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Chemistry

Atom and It's Structure

Lecture :- 2

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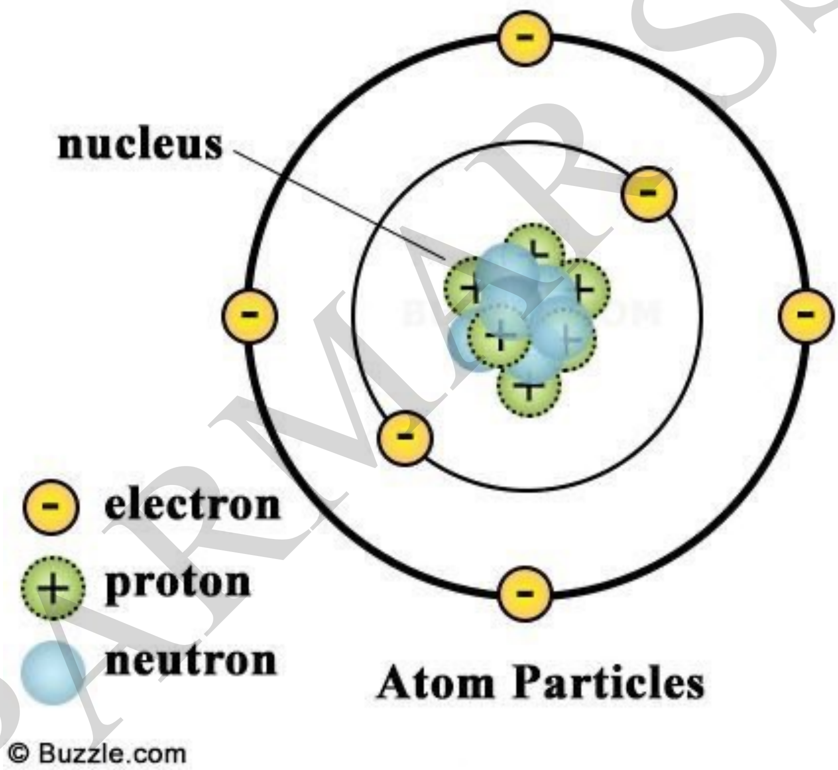
STRUCTURE OF ATOMS



What are atoms?

- Building blocks of matter
- Democritus named atom

Laws of Chemical Combination

- Given by Lavoisier and Joseph Proust

Law of Conservation of Mass

- In a chemical reactions the mass of reactants and product remain constant

Law of Constant Proportion

- Many compounds were composed of two or more elements and each such compounds had the same elements in the same proportion, irrespective of where the compound came from or who prepared it

Dalton's Atomic Theory

1. All matter is made of very tiny particle called atoms
2. Atoms are indivisible particles, which cannot be created or destroyed in a chemical reaction
3. Atoms in a given element are identical in mass and chemical properties
4. Atoms of different elements have different masses and chemical properties
5. Atoms combine in the ratio of small whole numbers to form compounds
6. The relative number and kind of atoms are constant in a given compound

Symbols of Elements

- The symbol of iron is Fe → from Latin name ferrum
- Na from natrium
- Potassium symbol K → from Kalium
- Copper → Cyprus (country name)
- Berzelius → gave for the first time the symbol for chemical element
- Dalton used it for the first time

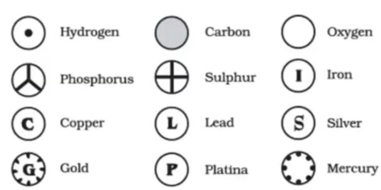
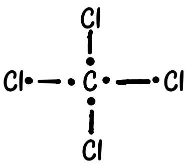


