

University of Fallujah
College of Medicine
Department of Chemistry
and biochemistry



Alcohols, Phenols and Ether

Lecture : Medical Chemistry

Stage : 1st Stage

Lecturer : Dr. Mustaf A-Jabbar Al-Jumaili

Department: Chemistry and Biochemistry

29/1/2026

Medical Chemistry Lecture Objectives: Alcohols, Phenols, and Ethers

- **Structure & Nomenclature:** Define structures (R-OH, R-O-R'), apply IUPAC & common naming.
- **Physical Properties:** Explain H-bonding's effect on BP & solubility.
- **Classification & Preparation:** Classify alcohols (1°, 2°, 3°); describe synthesis (e.g., alkene hydration).
- **Reactions & Importance:** Understand oxidation; recognize ethanol, methanol, Vitamin E's biological roles.
- **Ethers:** Describe inert solvents & historical anesthetics.

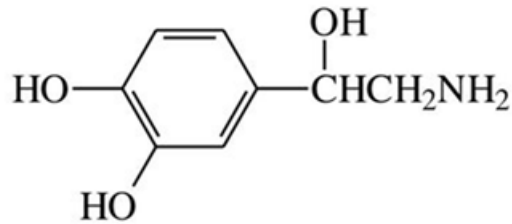
Alcohols

- To many people alcohol means an alcoholic drinks.
- However, to organic chemists, the word alcohol refers to a class of compounds that contain an **OH** group, called a **hydroxyl** or **hydroxy group**, bonded to an **alkyl group**.
- One specific example of this type of compound is ethyl alcohol, $\text{CH}_3\text{CH}_2\text{OH}$, the intoxicating alcohol.
- Alcohol can be viewed as organic analogs of water in which one hydrogen is replaced by an alkyl group.

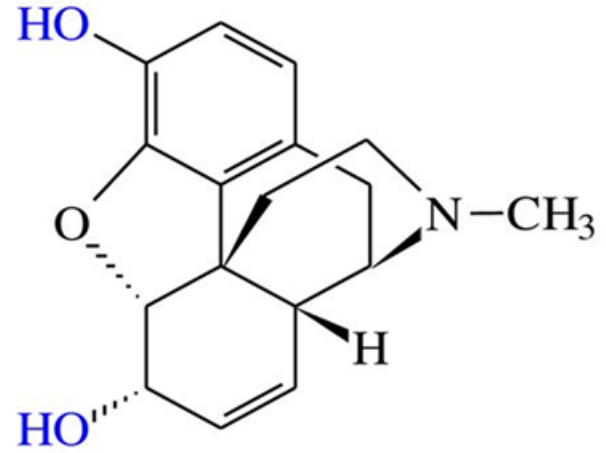
Some alcohols



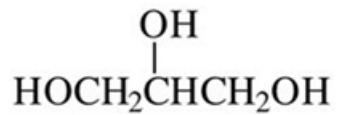
ethanol



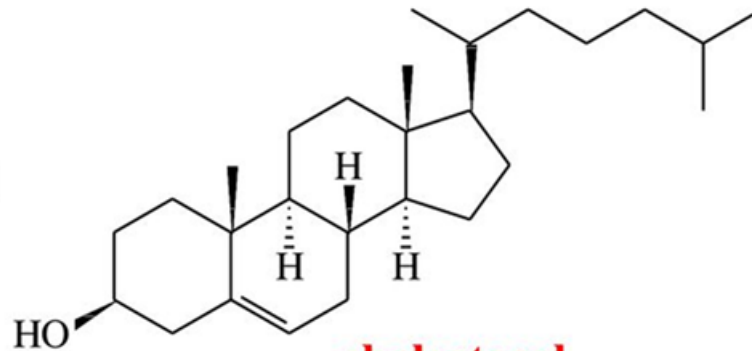
adrenaline (epinephrine)



Morphine



glycerol



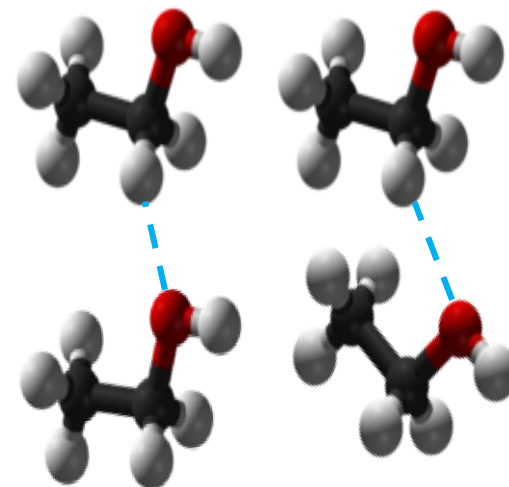
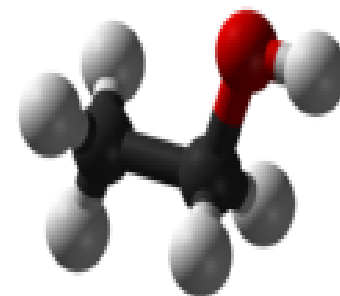
cholesterol

Physical properties of alcohols

- The boiling point of alcohols are much higher than those of alkanes with similar molecular weights.
- For example, ethanol, with a molecular weight (**46**), has a boiling point of (**78°C**) , where propane (**44**) has a boiling point of (**-42°C**).
- Such a large difference in boiling points indicates that molecules of ethanol are attracted to one another much more strongly than propane molecules.
- Most of this difference results from the ability of ethanol and other alcohols to form intermolecular hydrogen bonds.

