TVET CERTIFICATE III

General Chemistry

GENAM301

APPLY GENERAL CHEMISTRY

Competence

Credits: 6

Sector: All

Sub-sector: All

learning hours: 60

Module Note Issue date: July, 2020

Purpose statement

This module describes the skills, knowledge and attitudes required to describe the transition metals, perform chemical titration, perform electrochemical cell reactions, and to describe polymerization. At the end of this module, candidates will be able to demonstrate electronic structure of transition metals, and describe its properties; describe types of solutions and apply different titration methods; describe oxidation-reduction reactions in electrochemical cells; describe polymerization process based on different monomers.

Learning units: Describe the essential outcomes of a competence.

Performance criteria: Describe the required performance needed to demonstrate achievement of the learning unit.

By the end of the module, the trainee will be able to:

Elements of competence and performance criteria		**Page No.**
Learning Unit	**Performance Criteria**	
1. Describe the transition metals	1.1: Proper identification of the group of transition metals according to their location on the periodic table	3
	1.2: Proper demonstration of the electronic configuration of each transition metal according to its atomic number (Z)	
	1.3: Effective description of the properties of transition metals based on their electronic configuration.	
2. Perform chemical titration	2.1: Proper identification of the types of solutions based on solutes and solvents	12
	2.2: Accurate description of solubility according to the nature of solution.	
	2.3: Proper application of titration methods according to the procedure	
3. Perform the electrochemical cell reactions	3.1: Proper description of electrochemical cells according to general representation	25
	3.2: Proper description of reduction and oxidation reactions in electrochemical cells according to the component of electrodes.	
	3.3: Accurate demonstration of electrochemical cell reaction and its overall energy based on the electrodes.	
4. Describe polymerization	4.1: Proper identification of organic compounds according to their functional groups.	31
	4.2: Proper identification of types of polymers according to the monomers.	
	4.3: Accurate demonstration of polymerization process according the monomers.	

LU 1: describe the transition metals

LO 1.1: identify the group of transition metal

- **18 groups of elements on the periodic table** (group 1-group 18)
  - ✓ Atomic number (Z)

The number of protons in the nucleus of an atom, which is characteristic of a chemical element and determines its place in the periodic table.

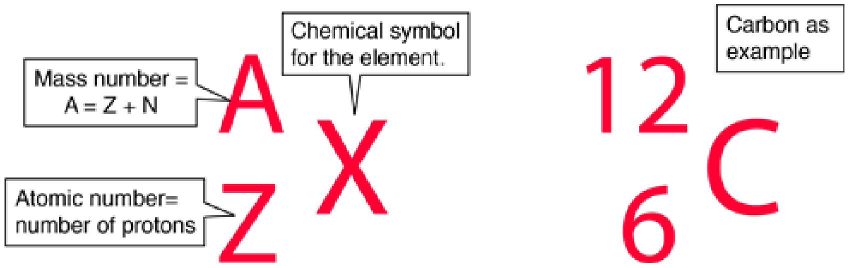
- ✓ Atomic mass (A)

The mass of an atom of a chemical element expressed in atomic mass units. It is approximately equivalent to the number of protons and neutrons in the atom (the mass number) or to the average number allowing for the relative abundances of different isotopes.

- ✓ Symbol

Chemical symbols are abbreviations used in chemistry for chemical elements. Element symbols for chemical elements normally consist of one or two letters from the Latin alphabet and are written with the first letter capitalised.

- ✓ Name



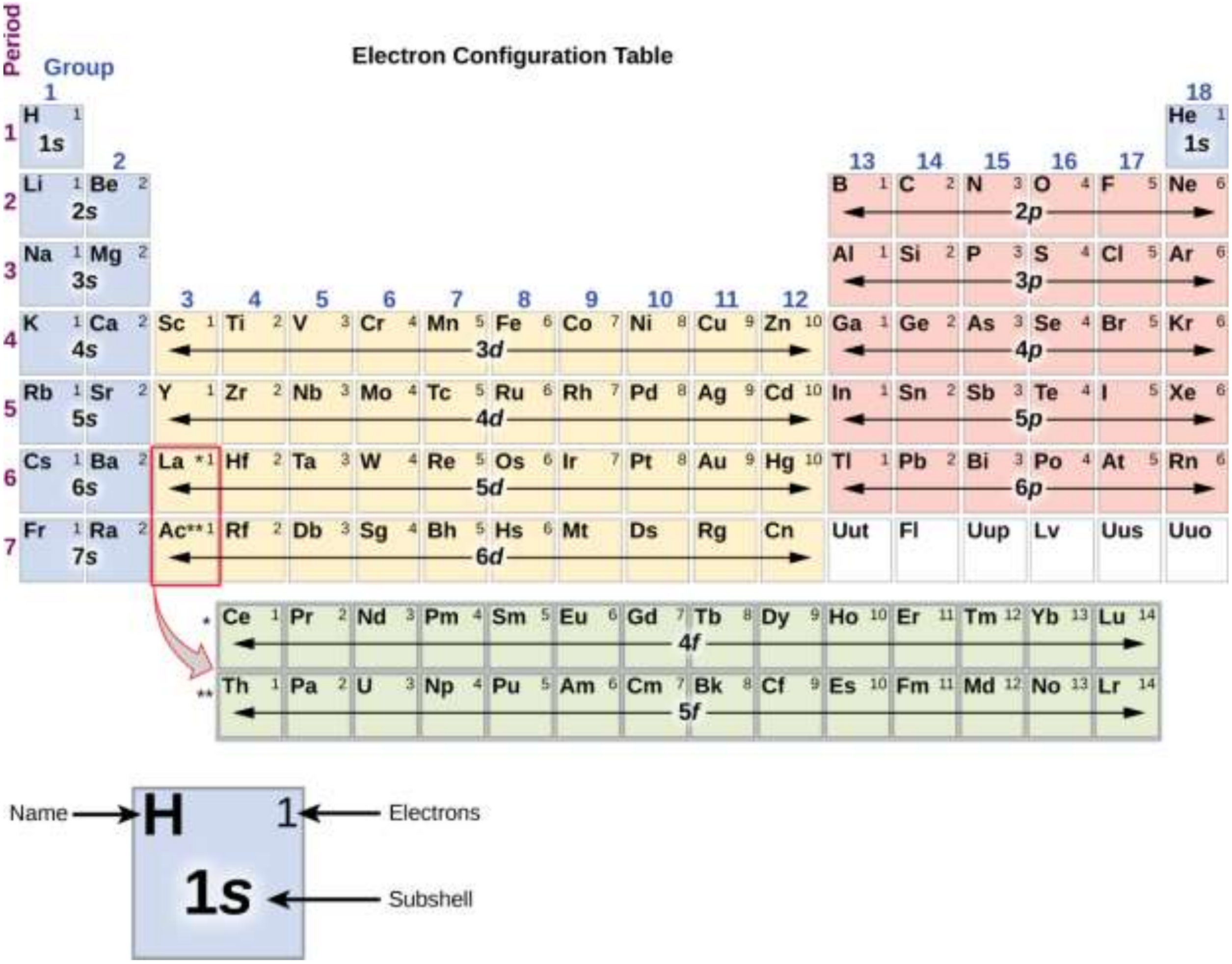
- ✓ Electronic configuration

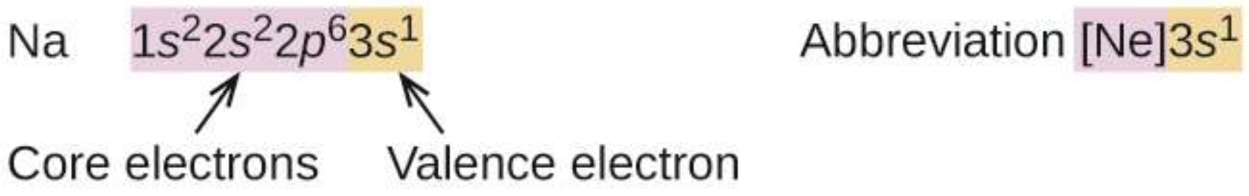
In chemistry, the electron configuration **is the distribution of** electrons **of an** atom **in** atomic orbitals**.** For example, the electron configuration of the neon atom is $1s^2\ 2s^2\ 2p^6$,

- ✓ S,p,d,f orbitals on periodic table.

There are many types of atomic orbital (s, p, d, f, g, h …), but only the first four are occupied in the ground state of an atom.

The electron configuration of an element **describes how electrons are distributed in its atomic orbitals.** Electron configurations of atoms **follow a** standard notation in which all electron-containing atomic subshells (with the number of electrons they hold written in superscript) are placed in a sequence. For example, the electron configuration of sodium is $1s^2 2s^2 2p^6 3s^1$.





- Transition metals groups on the periodic table in d-block:
  - ✓ From group 3 up to group 12

The transition metals are the **largest group** of elements on the periodic table. They got their name because English chemist Charles Bury described a *transition series* of elements in 1921.

The most common definition of a transition metal is the one accepted by the **International Union of Pure and Applied Chemistry** (IUPAC). A transition metal is an element with a partially-filled *d* subshell or the capacity to produce cations with an incomplete *d* subshell.

Other people consider the transition metals to include any *d*-block element on the periodic table. Under this definition, groups 3 to 12 are the transition metals and the *f*-block lanthanide and actinide series are called the **"inner transition metals."**

These are the transition metals, according to the IUPAC definition.

Using the IUPAC definition, there **are 40 transition metals**. They are:

- Atomic numbers 21 (scandium) to 30 (zinc)
- Atomic numbers 39 (yttrium) to 48 (cadmium)
- Atomic numbers 71 (lutetium) to 80 (mercury)
- Atomic numbers 103 (lawrencium) to 112 (copernicium)

The full list is:

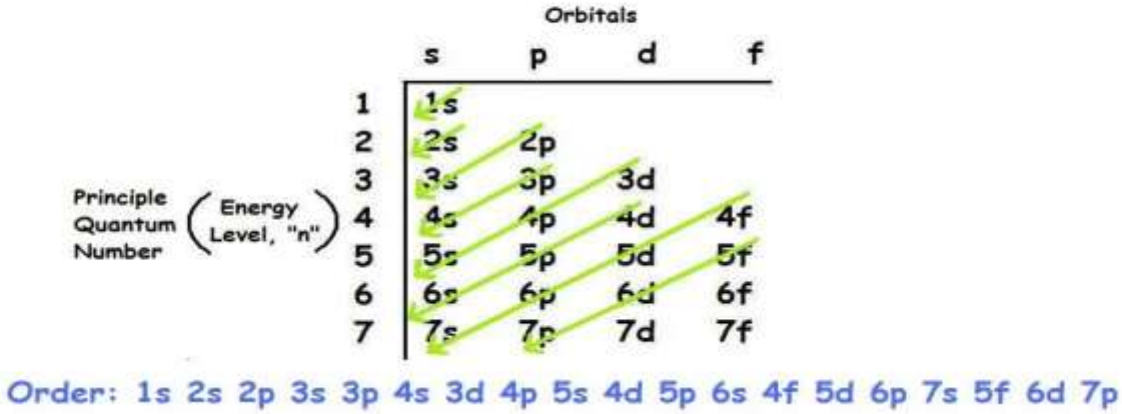
1. Scandium
2. Titanium
3. Vanadium
4. Chromium
5. Manganese
6. Iron
7. Cobalt
8. Nickel
9. Copper
10. Zinc
11. Yttrium
12. Zirconium
13. Niobium
14. Molybdenum
15. Technetium
16. Ruthenium
17. Rhodium
18. Palladium
19. Silver
20. Cadmium
21. Lutetium
22. Hafnium
23. Tantalum
24. Tungsten
25. Rhenium
26. Osmium
27. Iridium
28. Platinum
29. Gold
30. Mercury
31. Lawrencium
32. Rutherfordium
33. Dubnium
34. Seaborgium
35. Bohrium
36. Hassium
37. Meitnerium
38. Darmstadtium
39. Roentgenium
40. Copernicium

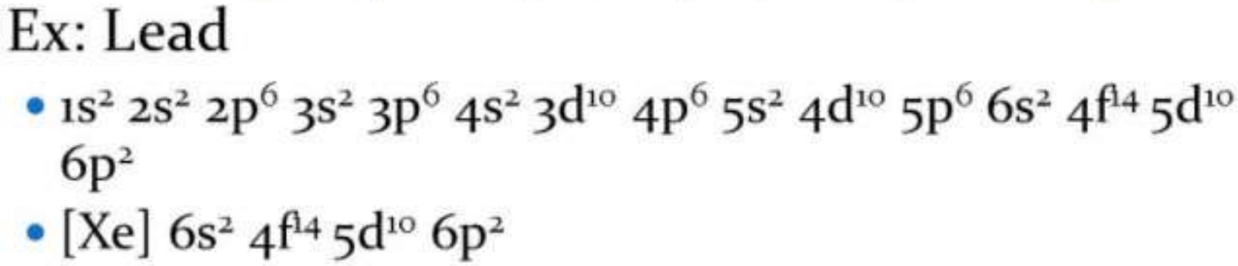
Technically, the elements zinc, cadmium, and mercury (group 12) should be considered post-transition rather than transition metals **because** they have a full **d^{10}** configuration and normally produce ions that retain this configuration. Experimental evidence of mercury behaving as a transition metal **was obtained in 2007.** Copernicium should probably be excluded on the same basis, although its oxidation properties have not been verified experimentally. However, most people include these elements in the transition metal list.

Some people exclude lutetium and lawrencium from the list. But, **lutetium and lawrencium are technically group 3 elements** that fit in the **"space"** in the periodic table. There are also scientists and educators who include the full lanthanide and actinide series as transition metals.

LO 1.2: DEMONSTRATE THE ELECTRONIC CONFIGURATION OF TRANSITION METAL.

- Distribution of electrons in orbits
  - ✓ Arrangement of electrons in s,p,d and f orbitals





Ex: Lead

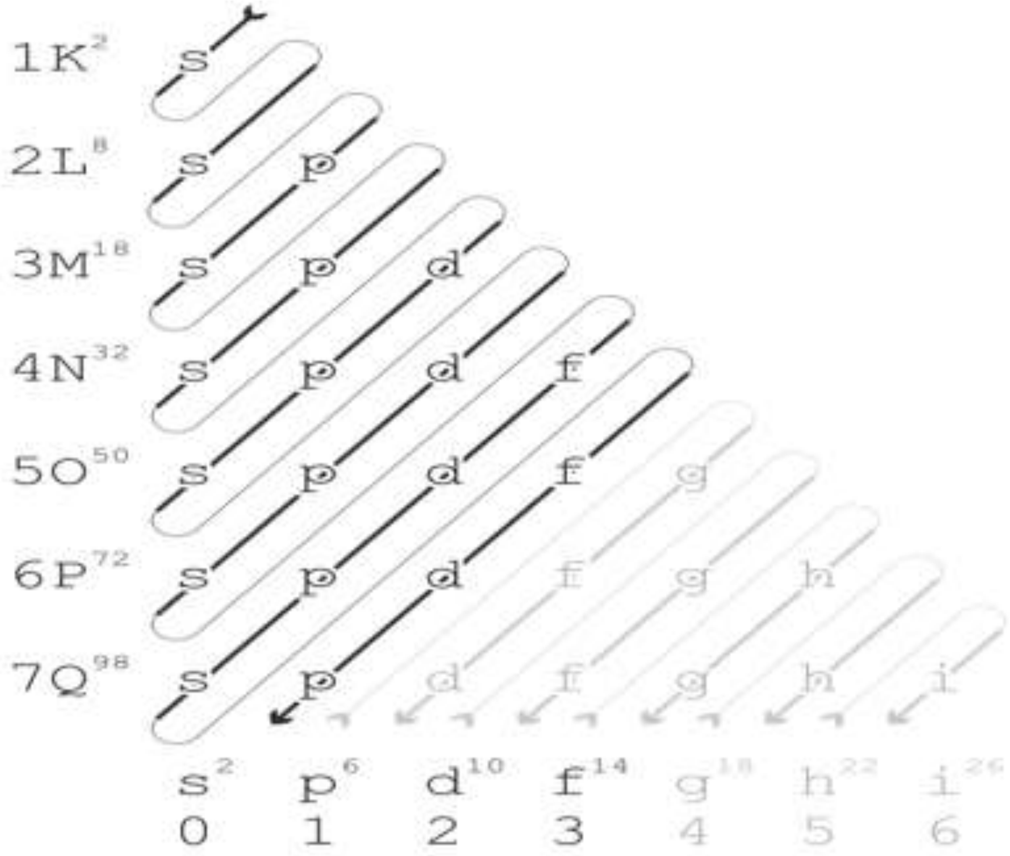
- $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^6\ 6s^2\ 4f^{14}\ 5d^{10}\ 6p^2$
- $[Xe]\ 6s^2\ 4f^{14}\ 5d^{10}\ 6p^2$

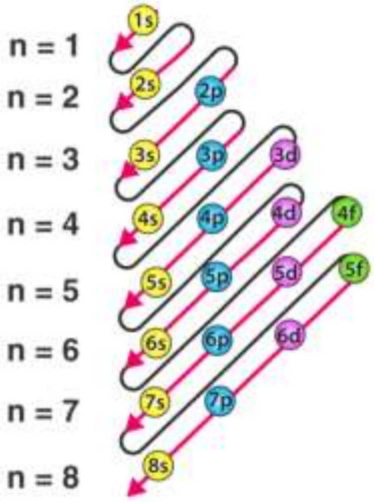
- ✓ Orbitals are filled based on Pauli exclusion principle

1. Aufbau Principle

- This principle is named after the German word 'Aufbeen' which means '**build up'**.
- The Aufbau principle dictates that electrons will occupy the orbitals having lower energies before occupying higher energy orbitals.
- The energy of an orbital is calculated by the sum of the principal and the azimuthal quantum numbers.
- According to this principle, electrons are filled in the following order: **1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s, 5f, 6d, 7p…**

The order in which electrons are filled in atomic orbitals as per the Aufbau principle is illustrated below.

