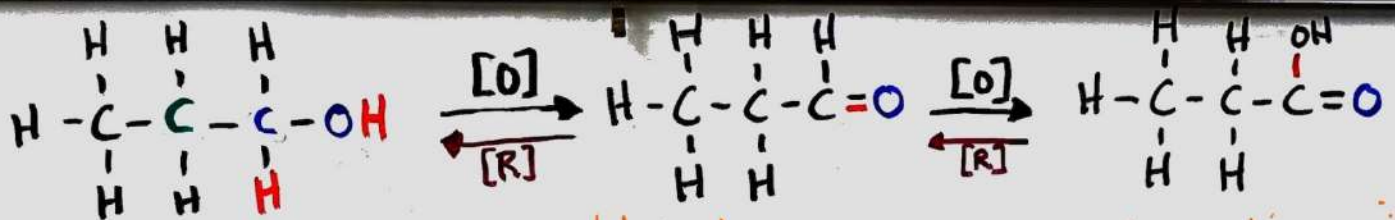
Alcohols and Phenols

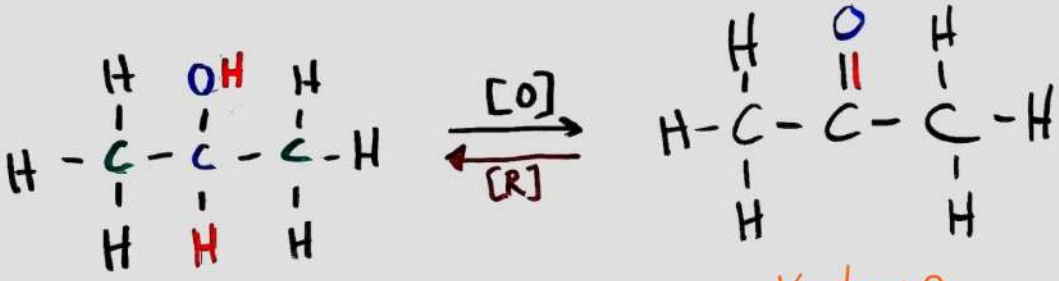
1° alcohol (primary)



aldehyde

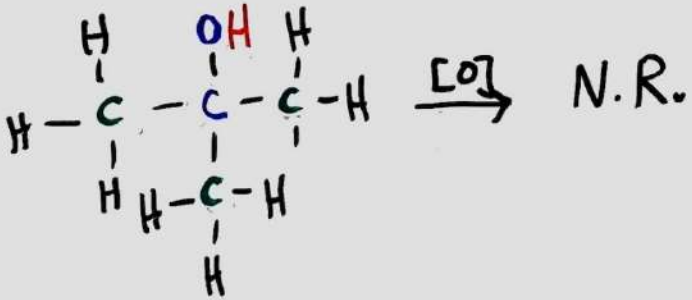
carboxylic acid

2° alcohol (Secondary)



Ketone

3° alcohol (Tertiary)



N.R.

"C" = the alcohol carbon

"c" = a carbon attached to the alcohol carbon.

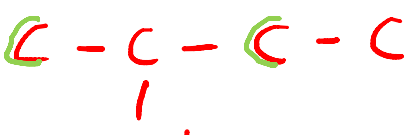
Alcohols

Alcohols are classified by the number of R groups *(i.e. carbon atoms)* attached to the hydroxyl carbon as shown here. Classification

primary (1°)

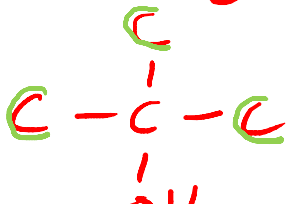
(OH is on the end)

Secondary (2°)

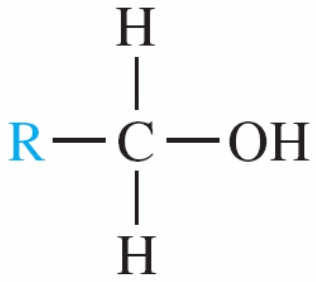


(OH in middle)

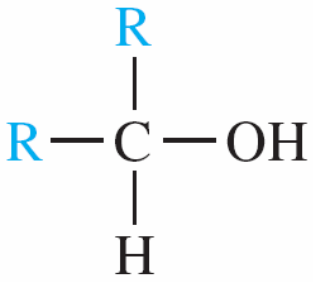
Tertiary (3°)



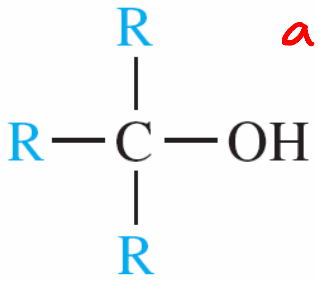
(OH in center boxed in ~~each~~ by another carbon)



primary (1°)



secondary (2°)



tertiary (3°)

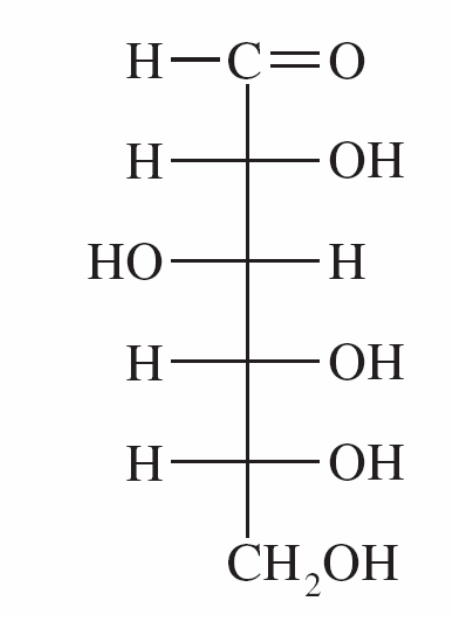
Types of Alcohols

1. $CH_3CH_2CH_2CH_2OH$

2. $CH_3CH_2CHCH_3$
   |
   OH

3. CH_3
   |
   CH_3CCH_3
   |
   OH

Alcohols with more than one –OH group are known as polyhydroxy alcohols. These include diols, triols, and carbohydrates like glucose.



D-glucose

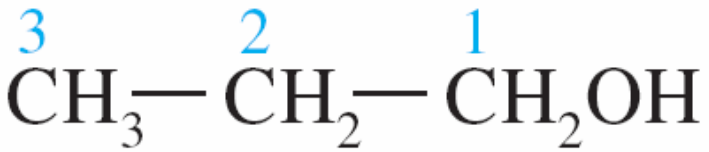
(a polyhydroxy alcohol)

IUPAC Rules for Naming Alcohols

1. Name the longest continuous carbon chain containing the hydroxyl group.

2. Drop an *–e* from the corresponding alkane parent name and add the suffix *–ol*.

For example,

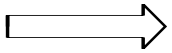


1-propanol

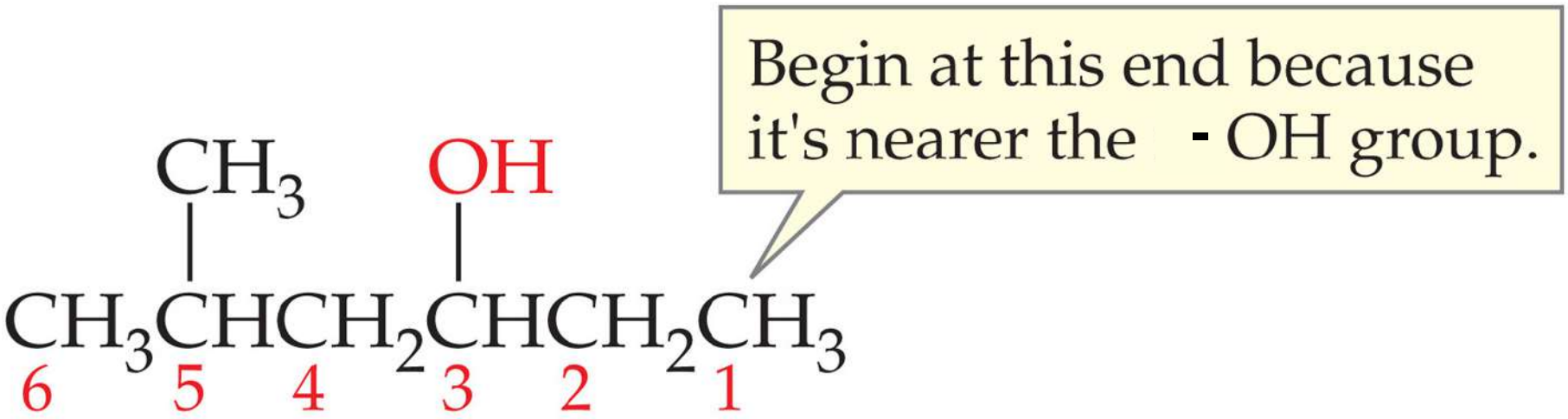
IUPAC Rules for Naming Alcohols

3. Carbon chains with three or more carbon atoms are numbered so the -OH group carbon atom is assigned the lowest possible number. This number is given as a prefix in the name.

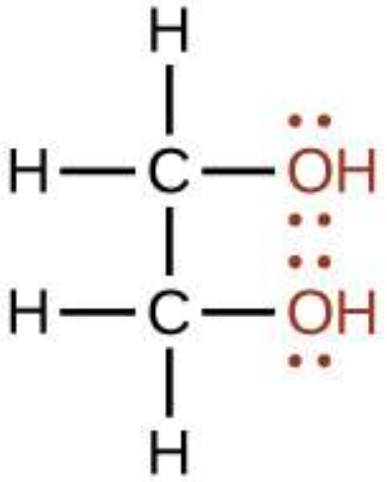
4. Attached groups are named and numbered as stated previously.

