

*Electronic Supporting Information for:*

# Microwave-assisted Generation of Alkoxy Radicals and their Use in Additions, $\beta$ -Fragmentations, and Remote Functionalizations

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## 1 General Remarks

(i) The compound numbering in this Supporting Information is consistent with that of the accompanying publication, with the exception of heterocycles **19–21** that exclusively appear in the Supporting Information. (ii) References refer exclusively to the Supporting Information. The abbreviation DTA stands for differential thermoanalysis.

## 2 Instrumentation

Melting points [°C] were determined on a Koffler hot-plate melting point microscope (*Reichert*). Differential-thermoanalyses (DTA) of substituted *N*-(alkoxy)thiazole-2(3*H*)-thiones were performed with a Thermal-Analyser 9000 (*Du Pont*). Photoreactions were performed using a Rayonet<sup>®</sup> chamber reactor, equipped with RPR-350 nm lamps (*Southern New England*). <sup>1</sup>H And <sup>13</sup>C spectra were recorded with a AC 400 and a AC 250 spectrometer (*Bruker*). Chemical shifts refer to the  $\delta$ -scale (coupling constants *J* are given in Hz). The residual protons of deuterated solvents CDCl<sub>3</sub> or C<sub>6</sub>D<sub>6</sub> were used as internal standards. Mass spectra (EI, 70 eV) and high resolution mass spectra (HRMS) were recorded with a Match 7 instrument (*Varian*). UV/Vis-spectra were recorded in 1 cm-quartz cuvettes with a Cary 50 spectrometer (*Varian*) at 20 °C using analytical grade EtOH or *n*-hexane as solvents. Molar extinction coefficients ( $\epsilon$ ) are reported in dm<sup>3</sup> × mol<sup>-1</sup> × cm<sup>-1</sup>. GC Analyses were performed on a GC 6000, Vega Series 2, FID (*Carlo Erba Instruments*). C,H,N,S-analyses were performed on a *Carlo Erba* 1106 instrument (Mikroanalytisches Labor, Universität Würzburg). Epr spectra were recorded with an ESP 300 spectrometer (*Bruker*) operating in the X-band mode at 15 mW microwave power and a modulation amplitude of 1.0 G at 20 °C.

## 3 Synthesis of *N*-(Alkoxy)-4-(*p*-chlorophenyl)thiazole-2(3*H*)-thiones

*N*-(Alkoxy)-4-(*p*-chlorophenyl)thiazolethiones **2** were prepared by treatment of *N*-hydroxy-4-(*p*-chlorophenyl)thiazole-2(3*H*)-thione tetraethylammonium salt with a suitable alkyl tosylate or chloride in anhydrous DMF as reported previously.<sup>1,2</sup>

**3.1** *N*-(2-Phenyl-4-penten-1-oxy)-4-(*p*-chlorophenyl)thiazole-2(3*H*)thione (**2e**): (0.85 g, 74 %); DTA 114 °C (endotherm.) 150 °C (exotherm.); white solid (from petroleum ether/Et<sub>2</sub>O); *R*<sub>f</sub> = 0.35 [SiO<sub>2</sub>, petroleum ether/Et<sub>2</sub>O = 3:1 (v/v)].<sup>2</sup>

**3.2** *N*-(5-Methyl-1-phenyl-4-hexen-1-oxy)-4-(*p*-chlorophenyl)-thiazole-2(3*H*)thione (**2h**): (0.91 g, 48 %); m.p. 103–105 °C; pale yellow solid (from petroleum ether/Et<sub>2</sub>O); *R*<sub>f</sub> = 0.45 [SiO<sub>2</sub>, petroleum ether/Et<sub>2</sub>O = 5:1 (v/v)].<sup>3</sup>

**3.3** *N*-(1-Pentoxy)-4-(*p*-chlorophenyl)thiazole-2(3*H*)thione (**2k**): (0.69 g, 57 %); m.p. 62–64 °C; colorless solid; *R*<sub>f</sub> = 0.35 [SiO<sub>2</sub>, petroleum ether/Et<sub>2</sub>O = 3:1 (v/v)].<sup>2</sup>

