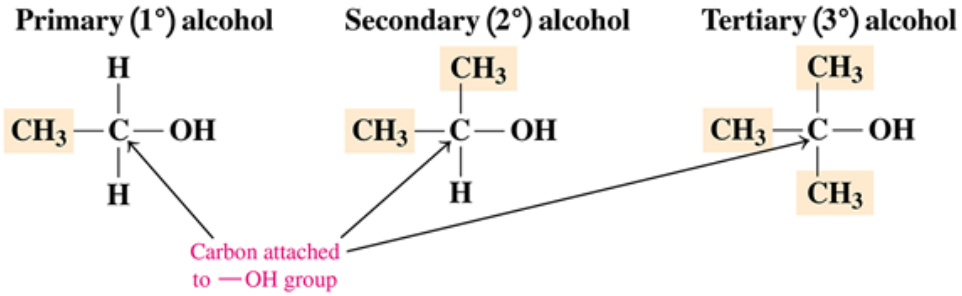
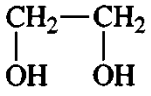
ALCOHOLS

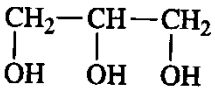
- Organic molecules that possess a **hydroxyl** group (—OH) are classified as **alcohols**.
- Alcohols are classified as primary (1°), secondary (2°) or tertiary (3°) depending on whether the carbon atom to which the —OH is attached is directly bonded to 1, 2, or 3 other carbon atoms, respectively.



- Compounds that possess more than one alcohol group are called polyhydroxy alcohols. These compounds are important molecules in living cells and include carbohydrates.
- Two simple and important polyhydroxy alcohols are ethylene glycol and glycerol.



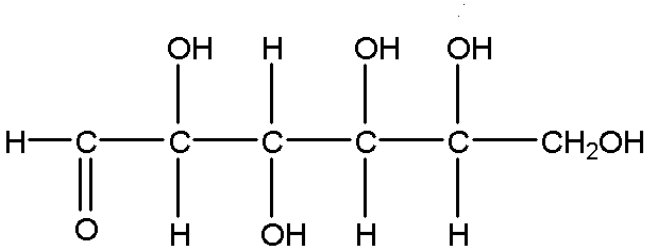
1,2-Ethanediol
(Ethylene glycol)



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

Examples:

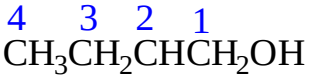
Blood sugar is a polyhydroxy compound with 5 alcohol groups. Identify each as primary, secondary or tertiary.



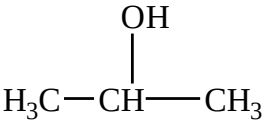
NAMING OF ALCOHOLS

- The IUPAC system for naming alcohols is the following:

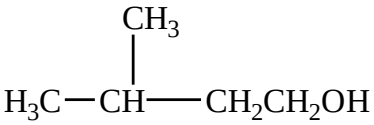
  1. Select the longest continuous chain of carbon atoms containing the hydroxyl group.
  2. Number the carbon atoms in the chain so that the one bearing the hydroxyl group has the lowest possible number.
  3. Name the parent chain as an alkane, with the end changing from ***–e*** to ***–ol***
  4. Name the alkyl side chains and designate their position by number.



1-butanol

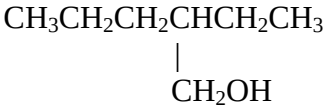


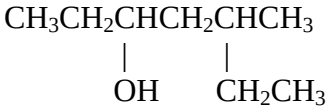
2-propanol

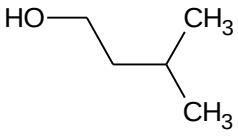


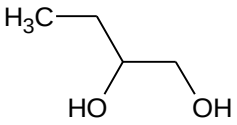
3-methyl-1-butanol

Examples:
Name each alcohol shown below:

1) 

2) 

3) 

4) 

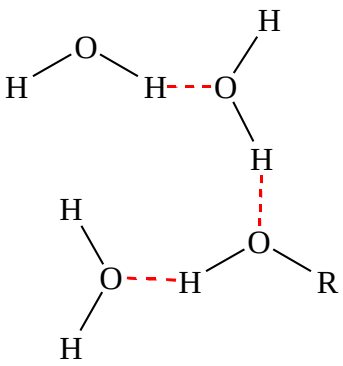
PHYSICAL ROPERTIES OF ALCOHOLS

- The physical properties of alcohols are related to those of both water and alkanes. This results from the similarity of alcohol molecules to both water and alkanes.

