Supporting Information

Facile one-pot synthesis of sulfonyl fluorides from sulfonates or sulfonic acids

Ying Jiang[a] Njud S. Alharbi[b] Bing Sun,[a]* and Hua-Li Qin,[a]*

[a]School of Chemistry, Chemical Engineering and Life Science, Wuhan University of Technology, Wuhan, Hubei Province 430070, People's Republic of China

[b]Biotechnology Research group, Deportment of Biological Sciences, Faculty of Science, King Abdulaziz University, Jeddah, Saudi Arabia

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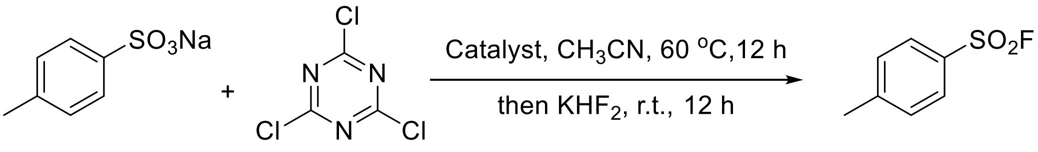
1. General considerations

All reactions were carried out in dried glassware. All reagents were purchased from commercial sources and used without further purification. Unless otherwise specified, NMR spectra were recorded in $CDCl_3$ or DMSO-d_6 on a 500 MHz (for ^1H), 471 MHz (for ^{19}F), 126 MHz (for ^{13}C) spectrometer. All chemical shifts were reported in ppm relative to TMS (^1H NMR, 0 ppm) as internal standards. The HPLC experiments were carried out on a Waters e2695 instrument (column: J&K, RP-C18, 5 μm, 4.6 × 150 mm), and the yields of the products were determined by using the corresponding pure compounds as the external standards. The coupling constants were reported in Hertz (Hz). The following abbreviations were used to explain the multiplicities: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad. MS experiments were performed on a TOF-Q ESI or CI/EI instrument. Melting points were measured and uncorrected.

2. Screening the optimized reaction conditions

2.1 Screening the optimized reaction conditions for Sodium sulfonate

Table 1 Screening the Catalyst[a]

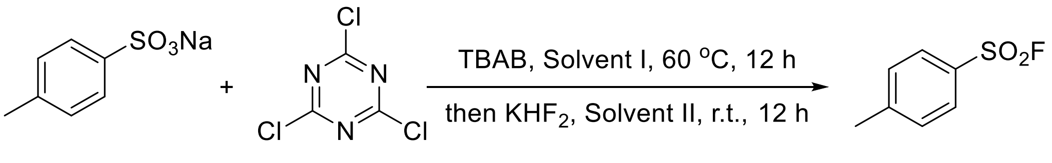


1a **2** **3a**

Entry	Catalyst (X mol %)	Yield (**3a**, %)[b]
1	TBAI (20)	12
2	TBAA (20)	17
3	TMAC (20)	70
4	TBAB (20)	74
5	TBAB (10)	74
6	TBAB (8.0)	75
7	**TBAB (5.0)**	**74**
8	TBAB (3.0)	60
9	/	Trace

[a] General conditions: A mixture of sodium 4-methylbenzenesulfonate (**1a**, 0.2 mmol), cyanuric chloride (**2**, 0.22 mmol, 1.1 eq.), Catalyst (X mol%), and CH_3CN (2.0 mL) was allowed to stir at 60 °C in an oven-dried tube for 12 h before KHF_2 (5.0 eq.) was added and the reaction was operated at the room temperature for an additional 12 h. [b] Yields were determined by HPLC using the pure 4-methylbenzenesulfonyl fluoride (**3a**, 0.2 mmol) as the external standard (t_R = 3.9 min, λ_{max} = 228.7 nm, CH_3CN/H_2O = 70 : 30 (v / v)).

Table 2 Screening the solvent[a]

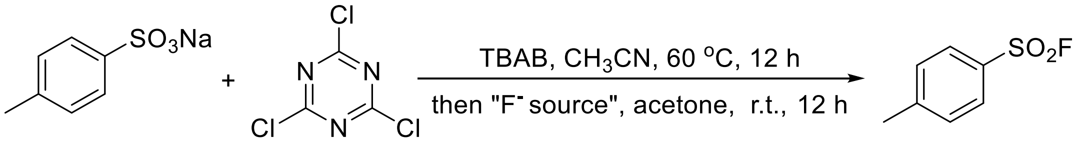


1a **2** **3a**

Entry	Solvent I (1.0 mL)	Solvent II (1.0 mL)	Yield (**3a**, %)[b]
1	acetone	acetone	75
2	acetone	CH_3CN	68
3	CH_3CN	CH_3CN	74
4	**CH_3CN**	**acetone**	**86**
5	CH_3CN	DCM	42
6	CH_3CN	$PhCF_3$	23

[a] General conditions: A mixture of sodium 4-methylbenzenesulfonate (**1a**, 0.2 mmol), cyanuric chloride (**2**, 0.22 mmol, 1.1 eq.), TBAB (5 mol%), and solvent I (1.0 mL) was allowed to stir at 60 °C in an oven-dried tube for 12 h before KHF_2 (5.0 eq.), solvent II (1.0 mL) were added and the reaction was operated at the room temperature for an additional 12 h. [b] Yields were determined by HPLC using the pure 4-methylbenzenesulfonyl fluoride (**3a**, 0.2 mmol) as the external standard (t_R = 3.9 min, λ_{max} = 228.7 nm, CH_3CN/H_2O = 70 : 30 (v / v)).

Table 3 Screening the "F$^-$ source"[a]

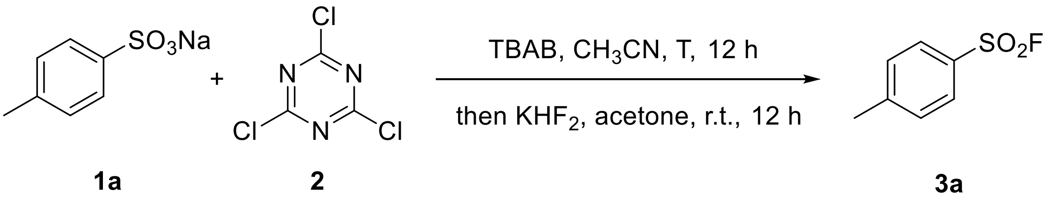


1a **2** **3a**

Entry	F^- source (X eq.)	Yield (**3a**, %)[b]
1	CsF (5.0)	<10
2	KF (5.0)	82
3	CuF_2 (5.0)	Trace
4	KHF_2 (5.0)	86
5	KHF_2 (6.0)	85
6	KHF_2 (8.0)	87
7	**KHF_2 (3.0)**	**86**
8	KHF_2 (2.5)	75
9	KHF_2 (2.0)	58

[a] General conditions: A mixture of sodium 4-methylbenzenesulfonate (**1a**, 0.2 mmol), cyanuric chloride (**2**, 0.22 mmol, 1.1 eq.), TBAB (5 mol %), and CH_3CN(1.0 mL) was allowed to stir at 60 °C in an oven-dried tube for 12 h before "F^- source" (X eq.), acetone (1.0 mL) were added and the reaction was operated at the room temperature for an additional 12 h. [b] Yields were determined by HPLC using the pure 4-methylbenzenesulfonyl fluoride (**3a**, 0.2 mmol) as the external standard (t_R = 3.9 min, λ_{max} = 228.7 nm, CH_3CN/H_2O = 70 : 30 (v / v)).

