(80 μl, 0.810 mmol). The contents were allowed to stand at room temperature overnight, after which they were washed with water, and the ether layer was dried with anhydrous sodium sulfate, filtered, and evaporated. This left an oily, white solid residue, mp 49–54°, yield 0.09 g (56%). Recrystallization from Cellosolve B gave white crystals, yield (0.01 g (6%), mp 54–55°, mmp 55–56° with material from procedure A. Infrared spectra of both products A and B were identical, as were tlc retention times (benzene, on silica gel).

Reaction of Triphenylphosphine with *O*-Pivaloylhydroxylamine.—A chilled solution of triphenylphosphine (K & K, 0.104 g, 0.397 mmol) in carbon tetrachloride (0.801 g) was prepared. Neat *O*-pivaloylhydroxylamine (0.0299 g, 0.255 mmol) was added, and the resulting solution was allowed to warm to room temperature while being stirred. A white precipitate of triphenylphosphine oxide quickly developed, yield 0.0555 g (78%), mp 156–157° (lit.[16] mp 156°).

Reaction of Triphenylphosphine with *O*-Pivaloylhydroxylamine Hydrochloride.—A solution of *O*-pivaloylhydroxylamine hydrochloride (0.60 g, 3.90 mmol) in absolute methanol (6 ml) was combined with a solution of triphenylphosphine (1.02 g, 3.90 mmol) in absolute methanol (10 ml). Crude iminotriphenylphosphorane hydrochloride was precipitated out of solution upon the addition of ether, yield 0.58 g (48%), mp 218° (lit.[17] mp 230–232°). *Anal.* Calcd for $C_{18}H_{17}ClNP$: Cl, 11.32. Found: Cl, 11.21. A small amount was recrystallized from methanol–ether, mp 233°. *Anal.* Calcd for $C_{18}H_{17}ClNP$: C, 68.90; H, 5.42; Cl, 11.32; N, 4.46; P, 9.89. Found: C, 69.00; H, 5.59; Cl, 11.09; N, 4.43; P, 10.10. Treatment of an aqueous solution of this product with aqueous sodium hydroxide liberates ammonia and triphenylphosphine oxide. Treatment with aqueous silver nitrate produces a white precipitate insoluble in nitric acid.

Conversion of Dibenzylamine to *N*,*N*-Dibenzylhydrazine. A.—The neat base, *O*-pivaloylhydroxylamine (0.488 g, 4.17 mmol), was added to neat dibenzylamine (Chem. Service, Media, Pa., used as received) (0.801 ml, 4.17 mmol). A slight exotherm was detectable. The contents were heated for 1 min at 100°. The $FeCl_3$ complexing test on the crude product mixture confirmed the absence of pivalohydroxamic acid. To the filtrate was added acetic acid (3 ml) and benzaldehyde (2 ml). After work-up per Carpino,[3] the dibenzylhydrazone of benzaldehyde was isolated, yield 0.18 g (14%), mp 76–78°.

B.—A solution of *O*-pivaloylhydroxylamine in chloroform-*d* was treated with dibenzylamine. The contents were sealed into an nmr tube previously flushed with nitrogen. Immediate nmr analysis showed only starting materials, in a molar ratio (amine: *O*-acylhydroxylamine) of 5:1: δ 1.2 [s, 9 H, $(CH_3)_3C$], 3.73 [s, 20 H, benzylic $(CH_2)_2$ of amine], 7.15 (m, aromatic H of amine). The sealed tube was heated for 16 hr at 78°, after which the following nmr spectrum was observed: δ 1.2 [s, 9 H, $(CH_3)_3C$], 3.67 [s, 4 H, benzylic $(CH_2)_2$ of hydrazine], 3.75 [s, 16 H, benzylic $(CH_2)_2$ of amine], 4.95 (s, NH), 7.15, (m, aromatic H). The contents were treated with benzaldehyde, per Carpino,[3] and the resulting dibenzylhydrazone of benzaldehyde was observed by thin layer chromatography. Prior to the benzaldehyde addition, the product mixture tested negative to *O*-acylhydroxylamine (starch–iodide) and negative to hydroxamic acid ($FeCl_3$).

Registry No.—**1** (R = *t*-Bu), 35657-34-2; **1** (R = *t*-Bu) HCl, 35657-35-3; **1** (R = 4-$NO_2C_6H_4$), 35657-36-4; **1** (R = 4-$NO_2C_6H_4$)HCl, 35657-37-5; **1** (R = 3-Cl-C_6H_4), 35657-38-6; **1** (R = 3-ClC_6H_4) HCl, 35657-39-7; **4** (R = *t*-Bu), 35657-40-0; **4** (R = 4-$NO_2C_6H_4$), 35657-41-1; **5**, 10576-12-2; **6** (R = *t*-Bu), 35657-43-3; **6** (R = 2,5-$Cl_2C_6H_3$), 35657-44-4; **6** (R = CF_3), 35657-45-5; ethyl *N*-methanesulfonoxyacetimidate, 35657-46-6; *O*-pivaloylcylcyclohexanone oxime, 35657-47-7; triphenylphosphine, 603-35-0; iminotriphenylphosphorane hydrochloride, 21612-82-8; benzaldehyde dibenzylhydrazone, 21136-32-3.

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(17) H. H. Sisler, A. Arkis, H. S. Ahuja, R. J. Drago, and N. L. Smith, *J. Amer. Chem. Soc.*, **81**, 2982 (1959).

Reduction of Dehydroascorbic Acid Osazone and Related Compounds

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Reduction of dehydro-L-ascorbic acid phenylosazone (**1**) with $LiAlH_4$ resulted in the hydrogenation of the hydrazone residues and cyclization to a bicyclic compound **2**, which was dehydrated during acetylation with boiling Ac_2O to give diacetate **3**, and then partially hydrolyzed to monoacetate **4**. Reduction of the L-threo and D-erythro derivatives of 1-phenyl-3-trihydroxypropyl-4,5-pyrazoledione-4-phenylhydrazone (**5**) with Zn in AcOH afforded the bis(L-*threo*- and -(D-*erythro*-trihydroxypropyl)rubiazonic acid analogs **6**, which could be converted to the starting pyrazoles by treatment with phenylhydrazine, or oxidized with periodate to the formylrubiazonic acid.

