Conversion to the dibenzamide gave crystals, mp 286° (from methylene chloride). *Anal.* Calcd for $C_{21}H_{10}N_2O_2$: C, 75.88; H, 6.07; N, 8.43. Found: C, 76.15; H, 6.38; N, 8.15.

Conversion to the diacetamide with acetic anhydride and triethylamine in ether afforded white precipitate: mp 220–225°; nmr in accord with 70% *trans*–30% *cis* mixture. *Anal.* Calcd for $C_{11}H_{16}N_2O_2$: C, 63.44; H, 7.74; N, 13.45. Found: C, 63.47; H, 7.88; N, 13.34. Recrystallization from methanol afforded white crystals: mp 278–281°, the *cis-exo* isomer; nmr (2:1 D_2O–CD_3OD) δ 3.7 (m, 2, *endo*-CHN), 2.2 (m, 1, C_4–H), 2.0 (s, 6, CH_3), and 1.5 ppm (m, 5). Recrystallization of the second crop from methanol gave the *trans* isomer: mp 226–227°; nmr (D_2O) δ 4.0 (m, 1, *exo*-CHN), 3.7 (m, 1, *endo*-CHN), 2.1 (m, 1, C_4–H), 2.02 (s, 3, CH_3), 2.01 (s, 3, CH_3), and 1.5 ppm (m, 5).

Registry No.—Dinitrogen trioxide, 10544-73-7; IV, 24695-03-2; IVa, 24695-04-3; V, 24695-05-4; Va, 24695-06-5; VI, 24695-07-6; VII, 24711-06-6; VIII, 24711-07-7; IX, 4442-85-7; IX hydrochloride, 5471-55-6; X, 24711-10-2; XI, 24711-11-3; XII dihydrochloride, 24704-32-3; XIV, 24711-12-4; XV hydrochloride, 24711-13-5; XVI, 10573-58-7; XVIII, 24704-33-4; XVIII hydrochloride, 24704-34-5; XVIII dibenzamide, 24711-15-7; XVIII diacetamide, 24711-16-8; XXII, 24695-08-7; XXII dihydrochloride, 24694-51-7; XXII dibenzamide, 24695-10-1; XXII diacetamide, 24694-52-8; XXIII, 24694-09-8; XXIII dihydrochloride, 24694-53-9; XXIII dibenzamide, 24694-54-0; XXIII diacetamide, 24694-55-1.

Acknowledgment.—The author is indebted to Mr. J. J. Porcelli for experimental assistance.

1,2-Hydroxylamino Oximes and Pyrazine N,N-Dioxides

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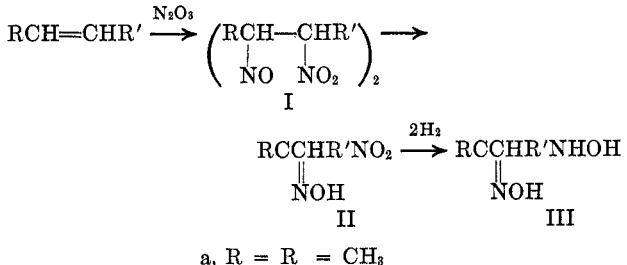
Received September 15, 1969

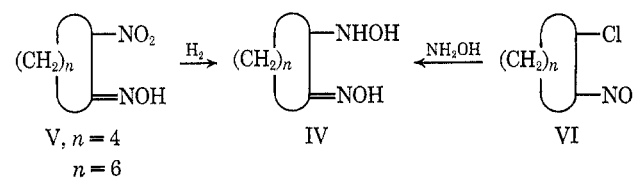
1,2-Nitroximes obtained from the isomerization of olefin–dinitrogen trioxide adducts are selectively reduced with palladized carbon to afford 1,2-hydroxylamino oximes. The latter class of compounds can be reduced to vicinal diamines, oxidized to 1,2-dioximes, form stable chelates with mercuric salts, and undergo a novel acid-catalyzed autocondensation to pyrazine N,N-dioxides.

