

# Propylene glycol

**Propylene glycol** (IUPAC name: **propane-1,2-diol**) is a viscous, colorless liquid, which is nearly odorless but possesses a faintly sweet taste. Its chemical formula is CH<sub>3</sub>CH(OH)CH<sub>2</sub>OH. Containing two alcohol groups, it is classed as a diol. It is miscible with a broad range of solvents, including water, acetone, and chloroform. In general, glycols are non-irritating and have very low volatility.<sup>[4]</sup>

It is produced on a large scale primarily for the production of polymers. In the European Union, it has E-number E1520 for food applications. For cosmetics and pharmacology, the number is E490. Propylene glycol is also present in propylene glycol alginate, which is known as E405. Propylene glycol is a compound which is GRAS (generally recognized as safe) by the US Food and Drug Administration under 21 CFR x184.1666, and is also approved by the FDA for certain uses as an indirect food additive. Propylene glycol is approved and used as a vehicle for topical, oral, and some intravenous pharmaceutical preparations in the U.S. and in Europe.

## Contents

### Structure

### Production

Industrial

Laboratory

### Applications

Polymers

Food & Drug

Antifreeze

Electronic cigarettes liquid

### Miscellaneous applications

### Safety in humans

Oral administration

Skin, eye and inhalation contact

Intravenous administration

Animals

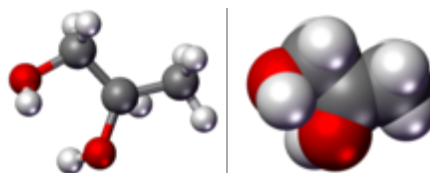
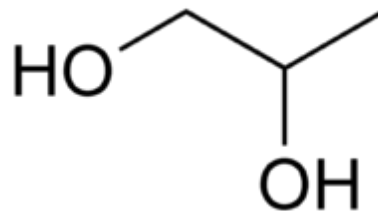
Allergic reaction

### Environmental

### References

### External links

## Propylene glycol<sup>[1]</sup>



### Names

Preferred IUPAC name

Propane-1,2-diol

Other names

Propylene glycol

α-Propylene glycol

1,2-Propanediol

1,2-Dihydroxypropane

Methyl ethyl glycol

Methylethylene glycol

### Identifiers

CAS Number

57-55-6 ([https://commonchemistry.cas.org/detail?cas\\_rn=57-55-6](https://commonchemistry.cas.org/detail?cas_rn=57-55-6)) racemic ✓

4254-15-3 ([https://commonchemistry.cas.org/detail?cas\\_rn=4254-15-3](https://commonchemistry.cas.org/detail?cas_rn=4254-15-3)) S-enantiomer

3D model (JSmol)

Interactive image (<https://chemapps.stolaf.edu/jmol/jmol.php?model=CC%28O%29CO>)

ChEBI

CHEBI:16997 (<https://www.ebi.ac.uk/chem>)

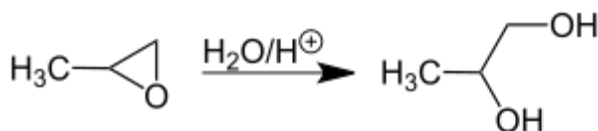
## Structure

The compound is sometimes called (alpha)  **$\alpha$ -propylene glycol** to distinguish it from the isomer propane-1,3-diol, known as (beta)  $\beta$ -propylene glycol. Propylene glycol is chiral. Commercial processes typically use the racemate. The S-isomer is produced by biotechnological routes.

## Production

### Industrial

Industrially, propylene glycol is mainly produced from propylene oxide (for food-grade use). According to a 2018 source, 2.16 M tonnes are produced annually.<sup>[4]</sup> Manufacturers use either non-catalytic high-temperature process at 200 °C (392 °F) to 220 °C (428 °F), or a catalytic method, which proceeds at 150 °C (302 °F) to 180 °C (356 °F) in the presence of ion exchange resin or a small amount of sulfuric acid or alkali.<sup>[5]</sup>



Final products contain 20% propylene glycol, 1.5% of dipropylene glycol, and small amounts of other polypropylene glycols.<sup>[6]</sup> Further purification produces finished industrial grade or USP/JP/EP/BP grade propylene glycol that is typically 99.5% or greater. Use of USP (US Pharmacopoeia) propylene glycol can reduce the risk of Abbreviated New Drug Application (ANDA) rejection.<sup>[7]</sup>

Propylene glycol can also be obtained from glycerol, a byproduct from the production of biodiesel.<sup>[4]</sup> This starting material is usually reserved for industrial use because of the noticeable odor and taste that accompanies the final product.

### Laboratory

S-Propanediol is synthesized via fermentation methods. Lactic acid and lactaldehyde are common intermediates. Dihydroxyacetone phosphate, one of the two products of breakdown (glycolysis) of fructose 1,6-bisphosphate, is a precursor to methylglyoxal. This conversion is the basis of a potential biotechnological route to the commodity chemical 1,2-propanediol. Three-carbon deoxysugars are also precursor to the 1,2-diol.<sup>[4]</sup>

A small-scale, nonbiological route from D-mannitol is illustrated in the following scheme:<sup>[8]</sup>