Although the properties of reducing sugar osazones have been extensively studied,[1] the seemingly different reactions of dehydroascorbic acid osazones have only recently been investigated.[2-8] The presence of an additional carbonyl group enables dehydroascorbic acid osazones to undergo numerous cyclization reactions which do not occur with reducing sugar osazones, for example, the formation of 1-aryl-3-hydroxyalkyl-4,5-pyrazoledione-4-phenylhydrazones of type **5** by participation of the C-3 hydrazone nitrogen. This reaction is so facile that pyrazoles of this type are formed

(1) For a review, see H. El Khadem, *Advan. Carbohyd. Chem.*, **20**, 139 (1965).
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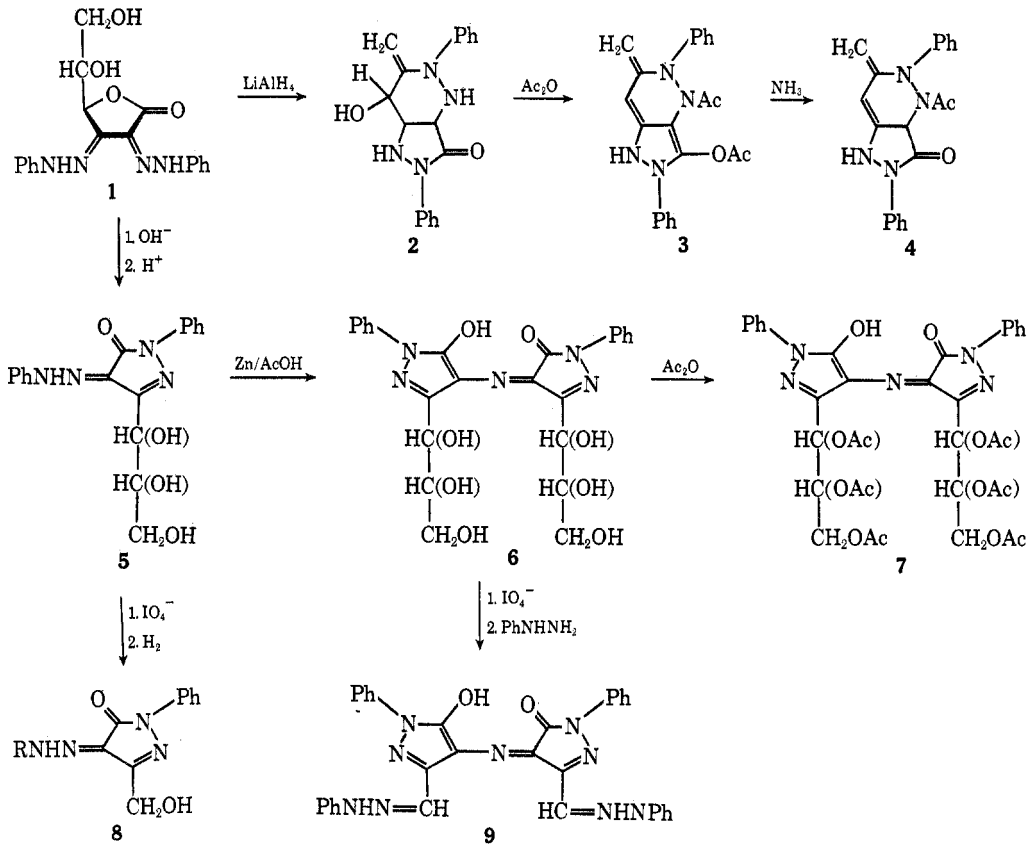


even when they are unwanted, namely, during the preparation of dehydroascorbic acid osazones. Another peculiar reaction takes place during oxidation, and, unlike the sugar osazones, which yield the corresponding osotriazoles, dehydroascorbic acid osazones are oxidized to phenylazo derivatives which can revert back to the starting osazones by mild reduction.[7,8]

The present study deals with the reduction of dehydro-L-ascorbic acid phenylosazone (**1**) and of 1-phenyl-3-trihydroxypropyl-4,5-pyrazoledione-4-phenylhydrazones (**5**) and the elucidation of the structure of the crystalline heterocycles produced.

Reduction of dehydro-L-ascorbic acid phenylosazone with lithium aluminum hydride in dioxane resulted in a reduction of the hydrazone residues instead of the carbonyl group. This was apparent in the ir spectrum of the reduction product, which showed a carbonyl absorption at 1675 cm^{-1} assigned to an amide I band. The replacement of the lactone band of the starting osazone (1720 cm^{-1}) by this amide band suggested that a rearrangement had occurred, possibly with the formation of a pyrazoledione, which absorbs in the same region. Combustion analyses of the reduction product agreed with the formula $C_{18}H_{18}N_4O_2$, denoting that the starting osazone ($C_{18}H_{18}N_4O_4$) might have added two molecules of hydrogen, then lost two water molecules. The mass spectrum of **2** (Figure 1) showed a weak molecular peak at *m/e* 322 followed by another weak M − OH fragment. The base peak at *m/e* 290 resulted from the loss of both the OH and the side chain, possibly *via* the tautomeric α-methylenol, and afforded on further loss of C=O a peak at *m/e* 262. At smaller units appeared fragments corresponding to Ph (*m/e* 77), $PhNH_2$ (*m/e* 93), and PhNC (*m/e* 103), which may be expected from structure **2**. The formation of compound **2** in this reaction is rationalized by assuming that a reduction of the bishydrazone residues to bishydrazines was followed by (a) an attack by the nitrogen of the C-3 hydrazine on the carbonyl group at C-1 to form the pyrazoledione ring, and (b) by another attack from the C-2 hydrazine nitrogen on C-5 to form the pyrazine ring, and (c) finally by dehydration of the C-6 OH to afford compound **2**. Such reactions are by no means uncommon with dehydroascorbic acid bishydrazones. Thus the cyclization of the C-3 hydrazine to a pyrazoledione[5] as mentioned earlier is very easy; similarly, the cyclization of a C-2 hydrazone to a pyrazine and the formation of an olefinic compound by dehydration of the side chain has been previously observed with dehydroascorbic acid mono- and bishydrazones.[6]

Acetylation of compound **2** with boiling acetic anhydride gave a crystalline diacetate **3**, whose combustion analysis indicated that during acetylation a further dehydration had taken place. It seems that under the vigorous conditions used for acetylation the triacetate formed initially eliminated the C-5 OAc group to give diacetate **3**. The infrared spectrum of **3** showed an *O*-acetate band at 1720 cm^{-1} and an *N*-acetyl band at 1680 cm^{-1}. Its nmr spectrum showed the *O*-Ac protons at δ 2.13 and the *N*-acetyl protons at δ 2.62. This was followed at lower field by a signal of two-proton intensity at δ 5.12 due to the methylene group of the side chain. At δ 6.90 appeared a singlet of one-proton intensity assigned to the methyne of the diazine ring; the proton of the phenyl ring appeared at δ 7.55. The mass spectrum of **3** (Figure 1) showed no peaks corresponding to the molecular weight, but

