Supporting Information

The Hexameric Resorcinarene Capsule is a Brønsted Acid: Investigation and Application to Synthesis and Catalysis

Qi Zhang and Konrad Tiefenbacher*

Department Chemie, Technische Universität München, D-85747 Garching, Germany

konrad.tiefenbacher@tum.de

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1. General information

Experimental. Reactions were carried out under an atmosphere of argon unless otherwise indicated. Analytical thin-layer chromatography (TLC) was performed on Merck silica gel 60 F_{254} glass-baked plates. ^{1}H NMR and ^{13}C NMR spectra were recorded at 500 MHz and 126 MHz respectively, using a Bruker AV 500 spectrometer. Chemical shifts of ^{1}H NMR and ^{13}C NMR (measured at 298 K unless otherwise stated) are given in ppm by using $CHCl_3$ and $CDCl_3$ as references (7.26 ppm and 77.16 ppm respectively). Coupling constants (*J*) are reported in Hertz (Hz). Standard abbreviations indicating multiplicity were used as follows: s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet), dt (doublet of triplets), dq (doublet of quartets). 2D-DOSY spectrum was recorded with a Bruker AV 500 spectrometer using the Bruker standard DOSY routine. Infrared spectra were recorded on a JASCO FT/IR-4100 spectrometer. Mass spectra and high-resolution mass spectra were performed on a Finnigan MAT 8200 or a Thermo Scientific DFS mass spectrometer.

Source of chemicals. Anhydrous CH_2Cl_2 and THF were taken from a solvent drying system (MBraun SPS-800). $CDCl_3$ was purchased from Deutero GmbH. Anhydrous ethanol, toluene, oxalyl chloride, 4-tetradecylaniline, 1-bromooctadecane, dioctadecylamine, tetrakis-(triphenylphosphine)palladium(0), sodium borohydride, bromoacetyl bromide, triphenylphosphine, propanal, butanal, octanal were purchased from Sigma-Aldrich. 3,5-dibromobenzalaldehyde, 4-*tert*-butylphenylboronic acid, 3,3,3-triphenylpropionic acid, pentanal, hexanal, dodecanal, acetaldehyde diethyl acetal were purchased from Alfa Aesar. 3-ethylpentane and propionaldehyde diethyl acetal were purchased from TCI. Triethylamine, Silica gel (0.040-0.063 mm, 230-400 mesh ASTM) and alunimium oxide 60 active basic (activity stage I, 0.063-0.200 mm, 70-230 mesh ASTM) were purchased from Merck KGaA. Anhydrous DMF and molecular sieves 3 Å powder were purchased from Acros Organics. All chemicals were used as received. Sonication was performed in a VWR Ultrasonic Cleaner USC-300TH. Transfer of liquids with a volume ranging from 1 to

10 µL or from 10 to 100 µL was performed with a microman M1 pipette (Gilson) equipped with 10 µL or 100 µL pipette tips, respectively.

Resorcin[4]arene **1** was synthesized according to literature procedures[1] and had a methanol (from recrystallization) content of 0.20 µmol/mg (0.22 eq MeOH/**1**), which improved the solubility of **1** in $CDCl_3$. The experimental results were reproducible when a commercial available resorcin[4]arene **1** (as mono hydrate and methanol-free, purchased from Sigma Aldrich) was employed.

4,4''-di-*tert*-butyl-[1,1':3',1''-terphenyl]-5'-carbaldehyde was prepared according to a literature procedure.[2]

General procedure for binding/protonation studies: Water saturated $CDCl_3$ was prepared by filtration of $CDCl_3$ (20 mL) through basic aluminium oxide 60 active (5 mL, activity stage I), adding distilled water (0.10 mL) and mixing the sample by agitation. After letting the mixture equilibrate for 30 min. the $CDCl_3$-phase was directly used for the experiments.

Preparation of resorcin[4]arene stock solution: Water saturated $CDCl_3$ (ca. 1.5 mL) was added to resorcin[4]arene **1** (120 mg) in a 2 mL-volumetric flask and the sample homogenized by sonication, gentle heating with a heat gun and agitation to give a clear solution. The volumetric flask was filled up to the calibration mark with water saturated $CDCl_3$ and again homogenized by agitation to give a solution with a concentration of 54.3 mmol/L.

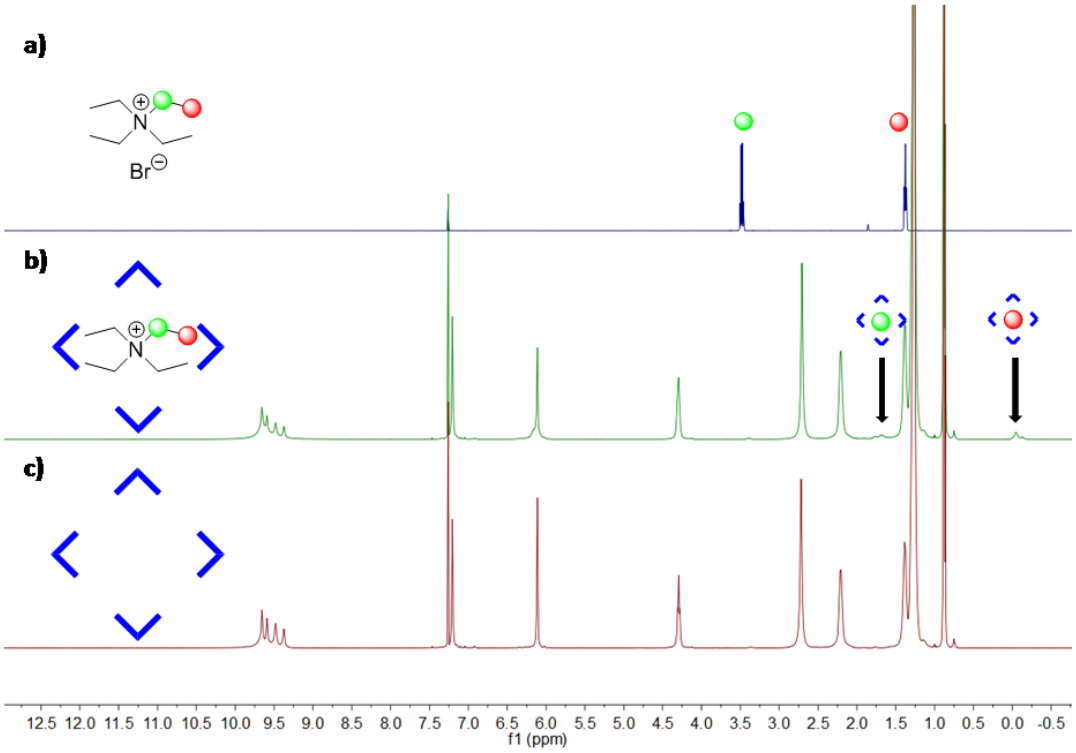
Preparation of guest stock solution: Stock solutions of guests/bases were prepared with a concentration of 41.7 mmol/L in water saturated $CDCl_3$.

Sample preparation: To resorcin[4]arene stock solution (185 µL, 11.1 mg, 10.0 µmol, 6 eq) in a NMR-tube was added water saturated $CDCl_3$ (295 µL) and guest stock solution (20 µL, 0.834 µmol, 0.5 eq). The sample was homogenized by agitation.

Determination of the encapsulation/protonation ratio: In case of binding studies, the integral of the methine group (4.29 ppm, t, J = 7.7 Hz, 24H) or the *o*-aromatic proton (6.11 ppm, s, 24H) of the assembly of resorcin[4]arene **1** were used as references to determine the encapsulation ratio. For guest integration the terminal methyl group, located between 0 and -2 ppm after encapsulation (see ***SI Figure 1-2***), was used. In case of protonation studies (see ***SI Figure 5-8***), the ratio of protonation was determined by comparing the integral of the remaining phenolic protons to its original value (9.66 – 9.37 ppm, m, 48H). All the experiments were conducted in triplicate and the average values including standard deviations are reported. NMR spectra recorded 30 min and 12 h after the sample preparation showed comparable results, indicating that the encapsulation and protonation equilibrium of the investigated guests/bases is reached within 30 min.

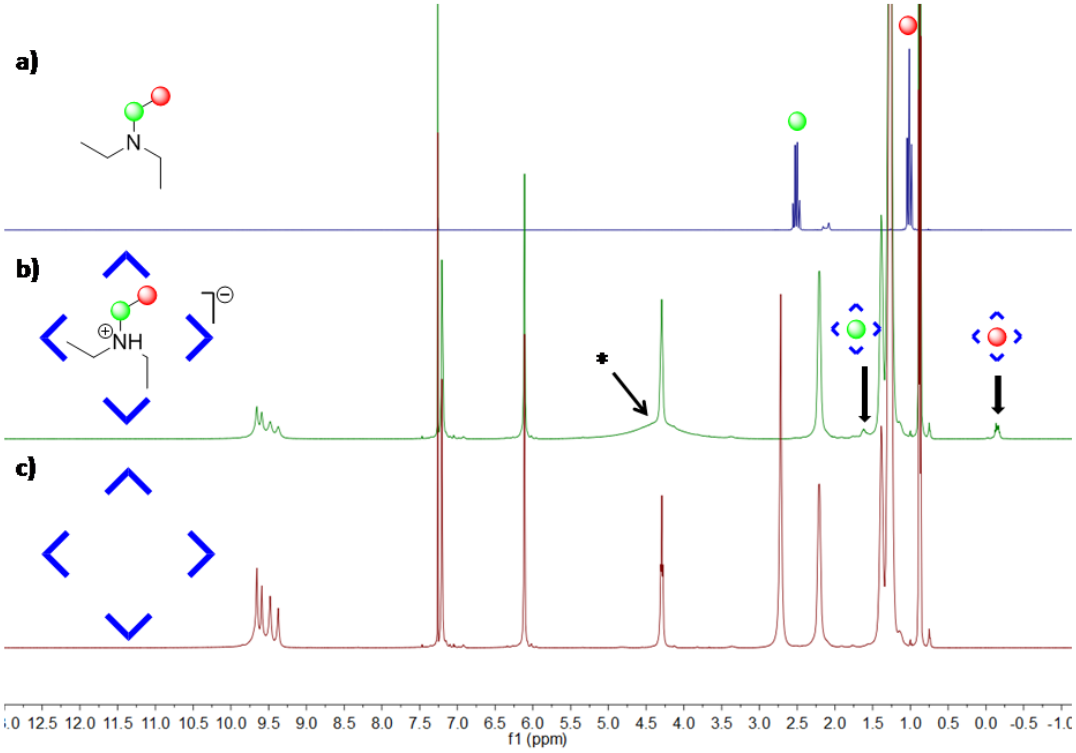
2. Binding studies of resorcin[4]arene capsule I

2.1 With tetraethylammonium bromide (2)



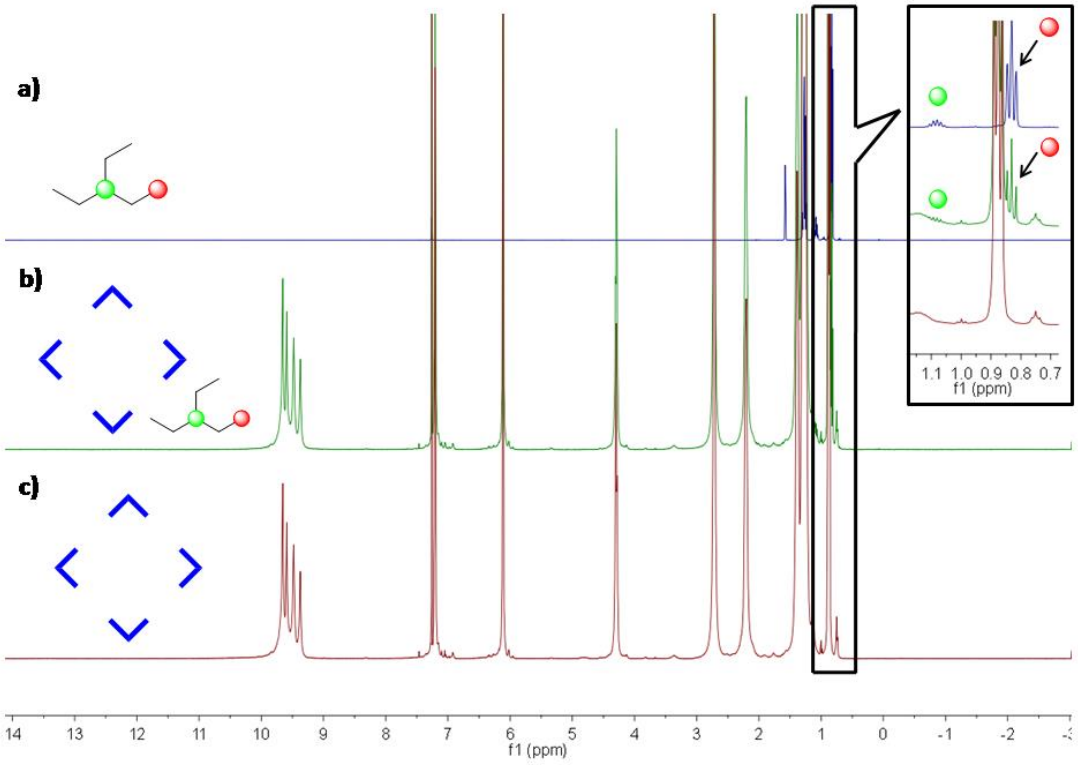
SI-Figure 1: Binding studies with $Et_4N^+Br^-$ (**2**). a) $Et_4N^+Br^-$ (**2**); b) **2**@**I**: **I** (3.30 mM), **2** (1.65 mM); c) **I** (3.30 mM).

2.2 With triethylamine (3)



SI-Figure 2: Binding studies with Et_3N (**3**). a) Et_3N (**3**); b) $HNEt_3^+$@$\mathbf{I}^-$: **I** (3.30 mM), **3** (1.65 mM); c) **I** (3.30 mM). The broad peak corresponding to water and shifted phenolic protons is highlighted by an asterisk.

2.3 With 3-ethyl-pentane (4)



SI-Figure 3: Binding studies with 3-ethylpentane (**4**). a) 3-ethylpentane (**4**); b) **I** (3.30 mM), **4** (1.65 mM); c) **I** (3.30 mM).

3. Protonation studies of resorcin[4]arene capsule I

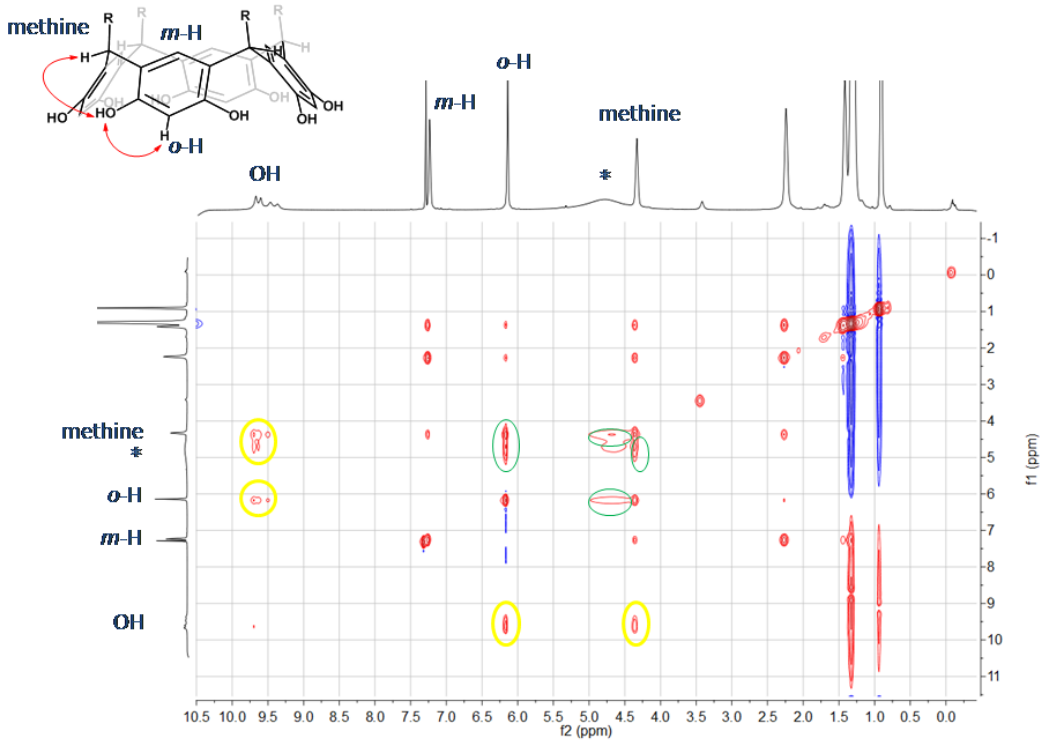
3.1 Titration with NEt_3

To the stock solution of resorcin[4]arene **1** (185 µL, 11.1 mg, 10.0 µmol, 6 eq) in a NMR-tube was added NEt_3-stock solution with a concentration of 16.7 mmol/L (a multiple of 20 µL, 0.334 µmol, 0.2 eq.) and then diluted to a volume of 0.50 mL to prepare the sample of a desired **I**/NEt_3-ratio. After agitation the sample was allowed to equilibrate for 30 min and then subjected to NMR-spectroscopy. The quantity of the shifted phenolic peaks (see ***SI-Table 1***) is determined by careful integration of the corresponding broad peak (maximum located between 3.22 ppm and 5.73 ppm, depending on the amount of added triethylamine) and subsequent subtraction of the water peak integral (58.1H in water saturated $CDCl_3$ used for the stock solution preparation) and other overlapping peaks (methine: 24H, *o*-Ar-H: 24H, *m*-Ar-H+$CHCl_3$: 29.4H).

