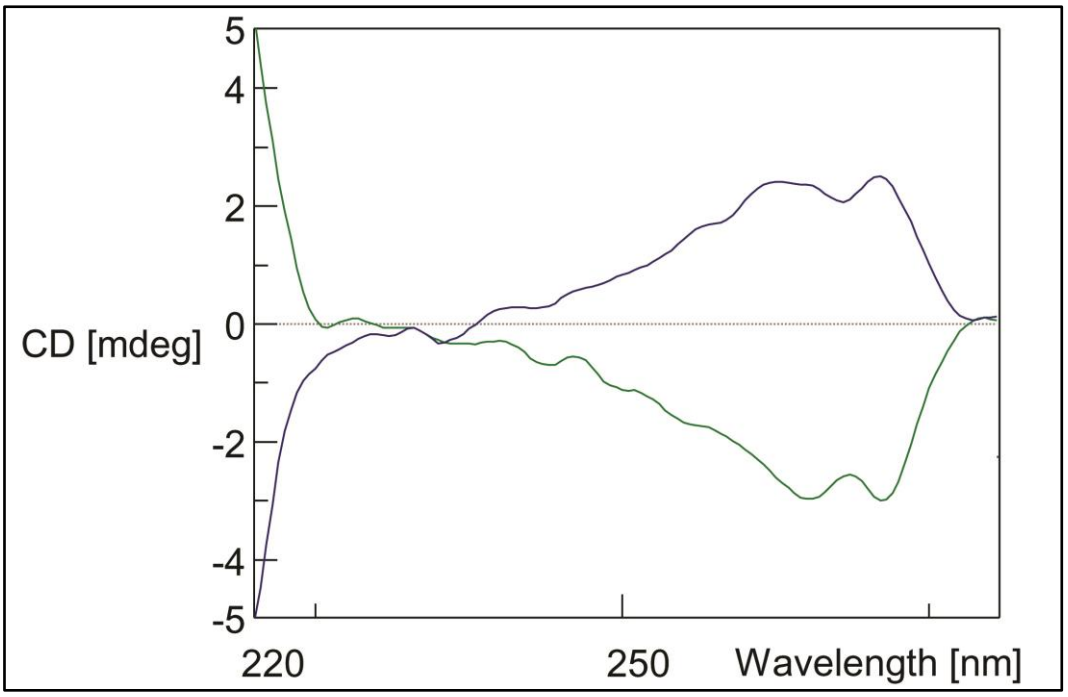
Electronic Supplementary Material (ESI) for RSC Advances.

Supporting information

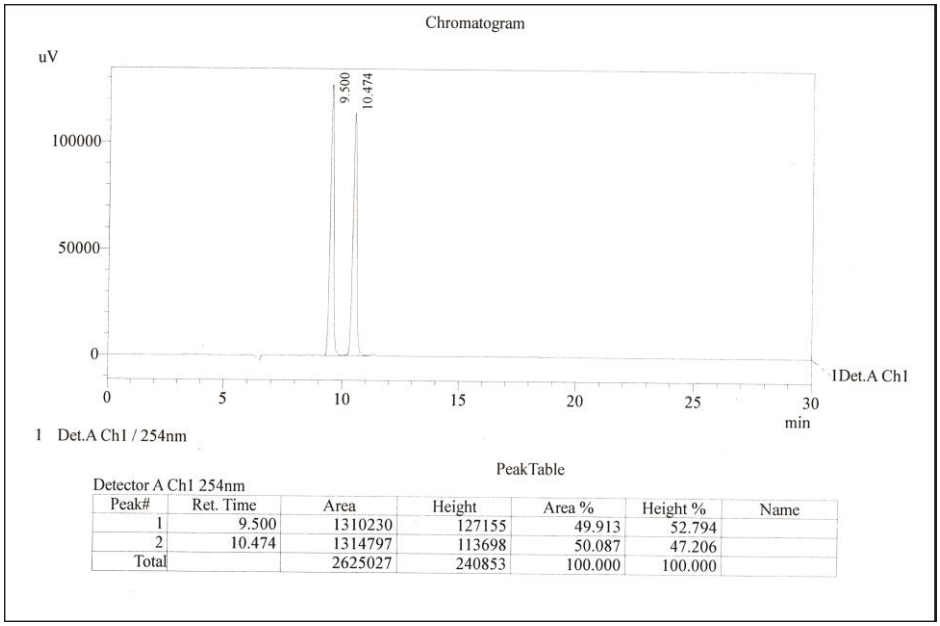
Modified Kagan's Amide, Synthesis and Applications as Chiral Solvating Agent for Hydrogen-Bonding Based Chiral Discrimination in NMR

Nilesh Jain, Ravi B. Patel and Ashutosh V. Bedekar*

Index



CD spectra of (*S*)-**3** & (*R*)-**3** alcohol in Acetonitrile $1x10^{-4}$ (Blue line for (*S*)-isomer & Green line for (*R*)-isomer

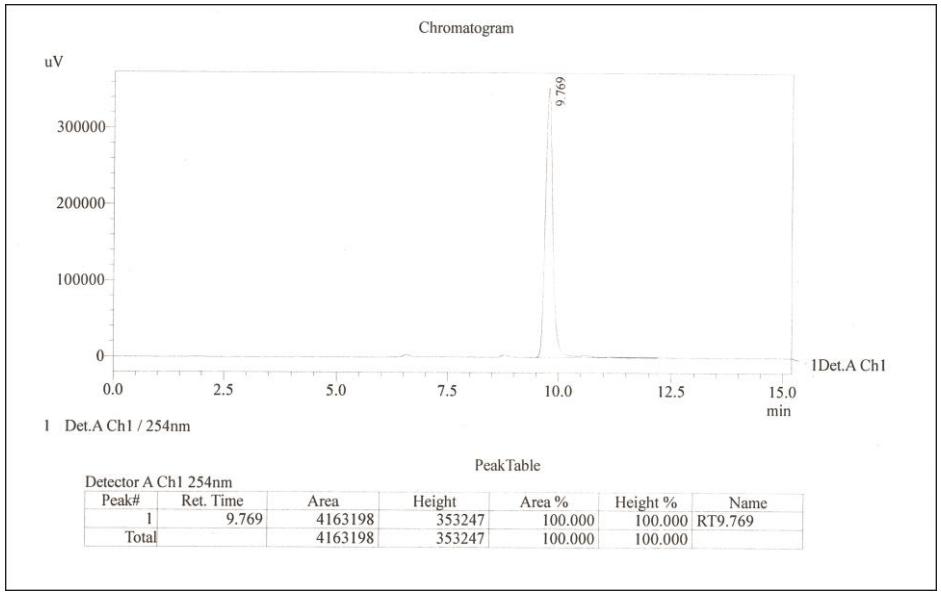


PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %	Name
1	9.500	1310230	127155	49.913	52.794	
2	10.474	1314797	113698	50.087	47.206	
Total		2625027	240853	100.000	100.000	

HPLC chart of racemic (±)-**3**

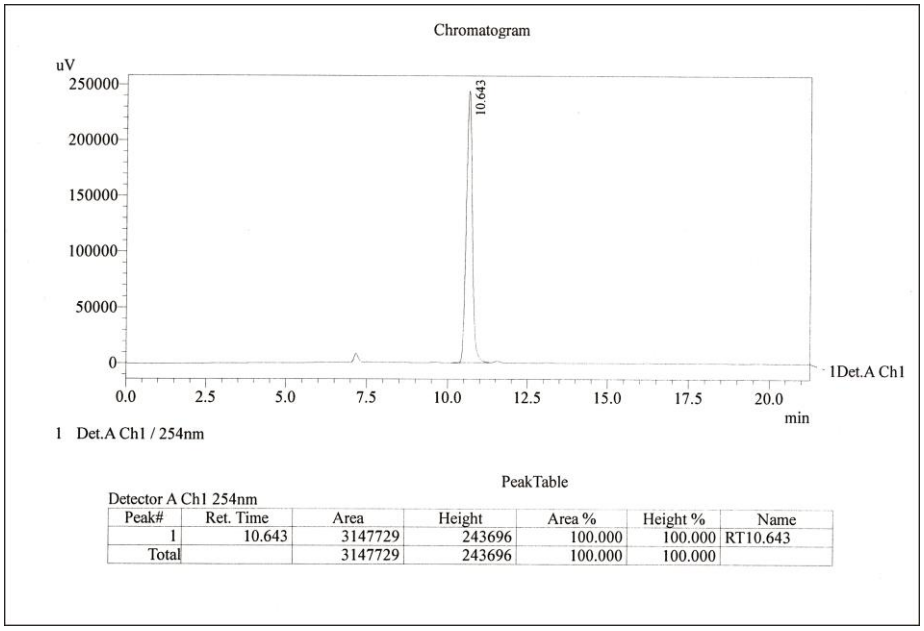


PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %	Name
1	9.769	4163198	353247	100.000	100.000	RT9.769
Total		4163198	353247	100.000	100.000	

HPLC chart of compound (*S*)-3

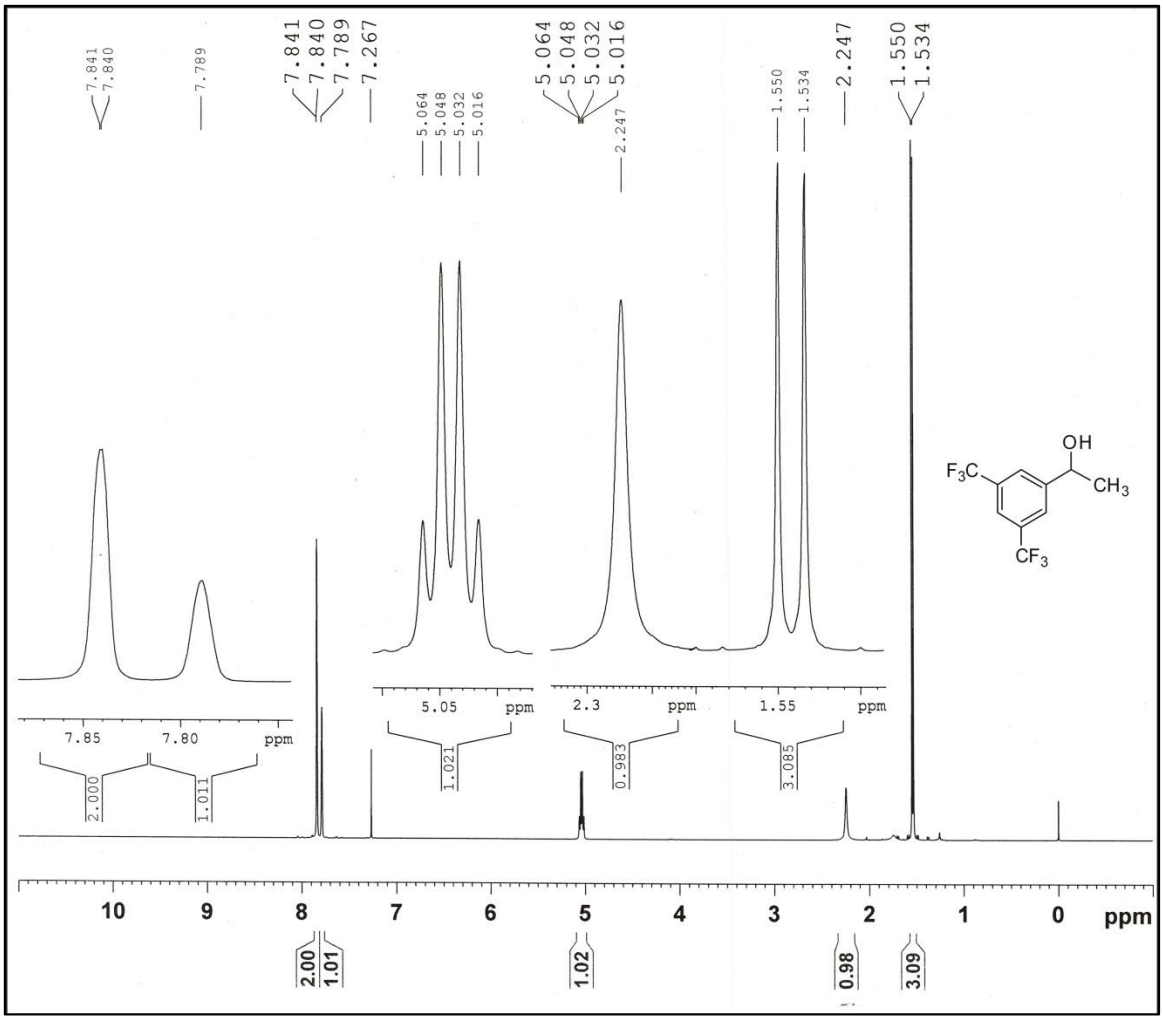


PeakTable

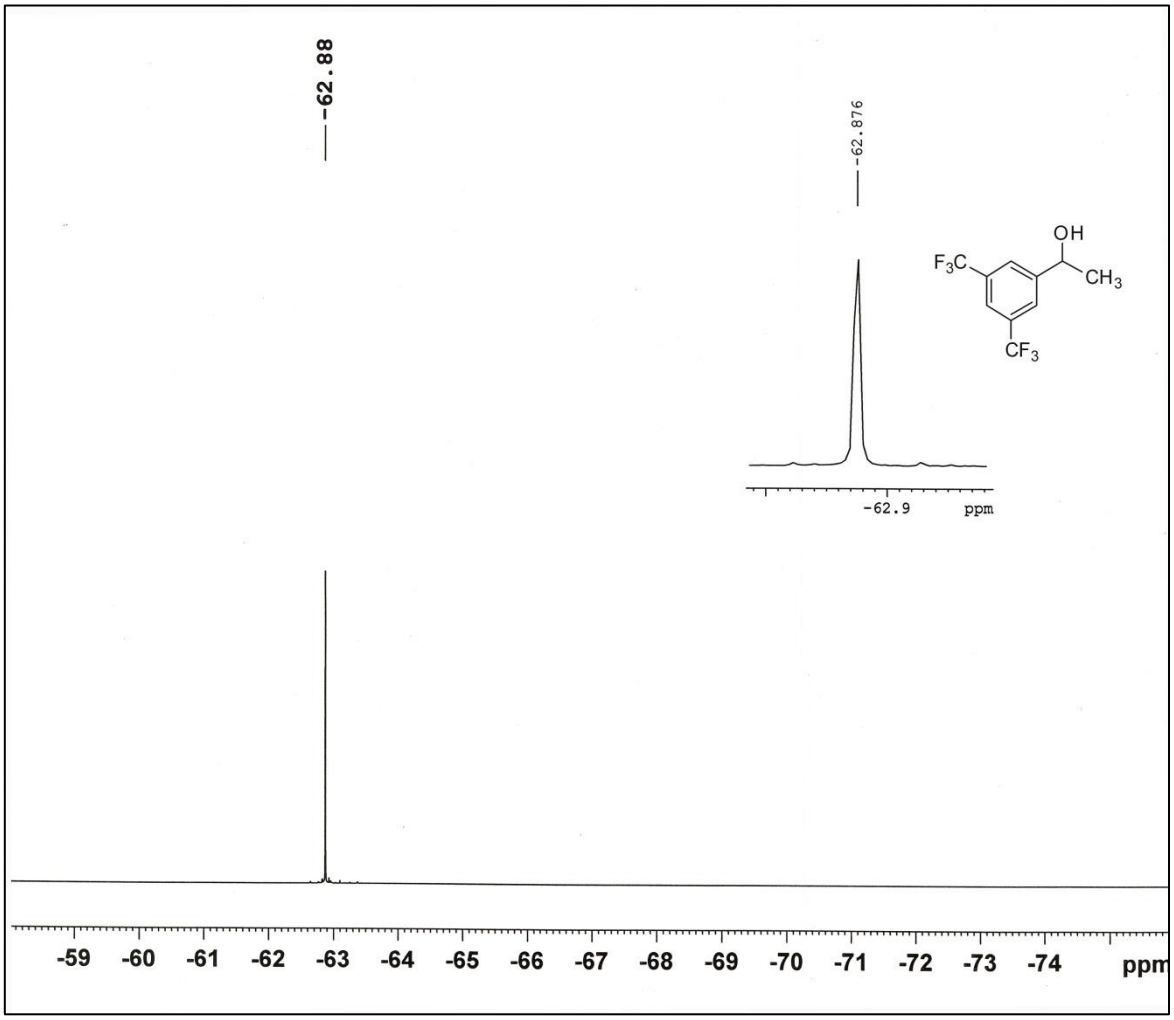
Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %	Name
1	10.643	3147729	243696	100.000	100.000	RT10.643
Total		3147729	243696	100.000	100.000	

