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Rajasthan Public Service Commission

Assistant Engineer Examination

GENERAL SCIENCE

Comprehensive Theory with Practice questions *and* Previous year solved questions

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RPSC Assistant Engineer Examination:
General Science

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Preface


B. Singh (Ex. IES)

The compilation of this book **General Science** was motivated by the desire to provide a concise book which can benefit students who are preparing for Rajasthan Public Service Commission (RPSC) Assistant Engineer Examination.

It would be worth mentioning that the entire syllabus of General Studies for RPSC Assistant Engineer Examination consists of five subjects namely Current Affairs, History & Culture, General Science, G.K. & Economic Developments with special reference to Rajasthan, and Geography & Natural Resources. The textbook of all five subjects to be launched separately. These all books will have special focus to Rajasthan which will help the aspirants immensely.

This particular textbook provides all the requirements of the students, i.e. comprehensive coverage of theory, fundamental concepts and objective type questions articulated in a lucid language. The concise presentation will help the readers grasp the theory of this subject with clarity and apply them with ease to solve objective questions quickly. This book not only covers the syllabus of RPSC Assistant Engineer Examination in a holistic manner but is also useful for other examinations conducted by RPSC. All the topics are given the emphasis they deserve so that mere reading of the book clarifies all the concepts. We have put in our sincere efforts to present detailed theory and MCQs without compromising the accuracy of answers.

Our team has made their best efforts to remove all possible errors of any kind. Nonetheless, we would highly appreciate and acknowledge if you find and share with us any printing and conceptual errors.

It is impossible to thank all the individuals who helped us, but we would like to sincerely thank all the authors, editors and reviewers for putting in their efforts to publish this book.

With Best Wishes

B. Singh

CMD, MADE EASY Group

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General Science

Chapter 2

Chemistry

INTRODUCTION

- Chemistry is a branch of science concerned with the substances of which matter is composed, the formulation of their reactions and properties, and the use of such reactions to form new substances.
- Every substances, whether naturally occurring or artificially produced, consists of atoms- the basic building blocks of chemical substances. Therefore, chemistry is concerned with the properties of atoms and the laws governing their combinations and how the knowledge of these properties can be used to achieve specific purposes.

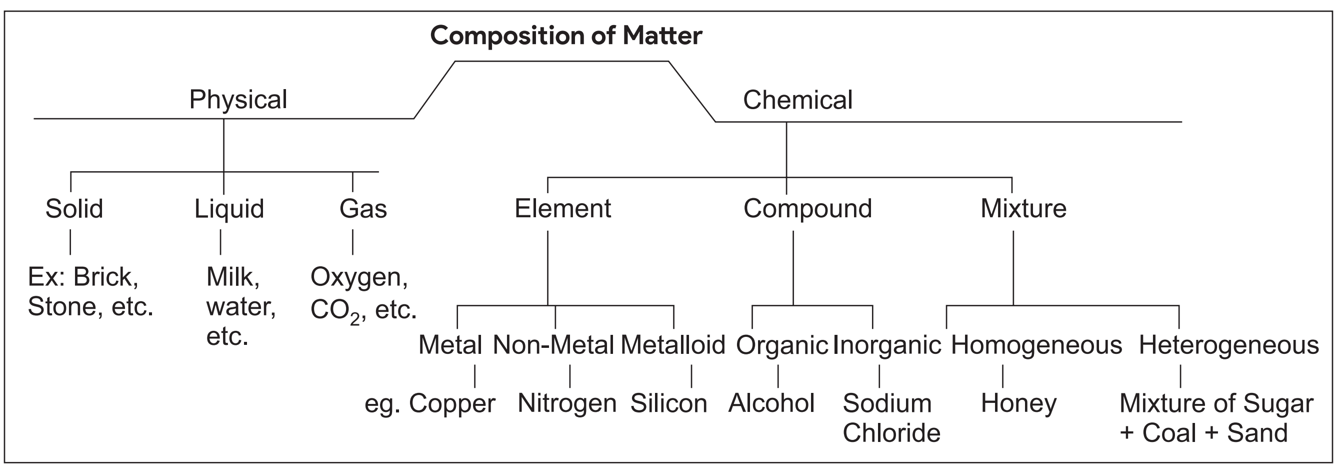
PHYSICAL CHEMISTRY

Matter

- Anything that has mass and occupies space is called matter. Matter can be classified on the basis of physical state and chemical constitution. In the physical state it is found in the form of solids, liquids and gases. These three forms of matter are found because of intermolecular force (force among atoms and molecules).
- Solids have a definite shape because of strong intermolecular force. The molecular force is not so strong in liquids, and therefore, liquids do not have a definite shape and have fluidity. Because of extremely weak intermolecular force, gases move freely, and can occupy any space. According to chemical composition, matter can be classified into elements, compounds and mixtures.

Composition of Matter

- **Substance:** A substance is a matter which cannot be separated into other kinds of matter by any physical force.
- **Element:** It is the purest form of a substance which cannot be broken into simpler substances by any chemical or physical process. Only one kind of atom is present in an element. There are 118 known elements, out of which 22 are man-made.



Elements can be divided into three groups: metals, non-metals and metalloids.

1. **Metals:** Any chemical element that is an effective conductor of electricity and heat can be defined as a metal. These are 90 in number.
2. **Non-metals:** These are substances that do not exhibit such characteristic properties of metals as hardness, mechanical adaptability, or the ability to conduct electricity. There are 24 non-metals, out of which 12 found in solid state, one in liquid (Br) state and 11 in gaseous state.
3. **Metalloids:** Metalloids possess the characteristics of both metal and non-metal, e.g. Silicon (Si), Germanium (Ge) and Antimony (Sb).

- **Compound:** Two or more elements chemically combined to form a substance is called a compound.
- **Mixture:** More than one substance (elements or/and compounds) is combined together to form a mixture. It can be separated by physical processes into two or more substances.

Classification of mixture is done under two categories:

(i) **Homogeneous mixture:** A homogeneous mixture, which is also called a solution, has a uniform composition throughout. For example: Air with nitrogen and oxygen as two main constituents, honey, a solution of salt or sugar, etc.

(ii) **Heterogeneous mixture:** A mixture which consists of basically distinct parts, each with different properties, is called a heterogeneous mixture. For example: When oil is mixed with water it forms a heterogeneous mixture.

Filtration, sublimation, decantation, chromatography, crystallization, etc. are some of the methods by which substances can be separated from a mixture.

Separation of Matter

- **Filtration:** It is a process of separating a suspended solid, such as a precipitate, from the liquid in which it is already suspended by straining it through a porous medium that can be penetrated easily by liquids.
- **Sublimation:** Heating certain substances which directly change into vapour without changing into liquid. For example: Camphor, Ammonium chloride (NH_4Cl), etc.
- **Decantation:** This process is applied to a mixture in which one compound is a liquid and the other an insoluble solid heavier than the liquid.
- **Crystallization:** For the separation and purification of solid substances, this method is most widely used.

Processes and Terms Related to Matter

- **Diffusion of Gases:** Diffusion is the movement of a gas into space or the mixing of one gas with another: e.g. when deodorants or perfumes are released in one part of a room, they diffuse and one can soon detect the odour in all parts of the room. The detection of leakage of LPG, because of mixing of ethyl mercaptan, is also an example of diffusion of gases.
- **Effusion of Gases:** It is the escape of a gas through a tiny hole. If gases are placed in a container with porous walls, such as in a balloon, the particles effuse through its walls, causing the volume to gradually decrease.
- **Freezing Point:** The temperature at which a liquid freezes at a certain pressure is known as the freezing point. Due to the presence of impurities in a substance, its melting point (MP) and freezing point (FP) decreases. This is the reason that in an ice-cream factory a little amount of salt (NaCl) is mixed with the substance to be freezed.
- **Melting Point:** The melting point is the temperature at which a solid changes into a liquid.
- **Boiling Point:** The temperature at which a liquid changes into gas or vapour is known as the boiling point. The boiling point of water is 100°C.

Do You Know?

- The melting point of an alloy is less than that of its constituent elements due to the presence of impurities.
- The boiling point of alcohol is lower than that of water.

- **Evaporation:** Evaporation is the process of change of liquid into a gas. Evaporation takes place at all temperatures. Wet clothes dry even in shadow due to evaporation.

Atomic Structure

- In 1803, John Dalton propounded the atomic theory, according to which an atom is indivisible, and this concept remained predominant up to the end of the 19th century. But later atomic models and atomic theories proved that atoms are divisible and they have a definite internal configuration and composition.
- Atomic models like Rutherford's model and Bohr's model have confirmed that the atoms are composed of a number of micro particles like electron, proton and neutron. Apart from electron, proton and neutron, some micro particles such as positron, meson and neutrino are also present.

Atom and Molecule:
The atom of an element is that smallest particle which takes part in a chemical reaction but doesn't exist in a free state. Similarly, the molecule of an element or compound is that smallest particle which doesn't take part in a chemical reaction but exists in a free state.

Fundamental Particles of the Atom

- **Electron:** This fundamental particle was invented by J. J. Thomson in 1897. It is a negatively charged particle that rotates in various orbits around the nucleus.
- The mass of an electron = 9.1×10^{-31} kg and the charge of an electron = -1.6×10^{-19} coulomb. The mass of electron can be equated to 1/1837 of that of a hydrogen atom.
- **Proton:** This fundamental particle was invented by Goldstein in 1919 and it is a positively charged stable particle. The mass of a proton = 1.67×10^{-27} kg and the charge of a proton = $+1.6 \times 10^{-19}$ coulomb.
- **Neutron:** This fundamental particle was invented by Chadwick in 1932. It is a neutral unstable particle. The masses of a proton and neutron are nearly equal.

Particle	Mass (kg)	Charge	Relative charge
Electron (e)	9.10×10^{-31}	-1.6×10^{-19}C	-1
Proton (P)	1.67×10^{-27}	$+1.6 \times 10^{-19}$C	$+1$
Neutron (n)	1.67×10^{-27}	0	0

- **Nucleus:** The nucleus consists of protons and neutrons and these are collectively known as nucleons. Since the electrons are of negligible mass, the entire mass of the atom is due to the nucleus, i.e. nucleons. The sum of the neutrons and protons is known as the mass number.

  Mass number = No. of protons + No. of neutrons

  Mass number is generally represented by the letter A.

Rutherford Atomic Model

In 1911, Rutherford conducted an experiment to detect the inner composition or configuration of an atom. It was called Rutherford's alpha particle scattering experiment.

This model has the following conclusions:

(i) In an atom there is a central massive part called nucleus, which is surrounded by the electrons. In this nucleus protons and neutrons are packed together.

(ii) The atom is spherical and most of its part is empty.

(iii) The size of the nucleus is very small in comparison to the entire atom.

(iv) Rutherford predicted empirically that the electrons rotate in the various orbits around the nucleus, while the electrons and the proton of the nucleus have a force of attraction which is equal to the centripetal force to keep the electron orbiting in the circular orbits.

Bohr Atomic Model

In 1913, Neils Bohr introduced a quantum concept to explain the stability of an atom.
Bohr provided the following new ideas on the basis of Planck's quantum theory called the postulates of Bohr's theory, which are as given below:

(i) The centripetal force required for an orbiting electron is counterbalanced by the electrostatic Coulombian force of attraction between the nucleus and the electron.

(ii) The electrons in an atom revolve only in a certain definite orbit in which energy is fixed and quantized. This orbit is stationary and in any such orbit electron doesn't radiate any energy although it is accelerated.

(iii) Electrons of greater radii possess greater energy and vice-versa. But if any electron jumps from any higher orbit to any lower one then a quantum of energy appears to be radiated, while when an electron moves from a lower orbit to a higher orbit a quantum of energy appears to be absorbed.

