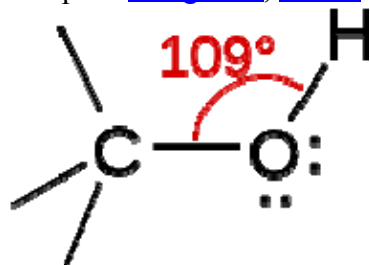


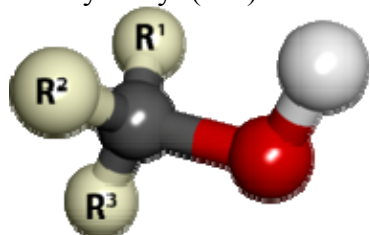
# Alcohol

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The hydroxyl (OH) functional group with bond angle, in a generic alcohol molecule



[Ball-and-stick model](#) of the hydroxyl (OH) functional group in an alcohol molecule. The three "R's" stand for carbon substituents or hydrogen atoms. This is the same as the space-filling model below

In [chemistry](#), an **alcohol** is an [organic compound](#) in which the [hydroxyl functional group](#) (-OH) is bound to a [carbon](#) atom. In particular, this carbon center should be saturated, having single bonds to three other atoms.<sup>[1]</sup>

An important class of alcohols are the simple [acyclic](#) alcohols, the general formula for which is  $C_nH_{2n+1}OH$ . Of those, [ethanol](#) ( $C_2H_5OH$ ) is the type of alcohol found in [alcoholic beverages](#), and in common speech the word **alcohol** refers specifically to ethanol.

Other alcohols are usually described with a clarifying adjective, as in [isopropyl alcohol](#) (*propan-2-ol*) or *wood alcohol* (*methyl alcohol*, or [methanol](#)). The suffix *-ol* appears in the [IUPAC chemical name](#) 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 [IUPAC](#) name. The suffix *-ol* in non-systematic names (such as [paracetamol](#) or [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](#) and [sucrose](#)) contain hydroxyl functional groups without using the suffix.

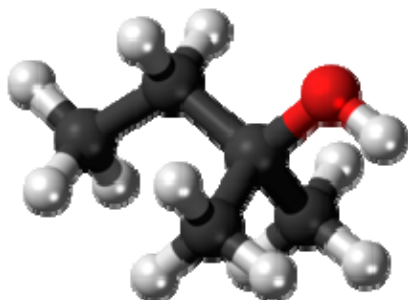
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## Toxicity

*Main article:* [Alcoholic beverages#Alcohols](#)



 Ball-and-stick model of the 2-Methyl-2-butanol (2M2B) molecule, which is 20 times the intoxicating effects of ethanol and does not cause hangover.



 Most significant of the possible [long-term effects of ethanol](#). In addition, in pregnant women, it causes [fetal alcohol syndrome](#).

Alcoholic beverages has been consumed by humans since prehistoric times for a variety of hygienic, dietary, medicinal, religious, and recreational reasons.

Primary alcohols ( $R-CH_2-OH$ ) can be oxidized either to [aldehydes](#) ( $R-CHO$ ) (eg acetaldehyde as described below) or to [carboxylic acids](#) ( $R-CO_2H$ ), while the oxidation of secondary alcohols ( $R^1R^2CH-OH$ ) normally terminates at the [ketone](#) ( $R^1R^2C=O$ ) stage. Tertiary alcohols ( $R^1R^2R^3C-OH$ ) are resistant to oxidation.

Ethanol's toxicity is largely caused by its primary metabolite; [acetaldehyde](#) (systematically ethanal)<sup>[2][3]</sup> and secondary metabolite; [acetic acid](#).<sup>[3][4][5][6]</sup> All primary alcohols are broken down into aldehydes then to carboxylic acids, and whose toxicities are similar to acetaldehyde and acetic acid. Metabolite toxicity is reduced in rats fed [N-acetylcysteine](#)<sup>[2][7]</sup> and [thiamine](#).<sup>[8]</sup>

Tertiary alcohols are unable to be metabolised into aldehydes<sup>[9]</sup> and as a result they cause no hangover or toxicity through this mechanism. Some [secondary](#) and [tertiary alcohols](#) are less poisonous than ethanol because the liver is unable to metabolise them into these toxic by-products. This makes them more suitable for recreational<sup>[10][11]</sup> and medicinal<sup>[12]</sup> use as the chronic harms are lower. [tert-Amyl alcohol](#) found in alcoholic beverages are a good example of a tertiary alcohol which saw both medicinal and recreational use.