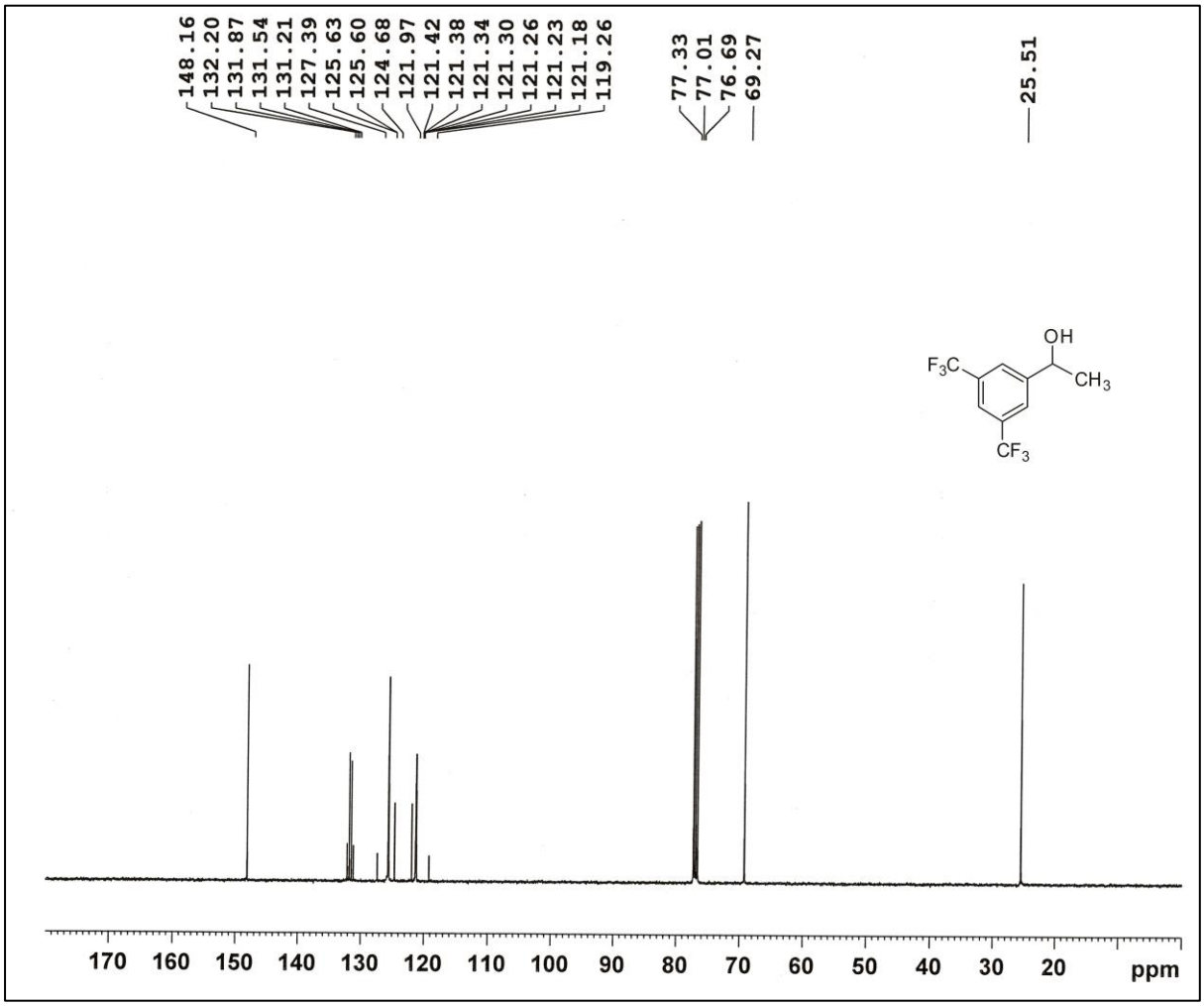
HPLC chart of compound (*R*)-**3**



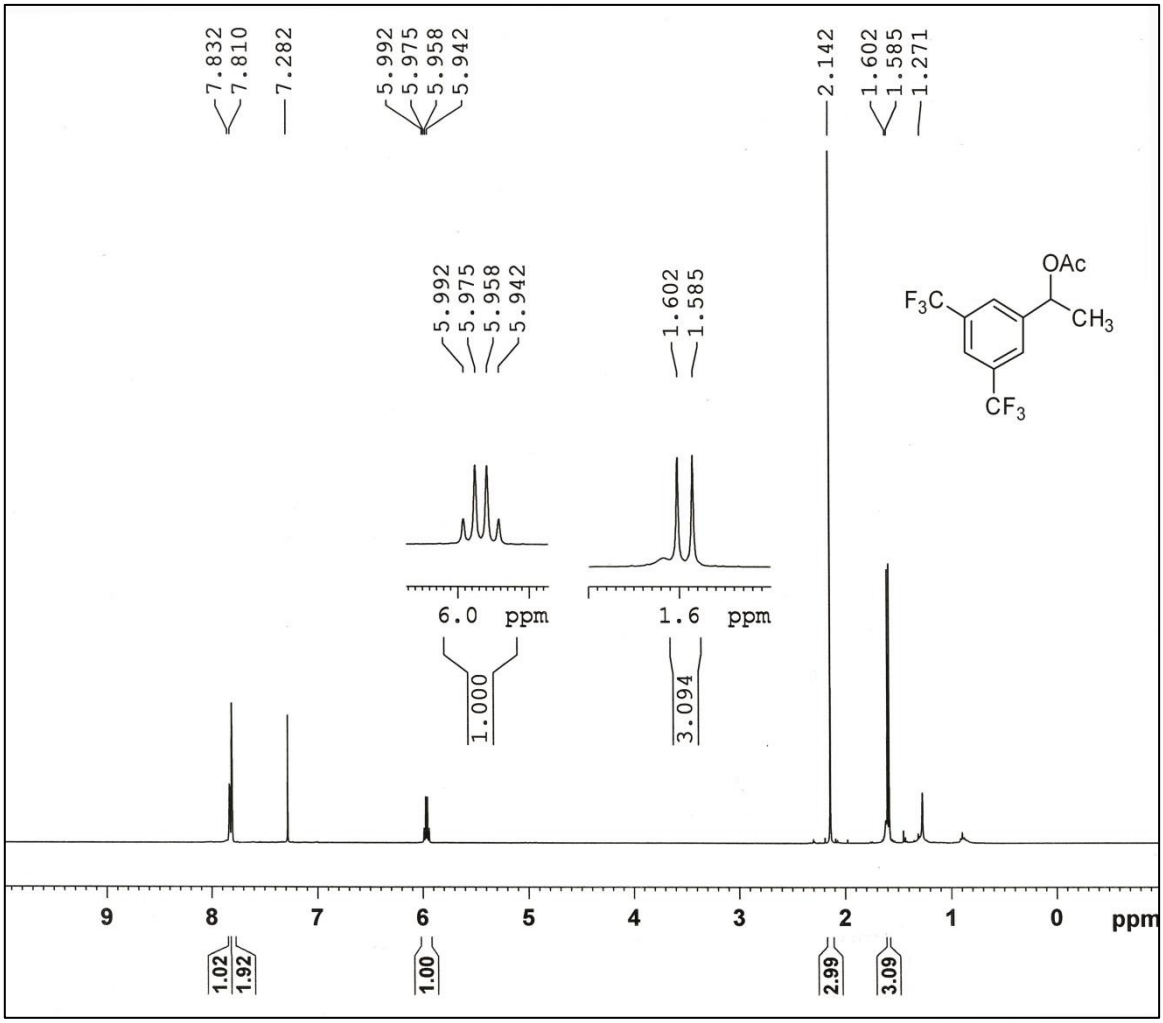
^{1}H-NMR spectra of compound (*S*)-**3** in $CDCl_3$



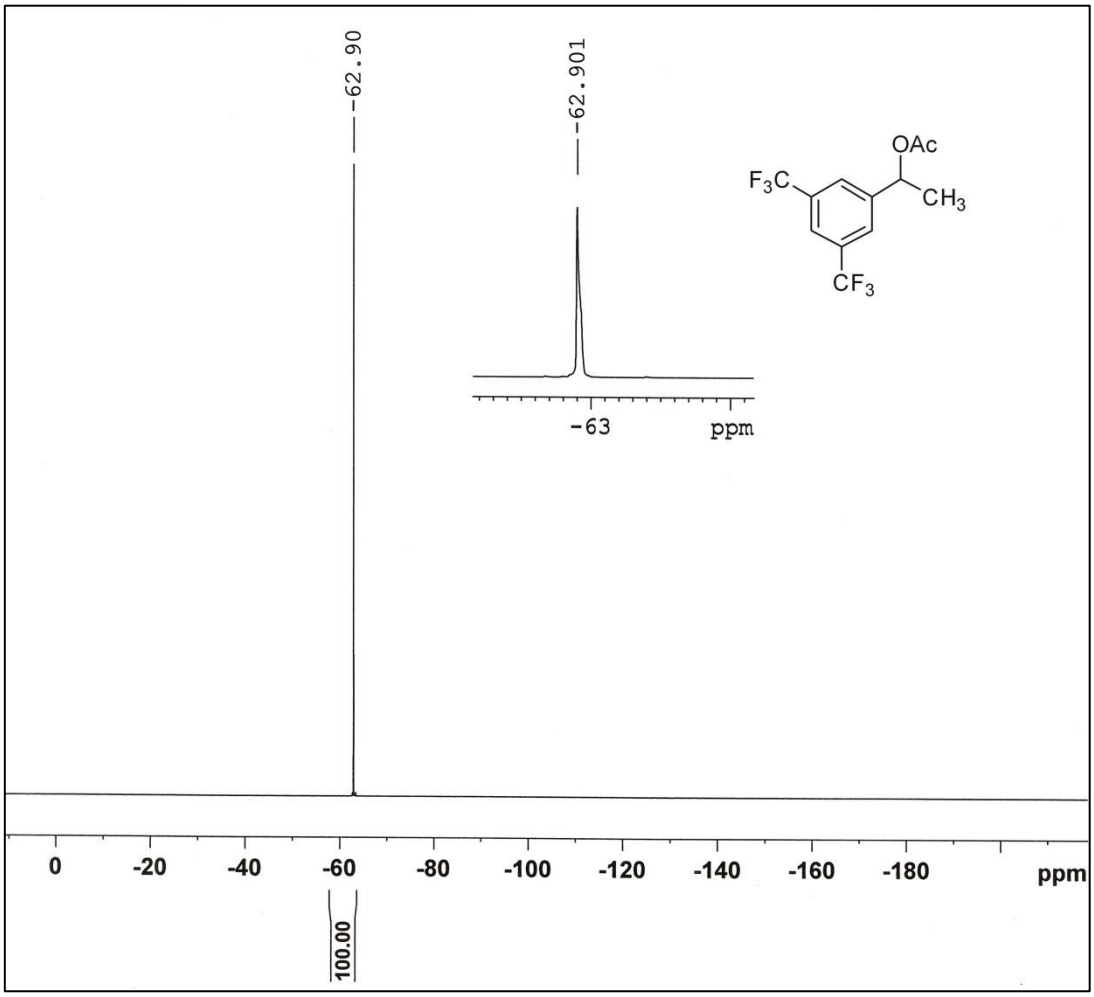
^{19}F-NMR spectra of compound (*S*)-**3** in $CDCl_3$



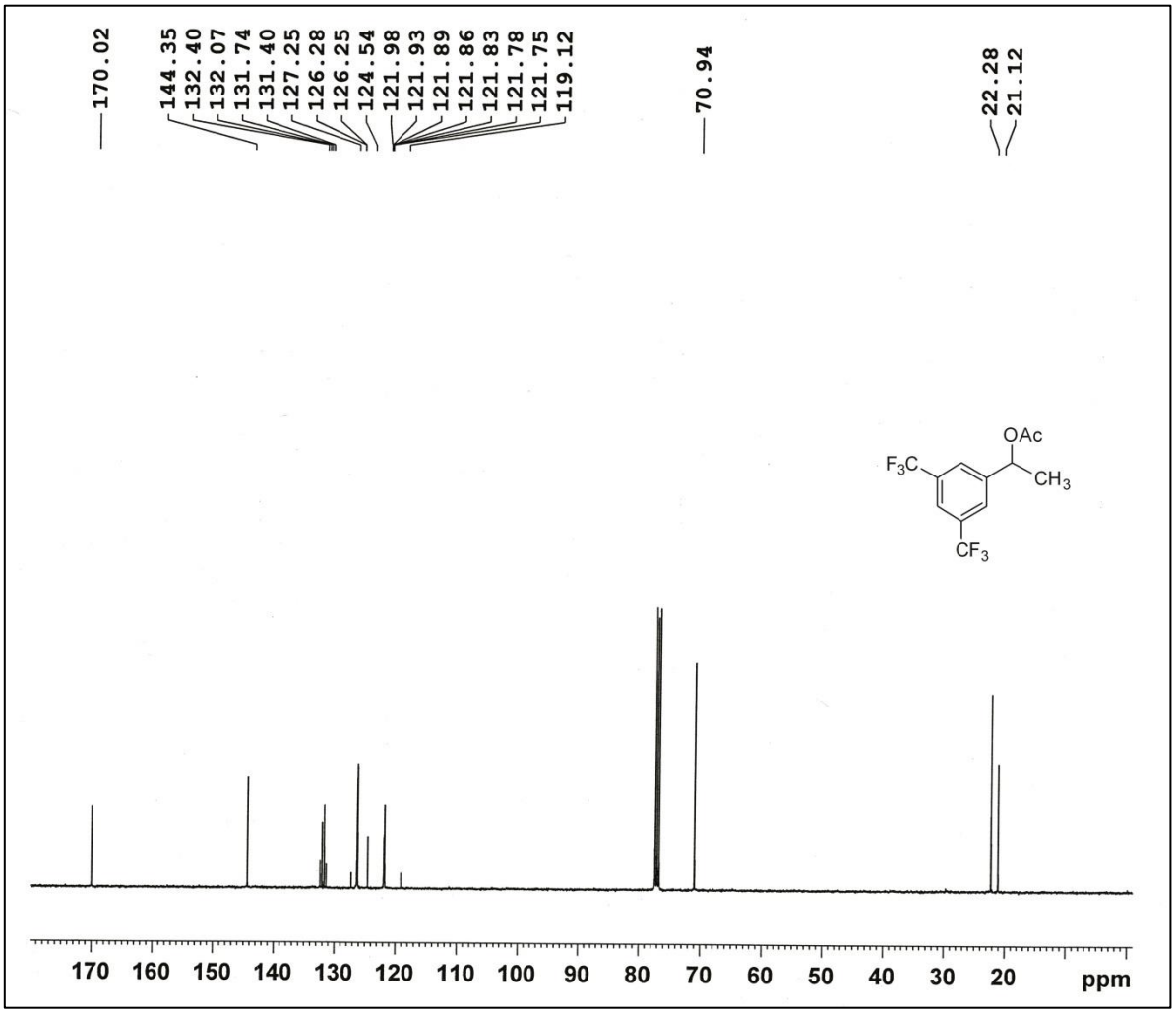
^{13}C-NMR spectra of compound (*S*)-**3** in $CDCl_3$



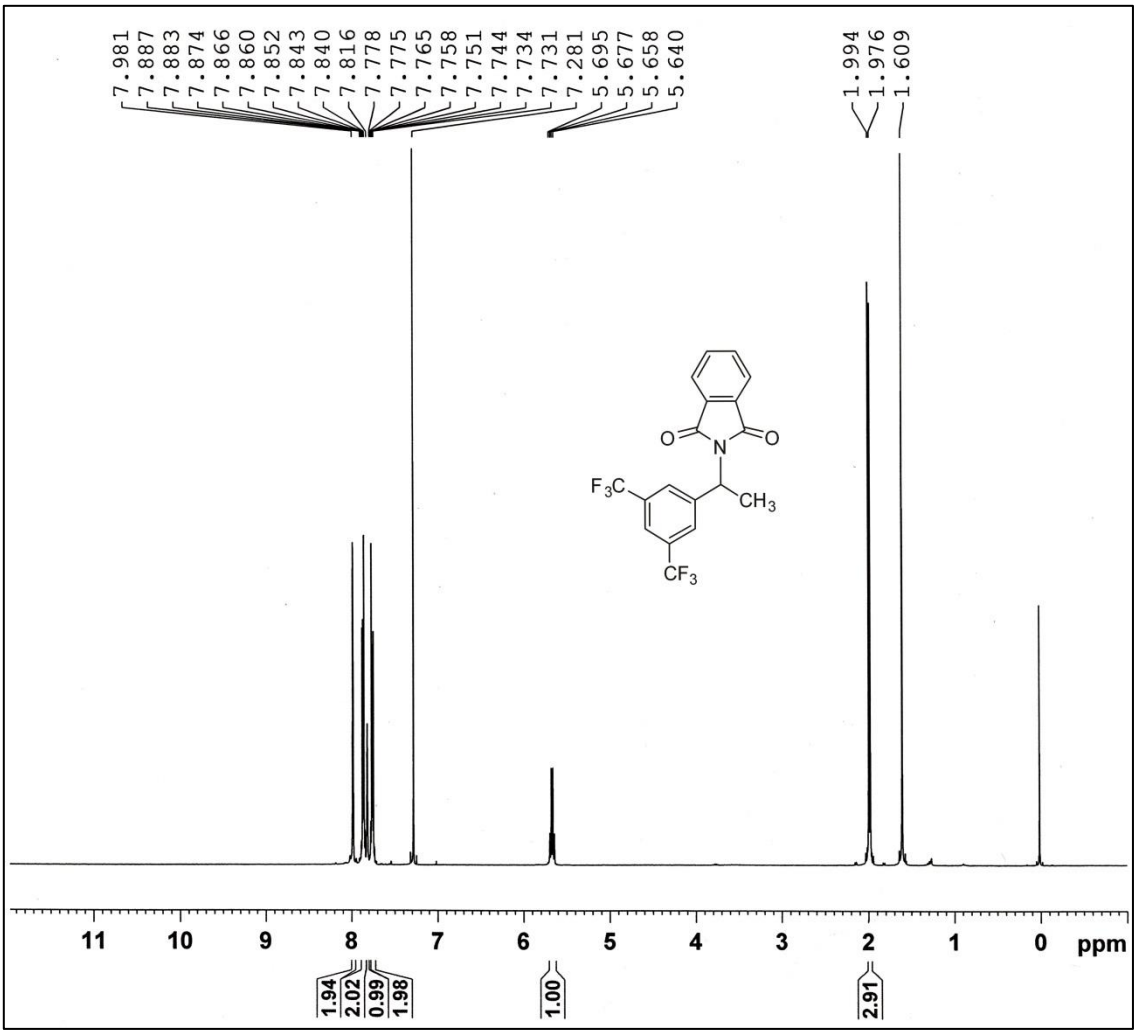
^{1}H-NMR spectra of compound (*R*)-**4** in $CDCl_3$



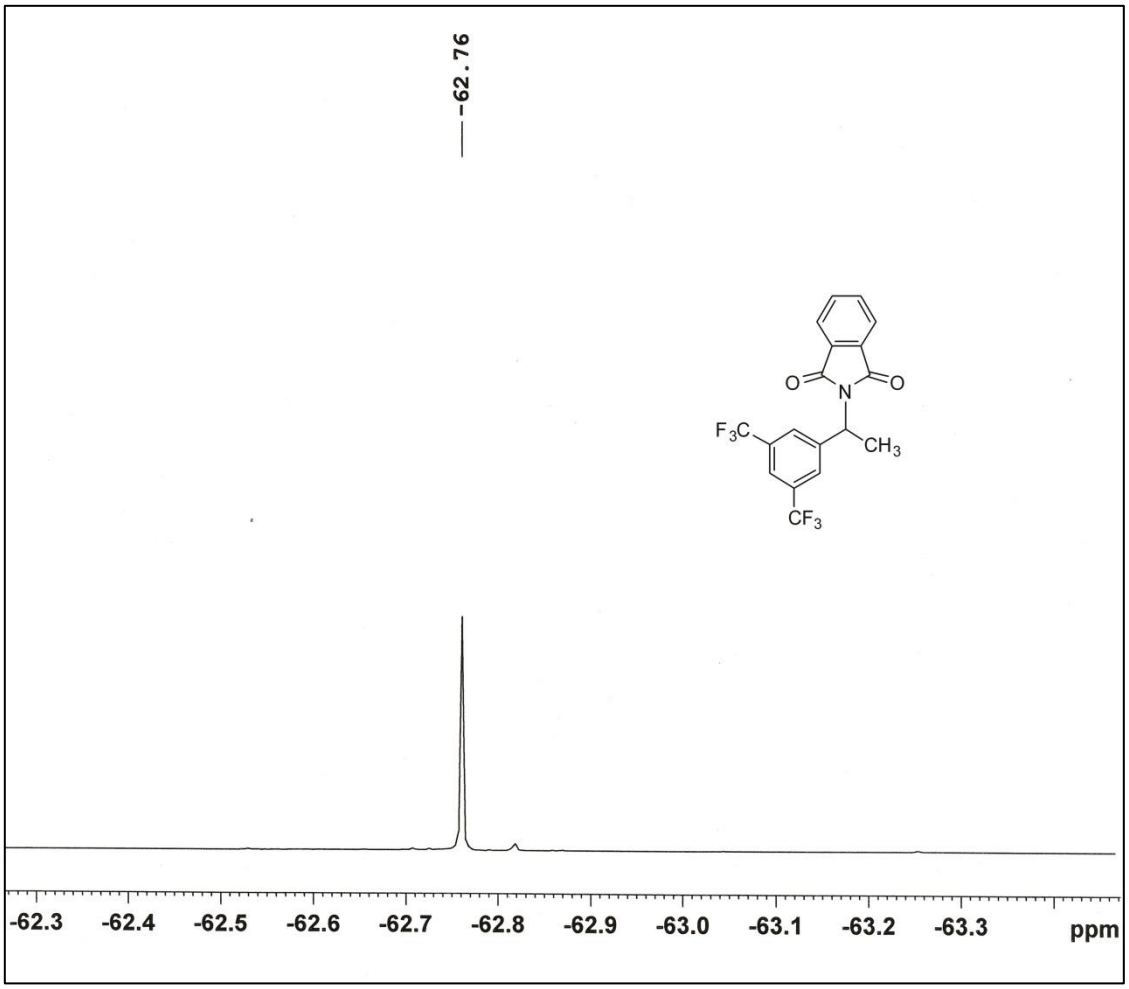
^{19}F-NMR spectra of compound (*R*)-**4** in $CDCl_3$