The reaction of dinitrogen trioxide with olefins affords 1,2-nitronitroso dimers, commonly referred to as pseudonitrosites I.[2] These adducts can be converted to the more soluble isomers, the corresponding 1,2-nitroximes II.[2,3] The latter undergo a general, selective hydrogenation to 1,2-hydroxylamino oximes III in the presence of a palladized carbon catalyst. The derivatives are readily isolated as the acetic acid salts which can be smoothly converted back to free hydroxylamino oximes. Thus, the nitroxime derived from N_2O_3 addition to *cis*- or *trans*-butene-2 is converted to IIIa, and α-nitroacetophenone oxime (IIIb) derived from styrene is converted to IIIb in over 90% yield.



a, R = R′ = CH_3
b, R = C_6H_5; R′ = H
c, R = *c*-C_6H_{11}; R′ = H

Two equivalents of hydrogen are consumed to reduce the nitro group, and olefinic double bonds present in the nitroxime also undergo reduction. Thus, the same hydroxylamino oxime IVb (n = 6) is obtained from either the saturated nitroxime Vb, derived from cyclooctene, or the unsaturated derivative, 1,5-cyclooctadiene nitroxime, with the consumption of 2 or 3 mol of hydrogen, respectively. Similarly, IIIc can be obtained from either IIc or from the unsaturated nitroxime derived from 4-vinylcyclohexene-1.[3] The cyclohexene derivative IVa (n = 4) is identical with that prepared from the reaction of hydroxylamine with the nitrosyl chloride adduct of cyclohexene VIa (n = 4).[4] Owing to the mechanistic differences in orientation between nitrosyl chloride and dinitrogen trioxide additions to olefins, different hydroxylamino oximes would be expected, starting with unsymmetrical olefins from the two synthetic approaches.



The 1,2-hydroxylamino oxime derivatives possess a pair of vicinal carbon–nitrogen bonds which can be reduced to diamines. Either lithium aluminum hydride or Raney nickel catalyzed hydrogenation converts IVb to the corresponding *vic*-diamine, namely 1,2-diaminocyclooctane. The hydroxylamino group is susceptible to oxidation, and in the case of the styrene derivative IIIb, treatment with ferric chloride affords the 1,2-dioxime of phenylglyoxal. Similarly, the butene-2 derivative VIIa is converted to dimethylglyoxime, but in other cases oxidation by ferric chloride pro-

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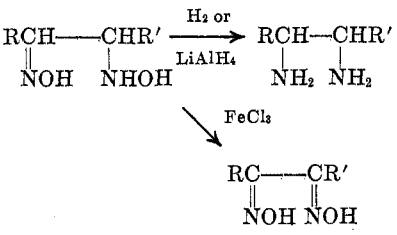
(2) (a) H. Wieland, *Justus Liebigs Ann. Chem.*, **424**, 71 (1920); *Ber.*, **36**, 2558 (1903). (b) D. Klamann, W. Koser, P. Weyerstahl, and M. Fligge, *Chem. Ber.*, **98**, 1831 (1965). (c) M. L. Scheinbaum, *Amer. Chem. Soc. Div. Petrol. Chem., Prepr.*, **13**, 193 (1968).

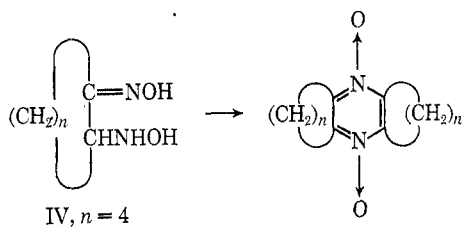
(3) M. L. Scheinbaum, *J. Org. Chem.*, **35**, 2785 (1970).

(4) L. B. Volodarskii and Yu. G. Putsykin, *J. Org. Chem. USSR*, **3**, 1642 (1967).

ceeds further, sometimes regenerating the nitroxime. Reaction of IIIb with mercuric chloride affords a stable 2:1 chelate.



