

## Efficient Colorimetric and Fluorescent Detection of Fluoride in Aqueous Media with Arylaldoximes

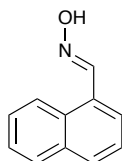
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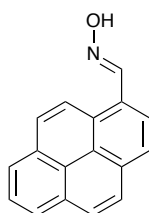
### Additional synthesis data

#### 1-Naphthaldoxime (1)<sup>[1]</sup>



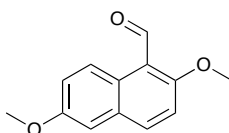
<sup>1</sup>H NMR (400 MHz, DMSO-*d*<sub>6</sub>) δ 11.46 (s, 1H), 8.78 (s, 1H), 8.67 (d, *J* = 7.8, 1H), 8.04 – 7.89 (m, 2H), 7.8 (d, *J* = 7.2, 1H), 7.66 – 7.46 (m, 3H). <sup>13</sup>C NMR (100 MHz, DMSO-*d*<sub>6</sub>) δ 148.3, 133.5, 130.0, 129.7, 128.8, 128.6, 127.0, 127.0, 126.2, 125.5, 124.7. HRMS (ESI) [M+H]<sup>+</sup> calc.: 172.0757; found: 172.0760. Mp (Uncorr.): 101.5-102.2 °C.

#### 1-Pyrenecarboxaldehyde oxime (2)<sup>[2]</sup>



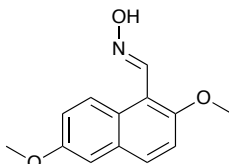
<sup>1</sup>H NMR (400 MHz, DMSO-*d*<sub>6</sub>) δ 11.63 (s, 1H), 9.16 (s, 1H), 8.80 (d, *J* = 9.3, 1H), 8.41 (d, *J* = 8.1, 1H), 8.37 – 8.17 (m, 6H), 8.10 (t, *J* = 7.6, 1H). <sup>13</sup>C NMR (100 MHz, DMSO-*d*<sub>6</sub>) δ 147.4, 131.3, 130.8, 130.2, 128.3, 128.0, 127.9, 127.3, 126.5, 126.2, 125.8, 125.5, 125.1, 124.9, 124.1, 123.8, 123.3. HRMS (ESI) [M+H]<sup>+</sup> calc.: 246.0913; found: 246.0916. Mp (Uncorr.): 194.2-194.7 °C.

