

Synthesis of Benzocyclo-octene-5,6-dione, Benzocyclo-octene-5,10-dione, and 2,3-Benzobishomotropone Derivatives by Dichlorocarbene Ring Enlargement, and of 7,8,9,10-Tetrahydrobenzocyclo-octene-5,6-dione ¹

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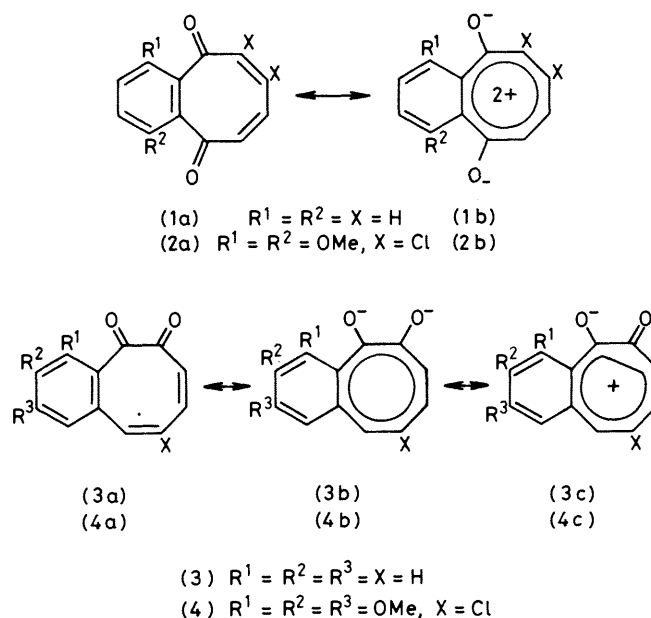
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Addition of dichlorocarbene by the use of a phase transfer catalyst to 1,4,5,8-tetramethoxynaphthalene (5) and to 2,3,4,6-tetramethoxybenzocyclohepten-5-one (9) afforded benzocyclo-octene-5,10-dione (2) and benzocyclo-octene-5,6-dione (4) together with 1,2:3,4-dimethylenenaphthalene (6) and 2,3-benzobishomotropone (10), respectively. Compounds (2) and (4) had no 8C-6 π character. 7,8,9,10-Tetrahydrobenzocyclo-octene-5,6-dione (14) was synthesized by three different methods from 7,8,9,10-tetrahydrobenzocyclo-octen-5(6*H*)-one (12). This compound had an unusually rigid conformation and could not be converted into the benzocyclo-octene-5,6-dione (3).

Various nonbenzenoid quinones † have been reported ² including *o*- and *p*-troquoquinones,^{2b} 2,3,6,7-dibenzobicyclo[6.2.0]-deca-2,6,8-trien-4-yne-9,10-dione,^{2c} *o*- and *p*-pleiadienequinones,^{2d} heptalenequinone,^{2e} heptatriafulvalenequinone,^{2f} azulenediones,^{2g} and new cyclobutadienediones,^{2c,h} but their chemical and pharmacological properties have been little investigated.³ Among eight-membered ring systems, cyclo-octatetraene-1,2- and -1,4-quinones ($n = 2$),⁴ [4*n*] annulenediones, and their tetra-,⁵ di-,⁶ and mono-benzo derivatives ¹ have been synthesized. The central problem of the cyclo-octatetraenequinone system is its reduction potential and potential aromaticity as a 8C-6 π Hückeloid system (1b) and (3b); this was first pointed out by Proctor.⁷ The existence of the 8C-6 π Hückeloid system was later confirmed ⁸ for 1,3,5,7-tetramethylcyclo-octatetraene under superacid conditions; this contrasts with the earlier establishment of the cyclo-octatetraene dianion,⁹ a 8C-10 π system.

In the preliminary communication,¹ the synthesis of two benzocyclo-octenediones (2) and (4) along with the dimethylenenaphthalene (6) and the 2,3-benzohomotropones, (10) and (11), by a dichlorocarbene ring-expansion reaction was reported. In this paper we describe the syntheses of these compounds in more detail, and also the synthesis and the unusually rigid conformation of 7,8,9,10-tetrahydrobenzocyclo-octen-5(6*H*)-one (14). This compound was obtained in the course of an attempted synthesis of benzocyclo-octene-5,6-dione (3), which has the same basic skeleton as compound (4) (Scheme 1).

The ring expansion reaction of monomethoxynaphthalenes to benzotropone derivatives with dichlorocarbene was first studied by Parham;¹⁰ the orientation effect of a methoxy group on the dichlorocarbene addition to mono- and poly-methoxynaphthalenes was investigated and various kinds of halogenated 2,3- and/or 3,4-benzotropones were synthesized.¹¹ It was suggested ¹ that the extension of this reaction to tetramethoxybenzocyclohepten-5-one (9) or tetramethoxynaphthalene (5) might yield hitherto unknown benzocyclo-octenedione or heptalenequinone compounds.^{2e} The reaction of 1,4,5,8-tetramethoxynaphthalene (5) with a large excess of dichlorocarbene generated from a mixture of chloroform, 50% sodium hydroxide, and trimethylbenzylammonium chloride afforded 1,2:3,4-dimethylenenaphthalene (6) (6%) and benzocyclo-octene-5,10-dione (2) (12%) (Scheme 2). Both *cis*- and *trans*-

