Reaction of Enol Ethers with the I$_2$–H$_2$O$_2$ System: Synthesis of 2-Iodo-1-methoxy Hydroperoxides and Their Deperoxidation and Demethoxylation to 2-Iodo Ketones

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Abstract: The reaction of enol ethers with the I$_2$–H$_2$O$_2$ system in diethyl ether affords 2-iodo ketones and the previously unknown 2-iodo-1-methoxy hydroperoxides. In the presence of the I$_2$–H$_2$O$_2$ system, the latter compounds undergo deperoxidation and demethoxylation to form 2-iodo ketones. The reaction conditions were found for the synthesis of 2-iodo ketones from enol ethers in 67–94% yields.

Key words: enol ethers, hydrogen peroxide, iodine, peroxides, peroxidation

In the last two decades, synthetic routes to organic peroxides have attracted much research interest because these compounds have potent antimalarial activity.¹ Compounds with activity comparable or even superior to that of the natural peroxide artemisinin, which is widely used in the therapy, were synthesized.² A search for natural and synthetic compounds with antitumor activity is a rather new and promising field of application of organic peroxides.³

In the industry, peroxides are widely used as radical polymerization initiators and cross-linking agents. The above-listed practical applications of peroxides stimulated the development of new methods for the synthesis of these compounds.

The present study contributes to the research on the use of the I$_2$–H$_2$O$_2$ system for the peroxidation and halogenation of organic compounds. In recent years, the idea of the combined use of iodine and hydroperoxides or hydrogen peroxide has been applied to the synthesis of peroxides from carbonyl compounds⁴ and alkenes,⁵ as well as to the synthesis of compounds with the monoperoxy ketal moiety⁶ and cyclic triperoxides.⁷ The I$_2$–H$_2$O$_2$ system shows versatile reactivity. In this system, hydrogen peroxide acts not only as the reagent for the formation of the O–O group but also as the iodine activator in the iodoalkylation of alkenes⁸ and the iodination of arenes,⁹ ketones,¹⁰ and alkynes.¹¹ This system was used for the Baeyer–Villiger oxidation of ketones to lactones¹² and the ring contraction in 1,2-quinones to form cyclopentenones.¹³ Results of studies on the electrophilic iodination of organic compounds, including those with hydrogen peroxide, were surveyed in the review.¹⁴

In the present study, we have examined the reactions of cyclic enol ethers 1a–f and linear enol ethers 2a,b with the I$_2$–H$_2$O$_2$ system in diethyl ether and acetonitrile (Scheme 1). It was found that the nature of the solvent has a decisive effect on the reaction pathway. Thus, the reactions in diethyl ether afford 2-iodo ketones and 2-iodo-1-methoxy hydroperoxides, whereas the reactions in aceto-
nitrile give complex mixtures of peroxides and trace amounts of 2-iodo ketones.

Reactions of Enol Ethers with the I$_2$–H$_2$O$_2$ System in Diethyl Ether

The reactions of enol ethers with the I$_2$–H$_2$O$_2$ system in Et$_2$O were carried out with the use of a five-fold molar excess of H$_2$O$_2$ (according to the stoichiometry, a two-fold molar excess of H$_2$O$_2$ is sufficient for the synthesis of iodo dihydroperoxides A) and a stoichiometric amount of iodine (0.5 mole per mole of enol ether). However, the expected 1,1-dihydroperoxy-2-iodoalkanes A (products of the addition hydrogen peroxide and the iodine-catalyzed replacement of the methoxy group) were not obtained at all; instead, the reaction afforded the previously unknown 2-iodo-1-methoxy hydroperoxides 3a–f and 4a,b (in 32–41% yields) and 2-iodo ketones 5a–f and 6a,b (in 40–57% yields) (Table 1, Scheme 2).

2-Iodo-1-methoxy hydroperoxides 3a–f are stable compounds. Under ambient conditions, these compounds remain stable overnight, and they can be stored without decomposition for months at temperatures below –10 °C. These compounds can easily be isolated in the pure state by silica gel column chromatography. The synthesis of iodo peroxides 3c,f was scaled up by a factor of 20 to prepare gram amounts of the compounds in yields given in Table 1.

