behavior similar to that of isocyanates. The reaction with alcohols which we have shown to take place is similar, at least in the first step, to the reaction of isocyanates with alcohols. The structure Ar—N═S═O must therefore be reconsidered as a possible structure for the N-sulfinyl amine group.

## EXPERIMENTAL

The ultraviolet spectra were determined using either a Beckman DU spectrophotometer or a Beckman DK recording spectrophotometer. Solutions of the *N*-sulfinyl amines containing about 5 × $10^{-3}$ grams/liter were measured in 1 or 2 cm. silica absorption cells.

The following aliphatic *N*-sulfinyl amines have a single maximum as indicated: *n*-propyl- 234 mμ, log ε 3.68; *n*-butyl- 234 mμ, log ε 3.72; *n*-heptyl- 235 mμ, log ε 3.67; cyclohexyl- 235 mμ, log ε 3.83.

*Isolation of dimethyl sulfite from N-sulfinylaniline and methyl alcohol.* A mixture of 13.9 g. (0.10 mole) of *N*-sulfinylaniline, 9.6 g. (0.30 mole) of methyl alcohol, and 20 ml. of dry ether was allowed to stand at room temperature for 3 days. Distillation of the mixture gave 2.4 g. (24%) of dimethyl sulfite boiling at 122–123°.

*Preparation of N-sulfinyl amines.* These compounds were prepared in good yield following a procedure similar to that described by Michaelis.[4]

LEXINGTON, KY.

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[CONTRIBUTION FROM THE UNIVERSITY OF CALIFORNIA, LOS ALAMOS SCIENTIFIC LABORATORY]

# Nitration of α-Oximino Esters and Acids[1]

H. E. UNGNADE AND L. W. KISSINGER

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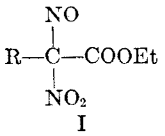
α-Oximino esters RC(═NOH)COOEt react with an equimolar mixture of 100% nitric acid and ammonium nitrate or with nitrogen dioxide in ether to give good yields of α-nitro-α-nitroso esters. The latter can be reconverted to α-oximino esters or oxidized to α,α-dinitro esters. The action of 100% nitric acid and ammonium nitrate upon other oximino esters, oximino acids, and related compounds has been investigated.

Oximino compounds have been utilized in various ways for the preparation of nitro compounds. A direct conversion of isonitroso to nitro groups can be accomplished by the oxidation of oximino compounds with sodium dichromate and sulfuric acid,[2] potassium permanganate,[3] hydrogen peroxide,[4] or peroxytrifluoroacetic acid.[5] The method of Iffland is less direct and involves bromination, oxidation, and debromination of oximes.[6]

Ketoximes react with nitrogen dioxide to yield pseudonitroles[7–11] which can be oxidized to *gem*-dinitro compounds with chromium trioxide in acetic acid,[7a] with nitric acid,[8] boiling ethanol,[10] or photochemically in benzene or ether.[8] In some cases the pseudonitroles are formed from ketoximes also by the action of fuming nitric acid,[10] and in a few instances the reaction with nitrogen dioxide[12,13] or nitric acid[13] will produce *gem*-dinitro compounds from ketoximes in one step.

In the present investigation α-oximino esters RC(═NOH)COOEt (R═alkyl) have been nitrated under various conditions. A mixture of 90% nitric acid and 15% fuming sulfuric acid at 5–15° gives products characterized by strong nitrate bands in the infrared (at 6.06, 7.86 ,and 11.74μ). Nitration with 100% nitric acid at 0–10° produces only small yields of mixtures containing nitrate esters which cannot be separated by molecular distillation. When the oximino esters are treated with an equimolar mixture of 100% nitric acid and ammonium nitrate, or with nitrogen dioxide in ether, insoluble blue oils, identified as α-nitro-α-nitroso esters (I), are formed in excellent yield.



$$R-\overset{NO}{\underset{NO_2}{C}}-COOEt$$

I

The new compounds (I, R = alkyl) are characterized by low-intensity absorption bands at 630–635 mμ. Their infrared spectra show two bands (NO, $NO_2$) in the 6.3μ region. They are sensitive to light, oxygen, heat, and prolonged exposure to

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(1) (a) This work was performed under the auspices of the U. S. Atomic Energy Commission. (b) Presented before the Organic Section of the American Chemical Society at the 134th meeting, Chicago, September 1958.

