The details of the precise photochemical origin of the described photoproducts is under further investigation.

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An Unusual Photochemical Rearrangement in the Synthesis of Adenine from Hydrogen Cyanide[1]

Sir:

We have described the syntheses of aminomalononitrile and 4-amino-5-cyanoimidazole and discussed the relevance of these intermediates to the prebiological synthesis of adenine and other heterocyclics.[2] Further study shows: (1) the reaction of 4-amino-5-cyanoimidazole (II) (0.05 *M*) with formamidine acetate (0.1 *M*) in aqueous solution (pH 8–8.5) proceeds slowly at 30° and yields only adenine (III) and 4-aminoimidazole-5-carboxamide in the ratio of about 100:1. After 5 days about 3% of adenine had been formed in a typical experiment. Little or no reaction occurred if formamidine was replaced by 0.1 *M* cyanide or 0.1 *M* cyanide–0.1 *M* ammonia mixtures. Ultraviolet irradiation (253 mμ) did not accelerate any of the above reactions.

(2) The slow addition (5 hr) of aminomalononitrile (0.01 *M*) to formamidine acetate (0.1 *M*) at 25–30° and pH 8–8.5 gives a 5% yield of 4-amino-5-cyanoimidazole (II) with the remainder of the aminomalononitrile apparently giving polymeric material. A 50% yield of 4-amino-5-cyanoimidazole is obtained when the aminomalononitrile (0.01 *M*) is added over a 24-hr period to 0.1 *M* formamidine acetate at 50°. However, the reaction of aminomalononitrile with cyanide to give HCN tetramer (diaminomaleonitrile, I) is much more rapid; if aminomalononitrile (0.01 *M*) is added to a solution 0.1 *M* in both cyanide and formamidine the yield of HCN tetramer (I) exceeds that of aminoimidazolenitrile (II) by about 100:1.

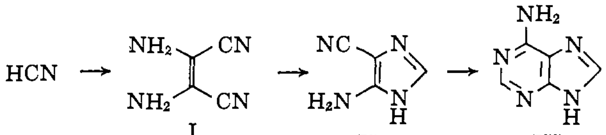
It is apparent that the prebiotic formation of adenine (III) could proceed by the reaction of a dilute solution of formamidine with 4-amino-5-cyanoimidazole (II) (0.001 *M* formamidine should give comparable rates of hydrolysis and adenine synthesis). The formation of 4-amino-5-cyanoimidazole from aminomalononitrile, however, would not proceed efficiently under these circumstances and the alternative reaction with cyanide ion to give the HCN tetramer would surely be more important under plausible prebiotic conditions.

We therefore investigated the reactions of the HCN tetramer (I). Direct reaction of formamidine with I gives a very poor yield of II, but when an aqueous solution of HCN tetramer (10^{-4} *M*) is irradiated at 25° with a 350 mμ lamp a 77–82% yield of 4-cyano-5-aminoimidazole (II) is obtained. The identity of the product with an authentic specimen of II was confirmed by chromatography, ultraviolet spectroscopy, and quantitative hydrolysis to the well-known 5-aminoimidazole-4-carboxamide. Yields were estimated from the intensity of the 247 mμ peak of II.

Preliminary studies on the scope of this photochemical rearrangement at 253 mμ show that 1,1-diamino-2,2-dicyanoethylene[3] in tetrahydrofuran solution, but not in water, also yields 4-amino-5-cyanoimidazole along with other products. 3-Aminocrotononitrile is converted to 4-methylimidazole in 50–60% yield. Aminomethylenemalononitrile,[4] *o*-aminobenzonitrile,[5] and 1,1-dimorpholino-2,2-dicyanoethylene[6] do not rearrange to imidazoles.

3-Amino-4-cyanopyrazole also rearranges to II, but only when irradiated by lamps emitting at 253 mμ.[7,8] Since the rearrangement of the HCN tetramer proceeds readily with lamps emitting mainly at 350 mμ, the pyrazole cannot be an intermediate. Pathways for the photochemical rearrangement of I involving the formation of intermediates containing either a three-membered or a four-membered ring[9] can be written, but at present we have no evidence for or against either intermediate.

The most plausible route to adenine from HCN under prebiotic conditions which can be proposed at the moment appears to be



I II III

However, we shall not indulge in detailed speculation until we have investigated other routes.

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[1] This work was supported by Grant GB-3152 from the National Science Foundation.

