grade distilled under vacuum; nitrogen, Canadian Liquid Air Co. "oxygen-free" nitrogen bubbled twice through alkaline pyrogallol and then passed hot copper filings to remove traces of oxygen.

The reaction flask is illustrated in Fig. 5. By proper manipulation of the stopcocks nitrogen could be bubbled through the solution to displace oxygen and to stir the contents or nitrogen pressure could be used to force the solution into the sampling pipet inserted at A and then blow out the unused portion of the sample. After nitrogen had been bubbled through the solution for three-quarters of an hour, the deoxygenated final solution (iron(II) plus α,α'-bipyridyl, if used) was forced by nitrogen pressure into the flask through a buret inserted at B. Previous work showed that the order of addition of CHP and iron(II) was without effect at these low concentrations in the absence of monomer,[4] and the order probably would have still less effect when there is monomer present to react with the radicals which might induce hydroperoxide decomposition.

Samples were removed at intervals, centrifuged to remove any polyacrylonitrile if monomer were present initially and analyzed for residual iron(II) by the method outlined previously[4] along with the method of analysis for the CHP. The final iron(II) concentration was determined after a 24-hour period.

In the work on the effect of α,α'-bipyridyl on the reaction, the concentration of $Fe(bip)_3^{++}$ was measured colorimetrically with all reagents added except the CHP. In this determination it was assumed that absorption by the other complexes is negligible. Experimental evidence indicates that this is a valid assumption for the green filter (Klett-Summerson 54) used in these experiments since the optical density of a 1.0×10^{-1} *M* solution of iron(II) is unchanged on the addition of 3.0×10^{-5} *M* bipyridyl. Presumably this solution contains the $Fe(bip)^{++}$ and $Fe(bip)_2^{++}$ intermediates.[5] Acetate buffers were used to maintain *p*H values of 3 or 4. Lower *p*H values were obtained using sulfuric acid.

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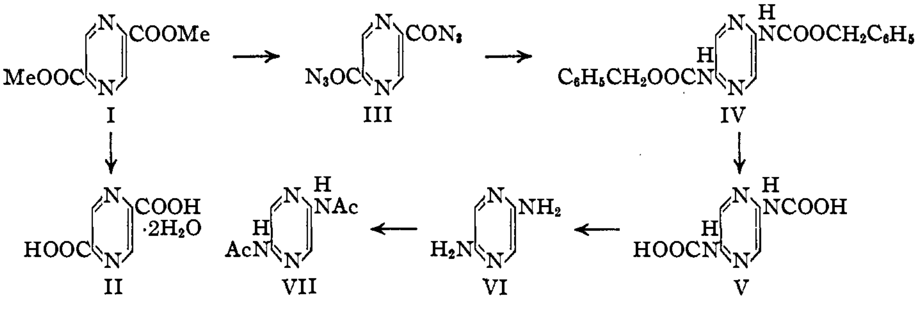
[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY OF THE POLYTECHNIC INSTITUTE OF BROOKLYN]

Syntheses in the Pyrazine Series; Synthesis of 2,5-Diaminopyrazine[1]

BY DAVID M. SHAREFKIN AND PAUL E. SPOERRI

The synthesis of 2,5-diaminopyrazine from its dibenzylurethan derivative is described. The failure of 2,5-dicarbomethoxypyrazine to undergo the Schmidt reaction is accounted for in terms of its normal ionization and "*i*" values in 100% sulfuric acid. 2,5-Dicarboxypyrazine dihydrate is obtained as the product of the Schmidt reaction. Also included are ultraviolet absorption spectra curves for 2,5-disubstituted pyrazines.

The preparation of 2,5-diaminopyrazine (VI) has been investigated in view of the recorded failure of others[2] to prepare this compound. During this investigation, the isomeric 2,3-diaminopyrazine was prepared by a Hofmann degradation[3] and the 2,6-diaminopyrazine by ammoniation[4] of the halogenated pyrazine. These reactions have failed to produce 2,5-diaminopyrazine.



Newman[5] and Smith[6] have pointed out that the Schmidt reaction should be acid catalyzed, preferably by the use of trichloroacetic acid in the sulfuric acid medium. The solid obtained from the acid-catalyzed Schmidt reaction on 2,5-dicarbomethoxypyrazine proved to be 2,5-dicarboxypyrazine dihydrate (II). The identity of the 2,5-dicarboxypyrazine dihydrate was established by analysis, and by electrometric titration with standard alkali. The curves obtained, by plotting *p*H *versus* alkali added, corresponded to the second stoichiometrical point, *i.e.*, for a weak dibasic acid.