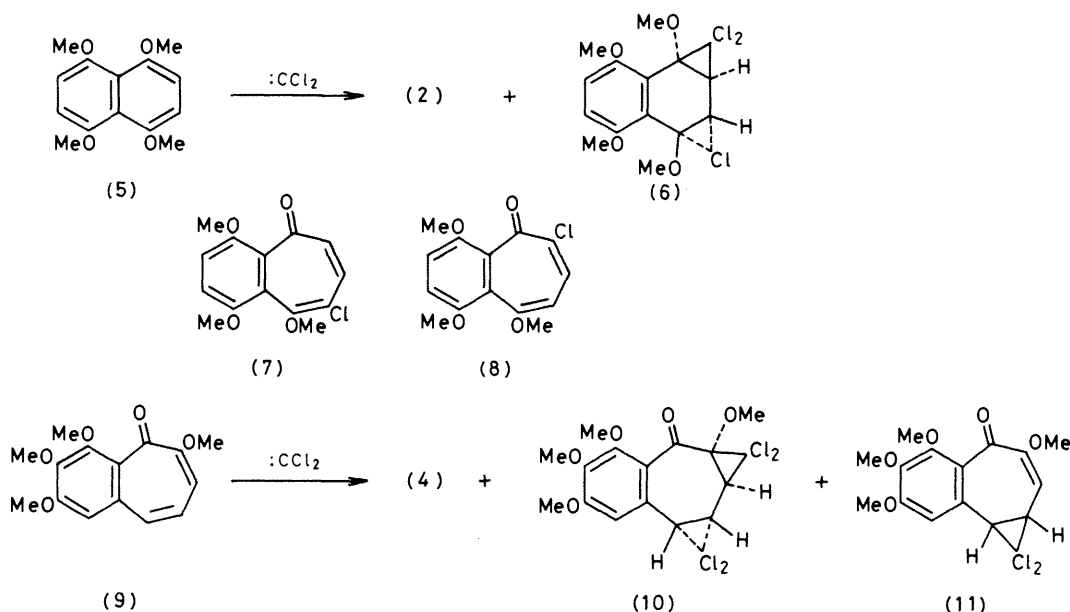


Scheme 1.

1,2:3,4-dimethylenenaphthalene derivatives were reported ¹² from the addition of ethoxycarbonylcarbene to naphthalene, but in this case a *trans*-configuration for compound (6) was tentatively assigned from the molecular models which indicated a strong interaction between the two chlorine atoms. Compound (2) showed double doublets in the ¹H n.m.r. spectrum at δ 6.39 (9-H) and 7.06 (8-H), coupling constant *J* 12.7 Hz, and two different absorption peaks in the i.r. spectrum at 1 702 and 1 659 cm^{-1} , indicating an asymmetric benzocyclo-octene-5,10-dione structure. The high frequency of the i.r. carbonyl absorption at 1 702 cm^{-1} and the ¹H n.m.r. signal at δ 6.39 suggested a non-planar conformation of the cyclo-octenedione ring and a weak contribution from polar structures such as (2b). The formation of the dione (2) most probably proceeded *via* the intermediate generation of 8-chloro-1,4,9-trimethoxybenzocyclohepten-5-one (7) and/or 6-chloro-1,4,9-trimethoxybenzocyclohepten-5-one (8).

2,3,4,6-Tetramethoxybenzocyclohepten-5-one (9) similarly afforded the 2,3-benzo-*trans*-bishomotropone (10) (23%), the benzocyclo-octene-5,6-dione (4) (3%), and small amounts of the 2,3-benzo-4,5-homotropone (11). The elemental analysis

† Although most of these compounds are [4*n*]- or [4*n* + 2]-annulenediones, some of them do not seem to belong to either class.



Scheme 2.

and mass spectrum showed the bishomotropone to have four chlorine atoms, the ^1H n.m.r. spectrum showed the existence of four methoxy groups, one aromatic proton, and three coupled cyclopropyl protons, and the i.r. spectrum showed a benzoyl carbonyl group at $1\ 693\ \text{cm}^{-1}$. These results indicate a 2,3-benzobishomotropone structure.¹³ The coupling constant of $J\ 1.5\ \text{Hz}$ between two different cyclopropyl protons leads to a dihedral angle of 115° . The *cis*-configuration is unlikely considering the interaction between the *gem*-dichloromethyl groups. Compound (4) showed ^1H n.m.r. signals for two coupled olefinic protons at $\delta\ 6.35$ (7-H) and $\delta\ 6.72$ (8-H) with a large coupling constant $J\ 13.4\ \text{Hz}$, and a proton at $\delta\ 6.61$ (10-H), and i.r. carbonyl absorptions at $1\ 273$ and $1\ 675\ \text{cm}^{-1}$. These indicate a benzocyclo-octene-5,6-dione structure with a non-planar cyclo-octene ring. Therefore the contribution from polar structures such as (4b) or (4c) is hardly significant. Compound (11) was very unstable in solution and its ^1H n.m.r. spectrum showed the existence of four methoxy groups, one aromatic proton, two cyclopropyl protons, and one olefinic proton. The coupling constants, $J\ 11.5\ \text{Hz}$ and $J\ 3.4\ \text{Hz}$, between these last three protons indicated a 2,3-benzohomotropone structure^{13b} for (11), which would be a precursor to compounds (10) and/or (4). In concentrated sulphuric acid the dione (2) gave a violet colour and the ^1H n.m.r. signals of 8- and 9-H shifted to lower field compared with those in deuteriochloroform, by 1.04 and 0.63 p.p.m. respectively. Since the change from $8\pi\text{-}8\text{C}$ to $6\pi\text{-}8\text{C}$ resulted in a chemical shift difference of 4.63 p.p.m.⁸ it is probable that only protonation of (2) had occurred in this case, and compound (2) could be recovered. In concentrated sulphuric acid the dione (4) gave a red colour and complicated ^1H n.m.r. signals in the olefinic region. It could not be recovered, but gave a resinous brown material.