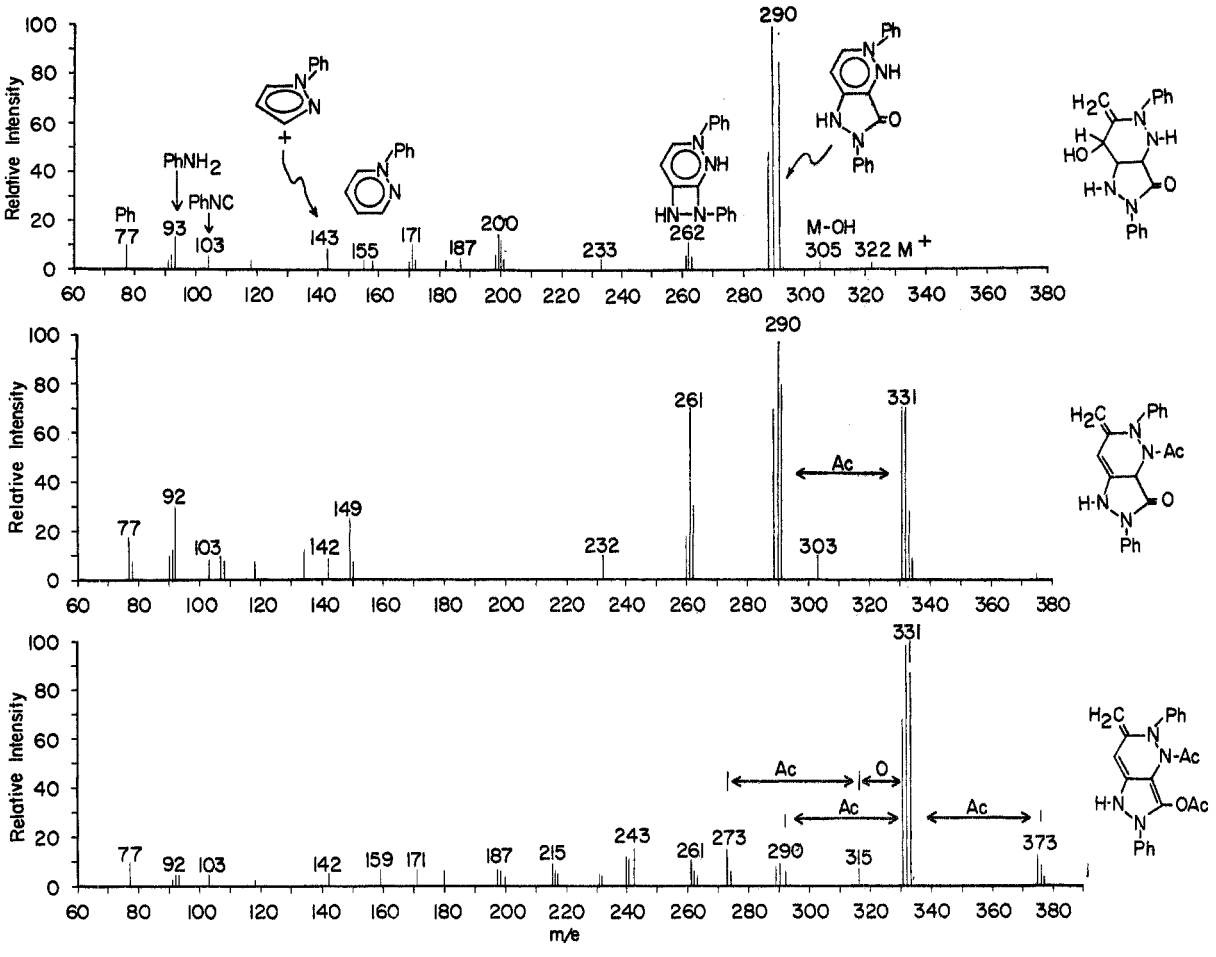
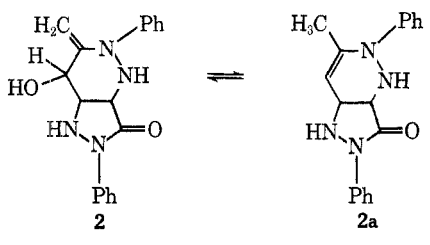


Figure 1.—Mass spectra of compounds **2** (upper), **4** (middle), and **3** (bottom); Ac = 42, McLafferty rearrangement.

showed a small peak at *m/e* 373 probably due to the loss of the side chain. This was followed by the base peak at *m/e* 331, probably formed by the loss of both the side chain and one acetyl group. Alternate loss of acetoxy and/or another acetyl group afforded peaks at *m/e* 290, 315, and 273. The remaining peaks of the spectrum were identical with those of compound **2**. Partial deacetylation of compound **3** with ammonia afforded a mono-*N*-acetyl derivative which now showed an amide band at 1690 cm^{-1} and whose mass spectrum (Figure 1) was quite similar to that of the diacetate **3**, showing major peaks at *m/e* 331, 290, etc. Its nmr spectrum was also similar to that of compound **3** except that it lacked the *O*-acetyl protons. It revealed that the *N*-acetyl protons at δ 2.58, the methylene proton at δ 4.63, and the methyne proton at δ 6.9 and the phenyl protons appeared between δ 7.3 and 7.6 in approximately the same positions as in compound **3**.

In the light of the above, the reduction product of dehydro-L-ascorbic acid osazone was tentatively given structure **2**; its acetylation product was assigned



2 **2a**

structure **3** and its partial deacetylation products structure **4**. It should be noted that compounds **2**, **3**, and **4** may exist in other tautomeric forms, such as that depicted for compound **2**. These forms may be significant enough in the solid state to contribute to the mass spectra, but in solution they constitute less than 10% of the equilibrium as evidenced by the nmr data.

Careful reduction of the L-threo- and D-erythro isomers of 1-phenyl-3-(1,2,3-trihydroxypropyl)-4,5-pyrazoledione-4-phenylhydrazone (**5**) with zinc and acetic acid afforded the substituted L-*threo*- and D-*erythro*-rubiazonic acid **6**. This is a one-step modification of Duffin and Kendall's[9] reduction of the hydroxymethyl derivative, 3-hydroxymethyl-1-phenyl-4,5-pyrazoledione-4-phenylhydrazone, with zinc and hydrochloric acid to the 4-amino compound and oxidation of the latter with ferric chloride to the hydroxy rubiazonic acid. The bis-L-*threo*- and -D-*erythro*-trihydroxypropyl derivatives (**6**) showed the characteristic color reactions[9] of rubiazonic acids, their ir spectra exhibited a characteristic amide band at 1680 cm^{-1}, and their mass spectra (Figure 2) exhibited a hydroxyalkyl fragmentation pattern similar to that of the parent 1-phenyl-3-trihydroxypropyl-4,5-pyrazoledione-4-phenylhydrazone (**5**) and the hydroxymethyl derivative depicted in Figure 3. Upon acetylation they afforded hexaacetates, which now showed ester bands at 1740 cm^{-1} and amide bands at 1680 cm^{-1}. Their mass

(9) G. F. Duffin and J. D. Kendall, *J. Chem. Soc.*, 3969 (1955).

