

Supplementary Material for

Dehydrogenative Coupling of Hydrosilanes and Alcohols by Alkali Metal Catalysts for Facile Synthesis of Silyl Ethers

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Experimental Section

General: All manipulations of air-sensitive materials were performed under inert atmosphere in flame dried Schlenk-type glassware, either on a dual manifold Schlenk line interfaced with a high vacuum (10^{-4} Torr) line, or in an argon-filled M. Braun glovebox. ^1H NMR (400 MHz) and $^{13}\text{C}\{^1\text{H}\}$ (100 MHz), spectra were recorded on a BRUKER AVANCE III-400 spectrometer. All alcohols and silanes were purchased from either Sigma Aldrich or Alfa Aesar. Alcohols (methanol and ethanol) were distilled over Sodium metal prior to use. $\text{LiN}(\text{SiMe}_3)_2$, $\text{NaN}(\text{SiMe}_3)_2$ and $\text{KN}(\text{SiMe}_3)_2$ were purchased from Sigma Aldrich and used as received. NMR solvent (CDCl_3) was purchased from Alfa aesar.

Typical procedure for CDC reactions: Catalyzed cross-dehydrocoupling (CDC) reactions were carried out by using the following standard protocol. In the glove-box, the chosen precatalyst (0.05 mmol) was loaded into a Schlenk tube and subsequently the alcohol ($n \times 0.05$ mmol, n equiv) followed by silane ($n' \times 0.05$ mmol, n' equiv) were added to the Schlenk tube. The reaction was stirred in an oil bath at the desired temperature (30°C). After the required period of time, the reaction was quenched by adding CDCl_3 to the mixture. Substrate conversion was monitored by examination of the ^1H NMR spectrum of the reaction mixture, comparing relative intensities of resonances characteristic of the substrates and products.

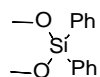
Product – A



The dehydrogenative coupling of phenylsilane (54 mg, 0.5 mmol) into methanol (48 mg, 1.5 mmol) was carried out following the general procedure described above. trimethoxy(phenyl)silane (A) was obtained in 99 % yield after a reaction time of 1 hour.

Yield: 98.2 mg,

Product – B



The dehydrogenative coupling of Diphenylsilane (92 mg, 0.5 mmol) into methanol (32 mg, 1.5 mmol) was carried out following the general procedure described above. dimethoxydiphenylsilane (**B**) was obtained in 99 % yield after a reaction time of 2 hour.

Yield: 120.95 mg,

Product – C



The dehydrogenative coupling of triphenylsilane (130.1 mg, 0.5 mmol) into methanol (16 mg, 0.5 mmol) was carried out following the general procedure described above. methoxytriphenylsilane (**C**) was obtained in 99 % yield after a reaction time of 2 hour.

Yield: 144 mg,

Product – D



The dehydrogenative coupling of diethylsilane (44mg, 0.5 mmol) into methanol (32 mg, 1.0 mmol) was carried out following the general procedure described above. diethyldimethoxysilane (**D**) was obtained in 72 % yield after a reaction time of 3 hour.

Yield: 53 mg,

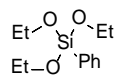
Product – E



The dehydrogenative coupling of triethylsilane (58.1 mg, 0.5 mmol) into methanol (16 mg, 0.5 mmol) was carried out following the general procedure described above. triethyl(methoxy)silane (**E**) was obtained in 88 % yield after a reaction time of 3 hour.

Yield: 65 mg,

Product – F



The dehydrogenative coupling of Phenylsilane (54 mg, 0.5 mmol) into ethanol (69 mg, 1.5 mmol) was carried out following the general procedure described above. triethoxy(phenyl)silane (**F**) was obtained in 96 % yield after a reaction time of 3 hour.

Yield: 115 mg,

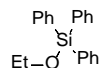
Product – G



The dehydrogenative coupling of diphenylsilane (92 mg, 0.5 mmol) into ethanol (46 mg, 1.0 mmol) was carried out following the general procedure described above diethoxydiphenylsilane (**G**) was obtained in 93 % yield after a reaction time of 3 hour.

Yield: 127 mg,

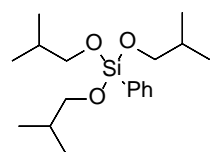
Product – H



The dehydrogenative coupling of triphenylsilane (130.1 mg, 0.5 mmol) into ethanol (23 mg, 0.5 mmol) was carried out following the general procedure described above. ethoxytriphenylsilane (**H**) was obtained in 94 % yield after a reaction time of 3 hour.

Yield: 143 mg,

Product – I

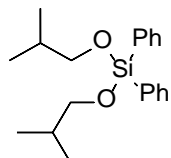


The dehydrogenative coupling of Phenylsilane (54 mg, 0.5 mmol) into isopropanol (111.3 mg, 1.5 mmol) was carried out following the general procedure described above. triisobutoxy(phenyl)silane (**I**) was obtained in 97 % yield after a reaction time of 3 hour.

Yield: 158 mg,

^1H NMR (400 MHz, CDCl_3) δ 7.58- 7.56 (m, 2H), 7.28 – 7.22 (m, 3H), 3.49 (d, J = 6.5 Hz, 6H), 1.77 -1.67 (m, 3H), 0.80 (d, J = 6.7 Hz, 18H) ppm. ^{13}C {1H} (100 MHz) 134.92, 127.81, 69.62, 30.74, 19.03. MS: m/z 324.53 (M^+).

Product – J

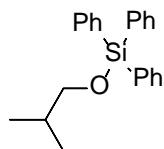


The dehydrogenative coupling of diphenylsilane (92 mg, 0.5 mmol) into isopropanol (74.2 mg, 1.0 mmol) was carried out following the general procedure described above. diisobutoxy(diphenyl)silane (**J**) was obtained in 96 % yield after a reaction time of 3 hour.

Yield: 158 mg,

^1H NMR (400 MHz, CDCl_3) δ 7.96- 7.57 (m, 10H), 3.81 (d, J = 6.5 Hz, 4H), 2.11 (sept, 3H), 1.18 (d, J = 6.7 Hz, 12H) ppm. ^{13}C {1H} (100 MHz) 135.19, 127.99, 69.78, 30.96, 19.27. MS: m/z 328.18 (M^+).

Product – K

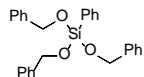


The dehydrogenative coupling of triphenylsilane (130.1 mg, 0.5 mmol) into isopropanol (37.1 mg, 0.5 mmol) was carried out following the general procedure described above. isobutoxy(triphenyl)silane (**K**) was obtained in 95 % yield after a reaction time of 3 hour.

Yield: 158 mg,

^1H NMR (400 MHz, CDCl_3) δ 7.57 - 7.29 (m, 15H), 3.81 (d, $J = 6.5$ Hz, 4H), 1.82 (sept, 1H), 0.84 (d, $J = 6.7$ Hz, 6H) ppm. ^{13}C {1H} (100 MHz) 135.44, 134.55, 129.93, 127.83, 70.40, 30.82, 19.08. MS: m/z 332.15 (M^+).

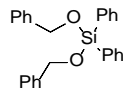
Product – L



The dehydrogenative coupling of Phenylsilane (54 mg, 0.5 mmol) into benzylalcohol (162 mg, 1.5 mmol) was carried out following the general procedure described above. tris(benzyloxy)(phenyl)silane (**L**) was obtained in 68 % yield after a reaction time of 4 hour.

Yield: 145 mg,

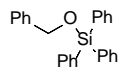
Product –M



The dehydrogenative coupling of diphenylsilane (92 mg, 0.5 mmol) into benzylalcohol (108 mg, 1.0 mmol) was carried out following the general procedure described above. bis(benzyloxy)(diphenyl)silane (**M**) was obtained in 68 % yield after a reaction time of 4 hour.

Yield: 135 mg,

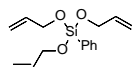
Product – N



The dehydrogenative coupling of triphenylsilane (130.1 mg, 0.5 mmol) into benzylalcohol (54 mg, 0.5 mmol) was carried out following the general procedure described above. benzyloxy(triphenyl)silane (**N**) was obtained in 57 % yield after a reaction time of 3 hour.

Yield: 104.5 mg,

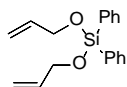
Product –O



The dehydrogenative coupling of Phenylsilane (54 mg, 0.5 mmol) into allyl alcohol (87 mg, 1.5 mmol) was carried out following the general procedure described above. phenyltris(vinyloxy)silane (**O**) was obtained in 88 % yield after a reaction time of 3 hour.

Yield: 122 mg,

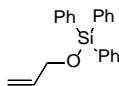
Product –P



The dehydrogenative coupling of diphenylsilane (92 mg, 0.5 mmol) into allyl alcohol (58mg, 1.0 mmol) was carried out following the general procedure described above. diphenylbis(vinyloxy)silane (**P**) was obtained in 82 % yield after a reaction time of 3 hour.

Yield: 122 mg,

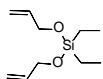
Product – Q



The dehydrogenative coupling of triphenylsilane (130.1 mg, 0.5 mmol) into allyl alcohol (29 mg, 0.5 mmol) was carried out following the general procedure described above. triphenyl(vinyloxy)silane (**Q**) was obtained in 75 % yield after a reaction time of 4 hour.

Yield: 119 mg,

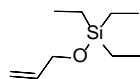
Product – R



The dehydrogenative coupling of diethylsilane (44 mg, 0.5 mmol) into allyl alcohol (58 mg, 1 mmol) was carried out following the general procedure described above. diethylbis(vinyloxy)silane (**R**) was obtained in 82 % yield after a reaction time of 4 hour.

Yield: 83 mg,

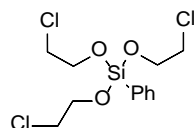
Product –S



The dehydrogenative coupling of triethylsilane (58 mg, 0.5 mmol) into allyl alcohol (29 mg, 0.5 mmol) was carried out following the general procedure described above. triethyl(vinyloxy)silane (**A**) was obtained in 70 % yield after a reaction time of 4 hour.

Yield: 61 mg,

Product – T

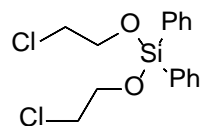


^1H NMR (400 MHz, CDCl_3) δ 7.56 - 7.23 (m, 5H), 3.99 (t, $J = 5.8$ Hz, 6H), 3.54 (t, $J = 5.8$ Hz, 6H) ppm. ^{13}C {1H} (100 MHz) 135.36, 135.63, 129.09, 128.65, 64.06, 45.41. MS: m/z 342.00 (M^+).

The dehydrogenative coupling of Phenylsilane (54 mg, 0.5 mmol) into 2-chloroethanol (120.8 mg, 1.5 mmol) was carried out following the general procedure described above. tris(2-chloroethoxy)phenylsilane (**T**) was obtained in 87% yield after a reaction time of 4 hour.

Yield: 150 mg,

Product – U

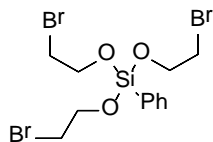


^1H NMR (400 MHz, CDCl_3) δ 7.55 - 7.21 (m, 10H), 3.90 (t, $J = 5.8$ Hz, 4H), 3.49 (t, $J = 5.9$ Hz, 4H) ppm. ^{13}C {1H} (100 MHz) 135.42, 131.20, 128.51, 63.93, 45.49. MS: m/z 340.04 (M^+).

The dehydrogenative coupling of diphenylsilane (92 mg, 0.5 mmol) into 2-chloroethanol (80.51 mg, 1 mmol) was carried out following the general procedure described above. bis(2-chloroethoxy)diphenylsilane (**U**) was obtained in 95 % yield after a reaction time of 4 hour.

Yield: 162 mg.

Product – V

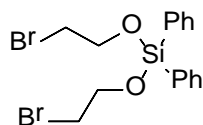


The dehydrogenative coupling of Phenylsilane (54 mg, 0.5 mmol) into 2-bromoethanol (185.9 mg, 1.5 mmol) was carried out following the general procedure described above. tris(2-bromoethoxy)phenylsilane methoxyphenylsilane (**V**) was obtained in 92 % yield after a reaction time of 4 hour.

Yield: 219 mg,

$^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.56 - 7.20 (m, 5H), 3.99 (t, $J = 6.2$ Hz, 6H), 3.34 (t, $J = 6.2$ Hz, 6H) ppm. $^{13}\text{C}\{^1\text{H}\}$ (100 MHz) 136.25, 135.28, 130.24, 128.95, 128.54, 63.82, 33.29. MS: m/z 475.84 (M^+).

Product – W



The dehydrogenative coupling of diphenylsilane (92 mg, 0.5 mmol) into 2-bromoethanol (123.9 mg, 1.0 mmol) was carried out following the general procedure described above. bis(2-bromoethoxy)phenylsilane dimethoxy(phenyl)silane (**W**) was obtained in 96 % yield after a reaction time of 4 hour.

Yield: 206.5 mg,

$^1\text{H NMR}$ (400 MHz, CDCl_3) δ 7.59 - 7.08 (m, 10H), 3.96 (t, $J = 6.0$ Hz, 4H), 3.35 (t, $J = 6.2$ Hz, 4H) ppm. $^{13}\text{C}\{^1\text{H}\}$ (100 MHz) 135.42, 130.68, 128.16, 128.09, 63.96, 33.23. MS: m/z 429.94 (M^+).

[KN(SiMe₃)₂] (KBTSA) as a catalyst

A typical kinetics study was conducted to establish the reaction order with respect to Ph₃SiH, MeOH and KBTSA (catalyst). For dehydrogenative coupling reaction Ph₃SiH (0.130 g, 0.5 mmol) and MeOH (0.016 g, 0.5 mmol) was added to a solution of KBTSA (0.025, 0.03, 0.035, 0.04, 0.045 M) in C₆D₆ (0.4 mL), respectively. The solution was set in the NMR tube at 25°C. At the indicated time intervals, the tube was analyzed by ¹H NMR. The Ph₃SiH concentration was determined by integrating the singlet peak of SiH at 5.01 ppm and broad MeOH concentration was determined by integrating the singlet peak at 3.2-3.4 ppm. As expected, plots of Formation rates of Ph₃SiOMe versus the ratios of Ph₃SiH/MeOH vs. time for a wide range of catalyst [KBTSA] are linear. (Fig S1, Table S1). A plot of (*k*_{obs}) vs. [KBTSA] (Fig 2, Table 2) is also linear, with slope 0.50 which indicate the rate law of the reaction follow first order dependence with respect to catalyst KBTSA. Same experiment also conducted varying wide range of concentration of Ph₃SiH (0.3, 0.4, 0.5, 0.6, 0.7 M) and MeOH (0.4, 0.5, 0.6, 0.7, 0.8 M) which were also linear and follows first order dependence with respect to Ph₃SiH and MeOH. (Fig 3, Table3, Fig 4, Table4).

Table 1. First order kinetics plots for Ph₃SiH with time in C₆D₆ (0.4 mL) with different concentration of catalyst.

S.No	[Ph ₃ SiH]/[K]	Time(h:m)	Conversion ^a	[Product]	[Ph ₃ SiH] ^t	ln([Ph ₃ SiH] _t / [Ph ₃ SiH] ₀)
1	100/5	00.00	0%	0	0.5	0
2	100/5	00.15	26%	0.13	0.36	-0.31
3	100/5	00.30	36%	0.18	0.32	-0.45
4	100/5	00.45	44%	0.22	0.28	-0.57
5	100/5	01.00	53%	0.27	0.23	-0.75
6	100/5	01.15	56%	0.28	0.21	-0.84
7	100/5	01.30	62%	0.31	0.19	-0.97
8	100/5	01.45	67%	0.33	0.166	-1.1
9	100/5	02.00	71%	0.35	0.14	-1.25

11	100/6	00.00	0%	0	0.5	0
12	100/6	00.15	33%	0.16	0.3	-0.4
13	100/6	00.30	43%	0.21	0.29	-0.544
14	100/6	00.45	48%	0.24	0.26	-0.653
15	100/6	01.00	55%	0.28	0.22	-0.82
16	100/6	01.15	60%	0.30	0.20	-0.916
17	100/6	01.30	65%	0.33	0.17	-1.07
18	100/6	01.45	73%	0.36	0.136	-1.3
19	100/6	02.00	76.5%	0.38	0.12	-1.45
20	100/5	00.00	0%	0	0.5	0
21	100/7	00.15	35%	0.17	0.325	-0.43
22	100/7	00.30	46%	0.23	0.27	-0.62
23	100/7	00.45	52%	0.26	0.24	-0.733
24	100/7	01.00	58%	0.29	0.21	-0.867
25	100/7	01.15	65%	0.33	0.17	-1.07
26	100/7	01.30	72%	0.36	0.14	-1.25
27	100/7	01.45	77%	0.38	0.117	-1.45
28	100/7	02.00	80%	0.4	0.10	-1.6
29	100/8	00.00	0%	0	0.5	0
30	100/8	00.15	38%	0.19	0.31	-0.48
31	100/8	00.30	48%	0.24	0.26	-0.653
32	100/8	00.45	54%	0.27	0.23	-0.776
33	100/8	01.00	62%	130.31	0.19	-0.99
34	100/8	01.15	69%	0.35	0.15	-1.2
35	100/8	01.30	74%	0.37	0.13	-1.34
36	100/8	01.45	78%	0.39	0.11	-1.56
37	100/8	02.00	83%	0.42	0.08	-1.83
38	100/9	00.00	0%	0	0.5	0
39	100/9	00.15	42%	0.21	0.29	-0.53
40	100/9	00.30	50%	0.25	0.25	-0.693

41	100/9	00.45	56%	0.28	0.22	-0.821
42	100/9	01.00	70%	0.35	0.15	-1.18
43	100/9	01.15	77%	0.38	0.12	-1.45
44	100/9	01.30	81%	0.40	0.096	-1.65
45	100/9	01.45	88%	0.44	0.06	-2.11
46	100/9	02.00	92%	0.46	0.04	-2.53

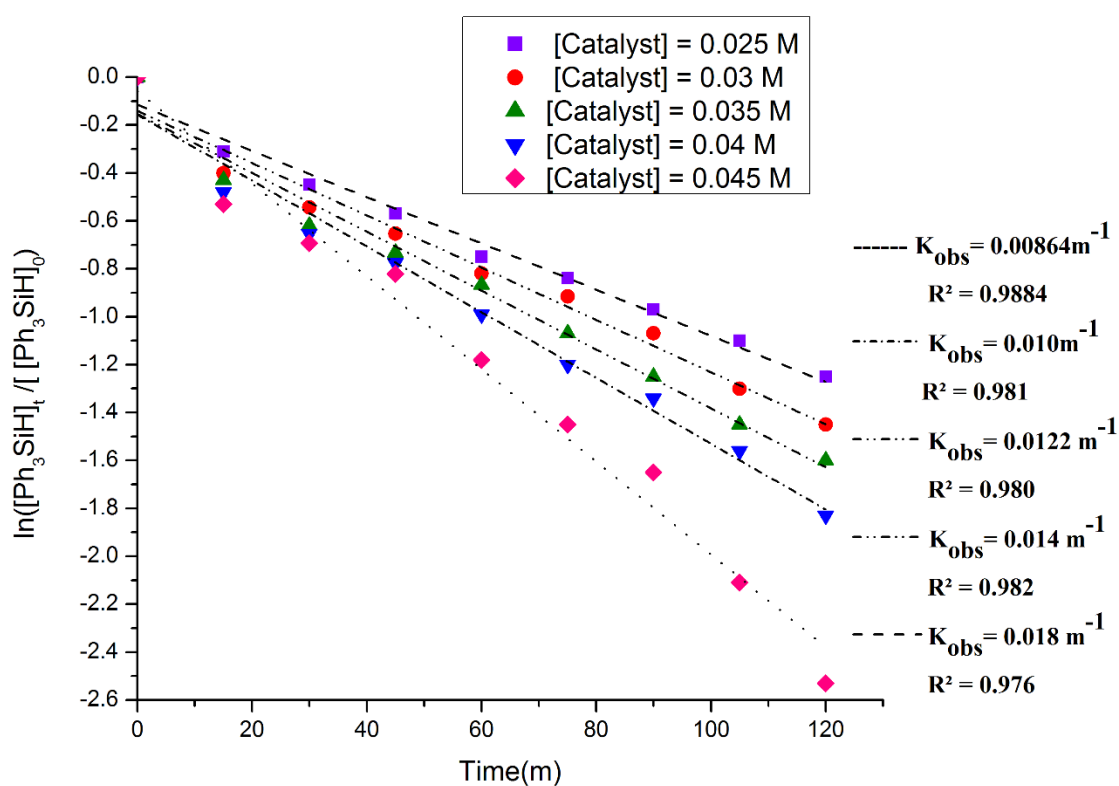


Figure 1. First order kinetics plots for $\ln[\text{Ph}_3\text{SiH}]_t / [\text{Ph}_3\text{SiH}]_0$ with time in C_6D_6 (0.4 mL) with different concentration of [KBTSA] (**1**) at 25°C .

Table 2. Kinetics plots of K_{obs} vs [KBTSA] for the reaction of $[\text{Ph}_3\text{SiH}] = 0.05 \text{ M}$ with $[\text{MeOH}] = 0.5 \text{ M}$ in C_6D_6 (0.4 mL) at 25°C .

S.NO.	[(KBTSA)]	K_{obs} ($\text{molL}^{-1}\text{m}^{-1}$)
1	0.025	0.008
2	0.03	0.01
3	0.035	0.0122
4	0.04	0.014
5	0.045	0.018

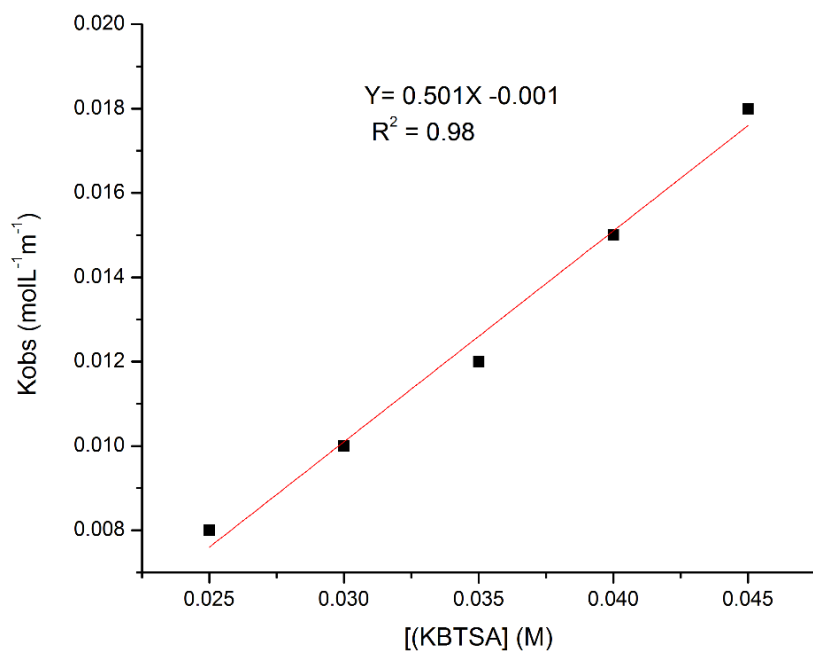


Figure 2. Kinetics plots of K_{obs} vs [KBTSA] for the reaction of $[\text{Ph}_3\text{SiH}] = 0.05 \text{ M}$ with $[\text{MeOH}] = 0.5 \text{ M}$ in C_6D_6 (0.4 mL) at 25°C .

Table 3. Table for the Kinetics plots for Formation rates of Ph₃SiOMe versus the ratios of Ph₃SiH/MeOH in C₆D₆ at 298 K, indicating a linear dependence. Conditions: KBTSA (5 mol%, 0.025 mmol), MeOH (0.5 mmol), C₆D₆(0.4 mL).

S.NO.	[Ph ₃ SiH]	<i>K</i> _{obs} (molL ⁻¹ m ⁻¹)
1	0.3	0.009
2	0.4	0.012
3	0.5	0.014
4	0.6	0.016
5	0.7	0.019

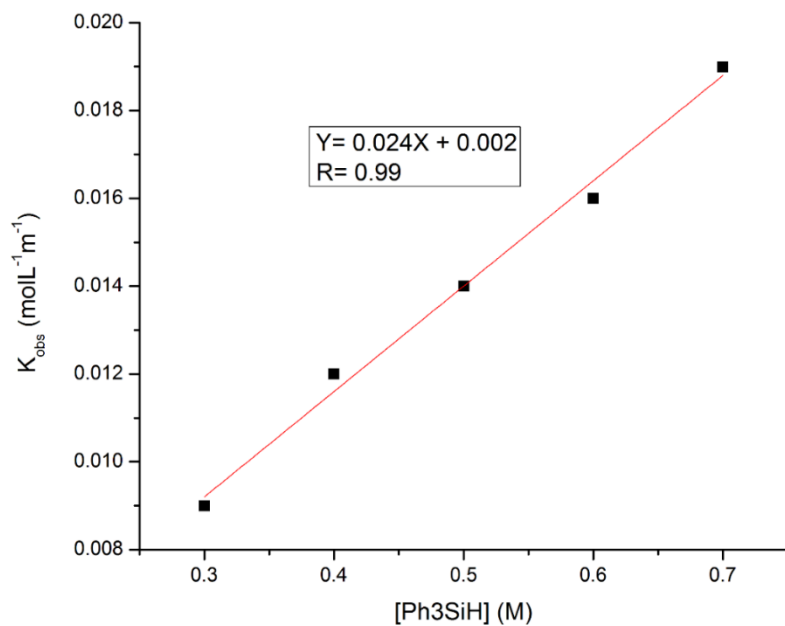


Figure 3. Kinetics plots for Formation rates of Ph₃SiOMe versus the ratios of Ph₃SiH/MeOH in C₆D₆ at 298 K, indicating a linear dependence. Conditions: KBTSA (5 mol%, 0.025 mmol), MeOH (0.5 mmol), C₆D₆(0.4 mL).

