days. The reaction mixture was then hydrolyzed with a mixture of ice and 10% sulfuric acid.

1. Grignard: amide ratio less than 4:1. The solid material which was insoluble in both the aqueous and organic phases was filtered and heated in 10 ml. of sulfuric acid on a water bath until it dissolved. The solution was cooled to room temperature, added to 90 ml. of water, and the mixture filtered. The solid did not depress the melting point of authentic *o*-bromobenzoic acid. The acidic filtrate was tested for magnesium ions as magnesium ammonium phosphate and gave a positive test.

The aqueous-organic filtrate, after removal of the magnesium *o*-bromobenzoate, was separated, discarding the aqueous layer, and extracted with 10% sodium carbonate solution and finally 5% sodium hydroxide solution. Acidification of the alkaline extracts with 1:1 hydrochloric acid gave a precipitate which did not depress the melting point of authentic *o*-bromobenzoic acid.

The organic layer was dried over anhydrous sodium sulfate and distilled to give *o*-bromobenzamide, b.p. 158–161° (12 mm.).

2. Grignard: amide ratio 4:1. The organic layer from the hydrolysis step was separated, extracted with 10% sodium carbonate solution, and then with 5% sodium hydroxide. The combined alkaline layers were acidified with 1:1 hydrochloric acid, but no precipitate formed.

The organic layer was washed with water, dried over anhydrous sodium sulfate, and vacuum distilled to yield α-phenyl-2-bromoacetophenone as a yellow oil, b.p. 203–206° (2 mm.).

3. Grignard: amide ratio greater than 4:1. The organic layer from the hydrolysis step was separated, extracted with 10% sodium carbonate solution, and then with 5% sodium hydroxide. The combined layers were acidified with 1:1 hydrochloric acid, but no precipitate appeared.

The organic layer was washed with water, dried over anhydrous sodium sulfate, and vacuum distilled to give α-phenylacetophenone, b.p. 176–178° (12 mm.).

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Aminohydrins from Aziridine

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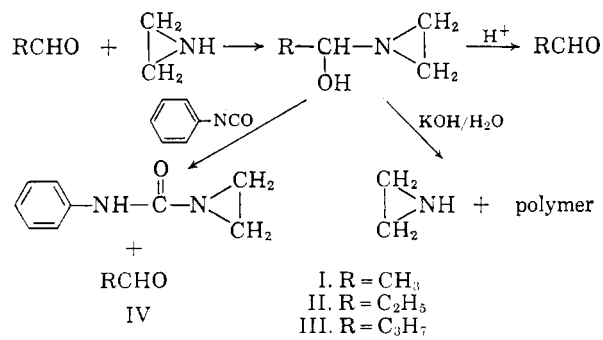
Received September 11, 1961

Aminohydrins, $R_2C(OH)NR_2$, are unknown generally except as certain reactive intermediates from the addition of aldehydes to amines. The products from the reaction of secondary amines and carbonyl compounds usually are water and enamines or alkylidenediamines.[1] The secondary heterocyclic amine aziridine reacting in the cold with carbonyl compounds yields addition products containing oxygen[2] which have been formulated as aminohydrins[3] without adequate proof of structure. The comparable reaction under prolonged reflux in ether solution opens the aziridine ring and gives 2-oxazolidines.[4] Kostyanovskii has reported from the reaction of aziridine and formaldehyde the formation of two products: aziridinemethanol and methylenebisaziridine.[5]

We have prepared stable addition products of aziridine and acetaldehyde, propionaldehyde, and butyraldehyde. Infrared spectra along with other physical properties indicate that these addition products are stable aminohydrins, 1-aziridine-1-alkanols, $RCH(OH)N(CH_2)_2$. The infrared spectra of all three products exhibited similarities and showed a strong hydroxyl absorption band at 3.1 μ which nearly obscured the strong aziridine C—H stretching band at 3.25 μ. The strong C—O stretching band at 9.0 μ is evidence of secondary hydroxyl groups. Intact aziridine rings were indicated by the strong bands at 3.25 μ, strong symmetric ring breathing deformations at 8.0 μ, and additional aziridine ring deformations in the 11.8- and 12.2-μ region.[6]