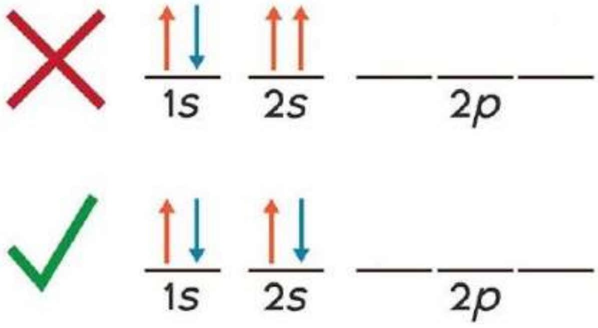




It is important to note that there exist many exceptions to the Aufbau principle such as chromium and copper. These exceptions can sometimes be explained by the stability provided by half-filled or completely filled subshells.

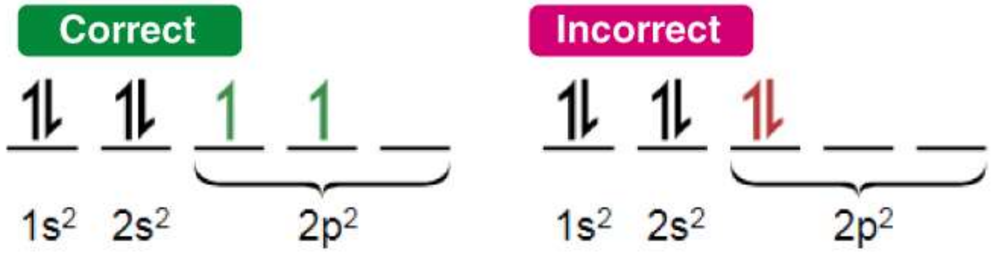
1. **Pauli Exclusion Principle:**

- The Pauli Exclusion Principle states that a maximum of two electrons, each having opposite spins, can fit in an orbital.
- This principle can also be stated as "no two electrons in the same atom have the same values for all four quantum numbers".
- Therefore, if the principal, azimuthal, and magnetic numbers are the same for two electrons, they must have opposite spins.



2. Hund's Rule

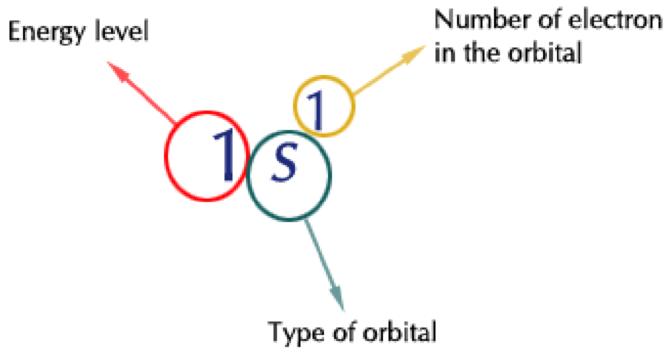
- This rule describes the order in which electrons are filled in all the orbitals belonging to a subshell.
- It states that every orbital in a given subshell is singly occupied by electrons before a second electron is filled in an orbital.
- In order to maximize the total spin, the electrons in the orbitals that only contain one electron all have the same spin (or the same values of the spin quantum number).



An illustration detailing the manner in which electrons are filled in compliance with Hund's rule of maximum multiplicity is provided above.

- ✓ Four orbitals are filled according to:
- energy level
- valence electrons

Energy levels: (also called electron shells) are fixed distances from the nucleus of an atom where electrons may be found.



Valence electrons:

Electrons in the outermost or valence shell of a ground-state atom. Determine how an element reacts.

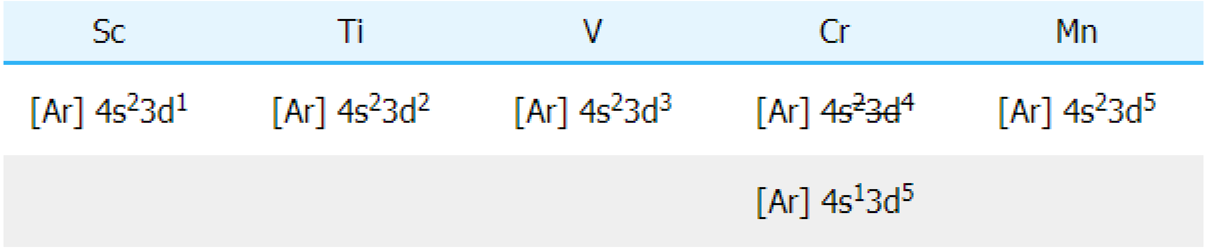
Valence shell:

Outermost shell of electrons in a ground-state atom; for main group elements, the orbitals with the highest *n* level (*s* and *p* subshells) are in the valence shell, while for transition metals, the highest energy *s* and *d* subshells make up the valence shell and for inner transition elements, the highest *s*, *d,* and *f* subshells are included

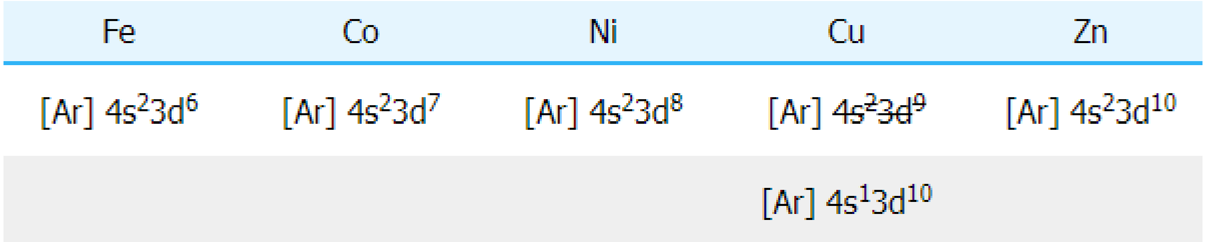
- ✓ d-orbitals are partially filled

When building electronic structure of transition metals, **4s** orbital is filled before **3d** orbitals. The transition elements are stable when their d-orbitals are filled **(d^{10})** or when their d-orbitals are half filled **(d^5).**This explains the electronic structure of copper, **[Ar] $4s^13d^{10}$**instead of **[Ar] $4s^23d^9$.** The same applies for **Cr: [Ar] $4s^13d^5$** and not **[Ar] $4s^23d^4$.**

In order to attain that stability an electron can jump from **4s** orbital to **3d** orbital because those two orbitals are close in energy.



Sc	Ti	V	Cr	Mn
[Ar] $4s^23d^1$	[Ar] $4s^23d^2$	[Ar] $4s^23d^3$	[Ar] ~~$4s^23d^4$~~	[Ar] $4s^23d^5$
			[Ar] $4s^13d^5$	

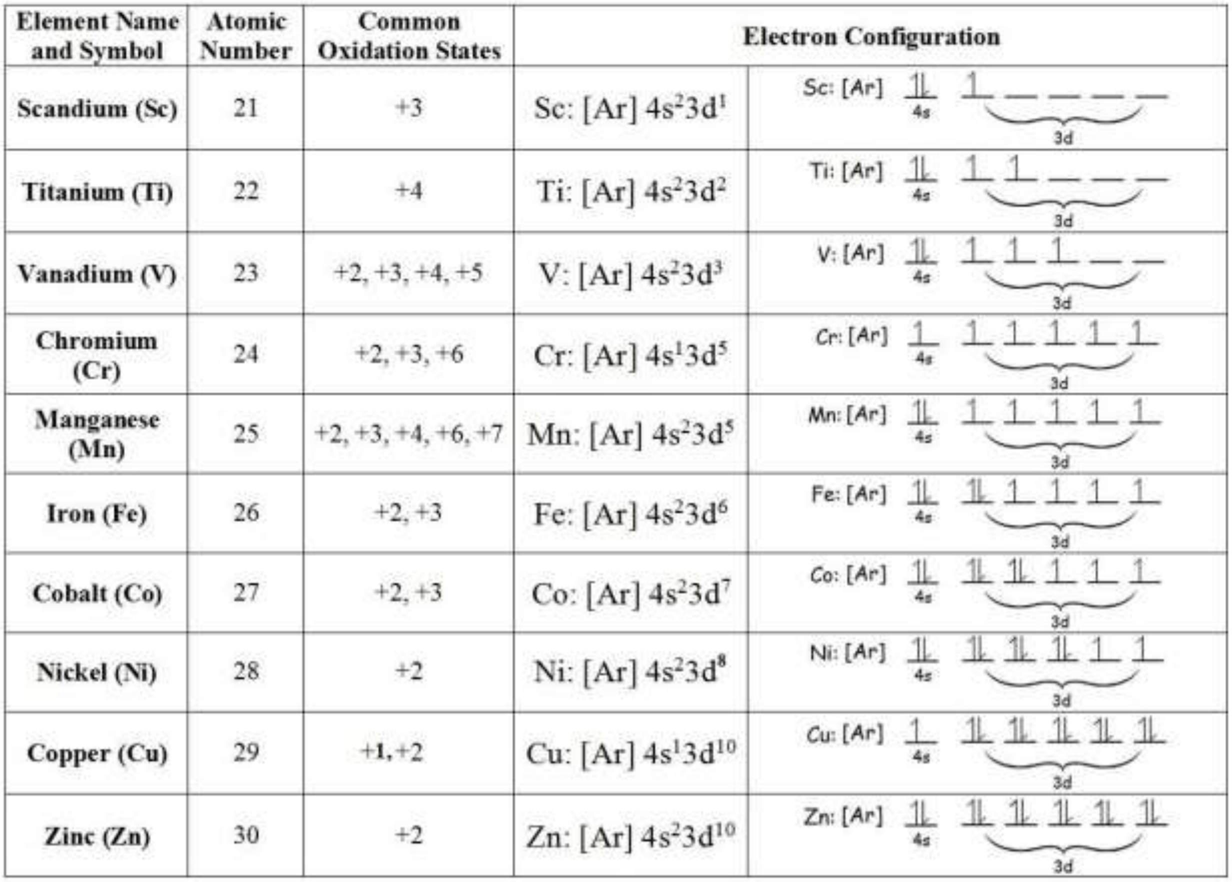


Fe	Co	Ni	Cu	Zn
[Ar] $4s^23d^6$	[Ar] $4s^23d^7$	[Ar] $4s^23d^8$	[Ar] ~~$4s^23d^9$~~	[Ar] $4s^23d^{10}$
			[Ar] $4s^13d^{10}$	

- Transition can have different oxidation states.

  - ✓ Metal can lose or gain more than one electron (They have unpaired electrons in their d-subshell)

Oxidation state is a number assigned to an element in chemical combination, which represents the number of electrons lost or gained. They show variable valence in their compounds. Some basic oxidation states of the elements are given below in tables.



Element Name and Symbol	Atomic Number	Common Oxidation States	Electron Configuration	
Scandium (Sc)	21	+3	Sc: [Ar] $4s^2 3d^1$	Sc: [Ar] $\underset{4s}{\uparrow\downarrow}\ \underbrace{\uparrow\ \_\ \_\ \_\ \_}_{3d}$
Titanium (Ti)	22	+4	Ti: [Ar] $4s^2 3d^2$	Ti: [Ar] $\underset{4s}{\uparrow\downarrow}\ \underbrace{\uparrow\ \uparrow\ \_\ \_\ \_}_{3d}$
Vanadium (V)	23	+2, +3, +4, +5	V: [Ar] $4s^2 3d^3$	V: [Ar] $\underset{4s}{\uparrow\downarrow}\ \underbrace{\uparrow\ \uparrow\ \uparrow\ \_\ \_}_{3d}$
Chromium (Cr)	24	+2, +3, +6	Cr: [Ar] $4s^1 3d^5$	Cr: [Ar] $\underset{4s}{\uparrow}\ \underbrace{\uparrow\ \uparrow\ \uparrow\ \uparrow\ \uparrow}_{3d}$
Manganese (Mn)	25	+2, +3, +4, +6, +7	Mn: [Ar] $4s^2 3d^5$	Mn: [Ar] $\underset{4s}{\uparrow\downarrow}\ \underbrace{\uparrow\ \uparrow\ \uparrow\ \uparrow\ \uparrow}_{3d}$
Iron (Fe)	26	+2, +3	Fe: [Ar] $4s^2 3d^6$	Fe: [Ar] $\underset{4s}{\uparrow\downarrow}\ \underbrace{\uparrow\downarrow\ \uparrow\ \uparrow\ \uparrow\ \uparrow}_{3d}$
Cobalt (Co)	27	+2, +3	Co: [Ar] $4s^2 3d^7$	Co: [Ar] $\underset{4s}{\uparrow\downarrow}\ \underbrace{\uparrow\downarrow\ \uparrow\downarrow\ \uparrow\ \uparrow\ \uparrow}_{3d}$
Nickel (Ni)	28	+2	Ni: [Ar] $4s^2 3d^8$	Ni: [Ar] $\underset{4s}{\uparrow\downarrow}\ \underbrace{\uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow\ \uparrow\ \uparrow}_{3d}$
Copper (Cu)	29	+1, +2	Cu: [Ar] $4s^1 3d^{10}$	Cu: [Ar] $\underset{4s}{\uparrow}\ \underbrace{\uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow}_{3d}$
Zinc (Zn)	30	+2	Zn: [Ar] $4s^2 3d^{10}$	Zn: [Ar] $\underset{4s}{\uparrow\downarrow}\ \underbrace{\uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow}_{3d}$

LO 1.3: DESCRIBE THE PROPERTIES OF TRANSITION METALS

Common properties of transition metals:

Transition Metal Properties:

- ➢ They display multiple positive oxidation states.
- ➢ They are good catalysts.
- ➢ They are silver metals at room temperature. The exceptions are copper and gold.
- ➢ They are **solids** at room temperature. The exception is mercury.
- ➢ They are paramagnetic (attracted to a magnetic field).
- ➢ They are hard.
- ➢ The metals have high melting and boiling points (except mercury).
- ➢ They are good electrical conductors.
- ➢ They form alloys.

- Physical Properties:

  - ✓ High melting and boiling points
  - ✓ Hard and high densities
  - ✓ Good conductors of electricity and heat

- Chemical properties:

  - ✓ Less reactive than alkali metals
  - ✓ High catalytic activity
  - ✓ Variable oxidation state

- Catalyst and alloy formation

A catalyst is a substance that can speed up or that can slow down the speed of reaction.

During the catalytic activity, transition metal ions undergo changes in their oxidation states but are regenerated at the end of the reaction.

The reasons for transition metals to work as catalysts:

1. Presence of empty d-orbital which enable transition metal ions (or atoms) to form temporary bonds with reactant molecules at the surface of a catalyst and weaken the bond in the reactant molecules.

- **Formation of alloys**

An alloy is a mixture (solid solution) made by combining two or more elements where at least one is a metal.

- **Importance of alloying**
  - ✓ Increase of the strength of a metal,
  - ✓ Resistance to corrosion,
  - ✓ Gives to the metal a good appearance

Example, brass (alloy of zinc and copper) is much stronger than either pure copper or pure zinc.