Table 4. Table for the Kinetics plots for Formation rates of Ph₃SiOMe versus the ratios of Ph₃SiH/MeOH in C₆D₆ at 298 K, indicating a linear dependence. Conditions: KBTSA (5 mol%, 0.025 mmol), Ph₃SiH (0.5 mmol), C₆D₆(0.4 mL).

S.NO.	[MeOH]	K_{obs} (molL ⁻¹ m ⁻¹)
1	0.4	0.007
2	0.5	0.011
3	0.6	0.013
4	0.7	0.016
5	0.8	0.018

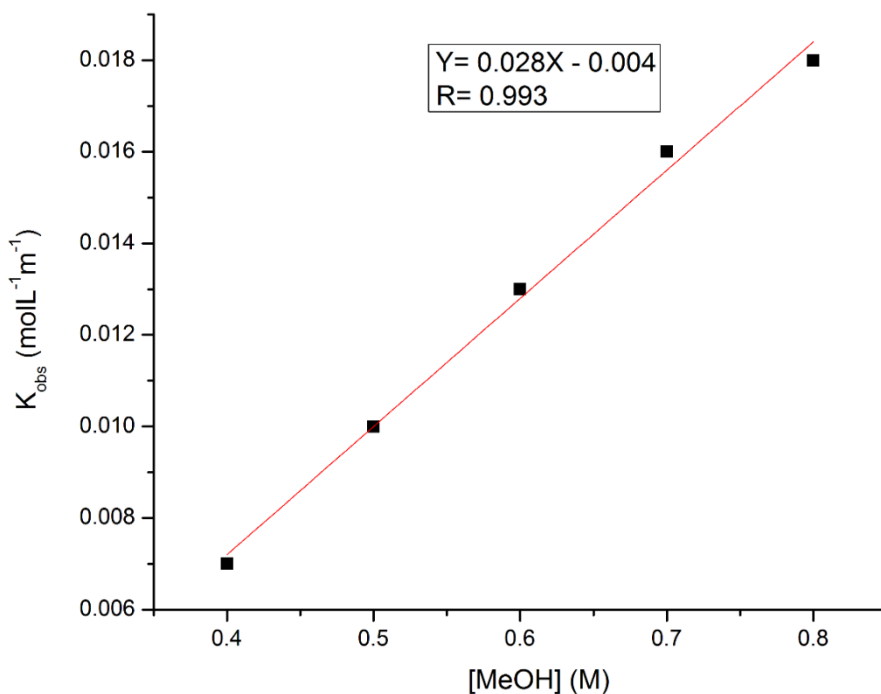


Figure 4. Kinetics plots for Formation rates of Ph₃SiOMe versus the ratios of Ph₃SiH/MeOH in C₆D₆ at 298 K, indicating a linear dependence. Conditions: KBTSA (5 mol%, 0.025 mmol), Ph₃SiH (0.5 mmol), C₆D₆(0.4 mL).

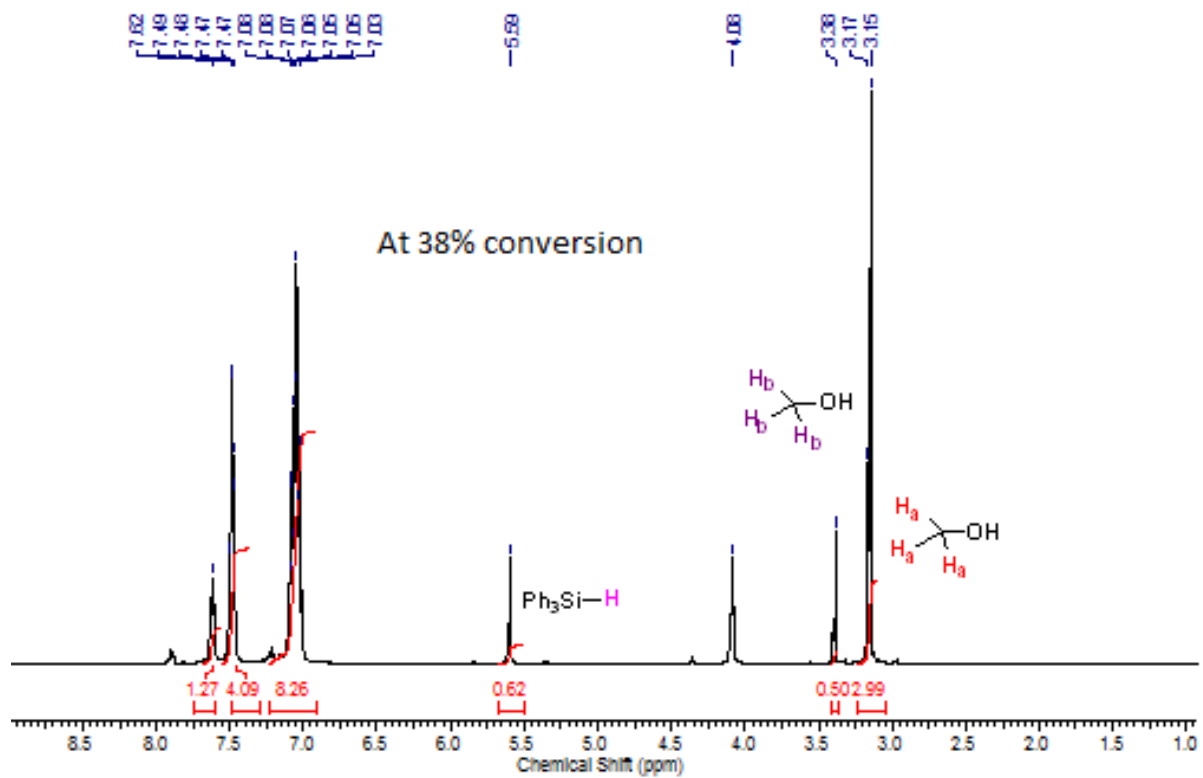


Figure 5. At 38% conversion.

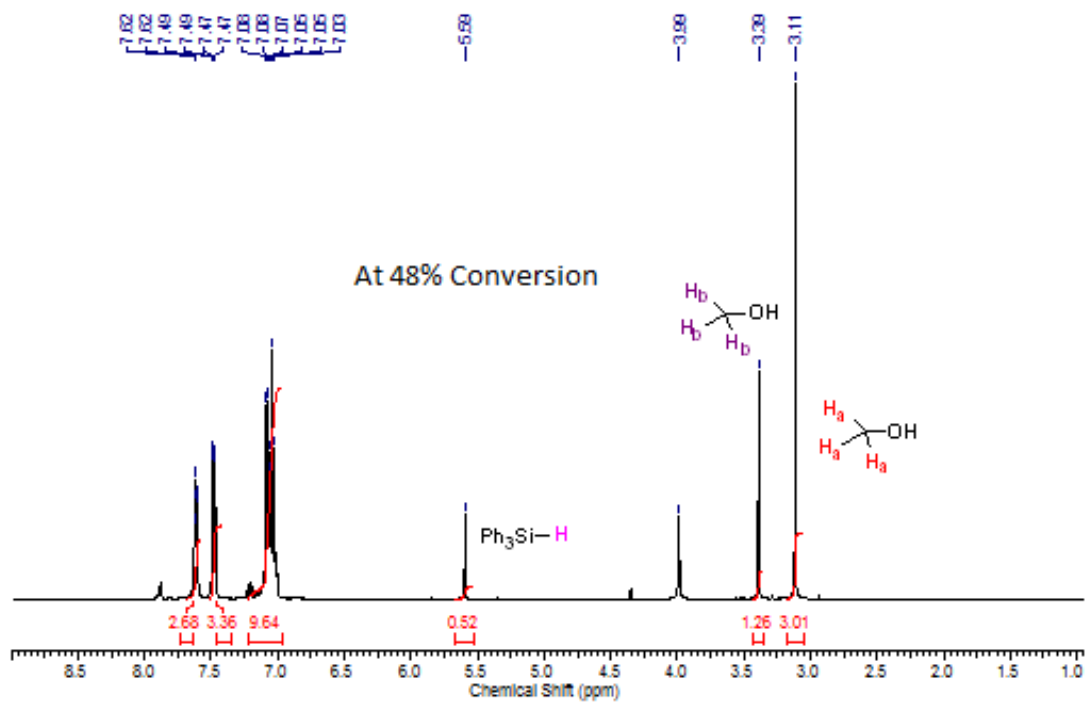


Figure 6. At 48% conversion

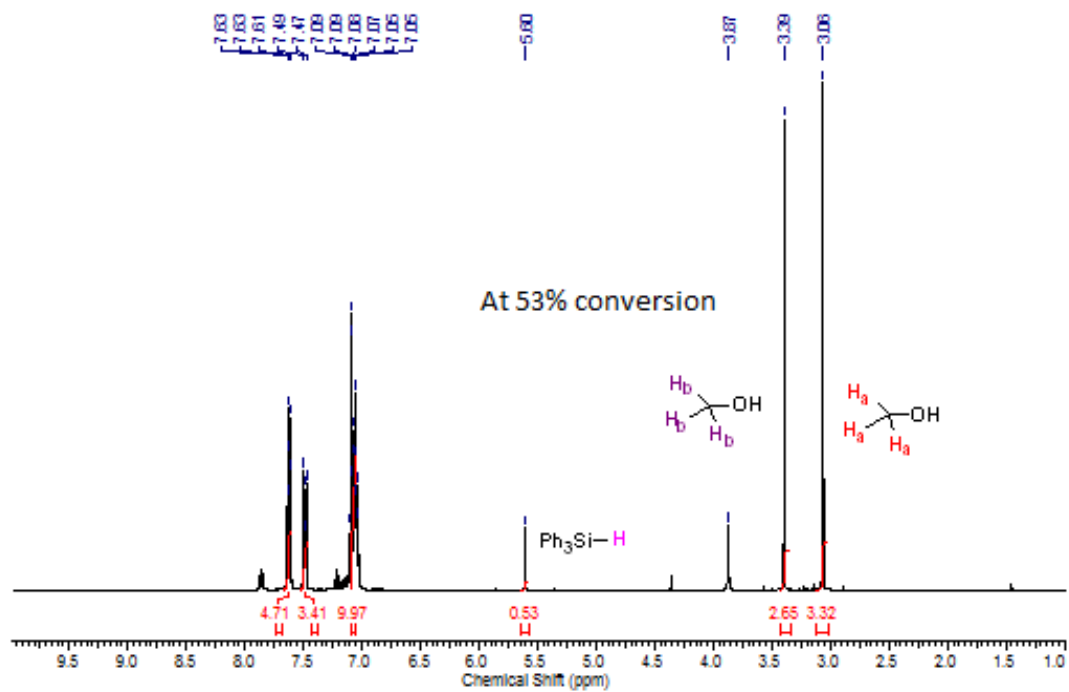


Figure 7. At 53% conversion

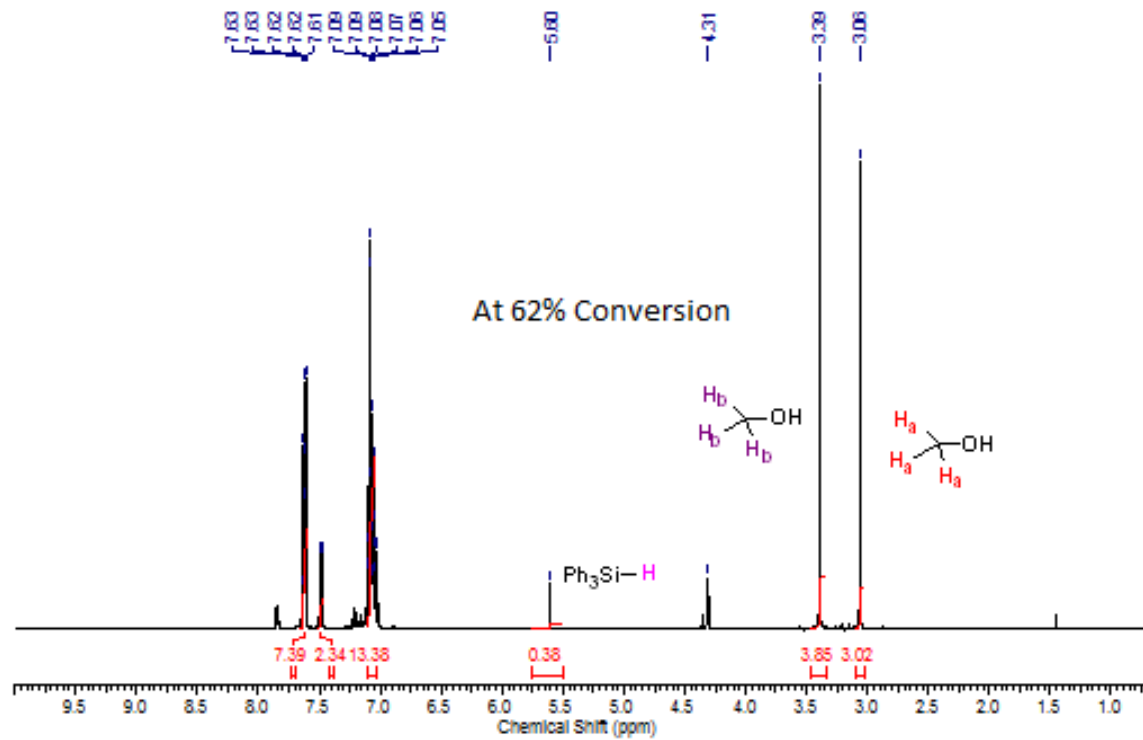


Figure 8. At 62% conversion.

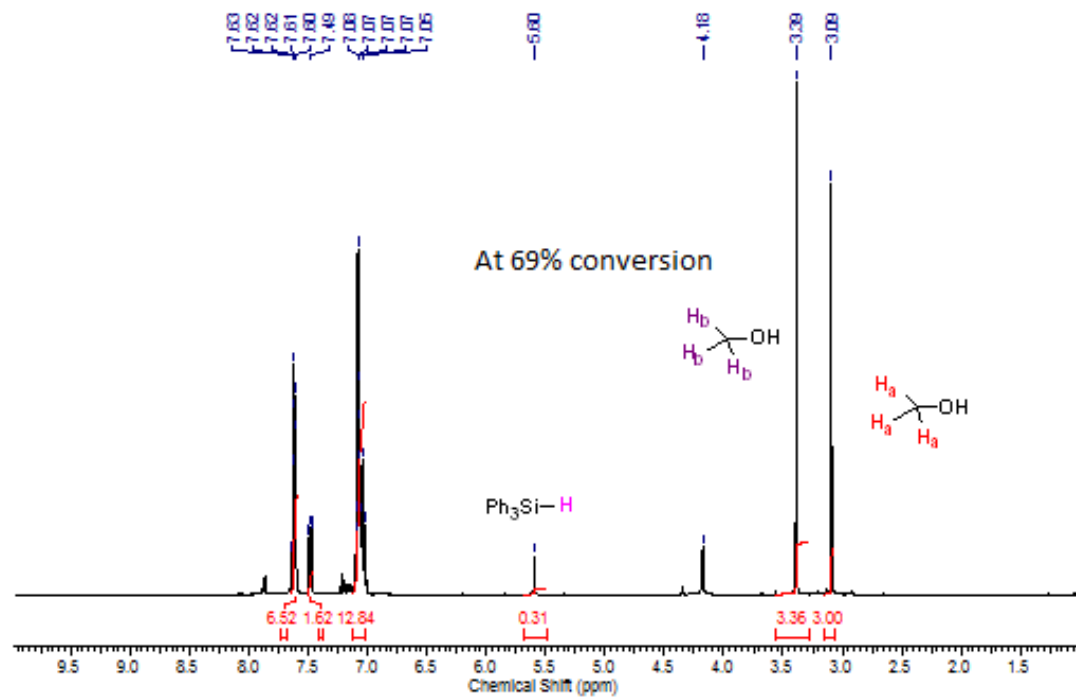


Figure 9. At 69% conversion.

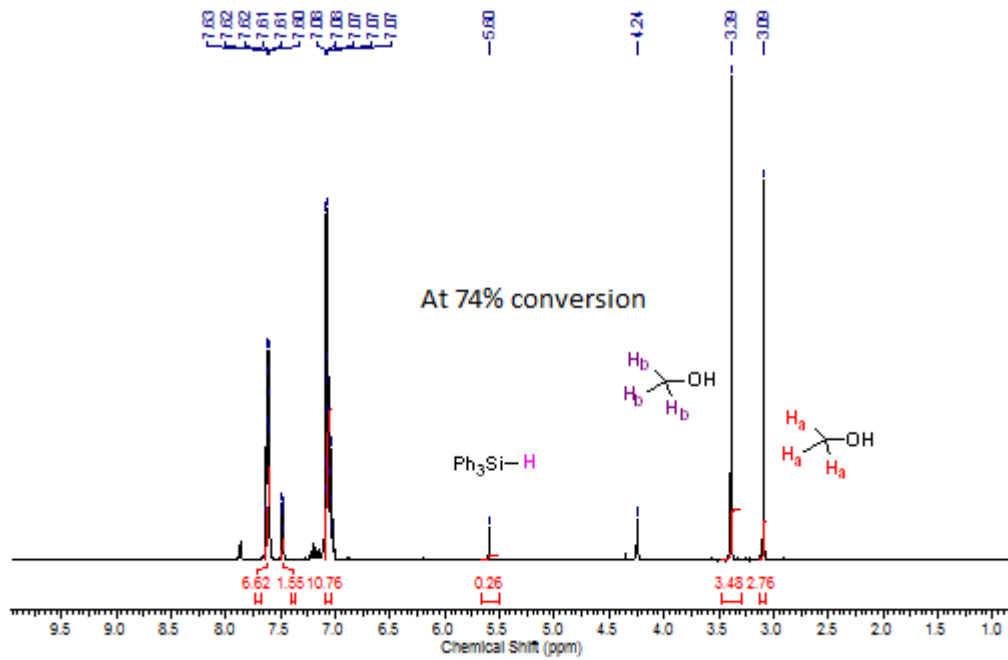


Figure 10. At 74% conversion.

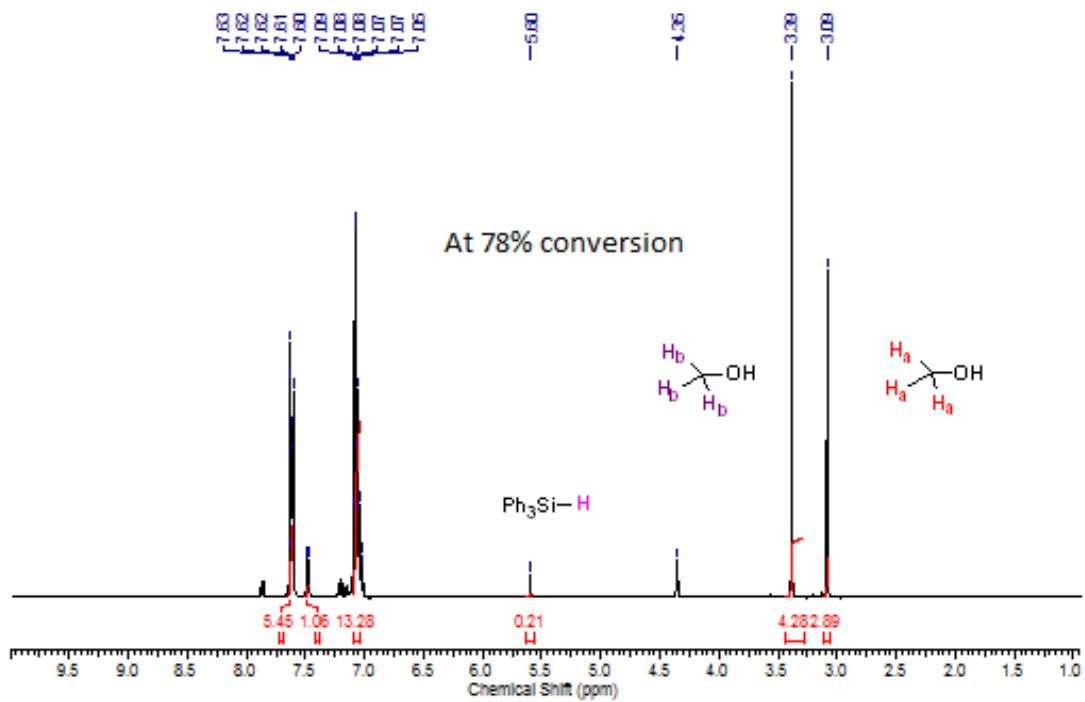


Figure 11. At 78% conversion.

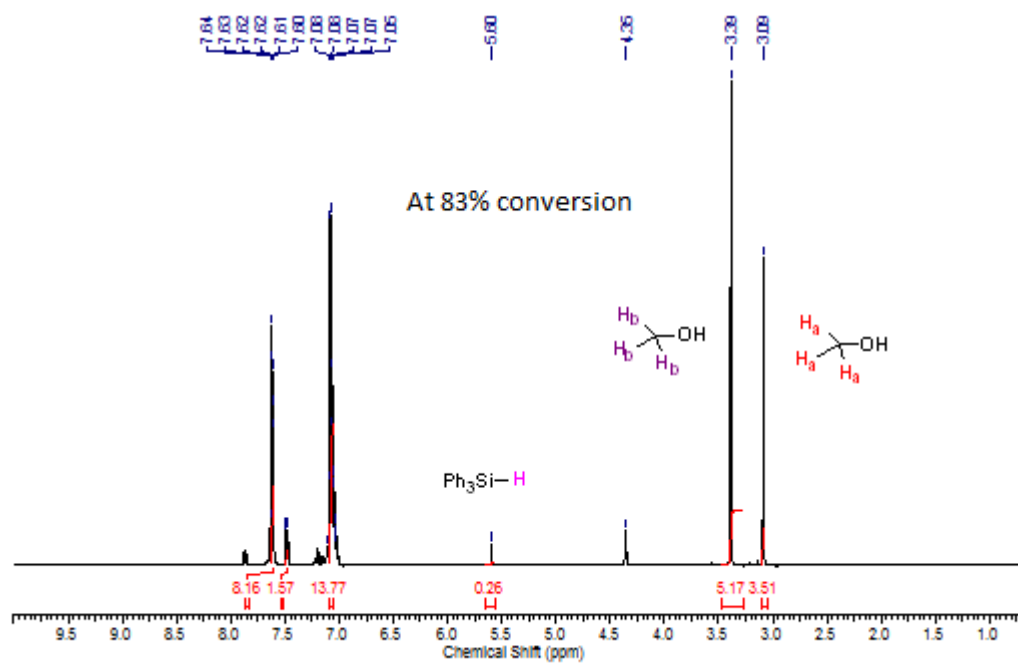


Figure 12. At 83% conversion.