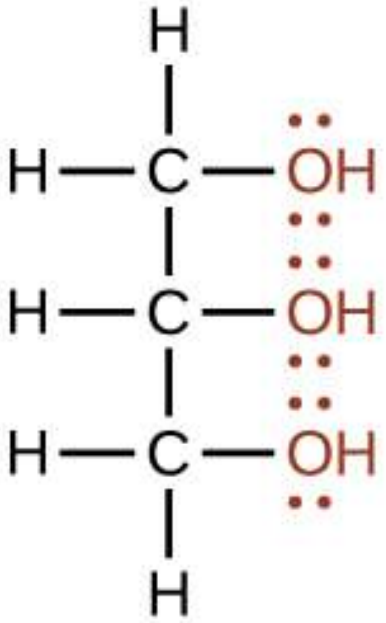


4-methyl-2-hexanol

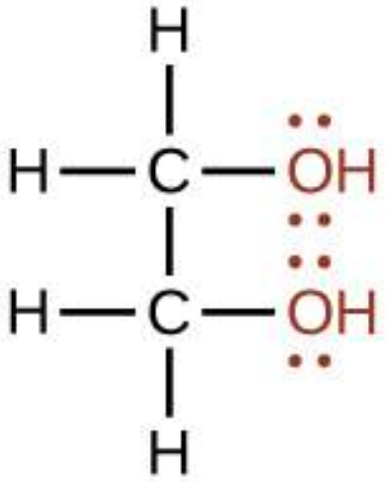


Naming Diols and Triols

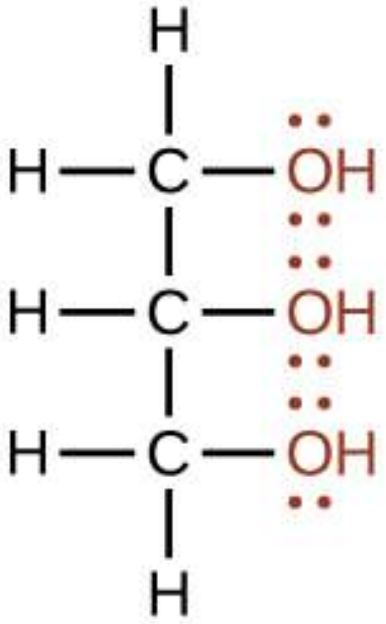




Naming Diols and Triols



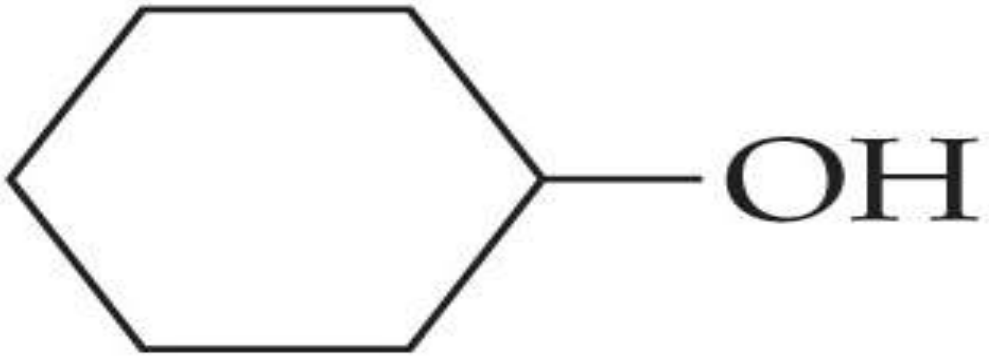
1,2-ethanediol



1,2,3-propanetriol

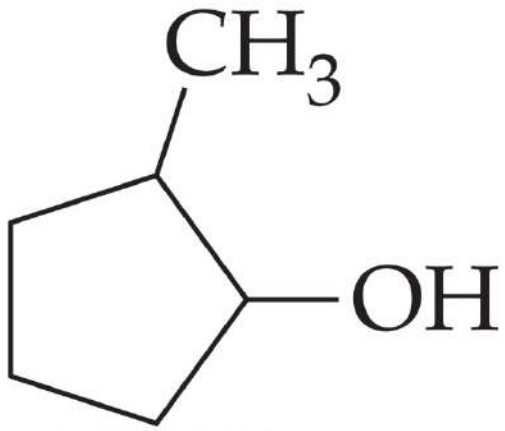
Naming Alcohols of Cycloalkanes

1. Because the –OH group is always on the number 1 carbon in a ring, the 1 is not shown in the name.



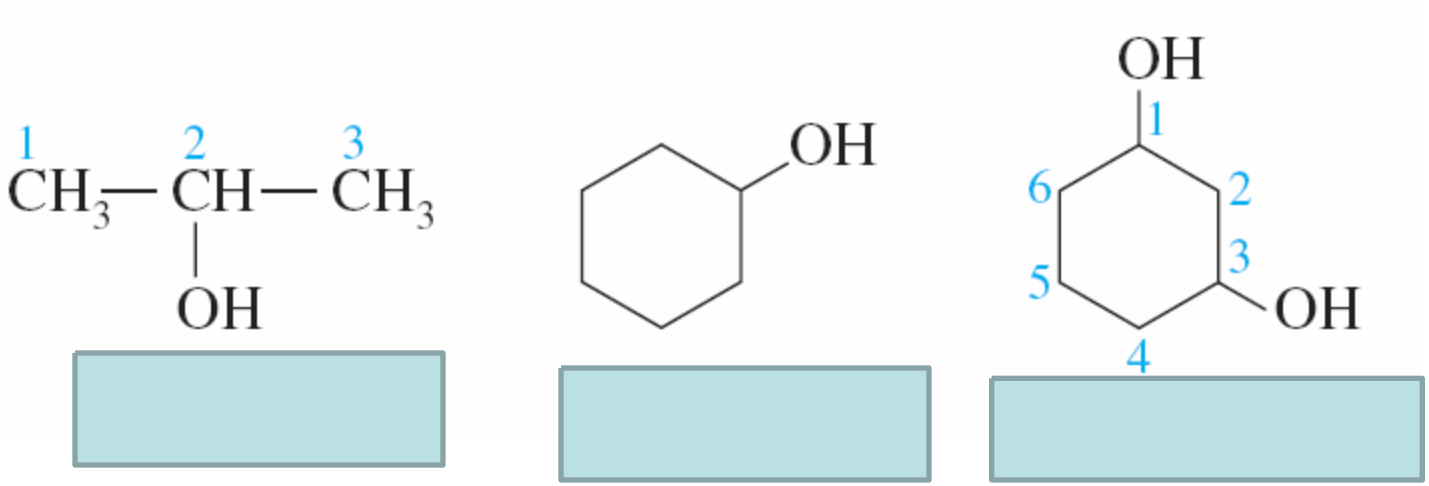
What's My Name

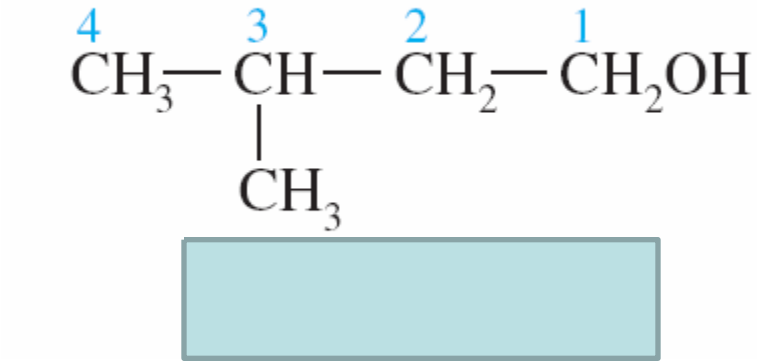
(e)

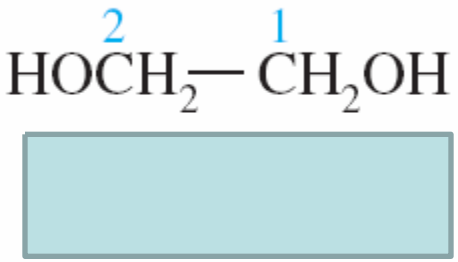


(b) $CH_3CH_2CHCHCH_3$ (HO on the second carbon, CH_3 on the third carbon)

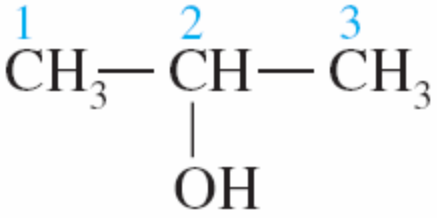
Other Examples of Naming Alcohols



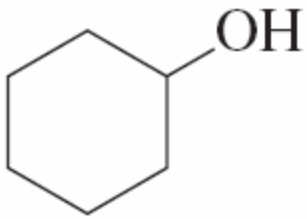




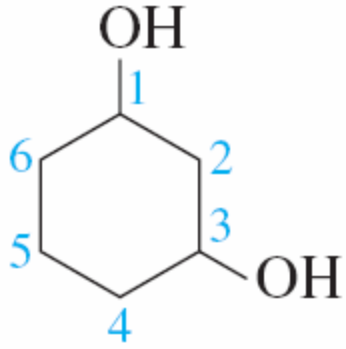
Other Examples of Naming Alcohols



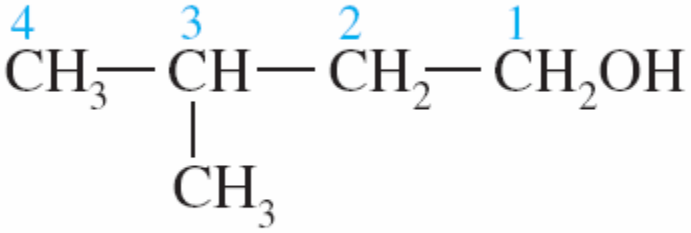
2-propanol



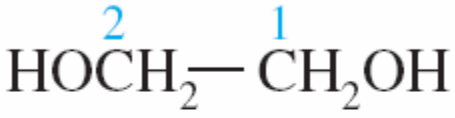
cyclohexanol



1,3-cyclohexanediol



3-methyl-1-butanol



1,2-ethanediol

Oxidation of Alcohols Lab

1 mL alcohol + 10 drops of acidified sodium dichromate

→ if oxidation occurred, the color changed from bright orange to another color.

methanol

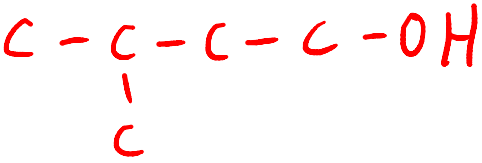
ethanol

1-propanol

2-propanol (isopropyl)

1-butanol

2-butanol (sec-butyl)



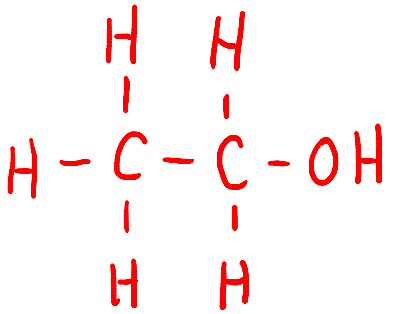
2-methyl-2-propanol (tert butyl) → No Reaction

2-methyl-1-propanol (isobutyl)

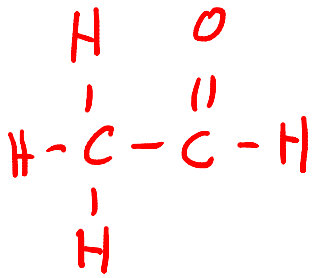
3-methyl-1-butanol (isoamyl)

1° alcohol $\xrightarrow{[O]}$ aldehyde $\xrightarrow{[O]}$ carboxylic acid

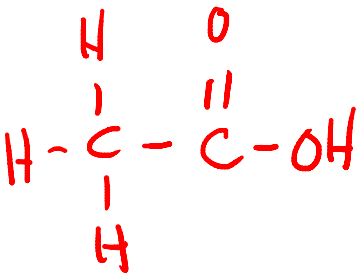
1°



ethanol



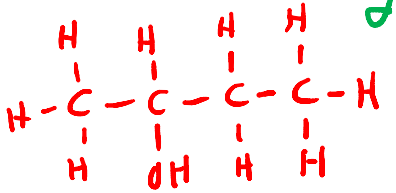
ethanal



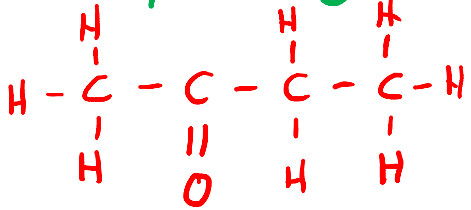
ethanoic acid

2° alcohol $\xrightarrow{[O]}$ Ketone

2°

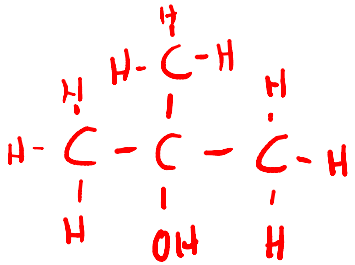


2 - butanol



2 - butanone

3°

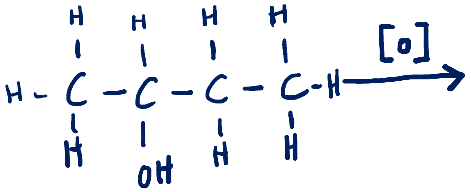


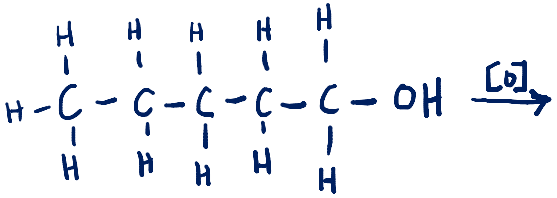
$\xrightarrow{[O]}$ N.R.

