Brahmastra Academy

Celebrating Knowledge Progressively

GENERAL SCIENCE

CHEMISTRY

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Trend Analysis (2016-2014)

CHEMISTRY

S.No.	Chapter Name	2016 (I)	2015 (II)	2015 (I)	2014 (II)
1	Physical and Chemical Changes	1	-	-	1
2	Elements, Mixtures and Compounds	3	-	-	1
3	Laws of Chemical Combination and Gas Laws	-	1	-	-
4	Concept of Atomic, Molecular and Equivalent Masses	1	-	-	3
5	Atomic Structure and Radioactivity	1	2	-	2
6	Periodic Classification of Elements	-	3	1	-
7	Chemical Bonding	1	-	1	2
8	Acids, Bases and Salts	3	2	1	1
9	Oxidation, Reduction and Electrochemistry	2	-	1	1
10	Non-Metals and Their Compounds	9	3	6	2
11	Some Important Chemical Compounds	2	1	6	2
	Total	**23**	**12**	**16**	**15**

01

PHYSICAL AND CHEMICAL CHANGES

Generally 1-2 questions are asked from this chapter. Questions from this chapter are mostly based upon the facts about physical and chemical changes.

There are some changes during which no new substances are formed whereas during some other changes new substances are formed. Therefore on this basis we can classify all the changes into two groups- physical changes and chemical changes.

1. Physical Changes

A physical change is a change in which the composition of a substance is not affected, i.e. no new substance is formed.
e.g. Interconversion of states is a physical change because these changes occur without a change in composition and no change in the chemical nature of the substance.

When an ordinary piece of iron is magnetised in the presence of a strong magnetic field. Here the colour, density, mass and the composition remains the same. Hence, magnetisation is a physical change. The physical changes are reversible. Magnetisation can be reversed by heating the piece of iron.

Evaporation, distillation, sublimation, condensation and crystallisation are examples of physical changes.

The blue colour of copper sulphate crystal disappears when it is heated strongly because on heating water of crystallisation of crystal is lost. It regains its blue colour when moistened with a drop of water.

$$\underset{\text{Blue}}{CuSO_4 \cdot 5H_2O} \xrightarrow{\text{Heat}} \underset{\text{White}}{CuSO_4} + 5H_2O$$

It is an example of a physical change.

Some facts about the physical changes are

(i) Physical changes are temporary and reversible.

(ii) Composition of the constituent of matter remains same during physical change i.e. constituent particles of matter does not change.

(iii) Physical changes are due to the change in physical properties like density, volume, state temporarily.

Note

- Amount of space that a substance or object occupies is called volume of that substance.
- Density is the degree of compactness of a substance. It is defined as mass per unit volume.

  i.e. $\text{Density} = \frac{\text{Mass}}{\text{Volume}}$

2. Chemical Changes

These changes result in the formation of new substances. In a chemical change, the composition and molecular structure of the substance undergoing changes are considered.

e.g. When a piece of iron or nail is left in moist air for a long time, it rusts and gives a reddish brown look. During rusting process iron combines with oxygen to give a new product.

Here rusting, is a chemical change which cannot be reversed back by any physical process. As we eat food, the digestion of food starts from the mouth and during this process many chemical changes take place in the stomach.

The complex food material gets converted into simple molecules of glucose which is oxidised in the body cells to release energy.

Similarly, burning of any substance is a chemical change. Burning is always accompanied by the production of heat. Explosion of a fire work is also a chemical change (heat, light, sound and unpleasant gases are produced in explosion).

Blue copper sulphate crystals on heating loses its all water molecules giving white anhydrous salt which decomposes into black cupric oxide and sulphur trioxide on strong heating.

$$\underset{\text{Blue}}{CuSO_4 \cdot 5H_2O} \xrightarrow[-5H_2O]{\text{Heat}} \underset{\text{White}}{CuSO_4} \xrightarrow[\text{heat}]{\text{Strongly}} \underset{\text{Black}}{CuO} + SO_3$$

➧ **Note**

- Burning of a candle is an example of both physical and chemical changes.
- Ozone is decomposed to oxygen in the presence of ultraviolet rays. It is an example of chemical change.

Some facts about the chemical changes are

(i) During chemical changes, the composition of the substance changes due to change in constituent particles of substance.

(ii) Identity of the substance is lost during a chemical change.

(iii) Energy is absorbed or released during a chemical change.

(iv) Chemical change is permanent and irreversible.

PRACTICE EXERCISE

1. Which of the following is a true statement about the physical change?
(a) Physical changes are temporary changes and can be reversed
(b) During physical changes the composition of constituents molecule changes.
(c) Energy is absorbed or released during a physical change
(d) Identity of the substance is lost after the physical change

2. Which of the following is not a chemical change?
(a) Combustion of fuel
(b) Electrolysis of acidified water
(c) Oxidation reaction of cells at anode
(d) Glowing of a platinum wire

3. Which of the following is a physical change?
(a) Oxidation (b) Reduction
(c) Both (a) and (b) (d) None of these

4. Which of the following is a physical change?
(a) Formation of curd
(b) Burning of candle
(c) Rusting of iron rod
(d) Heating of copper wire by electricity

5. Which of the following is a chemical change?
(a) Heating of iron to red hot
(b) Magnetisation of iron piece
(c) Rusting of iron
(d) All of the above

6. Which of the following is a chemical change?
(a) Evaporation (b) Dissolution
(c) Sublimation (d) Precipitation

7. Which of the following is always accompanied during a chemical change?
(a) Evolution of light
(b) Evolution or absorption of heat
(c) Evolution of heat only
(d) Absorption of heat only

8. Which of the following substances undergo chemical changes on heating?
(a) Sodium chloride
(b) Silica
(c) Lead nitrate
(d) Platinum wire

9. Which one among the following is a chemical process?
(a) Distillation of sea (salty) water
(b) Crystallisation of impure salt (NaCl)
(c) Production of iodine (I_2) from seaweeds
(d) Sublimation of iodine (I_2)

10. Which among the following is a chemical change?
(a) A wet towel dries in the sun
(b) Lemon juice added to tea causing its colour to change
(c) Hot air rises over a radiator
(d) Coffee is brewed by passing steam through ground coffee

11. Any change in matter that results in the disappearance of one or more substances and the appearance of one or more substances, each having its own set of intensive properties is known as
(a) extrinsic change
(b) intrinsic change
(c) physical change
(d) chemical change

12. Heating of a substance results in
(a) a physical change
(b) a chemical change
(c) a physical or a chemical change
(d) None of the above

13. An endothermic reaction is accompanied by
(a) evolution of light and water
(b) evolution of heat
(c) absorption of heat
(d) None of the above

14. Combustion of a candle is a/an
(a) physical change
(b) reduction reaction
(c) endothermic reaction
(d) exothermic reaction

15. Which of the following represent a physical change?
I. Cutting of carrot into pieces.
II. Separation of iron and sulphur from their mixture
III. Formation of salt from sea-water
Codes
(a) I and II (b) II and III
(c) I and III (d) All of these

16. Which of the following represent both physical and chemical change?
I. Burning of candle
II. Burning of methane
III. Decomposition of salt
Codes
(a) I and II (b) II and III
(c) I and III (d) Only I

Directions (Q. Nos. 17-19) *Following questions consist of two statements, I and II. Examine these two statements and select the correct choice according to the codes given below.*

(a) Both the statements are true and Statement II is the correct explanation of Statement I
(b) Both the statements are true but Statement II is not the correct explanation of Statement I
(c) Statement I is true, but Statement II is false
(d) Statement I is false, but Statement II is true

17. **Statement I** Sublimation of NH_4Cl is a chemical change.
Statement II Sublimation is a phenomenon in which a solid on heating directly changes into gas without changing to liquid.

18. **Statement I** Emission of light from stars is a chemical change.
Statement II Source of light from stars is nuclear fission reactions.

19. **Statement I** Making of soda water by dissolving carbondioxide in water is a chemical change.
Statement II A change in which chemical composition remains same is called physical change.

20. Which of the following processes related to physical change?
I. Salt dissolved in water.
II. Dissociation of salt in water
III. Decomposition of salt by electrolysis
Codes
(a) I and II (b) II and III
(c) I and III (d) All of these

21. Which of the following represent a chemical change?
I. Magnetisation of iron
II. Condensation of liquid
III. Burning of fuel
IV. Rusting of iron
Codes
(a) I and II (b) II and III
(c) III and IV (d) I and IV

22. Which of the following processes related to chemical change?
I. Movement of free electrons in copper wire.
II. Electric current passes through copper wire.
III. Electric current passes through NaCl aqueous solution.
Codes
(a) I and II
(b) II and III
(c) I and III
(d) III only

23. Which of the following processes responsible for chemical change?
I. Electrolysis II. Sublimation
III. Corrosion IV. Decomposition
Codes
(a) I and II
(b) II and III
(c) III and IV
(d) I, III and IV

24. Which of the following changes are chemical changes?
I. Burning of candle
II. Breaking of chalk
III. Melting of wax
IV. Formation of water from hydrogen and oxygen.
Codes
(a) I and II (b) II and III
(c) III and IV (d) I and IV

25. Match the following

List I	List II
A. Formation of cloud	1. Dissolution of salt
B. Formation of acid rain	2. Rusting
C. Corrosion of iron	3. Chemical change
D. Physical process	4. Physical change

Codes

	A	B	C	D
(a)	4	3	2	1
(b)	1	2	3	4
(c)	1	3	4	2
(d)	4	2	3	1

Previous Years' Questions

Directions (Q. Nos. 26-27) *Following questions consist of two statements, I and II. Examine these two statements and select the correct choice according to the codes given below.*

(a) Both the statements are true and Statement II is the correct explanation of Statement I.
(b) Both the statements are true but Statement II is not the correct explanation of Statement I.
(c) Statement I is true, but Statement II is false.
(d) Statement I is false, but Statement II is true.

26. **Statement I** Conversion of blue copper sulphate to black cupric oxide on heating is a physical change.
Statement II A change in which chemical composition does not change is called physical change. **2012 (I)**

27. **Statement I** The bule colour of copper sulphate crystal disappears when it is heated strongly.
Statement II Due to heating water of crystallisation of crystal is lost. **2012 (I)**

28. Which one among the following is not a chemical change? **2013 (I)**
(a) Curdling of milk (b) Ripening of fruits
(c) Evaporation of water
(d) Burning of coal

29. A sample of carbon dioxide that undergoes a transformation from solid to liquid and then to gas would undergo **2014 (II)**
(a) a change in mass
(b) a change in density
(c) a change in composition
(d) no change in physical properties

30. Which one of the following is not a chemical change? **2016 (I)**
(a) Ripening of fruits
(b) Curdling of milk
(c) Freezing of water
(d) Digestion of food

ANSWERS

1	*a*	2	*d*	3	*d*	4	*d*	5	*c*	6	*d*	7	*b*	8	*c*	9	*c*	10	*d*
11	*d*	12	*c*	13	*c*	14	*d*	15	*d*	16	*d*	17	*d*	18	*c*	19	*d*	20	*a*
21	*c*	22	*d*	23	*d*	24	*d*	25	*a*	26	*d*	27	*a*	28	*c*	29	*b*	30	*c*

02

ELEMENTS, MIXTURES AND COMPOUNDS

Usually 2-3 questions are asked from this chapter. Questions are mostly based upon the states of matter and also on the basic knowledge of element, compound and mixture.

MATTER

Anything that occupies space and possesses mass is termed as **matter**.

Matter is made up of small particles. There are intermolecular spaces between the constituent particles of matter. The matter may be classified as follows:

(i) **Physical classification** *Matter may be classified into five states:* Solids, liquids, gases, plasma and Bose-Einstein condensate. Plasma and Bose–Einstein condensate states can be seen in specific conditions.

(ii) **Chemical classification** *Matter may be classified into*
(a) pure substances (elements and compounds)
(b) mixtures

States of Matter

Almost all substances exist in three states under appropriate conditions of temperature and pressure.

1. Solids

Characteristics of solids are as follows:

(i) Solids have a definite shape and a definite volume.

(ii) Intermolecular forces operating between the molecules are very strong due to which their positions are fixed. Molecules can only vibrate to and fro about their mean position.

(iii) Molecules are closely packed and associated with minimum energy.

➨ **Note**

- The melting point of a solid is an indication of strength of intermolecular forces of attraction.
- Melting point of a solid ∝ strength of intermolecular forces.

Solids can be of the following two types:

(i) **Amorphous solids** Constituent particles do not possess the orderly arrangement over the long range. e.g. glass, rubber and plastic etc. Glass is a supercooled liquid.

(ii) **Crystalline solids** Constituent particles are arranged in an orderly arrangement over the long range. e.g. graphite, diamond, NaCl etc.

Crystalline solids can be further classified as:

(a) **Ionic solids** Constituent particles are ions and interparticle forces are strong electrostatic forces of attraction, e.g. NaCl, $BaCl_2$, ZnS.

(b) **Metallic solids** Constituent particles are positively charged kernels and free electrons. Interparticle forces are metallic bonds. e.g. Fe, Cu, Al etc.

(c) **Covalent solids** Constituent particles are atoms and interparticle forces are strong covalent bonds. e.g., diamond, quartz, SiO_2.

(d) **Molecular solids** Constituent particles are molecules and interparticle forces are hydrogen bonds or van der Waals' forces. e.g. solid CO_2, I_2 etc.

2. Liquids

Characteristics of liquids are as follows:

(i) Liquids have no definite shape but have a definite volume.
(ii) Intermolecular forces operating between the molecules are weak due to which they can slide over one another but cannot escape the boundary in normal conditions.
(iii) Molecules are closely packed and associated with intermediate energy due to motion.

3. Gases

Characteristics of gases are as follows:

(i) Gases have neither definite shape nor volume.
(ii) Intermolecular forces operating between the molecules are very weak due to which their positions are not fixed and thus, they can move freely.
(iii) Molecules are wide apart and are associated with maximum energy.
(iv) Gases exert pressure on the walls of the container due to collision of molecules with the walls of the container.

➨ **Note** Compressibility depends upon the intermolecular spaces between the particles of matter. Compressibility ∝ intermolecular spaces

Solid < liquid < gas

CHANGE IN STATE AND LATENT HEAT

The conversion of a substance from one state to another state at a definite temperature is known as change in state. The state of substance can be changed by changing temperature or pressure.

e.g. Solid state $\underset{\text{cool}}{\overset{\text{heat}}{\rightleftharpoons}}$ Liquid state $\underset{\text{cool}}{\overset{\text{heat}}{\rightleftharpoons}}$ Gaseous state

During the change in state the temperature of the substance does not change but internal potential energy of molecules change.(kinetic energy of molecules remain same).

The amount of heat energy required by a substance from one state to another state at atmospheric pressure is called latent heat of that substance.

Terms Related to Change of State

Melting point The temperature at which a solid melts to become a liquid at the atmospheric pressure is called its melting point. When a solid melts, its temperature remains the same. Melting point of those substances which contract upon melting reduces on increasing pressure. On the other hand melting point of those substances which expand upon melting increases with increasing pressure.

Freezing point The temperature at which a liquid becomes solid at the atmospheric pressure is called its freezing point.

Boiling point The temperature at which a liquid starts boiling at the atmospheric pressure is called its boiling point. Boiling is a bulk phenomenon. Boiling point of water increases in presence of impurities in the water. Boiling point in creases on increasing pressure upon liquid that's why food cooks comparatively faster in pressure cooker.

PURE SUBSTANCES

These substances have fixed composition and non-variable properties.

These can not be separated into simple substances by physical methods. Elements and compounds are pure substances.

1. Elements

An element is a substance which cannot be split up into two or more simpler substances by the usual chemical methods of applying heat, light or electric energy.

There are 118 elements known at present, out of which 92 elements occur in nature, while remaining 26 elements have been prepared artificially except one.

Elements may be found in all the three forms as solid, liquid or gas.

Solid Sodium (Na), carbon (C), aluminium (Al) etc.

Liquid Mercury (Hg), bromine (Br) etc.

Gas Oxygen (O_2), hydrogen (H_2) etc.

Elements are divided in the following forms:

(i) **Metals** The elements which have a tendency to form positive ions by loss of electrons are called metals, e.g. silver, tin, zinc etc. Metals are the elements having lustre, ductility, malleability, conductivity etc. All metals except mercury exists as solids at room temperature. Oxides of metals are basic or amphoteric in nature. Aluminium is the most abundant metal in the earth's crust.
(ii) **Non-metals** The elements which have a tendency to form negative ion by gain of electrons are called non-metals. e.g. hydrogen, oxygen, sulphur etc. They are in solid or gaseous form under normal conditions except bromine which exists as liquid. Oxides of non-metals are neutral (in low oxidation state) or acidic (in higher oxidation state) in nature.
(iii) **Metalloids** They are the elements whose properties fall between those of metals and non-metals. e.g. boron (B), silicon (Si), germanium (Ge), arsenic (As), antimony (Sb), tellurium (Te) and polonium (Po) etc.

Symbols Derived from Latin Name of the Elements

English name of the element	*Latin name of the element*	*Symbol*
Copper	Cuprum	Cu
Gold	Aurum	Au
Iron	Ferrum	Fe
Lead	Plumbum	Pb
Mercury	Hydrargyrum	Hg
Potassium	Kalium	K

English name of the element	*Latin name of the element*	*Symbol*
Silver	Argentum	Ag
Sodium	Natrium	Na
Tin	Stannum	Sn
Tungsten	Wolfram	W

2. Compounds

A compound is a substance made up of two or more elements chemically combined in a fixed proportion by weight, e.g. water, NaCl, NH_4OH and CO_2 etc.

Silicon (Si) is an element and silica (SiO_2) is a compound.

Properties of Compounds

Following are the main properties of compounds:

- A compound cannot be separated into its components by physical methods.
- The properties of a compound are entirely different from those of its constituent elements.
- The composition of a compound is fixed, i.e. the constituents are present in fixed proportion by weight.
- Compounds have fixed melting point, boiling point etc.
- A compound is a homogeneous substance.

MIXTURES

A mixture is a substance which consists of two or more elements or compounds not chemically combined together. e.g. air, milk, ink, brine, lime water, glass, paints, soil, food, wood, kerosene etc.

There are two types of mixtures, which are as follows

1. **Homogeneous Mixture or Solution**
   A homogeneous mixture has a same composition throughout its mass. It has no visible boundaries of separation between the various constituents, e.g. solution of sugar in water, alloy, solution of salt in water, a mixture of alcohol and water etc.
2. **Heterogeneous Mixture** A heterogeneous mixture does not have a uniform composition throughout its mass. It has visible boundaries of separation between the various components, e.g. solution of $K_2Cr_2O_7$ in water, solution of $CaCO_3$ in water, solution of oil in water, gun powder, soil, etc.

➧ **Note** A mixture which boils at a definite temperature and distils over without any change in composition is called **azeotropic mixtures**. e.g. ethanol-water, acetone-benzene, benzene-chloroform etc.

Properties of a Mixture

Following are the main properties of a mixture:

- A mixture can be separated into its components by physical methods like, filtration, evaporation, sublimation, distillation, magnet etc.
- A mixture shows the properties of all the constituents present in it. Energy is usually neither given out nor absorbed during the preparation of a mixture.
- The composition of a mixture is variable, i.e. the constituents can be present in any proportion by weight.
- A mixture does not have a definite melting point, boiling point etc. (except azeotropic mixture).

Methods for Separation of Mixture

General methods used for the separation of a mixture are as follows:

(i) **Crystallisation** This method is based on the difference in the solubility of the various compound dissolved in a common solvent. e.g. a mixture of KNO_3 and NaCl can be separated by this process.

(ii) **By separatory funnel** This method is used to separate a mixture of two immiscible liquids. e.g. mixture of oil and water, extraction of iron from its ore.

(iii) **Sublimation** When a solid changes directly from solid to gaseous state on heating, the process is known as sublimation. This process is used to separate such mixtures that contain a sublimable volatile component from a non-sublimable impurity. This process is generally used for the separation of naphthalene, anthracene, benzoic acid, camphor, NH_4Cl, iodine etc.

Iodine (I_2) is the only halogen which sublimes.

NH_4Cl sublimes due its decomposition.

(iv) **Distillation** This method is used for the purification of liquids which boils without decomposition and contain non-volatile impurities. e.g. pure water can be obtained from sea water by distillation, mixture of ether and toluene, benzene and aniline, etc.

(v) **Fractional distillation** This process is used to separate a mixture of two or more miscible liquids which possess their boiling points within the limit of 10 to 15 K. e.g. petrol, diesel, kerosene.

(vi) **Distillation under reduced pressure** This process is used for those liquids which decomposes below their boiling point under reduced pressure, liquid boils at low temperature. Hence, the temperature for decomposition is not reached. Thus, this process is known as **vacuum distillation**, e.g. glycerol can be separated by this method. It is also used for the concentration of sugar cane juice in sugar industry.

(vii) **Steam distillation** It is used for the separation and purification of liquids which are appreciably volatile in steam from non-volatile components of mixture, e.g. *o*-nitrophenol and *p*-nitrophenol are separated by this method. Aniline is also purified by this method.

(viii) **Evaporation** It is the process by which soluble solids can be obtained from their solution by allowing the solvent to vaporise, e.g. salt can be obtained from salt solution by evaporation.

(ix) **Chromatography** It is a modern method proposed by Tswett in 1903. This method is based on the difference in the rates at which the components of a mixture are adsorbed on a suitable adsorbent.

This method has been used

(a) to separate *o* and *p*-nitrophenol,

(b) to separate blue and red dyes,

(c) to separate plant pigments and other natural products.

(x) **Atmolysis** It is used for separating the mixture of gases. This method is based on the difference in their rates of diffusion.

$^{235}UF_6$ and $^{238}UF_6$ can be separated by this method.

(xi) **Dialysis** The process of separating the colloidal particles from those of crystalloids by diffusion of mixture through a parchment or animal membrane is known as dialysis e.g. A ferric hydroxide sol can be purified by this method.

PRACTICE EXERCISE

1. The most abundant gas in the atmosphere is
(a) nitrogen (b) oxygen
(c) helium (d) carbon dioxide

2. Which one of the following is most abundant metallic element?
(a) Aluminium (b) Iron
(c) Gold (d) Silver

3. An element which is not found in nature is
(a) Pt (b) K
(c) Zn (d) Pu

4. Which one of the following is not a mixture?
(a) Air (b) Mercury
(c) Milk (d) Cement

5. Which one among the following is an element?
(a) Graphite (b) Glass
(c) Brass (d) Steel

6. Metalloids are
(a) alloys of alkali metals with other metals
(b) colloids of metals
(c) element having some properties of metals and non-metals
(d) metals heavier than lead

7. Purest form of iron is
(a) cast iron (b) pig iron
(c) steel (d) wrought iron

8. Magnesium is present in
(a) haemoglobin (b) chlorophyll
(c) vitamin B_{12} (d) ascorbic acid

9. Match list I with list II and select the correct answer from the codes given below the lists.

List I (Element)	**List II** (Symbol)
A. Thallium	1. Tm
B. Thorium	2. Tl
C. Thulium	3. Tb
D. Terbium	4. Th

Codes

	A	B	C	D		A	B	C	D
(a)	2	4	3	1	(b)	2	4	1	3
(c)	1	3	2	4	(d)	4	2	1	3

10. Which of the following is neither an element nor a compound?
(a) Air (b) Water
(c) Mercury (d) Sodium chloride

11. LPG (Liquefied petroleum gas) is a
(a) mixture (b) compound
(c) element (d) None of these

12. A student by chance mixed acetone with alcohol. This mixture of acetone and alcohol can be separated by
(a) filtration
(b) separating funnel
(c) fractional crystallisation
(d) fractional distillation

13. Tinstone and wolframite is separated by
(a) magnetic method
(b) atmolysis
(c) chromatography
(d) None of the above

14. A mixture of $^{235}UF_6$ and $^{238}UF_6$ is separated by
(a) sublimation (b) filtration
(c) atmolysis (d) None of these

15. The boiling points of two miscible liquids *X* and *Y* are close to each other. Their separation is best carried out by
(a) simple distillation
(b) vacuum distillation
(c) steam distillation
(d) None of the above

16. Which of the following are correctly matched with the method used for separating them?
I. Lanthanides—chromatography
II. H_2O and CCl_4—steam distillation
III. Glycerine and H_2O—vacuum distillation
IV. Phenol and benzoic acid—separating funnel

Codes
(a) Only III (b) I and III
(c) Only IV (d) IV and I

17. A mixture containing SiO_2, NaCl and NH_4Cl is taken for separating the constituents. The suitable steps required for this are
(a) sublimation-dissolution filtration crystallisation
(b) dissolution-filtration-crystallisation distillation
(c) sublimation-evaporation-dissolution decomposition
(d) dissolution-distillation-decomposition-evaporation

18. Steam distillation is used to separate
(a) lemon oil
(b) sandal wood oil
(c) aniline
(d) All of the above

19. A mixture that can be separated by the sublimation method is
(a) $MgCl_2 + NaCl$ (b) $HgCl_2 + NaCl$
(c) $AgCl + NaCl$ (d) $BaCl_2 + 2NaCl$

20. Iodine is separated from sand by
(a) sublimation
(b) chromatography
(c) crystallisation
(d) evaporation

21. A mixture of methanol and acetone is separated by
(a) fractional distillation
(b) steam distillation
(c) vacuum distillation
(d) None of the above

22. A mixture of red and blue ink can be separated by
(a) distillation
(b) crystallisation
(c) chromatography
(d) sublimation

23. Choose the correct statements using the codes given below.
I. Impure glycerine is purified by vacuum distillation.
II. Glycerine dissolves in water.
III. Water is a homogeneous mixture of hydrogen and oxygen.
Codes
(a) I and II (b) II and III
(c) I and III (d) All of these

24. Chromatography is used to separate
(a) plant pigment
(b) blue and red ink
(c) *o* and *p*-nitrophenol
(d) All of the above

25. In column chromatography, the substance obtained in the top most region of column is
(a) maximum adsorbed
(b) minimum adsorbed
(c) have maximum rate of diffusion
(d) have the highest molecular weight

26. During fractional distillation, the substance with
(a) lower boiling point is obtained first
(b) higher boiling point is obtained first
(c) higher molecular weight is obtained first
(d) lowest melting point is obtained first

27. Dialysis is used for the purification of
(a) suspensions
(b) true solutions
(c) homogeneous mixture
(d) colloidal solution

28. Solution of $CaCO_3$ in water forms a
(a) homogeneous mixture
(b) heterogeneous mixture
(c) azeotropic mixture
(d) None of the above

29. Pure water is obtained from sea water by
(a) filtration
(b) distillation
(c) evaporation
(d) All of the above

30. I_2 in water is extracted with the help of
(a) chloroform
(b) carbon tetrachloride
(c) carbon disulphide
(d) All of the above

31. Which one of the following is not separated by sublimation?
(a) Corrosive sublimate
(b) Calomel
(c) $CuSO_4$
(d) Both (b) and (c)

32. By decreasing pressure boiling point of a liquid
(a) increases (b) decreases
(c) may increase or decrease depending upon temperature of liquid
(d) remains unchanged

33. Water is a compound because
(a) it exists as solid, liquid or gas
(b) it contains hydrogen and oxygen
(c) it contains two different elements joined by chemical bonds
(d) it can be split up into simpler substance by chemical means

34. Which one of the following is the most abundant compound?
(a) H_2O (b) SiO_2 (c) Al_2O_3 (d) Air

35. First organic compound which was prepared in laboratory is
(a) methane (b) urea
(c) formaldehyde (d) water

36. Who prepared the first organic the compound in laboratory?
(a) Dalton (b) Wohler
(c) Kolbe (d) Berthelot

37. Barium carbonate is a/an
(a) compound (b) mixture
(c) element (d) alloy

38. Which one of the following is a compound?
(a) Glass (b) Water gas
(c) CNG (d) Plaster of Paris

39. Which of the following is a compound?
(a) Rhombic sulphur
(b) Marble
(c) Diamond
(d) Quick silver

40. False statement is
(a) germanium is a semi-conductor
(b) steel is an alloy
(c) graphite is an element
(d) the fundamental unit in silicates is Si_2O_3

41. Match List I with List II and select the correct answer from the codes given below the lists

List I	List II
A. Bronze	1. Solution
B. CO_2	2. Compound
C. Mixture of oil and water	3. Heterogeneous mixture
D. Mixture of water and alcohol	4. Solid solution

Codes

	A	B	C	D		A	B	C	D
(a)	4	2	3	1	(b)	1	2	3	4
(c)	2	1	4	3	(d)	2	4	3	1

42. Consider the following statements.
I. Aqueous solution of NaCl is a homogeneous mixture.
II. Alloy is solid solution.
III. Milk is a mixture.
Codes
(a) I and II (b) II and III
(c) I and III (d) All of these

43. Consider the following statements.
I. Brass is a solid solution.
II. Sand and water is a solution.
III. Salt and sand is homogeneous mixture.
IV. Air is a solution.
Codes
(a) I and II (b) II and III
(c) III and IV (d) I and IV

44. Consider the following statements.
I. Pure milk is mixture.
II. Bronze is solution.
III. Brine is solution.
IV. Graphite is pure substance.
Codes
(a) I and II
(b) II and III
(c) III and IV
(d) All of the above

Directions (Q. No. 45-47) *The following items consist of two statements, Statement* I *and Statement* II. *You have to examine these two statements carefully and select the answer to these items using the codes given below.*

Codes
(a) Both the statements are true and Statement II is the correct explanation of Statement I.
(b) Both the statements are true but Statement II is not the correct explanation of Statement I.
(c) Statement I is true, but Statement II is false.
(d) Statement I is false, but Statement II is true.

45. **Statement I** The formation of a mixture neither requires nor releases heat, light and electricity.
Statement II A mixture is a combination of two or more pure substances that are not chemically united.

46. **Statement I** In paper chromatography, both the fixed phase and mobile phase are liquids.
Statement II Distribution of the solute between the two liquids makes the separation possible.

47. **Statement I** *o* and *p*-nitrophenol can be separated by steam distillation.
Statement II *o*-nitrophenol contains intermolecular H-bonding while *p*-nitrophenol exists as associated molecules.

Previous Years' Questions

48. Which one among the following is not a mixture? **2012 (II)**
(a) Graphite (b) Glass
(c) Brass (d) Steel

49. Air is **2012 (II)**
(a) always a compound
(b) always a mixture
(c) a compound in pollution-free zones
(d) a mixture in industrial zones

50. A mixture of sodium chloride and naphthalene can be separated by **2013 (II)**
(a) extraction with hot water
(b) extraction with cold water
(c) sublimation
(d) steam distillation

51. Metalloids are **2013 (II)**
(a) alloys of alkali metals with other metals
(b) colloids of metals
(c) elements having some properties of both metals and non-metals
(d) metals heavier than lead

52. **Statement I** Glass is not considered as a true compound.
Statement II Glass does not have a definite melting point.
Codes **2013 (II)**
(a) Both the statements are true and Statement II is the correct explanation of Statement I.
(b) Both the statements are true but Statement II is not the correct explanation of Statement I.
(c) Statement I is true, but Statement II is false.
(d) Statement I is false, but Statement II is true.

53. The latest discovered state of matter is **2014 (I)**
(a) solid
(b) Bose-Einstein condensate
(c) gas
(d) liquid

54. The symbol of the element 'tungsten' is **2015(II)**
(a) Ta (b) W
(c) Tl (d) Tc

55. Matter around us can exist in three different states namely, solid, liquid and gas. Correct order of their compressibility is
(a) Liquid < Gas < Solid **2016 (I)**
(b) Solid < Liquid < Gas
(c) Gas < Liquid < Solid
(d) Solid < Gas < Liquid

56. The temperature at which a solid melts to become a liquid at the atmospheric pressure is called its melting point. The melting point of a solid is an indication of **2016 (I)**
(a) strength of the intermolecular forces of attraction
(b) strength of the intermolecular forces of repulsion
(c) molecular mass
(d) molecular size

57. When a solid is heated, it turns directly into a gas. This process is called **2016 (I)**
(a) Condensation
(b) Evaporation
(c) Sublimation
(d) Diffusion

ANSWERS

1	*a*	2	*a*	3	*d*	4	*b*	5	*a*	6	*c*	7	*d*	8	*b*	9	*b*	10	*a*
11	*a*	12	*d*	13	*a*	14	*c*	15	*d*	16	*b*	17	*a*	18	*d*	19	*b*	20	*a*
21	*a*	22	*c*	23	*a*	24	*b*	25	*a*	26	*b*	27	*d*	28	*b*	29	*b*	30	*d*
31	*d*	32	*b*	33	*c*	34	*a*	35	*b*	36	*b*	37	*a*	38	*d*	39	*b*	40	*d*
41	*a*	42	*d*	43	*d*	44	*d*	45	*a*	46	*a*	47	*a*	48	*a*	49	*b*	50	*c*
51	*c*	52	*a*	53	*b*	54	*b*	55	*b*	56	*a*	57	*c*						

03

LAWS OF CHEMICAL COMBINATION AND GAS LAWS

In last 2-3 years only 1 question has been asked from this chapter, based upon the understanding of laws of chemical combination.

During the quantitative studies of chemical changes, the combination of elements to form compounds is governed by some basic laws, these are known as **Laws of chemical combination**.

Law of Conservation of Mass

This law establish the relationship between the masses of reactants and products during a chemical reaction. This law was postulated by **A. Lavoisier** in 1750.

This law states "During any physical or chemical change, the total mass of the products is equal to the total mass of the reactants."

Or

"Matter can neither be created nor destroyed during any physical or chemical change".

e.g. $\underset{12g}{C} + \underset{32g}{O_2} \longrightarrow \underset{44g}{CO_2}$

12 g carbon combines with 32 g oxygen to give 44 g carbon dioxide. This law may be explained with the help of Landolt's experiments.

Law of Conservation of Mass in the Light of Modern Research

It is stated by modern research that mass can be converted into energy. There is some energy formed in each reaction, by which some mass has been lost. According to Einstein, mass and energy are related as $E = mc^2$

where, m = the mass of substance, c = velocity of light (3×10^8 m/s) and E = energy.

But in chemical reactions energy released or absorbed is too less, hence, the change in mass (decrease or increase)taking place becomes negligible. These changes can be clearly seen in nuclear reactions.

Law of Constant Composition

This law was stated by French chemist **Joseph Proust.** This law states that

"A sample of a pure chemical compound always consists same elements combined together in the same definite proportions by mass, whatever be its source".

e.g. it is found by the analysis of water (take from various places like river, falls and wells) that in each sample of water, the ratio of hydrogen and oxygen is 2 : 16 or 1 : 8 by mass.

Law of Multiple Proportions

This law was proposed by **John Dalton**. It states that, ''An element may form more than one compound with another element. For a given mass of an element, the masses of other elements (in two or more compounds) come in the ratio of small integers.''

e.g. in NH_3, 14 g of nitrogen requires 3 g of hydrogen and in hydrazine (N_2H_4) 14 g of nitrogen requires 2 g of hydrogen.

Hence, fixed mass of nitrogen required hydrogen in the ratio 3 : 2 in two different compounds (3 : 2 is a simple ratio). Thus, this is in agreement with ''law of multiple proportions''.

Law of Reciprocal Proportions

This law was proposed by **Richter** in 1972. This law is known as the law of equivalent proportions or law of combining weights. This law states that "When two different elements combine separately with the same weight of a third element the ratio in which they do so will be the same or some simple multiple of the ratio in which they combine with each other. e.g. carbon and sulphur react separately with oxygen (third element) to give carbon dioxide (CO_2) and sulphur dioxide (SO_2). They also react together to form carbon disulphide (CS_2).

Now, in carbon dioxide 12 parts by weight of carbon are combine with 32 parts by weight of oxygen and in sulphur dioxide (SO_2) 32 parts by weight of sulphur combine with 32 parts by weight of oxygen.

Ratio of weight of carbon and sulphur which combine with fixed weight (32 parts) of oxygen is

$$= 12 : 32 \text{ or } 3 : 8 \qquad ...(i)$$

In carbon disulphide, 12 parts of weight of carbon reacts with 64 parts by weight of sulphur. Hence, ratio of weight of carbon and sulphur in which they combines to form CS_2 is

$$= 12 : 64 \text{ or } 3 : 16 \qquad ...(ii)$$

Ratio (i) and (ii) are related to each other as follows:

3 : 8 and 3 : 16 or 3 : 3 and 8 : 16 and 1 : 2

Thus, this is an agreement with "law of reciprocal proportions."

Gay-Lussac's Law of Combining Volumes

This law was proposed by **Gay-Lussac.** This law deals with the relation between volumes of reactants and products during chemical reactions.

This law states that "Under the same conditions of temperature and pressure whenever gases react together, the volume of the reacting gases as well as products bears a simple whole number ratio."

e.g. one volume of hydrogen react with one volume of chlorine to give two volumes of hydrogen chloride (gas).

$$\underset{1\text{ Vol}}{H_2} + \underset{1\text{ Vol}}{Cl_2} \longrightarrow \underset{2\text{ Vol}}{2HCl}$$

Hence, volume ratio of $H_2 : Cl_2 : 2HCl$ is 1 : 1 : 2.

GAS LAWS

Gaseous state is the simple state of the matter. The behaviour of gases is governed by some general laws known as **Gas laws**. These laws are relationships between temperature, pressure, volume and mass.

Gas laws are as follows:

Boyle's Law According to Boyle's law, at constant temperature, pressure of a gas varies inversely with its volume.

$$p \propto \frac{1}{V} \qquad [\text{at constant } T]$$

$$\Rightarrow \quad pV = K \qquad [K = \text{constant}]$$

$$\Rightarrow \quad p_1V_1 = p_2V_2$$

Charles' Law According to this law, at constant pressure the volume of a given mass of a gas varies directly with its temperature.

$$V \propto T \qquad [\text{at constant } p]$$

$$V = KT \qquad [K = \text{constant}]$$

$$\Rightarrow \quad \frac{V}{T} = K$$

$$\Rightarrow \quad \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Bursting of hydrogen balloon and making of chappati are the applications of Charles' law.

Gay-Lussac's Law According to this law, "At a constant volume, the pressure of a given mass of a gas is directly proportional to its absolute temperature."

$$P \propto T \text{ or } \frac{P}{T} = \text{constant}, \quad \frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Avogadro's Law Under similar conditions of temperature and pressure, equal volume of all gases contain equal number of molecules.

Or

At a given temperature and pressure, the volume of any gas is directly proportional to the number of moles of gas.

$V \propto n$ where, n = number of moles

$$\frac{V}{n} = K \text{ (constant)}$$

Dalton's Law of Partial Pressure

According to this law, if two or more gases, which do not react chemically, are enclosed in a vessel, the total pressure exerted by the gaseous mixture is the sum of partial pressures exerted by the constituent gases".

$$p = p_1 + p_2 + p_3 + \ldots\ldots$$

Where, p = Total pressure of mixture

$p_1, p_2, p_3 \ldots\ldots$ = Partial pressures of gases 1, 2, 3 .....

IDEAL GAS

The gas which obeys gas laws at all conditions of temperature and pressure is known as ideal gas.

Characteristics of an Ideal Gas

These are as follows:

(i) It obeys Boyle's law, Charles' law and Avogadro's law at all conditions of temperature and pressure.

(ii) It is hypothetical.

(iii) Attractive forces among the molecules do not exist therefore an ideal gas cannot be converted into liquid or solid.

➨ **Note** Real gases show ideal behaviour only at low pressure and high temperature. H_2, O_2, N_2 etc. are real gases.

Ideal Gas Equation

From Boyle's law and Charles' law,

we have $\frac{PV}{T} = \text{constant}$ ... (i)

for 1 mole gas,

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \quad \text{... (ii)}$$

This relation is known as gas equation.

Therefore gas equation for 1 mole gas, $\frac{PV}{T} = R$ or $PV = RT$

For n mole gas, $pV = nRT$ or $pV = \frac{W}{M}RT$ or $pM = dRT$

Where, W = mass of a gas, M = molar mass of a gas, d = density of a gas, p = pressure of a gas, T = temperature in Kelvin, V = volume

Here, R is a gas constant (universal gas constant). Its different values are as follows:

$$R = 0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1}$$
$$= 8.314 \times 10^7 \text{ erg mol}^{-1} \text{ K}^{-1} = 1.99 \text{ cal mol}^{-1} \text{ K}^{-1}$$

IMPORTANT FACTS

- At higher temperature kinetic energy of gas molecules is higher due to which pressure of gas increased.
- Standard temperature and pressure (STP or NTP) mean 273·15 K (0°C) temperature and 1 bar (i.e. 10^5 pascal pressure. At STP molar volume of an ideal gas is 22·71098 mol^{-1}.
- The volume of 1 mole of any gas at STP is 22.4 L.

PRACTICE EXERCISE

1. Which of the following law deals with mass of reactants and products during a chemical reaction?
(a) Law of definite proportions
(b) Law of conservation of energy
(c) Law of conservation of mass
(d) Law of reciprocal proportions

2. Law of conservation of mass is not correct for
(a) radioactive change
(b) oxidation
(c) hydrolysis
(d) None of the above

3. Chemical equation is balanced according to the law of
(a) multiple proportions
(b) reciprocal proportion
(c) conservation of mass
(d) definite proportion

4. Radioactive change follows the law of
(a) conservation of mass
(b) conservation of mass-energy
(c) Both (a) and (b)
(d) None of the above

5. Which of the following statement is correct about the reaction given below?

$$4\,Fe(s) + 3O_2 \longrightarrow 2\,Fe_2O_3(g)$$

(a) Total mass of reactants = Total mass of product therefore it follows law of conservation of mass.
(b) Total mass of reactants = total mass of product, therefore, law of multiple proportions is followed
(c) Amount of Fe_2O_3 can be increased by taking any one of the reactants (iron or oxygen) in excess
(d) Amount of Fe_2O_3 produced will decrease if the amount of any one of the reactants (iron or oxygen is taken in excess

6. If 2.0 g of the hydrogen reacts with 16.0 g of oxygen to form 18.0 g of water, which of the following laws is applicable?
(a) Law of conservation of mass
(b) Law of constant compositions
(c) Law of multiple proportions
(d) Law of reciprocal proportions

7. Which of the following is the best example of the law of conservation of mass?
(a) When 12 g of carbon is heated in vacuum, there is no change in mass.
(b) Weight of platinum wire is the same before and after heating.
(c) A sample of air increases in volume when heated at constant pressure but mass remains unchanged.
(d) 12 g of carbon combines with 32 g of oxygen to give 44 g of carbon dioxide.

