[Template:About](/wiki/Template:About" \o "Template:About) [Template:Pp-semi-indef](/wiki/Template:Pp-semi-indef) [Template:Pp-move-indef](/wiki/Template:Pp-move-indef) [Template:Use dmy dates](/wiki/Template:Use_dmy_dates) [180px|thumb|right|](/wiki/File:Alcohol.png)[Ball-and-stick model](/wiki/Ball-and-stick_model) of the hydroxyl (-OH) functional group in an alcohol molecule (R3COH). The three "R's" stand for carbon substituents or hydrogen atoms.[[1]](#cite_note-1)

[180px|thumb|right|The hydroxyl (-OH) functional group with bond angle](/wiki/File:Alcohol_general.svg) In [chemistry](/wiki/Chemistry), an **alcohol** is any [organic compound](/wiki/Organic_compound) in which the [hydroxyl](/wiki/Hydroxyl) [functional group](/wiki/Functional_group) (–[O](/wiki/Oxygen)[H](/wiki/Hydrogen)) is bound to a [saturated](/wiki/Saturation_(chemistry)) [carbon](/wiki/Carbon) atom.[[2]](#cite_note-2) The term alcohol originally referred to the primary alcohol [ethanol](/wiki/Ethanol) (ethyl alcohol), the predominant alcohol in [alcoholic beverages](/wiki/Alcoholic_beverage).

The suffix *-ol* appears in the [IUPAC chemical name](/wiki/IUPAC_nomenclature_of_organic_chemistry) of all substances where the hydroxyl group is the functional group with the highest priority; in substances where a higher priority group is present the prefix *hydroxy-* will appear in the [International Union of Pure and Applied Chemistry](/wiki/International_Union_of_Pure_and_Applied_Chemistry) (IUPAC) name. The suffix *-ol* in non-systematic names (such as [paracetamol](/wiki/Paracetamol) or [cholesterol](/wiki/Cholesterol)) also typically indicates that the substance includes a hydroxyl functional group and, so, can be termed an alcohol. But many substances, particularly sugars (examples [glucose](/wiki/Glucose) and [sucrose](/wiki/Sucrose)) contain hydroxyl functional groups without using the suffix. An important class of alcohols, of which [methanol](/wiki/Methanol) and ethanol are the simplest members is the [saturated straight chain](/wiki/Aliphatic_compound) alcohols, the general formula for which is CnH2n+1OH. [Template:TOC limit](/wiki/Template:TOC_limit)

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## Occurrence in nature[[edit](/index.php?title=(none)&action=edit&section=1)]

[Ethanol occurs naturally](/wiki/Ethanol#Natural_occurrence) as a byproduct of the [metabolic process](/wiki/Metabolism) of yeast. As such, ethanol will be present in any yeast habitat. Ethanol can commonly be found in overripe fruit.

[Methanol is produced naturally](/wiki/Methanol#Occurrence) in the [anaerobic](/wiki/Anaerobic_organism) [metabolism](/wiki/Metabolism) of many varieties of bacteria, and is commonly present in small amounts in the environment.

The person who discovered pure alcohol (Ethanol) by distilling wine was the Iranian/Persian alchemist [Muhammad ibn Zakariya al-Razi](/wiki/Muhammad_ibn_Zakariya_al-Razi) (854 CE – 925 CE).[[3]](#cite_note-3) Alcohols have been found outside the [Solar System](/wiki/Solar_System) in low densities in star and planetary-system-forming regions of space.[[4]](#cite_note-4)[[5]](#cite_note-5)

## Toxicity[[edit](/index.php?title=(none)&action=edit&section=2)]

[Template:Medref](/wiki/Template:Medref) [thumb|Ball-and-stick model of](/wiki/File:2-Methyl-2-butanol-3D-balls.png) [*tert*-Amyl alcohol](/wiki/Tert-Amyl_alcohol), which is 20 times more intoxicating than ethanol and like all tertiary alcohols, cannot be metabolised to toxic aldehydes.[[6]](#cite_note-6)[[7]](#cite_note-7)[Template:Better source](/wiki/Template:Better_source)[[8]](#cite_note-8)[Template:Better source](/wiki/Template:Better_source) Ethanol is thought to cause harm partly as a result of direct damage to DNA caused by its metabolites.[[9]](#cite_note-9)[thumb|Most significant of the possible](/wiki/File:Possible_long-term_effects_of_ethanol.svg) [long-term effects of ethanol](/wiki/Long-term_effects_of_ethanol). In addition, in pregnant women it may cause [fetal alcohol syndrome](/wiki/Fetal_alcohol_syndrome).

Ethanol's toxicity is largely caused by its primary metabolite, [acetaldehyde](/wiki/Acetaldehyde) (systematically ethanal)[[10]](#cite_note-10)[[11]](#cite_note-11) and secondary metabolite, [acetic acid](/wiki/Acetic_acid).[[11]](#cite_note-11)[[12]](#cite_note-12)[[13]](#cite_note-13)[[14]](#cite_note-14) Many primary alcohols are metabolized into aldehydes then to carboxylic acids whose toxicities are similar to acetaldehyde and acetic acid.[Template:Citation needed](/wiki/Template:Citation_needed) Metabolite toxicity is reduced in rats fed [*N*-acetylcysteine](/wiki/Acetylcysteine)[[10]](#cite_note-10)[[15]](#cite_note-15) and [thiamine](/wiki/Thiamine).[[16]](#cite_note-16) Tertiary alcohols cannot be metabolized into aldehydes[[17]](#cite_note-17) and as a result they cause no hangover or toxicity through this mechanism.