#### 2,6-Dimethoxy-1-naphthaldehyde<sup>[3]</sup>



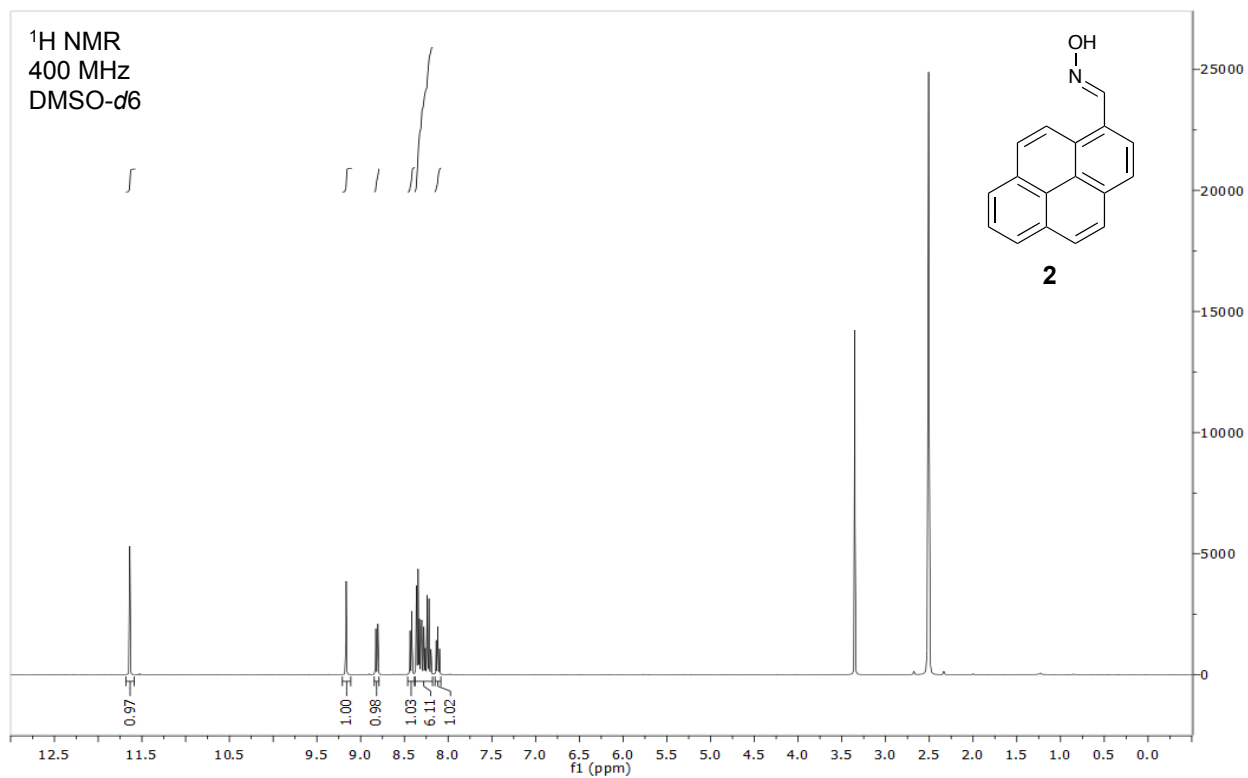
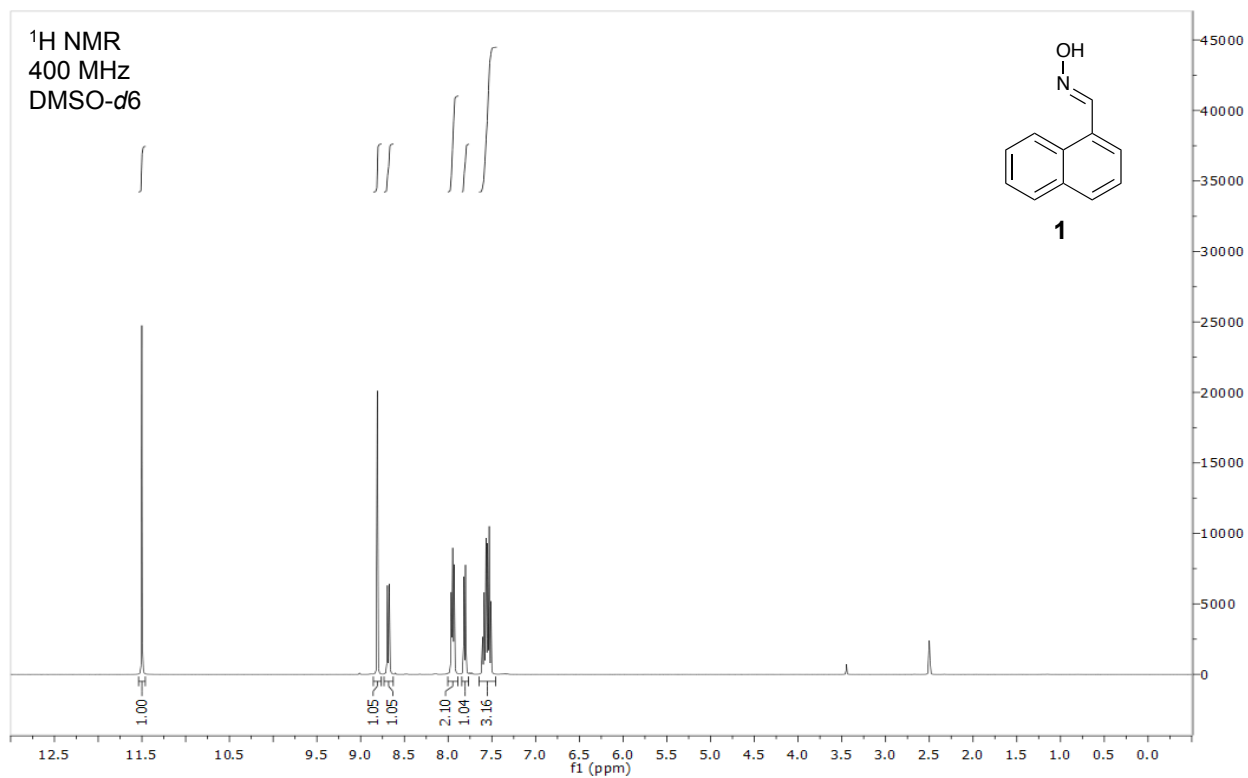
To a stirred solution of 2,6-dimethoxynaphthalene (500.0 mg, 2.66 mmol) in anhydrous DMF (8 mL) was slowly added triflic anhydride (2.68 mL, 15.94 mmol) under a slow argon flow. The reaction mixture was then heated to 60 °C and stirred under argon atmosphere for 4 hours. After cooling to room temperature the mixture was poured into EtOAc (50 mL). The organic phase was washed with brine (4 x 75 mL), dried over anhydrous Na<sub>2</sub>SO<sub>4</sub>, filtered and the solvent removed *in vacuo*. The crude product was purified by flash column chromatography (DCM) yielding the desired aldehyde as a yellow solid (357.8 mg, 62%). <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 10.77 (s, 1H), 9.14 (d, *J* = 9.4 Hz, 1H), 7.80 (d, *J* = 9.1 Hz, 1H), 7.21 (dd, *J* = 2.8, 9.4 Hz, 1H), 7.10 (d, *J* = 9.1 Hz, 1H), 6.96 (d, *J* = 2.8 Hz, 1H), 3.89 (s, 3H), 3.82 (s, 3H). <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 191.9, 162.4, 156.3, 136.1, 129.7, 126.5, 126.4, 121.7, 116.6, 113.0, 106.5, 56.4, 55.1. HRMS (ESI) [M+H]<sup>+</sup> calc.: 217.0859; found: 217.0863. Mp (Uncorr.): 90.2-90.8 °C.

