

Formation of Styrene Derivatives from Dibromocarbene Adducts of Cyclohexa-1,4-dienes

By George M. Iskander, Department of Chemistry, University of Khartoum, Sudan

The bisdibromocarbene adduct (I; $R^1 = R^2 = \text{OMe}$) from 1,4-dimethoxycyclohexa-1,4-diene, when heated in basic and in neutral media, gave 2,3'-dibromo-4'-methoxyacetophenone and 3'-bromo-4'-methoxyacetophenone. The diadduct (I; $R^1 = \text{H}, R^2 = \text{OMe}$) from 1-methoxycyclohexa-1,4-diene in neutral medium gave the two isomeric 3,β-dibromo-4-methoxystyrenes (VIII; $R^1 = \text{H}$), and 4'-bromo-3'-methoxyacetophenone, besides a small amount of 3-bromobenzoic acid. The adduct (I; $R^1 = R^2 = \text{H}$) from cyclohexa-1,4-diene itself showed no significant reaction.

THE reactions of mono- and di-halogenocyclopropanes with acids¹ and with silver salts in acidic media² have been investigated. A preliminary investigation of alkoxy-derivatives of enol ethers with hot quinoline³ or pyridine has also been reported.

We have investigated the reactions of dibromocarbene adducts of alkoxy-cyclohexa-1,4-dienes in hot neutral and in basic media. In contrast with previous observations, styrene and acetophenone derivatives were obtained.

With pyridine the diadduct (I; $R^1 = R^2 = \text{OMe}$) of dibromocarbene with 1,4-dimethoxycyclohexa-1,4-diene gave mainly 2,3'-dibromo-4'-methoxyacetophenone during aqueous work-up. However, steam distillation of the product mixture after boiling with pyridine afforded 3'-bromo-4'-methoxyacetophenone. The latter product was also obtained from the diadduct (I; $R^1 =$

$R^2 = \text{OMe}$) after boiling with dimethylformamide followed by steam distillation of the product mixture.

The monomethoxy-adduct (I; $R^1 = \text{H}, R^2 = \text{OMe}$) in boiling dimethylformamide gave the *cis*- and *trans*-isomers of 3,β-dibromo-4-methoxystyrene (VIII; $R^1 = \text{H}$) (identified by analyses and spectra and their ready oxidation to 3-bromo-4-methoxybenzoic acid), 4'-bromo-3'-methoxyacetophenone, and *m*-bromobenzoic acid.

The reaction mechanism involves two steps: formation of the cyclo-octatetraene derivative (V) and thermal conversion of (V) into products. The fission of a cyclopropane ring is probably concerted and heterolytic, giving bromide ion and an allylic carbonium ion (III) according to the predictions of Woodward and Hoffmann,⁴ and is followed by loss of a proton giving the diene (IV). Opening of the second cyclopropane ring would then lead to an intermediate cyclo-octatetraene (V) (Scheme 1).

¹ V. Joan, F. Bardea, and M. Farcasiu, *Rev. Chim. (Roumania)*, 1962, **7**, 947.

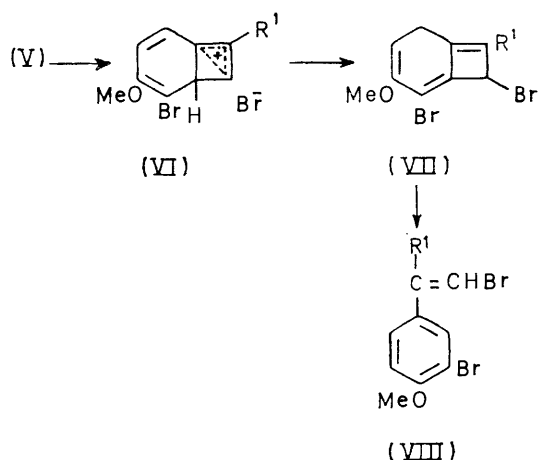
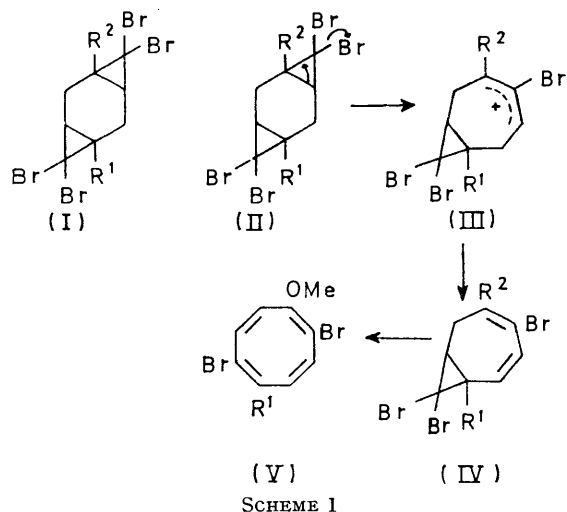
² (a) A. J. Birch, J. M. Graves, and F. Stansfield, *Proc. Chem. Soc.*, 1962, 282; (b) A. J. Birch, J. M. H. Graves, and J. B. Siddall, *J. Chem. Soc.*, 1963, 4234; (c) A. J. Birch, J. M. Brown, and F. Stansfield, *ibid.*, 1964, 5343; (d) A. J. Birch, G. M. Iskander, and F. Stansfield, *ibid.*, 1965, 1390; (e) G. M. Iskander, B. I. Magboul, and F. Stansfield, *ibid.*, 1967, 358.