Fig. 3.3: Symbols for some elements as proposed by Dalton

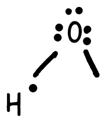
Atomicity

H• —— •H → H_2 → Diatomic

He: → Monoatomic



→ CCl_4



→ H_2O → Triatom

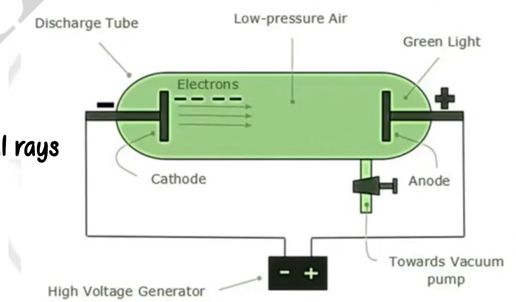
Table 3.3 : Atomicity of some elements

Types of Element	Name	Atomicity
Non-Metal	Argon	Monoatomic
	Helium	Monoatomic
	Oxygen	Diatomic
	Hydrogen	Diatomic
	Nitrogen	Diatomic
	Chlorine	Diatomic
	Phosphorus	Tetra-atomic
	Sulphur	Poly-atomic
Metal	Sodium	Monoatomic
	Iron	Monoatomic
	Aluminium	Monoatomic
	Copper	Monoatomic

- Dalton mentioned atoms are indivisible particle but subatomic particles (electron, proton, neutron)

- Electron discovered by J J Thomson
- Proton discovered by Rutherford or Goldstein
- Neutron discovered by Chadwick

discovered Canal rays



Discovery of Electrons

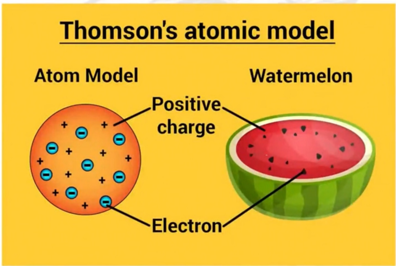
Comparison of the Characteristics of Electron, Proton and Neutron

Particle	Charge on the particle	Mass of the particle	Symbol	Location in the atom
1. Electron	−1 unit (−1.602 × 10^{-19} coulomb)	9.11 × 10^{-31} kg ($\frac{1}{1840}$ u)	$_{-1}^{0}e$	Outside the nucleus (Extranuclear part)
2. Proton	+1 unit (+1.602 × 10^{-19} coulomb)	1.673 × 10^{-27} kg (1 u)	$_{+1}p^{1}$	In the nucleus
3. Neutron	No charge	1.675 × 10^{-27} kg (1 u)	$_{0}^{1}n$	In the nucleus

Thomson's Atomic Model

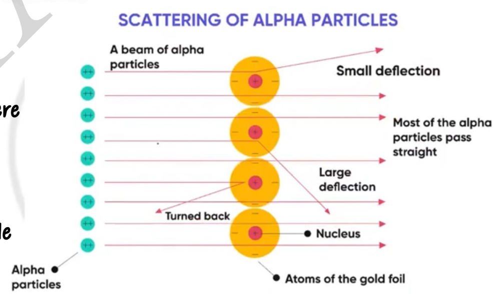
- J J Thomson is 1904 proposed that an atom was a sphere of +ve electricity in which were embedded no of e- sufficient to neutralise the +ve charge
- This may be compared with a watermelon in which seeds were embedded or with a pudding containing currents (dry fruits)
- This model of atom is called Thomson Model

Demonstration :-



Rutherford Model

- Ernst Rutherford was interested in knowing how the e- are arranged within an atom. Rutherford an experiment for this
- In this experiment fast moving α-particle were made to fall on thin gold foil



- Gold foil → He wanted a thin layer as possible
  ↓
  About 1000 atoms thick

- $\alpha \rightarrow {}^{4}_{2}He$

2 → Deflect
1 → Rebound
6 → Passed without deflection

- It was expected that particle would be deflected by the subatomic particles in the gold atoms. Since, the α-particle were much heavier than the proton, he did not expect to see large deflection
- But the α-particle scattering experiment gave totally unexpected result

Observations

1. Most of the fast moving α-particles passed straight through the gold foil, i.e. went undeflected
2. Some of the particles were deflected through small angle, and a few were deflected through large angle
3. Surprisingly, one out of 12000 particles (very few) appeared to rebound

In other words of Rutherford, "This result was almost as incredible as if you fire a 15-inch shell at a piece of tissue paper and it comes back and hits you"

Explanations

1. Most of the space inside atom is empty because most of the α particles passed through the gold foil without getting deflected
2. Some particles were deflected from their path, indicating that there is a positively charged body in an atom
3. The α-particles deflected through small angles were those which passed close to this positive body
4. The α-particles deflected through large angles were which passed very close to the positive body

