



A Publication
of Reliable Methods
for the Preparation
of Organic Compounds

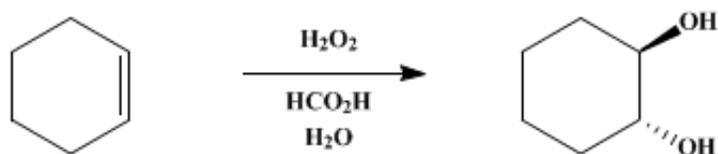
Working with Hazardous Chemicals

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.

In some articles in *Organic Syntheses*, chemical-specific hazards are highlighted in red "Caution Notes" within a procedure. It is important to recognize that the absence of a caution note does not imply that no significant hazards are associated with the chemicals involved in that procedure. Prior to performing a reaction, a thorough risk assessment should be carried out that includes a review of the potential hazards associated with each chemical and experimental operation on the scale that is planned for the procedure. Guidelines for carrying out a risk assessment and for analyzing the hazards associated with chemicals can be found in Chapter 4 of Prudent Practices.

The procedures described in *Organic Syntheses* are provided as published and are conducted at one's own risk. *Organic Syntheses, Inc.*, its Editors, and its Board of Directors do not warrant or guarantee the safety of individuals using these procedures and hereby disclaim any liability for any injuries or damages claimed to have resulted from or related in any way to the procedures herein.

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.

trans*-1,2-CYCLOHEXANEDIOL*[1,2-Cyclohexanediol, *trans*-]**

Submitted by Alan Roebuck and Homer Adkins.

Checked by Arthur C. Cope and Claude F. Spencer.

1. Procedure

*Caution! Reactions and subsequent operations involving peracids and peroxy compounds should be run behind a safety shield. Peroxy compounds should be added to the organic material, never the reverse. For relatively fast reactions, the rate of addition of the peroxy compound should be slow enough so that it reacts rapidly and no significant unreacted excess is allowed to build up. The reaction mixture should be stirred efficiently while the peroxy compound is being added, and cooling should generally be provided since many reactions of peroxy compounds are exothermic. New or unfamiliar reactions, particularly those run at elevated temperatures, should be run first on a small scale. Reaction products should never be recovered from the final reaction mixture by distillation until all residual active oxygen compounds (including unreacted peroxy compounds) have been destroyed. Decomposition of active oxygen compounds may be accomplished by the procedure described in Korach, M.; Nielsen, D. R.; Rideout, W. H. *Org. Synth.* 1962, 42, 50 (*Org. Synth.* 1973, Coll. Vol. 5, 414). [Note added January 2011].*

One hundred and forty milliliters of 30% hydrogen peroxide (1.4 moles) (Note 1) is added to 600 ml. of 88% formic acid (13.7 moles) (Note 2) in a 1-l. three-necked flask equipped with a thermometer and a motor-driven stirrer. Freshly distilled cyclohexene (82 g., 1.0 mole) (Note 3) is added slowly from a dropping funnel over a period of 20–30 minutes while the temperature of the reaction mixture is maintained between 40° and 45° by cooling with an ice bath and by controlling the rate of addition (Note 4). The reaction mixture is kept at 40° for 1 hour after all the cyclohexene has been added, and then it is allowed to stand overnight at room temperature.

The formic acid and water are removed by distillation from a steam bath under reduced pressure. An ice-cold solution of 80 g. of sodium hydroxide in 150 ml. of water is added in small portions to the residual viscous mixture of the diol and its formates, with care that the temperature of the mixture does not exceed 45°. The alkaline solution is warmed to 45°, and an equal volume (350 ml.) or more of ethyl acetate is added. After thorough extraction, the lower layer is separated and extracted at 45° six times with equal volumes of ethyl acetate. The seven ethyl acetate solutions (Note 5) are combined (total volume about 2.1 l.), and the solvent is distilled from a steam bath until the residual volume is 300–350 ml. and the solid product begins to crystallize. The mixture is cooled to 0°, and the product is separated by filtration (77–90 g., melting in the range of 90–98°). The mother liquor is concentrated on a steam bath to a volume of 65–75 ml., and more solid crystallizes. The mixture is cooled and filtered as before and yields an additional 4–15 g. of crude product melting in the range of 80–89°. *trans*-1,2-Cyclohexanediol, b.p. 120–125°/4 mm., is obtained by distillation of the combined crude products, with the use of an oil bath and a flask having a side arm and an air condenser sufficiently wide that they will not become plugged as the product solidifies (Note 6). The yield of product of m.p. 101.5–103° is 75–85 g. (65–73%) (Note 7).