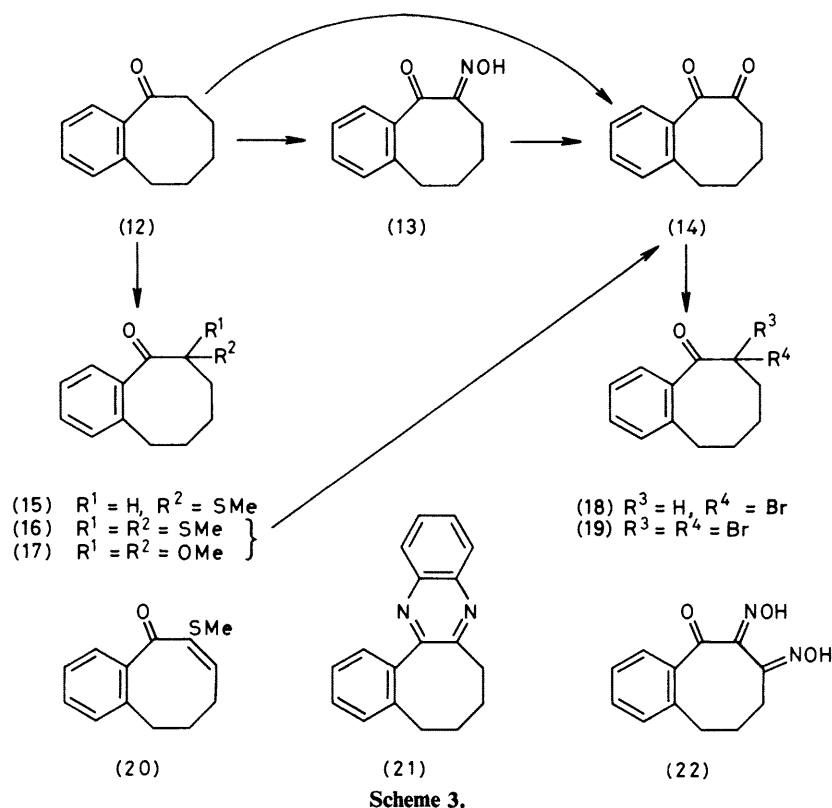
In order to synthesize benzocyclo-octene-5,6-dione (3a), the monoketone (12)¹⁴ was used as the starting material. Some reactions, which have been successfully used to convert polyhydrobenzocycloalken-5-ones into polyhydrobenzocycloalkene-5,6-diones with a five-, six-, or seven-membered ring were also applied to this eight-membered ring system.

Oxidation of compound (12) with selenium dioxide¹⁵ in refluxing ethanol for 24 h afforded the dione (14) (20%) as a yellow oil, while treatment with 3-methylbutyl nitrite¹⁶

afforded the oxime (13) (35%), which was then hydrolysed^{16,17} with 12M-hydrochloric acid and 37% formaldehyde at room temperature to give (14) (34%) (Scheme 3). Attempted introduction of an acetoxy group α to the carbonyl group with lead tetra-acetate¹⁸ was also discouraging. Treatment of (12) with methyl 2-nitrophenyl disulphide¹⁹ and sodium hydride in tetrahydrofuran gave the bis(methylthio)derivative (16) (75%), which was hydrolysed by mercuric perchlorate to give the dione (14) (18%) and the thioenol ether (20) (56%). Mercuric chloride, silver nitrate-*N*-chlorosuccinimide,²⁰ chloramine-T-mercuric chloride,²¹ and cadmium carbonate-mercuric chloride,²⁰ did not give useful results. The conversion of the bis(methylthio) compound (16) into the dimethoxy derivative (17) by thallium trinitrate¹⁹ in methanol was achieved in 80% yield; subsequent hydrolysis gave the dione (14) in 75% yield. The structure of (14) was confirmed by the formation of the quinoxaline derivative (21) on reaction with *o*-phenylenediamine.

Oxidation of the diketone (14) with 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (4 mol equiv.) in refluxing benzene or dioxane did not proceed at all. Treatment with bromine afforded the α -dibromoketone (19) in high yield; subsequent treatment of (19) with lithium carbonate [hexamethylphosphoric triamide (HMPT)],²² a mixture of lithium carbonate, lithium fluoride, and powdered glass (HMPT),²³ or 1,8-diazabicyclo[5.4.0]undec-7-ene only yielded unidentified material instead of olefinic compounds or products of transannular reaction. Treatment of the dibromo compound (19) with a large excess of *N*-bromosuccinimide (carbon tetrachloride, benzoyl peroxide) resulted in quantitative recovery, while treatment with lithium chloride [*N,N*-dimethylformamide (DMF)],²² lithium carbonate (DMF),²² or silver acetate (acetic acid) afforded the α -monobromoketone (18) as the only identified product. These results strongly suggested that introduction of a double bond into this dione system would be difficult because of strain. From a consideration of molecular models it might be expected that conjugation of the 6-carbonyl with an olefinic bond between C-7 and C-8 would be difficult even if the latter were introduced.