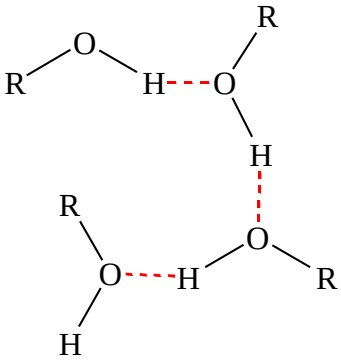
H—O—H	R—O—H	R—H
Water	Alcohol	Alkane

- Similar to water, alcohols are polar molecules. As a result, many alcohols are quite soluble in water. This is in contrast to alkanes which are non-polar and therefore insoluble in water.

- The hydroxyl group in alcohol molecule is responsible for both the solubility and the relatively high boiling point of alcohol. The hydroxyl groups can hydrogen bond between water and alcohol molecules.



water-alcohol

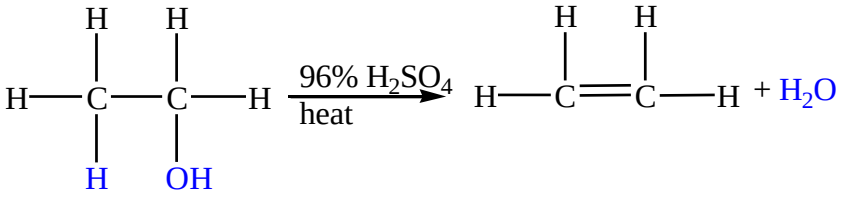


alcohol-alcohol

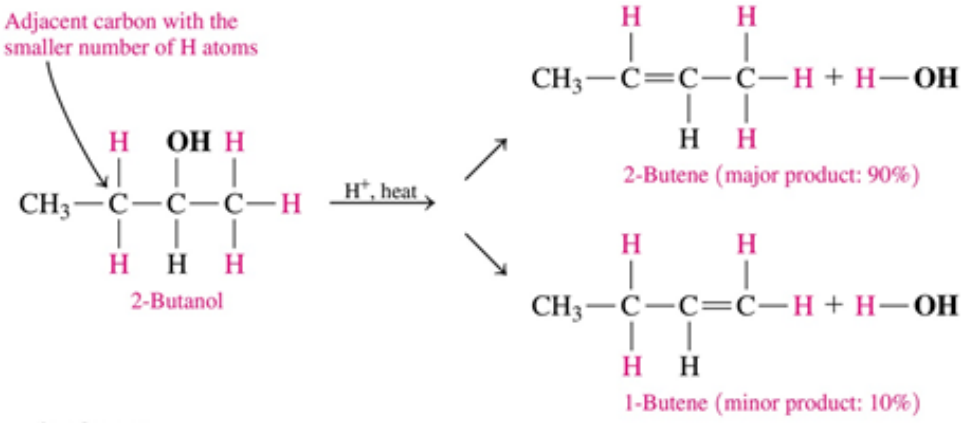
- Hydrogen bonding between water and alcohol leads to increased solubility, while hydrogen bonding between alcohol and alcohol molecules accounts for the high boiling point.

REACTIONS OF ALCOHOLS

- The main reactions of alcohols are dehydration and oxidation.
- Dehydration reactions occur when a water molecule is lost from an alcohol and an alkene is produced.

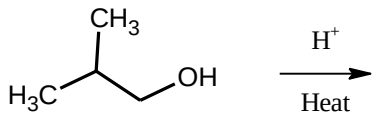


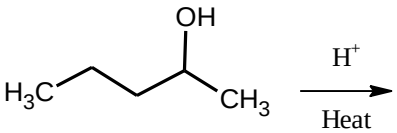
- For many alcohols, there is more than one way to remove water. Therefore the double bond can be located in different positions.
- The major product in such cases is the alkene in which the C=C bond has the greatest number of alkyl substituents on it (or the least number of hydrogens). For example, when 2-butanol is dehydrated, the major product is 2-butene, as shown below:



Examples:

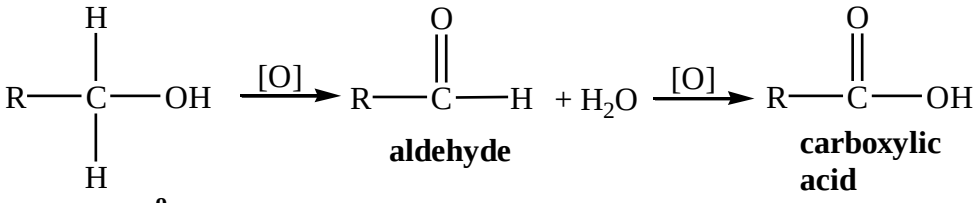
Predict and name the major product formed by the dehydration of each of the following alcohols:

1. 