SI-Table 1: Integral and chemical shift of the shifted phenolic peaks.

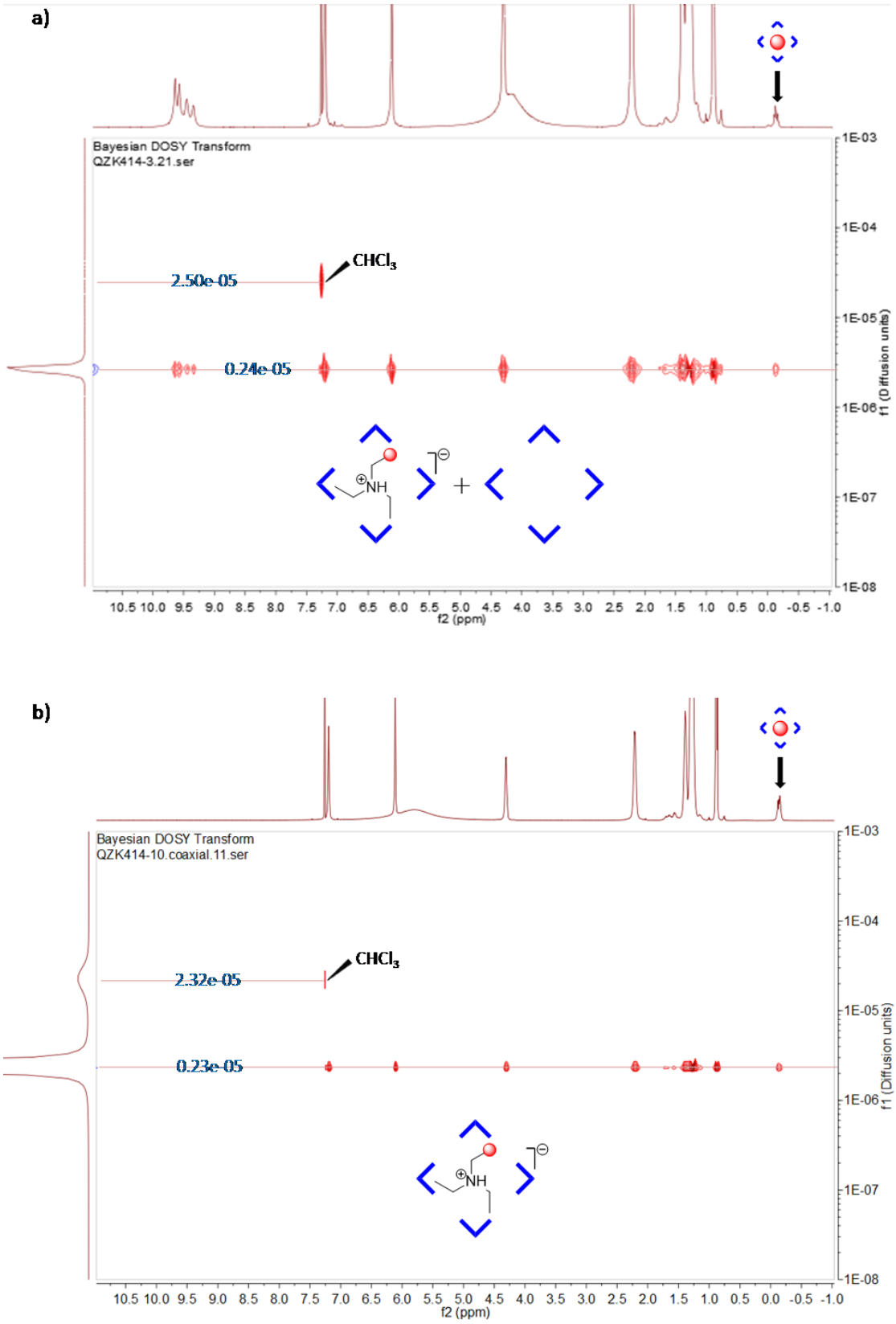
ratio: **I**/NEt_3	integral of encapsulated Me protons	chemical shift of the broad peak in ppm	phenolic protons		
			remaining	shifted	total
1: 0.2	1.84	3.22	41.5	6.60	48.1
1: 0.4	3.57	3.91	31.6	16.1	47.7
1: 0.6	5.37	4.51	23.0	24.5	47.5
1: 0.8	7.20	5.03	14.4	33.4	47.8
1: 1.0	9.01	5.39	8.15	38.5	46.7
1: 1.2	10.4	5.63	3.44	41.7	45.2
1: 1.4	12.5	5.73	1.69	46.0	47.6

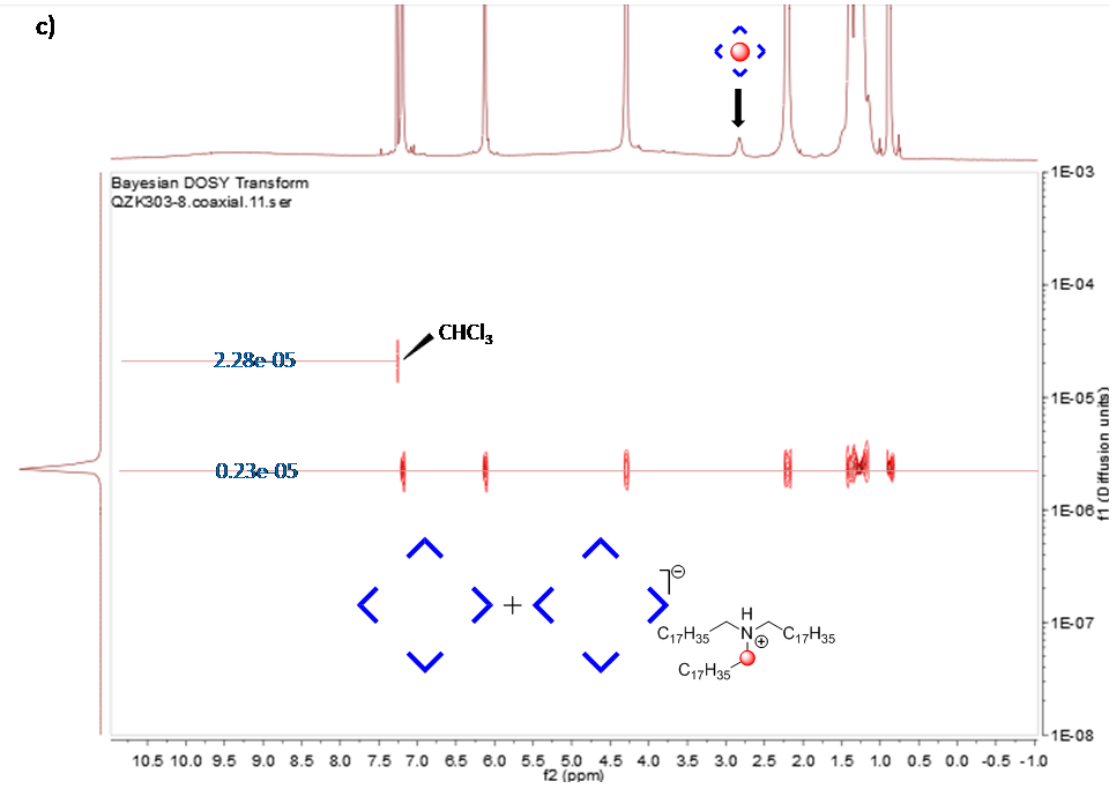
3.2 NOESY-experiment of I with 0.6 eq Et_3N



***SI-Figure 4*:** NOESY spectrum of the sample with a **I**/NEt_3-ratio of 1:0.6. The important cross-peaks of the original phenolic protons (yellow) and of the shifted phenolic protons (green) are highlighted. The broad peak corresponding to water and shifted phenolic protons is highlighted by an asterisk.

3.3 DOSY-experiments of resorcin[4]arene capsule I

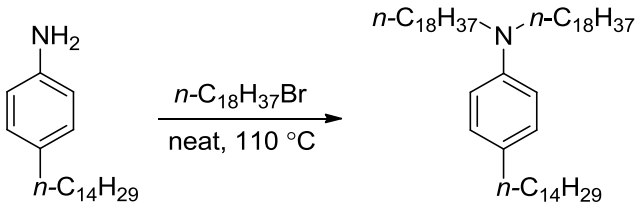




***SI-Figure 5*:** DOSY spectra of resorcin[4]arene capsule **I**. The diffusion coefficients of $CHCl_3$ and resorcin[4]arene capsule **I** are given in cm^2/s. a) **I**/NEt_3 = 1/0.4, **I** (3.30 mM), NEt_3 (1.32 mM); b) **I**/NEt_3 = 1/1.4, **I** (3.30 mM), NEt_3 (4.62 mM); c) **I**/**5** = 1/0.6, **I** (3.30 mM), trioctadecylamine (**5**) (1.98 mM).

3.4 With *N*,*N*-dioctadecyl-4-tetradecylaniline (6)

3.4.1 Synthesis of *N*,*N*-dioctadecyl-4-tetradecylaniline (6)



A mixture of 4-tetradecylaniline (1.00 g, 3.45 mmol) and 1-bromooctadecane (3.43 g, 10.4 mmol) was stirred at 110 °C for 16 h. After the sample was allowed to cool to rt, the reaction mixture was dissolved in diethylether, washed with 2 M aq. NaOH (70 mL) and the aq. phase was extracted with Et_2O (3x). The combined organic phases were dried over sodium sulfate. After removing all volatiles under vacuum, the crude product was treated with 1-bromooctadecane (2.01 g, 6.08 mmol) and stirred for another 16 h at 110 °C. After the sample was allowed to cool to rt, the reaction mixture was dissolved in diethylether, washed with 2 M aq. NaOH (70 mL) and the aq. phase was extracted with Et_2O (3x). The combined organic phases were evaporated under vacuum and subjected to flash column chromatography (150 mL silica gel, pentane to pentane/EtOAc = 60/1) to afford *N*,*N*-dioctadecyl-4-tetradecylaniline (**6**) (574 mg, 21%) as a pale yellow solid.

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.01 (d, J = 7.9 Hz, 2H), 6.57 (d, J = 7.9 Hz, 2H), 3.20 (t, J = 7.6 Hz, 4H), 2.47 (t, J = 7.7 Hz, 2H), 1.34-1.21 (m, 84H), 0.88 (t, J = 6.6 Hz, 9H).

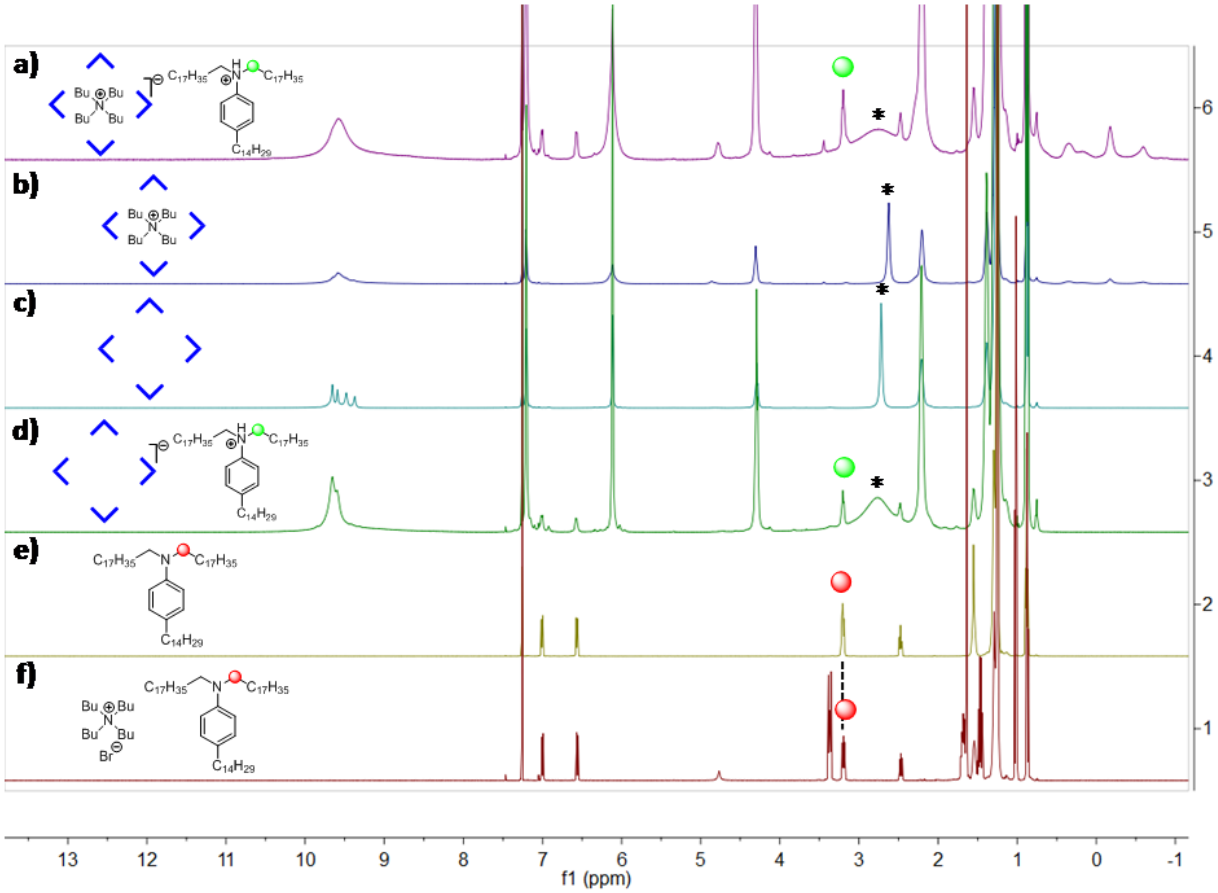
^{13}C NMR (126 MHz, $CDCl_3$): δ 146.4, 129.7, 129.2, 111.9, 77.4, 77.2, 76.9, 51.4, 35.0, 29.9, 29.9, 29.8, 29.8, 29.8, 29.8, 29.7, 29.6, 29.5, 27.4, 27.4, 22.9, 14.3.

HRMS (EI, 70eV): calcd. for $C_{42}H_{79}N$ [$(M\text{-}C_{14}H_{28})^+$]: 597.6207, found: 597.6213.

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2921, 2851, 1518.

TLC: R_f = 0.80 (pentane/EtOAc = 20/1) [UV]

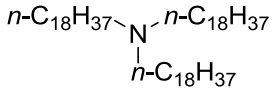
3.4.2 Protonation studies with dioctadecylaniline 6



SI-Figure 6: Protonation studies with dioctadecylaniline **6**. a) Bu_4NBr@**I**$^-$, dioctadecylaniline **6**: **I** (3.30 mM), Bu_4NBr (3.30 mM), **6** (3.30 mM); b) Bu_4NBr@**I**: **I** (3.30 mM), Bu_4NBr (3.30 mM); c) **I** (3.30 mM); d) **I** (3.30 mM), **6** (3.30 mM); e) dioctadecylaniline **6**; f) Bu_4NBr (3.30 mM), **6** (3.30 mM). The broad peak corresponding to water and shifted phenolic protons is highlighted by an asterisk.

3.5 With trioctadecylamine (5)

3.5.1 Synthesis of trioctadecylamine (5)



Trioctadecylamine was synthesized according to the synthetic procedure of aniline **6** using dioctadecylamine (1.00 g, 1.92 mmol) and 1-bromooctadecane (962 mg, 2.89 mmol). The crude product was purified by flash column chromatography (110 mL silica gel, pentane/EtOAc = 50/1 to 30/1) to yield trioctadecylamine (**5**) (603 mg, 41%) as a white solid.

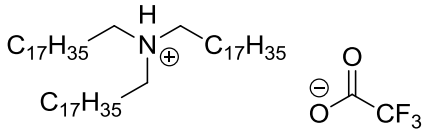
^{1}H NMR (500 MHz, $CDCl_3$): δ 2.37 (t, J = 7.2 Hz, 6H), 1.44 – 1.37 (m, 6H), 1.35 – 1.17 (m, 90H), 0.88 (t, J = 6.9 Hz, 9H).

^{13}C NMR (126 MHz, $CDCl_3$): δ 32.1, 29.9 (br), 29.8 (br), 29.5, 22.9, 14.3.

