identified by melting points and mixture melting points. The esters were identified by comparing their infrared spectra with those of authentic samples. It was found that the relative ratios of the products are nearly independent of the concentration of m-chlorobenzaldehyde. When the epoxide, phosphine and m-chlorobenzaldehyde, in equimolar amounts, were allowed to react for 20 hr., the ratios reported above remained essentially unchanged (with the exception of m-chlorobenzaldehyde).

Competition experiments in which carbomethoxymethylenetriphenylphosphorane was treated with mixtures of benzaldehyde and m-chlorobenzaldehyde in various mole ratios have shown, as does the rate data, that the ylid prefers the more reactive m-chlorobenzaldehyde. Consequently, the relatively large amount of ethyl cinnamate obtained from the reaction of the epoxide with tributylphosphine suggests that mechanism (d) rather than mechanism (c) is operative and that the rate constants for decomposition of the betaine to tributylphosphine oxide and ethyl cinnamate and to carbethoxymethylenetributylphosphorane and benzaldehyde are of the same order of magnitude. However, we cannot rule out mechanism (c), for it is possible that some or all of the ethyl cinnamate is being formed by attack of tributylphosphine at the epoxy oxygen, a reaction path which does not require the intermediacy of the betaine. Tributylphosphine is not peculiar in its reaction with epoxides because triphenylphosphine also behaves in an analogous manner in its reaction with trans-ethyl phenylglycidate.[8]

The data obtained from the reaction of tributylphosphine with trans-ethyl phenylglycidate provide conclusive proof that betaine formation in the Wittig reaction of stable ylids is reversible and mechanisms (a) and (b) are thus eliminated.

Work is continuing in these laboratories to distinguish between mechanisms (c) and (d), and the mechanism of the Wittig reaction will be the subject of a forthcoming publication.

(8) The stereochemistry and modes of reaction of 2,3-epoxy esters and amides with tributylphosphine and triphenylphosphine will be the subject of a forthcoming publication by A. J. Speziale and C. C. Tung; manuscript in preparation.

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The Mechanism for the Formation of 1,2-cis-Pyridine Nucleosides from 1,2-cis-Acetohalogenosugars. A Novel Rearrangement

Sir:

The reaction of tetra-O-acetyl-α-D-glucopyranosyl bromide (I) with dry pyridine yielded a mixture of the anomeric N-(2,3,4,6-tetra-O-acetyl-D-glucosyl)-pyridinium bromides. The anomeric hydrogens of these products in deuterium oxide produced doublets in their n.m.r. spectra at 6.89 p.p.m. (spacing, 3 c.p.s.) and 6.34 p.p.m. (spacing, 8 c.p.s.) from tetramethylsilane (external) which are characteristic[1,2] for the α-(VII) and β-(II) anomers,[3] respectively. Thus, the relative intensities of these signals provided a convenient analysis of the product. When the reaction was followed polarimetrically, the change in optical rotation corresponded closely to a first-order process when the initial concentration of I was low, 2.1% (w./v.), and virtu-

