1,2-Deoxygenation of vic-Dihydroxyindenoimidazoles: Optimization of a Novel Deoxygenation Reagent

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Dedicated to Prof. Dr. Hans-Dieter Höltje on the occasion of his 65th birthday

Treatment of vic-dihydroxyindeno[1,2-d]imidazoles with N,N,N',N'-tetraalkyl sulfurous diamides yields indeno[1,2-d]imidazoles by deoxygenation. Isochromeno[3,4-d]imidazoles are formed as byproducts. An X-ray crystal structure analysis confirmed the structure of deoxygenated products. The ratio of products depending on the reaction conditions was analyzed. A mechanism of the reaction is discussed.

Key words: Indeno[1,2-d]imidazoles, Isochromeno[3,4-d]imidazoles, N,N,N',N'-Tetraalkylsulfurous Diamides, 1,2-Bis-deoxygenation, Crystal Structure

Introduction

Ninhydrin (1), the hydrate of indan-1,2,3-trione, is well known as an analytical reagent for the detection of α-amino acids and its forensic application in fingerprint development. In synthetic applications of 1 with suitable 1,3-dinucleophiles, the carbonyl functionalities are involved in a (2+3)-cyclization to form indene-annulated heterocycles [1]. Thus the addition of urea or thiourea to 1 gives imidazole derivatives 2a [2a]. The reaction of β-aminocrotonic acid derivatives and 1 yields indenopyrroles 2b [2b]. The addition of acetonamides to 1 gives rise to the formation of indenopyrrole derivatives 2c [2c].

We recently reported on the addition of N-substituted amidines 3a–g to 1 which afforded mixtures of regioisomeric indenoimidazoles 4 and 5 (Scheme 1) [3]. Because indenoimidazoles show some biological and pharmaceutical effects, syntheses have been developed using the reaction of 2-amino-
fore decided to study the reaction of 4, 5 with electrophilic reagents used in the syntheses of olefins from vic-diols.

In the present work we report on the results of our studies of developing a novel 1,2-deoxygenation reagent and its use for the olefination of the vic-diols 4 and 5.

Results

We recently published the synthesis of mixtures of regioisomeric indenoimidazoles 4 and 5 by addition of N-substituted amidines 3a–g to 1 [3]. The major products were identified as compounds 4a–g. Due to equilibria in solutions, attempts to isolate the pure regioisomers 5 were not successful. Therefore the following experiments refer to purified mixtures of 4 and 5 even if not explicitly mentioned.

Preliminary experiments to deoxygenate 4g were made using procedures which have proven to be efficient in olefin synthesis by deoxygenation of vic-diols. The Corey-Winter elimination proved unsuited because the cyclic precursors, needed in this reaction, could not be obtained when 4g was allowed to react with thioxocarbonyldiimidazole [6]. In another approach attempts to get the cyclic precursor of the Eastwood fragmentation by reacting 4g with dimethylformamide dimethyl acetal gave small amounts of 7g as the only product [7].

Reaction of vic-Dihydroxyindenoimidazoles with Sulfurous Acid Derivatives

The olefin forming radical 1,2-elimination of 2,1,3-thiadioxolane-2,2-dioxides has been published recently [8, 9]. The substrates of this reaction usually are synthesized by reacting vic-diols and thionyl chloride to yield 2,1,3-thiadioxolane-2-oxides, which after oxidation gave the heterocyclic precursors of the olefination. The approach to synthesize 2,1,3-thiadioxolan-2-oxides via the reaction of 4g and thionyl chloride / pyridine (10) resulted in the formation of largely intractable polymers from which two compounds could be isolated. Besides isochromene 7g deoxygenation product 6g was found in small amounts.

The structure of 6g was confirmed by X-ray diffraction analysis of the HClO₄ adduct (Fig. 1) [10] which was validated by spectral and analytical data. The mass spectrum of 6g with a molecular ion of 238 amu and the elemental analysis confirm the loss of two OH groups in full agreement with the result of X-ray analysis. In the ¹H NMR spectra the expected aromatic and aliphatic protons could be detected but no exchangeable proton was found; likewise the ¹³C NMR spectra include no signals corresponding to hydroxy substituted aliphatic bridgehead carbons of the educts. The carbonyl resonance appears at $\delta = 180$ ppm indicating the incorporation in an unsaturated cyclus.

Mass spectrum and elemental analysis of isochromenoimidazole 7g confirm the loss of water. ¹H and ¹³C NMR spectra are consistent with the proposed structure. In the ¹H NMR spectrum the anisotropy of the carbonyl group causes a significant downfield shift of aromatic ortho-proton 4-H to $\delta = 8.3$ ppm. The ¹³C NMR spectrum shows a carbonyl resonance at $\delta = 160.9$ ppm indicating a lactone carbonyl [11]. No resonances of hydroxy substituted aliphatic bridgehead carbons were detected.