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2953, 2914, 2843, 1471, 717.

TLC: R_f = 0.50 (pentane/EtOAc = 10/1) [$KMnO_4$]

3.5.2 Synthesis of trioctadecylammonium 2,2,2-trifluoroacetate (21)

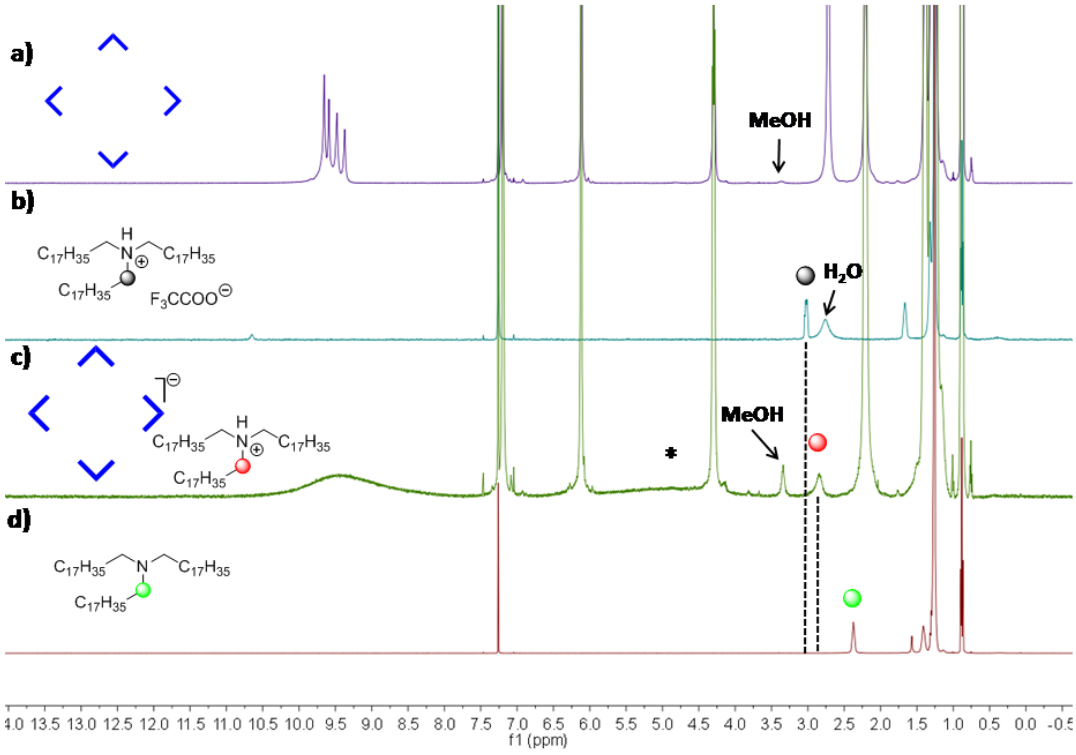


Stock solutions of trioctadecylamine (**5**) and trifluoroacetic acid were prepared in water saturated $CDCl_3$ with a concentration of 41.7 mmol/L. To the stock solution of trioctadecylamine (**5**) (20 µL, 0.83 µmol, 1 eq) in a NMR-tube was added water saturated $CDCl_3$ (0.46 mL) and the stock solution of trifluoroacetic acid (20 µL, 0.83 µmol, 1 eq). The sample was homogenized by agitation and then subjected to NMR-spectroscopy.

^{1}H NMR (500 MHz, $CDCl_3$): δ 10.65 (s, 1H), 3.02 (dt, J = 12.5, 4.8 Hz, 6H), 1.74 –

1.53 (m, 6H), 1.43 – 1.11 (m, 90H), 0.88 (t, *J* = 6.8 Hz, 9H).

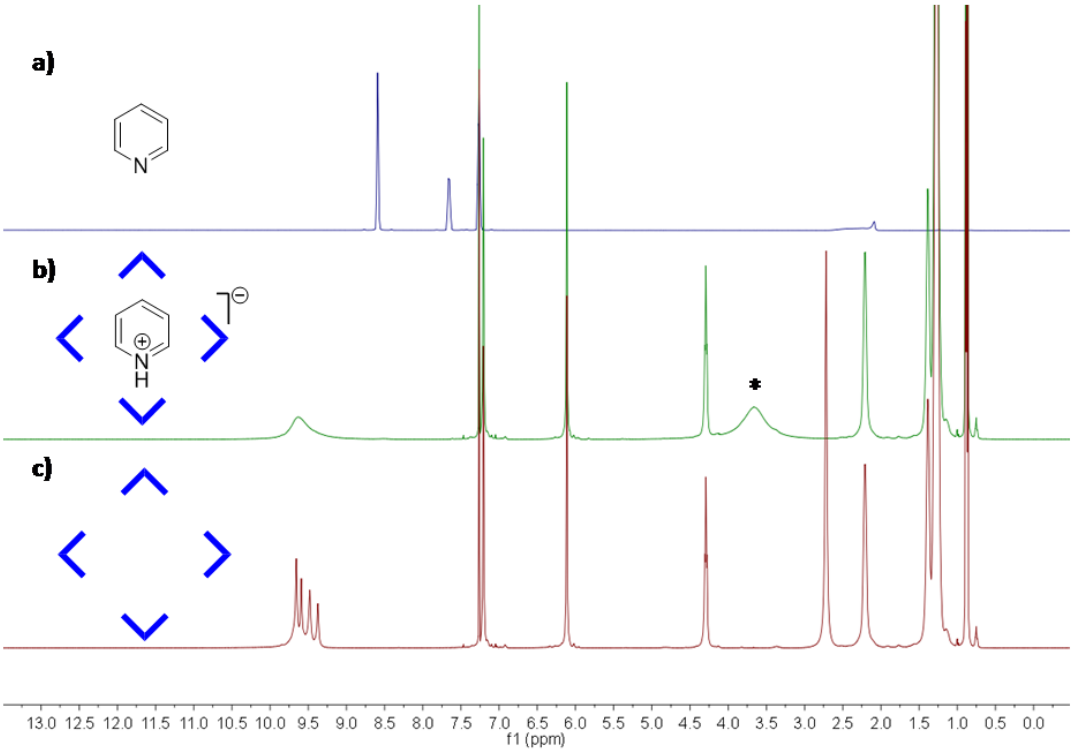
3.5.3 Protonation studies with trioctadecylamine (5)



SI-Figure 7: Protonation studies with trioctadecylamine (**5**). a) **I** (3.30 mM); b) $(C_{18}H_{37})_3N^+TFA^-$ (**21**); c) **I** (3.30 mM), **5** (1.65 mM); d) trioctadecylamine (**5**). The broad peak corresponding to water and shifted phenolic protons is highlighted by an asterisk.

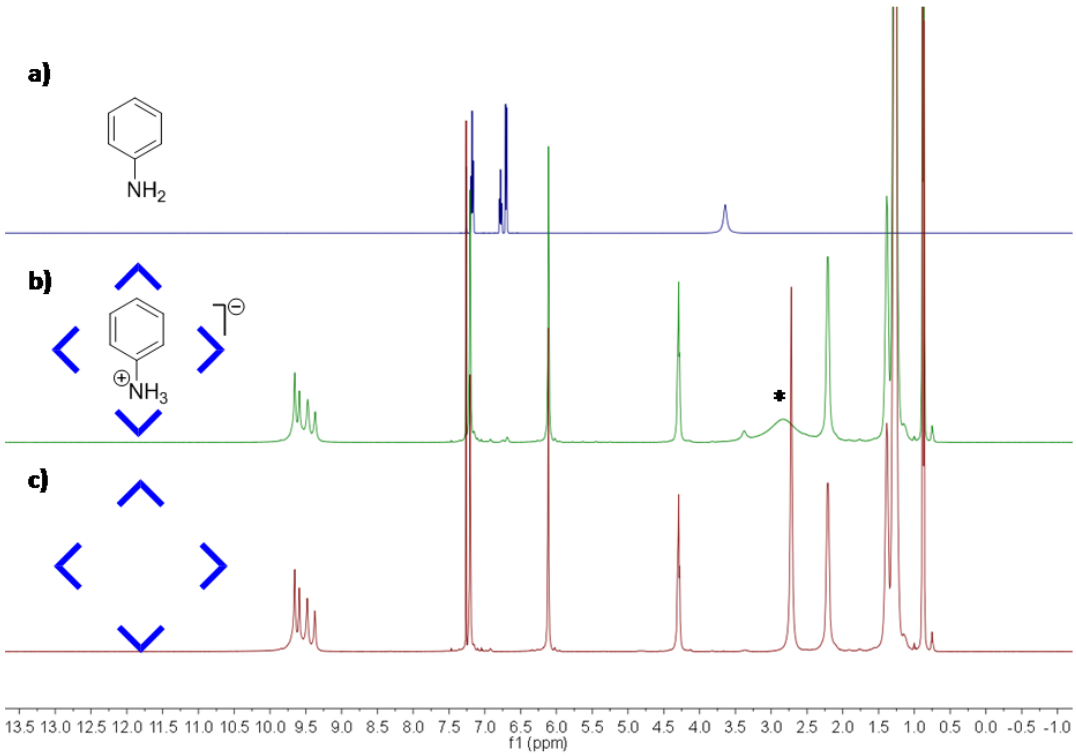
3.6 Determination of the p*Ka* value of resorcin[4]arene I

3.6.1 With pyridine



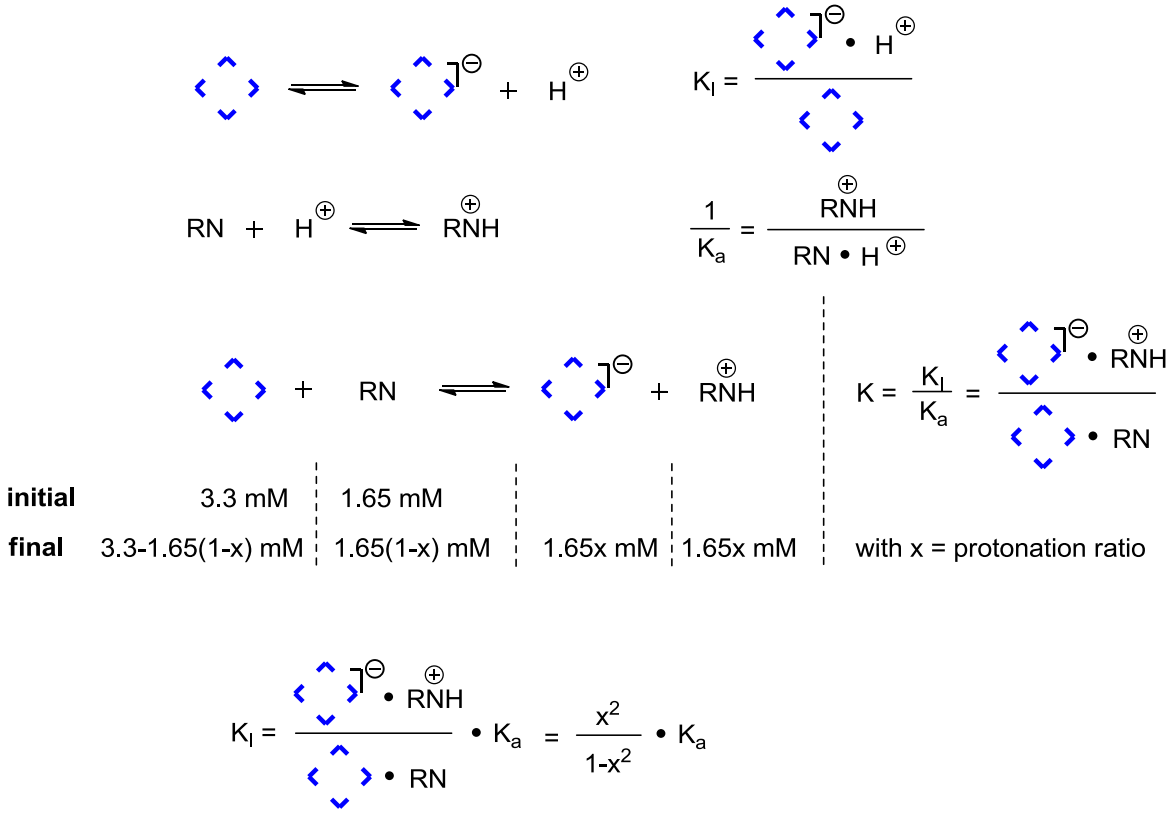
SI-Figure 8: Protonation studies with pyridine. a) pyridine C_5H_5N; b) $C_5H_5NH^+$@**I**$^-$: **I** (3.30 mM), pyridine (1.65 mM); c) **I** (3.30 mM). 53 ± 1% of added pyridine was protonated by **I** as indicated by the integral of remaining phenolic protons. The broad peak corresponding to water and shifted phenolic protons is highlighted by an asterisk.

3.6.2 With aniline



SI-Figure 9: Protonation studies with aniline. a) aniline $C_6H_5NH_2$; b) $C_6H_5NH_3^+$@**I**$^-$: **I** (3.30 mM), aniline (1.65 mM); c) **I** (3.30 mM). 23 ± 2% of added aniline was protonated by **I** as indicated by the integral of remaining phenolic protons. The broad peak corresponding to water and shifted phenolic protons is highlighted by an asterisk.

3.6.3 Calculation of the p*K*a value of resorcin[4]arene I

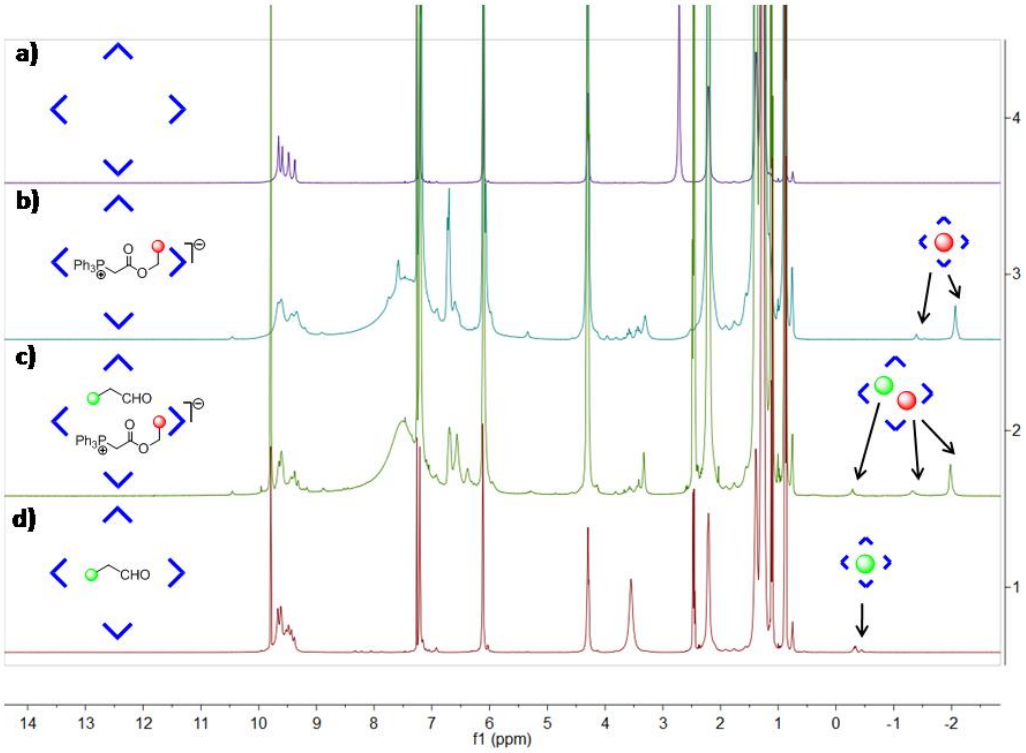


In case of pyridine, $K_a = 10^{-5.2}$, x = 53%, → pK_I = 5.6.

In case of aniline, $K_a = 10^{-4.6}$, x = 23%, → pK_I = 5.9.

