Alcohol, phenol & ether

Alcohol, phenol, ether are classes of organic compounds which find wide usage in a broad range of industries as well as for domestic purposes.

Alcohol is formed when a saturated carbon atom is bonded to a hydroxyl (-OH) group.

Phenol is formed when a hydrogen atom in a benzene molecule is replaced by the -OH group.

Ether is formed when an oxygen atom is connected to two alkyl or aryl groups.

Classification of Alcohol

Depending on the number of hydroxyl groups attached, alcohols can be classified into three types.

Monohydric alcohols: They contain one -OH group. Example, CH3CH2-OH

Dihydric alcohols: They contain two -OH groups. Example, 1,2-Ethandiol.

Trihydric alcohols: They contain three -OH groups. Example 1,2,3-Propantriol.

Depending on the number of carbon atoms which are directly attached to the carbon that is bonded with the -OH group, alcohols can be classified into three types.

Primary alcohols: One carbon atom is directly attached.

Secondary alcohols: Two carbon atoms are directly attached.

Tertiary alcohols: Three carbon atoms are directly attached.

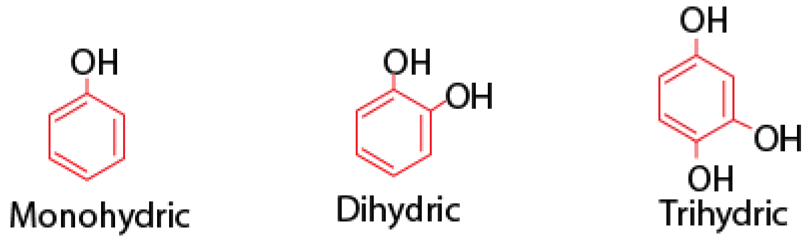
Classification of Phenol

Depending on the number of hydroxyl groups attached, phenols can be classified into three types.

Monohydric phenols: They contain one -OH group.

Dihydric phenols: They contain two -OH groups. They may be ortho-, meta- or para- derivative.

Trihydric phenols: They contain three -OH groups.

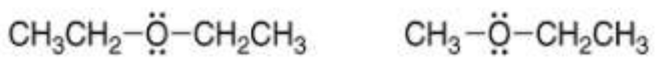


Classification of Ether

Depending on the type of the alkyl or aryl groups attached to the oxygen atom in ether, it can be classified into two types.

Symmetrical ether: Also known as the simple ether, the alkyl or the aryl group attached to either side of the oxygen atoms are the same. Examples are CH3OCH3, C2H5OC2H5, etc.

Unsymmetrical ether: Also known as the mixed either, the alkyl or the aryl group attached to either side of the oxygen atoms, are not the same. Examples are CH3OC2H5, C2H5OC6H5, etc.



symmetrical ether **unsymmetrical ether**

Nomenclature

Alcohols: Rules for naming alcohols follow the guidelines already given for alkanes, in summary

The number of carbon atoms in the longest carbon chain containing the OH group gives the stem

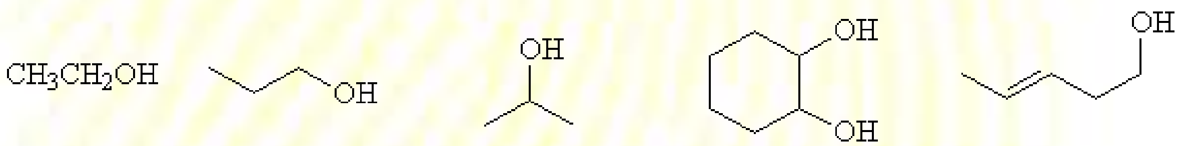
Use a prefix to identify the position of the carbon carrying the OH and a suffix of -ol. Number from the end of the chain closest to the alcohol group

Use numbers and di-, tri- etc as appropriate

If a molecule contains a multiple bond as well as an alcohol group, give the carbon with the OH group attached the lowest possible number

Alcohols may be classified as primary (1°), secondary (2°), tertiary (3°) depending on whether the carbon atom carrying the OH is attached to 1 other carbon group, 2 other carbon groups or 3 other carbon groups respectively.