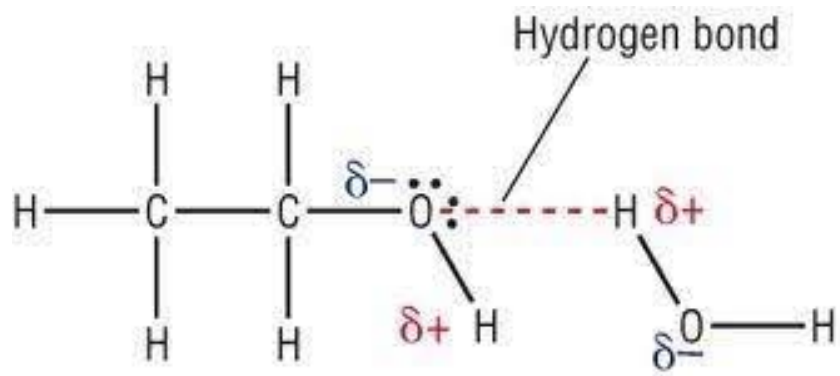
Alcohols: Structure and Physical Properties

- ❖ An organic compound containing a **hydroxyl group (OH)** attached to an alkyl group
- ❖ Alcohols have the general formula **R-OH**
- ❖ Hydroxyl group is **very polar**.
- ❖ Hydrogen bonds can form readily.
- ❖ Alcohols have **high Boiling points** relative to their molecular weights due to their ability to hydrogen bond



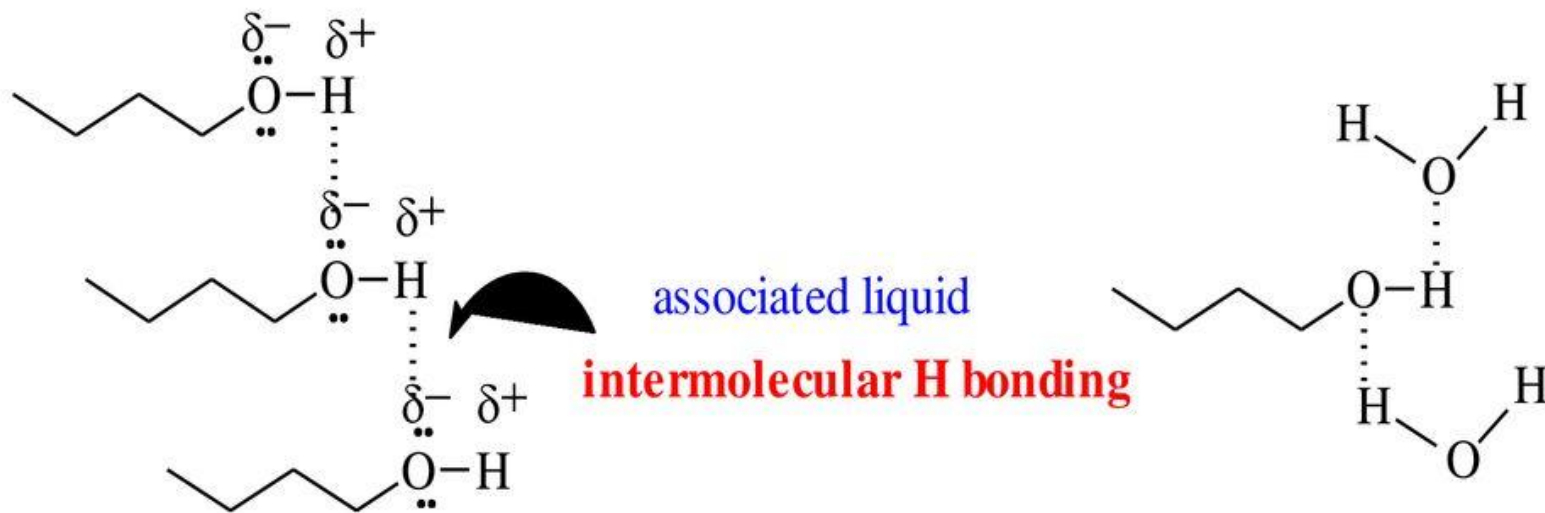
Solubility

- Low molecular weight alcohols (up to **5-6** carbons) are soluble in water (**very polar**)
- As molecular weight increases, alcohols become insoluble in water still polar but, the ratio of hydroxyl groups to carbons in the chain determines solubility.
- Diols and triols alcohols are more soluble than those with only a single hydroxyl group



Formula	Name	Solubility in Water (g/100g)
CH ₃ OH	methanol	infinitely soluble
CH ₃ CH ₂ OH	ethanol	infinitely soluble
CH ₃ (CH ₂) ₂ OH	propanol	infinitely soluble
CH ₃ (CH ₂) ₃ OH	butanol	9
CH ₃ (CH ₂) ₄ OH	pentanol	2.7
CH ₃ (CH ₂) ₅ OH	hexanol	0.6
CH ₃ (CH ₂) ₆ OH	heptanol	0.18
CH ₃ (CH ₂) ₇ OH	octanol	0.054
CH ₃ (CH ₂) ₉ OH	decanol	insoluble in water

Intermolecular H-Bonding



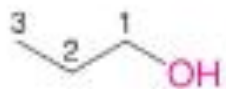
The Common and systemic name of alcohols

❖ The common names for alcohols consist of the alkyl group name, a space, and the word alcohol

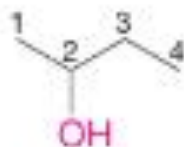
Alcohol	Common Name	IUPAC Name
CH_3OH	Methyl Alcohol	Methanol
$\text{CH}_3\text{CH}_2\text{OH}$	Ethyl Alcohol	Ethanol
$\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$	Propyl Alcohol	1-Propanol
$\text{CH}_3\underset{\text{OH}}{\text{CH}}\text{CH}_3$	Isopropyl Alcohol	2-Propanol

Naming of Alcohol

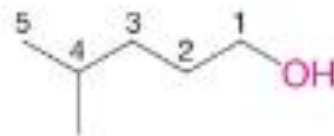
- ❖ **IUPAC**: based on the longest chain containing the OH carbon
The *-e* of the alkane name is replaced with *-ol*
- ❖ The chain is numbered from the end giving the **-OH** carbon the lower number
- ❖ The name is **prefixed** with the number indicating the **position** of the **OH** group
- ❖ For cyclic alcohols, the OH is at C-1
- ❖ The suffix **-ol** is used for one hydroxyl group, **diol** for two, **triol** for three, and so forth .



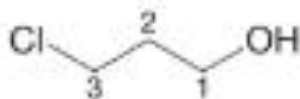
1-Propanol



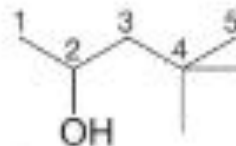
2-Butanol



4-Methyl-1-pentanol
or 4-methylpentan-1-ol
(not 2-methyl-5-pentanol)



3-Chloro-1-propanol
or 3-chloropropan-1-ol

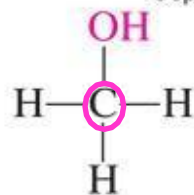


4,4-Dimethyl-2-pentanol
or 4,4-dimethylpentan-2-ol

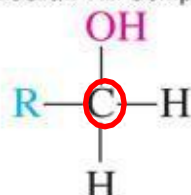
Classification of Alcohols

- Alcohols, depending on the number of alkyl groups attached to the **carbinol carbon**, are classified as **Primary**, **Secondary** and **Tertiary**.
- Carbinol carbon** is the carbon bearing the **hydroxyl group**.