#### 2,6-Dimethoxy-1-naphthaldoxime (3)<sup>[4]</sup>

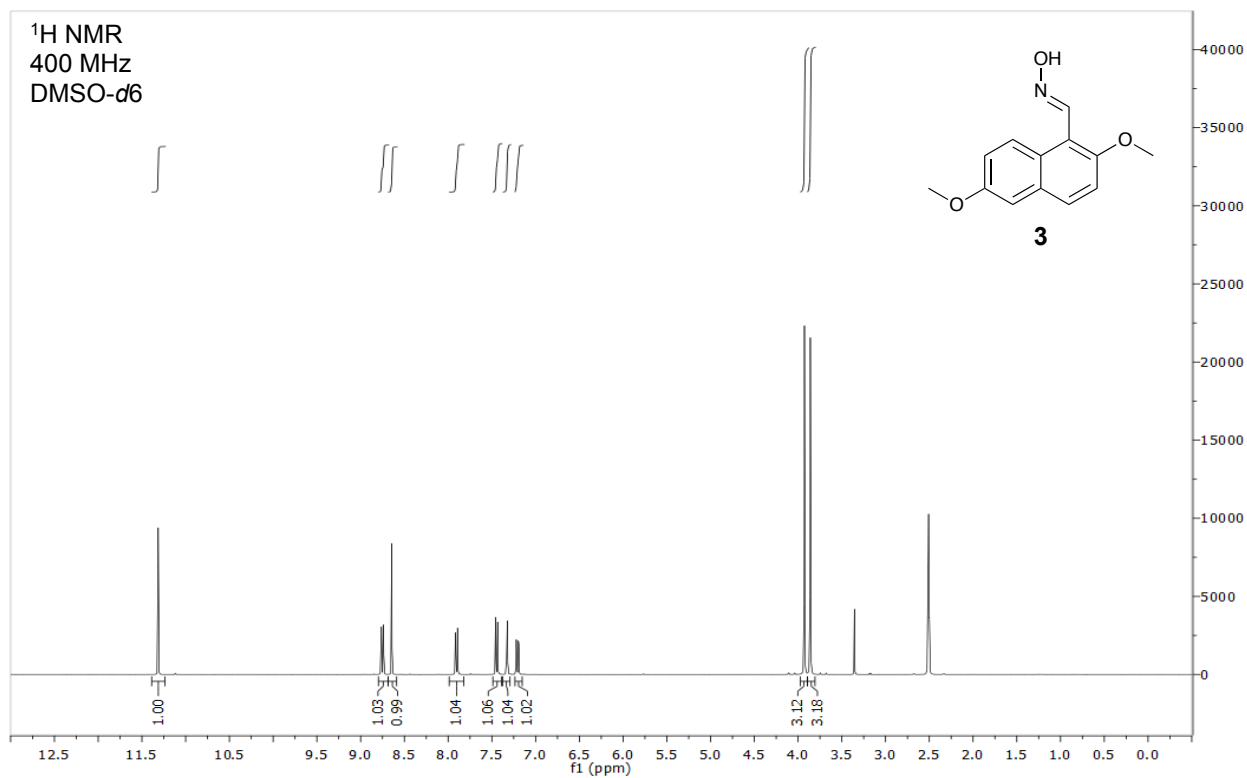
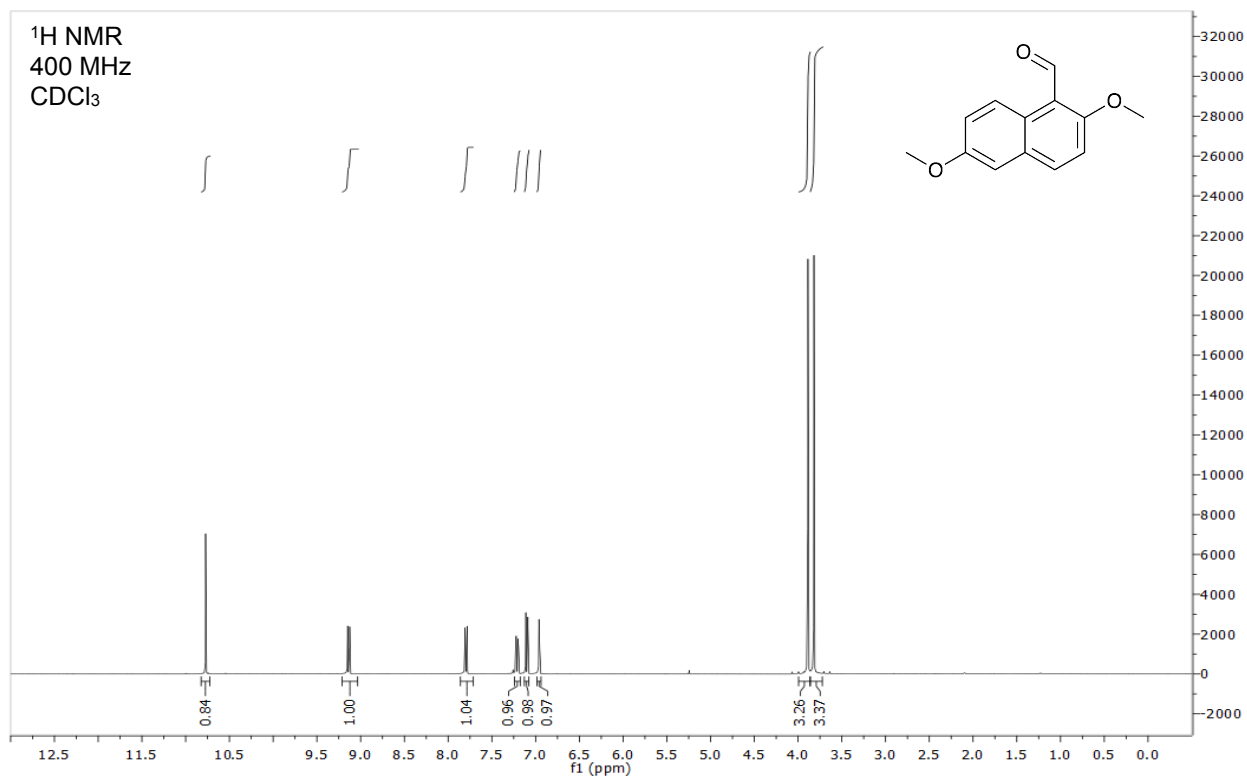


<sup>1</sup>H NMR (400 MHz, DMSO-*d*<sub>6</sub>) δ 11.29 (s, 1H), 8.75 (d, *J* = 9.4, 1H), 8.64 (s, 1H), 7.89 (d, *J* = 9.1, 1H), 7.43 (d, *J* = 9.1, 1H), 7.31 (d, *J* = 2.8, 1H), 7.20 (dd, *J* = 2.8, 9.4, 1H), 3.92 (s, 3H), 3.85 (s, 3H). <sup>13</sup>C NMR (100 MHz, DMSO-*d*<sub>6</sub>) δ 155.6, 154.9, 145.3, 130.2, 130.0, 127.1, 125.9, 119.8, 114.0, 113.7, 106.7, 56.7, 55.1. HRMS (ESI) [M+H]<sup>+</sup> calc.: 232.0968; found: 232.0976. Mp (Uncorr.): 162.7-164.1 °C.

Electronic Supplementary Information

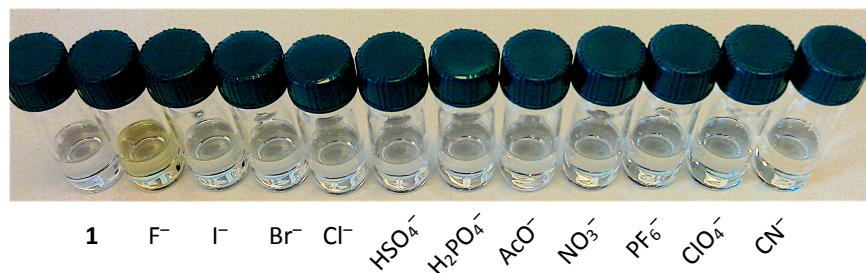


Electronic Supplementary Information





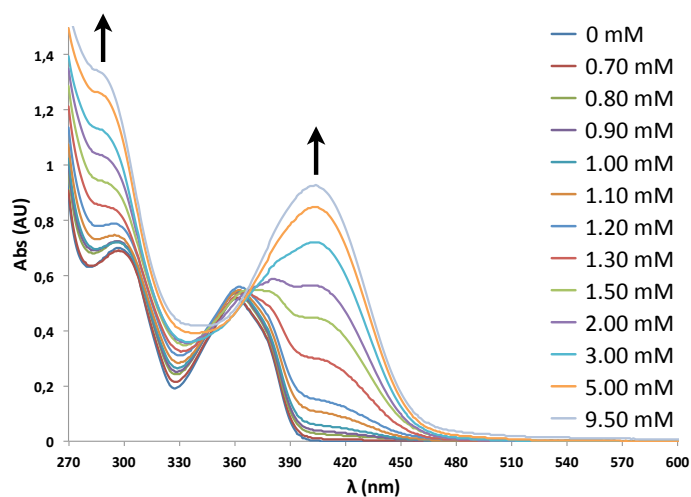
### Naked-eye visible color change of 1-naphthldoxime (1)