8. Which one of the following is a correct relationship between mass and energy?
(a) $E = hc$ (b) $E = \frac{m}{c^2}$
(c) $c = \sqrt{E/m}$ (d) $m = Ec^2$

9. The law of constant proportion was proposed by
(a) Proust (b) Einstein
(c) Richter (d) Dalton

10. The ratio in weight by which carbon and oxygen combine in a molecule of carbon monoxide is
(a) 3 : 4 (b) 3 : 3 (c) 3 : 2 (d) 3 : 1

11. Calcium carbonate is naturally available as limestone and can also be synthesised from quick lime. It is seen that the composition of the elements in both the natural and synthetic calcium carbonate are same. The validity of which one among the following laws is confirmed by this observation?
(a) Law of conservation of mass
(b) Law of definite proportions
(c) Law of multiple proportions
(d) Avogadro's law

12. Two different oxides of a metal contain 20% and 27% oxygen by weight. This is an accordance with the law of
(a) conservation of mass
(b) constant composition
(c) multiple proportion
(d) reciprocal proportion

13. The law of multiple proportions was proposed by
(a) Lavoisier (b) Dalton
(c) Proust (d) Gay-Lussac

14. Different proportions of oxygen in the various oxides of nitrogen prove the law of
(a) equivalent proportion
(b) multiple proportions
(c) constant proportions
(d) conservation of matter

15. Two samples of lead oxide were separately reduced to metallic lead by heating in a current of hydrogen. The weight of lead from one oxide was half the weight of lead obtained from the other oxide. The data illustrate
(a) law of reciprocal proportions
(b) law of constant proportions
(c) law of multiple proportions
(d) law of equivalent proportions

16. Two elements A and B combine to form two compounds in which a_1 g of A combines with b_1 and b_2 g of B respectively. According to the law of multiple proportions
(a) $b_1 = b_2$
(b) b_1 and b_2 bear a simple whole number ratio
(c) a_1 and b_1 bear whole number ratio
(d) no relation exists between b_1 and b_2

17. Which one of the following pairs of compounds illustrate the law of multiple proportion?
(a) H_2O, Na_2O (b) H_2O, H_2O_2
(c) Na_2O, BaO (d) All of these

18. Which of the following compound confirm the law of multiple proportion?
(a) H_2O and H_2O_2 (b) CaO and Na_2O
(c) H_3PO_4 and $Ca_3(PO_4)_2$
(d) NaCl and AgCl

19. The law of multiple proportions is not illustrated by which pair of compounds.
(a) CO and CO_2 (b) CuO and Cu_2O
(c) CO_2 and H_2CO_3 (d) SO_2 and SO_3

20. Which of the following compounds confirm the law of multiple proportion?
(a) $HgCl_2$ and Hg_2Cl_2
(b) Na_2O and CaO (c) NaCl and $BaCl_2$
(d) H_3PO_4 and $Ca_3(PO_4)_2$

21. One part of an element A combines with two parts of another element B. Six parts of the element C combines with four parts of the element B. If A and C combined together the ratio of their weights will be governed by
(a) law of definite proportions
(b) law of multiple proportions
(c) law of reciprocal proportions
(d) law of conservation of mass

22. Hydrogen, sulphur and oxygen gives H_2S, SO_2 and H_2O. This is according to the law of
(a) constant proportions
(b) multiple proportions
(c) reciprocal proportions
(d) conservation of mass

23. 8 g of oxygen combine with 1 g of hydrogen and 20 g of calcium therefore, when calcium combines with hydrogen it must combine in the ratio of 20 : 1. This statement confirms to the law of
(a) multiple proportions
(b) reciprocal proportions
(c) definite proportions
(d) gaseous volume

24. Equal volumes of all gases under same temperature and pressure contain equal number of molecules according to
(a) Avogadro's law (b) Charles' law
(c) Boyle's law (d) Graham's law

25. Law of combining volumes was given by
(a) Dalton (b) Tswett
(c) Gay-Lussac (d) Einstein

26. According to which one of the following laws it is indicated that when two or more gases react with one another, their volume bear a simple ratio?
(a) Law of mass action
(b) Law of multiple proportions
(c) Law of reciprocal proportions
(d) Law of combining volumes

27. In the reaction, $N_2 + 3H_2 \longrightarrow 2NH_3$, ratio by volume of N_2, H_2 and NH_3 is 1 : 3 : 2. This suggested law of
(a) definite proportions
(b) multiple proportions
(c) reciprocal proportions
(d) combining volume

28. Equal masses of oxygen, hydrogen and methane are kept under identical conditions. The ratio of the volumes of gases will be
(a) 1 : 1 : 1 (b) 1 : 16 : 2
(c) 2 : 16 : 1 (d) 1 : 4 : 1

29. Real gas will approach the behaviour of ideal gas at
(a) low temperature and high pressure
(b) high temperature and low pressure
(c) low temperature and low pressure
(d) high temperature and high pressure

30. Which of the following reactions is not correct according to the law of conservation of mass?
(a) $2Mg + O_2 \longrightarrow 2MgO$
(b) $C_3H_8 + O_2 \longrightarrow CO_2 + H_2O$
(c) $P_4 + 5O_2 \longrightarrow P_4O_{10}$
(d) $CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$

31. Pressure of a gas increases due to increase of its temperature because at higher temperature
(a) gas molecules repel each other
(b) potential energy of the gas molecules is higher
(c) kinetic energies of the gas molecules are higher
(d) gas molecules attract each other

32. A pressure cooker works on the principle of
(a) elevation of boiling point of water by the application of pressure
(b) making the food-grains softer by the application of pressure
(c) making the food-grains softer by the application of pressure and temperature
(d) keeping the food grains inside steam for a longer time

33. With regard to the gaseous state of matter which of the following statements are correct?
(a) Complete order of molecules.
(b) Complete disorder of molecules
(c) Random motion of molecules
(d) Both (b) and (c)

34. Ideal gas equation is the combination of
I. Boyle's law II. Charles' law
III. Avogadro law
IV. Dalton's law of partial pressure
Choose the correct option.
(a) I and II (b) I, II and III
(c) II and III (d) I, III and Iv

35. Consider the following statements.
I. The ideal gas consists of a large number of small particles called molecules.
II. Under the same conditions of temperature and pressure equal volumes of gases contain the same number of molecules.
III. Volume of a definite quantity of gas at constant pressure is directly proportional to absolute temperature.
Which of the above statements is Avogadro's hypothesis?
(a) Only I (b) Only II
(c) I and II
(d) None of the above

36. Consider the following laws.
I. Law of conservation of mass
II. Law of definite proportions
III. Law of multiple proportions
Which of these govern(s) the quantitative aspects of chemical changes?
(a) Only I (b) II and III
(c) I and II
(d) All of the above

Directions (Q. Nos. 37-38) *The following items consist of two statements, Statement* I *and Statement* II. *You have to examine these two statements carefully and select the answer to these items using the codes given below.*
(a) Statement I is true, Statement II is true, Statement II is a correct explanation for Statement I.
(b) Statement I is true, Statement II is true, Statement II is not a correct explanation for Statement I.
(c) Statement I is true, Statement II is false.
(d) Statement I is false, Statement II is true.

37. **Statement I** One molecule of ammonia always contains one atom of nitrogen and three atoms of hydrogen.
Statement II According to the law of conservation of mass matter can neither be created nor destroyed in a chemical reaction.

38. **Statement I** On increasing the temperature of an ideal gas 10°C at constant volume, the pressure increases by 10%.
Statement II At a constant volume, the pressure of a given mass of a gas is directly proportional to its absolute temperature.

Previous Years' Question

39. Ammonia (NH_3) obtained from different sources always has same proportion of nitrogen and hydrogen. It proves the validity the law of **2015 (II)**
(a) reciprocal proportion
(b) constant proportion
(c) multiple proportions
(d) None of the above

ANSWERS

1	c	2	a	3	c	4	b	5	a	6	a	7	a	8	c	9	a	10	a
11	b	12	c	13	b	14	b	15	c	16	b	17	b	18	a	19	c	20	a
21	c	22	c	23	b	24	a	25	c	26	d	27	d	28	b	29	b	30	b
31	c	32	a	33	d	34	b	35	b	36	d	37	b	38	a	39	b		

Solutions

5. *(a)* According to the law of conservation of mass.
Total mass of reactants = Total mass of products

6. *(a)* $\underset{2\,g}{H_2} + \frac{1}{2}\underset{16\,g}{O_2} \longrightarrow \underset{18\,g}{H_2O}$
According to law of conservation of mass, mass of reactants = mass of products.

8. *(c)* Einstein equation for the relationship between mass and energy is $E = mc^2$ or or $c = \sqrt{E/m}$

10. *(a)* In a molecule of carbon monoxide, the ratio of carbon and oxygen by weight is 12 : 16 or 3 : 4.

11. *(b)* A pure compound contains the same elements in the fixed ratio of their weights whatever its methods of preparation may be. Therefore, $CaCO_3$ always contains 40 : 12 : 48 or 10 : 3 : 12 ratio of calcium, carbon and oxygen by weight respectively.

27. *(d)* $\underset{1\,Vol}{N_2} + \underset{3\,Vol}{3H_2} \longrightarrow \underset{2\,Vol}{2NH_3}$
According to law of combining volumes; when gases react together, they always do so in volumes which bear a simple ratio to one another and to the volume of the products.

28. *(b)* Oxygen Hydrogen Methane
(O_2) (H_2) (CH_4)
Number of moles
$\frac{1}{32} = 0.031$; $\frac{1}{2} = 0.5$; $\frac{1}{16} = 0.0625$
Simple ratio 1 6 2
Equal number of moles of gases occupy equal volumes under similar conditions of temperature and pressure, therefore the ratio of the volumes of gases will be 1 : 16 : 2.

30. *(b)* In equation,
$\underset{44g}{C_3H_8} + \underset{32g}{O_2} \longrightarrow \underset{44g}{CO_2} + \underset{18}{H_2O}$
Mass of reactants ≠ mass of products. Hence, law of conservation of mass is not followed.

04

CONCEPT OF ATOMIC, MOLECULAR AND EQUIVALENT MASSES

Generally 2-4 questions are asked from this chapter. Questions from this section are mostly based upon chemical equations, balancing of chemical equation and equation based problems.

Atomic Mass

The average relative mass of an atom of an element as compared to $\frac{1}{12}$th the mass of one atom of carbon-12 (C – 12). In other words atomic mass is a number which expresses as to how many times an atom of the element is heavier than 1/12th of the mass of carbon atom. Therefore,

$$\text{Atomic mass} = \frac{\text{Mass of an atom of the element}}{\frac{1}{12}\text{ th mass of one carbon atom (C - 12)}}$$

Atomic mass is expressed in atomic mass unit (amu or u). Atomic mass unit (u) is defined as $\frac{1}{12}$ th the mass of carbon atom C – 12.

Average Atomic Mass

It has been found that majority of the elements found to possess several isotopes. Isotopes are the different atoms of the same element possessing different atomic masses but same atomic number. The atomic mass of each **isotope** is determined separately and then combined according to the ratio of their proportion of occurrence. This is known as average atomic mass. If an element have three isotopes with atomic masses m_1, m_2 and m_3 and these occur in the ratio of x, y and z respectively, then its average atomic mass

$$= \frac{m_1 \times x + m_2 \times y + m_3 \times z}{x + y + z}$$

e.g. Boron occurs in nature in the form of two isotopes B^{10}, B^{11} with atomic mass 10 and 11 in the ratio of 1 : 4 respectively.

Therefore, average atomic mass of boron

$$= \frac{10 \times 1 + 11 \times 4}{4 + 1} = \frac{10 + 44}{5} = \frac{54}{5} = 10.8$$

Gram Atomic Mass

The atomic mass of an element expressed in grams is the gram atomic mass or it is also called gram atom, e.g. the atomic mass of oxygen is 16 u, therefore gram atomic mass of oxygen is 16 g.

Molecular Mass

The sum of the atomic masses of all the atoms in a molecule of the substance is called molecular mass of the substance. It is expressed in atomic mass unit(u).

e.g. Molecular mass of H_2SO_4 = 2× atomic mass of hydrogen + atomic mass of sulphur + 4 × atomic mass of oxygen = $2 \times 1 + 32 + 4 \times 16 = 98$

Gram Molecular Mass

Molecular mass of a substance expressed in grams is called gram molecular mass. It is also called as gram molecule, e.g. molecular mass of N_2 is 14 and its gram molecular mass is 14 g.

Equivalent Mass or Equivalent Weight

The number of parts of a substance that combines with or displaces, directly or indirectly, 1.008 parts by mass of hydrogen or 35.5 parts by mass of chlorine or 8 parts by mass of oxygen is called the equivalent mass of the substance.

1. Eq. wt. of metal $= \dfrac{\text{Mass of metal}}{\text{Mass of hydrogen displaced}} \times 1.008$

   or $= \dfrac{\text{Mass of metal}}{\text{Mass of oxygen combined}} \times 8.0$

   or $= \dfrac{\text{Mass of metal}}{\text{Mass of chlorine combined}} \times 35.5$

e.g. In H_2O, NH_3 and CH_4 one mole hydrogen combines with $\frac{1}{2}$ mole oxygen, $\frac{1}{3}$ mole nitrogen and $\frac{1}{4}$ mole carbon respectively. Hence,

Equivalent weight of oxygen $= \frac{1}{2} \times 16 = 8.0$

Equivalent weight of nitrogen $= \frac{1}{3} \times 14 = 4.67$

Equivalent weight of carbon $= \frac{1}{4} \times 12 = 3$

Relation between atomic weight, equivalent weight and valency

Atomic weight = equivalent weight × valency

2. Equivalent weight of acid

$$= \frac{\text{Molecular weight of acid}}{\text{Basicity (number of replaceable } H^+)}$$

e.g. Equivalent weight of $H_2SO_4 = \frac{98}{2} = 49$

3. Equivalent weight of base

$$= \frac{\text{Molecular weight of base}}{\text{Acidity (number of replaceable } OH^-)}$$

e.g. Equivalent weight of NaOH $= \frac{40}{1} = 40$

Equivalent weight of $Ca(OH)_2 = \frac{74}{2} = 37$

4. Eq. wt. of salt $= \dfrac{\text{Molecular weight of salt}}{\text{Total positive valency of metal atoms}}$

e.g. Equivalent weight of NaCl $= \frac{58.5}{1} = 58.5$

e.g. Equivalent weight of $Na_2CO_3 = \frac{106}{2} = 53$

5. Equivalent weight of a substance that undergoes oxidation/reduction $= \dfrac{\text{Molecular weight}}{\text{Change in oxidation number}}$

e.g. When $KMnO_4$ reacts under acidic conditions, change in oxidation number (from +7 to + 2) is 5, hence;

Equivalent weight of $KMnO_4$ in acidic medium

$$= \frac{158}{5} = 31.6$$

Vapour Density

Vapour density of a gas is the ratio of the mass of a certain volume of the gas to the mass of equal volume of hydrogen, measured under same conditions of temperature and pressure.

$$\text{Molecular weight} = 2 \times \text{vapour density}$$

$$\text{Atomic weight} = 2 \times \frac{\text{vapour density}}{\text{atomicity}}$$

Mole

A mole is the amount of substance that contains as many as particles that are present in 12 g of **carbon-12 isotope**. There are 6.023×10^{23} atoms in 12 g carbon-12.

$$\text{Number of mole} = \frac{\text{Weight of substance in grams}}{\text{Gram molecular weight}} = \frac{\text{Number of particles/atoms}}{\text{Avogadro's number}} = \frac{\text{Volume of gas in litres at NTP}}{22.4 \text{ L}}$$

Example 1 mole of an element contains atoms which are equal to Avogadro number. Which of the following has largest number of atoms?

(a) 4 g He (b) 46 g Na

(c) 0.40 g Ca (d) 12 g He

Sol. (d) All the given species are monoatomic therefore, first we calculate number of moles and then compare the number of atoms. We also known that equal number of moles contain equal number of atoms.

No. of moles in 4 g He = 4/4 = 1 mole

No. of moles in 46 g Na = 46/23 = 2 mole

No. of moles in 0.40 g Ca = 0.40/40 = 0.1 mole

No. of moles in 12 g He = 12/4 = 3 mole

Hence, 12 g He contains largest number of atoms.

Gram Molar Volume

The volume occupied by 1 mole of a substance is called the gram molar volume of the substance. The gram molar volume of perfect gas is 22.4 L at STP or NTP.

STP or NTP means 273.15 K (0°C) temperature and 1 bar (10^5 pascal) pressure.

e.g. volume of 1 mole of H_2 at STP = 22.4 L

volume of $\frac{1}{4}$ mole of $H_2 = \frac{22.4}{4} = 5.6$ L

CHEMICAL EQUATION

A chemical equation is the symbolic representation of an actual chemical change,

e.g. $Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2\uparrow$

A chemical equation represents:

- Compounds taking part in the reaction.
- Products or compounds formed during the reaction.
- Catalysts used for the reaction (if any).

Balancing of a Chemical Equation

When the number of atoms of an element present on right hand side [RHS] of the equation becomes equal to that of present on left hand side [LHS] of the equation, the equation is said to balanced. To balance a chemical equation,following steps are followed:

- Check the number of atoms of each element present on RHS and LHS of a equation whether they are equivalent or not.
- If not, multiply the element by a number to the corresponding element.
- Continue multiplying until all numbers become equivalent to the corresponding element.

e.g. $Na_2O + HCl \longrightarrow NaCl + H_2O$

Balancing of Equation

Element	*LHS*	*RHS*
Na	2	1×2 =2
O	1	1
H	1×2 =2	2
Cl	1×2 =2	1×2 =2

The balanced chemical equation is

$$Na_2O + 2HCl \longrightarrow 2NaCl + H_2O$$

Equation Based Problem

Suppose, the equation is $\underset{2\text{ moles}}{2H_2} + \underset{1\text{ mole}}{O_2} \longrightarrow \underset{2\text{ moles}}{2H_2O}$

2 moles of H_2 react with 1 mole of O_2 gives 2 moles of H_2O.

$$\underset{2\text{ molecules}}{2H_2} + \underset{1\text{ molecule}}{O_2} \longrightarrow \underset{2\text{ molecules}}{2H_2O}$$

2 molecules of H_2 react with 1 molecule of O_2 gives 2 molecules of H_2O.

$$\underset{2\times 2\text{ g}}{2H_2} + \underset{32\text{ g}}{O_2} \longrightarrow \underset{2\times 18\text{ g}}{2H_2O}$$

4 g of H_2 reacts with 32 g of O_2 gives 36 g of H_2O.

Limiting Reagent

The substance that is completely consumed in a reaction is called limiting reagent because it determines the amount of product. The other reactant present in excess is called excess reagent e.g.

	$2H_2(g)$	$+ O_2(g) \longrightarrow$	$2H_2O(g)$
Mole before reaction	10	7	0
Mole after reaction	0	2	10

Thus, H_2 is limiting reagent and O_2 is excess reagent.

Strength of a Solution

It is generally expressed in terms of molarity and normality.

(i) **Molarity** (M) It is the number of moles of solute present in 1L of the solution. It is denoted by M.

$$\text{Molarity } (M) = \frac{\text{Number of moles of solute}}{\text{Volume of solution (in L)}}$$

e.g. 0.25 mol L^{-1} (or 0.25 M) solution of NaOH means that 0.25 mol of NaOH is dissolved in 1 L of solution.

(ii) **Formality** (F) It is the number of gram formula weight of solute dissolved in 1 litre of solution when formula weight equals to the atomic weight, then formality equals to molarity.

$$\text{Formality } (F) = \frac{\text{Gram formula weight of solute}}{\text{Volume in litre}}$$

(iii) **Normality** (N) It is the number of gram equivalents of solute dissolved per litre of the solution.

$$\text{Normality } (N) = \frac{\text{Gram equivalent of solute}}{\text{Volume of solution (L)}}$$

e.g. 0.50 g equiv.L^{-1} (or 0.50 N) solution of H_2SO_4 means that 0.50 g equiv. of H_2SO_4 is dissolved in 1 litre of solution.

(iv) **Molality** (m) It is the number of moles of the solute dissolved in 1 kg of solvent. It is denoted by m.

$$\text{Molality } (m) = \frac{\text{Number of moles of solute}}{\text{Mass of solute (in kg)}}$$

e.g. 1.00 m kg^{-1} (or 1.00 m) solution of KCl means that 1 mol (74.5 g) KCl is dissolved in 1 kg of water.

Molality is independent of temperature whereas molarity, normality and formality change with temperature. This is because volume depends upon temperature and the mass do not.

PRACTICE EXERCISE

1. Number of atoms present in a molecule is called
(a) mole ratio (b) molecularity
(c) atomicity
(d) Avogadro's number

2. 1u is equal to
(a) $\frac{1}{12}$ of C^{12} (b) $\frac{1}{14}$ of O^{16}
(c) 1g of H_2 (d) 1.66×10^{-23} kg

3. The statement which is wrong about gram atomic mass is
(a) it is the atomic mass expressed in grams
(b) it is also called gram atom
(c) one gram atom of an element contain 6×10^{23} atoms
(d) None of the above

4. Chlorine occurs in nature in the form of two isotopes with atomic mass 35 and 37 in the ratio of 3 : 1 respectively. The average atomic mass of chlorine is
(a) 38.5 (b) 35.5
(c) 36 (d) None of these

5. If M is the molecular mass of $KMnO_4$ then equivalent weight of $KMnO_4$ in acidic medium is
(a) $M/2$ (b) $M/4$ (c) $M/7$ (d) $M/5$

6. What is the equivalent mass of $KMnO_4$ when it change into $Mn_2(SO_4)_3$?
(a) M (b) $M/5$ (c) $M/6$ (d) $M/4$

7. 74 g of a metallic chloride contains 35.5 g of chlorine. The equivalent weight of the metal is
(a) 38.5 (b) 74.4 (c) 35.5 (d) 71

8. Approximate atomic weight of a metal is 26.89. If its equivalent weight is 8.9 its exact atomic weight will be
(a) 26.7 (b) 8.9 (c) 26.89 (d) 17.8

9. Potassium permanganate gives the following reactions in neutral
$MnO_4^- + 2H_2O + 3e^- \longrightarrow MnO_2 + 4OH^-$
The equivalent weight of $KMnO_4$ is (atomic mass of Mn = 55u)
(a) 158 (b) 79
(c) 52.66 (d) 31.6

10. Equivalent weight of crystalline oxalic acid is
(a) 45 (b) 90 (c) 126 (d) 63

11. Equivalent weight of nitrogen varies in its oxides, because it
(a) contains five electrons in its valence orbit
(b) contains half-filled p -orbitals
(c) is a diatomic molecule
(d) has variable valency

12. Atomic weight of a trivalent element of equivalent weight 9 is
(a) 9 (b) 27 (c) 18 (d) 36

13. A reaction between HCl and O_2 is given by
$4HCl + O_2 \longrightarrow 2H_2O + 2Cl_2$
The equivalent weight of HCl is equal to
(a) its molecular weight
(b) half of its molecular weight
(c) twice of its molecular weight
(d) four times its molecular weight

14. Equivalent weight of sulphur in SCl_2 is 16. What is the equivalent weight of S in S_2Cl_2?
(a) 16 (b) 64 (c) 32 (d) 8

15. Equivalent weight of a metal is 29.4. It forms metal sulphate isomorphous with epsom salt. The atomic weight of the metal is
(a) 58.8 (b) 14.7 (c) 29.4 (d) 88.2

16. The mass of an atom of nitrogen is
(a) $\frac{14}{6.022 \times 10^{23}}$g (b) $\frac{28}{6.022 \times 10^{23}}$g
(c) $\frac{1}{6.022 \times 10^{23}}$g (d) 14 u

17. How many atoms are present in a mole of H_2SO_4?
(a) $3 \times 6.02 \times 10^{23}$ (b) $5 \times 6.022 \times 10^{23}$
(c) $6 \times 6.02 \times 10^{23}$ (d) $7 \times 6.02 \times 10^{23}$

18. 2 g of oxygen contain number of atoms equal to that contained in
(a) 0.5 g hydrogen (b) 4.0 g sulphur
(c) 7.0 g nitrogen (d) 2.3 g sodium

19. The number of sulphur atoms in its 40 g is
(a) $40 \times 6.022 \times 10^{23}$ (b) $32 \times 6.022 \times 10^{23}$
(c) $\frac{40 \times 6 \times 10^{23}}{32}$ (d) $\frac{32 \times 6 \times 10^{23}}{40}$

20. Number of atoms in 4.25 g of NH_3 is (approx.)
(a) 1×10^{23} (b) 1.5×10^{23}
(c) 2×10^{23} (d) 6×10^{23}

21. Which of the following has maximum number of atoms?
(a) 18 g of water (b) 16 g of O_2
(c) 4.4 g of O_2 (d) 16 g of CH_4

22. The mass of a molecule of water is
(a) 3×10^{-26} kg (b) 3×10^{-25} kg
(c) 1.5×10^{-26} kg (d) 2.5×10^{-26} kg

23. Which of the following has largest number of atoms?
(a) 71 g of chlorine
(b) 48 g of magnesium
(c) 127 g of iodine
(d) 4 g of hydrogen

24. The number of moles of CO_2 which contain 16 g of oxygen is
(a) 0.25 (b) 0.50 (c) 1 (d) 2

25. A mole of compound is composed of 6.023×10^{23} atoms of hydrogen, 35.5 g of chlorine and 48 g of oxygen. The compound is
(a) HClO (b) $HClO_2$
(c) $HClO_3$ (d) $HClO_4$

26. How many moles of electrons weigh one kilogram?
(a) 6.023×10^{23} (b) $\frac{1}{9.08} \times 10^{31}$
(c) $\frac{6.023}{9.108} \times 10^{54}$ (d) $\frac{1}{9.108 \times 6.023} \times 10^{8}$

27. Number of electron present in 10 g of H_2O is
(a) $\frac{6.022 \times 10^{-23}}{6}$ (b) $\frac{6.02 \times 10^{25}}{18}$
(c) $\frac{6.022 \times 10^{22}}{6}$ (d) None of these

28. The volume occupied by 4.4 g of CO_2 at STP is
(a) 22.4 L (b) 2.24 L
(c) 0.224 L (d) 0.1 L

29. Consider the following equation for the formation of ammonia from nitrogen and hydrogen
$N_2 + 3H_2 \longrightarrow 2NH_3$

How many hydrogen molecules are required to react with 100 molecules of nitrogen?
(a) 100 (b) 200 (c) 300 (d) 400

30. What weight of SO_2 can be made by burning sulphur in 5.0 moles of oxygen?
(a) 640 g (b) 160 g (c) 80 g (d) 320 g

31. Which of the following statements are true?
I. The valencies of elements forming isomorphous compounds are same.
II. Equivalent mass may vary with change of valency.
III. Some elements show variable valency.
Select the correct answer using the codes given below.
(a) I and II (b) II and III
(c) I and III (d) All of these

32. Consider the following statements.
I. The number of moles is directly proportional to the number of molecules of the substance.
II. Mole concept is also applicable to ionic compounds, which do not contain molecules.
III. 'Molecular mass' word is not suitable word for the ionic compounds.
IV. Formula mass unit is taken for ionic compounds.
Select the correct answer using the codes given below
Codes
(a) I, II and III (b) II, III and IV
(c) I, III and IV (d) All of these

Directions (Q. Nos. 33-34)
Following questions consist of two Statements, I and II. Examine these two statements and select the correct choice according to the codes given below.
(a) Both the statements are true and Statement II is the correct explanation of Statement I.
(b) Both the statements are true but Statement II is not the correct explanation of Statement I.
(c) Statement I is true but Statement II is false.
(d) Statement I is false but Statement II is true.

33. **Statement I** Average atomic mass of elements may be in fraction.
Statement II Due to presence of isotopes of elements.

34. **Statement I** Equivalent mass of element may vary.
Statement II Valency of element may vary.

35. Match List I with List II and select the correct answer from the codes given below the lists:

List I	List II
A. Molarity	1. Gram formula weight of solute in one litre of solution.
B. Molality	2. Number of gram equivalents of solute dissolved in one litre of solution
C. Normality	3. Number of moles of solute dissolved in 1kg of solvent.
D. Formality	4. Number of moles of solute in one litre of solution

Codes

	A	B	C	D
(a)	4	3	2	1
(b)	1	2	3	4
(c)	4	2	3	1
(d)	2	3	4	1

Previous Years' Questions

36. Which one among the following equations is correctly balanced? **2012 (II)**
(a) $NaOH + Al + H_2O \longrightarrow 2H_2 + NaAlO_2$
(b) $2NaOH + 2Al + 2H_2O \longrightarrow 3H_2 + 2NaAlO_2$
(c) $2NaOH + 2Al + 3H_2O \longrightarrow 4H_2 + 2NaAlO_2$
(d) $2NaOH + 2Al + H_2O \longrightarrow H_2 + 2NaAlO_2$

37. Which one among the following is the equivalent weight of sulphuric acid?
(Atomic weight : H = 1, S = 32 and O = 16) **2012 (II)**
(a) 98 (b) 60
(c) 100 (d) 49

38. The number of aluminium ions present in 54 g of aluminium (atomic weight = 27) is **2014 (I)**
(a) 2 (b) 18
(c) 1.1×10^{24} (d) 1.2×10^{24}

39. Consider the following balanced chemical equation,
$2CO + O_2 \rightleftharpoons 2CO_2$
Which one of the following statements is significant in relation to the above chemical equation? **2014 (II)**
(a) One can add to a vessel only 2 moles of CO for each moles of O_2 is added
(b) No matter how much of these two reagents are added to a vessesl, 1 mole of O_2 is consumed
(c) When they react, CO reacts with O_2 in a 2:1 mole ratio
(d) When 2 moles of CO and 1 mole of O_2 are placed in a vessel, they will react to give 1 mole of CO_2

40. If the reaction of 1.0 mole $NH_3(g)$ and 1.0 mole $O_2(g)$
$4NH_3(g) + 5O_2(g) \longrightarrow 4NO(g) + 6\,H_2O(l)$ is carried to completion, then **2014 (II)**
(a) all the $O_2(g)$ is consumed
(b) 4.0 moles of $NO(g)$ is produced
(c) 1.5 moles of $H_2O(l)$ is produced
(d) all the $NH_3(g)$ is consumed

41. How many grams of $MgCO_3$ contain 24.00 g of oxygen? (The molar mass of $MgCO_3$ is 84.30 g mol^{-1}) **2014 (II)**
(a) 42.15 g
(b) 84.30 g
(c) 126.00 g
(d) 154.00 g

42. Consider the following reaction,
$xAs_2S_3 + yO_2 \longrightarrow zAs_2O_3 + wSO_2$
What is y (the coefficient for O_2) when this equation is balanced using whole number coefficients? **2014 (II)**
(a) 5 (b) 7
(c) 9 (d) 11

43. A compound X_2O_3 contains 31.58% oxygen by weight. The atomic mass of X is **2014 (II)**
(a) 34.66 g mol^{-1}
(b) 45.01 g mol^{-1}
(c) 52.00 g mol^{-1}
(d) 104.00 g mol^{-1}

44. What is the number of mole(s) of H_2(g) required to saturate one mole of benzene? **2016 (I)**
(a) 1 (b) 2
(c) 3 (d) 4

45. Which one of the following has different number of molecules? (All are kept at normal temperature and pressure) **2016 (II)**
(a) 3 gram of Hydrogen
(b) 48 gram of Oxygen
(c) 42 gram of Nitrogen
(d) 2 gram of Carbon

ANSWERS

1	*c*	2	*a*	3	*d*	4	*b*	5	*d*	6	*d*	7	*a*	8	*a*	9	*c*	10	*d*
11	*d*	12	*b*	13	*a*	14	*c*	15	*a*	16	*a*	17	*d*	18	*b*	19	*c*	20	*d*
21	*d*	22	*a*	23	*d*	24	*b*	25	*c*	26	*d*	27	*b*	28	*b*	29	*c*	30	*d*
31	*d*	32	*d*	33	*a*	34	*a*	35	*a*	36	*b*	37	*d*	38	*d*	39	*c*	40	*a*
41	*a*	42	*c*	43	*c*	44	*c*	45	*d*										

Solutions

3. *(d)* 1 g-atom = N atoms = 6.023×10^{23} atoms = g-atomic weight

e.g. 1 g atom of oxygen = N atoms of oxygen

$= 6.023 \times 10^{23}$ atoms of oxygen = 16 g

4. *(b)* $M_{av} = \dfrac{35 \times 3 + 37 \times 1}{3 + 1} = 35.5$

5. *(d)* Eq. wt. of an oxidising agent

$$= \frac{\text{Molar mass } (M)}{\text{Change in oxidation number}} = \frac{M}{5}$$

7. *(a)* The number of parts of a substance that combines with 35.5 parts by mass of chlorine is called the equivalent mass of the substance. Therefore, equivalent weight (mass) of the metal is

$$74\text{g} - 35.5\text{g} = 38.5\text{g}$$

9. *(c)* $\overset{+7}{Mn}O_4^- + 2H_2O + 3e^- \rightarrow \overset{+4}{Mn}O_2 + 4\,OH^-$

Change in oxidation number = 3

Equivalent weight of

$$KMnO_4 = \frac{158}{3} = 52.66$$

10. *(d)* Eq. wt. of an acid = $\dfrac{\text{Mol. wt.}}{\text{Basicity of acid}}$

$$= \frac{126}{2} = 63$$

12. *(b)* At. wt. of an element = eq. wt × valency = $9 \times 3 = 27$

15. *(a)* Atomic wt. of a metal = eq. wt × valency = $29.4 \times 2 = 58.8$

16. *(a)* Mass of an atom of an element

$$= \frac{\text{Molar mass of an atom of element}}{6.023 \times 10^{23}}$$

$$= \frac{14}{6.022 \times 10^{23}}\ \text{g}$$

17. *(d)* 1 mole H_2SO_4 = 2 mole of H atoms + 1 mole of S atom + 4 mole of O atoms

= 7 mole atoms

$= 7 \times 6.023 \times 10^{23}$ atoms

18. *(b)* Equal number of moles contain equal number of atoms

2g of oxygen = $\dfrac{2}{16}$ mole = 0.125 mole

Similarly 4 g sulphur = $\dfrac{4}{32} = \dfrac{2}{16}$ mole

= 0.125 mole

0.5 g hydrogen = $\dfrac{0.5}{1} = 0.5$ mole

7.0 g nitrogen = $\dfrac{7}{14} = 0.5$ mole

2.3 g sodium = $\dfrac{23}{23} = 0.1$ mole

Therefore atoms in 2 g oxygen = atoms in 4.0 g sulphur.

19. *(c)* 40 g sulphur = $\dfrac{40}{32}$ mole

1 mole = 6.023×10^{23} atoms

$\dfrac{40}{32}$ mole = $\dfrac{40 \times 6.023 \times 10^{23}\,\text{atoms}}{32}$

20. *(d)* 4.25 g $NH_3 = \dfrac{4.25}{17}$ = mole NH_3

$$\frac{4 \times 4.25 \times 6.023 \times 10^{23}}{17} = 6.023 \times 10^{23}\,\text{atoms}$$

(1 mole NH_3 = 1 mole N atoms + 3 mole H atoms = 4 mole atoms)

21. *(d)* 18 g water = $\dfrac{18}{18} = 1$ mole

$= 1 \times 3 \times 6.023 \times 10^{23}$ atoms

16 g $O_2 = \dfrac{16}{32} = 0.5$ mole

$= 0.5 \times 2 \times 6.023 \times 10^{23}$ atoms

4.4 g $O_2 = \dfrac{4.4}{32} = 0.1375$ mole

$= 0.1375 \times 2 \times 6.023 \times 10^{23}$ atoms

16 g $CH_4 = \dfrac{16}{16} = 1$ mole

$= 1 \times 5 \times 6.023 \times 10^{23}$ atoms (maximum)

22. *(a)* Mass of 1 molecule of H_2O = $\dfrac{18}{6.023 \times 10^{23}}$ g

$= 2.9885 \times 2$

$= 2.9885 \times 10^{-26}$ kg $\approx 3 \times 10^{-26}$ kg

23. *(d)* 71g chlorine = $\dfrac{71}{71} = 1$ mole Cl_2

$= 2 \times 6.023 \times 10^{23}$ atoms

48g magnesium = $\dfrac{48}{24} = 2$ mole Mg

$= 2 \times 6.023 \times 10^{23}$ atoms

127g iodine = $\dfrac{127}{127 \times 2} = 0.5$ mole I_2

$= 2 \times 0.5 \times 6.023 \times 10^{23}$ atoms

4g hydrogen = $\dfrac{4}{2}$

= 2 mole H_2

$= 2 \times 2 \times 6.023 \times 10^{23}$ atoms (maximum atoms)

24. *(b)* 32 g oxygen present in 1 mole CO_2

therefore 16g oxygen present in = $\dfrac{16 \times 1}{32} = 0.5$ mole CO_2

25. *(c)* 100 molecules of N_2 will react with 300 molecules of H_2

6.023×10^{23} atom of H = 1 mole H atom

35.5 g chlorine = 1 mole Cl atom

48 g oxygen = 3 mole O atoms

Chemical formula of the compound = $HClO_3$

26. *(d)* 9.108×10^{-31} kg = mass of 1 electron

$$1 \text{ kg} = \frac{1}{9.108 \times 10^{-31}}$$

$$= \frac{1 \times 10^{31}}{9.108} \text{ electrons}$$

6.023×10^{23} electrons = 1 mole

$$\frac{1 \times 10^{31}}{9.108} \text{ electrons}$$

$$= \frac{1 \times 10^{31}}{9.108 \times 6.023 \times 10^{23}} \text{ moles}$$

$$= \frac{10^{8}}{9.108 \times 6.023} \text{ moles of electrons}$$

27. *(b)* 18g H_2O contains

= 10 mole electrons

$= 10 \times 6.023 \times 10^{23}$ electrons

10g H_2O will contain

$$= \frac{10 \times 10 \times 6.023 \times 10^{23}}{18} \text{ electrons}$$

$$= \frac{6.023 \times 10^{25}}{18} \text{ electrons}$$

28. *(b)* Volume occupied by 1 mole (44g) CO_2 = 22.4 L (at STP)

Hence, $\frac{4.4}{44}$ mole CO_2 will occupy

$$= \frac{22.4 \times 4.4}{44}$$

= 2.24 L

29. *(c)* $\underset{1}{N_2} + \underset{3}{3H_2} \longrightarrow 2NH_3$

1 molecule of N_2 reacts with 3 molecules of H_2.

100 molecules of N_2 = 300 molecules of H_2

30. *(d)* $S + \underset{1 \text{ mole}}{O_2} \longrightarrow \underset{(32+2\times16=64\,g)}{SO_2}$

1 mole O_2 gives = 64 g SO_2

Therefore, 5 mole O_2 will give = 64×5 = 320g SO_2

37. *(d)* Equivalent weight

$$= \frac{\text{Molecular weight}}{\text{Basicity}}$$

Basicity of H_2SO_4 = 2

Equivalent weight = $\frac{98}{2}$ = 49

38. *(d)* Number of aluminium ions present in 54 g of aluminium

$$= \frac{6.023 \times 10^{23} \times 54}{27}$$

$$= 1.2 \times 10^{24}$$

40. *(a)* $4NH_3(g) + 5O_2(g) \longrightarrow$

$$\underset{4 \text{ mol}}{4NO(g)} + \underset{5 \text{ mol}}{6H_2O(l)}$$

1 mole of NH_3 requires $\frac{5}{4}$ moles of O_2 = 1.25 mol

Since, for 1 mole of NH_3, 1.25 moles of O_2 are required, therefore, O_2 is the limiting factor (here O_2 is only 1 mole). Hence, all the O_2 will be consumed in reacting with 1 mole of NH_3.

41. *(a)* In $MgCO_3$, there are 3 oxygen atoms in each mole.

Atomic mass of oxygen is 16 g/mol. So, there are $(16 \times 3) = 48$ grams of oxygen in one mole of $MgCO_3$.

Molar mass of $MgCO_3$ = 84.30 g mol^{-1}

$$\frac{48 \text{ g of O}}{84.3 \text{ } MgCO_3} = \frac{24 \text{ g O}}{x \text{ g } MgCO_3}$$

$$x = 42.15 \text{ g}$$

42. *(c)* Balanced chemical equation is $2As_2S_3 + 9O_2 \longrightarrow 2As_2O_3 + 6SO_2$

So, y is 9.

43. *(c)* In compound X_2O_3,

Percentage of oxygen by weight = 31.58

Percentage of X by weight = 68.42

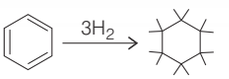
Let the atomic mass of $X = x$

$$\frac{2x}{2x + 48} \times 100 = 68.42$$

$\therefore \quad x = 51.65 \approx 52$

So, atomic mass of X is 52 g mol^{-1}.

44. *(c)*



3 moles of H_2(g) is required to saturate one mole of benzene.

45. *(d)* The mass of 1 mole of a substance is equal to its relative atomic or molecular mass in grams.

1 mole = 6.022×10^{23}

1 gram hydrogen

$= 6.022 \times 10^{23}$ atoms

3 gram hydrogen

$= 3 \times 6.022 \times 10^{23}$ atoms

$= \frac{3}{2} \times 6.022 \times 10^{23}$ molecules (since hydrogen is diatomic molecule)

16 gram oxygen = 6.022×10^{23} atoms

48 gram oxygen

$= 3 \times 6.022 \times 10^{23}$ atoms

$= \frac{3}{2} \times 6.022 \times 10^{23}$ molecules

(As oxygen is diatomic molecule)

Similarly, 42 gram of nitrogen contains $\frac{3}{2} \times 6.022 \times 10^{23}$ molecules.

12 gram carbon = 6.022×10^{23} atoms

2 gram carbon

$= \frac{1}{6} \times 6.022 \times 10^{23}$ atoms

$= \frac{1}{6} \times 6.022 \times 10^{23}$ molecules

(As carbon is monoatomic molecule.)

Hence, 2 gram of carbon contains different number of molecules.

05

ATOMIC STRUCTURE AND RADIOACTIVITY

Generally 2-4 questions are asked from this chapter. Questions from this chapter are based upon properties of cathode rays, α-particle scattering experiment, Bohr's atomic model, atomic number and mass number, isotopes, electronic configuration of elements and basic knowledge of radioactivity.

DALTON'S ATOMIC THEORY

The first definite theory about the structure of the matter was put forward by **John Dalton** in **1890.**

Its main postulates are

- All matter is made up of very small particles known as atoms.
- Atom neither be created nor be destroyed, it is the smallest particle that takes part in a chemical reaction.
- All atoms of an element are alike and of different elements are different.
- Atoms of different elements have different masses and chemical properties.
- Atoms combine together in the ratio of small whole numbers.

Drawbacks of Dalton's Atomic Theory

- It does not explain why atoms of different elements differ in their mass, valencies etc.
- It does not explain the existence of isotopes and isobars.
- It does not explain how and why atoms of elements combine with each other to form molecules.

Constitution of Atom

Several phenomenon like radioactivity reveals that atoms are divisible and comprises of three fundamental particles namely electron, proton and neutron.

Electron ($_{-1}e^{0}$)

Electron was discovered by **J.J. Thomson** in 1897. When an electric charge at high voltage is passed through a gas at low pressure, (10^{-6} atm) a stream of rays is emitted from the cathode surface. These are called as **cathode rays.**

- Magnitude of charge on electron = -1.6×10^{-19} C.
- Mass of electron = 9.108×10^{28} g.

Properties of Cathode Rays

- Cathode rays always travel in straight line path away from the cathode and cast shadows of metallic objects placed in their path.
- Cathode rays produce mechanical motion of a spin wheel placed in their path. Thus, they possess kinetic energy and must be material particles.
- The beam of cathode rays are deflected towards the positively charged plate, hence the particles in the cathode rays carry negative charge.

- Cathode rays can be deflected by an electric and as well as in magnetic field.
- Cathode rays can penetrate through thin layers of matter.
- Cathode rays produce X-rays when they strike a metallic target with high melting point like tungsten.
- Cathode rays upon striking glass or certain other material cause them to glow.
- The nature of cathode rays is independent of (i) the nature of the cathode and (ii) the gas in the discharge tube.

Charge/Mass Ratio [e/m]

J.J. Thomson determined the ratio of the charge (e^-) of the electron to its mass (m) by measuring the deflection under the simultaneous influence of electric and magnetic fields.

- The value of e/m was found to -1.7588×10^{11} C kg^{-1} for electrons.
- The charge on the electron was measured by **R.A. Millikan**.

Proton ($_1p^1$ or $_1H^1$)

The existence of positively charged particles in an atom was shown by **E. Goldstein** in 1886. When high voltage is supplied across the electrodes a new kind of rays produced which passed through the perforated cathode and caused a glow on the wall opposite to the anode. These rays are also known as **anode rays** or **canal rays**.

- The magnitude of charge on proton is 1.6×10^{-19} C.
- Mass of proton = 1.673×10^{-27} kg.

Properties of Anode Rays

- The anode rays travel in a straight line and cast shadow.
- The anode rays are deflected by the magnetic and electric field and bent in the opposite direction of cathode rays.
- The anode rays can also rotate the wheel placed in their path and also have heating effect.
- The charge to **mass ratio** (e/m) for positive rays depends upon the nature of the gas taken in the tube and it is less than e/m of electron.

$$\frac{e}{m} = 9.579 \times 10^7 \text{C kg}^{-1}$$

- The removal of electrons from neutral atoms or molecules of gas results in the formation of positively charged ions. These positively charged ions move towards perforated cathode and constitute beam of **positive rays**.

Neutron ($_0n^1$)

The neutrons were discovered by **James Chadwick**. These particles are neutral having charge equals to zero. Their mass is approximate same as that of a hydrogen atom,

i.e. 1.675×10^{-27} kg.

ATOMIC MODELS

Various atomic models were proposed to show the arrangement and distribution of particle [electrons, protons and neutrons] within an atom.

Thomson's Atomic Model

The first simple model of an atom was proposed by **J.J. Thomson**. According to Thomson, an atom is a positively charged uniform sphere of radius 10^{-8} cm in which electrons are embedded in such a way that negative charge equals to positive charge. This model also called **plum-pudding model** and **watermelon model**. This model was unable to explain the stability of an atom.

Rutherford's Atomic Model (1912)

This model was based upon α-particle scattering experiment. The α-particles scattering experiments performed by Rutherford are concerned with the discovery of the nucleus.

The following conclusions were drawn from these experiments:

- A major portion of the atom is empty space because most of α-particles passed straight through the atom.
- The atom has a very small rigid, positively charged body called nucleus and the α-particles are repelled from the metal foil due to this positively charged nucleus.
- The whole mass of the atom is concentrated in the nucleus, so it is very heavy and rigid.

Main postulates of this model are as follows

- An atom mainly consists of free space. Each atom contain a heavy positively charged body at its centre called the **nucleus**.
- The negatively charged electrons revolving around the nucleus are called planetary electrons.
- The size of the nucleus ($r = 10^{-15}$ m) is very small as compared to that of atom ($r = 10^{-10}$ m).
- All protons and neutrons are stablised in the nucleus by a strong interaction force.
- Rutherford atomic model failed because he could not explain the electronic structure of atom. In other words it does not tell about the distribution of electrons around the nucleus.

➨ **Note** During α-particle scattering experiment, α-particles were subjected to bombard a thin sheet of heavy metals like gold, platinum because their nuclei is large, thus provides good results.

Electromagnetic Radiations

These radiations exhibit both particle and wave like properties. These radiations do not require medium and can move in vacuum. Order of different types of electromagnetic radiations according to their increasing wavelength is as follows

Cosmic rays < γ-rays < X-rays < UV rays < visible light < infrared rays < microwaves < FM radiowaves < long radiowaves

- The small portion around 10^{15} Hz is called visible light.
- Relation between frequency (ν), wavelength (λ) and velocity of light (c) is as follows

$$c = \nu \lambda$$

Wave number $\bar{\nu} = \frac{1}{\lambda}$. Its unit is m^{-1}.

➨ **Note** X-rays are produced effectively when electrons strike the dense metal anode and have a very high penetrating power through the matter that's why these rays are used to study the interior of objects.

- Penetrating power of X-rays can be increased by increasing potential difference between anode and cathode.

PLANCK'S QUANTUM THEORY

This theory was proposed by **Max Planck**.