Table 4 Screening the Temperature[a]

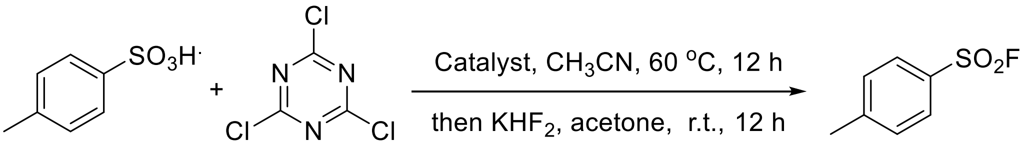


Entry	T(°C)	Yield (**3a**, %)[b]
1	rt.	4
2	40	15
3	**60**	**86**

4	80	84

[a] General conditions: A mixture of sodium 4-methylbenzenesulfonate (**1a**, 0.2 mmol), cyanuric chloride (**2**, 0.22 mmol, 1.1 eq.), TBAB (5 mol%), and CH_3CN(1.0 mL) was allowed to stir at corresponding temperature in an oven-dried tube for 12 h before KHF_2(3.0 eq.), acetone (1.0 mL) were added and the reaction was operated at the room temperature for an additional 12 h. [b] Yields were determined by HPLC using the pure 4-methylbenzenesulfonyl fluoride (**3a**, 0.2 mmol) as the external standard (t_R = 3.9 min, λ_{max} = 228.7 nm, CH_3CN/H_2O = 70 : 30 (v / v)).

2.2 Screening the optimized reaction conditions for sulfonic acid[a]



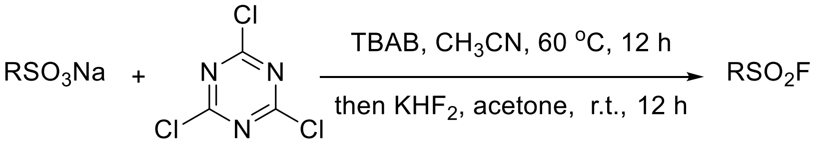
4a **2** **3a**

Entry	Catalyst (X mol %)	Yield (**3a**, %)[b]
1	DBU (20)	56
2	Et_3N (20)	60
3	DIPEA (20)	54
4	DMF (20)	72
5[c]	DMF (20)	Trace
6	TMEDA (20)	51
7	TBAB (20)	67
8	TBAI (20)	42
9	TMAC (20)	85
10	TMAC (10)	86
11	TMAC **(5.0)**	**85**
12	TMAC (3.0)	76

[a] General conditions: A mixture of 4-methylbenzenesulfonic acid (**4a**, 0.2 mmol), cyanuric chloride (**2**, 0.22 mmol, 1.1 eq.), Catalyst (X mol%) and CH_3CN (1.0 mL) was allowed to stir at 60 °C in an oven-dried tube for 12 h before KHF_2 (3.0 eq.), acetone (1.0 mL) were added and the reaction was operated at the room temperature for an additional 12 h. [b] Yields were determined by HPLC using the pure 4-methylbenzenesulfonyl fluoride (**3a**, 0.2 mmol) as the external standard (t_R = 3.9 min, λ_{max} = 228.7 nm, CH_3CN/H_2O = 70 : 30 (v / v)). [c]DMF as the solvent.

3. General procedure

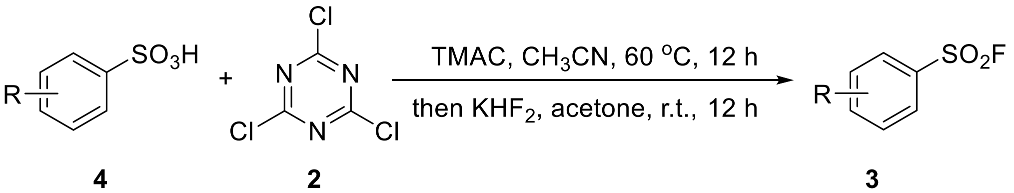
3.1 General procedure for synthesis of 3 from 1 (Procedure A)



1 **2** **3**

Sodium sulfonate **1** (2.0 mmol), cyanuric chloride **2** (405.9 mg, 2.2 mol, 1.1 eq.), TBAB (32.2 mg, 5 mol %) and 10 mL CH_3CN were added to an oven-dried reaction tube (50 mL) equipped with a stirrer bar, then the mixture was stirred at 60 °C for 12 h. After the Sodium sulfonate was completely consumed, KHF_2 (468.6 mg, 6.0 mmol, 3.0 eq.) and acetone (10 mL) were added into the reaction mixture. The solution was subsequently stirred at room temperature for another 12 h. After that, the reaction was diluted with water and extracted with EtOAc (3×20 ml) and the combined organic layers were washed with brine, dried over anhydrous Na_2SO_4, and concentrated to dryness. The residue was purified by column chromatography on silica gel to afford the desired product **3**.

3.2 General procedure for synthesis of 3 from 4 (Procedure B)

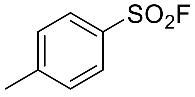


4 **2** **3**

Sulfonic acid **4** (2 mmol), cyanuric chloride **2** (405.9 mg, 2.2 mmol, 1.1 eq.), TMAC

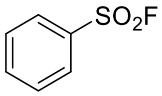
(11.0 mg, 5 mol %) and 10 mL CH_3CN were added to an oven-dried reaction tube (50 mL) equipped with a stirrer bar, then the mixture was stirred at 60 ºC for 12 h. After the Sodium sulfonate was completely consumed, KHF_2 (468.6 mg, 6.0 mmol, 3.0 eq.) and acetone (10 mL) were added into the reaction mixture. The solution was subsequently stirred at room temperature for another 12 h. After that, the reaction was diluted with water and extracted with EtOAc (3×20 ml) and the combined organic layers were washed with brine, dried over anhydrous Na_2SO_4, and concentrated to dryness. The residue was purified by column chromatography on silica gel to afford the desired product **3**.

4. Product Characterization



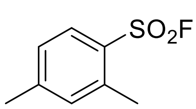
3a

4-Methylbenzenesulfonyl fluoride (**3a**). White solid (296 mg, isolated yield 85%, following the Procedure A; 296 mg, isolated yield 85 %, following the Procedure B). The NMR data is identical to that reported in literature.[1] ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.89 (d, *J* = 8.2 Hz, 2H), 7.42 (d, *J* = 8.0 Hz, 2H), 2.49 (s, 3H). ^{19}F NMR ($CDCl_3$, 471 MHz): δ 66.2.



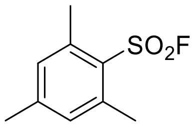
3b

Benzenesulfonyl fluoride (**3b**). Colorless liquid (231 mg, isolated yield 72%, following the Procedure A; 224 mg, isolated yield 70 %, following the Procedure B). The NMR data is identical to that reported in literature.[1] ^{1}H NMR ($CDCl_3$, 500 MHz) δ 8.02 (d, *J* = 7.9 Hz, 2H), 7.78 (t, *J* = 7.4 Hz, 1H), 7.64 (t, *J* = 7.7 Hz, 2H). ^{19}F NMR ($CDCl_3$, 471 MHz): δ 65.8.