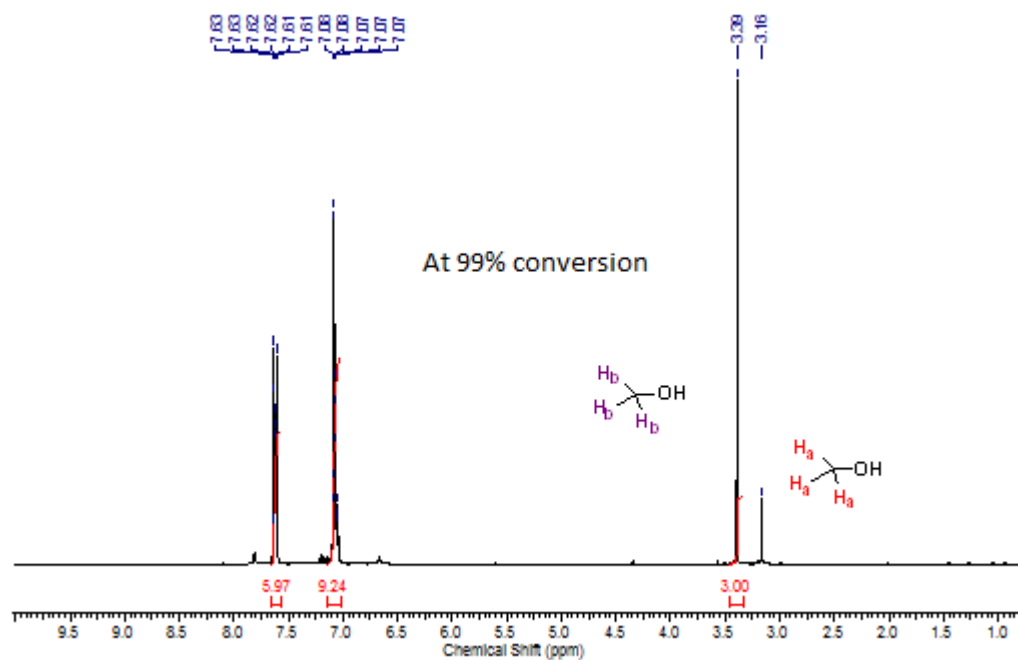


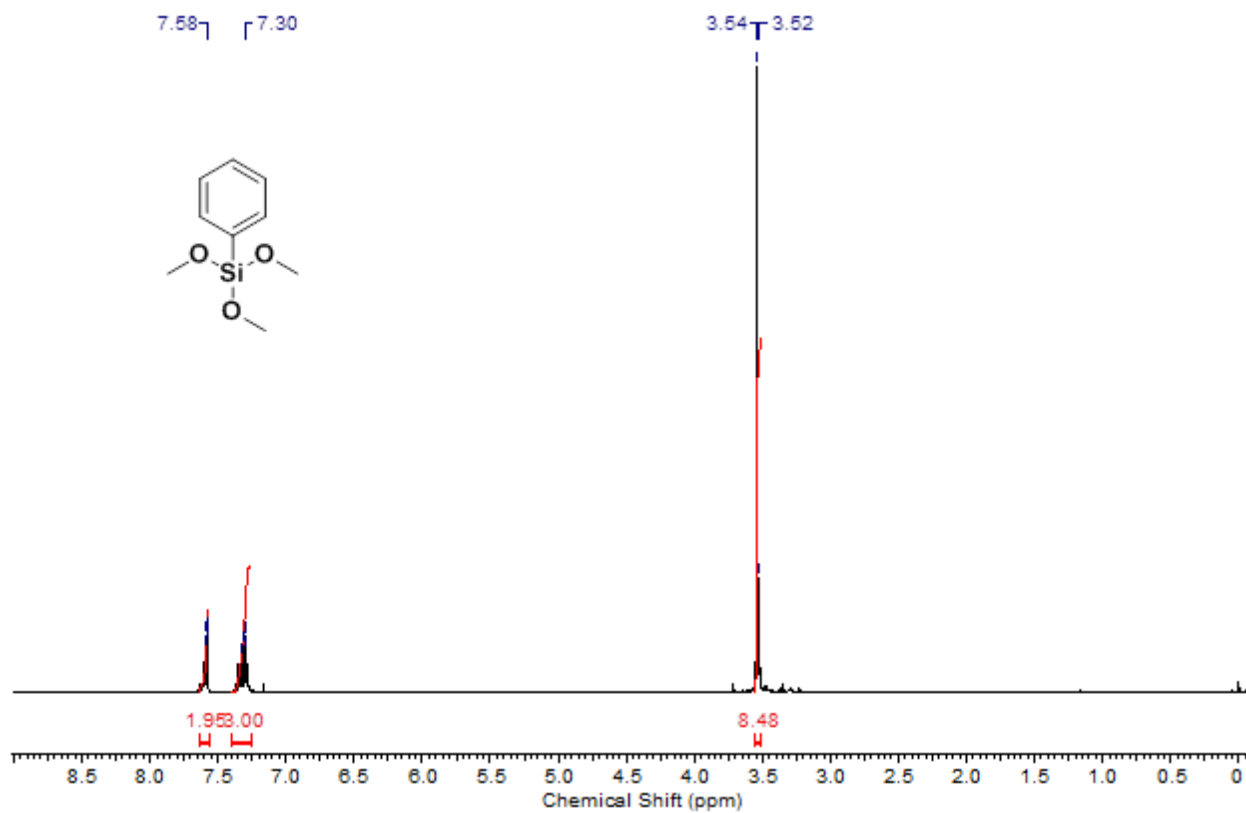
Figure 13. At 99% conversion.

References.

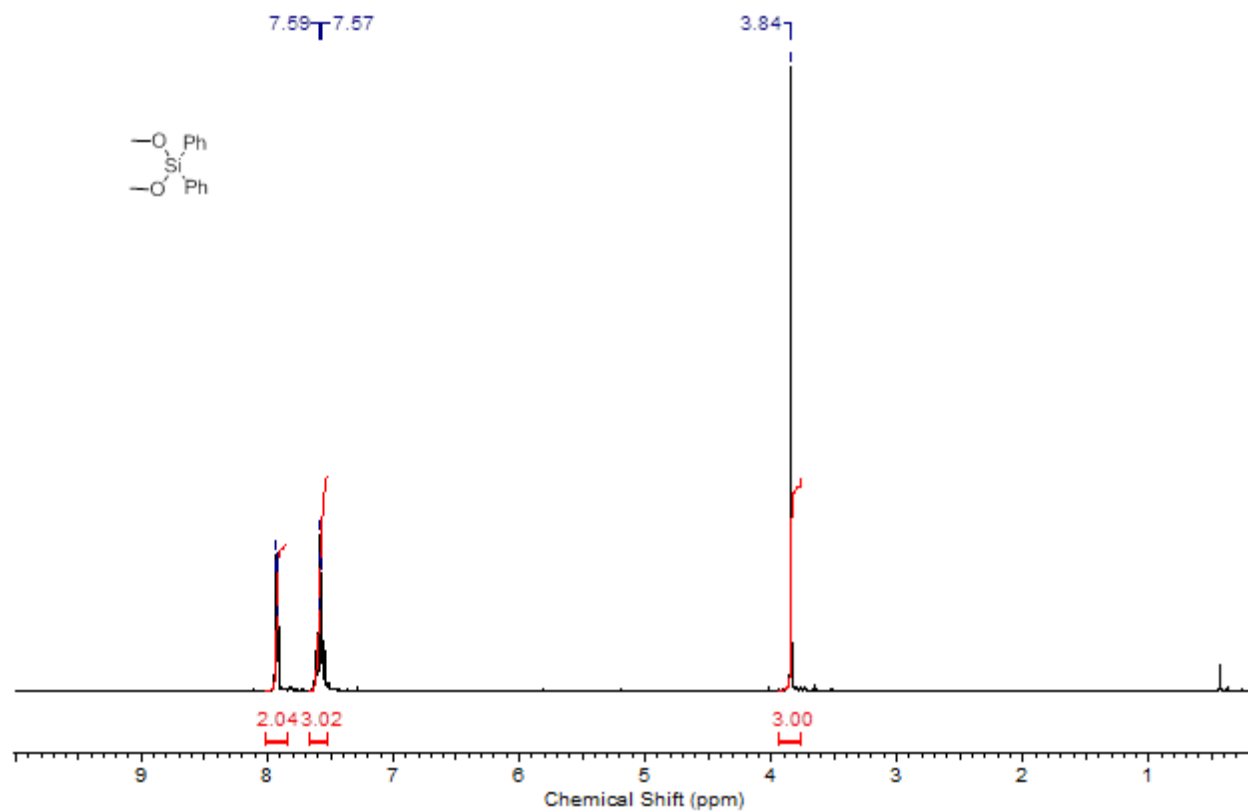
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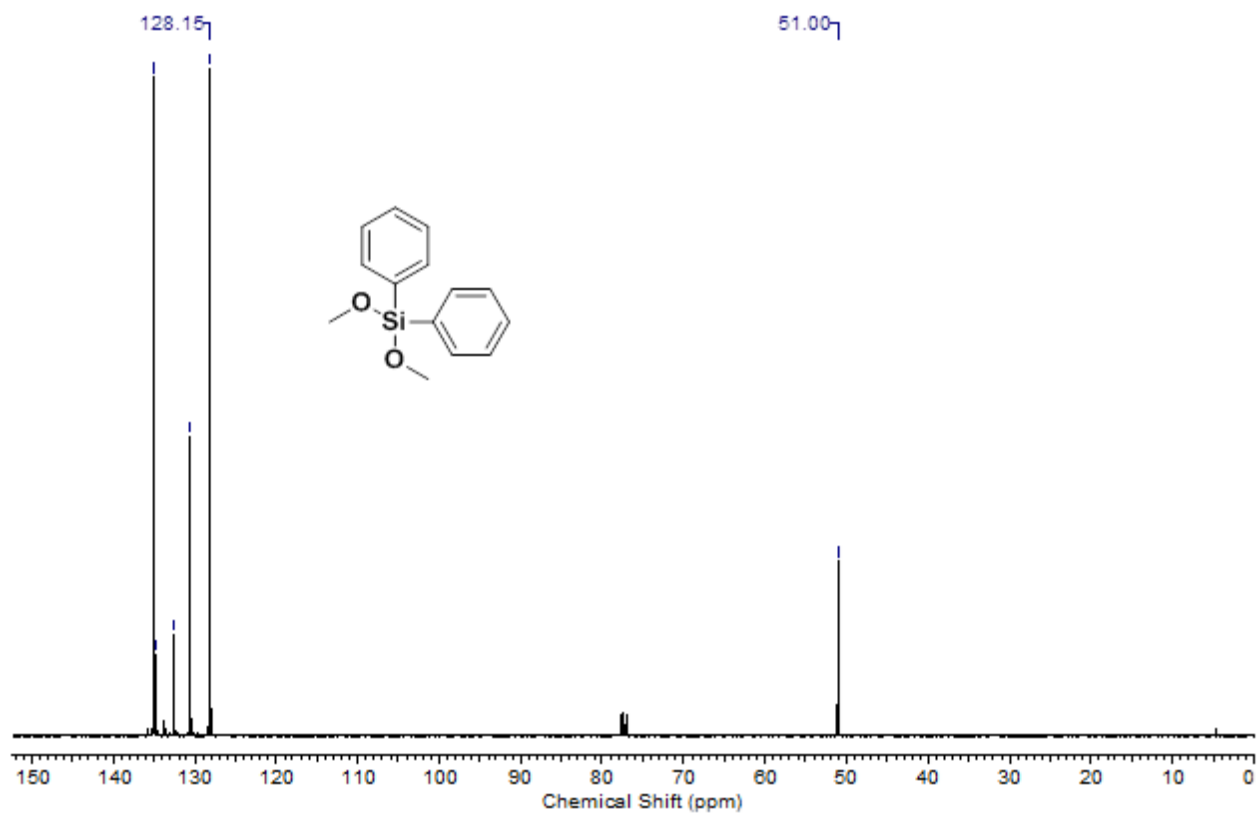
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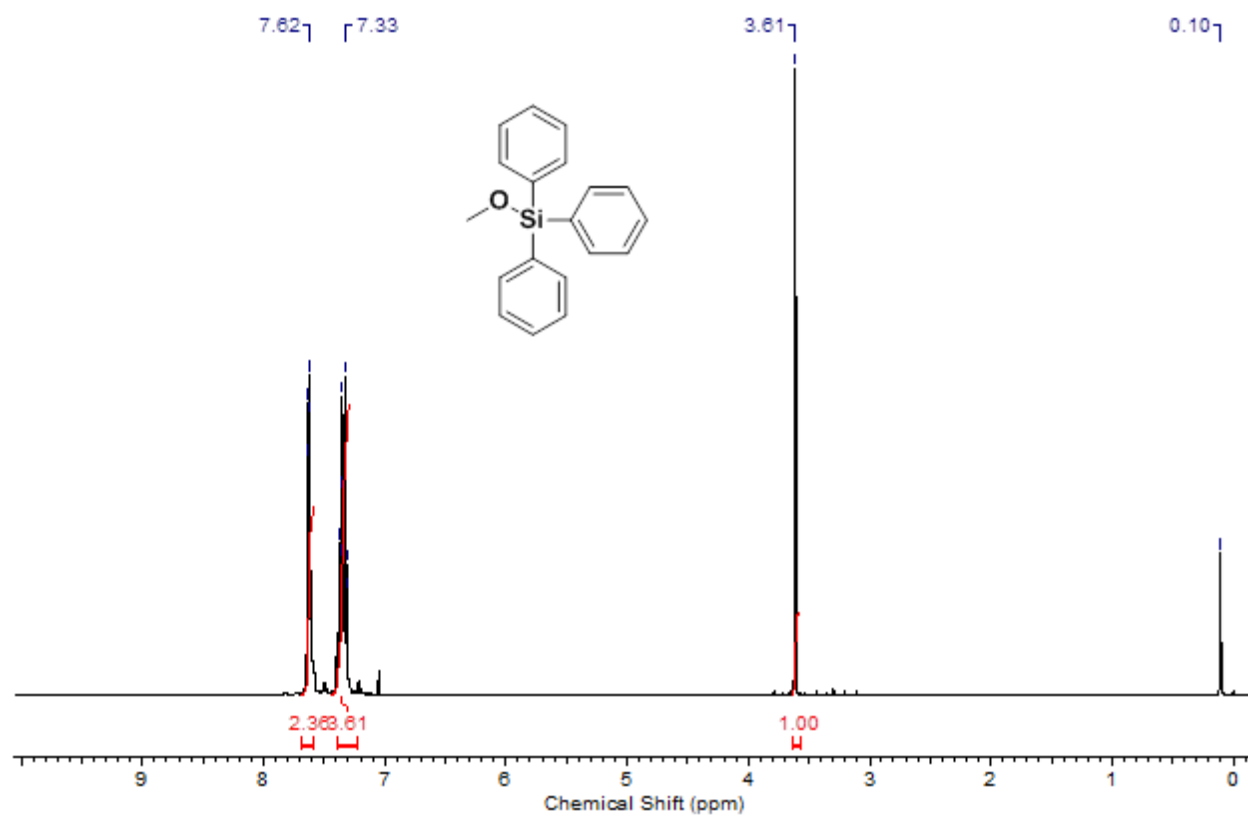
S1. ^1H NMR spectrum (400 MHz, 25°C, CDCl_3) of Product A.



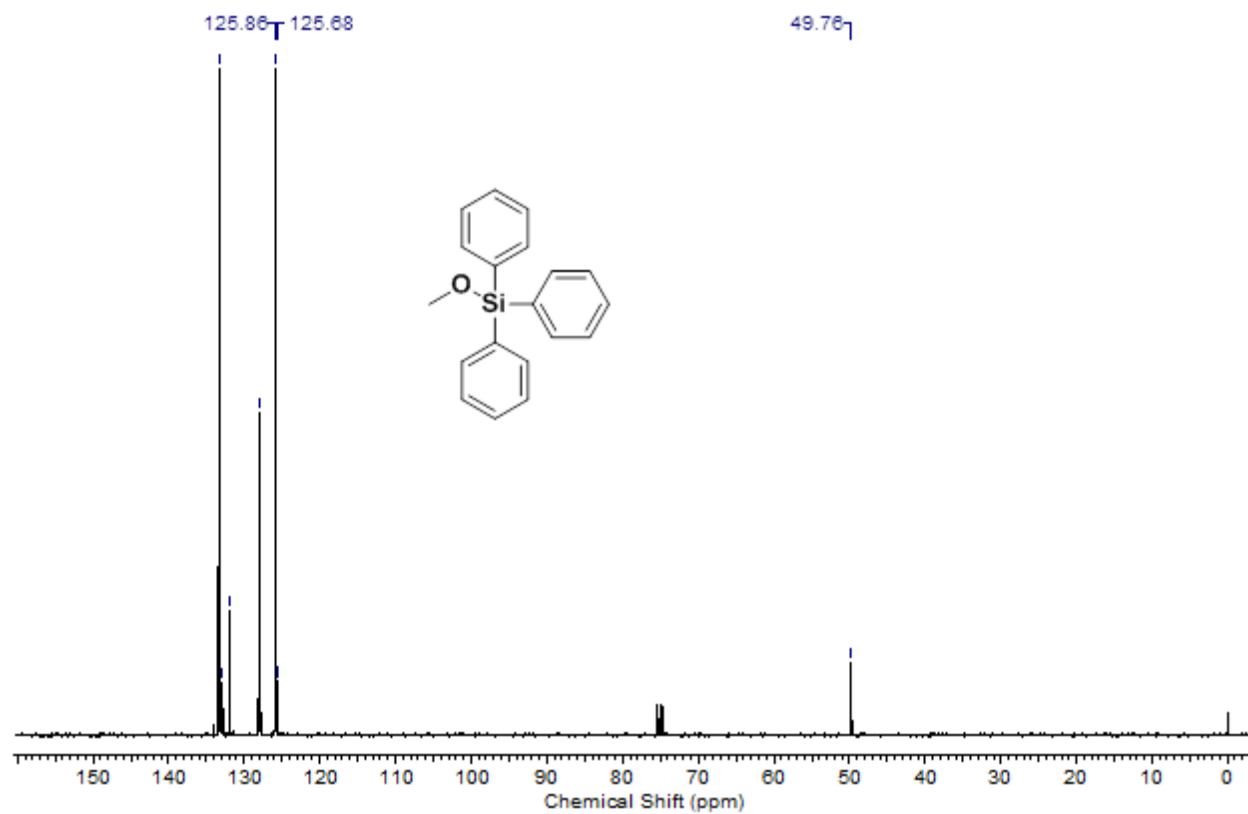
S2. ^1H NMR spectrum (400 MHz, 25°C, CDCl_3) of Product **B**.



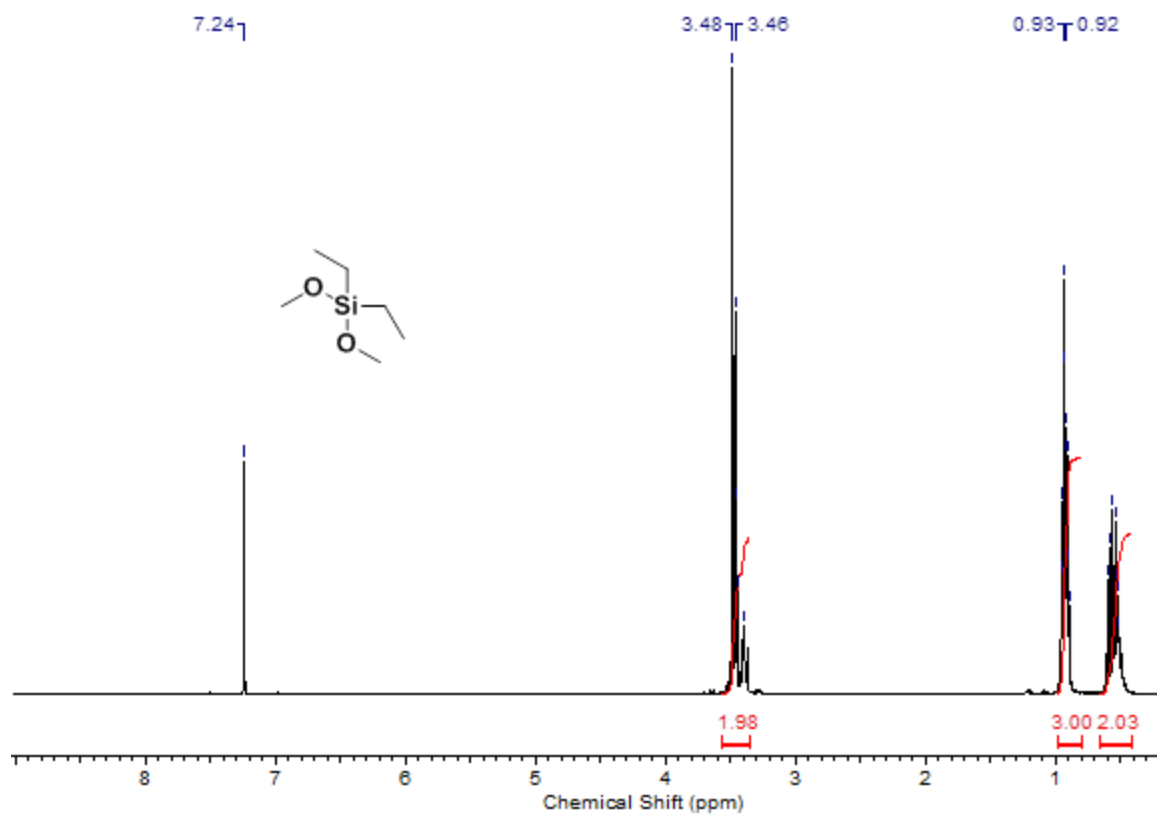
S3. ^{13}C NMR spectrum (400 MHz, 25°C, CDCl_3) of product **B**.



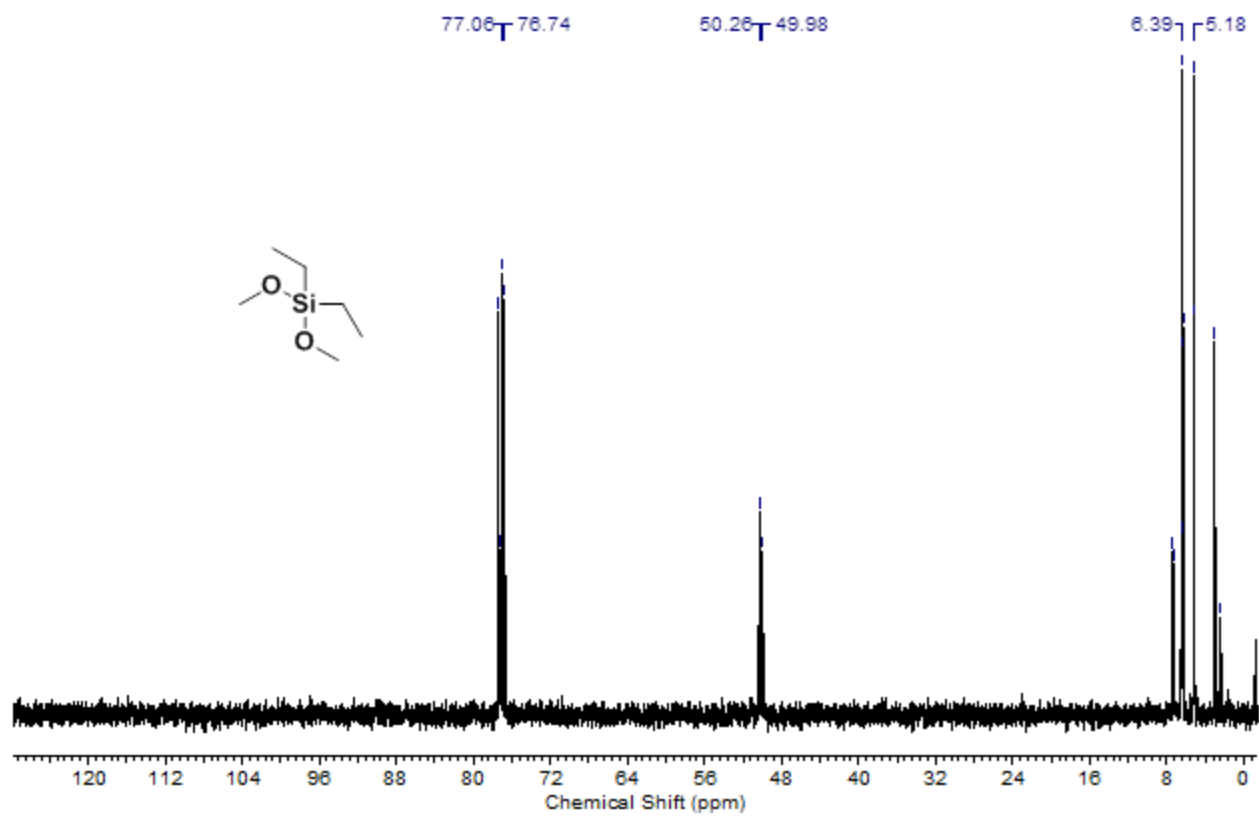
S4. ¹H NMR spectrum (400 MHz, 25°C, CDCl₃) of product C.