(2) V. M. Rodionov, I. V. Machinskaya, and V. M. Belikow, *Akad. Nauk S.S.S.R., Inst. Org. Khim. Sintezy Org. Soedinenii Sbornik I*, 117 (1950).

(3) M. Conrad and A. Schulze, *Ber.*, **42**, 739 (1909).

(4) J. Schmidt and A. Haid, *Ann.*, **377**, 23 (1910); J. Schmidt and K. T. Widman, *Ber.*, **42**, 1896 (1909).

(5) W. D. Emmons and A. S. Pagano, *J. Am. Chem. Soc.*, **77**, 4557 (1955).

(6) D. C. Iffland and G. X. Criner, *J. Am. Chem. Soc.*, **75**, 4047 (1953); D. C. Iffland and T. Yen, *J. Am. Chem. Soc.*, **76**, 4083 (1954).

(7) (a) V. Meyer, *Ber.*, **9**, 701 (1876); G. Born, *Ber.*, **29**, 93 (1896). (b) V. Meyer, *Ann.*, **175**, 120 (1875).

(8) H. Rheinboldt and M. Dewald, *Ber.*, **60**, 250 (1927).

(9) R. Scholl, *Ber.*, **21**, 506 (1888).

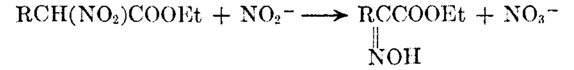
(10) W. Charlton, J. C. Earl, J. Kenner, and A. A. Luciano, *J. Chem. Soc.*, 30 (1932) .

(11) R. Scholl and K. Landsteiner, *Ber.*, **29**, 89 (1896).

(12) G. Ponzio and F. Biglietti, *Gazz. chim. ital.*, **64**, 861 (1934).

(13) R. Scholl, *Ber.*, **23**, 3490 (1890).

water, but may be stored for several weeks at temperatures below 10°. They have been postulated as unstable intermediates in the conversion of α-nitro esters to α-oximino esters with sodium nitrite in aqueous ethanol.[14] This theory is now supported



$$RCH(NO_2)COOEt + NO_2^- \longrightarrow \underset{\|\atop NOH}{RCCOOEt} + NO_3^-$$

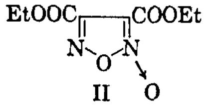
by the observation that the pure α-nitro-α-nitroso esters react with 50% aqueous alcoholic sodium nitrite to give α-oximino esters in good yield.

Oxidation with air, oxygen (especially when catalyzed by light), chromic oxide, or peroxytrifluoroacetic acid converts the α-nitro-α-nitroso esters (I) to α,α-dinitro esters prepared previously by another procedure.[15] These dinitro esters are formed also when the α-nitro-α-nitroso esters (I) are permitted to react with 100% nitric acid and ammonium nitrate without stirring.

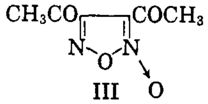
Ethyl oximinoacetate reacts exothermically with gaseous nitrogen dioxide giving ethyl nitroöximinoacetate and its decomposition product 3,4-dicarbethoxyfuroxan (II).[16] With 100% nitric acid and ammonium nitrate the same initial products are probably formed; the nitrolic acid, however, is further oxidized and dinitroacetate is isolated.[17] 3,4-Dicarbethoxyfuroxan (II) is the only insoluble product when ethyl aminooximinoacetate is nitrated under the same conditions.

Oximino esters with negative substituents, such as ethyl chlorooximinoacetate and ethyl oximinomalonate, are converted in good yields to the corresponding α-nitro esters by 100% nitric acid and ammonium nitrate.