Some [secondary](/wiki/Alcohol#Systematic_names) and [tertiary alcohols](/wiki/Alcohol#Systematic_names) are less poisonous than ethanol, because the liver is unable to metabolize them into toxic by-products.[[18]](#cite_note-18) This makes them more suitable for pharmaceutical use as the chronic harms are lower.[[19]](#cite_note-19) [Ethchlorvynol](/wiki/Ethchlorvynol) and [*tert*-amyl alcohol](/wiki/Tert-Amyl_alcohol) are tertiary alcohols which have seen both medicinal and recreational use.[[20]](#cite_note-20) Other alcohols are substantially more poisonous than ethanol, partly because they take much longer to be metabolized and partly because their metabolism produces substances that are even more toxic. Methanol (wood alcohol), for instance, is oxidized to [formaldehyde](/wiki/Formaldehyde) and then to the poisonous [formic acid](/wiki/Formic_acid) in the liver by [alcohol dehydrogenase](/wiki/Alcohol_dehydrogenase) and [formaldehyde dehydrogenase](/wiki/Formaldehyde_dehydrogenase) [enzymes](/wiki/Enzyme), respectively; accumulation of formic acid can lead to blindness or death.[[21]](#cite_note-21) Likewise, poisoning due to other alcohols such as [ethylene glycol](/wiki/Ethylene_glycol) or [diethylene glycol](/wiki/Diethylene_glycol) are due to their metabolites, which are also produced by alcohol dehydrogenase.[[22]](#cite_note-22)[[23]](#cite_note-23) Methanol itself, while poisonous ([LD50](/wiki/Median_lethal_dose) 5628 mg/kg, oral, rat[[24]](#cite_note-24)), has a much weaker [sedative](/wiki/Sedative) effect than ethanol.

Isopropyl alcohol is oxidized to form acetone by [alcohol dehydrogenase](/wiki/Alcohol_dehydrogenase) in the liver, but has occasionally been abused by [alcoholics](/wiki/Alcoholism), leading to a range of adverse health effects.[[25]](#cite_note-25)[Template:Better source](/wiki/Template:Better_source)[[26]](#cite_note-26)[Template:Better source](/wiki/Template:Better_source)

### Treatment[[edit](/index.php?title=(none)&action=edit&section=3)]

An effective treatment to prevent toxicity after methanol or ethylene glycol ingestion is to administer ethanol. Alcohol dehydrogenase has a higher affinity for ethanol, thus preventing methanol from binding and acting as a [substrate](/wiki/Substrate_(chemistry)). Any remaining methanol will then have time to be excreted through the kidneys.[[21]](#cite_note-21)[[27]](#cite_note-27)[[28]](#cite_note-28)

## Nomenclature[[edit](/index.php?title=(none)&action=edit&section=4)]

### Systematic names[[edit](/index.php?title=(none)&action=edit&section=5)]

[IUPAC nomenclature](/wiki/Chemical_nomenclature) is used in scientific publications and where precise identification of the substance is important, especially in cases where the relative complexity of the molecule does not make such a systematic name unwieldy. In the IUPAC system, in naming simple alcohols, the name of the alkane chain loses the terminal "e" and adds "ol", *e.g.*, as in "methanol" and "ethanol".<ref name = reusch-alcohols>[Template:Cite web](/wiki/Template:Cite_web)</ref> When necessary, the position of the hydroxyl group is indicated by a number between the alkane name and the "ol": [propan-1-ol](/wiki/Propan-1-ol) for CH3CH2CH2OH, [propan-2-ol](/wiki/Isopropyl_alcohol) for CH3CH(OH)CH3. If a higher priority group is present (such as an [aldehyde](/wiki/Aldehyde), [ketone](/wiki/Ketone), or [carboxylic acid](/wiki/Carboxylic_acid)), then the prefix "hydroxy" is used,<ref name = reusch-alcohols/> e.g., as in 1-hydroxy-2-propanone (CH3C(O)CH2OH).[[29]](#cite_note-29) [600px|thumb|left|Some examples of simple alcohols and how to name them](/wiki/File:Alcohol_examples.png) [Template:Clear](/wiki/Template:Clear)

### Common names[[edit](/index.php?title=(none)&action=edit&section=6)]

In other less formal contexts, an alcohol is often called with the name of the corresponding alkyl group followed by the word "alcohol", e.g., [methyl](/wiki/Methyl_group) alcohol, [ethyl](/wiki/Ethyl_group) alcohol. [Propyl](/wiki/Propyl) alcohol may be [*n*-propyl alcohol](/wiki/Propanol) or [isopropyl alcohol](/wiki/Isopropyl_alcohol), depending on whether the hydroxyl group is bonded to the end or middle carbon on the straight [propane](/wiki/Propane) chain. As described under systematic naming, if another group on the molecule takes priority, the alcohol moiety is often indicated using the "hydroxy-" prefix.