Examples:



Ethanol 1-Propanol 2-Propanol 1,2-Cyclohexandiol Pent-3-en-1-ol

Ethers: Two ways of naming ethers

The alkyl (or aryl) groups attached to the -O- are named in alphabetical order as two separate words and the word ether added.

If both of the groups attached to the ether oxygen are the same, the ether name is simplified by using the prefix "di-" with the name of the group e.g. CH3OCH3 is called dimethyl ether.

Alternatively, ethers may be named as alkoxy derivatives of alkanes. In this method of naming, the longest continuous alkyl chain forms the stem of the ether name and the alkoxy group is named as a substituent on the alkane backbone.

Examples:

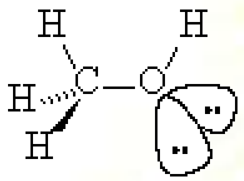
$CH_3CH_2—O—CH_3$

Ethyl methyl ether
or methoxyethane

$CH_3CH_2—O—CH_2CH_3$

Diethyl ether

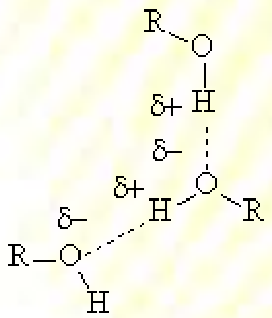
Structure and properties



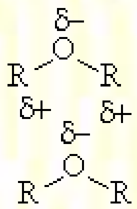
The oxygen atom of an alcohol is sp3 hybridised and has two non bonding pairs of electrons

The O-H bond of alcohols is strongly polarised and hydrogen bonding occurs in much the same way as in water molecules

As a consequence, alcohols have relatively high boiling points compared to other organic compounds of a similar molecular weight and alcohols (particularly the lower members of the series) are significantly more water soluble than other classes of organic compounds which are not capable of hydrogen bonding



Hydrogen bonding between alcohol molecules



Weak dipole-dipole attractions between ether molecules only

Phenol also shows hydrogen bonding and is partially soluble in water. However ethers are not hydrogen bond donors and so are not soluble in water

Name	Structure	Molecular Mass	bp (ºC)	Water Solubility
Ethanol	CH3CH2OH	46	78	3
Dimethyl ether	CH3OCH3	46	-24	7

Propane	CH3CH2CH3	44	-42	7
1-butanol	CH3CH2CH2CH2OH	74	117	(3)
Diethyl ether	CH3CH2OCH2CH3	74	35	7
Phenol	C6H5OH	94	182	(3)

Alcohols absorb radiation strongly ~ 3500 cm-1 in the infrared region

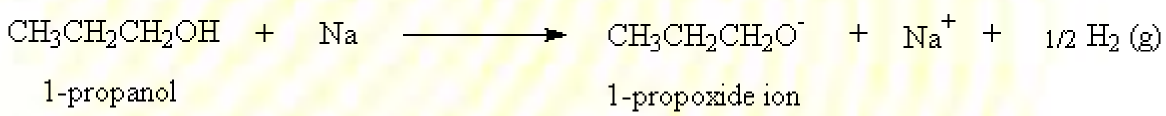
<u>Reactions of Alcohols, Phenol and Ethers</u>

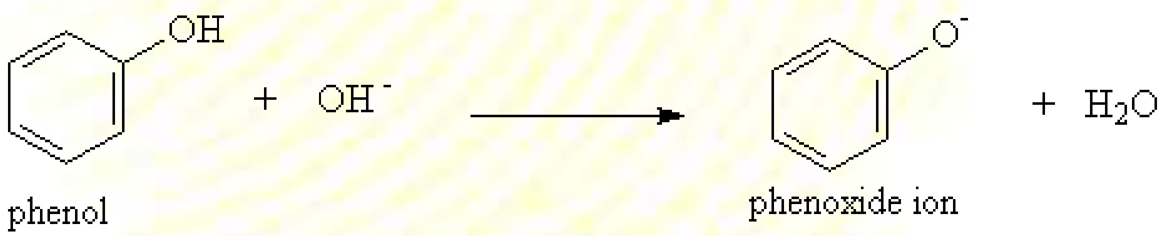
1. Acid-base reaction of alcohols and phenol