When studying the behavior of peroxides 3 in the reaction medium under the synthesis conditions (in contact with hydrogen peroxide and iodine), we found that peroxides undergo deperoxidation and demethoxylation to form 2-iodo ketones 5 (Scheme 3).

In diethyl ether, authentic samples of 2-iodo-1-methoxy cycloalkyldihydroperoxides 3a,d,f were transformed into 2-iodo cycloalkanones 5a,d,f in 93–96% yields in the presence of a two-fold molar excess of hydrogen peroxide and iodine (1 mole per mole of 3).

Taking into accounts the above results, we developed a procedure for the preparative synthesis of iodo ketones from enol ethers. As exemplified by iodo ketone 5d, the use of an excess amount of iodine is the key factor determining the selective synthesis from enol ether 1d. In this case, iodomethoxy hydroperoxide 3d was obtained as a by-product. The formation of diiodide B expected in the presence of a large excess of iodine was not observed (Scheme 4, Table 2).

An increase in the amount of iodine from 1 to 2.5 mole(s) per mole of 1d increases the selectivity of the reaction and the yield of iodo ketone 5d; iodo hydroperoxide 3d is generated in trace amounts. The addition of water in an amount equivalent to enol ether has no effect on the yield of iodo ketone 5d.

A series of experiments was carried out with the use of 2 moles of I$_2$ per mole of 1d (see Experimental section) with varying the reaction time (3, 6, and 12 h) and the amount of hydrogen peroxide (3 and 6 moles per mole of 1d). Under these reaction conditions, iodo ketone 5d was obtained in 75–80% yield.

### Table 1

Yields of 2-Iodo-1-methoxy Hydroperoxides 3a–f and 4a,b and 2-Iodo Ketones 5a–f and 6a,b in the Reaction of Enol Ethers 1a–f and 2a,b with I$_2$ and H$_2$O$_2$ in Et$_2$O

<table>
<thead>
<tr>
<th>Enol ether</th>
<th>1a</th>
<th>1b</th>
<th>1c</th>
<th>1d</th>
<th>1e</th>
<th>1f</th>
<th>2a</th>
<th>2b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield of 3a–f,4a,b (%)</td>
<td>3a: 33</td>
<td>3b: 38</td>
<td>3c: 35</td>
<td>3d: 34</td>
<td>3e: 35</td>
<td>3f: 41</td>
<td>4a: 33</td>
<td>4b: 32</td>
</tr>
<tr>
<td>Yield of 5a–f,6a,b (%)</td>
<td>5a: 40</td>
<td>5b: 45</td>
<td>5c: 54</td>
<td>5d: 41</td>
<td>5e: 43</td>
<td>5f: 44</td>
<td>6a: 57</td>
<td>6b: 49</td>
</tr>
</tbody>
</table>

*Reaction conditions: an ethereal solution of H$_2$O$_2$ (2.53 mL, 6.15 mmol, $c = 2.43$ mol/L) was added to a solution of enol ether (1.23 mmol) in Et$_2$O (6 mL), and then I$_2$ (0.16 g, 0.62 mmol) was added. The reaction mixture was kept at 18–22 °C for 6 h.*
Table 2  Influence of the Amount of I₂ on the yields of Iodo Ketone 5d and Hydroperoxide 3d in the Reaction of Enol Ether 1d with the I₂–H₂O₂ System a

<table>
<thead>
<tr>
<th>Mole of I₂</th>
<th>Yield (%) of 2-iodo-1-methoxy-</th>
<th>Yield (%) of iodo cyclohexyl hydroperoxide 3d</th>
<th>Yield (%) of iodo ketone 5d</th>
</tr>
</thead>
<tbody>
<tr>
<td>per mole of 1d</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>25</td>
<td></td>
<td>54</td>
</tr>
<tr>
<td>1.5</td>
<td>17</td>
<td></td>
<td>61</td>
</tr>
<tr>
<td>2</td>
<td>~2</td>
<td></td>
<td>78</td>
</tr>
<tr>
<td>2 b</td>
<td>~2</td>
<td></td>
<td>80</td>
</tr>
<tr>
<td>2.5</td>
<td>~2</td>
<td></td>
<td>79</td>
</tr>
</tbody>
</table>

a Reaction conditions: An ethereal solution of H₂O₂ (2.45 mL, 5.95 mmol, ε = 2.43 mol/L) was added to a solution of 1-methoxycycloheptene (1d; 0.15 g, 1.19 mmol) in Et₂O (6 mL), then I₂ (0.30–0.76 g, 1.19–2.98 mmol) was added, and the reaction mixture was kept at 18–22 °C for 6 h.