Because 6g represented just the type of product we were searching for we were prompted to study this reaction in detail.

When 4 suspended in trichloromethane was allowed to react with thionyl chloride, only small amounts of
In order to enhance the yields of the deoxygenation products 6 and to avoid the formation of the transformation products 7, the sulfurous acid diamides \( \text{SO}(\text{NR}_2)_2 \) 10a–d (a: \( R = \text{1-imidazolyl}, \) b: \( R = \text{CH}_3, \) c: \( R = \text{C}_2\text{H}_5, \) d: \( R = \text{iso-C}_3\text{H}_7) \) were synthesized and allowed to react with 4 and 5.

Treatment of mixtures of 4/5 with 10a in DMF resulted in a rapid coloring of the solution with formation of 6/8 in higher yields besides still considerable amounts of 7/9 and with decreased overall yields (Table 1). Using 10b, no significant change of the rate of formation of deoxygenation products 6/8 was observed monitoring by tlc. The mixture of products contained only small amounts of 7/9 but the overall yields decreased. This may be caused by decomposition of educts, due to the prolonged reaction times necessary. Only small yields of 6b and 7b/9b could be detected when 4b/5b was treated with 10b, whereas 4d/5d gave pure deoxygenation product 6d in 64% yield under the same conditions. No reaction was observed when 4d/5d was used with the same reagent in dichloromethane. The addition of 20% acetic acid to the solution of 4/5 in dimethyl formamide caused a significant improvement in the formation of deoxygenation products. The yields of 6a/8a raised to 46%, for 6b from 11% to 80% and for 6g/8g from 25% to 52%. In all cases only small amounts of 7/9 could be detected.

No deoxygenated compound could be obtained from the reaction of the highly sensitive diol 4e with 10b, but 10c gave the deoxygenation product 6c with a yield of 35%. No reaction at all could be observed in the reaction of 10d with 4/5.

From DMF distillates of the reaction mixtures a crystalline solid deposited, which produced a mass spectrometric molecular ion of 125 amu or 153 amu, respectively, depending on whether 10b or 10c had been used for deoxygenation. However, analytically pure samples of the corresponding sulfonic acids \( \text{R}_2\text{NSO}_3\text{H} (\text{R} = \text{CH}_3; \text{R} = \text{C}_2\text{H}_5) \) could not be obtained.

**Fig. 2. Intramolecular NOE-enhancement of regioisomers 6a and 8a.**

The deoxygenation of the mixtures of 4a/5a and 4g/5g respectively gave mixtures of the regioisomers 6a/8a and 6g/8g. Distinction of the regioisomers 6a and 8a was established by \( ^1\text{H} \) NMR spectroscopy. After assignment of protons had been accomplished by \( ^1\text{H} \) H,H correlation, the structures of 6a and 8a were confirmed by measuring homonuclear NOE difference spectra (Fig. 2). Upon irradiation of the methyl-H resonance of 8a a marked enhancement of the 4-H multiplet and of the ortho-protons of the phenyl substituent in 2-position was observed. Irradiation of the methyl-H resonance of 6a only caused enhancement of the latter protons but not of the 4-H multiplet.

Additionally, reduction experiments were done with compounds 6a.g and 8a.g for further characterisation of the regioisomers. The reduction with sodium borohydride afforded the hydroxy compounds 11a.g and 14a.g, respectively. Catalytic hydrogenation yielded 12a.g or 15a.g which were subsequently quaternized by methylation with dimethyl sulfate. The treatment of the sulfates with 70% perchloric acid gave

### Table 1. Yields of deoxygenation products 6 (+8) and transformation products 7 (+9)

<table>
<thead>
<tr>
<th>Reagent</th>
<th>10</th>
<th>10a</th>
<th>10b</th>
<th>10c</th>
<th>10d</th>
<th>10e</th>
<th>10f</th>
<th>10g</th>
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<tr>
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<td>Yield [%]</td>
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<td>Yield [%]</td>
<td>Yield [%]</td>
</tr>
<tr>
<td>4a (+5a)</td>
<td>21</td>
<td>56</td>
<td>45</td>
<td>11</td>
<td>–</td>
<td>–</td>
<td>46</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>4b (+5b)</td>
<td>7</td>
<td>49</td>
<td>10</td>
<td>24</td>
<td>11</td>
<td>9</td>
<td>80</td>
<td>16</td>
</tr>
<tr>
<td>4c</td>
<td>13</td>
<td>64</td>
<td>35</td>
<td>44</td>
<td>21</td>
<td>2</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>4d (+5d)</td>
<td>20</td>
<td>69</td>
<td>52</td>
<td>28</td>
<td>64</td>
<td>0</td>
<td>65</td>
<td>0</td>
</tr>
<tr>
<td>4f (+5f)</td>
<td>4</td>
<td>37</td>
<td>–</td>
<td>–</td>
<td>25</td>
<td>&lt; 1</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>4g (+5g)</td>
<td>23</td>
<td>65</td>
<td>23</td>
<td>12</td>
<td>25</td>
<td>&lt; 1</td>
<td>52</td>
<td>7</td>
</tr>
</tbody>
</table>

* The ratio of products was analyzed by means of \( ^1\text{H} \) NMR spectroscopic analysis and by HPLC of the crude reaction products; the experiments were performed with purified mixtures of regioisomers as indicated; yields refer to mixtures of 6 and 8.
the quaternary perchlorates 13g and 16g, respectively (Scheme 3).