[Template:Anchor](/wiki/Template:Anchor) Alcohols are then classified into primary, secondary (*sec-*, *s-*), and tertiary (*tert-*, *t-*), based upon the number of carbon atoms connected to the carbon atom that bears the [hydroxyl](/wiki/Hydroxyl) [functional group](/wiki/Functional_group). (The respective numeric shorthands 1°, 2°, and 3° are also sometimes used in informal settings.[[30]](#cite_note-30)) The primary alcohols have general formulas RCH2OH. The simplest primary alcohol is methanol (CH3OH), for which R=H, and the next is ethanol, for which R=CH3, the [methyl group](/wiki/Methyl_group). Secondary alcohols are those of the form RR'CHOH, the simplest of which is 2-propanol (R=R'=CH3). For the tertiary alcohols the general form is RR'R"COH. The simplest example is [tert-butanol](/wiki/Tert-butanol) (2-methylpropan-2-ol), for which each of R, R', and R" is CH3. In these shorthands, R, R', and R" represent [substituents](/wiki/Substituents), alkyl or other attached, generally organic groups.

|  |  |  |
| --- | --- | --- |
| **Chemical formula** | [**IUPAC**](/wiki/IUPAC) **Name** | **Common name** |
| *Monohydric alcohols* | | |
| CH3OH | [methanol](/wiki/Methanol) | wood alcohol |
| C2H5OH | [ethanol](/wiki/Ethanol) | alcohol |
| C3H7OH | [propan-2-ol](/wiki/Propan-2-ol) | isopropyl alcohol, rubbing alcohol |
| C4H9OH | [butan-1-ol](/wiki/Butan-1-ol) | butanol, butyl alcohol |
| C5H11OH | [pentan-1-ol](/wiki/Pentan-1-ol) | pentanol, amyl alcohol |
| C16H33OH | hexadecan-1-ol | [cetyl alcohol](/wiki/Cetyl_alcohol) |
| *Polyhydric alcohols* | | |
| C2H4(OH)2 | ethane-1,2-diol | [ethylene glycol](/wiki/Ethylene_glycol) |
| C3H6(OH)2 | propane-1,2-diol | [propylene glycol](/wiki/Propylene_glycol) |
| C3H5(OH)3 | propane-1,2,3-triol | [glycerol](/wiki/Glycerol) |
| C4H6(OH)4 | butane-1,2,3,4-tetraol | [erythritol](/wiki/Erythritol), [threitol](/wiki/Threitol) |
| C5H7(OH)5 | pentane-1,2,3,4,5-pentol | [xylitol](/wiki/Xylitol) |
| C6H8(OH)6 | hexane-1,2,3,4,5,6-hexol | [mannitol](/wiki/Mannitol), [sorbitol](/wiki/Sorbitol) |
| C7H9(OH)7 | heptane-1,2,3,4,5,6,7-heptol | [volemitol](/wiki/Volemitol) |
| *Unsaturated* [*aliphatic*](/wiki/Aliphatic) *alcohols* | | |
| C3H5OH | Prop-2-ene-1-ol | [allyl alcohol](/wiki/Allyl_alcohol) |
| C10H17OH | 3,7-Dimethylocta-2,6-dien-1-ol | [geraniol](/wiki/Geraniol) |
| C3H3OH | Prop-2-yn-1-ol | [propargyl alcohol](/wiki/Propargyl_alcohol) |
| [*Alicyclic*](/wiki/Alicyclic) *alcohols* | | |
| C6H6(OH)6 | cyclohexane-1,2,3,4,5,6-hexol | [inositol](/wiki/Inositol) |
| C10H19OH | 2 - (2-propyl)-5-methyl-cyclohexane-1-ol | [menthol](/wiki/Menthol) |

#### Alkyl chain variations in alcohols[[edit](/index.php?title=(none)&action=edit&section=7)]

Short-chain alcohols have alkyl chains of 1–3 carbons. Medium-chain alcohols have alkyl chains of 4–7 carbons. Long-chain alcohols (also known as [fatty alcohols](/wiki/Fatty_alcohols)) have alkyl chains of 8–21 carbons, and very long-chain alcohols have alkyl chains of 22 carbons or longer.[[31]](#cite_note-31)

#### Simple alcohols[[edit](/index.php?title=(none)&action=edit&section=8)]

"Simple alcohols" appears to be a completely undefined term. However, simple alcohols are often referred to by common names derived by adding the word "alcohol" to the name of the appropriate alkyl group. For instance, a chain consisting of one carbon (a methyl group, CH3) with an OH group attached to the carbon is called "methyl alcohol" while a chain of two carbons (an ethyl group, CH2CH3) with an OH group connected to the CH2 is called "ethyl alcohol." For more complex alcohols, the IUPAC nomenclature must be used.[[32]](#cite_note-32) Simple alcohols, in particular ethanol and methanol, possess [denaturing](/wiki/Denaturation_(biochemistry)) and inert rendering properties, leading to their use as anti-microbial agents in medicine, pharmacy, and industry.[Template:Citation needed](/wiki/Template:Citation_needed)

#### Higher alcohols[[edit](/index.php?title=(none)&action=edit&section=9)]

Encyclopædia Britannica states, "The higher alcohols—those containing 4 to 10 carbon atoms—are somewhat viscous, or oily, and they have heavier fruity odours. Some of the highly branched alcohols and many alcohols containing more than 12 carbon atoms are solids at room temperature."[[33]](#cite_note-33) Like ethanol, [butanol](/wiki/N-Butanol) can be produced by fermentation processes. Saccharomyces yeast are known to produce these higher alcohols at temperatures above [Template:Convert](/wiki/Template:Convert). The bacterium [*Clostridium acetobutylicum*](/wiki/Clostridium_acetobutylicum) can feed on [cellulose](/wiki/Cellulose) to produce butanol on an industrial scale.