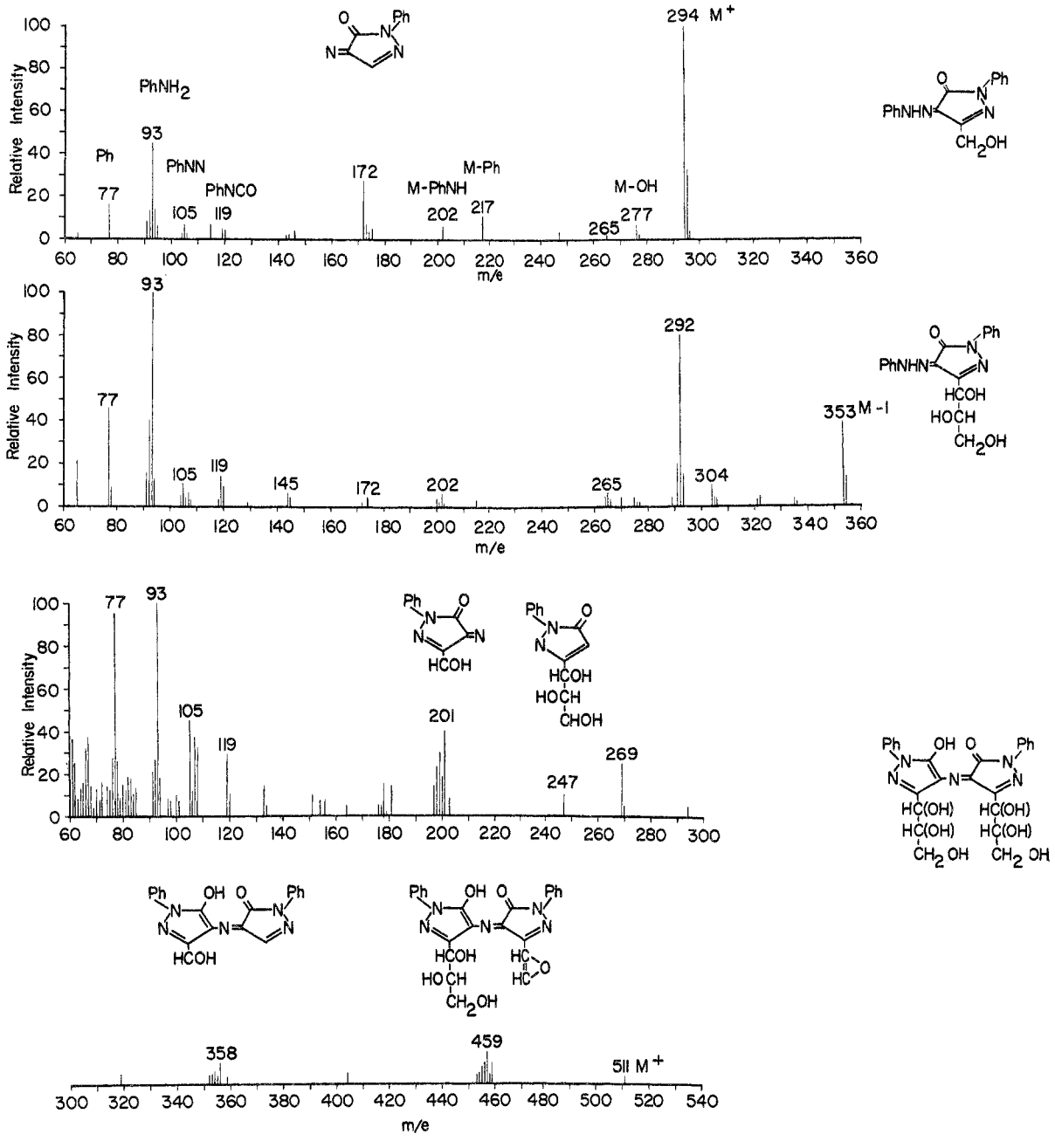


Figure 2.—Mass spectra of 3-hydroxymethyl-1-phenyl-4,5-pyrazoledione-4-phenylhydrazone (upper), 1-phenyl-3-(L-*threo*-trihydoxypropyl)-4,5-pyrazoledione-4-phenylhydrazone (**5**) (middle), and bis(L-*threo*-trihydroxypropyl)rubiazonic acid (**6**) (bottom).

spectra were identical and showed no molecular peaks (*m/e* 763). The heaviest fragment was at *m/e* 732 (M − 2Me), which was followed by a peak at *m/e* 699 corresponding to the loss of CH_2OAc and a series of peaks resulting from the consecutive loss of acetyl (*m/e* 43) and *O*-acetyl (*m/e* 59) groups characteristic of acetoxyalkyl chains. Fragments arising from the disruption of the bond linking the two rings of the dimer appeared at *m/e* 314 and 286. The nmr spectra of the L-threo- and D-erythro acetates **7** were quite similar, differing only slightly in the coupling constants of the side-chain protons. The equivalence of the two side chains of the dimer **7** was apparent in the fact that three distinct *O*-acetyl protons were observed instead of six. Similarly, the methylene protons appeared as two quartets having a geminal coupling of 10 Hz and couplings of 5.2 and 3 Hz for the A and B halves of the ABX system. This was followed by a multiplet at δ 5.80 and a doublet at δ 6.40 (J = 5 Hz) due to the proton α to the heterocyclic ring.

Treatment of dimeric reduction product **6** with phenylhydrazine regenerated the starting pyrazole **5**. This reaction opens the way for the synthesis of substituted 2-phenyl-5-trihydroxypropyl-3,4-pyrazolediones having various 3-aryl or 3-aroyl hydrazones by treatment of the dimer **6** with the desired substituted hydrazines. Furthermore, periodate oxidation of **6** afforded a formyl derivative which was characterized by conversion to the phenylhydrazone (**9**). Finally, periodate oxidation of **5** followed by reduction with sodium borohydride afforded 3-hydroxymethyl-1-phenyl-4,5-pyrazoledione-4-phenylhydrazone (**8**), which was characterized by conversion to the acetate and benzoate.