To determine the extent of the preferential acid–base reaction between the pyrazine ring nitrogens and the solvent protons, that part of the Schmidt reaction mixture concerned with the formation of a pyrazine oxocarbonium ion was studied. The hydrolysis method of Hammett and co-workers[7] was used to determine the mode of ionization of 2,5-dicarbomethoxypyrazine in sulfuric acid solution. A solution of 2,5-dicarbomethoxypyrazine (I) in cold concentrated sulfuric acid was poured into ice water. The ester was recovered unchanged, indicating its normal ionization in the medium.

Quantitative determination of "*I*" values for 100% sulfuric acid solutions of 2,5-dicarbomethoxypyrazine, by the freezing point method adapted by Newman,[8] gave an average "*I*" value of 2.55. The acceptance by the solute of an average of 2.55 protons rather than the theoretical maximum of five protons demonstrated the failure of the 2,5-dicarbomethoxypyrazine to undergo the Schmidt reaction.

(1) From thesis presented in partial fulfillment for the degree of Doctor of Philosophy at the Polytechnic Institute of Brooklyn.

(2) Spoerri and Erickson, THIS JOURNAL, **60**, 400 (1938); Ellingson and Henry, *ibid.*, **71**, 2798 (1949).

(3) McDonald and Ellingson, *ibid.*, **69**, 1034 (1947).

(4) Schaaf and Spoerri, *ibid.*, **71**, 2043 (1949).

(5) Newman, *et al.*, *ibid.*, **63**, 2431 (1941); **70**, 317 (1948).

(6) Smith, *ibid.*, **70**, 320 (1948).

(7) Hammett and Deyrup, *ibid.*, **55**, 1900 (1933); Treffers and Hammett, *ibid.*, **59**, 1708 (1937).

(8) Newman, Kuivila and Garrett, *ibid.*, **67**, 1704 (1945).

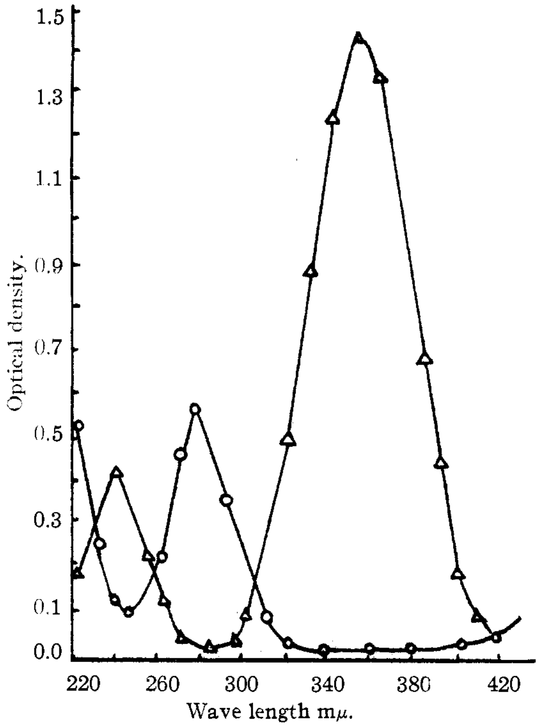


Fig. 1.—Absorption spectra of O, 2,5-dicarboxypyrazine; △, 2,5-diaminopyrazine.

Though the literature revealed the resistance of pyrazine 2,5-diurethan to strong acid hydrolysis,[2] the 2,5-dibenzylurethan of pyrazine (IV) was prepared with the expectancy that it would yield to hydrolysis with cold concentrated sulfuric acid[9] and then subsequent polymerization of the liberated benzyl alcohol by the sulfuric acid. The 2,5-dicarbamic acid (V) would then decompose in the acid medium to form the 2,5-diaminopyrazine (VI).

The 2,5-dibenzylurethan (V) was prepared from the 2,5-diacid azide (III) and anhydrous benzyl alcohol, and then subjected to sulfuric acid hydrolysis and polymerization at room temperature to produce the 2,5-diaminopyrazine (VI). The diamine was extracted from the aqueous medium at *p*H 6.9 instead of the usual strongly alkaline solution, since it was found to be very sensitive to oxidation in neutral and alkaline solution.

Solutions of 2,5-diaminopyrazine were found to be strongly fluorescent in sunlight and under ultraviolet light. Ultraviolet absorption spectra measurements were made on 2,5-diamino and 2,5-dicarboxypyrazines as representative of 2,5-disubstituted pyrazines. The 2,5-diaminopyrazine exhibited two points of maxima mμ as compared to other 2,5-disubstituted pyrazines with only one point of maximum mμ.

Experimental

Hydrolysis.—The hydrolysis experiments were carried out as previously described.