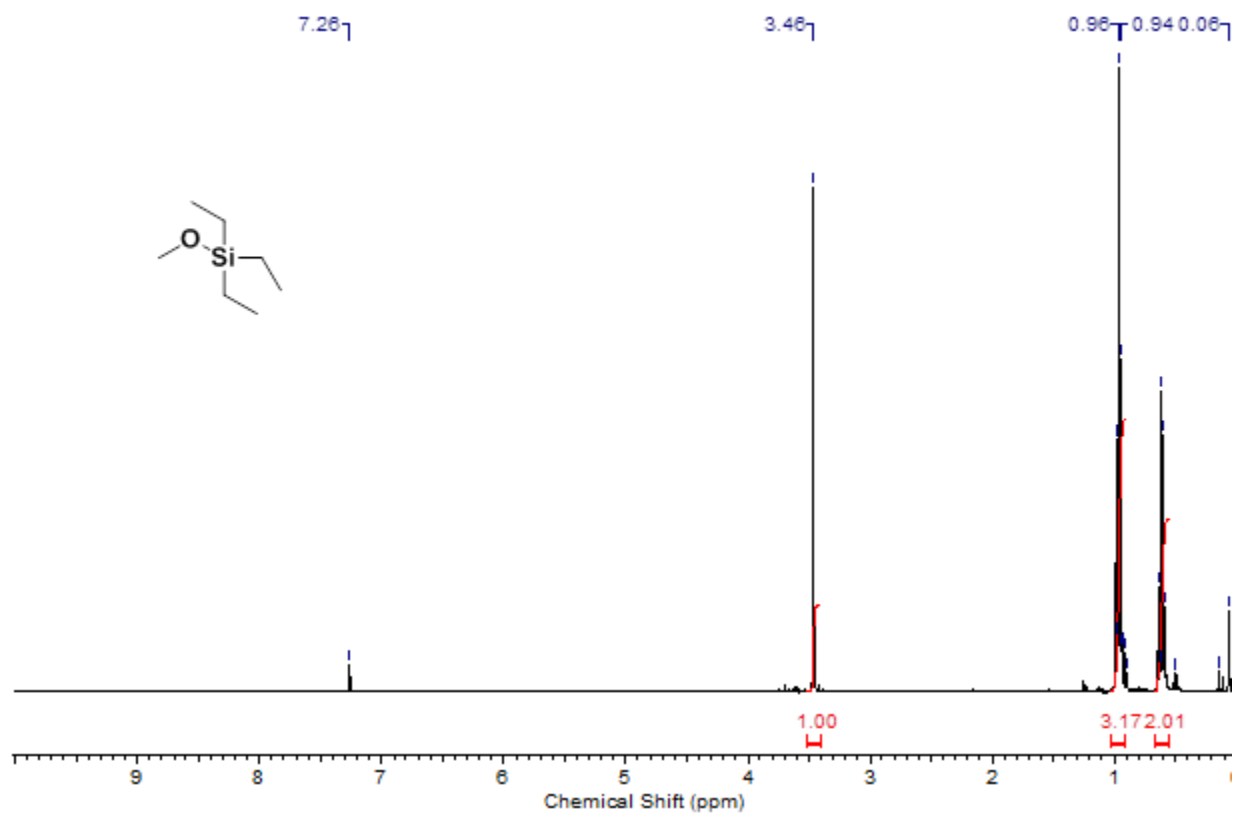
S5. ^{13}C NMR spectrum (400 MHz, 25°C, CDCl_3) of product C.



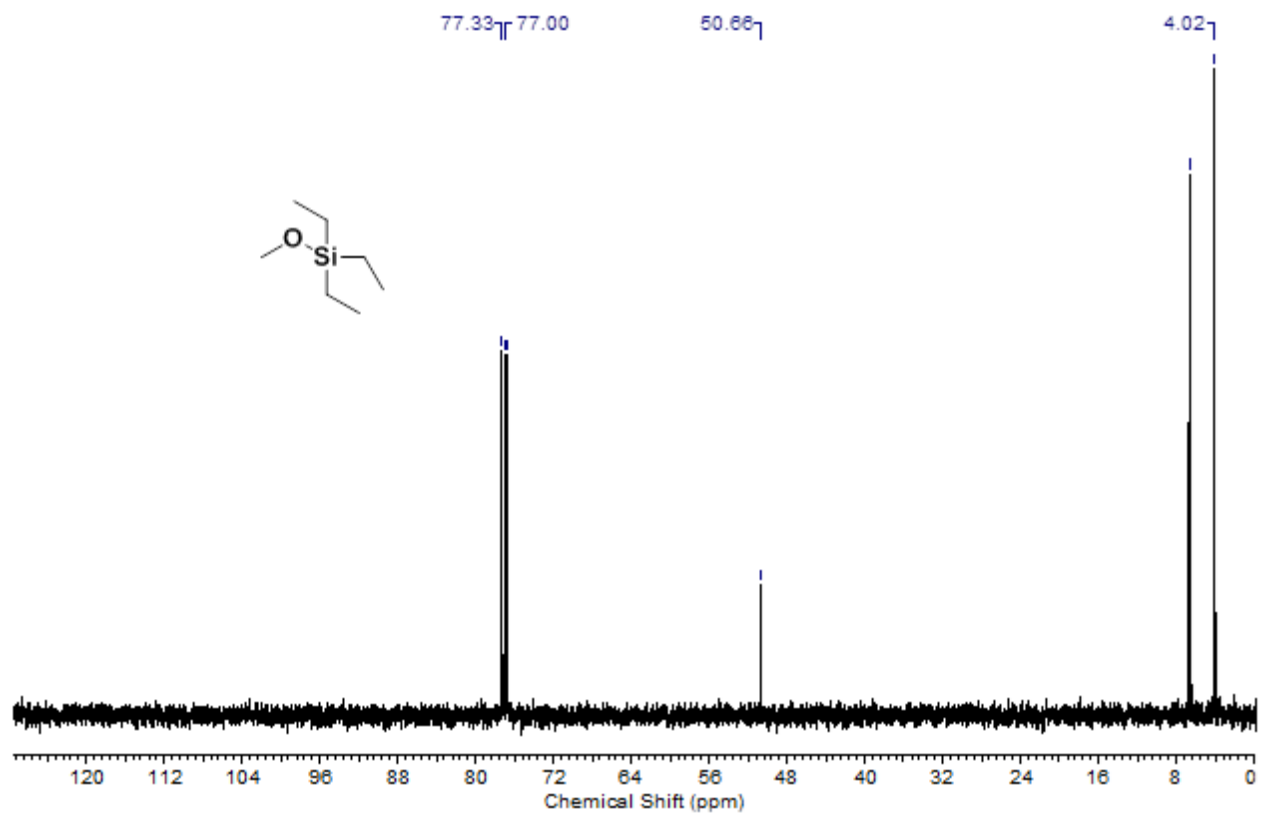
S6. ¹H NMR spectrum (400 MHz, 25°C, CDCl₃) of product D.



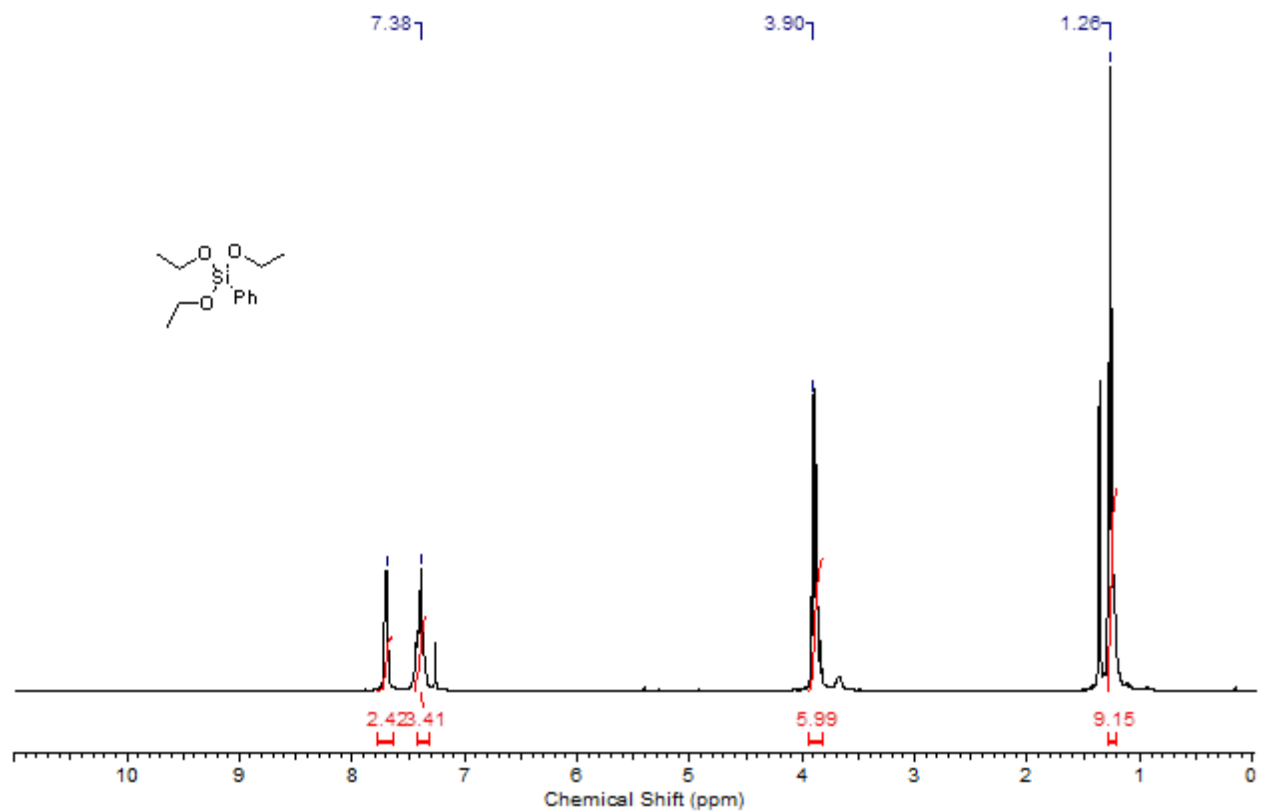
S7. ^{13}C NMR spectrum (400 MHz, 25°C, CDCl_3) of product **D**.



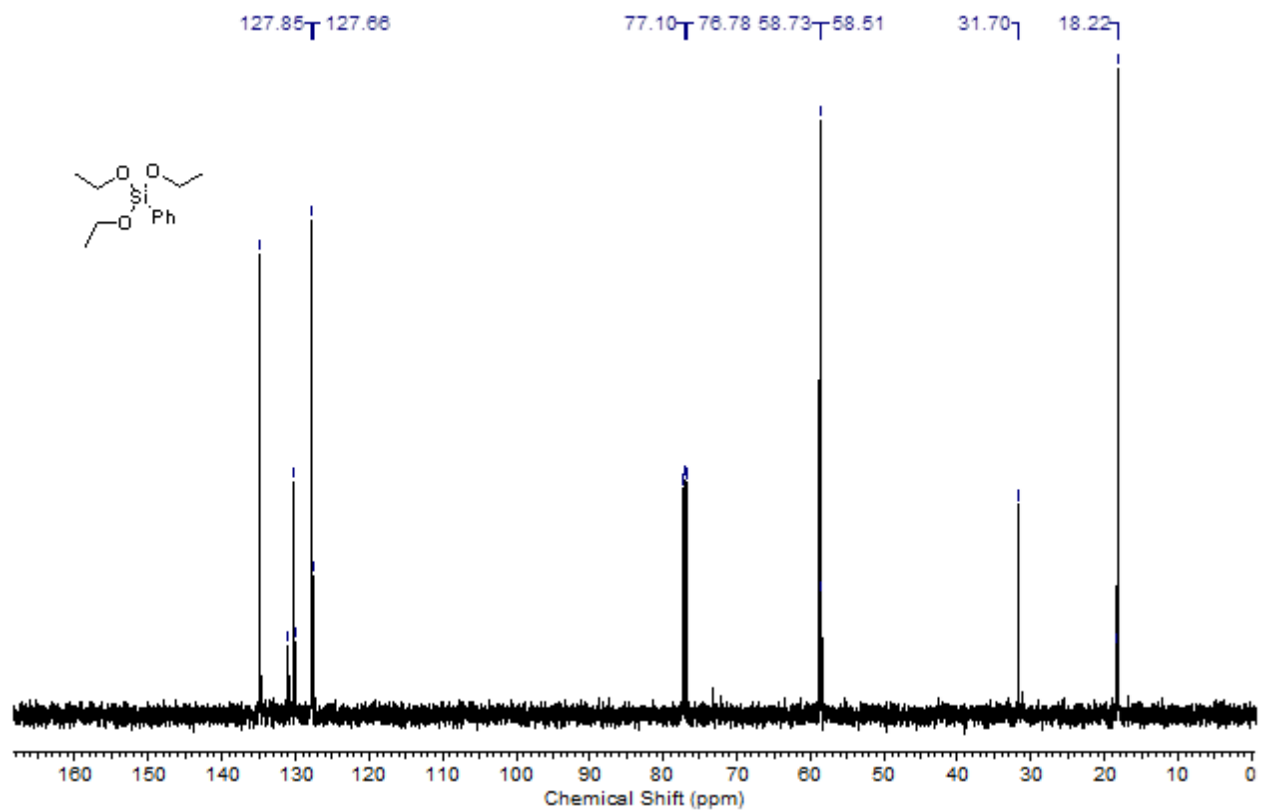
S8. ^1H NMR spectrum (400 MHz, 25°C, CDCl_3) of product E.



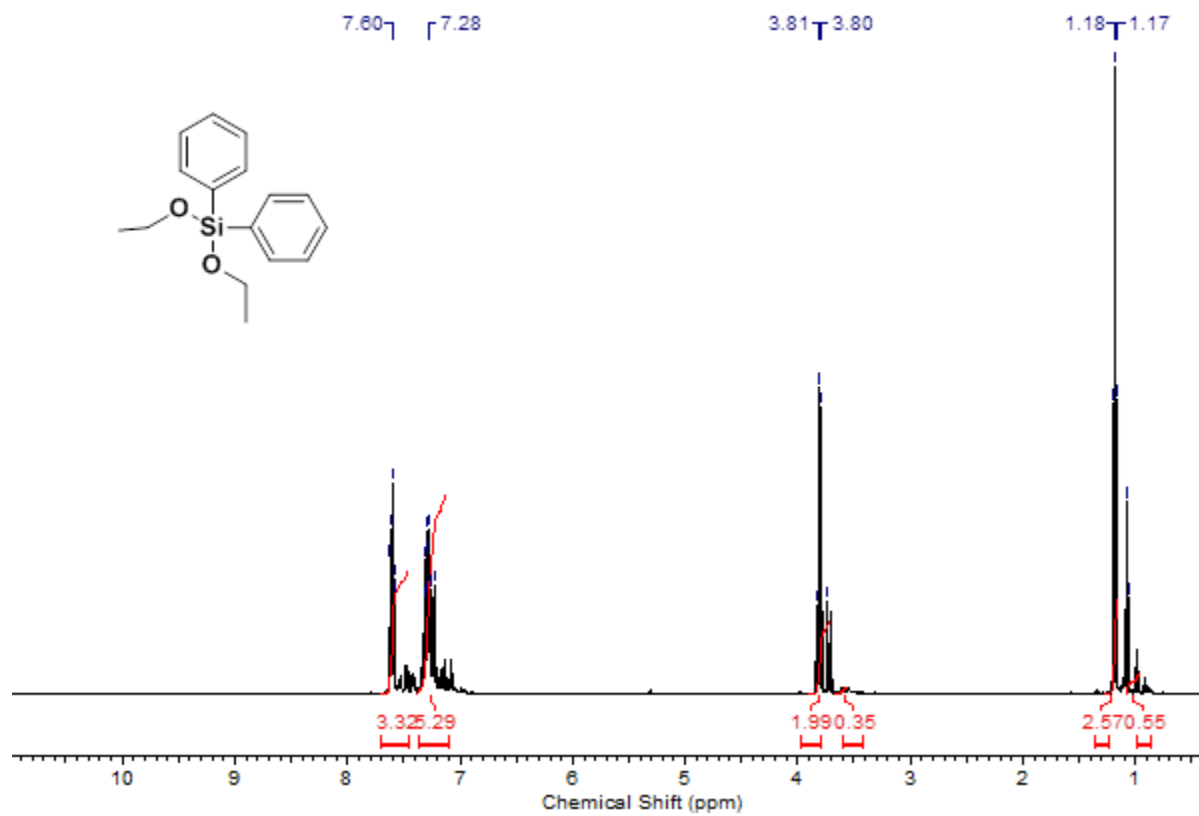
S9. ^1H NMR spectrum (400 MHz, 25°C, CDCl_3) of product E.



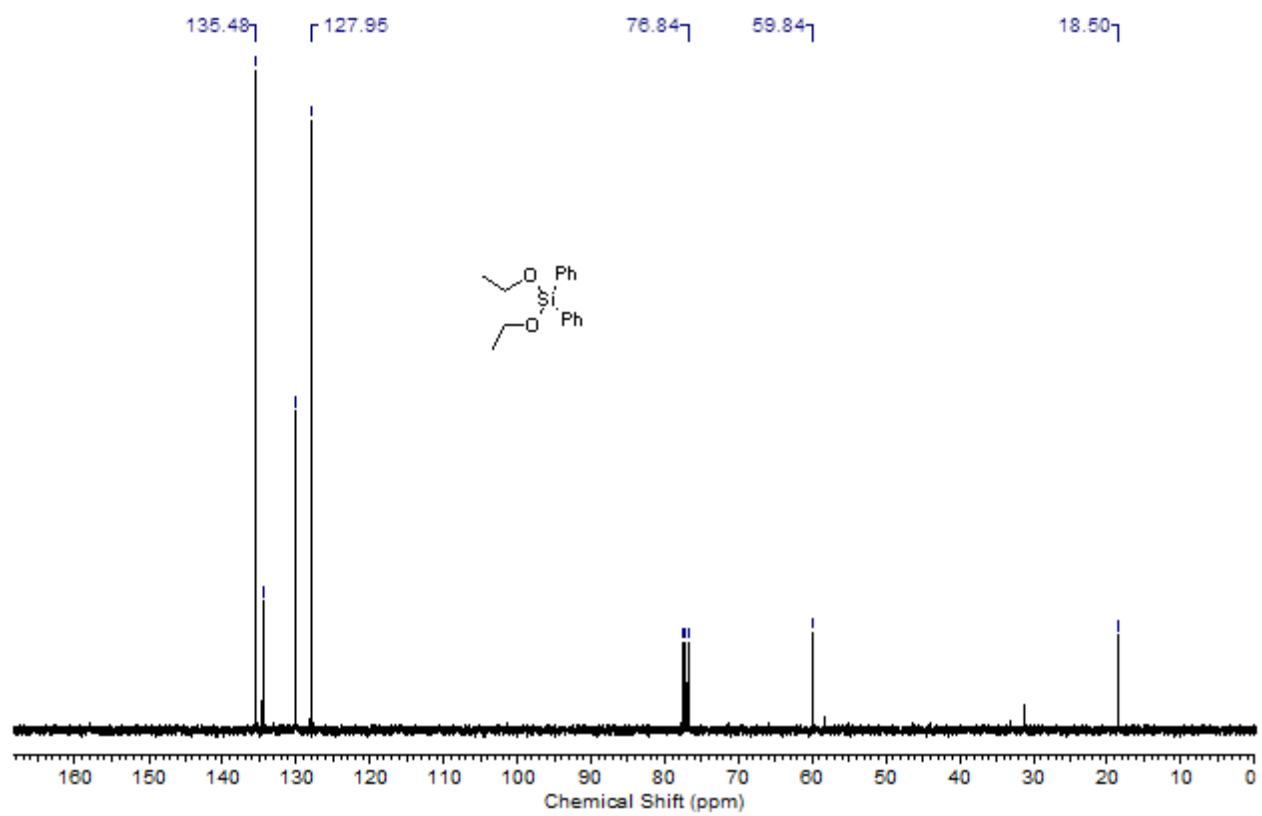
S10. ¹H NMR spectrum (400 MHz, 25°C, CDCl₃) of product F.



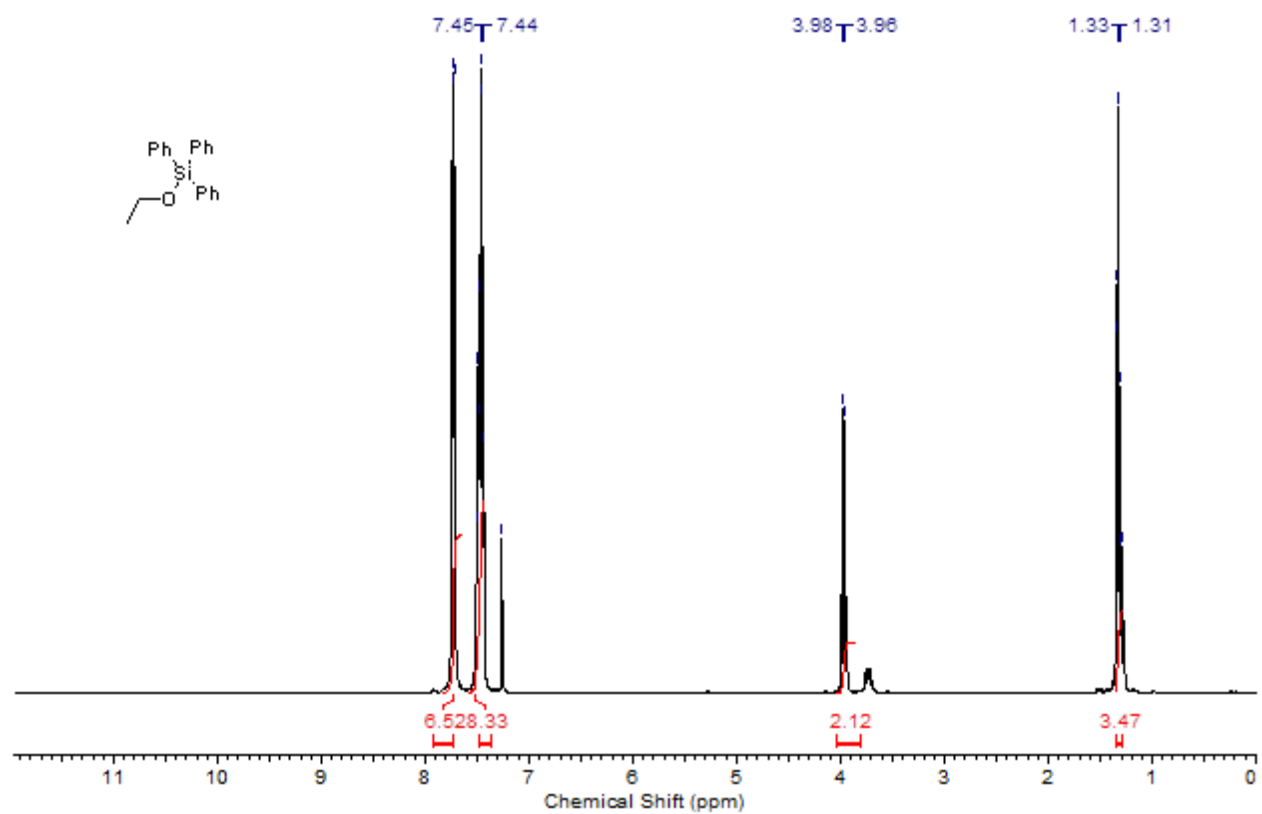
S11. ^{13}C NMR spectrum (400 MHz, 25°C, CDCl_3) of product **F**.



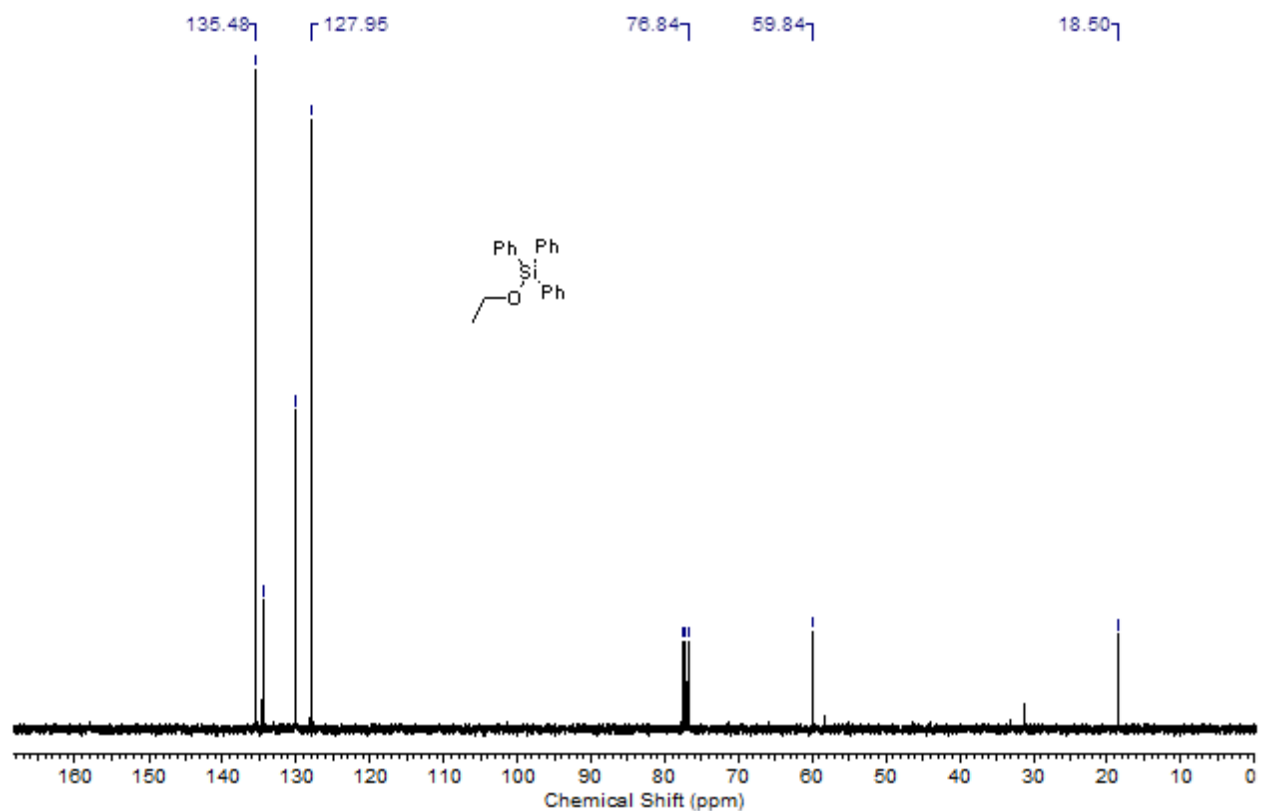
S12. ^1H NMR spectrum (400 MHz, 25°C, CDCl_3) of product **G**.