Rutherford Model

- The small heavy positively charged body present within the atom was called nucleus
- Rutherford put forward a model of atom known as Rutherford's nuclear model
- An atom consists of two parts:
  - Nucleus
  - Extranuclear part
- The entire mass of the mass of the atom is concentrated in the nucleus. Since the e^- have neglible mass, the mass of the atom is mainly due to protons. Hence, protons must be present in the nucleus
- Since some α-particles are deflected back and α-particles are heavy particles, these could be deflected back only when they strike heavier body inside the atom
- Since number of deflection is very small this shows that the heavy body present in the atom must be occupying a very small volume

Drawbacks of the Model

- The revolution of e^- in a circular orbit is not expected to be stable
- Any particle is a circular orbit would undergo acceleration
- During acceleration, charged particles would radiate energy
- Thus, the revolving e^- would lose energy and finally fall into the nucleus
- If this were so, the atom should be highly unstable and hence matter would not exist in the form we know
- We know that atoms are quite stable
- The e- do not fall into the nucleus as a result of attraction, Rutherford suggested that e were not stationary but were revolving around the nucleus in certain circular orbits. As a result, centrifugal force comes into play which balances the force of attraction

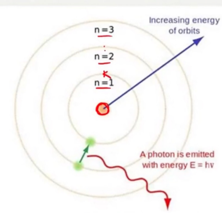
Bohr's Model of the Atom

- To explain the stability of atom, Niels Bohr, a Danish physicist in 1913 proposed a new model of atom
- e^- revolve only in certain fixed orbits around the nucleus without losing energy in the form of radiations
- The main points of this model of atom (called postulates of Bohr's model of atom) are as follows:

1. An atom consists of a small heavy positively charged nucleus in the centre and the electrons revolve around it in circular paths called orbits
2. So as long as an e-revolving in a particular orbit, it can neither lose or gain energy. Thus, the atom is stable and does not collapse. The atom with lowest energy is called ground state of atom
3. Energy lost or gained, when e^- jumps from one orbit to another

$$\Delta E = E_{n_1} \sim E_{n_2}$$

Bohr's atomic model



$E_1 < E_2 < E_3 < E_4$

K, L, M, N , ...

N > M > L > K

Ions

- The charged species are called ions
- -ve charged ion → Anion
- +ve charged ion → Cation
- Positron → Discovered in 1932 by Carl Anderson

Eg: Sodium Chloride (NaCl) constitutes +ve charged Na+ (sodium) and -ve charged Cl- (chlorine)

Neutrons

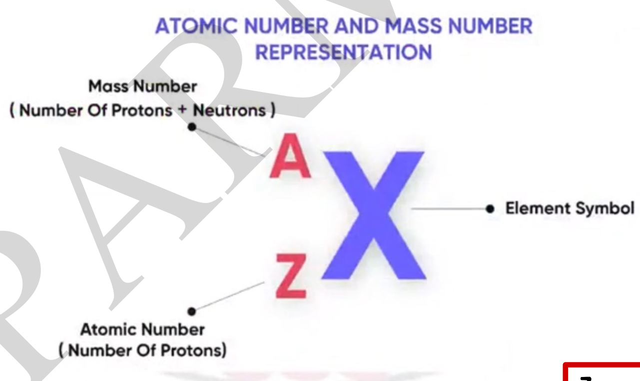
- Sub-atomic or fundamental particle which carries no charge
- It is neutral particle but has a mass nearly equal to that of proton (i.e., 1 amu)

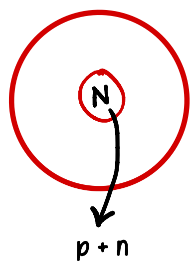
Atomic Number

- Z = no of proton
- Atomic no is always a whole no., because they contains whole no. of protons
- All atoms of the same element have the same no of protons in the nucleus and hence have same atomic no.
- No two elements have the same atomic no.
- Atomic no. is always a whole no. This is because an atomic no. of an element does not change during a chemical reaction

Mass Number

- Mass no of an element is the sum of the no. of protons and neutrons present in the atom of the element
- Since protons and neutrons are present in the nucleus, these particles are collectively called nucleons. Thus, Mass no. of an element is equal to no. of nucleons in the atom of that element