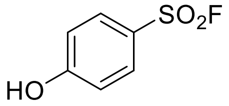
3c

2, 4-Dimethylbenzenesulfonyl fluoride (**3c**). Colorless liquid (339 mg, isolated yield 90%, following the Procedure A; 320 mg, isolated yield 85 %, following the Procedure B). ^{1}H NMR (CDCl$_3$, 500 MHz) δ 7.90 (d, *J* = 8.1 Hz, 1H), 7.22 (s, 1H), 7.19 (d, *J* = 8.2 Hz, 1H) 2.64 (s, 3H), 2.43 (s, 3H). ^{19}F NMR (CDCl$_3$, 471 MHz): δ 60.5. ^{13}C NMR (CDCl$_3$, 126 MHz): δ 146.8, 138.9, 133.7, 130.3, 130.2, 127.3, 21.6, 20.2. ESI-MS HRMS calculated for $C_8H_{10}FO_2S$ [M+H]$^+$ 189.0380, found: 189.0387.



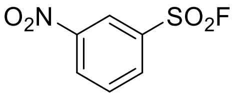
3d

2, 4, 6-Trimethylbenzenesulfonyl fluoride (**3d**). White solid (380 mg, isolated yield 94%, following the Procedure A). The NMR data is identical to that reported in literature.[1] ^{1}H NMR (CDCl$_3$, 500 MHz) δ 7.04 (s, 2H), 2.64 (s, 6H), 2.35 (s, 3H). ^{19}F NMR (CDCl$_3$, 471 MHz): δ 68.2.



3e

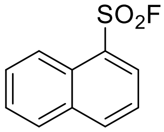
4-Hydroxybenzenesulfonyl fluoride (**3e**). White solid (225 mg, isolated yield 64%, following the Procedure A and Additional 3 h at 70 °C was required after reacting at 60 °C for 12 h; 218 mg, isolated yield 62 %, following the Procedure B). The NMR data is identical to that reported in literature.[4] ^{1}H NMR (CDCl$_3$, 500 MHz) δ 7.90 (d, *J* = 8.7 Hz, 2H), 7.01 (d, *J* = 8.7 Hz, 2H), 6.68 (brs, 1H). ^{19}F NMR (CDCl$_3$, 471 MHz): δ 67.1.



3f

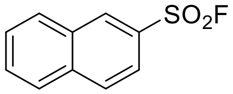
3-Nitrobenzenesulfonyl fluoride (**3f**). Light yellow oil (185 mg, isolated yield 45%, following the Procedure A). The NMR data is identical to that reported in literature.[2]

^{1}H NMR ($CDCl_3$, 500 MHz) δ 8.88 (s, 1H), 8.65 (d, *J* = 8.0 Hz, 1H), 8.36 (d, *J* = 7.7 Hz, 1H), 7.91 (t, *J* = 7.7 Hz, 1H). ^{19}F NMR ($CDCl_3$, 471 MHz): δ 66.3.



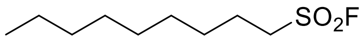
3g

Naphthalene-1-sulfonyl fluoride (**3g**). Colorless liquid (268 mg, isolated yield 64%, following the Procedure A with a slight modification and TBAB was 20 mol%, additional 3 h at 70 °C was required after reacting at 60 °C for 12 h.) The NMR data is identical to that reported in literature.[3] ^{1}H NMR ($CDCl_3$, 500 MHz) δ 8.55 (dd, *J* = 8.5 Hz, 1.8 Hz, 1H), 8.37 (d, *J* = 7.3 Hz, 1H), 8.24 (d, *J* = 8.3 Hz, 1H), 8.00 (d, *J* = 8.3 Hz, 1H), 7.78 (t, *J* = 7.8 Hz,1H), 7.69 (t, *J* = 7.6 Hz,1H), 7.62 (t, *J* = 7.6 Hz,1H).^{19}F NMR ($CDCl_3$, 471 MHz): δ 62.6.



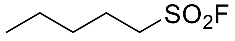
3h

Naphthalene-2-sulfonyl fluoride (**3h**). White solid (390 mg, isolated yield 93%, following the Procedure A; 311 mg, isolated yield 74 %, following the Procedure B). The NMR data is identical to that reported in literature.[1] ^{1}H NMR ($CDCl_3$, 500 MHz) δ 8.62 (s, 1H), 8.07-8.03 (m, 2H),7.98 (d, *J* = 8.2 Hz, 1H), 7.94 (dd, *J* = 8.7 Hz, 1.8 Hz, 1H), 7.76 (td, *J* = 8.1 Hz, 1.1 Hz, 1H), 7.70 (td, *J* = 8.0 Hz, 0.9 Hz, 1H). ^{19}F NMR ($CDCl_3$, 471 MHz): δ 66.3.



3i

Nonane-1-sulfonyl fluoride (**3i**). Colorless liquid (348 m, isolated yield 83%, following the Procedure A). ^{1}H NMR ($CDCl_3$, 500 MHz) δ 3.67-3.64 (m, 1H), 3.37-3.33 (m, 1H), 2.07-2.00 (m, 1H), 1.97-1.91 (m, 1H), 1.52-1.45 (m, 2H), 1.37-1.28 (m, 10H), 0.88 (t, *J* = 7.0 Hz, 3H). ^{19}F NMR ($CDCl_3$, 471 MHz): 53.2. ^{13}C NMR ($CDCl_3$, 126 MHz): δ 65.6, 31.8, 29.2, 29.2, 29.2, 27.9, 24.4, 22.7, 14.1. ESI-MS HRMS calculated for $C_9H_{20}FO_2S$ $[M+H]^+$ 211.1163, found: 211.1170.



3j

Pentane-1-sulfonyl fluoride (**3j**). Colorless liquid (209 mg, isolated yield 68%, following the Procedure A and with a slight modification and TBAB was 20 mol%). ^{1}H NMR (CDCl$_3$, 500 MHz) δ 3.38-3.34 (m, 2H), 1.99-1.92 (m, 2H), 1.50-1.44 (m, 2H), 1.42-1.35 (m, 2H), 0.94 (t, *J* = 7.2 Hz, 3H). ^{19}F NMR (CDCl$_3$, 471 MHz): δ 53.2. ^{13}C NMR (CDCl$_3$, 126 MHz): δ 65.6, 29.7, 24.1, 22.1, 13.7. ESI-MS HRMS calculated for $C_5H_{12}FO_2S$ [M+H]$^+$ 155.0537, found: 155.0543.

5. References

[1] L. Tang, Y. Yang, L. Wen, X. Yang, Z. Wang, *Green Chem.*, 2016, **18**, 1224.

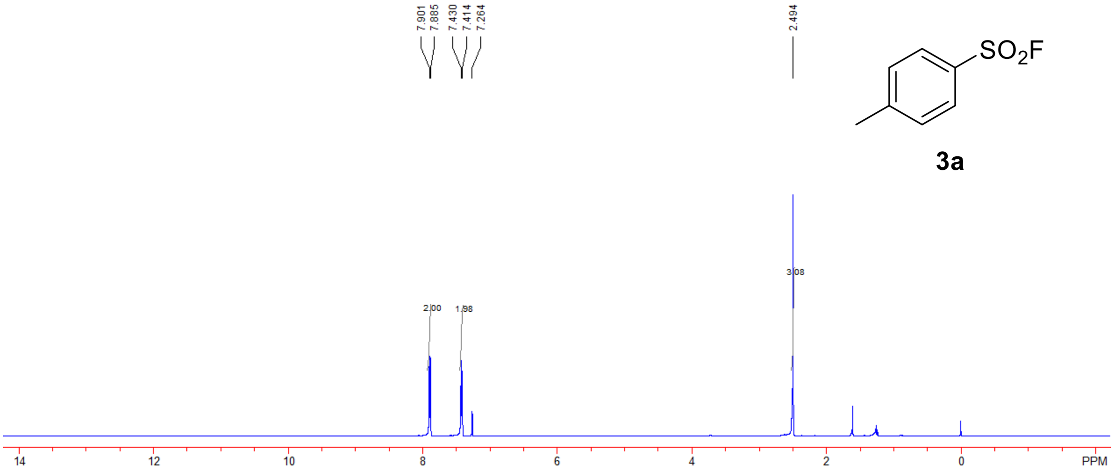
[2] H. Mukherjee, J. Debreczeni, J. Breed, S. Tentarelli, B. Aquila, J. E. Dowling, A. Whitty, N. P. Grimster, *Org. Biomol. Chem.,* 2017*,* **15**, 9685.