³ W. E. Parham, R. W. Soeder, J. R. Throckmorton, K. Kunel, and R. M. Dodson, *J. Amer. Chem. Soc.*, 1965, **87**, 321.

⁴ R. B. Woodward and R. Hoffmann, *J. Amer. Chem. Soc.*, 1965, **87**, 395.

The subsequent thermal conversion of the cyclo-octa-tetraene derivative (V) is summarised in Scheme 2. Huisgen and his co-workers⁵ have shown that bromo-cyclo-octatetraenes undergo valence tautomerism *via* cyclopropenium ions⁶ to cyclobutene derivatives. By analogy, the intermediate (V) would give the cyclobutene derivative (VII), which by conrotatory ring cleavage would afford *trans*- β -bromostyrenes (VIII; R¹ = H or OMe). The *cis*- β -bromostyrene derivative might arise as suggested previously⁵ from ion recombination on the opposite side of structure (VI) giving the epimer of (VII).

In the case of the diadduct (I; R¹ = R² = OMe), the styrenes produced (VIII; R¹ = OMe), being enol ethers, are hydrolysed easily to the corresponding ketones.



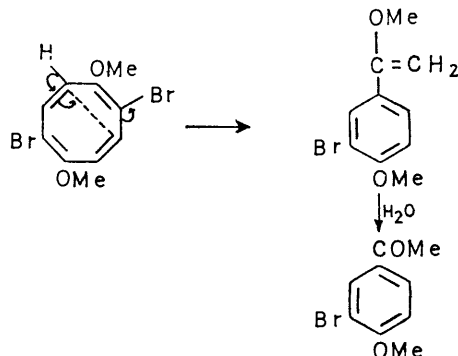
3'-Bromo-4'-methoxyacetophenone obtained from the dimethoxy-diadduct might arise through a transannular ring contraction of the intermediate (V), possibly as in Scheme 3.

The unsubstituted dibromocyclopropane adduct (I; R¹ =

⁵ R. Huisgen and W. E. Konz, *J. Amer. Chem. Soc.*, 1970, **92**, 4102, 4104.

⁶ T. J. Katz and E. H. Gold, *J. Amer. Chem. Soc.*, 1964, **86**, 1600.

R² = H) showed no significant reaction under the same conditions, presumably because there is no alkoxy-group to stabilise the intermediate carbonium ion (III; R¹ = H) (Scheme 1).



In an analogous reaction, pyrolysis of the dichlorocarbene adduct of 1-ethoxycyclohexene in dimethylformamide or in pyridine afforded 1-ethoxycyclohepta-1,3,5-triene, as reported by earlier workers³ for pyrolysis in quinoline.

EXPERIMENTAL

I.r. spectra were obtained for either liquid films or Nujol mulls with Unicam SP 200 and SP 1000 spectrophotometers. U.v. absorption measurements were made with a Unicam SP 800 instrument. ¹H N.m.r. spectra (60 MHz) were recorded with a Varian A60 or Perkin-Elmer instrument, with tetramethylsilane as internal standard. G.l.c. was carried out on a Pye gas chromatograph (series 104 model 64) with flame-ionisation detector containing a 7 ft column of Apiezon L on 60–72 mesh silanised Diatomite C (oven temperature 190°).

Petroleum refers to the fraction of b.p. 60–80°.