Exercises

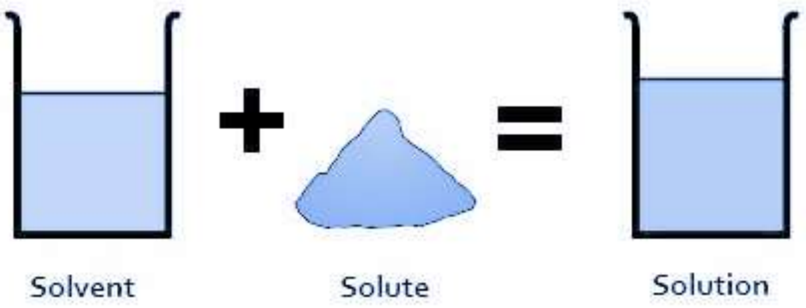
1. Define the following terms:
   a. Electronic configuration
   b. Transition metals
   c. Oxidation state
   d. Valence electrons
   e. Catalyst
2. Write down at least 6 types of atomic orbitals
3. Outline 5 examples of transition metals you know.
4. The elements zinc, cadmium and mercury should be considered post transition rather than transition metals. Why?
5. Give 5 properties of transition metals.
6. State Aufbau principle.
7. Give 2 importance of alloying.

LU 2: Perform chemical

LO 2.1: Identify the types of solutions

Solution is a homogeneous mixture composed of two or more substances.

- A chemical solution is made up of:
  - Solute
  - Solvent



- Types of solutions based on:
  - Physical state:
    - Solid
    - Liquid
    - Gas

Types of Solutions based on physical state of solute and solvents

Type	Example	Solute	Solvent
Gas in gas	Air	Oxygen (gas)	Nitrogen (gas)
Gas in liquid	Soda	CO2 (gas)	Water (liquid)
Liquid in liquid	Vinegar	Acetic acid (liquid)	Water (liquid)
Solid in liquid	Seawater	Salt (solid)	Water (liquid)
Liquid in solid	Dental amalgam	Mercury (liquid)	Silver (solid)
Solid in solid	Brass	Zinc (solid)	Copper (solid)

This table shows some of the solutions with their examples are listed below

Solute	Solvent	Solution	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

- ✓ Nature of mixture:
    - Homogeneous
    - Heterogeneous

When various elements or compounds mix together, it is called as mixture.

On the basis of nature of components; mixtures can be further classified as homogeneous or heterogeneous mixtures.

Homogenous mixtures have uniform composition due to even distribution of their components. For example; the mixture of salt in water is an example of homogenous mixture. Homogenous mixtures are also called as solution.

Sugar-water or salt-water solutions, aerated drinks, fruit juices, and even air are good examples of solutions.

Some of the solutions are **heterogeneous** in nature and called as suspension. In such solutions, solute particles remain suspended in solvent. Such suspended particles can be seen quite clearly in the solution. Diesel and water or flour and water mixture, medicated syrups are good examples of suspensions.

- ✓ Solute/solvent proportion (Empirical solution):
    - Diluted
    - Concentrated
    - Unsaturated
    - Super-saturated

Dilute solutions contains less amount of solute.

Concentrated solutions contains large amount of solute

Unsaturated solution can be defined as the solution in which solvent is capable of dissolving any more solute at given temperature.

Saturated solution is the solution in which solvent is not capable of dissolving any more solute at given temperature.

Super saturated solution contains large amount of solute at that temperature and as temperature will become reduce, the extra solute will crystallize quickly.

- Solution concentration concepts:
  - ✓ Molarity
  - ✓ Molality
  - ✓ Normality
  - ✓ Percentage

Concentration: Is the measure of how of a given substance (solute) there is mixed with another substance (solvent). In this work we will use molar concentration.

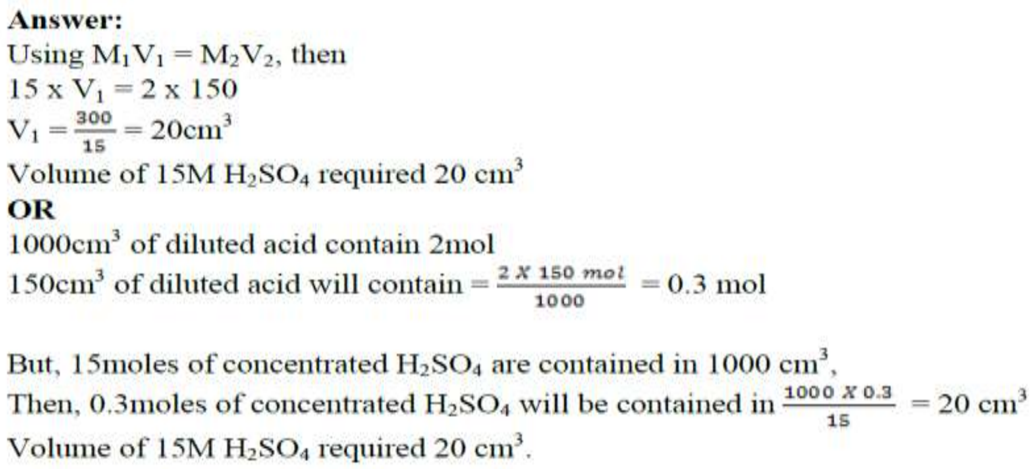
Molar concentrations are the most useful in chemical reaction calculations because they directly relate the moles of solute to the volume of solution. The formula for molarity is:

$$Molarity = \frac{moles\ of\ solute}{volume\ of\ solution}$$

$$c = \frac{n}{V} \qquad (\text{mol dm}^{-3} \text{ or M}) \qquad \text{or} \qquad c = \frac{m}{MV}$$

ıere V – is the volume of solution (in dm^3)
m – is the mass of a given substance (in grams)
M – is the molar mass (in g mol^{-1})

Example 1: Calculate the volume of 15M H_2SO_4 that would be required to prepare 150cm^3 of 2MH_2SO_4.



Answer:

Using $M_1V_1 = M_2V_2$, then

$15 \times V_1 = 2 \times 150$

$V_1 = \frac{300}{15} = 20cm^3$

Volume of 15M H_2SO_4 required 20 cm^3

OR

$1000cm^3$ of diluted acid contain 2mol

$150cm^3$ of diluted acid will contain $= \frac{2 X 150 \ mol}{1000} = 0.3$ mol

But, 15moles of concentrated H_2SO_4 are contained in 1000 cm^3,

Then, 0.3moles of concentrated H_2SO_4 will be contained in $\frac{1000 X 0.3}{15} = 20 \ cm^3$

Volume of 15M H_2SO_4 required 20 cm^3.

LO 2.2: Describe solubility

- Description of solubility
    - ✓ Definition of solubility

Solubility is a **chemical** property referring to the ability for a given substance, the solute, to dissolve in a solvent.

In general, the solubility of a solid in water is given by the number of grams or number of moles of the solid that will dissolve in 100g of water at a given temperature.

Molar solubility

Molar solubility can be expressed as the number of moles of a solute that can be dissolved per liter of solution before the solution becomes saturated.

The solubility product is the equilibrium constant expressed in terms of concentrations of the ions produced from a sparingly soluble solid in contact with a saturated solution.

A solubility product is generally a special example of a heterogeneous equilibrium constant. It involves more than one phase; that is solids in contact with liquids.

- Factors that affect solubility
    - ✓ Temperature

Depending on the nature of the solute the solubility may increase or decrease with temperature.

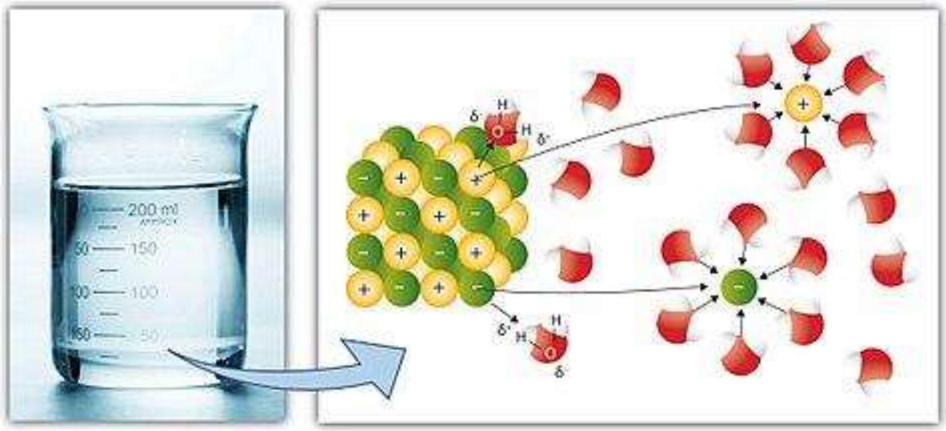
- ✓ Pressure

The pressure dependence of solubility is typically weak and usually neglected in practice.

✓ Polarity

Indicates that a solute will dissolve best in a solvent that has a similar chemical structure to itself. This view is simplistic, but it is a useful rule of thumb. The overall solvation capacity of a solvent depends primarily on its polarity.

For example, a very polar (hydrophilic) solute such as urea is very soluble in highly polar water, less soluble in fairly polar methanol, and practically insoluble in non-polar solvents such as benzene.



Dissolution of sodium chloride in water.

✓ Molecular size of solute

- Solubility product
    - ✓ Definition of solubility Product
    - ✓ Symbol of solubility Product
    - ✓ Equilibrium constant

Solubility is commonly expressed as a concentration:

For example, as g of solute per kg of solvent, the maximum equilibrium amount of solute that can dissolve per amount of solvent is the solubility of that solute in that solvent under the specified conditions.

Sugar will not dissolve in gasoline, since sugar is too polar in comparison with gasoline. A mixture of gasoline and sugar can therefore be separated by filtration or extraction with water.

(b) The solubility of calcium sulphate $CaSO_4$ at 298K is 0.67g/dm^3. Calculate the solubility product at this temperature. (O=16, S=32, Ca=40)

solution

$CaSO_{4(s)} \leftrightarrow Ca^{2+}{}_{(aq)} + SO_4{}^{2-}{}_{(aq)}$

Key point: number of moles=mass(g)/molar mass(gmol^{-1})

The concentration is given in g/dm^3; Convert it to mol/dm^3
1 mole of $CaSO_4$ weighs:40+32+(16×4)=136g
0.67 corresponds to 0.67/136=4.93×10^{-3} mol/dm^3
The solubility of calcium sulphate is 4.93×10^{-3} mol/dm^3
Each mole of calcium sulphate that dissolves produce 1 mole of Ca^{2+} ions and 1 mole of $SO_4{}^{2-}$ ions in solution.

$[Ca^{2+}]=4.93 \times 10^{-3}$ mol/dm^3
$[SO_4{}^{2-}]=4.93 \times 10^{-3}$ mol/dm^3
$Ksp=[Ca^{2+}][SO4^{2-}]$
$Ksp = (4.93 \times 10\text{-}3)^2$
$=2.4 \times 10^{-5}$ mol^{2}dm^{-6}

Calculating solubility from solubility product

Examples

a. Calculate the solubility in mol/dm^3 of silver chloride, AgCl, at 298K if its solubility product is 1.8×10^{-10} mol^{2}dm^{-6}

Solution2

$AgCl(s) \leftrightarrow Ag^+(aq) + Cl^-(aq)$

Key points

For every mole of silver chloride that dissolves, the solution will contain 1 mole of $Ag^+(aq)$ and 1 mole of $Cl^-(aq)$ so if "s" moles dissolved, the solution will contain "s" moles of each ion.

$[Ag+]=$ **s** moldm^{-3}
$[Cl^-]=$ **s** moldm^3
$Ksp= [Ag^+][Cl^-]$
$1.8 \times 10^{-10} = s \text{ x } s$

$S=\sqrt{1.8 \ x \ 10^{-10}}$

S =1.3×10^{-3}mol/dm^3

b. Calculate the molar solubility of $PbSO_4$ (lead II sulphate), given its solubility product equal to 1.6×10^{-8}.
Solution.

$PbSO_{4(s)} \leftrightarrow Pb^{2+}{}_{(aq)} + SO_4^{2-}{}_{(aq)}$

Key points

One mole of lead II sulphate dissolves to produce 1 mole of a Pb^{2+} and 1 mole of SO_4^{2-} ions in solution.

$[Pb^{2+}]=s\,moldm^{-3}$

$[SO_4^{2-}]=s\,moldm^{-3}$

Where "s"= $moldm^{-3}$ $PbSO_4$ that dissolved (the molar solubility)

$Ksp=[Pb^{2+}][SO_4^{2-}]=1.6\times10^{-8}$

$(s)(s)= 1.6\times10^{-8}$

$$s = \sqrt{1.6 \, x \, 10^{-8}} = 1.26 \, x \, 10^{-4}$$

Molar solubility= $1.26\times10^{-4}M$

LO 2.3: Apply titration methods

- Description of titration
  - ✓ **Define titration**

Titration is the controlled addition and measurement of the amount of a solution of known concentration required to react completely with a measured amount of a solution of unknown concentration.

An indicator is a substance which is used to determine the end point in a titration.

- ✓ **Types of titration:**

    - Acid-base titration
    - Redox titration
- ✓ **Common indicators**
  - Methyl violet
  - Bromophenol blue
  - Methyl orange
  - Methyl red
  - Litmus
  - Phenolphthalein
  - Alizarin yellow

Example of some common indicators and their pH range:

Indicator	pKIn	Color		pH range
		Acid	Base	
Methyl orange	3.7	Red	Yellow	3.2 - 4.4
Bromophenol blue	4.0	Yellow	Blue	3.0 – 4.6
Bromocresol Green	4.7	Yellow	Blue	3.8 - 5.4
Methyl red	5.1	Red	Yellow	4.8 - 6.0
Bromothymol blue	7.0	Yellow	Blue	6.0 - 7.6
Phenol red	7.9	Yellow	Red	6.8 - 8.4
Phenolphthalein	9.3	Colorless	Red	8.2 - 10.0

Indicators which are suitable for particular types of acid-base titrations are given in the Table

Acid-base titration	**Example**	**Choice of indicator**
Strong acid/strong base	H_2SO_4 and NaOH	Any indicator
Weak acid/strong base	CH_3COOH and KOH	Phenolphtalein
Strong acid/weak base	HCl and NH_3	Methyl orange
Weak acid/weak base	CH_3COOH and NH_3	No satisfactory indicator available

Choice of indicators in acid-base titrations:

The principle on which a choice of indicator is made concerns the strength of the acid or base involved in the reaction. Example of strong and weak acids and bases and choice of indicator are given in the Table below.

Examples of strong/weak acids and bases:

Acids		**Base**	
Strong	**Weak**	**Strong**	**Weak**
Hydrochloric acid, HCl	Ethanoic acid, CH_3COOH	Sodium hydroxide, NaOH	Ammonia, NH_3
Nitric acid, HNO_3	Methanoic acid, HCOOH	Potassium hydroxide, KOH	
Sulphuric acid, H_2SO_4	Carbonic acid, H_2CO_3	Sodium carbonate, Na_2CO_3	

- Some uses of titration:
  - ✓ Wastewater analysis
  - ✓ Food and beverage
  - ✓ Pharmacology
  - ✓ Sample analysis in laboratory
  - ✓ Medicine
  - ✓ Petrochemicals

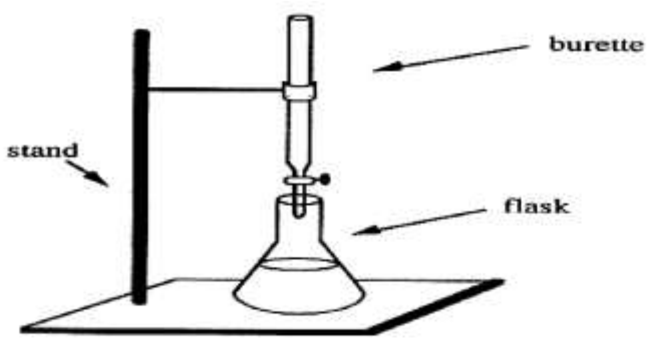
- Laboratory titration practical
  - ✓ Workplace preparation
    - Procedure
    - Equipment and materials
    - Reagents
    - Titrant and analytes

How to perform titrations:

- The apparatus should be arranged as shown in the above Figure.
- The burette tap is opened with the left hand and the right hand is used to shake the conical flask.
- The equivalence-point is reached when the indicator just changes permanently the color.
- At the end-point, the level of the titrant is read on the burette
- The titration is now repeated, three more times are recommended. Towards the end-point, the titrant is added drop wise to avoid overshooting.

The common equipment used in a titration:

- Burette
- Pipette
- PH-indicator/acid-base indicator
- White tile: used to see a color change in the solution (a white paper can also be used)
- Conical flask (Erlenmeyer flask)
- Titrant: a standard solution of known concentration
- **Analyte**: a solution of unknown concentration



- ✓ Conduct titration
- ✓ Work done interpreted

LU 3: Perform the electrochemical cell reactions

LO 3.1: Describe electrochemical cell

- Description of electrochemical cell
  - ✓ Definition of electrolysis
  - ✓ Definition of electrochemical cell
    - Electrolytic
    - Galvanic

A spontaneous reaction is a reaction that favors the formation of products without external energy. For example, a ball will roll down an incline, water will flow downhill, radioisotopes will decay, and iron will rust.