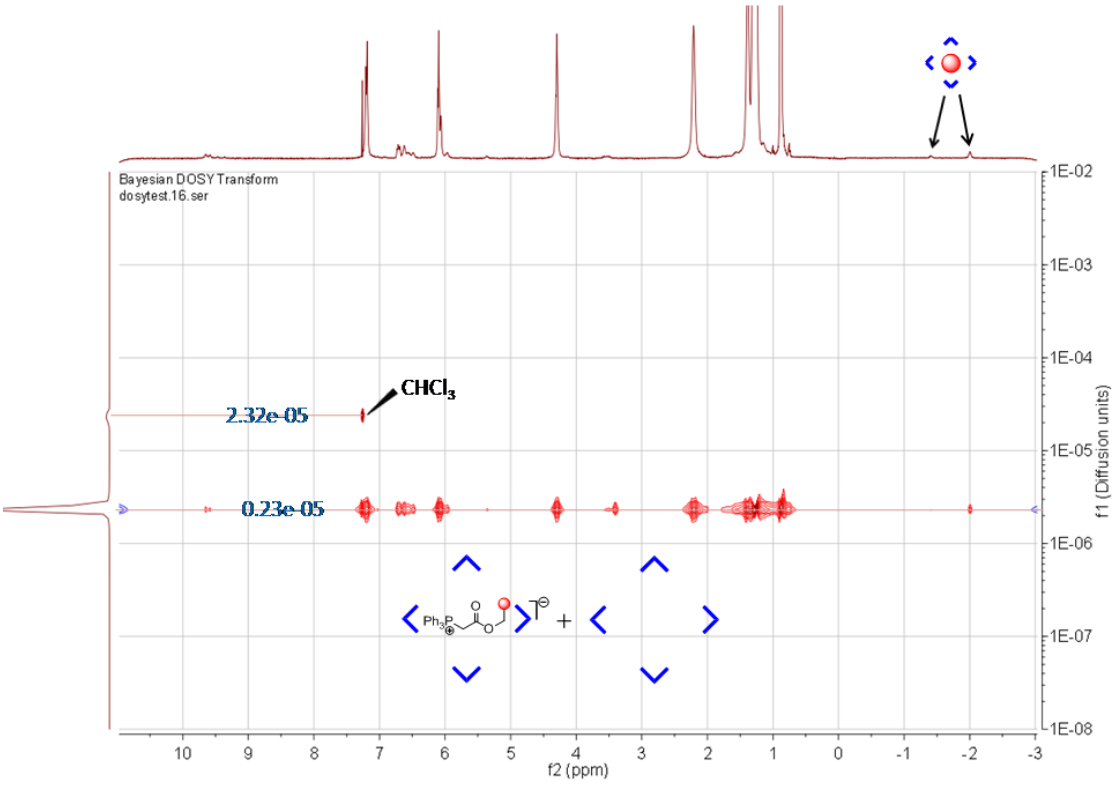
4. Synthetic application: Wittig reaction

4.1 Binding studies and reactivity test of Wittig ylide 7



SI-Figure 10: Binding of protonated Wittig ylide **7** and EtCHO. a) **I** (8.00 mM); b) **7**-$\mathbf{H}^+$@$\mathbf{I}^-$: **I** (8.00 mM), **7** (6.80 mM); c) **7**-$\mathbf{H}^+$+EtCHO@$\mathbf{I}^-$: **I** (8.00 mM), **7** (6.80 mM), EtCHO (80.0 mM); d) EtCHO@**I**: **I** (8.00 mM), EtCHO (80.0 mM)**.**

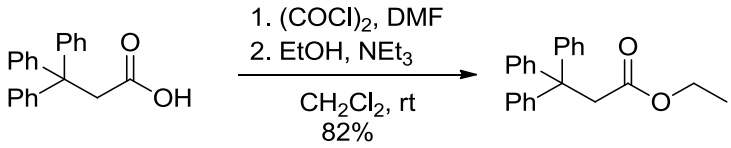
4.2 DOSY-experiment of resorcin[4]arene capsule I with 0.85 eq 7



***SI-Figure 11*:** DOSY spectrum of the **I** with 0.85 eq Wittig ylide **7**. **I** (3.30 mM), **7** (2.81 mM). The diffusion coefficients of $CHCl_3$ and resorcin[4]arene capsule **I** are given in cm^2/s.

4.3 Binding studies with ethyl 3,3,3-triphenylpropanoate (8)

4.3.1 Synthesis of ethyl 3,3,3-triphenylpropanoate (8)



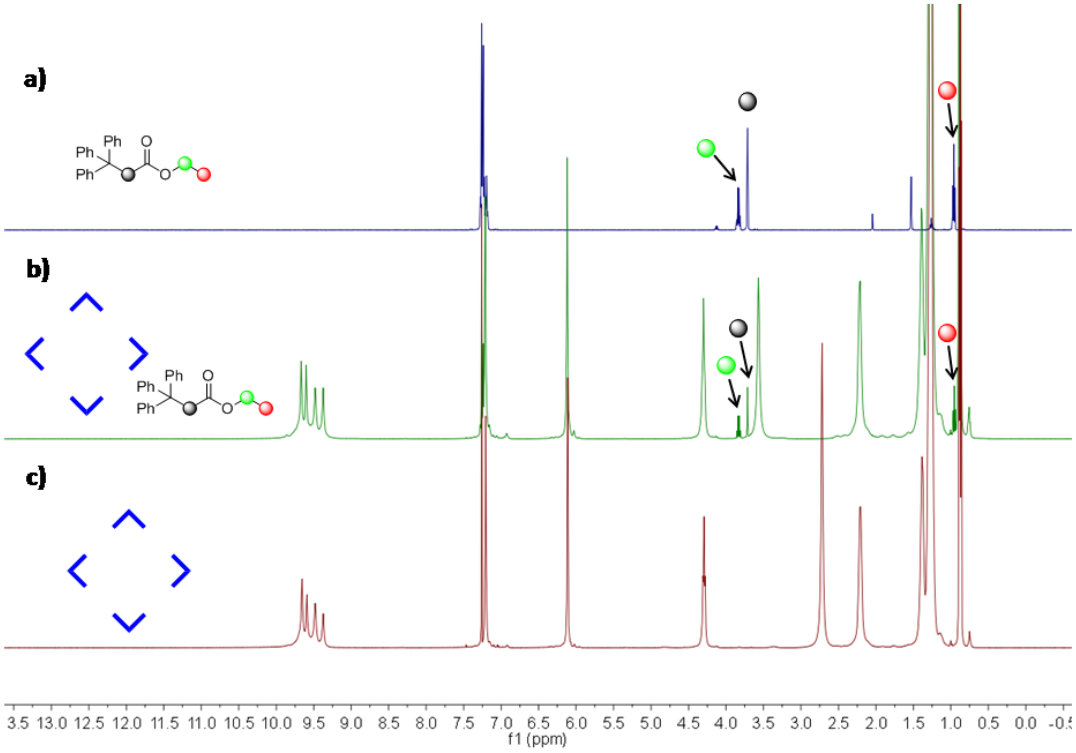
To a stirred solution of 3,3,3-triphenylpropionic acid (500 mg, 1.65 mmol) in anhydrous CH_2Cl_2 (6.5 mL) was added anhydrous DMF (6.40 µL, 83.1 µmol) and $(COCl)_2$ (0.23 mL, 3.44 mmol). After gas formation has stopped, the reaction mixture was concentrated under vacuum, dissolved in anhydrous CH_2Cl_2 (4.0 mL) and added to a mixture of anhydrous EtOH (0.29 mL, 4.97 mmol) and triethylamine (0.47 mL,

3.37 mmol) in anhydrous CH_2Cl_2 (2.0 mL). The reaction was stirred for 30 min, quenched with H_2O (3 mL) and extracted with CH_2Cl_2 (3x). The combined organic phases were dried over sodium sulfate and concentrated under vacuum. The crude product was purified by flash column chromatography (20 mL silica gel, pentane/EtOAc = 20/1) to yield ethyl 3,3,3-triphenylpropanote (**8**) (448 mg, 82%) as a white solid.

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.28-7.18 (m, 15H), 3.83 (q, J = 7.1 Hz, 2H), 3.71 (s, 2H), 0.96 (t, J = 7.1 Hz, 3H).

The ^{1}H-spectrum is consistent with that reported in literature.[3]

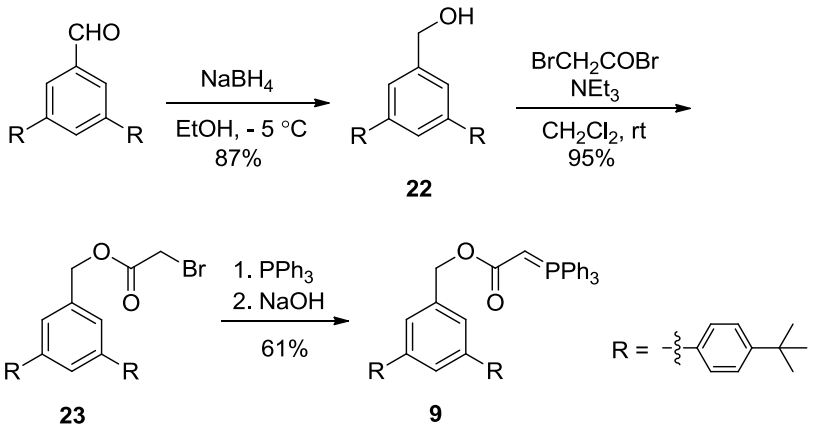
4.3.2 Binding studies with ethyl 3,3,3-triphenylpropanoate (8)



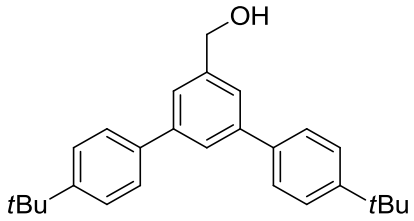
SI-Figure 12: Binding studies with ethyl 3,3,3-triphenylpropanoate (**8**). a) ethyl 3,3,3-triphenylpropanoate (**8**); b) **I** (8.00 mM), **8** (4.00 mM); c) **I** (8.00 mM).

4.4 Competition reaction of Wittig ylides

4.4.1 Synthesis of Wittig ylide 9



(4,4''-di-tert-butyl-[1,1':3',1''-terphenyl]-5'-yl)methanol (22)



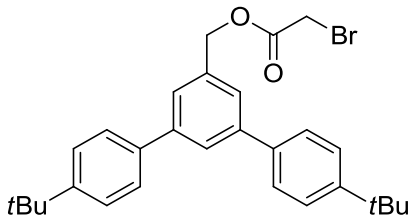
To a cooled suspension (0 °C) of 4,4''-di-tert-butyl-[1,1':3',1''-terphenyl]-5'-carbaldehyde (680 mg, 1.84 mmol) in anhydrous EtOH (17 mL) was added $NaBH_4$ (36.0 mg, 0.95 mmol) portionswise. The reaction was stirred at the same temperature for 1 h and afterwards quenched with water (5 mL) and extracted with Et_2O (3x). The combined organic phases were dried over sodium sulfate. Evaporation under vacuum yielded alcohol **22** (589 mg, 87%) as a colorless oil.

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.74 (t, J = 1.7 Hz, 1H), 7.60 (d, J = 8.6 Hz, 4H), 7.56 (d, J = 1.7 Hz, 2H), 7.49 (d, J = 8.6 Hz, 4H), 4.82 (s, 2H), 1.38 (s, 18H).

^{13}C NMR (126 MHz, $CDCl_3$): δ 150.7, 142.1, 141.9, 138.2, 127.0, 125.9, 125.4, 124.5, 65.7, 34.7, 31.5.

The ^{1}H-spectrum is consistent with that reported in the literature.[4]

(4,4''-di-tert-butyl-[1,1':3',1''-terphenyl]-5'-yl)methyl-2-bromoacetate (23)



To a stirred solution of alcohol **22** (560mg, 1.50 mmol) and triethylamine (520 µL, 3.73 mmol) in anhydrous CH_2Cl_2 (5 mL) was added bromoacetyl bromide (0.40 mL, 4.60 mmol) dropwise. After TLC (pentane/EtOAc = 10/1) showed complete conversion of alcohol **22**, the reaction mixture was quenched with saturated aq. $NaHCO_3$ (2 mL) and extracted with Et_2O (3x). The combined organic phases were dried over sodium sulfate, filtered and concentrated under vacuum. The crude product was purified by flash column chromatography (110 mL silica gel, eluted with pentane/EtOAc = 15/1) to afford ester **23** (703 mg, 95%) as colorless oil.

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.79 (t, J = 1.6 Hz, 1H), 7.59 (d, J = 8.4 Hz, 4H), 7.55 (d, J = 1.6 Hz, 2H), 7.50 (d, J = 8.4 Hz, 4H), 5.33 (s, 2H), 3.91(s, 2H), 1.38 (s, 18H).

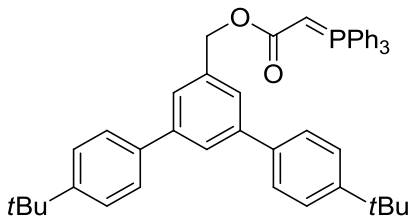
^{13}C NMR (126 MHz, $CDCl_3$): δ 167.3, 150.9, 142.2, 137.9, 135.9, 127.0, 126.3, 126.0, 125.8, 68.2, 34.7, 31.5, 26.0.

HRMS(EI, 70eV): calcd. for $C_{29}H_{33}O_2{}^{79}Br$ [M^+]: 492.1658, found: 492.1652.

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2960, 1741, 1600, 1515, 1457, 1272, 828.

TLC: R_f = 0.52 (pentane/EtOAc = 10/1) [UV]

Wittig ylide 9



A solution of ester **23** (636 mg, 1.29 mmol) and triphenylphosphine (429 mg, 1.64 mmol) in anhydrous toluene (2.8 mL) was stirred at 45 °C. After TLC

(pentane/EtOAc = 10/1) showed complete conversion of ester **23**, the reaction mixture was filtered and washed with toluene. The filtrate was dissolved in water (20 mL) and basified with 2 M aq. NaOH to pH 8-9. The resulting suspension was extracted with EtOAc (3x) and the combined organic phases were dried over sodium sulfate and concentrated under vacuum. The crude product was subjected to flash column chromatography (75 mL silica gel, pentane/EtOAc/NEt_3= 3/1/0.01) to afford Wittig ylide **9** (530 mg, 61%) as a white solid.

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.64-7.35 (m, 26H), 5.11 (s, 2H), 2.99 (s, 1H), 1.38 (s, 18H).

^{13}C NMR (126 MHz, $CDCl_3$): δ 150.3, 141.5, 138.6, 133.1, 133.1, 132.0, 128.9, 128.8, 128.2, 127.5, 127.1, 125.7, 125.5, 124.8, 64.3, 34.7, 31.6.

HRMS (ESI): calcd. for $C_{47}H_{48}O_2P$ [$(M+H)^+$]: 675.3386, found: 675.3386.

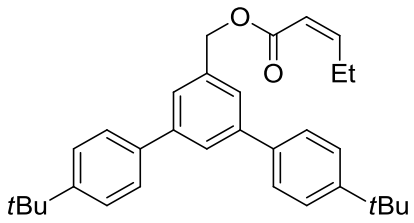
IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2960, 1735, 1618, 1515, 1105, 829, 719, 691.

TLC: R_f = 0.12 (pentane/EtOAc/NEt_3 = 3/1/0.01) [UV]

4.4.2 Competition reaction of Wittig ylides

(Ethoxycarbonylmethylene)triphenylphosphorane (**7**) (15.0 mg, 44.5 μmol) and Wittig ylide **9** (30.1 mg, 44.5 μmol) were added simultaneously to a stirred solution of resorcin[4]arene **1** (360 mg, 326 μmol) in water saturated $CDCl_3$ (6.5 mL). After 1 h, propionaldehyde (5.5 μL, 66.8 μmol) was added and stirring continued for 23 h at 30 °C. Afterwards the reaction mixture was concentrated under vacuum and purified by flash column chromatography (40 mL silica gel, pentane/EtOAc = 40/1 to pentane/EtOAc/NEt_3 = 5/1/0.01) to yield (*Z*)-alkene **23** (0.4 mg, 2%) and (*E*)-alkene **11** (14.2 mg, 72%) both as a colorless oil and to recover unreacted (ethoxy-carbonylmethylene)triphenylphosphorane (**7**) (11.2 mg, 72%) as a white solid.

(*Z*)-(4,4''-di-tert-butyl-[1,1':3',1''-terphenyl]-5'-yl)methyl-pent-2-enoate (24)



^{1}H NMR (500 MHz, $CDCl_3$): δ 7.75 (s, 1H), 7.58 (d, J = 8.2 Hz, 4H), 7.54 (s, 2H), 7.49 (d, J = 8.2 Hz, 4H), 6.26 (dt, J = 11.4, 7.5 Hz, 1H), 5.82 (d, J = 11.5 Hz, 1H), 5.27 (s, 2H), 2.70 (quintet, J = 7.5 Hz, 2H), 1.37 (s, 18H), 1.07 (t, J = 7.6 Hz, 3H).

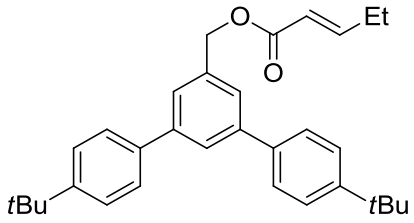
^{13}C NMR (126 MHz, $CDCl_3$): δ 166.3, 153.0, 150.7, 142.1, 138.1, 137.1, 127.1, 125.9, 125.9, 125.7, 118.9, 65.9, 34.7, 31.5, 22.7, 13.6.

HRMS (ESI): calcd. for $C_{32}H_{42}O_2N$ $[(M+NH_4)^+]$: 472.3210, found: 472.3212.

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2961, 1720, 1618, 1600, 1516, 1166, 828.