	<a href="https://pubchem.ncbi.nlm.nih.gov/compound/16997">ebi/searchId.do?chebild=16997</a> ✓
<a href="#">ChEMBL</a>	<a href="https://www.ebi.ac.uk/chembl/index.php/compound/inspect/ChEMBL286398">ChEMBL286398</a> ( <a href="https://www.ebi.ac.uk/chembl/index.php/compound/inspect/ChEMBL286398">https://www.ebi.ac.uk/chembl/index.php/compound/inspect/ChEMBL286398</a> ) ✓
<a href="#">ChemSpider</a>	<a href="http://www.chemspider.com/Chemical-Structure.13835224.html">13835224</a> ( <a href="http://www.chemspider.com/Chemical-Structure.13835224.html">http://www.chemspider.com/Chemical-Structure.13835224.html</a> ) ✓
<a href="#">ECHA InfoCard</a>	<a href="https://echa.europa.eu/substance-information/-/substanceinfo/100.000.307">100.000.307</a> ( <a href="https://echa.europa.eu/substance-information/-/substanceinfo/100.000.307">https://echa.europa.eu/substance-information/-/substanceinfo/100.000.307</a> ) ✓
<a href="#">EC Number</a>	200-338-0
<a href="#">E number</a>	E1520 (additional chemicals)
<a href="#">PubChem CID</a>	<a href="https://pubchem.ncbi.nlm.nih.gov/compound/1030">1030</a> ( <a href="https://pubchem.ncbi.nlm.nih.gov/compound/1030">https://pubchem.ncbi.nlm.nih.gov/compound/1030</a> )
<a href="#">RTECS number</a>	TY6300000
<a href="#">UNII</a>	<a href="https://fdasis.nlm.nih.gov/srs/srsdirect.jsp?regn=6DC9Q167V3">6DC9Q167V3</a> ( <a href="https://fdasis.nlm.nih.gov/srs/srsdirect.jsp?regn=6DC9Q167V3">https://fdasis.nlm.nih.gov/srs/srsdirect.jsp?regn=6DC9Q167V3</a> ) ✓ <a href="https://fdasis.nlm.nih.gov/srs/srsdirect.jsp?regn=942194N4TD">942194N4TD</a> ( <a href="https://fdasis.nlm.nih.gov/srs/srsdirect.jsp?regn=942194N4TD">https://fdasis.nlm.nih.gov/srs/srsdirect.jsp?regn=942194N4TD</a> ) (S enantiomer) ✓
<a href="#">CompTox Dashboard (EPA)</a>	<a href="https://comptox.epa.gov/dashboard/DTXSID0021206">DTXSID0021206</a> ( <a href="https://comptox.epa.gov/dashboard/DTXSID0021206">https://comptox.epa.gov/dashboard/DTXSID0021206</a> ) ✓
<a href="#">InChI</a>	InChI=1S/C3H8O2/c1-3(5)2-4/h3-5H,2H2,1H3 ✓ Key: DNIAPMSPWPWGF-UHFFFAOYSA-N ✓
<a href="#">SMILES</a>	

CC(O)CO


### Properties

<u>Chemical formula</u>	C <sub>3</sub> H <sub>8</sub> O <sub>2</sub>
<u>Molar mass</u>	76.095 g·mol <sup>-1</sup>
<u>Appearance</u>	colourless liquid
<u>Odor</u>	odorless
<u>Density</u>	1.036 g/cm <sup>3</sup>
<u>Melting point</u>	-59 °C (-74 °F; 214 K)
<u>Boiling point</u>	188.2 °C (370.8 °F; 461.3 K)
<u>Solubility in water</u>	Miscible
<u>Solubility in ethanol</u>	Miscible
<u>Solubility in diethyl ether</u>	Miscible
<u>Solubility in acetone</u>	Miscible
<u>Solubility in chloroform</u>	Miscible
<u>log <i>P</i></u>	-1.34 <sup>[2]</sup>
<u>Thermal conductivity</u>	0.34 W/m-K (50% H <sub>2</sub> O @ 90 °C (194 °F))
<u>Viscosity</u>	0.042 Pa·s

### Pharmacology

<u>ATCvet code</u>	QA16QA01 (WHO ( <a href="https://www.whocc.no/atcvet/atcvet_index/?code=QA16QA01">https://www.whocc.no/atcvet/atcvet_index/?code=QA16QA01</a> ))
--------------------	--

### Hazards

<u>S-phrases</u> <i>(outdated)</i>	<u>S24</u> <u>S25</u>
<b>NFPA 704</b> (fire diamond)	

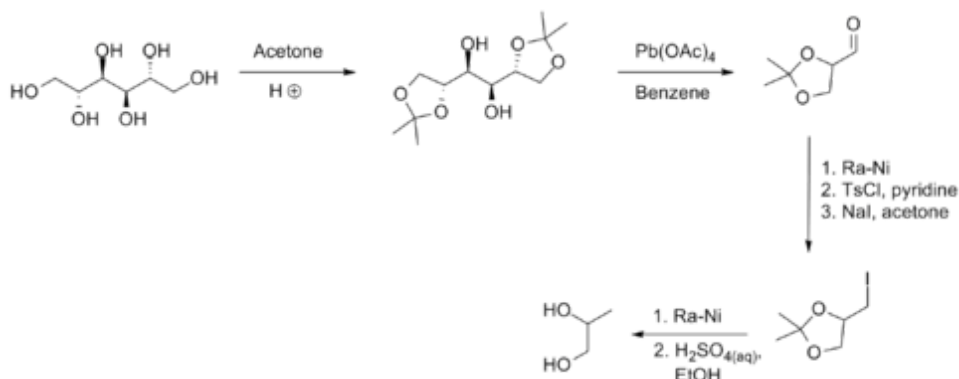
### Related compounds

<u>Related glycols</u>	Ethylene glycol, <u>1,3-propanediol</u>
------------------------	---

Except where otherwise noted, data are given for materials in their standard state (at 25 °C [77 °F], 100 kPa).

✓ verify (what is ✓✗ ?)

[Infobox references](#)



## Applications

### Polymers

Forty-five percent of propylene glycol produced is used as a chemical feedstock for the production of unsaturated polyester resins. In this regard, propylene glycol reacts with a mixture of unsaturated maleic anhydride and isophthalic acid to give a copolymer. This partially unsaturated polymer undergoes further crosslinking to yield thermoset plastics. Related to this application, propylene glycol reacts with propylene oxide to give oligomers and polymers that are used to produce polyurethanes.<sup>[4]</sup> Propylene glycol is used in waterbased acrylic architectural paints to extend dry time which it accomplishes by preventing the surface from drying due to its slower evaporation rate compared to water.

