2

ATOMIC STRUCTURE

- **Atom (Given by Dalton):** Matter is made up of extremely small particles which are indivisible in nature. It consists of subatomic particles electron, proton and neutrons knows as ***fundamental particles.***

1. **Electron (Named by Stoney):** Discovered by Cathode Ray experiment [In ***crook's tubes***]. A long glass tube with two metal electrodes. At every low pressure when high voltage is applied a flow is produced due to flow of − ve charge particle [known as electron], cathode rays. Cathode rays have −ve change, travel in straight lines has electric and magnetic field have heating effect more penetrating effect. Charge on e^- was found by ***Oil drop*** experiment [***Millikan***].

2. **Proton (Discovered by Goldstein in anode ray experiment:** In a perforated cathode tube with gas at low pressure high voltage was passed between electrode rays from cathode produced green ***fluorescence*** on ZnS all. These were called as ***anode rays***. They travel in straight line, with + ve charge, get defected in electric and magnetic field.

3. **Neutron:** Fundamental particle which carries no charge but has mass equal to N atom or Proton. Discovered by ***James Chadwick***.

Table 2.1 Fundamental particles of atom and their characteristics

Particle	Symbol	Mass/ kg	Actual Charge / C	Relative charge
Electron	*e*	$9.109\ 389 \times 10^{-31}$	$-1.602\ 177 \times 10^{-19}$	−1
Proton	*p*	$1.672\ 623 \times 10^{-27}$	$1.602\ 177 \times 10^{-19}$	+1
Neutron	*n*	$1.674\ 928 \times 10^{-27}$	0	0

Atomic Number, Mass Number, Isotopes and Isobars

- **Atomic number (Z):** The no. of protons or electron in a neutral atom or No. of protons in an atom (or ion).
- **At mass no. (A):** Total no. of protons and neutron in an atom

$A = \text{No. of } (P + n)$ $\qquad$ $A - Z = \text{No. of neutrons}$

- **Isotopes:** Atoms of same element with different mass no. $[{}^{14}_{7}N, {}^{15}_{7}Al]$
- **Isobars:** Atoms of different element with same mass no. $[{}^{40}_{20}Ca; {}^{40}_{18}Ar]$
- **Isotones:** Atoms of different element with same no. of neutron. $[{}^{23}_{11}Na; {}^{24}_{12}Mg]$
- **Isoelectronic:** Atoms, molecules or ions with same no. of e^-[Ne; O^{2-}].

Earlier Models

Thomson's Model

- **J.J. Thomson:** The sphere of +ve change nucleus model of atom is 14 Chemistry balanced by coulombic force of attraction of e^-. ***Like a Raisin Pudding Model***

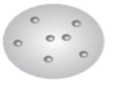


Fig. 2.1: A pictorial representation of Thomson's plum-pudding model

Rutherford's Experiment

- **Ruther Ford (Discovery of nucleus):** particles (+ve charge) bombarded on gold foil.

a. **99.9% passed without deflection:** Most space inside the atom is empty. (b) Only few deflected therefore mass of atom centrally placed called ***nucleus***.

b. Very few deflected back therefore mass of atom contains *+ve* charge particles [***Protons***].

c. Atom is electrically neutral hence *−ve* change particles placed outside the nucleus and have very less mass.

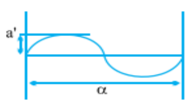
- **Limitations:** No distribution and energies of e^- considered, could not explain e^- does not fall into the nucleus or not; no details of line spectra of H atom.

Electromagnetic Radiations

- Energy emitted from any source (in forms of waves) in which electric and magnetic fields oscillated perpendicular to each other and travelling with a velocity to light is known as EM radiation.

Characteristic Parameters of Electromagnetic Radiations

a. **Wavelength:** the distance of one crest and one trough in a wave. Denoted by 'λ'



b. **Frequency:** no. of waves passing through a given point in one second.