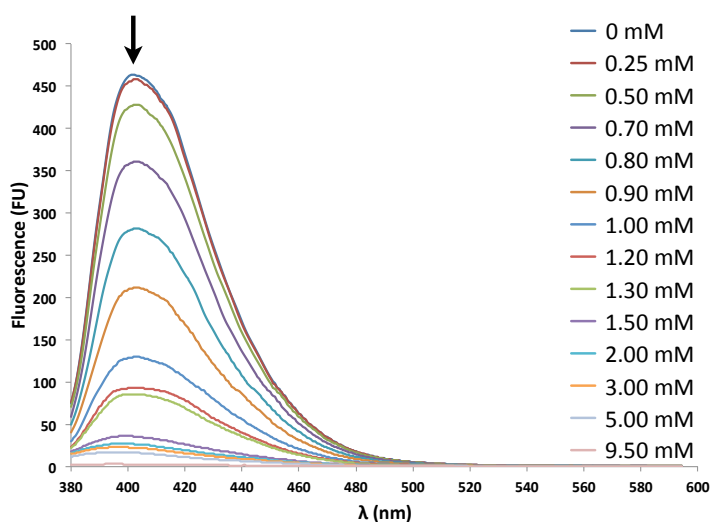
**Figure S1.** Naked-eye visible colorimetric readout of **1** (100  $\mu$ M) in DMSO in the absence and presence of different TBA<sup>+</sup> anion combinations (>100 eq.).

### Additional spectroscopic data

All oxime-fluoride solutions should be handled in plastic vials, to avoid fluoride interacting with silicon containing residues released from the glassware causing slightly irreproducible results.

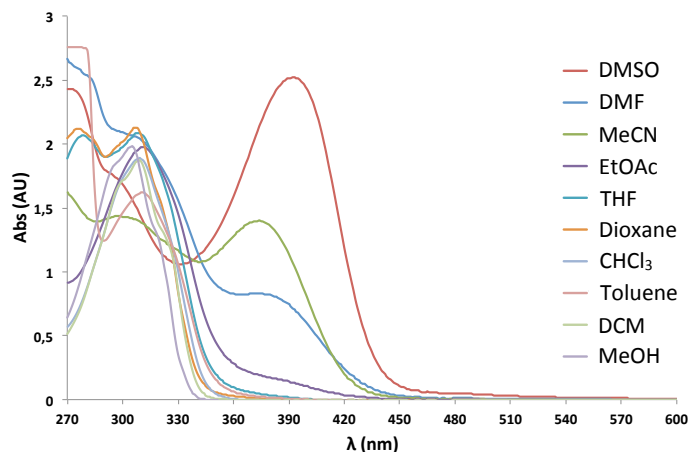


**Figure S2.** UV-Vis absorbance titration spectra of **3** (100  $\mu$ M) in DMSO with different concentrations of TBAF (0 mM to 9.5 mM).

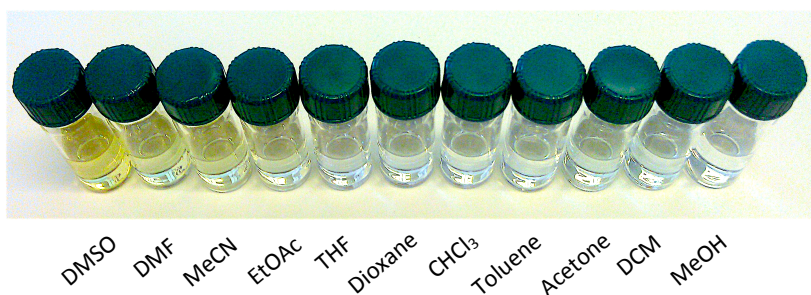


**Figure S3.** Fluorescence titration spectra of **3** (100  $\mu$ M) in DMSO with different concentrations of TBAF (0 mM to 9.5 mM).

