



**Muthanna University**

**College of Dentistry**



**MEDICAL CHEMISTRY**

**First Class**

**BY**

**M.Sc. Dhurgham Aziz Katia**

**2022-2023**

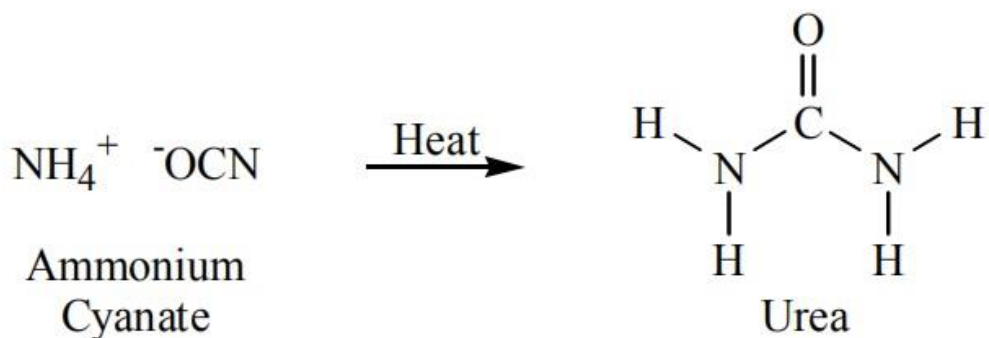
# Organic Chemistry

## What is Organic Chemistry?

- Organic chemistry is concerned with the study of the structure and properties of compounds containing carbon.
- All organic compounds contain carbon atoms.
- Inorganic compounds contain no carbons. Most inorganic compounds are ionic compounds.
- Some carbon compounds are not considered to be organic (mostly for historical reasons), such as CO, CO<sub>2</sub>, diamond, graphite, and salts of carbon-containing polyatomic ions (e.g., CO<sub>3</sub><sup>2-</sup>, CN<sup>-</sup>).
- Inorganic chemistry is the study of the other elements and non-carbon containing compounds.

## Origins of Organic Chemistry

- Organic literally means “derived from living organisms” — organic chemistry was originally the study of compounds extracted from living organisms and their natural products.
- It was believed that only living organisms possessed the “vital force” necessary to create organic compounds (“vitalism”).
- This concept started to change in 1828 after Friedrich Wöhler showed that it was possible to make urea, a known “organic compound” from a mineral source:

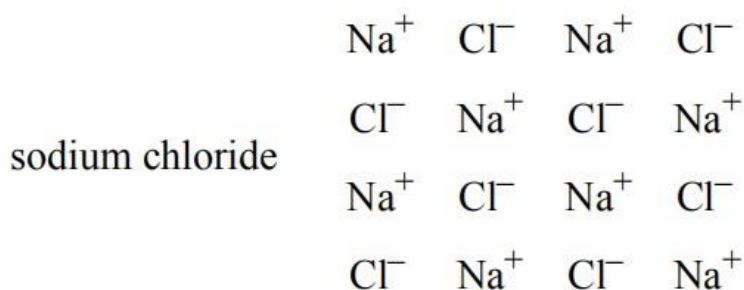
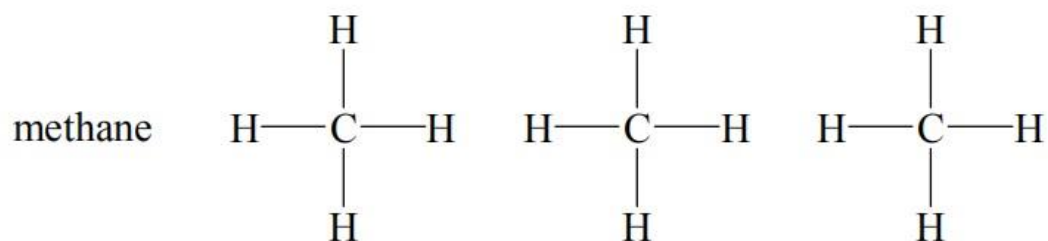


## What's So Great About Carbon?

- Complex organic compounds can perform a number of useful biological functions (vitamins, carbohydrates, lipids, proteins, enzymes, ATP, DNA, RNA are all organic compounds) which are studied in biochemistry.
- Complex organic compounds are present in the foods we eat (carbohydrates, proteins, fats, etc.)
- Most medicines, whether they come from a chemical plant or a green plant, are organic compounds.
- Most fuels are organic compounds (wood, coal, natural gas, gasoline, kerosene, diesel fuel, oil, and other petroleum-based products).
- Complex organic compounds are also useful in technology (paints, plastics, rubber, textiles, etc.).

## Organic vs. Inorganic Compounds

- Organic compounds are held together by covalent bonds, while inorganic compounds are held together by ionic bonds.



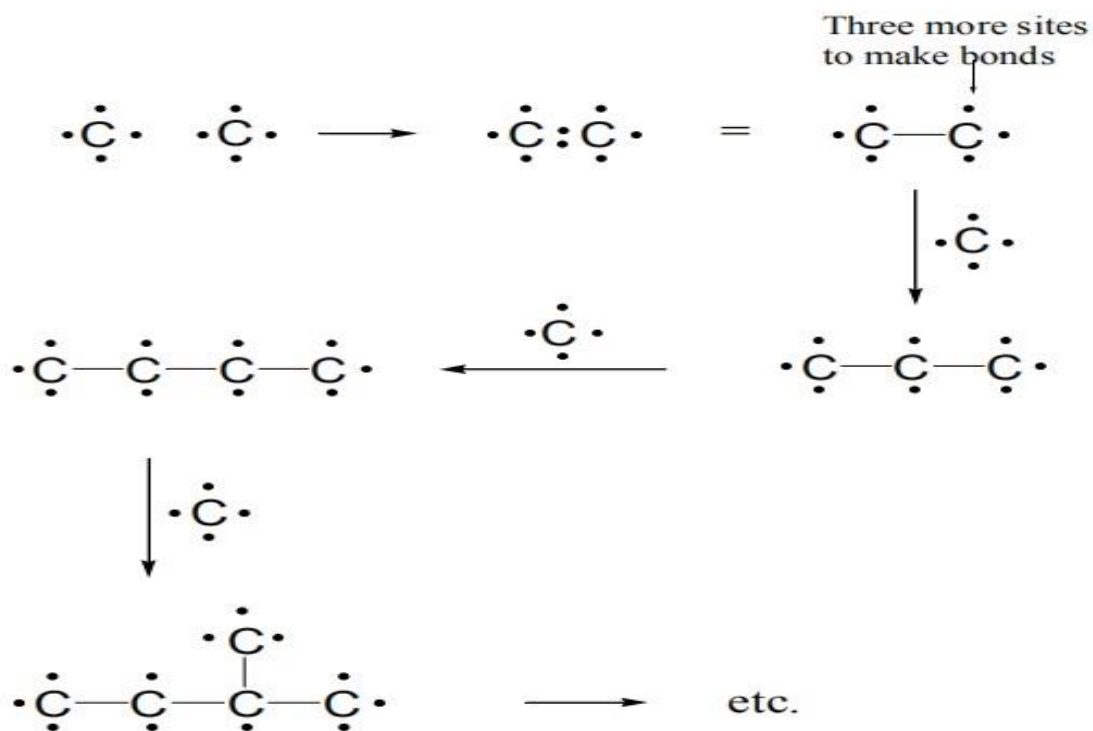
## Organic vs. Inorganic Compounds

**Table 1.1 Properties of typical organic and inorganic compounds.**

Property	Organic	Inorganic
Bonding within molecules	Covalent	Often ionic
Forces between molecules	Generally weak	Quite strong
Normal physical state	Gases, liquids, or low melting-point solids	Usually high melting-point solids
Flammability	Often flammable	Usually nonflammable
Solubility in water	Often low	Often high
Conductivity of aqueous solutions	Nonconductor	Conductor

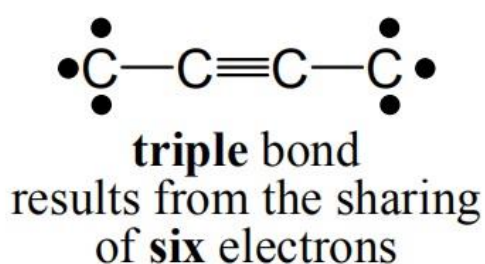
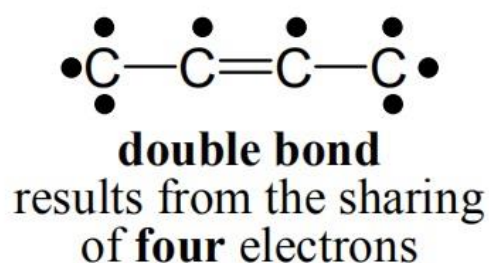
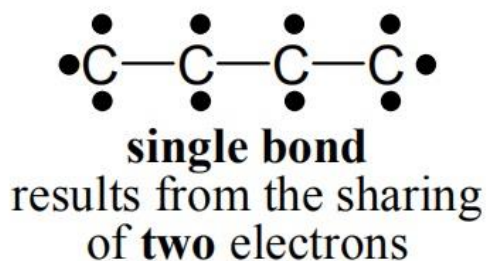
### Carbon Chains

- Each carbon atom can form four bonds, either to other carbon atoms, or to different atoms (such as H, O, N, S, P, etc.).



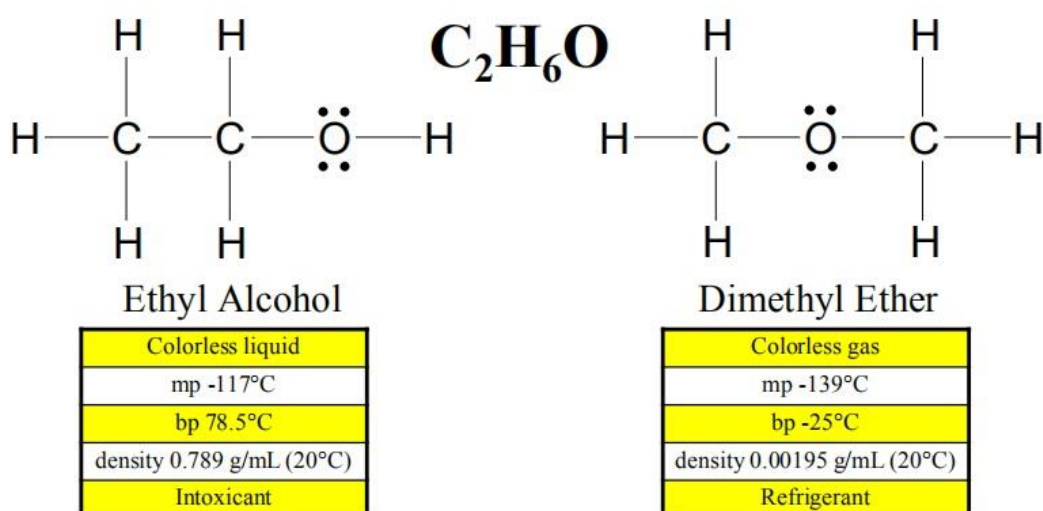
## Multiple Bonds

- Carbon atoms form four bonds to other things, but sometimes those bonds are multiple bonds (double or triple bonds):



## Isomers

- Isomers — compounds having identical molecular formulas, but different arrangements of atoms.
- Structural Isomers — the atoms in each molecule are connected in a different order.




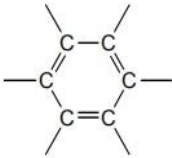

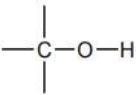
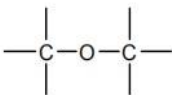
### Examples: Isomers

- Draw all possible structures having the formulas ( $C_4H_{10}$ ,  $C_5H_{12}$ , and  $C_6H_{14}$ ).

## Functional Groups

- Organic molecules are often organized by structures called functional groups, which are characteristic arrangement of atoms which define many of the physical and chemical properties of a class of organic compounds.
  - The simplest of the functional groups are the hydrocarbons, which include the alkanes, alkenes, alkynes, and aromatic hydrocarbons.
  - Many functional groups contain oxygen atoms, such as alcohols, ethers, aldehydes, ketones, carboxylic acids, and esters.
  - Some other functional groups contain nitrogen atoms, such as the amines and amides.
- Molecules with the same functional group tend to share similar chemical and physical properties.

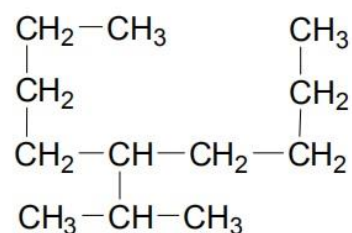
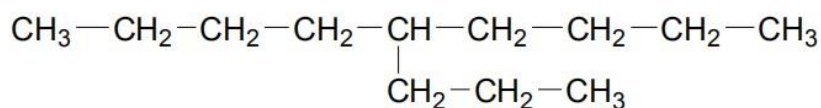
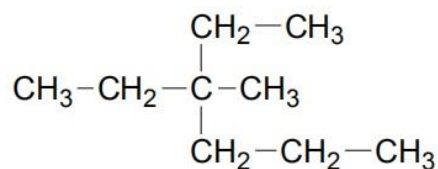
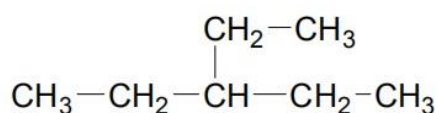
**Table 1.2 Classes and functional groups of organic compounds**

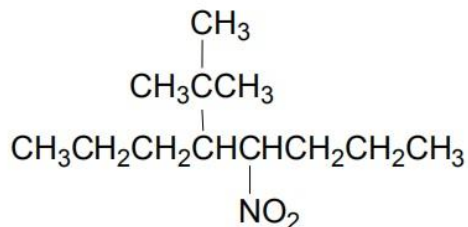
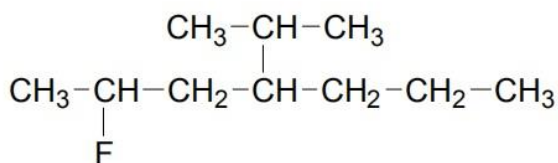
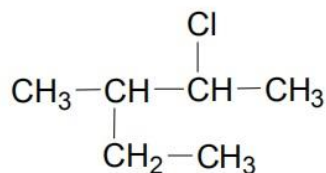
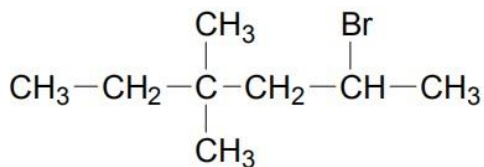
Class	Functional Group	Example of expanded structural formula	Example of condensed structural formula	IUPAC / Common name
Alkane	None	$\begin{array}{c} \text{H} \quad \text{H} \\   \quad   \\ \text{H}-\text{C}-\text{C}-\text{H} \\   \quad   \\ \text{H} \quad \text{H} \end{array}$	$\text{CH}_3\text{CH}_3$	ethane
Alkene		$\begin{array}{c} \text{H} \quad \text{H} \\ \diagdown \quad / \\ \text{C}=\text{C} \\ / \quad \diagdown \\ \text{H} \quad \text{H} \end{array}$	$\text{H}_2\text{C}=\text{CH}_2$	ethene (ethylene)
Alkyne	$-\text{C}\equiv\text{C}-$	$\text{H}-\text{C}\equiv\text{C}-\text{H}$	$\text{HC}\equiv\text{CH}$	ethyne (acetylene)
Aromatic		$\begin{array}{c} \text{H} \quad \text{H} \\   \quad   \\ \text{H}-\text{C}=\text{C}-\text{H} \\ / \quad \diagdown \\ \text{H} \quad \text{H} \end{array}$		benzene
Alcohol		$\begin{array}{c} \text{H} \quad \text{H} \\   \quad   \\ \text{H}-\text{C}-\text{C}-\text{O}-\text{H} \\   \quad   \\ \text{H} \quad \text{H} \end{array}$	$\text{CH}_3\text{CH}_2\text{OH}$	ethyl alcohol
Ether		$\begin{array}{c} \text{H} \quad \text{H} \\   \quad   \\ \text{H}-\text{C}-\text{O}-\text{C}-\text{H} \\   \quad   \\ \text{H} \quad \text{H} \end{array}$	$\text{CH}_3\text{OCH}_3$	methoxymethane (dimethyl ether)