A non-spontaneous reaction (also called an unfavorable reaction) is a chemical reaction that necessitates external energy to occur. For example, without an external energy source, water will remain water forever.

An electrolyte is substance containing free ions which are the carriers of electric current in the electrolyte. When electric current (direct current) flows through an electrolyte, it decomposes it. This phenomenon is called electrolysis.

The electrode connected to the positive terminal of the direct current is called the anode and the one connected to the negative terminal is the cathode.

An electrochemical cell is a device which is capable of either producing electrical energy from chemical reactions or causes chemical reactions to take place through the introduction of electrical energy.

- **Types of electrochemical cells**
  - ✓ Galvanic
  - ✓ Electrolytic

Galvanic (Voltaic) Cell: is a device used to convert chemical energy of a redox reaction into electrical energy.

A galvanic cell is named after Luigi Galvani, an Italian physicist (1780). It is also called Voltaic cell, after an Italian physicist, Alessandro Volta (1800).

Both L. Galvani and A. Volta contributed greatly in the existence of this type of electrochemical cells.

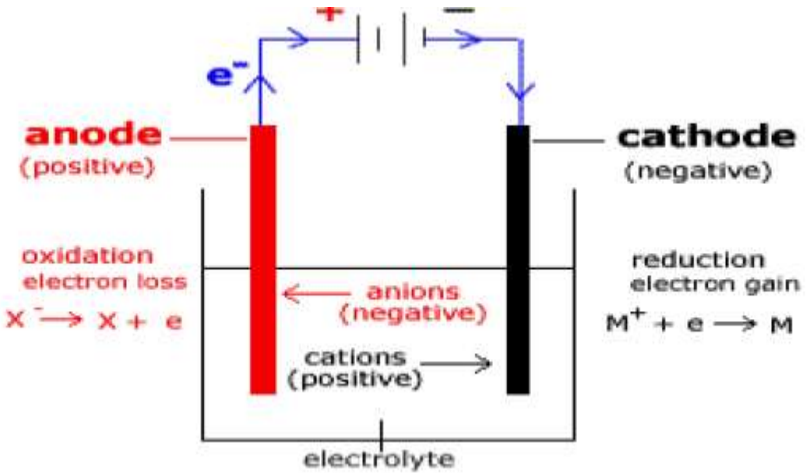
Both types of cells contain electrodes where the oxidation and reduction reactions occur.

Oxidation occurs at the electrode called the anode and reduction occurs at the electrode called the cathode.

Electrolytic cell is an electrochemical cell that drives a non-spontaneous redox reaction through the application of external electrical energy.

- Parts of electrochemical cells:
  - Electrolyte
  - Two electrodes:
  - Cathode
  - Anode

An electrolytic cell has three component parts: an electrolyte and two electrodes (a cathode and an anode).



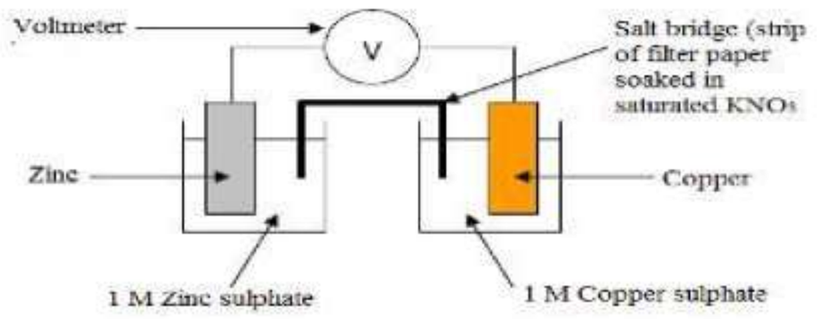
- Types of batteries
  - A galvanic cell

A galvanic cell generally consists of two different metal rods called electrodes. Each electrode is immersed in a solution containing its own ions (in the separate containers) and these form a half cell. The solutions in which the electrodes are immersed are called electrolytes i.e. made of ions. One electrode acts as anode in which oxidation takes place and the other acts as the cathode in which reduction takes place.

  - Primary cell
    - Daniell
    - Dry
    - Mercury

The Daniell cell was invented by a **British chemist, John Frederic Daniell.**

Is an electrochemical cell consisting of a zinc electrode in zinc sulphate solution and a copper electrode in copper sulphate solution, linked by a salt bridge



Oxidation occurs at the anode and reduction occurs at the cathode.

The anode of an electrolytic cell is positive, since it attracts anions from the solution, whereas the cathode is negative and attracts positive ions.

In a galvanic cell,

- The anode is negatively charged, since the spontaneous oxidation at the anode is the source of the cell's electrons or negative charge.

-The cathode of a galvanic cell is its positive terminal.

In both galvanic and electrolytic cells, oxidation takes place at the anode and electrons flow from the anode to the cathode.

- Secondary cell
- Lead acid
- Nickel cadmium
- Fuel cell
- Half - cells

LO 3.2: Describe reduction and oxidation reaction in electrochemical cells

- Oxidation reaction in electrochemical cell
- ✓ Decrease of oxidation
- ✓ Loss of electrons
- ✓ Happens at anode
- Reduction reaction in electrochemical cell
- ✓ Increase of oxidation number
- ✓ Gain of electron
- ✓ Happens at cathode

Each chamber of an electrochemical cell constitutes a **half-cell** containing an electrode and an electrolyte. **Half-cells** are sometimes known as **redox electrodes or redox couples.**

❖ Types of half cells

The half cells may be categorized into three types: Metal, non-metal and ion half-cells.

✓ Metal half cells

This half-cell is made of metal and its aqueous ions. It consists of a metal (electrode) dipped into an aqueous solution containing its own ions. For example: Zn/Zn^{2+} half-cell.

✓ Non-metal half cells

This half-cell is made from a non-metal and its aqueous ions. For example, hydrogen half-cell comprises hydrogen gas in contact with hydrogen ions: $H_2/2H^+$

✓ Ion half cell

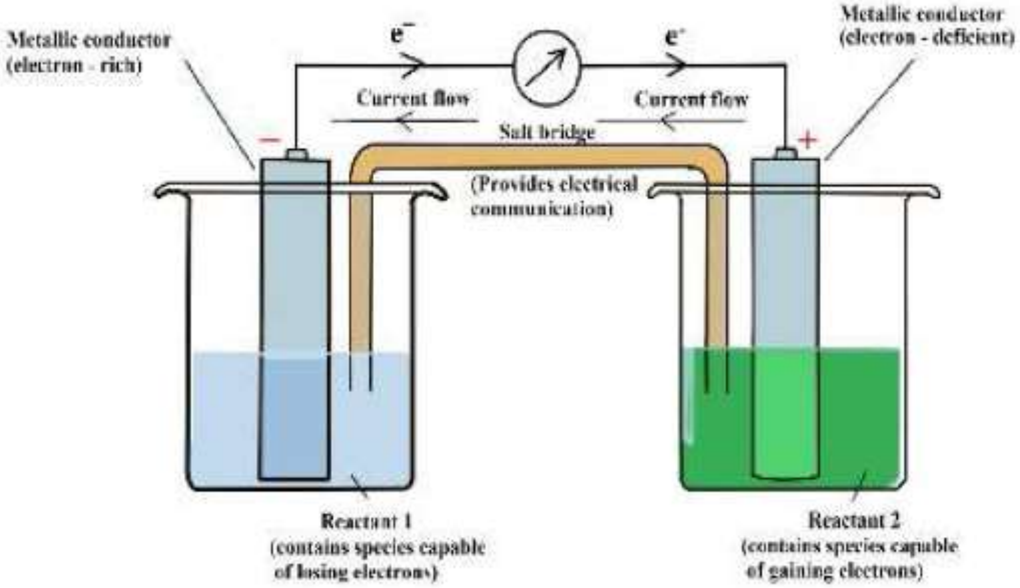
This type of half-cell consists of an inert electrode such as platinum electrode dipping into a Solution containing ions of the same metal in two different oxidation states. For example, a half cell containing Fe^{3+} (aq) and Fe^{2+} (aq) ions: Fe^{3+} (aq), Fe^{2+} (aq)/Pt

LO 3.3: Demonstrate electrochemical cell reactions and its overall energy

- General representation of electrochemical cell
- ✓ Parameters of electrodes
  - Anode
  - Cathode

- ✓ Signs of electrodes
  - Positive
  - Negative

A simple electrochemical cell can be made by connecting together **two half cells** with different electrode potentials.



One half cell releases electrons (oxidation at the anode).

The other half cell gains electrons (reduction at the cathode).

For example, when a strip of zinc metal is dipped in aqueous solution of zinc sulphate, some zinc atoms are oxidized. Each zinc atom that is oxidized leaves behind 2 electrons and enters the solution as Zn^{2+} ion.

- ✓ Half reactions
  - Reduction
  - Oxidation

Oxidation: $Zn(S) \rightarrow Zn^{2+} (aq) + 2e$

At the same time, some Zn^{2+} ions in the solution gain 2 electrons from the zinc strip and deposit as zinc atoms. They are reduced.

Reduction: $Zn^{2+} (aq) + 2e \rightarrow Zn(s)$

The opposing oxidation and reduction processes quickly come to an equilibrium:

$$Zn^{2+}{}_{(aq)} + 2e^- \underset{\text{Oxidation}}{\overset{\text{Reduction}}{\rightleftharpoons}} Zn_{(s)}$$

By convention, the equilibrium is written with the electrons on the left-hand side.

- ✓ Movement of electrons
- ✚ Inside the cell
- ✚ Outside the cell

Note that, in the electrochemical cell, the electrons flow from the negative terminal (anode) to the positive terminal (cathode) and the current flows in the opposite direction i.e. from cathode to anode.

In the Daniell cell,

Copper and zinc electrodes are immersed in a solution of copper (II) sulphate (CuSO4 (aq)) and

Zinc (II) sulfate (ZnSO4 (aq)) respectively. The two half cells are connected through a salt bridge.

Here, zinc acts as anode and copper acts as cathode.

$Zn(s) + CuSO_4 (aq) \rightarrow ZnSO_4 (aq) + Cu(s)$

The half-reactions are:

At Anode: Anode is an electrode at which oxidation occurs. $Zn(s) \rightarrow Zn^{2+} (aq) + 2e-$

At Cathode: Cathode is an electrode at which reduction occurs. $Cu^{2+} (aq) + 2e- \rightarrow Cu(s)$

Total cell reaction is the sum of the two half-cell reactions:

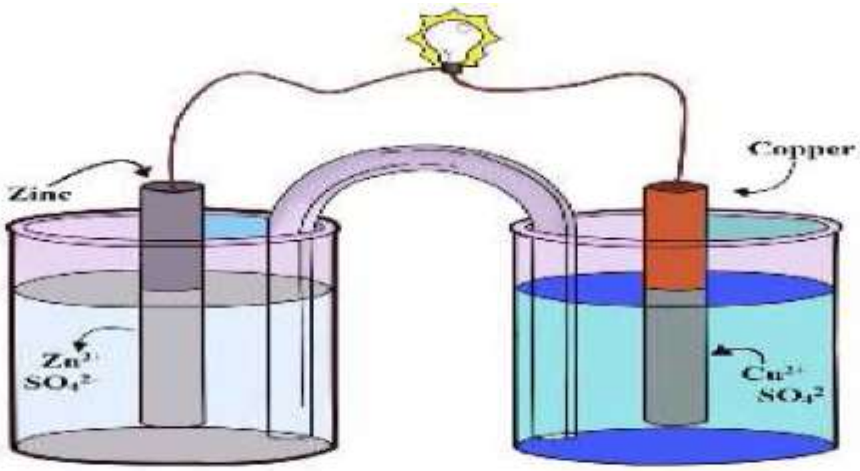
$Zn(s) + Cu^{2+} (aq) \rightarrow Zn^{2+} (aq) + Cu(s)$.

Zinc is oxidized to Zn^{2+} and releases 2 electrons; it is the anode of the cell.

Cu^{2+} is reduced to copper and captures two electrons; it is the cathode where copper metal is deposited.

In half-Zn cell, Zn^{2+} ions are produced, which means that the solution is positively charged.

In half-cell of Cu, Cu^{2+} ions are deposited and there is an excess of SO_4 2-ions, so that the solution becomes negatively charged.



The flow of electrons takes place through the external circuit. As electrons leave one half of a galvanic cell and flow to the other, a difference in charge is established. If no salt bridge were used, this charge difference would prevent further flow of electrons.

The salt bridge and wire join the two half cells:

The salt bridge connects the two solutions, allowing ions to be transferred between the half cells. The wire connects the two metals, allowing the electrons to be transferred between the two half cells.

- Electrode potential, E
  - ✓ Demonstrate oxidation
  - ✓ Demonstrate reduction
  - ✓ Overall energy of the cell

The two equilibrium which are set up in the half cells are:

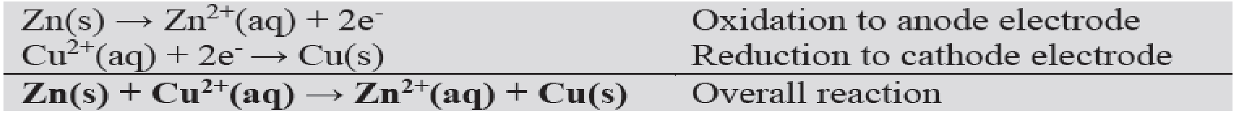
Zn^{2+} (aq) + 2e- Zn(s) E^o = - 0.76 V

Cu^{2+} (aq) + 2e- Cu(s) E^o = + 0.34 V

The negative sign of the zinc E^0 value shows that it releases electrons more readily than

Hydrogen does while the positive sign of the copper E^0shows that it releases electrons less readily than hydrogen.

You can add the two electron-half-equations above to give the overall ionic equation for the reaction.



$Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^-$	Oxidation to anode electrode
$Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$	Reduction to cathode electrode
$\mathbf{Zn(s) + Cu^{2+}(aq) \longrightarrow Zn^{2+}(aq) + Cu(s)}$	Overall reaction

LU 4: Describe polymerization

LO 4.1: Identify organic compounds according to their functional groups

- Description of organic compound

✓ Defining organic compounds

✓ Classification of organic compounds

- Natural compounds
- Synthetic compounds

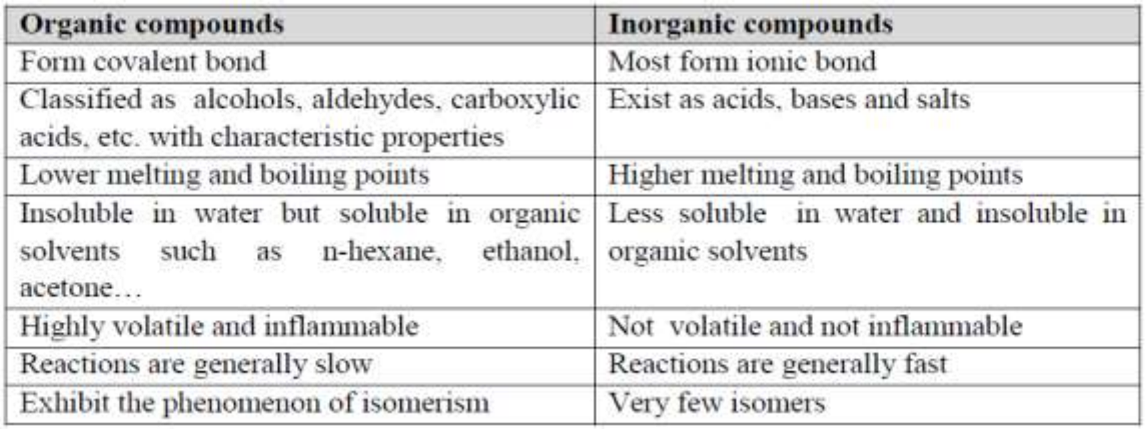
✓ Identification of functional group
✓ Nomenclature of organic compounds
✓ Properties of organic compounds
- Physical properties
- Chemical properties

- Functional group

✓ Defining functional group
✓ Types of functional groups
- Alkanes
- Alkenes
- Alcynes
- Alcohol
- Aldehydes
- Ketones
- Carboxylic acid
- Ester
- Amide
- Amine
- Ether
- Thiols
- Nitriles
- Ether-oxides
- Sulfides

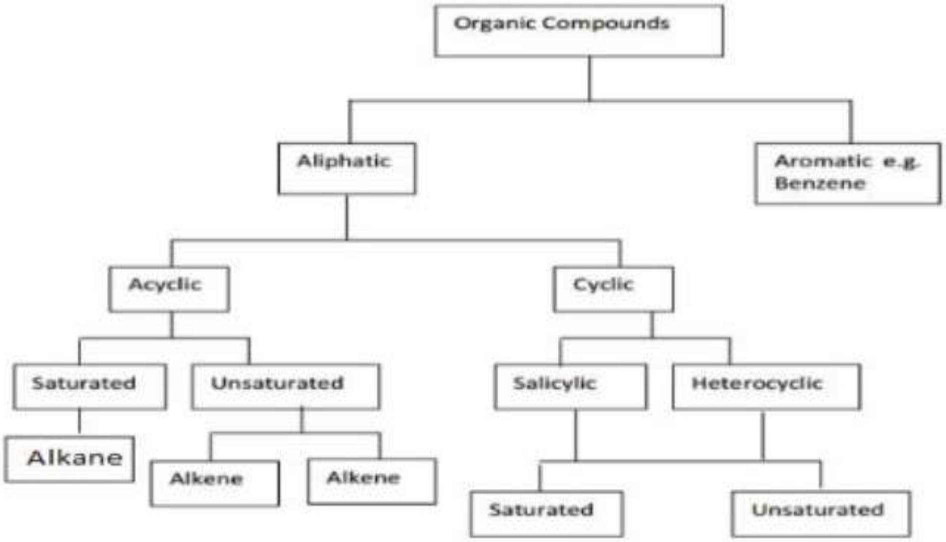
Organic chemistry: Is **“**the study of hydrocarbons and the compounds which could be thought of as their derivatives”.