Z = no. of e^- = no. of p^+

$A = p + n$

$A = Z + n$

$A - Z = n$

For fluorine, A = 19, Z = 9, calculate p, n, e in the neutral atom and the ion formed by it

→ $p = e^- = 9$

$n = A - Z = 10$

9 = 2, 7

Valency = 1

Distribution of e–

- The maximum number of e that can be present in the nth shell is equal to $2n^2$. Thus, we have
- Last shell/orbit → Valence shell → e^- → Valence e^-

Shell	Maximum no. of electrons present
1st shell or K-shell (n=1)	$2x1^2 = 2$
2nd shell or L-shell (n=2)	$2x2^2 = 8$
3rd shell or M-shell (n=3)	$2x3^2 = 18$
4th shell or N-shell (n=4)	$2x4^2 = 32$

Electronic Configuration of First 20 Elements

Element	Atomic symbol	Atomic number	Number of protons	Electronic Configuration- Distribution of electrons in the Shells				Number of Neutrons	Mass Number	Molecular formula
				K	L	M	N			
Hydrogen	H	1	1	1				0	1	H_2
Helium	He	2	2	2				2	4	He
Lithium	Li	3	3	2	1			4	7	Li
Beryllium	Be	4	4	2	2			5	9	Be
Boron	B	5	5	2	3			6	11	B
Carbon	C	6	6	2	4			6	12	C
Nitrogen	N	7	7	2	5			7	14	N_2
Oxygen	O	8	8	2	6			8	16	O_2
Fluorine	F	9	9	2	7			10	19	F_2
Neon	Ne	10	10	2	8			10	20	Ne
Sodium	Na	11	11	2	8	1		12	23	Na
Magnesium	Mg	12	12	2	8	2		12	24	Mg
Aluminium	Al	13	13	2	8	3		14	27	Al
Silicon	Si	14	14	2	8	4		14	28	Si
Phosphorus	P	15	15	2	8	5		16	31	P
Sulphur	S	16	16	2	8	6		16	32	S
Chlorine	Cl	17	17	2	8	7		18	35	Cl_2
Argon	Ar	18	18	2	8	8		22	40	Ar
Potassium	K	19	19	2	8	8	1	20	39	K
Calcium	Ca	20	20	2	8	8	2	20	40	Ca

Valency of e⁻

- The e⁻ present in outermost shell of the atom of an element is called valance e⁻, outermost shell is called valance shell

Valency

- The no. of e⁻ gained, lost or shared by the atom of an element so as to complete its octet, called valency of the elements
- Also known as combining capacity of an element

Calculation

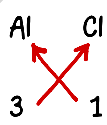
- To calculate the valency of an element, the electronic configuration of the element to 1st written, then the valency of element calculated as follows
- For elements having valence e⁻ 1,2,3, valency = no. of valence e⁻
- For elements having valence e⁻ 4,5,6,7 valency = no. e⁻ to be added so that the valence shell has 8 e⁻ i.e.; Valency = 8 – no. of valence e⁻

Examples

F → Z= 9, E.C = 2,7 and Chlorine → Z= 17, E.C = 2,8,7 have 7 valence e⁻ → Valency → 8–7 = 1
O → Z= 8, E.C = 2,6 and Sulphur → Z = 16, E.C = 2,8,6 have 6 valence e⁻ → Valency → 8–6 = 2
N → Z = 7, E.C = 2,5 and Phosphorus → Z = 15, E.C = 2,8,5 have 5 valence e⁻ → Valency → 8–5 = 3

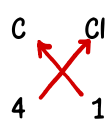
Writing Chemical Formulae of a Compound

- For eg:
- Aluminium Chloride



$AlCl_3$

- Carbon Tetachloride



CCl_4

An ion M^{3+} contains

$e = 10$

$n = 14$

$A = ?$

$Z = ?$

What is A and Z of element M?