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ally only the β-anomer (II) was formed. However, when the initial concentration of I was 32.7%, an induction period was noted and, therefore, it was apparent that the product of the initial reaction became involved in a faster process. The relative amounts of the β (II) and α (VII) anomeric forms found in the product was now 2:3. Thus, the induced reaction led to the formation of the α-anomer (VII).
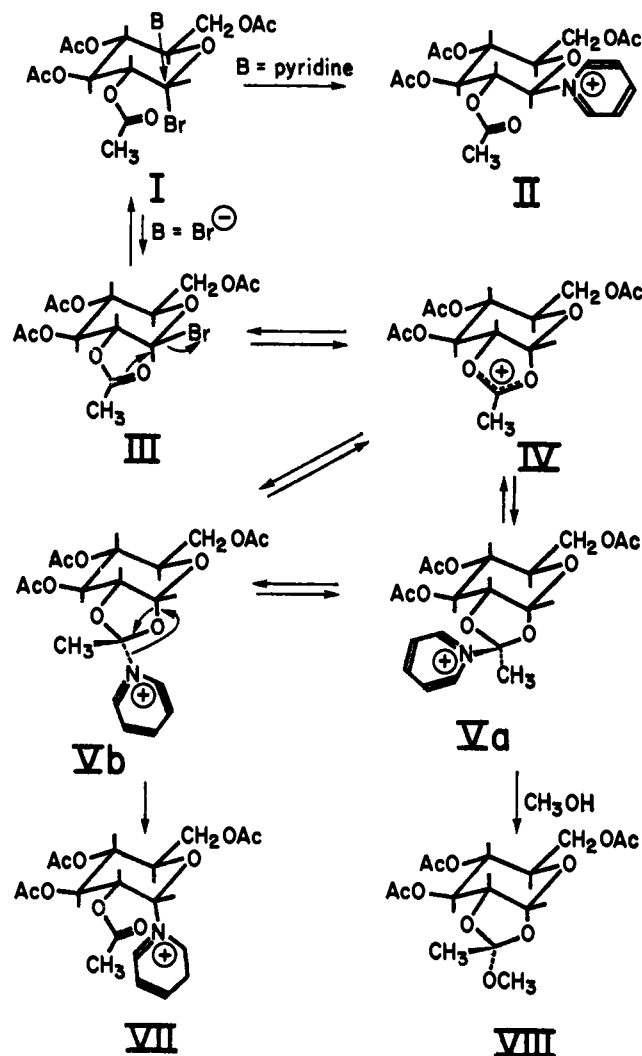
The induction period was also present when the initial concentration of I was about 16% and the anomers were formed in equal amounts. The same course of reaction was obtained when half of the pyridine was replaced by acetonitrile although the more polar solvent gave rise to a somewhat increased rate of reaction. When the reaction of I (16% initial concentration) was carried out in pyridine containing one mole of tetra-n-butylammonium bromide per mole of I, the rate of reaction was much greater and the induction period was not present. Only the α-pyridinium glucoside (VII) was formed. When tetra-n-butylammonium perchlorate was used instead of the bromide, the induction period reappeared and the product comprised a 2:3 mixture of the β- and α-forms, respectively.

These results clearly pointed to an initial reaction wherein the α-bromide (I) underwent nucleophilic attack by pyridine with inversion of the anomeric center to produce the β-pyridinium bromide (II). The bromide ion thus liberated then participated in the faster process by making a nucleophilic attack on the starting material (I) to form the anomer of I, tetra-O-acetyl-β-D-glucopyranosyl bromide (III). It is conceivable that VII was formed by direct replacement of

the equatorially oriented bromide of III by pyridine with inversion of the anomeric center. If so, this re-reaction would have to be very rapid as compared to the formation of II from I since the results require the formation of III to be rate-controlling in the sequence of reactions leading to VII. Also, the concentration of III must be very small throughout the course of the reaction since, although it is the anomer with the bromine in equatorial orientation, it is the thermodynamically less stable anomer.[4,5] The driving force for this condition has been termed the "anomeric effect."[6,7]