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](#) and then to the poisonous [formic acid](#) in the liver by [alcohol dehydrogenase](#) and [formaldehyde dehydrogenase enzymes](#), respectively; accumulation of formic acid can lead to blindness or death.<sup>[13]</sup> Likewise, poisoning due to other alcohols such as [ethylene glycol](#) or [diethylene glycol](#) are due to their metabolites, which are also produced by alcohol dehydrogenase.<sup>[14][15]</sup> 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](#). Any remaining methanol will then have time to be excreted through the kidneys.<sup>[13][16][17]</sup>

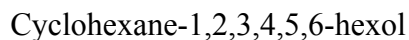
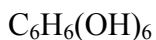
Methanol itself, while poisonous (LD50 5628mg/kg, oral, rat<sup>[18]</sup>), has a much weaker [sedative](#) effect than ethanol.

Isopropyl alcohol is oxidized to form acetone by [alcohol dehydrogenase](#) in the liver but have occasionally been abused by [alcoholics](#), leading to a range of adverse health effects.<sup>[19][20]</sup>

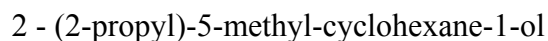
## Nomenclature

### Common names

Chemical Formula	IUPAC Name	Common Name
<i>Monohydric alcohols</i>		
CH <sub>3</sub> OH	<a href="#">Methanol</a>	Wood alcohol
C <sub>2</sub> H <sub>5</sub> OH	<a href="#">Ethanol</a>	Grain alcohol
C <sub>3</sub> H <sub>7</sub> OH	<a href="#">Isopropyl alcohol</a>	Rubbing alcohol
C <sub>4</sub> H <sub>9</sub> OH	<a href="#">Butyl alcohol</a>	Butanol
C <sub>5</sub> H <sub>11</sub> OH	Pentanol	<a href="#">Amyl alcohol</a>
C <sub>16</sub> H <sub>33</sub> OH	Hexadecan-1-ol	<a href="#">Cetyl alcohol</a>
<i>Polyhydric alcohols</i>		
C <sub>2</sub> H <sub>4</sub> (OH) <sub>2</sub>	Ethane-1,2-diol	<a href="#">Ethylene glycol</a>
C <sub>3</sub> H <sub>6</sub> (OH) <sub>2</sub>	Propane-1,2-diol	<a href="#">Propylene Glycol</a>
C <sub>3</sub> H <sub>5</sub> (OH) <sub>3</sub>	Propane-1,2,3-triol	<a href="#">Glycerol</a>
C <sub>4</sub> H <sub>6</sub> (OH) <sub>4</sub>	Butane-1,2,3,4-tetraol	<a href="#">Erythritol</a> , <a href="#">Threitol</a>
C <sub>5</sub> H <sub>7</sub> (OH) <sub>5</sub>	Pentane-1,2,3,4,5-pentol	<a href="#">Xylitol</a>
C <sub>6</sub> H <sub>8</sub> (OH) <sub>6</sub>	Hexane-1,2,3,4,5,6-hexol	<a href="#">Mannitol</a> , <a href="#">Sorbitol</a>
C <sub>7</sub> H <sub>9</sub> (OH) <sub>7</sub>	Heptane-1,2,3,4,5,6,7-heptol	<a href="#">Volemitol</a>
<i>Unsaturated <a href="#">aliphatic</a> alcohols</i>		
C <sub>3</sub> H <sub>5</sub> OH	Prop-2-ene-1-ol	<a href="#">Allyl alcohol</a>
C <sub>10</sub> H <sub>17</sub> OH	3,7-Dimethylocta-2,6-dien-1-ol	<a href="#">Geraniol</a>
C <sub>3</sub> H <sub>3</sub> OH	Prop-2-in-1-ol	<a href="#">Propargyl alcohol</a>
<i><a href="#">Alicyclic</a> alcohols</i>		



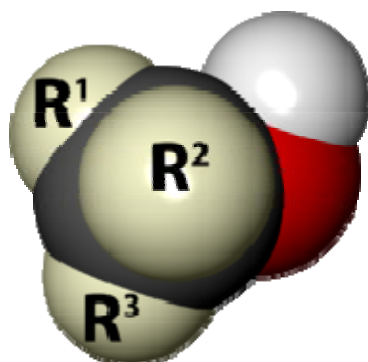
[Inositol](#)