The possibility of the formation of iodo ketones by iodination of ketones, which can be generated in small amounts through aqueous hydrolysis of enol ethers, was discarded by experiments, in which the reactions of cyclohexanone and cycloheptanone were carried out with a three-fold molar excess of H₂O₂ and a two-fold molar excess of I₂. After storage of the reaction mixture at 18–22 °C for 6 hours, 2-iodocyclohexanone and 2-iodocycloheptanone were isolated in 6% and 5% yield, respectively. In this case, the iodine-catalyzed peroxidation of ketones proceeds as the major reaction. This is consistent with the results of the study, a b in which iodine catalyzed the peroxidation of ketones in acetonitrile and methanol under similar conditions. Under the optimized conditions of the synthesis of iodo ketone 5d, iodo ketones 5a–f and 6a,b were generated in good yields and with good selectivity from enol ethers 1a–f and 2a,b, respectively (Table 3).

Table 3  Synthesis of Iodo Ketones 5a–f and 6a,b from Enol Ethers 1a–f and 2a,b Under Optimized Conditions a

<table>
<thead>
<tr>
<th>Iodo ketone</th>
<th>5a</th>
<th>5b</th>
<th>5c</th>
<th>5d</th>
<th>5e</th>
<th>5f</th>
<th>6a</th>
<th>6b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield (%)</td>
<td>71</td>
<td>67</td>
<td>68</td>
<td>79</td>
<td>79</td>
<td>88</td>
<td>94</td>
<td>91</td>
</tr>
</tbody>
</table>

a General reaction conditions: an ethereal solution of H₂O₂ (2.45 mL, 5.95 mmol, ε = 2.43 mol/L) was added to a solution of enol ether 1a–f or 2a,b (1.19 mmol) in Et₂O (6 mL), and then I₂ (0.61 g, 2.4 mmol) was added; the reaction time was 3 h at 18–22 °C.

The yield of iodo ketones 5 from cyclic enol ethers increases with increasing ring size. The reaction of linear enol ethers 2a,b affords iodo ketones 6a,b in the maximum yield (94 and 91%, respectively). An increase in the yield is apparently associated with a decrease in the influence of the iodine-induced polymerization, whose contribution decreases with increasing ring size and in the case of linear structures containing the internal double bond. This conclusion is consistent with the experimental observations, according to which the addition of iodine to ethereal solutions of enol ethers (in the absence of hydrogen peroxide) results in the rapid resinification.

Reactions of Enol Ethers with the I₂–H₂O₂ System in Acetonitrile

In acetonitrile, which has found use as the solvent in the peroxidation of organic compounds, a the results of the reactions of enol ethers with the I₂–H₂O₂ system are substantially different from those obtained in diethyl ether. Under the conditions used for the synthesis of 2-iodo-1-methoxy hydroperoxides (Table 1), the reaction in acetonitrile affords a mixture of peroxides. According to the TLC analysis (by comparing with authentic samples) and based on the characteristic signals of the OOCOO fragments in the 13C NMR spectra, a, b 16 the following products of the reactions of 1-methoxycyclohexene 1a and 1-methoxycyclohexane 1d with the I₂–H₂O₂ system were identified: geminal dihydroperoxycyclohexane (7a) (110.4 ppm) and dihydroperoxycyclohexane (7d) (115.7 ppm), 1,1’-dihydroperoxydicyclohexylperoxide (8a) (111.0 ppm) and 1,1’-dihydroperoxydicyclohexylperoxide (8d) (116.3 ppm), and cyclohexane triperoxide (9a) (107.6 ppm) and cycloheptane triperoxide (9d) (112.7 ppm), respectively.

Influence of the Nature of the Reaction Medium on the Composition of the Reaction Products of Enol Ethers with the I₂–H₂O₂ System

It is known that iodine is oxidized by hydrogen peroxide according to a multistep procedure (Bray–Liebhafsky reactionb) through the intermediate formation of H⁺. The reactions of enol ethers with the I₂–H₂O₂ system in diethyl ether and acetonitrile occur by different paths A and B, which is apparently attributed to the different basicity of these solvents (Scheme 5).