The i.r. spectrum of the dione (14) showed two carbonyl absorption bands at $1\ 710\ \text{cm}^{-1}$ for the β -carbonyl (C-6) and at $1\ 658\ \text{cm}^{-1}$ for the α -carbonyl (C-5) groups. The latter



absorption is low for a benzoyl carbonyl group²⁴ and lower than the absorption for 5-cyclo-octene-1,2-dione by 50 cm^{-1} (CHCl_3). The difference in carbonyl absorption between alicyclic ketones and polyhydrobenzocycloalken-5-ones are, 30 (CCl_4), 31 (CHCl_3), 34 (CHCl_3), and 29 cm^{-1} (CCl_4) for five-, six-, seven-, and eight-membered rings, respectively, *i.e.* consistently *ca.* 30 cm^{-1} .²⁴ Since the dipole-dipole repulsion between two adjacent carbonyl groups should decrease the polarization of the α -carbonyl group and the absorption is expected to shift towards higher wavenumber, this abnormally large difference could be explained by the unusually high electron-flow from the benzene ring, which might be brought about by unusual coplanarity of the α -carbonyl group and the benzene ring. The ^1H n.m.r. spectrum of the diketone (14) showed that a hydrogen at the *peri* position (C-4) appears at δ 8.1–8.3 indicating strong paramagnetic shielding from the α -carbonyl group, whereas indan-1-one, α -tetralone, benzosuberone, and benzocyclo-octen-5-one show δ 7.00–7.81 for a hydrogen atom *peri* to the α -carbonyl group.²⁵ This supports the evidence from the i.r. spectrum, showing that there is unusual coplanarity between the benzene ring and the α -carbonyl group. In the electronic spectrum the longer wave absorption of the α -dicarbonyl group is ascribed to the $n\text{-}\pi^*$ transition. It is known to depend upon the dihedral angle between the two carbonyl groups,²⁶ and the absorption at 368 nm ($\log \epsilon$ 1.98) of compound (14) would indicate a dihedral angle of $60\text{--}90^\circ$. Thus (14) must have an unexpectedly rigid partial conformation and the prevailing conformers must be (14a) and (14b) as shown in the Figure.

Experimental

M.p.s were determined with a Mitamura air-bath apparatus and are not corrected. ^1H N.m.r. spectra (tetramethylsilane as internal standard) were determined with a Varian A-60 D spectrometer. I.r. spectra were determined with a JASCO G,

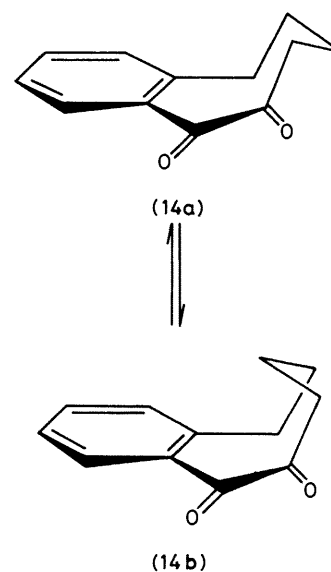


Figure. Conformation of 7,8,9,10-tetrahydrobenzocyclo-octene-5,6-dione (14)

or a JASCO A-2 instrument, electronic spectra (u.v.) with a JASCO UV-254II or a Hitachi 340 spectrometer, and mass spectra with a JEOL-JMS-01SG-2 spectrometer. The spectra were taken in the following solvents unless otherwise stated: u.v., CHCl_3 ; i.r., KBr ; ^1H n.m.r., CDCl_3 . Preparative column chromatography was carried out with Kieselgel 60 (Merck 70-230 mesh). Ether refers to diethyl ether.

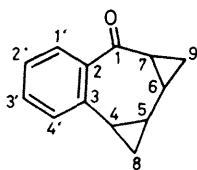
9,9,10,10-Tetrachloro-1,4,5,8-tetramethoxy-trans-1,2:3,4-dimethylenenaphthalene (6) and 6,7-Dichloro-1,4-dimethoxy-