[Menthol](#)

## Simple alcohols

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,  $\text{CH}_3$ ) with an OH group attached to the carbon is called "methyl alcohol" while a chain of two carbons (an ethyl group,  $\text{CH}_2\text{CH}_3$ ) with an OH group connected to the  $\text{CH}_2$  is called "ethyl alcohol." For more complex alcohols, the IUPAC nomenclature must be used.<sup>[21]</sup>



 Space filling model of the hydroxyl (OH) functional group in an alcohol molecule. This is the same as the ball-and-stick model above

The most commonly used alcohol is [ethanol](#),  $\text{C}_2\text{H}_5\text{OH}$ , with the [ethane](#) backbone. Ethanol has been produced and consumed by humans for millennia, in the form of fermented and distilled [alcoholic beverages](#). It is a clear, flammable liquid that boils at  $78.4^\circ\text{C}$ , which is used as an industrial solvent, [car fuel](#), and raw material in the chemical industry. In the [US](#) and some other countries, because of legal and tax restrictions on alcohol consumption, ethanol destined for other uses often contains additives that make it unpalatable (such as [denatonium benzoate](#)) or poisonous (such as methanol). Ethanol in this form is known generally as [denatured alcohol](#); when methanol is used, it may be referred to as [methylated spirits](#) or "surgical spirits".

The simplest alcohol is [methanol](#),  $\text{CH}_3\text{OH}$ , which was formerly obtained by the distillation of wood and, therefore, is called "wood alcohol". It is a clear liquid resembling ethanol in smell and properties, with a slightly lower boiling point ( $64.7^\circ\text{C}$  /  $148.5^\circ\text{F}$ ), and is used mainly as a solvent, fuel, and raw material. Unlike ethanol, methanol is extremely toxic: As little as 10 ml can cause permanent blindness by destruction of the [optic nerve](#) and 30 ml (one fluid ounce) is potentially fatal.<sup>[22]</sup>

Simple alcohols, in particular, ethanol and methanol, possess [denaturing](#) and inert rendering properties, leading to their use as anti-microbial agents in medicine, pharmacy, and industry.<sup>[citation needed]</sup>

## Higher alcohols

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.<sup>[23]</sup>

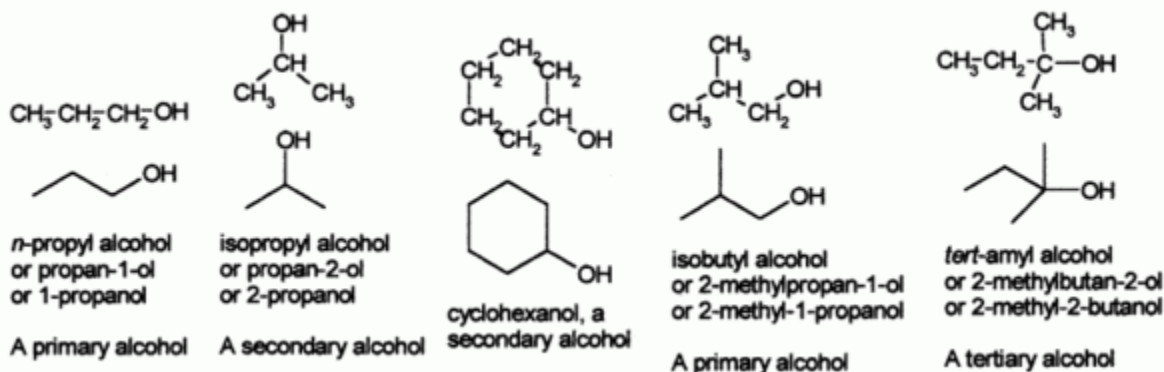
Like ethanol, [butanol](#) can be produced by fermentation processes. (However, the fermenting agent is a bacterium, *Clostridium acetobutylicum*, that feeds on [cellulose](#), not sugars like the *Saccharomyces* yeast that produces ethanol.) *Saccharomyces* yeast are known to produce these higher alcohols at temperatures above 75 °F (24 °C). These alcohols are called [fusel alcohols](#) or fusel oils in [brewing](#) and tend to have a spicy or peppery flavor. They are considered a fault in most styles of [beer](#).<sup>[24]</sup>