### Etymology[[edit](/index.php?title=(none)&action=edit&section=10)]

The word *alcohol* appears in English as a term for a very fine powder in the sixteenth century. It was borrowed from French, which took it from medical [Latin](/wiki/Middle_Latin).

Ultimately the word is from the [Arabic](/wiki/Arabic) [Template:Lang](/wiki/Template:Lang) ([*Template:Transl*](/wiki/Template:Transl)*,* "[kohl](/wiki/Kohl_(cosmetics)), a powder used as an eyeliner"). [Al-](/wiki/Al-) is the Arabic [definitive article](/wiki/Article_(grammar)), equivalent to *the* in English; *alcohol* was originally used for the very fine powder produced by the [sublimation](/wiki/Sublimation_(chemistry)) of the natural mineral [stibnite](/wiki/Stibnite) to form [antimony](/wiki/Antimony) [sulfide](/wiki/Sulfide) [Sb](/wiki/Antimony)2[S](/wiki/Sulfur)3 (hence the essence or "spirit" of the substance), which was used as an [antiseptic](/wiki/Antiseptic), eyeliner, and cosmetic (see [kohl (cosmetics)](/wiki/Kohl_(cosmetics))) According to this theory, the meaning of alkuhul would have been first extended to distilled substances in general, and then narrowed to ethanol.<ref name=vias>[Etymology of the Word "Alcohol"](http://www.vias.org/encyclopedia/Alcohol_004.html)</ref>

[Bartholomew Traheron](/wiki/Bartholomew_Traheron), in his 1543 translation of [John of Vigo](/wiki/John_of_Vigo), introduces the word as a term used by "barbarous" ([Moorish](/wiki/Moorish)) authors for "fine powder." Vigo wrote: *the barbarous auctours use alcohol, or (as I fynde it sometymes wryten) alcofoll, for moost fine poudre.*

The 1657 [*Lexicon Chymicum*](https://books.google.com/books/about/Lexicon_Chymicum.html?id=d645AAAAcAAJ), by William Johnson glosses the word as *antimonium sive stibium.* By extension, the word came to refer to any fluid obtained by distillation, including "alcohol of wine," the distilled essence of wine. [Libavius](/wiki/Libavius) in *Alchymia* (1594) refers to *vini alcohol vel vinum alcalisatum*. Johnson (1657) glosses *alcohol vini* as *quando omnis superfluitas vini a vino separatur, ita ut accensum ardeat donec totum consumatur, nihilque fæcum aut phlegmatis in fundo remaneat.* The word's meaning became restricted to "spirit of wine" (the chemical known today as [ethanol](/wiki/Ethanol)) in the 18th century and was extended to the class of substances so-called as "alcohols" in modern chemistry after 1850.

The term *ethanol* was invented 1838, modeled on the German word äthyl (Liebig), which is in turn based on Greek *aither* [ether](/wiki/Ether) and *hyle* "stuff."[[34]](#cite_note-34)

## Physical and chemical properties[[edit](/index.php?title=(none)&action=edit&section=11)]

Alcohols have an odor that is often described as "biting" and as "hanging" in the nasal passages. Ethanol has a slightly sweeter (or more fruit-like) odor than the other alcohols.

In general, the [hydroxyl group](/wiki/Hydroxyl_group) makes the alcohol molecule [polar](/wiki/Polar_molecule). Those groups can form [hydrogen bonds](/wiki/Hydrogen_bond) to one another and to other compounds (except in [certain large molecules](/wiki/2,2,4,4-tetramethyl-3-t-butyl-pentane-3-ol) where the hydroxyl is protected by [steric hindrance](/wiki/Steric_hindrance) of adjacent groups[[35]](#cite_note-35)). This hydrogen bonding means that alcohols can be used as [protic solvents](/wiki/Protic_solvent). Two opposing solubility trends in alcohols are: the tendency of the polar OH to promote solubility in water, and the tendency of the carbon chain to resist it. Thus, methanol, ethanol, and propanol are [miscible](/wiki/Miscible) in water because the hydroxyl group wins out over the short carbon chain. [Butanol](/wiki/N-Butanol), with a four-carbon chain, is moderately soluble because of a balance between the two trends. Alcohols of five or more carbons such as [pentanol](/wiki/Amyl_alcohol) and higher are effectively insoluble in water because of the hydrocarbon chain's dominance. All simple alcohols are miscible in organic solvents.

Because of [hydrogen bonding](/wiki/Hydrogen_bonding), alcohols tend to have higher boiling points than comparable [hydrocarbons](/wiki/Hydrocarbon) and [ethers](/wiki/Ether). The boiling point of the alcohol ethanol is 78.29 °C, compared to 69 °C for the hydrocarbon [hexane](/wiki/Hexane) (a common constituent of [gasoline](/wiki/Gasoline)), and 34.6 °C for [diethyl ether](/wiki/Diethyl_ether).

Alcohols, like water, can show either acidic or basic properties at the -OH group. With a [pKa](/wiki/PKa) of around 16-19, they are, in general, slightly weaker [acids](/wiki/Acid) than [water](/wiki/Water_(molecule)), but they are still able to react with strong bases such as [sodium hydride](/wiki/Sodium_hydride) or reactive metals such as [sodium](/wiki/Sodium). The [salts](/wiki/Salt) that result are called [**alkoxides**](/wiki/Alkoxide), with the general formula [RO](/wiki/Alkyl)− [M](/wiki/Metal)+.