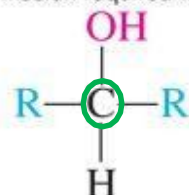
Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



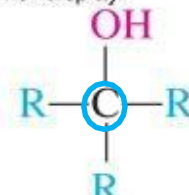
Methyl alcohol



1° Alcohol



2° Alcohol



3° Alcohol



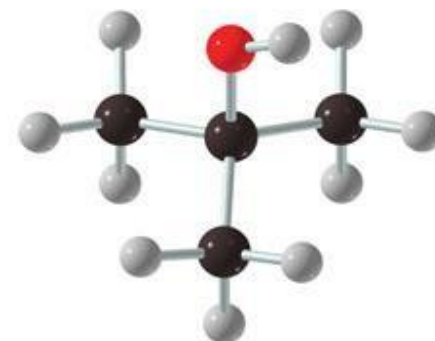
Methanol
(methyl alcohol)



Ethanol
(1° alcohol)



2-Propanol
(2° alcohol)

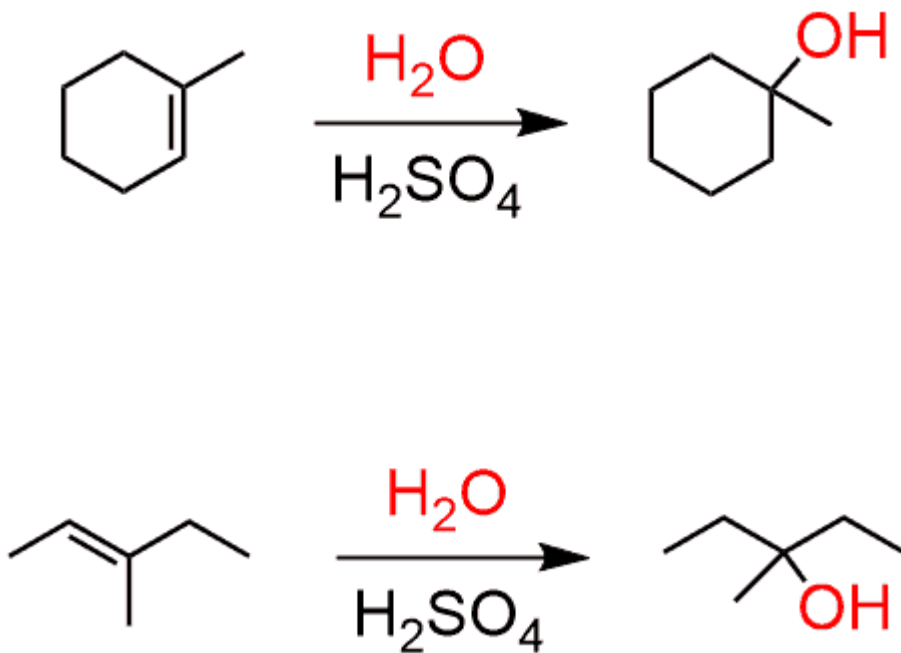
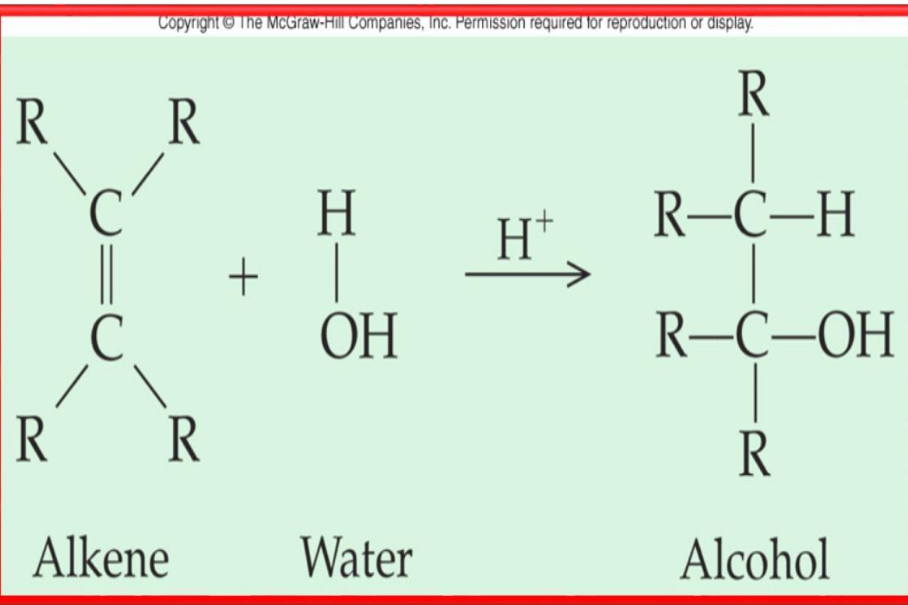


2-Methyl-2-propanol
(3° alcohol)

Preparation of Alcohols

1) Hydration

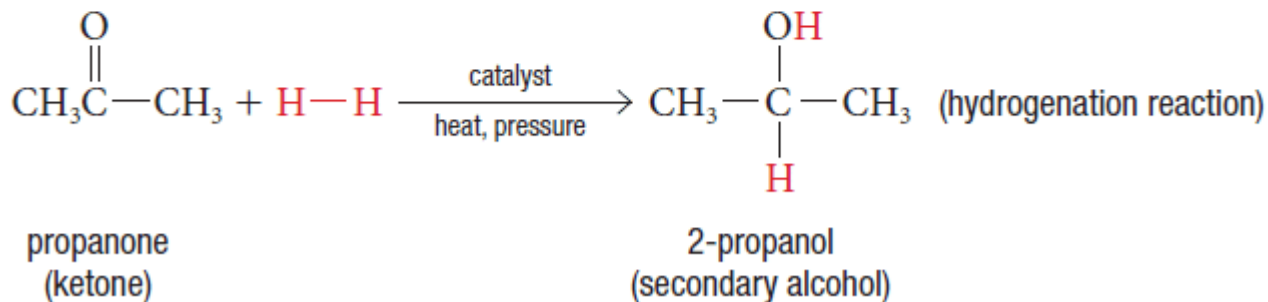
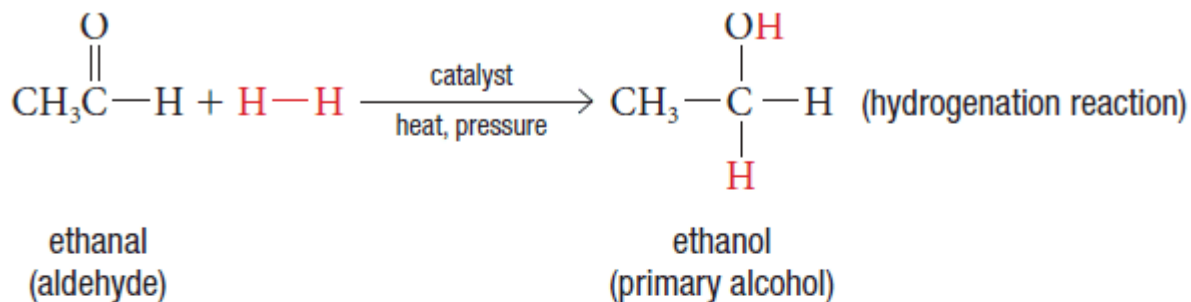
- Addition of water to the carbon-carbon double bond of an alkene produces an alcohol
- A type of addition reaction called *hydration*
- Requires a trace of acid as a catalyst



