A Stereospecific Arbuzov Reaction of 2,7,8-Trioxa-1-phosphabicyclo[3,2,1]octane involving Intramolecular Competition between 5-, 6-, and 7-Membered Phosphite Rings

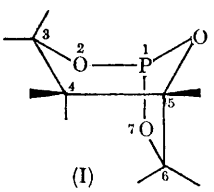
By R. S. EDMUNDSON and E. W. MITCHELL

(*Department of Chemical Technology, Bradford Institute of Technology, Bradford*, 7)

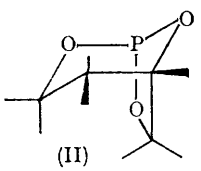
THE chemistry of the structurally symmetrical 4-alkyl-2,6,7-trioxa-1-phosphabicyclo[2,2,2]octanes has been investigated extensively by Verkade and co-workers[1] and Wadsworth and Emmons.[2] During the Arbuzov reaction, ring-opening occurs leading to the formation of monocyclic phosphonates (1,3,2-dioxaphosphorinans) stereospecifically substituted at position 5, although views differ as to the conformation of groups at the phosphorus end of the ring.

We required 1,3,2-dioxaphosphorinans stereospecifically substituted at position 4, and we therefore examined the Arbuzov reaction with respect to the hitherto unknown title compound. This,

(I) or (II), b.p. 45—50°/0·2 mm., was prepared in 75% yield by transesterification between trimethyl phosphite and butane-1,2,4-triol. Its infrared spectrum exhibited bands in the region 1200—1000 cm.$^{-1}$ characteristic of P–O–C linkages in five- and six-membered rings possessing such systems[3] and gas–liquid chromatography (g.l.c.) showed a single component only. By virtue of the possibility of boat and chair forms of the dioxaphosphorinan ring, two structures are possible for the polycyclic phosphite. The complexity of the ^{1}H nuclear magnetic resonance (n.m.r.) spectrum of the latter does not at present permit a distinction to be made between these, nevertheless, a consideration of hydrogen–hydrogen interactions, particularly at C-4 and C-5, suggests that the chair structure (II) is probably a more accurate representation than structure (I) containing the boat ring.

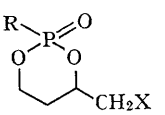


(I)

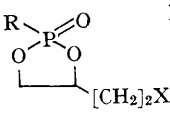


(II)

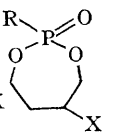
The bicyclic phosphite with benzyl chloride at 200° yielded the racemic benzylphosphonate (III; X = Cl, R = CH_2Ph), b.p. 185—192°/0·2 mm., m.p. 159°, in about 20% yield. This, in both the crude and the purified forms was shown by g.l.c. to contain a single component only. The infrared spectrum ($\nu_{P=O}$ 1260 cm.$^{-1}$) appears to be characteristic of monocyclic benzylphosphonates. Structure (III) is suggested on the basis of the known tendency of 1,3,2-dioxaphospholan phosphite rings to open when treated with benzyl chloride[4] as opposed to ring-retention with corresponding six-membered phosphite rings.[5] The forcing conditions found to be necessary for reaction were however surprising. Structure (III), as opposed to the other possibilities (IV) and (V), is further supported by the stability of the compound under aqueous conditions, and its n.m.r. spectrum. This, in $CDCl_3$ with tetramethylsilane as internal standard and at 60 mc./sec., shows three peaks at τ = 6·37, 6·49, and 6·86 of relative intensities 1 : 2 : 1 and which we ascribe to overlapping CH_2Cl and benzyl-methylene doublets centred at 6·42 and 6·67. Similarly positioned benzyl-methylene doublets have been reported elsewhere[6] for monocyclic benzylphosphonates.



(III)



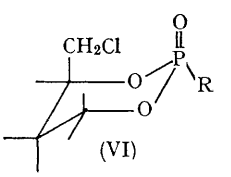
(IV)



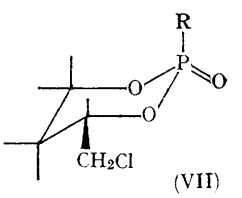
(V)

The bicyclic phosphite and bromine gave the 4-bromomethylphosphorobromidate (III; X = R = Br) characterised as the *N*-cyclohexylphosphoramidate (III; X = Br, R = NHC_6H_{11}-cyclo), m.p. 153°. As with other monocyclic 1,3,2-dioxaphospholan-type phosphites, the reaction of the bicyclic phosphite with water is exothermic and has given a product believed to be the hydrogen phosphonate (III; X = OH, R = H).

The conformation of the final products is as yet unknown. Initially the product of the Arbuzov reaction would be (VI) and presumably could remain in this form if group R were large enough. There is little steric interference between phosphoryl oxygen and the chloromethyl group, and the P=O group could thus occupy the axial position. If R were small, conversion into structure (VII) would presumably follow.



(VI)



(VII)

We are extending our studies to include other polycyclic esters. So far, all attempts to prepare 2,6,7-trioxa-1-phosphabicyclo[2,1,2]heptane have failed. Ring opening of this would have led to specific isomers in the 5-halogeno-1,3,2-dioxaphosphorinan series. These and their conformers we have prepared from 2-chloropropane-1,3-diol.

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