2. Notes

1. The concentration of the [hydrogen peroxide](#) may be determined by titration with 0.2 *N* [potassium permanganate](#) in acid solution.
2. Less [formic acid](#) than is specified may be used, but the yields are lower and the reaction is not so easily controlled.
3. The [cyclohexene](#) used may be the commercial product or it may be prepared from [cyclohexanol](#).¹
4. If the temperature rises above 45°, the reaction may be stopped by discontinuing the stirring.
5. The total quantity of [ethyl acetate](#) required is less if the first three extractions are combined and the solvent required for successive extractions is distilled at a steam bath from this solution.
6. If there is an appreciable quantity of solid residue in the flask, it may be dissolved in hot water and crystallized by cooling in ice. The crystals of [cyclohexanediol](#), after being dried, may be distilled as described above.
7. The product can be recrystallized from [ethyl acetate](#).

3. Discussion

The method described is essentially that of Swern, Billen, Findley, and Scanlan.² In addition to the performic acid method,³ [trans-1,2-cyclohexanediol](#) may be obtained through hydrolysis of the monoacetate^{4,5} or [cyclohexene oxide](#).⁴ It has also been obtained by a [peracetic acid](#) oxidation of [cyclohexene](#) with [tungsten trioxide](#),⁶ and as a by-product in several instances.^{7,8} [cis-1,2-Cyclohexanediol](#) has been prepared by reaction of [cyclohexene](#) with [hydrogen peroxide](#) in [tert-butyl alcohol](#) with [osmium tetroxide](#) as a catalyst.^{6,9} Mixtures of *cis* and *trans* isomers have resulted from the hydrogenation ([Raney nickel](#)) of [catechol](#),^{10,11} and the [sodium-alcohol](#)¹² or catalytic¹³ reduction of adipoin.

References and Notes

1. *Org. Syntheses Coll. Vol. 1*, 183 (1941).
2. Swern, Billen, Findley, and Scanlan, *J. Am. Chem. Soc.*, **67**, 1786 (1945).
3. English and Gregory, *J. Am. Chem. Soc.*, **69**, 2120 (1947).
4. Criegee and Stanger, *Ber.*, **69**, 2753 (1936).
5. Clarke and Owen, *J. Chem. Soc.*, **1949**, 315.
6. Mugdan and Young, *J. Chem. Soc.*, **1949**, 2988.
7. McKusick, *J. Am. Chem. Soc.*, **70**, 1976 (1948).
8. Price and Mueller, *J. Am. Chem. Soc.*, **66**, 628 (1944).
9. Milas and Sussman, *J. Am. Chem. Soc.*, **59**, 2345 (1937).
10. Donald Robinson, Ph.D. Thesis, University of Wisconsin, 1948.
11. English and Barber, *J. Am. Chem. Soc.*, **71**, 3310 (1949).
12. Treibs and Bast, *Ann.*, **561**, 165 (1949).
13. U. S. pat. 2,467,451 [*C. A.*, **43**, 6229 (1949)].

Appendix

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

adipoin

[alcohol](#) (64-17-5)

[ethyl acetate](#) (141-78-6)

[sodium hydroxide](#) (1310-73-2)

Cyclohexanol (108-93-0)
potassium permanganate (7722-64-7)
Cyclohexene (110-83-8)
formic acid (64-18-6)
Raney nickel (7440-02-0)
sodium (13966-32-0)
Catechol (120-80-9)
hydrogen peroxide (7722-84-1)
Cyclohexene oxide (286-20-4)
cyclohexanediol
peracetic acid (79-21-0)
tungsten trioxide
osmium tetroxide (20816-12-0)
tert-butyl alcohol (75-65-0)
trans-1,2-Cyclohexanediol,
1,2-Cyclohexanediol, trans- (1460-57-7)
cis-1,2-Cyclohexanediol (1792-81-0)