General features of organic and inorganic compounds:



Organic compounds	Inorganic compounds
Form covalent bond	Most form ionic bond
Classified as alcohols, aldehydes, carboxylic acids, etc. with characteristic properties	Exist as acids, bases and salts
Lower melting and boiling points	Higher melting and boiling points
Insoluble in water but soluble in organic solvents such as n-hexane, ethanol, acetone…	Less soluble in water and insoluble in organic solvents
Highly volatile and inflammable	Not volatile and not inflammable
Reactions are generally slow	Reactions are generally fast
Exhibit the phenomenon of isomerism	Very few isomers

- **Classification of organic compounds**



- ✓ **Aliphatic compounds**

Aliphatic compounds are organic compounds in which the carbon atoms are arranged in a straight or branched chain.

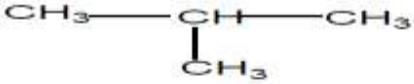
Examples

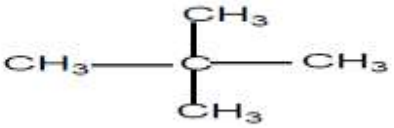
1) $CH_3-CH_2-CH_2-CH_3$

2) $CH_3-CH=CH-CH_3$

3)

$H_2C=CH\underset{CH_3}{\underset{|}{C}}HCH_3$

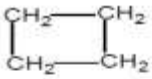
4)

$CH_3-\underset{CH_3}{\underset{|}{CH}}-CH_3$

5)

$CH_3-\overset{CH_3}{\overset{|}{\underset{CH_3}{\underset{|}{C}}}}-CH_3$

- ✓ **Alicyclic compounds**

Alicyclic compounds are organic compounds that contain one or more carbon rings that may be saturated or unsaturated.

Example: 1) cyclobutane



2) Cyclopentane

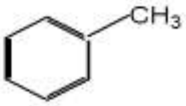
3) Cyclobutene

- ✓ **Aromatic compounds**

Aromatic compounds are compounds that contain a closed ring that consists of alternating single and double bonds with delocalized pi electrons.

Example: 1) Benzene (C_6H_6)

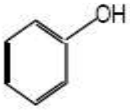
2) Toluene (C_6H_5-CH_3)



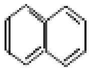
Aromatic compounds are designated as monocyclic, bicyclic and tricyclic if they contain one, two or three rings, respectively.

Examples:

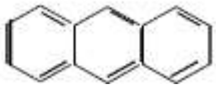
1) Phenol (C_6H_5OH): Monocyclic



2) Naphthalene: Bicyclic



3) Anthracene: Tricyclic

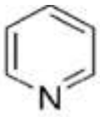


Note:

Heterocyclic compounds: Are also classified as cyclic compounds which include one or two atoms other than carbon (O, N, S) in the ring. Thus furan, thiophene and pyridine are heterocyclic compounds.

Furan

Thiophene



Pyridine

❖ Types of formulas for organic compounds

Atoms bond together to form molecules and each molecule has a chemical formula. In organic chemistry, we can distinguish empirical, molecular and structural formulas.

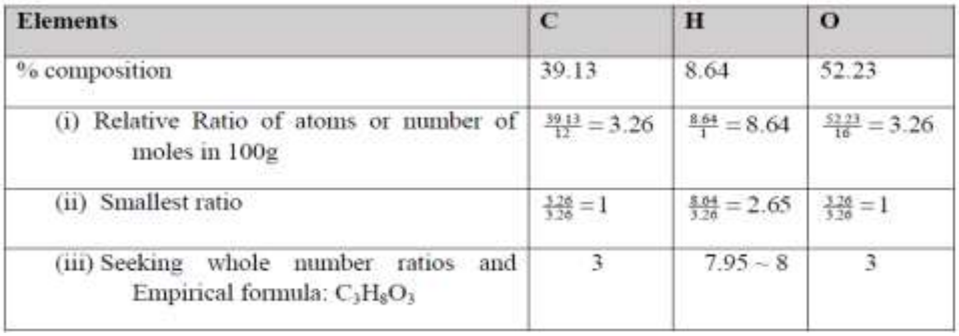
✓ Empirical formula

The empirical formula is the simplest formula which expresses the ratio of the number of atoms of each element present in a particular compound.

Example:

An analysis of organic compound showed that it has 39.13% carbon, 52.23% oxygen and the remaining is hydrogen. Determine the empirical formula of the compound.

Answer:



Elements	C	H	O
% composition	39.13	8.64	52.23
(i) Relative Ratio of atoms or number of moles in 100g	$\frac{39.13}{12} = 3.26$	$\frac{8.64}{1} = 8.64$	$\frac{52.23}{16} = 3.26$
(ii) Smallest ratio	$\frac{3.26}{3.26} = 1$	$\frac{8.04}{3.26} = 2.65$	$\frac{3.26}{3.26} = 1$
(iii) Seeking whole number ratios and Empirical formula: $C_3H_8O_3$	3	$7.95 \sim 8$	3

Note:

2.65 cannot be adjusted to 3 and it is multiplied by 3 equals to 7.95 which is rounded to 8.

- ✓ **Molecular formula**

The molecular formula is a formula expressing the exact number of atoms of each element present in a molecule.

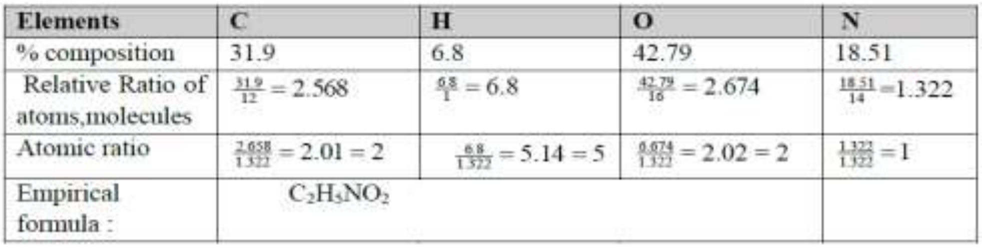
Molecular formula = Empirical formula x n

Where: $n = \frac{molecular\ mass}{empirical\ mass}$

Example 1:

An organic compound contains 31.9% by mass of carbon, 6.8% hydrogen and 18.51% nitrogen and the remaining percentage accounts for oxygen. The compound has a vapor density of 37.5. Calculate the molecular formula of that compound.

Answer:



Elements	C	H	O	N
% composition	31.9	6.8	42.79	18.51
Relative Ratio of atoms,molecules	$\frac{31.9}{12} = 2.568$	$\frac{6.8}{1} = 6.8$	$\frac{42.79}{16} = 2.674$	$\frac{18.51}{14} = 1.322$
Atomic ratio	$\frac{2.658}{1.322} = 2.01 = 2$	$\frac{6.8}{1.322} = 5.14 = 5$	$\frac{0.674}{1.322} = 2.02 = 2$	$\frac{1.322}{1.322} = 1$
Empirical formula :	$C_2H_5NO_2$			

Vapour density = a half molecular mass

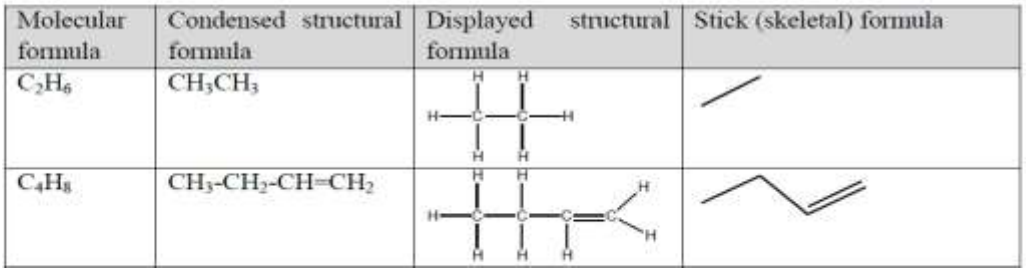
Molecular mass = 2 x vapour density = 2 x 37.5 = 75g/mol

$$n = \frac{molecular\ mass}{empirical\ mass} = \frac{75}{75} = 1$$

Hence the molecular formula = empirical formula = $C_2H_5NO_2$

- ✓ **Structural formulas**

Structural formula shows how the different atoms in a molecule are bonded (i.e. linked or connected)

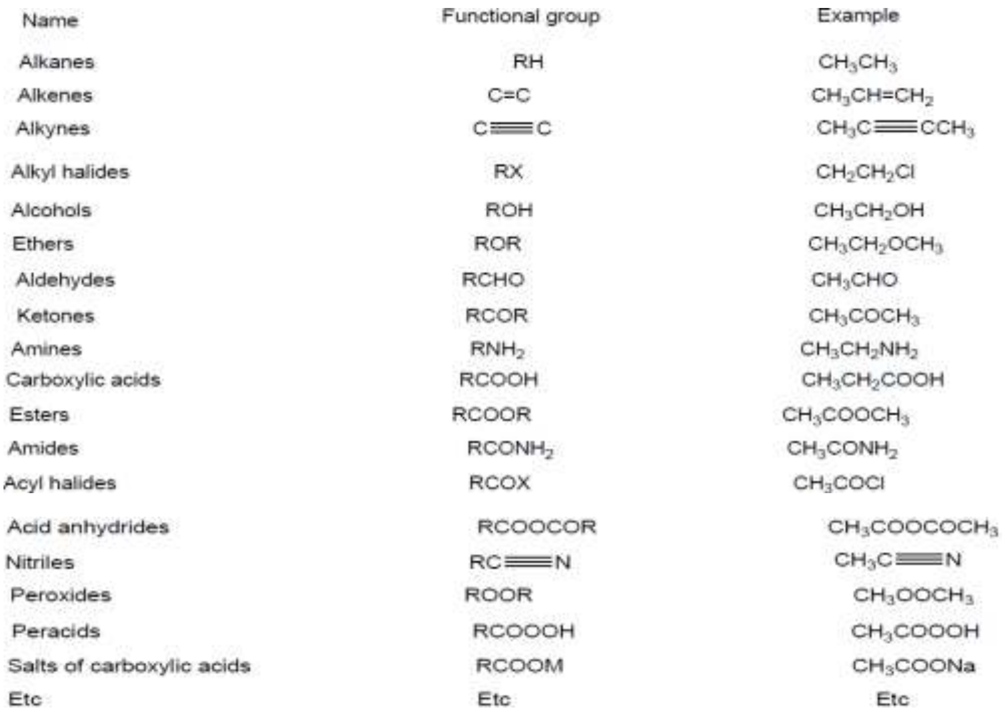


Molecular formula	Condensed structural formula	Displayed structural formula	Stick (skeletal) formula
C_2H_6	CH_3CH_3		
C_4H_8	CH_3-CH_2-CH=CH_2		

FUNCTIONAL GROUPS

❖ Defining functional group

A **functional group** is an atom or group of atoms in a molecule which determines the characteristic properties of that molecule.



Name	Functional group	Example
Alkanes	RH	CH_3CH_3
Alkenes	C=C	$CH_3CH=CH_2$
Alkynes	$C\equiv C$	$CH_3C\equiv CCH_3$
Alkyl halides	RX	CH_2CH_2Cl
Alcohols	ROH	CH_3CH_2OH
Ethers	ROR	$CH_3CH_2OCH_3$
Aldehydes	RCHO	CH_3CHO
Ketones	RCOR	CH_3COCH_3
Amines	RNH_2	$CH_3CH_2NH_2$
Carboxylic acids	RCOOH	CH_3CH_2COOH
Esters	RCOOR	CH_3COOCH_3
Amides	$RCONH_2$	CH_3CONH_2
Acyl halides	RCOX	CH_3COCl
Acid anhydrides	RCOOCOR	$CH_3COOCOCH_3$
Nitriles	$RC\equiv N$	$CH_3C\equiv N$
Peroxides	ROOR	CH_3OOCH_3
Peracids	RCOOOH	CH_3COOOH
Salts of carboxylic acids	RCOOM	CH_3COONa
Etc	Etc	Etc

❖ **Type of functional groups**

- ✓ Alkanes
- ✓ Alkenes
- ✓ Alcynes
- ✓ Alcohol
- ✓ Aldehyde
- ✓ Ketones

- ✓ Carboxylic acid
- ✓ Ester
- ✓ Amide
- ✓ Amine
- ✓ Ether
- ✓ Thiols
- ✓ Nitriles
- ✓ Ether-oxides

- **ALKANES**

They are made of carbon and hydrogen atoms only and contain two types of bonds, carbon-hydrogen (C-H) and carbon-carbon (C-C) single covalent bonds.

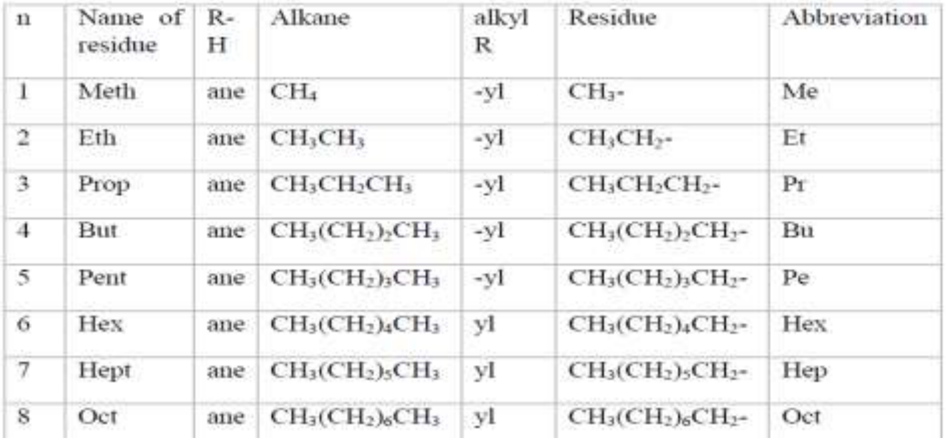
Alkanes form a homologous series with the general formula **CnH2n+2** where n is the number of carbon atoms in the molecule.