Atomic and Molecular Masses

- In 1961, the International Union of Chemists selected a new unit of expressing the atomic masses. They accepted the stable isotope of carbon (C-12) with mass number 12 as the standard for comparing the atomic and molecular masses of elements and compounds. This scale is known as mass spectrometer. The atomic mass can be determined by this instrument by comparing the mass of an atom with the mass of a particular atom chosen as standard.
- This scale of relative masses of atoms is called atomic mass unit scale and is abbreviated as a.m.u. Hence, one atomic mass unit is defined as the quantity of mass equal to $1/12^{th}$ of the mass of an atom of carbon (C-12).
- Thus, the atomic mass of an element is defined as the average relative mass of an atom of an element as compared to the mass of an atom of carbon (C-12) taken as 12.
- In other words, atomic mass is a number which expresses as to how many times an atom of the element is heavier than $1/12^{th}$ of the mass of carbon atom (C-12).

$$\text{Atomic mass} = \frac{\text{Mass of an atom}}{\frac{1}{12}\text{ mass of a carbon atom }(C^{12})}$$

$$\text{and } 1 \text{ amu} = 1.66056 \times 10^{-24}\text{g}$$

Mole Concept

- A mole is a collection of 6.022×10^{23} particles. The number 6.022×10^{23} is called Avogadro Number and is symbolised as letter "N". In other words, a mole is an Avogadro number of particles.
- **For example:**
  - 1 mole of hydrogen atoms = 6.022×10^{23} hydrogen atoms.
  - 1 mole of hydrogen molecules = 6.022×10^{23} hydrogen molecules.
  - 1 mole of sodium ions = 6.022×10^{23} sodium ions.
  - 1 mole of electrons = 6.022×10^{23} electrons.
  - Thus, a mole is defined as the amount of substance that contains the same number of entities (atoms, molecules, ions or other particles) as the number of atoms present in 12 g (or 0.012 kg) of carbon-12 isotope.

Mole as a Volume

- Mole is also related to the volume of the gaseous substance. The volume of one mole of any substance is called its molar volume. The molar volume of solids and liquids can be easily calculated if the molar mass and density at any given temperature and pressure are given, because these do not change much with temperature and pressure. However, the molar volumes of gases change considerably with temperature and pressure.
- It has been observed that one mole of an ideal gas (i.e., 6.022×10^{23} molecules) occupies 22.4 litres at normal temperature and pressure (N.T.P. i.e. 0°C and 1 atm pressure).

  For example,

  1 mole of hydrogen gas at N.T.P. = 22.4 litres

  1 mole of CO_2 gas at N.T.P. = 22.4 litres

Isotopes, Isobars and Isotones

Isotopes

- Isotopes are atoms of the same element which have the same atomic number but different mass number.
- Since, the atomic number of different isotopes of the same element is the same, it means that they have the same number of electrons and protons. The difference in their mass numbers is due to the different number of neutrons present in their nuclei.

  Example:
  - Hydrogen which is most abundant (99.985%) contains only one proton. It is also called protium $\left({}_1^1H\right)$. Rest of the hydrogen contains two isotopes, one containing 1 proton and 1 neutron called deuterium $\left({}_1^2D \text{ or } {}_1^2H, 0.015\%\right)$ and the other possessing 1 proton and 2 neutrons called tritium $\left({}_1^3H \text{ or } {}_1^3T\right)$. Tritium is found only in trace amounts on the earth. These have the same atomic number, i.e. 1,

but different mass numbers like 1, 2 and 3. These three isotopes are commonly known as hydrogen, deuterium and tritium as given below:

Hydrogen (H) (one proton only)	$Z = 1$, $A = 1$
Deuterium (D)	$Z = 1$, $A = 2$ (one proton and one neutron)
Tritium (T)	$Z = 1$, $A = 3$ (one proton and two neutrons)

Isobars

- Atoms of different elements having the same mass number but different atomic numbers are called isobars. Since isobars have same mass number, the sum of protons and neutrons in the nucleus of each atom is the same. These atoms differ in their atomic number and, therefore have different number of protons (or electrons) and also different number of neutrons.
- Isobars are atoms of different elements and hence they have different properties.

Isotones

Atoms having the same number of neutrons but different mass numbers are called isotones.

Atomic Number

- The number of protons or electrons of an atom of the element is called the atomic number of the element. It is represented by Z. The atomic number of any element is its basic characteristic.
- The hydrogen atom has one proton and one electron; that's why it is said to have atomic number 1. Similarly, nitrogen has seven protons and seven electrons, and thus its atomic number is 7.

Mass Number

- In every atom there is a small central massive part called nucleus, where almost all the mass of the atom is assumed to be concentrated.
- The nucleus of the atom consists of protons and neutrons, which are collectively called **nucleons**. The sum of the number of protons and neutrons in the nucleus of an atom of the element is called its mass number and it is represented by A.

Shell or Orbit

- The electrons revolve in the various orbits with different and definite energies in the atom and these orbits which are the trajectories or paths of the electrons are called shells.
- The innermost orbit or shell has the lowest energy and the outermost orbit or shell has the maximum energy. The various shells from lower to upper are represented symbolically by K, L, M, N, O, P, etc.

Subshell or Sub-orbit

- Every shell or orbit has a number of subshells in which various orbitals are found and these are represented by the various small letters s, p, d and f. As in every orbit the number of electrons is fixed, similarly in every orbital of various subshell the number of electrons is fixed.
- The maximum number of electrons in the orbitals s, p, d and f are 2, 6, 10 and 14 respectively.

Orbital

An orbital is the three-dimensional space around the nucleus of an atom where there is maximum probability of finding an electron.

Electronic Configuration

A comprehensive and proper distribution of various electrons in various shells and subshells of any atom is called electronic configuration. Examples:

Electronic configuration of Na (11) is $1s^2$, $2s^2\ 2p^6$, $3s^1$

Mg (12) has Electronic configuration of $1s^2$, $2s^2\ 2p^6$, $3s^2$

Ca (20) has Electronic configuration of $1s^2$, $2s^2\ 2p^6$, $3s^2\ 3p^6$, $4s^2$

Valance electron and Core electron

The electron present in the outermost orbit of the atom is called valence electron whereas the electron present in inner orbit of the atom is called core electron.

Aufbau Principle

- Aufbau principle gives the principle of building of the atomic structure of elements with electrons. According to this principle, the electrons are filled in atomic orbitals in the order of their increasing energy.
- An electron occupies the orbital of lowest energy first. When this orbital is filled up with electrons completely, the remaining electrons are accommodated in the orbital of the next higher energy. The orbital having the highest energy is filled at the end.
- According to Aufbau principle, the order of energy levels of the various subshells is 1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s < 4d < 5p < 6s < 4f < 5d < 6p < 7s < 5f.

Quantum Numbers

Quantum numbers are those numbers through which the positions of electrons and their respective energies in various shells, subshells or orbitals are known.

There are four quantum numbers:

1. Principal Quantum Number
2. Azimuthal Quantum Number
3. Magnetic Quantum Number
4. Spin Quantum Number

1. **Principal Quantum Number:** This quantum number simply indicates the orbit number of an electron and its energy is represented by n (=1, 2, 3,...), where n is an integer. For $n = 1$, the electron is said to be in the normal state.
2. **Azimuthal Quantum Number:** This quantum number represents the angular momentum of the revolving electron and it is indicated by l. For principal quantum number n, l has all the values from 0 to $(n - 1)$.

   Example :

   If $n = 1$ then $l = 0$; If $n = 2$ then $l = 0, 1$.

   If $n = 3$ then $l = 0,1, 2$; If $n = 4$ then $l = 0,1,2,3$, etc.
3. **Magnetic Quantum Number:** This quantum number indicates the direction of an orbit in space in a magnetic field and it is represented by m. The value of m depends on the value of l and its values are from $-l$ to $+l$ including zero.

   Examples:

   If $l = 0$ then $m = 0$; If $l = 1$ then m = $-1, 0, +1$

   If $l = 2$ then $m = -2, -1, 0, +1, +2$

   If $l = 3$ then $m = -3, -2, -1, 0, +1, +2, +3$

   Thus the total number of values of $m = 2l + 1$.
4. **Spin Quantum Number:** This quantum number represents the spin of the electron. It has been observed that electrons have two types of spin- clockwise (+ 1/2) and anticlock-wise (– 1/2). In fact, spinning electrons possess spin angular momentum that is quantized. Thus spin quantum number has two values + 1/2 and – 1/2 and is represented by s.

Quantum Number	Symbol	Description
Principal Quantum Number	n	Orbit number and the corresponding energy of the electron.
Azimuthal Quantum Number	l	Angular momentum of the revolving electron of a subshell.
Magnetic Quantum Number	m	Direction of an orbital in the space of magnetic field.
Spin Quantum Number	s	Spin of the electron.

Pauli's Exclusion Principle:

Pauli's Exclusion Principle states that *No two electrons in an atom can have the same set of four quantum numbers* and at the maximum a set of three quantum numbers for two electrons can be identical but the fourth quantum number must be different for them.

Radioactivity

- Henry Becquerel discovered the phenomenon of radioactivity in 1896 and observed that certain invisible rays are emitted from Uranium and its salts. In early times these invisible radiations were called Becquerel rays. Later Madame Curie and Pierre Curie asserted that the emission of invisible radiations from Uranium and its compounds are totally a nuclear phenomenon and this specific characteristic of Uranium and its compounds doesn't depend upon physical and chemical parameters.

- All natural elements from atomic number 1 (Hydrogen) to 83 (Bismuth) are stable because their nuclei are stable.
- Elements from atomic number 84 (Polonium) onwards have unstable nuclei and these are radioactive.

Interesting Fact

- In 1898, Madame Curie and Gerhard Schmidt detected that thorium and its compounds also exhibit the phenomenon of radioactivity.
- Again, in 1902, Madam Curie and Pierre Curie observed a mineral of Uranium called Pitch Blende, whose radioactivity is about more than four times than that of Uranium. Later, the Curies invented Radium from the Pitch Blende.

Radioactive Rays and their Properties

- Radioactive elements and their compounds, by the process of nuclear spontaneous disintegration into smaller fragments, emit invisible radiations which are called Becquerel rays.
- These compose positively charged alpha-rays (α-rays), negatively charged beta-rays (β-rays) and electrically neutral gamma-rays (γ-rays).

Properties of α-rays

- α-rays are the streams of He^{++} ions which have a mass of 4 a.m.u. and a charge of 2 units.
- They have the maximum power of ionisation through gases.
- The velocity of α-rays is less than that of light and it is equal to 1/10 of the velocity of light in vacuum (3×10^8 m/s).
- They have the least penetrating power as compared to that of β and γ-ray.

Properties of β-rays

- β-rays are streams of fast-moving electrons.
- Each β-particle is an electron having a mass of 1836/1 a.m.u. and the charge of -1 unit.
- Its velocity is equal to (33 - 92) % of the velocity of light.
- It has more penetrating power than α-rays and less penetrating power than γ-rays.

Properties of γ-rays

- γ-rays are electro-magnetic radiations of high energy.
- They are composed of photons (rest mass zero) of high energy.
- They have the highest penetrating power and can pass through 8 cm of thick lead block and 25 cm of thickened iron sheet.

Half-life period of a radioactive element:

The half-life period of a radioactive element is the time during which half of its total number of atoms disintegrate. Half-life period of any element = $0.696/\lambda$. Where λ is called disintegration constant or decay constant.

Characteristics of half-life period:

(i) Every radioactive element has its own constant half-life and thus different radioactive elements have different half-lives.

(ii) The half-life period of a radioactive element is independent of all external conditions such as temperature, pressure and mass.

(iii) The smaller the half-life period of a radioactive element, the larger its radioactivity, and vice versa.

Radioactive element	Half-life periods
${}_{92}U^{236}$	2.34×10^7 years
${}_{90}Th^{232}$	1.40×10^{10} years
${}_{89}Ac^{227}$	22 years
${}_{91}Pa^{231}$	3.27×10^4 years
${}_{88}Ra^{226}$	1622 years

Interesting Fact

Radioactive substances emit spontaneously either α-particles or β-particles and some γ-rays but α and β-particles both are never seen to be emitted simultaneously.

