Denaro and Hickling[2] and Hickling and Linacre[3] reported that the technique yields very high local concentrations of OH radicals in aqueous systems and suggested that it may be useful for electro-organic preparations.

We have converted formamide to oxamide by glow-discharge electrolysis. Most of the runs were made in a two-compartment cell like that described by Hickling, *et al.*[2,3] The discharge between the anode and the solution was maintained by power from a 750-watt fullwave rectifier with a maximum potential of 1500 v.

The electrolyte was usually an 0.8 N sulfuric acid solution and the formamide was dissolved in the anolyte. Most runs were made for one hour with 0.06 amp. The potential required for steady operation ranged from 470 to 600 v. The cell was immersed in a stirred ice water bath that maintained the temperature of the anolyte at 12 to 14°. Oxygen was admitted to the top of the anode compartment. Results of three of the better runs are summarized in Table I. The oxamide was a homogeneous, white crystalline product with the correct optical properties and powder X-ray pattern.[4]

Highest yields of oxamide were obtained with a solution of 10 ml. of formamide in 30 ml. of electrolyte in the anode compartment. An acidic electrolyte appeared most satisfactory. High yields were obtained with 0.1 to 0.8 N sulfuric acid solutions, but the yields decreased when the concentration of electrolyte was raised to 2 N. Increasing the concentration of acid apparently increased the hydrolytic degradation of the formamide. Addition of neutral salts, such as potassium sulfate, to the electrolyte had no significant effect.

Phosphoric acid worked equally as well as sulfuric acid, but a phosphate solution buffered to pH 7 gave low yields, and similar low yields were obtained with 1 N sodium hydroxide solution as the electrolyte.

Best operation was obtained when the temperature of the anolyte was above 0 and below 25°. At lower temperatures freezing of the electrolyte, and at higher temperatures excessive volatilization of the anolyte, lowered the yield.

TABLE I

PREPARATION OF OXAMIDE FROM FORMAMIDE BY GLOW-DISCHARGE ELECTROLYSIS

(One-hour runs; O_2 passed through anode compartment; pressure, 30 mm. absolute; catholyte, 40 ml. 0.8 N H_2SO_4; anolyte, 10 ml. formamide in 30 ml. 0.8 N H_2SO_4)

Current		Oxamide	
Amp.	Volts	Grams	Equivalents/ Faraday[a]
0.06	470	0.2822	2.9
.08	440	.4076	3.1
.12	480	.6073	3.1

[a] To conform to the usual practice of expressing yields in terms of equivalents of product per Faraday, 1 mole of oxamide is assumed to represent 2 equivalents.

The pressure in the cell was maintained at about 30 mm. absolute. High yields of oxamide were obtained when the atmosphere in the cell was oxygen or air, but the yields were low when the atmosphere was carbon monoxide.

Glow-discharge electrolysis of formamide alone also produced oxamide, but at a yield less than 1 equivalent per Faraday and with darkening and considerable decomposition of the formamide.

Ordinary electrolysis of formamide, alone or in an electrolytic solution, yielded no oxamide. In other attempts to prepare oxamide, we found that hydrogen peroxide does not react with formamide alone to yield oxamide. Addition of ferrous sulfate to the system, however, yielded a small amount of oxamide. The Fenton reaction with ferrous sulfate[5] involves the action of free hydroxyl radicals. It thus appears possible that the production of oxamide from formamide by glow-discharge electrolysis also involves free hydroxyl radicals.

[2] A. R. Denaro and A. Hickling, *J. Electrochem. Soc.*, **105**, 265 (1958).

[3] A. Hickling and J. K. Linacre, *J. Chem. Soc.*, 711 (1954).

[4] E. M. Ayerst and J. R. C. Duke, *Acta Cryst.*, **7**, 588 (1954).

[5] J. H. Merz and W. A. Waters, *J. Chem. Soc.*, S15 (1949).

An Effective General Method for Oxidizing Salts of Mononitro Compounds with Neutral Permanganate to Aldehydes and Ketones[1a]

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An important conversion reaction of primary and secondary nitro compounds is the acid-catalyzed hydrolysis of their salts to aldehydes and ketones[2] (the Nef reaction,[3] equation 1), respectively. The conversions have often been accomplished efficiently[3]; if, however, the nitronic acids which are intermediates in the hydrolytic decompositions suffer the consequences of steric factors,[4,5] the yields and the rates of conversion to carbonyl compounds may be greatly minimized. Further disadvantages arise in the Nef reaction if the nitronic acid which is being converted (a) contains other functional groups which are affected by the

$$2R_2C{=}NO_2Na + H_2SO_4 \longrightarrow 2R_2C{=}O + N_2O + Na_2SO_4 + H_2O \quad (1)$$

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[1] (a) Abstracted in part from the Ph.D. dissertation of Francis T. Williams, Jr., The Ohio State University, Columbus, Ohio, 1958; (b) Present address: Chemistry Department, Antioch College, Yellow Springs, Ohio.