[3] A. L. Tribby, I. Rodriguez, S. Shariffudin, N. D. Ball, *J. Org. Chem.*, 2017, **82**, 2294.

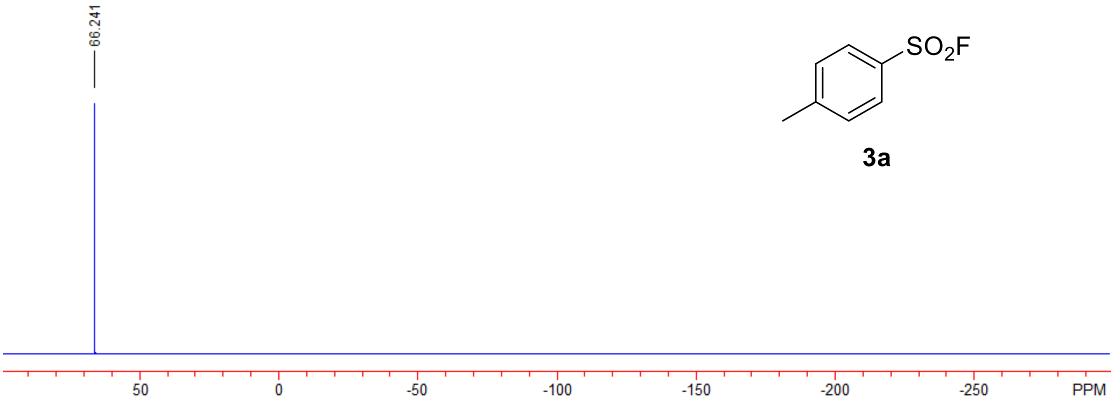
[4] W. Chen, J. Dong, L. Plate, D. E. Mortenson, G. J. Brighty, S. Li, Y. Liu, A. Galmozzi, P. S. Lee, J. J. Hulce, B. F. Cravatt, E. Saez, E. T. Powers, I. A. Wilson, K. B. Sharpless, J. W. Kelly, *J. Am. Chem. Soc.*, 2016, **138**, 7353.