TLC: R_f = 0.75 (pentane/EtOAc = 20/1) [UV]

(*E*) -(4,4''-di-tert-butyl-[1,1':3',1''-terphenyl]-5'-yl)methyl-pent-2-enoate (11)



^{1}H NMR (500 MHz, $CDCl_3$): δ 7.76 (s, 1H), 7.59 (d, J = 8.0 Hz, 4H), 7.56 (s, 2H), 7.50 (d, J = 8.2 Hz, 4H), 7.11 (dt, J = 15.7, 7.2 Hz, 1H), 5.90 (d, J = 15.7 Hz, 1H), 5.30 (s, 2H), 2.33 – 2.14 (m, 2H), 1.38 (s, 18H), 1.08 (t, J = 7.4 Hz, 3H).

^{13}C NMR (126 MHz, $CDCl_3$): δ 166.8, 151.7, 150.7, 142.1, 138.1, 137.1, 127.1, 125.9, 125.9, 125.8, 120.2, 66.2, 34.7, 31.5, 25.5, 12.2.

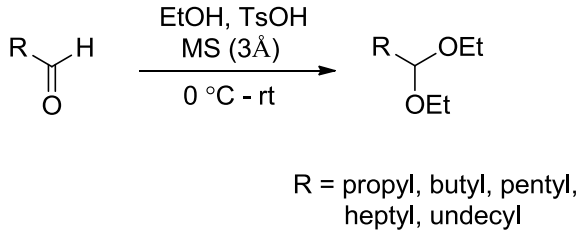
HRMS (ESI): calcd. for $C_{32}H_{42}O_2N$ $[(M+NH_4)^+]$: 472.3210, found: 472.3212.

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2961, 1718, 1600, 1513, 1459, 1171, 828.

TLC: R_f = 0.49 (pentane/EtOAc = 20/1) [UV]

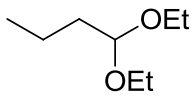
5. Catalytic application: acetal hydrolysis

5.1 General procedure for acetalization



To a stirred and cooled (0 °C) solution of *p*-toluenesulfonic acid mono hydrate (241 mg, 1.40 mmol) in anhydrous EtOH (6.0 mL) was added the respective aldehyde (7.00 mmol) dropwise and molecular sieves powder 3Å (900 mg). The reaction was stirred for 20 min at 0 °C and then at rt (18 h). Afterwards the reaction mixture was diluted with Et_2O (20 mL), filtered and basified with 2 M aq. NaOH. The aqueous phase was extracted with Et_2O (3x) and the combined organic phases were washed with brine, dried over sodium sulfate and carefully concentrated at 30 °C under reduced pressure (300 mbar in case of 1,1-diethoxybutane **14**, 250 mbar in case of 1,1-diethoxypentane **15**, 200 mbar in case of 1,1-diethoxyhexane **16**, 100 mbar in case of 1,1-diethoxyoctane **17**, 3 mbar in case of 1,1-diethoxydodecane **18**). The crude product was then purified by flash column chromatography (50 mL basic aluminium oxide, activity stage I, pentane/Et_2O = 50/1) to yield the corresponding acetal (10% for **14**, 12% for **15**, 75% for **16**, 15% for **17**, 33% for **18**) as a colorless oil.

1,1-diethoxybutane (14)



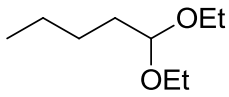
^{1}H NMR (500 MHz, $CDCl_3$): δ 4.49 (t, J = 5.8 Hz, 1H), 3.64 (dq, J = 9.2, 7.1 Hz, 2H), 3.49 (dq, J = 9.3, 7.1 Hz, 2H), 1.63 – 1.54 (m, 2H), 1.44 – 1.33 (m, 2H), 1.20 (t, J = 7.1 Hz, 6H), 0.92 (t, J = 7.4 Hz, 3H).

^{13}C NMR (126 MHz, $CDCl_3$): δ 102.9, 60.9, 35.8, 18.2, 15.5, 14.1.

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2933, 2853, 1738, 1600, 1463, 1272.

TLC: R_f = 0.33 (pentane/EtOAc/NEt_3 = 100/1/1) [2,4-dinitrophenylhydrazine]

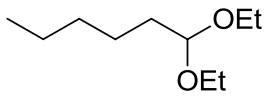
1,1-diethoxypentane (15)



^{1}H NMR (500 MHz, $CDCl_3$): δ 4.48 (t, J = 5.8 Hz, 1H), 3.64 (dq, J = 9.3, 7.1 Hz, 2H), 3.49 (dq, J = 9.3, 7.1 Hz, 2H), 1.64 – 1.58 (m, 2H), 1.39 – 1.27 (m, 4H), 1.20 (t, J = 7.1 Hz, 6H), 0.90 (t, J = 7.0 Hz, 3H).

The ^{1}H-spectrum is consistent with that reported in the literature.[5]

1,1-diethoxyhexane (16)



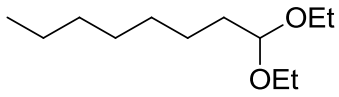
^{1}H NMR (500 MHz, $CDCl_3$): δ 4.48 (t, J = 5.8 Hz, 1H), 3.64 (dq, J = 9.3, 7.1 Hz, 2H), 3.49 (dq, J = 9.3, 7.0 Hz, 2H), 1.64 – 1.56 (m, 2H), 1.41 – 1.24 (m, 6H), 1.20 (t, J = 7.1 Hz, 6H), 0.88 (t, J = 6.8 Hz, 3H).

^{13}C NMR (126 MHz, $CDCl_3$): δ 103.1, 60.9, 33.7, 31.8, 24.6, 22.8, 15.5, 14.2.

IR (ATR): $\tilde{\nu}$ (cm^{-1}) = 2929, 2872, 1374, 1125, 1112, 1061.

TLC: R_f = 0.30 (pentane/EtOAc/NEt_3 = 100/1/1) [2,4-dinitrophenylhydrazine]

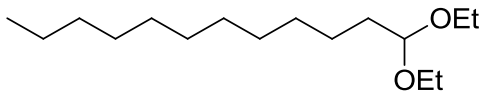
1,1-diethoxyoctane (17)



^{1}H NMR (500 MHz, $CDCl_3$): δ 4.50 (t, J = 5.8 Hz, 1H), 3.66 (dq, J = 9.2, 7.1 Hz, 2H), 3.51 (dq, J = 9.3, 7.1 Hz, 2H), 1.66 – 1.59 (m, 2H), 1.40 – 1.24 (m, 10H), 1.22 (t, J = 7.1 Hz, 6H), 0.89 (t, J = 6.8 Hz, 3H).

The ^{1}H-spectrum is consistent with that reported in the literature.[6]

1,1-diethoxydodecane (18)



^{1}H NMR (500 MHz, $CDCl_3$): δ 4.48 (t, J = 5.8 Hz, 1H), 3.64 (dq, J = 9.3, 7.1 Hz, 2H), 3.49 (dq, J = 9.4, 7.1 Hz, 2H), 1.63 – 1.57 (m, 2H), 1.37 – 1.20 (m, 18H), 1.20 (d, J = 7.1 Hz, 6H), 0.88 (t, J = 6.9 Hz, 3H).

The ^{1}H-spectrum is consistent with that reported in the literature.[7]

5.2 General procedure for hydrolysis of diethyl acetals in resorcin[4]arene capsule I

Stock solutions of acetals in water saturated $CDCl_3$ were prepared with a concentration of 837 mmol/L. To resorcin[4]arene **1** stock solution (185 µL, 11.1 mg, 10.0 µmol, 6 eq) in a NMR-tube was added water saturated $CDCl_3$ (295 µL in case of hydrolysis of a single acetal, 275 µL in case of a competition reaction) and the acetal stock solution (20 µL, 16.7 µmol, 10 eq, in case of hydrolysis of a single acetal; 20 µL of each acetal in case of a competition reaction). The sample was homogenized by agitation and then subjected to the NMR-spectroscopy.

In order to examine the reproducibility of the measurement, all the acetal hydrolysis reactions were carried out in duplicate. The two independent measurements of the same acetal hydrolysis gave comparable results (see ***SI Figure 13-14***).

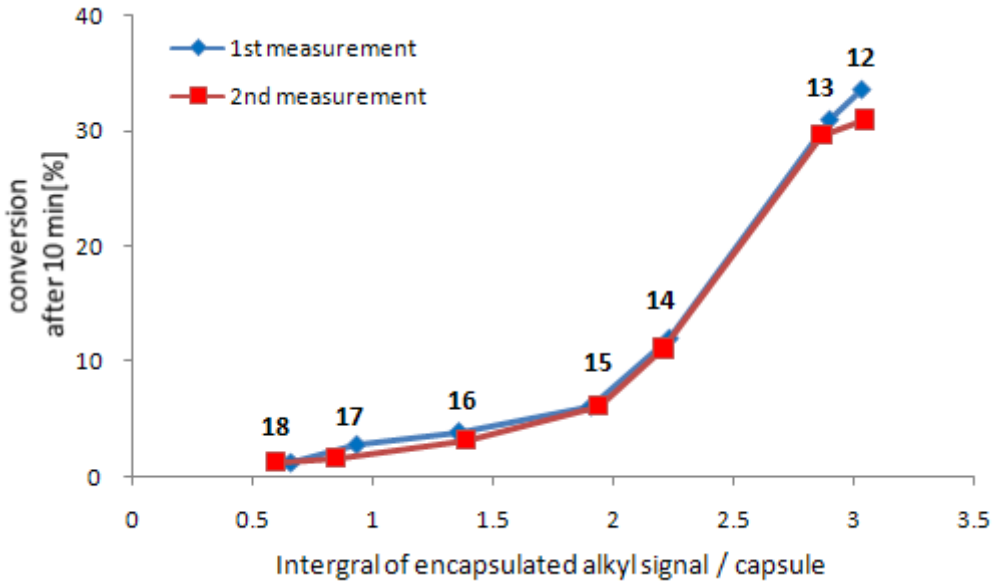
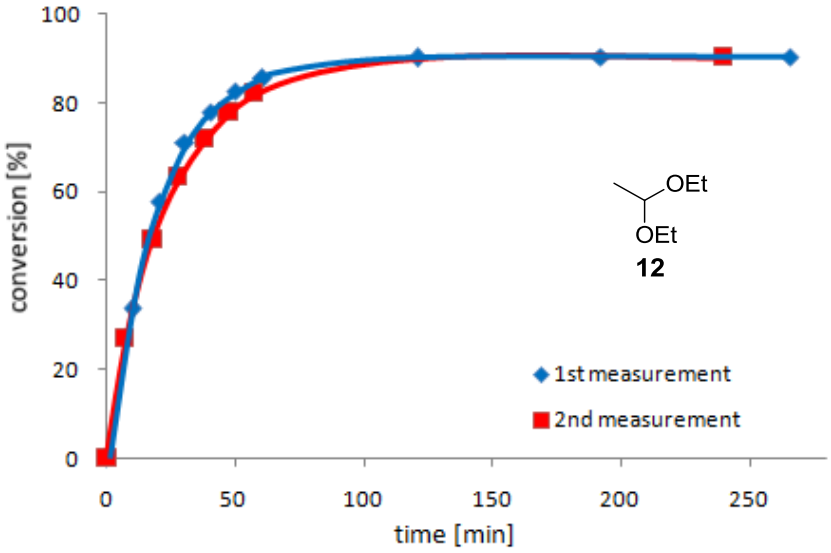
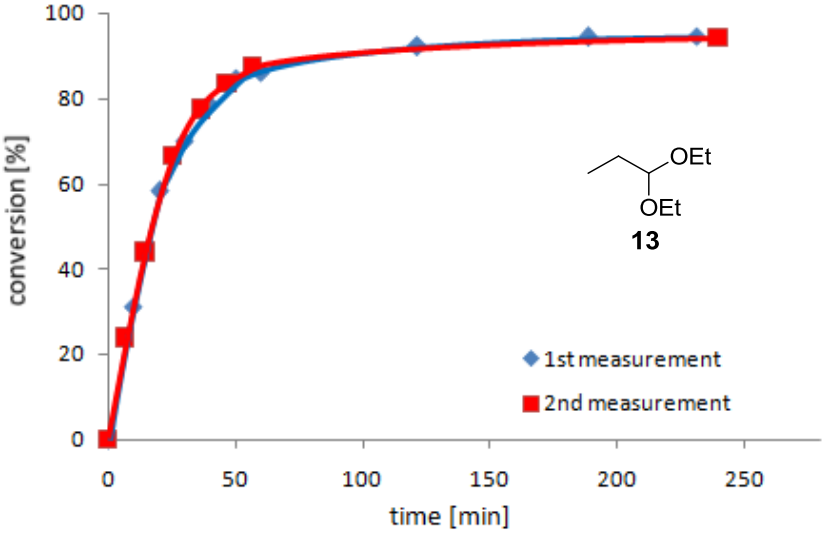
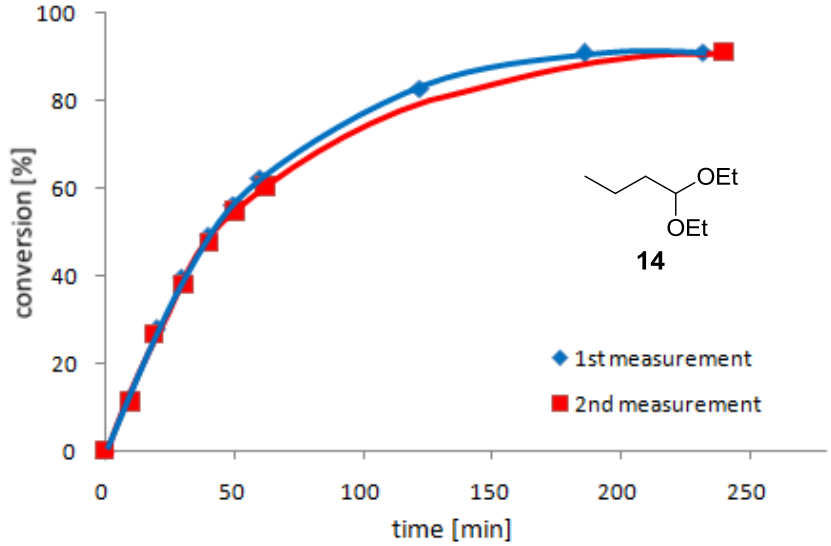
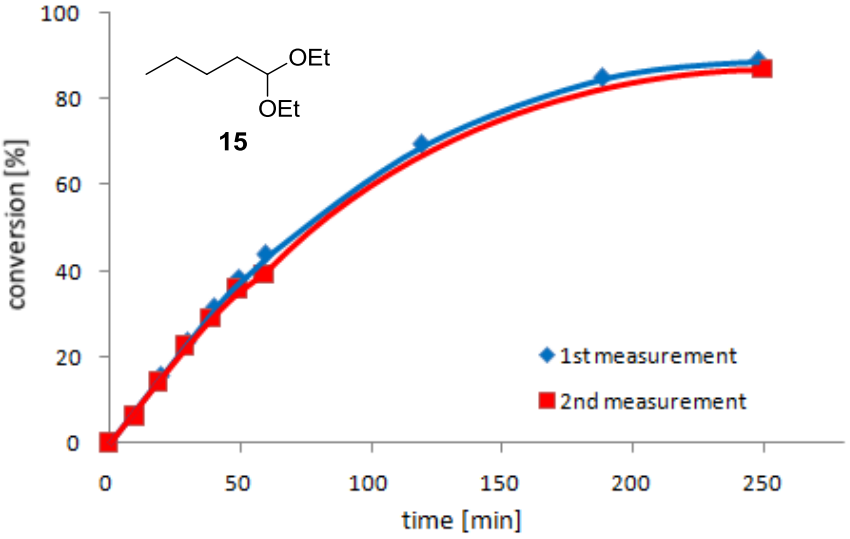


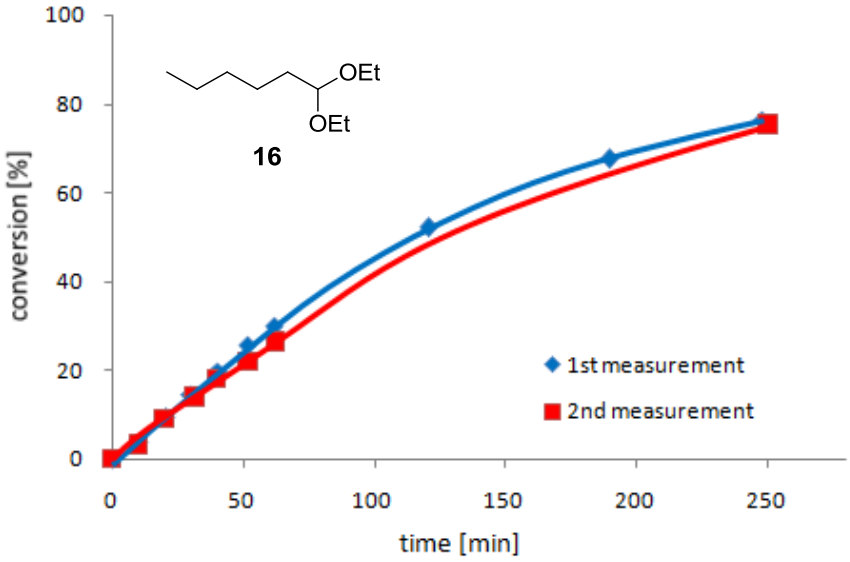
Figure 13: Comparison of the conversion after about 10 min to encapsulated alkyl signals (^{1}H –NMR region: 0.6 to -2 ppm).