### Food & Drug

Propylene glycol is also used in various edible items such as coffee-based drinks, liquid sweeteners, ice cream, whipped dairy products and soda.<sup>[9][10]</sup> Vaporizers used for delivery of pharmaceuticals or personal-care products often include propylene glycol among the ingredients.<sup>[4]</sup> In alcohol-based hand sanitizers, it is used as a humectant to prevent the skin from drying.<sup>[11]</sup> Propylene glycol is used as a solvent in many pharmaceuticals, including oral, injectable, and topical formulations. Many pharmaceutical drugs which are insoluble in water utilize propylene glycol as a solvent and carrier; benzodiazepine tablets are one example.<sup>[12]</sup> Propylene glycol is also used as a solvent and carrier for many pharmaceutical capsule preparations. Additionally, certain formulations of artificial tears use propylene glycol as an ingredient.<sup>[13]</sup>

### Antifreeze

The freezing point of water is depressed when mixed with propylene glycol. It is used as aircraft de-icing fluid.<sup>[4][14]</sup> Water-propylene glycol mixtures dyed pink to indicate the mixture is relatively nontoxic are sold under the name of RV or marine antifreeze. Propylene glycol is frequently used as a substitute for ethylene glycol in low toxicity, environmentally friendly automotive antifreeze. It is also used to winterize the plumbing

systems in vacant structures.<sup>[15]</sup> The eutectic composition/temperature is 60:40 propylene glycol:water/-60 °C.<sup>[16][17]</sup> The -50 °F/-45 °C commercial product is, however, water rich; a typical formulation is 40:60.<sup>[18]</sup>

## Electronic cigarettes liquid

Along with vegetable glycerin as the main ingredient (<1–92%) in e-liquid used in electronic cigarettes, where it is aerosolized to resemble smoke. It serves as both the carrier for substances like nicotine and cannabinoids, as well as for creating a vapor which resembles smoke.<sup>[19]</sup>

## Miscellaneous applications

---

- As a solvent for many substances, both natural and synthetic.<sup>[20]</sup>
- As a humectant (E1520).
- As a freezing point depressant for slurry ice.
- In veterinary medicine as an oral treatment for hyperketonaemia in ruminants.<sup>[21]</sup>
- In the cosmetics industry, where propylene glycol is very commonly used as a carrier or base for various types of makeup.<sup>[22]</sup>
- For trapping and preserving insects (including as a DNA preservative).<sup>[23]</sup>
- For the creation of theatrical smoke and fog in special effects for film and live entertainment. So-called 'smoke machines' or 'hazers' vaporize a mixture of propylene glycol and water to create the illusion of smoke. While many of these machines use a propylene glycol-based fuel, some use oil. Those which use propylene glycol do so in a process that is identical to how electronic cigarettes work; utilizing a heating element to produce a dense vapor. The vapor produced by these machines has the aesthetic look and appeal of smoke, but without exposing performers and stage crew to the harms and odors associated with actual smoke.<sup>[24][25]</sup>
- As an additive in PCR to reduce the melting temperature of nucleic acids for targeting of GC rich sequences.

## Safety in humans

---

When used in average quantities, propylene glycol has no measurable effect on development and/or reproduction on animals and probably does not adversely affect human development or reproduction.<sup>[26]</sup> The safety of electronic cigarettes—which utilize propylene glycol-based preparations of nicotine or THC and other cannabinoids—is the subject of much controversy.<sup>[27][28][29]</sup> Vitamin E acetate has also been identified in this controversy.

## Oral administration



Propylene glycol is commonly used to de-ice aircraft



A bottle of flavored e-liquid for vaping shows propylene glycol as one of the main ingredients along with vegetable glycerin.

The acute oral toxicity of propylene glycol is very low, and large quantities are required to cause perceptible health effects in humans; in fact, propylene glycol is three times less toxic than ethanol.<sup>[30]</sup> Propylene glycol is metabolized in the human body into pyruvic acid (a normal part of the glucose-metabolism process, readily converted to energy), acetic acid (handled by ethanol-metabolism), lactic acid (a normal acid generally abundant during digestion),<sup>[31]</sup> and propionaldehyde (a potentially hazardous substance).<sup>[32][33][34]</sup> According to the Dow Chemical Company, The LD<sub>50</sub> (Lethal Dose that kills in 50% of tests) for rats is 20 g/kg (rat/oral).<sup>[35][36]</sup>

Toxicity generally occurs at plasma concentrations over 4 g/L, which requires extremely high intake over a relatively short period of time, or when used as a vehicle for drugs or vitamins given intravenously or orally in large bolus doses.<sup>[37]</sup> It would be nearly impossible to reach toxic levels by consuming foods or supplements, which contain at most 1 g/kg of PG, except for alcoholic beverages in the US which are allowed 5 percent = 50g/kg.<sup>[38]</sup> Cases of propylene glycol poisoning are usually related to either inappropriate intravenous administration or accidental ingestion of large quantities by children.<sup>[39]</sup>

The potential for long-term oral toxicity is also low. In an NTP continuous breeding study, no effects on fertility were observed in male or female mice that received propylene glycol in drinking water at doses up to 10,100 mg/kg bw/day. No effects on fertility were seen in either the first or second generation of treated mice.<sup>[26]</sup> In a 2-year study, 12 rats were provided with feed containing as much as 5% propylene glycol, and showed no apparent ill effects.<sup>[40]</sup> Because of its low chronic oral toxicity, propylene glycol was classified by the U. S. Food and Drug Administration as "generally recognized as safe" (GRAS) for use as a direct food additive, including frozen foods such as ice cream and frozen desserts.<sup>[38][41]</sup> The GRAS designation is specific to its use in food, and does not apply to other uses.<sup>[42]</sup>

## Skin, eye and inhalation contact

Propylene glycol is essentially non-irritating to the skin.<sup>[43]</sup> Undiluted propylene glycol is minimally irritating to the eye, producing slight transient conjunctivitis; the eye recovers after the exposure is removed. A 2018 human volunteer study found that 10 male and female subjects undergoing 4 hours exposures to concentrations of up to 442 mg/m<sup>3</sup> and 30 minutes exposures to concentrations of up to 871 mg/m<sup>3</sup> in combination with moderate exercise did not show pulmonary function deficits, or signs of ocular irritation, with only slight symptoms of respiratory irritation reported.<sup>[44]</sup> Inhalation of propylene glycol vapors appears to present no significant hazard in ordinary applications.<sup>[45]</sup> Due to the lack of chronic inhalation data, it is recommended that propylene glycol not be used in inhalation applications such as theatrical productions, or antifreeze solutions for emergency eye wash stations.<sup>[46]</sup> Recently, propylene glycol (commonly alongside glycerol) has been included as a carrier for nicotine and other additives in e-cigarette liquids, the use of which presents a novel form of exposure. The potential hazards of chronic inhalation of propylene glycol or the latter substance as a whole are as-yet unknown.<sup>[47]</sup>



Propylene glycol is often used in electronic cigarettes.