Alcohols are very weak acids (somewhat weaker than water) but may loose H+ from the OH group if sodium or a sufficiently strong base is present

Phenol is more acidic than alcohols and H+ may be removed with sodium hydroxide solution. It is less acidic than carboxylic acids.

Example:





Relative acidities

	pKa	React with	React with	React with

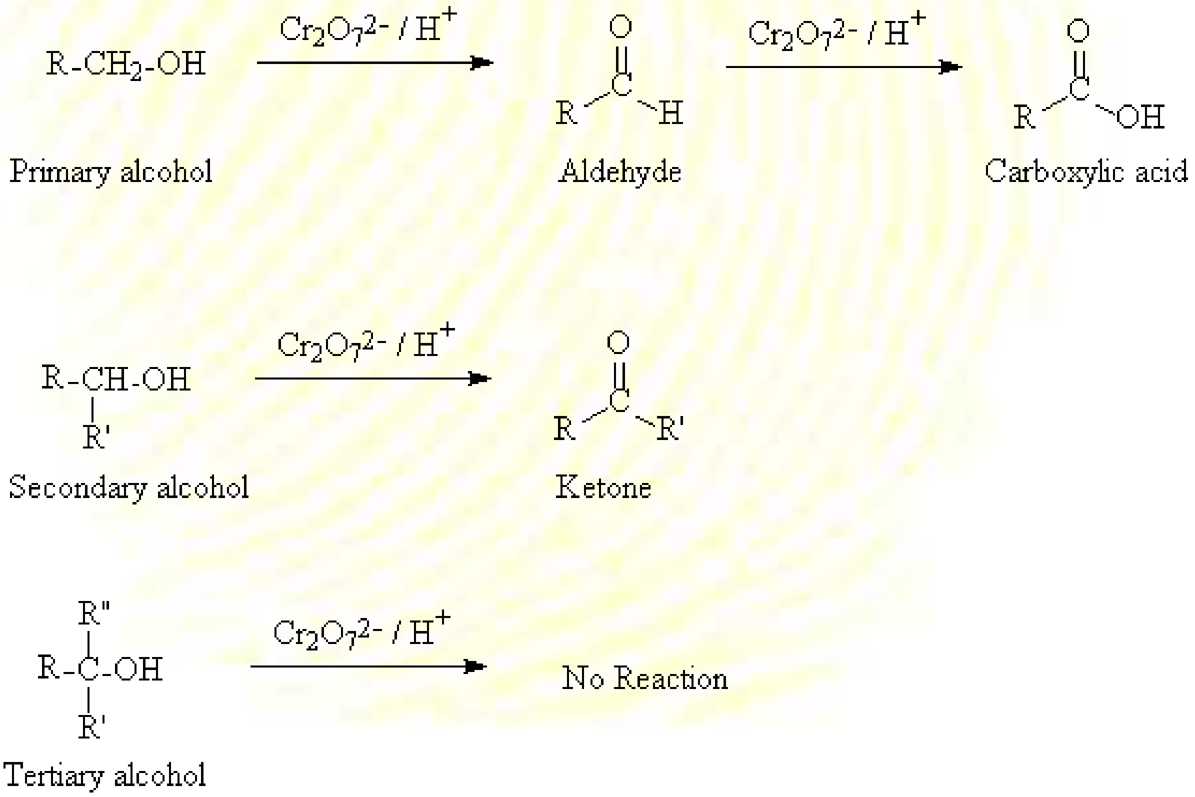
			Na	OH-	HCO3-
Ethanol	CH3CH2OH	16.0	ü	X	X
Phenol	C6H5OH	9.9	ü	ü	X
Acetic Acid	CH3COOH	4.8	ü	ü	ü

