REACTION PATHWAY IN THE PHOTOREARRANGEMENTS OF PHENYLISOTHIAZOLES

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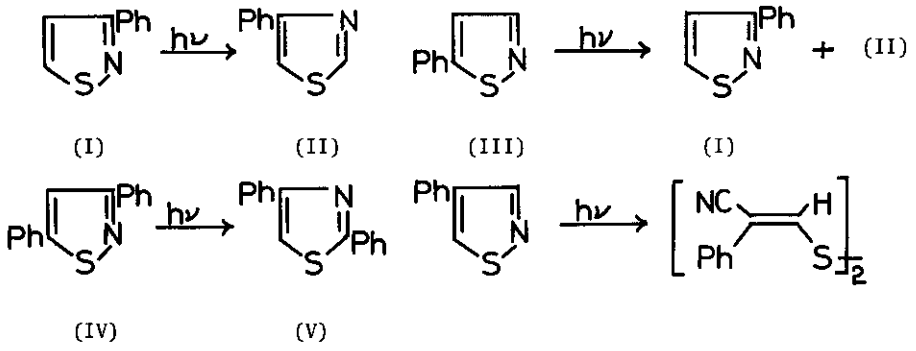
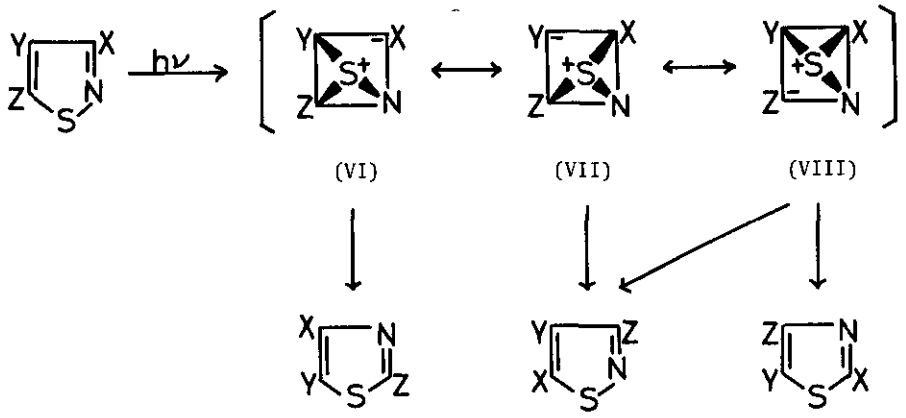
In the photorearrangement of 5-phenylisothiazole (III) in ether-deuterium oxide system, deuterium was incorporated into the product, 3-phenylisothiazole (I). It is supported that the photorearrangements of phenylisothiazoles proceed through tricyclic sulphonium cation intermediates.

The photochemical transposition reactions of isothiazoles in five-membered heteroaromatics have attracted increased attention in recent years.[1-6] The photorearrangements of phenylisothiazoles[2-5] in ether have been reported to afford the products shown in Scheme 1.



Scheme 1.

On the mechanism of these rearrangements, two different views have been proposed; one is the pathway involving a zwitterionic species, and the other is involving a Dewar benzene type bicyclic isomer (valence bond mechanism).[4] Ohashi et al.[2,5] have proposed that the photorearrangements of phenylisothiazoles would involve a tricyclic sulphonium cation (VI, VII, or VIII) shown in Scheme 2.



Scheme 2.

Their proposal involves the most stable tricyclic sulphonium cation in which the negative charge is stabilized by resonance with the phenyl group. Further argument for the intermediate has been based on the relationship between an excited state and geometry of isothiazole nucleus, and the change of bond order on excitation using ASMO-SCF treatment.[5]

A set of analogous tricyclic sulphonium cation intermediates have already been suggested by us in the photorearrangements of phenylthiazoles,[7] and the support for those intermediates has been provided by deuterium incorporation in the transformation of 2-phenylthiazole or 4-phenylthiazole to 3-phenylisothiazole.[8] On the photorearrangements of phenylisothiazoles, we have recognized an extreme similarity with those of phenylthiazoles. Therefore, our attention was directed

to a general mechanistic description of the photochemical behaviour of these system.

For a zwitterionic mechanism in the photorearrangements of phenylisothiazoles, three possible tricyclic sulphonium cations (VI, VII, and VIII) as suggested by Ohashi et al.[2,5] which afford rearrangement products, respectively, should be included. When the rearrangement proceeds through one of these intermediates, which involves a secondary carbanion, deuterium should be incorporated to the product under the presence of deuterium oxide. Under these consideration, irradiation of 3-phenylisothiazole (I) and 5-phenylisothiazole (III) was carried out in ether-deuterium oxide system,[9] and the nmr analyses of the products[10] were made after careful silica gel chromatography of the reaction mixture.