Dibromocyclopropanes (I) were prepared by the modified² method of Doering and Hoffmann.⁷

3'-Bromo-4'-methoxyacetophenones.—(i) *Reactions in pyridine.* The diadduct (I; R¹ = R² = OMe)^{2c} (3.0 g) was boiled under reflux with pyridine (15 ml) for 2 h. The solution was cooled and extracted with benzene (50 ml). The extract was washed with water, dried, and evaporated *in vacuo*. From the residue the product was isolated (0.8 g, 42%) by column chromatography (silica gel; benzene) and crystallised from carbon tetrachloride, then petroleum as yellowish needles of 2,3'-dibromo-4'-methoxyacetophenone, m.p. 112° (lit.,⁸ 105°) (Found: C, 35.5; H, 2.7. Calc. for C₉H₈Br₂O₂: C, 35.0; H, 2.6%), λ_{\max} (EtOH) 279 nm (ϵ 10,300), ν_{\max} (Nujol) 1675, 1590, and 1270 cm⁻¹, τ (CDCl₃) 1.72 (1H, d, *m*-coupled with proton at 1.95), 1.95 (1H, dd, further *o*-coupled with proton at 2.96, J_1 2.5 Hz), 2.96 (1H, d, J_2 8.5 Hz), 5.58 (2H, s, CH₂), and 5.90 (3H, s, OMe); the pyridinium salt had m.p. 225° (decomp.) (lit.,⁹ 224–225°).

In a subsequent experiment, the product obtained after boiling with pyridine was steam distilled. From the distillate needles were obtained, which afforded 3'-bromo-4'-methoxyacetophenone, m.p. 84–85° (from petroleum)

⁷ W. von E. Doering and A. K. Hoffmann, *J. Amer. Chem. Soc.*, 1954, **76**, 6162.

⁸ N. Hoan and B. Hoi, *Compt. rend.*, 1947, **224**, 1363.

⁹ F. Krohnke and K. Ellegast, *Chem. Ber.*, 1953, **86**, 1556.

(lit.,⁹ 87—88°) (Found: C, 47.3; H, 4.15. Calc. for $C_9H_9BrO_2$: C, 47.2; H, 3.9%), ν_{\max} (Nujol) 1675, 1590, and 1270 cm^{-1} , τ ($CDCl_3$) 1.76 (1H, d, *m*-coupled with proton at 2.02), 2.02 (1H, dd, further *o*-coupled with proton at 3.03, J_1 2.5, J_2 8.5 Hz), 3.03 (1H, d, J_2 8.5 Hz), 6.00 (3H, s, OMe), and 7.47 (3H, s, COMe).

(ii) *Reaction in dimethylformamide.* The diadduct (I; $R^1 = R^2 = OMe$) (4.84 g) was heated under reflux with dimethylformamide (15 ml) for 3 h under nitrogen. After cooling, the clear liquid was steam distilled. From the distillate a white solid was obtained which crystallised from petroleum as needles of 3'-bromo-4'-methoxyacetophenone (0.9 g, 40%), m.p. 82—84° (lit.,⁹ 87—88°).

Reaction of 4,4,8,8-Tetrabromo-1-methoxytricyclo-[5.1.0.0^{3,5}]octane with Boiling Dimethylformamide.—The diadduct (I; $R^1 = H$; $R^2 = OMe$)^{2c} (2.27 g) was heated under reflux with dimethylformamide (20 ml) for 5 h under nitrogen. The mixture was cooled and steam distilled and the distillate was extracted with dichloromethane (75 ml total). The extract was dried and evaporated *in vacuo* leaving a pale yellow liquid (0.95 g), which was chromatographed (silica gel; benzene) to give the following compounds (in order of elution).

cis-3,β-Dibromo-4-methoxystyrene (VIII; $R^1 = H$) formed needles (0.26 g) (from aqueous ethanol), m.p. 72—73° (Found: C, 37.15; H, 2.8; Br, 54.6. $C_9H_8Br_2O$ requires 37.0; H, 2.7; Br, 54.8%), λ_{\max} (EtOH) 221 (ϵ 22,900) and 270 nm (20,000), ν_{\max} (Nujol) 1600, 1060, and 1020 cm^{-1} , τ ($CDCl_3$) 2.52 (1H, d, *m*-coupled with proton at 2.83, J 2 Hz), 2.83 (1H, dd, *o*-coupled with proton at 3.20, J 2 and 10 Hz), 3.20 (1H, d, J 10 Hz), 3.00 and 3.60 (2H, dd, vinyl protons, J 8.0 Hz), and 6.33 (3H, s, OMe). Alkaline permanganate oxidation of this product gave 3-bromo-4-methoxybenzoic acid, m.p. 213—214° [lit.,¹⁰ 213—214°; lit.,¹¹ 218—218.5° (corr.)], ν_{\max} (Nujol) 2680, 1675, 1250, and 1020 cm^{-1} .