With other oximino compounds the nitrating mixture of 100% nitric acid and ammonium nitrate has proved less advantageous. Thus, acetone oxime gives the known 3,4-diacetylfuroxan (III), which also is formed from α-oximinoacetone by the action of $N_2O_4$ in ether.[18] Ethyl α-oximinoacetoacetate reacts to give essentially the same mixture of ethyl dinitroacetate and 3,4-dicarbethoxyfuroxan (II) as is obtained from ethyl oximinoacetate. Under milder conditions ($HNO_3$, d. 1.2) it yields a mixture of ethyl nitrooximinoacetate and II.[19]

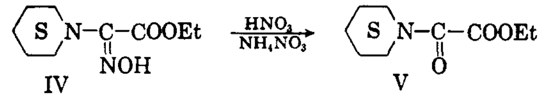


II



III

A still different type of reaction occurs with ethyl piperidinooximinoacetate (IV) which is converted to ethyl α-oxopiperidineacetate (V) by nitric acid and ammonium nitrate.



IV

V

α-Oximino acids (VI, R = alkyl) under similar conditions undergo simultaneous nitration and decarboxylation to dinitroparaffins (VII) which are

$$\underset{VI}{RC({=}NOH)COOH} + HNO_3 + NH_4NO_3 \longrightarrow \underset{VII}{RCH(NO_2)_2} + CO_2$$

isolated in small yields. Oximinocyanoacetic acid and β-amino-β-oximinopropionic acid have given only water-soluble nitration products.

## EXPERIMENTAL[20]

*Ethyl α-nitro-α-nitrosopropionate.* (a) Ammonium nitrate (80.0 g., 1.0 mole) was added with stirring to 100% nitric acid (63.0 g., 1.0 mole) at room temperature, and the suspension was cooled to 20°. A blue oil formed immediately when ethyl α-oximinopropionate (13.1 g., 0.1 mole) was added in small portions. The mixture was stirred at 23–25° for 2.5 hr. and poured on ice. The oil was taken up in methylene chloride, washed with water, and dried over sodium sulfate at 5°. After removal of the solvent under reduced pressure a blue oil (14.6 g., 83%) remained which had $n_D^{25}$ 1.4218, $\lambda_{max}$ 630 mμ, ε6.8 (in cyclohexane), λ(C=O) 5.69μ, $\lambda(NO_2)$ 6.31, 7.42μ, and λ(N=O) 6.40μ.

*Anal.* Calcd. for $C_5H_8N_2O_5$: C, 34.10; H, 4.57. Found: C, 34.34; H, 4.58.

(b) Nitrogen dioxide was added slowly to a solution of ethyl α-oximinopropionate (13.1 g., 0.1 mole) in ether (100 ml.), contained in an ice bath. The mixture was allowed to stand for 1 hr. and was distilled under reduced pressure below 20°, finally at 1 mm. The residual blue oil (16.5 g., 94%), $n_D^{25}$ 1.4260,[21] had an infrared spectrum identical with the above ester.

*Ethyl α-nitro-α-nitrosobutyrate.* The nitration of ethyl α-oximinobutyrate (7.2 g., 0.05 mole) with 100% nitric acid (0.5 mole) and ammonium nitrate (0.5 mole) at 20° under identical conditions gave 8.8 g. (93%) of blue oil with $n_D^{25}$ 1.4250, $\lambda_{max}$ 635 mμ, ε8.3 (in cyclohexane), λ(C=O) 5.69μ, $\lambda(NO_2)$ 6.30, 7.41μ, λ(NO) 6.41μ.

*Anal.* Calcd. for $C_6H_{10}N_2O_5$: C, 37.88; H, 5.30. Found: C, 37.84; H, 4.99.

The α-nitro-α-nitroso esters were insoluble in water and dissolved in ethanol, methanol, chloroform, acetic acid, benzene, and cyclohexane. They were unchanged in contact with water below room temperature but decomposed slowly on standing in water at 25°, yielding colorless oils containing dinitro esters.

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(14) N. Kornblum and J. H. Eicher, *J. Am. Chem. Soc.*, **78**, 1494 (1956).

(15) L. W. Kissinger and H. E. Ungnade, *J. Org. Chem.*, **23**, 1340 (1958).

(16) L. Bouveault and A. Wahl, *Bull. soc. chim.*, [3] **31**, 679 (1904).

(17) More recent evidence indicates that the nitrolic acid is an intermediate also in the reaction of ethyl bromoacetate with sodium nitrite in dimethylformamide [N. Kornblum and W. M. Weaver, *J. Am. Chem. Soc.*, **80**, 4333 (1958)]. Depending on the temperature, this may be then degraded to oxalic acid or 3,4-dicarbethoxyfuroxan. The isolation of pseudonitroles or nitrolic acids in the nitration of α-oximino esters appears to depend on the solubility of these compounds. They may be isolated when they are insoluble, as are the esters I, R = alkyl, but will react further when they are soluble in the reaction mixture.