The main postulates of this theory are as follows

- The energy emitted or absorbed by the atoms and molecules will be in the form of discrete packets of energy called **quanta**.
- The energy of quanta (E) is proportional to its frequency (ν)

$$E \propto \nu \text{ or } E = h\nu$$

where, h = Planck's constant (6.626×10^{-34} Js)

- The energy of quanta is quantised, thus, $E = nh\nu$

Bohr's Atomic Model (1913)

- **Neils Bohr** proposed this atomic model which is based upon the Planck's quantum theory of radiations.
- The electrons in an atom revolve around the nucleus only in certain selected circular paths called **orbits**. Each orbit have a definite amount of energy.
- Electron in the particular orbit, does not lose or gain energy.
- Only those orbits are permitted in which the angular momentum (mvr) of the electron is a whole number multiple of $\frac{h}{2\pi}$ ('h' is a Planck's constant i.e. $mvr = \frac{nh}{2\pi}$

where $n = 1, 2, 3 \ldots$

- The energy is emitted when an electron jumps from higher energy level to lower energy level and energy is absorbed when an electron jumps from lower energy level to higher energy level.
- The frequency of radiation absorbed or emitted when transition occurs between two different energy levels or states is given by

$$\nu = \frac{\Delta E}{h} = \frac{E_2 - E_1}{h}$$

where, E_1 and E_2 are the energies of lower and higher energy states.

- The energy of an electron residing in a particular energy level (n) is given by

$$E_n = -21.8 \times 10^{-12} \times \frac{Z^2}{n^2} \text{ erg atom}^{-1}$$

$$= -21.8 \times 10^{-19} \times \frac{Z^2}{n^2} \text{ J atom}^{-1}$$

$$= -13.6 \times \frac{z^2}{n^2} \text{ eV atom}^{-1}$$

$$E_n = \frac{hc}{\lambda_n} = -R_H \left(\frac{1}{n_2^2} - \frac{1}{n_1^2} \right) Z^2$$

- Radius of nth orbit $(r_n) = \frac{0.53\, n^2}{Z}$ Å.
- **Velocity of electron** in nth orbit $= \frac{2.18 \times 10^8 \ Z}{n}$ cm/s.

Failures of Bohr's Atomic Theory

- He could not explain the splitting of spectral lines in the presence of magnetic field (Zeeman effect) and electric field (Stark effect).
- He could not explain the line spectra of atoms containing more than one electron called multi-electron atoms.
- He could not explain the three dimensional existence of atom.
- Bohr's theory failed due to the dual nature of matter and uncertainty principle.

Energy of electron in a hydrogen atom in different energy levels

Energy level	*Energy* (Joule atom^{-1})
$n = 1$	-21.79×10^{-19}
$n = 2$	-5.42×10^{-19}
$n = 3$	-2.41×10^{-19}
$n = 4$	-1.36×10^{-19}
$n = 5$	-0.87×10^{-19}
$n = \infty$	0

The largest absorption of energy will be for transition $n = 1$ to $n = 2$. For transition $n = \infty$ to $n = 1$, is although maximum but in this transition energy will be released.

Example The ratio of the difference between 1st and 2nd Bohr's orbits energy to that between 2nd and 3rd orbits energy is

(a) $\frac{1}{2}$ (b) $\frac{1}{3}$ (c) $\frac{27}{5}$ (d) $\frac{5}{27}$

Sol. (*c*) $\Delta E_{1,2} = E_2 - E_1$

$$= \frac{E_H}{(n_2)^2} - \frac{E_H}{(n_1)^2} = E_H\left(\frac{1}{2^2} - \frac{1}{1^2}\right) = -\frac{E_H \times 3}{4}$$

$$\Delta E_{2,3} = E_3 - E_2 = -\frac{E_H \times 5}{36}$$

$$\frac{\Delta E_{1,2}}{\Delta E_{2,3}} = E_H \times \frac{3}{4} \times \frac{36}{E_H \times 5} = \frac{27}{5}$$

Atomic Number (*Z*)

- The concept of atomic number was given by **Moseley**.
- Atomic number (*Z*) = number of protons in the nucleus

For neutral atom, number of protons = number of electrons

Mass Number (*A*)

- The sum of number of protons and neutrons present in the nucleus is called mass number.
- Mass number (*A*) = number of protons + number of neutrons
- An atom with atomic number and mass number is represented as ${}_ZX^A$.
- Protons and neutrons are collectively called nucleons.

Different Atomic Species

There are different types of atomic species

Isotopes Isotopes were discovered by **F. Soddy**. Isotopes have the same atomic number but differ in their mass numbers. Isotopes have identical chemical properties but differ in physical properties. e.g., ${}_1H^1$ (Protium), ${}_1H^2$ (Deuterium) and ${}_1H^3$ (Tritium), ${}_8O^{16}$, ${}_8O^{17}$ and ${}_8O^{18}$. The element polonium (Po) possesses maximum isotopes. ${}_1H^1$ is the lightest isotope.

Isobars Isobars are atoms with same mass number but different atomic numbers. Isobars are the atoms of different elements and they possess different physical and chemical properties.

e.g., ${}_1H^3$ and ${}_2He^3$; ${}_{18}Ar^{40}$, ${}_{19}K^{40}$ and ${}_{20}Ca^{40}$; ${}_{52}Te^{130}$, ${}_{56}Ba^{130}$ and ${}_{54}Xe^{130}$.

Isotones Isotones are the atoms of different elements possessing the same number of neutrons but different mass numbers.

e.g., ${}_1H^3$ and ${}_2He^4$, ${}_{15}P^{31}$ and ${}_{16}S^{32}$, ${}_{19}K^{39}$ and ${}_{20}Ca^{40}$.

Isoelectronic Isoelectronic species have same number of electrons. e.g., Ne, Na^+, Mg^{2+} all have 10 electrons.

Quantum Mechanical Model of the Atom

The formulation of a quantum mechanical model of an atom is based upon two important concepts

1. Dual Nature of Material Objects [de-Broglie Concept]

In 1924 **de-Broglie** suggested that matter like radiation behaves as both particle and wave.

According to de-Broglie, the wavelength 'λ' associated with a particle of mass *m*, moving with velocity *v* is given by

$$\lambda = \frac{h}{mv} = \frac{h}{p} \qquad [\because p = mv]$$

where, *h* = Planck's constant, *p* = momentum

This equation is called de-Broglie equation.

2. Heisenberg's Uncertainty Principle

Heisenberg in 1927, pointed out that it is not possible to measure both position and momentum (or velocity) of a microscopic particle at the same time with absolute accuracy.

Mathematically, $\Delta x \times \Delta p = \frac{h}{4\pi}$

Here, Δx = uncertainty in position

Δp = uncertainty in momentum

Now, $p = mv$

Hence, $\Delta p = m\Delta v$

By putting the value of Δp in the above expression, we get

$$m\Delta v \times \Delta x \geq \frac{h}{4\pi} \quad \text{or} \quad \Delta v \times \Delta x \geq \frac{h}{4\pi \times m}$$

QUANTUM NUMBERS

Position and nature of electron is completely described by four sets of quantum numbers.

1. **Principal Quantum Number** (*n*) (Bohr) It determines the size of the electron orbits and energy of an electron. It is denoted by *n*, where $n = 1, 2, 3, \ldots, \infty$ (only positive integers). The various shells are designated as *K, L, M, …* respectively. Maximum numbers of electrons in any orbit is $2n^2$, where *n* is principal quantum number.
2. **Azimuthal Quantum Number** (*l*) (Sommerfeld) Also known as angular momentum quantum number or secondary quantum number. It determines the shape of electron orbit and orbital angular momentum of an electron and is denoted by *l*. It has the values from zero to $(n-1)$. '*l*' is equal to 0, 1, 2, 3 for *s, p, d* and *f* orbitals respectively.

3. **Magnetic Quantum Number** (m) (Lande) It determines direction of orientation of electrons in suborbit (subshell) because it gives the orientation or distribution of the electron cloud. It has all values from $-l$ through zero to $+l$, with total of $(2l+1)$ values. It explains splitting of spectral lines under the influence of magnetic field (Zeeman effect).
4. **Spin Quantum Number** (s) (Uhlenbech and Goldschmidt) It determines the orientation of the spin of the electron. It has two values of spinning of electron about its own axis. The spin quantum number either equal to $-\frac{1}{2}$ (anti-clockwise) and $+\frac{1}{2}$ (clockwise) depending upon the spin of electron.

e.g., Let us consider 5th electron of an atom

$$n = 2,\ l = 1\ (p\text{-orbit})$$
$$m = -1,\ s = -\frac{1}{2} \text{ or } +\frac{1}{2}$$

Electronic Configuration of Elements

The arrangement of electrons in various shells, subshells or orbitals of an atom is known as electronic configuration of the element.

Filling of electrons in different orbitals is governed by the following rules

Aufbau's Principle

According to this principle, "Sub-shells are filled with electrons in the increasing order of their energies."

This suggests that sub-shell of lower energy will be filled first with electrons followed by higher energy sub-shell.

- According to $(n+l)$ rule, the lower the value of $(n+l)$ for an orbital the lower is its energy e.g; between $3d$ and $4s$, the $4s$ $(4+0=4)$ will be filled before $3d$ $(3+2=5)$. If two orbitals have same value of $(n+l)$, the orbital with lower value of n will be filled first e.g; between $2p$ and $3s$, $2p$ $(2+1=3)$ will be filled first than $3s$ $(3+0=3)$. the order of increasing energies is summed as $1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s, 5f, 6d, 7p$

➨ **Note** $_{24}Cr$ and $_{29}Cu$ do not obey this law.

$$_{24}Cr = 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$$
$$_{29}Cu = 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^1$$

- The completely filled and completely half-filled sub-shells have lesser energy and thus assume more stability than any other arrangement. Thus, $3d^5 4s^1$ and $3d^{10} 4s^1$ are more stable arrangement than $3d^4 4s^2$ and $3d^9 4s^2$ respectively.

Hund's Rule of Maximum Multiplicity

According to this rule, "Pairing of electrons in a sub-shell starts after all the available atomic orbitals or the sub-shell are singly filled (half-filled)."

Pauli's Exclusion Principle

It states that, "No two electrons can have the same value of all the four quantum numbers."

RADIOACTIVITY

The spontaneous emission of electromagnetic radiations [α, β and γ-rays] due to the disintegration of unstable nucleus is called radioactivity. The elements showing radioactivity are called **radioactive elements**. It was discovered by **Prof. Henry Becquerel** in 1896 but the term radioactivity was coined by **Madam Curie**.

Radioactivity does not affected by temperature, pressure etc.

The activity of a radioactive material is measured in terms of the disintegrations per unit time. Its SI unit is becquerel which is the same as 1 disintegration per second.
$1\,\text{curie} = 3.7 \times 10^{10}$ disintegrations s^{-1}.

Stability of Nucleus

- If neutron-proton ratio, i.e. $n/p > 1.5$, nucleus is unstable. The maximum stability is attained by nucleus when $n/p = 1$
- Greater in the mass defect (A stable nucleus has less mass than its constituent particles. This difference is mass defect) lesser is the energy level of nucleus, more is its stability.

➨ **Note** Practical determination of the activity of radioactive substance is done by **Geiger Muller** counter.

Alpha Rays (α-rays)

- They are deflected towards negative plate in electric field.
- Each particle carry two units positive charge and four unit mass that is they are doubly ionised helium atom.
- Emission of α-particle decreases the atomic number by 2 and mass number by 4.
- They produce maximum ionisation in gases because of maximum kinetic energy.
- Their penetration power is very small because of large mass.

Beta Rays (β-rays)

- They are deflected towards positive plate in electric field.
- β-particles carries one unit negative charge and negligible mass that is these are electrons.
- Emission of one β-particle from unstable nucleus results in increase in number of protons by one unit.
- They produce lesser ionisation in gases than α-particles.
- β-particle is the strongest reducing agent.

Gamma Rays (γ-rays)

- γ-rays are electromagnetic radiations of very high frequencies even more than X-rays. Thus, the γ-rays have no charge and no mass.
- Emission of γ-rays does not have any affect on either atomic number or mass number.
- They are not deflected from their path in electric or magnetic field.
- They produce minimum ionisation in gases and possess maximum penetration power.

Disintegration Theory

Radioactive elements are unstable and undergo spontaneous breakdown from one chemical atom to another with the emission of either α- particle or β- particle. The process is continuous until finally a stable and non-radioactive nuclear species is obtained.

Group Displacement Law

In an α-particle emission, the resulting element has an atomic number less by 2 units (and atomic weight less by 4 units) hence it lies 2 columns to the left of the original element and in a β- particle emission, the resulting element has an atomic number increase by 1 unit (and same atomic weight) hence it lies 1 column to the right of the original element.

$$\alpha-\text{emission}-\ \underset{\text{(group II)}}{{}^{226}_{88}\text{Ra}} \longrightarrow \underset{\text{(group 0)}}{{}^{222}_{86}\text{Rn}} + {}^{4}_{2}\text{He}$$

$$\beta-\text{emission}-\ \underset{\text{(group IV)}}{{}^{210}_{82}\text{Pb}} \longrightarrow \underset{\text{(group V)}}{{}^{210}_{83}\text{Bi}} + {}^{0}_{-1}\text{e}$$

- There is no change in the atomic number and atomic mass during the emission of γ- particle.

Half-life Period

The time in which a substance remains half of its original amount is called the **half-life** of the substance. It is represented by $t_{1/2}$ and related to decay constant by the following expression $t_{1/2} = \dfrac{0.693}{\lambda}$

$$\text{Average-life} = \frac{1}{\lambda} = 1.44 \times t_{\frac{1}{2}}$$

Half life period of a radioactive element is independent of its amount.

$$N_t = N_o \times \left[\frac{1}{2}\right]^n$$

T (total time) $= t_{1/2} \times n$

Where N_o = initial amount and N_t = amount after time t and n = number of half lives.

Nuclear Fission

The reaction in which a heavy nucleus is broken down into two or more lighter nuclei is called nuclear fission. It is usually accompanied by the emission of neutrons alongwith a large amount of energy.

Nuclear fission reactions are of two types

(i) Uncontrolled chain reaction

(ii) Controlled chain reaction

- The principle of atom bomb is based on uncontrolled nuclear fission reaction.
- The principle of nuclear reactor is based on controlled nuclear fission reaction.

Nuclear Reactor

- It is a device that is used to produce electricity and permits a controlled chain nuclear fission.
- It contains fuels e.g., ${}_{92}U^{235}$, moderator (e.g., graphite and heavy water, D_2O) to slow down neutrons and control rods (made up of boron steel or cadmium) to absorb neutrons.
- It may also contain heavy water, liquid sodium or potassium as coolant.

Nuclear Fusion

The reaction in which two or more lighter nuclei combines to form a heavier nuclei is called nuclear fusion. This reaction takes place at extremely high temperature, therefore, these reactions are called **thermonuclear reactions**.

- Nuclear fusion is the source of sun's energy and stars.
- Hydrogen bomb is based on nuclear fusion.

Uses of Radioactive Isotopes

Radioactive isotopes are used in food irradiation; in nuclear medicine in two different ways; diagnosis and therapy; as tracers in chemical and biological processes and in carbon dating.

Tc^{99} – In the treatment of thyroid, brain, kidney

I^{123} – In the treatment of thyroid

Co^{60} – Cancer treatment

C^{14} – Age determination, photosynthesis research.

Na^{24} – To measure blood flow in the body

PRACTICE EXERCISE

1. According to Dalton's atomic theory the smallest particle which is capable of independent existence is
(a) element (b) atom
(c) molecule (d) ion

2. Electron was discovered by
(a) Crookes (b) J. J. Thomson
(c) Henry (d) Rutherford

3. The atomic number of an element of mass number 27, which has 13 neutron is
(a) 10 (b) 14 (c) 12 (d) 13

4. The atom of an element contains 2 electrons in its *M* shell. The element is
(a) aluminium (b) sodium
(c) chlorine (d) magnesium

5. Which of the following properties of the element can be a whole number?
(a) Atomic mass (b) Atomic number
(c) Atomic radius (d) Atomic volume

6. Which of the following is the correct sequence in terms of increasing mass?
(a) Proton, electron, alpha particle, hydrogen atom
(b) Electron, proton, hydrogen atom, alpha particle
(c) Hydrogen atom, proton, electron, alpha particle
(d) Alpha particle, proton, hydrogen atom, electron

7. Neutrons are present in all atoms except
(a) He (b) C
(c) H (d) N

8. Which one of the following pairs is correctly matched?
(a) Mass spectrograph–Chadwick
(b) Atomic number–Moseley
(c) Neutron–Millikan's
(d) Measurement of charge of an electron–Astron

9. The relation between energy of a radiation and its frequency was given by
(a) Bohr's (b) de-Broglie
(c) Rutherford (d) Planck's

10. Bohr's theory is applicable to
(a) H atom (b) He^+ ion
(c) Li^{2+} ions (d) All of these

11. According to Bohr's model of an element
(a) $mvr = nh/2\pi$ (b) $mvr = 2\pi/nh$
(c) $mvr = n^2h^2/2\pi^2$ (d) $mvr^2 = \frac{nh}{\pi}$

12. When a electron moves from a higher orbit to the lower orbit then
(a) emission of energy takes place
(b) the size of atom increases
(c) absorption of energy takes place
(d) an electron in an atom moves without emission or absorption

13. The value of Planck's constant is
(a) 6.6×10^{-32} g/m^{2}s
(b) 6.6×10^{-34} kgm^{2}s^{-1}
(c) 6.6×10^{-33} kg/ms^{-1}
(d) 6.6×10^{-34} gs^{-1}

14. Which of the following statements does not form part of Bohr's model of the hydrogen atom?
(a) Energy of the electrons in the orbit is quantised
(b) The electron in the orbit nearest the nucleus has the lowest energy
(c) Electrons revolve in different orbits around the nucleus
(d) The position and velocity of the electrons in the orbit cannot be determined simultaneously

15. The number of neutrons in $_{13}Al^{27}$ is
(a) 40 (b) 27 (c) 14 (d) 13

16. An element *M* has atomic mass 19 and atomic number 9. Its ion is represented as
(a) M^+ (b) M^{2+} (c) M^- (d) M^{2-}

17. The number of electrons in $_8O^{18}$ an isotope of oxygen is
(a) 8 (b) 6 (c) 12 (d) 10

18. Which one among the following most correctly determines the atomic number of an element?
(a) Number of protons
(b) Number of protons and neutrons
(c) Number of ions
(d) Number of nucleons

19. Consider the following statements. In $^{90}_{38}Sr^{2+}$
I. Atomic number is 36.
II. Number of electrons is 38.
III. Number of neutrons is 52.
IV. Number of protons is 38.
Which of the above statements is/are correct?
(a) I and II (b) II and III
(c) III and IV (d) I and IV

20. Consider the following statements in reference to the structure of atom.
I. Isotopes are the atoms of the same element having same atomic number but different mass-numbers.
II. Isobars are the atoms of different elements having different atomic number but same mass-number.
III. Isotones are atoms of different elements having same number of neutrons.
Which of the above statements is/are correct?
(a) Only I (b) Only II
(c) II and III (d) All of the above

21. Which of the following statement is incorrect?
(a) Isobars possess same chemical properties
(b) Isotopes occupy same position in periodic table
(c) Isotopes possess same atomic number
(d) In isobars the total number of protons and neutrons in the nucleus is same

22. The number of protons in a negatively charged atom (anion) is
(a) more than the atomic number of an element
(b) less than the atomic number of an element
(c) more than the number of electrons in the atom
(d) less than the number of electrons in the atom

23. Who modified Bohr's theory by introducing elliptical orbits for electron path?
(a) Hund (b) Thomson
(c) Sommerfeld (d) Rutherford

24. Which of the following electronic configuration is not possible?
(a) $1s^2$
(b) $1s^2 2s^2 2p^6 3d^{10} 3s^2$
(c) $1s^2 2s^2 2p^2$ (d) $1s^2 2s^2 2p^6 3s^1$

25. The rule which states that no two electrons can have same value of all the four quantum numbers is
(a) Pauli's exclusion principle
(b) Heisenberg's uncertainty principle
(c) Aufbau principle
(d) de-Broglie principle

26. The electronic configuration of chromium ($Z = 24$) is
(a) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^4 4s^2$
(b) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1$
(c) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 4p^4$
(d) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$

27. From amongst the following chemical species

I. ${}_{18}Ar^{39}$ II. ${}^{40}_{19}K^{+}$
III. ${}^{40}_{20}Ca^{2+}$ IV. ${}^{40}_{20}Ca^{+}$

The species having identical electronic configuration are
(a) I and II (b) II and III
(c) III and IV (d) I, II and III

28. A stable nucleus (light with $A < 10$) has
(a) exactly the same number of neutrons and protons
(b) more neutrons that protons
(c) no neutrons
(d) no protons

29. Protons and neutrons are bound in a nucleus by
(a) short range 'weak interaction'
(b) short range 'strong interaction'
(c) long range 'electromagnetic interaction'
(d) long range 'gravitational'

Directions *(Q. Nos. 30-33)*
Following questions consist of two statements labelled as Statement I and Statement II. Examine both the Statements carefully and mark the correct choice according to the codes given below.
(a) Both Statement I and Statement II are true and Statement II is the correct explanation of Statement I.
(b) Both Statement I and Statement II are true but Statement II is not the correct explanation of Statement I.
(c) Statement I is true, but Statement II is false.
(d) Statement I is false, but Statement II is true.

30. **Statement I** Bohr theory is not applicable to ionised hydrogen atom.
Statement II H^+ is devoid of electron.

31. **Statement I** An atom is electrically neutral.
Statement II Atoms contain equal number of proton and neutron.

32. **Statement I** Among C^{12}, C^{13} and C^{14} only C^{14} is radioactive.
Statement II The n/p ratio in C^{14} is higher.

33. **Statement I** Gamma rays are more penetrating than X-rays.
Statement II Gamma rays have wavelengths that are smaller than those of X-rays.

34. Match the following.

List I (Electronic configuration)	List II (Elements)
A. $1s^2$	1. Chlorine
B. $1s^2 2s^2 2p^6$	2. Fluoride ion
C. $1s^2 2s^2 2p^6 3s^2$	3. Hydride ion
D. $1s^2 2s^2 2p^6 3s^2 3p^5$	4. Magnesium

Codes

	A	B	C	D
(a)	3	2	4	1
(b)	3	4	2	1
(c)	4	2	1	3
(d)	2	3	4	1

Previous Years' Questions

35. Which one among the following transitions of electron of hydrogen atom emits radiation of the shortest wavelength? **2012 (I)**
(a) $n = 2$ to $n = 1$ (b) $n = 3$ to $n = 2$
(c) $n = 4$ to $n = 3$ (d) $n = 5$ to $n = 4$

36. The penetrating power of X-rays can be increased by **2012 (I)**
(a) increasing the current in the filament
(b) decreasing the potential difference between the cathode and the anode
(c) decreasing the current in the filament
(d) increasing the potential difference between the cathode and the anode

37. Which of the following statements is correct? **2012 (I)**
1. Isotopes atoms with same atomic number but different atomic mass.
2. Isobars atoms with same number of neutrons but different atomic number.
3. Isotones atoms with same mass number but different atomic number.

Select the correct answer using the codes given below
(a) Only 2 (b) Only 1
(c) 1 and 2 (d) All of these

38. The nucleus of a singly ionised carbon atom contains **2012 (I)**
(a) 6 protons and 6 neutrons
(b) 5 protons and 6 neutrons
(c) 6 protons, 6 neutrons and 6 electrons
(d) 12 protons, 6 neutrons and 6 electrons

39. The process of nuclear fusion in the sun requires **2012 (II)**
(a) very high temperature and very high pressure
(b) low temperature and high pressure
(c) high temperature and low pressure
(d) very high temperature and no pressure

40. Which one among the following transitions is associated with the largest change in energy in hydrogen atom? **2012 (II)**
(a) $n = 5$ to $n = 3$ (b) $n = 2$ to $n = 1$
(c) $n = 3$ to $n = 2$ (d) $n = 4$ to $n = 2$

41. Match the following **2012 (II)**

List I (Scientist)	List II (Discovery)
A. Goldstein	1. Atomic theory
B. Chadwick	2. Proton
C. J.J Thomson	3. Neutron
D. John Dalton	4. Electron

Codes

	A	B	C	D
(a)	2	3	4	1
(b)	2	4	3	1
(c)	1	4	3	2
(d)	1	3	4	2

42. Two atoms are said to be isotopes, if **2013 (I)**
(a) they have same atomic number but different mass numbers
(b) they have same number of neutrons but different mass number
(c) the sum of the number of protons and neutrons is same but number of protons are different
(d) they have same number of neutrons but different modes of radioactive decay

43. The phenomenon of radioactivity was discovered by **2013 (I)**
(a) Marie Curie (b) Pierre Curie
(c) Henry Becquerel (d) J J Thomson

44. The most of the mass of an atom can be found in **2014 (I)**
(a) electrons (b) charges
(c) nucleus (d) electron cloud

45. The mass number of an atom is determined by **2014 (I)**
(a) adding the number of neutrons and number of electrons
(b) adding the number of protons and number of electrons
(c) the number of protons only
(d) adding the number of neutrons and number of protons

46. Which one of the following is the correct electronic configuration of chlorine? **2014(II)**
(a) 2, 7, 8 (b) 2, 8, 7
(c) 2, 8, 8 (d) 7, 8, 9

47. Which one among the following contains the most neutrons? **2014(II)**
(a) $^{59}_{26}Fe$
(b) $^{61}_{29}Cu$
(c) $^{61}_{30}Zn$
(d) $^{60}_{30}Zn^{2+}$

48. A monoatomic species that has 18 electrons and a net charge of 2–has **2014(II)**
(a) the same number of electrons as a neutral argon atom
(b) more protons than electrons
(c) 2 unpaired electrons
(d) 20 protons

49. Which one of the following statements is correct? **2015 (II)**
(a) Rutherford's α-particle scattering experiment led to the discovery of electron
(b) J.J. Thomson suggested that the nucleus of an atom contains protons
(c) The atomic number of an element is the same as the number of protons in the nucleus of its atom
(d) The mass number of an atom is equal to the number of electrons in its shells

50. Which of the following are the properties of an electron? **2015 (II)**
1. Electron is a constituent of cathode ray.
2. Electron is a negatively charged particle.
3. The mass of the electron is equal to the mass of the proton.
4. Electron is deflected by the electric field but not by magnetic field.

Select the correct answer using the codes given below
(a) 1 and 2 (b) 1, 2 and 3
(c) 3 and 4 (d) 1 and 4

51. An atom of carbon has 6 protons. Its mass number is 12. How many neutrons are present in an atom of carbon? **2016 (I)**
(a) 12 (b) 6
(c) 10 (d) 14

ANSWERS

1	*b*	2	*b*	3	*b*	4	*d*	5	*d*	6	*b*	7	*c*	8	*b*	9	*d*	10	*d*
11	*a*	12	*a*	13	*b*	14	*d*	15	*c*	16	*c*	17	*a*	18	*a*	19	*c*	20	*d*
21	*a*	22	*d*	23	*c*	24	*b*	25	*a*	26	*b*	27	*d*	28	*a*	29	*b*	30	*a*
31	*c*	32	*a*	33	*a*	34	*a*	35	*a*	36	*d*	37	*b*	38	*a*	39	*a*	40	*b*
41	*a*	42	*a*	43	*c*	44	*c*	45	*d*	46	*b*	47	*a*	48	*a*	49	*c*	50	*a*
51	*b*																		

Solutions

11. *(a)* Angular momentum, $mvr = \frac{nh}{2\pi}$

15. *(c)* Number of neutrons in $^{27}_{13}Al$ is 14. (number of neutrons = mass number – atomic number)

16. *(c)* $^{19}_{9}M = 1s^2\ 2s^2\ 2p^5$

Its ion is represented by M^-.

19. *(c)* $^{90}_{38}Sr^{2+}$ Atomic number = 38 = number of protons.
Number of electrons = 38 – 2 = 36
Number of neutrons = 90 –38 = 52
Hence, statement III and IV are correct.

26. *(b)* $_{24}Cr = 1s^2, 2s^2, 2p^6, 3s^2, 3p^6\ 3d^5, 4s^1$

27. *(d)* $^{39}_{18}Ar, ^{40}_{19}K^+$ and $^{40}_{20}Ca^{2+}$ are isoelectronic species, thus, all these have same electronic configuration.

28. *(a)* A stable nucleus has exactly the same number of neutrons and protons. The maximum stability is attained when $\frac{n}{p} = 1$.

40. *(b)* The change in energy released or absorbed during transition is given by $\Delta E = 218 \times 10^{-18}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

$E \propto \frac{1}{n^2}$. Thus, for a transition of $n = 2$ to $n = 1$, largest change in energy is involved.

48. *(a)* A monoatomic species has the same number of electrons as a neutral argon atom. The monoatomic species must be S^{2-}.

Monoatomic species	Number of electrons
Sulphur (S)	16
Sulphur ion (S^{2-})	16 + 2 = 18
Argon (Ar)	18

51. *(b)* We know that,
Mass no. (A) = No of proton (p) + no. of neutron (n)
$12 = 6 + n \Rightarrow n = 6$
Mass number determines the atomic mass of atoms.

06

PERIODIC CLASSIFICATION OF ELEMENTS

Usually 1-2 questions are asked from this chapter. Questions are mostly based upon isoelectronic species and properties and uses of alkali metals.

PERIODIC CLASSIFICATION

The arrangement of elements in such a way so that elements having similar properties reappear at a regular interval, is called periodic classification or periodic arrangement of elements.

Earlier Development in Classification of Elements

Several attempts have been made for the classification of elements into group and it leads to the development of periodic classification and periodic table of elements.

Dobereiner's Triads

In 1817, Dobereiner found that elements could be arranged in a group of three called triads in such a way that the middle element had an atomic weight almost the average of other two, e.g.

Element	–	Li	Na	K
Atomic weight	–	7	23	39

$$\text{Mean of atomic masses} = \frac{7 + 39}{2} = 23$$

Newlands' Law of Octaves

John A.R. Newland (1866) found that, if the elements were arranged in the increasing order of their atomic weights, the properties of every eight elements were similar to those of first one. Newland called it law of octaves.

Lothar Meyer's Arrangement of Elements

Lothar Meyer (1869) plotted various physical properties such as atomic volume against atomic weight and said, "the properties of the elements were the periodic functions of their atomic volumes." He arranged the elements in a way resembling Mendeleev's arrangement of elements.

MENDELEEV'S PERIODIC TABLE

Mendeleev's periodic table is based on atomic weight. Mendeleev periodic law states that 'the properties of elements are the periodic functions of their atomic masses'.

- It contains vertical columns called groups and horizontal rows called periods. In this table, there were 8 groups and 7 periods.
- Mendeleev arranged 63 elements in this table.

Defects of Mendeleev's Periodic Table

- Position of hydrogen in the periodic table was not correctly defined.
- In certain pair of elements the increasing order of atomic masses was not obeyed. Isotopes have not been given separate places in the periodic table.
- Some similar elements were separated and dissimilar elements were grouped together.
- Mendeleev could not explain the cause of periodicity among the elements.

Modern Periodic Table

It was given by British chemist Moseley in 1913 on the basis of his discovery that atomic number is the most fundamental property. It is a tabular form of modern periodic law, according to which, 'the physical and chemical properties of the elements are the periodic function of their atomic numbers'.

Characteristics of Long Form of Periodic Table

- The horizontal rows are called **periods** and the vertical columns are called **groups**.
- The groups are numbered from 1 to 18 and there are altogether 7 periods.
- Elements having similar outer electronic configurations in their atoms are arranged in the vertical columns, *i.e.,* groups or families. That's why elements of a group possess similar chemical properties.
- The period number corresponds to the highest principal quantum number (n) of the elements in the period and each period marks a new electronic shell getting filled.
- The first period contains 2 elements and the subsequent periods consist of 8, 8, 18, 18 and 32 elements respectively and seventh period is incomplete.
- In this form of the periodic table, 14 elements of both six and seventh periods (lanthanoids and actinoids respectively) are placed in separate panels at the bottom.

CLASSIFICATION OF ELEMENTS

The electronic configuration of atoms provides a theoretical foundation for the periodic classification. Elements of a group exhibit similar chemical properties because they have same electronic configuration of their outermost shell.

Depending upon the type of orbital receiving the valence electron, the elements can be classified into following four blocks

s-block Elements (ns^{1-2})

The elements in which the last electron enters the *s*-orbital of their outermost energy level are called *s*-block elements and hence these elements are called representative elements.

The *s*-block elements are present on the extreme left in the periodic table.

It consists of elements of group IA and IIA.

Elements of IA group are called alkali metals while that of IIA group are called alkaline earth metals.

Properties of *s*-block Elements Except Hydrogen

- They all are metals, malleable, ductile and good conductors of heat and electricity.
- They show low ionisation potential.
- They are soft metals (due to weak metallic bond) and have low melting and boiling points.
- They are highly electropositive. They are powerful reducing agent, hence cannot be prepared by reduction. These are prepared by electrolysis of their salts in fused or molten state.
- Except Li and Be they form ionic compounds (because of small size of Li and Be form covalent compounds according to Fajans rule).
- The ionic nature of compounds increase from top to bottom.
- Elements of **IA form** monovalent cation while that of **IIA form** divalent cation. By the loss of electrons from their outermost shell.
- They do not show variable oxidation state.
- They form diamagnetic (no unpaired electrons) and colourless salts except dichromates and permanganates which are coloured.
- Due to high reactivity, alkali metals are stored under liquid paraffins.
- They form hydrides with hydrogen.
- Of all these elements, only hydrogen is a non-metallic gas.

p-block Elements (ns^2np^{1-6})

The elements in which the last electron enters the *p*-orbital of the outermost energy levels are called *p*-block elements. These elements are present in the right portion of periodic table. The elements of group 13 to 18 are in *p*-block.

Properties of *p*-block Elements

- *p*-block elements include metals, non-metals as well as metalloids.
- These elements have smaller atomic radii than *s*-block elements. The atomic radius decreases from left to right in a period due to increase in nuclear charge.
- They have high electronegativities. It is due to their small atomic size, *p*-block elements possess higher electron affinities than *s*-block elements.
- Halogens, oxygen, sulphur and phosphorus are reactive elements of *p*-block elements.
- They usually form covalent compounds.
- Some of these elements show variable valency and exist in more than one oxidation state in their compounds.
- Few elements, *viz* oxygen, sulphur, phosphorus etc. exhibit allotropy.
- They have high value of ionisation energy.
- Their oxides are acidic in nature.

d-block Elements $(n-1)d^{1-10}ns^{1-2}$

The element in which the last electron enters the *d*-orbitals, i.e. $(n-1)$ energy level constitute *d*-block element. They constitute group 3 to 12 in the periodic table.

The *d*-block comprises of three series which are

(i) First transition series scandium ($Z = 21$) to zinc ($Z = 30$)

(ii) Second transition series yttrium ($Z = 39$) to cadmium ($Z = 48$)

(iii) Third transition series lanthanum ($Z = 57$); hafnium ($Z = 72$) to mercury ($Z = 80$)

Properties of *d*-block Elements

- They are metals having high melting and boiling points (strong metallic bond).
- They are good conductor of heat and electricity due to free and mobile electrons. Silver is the best conductor of heat and lead is the poorest.
- Almost all of them show variable valence and exist in several oxidation state in their compounds.
- They form complex compounds.
- Transition elements and their compounds act as catalysts.
- They form both ionic and covalent compounds.
- Density of *d*-block elements are very high as compared to *s*-block elements.
- Properties of transition elements on moving across a period from left to right do not change gradually as those of *s* and *p*-block elements because the last two orbits are incomplete.
- Most of these ions contains unpaired electrons hence they are paramagnetic and coloured (due to *d-d* transition).
- Zinc, cadmium, mercury having d^{10} configuration do not form coloured salts.

f-block Elements $(n-2)f^{1-14}\,(n-1)d^{0-1}ns^2$

- The elements in which the last electron enter the *f*-orbitals of their atom are called *f*-block elements (penultimate orbit).
- The first series follows lanthanums (lanthanide series) from $Z = 58$ to $Z = 71$. This is also known as $4f$ inner-transition series.
- The second series follow actinium (actinide series) from $Z = 90$ to $Z = 103$ also known as $5f$ inner-transition series.

Properties of *f*-block Elements

- All *f*-block elements are metals and are highly reactive.
- These have high density, high melting and boiling points.
- They show variable valency. Their ions are coloured and paramagnetic in nature.
- They form complex compounds.
- They are radioactive.
- These are highly electropositive metals due to low ionisation energies.
- They generally form ionic compounds.

PERIODIC PROPERTIES

In a period as well as in a group there is a regular gradation (gradual increase or decrease in a particular property) in physical and chemical properties of elements with the change in atomic number. This regular gradation in properties is called periodicity. The reason of periodicity in properties is the repetition of similar configuration at regular intervals.

Atomic Radius

- It is defined as the distance from the centre of the nucleus to the outermost shell of electrons.
- In case of covalent bond, the radius is covalent radius; in ionic bond the radius is ionic radius and in absence of bond the radius is van der Waal's radius. In general, van der Waal's radius > covalent radius.
- Atomic radii of elements increases on moving down the group due to increase in number of shells by a factor of one, which reduces effective nuclear charge.
- Atomic radii of elements decreases on moving left to right in a period due to increase in on effective nuclear charge as the electrons enter in the same shell throughout the period.
- Radius of cation is always smaller than its neutral atom because of increase in effective nuclear charge per electron. e.g. $Sn > Sn^{2+} > Sn^{4+}$
- Radius of an anion is always larger than its neutral atom because of decrease in effective nuclear chatge per electron. e.g. $O^{2-} > O^{-} > O$
- **Isoelectronic species** These species have same number of electrons. In case of isoelectronic species, the ionic radii decreases with increase in atomic number.
  e.g. Ion $[\underset{(8)}{O^{2}} > \underset{(9)}{F^{-}} > \underset{(11)}{Na^{+}} > \underset{(12)}{Mg^{2+}}]$

Ionisation Potential (IP)

It is the minimum amount of energy required to remove an electron from outermost orbit of an isolated gaseous atom. IP measures tendency of cation formation.

- IP increases from left to right due to increase in effective nuclear charge while it decreases from top to bottom.
  $$IP \propto \frac{1}{\text{size of atom}}$$
- IP_1 of group 2 elements is greater than the corresponding elements of group 13. e.g. IP_1 of Mg > IP of Al.

- It is due to the stable configuration of group 2 elements (ns^2). Similarly IP_1 of group 15 elements is greater than the corresponding elements of group 16.
  e.g. IP_1 of N > IP_1 of O
- Zero group elements on account of the stable configuration exhibit exceptionally high value of IP (highest in its period).
- Within the same orbit IP decrease in order
  $s > p > d > f$

Electron Affinity (EA)

It is the energy released when an extra electron is added to an isolated gaseous atom. It measures the tendency of anion formation.

- EA increases in a period from left to right and decreases in a group from top to bottom.
- EA of zero group elements is extremely low.
- Fluorine has less EA than chlorine because of its small size F has more electron density and hence greater electron electron repulsion.
- Order of EA of halogens Cl > F > Br > I.

Electronegativity

It is the tendency of an atom to attract the shared pair of an electron towards itself.

- Decreasing order of electronegativity is

F > O > Cl ≈ N > Br > C ≈ I > H
4 3.5 3 3 2.8 2.5 2.5 2.1

Trends in Periodic Properties

Periodic property	*In a period from left to right*	*In a group from top to bottom*
Ionisation energy	Increase	Decrease
Electron affinity	Increase	Decrease
Electronegativity	Increase	Decrease
Non-metallic character	Increase	Decrease
Oxidising character	Increase	Decrease
Acidic nature of oxides	Increase	Decrease
Atomic size	Decrease	Increase
Electropositivity	Decrease	Increase
Metallic character	Decrease	Increase
Basic nature of oxides	Decrease	Increase

GROUPWISE STUDY OF ELEMENTS

IA Group Elements (Alkali Metals)
Li, Na, K, Rb, Cs, Fr

- The general electronic configuration is ns^1.
- Elements of **IA group** are called alkali metals because their oxides and hydroxides on dissolving in water gives alkaline solution.
- All alkali metals are soluble in liquid ammonia to give blue coloured solution (due to solvated or ammoniated electron) which conducts electricity. This solution acts as powerful reducing agent.
- Hydration energy decreases from Li to Cs because extent of hydration varies inversely with size.
- Alkali metals and their compounds impart characteristic colour to the flames.
- These metals have very low melting and boiling points which decreases on moving down the group. It is due to the presence of weak intermetallic bonds, which also become more weaker as the size increases.
- Li-red, Na-yellow, K-pale violet, Rb-violet and Cs-reddish violet.
- Li and Na burns in air to form peroxides (Li_2O and Na_2O while K, Rb and Cs forms superoxides (KO_2, RbO_2, CsO_2).
- Reactivity of alkali metals Li < Na < K < Rb < Cs
- Melting point of halides
  (a) For same halide

NaCl > LiCl > KCl > RbCl > CsCl
↓ max. m.pt. ↓ min. m.pt.

  (b) For same alkali metal

NaF > NaCl > NaBr > NaI
↓ max. m.pt. ↓ min. m.pt.

- Basic character and solubility of hydroxides

LiOH < NaOH < KOH < RbOH < CsOH
Increasing basic character and solubility

- Solubility and stability of carbonates

$Li_2CO_3 < Na_2CO_3 < K_2CO_3 < Rb_2CO_3 < Cs_2CO_3$
Increasing solubility and stability of carbonates

USES OF ALKALI METALS

- Lithium is used in aircraft manufacture and in certain batteries. Lithium carbonate is used in treatment of bipolar disorder.
- Sodium and potassium play a role in transmission of nerve signals. Calcium and magnesium are also essential for transmission of impulses along nerve fibres.
- In bones and teeth, Ca is present as apatite and fluorapatite. Ca^{2+} ions play a role in blood clotting and in contraction of muscles.
- Caesium is used in caesium atomic clocks.

IIA Group Elements
(Alkaline Earth Metals) (Be, Mg, Ca, Sr, Ba, Ra)

- General electronic configuration is ns^2.
- They impart characteristic colour to flame (except Be and Mg due to small size and high IP)

Ca	Sr	Ba	Ra
Brick red	Crimson	Apple green	Caramine

- Berrylium compound with N, Cl, S are covalent in nature while those of other alkaline elements are ionic.
- Reactivity of alkaline earth metals

$$Be < Mg < Ca < Sr < Ba$$

- Basic character and solubility of hydroxides

$$\underset{\text{(amphoteric)}}{Be(OH)_2} < Mg(OH)_2 < Ca(OH)_2 < Sr(OH)_2 < Ba(OH)_2$$

Increasing basic character and solubility →

Solubility of hydroxides increases from $Mg(OH)_2$ to $Ba(OH)_2$ due to decrease in lattice energy.

- The solubility and stability of carbonates

Their carbonates are quite insoluble.

$$\underset{\text{Slightly soluble}}{MgCO_3} > CaCO_3 > SrCO_3 > \underset{\text{Insoluble}}{BaCO_3}$$

$$\underset{\text{Min. stable}}{BeCO_3} < MgCO_3 < CaCO_3 < SrCO_3 < \underset{\text{Max. stable}}{BaCO_3}$$

- Solubility of sulphates

$$\underset{\text{Fairly soluble}}{BeSO_4} > \underset{\text{Sparingly soluble}}{MgSO_4} > \underset{\text{Sparingly soluble}}{CaSO_4} > \underset{\text{Insoluble}}{SrSO_4} > \underset{\text{Insoluble}}{BaSO_4}$$

IIIA Group Elements (B, Al, Ga, In, Tl)

- General electronic configuration is ns^2np^1.
- These generally show +3 oxidation state. Some elements also exhibit +1 oxidation state due to inert pair effect.
- Ba, Al show +3 oxidation state, while Ga, ln, Tl show +1 and +3 states. Compound of boron due to incomplete octet act as Lewis acids.
- All compounds of boron are used in manufacture of glass to reduce thermal expansion of glass.
- Boron absorbs neutrons, therefore, these are used in nuclear reactor.
- Aluminium form amphoteric oxide.
- Basic nature of oxides and hydroxides follows the order

$$B < Al < Ga < In < Tl$$

- Among hydroxide of elements of IIIA group, the order of acidity is

$$\underset{\text{Acidic}}{B(OH)_3} < \underset{\text{Amphoteric}}{Al(OH)_3} < \underset{\text{Basic}}{Ga(OH)_3} < In(OH)_3 < \underset{\text{Max. basic}}{Tl(OH)_3}$$

- Strength of Lewis acids of boron follows the order

$$BI_3 > BBr_3 > BCl_3 > BF_3$$

- Al and Ga have similar atomic radii due to poor shielding effect of *d*-electrons of Ga atom.
- Aluminium is powerful reducing agent, hence it is used in thermite process.
- Thallium is stored in air tight containers under kerosene, glycerine or vaseline.
- In general alums are potash alums. Alums containing aluminium are known by the name of monovalent metal atom whereas alums which do not contain aluminium are known by the name of trivalent metal atom.

IVA Group Elements (C, Si, Ge, Sn, Pb)

- General electronic configuration is ns^2np^2.
- Common oxidation states are +2 and +4. Ge, Sn and Pb are more stable in +2 oxidation state due to inert pair.
- Generally elements with +2 oxidation state form ionic compounds and +4 oxidation state form covalent compounds.
- Carbon lacks *d*-orbitals therefore, it cannot expand its valence shell so maximum covalency in its compound is not more than four. On the other hand, Si and elements of this group have vacant *d*-orbitals so it can extend its covalency from 4 to 6.
- Carbon due to catenation power (chain forming property) forms millions of compounds.
- Various compounds of carbon are used as fuel, e.g. coal gas, producer gas ($CO + N_2$), semiwater gas ($CO + N_2 + H_2$) etc. (semi water gas is a mixture of water gas and producer gas)
- Stability of their hydrides follows the order

$$CH_4 > SiH_4 > GeH_4 > SnH_4 > PbH_4$$

- Si forms most complicated compounds, e.g. zeolite, mica, talc, asbestos etc.
- CO_2 molecule is linear whereas SiO_2 is three dimensional giant molecule like diamond.
- The thermal stability of halides of IVA group is in the order

$$CCl_4 > SiCl_4 > GeCl_4 > SnCl_4 > PbCl_4$$

and the stability and volatility of tetrahalide is

$$\underset{\text{Most volatile}}{CF_4} > CCl_4 > CBr_4 > \underset{\text{Least volatile}}{Cl_4}$$

Order of hardness is $B_4C > SiC >$ Diamond > Glass.