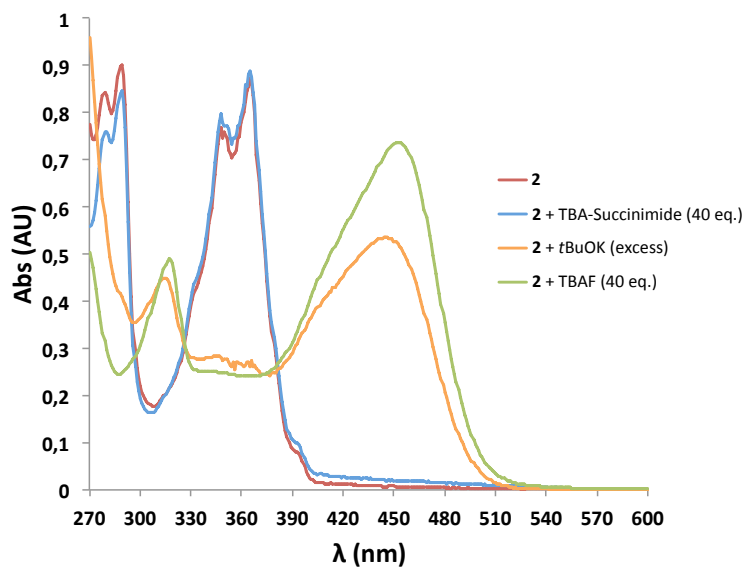
## Electronic Supplementary Information



**Figure S4.** UV-Vis absorbance spectra of **1** (150 μM) in different solvents in the presence of TBAF (>100 eq.).



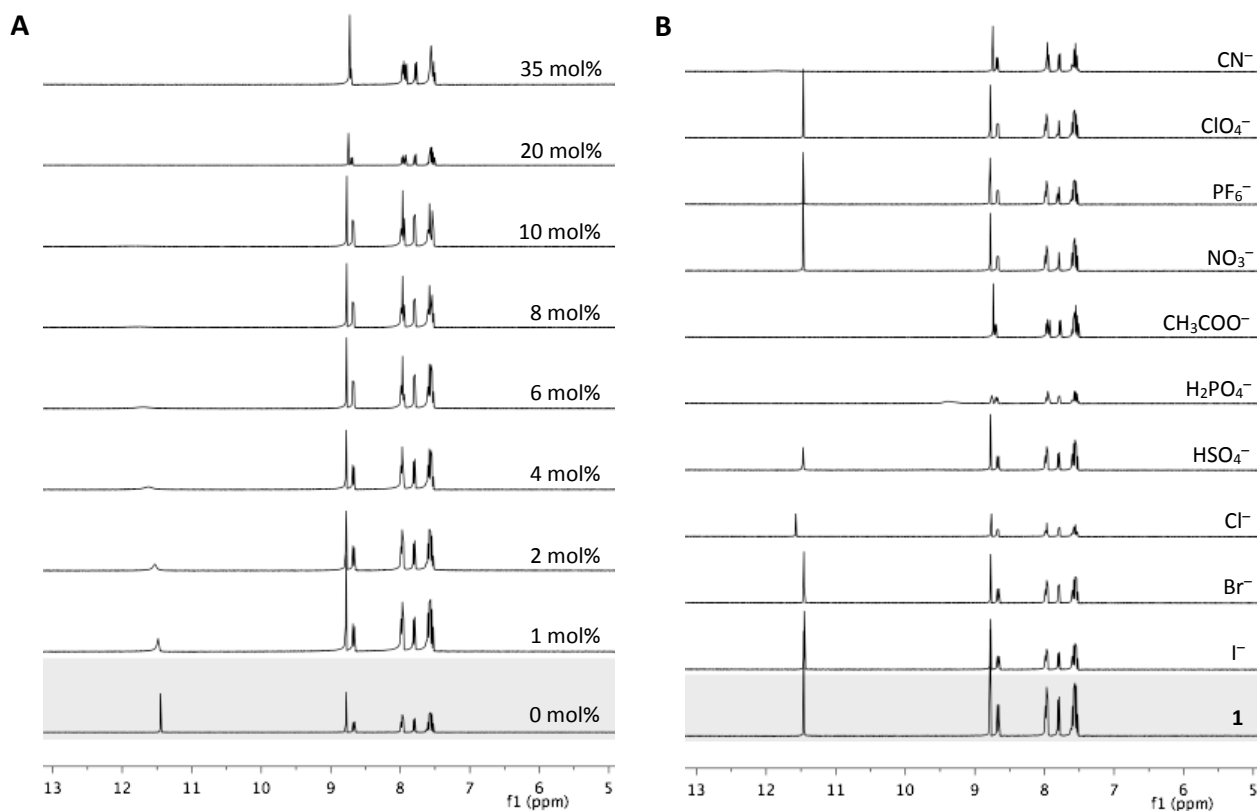
**Figure S5.** Naked-eye visible color change of **1** (150 μM) in different solvents in the presence of TBAF (>100 eq.). The color change is reflecting the UV-Vis absorbance results shown in **S4**.



**Figure S6.** UV-Vis absorbance spectrum of 1-pyrenecarboxaldehyde oxime (**2**) in DMSO (25 μM) in the presence of TBA-Succinimide (40 eq.), *t*BuOK (excess), and TBAF (40 eq.). TBAF and TBA-Succinimide have comparable pK<sub>a</sub> in DMSO (pK<sub>a</sub> ~ 15 for HF and 14.7 for succinimide), whereas *t*BuOK is a strong base in DMSO (pK<sub>a</sub> ~ 32.2 for *t*BuOH). TBA-Succinimide does not cause an absorbance red-shift, whereas *t*BuOK does.

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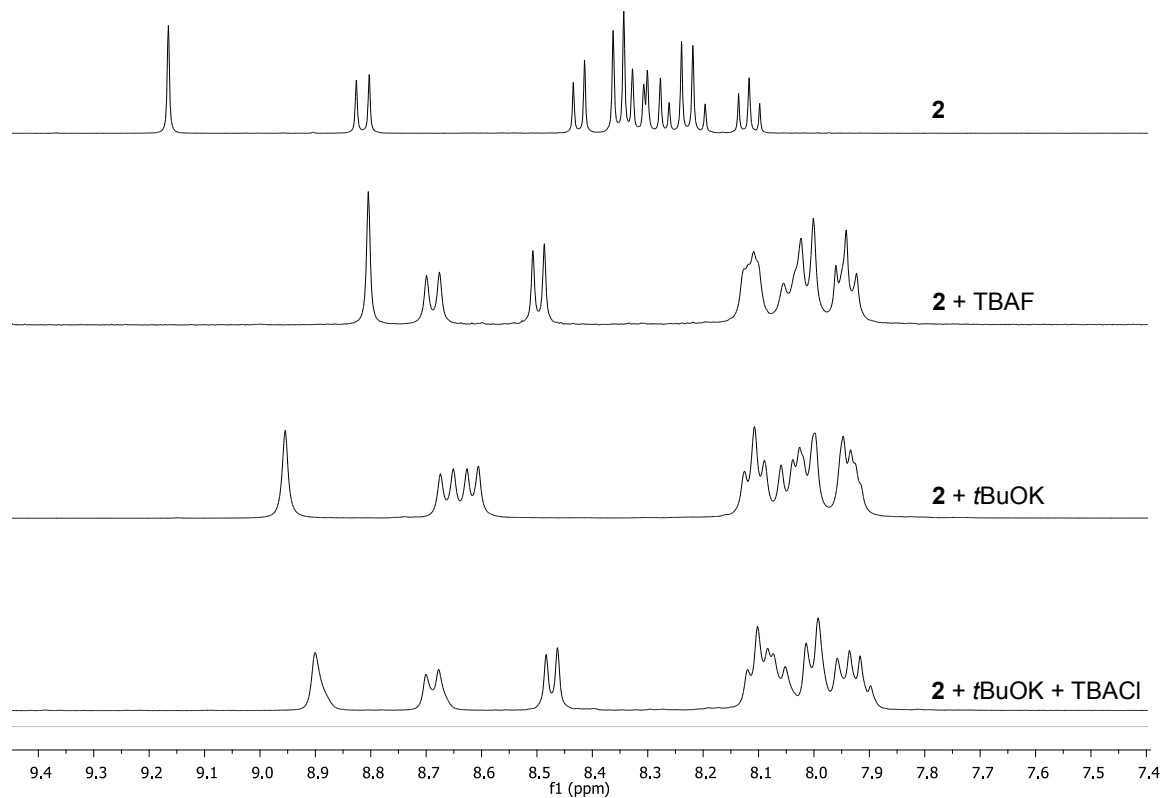
**<sup>1</sup>H NMR analysis of 1-naphthaldoxime (1)**