According to a 2010 study, the concentrations of PGEs (counted as the sum of propylene glycol and glycol ethers) in indoor air, particularly bedroom air, has been linked to increased risk of developing numerous respiratory and immune disorders in children, including asthma, hay fever, eczema, and allergies, with increased risk ranging from 50% to 180%. This concentration has been linked to use of water-based paints and water-based system cleansers. However, the study authors write that glycol ethers and not propylene glycol are the likely culprit.<sup>[48][49][50]</sup>



Propylene glycol has not caused sensitization or carcinogenicity in laboratory animal studies, nor has it demonstrated genotoxic potential.<sup>[51][52]</sup>

## Intravenous administration

Studies with intravenously administered propylene glycol have resulted in LD50 values in rats and rabbits of 7 mL/kg BW.<sup>[53]</sup> Ruddick (1972) also summarized intramuscular LD50 data for rat as 13-20 mL/kg BW, and 6 mL/kg BW for the rabbit. Adverse effects to intravenous administration of drugs that use propylene glycol as an excipient have been seen in a number of people, particularly with large bolus dosages. Responses may include CNS depression, "hypotension, bradycardia, QRS and T abnormalities on the ECG, arrhythmia, cardiac arrhythmias, seizures, agitation, serum hyperosmolality, lactic acidosis, and haemolysis".<sup>[54]</sup> A high percentage (12% to 42%) of directly-injected propylene glycol is eliminated or secreted in urine unaltered depending on dosage, with the remainder appearing in its glucuronide-form. The speed of renal filtration decreases as dosage increases,<sup>[55]</sup> which may be due to propylene glycol's mild anesthetic / CNS-depressant - properties as an alcohol.<sup>[56]</sup> In one case, intravenous administration of propylene glycol-suspended nitroglycerin to an elderly man may have induced coma and acidosis.<sup>[57]</sup> However, no confirmed lethality from propylene glycol was reported.

## Animals

Propylene glycol is an approved food additive for dog and sugar glider food under the category of animal feed and is generally recognized as safe for dogs,<sup>[58]</sup> with an LD<sub>50</sub> of 9 mL/kg. The LD<sub>50</sub> is higher for most laboratory animals (20 mL/kg).<sup>[59]</sup> However, it is prohibited for use in food for cats due to links to Heinz body formation and a reduced lifespan of red blood cells.<sup>[60]</sup> Heinz body formation from MPG has not been observed in dogs, cattle, or humans.

## Allergic reaction

Estimates on the prevalence of propylene glycol allergy range from 0.8% (10% propylene glycol in aqueous solution) to 3.5% (30% propylene glycol in aqueous solution).<sup>[61][62][63]</sup> The North American Contact Dermatitis Group (NACDG) data from 1996 to 2006 showed that the most common site for propylene glycol contact dermatitis was the face (25.9%), followed by a generalized or scattered pattern (23.7%).<sup>[61]</sup> Investigators believe that the incidence of allergic contact dermatitis to propylene glycol may be greater than 2% in patients with eczema or fungal infections, which are very common in countries with lesser sun exposure and lower-than-normal vitamin D balances. Therefore, propylene glycol allergy is more common in those countries.<sup>[64]</sup>

Because of its potential for allergic reactions and frequent use across a variety of topical and systemic products, propylene glycol was named the American Contact Dermatitis Society's Allergen of the Year for 2018.<sup>[65][66]</sup> Recent publication from The Mayo Clinic reported 0.85% incidence of positive patch tests to propylene glycol (100/11,738 patients) with an overall irritant rate of 0.35% (41/11,738 patients) during a 20-year period of 1997–2016.<sup>[67]</sup> 87% of the reactions were classified as weak and 9% as strong. The positive reaction rates were 0%, 0.26%, and 1.86% for 5%, 10%, and 20% propylene glycol respectively, increasing with each concentration increase. The irritant reaction rates were 0.95%, 0.24%, and 0.5% for 5%, 10%, and 20% propylene glycol, respectively. Propylene glycol skin sensitization occurred in patients sensitive to a number of other concomitant positive allergens, most common of which were: Myroxylon pereirae resin, benzalkonium chloride, carba mix, potassium dichromate, neomycin sulfate; for positive propylene glycol reactions, the overall median of 5 and mean of 5.6 concomitant positive allergens was reported.

# Environmental

---

Propylene glycol occurs naturally, probably as the result of anaerobic catabolism of sugars in the human gut. It is degraded by vitamin B12-dependent enzymes, which convert it to propionaldehyde.<sup>[68]</sup>

Propylene glycol is expected to degrade rapidly in water from biological processes, but is not expected to be significantly influenced by hydrolysis, oxidation, volatilization, bioconcentration, or adsorption to sediment.<sup>[69]</sup> Propylene glycol is readily biodegradable under aerobic conditions in freshwater, in seawater and in soil. Therefore, propylene glycol is considered as not persistent in the environment.

Propylene glycol exhibits a low degree of toxicity toward aquatic organisms. Several guideline studies available for freshwater fish with the lowest observed effect concentration of 96-h LC50 value of 40,613 mg/l in a study with *Oncorhynchus mykiss*. Similarly, the effect concentration determined in marine fish is a 96-h LC50 of >10,000 mg/l in *Scophthalmus maximus*.