**Table 1.2 Classes and functional groups of organic compounds**

Class	Functional Group	Example of expanded structural formula	Example of condensed structural formula	IUPAC / Common name
Aldehyde	$\begin{array}{c} \text{O} \\ \parallel \\ -\text{C}-\text{H} \end{array}$	$\begin{array}{c} \text{H} \quad \text{O} \\   \quad \parallel \\ \text{H}-\text{C}-\text{C}-\text{H} \\   \\ \text{H} \end{array}$	$\begin{array}{c} \text{O} \\ \parallel \\ \text{CH}_3\text{CH} \end{array}$	ethanal (acetaldehyde)
Ketone	$\begin{array}{c} \text{O} \\ \parallel \\ -\text{C}-\text{C}-\text{C}- \\   \quad   \end{array}$	$\begin{array}{c} \text{H} \quad \text{O} \quad \text{H} \\   \quad \parallel \quad   \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{H} \\   \quad   \\ \text{H} \quad \text{H} \end{array}$	$\begin{array}{c} \text{O} \\ \parallel \\ \text{CH}_3\text{CCH}_3 \end{array}$	2-propanone (acetone)
Carboxylic acid	$\begin{array}{c} \text{O} \\ \parallel \\ -\text{C}-\text{O}-\text{H} \end{array}$	$\begin{array}{c} \text{H} \quad \text{O} \\   \quad \parallel \\ \text{H}-\text{C}-\text{C}-\text{O}-\text{H} \\   \\ \text{H} \end{array}$	$\begin{array}{c} \text{O} \\ \parallel \\ \text{CH}_3\text{COH} \end{array}$	ethanoic acid (acetic acid)
Ester	$\begin{array}{c} \text{O} \\ \parallel \\ -\text{C}-\text{O}-\text{C}- \\   \end{array}$	$\begin{array}{c} \text{H} \quad \text{O} \quad \text{H} \\   \quad \parallel \quad   \\ \text{H}-\text{C}-\text{C}-\text{O}-\text{C}-\text{H} \\   \quad   \\ \text{H} \quad \text{H} \end{array}$	$\begin{array}{c} \text{O} \\ \parallel \\ \text{CH}_3\text{COCH}_3 \end{array}$	methyl ethanoate (methyl acetate)
Amine	$\begin{array}{c} \text{H} \\   \\ -\text{N}-\text{H} \end{array}$	$\begin{array}{c} \text{H} \quad \text{H} \\   \quad   \\ \text{H}-\text{C}-\text{N}-\text{H} \\   \\ \text{H} \end{array}$	$\text{CH}_3\text{NH}_2$	methylamine
Amide	$\begin{array}{c} \text{O} \\ \parallel \\ -\text{C}-\text{N}- \\   \end{array}$	$\begin{array}{c} \text{H} \quad \text{O} \\   \quad \parallel \\ \text{H}-\text{C}-\text{C}-\text{N}-\text{H} \\   \quad   \\ \vdots \quad \vdots \end{array}$	$\begin{array}{c} \text{O} \\ \parallel \\ \text{CH}_3\text{CNH}_2 \end{array}$	ethanamide (acetamide)

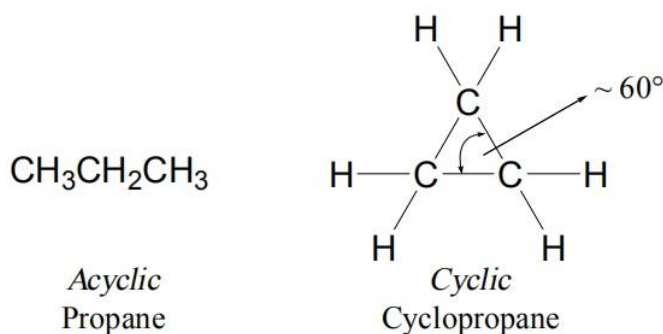
**Examples: Alkane Nomenclature Provide acceptable IUPAC names for the following molecules:**



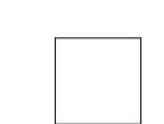


## Cycloalkanes

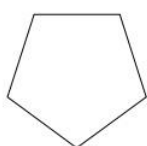
- Alkanes may also possess cyclic structures in addition to the straight- and branched-chain acyclic molecules we have already seen.
- General formula:  $\text{C}_n\text{H}_{2n}$  (for one ring).



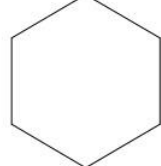
Note that these molecules are *not* structural isomers of each other!



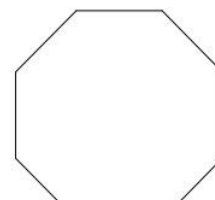
cyclobutane



cyclopentane



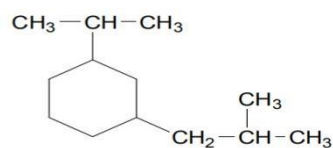
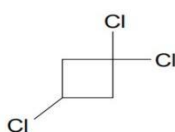
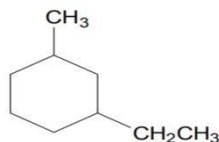
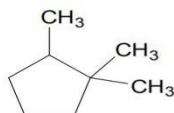
cyclohexane



cyclooctane

## Examples: Cycloalkane Nomenclature

- Provide acceptable IUPAC names for the following molecules:





## Stereoisomers of Cycloalkanes

### Stereoisomerism

It is also possible to arrange the atoms in molecules with the same structural formulae such that they have different spatial orientation.

This is known as stereoisomerism. There are two distinct types of stereoisomer: geometric and optical.

#### 1- Geometric isomerism

It is possible for single C-C bonds to rotate freely, however, double C=C bonds cannot.

#### 2- Optical isomerism

A carbon atom attached to four different groups (substituents) is termed a chiral center.

• The molecules below are different molecules because there is no free rotation around carbon-carbon bonds in cycloalkanes.



*cis*-1,2-dimethylcyclopentane      *trans*-1,2-dimethylcyclopentane

These molecules are stereoisomers — compounds with the same molecular and structural formula but different spatial arrangements of atoms.

• Stereoisomers in which the spatial arrangement is maintained by rings (or double bonds) are called geometric isomers or cis-trans isomers.

There are two isomers (cis and trans or E and Z) of many alkenes

The  $\pi$  bond has electron density both above and below the  $\sigma$  bond as the parallel p orbitals overlap

locking the bond rigid. Hence no rotation is possible about a double bond—the  $\pi$  bond must be broken before rotation can occur. One consequence of this locking effect of the double bond is that there

are two isomers of a disubstituted alkene. One is called a cis or **Z** alkene, the other a trans or **E** alkene.



a trans or E alkene

a cis or Z alkene

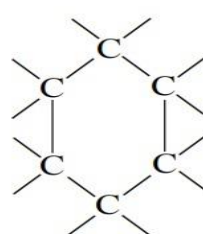
## The Alkenes

A homologous series of unsaturated compounds with general molecular formula  $C_nH_{2n}$  ( $n$  is an integer greater than 1) that contain a double bond.

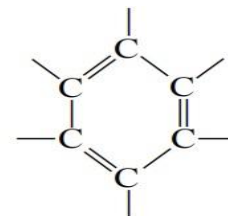
ethene  $C_2H_4$ , propene  $C_3H_6$ , butene  $C_4H_8$ , pentene  $C_5H_{10}$ , hexene  $C_6H_{12}$ , heptene  $C_7H_{14}$ , octene  $C_8H_{16}$ , nonene  $C_9H_{18}$ , decene  $C_{10}H_{20}$ , etc.

## AROMATIC COMPOUNDS

The aromatic organic compounds are all ring compounds or have cyclic groups of aromatic nature in their structure. The carbon atoms in these ring compounds have only one covalent bond, in contrast to those in aliphatic compounds with two.



Aliphatic ring



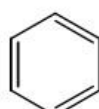
Aromatic ring

Aromatic compounds are stable cyclic systems of conjugated double bonds. There must be  $2n+1$  double bonds for the system to be stable.

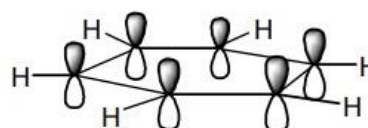
**Planar, fully conjugated, systems with  $(4n+2)$   $\pi$  electrons have a closed shell of electrons all in bonding orbitals and are exceptionally stable. Such systems are said to be aromatic.**



delocalised version

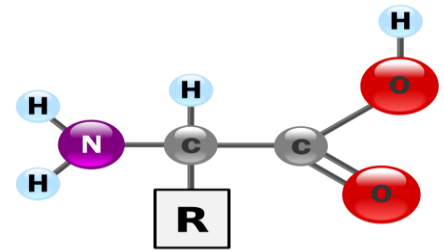


localised version



## Lecture 2

## Amino acids



**Amino acids:** are biologically important organic compounds composed of amine ( $\text{-NH}_2$ ) and carboxylic acid ( $\text{-COOH}$ ) functional groups, along with a side-chain specific to each amino acid.

The key elements of an amino acid are carbon, hydrogen, oxygen, and nitrogen, though other elements are found in the side-chains of certain amino acids.

About 500 amino acids are known, and can be classified in many ways. Structurally they can be classified according to polarity, pH level, and side chain group type (aliphatic, acyclic, aromatic, containing hydroxyl or sulfur, etc.).

Amino acids having both the amine and carboxylic acid groups attached to the first (alpha-) carbon atom have particular importance in biochemistry. They are known as 2-, alpha-, or  $\alpha$ -amino acids (generic formula  $\text{H}_2\text{NCHRCOOH}$  in most cases, where R is an organic substituent known as a "side-chain").

### Amino Acid Classifications

Each of the (20)  $\alpha$ -amino acids found in proteins can be distinguished by the R-group substitution on the  $\alpha$ -carbon atom. There are two broad classes of amino acids based upon whether the R-group is hydrophobic or hydrophilic.

\* The hydrophobic amino acids tend to repel the aqueous environment and, therefore, reside predominantly in the interior of proteins. This class of amino acids does not ionize nor participate in the formation of H-bonds.

\* The hydrophilic amino acids tend to interact with the aqueous environment, are often involved in the formation of H-bonds and are predominantly found on the exterior surfaces proteins or in the reactive centers of enzymes.

**Essential Amino Acids:** Obtained from diet because body cannot synthesize them: Phenylalanine, Tryptophan, Valine, Isoleucine, Leucine, Methionine, Lysine, and Threonine.

**Non-Essential Amino Acids:** All other Amino Acids body can synthesize them. Alanine, Asparagine, Aspartic acid, Cysteine, Glutamic acid, Glutamine, Glycine, Proline, Serine, and Tyrosine.

**Table of  $\alpha$ -Amino Acids Found in Proteins**

Amino Acid	Symbol	Structure*
<b>Amino Acids with Aliphatic R-Groups</b>		
<b>Glycine</b>	Gly - G	$\begin{array}{c} \text{H}-\text{CH}-\text{COOH} \\   \\ \text{NH}_2 \end{array}$
<b>Alanine</b>	Ala - A	$\begin{array}{c} \text{CH}_3-\text{CH}-\text{COOH} \\   \\ \text{NH}_2 \end{array}$
<b>Valine</b>	Val - V	$\begin{array}{c} \text{H}_3\text{C}-\text{CH}-\text{CH}-\text{COOH} \\   \quad   \\ \text{H}_3\text{C} \quad \text{NH}_2 \end{array}$
<b>Leucine</b>	Leu - L	$\begin{array}{c} \text{H}_3\text{C}-\text{CH}-\text{CH}_2-\text{CH}-\text{COOH} \\   \quad   \\ \text{H}_3\text{C} \quad \text{NH}_2 \end{array}$
<b>Isoleucine</b>	Ile - I	$\begin{array}{c} \text{H}_3\text{C}-\text{CH}_2-\text{CH}-\text{CH}-\text{COOH} \\   \quad   \\ \text{H}_3\text{C} \quad \text{NH}_2 \end{array}$
<b>Non-Aromatic Amino Acids with Hydroxyl R-Groups</b>		
<b>Serine</b>	Ser - S	$\begin{array}{c} \text{HO}-\text{CH}_2-\text{CH}-\text{COOH} \\   \\ \text{NH}_2 \end{array}$
<b>Threonine</b>	Thr - T	$\begin{array}{c} \text{H}_3\text{C}-\text{CH}-\text{CH}-\text{COOH} \\   \quad   \\ \text{HO} \quad \text{NH}_2 \end{array}$
<b>Amino Acids with Sulfur-Containing R-Groups</b>		

<b>Cysteine</b>	Cys - C	$\text{HS-CH}_2\text{-}\underset{\text{NH}_2}{\text{CH}}\text{-COOH}$
<b>Methionine</b>	Met-M	$\text{H}_3\text{C-S-(CH}_2\text{)}_2\text{-}\underset{\text{NH}_2}{\text{CH}}\text{-COOH}$
<b>Acidic Amino Acids and their Amides</b>		
<b>Aspartic Acid</b>	Asp - D	$\text{HOOC-CH}_2\text{-}\underset{\text{NH}_2}{\text{CH}}\text{-COOH}$
<b>Asparagine</b>	Asn - N	$\text{H}_2\text{N-C(=O)-CH}_2\text{-}\underset{\text{NH}_2}{\text{CH}}\text{-COOH}$
<b>Glutamic Acid</b>	Glu - E	$\text{HOOC-CH}_2\text{-CH}_2\text{-}\underset{\text{NH}_2}{\text{CH}}\text{-COOH}$
<b>Glutamine</b>	Gln - Q	$\text{H}_2\text{N-C(=O)-CH}_2\text{-CH}_2\text{-}\underset{\text{NH}_2}{\text{CH}}\text{-COOH}$
<b>Basic Amino Acids</b>		
<b>Arginine</b>	Arg - R	$\text{HN(CH}_2\text{)}_2\text{-CH}_2\text{-CH}_2\text{-}\underset{\text{NH}_2}{\text{CH}}\text{-COOH}$
<b>Lysine</b>	Lys - K	$\text{H}_2\text{N-(CH}_2\text{)}_4\text{-}\underset{\text{NH}_2}{\text{CH}}\text{-COOH}$
<b>Histidine</b>	His - H	$\text{Imidazole ring-CH}_2\text{-}\underset{\text{NH}_2}{\text{CH}}\text{-COOH}$
<b>Amino Acids with Aromatic Rings</b>		
<b>Phenylalanine</b>	Phe - F	$\text{Phenyl ring-CH}_2\text{-}\underset{\text{NH}_2}{\text{CH}}\text{-COOH}$

<b>Tyrosine</b>	Tyr - Y	
<b>Tryptophan</b>	Trp-W	
<b>Imino Acids</b>		
<b>Proline</b>	Pro - P	

\*Backbone of the amino acids is red, R-groups are black

### The Peptide Bond

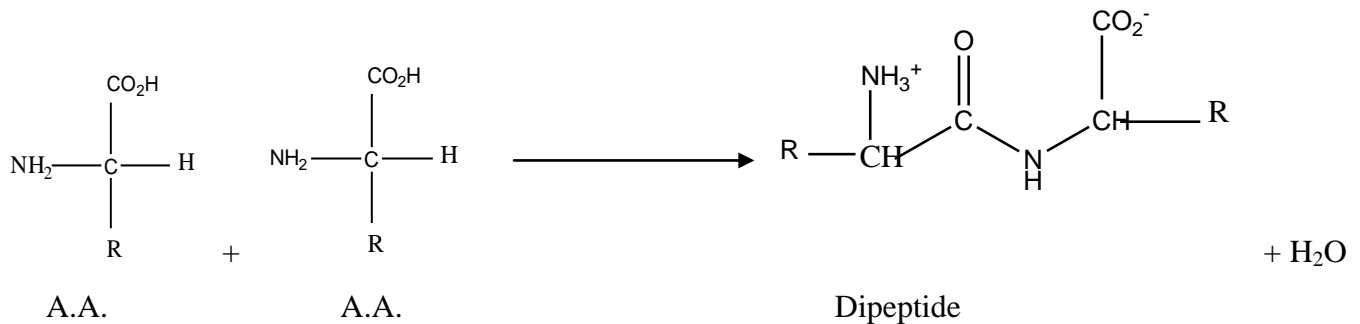
The simplest peptide, a **dipeptide**, contains a single peptide bond formed by the condensation of the carboxyl group of one amino acid with the amino group of the second with the concomitant elimination of water. Peptide bond formation is a condensation reaction leading to the polymerization of amino acids into peptides and proteins. Peptides are small consisting of few amino acids.

### **\*Importance of Peptides:**

1. A number of hormones (e.g. Insulin) and some neurotransmitters are peptides.
2. Several antibiotics (e.g. Gramacidin and Valinomycin) are peptides.
3. Some antitumor agents are peptides (e.g. Bleomycin).

@ Poly peptide chain is unbranched chain, rigid, and planer.

#-We started from amino group (**N-terminal residue**) from the left if we write the sequence of Amin Acid of Poly Peptide Chain.



