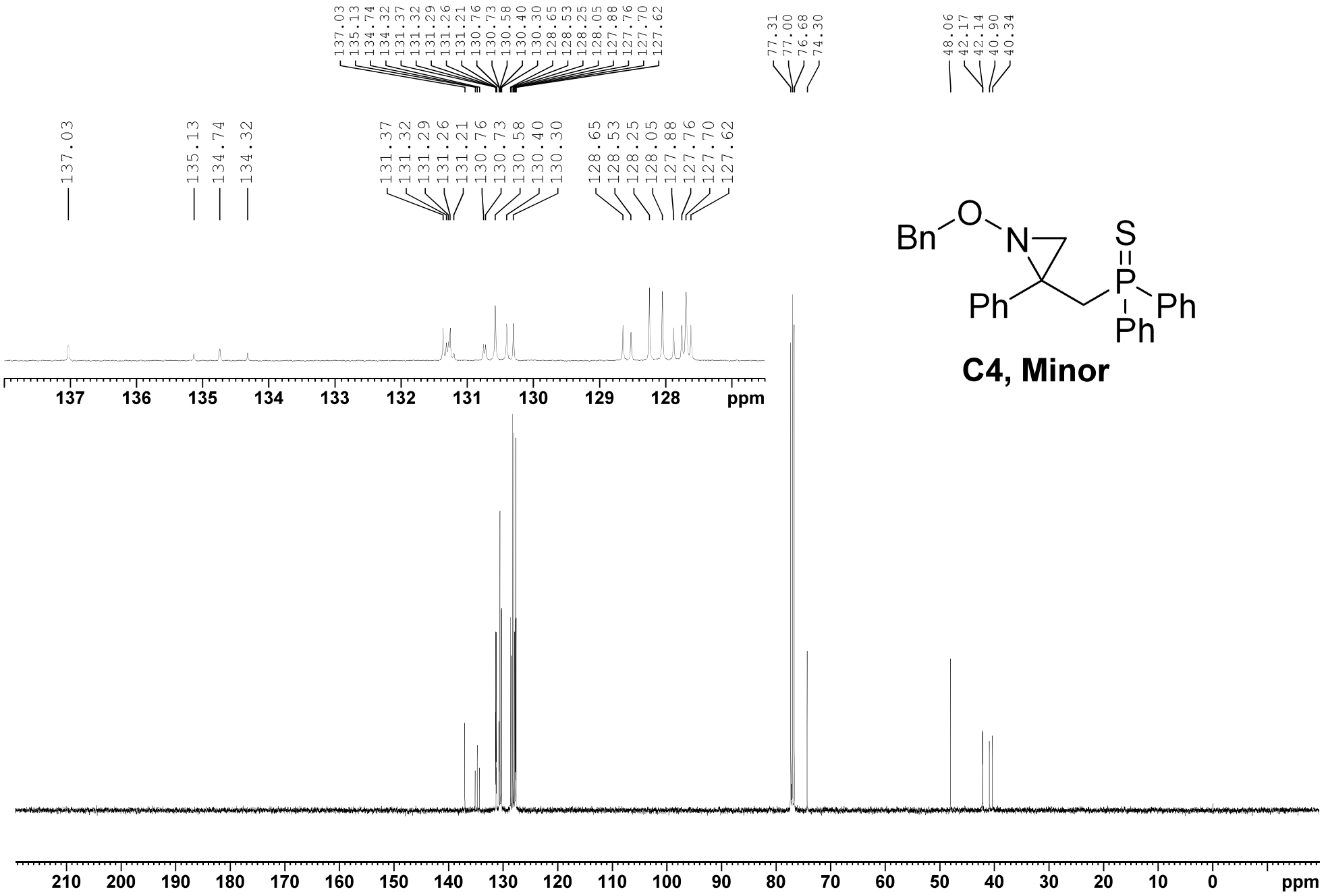




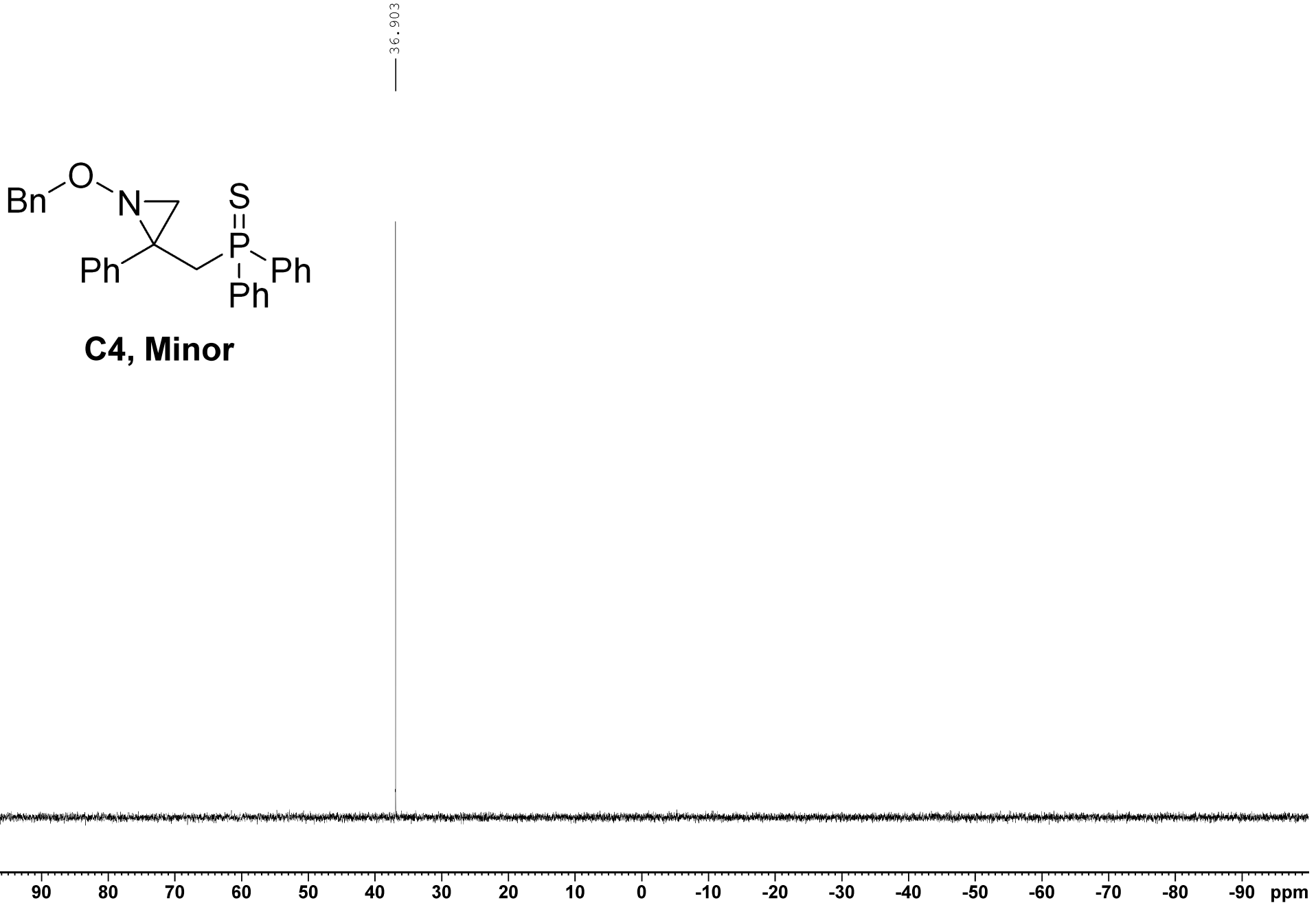
C4, Minor



^{13}C NMR (100 MHz, $CDCl_3$)

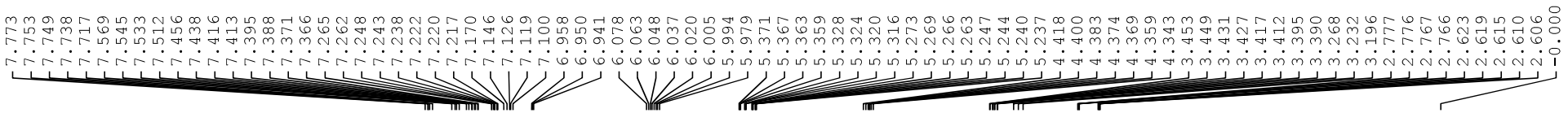


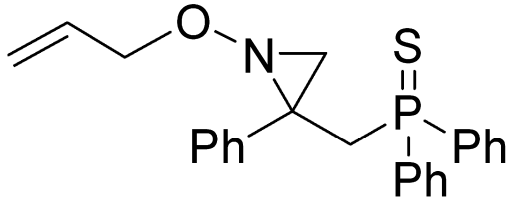
^{31}P NMR (162 MHz, $CDCl_3$)



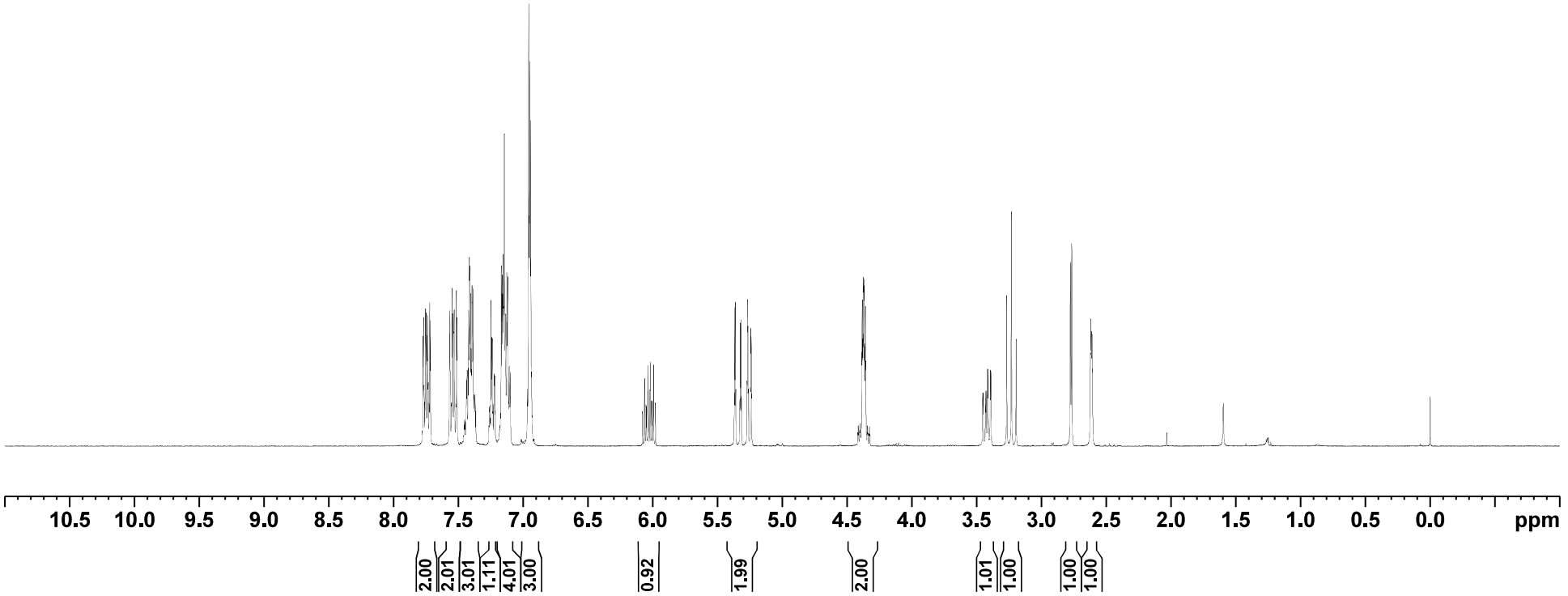
C4, Minor

^{1}H NMR ($CDCl_3$, 400 MHz)

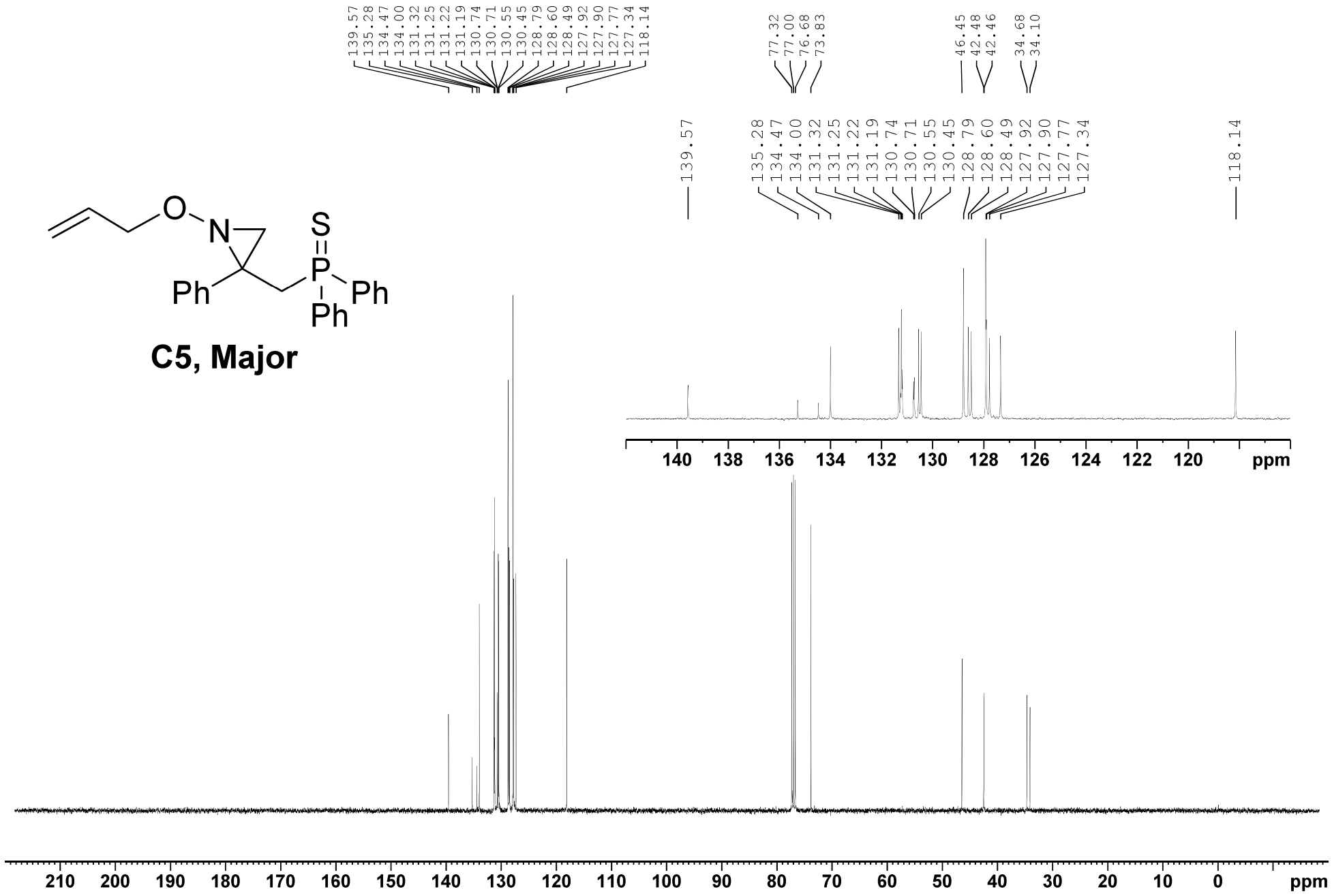




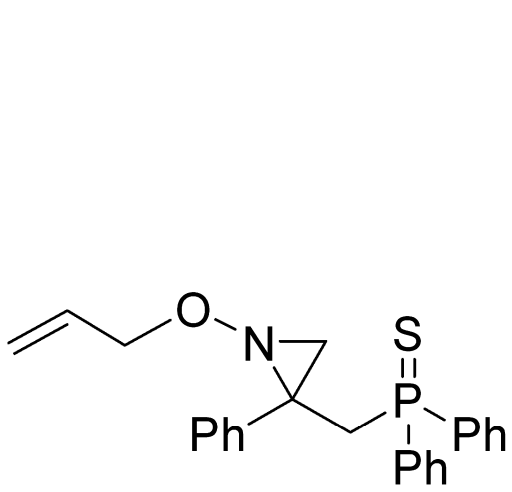
C5, Major



^{13}C NMR (100 MHz, $CDCl_3$)

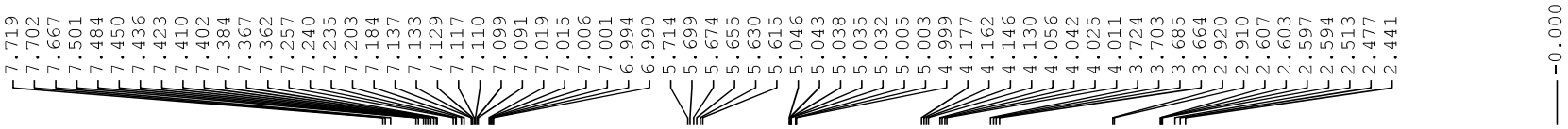


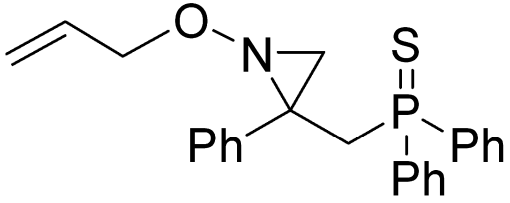
^{31}P NMR (162 MHz, $CDCl_3$)



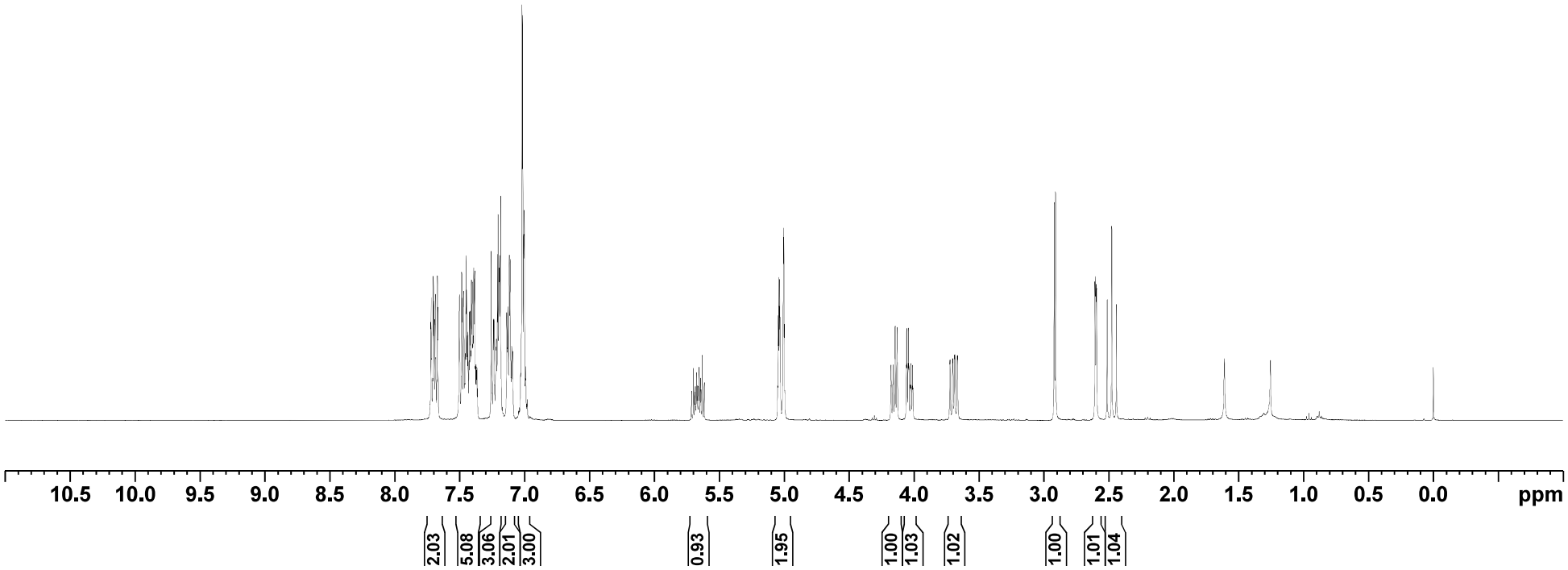
C5, Major

^{1}H NMR ($CDCl_3$, 400 MHz)

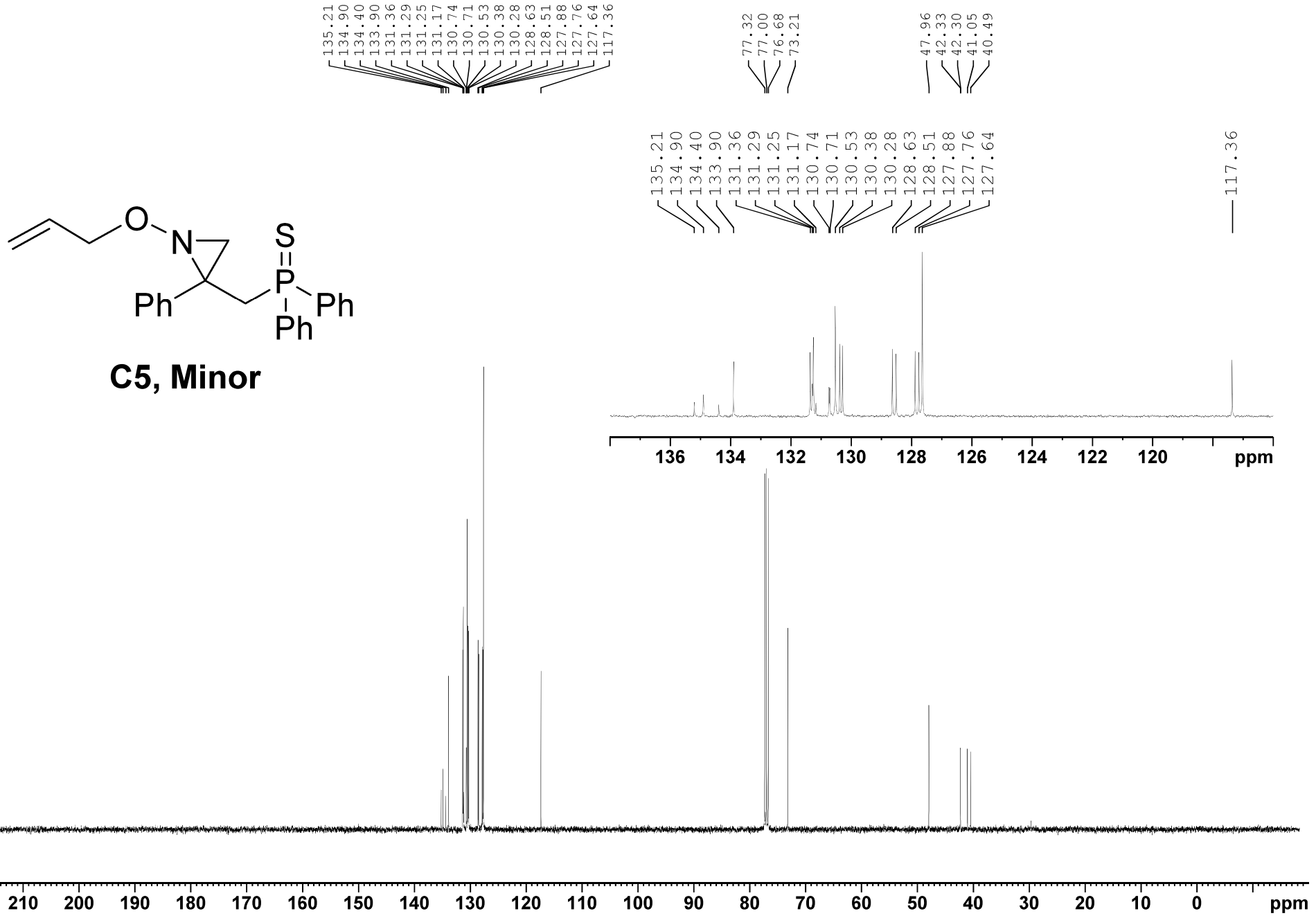




C5, Minor

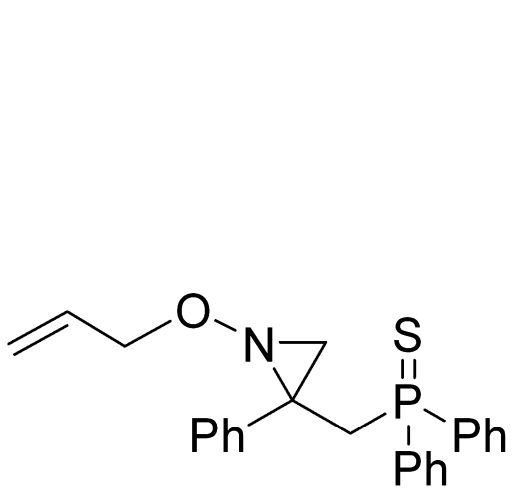


^{13}C NMR (100 MHz, $CDCl_3$)

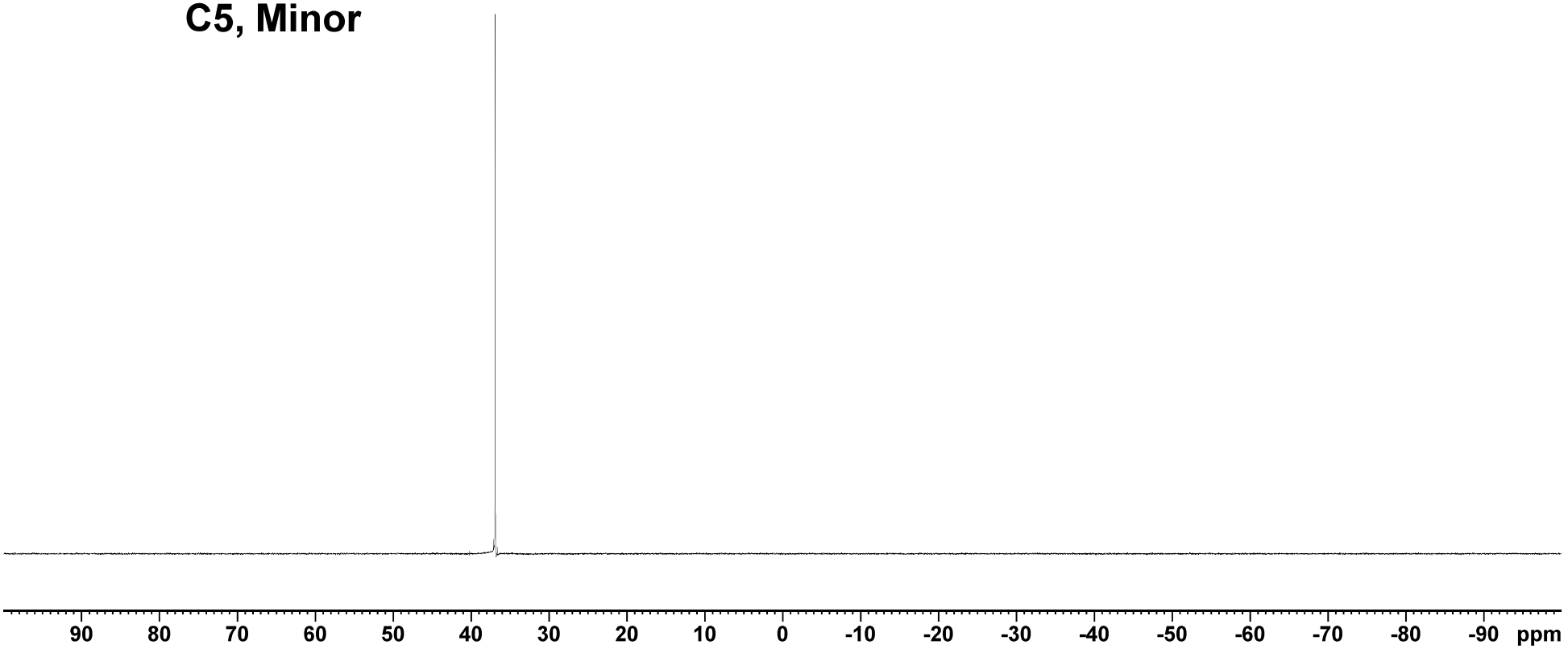


C5, Minor

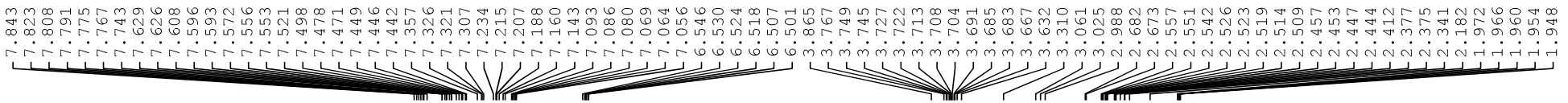
^{31}P NMR (162 MHz, $CDCl_3$)

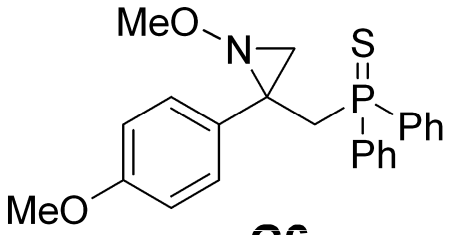


C5, Minor

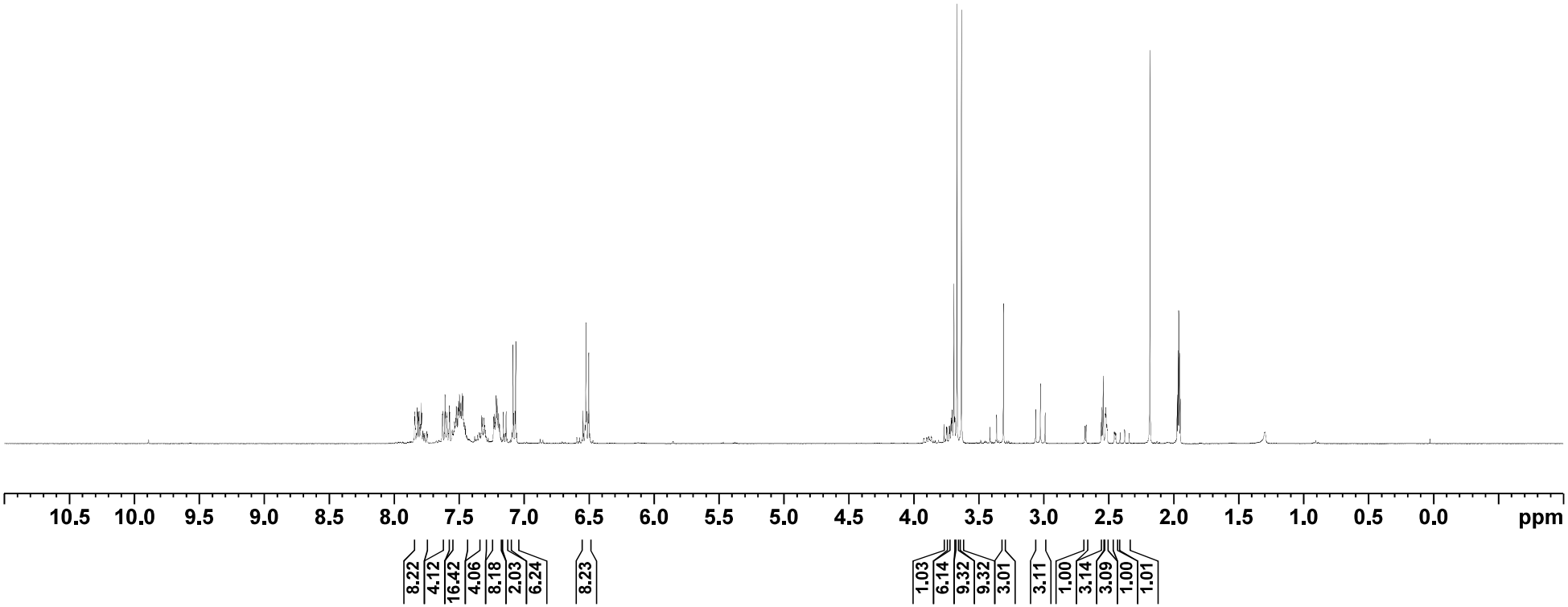


^{1}H NMR ($CDCl_3$, 400 MHz)

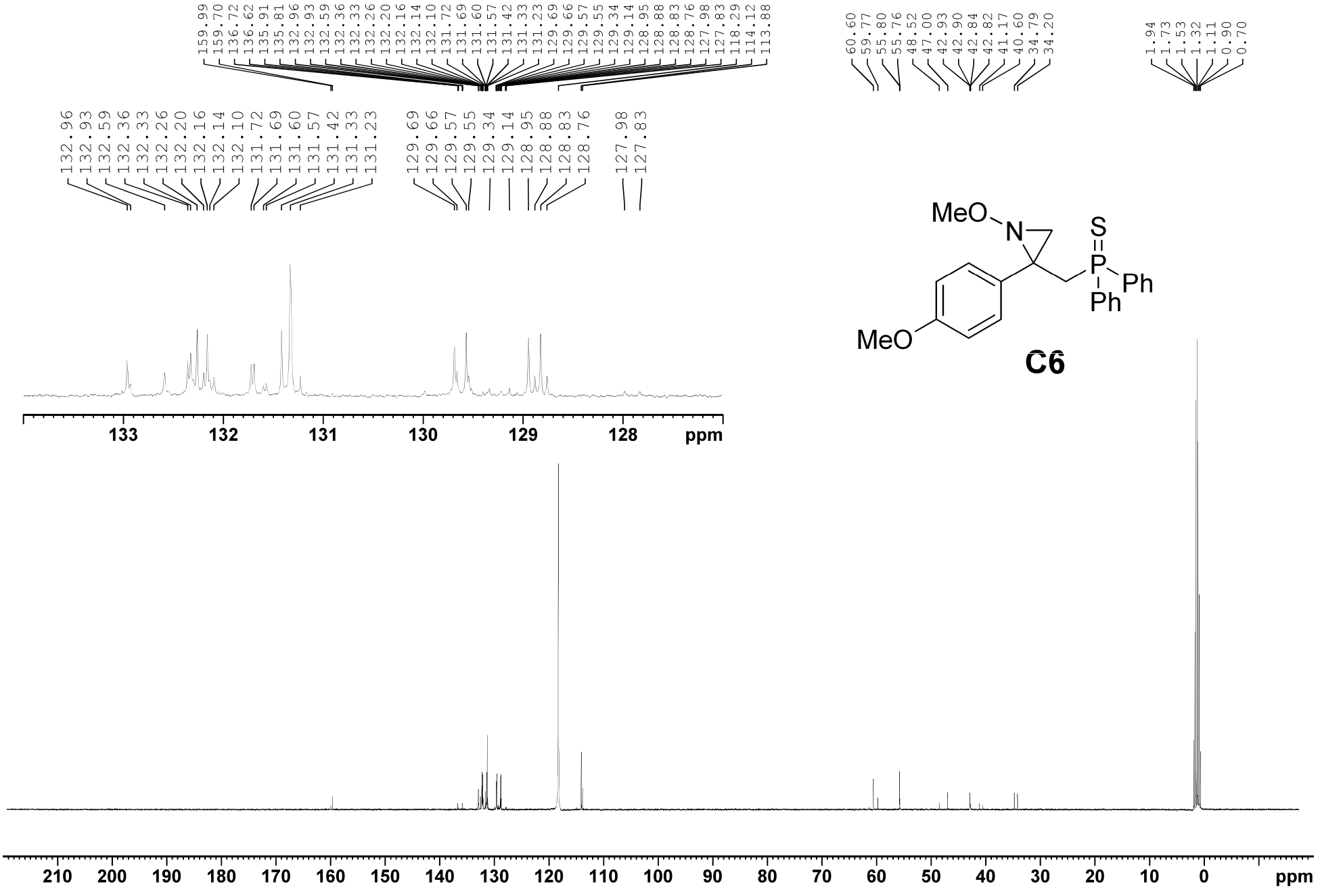




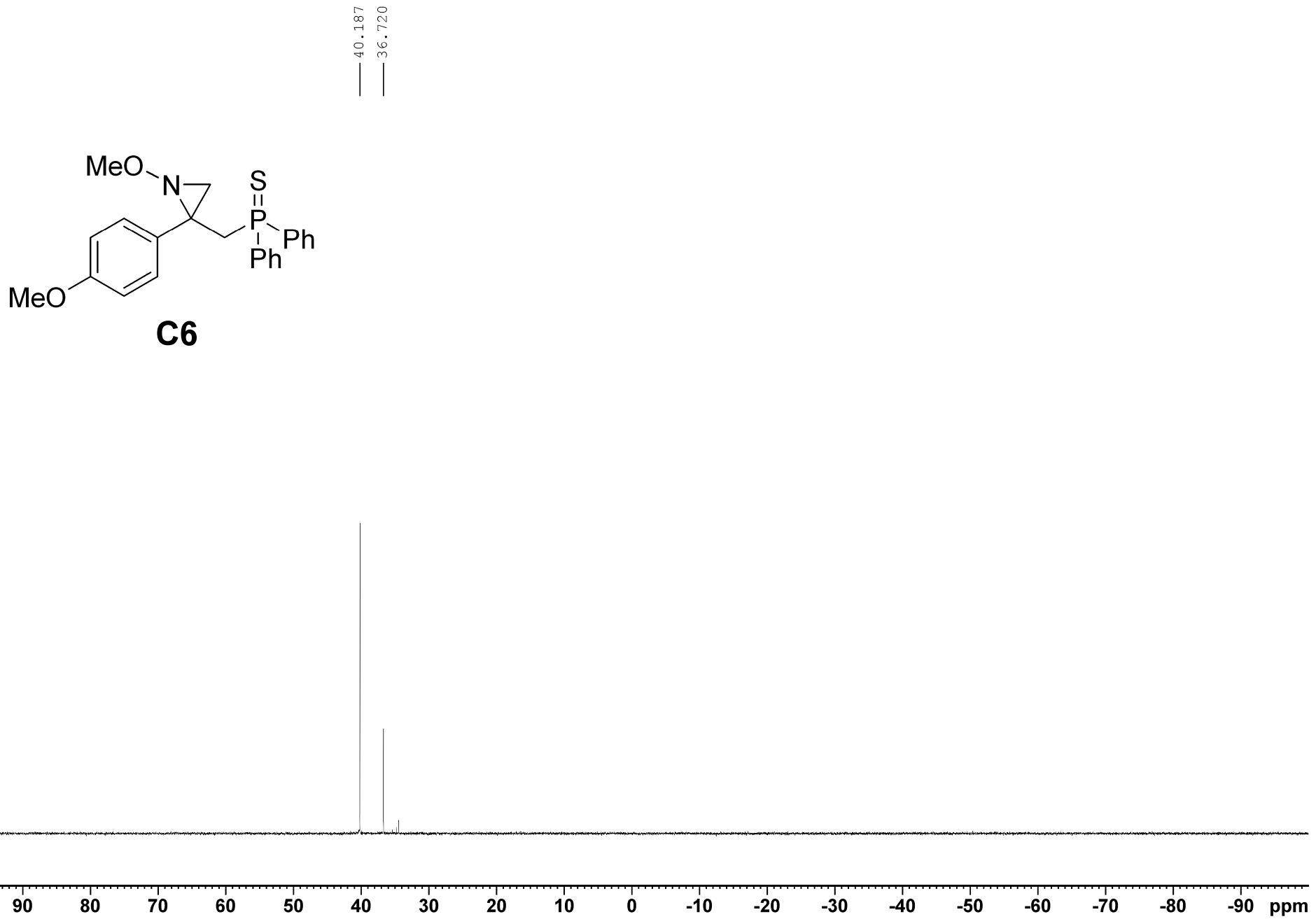
C6



^{13}C NMR (100 MHz, $CDCl_3$)

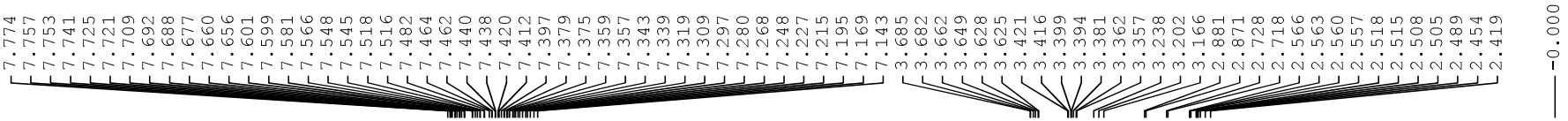


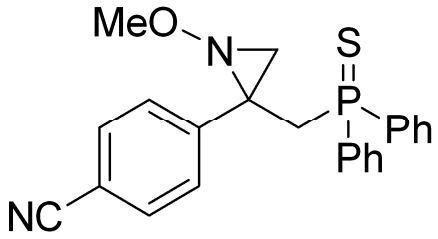
^{31}P NMR (162 MHz, $CDCl_3$)



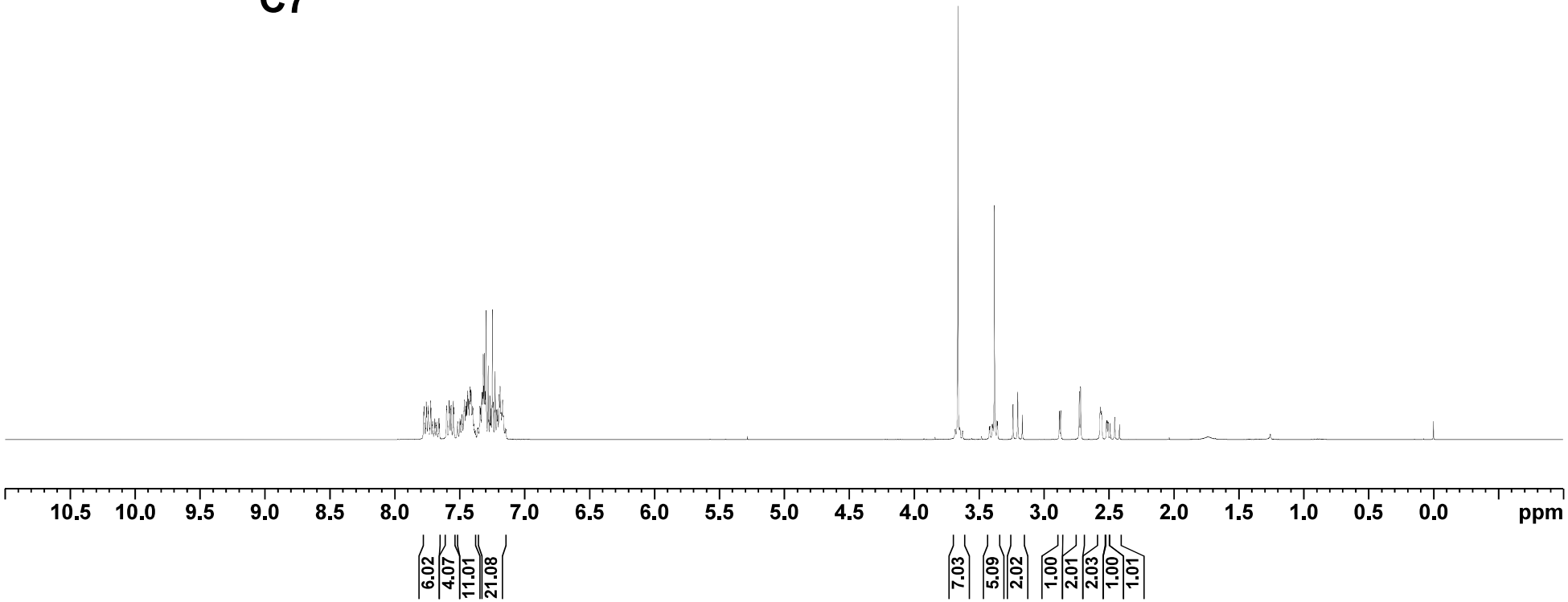
C6

^{1}H NMR ($CDCl_3$, 400 MHz)