(18) W. S. Mills, *Chem. News*, **88**, 228 (1903).

(19) M. Jowitschitsch, *Ber.*, **28**, 1215 (1895); **39**, 785 (1906).

(20) All temperatures are uncorrected. Microanalyses by M. Naranjo.

(21) The high refractive index in this sample is attributed to the presence of a small amount of dinitro ester.

*Ethyl α-oximinobutyrate from ethyl α-nitro-α-nitrosobutyrate.* When a solution of sodium nitrite (1.72 g., 0.025 mole) in 10 ml. of water was added to a blue solution of ethyl α-nitro-α-nitrosobutyrate (1.58 g., 0.0083 mole) in 10 ml. of 95% ethanol, the color changed to green immediately. It was yellow after 5 min. at 25°. The mixture was allowed to stand at 25° for 16 hr., diluted with 50 ml. of water, and extracted with ether. The extract was dried over sodium sulfate, filtered, and evaporated at 50 mm., leaving 1.0 g. (83%) of pale yellow oil which crystallized in colorless needles from hexane-petroleum ether, the needles melting at 59–60°. Melting point, mixed melting point, and infrared spectrum were identical with those of pure ethyl α-oximinobutyrate (lit. m.p. 58°).[22]

*Oxidation of ethyl α-nitro-α-nitrosobutyrate.* Ethyl α-nitro-α-nitrosobutyrate was oxidized to ethyl α,α-dinitrobutyrate under various conditions (Table I). The products were extracted with methylene chloride or chloroform, dried, and distilled to remove the solvents. They gave identical infrared spectra which also agreed with that of an authentic specimen,[15] boiled at 45–50° (0.1–0.2 mm.), and had analytical values corresponding to the dinitro ester.

TABLE I

OXIDATION OF ETHYL α-NITRO-α-NITROSOBUTYRATE

| Method | Yield, % | $n_D^{25}$ of Dinitro Ester |
|---|---|---|
| Chromium trioxide in HOAc at 15° | 25 | Not detd. |
| Peroxytrifluoroacetic acid[5] | 47 | 1.4342 |
| Air oxidation[a] | 64 | 1.4330 |
| Oxygen and GE 135W lamp[a] | 78 | 1.4356 |
| Nitric acid and ammonium nitrate[b] | 42 | 1.4348 |

[a] The gas was introduced into the liquid ester through a dispersion disk.

[b] The α-nitro-α-nitrosobutyrate was not isolated in this case. The stirrer was stopped when the blue oil was formed from the oximino ester and the mixture was allowed to warm exothermically.

*Nitration of other oximino compounds.* Each of the following compounds was added with stirring at 20° to a five- to ten-fold excess of an equimolar mixture of 100% nitric acid and ammonium nitrate. The reaction mixtures were stirred at 20–25° for 2 ± 0.5 hr., poured on ice, and extracted with methylene chloride. The extracts were washed with ice water, dried over sodium sulfate, and distilled.

(a) *Ethyl oximinomalonate* gave a 74% yield of ethyl nitromalonate, b.p. 50° (0.08 mm.), $n_D^{25}$ 1.4272, λ(C=O) 5.69, λ($NO_2$) 6.35, 7.31μ.

*Anal.* Calcd. for $C_7H_{11}NO_6$: C, 40.99; H, 5.40; N, 6.83. Found: C, 41.30; H, 5.86; N, 6.74.

Nitration of ethyl oximinomalonate with 100% nitric acid and concentrated sulfuric acid gave only a small yield of impure nitro ester.

*Ethyl α-chloro-α-oximinoacetate* yielded 51% of ethyl α-chloro-α-nitroacetate, b.p. 45° (0.03 mm.), $n_D^{25}$ 1.4358, λ(C=O) 5.67, λ($NO_2$) 6.31, 7.41μ.

*Anal.* Calcd. for $C_4H_6ClNO_4$: C, 28.66; H, 3.60; N, 8.36. Found: C, 28.72; H, 3.63; N, 8.20.