2 - methyl - 2 propanol

Review of Alcohol Oxidation

1. Name each alcohol
2. Predict the product(s) for the oxidation of each
3. Draw structure(s) for the product(s)
4. Name the product(s)

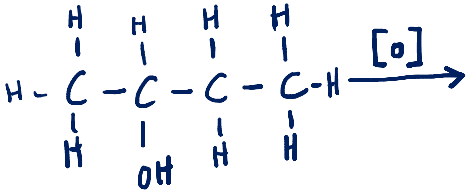




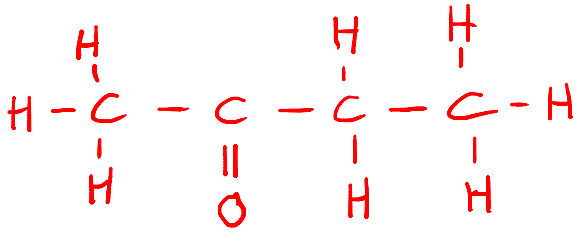
Review of alcohol oxidation

Answers

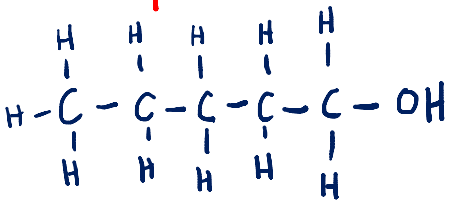
2-butanol



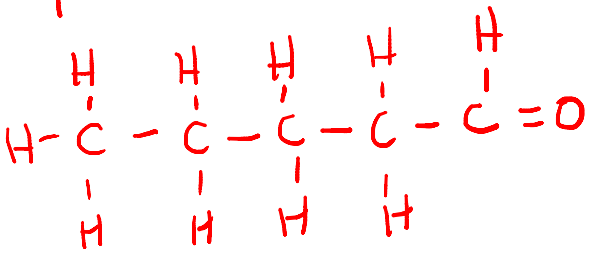
2-butanone



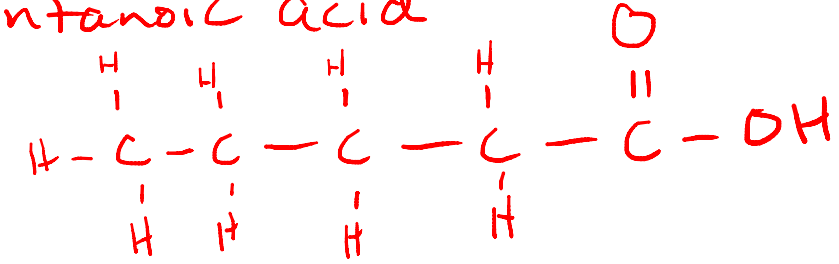
1-pentanol



pentanal

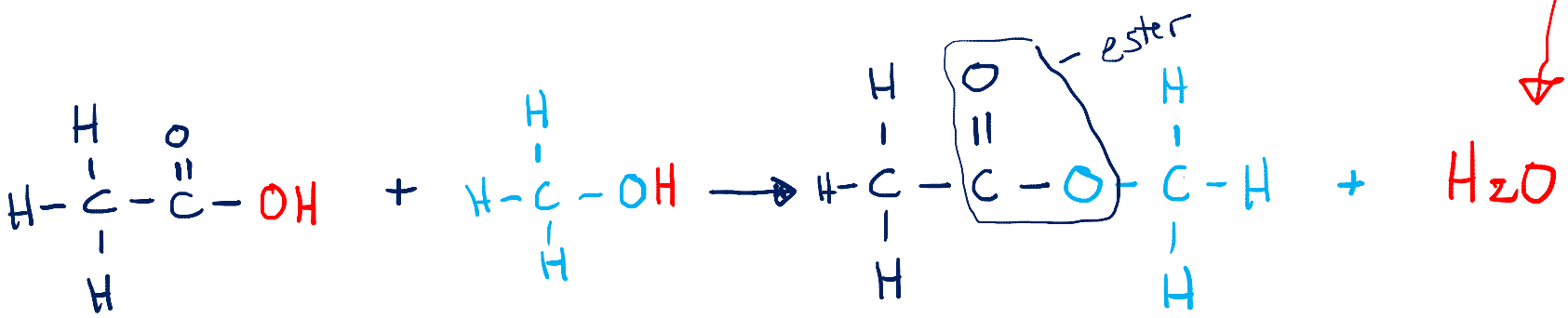


pentanoic acid



Introduction to esters

"Condensation" reaction

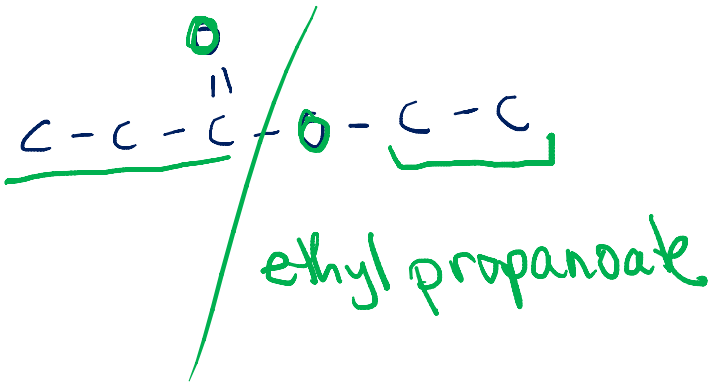


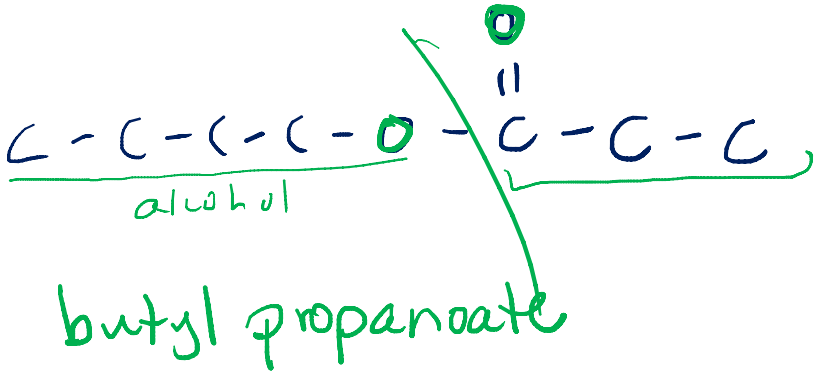
ethanoic acid + methanol → methyl ethanoate + water

Comes from the alcohol

Comes from the carboxylic acid

carboxylic acid + alcohol → Ester + water





Predict the name of the ester:

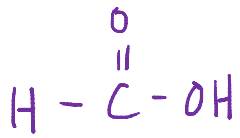
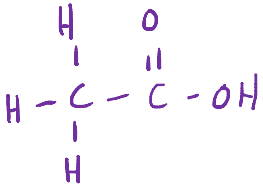
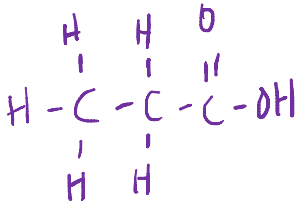
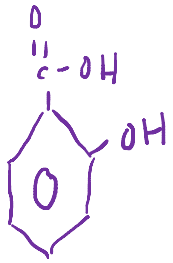
methanoic acid + 1-butanol → 1-butyl methanoate + water

ethanoic acid + 2-butanol → 2-butyl ethanoate + water

octanoic acid + 2-propanol → 2-propyl octanoate + water

2-hydroxybenzoic acid + methanol → methyl 2-hydroxybenzoate + water

Common Carboxylic Acids

Structure	Name	Common Name	Source
	methanoic acid	formic acid	ant bites
	ethanoic acid	acetic acid	vinegar
	propanoic acid	propionic acid	bacteria in sweat glands
	2-hydroxybenzoic acid	salicylic acid	willow bark aspirin

carboxylic acid alcohol ester water

Rum — apple?

butanoic acid + methanol → methyl butanoate + water

---

pineapple — Strawberry??

butanoic acid + ethanol →

---

pear

ethanoic acid + 1-propanol →

---

oranges

ethanoic acid + 1-octanol →

---

bananas

ethanoic acid + 3-methyl-1-butanol →

---

wintergreen

2-hydroxybenzoic acid + methanol →

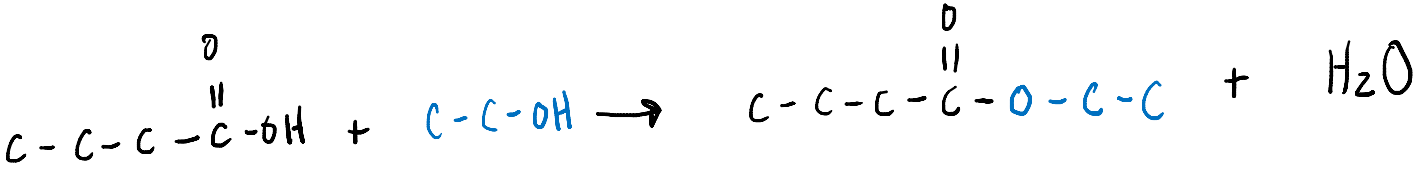
Strawberry — pineapple ??

butanoic acid + 1-butanol →

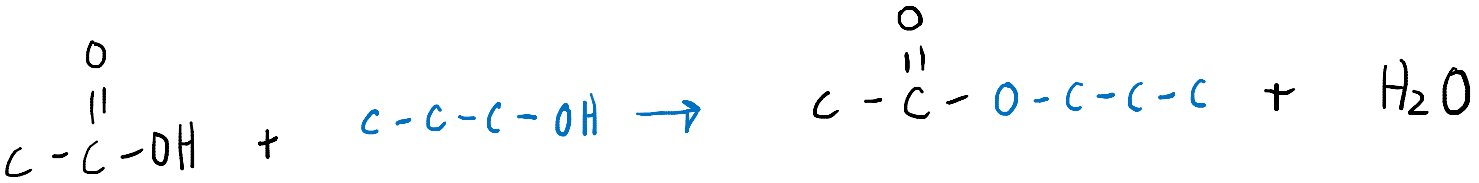
pineapple

Strawberry??