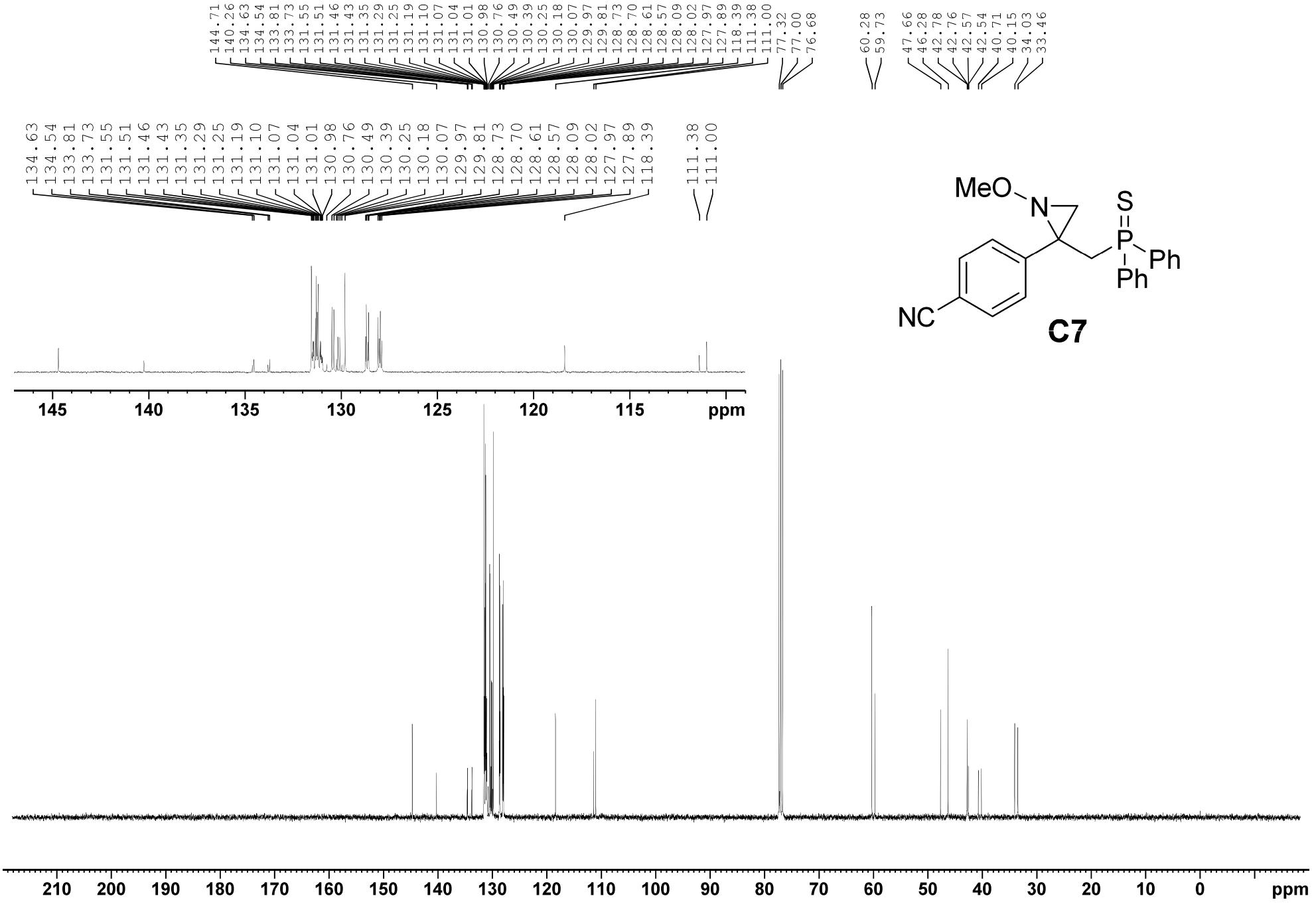




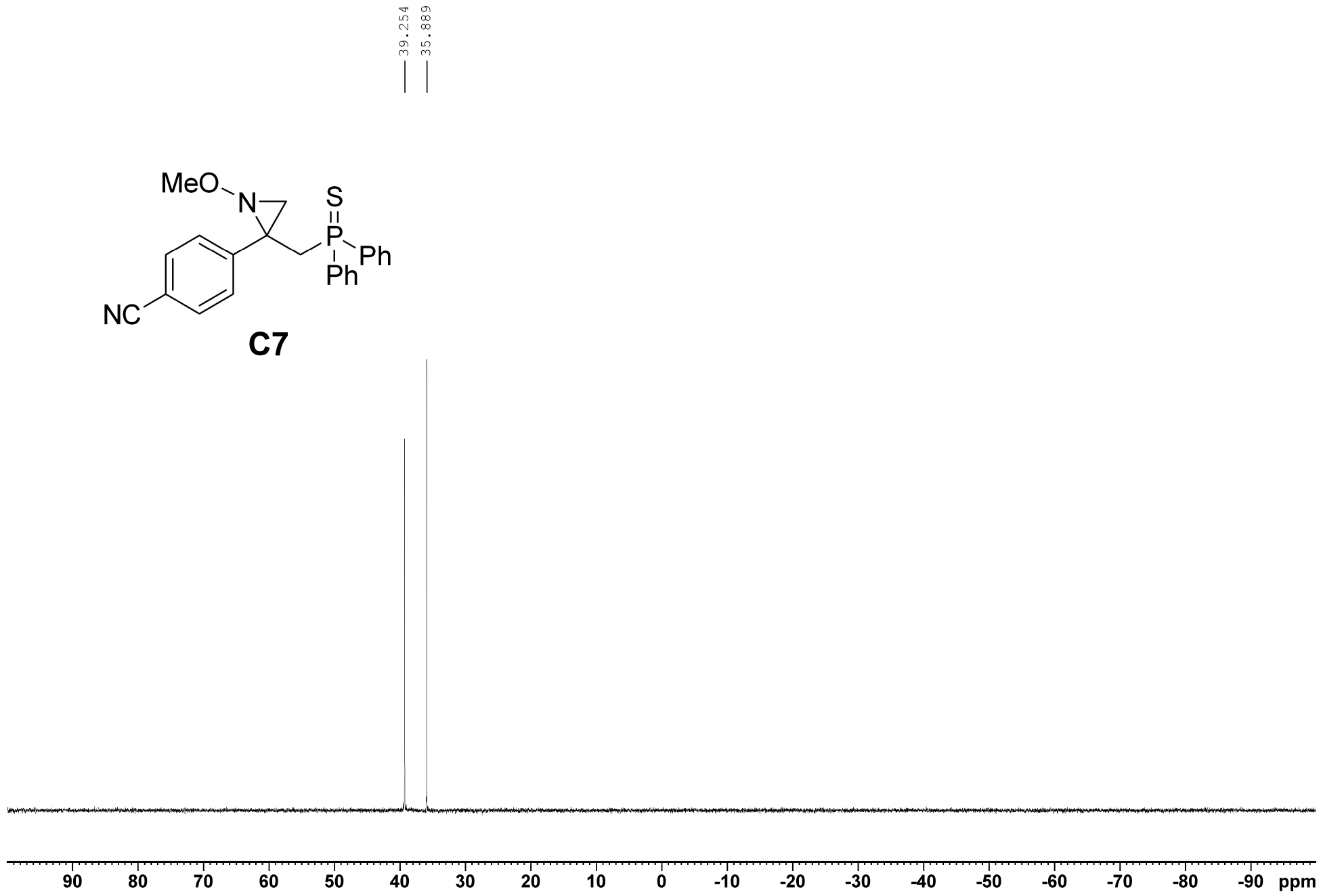
C7



^{13}C NMR (100 MHz, $CDCl_3$)

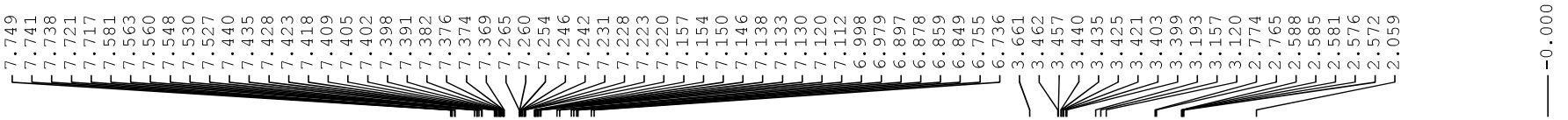


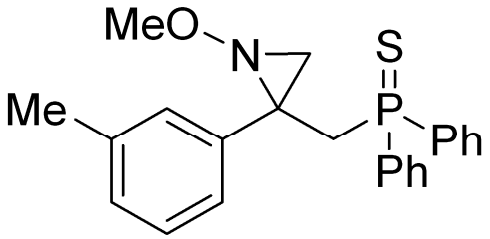
^{31}P NMR (162 MHz, $CDCl_3$)



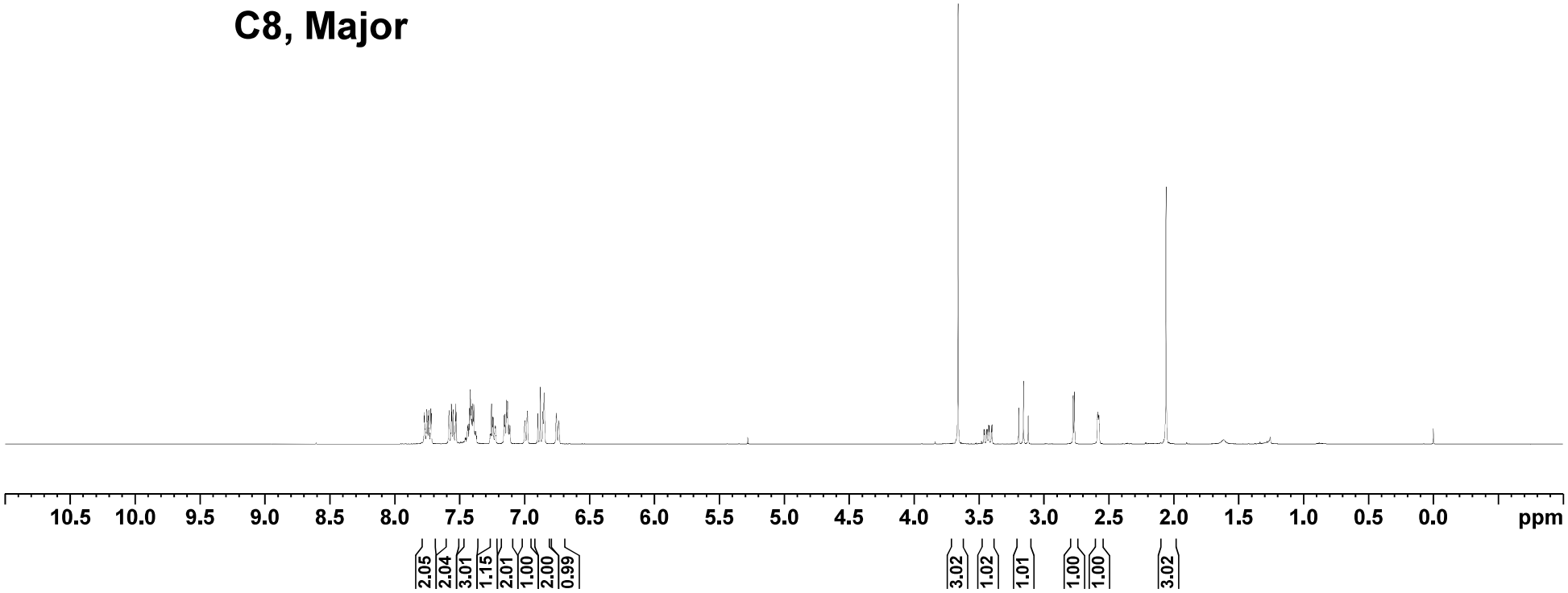
C7

^{1}H NMR ($CDCl_3$, 400 MHz)

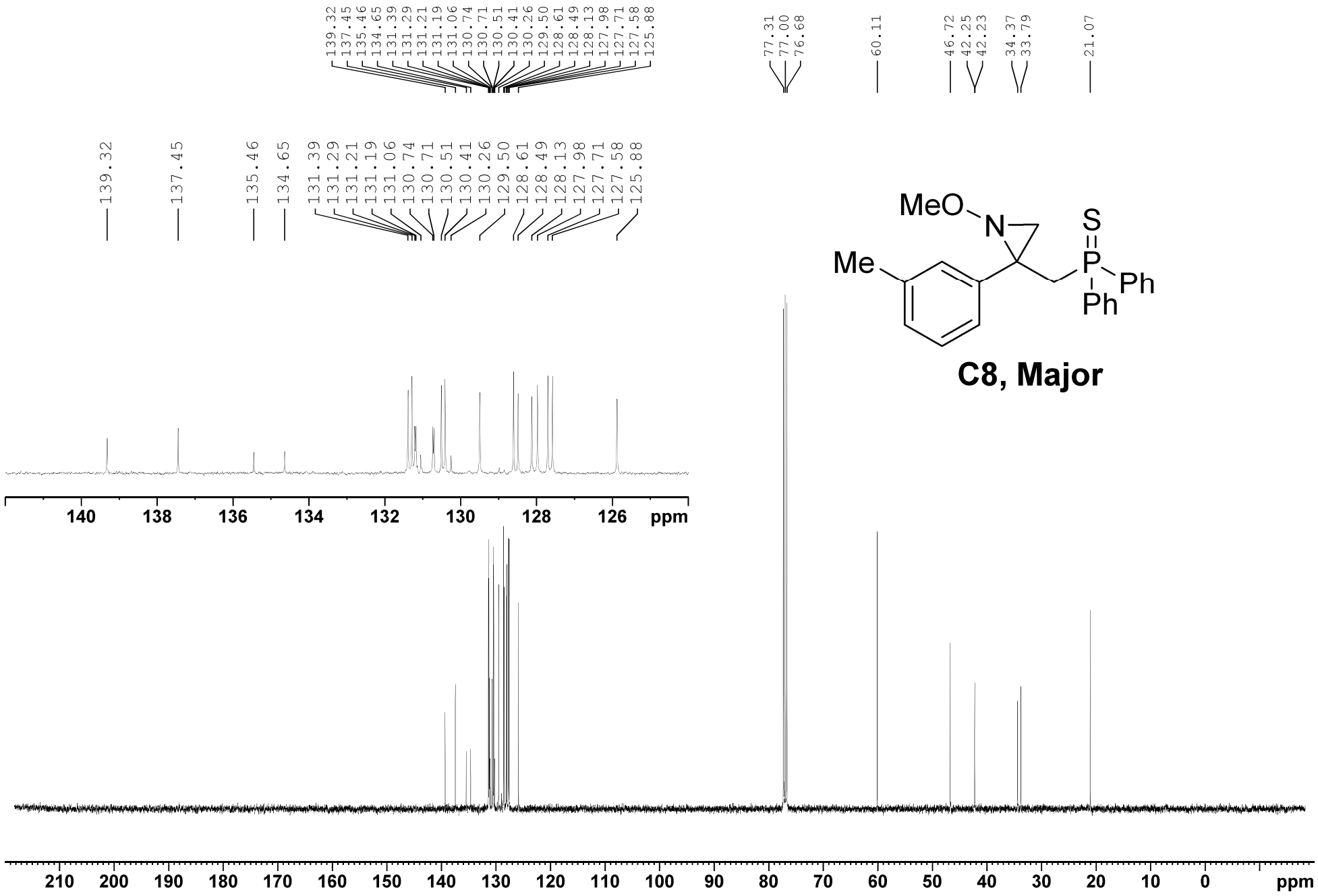




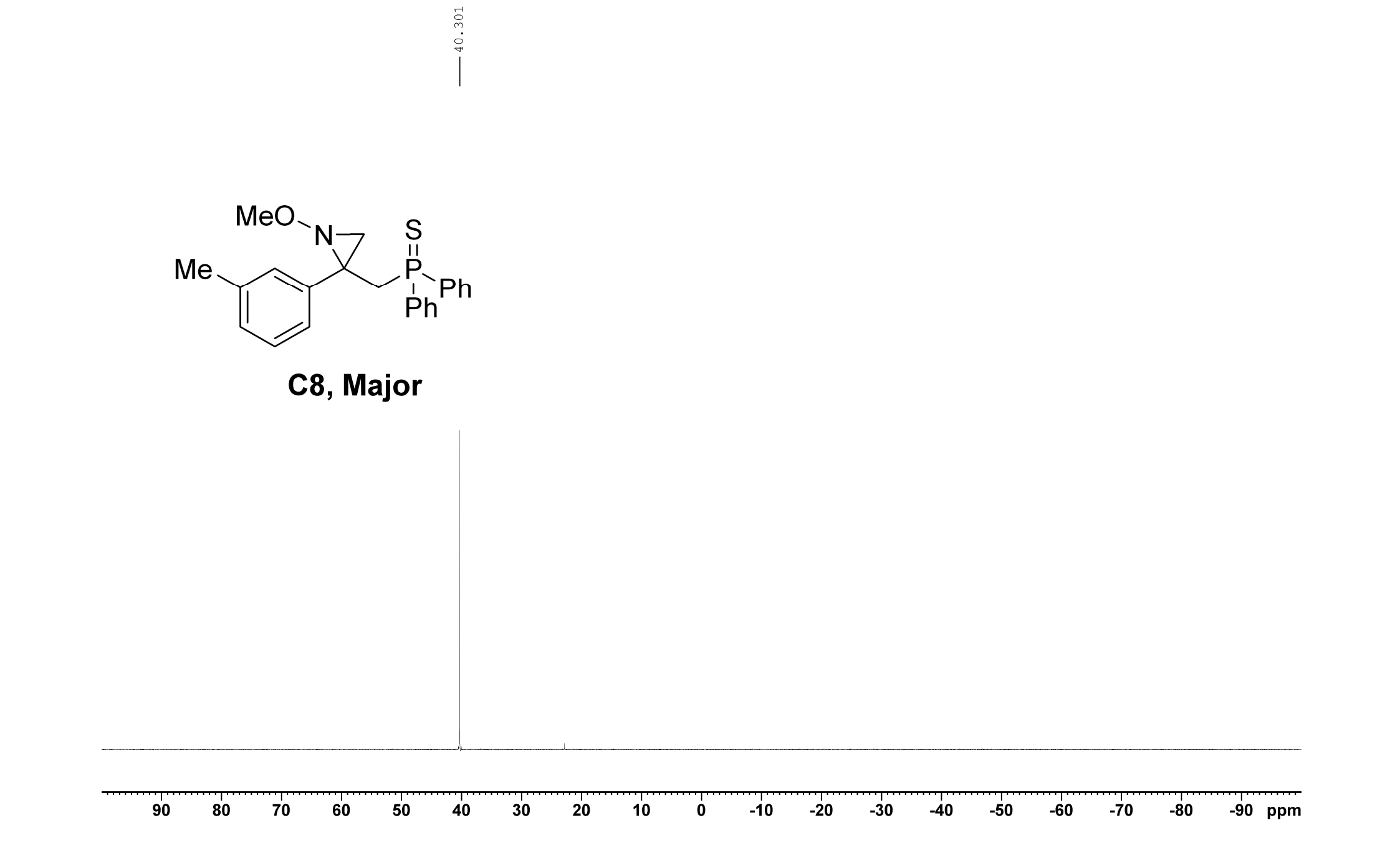
C8, Major



^{13}C NMR (100 MHz, $CDCl_3$)

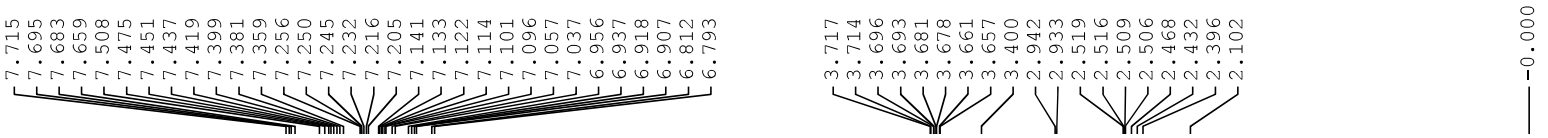


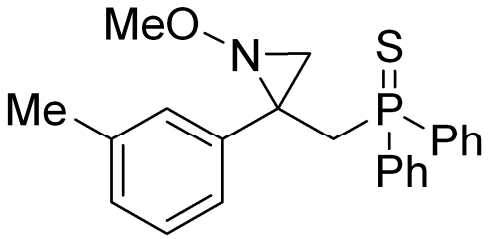
^{31}P NMR (162 MHz, $CDCl_3$)



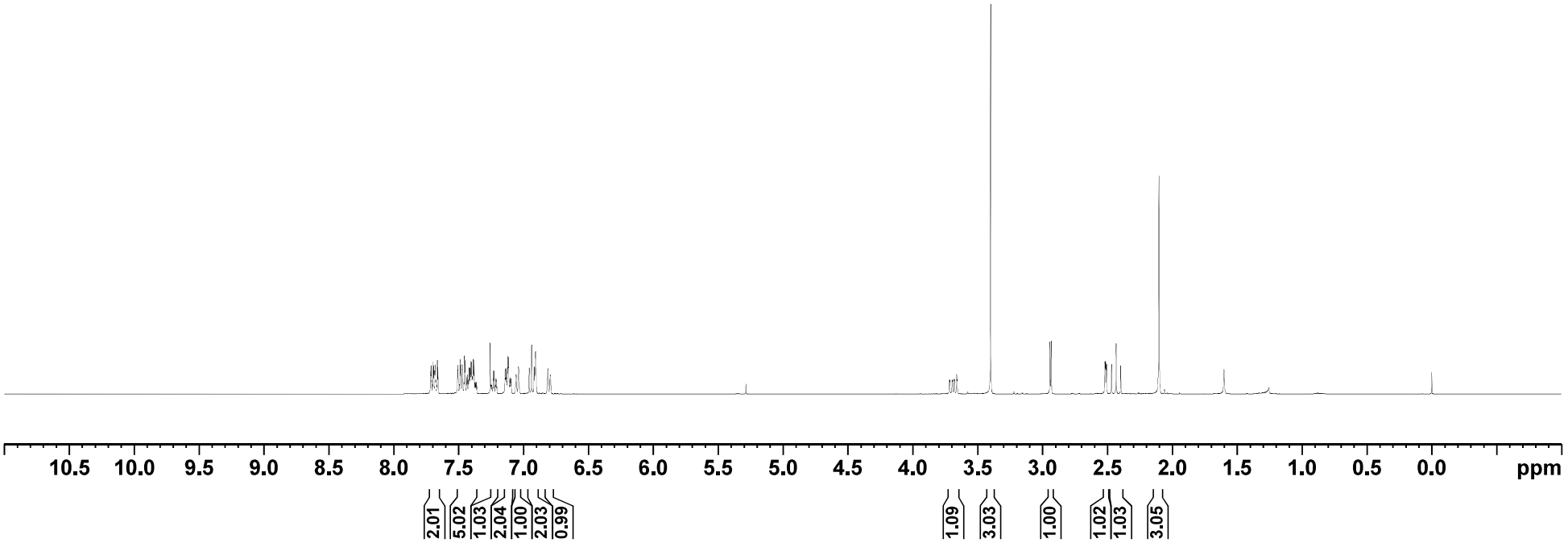
C8, Major

^{1}H NMR ($CDCl_3$, 400 MHz)





C8, Minor



^{13}C NMR (100 MHz, $CDCl_3$)

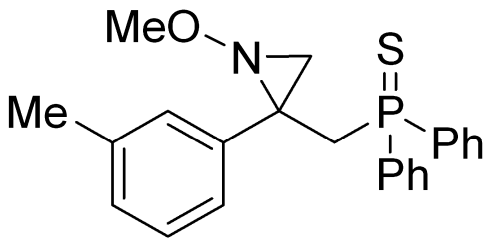
137.20
135.39
134.73
134.58
131.37
131.27
130.96
130.69
130.66
130.30
130.20
130.18
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128.60
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127.52
127.42

77.32
77.00
76.68

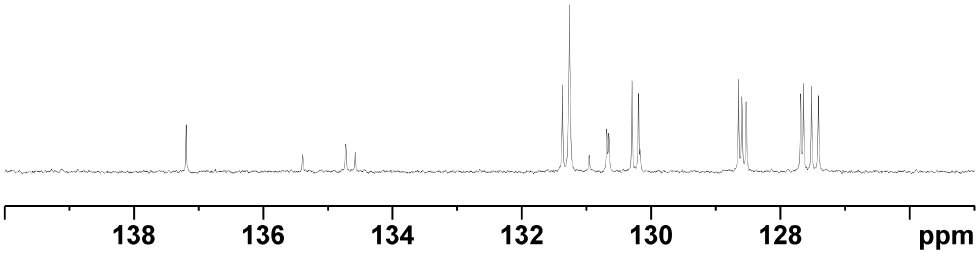
59.69

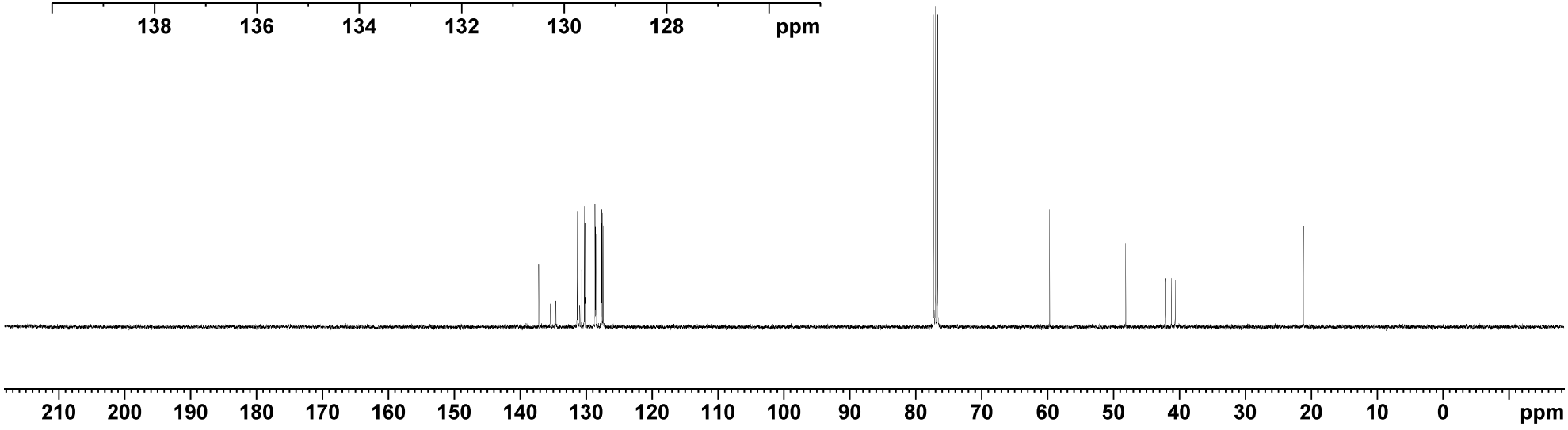
48.15
42.14
42.11
41.21
40.65

21.19

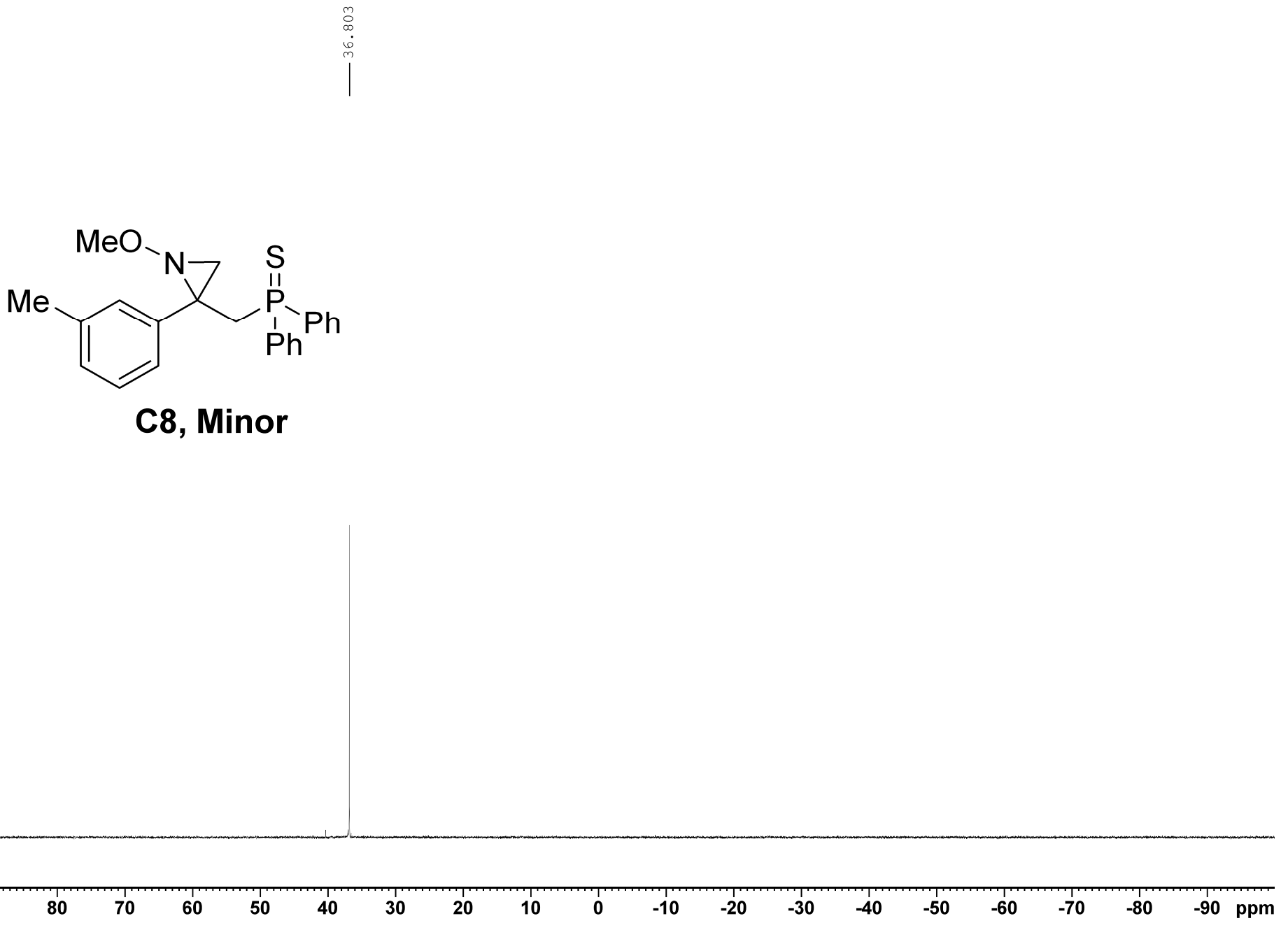


C8, Minor



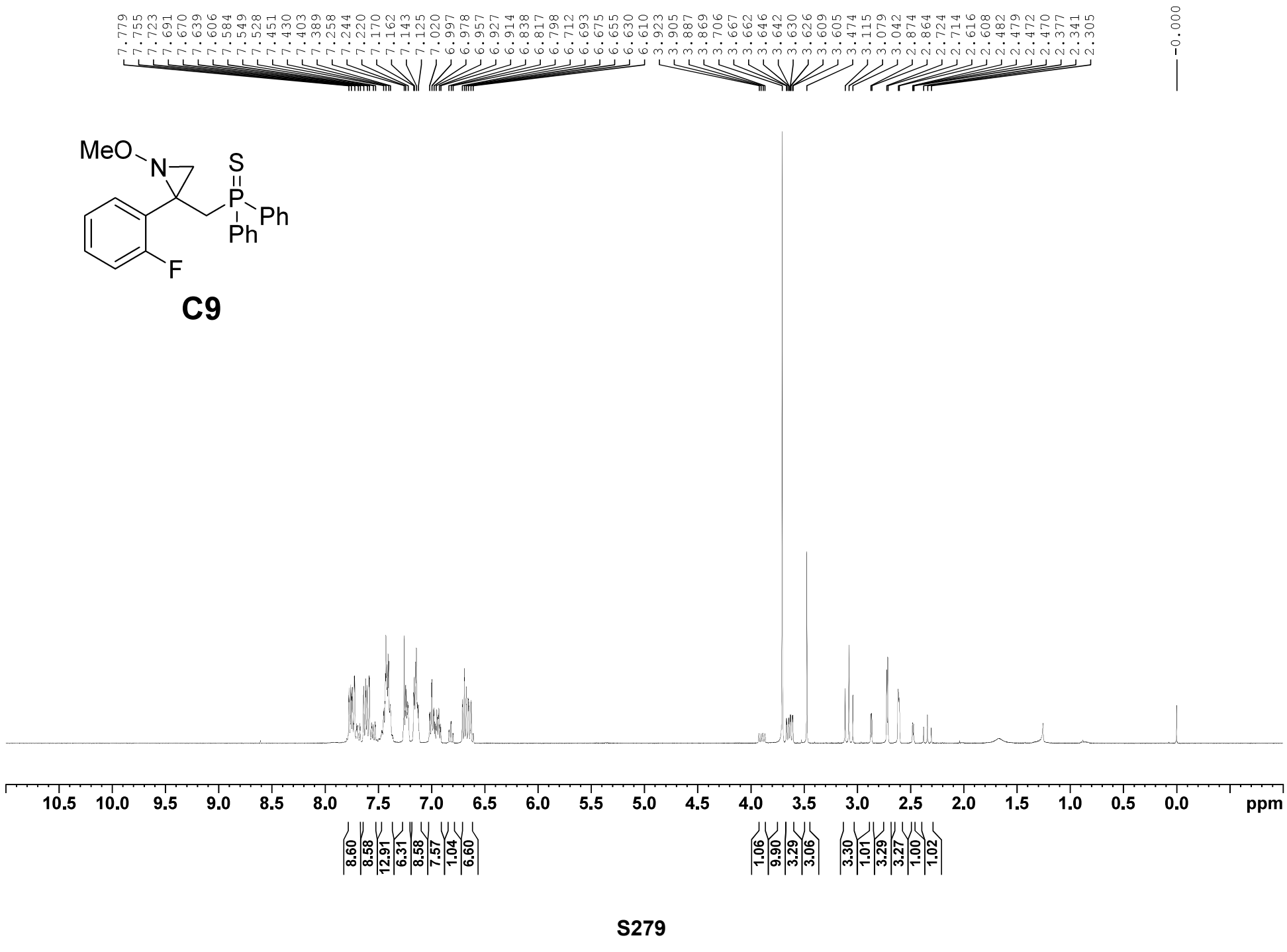


^{31}P NMR (162 MHz, $CDCl_3$)

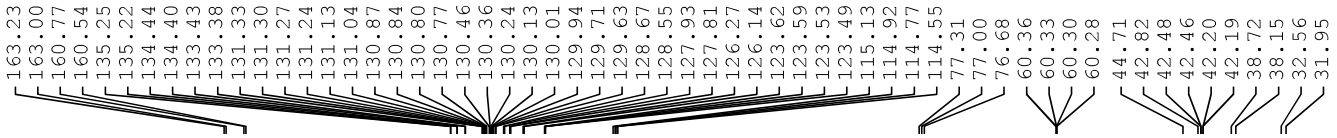


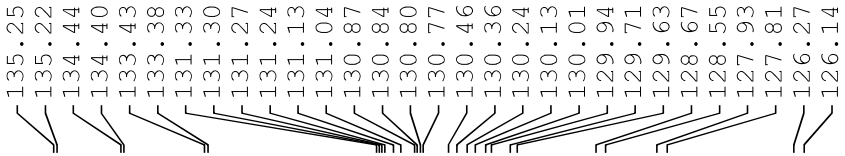
C8, Minor

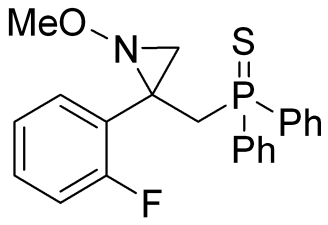
^{1}H NMR ($CDCl_3$, 400 MHz)



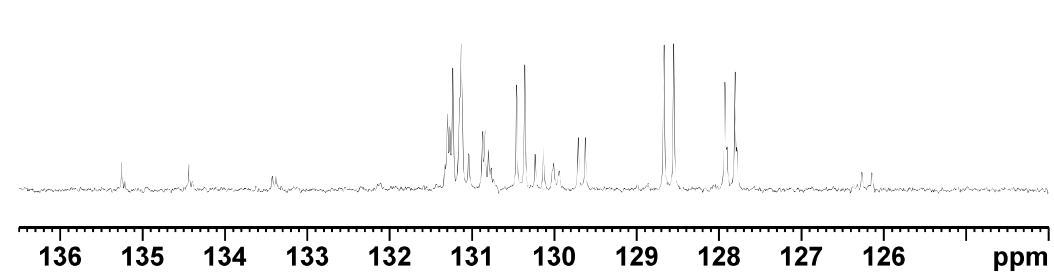
^{13}C NMR (100 MHz, $CDCl_3$)



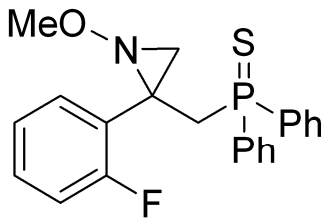




C9

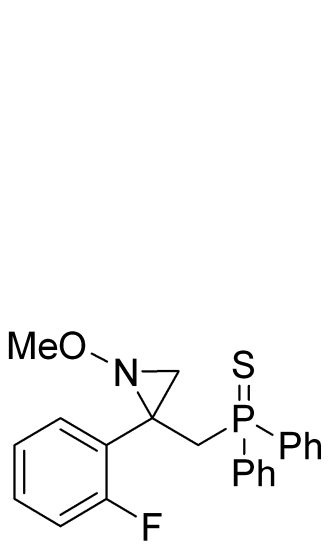


^{19}F NMR (376 MHz, $CDCl_3$)



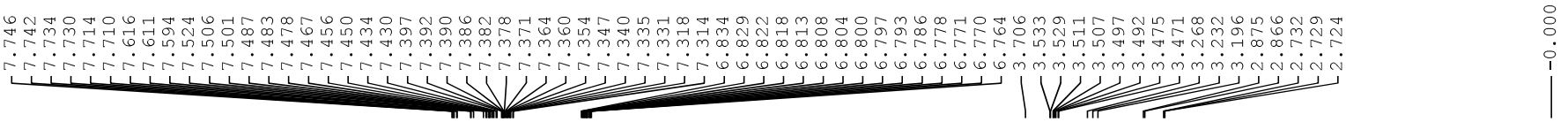
C9

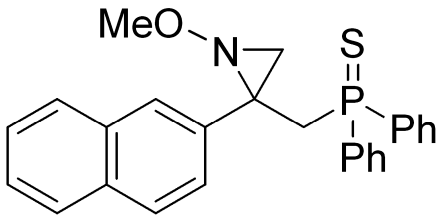
^{31}P NMR (162 MHz, $CDCl_3$)



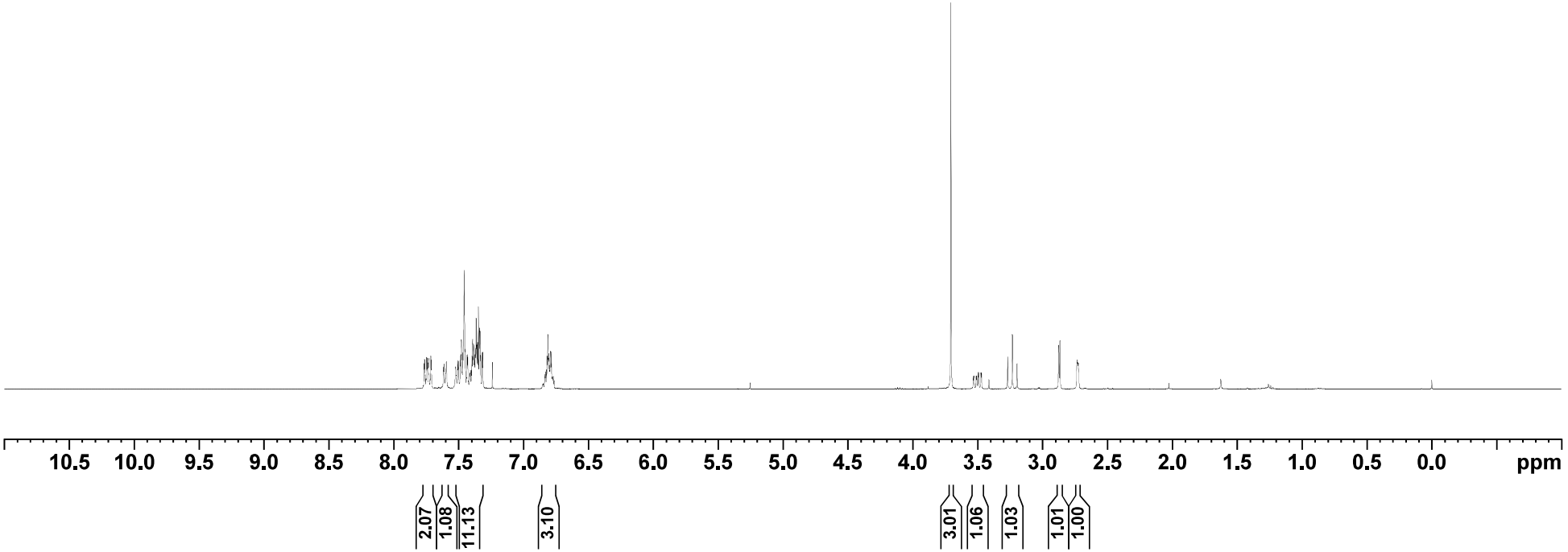
C9

^{1}H NMR ($CDCl_3$, 400 MHz)

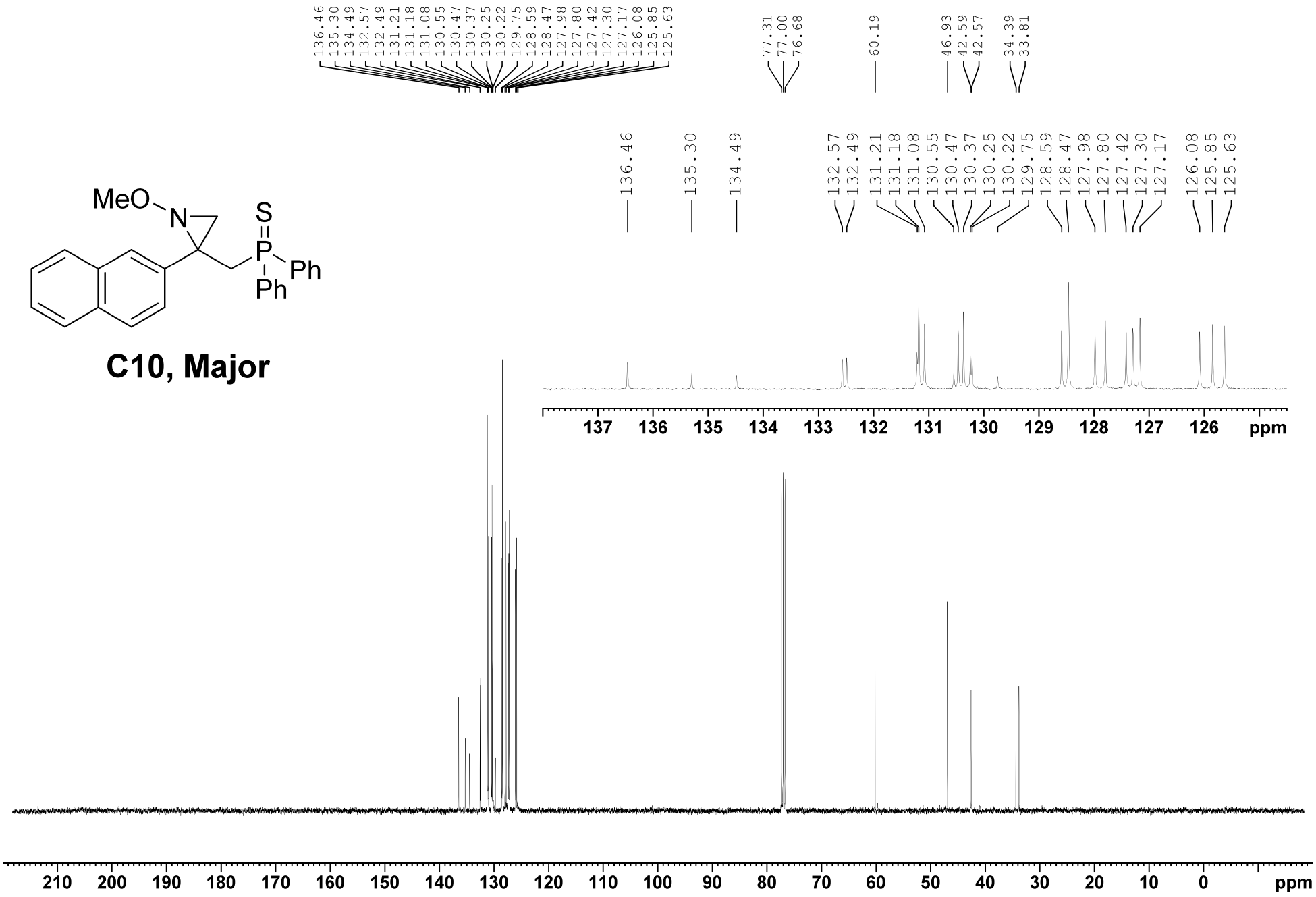




C10, Major

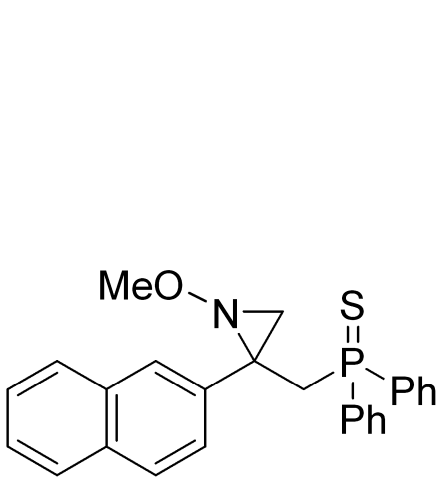


^{13}C NMR (100 MHz, $CDCl_3$)



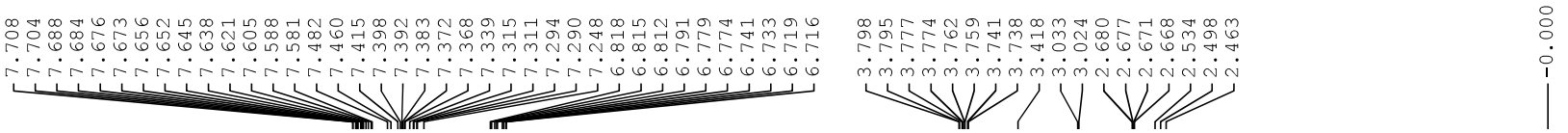
C10, Major

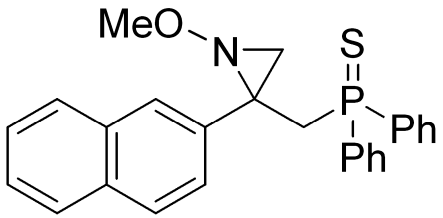
^{31}P NMR (162 MHz, $CDCl_3$)