**Figure S7.** (A) <sup>1</sup>H NMR titration spectra of **1** in DMSO-*d*<sub>6</sub> (178 mM) with different concentrations of TBAF (given in mol% compared to **1**). (B) <sup>1</sup>H NMR spectra of **1** in DMSO-*d*<sub>6</sub> (161 mM) in the presence of different TBA<sup>+</sup> anion combinations (1 eq., 161 mM).

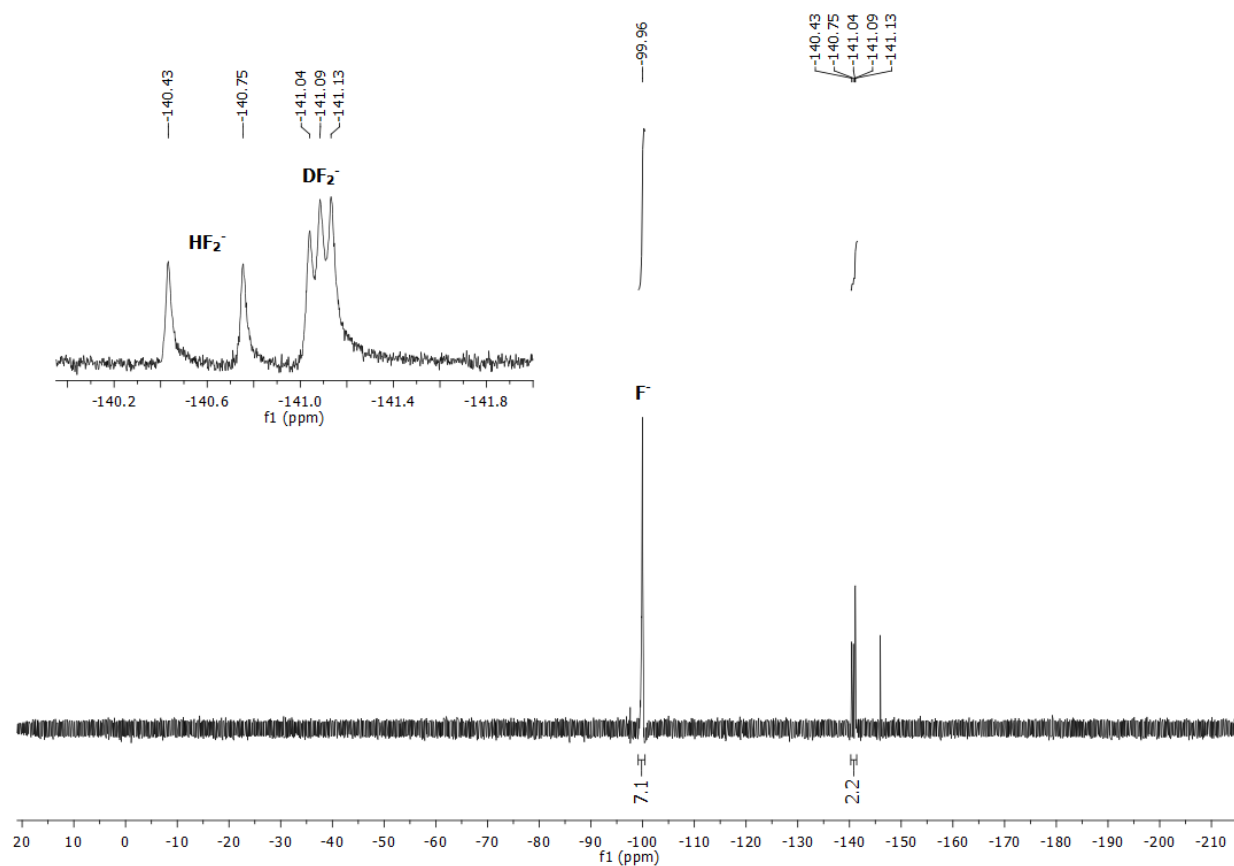
Electronic Supplementary Information

**<sup>1</sup>H NMR analysis of 1-pyrenecarboxaldehyde oxime (2) with strong base**



**Figure S8.** <sup>1</sup>H NMR spectra of 1-pyrenecarboxaldehyde oxime (2) in DMSO-*d*<sub>6</sub> (40 mM) with TBAF (2 eq.), tBuOK (1.5 eq.), and tBuOK (1.5 eq.) + TBACl (3 eq.). TBACl is added to show the effect of the counter-ion on the chemical shift.

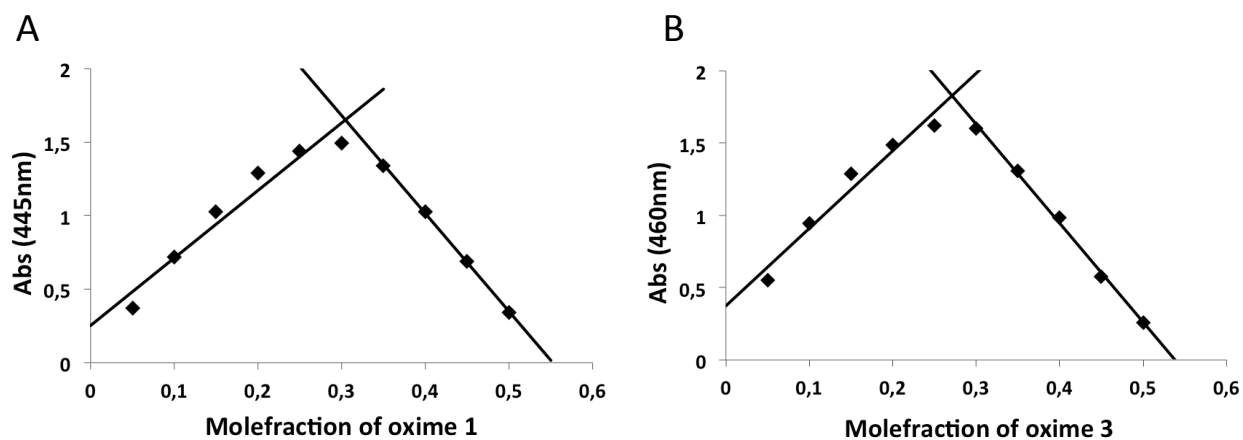
**$^{19}\text{F}$  NMR analysis of 1-pyrenecarboxaldehyde oxime (**2**) interaction with TBAF**