VA Group Elements (N, P, As, Sb, Bi)

- General electronic configuration is ns^2np^3.
- Due to half-filled orbitals these are quite inert and have abnormally higher IP and lower value of EA.
- They exhibit variable oxidation states as:

$$N = -3, -2, -1, +1, +2, +3, +4, +5$$
$$P, As, Sb = -3, +3, +5$$
$$Bi = +3, +5$$

- These form trihydrides which act as Lewis base.
- N shows anomalous behaviour than rest of the elements due to their small size, high electronegativity, high ionisation energy, non-availability of *d*-orbitals and ease of formation of multiple bonds.

- N_2 can show maximum four covalency in their compounds, e.g. NH_4^+. Various oxides of nitrogen are
  - N_2O : (laughing gas)-neutral, diamagnetic, linear.
  - NO : neutral, paramagnetic, exists as a dimer in solid state.
  - N_2O_3 : acidic, diamagnetic.
  - NO_2 : acidic, paramagnetic, V-shape.
  - N_2O_5 : most acidic (solid)
- Basic nature of hydrides follows the order
  $SbH_3 < AsH_3 < PH_3 < NH_3$
- Bond angle of hydrides decreases as
  $NH_3 > PH_3 > AsH_3 > SbH_3$
- Order of boiling point of hydrides
  $SbH_3 >$ $\underset{\text{(H– Bond)}}{NH_3}$ $> AsH_3 > PH_3$
- Among red and white phosphorus the former is less reactive and used in match industry.

VIA Group Elements (O, S, Se, Te, Po)

- The general electronic configuration is ns^2np^4. These elements are known as chalcogens or ore forming elements.
- The elements show +2, +4 and +6 oxidation state and a coordination number of +4 and +6.
- O_2 molecule is paramagnetic due to the presence of two unpaired electrons.
- Oxygen due to high electronegativity generally show –2 oxidation state. It also exhibit oxidation state of –1 (peroxides), 0 (O_2), +2 (OF_2) and +1 (O_2F_2).
- Ozone is an allotrope of oxygen and acts as a good bleaching agent.
- Order of acidic nature and reducing power of hydrides is
  $H_2O < H_2S < H_2Se < H_2Te$
- Bond angle shows the order $\underset{104.5°}{H_2O} > \underset{92.2°}{H_2S} > \underset{91.0°}{H_2Se} > \underset{90°}{H_2Te}$
- The decreasing order of volatile nature of hydrides of VIA group elements are
  $\underset{\text{Least volatile}}{H_2O} > H_2Te > H_2Se > \underset{\text{Most volatile}}{H_2S}$
- H_2S is more volalite than H_2O due to hydrogen bonding in H_2O.

VII A Group Elements (F, Cl, Br, I, At)

- General electronic configuration is ns^2np^5.
- These are known as halogens.
- F shows –1 oxidation state, while others show –1, +1, +3, +5 and +7 states.
- Reactivity of halogens follow the order
  $F > Cl > Br > I$
- Order of electron affinity of halogens
  $Cl > Br > F > I$
- Order of oxidising character of halogens
  $F_2 > Cl_2 > Br_2 > I_2$
- Strength of hydroacid and reducing character follow the order
  $HF < HBr < HCl < HI$.
- Order of stability of halides is HF > HCl > HBr > HI.
- Order of bond dissociation energy of halogens is
  $I_2 < Br_2 < F_2 < Cl_2$

Zero Group Elements (He, Ne, Ar, Kr, Xe, Rn)

General electronic configuration of these elements is $ns^2\ np^6$.

- The first noble gas compound Xe Pt F_6 was obtained by **N. Bartlett** in 1962.
- All the elements are colourless, tasteless and odourless gases.
- All these are present in atmosphere except radon.
- They are all monoatomic and their atomic size increases with the increase in the atomic number.
- All these gases have zero electron affinities.

USES OF NOBLE GASES

- He is used in gas cooled atomic reactors as a cooling medium.
- Mixture of 85% He and 15% H_2 is used for filling in balloons and airships as it is light, non-combustible gas.
- Mixture of He and O_2 is used for respiration of sea divers.
- Ne is used in neon discharge lamps and signs for advertising purposes.
- Mixture of 85% Ar and 15% N_2 is filled in electric bulb.
- Radon is used in treatment of cancer.

Transition Elements (VIII Group Elements)

- All the transition elements are *d*-block elements but all the *d*-block elements are not transition elements.
- Transition metals have small atomic size and hence their ionisation potential values are high.
- The characteristic property of transition elements is to show several oxidation states.
- They have high density, melting and boiling points.
- They form metallic bond.
- They are coloured and paramagnetic.
- The atomic volume of the transition elements are low as compared with group IA and IIA elements.
- Mn shows maximum oxidation state of +7 in $KMnO_4$.
- Insoluble silver halides are soluble in sodium thiosulphate therefore, sodium thiosulphate is used in photography as a fixer.

$$\underset{}{AgBr} + 2\ \underset{\text{Sodium thiosulphate}}{Na_2S_2O_3} \rightarrow \underset{\text{Sodium argento thiosulphate}}{Na_3[Ag(S_2O_3)_2]} + NaBr$$

- Most abundant transition element is Fe.

PRACTICE EXERCISE

1. Mendeleev corrected the atomic weight of
(a) Be (b) In
(c) Os (d) All of these

2. The base of modern periodic table is
(a) atomic weight (b) atomic number
(c) atomic volume (d) atomic energy

3. Group number and valency has no relation in
(a) zero group (b) first group
(c) IIIrd group (d) VII group

4. Which period and group in the long form of periodic table contain maximum number of elements?
(a) 5th period, IInd group
(b) 6th period, IIIrd group
(c) 6th period, IInd group
(d) Ist period, IInd group

5. Zero group was introduced by
(a) Lother Meyer (b) Mendeleev
(c) Ramsay (d) Lockyer

6. The block in which metals, metalloids, non-metals and inert gases are all present
(a) *s*-block (b) *p*-block
(c) *d*-block (d) *f*-block

7. Which of the following has least density?
(a) Na (b) Li (c) Mg (d) K

8. Which of the following groups may contain a metalloid?
(a) IA (b) IIA
(c) VIA (d) None of these

9. The element with electronic configuration $3d^5 4s^1$ is
(a) metalloid (b) non-metal
(c) transition metal (d) metal

10. In which of the following the tendency towards the formation of coloured ion is maximum?
(a) *s*-block elements
(b) *d*-block elements
(c) *p*-block elements
(d) All of the above

11. Which of the following is known as wonder element?
(a) Zr (b) Zn
(c) Ti (d) None of these

12. Element *A* belongs to group VIIA in *p*-block and element *B* belongs to group IA in *s*-block of the periodic table. Out of the following assumptions, the correct one is
(a) *A* and *B* are metals
(b) *A* and *B* are non-metals
(c) *A* is a metal and *B* is a non-metal
(d) *A* is a non-metal and *B* is a metal

13. All alkaline earth metal ions are
(a) coloured
(b) colourless
(c) paramagnetic
(d) colourless and diamagnetic

14. Which of the following belongs to representative group of elements of periodic table?
(a) Lanthanum (b) Argon
(c) Chromium (d) Aluminium

15. The common semiconductor material is
(a) nitrogen (b) phosphorus
(c) antimony (d) arsenic

16. Which of the following sets of elements belong to the same period?
(a) He, Ne, Ar (b) Ni, Cu, Zn
(c) Cl, Br, I (d) Na, Cu, Mg

17. Which of the following is most abundant transition element?
(a) Copper (b) Iron
(c) Zinc (d) Nickel

18. Which of the following is most electronegative?
(a) Lead (b) Silicon
(c) Carbon (d) Tin

19. Which has least ionisation potential?
(a) N (b) O (c) F (d) Ne

20. Which of the following has the largest ionic radius?
(a) Be^{2+} (b) Mg^{2+} (c) Ca^{2+} (d) Sr^{2+}

21. On descending a group, electropositive character of elements
(a) increases (b) decreases
(c) remains same (d) None of these

22. Which of the following order of ionisation energy is correct?
(a) Be < B < C < N < O
(b) B < Be < C < O < N
(c) Be > B > C > N > O
(d) B < Be < N < C < O

23. In the following, the elements with the highest electro-positivity is
(a) copper (b) cesium
(c) barium (d) chromium

24. In which of the following energy is absorbed?
(a) $F \rightarrow F^-$ (b) $Cl \rightarrow Cl^-$
(c) $O \rightarrow O^{2-}$ (d) $H \rightarrow H^-$

25. The electron affinity of Be is similar to that of
(a) Li (b) B (c) Na (d) Ne

26. The solubility of hydroxides of group IIA increases from $Mg(OH)_2$ to $Ba(OH)_2$ due to
(a) increase in lattice energy
(b) decrease in lattice energy
(c) increase in ionisation energy
(d) increase in thermal stability

27. Fluorine, the most electronegative element in Paulings scale have the value
(a) 1 (b) 2 (c) 3 (d) 4

28. In the context of lanthanoids, which of the following statements is not correct?
(a) There is a gradual decrease in the radii of the members with increasing atomic number in the series
(b) All the members exhibit + 3 oxidation state
(c) Because of similar properties the separation of lanthanoids is not easy
(d) Availability of 4*f*-electrons results in the formation of compounds in +4 state for all members of the series

29. Identify the incorrect statement among the following.
(a) *d*-block elements show irregular and erratic chemical properties among themselves
(b) La and Lu have partially filled *d*-orbitals and no other partially filled orbitals

(c) The chemistry of various lanthanoids is very similar
(d) 4*f* and 5*f*-orbitals are equally shielded

30. Al and Ga have the same covalent radius because of
(a) greater shielding power of *s*-electrons of Ga-atom
(b) poor shielding power of *s*-electrons of Ga-atom
(c) poor shielding power of *d*-electrons of Ga-atom
(d) greater shielding power of *d*-electrons of Ga-atom

31. The first ionisation potential of Na, Mg, Al, Si are in the order
(a) Na > Mg > Al > Si
(b) Na < Mg < Al < Si
(c) Na < Si < Al < Mg
(d) Na < Al < Mg < Si

32. Anomalous behaviour of nitrogen is due to
(a) small size and high electronegativity
(b) non-availability of *d*-orbital in valence shell
(c) ease of multiple bond formation
(d) All of the above are correct

33. Ionic radii of zirconium and hafnium become almost identical because
(a) they are *d*-block elements
(b) they belong to the same group
(c) of increased nuclear charge
(d) of lanthanide contraction

34. Which of the following statements concerning ionisation energy is not correct?
(a) The second ionisation energy is always more than the first
(b) With in a group, there is a gradual increase in ionisation energy because nuclear charge increases
(c) Ionisation energies of the Be is more than B
(d) Ionisation energies of noble gases are high

35. All the elements in a group (family) have a common valency. e.g. all the elements of the carbon family (carbon, silicon, germanium, tin and lead) have common valency four. However, some of the these elements can also have valency two which of the following have valency two?
(a) Silicon, germanium and tin
(b) Germanium and tin
(c) Germanium, tin and lead
(d) Tin and lead

36. The best and the poorest conductors of heat are respectively
(a) silver (Ag) and lead (Pb)
(b) copper (Cu) and aluminium (Al)
(c) silver (Ag) and gold (Au)
(d) copper (Cu) and gold (Au)

37. Match List I with List II and select the correct combination of ions and isoelectronic ions using the codes given below the lists.

List I	List II
A. SO_2	1. CO
B. N_2	2. Cl^-
C. H^-	3. CO_3^{2-}
D. K^+	4. Li^+

Codes

	A	B	C	D
(a)	3	1	2	4
(b)	3	1	4	2
(c)	4	2	1	3
(d)	4	2	3	1

38. Match the properties given in Column I with the metals given in Column II and choose the correct option from the codes given below.

Column I (Property)	Column II (Metal)
A. Element with highest second ionisation enthalpy	1. Co
B. Element with highest third ionisation enthalpy	2. Cr
C. *M* in $M(CO)_6$ is	3. Cu
D. Element with highest heat of atomisation	4. Zn

Codes

	A	B	C	D
(a)	1	2	3	4
(b)	3	4	2	1
(c)	4	3	2	1
(d)	2	1	4	3

39. Which one of the following is a transition metal?
(a) Aluminium (b) Manganese
(c) Magnesium (d) Calcium

40. Which one of the following elements exists in liquid state at room temperature?
(a) Mercury (b) Lead
(c) Sodium (d) Calcium

Previous Years' Questions

41. Which among the following is correct regarding ^{20}Ne, $^{23}Na^+$, $^{19}F^-$ and $^{24}Mg^{2+}$? **2012(I)**
(a) They are isomers of each other
(b) They are isotopes of each other
(c) They are isoelectronic with each other
(d All of the above

42. Which of the following pairs represents isoelectronic ions? **2014(I)**
(a) Na^+, K^+ (b) K^+, Mg^{2+}
(c) Mg^{2+}, Ca^{2+} (d) Ca^{2+}, S^{2-}

43. Match List I with List II and select the correct answer using the codes given below the lists. **2015(II)**

List I (Element)	List II (Use)
A. Li	1. Time keeper in atomic clocks
B. Na	2. Batteries
C. K	3. Transfer of nerve impulses
D. Cs	4. Control of the water content in the blood

Codes

	A	B	C	D
(a)	2	3	4	1
(b)	1	2	3	4
(c)	2	4	3	1
(d)	1	3	2	4

44. The alkali metals have relatively low melting point. Which one of the following alkali metals is expected to have the highest melting point? **2015(II)**
(a) Li (b) Na
(c) K (d) Rb

ANSWERS

1	*d*	2	*b*	3	*a*	4	*b*	5	*c*	6	*b*	7	*b*	8	*c*	9	*c*	10	*b*
11	*c*	12	*d*	13	*d*	14	*d*	15	*c*	16	*b*	17	*b*	18	*c*	19	*b*	20	*d*
21	*a*	22	*b*	23	*b*	24	*c*	25	*d*	26	*b*	27	*d*	28	*d*	29	*d*	30	*c*
31	*d*	32	*d*	33	*d*	34	*b*	35	*c*	36	*a*	37	*b*	38	*b*	39	*b*	40	*a*
41	*c*	42	*d*	43	*a*	44	*a*												

07

CHEMICAL BONDING

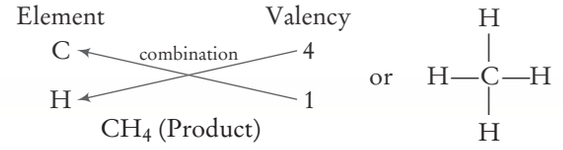
In general 1-2 questions are asked from this chapter. Questions are mainly asked upon the topics of valency and hydrogen bonding.

CHEMICAL BOND

The attractive force which holds various constituents (atoms, ions, etc) together in different chemical species is called a **chemical bond**. During the formation of a chemical bond, energy is released.

Valency

- The capacity of an element to form chemical bonds is known as its valency. The valency of an element is the combining capacity of an element.
- The valency of an element decides the number of other atoms which can combine with one atom of that element, e.g. the valency of carbon is 4 and that of hydrogen is 1. So, one atom of carbon can combine with four atoms of hydrogen to form a methane molecule CH_4 as follows:



- Valency of metal = Number of valence electrons in its atom, e.g. sodium (Na) = 2, 8, 1
  ∴ Valency of sodium = 1
- Valency of non-metal = 8 – Number of valence electrons in its atom. e.g. chlorine Cl_{17} = 2, 8, 7
  ∴ Valency of Cl = 8 – 7 = 1

Some important elements and their valencies are as follows:

(i) H, Cl, Br, I, Cu (ous) etc. are monovalent as their valency is 1.
(ii) O, S, Mg, Ca Zn, Fe (ous), Cu (ic), Pb, Co, Ni etc. are divalent as their valency is 2.
(iii) N, P, Al, Cr, B etc are trivalent as their valency is 3.
(iv) C, Si etc are tetravalent as their valency is 4.

- Some elements e.g., Cu, Fe etc. exhibit more than one valencies (variable valency). Cu and Hg exhibit + 1 and + 2 valencies and Fe exhibits + 2 and + 3 valencies.

Electronic Theory of Chemical Bonding (Octet Rule)

Kossel and Lewis in 1916 developed a theory of chemical combination between atoms known as electronic theory of chemical bonding which was based on inertness of noble gases.

According to this theory "atoms can combine either by transfer of valence electrons from one atom to another (gaining or losing) or by sharing of valence electrons in order to have an octet or stable configuration just like noble gases in their valence shells". This is known as **octet rule.**

TYPES OF CHEMICAL BOND

There are three types of chemical bond

1. Electrovalent or ionic bond
2. Covalent bond
3. Coordinate bond

1. Electrovalent or Ionic Bond

- These types of bonds are formed by the transference of one or more electrons from one atom to another atom.

e.g. $Na \bullet + \times \underset{\times\times}{\overset{\times\times}{Cl}}\overset{\times}{} \longrightarrow [Na]^+ \left[\overset{\times}{\bullet}\underset{\times\times}{\overset{\times\times}{Cl}}\overset{\times}{}\right]$ or Na^+Cl^-

2, 8 2, 8, 8

- Electrovalent bond is formed between most electropositive elements i.e. metals (like, Na, K, Ca, Ba, Mg,etc) and most electronegative elements i.e. non-metals (like, O, F, N, S, Cl, Br etc.,).
- The number of electrons lost or taken up by the element is called electrovalency of the element which is equal to charge of cation or anion respectively and these types of compounds are called **electrovalent compounds**.
- Electropositive elements form cations by losing electrons and electronegative elements form anions by gaining electrons.
- If the difference in electronegativity of the atoms is around 1.9 and more, then bond is generally ionic.

Characteristics of Ionic Compounds

The main characteristics are as following

(i) Ionic compounds are crystalline in nature. Their constituent units are ions. These ions are arranged together in a regular way in an ionic lattice, e.g., in NaCl lattice each sodium ion is bonded with six Cl^- ions and each Cl^- ion is surrounded by six Na^+ ions.

(ii) Ionic compounds are hard and brittle in nature due to the strong force of attraction between oppositely charged ions. These solids have low volatility, high stability and high density.

(iii) These have high melting and boiling points due to the presence of powerful electrostatic force between the ions.

(iv) These are good conductors of heat and electricity in molten state or aqueous medium due to the mobility of ions.

(v) These are soluble in polar solvents like water but insoluble in non-polar solvents like CCl_4, C_6H_6 etc.

(vi) Ionic compounds form ions in solution, hence exhibit ionic reactions which are quite fast and instantaneous.

(vii) The bond in ionic compound is non-rigid and non-directional, so these do not show isomerism.

Variable Electrovalency

The elements which change their valency and have more than one electrovalency are said to possess variable electrovalency. This is due to following two reasons

(i) **Inert pair effect** It is observed that in the case of heavy elements like Pb, Bi, etc ns^2 electrons have extra stability and hence do not take part in bond formation. This effect is called inert pair effect. This effect increases with increasing the atomic number in a group, e.g. Ge and Pb belongs to the 14th group of Periodic Table, but Ge stable in Ge^{4+} state and Pb stable in Pb^{2+} state. Thus, Pb^{2+} salts are stable than Pb^{4+} salts.

(ii) **Unstable configuration of the core** In *d*-block elements, core possess unstable arrangement of electrons. Hence, they show variable valency, e.g. Fe^{2+} ($3s^2$, $3p^6$, $3d^6$) lose an electron to change into $Fe,^{3+}$ which cannot lose further electrons.

2. Covalent Bonds

These types of bonds are formed by the mutual sharing of equal number of electrons by the atoms in the molecules. Thus, the bond formed by the sharing of electrons is called covalent bond and compounds possesing covalent bond are called covalent compounds.

Formation of H_2 molecule $H\bullet + \bullet H \longrightarrow H\!:\!H$ or (H – H)

- Single, double and triple bonds are formed by the sharing of one, two and three electron pairs respectively.

Covalent bonds are of two types

(i) **Non-polar Covalent Bonds** These types of covalent bonds are formed between two identical atoms or atoms having the same electronegativity. The atoms which share electrons have approximately equal electro negativity, the electron pair is equally shared between them, such a bond is called polar covalent bond e.g. Cl_2, O_2 etc.

(ii) **Polar Covalent Bonds** These types of covalent bonds are formed between different elements or elements having different electronegativity. In this bond the electron pair is attracted towards more electronegative atom, therefore one atom have partial negative charge and other atom have partial positive charge, e.g. HBr, HCl etc.

Characteristics of Covalent Compounds

The main characteristics are as following

(i) In general covalent compounds are gases or liquids. Some of the compounds are soft solids.

(ii) These compounds are slightly soluble in water but highly soluble in organic solvents such as alcohols, ethers etc.

(iii) Those covalent molecules which form hydrogen bonds with water molecules becomes fairly soluble in water. e.g. lower alcohols, lower carboxylic acids etc.

(iv) They are bad conductors of electricity because they do not contain ion, but, when a covalent molecule reacts with water, it dissolves and produces ions, and hence, begins to conduct electricity.

(v) They have relatively low melting and boiling points [except diamond, silica, carborundum (SiC)] due to weak covalent bonds.

(vi) Due to low melting and boiling points, covalent solids are more volatile than ionic solids and therefore have high vapour pressure.
(vii) They are generally rigid and directional hence show isomerism.
(viii) They undergo chemical reactions which are quite slow because these reactions involve breaking of older bonds and formation of new bonds.

Dipole Moment

The property which measures the extent of polarity in the bond is called dipole moment.

Dipole moment = Magnitude of charges (e) × distance (d)

- Dipole moments of diatomic molecules is zero because they are non-polar, e.g. H_2, Cl_2, F_2, O_2, N_2 etc.
- Dipole moments of HF, HCl, HBr and HI are very large due to their high electronegativity differences.
- Molecules like CO_2, CS_2 and BeF_2 are linear and possess polar covalent bonds. The bond moments of two bonds being equal but opposite in direction cancel each other so their dipole moment is zero.
- The dipole moment of CH_4, CCl_4, BF_3 are zero due to their symmetrical structure.

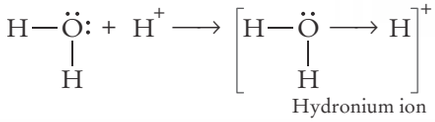
3. Coordinate or Dative Bond

The bond in which both electrons in the shared pair come from one atom is called coordinate covalent bond.

Such type of bond is formed between atoms one of which is deficient in atleast two electrons, while the other atom has already acquired stable noble **gas configuration.**

The atom which donates the electrons is called the donor while the other which only accepts the electrons pair is known as **acceptor.** This bond is usually represented by an arrow (→) pointing from donor to the acceptor atom.

e.g., a hydrogen ion can combine with water molecules by coordinate covalent bond to form hydronium ion (H_3O^+).



Coordinate Covalent Bonds in Complex Compounds

In complex compounds ligandsdonate a pair of electron to the central metal atom. Thus, in a complex, ligands join with central metallic atom by a coordinate covalent bond, e.g. $K_4[Fe(CN)_6]$.

- In complex salts, central metal atom act as **Lewis acid.**

Characteristics of Coordinate Covalent Compounds

The main characteristics are as following

(i) These exist as solids, liquids, and gases under normal conditions.
(ii) These are sparingly soluble in polar solvent like water but readily soluble in **non-polar solvents.**
(iii) These are bad conductor of heat and electricity.
(iv) The melting and boiling points are higher than purely covalent compounds.
(v) Coordinate bond is rigid and directional. Thus, these compounds show isomerism.
(vi) Compounds which have coordinate covalent bond possess high values of dielectric constant.

➨ **Note** According to octet rule, an atom has a tendency to occupy 8 electrons (2 in H like He) in its valence shell, which is stable arrangement, but a number of molecules are knwon which violates octet rule.

e.g. (i) BeF_2, BF_3 (incomplete octet)
(ii) NO, NO_2 (odd number electrons)
(iii) PCl_5, SF_6 (expanded octet)

HYDROGEN BOND

The attractive interaction of a hydrogen atom with an electronegative atom such as nitrogen (N), oxygen (O) or fluorine (F) that comes from another molecule or chemical group, is called hydrogen bond.

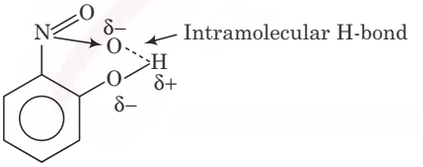
It is stronger than van der Waals' interaction and has energy 5 to 30 kJ/mol. It occurs in both inorganic molecules such as water and organic molecules such as DNA.

Hydrogen bonds can be of the following two types

(i) **Intermolecular H-bonding** It occurs between different molecules of a substance and results in increasing solubility in water and high boiling point
e.g. HF, H_2O, C_2H_5OH etc.

H — F.....H — F.....H — F

(ii) **Intramolecular H-bonding** It is found within different parts of a single molecule and results in decreasing solubility in water and low boiling point e.g. *o*-nitrophenol.



- Metals posses **metallic bond.**
- **Soft metals** like Na, K possess weak metallic bond and hence can be cut with a knife.
- The atoms of transition metals are held together by strong metallic bonds because of large number of unpaired electrons in their atoms. Therefore, all transition metals are much harder and less volatile.

PRACTICE EXERCISE

1. An element has the electronic configuration $1s^2, 2s^2 2p^6, 3s^2 3p^2$. The number of valence electrons will be
(a) 2 (b) 3 (c) 4 (d) 5

2. Outermost shells of two elements X and Y have two and six electrons respectively. If they combine the expected formula of the compound will be
(a) XY (b) X_2Y (c) X_2Y_3 (d) XY_3

3. The formula of a metallic chloride is MCl_2, the formula of its bicarbonate is
(a) MCO_3 (b) $MHCO_3$
(c) $M(HCO_3)_2$ (d) $M(CO_3)_2$

4. Two elements gallium and oxygen combine to form a compound Ga_2O_3. Which among the following is the valency of gallium?
(a) 1 (b) 2 (c) 3 (d) 4

5. The formation of chemical bond is accompanied by
(a) increase in energy
(b) decrease in energy
(c) neither decrease nor increase in energy
(d) the repulsive forces overcoming the attractive forces

6. An electrovalent compound does not show isomerism due to
(a) high melting point
(b) presence of ions
(c) strong electrostatic force between ions
(d) non-directional nature of electrovalent bond

7. Elements whose electronegativities are 1.2 and 3.0, bond formed between them would be
(a) ionic (b) covalent
(c) coordinate (d) metallic

8. Ionic bond formation is
(a) exothermic (b) endothermic
(c) Both (a) and (b) (d) None of these

9. Many ionic crystals dissolve in water because
(a) water is an amphiprotic solvent
(b) water is high boiling liquid
(c) the process is accompained by positive heat of solution
(d) water decreases the interionic attraction in the crystal lattice due to solvation

10. Which one of the following has high melting and boiling points?
(a) CCl_4 (b) $AlCl_3$ (c) $CaCl_2$ (d) NCl_3

11. Which one of the following has a giant covalent structure?
(a) PbO_2 (b) SiO_2 (c) NaCl (d) $AlCl_3$

12. Which one of the following is a covalent molecule?
(a) Al_2Cl_6 (b) Al_2O_3
(c) AlF_3 (d) All of these

13. Which one of the following is correct?
(a) Water is a non-polar molecule in normal conditions
(b) Water is a polar molecule in normal conditions
(c) Water exist in the form of H^+OH^- in normal conditions
(d) All of the above are correct

14. Carbon suboxide (C_3O_2) has recently been shown as a component of the atmosphere of Venus. Which of the following formulation represents the correct ground state Lewis structure for C_3O_2?
(a) :O :C :C ::O :
(b) :O :C ::C :O :
(c) :Ö ::C ::C ::C ::Ö :
(d) :O ::C :C ::O :

15. Hydrogen fluoride is a liquid unlike other hydrogen halides because
(a) HF molecule associate due to hydrogen bonding
(b) F_2 is highly reactive
(c) HF is the weakest acids of all hydrogen halides
(d) fluorine atoms is the smallest of all halides

16. Which one of the following has highest dipole moment?
(a) CO_2 (b) $CHCl_3$
(c) CCl_4 (d) CH_2Cl_2

17. Both ionic and covalent bond present in
(a) CH_4 (b) NaCl
(c) SO_2 (d) KOH

18. Which contain both polar and non-polar bonds?
(a) NH_4Cl (b) HCN (c) H_2O_2 (d) CH_4

19. Which of the following having electrovalent, covalent and coordinate covalent bond?
(a) BF_3 (b) $CuCl_2$
(c) $CuSO_4 \cdot 5H_2O$ (d) $FeCl_3 \cdot H_2O$

20. Type of bonds present in $K_4[Fe(CN)_6]$ molecule is
(a) covalent and electrovalent bonds
(b) covalent and coordinate covalent bonds
(c) electrovalent, covalent and dative bonds
(d) electrovalent bond and dative bonds

21. Which one of the following has odd electron bond?
(a) PCl_3 (b) SF_4 (c) NO (d) $POCl_3$

22. Which of the following is soluble in water?
(a) CS_2 (b) C_2H_5OH
(c) CCl_4 (d) $CHCl_3$

23. Consider the following statements.
I. NaCl is ionic solid.
II. Benzene is covalent compound.
III. Carbon has tetravalency.
Codes
(a) I and II (b) II and III
(c) I and III (d) All of these

24. Which of the following statements are true?
I. Water is liquid at room temperature due to hydrogen bonding.
II. Covalent bond is directional.
III. Co-ordinate or dative bond containing compounds have high values of dielectric constant.
Codes
(a) I and II (b) II and III
(c) I and III (d) All of these

25. Consider the properties related to co-ordinate or dative linkage compounds.
I. They are rigid and directional.
II. They exhibit isomerism.

III. They contain high dielectric constants.
IV. They are poor conductors of electricity in solid as well as in fused state.

Codes
(a) I, II and III (b) II, III and IV
(c) I, III and IV (d) All of these

Directions (Q. Nos. 26-28)
Following questions consist of two statements labelled as Statement I *and Statement* II. *Examine both the statements carefully and match the correct choice according to the codes given below.*
(a) Both Statement I and Statement II are true and Statement II is the correct explanation of the Statement I.
(b) Both Statement I and Statement II are true but Statement II is not the correct explanation of the Statement I.
(c) Statement I is true, but Statement II is false.
(d) Statement I is false, but Statement II is true.

26. **Statement I** Water (H_2O) is more polar than hydrogen sulphide (H_2S).
Statement II Oxygen is more electronegative than sulphur.

27. **Statement I** Purely covalent compounds cannot conduct electricity in their aqueous solution or in molten state.
Statement II Purely covalent compounds have lower melting and boiling points.

28. **Statement I** Fluorine exhibits the same oxidation state in all its compounds.
Statement II Fluorine atom has no *d*-orbital in its valence shell.

29. Match List I with List II and select the correct answer from the codes given below the lists:

List I		List II	
A.	Ionic compound	1.	NH_4Cl
B.	Polar covalent	2.	O_2
C.	Non-polor covalent molecule	3.	HCl
D.	Dative bond	4.	KCl

Codes

	A	B	C	D
(a)	4	3	2	1
(b)	1	3	2	4
(c)	4	1	2	3
(d)	1	2	4	3

30. Match List I with List II and select the correct answer from the codes given below the lists.

List I (Elements)		List II (Valency)	
A.	K	1.	two
B.	Zn	2.	one
C.	Al	3.	four
D.	C	4.	three

Codes

	A	B	C	D		A	B	C	D
(a)	2	1	4	3	(b)	2	3	1	4
(c)	3	1	4	2	(d)	3	4	1	2

Previous Years' Questions

31. Three elements Na, S and O combine to form a compound Na_2SO_3. What is the valency of S in this compound? **2012 (II)**
(a) +2 (b) +4 (c) +6 (d) +8

32. The bond which is present between water molecules is **2012 (II)**
(a) electrovalent bond
(b) covalent bond (c) hydrogen bond
(d) van der Waals' bond

33. The number of valence electrons in the O^{2-} ion is **2014(I)**
(a) 4 (b) 6
(c) 8 (d) 10

34. Which one of the following is the correct electronic configuration of chlorine? **2014(I)**
(a) 2, 7, 8 (b) 2, 8, 7
(c) 2, 8, 8 (d) 7, 8, 9

35. The high heat of vaporisation of water is mainly a result of **2014(II)**
(a) van der Waals' forces
(b) covalent bonds
(c) interionic attraction
(d) hydrogen bonding

36. Which of the following element combinations will form ionic compounds? **2014(II)**
1. Ca ($Z = 20$) and Ti ($Z = 22$)
2. Si ($Z = 14$) and Br ($Z = 35$)
3. Mg ($Z = 12$) and Cl ($Z = 17$)

Select the correct answer using the codes given below.
(a) Only 2
(b) Only 3
(c) 2 and 3
(d) All of the above

37. Which one among the following does not wet the walls of the glass vessel in which it is kept? **2015(I)**
(a) Water
(b) Alcohol
(c) Mercury
(d) Phenol

38. Which one of the following statements is correct? **2016(II)**
(a) Covalent bonds are directional
(b) Ionic bonds are directional
(c) Both covalent and ionic bonds are directional
(d) Both covalent and ionic bonds are non-directional

ANSWERS

1	c	2	a	3	c	4	c	5	b	6	d	7	a	8	a	9	d	10	c
11	b	12	a	13	b	14	c	15	a	16	d	17	d	18	c	19	c	20	c
21	c	22	b	23	d	24	d	25	d	26	a	27	b	28	a	29	a	30	a
31	b	32	c	33	c	34	b	35	d	36	b	37	c	38	a				

08

ACIDS, BASES AND SALTS

In general 2-3 questions have been asked from this chapter every year. Questions from this chapter usually test your basic knowledge of acids and bases which are used in your daily life. Properties and uses of acids and bases and pH of the solution are important topics of this chapter.

ACIDS

Substances, which have sour taste and turn blue litmus red, are called acids.

- According to **Arrhenius**, acids are the substances, which give H^+ ions in their aqueous solutions.

  e.g. $HCl \longrightarrow H^+ + Cl^-$

- According to **Bronsted-Lowry concept**, acids are proton donor.

  e.g. $\underset{\text{Acid}}{CH_3COOH} \longrightarrow \underset{\text{Conjugate base}}{CH_3COO^-} + \underset{\text{Proton}}{H^+}$

  Similarly, $\underset{\text{Acid}}{HCl} \longrightarrow \underset{\text{Conjugate base}}{Cl^-} + \underset{\text{Proton}}{H^+}$

  A conjugate base is obtained, when an acid give up a proton (H^+).

  $\text{Acid} - H^+ \longrightarrow \text{Conjugate base}$

  The acid and base which differ by a proton are said to form a conjugate acid-base pair. Generally, a strong acid has a weak conjugate base and a weak acid has a strong conjugate base.

- According to **Lewis concept**, acids are electron pair acceptor i.e. these are generally positively charged or electron deficient species. e.g. BF_3, $AlCl_3$, Na^+, K^+, PF_3, SF_4 etc.

Classification of Acids

Acids can be classified in the following classes:

***Class* I** On the basis of degree of dissociation, acids are of two types

(i) **Strong acids** Dissociates completely even in concentrated solution, e.g. HCl, HNO_3, H_2SO_4, $HClO_4$ etc.

$HCl + H_2O \longrightarrow H^+(aq) + Cl^-(aq)$

(ii) **Weak acids** Dissociates partially when dissolved in water, e.g. acetic acid (CH_3COOH), formic acid (HCOOH) etc.

$CH_3COOH + H_2O \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$

***Class* II** On the basis of the presence of oxygen or hydrogen in the acid, these can be divided into two classes

(i) **Hydracids** These do not contain oxygen. Besides hydrogen they contain other non-metallic elements like hydrochloric acid (HCl), hydrofluoric acid (HF) etc.

(ii) **Oxyacids** These contain both oxygen and hydrogen and also have another non-metallic element, e.g. sulphuric acid (H_2SO_4), nitric acid (HNO_3) etc.

Basicity of Acid

The number of displacing protons present in an acid is known as basicity of the acid.

- **Monobasic acid** has only one hydrogen ion and can combine with one hydroxyl (OH) group to give one kind of salt, e.g., HCl, HNO_3, CH_3COOH etc.

- **Boric acid** is a weak monobasic acid. It is not able to release H^+ ions on its own. It receives OH^- ions from water molecule to complete its octet and in turn release H^+ ions.
- **Dibasic acid** has two hydrogen ions and hence can combine with two hydroxyl groups to give two kinds of salts,
  e.g. H_2SO_4, H_2SO_3, $(COOH)_2$ etc.
- **Tribasic acid** has three hydrogen ions and can combine with three hydroxyl groups to give three kinds of salts,
  e.g. H_3PO_4 etc.

Factors Affecting Acidic Strength of Acids

- Acidic strength of acids increase with increase in the size of atom.
  e.g. $HF < HCl < HI$
- Acidic strength of acids increase with increase in electronegativity of elements.
  e.g. $H—CH_3 < H—NH_2 < H—OH < H—F$
- Among oxyacids of some element, acidic strength increase with increase in the oxidation state of that element.
  e.g. $\underset{+1}{HClO_1} < \underset{+3}{HClO_2} < \underset{+5}{HClO_3} < \underset{+7}{HClO_4}$

Properties of Acids

Acids possess the following general properties

- Acids when react with reactive metals like Zn, Fe, Na liberates hydrogen.
  $$Zn + 2HCl \longrightarrow ZnCl_2 + H_2\uparrow$$
- Acids when react with carbonates and bicarbonates produces CO_2 gas which turns lime water milky.
  $$\underset{\text{Marble (calcium carbonate)}}{CaCO_3} + \underset{\text{Sulphuric acid}}{H_2SO_4} \longrightarrow \underset{\text{Calcium sulphate}}{CaSO_4} + \underset{\text{Water}}{H_2O} + \underset{\text{Carbon dioxide}}{CO_2\uparrow}$$
- Acid react with base to give salt and water. It is known as neutralisation reaction
  $HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l)$
- Acids also react with metallic oxides to form salt and water.
  $$Na_2O + 2HCl \longrightarrow \underset{\text{Salt}}{2NaCl} + H_2O$$

Above reaction is similar to neutralisation reaction (Acid-base reaction). Therefore metallic oxides are also called basic oxides.

- Aqueous solution of acids conduct electricity.
- A concentrated solution of 3 part conc. HCl and 1 part conc HNO_3 is called aqua-regia. All metals dissolve in it.

Some Naturally Occurring Acids

Natural source	*Acids*
Vinegar	Acetic acid
Orange/Lemon	Citric acid
Tamarind	Tartaric acid
Tomato	Oxalic acid
Curd/Milk	Lactic acid
Nettle sting	Methanoic acid (formic acid)
Ant sting	Methanoic acid (formic acid)
Apple	Maleic acid
Curd	Lactic acid

Uses of Some Important Acids

- **Nitric acid** is used in manufacture of artificial silk, dyes, drugs, perfumes, explosives (TNT), fertilisers and in purification of silver and gold.
- **Sulphuric acid** (king of chemicals) is used in manufacture of hydrochloric acid, nitric acid, fertilisers, explosives, paints and pigments, coaltar, dyes, lead storage batteries and as an oxidising and dehydrating agent.
- **Hydrofluoric acid** is used in etching of glass and in pickling of alloy steel.
- **Hydrochloric acid** is the main constituent of gastric acid and is used in manufacture of chlorine, chlorides and in textile, dyeing and tanning industry.
- **Boric acid** is used as an antiseptic, for eye wash.
- **Acetic acid** is used in food processing, in the manufacture of acetone and as a solvent.

BASES

These are the substances, which have bitter taste and turn red litmus blue.

- According to **Arrhenius**, these give hydroxyl ion (OH^-) in aqueous solutions.
  e.g. $\underset{\text{Sodium hydroxide (base)}}{NaOH\,(aq)} \rightleftharpoons Na^+(aq) + \underset{\text{Hydroxyl ion}}{O\overline{H}\,(aq)}$
  Similarly, $\underset{\text{Potassium hydroxide}}{KOH\,(aq)} \rightleftharpoons K^+(aq) + \underset{\text{Hydroxyl ion}}{O\overline{H}(aq)}$
- According to **Bronsted-Lowry concept**, these are proton acceptors. e.g. $\underset{\text{Base}}{NH_3} + \underset{\text{Proton}}{H^+} \rightleftharpoons \underset{\text{Conjugate acid}}{NH_4^+}$
  Similarly, $\underset{\substack{\text{Water}\\\text{(base)}}}{H_2O} + \underset{\text{Proton}}{H^+} \rightleftharpoons \underset{\substack{\text{Hydronium ion}\\\text{(conjugate acid)}}}{H_3O^+}$
- According to **Lewis concept**, bases are electron pair donors. e.g. $\ddot{N}H_3$, $R\ddot{O}H$, $R_2\ddot{O}$, pyridine etc.

➨ **Note** Conjugate acid of a weak base is strong or *vice-versa*.
Base + H^+ ⟶ Conjugate acid

Types of Bases

On the basis of degree of dissociation bases are of two types

- **Strong base** Dissociates completely even in concentrated solutions, e.g. KOH, NaOH etc.
- **Weak base** Partially dissociates in water, e.g. $Mg(OH)_2$, NH_4OH, $NaHCO_3$, $Ca(OH)_2$ etc.

Properties of Bases

Bases possess the following general properties

(i) Bases react with metals to form salt with the evolution of hydrogen gas.

$$\underset{\text{Base}}{2NaOH} + Zn \rightarrow \underset{\text{Sodium zincate (salt)}}{Na_2ZnO_2} + H_2\uparrow$$

This reaction is not given by all bases.

(ii) The reaction of bases with acids is known as neutralisation reaction, which leads to the formation corresponding salt and water.

(iii) Bases react with non-metallic oxides to form salt and water.

$$\underset{\text{(Base)}}{\underset{\text{Sodium hydroxide}}{2NaOH}} + \underset{\text{Sulphur trioxide(acid)}}{SO_3} \longrightarrow \underset{\text{sulphate (salt)}}{\underset{\text{Sodium}}{Na_2SO_4}} + \underset{\text{Water}}{H_2O}$$

Above reaction is similar to neutralisation reaction (acid-base reaction). Therefore nature of non-metallic oxides is acidic.

(iv) Bases on dissolving in water give hydroxide ions (OH^- ions)

$$\text{e.g. } \underset{\text{Sodium hydroxide}}{NaOH\,(s)} \xrightarrow{\text{water}} Na^+(aq) + OH^-\,(aq)$$

All the bases do not dissolve in water. The bases which dissolve in water are called alkali e.g. NaOH, KOH, $Ca(OH)_2$, NH_4OH etc. Hence, all alkalis are bases but all the bases are not alkalis.

Acidity of Base

The number of hydroxyl ions present in a base is known as acidity of the base.

- **Monoacidic bases** which produces one hydroxide ions in aqueous solutions are called monoacidic bases.
  e.g. KOH, NH_4OH, NaOH.
- **Diacidic bases** which produces two hydroxide ions in aqueous solutions are called diacidic bases.
  e.g. $Ca(OH)_2$, $Fe(OH)_2$, $Zn(OH)_2$.
- **Triacidic bases** which produces three hydroxide ions in aqueous solutions are called triacidic bases.
  e.g. $Fe(OH)_3$, $Al(OH)_3$.

Uses of Some Important Bases

- **Sodium hydroxide** is used in manufacture of soap purification of bauxite and manufacture of rayon.
- **Potassium hydroxide** is used in the manufacture of soft soap. A suspension of **magnesium hydroxide** in water is used in medicines as an antacid. (milk of magnesia)
- **Calcium hydroxide** is used in preparation of sodalime (mixture of calcium hydroxide and caustic soda), for white washing buildings and softening of hard water.

pH SCALE

- The acidic or basic strength of a solution is expressed on a scale known as **pH scale**. The idea of pH scale and the scale was given by **Sorensen**.
- pH of a solution is defined as the negative logarithm of the concentration in moles per litre of H^+ ions which it contains.

$$pH = -\log [H^+] = \log \frac{1}{[H^+]}$$

- pH is a measure of acidity. As the pH increases, the acidic nature decreases. For pure water or neutral solutions, pH = 7, for bases pH > 7 and for acids. pH < 7. (That's why pH of 10^{-8} *M*HCl or 10^{-9} *M*HCl is in between 6 to 7).
- pH of the solution of strong or weak neutral salt in water is always neutral.
- pH of the solution of acidic salt in water is always acidic (i.e. <7). pH of the solution of basic salt in water is always basic (i.e. >7).
- On dilution, pH of an acidic solution increases but pH of a basic solution decreases.

pH Range of Some Common Substances

Gastric juice	—	1.0 – 3.0
Soft drinks	—	2.0 – 4.0
Lemon	—	2.2 – 2.4
Vinegar	—	2.4 – 3.4
Urine (human)	—	4.8 – 8.4
Saliva (human)	—	6.5 – 7.5
Rain water	—	6.0
Tears	—	7.4
Sea water	—	8.5
Milk of magnesia	—	10.5
Milk (cow)	—	6.3 – 6.6
Blood plasma (human)	—	7.36 – 7.42

Indicator

An indicator is a substance which gives different colours in an acid and a base. Thus, it is possible to check whether a given substance is acid or base or neutral with the help of indicator.