### Chemical Nature of the Amino Acids:

\*All peptides and polypeptides are polymers of ( $\alpha$ ) alpha-amino acids.

\*There are (20)  $\alpha$ -amino acids that are relevant to the make-up of mammalian proteins (see below).

@ Several other amino acids are found in the body free or in combined states (i.e. not associated with peptides or proteins). These non-protein associated amino acids perform specialized functions.

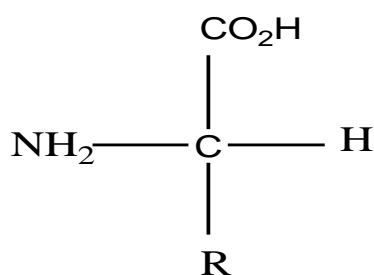
e.g.  $\gamma$ -Aminobutyric acid (GABA): involved in neurotransmission of nerve pulses.

e.g  $\beta$ -alanine: Part of the structure of Coenzyme A.

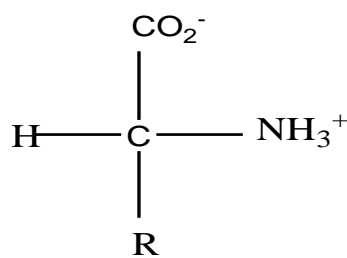
@ Several of the amino acids found in proteins also serve functions distinct from the formation of peptides and proteins: e.g. Tyrosine in the formation of thyroid hormones and other example is glutamate acting as a neurotransmitter.

@ The  $\alpha$ -amino acids in peptides and proteins (*excluding proline*) consist of a carboxylic acid (**-COOH**) and an amino (**-NH<sub>2</sub>**) functional group attached to the same tetrahedral carbon atom. This carbon is the  $\alpha$ -carbon.

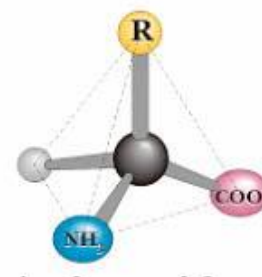
Distinct R-groups, that distinguish one amino acid from another, also are attached to the alpha-carbon (except in the case of glycine where the R-group is hydrogen). The fourth substitution on the tetrahedral  $\alpha$ -carbon of amino acids is hydrogen



*Neutral formula*



*Zwitterion formula*



*tetrahedral structure*

***Figure (1): General structure of amino acids. Neutral formula never found in the body.***

\*Crystalline amino acids are colorless, odorless, and melt with decomposition at temperature more than (200 °C). In aqueous solution amino acids exist predominantly in the form of zwitterion.



**Lipids**: Biological molecules that are insoluble in aqueous solutions and soluble in organic solvents are classified as lipids.

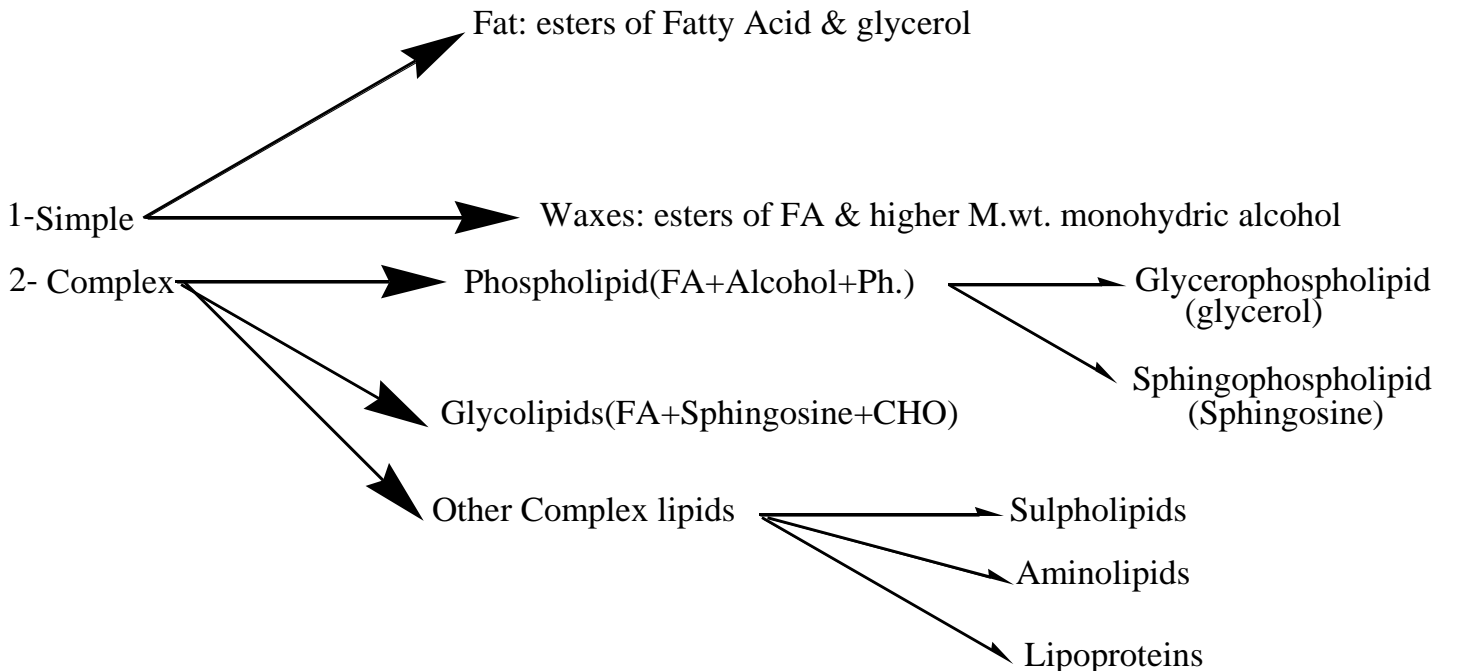
The lipids are a large and heterogeneous group of substances of biological origin that are easily dissolved in organic solvents such as methanol, acetone, chloroform, and benzene. By contrast, they are either insoluble or only poorly soluble in water

**Major Roles of Biological of Lipids:**

The lipids of physiological importance for humans have four major functions:

1. They serve as structural components of biological membranes.
2. They provide energy reserves, predominantly in the form of triacylglycerol.
3. Both lipids and lipid derivatives serve as vitamins and hormones.
4. Lipophilic bile acids aid in lipid solubilization.
5. Serve as thermal and electrical insulator.

**Classification of Lipids:**



3-Precursors and derived lipids: FA, Steroids, Ketone bodies, Some hormones, lipid soluble vitamins.

## 1-Fatty Acids:

**Fatty acids are long-chain hydrocarbon molecules containing a carboxylic acid moiety at one end.**

\*Fatty acids fill two major roles in the body:

1. as the components of more complex membrane lipids.
2. as the major components of stored fat in the form of triacylglycerol.

\* **Saturated fatty acids:** Fatty acids that contain no carbon-carbon double bonds.

\* **Unsaturated fatty acids:** Fatty acids that contain double bonds.

Fatty acids may be further subdivided as follows:

- (1) **Monounsaturated** (monoethenoid, monoenoic) acids, containing one double bond.
- (2) **Polyunsaturated** (polyethenoid, polyenoic) acids, containing two or more double bonds.
- (3) **Eicosanoids:** These compounds, derived from eicosa- (20-carbon) polyenoic fatty acids, comprise the **prostanoids**, **leukotrienes (LTs)**, and **lipoxins (LXs)**. Prostanoids include **prostaglandins (PGs)**, **prostacyclins (PGIs)**, and **thromboxanes (TXs)**.

#The site of unsaturation in a fatty acid is indicated by the symbol  $\Delta$  and the number of the first carbon of the double bond (e.g. palmitoleic acid is a 16-carbon fatty acid with one site of unsaturation between carbons 9 and 10, and is designated by 16:1 $\Delta^9$ ).

@ Naturally occurred unsaturated FA occurs in cis-form.

@ Body can biosynthesize lipids and can supply the body with all the various fatty acid structures needed except the essential FA.

\***Essential fatty acids;** must be provided in the diet (the highly unsaturated fatty acids: **linoleic acid** and **linolenic acid**) because they containing unsaturation sites beyond carbons 9 and 10.

## Prostaglandins:

Synthesized *in vivo* by cyclization of the center of the (20C-atoms unsaturated FA that called Eicosanoic acid) to form cyclopentane cycle. Examples of prostaglandins: thromboxane, prostaglandins 2 (PGE2).



**Figure: PEG2**

## 2-Basic Structure of Triacylglycerides

Triacylglycerides (TG) are composed of a glycerol backbone to which 3 fatty acids are esterified. TG are the stored lipids in the body tissues.

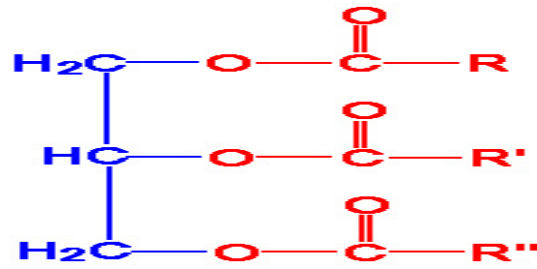


Figure: Basic composition of a triacylglyceride

## 3-Basic Structure of Phospholipids

The basic structure of phospholipids is very similar to that of the triacylglycerides except that C-3 of the glycerol backbone is esterified to phosphoric acid.

\*The building block of the phospholipids is **phosphatidic acid** (X= hydrogen atom).

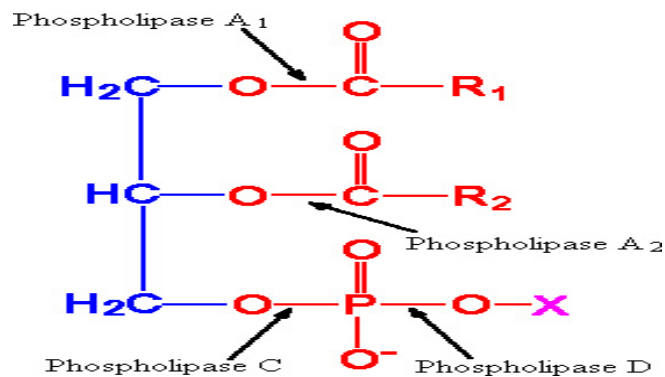
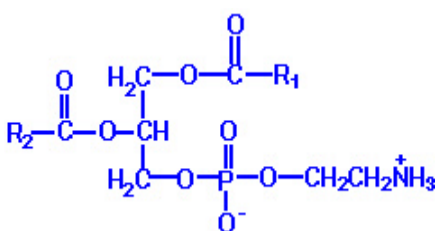
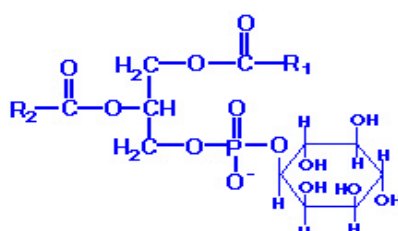


Figure: Basic composition of a phospholipid. X can be a number of different substituents.

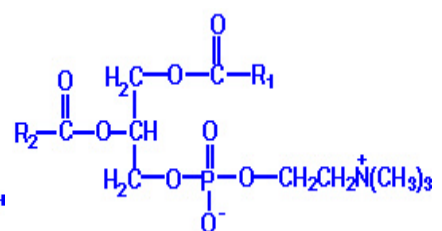
\*Substitutions include ethanolamine (**phosphatidylethanolamine**), choline (**phosphatidylcholine**, also called **lecithins**), serine (**phosphatidylserine**), glycerol (**phosphatidylglycerol**), *myo*-inositol (**phosphatidylinositol**, and phosphatidylglycerol (**diphosphatidylglycerol** more commonly known as **cardiolipins**).



Phosphatidylethanolamine



Phosphatidylinositol



Phosphatidylcholine (lecithin)

#### 4-Basic Structure of Plasmalogens

Plasmalogens are phospholipids substituted at C-1 (*sn*1) of glycerol contain either an *O*-alkyl or *O*-alkenyl ether species. One of the most potent biological molecules is **platelet activating factor**.

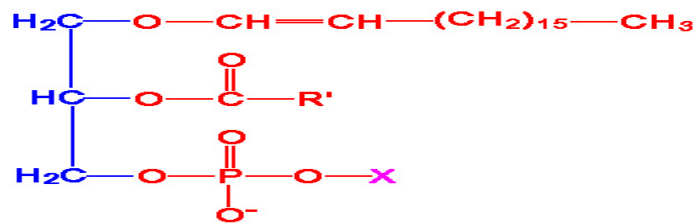


Figure: basic composition of *O*-alkenyl plasmalogens.

#### 5-Basic Structure of Sphingolipids

\*Sphingolipids are composed of a backbone of sphingosine which is derived itself from glycerol.

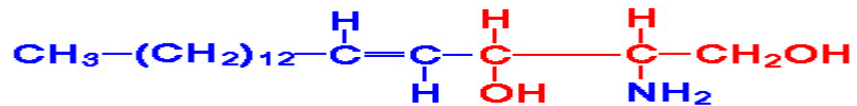


Figure: Sphingosine

**Ceramides:** A family of molecules composed of sphingosine when N-acetylated by a variety of fatty acids. Sphingolipids predominate in the myelin sheath of nerve fibers.

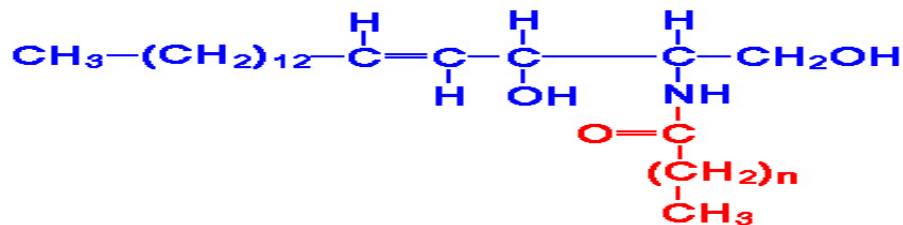


Figure: Ceramide

\***Sphingomyelin** is an abundant sphingolipid generated by transfer of the phosphocholine moiety of phosphatidylcholine to a ceramide, thus sphingomyelin is a unique form of a phospholipid.

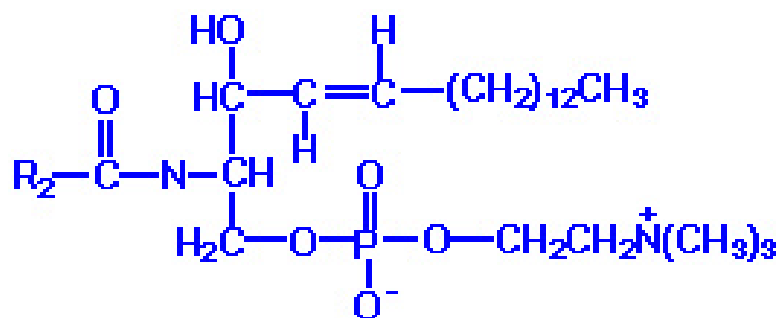


Figure: Sphingomyelin

The other major classes of sphingolipids (besides the sphingomyelins) are the **glycosphingolipids** generated by substitution of carbohydrates to the *sn1* carbon of the glycerol backbone of a ceramide. There are 4 major classes of glycosphingolipids:

**Cerebrosides:** contain a single moiety, principally galactose.

**Sulfatides:** sulfuric acid esters of galactocerebrosides.

**Globosides:** contain 2 or more sugars.

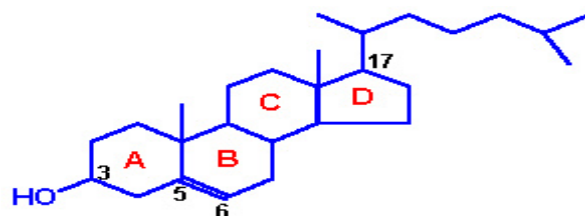
**Gangliosides:** similar to globosides except also contain sialic acid.

## 6- Steroids:

Steroids are lipids derived from the cyclopentanophenanthrene.

Cholesterol is an extremely important biological steroid: 1-Constituent of plasma membrane and lipoproteins 2- precursor for the synthesis of the **steroid hormones**, sex hormones, vitamin D, and bile acids.

@ Both dietary cholesterol and that synthesized *de novo* are transported through the circulation in **lipoprotein particles**. The same is true of cholesteryl esters, the form in which cholesterol is stored in cells.



**Figure: Cholesterol**

# What is Bond Polarity

Bond polarity is a concept that explains the polarity of covalent bonds. Covalent bonds are formed when two atoms share their unpaired electrons. Then, the bond electrons or the electrons that are involved in the bonding, belong to both atoms. Hence there is an electron density between two atoms.

