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DIMETHYL ACETYLENE DICARBOXYLATE ADDUCTS OF 2-VINYLFURAN AND 2-(β-METHOXYVINYL)BENZOFURAN

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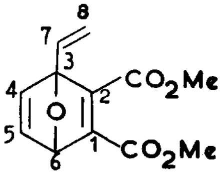
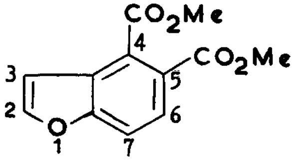
It has been shown that the exocyclic diene systems of 2-vinylfuran (1), substituted 2-vinylfurans (2), and 2-vinylbenzofurans (3) participate in cycloaddition with maleic anhydride to give the tetrahydrobenzofuran and tetrahydrodibenzofuran dicarboxylic acid anhydrides respectively.

We now report that dimethyl acetylene dicarboxylate (ADE) reacts readily with 2-vinylfuran and 2-(β-methoxyvinyl)benzofuran, giving rise to a variety of "adducts". In contrast to maleic anhydride, ADE does not react exclusively with the exocyclic diene system of 2-vinylfuran. In fact at room temperature a 1:1 mixture of the diesters (I) (4) and (II) is obtained (overall yield 10%).



I



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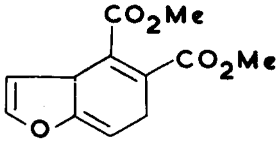

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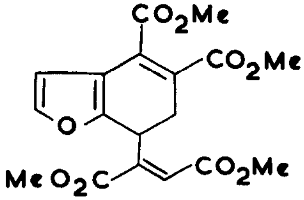

IV

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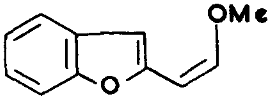
The structures of the diesters (I) and (II) follow from their spectroscopic properties. Dimethyl benzofuran-4,5-dicarboxylate (II) sublimed at 50°/0.5mm to form colourless crystals, m.p. 64-66°; λ_{max}^{EtOH} 225 mμ (log ε 4.55), 255 sh (3.74), 302 (3.57); nmr (all 60 Mcps, CCl_4), τ 2.17, 2.38 (dd, 2, J = 8.5 Hz, protons 6,7), 2.23, 2.97 (dd, 2, J = 2.4 Hz, protons 2,3) and 5.99, 6.06 (2s, 6, OMe protons). Dimethyl 3,6-epoxy-3-vinyl-3,6-dihydrophthalate (I) could only be isolated as a mixture with (II) but the spectroscopic properties could be assessed by subtraction; nmr τ 2.77 (dd, 1, J = 2.0, 5.0 Hz, proton 5), 2.89 (d, 1, J = 5.0 Hz, proton 4), 3.57 (q, 1, J = 11.0, 17.0 Hz, proton 7), 4.29 (d, 1, J = 2 Hz, proton 6), 4.41, 4.53 (2d, 2, J = 11.0, 17.0 Hz, protons 8,8') and 6.18, 6.22 (2s, 6, OMe protons).

The formation of the aromatic, dimethyl benzofuran-4,5-dicarboxylate (II) probably results from the facile autoxidation of the initially formed dihydrobenzofuran (III). The reduced selectivity in the site of cycloaddition to 2-vinylfuran in the above reaction may be the result of an equilibration, which is not observed with maleic anhydride due to the low solubility of the adduct formed. When the reaction was carried out at 80° (refluxing benzene) no (I), but the benzofuran (II) and a bis-adduct (IV) were isolated. IV was obtained as a yellow oil, λ_{max}^{EtOH} 229 mμ (log ε 4.36), 256 sh (3.93), 300 (3.60), 345 (3.13) and 356 (3.00); nmr τ 2.20, 2.95 (dd, 2, J = 2.4 Hz, protons 2,3), 2.31 (s, 1, olefinic proton), 5.15-5.52 (m, 1, methine proton), 6.00, 6.06 (2s, 6, OMe protons), 6.30 (s, 6, OMe protons) and 6.50-7.40 (m, 2, methylene protons).

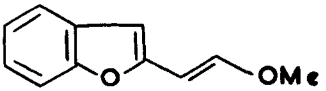
The formation of (IV) can readily be rationalised by considering a second mole of ADE to add to the 7,8- double bond of the intermediate adduct (III) by an indirect substitutive addition, the driving force being the aromatisation of the furan ring. Several analagous substitutive additions with ADE have been observed previously (5,6).

In the benzofuran series, the cycloaddition of ADE to 2-(β-methoxyvinyl)benzofuran (V) was investigated as a possible route to polyfunctional 3-methoxydibenzofurans. The latter compounds are of interest because of their close structural relationship with the lichen metabolites strepsilin (7a), didymic acid (7b) and related compounds.

The Wittig reaction of 2-formylbenzofuran (8) with methoxymethylenetriphenylphosphorane (9) gave an equimolar mixture of cis and trans 2-(β-methoxyvinyl)benzofuran (VA, VB respectively; overall yield, 50%). The enol ethers (VA, VB) could be separated by preparative TLC on silica gel. Both were obtained as yellow oils which could be readily differentiated by their n.m.r. spectra, in particular, by the coupling constants of the olefinic protons (*J* (VA), 7.2 Hz; *J* (VB), 12.5 Hz).