- Litmus, red cabbage leaves, turmeric (haldi) coloured petals of some flowers such as hydrangea, petunia and geranium etc. are natural acid-base indicators. Methyl orange, phenolphthalein etc. are synthetic indicators.
- **Universal indicator** is a mixture of several indicators. It shows different colours at different concentrations of hydrogen ions. We can estimate the strength of acids and bases by using universal indicators.

Some Important Indicators

1. **Alizarin** It is yellow at pH 5.5 and red at pH 6.8.
2. **Cochineal** It is yellow in acidic solution, and deep violet in alkaline solution.
3. **Curcumin** It is yellow at pH 7.4 and red at pH 8.6.
4. **Turmeric** Turmeric solution stays yellow in the presence of acids and changes to purple brown in the presence of bases. Dry turmeric paper is bright yellow and changes to red in the presence of bases.
5. **Phenolphthalein** Phenolphthalein is purple in very basic solutions and colourless in acidic solutions.
6. **Red cabbage** Red cabbage juice indicator is red in acid solution, purple in neutral solutions and greenish yellow in basic solutions. Cabbage paper turns green in the presence of bases and pink to red in the presence of acids.

BUFFER SOLUTIONS

- The solution which maintains its pH or reserve acidic or basic nature even upon addition of a small amount of acid or a base is called buffer solution.
- These solutions have a definite pH value.
- In industries, buffer solutions are used for alcoholic fermentation (pH 5 to 6.5), tanning of leather, electroplating, sugar and paper industries.
- In biological systems buffer system of carbonic acid and sodium bicarbonate is found in our blood. It maintains the pH of our blood (about 7.4).

Types of Buffers

Synthetic buffers are of two types

(i) **Acidic Buffer** These are the mixtures of weak acids and its conjugate bases.
e.g. $CH_3COOH + CH_3COONa$

(ii) **Basic Buffer** These are the mixtures of weak bases and its conjugate acids. e.g. $NH_4Cl + NH_4OH$

SALTS

When acid and base react together, they form salt and water. This reaction is known as **neutralisation reaction**. e.g.

$$\underset{\text{Acid}}{HNO_3} + \underset{\text{Base}}{KOH} \longrightarrow \underset{\text{Salt}}{KNO_3} + \underset{\text{Water}}{H_2O}$$

When acid and base both are strong, 13.7 kcal energy is released. However, if either the acid or the base is weak, energy released is less than 13.7 kcal. This is because some of the energy is utilised to ionise the weak acid or weak base. The energy released is called **enthalpy of neutralisation**.

Types of Salts

Salts are of the following types

(i) **Simple salts** These salts are obtained by the complete neutralisation reaction of acids and bases.
e.g. NaCl, KCl, $BaCl_2$, $CaCl_2$ etc.

(ii) **Acidic salts** Salts having replaceable H-atom are known as acidic salt. These are formed due to incomplete neutralisation reactions e.g. $NaHSO_4$, NaH_2PO_4 etc.

(iii) **Basic salts** Salts having replaceable OH group are known as basic salts. These are also formed due to incomplete neutralisation reactions, e.g. $Ca(OH)NO_3$.

(iv) **Double salts** In these salts two or more normal salts are present in a molecule in crystalline state,

e.g. Mohr's salt $FeSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$
Potash alum $K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$
Carnallite $KCl \cdot MgCl_2 \cdot 6H_2O$

(v) **Mixed salts** In these salts more than one type of cations or anions are present. e.g, $NaKSO_4$, Ca(OCl) Cl, Mg (NH_4), PO_4 etc.

(vi) **Complex salts** Complex salts retain their identity even when dissolved in water, e.g. when ferrous sulphate solution and potassium cyanide solution are mixed together, $K_4[Fe(CN)_6]$ is formed.

$$FeSO_4 + 6KCN \longrightarrow K_4[Fe(CN)_6] + K_2SO_4$$

Hydrolysis of Salts

- When a salt of strong base and weak acid or weak base and strong acid is dissolved in water, it reacts with water to give back the original acid and base from which the salt was formed. This process is known as salt hydrolysis.
- Hydrolysis is the reverse process of neutralisation reaction.
- Only salt of weak acid + strong base, weak base + strong acid undergo hydrolysis.
- The phenomena in which cation or anion of both of a salt react with water to produce acidic or alkaline solution is known as hydrolysis

$$\underset{\text{Salt}}{CA} \xrightarrow[\text{hydrolysis}]{HOH} \underset{\text{Cation}}{C^+} + \underset{\text{Anion}}{A^-}$$

- The interaction of cation of a salt with water to give acidic solution is called cationic hydrolysis.

$$\underset{\text{Cation}}{C^+} + 2H_2O \rightleftharpoons \underset{\text{base}}{COH} + \underset{\text{ion}}{H_3O^+}$$

- The interaction of anion of a salt with water to give alkaline solution is called anionic hydrolysis.

$$\underset{\text{of salt}}{A^-} + H_2O \rightleftharpoons \underset{\text{acid}}{HA} + OH^-$$

- The aqueous solution of salt of strong acid and strong base is neutral e.g. NaCl, KCl, Na_2SO_4 etc.
- The aqueous solution of salt of strong acid and weak base is acidic e.g. $FeCl_3$, NH_4Cl, $(NH_4)_2SO_4$ etc.
- The aqueous solution of salt of weak acid and strong base is basic e.g. CH_3COONa, Na_2CO_3 etc.

PRACTICE EXERCISE

1. According to Arrhenius theory, an acid is a substance which
(a) gives a proton in aqueous solution
(b) accepts a proton in aqueous solution
(c) gives a hydrogen ion in aqueous solution
(d) accepts a lone pair of electron

2. Aqueous solution of acetic acid contains
(a) CH_3COOH, CH_3COO^-
(b) CH_3COO^-, H^+,
(c) CH_3COOH, CH_3COO^-, H_3O^+
(d) CH_3COOH, H^+

3. Acids generally react with alkalies to form salt and water. Which one of the following bases, on reaction with acid, does not produce water along with salt?
(a) Ammonia
(b) Sodium bicarbonate
(c) Sodium hydroxide
(d) Calcium hydroxide

4. Human stomach produces acid *X* which helps in digestion of food. Acid *X* is
(a) acetic acid (b) methanoic acid
(c) hydrochloric acid
(d) citric acid

5. Which one of the following is the strongest acid?
(a) $ClO_3(OH)$ (b) $ClO_2(OH)$
(c) $ClO(OH)$ (d) $Cl(OH)$

6. Amongst the trihalides of nitrogen, which one is least basic?
(a) NF_3 (b) NCl_3 (c) NBr_3 (d) NI_3

7. The conjugate acid of NH_2^- is
(a) NH_3 (b) NH_2OH
(c) NH_4^+ (d) N_3H

8. Which one of the following is amphiprotic in nature?
(a) F^- (b) HPO_4^{2-}
(c) PO_4^{3-} (d) Cl^-

9. When an organic compound is heated with cupric oxide, a gas *X* and H_2O produced as a result. When the gas *X* is passed through the lime water, it turns the lime water into milky. When it passed in the excess the milky colour disappears. By the litmus solution it is found that the gas *X* is acidic in nature. The gas *X* is
(a) CO (b) CO_2 (c) SO_2 (d) SO_3

10. Select the strongest acid among the following.
(a) HCOOH (b) CH_3COOH
(c) C_2H_5COOH (d) C_3H_7COOH

11. Reaction,
$\ddot{N}H_3 + BF_3 \longrightarrow NH_3 \rightarrow BF_3, NH_3$ and BF_3 are
(a) Lewis base and Lewis acid
(b) Lewis base and Lewis base
(c) Lewis acid and Lewis base
(d) Arrhenius acid and base

12. A strong acid has a conjugate
(a) strong base
(b) weak base
(c) strong acid
(d) weak acid

13. Which of the following is incorrect?
(a) HCOOH is stronger acid than CH_3COOH
(b) HClO is stronger acid than $HClO_4$
(c) Water is more acidic than methanol
(d) All of the above

14. Base turn red litmus blue and acids turn blue litmus red. A student tested a liquid with a red litmus paper and it stayed red with no change. This shows that the liquid
(a) must be pure water
(b) must be an acid
(c) is not a base
(d) is neither a base nor an acid

15. When concentrated H_2SO_4 spilts on the surface, it should be immediately cleaned
(a) with a piece of cloth
(b) by adding cold water
(c) by adding solid Na_2CO_3
(d) by adding solid $BaCl_2$

16. A student heated some sulphur in a spatula and collected the gas '*X*'. Which one among the following is correct about '*X*'?
(a) *X* is SO_2 and it turns moist litmus to blue
(b) *X* is SO_3 and it turns moist litmus to red
(c) *X* is SO_2 and it turns moist litmus to red
(d) *X* is SO_3 and it turns dry litmus to blue

17. pH values for acids A, B, C, D are 1, 2, 4, and 2.5 respectively. Which one of the strongest acid?
(a) A (b) B
(c) C (d) D

18. Solutions in test tubes containing H_2O and aqueous NaOH can be differentiated with the help of
(a) red litmus (b) blue litmus
(c) Na_2CO_3 (d) HCl (aqueous)

19. Iodised salt is a
(a) mixture of potassium iodide and common salt
(b) mixture of molecular iodine and common salt
(c) compound formed by combination of potassium iodide and common salt
(d) compound formed by combination of molecular iodine and common salt

20. Acidity of BF_3 can be explained on the basis of which of the following concepts?
(a) Arrhenius concept
(b) Bronsted Lowry concept
(c) Lewis concept
(d) Bronsted Lowry as well as Lewis concept

21. A soda water bottle has pH
(a) < 7 (b) > 7
(c) $= 7$ (d) unpredictable

22. The pH of the blood is maintained by the carbonic acid and bicarbonate buffer. The pH of the blood is
(a) 8.0 (b) 5.0
(c) 6.0 (d) 7.4

23. pH of the solution produced when aqueous solution of pH = 5 is mixed with equal volume of an aqueous solution of pH = 3 is
(a) 3.3 (b) 3.5 (c) 4.5 (d) 4.0

24. Fear or excitement, generally cause on to breathe rapidly and it results in the decrease of CO_2 concentration in blood. In what way will it change the pH of blood?
(a) pH will increase (b) No change
(c) pH will decrease
(d) pH will adjust to 7

25. The concentration of hydrochloric acid in a given solution is 10^{-8} M. What is the value of pH for this solution?
(a) 7 (b) > 7 but nor 14
(c) < 7 (d) 14

26. Arrange the following base in increasing order of their, basic strength.
I. Sodium hydroxide
II. Magnesium hydroxide
III. Aluminium hydroxide
IV. Ammonium hydroxide
Select the correct answer.
(a) IV< II< I< III (b) IV< I< II< III
(c) IV< III< II< I (d) I< II< III< IV

27. When applied to the affected area, which one of the following will relieve the pain due to ant-bite or bee-sting?
(a) Lemon juice (b) Vinegar
(c) Baking soda (d) Caustic soda

28. NH_4Cl is a salt of a
(a) weak acid and weak base
(b) weak acid and strong base
(c) strong acid and strong base
(d) strong acid and weak base

29. Which one of the following salts when dissolved in water makes the solution acidic?
(a) Sodium sulphate
(b) Potassium nitrate
(c) Sodium acetate
(d) Ferric sulphate

30. Aqueous solution of $CuSO_4$ changes blue litmus to red as
(a) Cu^{2+} is present
(b) SO_4^{2-} is present
(c) hydrolysis takes place
(d) reduction takes place

31. An aqueous solution of potash alum is
(a) alkaline (b) acidic
(c) neutral (d) soapy to touch

32. An aqueous solution of borax is
(a) alkaline (b) corrosine
(c) neutral (d) acidic

33. The aqueous solution of $AlCl_3$ is acidic due to the hydrolysis of
(a) aluminium ion (b) chloride ion
(c) Both aluminium and chloride ion
(d) None of the above

34. An aqueous solution of sodium carbonate is alkaline because sodium carbonate is a salt of
(a) weak acid and weak base
(b) strong acid and weak base
(c) weak acid and strong base
(d) strong acid and strong base

35. If acetic acid is mixed with sodium acetate then H^+ ion concentration will
(a) increase
(b) decrease
(c) remain unchanged
(d) pH decreases

36. Which one among the following is not a property of salt?
(a) Salt have ordered packing arrangements called lattices
(b) Salts have low melting points but high boiling points
(c) Salts are brittle
(d) Salts conduct electricity when dissolved in water or even in the molten state

37. Which among the following statements with regard to pH scale is/are correct?
I. It is logarithmic scale.
II. The scale is limited to 0 – 14 because the ionic product of water is about 10^{-14}.
III. The lower the value of pH the greater is the acidity of the solution.
Select the correct answer using the codes given below.
(a) I and II (b) Only II
(c) I and III (d) All of these

Directions (Q. Nos. 38-40) *Following questions consist of two statements labelled as Statement* I *and Statement* II. *Examine both the statements carefully and match the correct choice according to the codes given below.*
(a) Both Statement I and Statement II are true and Statement II is the correct explanation of the Statement I.
(b) Both Statement I and Statement II are true but Statement II is not the correct explanation of the Statement I.
(c) Statement I is true, but Statement II is false.
(d) Statement I is false, but Statement II is true.

38. **Statement I** Aqueous solution of ammonium acetate is neutral.
Statement II Ammonium acetate is the salt of acetic acid and ammonium hydroxide.

39. **Statement I** Na_2SO_4 forms a neutral solution upon hydrolysis.
Statement II Na_2SO_4 is the salt of strong acid and strong base.

40. **Statement I** $HClO_4$ is the strongest oxyacid of chlorine.
Statement II In $HClO_4$, Cl is in +7 oxidation state.

41. Match List I and List II and select the correct answer using the codes given below the lists.

List I	List II
A. $AlCl_3$	1. Lewis base
B. Theory of ionisation	2. Bronsted-Lowry
C. Conjugate acid-base pairs	3. Lewis acid
D. Alcohol	4. Arrhenius

Codes

	A	B	C	D		A	B	C	D
(a)	3	2	4	1	(b)	2	1	3	4
(c)	2	3	1	4	(d)	3	4	2	1

42. Match List I and List II and select the correct answer using the codes given below the lists.

List I	List II
A. Amphoteric oxide	1. SO_2
B. Basic oxide	2. PbO
C. Acidic oxide	3. N_2O
D. Neutral oxide	4. MgO

Codes

	A	B	C	D		A	B	C	D
(a)	4	2	3	1	(b)	4	2	1	3
(c)	2	4	1	3	(d)	2	4	3	1

Previous Years' Questions

43. Sometimes, indigestion is caused by the secretion of too much hydrochloric acid in the stomach. To ease the pain caused a tablet can be taken that reacts to reduce the amount of acid present which one among the following would be inappropriate for a manufacture

to include as a major reactant in the table? **2012 (I)**

(a) $CaCO_3$ (b) $MgCO_3$
(c) NaOH (d) $Mg(OH)_2$

44. Which one among the following is the correct order of strength of acids? **2012 (II)**

(a) $H_2SO_4 > H_3PO_3 > CH_3COOH$
(b) $H_3PO_3 > H_2SO_4 > CH_3COOH$
(c) $CH_3COOH > H_3PO_3 > H_2SO_4$
(d) $CH_3COOH > H_2SO_3 > H_3PO_3$

45. Which one among the following is a double salt ? **2012 (II)**

(a) $K_4[Fe(CN)_6]$
(b) $K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$
(c) $CuSO_4 \cdot 5H_2O$
(d) NaCl

46. The acid contained in vinegar is **2013 (I)**

(a) acetic acid
(b) ascorbic acid
(c) citric acid
(d) tartaric acid

47. The acid in gastric juice is **2013 (I)**

(a) acetic acid (b) nitric acid
(c) hydrochloric acid (d) sulphuric acid

48. The pH of fresh milk is 6,when it turns sour the pH **2013 (I)**

(a) becomes < 6
(b) remains the same, i.e. 6
(c) becomes > 6
(d) becomes neutral, i.e. 7

49. Turmeric (Haldi) rapidly becomes colourless on addition of **2013 (II)**

(a) baking soda (b) vinegar
(c) lemon juice (d) alcohol

50. The pH of the solution obtained by dissolving pure sodium chloride in water is **2013 (II)**

(a) acidic (b) basic
(c) neutral
(d) dependent on the amount of sodium chloride dissolved in water

51. Which of the following acids is a mineral acid? **2014 (I)**

(a) Citric acid (b) Hydrochloric acid
(c) Ascorbic acid (d) Tartaric acid

52. Which one of the following is/are amphoteric? **2014 (I)**

(a) $Al(OH)_3$ (s) and $Fe(OH)_3$ (*aq*)
(b) $Al(OH)_3$ (s) and HCO_3^- (*aq*)
(c) $Ba(OH)_2$(s) and NaOH(*aq*)
(d) Only $Al(OH)_3$(*s*)

53. The burning sensation of a bee sting can be stopped by rubbing the affected area with soap. This is because **2014 (II)**

(a) a bee sting is acidic and soap, an alkali, neutralises it
(b) a bee sting is alkaline and soap, an acid, neutralises it
(c) soap cleans the affected area and removes the sting
(d) soap acts as an anaesthetic and dulls the sensation

54. Match List I with List II and select the correct answer using the codes given below the lists. **2015 (I)**

List I (Compound)	List II (Nature)
A. Sodium hydroxide	1. Strong acid
B. Calcium oxide	2. Alkali
C. Acetic acid	3. Weak acid
D. Hydrochloric acid	4. Base

Codes

	A	B	C	D		A	B	C	D
(a)	2	3	4	1	(b)	2	4	3	1
(c)	1	4	3	2	(d)	1	3	4	2

55. Boric acid is an acid because its molecule **2015 (II)**

(a) accepts OH^- from water releasing proton
(b) combines with proton from water molecule
(c) contains replaceable H^+ ion
(d) gives up a proton

56. Suppose you have four test tubes labelled *A*, *B*, *C* and *D*. *A* contains water, *B* contains solution of an alkali, *C* contains solution of an acid, and *D* contains solution of sodium chloride. Which one of these solutions will turn phenolphthalein solution pink? **2015 (II)**

(a) Solution *A* (b) Solution *B*
(c) Solution *C* (d) Solution *D*

57. Which one of the following oxides of nitrogen is known as 'anhydride' of nitric acid? **2016 (I)**

(a) N_2O (b) N_2O_3 (c) NO_2 (d) N_2O_5

58. Which one of the following oxides dissolve in water? **2016 (I)**

(a) CuO (b) Al_2O_3 (c) Fe_2O_3 (d) Na_2O

59. Which one of the following is the chemical name for baking soda? **2016 (I)**

(a) Sodium bicarbonate (sodium hydrogen carbonate)
(b) Sodium carbonate
(c) Potassium bicarbonate (potassium hydrogen carbonate)
(d) Potassium carbonate

ANSWERS

1	*c*	2	*c*	3	*a*	4	*c*	5	*a*	6	*a*	7	*a*	8	*b*	9	*b*	10	*a*
11	*a*	12	*b*	13	*b*	14	*c*	15	*d*	16	*c*	17	*a*	18	*a*	19	*a*	20	*c*
21	*a*	22	*d*	23	*a*	24	*b*	25	*c*	26	*c*	27	*c*	28	*d*	29	*d*	30	*c*
31	*d*	32	*a*	33	*a*	34	*c*	35	*b*	36	*b*	37	*d*	38	*b*	39	*a*	40	*a*
41	*d*	42	*c*	43	*d*	44	*a*	45	*b*	46	*a*	47	*c*	48	*a*	49	*c*	50	*c*
51	*b*	52	*d*	53	*a*	54	*b*	55	*a*	56	*b*	57	*d*	58	*d*	59	*a*		

09

OXIDATION, REDUCTION AND ELECTROCHEMISTRY

Generally 1-2 questions are asked from this chapter. Questions are mainly based upon the basic knowledge of oxidation, reduction, oxidising agents, reducing agents and calculation of oxidation number.

OXIDATION

The process of addition of oxygen or any other electronegative element or removal of hydrogen or any other electropositive element (or radical) by a substance, is known as oxidation,

e.g. $C + O_2 \longrightarrow CO_2$ (oxidation of carbon)

$SnCl_2 + Cl_2 \longrightarrow SnCl_4$ (oxidation of $SnCl_2$)

$H_2S + Cl_2 \longrightarrow 2HCl + S$ (oxidation of H_2S)

$2KI + H_2O \longrightarrow 2KOH + I_2$ (oxidation of KI)

The loss of one or more electrons by an atom, ion or molecule, is known as oxidation.

e.g. $Na \longrightarrow Na^+ + e^-$

$Fe^{2+} \longrightarrow Fe^{3+} + e^-$

$2I^- \longrightarrow I_2 + 2e^-$

➨ Increase in valency or oxidation number of an element is oxidation,

e.g. $FeCl_2 \longrightarrow FeCl_3$

(valency of Fe changes from +2 to +3)

$$\overset{0}{Zn} + \overset{+2}{CuSO_4} \longrightarrow \overset{+2}{ZnSO_4} + \overset{0}{Cu}$$

Oxidation

(oxidation number of Zn changes from zero to +2)

Oxidising Agents

- The substance which undergoes reduction in a chemical reaction is known as **oxidising agent** or **oxidant**. Thus, oxidant is an electron acceptor.

$$Zn + \overset{+2}{CuSO_4} \longrightarrow ZnSO_4 + \overset{0}{Cu}\downarrow$$

Reduction

As in above reaction, $CuSO_4$ undergoes reduction, therefore, $CuSO_4(Cu^{2+})$ is an oxidising agent.

- F_2 is the strongest oxidising agent.
- Some oxides like MgO, CuO, CO_2 and CrO_3 are oxidants.
- Some molecules are made up of electronegative elements, e.g. O_2, O_3, Cl_2, Br_2, I_2, H_2O_2 etc., acts as oxidants.
- The compounds in which elements are present in its highest oxidation number are oxidising agent, e.g. HNO_3, $KMnO_4$, $K_2Cr_2O_7$, $Na_2Cr_2O_7$, H_2SO_4, $FeCl_3$, $CuCl_2$ etc.
- All the positively charged species behaves as oxidising agents.
- Oxidising agents are Lewis acids.

REDUCTION

The process of addition of hydrogen or any other electropositive element (or radical) or removal of oxygen or any other electronegative element (or radical) by a substance, is known as reduction, e.g.

$$H_2S + Cl_2 \longrightarrow 2HCl + S \quad \text{(reduction of } Cl_2\text{)}$$
$$2FeCl_3 + Fe \longrightarrow 3FeCl_2 \quad \text{(reduction of } FeCl_3\text{)}$$
$$CuO + H_2 \longrightarrow Cu + H_2O \quad \text{(reduction of CuO)}$$
$$FeCl_3 + H_2S \longrightarrow FeCl_2 + S \quad \text{(reduction of } FeCl_3\text{)}$$

- The process of gain of one or more electrons by an atom, ion or molecule is known as reduction, e.g.

$$Hg^{2+} + e^- \longrightarrow Hg^+$$
$$I_2 + 2e^- \longrightarrow 2I^-$$
$$Cl + e^- \longrightarrow Cl^-$$

- Decrease in valency or oxidation number of an element is reduction, e.g.

$$Zn + \overset{+2}{CuSO_4} \longrightarrow ZnSO_4 + \overset{0}{Cu}\downarrow$$
(Reduction)

Reducing Agents

- The substance which undergoes oxidation in a chemical reaction is known as reducing agent or reductant. Thus, reductant is an **electron loser.** e.g. in the above example Zn is reducing agent.
- All metals like Zn, Na, Fe, Al, Mg, K and few non-metals C, S etc., are reductants.
- Hydracids of electronegative elements e.g. HCl, HBr, HI, H_2S etc., are reductants.
- Compounds containing element in its lower oxidation state are also reductant, e.g. Cu_2Cl_2, Hg_2Cl_2, $SnCl_2$, $FeCl_2$, CO, Cu_2O, $Na_2S_2O_3$, KI etc.
- All negatively charged species behave like reducing agents.
- Reducing agents are Lewis bases.

➨ **Note** White phosphorus has the property of only slow oxidation in air.

REDOX REACTIONS

The reactions involving oxidation and as well as reduction as its two half reactions are called **redox reactions**. In these reactions, one substance is oxidised and other substance is reduced.

e.g.

$$\overset{+1}{2\,Cu_2O} + \overset{2-}{Cu_2S} \longrightarrow \overset{0}{6Cu} + \overset{+4}{SO_2}$$
(Reduction on Cu; [OA] on Cu_2O; [RA] on Cu_2S; Oxidation on S)

OA → oxidising agent

RA → reducing agent

The reaction in which same element is oxidised as well as reduced is called **disproportion reaction**.

e.g.

$$\overset{0}{Cl_2} + NaOH \longrightarrow \overset{-1}{NaCl} + \overset{+5}{NaClO_3} + H_2O$$
(Oxidation on $NaClO_3$; Reduction on NaCl)

- Oxidation and reduction take place together in equivalent amounts.
- All metal displacement reactions are redox reactions.
- The formation of ionic solid from its elements is always a redox reaction.

$$\overset{0}{Zn} + \overset{-2}{CuSO_4} \longrightarrow \overset{-2}{ZnSO_4} + \overset{0}{Cu}$$
(Oxidation on Zn; Reduction on Cu)

➨ **Note** Compounds like H_2O, O_3, HNO_3, H_2SO_3, $NaNO_2$, SO_2, $NO_2S_2O_3$ act as oxidising as well as reducing agents.

Reducing agents are oxidised and oxidising agents are reduced in a chemical reaction.

OXIDATION NUMBER

The real or imaginary charge which an atom appears to have in its combined state, is called oxidation number of that atom. Oxidation number of an element in a compound is determined as the number of electrons that have passed from one atom of a given element to other atom (positive oxidation) or to one atom of a given element from other atom (negative oxidation). Thus, oxidation number gives the effective charge associated with an element (it may be positive or negative).

General Rules for Calculation of Oxidation Number

- The oxidation number of hydrogen is +1 in all its compounds but in metallic hydride the oxidation state of hydrogen is – 1 (NaH, CaH_2).
- The common oxidation state of oxygen is – 2.
- Oxidation number of oxygen in peroxides like H_2O_2, Na_2O_2 is – 1, in superoxides like KO_2, RbO_2 it is – 1/2 and compounds in which O-atom bonded to fluorine like OF_2, O is in + 2 while in O_2F_2 is in + 1 state.
- The common oxidation state of halogen (Cl, F, etc.) is –1.
- The common oxidation state of alkali metal (e.g. Li, Na, K etc.) is +1.
- The oxidation number of alkaline earth metals (e.g. Be, Mg, Ca, Ba, etc.) is +2.
- Oxidation number of elements in its elementary state is taken to be zero. e.g. N_2, Cl_2, O_2 H_2, Br_2 etc., has oxidation number zero.

- Oxidation number of an ion is same as its charge, e.g. oxidation number of Na^+, Ba^{2+}, Al^{3+}, Cl^- is + 1, + 2, + 3, – 1, respectively.
- Oxidation number of metal in metal carbonyl is zero e.g., Fe is in 0 oxidation state in $Fe(CO)_5$.
- In C_3O_2 [carbon suboxide] oxidation number of carbon is 4/3, Br_3O_8 [tribromooctaoxide], Br is in 16/3 oxidation state and $Na_2S_4O_6$ [sodium tetrathionate], S is in 2.5 oxidation state.
- The sum of the oxidation numbers of all the atoms in the formula of compound is always zero.

Some Examples

(*i*) Oxidation number (ON) of S in H_2SO_4.

Let oxidation number of S be *x*.

Now, oxidation number of hydrogen is +1, oxygen is –2.

$$\therefore \quad 2\times1+x+(-2)\times4=0$$

$$\Rightarrow \quad 2+x-8=0$$

$$x=+6$$

(*ii*) Oxidation number of Mn in $KMnO_4$ (potassium permanganate).

Let oxidation number of Mn be *x*.

Now, oxidation number of K is +1 and O is –2.

$$\therefore \quad +1+x+(-2)\times4=0$$

$$x+1-8=0;\ x=+7$$

(*iii*) Oxidation number of Fe in $[Fe(H_2O)_5\ NO]SO_4$.

Let oxidation number of Fe be *x*

Oxidation number of $H_2O = 0$, $NO = +1$, $SO_4 = -2$.

$$[Fe(H_2O)_5\ NO]SO_4 = x+0\times5+(+1)-2=0$$

$$\Rightarrow \quad x+1-2=0 \ \Rightarrow\ x=+1$$

ELECTROCHEMISTRY

The branch of chemistry dealing with the interconversion of chemical energies and electrical energies during spontaneous redox reactions.

These are following important terms which are related to electrochemistry.

Electrolytes

The substances, which allow the electricity to pass through them in their molten state or aqueous solution are called **electrolytes**. e.g. common salt (NaCl), sulphuric acid (H_2SO_4) etc.

Non-Electrolytes

The substances which do not allow the electricity to pass through them in their molten state or aqueous solution are called **non-electrolytes**. e.g. sugar, wax, naphthalene etc.

Electrochemical Cell

A device in which spontaneous redox reaction is carried out to produce an electric current is called electrochemical cell.

- An electrochemical cell comprises of two metallic electrodes namely anode [*–ve* electrode] and cathode [*+ve* electrode] dipped in electrolytic solution.
- There are two types of electrochemical cell **galvanic cell** and **electrolytic cell**. In galvanic cell, the chemical energy of a spontaneous redox reaction is converted into electrical energy while in electrolytic cells, electrical energy is used to carry out a non-spontaneous reaction.

Electrode

It is a metal conducting plate (anode or cathode) that emits or collects electrons in a cell. Electrode made up of an element with lower reduction potential act as **anode. Oxidation** takes place at anode. While reduction takes place at cathode.

Electrode Potential

The potential of an electrode with respect to its solution is called the electrode potential. It is a measure of its tendency to lose or gain electrons, when it comes in contact with a solution of its own ions. The tendency of an electrode to gain electrons or to get reduced is called its reduction potential while the tendency of an electrode to lose electrons or to get oxidised is called its oxidation potential. It depends upon the following

(*i*) Concentration of solution
(*ii*) Nature of electrolyte
(*iii*) Nature of metal
(*iv*) Conditions of temperature and pressure

BATTERY

The arrangement of one or more cells in a series connection is called battery. It is basically a galvanic cell.

There are two types of battery

(*i*) **Primary battery** (non-rechargeable) can be used only once. e.g. dry cell (Lechlanche cell), mercury cell.

(*ii*) **Secondary battery** (rechargeable) can be reused again and again. This battery can act both as galvanic and electrolytic cell. e.g. lead storage battery, nickel-cadmium battery.

Fuel Cell

The type of galvanic cell in which the energy released by the combustion of fuels (hydrogen,methane, methanol) is directly converted into electrical energy is called **fuel cell**. e.g. fuel cell using H_2 and O_2 to form water in order to produce electricity. Efficiency of these cells is 70%. This cell was used first-time in Apollo Space Programme.

ELECTROLYSIS

The process of decomposition of an electrolyte on passing an electric current through its aqueous solution or in the fused state is called **electrolysis**. Cations move towards cathode, gain electrons and become neutral atoms. Similarly anions move towards anode, lose electrons and become neutral atoms. In electrorefining of metals, impure metals act as anode and a strip of pure metal acts as cathode.

Faraday's Laws of Electrolysis

Faraday gave following two laws to explain a relation of amount of substance produced with current or its equivalent weight.

First Law of Electrolysis It states that "the quantity (mass) of any substance deposited or liberated at any electrode is directly proportional to the quantity of electricity passed through electrolyte."

$w \propto Q \Rightarrow w = ZQ = Zit$

$\because$ Charge (Q) = current (i) × time (t)

Z = Electrochemical equivalence $= \frac{E}{96500}$

(where, E = Equivalent weight)

Second Law of Electrolysis It states, "when same quantity of electricity is passed through solutions of different electrolytes connected in series, the weight of substance produced at the electrodes is directly proportional to their equivalent weight".

i.e. $\frac{\text{Weight of Cu deposited } (w_1)}{\text{Weight of Ag deposited } (w_2)} = \frac{\text{Equivalent weight of Cu } (E_1)}{\text{Equivalent weight of Ag } (E_2)}$

Electrochemical Series

- The arrangement of elements in order of increasing their standard reduction potential values is known as electrochemical series or activity series.

  K< Ca< Na< Mg< Al< Zn< Cr<
  Fe < Ni < Sn < H_2 < Cu< Hg< Ag< Pd< Pt< Au
  [as reactivity follows the reverse order].

- Thus, gold is least reactive while potassium is most reactive element.
- Substances which have lower reduction potentials are stronger reducing agents.

  Reducing power $\propto \frac{1}{\text{reduction potential}}$
- Only those metals can liberate hydrogen from the acid which have negative values of reduction potentials or which are placed before H-atom.
- The more reactive metals of the activity series displaces the less reactive metals from their salt solutions.

  $Cu + FeSO_4 \longrightarrow$ No reaction

  $Fe + \underset{\text{Blue coloured solution}}{CuSO_4} \longrightarrow \underset{\text{Colourless}}{FeSO_4} + Cu$

CORROSION

- It is a process of oxidative deterioration of a metal as a result of its reaction with air and moisture present in the environment.
- Corrosion of iron is called **rusting**. Rust is hydrated iron (III) oxide.
- Similarly, in presence of moist air, copper acquires a green coating of basic copper carbonate, $[Cu(OH)_2 \cdot CuCO_3]$ silver acquires a black coating of silver sulphide $[Ag_2S]$ and aluminium acquires a dull coating of aluminium oxide (a protective layer).
- A sliced apple turns brown if left open for sometime due to the **oxidation of iron** present in it as a nutrient.
- The rusting of iron can be prevented by painting, oiling, greasing, galvanising (coating of iron with zinc) and chrome plating.
- Anodisation (an electrolytic process) is the process of forming a thick oxide layer on the surface of metal. This oxide layer is protective and prevents the metal from further oxidation.
- Formation of a layer of Al_2O_3 on aluminium surface protects the metal from further corrosion.

PRACTICE EXERCISE

1. A reducing agent is a substance which can
(a) accept electrons
(b) donate electrons
(c) accept protons (d) donate protons

2. The reaction which takes place at the anode is
(a) oxidation (b) reduction
(c) dissociation (d) ionisation

3. The strongest reducing agent is
(a) HNO_3 (b) H_2S
(c) H_2SO_3 (d) $SnCl_2$

4. Which one of the following is not a reducing agent?
(a) $NaNO_2$ (b) $NaNO_3$
(c) HI (d) $SnCl_2$

5. Which of the following act as an oxidising agent?
(a) HNO_3 (b) $K_2Cr_2O_7$
(c) $KMnO_4$ (d) All of these

6. Which of the following is best reducing agent?
(a) Na (b) Ca (c) Sr (d) Ba

7. Which is strongest reducing agent?
(a) F^- (b) Cl^- (c) Br^- (d) I^-

8. The process of $^{56}_{28}Fe^{2+} \longrightarrow {}^{56}_{28}Fe^{3+}$ is appropriate classified as
(a) ionisation (b) oxidation
(c) reduction (d) nuclear reaction

9. In the reaction,
$4\,Fe + 3O_2 \longrightarrow 4\,Fe^{3+} + 6O^{2-}$
Which of the following statements is incorrect?
(a) It is redox reaction
(b) Metallic iron is a reducing agent
(c) Fe^{3+} is an oxidising agent
(d) Metallic iron is reduced to Fe^{3+}

10. Among Cl^-, Br^- and I^- the correct order for being oxidised to dihalogen is
(a) $I^- > Cl^- > Br^-$ (b) $Cl^- > Br^- > I^-$
(c) $I^- > Br^- > Cl^-$ (d) $Br^- > I^- > Cl^-$

11. Among the following chemical compounds, which one of the following has the highest reducing power?
(a) AsH_3 (b) BiH_3 (c) NH_3 (d) PH_3

12. The process in which oxidation number of element increases is
(a) oxidation (b) reduction
(c) autoxidation (d) None of these

13. Oxidation state of Ni in $Ni(CO)_4$ is
(a) +2 (b) 0 (c) +4 (d) – 8

14. Oxidation number of oxygen in ozone
(a) 0 (b) – 2 (c) +2 (d) – 6

15. Oxygen has an oxidation state +2 in
(a) H_2O_2 (b) OF_2 (c) H_2O (d) SO_2

16. Oxidation state of oxygen atom in potassium superoxide is
(a) $-\frac{1}{2}$ (b) –1 (c) –2 (d) 0

17. In haemoglobin the iron is in oxidation state of
(a) +2 (b) +1 (c) +3 (d) +4

18. Oxidation number of sulphur in perdisulphuric acid is
(a) +8 (b) – 6 (c) +6 (d) +4

19. The oxidation number of iron in Fe_3O_4 is
(a) +2 (b) +3
(c) $\frac{8}{3}$ (d) $\frac{2}{3}$

20. Oxidation number of oxygen in hydrogen peroxide is
(a) –1 (b) +1
(c) –2 (d) None of these

21. In the reaction of potassium permanganate in acidic medium (mol. wt. = 158.04) with ferrous ammonium sulphate (mol. wt. = 392.14), the change in the oxidation state of manganese in potassium permanganate is
(a) +5 to +2 (b) +6 to +2
(c) +7 to +2 (d) +7 to +3

22. Which of the following is correct?
(a) Oxidation state of bromine varies from –1 to +6
(b) Among IO_4^-, ClO_4^- and BrO_4^-, the last one (BrO_4^-) is the strongest oxidising agent
(c) HNO_3 is an oxidising agent
(d) All of the above

23. The correct statement is
(a) zinc displaces Cu from $CuSO_4$
(b) Cu cannot displace Fe from $FeSO_4$
(c) Zn metal displaces H_2 gas from H_2SO_4
(d) All of the above

24. Which of the following statement(s) is/are false for electrolytic cell?
(a) External source of voltage is applied to carry the chemical reaction
(b) These cells are mainly used in laboratory and chemical industry
(c) These cells consist of two copper strips dipped in an aqueous solution of $CuSO_4$
(d) None of the above

25. Mark the correct statement(s) for the corrosion.
(a) It fastly coats the surfaces of metallic object
(b) Its examples are— Rusting of iron, tarnishing of silver
(c) It does not cause damage to buildings, ship made metals especially that are made up of iron
(d) All of the above

26. Consider the following equation,
$Cr_2O_7^{2-}(aq) + Br^-(aq) + H^+(aq) \longrightarrow Br_2(l) + Cr^{3+}(aq) + H_2O(l)$.
In this reaction which one of the following is a reducing agent?
(a) Br_2 (b) Br^- (c) H^+ (d) $Cr_2O_7^{2-}$

27. A compound contains atom, *X, Y, Z*. The oxidation number of *X* is +2, *Y* is +5 and *Z* is –2, therefore, a possible formula of the compound is
(a) XY_1Z_2 (b) $X_2(YZ_3)_2$
(c) $X_3(YZ_4)_2$ (d) $X_3(Y_4Z)_2$

28. In the reaction,
$3Br_2 + 6CO_3^{2-} + 3H_2O \longrightarrow 5Br^- + BrO_3^- + 6\,HCO_3^-$
(a) bromine is oxidised and carbonate is reduced
(b) bromine is both reduced and oxidised
(c) bromine is neither reduced nor oxidised
(d) bromine is reduced and water is oxidised

29. The correct oxidation states of N in NH_4NO_3 molecule are
(a) –3 and +5 (b) +3 and –5
(c) –3 and +3 (d) –5 and +5

30. An oxidising agent is a substance which
(a) increases the oxidation number of an element in a given substance
(b) decreases the oxidation number of an element in a given substance
(c) is oxidised itself in an oxidation reduction reaction
(d) loses electrons in an oxidation reduction reaction

31. When a copper rod is dipped in aqueous silver nitrate solution, the colour of the solution changes to blue. This is because
(a) Cu is more easily reduced than Ag
(b) Ag is more easily reduced than Cu
(c) nitrate ion acts as an oxidising agent
(d) nitrate ion acts as a reducing agent

32. Iron nails are dipped into blue copper sulphate solution. After some time iron nails are
(a) dissolved and blue colour is discharged
(b) dissolved but blue colour is not discharged
(c) not dissolved and blue colour is not discharged
(d) not dissolved but blue colour is discharged

33. Which one among the following metals is more reactive than hydrogen?
(a) Mercury (b) Copper
(c) Silver (d) Tin

34. Which one among the following is the correct order of reactivity of the elements?
(a) Cu > Mg > Zn > Na
(b) Na > Zn > Mg > Cu
(c) Cu > Zn > Mg > Na
(d) Na > Mg > Zn > Cu

35. Aluminium is more reactive than iron but aluminium is less easily corroded than iron, because
(a) oxygen forms a protective oxide layer
(b) it is a noble metal
(c) iron undergoes reaction easily with water
(d) iron forms ions

36. Silver ware turns black after a period of time due to formation of
(a) nitrate coating on silver
(b) sulphide coating on silver
(c) chloride coating on silver
(d) oxide coating on silver

37. Which of the statements is/are true?
I. The process of oxidation leads to gain of electrons.
II. The process of oxidation leads to loss of electrons.
III. The process of reduction leads to gain to electrons.
IV. The process of reduction leads to loss of electrons.
Select the correct answer from the codes given below.
(a) I and IV (b) II and III
(c) Only I (d) Only IV

38. Which of the following cause the rusting of iron?
I. Oxidation II. Reduction
III. Chemical reaction with oxygen
IV. Chemical reaction with CO_2
Select the correct answer from the codes given below.
(a) I and II (b) I and III
(c) II and III (d) III and IV

39. In oxidation
I. Hydrogen is displaced from a substance.
II. An electropositive element is added to or proportion of electropositive element increase in a substance.
Select the correct answer using the codes given below
(a) Only I
(b) Only II
(c) Both I and II
(d) Neither I nor II

40. Match the terms of Column I and Column II and choose the correct option from the codes given below.

Column I	Column II
A. Leclanche cell	1. Cell reaction $2H_2 + O_2 \rightarrow 2H_2O$
B. Ni-Cd cell	2. Does not involve any ion in solution and is used in hearing aids.
C. Fuel cell	3. Rechargeable
D. Mercury cell	4. Reaction at anode, $Zn \rightarrow Zn^{2+} + 2e^-$
	5. Converts energy of combustion into electrical energy

Codes

	A	B	C	D
(a)	1	2	3,4	5
(b)	5	2	1,3	4
(c)	2	3	1,5	4
(d)	4	3	1,5	2

41. Match List I and List II and select the correct answer by using the codes given below the lists.

List I (The atom for which the oxidation state is to the found)		List II (Oxidation state)	
A.	Oxygen in BaO_2	1.	–1
B.	Sulphur in $S_2O_6^{2-}$	2.	0
C.	Carbon in $C_{12}H_{22}O_{11}$	3.	+7
D.	Manganese in MnO_4^-	4.	–2
		5.	5

Codes

	A	B	C	D
(a)	1	4	2	3
(b)	1	5	2	3
(c)	4	1	2	3
(d)	4	5	3	1

Directions (Q. Nos. 42-43) *Following questions consist of two statements labelled as Statement* I *and Statement* II. *Examine both the statements carefully and match the correct choice according to the codes given below.*
(a) Both Statement I and Statement II are true and Statement II is the correct explanation of the Statement I.
(b) Both Statement I and Statement II are true but Statement II is not the correct explanation of the Statement I.
(c) Statement I is true, but Statement II is false.
(d) Statement I is false, but Statement II is true.

42. **Statement I** Fluorine exhibits the same oxidation state in all its components.
Statement II Fluorine atom has no *d*-orbital in the valence shell.

43. **Statement I** When hydrogen gas is passed over heated metallic oxide it removes the oxygen from it.
Statement II Hydrogen is an oxidising agent.

44. The standard electrode potential values of the element *A, B* and *C* are 0.68 V, –2.50 V and –0.50 V respectively. The order of their reducing power is
(a) $A > B > C$
(b) $A < C > B$
(c) $C > B > A$
(d) $B > C > A$

Previous Years' Questions

45. The following equation is an example of a redox reaction, in which Cl_2 is the oxidising agent and $FeBr_3$ is the reducing agent **2012 (I)**

$$2\,FeBr_3\,(aq) + 3\,Cl_2(g) \longrightarrow 2FeCl_3(aq) + 3Br_2\,(l)$$

Which one among the following statements is incorrect for this redox reaction?

(a) Oxidising agents are themselves reduced
(b) Reducing agents gain or appear to gain electrons
(c) Reducing agents are themselves oxidised
(d) Oxidising agents oxidise other substances

46. Which of the following statements regarding oxidation and reduction are correct?

I. In oxidation loss of electron takes place whereas in reduction, gain of electron takes place.
II. In oxidation, gain of electron takes place whereas in reduction, loss of electron takes place.
III. Oxidising agent decreases the oxidation number but reducing agent increases the oxidation number.
IV. Oxidising agent incrases the oxidation number but reducing agent reduces the oxidation number.

Select the correct answer using the codes given below. **2012 (I)**

(a) I and III (b) II and IV
(c) II and III (d) I and IV

47. Which one among the following is an electrochemical cell that cannot be charged? **2012 (II)**

(a) Electrolytic cell (b) Storage cell
(c) Primary cell (d) Fuel cell

48. In $KMnO_4$ molecule, the oxidation states of the elements potassium (K), manganese (Mn) and oxygen are respectively **2012 (II)**

(a) +1, +5, –2 (b) +1, + 7, – 2
(c) 0, 0, 0 (d) +1, + 7, 0

49. **Statement I** Zinc is used for galvanisation to protect iron from rusting.

Statement II Zinc is more reactive towards oxygen than iron. **2013 (II)**

(a) Both the statements are true and Statement II is the correct explanation of Statement I.
(b) Both the statements are true, but Statement II is not the correct explanation of Statement I.
(c) Statement I is true, but Statement II is false.
(d) Statement I is false, but Statement II is true.