## References

---

1. *The Merck Index: An Encyclopedia of Chemicals, Drugs, and Biologicals* (<https://archive.org/details/merckindexency00buda>). Merck & Co. 1989. ISBN 978-0911910285.
2. "Propylene Glycol\_msd" ([https://www.chemsrc.com/en/cas/57-55-6\\_674628.html](https://www.chemsrc.com/en/cas/57-55-6_674628.html)).
3. "PROPYLENE GLYCOL - CAMEO Chemicals" (<http://cameochemicals.noaa.gov/chemical/9030>). NOAA Office of Response and Restoration. NOAA. Retrieved 3 October 2018.
4. Sullivan, Carl J.; Kuenz, Anja; Vorlop, Klaus-Dieter (2018). "Propanediols". *Ullmann's Encyclopedia of Industrial Chemistry*. Weinheim: Wiley-VCH. doi:10.1002/14356007.a22\_163.pub2 ([https://doi.org/10.1002%2F14356007.a22\\_163.pub2](https://doi.org/10.1002%2F14356007.a22_163.pub2)).
5. Chauvel, Alain; Lefebvre, Gilles (1989). *Petrochemical Processes*. Volume 2: Major Oxygenated, Chlorinated and Nitrated Derivatives. Editions Technip. p. 26. ISBN 9782710805632.
6. "1,2-propanediol: chemical product info at CHEMINDUSTRY.RU" (<http://chemindustry.ru/1,2-Propanediol.php>). Retrieved 3 October 2018.
7. "Propylene Glycol USP" (<https://berrymanchemical.com/blog/propylene-glycol-usp/>). Berryman Chemical. 2020-07-20. Retrieved 2020-07-28.
8. Hanessian, Stephen (1983). *Total Synthesis of Natural Products: The 'Chiron' Approach*. Pergamon press. p. 41. ISBN 978-0080307152.
9. "Quackmail: Why You Shouldn't Fall For The Internet's Newest Fool, The Food Babe" (<https://www.forbes.com/sites/trevorbutterworth/2014/06/16/quackmail-why-you-shouldnt-fall-for-the-internets-newest-fool-the-food-babe/>). Butterworth, Trevor. Forbes. 16 June 2014. Retrieved 18 March 2015.
10. G. Jackson, R. T. Roberts and T. Wainwright (January 1980). "Mechanism of Beer Foam Stabilization by Propylene Glycol Alginate". *Journal of the Institute of Brewing*. **86** (1): 34–37. doi:10.1002/j.2050-0416.1980.tb03953.x (<https://doi.org/10.1002%2Fj.2050-0416.1980.tb03953.x>).
11. Lohrey, Jackie. "Ingredients in Hand Sanitizer" (<https://www.livestrong.com/article/164674-ingredients-in-hand-sanitizer/>). LIVESTRONG.COM. Retrieved 2018-06-11.
12. Janusz Szajewski, MD, Warsaw Poison Control Centre (August 1991). "Propylene glycol (PIM 443)" (<http://www.inchem.org/documents/pims/chemical/pim443.htm>). IPCS INChem. Retrieved July 2, 2009.



13. Pucker AD, Ng SM, Nichols JJ (2016). "Over the counter (OTC) artificial tear drops for dry eye syndrome" (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5045033>). *Cochrane Database Syst Rev.* **2**: CD009729. doi:10.1002/14651858.CD009729.pub2 (<https://doi.org/10.1002%2F14651858.CD009729.pub2>). PMID 26905373 (<https://pubmed.ncbi.nlm.nih.gov/26905373>).
14. "What's That Stuff? Aircraft Deicers" (<http://pubs.acs.org/cen/whatstuff/stuff/7901scit5.html>). *Chemical & Engineering News*. American Chemical Society. 2000-07-10. Retrieved 2013-06-21.
15. "5 Ways to Winterize a Vacant Home" (<https://www.wikihow.com/Winterize-a-Vacant-Home>). wikiHow. 2012-06-11. Retrieved 2014-02-27.
16. "Properties of Some Particular Solutions" (<http://webserver.dmt.upm.es/~isidoro/bk3/c07sol/Solution%20properties.pdf>) (PDF). Portal del DMT. Retrieved 2014-02-27.
17. Salnick, Robert (2010-08-04). "Windborne in Puget Sound: Why does a holding plate work?" (<http://windborneinpugetsound.blogspot.com/2010/08/why-does-holding-plate-work.html>). Windborneinpugetsound.blogspot.com. Retrieved 2014-02-27.
18. "Material Safety Data Sheet: Winter Care RV Antifreeze" ([http://www.chemicalspec.com/Winter\\_Care\\_4060\\_RV\\_Antifreeze.pdf](http://www.chemicalspec.com/Winter_Care_4060_RV_Antifreeze.pdf)) (PDF). Chemical Specialties. Retrieved 2014-02-27.
19. Simon, Harvey (2011-09-22). "Electronic cigarettes: Help or hazard?" (<http://www.health.harvard.edu/blog/electronic-cigarettes-help-or-hazard-201109223395>). Harvard Medical School - Harvard Health Publications. Retrieved Sep 22, 2011.
20. Bradley, Jean-Claude; Abraham, Michael H; Acree, William E; Lang, Andrew (2015). "Predicting Abraham model solvent coefficients" (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4369285>). *Chemistry Central Journal.* **9** (1): 12. doi:10.1186/s13065-015-0085-4 (<https://doi.org/10.1186%2Fs13065-015-0085-4>). ISSN 1752-153X (<https://www.worldcat.org/issn/1752-153X>). PMID 25798192 (<https://pubmed.ncbi.nlm.nih.gov/25798192>).
21. Nielsen, Nicolaj (2004). "Propylene glycol for dairy cows" (<https://www.researchgate.net/publication/248332819>). *Animal Feed Science and Technology.* **115** (3–4): 191–213. doi:10.1016/j.anifeedsci.2004.03.008 (<https://doi.org/10.1016%2Fj.anifeedsci.2004.03.008>).
22. Fiume, Monice M.; Bergfeld, Wilma F.; Belsito, Donald V.; et al. (September 2012). "Safety assessment of propylene glycol, tripropylene glycol, and PPGs as used in cosmetics". *International Journal of Toxicology.* **31** (5 Suppl): 245S–60S. doi:10.1177/1091581812461381 (<https://doi.org/10.1177%2F1091581812461381>). ISSN 1092-874X (<https://www.worldcat.org/issn/1092-874X>). PMID 23064775 (<https://pubmed.ncbi.nlm.nih.gov/23064775>). S2CID 24754435 (<https://api.semanticscholar.org/CorpusID:24754435>).
23. Rubin, Benjamin E. R.; Czekanski-Moir, Jesse E.; Wray, Brian D.; Moreau, Corrie S. (2013-03-13). "DNA preservation: a test of commonly used preservatives for insects". *Invertebrate Systematics.* **27** (1): 81–86. doi:10.1071/IS12067 (<https://doi.org/10.1071%2FIS12067>). ISSN 1447-2600 (<https://www.worldcat.org/issn/1447-2600>). S2CID 4820463 (<https://api.semanticscholar.org/CorpusID:4820463>).
24. Nevada Film Office (February 19, 2019). "Production Notes: Haze Machines" (<https://nevadafilm.com/production-notes-haze-machines/>). *nevadafilm.com*. Retrieved November 1, 2019.
25. Daniel, Brea (July 15, 2016). "Atmosphere: Hazers, Fazers, Smoke and Fog 101 by Daniel Brea" (<https://web.archive.org/web/20160719141901/http://www.provideocoalition.com/atmosphere101>). *provideocoalition.com*. Archived from the original (<https://www.provideocoalition.com/atmosphere101>) on 2016-07-19. Retrieved November 1, 2019.
26. National Toxicology Program NIEHS (2004). "NTP-CERHR Monograph on the Potential Human Reproductive and Developmental Effects of Propylene Glycol". NIH Publication No. 04-4482.
27. CDC (March 11, 2019). "Electronic Cigarettes" ([https://www.cdc.gov/tobacco/basic\\_information/e-cigarettes/index.htm](https://www.cdc.gov/tobacco/basic_information/e-cigarettes/index.htm)).
28. Havelka, Jacqueline (April 27, 2017). "Is Vaping Safe?" (<https://www.leafly.com/news/health/vaping-vs-smoking-marijuana-safety>). *leafly.com*.