**Discussion**

The formation of regioisomeric indenoimidazoles 6 and 8 from the diols 4 and 5 requires the 1,2-elimination of hydroxy groups which then results in an olefinic bond. Examples of this type of deoxygenation have been published but to the best of our knowledge never by reaction of vic-diols with sulfurous diamides. In the formation of 6 we assume that a cyclization to β-sultins could be accomplished by a condensation of N,N,N',N'-tetraalkylsulfurous diamides and the intramolecular nucleophilic addition of sulfur to the intermediate iminium compound 4A (Scheme 4) generated by dissociation of the second gem-hydroxyamine functionality [12]. The fragmentation of the tricyclic intermediate results in the formation of 6. The addition of acetic acid to the reaction may increase the formation of 4A and probably enhances the reactivity by intermediate formation of a mixed amidosulfurous acid anhydride [13].

The process and our results may have some similarities to the olefin forming 1,2-elimination of β-hydroxy sulfinamides reported by Corey and Durst. They argued for a 1,2-cycloelimination pathway, which required hydroxy- and sulfonic acid amide functionalities standing cis to one another and the intermediate formation of β-sultins which gave olefins by decomposition [14]. The easy fragmentation of β-sultins at ambient temperature was already reported elsewhere [15].

The formation of the isochromeno-imidazoles which is favored in the reaction of thionyl chloride can be explained by dissociation of the gem-hydroxy group and formation of iminium compound 4B with α-hydroxy ketone functionalities. Intermediate 4B undergoes a rearrangement to form isochromeno-imidazoles 7. Similar transformations of α-hydroxy-indanones have been published [16].

In conclusion, we found a facile and efficient method for the synthesis of indeno[1,2-d]imidazoles and indeno[2,1-d]imidazoles via 1,2-bis-deoxygenation of the respective vic-diols 4 and 5. The applicability of this previously unreported reaction to further vic-diols with hemi-N,O-ketal functionalities will be studied.

**Experimental Section**

*General Information:* Melting points: Büchi melting point apparatus by Dr. Tottoli; not corrected. IR spectra: Perkin Elmer 177 and FT-IR 1600, using KBr discs. 1H NMR spectra and 13C NMR spectra: Varian FT 80 (80 MHz/20 MHz), Bruker AC 200F (200 MHz/50 MHz) and Varian VXR 300 (300 MHz/75 MHz) in the designated solvents with TMS as internal standard, using the δ (ppm) scale; signals labeled by * exchanged by addition of D2O. EI mass-spectra: Finnigan 4200 quadrupole mass spectrometer, equipped with a MASPEC datasystem; 70 eV ionizing potential. Microanalyses: Perkin Elmer Elemental Analyzer 2400. HPLC-analyses: Hewlett-Packard 1084B, equipped with a Waters PAD-Detector 990. Catalytic hydrogenation: Low-pressure apparatus “Roche-Kühner”. Solvents were purified by standard methods and dried over molecular sieves or sodium. Thionyl chloride was purified by the procedure of Martin and Fieser [17]. Bis-(1-imidazolyl)sulfoxide 10a [18a], N,N,N',N'-tetramethylsulfurous diamide 10b, N,N,N',N'-tetraethylsulfurous diamide 10c [18b] and N,N,N',N'-
tetraisopropylsulfuric diamide 10d [18c] were prepared according to the literature.

General Procedures

A) Reaction with thionyl chloride/pyridine (10)

-vic-Dihydroxyindenoimidazoles 4/5 (0.01 mol) and dry pyridine (0.1 mol), dissolved in 100 ml of CHCl₃, were placed in a round-bottom flask. Nitrogen was passed through the solution. To the stirred and cooled solution thionyl chloride (0.05 mol in 20 ml of CHCl₃) was added, so that the temperature did not exceed 30 °C. After stirring for several hours at 20 °C, water (30 ml) was added under cooling and vigorous stirring. The organic layer was separated and the solvent removed in vacuo. The residue was purified by column chromatography on silica (CHCl₃).