Acid-catalyzed condensation with carbonyl compounds has been reported to result in the formation of imidazole oxide derivatives.[5] A related acid-catalyzed autocondensation occurs when hydroxylamino oximes are treated with concentrated sulfuric acid. The reaction may involve elimination of hydroxylamine along with accompanying oxidation. The major product is the pyrazine N,N-dioxide derivative. Thus, the cyclohexene derivative IVa affords octahydrophenazine N,N-dioxide (VIIa, $n = 4$) in 30% yield. The nmr of VIIa contains multiplets of equal area at δ 2.9 (CH_2C=) and 1.9 ppm (CH_2CH_2C=). Reaction of the N,N-dioxide with selenium affords phenazine in poor yield. In like manner, IVb is converted to the corresponding pyrazine N,N-dioxide (VIIb, $n = 6$) in 50% yield on treatment with sulfuric acid. The nmr spectrum of VIIb has three equal area multiplets at δ 2.9 (CH_2C=), 1.9 (CH_2CH_2C=), and 1.5 ppm ($CH_2CH_2CH_2C$=).



IV, $n = 4$
$n = 6$

VII

a, $n = 4$
b, $n = 6$

Experimental Section

Infrared spectra were taken on a Beckman IR-5, nmr spectra with a Varian A-60, using TMS as internal reference. Melting points are uncorrected. Elemental analyses were carried out by Galbraith Laboratories.

Dinitrogen Trioxide Adducts.—Adducts of olefins and N_2O_3 were obtained by treating ethereal solutions of olefin at −20 to 0° with a 2:1 stream of nitric oxide–air until unabsorbed, brown nitrogen dioxide gas was observed at the surface of the reaction mixture. Pseudonitrosites of the following olefins were obtained: butene-2 (29%),[2b] vinylcyclohexane (8%),[2c] 4-vinylcyclohexene-1 (11%),[2c] styrene (60%),[1c] cyclohexene (47%),[2b] cyclooctene (27%),[2b] and 1,5-cyclooctadiene (83%).[2b]

Preparation of Nitroximes.—A mixture of 0.25 mol of olefin–dinitrogen trioxide adduct, 5.0 g anhydrous zinc chloride, and 1 l. of absolute ethanol or methanol was refluxed under nitrogen. The adduct dissolved to form a blue solution which changed to green and finally yellow as the nitroso monomer was converted to nitroxime. Completion of the isomerization required about an hour and was indicated by disappearance of the green color. The mixture was cooled, treated with 2 l. of saturated aqueous ammonium chloride solution and extracted several times with methylene chloride. The extracts were washed with saturated sodium chloride solution, dried (sodium sulfate), and evaporated to give high yields of nitroximes.

(5) L. B. Volodarskii and G. A. Kutikova, *Tetrahedron Lett.*, No. 9, 1065 (1968).

3-Nitrobutan-2-one oxime (IIa), an oil, identical in properties with that described by Klamann, *et al.*,[2b] nmr (in CCl_4) δ 5.2 (q, 1, $CHNO_2$), 1.9 (5,3, CH_3), and 1.8 ppm (d, 3, CH_3), was obtained (over 90%) from the pseudonitrosite of *cis*- or *trans*-butene-2. α-Nitroacetophenone oxime[1a] (IIb), mp 91° (from ether–hexane), nmr ($CDCl_3$) δ 7.5 (m, 5, C_6H_5) and 5.7 ppm (s, 2, CH_2), was obtained in over 90% yield from styrene pseudonitrosite. 2-Nitrocyclohexanone oxime (IVa), oil, was obtained from cyclohexene pseudonitrosite. Conversion to the 2,4-dinitrophenylhydrazone of 2-nitrocyclohexanone, mp 154°, occurred in over 90% yield. Calcd for $C_{12}H_{13}N_5O_6$: C, 44.71; H, 4.07; N, 21.71. Found: C, 44.60; H, 4.28; N, 21.01. The nitroximes obtained exhibited the following ir bands ($CHCl_3$): 3550 (OH), ~1790 (C=N), and 1550 cm^{-1} (NO_2).

Preparation of Hydroxylamino Oximes.—A solution of 0.05 mol of nitroxime in 250 ml of absolute ethanol along with 0.5 g of 5% palladium on carbon catalyst was hydrogenated in a Parr apparatus at ambient temperature until 0.1 mol of hydrogen was consumed. The catalyst was filtered and the solvent was evaporated to afford crude hydroxylamino oximes which could either be crystallized directly by trituration with methylene chloride or treated with acetic acid and ether to give the crystalline acetic acid salts, which could be readily regenerated to the free hydroxylamino oximes. The following derivatives were obtained.

