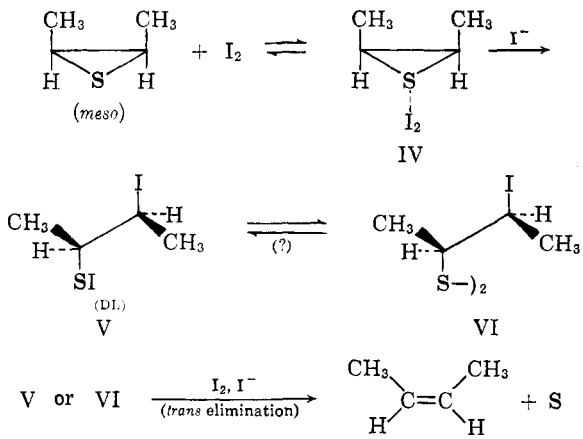
TABLE I
BUTENE ISOMER COMPOSITION IN IODINE DESULFURIZATION OF THIIRANES

2,3-Dimethylthiirane	Solvent	% *cis*	% *trans*
meso	Acetone	99.1	0.9
meso	Benzene	98.2	1.8
DL	Acetone	0.4	99.6
DL	Benzene	1.1	98.9

The yield of butenes was 40–50% in acetone solvent and about 80% in benzene solvent. The yield of sulfur, determined spectrophotometrically after isolation by chromatography on neutral alumina, was about 60%, a value slightly lower than that for butene.

When the reaction of thiiranes with iodine was carried out in the cold in methylene chloride, two moles of sulfide were required per mole of iodine. No butene was produced, and on evaporation of the solvent at reduced pressure a clear liquid was obtained which was unstable to heat and could not be isolated in sufficiently pure form for elemental analysis. When the liquid was treated with iodine in refluxing benzene the appropriate butene isomer (related to the starting thiirane) was obtained in fair yield. It is proposed that the liquid is an iodine analog of compound II, for then the stoichiometric relationship of the reaction would be satisfied and a substitution–elimination process proceeding *via* a sulfenyl halide (V) or disulfide (VI) would predict the proper stereochemical result.



The coördination of iodine with sulfur in the thiirane (intermediate IV) should facilitate subsequent nucleophilic ring-opening by iodide, and a corresponding coördination with the sulfur atom in V or VI followed by iodide attack on iodine and resulting in a *trans* elimination is consistent with the nature of the products.

Experimental

Desulfurization of 2,3-Dimethylthiirane.—A solution of 1.0 g. (0.004 mole) of iodine in 8 ml. of reagent grade benzene was introduced into a 50-ml. two-necked flask fitted with a dropping funnel and condenser. The end of the condenser was fitted with a delivery tube leading to a trap at Dry Ice–acetone temperature. The mixture was brought to reflux and 0.9 g. (0.010 mole) of DL-2,3-dimethylthiirane was added over a period of 1 hr. Heating was continued for an additional hour. The yield of butene was 0.45 g., 80% (see Table I for isomer distribution). The reaction mixture was evaporated to near dryness, added to a chromatographic column packed with 30 g. of neutral alumina, and eluted with carbon disulfide. The carbon disulfide was evaporated and the residual sulfur was dissolved in ethanol and determined spectrophotometrically[5]; yield, 62%.

Acknowledgment.—This investigation was supported by an intramural research grant by the University of California.

(5) J. E. Baer and M. Carmack, *J. Am. Chem. Soc.*, **71**, 1215 (1949).

The Isomerization of Aziridine Derivatives. VI. The Rearrangement of Some 2-(1-Aziridinyl)quinoxalines[1]

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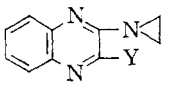
Earlier communications in this series described the isomerization of 1-(*N*-arylbenzimidoyl)aziridines into 1,2-diaryl-2-imidazolines,[2] 2,4,6-tris-(1-aziridinyl)-*s*-triazine into 2,3,6,7,10,11-hexahydrotrisimidazo[1,2-*a*; 1′,2′-*c*; 1″, 2″-*e*]-*s*-triazine,[3] and 1-(arylazo) aziridines into 1-aryl-Δ^2-1,2,3-triazolines.[4] In each of these examples the aziridinyl moiety could be converted by a suitable nucleophile into an effective alkylating agent for a neighboring nitrogen. It would appear that this reaction might be quite general and could be employed for the synthesis of novel heterocyclic compounds. We now wish to report the isomerization of some 2-(1-aziridinyl)quinoxalines to 1,2-dihydroimidazo[1,2-*a*]quinoxalines, a new heterocyclic ring system.[5]