If the two atoms are of the same chemical element, then no bond polarity can be observed since both atoms show equal attraction to the bond electrons. But if the two atoms belong to two different chemical elements, the more electronegative atom will attract the bond electrons than the less electronegative atom. Then, the less electronegative atom gets a partial positive charge since the electron density around that atom is reduced. But the more electronegative atom gets a partial negative charge because the electron density around that atom is high. This charge separation is known as bond polarity in covalent bonds.

When there is a charge separation, that bond is known as a polar bond. In the absence of bond polarity, it is known as a nonpolar bond. Let us consider two examples in order to understand bond polarity.



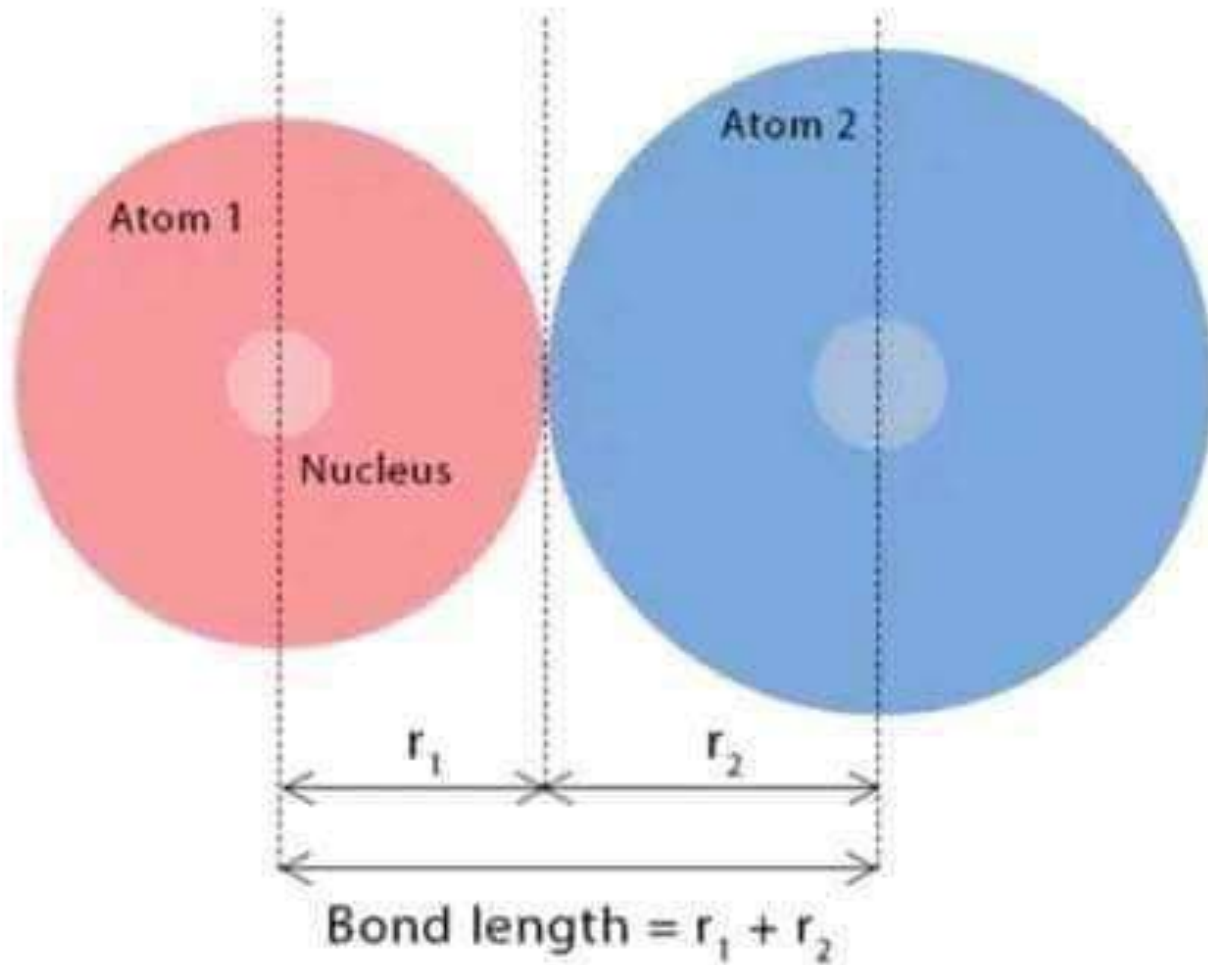
## Examples of Bond Polarity

### CF

Here, C is less electronegative than F atom. Therefore the bond electrons are more attracted towards the F atom. Then, F atom obtains a partial negative charge whereas C atom gets a partial positive charge.



# Bond Length



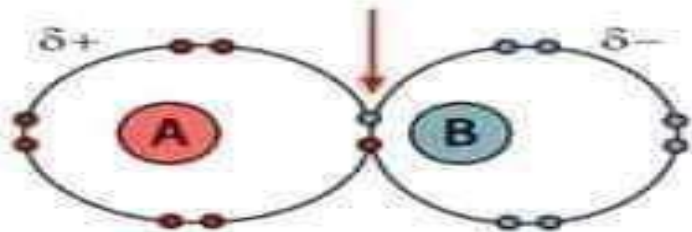
# Polar vs Nonpolar Covalent Bond

## Polar Covalent Bond

Unpaired  
valence electrons

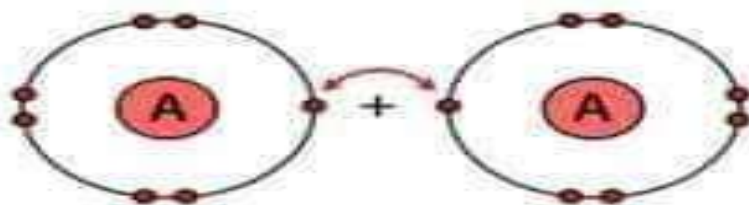


Unequal sharing of  
valence electrons

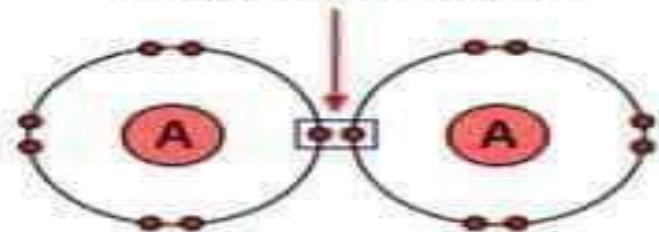


## Nonpolar Covalent Bond

Unpaired  
valence electrons

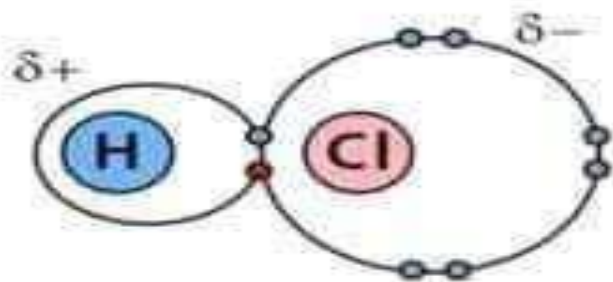


Equal sharing of  
valence electrons

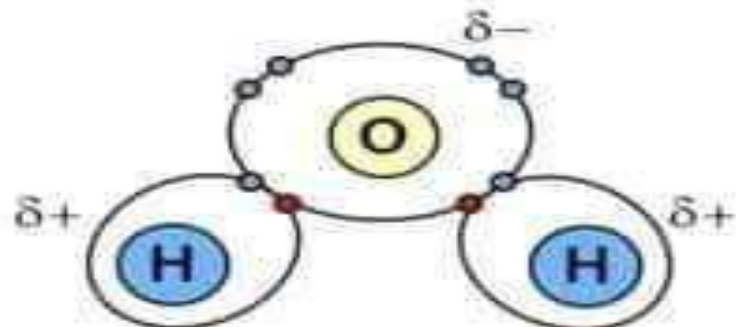


# Polar Covalent Bond Examples

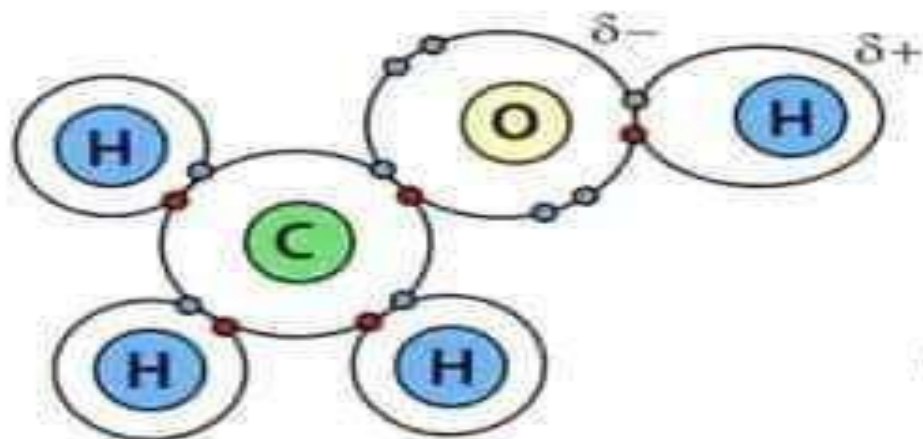
## 1. Hydrogen chloride



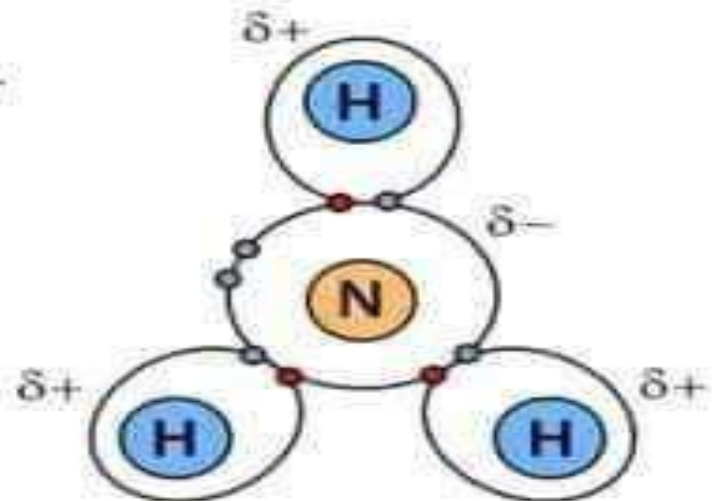
## 2. Water



## 3. Methanol

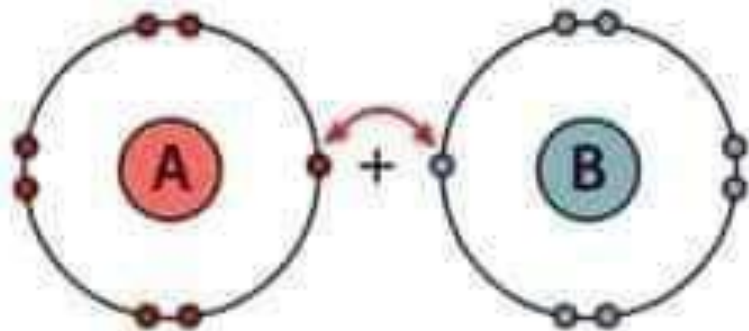


## 4. Ammonia



# Polar Covalent Bond

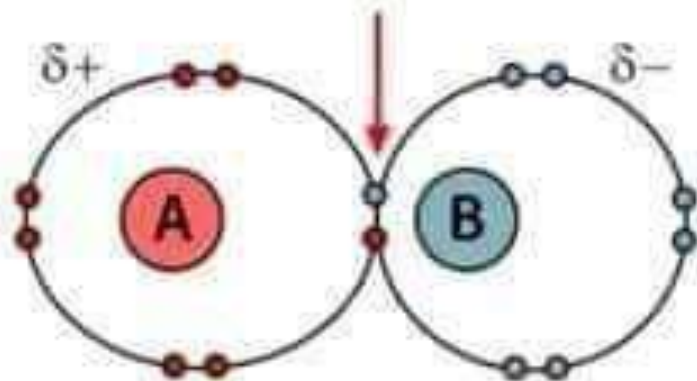
Unpaired  
valence electrons



Atom 1  
(nonmetal)

Atom 2  
(nonmetal or  
metalloid)

Unequal sharing of  
valence electrons



Polar covalent molecule

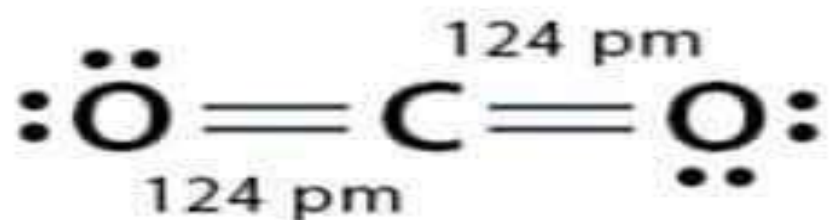
**Example:** Carbon dioxide (CO<sub>2</sub>)

1. Draw the Lewis structure of CO<sub>2</sub>



2. Find the covalent radii of carbon and oxygen double bonds from the chart: (C=): 67 pm and (O=): 57 pm

3. Add the sum of the two radii: 67 pm + 57 pm = 124 pm



# How to Find Bond Length

The bond length can also be determined from the Lewis structure of the molecule. Here are the steps.

- 1 Draw the Lewis structure of the compound and identify the bond of interest.
- 2 Look up the covalent radius of the two atoms from the chart.
- 3 Calculate the sum of the two radii.

2. Bond strength and bond disassociation energy:

The stronger the bond, the shorter will be the bond length. In other words, if the bond strength increases, the bond length decreases.

## **Factors Affecting Bond Length** [1,6]

1. Bond order (or the number of bonded electrons):

The more the electrons, the shorter the bond is.

Order of bond length: single bond > double bond > triple bond



The order of bond lengths of carbon and other atoms are as follows:



It is clear that as the covalent radius of the elements decreases, the bond length also decreases. Hence, **the bond length decreases across a period of the periodic table.**

The order of bond length of hydrogen halide is as follows:



It is clear that as the covalent radius of the halogens increases, the bond length also increases. Hence, **the bond length increases down a group in the periodic table.**

Carbon dioxide  (CO <sub>2</sub> )	O=C=O	116
Water (H <sub>2</sub> O)	H-O-H	97
Ammonia (NH <sub>3</sub> )	N-H	101

**Nitrogen** (N<sub>2</sub>)

N-N

142

N=N

120

N≡N

108

**Oxygen** (O<sub>2</sub>)

O-O

129

O=O

114

O≡O

106

<b>Compound</b>	<b>Bond</b>	<b>Bond length (pm)</b>
<b><u>Hydrogen</u></b> (H <sub>2</sub> )	H-H	74
Alkane	C-C	151
Alkene	C=C	134
Alkyne	C≡C	120

# Bond Length and Resonance

Resonance is the delocalization of electrons in a conjugated system. The bond length of a single bond decreases since it gets some double bond character, and that of a double bond increases as it loses some of its character. As a result, the lengths of single and double bonds change to intermediate values. The resonance structures allow one to predict bond length <sup>[1]</sup>.