2. 

REACTIONS OF ALCOHOLS

- Oxidation of alcohols can yield aldehydes, ketones and carboxylic acids.
- Mild oxidation of primary alcohols yields aldehydes. Further oxidation of these compounds yields carboxylic acids.

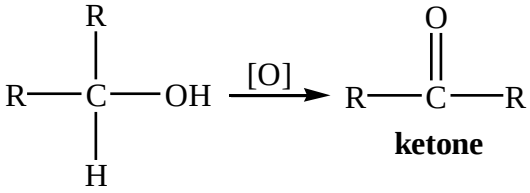


aldehyde

carboxylic acid

primary (1^o) alcohol

- Oxidation of secondary alcohols yields ketones.



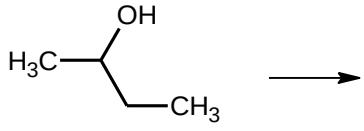
ketone

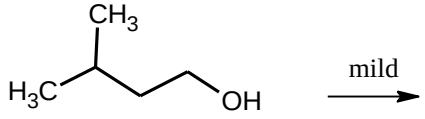
secondary (2^o) alcohol

- Tertiary alcohols do not undergo oxidation.

Examples:

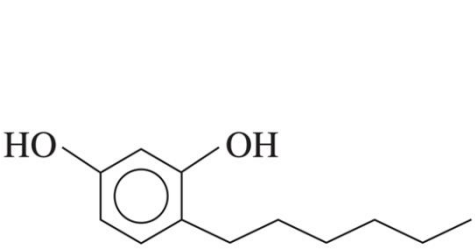
Predict the major product formed by the oxidation of each of the following alcohols:

1. 

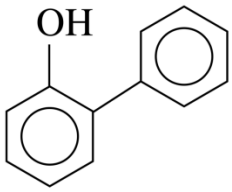
2. 

PHENOLS

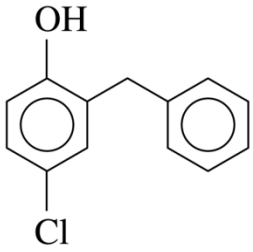
- Phenols are compounds in which the hydroxyl group (–OH) is directly attached to a benzene ring. Phenol and its derivatives have been used as antiseptics to kill microorganisms that cause infection. Shown below are several of these compounds that are currently used in topical antiseptics, throat lozenges, mouthwash and throat sprays.



4-Hexylresorcinol



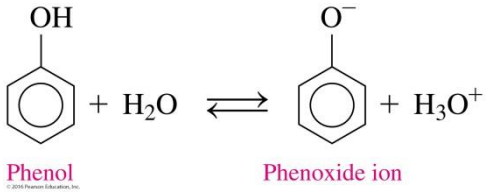
2-Phenylphenol



2-Benzyl-4-chlorophenol

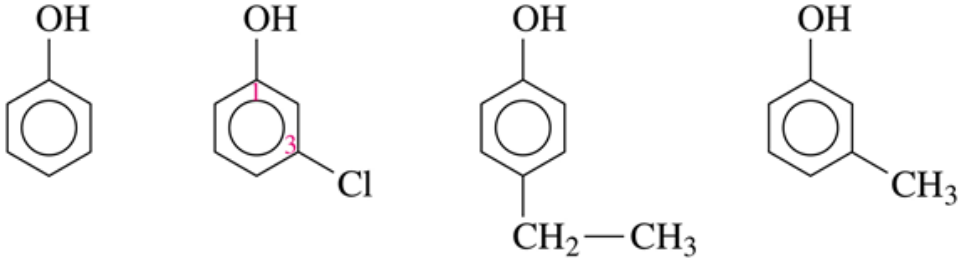
- Phenol has a high boiling point (182°C) because the –OH group allows phenol molecules to hydrogen bond with one another. Phenol is slightly soluble in water because the –OH group can form hydrogen bonds with water molecules.

- In water, the –OH group ionizes slightly, which makes phenol slightly acidic, as indicated by its early name, *carbolic acid*.