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[7] R. K. Robins, *J. Am. Chem. Soc.*, **78**, 784 (1956).

[8] H. Tiefenthaler, W. Dorscheln, H. Goth, and H. Schmid, *Tetrahedron Letters*, 2999 (1964).

[9] A similar intermediate was postulated for the reverse reaction in the photochemical isomerization of cytosine: K. L. Wierzchowski and D. Shugar, *Photochem. Photobiol.*, **2**, 377 (1963). (No cytosine was formed on the irradiation of aminomethylenemalononitrile.)

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The Oxidative Dealkylation of Mesitol with Activated Manganese Dioxide

Sir:

During the course of a survey of the reactions of phenols with hydrogen peroxide and acidified ferrous sulfate, Cosgrove and Waters[1] reported the formation of 4,4′-dihydroxy-3,3′,5,5′-tetramethyldiphenylmethane (VIII) from mesitol (I) in low yield. Bacon and Munro[2] observed this same product in 13% yield in the silver persulfate oxidation of I. A loss of a methyl group was inferred by Becconsall, *et al.*,[3] during an electron spin resonance study of the lead dioxide oxidation of 4-methyl-2,6-di-*t*-butylphenol. In this communication, we wish to report results which not only expand the scope of this curious reaction to another oxidant,

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[1] S. L. Cosgrove and W. A. Waters, *J. Chem. Soc.*, 1726 (1951).

[2] R. G. R. Bacon and D. J. Munro, *ibid.*, 1339 (1960).

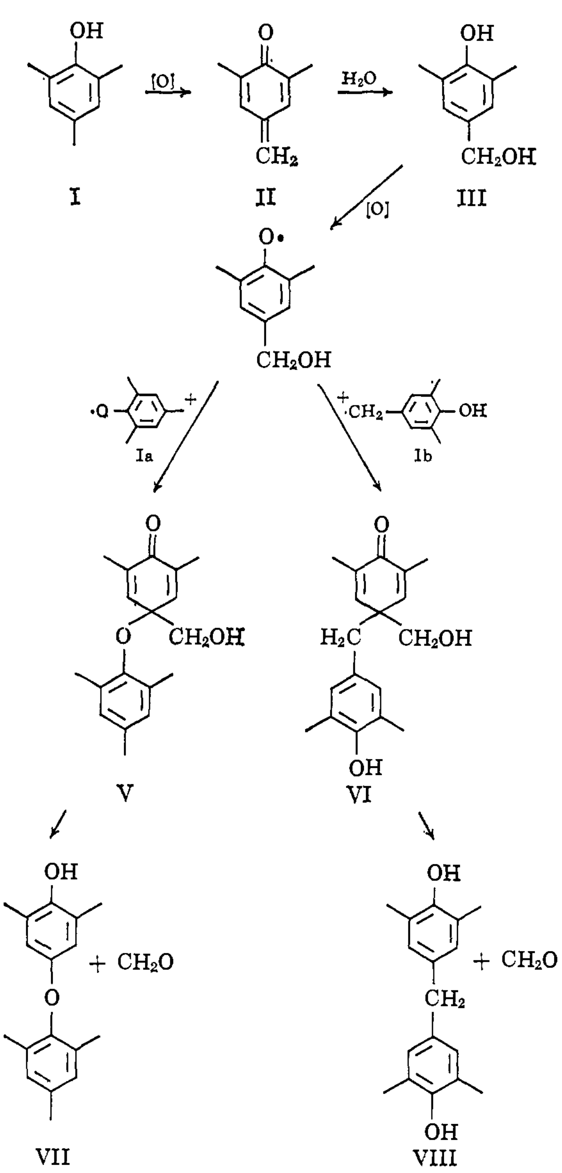
[3] J. K. Becconsall, S. Clough, and G. Scott, *Proc. Chem. Soc.*, 308 (1959).

activated manganese dioxide, but also demonstrate the formation of another unexpected product, a dealkylated polymer of mesitol. A suggested reaction pathway is supported and proposed as a model for the oxidative dealkylation of certain phenolic natural products.