29. Peki, Winston (May 5, 2019). "Are Vaporizers Safe?" (<https://www.herbonaut.com/are-vaporizers-safe/>). *herbonaut.com*.
30. Lehman A, Newman H (1937). "Propylene glycol: Rate of metabolism absorption, and excretion, with a method for estimation in body fluids". *J Pharmacol Exp Ther.* **60**: 312–322.
31. Hamilton, D. J. (1890). "Gastric Dyspepsia". *The Lancet.* **2** (3493): 306. doi:10.1016/S0140-6736(02)17110-8 (<https://doi.org/10.1016%2FS0140-6736%2802%2917110-8>).
32. "Material Safety Data Sheet Propionaldehyde MSDS" ([http://www.sciencelab.com/msds.php?m\\_sdsId=9924730](http://www.sciencelab.com/msds.php?m_sdsId=9924730)). ScienceLab.com. 2010.
33. Miller DN, Bazzano G; Bazzano (1965). "Propanediol metabolism and its relation to lactic acid metabolism". *Ann NY Acad Sci.* **119** (3): 957–973. Bibcode:1965NYASA.119..957M (<https://ui.adsabs.harvard.edu/abs/1965NYASA.119..957M>). doi:10.1111/j.1749-6632.1965.tb47455.x (<https://doi.org/10.1111%2Fj.1749-6632.1965.tb47455.x>). PMID 4285478 (<https://pubmed.ncbi.nlm.nih.gov/4285478>). S2CID 37769342 (<https://api.semanticscholar.org/CorpusID:37769342>).
34. Ruddick JA (1972). "Toxicology, metabolism, and biochemistry of 1,2-propanediol". *Toxicol Appl Pharmacol.* **21** (1): 102–111. doi:10.1016/0041-008X(72)90032-4 (<https://doi.org/10.1016%2F0041-008X%2872%2990032-4>). PMID 4553872 (<https://pubmed.ncbi.nlm.nih.gov/4553872>).
35. rocklinusd. "Lethal dose table" ([http://whs.rocklinusd.org/documents/Science/Lethal\\_Dose\\_Table.pdf](http://whs.rocklinusd.org/documents/Science/Lethal_Dose_Table.pdf)) (PDF).
36. Alton E. Martin - Frank H. Murphy DOW CHEMICAL COMPANY. "GLYCOLS - PROPYLENE GLYCOLS" ([http://msdssearch.dow.com/PublishedLiteratureDOWCOM/dh\\_006e/0901b8038006e13c.pdf?filepath=propyleneglycol/pdfs/noreg/117-01785.pdf&fromPage=GetDoc](http://msdssearch.dow.com/PublishedLiteratureDOWCOM/dh_006e/0901b8038006e13c.pdf?filepath=propyleneglycol/pdfs/noreg/117-01785.pdf&fromPage=GetDoc)) (PDF).
37. Flanagan RJ; Braithwaite RA; Brown SS; et al. The International Programme on Chemical Safety: Basic Analytical Toxicology. WHO, 1995.
38. U.S. Food and Drug Administration (FDA). "Subchapter B - Food for Human Consumption. § 184.1666. Propylene glycol." *Code of Federal Regulations*, **21 CFR 184.1666** (<https://ecfr.federalregister.gov/current/title-21/section-184.1666>)
39. National Library of Medicine; Propylene glycol is used in antifreezes Human Toxicity Excerpts: CAS Registry Number: 57-55-6 (1,2-Propylene Glycol). Selected toxicity information from HSDB. 2005.
40. Gaunt, I. F.; Carpanini, F. M. B.; Grasso, P.; Lansdown, A. B. G. (1972). "Long-term toxicity of propylene glycol in rats". *Food and Cosmetics Toxicology.* **10** (2): 151–162. doi:10.1016/S0015-6264(72)80193-7 (<https://doi.org/10.1016%2FS0015-6264%2872%2980193-7>). PMID 5072816 (<https://pubmed.ncbi.nlm.nih.gov/5072816>).
41. "Database of Select Committee on GRAS Substances (SCOGS) Reviews" (<http://www.accessdata.fda.gov/scripts/fcn/fcnDetailNavigation.cfm?rpt=scogslisting&id=262>). FDA. Retrieved 2016-05-11.
42. FDA. "Subchapter B - Food for Human Consumption. § 182.1. Substances that are generally recognized as safe." *Code of Federal Regulations*, **21 CFR 182.1** (<https://ecfr.federalregister.gov/current/title-21/section-182.1>)
43. Agency for Toxic Substances and Disease Registry (2008). "Addendum to the Toxicological Profile for Propylene Glycol": 7.
44. Dalton P; Soreth B; Maute C; et al. (2018). "Lack of respiratory and ocular effects following acute propylene glycol exposure in healthy humans". *Inhal. Toxicol.* **30** (3): 124–132. doi:10.1080/08958378.2018.1470207 (<https://doi.org/10.1080%2F08958378.2018.1470207>). PMID 29764241 (<https://pubmed.ncbi.nlm.nih.gov/29764241>). S2CID 21711274 (<https://api.semanticscholar.org/CorpusID:21711274>).
45. Robertson, OH; Loosli, CG; Puck, TT; et al. (September 1947). "Tests for the chronic toxicity of propylene glycol and triethylene glycol on monkeys and rats by vapor inhalation and oral administration" (<http://jpet.aspetjournals.org/content/91/1/52.abstract>). *Journal of Pharmacology and Experimental Therapeutics.* **91** (1): 52–76. PMID 20265820 (<https://pubmed.ncbi.nlm.nih.gov/20265820>). "air containing these vapors in amounts up to the saturation point is completely harmless"