B) Deoxygenation with bis(1-imidazolyl)sulfoxide 10a

The diols 4/5 (0.01 mol) were dissolved in 30 ml of an appropriate solvent (DMF or tetramethylurea) and a solution of 10a in 80 ml of THF was added by suction. Nitrogen was passed through the solution and stirring was continued for several hours. Then the solvent was removed in vacuo, 150 ml of water were added to the residue and the solution was extracted with CHCl₃. After removing the solvent from organic extracts, the residue was purified by column chromatography on silica.

C) Deoxygenation with N,N,N',N'-tetraalkylsulfuric diamides 10b, 10c

The diols 4/5 (0.01 mol) were dissolved in 30 ml of DMF or tetramethylurea and 10b or 10c (0.05 mol) in 20 ml of the same solvent was added. After stirring at 20 °C for 48 h 300 ml of water were added and the solution was extracted with CHCl₃. The reaction products were separated by column chromatography on silica (CHCl₃).

D) Deoxygenation in DMF-acetic acid

According to general procedure C, but 5 ml of acetic acid were added just before addition of 10b or 10c.

1-Methyl-2-phenyl-1H-indeno[1,2-d]imidazol-8-one (6a)

M. p. 126 – 7 °C (MeOH). – IR (KBr): ν = 1704 (C=O), 1613, 1492, 1467, 1405, 1161 cm⁻¹. – ¹H NMR (300 MHz, CDCl₃): δ = 3.83 (s, 3H, CH₃), 7.10 – 7.13 (m, 1H, 6-H), 7.24 – 7.27 (m, 2H, 4-H, 5-H), 7.34 – 7.37 (m, 1H, 7-H), 7.48 – 7.52 (m, 3H, 3'-H, 4'-H, 5'-H), 7.8 – 8.1 (m, 2H, 2'-H, 6'-H). – ¹³C{¹H} NMR (75 MHz, CDCl₃): δ = 33.6 (CH₃), 118.4, 123.5, 128.4, 128.7, 128.8, 128.9, 130.0, 132.0, 133.3, 136.8, 138.5, 156.7, 163.8, 180.2 (C=O). – MS (EI, 70 eV): m/z (%) = 260 (17) [M⁺], 177 (30), 159 (100), – C₁₇H₁₂N₂O (260.30): calcd. C 78.45, H 4.65, N 10.76; found C 78.34, H 4.80, N 10.43.

3-Methyl-2-phenyl-3H-indeno[2,1-d]imidazol-8-one (8a)

Following general procedure A, a mixture of 4a/5a (2.94 g, 0.01 mol) was treated with 10. After 12 h at 20 °C CHCl₃ (100 ml) was added and the solution was extracted with 5 × 20 ml portions of aqueous 5% HCl solution. The organic layers were washed with water, dried over sodium sulfate and the solvent removed in vacuo. The residue was purified by flash chromatography on silica, elution with CHCl₃/MeOH (98 : 2; v/v). To yield 380 mg (14.6%) of 8a. The HCl-extracts were unified, washed with CHCl₃, and basified by adding aqueous 10% sodium carbonate. Extraction of the aqueous solution with trichloromethane gave organic extracts which were evaporated. The residue was purified by flash chromatography on silica, elution with CHCl₃/MeOH (98 : 2; v/v) to yield 165 mg (6.5%) of 8a.

1-Benzyl-2-phenyl-1H-indeno[1,2-d]imidazol-8-one (6b)

M. p. 169 – 70 °C (MeOH/H₂O). – IR (KBr): ν = 1697 (C=O), 1616, 1603 cm⁻¹. – ¹H NMR (80 MHz, CDCl₃): δ = 1.3 – 2.4 (m, 10H, cyclohexyl-H), 4.1 (m, 1H, NCH₂(CH₂)₂), 6.95 – 7.7 (m, 9H, aromat. H). – ¹³C NMR (20 MHz, CDCl₃): δ = 24.6, 25.5, 32.4 (5 CH₂), 57.0 (NCH), 118.1, 123.5, 128.4, 128.9, 129.0, 130.0, 133.5, 132.0, 137.0, 138.3, 156.3, 156.5, 179.3 (C=O). – MS (EI, 70 eV): m/z (%) = 328 (18) [M⁺], 246 (100), 218 (8), 190 (9), 143 (6), 130 (10), 115 (43), 134 (39), 89 (11), 88 (20), 77 (10), 61 (61). – C₂₂H₁₄N₂O (328.41): calcd. C 80.46, H 6.14, N 8.53; found C 80.45, H 6.13, N 8.48.