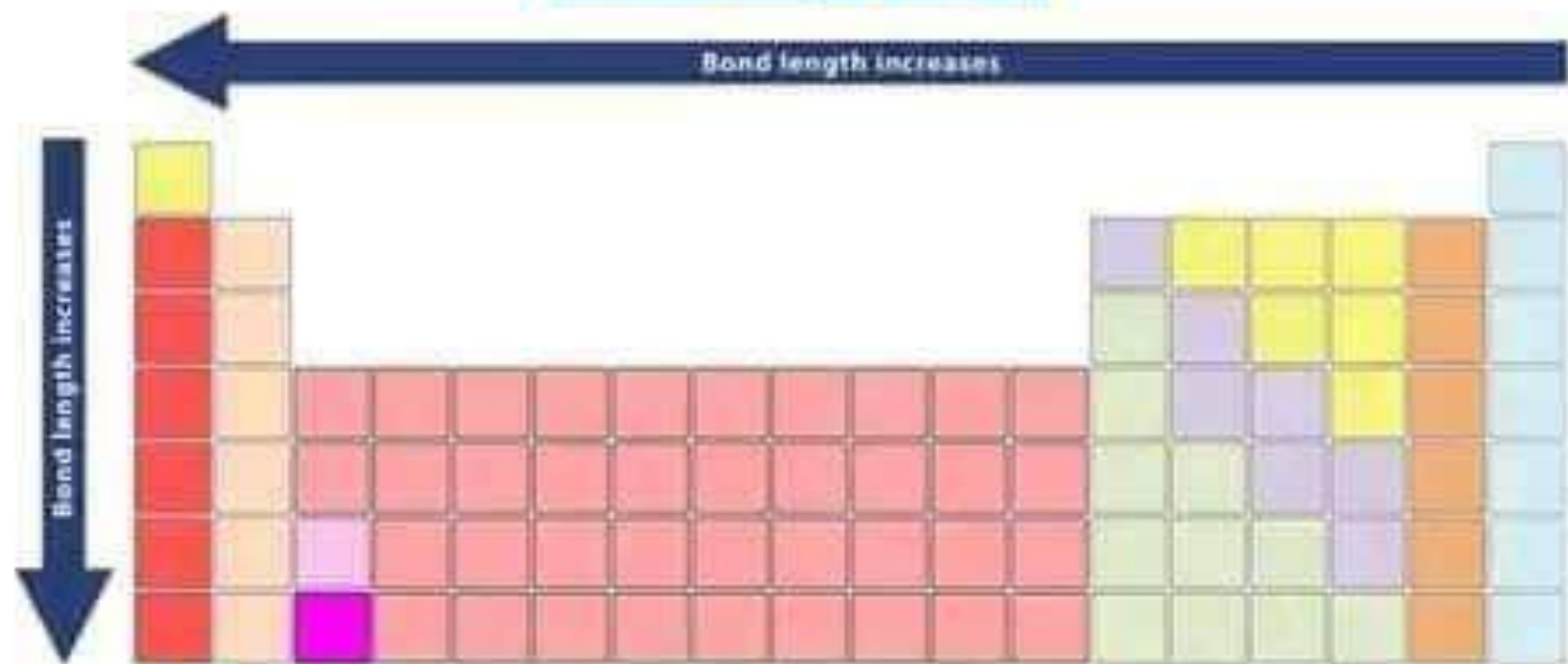
For this reason, the carbon-carbon bond lengths in benzene are equal. The carbon-carbon bond alternates between C-C and C=C. The bond length between two carbon atoms is 139.9 pm, between C-C (151 pm) and C=C (134 pm).

# Bond Length and Bond Energy

The amount of energy required to break all covalent bonds of the same type in one mole of a compound in a gaseous state is called bond energy. The bond energy is inversely proportional to the bond length. In other words, shorter bond length has higher bond energy. The following table shows the bond length and bond energy of carbon-carbon bonds <sup>[8]</sup>.

Bond	Bond Length (pm)	Bond Energy (kJ/mol)
C-C	151	347
C=C	134	614
C≡C	120	839

## Bond Length Trend



**Bond length trend**

## Solutions

A solution is a homogeneous mixture of two or more components in which the particle size is smaller than 1 nm.

Common examples of solutions are sugar in water and salt in water solutions, soda water, etc. In a solution, all the components appear as a single phase. There is particle homogeneity i.e. particles are evenly distributed. This is why a whole bottle of soft drink has the same taste throughout.



### Characteristics of Solution

Solutions have two components, one is solvent and the other is solute.

#### 1. What is a Solvent?

The component that dissolves the other component is called the solvent.

#### 2. What is Solute?

The component(s) that is/are dissolved in the solvent is/are called solute(s).

Generally solvent is present in major proportion compared to the solute. The amount of solute is lesser than the solvent. The solute and solvent can be in any state of matter i.e. solid, liquid or gas.

Solutions that are in the liquid state consist of a solid, liquid or gas dissolved in a liquid solvent. Alloys and air are examples of solid and gaseous solutions, respectively.

#### 3. Solution Examples

The following examples illustrate solvent and solute in some solutions.

- Air is a homogeneous mixture of gases. Here both the solvent and the solute are gases.



- Sugar syrup is a solution where sugar is dissolved in water using heat. Here, water is the solvent and sugar is the solute.
- Tincture of iodine, a mixture of iodine in alcohol. Iodine is the solute whereas alcohol is the solvent.

## Types of Solution

Liquid solutions, such as sugar in water, are the most common kind, but there are also solutions that are gases or solids. Any state of matter (solid, liquid, or gas) can act both as a solute and as a solvent during the formation of a solution. Therefore, depending on the physical states of solute and solvent, we can classify solutions into nine different types.

S.No	Types of Solution	Solute	Solvent	Examples
1	Solid-solid	solid	solid	Alloys like brass, bronze etc.
2	Solid-liquid	solid	liquid	The solution of sugar, salt etc in water.
3	Solid-gas	solid	gas	Sublimation of substances like iodine, camphor etc into the air.
4	Liquid-solid	liquid	solid	Hydrated salts, mercury in amalgamated zinc, etc.
5	Liquid-liquid	liquid	liquid	Alcohol in water, benzene in toluene
6	Liquid-gas	liquid	gas	Aerosol, water vapour in the air.
7	Gas-solid	gas	solid	Hydrogen absorbed in palladium
8	Gas-liquid	gas	liquid	Aerated drinks
9	Gas-gas	gas	gas	A mixture of gases, etc

On the basis of physical states of solvent and solute can be categorized as solid, liquid and gaseous solutions. In solid solutions, solute and solvent are in the solid-state. For example ceramics and polymer blends. In liquid solutions, solid, gas or liquid is mixed in a liquid state. Gaseous solutions are usually homogenous mixtures of gases like air. Depending upon the number of solutions and solutes, it can be classified into dilute and concentrated solutions.

## Different Types of Solutions

Depending upon the dissolution of the solute in the solvent, solutions can be categorized into **supersaturated solution**, **unsaturated** and **saturated solutions**.

- A **supersaturated solution** comprises a large amount of solute at a temperature wherein it will be reduced, as a result the extra solute will crystallize quickly.
- An **unsaturated solution** is a solution in which a solvent is capable of dissolving any more solute at a given temperature.
- A **saturated solution** can be defined as a solution in which a solvent is not capable of dissolving any more solute at a given temperature.

The solutions are of two forms, depending on whether the solvent is water or not.

- **Aqueous solution** – When a solute is dissolved in water the solution is called an aqueous solution. Eg, salt in water, sugar in water and copper sulfate in water.
- **Non-aqueous solution** – When a solute is dissolved in a solvent other than water, it is called a non-aqueous solution. Eg, iodine in carbon tetrachloride, sulphur in carbon disulfide, phosphorus in ethyl alcohol.

Solutions are spoken of as having two components, the solvent and the solute. Another classification of the solution depends on the amount of solute added to the solvent.

- A **dilute solution** contains a small amount of solute in a large amount of solvent.
- A **concentrated solution** contains a large amount of solute dissolved in a small amount of solvent.

## Properties of Solution

Different properties of solutions are as follows:

- It is a homogeneous mixture.
- Its particles are too tiny and have a diameter of less than 1 nm.
- The particles are not visible to naked eyes.
- Particles don't scatter a beam of light passing through it and hence the path of the light is not visible.
- Solutes are inseparable from the mixture and do not sediment. A solution is stable.
- The components of a mixture cannot be separated using **filtration**.

## What is a Mixture?

Mixtures are substances that consist of two or more types of matter. Air, soil, blood, etc. are different examples of mixtures. Based on the nature of the components and their distribution, mixtures are classified as homogeneous and heterogeneous mixtures.

- A mixture that has its components uniformly distributed is known as a **homogeneous mixture**.
- While if the distribution is non-uniform, the mixture is called a **heterogeneous mixture**.

A solution is a homogeneous mixture of two or more components. Let's learn more about solutions, their properties, and how to find a concentration of solutions.

### Homogenous and Heterogeneous Solutions

Homogeneous solutions are solutions with uniform composition and properties throughout the solution. For example a cup of coffee, perfume, cough syrup, a solution of salt or sugar in water, etc.

Heterogeneous solutions are solutions with non-uniform composition and properties throughout the solution. A solution of oil and water, water and chalk powder and solution of water and sand, etc.

Examples

Solute	Solvent	Solution is called as	Example
Gas	Liquid	Foam	Whipped cream
Liquid	Liquid	Emulsion	Mayonnaise
Liquid	Solid	Gel	Gelatin
Solid	Solid	Solid sol	Cranberry glass
Solid	Gas	Solid aerosol	Smoke

## The Concentration of a Solution

The amount of solute in a given solution is called the concentration of a solution. The proportion of solute and solvent in solutions is not even. Depending upon the proportion of solute, a solution can be:

$$\textit{The concentration of solution} = \frac{\textit{Amount of solute}}{\textit{Amount of solution}}$$

Or

$$\textit{The concentration of solution} = \frac{\textit{Amount of solute}}{\textit{Amount of solvent}}$$

## What determines properties of solutions?

It can be represented in a number of ways. Colligative characteristics of a solution rely on the total number of dissolved particulates in solution, not on their chemical identity. Vapor pressure, boiling point, freezing point, and osmotic pressure are all colligative qualities.

## What are the 3 types of solutions?

Solid solution, Liquid solution, Gaseous solution.

## Which component in a solution that has the largest quantity?

A solution is a mixture of two or more components that is homogenous. The solvent is the material that is present in the maximum amount, whereas the solute is the substance that is present in the least amount.

## What are the two classification of solutions?

There are two types of solutions based on if the solvent is water or not. Aqueous solutions are those where the solvent is water. Sugar in water, carbon dioxide in water, etc. are examples. Non-Aqueous Solutions do not use water as a solvent.

## Why concentrated solution should not be heated for a long time?

The concentrated solution is more powerful than regular solutions. If they've been heated for a long period, there's a potential they'll become more powerful and concentrated, making them more difficult to handle.

# Acid and Base Balance and Imbalance

# pH Review

- $\text{pH} = -\log [\text{H}^+]$
- $\text{H}^+$  is really a proton
- Range is from 0 - 14
- If  $[\text{H}^+]$  is high, the solution is acidic;  $\text{pH} < 7$
- If  $[\text{H}^+]$  is low, the solution is basic or alkaline ;  $\text{pH} > 7$

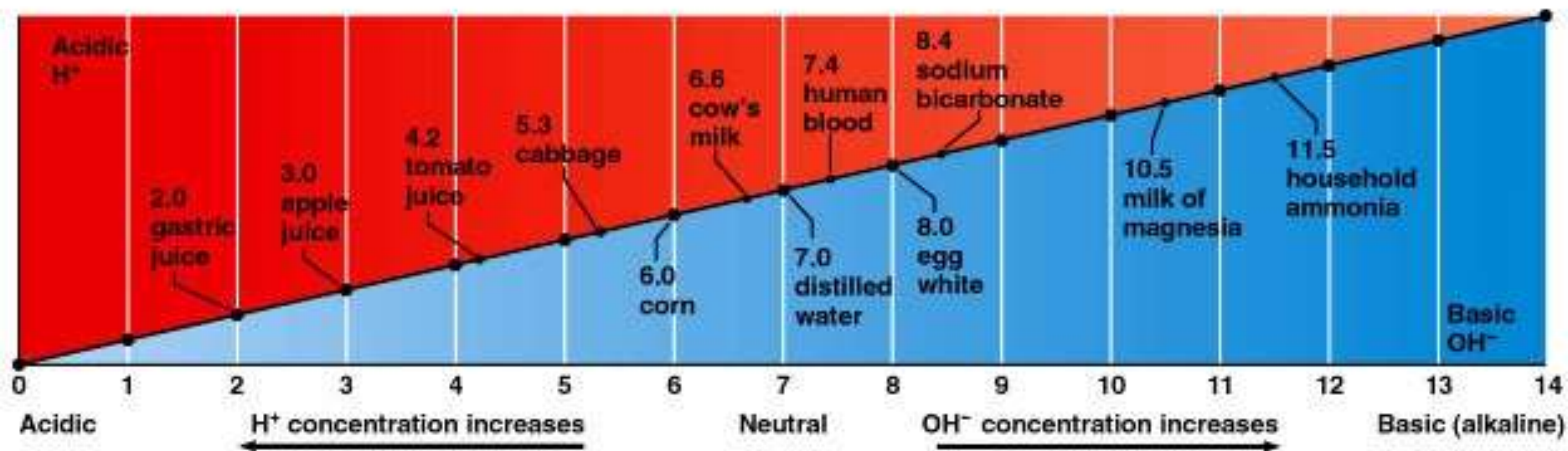


table 2.5 Hydrogen Ion Concentrations and pH		
Grams of H <sup>+</sup> per Liter	pH	
0.0000000000000001	14	↑ Increasingly basic
0.000000000000001	13	
0.00000000000001	12	
0.0000000000001	11	
0.000000000001	10	
0.0000000001	9	Neutral—neither acidic nor basic
0.000000001	8	
0.00000001	7	
0.0000001	6	
0.000001	5	
0.0001	4	↓ Increasingly acidic
0.001	3	
0.01	2	
0.1	1	
1.0	0	



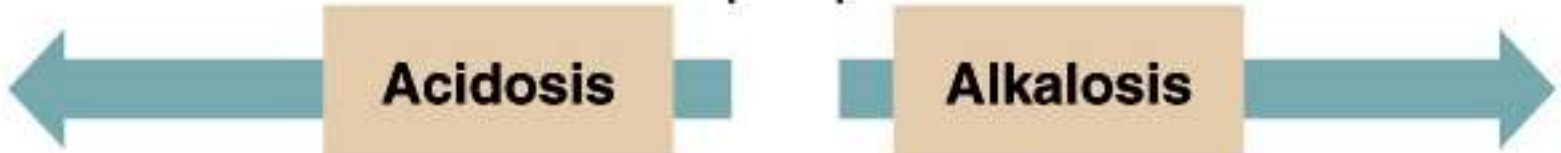
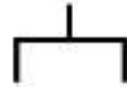
- Acids are  $H^+$  donors.
- Bases are  $H^+$  acceptors, or give up  $OH^-$  in solution.
- Acids and bases can be:
  - Strong – dissociate completely in solution
    - $HCl$ ,  $NaOH$
  - Weak – dissociate only partially in solution
    - Lactic acid, carbonic acid

# The Body and pH

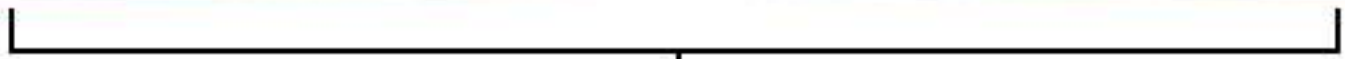
- Homeostasis of pH is tightly controlled
- Extracellular fluid = 7.4
- Blood = 7.35 – 7.45
- < 6.8 or > 8.0 death occurs
- Acidosis (acidemia) below 7.35
- Alkalosis (alkalemia) above 7.45

# pH of arterial blood

Normal pH range



pH scale



Survival range

# Small changes in pH can produce major disturbances

- Most enzymes function only with narrow pH ranges
- Acid-base balance can also affect electrolytes ( $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Cl}^-$ )
- Can also affect hormones

# The body produces more acids than bases

- Acids take in with foods
- Acids produced by metabolism of lipids and proteins
- Cellular metabolism produces  $\text{CO}_2$ .
- $\text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{H}^+ + \text{HCO}_3^-$

# Control of Acids

## 1. Buffer systems

Take up  $H^+$  or release  $H^+$  as conditions change

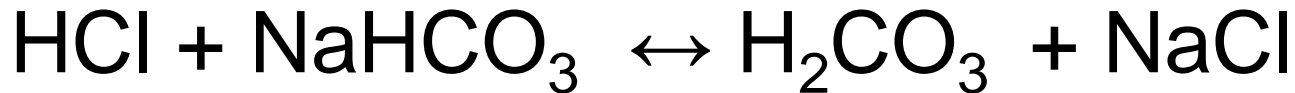
Buffer pairs – weak acid and a base

Exchange a strong acid or base for a weak one

Results in a much smaller pH change

# Bicarbonate buffer

- Sodium Bicarbonate ( $\text{NaHCO}_3$ ) and carbonic acid ( $\text{H}_2\text{CO}_3$ )
- Maintain a 20:1 ratio :  $\text{HCO}_3^-$  :  $\text{H}_2\text{CO}_3$



# Phosphate buffer

- Major intracellular buffer
- $\text{H}^+ + \text{HPO}_4^{2-} \leftrightarrow \text{H}_2\text{PO}_4^-$
- $\text{OH}^- + \text{H}_2\text{PO}_4^- \leftrightarrow \text{H}_2\text{O} + \text{HPO}_4^{2-}$



# Protein Buffers

- Includes hemoglobin, work in blood and ISF
- Carboxyl group gives up  $H^+$
- Amino Group accepts  $H^+$
- Side chains that can buffer  $H^+$  are present on 27 amino acids.