1-Aziridine-1-ethanol (I) from aziridine and acetaldehyde was sufficiently pure after distillation for characterization (Table I). It was soluble in ethyl ether, ethanol, and water, but insoluble in petroleum ether. 1-Aziridine-1-propanol (II) and 1-aziridine-1-butanol (III) were soluble in the same solvents and in petroleum ether. The latter two products after distillation were believed to contain some of the corresponding 1,1-alkylidenebisaziridines (1 to 4%), and were purified further by recrystallization from petroleum ether at −20° (Table I). 1-Aziridine-1-butanol treated with 2,4-dinitrophenylhydrazine reagent gave a 93% yield of butyraldehyde 2,4-dinitrophenylhydrazone.

1-Aziridine-1-ethanol did not react with ammonia either in ethyl ether or aqueous solution. Warming with aqueous potassium hydroxide under reduced pressure returned aziridine in 50% yield. Reaction with phenyl isocyanate in ethyl ether solution gave the unsymmetrical urea derivative (IV) rather than the urethan. The aziridine aminohydrins have remained stable and clear for several weeks at room temperature in the presence of a little calcium hy-



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(5) R. G. Kostyanovskii, *Doklady Akad. Nauk S.S.S.R.*, **135**, 853 (1960); *Chem. Abstr.* **55**, 12380a (1961).

(6) The authors express appreciation to H. L. Spell for the infrared spectra and aziridine band assignments.

TABLE I

PROPERTIES OF AZIRIDINE AMINOHYDRINS

	1-Aziridine-1-ethanol		1-Aziridine-1-propanol		1-Aziridine-1-butanol[a]	
n_D^{23}	1.4425		1.4432		1.4485	
d_4^{25}	0.967		0.923		0.924	
B.p.	30°/30 mm.		33°/25 mm.		35°/20 mm.	
M.p.	<0°		11–12°		20–21°	
Yield	57%		83%		58%	
	Calcd.	Found	Calcd.	Found	Calcd.	Found
N.E.[b]	87.1	85	101	101	115	117
MR_D	23.88	23.94	28.56	29.06	33.14	33.40
%C	55.14	54.99	59.37	59.42	62.57	62.58
%H	10.41	10.29	10.96	11.09	11.38	11.51
%N	16.08	16.24	13.85	13.76	12.16	12.46
Mol. wt.	87.12	82[c]	101.15		115.18	

[a] *Cf.* Dornow and Schacht, *op. cit.* [b] N.E.—Neutralization equivalent. [c] Determined cryoscopically in dioxane.

dride with no change in appearance or infrared spectrum.

Recently Brown and Tsukamoto have reported that the reduction of 1-acylaziridines with lithium aluminum hydride gives a product which then yields the corresponding aldehyde upon acid treatment.[7] It is suggested that the formation of stable aminohydrins in lithium aluminum hydride reductions offers an explanation for the high yield of aldehyde obtained by subsequent acid hydrolysis. 1-Aziridine-1-ethanol has been isolated in 14% yield from the lithium aluminum hydride reduction of 1-acetylaziridine.[8]

EXPERIMENTAL

Preparation of aziridine aminohydrins. Aldehyde (2 moles) cooled to 0° was added to aziridine (2.2 moles) likewise cooled to 0° in an ice bath with stirring and in the presence of 35 g. of anhydrous potassium carbonate over a period of about 1 hr. After stirring for an additional hr., the product was permitted to warm to room temperature, decanted from the solid potassium carbonate, and distilled under reduced pressure through a 24-inch Vigreux column. The distillation pot contained 2–5 g. of calcium hydride to ensure alkaline conditions and to determine if water was formed upon warming. The calcium hydride was not consumed (*cf.* Table I). 1-Aziridine-1-propanol and 1-aziridine-1-butanol were dissolved in petroleum ether and placed in a refrigerator at −25° overnight. The white crystals which formed were filtered on a Buchner funnel and pressed dry under vacuum with the aid of a rubber dam. The crystals were transferred to a closed container before melting.

Preparation of the 2,4-dinitrophenylhydrazone. 1-Aziridine-1-butanol (1.15 g., 0.01 mole) was treated with 4 g. of 2,4-dinitrophenylhydrazine reagent in 20 ml. of sulfuric acid, 40 ml. water, and 100 ml. ethyl alcohol.[9] There was obtained 2.33 g. of crude precipitate, 93% yield of butyraldehyde 2,4-dinitrophenylhydrazone, m.p. 121° after recrystallization from 75% aqueous ethanol.

