# 2,3-Epoxyindanone. Synthesis and Reactions

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2,3-Epoxyindanone has been synthesised by the bromohydrin-epoxide reaction from 2-bromo-3-hydroxy-1-indanone by means of silver oxide; both the intermediates and the epoxide are sensitive to alkali. Direct epoxidation of 1-indenone was less satisfactory. Both irradiation and Lewis acid catalysis resulted in rearrangement of the epoxide to isocoumarin. 2-Hydroxy-1-indanone was almost quantitatively oxidised to 1,2-indanedione by N-bromosuccinimide.

In a recent paper we have described a synthesis of N-substituted 1a,6a-dihydroindeno[1,2-b]azirin-6(1H)-ones and the photochemical transformation of these compounds into the valence isomeric isoquinolinium-4-oxides.[1] In this report we describe a synthesis and some reactions of 1a,6a-dihydroindeno[1,2-b]oxiren-6-one (4) which is the oxygen analogue. Disubstituted derivatives of 4 are known in the literature as indanone oxides;[2] in this work they are named indenone epoxides. Most attention has been devoted to 2,3-diphenylindanone epoxide (1, R = Ph) which exists in equilibrium with the valence isomeric benzopyrylium-4-oxide (2) or ylide;[2,3] the equilibrium position varies with the conditions but is far over towards the epoxide form. The compound readily undergoes 1,3-dipolar cycloadditions via a carbonyl ylide. Valence isomerisation of the epoxide (4) would yield the parent benzo[c]-pyrylium-4-oxide (2, R = H) which in the absence of stabilising phenyl groups is expected to be unstable; this postulate is also in accordance with recent experience for the thio analogue.[4]

The desired epoxide 4 can in principle be prepared by oxidation of 1-indenone (3). A satisfactory synthesis of the latter has been developed,[1] but indenone polymerises very readily under acidic or alkaline conditions.[1,5] A slow peracid oxidation (electrophilic) is likely
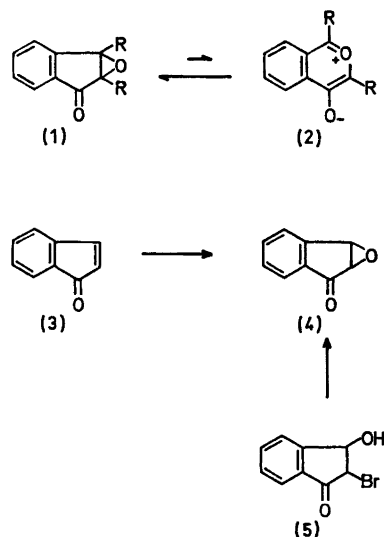
Scheme 1.

to result in extensive polymerisation besides competitive Baeyer-Villiger oxidation as reported for related [6,7] systems. Instead a Michael type oxidation [8] was employed using t-butylhydroperoxide in benzene solution in the presence of catalytic amounts of Triton-B as base. Some of the desired epoxide 4 was obtained by this method but the major product was polymeric. With phenyl group stabilisation epoxidation proceeds readily in alkaline hydrogen peroxide.[9] Since the direct epoxidation of indenone was preparatively unsatisfactory, the synthesis of the epoxide was directed through the vicinal bromohydroxy indanone (5). The synthesis of the latter is shown in Scheme 2. Free radical bromination of indanone readily yields 3-bromo-1-indanone (6).[1] Heating of the latter with silver acetate in acetic acid furnished the

acetate *8*. During our work an alternative synthesis of *8* was reported which consists in reductive acetylation of 1,3-indanedione.[10] Ionic bromination of *8* furnished the 2-bromo derivative *9*. In the ensuing ester hydrolysis, alkaline conditions are to be avoided to prevent ready elimination to the indenone which would polymerise. Hydrolysis of the acetate group in *9* was therefore carried out under acidic conditions. We prefer, however, to carry out ester hydrolysis before bromination; the ester *8* is suspended in 3 N HCl in the cold for one day to yield 3-hydroxyindanone (*7*). Less satisfactory was the direct preparation of *7* by heating of the bromo derivative *6* in aqueous acetone. Ionic bromination as above then furnished *5*.