When a solution of mesitol (33 mmoles) in benzene (50 ml) was refluxed in a nitrogen atmosphere for 2 hr over activated manganese dioxide[4] (100 mmoles), VIII was isolated in 15% yield. Characterization was made by comparison with authentic material[5] in melting point and infrared, ultraviolet, nmr, and mass spectra. An oligomeric product was formed in 53 weight % yield. Its nuclear magnetic resonance pattern displayed two singlets at 2.1 and 6.5 ppm relative to $(CH_3)_4Si$ in an intensity ratio of 3:1. Its infrared spectrum was identical with that of the 2,6-xylenol polymer[6] except for a band at 8.7 μ. These results suggest that the oligomer has a backbone of 2,6-xylenoxy units extending from a mesitoxy unit. This assignment is supported by mass spectral data. A mass spectrum of the lower molecular weight portions of the oligomer shows strong peaks at 256, 376, and 496, indicative of one, two, and three xylenoxy units, respectively, attached to a mesitoxy unit. Furthermore, the treatment of the oligomer with activated manganese dioxide in an esr cavity afforded a signal whose principal pattern was seven lines split 5.0 ± 0.1 oersteds with a triplet subsplitting of 1.0 ± 0.1 oersted. This is identical with the esr signal[7] obtained from the 2,6-xylenol polymer with activated manganese dioxide.

A "dimeric" form of this oligomer is structure VII, which was isolated from the reaction products by distillation of base-insoluble products. This substance was identical with synthesized VII in melting point and infrared, nmr, and mass spectra. Authentic VII was prepared by hydriodic acid cleavage of the Ullmann reaction product between the methyl ether of 4-bromo-2,6-xylenol and mesitol.

Increasing the MnO_2:mesitol molar ratio to 6:1 brought about an increase in oligomer yield to 79%, whereas decreasing that ratio to 1.5 afforded a yield increase of VIII to 30%. A sample of coagulated oligomer had a molecular weight of 1800. Other products of this reaction are III (detected by vpc and mass spectra), the benzaldehyde derived from III (isolated as such), and a material believed to be the quinone methide of VIII (inferred by mass spectra and reduction to VIII). Mass spectral data on the dealkylated oligomer also indicate small amounts of other oligomeric species, whose structures await further experimental clarification.



A mechanism accounting for oxidative dealkylation is suggested, wherein I is converted to the quinone methide[8] II which adds water to form III. This alcohol can couple oxidatively either with a mesitoxyl radical Ia or with a benzyl radical Ib to give intermediate cyclohexadienones V and VI which decompose to formaldehyde and products VII and VIII. The formation of formaldehyde is indicated by the addition of reaction mixtures to dimedone solutions to give low yields of the dimedone–formaldehyde adduct[9] which was determined by mixture melting point with authentic material and by infrared and mass spectra. Oxidative dimer VII can react similarly with III to continue the oligomeric formation. The "dimer" may also react to form oligomer by the quinone ketal mechanism shown to be operable in the 2,6-xylenol dimer polymerization with activated manganese dioxide.[7] The presence of a quinone methide II was shown by using methanol as solvent and isolating the α-methyl ether of III (mp 54–55°; mol wt, 166, mass spectrum). Treatment of authentic[10] III with activated manganese dioxide afforded in 65% yield an oligomeric product with the 2,6-xylenol backbone as shown by nmr and infrared spectra.

Magnusson[11] ascribed such demethylation reactions to the formation of III which under acidic conditions (less than pH 3[12]) is converted to VIII. Although this explanation seems reasonable with the acidic Fenton

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[4] E. F. Pratt and J. F. VanDeCastle, *J. Org. Chem.*, **26**, 2975 (1961).

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[7] E. McNelis, Abstracts, 150th National Meeting of the American Chemical Society, Atlantic City, N. J., Sept 1965, p 15S.

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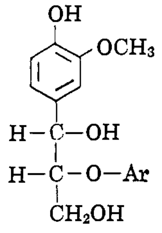
[10] E. Bamberger, *Chem. Ber.*, **36**, 2028 (1903).

[11] R. Magnusson, *Acta Chem. Scand.*, **18**, 759 (1964).

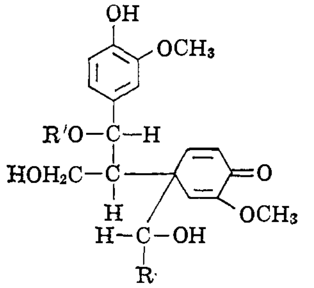
[12] G. E. Little, *J. Appl. Chem.*, **12**, 196 (1965).

system[1] and mildly acidic persulfate system,[3] it is not in keeping with the nonacidic reaction conditions of the lead dioxide[3] and manganese dioxide systems and the reactivity of III with the latter oxidant.