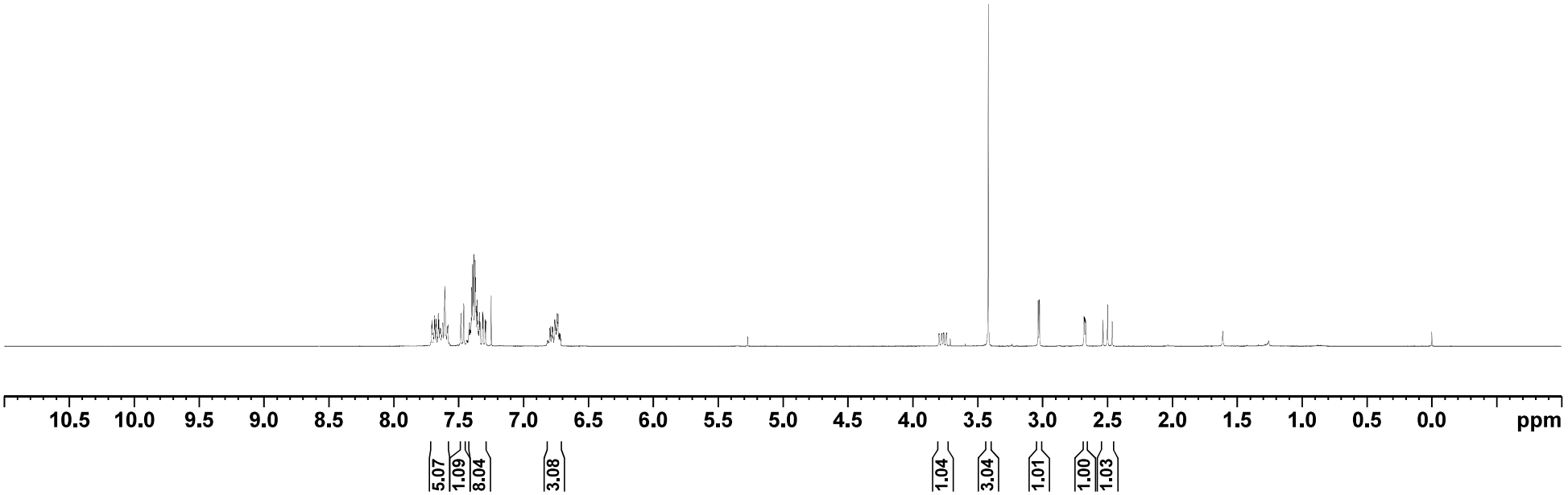
C10, Major

^{1}H NMR ($CDCl_3$, 400 MHz)

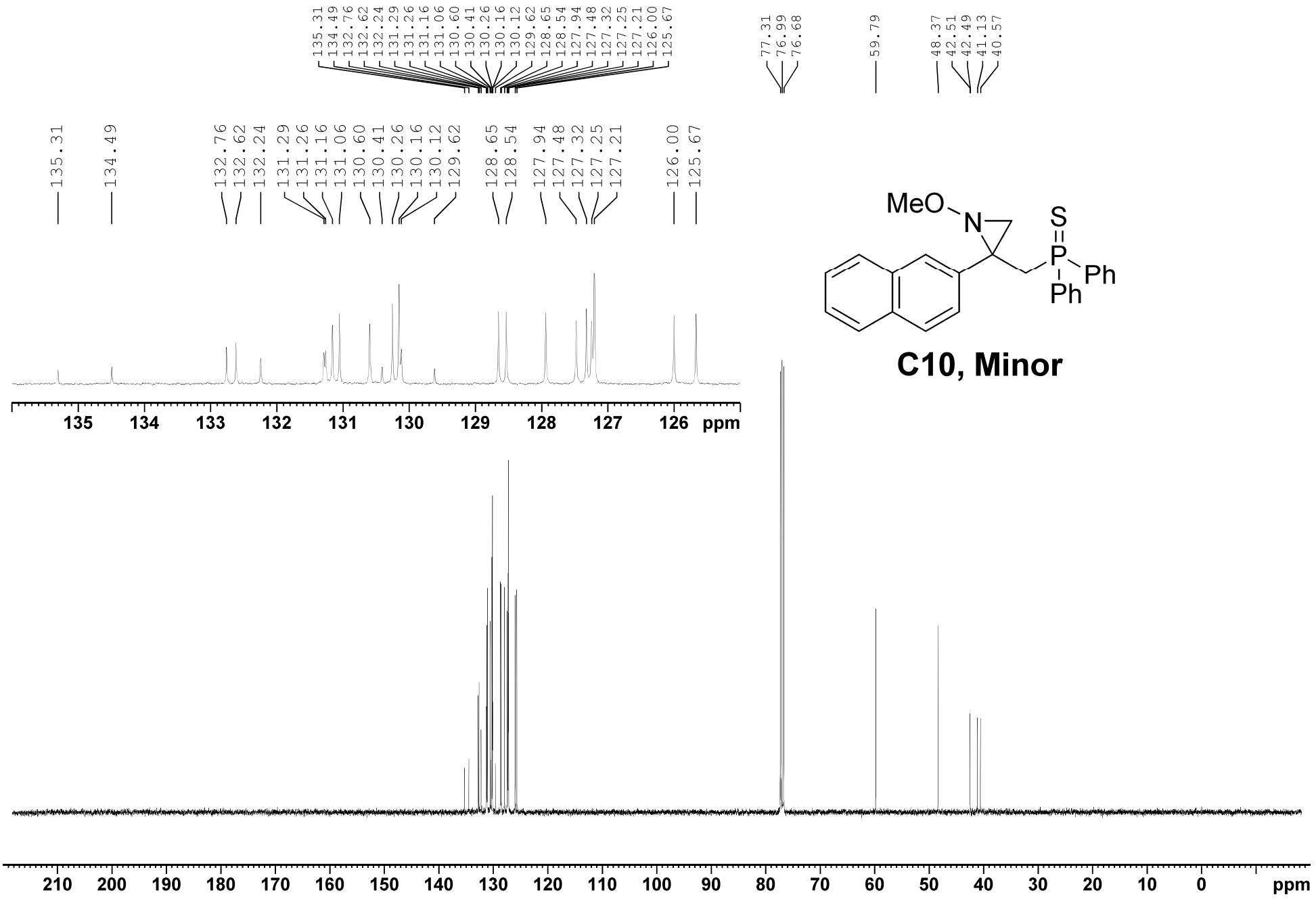




C10, Minor

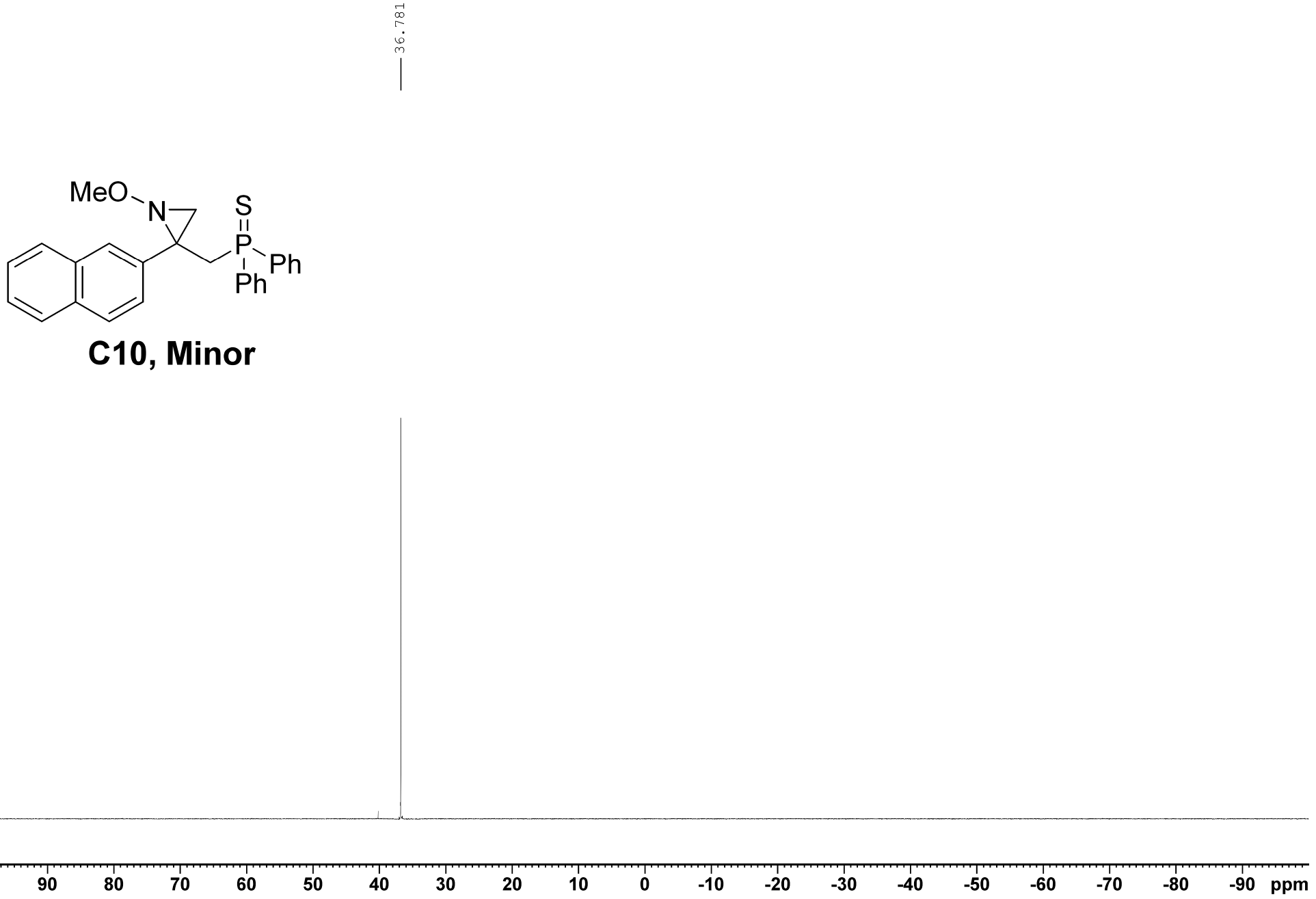


^{13}C NMR (100 MHz, $CDCl_3$)



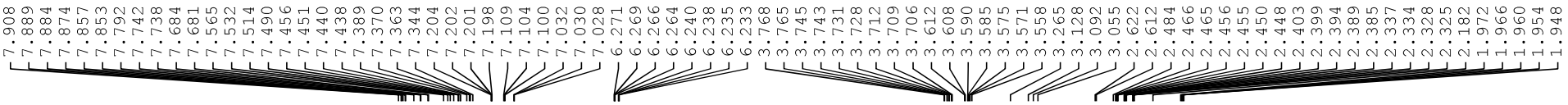
C10, Minor

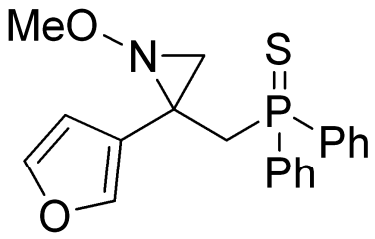
^{31}P NMR (162 MHz, $CDCl_3$)



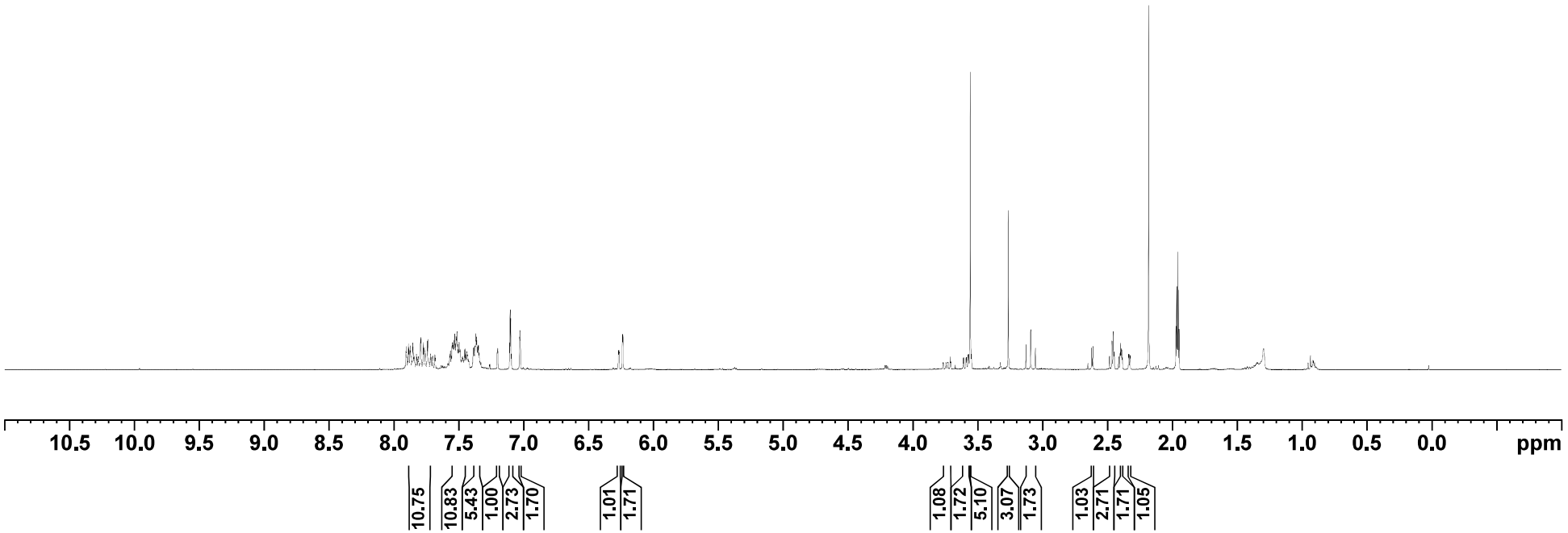
C10, Minor

^{1}H NMR ($CDCl_3$, 400 MHz)

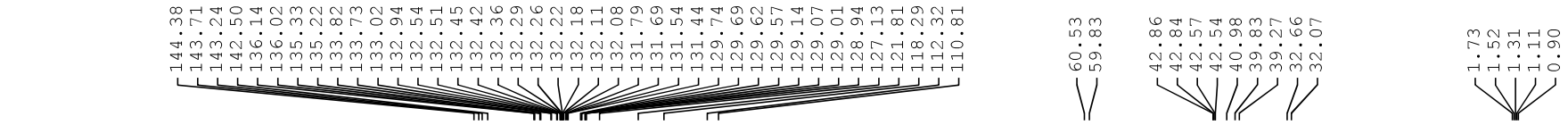


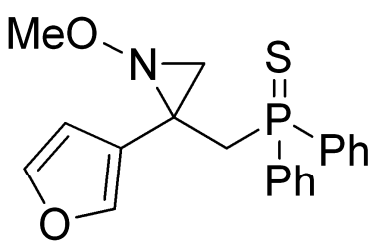


C11



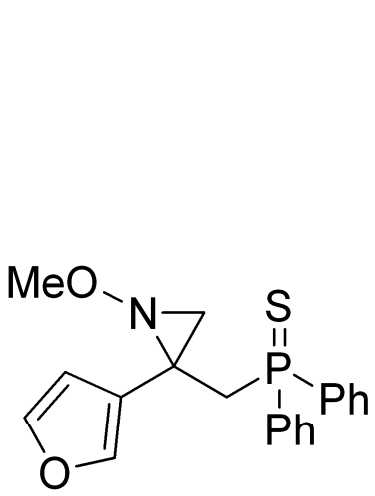
^{13}C NMR (100 MHz, $CDCl_3$)





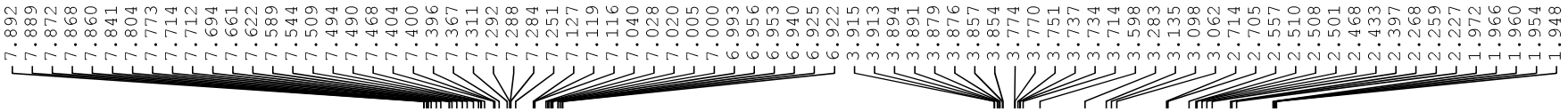
C11

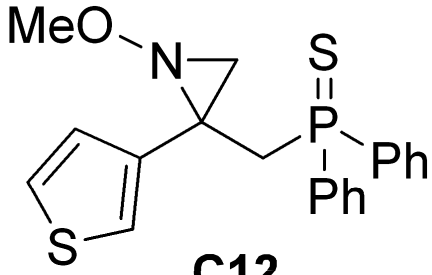
^{31}P NMR (162 MHz, $CDCl_3$)



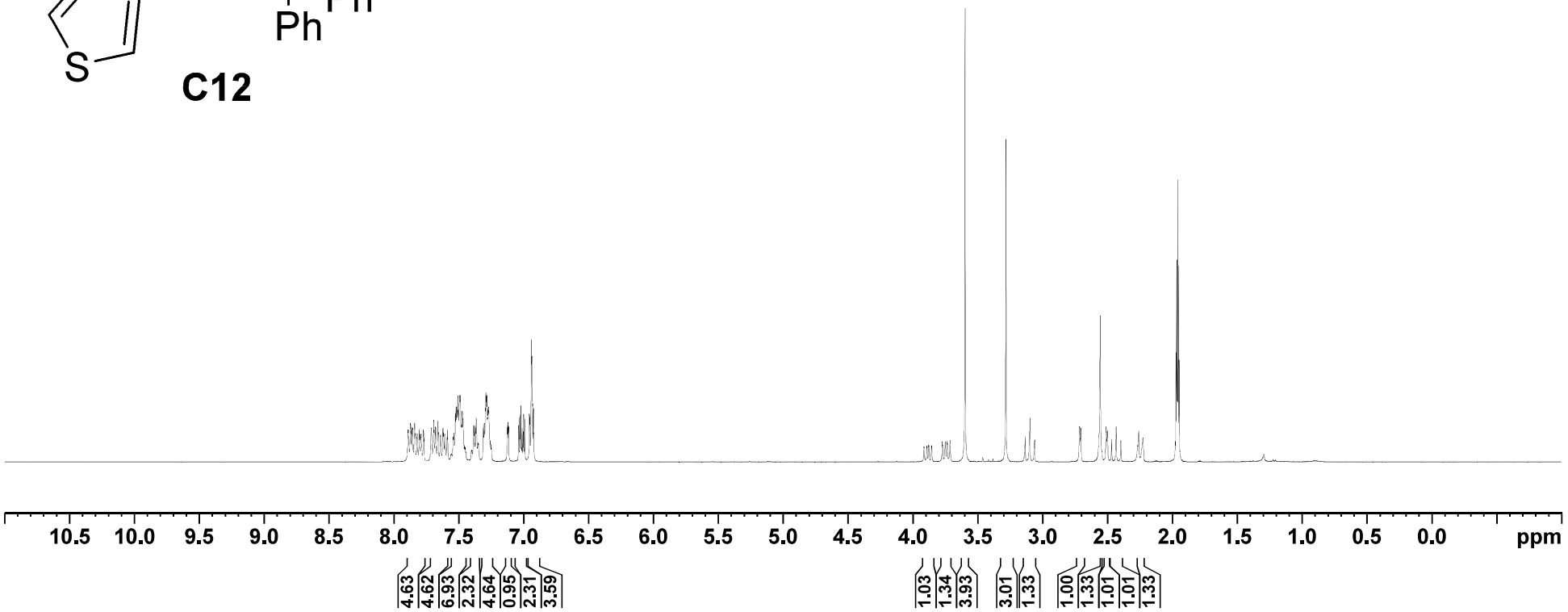
C11

^{1}H NMR ($CDCl_3$, 400 MHz)

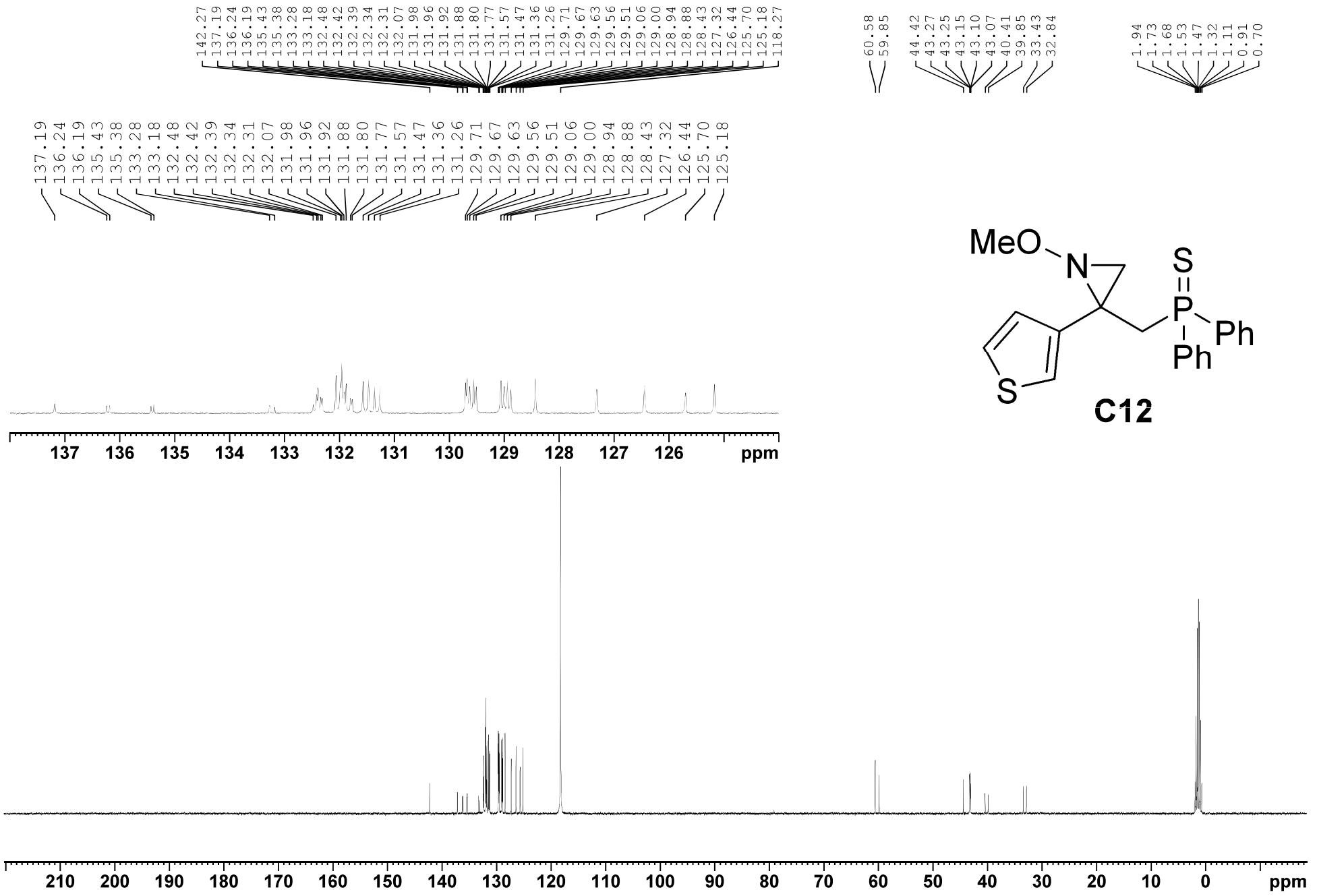




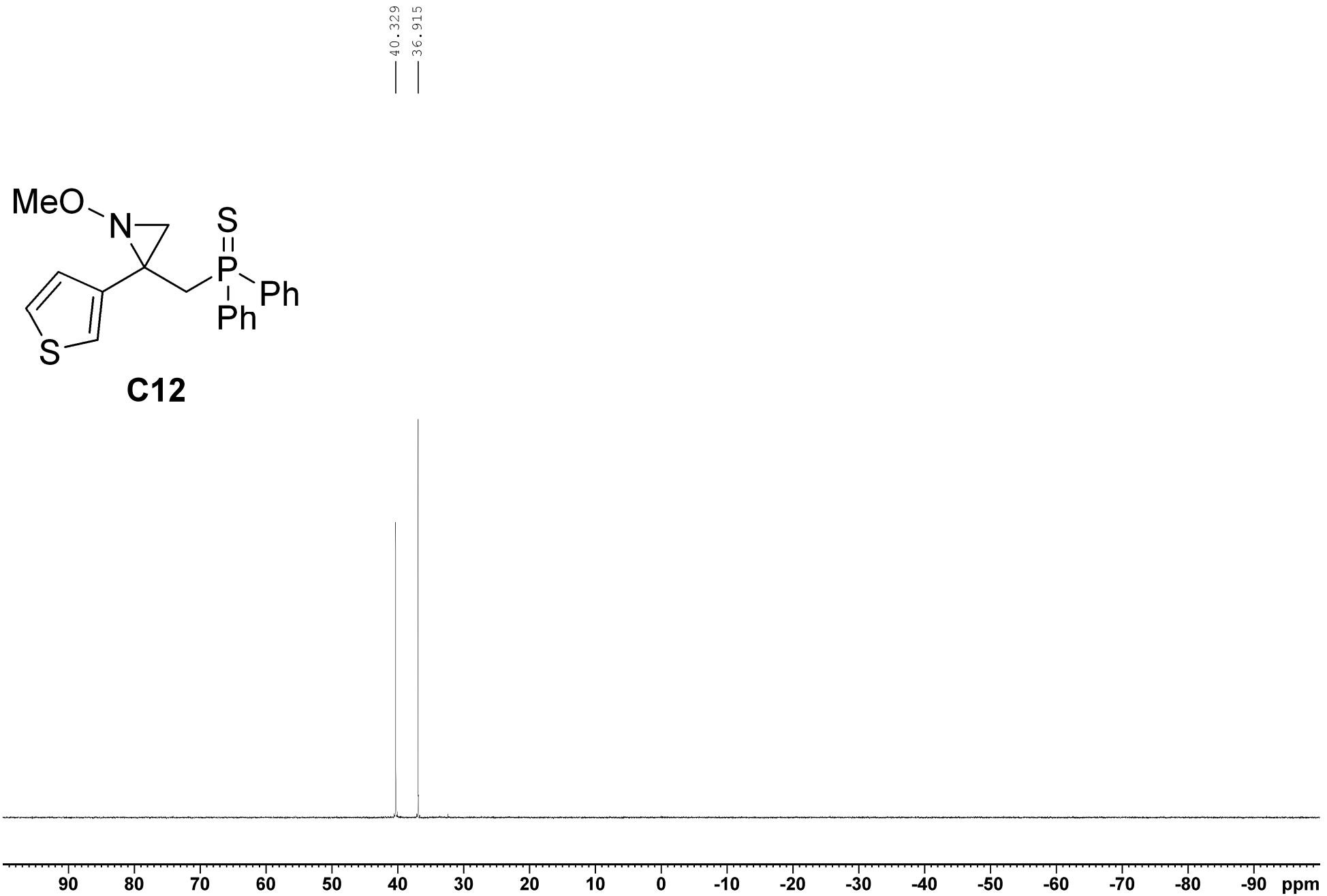
C12



^{13}C NMR (100 MHz, $CDCl_3$)

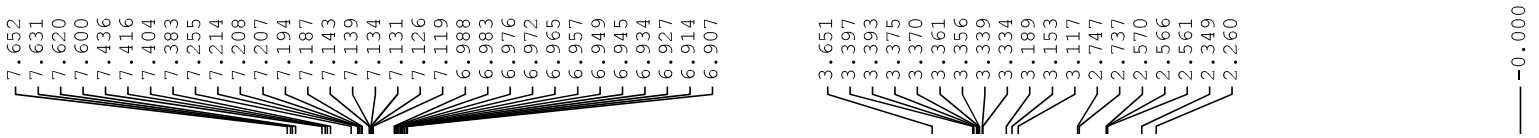


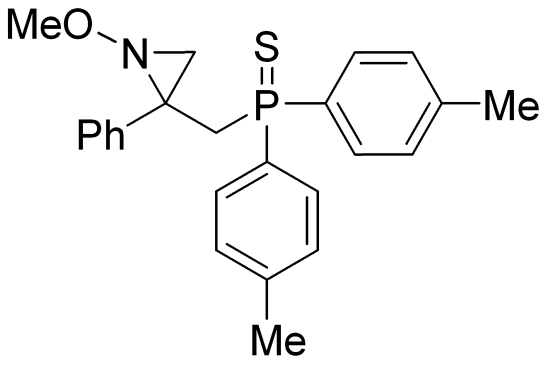
^{31}P NMR (162 MHz, $CDCl_3$)



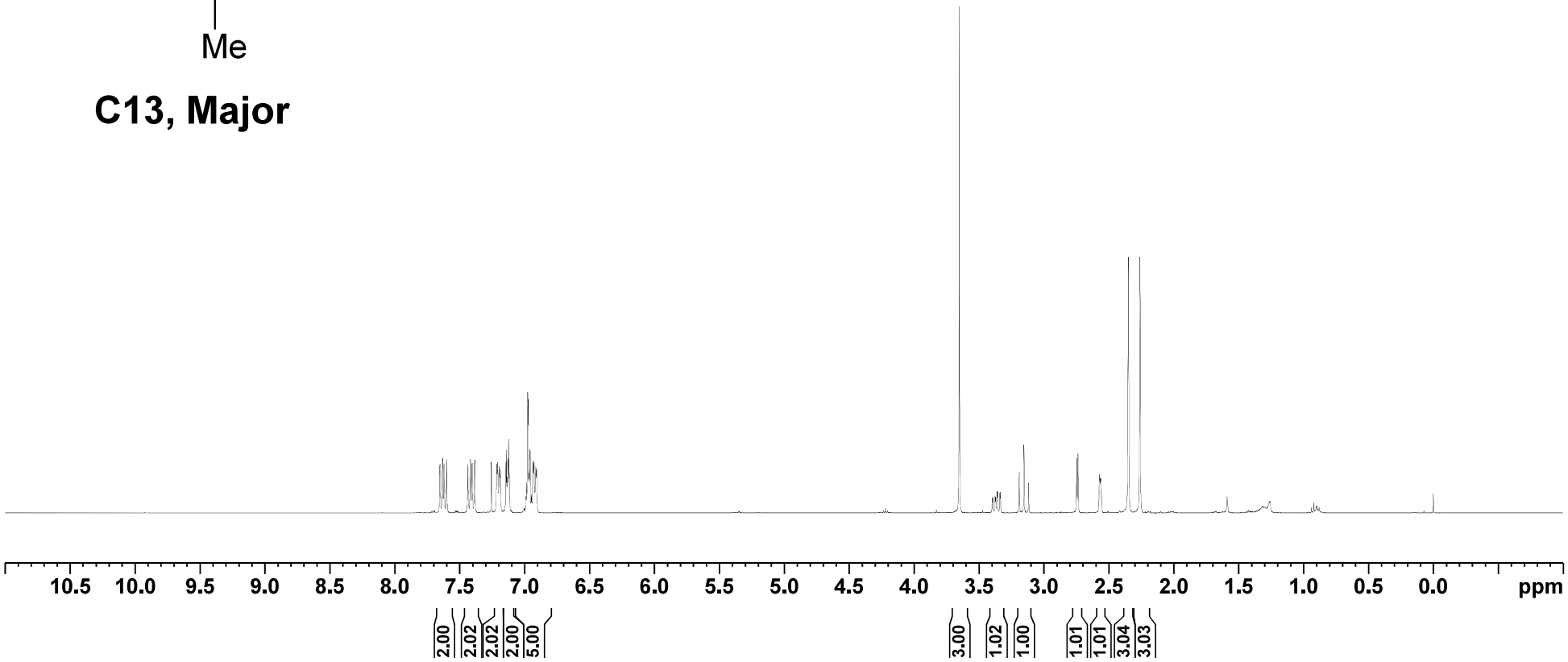
C12

^{1}H NMR ($CDCl_3$, 400 MHz)

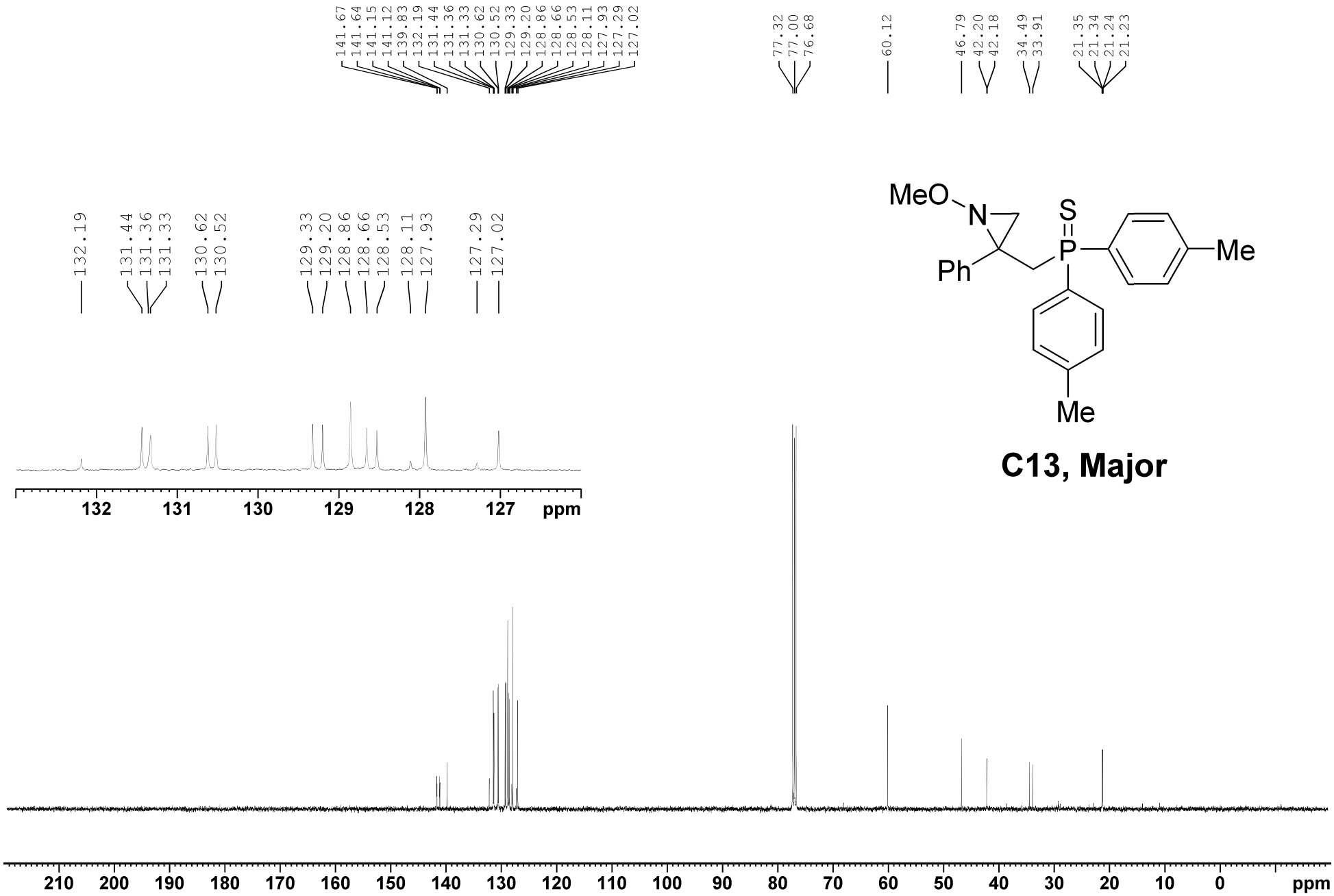




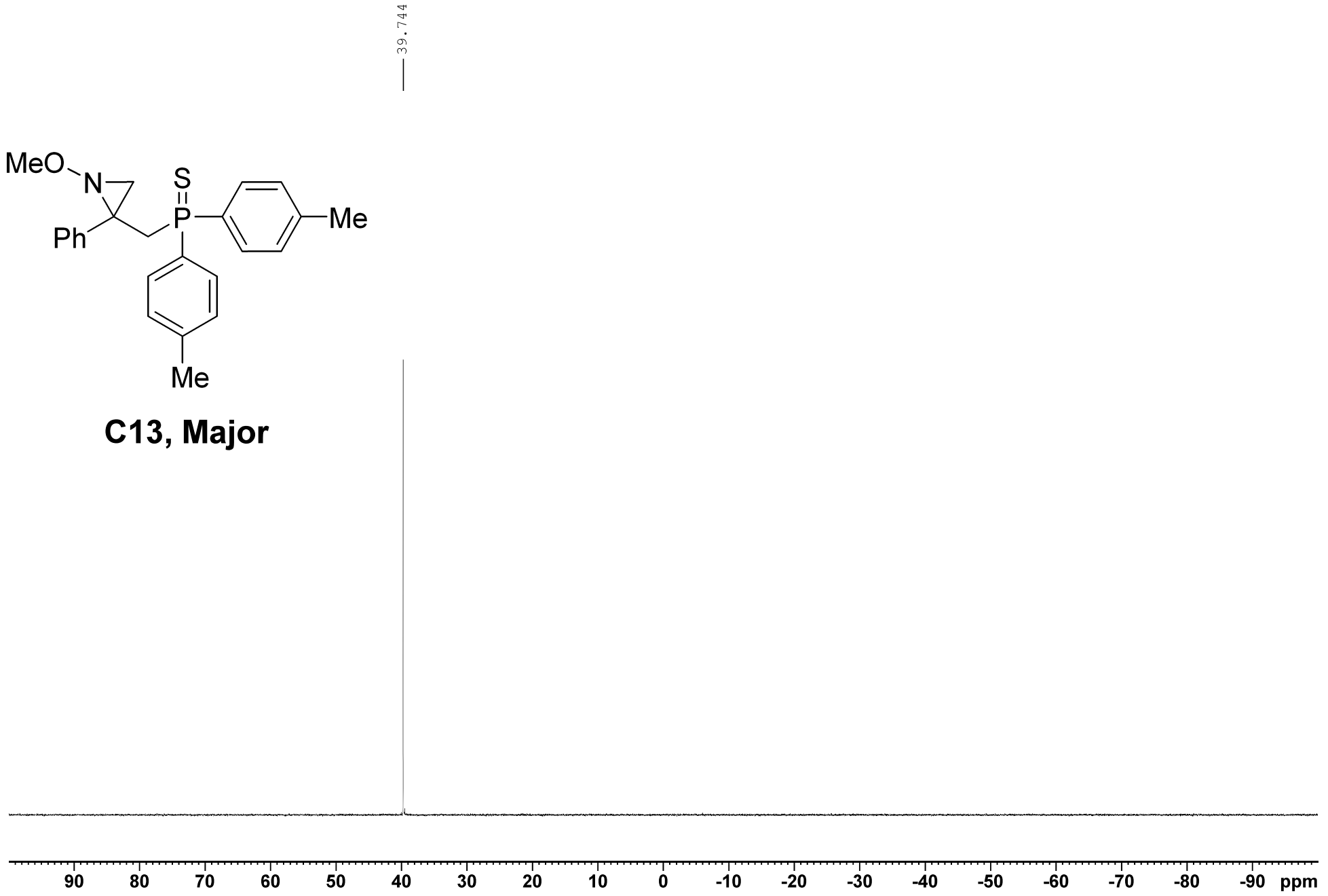
C13, Major



^{13}C NMR (100 MHz, $CDCl_3$)

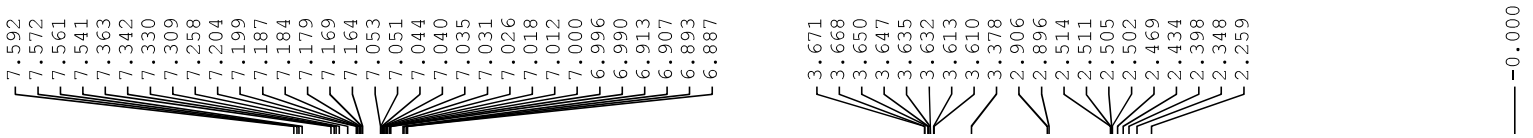


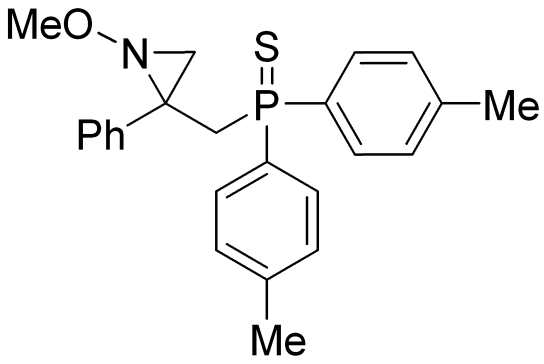
^{31}P NMR (162 MHz, $CDCl_3$)



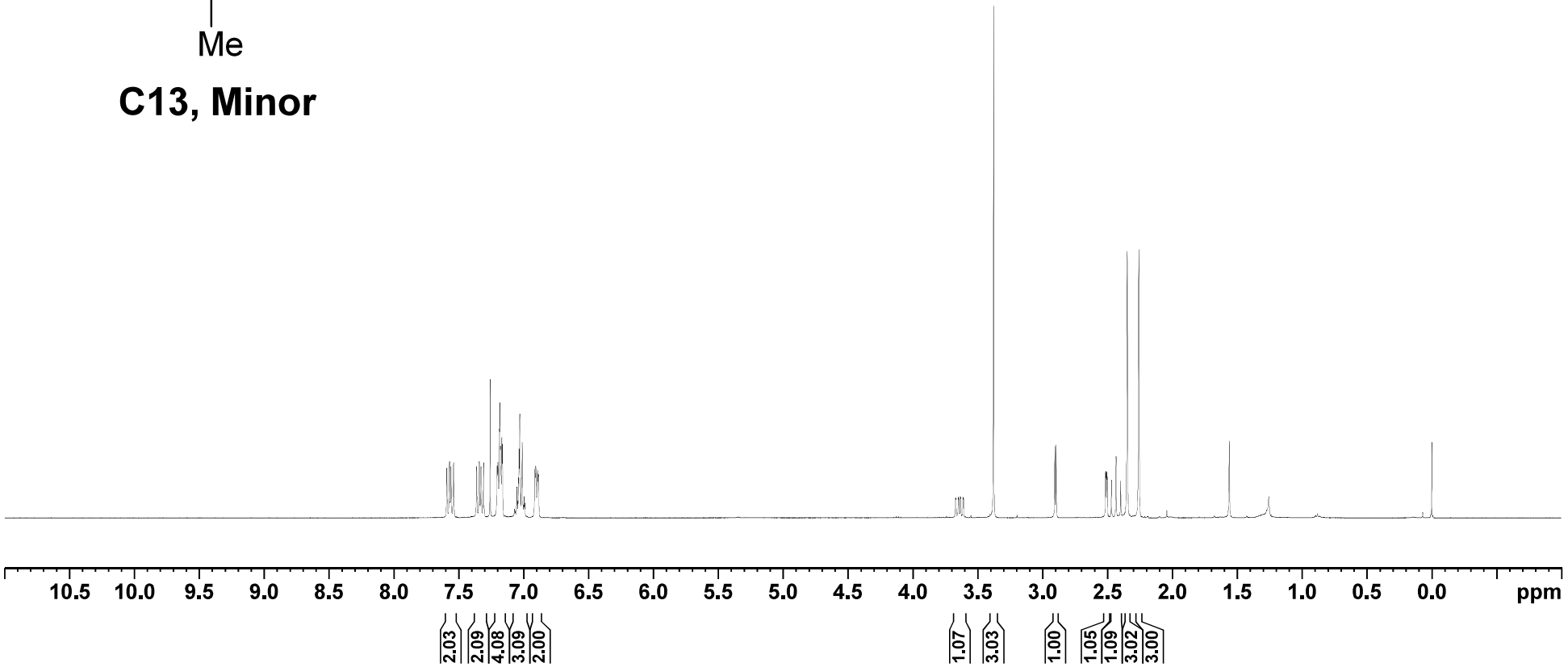
C13, Major

^{1}H NMR ($CDCl_3$, 400 MHz)