[2] (a) M. Konovalov, *J. Russ. Phys. Chem. Soc.*, **25**, I. 509 (1893); (b) M. Konovalov, *Ber.*, **29**, 2193 (1896); (c) J. U. Nef, *Ann.*, **280**, 263 (1894).

[3] For a general summary of the Nef reaction, see W. E. Noland, *Chem. Rev.*, **55**, 137 (1955).

acidic medium, (b) is isomerized extensively to its isomeric nitro compound,[6] or (c) undergoes molecular rearrangement.[7]

It has been reported that salts of *o*-nitrophenylnitromethane,[8a] nitrocyclohexane,[8b] 1-nitrodecalin,[8c] and 4-methyl-6-nitrocamphene[8d] are oxidized by potassium permanganate (equation 2) in the presence of magnesium sulfate[9] to *o*-nitrobenzaldehyde, cyclohexanone, fluorenone, 1-decalone, and

$$3R_2C{=}NO_2K + 2KMnO_4 + H_2O \longrightarrow 3R_2C{=}O + 2MnO_2 + 3KNO_2 + 2KOH \quad (2)$$

6-keto-4-methylcamphene[10] in 90, 84, 90, 50, and 88% yields, respectively. Ketones have also been prepared by permanganate oxidation of salts of 2-nitrocamphanes[11a], 5-nitroisocamphanes,[11b] 2- and 6-nitrocamphenilanes,[11c] 2- and 6-nitrofenchanes,[11d] 4-methyl-2-nitrocamphane,[11e] and 6-nitrocamphene,[8d] but the yields are not reported.

The present investigation was undertaken to determine whether conversion of salts of various mononitro compounds to their corresponding carbonyl derivatives could be accomplished more effectively by oxidation with neutral permanganate than by the Nef reaction. The possible oxidation of primary alkanenitronates to aldehydes was of particular importance to this study.

The results of the present investigation (Tables I and II) show that, in general, if the stoichiometry of oxidant to alkanenitronate is properly chosen, permanganate will convert salts of primary nitro compounds (Table I) into aldehydes in satisfactory yields and conversion of hindered or sensitive secondary nitronates (Table II) to ketones is an excellent preparative method. In general it has been found for purposes of synthesis or proof of structure that oxidation of highly branched or (certain) complicated nitronates to their corresponding aldehydes or ketones by permanganate is superior to the usual Nef method.

Oxidation of either a primary or secondary nitronate in aqueous solution occurs almost instantly. If excess permanganate is used, salts of primary nitro compounds are converted rapidly and efficiently to their corresponding carboxylic acids; when equivalent quantities of oxidant (equation 2) are used at 0–5°, the aldehydes are produced in 68–84% yield. Though reaction of permanganate with a primary alkanenitronate is faster than that of its corresponding aldehyde, during the latter stages of oxidation the concentration of aldehyde to nitronate anion becomes sufficiently great so that the aldehyde becomes competitively oxidized to carboxylic acid. It may thus be found expedient ($\sim$97% yields, Table I) to oxidize the salt of a primary nitro compound with insufficient permanganate (70–90% of theory) and then effect subsequent oxidation of the remaining nitronate after separation of the initial product.[12]

Experimental

General Procedure.—To the nitro compound (0.001–0.006 mole) dissolved in aqueous potassium hydroxide (100–180 ml. 0.10 *N* 0.010–0.015 mole) was added aqueous magnesium sulfate (15–25 ml. *ca.* 2 *M*) and sufficient water to make the final volume approximately 500 ml. The calculated amount of aqueous potassium permanganate was then added dropwise to the stirred mixture at 0–5°. The color of permanganate disappeared rapidly upon the addition.[13] With secondary nitroalkanes the color does not persist until an excess of permanganate has been added; the end point is obscured, however, by the manganese dioxide produced. After addition was completed, the reaction mixture was steam distilled (*ca.* 100 ml.) into an aqueous solution of hydrochloric acid (2 *N*) saturated with 2,4-dinitrophenylhydrazine.[14] The precipitate which formed was filtered, dried in vacuum (5 mm.) over anhydrous calcium chloride, and weighed. The experimental results are summarized in Tables I and II.