Example:

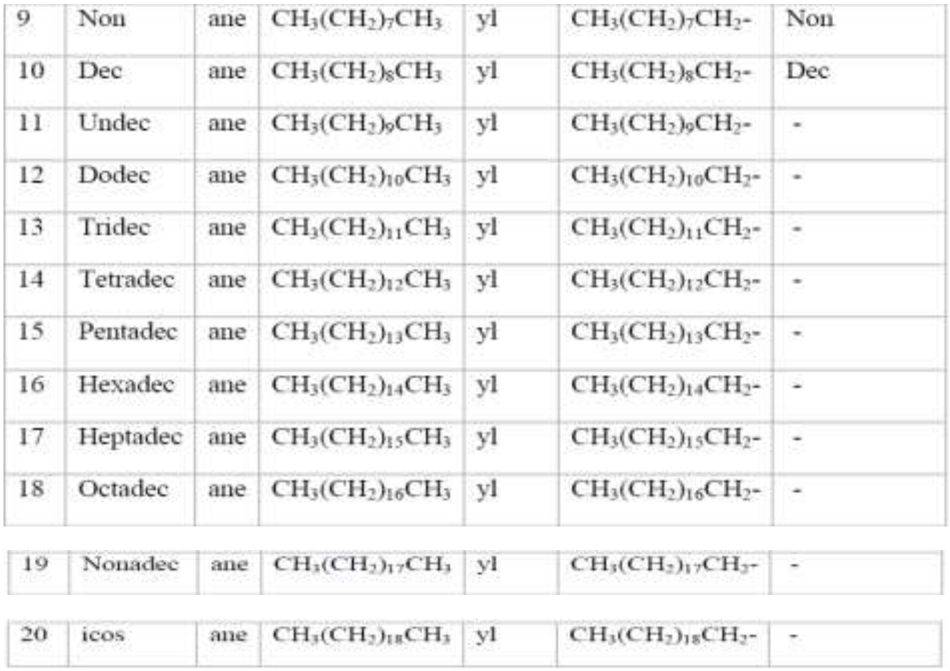
Methane (CH_4), (2) Butane (C_4H_{10}), (3) Propane (C_3H_8)…

❖ Nomenclature of alkanes

Examples of naming alkanes



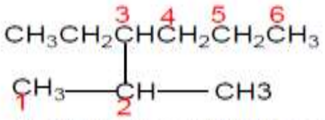
n	Name of residue	R-H	Alkane	alkyl R	Residue	Abbreviation
1	Meth	ane	CH_4	-yl	CH_3-	Me
2	Eth	ane	CH_3CH_3	-yl	CH_3CH_2-	Et
3	Prop	ane	$CH_3CH_2CH_3$	-yl	$CH_3CH_2CH_2$-	Pr
4	But	ane	$CH_3(CH_2)_2CH_3$	-yl	$CH_3(CH_2)_2CH_2$-	Bu
5	Pent	ane	$CH_3(CH_2)_3CH_3$	-yl	$CH_3(CH_2)_3CH_2$-	Pe
6	Hex	ane	$CH_3(CH_2)_4CH_3$	yl	$CH_3(CH_2)_4CH_2$-	Hex
7	Hept	ane	$CH_3(CH_2)_5CH_3$	yl	$CH_3(CH_2)_5CH_2$-	Hep
8	Oct	ane	$CH_3(CH_2)_6CH_3$	yl	$CH_3(CH_2)_6CH_2$-	Oct



9	Non	ane	$CH_3(CH_2)_7CH_3$	yl	$CH_3(CH_2)_7CH_2$-	Non
10	Dec	ane	$CH_3(CH_2)_8CH_3$	yl	$CH_3(CH_2)_8CH_2$-	Dec
11	Undec	ane	$CH_3(CH_2)_9CH_3$	yl	$CH_3(CH_2)_9CH_2$-	-
12	Dodec	ane	$CH_3(CH_2)_{10}CH_3$	yl	$CH_3(CH_2)_{10}CH_2$-	-
13	Tridec	ane	$CH_3(CH_2)_{11}CH_3$	yl	$CH_3(CH_2)_{11}CH_2$-	-
14	Tetradec	ane	$CH_3(CH_2)_{12}CH_3$	yl	$CH_3(CH_2)_{12}CH_2$-	-
15	Pentadec	ane	$CH_3(CH_2)_{13}CH_3$	yl	$CH_3(CH_2)_{13}CH_2$-	-
16	Hexadec	ane	$CH_3(CH_2)_{14}CH_3$	yl	$CH_3(CH_2)_{14}CH_2$-	-
17	Heptadec	ane	$CH_3(CH_2)_{15}CH_3$	yl	$CH_3(CH_2)_{15}CH_2$-	-
18	Octadec	ane	$CH_3(CH_2)_{16}CH_3$	yl	$CH_3(CH_2)_{16}CH_2$-	-
19	Nonadec	ane	$CH_3(CH_2)_{17}CH_3$	yl	$CH_3(CH_2)_{17}CH_2$-	-
20	icos	ane	$CH_3(CH_2)_{18}CH_3$	yl	$CH_3(CH_2)_{18}CH_2$-	-

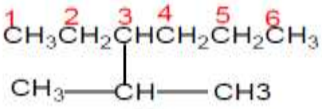
In case of chains of the same length, the priority is given for part where many branched of alkyl groups appear.

Example:



$$CH_3CH_2\underset{CH_3-CH-CH3}{CH}CH_2CH_2CH_3$$

3-ethyl-2-methylhexane
(two substituents)



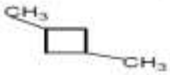
$$CH_3CH_2\underset{CH_3-CH-CH3}{CH}CH_2CH_2CH_3$$

not
3-isopropylhexane
(one substituent)

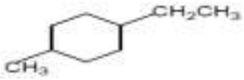
g) For cyclanes or cycloalkanes, the prefix —**cyclo**" is recommended, followed by the name of the alkanes of the same carbon number.

Examples:

methylclopropane

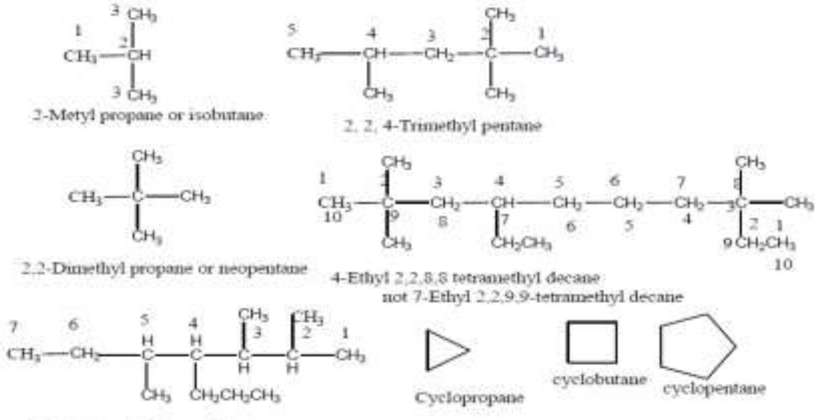


1,3-dimethylcyclobutane



1-ethyl-4-methylcyclohexane

Examples of alkanes and cyclanes:



2-Metyl propane or isobutane

2, 2, 4-Trimethyl pentane

2,2-Dimethyl propane or neopentane

4-Ethyl 2,2,8,8 tetramethyl decane not 7-Ethyl 2,2,9,9-tetramethyl decane

2,3,5 Trimethyl-4-propyl heptane

Cyclopropane

cyclobutane

cyclopentane

❖ Physical properties of alkanes

The boiling and melting points depend on the magnitude of the Van Der Waal's forces that exist between the molecules.

❖ Chemical properties of alkanes

- ✓ The C-C bond and C-H bonds are strong and do not break easily.
- ✓ Carbon and hydrogen have nearly the same electronegativity value.
- ✓ C-H bond only slightly polarized; generally C-H bond is considered as covalent.
- ✓ They have unshared electrons to offer.

▪ ALKENES AND ALKYNES

Alkenes are a homologous series of hydrocarbons which contain a carbon-carbon double bond.

The general formula of alkenes is C_nH_{2n}.

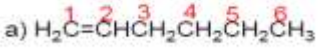
The name given to the chain is obtained from the name of the corresponding alkane by changing the suffix from –**ane** to –**ene**.

Example: Ethene (C_2H_4)

If a compound contains two or more double bonds, its location is identified by a prefix number. The ending is modified to show the number of double bonds:

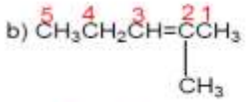
- ✓ **a diene** for two double bonds,
- ✓ **a triene** for two three bonds
- ✓ **a tetraene** for four double bonds

Examples:

a) 

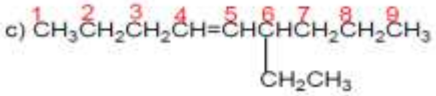
$H_2C=CHCH_2CH_2CH_2CH_3$

1-hexene or hex-1-ene

b) 

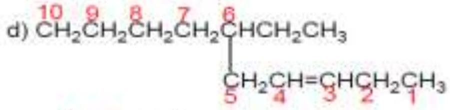
$CH_3CH_2CH=C(CH_3)CH_3$

2-metyl-2-pentene or 2-methylpent-2-ne

c) 

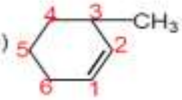
$CH_3CH_2CH_2CH=CHCH(CH_2CH_3)CH_2CH_2CH_3$

6-ethyl-4-nonene or 6-ethylnon-4-ene

d) 

$CH_3CH_2CH_2CH_2CH(CH_2CH_3)CH_2CH=CHCH_2CH_3$

6-ethyl-3-decene or 6-ethyldec-3-ene

e) 

3-methylcyclohexene

Physical properties of alkenes

- ✓ Alkenes which have less than 5 carbon atoms are gaseous at ordinary temperature, the other are liquid up to 18 while others are solids as the number of carbon atoms increases.
- ✓ Boiling points and melting points of alkenes are less than those of alkanes but also increase as the molecular weight increase.
- ✓ Alkenes are insoluble in water but soluble in most organic solvents.

- **ALCOHOLS AND ETHERS:**

1. **Alcohols** are organic compounds that are derivatives of hydrocarbons where one or more hydrogen atoms of hydrocarbon is or are replaced by hydroxyl (-OH) group.

The general formula: **C_nH_{2n}+1OH** or **ROH** where R is a radical:

Nomenclature

According to IUPAC system, alcohols are named by replacing the final **e**'' of the parent hydrocarbon with"**ol"**, then specify the position of **-OH** group before ending by **ol**.

Example:

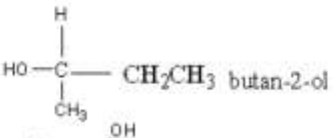
CH_3OH: Methanol

CH_3-CH_2-OH: ethanol

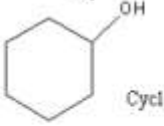
CH_3-CH_2-CH_2-OH: Propan-1-ol

CH_3-CHOH-CH_3: Propan-2-ol

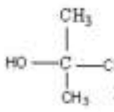
CH_3-CH_2-CH_2-CH_2OH: Butan-1-ol



butan-2-ol



Cyclohexanol



2-methyl propan-2-ol or tertiobutanol

Examples: When there are more than one hydroxyl group present, prefixes, **di, tri, tetra**... are used.

Examples:

HOCH2-CH2OH: Ethane-1, 2-diol (ethylene glycol)

HOCH2-CHOH-CH2OH: propane-1, 2, 3-triol (glycerin or glycerol)

Notice: -OH group takes priority over alkyls substituents, double or triple bonds and even halides.

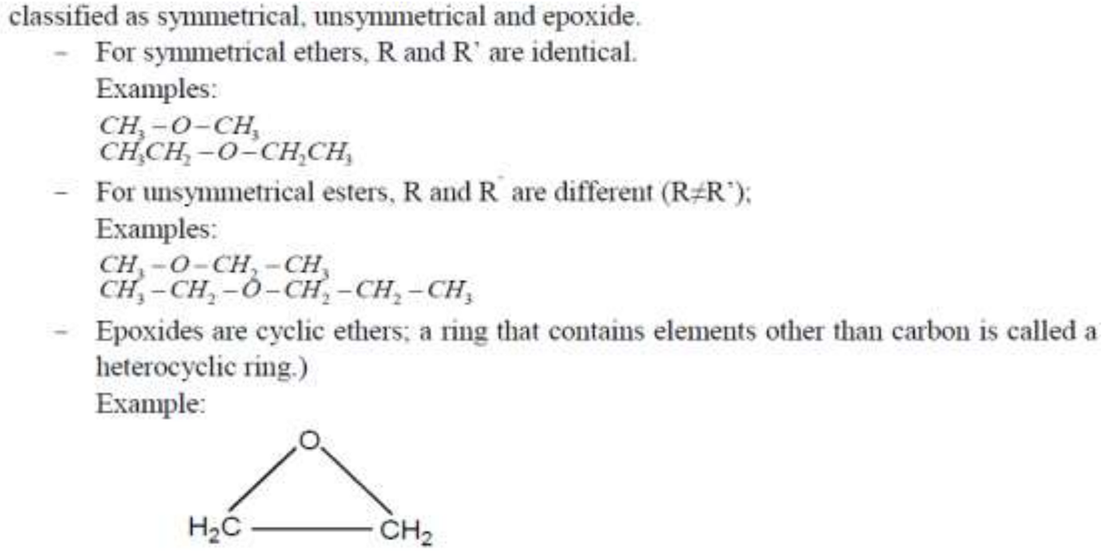
Examples:

CH3-CH=CH-CHOH-CH2-CHCl-CH3: 6-Chloro hept-2-en-4-ol

(CH3)2 CH-CHOH-CCH: 4-Methyl pent-1-yn-3-ol

2. **Ethers** are organic compounds in which two carbon groups are connected to a single oxygen.

The general formula of ether is R-O-R‘.



classified as symmetrical, unsymmetrical and epoxide.

- For symmetrical ethers, R and R' are identical.
  Examples:
  CH_3-O-CH_3
  $CH_3CH_2-O-CH_2CH_3$
- For unsymmetrical esters, R and R' are different (R≠R');
  Examples:
  $CH_3-O-CH_2-CH_3$
  $CH_3-CH_2-O-CH_2-CH_2-CH_3$
- Epoxides are cyclic ethers; a ring that contains elements other than carbon is called a heterocyclic ring.)
  Example:

- **HALOGENOALKANES (ALKYL HALIDES)**

Definition

Halogen alkane’s compounds are compounds in which the halogen atoms like **chlorine, bromine, iodine** or **fluorine** are attached to a hydrocarbon chain.

Nomenclature of halogen alkanes

Halogen alkanes are organic compounds that contain a **halogen** atom: **F, Cl, Br, I**.

They are named using the prefixes **fluoro-, chloro-, bromo-** and **iodo-**.

Numbers are used if necessary to indicate the position of the halogen atom in the molecule.

Examples: CH3CH2Cl: Chloro-ethane; here it is not necessary to indicate the number 1. CH3CHBrCH3: 2-bromopropane. If the molecule contains more than one halogen atom of the same kind, the prefixes **di-, tri-, tetra-**, etc… are used.

Examples:

CH2ClCH2Cl: 1, 2-dichloroethane

CHCl2CHClCH3:1, 1, 2-trichloropropane.

- **CARBONYL COMPOUNDS:**

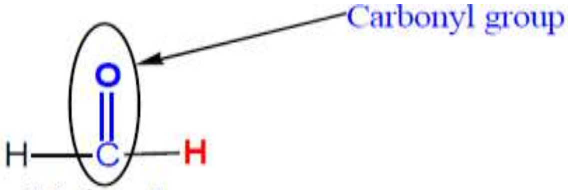
ALDEHYDES AND KETONES

Carbonyl compounds are compounds that contain carbon-oxygen double bond (C=O).

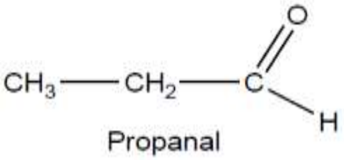
Carbonyl compounds are classified into two general categories based on the kinds of chemistry they undergo.

In one category there are aldehydes and ketones; in the other category there are carboxylic acids and their derivatives.

Aldehyde molecules



Methanal

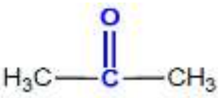


Propanal

Ketone molecules

Ketone has two alkyl groups attached to the carbonyl group.

Examples:



Propanone

Ketones **don't** have a hydrogen atom attached to the carbonyl group.

General rules of nomenclature of organic compounds according to IUPAC

In general, an IUPAC name has three essential parts:

- A **prefix** that indicates the type and the position of the substituents on the main chain.

- The **base** or **root** that indicates a major chain or ring of carbon atoms found in the molecule‘s structure. e.g. **Meth-** for one carbon atom, **eth**- for 2 carbon atoms, **prop-** for 3 carbon atoms, **hex-** for six carbon atoms, etc.

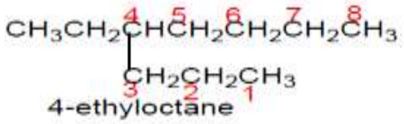
- The suffix designates the functional group.