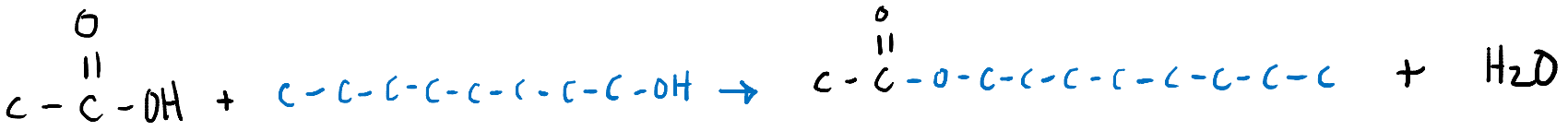
butanoic acid + ethanol → ethyl butanoate + water



pear ethanoic acid + 1-propanol → 1-propyl ethanoate + water



oranges ethanoic acid + 1-octanol → 1-octyl ethanoate + water



bananas ethanoic acid + 3-methyl-1-butanol →

wintergreen 2-hydroxybenzoic acid + methanol →

Strawberry

pineapple ??

butanoic acid + 1-butanol →

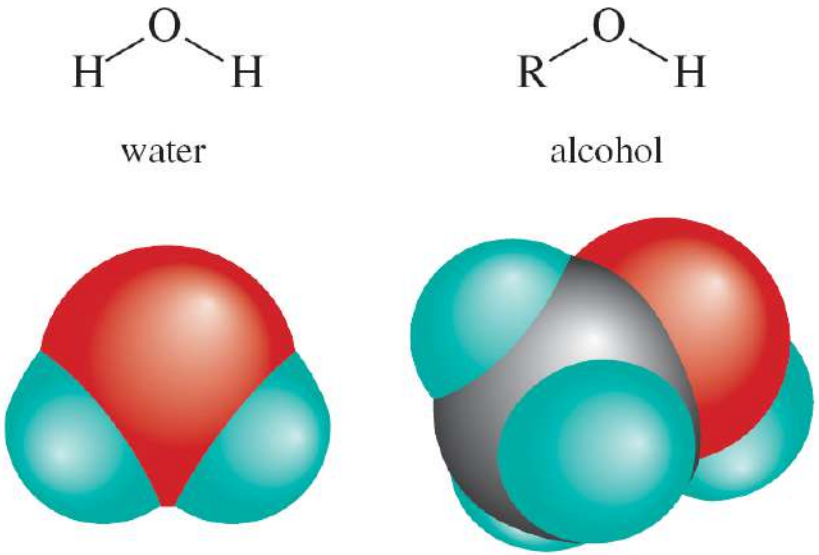
Types of Intermolecular Forces

- 1) Van der Waals

Physical Properties of Alcohols

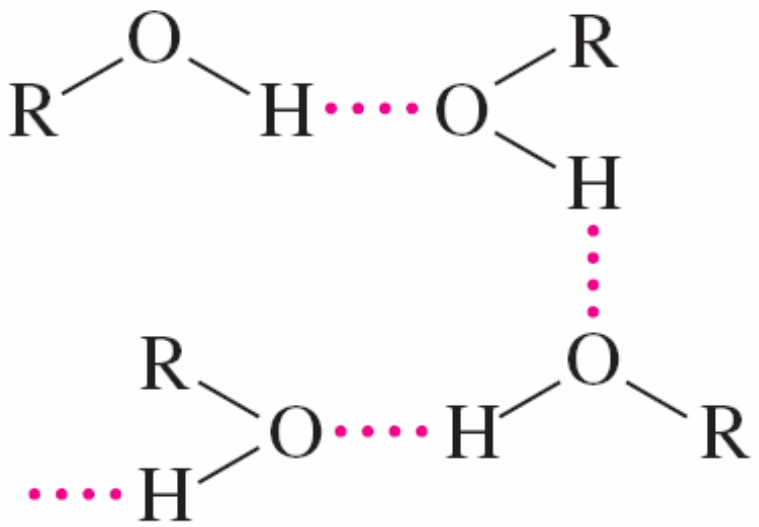
Alcohols contain the polar hydroxyl group (–OH).

The –OH group can undergo hydrogen bonding which affects the solubility and boiling point of alcohols.



Hydrogen Bonding and Boiling Point

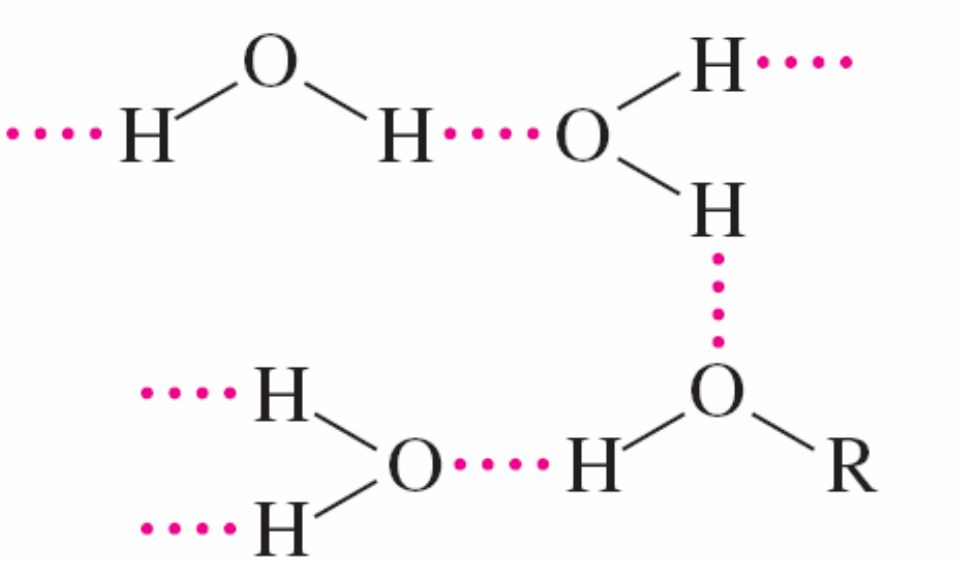
Hydrogen bonding between alcohol molecules explains the increase in boiling points of alcohols compared to alkanes.



alcohol–alcohol

Hydrogen Bonding and Solubility

Hydrogen bonding between alcohol and water molecules is the reason for the increased solubility of alcohols.



water–alcohol

Effect of Hydroxyl Groups on Boiling Points

Increasing the number of –OH groups in a molecule increases the boiling point and solubility of the molecule.

Notice in Table 22.3 that the b.p. of 1,2-ethanediol is 100°C higher than the b.p. of 1-propanol because of an additional -OH group.

Table 22.3 Comparison of the Boiling Points of Ethanol, 1,2–Ethanediol, and 1–Propanol

Name	Formula	Molar mass	Boiling point (°C)
Ethanol	CH_3CH_2OH	46	78
1,2-Ethanediol	$CH_2(OH)CH_2OH$	62	197
1-Propanol	$CH_3CH_2CH_2OH$	60	97

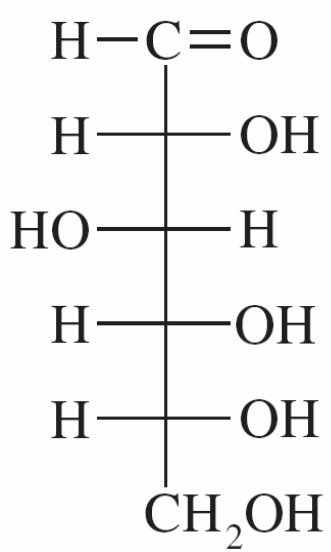
Effect of Hydroxyl Groups on Solubility

The effect of added –OH groups on solubility can be more significant for a carbohydrate like glucose.
Note the difference in solubility of hexanol *(only one –OH group)* and glucose *(five –OH groups)*.

$CH_3CH_2CH_2CH_2CH_2CH_2OH$

1-hexanol

(solubility = 0.6g/100g H_2O)



D-glucose

(solubility = 95g/100g H_2O)

General Solubility of Alcohols

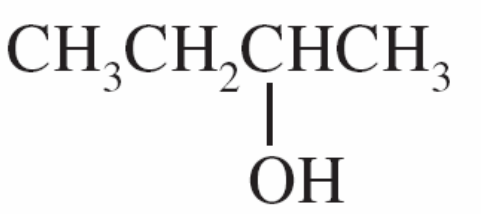
Alcohols with three carbon atoms or less are infinitely soluble in water while those with four or more carbon atoms have limited solubility in water.

However , all hydrocarbons are insoluble in water.

Effect of Branching on Boiling Point

A branched-chain alcohol will have a lower boiling point than the corresponding straight-chain alcohol.

For example 2-butanol is branched and has a b.p. of 91.5 °C versus 118° C for 1-butanol.

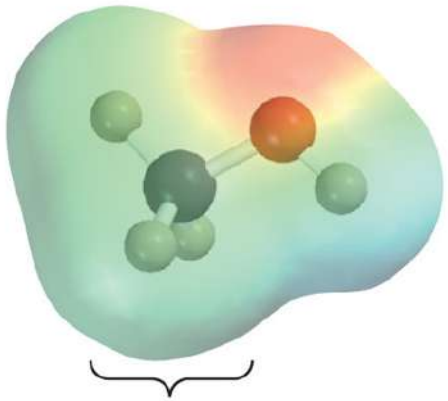


2-butanol

$CH_3CH_2CH_2CH_2OH$

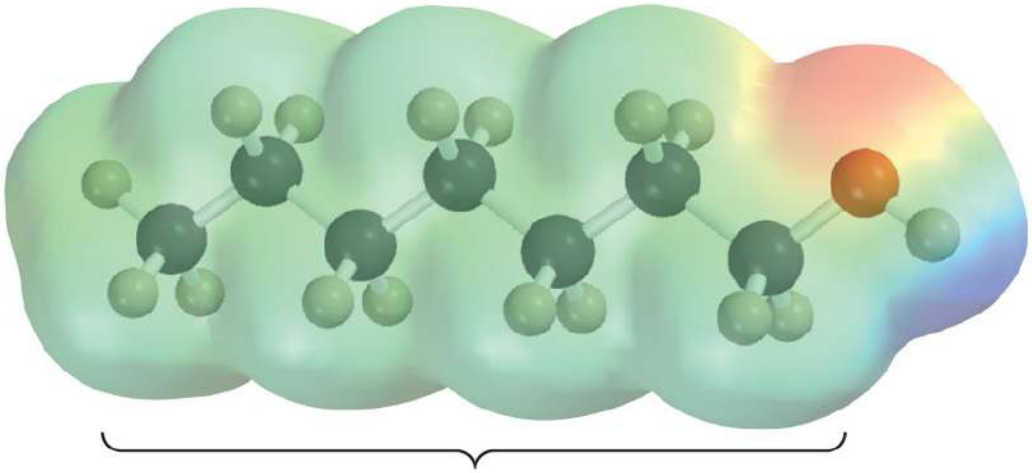
1-butanol

$CH_3—OH$



Methanol: has a small organic part and is therefore water-like.

$CH_3CH_2CH_2CH_2CH_2CH_2CH_2—OH$



1-Heptanol: has a large organic part and is therefore alkane-like.