1-Benzyl-2-phenyl-1H-indeno[1,2-d]imidazol-8-one (6c)

M. p. 135 – 6 °C (MeOH). – IR (KBr): ν = 1690 (C=O), 1608, 1485, 1446, 1402, 1275, 1245 cm⁻¹. – ¹H NMR (80 MHz, DMSO-d₆): δ = 5.31 (s, 2H, CH₂), 7.0 – 7.7 (m, 14H, aromat. H). – ¹³C{¹H} NMR (20 MHz, DMSO-d₆): δ = 21.6 (CH₃), 118.4, 123.6, 127.0, 127.7, 128.3, 128.5, 129.0, 129.2, 130.2, 133.3, 135.8, 136.9, 138.4, 157.1, 164.4, 179.9 (C=O). – MS (EI, 70 eV): m/z (%) = 336 (10) [M⁺], 245 (3), 114 (14), 91 (100), 98 (4), 88 (4), 65 (13).
1,2-Diphenyl-1H-indeno[1,2-d]imidazol-8-one (6d)

M. p. 211 – 2°C (MeOH). – IR (KBr): ν = 2967, 1698 (C=O), 1674, 1611, 1498, 1410, 1392, 1296, 1142 cm⁻¹. – 1H NMR (500.13 MHz, CDCl₃): δ = 1.9 – 2.1 (m, 4H, 9-H), 2.85 – 3.05 (m, 2H, 6-H), 4.0 – 4.15 (m, 2H, 9-H), 7.0 – 7.4 (m, 4H, aromat. H). – 13C NMR (125 MHz, CDCl₃): δ = 20.0, 22.2, 25.2, 44.5, 118.0, 123.4, 128.7, 129.0, 129.2, 133.7, 135.5, 136.1, 138.1, 153.4, 158.2, 183.4. – MS: m/z (%) = 322 (54) [M⁺], 321 (20), 294 (6), 219 (11), 190 (49), 164 (12), 114 (26), 88 (36), 77 (100), 76 (11), 51 (56). – C₂₂H₁₆N₂O·3HClO₄ (422.82): calcd. C 62.69, H 3.62, found C 62.64, H 3.61, N 6.52.

2,3,4a,9a-Tetrahydro-4a,9a-dihydropyrido[1′,2′:4,5]imidazol-9-one (4e); 2,3,4a,9b-tetrahydro-4a,9b-dihydro-1H-indeno[2′,1′:4,5]imidazol-5-one (5e)

Equimolar amounts of 1 and 2-iminopyridoline hydrochloride (3g) were suspended in methanol and stirred several days at ambient temperature. The solid was separated and washed with CHCl₃. A mixture of regioisomeric hydrochlorides was obtained in 95% yield. M. p. 164 – 6°C (MeOH). – IR (KBr): ν = 3375 (OH), 3190, 3020, 1740 (C=O), 1618, 1605, 1588, 1575, 1420, 1360, 1148 cm⁻¹. – 1H NMR (80 MHz, D₂O): δ = 2.0 – 2.6 (m, 2H, C₂H₂), 2.6 – 3.0 (m, 2H, C₂H₂), 3.2 – 3.9 (m, 2H, NC₂H₂), 7.2 – 8.0 (m, 4H, aromat. H), 11 – 13 (broad, 3H). – 13C NMR (20 MHz, D₂O): δ = 20.2, 22.2, 22.9, 23.8, 24.3 (all CH₃), 89.2, 90.7, 96.9, 98.0 (all COH), 124.3, 124.6, 125.6, 131.4, 131.6, 133.1, 133.4, 137.7, 146.8, 148.7, 170.4, 170.9, 171.3, 192.1, 193.7 (2 C=O). – C₂₁H₁₄N₂O·2CH₃OH (280.71): calcd. C 75.62, H 4.67, N 9.98; found C 75.52, H 4.62, N 9.83.

2,3-Dihydro-1H-indeno[1,2-d]pyrrolo[1′,2′-a]imidazol-9-one (6c)

To a suspension of the hydrochlorides of 4e, 5e (1.40 g, 0.005 mol) in DMF (20 ml), acetic acid (5 ml) and 10e (3.84 g, 0.02 mol) were added. The mixture was stirred for 12 h at ambient temperature and then evaporated in vacuo. The residue was dissolved in CH₂Cl₂ (100 ml) and washed with water (3 × 50 ml). The organic layers were unified, dried and concentrated. The residue was subjected to column chromatography (silica, CHCl₃-MeOH, 99 : 1, v/v). M. p. 197 – 8°C (EtOAc) – IR (KBr): ν = 1697 (C=O), 1608, 1503, 1404, 1384 cm⁻¹. – 1H NMR (200.13 MHz, CDCl₃): δ = 2.6 – 2.85 (m, 2H, 2-, H₂), 2.88 – 3.0 (m, t, 2H, 3-H), 4.0 – 4.15 (m, t, 2H, 1-, H₁), 7.0 – 7.5 (m, 4H, aromat. H). – 13C NMR (50.32 MHz, CDCl₃): δ = 23.4, 25.7, 44.7, 117.9, 123.5, 127.3, 128.3, 133.0, 137.5, 137.7, 164.5, 170.3, 178.9. MS (EI, 70 eV): m/z (%) = 210 (100) [M⁺], 209 (29), 182 (14), 181 (10), 154 (11), 149 (8), 130 (13), 127 (11), 115 (11), 114 (14), 57 (11). – C₁₃H₁₂O₂N₂ (205.23): calcd. C 74.27, H 4.79, N 13.32; found C 74.11, H 4.90, N 13.10.