Path A: In diethyl ether, the proton of hydroiodic acid is accepted by the ethereal oxygen atom and is removed from the reaction. Iodine and hydrogen peroxide are successively added to enol ether C to form iodomethoxy peroxides 3 and 4, which are reduced with HI (with formation of D) under the reaction conditions and then, after elimination of methanol, are transformed into 2-iodo ketones 5 and 6.

Path B: In acetonitrile, the proton, which is not accepted by the solvent, catalyzes the reaction. The addition of the proton to enol ether E followed by the reaction with hydrogen peroxide affords methoxy hydroperoxide F. After protonation, elimination of methanol, and the addition of hydrogen peroxide, compound F is transformed into geminal dihydroperoxide 7. Then the elimination of hydrogen peroxide H followed by homocondensation affords 1,1’-dihydroperoxydialkylperoxide 8, which reacts with the starting enol ether to form triperoxide 9. Hence, the higher

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basicity of diethyl ether compared to acetonitrile is a key factor determining the reaction pathway.

Structure Determination

The structures of iodo ketones 5 and 6 were established by $^1$H and $^{13}$C NMR spectroscopy based on the characteristic signals for the C=O ($^{13}$C, 203.9–209.7 ppm) and CHI ($^{13}$C, 28.1–33.9 ppm; $^1$H, 4.1–4.4 ppm) groups. $^{10}$

2-Iodo-1-methoxy hydroperoxides 3 and 4 are novel unusual structures containing the oxidizing (OOH), reducing (I), and highly reactive (methoxy hydroperoxide) moieties. The structures of these compounds were proved by $^1$H and $^{13}$C NMR spectroscopy. Thus, the $^{13}$C NMR spectra show signals characteristic of the OCOO (104.7–108.4 ppm), $^1$CI (29.1–36.3 ppm), $^{10}$ and OCH$_3$ (48.3–51.9 ppm) groups corresponding to the known values. The $^1$H NMR spectrum shows the signal at 7.8–8.4 ppm characteristic of the OOH group. $^{6,11}$ Peroxides 3e,f and 4a,b were obtained as mixtures of diastereomers, as evidenced from the doubled number of the signals in the $^{13}$C NMR spectra (the isomers are virtually inseparable by TLC); the starting enol ethers 1f and 2a,f are mixtures of cis-, trans, and E-, Z-isomers.

The 2D NOESY experiment on the establishment of the configuration of iodoperoxide 3a showed the presence of the nuclear Overhauser effect between the proton of the CHI group and the methyl protons, which suggests that they are in equatorial positions, whereas the hydroperoxide group and iodine are in axial positions (Figure 1).

![Figure 1 Conformation of iodoperoxide 3a](image)

Scheme 5  Mechanism of the reaction of enol ethers with the I$_2$–H$_2$O$_2$ system in Et$_2$O and MeCN

![Scheme 5](image)

![Figure 2 Molecular structure of 2-iodo-1-methoxycyclododecyl hydroperoxide (3f) with thermal ellipsoids drawn at 50% probability level](image)
The problem of determining the structures of new peroxides is often difficult to solve based only on the NMR spectroscopic and elemental analysis data. In the present investigation, the structures of 2-iodo-1-methoxy hydroperoxides were unambiguously established by the X-ray diffraction study of the peroxide 3f (Figure 2).

Molecule 3f has standard bond lengths and bond angles. The ring adopts the [4.4.4.4] arrangement; the iodine atom and the O(2) atom of the peroxide group are in nearly axial positions and are in the trans arrangement, which in agreement with the establishment of the configuration of iodo peroxides 3a by NMR spectroscopy. The O(1) atom of the methoxy group deviates from the mean plane of the ring in the same direction as the iodine atom. In the crystal structure, the molecules form dimers through the O(3)-H(3O),O(1)···hydrogen bonds [O···O, 2.832(3) Å; H(3O)···O(1), 2.06(4) Å; the angle at the H(3O) atom is 163.0(9)°]. The dimers are linked into layers parallel to the xy0 plane by the weak I1···(12a) hydrogen bonds [I1···H(12a), 3.04 Å].