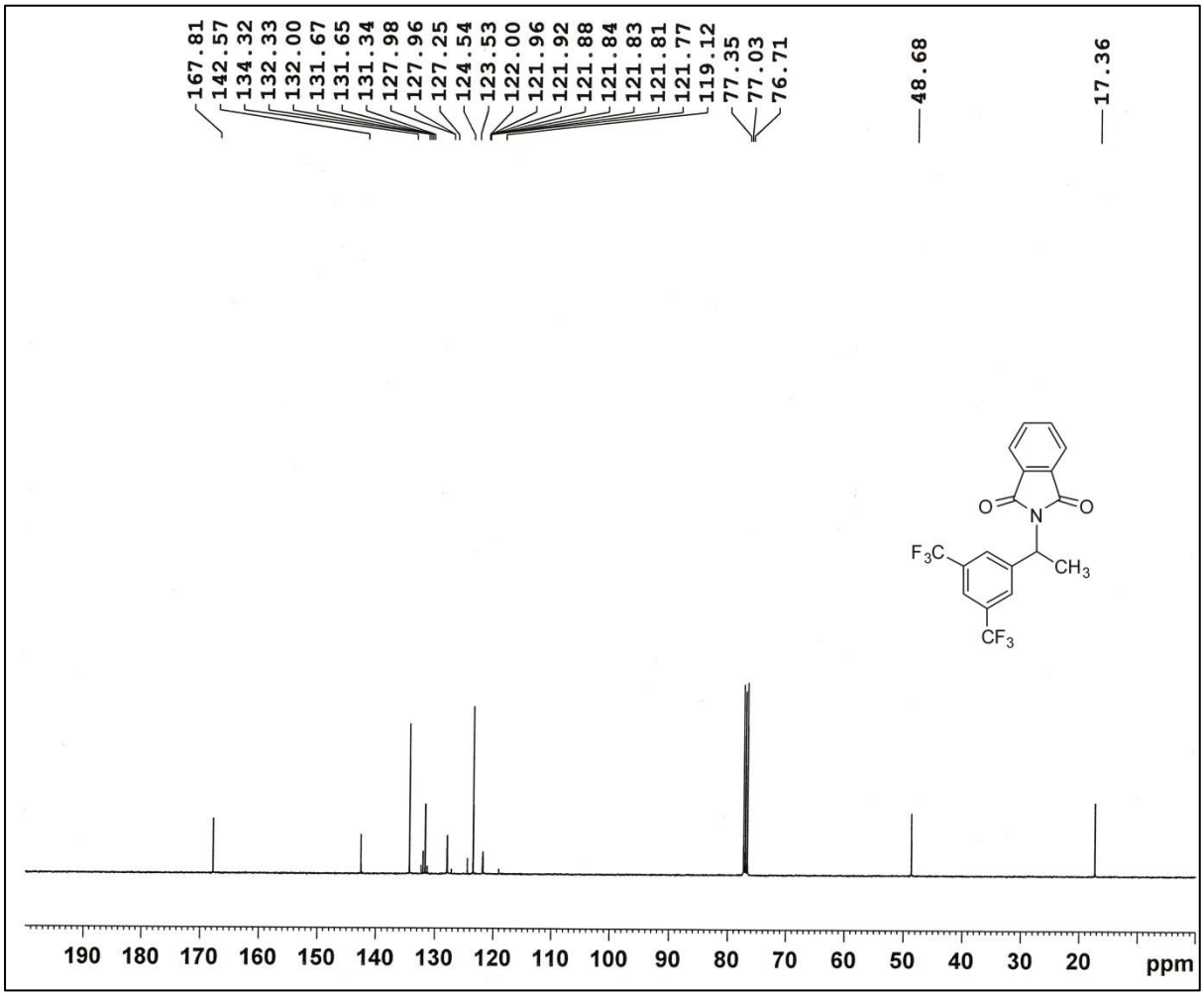
^{13}C-NMR spectra of compound (*R*)-**4** in $CDCl_3$



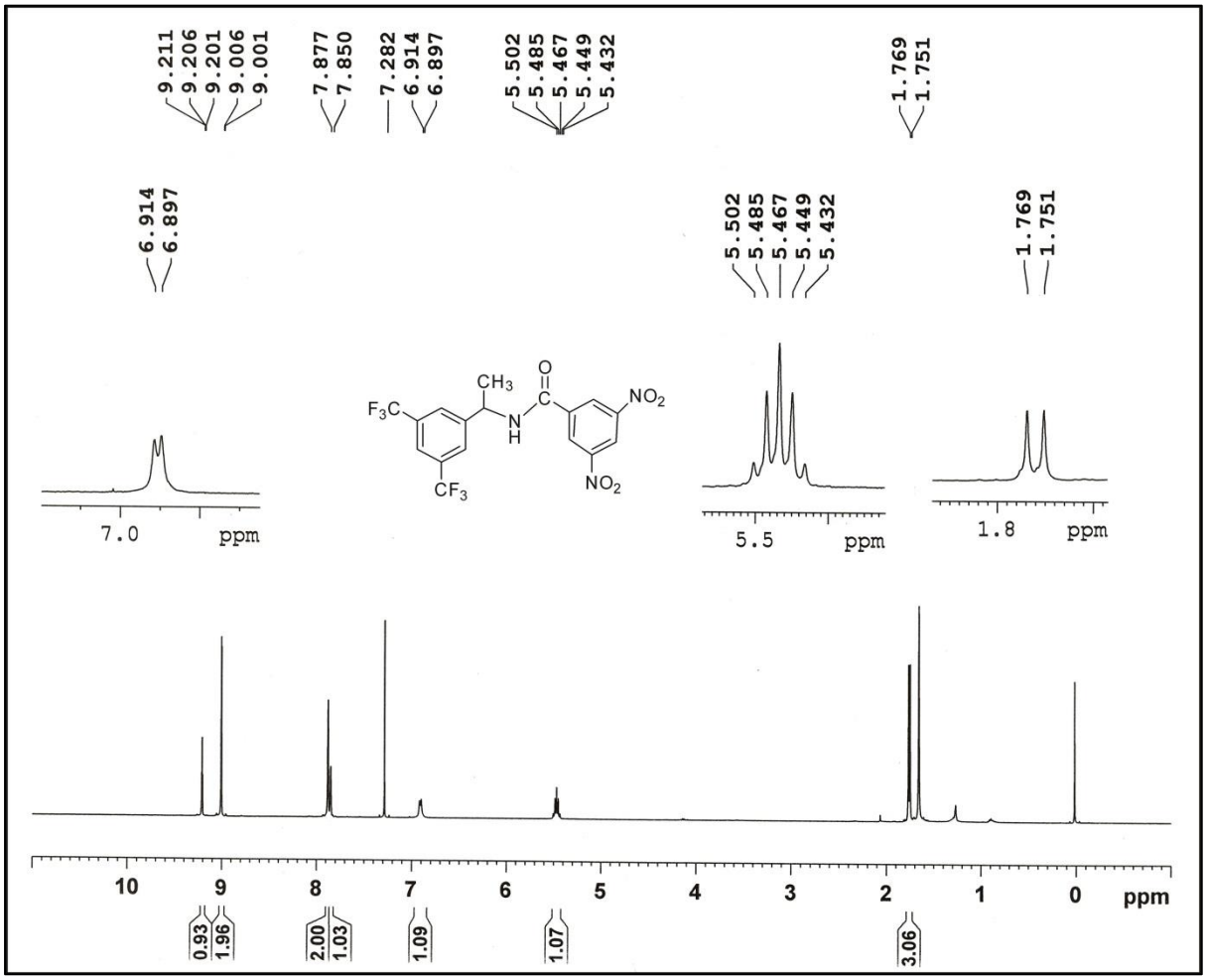
^{1}H-NMR spectra of compound (*S*)-**5** in $CDCl_3$



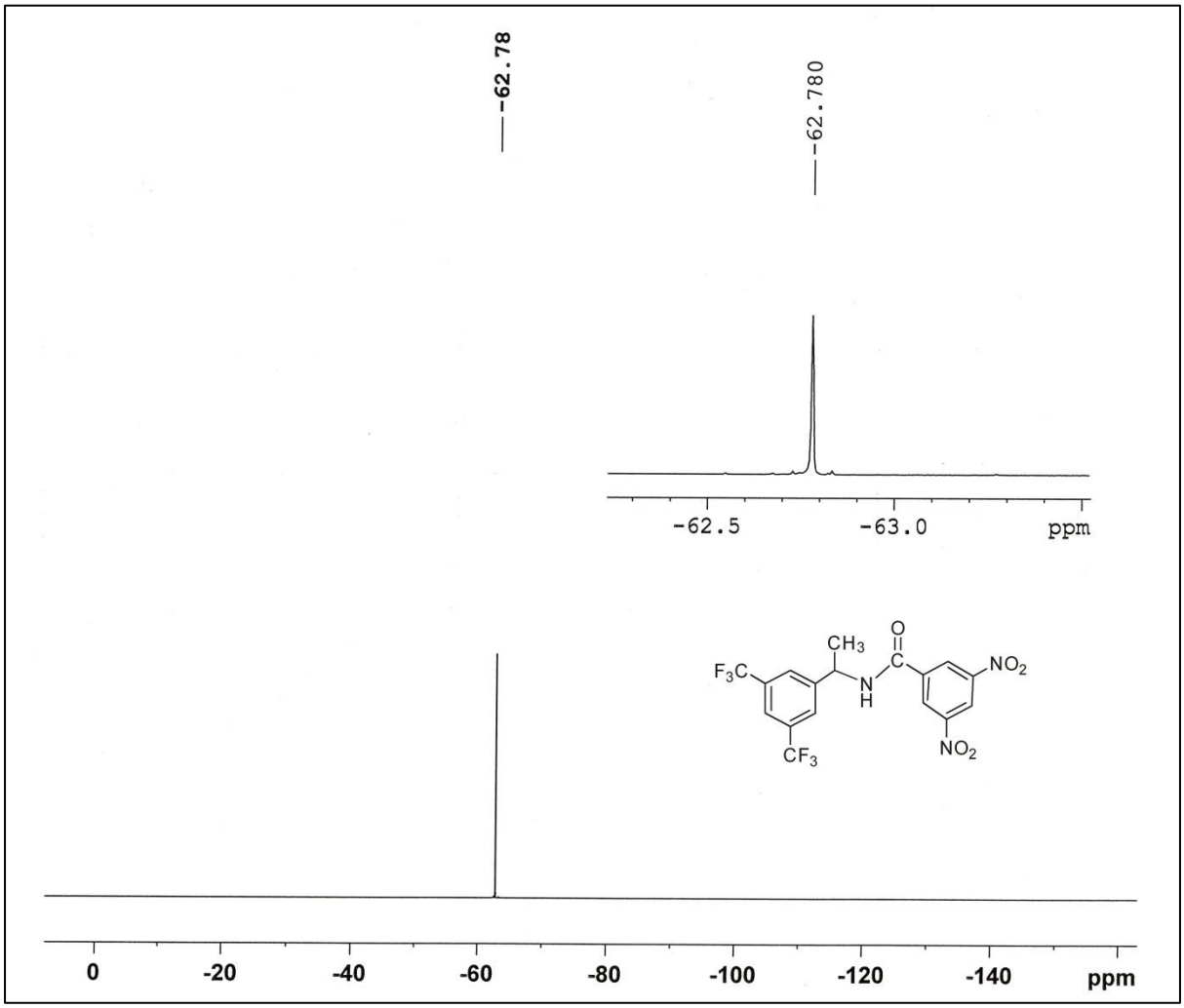
^{19}F-NMR spectra of compound (*S*)-**5** in $CDCl_3$



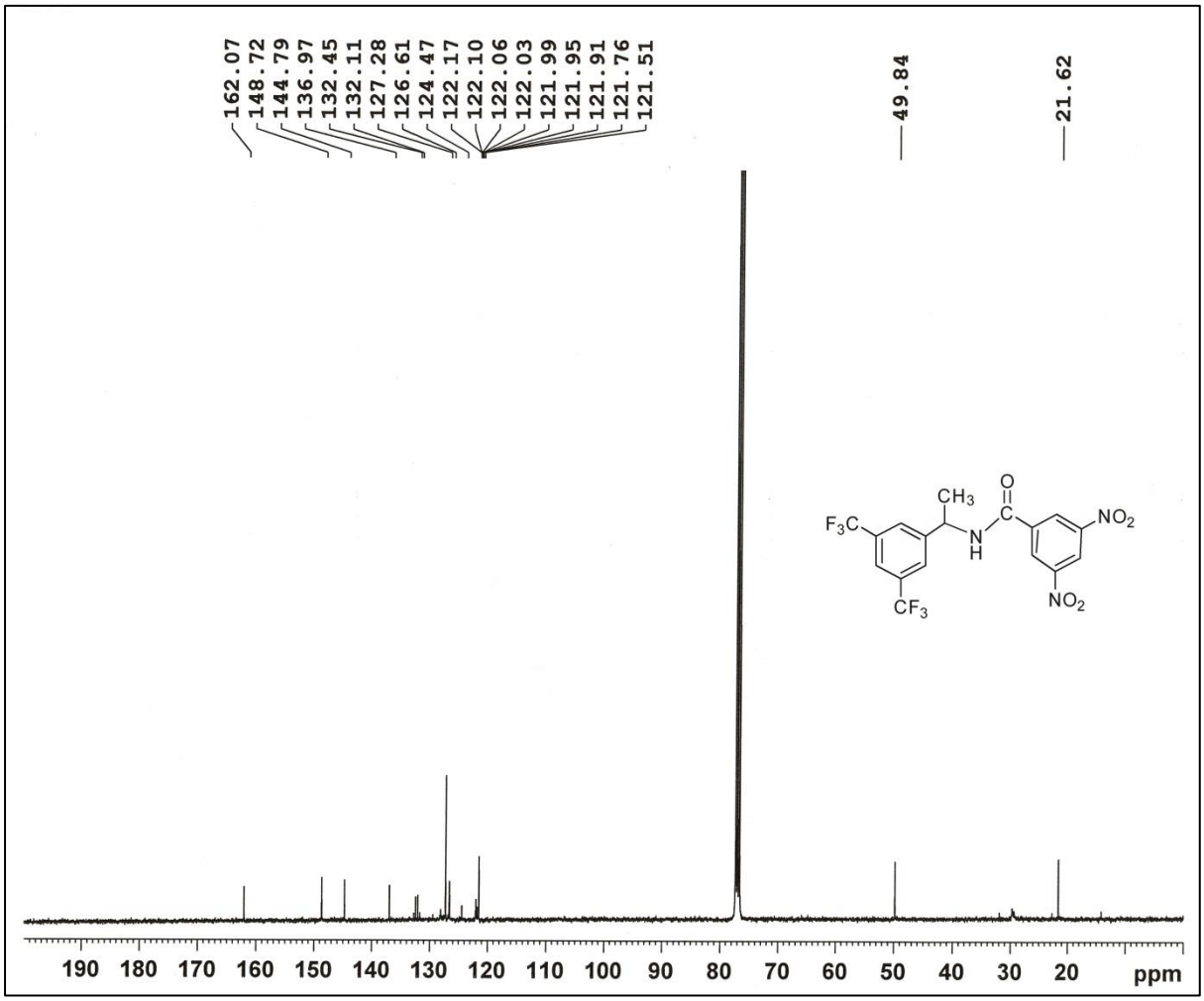
^{13}C-NMR spectra of compound (*S*)-**5** in $CDCl_3$



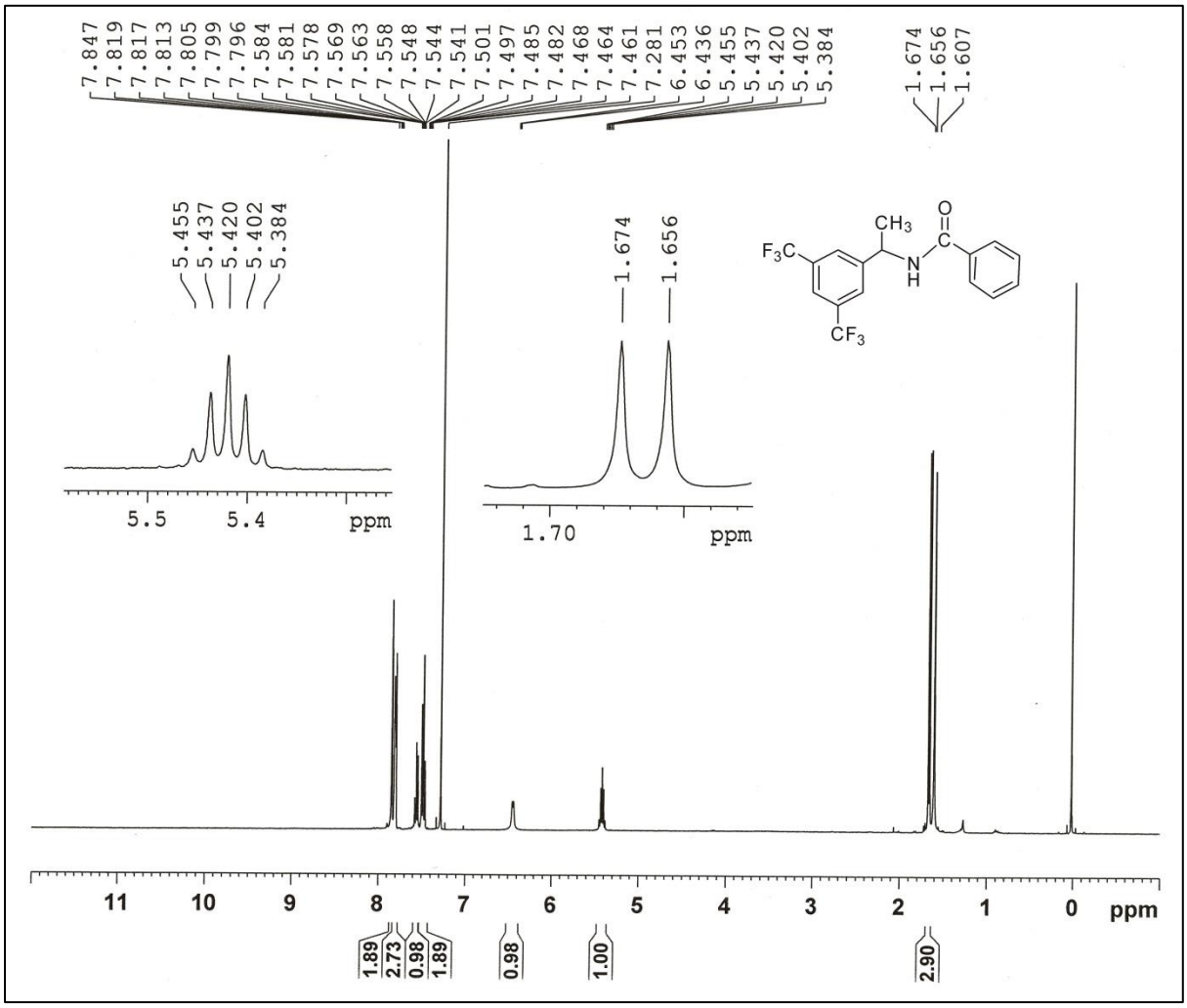
^{1}H-NMR spectra of compound (*S*)-**2** in $CDCl_3$



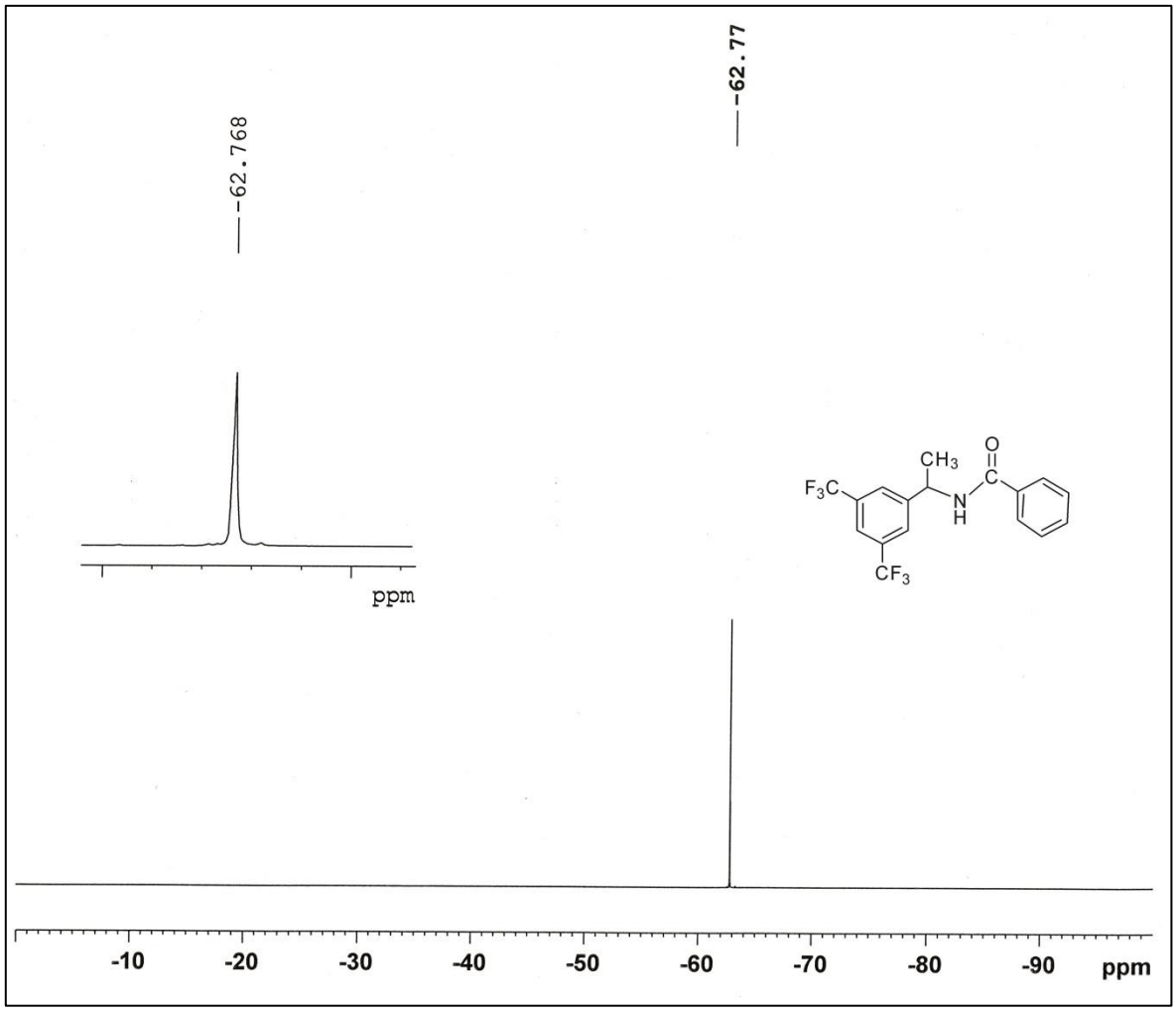
^{19}F-NMR spectra of compound (*S*)-**2** in $CDCl_3$