## Systematic names

In the [IUPAC](#) system, the name of the alkane chain loses the terminal "e" and adds "ol", e.g., "methanol" and "ethanol".<sup>[25]</sup> When necessary, the position of the hydroxyl group is indicated by a number between the alkane name and the "ol": [propan-1-ol](#) for  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ , [propan-2-ol](#) for  $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$ . Sometimes, the position number is written before the IUPAC name: 1-propanol and 2-propanol. If a higher priority group is present (such as an [aldehyde](#), [ketone](#), or [carboxylic acid](#)), then it is necessary to use the prefix "hydroxy",<sup>[25]</sup> for example: 1-hydroxy-2-propanone ( $\text{CH}_3\text{COCH}_2\text{OH}$ ).<sup>[26]</sup>

The IUPAC nomenclature is used in scientific publications and where precise identification of the substance is important. 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](#) alcohol, [ethyl](#) alcohol. [Propyl](#) alcohol may be [n-propyl alcohol](#) or [isopropyl alcohol](#), depending on whether the hydroxyl group is bonded to the 1st or 2nd carbon on the [propane](#) chain.

Alcohols are classified into 0°, primary (1°), secondary (2°; also italic abbreviated *sec-* or just *s-*), and tertiary (3°; also italic abbreviated *tert-* or just *t-*), based upon the number of carbon atoms connected to the carbon atom that bears the [hydroxyl](#) (OH) [functional group](#). The primary alcohols have general formulas  $\text{RCH}_2\text{OH}$ ; secondary ones are  $\text{RR}'\text{CHOH}$ ; and tertiary ones are  $\text{RR}'\text{R}''\text{COH}$ , where R, R', and R'' stand for alkyl groups. Methanol ([CH<sub>3</sub>OH](#) or  $\text{CH}_4\text{O}$ ) is a 0° alcohol. Some sources include [methanol](#) as a primary alcohol,<sup>[27][28]</sup> including the 1911 edition of the [Encyclopædia Britannica](#),<sup>[29]</sup> but this interpretation is less common in modern texts.





Some examples of simple alcohols and how to name them

## History and etymology

The first alcohol (today known as ethyl alcohol) was discovered by the tenth-century Persian alchemist [al-Razi](#).

*kuhl* (kohl) was originally the name given to the very fine powder produced by the [sublimation](#) of the natural mineral [stibnite](#) to form [antimony sulfide](#)  $\text{Sb}_2\text{S}_3$  (hence the essence or "spirit" of the substance), which was used as an [antiseptic](#), eyeliner and cosmetic (see [kohl \(cosmetics\)](#)). [Bartholomew Traheron](#) in his 1543 translation of [John of Vigo](#) introduces the word as a term used by "barbarous" ([Moorish](#)) authors for "fine powder":

*the barbarous auctours use alcohol, or (as I fynde it sometymes wryten) alcofoll, for moost fine poudre.*

The word *alcohol* appears in English, as a term for a very fine powder, in the 16th century, loaned via French from medical [Latin](#), ultimately from the [Arabic](#) [الكحل](#) (*al-kuhl*, "the [kohl](#), a powder used as an eyeliner"). [Al-](#) is the Arabic [definitive article](#), equivalent to *the* in English.

[William Johnson](#) in his 1657 *Lexicon Chymicum* 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](#) in *Alchymia* (1594) has *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](#)) in the 18<sup>th</sup> century, and was extended to the class of substances so-called as "alcohols" in modern chemistry, after 1850.

The current Arabic name for alcohol in The Qur'an, in verse 37:47, uses the word الغول *al-gawl*—properly meaning "spirit" or "demon"—with the sense "the thing that gives the wine its headiness."<sup>[30]</sup> Also, the term *ethanol* was invented 1838, modeled on German äthyl (Liebig), from Greek aither (see ether) + hyle "stuff."<sup>[31]</sup> *Ether* in late 14c. meant "upper regions of space," from Old French ether and directly from Latin aether "the upper pure, bright air," from Greek aither "upper air; bright, purer air; the sky," from aithein "to burn, shine," from PIE root \*aidh- "to burn" (see edifice).<sup>[32]</sup>