Reactions of Alcohols

Alcohols undergo many reactions including these two:

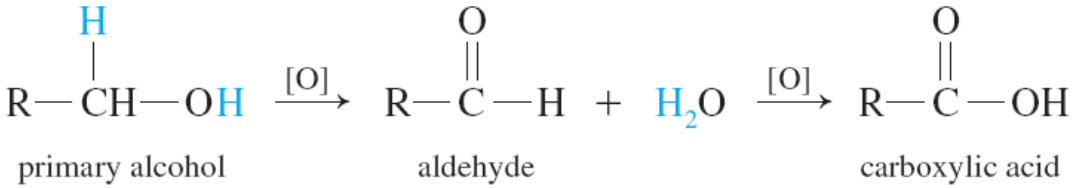
- Oxidation to form aldehydes, ketones, or carboxylic acids
- Dehydration to form alkenes and ethers

Three definitions for oxidation

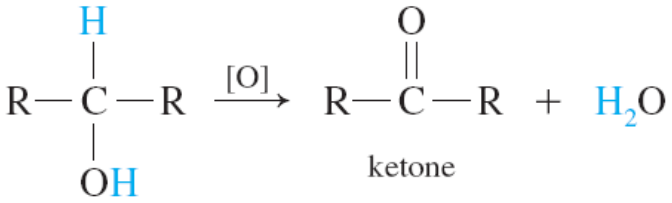
- Oxidation is the loss of electrons
- Oxidation is the loss of two hydrogens
- Oxidation is the gain of oxygen or bonds

Oxidation

Alcohols are oxidized to form aldehydes, ketones, or carboxylic acids . [O] is the general symbol for oxidizing agents with some common oxidizing agents being $KMnO_4$, $K_2Cr_2O_7$, and O_2.

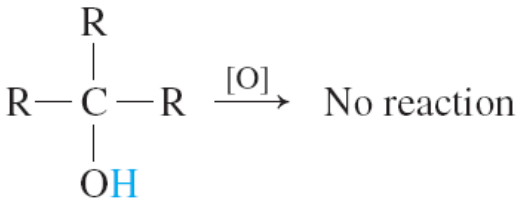


primary alcohol aldehyde carboxylic acid



ketone

secondary alcohol



tertiary alcohol

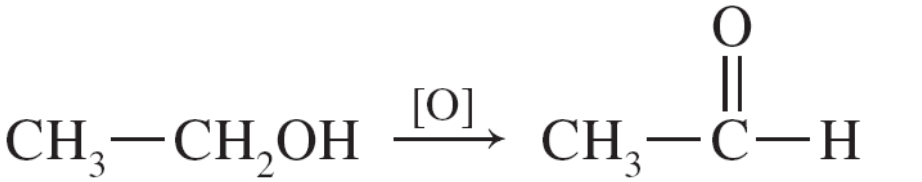
Application of an Oxidation Reaction

The oxidation of ethanol is used in the breath analyzer test.

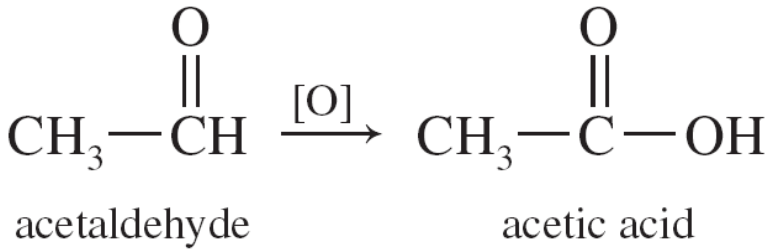
The orange color of $K_2Cr_2O_7$ in the picture on the left partially changes to green in the picture on the right when it reacts with ethanol *(CH_3CH_2OH)* from the balloon.

Oxidation: Biochemistry of Ethanol

Ethanol is toxic because it is oxidized to ethanal which can cause cirrhosis of the liver.

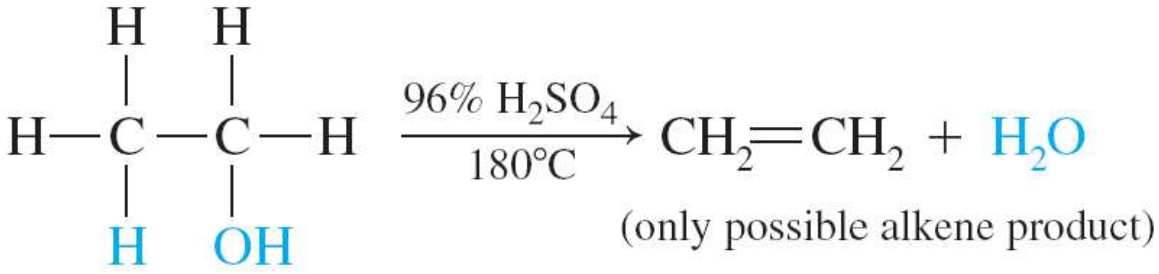


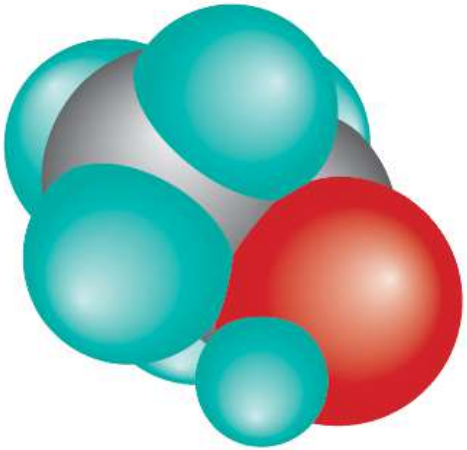
Ethanal in turn is oxidized to acetic acid which can contribute to obesity if ethanol is consumed in excess.

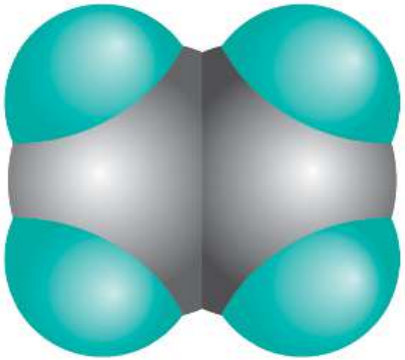


Dehydration

Alcohols are dehydrated to form alkenes.







Utility of the Hydroxyl Functional Group

The –OH functional group is a valuable intermediate because it is a “ gateway’ functional group to the synthesis of the functional groups listed in Figure 22.2.

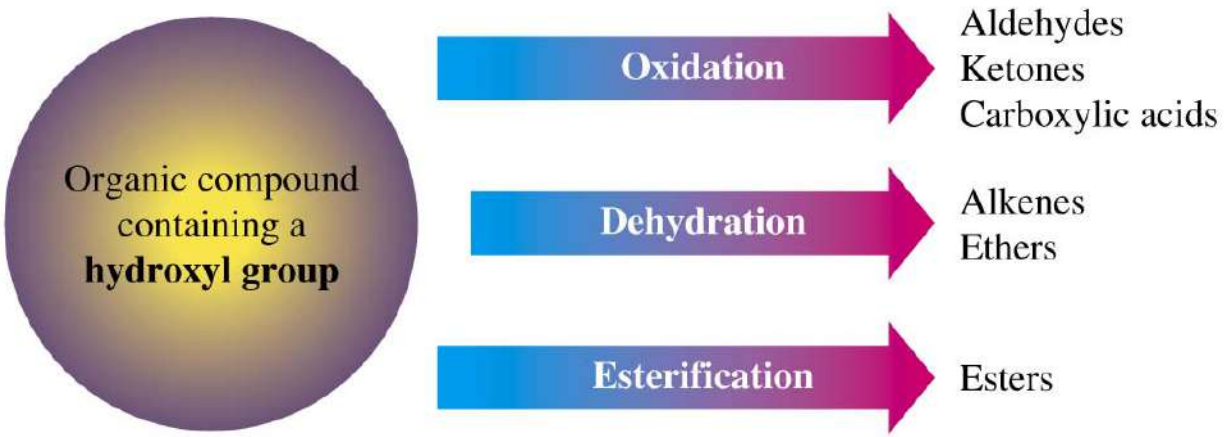


Figure 22.2 Hydroxyl group reactions

Methanol: Properties and Applications

Methanol has a b.p. of 65 °C making it a highly flammable liquid.

Methanol is poisonous and can cause blindness or death when taken internally.

It is also used as an industrial solvent and as a denaturant for ethanol.

Methanol Poisoning Treatment

- Antidote therapy is directed towards delaying methanol metabolism
- Administer ethanol because ADH has higher affinity for ethanol
- Administer fomepizole which is also metabolized by ADH
- Hemodialysis removes methanol and formic acid

Preparation of Ethanol

Ethanol can be prepared by fermentation or by the acid-catalyzed addition of water to ethylene.

Fermentation

$$\underset{\text{glucose}}{C_6H_{12}O_6} \xrightarrow[H_2O]{\text{yeast}} 2\,CH_3CH_2OH + 2\,CO_2$$

ethanol

Hydration

$$CH_2{=}CH_2 + H_2O \xrightarrow{H^+} CH_3CH_2OH$$

Ethanol: Properties and Applications

Pure ethanol has a b.p. of 78° C and is very hygroscopic. 100% ethanol takes up water very quickly until a stable concentration of 95.6% ethanol is reached.

Ethanol can act in the body as a food, drug, or a poison depending on the quantity consumed.

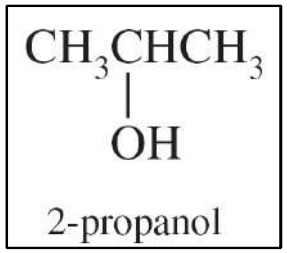
Ethanol: Applications

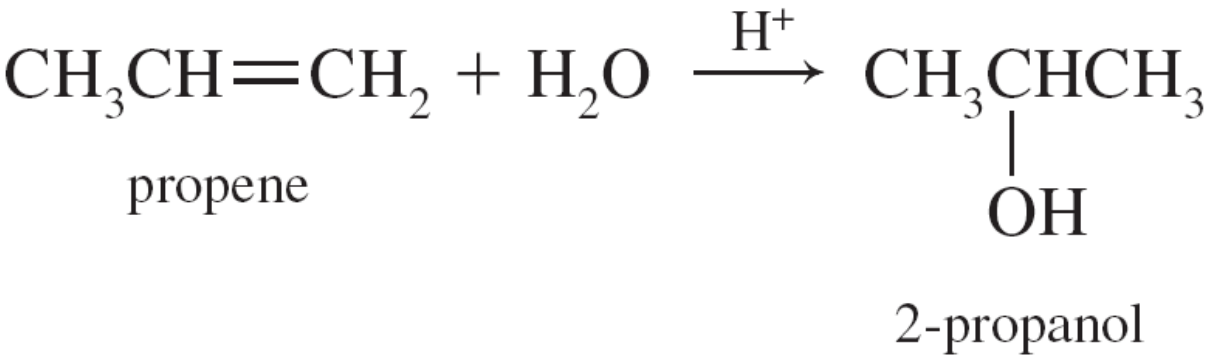
Ethanol is used commercially as an intermediate in the manufacture of other chemicals such as acetic acid.