6. NMR Spectra

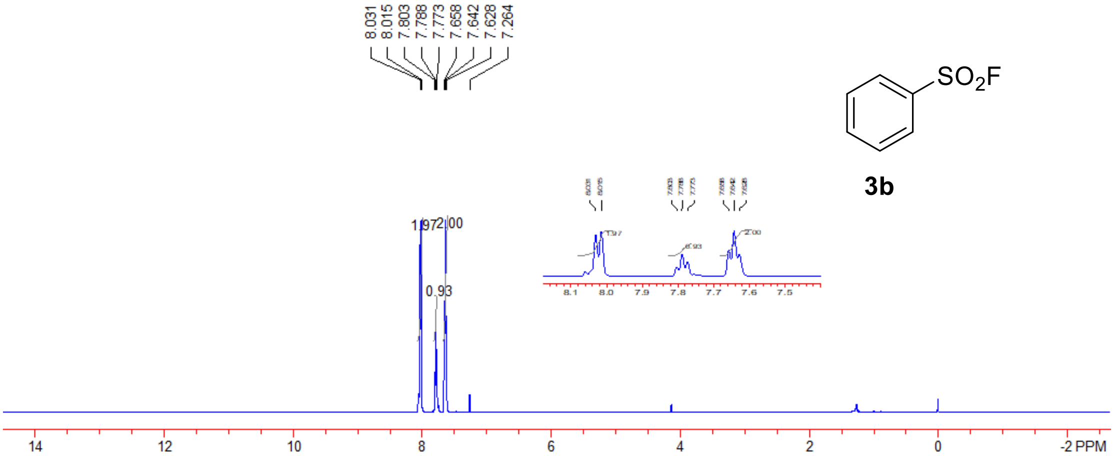
3a, ^{1}H NMR, 500 MHz, CDCl$_3$



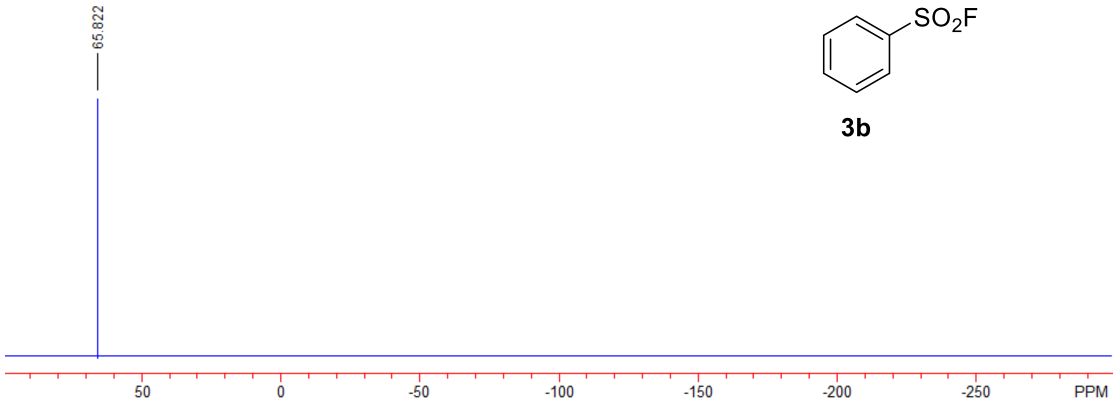
3a, ^{19}F NMR, 471 MHz, CDCl$_3$



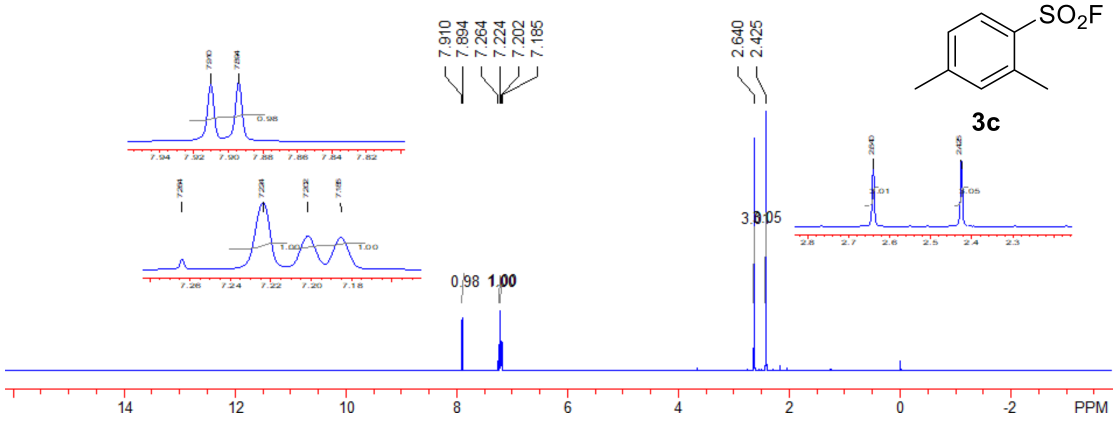
3b, ^{1}H NMR, 500 MHz, CDCl$_3$



3b, ^{19}F NMR, 471 MHz, CDCl$_3$



3c, ^{1}H NMR, 500 MHz, CDCl$_3$



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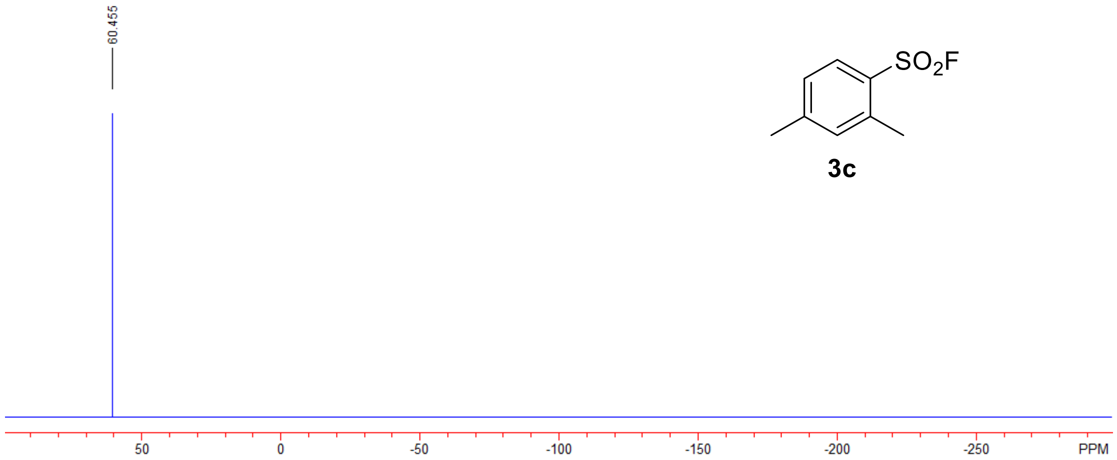
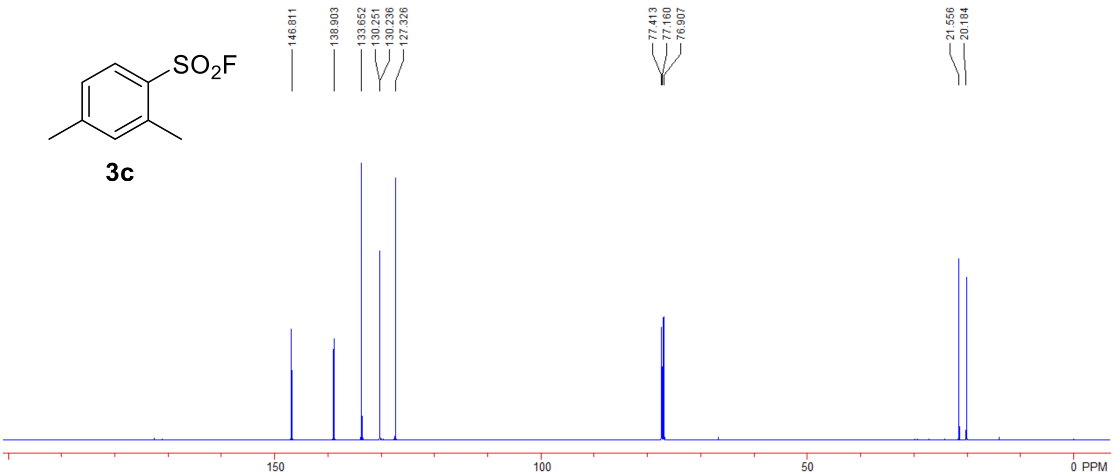
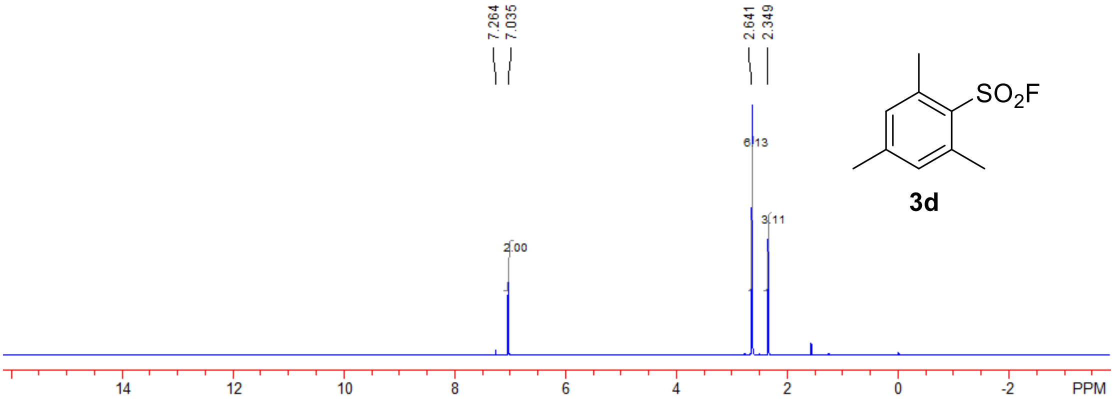