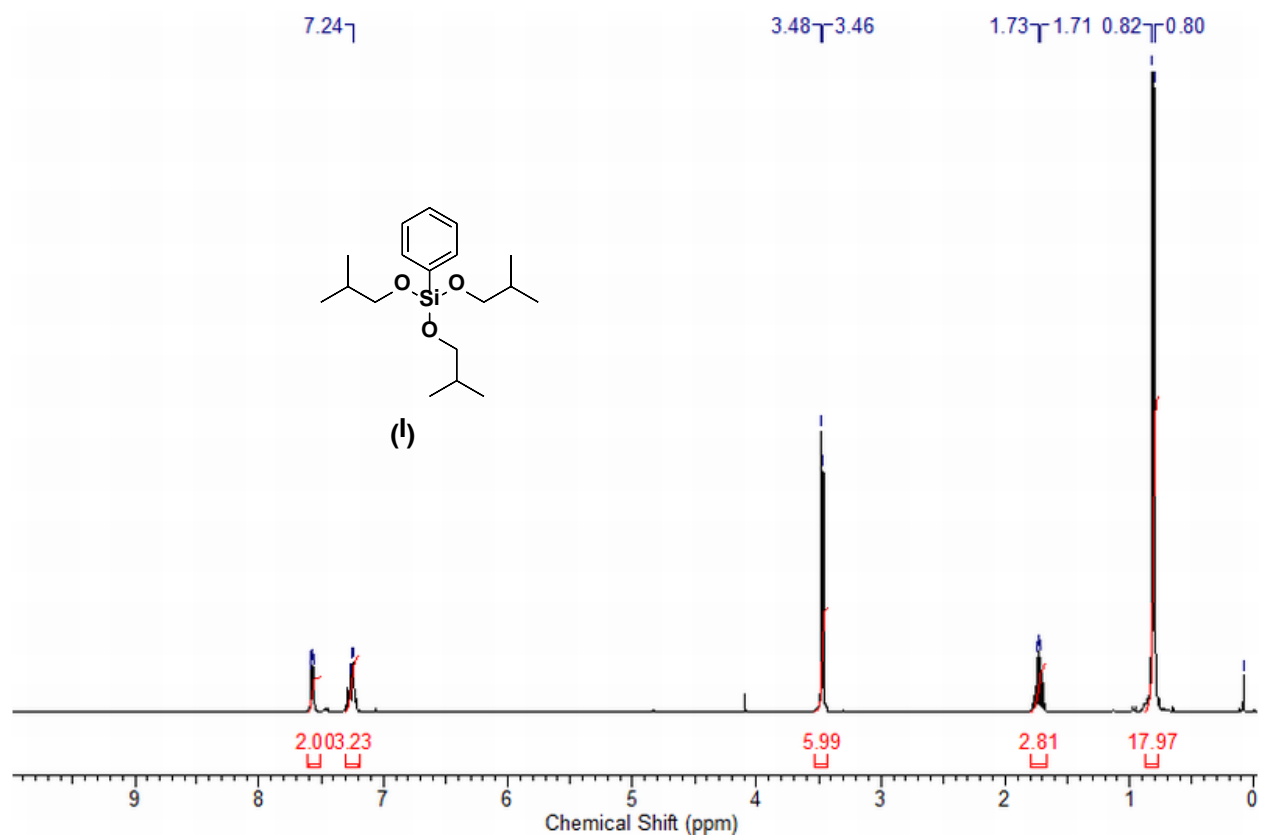
S13. ^{13}C NMR spectrum (400 MHz, 25°C, CDCl_3) of product **G**.



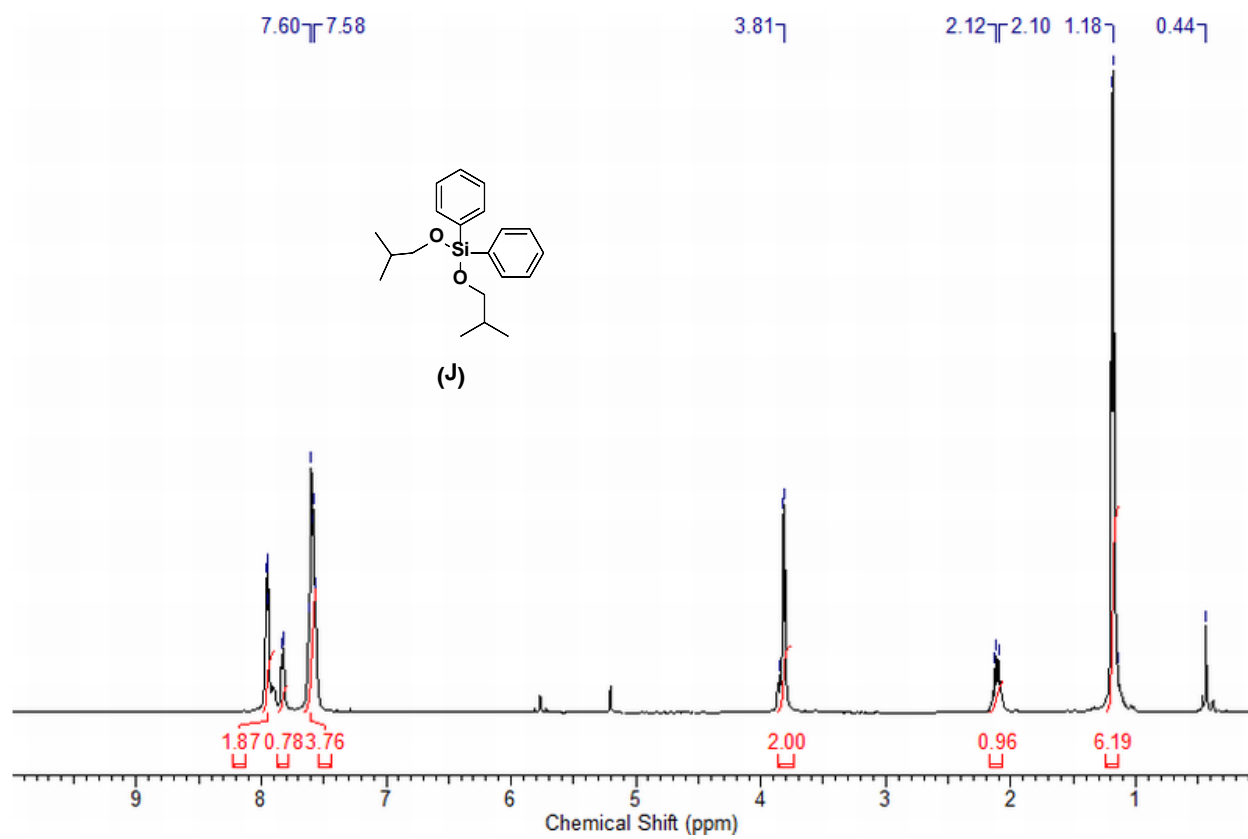
S14. ^1H NMR spectrum (400 MHz, 25°C, CDCl_3) of product **H**.



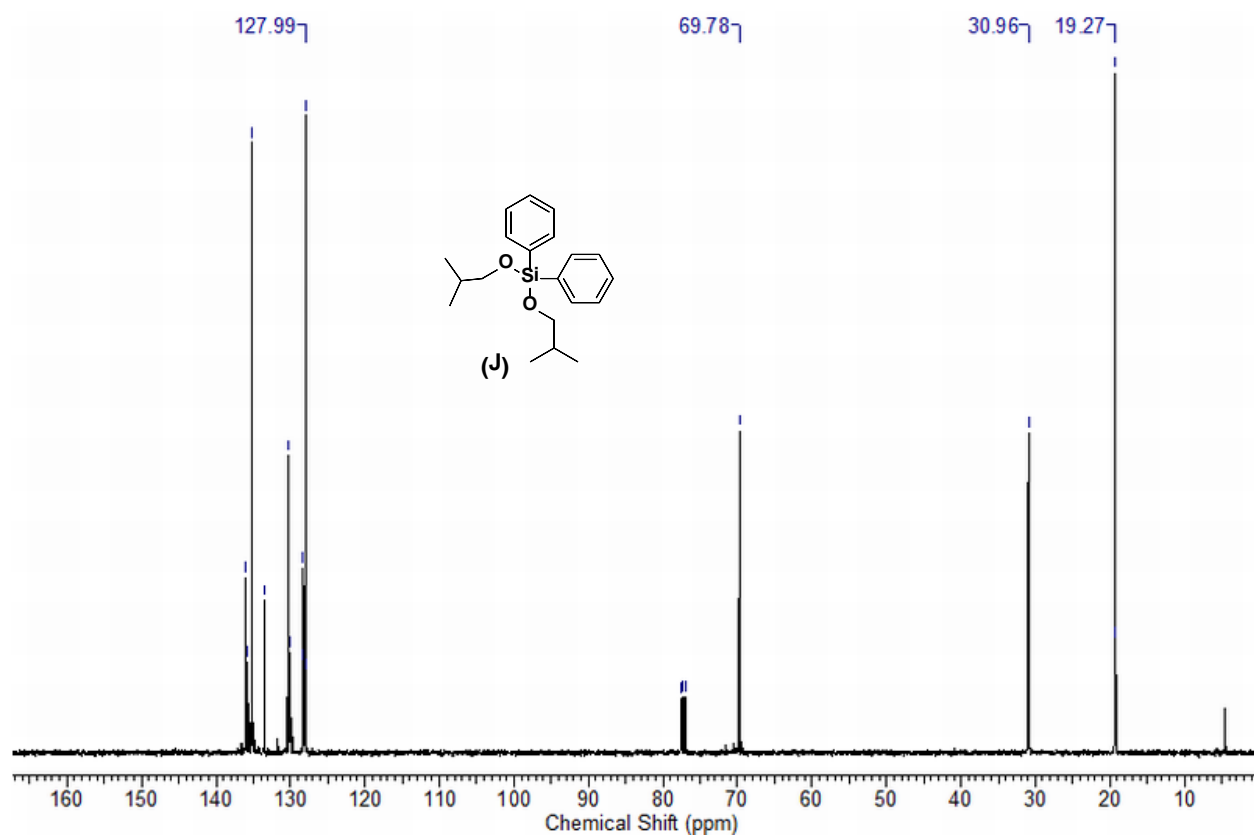
S15. ^{13}C NMR spectrum (400 MHz, 25°C, CDCl_3) of product **H**.



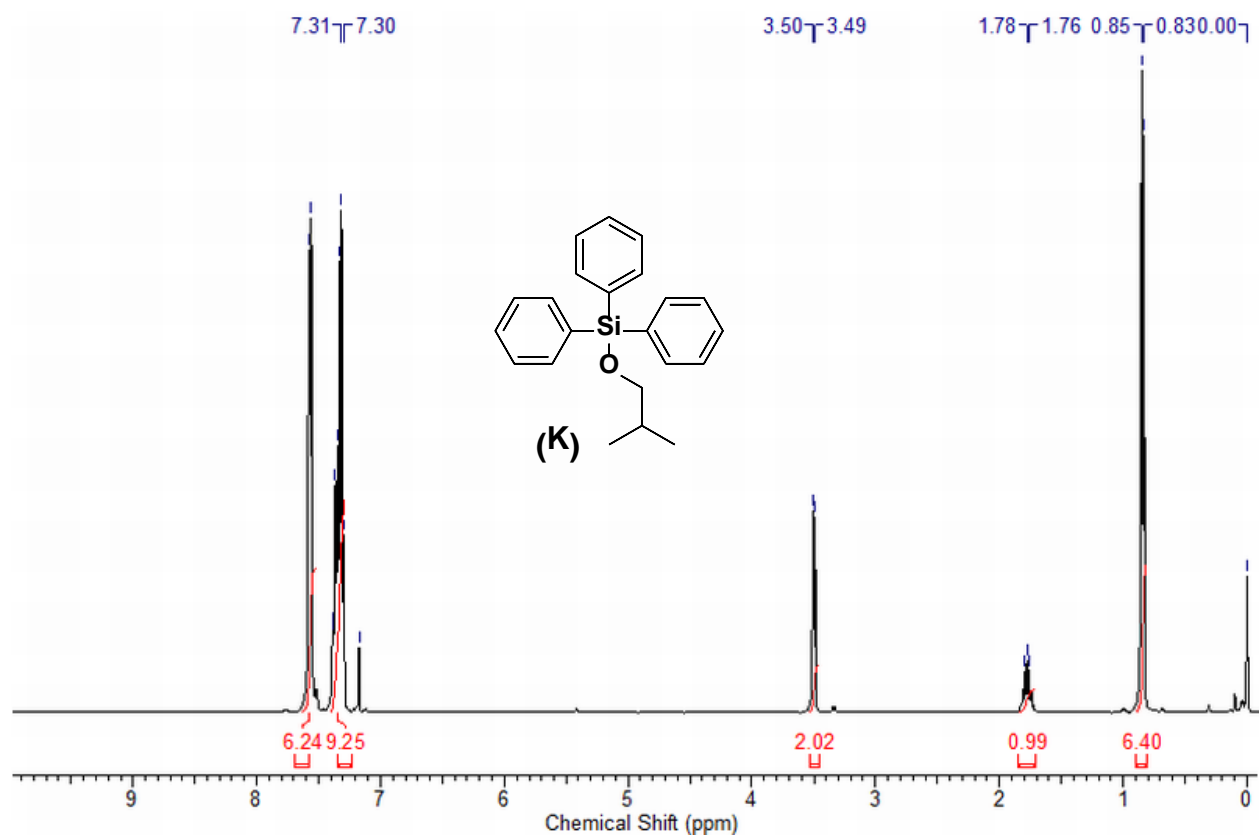
S16. ^1H NMR spectrum (400 MHz, 25°C, CDCl_3) of product **I**.



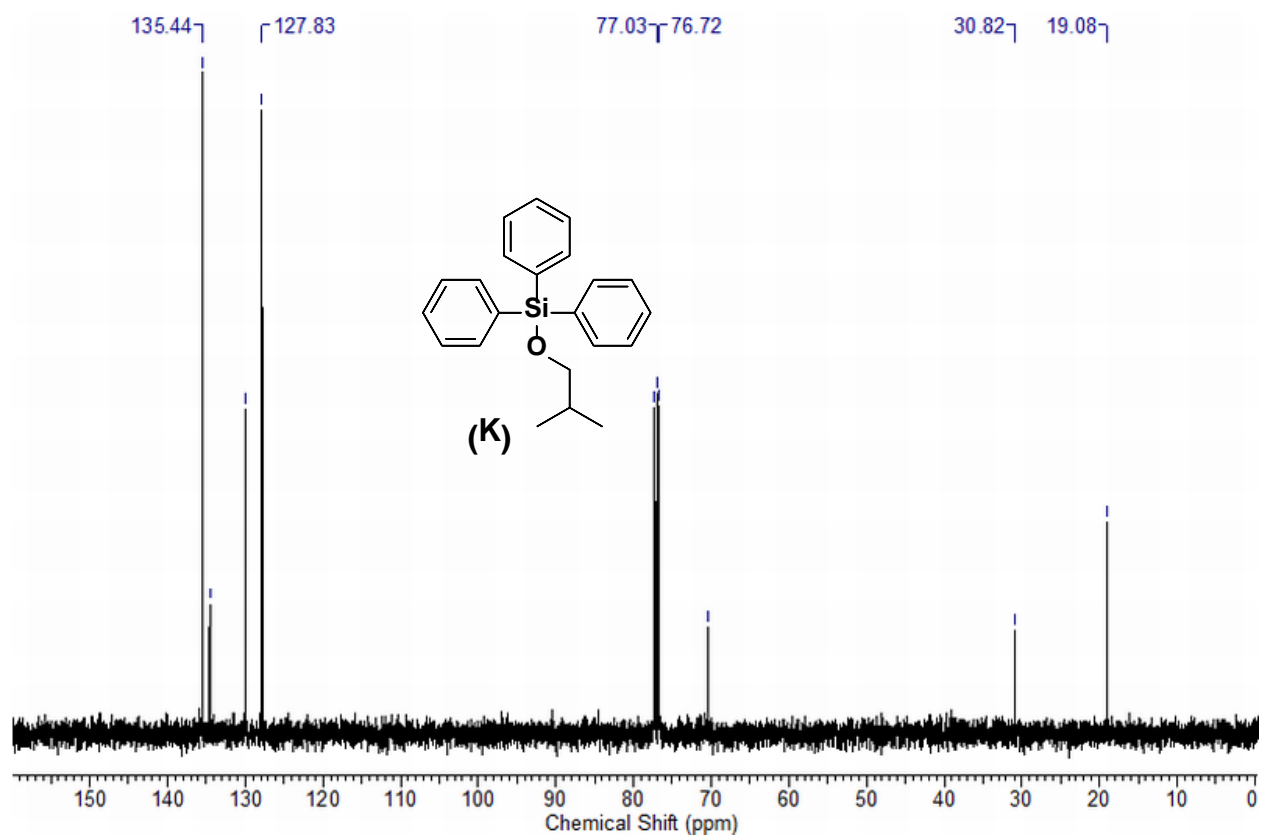
S18. ¹H NMR spectrum (400 MHz, 25°C, CDCl₃) of product **J**.



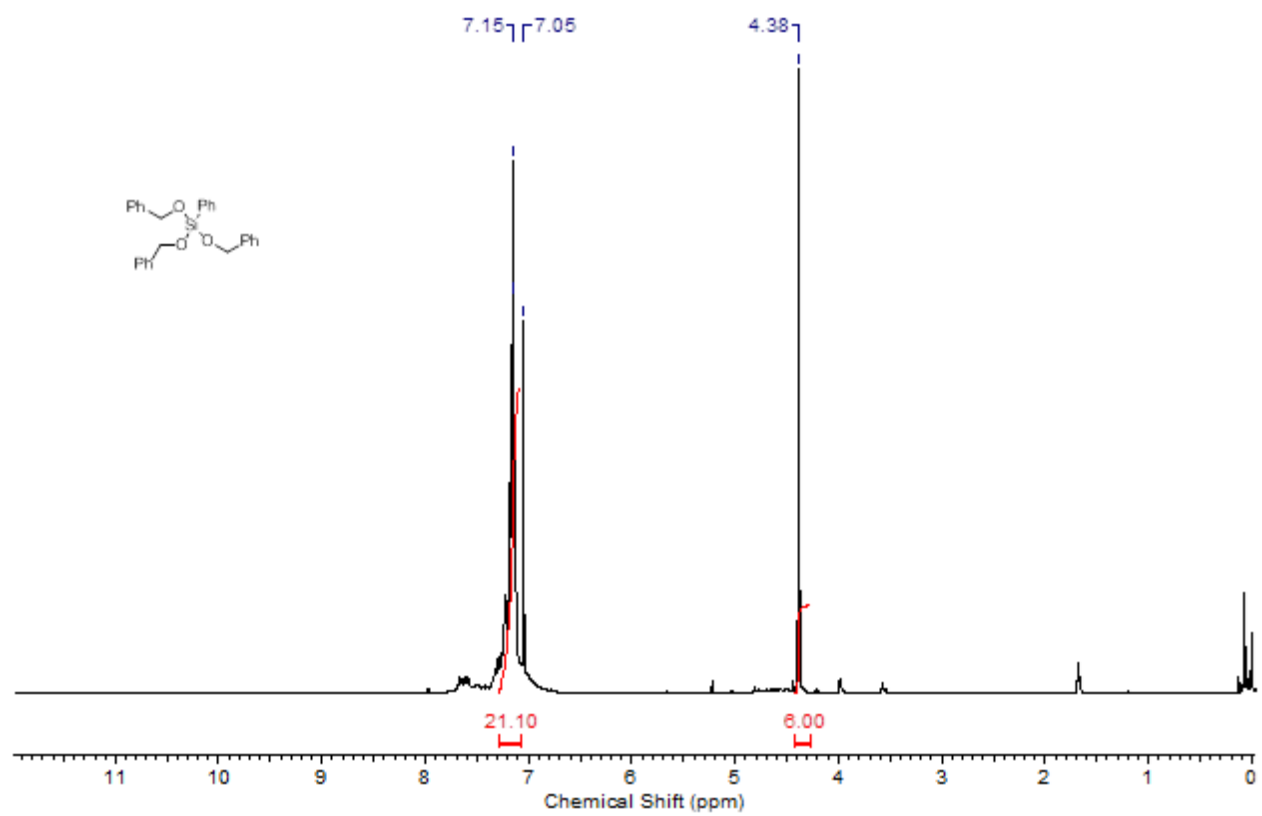
S19. ^{13}C NMR spectrum (100 MHz, 25°C, CDCl_3) of product **J**.



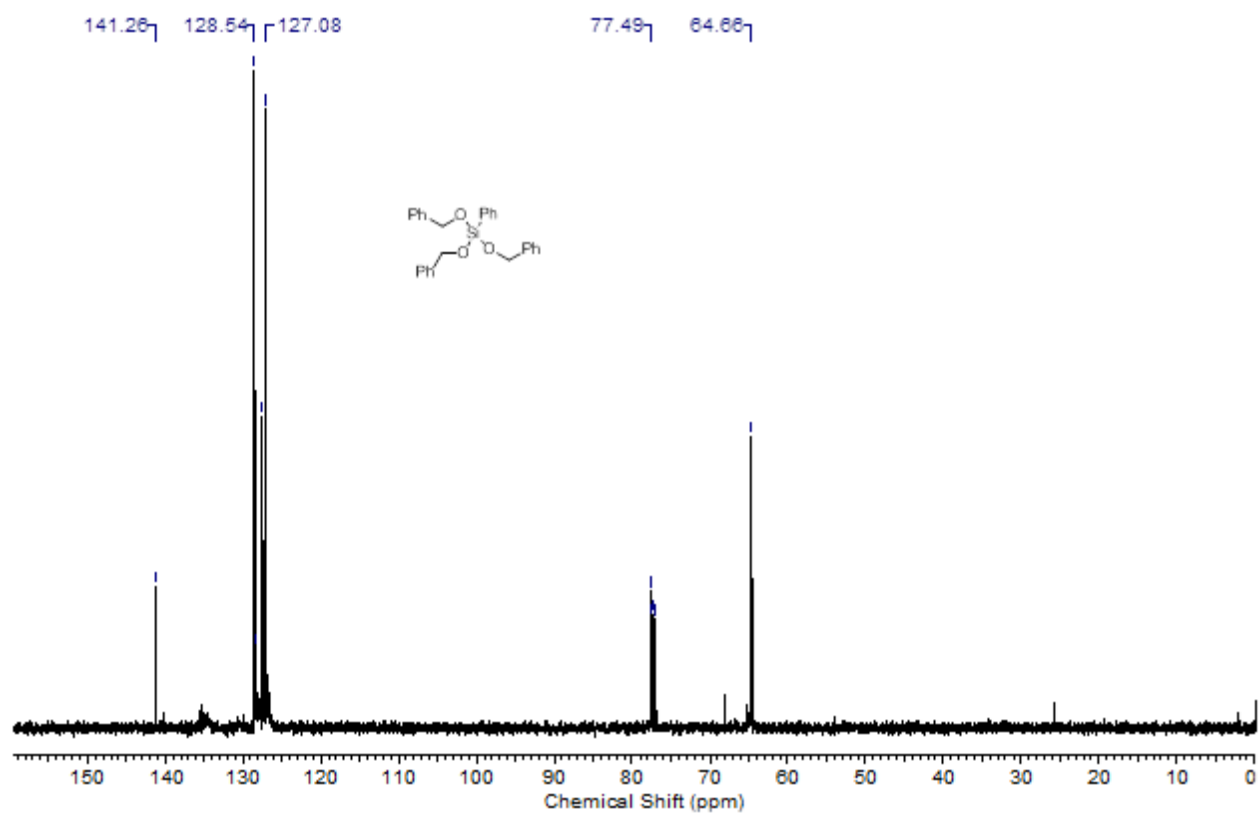
S20. ^1H NMR spectrum (400 MHz, 25°C , CDCl_3) of product **K**.