It is also used as a solvent for many organic substances, as a compounding ingredient for pharmaceuticals, perfumes, flavorings, etc., and as a major component in alcoholic beverages.

2-Propanol *(Isopropyl Alcohol)*

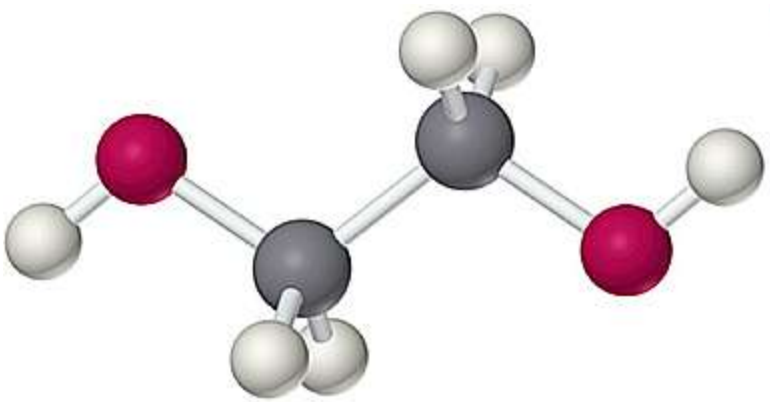
2-propanol is a secondary alcohol prepared from propene.





Commercial uses include the manufacture of chemicals like acetone, as an industrial solvent, and in rubbing-alcohol formulations.

Ethylene Glycol



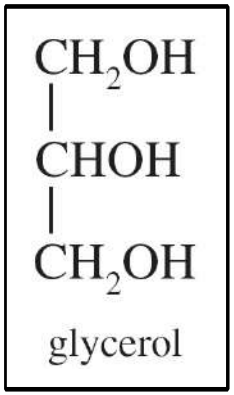
Ethylene glycol


Comma
CONCENTRATED
Anti
Freeze
2 FULL Protection
WINTER Protection
+45°C SUMMER Protection
SUPER COLDMASTER

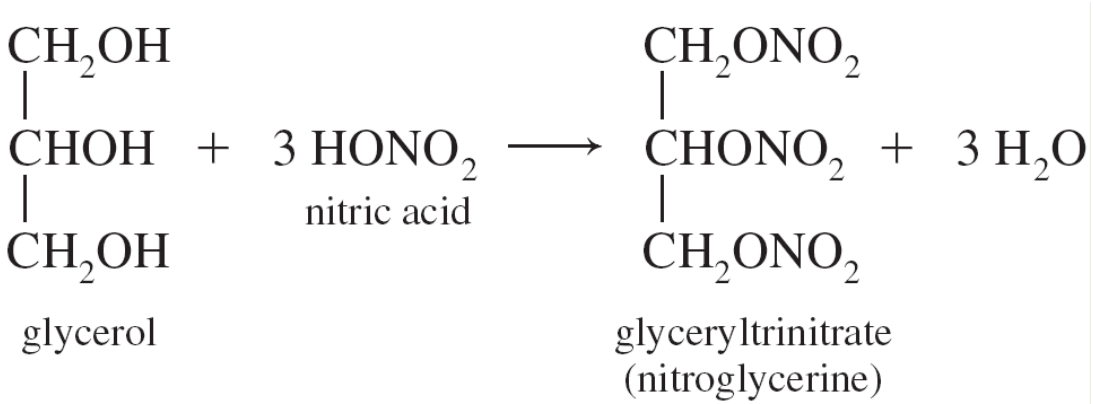

ANTIFREEZE
ANTIFREEZE
KILLS!

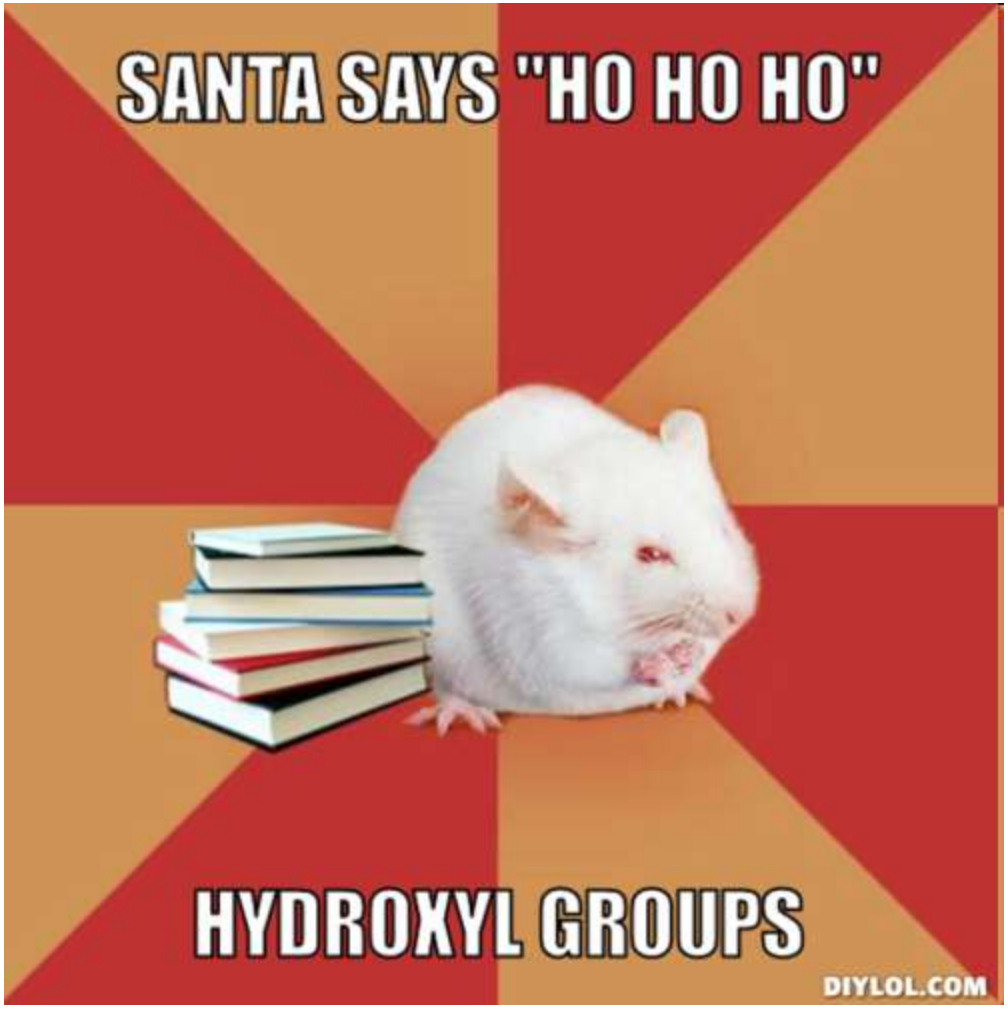
Glycerol *(1,2,3-Propanetriol)*

Glycerol (*i.e. glycerine)* is a polyhydroxy alcohol. It is a desirable commercial chemical because of its attraction for water which is due to the polarity of its hydroxyl groups.



Commercial uses include the manufacture of polymers and explosives *(see reaction below)*, as an emollinet in cosmetics, as a humectant in tobacco products, and as a sweetner.

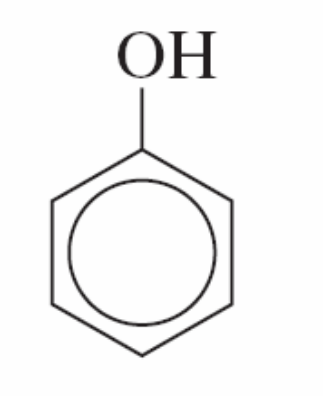



SANTA SAYS "HO HO HO"
HYDROXYL GROUPS
DIYLOL.COM

Phenols

Phenols are organic compounds that have a hydroxy group attached to an aromatic ring.

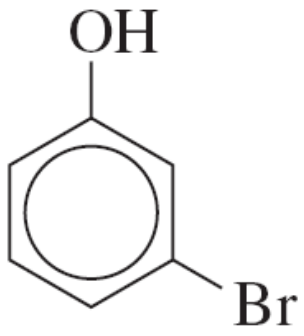
The name of the parent compound, C_6H_5OH, is phenol.



phenol

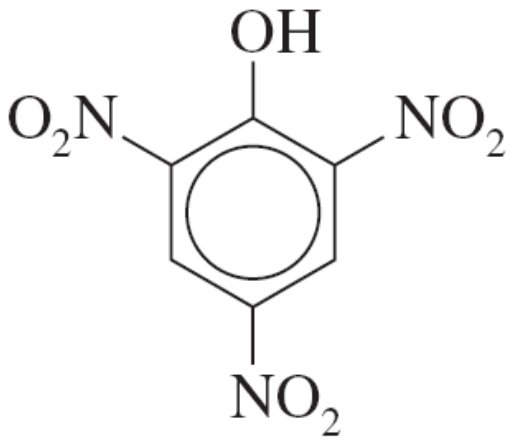
Naming Phenols

Derivatives of phenols are named using the general methods for naming aromatic compounds as shown here.



m-bromophenol

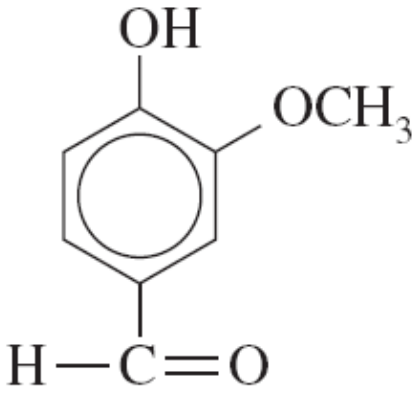
p-aminophenol



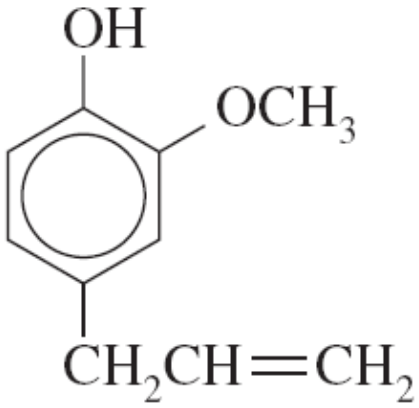
2,4,6-trinitrophenol
(picric acid)

Phenols as Flavoring Agents

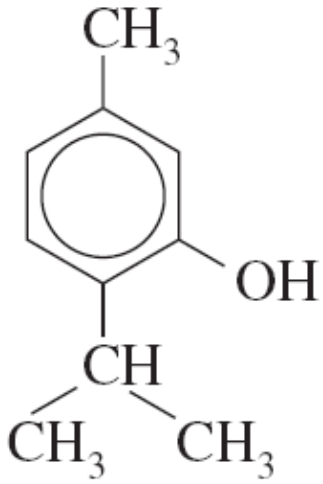
These phenols are often used as flavoring agents.



vanillin



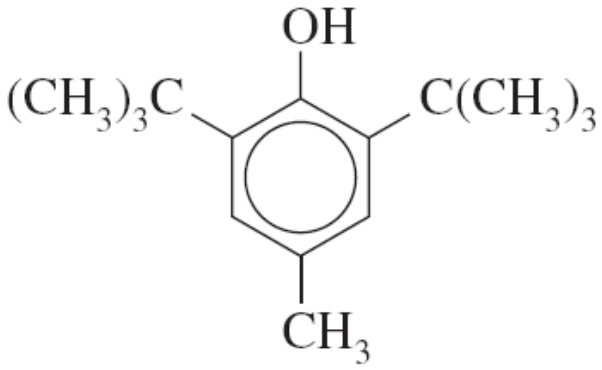
eugenol



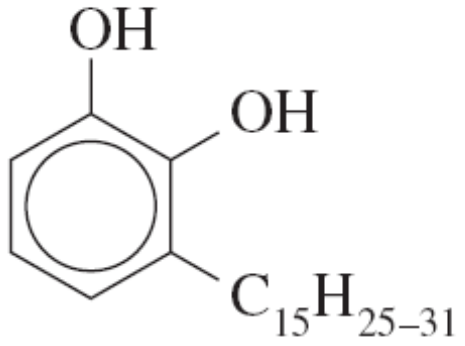
thymol

Phenols as Antioxidants

BHT is an antioxidant preservative for food while urushiols are the active ingredients in poison ivy and poison oak.