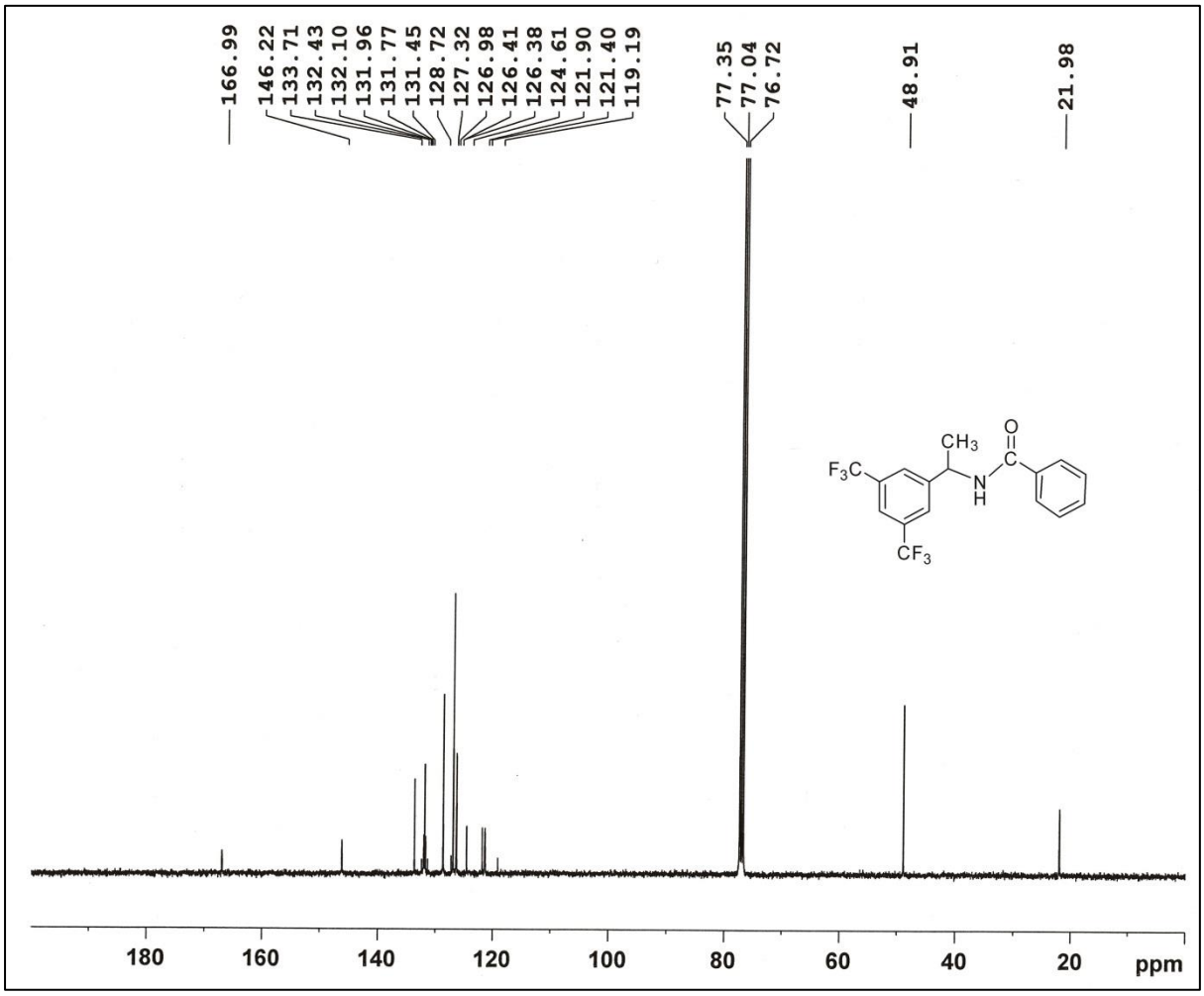
^{13}C-NMR spectra of compound (*S*)-**2** in $CDCl_3$



^{1}H-NMR spectra of compound (*S*)-**7** in $CDCl_3$

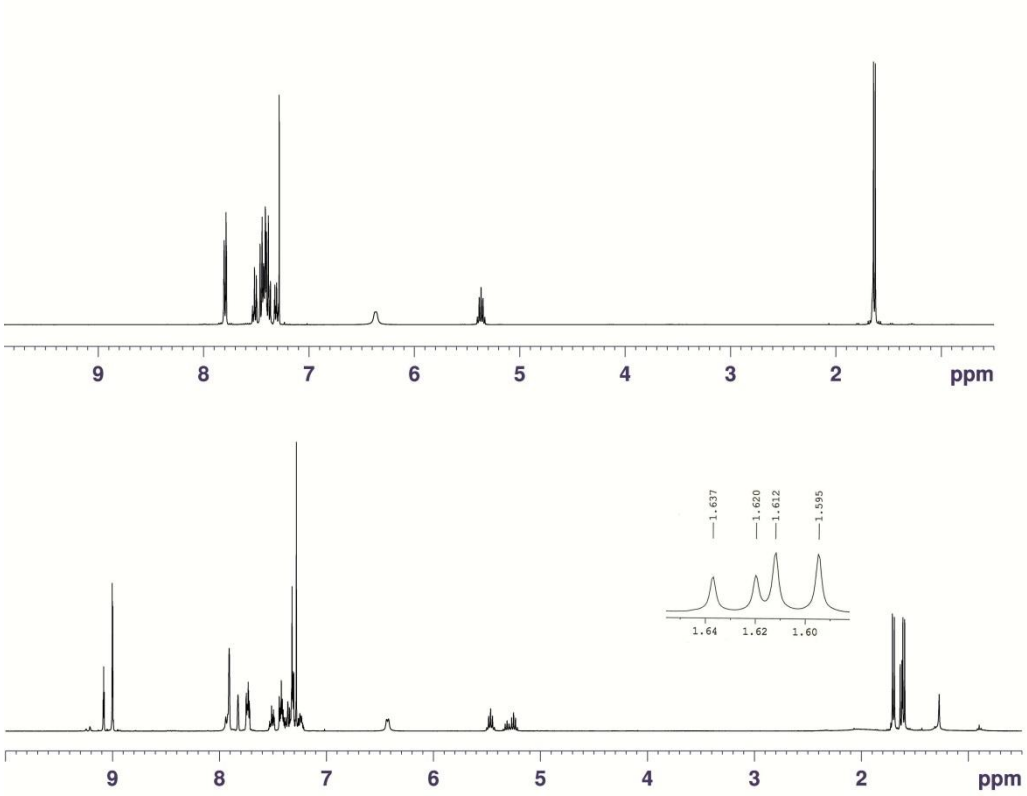


^{19}F-NMR spectra of compound (*S*)-**7** in $CDCl_3$

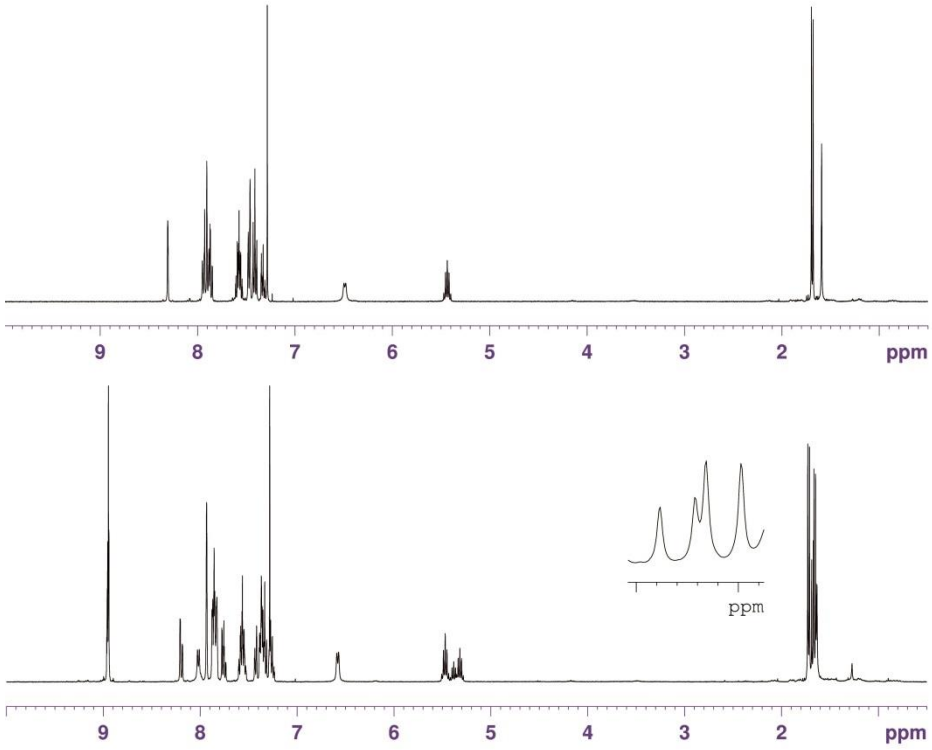


^{13}C-NMR spectra of compound (*S*)-**7** in $CDCl_3$

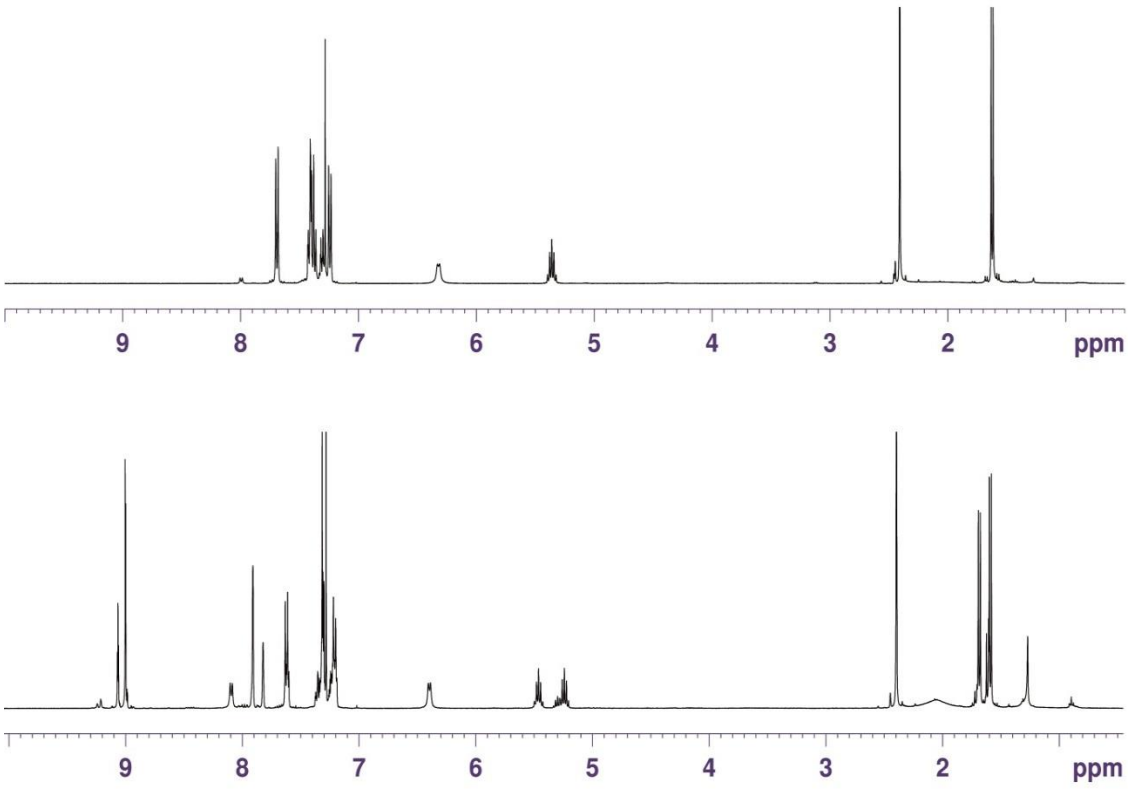
NMR spectra of CSA study



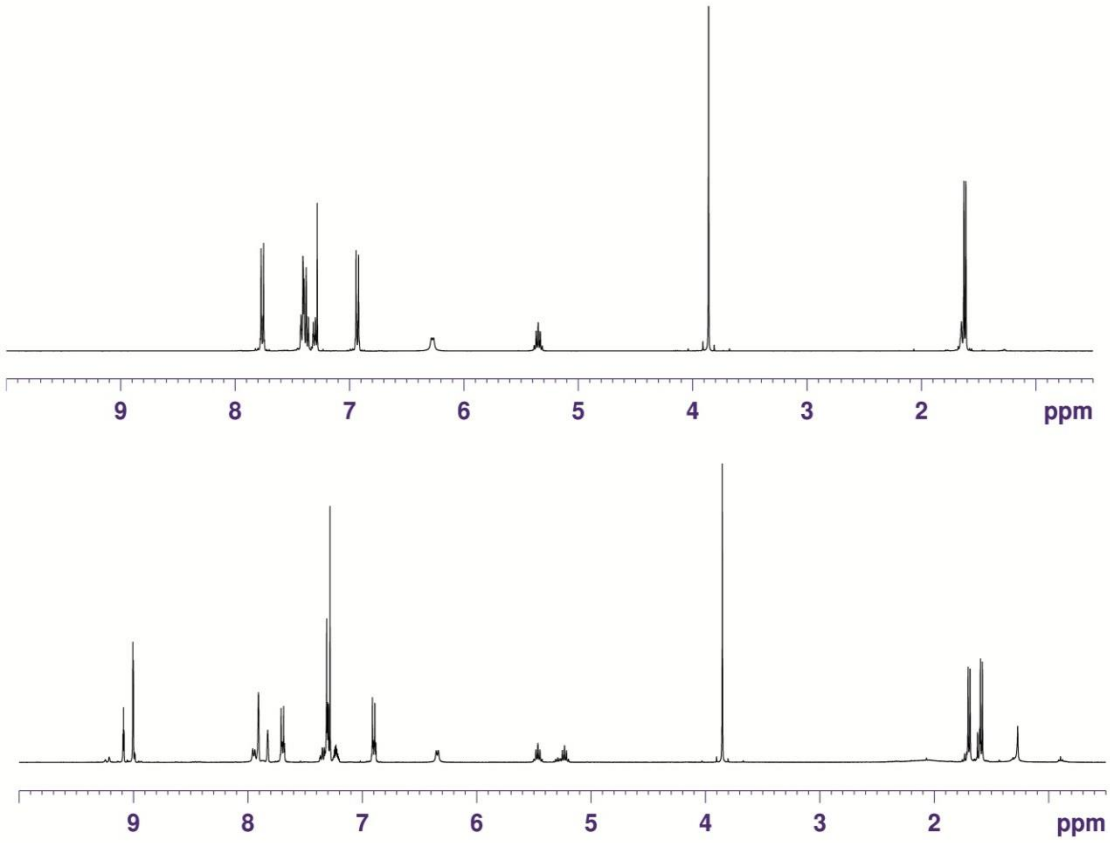
^{1}H-NMR spectra of **8a** (*R*:*S* ratio,1:2)[top], in presence of (*S*)-**2** [bottom] in $CDCl_3$



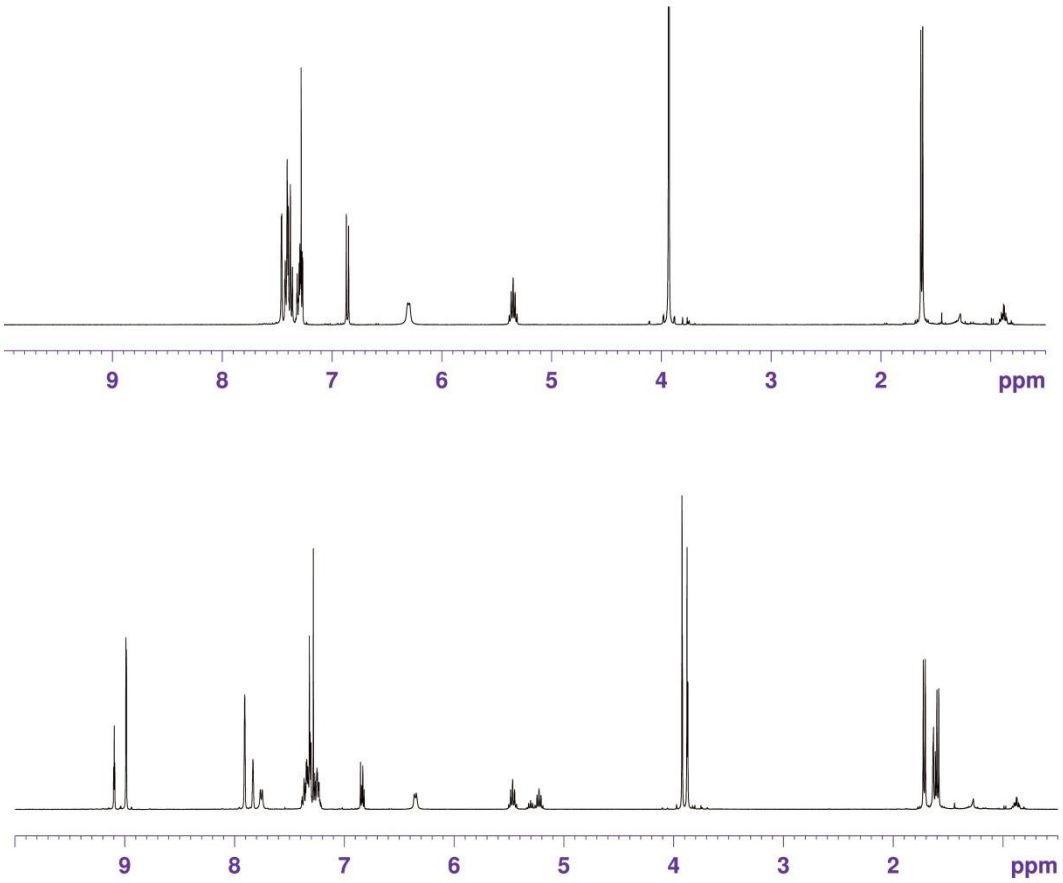
^{1}H-NMR spectra of **8b** (*R*:*S* ratio,1:2) [top], in presence of (*S*)-**2** [bottom] in $CDCl_3$