After irradiation of 3-phenylisothiazole (I) for 27 hr, the nmr spectra of the recovered starting material (59%) and the product, 4-phenylthiazole (II)(2.3%), indicated that there were no detectable incorporation of deuterium. On the other hand, in the case of 5-phenylisothiazole (III)(5 hr irradiation), incorporation of deuterium into the recovered starting material (62%) was not recognized in its nmr spectrum, but the nmr analysis of the product, 3-phenylisothiazole (I)(6.3%) demonstrated that deuterium has been incorporated at position 4 in ratio of 16%. As shown in Fig. 1, signal 1 at 8.67 ppm (singlet) is assigned to hydrogen at position 5 of the isothiazole ring, in addition, signal 2 at 8.67 ppm (doublet, J 4.8 Hz) is assigned to hydrogen at position 5 coupling with an adjacent ring hydrogen, and signal 3 at 7.58 ppm (doublet, J 4.8 Hz) is assigned to hydrogen at position 4 coupling with hydrogen at position 5.[11] When (I) or (III) in ether-deuterium oxide system was refluxed in the dark, there was no detectable incorporation of deuterium, indicating that deuterium incorporation occurred on excitation before the formation of final product.

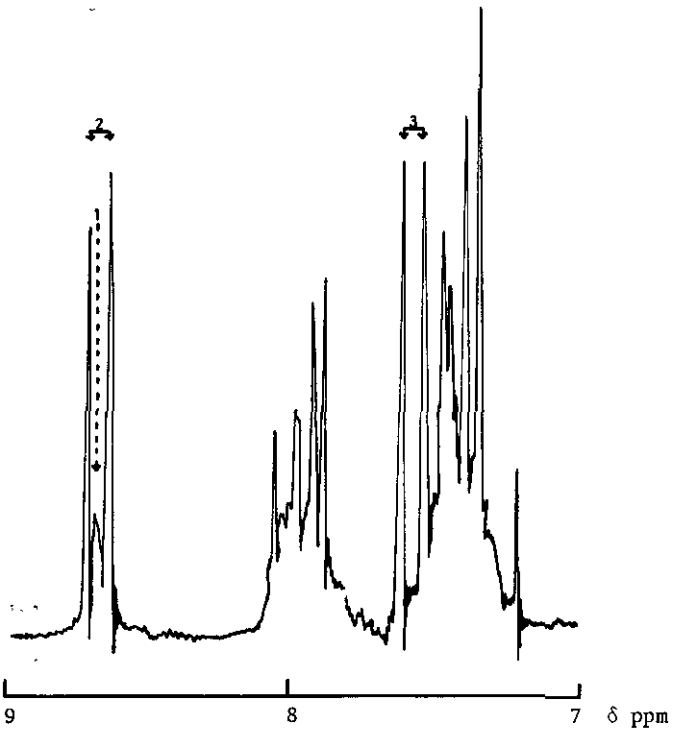


Figure 1. Nmr spectrum of 3-phenylisothiazole obtained from irradiation of 5-phenylisothiazole (III) in ether-deuterium oxide system.

The above results demonstrate a mechanism involving at least tricyclic sulphonium cation (VII)(X=Y=H, Z=Ph) as an intermediate in the transformation of (III) to (I). When (III) is transformed on irradiation to the intermediate (VII) (X=Y=H, Z=Ph) which involves a secondary carbanion, it incorporates deuterium to give the deuterio product. It is not necessary to consider the intermediate (VI)(X=Y=H, Z=Ph) because of no deuterium incorporation at position 5 of the product (I). However, a pathway involving the intermediate (VIII)(X=Y=H, Z=Ph) which may be reformed from (VII)(X=Y=H, Z=Ph) in the conversion of (III) to (I)

could not be excluded.[12] The intermediate (VI)(X=Ph, Y=Z=H) for the conversion of (I) to (II) is supported because of no deuterium incorporation into the product (II).

This finding is also of particular interest in connection with account concerning the role of tricyclic sulphonium cation intermediates in the thiazole-isothiazole transformation.[7,8] Considering the results for thiazole-isothiazole photorearrangement, it is suggested that the intermediate (VII)(X=Y=H, Z=Ph) formed in the conversion of (III) to (I) becomes identical with that formed in the conversion of 2-phenylthiazole to (I).[8] Accordingly, our finding provides a strong suggestion that reactions proceed through tricyclic sulphonium cation intermediates as the common mechanism on the photo-rearrangements of phenylisothiazoles and phenylthiazoles.

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9 Deuterium oxide (99.9%, 10 ml) was added to a solution of phenylisothiazole (about 2g) in dry ether (500 ml) under stirring. All irradiations were carried out at 35°C using Riko 30 W-low pressure mercury lamp with a quartz filter, and dry nitrogen was bubbled through the solution during irradiation.

10 All nmr spectra were taken with TMS as an internal reference on a JMN PS-100 spectrometer and all samples were taken as 10% solutions in $CDCl_3$ or CCl_4.

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12 Unfortunately it was unsuccessful to isolate 4-phenylthiazole (II) previously reported (ref. 4,5) in irradiation of 5-phenylisothiazole (III) due to its much lower yield. However, the product (II) in irradiation of (III) should be a secondary product from (I) formed initially.

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