50. A gas is evolved when a piece of zinc metal is placed in dilute sulphuric acid (H_2SO_4) what is the gas? **2013 (II)**

(a) Hydrogen (b) Oxygen
(c) Water vapour (d) Sulphur dioxide

51. Which one of the following is correct regarding the reaction of fluorine with water? **2014 (I)**

$$2F_2\,(g) + 2H_2O(l) \longrightarrow 4H^+(aq) + 4F^-(aq) + O_2\,(g)$$

(a) Fluorine is oxidised to F^-
(b) Water is oxidised to O_2
(c) Water is reduced to H^+
(d) Oxidation state of fluorine does not change

52. What is the oxidising agent in the following equation? **2014 (II)**

$$HAsO_2\,(aq) + Sn^{2+}(aq) + H^+(aq) \longrightarrow As(s) + Sn^{4+}(aq) + H_2O(l)$$

(a) $HAsO_2(aq)$ (b) $Sn^{2+}(aq)$
(c) $H^+(aq)$ (d) $Sn^{4+}(aq)$

53. In the reaction, $ZnO + C \longrightarrow Zn + CO$, 'C' acts as a/an **2015 (I)**

(a) acid
(b) base
(c) oxidising agent
(d) reducing agent

54. White phosphorus glows in the dark due to

(a) amorphous character **2015 (II)**
(b) slow oxidation
(c) high ignition temperature
(d) good conducting property of electricity

55. Which one of the following is a reduction reaction? **2016 (I)**

(a) $2Mg(s) + O_2(g) \longrightarrow 2MgO(s)$
(b) $S(s) + O_2(g) \longrightarrow SO_2(g)$
(c) $2HgO(s) \xrightarrow{Heat} 2\,Hg(l) + O_2(g)$
(d) $Mg(s) + S(s) \longrightarrow MgS(s)$

ANSWERS

1	*b*	2	*a*	3	*b*	4	*b*	5	*d*	6	*d*	7	*d*	8	*b*	9	*d*	10	*c*
11	*b*	12	*a*	13	*b*	14	*a*	15	*b*	16	*a*	17	*a*	18	*c*	19	*c*	20	*a*
21	*c*	22	*d*	23	*d*	24	*d*	25	*b*	26	*b*	27	*c*	28	*b*	29	*a*	30	*a*
31	*b*	32	*a*	33	*d*	34	*d*	35	*a*	36	*b*	37	*b*	38	*b*	39	*a*	40	*d*
41	*b*	42	*a*	43	*c*	44	*d*	45	*b*	46	*d*	47	*c*	48	*b*	49	*a*	50	*a*
51	*b*	52	*a*	53	*d*	54	*b*	55	*c*										

10

NON-METALS AND THEIR COMPOUNDS

Generally 2-5 questions are asked from this chapter. Questions are mostly based upon preparation and properties of hydrogen, hard and soft water, diamond and graphite, oxides of carbon and nitrogen, water gas and producer gas. A good number of statement based questions have been asked from this chapter.

Non-metals have the properties opposite of metals. Non-metals such as sulphur, chlorine etc. are found on the right side of the periodic table. In the modern periodic table total non-metals are 22(11-gas, 10-solid and 1 liquid).

HYDROGEN

Hydrogen is the first element in the periodic table and is the lightest element known. It exists as a diatomic molecule H_2 (dihydrogen). It was discovered by **Henry Cavendish**, but name hydrogen was given by **Lavoisier**. He prepared the gas by treating iron with dilute. H_2SO_4. Its atomic number is 1 and it has the electronic configuration $1s^1$. It resembles both alkali metals and halogens.
e.g. it may donate one electron forming H^+ like alkali metals or may accept one electron forming H^- like halogens. But some properties of hydrogen are different with respect to these properties, therefore it is unique in behaviour so it is placed separately in the periodic table. It is the most abundant element in the universe. Jupiter and Saturn planets consist mainly of hydrogen. It constitutes about 0.9% by weight of earth crust.

Isotopes

Hydrogen has three isotopes with mass numbers 1, 2 and 3 and these are called protium, deuterium and tritium respectively.

Isotopes of Hydrogen and their Mass Number

Name	*Symbol*	*Atomic number*	*Mass number*	*Nature*
Protium	$_1H^1$ or H	1	1	Non-radioactive
Deuterium	$_1H^2$ or D	1	2	Non-radioactive
Tritium	$_1H^3$ or T	1	3	Radioactive

Method of Preparation of Dihydrogen (H_2) or Hydrogen Gas

Some methods for preparation of hydrogen gas are as follows :

(i) **Laboratory preparation of dihydrogen**

$$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2\uparrow$$

Hydrogen is collected over water by upward displacement as H_2 is lighter than water.

(ii) **By the electrolysis of water** Dihydrogen of high purity is prepared by the electrolysis of water in the presence of a small amount of acid or base.
(During electrolysis dihydrogen is collected at cathode).

e.g., $$2H_2O(l) \xrightarrow[(H^+)]{\text{Electrolysis}} 2H_2(g) + O_2(g)$$

(iii) **By the action of acids on metal** Those metals which are placed above the hydrogen in the electrochemical series or have positive value of standard oxidation

potential [E°_{oxid}] liberate hydrogen gas from acids.

e.g.

$$\underset{\text{Granulated zinc}}{Zn} + H_2SO_4(\text{dil.}) \longrightarrow ZnSO_4(aq) + H_2(g)\uparrow$$

$$Fe + 2HCl(aq) \longrightarrow FeCl_2 + H_2\uparrow$$

Some amount of SO_2 is also produced in this reaction because H_2 reduced H_2SO_4 to SO_2.

The reactivity of metals decreases as follows

K > Ca > Na > Mg > Al > Mn > Zn > Cr > Fe > Co > Ni > Pb > H > Cu > Ag > Au

(iv) **By the action of alkali on metals** Metals like Zn, Mg, Sn etc., liberates hydrogen on reaction with alkalies.

e.g. $2Al + 2NaOH + 2H_2O \longrightarrow 2NaAlO_2 + 3H_2(g)$

$$Sn + 2NaOH + H_2O \longrightarrow Na_2SnO_3 + 2H_2$$

$$Zn + 2NaOH \longrightarrow Na_2ZnO_2 + H_2(g)$$

(v) **By the action of water on metals** Very active metals like Na, K and Ca react with water at room temperature.

$$2Na + \underset{\text{Cold}}{2H_2O} \longrightarrow 2NaOH + H_2\uparrow$$

(so, sodium is kept under kerosene oil)

Less reactive metal like Zn, Mg, Al etc., can react with water only upon heating.

$$Mg + H_2O \xrightarrow{\text{Heat}} MgO + H_2\uparrow$$

$$2Al + 6H_2O \longrightarrow 2Al(OH)_3 + 3H_2\uparrow$$

(vi) **Bosch process** (Manufacture method) Dihydrogen is prepared by passing steam over red hot coke at 1270 K.

$$\underset{\substack{\text{(Coke at}\\ \text{400-600°C)}}}{C} + \underset{\text{Superheated steam}}{H_2O} \longrightarrow \underset{\substack{\text{Water gas}\\ \text{or syn gas}}}{CO + H_2}$$

$$\underbrace{H_2 + CO}_{\text{Water gas}} + \underset{\text{Steam}}{H_2O} \xrightarrow[\substack{Fe_2O_3 + Cr_2O_3\\ \text{(Catalyst)}}]{773\ K} CO_2 + 2H_2$$

CO_2 is removed either by dissolving in water under pressure of 25-30 atm or by scrubbing the mixture with sodium arsenite.

(vii) **Lane's process** Hydrogen is prepared by passing the alternate currents of steam and water gas over red hot iron.

This method consists of two stages:

(a) **Oxidation stage** Superheated steam is passed over iron filings heated about 1025–1075 K.

$$\underset{\text{Iron filings}}{3Fe} + \underset{\text{Steam}}{4H_2O} \xrightarrow{1025-1075\ K} \underset{\substack{\text{Magnetic oxide}\\ \text{of iron}}}{Fe_3O_4} + 4H_2 + 161kJ$$

(b) **Reduction stage** When the whole iron has been oxidised then steam is stopped and water gas is passed to reduce Fe_3O_4.

$$Fe_3O_4 + 4\,CO \longrightarrow 3\,Fe + 4\,CO_2$$

$$Fe_3O_4 + 4\,H_2 \longrightarrow 3\,Fe + 4\,H_2O$$

Physical Properties

Some physical properties of hydrogen are given below:

- It is a colourless, tasteless and odourless gas.
- It is slightly soluble in water because its molecules are non-polar. Hydrogen forms diatomic molecules H_2 and the two atoms are joined by very strong covalent bond (enthalpy) 435.9 $kJmol^{-1}$.
- It is the lightest known substance. Its relative density is 0.0695. Its melting point is 13.8 K and boiling point is 20.4 K. It is highly combustible. It can be liquefied at very low temperature and high pressure.
- Metals like Ni, Pt, Pd, Fe, Au etc. can adsorb or occlude large volumes of H_2 gas at different temperatures (Pd can occlude 1000 times of its own volume).

Chemical Properties

Some chemical properties of hydrogen are given below:

(i) Dihydrogen is **quite stable** due to its high bond dissociation energy thus is not very reactive.

$$H_2 \xrightarrow{2000\ K} H + H$$

(ii) Dihydrogen is **neutral** to litmus paper.

(iii) **Action with metals** It combines with metals like Na, K, Ca etc., to give corresponding interstitial hydrides which are ionic in nature.

$$2\,Na + H_2 \xrightarrow{\Delta} 2\ NaH$$

$$Ca + H_2 \xrightarrow{\Delta} CaH_2$$

(iv) **Reaction with non-metals** The reactivity of halogens towards dihydrogen decreases as

$$F_2 > Cl_2 > Br_2 > I_2$$

$$H_2 + F_2 \xrightarrow{\text{Dark}} 2HF$$

$$H_2 + Cl_2 \xrightarrow{\text{Diffused sunlight}} 2\,HCl$$

$$H_2 + Br_2 \xrightarrow{673\ K} 2\,HBr$$

$$H_2 + I_2 \xrightarrow{673\ K,\ Pt} 2HI$$

$$H_2 + S \xrightarrow{700\ K} H_2S$$

(v) **Reaction with metal oxides** Dihydrogen acts as a strong reducing agent and thus it reduces metal oxides to metal.

$$CuO + H_2 \xrightarrow{\Delta} Cu + H_2O$$

$$ZnO + H_2 \xrightarrow{\Delta} Zn + H_2O$$

$$PbO + H_2 \xrightarrow{\Delta} Pb + H_2O$$

(vi) **Reaction with unsaturated hydrocarbons** Dihydrogen reacts with unsaturated hydrocarbons to give saturated hydrocarbons.

$$\underset{\text{Ethylene}}{H_2C=CH_2} + H_2 \xrightarrow[473\ K]{\text{Ni or Pt or Pd}} \underset{\text{Ethane}}{H_3C—CH_3}$$

$$\underset{\text{Ethylene}}{HC\equiv CH} + 2H_2 \xrightarrow[473\ K]{\text{Ni or Pt or Pd}} \underset{\text{Ethane}}{H_3C—CH_3}$$

This reaction is used in the hydrogenation of oils.

$$\underset{\text{(Liquid)}}{\text{Vegetable oil}} + H_2 \xrightarrow[473\ K]{Ni} \underset{\text{(Solid)}}{\text{Fat}}$$

The vegetable ghee such as Dalda are prepared by this process.

Uses of Dihydrogen

Some uses of dihydrogen are given below

- It is used in the manufacture of synthetic petrol.
- It is used as a rocket fuel in the form of liquid hydrogen which does not cause any pollution and produces greater energy per unit mass of fuel.
- It is used in the hydrogenation of vegetable oils.
- It is used as a reducing agent in the laboratory and industry.
- It is used in the preparation of compounds like ammonia (Haber's process), water gas, and fertiliser such as urea, ammonium sulphate etc.
- It is used in the preparation of many organic compounds such as methanol.

$$CO(g) + 2H_2(g) \xrightarrow[\text{Catalyst}]{Cu/ZnO-Cr_2O_3} CH_3OH(l)$$

Ortho and *para* Hydrogen

- A molecule of dihydrogen contains two atoms, the nuclei of both the atom in each molecule are spining.
- Molecules of hydrogen in which spins of both the nuclei are in same directions are called ***ortho* hydrogen.**
- Molecules in which both the nuclei spin in the opposite directions are called ***para* hydrogen.** The compound usually consist of discrete covalent molecules. Only weak van der Waals' forces holding the molecule together.
- *para* hydrogen has lower energy and at 0°K the gas contains 100 % *para* hydrogen.
- At room temperature, the ratio of *ortho* to *para* hydrogen is 3 : 1.
- *Ortho* and *para* hydrogen, both have similar chemical properties but their properties like boiling points, heating conductivity and specific heat etc. are different.

Hydrides

Compounds of hydrogen in which hydrogen is suppose to be present as H^- are called hydrides. Oxidation state of H in these compounds is –1. These are the binary compounds of hydrogen with other elements.

Types of Hydrides

Hydrides are the following types

(i) **Ionic or Saline Hydrides** These are formed by reaction of alkali metal, alkaline earth metals (except Be and Mg) and some lanthanides with hydrogen. These hydrides are crystalline, non-volatile and conducting in fused state. Their aqueous solution is alkaline in nature. Their reaction with water is explosive.

$$NaH + H_2O \longrightarrow NaOH + H_2\uparrow$$

(ii) **Covalent or Molecular Hydrides** These are formed by reaction of *p*-block elements (except noble gases) and by Be and Mg with hydrogen.

Molecular hydrides are of three types

(a) **Electron-deficient hydrides** These are formed by group-13 (IIIA) elements e.g. B_2H_6 etc.

(b) **Electron-precise hydrides** These are formed by group-14 (IV A) elements e.g. CH_4 etc.

(c) **Electron rich hydrides** These are formed by group 15, 16 and 17 elements e.g. NH_3, H_2O, HF etc.

(iii) **Metallic or Interstitial** (Non-stoichiometric) **Hydrides** These are formed by reaction of transition metals and inner-transition metals with hydrogen.

These are non-stoichiometric compounds and show conductivity. *d*-block elements of group 7, 8 and 9 do not form hydride, therefore this region in the periodic table is called **hydride gap**.

(iv) **Polymeric Hydrides and Complex Hydrides** These are formed by reaction of elements having electronegativity in the range 1.4 to 2.0 like Al, Si etc with hydrogen.

Water

A major part of all living organisms is made up of water (H_2O). Human body has 65% (about) and some plants have as much as 95% water. 97% part of the entire water is assumed to be confined in oceans while rest is present in pure form. Rain water is the purest form of water.

Properties of Water

Some properties of water are given below

- Water is the neutral oxide of hydrogen.
- It is colourless liquid under ordinary conditions.
- It is polar compound (dipole moment = 1.85 D) and possesses a high dielectric constant (approx 81). Which makes it is a universal solvent.
- It has abnormally high melting point and boiling point due to the association of H_2O molecules through hydrogen bonding.
- **Melting point** of ice is lowered with increase in pressure.
- In solid state (ice) water molecules are joined together in three dimension network. It is responsible for low density of water. As the temperature of ice is increased above 0°C, some **H-bond** are broken, this results in decrease in volume and increase in density. Density of water is maximum at 4°C.

- **Density** of ice is less than water hence it floats on water.
- pH of water is 7.
- **Covalent molecules** which are capable of forming hydrogen bonds with water molecules get dissolved e.g. lower alcohols, lower carboxylic acid, sugars are soluble in water due to hydrogen bond formation.
- Covalent molecules which cannot form hydrogen bonds with water are not soluble in it, e.g. $CHCl_3$, CCl_4, benzene, alkanes etc.

Water is a universal solvent

The various properties of water which make it a universal solvent are

(i) The polar nature of water molecule.
(ii) The ability of water molecule to make hydrogen bonds with molecules of many compounds.
(iii) High dielectric constant of water molecule.
(iv) The ability of water molecule undergo chemical reaction with many element and compounds.

Hard Water

Presence of calcium and magnesium salts (mainly) and iron salt in the form of hydrogen carbonate, chloride and sulphate in water makes water hard. Hard water does not give lather with soap. Hard water forms scum/precipitate with soap. It is, therefore, unsuitable for laundry. It is **harmful for boilers** as well because of deposition of salts in the form of scale.

Soft Water

Rain water is almost pure. The water free from soluble salts of calcium and magnesium, is called soft water. It gives lather with soap.

Temporary Hardness

Temporary hardness is due to the presence of magnesium and calcium hydrogen carbonates in water. It can be removed by

(i) **Boiling** During boiling, the soluble magnesium hydrogen carbonate is converted into insoluble magnesium hydroxide and calcium hydrogen carbonate is converted into insoluble calcium carbonate. These insoluble precipitates can be removed by filtration.
(ii) **Clark's Method** In this method, calculated amount of lime is added to hard water. It precipitates out calcium carbonate and magnesium hydroxide which can be filtered off.

Permanent Hardness

It is due to the presence of soluble salts of magnesium and calcium in the form of chlorides and sulphates in water.

Permanent hardness can be removed by the following methods

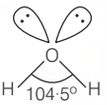
(i) **Treatment with Washing Soda** (Na_2CO_3 or Sodium Carbonates) Washing soda reacts with soluble calcium and magnesium chlorides and sulphates in hard water to form insoluble carbonates.
(ii) **Calgon's Method** Sodium hexametaphosphate ($Na_6P_6O_{18}$), commercially called 'calgon', when added to hard water, complex anions are formed. The complex anion keeps the Mg^{2+} and Ca^{2+} ions in solution.
(iii) **Ion Exchange Method** This method is also called **zeolite/permutit** process. Hydrated sodium aluminium silicate is called zeolite. When zeolite is added to hard water, exchange reactions take place which results in softening of water.

$Na_2Al_2Si_2O_8 \cdot xH_2O$, (also known as zeolites) which have property of exchanging cations such as Ca^{2+}, Mg^{2+} with sodium salt ions.

(iv) **Synthetic Resins Method** Now-a-days hard water is softened by using synthetic cation exchangers. This method is more efficient than zeolite process.

Structure of Water Molecule

- The molecule of water consists of two hydrogen atoms bonded to oxygen atom by **covalent bonds.**
- The density of ice is less than water.
- In water molecule, the central oxygen atom is sp^3 hybridised and contain two lone pairs.
- The geometry of water is distorted and H—O—H bond angle is 104.5°.



Structure of H_2O

Heavy Water

- Chemically heavy water is deuterium oxide (D_2O). It was discovered by **Urey** in 1932. It is colourless, odourless and tasteless liquid.
- It is used in nuclear reactor as moderator because it slow down the fast moving neutrons.

Properties of H_2O and D_2O

Property	*H_2O*	*D_2O*
Freezing point	0°C	3.8°C
Boiling point	100°C	101.42°C
Temperature of maximum density	4°C	11.6°C
Dielectric constant	81	80
Solubility of substances	High	Low
Density	1.0000 g cm^{-3}	1.1059 g cm^{-3}

CARBON

Carbon is the first element of **IV A group** of periodic table. It occurs in the free state in the form of coal, diamond and graphite. In combined state carbon is found as carbonates of metals like calcium and magnesium and as hydrocarbons and in air as CO_2 (0.03)%.

The **phenomenon of existence** of an element in more than one form and each form has different physical properties but identical chemical properties are known as allotropy and these different forms are called allotropes. Carbon shows allotropism due to the property of catenation and $p\pi - p\pi$ bond. Carbon exists in two different allotropic forms

(i) **Crystalline form** Diamond, graphite and fullerene.

(ii) **Amorphous form** Coal, wood charcoal, animal charcoal, lamp black, coke etc.

Crystalline Forms of Carbon

Diamond

Diamond is the purest form of carbon. Diamond prepared in laboratory is called artificial diamond.

Properties of Diamond

Some properties of diamond are given below

- It is the hardest substance. Its m.pt. is very high (about 3600°C).
- It is colourless, shining and transparent crystalline solid. It has a density about 3.51 g/cm^3.
- It is bad conductor of heat and electricity.
- It burns in air at 900°C to give CO_2.
- It is insoluble in all the solvents.
- Due to the lattice vibrations, it has the highest thermal conductivity among all known materials.
- Diamond is a covalent solid. In its crystal, each carbon atom is covalently bonded to four other carbon atoms situated around it tetrahedrally.
- The hybridisation of carbon in diamond is sp^3.
- The carbon-carbon bond distance in diamond is 1.54 Å.
- Diamonds are the transparent to light and have very high refractive index (2.5).

➨ **Note** X-rays penetrate diamond but these rays do not penetrate glass (identification test for glass and diamond).

Uses of Diamond

Some uses of diamond are given below

- It is used for cutting glass, making bores for rock drilling and for making abrasives.
- Diamond is used as a gem stone on account of reflection and refraction of light.
- It is used for grinding and polishing hard materials.
- It is also used for making dies for drawing thin wires from metals.
- Sequence of hardness is boron carbide (B_4C) > silicon carbide (SiC) > diamond > glass > iron.

Graphite

It is an important allotrope of carbon which is more widely distributed in nature than diamond. It is also called black lead. It can be prepared by heating anthracite coal with a small amount of iron or silica in an electric furnace.

Properties of Graphite

Some properties of graphite are given below

- It is shining gray, opaque solid.
- It is softer than diamond.
- It has a density about 2.25 g/cm^3.
- Its melting point is very high (3500°C).
- It is good conductor of heat and electricity.
- It is also pure but less than that of diamond (95–97% C).
- It burns in air at 973 –1073 K to give CO_2.
- Two dimensional layer structure having regular hexagonal sheets.
- Only 3 of the 4 valence electrons of C participate in bonding. Thus, hybridisation is sp^2 having 3 covalent bonds with 3 other C-atoms in the same plane. This fourth free electron is responsible for its conductivity.
- The carbon-carbon bond distance in graphite (1.42 Å) is shorter than diamond (1.54 Å). It is insoluble in ordinary solvents like water, alcohol, ether etc.

Uses of Graphite

Some uses of graphite are given below

- It is used in making electrodes.
- It is used as a lubricant for heavy machines.
- It is used in the manufacture of crucibles which can withstand high temperatures.
- Mixed with clay it is used for making lead pencils.
- It is also used as a moderator for fast moving neutrons in atomic reactors.

Fullerene

- Fullerene or Bucky balls were discovered in 1980. Its general formula is C_{2n} (where $n = 30 - 48$).
- Buckminster fullerene, C_{60} has soccer ball like shape with 12 pentagons and 20 hexagon rings of carbon atoms. While C_{70} has rugby ball shape. In fullerene each carbon is sp^2-hybridised.
- These are the only pure form of carbon.
- These are soluble in organic solvents due to their covalent nature and form coloured solutions.
- These react with metals of group 1 and form solids e.g. K_3C_{60}. These compounds act as superconductors below 18 K. Their thermal stability is less than that of diamonds and graphite.

➨ **Note** Thermodynamically most stable allotrope of carbon is graphite. Therefore $\Delta fH°$ for graphite is zero. Whereas $\Delta fH°$ for diamond and fullerene is 1.90 and 38.1 kJmol^{-1} respectively.

Micro Crystalline Forms of Carbon

Coal

It is a complex mixture of compounds of carbon (mainly), hydrogen, oxygen and some free carbon. The compounds of nitrogen, sulphur are also present in a very small amount in coal. Coal was formed by the decomposition of large plants and trees buried under the earth millions of years ago. This is slow chemical process. This process of conversion of dead vegetation into coal is called **carbonisation**.

- Peat is the most inferior and anthracite is the most superior quality of coal.
- Bituminous coal is the most common variety of coal, used in house holds.
- Wood contains about 40% carbon.

Different Varieties of Coal are as follows

Types of coal	*Carbon content*
Peat	60% carbon
Lignite (brown coal)	70% carbon
Bituminous (household coal)	80% carbon
Anthracite (hard coal)	90% carbon

Uses of Coal

Some uses of coal are given below

- Coal is used as a fuel.
- Coal is used in the manufacture of fuel gases like coal gas, water gas, producer gas etc.
- **Coal gas** is the mixture of CO, H_2, CH_4 and hydrocarbon.
- **Water gas** is the mixture of CO and H_2.
- **Producer gas** is $CO + N_2$.
- Coal is also used in the manufacture of synthetic petrol, coke, natural gas etc.
- Coal is a source of organic compounds like benzene, toluene, phenol, aniline, naphthalene, phenanthrene, anthracene etc.

➨ **Note Oil gas** is a mixture of methane, ethylene and acetylene. It is used in burners in laboratory.
Calorific value of coal gas is higher than the producer gas.

Charcoal

- It is a black, soft, and highly porous substance.
- It is prepared by the strong heating of wood in closed vessels in the absence of air. Thus, charcoal is prepared by the destructive distillation of wood. Charcoal is most reactive form of carbon.
- Charcoal is used as black pigment and a fuel for domestic heating purpose.
- Charcoal is however a good fuel than wood because charcoal has a higher calorific value (33 kJ/g) than wood (17 kJ/g) and charcoal does not produce smoke while burning, whereas wood produces a lot of smoke on burning and pollutes air.

It can be obtained in three varieties

(i) **Wood charcoal** It is obtained by heating wood in a limited supply of air. Most impure form of carbon is wood charcoal. It is highly porous and is therefore, used as an adsorbent for gases and in making gas masks.

(ii) **Animal charcoal** It is obtained by destructive distillation of bones and is also known as **bone black**. It contains about 10% carbon. It is mainly used for decolourising sugar syrup in the manufacture of sugar and other organic substance.

(iii) **Sugar charcoal** It is the purest form of amorphous carbon and is obtained by the action of concentrated sulphuric acid on cane sugar.

$$C_{12}H_{22}O_{11} \xrightarrow{\text{Conc. } H_2SO_4} 12\,C + 11\,H_2O$$

Fuel

Fuels are those substances which produce heat and sound upon heating e.g. coal, petroleum, wood, kerosene etc.

- In general fuels are the compounds of carbon and hydrogen.
- Ideal fuel is cheap, readily avialable, readily combustible and easly to transport.
- Fuel efficiency is expressed in terms of its calorific value which is expressed in $kJkg^{-1}$. The amount of heat energy produced on complete combustion of 1 kg of a fuel is called its **calorific value**.
- On the basis of origin fuels are of two types:
  (i) **Primary fuels** These fuels are obtained directly from nature e.g. wood, petroleum.
  (ii) **Secondary fuels** These fuels are obtained from primary fuels e.g. petrol, diesel, kerosene, water gas, coal gas etc.

Importance of liquid and gas fuels

Liquid and gas fuels are more useful than that of the solid fuels because

(i) These fuels do not produce residues, burn easily without smoke, have low ignition temperature.
(ii) Their calorific value is high so produce more heat.

Petroleum

It is a dark oily liquid with an unpleasant odour. It is a mixture of various hydrocarbons.

The process of separating the various constituents of petroleum is known as refining. It is carried out in refinery. Various constituents of petroleum and their uses are as follows:

Petroleum is also known as **black gold** as it is more precious than gold.

	Constituents of petrol	*Uses*
(i)	Petroleum gas in liquid form	Fuel for home and industry
(ii)	Petrol	Motor fuel, aviation fuel, solvent for dry cleaning
(iii)	Kerosene	Fuel for stoves, lamps, for jet aircrafts
(iv)	Diesel	Fuel for heavy motor vehicles, electric generators
(v)	Lubricating oil	Lubrication
(vi)	Paraffin wax	Ointments, candles, vaselines etc.
(vii)	Bitumen	Paints, road surfacing

Octane Number

In the cylinder of combustion engine, some fuels burn before time and produce objectionable metallic sound known as **knocking**. It leads to wastage of fuel. Therefore, an antiknock compound e.g. tetraethyl lead is added to gasoline (petrol) to reduce knocking. Generally 0.15 mL TEL is mixed with ethyl bromide in each litre petrol.

Octane number of a gasoline is defined as the volume percentage of iso-octane in a mixture of iso-octane and *n*-heptane which matches the fuel (gasoline) in knocking. Higher the octane number of a gasoline, better is its quality.

- Octane number of iso-octane (2, 2, 4-trimethyl pentane) is 100.
- Octane number of *n*-heptane is zero.
- Benzene toluene xylene (BTX) is also a good antiknocking compound.

Gasohole

It is a mixture of petrol (10%) and ethanol (90%).

- It is used to minimise the pollution created by burning petroleum products.
- Ethanol is obtained by the fermentation of sugarcane juice.

Some other fuels

These are as follows

(i) **Liquefied Petroleum Gas** (LPG) It is a mixture of butane (C_4H_{10}), iso-butane (C_4H_{10}) and some propane (C_3H_8). A strong foul smelling substance ethyl mercaptan or thioethanol (C_2H_5SH) is also added to LPG to detect its leakage because LPG is a colourless and odourless gas. It is used in cylinders for domestic purposes. Its calorific value is 50 kJg^{-1}.

(ii) **Natural Gas** It is a mixutre of methane (80-90%), ethane and propane. Its calorific value is 50 kJg^{-1}.

(iii) **Bio Gas** Biogas is obtained by breakdown of organic matter in absence of oxygen. It is a mixture of methane (mainly), CO_2, H_2S, moisture and siloxanes.

(iv) **Compressed Natural Gas** The use of diesel and petrol as fuels in automobiles is being replaced by CNG (Compressed natural gas), because it produces 70% Co and 87% nitrogen oxide lesser than that of petrol and diesel. CNG is a cleaner fuel.

Flame

A hot glowing visible gaseous part of a fire. The substances which vaporise during burning, give flames. There are three zones of the flame:

(i) **Outer zone of complete combustion** It is the hottest part of the flame and blue in colour.

(ii) **Middle zone of partial combustion** Yellow in colour due to incomplete combustion of carbon.

(iii) **Inner zone of unburnt wax vapours** Black in colour due to the presence of unburnt carbon particles.

- Blue flame is non-luminous whereas yellow flame is luminous.

Organic Compounds

Compounds of carbon and hydrogen and their derivatives are called **organic compounds**. In earlier time, the chemical substances found in the living beings were called organic compounds.

- Methane, ethane, ethene, (ethylene), ethyne (acetylene) etc. are the examples of organic compounds.
- Urea is the first synthesised organic compound. F. Wohler synthesised urea by heating a mixture of ammonium sulphate and potassium cyanate.
- The property of catenation in carbon and ability of carbon to form multiple bonds form the basis of multiplicity of carbon compounds in organic chemistry.
- Hydrocarbons are classified into saturated hydrocarbons and unsaturated hydrocarbons.
- Methane, ethane, propane etc. are saturated hydrocarbons whereas ethylene, acetylene, butane, butyne are unsaturated hydrocarbons.

Some Important Organic Compounds

(i) **Methane** (CH_4) It is also called marsh gas. It is used in preparation of carbon black, organic compounds and as a gaseous fuel. Its mixutre with air is explosive that's why methane is responsible for explosion in coal mines.

(ii) **Ethylene** (C_2H_4) It is used in mustard gas ($ClCH_2CH_2SCH_2CH_2Cl$) preparation, in the form of an anaesthesia, in the production of oxyethylene flame for cutting and welding of metals and in the artificial ripening of fruits.

(iii) **Acetylene** (C_2H_2) It is prepared in laboratory by the reaction of calcium carbide with water. It is used in preparation of lewisite gas ($C_2H_2AsCl_3$), in production of light, in making camphor, in the form of anaesthesia, in oxyacetylene flame for cutting and welding of metals.

(iv) **Acetic acid** (CH_3COOH) In vinegar 6-7% acetic acid is present.

➨ **Note** All common activities of a living organism involve reactions of certain organic compounds. Such compounds are called biomolecules. Carbohydrates, lipids, proteins, vitamins,hormones, nucleic acids etc. are biomolecules.

IMPORTANT POINTS

- Hydrocarbons are the compounds of carbon and hydrogen. In hydrocarbons calorific value increase with increase in % of hydrogen and decrease with increase in oxygen content.
- In complete combustion of even saturated hydrocarbons giving a sooty flame.

OXIDES OF CARBON

Carbon dioxide and carbon monoxide are the two important oxides of carbon.

Carbon Dioxide

Carbon dioxide is an oxide of carbon in which the oxidation state of carbon is +4. Carbon dioxide occurs about 0.03–0.05% in the atmosphere. It is a product of combustion of carbon and carbon containing fuels, respiration and fermentation.

Methods of Preparation

Laboratory Method

In laboratory carbon dioxide is prepared by the action of cold dilute HCl on marble chips in a Kipp's apparatus.

$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2\uparrow$$

This gas is collected by the upward displacement of air. Dilute H_2SO_4 is not used for the preparation as coating of insoluble $CaSO_4$ is formed on the surface which prevents further reaction between acid and $CaCO_3$.

By Carbon or CO

Carbon dioxide is prepared by burning carbon, a hydrocarbon, or carbon monoxide in excess of air.

$$C + O_2 \longrightarrow CO_2$$
$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$
$$2CO + O_2 \longrightarrow 2CO_2$$

From Carbonates

Pure carbon dioxide can be prepared by heating metallic carbonates and bicarbonates.

$$CaCO_3 \xrightarrow{\Delta} CaO + CO_2$$
$$Li_2CO_3 \xrightarrow{\Delta} Li_2O + CO_2$$
$$2NaHCO_3 \xrightarrow{\Delta} Na_2CO_3 + H_2O + CO_2$$

➨ Seth's Carbonates of Fr, K, Rb, Cs, does not give CO_2 on heating.

Carbon dioxide can also be prepared by the action of dilute acids on carbonates and bicarbonates.

$$Na_2CO_3 + H_2SO_4 \longrightarrow Na_2SO_4 + H_2O + CO_2$$
$$MgCO_3 + 2HCl \longrightarrow MgO + H_2O + CO_2$$
$$NaHCO_3 + HCl \longrightarrow NaCl + H_2O + CO_2$$

By Fermentation of Molasses

Carbon dioxide can also be prepared from fermentation of molasses with yeast in the formation of ethanol.

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow[\text{Yeast}]{\text{Invertase}} \underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{fructose}}{C_6H_{12}O_6}$$

$$C_6H_{12}O_6 \xrightarrow{\text{Zymase (yeast)}} \underset{\text{ethanol}}{2C_2H_5OH} + 2CO_2$$

It is also obtained as a byproduct in the preparation of ethanol by the fermentation of starch.

Physical Properties

Some physical properties of CO_2 are given below

- It is colourless, odourless gas about 1.5 times heavier than air. It is fairly soluble in water more than CO. Aerated water is a solution of carbon dioxide in water under pressure. The solubility increases with increasing pressure.
- Carbon dioxide can be easily liquefied under a pressure of 50–60 atm at room temperature. Solid carbon dioxide used for refrigeration and it is also called **dry ice**.
- CO_2 is not poisonous in nature.
- KOH absorbs CO_2

Chemical Properties

Some chemical properties of CO_2 are given below

- Carbon dioxide is a stable gas and it is not decomposed.
- Ordinary carbon dioxide is neither combustible nor supporter of combustion. However certain active metals like K, Mg, Na, etc., burn in atmosphere of CO_2.

$$4K + 3CO_2 \longrightarrow 2K_2CO_3 + C$$
$$2Mg + CO_2 \longrightarrow 2MgO + C$$

- It dissolves in water to form carbonic acid

$$H_2O + CO_2 \longrightarrow H_2CO_3$$

Carbonic acid is a weak acid and forms two series of salts. CO_2 is an anhydride of carbonic acid.

- Carbon dioxide turns blue litmus into red, thus, it is an acidic oxide.
- On passing carbon dioxide gas through lime water it turns milky. Milkiness is due to the formation of $CaCO_3$.

$$Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$$

In excess of CO_2 milkiness disappears due to the formation of soluble calcium bicarbonate.

$$CaCO_3 + H_2O + CO_2 \longrightarrow Ca(HCO_3)_2$$

Uses of Carbon Dioxide

Some uses of carbon dioxide are given below

- As a fire extinguisher.
- In the preparation of aerated waters like soda water.
- As a refrigerant under the commercial name drikold.
- For artificial respiration as a mixture of $O_2 + CO_2$ called carbogen.
- In creating inert atmosphere free from air.

Carbon Monoxide

When CO_2 is passed through red hot coke, CO is obtained.

$$CO_2 + C \xrightarrow{\text{Red hot}} 2CO$$

Carbon monoxide is extremely poisonous because it combines with haemoglobin to form a stable salt carboxy haemoglobin and a result of this suffocation taken place (Asphyxia). Low level poisoning results in headache and drowsiness whereas high level poisoning may cause death. It is neutral to litmus. It reduces metal oxide to metal and is used in the manufacture of methanol, formic acid and phosgene gas. It is used in purification of nickel by Mond's process and in preparation of metal carbonyls.

OXYGEN

Oxygen belongs to group VIA (group 16) of the periodic table. The atomic number of oxygen is 8 and electronic configuration is $1s^2 2s^2 2p^4$.

In air it occurs in free state and constitute 21% by volume of air. In combined state it constitutes about 88.8% by mass of water and 46.5% by mass of earth's crust. Almost all of the dioxygen in the atmosphere is believed to be due to the photosynthesis taking place in green plants in the presence of sunlight.

$$xH_2O + xCO_2 \xrightarrow[\text{Photosynthesis}]{\text{Sunlight}} \underset{\text{Carbohydrate}}{(CH_2O)_x} + xO_2$$

It is an essential constituent of all acids.

Method of Preparation of Dioxygen (O_2)

Oxygen molecule is diatomic therefore it is also called dioxide.

(i) **By decomposition of oxygen rich compounds** Certain compounds containing large amounts of oxygen such as chlorates, nitrates, permanganates etc., give dioxygen on strong heating.

$$\underset{\text{Potassium chlorate}}{2\,KClO_3} \xrightarrow[MnO_2]{\text{Heat}} 2\,KCl + 3\,O_2\uparrow$$

Here MnO_2 acts as a catalyst.

$$\underset{\text{Potassium nitrate}}{2\,KNO_3} \xrightarrow{\text{Heat}} 2\,KNO_2 + O_2\uparrow$$

$$2\,HgO \xrightarrow{\text{Heat}} 2\,Hg + O_2\uparrow$$

(ii) **By heating dioxides, peroxides and higher oxides** Oxides of certain metals, on heating give dioxygen.

$$2\,Ag_2O \xrightarrow{\text{Heat}} 4\,Ag + O_2$$

$$2\,Pb_3O_4 \xrightarrow{\text{Heat}} 6\,PbO + O_2$$

$$2\,BaO_2 \xrightarrow{\text{Heat}} \underset{\text{Barium oxide}}{2BaO} + O_2$$

(iii) **By the action of water on sodium peroxide** (Used in laboratory)

$$2\,Na_2O_2 + 2\,H_2O \longrightarrow 4\,NaOH + O_2$$

(iv) **By the decomposition of peroxide or hypochlorites**

$$2H_2O_2(l) \longrightarrow 2\,H_2O(l) + O_2$$

$$\underset{\text{Bleaching powder}}{2\,CaOCl_2} \xrightarrow{\Delta} 2\,CaCl_2 + O_2$$

(v) **By the action of chemical reagent on compounds rich in oxygen**

$$2MnO_2 + 2H_2SO_4 \longrightarrow 2MnSO_4 + 2H_2O + O_2\uparrow$$

$$4\,KMnO_4 + 6H_2SO_4 \longrightarrow 2K_2SO_4 + 4MnSO_4 + 6H_2O + 5O_2$$

$$2K_2Cr_2O_7 + 8H_2SO_4 \longrightarrow 2K_2SO_4 + 2Cr_2(SO_4)_3 + 8H_2O + 3O_2$$

(vi) **Industrial preparation**

(a) **From air** Oxygen is prepared by fractional distillation of air. During this process dinitrogen with less boiling point (78 K) distills as vapour while dioxygen with higher boiling point (90 K) remains in the liquid state and can be separated.

(b) **From water** Dioxygen is obtained by electrolysis of water containing small amount of acid or alkali.

$$2H_2O \underset{}{\overset{\text{Electrolysis}}{\rightleftharpoons}} 2\,H_2(g) + O_2(g)$$

Physical Properties

Some physical properties of oxygen are given below

- Dioxygen is a colourless, tasteless and odourless gas.
- It is slightly soluble in water and can be liquefied to a pale blue liquid and can be solidified to bluish white solid at –291°C under pressure.
- Its melting point is 54.4 K and boiling point is 90.2 K.
- It exists in three isotopic forms of ${}_8O^{16}$, ${}_8O^{17}$, ${}_8O^{18}$ in the ratio of 1000 : 1 : 8. ${}_8O^{18}$ is radioactive.
- It is slightly heavier than air and sparingly soluble in water.
- Oxygen is absorbed by alkaline pyrogallol solution which turns brown.
- Oxygen does not burn itself but it is a supporter of combustion.
- Oxygen has two unpaired electrons in its *p*-orbital, so it is paramagnetic in nature.

Chemical Properties

Some chemical properties of oxygen are given below:

(i) The dioxygen is quite stable in nature as its bond dissociation energy is very high.

(ii) Chemical reactions of dioxygen are exothermic.

(iii) **Action with litmus** It is neutral and has no effect on blue or red litmus.

(iv) **Reaction with metals** Almost all the metals burn in oxygen or air to form oxides most of which are basic in nature.

$$2\,Mg + O_2 \longrightarrow 2\,MgO$$

$$4\,Fe + 3\,O_2 \longrightarrow 2\,Fe_2O_3$$

Oxides of Zn, Al and Sn are amphoteric in nature.

(v) **Reaction with non-metals** Non-metals also burn in oxygen gives acidic oxides which are soluble in water.

$$S + O_2 \xrightarrow{\Delta} SO_2\uparrow$$

$$C + O_2 \xrightarrow{\Delta} CO_2\uparrow$$

$$P_4 + 5\,O_2 \xrightarrow{\Delta} P_4O_{10}$$

However, some non-metals such as carbon (CO) and nitrogen (NO, N_2O) form neutral oxides.

(vi) **Reaction with compounds** Dioxygen is an oxidising agent and it oxidises many compounds under specific conditions.

$$4\,HCl + O_2 \xrightarrow[CuCl_2]{700\ K} 2\,Cl_2 + 2H_2O$$

(Reaction with HCl—Deacon's process)

$$4\,NH_3 + 5\,O_2 \xrightarrow[Pt]{1073\ K} \underset{\text{Nitric oxide}}{4\,NO} + 6\,H_2O$$

(Ostwald process for manufacture of NO)

$$2\,SO_2 + O_2 \xrightarrow[Pt\ or\ V_2O_5]{723\ K} 2\,SO_3$$

(vii) **Reaction with hydrocarbons** Saturated as well as unsaturated hydrocarbons burn in excess of air or oxygen to give CO_2 and H_2O.

$$\underset{\text{Methane}}{CH_4} + 2\,O_2 \longrightarrow CO_2 + 2\,H_2O, \quad \Delta H = -890\ kJ\ mol^{-1}$$

$$C_2H_4 + 3O_2 \longrightarrow 2\,CO_2 + 2\,H_2O$$

$$\underset{\text{Glucose}}{C_6H_{12}O_6} + 6\,O_2 \longrightarrow 6\,CO_2 + 6\,H_2O$$

Uses of Oxygen

Some uses of oxygen are given below:

- It is used in the oxy-hydrogen or oxy-ethylene or oxy-acetylene torches which are used for welding and cutting of metals.
- Liquid oxygen is used as a rocket fuel.
- It is used as an oxidising agent and bleaching agent.
- Oxygen–18 isotope is used as a tracer in the study of reaction mechanism.
- A mixture of carbon dust and liquid oxygen is used as explosive for coal mining.
- It is used for artificial respiration in case of surgery.

Oxides

The binary compounds of oxygen with other elements are known as oxides. They are classified on the basis of their chemical properties and their oxygen content.

1. Classification on the basis of Chemical Properties

(i) **Acidic oxides** Those oxides which dissolve in water giving oxy-acids and neutralise alkali are called acidic oxides. Generally non-metals form acidic oxides. e.g. B_2O_3, SiO_2, CO_2, N_2O_3, P_2O_5 , I_2O_5 etc.

(ii) **Basic oxides** These oxides dissolve in water to give alkali. They are metallic oxides. They neutralise acids. e.g. K_2O, CaO, BaO, BaO_2 etc.

(iii) **Neutral oxides** These oxides have no action on litmus. They produce neither base nor acid with water, e.g. CO, N_2O, NO etc.

(iv) **Amphoteric oxides** These oxides behave like acids and also as bases depending upon conditions, e.g. ZnO, Al_2O_3, SnO, SnO_2, As_2O_3, PbO, BeO, SbO and PbO_2 etc.

2. Classification on the basis of Oxygen Content

(i) **Normal oxides** These oxides contain as much oxygen as needed according to the oxidation number of the element, e.g. H_2O, MgO, Al_2O_3, SiO_2 etc.

(ii) **Polyoxides** They contain more oxygen than permitted by the normal oxidation number of element, e.g. BaO_2, KO_2, PbO_2, MnO_2 etc.

(iii) **Suboxides** They contain less oxygen that expected from the normal oxidation number of element, e.g. N_2O, C_3O_2 (carbon suboxide) etc.

(iv) **Mixed oxides** These oxides are made up of two simpler oxides, e.g. Pb_3O_4, Fe_3O_4 etc.