7,8,9,10-Tetrahydro-6H-indeno[1′,2′:4,5]imidazo[1,2-a]pyridin-11-one (6f)

From 4g/5g by procedure A, work-up as described for 6a/8a. – M. p. 149 – 50°C (MeOH). – IR (KBr): ν = 2930, 1718 sh, 1699 (C=O), 1610, 1477, 1411, 1337, 1306 cm⁻¹. – 1H NMR (80 MHz, CDCl₃): δ = 1.8 (m, broad, 6H, 7-H, 8-H, 9-H), 2.9 (m, broad, 2H, 6-H), 4.25 (m, broad, 2H, 10-H), 6.8 – 7.4 (m, 4H, aromat. H). – 13C NMR (50.32 MHz, CDCl₃): δ = 25.1, 28.3, 29.9, 30.7, 46.7, 117.8, 123.4, 128.0, 133.0, 137.1, 138.4, 161.2, 162.9, 180.0. – MS (EI, 70 eV): m/z (%) = 238 (100) [M⁺], 210 (18), 209 (39), 197 (27), 184 (5), 183 (10), 812 (7), 181 (6), 168 (6), 130 (16), 115 (14), 114 (19), 102 (11), 88 (14). – C₁₅H₁₄N₂O₂ (238.29): calcd. C 75.61, H 5.92, N 11.76; found C 75.66, H 5.93, N 11.68.

7,8,9,10-Tetrahydro-6H-indeno[2′,1′:4,5]imidazo[1,2-a]azeoporin-12-one (6g)

From 4g/5g by procedure A, work-up as described for 6a/8a. – M. p. 165 – 6°C (MeOH). – IR (KBr): ν = 2928, 1704 (C=O), 1608, 1533, 1508, 1448 cm⁻¹. – 1H NMR (80 MHz, CDCl₃): δ = 1.85 (m, broad, 6H, 7-H, 8-H, 9-H), 2.85 (m, broad, 2H, 6-H), 4.0 (m, broad, 2H, 10-H), 6.7 – 7.5 (m, 4, aromat. H). – 13C NMR (20 MHz, CDCl₃): δ = 25.5, 28.7, 29.8, 30.7, 47.7, 116.4, 123.6, 128.5, 132.4, 133.4, 138.1, 139.6, 153.4, 158.2, 183.4. – MS: m/z (%) = 238 (100) [M⁺], 237 (51), 210 (24), 209 (39), 197 (8), 195 (10), 183 (10), 182 (29), 181 (29), 154 (12), 130 (41), 129 (23), 128 (13), 127 (17), 115 (23), 114 (25), 103 (20), 102 (39), 111 (9), 89 (12), 88 (18). – C₁₅H₁₄N₂O₂ (238.29):
8-H), 8.29 (d, \(J\) = 1614, 1518, 1470, 1450, 1421, 1366, 1258 cm\(^{-1}\)).

207 (9), 159 (6), 130 (22), 104 (26), 103 (38), 102 (14), 77 (65), 51 (27). – \(\text{C}_1\text{H}_2\text{N}_2\text{O}_2\) (276.36): calcd. C 73.90, H 4.38, N 10.14; found C 73.78, H 4.43, N 10.09.

1-Methyl-2-phenyl-1H-isochromeno[3,4-d]imidazol-5-one

M. p. 233 – 4 °C (MeOH). – IR (KB): \(\bar{\nu}\) = 3097, 1627, 1506, 1438, 1412, 1308, 1258, 1242, 1207, 1088, 1052, 940, 822, 770, 766, 747, 731, 722, 692, 670, 651 cm\(^{-1}\). – 1H NMR (80 MHz, CDCl\(_3\)): \(\delta\) = 1.1 – 2.5 (m, 10H, 5 cyclohexyl-CH\(_2\)).

4.19 (tt, J\(_{\text{ax,ax}}\) = 12.2 Hz, J\(_{\text{ax,eq}}\) = 3.7 Hz, 1H, CH-cyclohexyl), 7.41 (m, H-9.9. = 5 H, 7.6 Hz, H-J.9.9. = 1.0 Hz, 7-H), 7.45 – 7.65 (m, 5H, H-phenyl), 7.78 (m, J\(_{\text{ax,ax}}\) = 1.1 Hz, 7-H, 1H, 8-H), 8.08 (d, \(J\) = 7.7 Hz, 1H, 9-H), 8.31 (d, \(J\) = 7.7 Hz, 1H, 6-H). – MS (EI, 70 eV): \(m/z\) (%) = 276 (22) [M\(^+\)], 145 (19), 130 (8), 117 (100), 102 (12). – \(\text{C}_1\text{H}_7\text{N}_2\text{O}_2\) (276.30): calcd. C 73.90, H 4.38, N 10.14; found C 73.78, H 4.43, N 9.91.

