# NEET | JEE ESSENTIALS

Class XI

Maximise your chance of success, and high rank in NEET, JEE (Main and Advanced) by reading this column. This specially designed column is updated year after year by a panel of highly qualified teaching experts well-tuned to the requirements of these Entrance Tests.

## Unit 1 SOME BASIC CONCEPTS OF CHEMISTRY | STRUCTURE OF ATOM

## SOME BASIC CONCEPTS OF CHEMISTRY

### Introduction

- Chemistry is the branch of science which deals with the study of composition, structure and properties of matter and the changes which the matter undergoes under different conditions and the laws which govern these changes.

**Importance and Scope of Chemistry**

- To increase the yield of crop by providing chemical fertilizers, insecticides, fungicides.
- Contribution to better health and sanitation by providing effective medicines like *cis*-platin and taxol for cancer therapy and AZT for helping AIDS victims.
- In industry like plastic, sugar, pharmaceuticals, petroleum, etc.

### Physical Quantities and their Measurements

| Measure | Unit |
|---|---|
| Length ($l$) | Metre (m) |
| Mass ($m$) | Kilogram (kg) |
| Time ($t$) | Second (s) |
| Temperature ($T$) | Kelvin (K) |
| Electric current ($i$) | Ampere (A) |
| Intensity ($I_v$) | Candela (Cd) |
| Amount of substance ($n$) | Mole (mol) |

| Measure | Derivation |
|---|---|
| Volume ($V$) | Length × Height × Breadth $= \mathrm{m \times m \times m = m^3}$ |
| Density ($d$) | $\frac{\text{Mass}}{\text{Volume}} = \frac{\text{kg}}{\text{m}^3} = \text{kg m}^{-3}$ |
| Velocity ($v$) | $\frac{\text{Distance}}{\text{Time}} = \frac{\text{m}}{\text{s}} = \text{m s}^{-1}$ |
| Force ($F$) | Mass × Acceleration $= m \times a$ $= \text{kg m s}^{-2}$ = Newton (N) |
| Work ($W$) | Force × Displacement $= F \times d$ $= \text{kg m}^2\ \text{s}^{-2}$ = Joule |
| Temperature ($T$) | K = °C + 273.15 |

### Uncertainty in Measurement

#### Precision & Accuracy

- If the average value of different measurements is close to the correct value, the measurement is said to be accurate. If the value of different measurements are close to each other and hence close to their average value, the measurement is said to be precise.

### Significant Figures

- Significant figures in a number are all the certain digits plus one uncertain digit.