3-Hydroxylaminobutan-2-one oxime (IIIa) was obtained from IIa in 90% yield: mp 78° (from methylene chloride–ether); ir ($CHCl_3$) 3600 (OH) and 3300 cm^{-1} (NH); nmr (CD_3OD) δ 3.3 (q, 1, CHN), 1.6 (s, 3, CH_3), and 0.9 ppm (d, $J = 7$ Hz, 3, CH_3). *Anal.* Calcd for $C_4H_{10}N_2O_2$: C, 40.66; H, 8.53; N, 23.71; mol wt 118. Found: C, 40.50; H, 8.54; N, 23.95 mol wt 119.

α-Hydroxylaminoacetophenone oxime (IIIb) was obtained from IIb in 90% yield: mp 128° (from 95% alcohol); nmr (CD_3OD) δ 7.5 (m, j, C_6H_5) and 4.1 ppm (s, 2, CH_2). *Anal.* Calcd for $C_8H_{10}N_2O_2$: C, 57.82; H, 6.07; N, 16.86. Found: C, 57.98; H, 6.11; N, 16.82.

2-Hydroxylaminocyclohexanone oxime (IVa) from Va in 90% yield, mp 100° (from 95% ethanol), was identical in properties with a sample prepared by the method of Volodarskii and Putsykin.[4] *Anal.* Calcd for $C_6H_{12}N_2O_2$: C, 49.98; H, 9.39; N, 19.43; mol wt 144. Found: C, 49.85; H, 8.25; N, 19.32; mol wt, 147. The preparations of IVb and IIIc have previously been described.[2]

Ferric Chloride Oxidation.—A solution of 0.01 mol (1.66 g) of α-hydroxylaminoacetophenone oxime (IIIb) and 0.01 mol (2.71 g) of $FeCl_3 \cdot 6H_2O$ in 100 ml of ethanol was filtered and evaporated to give a dark oil which was dissolved in 1:1 methylene chloride–ether, washed with saturated aqueous ammonium chloride solution, dried (Na_2SO_4), and evaporated to give 0.4 g (25% yield) of the dioxime of phenylglyoxal: mp 147° (from ether–hexane); nmr (CD_3CN) δ 8.2 (s, 1, CH=N) and 7.2 ppm (m, 5, C_6H_5). *Anal.* Calcd for $C_8H_8N_2O_2$: C, 58.53; H, 4.91; N, 17.07; mol wt, 164. Found: C, 58.48; H, 4.65; N, 16.73; mol wt, 170.

In the same manner 3-hydroxylaminobutan-2-one oxime (IIIa) was converted to dimethylglyoxime in 42% yield: mp 243° (from hexane); nmr (d_6-acetone) δ 1.4 ppm (s, CH_3). *Anal.* Calcd for $C_4H_8N_2O_2$: C, 41.37; H, 6.94; N, 24.13. Found: C, 41.83; H, 7.14; N, 23.75.

Preparation of the $HgCl_2$ Complex of VIIb ($(C_8H_{10}N_2O_2)_2 \cdot HgCl_2$.—A mixture of 1.66 g (0.01 mol) of α-hydroxylaminoacetophenone oxime (IIIb), 2.72 g (0.01 mol) of mercuric chloride, and 100 ml of absolute ethanol was stirred under nitrogen at ambient temperature for 12 hr and evaporated to give a purple-tinged solid which on extraction and crystallization from ether–pentane afforded 0.7 g (23%) of white crystals: mp 192°; nmr (CD_3CN–D_2O) δ 7.6–7.1 (m, 5, C_6H_5) and 4.6 ppm (s, 2, CH_2). *Anal.* Calcd for $C_{16}H_{20}N_4O_4HgCl_2$: C, 31.82; H, 3.33; N, 9.28; Cl, 11.74; Hg, 33.22. Found: C, 31.68; H, 3.26; N, 9.18; Cl, 11.28; Hg, 29.