"*i*" Value of 2,5-Dicarbomethoxypyrazine (I).—The dicarbomethoxypyrazine was prepared by the method of Erickson and Spoerri.[2] The freezing point depression measurements[10] were made according to the method of Newman, *et al.*,[8] except that a Beckmann thermometer was used instead of a resistance thermometer. Table I contains the results of the freezing point depression measurements. The last column gives the "*i*" value calculated from the equation $i = dT/dM \times 6.154(1 - 0.0047t)$, where t is the difference between the freezing point of 100% sulfuric acid and the observed freezing point.

Table I

Determination of "I" Values

Sample, g.	d*M*	F.p., °C.	d*T*	
		3.676		
0.17705	0.01236	3.483	0.193	2.60
		3.464		
.1867	.0130	3.267	.197	2.51

2,5-Dicarboxypyrazine Dihydrate (II).—2,5-Dicarbomethoxypyrazine (I) (0.4 g., 0.002*M*) was added to 4 cc. of cold concentrated sulfuric acid with continuous stirring at room temperature. Then the temperature was raised to 60° and 3 g. of trichloroacetic acid was added. This was followed by addition of sodium azide (0.39 g., 0.005*M*) over the period of an hour. The reaction was maintained at 60° for three hours. The reaction mixture was poured on 10 g. of crushed ice, and then ether added to precipitate the solid. After filtration the crude product was washed with ether and recrystallized from absolute methanol and Nuchar. The white solid melted at 263–264°.

Anal. Calcd. for $C_6H_8O_6N_2(C_6H_4O_2 \cdot 2H_2O)$: C, 35.53; H, 3.95; N, 13.75. Found: C, 35.13; H, 3.93; N, 13.81.

When the solid was recrystallized from water, it melted at 255°; recorded for 2,5-dicarboxypyrazine.[2] It gave the characteristic wine red color test with a solution of ferrous sulfate for pyrazinecarboxy acids. Titration with standard alkali indicated the presence of two acid groups in a weak dibasic organic acid.

2,5-Dibenzylurethan of Pyrazine (IV).—2,5-Diacid azide of pyrazine (III) (1.09 g., 0.05*M*) was suspended in 125 cc. of anhydrous benzyl alcohol. The mixture was heated slowly to 180° and held for thirty minutes or until gas evolution ceased. Then the oil-bath temperature was raised to 220° and held for fifteen minutes. The solution was allowed to cool to room temperature and then chilled overnight at 2°. The solid was collected as fine needles, washed with benzene and ether and dried. The filtrate was reduced in volume *in vacuo* to yield a second crop of crystals. The total weight of solid was 1.4 g. or 78%. For analysis, the solid was digested in a large volume of dry benzene and dried *in vacuo*. The melting point was 290°.

Anal. Calcd. for $C_{20}H_{18}O_4N_4$: N, 14.82. Found: N, 14.66.

2,5-Diaminopyrazine (VI).—2,5-Dibenzylurethan (IV) (1.89 g.) was added in small portions to 8.5 cc. of concentrated sulfuric acid with constant stirring over a thirty-minute period. The mixture was smoothed out to a fine paste and then poured on 10 g. of crushed ice. The mixture was brought to *p*H 6.9 with 20% sodium hydroxide solution and then immediately extracted with one liter of ethyl acetate in five portions. The combined extracts were dried over anhydrous sodium sulfate and then reduced *in vacuo* to 100 cc. It was dried again over sodium sulfate and the volume reduced to 10 cc. On chilling, fine, green-yellow crystals formed and were removed by filtration. The solid was purified by recrystallization from anhydrous ethyl acetate and Nuchar. The yield was 0.4 g. of fine crystals which melted at 215°. The crystals were slightly soluble in ether, soluble in ethyl acetate. The ether solution was unstable due to presence of ether peroxides. Aqueous and ethyl acetate solutions of the diaminopyrazine displayed strong blue fluoresence to sunlight and to ultraviolet light.

Anal. Calcd. for $C_4H_6N_4$: C, 43.62; N, 50.88; H, 5.49. Found: C, 43.74; N, 48.41; H, 5.30.

2,5-Diacetamidopyrazine (VII).—2,5-Diaminopyrazine (VI), 0.3 g., was acetylated in acetic anhydride. After two hours, the solid was filtered off, washed with ether and dried. The crude product melted at 360°. It was recrystallized three times from absolute methanol and Nuchar to yield a fine white amorphous powder melting at 365°.

Anal. Calcd. for $C_8H_{10}O_2N_4$: N, 28.80. Found: N, 28.67.

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[9] Day and Ingold, *Trans. Faraday Soc.*, **37**, 694 (1941).

[10] "*i*" values were measured by Dr. Lester Kuhn, Ballistics Laboratory, Aberdeen Proving Grounds, Md.