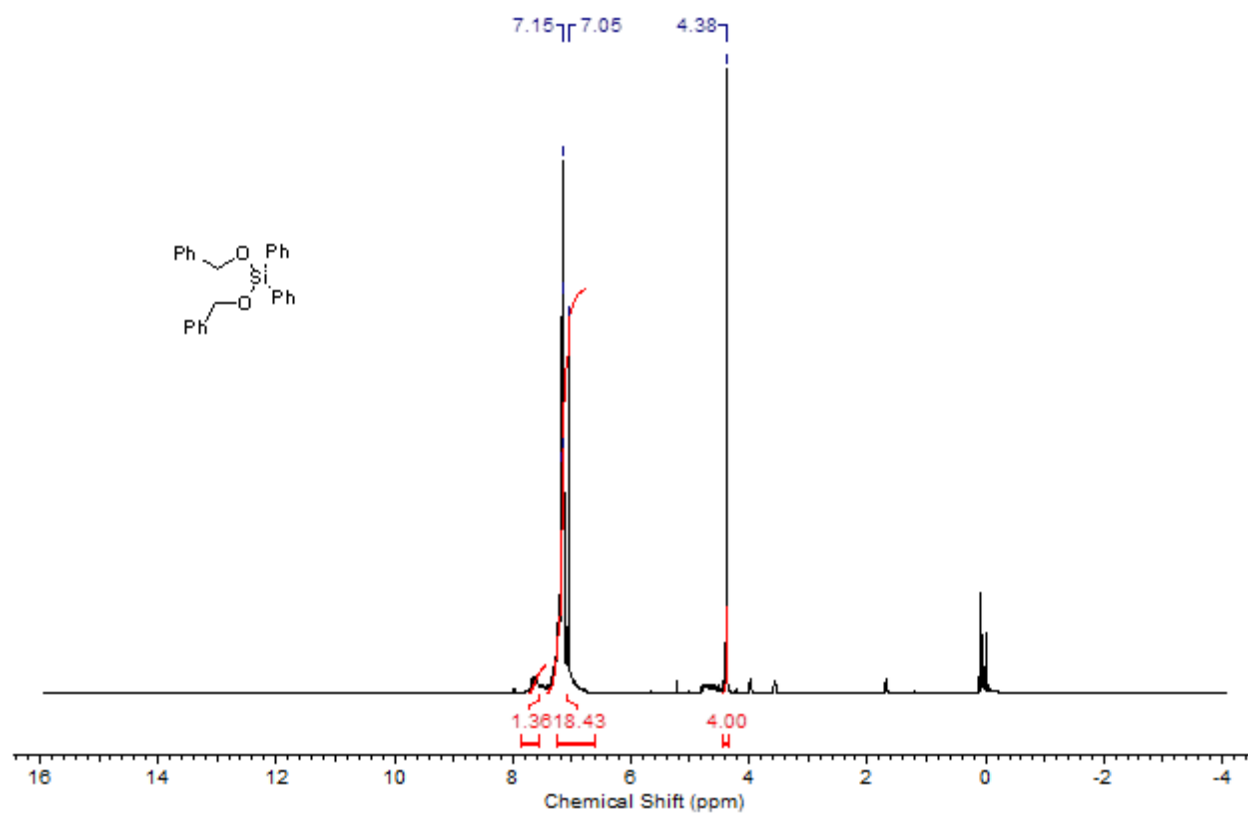
S21. ^{13}C NMR spectrum (100 MHz, 25°C, CDCl₃) of product **K**.



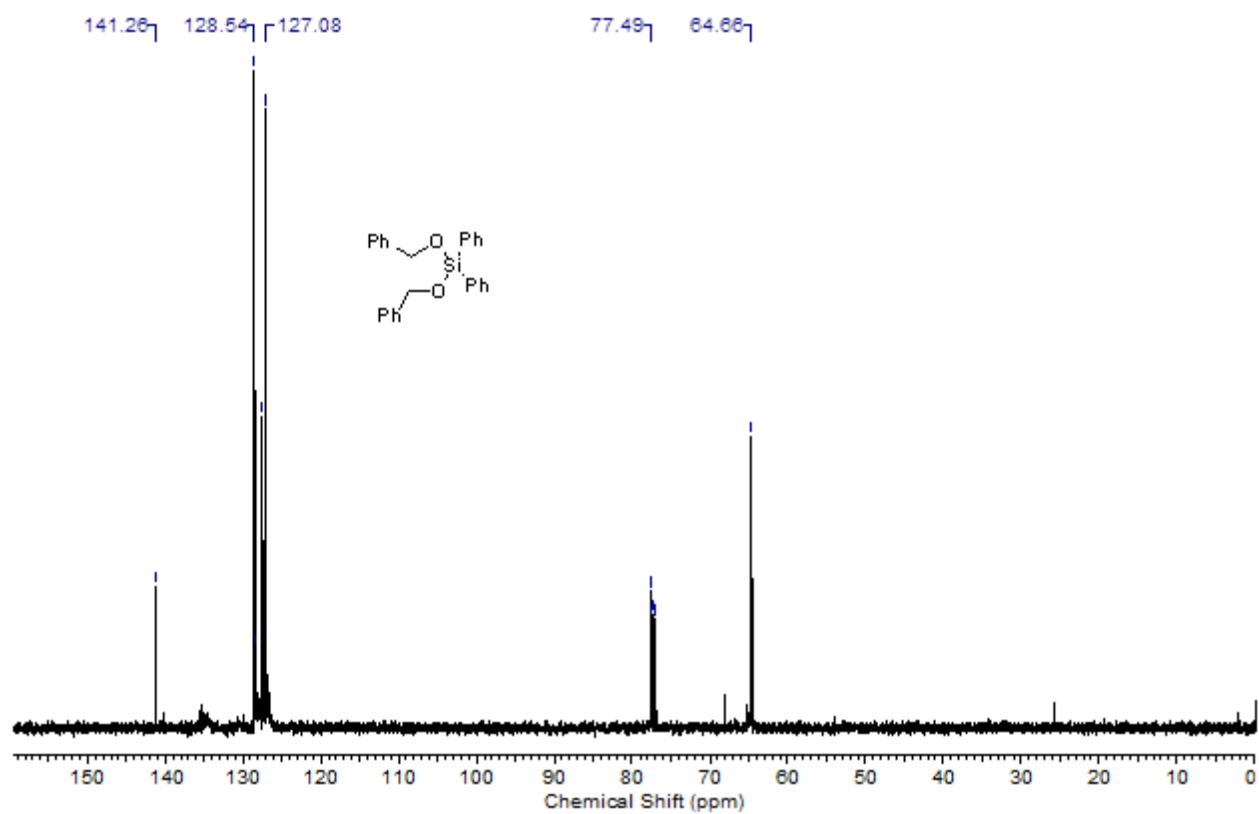
S22. ^1H NMR spectrum (100 MHz, 25°C, CDCl_3) of product L.



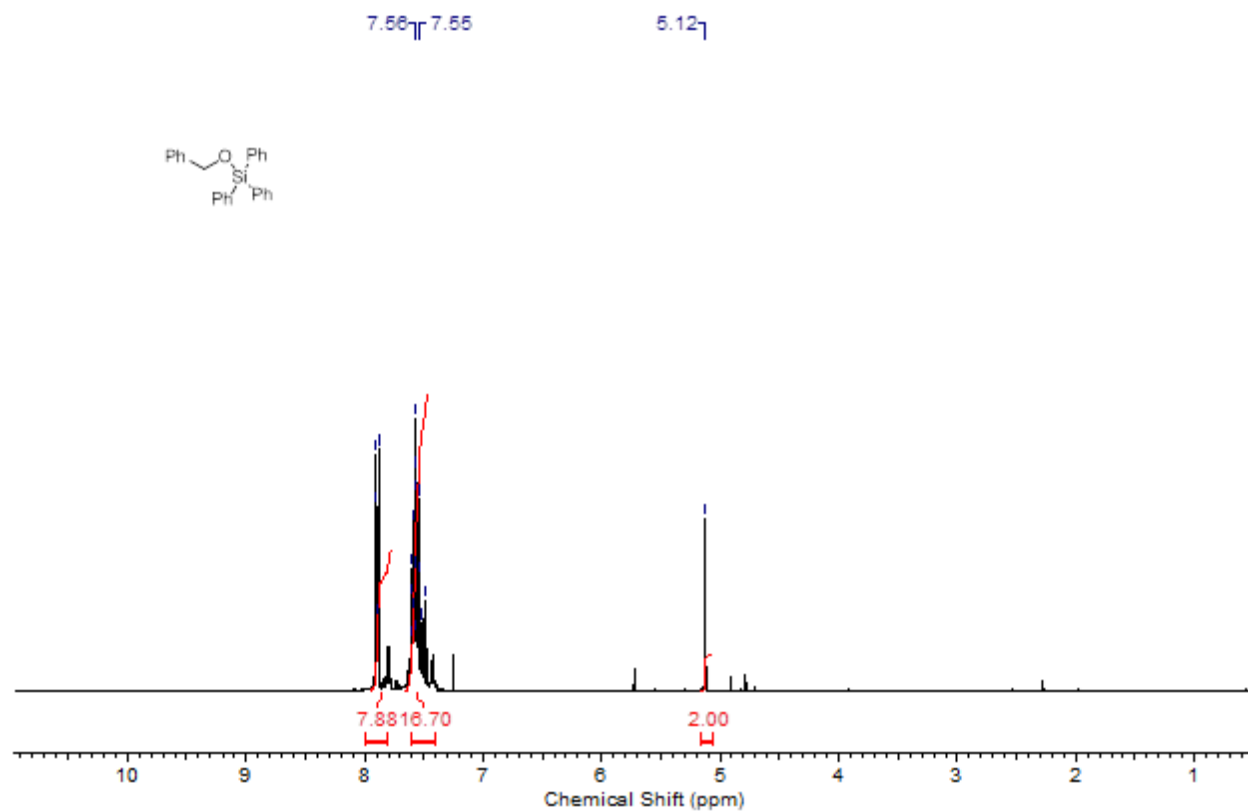
S23. ^{13}C NMR spectrum (100 MHz, 25°C, CDCl_3) of product L.



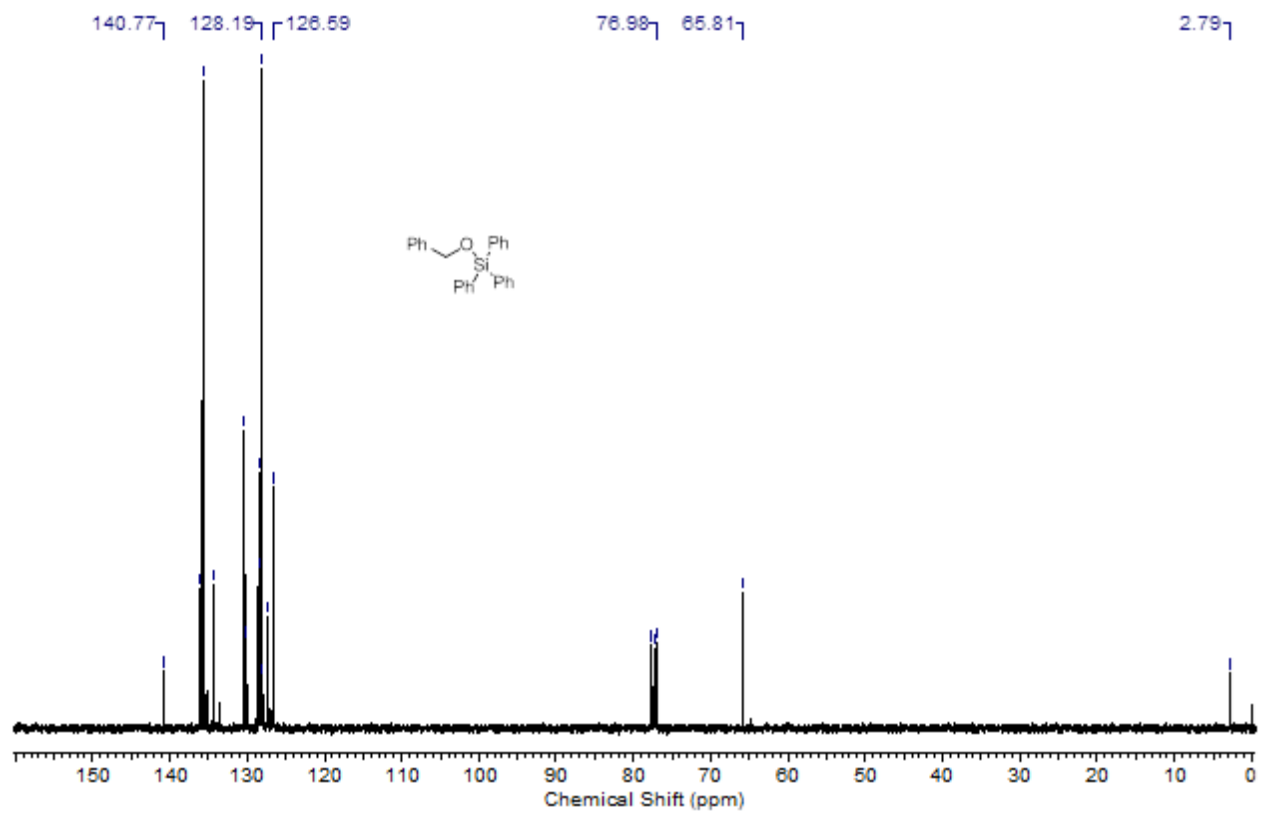
S24. ^1H NMR spectrum (100 MHz, 25°C, CDCl_3) of product **M**.



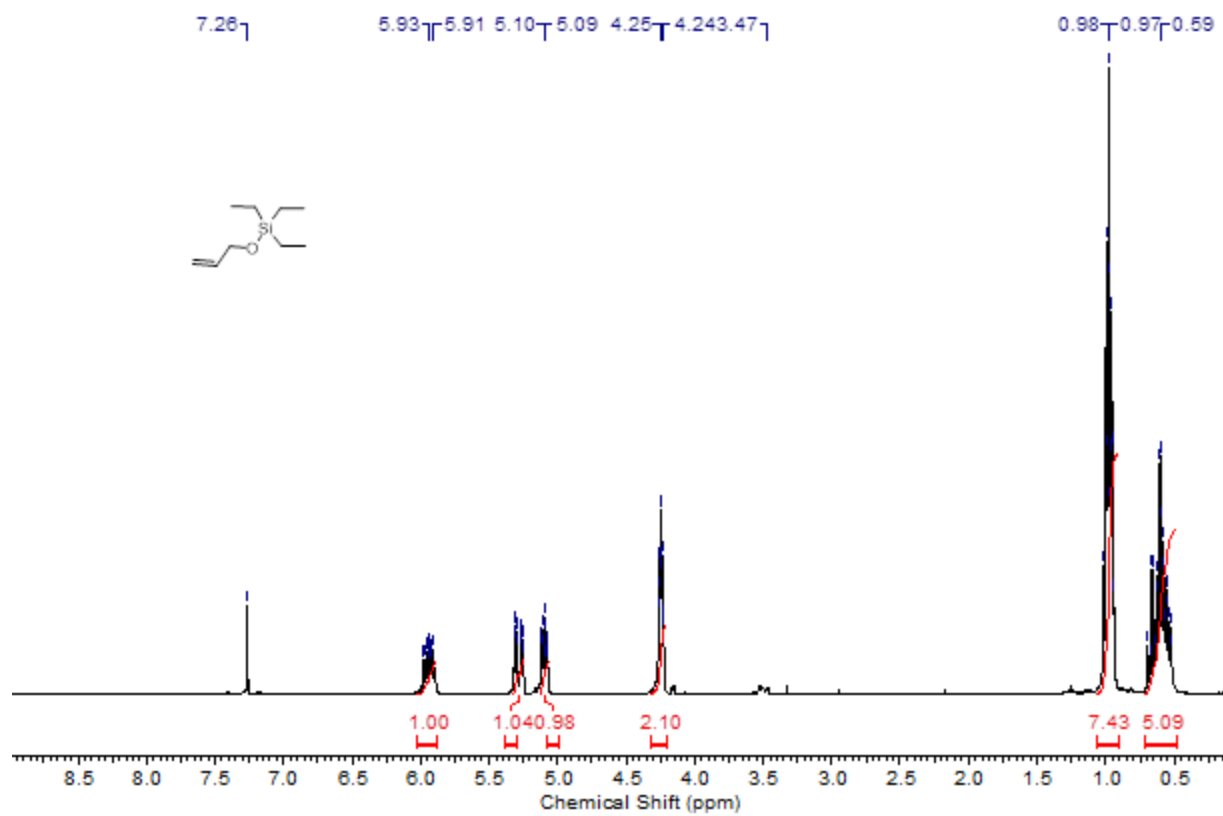
S25. ^{13}C NMR spectrum (100 MHz, 25°C, CDCl_3) of product **M**.



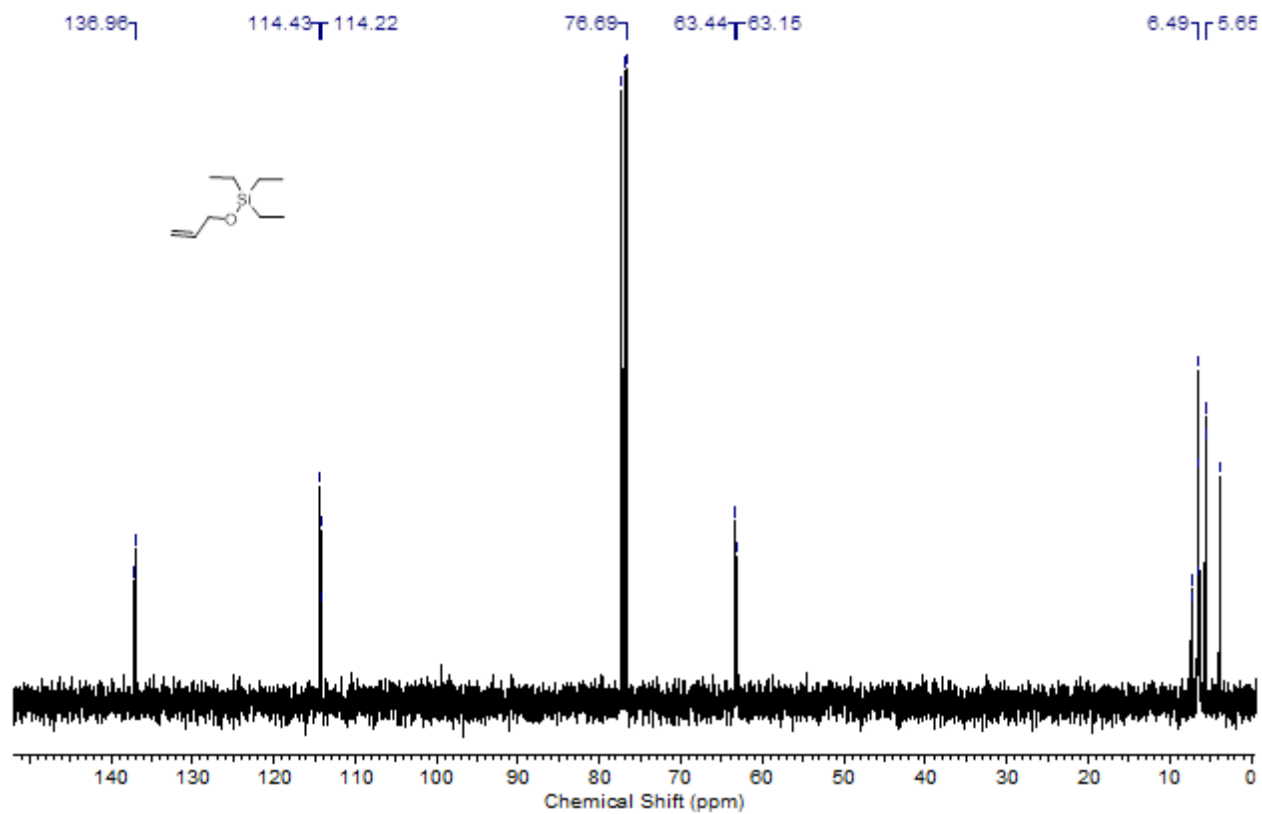
S26. ^1H NMR spectrum (100 MHz, 25°C, CDCl_3) of product **N**.



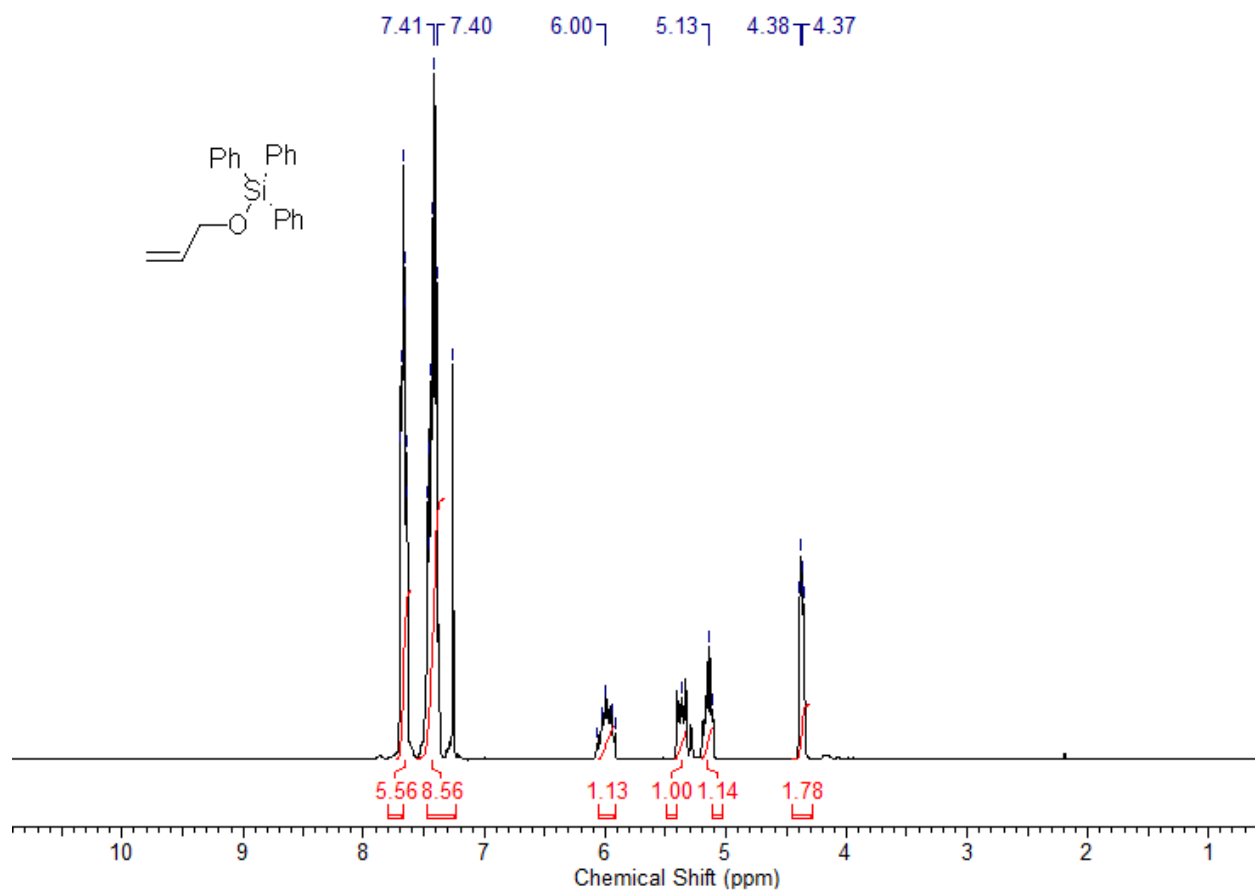
S27. ^{13}C NMR spectrum (100 MHz, 25°C, CDCl_3) of product N.