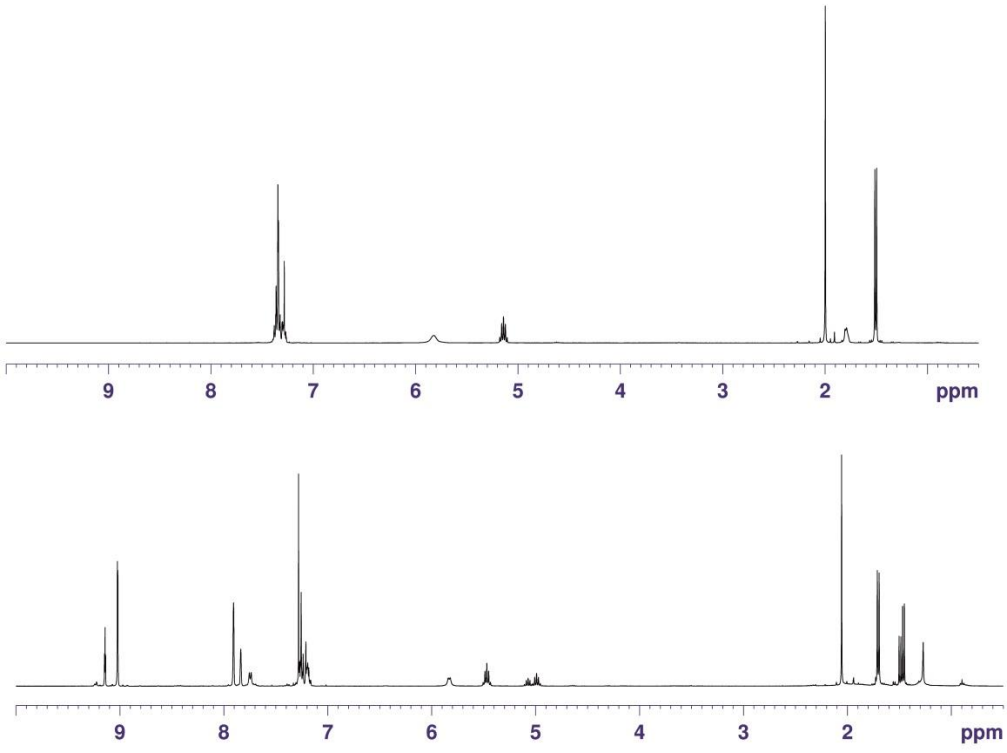
^{1}H-NMR spectra of **8g** (*R*:*S* ratio,1:2) [top], in presence of (*S*)-**2** [bottom] in $CDCl_3$



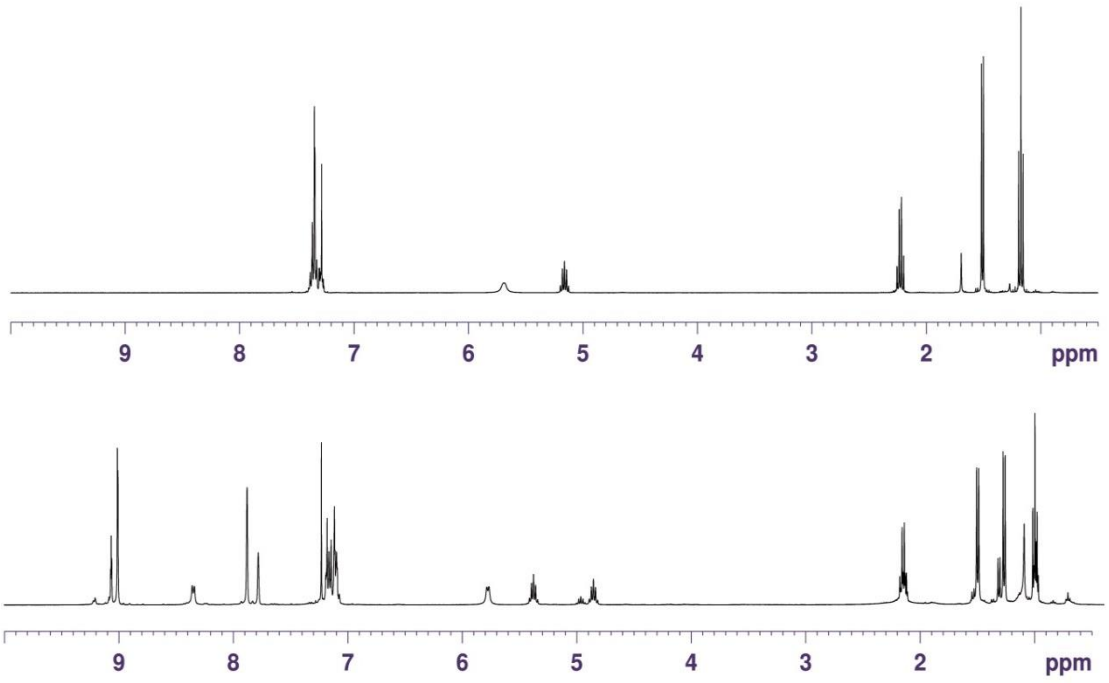
^{1}H-NMR spectra of **8h** (*R*:*S* ratio,1:2) [top], in presence of (*S*)-**2** [bottom] in $CDCl_3$



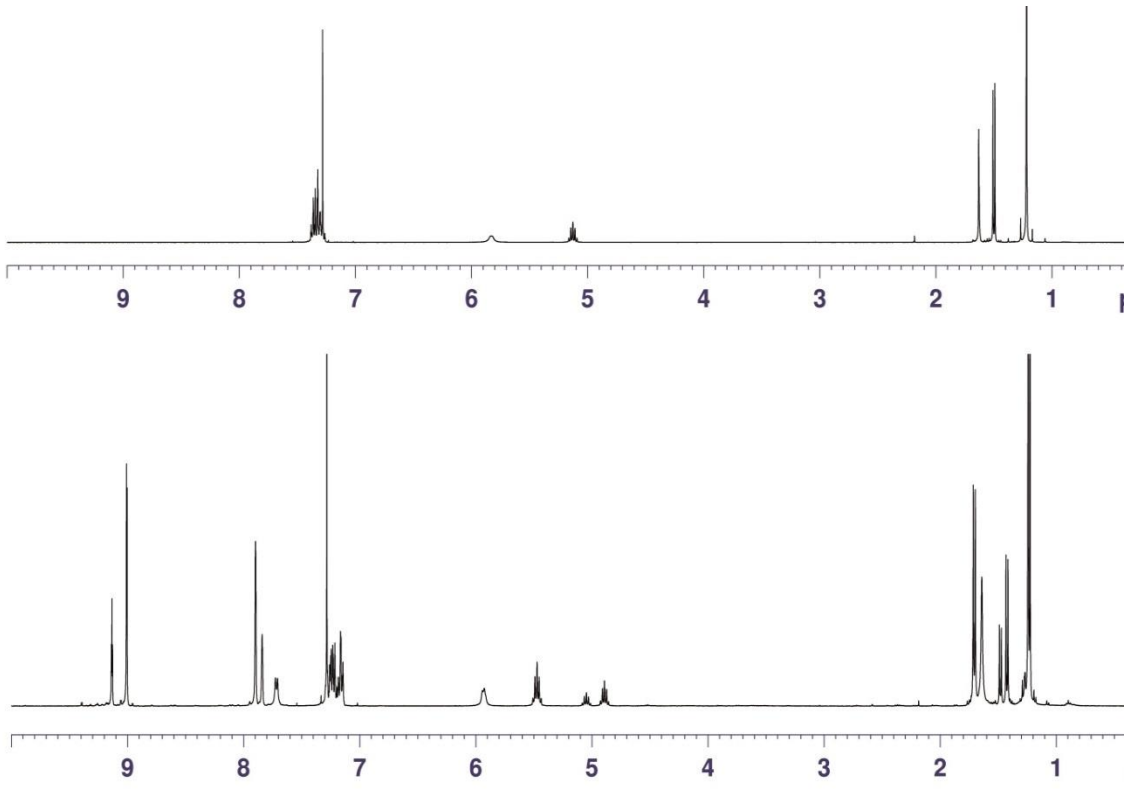
^{1}H-NMR spectra of **8i** (*R*:*S* ratio,1:2) [top], in presence of (*S*)-**2** [bottom] in $CDCl_3$



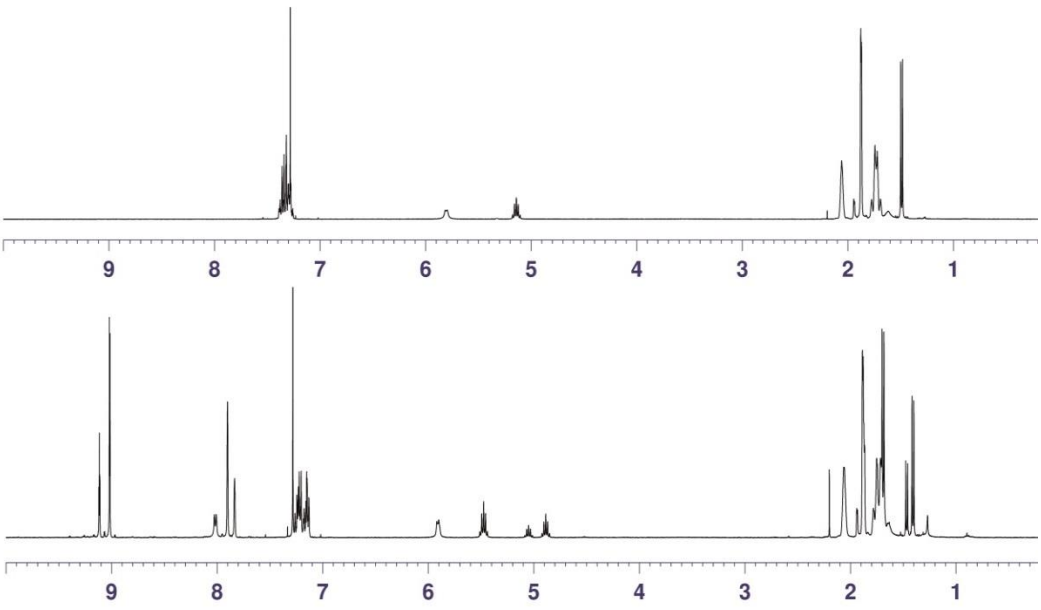
^{1}H-NMR spectra of **8j** (*R*:*S* ratio,1:2) [top], in presence of (*S*)-**2** [bottom] in $CDCl_3$



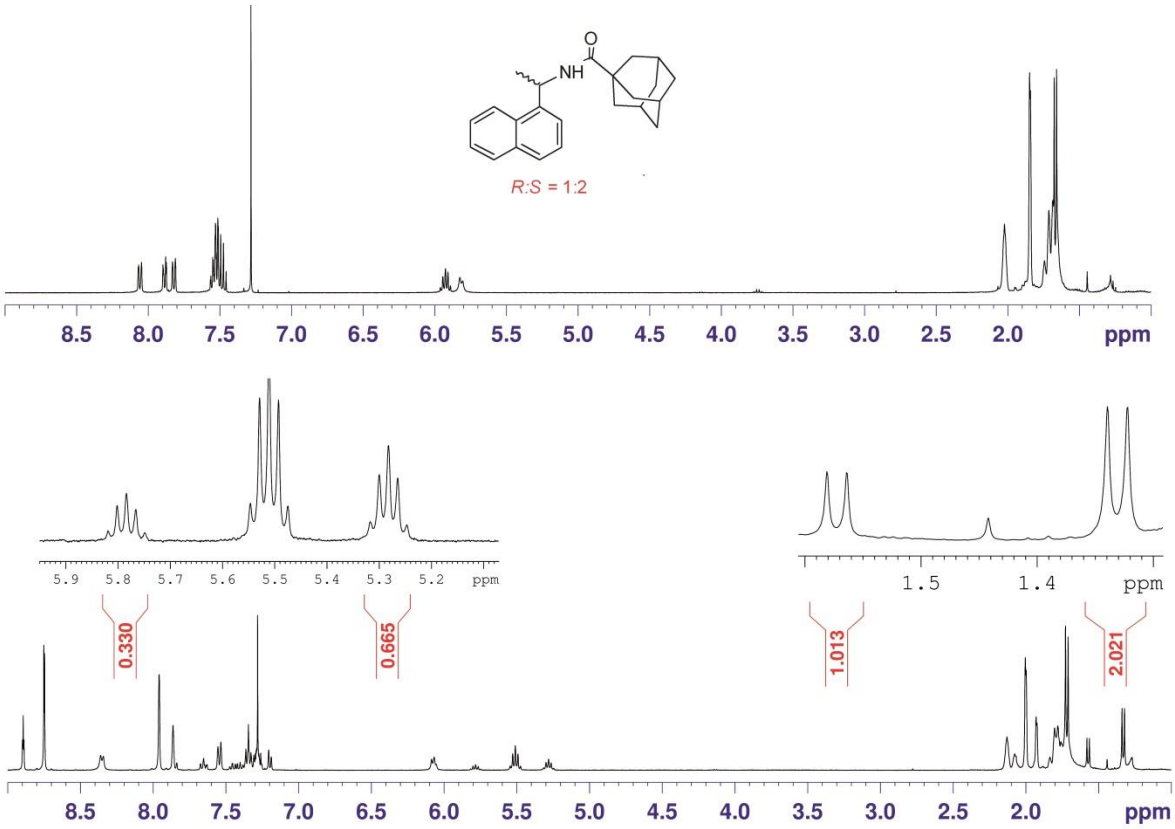
^{1}H-NMR spectra of **8k** (*R*:*S* ratio,1:3) [top], in presence of (*S*)-**2** [bottom] in $CDCl_3$



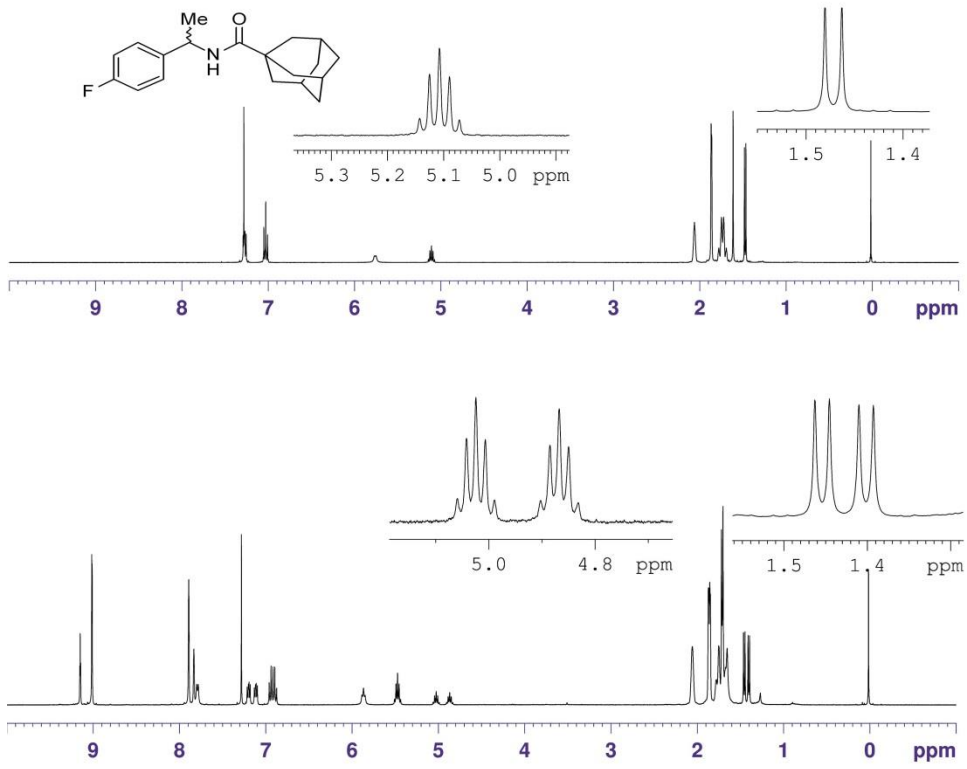
^{1}H-NMR spectra of **8l** (*R*:*S* ratio,1:2) [top], in presence of (*S*)-**2** [bottom] in $CDCl_3$



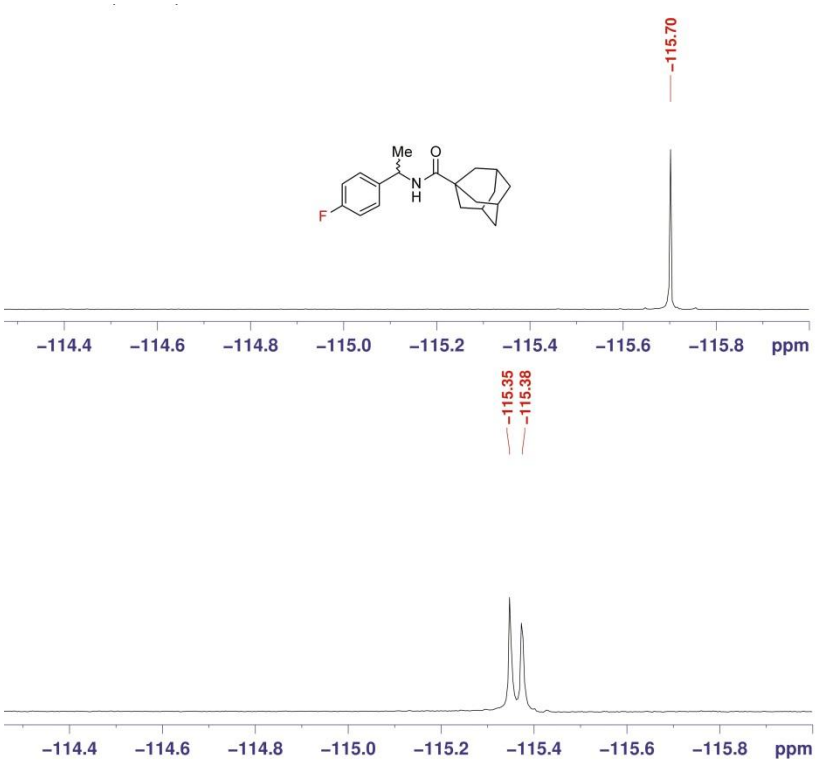
^{1}H-NMR spectra of **8m** (*R*:*S* ratio,1:2) [top], in presence of (*S*)-**2** [bottom] in $CDCl_3$



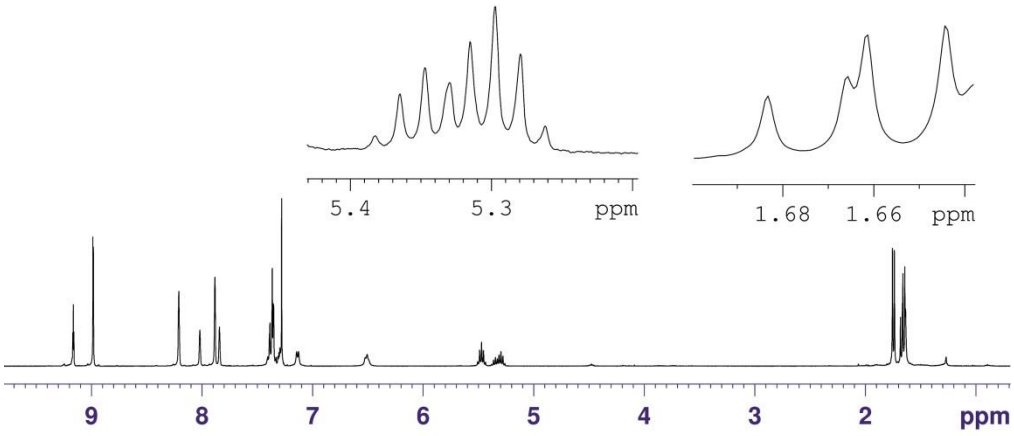
^{1}H-NMR spectra of **8n** (*R*:*S* ratio,1:2) in presence of (*S*)-**2** [bottom] in $CDCl_3$