A control experiment was conducted in which 1-nitrobutane was carried through the general procedure in the absence of potassium permanganate; there was no detectable quantity of butyraldehyde 2,4-dinitrophenylhydrazone produced. The conversion of nitro compounds to 2,4-dinitrophenylhydrazones was corrected (Table I) to account for experimental errors resulting in the analytical

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(4) (a) 1-Nitrobutane is converted to butyraldehyde in 85% yield,[4b] whereas the conversion of 2-methyl-1-nitropropane to isobutyraldehyde is only 36%[4b]; the yield of trimethylacetaldehyde from 2,2-dimethyl-1-nitropropane is poor[4c]; (b) K. Johnson and E. F. Degering, *J. Org. Chem.*, **8**, 10 (1943); (c) A. P. Howe and H. B. Hass, *Ind. Eng. Chem.*, **38**, 251 (1946) have reported that the sodium salt of 2,2-dimethyl-1-nitropropane undergoes the Nef reaction in unstated yield. The present investigators have found that reaction of salts of 2,2-dimethyl-1-nitropropane under the usual Nef conditions gives low yields of trimethylacetaldehyde; (d) salts of 4,4-dimethyl-5-nitro-2-pentanone are reported not to undergo the Nef reaction.[5a]

(5) For discussion of these factors see: (a) E. E. van Tamelen and R. J. Thiede, *J. Am. Chem. Soc.*, **74**, 2615 (1952), and (b) M. F. Hawthorne, *ibid.*, **79**, 2510 (1957).

(6) (a) N. Kornblum and G. E. Graham, *ibid.*, **73**, 4041 (1951), have shown that resonance stabilized nitronic acids, such as phenylmethanenitronic acid, tautomerize efficiently to their corresponding nitro compounds in strongly acidic media; (b) H. Feuer and A. T. Nielsen, *ibid.*, **84**, 688 (1962) have reported a direct Nef reaction in that 2-nitroöctane is hydrolyzed by hydrochloric acid to 2-octanone; the conversion to 2-octanone is low however.

(7) W. E. Noland, J. H. Cooley, and P. A. McVeigh, *ibid.*, **81**, 1209 (1959).

(8) (a) German Patent 237,358 (1909), Soc. Chim. des Usines du Rhone; German Patent 246,659, Soc. Chim. des Usines du Rhone; (b) S. Nametkin and E. Posdnjakova, *J. Russ. Phys. Chem. Soc.*, **45**, 1420 (1913); (c) S. Nametkin and O. Madaef-Ssitscheff, *Ber.*, **59**, 370 (1926); (d) S. Nametkin and A. Zabrodina, *ibid.*, **69**, 1789 (1936).

(9) The principal function of the magnesium sulfate is to maintain the neutrality of the oxidation mixture by precipitating hydroxide ion as magnesium hydroxide.

(10) It is to be noted in the conversion of the salt of 4-methyl-6-nitrocamphene to 6-keto-4-methylcamphene that the nitronate function rather than the olefinic center is oxidized by the permanganate.[4d]

(11) (a) S. Nametkin, M. Dobrovolskaja, and M. Oparina, *J. Russ. Phys. Chem. Soc.*, **47**, 409 (1915); (b) S. Nametkin and L. A. Abakumovskaja, *ibid.*, **47**, 414 (1915). (c) S. Nametkin and A. Chuchrikova, *ibid.*, **47**, 425 (1915); (d) S. Nametkin, *ibid.*, **47**, 1590 (1915); (e) S. Nametkin and L. Bruessoff, *Ann.*, **459**, 144, 153 (1927).

(12) For studies of the various actions of other oxidants on salts of nitro compounds see: (a) H. Shechter and R. B. Kaplan, *J. Am. Chem. Soc.*, **75**, 3980 (1953); (b) R. B. Kaplan and H. Shechter, *ibid.*, **83**, 3535 (1961); and (c) A. L. Pagano, Ph.D. dissertation, The Ohio State University, 1960.

(13) The amount of potassium permanganate used was calculated on the basis of equation 2 to give a slight excess (3–7%) for oxidation of secondary nitronates and to give the stoichiometric amount or less for primary nitronates.

(14) N. A. Iddles and C. E. Jackson, *Ind. Eng. Chem.* (*Anal. Ed.*), **6**, 484 (1934).