→ $e = 10$

$Z = 13$

$n = M - Z$

$14 = M - 3$

$M = 27$

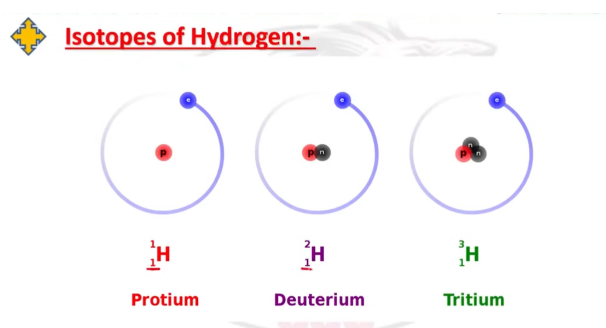
$^{27}_{13}M$

Isotopes

- Isotopes are the atoms of the same elements which have same atomic number but different mass number
- That isotope of an element differ only in the number of neutrons present in the nucleus

Isotope of Hydrogen

1. $^{1}_{1}H$ ($e^- = p = 1, n = 0$) → Protium
2. $^{2}_{1}H$ ($e^- = p = 1, n = 1$) → Deuterium
3. $^{3}_{1}H$ ($n = 2, p = e^- = 1$) → Tritium ↓ radioactive



Isotopes of Carbon

1. ${}_{6}C^{12}$ (e = p = 6, n = 6)
2. ${}_{6}C^{14}$ (e = p = 6, n = 8) → We use to determine Rock age
3. ${}_{6}C^{13}$ = p = 6, n = 7

Characteristics of Isotope

1. Same chemical properties

same electronic configuration, so same no. of valence e^-. Since chemical property depends upon the no. of valence e^-. Therefore they have same chemical properties

2. Different physical properties

Since, the isotopes of an element have different masses, different physical properties like melting point, boiling point, density etc

Atomic mass of chlorine = 35.5

${}^{35}_{17}Cl$: ${}^{37}_{17}Cl$
3 : 1

$$\text{Atomic mass} = \frac{35 \times 3 + 37 \times 1}{3 + 1}$$

= 35.5

Isobars

- Atoms of different element have same mass number but different atomic number
- A = same, z → Different, ∴ e^-, p → Different

Eg: ${}_{18}Ar^{40}$ → e^- = p = 18, n = 22
${}_{20}Ca^{40}$ → e^- = p = 20, n = 20 } Isobars

Important Characteristics

1. They are atoms of different element
2. Z = different, A = same
3. Have different physical and chemical properties
4. No. of protons, electrons, neutron are different

Some important characteristics of isobars

- They are atoms of different elements
- They have different atomic number
- They have same mass number
- They possess different physical and chemical properties
- They have different number of protons, electrons, neutrons

Eg:

- $_8O^{16}$ → $e = p = 8, n = 8$
- $_7N^{15}$ → $e = p = 7, n = 7$

} Isotone

- $_{92}U^{235}$, $_{92}U^{238}$ $Z = 92$ for both → Isotope
- $_{19}K^{40}$, $_{20}Ca^{40}$ $A = 40$ for both → Isobar
- $_2He^3$, $_2He^4$ $Z = 2$ for both → Isotope
- $_8X^{16}$ $_8X^{18}$ $Z = 8$ for both → Isotope

Mole Concept

- Avogadro no. = 6.022×10^{23}
  ↓
  1 mole

- No. of mole = $\frac{\text{Given mass (m)}}{\text{Molecular mass (M)}} = \frac{\text{Given no. of particles (N)}}{\text{Avogadro no. } (N_o)}$

$$n = \frac{m}{M} = \frac{N}{N_o}$$

- What will be no. of moles in 2 g of He?

→ $n = \frac{2}{4} = \frac{1}{2} = 0.5$ mole

- No. of moles in 12.044×10^{24} particles of N atom?

→ $n = \frac{12.044 \times 10^{24}}{6.022 \times 10^{23}} = 20$

- The proton/neutron is 1836/1840 times heavier than electron

- No. of e−determines chemical properties

An atom has:
$A = 37$
$Z = 17$
protons = ?

→ $p = e^{-} = Z$
$= 17$

- Orbit/shell close to nucleus is K shell

- Mass of e in orbital shell = 9.108×10^{-28} g

- Value of proton = $+0.16 \times 10^{-18}$ C

- Weight of atom depends on proton and neutron

- If both K and L shell are full, the Z of an electron will be: 10 → He