Results

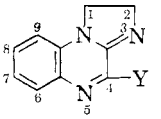
The starting materials used for the isomerization studies were 2-(1-aziridinyl)-3-chloroquinoxaline (Ia) and 2-(1-aziridinyl)-3-methoxyquinoxaline (Ib). These compounds are readily prepared by reaction of aziridine with 2,3-dichloroquinoxaline and 2-chloro-3-methoxyquinoxaline in benzene containing triethylamine. The 2-(1-aziridinyl)-3-methoxyquinoxaline was also readily available by treatment of Ia with sodium methoxide.

(1) Aided by Grant No. T-143A from the American Cancer Society.
(2) H. W. Heine and H. S. Bender, *J. Org. Chem.*, **25**, 461 (1960).
(3) H. W. Heine, W. G. Kenyon, and E. M. Johnson, *J. Am. Chem. Soc.*, **83**, 2570 (1961).
(4) H. W. Heine and D. Tomalia, *ibid.*, **84**, 993 (1962).
(5) We wish to thank Leonard T. Capell of The Chemical Abstracts Service for the naming and numbering of this new heterocyclic system.

Conversion of Ia into the isomeric 1,2-dihydro-4-chloroimidazo[1,2-*a*]quinoxaline (IIa) was easily accomplished by dissolving Ia in acetone containing sodium iodide. Similarly isomerization of Ib afforded 1,2-dihydro-4-methoxyimidazo[1,2-*a*]quinoxaline (IIb). Compound IIb could be obtained as well by refluxing IIa with sodium methoxide solution.



Ia. Y = Cl
Ib. Y = OCH_3

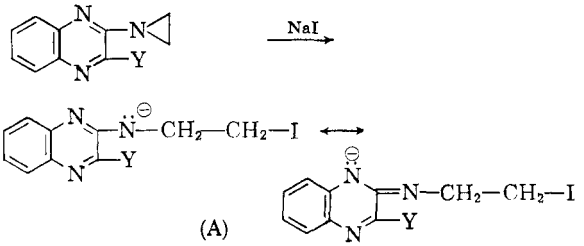


IIa. Y = Cl
IIb. Y = OCH_3

Structural proof of IIb was adduced by the hydrobromination of Ia which gave as expected 2-(β - bromoethylamino) - 3 - chloroquinoxaline hydrobromide (III) and by transformation of III into IIb by hot sodium methoxide solution. It should be noted that displacement of the 3-chloro atom by methoxide ion also occurs during this transformation.

Discussion

A mechanism that was suggested for the isomerization of 1-aroylaziridines[3,6] and 1-(*N*-arylbenzimidoyl)aziridines[2] by nucleophiles seems appropriate to evoke in the present study. This would involve an attack on the aziridinyl carbon by iodide ion to form the anion (A). Subsequent expulsion of iodide by the nitrogen of the quinoxaline ring would give the products of rearrangement.



(A)

The formation of (A) as an intermediate seems even more probable in view of the fact that IIb is produced from the reaction of sodium methoxide on 2-(β-bromoethylamino)-3-chloroquinoxaline. In this case the methoxide ion reacts with the hydrogen of the β-bromoethylamino group to give an ion quite analogous to (A).

Experimental

2-(1-Aziridinyl)-3-chloroquinoxaline (Ia).—To a flask containing 7.96 g. of 2,3-dichloroquinoxaline, 8.08 g. of triethylamine, and 50 ml. of benzene was added a solution of 4.04 g. of aziridine in 50 ml. of benzene. The reaction mixture was kept at room temperature overnight, then heated for 1 hr. and the triethylamine hydrochloride which formed filtered. The solvent was evaporated and 6.97 g. of crude Ia melting at 79–85° was isolated. Recrystallization from petroleum ether (b.p. 40–70°) gave Ia with melting point 95–96°.[7]

Anal. Calcd. for $C_{10}H_8ClN_3$: N, 20.43. Found: N, 20.66.