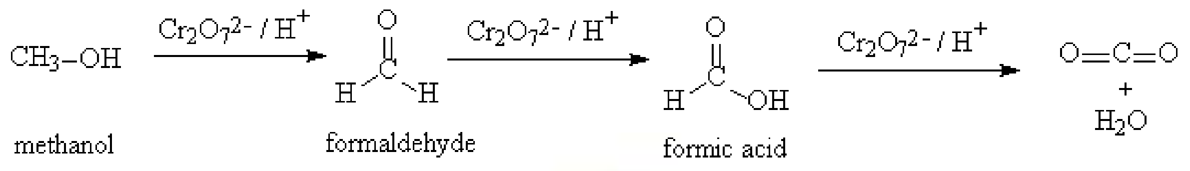
2. Oxidation of alcohols

Alcohols are oxidised by a variety of oxidising agents, e.g. potassium permanganate in either acidic or basic solution (KMnO4/H+ or KMnO4/OH) or potassium dichromate in acidic solution (K2Cr2O7/H+).

The product of alcohol oxidation depends on whether the starting alcohol is a primary, secondary or tertiary alcohol.

Oxidation of methanol is unique amongst alcohols as the eventual products of methanol oxidation are water and carbon dioxide.





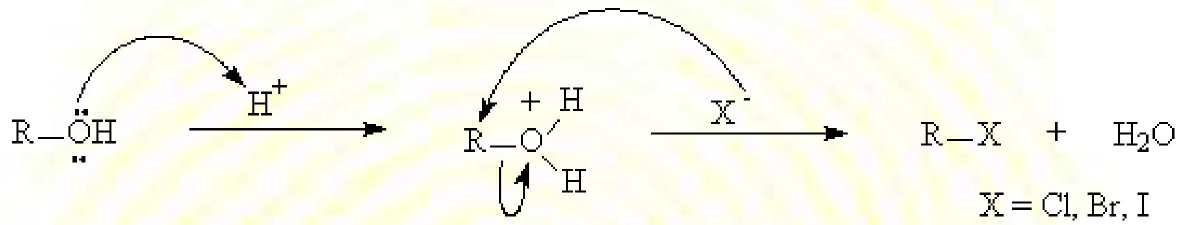
3. Nucleophilic substitution of alcohols

Concentrated HX acids (X = Cl, Br, or I) directly convert alcohols to alkyl halides

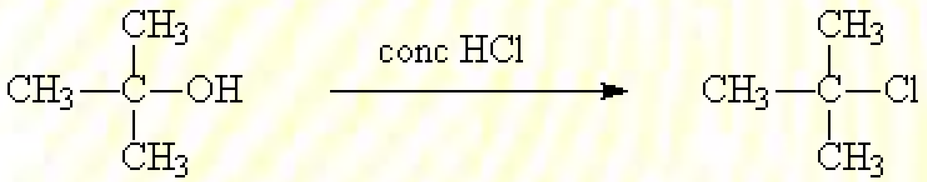
The reaction takes place in two steps: protonation followed by substitution

Protonation converts the R-OH group to R-OH2+ which can then loose H2O

Substitution of the halide ion for the protonated -OH group affords an alkyl halide