Meanwhile, the oxygen atom has [lone pairs](/wiki/Lone_pair) of nonbonded electrons that render it weakly [basic](/wiki/Base_(chemistry)) in the presence of strong acids such as [sulfuric acid](/wiki/Sulfuric_acid). For example, with methanol:

[500px|Acidity & basicity of methanol](/wiki/File:Methanol_acid_base.gif)

Alcohols can also undergo [oxidation](/wiki/Oxidation) to give [aldehydes](/wiki/Aldehyde), [ketones](/wiki/Ketone), or [carboxylic acids](/wiki/Carboxylic_acid), or they can be dehydrated to [alkenes](/wiki/Alkene). They can react to form [ester compounds](/wiki/Ester_compound), and they can (if activated first) undergo [nucleophilic substitution](/wiki/Nucleophilic_substitution) reactions. The lone pairs of electrons on the oxygen of the hydroxyl group also makes alcohols [nucleophiles](/wiki/Nucleophile). For more details, see the [reactions of alcohols](/wiki/Alcohol#Reactions) section below.

As one moves from primary to secondary to tertiary alcohols with the same backbone, the hydrogen bond strength, the boiling point, and the acidity typically decrease.

## Applications[[edit](/index.php?title=(none)&action=edit&section=12)]

[thumb|200px|Total recorded](/wiki/File:Alcohol_by_Country.png) [alcohol per capita consumption](/wiki/Alcohol_consumption_by_country) (15+), in litres of pure alcohol[[36]](#cite_note-36) Alcohol has a long history of several uses worldwide. It is found in alcoholic beverages sold to adults, as fuel, and also has many scientific, medical, and industrial uses. The term **alcohol-free** is often used to describe a product that does not contain alcohol. Some consumers of some commercially prepared products may view alcohol as an undesirable ingredient, particularly in products intended for children.

### Alcoholic beverages[[edit](/index.php?title=(none)&action=edit&section=13)]

[Alcoholic beverages](/wiki/Alcoholic_beverage), typically containing 3–40% [ethanol](/wiki/Ethanol) by volume, have been produced and consumed by humans since pre-historic times. Other alcohols such as [2-methyl-2-butanol](/wiki/2-methyl-2-butanol) (found in [beer](/wiki/Beer)) and [γ-hydroxybutyric acid](/wiki/Gamma-Hydroxybutyric_acid) (GHB) are also consumed by humans for their psychoactive effects.

### Antifreeze[[edit](/index.php?title=(none)&action=edit&section=14)]

A 50% [v/v](/wiki/Volume_fraction) (by volume) solution of [ethylene glycol](/wiki/Ethylene_glycol) in water is commonly used as an [antifreeze](/wiki/Antifreeze).

### Antiseptics[[edit](/index.php?title=(none)&action=edit&section=15)]

Ethanol can be used as an [antiseptic](/wiki/Antiseptic) to disinfect the skin before injections are given, often along with [iodine](/wiki/Iodine). Ethanol-based [soaps](/wiki/Soap) are becoming common in restaurants and are convenient because they do not require drying due to the volatility of the compound. Alcohol based gels have become common as [hand sanitizers](/wiki/Hand_sanitizer).

### Fuels[[edit](/index.php?title=(none)&action=edit&section=16)]

Some alcohols, mainly [ethanol](/wiki/Ethanol) and [methanol](/wiki/Methanol), can be used as an [alcohol fuel](/wiki/Alcohol_fuel). Fuel performance can be increased in [forced induction](/wiki/Forced_induction) [internal combustion engines](/wiki/Internal_combustion_engine) by injecting alcohol into the air intake after the [turbocharger](/wiki/Turbocharger) or [supercharger](/wiki/Supercharger) has pressurized the air. This cools the pressurized air, providing a denser air charge, which allows for more fuel, and therefore more power.

### Preservative[[edit](/index.php?title=(none)&action=edit&section=17)]

Alcohol is often used as a [preservative](/wiki/Preservative) for [specimens](/wiki/Biological_specimen) in the fields of science and medicine.

### Solvents[[edit](/index.php?title=(none)&action=edit&section=18)]

Hydroxyl groups (-OH), found in alcohols, are [polar](/wiki/Chemical_polarity) and therefore [hydrophilic](/wiki/Hydrophilic) (water loving) but their carbon chain portion is [non-polar](/wiki/Non-polar) which make them [hydrophobic](/wiki/Hydrophobic). The molecule increasingly becomes overall more nonpolar and therefore less soluble in the polar water as the carbon chain becomes longer.[[37]](#cite_note-37) Methanol has the shortest carbon chain of all alcohols (one carbon atom) followed by ethanol (two carbon atoms.)

Alcohols have applications in industry and science as reagents or [solvents](/wiki/Solvent). Because of its relatively low toxicity compared with other alcohols and ability to dissolve [non-polar](/wiki/Non-polar) substances, ethanol can be used as a solvent in medical drugs, [perfumes](/wiki/Perfume), and vegetable essences such as [vanilla](/wiki/Vanilla). In [organic synthesis](/wiki/Organic_synthesis), alcohols serve as versatile intermediates.