OZONE

- Ozone is a highly unstable triatomic allotropic form of oxygen and it is known as ozonised oxygen.
- Ozone is dark blue in colour.
- Ozone is prepared in the laboratory by Siemen's ozoniser and Brodie's ozoniser.

$$3O_2 \rightleftharpoons 2O_3;\ \Delta H = +68\ kCal$$

- It acts as oxidising as well as reducing agent.
- Ozone is heavier than air and slightly soluble in water.
- Ozone is diamagnetic.
- Mercury loses its meniscus in contact with ozone (tailing of mercury). It is used as a test for ozone.
- Ozone is used for disinfecting water for drinking purposes because of its *germicidal* properties.
- Ozone is used for bleaching fabrics, oils, starch, ivory etc.
- It is used for making camphor and artificial silk.

NITROGEN

Nitrogen belongs to group VA (or 15) of the periodic table. Its atomic number is 7 and electronic configuration is $_7N^{14} = 1s^2 2s^2 2p^3$. It is a diatomic molecule with a triple bond ($N \equiv N$). It was discovered by **D Rutherford** in 1772

Nitrogen occurs in the atmosphere to the extent of 78% by volume. In combined state it is present in many compounds such as potassium nitrate (KNO_3) and many ammonium compounds.

➨ **Note** It is an essential constituent of plants, animals (as plant and animal protein) and soil (in the form of nitrites, nitrates and ammonium compounds). The **non-leguminous plants** like Ginkgo also fix atmospheric nitrogen.

Methods of Preparation

Some methods for preparation of nitrogen are as follows

(i) **Laboratory preparation** In laboratory nitrogen is prepared by heating an aqueous solution of ammonium chloride and sodium nitrite.

$$NH_4Cl(aq) + NaNO_2(aq) \longrightarrow N_2\uparrow + 2\,H_2O(l) + NaCl$$

(ii) **By thermal decomposition of ammonium dichromate** or **ammonium nitrite**

$$(NH_4)_2Cr_2O_7 \xrightarrow{\text{Heat}} Cr_2O_3 + N_2 + 4\,H_2O$$

$$NH_4NO_2 \xrightarrow{\text{Heat}} N_2 + 2H_2O$$

(iii) **From ammonia**

(a) Nitrogen can be prepared from ammonia by passing over red hot copper in the presence of NO.

$$4\,NH_3 + 6\,NO \xrightarrow{Cu} 6\,H_2O + 5\,N_2$$

(b) By oxidation of ammonia with chlorine or cupric oxide or bleaching powder.

$$8NH_3 + 3Cl_2 \longrightarrow 6NH_4Cl + N_2$$

$$2\,NH_3 + 3\,CuO \xrightarrow{\text{Heat}} 3\,Cu + N_2 + 3\,H_2O$$

$$2\,NH_3 + 3\,\underset{\text{Bleaching powder}}{CaOCl_2} \xrightarrow{\text{Heat}} 3\,CaCl_2 + N_2 + 3\,H_2O$$

(iv) **Commercial preparation** Commercially dinitrogen is prepared by the fractional distillation of liquid air.

Physical Properties

Some physical properties of nitrogen are given below

- Dinitrogen is a colourless, odourless and tasteless gas.
- It is a **non-toxic** gas however animals die in an atmosphere of N_2 for want of oxygen.
- It is slightly lighter than air and the vapour density is 14.
- Its melting point is 63.2 K and boiling point is 77 K.
- It is slightly soluble in water.

Chemical Properties

Some chemical properties of nitrogen are given below

(i) Dinitrogen is chemically unreactive at ordinary temperatures. The N—N bond in nitrogen molecule is a triple bond ($N \equiv N$).

(ii) The low reactivity of nitrogen is due to its very small molecular size and high bond dissociation energy.

(iii) **Action with litmus** Dinitrogen is neutral towards litmus.

(iv) Its maximum covalency is four because of the absence of *d*-orbitals.

(v) It forms nitrides on heating strongly with a number of active metals.

$$6\,Li + N_2 \longrightarrow 2\,Li_3N$$

$$3\,Mg + N_2 \longrightarrow Mg_3N_2$$

$$2\,Al + N_2 \longrightarrow 2\,AlN$$

(vi) Dinitrogen combines with dihydrogen and dioxygen.

$$N_2 + 3\,H_2 \rightleftharpoons \underset{\text{Ammonia}}{2\,NH_3} \text{ (Haber's process)}$$

$$N_2 + O_2 \rightleftharpoons \underset{\text{Nitric oxide}}{2\,NO}$$

Uses of Dinitrogen

Some uses of dinitrogen are given below

- Dinitrogen is used in the manufacture of compounds like ammonia, nitric acid, calcium cyanamide etc.
- Liquid nitrogen is used as refrigerant to preserve biological specimens and freezing foodstuffs and also in cryosurgery.
- It is used in providing inert atmosphere in iron and steel industries.
- It is used in gas filled thermometers used for measuring high temperatures.

Oxides of Nitrogen

- Nitrogen and oxygen react together to form oxides of nitrogen during lighting in the clouds in the rainy season.
- N_2O causes laughing **hysteria** when inhaled.
- N_2O_3 (dinitrogen trioxide) is anhydride of nitrous acid.
- NO_2 is a reddish brown gas, it dimerises to N_2O_4. It is known as the mixed ahydride of nitrous acid and nitric acid.

$$2NO_2 + H_2O \rightleftharpoons HNO_2 + HNO_3$$

- N_2O_5 is anhydride of nitric acid and it is most **acidic oxide**.

Ammonia

- It was first isolated by **Priestley** in 1774.
- In laboratory it is prepared by heating ammonium chloride with slaked lime.

$$2NH_4Cl + Ca(OH)_2 \longrightarrow CaCl_2 + 2H_2O + 2NH_3 \uparrow$$

- It is prepared on industrial scale by Haber's process.
- It is a strong Lewis base. Its aqueous solution is basic in nature.
- Ammonia is used in the manufacture of nitric acid, sodium carbonate and rayon.
- It is used in preparation of tear gas. Its aqueous solution (NH_4OH) is used as a laboratory reagent.
- In the form of ammonium nitrate, ammonium sulphate is used as a fertilizer.

Nitric Acid

- It is the hydrate of N_2O_5.
- Nitric acid (HNO_3) is manufactured by Ostwald process.
- Anhydrous nitric acid is colourless fuming liquid with a pungent smell.
- Nitric acid usually acquires yellow colour due to its decomposition into NO_2 by sunlight. This colour can be removed by passing O_2 through it.
- Nitric acid is very strong oxidising agent and nitrating agent.
- Nitric acid is used in manufacture of TNT, nitro glycerine, picric acid, dynamite, gun cotton and amatol (80% NH_4NO_3 + 20% TNT) etc.

PRACTICE EXERCISE

1. The radioactive isotope of hydrogen is
(a) hydrogen (b) parahydrogen
(c) deuterium (d) tritium

2. Hydrogen was discovered by
(a) Lavoisier (b) Cavendish
(c) Dalton (d) Newton

3. Tritium is composed of
(a) one proton, one electron and two neutrons
(b) one proton, two electrons and one neutron
(c) two protons and one electron
(d) one proton, one electron and one neutron

4. Select the true statement.
(a) Among protium, deuterium and tritium, protium has largest atomic radius
(b) Absolutely pure *ortho* hydrogen is formed at 20 K
(c) Atomic weight of deuterium is 3 and that of hydrogen is 2
(d) *Para* and *ortho* hydrogen possess same chemical properties

5. The metal which cannot liberate hydrogen from acid is
(a) platinum (b) silver
(c) gold (d) All of these

6. Hydrogen from HCl can be prepared from
(a) copper (b) phosphorus
(c) magnesium (d) mercury

7. Hydrogen acts as a
(a) reducing agent
(b) oxidising agent
(c) both reducing and oxidising agent
(d) neither reducing nor oxidising agent

8. Hydrogen will not reduce heated
(a) CuO (b) Fe_2O_3 (c) Al_2O_3 (d) SnO_2

9. Which of the following metal adsorb hydrogen?
(a) Zn (b) Pd (c) Al (d) K

10. In Bosch process hydrogen is obtained from
(a) natural gas (b) water
(c) water gas (d) None of these

11. In Lane process reduction of steam is carried out by heated
(a) Ca (b) Fe (c) K (d) Sr

12. Moist hydrogen cannot be dried over conc. H_2SO_4 because
(a) it can catch fire
(b) it is reduced by H_2SO_4
(c) it can oxidised by H_2SO_4
(d) it decomposes by H_2SO_4

13. Hydrogen is not obtained when zinc reacts with
(a) cold water (b) dil. H_2SO_4
(c) dil. HCl (d) hot 20% NaOH

14. Zinc react with conc. H_2SO_4 to form
(a) $ZnSO_4 + H_2$ (b) $ZnSO_4$
(c) $ZnSO_4 + SO_2 + H_2O$
(d) None of the above

15. Hydrogen is collected
(a) over water (b) over mercury
(c) over alcohol (d) None of these

16. Consider the following statements about *ortho* or *para* forms of hydrogen
I. *Ortho* or *para* hydrogens are isotopes of hydrogen.
II. Specific heats of the two forms are same.
III. Chemical properties of two forms are same.
IV. Boiling points of two forms are same.
Which of these is/are correct statements?
(a) I and II (b) Only III
(c) III and IV (d) IV and I

17. When hydrogen is passed over Pd, hydrogen is adsorbed over the surface of Pd, this process is called
(a) hydrogenation (b) occulusion
(c) evaporation (d) halogenation

18. Which one of the following elements is used as catalyst in the hydrogenation of vegetable oils?
(a) Pt (b) Na
(c) Ru (d) P

19. Dihydrogen reacts with CO at 700 K in the presence of a catalyst to form methanol, the catalyst is
(a) $ZnO \cdot C_2O_3$ (b) $ZnO \cdot C_2O_4$
(c) $ZnO \cdot CrO$ (d) $ZnO \cdot Cr_2O_3$

20. Nascent hydrogen consists of
(a) hydrogen atom with excess of energy
(b) hydrogen ions in excited state
(c) hydrogen molecule with excess of energy
(d) solvated proton

21. Consider the following types of hydrides
I. Covalent hydride
II. Ionic hydride
III. Metallic hydride
Which of these are formed by hydrogen?
(a) I and II (b) I and III
(c) II and III (d) All of these

22. Ionic hydrides are formed by
(a) highly electropositive element
(b) transitional metals
(c) highly electronegative element
(d) inner-transitional element

Directions *(Q. Nos. 23-29) Following questions consist of two statements labelled as Statement I and Statement II. Examine both the statements carefully and mark the correct choice according to the codes given below.*
(a) Both Statement I and Statement II are true and Statement II is the correct explanation of Statement I.
(b) Both Statement I and Statement II are true but Statement II is not the correct explanation of Statement I.
(c) Statement I is true, but Statement II is false.
(d) Statement I is false, but Statement II is true.

23. **Statement I** Fused lithium hydride liberates hydrogen gas at anode on its electrolysis.
Statement II In lithium hydride, hydrogen is in negative oxidation state.

24. **Statement I** Hydrogen forms largest number of compounds in chemistry.
Statement II Hydrogen is the most abundant element in the universe.

25. **Statement I** In the reaction between Na and H_2, hydrogen behave like an oxidising agent.
Statement II Hydrogen atom accepts an electron.

26. **Statement I** Nitrogen is an inert diatomic gas with the structure
$\overset{\bullet\bullet}{N} \equiv \overset{\bullet\bullet}{N}$
Statement II The heat of dissociation of N_2 is extremely large (954 kJ).

27. **Statement I** Nitrogen is a poisonous gas.
Statement II Animals die in its atmosphere for want of oxygen.

28. **Statement I** Oxygen is oxidised on combination with fluorine.
Statement II Fluorine is more electronegative element than oxygen.

29. **Statement I** Oxygen is paramagnetic.
Statement II Hydride of oxygen is less volatile than that of sulphur.

30. Which is the most abundant element in earth's crust?
(a) Ca (b) C
(c) Si (d) O

31. Carbon forms large number of compounds because it has
(a) hardness
(b) catenation property
(c) tetravalent structure
(d) variable valency

32. The nature of chemical bonds in diamond is
(a) ionic (b) covalent
(c) coordinate bond (d) metallic

33. Carbon atoms in diamond are bonded with each other in which configuration?
(a) Planar (b) Linear
(c) Octahedral (d) Tetrahedral

34. Use of diamond as a gem depends upon its
(a) high cost
(b) refractive index
(c) extreme hardness
(d) bad conductance

35. The inert form of carbon is
(a) diamond (b) graphite
(c) coal (d) charcoal

36. Diamond is a
(a) good conductor and soft
(b) non-conductor and soft
(c) non-conductor and hard
(d) good conductor and hard

37. Lead pencil contains
(a) lead sulphate (b) lead
(c) ferrous sulphate (d) graphite

38. Distance between two layers of carbon atoms in graphite is
(a) 335 pm (b) 154 pm
(c) 5.33 pm (d) None of these

39. Graphite is used in nuclear reactor
(a) as a lubricant (b) as a fuel
(c) for lining the inside of the reactor as insulator
(d) for reducing the velocity of neutrons

40. Graphite is a good conductor because
(a) carbon has sp^2-hybridisation
(b) graphite has free electrons
(c) graphite is crystalline
(d) graphite has free atoms

41. Difference between diamond and graphite is that
(a) graphite combines with oxygen to form carbon dioxide but diamond does not
(b) the atoms in each have different masses
(c) the crystal structure in diamond is different form that in graphite
(d) All of the above

42. Diamond and graphite both are made of carbon atoms. Diamond is extremely hard whereas graphite is soft. This is because
(a) the chemical bonds between any two carbon atoms in diamond are stronger
(b) diamond is ionic whereas graphite is covalent
(c) each carbon atom in diamond is chemically bonded to a greater number of neighbouring carbon atoms
(d) certain atoms in diamond are smaller in size

43. The variety of coal having the highest carbon content is
(a) anthracite (b) bituminous
(c) lignite (d) peat

44. The variety of coal having the lowest carbon content is
(a) peat (b) lignite
(c) bituminous (d) anthracite

45. What happens when steam is passed over red hot carbon?
(a) $CO_2 + H_2$ are formed
(b) $H_2 + O_2$ + steam are formed
(c) $CO + H_2$ are formed
(d) None of the above

46. Activated charcoal is employed to remove colouring matter from pure substance it works by
(a) bleaching (b) oxidation
(c) reduction (d) adsorption

47. Formation of coal from wood is
(a) adsorption (b) carbonisation
(c) decarboxylation (d) None of these

48. The charcoal used to decolourise brown sugar solution is
(a) wood charcoal
(b) coconut charcoal
(c) animal charcoal
(d) sugar charcoal

49. The most reactive form of carbon is
(a) diamond (b) graphite
(c) coal (d) charcoal

50. Charcoal is activated by treating with
(a) steam in retort
(b) super heated water
(c) hot air
(d) None of the above

51. Coke is obtained from wood by
(a) cracking
(b) destructive distillation
(c) fractional distillation
(d) None of the above

52. Coal gas is a mixture of
(a) H_2 and CO (b) H_2, CO and CH_4
(c) H_2O and CO (d) CO and CH_4

53. Producer gas is a mixture of
(a) air and water (b) CO, H_2 and N_2
(c) CO and N_2 (d) CO and H_2

54. Which has the highest calorific value?
(a) Coal gas (b) Coal
(c) Producer gas (d) CO_2

55. Maximum calorific value is of
(a) peat (b) lignite
(c) bituminous (d) anthracite

56. Which one of the following oxide of carbon is most stable?
(a) CO (b) C_3O_2 (c) CO_2 (d) CO_3

57. Drikold is
(a) carbon dioxide
(b) carbon monoxide
(c) carbon suboxide
(d) water

58. Soda water contains
(a) formic acid (b) sulphuric acid
(c) carbonic acid (d) acetic acid

59. An anhydride of carbonic acid is
(a) CO (b) C_3O_2
(c) CO_2 (d) None of these

60. Fixation of carbon dioxide by plants is called
(a) photosynthesis (b) fermentation
(c) respiration
(d) burning of oxygen

61. Dry powder extinguishers contain
(a) sand
(b) sand + Na_2CO_3
(c) sand + baking soda
(d) sand and K_2CO_3

62. Carbon dioxide is not used as a fire extinguisher in fire caused by
(a) metal
(b) non-metal
(c) acids
(d) None of the above

63. Which one of the following is a linear molecule?
(a) H_2O (b) CO_2
(c) N_2O_3 (d) NO_2

64. Which of the following is decomposed on heating?
(a) Na_2CO_3
(b) Li_2CO_3
(c) Both (a) and (b)
(d) None of the above

65. Carbogen is a mixture of
(a) oxygen + carbon dioxide
(b) oxygen + chlorine
(c) oxygen + carbon monoxide
(d) None of the above

66. Pick up the false statement.
(a) Solid CO_2 is known as drikold
(b) Dry ice is used as a refrigerant
(c) Dry ice sublimes on heating
(d) Dry ice is covalent solid

67. Which one of the following statement is not correct?
(a) Carbon dioxide is heavier than air
(b) The solubility of carbon dioxide decreases with increase in pressure
(c) Carbon monoxide reduces metal oxides to metal
(d) Carbon monoxide is used in the manufacture of methanol

68. Conversion of glucose into ethanol is called
(a) formylation (b) fermentation
(c) conversion (d) photosynthesis

69. Compound formed on heating CO with NaOH under pressure is
(a) sodium carbide (b) sodium formate
(c) sodium acetate (d) sodium oxalate

70. Carbon dioxide can oxidise
(a) red hot iron (b) red hot carbon
(c) red hot silver (d) red hot lead

71. A gas which reacts with CaO not with $NaHCO_3$ is
(a) CO_2 (b) Cl_2 (c) O_2 (d) N_2

72. Dry ice is used for making cold-baths in laboratories by mixing with volatile organic solvents. Identify the form of dry ice from the following.
(a) Gaseous carbon dioxide
(b) Liquid carbon dioxide
(c) Solid carbon dioxide
(d) Solid hydrogen oxide

73. Identify the correct statement
(a) Carbogen is an antidote for carbon monoxide poisoning
(b) Foamite fire extinguisher contains solutions of aluminium sulphate and baking soda
(c) Dry powder extinguisher contain sand and baking soda
(d) All of the above

74. Which is the correct representation of the reaction when steam is passed over red hot coke at 1000°C?
(a) $C + H_2O \longrightarrow CO + H_2$
(b) $C + 2H_2O \longrightarrow CO_2 + 2H_2$
(c) $2H_2O \longrightarrow 2H_2 + O_2$
(d) None of the above

75. Suppose you have to determine the percentage of carbon dioxide in a sample of a gas available in a container. Which of the following would be the best absorbing material for the carbon dioxide?
(a) Cold, solid calcium hydroxide
(b) Cold, solid calcium chloride
(c) Heated copper oxide
(d) Heated charcoal

76. Consider the following statements with regard to diamond and graphite.
I. Diamond and graphite are isotopes of carbon.
II. In diamond each carbon atom is sp^3-hybridised whereas in graphite each carbon atom is sp^2-hybridised.
III. C—C bond length in diamond is greater than that in graphite.
IV. Graphite is less reactive than diamond.
Which of these statements are correct?
(a) I and II (b) II and III
(c) III and IV (d) II and IV

77. Which of the following statements about diamond are correct?
I. It is used as a gem in jewellery because of its ability to reflect light.
II. It is a good conductor of electricity.
III. It is used for cutting glass, marble, stones and other hard materials.
IV. It is used for drilling of rocks.
Select the correct answer using the codes given below.
(a) I, III and IV (b) II, III and IV
(c) I, II and III (d) II and IV

78. Consider the following statements regarding diamond.
I. It is an allotrope of silicon.
II. It is a bad conductor of heat and electricity.
III. It is the hardest substance.
IV. It burns to produce carbon dioxide.
Which of the statements given above are correct?
(a) I, III, and IV (b) II, III and IV
(c) I and II (d) All of these

79. Crude oil is a direct source of
I. Asphalt II. Paraffin wax
III. Fatty acids IV. Gas oil
Which of the above are correct?
(a) I and II (b) II and III
(c) I and IV (d) I, II and IV

80. Following statements are made in connection with carbon dioxide (CO_2)
I. CO_2 is a poisonous gas.
II. CO_2 is an acidic oxide.
III. CO_2 turns lime water milky.
Which of the statements given above is/are correct?
(a) I and II (b) II and III
(c) Only III (d) I and III

81. Following statements are made in Connection with carbon dioxide (CO_2).
I. Carbon dioxide is prepared by burning carbon or by the reaction of a carbonate and an acid or by decomposition of lime stone.
II. In all these methods of preparation of CO_2, the elements carbon and oxygen are available in a fixed ratio 3 : 8.
III. When CO_2 is continuously bubbled through lime water, initially lime water turns milky and then again colourless.
Which of the statements given above is/are correct?
(a) I and III (b) II and III
(c) I and III (d) All of these

Directions *(Q. Nos. 82-89) Following questions consist of two statements labelled as Statement I and Statement II. Examine both the statements carefully and mark the correct choice according to the codes given below.*
(a) Both Statement I and Statement II are true and Statement II is the correct explanation of Statement I.
(b) Both Statement I and Statement II are true but Statement II is not the correct explanation of Statement I.
(c) Statement I is true, but Statement II is false.
(d) Statement I is false, but Statement II is true.

82. **Statement I** Diamond is used as a precious stone.
Statement II In diamond carbon atoms are tetrahedrally arranged.

83. **Statement I** Graphite behaves as a lubricant.
Statement II The layers of carbon atoms in graphite can slip past one over another.

84. **Statement I** Graphite is more reactive than diamond.
Statement II Graphite has a two dimensional sheet like structure, where the adjacent layers are held by weak van der Waals' forces.

85. **Statement I** Diamond, graphite and charcoal when burnt in oxygen change to carbon dioxide.
Statement II Chemical properties of the elements in solid state depends upon the arrangement of atoms.

86. **Statement I** Diamond is very hard and has high melting point.
Statement II In diamond, each carbon is covalently bonded to four other carbon atoms to form a three-dimensional network.

87. **Statement I** Carbon can form more compounds than any other element.
Statement II Carbon can exist in various allotropes.

88. **Statement I** CO is neutral but CO_2 is an anhydride of carbonic acid.
Statement II CO_2 dissolves in H_2O forming carbonic acid.

89. **Statement I** Carbon dioxide turns lime water milky.
Statement II Calcium carbonate is insoluble in water.

90. Match the list I with list II and select the correct answer using the codes given below the list.

List I	List II
A. CO_2	1. Fermentation
B. Zymase	2. Non-metal
C. Carbon	3. Fire extinguishing
D. $CaCO_3$	4. Chalk

Codes

	A	B	C	D		A	B	C	D
(a)	2	3	1	4	(b)	3	1	2	4
(c)	1	3	4	2	(d)	4	2	1	3

91. Match the list I with list II and select the correct answer using the codes given below the list.

List I	List II
A. Marble	1. Formation of urea
B. Hydrated CO_2	2. KOH
C. CO_2 absorbs	3. H_2CO_3
D. Use of CO_2	4. $CaCO_3$

Codes

	A	B	C	D		A	B	C	D
(a)	4	3	2	1	(b)	4	2	3	1
(c)	1	2	3	4	(d)	1	3	2	4

92. Oxygen was discovered by
(a) Priestley (b) Boyle
(c) Scheele (d) Canvendish

93. Gases respectively absorbed by the alkaline pyrogallol and oil of cinnamon are
(a) O_3, CH_4 (b) O_2, O_3
(c) SO_2, CH_4 (d) Na_2O, O_3

94. O_2 molecule is paramagnetic in
(a) solid state (b) liquid state
(c) gaseous state (d) All of these

95. Oxygen is obtained by heating
(a) ammonium dichromate
(b) sodium peroxide
(c) potassium permangnate
(d) green vitriol

96. The molecule having two unpaired electrons is
(a) CO (b) NO (c) CN (d) O_2

97. Which of the following is neutral oxide?
(a) H_2O_2 (b) Na_2O
(c) NO (d) PbO

98. Which one is known as oil of vitriol?
(a) $H_2S_2O_3$ (b) H_2SO_4
(c) H_2SO_5 (d) $H_2S_2O_8$

99. Ozone is the name given to
(a) ozonised oxygen (b) Na_2O_2
(c) KO_2 (d) pyrogallol

100. Oxygen and ozone are
(a) allotropes (b) isomers
(c) isotopes (d) isobars

101. B_2O_3 is
(a) acidic (b) basic
(c) neutral (d) amphoteric

102. Which one of the following is not a basic oxide?
(a) SiO_2 (b) MgO
(c) Na_2O (d) CaO

103. Which of the following statements are true regarding oxygen?
I. It reacts with non-metals to form oxides, which are basic in nature.
II. Ozone is an allotrope of oxygen.
III. It is soluble in acidic pyrogallol.
IV. It is slightly heavier than air.
Select the correct answer using codes given below
(a) I and III (b) II and IV
(c) III and IV (d) I and IV

104. Nitrogen can be obtained from air by removing
(a) oxygen (b) hydrogen
(c) carbon dioxide (d) Both (a) and (b)

105. The name azota is used for
(a) nitrogen
(b) oxygen
(c) hydrogen
(d) None of the above

106. Which of the following gives nitrogen on heating?
(a) $NaNO_2$ (b) $AgNO_2$
(c) $Ba(NO_2)_2$ (d) NH_4NO_2

107. Which one of the following element does not have allotropic forms?
(a) Oxygen (b) Nitrogen
(c) Sulphur (d) Phosphorus

108. When ammonia is passed over hot CuO it is oxidised to
(a) N_2 (b) NO_2
(c) N_2O (d) HNO_2

109. Nitrogen has no *d*-orbital in its valence shell and therefore it cannot
(a) exhibit the oxidation state of +5
(b) have covalency greater than 4
(c) exhibit orbital hybridisation
(d) form oxides with oxidation states greater than +3

110. Man dies when nitrous oxide is inhaled in large quantities because
(a) it is poisonous
(b) it combines with haemoglobin
(c) it causes laughing hysteria
(d) None of the above

111. The correct order for the increasing acidic strength of oxides of nitrogen is
(a) $N_2 < NO < N_2O_4 < N_2O_3 < N_2O_5$
(b) $NO < N_2O < N_2O_4 < N_2O_5$
(c) $N_2O < N_2O_3 < N_2O_4 < N_2O_5 < NO$
(d) $N_2O < NO < N_2O_3 < N_2O_4 < N_2O_5$

112. The yellow colour of nitric acid can be removed by
(a) boiling the acid
(b) bubbling air through the warm acid
(c) passing ammonia through acid
(d) adding a little Mg powder

113. Which of the following is obtained when N_2 reacts with calcium carbide?
(a) Calcium cyanate
(b) Calcium acetate
(c) Calcium cynamide
(d) Calcium carbonate

114. The one which does not form pentachloride is
(a) N (b) P (c) As (d) Sb

115. Oxidation of NO in air produces
(a) N_2O (b) N_2O_3 (c) NO_2 (d) N_2O_5

116. Ammonia can be dried by
(a) conc. H_2SO_4 (b) P_4O_{10}
(c) CaO (d) anhydrous $CaCl_2$

117. Which one of the following is not correct for N_2O?
(a) It is laughing gas
(b) It is nitrous oxide
(c) It is not a linear molecule
(d) It is least reactive of all the oxides of nitrogen

118. Nitrogen is used to fill electric bulbs because it
(a) is lighter than air
(b) makes the bulb give more light
(c) does not support combustion
(d) is non-toxic

Previous Years' Questions

119. Which one of the following elements will replace hydrogen from acids to form salts? **2012(I)**
(a) Sulphur (S) (b) Silicon (Si)
(c) Zinc (Zn) (d) Phosphorus (P)

120. **Statement I** At high temperature, hydrogen can reduce PbO to elemental lead.
Statement II Hydrogen has great affinity to oxygen. **2012(I)**
(a) Both the Statements I and II are correct and Statement II is the corrrect explanation of the Statement I.
(b) Both the Statements I and II are correct but Statement II is not the correct explanation of the Statement I.
(c) Statement I is true, but Statement II is false.
(d) Statement I is false, but Statement II is true.

121. **Statement I** Water is a high boiling point liquid.
Statement II Hydrogen bonding in water is responsible for high boiling point of water. **2012 (I)**
(a) Statements I and II are true and Statement II is the correct explanation for Statement I.
(b) Statements I and II are true and Statement I is not the correct explanation for Statement I.
(c) Statement I is true, but Statement II is false.
(d) Statement I is false, but Statement II is true.

122. Deionised water is produced by **2012 (II)**
(a) Calgon's process
(b) Ion-exchange resin process
(c) Clark's process
(d) Permutit process

123. **Statement I** Hard water does not give lather with soap.
Statement II Calcium and magnesium salts present in hard water form participate with soap. **2012 (II)**
(a) Statements I and II are true and Statement II is the correct explanation for Statement I.
(b) Statements I and II are true and Statement I is not the correct explanation for Statement I.
(c) Statement I is true, but Statement II is false.
(d) Statement I is false, but Statement II is true.

124. Which one among the following does not have an allotrope? **2012(II)**
(a) Oxygen (b) Sulphur
(c) Nitrogen (d) Carbon

125. Consider the following statements.
I. Diamond is hard and graphite is soft.
II. Diamond is soft and graphite is hard.
III. Diamond is a bad conductor, but graphite is a good conductor.
IV. Diamond is a good conductor, but graphite is a bad conductor. **2012(II)**
Which of the statement (s) given above is/are correct?
(a) I and III (b) Only I
(c) II and III (d) I and IV

126. The pure form of carbon is **2013(I)**
(a) diamond (b) graphite
(c) charcoal (d) fullerene

127. Biogas consists of mainly **2013 (I)**

(a) methane (b) ethane
(c) butane (d) carbon dioxide

128. Which of the following statements in connection with the properties of water is/are correct? **2013 (I)**

I. Water has higher specific heat in comparison with other liquids.
II. Water has no dipole moment.
III. Water has low heat of vaporisation.

Select the correct answer using the codes given below.

(a) Only I (b) II and III
(c) I and III (d) Only III

129. Water is a good solvent. This is due to high **2013 (I)**

(a) dielectric constant of water
(b) surface tension of water
(c) specific heat of water
(d) heat of fusion of water

130. Which one of the following statements regarding the property of hard water is/are correct? **2013 (I)**

I. Temporary hardness of water is due to the presence of soluble magnesium and calcium hydrogen carbonate.
II. Temporary hardness of water can be removed by boiling.
III. Calgon's method is applied to remove temporary hardness of water.
IV. Permanent hardness of water is removed by Clark's method.

Select the correct answer using the codes given below.

(a) I and II (b) I, II and III
(c) III and IV (d) Only II

131. **Statement I** Very little hydrogen is produced when sulphuric acid is added to calcium.
Statement II The salt calcium sulphate, produced is insoluble. **2013(II)**

(a) Both the Statements I and II are correct and Statement II is the corrrect explanation of the Statement I.
(b) Both the Statements I and II are correct but Statement II is not the correct explanation of the Statement I.
(c) Statement I is true, but Statement II is false.
(d) Statement I is false, but Statement II is true.

132. Oxygen on reactions with non-metals forms oxides which are **2013(II)**

(a) basic oxide (b) acidic oxide
(c) amphoteric oxide (d) neutral oxide

133. A gas is evolved when a piece of zinc metal is placed in dilute sulphuric acid (H_2SO_4). What is the gas? **2013(II)**

(a) Hydrogen (b) Oxygen
(c) Water vapour (d) Sulphur dioxide

134. Two reactants in a flask produce bubbles of gas and it turns lime water into milky. The reactants in the flask are **2013 (II)**

(a) zinc and hydrochloric acid
(b) magnesium carbonate and hydrochloric acid
(c) magnesium nitrate and hydrochloric acid
(d) magnesium sulphate and hydrochloric acid

135. The most stable form of carbon is **2014 (I)**

(a) diamond (b) graphite
(c) fullerene (d) coal

136. Which one of the following statements about hydrogen is/are correct? **2014(II)**

1. Hydrogen has three isotopes of which protium is the most common.
2. Hydrogen ion (H^+) exists freely in the solution.
3. Dihydrogen (H_2) acts as a reducing agent.

Select the correct answer using the codes given below.

(a) Only 1 (b) 1 and 3
(c) Only 3 (d) All of these

137. Which one of the following statements is correct? **2014 (II)**

(a) Fullerenes have only six-membered carbon rings
(b) Fullerenes are cage-like molecules
(c) Diamond is thermodynamically the most stable allotrope of carbon
(d) Graphite is slippery and hard and is therefore, used as a dry lubricant in machines

138. Dihydrogen can be prepared on a commercial scale by the action of steam on hydrocarbons, when a mixture of CO and H_2 gas is formed. It is known as **2014(II)**

(a) water gas (b) producer gas
(c) industrial gas (d) fuel gas

139. A sample of gas is to be identified by means of its behaviour in the presence of a glowing splint. Which of the following gases will neither itself burn nor cause the splint to burn? **2014(II)**

(a) Oxygen (b) Nitrogen
(c) Hydrogen (d) Methane

140. **Statement I** Colour of nitrogen dioxide changes to colourless at low temperature. **2015(I)**
Statement II At low temperature, nitrogen tetraoxide (N_2O_4) is formed, which is colourless.

(a) Both the Statements I and II are correct and Statement II is the corrrect explanation of the Statement I.
(b) Both the Statements I and II are correct but Statement II is not the correct explanation of the Statement I.
(c) Statement I is true, but Statement II is false.
(d) Statement I is false, but Statement II is true.

141. Why is the graphite used in electrolytic cells? **2015 (I)**

(a) Graphite is soft and can be easily moulded into electrodes
(b) Graphite is made up of layers of carbon atoms which can be slide
(c) Graphite is inert to most of the chemicals and remains intact in electrolytic cells
(d) Graphite is a good conductor of electricity

142. Permanent hardness of water is due to the presence of **2015 (I)**

(a) sulphates of sodium and potassium
(b) sulphates of magnesium and calcium
(c) carbonates of sodium and magnesium
(d) bicarbonates of magnesium and calcium

143. Which of the following statements regarding heavy water are correct? **2015 (II)**

I. It is extensively used as a moderator in nuclear reactors.
II. It cannot be used in exchange reaction to study reaction mechanism.
III. Viscosity of heavy water is relatively smaller than that of ordinary water.
IV. The dielectric constant of heavy water is smaller than that of ordinary water.

Select the correct answer using the codes given below:

(a) I and II
(b) II and III
(c) III and IV
(d) I and IV

144. **Statement I** Oxygen gas is easily produced at a faster rate by heating a mixture of potassium chlorate and manganese dioxide than heating potassium chlorate alone.
Statement II Manganese dioxide acts as a negative catalyst. **2015(II)**
(a) Both the Statements I and II are correct and Statement II is the corrrect explanation of the Statement I.
(b) Both the Statements I and II are correct but Statement II is not the correct explanation of the Statement I.
(c) Statement I is true, but Statement II is false.
(d) Statement I is false, but Statement II is true.

145. To weld metals together, high temperature is required. Such a high temperature is obtained by burning **2015(II)**
(a) acetylene in oxygen
(b) LPG in oxygen
(c) methane in oxygen
(d) acetylene in nitrogen

146. Graphite is a much better conductor of heat and electricity than diamond. This is due to the fact that each carbon atom in graphite **2015 (II)**
(a) undergoes sp^2-hybridisation and forms three sigma bonds with three neighbouring carbon atoms
(b) undergoes sp^3-hybridisation
(c) is tetrahedrally bonded
(d) is free from van der Waals' force

147. Consider the following reaction,
$$CH_4(g) + H_2O(g) \xrightarrow{1270\ K} CO(g) + 3H_2(g)$$
In the reaction given above, the mixtre of CO and H_2 is **2015 (II)**
(a) natural gas (b) water gas
(c) producer gas (d) industrial gas

148. Which one of the following elements will not react with dilute HCl to produce H_2 ? **2016(I)**
(a) Hg (b) Al (c) Mg (d) Fe

149. Which one of the following oxides of nitrogen is known as 'anhydride' of nitric acid? **2016(I)**
(a) N_2O (b) N_2O_3 (c) NO_2 (d) N_2O_5

150. **Statement I** Petroleum is a mixture of many different hydrocarbons of different densities.
Statement II The grade of petroleum depends mainly on the relative proportion of the different hydrocarbons. **2016 (I)**
Codes
(a) Both the statements are true and Statement II is the correct explanation of Statement I.
(b) Both the statements are true, but Statement II is not the correct explanation of Statement I.
(c) Statement I is true, but Statement II is false.
(d) Statement I is false, but Statement II is true.

151. Which of the following carbon compounds will not give a sooty flame? **2016 (I)**
(a) Benzene
(b) Hexane
(c) Naphthalene
(d) Anthracene

152. Which of the following is watergas? **2016 (I)**
(a) Mixture of carbon monoxide and hydrogen
(b) Mixture of carbon monoxide and nitrogen
(c) Mixture of carbondioxide and water vapour
(d) Mixture of carbon monoxide and water vapour

153. A glass vessel is filled with water up to the brim and a lid is fixed to it tightly. Then it is kept inside a freezer for hours. What is expected to happen? **2016 (I)**
(a) The water freezes to ice and the level of ice comes down
(b) The water in the glass vessel summer freezes to ice
(c) The glass vessel breaks due to expansion as water freezes to ice
(d) The water does not freeze at all

154. Density of water is **2016 (I)**
(a) maximum at 0°C
(b) minimum at 0°C
(c) maximum at 4°C
(d) minimum at – 4°C

ANSWERS

1	*d*	2	*b*	3	*a*	4	*d*	5	*d*	6	*c*	7	*c*	8	*c*	9	*b*	10	*c*
11	*b*	12	*a*	13	*a*	14	*c*	15	*a*	16	*b*	17	*b*	18	*a*	19	*d*	20	*a*
21	*d*	22	*a*	23	*a*	24	*b*	25	*a*	26	*a*	27	*a*	28	*a*	29	*b*	30	*d*
31	*b*	32	*b*	33	*d*	34	*b*	35	*a*	36	*c*	37	*d*	38	*a*	39	*d*	40	*b*
41	*c*	42	*c*	43	*a*	44	*a*	45	*c*	46	*d*	47	*b*	48	*c*	49	*d*	50	*a*
51	*b*	52	*b*	53	*c*	54	*a*	55	*d*	56	*c*	57	*a*	58	*c*	59	*c*	60	*a*
61	*c*	62	*c*	63	*b*	64	*c*	65	*a*	66	*a*	67	*b*	68	*b*	69	*b*	70	*b*
71	*a*	72	*c*	73	*d*	74	*a*	75	*d*	76	*b*	77	*a*	78	*b*	79	*d*	80	*b*
81	*d*	82	*b*	83	*a*	84	*b*	85	*c*	86	*a*	87	*b*	88	*b*	89	*a*	90	*b*
91	*a*	92	*a*	93	*b*	94	*d*	95	*b*	96	*d*	97	*c*	98	*b*	99	*a*	100	*a*
101	*a*	102	*a*	103	*b*	104	*a*	105	*a*	106	*d*	107	*b*	108	*a*	109	*b*	110	*c*
111	*d*	112	*b*	113	*c*	114	*a*	115	*c*	116	*c*	117	*c*	118	*c*	119	*c*	120	*c*
121	*a*	122	*b*	123	*a*	124	*c*	125	*a*	126	*d*	127	*a*	128	*a*	129	*a*	130	*a*
131	*a*	132	*b*	133	*a*	134	*b*	135	*b*	136	*b*	137	*b*	138	*a*	139	*b*	140	*a*
141	*d*	142	*b*	143	*d*	144	*c*	145	*a*	146	*a*	147	*b*	148	*a*	149	*d*	150	*b*
151	*b*	152	*d*	153	*c*	154	*c*												

11

SOME IMPORTANT CHEMICAL COMPOUNDS

In general 3-7 questions are asked from this chapter. Questions are mainly based upon raw materials and composition of soaps, glass, cement, gun powder and nitrogeneous fertilizers. A good number of statement based questions have been asked from this chapter.

There is hardly any work of life where we do not need the chemical compounds. Chemical compounds such as soaps, detergents, paints, drugs, fertilizers etc. play an important role in our daily life.

CLEANSING AGENTS

In fact, those chemicals which concentrate at the surface of the solution or interfaces, reduce surface tension of the solution and help in removing dirt and dust by emulsifying grease are known as surfactants. Soaps and detergents belong to this class.

Soaps

Soaps are sodium or potassium salt of higher fatty acids like, stearic acid, oleic acid, palmitic acid etc. Soaps are obtained by the alkaline hydrolysis of oils and fats. Only glycerides of fatty acid give soaps on alkaline hydrolysis.

Raw Materials

The important raw material used for the manufacture of soaps are

(i) **Oil or Fat** Mustard oil, mohwa oil, coconut oil, cotton seed oil, olive oil or animal fat.

(ii) **Fillers** The substance added to increase the weight and volume of soaps, e.g. sodium silicates, powdered pumice, starch, sodium carbonate.

(iii) **Alkali** Caustic soda for hard or washing soaps and caustic potash for soft soap is used for saponification.

(iv) **Colouring Material**

ZnO	:	White colour
Methylene blue	:	Blue colour
Uranium	:	Yellow
Eosine	:	Red

(v) **Perfumes** Perfumes are used to make soap pleasant smelling, e.g. lemon grass oil.

Types of Soaps

There are following types of soaps

(i) **Washing Soaps** These are made from cheaper fats like mohwa oil, resin oil etc.

(ii) **Toilet Soaps** These are made from best quality animal or vegetable fats or mixture of both. These soaps do not injure the skin.

(iii) **Medicated Soaps** Toilet soaps containing some substance of medicinal value, e.g. carbolic soap, neem soap etc.

(iv) **Metallic Soaps** These soaps contains salt of metals other than sodium and potassium.

(v) **Transparent Soaps** These are prepared by dissolving toilet soaps in alcohol and evaporating the filtrate. These contain glycerol.

(vi) **Shaving Soaps** These toilet soaps contain gum and glycerol. Their mildness increases by adding potassium carbonate. Resin is also added to shaving soaps as it forms lather well.

(vii) **Liquid Soaps** These soaps are obtained by the action of coconut oil and caustic potash and contain about 8% of water.

(viii) **Floating Soaps** These soaps are obtained by beating large amount of air into soap while it is in creamy stage.

Detergents

Detergents are generally ammonium or sulphonate salts of long chain carboxylic acids. Although these do not contain soaps like sodium salts of fatty acids. Hence, these are known as 'soapless soap'.

- These can be used even in acidic solutions and have a strongest cleansing action.
- These are more soluble in water and can be used with hard water as these produces no precipitates with Ca^{2+}, Mg^{2+}, Fe^{3+} ions present in hard water. They are used in powder form for domestic purpose.
- The liquid form may be used for dish washing, cleaning of floors etc.
- Biological degradation is an important property of good detergent.

Cleansing Action of Soap or Detergent

- The principle of cleaning by soap is surface tension.
- A soap (or detergent) molecule is made up of two parts : A long hydrocarbon part and a short ionic part containing —COO^- Na^+ group.
- The long hydrocarbon chain is **hydrophobic** (water—repelling) so it is insoluble in water but soluble in oil and grease and the ionic part is hydrophilic (water—attracting). Thus, soluble in water.
- When soap is applied to dirty clothes soaked in water, the hydrocarbon part of the soap molecules attach themselves to the greasy and oily dirt particles whereas the ionic part of the soap molecule remain attached to water.
- When the dirty cloth is agitated in soap solution, dirt particles attached to the soap molecules get washed away in water and the cloth gets cleaned.

➨ **Note** The cluster of molecules in which the hydrophobic tails are in the interior of the cluster and the ionic ends are on the surface of the cluster is called a micelle.

GLASS

Glass is an amorphous hard, brittle, super cooled liquid. It is not a true solid.

Chemically glass is a mixture of number of silicates and has no definite formula. But the general composition can be represented as $xM_2O \cdot yM'O \cdot 6SiO_2$ where M is monovalent alkali metal like Na, K, etc., M' is a bivalent metal like Zn, Pb etc., and x, y are whole numbers. Silica is the major constituent of all glasses.

- Glass is a mixture and not a compound.
- Glass is chemically inert towards a lot of chemicals.
- Glass is known as super cooled liquid with no sharp melting and boiling point.
- Glass stoppers should not be used in containers of NaOH or KOH.
- Glass is soluble in HF due to formation of H_2SiF_6. Therefore, HF solution is used for etching of glass.

Raw Material

The important raw material used for the manufacture of glass are

(i) Silica (SiO_2) and cullet (glass pieces)

(ii) Compounds of alkali metals e.g. Na_2CO_3, $NaNO_3$, K_2CO_3,KNO_3, Na_2SO_4 and K_2SO_4.

(iii) Compounds of alkaline earth metals (e.g. $CaCO_3$, $BaCO_3$, CaO).