Preparation of Pyrazine N,N-Dioxides.—A finely powdered sample of 15 g (0.075 mol) of the acetic acid salt of 2-hydroxylaminocyclohexanone oxime (IVa) was introduced in small portions at a time to 10 ml of concentrated sulfuric acid (sp gr 1.84) at 0° with mechanical stirring. The slurry was gradually warmed to ambient temperature and allowed to stir for 24 hr. The crude reaction mixture was poured into ice, made basic with 2 *N* NaOH solution to pH 8–9, and extracted several times with ethyl acetate at 0°. The extracts were washed with

saturated NaCl solution, dried (Na_2SO_4), and evaporated to give 4.9 g of yellow oil which on trituration with ether gave pale yellow crystals of octahydrophenazine N,N-dioxide (VIIa) (30% yield). Recrystallization from methylene chloride–pentane afforded white crystals: mp 230°; ir ($CHCl_3$), 3000, 1720 (w), 1580 (w), 1470, 1360, 1340, and 1100 cm^{-1} (s); nmr ($CDCl_3$) δ 2.9 (m, 8, $CH_2C{=}$) and 1.9 ppm (m, 8, CH_2). *Anal.* Calcd for $C_{12}H_{16}N_2O_2$: C, 65.43; H, 7.32; N, 12.72; mol wt, 220. Found: C, 64.76; H, 7.13; N, 12.70; mol wt, 250.

In like manner, VIIb was prepared in 50% yield from 2-hydroxylaminocyclooctane oxime (IVb).[2] White crystals, mp 248° (from methylene chloride–pentane), were obtained: ir ($CHCl_3$) 3000, 1730 (w), 1610 (w), 1460, 1340 (s), 1290, and 1100 cm^{-1} (s); nmr ($CDCl_3$) δ 3.2 (m, 8, $CH_2C{=}C$), 1.9 (m, 8, CH_2), and 1.5 ppm (m, 8, CH_2). *Anal.* Calcd for $C_{16}H_{24}N_2O_2$: C, 69.53; H, 8.75; N, 10.14; mol wt, 276. Found: C, 69.67; H, 8.83; N, 10.04; mol wt, 295.

Treatment of VIIa (0.5 g) with 0.5 g of selenium at 350° under nitrogen for several hours gave a condensate which on extraction with methylene chloride and evaporation provided 50 mg of orange oil. Vacuum distillation of this residue in a Kugelrohr tube afforded 5 mg of sublimate which was identical in mixture melting point and vpc properties with phenazine.

Registry No.—IIa, 2567-33-1; IIb, 21205-24-3; IIIa, 24707-22-0; IIIb, 24707-24-2; IVa, 13757-09-0; VIIa, 24716-05-0; VIIb, 24716-06-1; 2-nitrocyclohexanone (2,4-dinitrophenylhydrazone), 10269-95-1; phenylglyoxal (dioxime), 4589-97-3; dimethylglyoxime, 95-45-4.

Acknowledgment.—The author is indebted to Mr. J. J. Porcelli for experimental assistance.

Aromatic N-Oxides. VI. Anhydro Base Intermediate and the Rate-Controlling Step in the Reaction of 4-Alkylpyridine N-Oxide with Acid Anhydrides[1]

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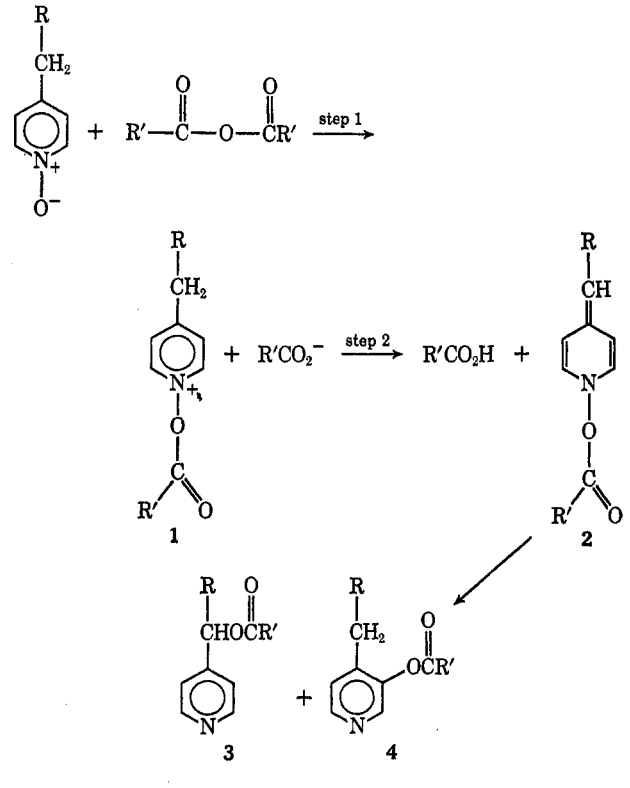
Received December 10, 1969