**Conclusions**

In solvents of strongly different basicity, the reactions of enol ethers with the I2–H2O2 system are found to occur by different paths. Thus, the reactions in diethyl ether afford 2-iodo ketones and the previously unknown 2-iodo-1-methoxy hydroperoxides, whereas the reactions in acetone/titrle give mixtures of geminal diperoxides. The synthesis of 2-iodo-1-methoxy hydroperoxides from enol ethers, which are generated based on ketones or alkynes, can be scaled up to prepare gram amounts of the target compounds. It was found that the same reagents that are used for the synthesis of 2-iodo-1-methoxy hydroperoxides cause the deperoxidation and demethoxylation of the latter compounds to form 2-iodo ketones. The selective method was developed for the synthesis of 2-iodo ketones in 67–94% yields.

NMR spectra were recorded on Bruker OC-200 and Bruker AM-300 spectrometers (CDCl3 as the solvent). TLC analyses were carried out on Silufol UV-254 plates. Column chromatography was performed with silica gel 63–200 mesh (Acros). Melting points were measured on a Kofler hot-stage apparatus. The solvents Et2O, MeCN, CH2Cl2, hexane, and EtOAc (high-purity grade) were distilled before use over the corresponding drying agents. The reagents I2, Na2S2O3·5H2O, and Na2SO4 were of high-purity grade. A H2O2 solution of 1.0 mL, 14.37 mmol, was added to a solution of 1-methoxycycloheptene (0.2 g, 0.74 mmol) in Et2O (6 mL). Then I2 (0.19 g, 0.74 mmol) was added to the reaction mixture with vigorous stirring, and the mixture was kept at 18–22 °C for 6 h. CH2Cl2 (10 mL) and finely dispersed Na2S2O3·5H2O (1 g) were added, and the suspension was vigorously stirred until the formation of a pale-yellow solution. The solution was filtered through a thin layer of silica gel (1 cm) and the solvent was evaporated. The residue was separated by silica gel column chromatography using a hexane–EtOAc mixture as the eluent with an EtOAc gradient from 2 to 20% (v/v). 1-Hydroperoxy-2-iodo-1-methoxycyclohexane (3a) was obtained in 33% yield (0.11 g, 0.40 mmol) and 2-iodocyclohexanone (5a) was obtained in 40% yield (0.11 g, 0.39 mmol).

In addition, iodo peroxides 3c,f were synthesized from enol ethers 1c,f using the starting reagents in 20 times higher amounts.

2-Iodocycloalkanones 5a,d,f from 1-Hydroperoxy-2-iodo-1-methoxycycloalkanones 3a,d,f; Typical Procedure

An ethereal solution of H2O2 (2.53 mL, 6.15 mmol, c = 2.43 mol/L) was added to a solution of 3a (0.2 g, 0.74 mmol) in Et2O (6 mL). Then I2 (0.19 g, 0.74 mmol) was added to the reaction mixture with vigorous stirring, and the mixture was kept at 18–22 °C for 6 h. Then CH2Cl2 (10 mL) and finely dispersed Na2S2O3·5H2O (1 g) were added, the suspension was vigorously stirred until the formation of a pale-yellow solution. The solution was filtered through a thin layer of silica gel (1 cm) and the solvent was evaporated. The residue was separated by silica gel column chromatography using a hexane–EtOAc mixture as the eluent with an EtOAc gradient from 2 to 20% (v/v). 2-Iodocyclohexanone (5a) was observed in 94% yield (0.16 g, 0.70 mmol).

**Influence of the Amount of Iodine on the Yields of Iodo Ketone 5d and Hydroperoxide 3d in the Reaction of Enol Ether 1d with the I2–H2O2 System; 2-Iodo-1-methoxy-cycloheptyl Hydroperoxide (3d) and 2-Iodocyclohexanone (5d) (Table 2)**