Units and Measurement of Radioactivity

There are various units of radioactivity, namely:

Curie: The radioactivity of 1 g of pure radium is called curie.

1 curie = 3.7×10^{10} disintegrations/second or decays/second.

Rutherford: The amount of a radioactive substance which gives 10^6 disintegration per second.

$\Rightarrow$ 1 Rutherford = 10^6 disintegration/second

Becquerel (S.I. Unit): It is defined as that amount of radioactive substance which gives 1 disintegration per second.

⇒ 1 Becquerel = 1 disintegration/second or decay/second

Note:

The radioactivity of a radioactive substance is measured by an instrument called Geiger Muller Counter.

Radioactive Dating or Radio Isotope Dating

- The technique of detecting the amount or quantity of any radio isotope in the sample of the rock, dead plants or organism in any bio residue to estimate and measure its actual or exact age is called radioactive or radio isotope dating.
- Naturally occurring radioactive isotopes have been very useful in dating (estimating age) of the geological events.
- Radio carbon (${}_6C^{14}$) is unstable and decays to nitrogen with a half-life period of 5600 years. By measuring the ratio of the concentration of ${}_6C^{14}$ to ${}_6C^{12}$ in any ancient organism like fossils, dead trees or plants, one can measure or estimate the exact age.
- The ages of non-living ancient geological substances like old rocks and earth are estimated by the use of uranium or its most suitable mineral Pitch Blende, in which Uranium and Thorium both are found. This technique is called Uranium dating. But for the most ancient geological rocks, Potassium- Argon dating technique is used.

Applications of Radio-isotopes

- Radio-isotopes are used in the form of tracer in medicine. Tumours of unwanted growth of cells in human body are detected by the Tracer technique.
- Cancerous cells are destroyed completely by the use of radio-isotopes. For example, cobalt-isotope (${}_{27}Co^{60}$) is today frequently used in the therapy of cancer and in destroying brain tumours. The element radium (Ra) has been used for burning and destroying cancerous cells.
- Radio-isotopes (Radio-sodium) are used to detect any residue or unwanted circulatory system.
- Radio-iodine is used to detect any side effect appearing inside the thyroid gland.
- Radio-phosphorus is used in curing bone diseases.
- Radio-sodium is used to measure the speed of blood flow in the human body.
- Radio-iron is used to detect diseases like anaemia, tuberculosis and other malnutrient diseases.

Chemical Bonding

The binding force of the constituent atoms of the molecule to maintain a mutual atomic order and a definite but specific geometrical shape is called chemical bonding.

Types of chemical bonding

There are three types of chemical bonding:

1. Electrovalent or Ionic bonding
2. Covalent bonding
3. Co-ordinate covalent bonding

Electrovalent Bonding

- The bond formed as a result of the electron transfer from one atom to another is called electrovalent or ionic bonding.
- The transfer of electrons takes place in such a way that ions obtained after electron transfer have a configuration of like that of inert gases.

  Example:

  Na^+ + Cl^- → NaCl
  2, 8, 1   2, 8, 7   (2, 8) (2, 8, 8)

Here, one electron is donated by sodium and accepted by chlorine.

Characteristics of electrovalent compounds

(i) These compounds are generally soluble in water because they generally ionise in water, ions become heavily hydrated and they disappear in the intermolecular spaces of water molecules and dissolve.

(ii) In aqueous solution they get ionised as given below:

$$NaCl \xrightarrow{\text{Water}} Na^+ + Cl^-$$
$$K_2SO_4 \xrightarrow{\text{Water}} 2K^+ + SO_4^{--}$$

(iii) The fused state of these electrovalent or ionic compounds is also a good conductor of electricity, because ions become mobile and can carry electricity across the fused mass. Electrovalent compounds are good electrolytes in aqueous solutions and in fused state.

Covalent Bonding

The bond formed as a result of sharing of electrons between two atoms in which atoms form the chemical bonding in such a way that the molecules form attains the permanent electronic structure of the inert gas, is called covalent bonding.

Example:

(i) When a pair of electrons is produced by the electrons of two hydrogen atoms sharing in a hydrogen molecule, a single covalent bond is formed.

(ii) When two pairs of electrons are produced by the sharing of electrons by two oxygen atoms in an oxygen molecule, a double covalent bond is formed.

Characteristics of covalent compounds

(i) Covalent compounds are insoluble in water but soluble in organic solvents.

(ii) Covalent compounds in liquefied state or in the form of their solution are bad conductors of electricity because in these states they don't produce any ions. But covalent compounds like HCl and NH_3 in the form of their aqueous solution conduct electricity because of the presence of ions.

Co-ordinate Covalent Bonding

In a co-ordinate covalent bond, the pair of electrons is obtained from only a single atom. In the bonding, the atom which supplies the electron pair is called the donor and the atom which receives the pair of electrons is called the acceptor. The electron pair donated by the donor atom is called single atom pair. Usually co-ordinate covalent bond is represented by an arrow ($\rightarrow$). Here a convention is followed in which a +ve charge (S^+) is shown on the donor atom and a -ve charge (S^-) on the acceptor atom.

Example:

Ions like carbonate (CO_3^-) and ammonium (NH_4^+) are examples of co-ordinate covalent bond.

Electronic Theory of Valency

- This theory of valency is based on the electronic structures of elements and hence it is called electronic theory of valency. According to this theory, inert gases like Neon (Ne), Argon (Ar), Krypton (Kr), Xenon (Xe) and Radon (Rn), except Helium (He), do not exhibit valency because they contain a set of eight electrons called octet and their valency is said to be zero.
- This makes their electronic structures very stable and they do not participate in any chemical reaction.
- Helium (He) contains two electrons in the first orbit of its atom. Hence its first orbit becomes completely filled and its structure is therefore very stable

Oxidation-Reduction

Oxidation: Oxidation is the chemical process in which either the ratio of electronegative atoms or radicals of any element or compound increases or the ratio of electropositive atoms or radicals of the element or compound decreases.

$$2Mg + O_2 \rightarrow 2\,MgO, \qquad C + O_2 \rightarrow CO_2$$
$$2H_2 + O_2 \rightarrow 2\,H_2O$$

Reduction: Reduction is the chemical process in which either the ratio of electropositive atoms or radicals of any element or compound increases or the ratio of electronegative atoms or radicals of the element or compound decreases.

$$Cl_2 + H_2S \rightarrow 2HCl + S$$
$$2FeCl_3 + H_2 \rightarrow 2FeCl_2 + 2HCl$$

Acids, Bases and Salts

Acid

An acid may be defined as a substance which releases one or more H^+ ions in an aqueous solution.

Properties:

1. It turns blue litmus paper red.
2. It tastes sour.
3. It contains Hydrogen ions (H^+).
4. It donates protons.
5. It turns Methyl Orange pink.

Examples:

Some of the examples of acids are:

Hydrochloric acid (HCl), Nitric Acid (HNO_3), Sulphuric Acid (H_2SO_4), Acetic Acid (CH_3COOH), Formic Acid (HCOOH), etc.

Sources of Acids			
Name of Acid	**Sources**	**Name of Acid**	**Sources**
Formic acid	Red ants	Butyric acid	Rancid butter
Citric acid	Lemons and oranges	Uric acid	Urine of mammals
Lactic acid	Sour milk	Oxalic acid	Tomato
Acetic acid	Vinegar	Hydrochloric acid	Gastric juice (0.4%)
Maleic acid	Apples	Stearic acid	Fat
Tartaric acid	Grapes	Carbonic acid	Soda water and aerated drinks

Some Common Acids			
Name	**Type**	**Chemical Formula**	**Where found or used**
Carbonic acid	Mineral acid	H_2CO_3	In soft drinks.
Hydrochloric acid	Mineral acid	HCl	In stomach as gastric juice, used in cleaning metal surfaces and in tanning industry.
Nitric acid	Mineral acid	HNO_3	Used in the manufacture of explosives like T.N.T. and fertilizers like ammonium nitrate.
Sulphuric acid	Mineral acid	H_2SO_4	Commonly used in car batteries, in the manufacture of fertilizers, detergents, dyes, explosives etc. It is often called king of chemicals.
Phosphoric acid	Mineral acid	H_3PO_4	Used in anti-rust paints and in fertilizers.
Formic acid	Organic acid	HCOOH or (or CH_2O_2)	Found in the sting of ants, nettle and bees; used in tanning leather and in medicines for treating gout
Acetic acid	Organic acid	CH_3COOH	Used for preparing vinegar.
Benzoic acid	Organic acid	C_6H_5COOH	Used as food preservative.
Citric acid	Organic acid	$C_6H_8O_7$	Present in lemons, organs and other citric fruits.
Tartaric acid	Organic acid	$C_4H_6O_6$	Present in tamarind.
Oxalic acid	Organic acid	$C_2H_2O_4$	Present in tomatoes.

Bases

A base may be defined as a substance capable of releasing one or more OH^- ions in aqueous solution.

Properties:

1. Bases are bitter in taste.
2. Turn red litmus paper blue.
3. Contain replaceable hydroxide group (OH^-).
4. Bases turn methyl orange yellow.

Note: All water-soluble bases are called alkalis.

Some common bases and their uses			
Name	**Commercial name**	**Chemical formula**	**Uses**
Sodium hydroxide	Caustic soda	$NaOH$	In the manufacturing of soap, refining of petroleum, paper, pulp, etc.
Potassium hydroxide	Caustic potash	KOH	In alkaline storage battery, manufacture of soap, absorbing CO_2 gas, etc.
Calcium hydroxide	Slaked lime	$Ca(OH)_2$	In the manufacture of bleaching powder, softening of hard water, for whitewash etc.
Magnesium hydroxide	Milk of magnesia	$Mg(OH)_2$	As an antacid to remove acidity from stomach.
Aluminium hydroxide	—	$Al(OH)_3$	As foaming agent in fire extinguishers.
Ammonium hydroxide	—	NH_4OH	In removing grease stains from clothes, and in cleaning window panes.

The pH Scale

A pH scale is used to measure the strength of an acid or a base solution. In general, the lesser the pH of a solution, the more will be its acidic strength. Similarly, the higher the pH of a solution, the more will be its basic strength. The scale runs from 0 to 14.

The characteristics of the pH scale are:

1. Acids have pH less than 7.
2. Neutral solutions (e.g., water) have pH of 7.
3. Alkalis have pH more than 7.
4. The more alkaline a solution, the higher its pH.

Solution	Approximate pH
Concentrated HCl	0
Gastric juices	1.0 to 1.2
Lemon juice	2.2 to 2.4
Vinegar	3.0
Beer	4.0 to 5.0
Tomato juice	4.1
Coffee	4.5 to 5.5
Acid rain	5.6
Milk	6.5
Human saliva	6.5 to 7.5
Pure water	7.0
Human blood	7.36 to 7.42
Baking soda solution	8.4
Sea water	8.5
Washing soda solution	9.0
Milk of magnesia	10.5
House hold ammonia	12.0
Concentrated NaOH	14.0

Interesting Fact

In word "pH scale", '*p*' stands for 'potenz' meaning 'power' in German.

Salts

Salts are formed by the reaction between acids and bases.

$$NaOH + HCl \rightarrow \underset{\text{(Common salt)}}{\underset{\downarrow}{NaCl}} + H_2O$$

Common Salt (NaCl) is formed as a product when Sodium Hydroxide (NaOH) reacts with Hydrochloric Acid (HCl).

Uses

1. **Sodium Chloride (NaCl):**
   (a) To make food salty or as a flavouring agent.
   (b) In case of dehydration, an injection of saline water is given (0.9% NaCl).