## Production[[edit](/index.php?title=(none)&action=edit&section=19)]

### Ziegler and oxo processes[[edit](/index.php?title=(none)&action=edit&section=20)]

In the [Ziegler process](/wiki/Ziegler_process), linear alcohols are produced from ethylene and [triethylaluminium](/wiki/Triethylaluminium) followed by oxidation and hydrolysis.<ref name=Falbe>Jürgen Falbe, Helmut Bahrmann, Wolfgang Lipps, Dieter Mayer "Alcohols, Aliphatic" in *Ullmann's Encyclopedia of Chemical Technology* Wiley-VCH Verlag; Weinheim, 2002. [Template:Doi](/wiki/Template:Doi)</ref> An idealized synthesis of [1-octanol](/wiki/1-octanol) is shown:

Al(C2H5)3 + 9 C2H4 → Al(C8H17)3

Al(C8H17)3 + 3 O + 3 H2O → 3 HOC8H17 + Al(OH)3

The process generates a range of alcohols that are separated by [distillation](/wiki/Distillation).

Many higher alcohols are produced by [hydroformylation](/wiki/Hydroformylation) of alkenes followed by hydrogenation. When applied to a terminal alkene, as is common, one typically obtains a linear alcohol:<ref name=Falbe/>

RCH=CH2 + H2 + CO → RCH2CH2CHO

RCH2CH2CHO + 3 H2 → RCH2CH2CH2OH

Such processes give [fatty alcohols](/wiki/Fatty_alcohol), which are useful for detergents.

### Hydration reactions[[edit](/index.php?title=(none)&action=edit&section=21)]

Low molecular weight alcohols of industrial importance are produced by the addition of water to alkenes. Ethanol, isopropanol, 2-butanol, and tert-butanol are produced by this general method. Two implementations are employed, the direct and indirect methods. The direct method avoids the formation of stable intermediates, typically using acid catalysts. In the indirect method, the alkene is converted to the [sulfate ester](/wiki/Sulfate_ester), which is subsequently hydrolyzed. The direct [hydration](/wiki/Hydration_reaction) using [ethylene](/wiki/Ethylene) ([ethylene hydration](/wiki/Ethanol#Ethylene_hydration))[[38]](#cite_note-38) or other alkenes from [cracking](/wiki/Cracking_(chemistry)) of fractions of distilled [crude oil](/wiki/Crude_oil).

Hydration is also used industrially to produce the diol [ethylene glycol](/wiki/Ethylene_glycol) from [ethylene oxide](/wiki/Ethylene_oxide).

### Biological routes[[edit](/index.php?title=(none)&action=edit&section=22)]

Ethanol is obtained by [fermentation](/wiki/Fermentation_(biochemistry)) using [glucose](/wiki/Glucose) produced from sugar from the [hydrolysis](/wiki/Hydrolysis) of [starch](/wiki/Starch), in the presence of yeast and temperature of less than 37 °C to produce ethanol. For instance, such a process might proceed by the conversion of [sucrose](/wiki/Sucrose) by the enzyme [invertase](/wiki/Invertase) into [glucose](/wiki/Glucose) and [fructose](/wiki/Fructose), then the conversion of [glucose](/wiki/Glucose) by the enzyme [zymase](/wiki/Zymase) into [ethanol](/wiki/Ethanol) (and carbon dioxide).

Several of the benign bacteria[Template:Which](/wiki/Template:Which) in the intestine use [fermentation](/wiki/Fermentation_(food)) as a form of [anaerobic metabolism](/wiki/Anaerobic_metabolism). This [metabolic](/wiki/Metabolism) reaction produces [ethanol](/wiki/Ethanol) as a waste product, just like [aerobic respiration](/wiki/Aerobic_respiration) produces [carbon dioxide](/wiki/Carbon_dioxide) and [water](/wiki/Water_(molecule)). Thus, human bodies contain some quantity of alcohol endogenously produced by these bacteria. In rare cases, this can be sufficient to cause "[auto-brewery syndrome](/wiki/Auto-brewery_syndrome)" in which intoxicating quantities of alcohol are produced.[[39]](#cite_note-39)[[40]](#cite_note-40)[[41]](#cite_note-41)

### Laboratory synthesis[[edit](/index.php?title=(none)&action=edit&section=23)]

Several methods exist for the preparation of alcohols in the laboratory.

#### Substitution[[edit](/index.php?title=(none)&action=edit&section=24)]

Primary [alkyl halides](/wiki/Alkyl_halide) react with aqueous [NaOH](/wiki/Sodium_hydroxide) or [KOH](/wiki/Potassium_hydroxide) mainly to primary alcohols in [nucleophilic aliphatic substitution](/wiki/Nucleophilic_aliphatic_substitution). (Secondary and especially tertiary alkyl halides will give the elimination (alkene) product instead). [Grignard reagents](/wiki/Grignard_reagent) react with [carbonyl](/wiki/Carbonyl) groups to secondary and tertiary alcohols. Related reactions are the [Barbier reaction](/wiki/Barbier_reaction) and the [Nozaki-Hiyama reaction](/wiki/Nozaki-Hiyama_reaction).

#### Reduction[[edit](/index.php?title=(none)&action=edit&section=25)]

[Aldehydes](/wiki/Aldehydes) or [ketones](/wiki/Ketone) are [reduced](/wiki/Redox) with [sodium borohydride](/wiki/Sodium_borohydride) or [lithium aluminium hydride](/wiki/Lithium_aluminium_hydride) (after an acidic workup). Another reduction by aluminiumisopropylates is the [Meerwein-Ponndorf-Verley reduction](/wiki/Meerwein-Ponndorf-Verley_reduction). [Noyori asymmetric hydrogenation](/wiki/Noyori_asymmetric_hydrogenation) is the asymmetric reduction of β-keto-esters.