Phenol Phenoxide ion

- The term phenol is the IUPAC name when an –OH group is attached to a benzene ring. When a second substituent is bonded to the benzene ring, the benzene ring is numbered from carbon 1, which is the carbon bonded to the –OH group. Also, the terms ortho-, meta- and para- (abbreviated as o-, m-, and p-) can also be used to name phenols.

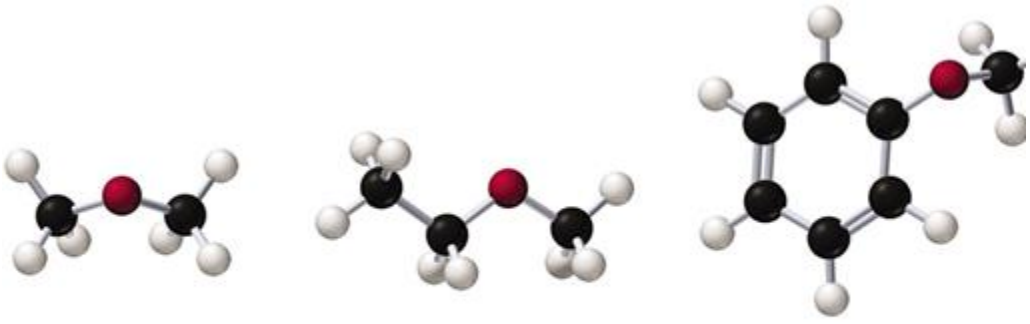


Phenol | 3-Chlorophenol (*m*-chlorophenol) | 4-Ethylphenol (*p*-ethylphenol) | 3-Methylphenol (*m*-cresol)

ETHERS

- An ether consists of the functional group that has an oxygen atom (–O–) attached by single bonds to two carbon atoms that are alkyl or aromatic groups. Molecules of ether, like alcohols and phenols, have ben shape around the oxygen atom, similar to water.

- Smaller ethers are commonly named by their common names which names the alkyl or aromatic groups attached to the oxygen atom in alphabetical order followed by the word ether.



$CH_3—O—CH_3$ $CH_3—CH_2—O—CH_3$ CH_3

Methoxymethane (dimethyl ether) Methoxyethane (ethyl methyl ether) Methoxybenzene (methyl phenyl ether)

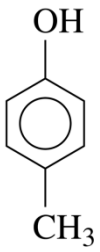
- Although ethers form hydrogen bonds with water, they do not form as many as do the alcohols. As a result, ethers up to 4 carbons are slightly soluble in water.

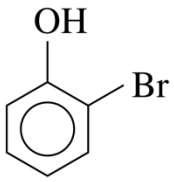
- Ethers do not form hydrogen bonds with other ether molecules, since they do not contain H atoms connected to an very electronegative element (O, N or Cl). As a result ethers have low boiling points compared to alcohols of the same size. The table below compares the solubility and boiling points of alcohols and ethers with similar molar masses.

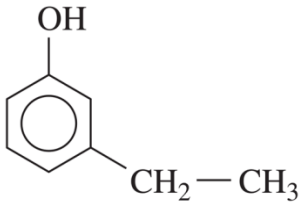
Compound	Condensed Structural Formula	Number of Carbon Atoms	Boiling Point (°C)	Solubility in Water
Methanol	$CH_3—OH$	1	65	Soluble
Ethanol	$CH_3—CH_2—OH$	2	78	Soluble
1-Propanol	$CH_3—CH_2—CH_2—OH$	3	97	Soluble
1-Butanol	$CH_3—CH_2—CH_2—CH_2—OH$	4	118	Slightly soluble
1-Pentanol	$CH_3—CH_2—CH_2—CH_2—CH_2—OH$	5	138	Insoluble
Dimethyl ether	$CH_3—O—CH_3$	2	−23	Slightly soluble
Ethyl methyl ether	$CH_3—O—CH_2—CH_3$	3	8	Slightly soluble
Diethyl ether	$CH_3—CH_2—O—CH_2—CH_3$	4	35	Slightly soluble
Ethyl propyl ether	$CH_3—CH_2—O—CH_2—CH_2—CH_3$	5	64	Insoluble

Examples:

1. Write the IUPAC name for each of the following molecules:

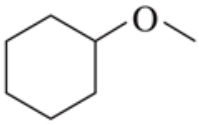
a) 

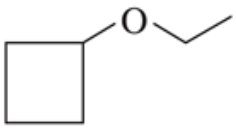
c) 

b) 

2. Name each ether below by the common name method:

a. $CH_3—O—CH_2—CH_3$

b. 

c. 

d. $CH_3—CH_2—CH_2—O—CH_3$