benzocyclo-octene-5,10-dione (2).—A mixture of 1,4,5,8-tetramethoxynaphthalene (5) (1.805 g, 7.26 mmol), chloroform (24 ml, 298 mmol), 50% sodium hydroxide, and trimethylbenzylammonium chloride (120 mg, 0.673 mmol) was stirred for 17 h at room temperature. To this reaction mixture was added water (100 ml), the mixture was extracted with chloroform (200 ml), and the organic layer dried (Na_2SO_4). After removal of chloroform under reduced pressure the residue was purified by silica gel chromatography with benzene as eluant to afford the dimethylenenaphthalene (6) (183 mg, 6.1%) as colourless prisms, m.p. 184–185 °C (from benzene-hexane, or methanol) (Found: C, 46.05; H, 3.9. Calc. for $\text{C}_{16}\text{H}_{16}\text{Cl}_4\text{O}_4$: C, 46.40; H, 3.88%); λ_{max} (MeOH) 313.5 (log ϵ 3.11) and 325sh nm (2.97); δ 2.28 (2 H, s, 2- and 3-H), 3.13 (6 H, s, 2OMe), 3.92 (6 H, s, 2 MeOAr), and the *benzocyclo-octenedione* (2) (283 mg, 12.4%) as yellowish orange needles, m.p. 195–196 °C (from methanol) (Found: C, 53.8; H, 3.55. $\text{C}_{14}\text{H}_{10}\text{Cl}_2\text{O}_4$ requires C, 54.00; H, 3.21%); λ_{max} 300 nm (log ϵ 3.09); ν_{max} 1 702 (C=O), 1 659 (C=O), 1 653, 1 635, 1 597, 1 581, 1 533, 1 283, 1 270, 1 071, 1 029, 996, 917, 816, 709, and 655 cm^{-1} ; δ 3.86 (6 H, s, 2 OMe), 6.39 (1 H, d, J 12.7 Hz, 9-H), 7.06 (1 H, d, J 12.7 Hz, 8-H), and 7.11 (2 H, s, 2- and 3-H); δ (conc. H_2SO_4) 3.85 (3 H, s, OMe), 4.25 (3 H, s, OMe), 7.02 (1 H, d, J 12.5 Hz, 9-H), 7.63 (1 H, s, 2-H), 7.79 (1 H, s, 3-H), and 8.10 (1 H, d, J 12.5 Hz, 8-H).

8,8,9,9-Tetrachloro-1',2',3',7-tetramethoxy-2,3-benzo-trans-4,5:6,7-bishomotropone (10),* 8,8-Dichloro-2',3',4',7-tetramethoxy-2,3-benzo-4,5-monohomotropone (11),* and 9-Chloro-2,3,4-trimethoxybenzocyclo-octene-5,6-dione (4).—A mixture of 2,3,4,6-tetramethoxybenzocyclohepten-5-one (9) (4.11 g, 14.9 mmol), chloroform (30 ml, 372 mmol), acetyltrimethylammonium chloride (200 mg, 0.623 mmol), and 50% sodium hydroxide (60 ml) was stirred at room temperature for 17 h under nitrogen. Water (300 ml) was added, the reaction mixture was extracted with methylene dichloride, and the extract dried (Na_2SO_4). After removal of the solvent, the residue was separated by silica gel column chromatography into three fractions with benzene as eluant. The first fraction gave the *benzobishomotropone* (10) (1.492 g, 22.7%) as colourless plates, m.p. 150–151.5 °C (sublimed at 150–170 °C/267 Pa and recrystallized from cyclohexane or methanol) (Found: C, 46.35; H, 3.8. $\text{C}_{17}\text{H}_{16}\text{Cl}_4\text{O}_5$ requires C, 46.18; H, 3.64%); λ_{max} (MeOH) 281 nm (log ϵ 3.49); ν_{max} 1 693 and 1 588 cm^{-1} ; δ 2.18 (1 H, d, J 1.5 Hz, 6-H), 2.38 (1 H, dd, J 10.3 and 1.5 Hz, 5-H), 2.90 (1 H, d, J 10.3 Hz, 4-H), 3.61 (3 H, s, OMe), 3.72 (3 H, s, MeOAr), 3.97 (6 H, s, 2 MeOAr), and 6.69 (1 H, s, 4'-H).

The second fraction gave the *benzohomotropone* (11) (135 mg, 2.94%) as colourless microrods, m.p. 142–143 °C (from methanol or cyclohexane) (Found: C, 53.5; H, 4.5. $\text{C}_{16}\text{H}_{16}$ -

* These names are not fully systematic, but are retained for consistency with the literature. The numbering scheme used is as follows:



The systematic names for (10) and (11) are 6,7:8,9-bis(dichloromethylene)-2,3,4,6-tetramethoxy-6,7,8,9-tetrahydrobenzocyclohepten-5-one and 8,9-dichloromethylene-2,3,4,6-tetramethoxy-8,9-dihydrobenzocyclohepten-5-one respectively.

Cl_2O_5 requires C, 53.50; H, 4.48%); δ 2.65 (1 H, dd, J 11.5 and 3.4 Hz, 5-H), 3.17 (1 H, d, J 11.5 Hz, 4-H), 3.68 (3 H, s, OMe), 3.91 (6 H, s, 2 MeOAr), 3.98 (3 H, s, MeOAr), 5.09 (1 H, d, J 3.4 Hz, 6-H), and 6.71 (1 H, s, 4'-H).

The third fraction gave the *benzocyclo-octenedione* (4) as a yellow oil, b.p. 100 °C/267 Pa (135 mg, 2.94%) (Found: C, 58.3; H, 4.5. $\text{C}_{15}\text{H}_{13}\text{ClO}_5$ requires C, 58.48; H, 4.24%); λ_{max} 300sh nm (log ϵ 2.81); ν_{max} (CCl_4) 1 723 (C=O), 1 675 (C=O), 1 585, 1 555, 1 492, 1 400, 1 350, 1 280, 1 250, 1 195, 1 129, 1 101, and 1 000 cm^{-1} ; δ 3.92 (9 H, s, 3 MeOAr), 6.35 (1 H, d, J 13.4 Hz, 7-H), 6.61 (1 H, s, 10-H), 6.72 (1 H, d, J 13.4 Hz, 8-H), and 7.23 (1 H, s, 1-H).