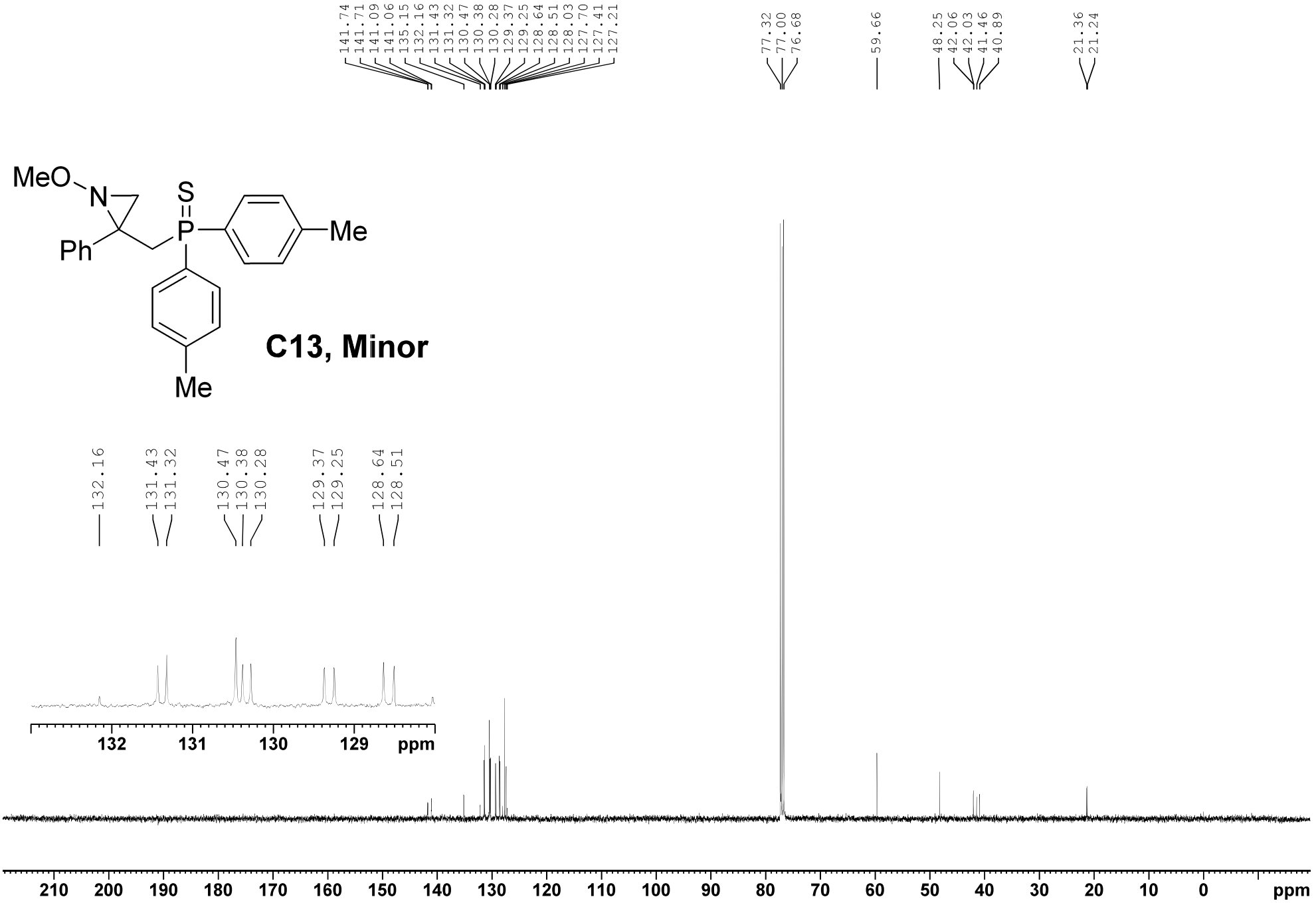




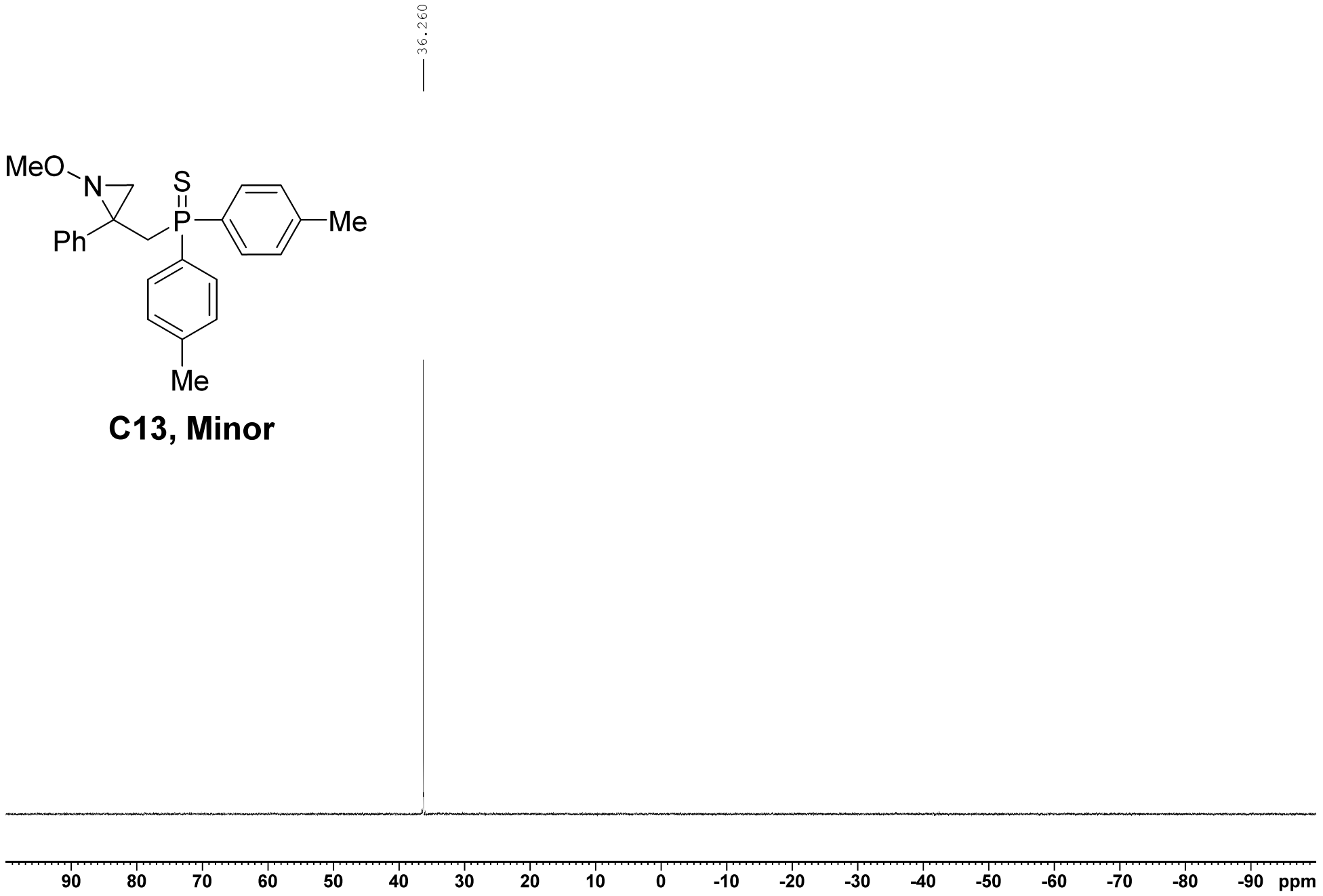
C13, Minor



^{13}C NMR (100 MHz, $CDCl_3$)

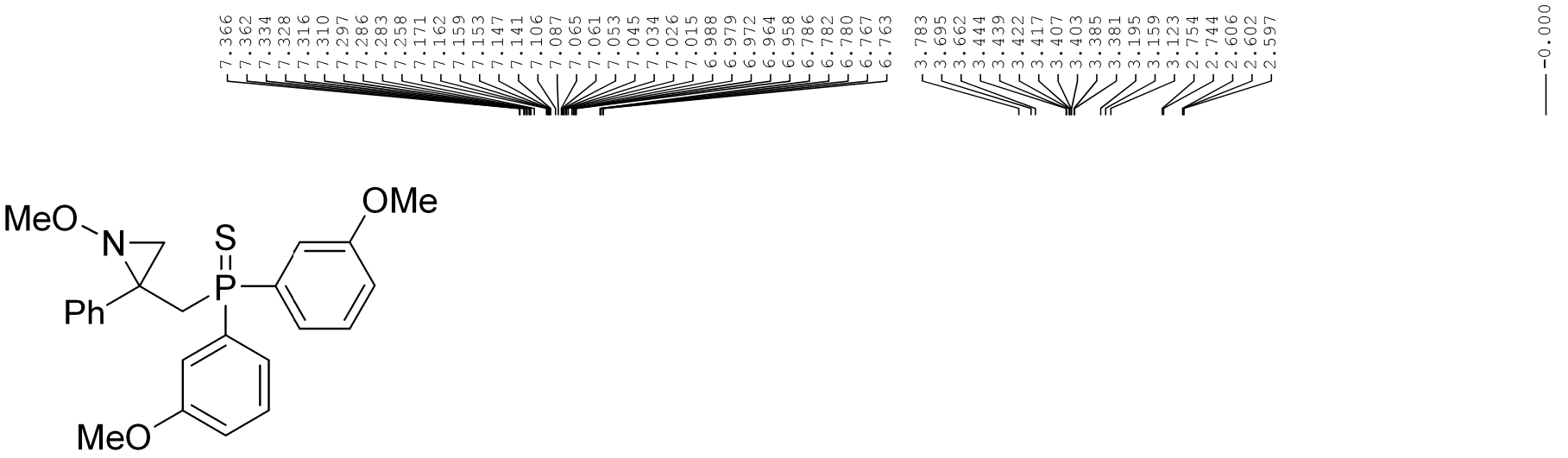


^{31}P NMR (162 MHz, $CDCl_3$)



C13, Minor

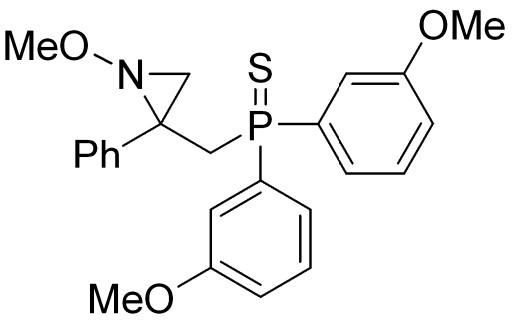
^{1}H NMR ($CDCl_3$, 400 MHz)



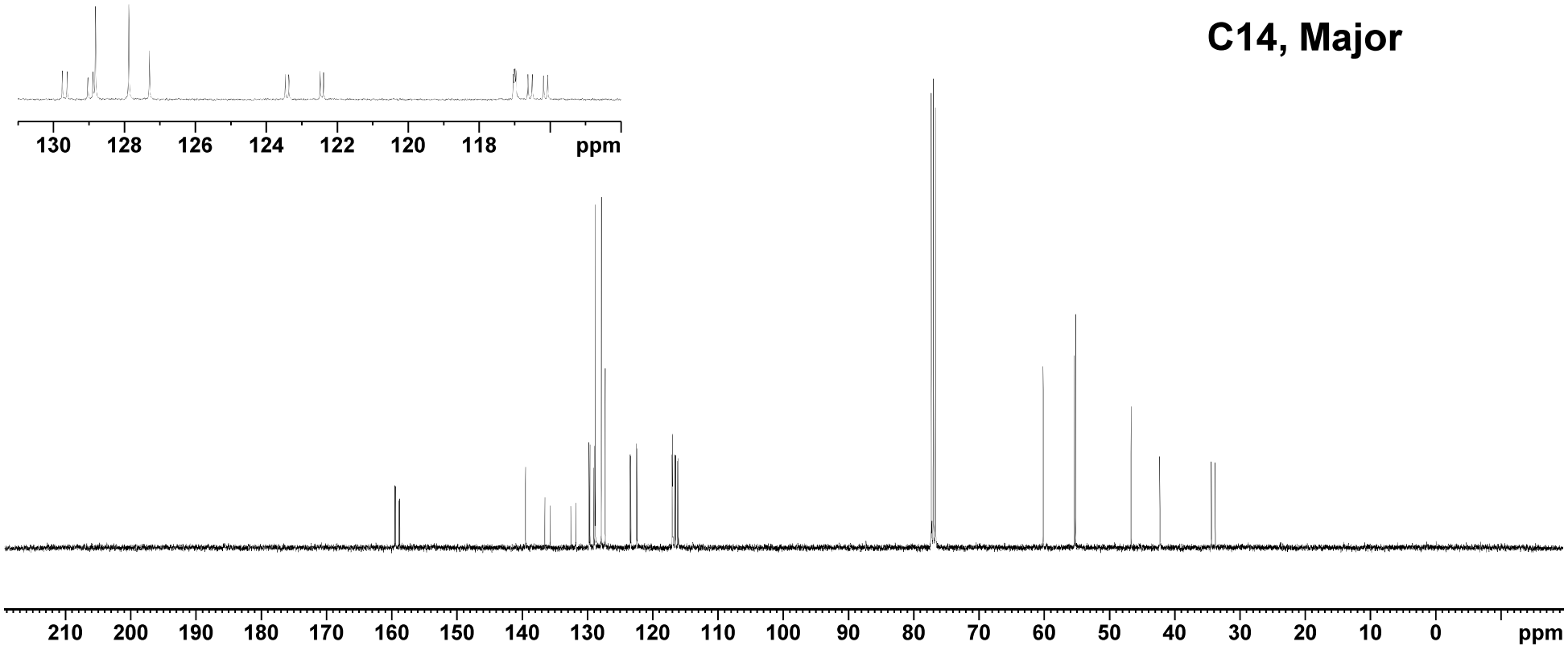
C14, Major

^{13}C NMR (100 MHz, $CDCl_3$)

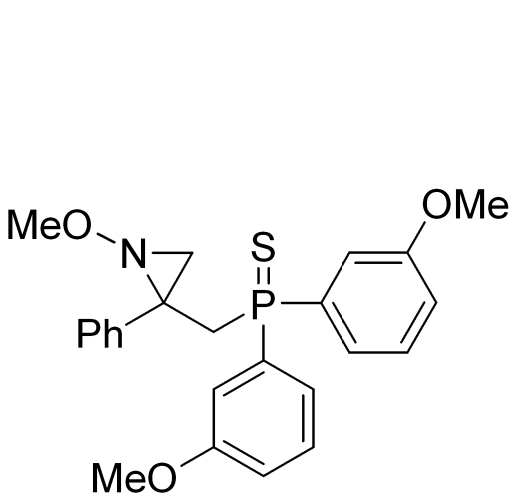
159.56
159.41
158.94
158.79
139.51
136.54
135.73
132.57
131.78
129.76
129.62
129.03
128.89
128.82
127.88
127.30
123.46
123.37
122.49
122.39
117.04
117.01
116.99
116.96
116.63
116.51
116.19
116.07
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77.00
76.68
60.16
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46.68
42.30
42.28
34.37
33.79



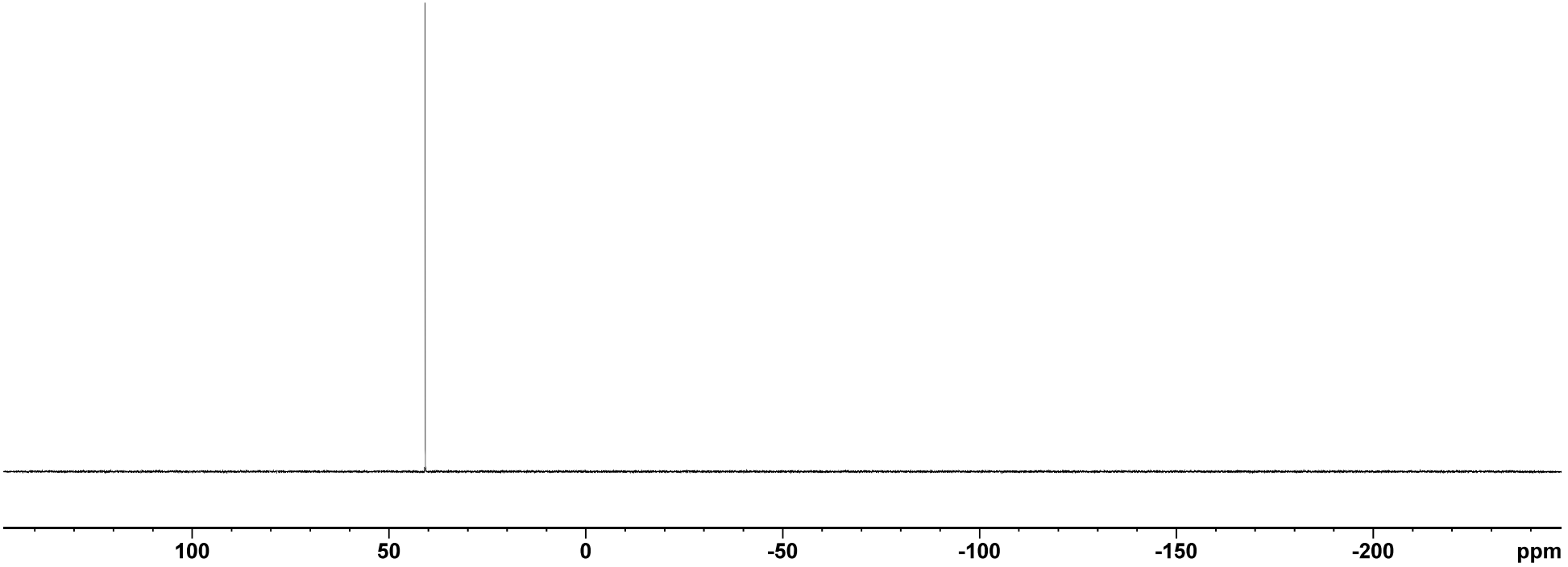
C14, Major



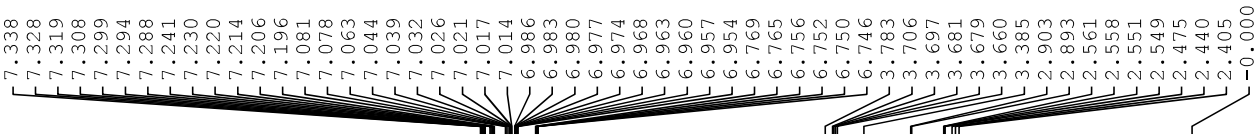
^{31}P NMR (162 MHz, $CDCl_3$)

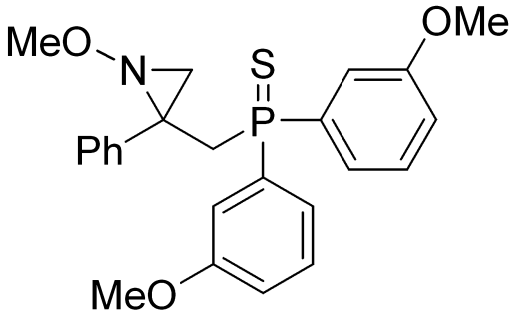


C14, Major

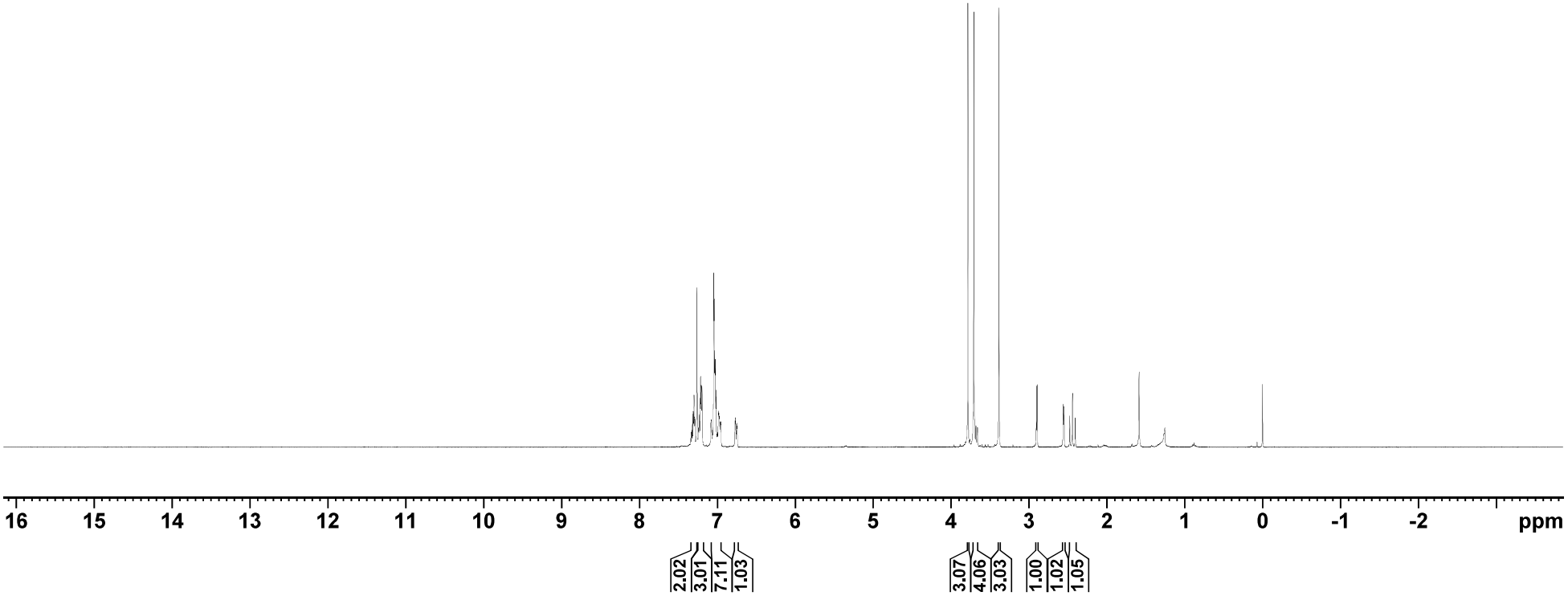


^{1}H NMR ($CDCl_3$, 400 MHz)

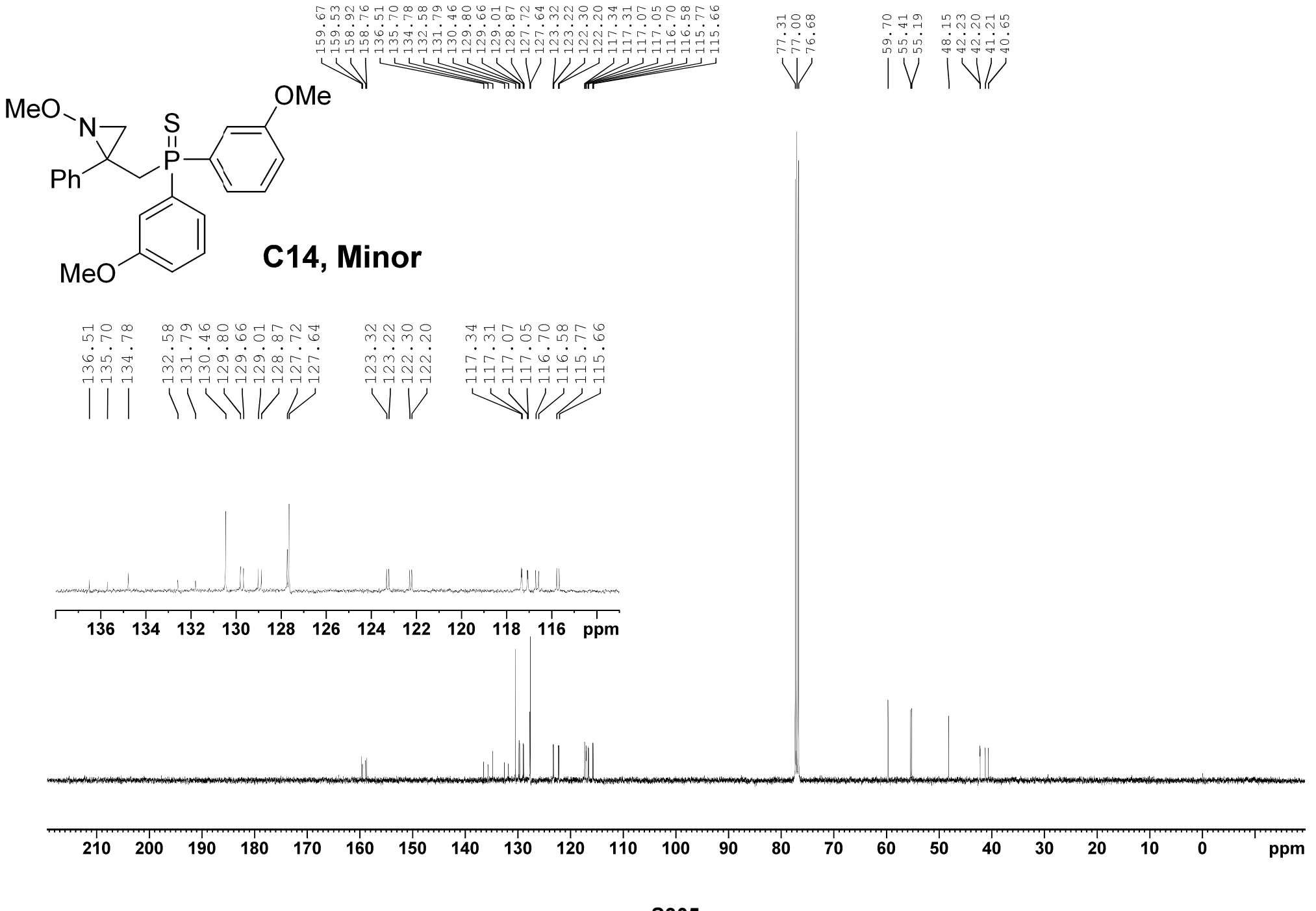




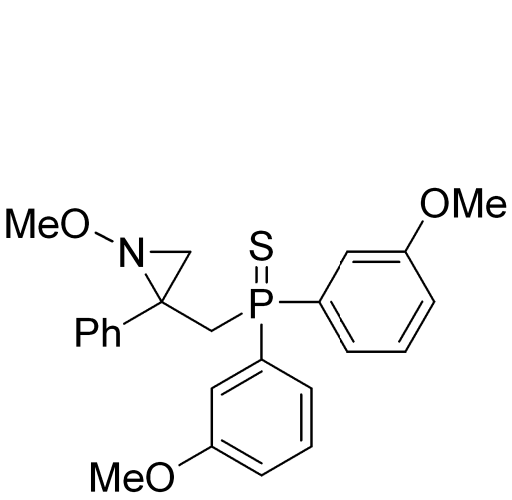
C14, Minor



^{13}C NMR (100 MHz, $CDCl_3$)

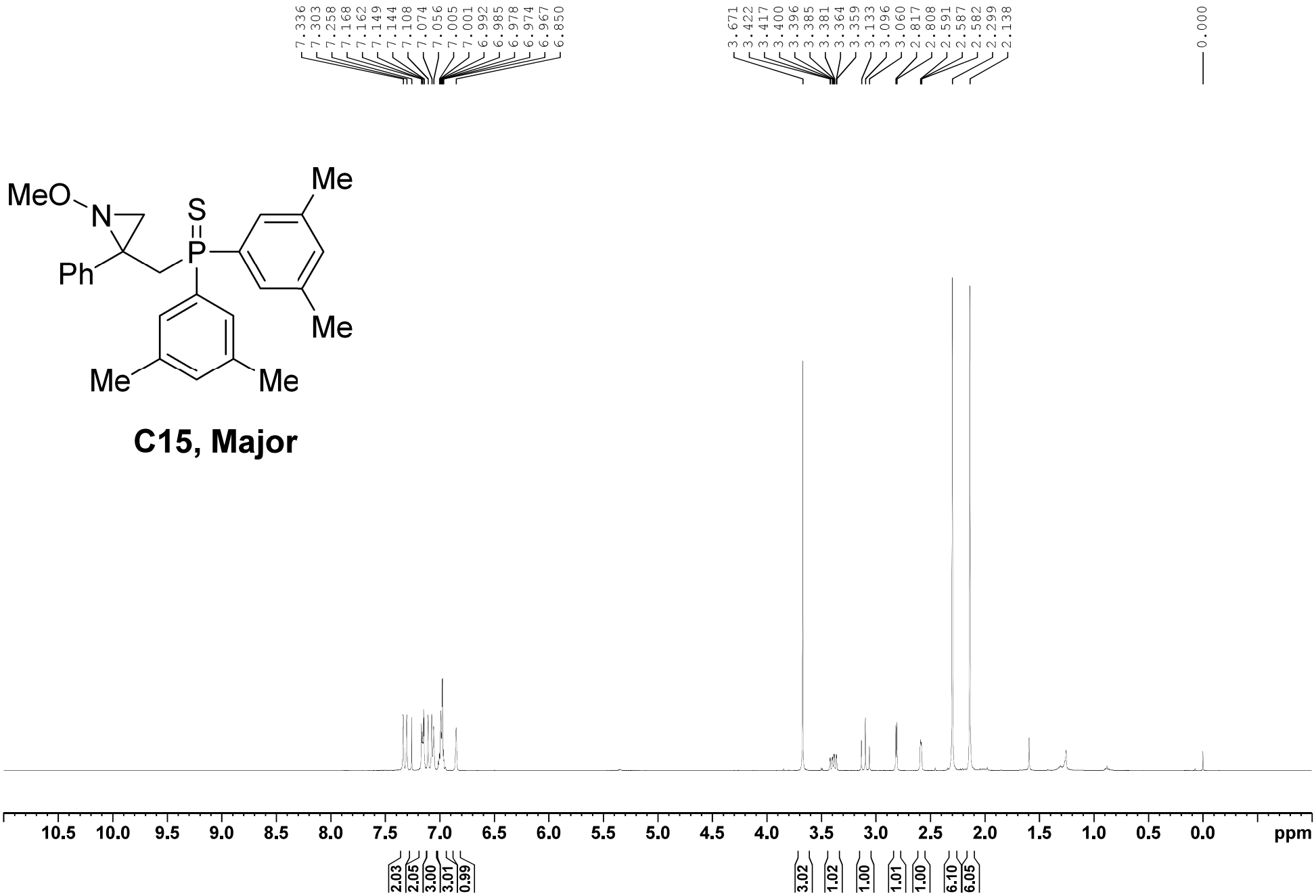


^{31}P NMR (162 MHz, $CDCl_3$)



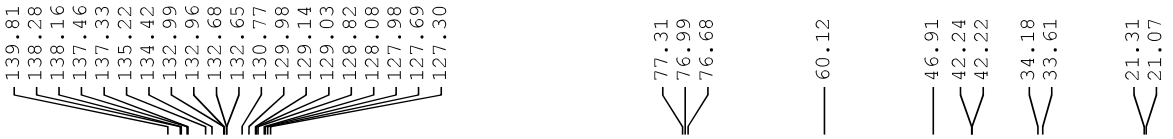
C14, Minor

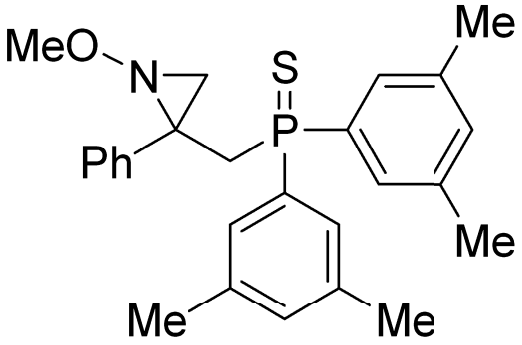
^{1}H NMR ($CDCl_3$, 400 MHz)



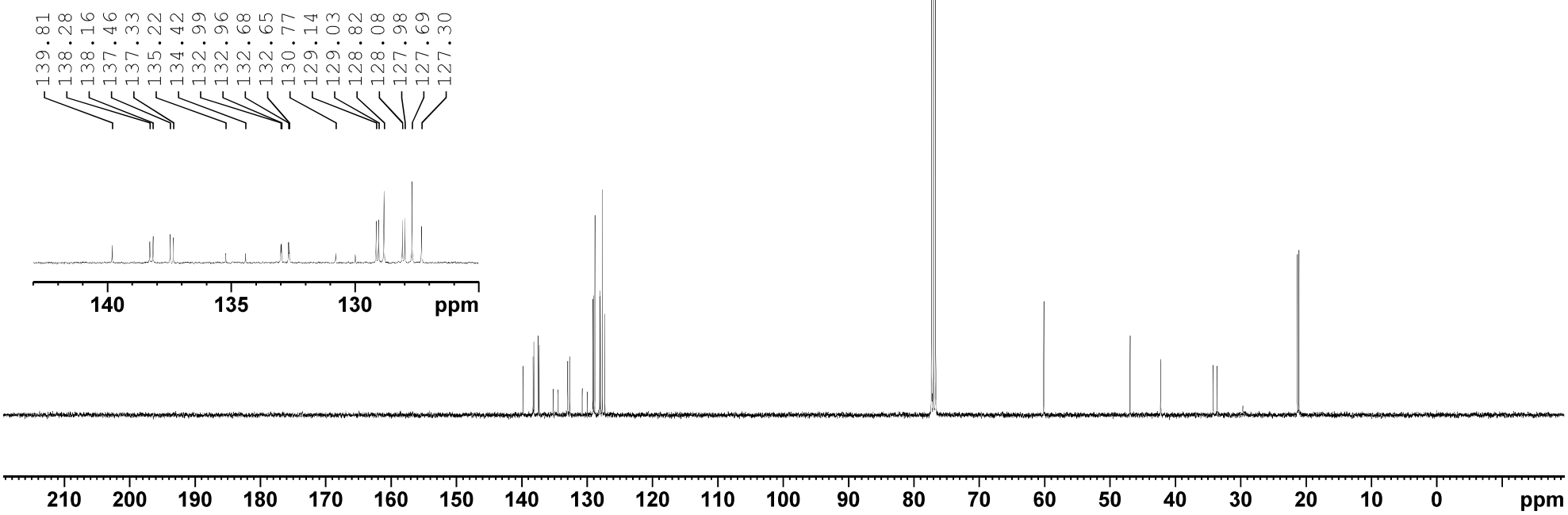
C15, Major

^{13}C NMR (100 MHz, $CDCl_3$)

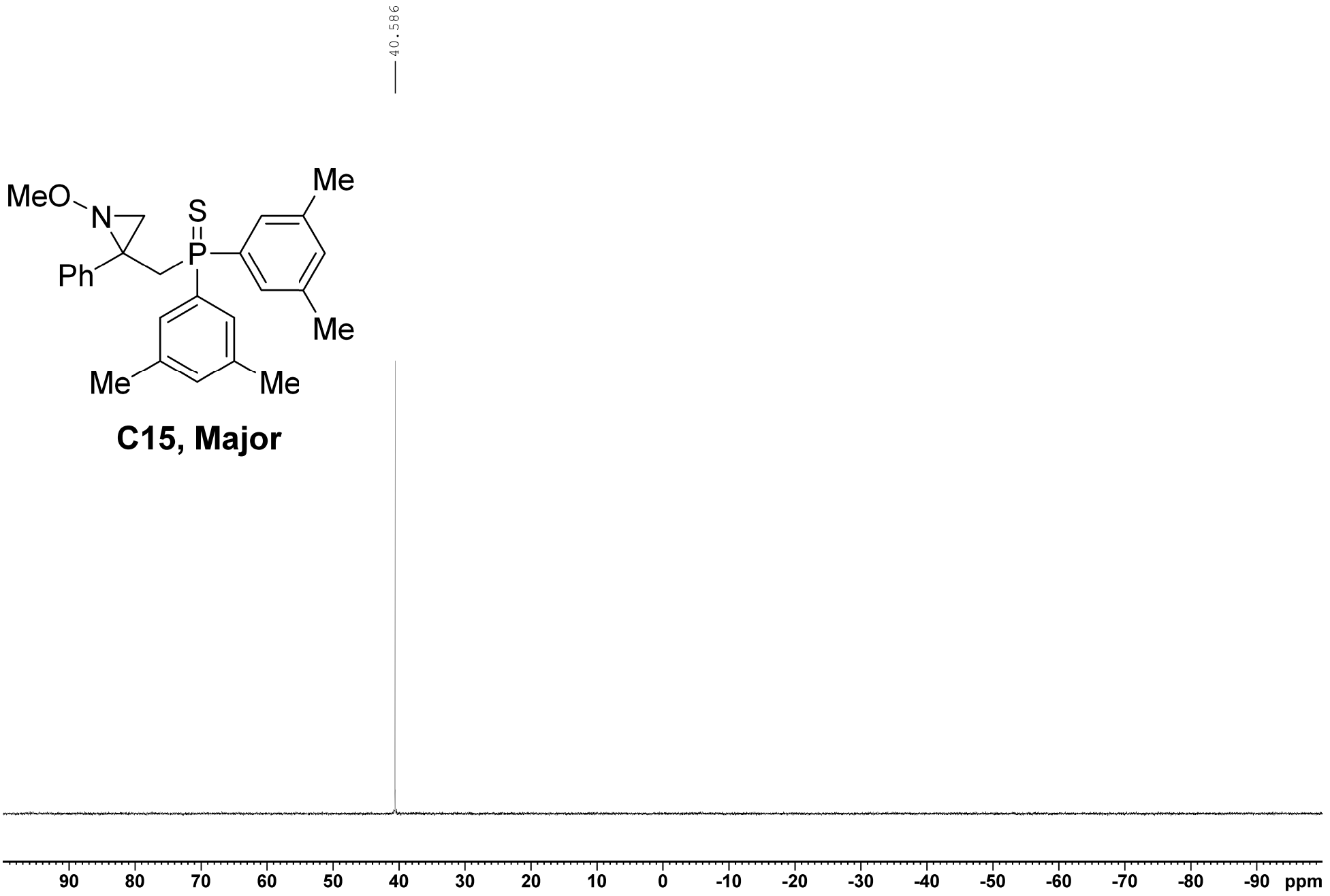




C15, Major

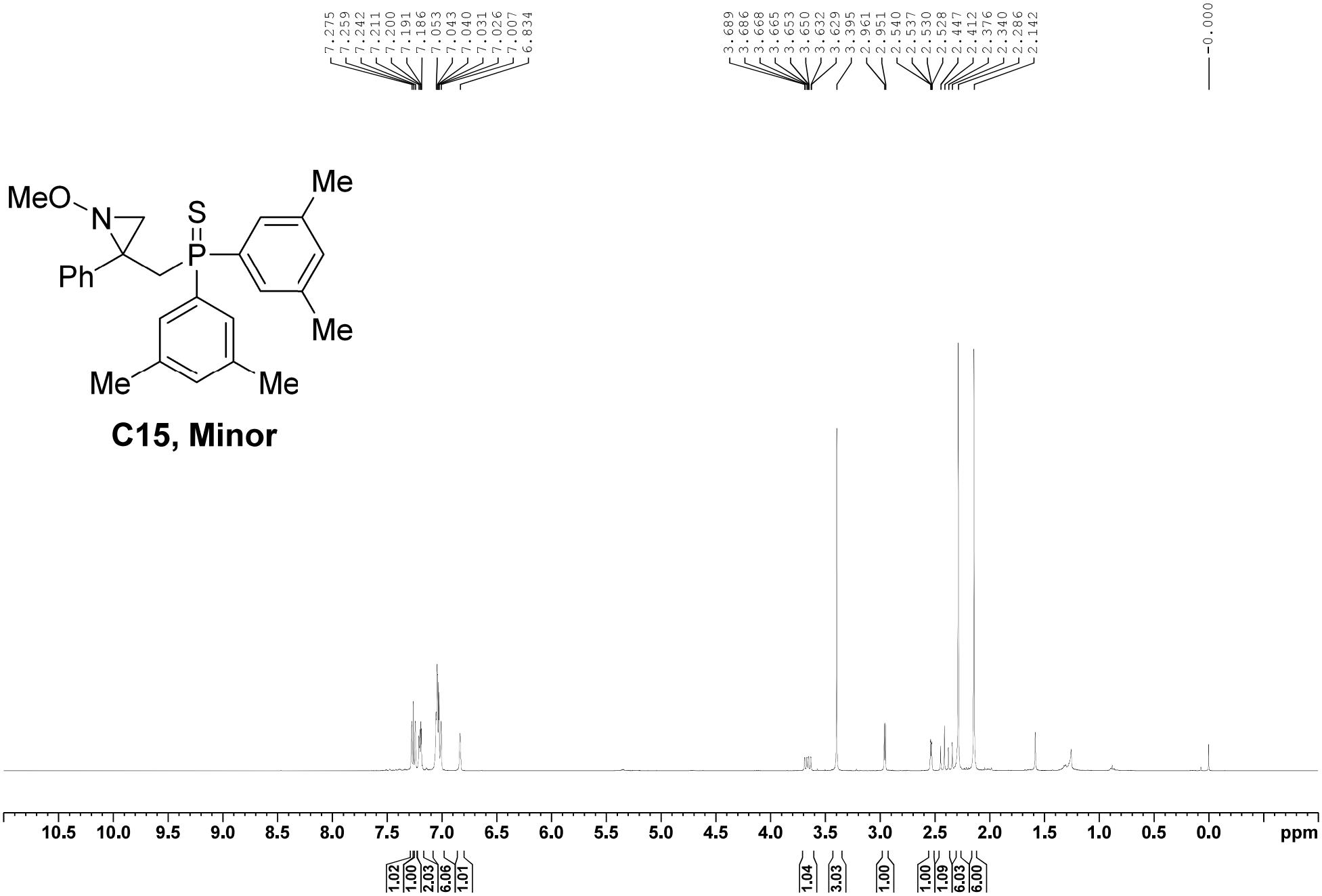


^{31}P NMR (162 MHz, $CDCl_3$)



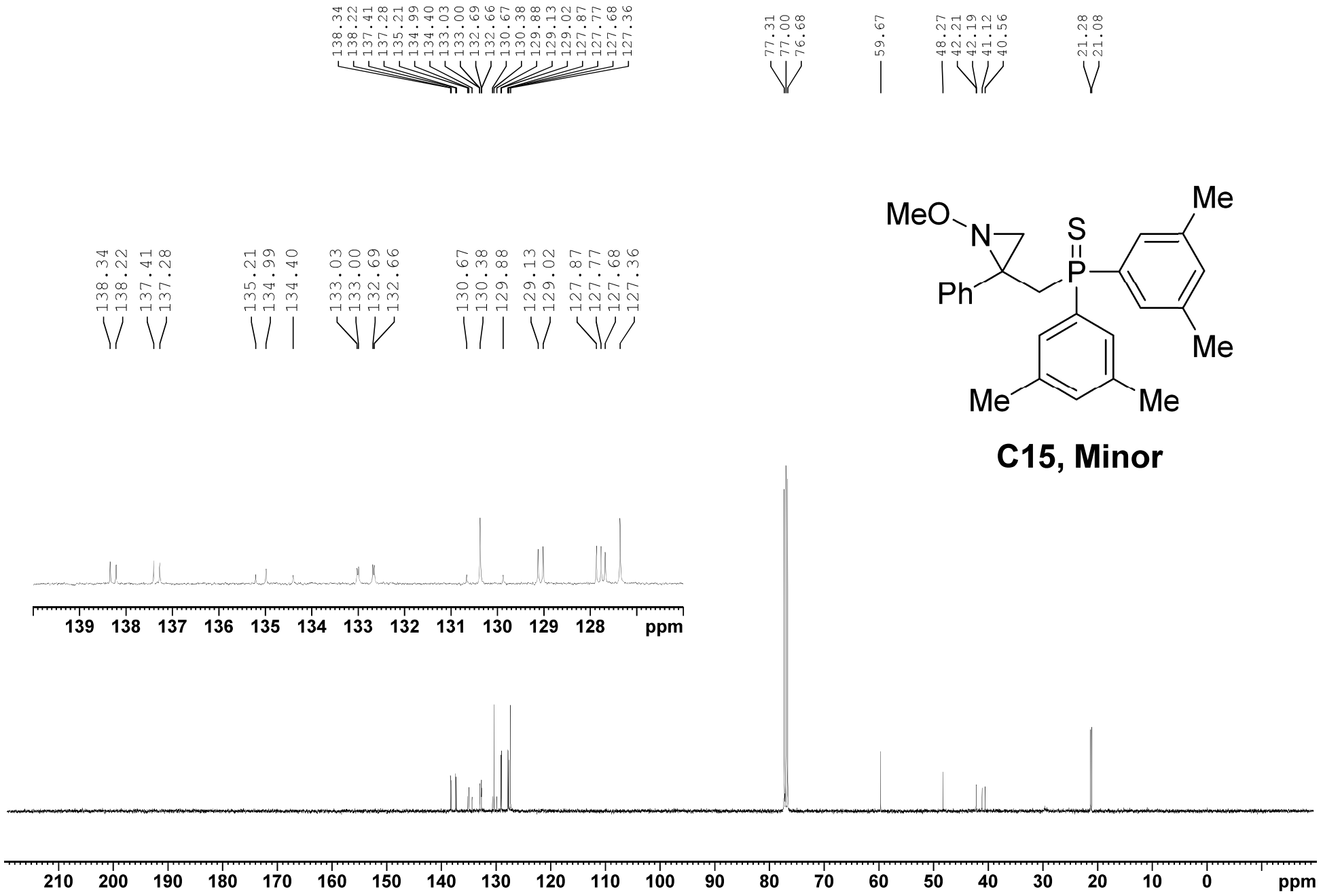
C15, Major

^{1}H NMR ($CDCl_3$, 400 MHz)