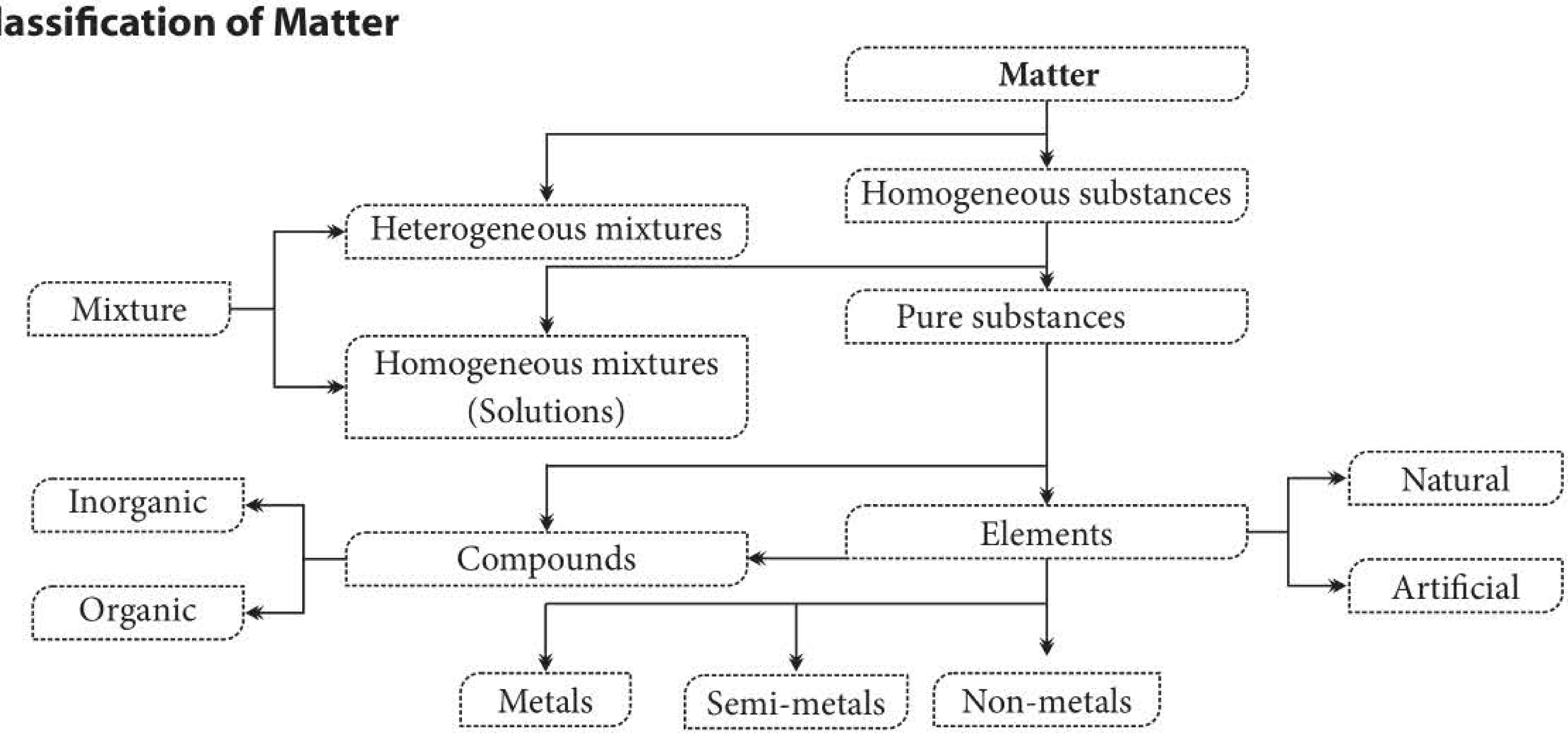
#### Rules to determine significant numbers

- All non-zero digits as well as the zeros present between the non-zero digits are significant.
- Zeros to the LHS of the first non-zero digit in a given number are not significant figures.
- In a number ending with zeros, if the zeros are present at right of the decimal point then these zeros are significant figures.
- Zeros at the end of a number without a decimal are not counted as significant figures.
- The result of division or multiplication must be reported to the same number of significant figures as possessed by the least precise term.
- The result of subtraction or addition must be reported to the same number of significant figures as possessed by the least precise term.

## MATTER

- Anything which has mass and occupies space is known as matter.

### Classification of Matter




## LAWS OF CHEMICAL COMBINATIONS

**Laws of Chemical Combinations**

**Law of Conservation of Mass (*Lavoisier*)**
Matter can neither be created nor destroyed.

**Law of Constant Composition or Definite Proportions (*Proust*)**
A given compound always contains exactly the same proportion of elements by weight.

**Law of Multiple Proportions (*Dalton*)**
If two elements can combine to form more than one compound, the masses of one element that combine with a fixed mass of the other element, are in the ratio of small whole numbers.

**Law of Reciprocal Proportions (*Richter*)**
The ratio of the masses of two elements *A* and *B* which combine separately with a fixed mass of the third element *C* is either the same or some simple multiple of the ratio of the masses in which *A* and *B* combine directly with each other.

**Gay Lussac's Law of Gaseous Volumes**
When gases combine or are produced in a chemical reaction they do so in a simple ratio by volume provided all gases are at same temperature and pressure.

**Avogadro's Law**
Equal volumes of gases at the same temperature and pressure should contain equal number of molecules.

## Dalton's Atomic Theory

- All substances are made up of tiny, indivisible particles, called atoms. The word atom was derived from the Greek word atomos (meaning - indivisible.)
- Atoms cannot be created, divided or destroyed during any chemical or physical change (the law of conservation of mass.)
- Each element is composed of its own kind of atoms.
- The atoms of a given element are alike, and have the same mass. The atoms of different elements differ in mass and properties.
- The atoms combine with each other in simple whole number ratios to form a compound.

## Atomic Mass

- The atomic mass of an element is the average relative mass of its atoms as compared with an atom of carbon-12 isotope taken as 12.

## Molecular Mass

- The molecular mass of a substance is the average relative mass of its molecules as compared with an atom of carbon–12 isotope taken as 12.