Table I

Oxidation of Primary Alkanenitronates with Potassium Permanganate

Nitro compound	Moles × 10^3 of nitronate	Equiv. × 10^3 of KMnO$_4$^{a}	Ratio of reactants^b	Aldehyde 2,4-DNPH,^{c} g.	Yield,^{d} %	Yield^e (cor.), %
1-Nitrobutane	5.77	5.77	1.00	1.110	76	83
1-Nitrobutane	3.11	3.11	1.00	0.599	77	84
1-Nitrobutane	3.46	3.11	0.90	0.703	90	97
1-Nitrobutane	6.88	6.22	.90	1.390	89	96
2-Methyl-1-nitropropane	6.6	6.6	1.00	1.21	73^f	
2,2-Dimethyl-1-nitropropane	0.835	0.835	1.00	0.14	63^f	
2,2-Dimethyl-1-nitropropane	1.6	1.2	0.75	.22	69^f	
Cyclobutylnitromethane	0.92	0.62	.67	.155	91^f	
Phenylnitromethane	2.22	2.22	1.00	.401	63	68
Phenylnitromethane	4.5	3.1	0.70	.800	90	97

[a] Based on equation 2. [b] Equivalents of potassium permanganate to moles of nitronate. [c] The aldehyde formed was isolated as its 2,4-dinitrophenylhydrazone, see Experimental. The melting points of the derivatives after crystallization from ethanol agreed satisfactorily with literature values. [d] Based on potassium permanganate added and weight of derivative isolated. [e] Equals yield multiplied by experimental correction factor, see Experimental. [f] Minimum yield; corrections were not made for solubility losses.

Table II

Oxidation of Secondary Alkanenitronates with Potassium Permanganate

Nitro compound	Moles × 10^3 of nitronate	Equiv. × 10^3 of KMnO$_4$^{a}	Ratio of reactants^b	Ketone 2,4-DNPH,^{c} g.	Yield, %
2-Nitropropane					96^d
2-Nitrobutane	2.03	2.18	1.07	0.478	94
3-Methyl-3-nitrobutane	2.22	2.30	1.04	.552	94
2,2-Dimethyl-3-nitrobutane^e	1.795	1.87	1.03	.264	66
1-Cyclopropylnitroethane	2.22	2.85	1.28	.450	77^f
Dicyclopropylnitromethane^f	2.05	2.85	1.39	.485	81^f
Nitrocyclobutane^g					94^g

[a] Based on equation 2. [b] Equivalents of potassium permanganate to moles of nitronate. [c] The ketone was isolated as its 2,4-dinitrophenylhydrazone, see Experimental. Melting points of recrystallized derivatives agreed satisfactorily with literature values. [d] Yield reported in reference 12a. [e] There is question about the purity of the sample of 2,2-dimethyl-3-nitrobutane used. The experimental extinction coefficient at its absorption maximum (229 mμ) is 8600. Related nitronates have extinction coefficients of ∼11,000 at their absorption maxima. [f] The results were obtained before the optimum present procedure was developed. The yields should be regarded as minimal. [g] P. W. K. Flanagan, Ph.D. dissertation, The Ohio State University, 1957. The yield has been corrected for solubility losses.

procedure. The procedure used in determining the correction factor was as follows. A purified sample of aldehyde (0.002–0.006 mole) was steam distilled (*ca.* 100 ml.) into an aqueous solution of hydrochloric acid (2 *N*) saturated with 2,4-dinitrophenylhydrazine. The precipitate obtained was filtered, dried at 5 mm. over calcium chloride and weighed. The correction factor for the yield of butyraldehyde and of benzaldehyde 2,4-dinitrophenylhydrazones was 1.09.

2,3-Dihydrothiazolo[2,3-*b*]quinazolin-5-one

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As part of synthesis program aimed at discovering new chemotherapeutic agents it was desirable to synthesize the title compound (I). Although this substance (m.p. 240°) was reported by Narang and co-workers as the product of the reaction between ethyl N-thiocarbamoylanthranilate and ethylene bromide, structure assignment was tentative and attempts to synthesize it by an unequivocal route failed.[2,3] We repeated the synthesis and obtained a compound of identical melting point and correct elemental analysis.

While searching for a more convenient synthesis we prepared a compound isomeric with that described by Narang and have established its structure as I by independent synthesis. The preparation of I was effected by the reaction of the sodium salt of 2-mercapto-4(3H)-quinazolinone (III) with ethylene bromide. This method, of course, might have produced either I or the "angular" isomer II. To provide an unambiguous route to I we applied the thiazoline synthesis first reported by Gabriel and Stelgner.[4] Ethyleneimine was added to methyl *o*-isothiocyanatobenzoate (IV) and the resulting aziridine (V) was refluxed in concentrated hydrochloric acid. The intermediate thiazoline (VI) was not isolated, apparently the

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(2) K. S. Narang, M. C. Khosla, O. P. Vig, and I. S. Gupta, *J. Sci. Ind. Res.* (India), **12B**, 466 (1953).

(3) K. S. Narang, G. M. Sharma, and I. S. Gupta, *Res. Bull. Panjab Univ.*, **87**, 49 (1956); *Chem. Abstr.*, **51**, 7379 (1957).

(4) S. Gabriel and R. Stelgner, *Ber.*, **28**, 2929 (1895).