Preparation of Alcohols

2) Hydrogenation of Aldehydes and Ketones

- Hydrogenation of aldehydes and ketones is generate alcohols.



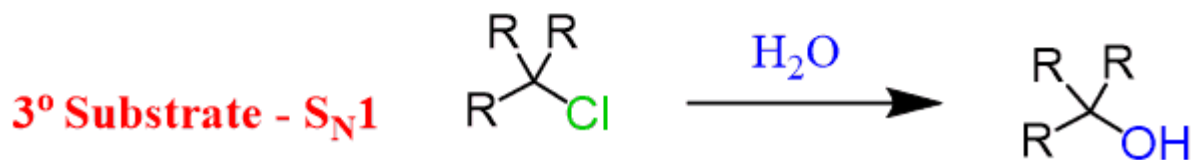
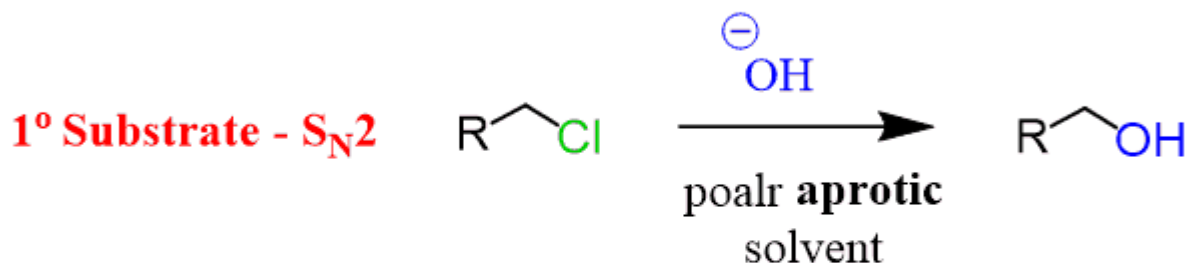
- This type of reaction can only happen under high temperature and high pressure, with the present of a catalyst.

Dr Mustafa Abdul-Jabbar Al-Jumaili

3) Preparation of Alcohols from Alkyl Halides

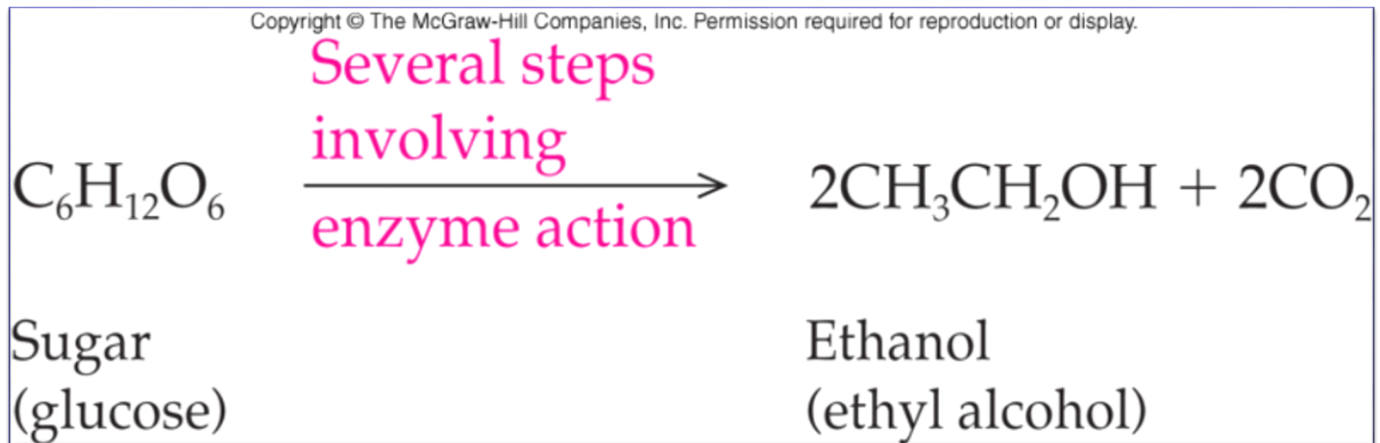
- Alcohols can be prepared by substitution reactions using hydroxides and substrates with good leaving groups, such as alkyl halides.