Steps followed for naming organic compounds:

(1) Identify the parent hydrocarbon:

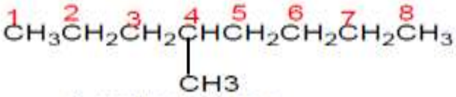
- It should have the maximum length, or the longest chain

Example:



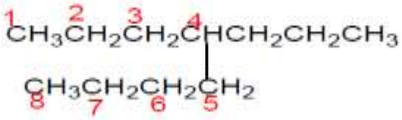
$$\begin{array}{l} CH_3CH_2CHCH_2CH_2CH_2CH_3 \\ \qquad\quad | \\ \qquad\quad CH_2CH_2CH_3 \end{array}$$

4-ethyloctane



$$\begin{array}{l} CH_3CH_2CH_2CHCH_2CH_2CH_2CH_3 \\ \qquad\qquad\quad | \\ \qquad\qquad\quad CH3 \end{array}$$

4-methyloctane

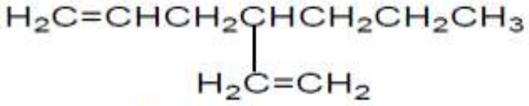


$$\begin{array}{l} CH_3CH_2CH_2CHCH_2CH_2CH_3 \\ \qquad\qquad\quad | \\ CH_3CH_2CH_2CH_2 \end{array}$$

4-propyloctane

- It should have the maximum number of multiple bonds.

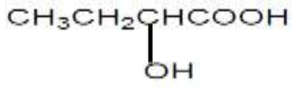
Example:



$$\begin{array}{l} H_2C{=}CHCH_2CHCH_2CH_2CH_3 \\ \qquad\qquad\quad | \\ \qquad\qquad H_2C{=}CH_2 \end{array}$$

3-propylhexa-1,5-diene and not 4-vinyl-1-heptene

(2) Identify the parent functional group, if any, with the highest order of priority.



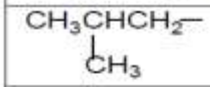
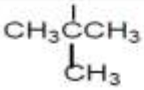
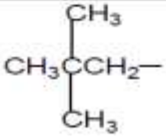
$$\begin{array}{l} CH_3CH_2CHCOOH \\ \qquad\quad | \\ \qquad\quad OH \end{array}$$

eg: 2-hydoxybutanoic acid

(3) Identification of the side chains.

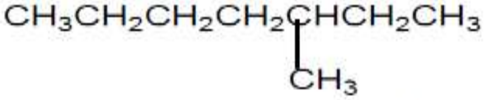
Side chains are usually alkyl groups. An **alkyl group** is a group obtained by a removal of one hydrogen atom from an alkane. The name of alkyl group is obtained by replacing **-ane** of the corresponding alkane by **–yl**

Nomenclature of alkyl group

Formula of alkyl group	Corresponding alkane	Name of the alkyl group
$C_nH_{2n+1}-$	Alkane	Alkyl
CH_3-	Methane	Methyl
CH_3CH_2- (C_2H_5-)	Ethane	Ethyl
$CH_3CH_2CH_2-$	Propane	Propyl
$CH_2\underset{\vert}{C}HCH_3$	Propane	Isopropyl
CH_3CH_2 CH_2CH_2-	Butane	Butyl
$CH_2\underset{\vert}{C}HCH_2CH_3$	Butane	Sec-(s-) butyl
 $CH_3\underset{\underset{CH_3}{\vert}}{C}HCH_2-$	Methylpropane (isobutene)	Isobutyl
 $CH_3\overset{\vert}{\underset{\underset{CH_3}{\vert}}{C}}CH_3$	Methylpropane (isobutene)	Tertio-(t-) butyl
CH_3CH_2 CH_2 CH_2CH_2-	Pentane	Pentyl
 $CH_3\overset{\overset{CH_3}{\vert}}{\underset{\underset{CH_3}{\vert}}{C}}CH_2-$	2,2-dimethylpropane (neopentane)	Neopentyl

A side chain must be identified by the smallest possible numbers.

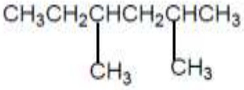
Example:


$CH_3CH_2CH_2CH_2\underset{\underset{CH_3}{\vert}}{C}HCH_2CH_3$

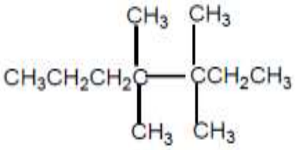
3-methylheptane and not 5-methylheptane

3. If the same substituent occurs two or more times, the prefix **di**, **tri**, **tetra**, ...is attached to substituent's name.

Its locants separate the prefix from the name of the substituent.

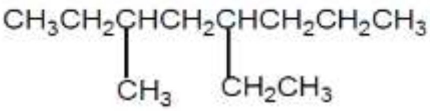

$CH_3CH_2\underset{\underset{CH_3}{\vert}}{C}HCH_2\underset{\underset{CH_3}{\vert}}{C}HCH_3$

2,4-dimethylhexane


$CH_3CH_2CH_2\overset{\overset{CH_3}{\vert}}{\underset{\underset{CH_3}{\vert}}{C}}-\overset{\overset{CH_3}{\vert}}{\underset{\underset{CH_3}{\vert}}{C}}CH_2CH_3$

3,3,4,4-tetramethyiheptane

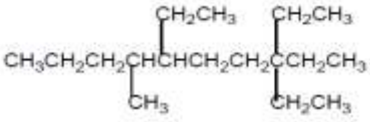
(5) Identify the remaining functional groups, if any, and name them. Different side chains and functional groups will be listed in alphabetical order.


$CH_3CH_2\underset{CH_3}{C}HCH_2\underset{CH_2CH_3}{C}HCH_2CH_2CH_3$

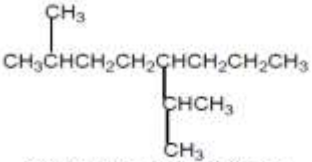
5-ethyl-3-methyloctane
not 3-methyl-5-ethyloctane

(6) The prefixes **di, tri, tetra**...are not taken into consideration when grouping alphabetically. But prefixes such **iso-, neo-** are taken into account.

Example:


$CH_3CH_2CH_2\underset{CH_3}{\overset{CH_2CH_3}{C}}HCHCH_2CH_2\underset{CH_2CH_3}{\overset{CH_2CH_3}{C}}CH_2CH_3$

3,3,6-triethyl-7-decane

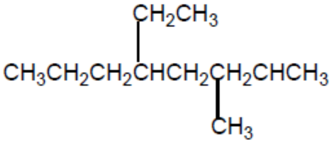

5-isopropyl-2-methyloctane

(7) Identify the position of the double/triple bond.

Example: CH3CH2CH=CHCH2CH2CH3: hept-3-ene (3-heptene)

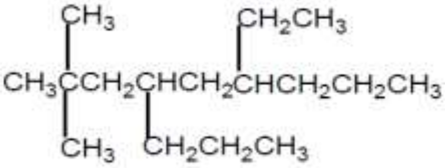
(8) Number the chain (left to right) or right to left).

The sum of the numbers which show the location of the substituents is the possible smallest. Examples:


$CH_3CH_2CH_2\overset{CH_2CH_3}{C}HCH_2\underset{CH_3}{C}H_2CHCH_3$

5-ethyl-3-methyloctane and not *4-ethyl-6-methyloctane*

(9) Numbers are separated by commas Hyphens are added between numbers and words. Successive words are merged in one word.


$CH_3\underset{CH_3}{\overset{CH_3}{C}}CH_2\underset{CH_2CH_2CH_3}{C}HCH_2\overset{CH_2CH_3}{C}HCH_2CH_2CH_3$

6-ethyl-2,2-dimethyl-4-propylnonane.

Define:

Homologous series

When members of a class of compounds having similar structures are arranged in order of increasing molecular mass, they are said to constitute a **homologous series**.

For example, the following sequence of straight chain of alcohols forms a homologous series.

CH_3-OH: Methyl alcohol

CH_3-CH_2-OH: Ethyl alcohol

CH_3-CH_2- CH_2-OH: Propyl alcohol

Characteristics of a homologous series:

(1) Any member of the series differs from the next by the unit $-CH_2-$ (methylene group)

(2) The series may be represented by a general formula of alcohols which is $C_nH_{2n+1}OH$ where n =1, 2, 3, etc.

(3) The chemical properties of the members of a homologous series are similar, though in some series the first members show different behavior.

(4) The physical properties such as density, melting point and boiling point generally increase within the molecular mass.

LO 4.2: Proper identification of types of polymers according to the monomers

Describe polymers

- Monomers

✓ Defining monomers

✓ Types of monomers

  - Simple sugar monomers (Monosaccharide)
  - Monomers of fats (Lipids: Glycerol, fatty acids)
  - Nucleotides as monomers (Nucleic acids: DNA, RNA)
  - Monomers of plastics (HDPE, LDPE)
  - Monomers of proteins (Amino-acids)

- Polymers

✓ Defining polymers

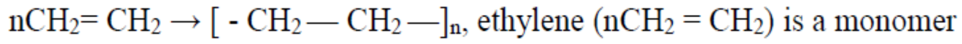
✓ Classification
  - Origin/Source
  - Structure
  - Molecular forces
  - Mode of polymerization
  - Types of monomers

- ✓ Properties
  - Heat capacity/Heat conductivity
  - Thermal expansion
  - Crystallinity
  - Permeability
  - Elastic modulus
  - Tensile strength
  - Resistance to electric current
  - Refractive index

Nowadays the materials made of plastics such as fibers, plastic and rubber materials are all around us and are commonly called polymers by chemists. Polymers are commonly used in household utensils, automobiles, clothes, furniture, space-aircraft, biomedical and surgical components.

❖ Monomers

The term monomer comes from mono "one" and meros "part", which expresses a single unit or a small molecular subunit that can be chemically, bind to another identical or different molecule to form larger molecule (polymer).



$nCH_2= CH_2 \rightarrow [- CH_2 — CH_2 —]_n$, ethylene ($nCH_2 = CH_2$) is a monomer

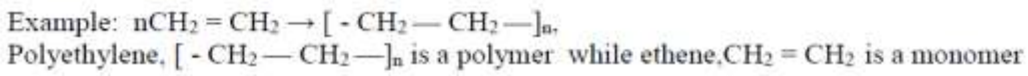
❖ Types of monomers

- ✓ Simple sugar monomers (Monosaccharide)
- ✓ Monomers of fats (Lipids: glycerol, fatty acids)
- ✓ Nucleotides as monomers (nucleic acids: DNA, RNA)
- ✓ Monomers of plastics (HDPE, LDPE)
- ✓ Monomers of proteins (Amino-acids)

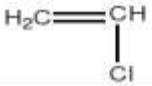
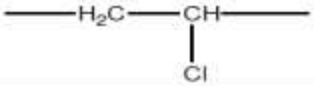
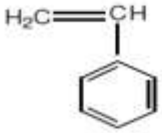
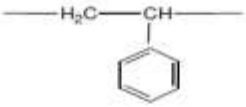
DESCRIPTION OF POLYMER

The term polymer comes from poly- meaning "many"; and meros meaning "part". A polymer is a large molecule (macromolecule or giant molecule) composed of smaller molecules (monomers)

Linked together by intermolecular covalent bonds.



Example: $nCH_2 = CH_2 \rightarrow [- CH_2 — CH_2 —]_n$,
Polyethylene, $[- CH_2 — CH_2 —]_n$ is a polymer while ethene, $CH_2 = CH_2$ is a monomer

Monomer		repeating unit/ monomeric unit	Polymer
$H_2C{=}CH_2$	Ethylene	$-H_2C-CH_2-$	Polyethylene
 $H_2C{=}CH(Cl)$	vinyl chloride	 $-H_2C-CH(Cl)-$	poly(vinyl chloride)
	Styrene		Polystyrene

❖ **Classes of polymers**

In general, polymers are classified into two classes such as natural polymers and synthetic polymers.

1. Natural polymers

Natural polymers are those that are obtained from natural sources. They are made naturally and are found in plants and animals or other living beings.

For examples:

a) Silk

A silk is a fine continuous protein fiber produced by various insects' larvae usually for

Cocoons.

Most arthropod species produce silks used for building structures to capture prey and protect their offspring against environmental hazards.

b) Cotton

Cotton is soft, fluffy staple fiber that grows in a boll, or protective case, around the seeds of the cotton plants. Cotton is natural cellulosic fiber.

c) Proteins

Proteins are highly complex substance made up of hundreds of thousands of smaller units called

Amino acids which are attached to one another to make along chain.

d) Natural rubber

Natural rubber is an elastic material obtained from the latex sap of trees that can be vulcanized

And finished into a variety of products

The molecular formula of natural rubber is: -CH2-C (CH3) =CH-CH2-C (CH3) =CH-CH2- which is polyisoprene, having the monomer of isoprene (CH2=C (CH3) CH=CH2.

e) Cellulose

Cellulose is an insoluble substance which is the main constituent of plant cell walls and the

Vegetable fibers such as cotton.

2. Synthetic polymers

Except the natural polymers, there are also synthetic polymers which are synthesized in the

Laboratory.

Examples: Polyethene is a polymer formed by linking together a large number of ethene

Molecules. PVC, Nylons, Terylene and Polystyrene.etc

❖ **Types of polymers**

The polymers can be classified into three main different types such as:

a) Plastics

The plastics are types of polymers that are the most commonly used. Plastics are polymerized

Organic substances, solid of high molar mass, which at some time in its manufacture can be shaped by flow. Their advantage is recycling and this allows them to be used many times.

The disadvantage of plastics is in their temperature

b) Rubbers

Rubber is a tough elastic polymeric substance made from the latex of a tropical plant or synthetically made.

There are two types of rubbers:

1. **Natural rubber**

Natural rubber is an elastic material obtained from the latex sap of trees that can be vulcanized

And finished into a variety of products.

2. **Synthetic rubber**

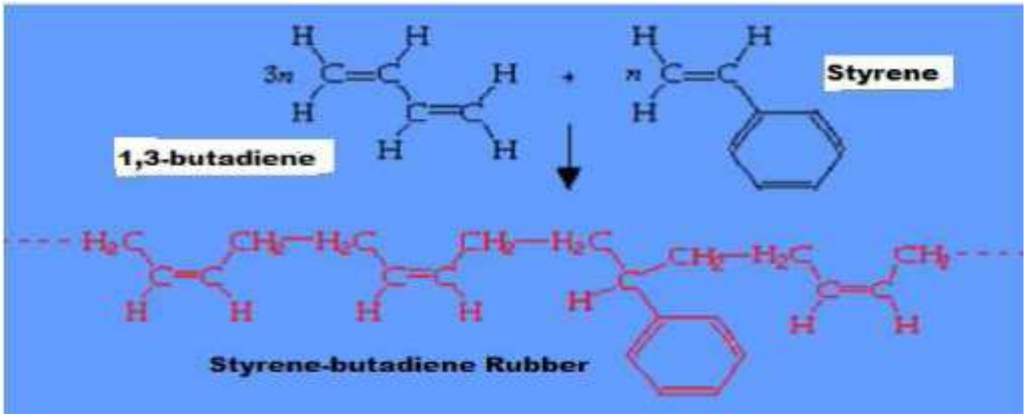
A synthetic rubber is any artificial elastomer (man-made polymer having elastic properties)

There are several synthetic rubbers in production.

The synthetic Rubber is an important addition of polymers that are obtained by polymerizing

A mixture of two or more monomers. An example is styrene-butadiene rubber (SBR), a synthetic Rubber formed by a mixture of 1, 3-butadiene and styrene in a 3 to 1 ratio, respectively.

The structure of SBR is the following:



c) Fibers

Fiber (from Latin Fibra) is a natural or synthetic substance that is significantly longer.

Fibers are strong polymers that do not change shape easily.

Nylon is an example.

1. **Natural fiber**

Natural fibers are substances produced by plants and animals that can be turned into filament, thread or rope and further be woven, woolen, matted or bound.

2. **Synthetic fiber**

A man made textile fibers including usually those made from natural materials such as rayon and

Acetate as well as fully synthetic fibers (such as nylon or acrylic fibers).

❖ **Properties of polymers**

Polymers or in general plastics have different properties depending on their nature.

1. Thermo-softening (thermoplastics) and thermosetting (thermosets) properties

Are properties of polymers on how they soften on heating and harden on cooling.

a) Properties of Thermo-softening polymers

Thermo-softening polymers have weak intermolecular forces and they can be remolded into new shapes. They can be softened between 65 °C and 200°C and can be returned to their original state by heating.

b) Properties of Thermosetting polymers

Thermosetting Polymers are some polymers which cannot be reshaped once heated as they are completely decomposed.

Examples: Bakelite, epoxy-resins, silicones, Formica .etc.

Advantages and disadvantages of the above mentioned properties:

Advantages:

1. Thermoplastics are not expensive. They are even recyclable.

2. Thermosets retain their strength and shape even when heated, they have high heat resistance and structural integrity.

Disadvantages:

1. Thermo-plasts melt and some degrade in direct sunlight or und high U.V light levels. Rather than deform under high stress.

2. Thermosets absorb moisture and toxicity easily.

3. They are not recyclable.

2. Biodegradable and non-biodegradable properties:

These are the properties of polymers depending on how they react overtime, to be broken by microorganisms.

a) Biodegradable polymers:

Biodegradable polymers are the polymers that are fully decomposed into carbon dioxide, methane, water, biomass and inorganic compounds under aerobic or anaerobic conditions and the action of living organisms.