46. A Guide to Glycols ([http://msdssearch.dow.com/PublishedLiteratureDOWCOM/dh\\_091b/0901b8038091b508.pdf?filepath=propyleneglycol/pdfs/noreg/117-01682.pdf](http://msdssearch.dow.com/PublishedLiteratureDOWCOM/dh_091b/0901b8038091b508.pdf?filepath=propyleneglycol/pdfs/noreg/117-01682.pdf)), Dow, page 36
47. <https://vapingcheap.com/vaping-vs-smoking/#tab-con-1>
48. "Everyday Substances Increase Risk of Allergies in Children, Swedish Study Reveals" (<https://www.sciencedaily.com/releases/2010/10/101019084607.htm>). *ScienceDaily*. Oct 19, 2010.
49. "Chemical Compounds Emitted From Common Household Paints and Cleaners Increase Risks of Asthma and Allergies in Children" (<http://www.hsph.harvard.edu/news/features/features/paint-s-cleaners-children-asthma-allergy.html>). Harvard. Retrieved 3 October 2018.
50. Choi, Hyunok; Norbert Schmidbauer; Jan Sundell; et al. (2010-10-18). Hartl, Dominik (ed.). "Common Household Chemicals and the Allergy Risks in Pre-School Age Children" (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2956675>). *PLOS ONE*. **5** (10): e13423. Bibcode:2010PLoSO...513423C (<https://ui.adsabs.harvard.edu/abs/2010PLoSO...513423C>). doi:10.1371/journal.pone.0013423 (<https://doi.org/10.1371%2Fjournal.pone.0013423>). PMC 2956675 (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2956675>). PMID 20976153 (<http://pubmed.ncbi.nlm.nih.gov/20976153>).
51. 1,2-Dihydroxypropane SIDS Initial Assessment Profile <"Archived copy" (<https://web.archive.org/web/20090219045910/http://www.chem.unep.ch/irptc/sids/OECDSIDS/57-55-6.pdf>) (PDF). Archived from the original (<http://www.chem.unep.ch/irptc/sids/OECDSIDS/57-55-6.pdf>) (PDF) on 2009-02-19. Retrieved 2008-01-08.>, UNEP Publications, SIAM 11, U.S.A, January 23–26, 2001, page 21.
52. Title 21, U.S. Code of Federal Regulations. 1999.
53. Ruddick (1972). "Toxicology, metabolism, and biochemistry of 1,2-propanediol". *Toxicol Appl Pharmacol*. **21** (1): 102–111. doi:10.1016/0041-008X(72)90032-4 (<https://doi.org/10.1016%2F0041-008X%2872%2990032-4>). PMID 4553872 (<https://pubmed.ncbi.nlm.nih.gov/4553872>).
54. Szajewski, Janusz. "Propylene Glycol (PIM 443)." 1991. 2 June 2010 <http://www.inchem.org/documents/pims/chemical/pim443.htm#SectionTitle:9.1%20%20Acute%2>
55. Speth, P. A. J.; Vree, T. B.; Neilen, N. F. M.; et al. (1987). "Propylene Glycol Pharmacokinetics and Effects after Intravenous Infusion in Humans". *Therapeutic Drug Monitoring*. **9** (3): 255–258. doi:10.1097/00007691-198709000-00001 (<https://doi.org/10.1097%2F00007691-198709000-00001>). PMID 3672566 (<https://pubmed.ncbi.nlm.nih.gov/3672566>). S2CID 23317790 (<https://api.semanticscholar.org/CorpusID:23317790>).
56. Seidenfeld, M. A.; Hanzlik, P. J. (1932). "The general properties, actions, and toxicity of propylene glycol". *J Pharmacol Exp Ther*. **44**: 109–121.
57. Demey, H.; Daelemans, R.; De Broe, M.E.; Bossaert, L. (1984). "Propylene glycol intoxication due to intravenous nitroglycerin". *The Lancet*. **323** (8390): 1360. doi:10.1016/S0140-6736(84)91860-9 (<https://doi.org/10.1016%2FS0140-6736%2884%2991860-9>). ISSN 0140-6736 (<https://www.worldcat.org/issn/0140-6736>). PMID 6145062 (<https://pubmed.ncbi.nlm.nih.gov/6145062>). S2CID 36606490 (<https://api.semanticscholar.org/CorpusID:36606490>).
58. FDA. "Subchapter E - Animal Drugs, Feeds, and Related Products; § 582.1666. Propylene glycol." *Code of Federal Regulations*, 21 CFR 582.1666 (<https://ecfr.federalregister.gov/current/title-21/section-582.1666>)
59. Peterson, Michael; Talcott, Patricia A. (2006). *Small animal toxicology*. St. Louis: Saunders Elsevier. p. 997. ISBN 978-0-7216-0639-2.
60. "Propylene glycol and cats" (<https://web.archive.org/web/20150227043018/http://www.lyondellbasell.com/techlit/techlit/2275.pdf>) (PDF). Archived from the original (<http://www.lyondellbasell.com/techlit/techlit/2275.pdf>) (PDF) on 2015-02-27. Retrieved 2013-06-21.
61. Warshaw, Erin M.; Botto, Nina C.; Maibach, Howard I.; et al. (January 2009). "Positive patch-test reactions to propylene glycol: a retrospective cross-sectional analysis from the North American Contact Dermatitis Group, 1996 to 2006". *Dermatitis: Contact, Atopic, Occupational, Drug*. **20** (1): 14–20. doi:10.2310/6620.2008.08039 (<https://doi.org/10.2310%2F6620.2008.08039>). ISSN 2162-5220 (<https://www.worldcat.org/issn/2162-5220>). PMID 19321115 (<https://pubmed.ncbi.nlm.nih.gov/19321115>). S2CID 959002 (<https://api.semanticscholar.org/CorpusID:959002>).