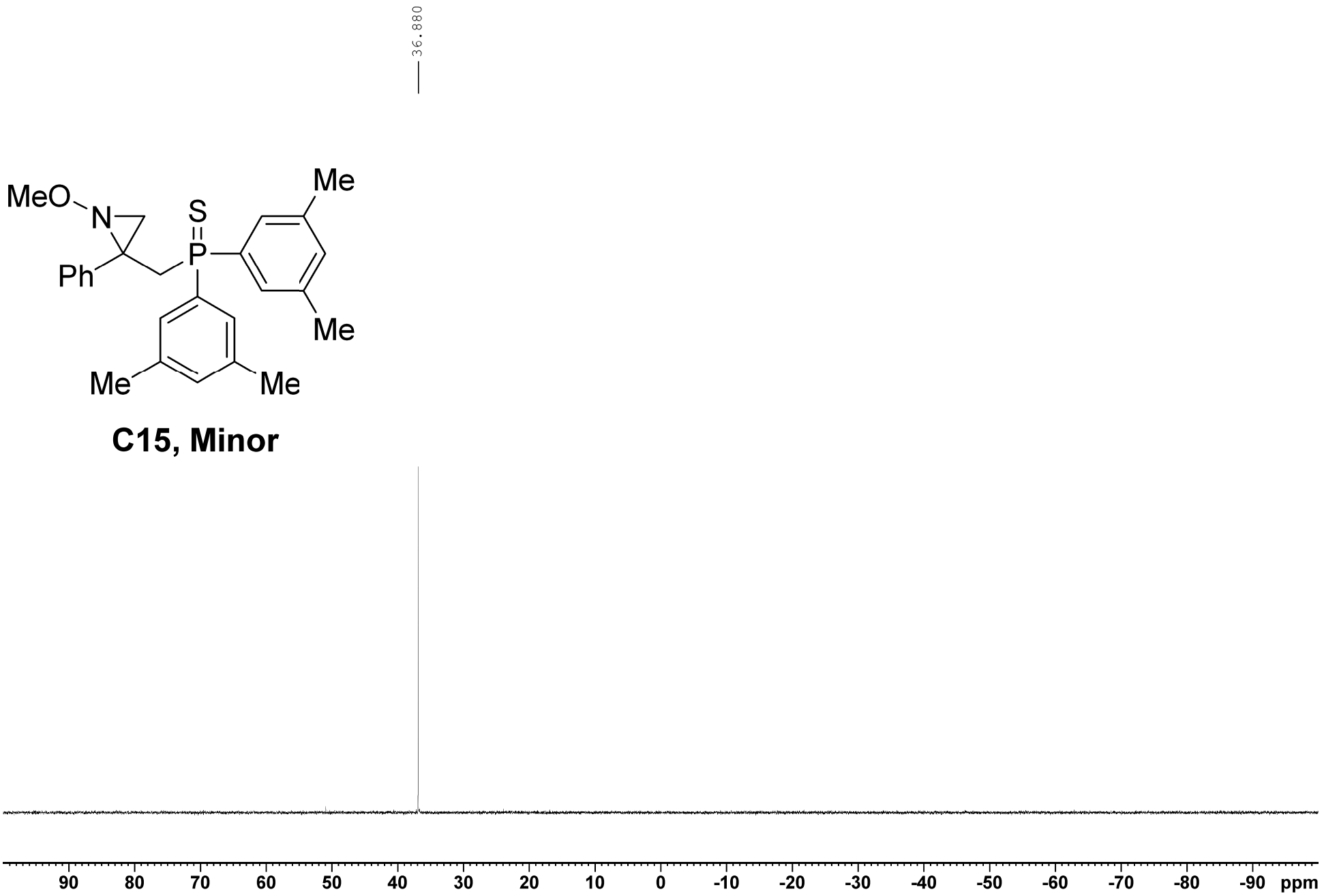
C15, Minor

^{13}C NMR (100 MHz, $CDCl_3$)



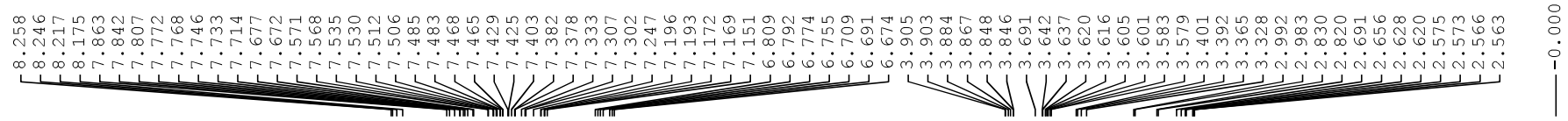
C15, Minor

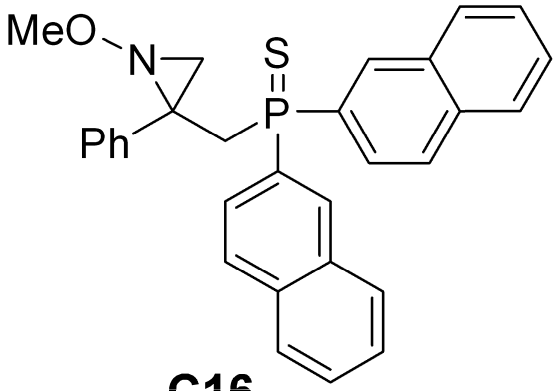
^{31}P NMR (162 MHz, $CDCl_3$)



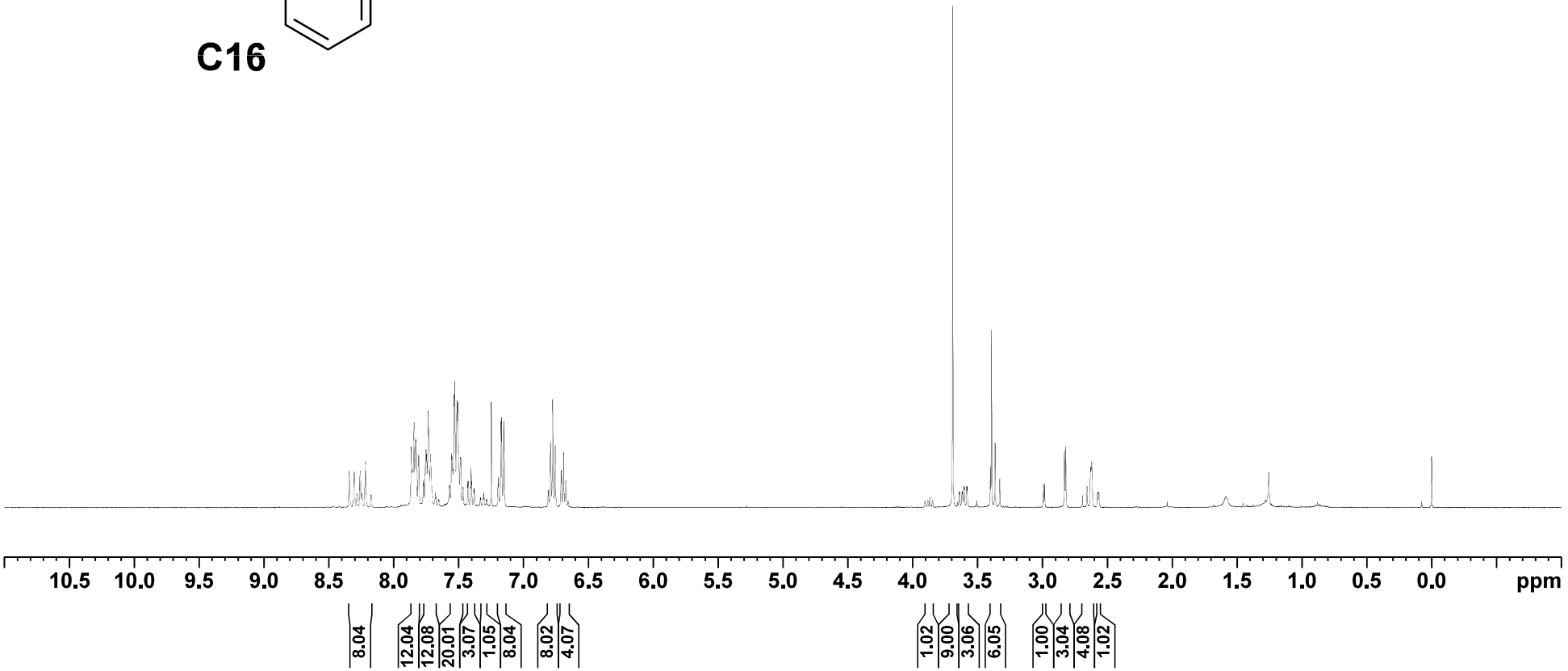
C15, Minor

^{1}H NMR ($CDCl_3$, 400 MHz)

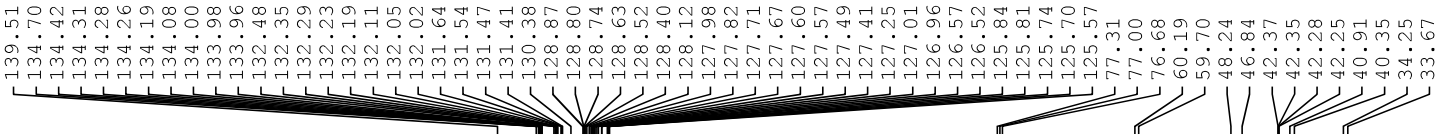


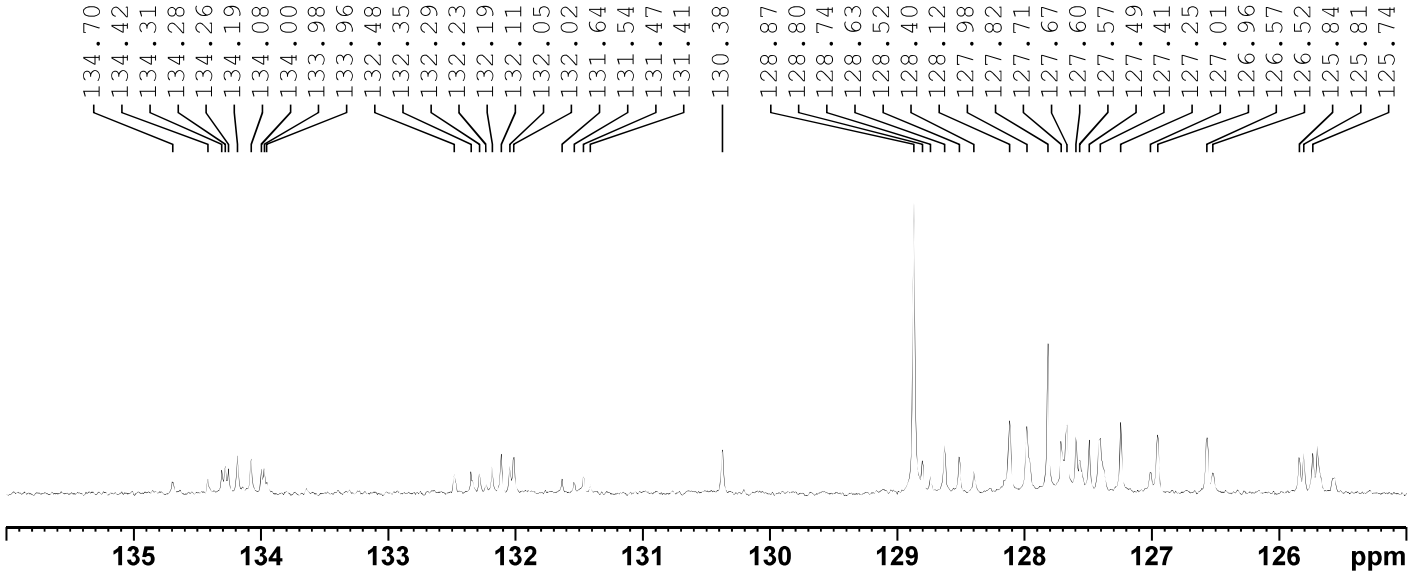


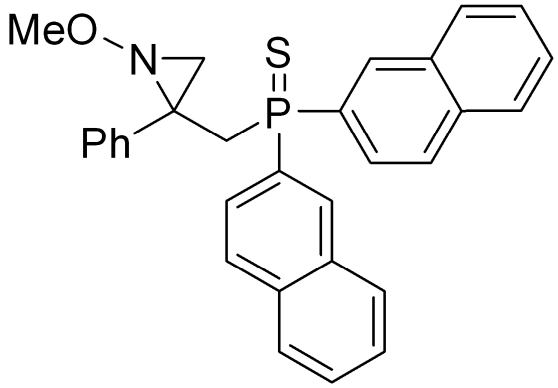
C16



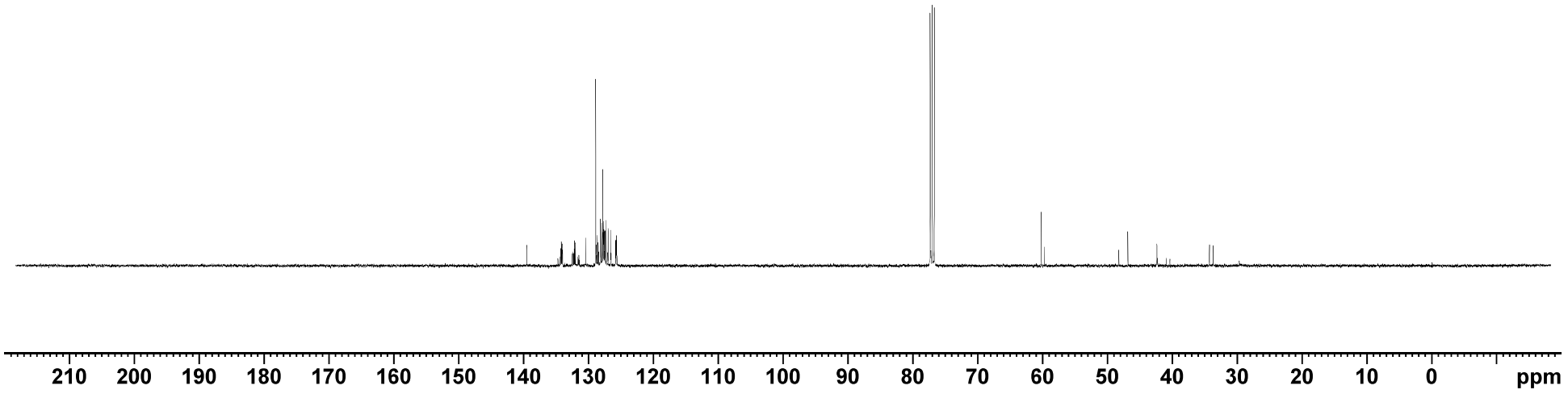
^{13}C NMR (100 MHz, $CDCl_3$)



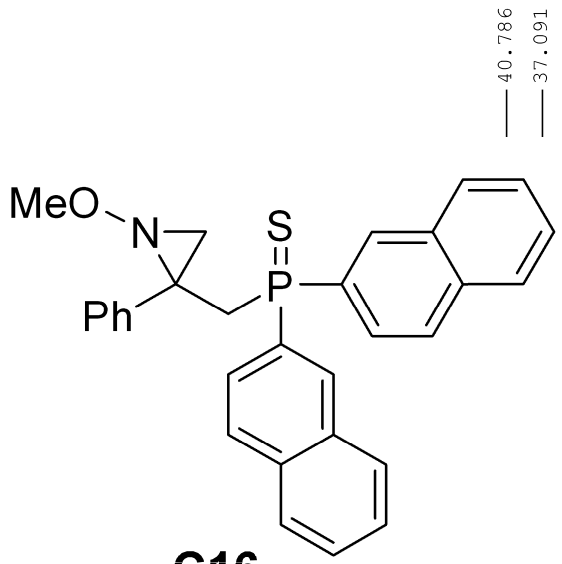




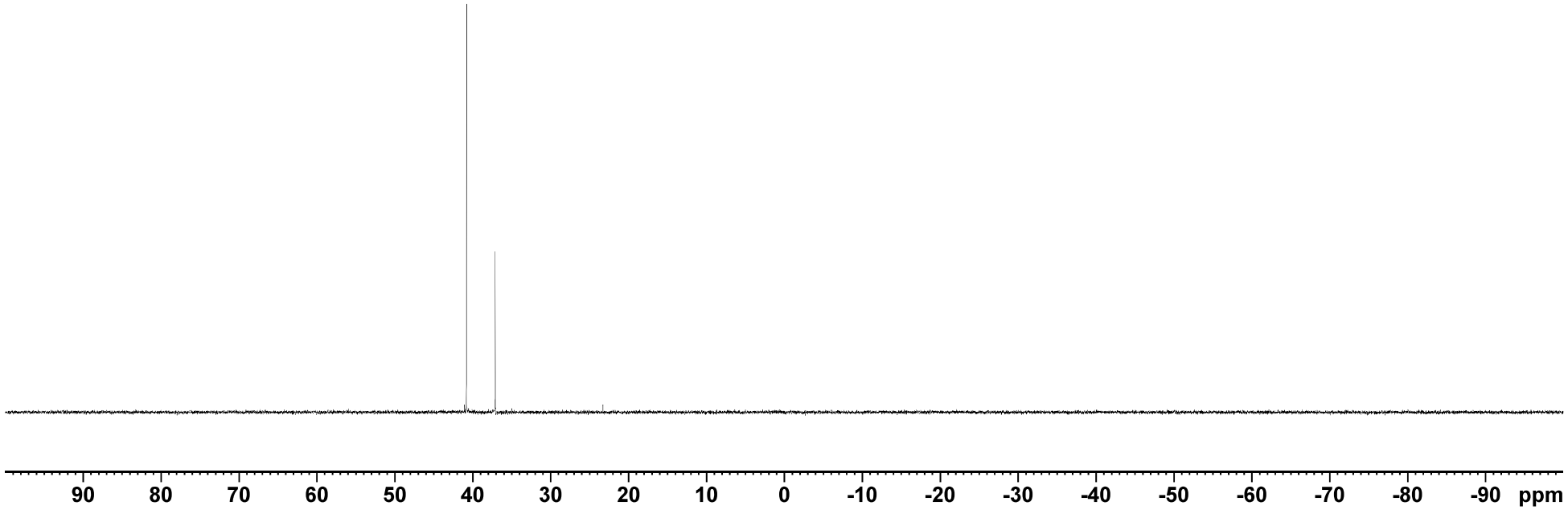
C16



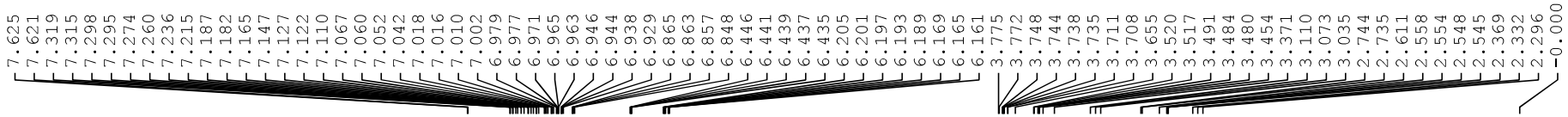
^{31}P NMR (162 MHz, $CDCl_3$)

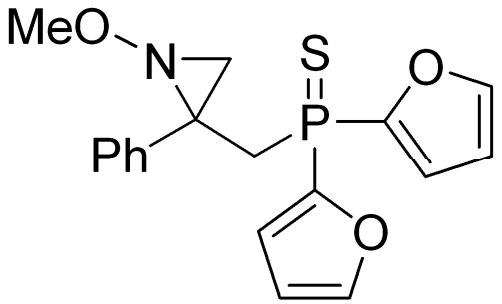


C16

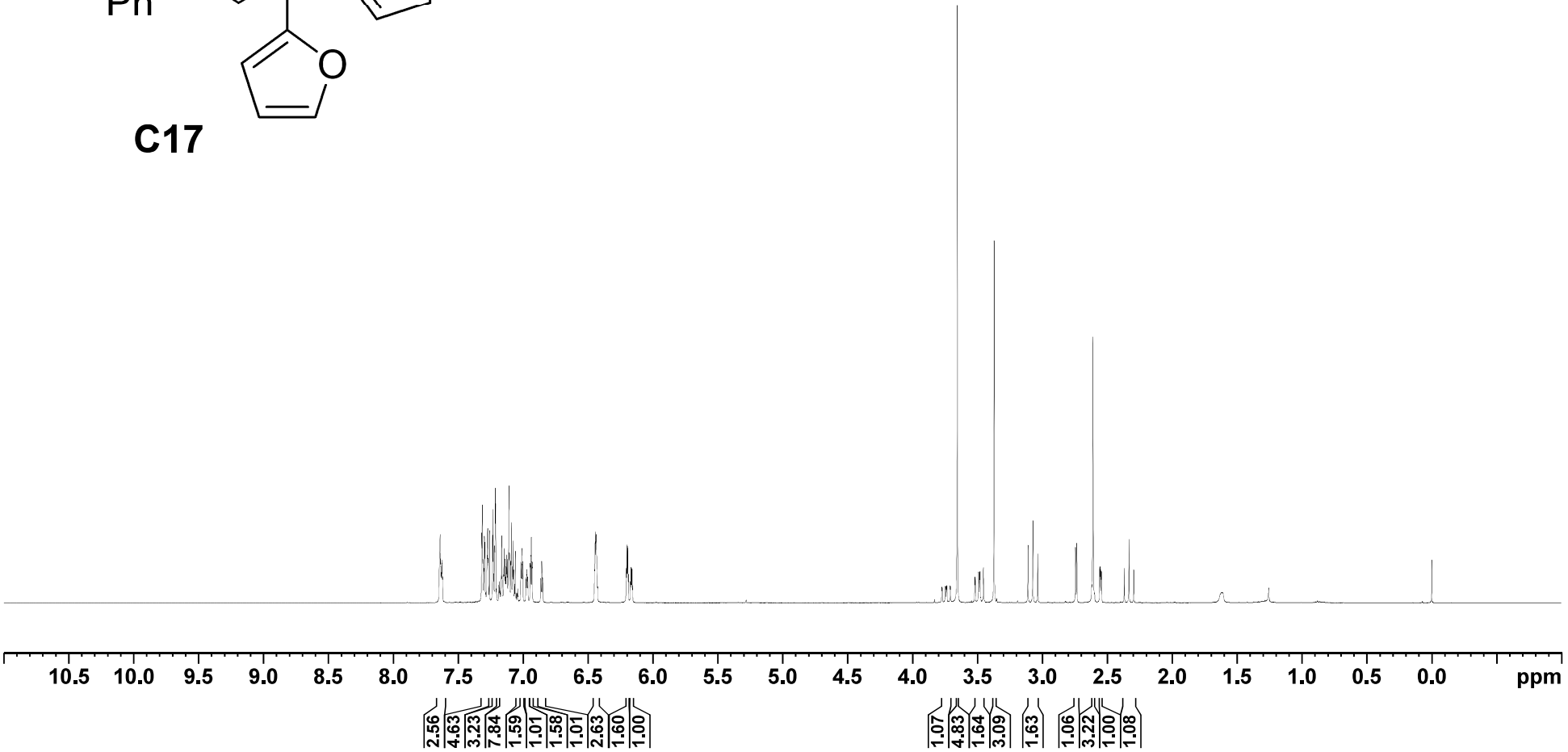


^{1}H NMR ($CDCl_3$, 400 MHz)

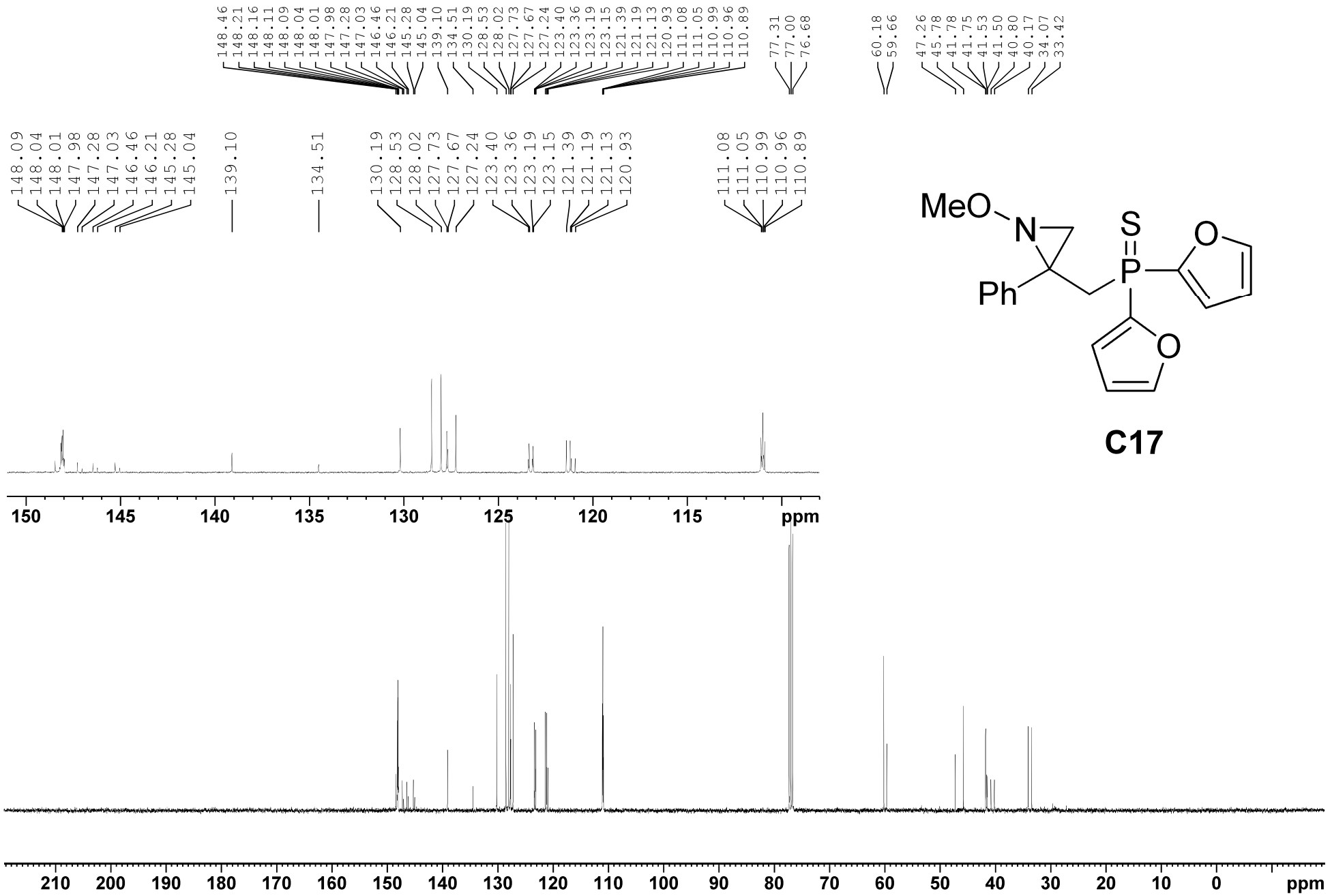




C17

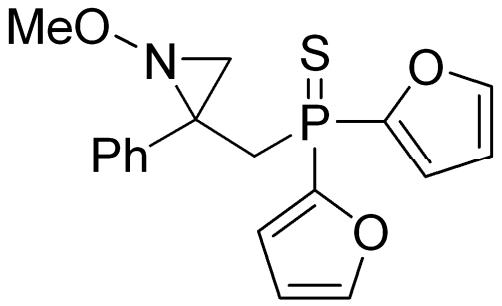


^{13}C NMR (100 MHz, $CDCl_3$)



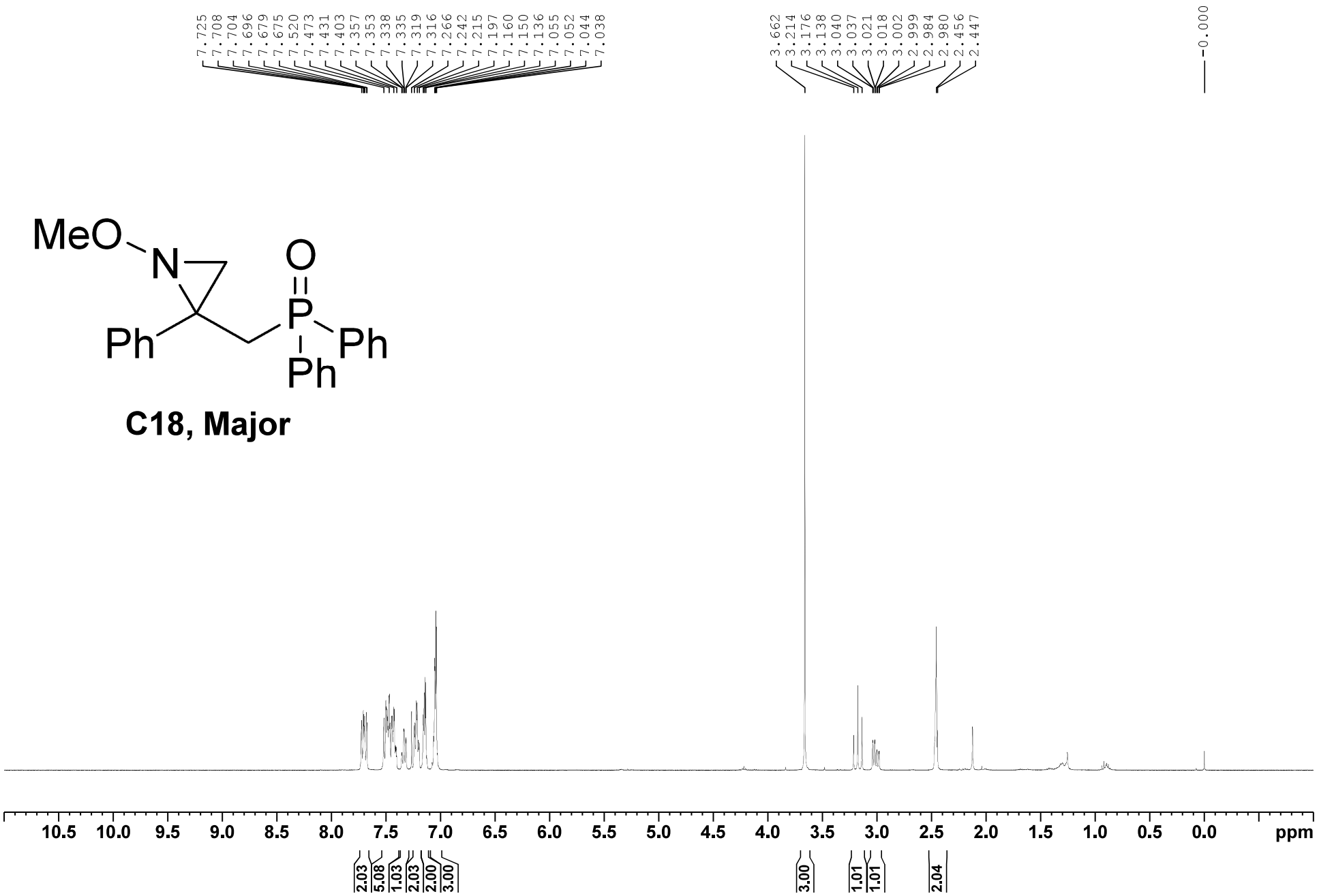
C17

^{31}P NMR (162 MHz, $CDCl_3$)



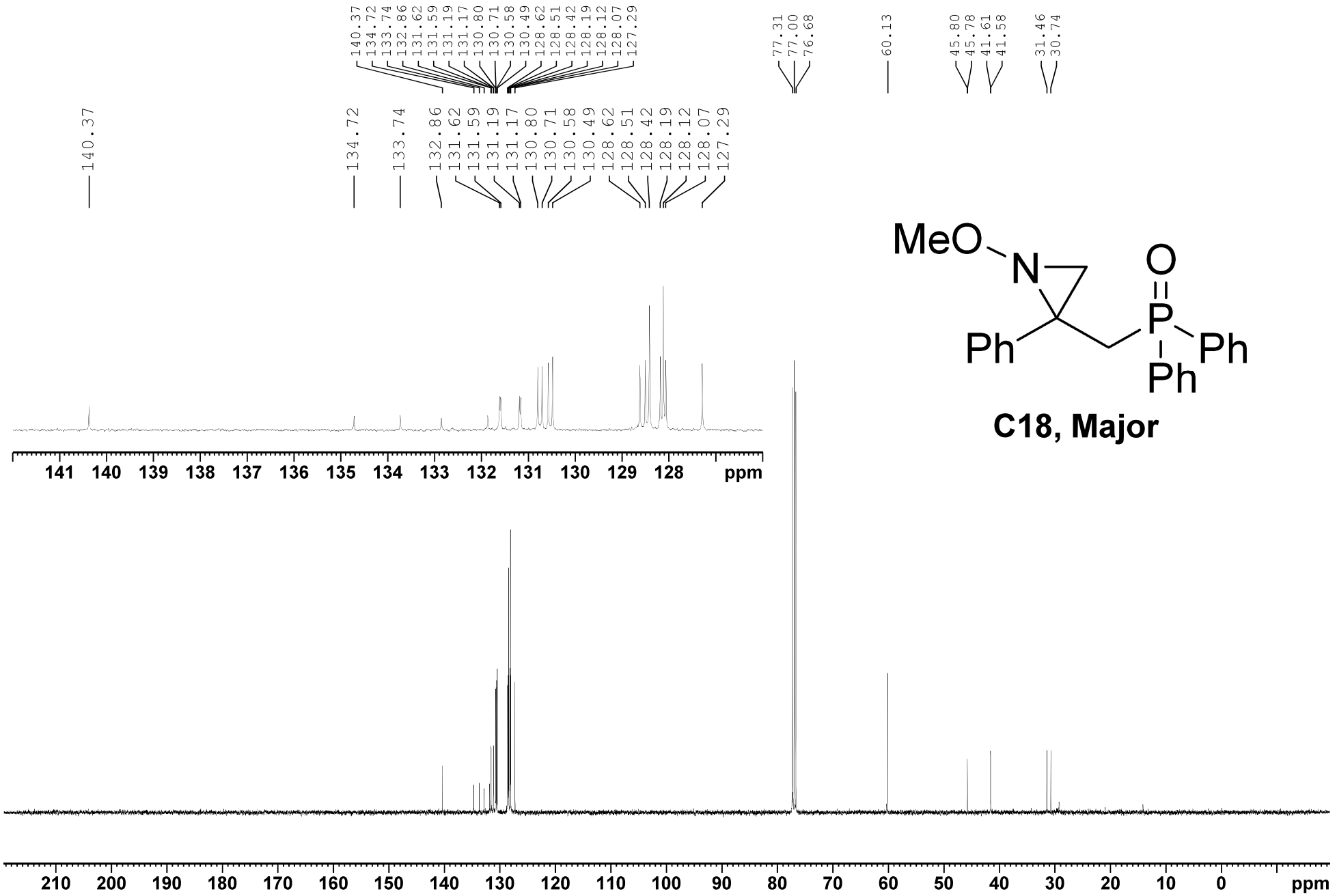
C17

^{1}H NMR ($CDCl_3$, 400 MHz)

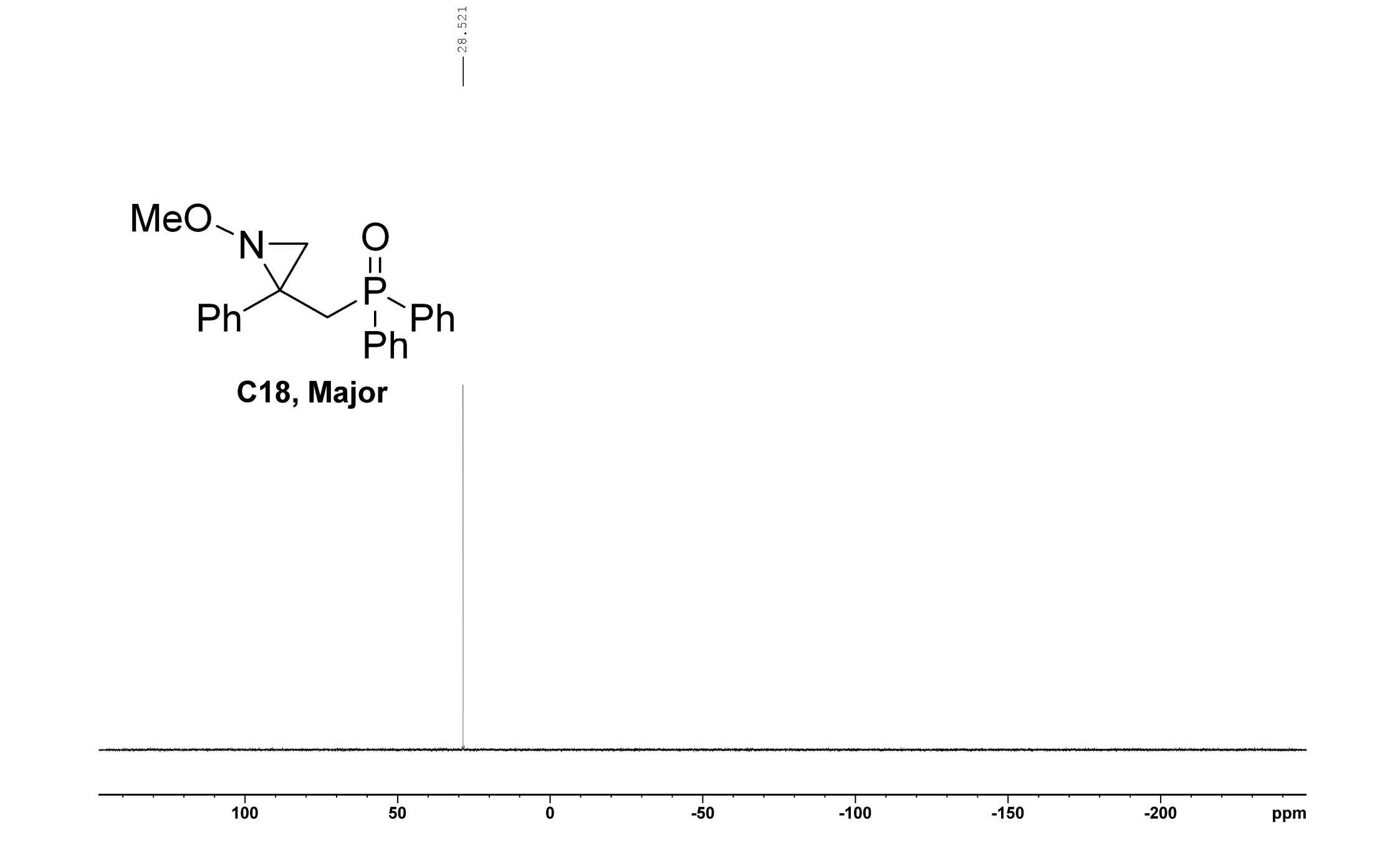


C18, Major

^{13}C NMR (100 MHz, $CDCl_3$)



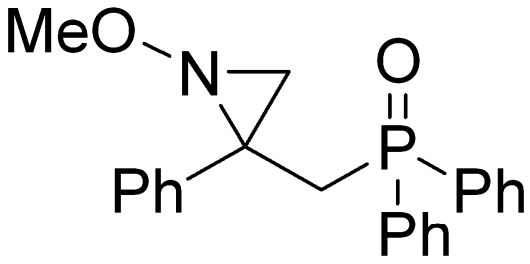
^{31}P NMR (162 MHz, $CDCl_3$)



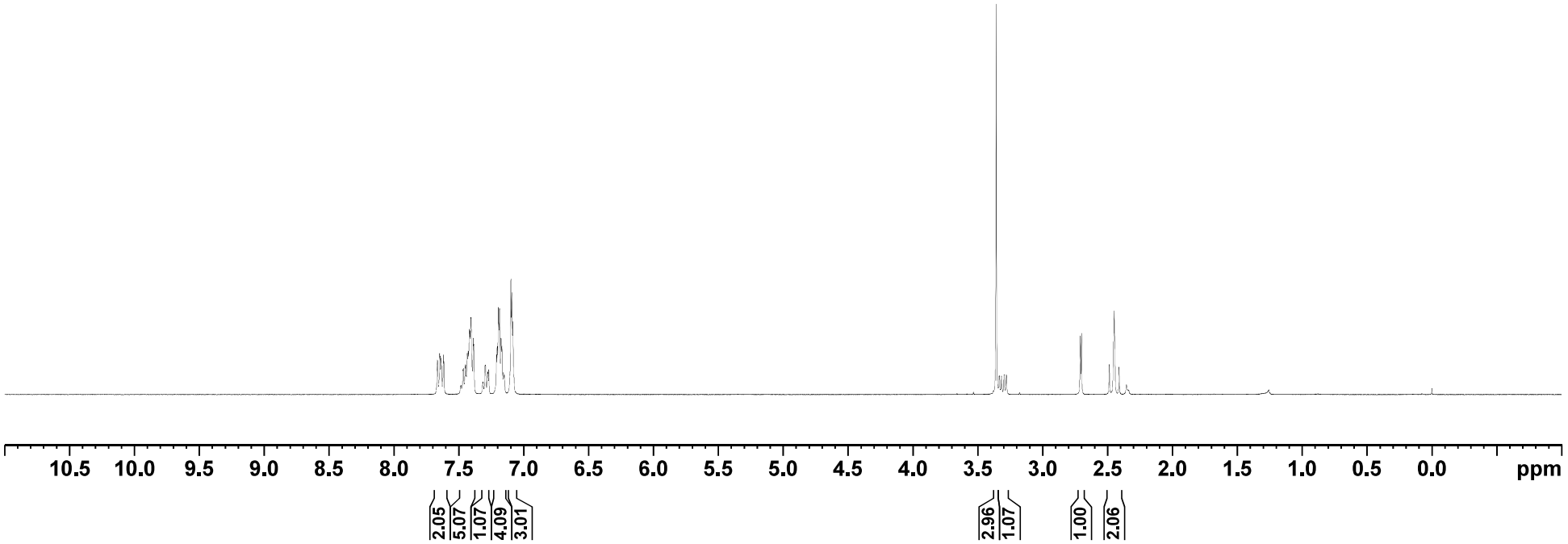
C18, Major

^{1}H NMR ($CDCl_3$, 400 MHz)

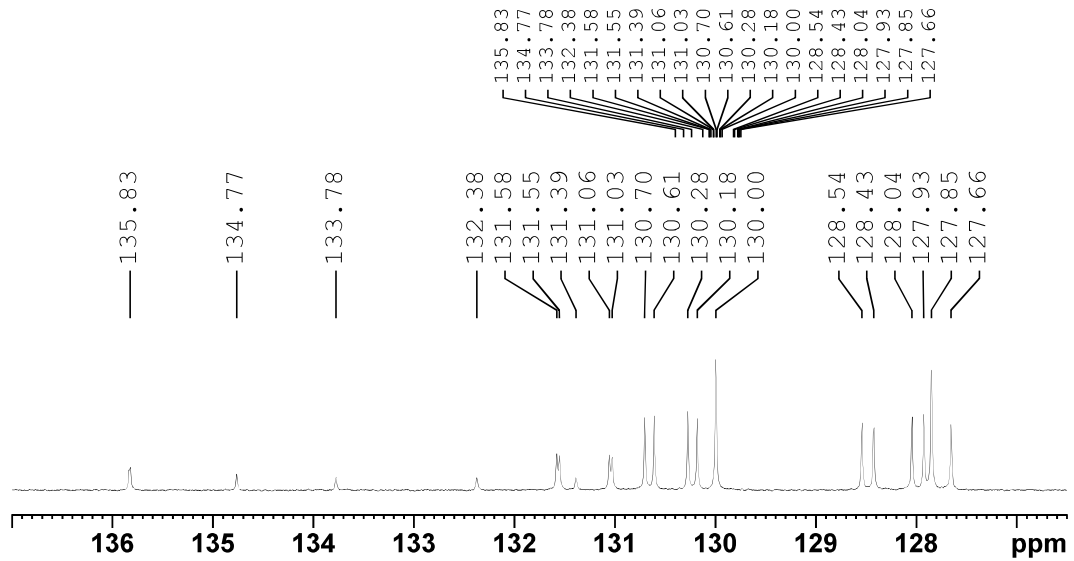


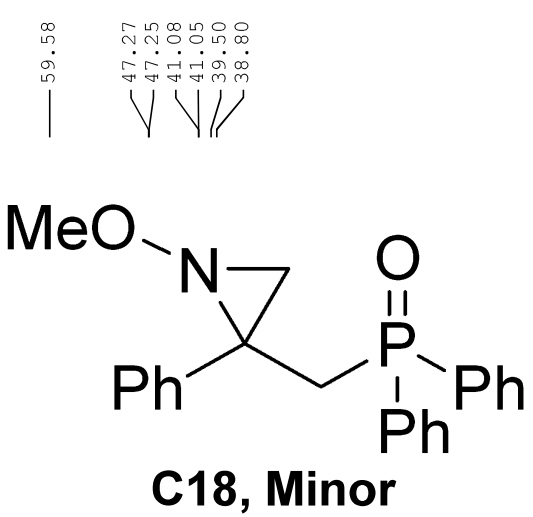


C18, Minor



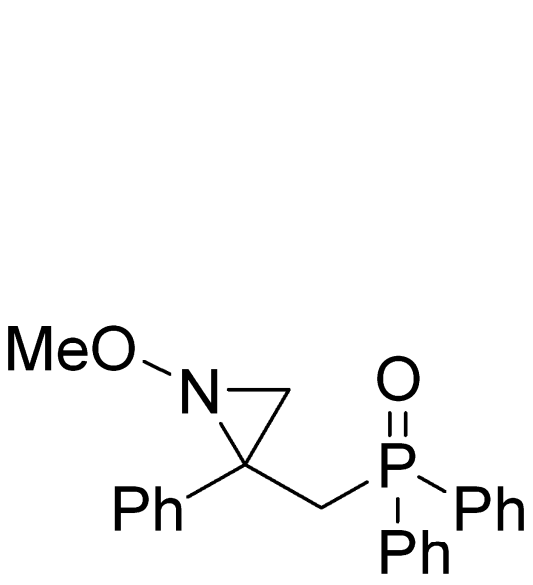
^{13}C NMR (100 MHz, $CDCl_3$)