Evidence for the first step of the reaction of 4-alkylpyridine N-oxides with acid anhydrides was obtained by isolation of 1-acetoxy-4-methylpyridinium and 1-acetoxy-4-benzylpyridinium perchlorates and their conversion by triethylamine in acetonitrile to the corresponding rearranged esters. The reaction of 1-acetoxy-4-benzylpyridinium perchlorate (1) and triethylamine was also examined spectroscopically and provided uv evidence for the intermediate anhydro base, 1-acetoxy-4-benzal-1,4-dihydropyridine (2), whose absorption spectrum resembled 1-methyl-4-benzal-1,4-dihydropyridine. The absence of deuterium exchange in the reaction of 1-acetoxy-4-(α,α-dideuteriobenzyl)pyridinium perchlorate with sodium acetate in acetic acid–acetonitrile and the dependence of the conversion of **1** to **2** on base strength support the assignment of this step as rate controlling.

The generally accepted mechanism for the reaction of 4-alkylpyridine N-oxides and acid anhydrides has been reviewed in several places.[1,3] In this report we offer evidence in support of the formation of the 1-acyloxy-4-alkylpyridinium cation (**1**) in step 1, of the anhydro-base intermediate (**2**), and of the rate-controlling step 2.

The isolation of cation **1** was accomplished as the perchlorate salt from the reaction of 4-methyl- and 4-benzylpyridine N-oxides and acetic anhydride in the presence of perchloric acid. Structural assignments for these salts were based on elemental analysis, a characteristic carbonyl frequency (1825–1830 cm^{-1}),[4,5] and the reaction of these salts with triethylamine in acetonitrile to produce the esters: 4-pyridylmethyl acetate (**3**, R = H, R′ = CH_3) and 3-acetoxy-4-methylpyridine (**4**, R = H, R′ = CH_3) (both esters identified spectroscopically) from 1-acetoxy-4-methylpyridinium (**1**, R = H, R′ = CH_3) perchlorate, and phenyl-4-pyridylmethyl acetate (**3**, R = C_6H_5, R′ = CH_3) from 1-acetoxy-4-benzylpyridinium (**1**, R = C_6H_5, R′ = CH_3) perchlorate. Identification of phenyl-4-pyridylmethyl acetate was achieved by comparison with an authentic sample, saponification of the ester to the known phenyl-4-pyridylmethanol,[6] and isolation of the



ester from the reaction of 4-benzylpyridine N-oxide and acetic anhydride. These conversions of the perchlorate salts of **1** by triethylamine in acetonitrile to the same esters as obtained from the corresponding 4-alkylpy-

(1) For paper V in this series see V. J. Traynelis and Sr. A. I. Gallagher, *J. Amer. Chem. Soc.*, **87**, 5710 (1965).
(2) (a) Department of Chemistry, West Virginia University, Morgantown, W. Va. (b) Abstracted from the Ph.D. dissertation of A. I. G.,
(3) V. J. Traynelis in "Mechanisms of Molecular Migrations," Vol. 2, B. S. Thyagarajan, Ed., Interscience Publishers, New York, N. Y., 1969, pp 31–37.
(4) C. W. Muth and R. S. Darlak, *J. Org. Chem.*, **30**, 1909 (1965).
(5) V. J. Traynelis and P. L. Pacini, *J. Amer. Chem. Soc.*, **86**, 4917 (1964).
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