Ozonization of Thioketones and Aryl Arenedithiocarboxylates, a Novel Route to Sterically Hindered Sulfines

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Table. Comparison of Reactant Proportions in the Sodium/Liquid Ammonia Reduction of 2-(Tetradec-9-ynyl)-tetrahydropyran (1) to £-2-(Tetradec-9-enyl)-tetrahydropyran (2)

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Alkyne 1 (mol)</th>
<th>Sodium (g-atom)</th>
<th>Liquid NH₃ (ml)</th>
<th>Ether (ml)</th>
<th>Ratio of trans-2:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.038</td>
<td>0.18</td>
<td>400</td>
<td>20</td>
<td>1.21:1</td>
</tr>
<tr>
<td>B</td>
<td>0.045</td>
<td>0.21</td>
<td>1000</td>
<td>50</td>
<td>8.55:1</td>
</tr>
<tr>
<td>C</td>
<td>0.038</td>
<td>0.18</td>
<td>1000</td>
<td>100</td>
<td>8.55:1</td>
</tr>
</tbody>
</table>

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Ozonization of Thioketones and Aryl Arene-dithiocarboxylates, a Novel Route to Sterically Hindered Sulfines

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We have earlier reported that the oxidation of thiocarbonyl compounds with peroxyacids provides a general route to a variety of sulfines. Ozonization is generally recognized as a clean, mild, and selective method of oxidation and therefore would be attractive for the preparation of sulfines. In the present communication, we report our results obtained in the ozonization of thioketones and aryl arenedithiocarboxylates.

When ozone was passed through a solution of thiobenzophenone (1a) in dichloromethane, rapid decolorization of the mixture was observed and benzophenone was isolated as the only product. The same result was obtained under strictly controlled reaction conditions (1 equiv of ozone in dichloromethane at —78°). 4,4'-Dimethoxythiobenzophenone (1b) reacts analogously. With sterically hindered thioketones (1c–f, Table 1), however, the reaction takes a different course giving rise to the formation of sulfines. Thus, from the ozonization of 2,4,6-trimethylthiobenzophenone (1c) using 1 equiv of ozone in dichloromethane at —78°, phenyl-(2,4,6-trimethylphenyl)sulfine was obtained in 61% yield as a mixture of the Z- and £-isomers.

Similar results were obtained with aryl arenedithiocarboxylates (Table 2). Whereas ozonization of phenyl dithiobenzoate (1g) affords S-phenyl thiobenzoate as the only product, ozonization of the sterically hindered dihioesters 1h–l using 1 equiv of ozone gives fair to good yields of the corresponding sulfines.

The remarkable difference in the behavior of unhindered and sterically hindered substrates may be rationalized by the following assumption (Scheme A). In the case of un-
hindered thiocarbonyl compounds, the thiocarbonyl group of 1 undergoes cycloaddition with ozone with subsequent loss of sulfur dioxide to give the carbonyl compound (2). In the case of sterically hindered substrates, the cycloaddition of ozone is rendered difficult or even impossible; instead, nucleophilic attack of the thiocarbonyl sulfur on the ozone molecule may take place; subsequent elimination of oxygen yields the sulfine (3).

As sulfines are themselves sensitive to oxidizing agents, we also investigated the reaction of these compounds with ozone. Upon treatment with 1 equiv of ozone, almost all of the sulfines listed in Table 3 (sulfine Z-3h is an exception) reacted smoothly to give the corresponding carbonyl compounds as the main products. In some cases reduction products, viz., the thiocarbonyl compounds (1) were also isolated. The predominant formation of carbonyl compounds (2) in this reaction may be explained by cycloaddition of ozone to the sulfine (3) and elimination of sulfur trioxide from the cycloaddition product, whereas the formation of thiocarbonyl compounds (1) could proceed via nucleophilic attack of the sulfine oxygen on the ozone molecule followed by elimination of oxygen.