6-Hydroxyimino-7,8,9,10-tetrahydrobenzocyclo-octen-5(6H)-one (13).—(a) To a well stirred mixture of sodium (1.65 g, 71.7 mmol), ethanol (35 ml), and ether (50 ml), a mixture of 7,8,9,10-tetrahydrobenzocyclo-octene-5(6H)-one (12) (12.32 g, 70.7 mmol), 3-methylbutyl nitrite (9.20 g, 78.5 mmol), and ether (150 ml) was added dropwise at –10 to 0 °C during 40 min. After 3 h, the reaction mixture was poured into water, neutralized with hydrochloric acid, and extracted with ether; the organic layer was washed with brine and dried (MgSO_4) overnight. After rotary evaporation of the solvent, the residue was purified by silica gel column chromatography with dichloromethane as eluant to give the *hydroxyimino-ketone* (13) (5.42 g, 37%) as colourless crystals, m.p. 116–117 °C (from cyclohexane) (Found: C, 70.65; H, 6.55; N, 6.7. $\text{C}_{12}\text{H}_{13}\text{NO}_2$ requires C, 70.91; H, 6.45; N, 6.89%); ν_{max} 3 200br (OH), 1 660 (C=O), and 1 630 cm^{-1} ; δ 1.55–2.05 (4 H, m), 2.47–2.78 (2 H, m), 2.78–3.05 (2 H, m), 7.10–7.70 (3 H, m), 7.73–7.97 (1 H, m, 4-H), and 9.0 (1 H, br, OH, exchangeable with deuterium).

(b) Into a mixture of dry ether (70 ml), compound (12) (1 g, 5.74 mmol), and 3-methylbutyl nitrite (1 g, 8.54 mmol), dry hydrogen chloride gas was passed at 0–10 °C and the mixture left overnight. The hydrochloride was collected on a glass filter and neutralized with sodium hydrogen carbonate. The organic material obtained was recrystallized from water to give the oxime (13) (305 mg, 26%), while the filtrate was poured into water, neutralized, and extracted with ether. The extracts were washed with water, dried, and rotary-evaporated, and the residue recrystallized from dichloromethane to give 6,7-bis(hydroxyimino)-7,8,9,10-tetrahydrobenzocyclo-octene-5(6H)-one (22) (104 mg, 7.8%) as colourless needles, m.p. 182–185 °C (Found: C, 61.8; H, 5.25; N, 12.0. $\text{C}_{14}\text{H}_{12}\text{N}_2\text{O}_3$ requires C, 62.06; H, 5.21; N, 12.06%); ν_{max} 3 180br (OH) and 1 685br cm^{-1} (C=O); δ ($\text{CF}_3\text{CO}_2\text{H}$) 2.1–2.5 (2 H, m, 9-H), 2.8–3.3 (4 H, m, 8- and 10-H), and 7.2–7.9 (4 H, m, aromatic).

7,8,9,10-Tetrahydrobenzocyclo-octene-5,6-dione (14).—(a) To a stirred mixture of compound (12) (3.00 g, 17.2 mmol) and absolute ethanol (20 ml), selenium dioxide (1.92 g, 17.2 mmol) in warm absolute ethanol (30 ml) was added during 2 h and the reaction mixture was refluxed for a further 24 h. After removal of the selenium, the solvent was rotary-evaporated and the residue purified on a silica gel column using benzene-ether as eluant with the benzene concentration decreasing from 95 to 0% to give as the first fraction a selenium containing dimer (1.04 g, 12%) as yellow crystals, m.p. 197–199 °C (from benzene-methylene dichloride) (Found: C, 57.55; H, 4.5. Calc. for $\text{C}_{24}\text{H}_{22}\text{O}_2\text{Se}_2$: C, 57.61; H, 4.43%); the mass spectral data were in accord with the molecular formula containing two selenium atoms. A second fraction was obtained, the *benzocyclo-octenedione* (14) (637 mg, 19.7%) as a yellow oil.

(b) To a mixture of compound (13) (1.50 g, 7.4 mmol) and a small amount of methanol, formalin (37%; 2.4 ml, 32 mmol),

and 12M-hydrochloric acid (4.75 ml, 57 mmol) were added and the mixture stirred at room temperature for 20 min. The reaction mixture was poured into water and extracted with methylene dichloride; the organic layer was washed with water and dried (MgSO₄). After the solvent had been rotary-evaporated, the residue was purified on a silica gel column with methylene dichloride as eluant to afford the dione (14) (483 mg, 34%).