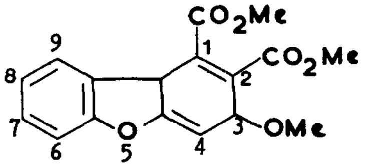
VA



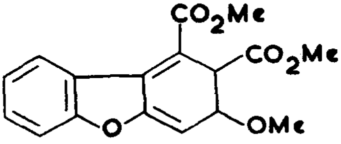
VB

trans-2-(β-Methoxyvinyl)benzofuran (VB) underwent a smooth cycloaddition with ADE in boiling toluene to give a mixture of three main adducts.

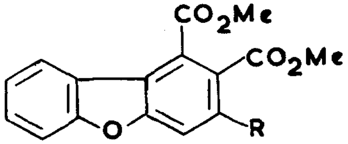
The predominant product (34%) was not the expected adduct (VI), but dimethyl 2,3-dihydro-3-methoxydibenzofuran-1,2-dicarboxylate (VII), a rearranged adduct. The diester (VII) was obtained as a viscous yellow oil; $\lambda_{max}^{Et_2O}$, 246 mμ (log ε 4.25), 271 (3.73), 278 (3.71), 284 (3.59), and 322 (3.65); nmr τ 2.50-2.85 (m, 4, aromatic protons), 2.88 (d, 1, *J* = 3.6 Hz, olefinic proton), 5.35 (q, 1, *J* = 3.6, 5.4 Hz, proton 3), 6.05, 6.22, 6.71 (3s, 9, OMe protons) and 6.85 (d, 1, *J* = 5.4 Hz, proton 2).



VI



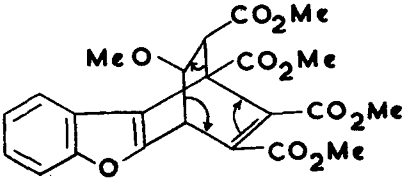
VII



VIII, R = OMe

IX , R = H

X , R = CO_2Me



XI

(VII) was slowly oxidised on standing in air to dimethyl 3-methoxydibenzofuran-1,2-dicarboxylate (VIII), which sublimed at 100°/0.5mm to form pale yellow needles, m.p. 104-106°;

λ_{max}^{EtOH} 218 mμ (log ε 4.53), 252 (4.44), 304 sh (3.99), and 322 (4.02); nmr τ 1.83-2.80 (m, 5, aromatic protons) and 6.00, 6.04, 6.14 (3s, 9, OMe protons). On a preparative scale it was more convenient to oxidise the dihydro-compound (VII) with *N*-bromosuccinimide in boiling carbon tetrachloride.

The major byproduct (20% yield) isolated from the reaction of ADE with (VB) was dimethyl dibenzofuran-1,2-dicarboxylate (IX), formed either by 1,4-elimination of methanol from the intermediate adduct (VI) or by 1,2-elimination from the rearranged adduct (VII) with concomitant aromatisation. The diester (IX) sublimed at 100°/0.5 mm to form pale yellow crystals, m.p. 121-123°; λ_{max}^{EtOH} 215 mμ (log ε 4.55), 237 (4.53), 247 (4.52), 290 (4.06), 300 sh (4.03) and 310 sh (3.81); nmr τ 1.85-2.70 (m, 6, aromatic protons), 5.87, 6.05 (2s, 6, OMe protons).

A minor byproduct (7%) of the cycloaddition was identified as trimethyl dibenzofuran-1,2,3-tricarboxylate (X). This triester crystallised from carbon tetrachloride as pale yellow needles, m.p. 147-149°; $\lambda_{max}^{Et_2O/EtOH}$ 214 mμ (log ε 4.39), 245 (4.41), 272 sh (3.95) and 303 (4.18; nmr τ 1.85-2.80 (m, 5, aromatic protons) and 5.98, 6.06, 6.10 (3s, 9, OMe protons). This compound is probably formed by cycloaddition of a second mole of ADE to the diene system of (VII) giving the intermediate bis-adduct (XI), which subsequently undergoes a thermal retro Diels-Alder reaction to give the observed aromatic product. This reaction could be duplicated by treating (VII) with excess ADE in boiling toluene.

NOTES AND REFERENCES

1. C.R. Paul, *Compt.rend.*, **208**, 1028 (1939).
2. C.H. Schmidt, *Naturwiss.*, **4**, 581 (1953).
3. B. Kamthong and A. Robertson, *J.Chem.Soc.*, 925 (1939); P.K. Ramachandran, T. Cheng and W.J. Horton, *Tetrahedron Letters*, 907 (1963).
4. Satisfactory elemental analyses or high resolution mass spectra were obtained for all new compounds.
5. K. Alder and H. von Brackel, *Ann.*, **651**, 141 (1962).
6. I.T. Millar and K.E. Richards, *Austral.J.Chem.*, **21**, 1551 (1968).
7. S. Shibata, *J.Pharm.Soc.Japan*, **64** (a) 50; (b) 8A, 20 (1944).
8. V.T. Suu, N.P. Buu-Hoi and N.D. Xuong, *Bull.Soc.Chim.Fr.*, 1875 (1962).
9. G. Wittig and M. Schlosser, *Chem.Ber.*, **94**, 1373 (1961).