3-Cyclohexyl-2-phenyl-3H-isochromeno[4,3-d]imidazol-5-one

M. p. 206 °C (EtOH). – IR (KB): \(\bar{\nu}\) = 2949, 1578, 1456, 1300 cm\(^{-1}\). – 1H NMR (80 MHz, CDCl\(_3\)): \(\delta\) = 1.1 – 2.5 (m, 10H, 5 cyclohexyl-CH\(_2\)).

4.19 (tt, J\(_{\text{ax,ax}}\) = 12.2 Hz, J\(_{\text{ax,eq}}\) = 3.7 Hz, 1H, CH-cyclohexyl), 7.41 (m, H-9.9. = 5 H, 7.6 Hz, H-J.9.9. = 1.0 Hz, 7-H), 7.45 – 7.65 (m, 5H, H-phenyl), 7.78 (m, J\(_{\text{ax,ax}}\) = 1.1 Hz, 7-H, 1H, 8-H), 8.08 (d, \(J\) = 7.7 Hz, 1H, 9-H), 8.31 (d, \(J\) = 7.7 Hz, 1H, 6-H). – MS (EI, 70 eV): \(m/z\) (%) = 276 (22) [M\(^+\)], 145 (19), 130 (8), 117 (100), 102 (12). – \(\text{C}_1\text{H}_7\text{N}_2\text{O}_2\) (276.30): calcd. C 73.90, H 4.38, N 10.14; found C 73.78, H 4.43, N 9.91.

3-Benzyl-2-phenyl-3H-isochromeno[4,3-d]imidazol-5-one

M. p. 233 – 4 °C (MeOH). – IR (KB): \(\bar{\nu}\) = 3097, 1627, 1506, 1438, 1412, 1308, 1258, 1242, 1207, 1088, 1052, 940, 822, 770, 766, 747, 731, 722, 692, 670, 651 cm\(^{-1}\). – 1H NMR (80 MHz, CDCl\(_3\)): \(\delta\) = 1.1 – 2.5 (m, 10H, 5 cyclohexyl-CH\(_2\)).

4.19 (tt, J\(_{\text{ax,ax}}\) = 12.2 Hz, J\(_{\text{ax,eq}}\) = 3.7 Hz, 1H, CH-cyclohexyl), 7.41 (m, H-9.9. = 5 H, 7.6 Hz, H-J.9.9. = 1.0 Hz, 7-H), 7.45 – 7.65 (m, 5H, H-phenyl), 7.78 (m, J\(_{\text{ax,ax}}\) = 1.1 Hz, 7-H, 1H, 8-H), 8.08 (d, \(J\) = 7.7 Hz, 1H, 9-H), 8.31 (d, \(J\) = 7.7 Hz, 1H, 6-H). – MS (EI, 70 eV): \(m/z\) (%) = 276 (22) [M\(^+\)], 145 (19), 130 (8), 117 (100), 102 (12). – \(\text{C}_1\text{H}_7\text{N}_2\text{O}_2\) (276.30): calcd. C 73.90, H 4.38, N 10.14; found C 73.78, H 4.43, N 9.91.
1,8-Dihydro-8-hydroxy-1-methyl-2-phenylindenoideno[1,2-d]-imidazole (11a)

6a (300 mg, 1.2 mmol), dissolved in 20 ml of methanol, was treated with sodium borohydride (1.00 g, 26.4 mmol). After 2 h, water (100 ml) was added and the aqeous solution was extracted with CH2Cl2. The extract was separated by column chromatography on silica. Yield: 162 mg (67%).

M. p. 219 – 20 (65), 130 (49), 118 (100). – C 17H14N2O (262.31): calcd. MS (EI, 70 eV): m/z 1498, 1470, 1440, 1394, 1295 cm

6,7,8,9,10,12-Hexahydro-12-hydroxyindeno[1′,2′:4,5]imidazo[1,2-a]azepine (11g)

6g (1.00 g, 4.2 mmol) was treated with lithium aluminium hydride (500 mg, 13.2 mmol) in dry THF (50 ml). After 2 h, water was added under cooling and the solution was extracted with Et2O. The solvent was removed in vacuo to yield a white solid which was crystallized. Yield: 560 mg (55%).