2. **Potassium Nitrate:** In gunpowder and matchsticks
3. **Sodium Benzoate:** As a food preservative for pickles
4. **Sodium Carbonate:** As washing soda; in the manufacturing of glass
5. **Sodium Iodate:** To prevent goitre
6. **Calcium Carbonate:** Cement Industry
7. **Calcium Sulphate:**
   (i) Plaster of Paris ($2CaSO_4.H_2O$) or $CaSO_4.\frac{1}{2}H_2O$
   (ii) Gypsum ($CaSO_4.2H_2O$)
8. **Potash Alum ($K_2SO_4.Al_2(SO_4)_3.24H_2O$)**
   (i) As an antiseptic after shave
   (ii) Purification of water
   (iii) In the dyeing industry

Gas Laws

Charles' Law

It states that "The volume of a definite amount of any gas at constant pressure is directly proportional to the absolute temperature".

$V \propto T$ or $\frac{V}{T} = K$, (where K is a constant)

or $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ (V = volume; T = temperature)

Boyle's Law

It states that "The volume of a definite amount of any gas at constant temperature is inversely proportional to the pressure".

$$V \propto \frac{1}{P}$$

or $PV = K$ K = Constant

or $P_1V_1 = P_2V_2$ (P = pressure, V = volume)

Gay-Lussac's Law

It states that "For a given mass and constant volume of an ideal gas, the pressure exerted is directly proportional to its absolute temperature.

$$P \propto T \text{ or } \frac{P}{T} = K$$

$\frac{P_1}{T_1} = \frac{P_2}{T_2}$ (P = pressure, T = temperature)

Gaseous Equation of State

It is obtained by combining both Boyle's and Charle's Law.

$$P \propto \frac{T}{V}, \text{ when } T \text{ and } V \text{ both vary}$$

$PV = RT$, Where R is a constant called Universal gas constant.
It is called gaseous equation of state.

Avogadro's Law

It states that the volume occupied by an ideal gas is directly proportional to the number of molecules of the gas present in the container.

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

Where,
n = number of molecules of gas or moles of gas.
V = volume of gas

Graham's Law of Diffusion

The rate of diffusion of various gases is inversely proportional to the square roots of their densities at constant temperature and pressure.

Rate of diffusion $\propto \sqrt{\frac{1}{\text{Density}}}$ or, $r\sqrt{\frac{1}{d}}$

or, $\frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}}$

Where r_1 = rate of diffusion of gas 1 (Lighter gas)
r_2 = rate of diffusion of gas 2 (Denser gas)
d_1 = density of gas 1
d_2 = density of gas 2

Absolute Temperature: The absolute temperature is equal to –273°C. In terms of Kelvin, it is equal to 0 K.

Standard Temperature and Pressure (STP):
0°C or 273K is called standard temperature, whereas 760 mm (76 cm) of mercury (Hg) is called standard pressure.

Electrolysis

The process of decomposition or dissociation by passing electric current through liquified state of the substance (compound) or through its aqueous solution is called electrolysis.

Applications of Electrolysis

(i) In electroplating: To give a low-quality metal long life and to make it attractive, a thin layer of good-quality metal is laminated on a low-quality metal by the process of electrolysis. This is called electroplating.

(ii) In electrotyping: The blocks, graphics etc. in the printing industry are composed by the process of electrolysis. This is called electrotyping.

(iii) In electro-refining of metals: Metals like copper, silver, gold etc. are obtained in the pure form by the process of electrolysis. This is called electro-refining of metals.

(iv) In electro-metallurgy: There are certain metals like sodium, potassium, aluminium, calcium, magnesium etc. that are extracted from their respective compounds by the process of electrolysis. This is called electrometallurgy.

(v) In the evaluation of equivalent weight of metals.

(vi) In the manufacturing of chemical compounds: By the process of electrolysis, various types of drugs, organic and inorganic compounds are manufactured.

Examples: Caustic soda, hydrogen peroxide, chloroform, ethane, acetylene etc. are produced by the above process.

INORGANIC CHEMISTRY

Periodic Classification of Elements

- The arrangement in which the substances of the same properties reappear again at a regular interval based upon some fundamental properties is called periodic classification.
- The main purpose of periodic classification of the elements of the same characteristic properties is to study chemistry in simple, convenient, transparent and a more comprehensive way.

Mendeleev's Classification of Elements

On the basis of the comparative study of the chemical compounds, Mendeleev propounded a law called Mendeleev's periodic law, which is stated below:

"The physical and chemical properties of the elements are the period functions of their atomic weights."

The modern periodic table was composed by Moseley. He removed almost all discrepancies of Mendeleev's periodic table.

Modern Periodic Table

Group→ ↓Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	118 Uuo

Lanthanides	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb
Actinides	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No

Chief Characteristics of a Period (Modern Periodic Table)

- In the periodic table, in any period from left to right the metallic properties of the elements decrease, while non-metallic properties increase.
- In the periodic table, in any period from left to right chemical reactivity of the elements first decrease and then increase.
- In a period, the valency of the elements increases from 1 to 4 and then it diminishes and becomes 0.
- In a period, the number of valence electrons increases from left to right from 1 to 8.
- Generally, in a period, the value of electron affinity increases from left to right. Also, in a period, the value of electronegativity of the elements increases from left to right.
- The value of ionization potential of the elements increases from left to right in a period.
- The size or atomic radius of the elements decreases from left to right in a period.

Chief characteristics of a Group (Modern Periodic Table)

- The metallic properties of the elements increase from top to bottom in a group.
- The chemical reactivities of the metallic elements increase from top to bottom in a group, while the chemical reactivities of the non-metallic elements decrease.
- The valency of the elements of any particular group is the same for all elements.
- The number of valence electrons are the same for all elements kept in a group.
- The value of the electron affinity of the elements decreases from top to bottom in the group.
- Generally the value of electronegativity of the elements decreases from top to bottom in a group.
- The value of ionization potential of the elements decreases from top to bottom in a group.
- The size or atomic radius of the elements increases from top to bottom in a group.

Major Facts About the Elements	
Total elements discovered	118
Elements existing in nature	88
Artificially produced (man -made) elements	27
Number of metallic elements	90
Number of non-metallic elements	22
The element found to be most abundant on the earth's surface	Oxygen
The lightest element	Hydrogen
The lightest metallic element	Lithium
The liquid metallic element	Mercury
The metal which is the best conductor of electricity	Silver
The metal which is the second best conductor of electricity	Copper
The most malleable element	Gold
The most reactive non-metallic element	Fluorine
The most reactive metallic element	Caesium
The most ionization potential (IP) dement	Helium
The most electro-negative element	Fluorine
The most powerful oxidising substance	Fluorine
The group of the most gaseous elements	Zero Group
The element kept inside kerosene oil	Sodium

Metals and Metallurgy

Metals

Metals have the capability to lose electrons and provide cations. They are located towards the left and in the middle in the periodic table.

Minerals

The natural solid materials containing compounds of metals in a combined state along with impurities and found abundantly beneath the earth's surface are called mineral.

Alloy:

It is the homogeneous mixture of two or more metals or metals and non-metals. Alloys have a lower melting point than the original metals.

Metals and their Ores

Metals	Ores	Formula
Iron (Fe)	Haemetite	Fe_2O_3
	Magnetite	Fe_3O_4
Uranium (U)	Pitchblende	U_3O_8
Lead (Pb)	Galena	PbS
Mercury (Hg)	Cinnabar	HgS
Zinc (Zn)	Calamine	$ZnCO_3$
Gold (Au)	Calaverite	$AuTe_2$
Sodium (Na)	Borax	$Na_2B_4O_7.10H_2O$
	Chile Saltpeter	$NaNO_3$
Aluminium (Al)	Bauxite	$Al_2O_3.2H_2O$
	Corundum	Al_2O_3
	Cryolite	Na_2AlF_6
Calcium (Ca)	Dolomite	$CaCO_3.MgCO_3$
	Gypsum	$CaSO_4.2H_2O$
Magnesium (Mg)	Dolomite	$MgCO_3.CaCO_3$
	Epsom Salt	$MgSO_4.H_2O$
Potassium (K)	Potassium Nitrate	KNO_3
	Carnallite	$KMgCl_3\ 6(H_2O)$

Metallurgy

The process of extraction of a particular metal from its ore is known as metallurgy.

Processes in Metallurgy

- The removal of impurities from a metal by chemical method is called **leaching**.
- **Calcination** is the heating of an ore below its melting point in the absence of air.
- **Roasting** is the heating of an ore below its melting point in excess of air.
- The reduction of a metal oxide with coke or carbon is called **smelting**.
- **Zone refining** and **van Arkel** method are used to get completely pure metals.

Ore

Those minerals from which the metals are extracted commercially and economically are called ores of the metals. For example, bauxite ($Al_2O_3.2H_2O$), Cuprite (Cu_2O) and Haemetite (Fe_2O_3) are the ores of Aluminium, Copper and Iron respectively.

Gangue

The impurities associated with the minerals are known as gangue.

Flux

The material added to the ores to remove gangue is called flux.

Slag

The substance formed as a result of flux and gangue is known as slag.
i.e. Gangue + Flux = Slag

For Example:

$$\underset{\text{(Gangue)}}{SiO_2} + \underset{\text{(Flux)}}{CaO} \rightarrow \underset{\text{(Slag)}}{CaSiO_3}$$

Metals and their Properties

Magnesium (Mg)

Magnesium is the sixth most abundant element following calcium. It occurs as dolomite ($MgCO_3.CaCO_3$), magnesite ($MgCO_3$), etc. The metal magnesium doesn't exist in nature in free-state because it is highly reactive. It occurs in crystal rocks mainly as insoluble carbonates, sulphates and silicates.

> **Do You Know?**
>
> The organic compound chlorophyll, which provides green colour to the leaves of the plants, has mainly magnesium in it.

Uses:

The metal magnesium is used in making flashlight ribbon, in photography and in fire crackers, in the composition of alloys etc.

Alloys:

Magnelium (Mg: 2%), and Duralumin (Mg: 0.5%)

Compounds

(i) Magnesia (MgO): It is also called milk of magnesia. It is a white-coloured powder. It is slightly soluble in water and fluorescent to light. It is fused at a very high temperature; that's why it is used in layer linking of the blast furnace. It is also used in removing acidity from the human stomach.

(ii) Magnesium Hydroxide [$Mg(OH)_2$]: It is a substance of white colour and slightly soluble in water. It is a base and is utilised in the production or extraction of sugar from molasses.

(iii) Magnesium Sulphate ($MgSO_4$): This compound naturally occurs in the form of Epsomite in Epsom, which is abundantly found in hot-water spring. It is a colourless crystalline solid substance. It is frequently utilised in cotton industry, in the manufacturing of soap, paint, etc.

(iv) Magnesium Carbonate ($MgCO_3$): This compound occurs naturally in the form of magnesite or dolomite, which is a white solid substance soluble in water. It is utilised in the production of printing ink, toothpaste, face-cleaning powder etc.

(v) Magnesium Alba [$Mg(OH)_2 . MgCO_3 . 3H_2O$]: This compound it used in removing acidity from the human stomach and used as an antacid.

Beryllium (Be)

The important uses of beryllium are:

(i) Beryllium is used in the manufacture of many alloys. For example, copper–beryllium alloys are used in the preparation of high-strength springs.

(ii) Metallic beryllium is used in making windows of X-ray tubes.

Calcium (Ca)

The important uses of calcium are:

(i) It is used to remove traces of air from vacuum tubes since it has strong affinity for both nitrogen and oxygen.

(ii) It is used to remove last traces of moisture from alcohol.

(iii) Compounds of calcium such as limestone and gypsum are used as constituents of cement and mortar.

(iv) When alloyed with lead, it is used for cable coverings. When alloyed with aluminium, it is used in casting and forging.

Some important compounds of Calcium

Calcium Oxide

It is prepared on a commercial scale by heating limestone ($CaCO_3$) in a special type of rotary kiln at 1070– 1270K.

Uses of calcium oxide

(i) It is an important primary material and is the cheapest form of alkali.