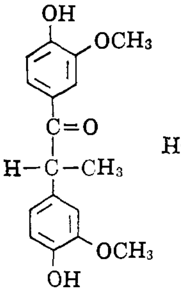
This oxidative dealkylation mechanism ought to be applicable to certain phenolic natural products. It provides a possible dealkylation pathway for many lignin oligomers such as IX (AR denotes any polyconiferyl alcohol oligomer) to aldehydic fragments which may serve to bond lignins to the carbohydrates of the plant cell wall. Recently, Lundquist and Miksche[13] have postulated structure X as an intermediate in order to explain product XI in Bjoerkman lignin oligomers. This reaction scheme also provides an extension to a proposed mode[14] of oxidative dealkylation of 3,5-diiodotyrosine to thyroxine (XII).



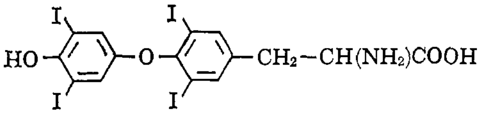
IX



X



XI



XII

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Precipitation of Sodium Chloride from Aqueous Solution by Compound Formation with an Organic Amine

Sir:

We wish to report the first example of the precipitation of simple sodium salts such as sodium chloride from aqueous solution by compound formation with a nonionic organic substance. The compound capable of precipitating these salts is racemic *p,p'*-diamino-2,3-diphenylbutane (I). Equally unique is that the compound, II, which results from combination of I with sodium chloride, is best described as a solid coordination compound of sodium with a nitrogen donor ligand.

Of the alkali metals only lithium salts are known to form isolable coordination compounds with nitrogen-donor ligands.[1] The more stable are those where the ligand is ammonia. Replacement of ammonia by amines decreases their stability. It is therefore very surprising that I, which is a weakly basic and bulky aromatic amine, can exhibit bonding with sodium. Furthermore, the previously reported amminelithium compounds are decomposed upon addition to water. Not only is II prepared by precipitation from aqueous solution, but it does so without incorporation of any detectable quantity of water. The hydrolytic stability of II is also evidenced by the fact that when a quantity of it sufficient to give a 6.1 g/l. solution of sodium chloride was shaken with water for 1 week at 30°, the amount of sodium chloride found in solution was only 1.03 g/l.

Compound II can be simply obtained by agitating an ether solution of I with saturated aqueous sodium chloride. A more convenient method was to add 0.288 g (5 mmoles) of sodium chloride dissolved in 8 ml of water to 2.40 g (10 mmoles) of I dissolved in 24 ml of ethanol. Recrystallization from 25 ml of 1:3 aqueous alcohol gave 1.91 g of II. Although the melting point of I is 84–85° and that of sodium chloride is 800°, II fuses to a clear melt at 200°. There is no apparent phase separation when II is kept at or above its melting point for an extended period of time.

Assignment of a coordination structure rather than a clathrate or inclusion compound not only requires that II be stoichiometric, but that it also have constant composition. This was found to be the case. Elemental analysis of II was that for a substance consisting of three molecules of I per sodium chloride. *Anal.* Found: C, 74.23; H, 7.78; N, 10.92; Na, 3.15; Cl, 4.53. X-Ray data provide supporting evidence for a 3 to 1 stoichiometry for II. Diffraction analysis and density measurements were those for a unit cell containing 12 formula units of I and 4 units of sodium chloride. The property of constant composition was demonstrated by the fact that unrecrystallized II prepared from 2:1 and 18:1 molar ratios of I to sodium chloride contained 3.12 and 3.15% sodium, respectively.

The infrared spectrum of II provides compelling evidence for assigning it a coordination structure. The infrared spectrum (hexachlorobutadiene mull) of II is very similar to that of I except that the two sharp N-H stretching vibrations have each shifted 53 cm^{-1} to lower frequency and have become more intense. This is important for two reasons. The magnitude of this shift offers good evidence for *sodium to nitrogen bonding*, since for Pt(en)Br_2 the shift in N-H stretching frequency from that of ethylenediamine is 70 cm^{-1}.[2] Also the fact that only two sharp N-H stretching frequencies are observed means that there continues to be *only one kind of amino group in II.* This, in conjunc-

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