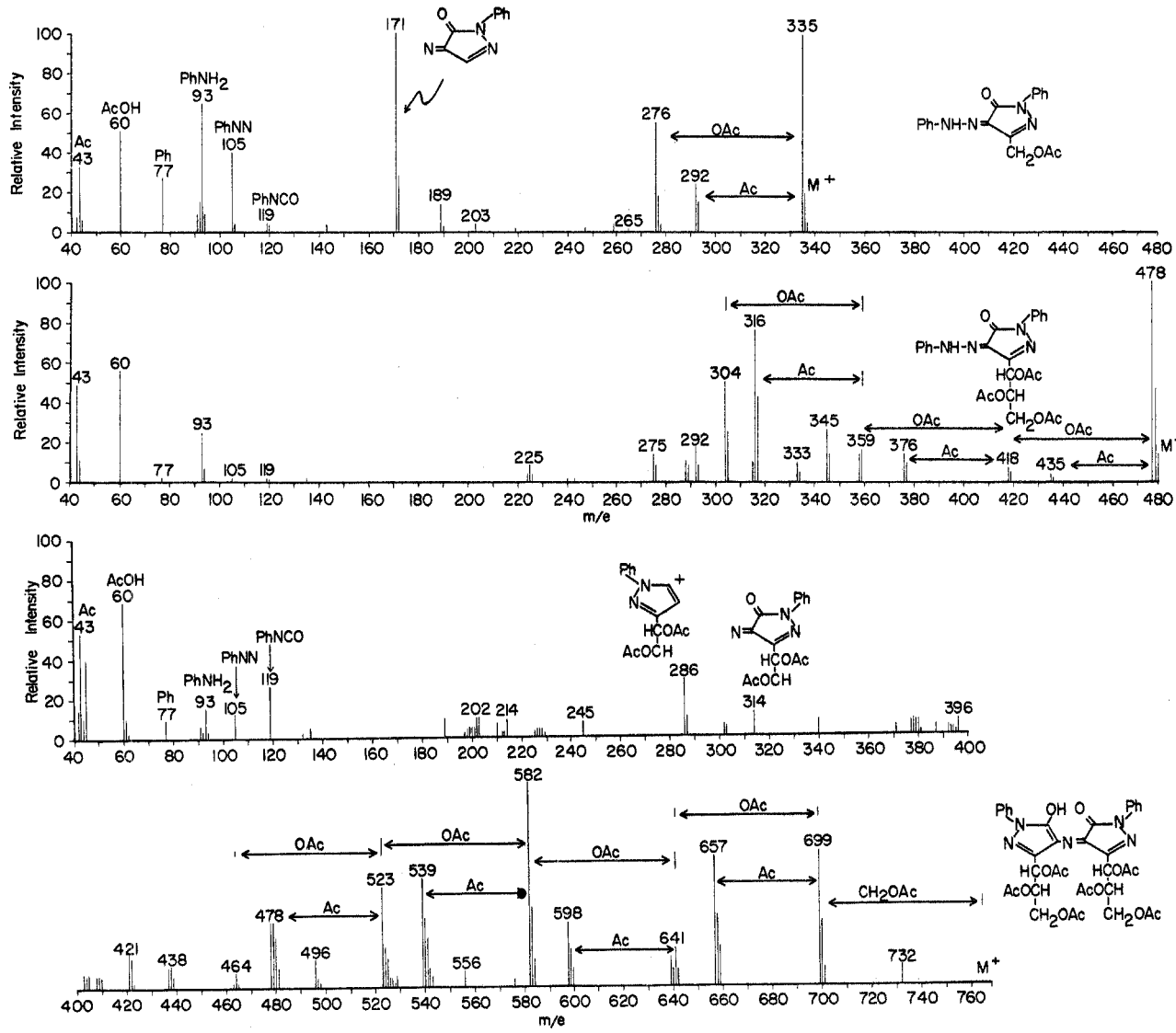


Figure 3.—Mass spectra of 3-acetoxymethyl-1-phenyl-4,5-pyrazoledione-4-phenylhydrazone (upper), 1-phenyl-3-(L-*threo*-triacetoxypropyl)-4,5-pyrazoledione-4-phenylhydrazone (middle), and bis(L-*threo*-triacetoxypropyl)rubiazonic acid (7) (bottom); Ac = 43.

Experimental Section

Melting points were measured on a Kofler block and are uncorrected; ir spectra were recorded for potassium bromide discs with a Unicam Sp 200 spectrophotometer; nmr and mass spectra were recorded and measured by Mr. M. P. Gilles, Department of Chemistry and Chemical Engineering, Michigan Technological University, on Varian HA-100 and M-66 instruments, respectively.

Reduction of Dehydro-L-ascorbic Acid Phenylosazone.—To a well-stirred solution of dehydro-L-ascorbic acid phenylosazone [L-*threo*-2,3-hexodiuolosono-1,4-lactone-2,3-bis(phenylhydrazone)][5] (2 g) in dry dioxane (50 ml), a suspension of lithium aluminum hydride (0.8 g) in dry *p*-dioxane was added dropwise during 0.5 hr and in an atmosphere of nitrogen. The reaction mixture was refluxed for 6 hr, and the excess of lithium aluminum hydride was decomposed by adding ethyl acetate (5 ml) followed by dilute sulfuric acid (10 ml). The solution was deionized with an Amberlite mixture of IR-120 and IRA-400, and the filtrate was evaporated under reduced pressure to dryness. Water was then added (250 ml) and the solid that separated was filtered off, washed with water and ethanol, and dried (yield 1 g). Reduction product **2** crystallized from ethanol as pale yellow needles, mp 223–225°, ν_{max}^{KBr} 1675 (CO) and 3400 cm^{-1} (OH). It is soluble in acetone, sparingly soluble in methanol, and insoluble in water.

Anal. Calcd for $C_{18}H_{18}N_4O_2 \cdot {}^1/_2\ H_2O$: C, 65.24; H, 5.78; N, 16.91. Found: C, 64.98; H, 5.39; N, 16.86.

Diacetate 3.—A solution of product **2** (0.1 g) in acetic anhydride (10 ml) was refluxed for 0.5 hr. The mixture was poured onto crushed ice, and the solid that separated was filtered off, washed with water, and dried (yield 0.09 g). The product crystallized from ethanol as colorless needles: mp 198–200°; ν_{max}^{KBr} 1680 (NAc) and 1720 cm^{-1} (OAc); nmr (100 MHz, chloroform-*d*) δ 2.13 (3 protons, OAc), 2.62 (3 protons, NAc), 5.12 (2 protons, methylene), 6.90 (1 proton, methyne), 7.55 (10 protons, 2 phenyls).