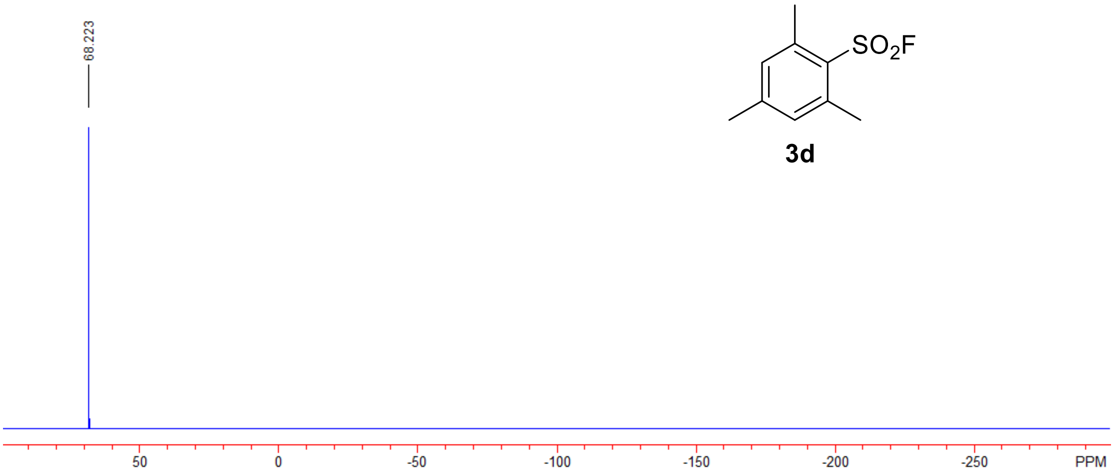
3c, ^{13}C NMR, 126 MHz, CDCl$_3$



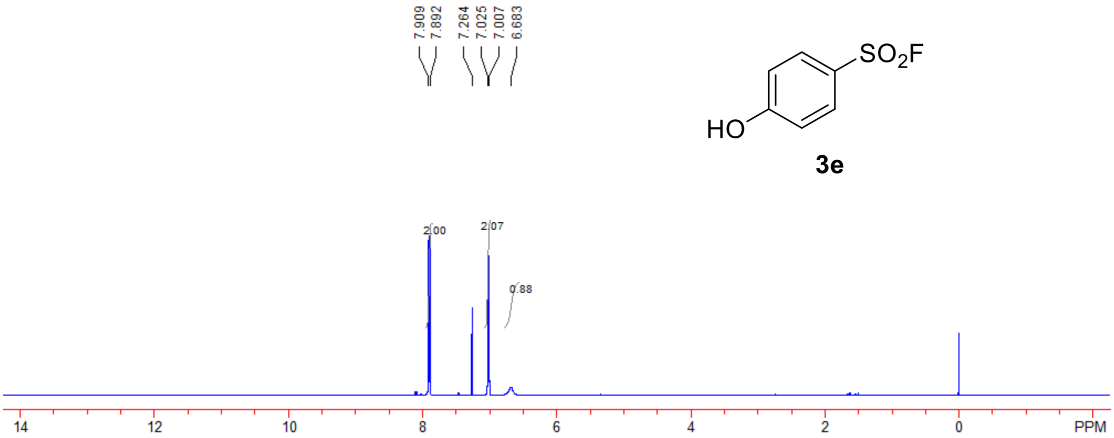
3d, ^{1}H NMR, 500 MHz, CDCl$_3$



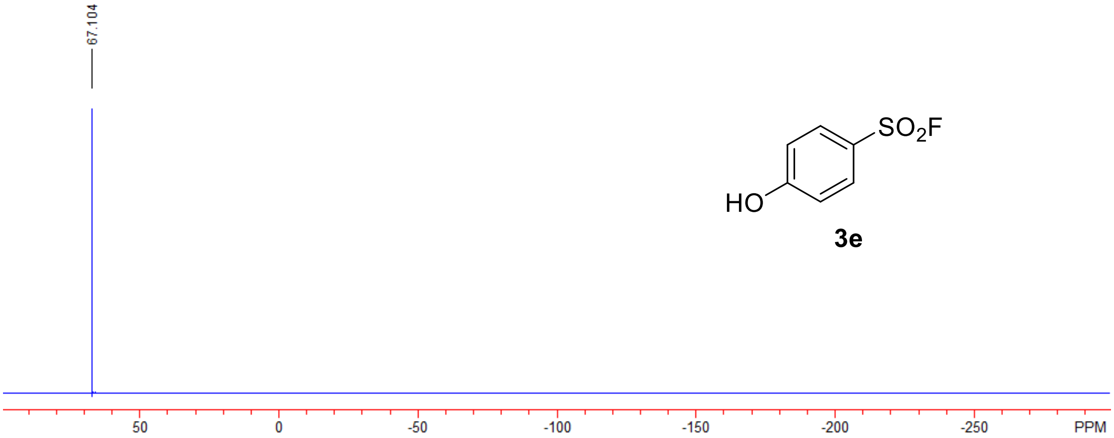
3d, ^{19}F NMR, 471 MHz, CDCl$_3$



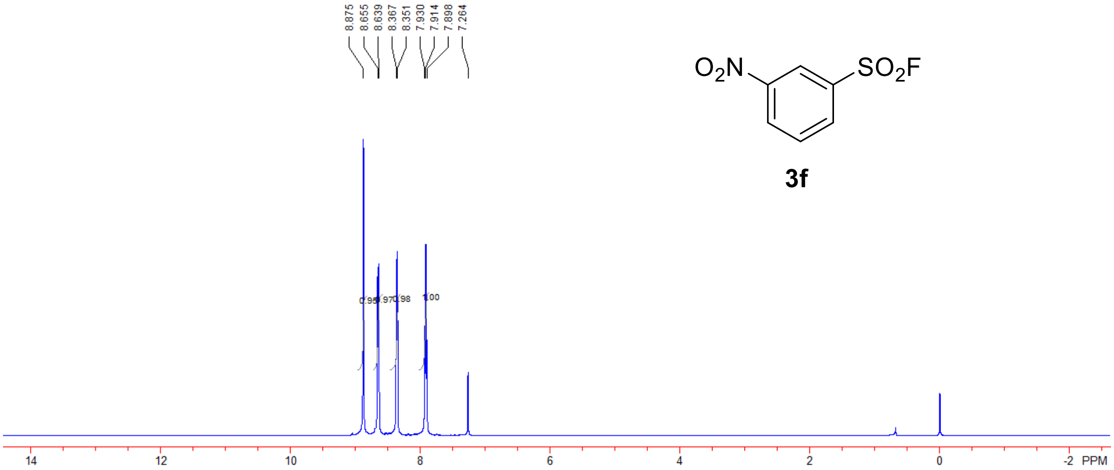
3e, ^{1}H NMR, 500 MHz, CDCl$_3$



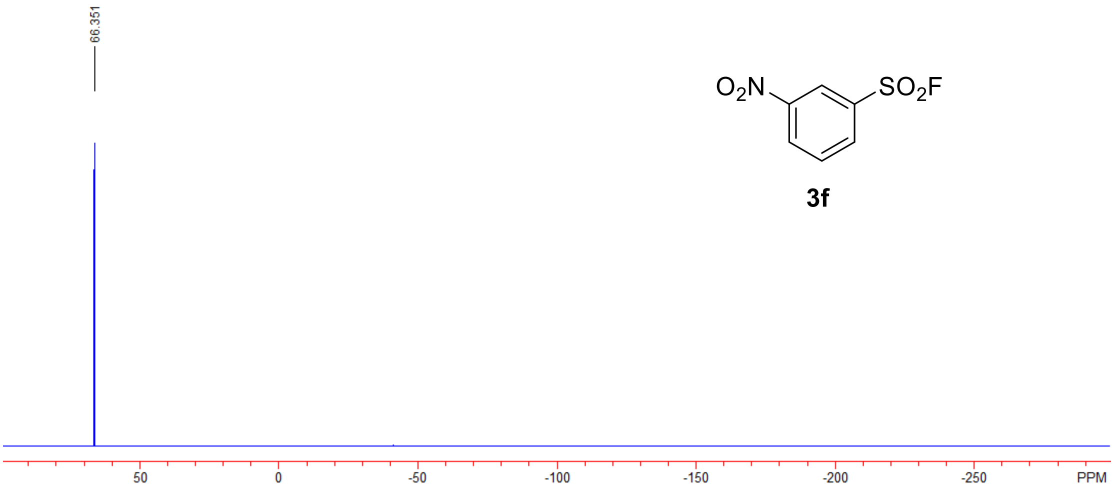
3e, ^{19}F NMR, 471 MHz, CDCl$_3$