Preparation of Alcohols By Substitution Reactions

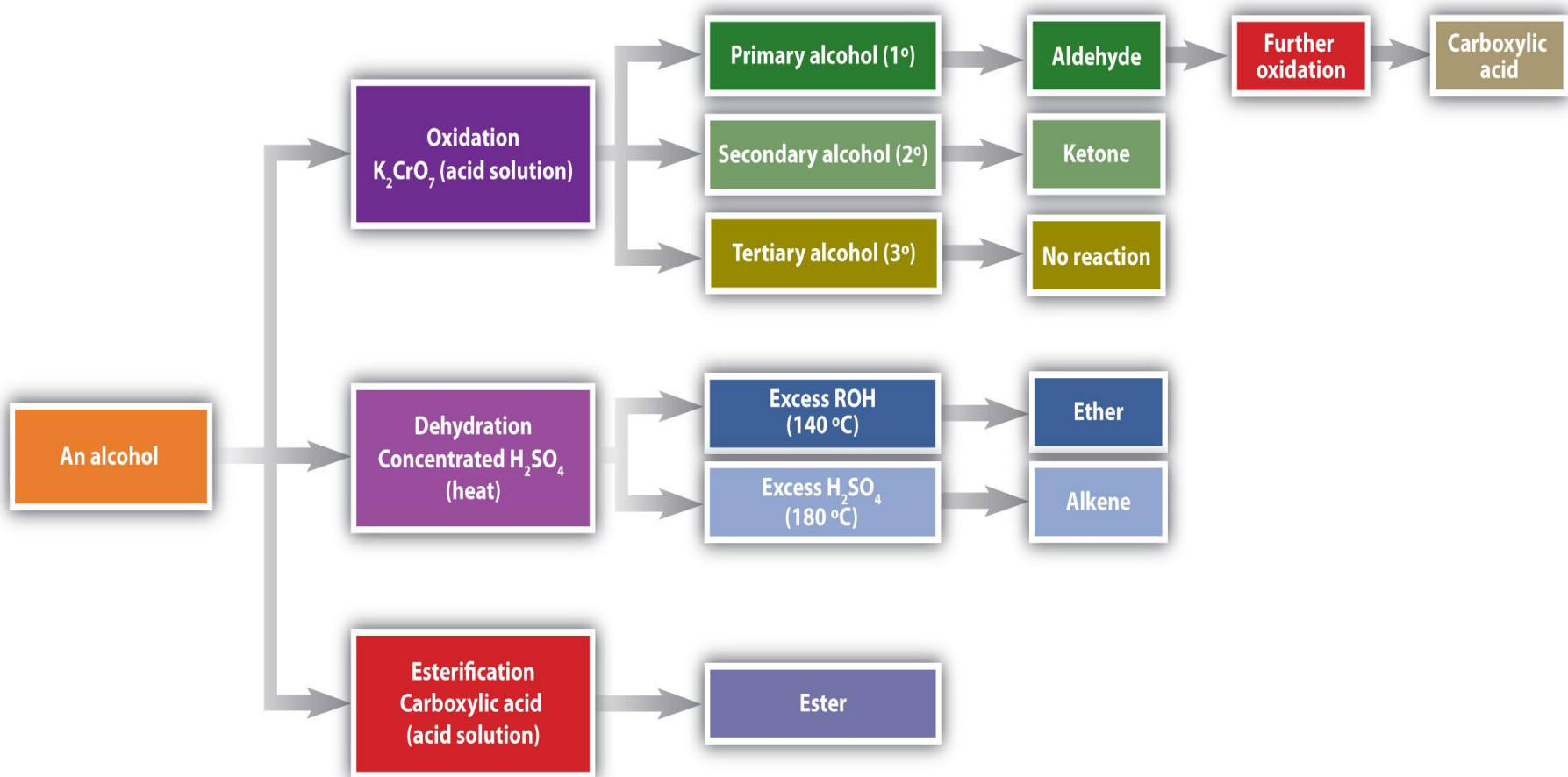


Source of Ethanol

- Ethanol is an odorless and colorless liquid widely used as a solvent.
- The alcohol in **alcoholic drinks** derived from fermentation of carbohydrates

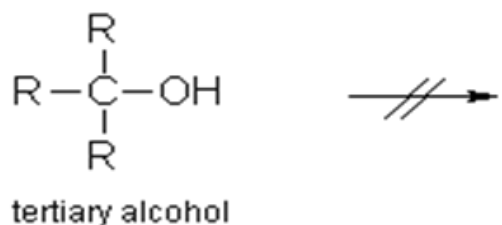
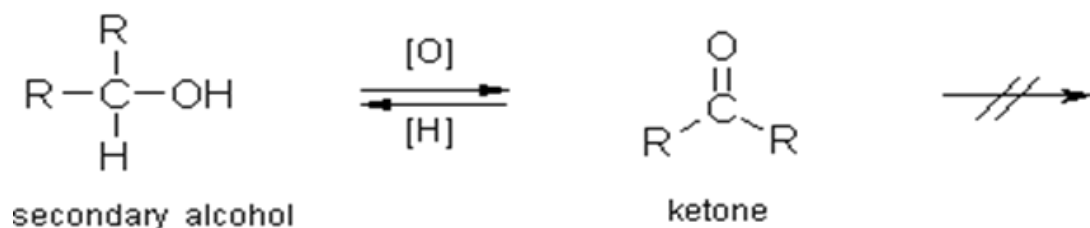
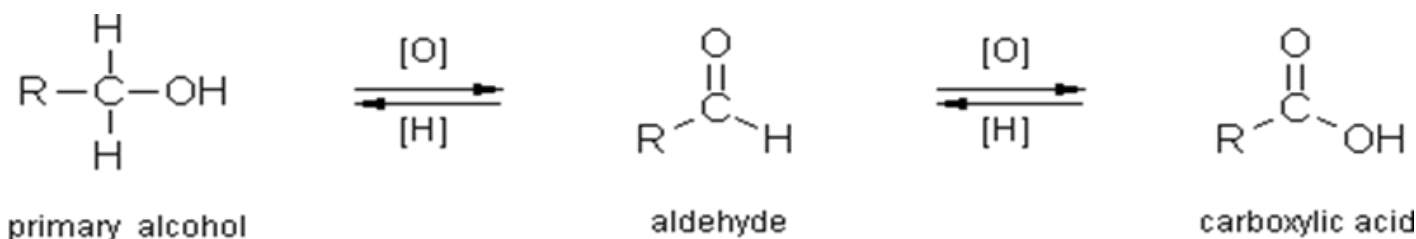