## 2. Respiratory mechanisms

- Exhalation of carbon dioxide
- Powerful, but only works with **volatile acids**
- Doesn't affect **fixed acids** like lactic acid
- $\text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{H}^+ + \text{HCO}_3^-$
- Body pH can be adjusted by changing rate and depth of breathing

# 3. Kidney excretion

- Can eliminate large amounts of acid
- Can also excrete base
- Can conserve and produce bicarb ions
- Most effective regulator of pH
- If kidneys fail, pH balance fails

# Rates of correction

- Buffers function almost instantaneously
- Respiratory mechanisms take several minutes to hours
- Renal mechanisms may take several hours to days

**First line of  
defense against  
pH shift**

**Chemical  
buffer system**

**Bicarbonate  
buffer system**

**Phosphate  
buffer system**

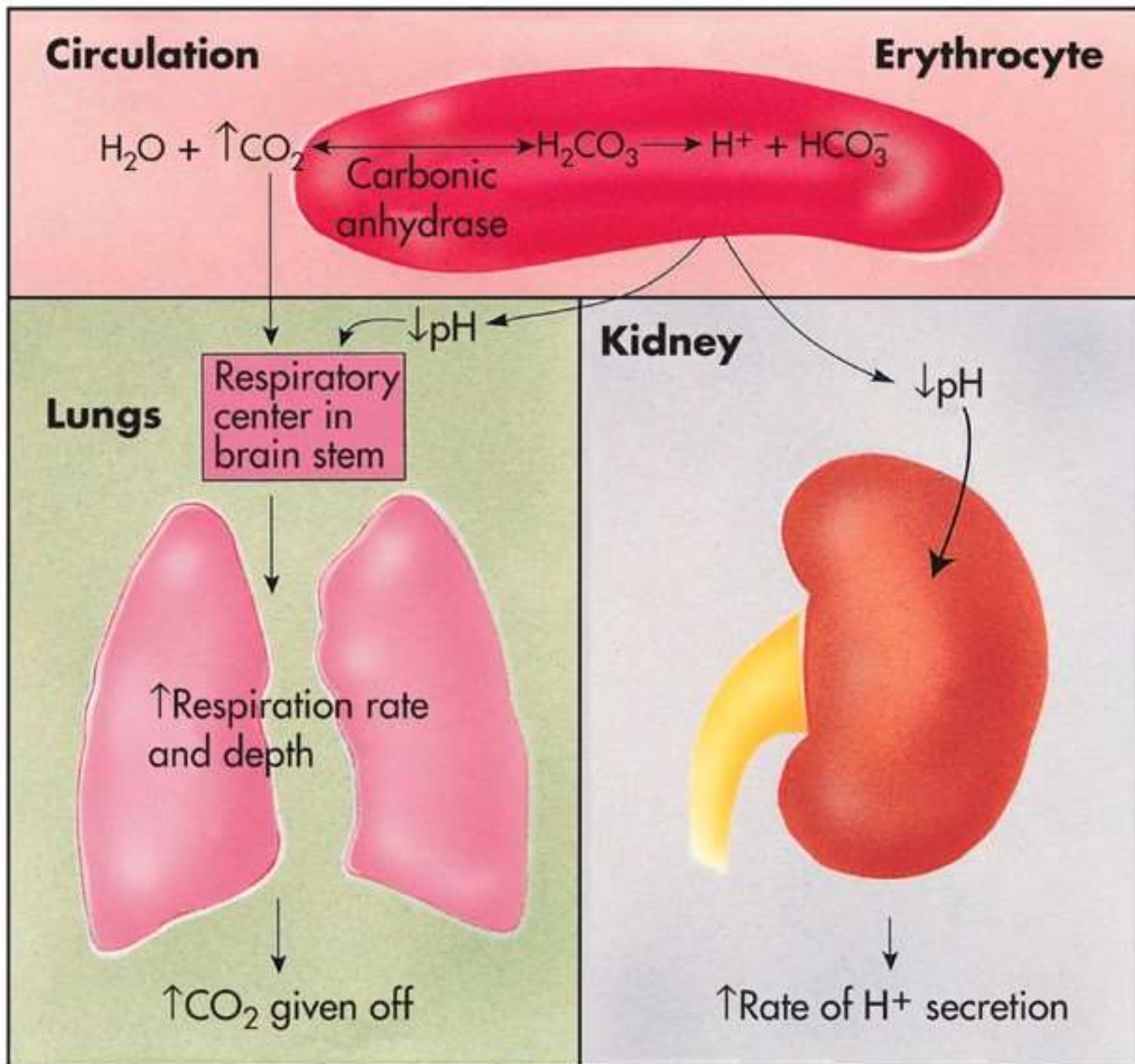
**Protein  
buffer system**

**Second line of  
defense against  
pH shift**

**Physiological  
buffers**

**Respiratory  
mechanism  
(CO<sub>2</sub> excretion)**

**Renal  
mechanism  
(H<sup>+</sup> excretion)**



From Thibodeau GA, Patton KT: *Anatomy & physiology*, ed 5, St Louis, 2003, Mosby.

Mosby items and derived items copyright © 2004, 2000 by Mosby, Inc.

# Acid-Base Imbalances

- $\text{pH} < 7.35$  acidosis
- $\text{pH} > 7.45$  alkalosis
- The body response to acid-base imbalance is called **compensation**
- May be **complete** if brought back within normal limits
- **Partial compensation** if range is still outside norms.

# Compensation

- If underlying problem is metabolic, hyperventilation or hypoventilation can help : **respiratory compensation.**
- If problem is respiratory, renal mechanisms can bring about **metabolic compensation.**

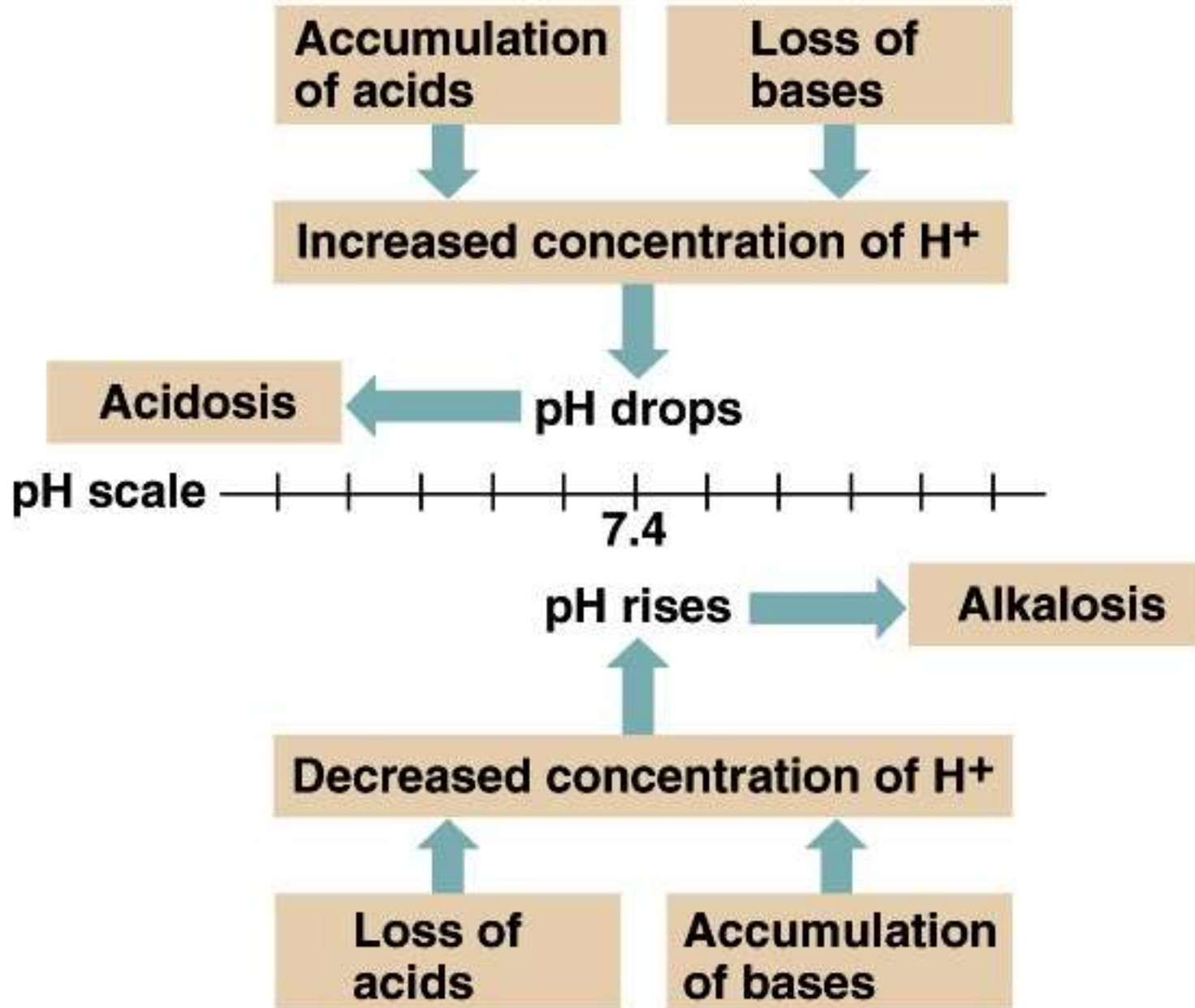


# Acidosis

- Principal effect of acidosis is depression of the CNS through ↓ in synaptic transmission.
- Generalized weakness
- Deranged CNS function the greatest threat
- Severe acidosis causes
  - Disorientation
  - coma
  - death

# Alkalosis

- Alkalosis causes over excitability of the central and peripheral nervous systems.
- Numbness
- Lightheadedness
- It can cause :
  - Nervousness
  - muscle spasms or tetany
  - Convulsions
  - Loss of consciousness
  - Death



# Respiratory Acidosis

- **Carbonic acid excess** caused by blood levels of CO<sub>2</sub> above 45 mm Hg.
- **Hypercapnia** – high levels of CO<sub>2</sub> in blood
- Chronic conditions:
  - Depression of respiratory center in brain that controls breathing rate – drugs or head trauma
  - Paralysis of respiratory or chest muscles
  - Emphysema

# Respiratory Acidosis

- Acute conditons:
  - Adult Respiratory Distress Syndrome
  - Pulmonary edema
  - Pneumothorax

# Compensation for Respiratory Acidosis

- Kidneys eliminate hydrogen ion and retain bicarbonate ion

# Signs and Symptoms of Respiratory Acidosis

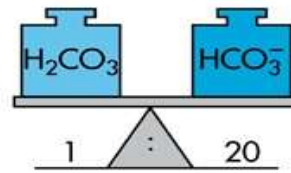
- Breathlessness
- Restlessness
- Lethargy and disorientation
- Tremors, convulsions, coma
- Respiratory rate rapid, then gradually depressed
- Skin warm and flushed due to vasodilation caused by excess CO<sub>2</sub>

# Treatment of Respiratory Acidosis

- Restore ventilation
- IV lactate solution
- Treat underlying dysfunction or disease

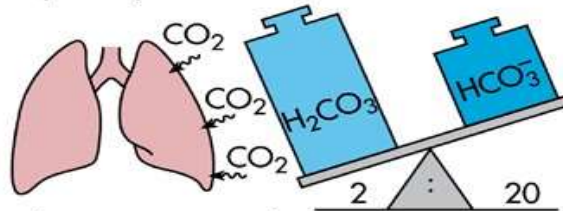


a) Metabolic balance before onset of acidosis



$H_2CO_3$  : Carbonic acid  
 $HCO_3^-$  : Bicarbonate ion  
 ( $Na^+ \cdot HCO_3^-$ )  
 ( $K^+ \cdot HCO_3^-$ )  
 ( $Mg^{++} \cdot HCO_3^-$ )  
 ( $Ca^{++} \cdot HCO_3^-$ )

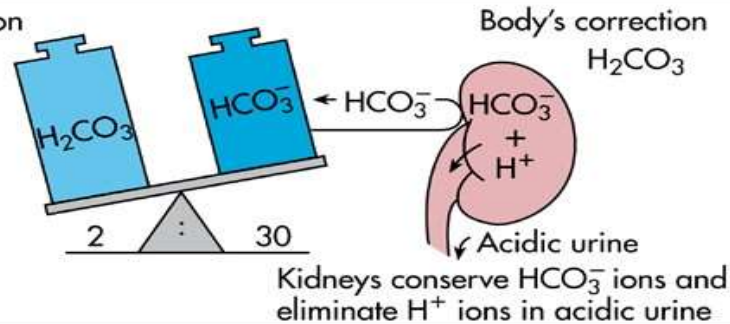
b) Respiratory acidosis



Primary change  
 pH — decreases  
 $PCO_2$  — increases  
 $HCO_3^-$  — no change

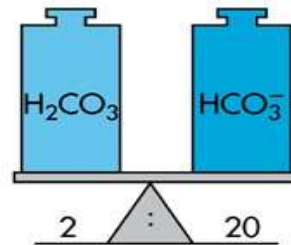
Breathing is suppressed, holding  $CO_2$  in body

c) Body's compensation



Kidneys conserve  $HCO_3^-$  ions and eliminate  $H^+$  ions in acidic urine

d) Therapy required to restore metabolic balance



Lactate solution used in therapy is converted to bicarbonate ions in the liver

# Respiratory Alkalosis

- Carbonic acid deficit
- $p\text{CO}_2$  less than 35 mm Hg (hypocapnea)
- Most common acid-base imbalance
- Primary cause is hyperventilation

# Respiratory Alkalosis

- Conditions that stimulate respiratory center:
  - Oxygen deficiency at high altitudes
  - Pulmonary disease and Congestive heart failure – caused by hypoxia
  - Acute anxiety
  - Fever, anemia
  - Early salicylate intoxication
  - Cirrhosis
  - Gram-negative sepsis

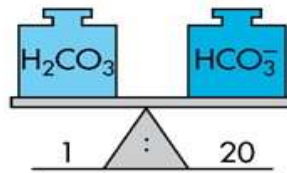
# Compensation of Respiratory Alkalosis

- Kidneys conserve hydrogen ion
- Excrete bicarbonate ion

# Treatment of Respiratory Alkalosis

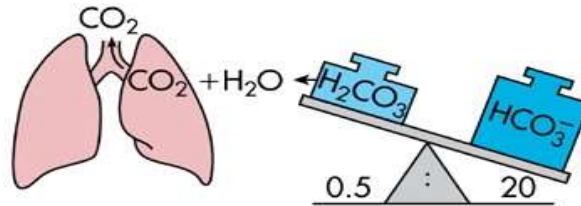
- Treat underlying cause
- Breathe into a paper bag
- IV Chloride containing solution –  $\text{Cl}^-$  ions replace lost bicarbonate ions

a) Metabolic balance before onset of alkalosis



$H_2CO_3$  : Carbonic acid  
 $HCO_3^-$  : Bicarbonate ion  
 ( $Na^+ \bullet HCO_3^-$ )  
 ( $K^+ \bullet HCO_3^-$ )  
 ( $Mg^{++} \bullet HCO_3^-$ )  
 ( $Ca^{++} \bullet HCO_3^-$ )

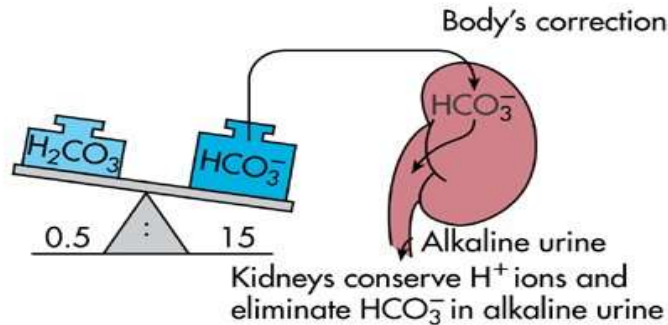
b) Respiratory alkalosis



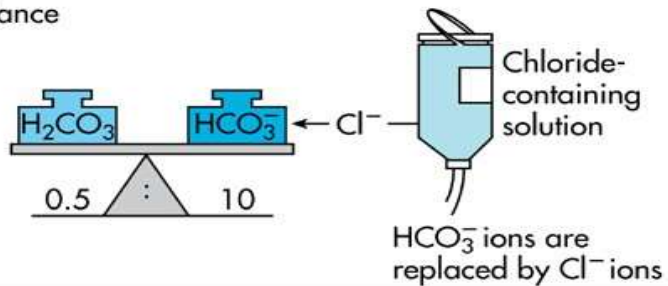
Primary change  
 pH — increases  
 $PCO_2$  — decreases  
 $HCO_3^-$  — no change