## Physical and chemical properties

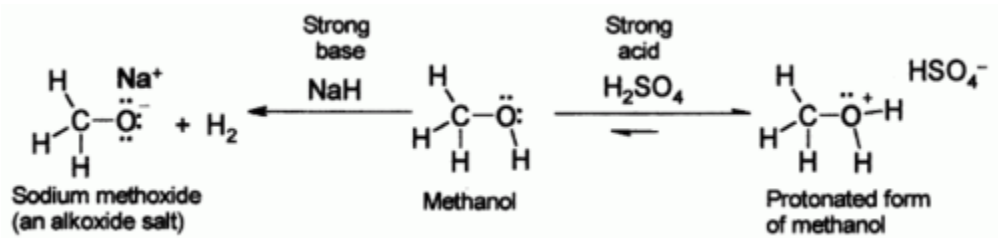
Alcohols have an odor that is often described as “biting” and as “hanging” in the nasal passages. Ethanol has a slightly sweeter (or more fruit-like) odor than the other alcohols.

In general, the [hydroxyl group](#) makes the alcohol molecule [polar](#). Those groups can form [hydrogen bonds](#) to one another and to other compounds (except in [certain large molecules](#) where the hydroxyl is protected by [steric hindrance](#) of adjacent groups<sup>[33]</sup>). This hydrogen bonding means that alcohols can be used as [protic solvents](#). 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 in water because the hydroxyl group wins out over the short carbon chain. [Butanol](#), with a four-carbon chain, is moderately soluble because of a balance between the two trends. Alcohols of five or more carbons ([pentanol](#) 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](#), alcohols tend to have higher boiling points than comparable [hydrocarbons](#) and [ethers](#). The boiling point of the alcohol ethanol is 78.29 °C, compared to 69 °C for the hydrocarbon [hexane](#) (a common constituent of [gasoline](#)), and 34.6 °C for [diethyl ether](#).

Alcohols, like water, can show either acidic or basic properties at the -OH group. With a [pK<sub>a</sub>](#) of around 16-19, they are, in general, slightly weaker [acids](#) than [water](#), but they are still able to react with strong bases such as [sodium hydride](#) or reactive metals such as [sodium](#). The [salts](#) that result are called [alkoxides](#), with the general formula  $\text{RO}^- \text{M}^+$ .

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



Alcohols can also undergo [oxidation](#) to give [aldehydes](#), [ketones](#), or [carboxylic acids](#), or they can be dehydrated to [alkenes](#). They can react to form [ester compounds](#), and they can (if activated first) undergo [nucleophilic substitution](#) reactions. The lone pairs of electrons on the oxygen of the hydroxyl group also makes alcohols nucleophiles. For more details, see the [reactions of alcohols](#) 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





 Total recorded [alcohol per capita consumption](#) (15+), in litres of pure alcohol<sup>[34]</sup>

Alcohol has a long history of several uses worldwide. It is found in beverages for 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

[Alcoholic beverages](#), typically containing 5% to 40% [ethanol](#) by volume, have been produced and consumed by humans since pre-historic times.

## Antifreeze

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

## Antiseptics

Ethanol can be used as an [antiseptic](#) to disinfect the skin before injections are given, often along with [iodine](#). Ethanol-based [soaps](#) 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](#).

## Fuels

Some alcohols, mainly [ethanol](#) and [methanol](#), can be used as an [alcohol fuel](#). Fuel performance can be increased in [forced induction internal combustion engines](#) by injecting alcohol into the air intake after the [turbocharger](#) or [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

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

## Solvents

Alcohols have applications in industry and science as reagents or [solvents](#). Because of its relatively low toxicity compared with other alcohols and ability to dissolve [non-polar](#) substances,

ethanol can be used as a solvent in medical drugs, [perfumes](#), and vegetable essences such as [vanilla](#). In [organic synthesis](#), alcohols serve as versatile intermediates.

## Production

In industry, alcohols are produced in several ways:

- By [fermentation](#) using [glucose](#) produced from sugar from the [hydrolysis](#) of [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](#) by the enzyme [invertase](#) into [glucose](#) and [fructose](#), then the conversion of [glucose](#) by the enzyme [zymase](#) into [ethanol](#) (and carbon dioxide).
- By direct [hydration](#) using [ethylene](#) ([ethylene hydration](#))<sup>[35]</sup> or other alkenes from [cracking](#) of fractions of distilled [crude oil](#).