2-(1-Aziridinyl)-3-methoxyquinoxaline (Ib). Method A.—To a solution of 500 mg. of Ia dissolved in 50 ml. of methanol was added 300 mg. of sodium methoxide in 50 ml. of methanol. The reaction mixture was refluxed for 1 hr., the solvent was evaporated, and the solid residue extracted with benzene. Evaporation of the benzene gave 425 mg. of crude Ib, m.p. 71–78°. Recrystallization from petroleum ether (b.p. 30–60°) gave Ib with m.p. 78–79°.

Anal. Calcd. for $C_{11}H_{11}N_3O$: N, 20.88. Found: N, 20.57.

Method B.—A mixture of 400 mg. of 2-chloro-3-methoxyquinoxaline,[8] 210 mg. of triethylamine, and 100 mg. of aziridine in 15 ml. of benzene was refluxed for 5 hr. The triethylamine hydrochloride was filtered and the benzene evaporated to yield 308 mg. of crude Ib. Recrystallization from petroleum ether gave Ib, m.p. 84–86°. A mixed melting point with a sample prepared by method A was 79–83°. Infrared spectra of samples prepared by methods A and B were identical.

Isomerization of Ia to 1,2-Dihydro-4-chloroimidazo[1,2-*a*]quinoxaline (IIa).—Two grams of Ia and 500 mg. of sodium iodide in 100 ml. of acetone was warmed gently for 2 hr. (refluxing causes darkening and lowering of yield). The solvent was evaporated and the solid residue extracted with 100 ml. of benzene. Evaporation of the benzene gave 1.7 g. of crude IIa, m.p. 131–139°. The crude IIa was purified by adding petroleum ether (b.p. 60–110°) to a hot saturated solution of IIa in benzene until cloudiness appeared. Cooling of this solution gave crystals of IIa, m.p. 151–153°.

Anal. Calcd. for $C_{10}H_8ClN_3$: N, 20.43. Found: N, 20.21.

1,2-Dihydro-4-methoxyimidazo[1,2-*a*]quinoxaline (IIb).—A solution of 400 mg. of IIa and 240 mg. of sodium methoxide in 100 ml. of methanol was refluxed for 1 hr. The methanol was evaporated and the residue extracted with benzene. The benzene was evaporated to yield 390 mg. of crude IIb, m.p. 134–137°. Recrystallization from petroleum ether gave IIb, m.p. 139–141°.

Anal. Calcd. for $C_{11}H_{11}N_3O$: N, 20.88. Found: N, 20.72.

IIb from Isomerization of Ib.—A mixture of 300 mg. of Ib, 100 mg. of sodium iodide, and 20 ml. of acetone was refluxed for 3 hr. The solvent was evaporated, the residue extracted with hot benzene, and the benzene evaporated to give 235 mg. of crude IIb, m.p. 140–141°. A mixed melting point with IIb prepared from Ia melted at 138–140°.

IIb from 2-(β-Bromoethylamino)-3-chloroquinoxaline Hydromide (III).—A solution of 360 mg. of III and 200 mg. of sodium methoxide in 50 ml. of methanol stood overnight at room temperature. The solvent was evaporated and the residue extracted with benzene. Evaporation of the benzene gave 270 mg. of crude IIb, m.p. 129–138°. Recrystallization as above gave IIb, m.p. 140–141°. Infrared spectra of the two samples were identical.

Synthesis of III.—Hydrogen bromide was bubbled for 4 min. into a solution of 500 mg. of Ia dissolved in 100 ml. of anhydrous ether. Crude III(474 mg.) precipitated at once. The salt was purified by precipitating it from absolute ethanol with anhydrous ether. It melted at 177–180°.

Anal. Calcd. for $C_{10}H_{10}ClBr_2N_3$: N, 11.43. Found: N, 12.02.

Acknowledgment.—A. C. Brooker wishes to acknowledge a National Science Undergraduate Research Participation Grant.

(6) H. W. Heine, M. E. Fetter, and E. M. Nicholson, *J. Am. Chem. Soc.*, **81**, 2202 (1959).

(7) Ia prepared by the method of W. R. Vaughan and M. S. Habib *J. Org. Chem.* **27**, 325 (1962) also melted at 95–96°.

(8) G. W. H. Cheeseman, *J. Chem. Soc.*, 1804 (1955).