Anal. Calcd for $C_{22}H_{20}N_4O_8$: C, 68.02; H, 5.19; N, 14.42. Found: C, 67.95; H, 5.52; N, 14.47.

Monoacetate 4.—The diacetate (0.05 g) was dissolved in ethanol (10 ml) and the mixture was saturated with ammonia at 0°. After 24 hr the solvent was evaporated under vacuum and the product was crystallized from dilute ethanol: mp 105°; ν^{KBr} 1690 cm^{-1}; nmr (100 MHz, chloroform-*d*) δ 2.58 (3 protons, NAc), 4.63 (2 protons, methylene), 4.63 (1 proton, methyne), 6.90 (10 protons, 2 phenyls).

Anal. Calcd for $C_{20}H_{18}N_4O_2$: C, 69.34; H, 5.24; N, 16.17. Found: C, 69.55; H, 5.36; N, 16.32.

Bis-L-*threo*-1,2,3-trihydroxypropyl Derivative (6).—A solution of 1-phenyl-3-(L-*threo*-1,2,3-trihydroxypropyl)-4,5-pyrazoledione-4-phenylhydrazone[5] (**5**) (5 g) in ethanol (200 ml) was treated with zinc dust (5 g) and the mixture was refluxed gently for 15 min while acetic acid (5 ml) was added dropwise. The reaction mixture was filtered off, and the filtrate was deionized with Amberlite mixture 1:1 IR-120 and IRA-400 (20 g). The solution was evaporated to dryness under diminished pressure, whereby a red, crystalline solid was obtained, which was filtered off, washed with ethanol, and dried (yield 3 g). The bis-L-*threo*-1,2,3-trihydroxypropyl derivative (**6**) crystallized from ethanol as red needles:

mp 219°; ν_{max}^{KBr} 1680 (CO) and 3450 cm^{-1} (OH); λ_{max}^{EtOH} 208, 254, 350, 540 nm (log ϵ 4.02, 4.43, 4.23, 4.00); λ_{min} 224, 308, 410 nm (log ϵ 3.87, 3.41, 3.54). It is soluble in acetone, sparingly soluble in methanol, and insoluble in water.

Anal. Calcd for $C_{24}H_{25}N_5O_8$: C, 56.36; H, 4.92; N, 13.71. Found: C, 56.82; H, 5.03; N, 13.71.

Bis-D-*erythro*-1,2,3-trihydroxypropyl Derivative (6).—When 1-phenyl-3-(D-*erythro*-1,2,3-trihydroxypropyl)-4,5-pyrazoledione-4-phenylhydrazine[3] (**5**) (1 g) was treated in exactly the same manner as for the threo derivative, it yielded 0.4 g of product, mp 205–207°.

Anal. Calcd for $C_{24}H_{25}N_5O_8$: C, 56.36; H, 4.92; N, 13.69. Found: C, 55.97; H, 5.20; N, 13.30.

Bis-L-*threo*-1,2,3-triacetoxypropyl Derivative (7).—A solution of L-*threo*-trihydroxypropyl derivative (**6**) (0.3 g) in pyridine (15 ml) was treated with acetic anhydride (5 ml) and left overnight at room temperature. The mixture was poured on crushed ice, and the product that separated was filtered off, washed with water, and dried (yield 0.3 g). The product crystallized from dilute ethanol in red needles: mp 130–132°; ν_{max}^{KBr} 1680 (CO), 1740 cm^{-1} (OAc); λ_{max}^{EtOH} 210, 255, 352, 541 nm (log ϵ 4.19, 4.35, 4.03, 4.04), λ_{min} 225, 310, 410 nm (log ϵ 3.95, 3.29, 3.45); nmr (100 MHz, chloroform-*d*) δ 2.06, 207, 216 (3 protons each, OAc), 432 (1 proton quadruplet, J_{AB} = 10, J_{AX} = 5.2 Hz), 4.54 (1 proton quadruplet, J_{BX} = 3 Hz), 5.80 (1 proton multiplet), 6.40 (1 proton doublet, J = 5 Hz), 725–791 (5 proton multiplet, phenyl).

Anal. Calcd for $C_{36}H_{37}N_5O_{14}$: C, 57.62; H, 4.88; N, 9.17 Found: C, 57.19; H, 4.89; N, 9.14.

Bis(D-*erythro*-1,2,3-triacetoxypropyl)rubiazonic Acid (7).—When the D-erythro-1,2,3-trihydroxy derivative (**6**) (0.3 g) was acetylated in the same manner as above, it yielded 0.4 g of the acetate, mp 101°.

Anal. Calcd for $C_{36}H_{37}N_5O_{14}$; C, 57.62; H, 4.88; N, 9.17. Found: C, 57.47; H, 5.03; N, 9.31.

Conversion of 6 to the Starting 1-Phenyl-3-(L-*threo*-1,2,3-trihydroxypropyl)-4,5-pyrazoledione-4-phenylhydrazone (5).—A solution of bis-L-*threo*-trihydroxypropyl derivative (**6**) (0.2 g) in ethanol (50 ml) was treated with phenylhydrazine (2 ml) and acetic acid (3 ml) and the solution was refluxed for 0.5 hr and concentrated to a small volume. Hot water was added to the solution to incipient turbidity, and the product was filtered off, washed with water, and dried (yield 0.1 g). 1-Phenyl-3-(L-*threo*-1,2,3-trihydroxypropyl)-4,5-pyrazoledione crystallized from chloroform–ethanol as orange needles, mp 212–215°, not depressed on admixture with an authentic sample; both samples had identical ir spectra.

1-Phenyl-3-(L-*threo*-1,2,3-trihydroxypropyl)-4,5-pyrazoledione-4-benzoylhydrazone.—Bis-L-*threo*-trihydroxypropyl derivative (**6**) (0.2 g) in ethanol (100 ml) was treated with benzoylhydrazine (0.3 g) and acetic acid (5 ml), and the solution was refluxed for 0.5 hr and concentrated to a small volume. Water was added to the solution to incipient turbidity, and the product was filtered off, washed with water, and dried (yield 0.2 g). 1-Phenyl-3-(L-*threo*-1,2,3-trihydroxypropyl)-4,5-pyrazoledione-4-benzoylhydrazone crystallized from ethanol as orange needles: mp 218°; ν_{max}^{KBr} 1660 (CO) and 3450 cm^{-1} (OH); λ_{max}^{EtOH} 243, 325 nm (log ϵ 4.79, 4.07), λ_{min} 290 nm (log ϵ 3.90).

Anal. Calcd for $C_{19}H_{18}N_4O_5$: C, 59.68; H, 4.74; N, 14.62, Found: C, 59.91; H, 4.85; N, 14.64.