(6)

(7) R = H
(8) R = Ac

(5) R = H
(9) R = Ac
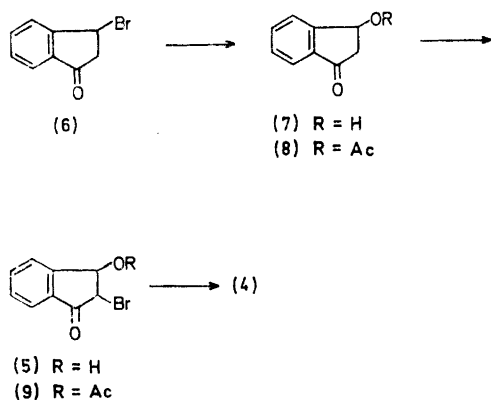
Scheme 2.

The vicinal bromo and hydroxy substituents in *5* must have the *trans* arrangement for cyclisation to the epoxide *4*. Bromination of the enolised ketone *7* is expected to yield the *trans* isomer for steric reasons; furthermore, ready epimerisation is likely to take place through the reversible enolisations. In the cyclisation reaction alkaline conditions are to be avoided. The reaction was therefore carried out with freshly prepared silver oxide [11] suspended in hexane/benzene under a nitrogen atmosphere; a "push and pull mechanism" is visualised. The absence of any 1,3-diketone in the reaction product excludes any reaction from the *cis* form.[12]

The NMR spectrum of the epoxide shows the methine protons as doublets at τ 5.5 (H-3) and

6.1 (H-2), J 2.5 Hz. The vinical coupling is less than for a simple epoxide but agrees with previous observations that fusion of a three-membered heterocyclic ring to another cyclic system decreases the vicinal coupling.[1,13]

The base peak in the mass spectrum at m/e 118 was due to [M − CO]. The only other important fragments are due to a further loss of CO (m/e 90, 40 %) and HCO (m/e 89, 35 %); the molecular ion (m/e 146) intensity was 40 %. The synthetic precursor for the epoxide, 2-bromo-3-hydroxyindanone, showed no molecular ion; ready bromine expulsion instead gave the base peak at m/e 147. The relative intensity for the mass number (146) corresponding to the epoxide was less than 2 %, which virtually excludes any pyrolytic cyclisation of *5* with HBr liberation. In fact the spectrum is almost identical with the spectrum of the acetate *9*. The latter by analogy to many acetates has ketene expulsion as the totally dominating initial fragmentation; the additional bromine expulsion gave the base peak at m/e 147.

The behaviour of the epoxide towards light was studied by illumination of a 0.02 M deoxygenated solution in benzene under nitrogen using a medium pressure Hg-lamp. The UV absorptions recorded during the illumination showed the appearance of a transient spectrum which disappeared on prolonged illumination with the precipitation of a polymeric material. The intermediate product has been identified as isocoumarin by comparison with authentic material prepared according to the literature.[14] Illumination of a solution of isocoumarin under the above conditions also led to polymer formation. With the use of a pyrex filter the maximum yield of isocoumarin was obtained after 30 min; without this filter the reaction should be stopped after 15 min.

Aza analogues of *4*, however, are transformed on photolysis to the valence isomeric isoquinolinium-4-oxides.[1] Substituted indanone epoxides such as 2,3-diphenylindanone epoxide exist in equilibrium with its benzopyrylium valence isomer *2*; the equilibrium position on irradiation is dependent on the wavelength of the light used.[2,15] Prolonged illumination led to dimerisation and formation of 3,4-diphenylisocoumarin. Substitution of the 2-phenyl group in the indanone with a methyl group leads to more rapid dimerisation.[16] The quantum yield for the

Scheme 3.   (14)   (15)   (16)
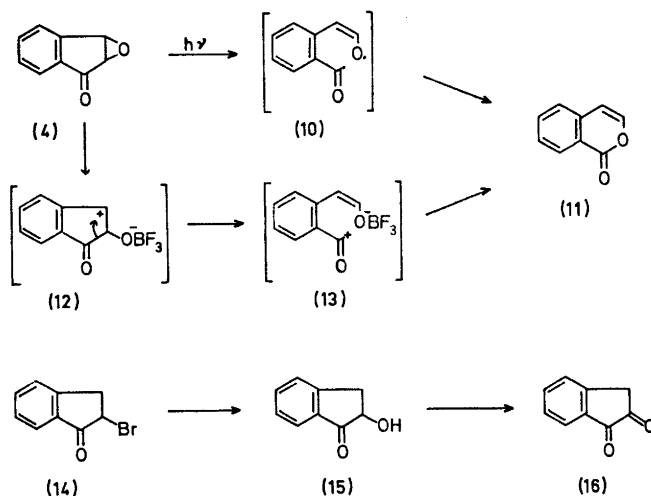
isomerisation of substituted indanone epoxides to benzo[c]pyrylium-4-oxides decreases when less bulky substituents are attached to the epoxide ring;[15] in the case of *4* no pyrylium betaine was detected.