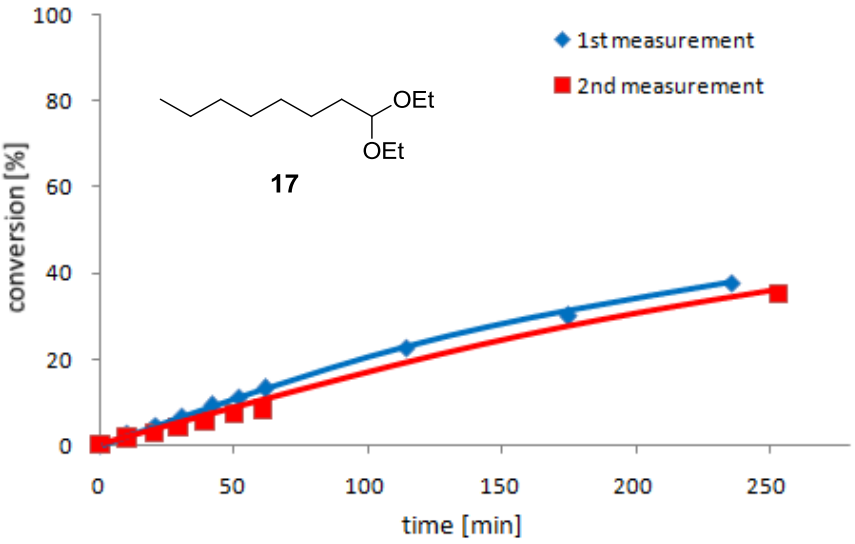

100
80
60
40
20
0
conversion [%]
0
50
100
150
200
250
time [min]
OEt
OEt
12
1st measurement
2nd measurement


100
80
60
40
20
0
conversion [%]
0
50
100
150
200
250
time [min]
OEt
OEt
13
1st measurement
2nd measurement


100
80
60
40
20
0
conversion [%]
0
50
100
150
200
250
time [min]
OEt
OEt
14
1st measurement
2nd measurement


100
80
60
40
20
0
conversion [%]
OEt
OEt
15
1st measurement
2nd measurement
0
50
100
150
200
250
time [min]


100
80
60
40
20
0
conversion [%]
OEt
OEt
16
1st measurement
2nd measurement
0
50
100
150
200
250
time [min]


100
80
60
40
20
0
conversion [%]
OEt
OEt
17
1st measurement
2nd measurement
0
50
100
150
200
250
time [min]

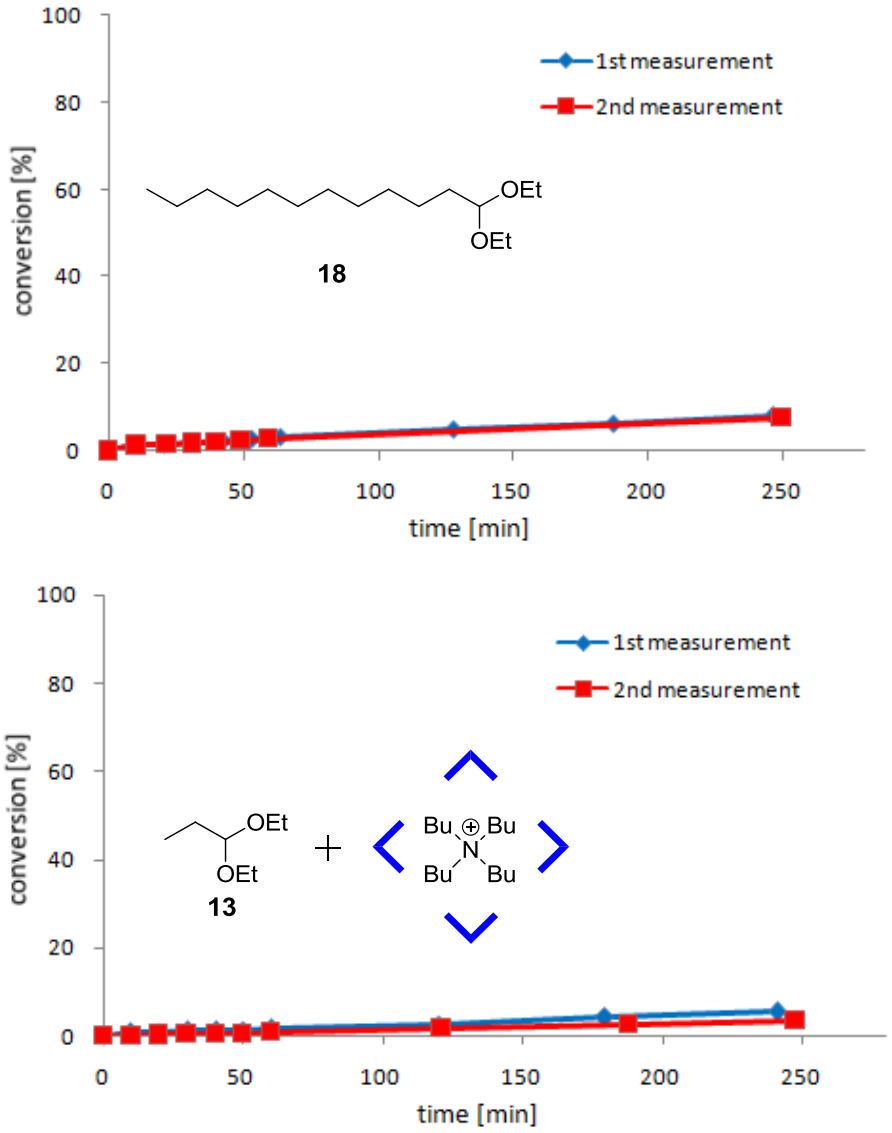


Figure 14: Catalytic hydrolysis of various diethyl acetals inside **I**.

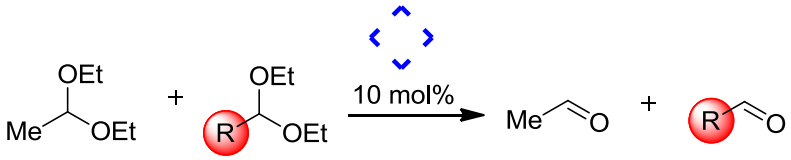
5.3 Determination of occupancy ratio of acetals in resorcin[4]arene capsule I

The cavity of resorcin[4]arene capsule **I** and the volumes of different diethyl acetals were computed with Swiss-PdbViewer[8] (Surface preference: Quality = 6). According to the computation, resorcin[4]arene capsule has a cavity of 1422 Å^3**.** The volumes of acetals and the corresponding occupancy ratios are listed in the following table.

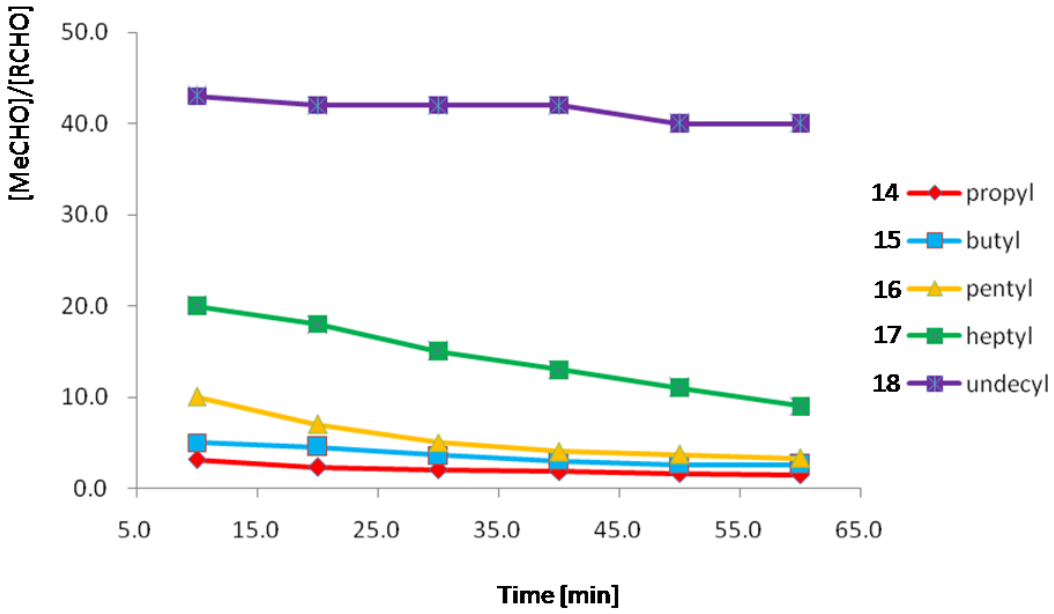
SI-Table 2: Determination of occupancy ratio of acetal in **I**.

substrate	**R**	**volume / (Å^3)**	**occupancy ratio**
1,1-diethoxyethane **12**	methyl	129	9%
1,1-diethoxypropane **13**	ethyl	145	10%
1,1-diethoxybutane **14**	propyl	163	11%
1,1-diethoxypentane **15**	butyl	181	13%
1,1-diethoxyhexane **16**	pentyl	198	14%
1,1-diethoxyoctane **17**	heptyl	232	16%
1,1-diethoxydodecane **18**	undecyl	311	22%

5.4 Competition reaction of diethyl acetals



R = propyl, butyl, pentyl, heptyl, undecyl



SI-Figure 15: Substrate selectivity versus time profile in the competition reaction.

SI-Table 3: Substrate selectivity of competition reactions in **I**.

competitor	R	MeCHO:RCHO		yield of MeCHO, 1h
		10 min	1 h	
1,1-diethoxybutane **14**	propyl	76:24	60:40	64%
1,1-diethoxypentane **15**	butyl	83:7	72:28	67%
1,1-diethoxyhexane **16**	pentyl	91:9	77:23	74%
1,1-diethoxyoctane **17**	heptyl	95:5	90:10	82%
1,1-diethoxydodecane **18**	undecyl	98:2	98:2	83%

The selectivity of acetal hydrolysis reaction was tested with a mixture of 1,1-diethoxyethane **12** and a second longer diethyl acetal (**14** - **18**). In all cases, the

formation of ethanal in the initial phase (0-10 min) was more selective than after longer reaction time. The selectivity rose when the size difference between the two substrates increased.

6. References

(1) a) Tunstad, L. M.; Tucker, J. A.; Dalcanale, E.; Weiser, J.; Bryant, J. A.; Sherman, J. C.; Helgeson, R. C.; Knobler, C. B.; Cram, D. J. *J. Org. Chem.* **1989**, *54*, 1305; b) Elidrisi, I.; Negin, S.; Bhatt, P. V.; Govender, T.; Kruger, H. G.; Gokel, G. W.; Maguire, G. E. M. *Org. Biomol. Chem.* **2011**, *9*, 4498.

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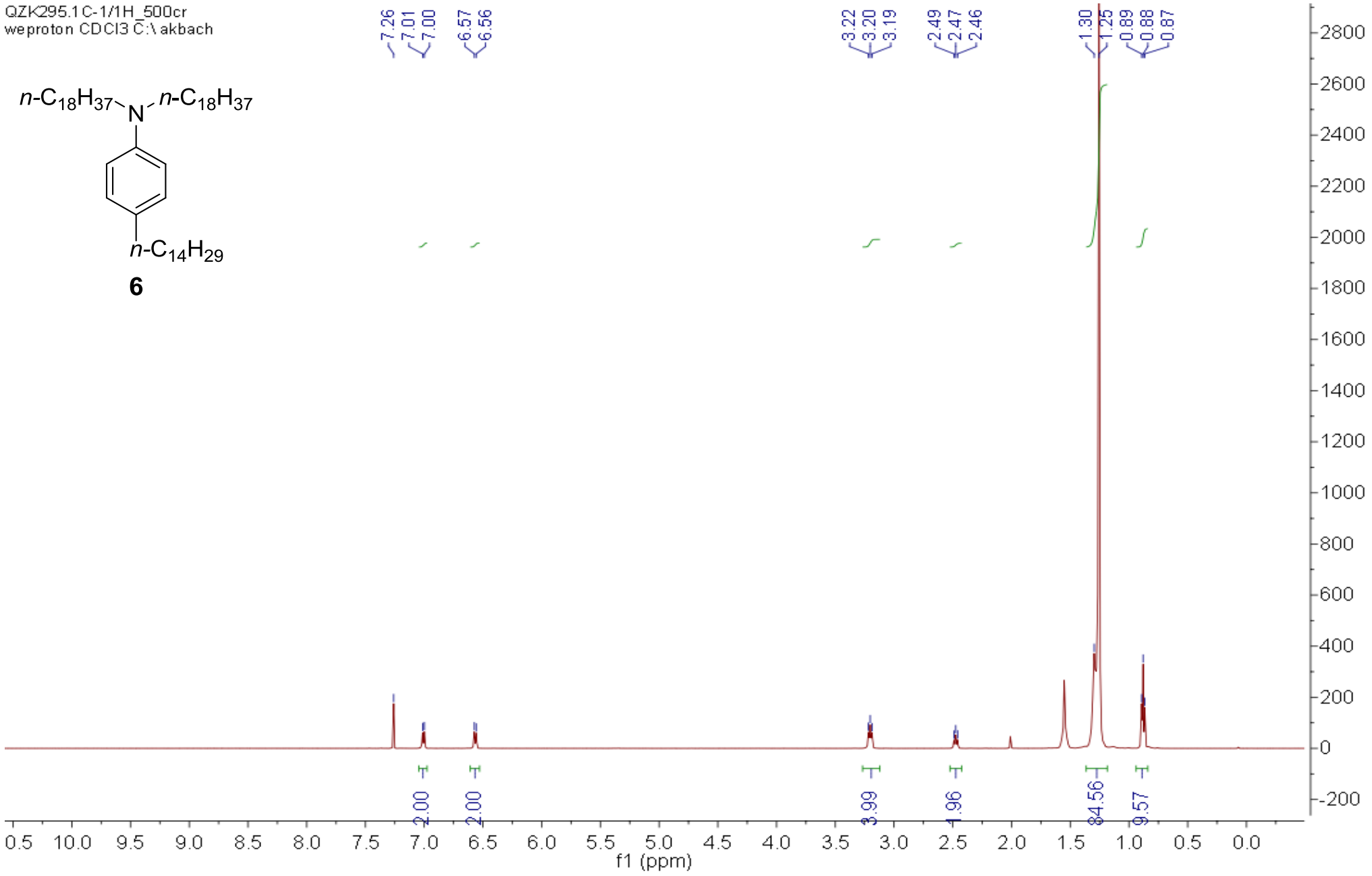
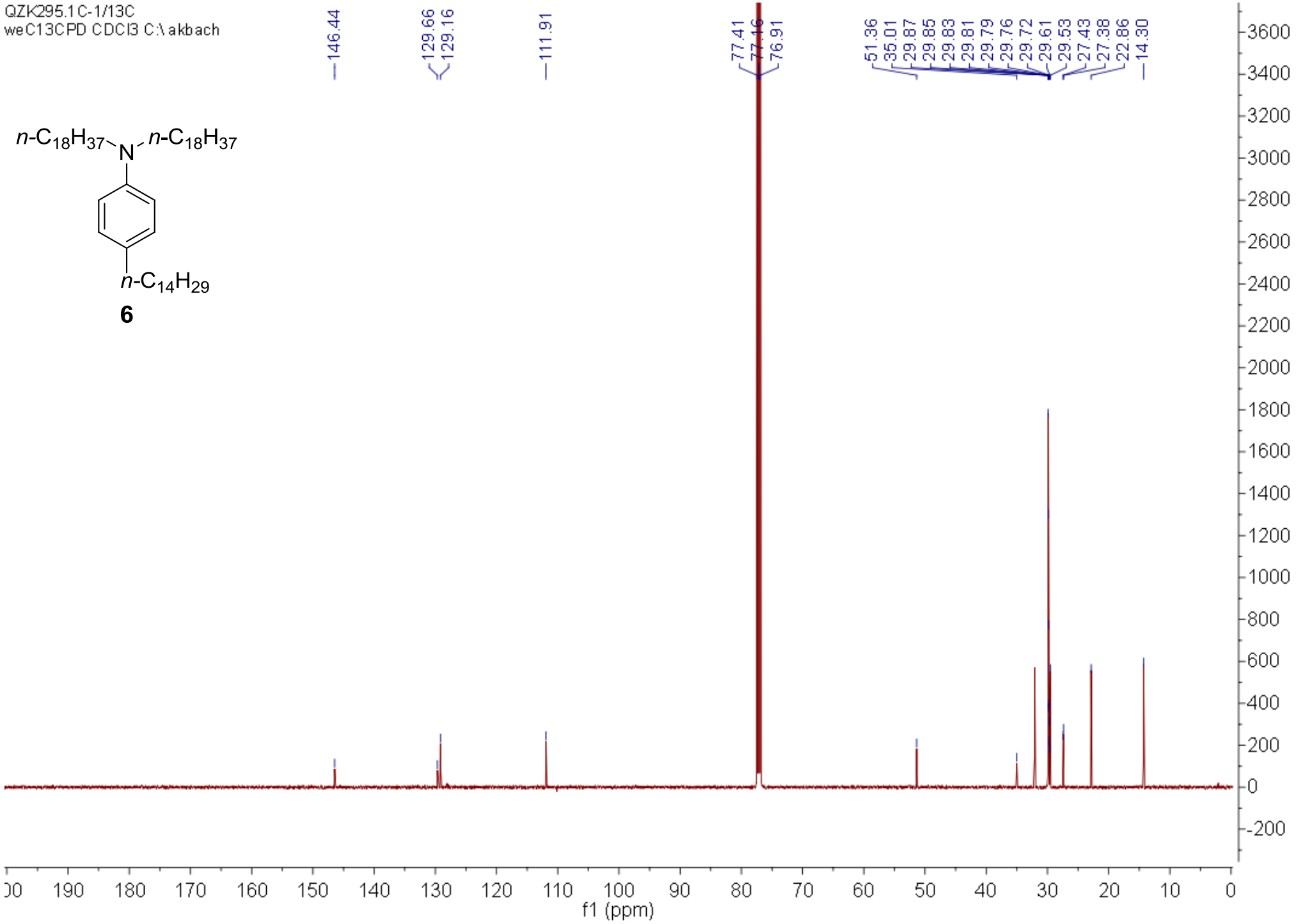
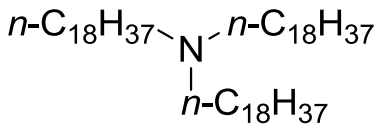
7. NMR spectra for new compounds