(iv) Oxides of heavy metals e.g. PbO, Pb_3O_4

Coloured Glass

These are obtained by mixing colour supplying substances in the molten or fused state of glass. Such substances are tabulated below

Colour producing substance and their colour

Substance Used	*Colour of Glass*
Cuprous oxide	Red
Cupric oxide	Peacock blue
Potassium dichromate	Green or greenish yellow
Ferrous oxide	Green
Ferric oxide	Brown
Manganese dioxide	Light pink, in excess black
Cobalt oxide	Blue
Gold chloride	Ruby red
Cadmium sulphide	Yellow
Carbon	Amber colour (brownish black)

Annealing of Glass

Glass is prepared at a very high temperature if it is cooled suddenly, glass being a bad conductor of heat, its upper layer cools down while interior portion remains in a state of strain, due to this unequal expansion glass cracks into pieces. To avoid this, glass is cooled slowly. This slow cooling is called as **annealing of glass.**

Types of Glasses, their Properties and uses

Types of Glasses	*Properties*	*Uses*
Soda glass or soft glass	Contains sodium carbonate, calcium carbonate and silica, brittle and cheapest.	Window glass, bottles, dishes, tubelights, domestic utensils etc
Potash glass or hard glass	Contains carbonate of K, Ca and silica, high temperature resistant.	Hard boiling glass test tubes, beakers, etc
Photochromatic glass	Turns dark in sun light because of the presence of embedded microcrystalline silver compound (silver chloride) in glass	Eye lenses and goggles
Pyrex glass (borosilicate glass)	Contains borax and silica, withstand sudden alterations in temperature	Laboratory equipments
Flint glass	Contains sodium, potassium and lead silicate, have high refractive index	Optical instruments like lens of camera, prisms, microscopes, telescope and in electric bulbs
Crown glass	Contains oxides of potassium, barium and silicon, have high refractive index.	Optical instruments
Jena glass (best form of glass)	Soft, strong and more resistant to acids and alkalies, contains zinc and barium borosilicate.	Bottles for keeping acids and alkalies in laboratory
Crook's glass	Contains cerium oxide (CeO_2) and silica, thus, absorbs UV rays.	Eye lenses used in different eye defects
Lead crystal glass	Contains potassium carbonate, lead oxide and silica, shows optical phenomenon of total internal reflection.	Various ornamental items, costly glass containers
Quartz glass or silica glass	Ultraviolet rays emerge out through it.	In making bulb of ultraviolet lamp, laboratory equipments

Ink

The knowledge of ink was known before 4000 years in Egypt. First time ink was prepared from coal and resin. On the basis of preparation, ink is of two types

(i) Aniline ink and (ii) Iron gel ink

Raw Material for Aniline Ink

The important raw material used for the manufacture of aniline ink

- Eosin, glycerine, carbonic acid, phenol.
- Carbonic acid (H_2CO_3) and boric acid (H_3BO_3) to prevent the production of fungi in ink, thus used as fungicide
- Glycerine is used in manufacturing the stamp pad ink.
- Resin or glue or gum for shine.

Colours of Ink due to Different Substances

Colour of ink	*Colouring substance*
Black-blue ink	Naphthalene black
Blue colour	Methylene blue
Red colour	Eosine and congo red
Green colour	Malachite green
Black colour	Aniline black

Raw Material for Iron Gel Ink

The important raw material used for the manufacture of iron gel ink

- Resin or glue or gum arabic, glycerine.
- Alcohol or spirit or phenol.
- Tannic acid and galic acid used in blue-black ink.
- Ferrous sulphate ($FeSO_4$) and dilute hydrochloric acid (HCl) are main constituents of this ink.

Paper

- Cellulose is used as raw material for the manufacture of paper. Paper is prepared by boiling small pieces of old rags, grass and pieces of wood with caustic soda. After cooling the mixture is bleached to a perfect white paste.
- Alum, white clay and resin are added to white paste to form thin sheets. Sheets prepared and dried by steam and cut in proper sizes.

Cement

- It is dirty greyish heavy powder containing limestone and clay. When mixed with water it set to a hard stone like mass similar to Portland rock a famous building stone of England. So, it is also known as Portland cement.
- It was first named by **Joseph Aspdin** as Portland cement and was discovered in England.

Approximate Composition of Portland Cement

- Calcium oxide (CaO) – 62%
- Silica (SiO_2) – 22%
- Alumina (Al_2O_3) – 7.5%
- Magnesia (MgO) – 2.5%
- Ferric oxide (Fe_2O_3) – 2.5%

Raw Material

The important raw material used for the manufacture of cement

- Limestone and clay. Limestone provides CaO while clay provides SiO_2, Al_2O_3 and Fe_2O_3.
- In cement almost entire amount of lime is present in the combined state as calcium silicate ($2CaO \cdot SiO_2$) and ($3CaO \cdot SiO_2$) and calcium aluminates ($CaO \cdot Al_2O_3 4CaO \cdot Al_2O_3$).

- When clay and lime are strongly heated together they fuse and react to form 'cement clinker'. 2-3% of gypsum ($CaSO_4 \cdot 2H_2O$) is added to slow down the setting of cement so that it becomes sufficiently hard.
- Excess of silica (SiO_2) decrease the setting time of cement and alumina (Al_2O_3) increase the setting time of cement.
- When cement is mixed with water it becomes hard due to the formation of a solid jelly. This process is called setting of cement.
- Setting of cement involves hydrolysis reaction in which heat is generated (exothermic process) therefore, cement structures have to be cooled during setting by sprinkling water. Cement containing tetracalcium aluminoferrite sets at the slowest rate.
- White cement does not contain colouring matter such as oxides of iron, chromium, magnesium and manganese.
- The function of sand in mortar is to prevent excessive shrinkage which might result in cracks.
- **Mortar** is a mixture of cement and sand in the ratio 1 : 3 in water.
- **Concrete** is a mixture of cement, sand and pieces of stones in the ratio of 1 : 2 : 4 in water.
- **Reinforced Cement Concrete** (RCC) Cement, sand and pieces of stone with iron frame-work used in making pillars, roofs, lenters etc.

Paints

Paint is a mixture of pigments suspended in a solvent. Paints are widely used in surface coatings.

- Plasticisers are added during the manufacturing of paint in order to provide elasticity to the film and minimise its cracking.
- Aluminium paints are heat resistant but cannot be used for water pipe. Lithopene [$BaSO_4 + ZnS$] is a substitute of white lead.
- Chromium oxide is used as an ingredient in paints to obtain green colour.
- Cadmium lithopones (cadmopones) (Cds + $BaSO_4$) is used as yellow pigment.
- Titanium dioxide (Titanox) is extensively used in the manufacture of paints and pigments.

Constituents of Paints

Main constituents of paints are as follows

(i) **Pigments** These substances give colour to another substance. These have a definite colour.

(ii) **Solvents** Normally some oil like terpentine oil is used as a solvent.

(iii) **Driers** The compounds which are used to dry the paints. These are cobalt, lead manganese, rosinates compounds. e.g. MnO, CoO, etc.

(iv) **Thinners** The substances which are used to reduce the viscosity of paints. These increase the volume of paint. e.g. alcohol, kerosene oil etc.

(v) **Fillers** or **extenders** The substances are used to increase the concentration of pigment or paint. These are low gravity material e.g. $BaSO_4 \cdot (CuSO_4) \cdot 2H_2O$ etc.

Commonly Used Pigments

Pigment	*Colour*	*Formula*
White lead	White	$2[Pb(OH)_2 \cdot 2PbCO_3]$
Chrome yellow	Yellow	$PbCrO_4$
Chrome red	Red	$PbCrO_4 \cdot PbO$
Basic lead sulphate	White	$2PbSO_4 \cdot PbO$
Red lead or sindhur	Red	Pb_3O_4
Lithopone	White	$BaSO_4 + ZnS$
Malachite	Green	$Cu(OH)_2 \cdot CuCO_3$
Azurite	Green	$Cu(OH)_2 \cdot 2CuCO_3$
Thenard	Blue	$CoO \cdot Al_2O_3$
Smelt	Blue	$K_2O \cdot CoO \cdot 3SiO_2$

Safety Matches

Modern safety match was developed only about two hundred years ago. A mixture of antimony trisulphide, potassium chlorate and white phosphorus with some glue and starch was applied on the head of a match made of suitable wood. These days the head of the safety match contains only antimony trisulphide (Sb_2S_3) and potassium chlorate ($KClO_3$). The rubbing surface has powdered glass and a little red phosphorus (which is less dangerous).

When the match is struck against the rubbing surface, some red phosphorus get converted into white phosphorus. This immediately reacts with potassium chlorate in the matchstick head to produce enough heat to ignite antimony trisulphide and start the combustion.

Gun Powder

It consists of a fuel (charcoal or sugar) and oxidiser (salt peter, nitre or potassium nitrate) and sulphur (allows for a stable reaction and **lower ignition temperature**).

- The granules of modern gun powder (black powder) are coated with graphite because graphite reduces the moisture absorbing capacity of the powder. Graphite also prevents the build-up of electrostatic charge to prevent accidental ignition.
- It is first chemical explosive and during explosion N_2 and CO_2 are evolved in the ratio of 1 : 3.

Note

- Water is the most common fire extinguisher but it is not suitable for fires involving oil, petrol and electrical equipment. In these cases CO_2 is the best extinguisher.
- **Dry powder** of chemical like sodium bicarbonate or potassium bicarbonate are used as a fire extinguisher. Sodium bicarbonate and sulphuric acid are used in soda acid fire extinguisher and aluminium sulphate in foam fire extinguisher.

Plastics

When unsaturated hydrocarbons e.g., ethylene, propylene, butylene etc. undergo polymerisation under specific conditions then higher polymer plastic is obtained.

These are of two types:

(i) **Thermoplastics** are linear in structure can be soften on heating and becomes harden on cooling. This character is maintained through out its existence. e.g. polythene, polystyrene, polyvinylchloride, teflon.

(ii) **Thermosetting plastics** undergo permanent change on heating due to excessive cross linking and cannot be remoulded and reused, e.g. bakelite, melmac.

Polymers along with their Monomers

Polymer	*Monomer*
Polyethylene	Ethene
Polystyrene	Styrene
Polyvinylchloride (PVC)	Vinylchloride
Polytetrafluoroethylene [PTFE/Teflon]	Tetrafluoroethene
Bakelite	Formaldehyde + Phenol
Urea-formaldehyde resin	Urea + Formaldehyde
Melmac	Melamine + Formaldehyde

Fibres

The solid substance which has thin long chain structure is called fibre. Cotton, jute, silk, wool are natural fibres whereas rayon, nylon, polyster are synthetic fibres. Fibres possess strong intermolecular forces like hydrogen bonding, e.g. nylon –66 dacron, orlon.

➨ Rayon (acetate rayon and viscose rayon) is called artificial silk.

Synthetic Fibres with their Monomers

Fibres	*Monomers*	*Uses*
Nylon-66	Adipic acid + hexamethylene diamine	In making bristles for brushes, parachutes, as a substitute for metal, in bearings.
Nylon-6 or perlon	Caprolactum	In making fibres, plastics tyre cords and ropes
Terylene or Dacron	Ethylene glycol and terephthalic acid	For making wash and wear fabrics, tyre cords, safety belts, tents etc.
Polyurethanes	Toluene diisocyanate + ethylene glycol	For making washable and long lasting mattresses, cushions

- Orlon is obtained by polymerisation of vinyl cyanide.
- Carbon fibres are made from long chains of carbon atoms in which corrosion does not take place. These are used in making parts of space vehicles and sports items.

Natural Rubber

- Natural rubber is a linear polymer of isoprene and it is also called *cis*-1, 4 poly isoprene. It is an elastomer which is insoluble in water, dilute acids and alkalies.
- Natural rubber absorbs a large amount of water and possess low tensile strength.
- The process of heating a natural rubber with 5% sulphur in the presence of ZnO at 373K in order to improve their properties is called vulcanisation of rubber. Carbon black is added to vulcanised rubber for hardening of tyres.

IMPORTANT POINTS

- Hydrofluoric acid (HF) is used in etching of glass.
- Silicon based chemicals are used in beauty parlours.
- Enzyme lipase easily removes the oily stains (fatty stains from cloth).
- Silver bromide is used in photography.
- Hydrogen peroxide is used as a bleaching agent.

FERTILIZERS

The chemical substances which are added to the soil to increase its fertility by providing essentials nutrients to the soil which are lost due to continuous cropping are called chemical fertilisers.

These are added to the soil during sowing season to avoid starvation of the plants to ensure healthy crops. About 16 elements are needed for the healthy growth of a plant. Among these, **nitrogen, phosphorus** and **potassium** are the major elements needed in large amounts.

Types of Fertilizers

There are two types of fertilizers

1. Chemical Fertilizers/Synthetic Fertilizer

These are man-made and nutrient specific fertilizers that are added to the soil according to their need. These fertilizers are also called artificial fertilizers.

Chemical fertilizers mainly of three types:

(i) Nitrogeneous Fertilizers

These fertilizers react with the moisture in the soil and produces ammonia which is converted into nitrates by soil bacteria.

These fertilizers mainly supply nitrogen. Plants require nitrogen for growth and protein content.

Some of them are as follows

(a) **Urea** (NH_2CONH_2)

- Urea is the best nitrogeneous fertilizer having 47% nitrogen by weight.

➨ **Note** Percentage of an element in a compound

$$= \frac{\text{Total mass of an element} \times 100}{\text{Molar mass of compound}}$$

$$\text{N\% by weight} = \frac{\text{Total mass of N}}{\text{Total mass of urea}} \times 100$$

$$\text{N\%} = \frac{2 \times 14}{60} \times 100 = 46.67\% \approx 47\%$$

- Urea is a white crystalline solid (melting point 133°C). It is soluble in water but insoluble in ether.
- Urea is not as stable as other nitrogeneous fertilisers and decomposes even at lower temperature in humid atmosphere.
- On hydrolysis, urea gives CO_2 and NH_3.

(b) **Ammonium Sulphate** $[NH_4]_2 \cdot SO_4$

- It is prepared by absorbing ammonia in sulphuric acid.

$$2NH_3 + H_2SO_4 \longrightarrow \underset{\text{Sindri fertilizer}}{(NH_4)_2SO_4}$$

- It is a white crystalline solid, soluble in water. It contains 21% nitrogen.
- Hydrolysis of ammonium sulphate produces H_2SO_4.

$$(NH_4)_2SO_4 + 2H_2O \longrightarrow 2NH_3 + H_2SO_4 + 2H_2O$$

Therefore, its repeated use makes the soil acidic and unfit for germination of seeds. To neutralise it, lime is added to acidic soil. Hence, ammonium sulphate should not be used very frequently.

(c) **Calcium Cyanamide or Nitrolim** ($CaCN_2$)

- It is prepared by passing a stream of nitrogen gas over hot CaC_2 at 1100°C, when nitrolim is obtained

$$CaC_2 + N_2 \xrightarrow{1100°C} \underset{\text{Calcium cyanamide}}{CaCN_2} + C$$

- Calcium cyanamide is a slow acting manure having 19% nitrogen by weight.
- It is black in colour. It contains 19% nitrogen. It is slowly hydrolysed by the soil moisture to ammonia and calcium carbonate.

$$CaCN_2 + 3H_2O \longrightarrow CaCO_3 + 2NH_3$$

(d) **Calcium Ammonium Nitrate** $[Ca(NO_3)_2 \cdot NH_4NO_3]$

- It is prepared by treating limestone with excess of nitric acid. The resulting solution is neutralised by passing ammonia gas. From the solution CAN is crystallised out.
- It contains nitrogen in readily palatable forms for plants.

(ii) Phosphatic Fertilizers

- These fertilizers mainly supply phosphorus. Phosphorus is needed for stimulating growth and enables the plants to resist the attack of diseases and also helps in the ripening of fruits.
- These fertilizers supply phosphorus whose content is expressed as P_2O_5.

Some of them are as follows

(a) **Calcium Superphosphate or Superphosphate of Lime** $[Ca(H_2PO_4)_2 + 2CaSO_4 \cdot 2H_2O]$

- The water soluble component of superphosphate of lime is calcium dihydrogenphosphate $[Ca(H_2PO_4)_2]$.
- It contains 15–16% of P_2O_5.

(b) **Triple Superphosphate** $[Ca(H_2PO_4)_2]$

- It is soluble in water.
- It is prepared by the action of 54% phosphoric acid on calcium phosphate.
- Triple superphosphate usually contain 43–46% of P_2O_5.

(c) **Thomas Slag** $Ca_3(PO_4)_2 \cdot (Ca\ SiO_3)$ (Phosphatic Slag)

- It is soluble in water in the presence of salt and carbon dioxide.
- Phosphatic slag gives a steady supply of phosphatic acid for the plant growth. It has 14–18% of P_2O_5.

(iii) Potash Fertilizers

- It gives structural growth to the plant. These are mainly required for the development of healthy roots and also aids ripening of cereals and fruits.
- These fertilisers are available in nature as soluble salts like KCl, K_2CO_3, KNO_3 and K_2SO_4. These supply mainly potassium to the plants, e.g. muriate of potash (KCl), potassium nitrate; (KNO_3), potassium sulphate, (K_2SO_4).
- Potassium sulphate has been found to be more stable for tobacco plants. It is because the ash of tobacco grown by it has a high melting point. Tobacco needed for making cigarettes should have high melting point.
- Potash fertilizer evaluated as K_2O.

Mixed Fertilizers or NPK Fertilizers

- These contain more than one fertilizing ingredient.
- NPK also called as Kisan Khad or Kisan Urea. It contains nitrogen, phosphorus and potassium.
- It is better to use these fertilizers as these supplies all the essential nutrients to the plants.
  e.g. nitrophosphate, ammonium phosphate.

Harmful Effects of Chemical Fertilizers

- These are expensive, and their production releases pollutants and cause pollution of soil, air and water.
- These are lost readily when applied in field.

2. Natural Fertilizers

Natural fertilizers are of biological origin. These can be classified as

Manure

- It contains large quantities of organic substances formed by the decomposition of animal excreta and plant waste.
- It supplies small quantities of nutrients to the soil.
- The bulk of organic matter in manure helps in improving soil structure.
- Manure includes farmyard manure, compost and green manure.

Green Manure

- Some plants like guar or sunhemp are grown and mulched by ploughing them into the soil. These plants turn into green manure.
- Green manure helps in enriching the soil in nitrogen and phosphorus.

Biofertilizers

- **Biofertilizers** are organism which can bring soil nutrient enrichment. The main sources of biofertilizers are bacteria, cyanobacteria and fungi.
- **Rhizobium and blue green algae** are two important biofertilizers.
- **Mycorrhiza** is a symbiotic association of certain fungi with roots of higher plants. It increase water and nutrient intake by plants and increases growth and yield of plants.
- Biofertilizer and green manures do not pollute the soil.
- Field with leguminous plants is rich with nitrogen element.
- Legumes revive soil fertility.

Important Reagents

- Fehling solution : $CuSO_4$ + Sodium potassium tartrate (Rochelle salt) + NaOH.
- Tollen's reagent : $AgNO_3$ solution + NaOH + NH_4OH
- Sodalime : $Ca(OH)_2$ + NaOH
- Lithopone : $BaSO_4$ + ZnS
- Nessler's reagent : $K_2[HgI_4]$
- Milk of magnesia : Suspension of $Mg(OH)_2$ in water.

Important Processes

- Nelson cell : NaOH
- Mac Arthur Forest process : Ag (cyanide process)
- Mond process : Ni
- Berkeland Eyde process : NO, HNO_3
- Lead chamber process : H_2SO_4

Some Important Compounds and Minerals

- Magnesite : $MgCO_3$
- Kieserite : $MgSO_4 \cdot H_2O$
- Epsomite : $MgSO_4 \cdot 7H_2O$
- Sorel's cement : $MgCl_2 \cdot 5MgO \cdot xH_2O$
- Limestone, marble, chalk : $CaCO_3$
- Gypsum : $CaSO_4 \cdot 2H_2O$
- Plaster of Paris : $CaSO_4 \cdot \frac{1}{2}H_2O$
- Quick lime : CaO
- Slaked lime : $Ca(OH)_2$
- Carnallite : KCl $MgCl_2 \cdot 6H_2O$
- Permutit (Zeolite) : $Na_2Al_2SiO_4 \cdot xH_2O$
- Soda ash : anhy. Na_2CO_3
- Washing soda : $Na_2CO_3 \cdot 10H_2O$
- Crystal carbonate : $Na_2CO_3 \cdot H_2O$
- Marshall's acid : $H_2S_2O_8$
- Borazine (Inorganic benzene) : $B_3N_3H_6$
- Blue vitriol : $CuSO_4 \cdot 5H_2O$
- Horn silver : AgCl
- Philosophere wool : ZnO
- Corundum : Al_2O_3
- Bauxite : $Al_2O_3 \cdot 2H_2O$
- Carborundum : SiC
- Calomel excess : Hg_2Cl_2
- Freon : CF_2Cl_2
- Oil of vitriol : conc. H_2SO_4
- Refrigerant : NH_3, CF_2Cl_2, CO_2 etc.

PRACTICE EXERCISE

1. To which class of organic compounds soap belongs?
(a) Aldehydes
(b) Salts of organic acid
(c) Esters
(d) Amines

2. Which of the following is not a fatty acids?
(a) Stearic acid (b) Palmitic acid
(c) Oleic acid (d) Phenyl acetic acid

3. Toilet soap is a mixture of
(a) calcium salt of fatty acids
(b) potassium salt of fatty acids
(c) fatty acids and alcohol
(d) phenol and olive oil

4. Washing soap can be prepared by saponification with alkali of which of the following oil?
(a) Olive oil (b) Paraffin oil
(c) Groundnut oil (d) Kerosene oil

5. The substance added to harden the soap is
(a) sodium silicate
(b) sodium carbonate
(c) soap stone
(d) All of these

6. Saponification of an oil or fat gives soap and
(a) methanol (b) ethanol
(c) pentanol (d) glycerol

7. Which gives white colour to soap?
(a) MnO (b) ZnO
(c) CaO (d) PbO

8. Which one of the following is used to increase the weight of soap?
(a) Starch
(b) Sodium carbonate
(c) Both (a) and (b)
(d) None of these

9. Which of the following enzymes hydrolysis triglycerides to fatty acids and glycerol?
(a) Amylase (b) Maltase
(c) Lipase (d) Pepsin

45. Fillers are used to
(a) increase the volume of paints
(b) increase the concentration of paints
(c) increase both volume and weight of paints
(d) None of the above

46. Match stick have some solid mixture at one end which is
(a) antimony sulphide + potassium chlorate + potassium dichromate
(b) antimony sulphide + lead + sodium chlorate
(c) antimony sulphide + potassium chlorate + potassium bicarbonate
(d) potassium chlorate + lead + lead trisulphide

47. Which one of the following is used on the side of matches box?
(a) P_2S_3 (b) P_2S_5
(c) powdered glass + red P
(d) All of the above

48. Gun powder is a mixture of
(a) KNO_3 + S + charcoal
(b) $KHCO_3$ + S + charcoal
(c) KNO_3 + S + coal
(d) All of the above

49. During explosion of gunpowder, which of the following gases are evolved in the proportion of 1 : 3 ?
(a) Oxygen : nitrogen
(b) Nitrogen : carbon monoxide
(c) Nitrogen : carbon dioxide
(d) Carbon dioxide : nitrogen

50. Artificial silk is
(a) rayon (b) nylon-6
(c) nylon-66 (d) None of these

51. Natural rubber is
(a) polyisoprene
(b) polyvinyl chloride
(c) polychloroprene
(d) polyfluoroethylene

52. Which of the following is a polyamide?
(a) Nylon (b) Orlon
(c) Teflon (d) Terylene

53. Which is an example of thermosetting polymer?
(a) Polythene (b) Neoprene
(c) PVC (d) Bakelite

54. The substance used to harden the rubber for tyre manufacture is
(a) wax (b) 1, 3-butadiene
(c) CaC_2 (d) carbon black

55. Monomer of teflon is
(a) difluoroethane (b) monofluoroethane
(c) tetrafluoroethene
(d) tetrafluoroethane

56. Terylene is made by polymerisation of terephthalic acid with
(a) ethylene glycol (b) phenol
(c) ethanol (d) catechol

57. Process involving heating of rubber with sulphur is called
(a) galvanisation (b) vulcanisation
(c) bessemerisation (d) sulphonation

58. Which of the following is used to make non-stick cookware?
(a) PVC
(b) Polystyrene
(c) Polyethylene
(d) Polytetrafluoroethylene

59. Bakelite is a polymer of
(a) formaldehyde and acetic acid
(b) formaldehyde and phenol
(c) ethylalcohol and phenol
(d) acetic acid and benzene

60. Bronze is often used to make statues and medals whereas brass is used in making utensils, scientific apparatus and cartridges. Both brass and bronze are copper containing alloys, yet they differ in their chemical composition for additionally containing
(a) Zinc in brass and tin in bronze
(b) Chromium in brass and nickel in bronze
(c) Nickel in brass and tin in bronze
(d) Iron in brass and nickel in bronze

61. Which one of the following chemicals is used in beauty parlours for hair-setting?
(a) Sulphur based
(b) Phosphorus based
(c) Silicon based
(d) Iron based

62. Which of the following is not correctly matched?
(a) Galena - Lead sulphide
(b) Blue vitriol - Copper sulphate
(c) Plaster of Paris - Calcium sulphate hemihydrate
(d) Calomel - Mercurous chloride

63. The common elements present in artificial fertilizers are
(a) nitrogen, phosphorus and potassium
(b) nitrogen, phosphorus and sodium
(c) calcium, potassium and sodium
(d) all elements of periodic table

64. Which one of the following cannot be used as a nitrogeneous fertilizer?
(a) $CaCN_2$ (b) NH_4NO_3
(c) HNO_3 (d) NH_2CONH_2

65. Which of the following substances is used as a fertilizer?
(a) $K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$
(b) $CaCN_2$
(c) $Ca(H_2PO_4)_2 \cdot H_2O + 2(CaSO_4 \cdot 2H_2O)$
(d) Both (b) and (c)

66. The metal atom, which is present in superphosphate, is
(a) sodium (Na) (b) potassium (K)
(c) calcium (Ca) (d) magnesium (Mg)

67. Which one of the following is not a nitrogeneous fertilizer?
(a) $Ca(CN)_2$ (b) $CaCN_2$
(c) NH_4NO_3 (d) Urea

68. What is the composition of nitrolim—a chemical fertilizer?
(a) Nitrogen and limestone
(b) Calcium carbide and nitrogen
(c) Calcium carbide and carbon
(d) None of the above

69. NPK is also called as
(a) vigyan urea (b) potash fertilizer
(c) mixed fertilizer
(d) nitrogeneous fertilizer

70. Which one has the highest percentage of nitrogen?
(a) Urea (b) CAN
(c) NH_4NO_3 (d) $CaNO_3$

71. Lime is sometimes applied to soil in order to
(a) control the acidity of soil
(b) increase the alkalinity of soil
(c) make the soil more porous
(d) restore nitrates of the soil

72. The nitrogen in urea is present in the form of
(a) ammonium (b) nitrate
(c) nitrite (d) amide

73. Which of the following refers to "green manure"?
(a) Putting NPK manure
(b) Putting farmyard manure
(c) Growing leguminous crops and ploughing it
(d) Applying slurry manure obtained from gobar gas plants

74. Potash fertilizers are evaluated as
(a) KO_2 (b) K_2O (c) K (d) K_2O_2

75. Which one of the following contains maximum percentage of nitrogen by mass?
(a) Urea (b) Ammonium cyanide
(c) Ammonium carbonate
(d) Ammonium nitrate

76. Which of the following is a balanced fertilizer for plants?
(a) Urea (b) Compost
(c) Nitrates
(d) Ammonium sulphate

77. Application of nitrogeneous manure to a plant causes
(a) vigorous vegetative growth
(b) early flowering
(c) early fruiting
(d) growth retardation due to toxity of NH_3

78. Nodules with nitrogen fixing bacteria are present in
(a) Mustard (b) Rice
(c) Gram (d) Cotton

79. Superphosphate of lime is obtained from the reaction of
(a) calcium carbonate with phosphoric acid
(b) calcium phosphate with hydrochloric acid
(c) calcium phosphate with ortho phosphoric acid
(d) bones with gypsum

80. Which of the following nitrogeneous fertilizer is not very effective in acidic soil?
(a) Ammonium sulphate
(b) Urea
(c) Nitrolium
(d) Calcium cyanamide

81. The correct sequence in decreasing order of the percentage of nitrogen in the given compounds is
(a) urea > ammonium chloride > ammonium nitrate > ammonium nitrite
(b) urea > ammonium nitrite > ammonium nitrate > ammonium chloride
(c) urea > ammonium nitrite > ammonium chloride > ammonium nitrate
(d) ammonium nitrate > ammonium nitrite > ammonium chloride > urea

82. Urea on hydrolysis gives
(a) only ammonia
(b) only carbon dioxide
(c) ammonia and carbon dioxide
(d) None of the above

83. At high temperature, nitrogen combines with calcium carbide to give
(a) calcium cyanamide
(b) calcium cyanide
(c) calcium carbonate
(d) calcium nitrate

84. Underground water is maximum contaminated by
(a) Nitrogeneous fertilizer
(b) Phosphatic fertilizer
(c) Potash fertilizer (d) Natural fertilizer

85. Which of the statements about glass are correct?
I. Glass is a supercooled liquid having infinite viscosity.
II. Violet coloured glass is obtained by adding MnO_2.
III. Glass is a man made silicate.
IV. Glass is a crystalline substance.
Select the correct answer using the codes given below.
(a) I, II and IV (b) II, III and IV
(c) I, II and III (d) I and III

86. Which among the following are the properties of good paint?
I. The paint should be opaque and have high covering power.
II. The solid particles in paint should reflect much of the destructive light to ensure long life of the paint.
III. Combination of pigments, e.g. white lead and TiO_2 give better result.
IV. Addition of plasticiser destroy the elasticity of the film and leads to cracking.
Select the correct answer using the codes given below.
(a) I, II and IV (b) I, II, and III
(c) II and III (d) I and III

87. Consider the following statements.
I. Soap cannot be used in acidic water.
II. Ionic part of a soap is $-COO^- \cdot Na^+$
III. Soap dissolves in water faster then detergent.
Which of the statements given above is/are correct?
(a) I and II
(b) II and III
(c) Only III
(d) Only II

88. Consider the following statements regarding aluminium paint.
I. It is fairly good heat-resistant.
II. It possesses good electrical resistance.
III. It cannot be used for hot water pipe.
Which of the statements given above is/are correct?
(a) I and III
(b) Only I
(c) I and II
(d) II and III

89. Which of the following statements are true about the fertilizers?
I. They are nutrient specific.
II. They do not provide any humus to the soil.
III. They are absorbed slowly by the plants as they are not much soluble in water.
(a) Only II (b) I and II
(c) II and III (d) All of these

90. Which of the following statements are true about urea?
I. Urea is the first organic compound which is synthesised in the laboratory.
II. Urea is the best water soluble nitrogeneous fertilizer.
III. Urea leaves only CO_2 after ammonia has been assimilated by plants.
Codes
(a) I and II (b) II and III
(c) I and III (d) AIII of these

91. Consider the following statements.
I. Plants require nitrogen for growth and protein content.
II. Phosphorus is needed for stimulating growth, ripening of fruits and protecting from diseases.
III. Potassium is required for the development of healthy roots and aids ripening of cereals and fruits.
Which of the above statememnts are correct?
(a) I and II (b) II and III
(c) I and III (d) All of these

92. Which of the following are nitrogen fertilizers?
I. Calcium cyanamide
II. Urea
III. Bone ash
IV. Ammonium sulphate
Select the correct answer using the codes given below.
(a) (I), (II) and (III) (b) (I), (II) and (IV)
(c) (II), (III) and (IV) (d) (I), (III) and (IV)

93. Consider the following statements.
I. Nitrogen, phosphorus and potassium are the major elements needed in large amounts for the healthy growth of a plant.
II. NPK is called as Kissan khad.
III. Mixed fertilizers provide nitrogen, phosphorus and potassium to the plants.

IV. Green manure helps in enriching the soil in nitrogen and phosphorus.

Which of the above statements are correct?

(a) I, II, and iII (b) II, III and IV
(c) I, III and IV (d) All of these

94. Consider the following statements relevant to fertilizers.

I. Superphosphate of lime contains $Ca(H_2PO_4)_2$ and $CaSO_4$.
II. Triple superphosphate is obtained by treating calcium phosphate with concentrated H_2SO_4 acid.
III. Chief potash manures are KCl, K_2SO_4 and KNO_3.
IV. The chemical manures must be soluble in soil moisture.

Which of the above statements are correct?

(a) I and II (b) II, III and IV
(c) I, II and III (d) I, III and IV

95. Consider the following statements:

I. The main sources of bio fertilizers are bacteria, cyanobacteria and fungi.
II. Biofertilizer and green manures do not pollute the soil.
III. Potash fertilizer evaluated as K_2O.
IV. Phosphatic fertilizer content is expressed as P_2O_5.

Select the correct answer using the codes given below.

(a) I, II and III (b) II, III and IV
(c) I, II and IV (d) All of the above

Directions (Q. Nos. 96-103)
Following questions consist of two statements labelled as Statement I *and Statement* II. *Examine both the statements carefully and match the correct choice according to the codes given below.*

(a) Both Statement I and Statement II are true and Statement II is the correct explanation of the Statement I.
(b) Both Statement I and Statement II are true but Statement II is not the correct explanation of the Statement I.
(c) Statement I is true, but Statement II is false.
(d) Statement I is false, but Statement II is true.

96. **Statement I** The growth of rice plant is better when it is cultivated along with a blue green algae.

Statement II Blue green algae increases, soil fertility through nitrogen fixation.

97. **Statement I** Pure potash is a good farm manure.

Statement II Potash minerals are vital to plants, assisting starch formation.

98. **Statement I** Legumes revive the soil fertility.

Statement II Microbes in the root nodules of leguminous plant fix the atmospheric nitrogen.

99. **Statement I** Lithopone is a better white pigment than white lead.

Statement II Lithopone (ZnS + $BaSO_4$) remains unaffected by the H_2S present in atmosphere.

100. **Statement I** Magnesium alloys are used in the manufacture of aeroplane part.

Statement II Magnesium alloys with metal to provide lightness and strength.

101. **Statement I** Red phosphorus is used for making matches.

Statement II Red phosphorus is non-poisonous and has high ignition temperature.

102. **Statement I** Rayon is a semisynthetic polymer and is taken as a better choice than cotton fabric.

Statement II Mechanical and aesthetic properties of cellulose can be improved by acetylation.

103. **Statement I** Network polymers are thermosetting.

Statement II Network polymers have high molecular mass.

104. Match List I and List II and select the correct answer using the codes given below the lists.

List I	List II
A. Glass	1. Soap
B. Cement	2. Supercooled liquid
C. $C_{17}H_{35}COONa$	3. Mixture
D. Paper	4. Cellulose

Codes

	A	B	C	D
(a)	3	2	1	4
(b)	2	3	1	4
(c)	4	1	3	2
(d)	1	4	2	3

105. Match List I and List II and choose the correct answer by the codes given below the lists.

List I	List II
A. Mercuric chloride	1. $K_2Cr_2O_7$
B. Mercurous chloride	2. $HgCl_2$
C. Potassium chromate	3. K_2CrO_4
D. Potassium dichromate	4. Hg_2Cl_2

Codes

	A	B	C	D		A	B	C	D
(a)	4	2	3	1	(b)	4	2	1	3
(c)	2	3	1	4	(d)	2	4	3	1

106. Match List I and List II and choose the correct answer by the codes given below the lists.

List I (Chemical compounds)	List II (Uses)
A. Silver bromide	1. Etching of glass
B. Hydrogen peroxide	2. Photography
C. Hydrofluoric acid	3. Purification of air
D. Ozone	4. Bleaching agent

Codes

	A	B	C	D		A	B	C	D
(a)	2	3	1	4	(b)	2	4	1	3
(c)	3	1	4	2	(d)	4	2	1	3

107. Match List I with List II and select the correct answer using the codes given below the lists.

List I (Metallic oxide)	List II (Colour imparted to glass)
A. Uranium oxide	1. Red
B. Cuprous oxide	2. Blue
C. Cobalt oxide	3. Green
D. Chromium oxide	4. Yellow

Codes

	A	B	C	D		A	B	C	D
(a)	4	1	2	3	(b)	3	2	1	4
(c)	4	2	1	3	(d)	3	1	2	4

108. Match List I and List II and choose the correct answer by the codes given below the lists.

List I (Material)	List II (Important ingredient)
A. Cement	1. Sodium salt of fatty acids
B. Glass	2. Carbon black
C. Ink	3. Silica in the form of quartz
D. Soap	4. Aluminates and silicates of calcium

Codes

	A	B	C	D		A	B	C	D
(a)	4	3	2	1	(b)	1	2	3	4
(c)	1	3	2	4	(d)	4	2	3	1

109. Match List I and List II and choose the correct answer by the codes given below the lists.

List I (Substance)	List II (Raw material)
A. Glass	1. Fat and caustic alkali
B. Soap	2. Cellulose fibre and gelatin
C. Paper	3. Silicates of calcium and aluminium
D. Cement	4. Silica

Codes

	A	B	C	D		A	B	C	D
(a)	3	2	1	4	(b)	4	2	1	3
(c)	3	1	2	4	(d)	4	1	2	3

110. Match List I with List II and select the correct answer from the codes given below the lists:

List I (Fertilisers)	List II (Chemical formula)
A. Urea	1. $(NH_4)_2 SO_4$
B. Nitrolim	2. $NH_2 CONH_2$
C. Thomas Slag	3. $Ca CN_2$
D. Sindri fertiliser	4. $Ca_3 (PO_4)_2$. $CaSiO_3$

Codes

	A	B	C	D		A	B	C	D
(a)	2	3	4	1	(b)	1	2	3	4
(c)	4	3	2	1	(d)	2	3	1	4

Previous Years' Questions

111. Which one among the following is the correct order of amount of lime (CaO), silica (SiO_2) alumina (Al_2O_3) and ferric oxide (Fe_2O_3) in Portland cement? **2012 (I)**

(a) $CaO > SiO_2 > Al_2O_3 > Fe_2O_3$
(b) $SiO_2 > CaO < Fe_2O_3 > Al_2O_3$
(c) $Al_2O_3 > SiO_2 > CaO > Fe_2O_3$
(d) $Fe_2O_3 > Al_2O_3 > SiO_2 < CaO$

112. Which one among the following is the major constituent of sodalime glass? **2012 (I)**

(a) Sodium oxide
(b) Calcium oxide
(c) Calcium carbonate
(d) Silica

113. Which one among the following nitrogen compounds has the least percentage of nitrogen by mass? **2012(I)**

(a) $(NH_4)_3PO_4$
(b) NH_3
(c) NH_4OH
(d) NH_4NO_3

114. Match List I (compound) with List II (use) and select the correct answer using the codes given below the lists. **2012 (II)**

List I (Compound)	List II (Uses)
A. Cellulose nitrate	1. Soft soap
B. Potassium sulphate	2. Gunpowder
C. Potassium salt of fatty acids	3. Fertiliser
D. Calcium oxide	4. Glass

Codes

	A	B	C	D		A	B	C	D
(a)	2	3	1	4	(b)	2	1	3	4
(c)	4	1	3	2	(d)	4	3	1	2

115. The most important raw materials used in the manufacture of cement are **2012 (II)**

(a) potassium nitrate, charcoal and sulphur
(b) limestone, clay and gypsum
(c) transition metal oxides, sodium hydroxide or potassium hydroxide
(d) limestone, sodium carbonate and silica

116. Given below is an approximate composition of a substance,
CaO–60-70%; SiO_2–20-25%
Al_2O_3–5-10%; Fe_2O_3–2-3%
The substance is **2012 (II)**

(a) plaster of Paris (b) cement
(c) marble stone (d) quartz

117. .Which one among the following is the chemical formula of gypsum, which is an ingredient of cement? **2013 (I)**

(a) Ca_2SiO_2 (b) $CaSO_4 \cdot 2H_2O$
(c) CaO (d) $CaSO_4 \cdot 3H_2O$

118. Sodium stearate is a salt and is used **2013 (I)**

(a) in gunpowder (b) in paint
(c) to make soap (d) to make fertiliser

119. The principle of cleaning by soap is **2013 (I)**

(a) surface tension (b) floatation
(c) viscosity (d) elasticity

120. Solutions of three enzymes were prepared namely lipase, trypsin and amylase, in order to remove stains from a piece of cloth. Out of these three enzyme solutions, only lipase could completely remove the stain. This indicates that the stain was due to **2013(I)**

(a) oil
(b) protein
(c) mixture of protein and oil
(d) starch containing plant pigment

Directions (Q. Nos. 121-122)
Following questions consist of two statements labelled as Statement I *and Statement* II. *Examine both the statements carefully and match the correct choice according to the codes given below.*

(a) Both Statement I and Statement II are true and Statement II is the correct explanation of the Statement I.
(b) Both Statement I and Statement II are true but Statement II is not the correct explanation of the Statement I.
(c) Statement I is true, but Statement II is false.
(d) Statement I is false, but Statement II is true.

121. **Statement I** Limestone decomposes when it is heated in air. **2013 (II)**

Statement II Increase in the content of CO_2 in the atmosphere in recent years is mainly due to the using of limestone in the manufacture of cement.

122. **Statement I** Glass is not considered as a true compound.

Statement II Glass does not have a definite melting point. **2013 (II)**

123. The presence of sulphur in gunpowder **2013 (II)**

(a) decreases the ignition temperature
(b) increases the final temperature
(c) increases explosiveness of the gunpowder
(d) makes the powder smokeless

124. Chromium oxide is used as an ingredient in paints to obtain **2013 (II)**

(a) green colour (b) blue colour
(c) red colour (d) violet colour

125. Calcium Ammonium Nitrate (CAN) is a popular nitrogen fertiliser because it is **2013(II)**

(a) slow supplier of nitrogen
(b) having more percentage of nitrogen in it
(c) fixing the nitrogen in the soil
(d) capable of making the soil acidic

126. A fertiliser contains 20% nitrogen by mass. To provide a fruit tree with an equivalent of 1 kg of nitrogen, the quantity of fertiliser required is **2014(I)**

(a) 20 kg (b) 0.20 kg
(c) 0.05 kg (d) 5 kg

127. Turpentine oil in paints is used as a **2014(II)**
(a) pigment
(b) film-forming material
(c) thinner (d) drier

128. Which one of the following substances is most likely to be used as soap? **2014(II)**
(a) $CH_3(CH_2)_{12}COOCH_3$
(b) $CH_3(CH_2)_5O(CH_2)_5CH_3$
(c) $CH_3(CH_2)_{12}COONa$
(d) $CH_3(CH_2)_{12}CHCl_2$

129. **Statement I** The granules of modern gunpowder (also called black powder) are typically coated with graphite.
Statement II Graphite prevents the build-up of electrostatic charge.
Codes **2015(I)**
(a) Both the statements are individually true and Statement II is the correct explanation of Statement I
(b) Both the statements are individually true but Statement II is not the correct explanation of Statement I
(c) Statement I is true, but Statement II is false
(d) Statement I is false, but Statement II is true

130. The chemical used as a fixer/developer in photography is **2015(I)**
(a) sodium sulphate
(b) sodium sulphide
(c) sodium thiosulphate
(d) sodium sulphite

131. Washing soda is the common name for **2015 (I)**
(a) calcium carbonate
(b) magnesium carbonate
(c) sodium carbonate
(d) potassium carbonate

132. Which one among the following is used in making gunpowder? **2015 (I)**
(a) Magnesium sulphate
(b) Potassium nitrate
(c) Sodium stearate
(d) Calcium sulphate

133. The cleansing action of soap and detergent in water is due to the formation of **2015 (I)**
(a) micelle (b) salt
(c) base (d) acid

134. Addition of gypsum to cement **2015 (I)**
(a) reduces setting time of cement
(b) produces very light colour of cement
(c) increases setting time of cement
(d) shining surface is formed

135. Which one of the following are the characteristics of organic farming?
1. Use of chemical fertilisers to improve soil fertility.
2. Frequent decomposing and fallowing.
3. Use of herbs to control pests.
4. Higher productivity per hectare.

Select the correct answer using the codes given below **2015(I)**
(a) 1 and 4
(b) 1, 3 and 4
(c) 2 and 3
(d) 2, 3 and 4

136. The phosphorus used in the manufacture of safety matches is **2016 (I)**
(a) red phosphorus
(b) black phosphorus
(c) white phosphorus
(d) scarlet phosphorus

137. Soap is the sodium or potassium salt of **2016 (I)**
(a) stearic acid
(b) oleic acid
(c) palmitic acid
(d) All of the above

ANSWERS

1	*b*	2	*d*	3	*b*	4	*a*	5	*d*	6	*d*	7	*b*	8	*c*	9	*c*	10	*a*
11	*d*	12	*d*	13	*b*	14	*b*	15	*d*	16	*a*	17	*b*	18	*c*	19	*d*	20	*a*
21	*c*	22	*d*	23	*c*	24	*a*	25	*c*	26	*c*	27	*c*	28	*c*	29	*c*	30	*b*
31	*a*	32	*a*	33	*d*	34	*a*	35	*a*	36	*d*	37	*b*	38	*d*	39	*b*	40	*a*
41	*b*	42	*b*	43	*a*	44	*c*	45	*b*	46	*a*	47	*c*	48	*a*	49	*c*	50	*a*
51	*a*	52	*a*	53	*d*	54	*d*	55	*c*	56	*a*	57	*b*	58	*d*	59	*b*	60	*a*
61	*c*	62	*b*	63	*a*	64	*c*	65	*d*	66	*c*	67	*a*	68	*d*	69	*c*	70	*a*
71	*a*	72	*d*	73	*c*	74	*b*	75	*b*	76	*b*	77	*a*	78	*c*	79	*c*	80	*a*
81	*b*	82	*c*	83	*a*	84	*a*	85	*c*	86	*b*	87	*a*	88	*a*	89	*b*	90	*d*
91	*d*	92	*b*	93	*d*	94	*d*	95	*d*	96	*a*	97	*d*	98	*a*	99	*a*	100	*a*
101	*a*	102	*a*	103	*b*	104	*b*	105	*d*	106	*b*	107	*a*	108	*a*	109	*d*	110	*a*
111	*a*	112	*d*	113	*a*	114	*a*	115	*b*	116	*b*	117	*b*	118	*c*	119	*a*	120	*a*
121	*b*	122	*a*	123	*a*	124	*a*	125	*b*	126	*d*	127	*c*	128	*c*	129	*b*	130	*c*
131	*c*	132	*b*	133	*a*	134	*c*	135	*d*	136	*a*	137	*d*						