The ylide nature of substituted pyrylium oxides has been widely used in cyclo-addition reactions.[2,3] Addition of dipolarophiles to solutions of the epoxide *4* followed by illumination failed to yield any adducts. The trapping experiment in itself, however, may not exclude pyrylium formation as it has been found that the thio analogue dimerises preferentially in the presence of added dipolarophiles.[4] No dimeric material from *4* was isolated; isocoumarin rather than pyrylium formation was favoured. Isocoumarin was also formed on Lewis acid isomerisation of *4* by treatment with boron trifluoride etherate. The incipient carbonium ion during the rearrangement is visualised in the benzylic position (Scheme 3). The usual facile migration of an acyl group in this case did not occur presumably because of four-ring formation. Hydride shift with carbonyl formation would lead to 1,2-indanedione in the product but was not seen in chromatographic comparisons with authentic 1,2-dione. The latter was prepared in almost quantitative yield by oxidation of 2-hydroxy-1-indanone with *N*-bromosuccinimide. This oxidation method is superior to the reported chromic acid oxidation which easily proceeds further to homophthalic acid.[17]

EXPERIMENTAL

NMR spectra were recorded with a Varian A-60 A instrument, the UV spectra with a Cary 14 spectrophotometer and the MS spectra with an AEI-902 mass spectrometer.

3-Acetoxy-1-indanone (8). A solution of 3-bromo-1-indanone[1] (10.8 g, 0.051 mol) and silver acetate (8.4 g, 0.051 mol) in acetic acid (300 ml) was heated under reflux for 24 h. The precipitated silver bromide was removed by filtration of the cold reaction mixture and the filtrate evaporated. The residual oil was purified by distillation; b.p. 89 °C/0.15 mmHg, yield 6.2 g (64 %). (Found: C 69.34; H 5.19. Calc. for $C_{11}H_{10}O_3$: C 69.40; H 5.26); $\tau(CCl)_4$ 8.0 (Me), 7.0 and 7.5 (2 H-2, ABX, J_{AB} 19 Hz, J_{AX} 7Hz, J_{BX} 3 Hz), 3.8 (H-3, ABX), 2.3 − 2.9 (4 H-arom.); λ_{max} (CH$_2$Cl$_2$) 240 (log ε 4.00), 280 (3.14), 289 nm (3.16).

3-Hydroxy-1-indanone (7). (a) A suspension of 3-acetoxy-1-indanone (6.0 g, 0.033 mol) in 3 N HCl (400 ml) was stirred at room temperature for 24 h. The reaction mixture was next extracted with chloroform, the extracts dried and evaporated, and the residual oily material crystallised from ether/petroleum at about 0 °C; yield 4.4 g (90 %), m.p. 51 °C (Found: C 72.65; H 5.40. Calc. for $C_9H_8O_2$: 72.90; H 5.40).

(b) 3-Bromo-1-indanone (7.0 g, 0.033 mol) was dissolved in water (500 ml) and acetone (300 ml). The solution was refluxed for 3 h, most of the acetone was evaporated, water was added and the title compound extracted into chloroform and isolated as above; yield 2.5 g (51 %).