An ethereal solution of H2O2 (2.45 mL, 5.95 mmol, c = 2.43 mol/L) was added to a solution of 1-methoxycycloheptane (1d; 0.15 g, 1.19 mmol) in Et2O (6 mL). Then I2 (0.15–0.76 g, 1.19–2.98 mmol) was added to the reaction mixture with vigorous stirring. In one experiment, H2O (0.022 g, 1.2 mmol) was added. The mixture was kept at 18–22 °C for 6 h. Then, CH2Cl2 (10 mL) and finely dispersed Na2S2O3·5H2O (1 g) were added, and the suspension was vigorously stirred until the formation of a pale-yellow solution. The solution was filtered through a thin layer of silica gel (1 cm), and the solvent was evaporated. The residue was separated by silica gel column chromatography using a hexane–EtOAc mixture as the eluent with an EtOAc gradient from 2 to 20% (v/v). 2-Iodo-1-methoxy-cycloheptyl hydroperoxide (3d) was obtained in 25–2% yield (0.07–0.005 g, 0.30–0.02 mmol); 2-iodocyclohexanone (5d) was obtained in 54–79% yield (0.18–0.27 g, 0.64–0.94 mmol).

**2-Iodocycloheptanone (5d); Variations of the Reaction Time and the Amount of Hydrogen Peroxide (Table 2)**

An ethereal solution of H2O2 (1.47 or 2.94 mL, 3.57 or 7.14 mmol, c = 2.43 mol/L) was added to a solution of 1-methoxycycloheptane (1d; 0.15 g, 1.19 mmol) in Et2O (6 mL). Then I2 (0.60 g, 2.38 mmol) was added to the reaction mixture with vigorous stirring. The mixture was kept at 18–22 °C for 3, 6, and 12 h. 2-Iodocycloheptanone (5d) was isolated according to the above-described procedure (see the experimental conditions to Table 2).
Reactions of Cyclohexanone and Cyclopentanone with Iodine and Hydrogen Peroxide

An ethereal solution of \( \text{H}_2\text{O}_2 \) (2.45 mL, 5.95 mmol, \( c = 2.43 \text{ mol/L} \)) was added to a solution of 1-methoxycyclohexene (1d) with the \( \text{I}_2–\text{H}_2\text{O}_2 \) System in MeCN at 18–22 °C for 6 h. The isolation of 2-iodocyclohexanone (5d) was isolated according to the above-described procedure (see the experimental conditions to Table 2).

Iodo Ketones 5a–f and 6a,b from Enol Ethers 1a–f and 2a,b Under Optimized Conditions; 2-Iodo cyclooctyl peroxide (8d), cyclohexane triperoxide (9a), and cycloheptane diperoxide (9d), and also by 1H and 13C NMR spectroscopy.

1H NMR (300 MHz, CDCl3): \( \delta = 0.85 \) (s, 9 H, CH3C), 1.19–1.38 (3 H, CH2), 1.54–2.16 (6 H, CH3), 3.30 (s, 3 H, CH3O), 4.71–4.76 (m, 1 H, CH), 7.93 (br s, 1 H, OOH).

Table 2: Diastereomeric mixture. Yellow oil.

1H NMR (300 MHz, CDCl3): \( \delta = 1.05–2.17 \) (m, 20 H, CH3), 3.42 (s, 1.2 H, CH2O), 3.63 (s, 1.8 H, CH3O), 4.22 (d, \( J = 11.0 \) Hz, 0.4 H, CHI), 4.35 (d, \( J = 11.0 \) Hz, 0.4 H, CHI), 7.91 (br s, 0.4 H, OOH), 8.08 (br s, 0.4 H, OOH), 8.34 (br s, 0.6 H, OOH).

2-Iodo-1-methoxy-cyclooctyl Hydroperoxide (3e)

White or light-yellow crystals; mp 79–81 °C.

1H NMR (300 MHz, CDCl3): \( \delta = 1.05–2.39 \) (m, 8 H, CH3), 3.31 (s, 3 H, CH3O), 4.60–4.73 (m, 1 H, CHI), 8.07 (br s, 1 H, OOH).

2-Iodo-1-methoxy-cyclocododecyl Hydroperoxide (3f)

White or light-yellow crystals; mp 41–42 °C.

1H NMR (300 MHz, CDCl3): \( \delta = 1.24–2.22 \) (m, 10 H, CH3), 3.32 (s, 1.2 H, CH2O), 3.36 (s, 1.8 H, CH3O), 4.61–4.68 (m, 0.6 H, CHI), 4.86–4.93 (m, 0.4 H, CHI), 8.08 (br s, 0.4 H, OOH), 8.34 (br s, 0.6 H, OOH).