(c) To a stirred mixture of mercuric chloride (1.85 g, 4.1 mmol) and tetrahydrofuran (10 ml), a mixture of the bis(methylthio) compound (16) (490 mg, 1.85 mmol) and tetrahydrofuran (8 ml) was added dropwise at room temperature during 5 min. After 15 min the reaction mixture was poured into water and the usual work-up by silica gel chromatography gave as the first band 6-methylthio-9,10-dihydrobenzocyclo-octene-5(8H)-one (20) (225 mg, 56%) as a reddish yellow oil, b.p. 65 °C/85 Pa (Found: C, 71.75; H, 6.45. C₁₃H₁₄OS requires C, 71.52; H, 6.46%); ν_{\max} (neat) 1 656 (C=O) and 1 625 cm⁻¹ (C=C); δ 1.6—2.5 (4 H, m, 8- and 9-H), 2.25 (3 H, s, SMe), 2.79 (2 H, t, J 6 Hz, 10-H), 6.22 (1 H, t, J 9 Hz, 7-H), and 7.0—7.9 (4 H, m, aromatic). Compound (14) (63 mg, 18%) was obtained from the second band.

(d) To a stirred mixture of the bis(methylthio) derivative (16) (290 mg, 1.07 mmol) and tetrahydrofuran (30 ml), mercuric perchlorate (1.26 g, 2.77 mmol) was added in one portion under nitrogen and the reaction mixture was stirred for 45 min. After the usual work-up on a silica gel column with benzene as eluant, compound (20) (200 mg, 85%) was obtained. A mixture of mercuric chloride (550 mg, 2.02 mmol) and acetonitrile (8 ml) was added to a mixture of the sulphide (20) (220 mg, 1.01 mmol), acetonitrile (6 ml), and water (2 ml), and the reaction mixture was refluxed for 4.5 h under nitrogen.²⁷ The usual work-up gave compound (14) (35 mg, 9.2%). A mixture of compound (20) (72 mg, 0.33 mmol), hydrochloric acid (3M; 12 ml), and tetrahydrofuran (8 ml) was warmed for 5.5 h at 45 °C under nitrogen. The usual work-up of the reaction mixture gave the dione (14) (9 mg, 13.5%).

(e) To a mixture of the dimethoxy derivative (17) (0.99 g, 42 mmol) and tetrahydrofuran (25 ml), hydrochloric acid (4M; 25 ml) was added and the reaction mixture was refluxed for 4 h. After the usual work-up, the residue was purified on a silica gel column (Merck, lohar column, size A) with hexane-methylene dichloride (3 : 2) as eluant under a slight pressure to give the dione (14) (0.6 g, 75%) as a yellow oil, b.p. 60 °C/80 Pa; m/z (75 eV) 188 (M^+ , 59%), 160 ($M^+ - CO$, 27), 132 ($M^+ - 2CO$, 52), 131 (100), 104 ($M^+ - 2CO - 2C_2H_4$, 87), and 81 (35) (Found: C, 76.7; H, 6.5. C₁₂H₁₂O₂ requires C, 76.57; H, 6.43%); λ_{\max} 260 (log_e 4.08), 298 (3.36), and 368 nm (1.98); ν_{\max} (CHCl₃) 1 710 (C=O), 1 658 (C=O), and 1 599 cm⁻¹; δ 1.57—2.17 (4 H, m, 8- and 9-H), 2.53—3.12 (4 H, m, 7- and 10-H), 7.02—7.79 (3 H, m, aromatic), and 8.01—8.27 (1 H, m, 4-H).

5,6,7,8-Tetrahydrobenzocyclo-octene[5,6-b]quinoxaline (21).—A mixture of (14) (190 mg, 1.01 mmol), *o*-phenylenediamine (110 mg, 1.02 mmol), and methanol (5 ml) was refluxed for 3 h and after the solvent had been rotary-evaporated the residue was purified on a silica gel column with ether-methylene dichloride (1 : 1) as eluant to afford the quinoxaline (21) (99 mg, 34%) as yellow granules, m.p. 138.0—138.5 °C (from methanol) (Found: C, 83.1; H, 6.25; N, 10.9. C₁₈H₁₆N₂ requires C, 83.05; H, 6.20; N, 10.76%); δ 1.5—3.5 (8 H, m, methylene) and 7.18—8.33 (8 H, m, aromatic).

6-Methylthio-7,8,9,10-tetrahydrobenzocyclo-octen-5(6H)-one (15) and 6,6-Bis(methylthio)-7,8,9,10-tetrahydrobenzocyclo-octen-5(6H)-one (16).—To a stirred and chilled mixture of compound (14) (5.17 g, 29.7 mmol), sodium hydride (2.81 g,

70.3 mmol), and tetrahydrofuran (100 ml), methyl 2-nitrophenyl disulphide (13.9 g, 68.8 mmol) in tetrahydrofuran (50 ml) was added dropwise during 30 min under nitrogen. The mixture was stirred for 4.5 h at room temperature, then poured into water, acidified with dilute hydrochloric acid, and extracted with ether; the organic layer was washed with aqueous sodium hydrogen carbonate, water, and brine, and dried (MgSO₄) overnight. After rotary evaporation of the ether, the residue was purified on a silica gel column with benzene as eluant to give initially a small amount of the *title compound* (15) as colourless needles, m.p. 75—76 °C (from hexane); m/z (75 eV) 220 (M^+), 205 ($M^+ - CH_3$, 25%), 173 ($M^+ - SCH_3$, 25), and 145 ($M^+ - SCH_3 - CO$, 33) (Found: C, 70.65; H, 7.35; S, 14.55. C₁₃H₁₆OS requires C, 70.87; H, 7.32; S, 14.55%); ν_{\max} (CHCl₃) 1 671 cm⁻¹; δ 1.3—2.5 (6 H, m, 7-, 8-, and 9-H), 2.15 (3 H, s, SMe), 2.6—3.1 (2 H, m, 10-H), 3.3—3.6 (1 H, m, 6-H), and 7.1—7.4 (4 H, m, aromatic).