Hyperactive breathing  
 "blows off"  $CO_2$

c) Body's compensation



d) Therapy required to restore metabolic balance



# Metabolic Acidosis

- **Bicarbonate deficit** - blood concentrations of bicarb drop below 22mEq/L
- **Causes:**
  - **Loss of bicarbonate through diarrhea or renal dysfunction**
  - **Accumulation of acids (lactic acid or ketones)**
  - **Failure of kidneys to excrete H<sup>+</sup>**

# Symptoms of Metabolic Acidosis

- Headache, lethargy
- Nausea, vomiting, diarrhea
- Coma
- Death



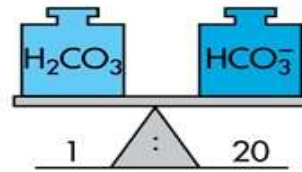
# Compensation for Metabolic Acidosis

- Increased ventilation
- Renal excretion of hydrogen ions if possible
- $K^+$  exchanges with excess  $H^+$  in ECF
- (  $H^+$  into cells,  $K^+$  out of cells)

# Treatment of Metabolic Acidosis

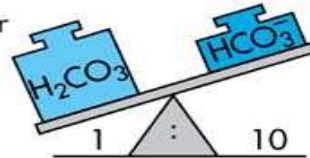
- IV lactate solution

a) Metabolic balance before onset of acidosis



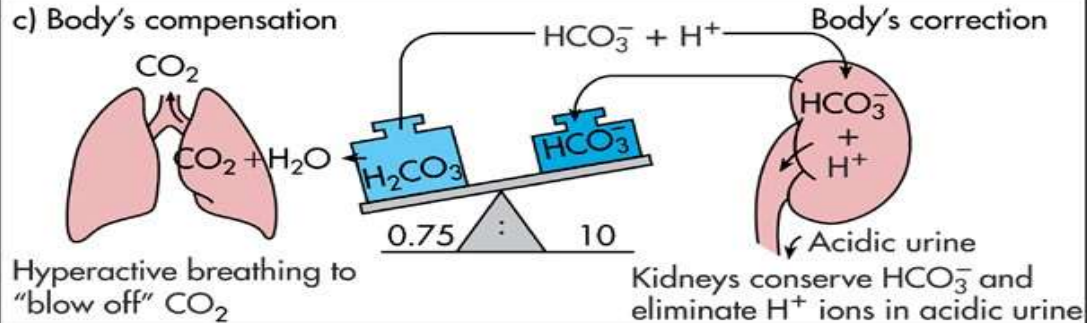
$H_2CO_3$  : Carbonic acid  
 $HCO_3^-$  : Bicarbonate ion  
 ( $Na^+ \cdot HCO_3^-$ )  
 ( $K^+ \cdot HCO_3^-$ )  
 ( $Mg^{++} \cdot HCO_3^-$ )  
 ( $Ca^{++} \cdot HCO_3^-$ )

b) Metabolic acidosis  
 $HCO_3^-$  decreases because of excess presence of ketones, chloride, or organic acid ions

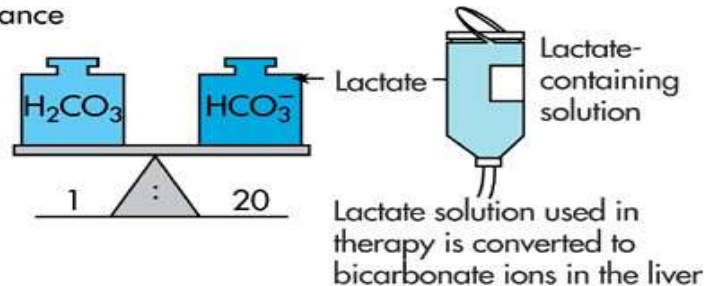


Primary change  
 pH — decreases  
 $P_{CO_2}$  — no change  
 $HCO_3^-$  — decreases

c) Body's compensation



d) Therapy required to restore metabolic balance



# Metabolic Alkalosis

- **Bicarbonate excess** - concentration in blood is greater than 26 mEq/L
- Causes:
  - Excess vomiting = loss of stomach acid
  - Excessive use of alkaline drugs
  - Certain diuretics
  - Endocrine disorders
  - Heavy ingestion of antacids
  - Severe dehydration

# Compensation for Metabolic Alkalosis

- Alkalosis most commonly occurs with renal dysfunction, so can't count on kidneys
- Respiratory compensation difficult – hypoventilation limited by hypoxia

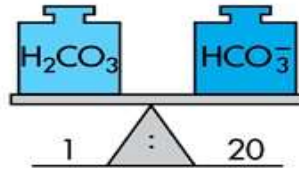
# Symptoms of Metabolic Alkalosis

- Respiration slow and shallow
- Hyperactive reflexes ; tetany
- Often related to depletion of electrolytes
- Atrial tachycardia
- Dysrhythmias

# Treatment of Metabolic Alkalosis

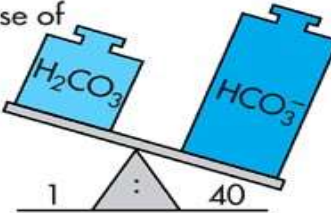
- Electrolytes to replace those lost
- IV chloride containing solution
- Treat underlying disorder

a) Metabolic balance before onset of alkalosis



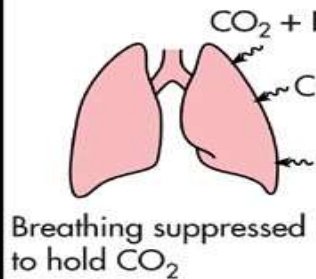
$\text{H}_2\text{CO}_3$  : Carbonic acid  
 $\text{HCO}_3^-$  : Bicarbonate ion  
 ( $\text{Na}^+ \bullet \text{HCO}_3^-$ )  
 ( $\text{K}^+ \bullet \text{HCO}_3^-$ )  
 ( $\text{Mg}^{++} \bullet \text{HCO}_3^-$ )  
 ( $\text{Ca}^{++} \bullet \text{HCO}_3^-$ )

b) Metabolic alkalosis  
 $\text{HCO}_3^-$  increases because of loss of chloride ions or excess ingestion of sodium bicarbonate

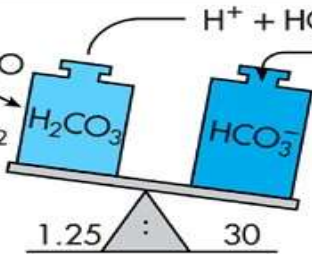


Primary change  
 pH — increases  
 $\text{PCO}_2$  — no change  
 $\text{HCO}_3^-$  — increases

c) Body's compensation

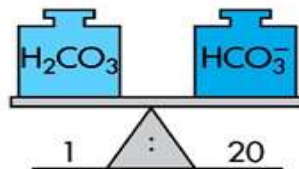


Breathing suppressed to hold  $\text{CO}_2$



Body's correction  
 $\text{H}^+ + \text{HCO}_3^-$   
  
 Alkaline urine  
 Kidneys conserve  $\text{H}^+$  ions and eliminate  $\text{HCO}_3^-$  in alkaline urine

d) Therapy required to restore metabolic balance



Chloride-containing solution  
 $\text{Cl}^-$   
 $\text{HCO}_3^-$  ions replaced by  $\text{Cl}^-$  ions



# Diagnosis of Acid-Base Imbalances

1. Note whether the pH is low (acidosis) or high (alkalosis)
2. Decide which value,  $p\text{CO}_2$  or  $\text{HCO}_3^-$ , is outside the normal range **and** could be the **cause** of the problem. If the cause is a change in  $p\text{CO}_2$ , the problem is respiratory. If the cause is  $\text{HCO}_3^-$  the problem is metabolic.

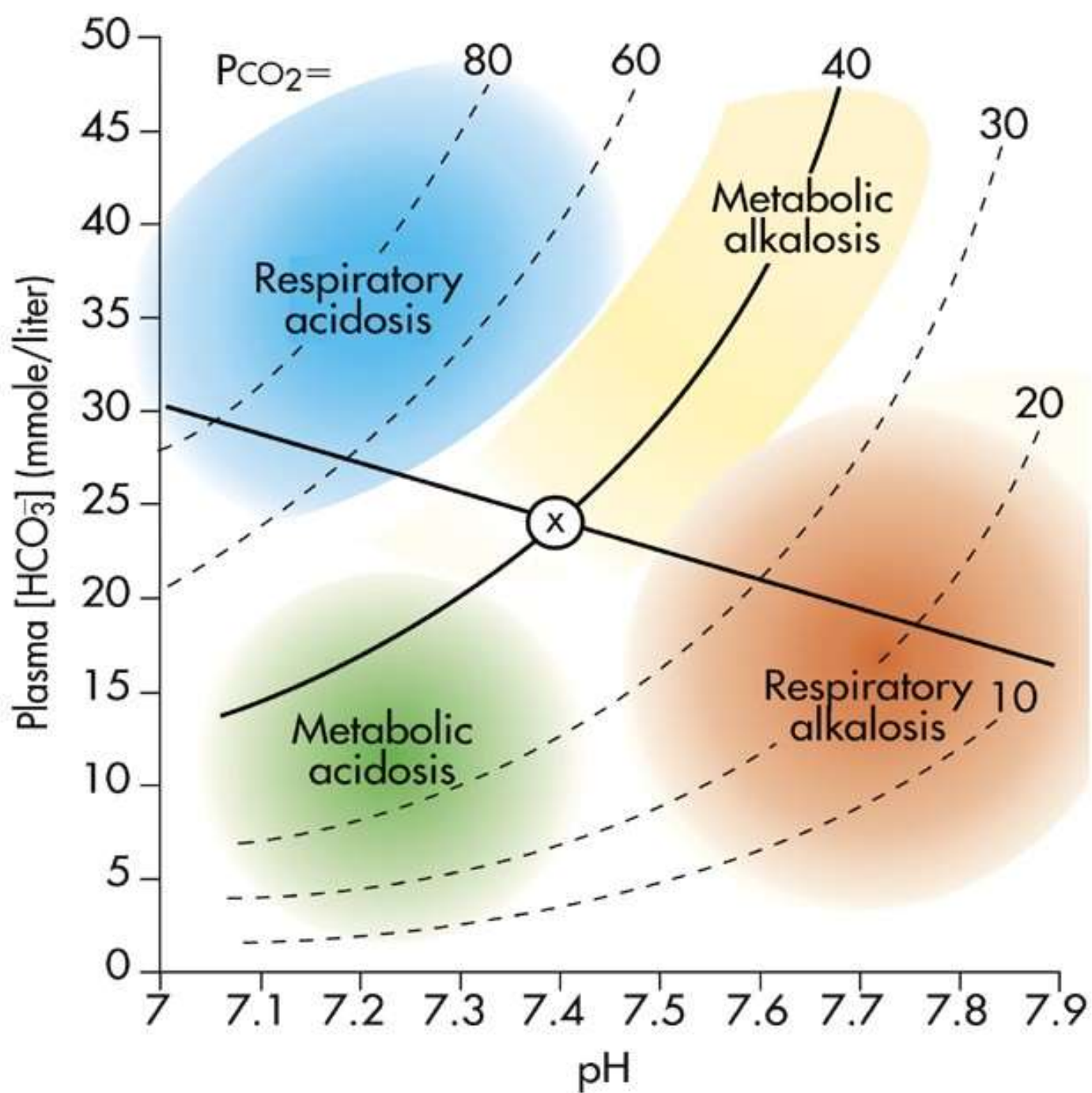
3. Look at the value that doesn't correspond to the observed pH change. If it is inside the normal range, there is no compensation occurring. If it is outside the normal range, the body is partially compensating for the problem.

# Example

- A patient is in intensive care because he suffered a severe myocardial infarction 3 days ago. The lab reports the following values from an arterial blood sample:
  - pH 7.3
  - $\text{HCO}_3^- = 20 \text{ mEq / L ( 22 - 26)}$
  - $\text{pCO}_2 = 32 \text{ mm Hg ( 35 - 45)}$

# Diagnosis

- Metabolic acidosis
- With compensation



## Carbohydrates

### Introduction:

Carbohydrates which contain the elements carbon, hydrogen, and oxygen are a class of organic compounds that includes sugars, starches, and cellulose. Originally all known carbohydrates were considered to be hydrates because they contain hydrogen and oxygen in the ratio of 2:1 as in water. So that the empirical formula is  $(\text{CH}_2\text{O})_n$ ; but there are some exception to this rule. The formula for glucose,  $\text{C}_6\text{H}_{12}\text{O}_6$ , was written as  $\text{C}_6(\text{H}_2\text{O})_6$ . Likewise sucrose,  $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ , was written as  $\text{C}_{12}(\text{H}_2\text{O})_{11}$ . Carbohydrates made in the plant by reaction of photosynthesis. Many plants contain quantities of carbohydrates as a food reserve and these are useful source of carbohydrates in the diet for man and other animals. After ingestion, they are broken down to their constituent monosaccharide, which can then be oxidized to carbon dioxide and water with the release of energy, or stored in the form of the polysaccharide glycogen in the liver and muscle of animals.

Classification: carbohydrates can be divided into:

1. Monosacchrides. [glucose, fructose, galactose]
2. Disaccharides. [sucrose, maltose, lactose]
3. Polysaccharides. [starch, cellulose, glycogen]

**Monosaccharides:** are simple sugar, colorless crystalline substances, soluble in ethanol, and sweet taste.

### **Qualitative Analysis of Carbohydrates**

1. **Solubility:** The monosaccharides and oligosaccharides are readily soluble in water due to polar hydroxyl groups, which forms H-bonds with water. The polysaccharides owing to their large molecular weight, however, make translucent colloidal solutions.

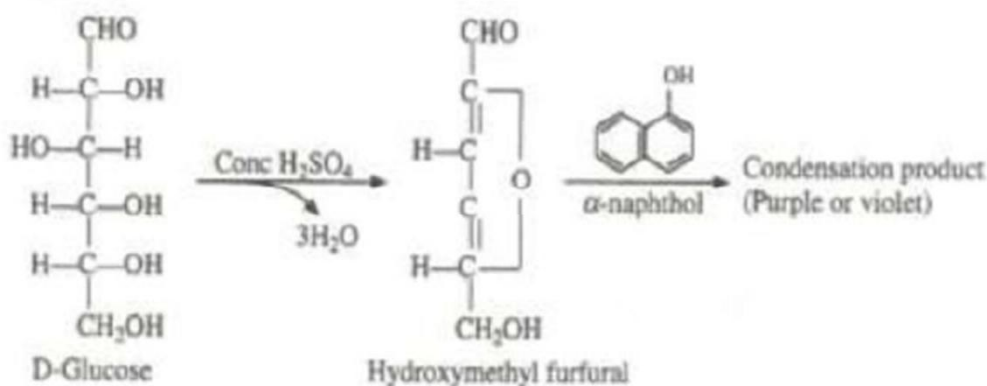
2. Qualitative tests for Carbohydrates: While analyzing a sample containing a mixture of carbohydrates, particularly the sugars, several difficulties are encountered in their qualitative as well as quantitative analysis. These difficulties are attributed to their structural and chemical similarity and also with respect to their stereoisomerism. Therefore, during biochemical investigation it becomes necessary to establish whether a given sample contains carbohydrates or not. Several rapid tests are available to establish the presence or absence of a sugar or a carbohydrate in a sample. These tests are based on specific colour reactions typical for their group. In the laboratory, it is advisable to perform these tests with the individual rather than mixture of sugars. The sensitivity of these tests can be confirmed by using sugar solutions of different concentrations (0.1- 1%).

**A. General tests for carbohydrates:** The most commonly used tests to detect the presence of carbohydrates in a solution are:

**a) Molish 's test:**

It is a group test for all carbohydrates, whether free or in combined form. Despite its limitations, it is routinely used to detect the presence of carbohydrates.

Principle: The reaction is based on the fact that concentrated  $H_2SO_4$  catalyses the dehydration of sugars to form furfural (from pentoses) or hydroxymethyl furfural (from hexoses). These furfurals then condense with sulfonated alpha-naphthol to give a purple or violet coloured product. Polysaccharides and glycoproteins also give a +ve reaction. In the event of the carbohydrate being a poly- or disaccharide, the acid first hydrolyses it into component monosaccharides, which then get dehydrated to form furfural or its derivatives.



Reagents:

- i) Conc.H<sub>2</sub>SO<sub>4</sub>
- ii) Molisch's reagent α-naphthol 5%(w/v) in 95% ethanol.

Procedure: Take 1-2 mL of unknown solution and add 2-3 drops of Molisch's reagent and mix the contents. Incline the tube and carefully pour 1-2 mL of conc.H<sub>2</sub>SO<sub>4</sub> down the side of tube so that the acid forms a layer beneath the aqueous solution. The formation of a purple or violet ring or zone at the junction of two layers indicates the presence of carbohydrates.

