A Publication
of Reliable Methods
for the Preparation
of Organic Compounds

Working with Hazardous Chemicals

The procedures in *Organic Syntheses* are intended for use only by persons with proper training in experimental organic chemistry. All hazardous materials should be handled using the standard procedures for work with chemicals described in references such as "Prudent Practices in the Laboratory" (The National Academies Press, Washington, D.C., 2011; the full text can be accessed free of charge at http://www.nap.edu/catalog.php?record_id=12654). All chemical waste should be disposed of in accordance with local regulations. For general guidelines for the management of chemical waste, see Chapter 8 of Prudent Practices.

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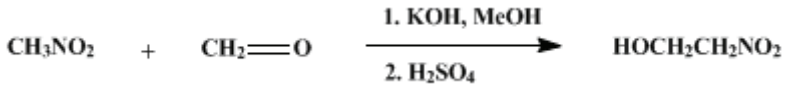
These paragraphs were added in September 2014. The statements above do not supersede any specific hazard caution notes and safety instructions included in the procedure.

DOI:10.15227/orgsyn.041.0067

Organic Syntheses, Coll. Vol. 5, p.833 (1973); Vol. 41, p.67 (1961).

2-NITROETHANOL

[Ethanol, 2-nitro-]



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1. Procedure

In a 5-l., three-necked, round-bottomed flask fitted with a 30-ml. dropping funnel, mechanical stirrer, and thermometer extending down into the liquid is placed a suspension of paraformaldehyde (trioxymethylene, 125 g., 4.16 moles) in freshly distilled (Note 1) nitromethane (2.5 l., 46.6 moles). The suspension is stirred vigorously, and 3*N* methanolic potassium hydroxide solution is added dropwise from the dropping funnel until, at an apparent pH of 6–8, but closer to pH 8 (pH paper), the paraformaldehyde begins to dissolve and the suspension assumes a clearer appearance. About 10 ml. of the alkaline solution is required, and the addition takes about 10 minutes. About 15–20 minutes after addition of the alkaline solution is complete, the paraformaldehyde dissolves completely. Shortly thereafter, the solution temperature reaches a maximum of 13–14 degrees above room temperature and then slowly drops. Stirring is continued 1 hour after addition of the alkaline solution is complete.

Stirring is continued while the added alkali is *completely* neutralized by adding concentrated (36*N*) sulfuric acid (1 ml.) dropwise from a medicine dropper over a period of about 3 minutes until an apparent pH of about 4 is reached (Note 2). The solution is then stirred for an hour, during which time the pH should not change (Note 3).

The precipitated potassium sulfate is filtered by passing the solution through a 12-cm. Büchner funnel. The light-yellow or yellowish green filtrate is transferred to a 5-l., one-necked, round-bottomed flask fitted with a Claisen head containing a capillary ebulliator tube and a thermometer, and connected to a water-cooled condenser. The condenser is connected through a vacuum adapter to a 3-l., one-necked, round-bottomed flask, cooled in ice, to act as a receiver. About 2.3 l. of pure, unchanged nitromethane is removed by distillation at aspirator pressure and a water-bath temperature of 40–50°. The distillation takes about 6–7 hours.

The golden-yellow residue (315–365 g.) is transferred to a 1-l., one-necked, round-bottomed flask containing an equal weight of diphenyl ether (Note 4). The flask is fitted with a Claisen head containing a capillary ebulliator tube and a thermometer, and connected to a water-cooled condenser. The condenser is connected to a 3- or 4-port fraction cutter fitted with 100–500 ml., one-necked, round-bottomed flasks, at least one of which is 500 ml. or larger to accommodate the main fraction (Note 5). The mixture is distilled under the vacuum of a good pump. The fore-run, b.p. 29–33° at about 0.10 mm., consisting of nitromethane (about 56 ml.), can be distilled at a water-bath temperature of 32–79° and usually passes directly into the Dry Ice trap protecting the vacuum pump. The temperature then rises as 2-nitroethanol and diphenyl ether codistil. The main fraction, a two-phase distillate initially richer in 2-nitroethanol than diphenyl ether, gradually changes in composition until the proportion of 2-nitroethanol becomes negligible. The main fraction of 410–425 g., b.p. 54–57° at about 0.10 mm. (or 64–66° at about 0.4 mm.), collects at a water-bath temperature of 79–88°. Care should be taken to prevent clogging of the condenser or fraction cutter with solid diphenyl ether (m.p. 27°). The distillation is continued until the proportion of 2-nitroethanol (lower layer) observed in the distillate becomes negligible, and the temperature suddenly starts to rise. At this point heating is stopped, *but the residue is cooled to room temperature or below before the vacuum is broken* (Note 6).