It seemed more likely that the rapid formation of VII by way of III would involve participation of the 2-acetoxy group in the reaction of III to lead to a 1,2-acetoxonium ion. In fact, the β-bromide (III) has recently been isolated[8] and its reaction properties correspond to those previously established for tetra-O-acetyl-β-D-glucopyranosyl chloride.[9] Since the reaction of the latter compound in pyridine containing an alcohol leads to the formation of α-D-glucopyranose 1,2-(alkyl orthoacetate) triacetate,[9,10] these observations related to the formation of VII led to the prediction that the addition of the α-bromide (I) to pyridine containing methanol would result in the formation of the 1,2-methyl orthoacetate (VI).[11] In fact, the reaction of I in pyridine containing 3 moles of methanol per mole of I, under conditions (30% of I) which in the absence of the methanol provided the α- and β-pyridinium glucosides in the ratio 3:2, gave as the product a mixture of the methyl orthoacetate (VI) and β-pyridinium glucoside (II) in the ratio 3:2. That is, the presence of the methanol blocked the route to the formation of the α-pyridinium compound (VII), precisely the result expected should the latter compound arise from the 1,2-acetoxonium ion intermediate (IV). The n.m.r. spectrum of the 1,2-orthoacetate (VI) in chloroform showed the presence of the two possible diastereoisomers arising from a change in the configuration of the new asymmetric center in the dioxolane ring.[12] The isomer, which produced signals for the methoxy and orthoacetyl groups at 3.30 and 1.72 p.p.m. (trimethylsilane), respectively, and believed on the basis of n.m.r. to have structure VIII, was formed in approximately 6.2 times greater amount than that with the corresponding signals at 3.46 and 1.57 p.p.m.

In order to confirm these notions, the reaction of tetra-O-acetyl-β-D-glucopyranosyl chloride with pyridine was examined. As expected, N-(tetra-O-acetyl-α-D-glucopyranosyl)-pyridinium chloride was formed but none of the β-isomer. It is therefore concluded that the driving force for the ready formation of VII from III is derived from the anchimeric assistance provided by the participation of the 2-acetoxy group and that, consequently, the last stage of the reaction involved an intramolecular rearrangement of a transient 1,2-orthoacetyl pyridinium bromide (Vb). The plausibility of such a migration is well supported through the consideration of a molecular model and the fact that the rupture of the Cl-to-oxygen bond in the dioxolane ring of Vb must involve participation by the oxygen of the pyranose ring. The latter type of participation is clearly involved in the first stage of all

displacement reactions at the anomeric center of sugar structures.

The occurrence of the above migration without doubt explains the stereochemical routes of reaction observed in the synthesis of 3-carboxamidopyridinium nucleosides.[2,13,14] Also, the discovery likely has an important bearing on the formation of both the anomeric forms in the syntheses of other types of nucleosides by way of O-acylated glycosyl halides.[15-17]

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CANADA

Electrophilic and Nucleophilic Substitution of Allylic Mercurials[1,2]

Sir:

Organomercurials have been studied extensively as substrates for electrophilic substitution at saturated carbon,[3] and more recently for generation of carbonium ions[4] by so-called "demercuration." The corresponding carbon–mercury bond cleavages are depicted by R:|Hg and R|:Hg, respectively. Both substitutions, electrophilic as well as nucleophilic, are especially interesting with allylic mercurials, and we report on this matter in the present communication. The present observations on the behavior of crotyl- and cinnamylmercuric derivatives furnish considerable insight into the competition between the two kinds of substitution and the mechanistic preferences displayed by each of them.

Crotylmercuric bromide,[5] prepared from the butenyl Grignard reagent and mercuric bromide, was recrystallized from pentane–acetone; m.p. 90.8–91.2° dec. The trans-crotyl structure was confirmed by the presence of only two vinyl protons as indicated by the n.m.r. spectrum in chloroform solvent, the absence of infrared bands at 905–915 cm.−1 and 985–995 cm.−1 for terminal methylene, and the presence of an infrared band at 965 cm.−1 for a trans-olefinic group. Crotylmercuric and cinnamylmercuric bromide,[6] on treatment with silver acetate in acetone, gave rise to the corresponding crotylmercuric acetate,[5] m.p. 76–77°, and cinnamylmercuric acetate,[5] m.p. 98.0–98.5°.

The predominant result from treatment of the allylic mercurials with acidic media depends on the nature of the anionic ligand in RHgX. Halide as the ligand is relatively unfavorable to nucleophilic substitution and, therefore, electrophilic cleavage of the mercurial is predominant. Thus, at room temperature crotylmercuric bromide is converted essentially quantitatively to olefin by excess hydrogen chloride in ethyl acetate

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