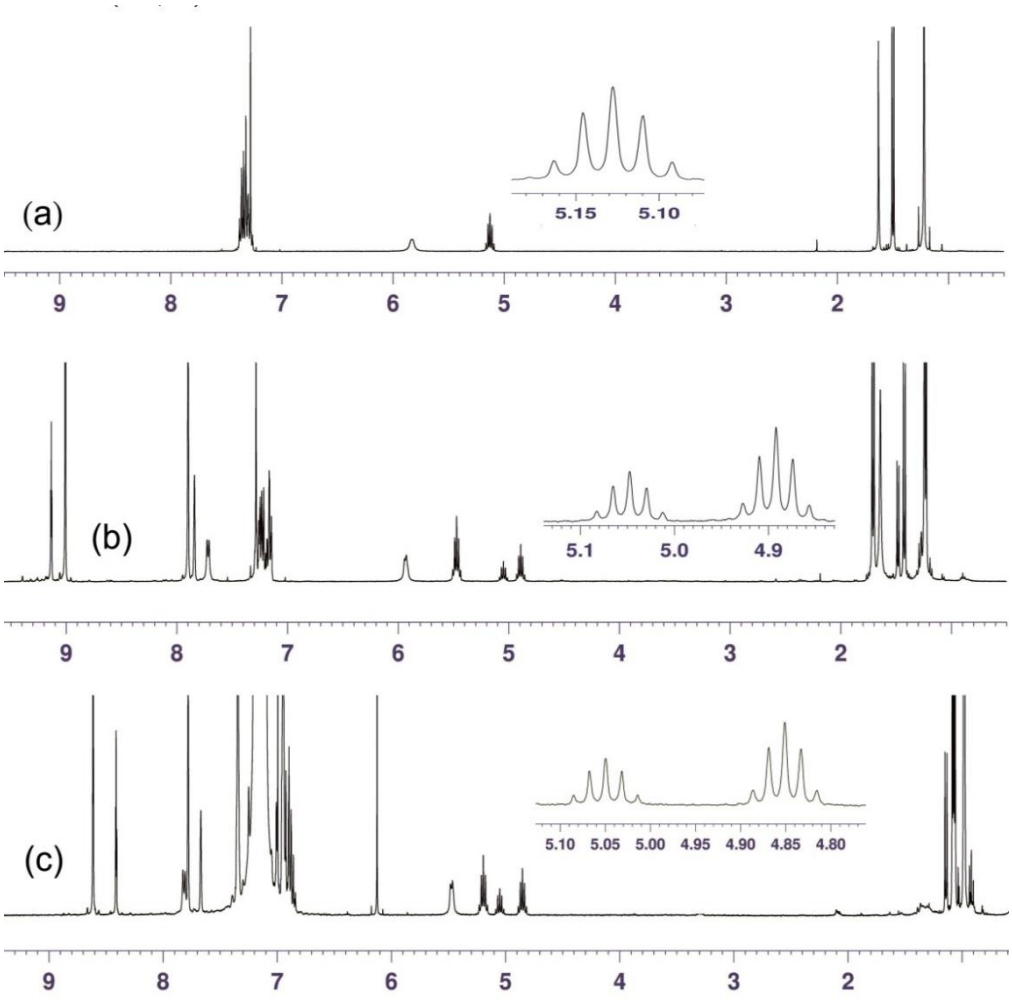
^{1}H-NMR spectra of **8O** [top], in presence of (*S*)-**2** [bottom] in $CDCl_3$



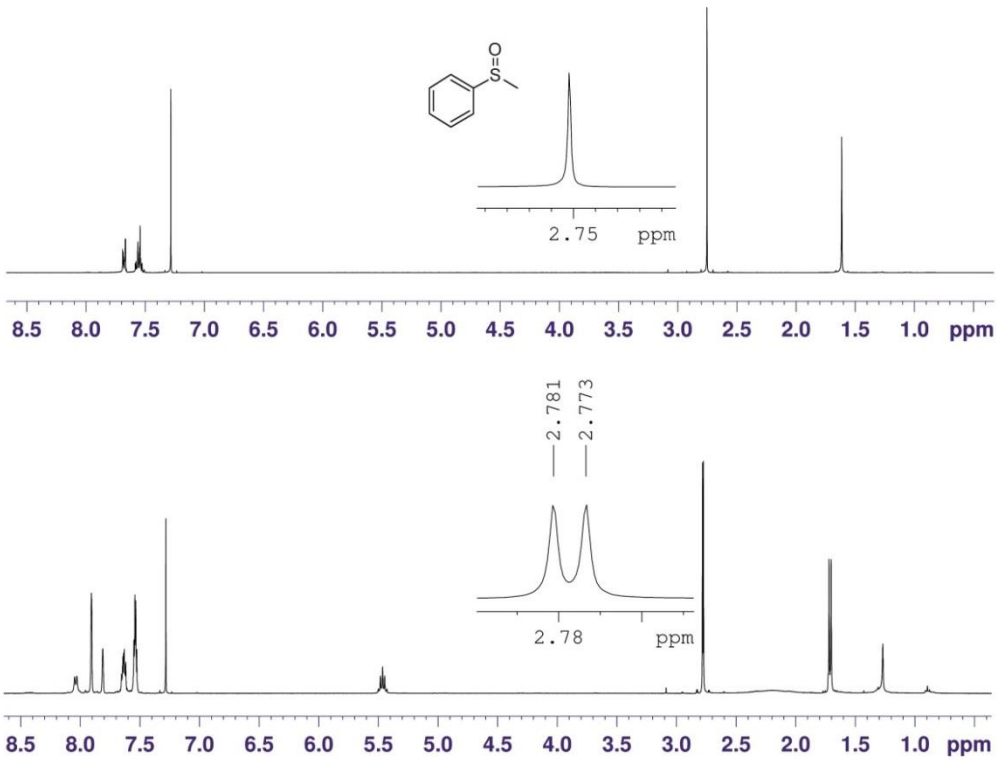
^{19}F-NMR spectra of **8O** [top], in presence of (*S*)-**2** [bottom] in $CDCl_3$



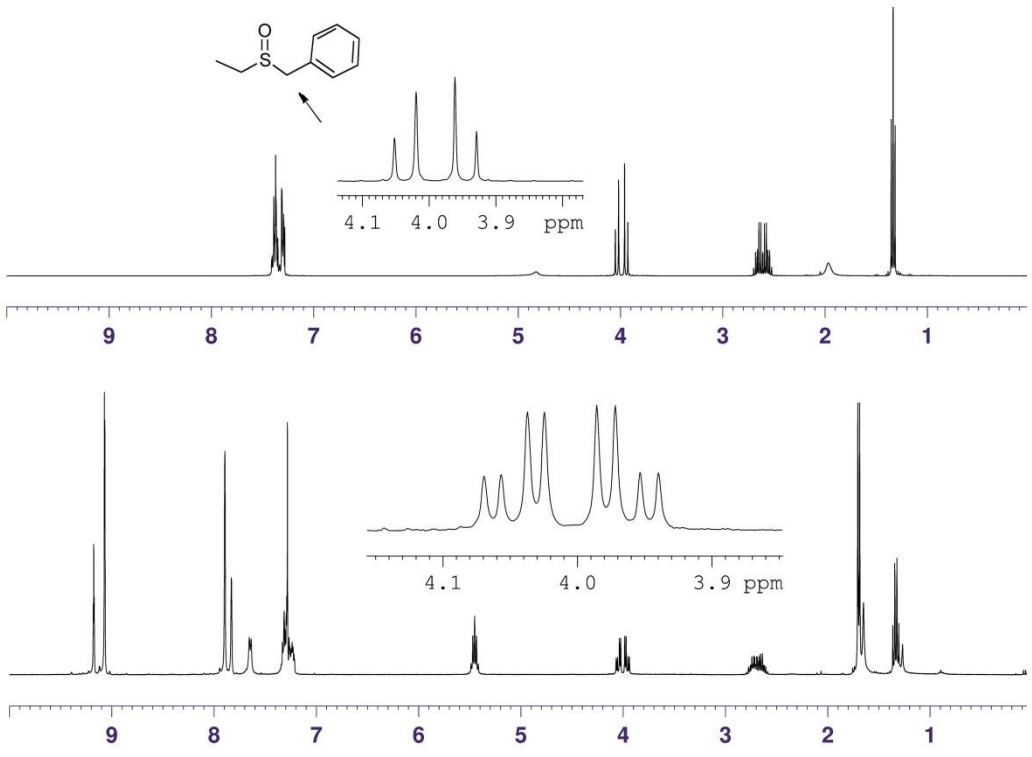
^{1}H-NMR spectra of **8p** (*R*:*S* ratio,1:2) in presence of (*S*)-**2** [bottom] in $CDCl_3$



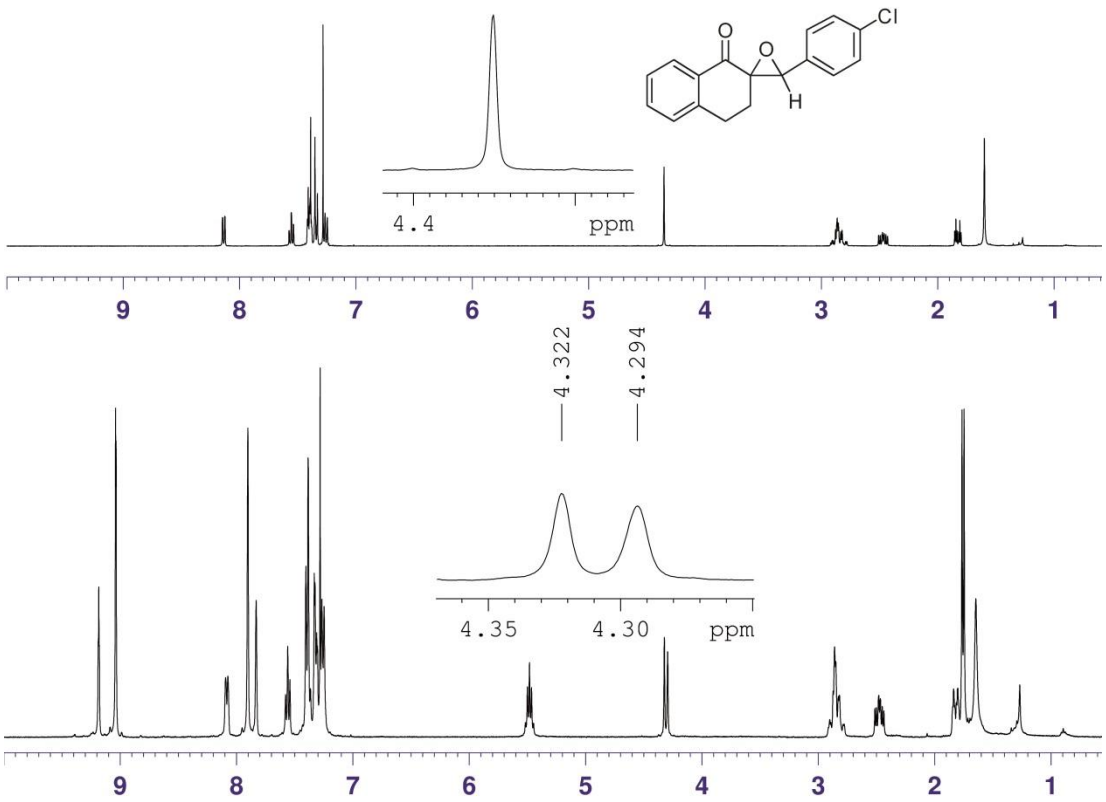
^{1}H-NMR spectra of (a) blank **8l** (b) in presence of (*S*)-**2** in $CDCl_3$ (c) in presence of (*S*)-**2** in C_6D_6



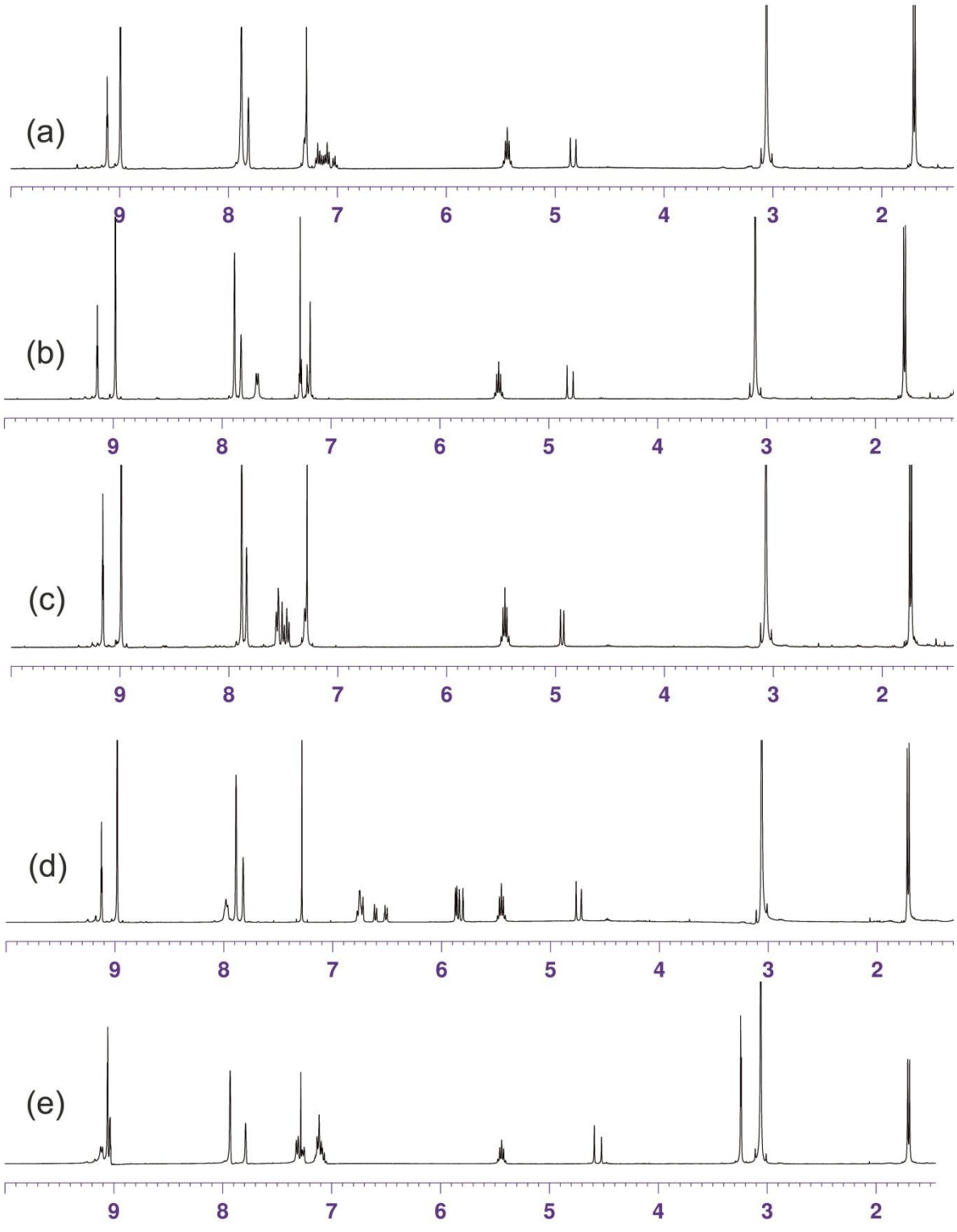
^{1}H-NMR spectra of **9a** [top], in presence of (*S*)-**2** [bottom] in $CDCl_3$



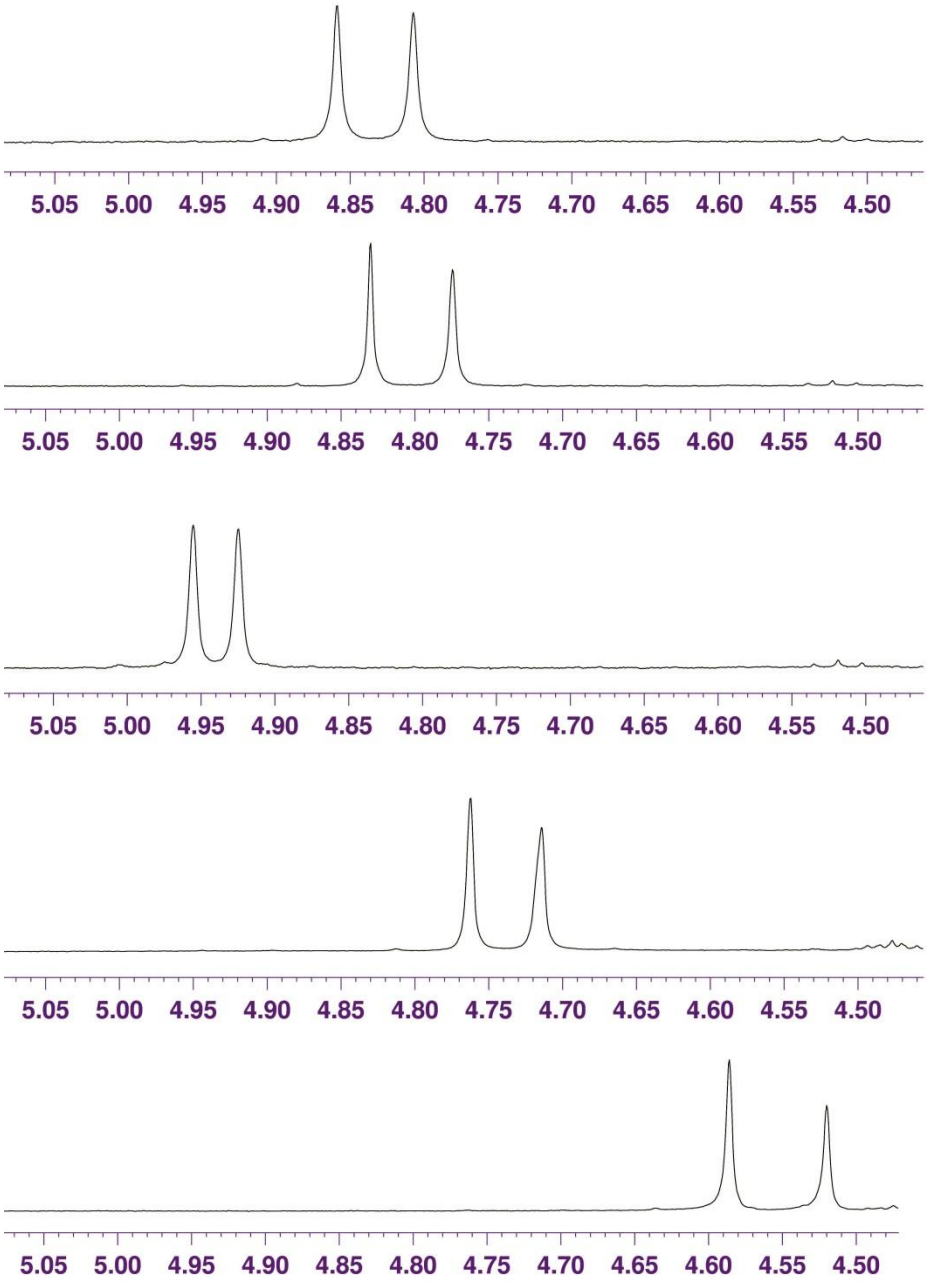
^{1}H-NMR spectra of **9d** [top], in presence of (*S*)-**2** [bottom] in $CDCl_3$



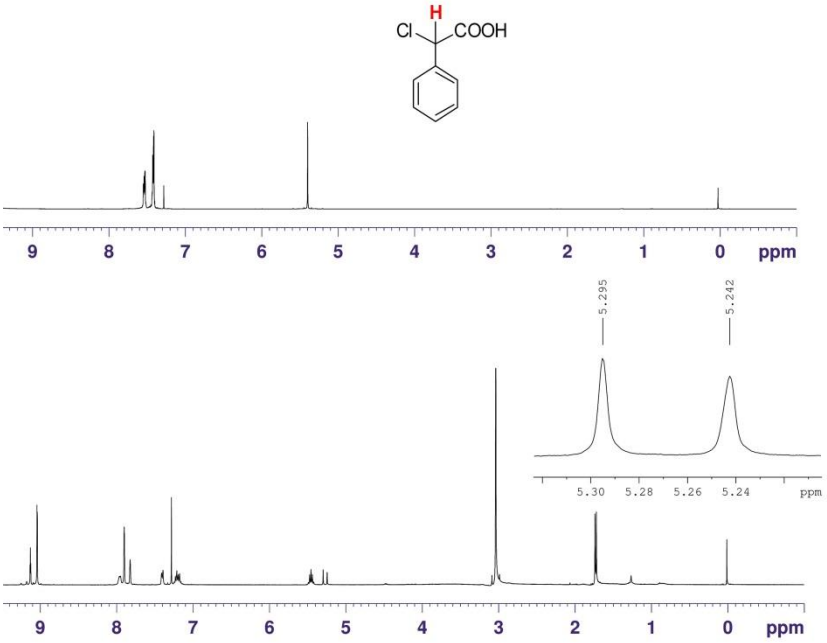
^{1}H-NMR spectra of **10b** [top], in presence of (*S*)-**2** [bottom] in $CDCl_3$