The two-phase main fraction of the distillate is placed in a 500-ml. separatory funnel and the lower layer of crude 2-nitroethanol (185–200 g., 146–158 ml., n_D^{25} 1.4493–1.4513, containing about 92–94

mole % 2-nitroethanol) is drawn off. The 2-nitroethanol is then extracted in a 500-ml. separatory funnel with an equal volume of light petroleum ether (b.p. 60–68°, such as Skellysolve B) or hexane, and the colorless lower layer of 2-nitroethanol (174–188 g., 46–49%, n_D^{25} 1.4432–1.4433, containing about 98 mole % 2-nitroethanol) is drawn off (Note 7) and (Note 8). The product turns light yellow after standing for a day or more.

2. Notes

1. Commercial nitromethane is sometimes quite acidic, and much more methanolic potassium hydroxide is required to initiate the reaction when such material is used. For safety, the nitromethane should be distilled at aspirator pressure instead of atmospheric pressure.
2. Sulfuric acid *must* be used in an amount slightly *more* than enough exactly to neutralize the alkali, and not just sufficient to make the reaction acidic. Otherwise, the metal salts of nitromethane can form explosive fulminates upon heating.
3. This is a suitable point at which to interrupt the experiment overnight.
4. 2-Nitroethanol prepared by the formaldehyde-nitromethane method should not be distilled without use of diphenyl ether as a heat-dispersing agent. The residue, consisting of di- and tri-condensation products of formaldehyde with nitromethane, when hot and concentrated, and particularly when the vacuum is broken and air is let in on the hot distillation residue, is very likely to undergo a flash detonation, or at least a fume-off which may proceed with explosive violence. Use of diphenyl ether is a wise safety precaution in the distillation of 2-nitroethanol made by other methods as well.
5. If a fraction cutter is not used, the residue should be cooled to room temperature each time before the vacuum is broken.
6. The large amount of diphenyl ether (80–125 g.) left as the upper layer in the distilling flask has served the useful purpose, by its mass and volatility, of preventing superheating of the residue and subsequent violent decomposition, as described in (Note 4).
7. This procedure has been carried out 30 times by students in the advanced organic laboratory course at the University of Minnesota. The extreme ranges of yields obtained were 32–52%, and the median yield was 46%.
8. The 2-nitroethanol obtained by this procedure is quite satisfactory for synthetic purposes, such as the preparation of nitroethylene. The small amount of light petroleum ether dissolved in the 2-nitroethanol can easily be removed under reduced pressure. Most of the remaining diphenyl ether can be removed by one redistillation under vacuum, since the fore-run is relatively rich in diphenyl ether. The main fraction has n_D^{25} 1.4425–1.4431. Although vacuum redistillation of 2-nitroethanol which has been freed by the present procedure from higher condensation products of formaldehyde with nitromethane is relatively safe, it is recommended that the procedure be carried out behind a safety shield or a barricade.

