Tetrahedron Letters No.19, pp. 1125-1130, 1964. Pergamon Press Ltd.
Printed in Great Britain.

STEREOSPECIFIC ADDITIONS TO OLEFINS. THE IODONIUM ION.

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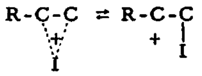
(Received 13 March 1964)

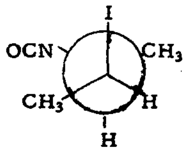
Since the first suggestion of a bromonium ion intermediate[2] to account for the stereospecifity of addition of bromine to olefins, many attempts have been made to prove or disprove that such intermediates are indeed formed.[3] Evidence for the existence of iodonium ion intermediates (type I) is largely based on studies of solvolysis rather than of addition reactions.[4] Addition of iodine chloride to styrene leads to α-chloro-β-iodoethylbenzene.[5] This suggests that the reaction might proceed via a benzyl carbonium ion (II, R:phenyl) or via an iodonium ion (I, R:phenyl)  $\mathrm{R{-}\underset{\overset{+}{I}}{C{-}C}} \rightleftharpoons \mathrm{R{-}\underset{+}{C}{-}\underset{I}{C}}$ which is in equilibrium with II.

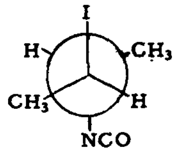
I II

In our work on stereospecific syntheses of certain isocyanates, urethanes and other N-containing functions it has been shown that addition of iodine isocyanate to cyclic olefins proceeds in a trans manner.[6] The particular suitability of steroids in testing the stereochemistry of reactions makes an examination of the reaction of iodine isocyanate with

2-cholestene enlightening. The product obtained in 90-95% yield is the diaxial 3α-iodo-2β-cholestanyl isocyanate. The diaxial nature of the iodine and isocyanate groups is confirmed by the half widths of the geminal proton absorption peaks in the NMR - 6 cps for the equatorial C_3-H at 5.43 τ and 8 cps for the equatorial C_2-H at 5.75 τ.[7] This stereospecificity is indicative of an iodonium ion intermediate opened, like an epoxide or aziridine, in a diaxial manner. This interpretation is corroborated by the finding that *cis* and *trans* 2-butene give stereospecifically and in high yield (85%) the *threo* and *erythro* 3-iodo-2-butyl isocyanates III and IV respectively. The diastereomers III and IV had the same boiling point (57-59°/1.5 mm) but differed from each other by infrared and nuclear magnetic resonance spectra and by mixed melting point of their urea derivatives.

The NMR spectra of the iodo isocyanates III and IV are interpretable on the basis of preferred conformations IIIa and IVa. The signal of the proton at C-3, geminal to the iodine[8], appears near 5.7τ split by the adjacent methyl group into a quartet, each line of which is further split into a doublet by the C-2 proton. The octet at 6.89τ in the spectrum of IIIa and at 6.56τ in the spectrum of IVa is assigned to the proton at C-2, geminal to the isocyanate group. The iodine atom in anti to the C-2 proton in the preferred conformation of the *threo* isomer (IIIa), while it is gauche to this proton in the *erythro* conformation IVa. Thus, by nature of its magnetic anisotropy, the iodine exerts unequal shielding of the nucleus of the C-2 hydrogen in the two isomers. The other protons in the molecule are at approximately the same distance from the iodine in both IIIa and IVa. The methyl hydrogens adjacent to the iodine bearing carbon appear as doublets (J = 7 cps) at about 8.1τ in both diastereomers; those adjacent to the isocyanate bearing carbon appear at 8.64 and 8.66τ