13C NMR (75 MHz, CDCl3): \( \delta = 21.0, 25.5, 26.6, 31.9, 32.2, 36.4 \) (CH, CH2, CH3), 49.1 (CH3O), 108.4 (COOH).

Anal. Calcd for \( \text{C}_{13}\text{H}_{27}\text{O}_3 \) : C, 43.61; H, 5.36; I, 44.07.

2-Iodo-1-methoxy-cyclooctyl Hydroperoxide (3e)

Diastereomeric mixture. Yellow oil.

1H NMR (300 MHz, CDCl3): \( \delta = 1.05–2.17 \) (m, 20 H, CH3), 3.42 (s, 1.2 H, CH2O), 3.63 (s, 1.8 H, CH3O), 4.22 (d, \( J = 11.0 \) Hz, 0.4 H, CHI), 4.35 (d, \( J = 11.0 \) Hz, 0.4 H, CHI), 7.91 (br s, 0.4 H, OOH), 8.08 (br s, 0.4 H, OOH), 8.34 (br s, 0.6 H, OOH).

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Diastereomeric mixture. White or light-yellow crystals; mp 79–81 °C.

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13C NMR (75 MHz, CDCl3): \( \delta = 21.0, 25.5, 26.6, 31.9, 32.2, 36.4 \) (CH, CH2, CH3), 49.1 (CH3O), 108.4 (COOH).

Anal. Calcd for \( \text{C}_{13}\text{H}_{27}\text{O}_3 \) : C, 43.61; H, 5.36; I, 44.07.

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Diastereomeric mixture. White or light-yellow crystals; mp 79–81 °C.

1H NMR (300 MHz, CDCl3): \( \delta = 1.05–2.17 \) (m, 20 H, CH3), 3.42 (s, 1.2 H, CH2O), 3.63 (s, 1.8 H, CH3O), 4.22 (d, \( J = 11.0 \) Hz, 0.4 H, CHI), 4.35 (d, \( J = 11.0 \) Hz, 0.4 H, CHI), 7.91 (br s, 0.4 H, OOH), 8.08 (br s, 0.4 H, OOH), 8.34 (br s, 0.6 H, OOH).

13C NMR (75 MHz, CDCl3): \( \delta = 19.2, 19.6, 21.7, 21.8, 21.9, 22.0, 22.5, 22.6, 24.5, 25.2, 25.47, 25.52, 25.91, 25.96, 25.98, 29.1, 31.5, 31.7 \) (CH), 30.4, 33.5 (CHI), 50.4, 51.9 (CH3O), 104.7, 105.6 (COOH).

Anal. Calcd for \( \text{C}_{13}\text{H}_{27}\text{O}_3 \) : C, 43.83; H, 7.07; I, 35.62. Found: C, 43.27; H, 6.54; I, 35.25.

1-Butyl-2-iodo-1-methoxybenzyl Hydroperoxide (4a)

Diastereomeric mixture. Yellow oil.

IR (CCl4): 3416 cm–1 (OOH).

1H NMR (300 MHz, CDCl3): \( \delta = 0.74–2.07 \) (m, 16 H, CH3, CH2), 3.39 (s, 2.25 H, CH3O), 3.40 (s, 0.75 H, CH3O), 4.27 (dd, \( J = 13.9 \), 2.9 Hz, 0.75 H, CHI), 4.37–4.48 (m, 0.25 H, CHI), 7.85 (br s, 1 H, OOH).

13C NMR (75 MHz, CDCl3): \( \delta = 31.5, 13.8 \) (CH3), 23.1, 23.2, 23.4, 25.6, 25.9, 29.6, 31.8, 32.2, 36.6, 36.8 (CH2), 37.6, 38.9 (CHI), 30.3, 51.1 (CH3O), 106.6 (COOH).


2-Iodo-1-isobutyl-1-methoxy-3-methylbutyl Hydroperoxide (4b)

Diastereomeric mixture. Yellow oil.

IR (CCl4): 3404 cm–1.
1H NMR (200 MHz, CDCl3): δ = 0.73–2.13 (m, 18 H, CH2, (CH3)2CHO, CH3), 3.42 (s, 0.45 H, CH2O), 3.45 (s, 2.55 H, CH2O), 4.37 (d, J = 2.4 Hz, 0.85 H, CH), 4.51 (d, J = 2.9 Hz, 0.15 H, CH), 7.91 (br s, 0.15 H, OOH), 8.04 (br s, 0.85 H, OOH).