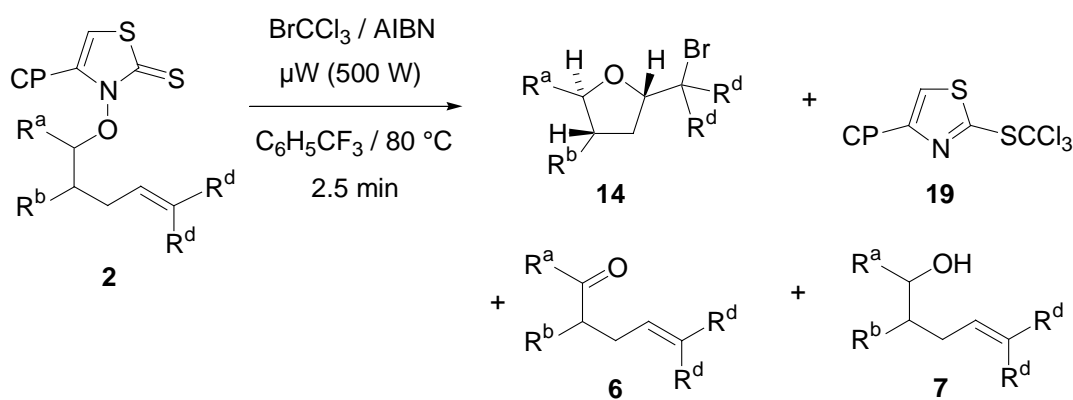
- 3.4 *N*-(*cis*-2-Methylcyclopentoxy)-4-(*p*-chlorophenyl)-thiazole-2(3*H*)thione *cis*-(2i):** (0.72 g, 64 %), DTA 88 °C (endotherm.) 101 °C (exotherm.); colorless solid (from petroleum ether);  $R_f = 0.40$  [ $\text{SiO}_2$ , petroleum ether/ $\text{Et}_2\text{O} = 3:1$  (v/v)];  $\text{C}_{15}\text{H}_{16}\text{ClNOS}_2$  requires C 55.29, H 4.95, N 4.30, S, 19.68 %; found C 55.46, H 5.13, N 4.18, S 19.39.  $\lambda_{\text{max}}$  (EtOH)/nm ( $\lg \epsilon$ ) 338 (4.14), 232 (4.16);  $\delta_{\text{H}}$  (400 MHz;  $\text{CDCl}_3$ ) 1.19 (d,  $J = 7.1$ , 3 H), 1.20–2.06 (m, 6 H), 5.32 (s, 1 H), 6.48 (s, 1 H), 7.28 (m<sub>c</sub>, 4 H, Ar-H);  $\delta_{\text{C}}$  (100 MHz;  $\text{CDCl}_3$ ) 14.0, 18.1, 29.6, 31.6, 39.8, 90.4, 105.7, 127.8, 128.1, 129.4, 130.1, 136.4, 142.0, 162.9, 181.5 (C=S);  $m/z$  (EI) 325 [ $\text{M}^+$ ] (8 %), 243 (100), 226 (37), 168 (64), 83 (31).
- 3.5 *N*-(*cis*-2-Phenylcyclopentyl-1-oxy)-4-(*p*-chlorophenyl)-thiazole-2(3*H*)thione *cis*-(2j):** (0.86 g, 48 %), DTA 132 °C (exotherm.); tan solid (from petroleum ether/ $\text{Et}_2\text{O}$ );  $R_f = 0.30$  [ $\text{SiO}_2$ , petroleum ether/ $\text{Et}_2\text{O} = 3/1$  (v/v)];  $\text{C}_{20}\text{H}_{18}\text{ClNOS}_2$  requires C 61.92, H 4.68, N 3.61 S 16.53 %; found C 62.10, H 5.01, N 3.65, S 16.07;  $\delta_{\text{H}}$  (400 MHz;  $\text{CDCl}_3$ ) 2.50 (m<sub>c</sub>, 4 H), 2.57 (m<sub>c</sub>, 2 H), 2.97 (br s, 1 H), 4.17 (br s, 1 H), 6.46 (s, 1 H), 7.33–7.41 (m, 5 H, Ph-H), 7.49 (m<sub>c</sub>, 2 H, Ar-H), 7.65 (m<sub>c</sub>, 2 H, Ar-H);  $\delta_{\text{C}}$  (100 MHz;  $\text{CDCl}_3$ ) 21.9, 30.1, 46.2, 55.8, 72.9, 105.8, 126.9, 128.3, 129.5, 130.0, 132.7, 136.8, 140.0, 144.1, 181.0 (C=S)  $m/z$  (EI, 70 eV) 387 [ $\text{M}^+$ ] (0.2 %), 371 (1), 227 (100), 168 (51), 133 (35).
- 3.6 *N*-(4-Phenyl-1-butoxy)-4-(*p*-chlorophenyl)thiazole-2(3*H*)-thione (2m):** (0.82 g, 28 %); DTA 38 °C (endotherm.) 100 °C (exotherm.); tan solid;  $R_f = 0.30$  [ $\text{SiO}_2$ , petroleum ether/ $\text{Et}_2\text{O} = 2:1$  (v/v)];  $\text{C}_{19}\text{H}_{18}\text{ClNOS}_2$  (375.93) requires C 60.71, H 4.83, N 3.73, S 17.06 %; found C 60.78, H 5.02, N 3.72, S, 16.79.  $\delta_{\text{H}}$  (400 MHz;  $\text{CDCl}_3$ ) 1.52–1.68 (m, 4 H), 2.52 (br s, 2 H), 4.10 (br s, 2 H), 6.50 (s, 1 H), 7.05–7.10 (m, 2 H, Ph), 7.15–7.21 (m, 1 H, Ph), 7.14–7.30 (m, 2 H, Ph), 7.42 (m<sub>c</sub>, 2 H, Ar-H), 7.51 (m<sub>c</sub>, 2 H, Ar-H);  $\delta_{\text{C}}$  (100 MHz;  $\text{CDCl}_3$ ) 27.5, 27.6, 35.6, 75.7, 105.8, 126.2, 127.0, 128.7, 129.6, 130.0, 136.7, 140.4, 142.0, 181.1 (C=S);  $m/z$  (EI, 70 eV) 375 [ $\text{M}^+$ ] (1 %), 359 (10), 298 (11), 227 (32), 192 (6), 168 (17), 104 (100), 91 (67).