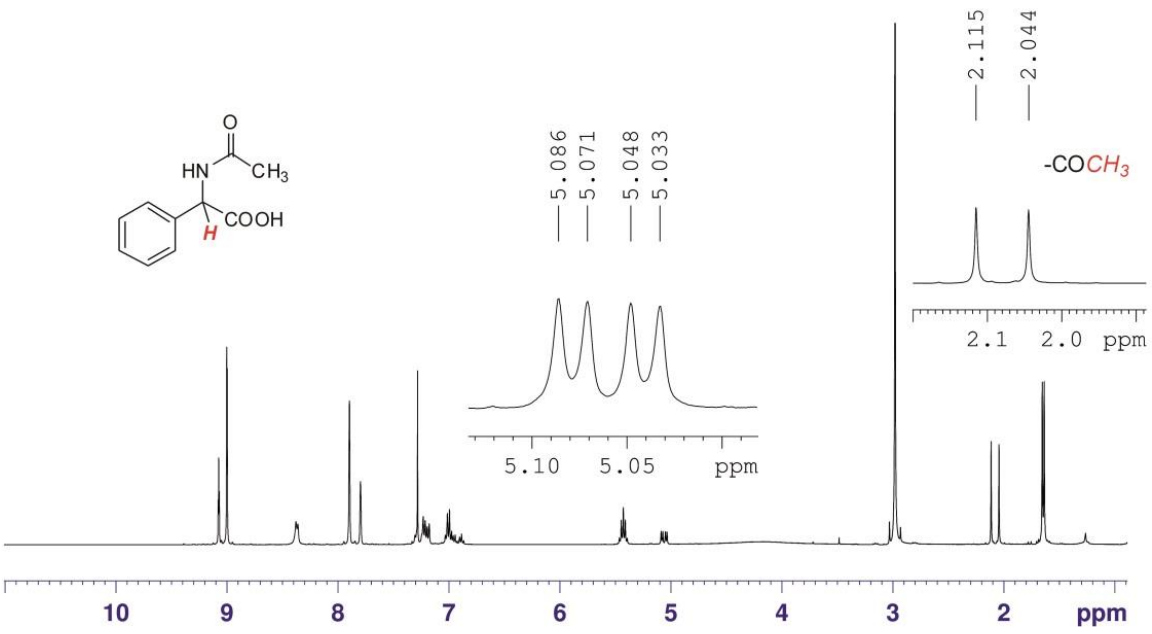
^{1}H-NMR spectra in presence of (*S*)-**2 &** DABCO in $CDCl_3$ **(a)** with **11a** (b) **11b** (c) **11c** (d) **11d** (e) **11e**



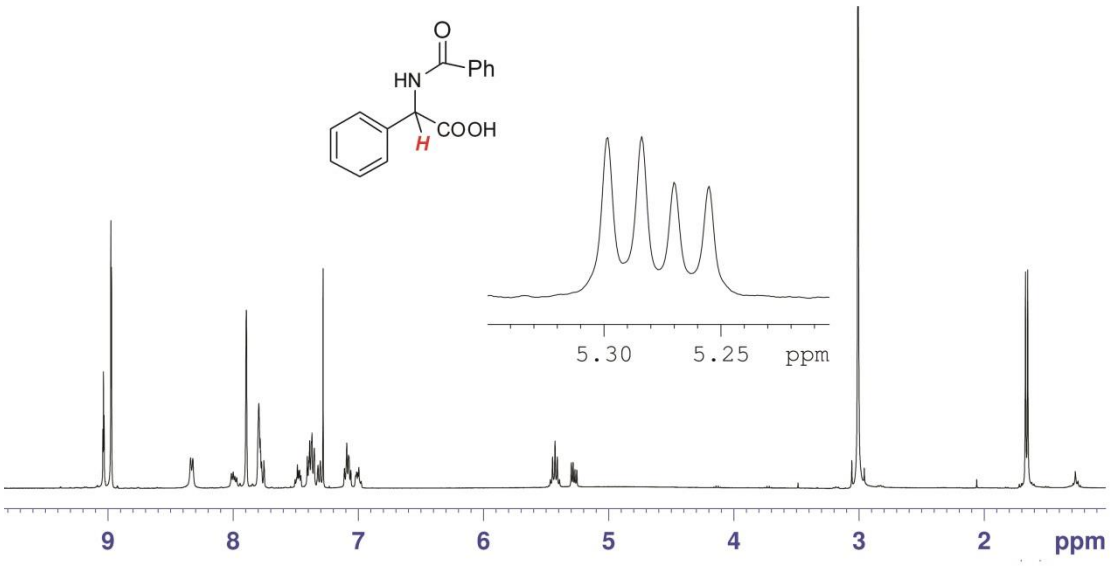
Selected region of ^{1}H-NMR spectra in presence of (*S*)-**2 &** DABCO in $CDCl_3$ **(a)** with **11a** (b) **11b** (c) **11c** (d) **11d** (e) **11e**



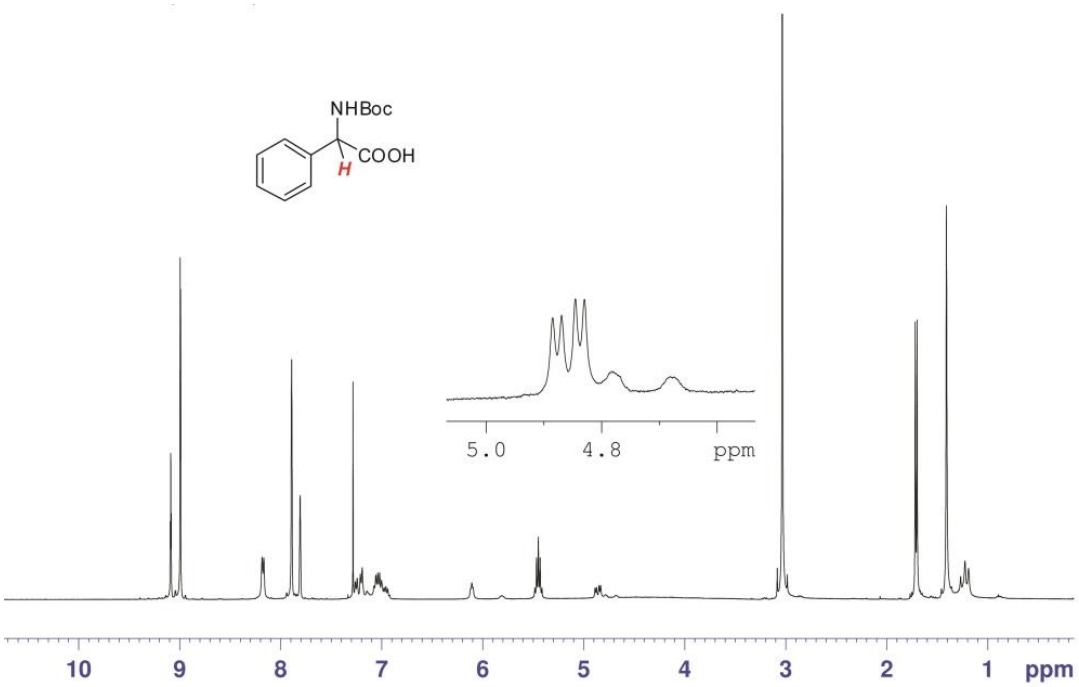
^{1}H-NMR spectra of **11f** [top], in presence of (*S*)-**2** [bottom] in $CDCl_3$



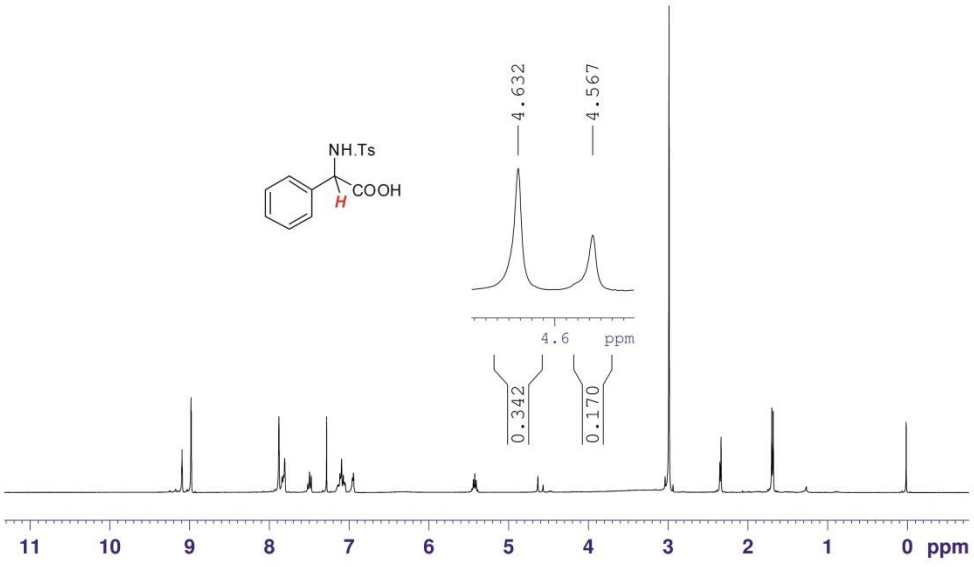
^{1}H-NMR spectra of **12a** in presence of (*S*)-**2** in $CDCl_3$



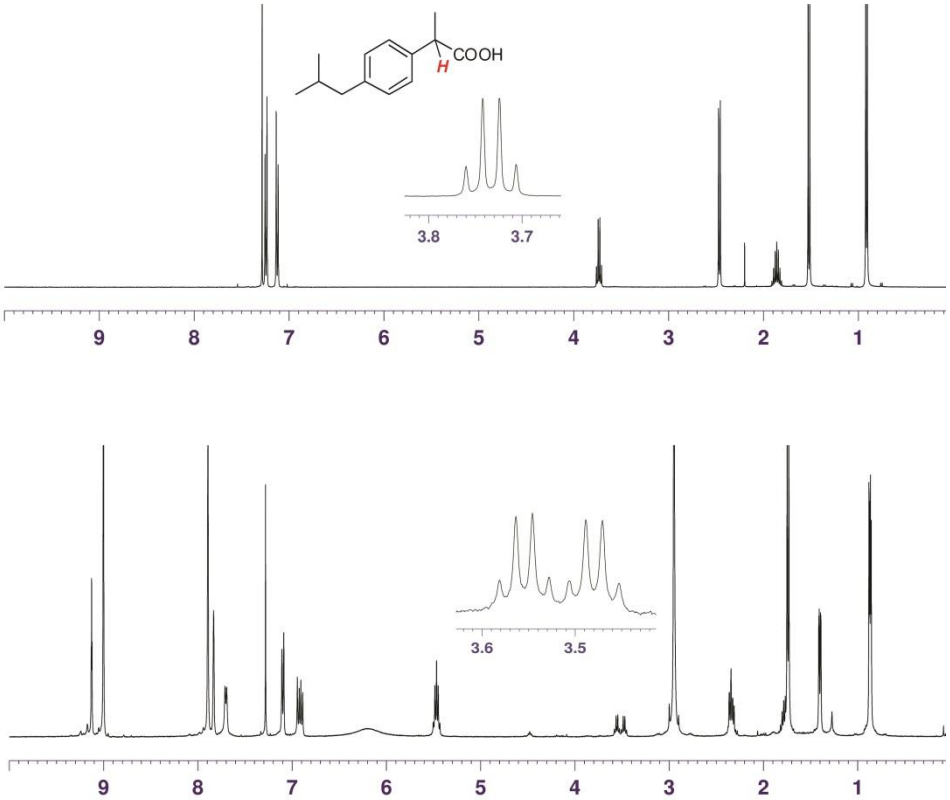
^{1}H-NMR spectra of **12b (**10% excess in D isomer**)** in presence of (*S*)-**2** in $CDCl_3$



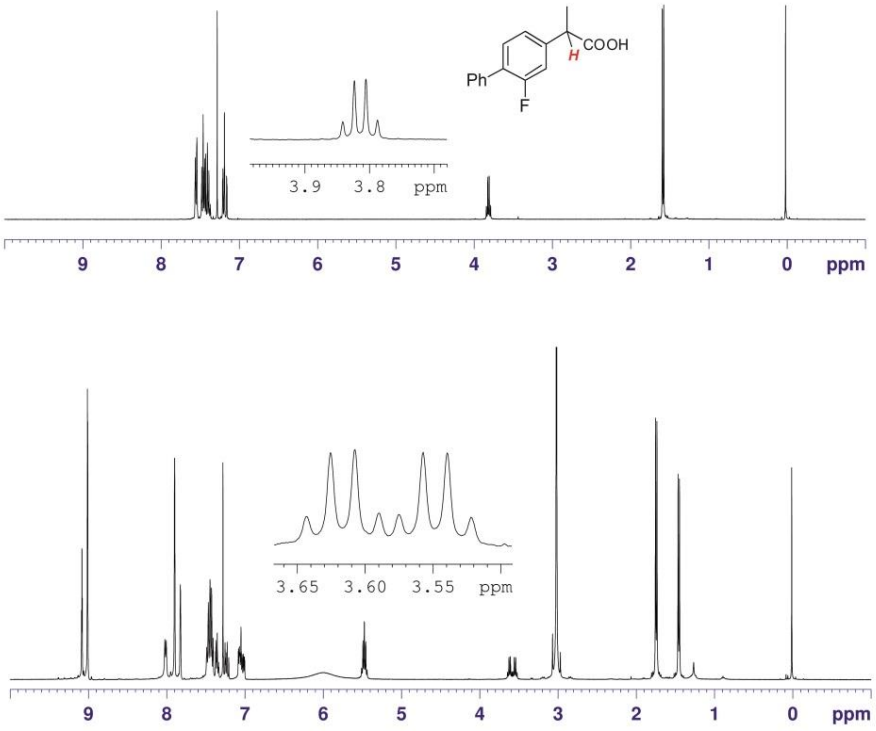
^{1}H-NMR spectra of **12c** in presence of (*S*)-**2** in $CDCl_3$



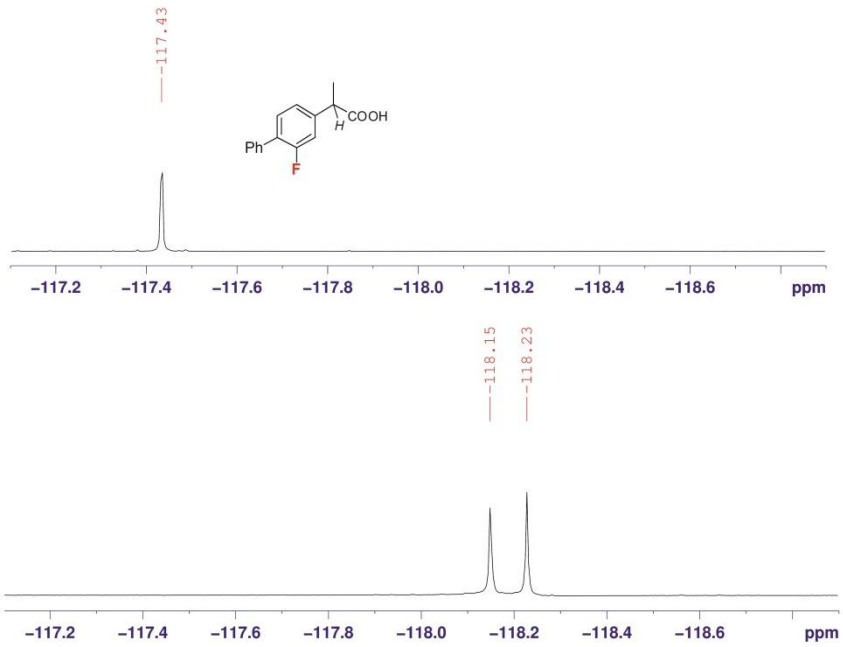
^{1}H-NMR spectra of **12d** [D:L Ratio 2:1**]** in presence of (*S*)-**2** in $CDCl_3$



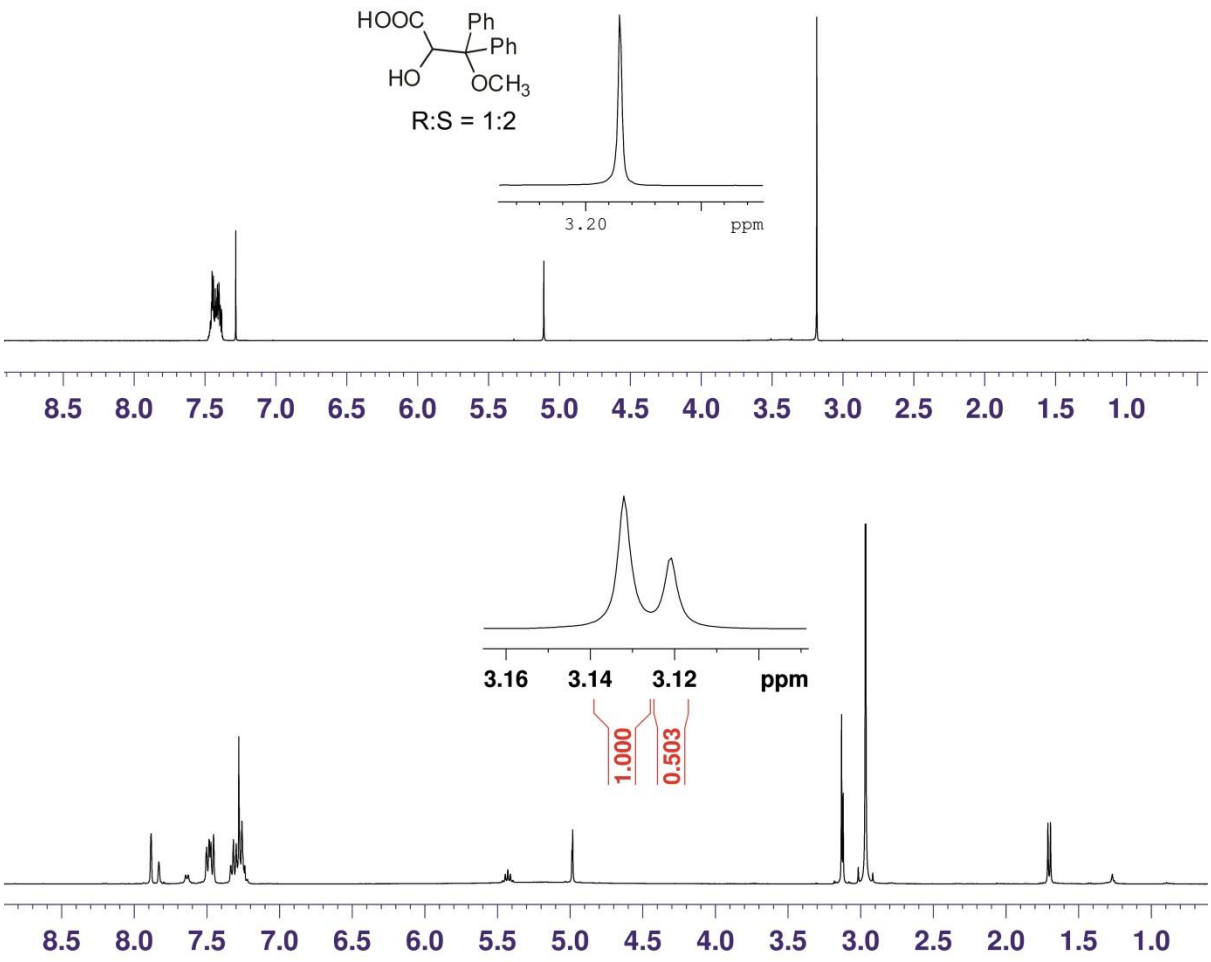
^{1}H-NMR spectra of **13a** [top], in presence of (*S*)-**2** [bottom] in $CDCl_3$