1-Phenyl-3-(L-*threo*-1,2,3-triacetoxypropyl)-4,5-pyrazoledione-4-benzoylhydrazone.—A solution of bis-1-phenyl-3-(L-*threo*-1,2,3-trihydroxypropyl)-4,5-pyrazoledione-4-benzoylhydrazone (0.1 g) in dry pyridine (5 ml) was treated with acetic anhydride (5 ml) and left overnight at room temperature. The mixture was poured onto crushed ice, and the product that separated was filtered off, washed with water, and dried (yield 0.1 g). 1-Phenyl-3-(L-*threo*-1,2,3-triacetoxypropyl)-4,5-pyrazoledione-4-benzoylhydrazone crystallized from ethanol as yellow needles: mp 150°; ν_{max}^{KBr} 1660 (CO) and 1710 cm^{-1} (OAc); λ_{max}^{EtOH} 238, 320 nm (log ϵ 4.52, 3.76), λ_{min} 295 nm (log ϵ 3.74).

Anal. Calcd for $C_{25}H_{24}N_4O_8$: C, 59.05; H, 4.75; N, 11.02. Found: C, 58.92; H, 4.64; N, 11.38.

1-Phenyl-3-(D-*erythro*-1,2,3-trihydroxypropyl)-4,5-pyrazoledione-4-benzoylhydrazone.—Bis-D-*erythro*-1,2,3-trihydroxypropyl derivative (0.5 g in 100 ml of ethanol) was treated with benzoylhydrazine (0.3 g) and acetic acid (5 ml), and the solution was refluxed for 0.5 hr and concentrated to a small volume. Hot water was added to the solution to incipient turbidity, and the product that separated was filtered off, washed with water, and dried (yield 0.5 g). 1-Phenyl-3-(D-*erythro*-1,2,3-trihydroxypropyl)-4,5-pyrazoledione-4-benzoylhydrazone crystallized from ethanol as orange needles: mp 205–207°; ν_{max}^{KBr} 1660 (CO) and 3450 cm^{-1} (OH); λ_{max}^{EtOH} 239, 318 nm (log ϵ 4.45, 3.83), λ_{min} 295 nm (log ϵ 3.79).

Anal. Calcd for $C_{19}H_{18}N_4O_5$: C, 59.68; H, 4.79; N, 14.63. Found: C, 59.34; H, 4.70; N, 14.81.

1-Phenyl-3-(D-*erythro*-1,2,3-triacetoxypropyl)-4,5-pyrazoledione-4-benzoylhydrazone.—A solution of 1-phenyl-3-(D-*erythro*-1,2,3-trihydroxypropyl)-4,5-pyrazoledione-4-benzoylhydrazone (0.1 g) in dry pyridine (10 ml) was treated with acetic anhydride (5 ml) and left overnight at room temperature. The mixture was poured onto crushed ice, and the product was filtered off, washed with water, and dried (yield 0.1 g). 1-Phenyl-3-(D-*erythro*-1,2,3-triacetoxypropyl)-4,5-pyrazoledione-4-benzoylhydrazone crystallized from ethanol as yellow needles: mp 138°; ν_{max}^{KBr} 1660 (CO) and 1740 cm^{-1} (OAc); λ_{max}^{EtOH} 235, 320 nm (log ϵ 4.34, 4.00); λ_{min} 295 nm (log ϵ 3.91).

Anal. Calcd for $C_{25}H_{24}N_4O_8$: C, 59.05; H, 4.76; N, 11.01. Found. C, 58.82; H, 4.68; N, 11.21.

Bis(formyl)rubiazonic Acid Phenylhydrazone (9).—Bis-L-*threo*-1,2,3-trihydroxypropyl derivative (**6**) (0.1 g) in water (20 ml) was shaken with excess sodium metaperiodate (0.5 g) for 24 hr, and the amorphous formyl derivative was filtered, washed with water, and treated with phenylhydrazine (0.1 g) in ethanol (10 ml) at room temperature. The hydrazone **9** separated and was crystallized from dilute ethanol as dark red needles, mp 178°.

Anal. Calcd for $C_{32}H_{25}N_9O_2$: C, 67.41; H, 4.44; N, 22.21. Found: C, 68.08; H, 4.80; N, 21.81.

3-Hydroxymethyl-1-phenylpyrazoline-4,5-dione-4-phenylhydrazone.—A solution of 1-phenyl-3-formylpyrazoline-4,5-dione-4-phenylhydrazone[5] (0.5 g) in ethyl alcohol (30 ml) was treated with a solution of sodium borohydride (0.5 g) in water (10 ml) in small portions and with continual shaking, and the solution was left overnight at room temperature. The solution was acidified with dilute acetic acid, and the solid that separated was filtered off, washed with water, and dried (yield 0.5 g). 3-Hydroxymethyl-1-phenylpyrazoline-4,5-dione-4-phenylhydrazone (**8**) crystallized from ethyl alcohol as orange-yellow needles: mp 155°; ν_{max}^{KBr} 1660 (CO) and 3450 cm^{-1} (OH); λ_{max}^{EtOH} 210, 240, 400 nm (log ϵ 4.01, 4.53, 4.65); λ_{min} 218, 300 nm (log ϵ 3.92, 3.87).

Anal. Calcd for $C_{16}H_{14}N_4O_2$: C, 65.30; H, 4.79; N, 19.03. Found: C, 65.28; H, 4.85; N, 19.11.

3-Acetoxymethyl-1-phenyl-4,5-pyrazoledione-4-phenylhydrazone.—A solution of 3-hydroxymethyl-1-phenyl-4,5-pyrazoledione-4-phenylhydrazone (0.1 g) in dry pyridine (5 ml) was treated with acetic anhydride (5 ml) and left overnight at room temperature. The mixture was poured onto crushed ice and the product that separated, on cooling, was filtered off, washed with water, and dried (yield 0.1 g). 3-Acetoxymethyl-1-phenyl-4,5-pyrazoledione-4-phenylhydrazone crystallized from ethanol as yellow-orange needles: mp 131°; ν_{max}^{KBr} 1660 (CO) and 1740 cm^{-1} (Ac); λ_{max}^{EtOH} 209, 240, 400 nm (log ϵ 4.11, 4.44, 4.34); λ_{min} 215, 300 nm (log ϵ 4.11, 3.08).

Anal. Calcd for $C_{18}H_{16}N_4O_3$: C, 64.28; H, 4.79; N, 16.66. Found: C, 64.10; H, 4.85; N, 16.95.