Reactions of Alcohols



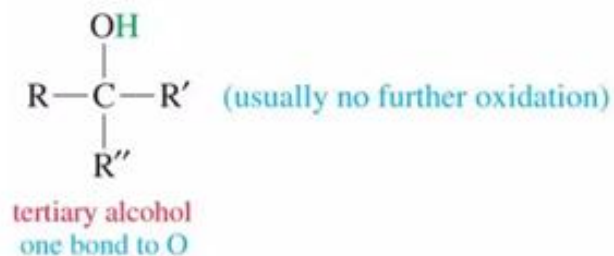
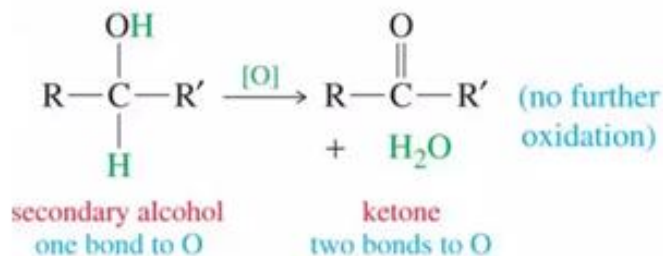
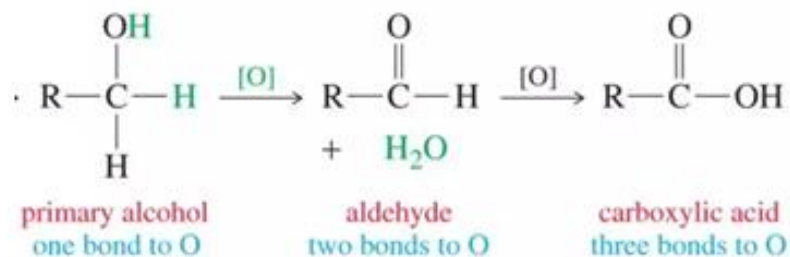
Oxidation of alcohols to aldehydes, ketones and carboxylic acids.

- Alcohols with at least one hydrogen atom attached to the hydroxyl-bearing carbon can be oxidized to carbonyl compounds.
- Primary alcohols give aldehydes**, which may be further oxidized to **carboxylic acids**.
- Secondary alcohols give ketones.**



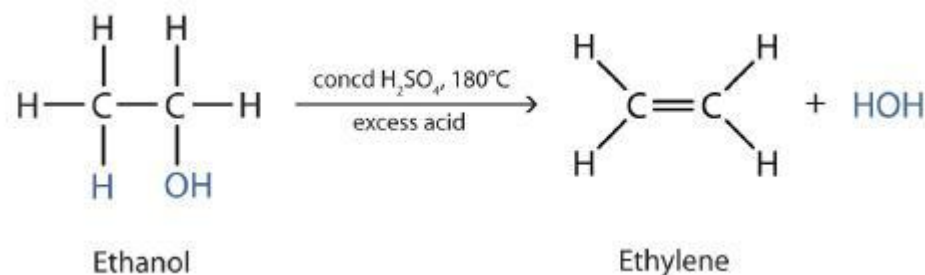
Dr Mustafa Abdul-Jabbar Al-Jumaili

Oxidation States of Carbons

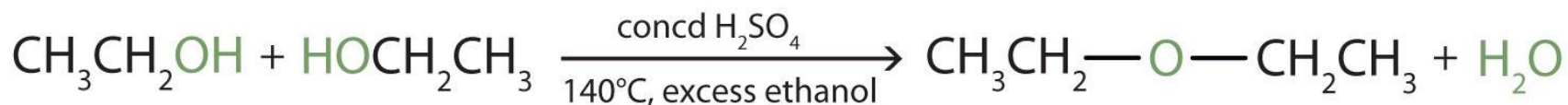


Dehydration of alcohols

- an alcohol undergoes dehydration in the presence of a catalyst to form an alkene and water. The reaction removes the OH group from the alcohol carbon atom and a hydrogen atom from an adjacent carbon atom in the same molecule:



Under the proper conditions, it is possible for the dehydration to occur between *two* Alcohol molecules. The entire OH group of one molecule and only the hydrogen atom of the OH group of the second molecule are removed. The two ethyl groups attached to an oxygen atom form an ether molecule



Two molecules of ethanol

Diethyl ether

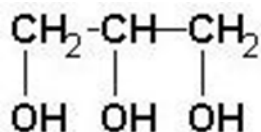
The most common alcohols

- Several alcohols have commercial importance.
- **Ethanol** ($\text{CH}_3\text{CH}_2\text{OH}$) is used in sterilizer and alcoholic drinks (Other alcohols are toxic).
- A dialcohol, **ethylene glycol** $\text{HOCH}_2\text{CH}_2\text{OH}$, is the major antifreeze for cars.
- **Isopropanol** (2-Propanol), is used as hand lotions, drug industry and other cosmetics.

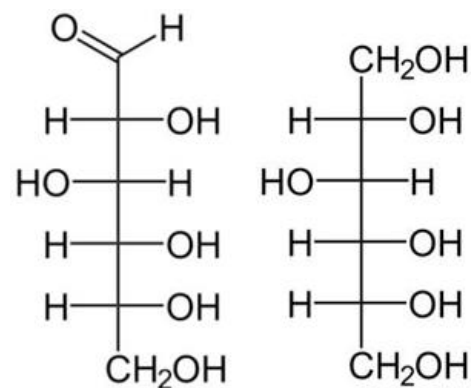


Alcohols with more than one hydroxyl group

- Compounds with more than two hydroxyl groups are also known, and several, such as glycerol and **sorbitol**, are important commercial chemicals.



glycerol



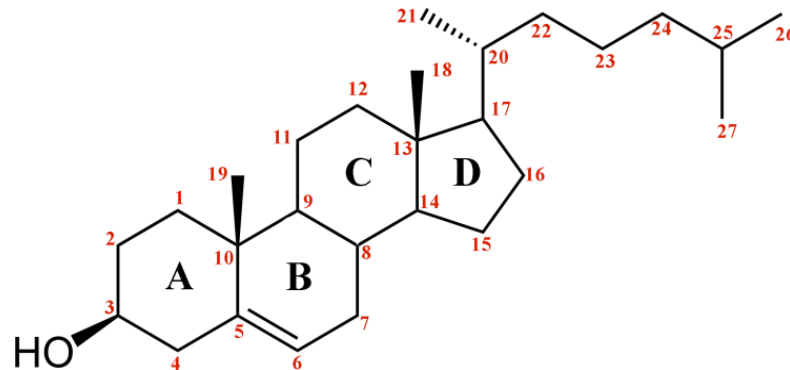
glucose

sorbitol

- **Glycerol** is a syrupy, colorless, water soluble liquid with a sweet taste. Glycerol is a naturally occurring alcohol. It is an odorless liquid that is used as a solvent, sweetening agent, and also as medicine.
- **Sorbitol** with its many hydroxyl groups, is water soluble.
 - ✓ It is almost as sweet as cane sugar and is used in candy making.