13C NMR (50 MHz, CDCl3): δ = 22.4, 22.6, 23.8, 23.9, 24.1, 24.6, 24.7, 29.1 (CH2CH2), 29.1 (CH2), 40.8, 41.9 (CH2), 49.5, 51.1 (CH(O), 107.0 (COO).

Anal. Calcd for C5H10O3: C, 41.69; H, 7.4; O, 50.91. Found: C, 41.6; H, 7.4; O, 50.9.

1H NMR (200 MHz, CDCl3): δ = 0.95–2.46 (m, 7 H, CH3, HCH- CO), 3.02–3.33 (m, 1 H, HCHCO), 4.55–4.81 (m, 1 H, CHI).

13C NMR (75 MHz, CDCl3): δ = 22.4, 26.6, 32.4, 36.3, 37.2, 204.6.

2-Iodoxyan-5-one (5a)

Yellow oil.

1H NMR (200 MHz, CDCl3): δ = 0.95–2.46 (m, 7 H, CH3, HCH- CO), 3.02–3.33 (m, 1 H, HCHCO), 4.55–4.81 (m, 1 H, CHI).

13C NMR (75 MHz, CDCl3): δ = 22.4, 26.6, 32.4, 36.3, 37.2, 204.6.

2-Iodoxyan-5-one (5b)

Yellow oil.

1H NMR (300 MHz, CDCl3): δ = 0.92–2.39 (m, 9 H, CH3, CH3, HCHCO, CH2CH3), 3.26–3.40 (m, 1 H, HCHCO), 4.54–4.59 (m, 1 H, CHI).

13C NMR (50 MHz, CDCl3): δ = 20.5, 27.4, 29.9, 34.5, 34.6, 43.6, 205.5.

4-tert-Butyl-2-iodoxyan-5-one (5c)

Yellow oil.

1H NMR (200 MHz, CDCl3): δ = 0.89 (s, 9 H, CH3C), 1.16–2.36 (m, 6 H, CH3, CHC, HCHCO), 3.10–3.40 (m, 1 H, HCHCO), 4.61–4.67 (m, 1 H, CHI).

13C NMR (50 MHz, CDCl3): δ = 27.3, 27.5, 29.6, 31.1, 34.8, 36.8, 42.1, 205.7.

2-Iodoxyan-5-one (5d)

Yellow oil.

1H NMR (300 MHz, CDCl3): δ = 1.05–2.48 (m, 9 H, CH3, HCH- CO), 2.84–2.98 (m, 1 H, HCHCO), 4.54 (dd, J = 16.1, 5.9 Hz, 1 H, CHI).

13C NMR (75 MHz, CDCl3): δ = 25.3, 28.3, 29.3, 32.21, 35.5, 38.2, 207.4.

2-Iodoxyan-5-one (5e)

Yellow oil.

IR (CCl4): 1702 cm⁻¹.

1H NMR (300 MHz, CDCl3): δ = 0.95–2.02 (m, 9 H, CH3, HCH- CO), 2.22–2.59 (m, 2 H, CH2CH2CO), 2.89–3.04 (m, 1 H, HCH- CO), 4.68 (dd, J = 16.1, 3.7 Hz, 1 H, CHI).

13C NMR (75 MHz, CDCl3): δ = 23.6, 25.3, 29.4, 29.7, 33.9, 34.1, 35.0, 209.7.

2-Iodoxyan-5-one (5f)

White or pale-yellow crystals; mp 48–50 °C (Lit. 58 mp 52–52.5 °C).

IR (CCl4): 1692 cm⁻¹.

1H NMR (300 MHz, CDCl3): δ = 1.11–2.03 (m, 17 H, CH3, HCH- CO), 2.37–2.58 (m, 2 H, CH2CH2CO), 2.90–3.02 (m, 1 H, HCH- CO), 4.68 (dd, J = 16.1, 3.7 Hz, 1 H, CHI).

13C NMR (75 MHz, CDCl3): δ = 22.1, 23.3, 24.20, 24.24, 24.4, 25.05, 25.12, 25.7, 28.1, 35.0, 36.4, 205.9.

4-Iodonan-5-one (6a)

Yellow oil.