#### Hydrolysis[[edit](/index.php?title=(none)&action=edit&section=26)]

[Alkenes](/wiki/Alkenes) engage in an acid catalysed [hydration reaction](/wiki/Hydration_reaction) using concentrated sulfuric acid as a catalyst that gives usually secondary or tertiary alcohols. The [hydroboration-oxidation](/wiki/Hydroboration-oxidation) and [oxymercuration-reduction](/wiki/Oxymercuration-reduction) of alkenes are more reliable in organic synthesis. Alkenes react with NBS and water in [halohydrin formation reaction](/wiki/Halohydrin_formation_reaction). [Amines](/wiki/Amine) can be converted to [diazonium salts](/wiki/Diazonium_salt), which are then hydrolyzed.

The formation of a secondary alcohol via reduction and hydration is shown:

[350px|Preparation of a secondary alcohol](/wiki/File:Secondary_alcohol_formation-diagram.svg)

## Reactions[[edit](/index.php?title=(none)&action=edit&section=27)]

### Deprotonation[[edit](/index.php?title=(none)&action=edit&section=28)]

Alcohols can behave as weak acids, undergoing [deprotonation](/wiki/Deprotonation). The deprotonation reaction to produce an [alkoxide](/wiki/Alkoxide) salt is performed either with a strong base such as sodium hydride or [*n*-butyllithium](/wiki/N-Butyllithium) or with sodium or potassium metal.

2 R-OH + 2 [NaH](/wiki/Sodium_hydride) → 2 R-O−Na+ + 2[H2](/wiki/Hydrogen)↑

2 R-OH + 2 [Na](/wiki/Sodium) → 2 R-O−Na+ + H2

2 [CH3CH2-OH](/wiki/Ethanol) + 2 Na → 2 CH3-CH2-O−Na+ + H2↑

Water is similar in [pKa](/wiki/PKa) to many alcohols, so with [sodium hydroxide](/wiki/Sodium_hydroxide) there is an [equilibrium](/wiki/Chemical_equilibrium) set-up, which usually lies to the left:

R-OH + NaOH ⇌ R-O−Na+ + H2O (equilibrium to the left)

It should be noted, however, that the bases used to deprotonate alcohols are strong themselves. The bases used and the alkoxides created are both highly moisture-sensitive chemical reagents.

The acidity of alcohols is also affected by the overall stability of the alkoxide ion. [Electron-withdrawing groups](/wiki/Electron-withdrawing_group) attached to the carbon containing the hydroxyl group will serve to stabilize the alkoxide when formed, thus resulting in greater acidity. On the other hand, the presence of [electron-donating group](/wiki/Electron-donating_group) will result in a less stable alkoxide ion formed. This will result in a scenario whereby the unstable alkoxide ion formed will tend to accept a proton to reform the original alcohol.

With [alkyl halides](/wiki/Alkyl_halide) alkoxides give rise to [ethers](/wiki/Ether) in the [Williamson ether synthesis](/wiki/Williamson_ether_synthesis).

### Nucleophilic substitution[[edit](/index.php?title=(none)&action=edit&section=29)]

The OH group is not a good [leaving group](/wiki/Leaving_group) in [nucleophilic substitution](/wiki/Nucleophilic_substitution) reactions, so neutral alcohols do not react in such reactions. However, if the oxygen is first protonated to give R−OH2+, the leaving group ([water](/wiki/Water_(molecule))) is much more stable, and the nucleophilic substitution can take place. For instance, tertiary alcohols react with [hydrochloric acid](/wiki/Hydrochloric_acid) to produce tertiary [alkyl halides](/wiki/Alkyl_halide), where the [hydroxyl group](/wiki/Hydroxyl_group) is replaced by a [chlorine](/wiki/Chlorine) atom by [unimolecular nucleophilic substitution](/wiki/Unimolecular_nucleophilic_substitution). If primary or secondary alcohols are to be reacted with [hydrochloric acid](/wiki/Hydrochloric_acid), an activator such as [zinc chloride](/wiki/Zinc_chloride) is needed. In alternative fashion, the conversion may be performed directly using [thionyl chloride](/wiki/Thionyl_chloride).[1]

[700px|Some simple conversions of alcohols to alkyl chlorides](/wiki/File:Alcohol_reaction_examples.gif)

Alcohols may, likewise, be converted to alkyl bromides using [hydrobromic acid](/wiki/Hydrobromic_acid) or [phosphorus tribromide](/wiki/Phosphorus_tribromide), for example:

3 R-OH + PBr3 → 3 RBr + H3PO3

In the [Barton-McCombie deoxygenation](/wiki/Barton-McCombie_deoxygenation) an alcohol is deoxygenated to an [alkane](/wiki/Alkane) with [tributyltin hydride](/wiki/Organotin) or a [trimethylborane](/wiki/Organoborane)-water complex in a [radical substitution](/wiki/Radical_substitution) reaction.

### Dehydration[[edit](/index.php?title=(none)&action=edit&section=30)]

Alcohols are themselves nucleophilic, so R−OH2+ can react with ROH to produce [ethers](/wiki/Ether) and water in a [dehydration reaction](/wiki/Dehydration_reaction), although this reaction is rarely used except in the manufacture of [diethyl ether](/wiki/Diethyl_ether).

More useful is the E1 [elimination reaction](/wiki/Elimination_reaction) of alcohols to produce [alkenes](/wiki/Alkene). The reaction, in general, obeys [Zaitsev's Rule](/wiki/Zaitsev's_Rule), which states that the most stable (usually the most substituted) alkene is formed. Tertiary alcohols eliminate easily at just above room temperature, but primary alcohols require a higher temperature.