(ii) It is used in the manufacture of sodium carbonate from caustic soda.

(iii) It is used as a flux in metallurgy.

(iv) It is used in the purification of sugar and in the manufacture of dye stuffs.

(v) It is used in drying gases and alcohol.

(vi) It is used as a building material.

Calcium hydroxide $Ca(OH)_2$

Preparation

1. **From quicklime:** Calcium hydroxide is prepared by adding water to quicklime, CaO. This process is called slaking of lime.

$$CaO + H_2O \rightarrow Ca(OH)_2$$

2. **From calcium chloride:** It can also be obtained by treating caustic soda with calcium chloride.

$$CaCl_2 + 2NaOH \rightarrow Ca(OH)_2 + 2NaCl$$

Uses of calcium hydroxide

(i) Calcium hydroxide is used in the preparation of mortar.

(ii) It is used as a whitewash due to its disinfectant nature.

(iii) It is used for the softening of hard water.

(iv) It is used for absorbing acidic gases.

(v) It is used for preparing ammonia from ammonium chloride.

(vi) It is used in glass making, tanning industry, for preparation of bleaching powder and for purification of sugar.

Calcium Carbonate or Limestone or Marble ($CaCO_3$)

It is also known as Limestone or Marble.

Preparation:

1. **From slaked lime:** It can be prepared by passing carbon dioxide through slaked lime in a limited amount.

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

2. **From calcium chloride:** It can be prepared by adding aqueous solution of sodium carbonate to calcium chloride.

$$Na_2CO_3 + CaCl_2 \rightarrow CaCO_3 + 2NaCl$$

Uses of Calcium Carbonate ($CaCO_3$)

(i) Calcium carbonate is used as a building material in the form of marble.

(ii) It is used in the manufacture of quicklime.

(iii) It is also used as a raw material for the manufacture of sodium carbonate.

(iv) It is used as a flux in the extraction of metals such as iron.

(v) Calcium carbonate is extensively used in the manufacture of high-quality paper.

(vi) It is also used as an antacid, a mild abrasive in toothpaste, a constituent of chewing gum and a filler in cosmetics.

Plaster of Paris ($CaSO_4 \frac{1}{2} H_2O$)

Preparation:

It is prepared by heating gypsum to 393K.

$$2(CaSO_4.2H_2O) \xrightarrow{393\,K} (CaSO_4).\tfrac{1}{2}H_2O + \tfrac{3}{2}H_2O$$

Thus, it contains one molecule of water for every two calcium and two sulphate ions. It may be noted that the temperature should not be allowed to rise because at 437K the whole of water is lost and the anhydrous salt left is called *dead burnt plaster*. It has no setting properties.

Properties:

(i) It is a white powder.

(ii) On mixing it with water, it forms a plastic mass which sets into a hard solid in 5-15 minutes. This is called setting of plaster of Paris. The setting is due to hydration of plaster of Paris into gypsum.

$$[CaSO_4.2H_2O] + 3H_2O \rightarrow 2CaSO_4.2H_2O$$

(iii) During setting, there is a slight increase in volume. This helps plaster of paris to take the shape of any mould in which it is added.

Uses of Plaster of Paris:

(i) Plaster of Paris is used for producing moulds for pottery, ceramics, etc.

(ii) It is used for making statues, models and other decorative materials.

(iii) It is used in the building industry as well as plasters.

(iv) It is used in surgical bandages known as plaster for setting broken and fractured bones in the body because it immobilises the affected part of the organ where there is a bone fracture.

(v) It is also used in dentistry.

Aluminium (Al)

Aluminium doesn't occur in nature in free state but occurs in the forms of compounds like Bauxite ($Al_2O_3.2H_2O$), Corundum (Al_2O_3), Diaspore ($Al_2O_3.H_2O$), Felspar ($K_2O.Al_2O_3.6SiO_2$), etc.

Compounds:

- **Alumina (Al_2O_3):** It occurs in nature in the form of bauxite, corundum etc. It is also found in the form of gems. On a large scale it is manufactured by the bauxite ore. It is white, crystalline and soluble in water. Also, Al_2O_3 is an amphoteric oxide: it reacts with both acid and base.
- **Potash Alum [$K.Al(SO_4)_2.12H_2O$]:** It is a double salt which appears as a colourless crystalline solid. It is used in pulp-paper and leather industries, as an antiseptic and germicide after shaving, as a germicide for purification of water, etc.
- **Aluminium Hydroxide [$Al(OH)_3$]:** It is a white amorphous powder insoluble in water. It is a covalent compound. It is used in making fire-proof and water-proof clothes. In the name of aluminium gel, it is used as a drying agent.

Iron (Fe)

- It is a transition metal. It doesn't occur in nature in a free state, instead it is found in the form of ore. It has fourth position among all the elements found on the earth's crust.

- In nature it is also found abundantly in green vegetables and in the haemoglobin of blood.
- There are various ores which naturally occur in nature; they are mainly red haemetite (Fe_2O_3), brown haemetite ($2Fe_2O_3.3H_2O$) and magnetite (Fe_3O_4).
- Most of the iron is extracted from red haemetite (Fe_2O_3) in the blast furnace by carbon-reduction process.

Varieties of iron:

- **Cast iron or Pig iron:** In this variety of iron, the amount of carbon (2.5%) is comparatively high. That's why such iron is hard and brittle. Also, very small amount of impurities like phosphorous, silicon, manganese etc. are found in it. Such iron is of a lower quality.

  It is of two types: white cast or pig iron and brown cast or pig iron. In white cast iron, most amount of the carbon is in complex form, while in brown cast iron most amount of the carbon is confined in the form of micro crystals of graphite and distributed in the entire body. It is used in the manufacturing of steel, wrought iron and in foundry work. It is also used in making utensils, typewriter cover etc.
- **Wrought iron:** It is obtained directly from cast iron or pig iron and it is comparatively a pure metallic iron.

  It is malleable and ductile; that's why foils, sheets and wires are made of it. The amount of carbon is very low (0.12 - 0.25%) in wrought iron.
- **Steel:** It is basically an alloy of iron and carbon. In steel, the amount of carbon is less than that of cast or pig iron. Thus, in steel, the amount of carbon is 0.25 to 1.5%. There are usually four types of steel.
- **Tempering of Steel:** When red hot steel is emerged in water or oil and quickly cooled then the steel becomes extremely strong and brittle. This process is called **hardening of steel** and this steel is called **quenched steel**. Again, if this steel be made to cool slowly and steadily, it becomes elastic and brittle.

Types of Steel, their Properties & Uses

Steel	Special composition	Properties	Uses
Stainless steel	Cr (12-15%)	Very hard and strong, doesn't form rust.	Used in making cooking utensils, surgical instruments, blades etc.
Manganese steel	Mn (6-15%)	Very hard, free from rusting.	Used in making railways tracks, switches, axles and cutting tools.
Chrome steel	Cr (5%)	Extremely hard and strong.	Used in making safe vaults, ball bearings, jaws of stone-crushing machine.
Nickel steel	Ni (3-4%)	Very hard and elastic, free from rusting.	Used in making axles, electric wire, aircraft, auto parts etc.
Tungsten steel	W (10-20%)	Very hard and strong.	Used in making springs, magnets saws, axles and cutting tools.
Chrome Vanadium steel	Cr (1-10%) V (0.15+-0.5%)	High tensile strength and load-bearing capacity.	Used in making ball bearings, gears and axles.

Silver (Ag)

Silver chloride (AgCl): It is called Horn silver and is frequently used in making **photochromatic glass**.
Silver nitrate ($AgNO_3$): It is the main compound of silver and is also called **Lunar Caustic**. It is prepared by the reaction of silver on hot and dilute HNO_3. It is a white crystalline substance whose melting point is 214°C. It is extremely soluble in water. It is used as laboratory reagent, in making hair dyes, in electroplating of silver

compounds, in making special ink which is used by washermen in marking clothes and as voter marker on the finger.

Do You Know?

Eating egg from a silver spoon is dangerous because silver directly reacts with the sulphur of the egg and forms black-coloured silver sulphide (Ag_2S), which damages the spoon.

Gold (Au)

- It occurs as metal in nature as well as in the forms of its ores. Some important ores of the gold are calaverite ($AuTe_2$), sylvanite (Ag, Au)Te_2 etc. Gold is also recovered from auriferous quartz and from alluvial auriferous sands. This is extracted from auriferous sand by the amalgamation process.

Physical and chemical properties of gold: It is a golden yellowish solid substance insoluble in any individual acid like HCl, HNO_3, H_2SO_4, etc. but soluble in aqua regia and NaCN solutions. It is the most malleable of all metals.

Compounds

Auric chloride ($AuCl_3$): It is a brownish-yellow crystalline solid substance moderately soluble in water and forms a golden yellow solution. It is used in making **antidote for snake poisoning**, in preparation of gold fulminate, purple of cassius, colloidal gold etc.

Rolled gold [Cu (90%), Al (10%)]: It is an artificial form of gold which resembles gold and is utilised in making cheap ornaments. In the electroplating process of gold, potassium aurocyanide is utilised as an electrolyte.

Zinc (Zn)

It is a bluish white, hard and brittle metallic substance. The melting point, boiling point and specific density of zinc are 419°C, 920°C and 7.1 respectively. At normal temperature it is neither malleable nor ductile. It is a good conductor of heat and electricity.

Uses:

It is used in the laboratory in the preparation of ZnS gas. It is also used in the galvanization of iron sheets to protect iron from rusting. Buckets, boxes and many household articles are made from these sheets. Zinc is used in making alloys like brass, bronze, german silver, and coins. It is also used in the extraction of gold, and in the production of smoke-screen in battle fields.

Compounds:

1. **Zinc sulphate ($ZnSO_4$):** Hydrated zinc sulphate ($ZnSO_4.7H_2O$) is called **white vitriol**. It is a colourless crystalline solid substance soluble in water.

   It is used in textile industry for soaking cotton threads before spinning, in making the preserver of wood, in the manufacturing of **lithopone**, in calico printing and dye industries.
2. **Zinc oxide (ZnO):** It is an amphoteric oxide. It is also called **philosopher's wool**.
3. **Lithopone ($ZnS+BaSO_4$):** The mixture of zinc sulphide (ZnS) and barium sulphate ($BaSO_4$) is called Lithopone. It is obtained by the reaction of $ZnSO_4$ and barium sulphide (BaS). It is a white pigment which is used to prepare white paint and this paint doesn't turn black because atmospheric H_2S has no action on it.
4. **Zinc sulphide (ZnS):** It occurs in nature in the form of zinc blende. It is a white solid substance which is insoluble in water. It exhibits the virtue of **phosphorescence** and that's why it is utilised in making phosphorescent screens.
5. **Zinc phosphide (ZnP):** It is used as rat poison.

Mercury (Hg)

Mercury, also called **quick silver**, is not found abundantly in free state. It occurs in the form of ores. The main ore of mercury is **cinnabar (HgS)**. Mercury is extracted from cinnabar by carbon reduction process.

Physical and chemical properties: Mercury is a white shining metal like silver which occurs in liquid state at ordinary temperature. It is a good conductor of heat and electricity. On mixing it with fats or sugar and shaking it vigorously, a grey powder is formed. This is called **deadening of mercury**. Mercury is neither malleable nor ductile. At 4.12 K its electrical resistance is gone completely and it becomes a superconductor.

Compounds:

Mercuric sulphide (HgS): It is also called **vermillion**, which is a red solid crystalline substance. It is insoluble in water and acid. But it dissolves easily in aqua regia and forms mercuric chloride ($HgCl_2$). It is used in making medicines, in preparing **water colours** etc.

Amalgam

An **amalgam** is a combination of metals in which one metal is mercury (Hg). The metal mercury is kept inside an iron pot (container) because it doesn't form amalgam with iron.

Do You Know?

Usually a tubelight is filled up with mercury vapour and argon gas.