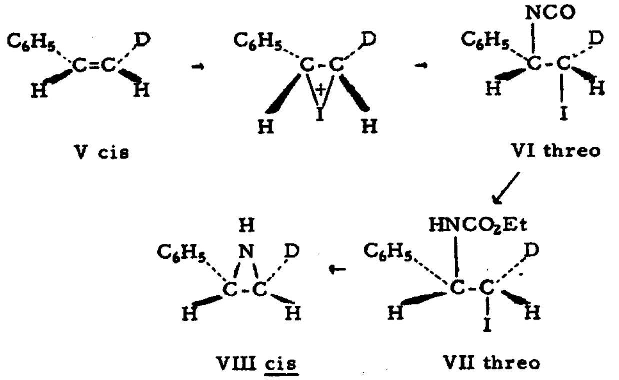
IIIa *threo*	IVa *erythro*
5.7 τ octet	5.7 τ octet
6.89 τ octet	6.56 τ octet
8.1 τ doublet	8.1 τ doublet
8.64 τ doublet	8.66 τ doublet

III and IV represent an unusual example of simple diastereomers showing distinct interpretable NMR spectra.

2-Methyl-2-butene, an unsymmetrical olefin, yields largely 3-iodo-2-methyl-2-butyl isocyanate (methyl carbamate m.p. 56-57°) with the isocyanate grouping on the tertiary carbon. Similarly arenes like styrene, indene, 1,2-dihydronaphthalene and phenylcyclohexene add iodine isocyanate to give products in which the isocyanate group is on the benzilic carbon. With the described cyclic arenes *trans* addition is observed exclusively. These results can be accommodated by one of the following: 1. a rapidly equilibrating iodonium ion intermediate (I⇌II);

2. an iodonium ion intermediate of type IX or 3. a classical carbonium ion intermediate, stabilized by resonance with the benzene ring, in which the bulky iodine atom sterically interferes with the approaching isocyanate moiety.[5]

To test whether a freely rotating carbonium ion is involved in these addition reactions we chose as a substrate β-deuterostyrene. The small difference in size between deuterium and hydrogen should minimize arguments of restricted rotation in a carbonium ion such as II. Iodine isocyanate was added at 25° to β-deuterostyrene consisting of 71% *cis* and 29% *trans* isomer and the product (VI) was directly converted to the β-iodocarbamate VII (no stereochemistry intended) in 80% overall yield. Ring closure of VII with base [6b] gave in 98% yield a mixture of 3-deutero-



V *cis*

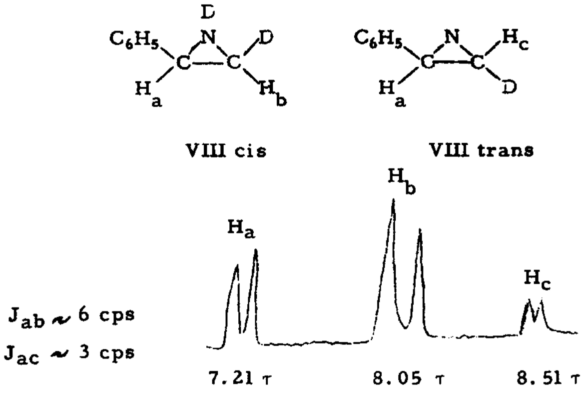
VI threo

VIII *cis*

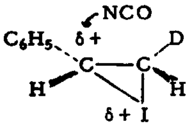
VII threo

2-phenylaziridine(VIII) and acetophenone (14%). The NMR spectrum (Fig. 1) of the phenylaziridine, after exchange of the N-hydrogen with deuterium, indicated the isomer distribution to be 71% *cis* and 29% *trans*.

Fig. 1. NMR Spectrum of a Mixture of VIII *cis* and VIII *trans*



Since ring closure of diastereomeric β-halo amines to aziridines are known to proceed stereospecifically *trans*,[10] the above results indicate that the addition of iodine isocyanate to β-deuterostyrene has taken place in a stereospecific manner. The intermediate ion IX is expected to have the C_α-I bond longer and thus weaker than the C_β-I bond due to the ability of the phenyl group to partially stabilize the net positive charge. Attack by isocyanate ion then occurs at the benzilic position giving the products as indicated above.



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Acknowledgment: This work was supported in part by Grant CA-4474 by the National Cancer Institute of the U.S. Public Health Service.

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