A second fraction gave the *title compound* (16) (5.65 g, 71%) as colourless cubes, m.p. 114.5—115 °C (from hexane); m/z (75 eV) 266 (M^+ , 42%), 219 ($M^+ - SCH_3$, 58), 191 ($M^+ - SCH_3 - CO$, 25), 172 ($M^+ - 2SCH_3$, 51), and 144 ($M^+ - 2SCH_3 - CO$, 100) (Found: C, 62.9; H, 6.95. C₁₄H₁₈O₂S₂ requires C, 63.12; H, 6.81%); ν_{\max} (CHCl₃) 1 673 cm⁻¹; δ 1.55—2.07 (6 H, m, 7-, 8-, and 9-H), 2.01 (6 H, s, SMe), 2.55—3.05 (2 H, m, 10-H), and 7.01—7.34 (4 H, m, aromatic).

6,6-Dimethoxy-7,8,9,10-tetrahydrobenzocyclo-octen-5(6H)-one (17).—To a mixture of thallium(III) nitrate trihydrate (5.37 g, 12.1 mmol) and methanol (25 ml), the bis(methylthio) compound (16) (1.20 g, 4.5 mmol) in tetrahydrofuran (8 ml) was added dropwise under nitrogen and the reaction mixture was stirred for 2 h at 40 °C. The reaction mixture was poured into water, extracted with ether, and the ether layer washed with brine and dried (MgSO₄). After rotary evaporation of the ether, the residue was purified on a silica gel column with benzene-dichloromethane (2 : 1) as eluant to give the *dimethoxy compound* (17) (0.84 g, 84%) as a colourless oil, b.p. 90 °C/80 Pa, m/z (75 eV) 234 (M^+) (Found: C, 71.8; H, 7.85. C₁₄H₁₈O₃ requires C, 71.77; H, 7.74%); ν_{\max} (CHCl₃) 1 715 cm⁻¹; δ 1.20—2.15 (6 H, m, 7-, 8-, and 9-H), 2.60—2.90 (2 H, m, 10-H), 3.32 (6 H, s, OMe), and 6.98—7.55 (4 H, m, aromatic).

6,6-Dibromo-7,8,9,10-tetrahydrobenzocyclo-octen-5(6H)-one (19).—To a mixture of compound (14) (605 mg, 3.22 mmol) and carbon tetrachloride (8 ml), bromine (1.035 mg, 6.47 mmol) in carbon tetrachloride (8 ml) was added at room temperature for 20 min and warmed at 50 °C for 3.5 h. After rotary evaporation of the solvent, the *title compound* (19) (1.08 g, 97%) was obtained as colourless needles, m.p. 83.0—84.0 °C (from hexane) (Found: C, 41.65; H, 2.75. C₁₂H₁₀Br₂O₂ requires C, 41.65; H, 2.91%); ν_{\max} (CHCl₃) 1 720 (C=O) and 1 658 cm⁻¹ (C=O); δ 1.62—2.10 (2 H, m, methylene), 2.51—2.83 (4 H, m, methylene), 7.04—7.72 (3 H, m, aromatic), and 7.99—8.20 (1 H, m, 4-H).

Attempted Debromination of the Dibromo Compound (19).—(a) A mixture of compound (19) (400 mg, 1.16 mmol), lithium chloride (270 mg, 6.36 mmol), and dimethylformamide (20 ml) was refluxed with stirring for 3 h and the reaction mixture was poured into water and extracted with ether. The usual work-up gave 6-bromo-7,8,9,10-tetrahydrobenzocyclo-octen-5(6H)-one (18) (12 mg, 3.9%) as colourless crystals, m.p. 65—67 °C (from hexane) (Found: C, 54.25; H, 4.35. C₁₂H₁₁BrO₂ requires C, 53.96; H, 4.15%); ν_{\max} (CHCl₃) 1 732 and 1 665 cm⁻¹; δ 1.65—3.08 (6 H, m, 8-, 9-, and 10-H), 4.84—5.10 (1 H, m, 7-H), 7.05—7.82 (3 H, m, aromatic), and 8.06—8.31 (1 H, m, 4-H).

(b) A mixture of compound (19) (17 mg, 0.06 mmol), lithium carbonate (20 mg, 0.26 mmol), and dimethylformamide (0.75 ml) was heated for 16 h at 100 °C. The usual work-up gave a few mg of the monobromo compound (18).

(c) A mixture of compound (19) (154 mg, 0.45 mmol), silver nitrate (165 mg, 1.00 mmol), and glacial acetic acid (6 ml) was refluxed for 19 h to give the product (18) (26 mg, 22%).

Reaction of the Ketone (12) with Lead Tetra-acetate.—A mixture of compound (12) (1.00 g, 5.74 mmol), lead tetraacetate (2.24 g, 4.56 mmol), and glacial acetic acid (7 ml) was heated for 3.5 or 24 h at 100 °C; (12) was recovered in a yield of 36 or 30%, respectively.

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