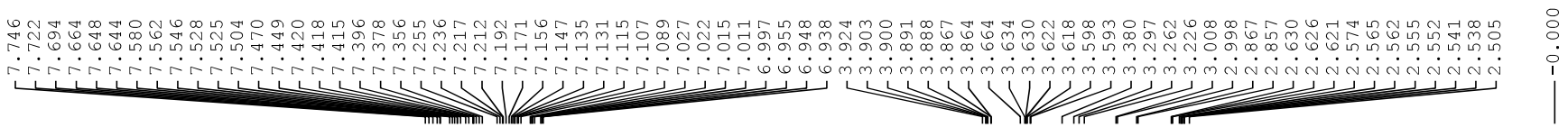
C18, Minor

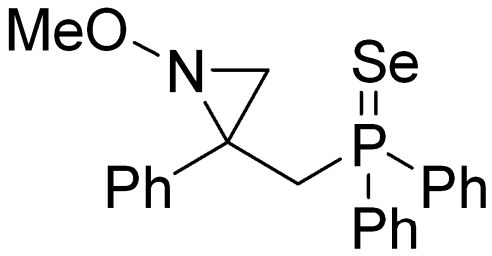
^{31}P NMR (162 MHz, $CDCl_3$)



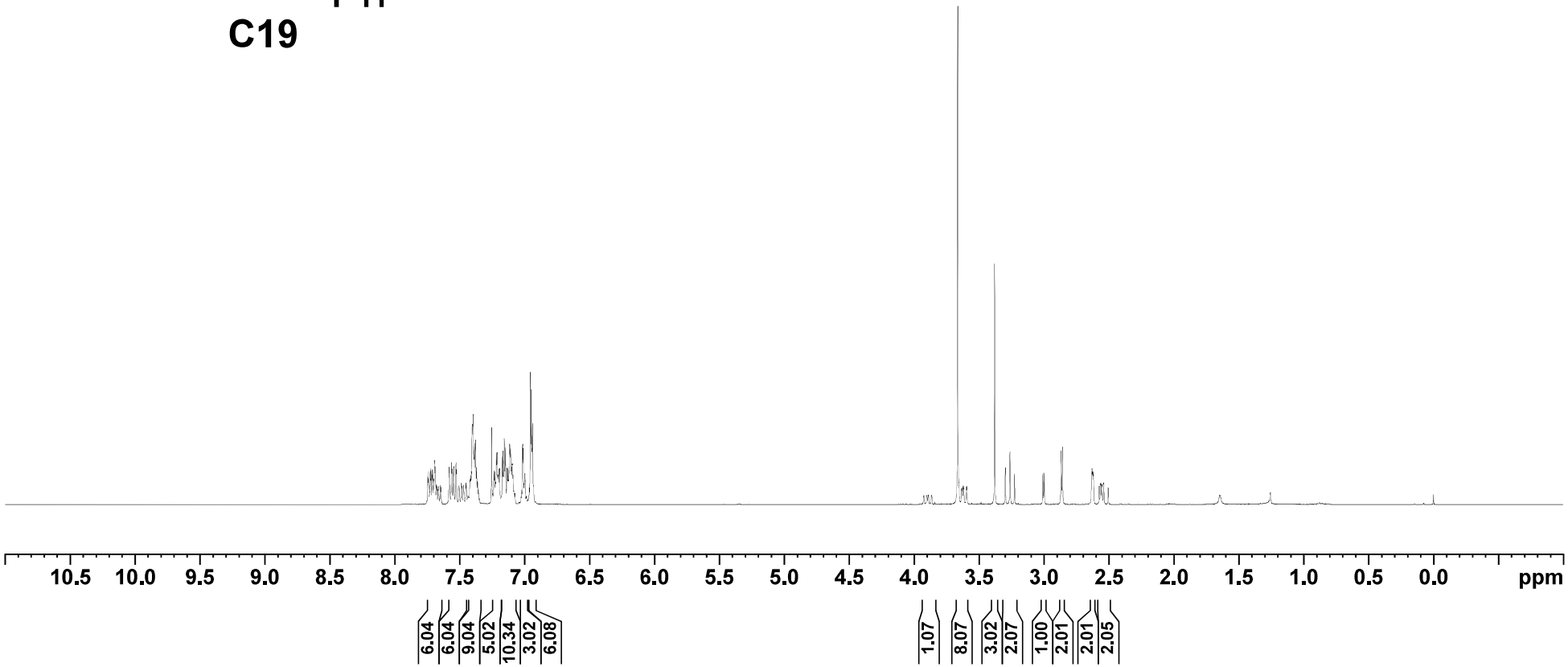
C18, Minor

^{1}H NMR ($CDCl_3$, 400 MHz)

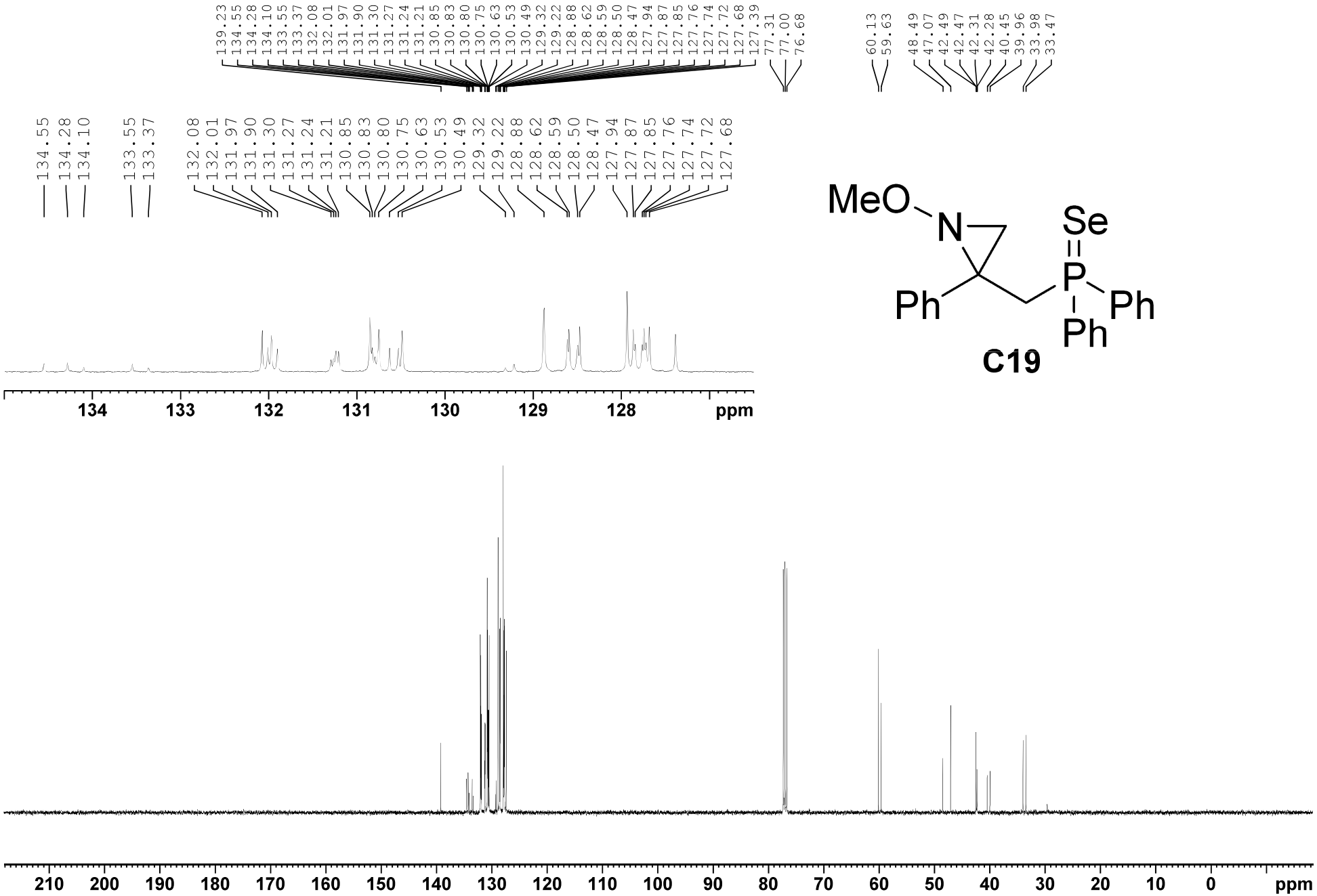




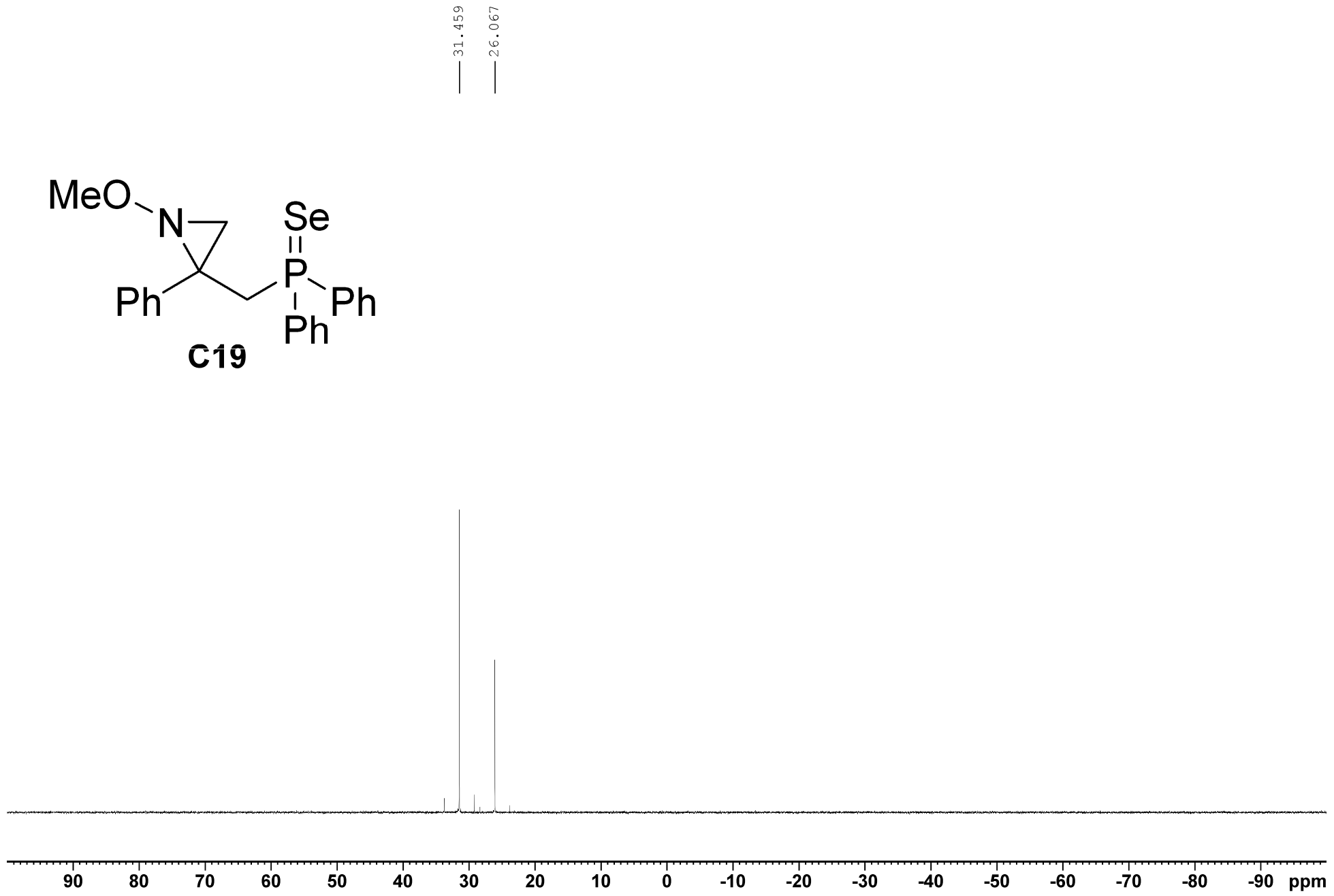
C19



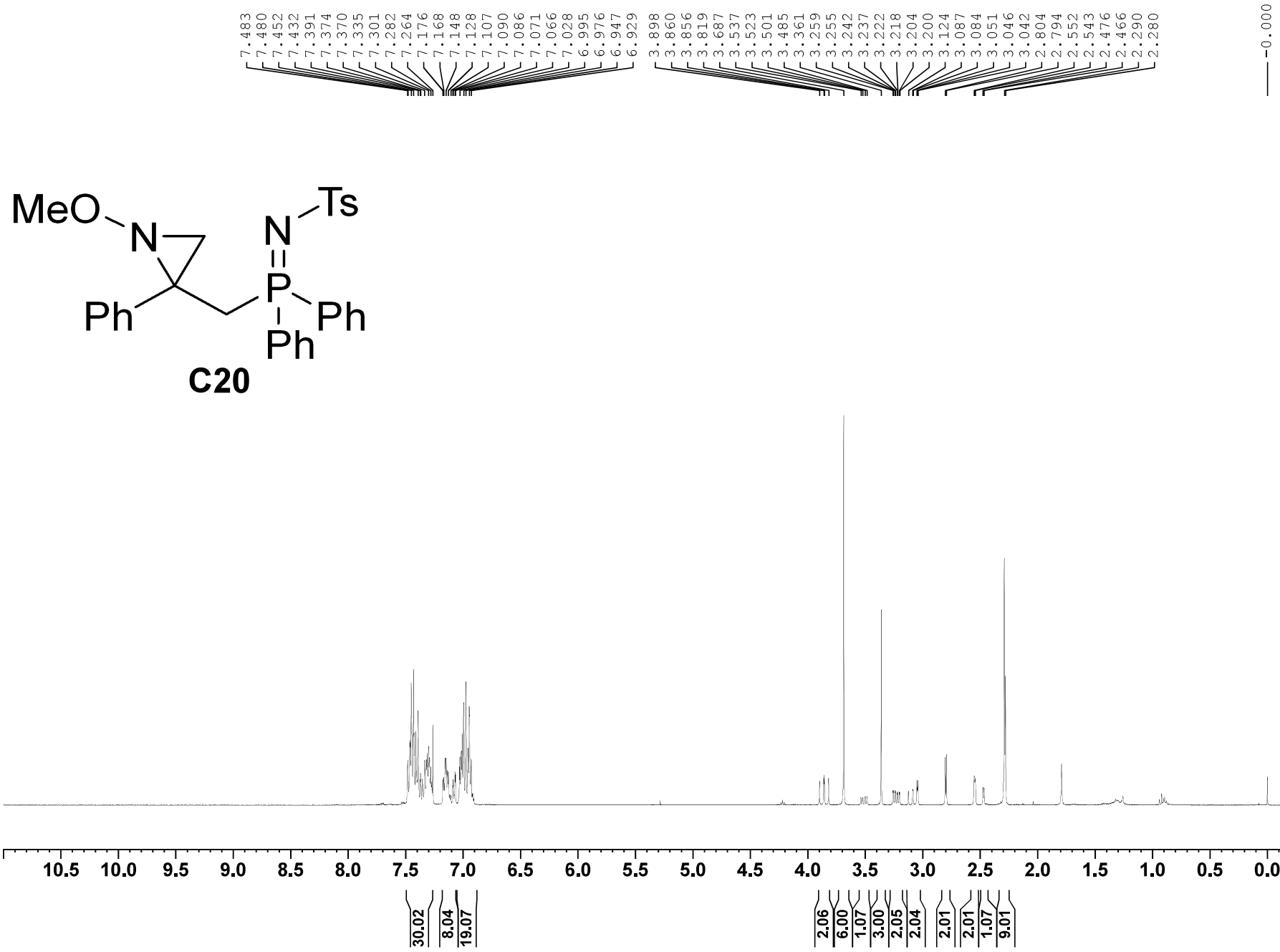
^{13}C NMR (100 MHz, $CDCl_3$)



^{31}P NMR (162 MHz, $CDCl_3$)



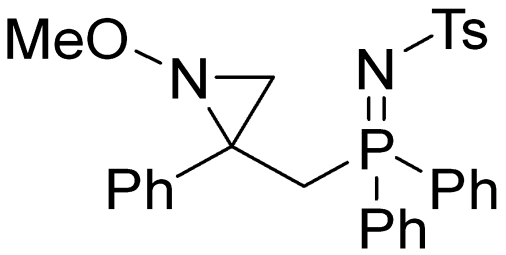
^{1}H NMR ($CDCl_3$, 400 MHz)



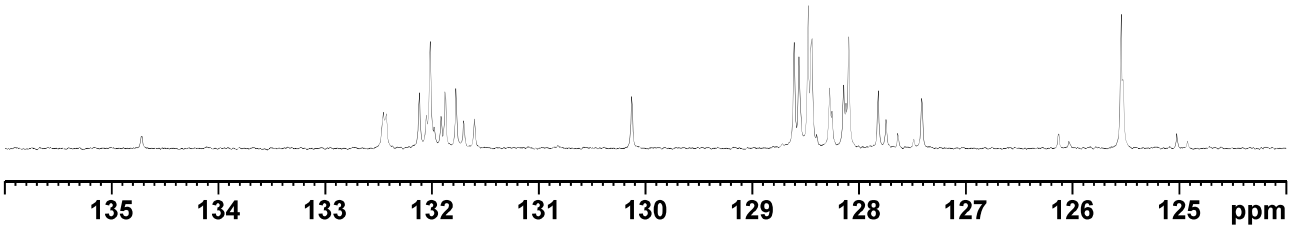
^{13}C NMR (100 MHz, $CDCl_3$)

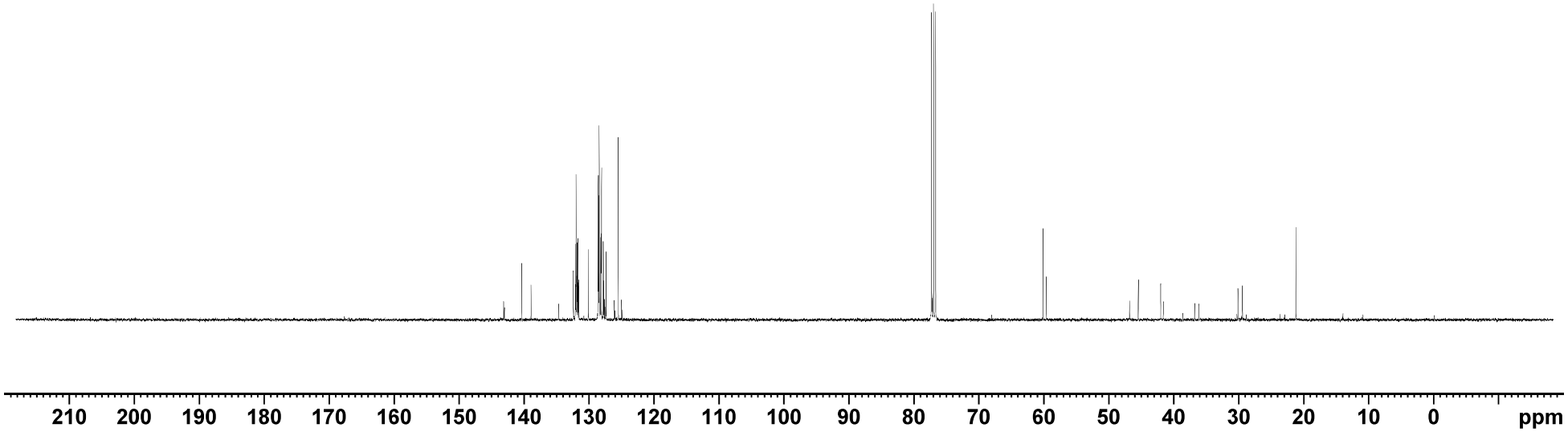
143.20 143.18 143.06 143.04 140.39 138.96 134.72 132.46 132.43 132.12 132.05 132.02 131.98 131.92 131.88 131.78 131.70 131.60 130.13 128.61 128.56 128.48 128.45 128.40 128.28 128.26 128.15 128.12 128.10 127.82 127.75 127.64 127.49 127.41 126.13 126.04 125.55 125.53 125.03 124.93 77.31 77.00 76.68 60.16 59.64 46.83 46.81 42.04 42.02 41.62 41.60 36.80 36.14 30.13 29.44 21.21

134.72 132.46 132.43 132.12 132.05 132.02 131.98 131.92 131.88 131.78 131.70 131.60 130.13 128.61 128.56 128.48 128.45 128.40 128.28 128.26 128.15 128.12 128.10 127.82 127.75 127.64 127.49 127.41 126.13 126.04 125.55 125.53 125.03 124.93

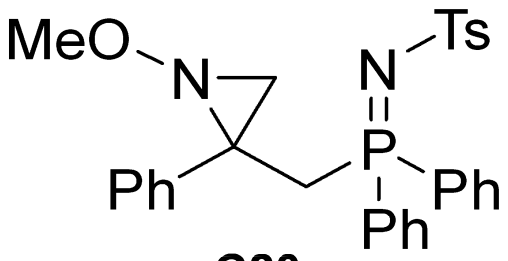


C20



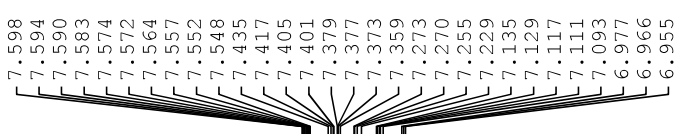


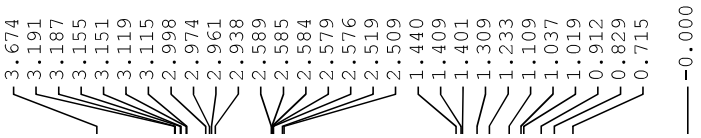
^{31}P NMR (162 MHz, $CDCl_3$)

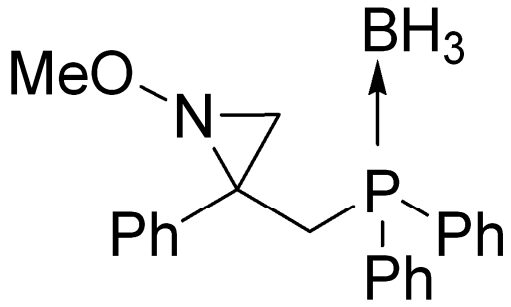


C20

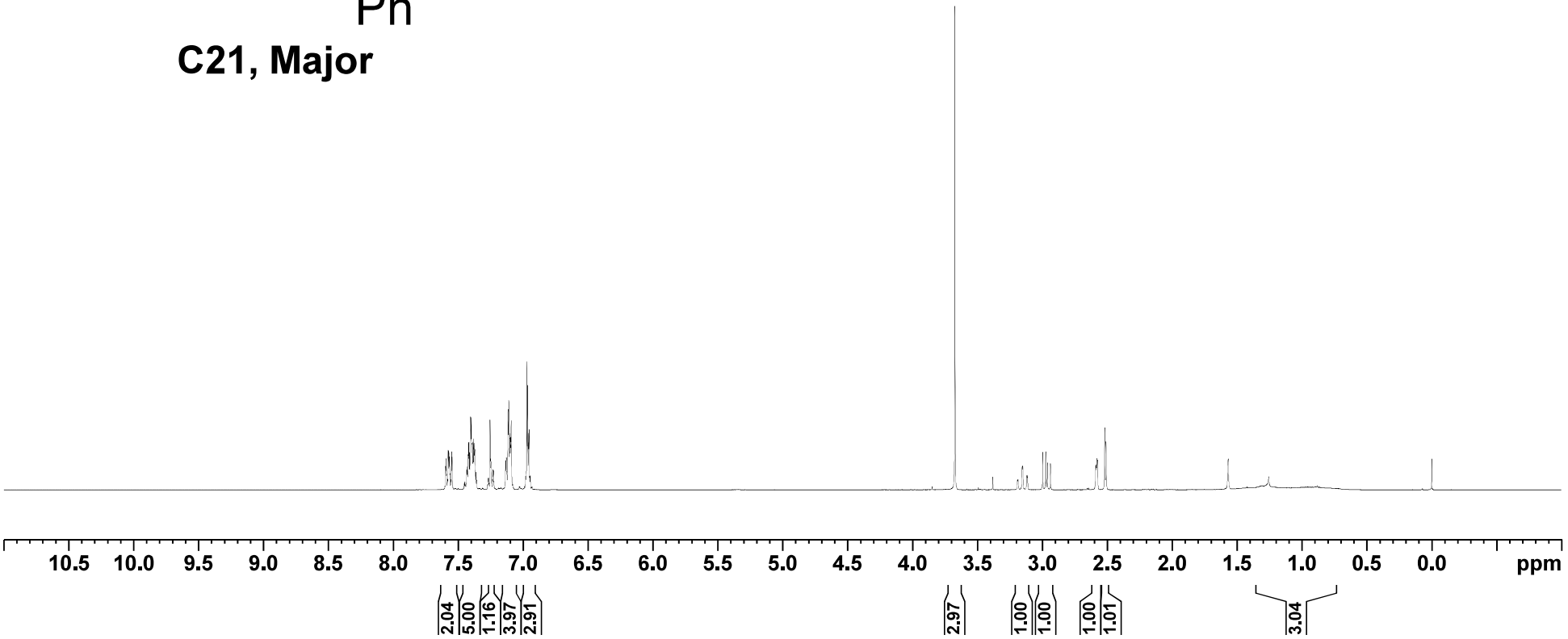
^{1}H NMR ($CDCl_3$, 400 MHz)



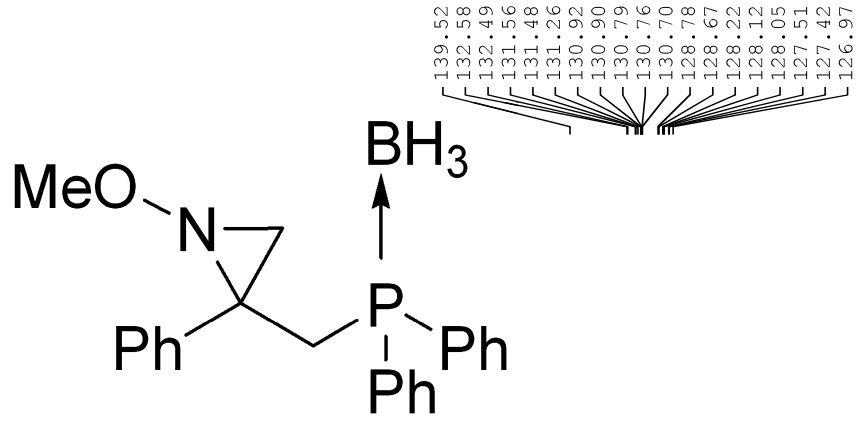




C21, Major

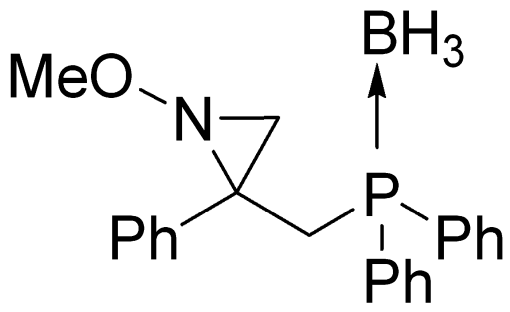


^{13}C NMR (100 MHz, $CDCl_3$)



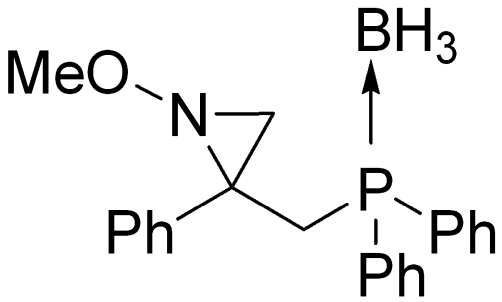
C21, Major

^{31}P NMR (162 MHz, $CDCl_3$)



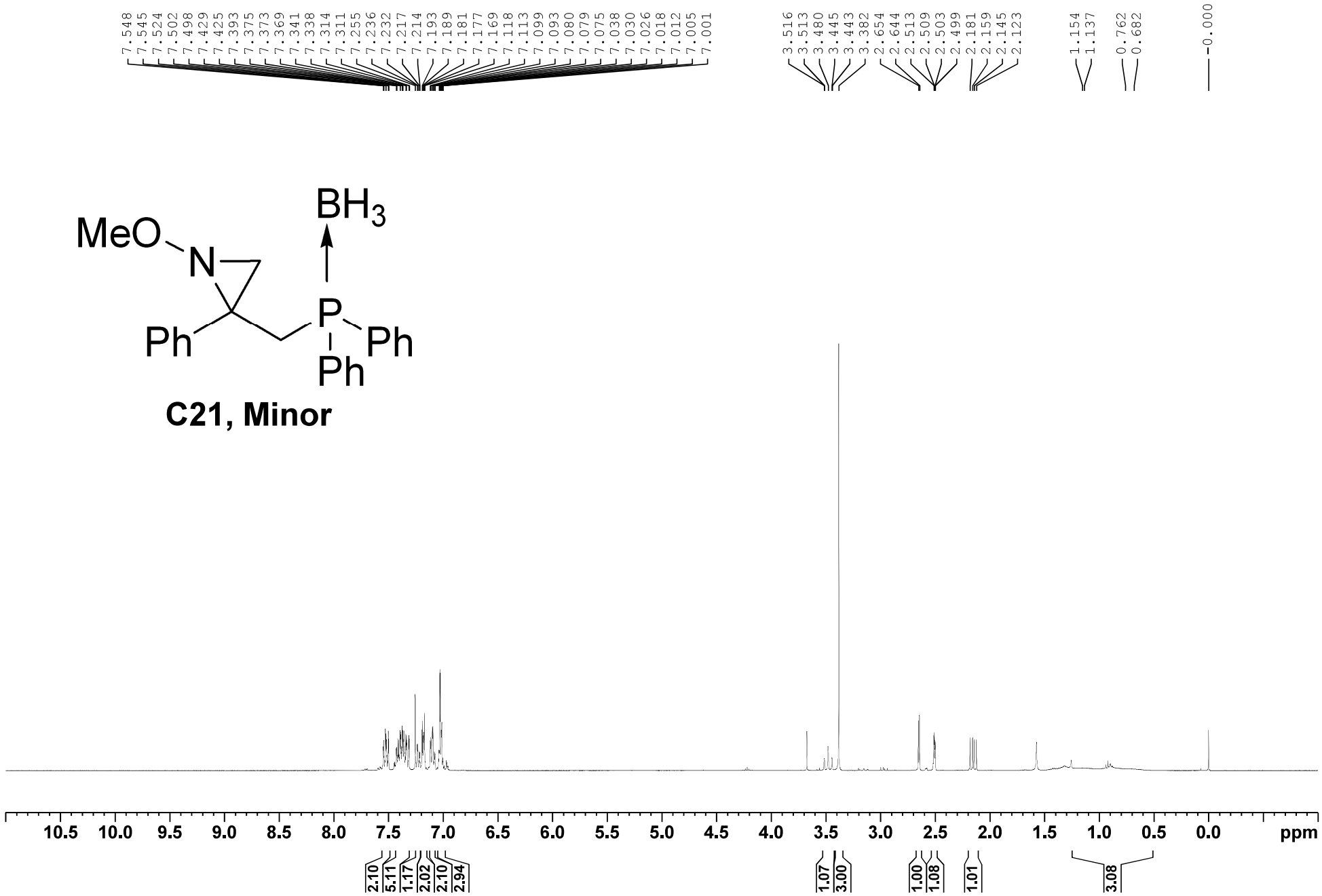
C21, Major

^{11}B NMR (128 MHz, $CDCl_3$)



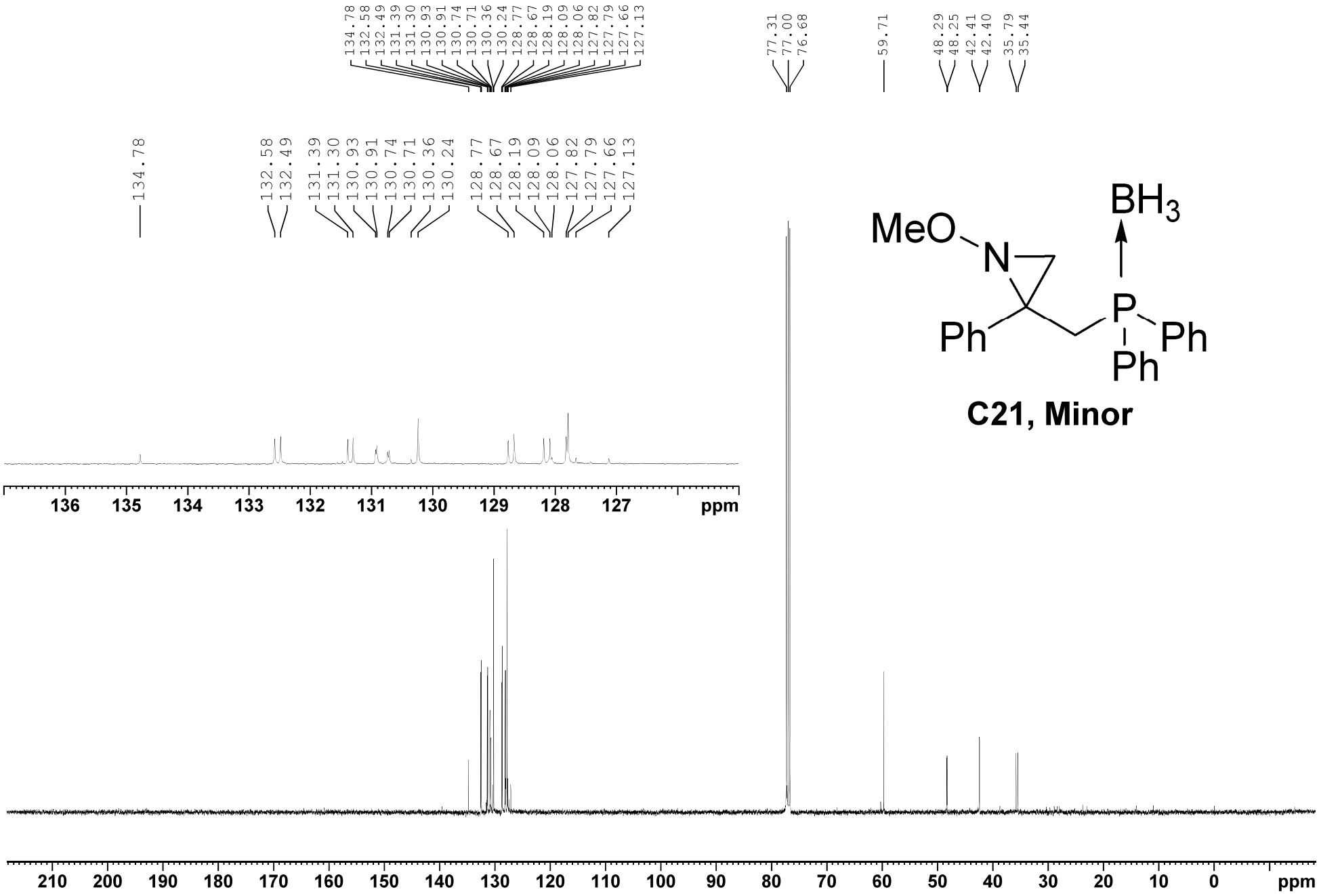
C21, Major

^{1}H NMR ($CDCl_3$, 400 MHz)

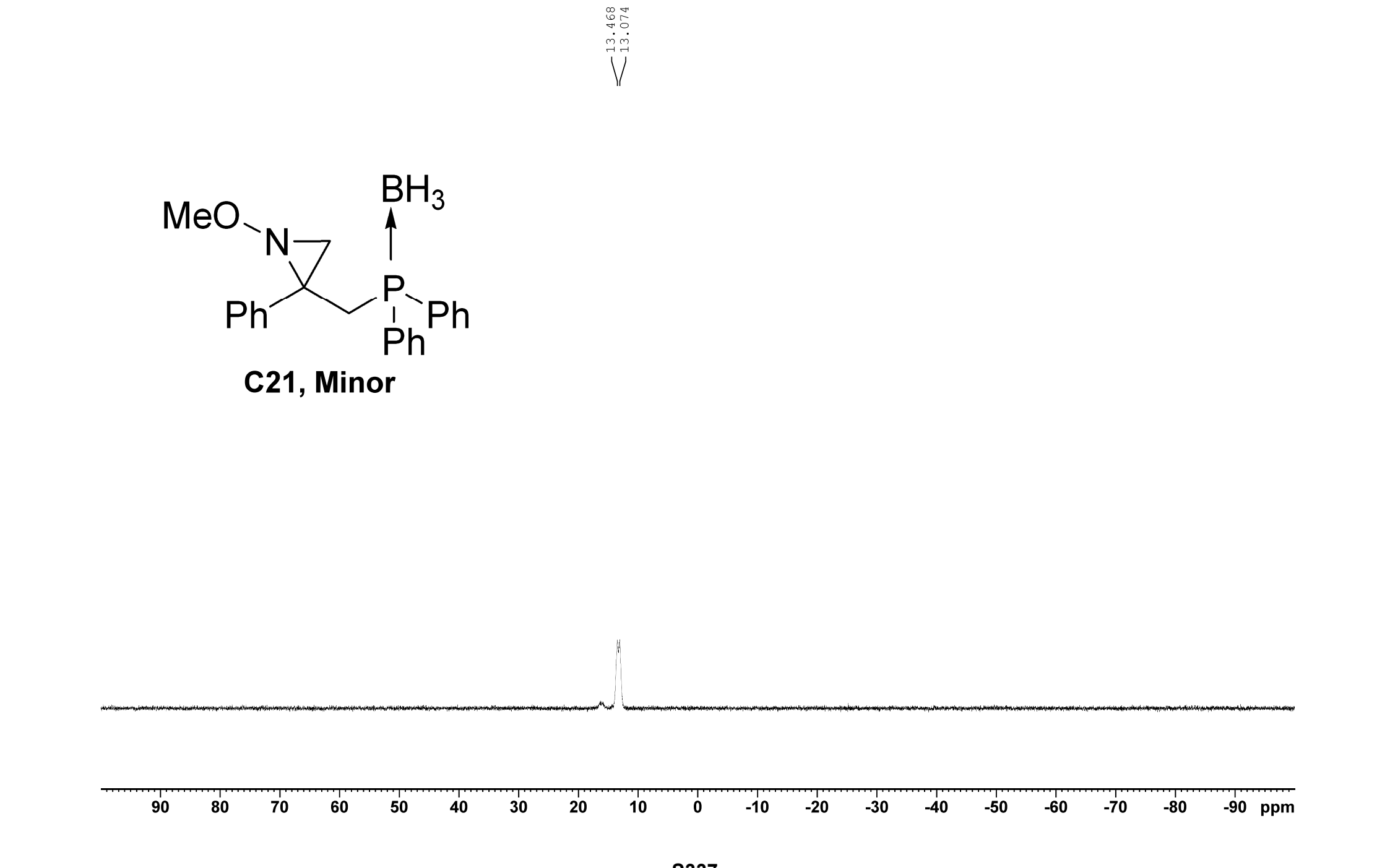


C21, Minor

^{13}C NMR (100 MHz, $CDCl_3$)

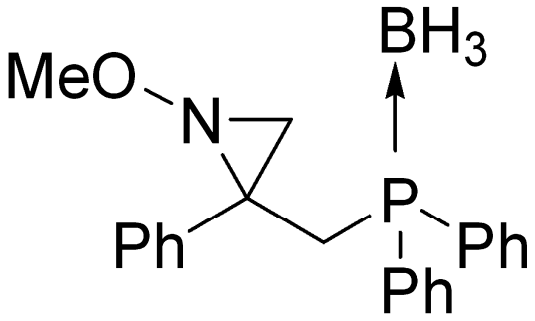


^{31}P NMR (162 MHz, $CDCl_3$)



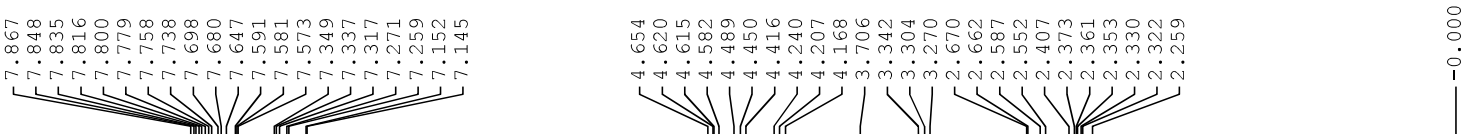
C21, Minor

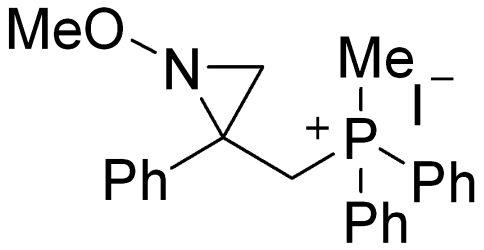
^{11}B NMR (128 MHz, $CDCl_3$)



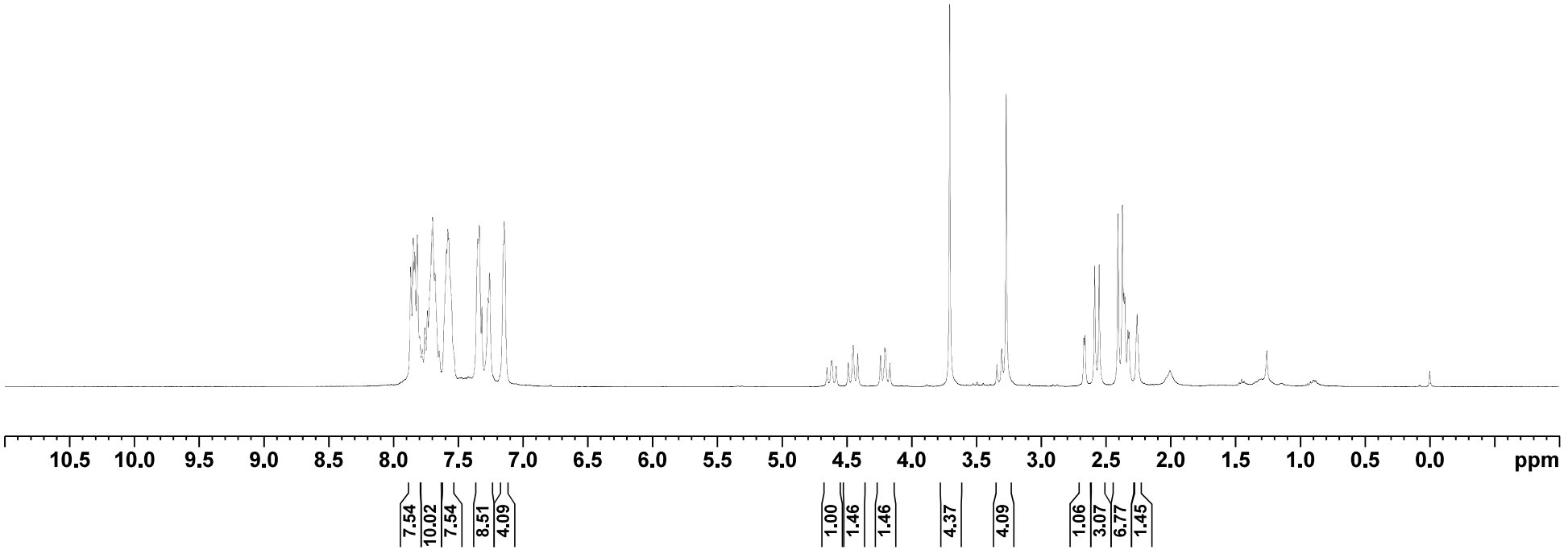
C21, Minor

^{1}H NMR ($CDCl_3$, 400 MHz)