## Mole Concept

Number of moles → $\dfrac{\text{Mass of the substance}}{\text{Molar mass of the substance}}$

↓

1 mol → $6.022 \times 10^{23}$ chemical units (atoms, ions, molecules)

↓

22.4 L of any gas at NTP

## Mole Concept in Solutions

- It is an expression to represent the amount of solute in a given quantity of solvent.

**Concentration of Solution**

- Mass percent = $\dfrac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$
- Molarity ($M$) = $\dfrac{\text{Moles of solute}}{\text{Volume of solution (L)}}$
- Mole fraction = $\dfrac{\text{Moles of a solute}}{\text{Total no. of moles of solution}}$
- Molality ($m$) = $\dfrac{\text{Moles of solute}}{\text{Mass of solvent (kg)}}$

## Determination of Empirical Formula and Molecular Formula

**Step 1 :** Moles of the element $= \dfrac{\text{Percentage of element}}{\text{At. mass}}$ → **Step 2 :** Simplest molar ratio = $\dfrac{\text{Molar ratio}}{\text{Minimum molar ratio}}$ → **Step 3 :** Empirical formula → **Step 4 :** $\dfrac{\text{Molar mass}}{\text{Empirical formula mass}} = n$

Molecular formula = $n$ × Empirical formula

$n$ is integer such as 1, 2, 3 ... etc.

INFOSHOTS

**Mass-energy conservation!**

The place where conservation of mass routinely falls down in nuclear fusion and fission, where large amounts of matter are converted to energy. Sunshine and starlight are the most visible examples. The sun converts about 5 million tons of mass to energy every second. In the process of fusing, 700 million tons of hydrogen convert to helium. It can go on at that rate for billions of years.

# STRUCTURE OF ATOM

## Sub-Atomic Particles

| | Electron ($e^-$) | Proton ($p$) | Neutron ($n$) |
|---|---|---|---|
| **Position** | Moves around the nucleus | Constituent of nucleus | Constituent of nucleus |
| **Charge** | $-1.6 \times 10^{-19}$ C | $+1.6 \times 10^{-19}$ C | neutral |
| **Absolute mass (kg)** | $9.1 \times 10^{-31}$ | $1.67 \times 10^{-27}$ | $1.67 \times 10^{-27}$ |
| **Relative mass** | 1/1836 | 1 | 1 |
| **Discovery** | J. J. Thomson | E. Goldstein | J. Chadwick |

## Atomic Models

**Rutherford's Model**
The positive charge is concentrated in extremely small region called nucleus.
Electrons move around the nucleus in circular path called orbits.

**Thomson Model**
Atom is spherical, in which positive charge is uniformly distributed.
The electrons are embedded into it.

Atomic number ($Z$) = Number of protons ($p$) → Elements having same atomic number but different atomic mass are called isotopes.

Mass number ($A$) = No. of protons ($p$) + No. of neutrons ($n$) → Elements having same mass number but different atomic number are called isobars.

Number of neutrons ($n$) $= A - Z$ → Elements having same number of neutrons are called isotones.

Symbol of elements $^{A}_{Z}X$

## Developments Leading to the Bohr's Model of Atom

**Electromagnetic Radiations :**
J.C Maxwell proposed that light and other forms of radiations propagate through space in the form of waves. These waves have electric and magnetic fields associated with them and are therefore called electromagnetic radiations.

**Wavelength($\lambda$)**
Distance between two consecutive points.

**Frequency ($\nu$)**
$\nu = \dfrac{\text{velocity}}{\text{wavelength}}$

**Wave Number ($\bar{\nu}$)**
$\bar{\nu} = \dfrac{1}{\lambda}$

**Electromagnetic spectrum :** It is the arrangement of components of different types of electromagnetic radiations in increasing order of wavelength or decreasing order of frequency.

| Cosmic rays | γ-rays | X-rays | UV | Visible | IR | Micro-waves | Radio-waves |
|---|---|---|---|---|---|---|---|

Increasing wavelength or decreasing frequency →

- Different types of spectra :

**Spectra**
- Atomic spectra
- Molecular spectra
- Line spectra — Each line in spectra represents one electronic transition
- Band spectra
- Absorption spectra
- Emission spectra
- Continuous spectra
- Discontinuous spectra

**Planck's Quantum Theory :**
- Definite amount of radiant energy is emitted or absorbed discontinuously in the form of small packets, called quanta.
- Amount of energy associated with quantum of radiation, is proportional to frequency of light *i.e.*