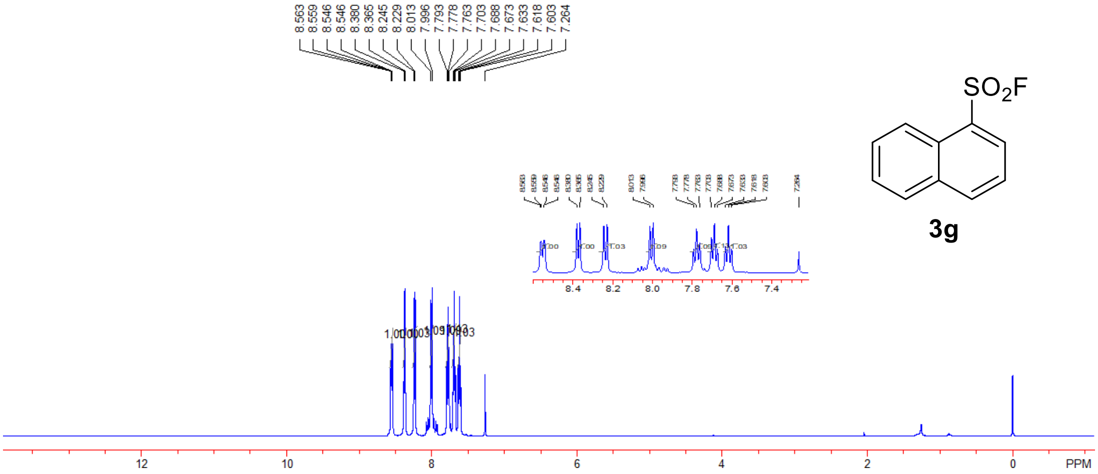
3f, ^{1}H NMR, 500 MHz, CDCl$_3$



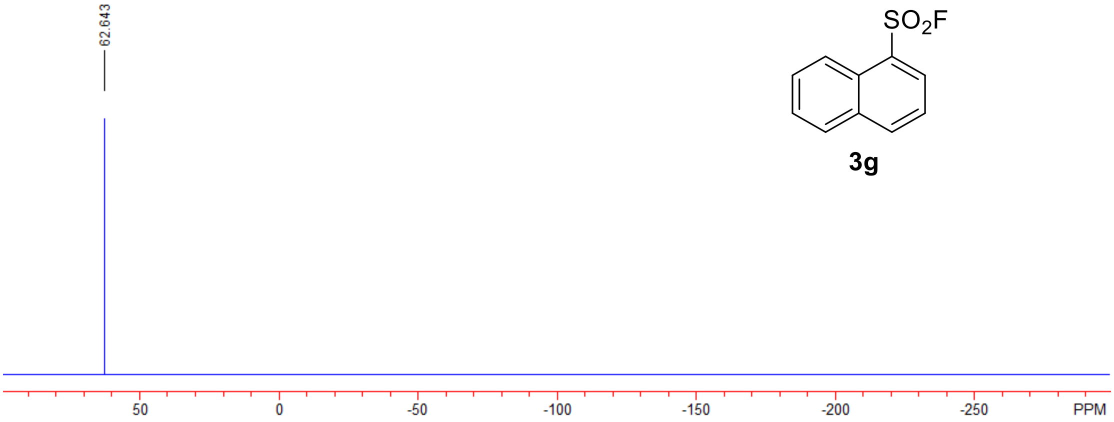
3f, ^{19}F NMR, 471 MHz, CDCl$_3$



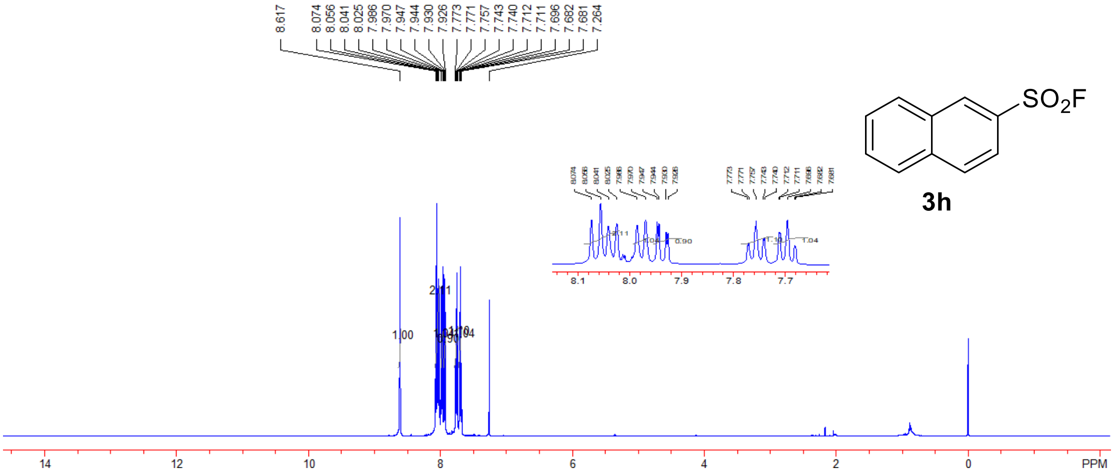
3g, ^{1}H NMR, 500 MHz, CDCl$_3$



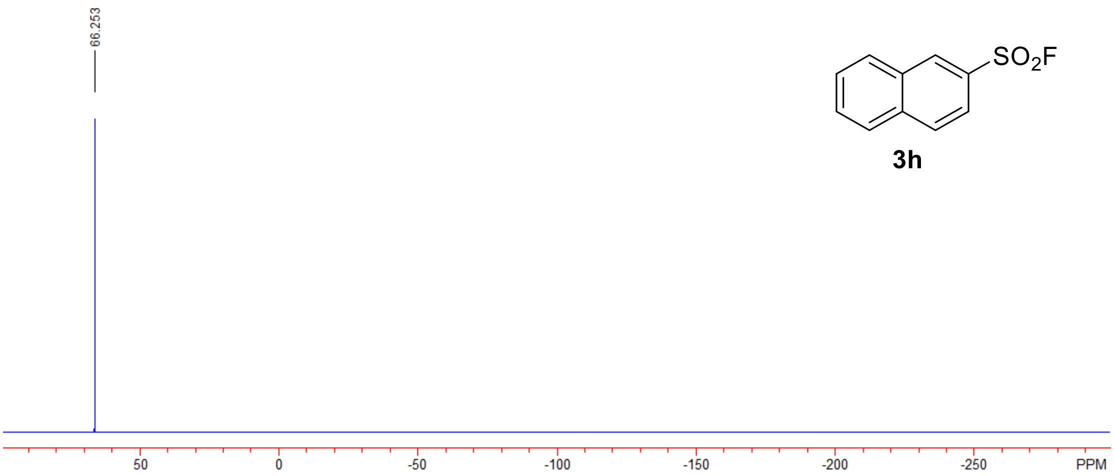
3g, ^{19}F NMR, 471 MHz, CDCl$_3$



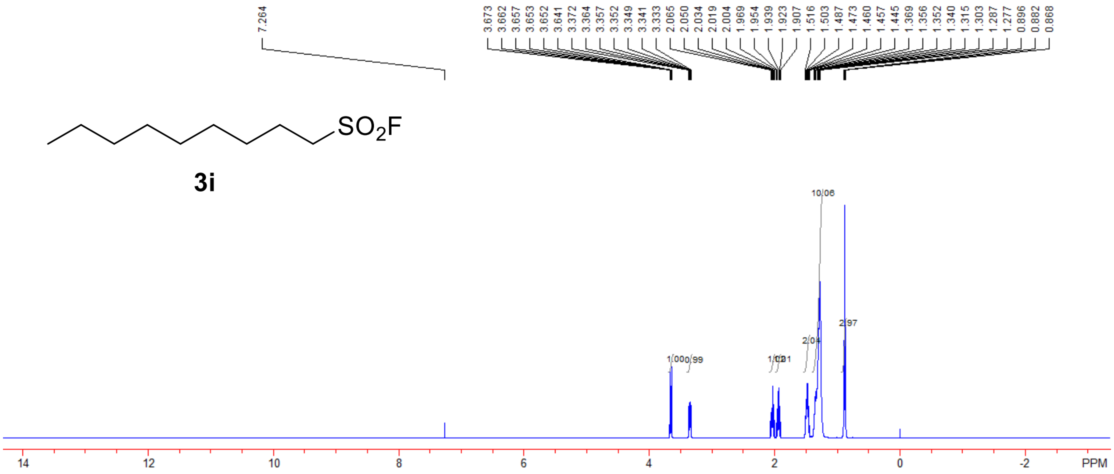
3h, ^{1}H NMR, 500 MHz, CDCl$_3$