Lead (Pb)

Lead occurs in nature mainly in the form of its ores. There are various ores of it which exist in nature such as galena (PbS) and anglesite ($PbSO_4$). The main ore is galena (PbS), from which lead is extracted by self-reduction process. Lead is the **most stable** among all the elements.

Compounds:

1. **Lead Oxide (PbO):** It is a volatile yellowish compound which is called **litharge**. It is an amphoteric oxide and is used in **rubber industry**, in the manufacture of **flint glasses** and storage batteries.
2. **Lead dioxide (PbO_2):** It is a chocolate-coloured insoluble powder and it is used in match industry for making **ignition surface of match boxes**, used for preparation of $KMnO_4$.
3. **Tri-plumbic tetraoxide (Pb_3O_4):** It is also called **red lead** and is used in making **red paint**, **flint glass**, red-lead element etc.
4. **Lead acetate [Pb ($CH_3COO)_2$] :** It is also called **sugar of lead**. It is a white crystalline sugar-like substance soluble in water and its crystals are sweet in taste. It is also called **inorganic sugar**. It is used as a laboratory reagent to examine chloride, sulphide and sulphate radicals. Lead acetate paper is used to detect the presence of H_2S and as a mordant.
5. **Lead carbonate Pb(CO_3) :** It is also called white lead due to its white colour. It is insoluble in water but soluble in HCl and HNO_3. It is basically used in making white pigment.
6. **Lead tetraethyl [Pb ($C_2HS)_4$]:** It is a colourless liquid having a special smell. It is soluble in petrol and is used as an antiknock agent. When a very small quantity of it is added to petrol, the knocking given by petrol in internal combustion engines is suppressed. Petrol mixed with tetraethyl lead is coloured red with an organic dye to distinguish it as a motor fuel.

Uranium (U)

It is a rarely found element in nature and it doesn't occur in free state. Almost all its minerals are radioactive. The main ore of uranium is **Uraninite (pitchblende)**.

Uses of Uranium: Uranium carbide is used as a catalyst in the production of ammonia (NH_3) by **Haber's process**. Uranium is used in the production of **nuclear energy**. It is used in the production of alloys and as electrodes in gas discharge device. The nitrate, chloride etc. of uranium are utilised in drug-manufacturing industries. The nitrate and acetate of uranium are used in photography etc.

Isotopes of Uranium: There are three isotopes of uranium: ${}_{92}U^{234}$, ${}_{92}U^{235}$ and ${}_{92}U^{238}$. The most abundantly occuring Uranium in nature is ${}_{92}U^{238}$ (99.28%) while ${}_{92}U^{235}$ (0.71%) and ${}_{92}U^{234}$ (0.006%) occur in very small amounts. The isotope ${}_{92}U^{235}$ is used in nuclear or atomic reactor as a nuclear fuel.

Plutonium (Pu)

Plutonium is a heavy radioactive element (metal) and is the most active member of Actinium radioactive series. It is in fact not a naturally existing element but formed artificially and specially utilised in the nuclear fission bomb. In most nuclear reactors or atomic reactors of the world, about 20 ton plutonium is used.

Do You Know?

Two cities of Japan, namely Hiroshima and Nagasaki were destroyed during World War II by nuclear fission bombs (atom bombs) and in these bombs plutonium was used.

Tungsten (W)

Tungsten used in steel. The symbol of Tungsten is W and its melting point is 3500°C.

Manganese (Mn)

Compounds of Manganese:

1. **Manganese Dioxide (MnO_2):** It is used in dry cells.
2. **Potassium Permanganate ($KMnO_4$):** It is called red medicine. It is used as a bleaching agent for wool and silk. It is also used as colour remover of oils and as germicide or insecticide of water.

Copper (Cu)

Copper is extracted mainly from **copper pyrites** ($CuFeS_2$). It is used in making household utensils, alloys and coins, therefore it is also called coinage metal.

Compounds

1. **Cuprous Oxide (Cu_2O):** Used in making **ruby glass** (due to its red colour).
2. **Cupric Sulphate ($CuSO_4$):** It is called **Blue Vitriol** or ($CuSO_4.5H_2O$). It is used in preparing **green dyes** and also in electroplating and electric cells.

Alloys of Copper		
Alloys	**Composition**	**Uses**
Brass	Cu (70%), Zn (30%)	Used in making idols, utensils.
Bronze	Cu (88%), Sn (12%)	Used in making coins, bells.
German Silver	Cu (60%), Zn (25%), Ni (15%)	Used in making idols, jewellery.
Rolled Gold	Cu (90%), Al (10%)	Used in making jewellery.
Gun Metal	Cu (88%), Sn (10%), Zn (2%)	Used in making gun, parts of machine.
Bell Metal	Cu (80%), Sn (20%)	Used in making bells, idols, coins.

Platinum (Pt)

Platinum is called **white gold**. It is also called **Adam's catalyst**. It is used in making ornaments and the tip of the nozzle of the pen.

Thorium (Th)

Thorium is used in the production of nuclear energy. It is used as **X-ray targets** and glow tube targets.
Germanium (Ge)
Uses: Germanium has largest use in transistor technology, in making transistors and other semiconductor devices. It is transparent to infrared light and is therefore also used for making prisms and lenses and window in infrared spectrometers and other scientific apparatus.

Tin (Sn)

Uses: Because of low strength and high cost of tin, it is rarely used by itself, but it is used for electroplating and as alloys. Tin plates obtained by electroplating steel with tin are extensively used for making cans, for food and drinks. It is used in the preparation of a number of important alloys such as **solder** (Sn and Pb or Cu, Pb, Sn, Sb), **pewter** (Pb, Sn, Sb, Cu), **type metal** (Pb, Sn, Sb), etc.

Non-Metals & their properties

The list of non-metals contains 22 entries, in which there are 11 gases, 1 liquid and 10 solids. [Bromine (Br) occurs in liquid state].

Hydrogen (H)

Hydrogen is the lightest element. Its atomic no. is 1. It is first element of the periodic table.

Uses of Hydrogen

- In the hydrogenation of edible oils such as groundnut oil, cotton seed oil etc. to form vegetable ghee, also called **margarine**.
- In the manufacture of compounds like ammonia, water gas ($CO + H_2$) and methyl alcohol (CH_3OH).
- As a rocket fuel in liquefied form.
- In the manufacture of hydrochloric acid.

Water

- Water is essential for all forms of life. It is the most common, abundant and easily obtainable of all chemical compounds. It is a solvent of great importance and is regarded as a universal solvent.
- It can be easily transformed from liquid to solid and to gaseous state. It is the principal constituent of the earth's surface
- Water constitutes about 65% of our body and is an essential for its growth.

Physical Properties of Water

Many of the properties of water are due to hydrogen bonding in their molecules.

The important physical properties of water are:

- Water is liquid with freezing point of 273.2 K and boiling point of 373.2 K.
- **Water has maximum density of 1.00 gcm^{-3} at 277 K (4°C)**.
- Water has strong hydrogen bonding in its molecules and exists as associated molecules.
- Water is polar in nature having dipole moment of 1.84D. It has solubility for a variety of substances and is regarded as a **universal solvent.**

Heavy Water (D_2O)

- Chemically heavy water is **deuterium oxide** (D_2O). It was discovered by Urey in 1932.
- It can be prepared by the prolonged electrolysis of water. When water is electrolysed, H_2 (hydrogen) is liberated much faster than D_2 (deuterium) and the remaining water becomes enriched in heavy water D_2O. If the process is continued until only a small volume remains, then almost pure D_2O is obtained. It has been estimated that about 29,000 litres of water must be electrolysed to get one litre of D_2O that is 99% pure.
- Like ordinary water, heavy water is colourless, odourless and tasteless liquid.
- The physical constants of heavy water are generally slightly higher than ordinary water (H_2O).

Uses of heavy water

The heavy water can be used:

1. **As a moderator:** Heavy water has been finding use in *nuclear reactors* as a ***moderator*** because it slows down the fast-moving neutrons and, therefore, **helps in controlling the nuclear fission process**.
2. **As a tracer compound:** Heavy water has also been used as a tracer compound to study mechanism of many chemical reactions.
3. **In nuclear magnetic resonance:** Heavy water is used as one of the references in nuclear magnetic resonance spectroscopy.
4. **For the preparation of deuterium:** Heavy hydrogen or deuterium can be obtained by the electrolysis of heavy water or its decomposition by Na metal.

Hard and Soft Water

Natural water contains dissolved salts. Depending upon its behaviour towards soap solution, water may be classified as soft water or hard water.

(a) **Soft water:** Water which produces lather with soap solution readily, is called **soft water**. For example, distilled water and demineralised water.

(b) **Hard water:** Water which does not produce lather with soap solution readily, is called **hard water**.

Cause of Hardness of Water

- The hardness of water is due to the presence of the bicarbonates, chlorides and sulphates of calcium and magnesium. These salts dissolve in water when it passes through the grounds or rocks.
- Hard water does not produce **lather** because the cations (Ca^{2+} and Mg^{2+}) present in hard water react with soap to form insoluble precipitates. **Soaps are sodium salts of higher fatty acids like stearic acid ($C_{17}H_{35}COOH$)**. When soap is added to hard water, these anions combine with Ca^{2+} and Mg^{2+} ions to form calcium and magnesium salts which are insoluble in water.

$$M^{2+} + \underset{\text{Sodium stearate}}{2C_{17}H_{35}COONa} \rightarrow \underset{\substack{\text{Metal stearate}\\ \text{(precipitate)}}}{(C_{17}H_{35}COO)_2M} + 2Na^{+}$$

Where, M = Ca or Mg

- Therefore, no lather is produced until all the calcium and magnesium ions are precipitated. This also results into wastage of a lot of soap. Hard water is unsuitable for laundry washing and dyeing.
- In addition, hard water is also harmful for steam boilers. The inner surface of the boiler gets crusted with scale known as *boiler scale*. It is mainly calcium sulphate, calcium carbonate and magnesium oxychloride. The deposition of scale decreases the efficiency of the boiler and also damages it. Therefore, hard water should not be used in boilers.

Type of Hardness of Water

The hardness of water is of two types: temporary hardness and permanent hardness.

(a) **Temporary hardness:** This type of hardness in water is due to the presence of *bicarbonates of calcium and magnesium dissolved in it*. The hardness is called temporary because it can be very easily removed by simply boiling the hard water for some time. Temporary hardness is also called **carbonate hardness**.

(b) **Permanent hardness:** This hardness is due to the presence of chlorides and sulphates of calcium and magnesium dissolved in water. Since the hardness cannot be easily removed, it is therefore, called permanent hardness. The permanent hardness is also called **non-carbonate hardness**.

Softening of Water

The process of the removal of hardness from water is called **softening of water**.

Hydrogen Peroxide (H_2O_2)

Hydrogen peroxide was discovered by a French chemist **JL Thenard** in 1818. Its molecular formula is H_2O_2. Hydrogen peroxide can be prepared in the laboratory by the action of cold, dilute sulphuric acid on sodium or barium peroxide.

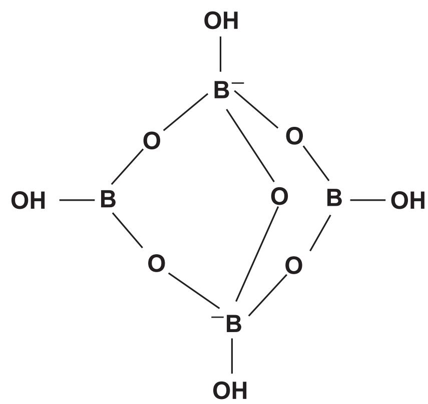
Uses of Hydrogen Peroxide

- It is used in industry as a **bleaching** agent for textiles, paper, pulp, straw, leather, oils, fats, etc.
- Domestically, it is used as a **hair bleach** and as a mild disinfectant.
- It is used in the manufacture of many inorganic compounds such as sodium perborates and percarbonates which are important constituents of high-quality detergents.
- It is used as an **antiseptic** for washing wounds, teeth and ears under the name *perhydrol*.
- It is used for the production of epoxides, propylene oxide and polyurethanes.
- It is used for the synthesis of hydroquinone, pharmaceuticals (cephalosporin), and food products like tartaric acid.
- It is used as an antichlor in bleaching.
- It is used for restoring the colour of lead paintings.
- It is used for preserving milk, wine and other liquors.
- Recently, H_2O_2 is being used in environmental chemistry such as in **pollution control,** treatment of domestic and industrial effluents, oxidation of cyanides and restoration of aerobic conditions to sewage wastes.