Recovery of aziridine. 1-Aziridine-1-ethanol (87 g., 1 mole) was added to 100 g. of 50% aqueous potassium hydroxide solution. The solution was distilled through a Vigreux column under reduced pressure (130 mm., pot temp. 50–60°, head temp. 30–31°). The distillate was dried with potassium hydroxide pellets, weighed, and identified as aziridine by its infrared spectrum and gas-liquid chromatogram, 22 g. 50% recovery.

Reactions with phenyl isocyanate. Phenyl isocyanate (119 g., 1 mole) dissolved in 250 ml. of ethyl ether and cooled in an ice bath, was treated with 1-aziridine-1-ethanol (I), (87 g., 1 mole) dissolved in 250 ml. of ethyl ether. The addition was conducted slowly with good stirring so as to keep the reaction temperature below 30°. The solution was placed in the refrigerator (0°) overnight for crystallization. The crystals were filtered on a Buchner funnel, pressed dry with a rubber dam, dried, and weighed, 116 g., m.p. 81–82.5°. A second crop of crystals was obtained by evaporating part of the ether under reduced pressure: 31 g., m.p. 77.5–80.5°. The total product (147 g.) represents a 91% yield of crude *N*-phenyl-*N'*,*N'*-ethyleneurea.[10] A portion of the first crystals was recrystallized from ethyl ether, m.p. 81–82°.

Anal. Calcd. for $C_9H_{10}N_2O$: C, 66.65; H, 6.22; N, 17.27. Found: C, 66.66, 66.49; H, 6.42, 6.27; N, 17.08, 17.25.

The same urea was obtained in similar fashion from 1-aziridine-1-propanol and 1-aziridine-1-butanol in yields of 80% and 67%, respectively.

The infrared spectra of all three *N*-phenyl-*N'*,*N'*-ethyleneureas obtained in mineral oil mulls were identical and consistent with the structural assignment.

Reduction of 1-acetylaziridine. 1-Acetylaziridine (43 g., 0.5 mole) was prepared and reduced with lithium aluminum hydride (7.5 g., 0.2 mole) according to Brown and Tsukamoto.[7] After the excess lithium aluminum hydride was decomposed with ethyl acetate (11 g., 0.25 mole), the reaction solution was treated carefully with water (9 g. in 50 ml. of methanol). This solution was stirred for 2 hr. at room temperature and permitted to stand overnight. The precipitated aluminum was filtered on a Buchner funnel, washed with ethyl ether, and rejected. The filtrate and washings were concentrated by distillation. The clear residue then was distilled through a Vigreux column under reduced pressure in the presence of calcium hydride (1 g.): b_{30} 30°, 6 g., 14% yield of 1-aziridine-1-ethanol, identified by its infrared spectrum which was identical to the spectrum of the known compound. The distillate in ethyl ether (10 ml.) was treated with phenyl isocyanate (9 g.) in ethyl ether (10 ml.). White crystals were obtained after standing overnight at 0°, 6 g., m.p.

(7) H. C. Brown and A. Tsukamoto, *J. Am. Chem. Soc.*, **83**, 2016 (1961).

(8) Attempts to increase the yield of aminohydrin by acid hydrolysis of the aluminum reduction complex always gave no yield of aminohydrin or of aziridine.

(9) R. L. Shriner, R. C. Fuson, and D. Y. Curtin, "The Systematic Identification of Organic Compounds," John Wiley and Sons, Inc., New York (1956), pp. 219–283.

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79–81°. The infrared spectrum in mineral oil mull was identical to that of the known derivative, *N*-phenyl-*N'*-*N'*-ethyleneurea.