![Scheme B](image)

Scheme B

In all ozonization experiments with sterically hindered thioketones and dithioesters using 1 equivalent of ozone considerable amounts of starting material can be recovered, while only small quantities of the corresponding ketones or 5-aryl thiocarboxylates, respectively, are found in the product mixture. This apparent loss of ozone is not caused by obvious reasons such as escape from the reaction vessel or thermal degradation of ozone. The isolation of reduction products during ozonization of sulfines (Scheme B) may account for this unexpected ozone consumption.

The mechanism proposed in Scheme B is also supported by the fact that the ozonization product obtained from Z-3h contains a considerable amount of the opposite isomer (E-3h).

Although the proposed Schemes A and B are rather speculative it is evident that the conversion of thiobenzophenone (1a) to benzophenone (2a) by ozonization does not proceed via the intermediacy of a sulfine since this would not be compatible with the observed consumption of only 1 equiv of ozone for quantitative conversion. The difference in the mechanisms of the ozonization of unhindered and hindered thiocarbonyl compounds (Scheme A) is related to the differences encountered in the ozonization of sterically unhindered and hindered alkenes.

Although all of the sulfines listed in Tables 1 and 2 may be prepared by peroxyacid oxidation of thioketones, the present simple ozonization method provides an attractive alternative, particularly in view of the considerably different Z/E ratio of the products obtained.

### Table 1. Ozonization of Thioketones using One Equivalent of Ozone

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Sulfine Yield (%)</th>
<th>Z/E Ratio</th>
<th>m.p.</th>
<th>Recovered Substrate Yield (%)</th>
<th>Ketone Yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>0</td>
<td>—</td>
<td>—</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>1b</td>
<td>0</td>
<td>—</td>
<td>—</td>
<td>9</td>
<td>47 (40% tar)</td>
</tr>
<tr>
<td>1c</td>
<td>61</td>
<td>60/40</td>
<td>Z: 98–101° E: 58–59°</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>1d</td>
<td>32</td>
<td>70/30</td>
<td>Z: 70.8–71.5° E: oil</td>
<td>0*</td>
<td>35</td>
</tr>
<tr>
<td>1e</td>
<td>43 one isomer*</td>
<td>oil, crystals at 0°</td>
<td>40</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>1f</td>
<td>27 one isomer*</td>
<td>49.5–51°</td>
<td>58</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

* This substrate is unstable and is rapidly converted to the ketone during chromatography.

* The geometry could not be established.
Table 2. Ozonization of Aryl Aroledithiocarboxylates using One Equivalent of Ozone

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Sulfine Yield (%)</th>
<th>Z/E Ratio</th>
<th>m.p.</th>
<th>Recovered Substrate (%)</th>
<th>S-Aryl Thio-carboxylate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1g</td>
<td>0</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>100</td>
</tr>
<tr>
<td>1h</td>
<td>41</td>
<td>65/35</td>
<td>Z: 98–100°</td>
<td>E: 69.5–70.5°</td>
<td>51</td>
</tr>
<tr>
<td>1i</td>
<td>37</td>
<td>45/55</td>
<td>Z: 124–125°</td>
<td>E: 27–28.5°</td>
<td>54</td>
</tr>
<tr>
<td>1k</td>
<td>38</td>
<td>40/60</td>
<td>Z: 197–199°</td>
<td>E: 130.1–130.2°</td>
<td>59</td>
</tr>
<tr>
<td>1l</td>
<td>23</td>
<td>80/20</td>
<td>Z: 102–103°</td>
<td>E: 62–63°</td>
<td>60</td>
</tr>
</tbody>
</table>

Table 3. Ozonization of Sulfines using One Equivalent of Ozone

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Carbonyl Compound</th>
<th>Recovered Substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yield (%)</td>
<td>% Z/E Ratio</td>
</tr>
<tr>
<td>3a</td>
<td>69</td>
<td>2</td>
</tr>
<tr>
<td>3b</td>
<td>64</td>
<td>0</td>
</tr>
<tr>
<td>3m</td>
<td>86</td>
<td>10</td>
</tr>
<tr>
<td>3n</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>E-3h</td>
<td>84</td>
<td>1</td>
</tr>
<tr>
<td>Z-3h</td>
<td>3</td>
<td>48</td>
</tr>
<tr>
<td>3l</td>
<td>72</td>
<td>23</td>
</tr>
</tbody>
</table>