3. Discussion

The present procedure is that of Controulis, Rebstock, and Crooks,[2] modified to include the diphenyl ether purification method of Roy.[3] 2-Nitroethanol has been prepared by condensation of formaldehyde (usually employed in the solid form as paraformaldehyde) with a large excess of nitromethane in the presence of an alkali catalyst,[2,4,5,6] as illustrated by the present procedure, or in the presence of a strongly basic ion-exchange resin.[7] Dimethoxymethane has also served as a source of formaldehyde in a reaction catalyzed by a mixture of acidic and basic ion-exchange resins.[8] 2-Nitroethanol has also been prepared by the action of silver nitrite on 2-iodoethanol (ethylene iodohydrin);[9,10,11,12] by selective catalytic hydrogenation over 5% palladium on barium sulfate in pyridine solution of halogenated derivatives, including 2-chloro-2-nitroethanol, 2,2-dichloro-2-nitroethanol, and 2-bromo-2-nitroethanol;[13] by the action of fuming nitric acid on ethylene;[14] and by the action of dinitrogen tetroxide on ethylene in the presence of oxygen[15,16,17,18,19] or nitric oxide,[20] or in carbon tetrachloride solution.[21] The preparation of 2-nitroethanol from ethylene oxide by the action of aqueous solutions of barium,[22] calcium,[22] magnesium,[23] or zinc[22] nitrite, or by the action of sodium nitrite and carbon dioxide,[24] has also been reported. The submitter has been unable to prepare 2-nitroethanol from ethylene oxide using the procedures described for barium[6] or sodium nitrite; his observation with respect to barium nitrite has been confirmed in another laboratory.[25] More recently, the preparation of 2-nitroethanol in 50% yield has been reported by adding ethylene oxide to aqueous sodium nitrite at 20° under nitrogen in the presence of a nitrite scavenger, such as sodium hydrosulfite

or phloroglucinol, at a pH of 7.1–7.3 controlled by the addition of phosphoric acid.[26] The action of dinitrogen tetroxide on ethylene oxide in chloroform solution has been reported to yield 2-nitroethyl nitrate, from which 2-nitroethanol could be obtained by alkaline saponification.[27] This report has since been refuted with the finding that the initial product is the mononitrite mononitrate ester of ethylene glycol, which saponifies to ethylene glycol mononitrate and diethylene glycol mononitrate.[28]

4. Merits of Preparation

The present procedure has the advantage of using inexpensive, commercially available starting materials, combined with an apparently safe method of isolating the product. 2-Nitroethanol is particularly valuable as a synthetic intermediate for the preparation of nitroethylene. Nitroethylene is conveniently prepared by heating 2-nitroethanol with phthalic anhydride and allowing the nitroethylene to distil under reduced pressure.[29,30]

References and Notes

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Appendix
Chemical Abstracts Nomenclature (Collective Index Number); (Registry Number)

petroleum ether

trioxymethylene

dinitrogen tetroxide

methanolic potassium hydroxide

mononitrate ester of ethylene glycol

sulfuric acid (7664-93-9)

formaldehyde (50-00-0)

chloroform (67-66-3)

potassium sulfate (37222-66-5)

magnesium (7439-95-4)

nitric acid (7697-37-2)

oxygen (7782-44-7)

carbon tetrachloride (56-23-5)

nitrogen (7727-37-9)

sodium nitrite (7632-00-0)

mononitrite (14797-65-0)

sodium hydrosulfite (7775-14-6)

carbon dioxide (124-38-9)

phthalic anhydride (85-44-9)

barium sulfate (7727-43-7)

pyridine (110-86-1)

potassium hydroxide (1310-58-3)

zinc (7440-66-6)

calcium (7440-70-2)

phosphoric acid (7664-38-2)

palladium (7440-05-3)

Ethylene oxide (75-21-8)

ethylene (9002-88-4)

nitric oxide

barium (7440-39-3)

Dimethoxymethane (109-87-5)

Nitromethane (75-52-5)

Phloroglucinol (108-73-6)

silver nitrite (7783-99-5)

diphenyl ether (101-84-8)

hexane (110-54-3)

2-Nitroethanol,
Ethanol, 2-nitro- (625-48-9)

nitroethylene (3638-64-0)

2-iodoethanol,
ethylene iodohydrin (624-76-0)

2-chloro-2-nitroethanol

2,2-dichloro-2-nitroethanol

barium nitrite

2-nitroethyl nitrate (4528-34-1)

ethylene glycol mononitrate

diethylene glycol mononitrate

2-bromo-2-nitroethanol

paraformaldehyde (30525-89-4)