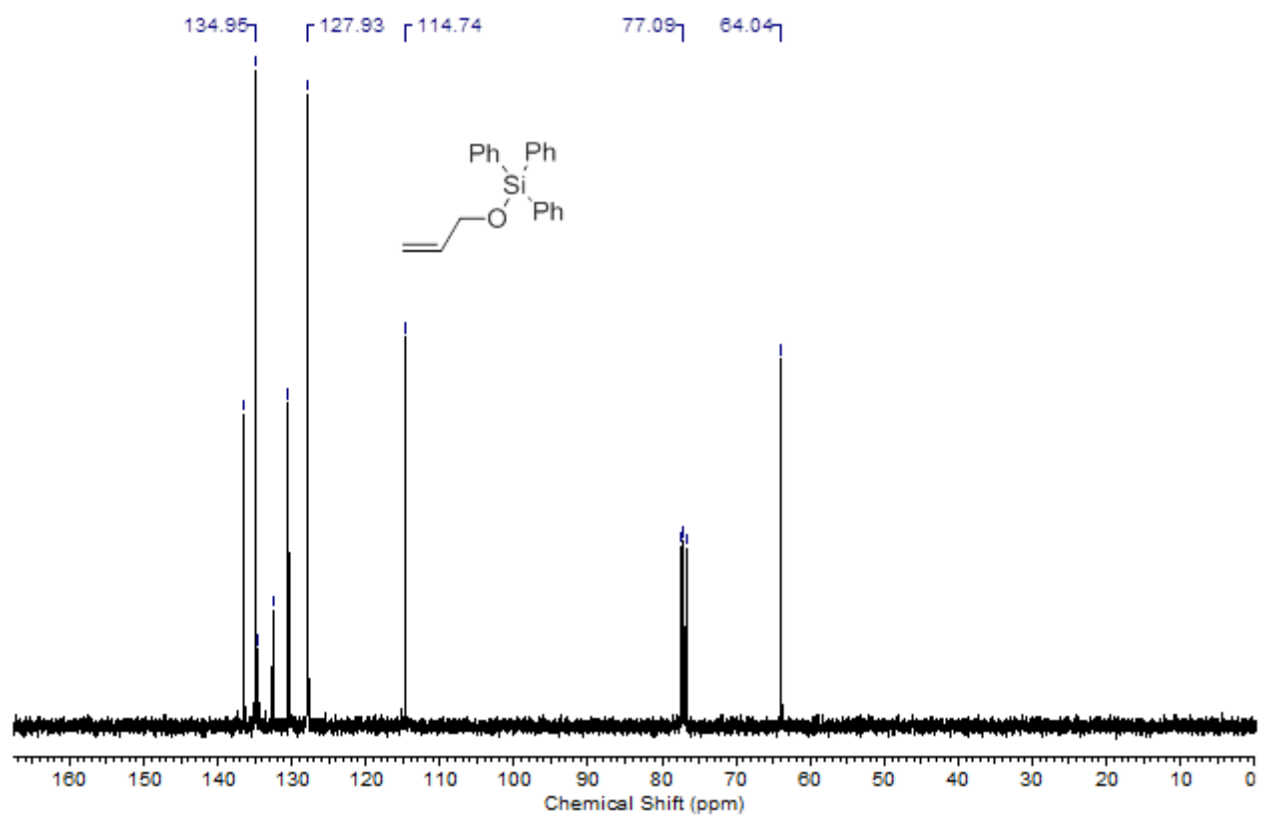
S28. ¹H NMR spectrum (400 MHz, 25°C, CDCl₃) of product O.



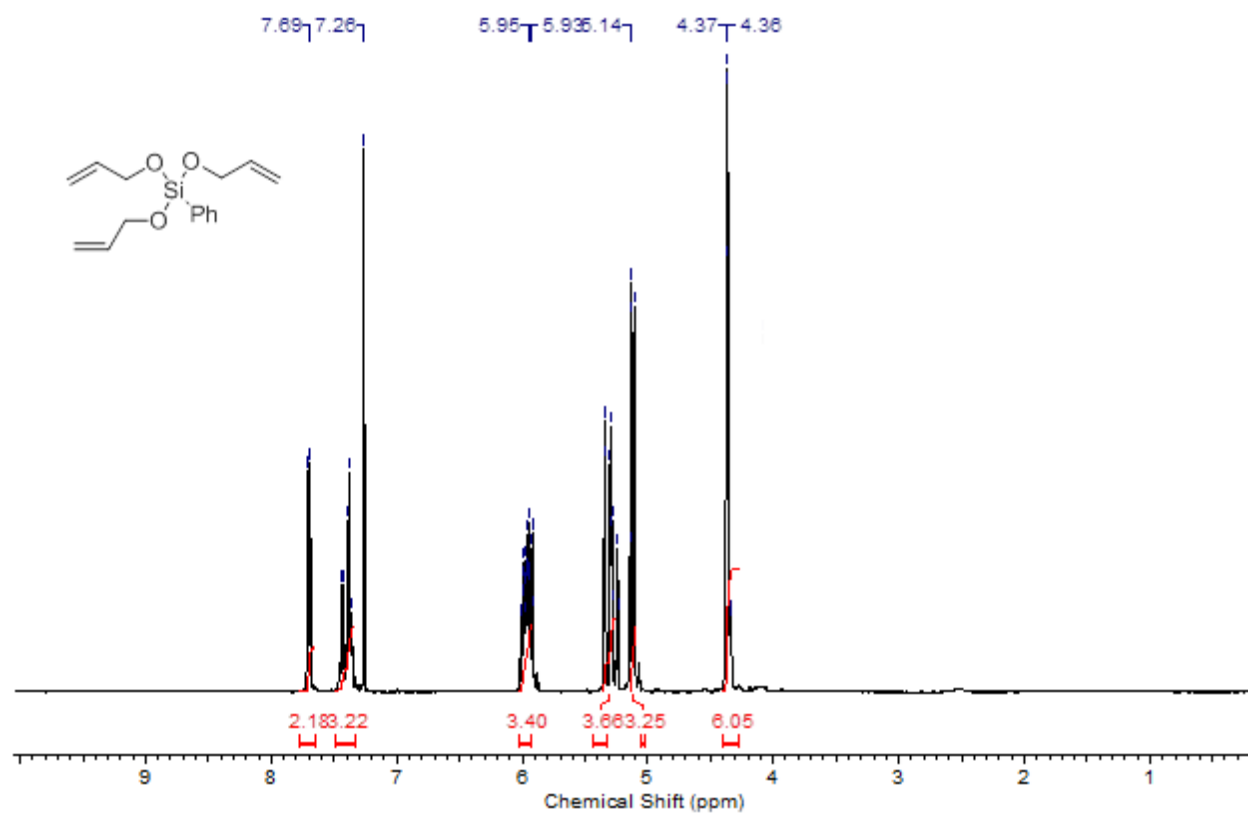
S29. ^{13}C NMR spectrum (400 MHz, 25°C, CDCl₃) of product **O**.



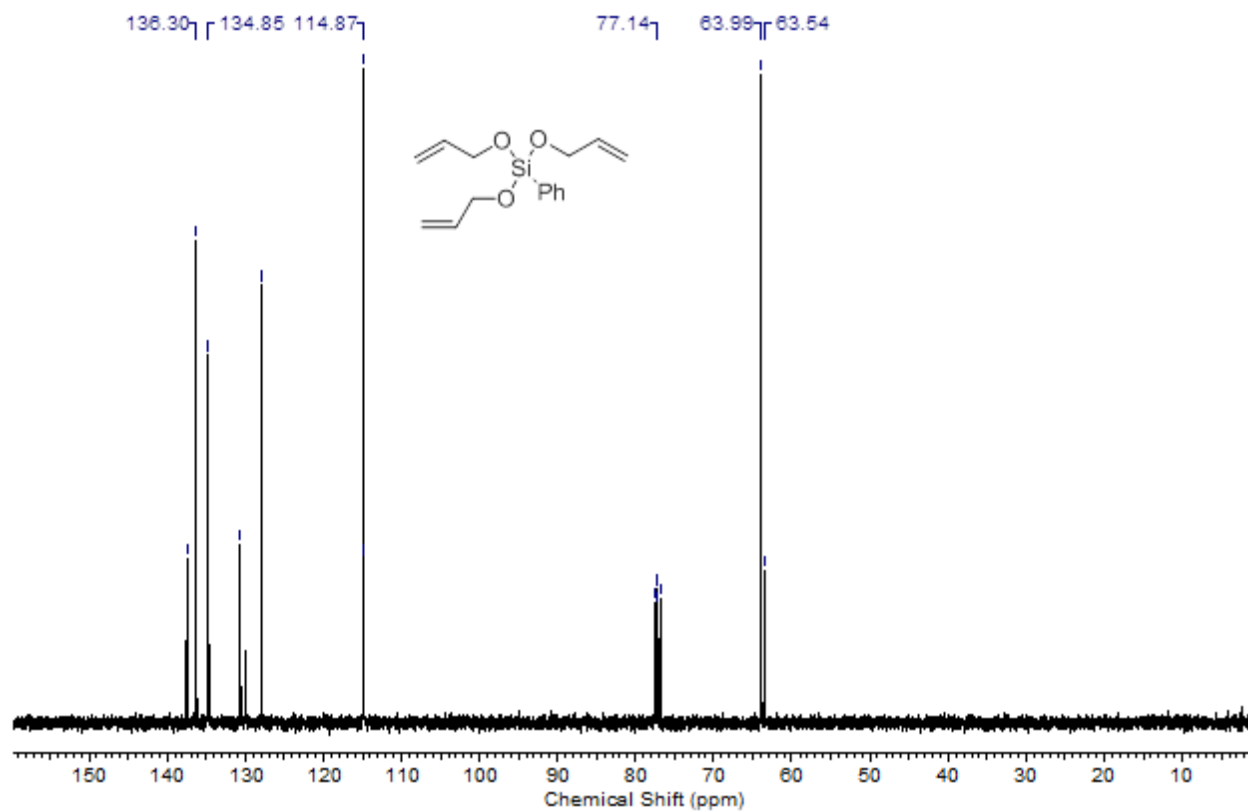
S30. ^1H NMR spectrum (400 MHz, 25°C, CDCl_3) of product **P**.



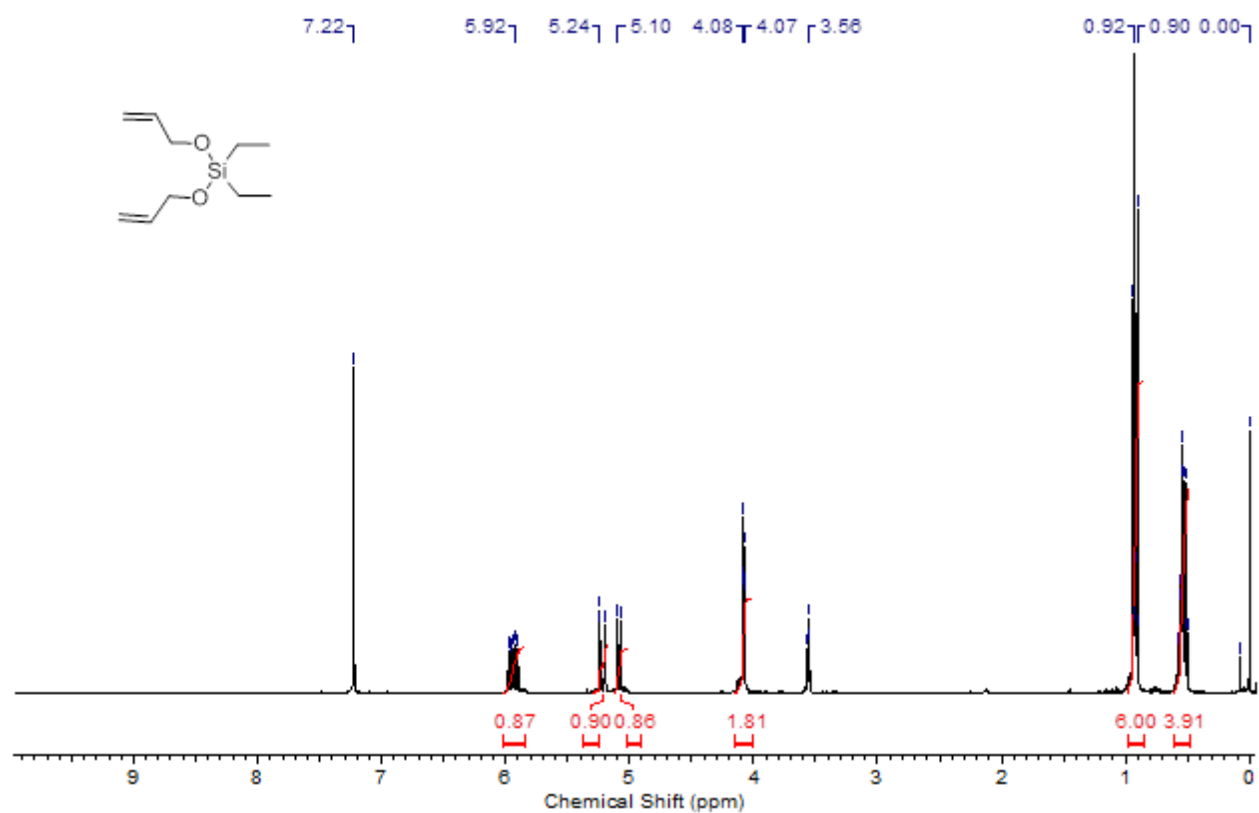
S31. ^{13}C NMR spectrum (400 MHz, 25°C, CDCl_3) of product **P**.



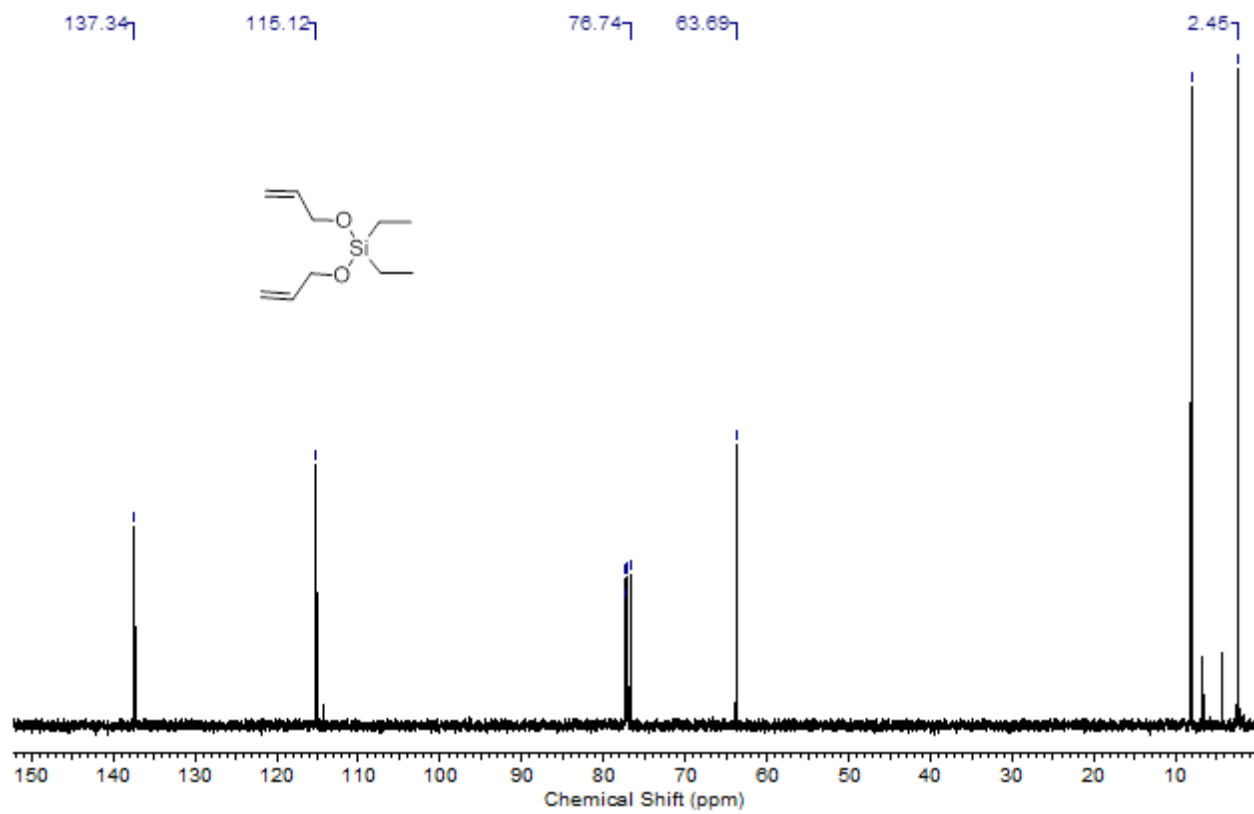
S32. ¹H NMR spectrum (400 MHz, 25°C, CDCl₃) of product Q.



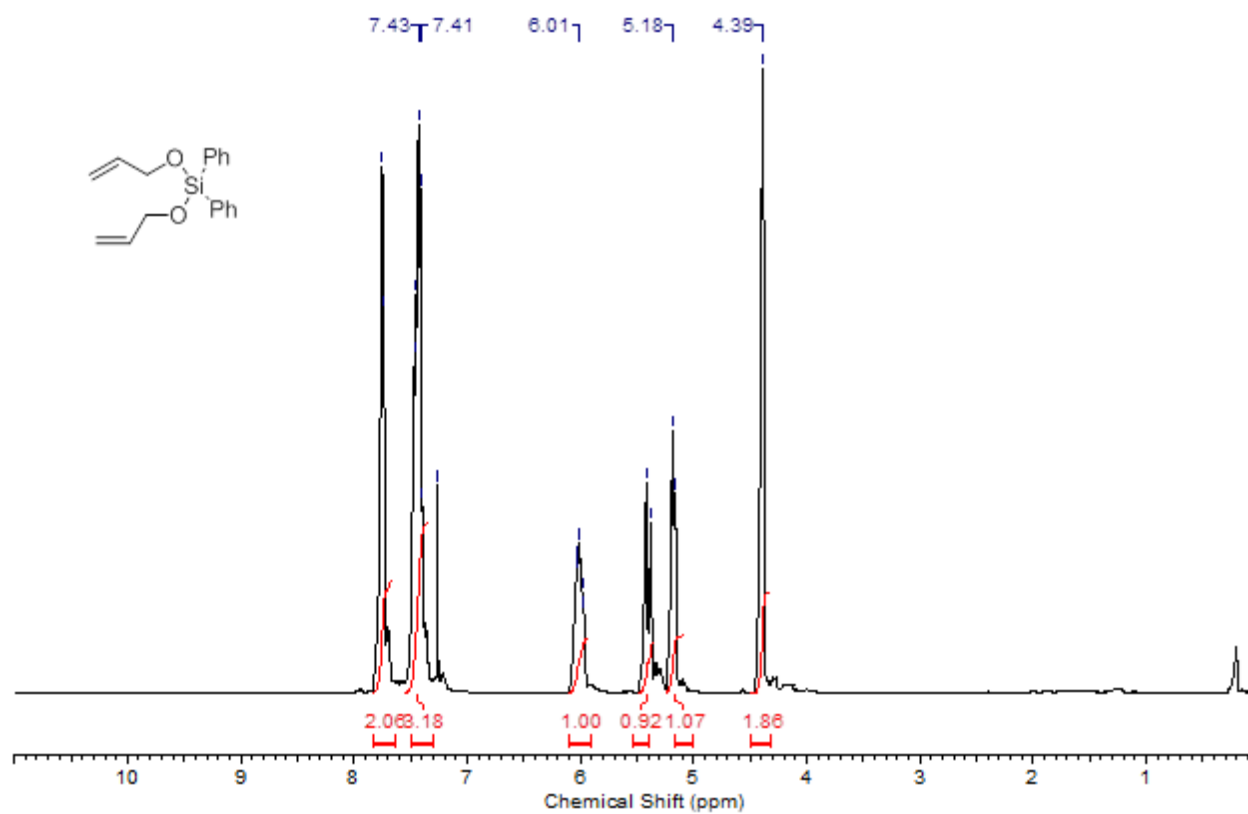
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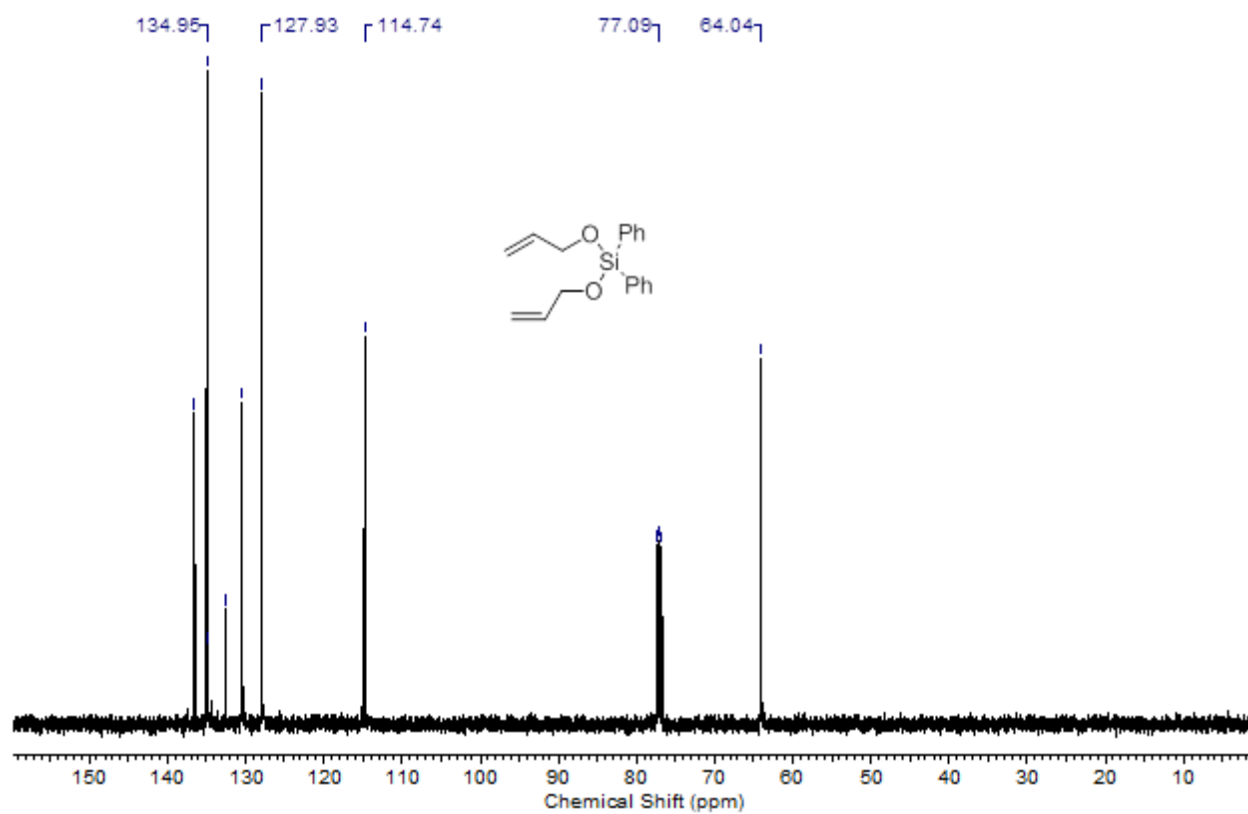
S34. ¹H NMR spectrum (400 MHz, 25°C, CDCl₃) of product **R**.



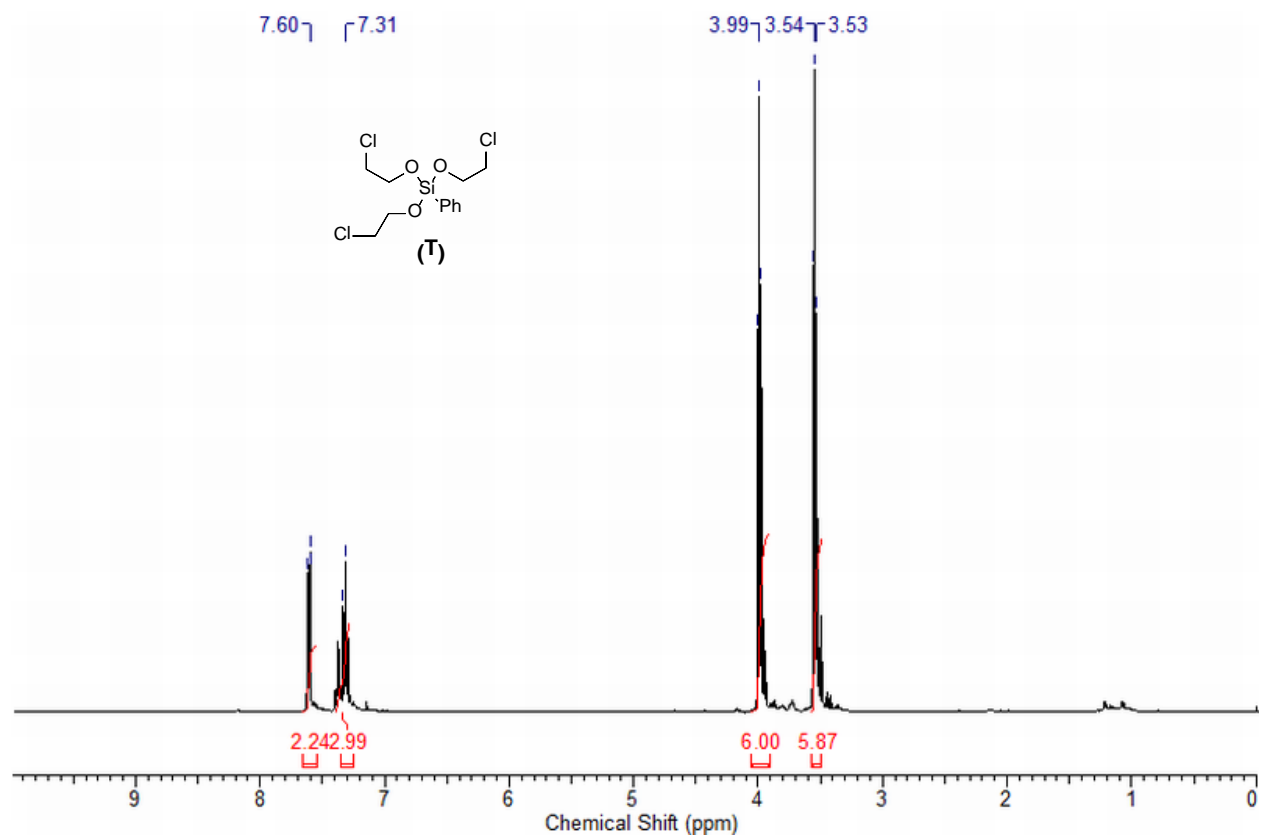
S35. ¹³C NMR spectrum (400 MHz, 25°C, CDCl₃) of product R.