Ozonization of Thiocarbonyl Compounds; General Procedure:
The reactions were carried out on a 0.4–2.0 mmol scale. Ozone was prepared by passing a stream of dried oxygen through a "Fischer ozone generator". The ozone thus formed was led into a known volume of dichloromethane at —78°. According to Rubin11, a saturated solution of ozone in dichloromethane at —78° contains 0.04 mol/l; this was checked by iodometric titration. Ozone was transferred from this saturated solution into a solution of the substrate (1 equiv) in dichloromethane at —78° within 20 min using a slow stream of nitrogen12. When the ozone transfer was completed the reaction mixture was allowed to warm to room temperature. The solvent was removed in vacuo and the residue was subjected to thick-layer chromatography on silica gel using benzene/petroleum ether as eluent. The pure Z- and E-isomers were thus obtained, except in the case of 3i and 3k. The products were characterized by elemental analysis. I.R., and 1H-N.M.R. spectrometry.
The above procedure was also used for the ozonization of the sulfines.
The use of more than 1 equiv of ozone in the above procedure leads to a raise in yield of sulfine; on the other hand, however, this also leads to increased formation of the corresponding ketone.
or 5-aryl thiocarboxylate, respectively, which usually are difficult to separate from the sulfine.

All sulfines listed in Tables 1 and 2 were also prepared by oxidation of the thiocarbonyl compounds with 3-chloroperbenzoic acid. The geometry of the Z- and E-isomers was established as described in Ref. 2 and Ref. 10.

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3 Formation of primary ozonide from an alkene and ozone, see R. Huisgen, Angew. Chem. 75, 604 (1963).
4 C. V. Criegee mechanism for the ozonolysis of alkenes, R. Criegee, Record Chem. Prog. 18, 111 (1957).
5 C. V. Criegee mechanism for the ozonolysis of alkenes, P. S. Bailey, Chem. Rev. 58, 925 (1958).

Synthesis of 1,2,3-Trimethyl-, 1,2,3,7-Tetramethyl-, and 1,2,3,5,6,7-Hexamethylnaphthalenes

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Division of Chemistry, National Research Council, Ottawa, Ontario, Canada

This report concludes our work on the synthesis of polymethylnaphthalenes from β-hydroxyketones by describing the synthesis of the title compounds from the appropriate Grignard reagents and 3-methylpentanedione. According to Kohler and Erickson[1], β diketones of the type R1—CO—CH(R2)—CO—R3 are cleaved by Grignard reagents. It has now been found, contrary to the results of these authors, that β-hydroxyketones (2) can in fact be obtained in 45-60% yields from 3-methylpentanediol (1) and benzylmagnesium chloride or its homologues by the method reported earlier by us.[2] The yields are generally somewhat lower than those obtained with 2,4-pentanediol but the method is nevertheless quite suitable for preparing these otherwise inaccessible compounds.

The α-methyl-β-phenyl-β-hydroxyketones (2) synthesized in this manner underwent cyclodehydration to polymethylnaphthalenes (3) in 50-55% yields. Here again, the yields are somewhat lower than those obtained with β-hydroxyketones unsubstituted in the CH2 group. Perhaps the presence of a methyl substituent facilitates trans dehydrogenation of the hydroxyketone prior to carbocation formation and cyclization.