4'-Bromo-3'-methoxyacetophenone formed needles (0.23 g) (from ethanol), m.p. 101—103° (Found: C, 47.1; H, 4.0; Br, 34.8. $C_9H_9BrO_2$ requires C, 47.1; H, 3.9; Br, 34.9%), λ_{\max} (EtOH) 231 (ϵ 16,460) and 275 nm (13,300), ν_{\max} (Nujol) 1680, 1590, and 1080 cm^{-1} , τ ($CDCl_3$) 1.48 (1H, d, *m*-coupled with proton at 2.20, J 2 Hz), 2.20 (1H, dd, further *o*-coupled with proton at 3.15, J 2 and 10 Hz), 3.15

(1H, J 10 Hz), 6.05 (3H, s, OMe), and 7.20 (3H, s, Me); *2,4-dinitrophenylhydrazone*, orange needles (from ethyl acetate), m.p. 72—73° (Found: C, 44.3; H, 3.2; N, 13.65. $C_{15}H_{13}BrN_4O_5$ requires C, 44.0; H, 3.2; N, 13.7%). Alkaline hypobromite oxidation of the ketone (50 mg) at *ca.* 30° gave needles (from aqueous ethanol) of 4-bromo-3-methoxybenzoic acid, m.p. 219° (lit.,¹² m.p. 220°).

trans-3,β-Dibromo-4-methoxystyrene formed stout needles (0.28 g) (from petroleum), m.p. 98—100° (Found: C, 36.8; H, 2.7; Br, 54.6. $C_9H_8Br_2O$ requires C, 37.0; H, 2.7; Br, 54.8%), λ_{\max} (EtOH) 221 (ϵ 23,000) and 270 nm (20,000), ν_{\max} (Nujol) 1580, 1120, 1080, 1050, and 1020 cm^{-1} , τ ($CDCl_3$) 2.48 (1H, d, *m*-coupled with proton at 2.78, J 2 Hz), 2.78 (1H, dd, further *o*-coupled with proton at 3.27, J 2 and 10 Hz), 3.27 (1H, d, J 10 Hz), 3.00 and 3.45 (2H, dd, vinyl protons, J 14 Hz), and 6.00 (3H, s, OMe). Alkaline permanganate oxidation of this compound gave 3-bromo-4-methoxybenzoic acid.

The bromostyrenes compounds showed mixed m.p. depression.

3-Bromobenzoic acid (35 mg) crystallised from water as needles, m.p. 154°, identical with an authentic specimen.

1-Ethoxycyclohepta-1,3,5-triene.—7,7-Dichloro-1-ethoxycyclo[4.1.0]heptane³ (6.27 g) was heated under reflux with dimethylformamide (27 ml) or pyridine (20 ml) for 4 h under nitrogen. The reaction mixture was steam distilled and the distillate extracted with dichloromethane (75 ml total). The extract was evaporated leaving an oil (1.29 g) which was chromatographed (silica gel; benzene) to give 1-ethoxycyclohepta-1,3,5-triene as a pale yellow oil (0.83 g, 31%), b.p. 90° at 30 mmHg (lit.,¹³ 52—53° at 4 mmHg) (Found: C, 79.2; H, 8.85. Calc. for $C_9H_{12}O$: C, 79.4; H, 8.8%), λ_{\max} (EtOH) 290 (ϵ 4050) and 207 nm (17,000), [lit.,¹³ λ_{\max} (EtOH) 290 (ϵ 3840) and 207 nm (17,050), ν_{\max} (film) 1620, 1540, 1120, and 1050 cm^{-1}].

Mild acidic hydrolysis¹³ of the product afforded cyclohepta-3,5-dienone as a yellow liquid (0.2 g, 90%), b.p. 30° at 3.6 mmHg (lit.,^{13,14} 43.5—45° at 4.6 mmHg), λ_{\max} (EtOH) 204 (ϵ 7000) and 275 nm (600) [lit.,^{13,14} λ_{\max} (EtOH) 204 (ϵ 6820) and 278 nm (602)].

I thank Dr. T. L. Gilchrist for advice.

[3/470 Received, 2nd March, 1973]

¹³ W. E. Parham, R. W. Soeder, and R. M. Dodson, *J. Amer. Chem. Soc.*, 1962, **84**, 1755.

¹⁴ J. Meinwald, S. L. Emerman, N. C. Yang, and G. Buchi, *J. Amer. Chem. Soc.*, 1955, **77**, 4401.

¹⁰ L. Balliano, *Gazzetta*, 1881, **11**, 396.

¹¹ L. Gatterman, *Ber.*, 1899, **32**, 1116.

¹² H. H. Hodgson and H. G. Beard, *J. Chem. Soc.*, 1925, **127**, 880.