(c) *Ethyl α-oximinoacetoacetate* and *ethyl oximinoacetate* both gave mixtures of ethyl dinitroacetate and 3,4-dicarbethoxyfuroxan (II) which were separated by extraction with 20% aqueous sodium carbonate solution. 3,4-Dicarbethoxyfuroxan boiled at 90° (0.1 mm.) and had $n_D^{25}$ 1.4730; yield 56 and 24%, λ(C=O) 5.73μ, λ(C=N) 6.15μ. Ethyl dinitroacetate was regenerated from its yellow sodium salt solution by acidification with concentrated hydrochloric acid at 0°. The ester was recovered in 31 and 11% yield, respectively, by extraction with methylene chloride and evaporation of the solution. It boiled at 40° (0.5 mm.) and had $n_D^{25}$ 1.4322, λ(C=O) 5.65μ, and λ($NO_2$) 6.31, 7.51μ.

*Anal.* Calcd. for $C_4H_6N_2O_6$: C, 26.98; H, 3.40; N, 15.74. Found: C, 27.09; H, 3.25; N, 15.07.

(d) *Ethyl aminooximinoacetate* furnished a 31% yield of 3,4-dicarbethoxyfuroxan (II), b.p. 90° (0.05 mm.), $n_D^{25}$ 1.4730, $\lambda_{max}$ 270 mμ (log ε 3.63) in ethanol.

*Anal.* Calcd. for $C_8H_{10}N_2O_6$: C, 41.76; H, 4.38; N, 12.18. Found: C, 42.09; H, 4.39; N, 11.79.

(e) *Ethyl piperidinooximinoacetate* (IV)[23] was converted to ethyl α-oxopiperidineacetate (V) both by the above nitrating agent and by nitrogen dioxide in chloroform in yields of 33–65%. The product was twice distilled from a molecular still and boiled at 75° (0.05 mm.), $n_D^{25}$ 1.4724; λ(C=O) 5.76 and 6.03μ.

*Anal.* Calcd. for $C_9H_{15}NO_3$: C, 58.33; H, 8.10; N, 7.56. Found: C, 58.39; H, 8.18; N, 6.92.

Its infrared spectrum was identical with that of an authentic specimen, prepared from ethyl oxalate and piperidine.[24]

(f) *Acetone oxime* gave a 35% yield of 3,4-diacetylfuroxan (III), b.p. 65° (0.1 mm.), $n_D^{25}$ 1.5032, λ(C=O) 5.83μ, λ(C=N) 6.24μ, $\lambda_{max_1}$ 221 mμ (log ε 3.94), $\lambda_{max_2}$ 272 mμ (log ε 3.82) in ethanol.

*Anal.* Calcd. for $C_6H_6N_2O_4$: C, 42.37; H, 3.55; N, 16.47. Found: C, 42.43; H, 3.38; N, 16.08.

(g) *α-Oximinopropionic acid* yielded 1,1-dinitroethane (29%), which was converted to the hydrazine salt, m.p. 137–138°.[15]

*Anal.* Calcd. for $C_2H_8N_4O_4$: C, 15.79; H, 5.26. Found: C, 15.44; H, 5.55.

(h) *α-Oximinobutyric acid* furnished 1,1-dinitropropane in 29% yield. Its hydrazine salt melted at 99–100°.[15]

*Anal.* Calcd. for $C_3H_{10}N_4O_4$: C, 21.69; H, 6.06. Found: C, 22.30; H, 6.47.

*Absorption spectra.* Infrared absorption spectra were determined with a Perkin-Elmer Model 21 spectrophotometer, ultraviolet absorption spectra with a Beckman DR spectrophotometer.

LOS ALAMOS, N. MEX.

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[22] R. Locquin, *Bull. soc. chim.*, [3] **31**, 1068 (1904); L. Bouveault and R. Locquin, *Compt. rend.*, **135**, 179 (1902); J. K. H. Inglis and L. E. Knight, *J. Chem. Soc.*, **93**, 1595 (1908).

[23] H. E. Ungnade and L. W. Kissinger, *J. Org. Chem.*, **23**, 1794 (1958).

[24] O. Wallach and F. Lehmann, *Ann.*, **237**, 245 (1887).