## Endogenous

Several of the benign bacteria<sup>[which?]</sup> in the intestine use [fermentation](#) as a form of [anaerobic metabolism](#). This [metabolic](#) reaction produces [ethanol](#) as a waste product, just like [aerobic respiration](#) produces [carbon dioxide](#) and [water](#). Thus, human bodies contain some quantity of alcohol endogenously produced by these bacteria.<sup>[36][37][38][39]</sup>

## Laboratory synthesis

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

### Substitution

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

### Reduction

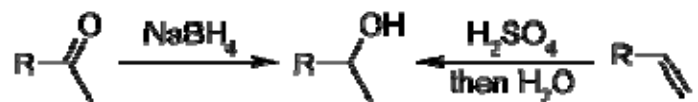
[Aldehydes](#) or [ketones](#) are [reduced](#) with [sodium borohydride](#) or [lithium aluminium hydride](#) (after an acidic workup). Another reduction by aluminiumisopropylates is the [Meerwein-Ponndorf-Verley reduction](#). [Noyori asymmetric hydrogenation](#) is the asymmetric reduction of  $\beta$ -keto-esters.

### Hydrolysis

[Alkenes](#) engage in an acid catalysed [hydration reaction](#) using concentrated sulfuric acid as a catalyst that gives usually secondary or tertiary alcohols. The [hydroboration-oxidation](#) and [oxymercuration-reduction](#) of alkenes are more reliable in organic synthesis. Alkenes react with

NBS and water in [halohydrin formation reaction](#). [Amines](#) can be converted to [diazonium salts](#), which are then hydrolyzed.

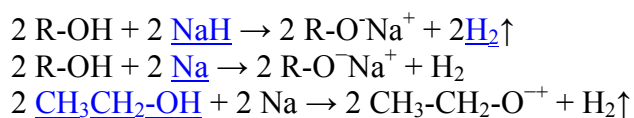
The formation of a secondary alcohol via reduction and hydration is shown:



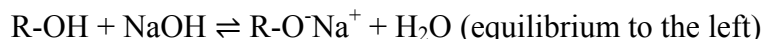
## Reactions

### Deprotonation

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



Water is similar in [pK<sub>a</sub>](#) to many alcohols, so with [sodium hydroxide](#) there is an [equilibrium](#) set-up, which usually lies to the left:



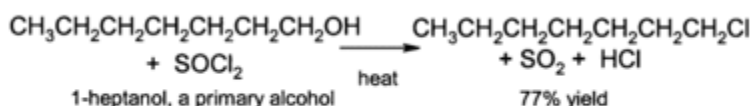
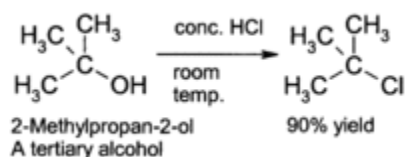
It should be noted, however, that the bases used to deprotonate alcohols are strong themselves. The bases used and the alkoxides created are both highly moisture-sensitive chemical reagents.

The acidity of alcohols is also affected by the overall stability of the alkoxide ion. [Electron-withdrawing groups](#) 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](#) 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.

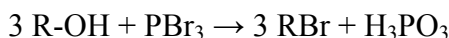
With [alkyl halides](#) alkoxides give rise to [ethers](#) in the [Williamson ether synthesis](#).

### Nucleophilic substitution

The OH group is not a good [leaving group](#) in [nucleophilic substitution](#) reactions, so neutral alcohols do not react in such reactions. However, if the oxygen is first protonated to give  $\text{R}-\text{OH}_2^+$ , the leaving group ([water](#)) is much more stable, and the nucleophilic substitution can take place. For instance, tertiary alcohols react with [hydrochloric acid](#) to produce tertiary [alkyl halides](#), where the [hydroxyl group](#) is replaced by a [chlorine](#) atom by [unimolecular nucleophilic substitution](#). If primary or secondary alcohols are to be reacted with [hydrochloric acid](#), an activator such as [zinc chloride](#) is needed. In alternative fashion, the conversion may be performed directly using [thionyl chloride](#).<sup>[1]</sup>