**Figure S9.**  $^{19}\text{F}$  NMR spectrum of **2** (10 mM) and TBAF (93 mM) in  $\text{DMSO-}d_6$  showing the formation of  $\text{HF}_2^-$ . Inset shows a zoom-in on the region -142 ppm to -140 ppm containing the  $^{19}\text{F}$  signals from  $\text{HF}_2^-$  and  $\text{DF}_2^-$ .

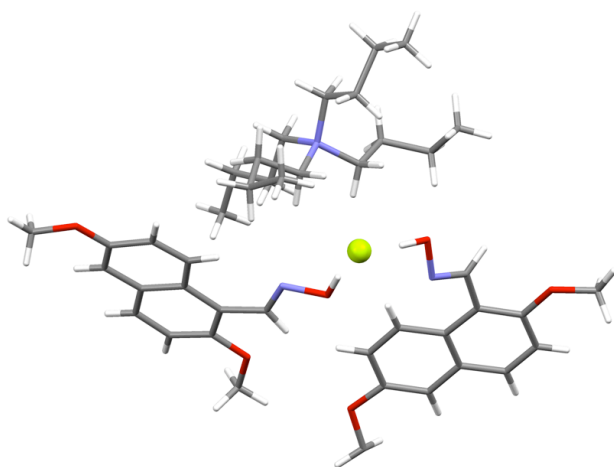
## Electronic Supplementary Information

### Job's analysis of 1-naphthaldoxime (1) and 2,6-dimethoxy-1-naphthaldoxime (3)



**Figure S10.** Job's analysis of (A) 1-naphthaldoxime **1** by measuring the absorbance at 445 nm and (B) 2,6-dimethoxy-1-naphthaldoxime **3** by measuring the absorbance at 460 nm, both (A) and (B) are measured at a constant total concentration of 10 mM.

### Crystal structures of oximes: TBAF



**Figure S11.** Crystal structure of 2,6-dimethoxy-1-naphthaldoxime **3** and TBAF. Two oximes coordinate through H-bonding with a single fluoride ion (green sphere), whereas the TBA<sup>+</sup> counter ion is located above the fluoride anion. The O-H...F distances are 2.484 Å (left oxime) and 2.478 Å (right oxime) and the  $\angle OFO$  is 88.64°.

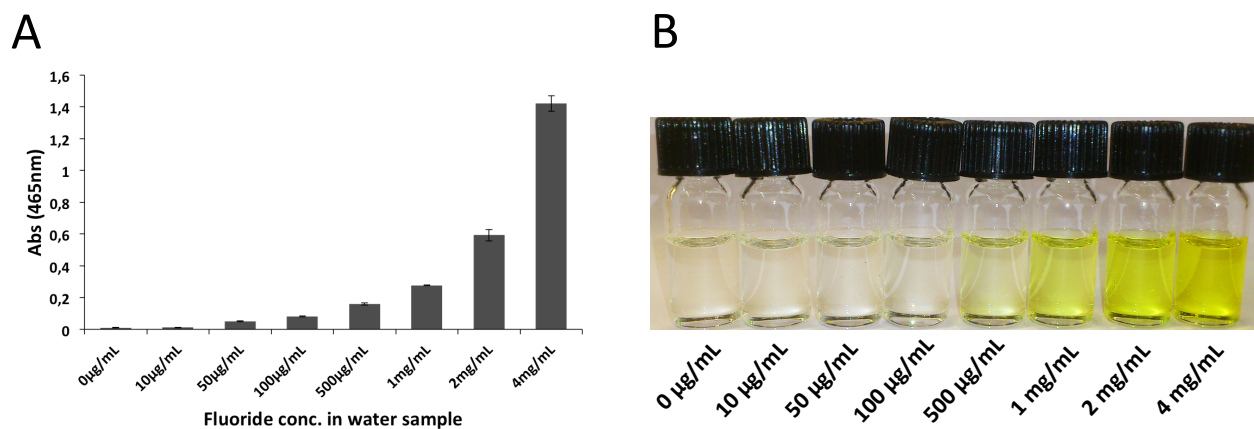
Electronic Supplementary Information

**Table S1.** Crystal structure data, data collection, and structure refinement

	<u>Oxime 1 + TBAF</u>	<u>Oxime 3 + TBAF</u>
Molecular formula	C <sub>38</sub> H <sub>54</sub> FN <sub>3</sub> O <sub>2</sub>	C <sub>42</sub> H <sub>62</sub> FN <sub>3</sub> O <sub>6</sub>
Formula weight	603.84	723.95
Crystal system	monoclinic	monoclinic
Space Group	P 1 21/c 1	P 1 21 1
a (Å)	17.2054	8.4365
b (Å)	8.3014	19.7096
c (Å)	23.741	11.9702
α (°)	90	90
β (°)	96.687	91.556
γ (°)	90	90
Volume (Å <sup>3</sup> )	3367.8	1989.7
Z	4	2
T (K)	100	100
ρ (g cm <sup>-1</sup> )	1.191	1.208
λ (Å)	0.71073	0.7107
μ (mm <sup>-1</sup> )	0.077	0.083
# measured reflections	12793	21857
# unique reflections	4105	9275
R <sub>int</sub>	0.0714	0.027
# parameters	406	485
R(F <sup>2</sup> ), all reflections	0.1256	0.041
R <sub>w</sub> (F <sup>2</sup> ), all reflections	0.1418	0.083
Goodness of fit	1.001	1.046