M. p. 235 – 6 (65), 130 (48). – C 77.84, H 5.38, N 10.68; found C 77.91, H 5.38, N 10.66.

3,8-Dihydro-8-hydroxy-3-methyl-2-phenylindenoideno[1,2-d]-imidazole (14a)

8a (300 mg, 1.2 mmol) was hydrogenated as described for the syntheses of 11a. Yield: 195 mg (62%). – M. p. 192 °C (EtOH/Et2O). – IR (KBr): ν = 3105, 3260, 1617, 1504, 1495, 1404, 1340, 1288, 1278 cm

3,8-Dihydro-3-methyl-2-phenylindenoideno[1,2-d]-imidazole (15a)

8% Pd/carbon (0.30 g) was added to a solution of 8a (200 mg, 0.77 mmol) in 100 ml of methanol. The solu-
tion was hydrogenated at atmospheric pressure. The reaction finished after a hydrogen uptake of 18 ml. After removal of the catalyst, the solvent was evaporated in vacuo and the residue was crystallized. An analytical sample was obtained by generation of the perchlorate. Yield: 138 mg (73%).

M. p. 194 °C (CH2Cl2/ether 3:1). – IR (KBr): ν = 3326, 3208, 3107, 3071, 2940, 1583, 1564, 1483 cm⁻¹. – ¹H NMR (80 MHz, [D₆]-DMSO): δ = 3.98 (s, 2H, 8-H), 4.08 (s, 3H, CH₃), 7.35 – 7.9 (m, 9H, aromat. H). Perchlorate: M. p. 238 – 9 °C (EtOH/ether 5:1). – C₁₅H₁₅ClN₂O₅, molecular mass: 338.79; calculated H 6.13, C 72.42, N 8.31; found H 6.12, C 72.35, N 8.39.

Preparation from 15g (200 mg, 0.9 mmol) as described for 13g. Yield: 138 mg (46%). M. p. 239 – 40 °C (EtOH/ether 3:1). – IR (KBr): ν = 3324, 1513, 1400 cm⁻¹. – ¹H NMR (80 MHz, [D₆]-DMSO): δ = 0.88 (broad, 6H, 7-H, 8-H, 9-H), 3.20 (m, broad, 2H, 10-H), 3.89 (s, 5, 12-H, CH₃). – C₁₅H₁₅ClN₂O₅, molecular mass: 338.79; calculated H 6.13, C 72.42, N 8.31; found H 6.12, C 72.35, N 8.39.

Crystal Structure Analysis of 6g·HClO₄ by X-Ray Diffraction

The solid-state structure of the HClO₄-adduct of 6g was established by X-ray crystal structure analysis. The molecular structure is displayed in Fig. 1. Except atoms C8, C9, and C10 the cation is planar within 0.127(2) ˚A. The ions are linked together by a hydrogen bond N2-HN...O 2.10(3) ˚A and an angle N-N...O of 162(3)°.

Crystal data: C₁₅H₁₅ClN₂O₅, monoclinic space group P2₁/n, a = 13.472(4), b = 6.356(2), c = 18.581(6) ˚Å, β = 106.42(2)°, V = 1526.28(13) ˚Å³ (by refinement of 29 reflections, 27 < 2θ < 32°; λ(Mo-Kα) = 0.71073 ˚Å, Z = 4, Dc = 1.474 mg mm⁻³, Dm = 1.466 mg mm⁻³, F(000) = 704; μ(Mo-Kα) = 0.28 mm⁻¹, approximate dimensions of crystal (yellow color) 0.7 × 0.3 × 0.2 mm.

Data collection: X-ray intensities were measured with monochromatized Mo-Kα-radiation on a Siemens/STOE diffractometer AED2, variable ω/θ-scan, scan range 1.1° (plus separation in θ-scan, scan speed 0.6 – 3.5° min⁻¹). 3098 intensities measured (3 < 2θ < 50°); indices hkl ranging from 0.0, −22 to 15, 7, 21. The final set of data contained 2428 symmetry-independent reflections (Rint = 0.016) of which 1808 were classified observed (I > 4σ(I)).

Structure solution and refinement: Direct methods [19] revealed all non-H atoms. Full matrix least-squares refinement [20] on F² using anisotropic displacement parameters (212 parameters) converged at wR2 = 0.136 for all data and R1 = 0.043 for the observed data. H atoms were included in a riding mode except the one at N2 which was refined freely. The residual electron density ranged from −0.25 to 0.57 eÅ⁻³, with the maximum in the vicinity of the Cl atom. However, a split model for the ClO₄⁻-ion did not improve the results. Preliminary results have been reported [10]. Crystallographic data for the structure have been deposited with the Cambridge Crystallographic Data Centre.
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CCDC-103288. Copies of the data can be obtained free of charge on application to the Director, CCDC, 12 Union Road, Cambridge CB2 1EZ (U.K.) (Fax: int.code+(1223)336-033; e-mail for inquiry: fileserv@ccdc.cam.ac.uk).