Denoted by υ. $\left[\begin{array}{l}\upsilon = \frac{1}{t} \Rightarrow \sec^{-1} \text{ or Hz} \\ t = \text{Time period}\end{array}\right]$

c. **Amplitude:** The height of crest or depth of a trough denoted by 'a'

d. **Wave no.:** No. of waves per unit length denoted by $\bar{\upsilon}$

$$\bar{\upsilon} = \frac{1}{\lambda} = cm^{-1} \text{ (or } m^{-1}\text{)}$$

e. **Velocity:** Linear distance travelled by a wave in one second.

$$\text{velocity of light } c = \frac{\text{Distance}}{\text{Time}} = \lambda \times \frac{1}{t} = \upsilon\lambda$$

$$\therefore \upsilon = \frac{c}{\lambda}$$

Electromagnetic Spectrum

- Energy wise order for EM radiation.

cosmic < γ rays < X rays < *uv* < VIBGYOR < IR < Microwaves < Radiowaves

$\longrightarrow$ λ Inc. $\longrightarrow$ υ Dec. $\longrightarrow$ $\bar{\upsilon}$ Dec. $\longrightarrow$ Energy Dec.

Line Spectrum

- When the vapors of some volatile substance are allowed to fall on the flame of a Bunsen burner and then analyzed with the help of a spectroscope. Some specific-colored lines appear on the photographic plate which is different for different substances. For example, sodium or its salts emit yellow light while potassium or its salts give out violet light.

Line Spectrum of Hydrogen Atom

- Hydrogen spectrum: When e^- in hydrogen atom is provided energy it gets excited to higher shell from ground state, it comes back to ground state by emitting energy in definite values.
- **"Quanta":** The emission of light energy is known as emission spectra. It corresponds to each atom depending upon which energy shell e^- is excited. It is discontinuousspectra as 'λ' of light

radiations do not merge with each other like is ***VIBGYOR*** (Continuous Spectra). When e^- falls from any excited state to

$$\frac{1}{\lambda} = 1{,}09{,}678\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]Z^2$$

a. I^{st} energy level $n_f = 1$, $n_i = 2, 3, 4, ...$ ***[Lyman series] (UV)***

b. When e^- to final state $n_f = 2$, $n_i = 3, 4, 5, ...$ ***[Balmer series] (VIBGYOR)***

c. When e^- to falls to final state $n_f = 3$ $n_i = 4, 5, 6$ ***[Paschem series] IR.***

d. When e^- to falls to final state $n_f = 4$ $n_i = 5, 6, 7$ ***[Bracket series] IR.***

e. When e^- to falls to final state $n_f = 5 n_i = 6, 7, 8$ ***[Pfund series] IR.***

Bohr's Model

- Bohr's theory for H [H like one e^- systems He^+; Li^{2+}]e^-revolving round the nucleus in circular path [stationery state; ***[Shell]***With a definite angular momentum $\frac{nh}{2\pi}$ [n no. of shell of e^-] and with definite energy

$$\left[\frac{-2\pi^2 me^4 z^2}{n^2h^2}\right] \Rightarrow -2.18 \times 10^{-18}\frac{Z^2}{n^2}\text{J/Atom}$$

- As n increases Z Decreases Energy of e^- becomes≤less -ve [Due to less, force of Proton attraction]
- As n Decreases Z increases Energy of e^- becomes More -ve [Due to more force of attraction by protons]
- In infinity shell e^- has zero force of attraction therefore zero energy.
- Electron energy only changes by definite values **$\Delta E = E_f - E_i$.**

$$\frac{hc}{\lambda} = 2.18 \times 10^{-18}\left[\frac{1}{n_i^2} - \frac{1}{n_f^2}\right]Z^2\ \text{J/Atom}$$

$$\frac{1}{\lambda} = \frac{2.18 \times 10^{-18}}{\lambda}\left[\frac{1}{n_i^2} - \frac{1}{n_f^2}\right]Z^2$$

$$\left[\begin{array}{l}\text{If } n_i > n_f \text{ energy emitted by } e^- \\ n_i > n_f \text{ energy absorbed by } e^-\end{array}\right]$$

$$= 109678\left[\frac{1}{n_i^2} - \frac{1}{n_f^2}\right]Z^2\ \text{cm}^{-1}$$

Rydberg constant

Wave – Particle Duality

- **Debroglie equation:** All material particles possess both matter should also exhibit wave like properties. Wave character as well as wave character as well as wave character.