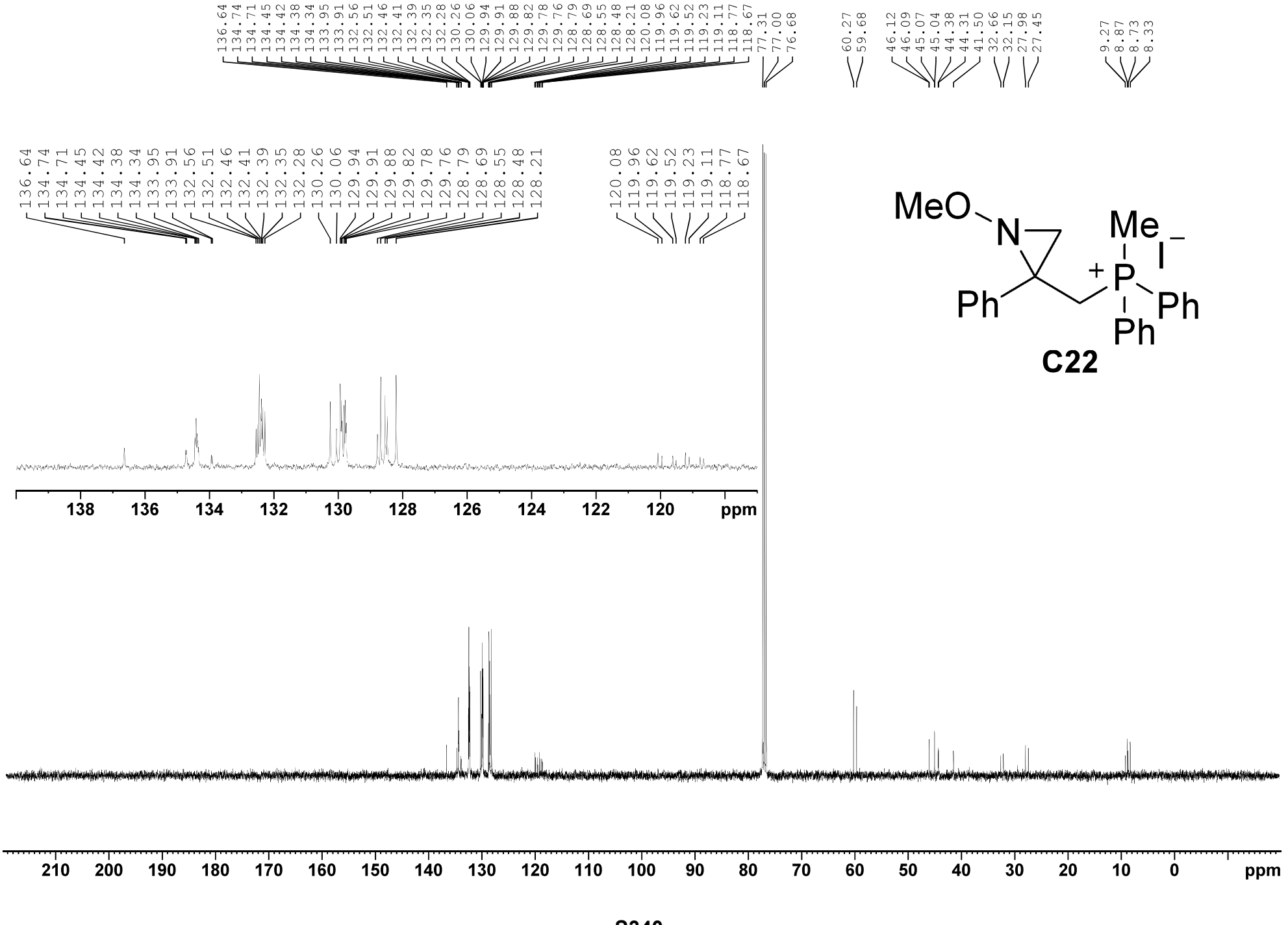




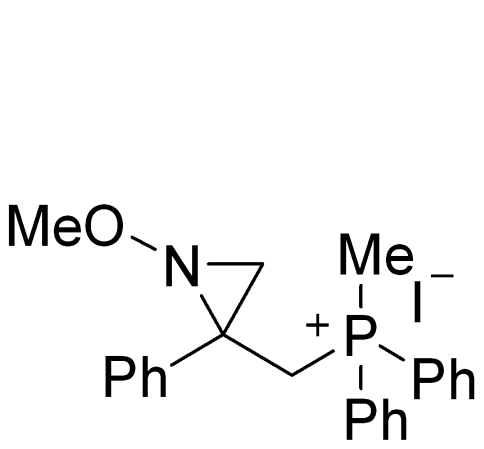
C22



^{13}C NMR (100 MHz, $CDCl_3$)

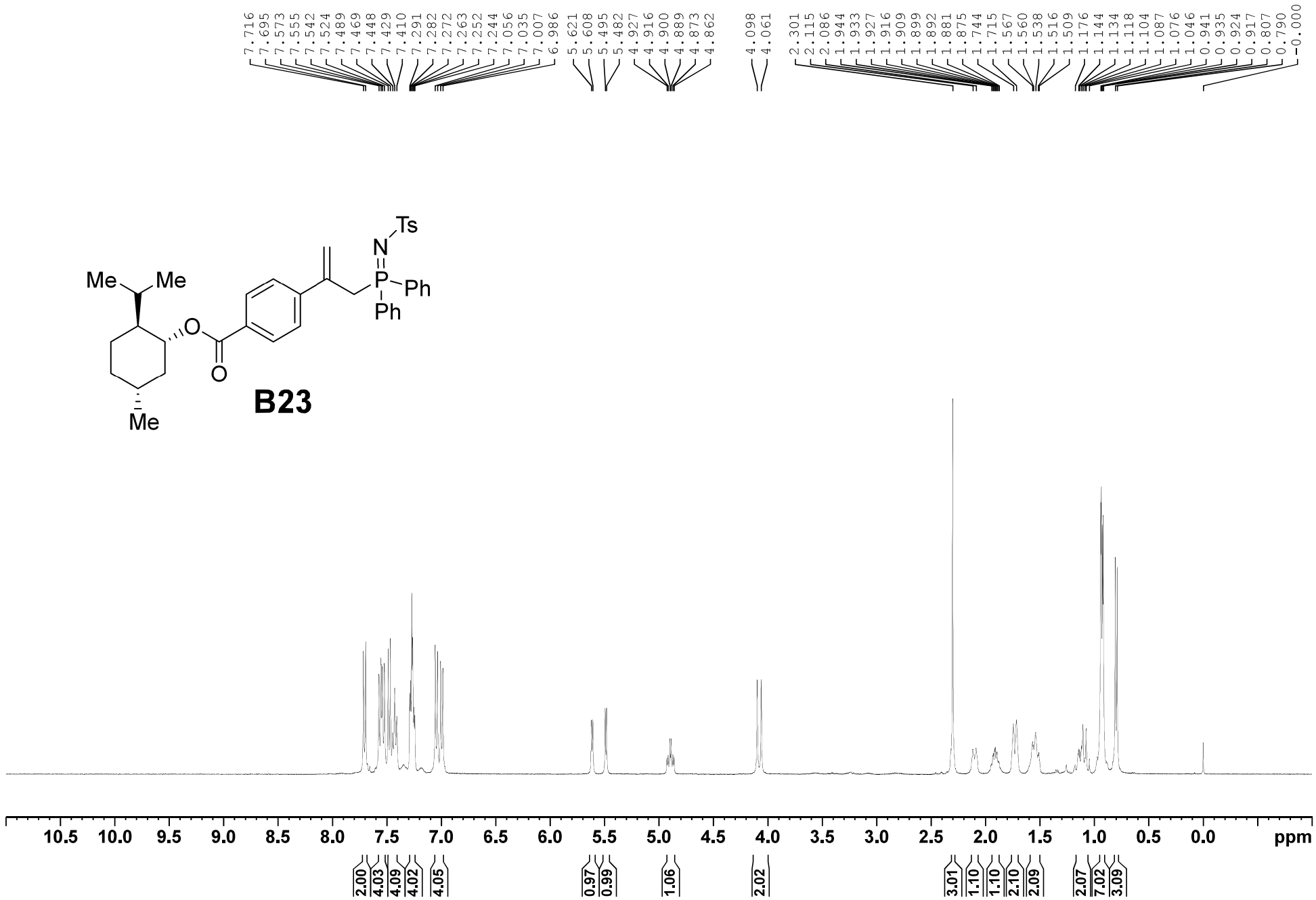


^{31}P NMR (162 MHz, $CDCl_3$)

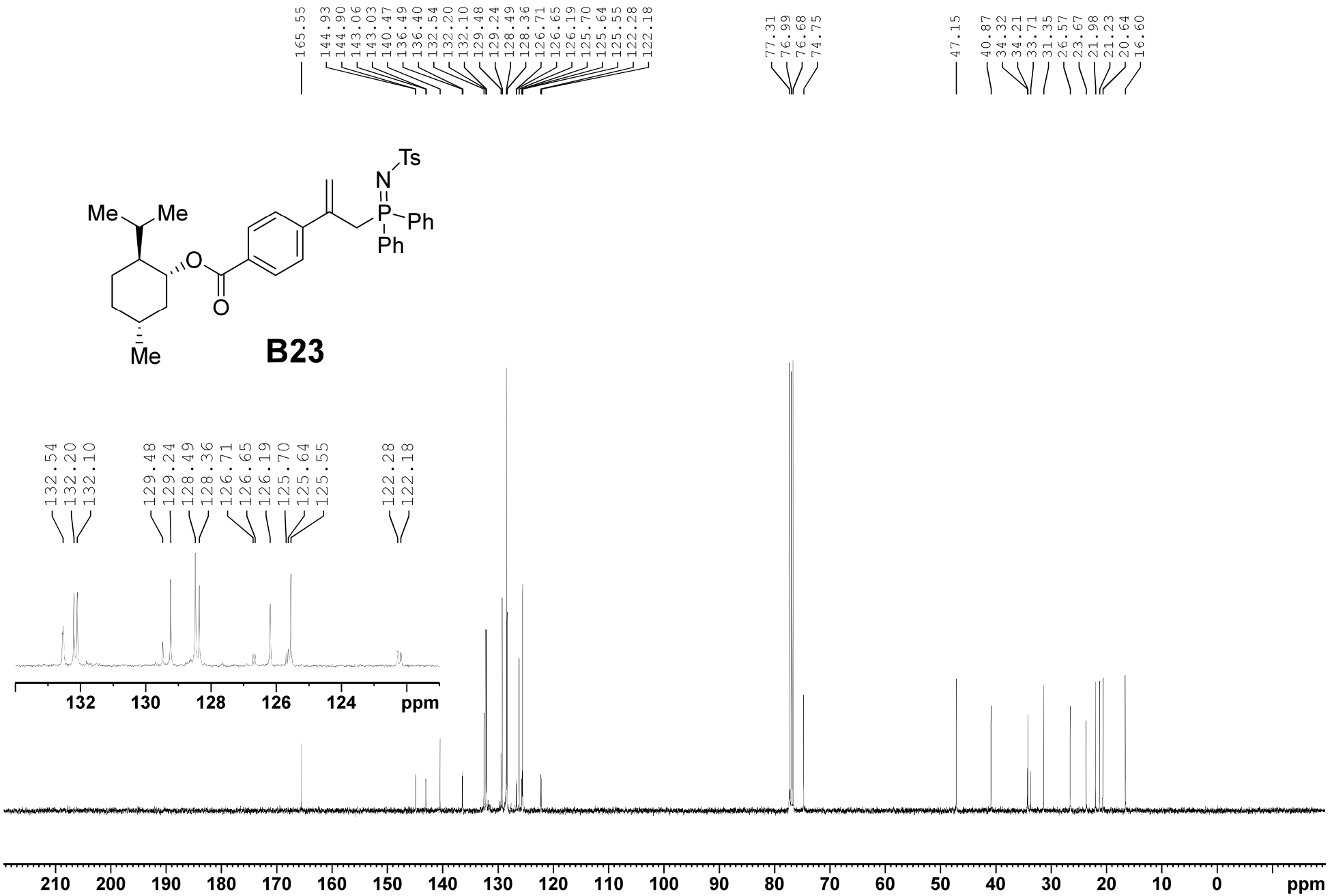


C22

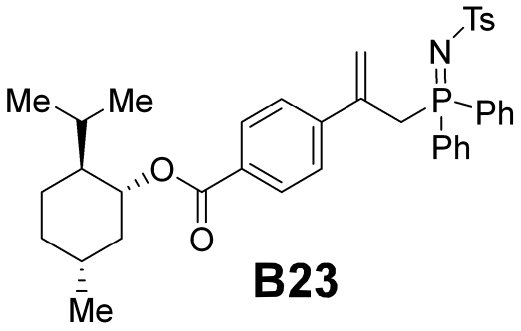
^{1}H NMR ($CDCl_3$, 400 MHz)



^{13}C NMR (100 MHz, $CDCl_3$)

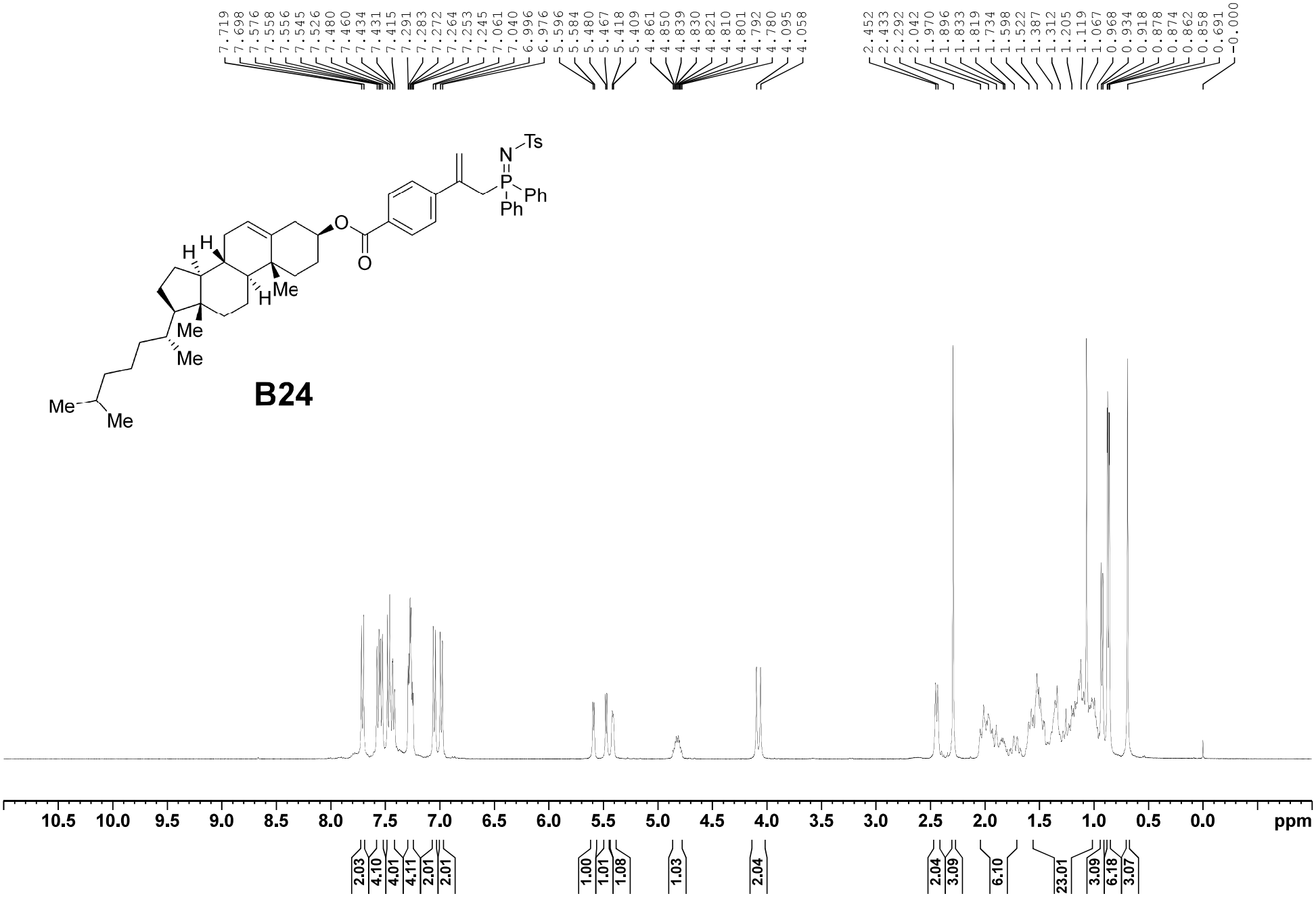


^{31}P NMR (162 MHz, $CDCl_3$)

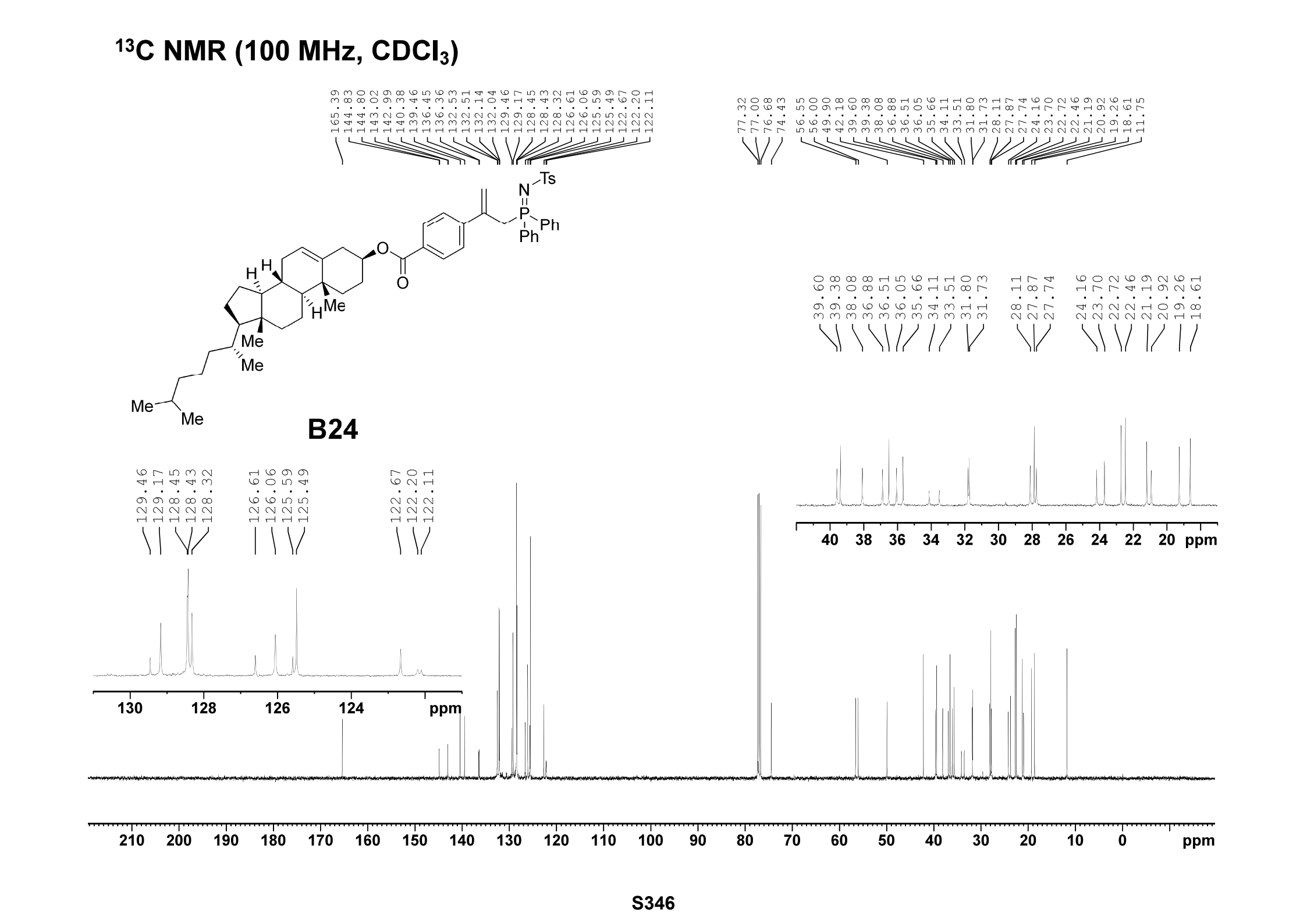


B23

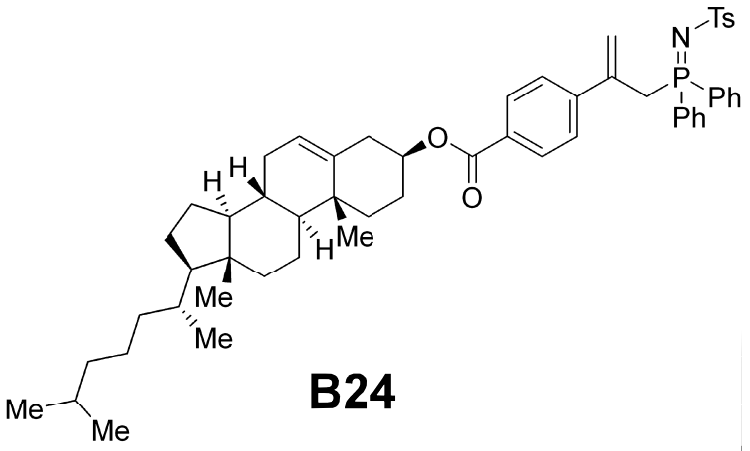
^{1}H NMR ($CDCl_3$, 400 MHz)



^{13}C NMR (100 MHz, $CDCl_3$)

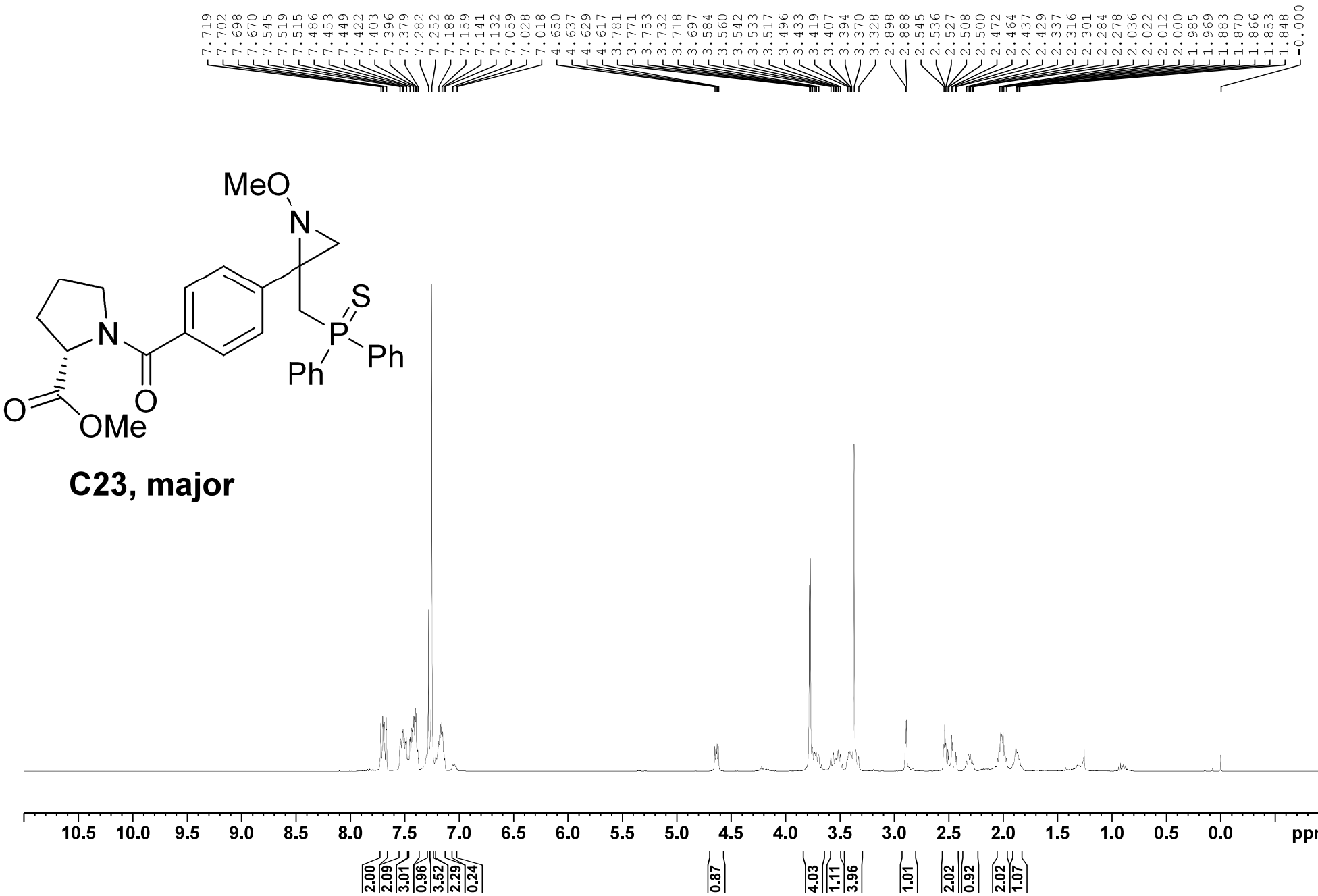


^{31}P NMR (162 MHz, $CDCl_3$)

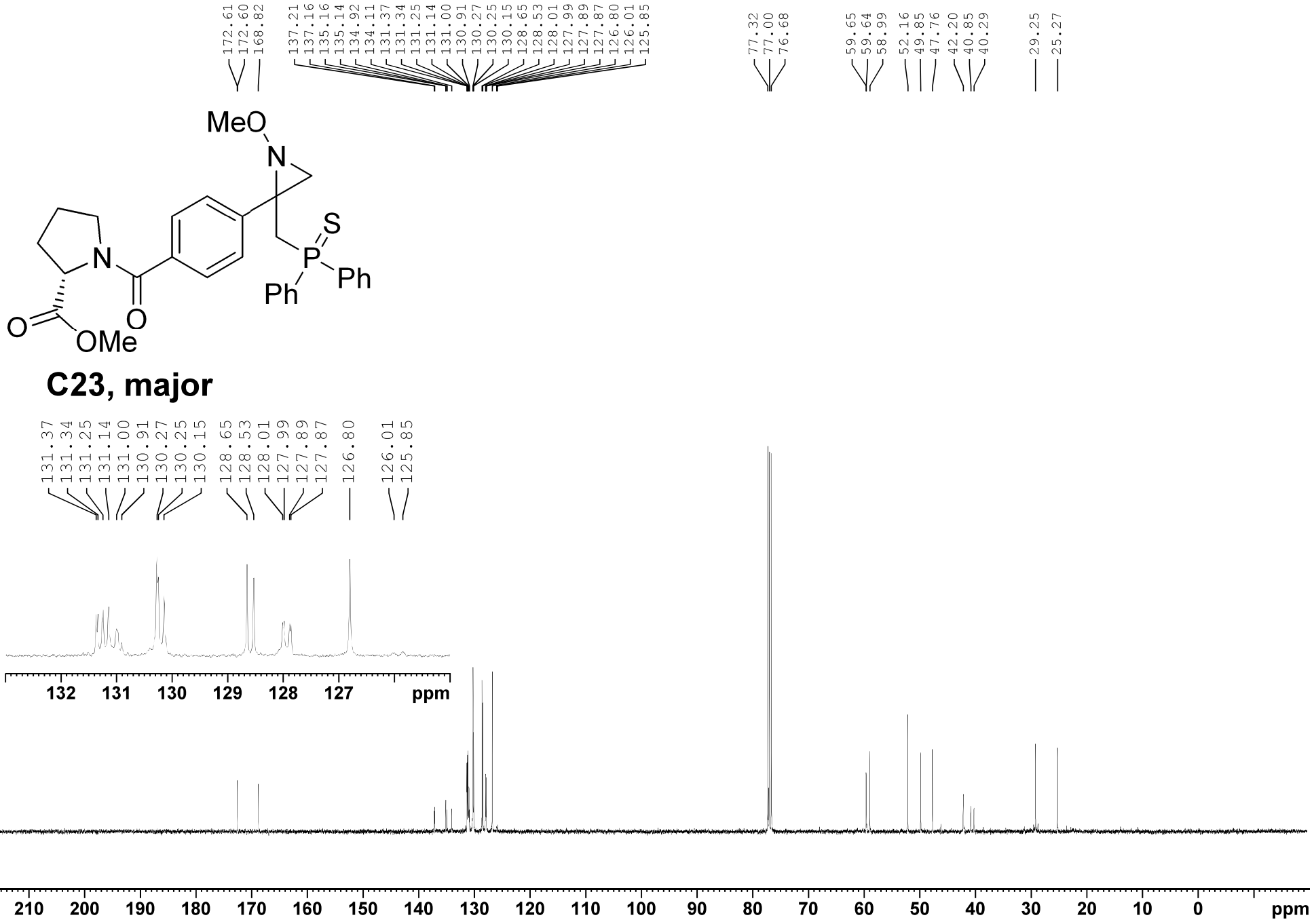


B24

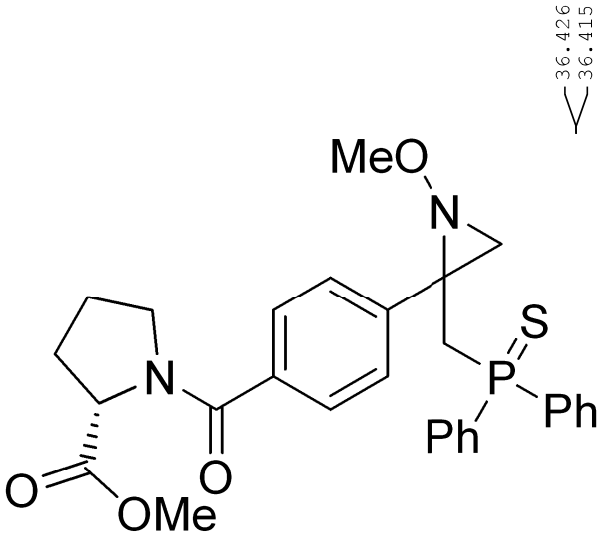
^{1}H NMR ($CDCl_3$, 400 MHz)



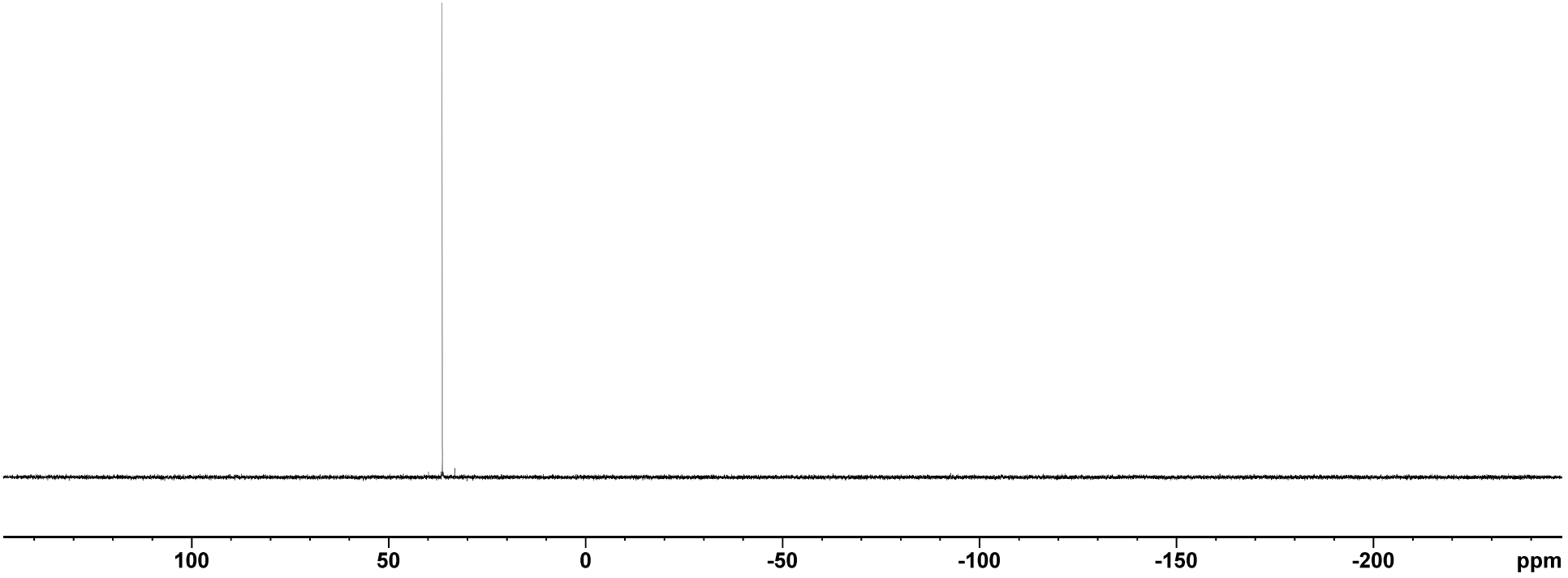
^{13}C NMR (100 MHz, $CDCl_3$)



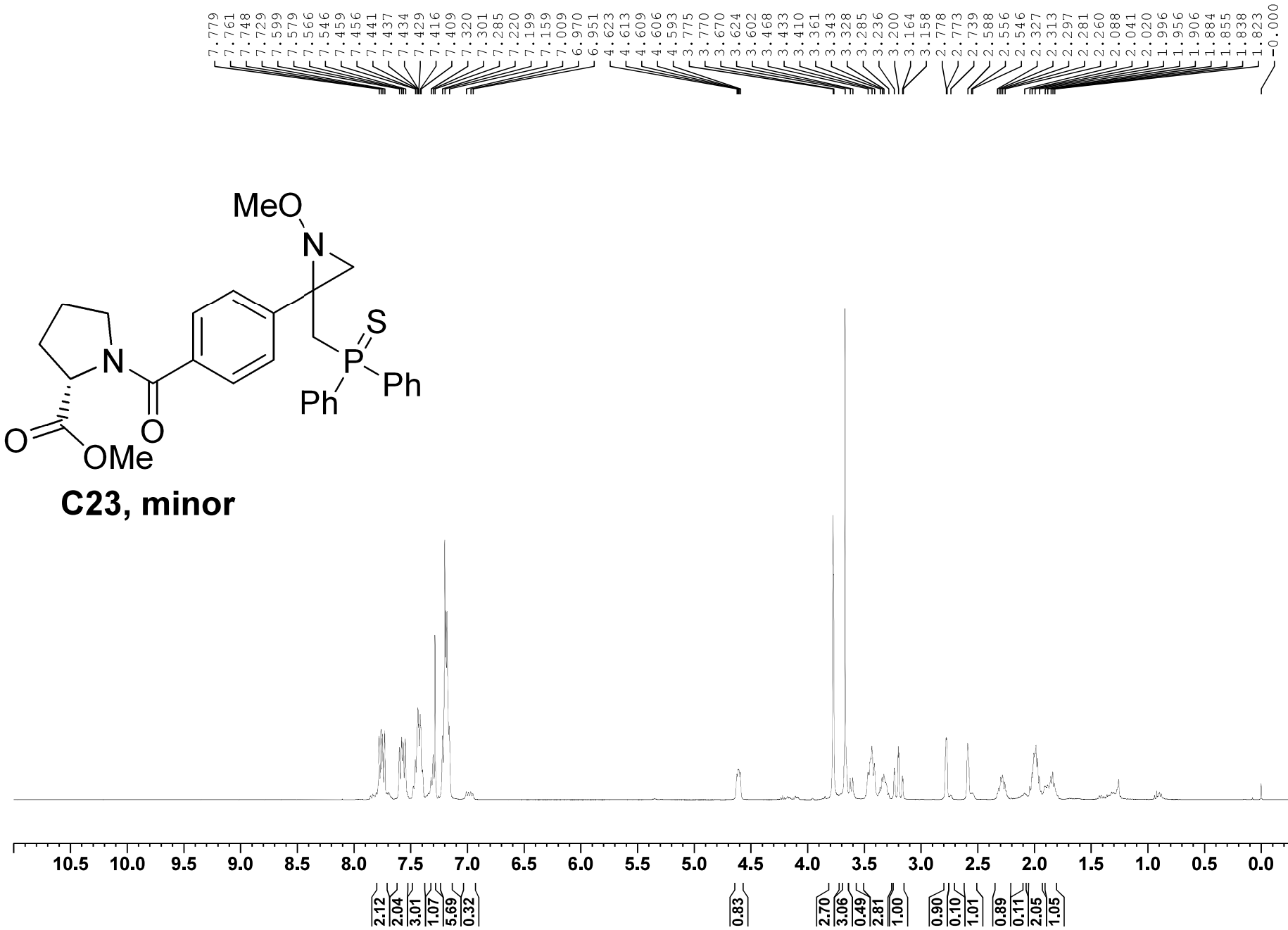
^{31}P NMR (162 MHz, $CDCl_3$)



C23, major

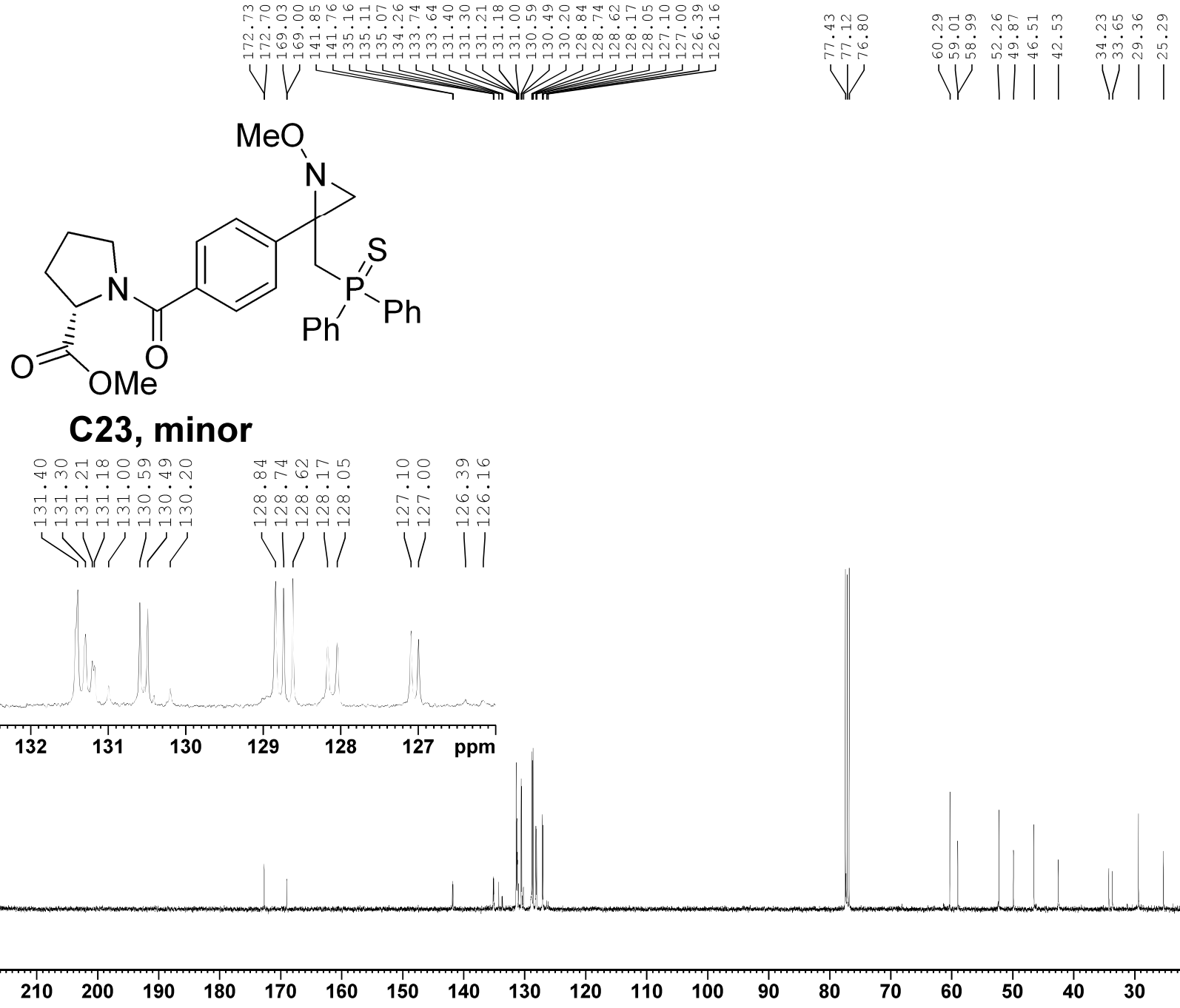


^{1}H NMR ($CDCl_3$, 400 MHz)

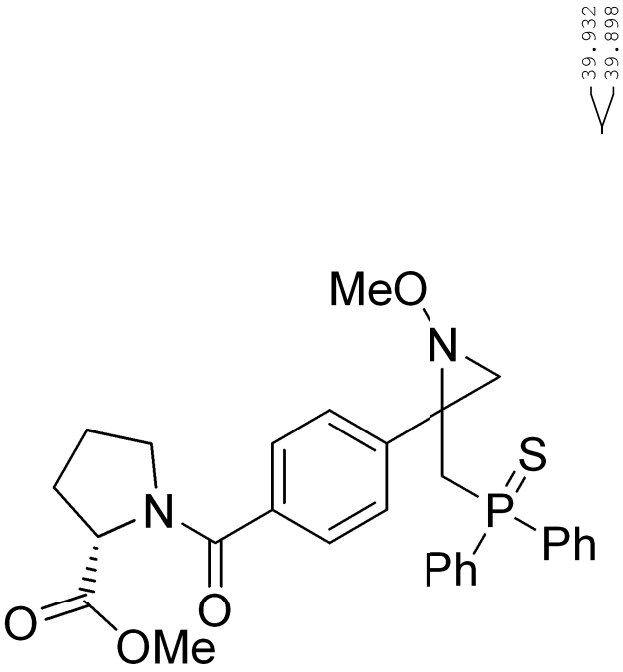


C23, minor

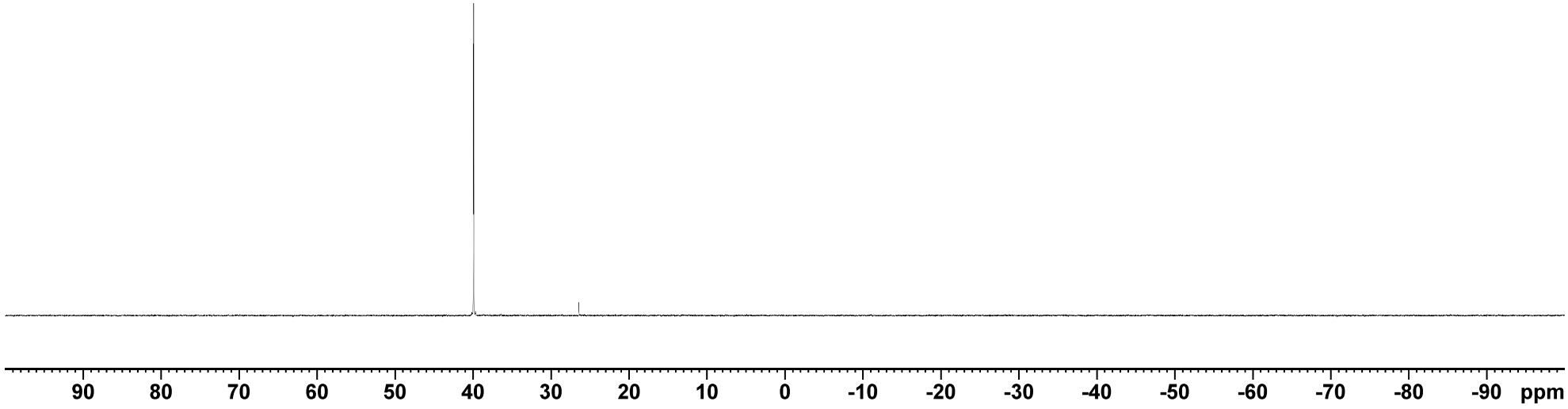
^{13}C NMR (100 MHz, $CDCl_3$)



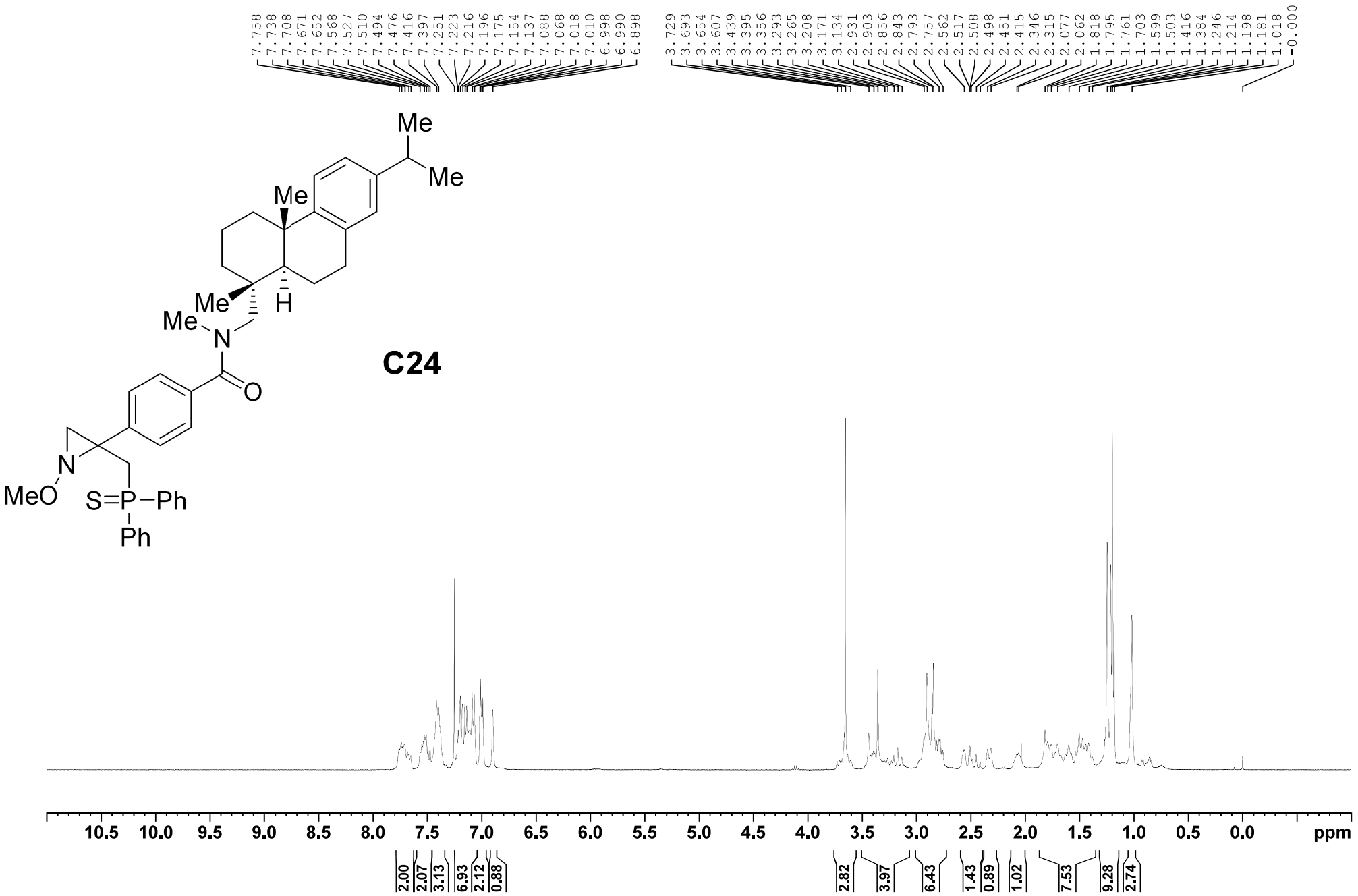
^{31}P NMR (162 MHz, $CDCl_3$)