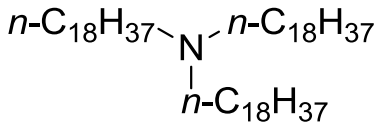

QZK295.1C-1/13C
weC13CPD CDCl3 C:\akbach
146.44
129.66
129.16
111.91
77.41
77.16
76.91
51.36
35.01
29.87
29.85
29.83
29.81
29.79
29.76
29.72
29.61
29.53
27.43
27.38
22.86
14.30
n-C18H37
N
n-C18H37
n-C14H29
6
f1 (ppm)

QZK341.1C-1.20.fid
csproton CDCl3 C:\\ akbach 53

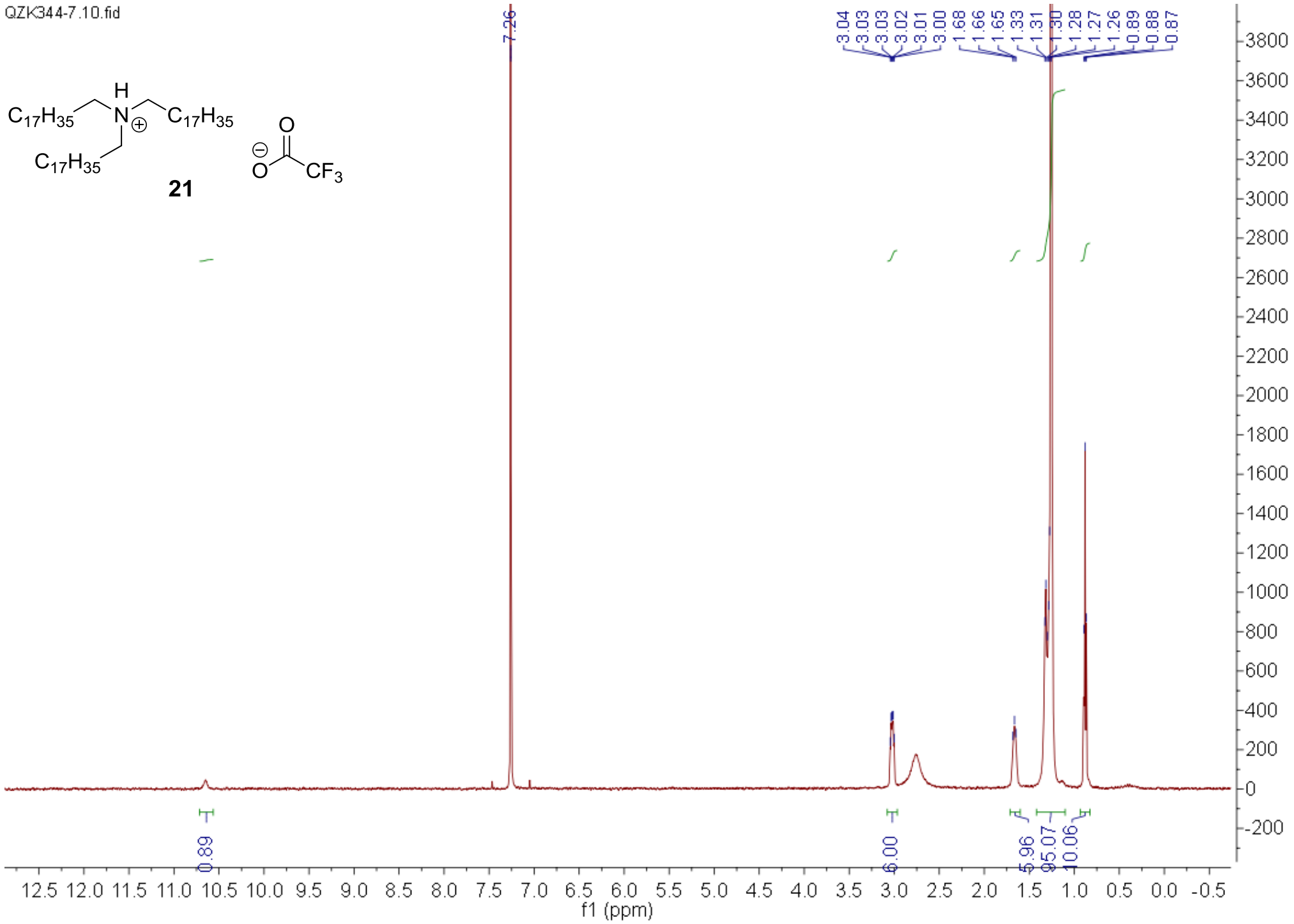


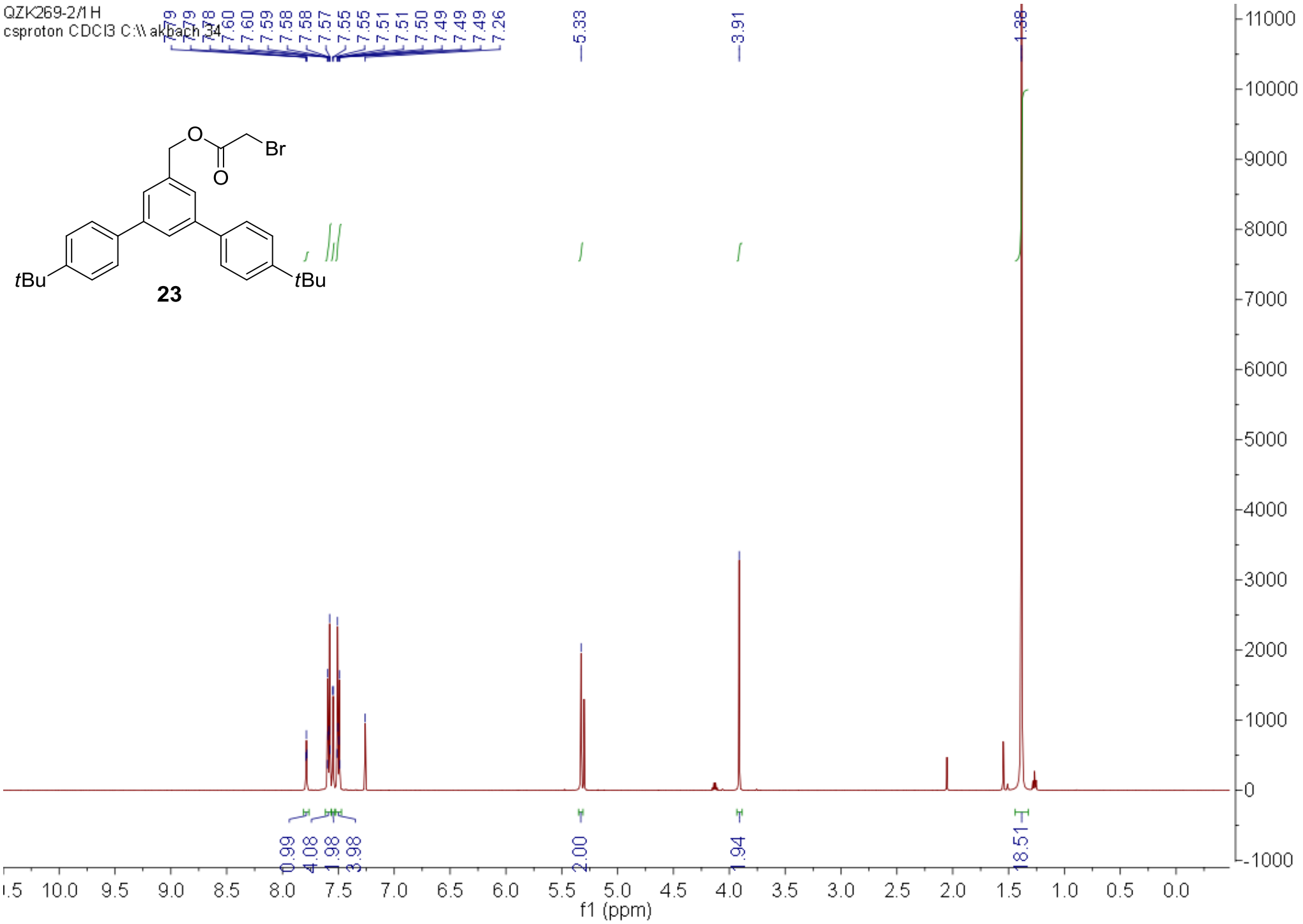
5

QZK341.1C-1.51.fid
weC13CPD CDCl3 C:\akbach

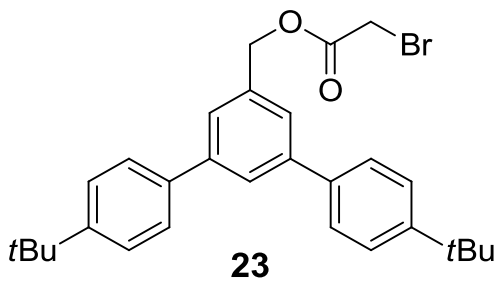


5


QZK344-7.10.fid
H
$C_{17}H_{35}$
N
$C_{17}H_{35}$
$C_{17}H_{35}$
O
O
CF_3
21
7.26
3.04
3.03
3.03
3.02
3.01
3.00
1.68
1.66
1.65
1.33
1.31
1.30
1.28
1.27
1.26
0.89
0.88
0.87
0.89
6.00
5.96
95.07
10.06
f1 (ppm)

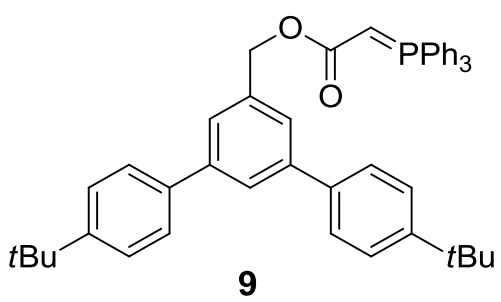

QZK269-2/1 H
csproton CDCl3 C:\\ akbach 34
7.79
7.79
7.78
7.60
7.60
7.59
7.58
7.58
7.57
7.55
7.55
7.51
7.51
7.50
7.49
7.49
7.49
7.26
5.33
3.91
1.38
O
Br
O
tBu
tBu
23
0.99
4.08
1.98
3.98
2.00
1.94
18.51
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