Boron

Some important compounds of Boron

(i) **Borax** or **sodium tetraborate:** It is an important compound of boron. It occurs naturally as tincal (*suhaga*) in certain driedup lakes of India, Tibet, Ceylon and California. Borax contains the tetranuclear units $[B_4O_5(OH)_4]^{2-}$ and, therefore, its correct formula is $Na_2[B_4O_5(OH)_4.8H_2O]$. The structure of $[B_4O_5(OH)_4]^{2-}$ ion is given below:



Uses of Borax

- Borax is used in the laboratory for borax bead test.
- It is used in the manufacture of **enamels and glazes** for earthen pots.
- It is used in the candle industry.
- It is used in the preparation of **medicinal soaps** due to its antiseptic character.
- It is used in making **optical glass**.
- It is used in **softening of water and cleansing agent**.

(ii) **Orthoboric acid (H_3BO_3)**
Boric acid is trivial name for orthoboric acid.

Uses of boric acid

- Boric acid is used in the manufacture of enamels and pottery glazes.
- It is used as a **food preservative** in food industry.
- It is used in the manufacture of **pigments and borax**.
- It is used in medicines as an **eyewash**.

Phosphorus (P)

It is found in rocks, minerals and animal bones. It exists in several allotropic forms, two of which are well known: red phosphorus and white phosphorus. **Red phosphorus is used in safety matches**. Phosphorus is present in DNA and RNA besides being present in bones and teeth.

Uses

1. Phosphates are utilized in the making of special glasses that are used for **Sodium lamps.**
2. Bone ash (Calcium Phosphate) is used in the production of **bone china**.
3. Phosphoric acid, made from elemental phosphorus, is used in food applications such as some **soda beverages**.

4. White Phosphorus, called 'WP' (Slang term "Willie Peter"), is used in military applications as incendiary bombs, for **smoke screening**, as smoke pots and **smoke bombs**.

Functions:

- The main function of phosphorus is in the formation of bones and teeth. It plays an important role in the body's utilization of carbohydrate and fats and in the synthesis of protein for the growth, maintenance and repair of cells and tissues.
- It is also crucial for the production of ATP (Adenosine Triphosphate), a molecule the body uses to store energy.
- Phosphorus works with vitamin B. It also assists in the **contraction of muscles**, in the functioning of kidneys, in maintaining the regularity of heartbeat and in **nerve conduction**.

Sulphur (S)

- It is a non-metallic element which occurs in many allotropic forms. It is mined by a special technique called **Frasch Process**. It is used for **vulcanizing of rubber** and in the manufacture of dyes and explosives.
- Sulphur is a multivalent non-metal. It is a yellow crystalline solid. Sulphur is infamous for its smell, frequently compared to **rotten eggs**. Compounds of Sulphurs are very useful as medicines, drugs and insecticides.
- The most important compound of Sulphur is Sulphuric Acid (H_2SO_4). Sulphur is used in batteries, detergents, fungicides, **gunpowder**, matches and **fireworks**. Other applications are making corrosion-resistant concrete, which has great strength.
- Sulphur is found in all living organisms where it forms part of the amino acids **cysteine** and **methionine** and also other proteins. Proteins like **Keratin** (found in hair, feathers, nails and claws) are rich in sulphur. Some bacteria can make use of sulphur. Some bacteria can make use of sulphur compounds, producing **hydrogen sulphide or rotten-eggs gas (H_2S)**. This gas may be produced by the breakdown of organic mater in swamps or sewers.

Uses

- Sulphur reacts with methane (CH_4) to give Carbon Disulphide (CS_2), which is used in the manufacturing of **cellophane** and **rayon**.
- One of the uses of Sulphur is in **Vulcanization of rubber**.
- Sulphides are used to bleach paper and as **preservatives of dried fruit**.
- **Gypsum** ($CaSO_4.2H_2O$) is mined for the use in **portland cement** and **fertilizer**.
- Sulphur is one of the components of **gunpowder**.
- The most important form of sulphur for fertilizer is the mineral **Calcium Sulphate**.
- **Epsom Salt** (Magnesium Sulphate), when in hydrated crystal form, can be used as a **laxative** and additive.
- **Dusting sulphur**, elemental sulphur in powdered form, is a common fungicide for grapes, strawberry and several other crops.
- In organic production, sulphur is the most important **fungicide**. It is the only fungicide used in organically formed apple production against the main disease apple scab.

Nitrogen (N)

It is about 78% in atmospheric air. Plants and trees take nitrogen in the form of nitrate from the soil. **Nitrogen is used in artificial insemination of cows** for which the sperm of bull is kept in it. Nitrogen is also present in urea. **About 46% of urea is nitrogen**. Nitrogen does not have any allotropes.

Nitrogen Fixation in Plants : In leguminous plants, in the joints of the roots, **rhizobium** bacteria helps in nitrogen fixation.

Compounds

1. **Ammonia (NH_3) :** It is prepared in the laboratory by **Haber process**. At high pressure, when ammonia is heated with carbon dioxide, urea is formed. Liquefied ammonia is used in freezing water in the refrigrerators.
2. **Ammonium Chloride (NH_4Cl):** It is used in dry cells.
3. **Nitrous Oxide (N_2O):** It is also called **laughing gas**. N_2O is used as **anaesthesia**.
4. **Aquaregia (Conc. HNO_3 + 3 Conc. HCL):** This is a mixture of one part conc. HNO3 and three parts conc HCl by volume. In aqua regia, gold, platinum and silver easily dissolve, which ordinarily do not dissolve in strong acids.

Facts

1. **Hydrazine** (NH_2) is used as fuel for rockets and aircraft.

2. **HNO_3** (Nitric acid) is used in the manufacture of explosives like Dynamite, TNT (trinitrotoluene) and TNB (trinitrobenzene).

Oxygen (O_2)

It is prepared in the laboratory by heating potassium chlorate ($KClO_3$) in the presence of a catalyst MnO_2 at 375°C.

Ozone (O_3)

It is an allotrope of oxygen. It is a very active gas. The ozone layer is a layer in the upper sphere, 10-50 km above the earth's surface. Ozone, the first allotrope of any chemical element, was named by **Christian Friedrich Schoanbein** in 1840.

Ozone is a pale blue gas, slightly soluble in water. It is responsible for absorbing a large proportion of the sun's UV (ultra-violet) radiation which is otherwise harmful. It also causes cancer.

The unit to express ozone in Earth's atmosphere is called **Dobson unit**. The highest levels of ozone in the atmosphere are in the **stratosphere**. Ozone in the stratosphere is mostly produced from short-wave ultraviolet rays reacting with oxygen.

Halogens

Halogen means salt producer. Halogens are Fluorine (F) Chlorine (Cl), Bromine (Br), Iodine (I). Iodine exhibits the characteristics of metalloid, because it has a metallic lustre.

1. Chlorine (Cl)

Bleaching powder and chloroform are compound of chlorine. Chlorine is used in the production of **Mustard Gas** and **phosgene**.

Uses of Chlorine:

(i) In sterilising drinking water and also water in swimming pools. This is because of the germicidal nature of chlorine which kills harmful bacteria present in water.

(ii) In the manufacture of Poly Vinyl Chloride **(PVC)**, chlorofluorocarbons **(CFCs)**, chloroform ($CHCl_3$), etc.

(iii) In the commercial preparation of bleaching powder and hydrochloric acid.

(iv) In the manufacture of pesticides and disinfectants.

2. Bromine (Br)

In India it is found in the form of brine in the Rann of Kutch. It is used in the manufacturing of **sleeping drugs** and **weeping gases**.

3. Iodine

In human body, iodine exists in the form of organic compound **thyroxin** in **thyroid gland**. Due to the deficiency of iodine, thyroid glands increase abruptly. This swelling in the gland is called **goitre**. The compound of iodine is used as pain relievers. The main source of iodine is nature is **chile saltpetre**, in which sodium iodate ($NaIO_3$) is its main component. Iodine occurs in abudance in laminarian seaweeds.

Inert Gases

Helium (He), Neon (Ne), Argon (Ar), Krypton (Kr), Xenon (Xe) and Radon (Rn) are **inert gases**. These are also known as **noble gases**.

1. **Helium (He):** It is the second largest element found in the universe. This gas is filled in balloons and left in open sky for making predictions and relevant calculations.
2. **Neon (Ne):** It is used in fluorescent bulbs and Neon lamps.
3. **Argon (Ar):** It is used in filling ordinary bulbs.
4. **Krypton (Kr):** It is often used with other rare gases in fluorescent lamps
5. **Xenon (Xe):** It is a colourless, dense, odorless noble gas found in the Earth's atmosphere.
6. **Radon (Rn):** This element is used in **radiotherapy** in the treatment of cancer. Radon is non-existent in nature. Rn comes out as a by-product of disintegration of radium.

Alloys and their uses

Alloy	Percentage Composition	Uses
Magnalium	Al = 95%, Mg=5%	Pressure cookers, balance beams, some light instruments.
Duralumin	Al = 95%, Cu=4%	Making parts of aeroplanes and automobiles, pressure cookers etc.

Alloys and their uses		
Alloy	**Percentage Composition**	**Uses**
Bronze	Cu=90%, Sn=10%	For making statues, coins, utensils etc.
Brass	Cu=80%, Zn = 20%	For making utensils, parts of machinery, condenser tubes, wires etc.
Gun metal	Cu=90%, Sn=10%	For making gun barrels.
Bell metal	Cu = 80%, Sn = 20%	For making bells and gongs.
German silver	Cu=60%, Zn=20%, Ni = 20%	For making silverware, resistance wires.
Phosphor bronze	Cu-95%, Sn=4.8%, P=0.2%	For making springs, electric switches.
Monel metal	Cu=30%, Ni=67%	For making corrosion-resistance pumps and containers for storing acids.
Coinage silver	Ag = 90%, Cu=10%	For making silver coins.
Silver solder	Ag=63%, Cu = 30%, Zn = 7%	For soldering.
Dental alloy	Ag = 33%, Hg=52%, Sn = 12.5%, Cu=2%, Zn = 0.5%	For filling teeth.
Solder	Pb=50%, Sn = 50%	For soldering broken pieces.
Type metal	Pb = 70%, Sb=20%, Sn=10%	For making printing type.
Stainless Steel	Fe=73%, Cr=18%,	Utensils, cycle and automobile parts, shaving blades, watch cases.
Nickel steel	Fe=98-96%, Ni = 2-4%	Cables, automobile and aeroplane parts, armour plates, gears and drilling machines.
Alnico	Fe=60%, Ni = 20%, Al = 12%, C = 8%	Permanent magnets.
Chrome steel	Fe=98%, Cr=2%	Axles, ball bearings, files and cutting tools.

Silicon (Si)

Uses:

- Silicon is used as n-type and p-type semiconductors. Silicon and germanium are extensively used in very pure forms in **semiconductor** devices, which are the basis of the whole electronic industry, including computer hardware.
- Silicon is a very important component of ceramics, glass and cement. It is added to steel or iron as such or more usually in the form of ferrosilicon to increase its resistance from attack by acids.
- Very pure silicon is used to make computer chips. Its alloys such as silicon bronze and manganese-silicon bronze possess strength and hardness even greater than steel. Silicon dioxide is also called silica.