This is a diagram of acid catalysed dehydration of ethanol to produce [ethene](/wiki/Ethene):

[550px](/wiki/File:DehydrationOfAlcoholWithH-.png)

A more controlled elimination reaction is the [Chugaev elimination](/wiki/Chugaev_elimination) with [carbon disulfide](/wiki/Carbon_disulfide) and [iodomethane](/wiki/Iodomethane).

### Esterification[[edit](/index.php?title=(none)&action=edit&section=31)]

To form an [ester](/wiki/Ester) from an alcohol and a [carboxylic acid](/wiki/Carboxylic_acid) the reaction, known as [Fischer esterification](/wiki/Fischer_esterification), is usually performed at [reflux](/wiki/Reflux) with a [catalyst](/wiki/Catalyst) of concentrated sulfuric acid:

R-OH + R'-COOH → R'-COOR + H2O

In order to drive the equilibrium to the right and produce a good [yield](/wiki/Yield_(chemistry)) of ester, water is usually removed, either by an excess of H2SO4 or by using a [Dean-Stark apparatus](/wiki/Dean-Stark_apparatus). Esters may also be prepared by reaction of the alcohol with an [acid chloride](/wiki/Acid_chloride) in the presence of a base such as [pyridine](/wiki/Pyridine).

Other types of ester are prepared in a similar manner[Template:Snd](/wiki/Template:Snd) for example, [tosyl](/wiki/Tosyl) (tosylate) esters are made by reaction of the alcohol with p-[toluenesulfonyl](/wiki/Toluenesulfonyl) chloride in pyridine.

### Oxidation[[edit](/index.php?title=(none)&action=edit&section=32)]

[Template:Main article](/wiki/Template:Main_article) Primary alcohols (R-CH2-OH) can be oxidized either to [aldehydes](/wiki/Aldehyde) (R-CHO) or to [carboxylic acids](/wiki/Carboxylic_acid) (R-CO2H), while the oxidation of secondary alcohols (R1R2CH-OH) normally terminates at the [ketone](/wiki/Ketone) (R1R2C=O) stage. Tertiary alcohols (R1R2R3C-OH) are resistant to oxidation.

The direct [oxidation of primary alcohols to carboxylic acids](/wiki/Oxidation_of_primary_alcohols_to_carboxylic_acids) normally proceeds via the corresponding aldehyde, which is transformed via an *aldehyde hydrate* (R-CH(OH)2) by reaction with water before it can be further oxidized to the carboxylic acid.

[500px|thumb|center|Mechanism of](/wiki/File:Alcohol_to_aldehyde_to_acid.png) [oxidation of primary alcohols to carboxylic acids](/wiki/Oxidation_of_primary_alcohols_to_carboxylic_acids) via aldehydes and aldehyde hydrates

Reagents useful for the transformation of primary alcohols to aldehydes are normally also suitable for the [oxidation of secondary alcohols to ketones](/wiki/Oxidation_of_secondary_alcohols_to_ketones). These include [Collins reagent](/wiki/Collins_reagent) and [Dess-Martin periodinane](/wiki/Dess-Martin_periodinane). The direct oxidation of primary alcohols to carboxylic acids can be carried out using [potassium permanganate](/wiki/Potassium_permanganate) or the [Jones reagent](/wiki/Jones_reagent).

## See also[[edit](/index.php?title=(none)&action=edit&section=33)]

[Template:Div col](/wiki/Template:Div_col)

* [Blood alcohol content](/wiki/Blood_alcohol_content)
* [Breathalyzer](/wiki/Breathalyzer)
* [Cooking with alcohol](/wiki/Cooking_with_alcohol)
* [Enol](/wiki/Enol)
* [Ethanol fuel](/wiki/Ethanol_fuel)
* [Fatty alcohol](/wiki/Fatty_alcohol)
* [History of alcoholic beverages](/wiki/History_of_alcoholic_beverages)
* [List of countries by alcohol consumption](/wiki/List_of_countries_by_alcohol_consumption)
* [Polyol](/wiki/Polyol)
* [Rubbing alcohol](/wiki/Rubbing_alcohol)
* [Sugar alcohol](/wiki/Sugar_alcohol)
* [Surrogate alcohol](/wiki/Surrogate_alcohol)
* [Transesterification](/wiki/Transesterification)

[Template:Div col end](/wiki/Template:Div_col_end)

## Notes[[edit](/index.php?title=(none)&action=edit&section=34)]

[Template:Reflist](/wiki/Template:Reflist)

## References[[edit](/index.php?title=(none)&action=edit&section=35)]

* [Template:Cite book](/wiki/Template:Cite_book)

## External links[[edit](/index.php?title=(none)&action=edit&section=36)]

[Template:Wiktionary](/wiki/Template:Wiktionary) [Template:Commons](/wiki/Template:Commons) [Template:Wikiquote](/wiki/Template:Wikiquote)

* [Alcohol (Ethanol)](http://www.periodicvideos.com/videos/mv_alcohol.htm) at [*The Periodic Table of Videos*](/wiki/The_Periodic_Table_of_Videos) (University of Nottingham)

[Template:Alcohols](/wiki/Template:Alcohols) [Template:Functional group](/wiki/Template:Functional_group) [Template:Bioenergy](/wiki/Template:Bioenergy) [Template:Alternative propulsion](/wiki/Template:Alternative_propulsion)

[Template:Authority control](/wiki/Template:Authority_control)

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