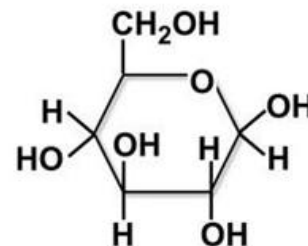
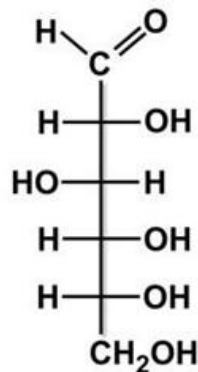
Biologically important alcohols

- **The hydroxyl group OH** appears in many biologically important molecules.
- **Cholesterol** a typical steroidal alcohol, has the following structure:



- **The chemistry of carbohydrates** usually involves two functional groups:
- **the carbonyl group (C=O)** of an aldehyde or ketone, and the alcohol **hydroxy group (OH)**.

Monosaccharide Structure



The toxicity of methanol



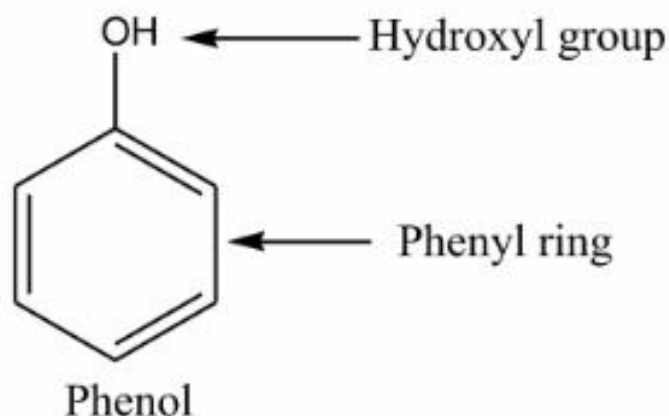
- The world production of methanol is approximately 11 million tons per year.
- It is a **colorless** liquid with a mild **alcoholic odor** which makes it difficult for us to distinguish it simply by the appearance and smell.
- Most of it is used to produce **formaldehyde** and other chemicals, but some is used as a solvent and antifreeze.
- **Methanol is highly toxic** and can cause **blindness**. Why?(**home work**)

Dr Mustafa Abdul-Jabbar Al-Jumaili

Phenol

The class of organic compounds characterized by hydroxyl (-OH) group attached to an aromatic ring.

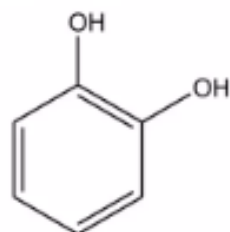
- Phenol is commonly known as carbolic acid.
- Phenols are aromatic components which contain one or more hydroxyl groups that are attached to an aromatic ring.
- Phenol is a benzene derivative and it consists of a phenyl bonded to a hydroxyl (-OH) group.
- General chemical formula of phenol is C_6H_5OH and molecular formula C_6H_6O .



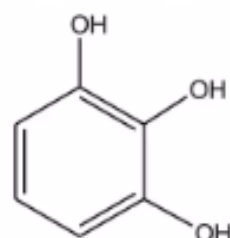
Nomenclature of Phenol

Phenol is a monohydroxy derivative of benzene prepared by the replacing of one of the hydrogen of benzene by hydroxyl group. Phenol contain two part one part is aryl group (phenyl) and other is hydroxyl group.

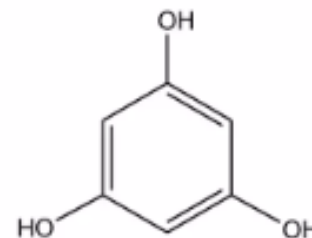
- On the basis of number of hydroxyl group bonded to benzene. It can be classified into di, tri, tetra hydroxyls benzene.



1,2-Dihydroxy benzene

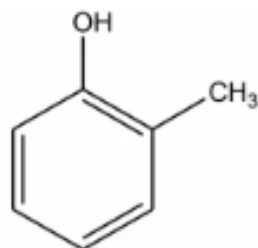


1,2,3-Trihydroxy benzene

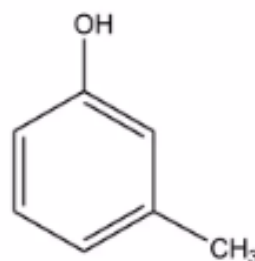


1,3,5-Trihydroxy benzene

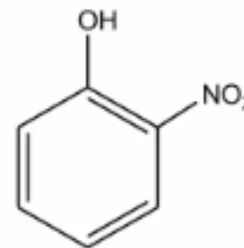
- In case of substituted phenol, the relative position is indicated by word Ortho (1, 2), Meta (1, 3) or Para (1, 4). However numbers are used if more than two substituents are present on ring.