$E \propto \nu,\ E = h\nu,\ E = \dfrac{hc}{\lambda}$

$h$ = planck's constant ($6.626 \times 10^{-34}$ Js)

**Black Body Radiation**
An ideal body which emits and absorbs radiations of all wavelengths or frequencies.

**Photoelectric Effect**
When a beam of light of suitable wavelength falls on a clean metal plate in vacuum, electrons are emitted from the surface of metal. This phenomenon is known as photoelectric effect
$h\nu = h\nu_0 + 1/2\, mv^2$;
$h\nu_0$ = Minimum energy required to eject an electron = work function ($w$)

**INFOSHOTS**

**How old is hydrogen in our body!**
Every hydrogen in your body is likely to be 13.5 billion years old, since they were created during the birth of the universe. All the other elements formed by fusing hydrogen into helium, which then fused into carbon and so on.

## Atomic Spectra of Hydrogen

- Radiations emitted by hydrogen in discharge tube experiment when passed through prism gives six series of lines named after the researchers.

| | Name of series | Wavelength | $n_1$ | $n_2$ | Region |
|---|---|---|---|---|---|
| 1. | Lyman | $\frac{1}{\lambda}=R_H\left[\frac{1}{1^2}-\frac{1}{n^2}\right]$ | 1 | $n > 1$ | UV |
| 2. | Balmer | $\frac{1}{\lambda}=R_H\left[\frac{1}{2^2}-\frac{1}{n^2}\right]$ | 2 | $n > 2$ | Visible |
| 3. | Paschen | $\frac{1}{\lambda}=R_H\left[\frac{1}{3^2}-\frac{1}{n^2}\right]$ | 3 | $n > 3$ | IR |
| 4. | Brackett | $\frac{1}{\lambda}=R_H\left[\frac{1}{4^2}-\frac{1}{n^2}\right]$ | 4 | $n > 4$ | IR |
| 5. | Pfund | $\frac{1}{\lambda}=R_H\left[\frac{1}{5^2}-\frac{1}{n^2}\right]$ | 5 | $n > 5$ | far IR |
| 6. | Humphrey | $\frac{1}{\lambda}=R_H\left[\frac{1}{6^2}-\frac{1}{n^2}\right]$ | 6 | $n > 6$ | far-far IR |

- Rydberg formula : $\bar{v}=\frac{1}{\lambda}=R_H\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)Z^2$ where, $R_H$ is Rydberg constant and has a value equal to 109,677 $cm^{-1}$.

## Bohr's Atomic Model for Hydrogen

- Around the nucleus there are circular regions called orbits or shells.

| Energy shell | $K$ | $L$ | $M$ | $N$ | $O$.... |
|---|---|---|---|---|---|
| $n$ | 1 | 2 | 3 | 4 | 5.... |

Energy and distance from nucleus increase from $K$ onwards

- Every orbit has a fixed amount of energy so, it is also referred to as an energy level.
- An electron revolves around the nucleus without any loss of energy in a particular orbit of definite energy that is why orbit is called stationary state also.
- Angular momentum ($mvr$) in each orbit is quantised, $mvr = n\frac{h}{2\pi} = n\hbar$

  here, $h$ is Planck's constant.

| $n$ : | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| $mvr$ : | $\frac{h}{2\pi}$ | $\frac{h}{\pi}$ | $1.5\frac{h}{\pi}$ | $2\frac{h}{\pi}$ |

- When electron changes its orbit, energy change occurs in quanta.

  $\Delta E = E_2 - E_1 = h\upsilon$ or $= \frac{hc}{\lambda}$

  $E_2 - E_1 > E_3 - E_2 > E_4 - E_3 > E_5 - E_4$ and so on.

- **Derived Formulae of Bohr's Theory (for $n^{th}$ orbit)**

| | For hydrogen | For H– like particles |
|---|---|---|
| Energy ($E_n$) | $\frac{-1312}{n^2}$ kJ/mol | $\frac{-1312\ Z^2}{n^2}$ kJ/mol |
| Radius ($r_n$) | $0.529 \times n^2$ Å | $\frac{0.529\ n^2}{Z}$ Å |
| Speed ($v_n$) | $\frac{2.18\times10^8}{n}$ cm $s^{-1}$ | $\frac{2.18\times10^8}{n}\times Z$ cm $s^{-1}$ |

## Limitations of Bohr's Model

- Mathematically, Bohr's model explains only mono-electronic atoms and fails to explain repulsion in multielectronic atoms.
- It does not explain the distribution of electrons in orbits.
- It does not provide mathematical support to assumption, $mvr = n\times\frac{h}{2\pi}$
- It is against de Broglie and Heisenberg's principles.
- It does not explain the splitting of spectral lines under the influence of electric field (Stark effect) and magnetic field (Zeeman effect).