Uses of Silica

- Different forms of silica have many uses. The most important application of **quartz** is as a **piezoelectric** material and is used in **crystal oscillators** for radios and computers, filters for frequency control and in electro-metallurgical devices such as **transducers** and pick-ups.
- Silica has made it possible to develop extremely accurate clocks, modern radio and television broadcasting and mobile radio communications. The coloured varieties of quartz are used as gemstones, e.g., **amethyst**, **jespar**, **opal**, etc.

Glass

- Glass is an amorphous and transparent or translucent solid obtained by the solidification of a mixture of silicates of different metals, one of which is always an alkyl metal.
- **Ordinary glass is a mixture of sodium and calcium silicates** and is obtained by heating a mixture of sand (SiO_2) with sodium carbonate and calcium oxide in a furnace at around 1700 K and then rapid cooling.

$$C(s)+\frac{1}{2}O_2(g)\xrightarrow{\text{Heat}}CO(g)$$

- This type of glass is called **soda lime glass** or **soft glass**. It has an approximate composition: $Na_2SiO_3.CaSiO_3.4SiO_2$ or $Na_2O.CaO.6SiO_2$

Carbon (C)

Dry ice

- **Solid carbon dioxide** is known as **dry ice**. It is soft, white, snow-like substance and looks like ice. However, it does not wet a piece of cloth or paper because it sublimes without melting. On the other hand, ordinary ice wets a piece of cloth on melting since it does not sublime. Solid carbon dioxide is used as a **refrigerant** under the commercial name **Drikold**.

Allotropes of Carbon

Elemental carbon exists in many allotropic forms. **Allotropic forms** or **allotropes** are the different forms of the same element having different physical properties but almost similar chemical properties.
The phenomenon of existence of allotropic forms of an element is called **allotropy**.

Carbon exists in two types of allotropic forms:

1. **Crystalline:** Diamond and graphite are two crystalline forms of carbon having a well-defined structure.
2. **Amorphous:** There are many amorphous forms of carbon such as coal, wood charcoal, animal charcoal, lamp black, coke, gas carbon, etc.

Diamond and Graphite

Diamond: There are various types of diamond which are found all over the world. The important ones are
(a) Culinan (3032 carats)
(b) Hopp (445 carats)
(c) Kohinoor (186 carats)
Diamond is deadly poisnous substance. It is transparent to x-ray. It is a bad conductor of heat and electricity.
Bort: Some diamonds are black which are called **Bort**. Extremely shining characteristics of diamond is due to **internal reflection** of light.
Use: Black diamonds (Bort) are used in making glass-cutting devices and rock-drilling machines. Bort is known as **carbonado** in market.

Uses of Diamond

(i) Due to its hardness, it is used for cutting glass, for making bores for rock drilling and for making abrasives for sharpening hard tools.
(ii) Due to its brilliance, diamond is used in jewellery as a precious stone. When it is cut at certain angles and polished, brilliant light is refracted from its surfaces, it becomes a precious gem.
(iii) It is used for grinding and polishing hard materials.
(iv) It is also used for making dice for drawing thin wires of metals.
(v) It is used in the manufacture of tungsten filaments for electric light bulbs.

Uses of Graphite

(i) Graphite is used in making electrodes.
(ii) It is used as a **lubricant for heavy machines** running at high temperature, where oil cannot be used as a lubricant.
(iii) It is used in the manufacture of crucibles which can withstand high temperatures.
(iv) Mixed with wax or clay, graphite is used for making **lead pencils**.
(v) Graphite is also used as a **moderator** for fast-moving neutrons in atomic reactors.

Some of the important properties of Diamond and graphite are:

(i) Diamond is denser than graphite. The density of diamond is 3.514 g cm^{-3} while that of graphite is 2.226 g cm^{-3}.

(ii) Diamond is hard while graphite is soft. Graphite has lubricating properties. On the other hand, diamond is the **hardest** substance known.

(iii) Diamond is a bad conductor of electricity while graphite is a good conductor of electricity.

(iv) Diamond is extremely chemically unreactive whereas graphite is quite reactive.

Uses of Carbon

Carbon is used extensively in its different forms.

- **Coal** is used as a fuel in boilers, engines, furnaces, etc. It is also used for the manufacture of coal gas, water gas, producer gas and synthetic petrol. It is largely used as a reducing agent in metallurgy.
- **Carbon black** is used as black pigment in black ink and as filler in automobile tyres.
- **Charcoal** (activated) being porous is used as an excellent adsorbent to purify and deodorize sugar and other chemicals. It is also used to adsorb poisonous gases in gas masks and for removing offensive odour from the air used in air conditioning processes. It is also used in water filters to remove organic contaminators.
- **Graphite**, being a good conductor of electricity, is used for making electrodes in batteries and industrial electrolysis. Graphite fibres embedded in plastic material form high strength, lightweight composites. The composites are used in products such as tennis rackets, fishing rods, aircraft and canoes. Graphite is also used in steel making, metal foundries for crucibles, as a lubricant and in pencils etc. Crucibles made from graphite are inert to dilute acids and alkalies. Graphite is also used as the moderator in the cores of gas-cooled nuclear reactors to slow down neutrons.

Diamonds (allotropes of carbon) are cut as gemstones and used in jewellery and other articles. It is measured in carats **(1 carat = 200 mg)**. It is also used for industrial purposes, mainly for making drills or as an abrasive powder for cutting and polishing.

Important compounds of Carbon

Carbon combines with a variety of other elements to form binary compounds such as oxides, halides and carbides.

Oxides of Carbon: Carbon burns in air or oxygen to form two oxides, namely (a) carbon monoxide (CO) and (b) carbon dioxide (CO2).

Carbon monoxide (CO)

Preparation:

- Carbon monoxide is prepared by the incomplete combustion of carbon or carbon-containing compounds in a limited supply of oxygen.

$$C(s) + \frac{1}{2}O_2(g) \xrightarrow{\text{Heat}} CO(g)$$

$$\text{or} \quad 2C(s) + O_2(g) \xrightarrow{\text{Heat}} 2CO(g)$$

- Carbon monoxide is present in exhaust gases from automobiles due to incomplete combustion of carbon or carbon compounds during burning of petrol or diesel.
- The mixture of **CO and H_2** is called **water gas** or **synthesis gas.** When air is passed instead of steam, a **mixture of CO and N_2** are formed. This mixture is called **producer gas**.

$$2C(s)+\underbrace{O_2(g)+4N_2(g)}_{\text{Air}} \xrightarrow{1273\text{ K}} \underbrace{2CO(g)+4N_2(g)}_{\text{Producer gas}}$$

- Water gas and producer gas are very important industrial fuels. Carbon monoxide present in water gas or producer gas can undergo further combustion, forming carbon dioxide with the evolution of heat.

$$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$$
$$\Delta_r H^\circ = -566 \text{ kJ mol}^{-1}$$

- Carbon monoxide is also present in volcanic gases, gases from the furnaces where coal is burnt, exhaust gases from automobile engines, fumes of tobacco, etc.

Properties:

1. Carbon monoxide is colourless, odourless and is almost insoluble in water.
2. **Toxic nature:**

   It is highly toxic in nature. The toxic nature of CO is due to its ability to form a complex with haemoglobin in the red blood cells.

   CO forms a complex with haemoglobin stronger than oxygen. The CO complex with haemoglobin is about 300 times more stable than the oxygen-haemoglobin complex. Therefore, if CO is present, it will form stable compound with haemoglobin and this will destroy the oxygen-carrying ability of blood. As a result, blood will not take up oxygen easily, causing suffocation and finally death.

Uses:

- Carbon monoxide is used as an industrial fuel in the form of water gas and producer gas:
- **Water gas** is a mixture of carbon monoxide and hydrogen. **It is obtained by passing steam over red hot coke.**

$$C + H_2O \text{ (steam)} \rightarrow \underbrace{CO + H_2}_{\text{Water gas}}$$

- Both water gas and producer gas contain CO as their important component which can undergo further oxidation to form carbon dioxide and liberate enormous amount of heat. Therefore, these are used as important industrial fuels.
- It is used in some metallurical processes. For example, in the metallurgy of iron, it is used as a reducing agent.

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

- It is used in *Mond's process* for the purification of nickel by forming nickel carbonyl.
- It is used in the manufacture of methyl alcohol, formic acid, etc.
- Its compound with iron (iron carbonyl) is used in the manufacture of magnetic tapes for tape recorders.

Carbon dioxide (CO_2)

- Carbon dioxide has different physical characteristics from carbon monoxide. Some important physical properties of CO_2:
- Carbon dioxide is slightly soluble in water. Its solubility in water, however, increases with increase in pressure. **Soda water and other aerated soft drinks are solutions of carbon dioxide in water** (containing sugar, some flavouring and colouring substances) under pressure.
- Carbon dioxide can be readily liquefied under a pressure of 50-60 atm. at room temperature.

Uses of carbon dioxide:

- in the preparation of aerated waters like soda water.
- as a fire extinguisher because it is a non-supporter of combustion.
- in the manufacture of washing soda by Solvay's process.
- as a refrigerant in the form of **solid carbon dioxide (dry ice)**. Solid carbon dioxide can sublime to the gaseous state without passing through the liquid state and, therefore, it is called dry ice. **It is also used as a coolant for preserving perishable food items such as meat**. Dry ice is also used for curing local burns and in hospitals for surgical operations of sores.
- in the manufacture of urea by its reaction with ammonia.
- for the purification of cane sugar juice in the manufacture of sugar.
- in plants during photosynthesis of glucose, starch and cellulose.

Important inorganic compounds and their formula

Name of Compound	Chemical Formula	Chemical Name
Baking Soda	$NaHCO_3$	Sodium Bicarbonate
Washing Soda	$NaCO_3.10H_2O$	Sodium Carbonate
Caustic Soda	$NaOH$	Sodium Hydroxide
Borax	$Na_2B_4O_7.10H_2O$	Sodium Borate
Potash Alum	$K_2SO_4Al_2(SO_4)_3.24H_2O$	Potassium Aluminium Sulphate
Bleaching Power	$CaOCl_2$	Calcium Oxychloride

Important inorganic compounds and their formula		
Name of Compound	**Chemical Formula**	**Chemical Name**
Gypsum	$CaSO_4.2H_2O$	Calcium Sulphate
Plaster of Paris	$CaSO_4.1/2H_2O$	Calcium Sulphate
Laughing Gas	N_2O	Nitrous Oxide
Red Vermilion	Pb_3O_4	Lead Peroxide
Oil of Vitriol	Conc.H_2SO_4	Cone. Sulphuric Acid
Aqua Regia	$HNO_3 + 3HCl$	Royal Water
Water Gas	$CO+H_2$	Mixture of Carbon Monoxide and Hydrogen
Bauxite	$Al_2O_3.2H_2O$	
Solid Ice/Dry Ice	CO_2	Solid Carbon Dioxide
Green Vitriol	$FeSO_4^{-}7H_2O$	Ferrous Sulphate
White Vitriol	$ZnSO_4.7H_2O$	Zinc Sulphate
Vermillion	HgS	Mercurid Sulphate
Heavy Water	D_2O	Deuterium Oxide
Blue Vitriol	$CuSO_4.5H_2O$	Copper Sulphate
Producer Gas	$CO + N_2$	Mixture of Carbon Monoxide and Nitrogen
Gammexene	$C_6H_6Cl_6$	Benzene Hexachloride
Vinegar	CH_3COOH	Dilute Solution of Acetic Acid
Juice of Grapes	$C_6H_{12}O_6$	Glucose
Freon	CF_2Cl_2	Dicholoro Difluoro Carbon
Urea	NH_2CONH_2	Carbamyde
Chloroform	$CHCl_3$	Trichloromethane
Iodoform	CHI_3	Tri-iodom ethane
MIC (Methyl Isocyanate)	CH_3NC	Methyl Isocyanate
Starch	$C_6H_{10}O_5$	
Sugar	$C_{12}H_{22}O_{11}$	