Characteristics of biodegradable polymers:

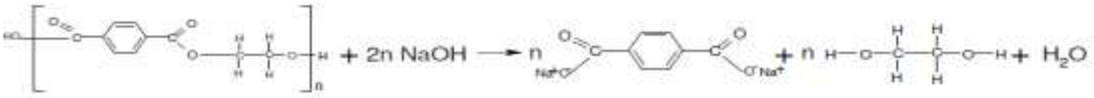
1. They are slightly soluble in water;

Example: poly (ethanol)''–(CH2-CHOH) $_{n-}$'' also called poly (vinyl alcohol or PVA)

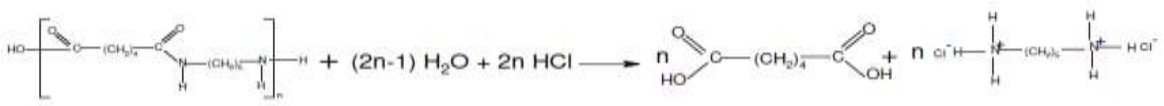
2. They decompose slowly at the sunlight (they are photodegradable).

The break-up of these polymers is carried out in aqueous solution and can be classed as hydrolysis reactions:

Polyesters are best hydrolyzed in strongly alkaline conditions, in which they undergo saponification:

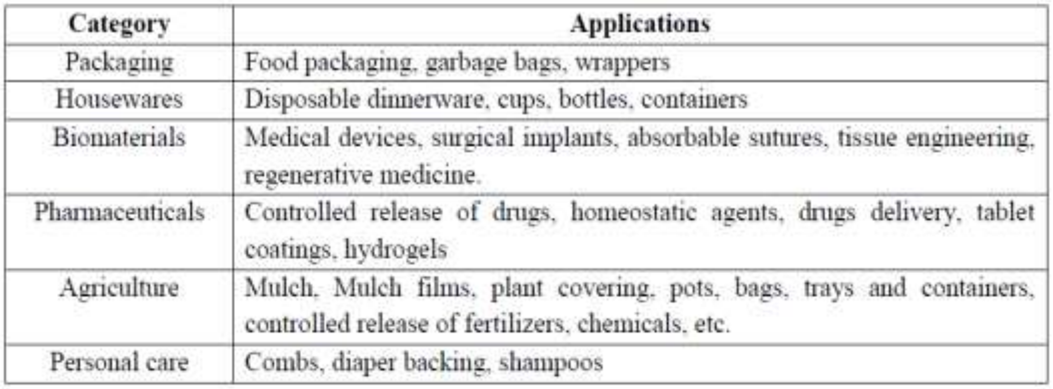


Polyamides are best hydrolyzed in strongly acidic conditions:



Physical and chemical durability is one of the reasons for their widespread use.

Application of biodegradable polymers



Category	Applications
Packaging	Food packaging, garbage bags, wrappers
Housewares	Disposable dinnerware, cups, bottles, containers
Biomaterials	Medical devices, surgical implants, absorbable sutures, tissue engineering, regenerative medicine.
Pharmaceuticals	Controlled release of drugs, homeostatic agents, drugs delivery, tablet coatings, hydrogels
Agriculture	Mulch, Mulch films, plant covering, pots, bags, trays and containers, controlled release of fertilizers, chemicals, etc.
Personal care	Combs, diaper backing, shampoos

b) Properties of Non-biodegradable polymers:

All kind of plastics and synthetic fibers are non-biodegradable. They are polymers which are resistant to environmental degradation thus accumulate in form of waste.

However their low reactivity means that they are not easily decomposed in nature and as a result have a very long lifetime.

LO 4.3: Demonstrate polymerization process

- Describing polymerization
  - ✓ Chain growth polymerization (addition)
  - Chain initiation
  - Chain propagation
  - Chain termination
  - Ionic polymerization

- Co-ordination polymerization
- ✓ Step-growth polymerization (Condensation)
- Addition
- Elimination

Polymerization is the process in which monomer units are linked by chemical reaction to form long chains (polymers).

For example:

Butadiene + butadiene + butadiene + … + butadiene → Polybutadiene

Note:

1. The degree of polymerization (n) is defined as the number of monomeric units in a macromolecule or polymer

2. A polymer formed by identical monomers is called **homopolymrer** while a polymer formed by different monomers is a **copolymer**.

❖ **Types of polymerization**

1. Addition polymerization

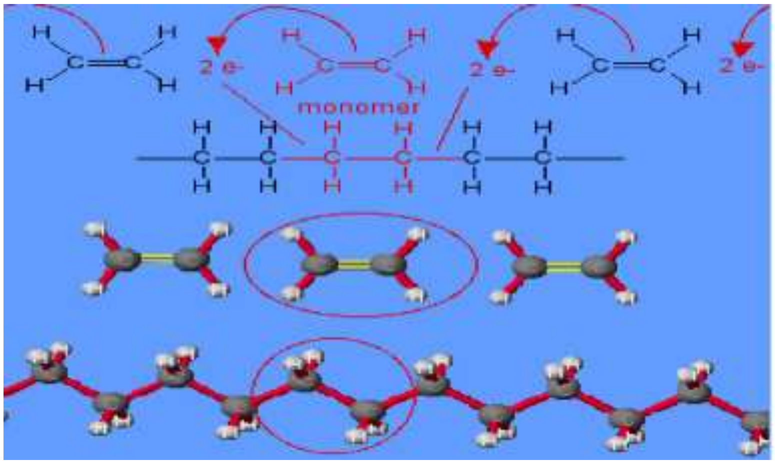
Addition polymerization is a process where monomers are linked together to form a polymer, without the loss of atoms from the molecules. When the monomer molecules add up to form the polymer, the process is called "**Addition polymerization**".

Example 1:

Formation of polyethene or polyethylene

Polyethene is formed by addition of $CH_2=CH_2$ monomer molecules linked together as follows

$$\underset{\text{Ethene}}{n\,CH_2 = CH_2} \rightarrow \underset{\text{Polyethene}}{[-\,CH_2 — CH_2 —]_n}$$



Example 2:

Formation of PVC (polyvinylchloride)

PVC (polyvinyl chloride) is found in plastic wrap, simulated leather, water pipes, and garden hoses, it is formed from vinyl chloride ($H_2C=CHCl$).

nCH2=CHCl → [-CH2-CHCl-] n, where **n** can be between 700-1500

Vinyl chloride Polyvinylchloride

Example 3:

Formation of rubber: Rubber can be natural or synthetic

Rubber: Is a natural polymer of isoprene (2-methyl-1, 3-butadiene).

Natural rubber has elastic properties because it has the ability to return to its original shape after being stretched or deformed.

Addition polymerization takes place in three steps:

i) **Chain initiation**

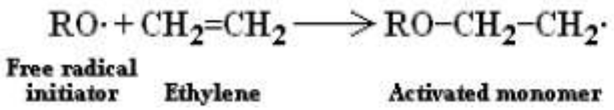
A peroxide molecule breaks up into two reactive free radicals. Light or heat can provide the energy needed for this process.

The process of initiation involves two parts:

1. The generation of free radicals is shown by the following equation:

$$\underset{\textbf{Peroxide}}{\mathrm{ROOR}} + \mathrm{energy} \longrightarrow \underset{\textbf{Free radical initiator}}{2\mathrm{RO}\cdot}$$

2. The second part of initiation occurs when the free radical initiator attacks and attaches to a monomer molecule.



$$RO\cdot + CH_2{=}CH_2 \longrightarrow RO{-}CH_2{-}CH_2\cdot$$

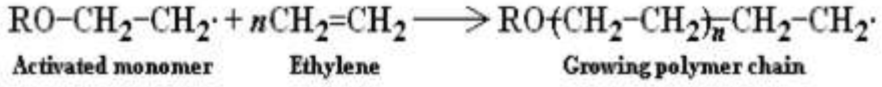
ii) **Chain propagation**

During this step, there is successive addition of large number of monomer molecules to form polymer free radical chain

This addition occurs again and again to make the long polymer chain.

Example of long chain that can be formed: $RO\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_2$.

The equation of the above polymer can be written as follows:



$$RO{-}CH_2{-}CH_2\cdot + nCH_2{=}CH_2 \longrightarrow RO(CH_2{-}CH_2)_n CH_2{-}CH_2\cdot$$

The "n" stands for any number of monomer molecules

iii) Chain termination

Termination step involves the coupling of two free radicals in order to produce a final molecule.

$R. + R. \rightarrow R\text{-}R$

Example: $R\text{-}(CH_2{=}CH_2)\ n\text{-}CH_2\text{-}CH_2 + CH_2\text{-}CH_2\text{-}(CH_2\text{-}CH_2)\ m\text{-}R \rightarrow R\text{-}(CH_2\text{-}CH_2)\ n\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_2\ (CH_2\text{-}CH_2)\ m\ –R$

Remember: The R and R' groups can be the original free radicals, the growing polymer chains or even one of each.

Condensation polymerization

Condensation polymerization is a process where two or more monomers chemically combine to form a polymer with elimination of simple molecules like water, ammonia, hydrogen chloride, alcohol, etc.

There are two main types:

1. Polyamides which are formed between a diol with a dicarboxylic acid.

2. **Polyesters** which are formed when a dicarboxylic acid and a diamine react to form nylons.

Example 1:

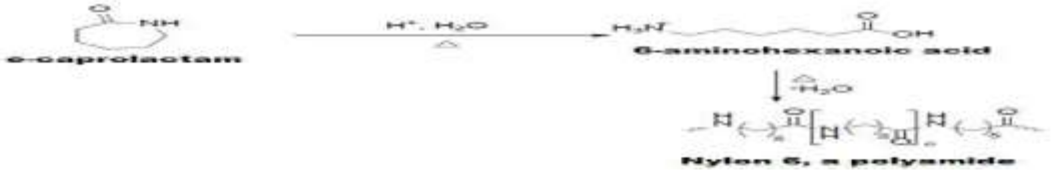
Formation of Polyamides

This type of polymers is formed by the result of generation of amide bonds in the polymerization reaction.

i) Formation of Nylon

Here the number 6 represents the number of carbon atoms present in the monomer

Unit.



Nylon -6, 6 is produced by the condensation reaction between two monomer units adipic acid and1, 6-hexanediamine in the presence of heat.

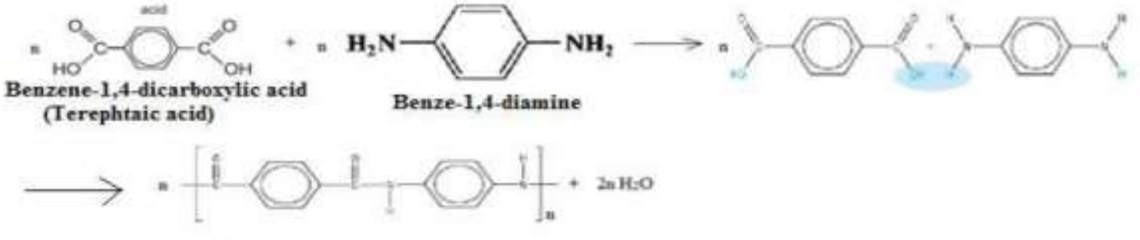
$$nH_2N\text{–}(CH_2)_6\text{–}NH_2 + nHOOC\text{–}(CH_2)_4\text{–}COOH \xrightarrow{-2nH_2O} -(NH\text{–}(CH_2)_6\text{–}NH\text{–}CO\text{–}(CH_2)_4\text{–}CO)_n-$$

1, 6-Hexanediamine   Adipic acid   Nylon -6,6

(ii) Formation of Kevlar

Kevlar is formed from the polymerization of benzene -1,4-diamine and benzene-1,4-dioic acid as follows:

Benzene-1,4-dioic acid + Benzene-1,4-diamine → Kevlar + water



Kevlar

In that polymerization –NH$_2$ group of hexamethylene diamine reacts with –COOH group of adipic acid to form –NH-CO- amide linkage with elimination of H2O.

Polyamides such as **nylon-6, 6** and **Kevlar** are widely used in clothing.

Kevlar has some remarkable properties, including fire resistance and higher strength than steel.

It is used to make protective clothing-for example for fighters, bulletproof vests and helmets.

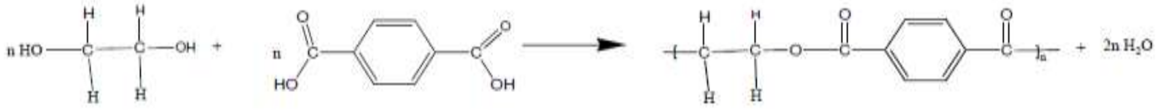
Example 2:

Formation of Polyesters

(i) Formation of Terylene

Terylene is formed by reacting 1, 2- ethanediol and benzene -1, 4-dicarboxylic acid with loss of Water molecules.

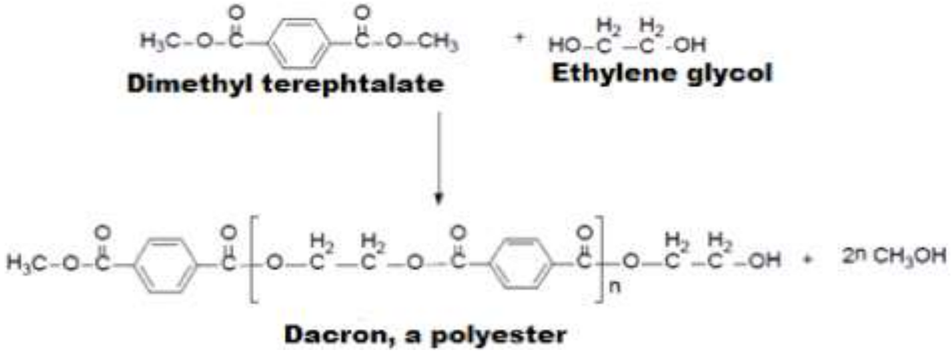
Benzene -1, 4-dicaboxylic acid + ethane-1, 2-diol (ethylene glycol) → Terylene + water

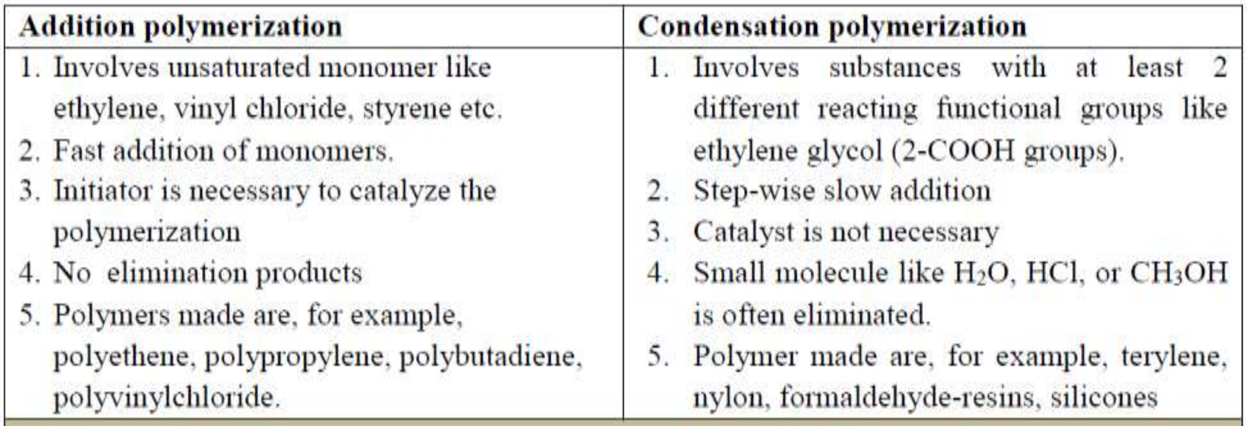


ii) Formation of Dacron

It is made from dimethyl -1, 4-benzene dicarboxylate and 1, 2-ethane diol:

Dimethyl -1, 4-benzene dicarboxylate + 1, 2-ethane diol → Dacron + methanol





Addition polymerization	Condensation polymerization
1. Involves unsaturated monomer like ethylene, vinyl chloride, styrene etc.	1. Involves substances with at least 2 different reacting functional groups like ethylene glycol (2-COOH groups).
2. Fast addition of monomers.	2. Step-wise slow addition
3. Initiator is necessary to catalyze the polymerization	3. Catalyst is not necessary
4. No elimination products	4. Small molecule like H_2O, HCl, or CH_3OH is often eliminated.
5. Polymers made are, for example, polyethene, polypropylene, polybutadiene, polyvinylchloride.	5. Polymer made are, for example, terylene, nylon, formaldehyde-resins, silicones

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