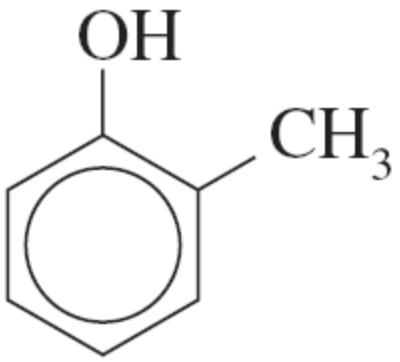
2,6-di-*t*-butyl-4-methylphenol
(butylated hydroxytoluene, BHT)



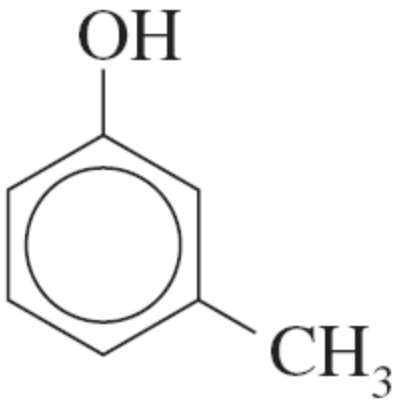
urushiols

Phenols as Disinfectants

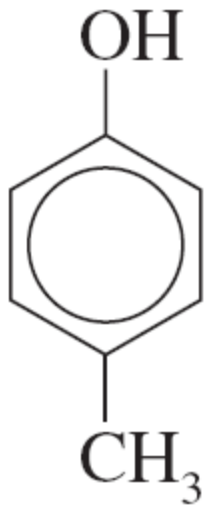
These phenol isomers are effective disinfectants



o-cresol



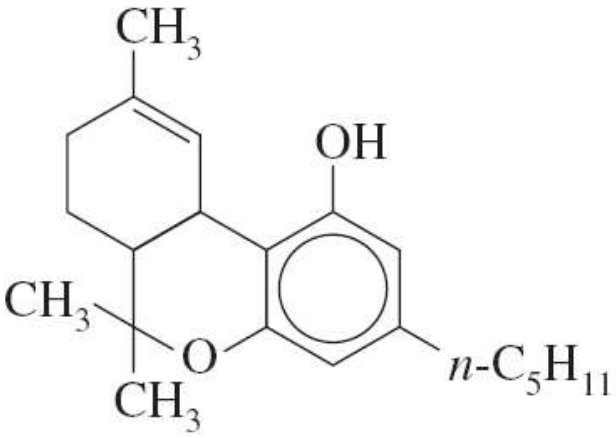
m-cresol



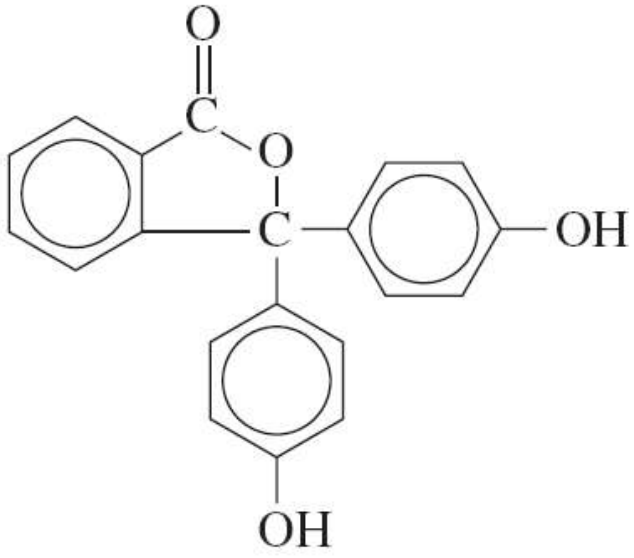
p-cresol

Phenols as a Natural Drug and Indicator

Phenols occur naturally in plants like marijuana and some phenols are used as pH indicators.



tetrahydrocannabinol
(from marijuana)

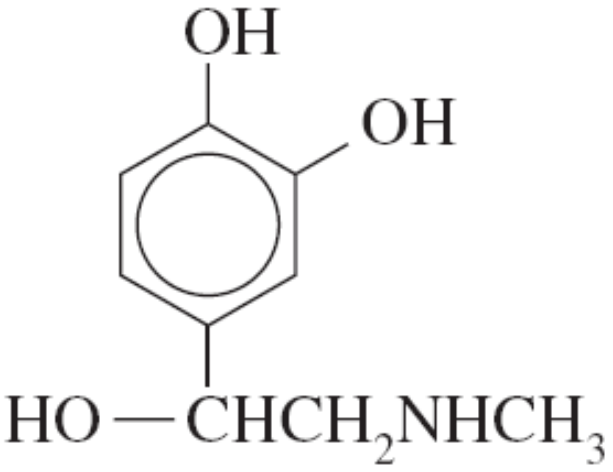


phenolphthalein

(a common lab pH indicator)

Phenols as Hormones

Adrenalin is a phenol that is a hormone.



adrenalin
(epinephrine)

(a hormone)

Properties of Phenol

Phenol is a weak acid with a melting point of 41°C.

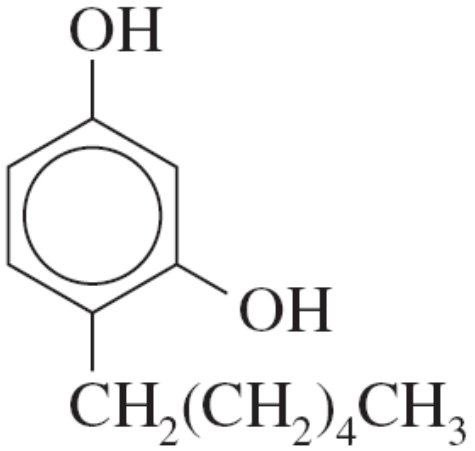
The table below is a comparison of the pH of phenol with the pH of water and acetic acid.

Substance	pH
Water	7.0
Phenol *(0.1M)*	5.5
Acetic acid *(0.1M)*	2.87

Properties of Phenols

The toxicity of phenols to microorganisms make them excellent antiseptics.

For example 4-hexylresorcinol is used as an antiseptic in many pharmaceutical preparations.



4-hexylresorcinol

Ethers

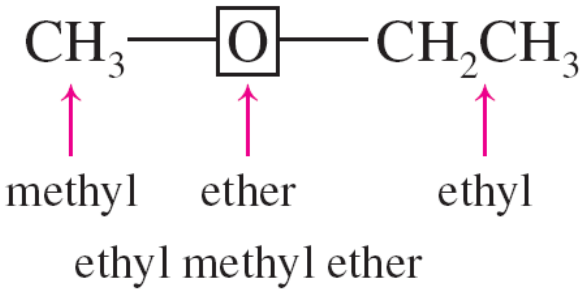
Ethers are organic compounds that have the general formula ROR` where both R groups can be the same or different.

Diethyl ether *(also named as ethoxyethane)* is a common ether used as an organic solvent and formerly used as an anesthetic.

diethyl ether

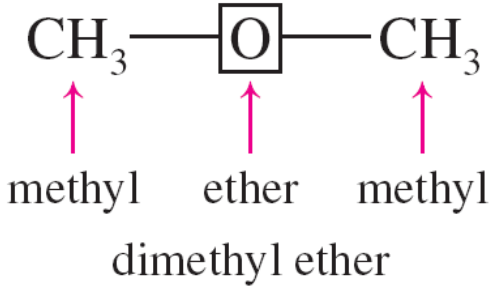
Naming Simple Ethers

Name each alkyl group in alphabetical order followed by the word ether as shown here.



ethyl methyl ether

Use a prefix if both alkyl groups are the same.

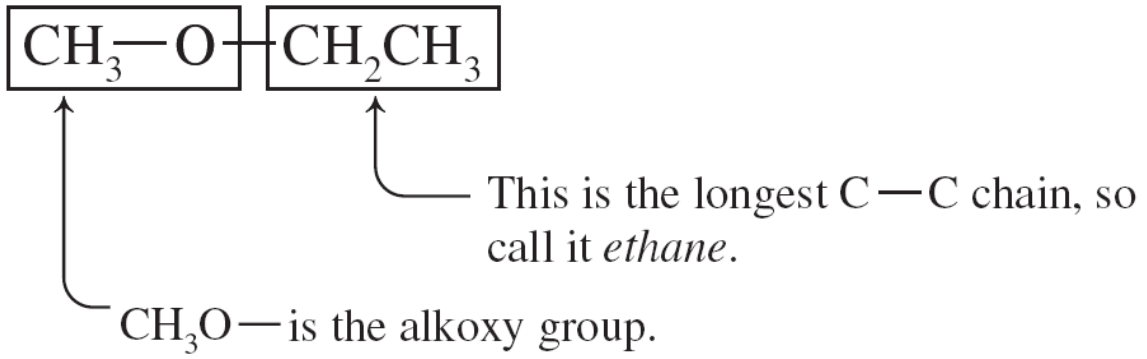


dimethyl ether

Naming Ethers Using IUPAC Rules

1. Name the longest continuous carbon chain corresponding to the parent alkane.
2. Name the remaining part as an alkoxy group.