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



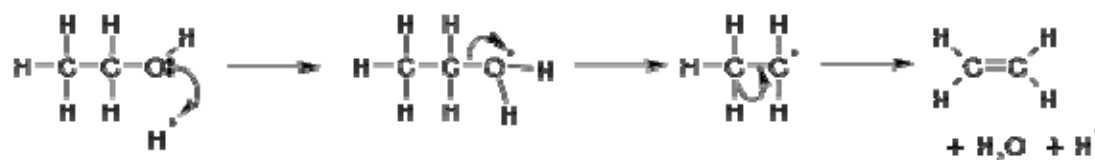
In the [Barton-McCombie deoxygenation](#) an alcohol is deoxygenated to an [alkane](#) with [tributyltin hydride](#) or a [trimethylborane](#)-water complex in a [radical substitution](#) reaction.

## Dehydration

Alcohols are themselves nucleophilic, so  $\text{R}-\text{OH}_2^+$  can react with ROH to produce [ethers](#) and water in a [dehydration reaction](#), although this reaction is rarely used except in the manufacture of [diethyl ether](#).

More useful is the E1 [elimination reaction](#) of alcohols to produce [alkenes](#). The reaction, in general, obeys [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.

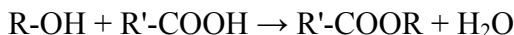
This is a diagram of acid catalysed dehydration of ethanol to produce [ethene](#):



A more controlled elimination reaction is the [Chugaev elimination](#) with [carbon disulfide](#) and [iodomethane](#).

## Esterification

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



In order to drive the equilibrium to the right and produce a good [yield](#) of ester, water is usually removed, either by an excess of  $\text{H}_2\text{SO}_4$  or by using a [Dean-Stark apparatus](#). Esters may also be prepared by reaction of the alcohol with an [acid chloride](#) in the presence of a base such as [pyridine](#).

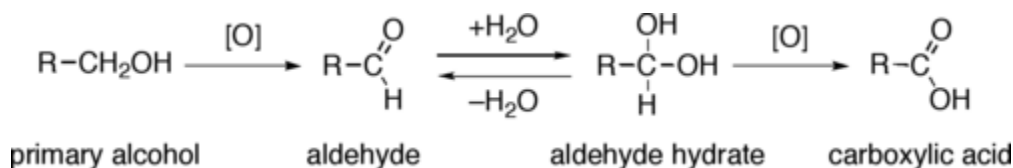
Other types of ester are prepared in a similar manner — for example, [tosyl](#) (tosylate) esters are made by reaction of the alcohol with p-[toluenesulfonyl](#) chloride in pyridine.

## Oxidation

*Main article:* [Alcohol oxidation](#)

Primary alcohols ( $\text{R-CH}_2\text{-OH}$ ) can be oxidized either to [aldehydes](#) ( $\text{R-CHO}$ ) or to [carboxylic acids](#) ( $\text{R-CO}_2\text{H}$ ), while the oxidation of secondary alcohols ( $\text{R}^1\text{R}^2\text{CH-OH}$ ) normally terminates at the [ketone](#) ( $\text{R}^1\text{R}^2\text{C=O}$ ) stage. Tertiary alcohols ( $\text{R}^1\text{R}^2\text{R}^3\text{C-OH}$ ) are resistant to oxidation.

The direct [oxidation of primary alcohols to carboxylic acids](#) normally proceeds via the corresponding aldehyde, which is transformed via an *aldehyde hydrate* ( $\text{R-CH(OH)}_2$ ) by reaction with water before it can be further oxidized to the carboxylic acid.



Mechanism of [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](#). These include [Collins reagent](#) and [Dess-Martin periodinane](#). The direct oxidation of primary alcohols to carboxylic acids can be carried out using [potassium permanganate](#) or the [Jones reagent](#).

## Occurrence in nature

Alcohol has been found outside the [Solar System](#). It can be found in low densities in star and planetary-system-forming regions of space.<sup>[40]</sup>

## See also

- [Blood alcohol content](#)
- [Breathalyzer](#)
- [Cooking with alcohol](#)
- [Enol](#)
- [Fatty alcohol](#)
- [History of alcoholic beverages](#)
- [List of countries by alcohol consumption](#)
- [Phenols](#)
- [Polyol](#)
- [Rubbing alcohol](#)
- [Sugar alcohol](#)
- [Surrogate alcohol](#)
- [Transesterification](#)
- [2-methyl-2-butanol](#)

## Notes

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