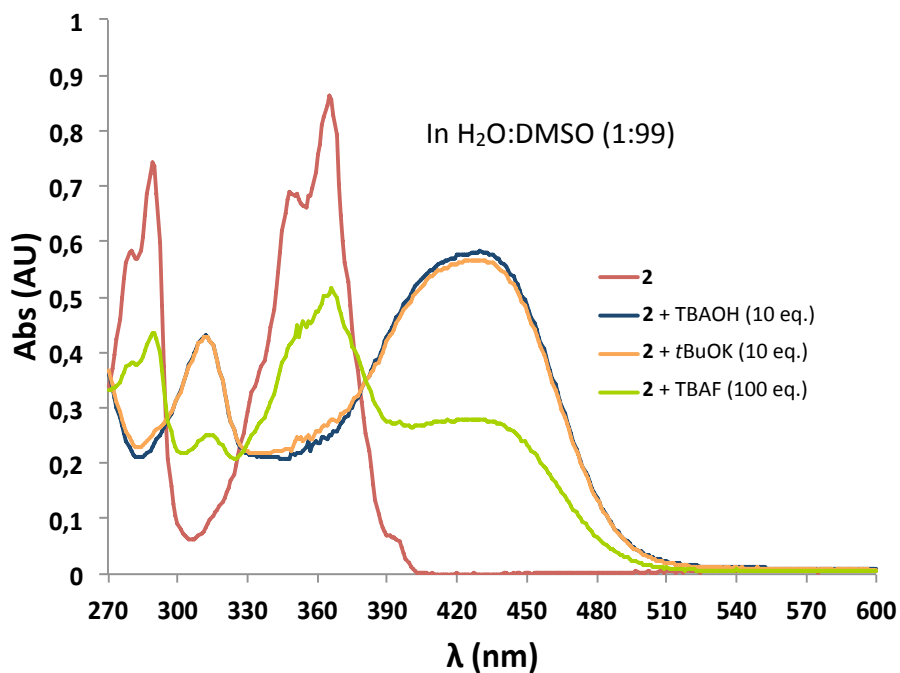
Electronic Supplementary Information

Fluoride detected in water samples (0-4 mg/mL)



**Figure S12.** A) UV-Vis absorption at 465 nm upon addition of 10  $\mu\text{L}$  water samples containing different amounts of fluoride to 990  $\mu\text{L}$  arylaloxime **2** in DMSO (10 mM). The UV-Vis absorbance is corrected according to the oxime background signal. (B) Corresponding naked-eye colorimetric readout upon addition of fluoride-containing water samples.

Absorbance red-shift from strong base in water samples

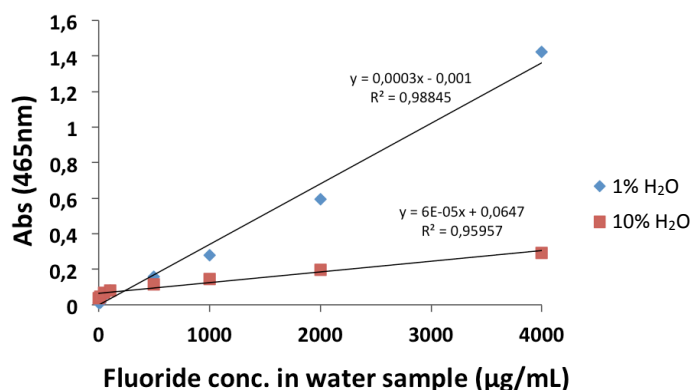


**Figure S13.** UV-Vis absorption spectrum of 25  $\mu\text{M}$  1-pyrenecarboxaldehyde oxime (**2**) in  $\text{H}_2\text{O}:\text{DMSO}$  (1:99) with TBAF or strong bases (TBAOH or *t*BuOK). To 990  $\mu\text{L}$  of **2** in DMSO was added 10  $\mu\text{L}$  base (TBAF, TBAOH or *t*BuOK) in water.



## Electronic Supplementary Information

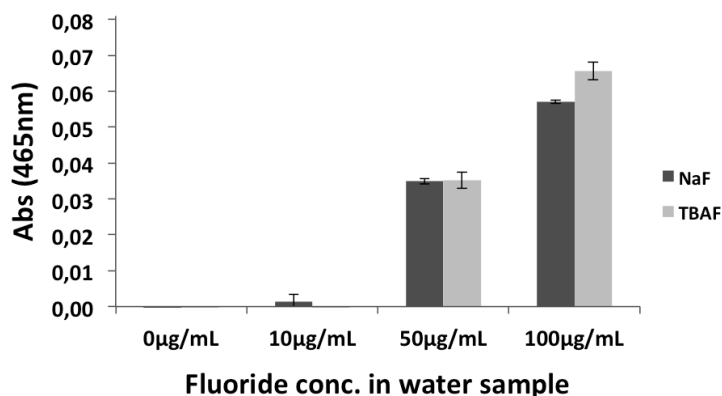
### Effect of the water concentration



**Figure S14.** Comparison of the effect of the final water concentration. To a solution of oxime **2** in DMSO (10 mM) was added different amounts of TBAF in water (corresponding to a final water concentration of either 1% or 10%).

### Detection of NaF in water samples

At elevated concentrations of NaF (>100 µg/mL), the UV-Vis absorbance did not increase further, which we ascribe to the low solubility of NaF in DMSO.<sup>[5]</sup>



**Figure S15.** Comparison of the UV-Vis absorbance of TBAF and NaF at different concentrations in water samples at 465 nm. Final concentration of water in DMSO is 1%. To 990 µL of a solution of oxime **2** in DMSO (10 mM) was added 10 µL of the fluoride containing water sample. The UV-Vis absorbance is corrected according to the oxime background.

- [1] R. S. Ramón, J. Bosson, S. Díez-González, N. Marion, S. P. Nolan, *J. Org. Chem.* **2010**, *75*, 1197–1202.
- [2] J. Y. Lee, Y. H. Lee, Y. G. Byun, *Phosphorus Sulfur Silicon Relat. Elem.* **2012**, *187*, 641–649.
- [3] G. R. Reddy, C.-C. Kuo, U.-K. Tan, M. S. Coumar, C.-Y. Chang, Y.-K. Chiang, M.-J. Lai, J.-Y. Yeh, S.-Y. Wu, J.-Y. Chang, et al., *J. Med. Chem.* **2008**, *51*, 8163–8167.
- [4] C. Grundmann, R. Richter, *J. Org. Chem.* **1968**, *33*, 476–478.
- [5] R. L. Benoit, S. Y. Lam, *J. Am. Chem. Soc.* **1974**, *96*, 7385–7390.