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Studies in Organic Sulfur Compounds. XI.[1] On the Reaction of Enamines with Hydrogen Sulfide[2]

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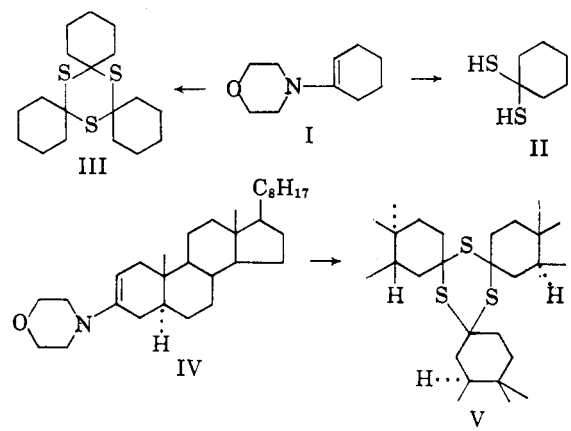
Received August 18, 1961

In a recent paper[3] we have pointed out that optically active thiones give rise to Cotton effects in the visible region of the spectrum and that a detailed optical rotatory dispersion study[4] of such thiones would be indicated if a general synthetic method for monomeric thiones were available. Nomura and Takeuchi[5] have now published what appears to be a general route to monomeric thiones—namely the reaction of morpholino-enamine derivatives of ketones with hydrogen sulfide in dimethylformamide solution. They substantiated this claim by treating 1-morpholinocyclohexene and cyclopentene with hydrogen sulfide and isolating in each instance a pink liquid, whidh was not analyzed, but which was assumed to be the monomeric thione because of an infrared band at 1130 cm.$^{-1}$ (found by us to be present in the spectrum of II) and the conversion of the substance into cyclohexanone 2,4-dinitrophenylhydrazone.

We have undertaken a repetition of the Japanese work, because, if confirmed, it would offer an extremely simple route to optically active, monomeric thiones. When analytically-pure 1-morpholinocyclohexene (I)[6] was treated with hydrogen sulfide under the conditions reported by the Japanese investigators,[5] there was isolated in over 90% an evil-smelling liquid, with a pink color, which faded within a few hours. Immediate spectroscopic measurement indicated the presence of a weak absorption band in the 510-mμ region, but by assuming an extinction coefficient of log ϵ 1.15 for the pure thione,[3] the present material could not have contained more than 5% of thione. The boiling point agreed with the literature values,[5] but the following measurements showed unquivocally that the product was in fact the known[7] 1,1-dithiocyclohexane (II). The empirical formula was established by carbon, hydrogen and sulfur analyses. The infrared spectrum exhibited a strong SH band at 2520 cm.$^{-1}$ and the NMR spectrum contained a very sharp singlet at 147 c.p.s. (relative to tetramethylsilane), which can be attributed to the SH proton, the area under this peak corresponding exactly to two out of twelve protons. Pyrolysis[7] of II provided dicyclohexyldisulfide, while treatment with an acidic solution of dinitrophenylhydrazine led to the 2,4-dinitrophenylhydrazone of cyclohexanone. *gem*-Dithiols are relatively rare substances[7] and it appears that the reaction of enamines with hydrogen sulfide may represent the best synthetic route to this class of sulfides. Repetition of the Japanese directions with 1-morpholinocyclopentene similarly led to 1,1-dithiocyclopentane rather than to the claimed[5] cyclopentane-1-thione, which according to spectroscopic measurements could not have been present to an extent of more than 5%.



Finally, 3-morpholino-Δ^2-cholestene (IV) was treated with hydrogen sulfide in dimethylformamide-ether solution, the ether having been added for solubility reasons. The resulting crystalline product appears to be the trimeric thione V, as evidenced by its analysis, lack of relevant infrared or ultraviolet bands, and absence of NMR signals attributable to protons attached to sulfur. The different reaction course is almost certainly due to the change in solvents, because when 1-morpholinocyclohexene (I) was treated with hydrogen sulfide in dimethylformamide-ether solution, rather than in dimethylformamide alone, there was isolated the trimer III instead of 1,1-dithiocyclohexane (II). The structure of the trimeric thione III was established by analysis, mass spectrometric molecular weight determination,[8] and spectral measure-

(1) Paper X, C. Djerassi, M. Shamma, and T. Y. Kan, *J. Am. Chem. Soc.*, **80**, 4723 (1958).

(2) Supported in part by grant No. CRTY-5061 from the National Cancer Institute of the National Institutes of Health, U. S. Public Health Service.

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(8) We are indebted to Dr. Herbert Budzikiewicz of our laboratory for this determination.