## 4 Microwave-assisted Transformations of *N*-(Alkoxy)-4-(*p*-chlorophenyl)thiazole-2(3*H*)-thiones

### 4.1 Formation of Functionalized Tetrahydrofurans – Additions

For microwave instrumentation, general procedures, and temperature profiles, refer to the Experimental Part of the associated publication.

**Table 4.1** Microwave-assisted conversion of *N*-(alkenoxy)thiazolethiones **2e** and **2h** in the presence of BrCCl<sub>3</sub><sup>a</sup>



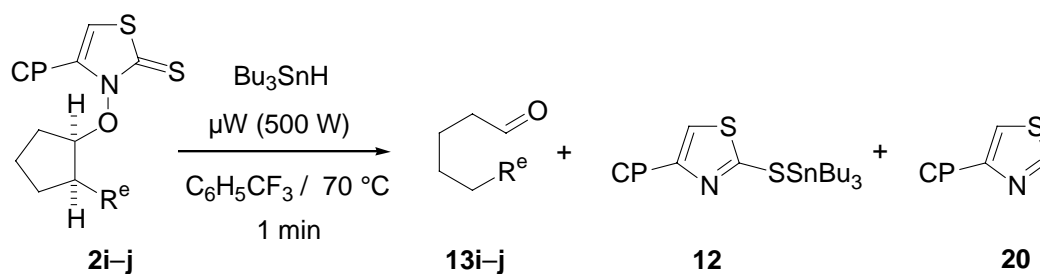
| entry | <b>2, 6, 7, 14</b> | R <sup>a</sup>                | R <sup>b</sup>                | R <sup>d</sup>  | <b>14</b> [%] <sup>b</sup> ( <i>cis:trans</i> ) | <b>6</b> [%] | <b>7</b> [%] | <b>15</b> [%] <sup>b</sup> |
|-------|--------------------|-------------------------------|-------------------------------|-----------------|---|--------------|--------------|----------------------------|
| 1     | <b>e</b>           | H                             | C <sub>6</sub> H <sub>5</sub> | H               | 61 [54] (88:12)                                 | 24           | 8            | 78 [65]                    |
| 2     | <b>h</b>           | C <sub>6</sub> H <sub>5</sub> | H                             | CH <sub>3</sub> | 46 (30:70)                                      | 21           | 9            | 81                         |

<sup>a</sup> CP = *p*-ClC<sub>6</sub>H<sub>4</sub>; 3.0 equiv. of BrCCl<sub>3</sub>; 3.0–5.0 equiv. of AIBN. Yields were determined via <sup>1</sup>H NMR, except of data provided in brackets [isolated yields].

## 4.2 Formation of Carbonyl Compounds – $\beta$ -Fragmentations

For microwave instrumentation, general procedures, and temperature profiles, refer to the experimental part of the associated publication.