$$\lambda = \frac{h}{mv} \quad \text{or} \quad \lambda = \frac{h}{p}$$

- For microscopic particles mass is very less therefore 'λ' more and more wave character.
- For macroscopic particles mass is large λ is less therefore more particle character.

$$\text{Dual behaviour}\left[\begin{array}{l}e^- \text{ behaves as a particle as well as wave} \\ \text{Photon behaves as wave as well as particle}\end{array}\right]$$

Heisenberg's Uncertainty Principle

- It is impossible simultaneously to determine the exact position and exact velocity of a subatomic particle.

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

Δx = uncertainty in position

Δv = uncertainty in momentum

- For microscopic (mass very less) certainty in position is less therefore Δx is more Δv is less.
- For macroscopic (large mass) certainty in position is more Δx is less Δv is more.

Wave Mechanical Model Of Atom

- ***Erwin Schrödinger*** proposed the quantum mechanical model of the atom, which treats electrons as matter waves. The wave mechanical model proposed that the electrons act like particles as well as waves of energy. According to the fields around, the electrons change their path and they move very fast, hence they are not in one place during any particular time. The wave mechanical model was used for the construction of an atom.

Significance of Quantum Numbers

1. Principal Q. No. : It describes the distance of e^- from nucleus 'n' i.e., defines the shell no. It is denoted by 'n'.

$n = 1, 2, 3, 4, 5, \ldots$
K, L, M, N, O .....

2. Azimutha Q. No. : It defines the path of e^- decided by angular momentum of e^-. Each angular momentum value corresponds to one subshell. The no. of subshells in a shell is 0 to n−1.

n	l (0 to n^{-1})				
1	0	$l = 0$	's'	subshell	
2	0, 1	$l = 1$	'p'	subshell	
3	0, 1, 2	$l = 2$	'd'	subshell	
4,	0, 1, 2, 3	$l = 3$	'f'	subshell	

All subshells are wave functions for locating e^-In the same shell energy wise ***S < P < d < f***

3. **Magnetic Q. No. :** It gives the no. of magnetic orientations an e^- can have in a subshell. The no. of magnetic orientation an e^- can have in a subshell. $\Rightarrow -l$ to 0 to $+l$.

4. **Spin Q. No. :** An e^- is continuously spinning on its own axis. This Q. No. describes e^- can have clockwise spin motion $\left(+\frac{1}{2}\text{value}\right)$ or e^- can have anticlockwise spin motion $\left(-\frac{1}{2}\right)$. An orbital can have mximum two e^- one with clockwise and other with anticlockwise spin.

Electronic Configuration of Elements

Aufbau (or building up) Principle

a. e^- are filled in increasing order of energy of subshell.

b. As 'n + l' value increases energy of e^- increases in that subshell.

c. For two subshells with some 'n + l' value. As 'n' value increases energy of e^- increases.

Pauli's Exclusion Principle

- No two e^- can have same set of 4 quantum nos. If two e^- are present in same shell, subshell, orbital they will have different spin value.

Hund's Rule

- The pairing of e^- in degenerate orbitals (different orbitals with same energy) will get paired only once they have been singly occupied. The no. of [Spherical nodes or radical nodes] = n - l -1.