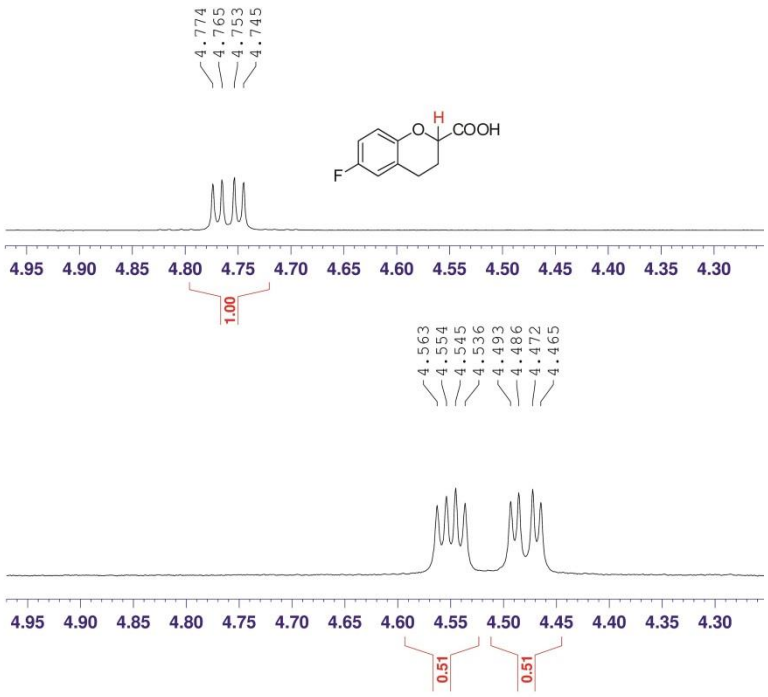
^{1}H-NMR spectra of **13e** [top], in presence of (*S*)-**2** [bottom] in $CDCl_3$



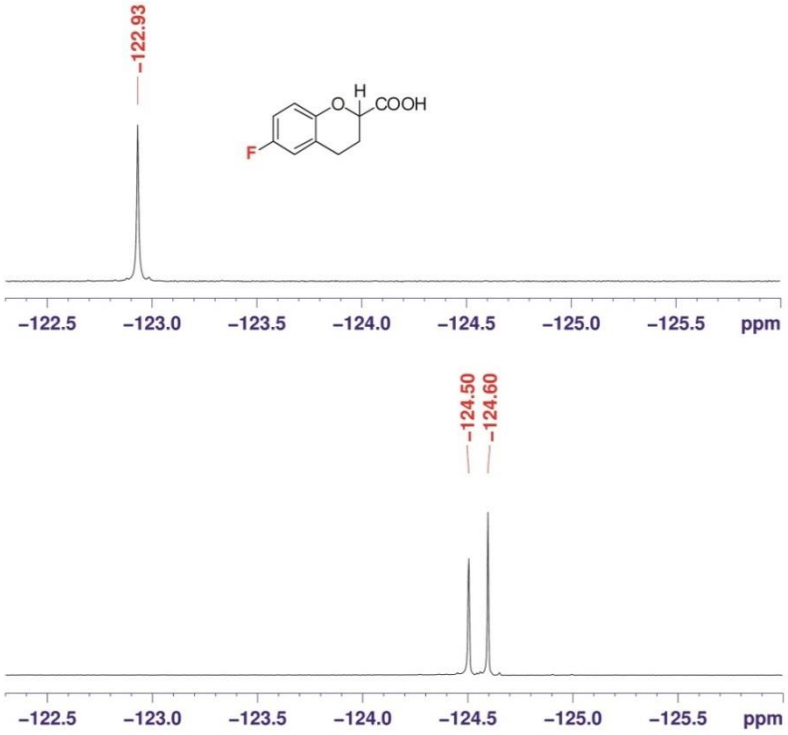
Selected region of ^{19}F-NMR spectra of **13e** [top], in presence of (*S*)-**2** [bottom] in $CDCl_3$



^{1}H-NMR spectra of **13d** (*R*:*S* ratio 1:2) [top], in presence of (*S*)-**2** [bottom] in $CDCl_3$



Selected region of ^{1}H-NMR spectra of **13f** [top], in presence of (*S*)-**2** [bottom] in $CDCl_3$



Selected region of ^{19}F-NMR spectra of **13f** [top], in presence of (*S*)-**2** [bottom] in $CDCl_3$

Crystal data CCDC NO 1042105

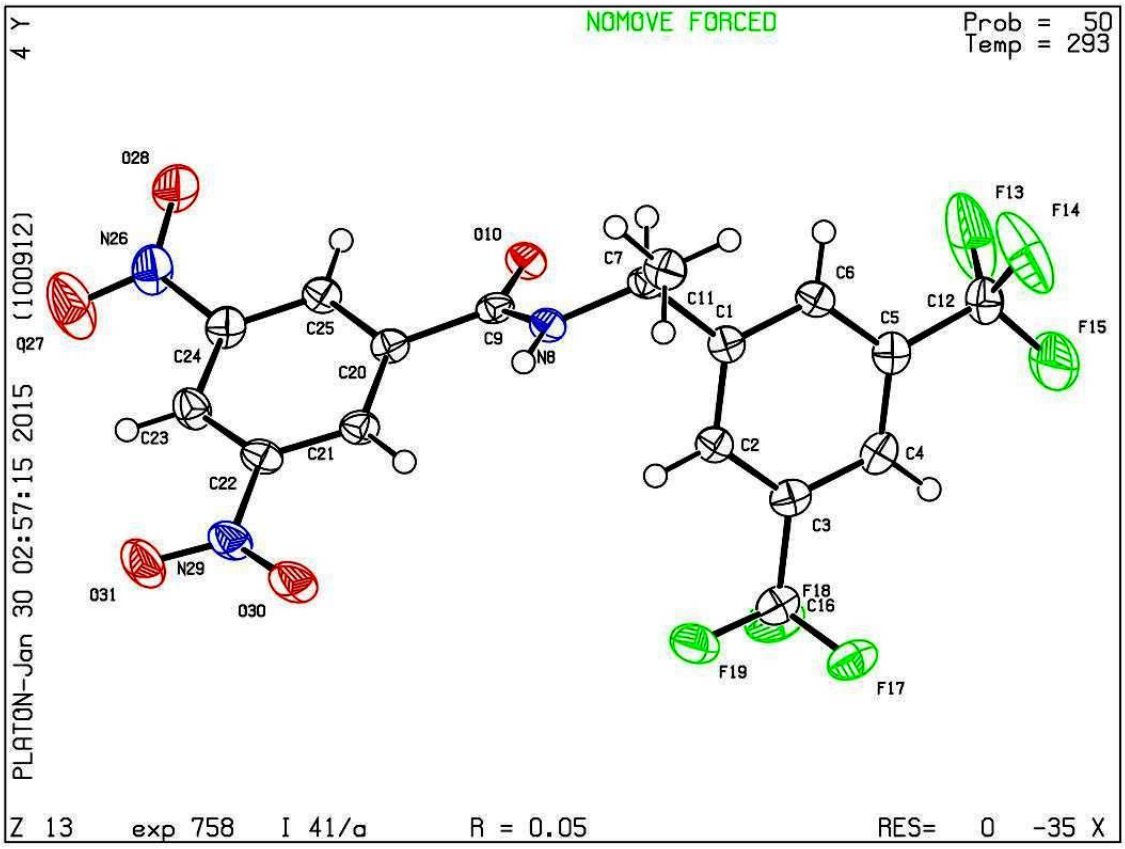


Table 1 Crystal data and structure refinement

Empirical formula	$C_{17}H_{11}F_6N_3O_5$
Formula weight	451.29
Temperature/K	134(8)
Crystal system	Tetragonal
Space group	$I4_1/a$
a/Å	19.6845(3)
b/Å	19.6845(3)
c/Å	19.3124(3)
α/°	90.00
β/°	90.00
γ/°	90.00
Volume/Å^3	7483.13(19)
Z	16
ρ_{calc}mg/mm^3	1.602
μ/mm^{-1}	1.403
F(000)	3648.0
2Θ range for data collection	8.98 to 146.12°
Index ranges	$-24 \leq h \leq 20$, $-23 \leq k \leq 21$, $-23 \leq l \leq 11$
Reflections collected	10978
Independent reflections	3716[R(int) = 0.0292]
Data/restraints/parameters	3716/0/281
Goodness-of-fit on F^2	1.054
Final R indexes [I>=2σ (I)]	R_1 = 0.0555, wR_2 = 0.1460
Final R indexes [all data]	R_1 = 0.0647, wR_2 = 0.1533
Largest diff. peak/hole / e Å^{-3}	0.74/-0.47

Table 2 Fractional Atomic Coordinates ($\times 10^4$) and Equivalent Isotropic Displacement Parameters ($Å^2 \times 10^3$) for exp_758. U_{eq} is defined as 1/3 of of the trace of the orthogonalised U_{IJ} tensor.

Atom	*x*	*y*	*z*	U(eq)
F17	5004.1(8)	3253.5(8)	243.9(9)	39.0(4)
O10	2175.9(9)	4895.6(9)	-1227.8(8)	26.2(4)
F18	4354.4(9)	2878.2(8)	-562.3(9)	44.9(4)
F19	3926.6(9)	3201.4(8)	405.4(10)	47.7(5)
O28	-316.7(10)	4662.9(12)	-1469.6(10)	42.8(5)
N8	2499.5(10)	5159.6(10)	-139.3(10)	22.6(4)
O31	175.7(11)	3557.9(12)	1475.1(10)	45.5(5)
F13	5088.0(12)	5259.2(18)	-2191.3(10)	97.8(11)
C20	1434.5(12)	4566.9(12)	-320.9(11)	22.4(5)
O30	1234.4(11)	3798.3(11)	1637.8(9)	40.7(5)
N29	723.7(12)	3772.8(12)	1276.9(11)	32.5(5)
C2	3768.7(12)	4445.8(12)	-210.2(12)	23.7(5)
C21	1384.2(12)	4300.1(12)	345.0(12)	24.9(5)
C7	3099.1(12)	5544.9(12)	-354.2(12)	23.0(5)
C22	773.7(13)	4025.6(13)	559.3(12)	26.9(5)
C5	4785.7(12)	4932.6(13)	-1075.0(12)	26.3(5)
C25	871.1(12)	4556.6(12)	-754.8(11)	24.4(5)
N26	-332.1(12)	4301.3(14)	-962.2(11)	38.4(6)
C23	204.5(13)	3998.7(14)	142.3(13)	29.5(5)
C16	4404.3(13)	3350.2(13)	-62.7(14)	31.1(5)
C6	4215.8(12)	5329.3(12)	-935.1(11)	24.0(5)
C4	4846.3(12)	4287.1(13)	-788.7(13)	27.1(5)
F14	5546.8(13)	5792.3(12)	-1384.4(12)	77.9(8)
F15	5853.5(12)	4807.3(14)	-1604.8(16)	95.5(10)
C24	276.2(13)	4277.5(14)	-513.7(12)	28.5(5)
C1	3705.8(12)	5088.6(12)	-502.9(11)	22.0(5)
C11	3264.3(13)	6069.6(13)	196.5(13)	30.2(5)
C9	2077.8(12)	4884.6(12)	-597.9(11)	22.2(5)
C12	5311.8(13)	5197.9(14)	-1567.7(13)	31.0(6)
C3	4336.0(13)	4052.5(12)	-355.9(12)	26.0(5)
O27	-823.7(13)	3978.3(18)	-782.9(14)	79.6(10)

Table 3 Anisotropic Displacement Parameters ($Å^2×10^3$) for exp_758. The Anisotropic displacement factor exponent takes the form: $-2\pi^2[h^2a^{*2}U_{11}+...+2hka×b×U_{12}]$

Atom	U_{11}	U_{22}	U_{33}	U_{23}	U_{13}	U_{12}
F17	40.4(9)	33.2(8)	43.4(9)	1.3(7)	-15.0(7)	5.6(6)
O10	32.4(9)	33.1(9)	13.0(8)	2.5(6)	1.9(6)	0.6(7)
F18	58.8(11)	28.1(8)	47.8(10)	-9.9(7)	-18.8(8)	6.8(7)
F19	50(1)	34.2(9)	59.0(11)	16.0(8)	13.3(9)	5.6(7)
O28	37.1(11)	67.0(14)	24.4(9)	9.4(9)	-8.4(8)	0.1(10)
N8	25.7(10)	29(1)	13.0(9)	3.2(7)	1.7(7)	1.2(8)
O31	42.7(12)	63.8(14)	30(1)	15.7(10)	3.7(9)	-13.3(10)
F13	62.6(14)	208(3)	23.3(10)	17.7(14)	-2.6(9)	-61.5(17)
C20	27.1(12)	25.6(11)	14.5(10)	-0.9(9)	-0.1(9)	2.7(9)
O30	45.8(12)	52.1(12)	24.3(9)	15.6(8)	-9.2(8)	-11.3(9)
N29	38.7(12)	37.9(12)	21(1)	7.5(9)	-1.4(9)	-5.5(9)
C2	26.4(11)	25.9(11)	18.8(10)	-1.1(9)	-1.3(9)	-0.5(9)
C21	28.4(12)	27.1(12)	19.3(11)	2.5(9)	-4.8(9)	0.0(9)
C7	26.9(12)	23.8(11)	18.4(10)	3.9(9)	1.5(9)	2.1(9)
C22	34.3(13)	29.9(12)	16.5(11)	3.9(9)	-0.7(9)	-1.1(10)
C5	26.9(12)	33.4(13)	18.4(11)	-5.7(10)	-1.9(9)	-2.2(10)
C25	28.9(12)	31.2(12)	13.1(10)	0.8(9)	-0.3(9)	1.2(9)
N26	30.4(12)	61.4(16)	23.4(11)	2.7(11)	-5.1(9)	-6.3(11)
C23	30.0(13)	36.6(14)	21.9(12)	1.8(10)	1.4(10)	-5.5(10)
C16	32.1(13)	29.0(13)	32.2(13)	-1.9(10)	-5.2(11)	4(1)
C6	29.3(12)	25.7(12)	17(1)	-1.1(9)	-1.5(9)	-1.5(9)
C4	24.8(12)	31.2(12)	25.2(11)	-7.2(10)	-1.9(9)	3.8(9)
F14	91.9(17)	70.5(14)	71.2(14)	-28.6(12)	49.5(13)	-45.0(13)
F15	60.4(14)	89.5(18)	137(2)	48.1(17)	63.2(16)	30.5(13)
C24	28.8(13)	38.5(14)	18.3(11)	-1.6(10)	-3.8(9)	-1.3(10)
C1	25.8(11)	26.2(11)	14.1(10)	-3.3(8)	-1.5(9)	-1.4(9)
C11	35.1(14)	29.7(13)	25.9(12)	-3.3(10)	4.2(10)	1.7(10)
C9	26.5(11)	24.5(11)	15.6(10)	2.5(8)	0.1(9)	5.9(9)
C12	28.2(13)	42.4(15)	22.5(12)	-5(1)	2.7(10)	-2.8(11)
C3	30.4(12)	25.5(12)	22.2(11)	-3.6(9)	-5.5(9)	0.8(9)
O27	49.6(15)	136(3)	52.9(15)	39.4(16)	-22.7(12)	-48.3(16)

Table 4 Bond Lengths for exp_758.

Atom	Atom	Length/Å	Atom	Atom	Length/Å
F17	C16	1.335(3)	C21	C22	1.381(4)
O10	C9	1.232(3)	C7	C1	1.522(3)
F18	C16	1.343(3)	C7	C11	1.518(3)
F19	C16	1.337(3)	C22	C23	1.381(4)
O28	N26	1.212(3)	C5	C6	1.393(3)

N8	C7	1.463(3)	C5	C4	1.391(4)
N8	C9	1.329(3)	C5	C12	1.500(3)
O31	N29	1.220(3)	C25	C24	1.375(3)
F13	C12	1.288(3)	N26	C24	1.479(3)
C20	C21	1.393(3)	N26	O27	1.209(3)
C20	C25	1.390(3)	C23	C24	1.388(3)
C20	C9	1.510(3)	C16	C3	1.500(3)
O30	N29	1.224(3)	C6	C1	1.389(3)
N29	C22	1.476(3)	C4	C3	1.386(4)
C2	C1	1.391(3)	F14	C12	1.307(3)
C2	C3	1.388(3)	F15	C12	1.317(3)

Table 5 Bond Angles

Atom	Atom	Atom	Angle/°	Atom	Atom	Atom	Angle/°
C9	N8	C7	121.74(19)	F17	C16	C3	112.2(2)
C21	C20	C9	122.9(2)	F18	C16	C3	111.1(2)
C25	C20	C21	119.6(2)	F19	C16	F18	106.4(2)
C25	C20	C9	117.5(2)	F19	C16	C3	113.2(2)
O31	N29	O30	124.2(2)	C1	C6	C5	120.5(2)
O31	N29	C22	118.1(2)	C3	C4	C5	118.8(2)
O30	N29	C22	117.8(2)	C25	C24	N26	118.6(2)
C3	C2	C1	119.8(2)	C25	C24	C23	123.6(2)
C22	C21	C20	119.1(2)	C23	C24	N26	117.7(2)
N8	C7	C1	112.38(19)	C2	C1	C7	122.0(2)
N8	C7	C11	109.08(19)	C6	C1	C2	119.3(2)
C11	C7	C1	111.46(19)	C6	C1	C7	118.6(2)
C21	C22	N29	118.1(2)	O10	C9	N8	123.6(2)
C23	C22	N29	118.7(2)	O10	C9	C20	119.3(2)
C23	C22	C21	123.1(2)	N8	C9	C20	117.15(19)
C6	C5	C12	118.9(2)	F13	C12	C5	112.9(2)
C4	C5	C6	120.3(2)	F13	C12	F14	106.9(3)
C4	C5	C12	120.7(2)	F13	C12	F15	106.3(3)
C24	C25	C20	118.8(2)	F14	C12	C5	112.6(2)
O28	N26	C24	118.2(2)	F14	C12	F15	104.5(3)
O27	N26	O28	124.1(2)	F15	C12	C5	113.0(2)
O27	N26	C24	117.6(2)	C2	C3	C16	120.6(2)

C22	C23	C24	115.8(2)	C4	C3	C2	121.3(2)
F17	C16	F18	106.5(2)	C4	C3	C16	118.0(2)
F17	C16	F19	106.9(2)				

Table 6 Hydrogen Atom Coordinates (Å×10^4) and Isotropic Displacement Parameters (Å^2×10^3)

Atom	*x*	*y*	*Z*	U(eq)
H8	2418	5110	295	27
H2	3432	4280	82	28
H21	1757	4307	641	30
H7	2986	5788	-782	28
H25	896	4735	-1200	29
H23	-201	3806	292	35
H6	4177	5758	-1133	29
H4	5222	4018	-886	32
H11A	2881	6365	260	45
H11B	3651	6332	53	45
H11C	3366	5844	625	45

Experimental

Single crystals of C17H11F6N3O5 were grown in Toluene. A suitable crystal was selected and on a Xcalibur, Eos, Gemini diffractometer. The crystal was kept at 134(8) K during data collection. Using Olex2 [1], the structure was solved with the ShelXS [2] structure solution program using Direct Methods and refined with the ShelXL [3] refinement package using Least Squares minimisation.

Crystal structure determination

Crystal Data for C17H11F6N3O5 (*M* =451.29): tetragonal, space group I41/a (no. 88), *a* = 19.6845(3) Å, *c* = 19.3124(3) Å, *V* =

7483.13(19) Å3, *Z* = 16, *T* = 134(8) K, μ(Cu Kα) = 1.403 mm-1, *Dcalc* = 1.602 g/mm3, 10978 reflections measured (8.98 ≤ 2Θ ≤ 146.12), 3716

Unique (*R*int = 0.0292) which were used in all calculations. The final *R*1 was 0.0555 (>2sigma(I)) and *wR*2 was 0.1533 (all data).