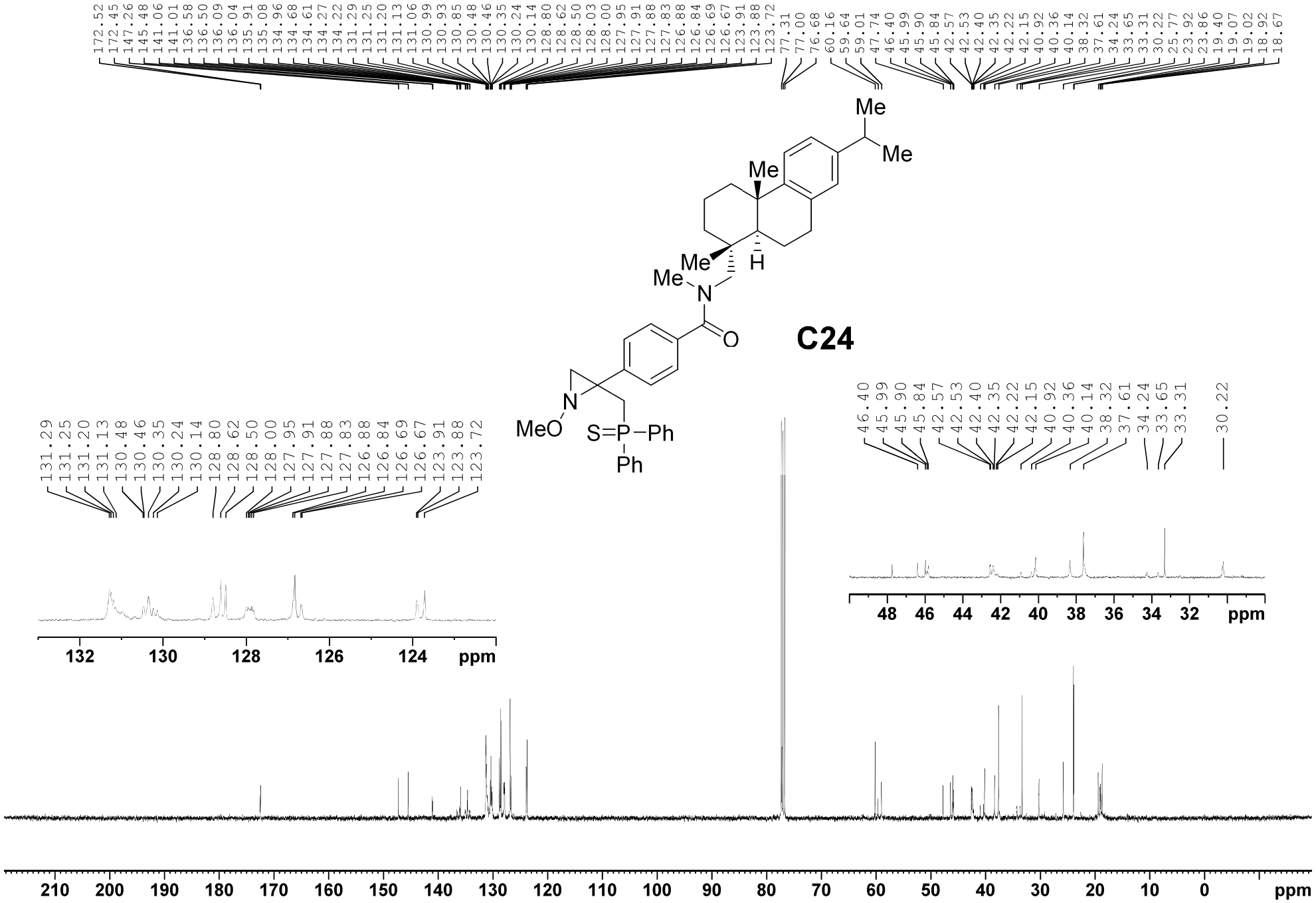
C23, minor



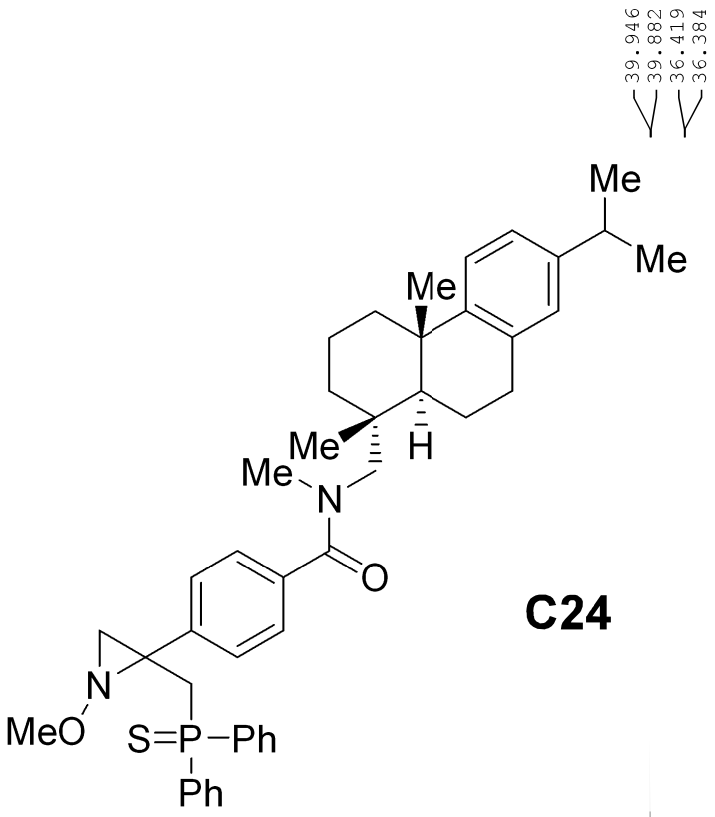
^{1}H NMR ($CDCl_3$, 400 MHz)



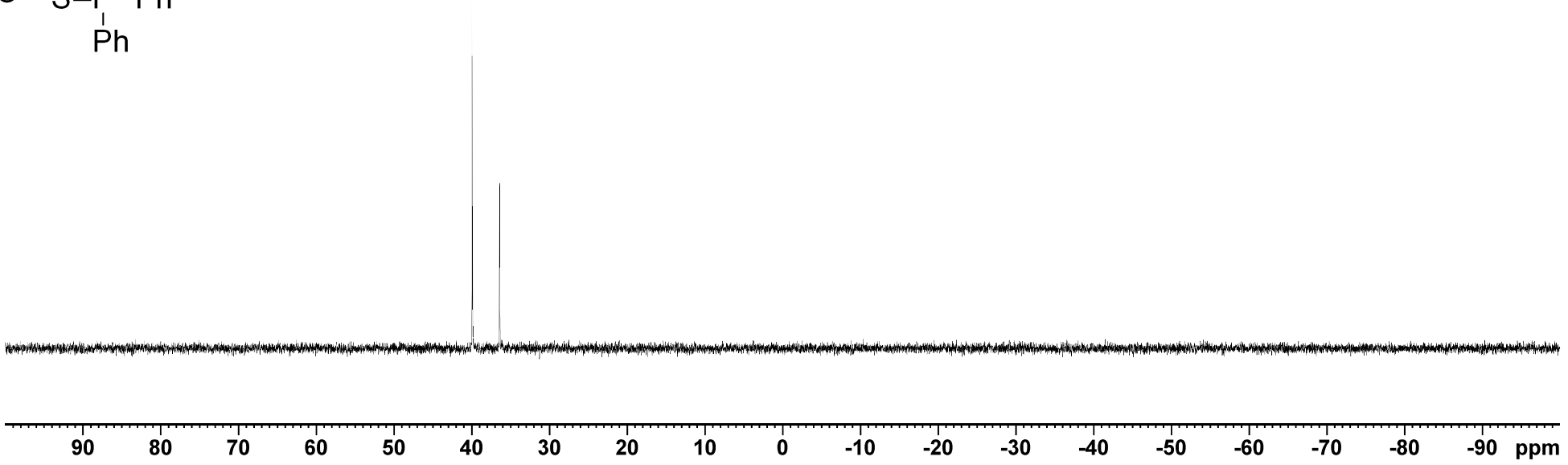
^{13}C NMR (100 MHz, $CDCl_3$)



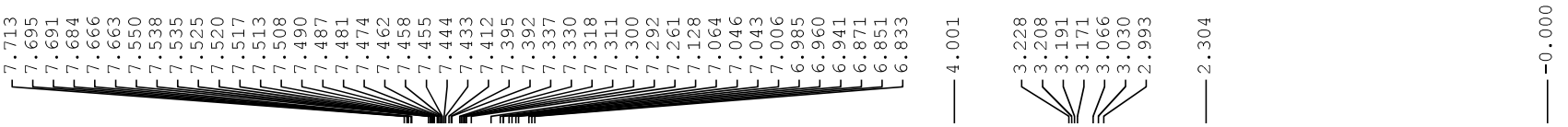
^{31}P NMR (162 MHz, $CDCl_3$)

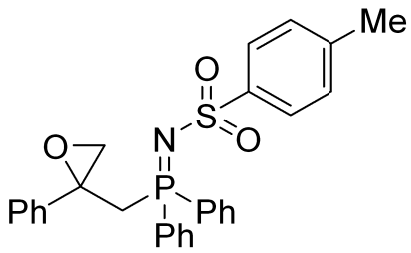


C24

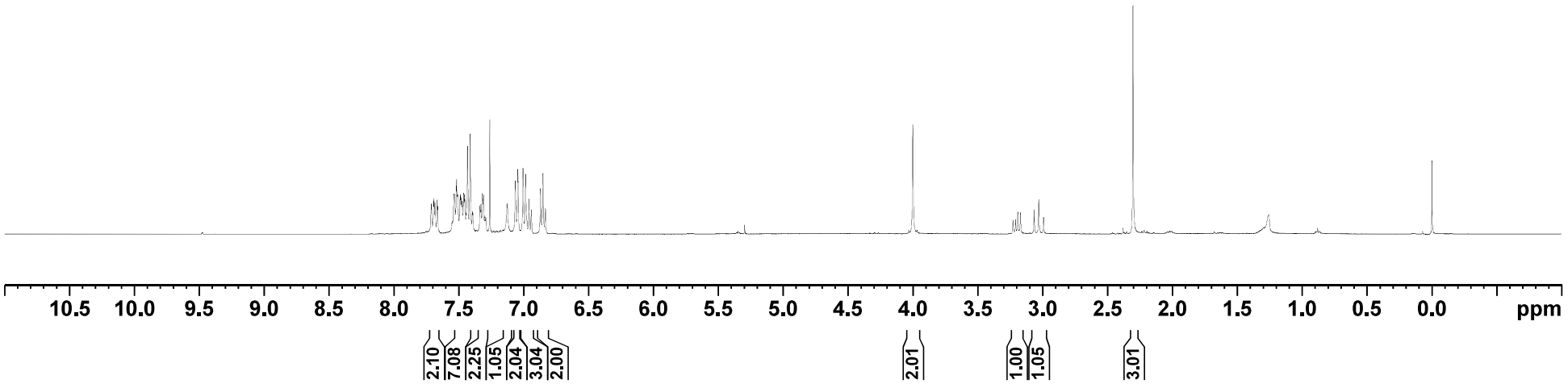


^{1}H NMR ($CDCl_3$, 400 MHz)

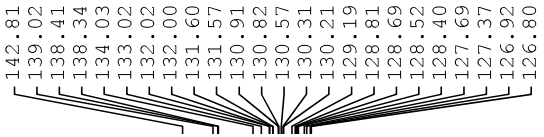


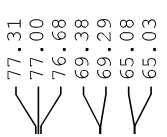


D1

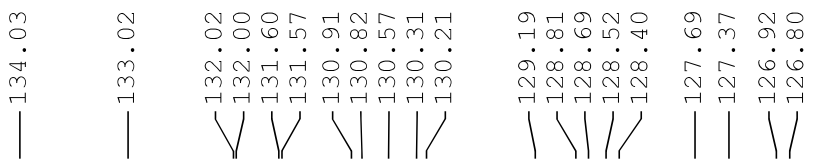


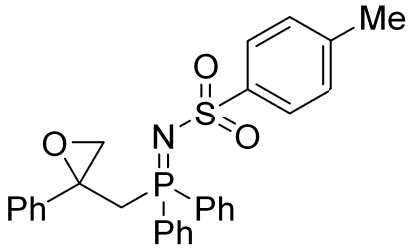
^{13}C NMR (100 MHz, $CDCl_3$)



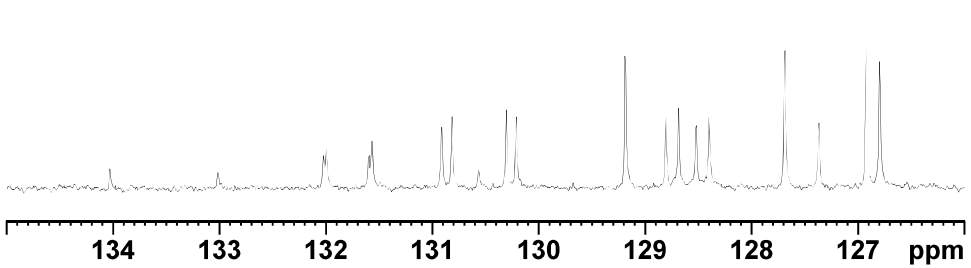




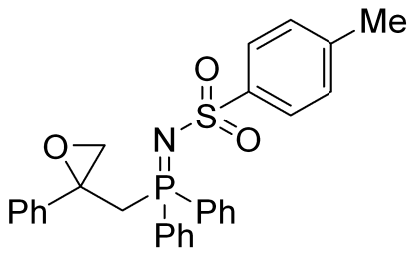




D1

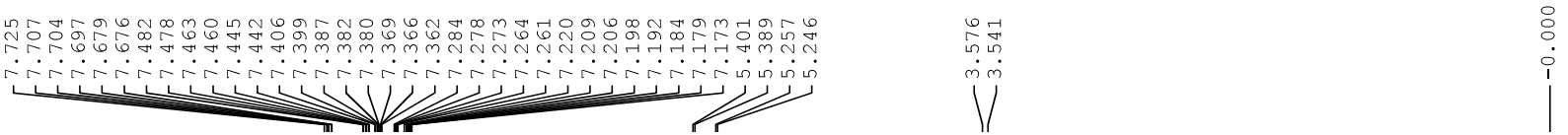


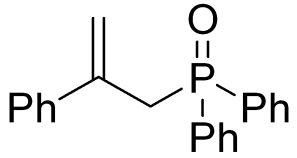
^{31}P NMR (162 MHz, $CDCl_3$)



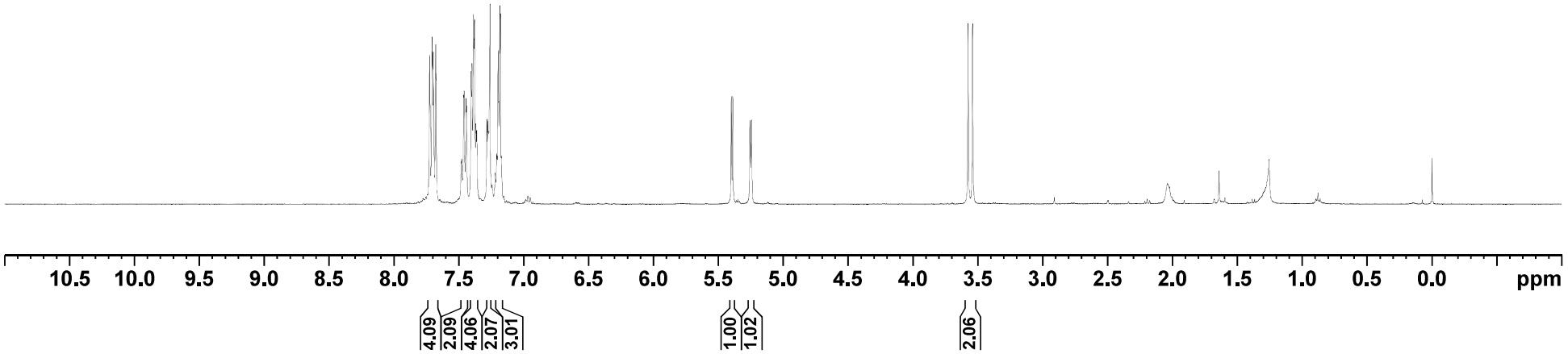
D1

^{1}H NMR ($CDCl_3$, 400 MHz)

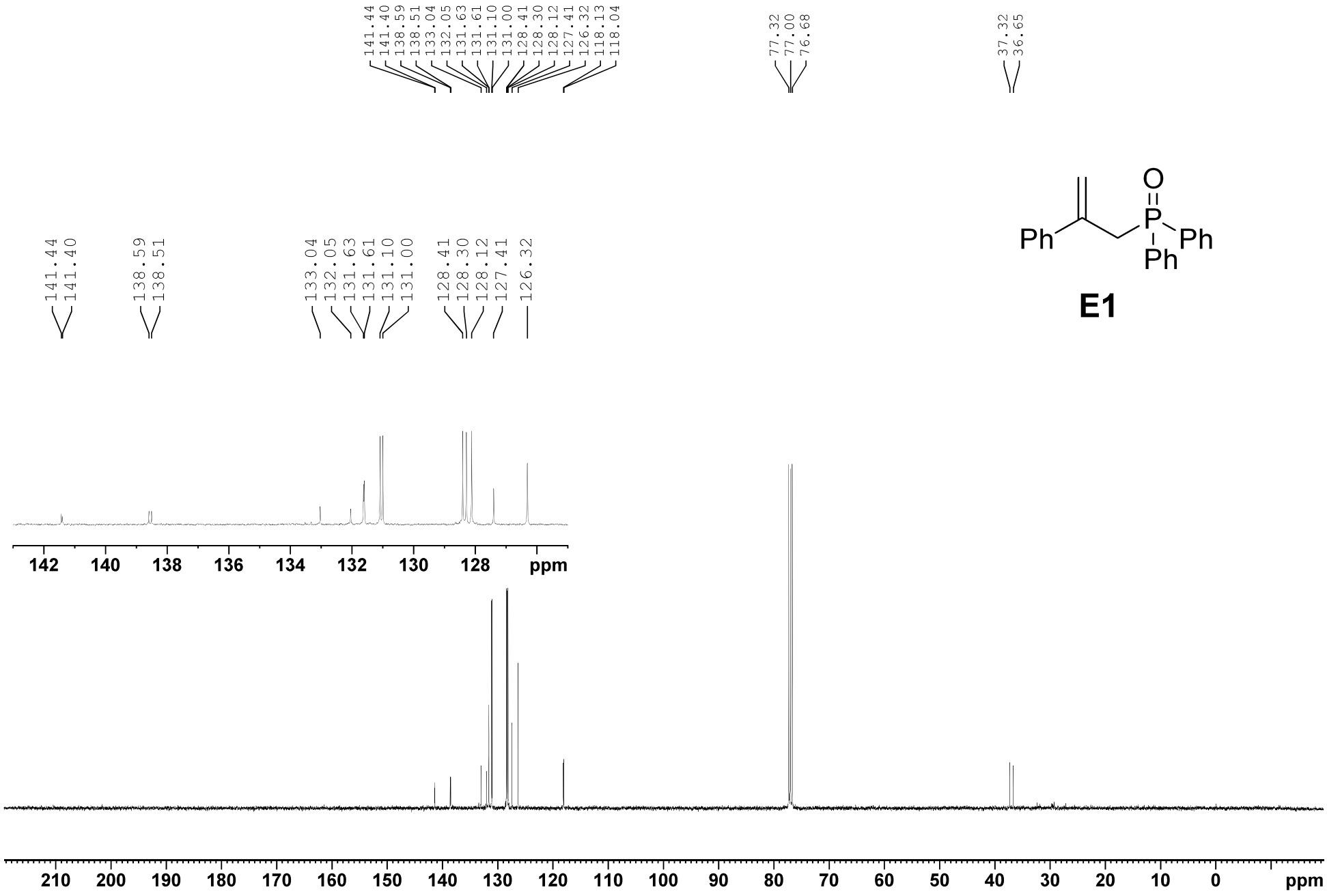




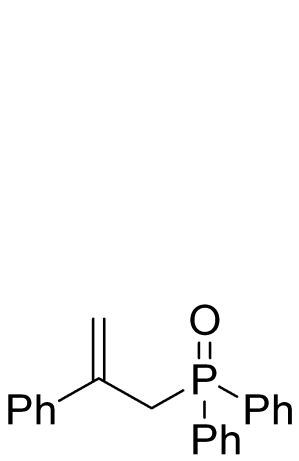
E1



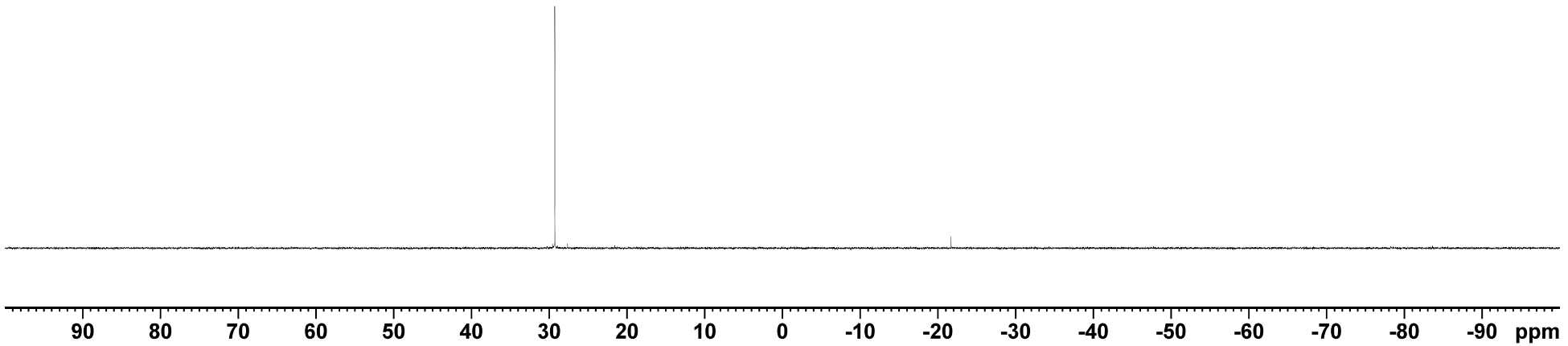
^{13}C NMR (100 MHz, $CDCl_3$)



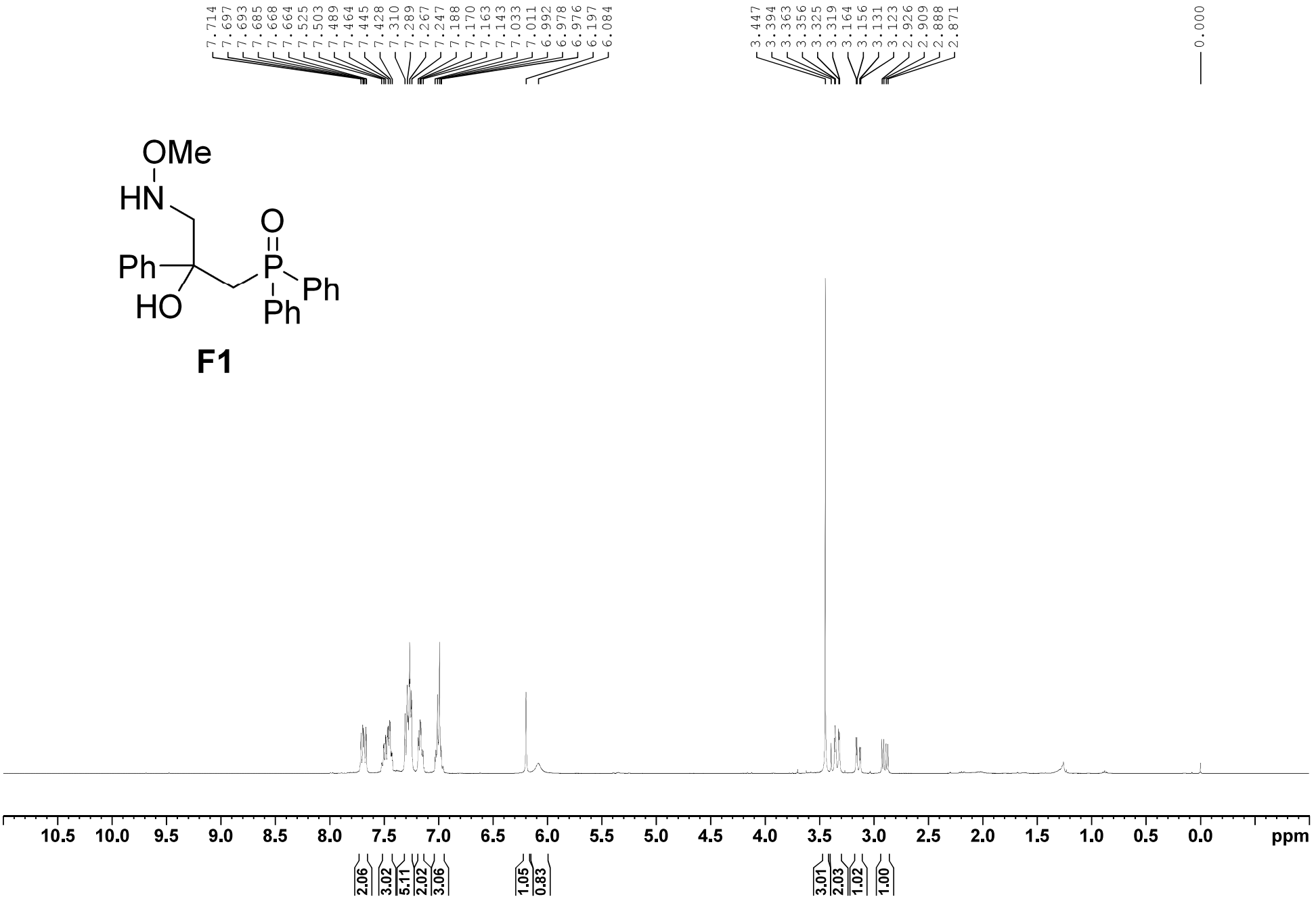
^{31}P NMR (162 MHz, $CDCl_3$)



E1

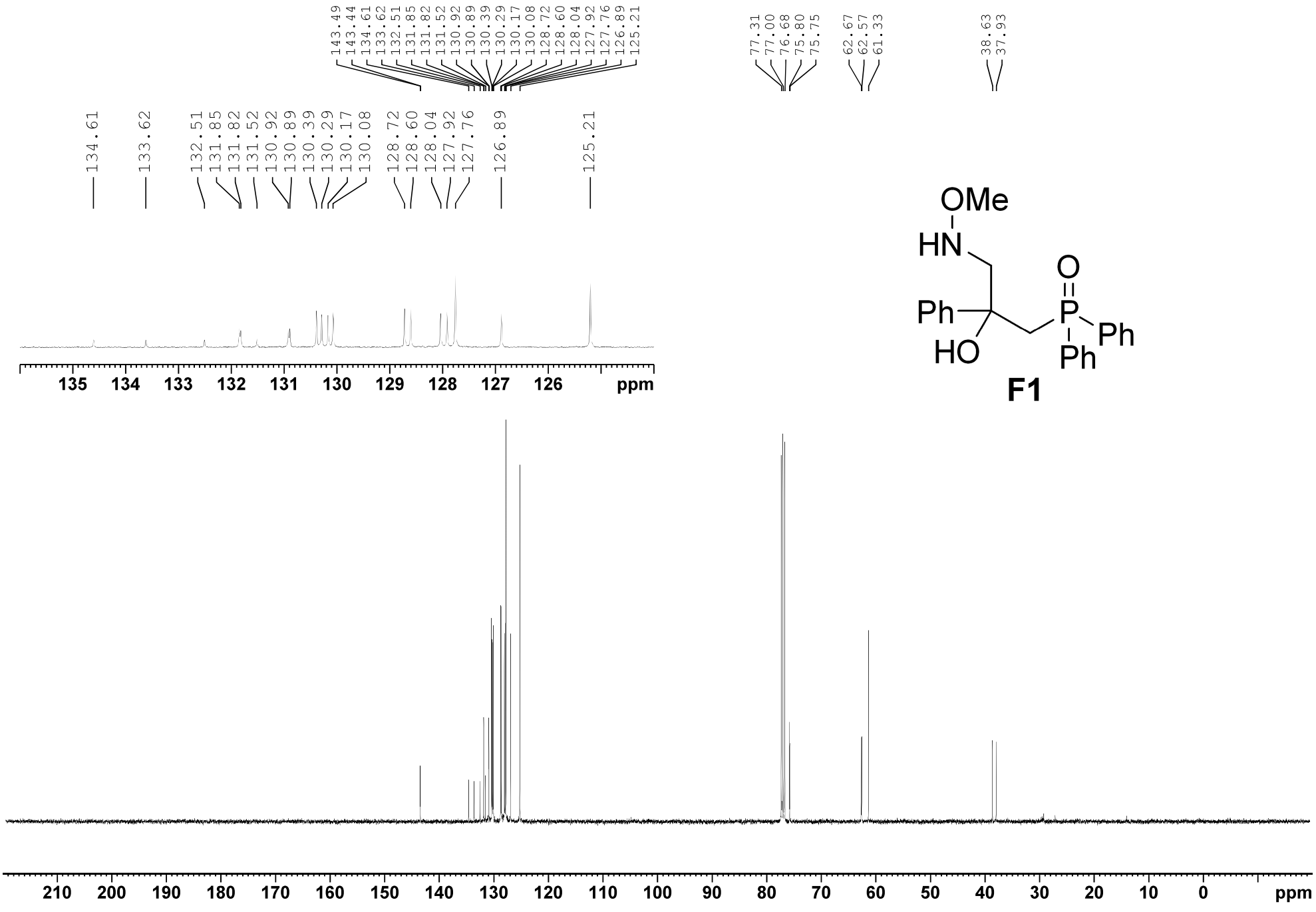


^{1}H NMR ($CDCl_3$, 400 MHz)

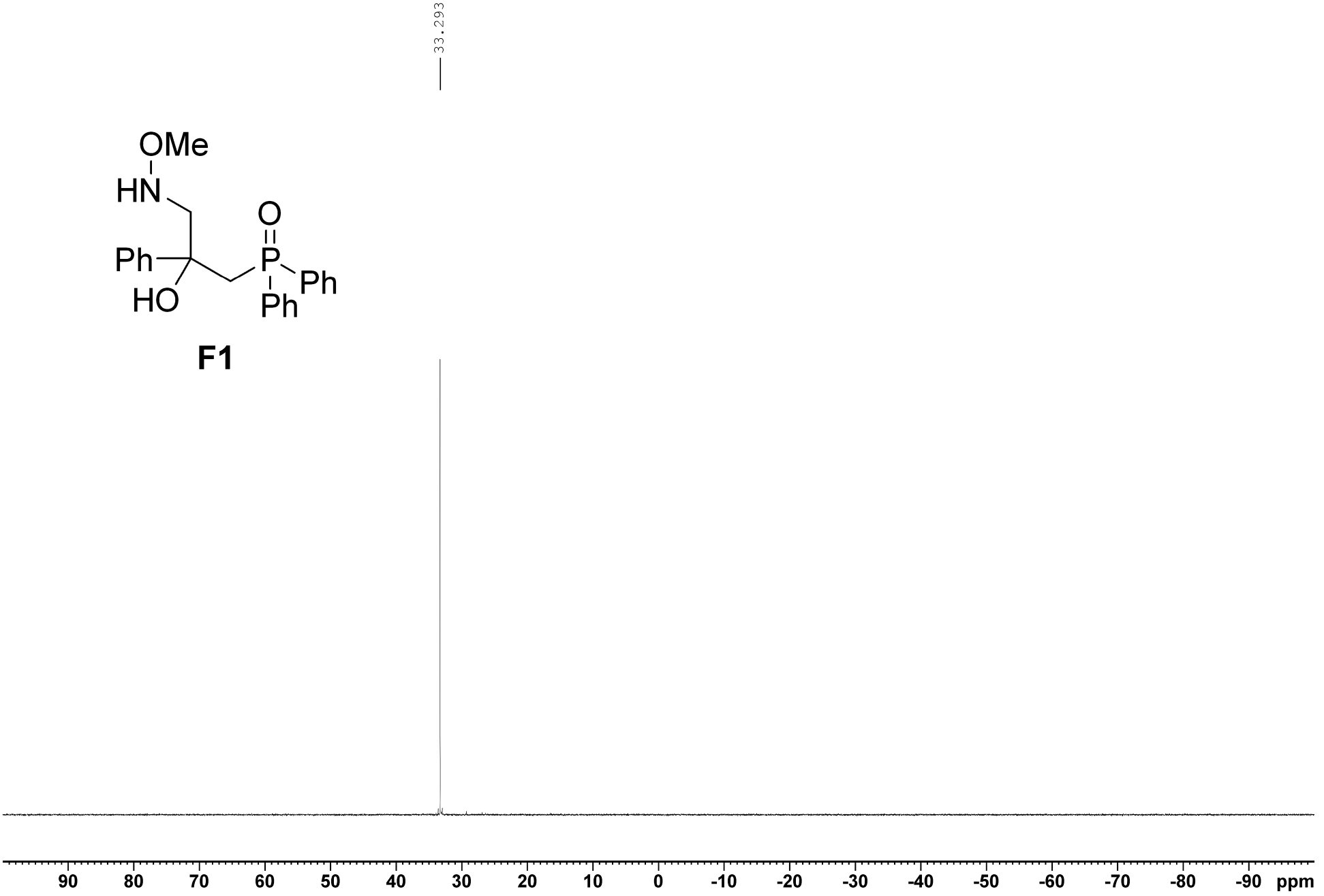


F1

^{13}C NMR (100 MHz, $CDCl_3$)

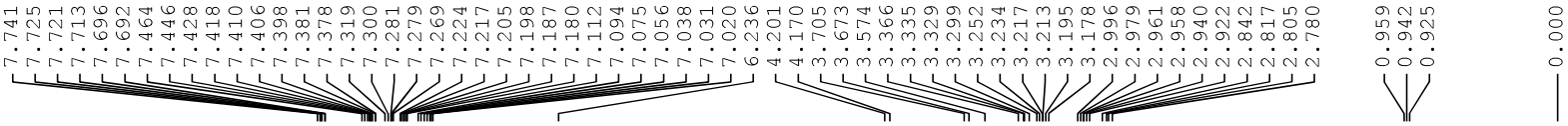


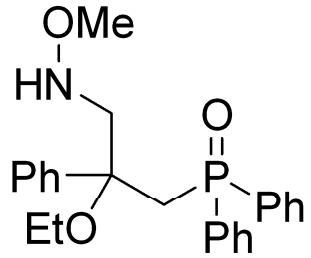
^{31}P NMR (162 MHz, $CDCl_3$)



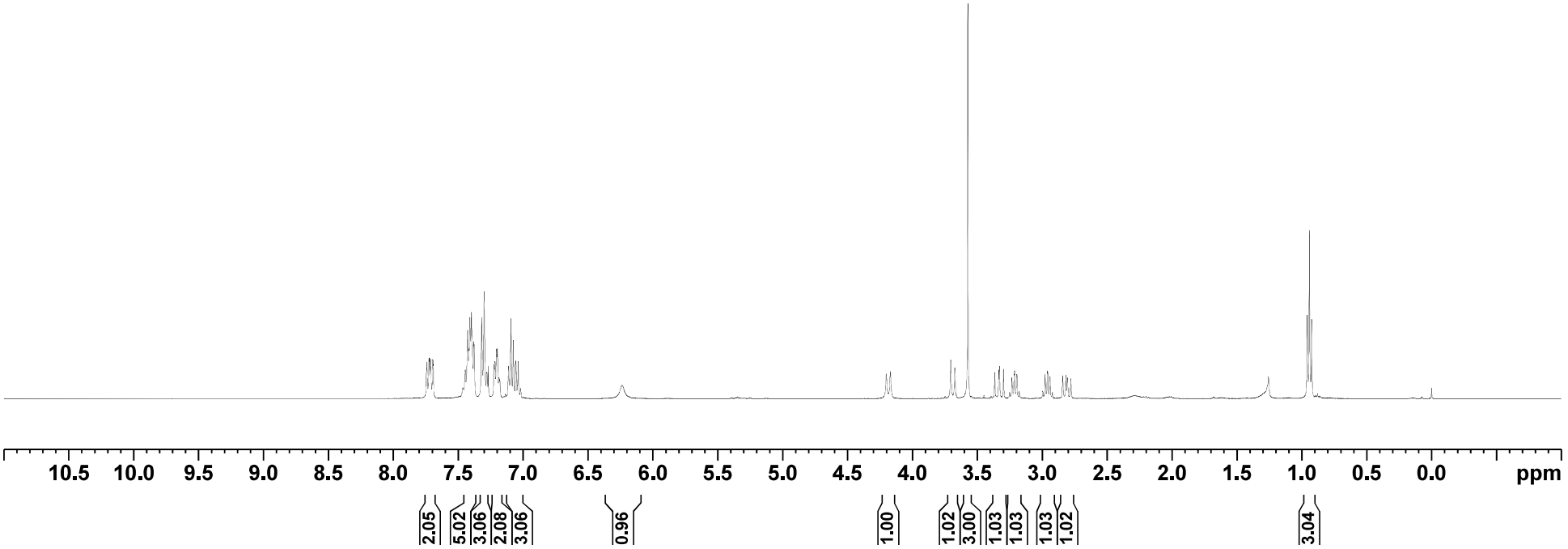
F1

^{1}H NMR ($CDCl_3$, 400 MHz)

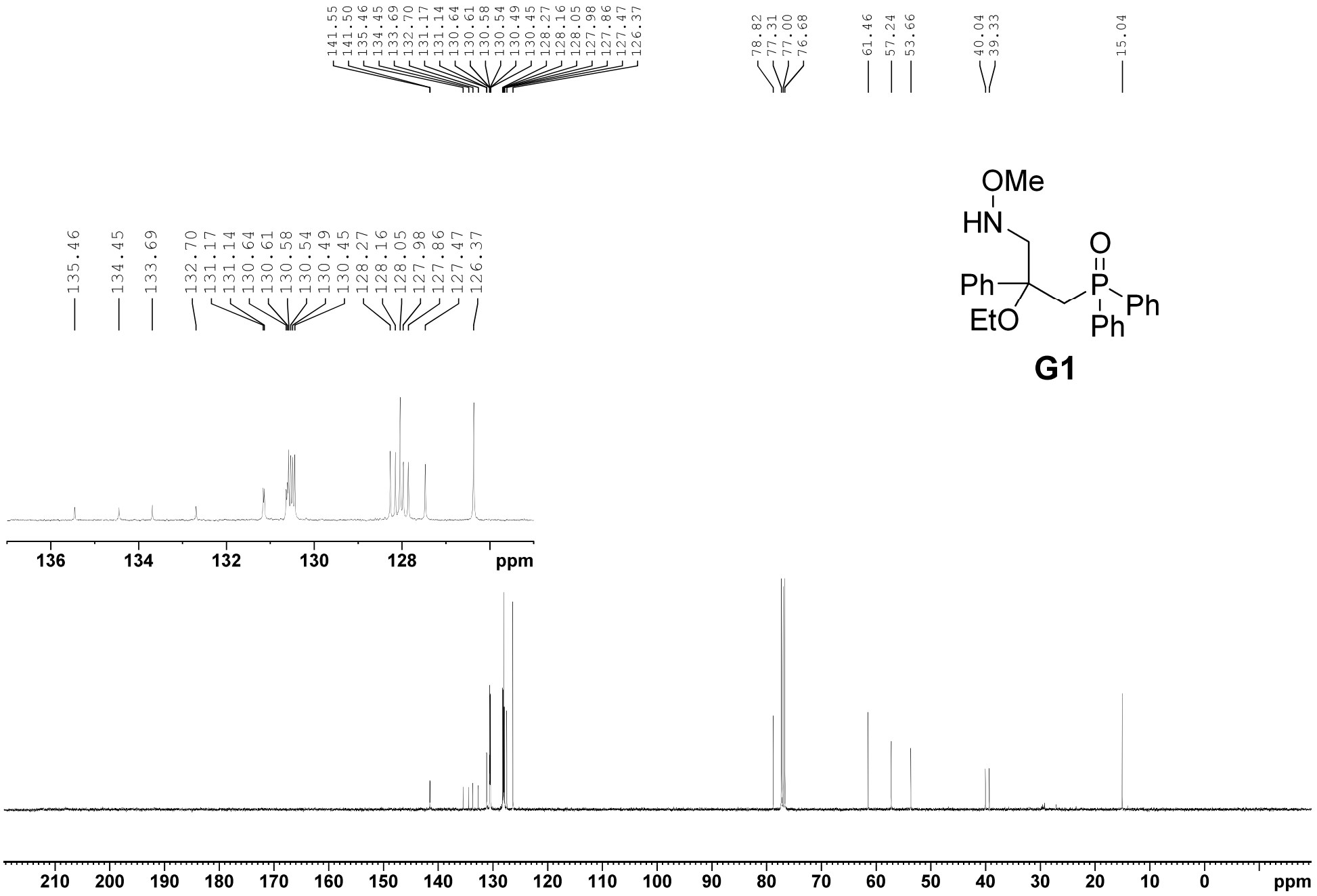




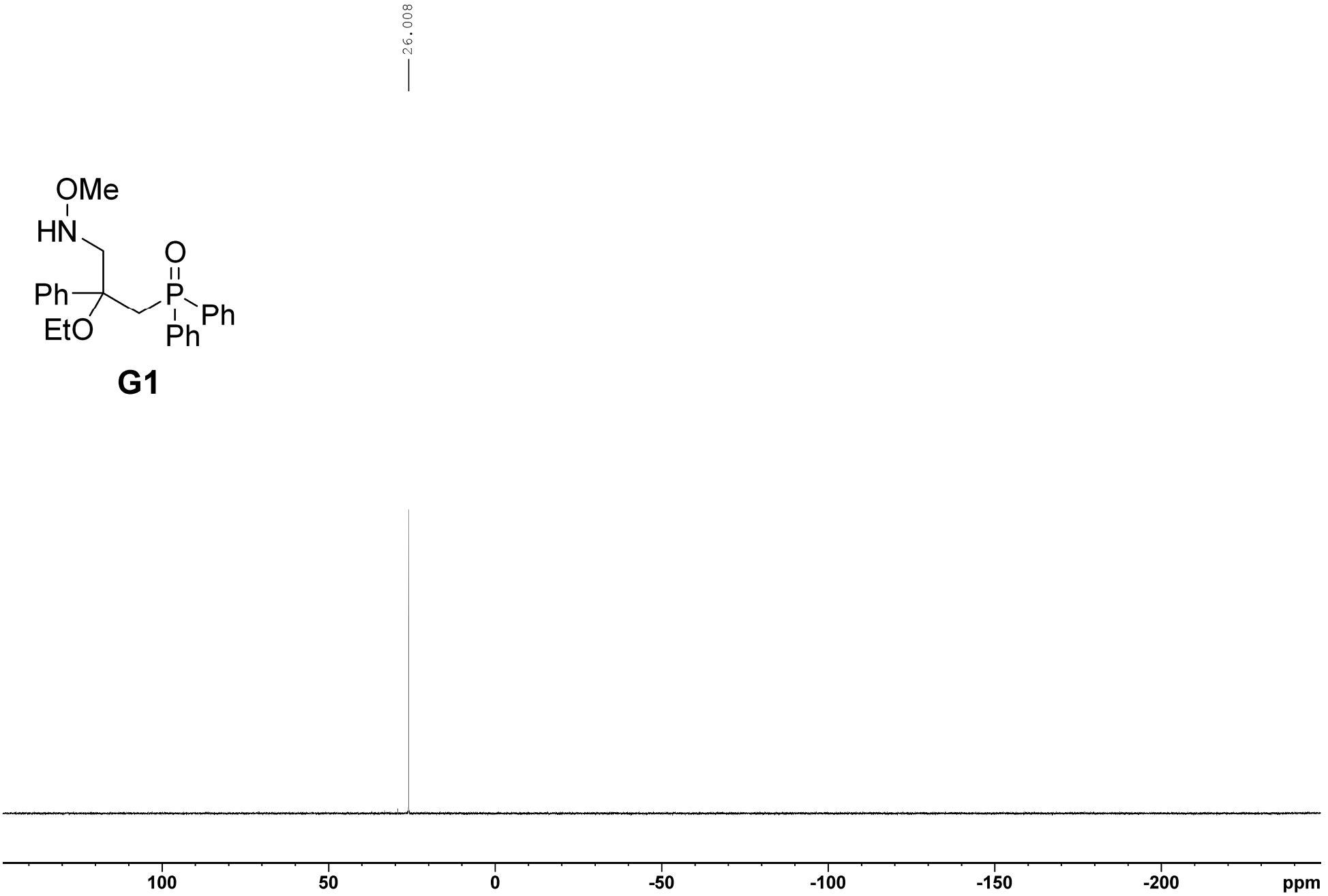
G1



^{13}C NMR (100 MHz, $CDCl_3$)



^{31}P NMR (162 MHz, $CDCl_3$)



G1