3-Benzoyloxymethyl-1-phenyl-4,5-pyrazoledione-4-phenylhydrazone.—A solution of 3-hydroxymethyl-1-phenyl-4,5-pyrazoledione-4-phenylhydrazone (0.1 g) in dry pyridine (10 ml) was treated with benzoyl chloride (0.5 ml) and the mixture was left overnight at room temperature. The mixture was poured onto crushed ice, and the product that separated was filtered off, washed with water, and dried (yield 0.1 g). 3-Benzoyloxymethyl-1-phenyl-4,5-pyrazoledione-4-phenylhydrazone crystallized from ethanol as yellow needles: mp. 151°; ν_{max}^{KBr} 1660 (CO) and 1750 cm^{-1} (OBz); λ_{max}^{EtOH} 208, 240, 400 nm (log ϵ 4.20, 4.44, 4.36); λ_{min} 215, 300 nm (log ϵ 4.11, 3.07).

Anal. Calcd for $C_{23}H_{18}N_4O_3$: C, 69.33; H, 4.55; N, 14.06. Found: C, 69.49; H, 4.69; N, 14.34.

Registry No.—**1**, 3909-11-3; **2**, 35426-80-3; **3**, 35426-81-4; **4**, 35426-82-5; L-**5**, 25314-31-2; D-**5**, 30694-70-3; L-**6**, 35454-88-7; D-**6**, 35426-84-7; L-**7**, 35426-85-8; D-**7**, 35426-86-9; **8**, 35426-87-0; **9**, 35426-88-1; 1-phenyl-3-(L-*threo*-1,2,3-trihydroxypropyl)-4,5-pyrazole-

dione-4-benzoylhydrazone, 35426-89-2; 1-phenyl-3-(L-*threo*-1,2,3-triacetoxypropyl)-4,5-pyrazoledione-4-benzoylhydrazone, 35426-90-5; 1-phenyl-3-(D-*erythro*-1,2,3-triacetoxypropyl)-4,5-pyrazoledione-4-benzoylhydrazone, 35426-91-6; 1-phenyl-3-(D-*erythro*-1,2,3-triacetoxypropyl)-4,5-pyrazoledione-4-benzoylhydrazone, 35426-92-7; 3-acetoxymethyl-1-phenyl-4,5-pyrazoledione-4-phenylhydrazone, 35426-93-8; 3-benzoyloxymethyl-1-phenyl-4,5-pyrazoledione-4-phenylhydrazone, 35426-94-9.

Elucidation of the Mechanism of Reductive Dehalogenation of *o*-Haloanisole under Aryne-Forming Conditions

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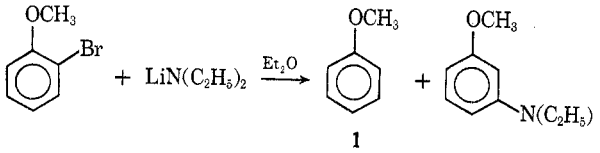
A method for distinguishing between the two proposed reductive dehalogenation mechanisms of haloanisoles is described. At large ratios of di-*n*-propylamine to lithium di-*n*-propylamide, 3-methoxybenzyne is essentially trapped by di-*n*-propylamine, affording the typical aryne addition product, **2**. At this point, reduction occurs solely *via* Mechanism B, direct halogen displacement, the extent of which varies as the haloaromatic is varied along the series I (76%) > F (9%) ~ Br (10%) > Cl (5%). Using low amine:amide values, Mechanism A, reduction of 3-methoxybenzyne by hydride, as well as Mechanism B are operable. In contrast to Wittig's results obtained in the *p*-halotoluene system, no products resulting from Schiff base addition to either aryne or aryl anions were observed.

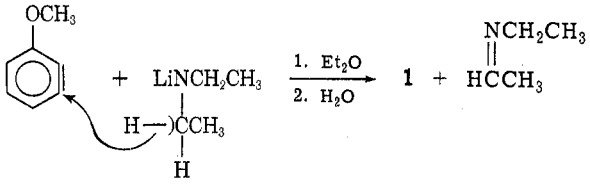
The reaction of haloaromatic compounds with lithium dialkylamides in ether generally yields typical benzyne addition products, *i.e.*, *N*,*N*-dialkylamino aromatics. However, there are many cases in which certain haloaromatic compounds are also reductively dehalogenated under these conditions.[2] For example, *o*-bromoanisole reacts in the presence of lithium diethylamide to afford *N*,*N*-diethyl-*m*-anisidine (33%) and anisole (10%).[3]



1

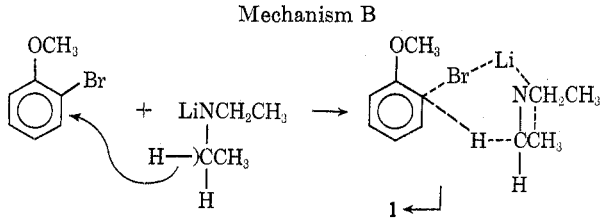
Two mechanisms have been proposed for the formation of anisole (**1**). Mechanism A, shown below, in-

Mechanism A



volves a hydride transfer from the α carbon of lithium diethylamide to the meta position of 3-methoxybenzyne.[4] Alternatively, Mechanism B postulates a direct displacement of halogen by a similar hydride transfer.[5]

Mechanism B



Both mechanisms may be operative in the reductive dehalogenation of *p*-fluoro- and *p*-iodotoluenes.[6] Product analysis indicated that *p*-fluorotoluene was reduced *via* Mechanism A. Conversely, Mechanism B was more likely involved in the formation of toluene from *p*-iodotoluene.

Obviously, deuterium-labeling experiments would provide an unambiguous method for differentiating between these mechanisms. That this study has not been reported is presumedly due to the synthetic and/or analytical difficulties involved in such an investigation.

We report another method for distinguishing between the two mechanisms. 3-Methoxybenzyne is an extremely reactive aryne.[7] Moreover, the reaction of *o*-bromoanisole in various dialkylamine solvents in the presence of undissolved sodamide yielded only the expected aryne addition products, *i.e.*, no anisole formation.[8] Consequently, dialkylamines are not capable of reducing either *o*-bromoanisole or 3-methoxybenzyne. These two facts should allow one to assess the relative amounts of reduction occurring *via* Mechanisms A and B in this system.

Scheme I illustrates the possible paths open to *o*-haloanisoles upon treatment with $LiNR_2$ in the presence of the corresponding secondary amine, R_2NH.

Accordingly, an increase in anisidine production with a concomitant decrease in reduction *via* Mechanism A should be observed as the amount of dialkylamine is increased relative to lithium dialkylamide. Moreover, a limiting value of the anisidine/anisole ratio may be reached even though the amine/amide ratio be further increased. At this point, 3-methoxybenzyne would be converted solely to *m*-anisidine derivatives,

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