**Table 4.2** Formation of aldehydes from 2-substituted *N*-(cyclopentoxy)thiazolethiones **2i** and **2j** and  $\text{Bu}_3\text{SnH}$ .<sup>a</sup>



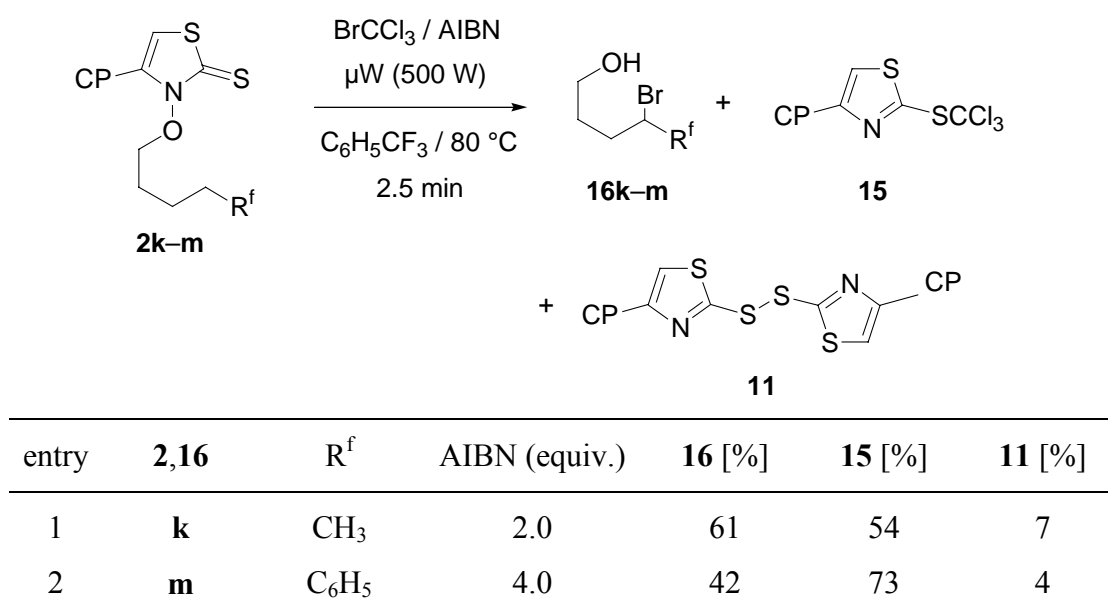
| entry | <b>2, 13</b> | $\text{R}^e$           | <b>13</b> [%]   | <b>12</b> [%] | <b>20</b> [%]  |
|-------|--------------|------------------------|-----------------|---------------|----------------|
| 1     | <b>i</b>     | $\text{CH}_3$          | 61 <sup>b</sup> | 94            | – <sup>c</sup> |
| 2     | <b>j</b>     | $\text{C}_6\text{H}_5$ | 35              | 73            | 6              |

<sup>a</sup> CP = *p*-ClC<sub>6</sub>H<sub>4</sub>; 2.0 equiv. (entry 1) or 2.5 equiv. of  $\text{Bu}_3\text{SnH}$  (entry 2). Unless otherwise noted, yields were determined via <sup>1</sup>H NMR. <sup>b</sup> GC. <sup>c</sup> Not detected (<sup>1</sup>H NMR).

### 4.3 Formation of $\delta$ -Bromohydrins – Homolytic Substitution

For microwave instrumentation, general procedures, and temperature profiles, refer to the Experimental Part of the associated publication.

**Table 4.3** Formation of  $\delta$ -bromohydrins **16** from *N*-(alkoxy)thiazolediones **1**<sup>a</sup>



<sup>a</sup> CP = *p*-ClC<sub>6</sub>H<sub>4</sub>; 5.0 equiv. of BrCCl<sub>3</sub>. Yields were determined via <sup>1</sup>H NMR.

## 5 References

- [1] J. Hartung and M. Schwarz, *Org. Synth.*, 2002, **79**, 228.
- [2] J. Hartung, M. Schwarz, I. Svoboda, H. Fuess and M.-T. Duarte, *Eur. J. Org. Chem.*, 1999, 1275
- [3] J. Hartung, R. Kneuer, S. Laug, P. Schmidt, K. Špehar, I. Svoboda and H. Fuess, *Eur. J. Org. Chem.*, 2003, 4033.