For example…

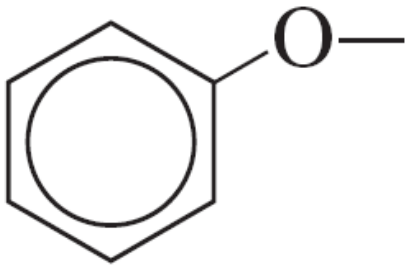


…would be named methoxyethane

Examples of Naming Alkoxy Groups

CH_3O- is called methoxy (meth + oxy)

CH_3CH_2O- is called ethoxy (eth + oxy)



is called phenoxy (phen + oxy)

Examples of Naming Ethers

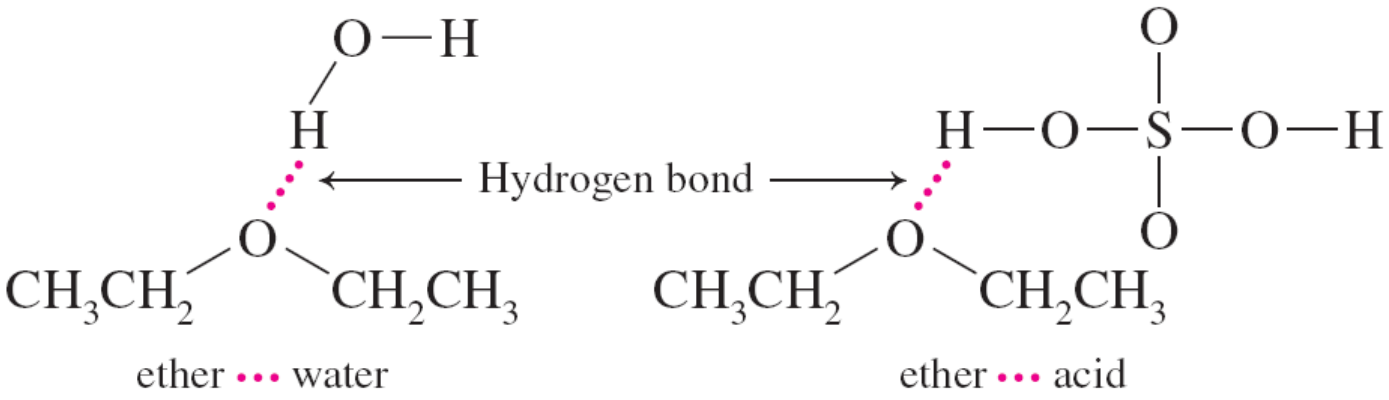
$CH_3CH_2—O—CH_2CH_3$ is ethoxyethane

$CH_3CH_2CH_2—O—CH_2CH_2CH_2CH_3$ is 1-propoxybutane

Properties of Ethers

Ethers are polar enough to dissolve some polar substances *(solubility in water is 7.5g/100g)* but also nonpolar enough to dissolve many organic compounds.

The slight solubility of ether in water can be explained by hydrogen bonding as shown here



Hazards of Using Ethers

Ethers are common solvents found in laboratories because they are good solvents for organic compounds.

However, ethers can be dangerous because of their highly flammable vapors.

Anaesthetic

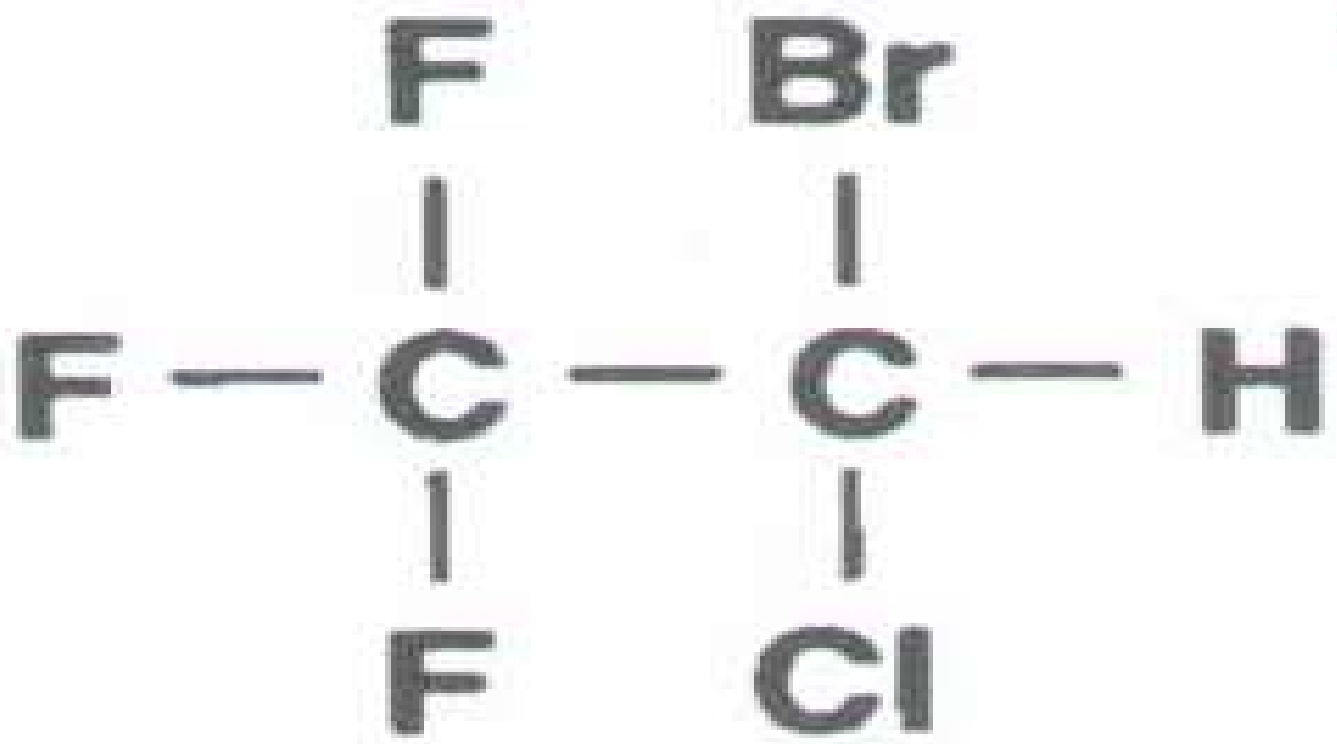
Ethers

Uses:

$$CH_3CH_2OCH_2CH_3$$

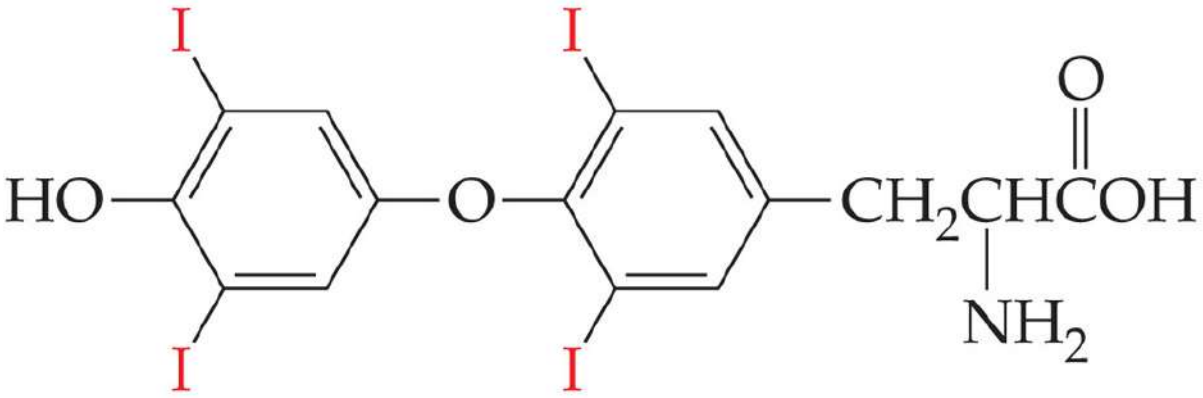
Diethylether

Once used as an anesthetic, however it is highly flammable and causes nausea. Most ethers are used primarily as solvents.



Halothane


THE



Thyroxine

Thyroid gland hormone; deficiency causes goiter

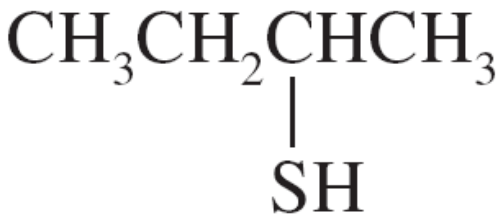
Thiols

Thiols are organic compounds that contain the –SH group as shown below. Thiols are also called mercaptans.

Thiols are named by adding the suffix *-thiol* to the alkane parent name.

CH_3SH

methanethiol
(methyl mercaptan)



2-butanethiol
(*sec*-butyl mercaptan)

Foul Odors of Thiols

Thiols have strong offensive odors. For example the scent of a skunk is due to thiol components.

The strong odor associated with natural gas is due to the additive methanethiol *(CH_3SH)*.

Compare the size of the S atom and the O atom.

CH_3SH CH_3OH

CAUTION

AREA PATROLLED

By

Attack Skunk

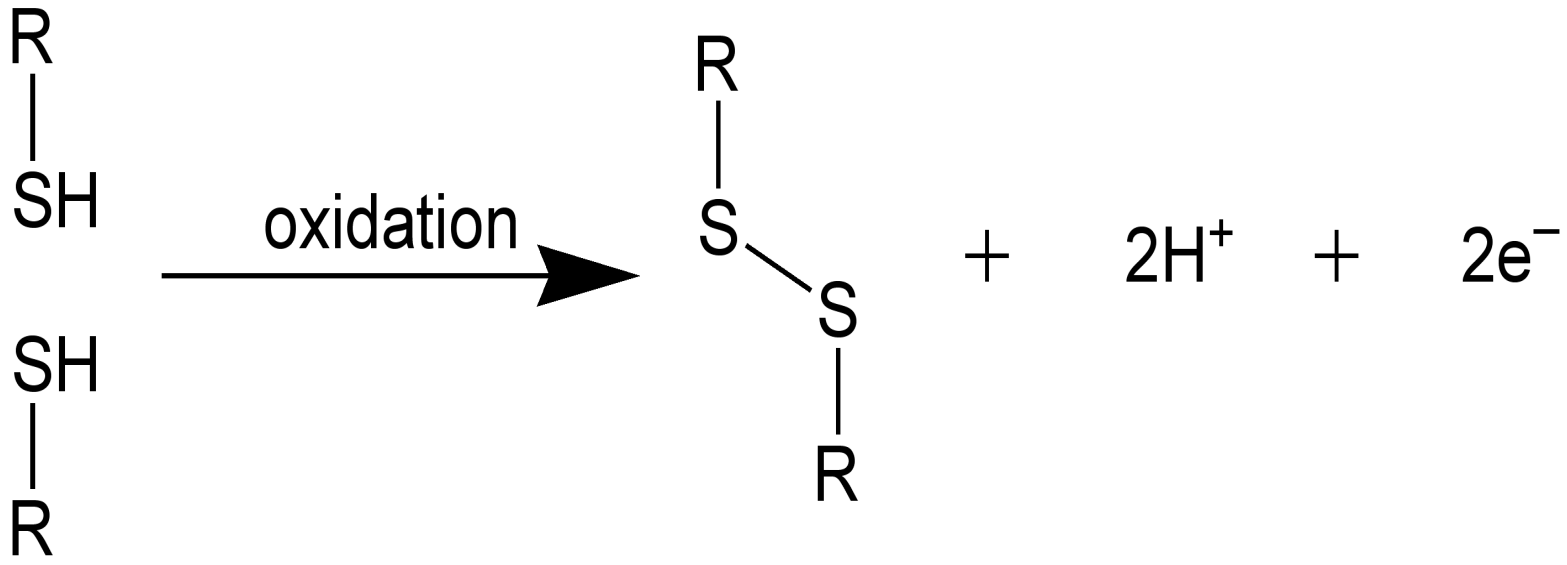
Security Co.

Biological Role of Thiol Derivatives

Thiol derivatives are found in hormones like insulin.

The disulfide bond *(RS-SR)* for example is used to bind proteins to create biologically useful three-dimensional shapes.

Disulfide Bond



- The End