2-Methyl phenol
o-cersol



3-Methyl phenol
m-cersol



2-nitro phenol
o-nitro phenol

Physical Properties of Phenol

Molecular formula

C_6H_6O

Molar mass

94.11 g/mole

Appearance

Colorless, Crystalline solid

Density

1.07 g/cm³

Melting point

41°C

Boiling point

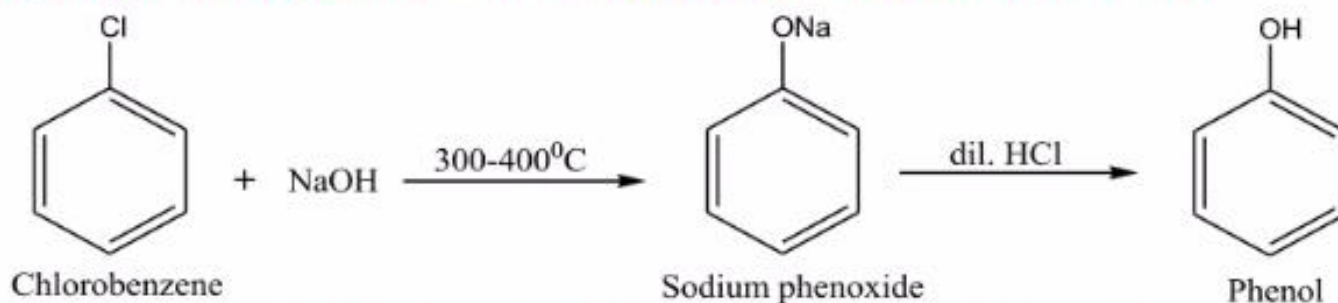
182°C

Solubility in water

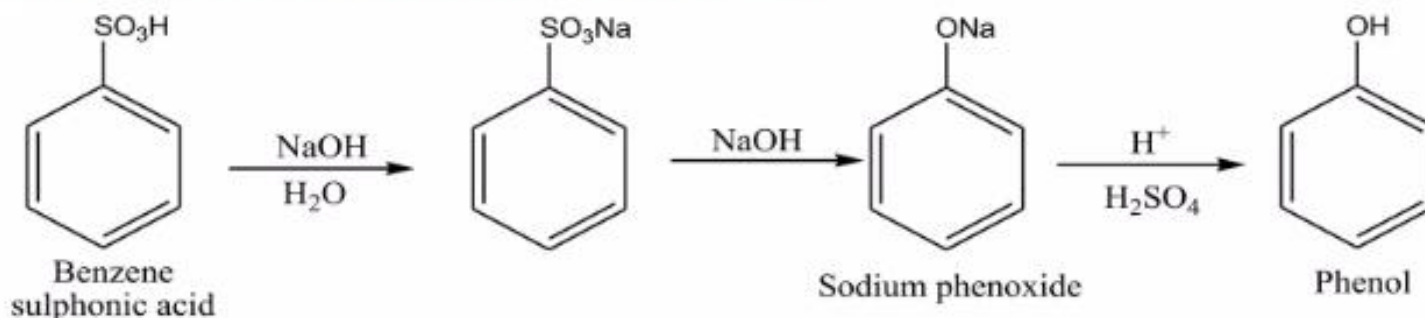
Soluble in water

Preparation Methods

1. From Aryl Halides (Dow's Process): Chlorobenzene when heated with dilute solution of sodium hydroxide at about $300-400^{\circ}\text{C}$ under 200 atm. pressure in presence of copper salt as catalyst to forms a sodium phenoxide which on treated with dil. HCl to give product phenol. This method is called Dows process.

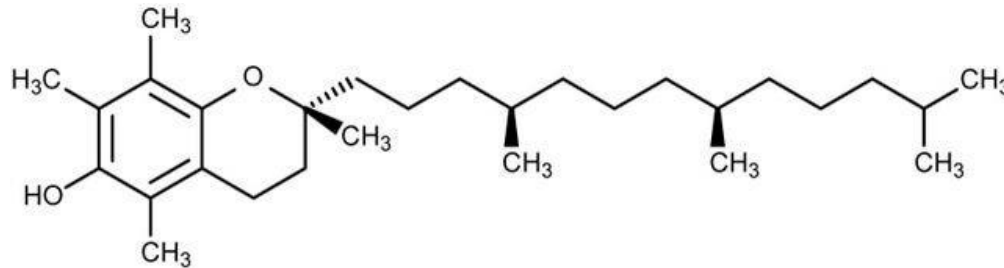


2. Benzene sulphonic acid: Benzene sulphonic acid when treated with NaOH to give sodium salt of benzene sulphonic acid (sodium benzene sulphonate). The sodium benzene sulphonate when fused with NaOH gives sodium phenoxide, which on hydrolysis with dilute H_2SO_4 give product Phenol.

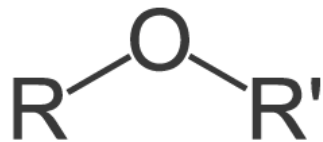


Biologically important Phenols

- **Vitamin E** (α -tocopherol) is a common naturally occurring phenol.
- One of its biological functions is to act as a natural **antioxidant**.



- **Biologically important phenols** are a diverse group of natural bioactive molecules, primarily derived from plants as secondary metabolites, characterized by having at least one aromatic ring bonded to one or more hydroxyl groups.
- They are essential for protecting against oxidative stress and reducing the risk of chronic diseases such as cancer, heart disease, and diabetes,



Ethers



- To most people the word **ether** is synonymous with **hospital smells** and the well-known **anesthetic**.
- That particular ether, however, is but one member of a general class of organic compounds known as ethers.
- These compounds have two organic groups connected to a single oxygen atom.
- The general formula for ethers is R-O-R', where R and R' may be identical or different.
- In the **common anesthetic**, both R and R' are ethyl groups:



diethyl ether

- ✓ **diethyl ether** is a colorless, highly volatile, sweet-smelling, extremely flammable liquid.
- ✓ It was formerly used as a general anesthetic, until non-flammable drugs were developed

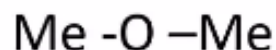
Ethers - R-O-R linkage

Symmetrical ethers

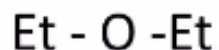
- $R = R'$

- *Simple ethers*

- Dimethyl ether



- Diethyl ether

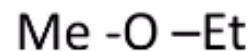


Unsymmetrical ethers

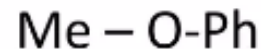
- $R \neq R'$

- *Mixed ethers*

- Ethyl methyl ether



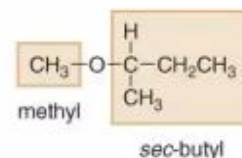
- Methyl phenyl ether



Nomenclature

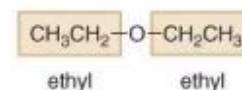


- Simple ethers - assigned common names
 - Name both alkyl groups bonded to the oxygen, arrange these names alphabetically, and add the word ether
 - For symmetrical ethers, name the alkyl group and add the prefix “di-”



sec-butyl methyl ether

[Alphabetize the **b** of **butyl**
before the **m** of **methyl**.]



diethyl ether

Preparing Ethers

- **1. Preparation of Ethers by Dehydration of Alcohols**

In the presence of protic acids ([sulphuric acid](#)), alcohols undergo dehydration to produce alkenes and ethers under different conditions. For example: in the presence of sulphuric acid, dehydration of ethanol at 443 K yields ethene whereas it yields ethoxyethane at 413 K. This is an ideal method of preparation through primary alcohols.



2. Preparations of Ethers by Williamson Synthesis

- Williamson's synthesis is an important method for the preparation of symmetrical and asymmetrical ethers in laboratories. In this method, an alkyl halide is reacted with sodium alkoxide which leads to the formation of ether. The reaction generally follows the S_N2 mechanism for primary alcohol.



Ethers as solvents



- Ethers are relatively **inert** compounds.
- They do not usually react with dilute acids, with dilute bases, or with common oxidizing and reducing agents.
- This general inertness, coupled with the fact that most organic compounds are ether-soluble, makes ethers excellent solvents in which to carry out organic reactions.
- Ethers are also used frequently to **extract** organic compounds from their natural sources. **Diethyl ether** is particularly good for this purpose.
- Its **low boiling point** makes it easy to remove from an extract and easy to recover by distillation.
- It is **highly flammable**, however, and must not be used if there are any flames in the same laboratory.