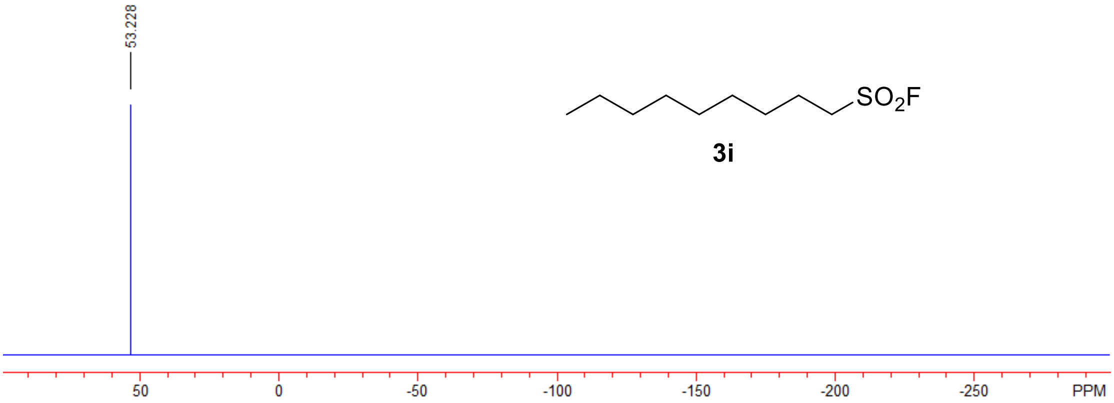
3h, ^{19}F NMR, 471 MHz, CDCl$_3$



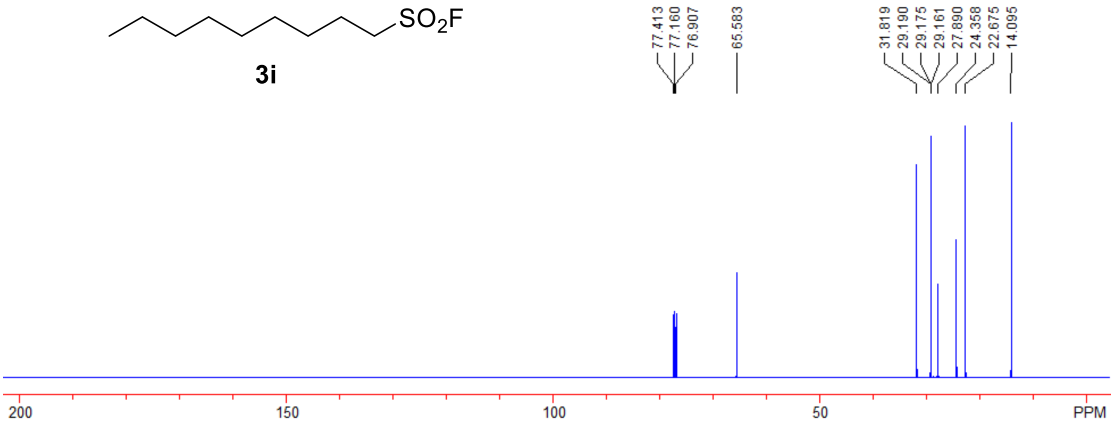
3i, ^{1}H NMR, 500 MHz, CDCl$_3$



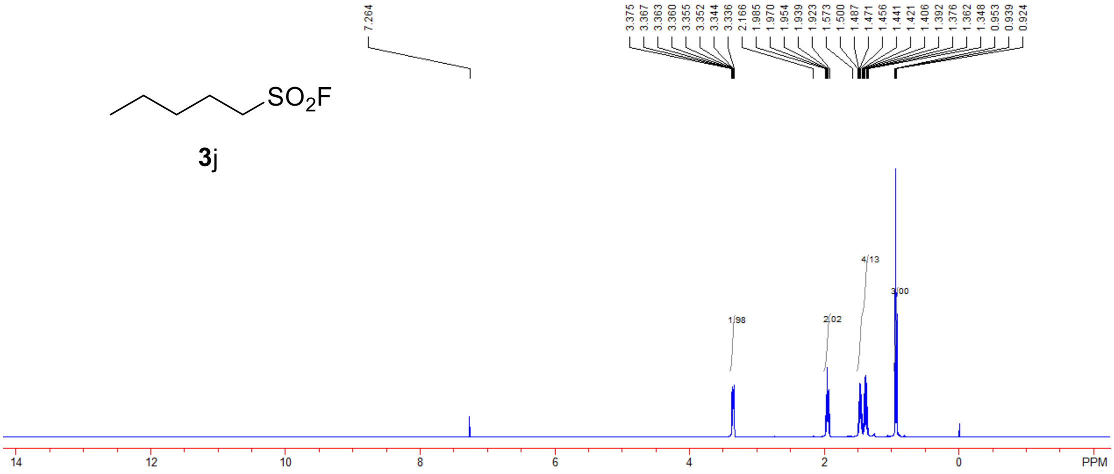
3i, ^{19}F NMR, 471 MHz, $CDCl_3$



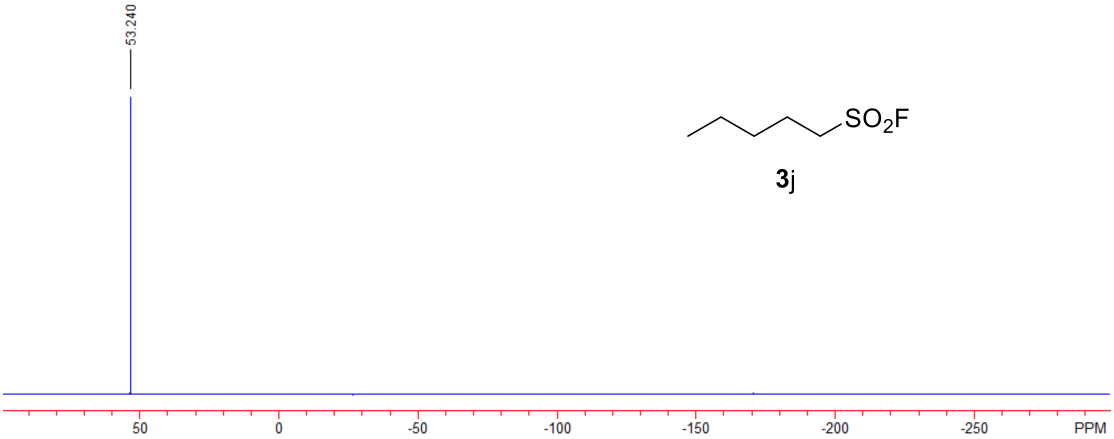
3i, ^{13}C NMR, 126 MHz, $CDCl_3$



3j, ^{1}H NMR, 500 MHz, $CDCl_3$



3j, ^{19}F NMR, 471 MHz, $CDCl_3$



3j, ^{13}C NMR, 126 MHz, $CDCl_3$