62. Lessmann, Holger; Schnuch, Axel; Geier, Johannes; Uter, Wolfgang (November 2005). "Skin-sensitizing and irritant properties of propylene glycol" (<https://doi.org/10.1111%2Fj.0105-1873.2005.00693.x>). *Contact Dermatitis*. **53** (5): 247–259. doi:10.1111/j.0105-1873.2005.00693.x (<https://doi.org/10.1111%2Fj.0105-1873.2005.00693.x>). ISSN 0105-1873 (<https://www.worldcat.org/issn/0105-1873>). PMID 16283903 (<https://pubmed.ncbi.nlm.nih.gov/16283903>). S2CID 13006333 (<https://api.semanticscholar.org/CorpusID:13006333>).
63. Wetter, David A.; Yiannias, James A.; Prakash, Amy V.; et al. (November 2010). "Results of patch testing to personal care product allergens in a standard series and a supplemental cosmetic series: an analysis of 945 patients from the Mayo Clinic Contact Dermatitis Group, 2000-2007". *Journal of the American Academy of Dermatology*. **63** (5): 789–798. doi:10.1016/j.jaad.2009.11.033 (<https://doi.org/10.1016%2Fj.jaad.2009.11.033>). ISSN 1097-6787 (<https://www.worldcat.org/issn/1097-6787>). PMID 20643495 (<https://pubmed.ncbi.nlm.nih.gov/20643495>).
64. American Medical Association, Council on Drugs (1994). *AMA Drug Evaluations Annual 1994*: 1224. Missing or empty |title= (help)
65. Jacob, Sharon E.; Scheman, Andrew; McGowan, Maria A. (January–February 2018). "Propylene Glycol". *Dermatitis: Contact, Atopic, Occupational, Drug*. **29** (1): 3–5. doi:10.1097/DER.0000000000000315 (<https://doi.org/10.1097%2FDER.0000000000000315>). ISSN 2162-5220 (<https://www.worldcat.org/issn/2162-5220>). PMID 29059092 (<https://pubmed.ncbi.nlm.nih.gov/29059092>). S2CID 24598433 (<https://api.semanticscholar.org/CorpusID:24598433>).
66. "Allergen of the year may be nearer than you think" (<https://www.mdedge.com/clinicianreviews/article/176541/contact-dermatitis/allergen-year-may-be-nearer-you-think>). *www.mdedge.com*. Retrieved 2019-04-08.
67. Lalla SC; Nguyen H; Chaudhry H; et al. (2018). "Patch Testing to Propylene Glycol: The Mayo Clinic Experience". *Dermatitis*. **29** (4): 200–205. doi:10.1097/DER.0000000000000393 (<https://doi.org/10.1097%2FDER.0000000000000393>). PMID 29923851 (<https://pubmed.ncbi.nlm.nih.gov/29923851>). S2CID 49311147 (<https://api.semanticscholar.org/CorpusID:49311147>).
68. Leal, Nicole A.; Havemann, Gregory D.; Bobik, Thomas A. (2003). "PduP is a coenzyme-a-acylating propionaldehyde dehydrogenase associated with the polyhedral bodies involved in B<sub>12</sub>-dependent 1,2-propanediol degradation by *Salmonella enterica* serovar Typhimurium LT2". *Archives of Microbiology*. **180** (5): 353–361. doi:10.1007/s00203-003-0601-0 (<https://doi.org/10.1007%2Fs00203-003-0601-0>). PMID 14504694 (<https://pubmed.ncbi.nlm.nih.gov/14504694>). S2CID 44010353 (<https://api.semanticscholar.org/CorpusID:44010353>).
69. 1,2-Dihydroxypropane SIDS Initial Assessment Profile <"Archived copy" (<https://web.archive.org/web/20090219045910/http://www.chem.unep.ch/irptc/sids/OECDSIDS/57-55-6.pdf>) (PDF). Archived from the original (<http://www.chem.unep.ch/irptc/sids/OECDSIDS/57-55-6.pdf>) (PDF) on 2009-02-19. Retrieved 2008-01-08.>, UNEP Publications, SIAM 11, U.S.A, January 23–26, 2001, page 21.

## External links

---

- [1] (<https://www.atsdr.cdc.gov/phs/phs.asp?id=1120&tid=240>) Agency for Toxic Substances and Disease Registry
- [2] ([http://msdssearch.dow.com/PublishedLiteratureDOWCOM/dh\\_006e/0901b8038006e13c.pdf?filepath=propyleneglycol/pdfs/noreg/117-01785.pdf%26fromPage=GetDoc](http://msdssearch.dow.com/PublishedLiteratureDOWCOM/dh_006e/0901b8038006e13c.pdf?filepath=propyleneglycol/pdfs/noreg/117-01785.pdf%26fromPage=GetDoc)) Alton E. Martin - Frank H. Murphy, DOW CHEMICAL COMPANY
- Propylene glycol (<http://www.propylene-glycol.com>) website
- WebBook page for C<sub>3</sub>H<sub>8</sub>O<sub>2</sub> (<http://webbook.nist.gov/cgi/cbook.cgi?ID=C57556>)
- ATSDR - Case Studies in Environmental Medicine: Ethylene Glycol and Propylene Glycol Toxicity (<http://www.atsdr.cdc.gov/csem/csem.asp?csem=12&po=0>) U.S. Department of Health and Human Services (public domain)

- [Propylene Glycol - chemical product info: properties, production, applications. \(http://chemindustry.ru/1,2-Propanediol.php\)](http://chemindustry.ru/1,2-Propanediol.php)
  - [ChemSub Online: Propylene glycol \(http://chemsub.online.fr/name/propylene\\_glycol.html\)](http://chemsub.online.fr/name/propylene_glycol.html)
- 

Retrieved from "[https://en.wikipedia.org/w/index.php?title=Propylene\\_glycol&oldid=1017773620](https://en.wikipedia.org/w/index.php?title=Propylene_glycol&oldid=1017773620)"

---

**This page was last edited on 14 April 2021, at 14:51 (UTC).**

Text is available under the Creative Commons Attribution-ShareAlike License; additional terms may apply. By using this site, you agree to the Terms of Use and Privacy Policy. Wikipedia® is a registered trademark of the Wikimedia Foundation, Inc., a non-profit organization.