Shapes of Orbitals

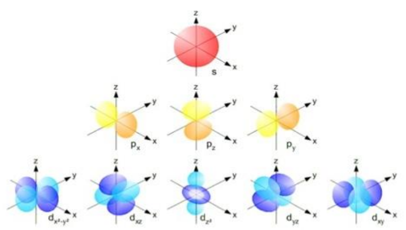


Fig. 2.18: The boundary surface diagrams (shapes) of the s, p, d-orbitals

Difference between psi and psi square:

(E) ψ(psi)	ψ^2(psi square)
A wave function for locating ane^-	The square of wave function where the probability of finding the e^- is maximum. [Each value of ψ^2 is a region and **defines** one orbital]

Difference between Orbit and Orbitals:

(F) Orbit	Orbital
(1) A definite distance from the nucleus for finding the e^- [e^- as a particle]	(1) A probability region for locating the e^- around the nuclues. It is a wave function [e^- as a wave]
(2) It has definite size and e^- in this orbit has definite energy.	(2) It does not define definite size. But only a boundry region diagram of a wave for locating the e^-.

Check Yourself

1. How many orbital's can have the following set of quantum numbers, n = 3, l = 1, m1 = 0?

(A) 3 (B) 1

(C) 4 (D) 2

2. Electronic configuration of the outer shell of the element Gd with atomic number 64 is

(A) $4f^4 5d^5 6s^1$ (B) $4f^3 5d^5 6s^2$

(C) $4f^5 5d^4 6s^1$ (D) $4f^7 5d^1 6s^2$

3. Maximum number of electrons in a subshell can be

(A) 4l + 2 (B) 4l – 2

(C) $2n^2$ (D) 2l + 1

4. The orientation of atomic orbital's depends on their

(A) Spin quantum number
(B) Magnetic quantum number

(C) Azimuthal quantum number
(D) Principal quantum number

5. A gas X has Cp and CV ratio as 1.4, at NTP 11.2 L of gas X will contain________ number of atoms

(A) 1.2×10^{23} (B) 3.01×10^{23}

(C) 2.01×10^{23} (D) 6.02×10^{23}

Stretch Yourself

1. Calculate the mass and charge of one mole of electrons.
2. Calculate the number of electrons which will together weigh one gram.
3. What is the value of the Bohr's radius for the first orbit of hydrogen atom?
4. Distinguish between a photon and a quantum
5. What type of metals is used in photoelectric cell? Give one example.

Test Yourself

Question: The Vividh Bharati station of All India Radio, Delhi, broadcasts on a frequency of 1,368 kHz (kilo hertz). Calculate the wavelength of the electromagnetic radiation emitted by transmitter. Which part of the electromagnetic spectrum does it belong to?

Answer: Wavelength =λ

Frequency = v = 1,368 kHZ

c = speed of light =v×λ

λ=c/λ=3×108/1368×103=219 meters

Answers

Check Yourself

Answer: 1(D); 2(C); 3(A); 4(B); 5(C)

Stretch Yourself

1. Mass of one mole of electrons is $9.11\times10^{-31}\times6.023\times10^{23}=5.486\times10^{-7}$kg.

Charge of 1 mole of electrons is $1.602\times10^{-19}\times6.023\times10^{23}=9.647\times10^{4}$C.

2. The number of electrons which will weigh 1 g is $10^{-3}\ \backslash 9.11\times10^{-31}=1.098\times10^{27}$

Mass of one mole of electrons is $9.11\times10^{-31}\times6.023\times10^{23}=5.486\times10-7$kg.

Charge of 1 mole of electrons is $1.602\times10^{-19}\times6.023\times10^{23}=9.647\times10^{4}$C.

3. Hint: We know that Neil Bohr was the first to explain the general features of hydrogen atom structure and its spectrum. Bohr's theory can be applied on the ions containing only one electron similar to that of hydrogen atom like Li2+, Be3+ and He+, such species are also called hydrogen like species.

Formula used: For hydrogen like species, the radii expression from bohr's theory is given as: **r_n=a°(n2)\Z pm**

4. The smallest packet of energy of any radiation is called a quantum whereas that of light is called photon.

5. When exposed to light, the alkali metals lose electrons. This is known as photoelectric effect. Electrons of lithium are strongly held by nucleus as Li is smaller in size and therefore, requires high energy to lose an electron. While on the other hand, Cs has low ionization energy. Hence, it can easily lose electrons and cannot be utilized in photoelectric cells.