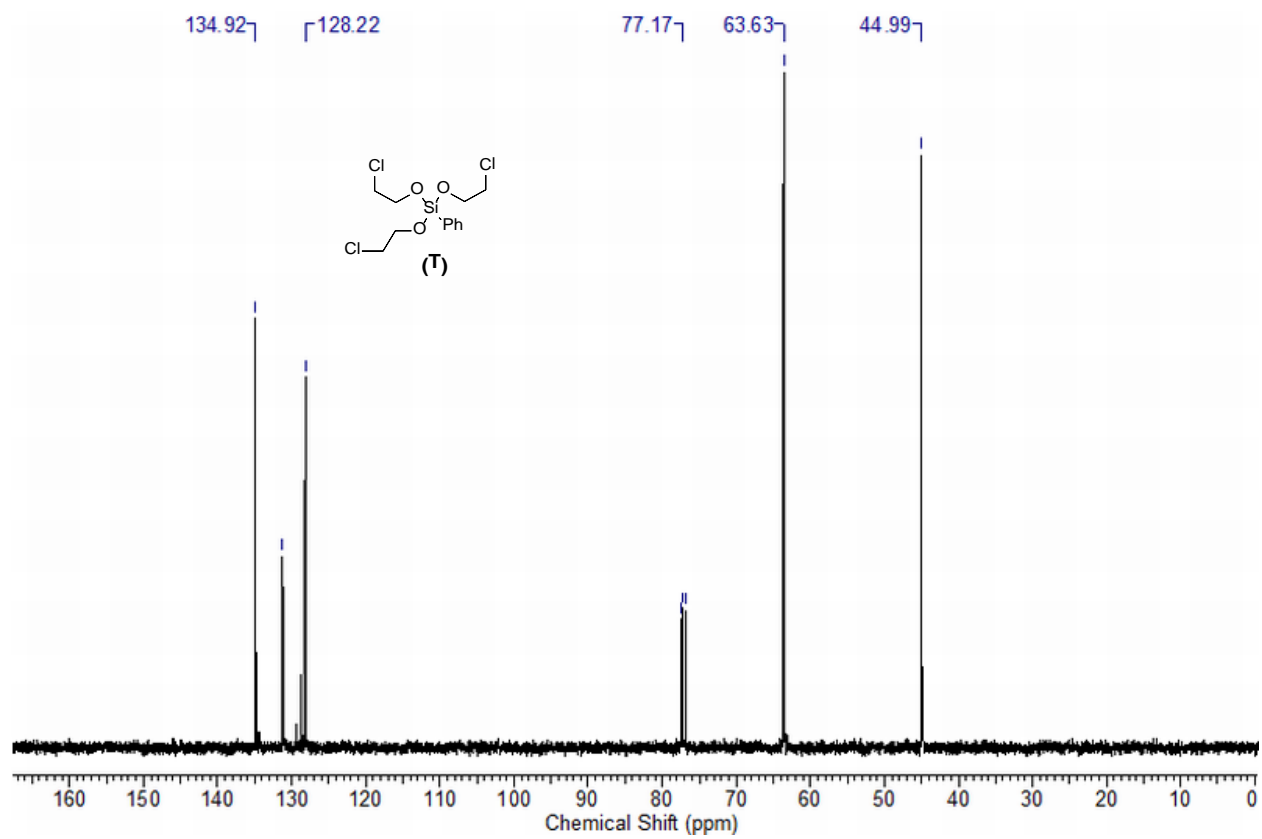
S36. ^1H NMR spectrum (400 MHz, 25°C, CDCl_3) of product **S**.



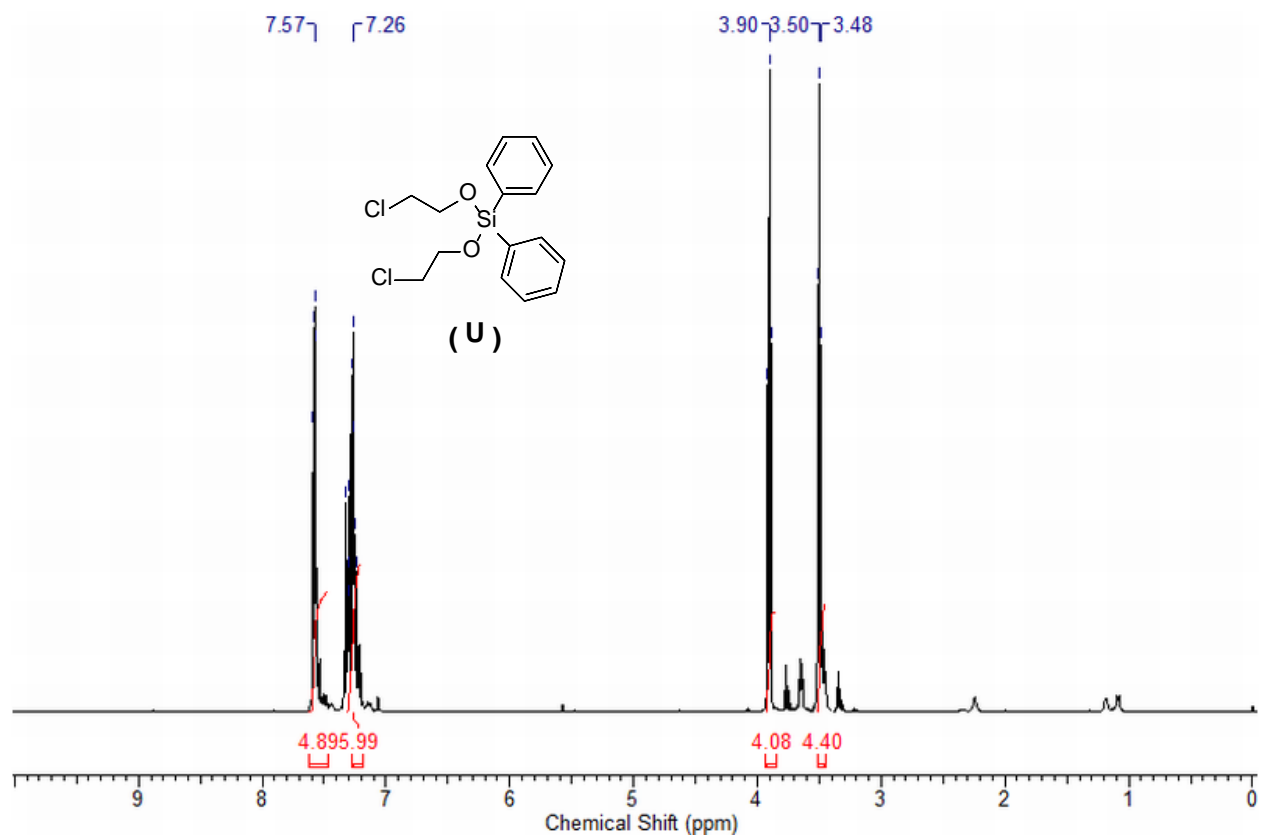
S37. ^{13}C NMR spectrum (400 MHz, 25°C, CDCl_3) of product S.



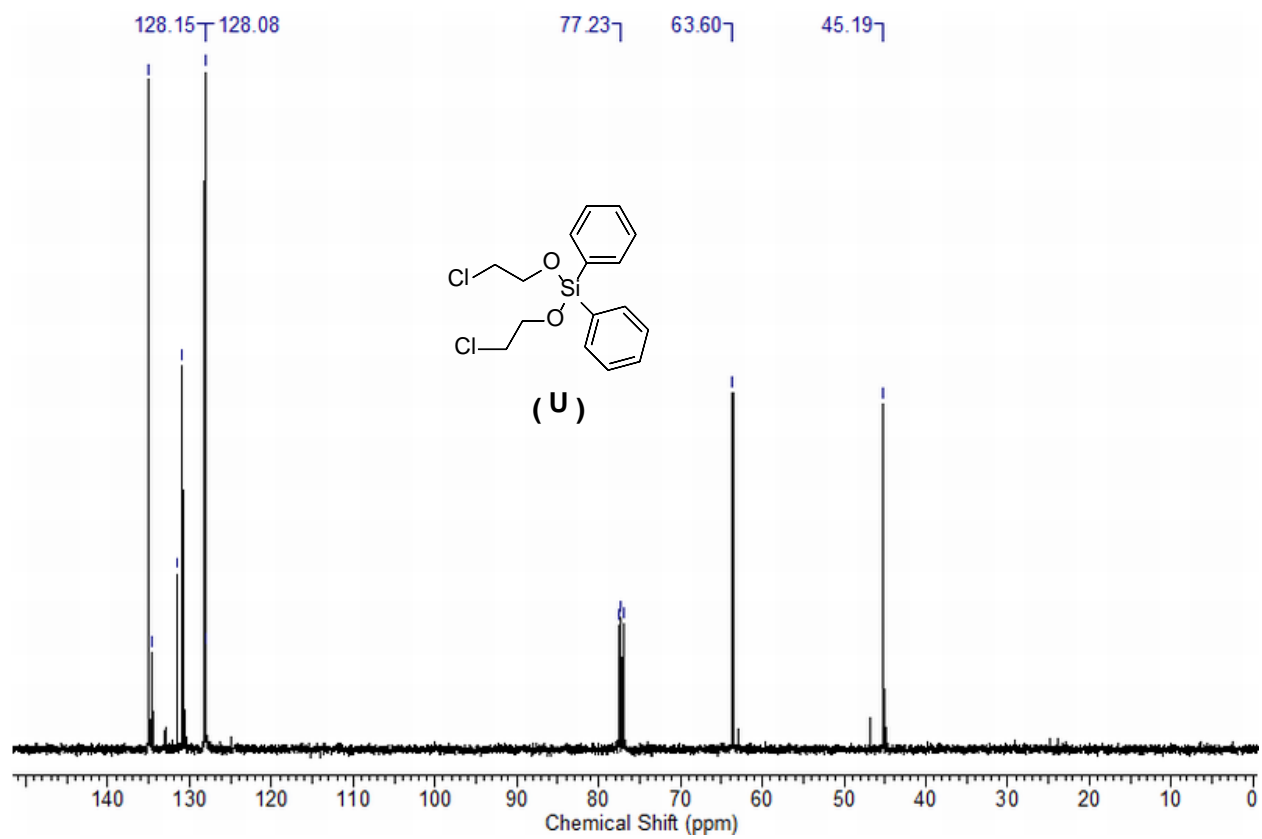
S38. ^1H NMR spectrum (400 MHz, 25°C , CDCl_3) of product **T**.



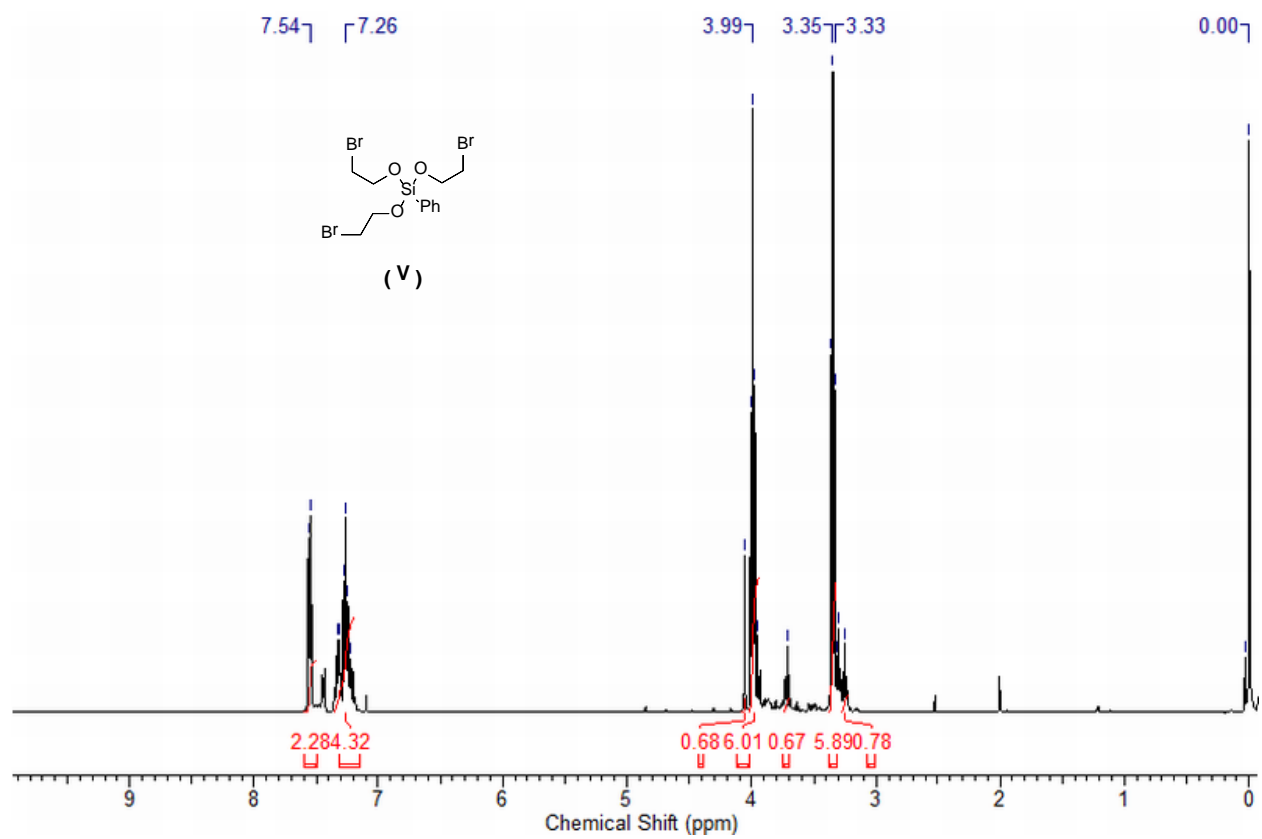
S39. ^{13}C NMR spectrum (100 MHz, 25°C, CDCl_3) of product **T**.



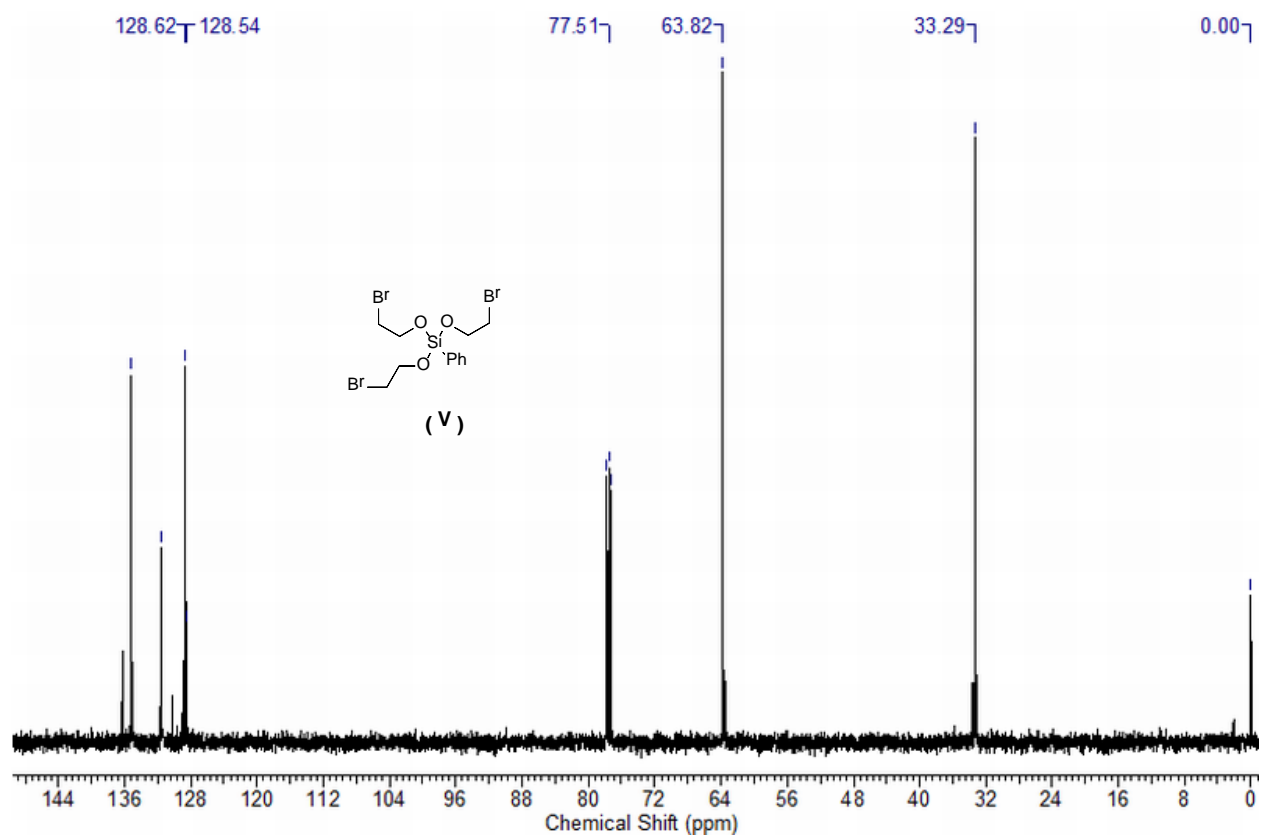
S40. ^1H NMR spectrum (400 MHz, 25°C, CDCl_3) of product U.



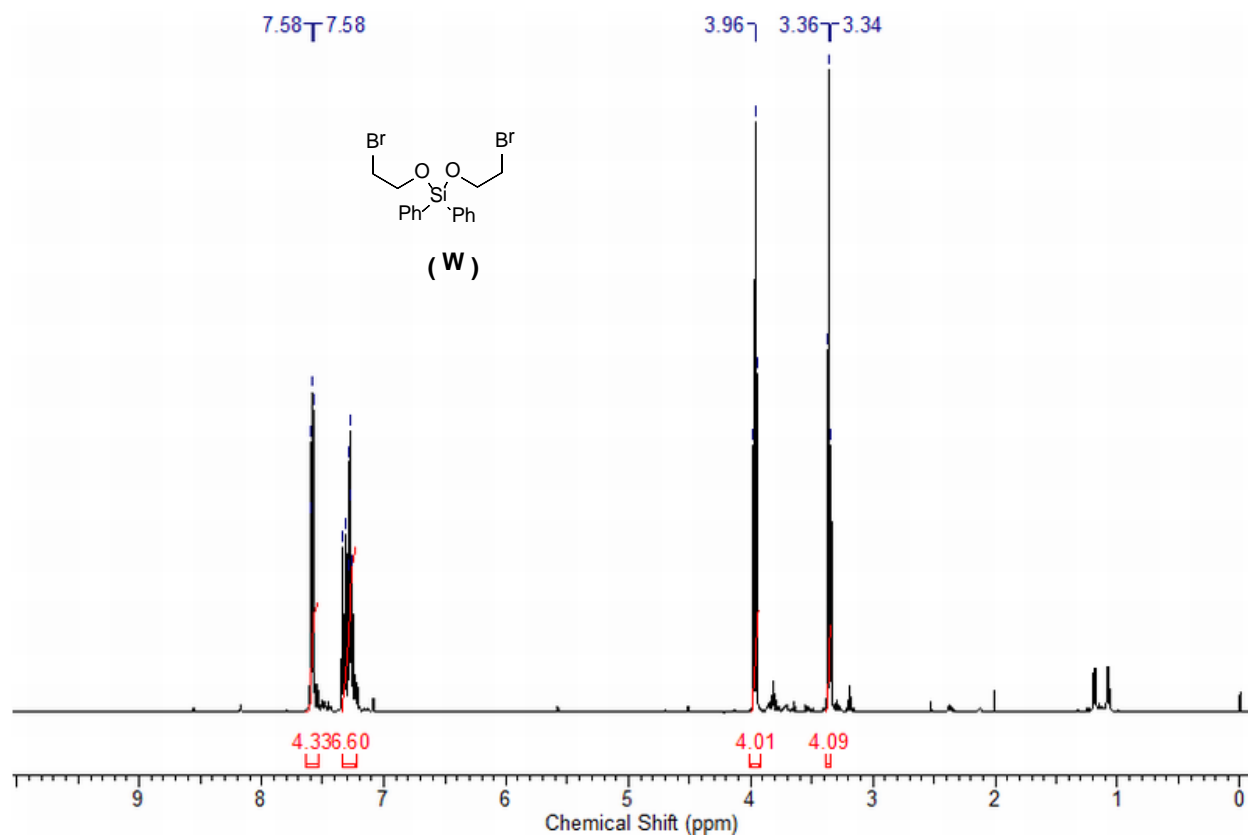
S41. ^{13}C NMR spectrum (100 MHz, 25°C, CDCl_3) of product U.



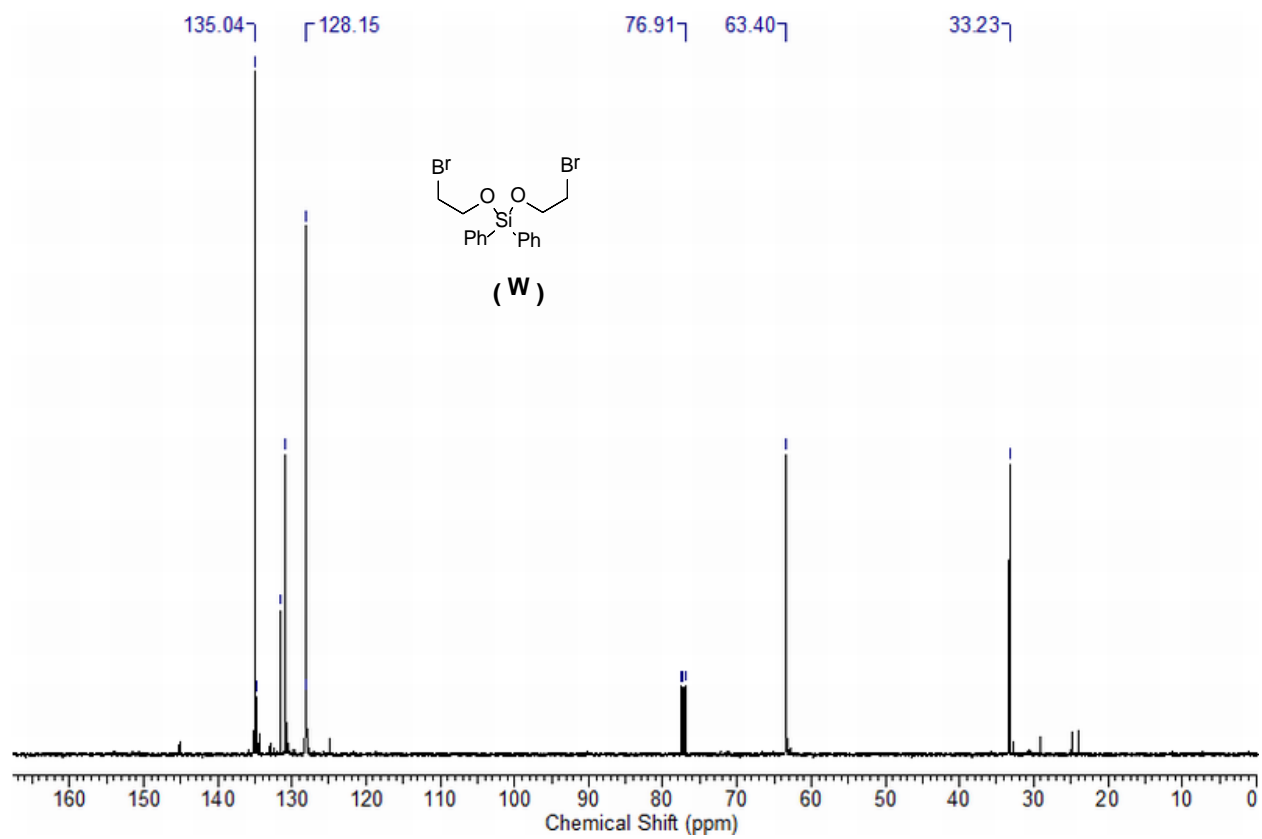
S42. ^1H NMR spectrum (400 MHz, 25°C, CDCl_3) of product V.



S43. ^{13}C NMR spectrum (100 MHz, 25°C, CDCl_3) of product V.



S44. ¹H NMR spectrum (400 MHz, 25°C, CDCl₃) of product W.



S45. ^{13}C NMR spectrum (100 MHz, 25°C, CDCl_3) of product **W**.