Precautions:

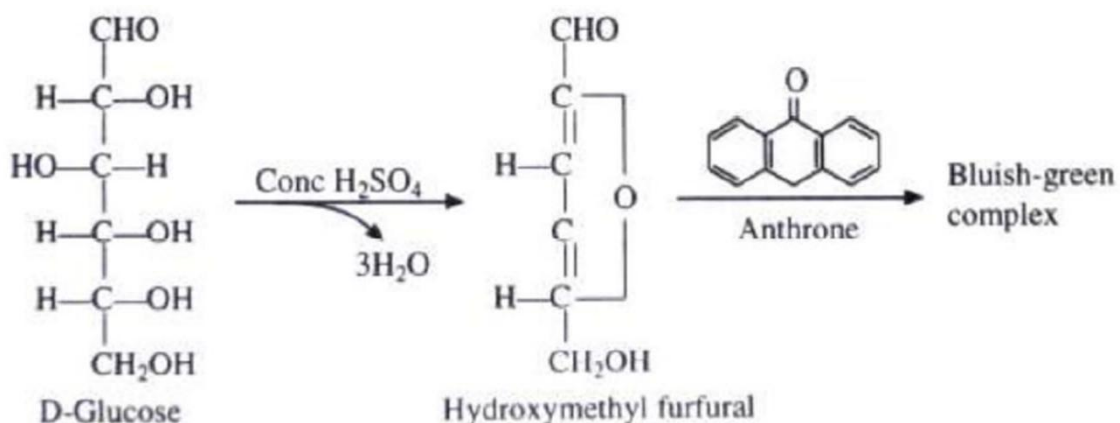
- i) Alpha-naphthol solution is unstable and should be prepared fresh.
- ii) The conc.H<sub>2</sub>SO<sub>4</sub> should be added carefully along the sides of the test tube causing minimal disturbance to the contents of the tube.

Limitations: - In addition to carbohydrates, furfurals as such, some organic acids, aldehydes and ketones also give this test. Secondly, a concentrated sugar solution may give a red colour instead of purple owing to charring action of acid.

#### **b) Anthrone test:**

Principle:- Anthrone reaction is another general test for carbohydrates. Its principle is same as that for molisch's test except that the furfurals and hydroxymethyl furfurals give condensation products with anthrone that are bluish green in colour.





Reagents:

i) Anthrone reagent: 0.2%(w/v) solution in conc.H<sub>2</sub>SO<sub>4</sub>.

Procedure: Add about 2 mL of Anthrone reagent to about 0.5-1mL of the test solution in a test tube and mix thoroughly. Observe whether the colour changes to bluish green. If not, then examine the tubes again after keeping them in boiling water bath for ten minutes. A blue green colour indicates positive test.

### B. Specific tests for carbohydrates:

**a) Iodine test for polysaccharides:** This test is performed to distinguish polysaccharides from mono- and disaccharides.

**Principle:** Iodine forms coloured adsorption complexes with different polysaccharides. These complexes are formed due to the adsorption of iodine on the polysaccharide chains.

The intensity of the colour depends on the length of the unbranched or linear chain available for the complex formation. Thus, amylose, the unbranched helical component of starch gives a deep blue colour and amylopectin, the branched component gives red colour because the chains do not coil effectively. Glycogen, which is also highly branched, gives red colour with iodine. This test is conducted in acidic or neutral solutions.

Reagents:

i) Iodine solution: Prepare 2%(w/v) solution of KI in water to which add a few crystals of iodine until the solution assume a deep yellow colour.

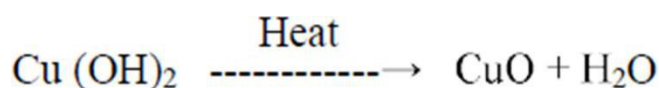
ii) Starch solution: Dissolve 1g starch in about 10-20mL boiling water and make the volume to 100mL with saturated sodium chloride solution.

Procedure: Take 2-3 mL of the test solution in a test tube and add 1-2 drops of dil.HCl. Mix and then add 1-2 drops of iodine solution. Mix and observe the colour change. Heat the tube and observe the colour again. Blue colour disappears on heating and reappears on cooling.

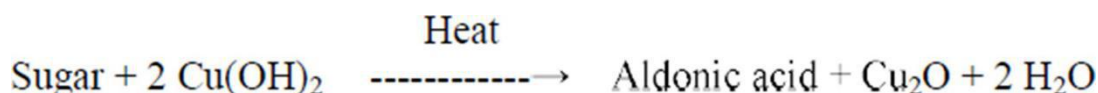
**b) Tests based on reducing property of carbohydrates:** Sugars possessing a free, or potentially free, aldehyde or ketone group act as reducing agents and this fact becomes the basis of the tests performed for distinguishing them from the non-reducing sugars.

Such

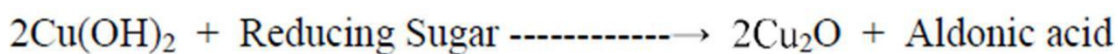
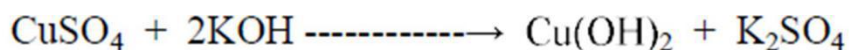
sugars have the property of readily reducing alkaline solutions of the metals like copper, bismuth, mercury, iron and silver. The aldo sugars are oxidized to the corresponding aldonic acids whereas the keto sugars give rise to shorter chain acids. If the alkaline copper solution is heated in the absence of reducing sugar, it forms black precipitate of cupric oxide:



In the presence of a reducing sugar, however, the alkaline solution of copper is reduced to insoluble yellow or red cuprous oxide:



**i) Fehling's test:** Rochelle salt acts as chelating agent in this reaction:



Reagents:

i) Fehling's solution A: Dissolve 69.38 g of Copper sulfate in DW and make the volume to 1 L.

ii) Fehling's solution B: Dissolve 250 g NaOH in DW, add 346 g of Sodium Potassium Tartrate and make the volume up to 1 L.

Mix equal volumes of A & B solutions just before use because mixing causes deterioration with time.

Procedure: Add 1ml of Fehling's reagent to 1ml of the test solution. Mix thoroughly and Place the test tubes in boiling water bath. Formation of yellow or red precipitates of Cuprous Oxide indicates the presence of reducing sugar.

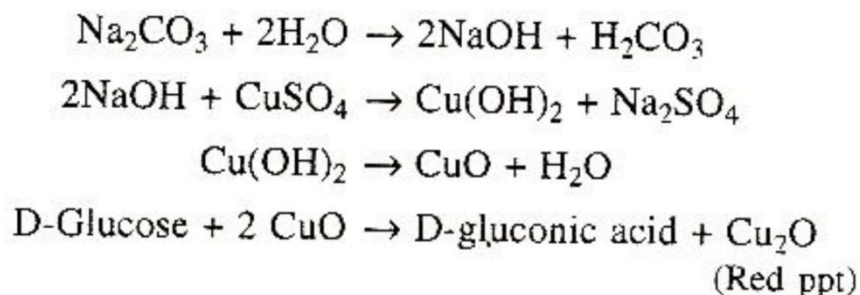
Note:

i) In case of mild reduction, leave the solution to stand for 10-15 minutes, then decant the supernatant. A small amount of red or yellow precipitates may then be seen adhering to the inner side of the tube.

ii) Fehling's test is performed only alkaline solution.

iii) Cuprous Oxide is dissolved by ammonia. Hence it is not possible to detect small quantities of reducing sugars in fluids saturated with ammonium salts e.g. urine.

**ii) Benedict's Test:** Benedict modified the Fehling's solution to produce an improved single reagent which quite stable. Sodium Citrate functions as a chelating agent. It is very sensitive and even small quantities of reducing sugars(0.1%) yield enough precipitates.



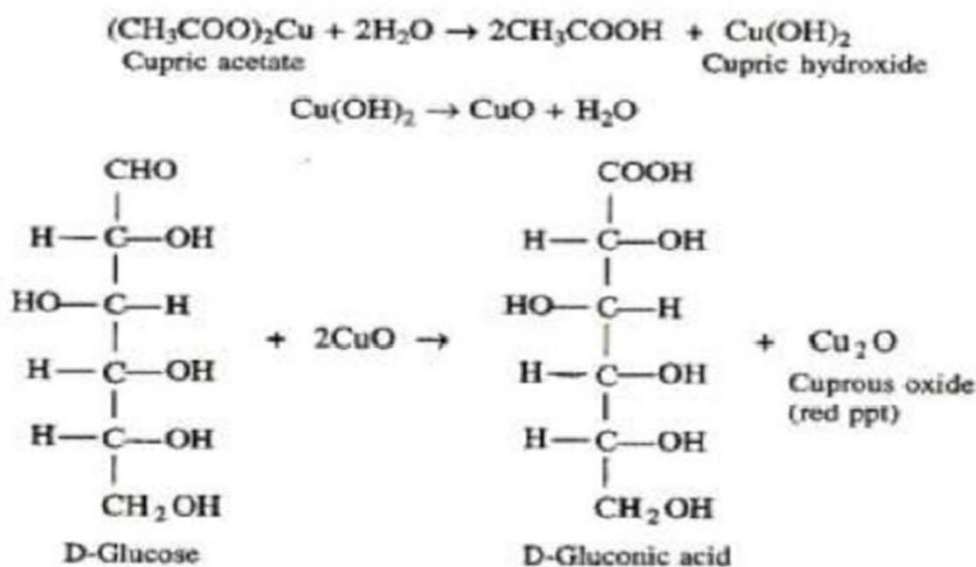
Reagents: Benedict's qualitative reagent: Dissolve 173g Sod. Citrate and 100g anhydrous Sod. Carbonate in about 800mL water by gently heating the contents. Then in a separate beaker dissolve 17.3g Copper Sulfate in about 100mL DW. Pour this solution slowly, with constant stirring into the Carbonate-Citrate mixture and make upto 1 L with DW. Procedure: Add 0.5-1 ml of the test solution to about 2ml of Benedict's reagent. Keep the test tube in boiling water bath. Observe the formation of green, orange, yellow or red precipitates which indicates the presence of reducing sugar in the given solution.

**Note: i)** This test is especially suitable for the detection of reducing sugar in urine because it is more specific than Fehling's test which is also positive for non-reducing substances such as urates present in urine.

**ii)** This is a semi-quantitative test.

**iii) Barfoed's test:** This test is performed to distinguish between a reducing mono- and disaccharide. Monosaccharides are more reactive reducing agents than disaccharides and thus react in about 1-2 min while the reducing disaccharides take 7-12 min to get hydrolysed in the acidic solution and then react. Thus, the difference in reducing property can be detected.

Reaction:



Reagent: i) Barfoed's: Dissolve 66.5 g of Cupric Acetate in about 900 mL DW. Boil and add 9 mL of Glacial Acetic Acid. Cool and make the volume to 1 L with DW and filter if necessary.

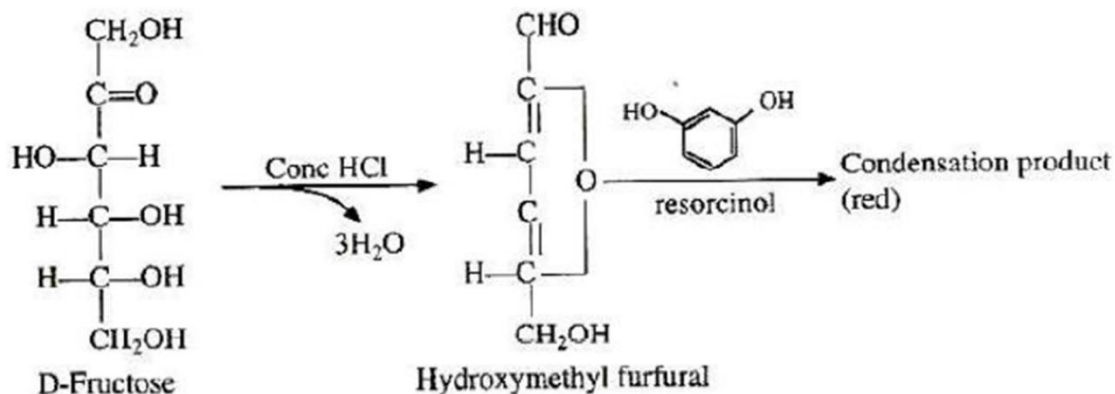
Procedure: Take 2-3 mL of Barfoed's reagent in a test tube and add 1mL of the given test solution. Keep the test tubes in boiling water bath for 1-2 min only. Then allow the tubes to cool down for a while. Thin red precipitates, at the bottom or sides of the tube indicates the presence of a reducing monosaccharide.

**Note: i)** The boiling should not be prolonged beyond 1-2min, otherwise reducing disaccharides also respond to this test.

**ii)** This test does not work in the detection of reducing sugar in urine owing to the presence of chloride ions.

### **c) Seliwanoff's test for keto sugars:**

Principle: This test is a timed colour reaction specific for keto hexoses. Thus it is used to distinguish aldoses from ketoses. In the presence of HCl ketohexoses undergo dehydration to yield 4-hydroxy methyl furfural more rapidly than aldohexoses. Further these furfural derivatives condense with resorcinol to form a red coloured complex.



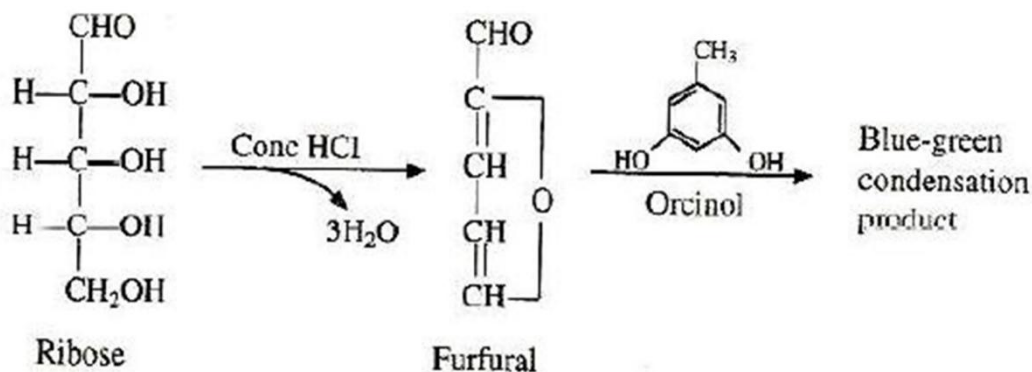
Reagents: i) Seliwanoff's reagent: Dissolve 50 mg resorcinol in 100ml dilute HCl (1:2)  
 Procedure: to about 2 mL of Seliwanoff's reagent add 1 mL of the test solution and warm in a boiling water bath for 1 min. Appearance of a red colour indicates the presence of ketohexose (fructose).

Note: i) Aldohexoses e.g. glucose also react if boiling is prolonged because it is transformed into fructose by the catalytic action of acid.

ii) Sucrose and inulin also give this test because these are hydrolysed by acid to give fructose.

#### **d) Bial's test for pentoses:**

Principle: This test is specific for pentoses and the compounds containing pentoses and thus useful for the determination of pentose sugars. Reaction is due to the formation of furfural in the acid medium which condenses with orcinol in the presence of ferric ions to give a blue green coloured complex.



Reagent: Bial's reagent: Dissolve 1.5 g of orcinol in 100 mL of conc. HCl and add 20-30 drops of 10 % ferric chloride solution to it. Prepare fresh.

Procedure: To about 2 mL of Bial's reagent add 4-5 drops of test solution. Heat in a boiling water bath until bubbles of gas rise to the surface. Formation of green solution and precipitate indicates the presence of a pentose sugar.

### **Hydrolysis of disaccharides and polysaccharides:**

Disaccharides hydrolyze in the presence of an acid to give the individual monosaccharides.

Sucrose + H<sub>2</sub>O + H<sup>+</sup> glucose + fructose

In the laboratory, we use water and acid to hydrolyze starches, which produce smaller saccharides such as maltose. Eventually, the hydrolysis reaction converts maltose to glucose molecule. In the body, enzymes in our saliva and from the pancreas carry out the hydrolysis. Complete hydrolysis produces glucose, which provides about 50% of our nutritional calories. (uses H<sup>+</sup> or amylase in the body as enzymes)

Amylase, amylopectin dextrins maltose many D-glucose

### **Iodine for polysaccharides:**

When iodine (I<sub>2</sub>) is added to amylose, the helical shape of the unbranched polysaccharides traps iodine molecules, producing a deep blue-black complex. Amylopectin, cellulose, and glycogen react with iodine to give red to brown colors. Glycogen produces a reddish-purple color. Mono-saccharides and disaccharides are too small to trap iodine molecules and do not form dark colors with iodine.

Note: several of the tests as the iodine test can be carried out with food products such as cereals, bread.