## Dual Nature of Radiation

- de Broglie has suggested that light can behave as a wave as well as like a particle. In 1924, de Broglie suggested that all microscopic particles such as electron, proton and atoms, etc. also have dual character.

  de Broglie wavelength, $\lambda = \frac{h}{mv} = \frac{h}{p}$

- Relation between Kinetic energy and wavelength,

$$\lambda = \frac{h}{\sqrt{2\times KE\times m}}$$

## Heisenberg's Uncertainty Principle

- According to this principle, it is impossible to determine simultaneously, the exact position and exact momentum (or velocity) of an electron. If the value of one is determined with certainty, the accuracy in determining the other value is compromised.

$$\Delta x . \Delta p \geq \frac{h}{4\pi}$$

$$\Delta x . m\Delta v \geq \frac{h}{4\pi}$$

Here, $\Delta x$ = uncertainty in position
$\Delta v$ = uncertainty in velocity

# Quantum Mechanical Model of Atom

## Schrodinger Wave Equation

$$\frac{d^2\psi}{dx^2}+\frac{d^2\psi}{dy^2}+\frac{d^2\psi}{dz^2}+\frac{8\pi^2 m}{h^2}(E-V)\psi=0$$

$\psi$ = amplitude of wave
$E$ = total energy of electron
$V$ = potential energy
$m$ = mass of electron

### Significance of $\psi$ and $\psi^2$

- $\psi$ : It has no physical significance. It represents amplitude of electron-wave or boundary surface of an orbital.
- $\psi^2$ : It is the probable electron density or it is the probability of finding electrons in any region (three dimensional space around the nucleus). If $\psi^2$ is positive, electrons are present and if $\psi^2$ is zero electrons are absent.

# Orbitals and Quantum Numbers

- **Orbital :** An orbital is a variably shaped, three dimensional region around the nucleus within which the probability of finding an electron is maximum.
- **Quantum numbers :** It is a set of four numbers which give complete information about all the electrons in an atom.

| Quantum Numbers | Values | Information Given |
|---|---|---|
| Principal quantum number | $n = 1, 2, 3$ ... | • Energy of main shell.<br>• Maximum number of electrons present in $n^{th}$ shell = $2n^2$ |
| Azimuthal quantum number ($l$) | For a given value of $n$, $l = 0$ to $n - 1$.<br>For $s$ subshell, $l = 0$<br>For $p$ subshell, $l = 1$<br>For $d$ subshell, $l = 2$<br>For $f$ subshell, $l = 3$ | • It determines number of subshells.<br>• Shape of subshell.<br>• Angular momentum of the electron $= \sqrt{l(l+1)}\frac{h}{2\pi}$ |
| Magnetic quantum number ($m$ or $m_l$) | For a given value of $l$, $m = -l$ to $+l$ possible values of $m_l = (2l + 1)$ | • It determines number of orbitals present in one subshell = $(2l + 1)$.<br>• Number of orientations of each orbital. |
| Spin quantum number ($s$ or $m_s$) | $s = +\frac{1}{2}$ or $-\frac{1}{2}$ | • It tells about direction of electron spin, *i.e.*, clockwise or anticlockwise. |

**Node :** It represents the region where probability of finding an electron is zero, (*i.e.*, $\psi$ and $\psi^2 = 0$.)

Calculation of Nodes :

Node = $(n - 1)$

Radial nodes $(n - l - 1)$ | Angular nodes $l$

**Aufbau Principle :** The principle states that electrons are added progressively to the various orbitals in the order of increasing energies. The increasing order of energies of various orbitals is
$1s\ 2s\ 2p\ 3s\ 3p\ 4s\ 3d\ 4p\ 5s\ 4d\ 5p\ 6s\ 4f\ 5d\ 6p\ 7s$ ...

**Rules for Filling of orbitals**

**Hund's Rule :** This rule states that the pairing of electrons in the orbital of a particular subshell ($p$, $d$, or $f$) does not take place until all the orbitals of the subshell are singly filled.

**Pauli Exclusion Principle :** No two electrons in an atom can have the same set of four quantum numbers or only two electrons may exist in the same orbital and these electrons must have opposite spin.