2-Bromo-3-hydroxy-1-indanone (5). (a) 3-Hydroxy-1-indanone (2.0 g, 0.014 mol) was dissolved in anhydrous ether (400 ml) and bromine (2.2 g, 0.014 mol) addition carried out in the following way: A drop of bromine was added to the solution at room temperature. The solution

was then cooled to about 5 °C and the bromine added dropwise at such a rate that the solution was decolorised before addition of the next drop of bromine. In this way selective mono-bromination is achieved. The decolorised solution was next washed with water, dried and the solvent evaporated. The residual oil was chromatographically homogeneous and was used further as such; yield 2.9 g (93 %). For analytical purposes a part of the material was crystallised from $CHCl_3/CCl_4$/petroleum at 0 °C, m.p. 84 – 86 °C. (Found: C 47.24; H 3.08. Calc. for $C_9H_7BrO_2$: C 47.58; H 3.11; τ(CDCl$_3$) 5.5 (H-2, $J_{2,3}$ 3.5 Hz), 4.6 (H-3), 1.9 – 2.5 (4 H-arom.); λ_{max} (CH$_2$Cl$_2$) 249 (log ε 4.03), 285 nm (3.28).

(b) 3-Acetoxy-2-bromo-1-indanone (2.0 g, 0.007 mol) in a solution of methanol (100 ml) and 3 N HCl (80 ml) was kept at room temperature for 24 h. Addition of water followed by chloroform extraction furnished the title compound as above; yield 1.4 g (86 %).

3-Acetoxy-2-bromo-1-indanone (9) was prepared as *5* above from 3-acetoxy-1-indanone; yield 87 %, m.p. 97 °C (ether/petroleum). (Found: C 48.56; H 3.50. Calc. for $C_{11}H_9BrO_3$: C 48.80; H 3.34); τ(CDCl$_3$) 7.8 (Me), 5.4 (H-2, $J_{2,3}$ 3 Hz), 3.6 (H-3), 2.2 – 2.5 (4 H-arom.); λ_{max} (CH$_2$Cl$_2$) 255 (log ε 4.24), 288 nm (3.25).

2,3-Epoxyindanone (4). 2-Bromo-3-hydroxy-1-indanone (2.9 g, 0.013 mol) was dissolved in a mixture of benzene (250 ml) and hexane (500 ml), and the solution was deoxygenated by bubbling nitrogen through. Activated silver oxide [11] was then added and the stirred suspension heated under reflux in a nitrogen atmosphere for 24 h. The insoluble material from the cold reaction mixture was removed by filtration and the solvent was evaporated at reduced pressure. The residual oil was extracted with, warm hexane (500 ml), the hexane evaporated under reduced pressure and the residual oil crystallised from hexane; yield 1.1 g (60 %), m.p. 62 °C. (Found: C 74.10; H 4.25. Calc. for $C_9H_6O_2$: C 73.97; H 4.11); τ(CDCl$_3$) 6.1 (H-2, $J_{2,3}$ 2.5 Hz), 5.5 (H-3), 1.8 – 2.8 (4 H-arom.); λ_{max} (CH$_2$Cl$_2$) 261 (log ε 3.79), 299 nm (3.04).

Photochemical isomerisations; Isocoumarin (11). A solution of 2,3-epoxyindanone (290 mg, 0.002 mol) in anhydrous benzene (100 ml) was deaerated by bubbling nitrogen gas through the solution. The solution was next illuminated at room temperature using a Hanovia medium pressure Hg-lamp with a pyrex filter. The illumination time was 30 min. The solution was then evaporated and the residual material chromatographed on a silica column. The major reaction product, isocoumarin, was eluted with benzene/ethyl acetate (4:1); yield 89 mg (33 %). The identity of the product was verified by comparison with authentic material prepared after the literature.[14]

Isocoumarin (11) by Lewis acid isomerisation. Boron trifluoride etherate (1 ml, 0.007 mol) was added to a solution of 2,3-epoxyindanone (250

mg, 0.0017 mol) in anhydrous ether (20 ml). The resultant solution was left for 15 min at room temperature. The solution was then washed with water, dried and evaporated. The residual material was chromatographed as above; the yield of isocoumarin was 39 % (96 mg).

1,2-Indanedione (16). 2-Hydroxy-1-indanone [17] was prepared from 2-bromo-1-indanone according to the literature.[17,18] The former (1.0 g, 0.007 mol), N-bromosuccinimide (1.2 g, 0.007 mol) and catalytic amounts of benzoyl peroxide were heated together in refluxing carbon tetrachloride (200 ml) for 20 min. The precipitated succinimide was removed from the cold reaction mixture at about 0 °C and the solvent evaporated. The residual solid was recrystallised from carbon tetrachloride; yield 1.0 g (99 %), m.p. 95 – 115 °C. The identity of the material was verified by comparison with an authentic sample otherwise prepared.[19]

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