QZK269-2/13C
weC13CPD CDCl3 C:\akbatch

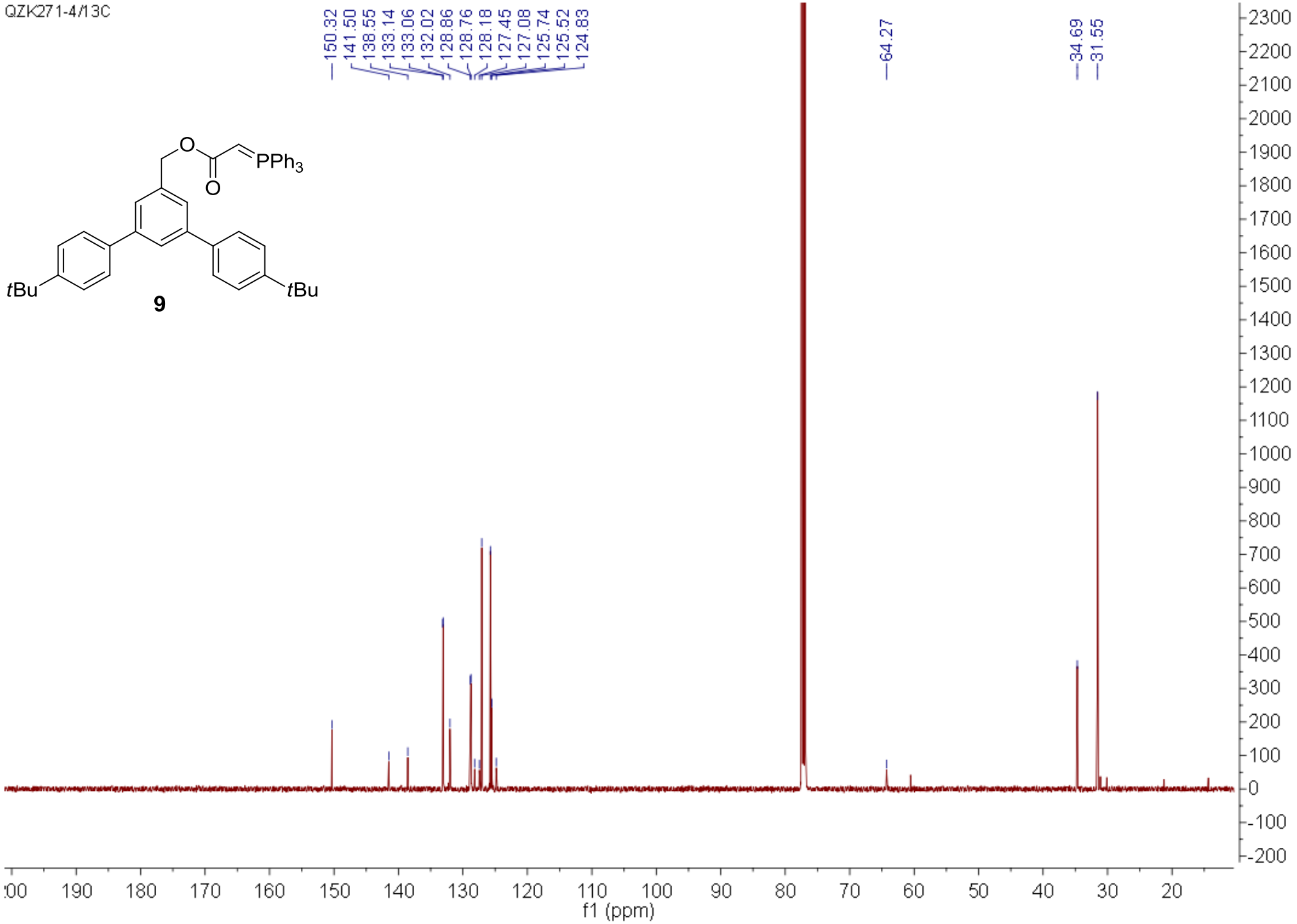


23

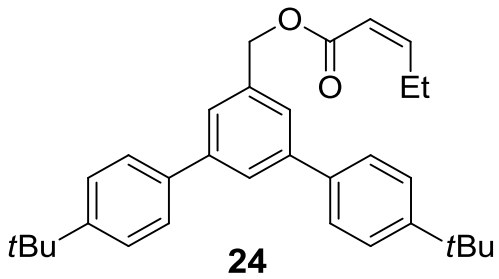
QZK271-4/1 H



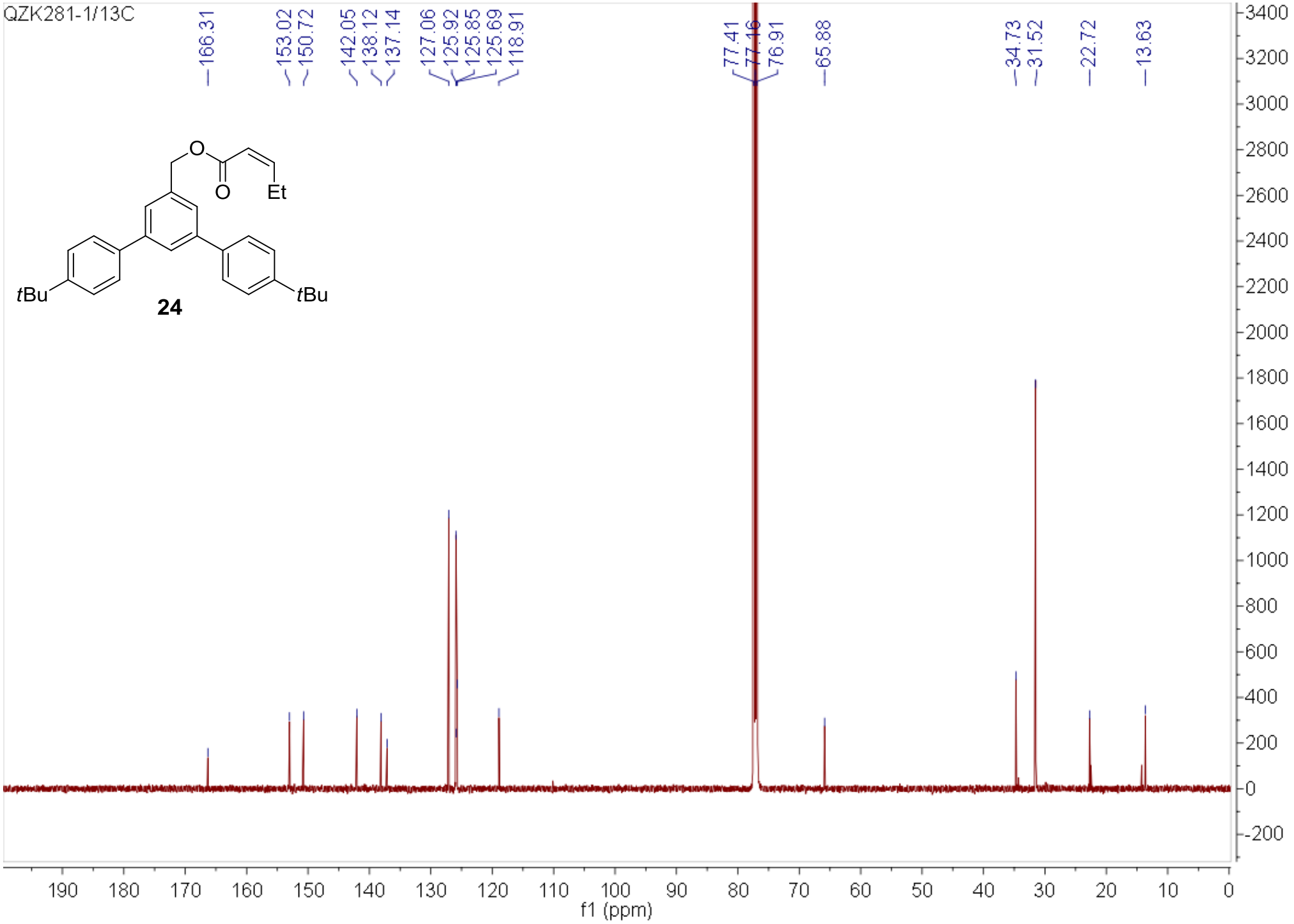
9


QZK271-4/13C
150.32
141.50
138.55
133.14
133.06
132.02
128.86
128.76
128.18
127.45
127.08
125.74
125.52
124.83
64.27
34.69
31.55
O
O
PPh3
tBu
tBu
9
f1 (ppm)

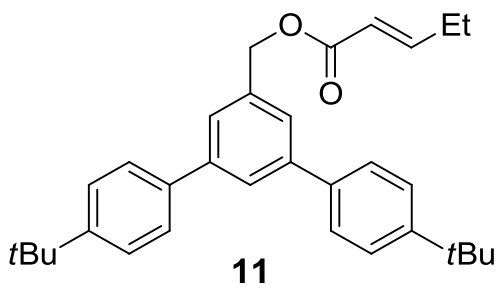
QZK281-1.10.fid



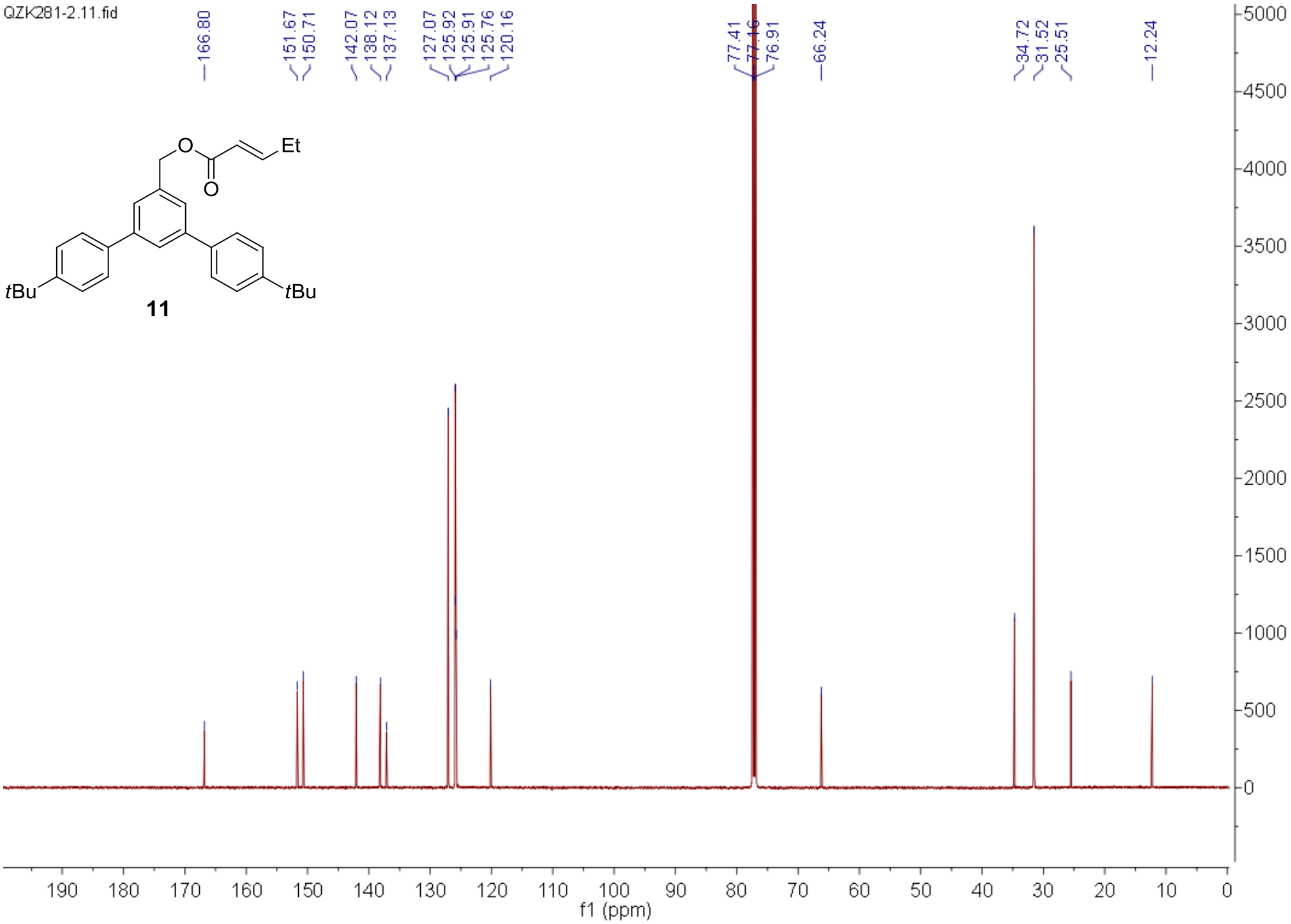
24


QZK281-1/13C
166.31
153.02
150.72
142.05
138.12
137.14
127.06
125.92
125.85
125.69
118.91
77.41
77.16
76.91
65.88
34.73
31.52
22.72
13.63
O
O
Et
tBu
tBu
24
f1 (ppm)

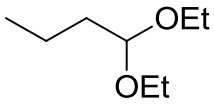
QZK281-2.10.fid



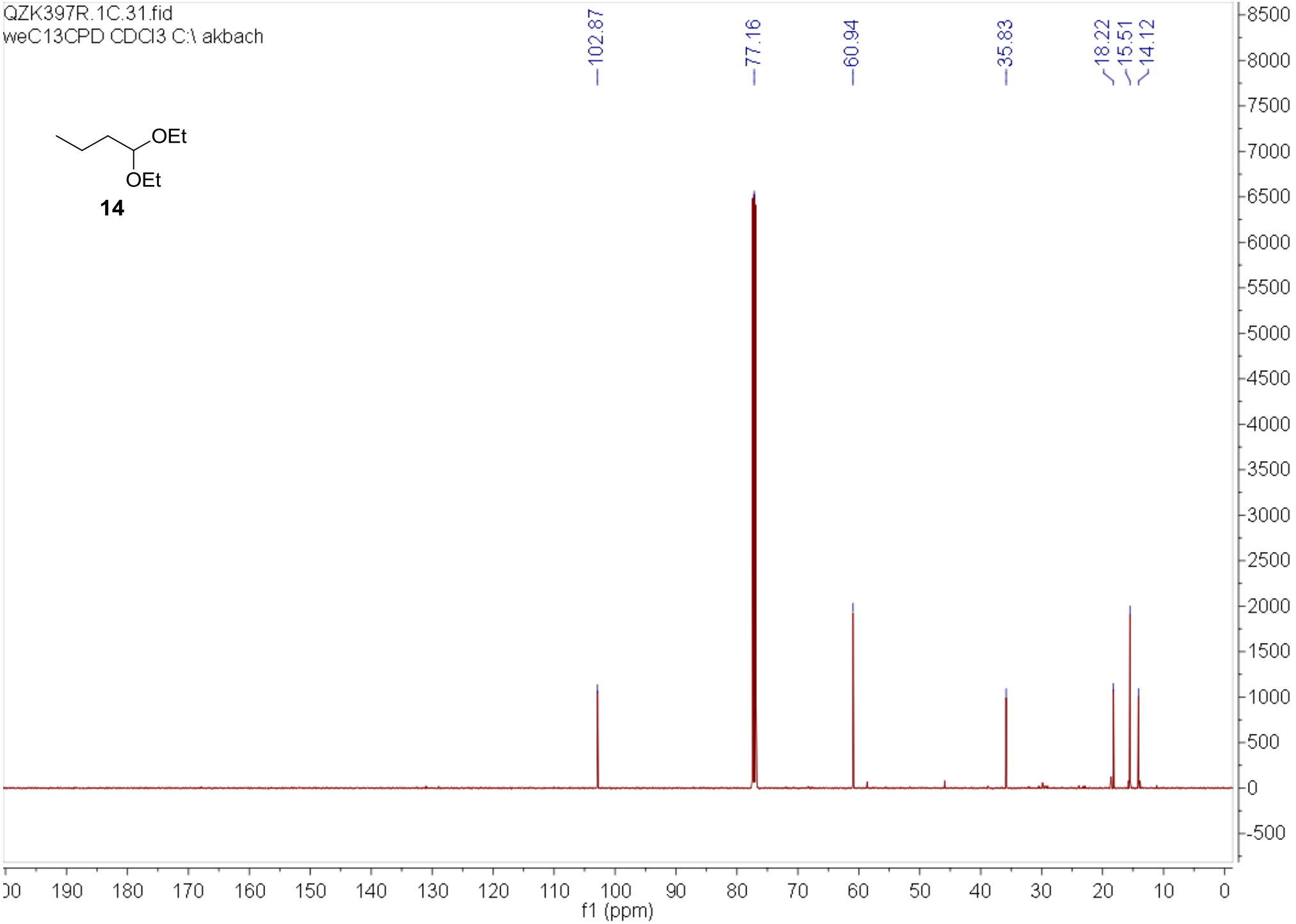
11


QZK281-2.11.fid
166.80
151.67
150.71
142.07
138.12
137.13
127.07
125.92
125.91
125.76
120.16
77.41
77.16
76.91
66.24
34.72
31.52
25.51
12.24
O
O
Et
tBu
tBu
11
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

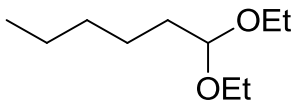
QZK397.1 C.10.fid
weproton CDCl3 C:\ akbach



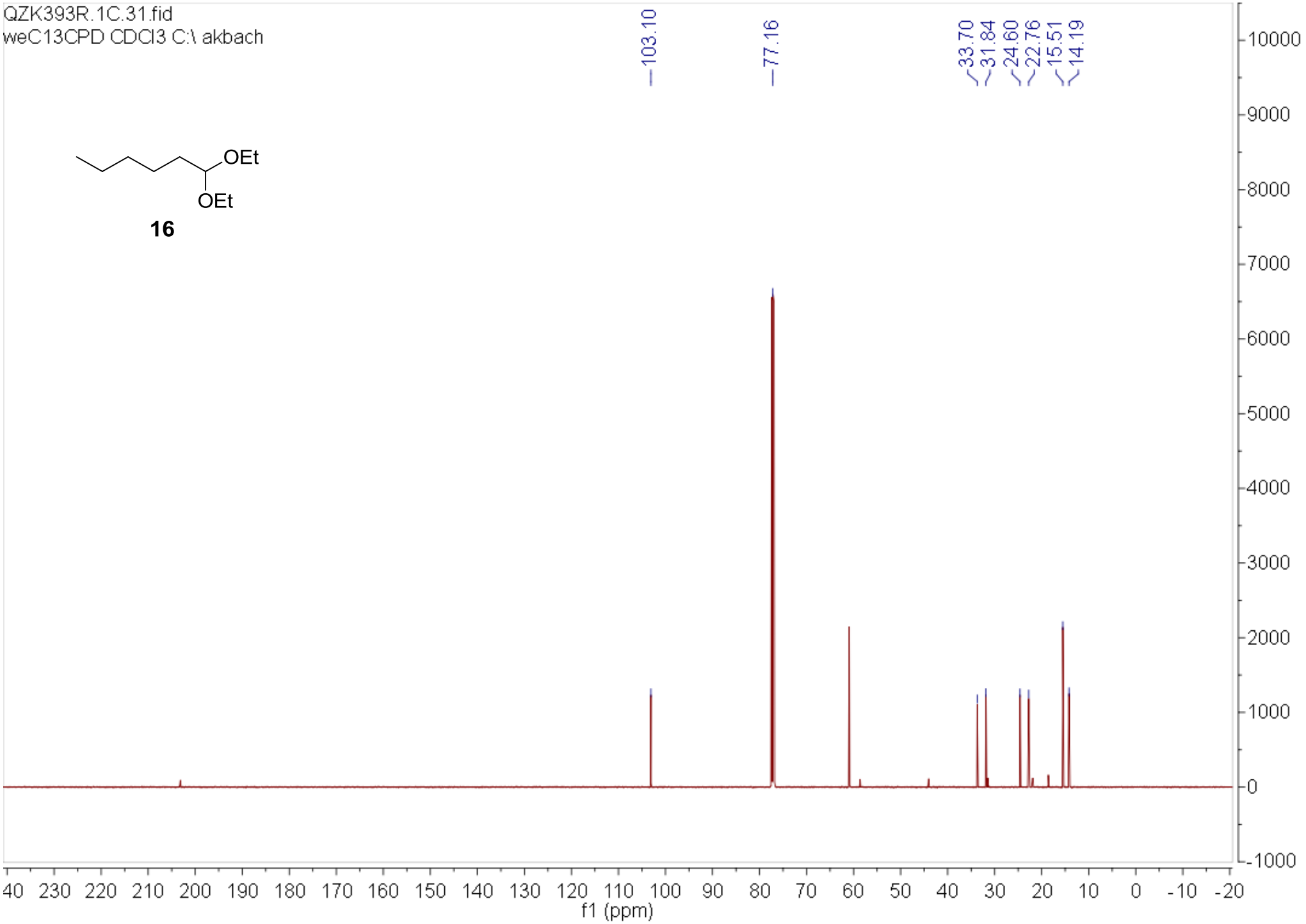
14


QZK397R.1C.31.fid
weC13CPD CDCl3 C:\ akbach
102.87
77.16
60.94
35.83
18.22
15.51
14.12
OEt
OEt
14
f1 (ppm)

QZK393R.1C.10.fid
PROTON CDCl3 C:\\ akbach 85



16


QZK393R.1C.31.fid
weC13CPD CDCl3 C:\ akbach
103.10
77.16
33.70
31.84
24.60
22.76
15.51
14.19
OEt
OEt
16
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
40 230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
f1 (ppm)