Example



4. Elimination of water from alcohols

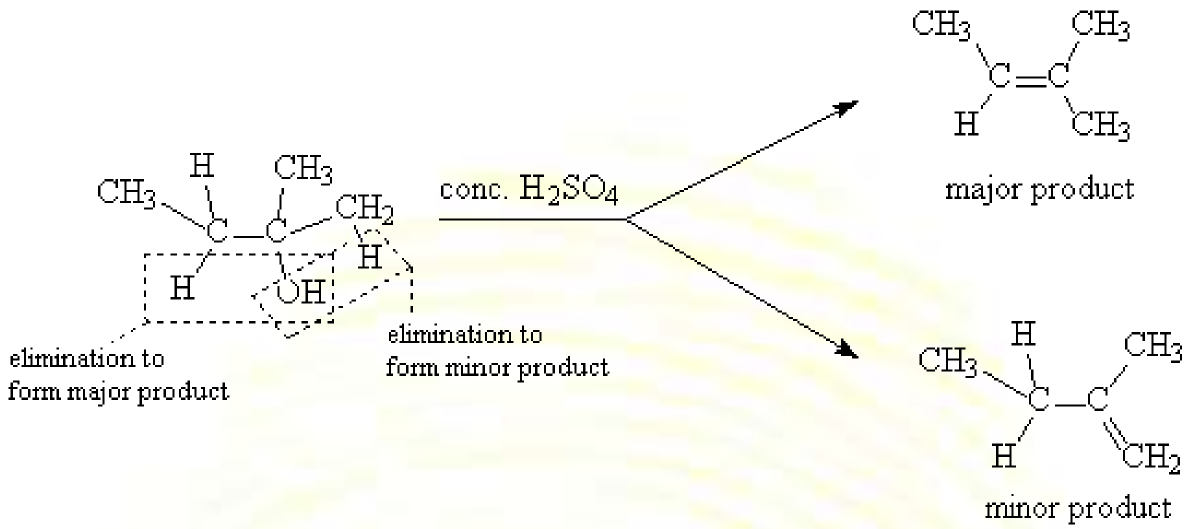
Alcohols can also undergo an elimination reaction to form an alkene. H2O is eliminated from the alcohol so the reaction is also called a dehydration reaction

This requires a dehydrating reagent, typically concentrated H2SO4

The OH is removed and a hydrogen from the adjacent carbon atom

Where there is a choice of hydrogens that can be eliminated, the one that results in the most substituted alkene is removed

Example:



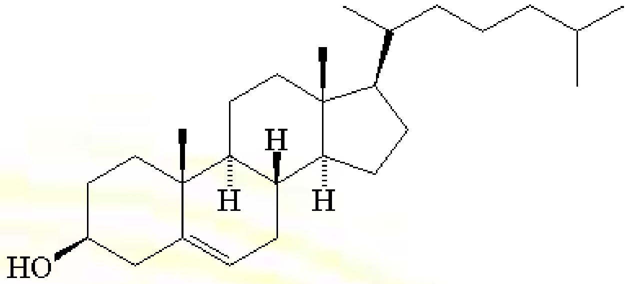
5 ETHERS

Ethers tend to be unreactive and consequently make good solvents.

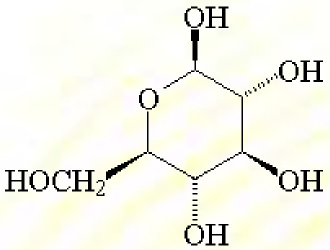
Some biologically active compounds containing the alcohol functional group:

$CH_3—CH_2—OH$

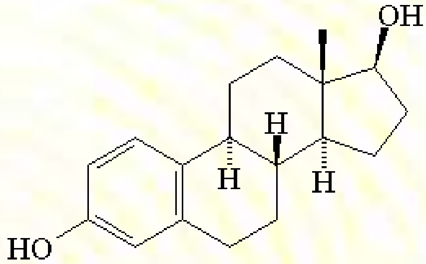
Ethanol



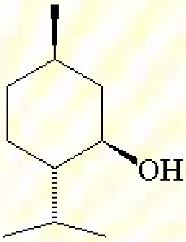
Cholesterol



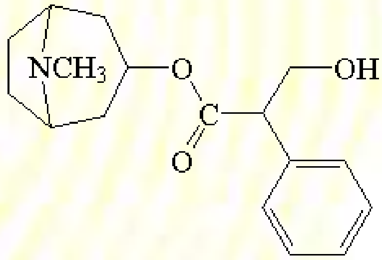
D-Glucose



Estradiol



Menthol



Atropine