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1 H-N.M.R. (CDCl3): δ = 7.23 (m, 5H arom), 2.24, 2.32, 2.48 ppm (3s, 9H, 3CH3).
2 2,3-Dimethyl-2-hydroxy-4-oxo-1-phenylpentane (2, R = H):

Hydroxyketone 2, R = H (70 g, 0.3 mol) was dissolved in polyphosphoric acid (320 ml) and the solution heated at 80° for 2 hr with stirring. The cold reaction mixture was poured into ice-cold 10% sodium hydroxide solution (3 l) and the oil was extracted with ether. The extract was freed of acid by washing with water, 5% aqueous sodium-hydroxide carbonate, and again water, and was dried with potassium carbonate. The ether was evaporated and the residue dissolved in aceton-free methanol (200 ml) and treated with Girard’s reagent T (30 g) and Rexyn 102 (H0) (Fisher Amberlite-IRC-150) resin (2.0 g) as catalyst. The alcohol was distilled off and the crude product purified by bulb-to-bulb distillation; yield: 95g (57%); b.p. 80-85°/0.02 torr.

C11H14O2 calc. C 75.69 H 8.79
(206.3) found 75.62 8.58

I.R.: νOH = 3586 (shoulder), δ = 1705-1, 1700-1.

1H-N.M.R. (CDCl3): δ = 7.87-8.06 (m, 5H arom), 2.16 ppm (s, 3H, CH3).
2.24, 2.32, 2.48 ppm (3s, 9H, 3CH3).

3-Methylpentanediol (1):

This diketone was prepared as described by Johnson, Markham, and Price[3].

3,2-Dimethyl-2-hydroxy-4-oxo-1-phenylpentane (2, R = H):

β-hydroxyketone was prepared by the method described earlier by us from 3-methylpentanediol (1; 0.8 mol) and benzylmagnesium chloride (0.8 mol) and benzylmagnesium chloride (2.0 mol). It was isolated by bulb-to-bulb distillation: yield: 95 g (57%); b.p. 80-85°/0.02 torr.

C11H14O2 calc. C 75.69 H 8.79
(206.3) found 75.62 8.58

I.R.: νOH = 3586 (shoulder), δ = 1705-1, 1700-1.

1H-N.M.R. (CDCl3): δ = 7.23 (m, 5H arom), 2.24, 2.32, 2.48 ppm (3s, 9H, 3CH3).

2,1,2,3-Trimethylnaphthalene (3, R = H):

Hydroxyketone 2, R = H (70 g, 0.3 mol) was dissolved in polyphosphoric acid (320 ml) and the solution heated at 80° for 2 hr with stirring. The cold reaction mixture was poured into ice-cold 10% sodium hydroxide solution (3 l) and the oil was extracted with ether. The extract was freed of acid by washing with water, 5% aqueous sodium-hydroxide carbonate, and again water, and was dried with potassium carbonate. The ether was evaporated and the residue dissolved in aceton-free methanol (200 ml) and treated with Girard’s reagent T (30 g) and Rexyn 102 (H0) (Fisher Amberlite-IRC-150) resin (2.0 g) as catalyst. The alcohol was distilled off and the crude product purified by bulb-to-bulb distillation to give a pale yellow oil; yield: 30 g (52%); m. p. 27 to 80°; m. p. of picrate (orange needles, from ethanol): 144-145° (Ref. 4, m. p. 142.5°; Ref. 5, m. p. 141-142°).

C11H14O2 calc. C 76.34 H 9.17
(220.3) found 76.75 8.83

I.R.: νOH = 3586 (shoulder), δ = 1705-1.

1H-N.M.R. (CDCl3): δ = 6.87-8.06 (m, 5H arom), 1.10 (s, 3H, CH3), 2.16 ppm (3s, 9H, 3CH3).

2,3-Dimethyl-2-hydroxy-1-(4-methylphenyl)-4-oxopentane (2, R = 4-CH3):

This compound was prepared from 3-methylpentanediol (1) and 4-methylbenzylmagnesium chloride by the same procedure as described above for 2, R = H; yield: 46%; b. p. 85-90°/0.02 torr.

C14H16O2 calc. C 76.34 H 9.17
(220.3) found 76.75 8.83

I.R.: νOH = 3586 (shoulder), δ = 1705-1.

1H-N.M.R. (CDCl3): δ = 7.09 (m, 4H arom), 2.77 (s, 2H, CH2CH3), 2.32 (s, 3H, CH3), 2.18 (s, 3H, COCH3), 1.11 ppm (3s, 3H, CH3).