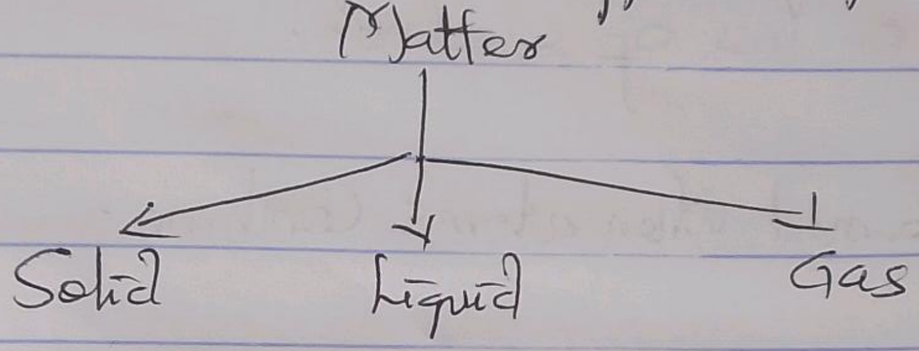
General Chemistry

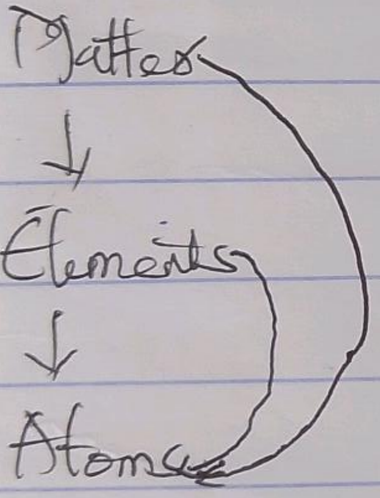
CHEM 101 24/11/2025

Lecturer: Dr. Obini

Topic: Atoms, Ions and Molecules

Matter: Is anything that has mass and occupy space.
Matter exists in three different forms.





Atoms constitute elements and elements constitute matter.

Atoms: are the smallest particle of an element. The first concept of Atoms was proposed by "John Dalton".

Ions: Are atoms which have lost or gained electron
Ions are atoms that carry charge.

* Atoms that become ions by gain of electron are called "Anions".
Similarly, Atoms that become ions by loss of electron are called "Cations".

* Every ion is made by the process of "Ionization" which is simply gain or loss of electron.

Molecules: Are formed when atoms combine.

eg 1: $H + H^+ = H_2$
↓ ↓ ↓
Atom Ion Molecule

eg 2: $2H + O = H_2O$
↓ ↓ ↓
Atom Ion Molecule

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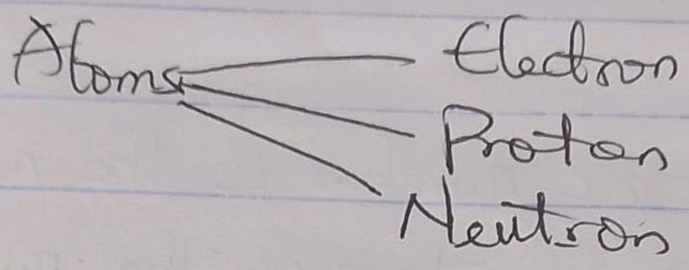
Topic 3

Atomic Masses

Atoms has sub particles which include;

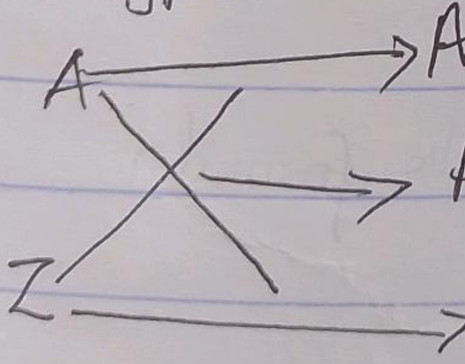


* Electron is the negatively charged particles of an element. Its mass is 0.0005 Amu. 1 Amu = 1.6605×10^{-24} g
Amu means Atomic mass Unit.

* The proton is a positively charged particle of an element found in the nucleus.

* The Neutron has no charge and it is found in the nucleus of an element.

A typical atom is represented as:



Eg

$^{12}_{6}C$

* Atomic Number [Z]: Atomic number is the number of protons in the nucleus of an atom or the number of electron in a neutral atom.

$^{19}_{19}K = 19$

K^+ = no. of Proton 19
no. of electron 18

* Mass number or atomic mass [A]: It is the number of protons and neutrons in the nucleus of an atom of an element. $A = P + N$

$A = p + N$

Making N the subject of the formula

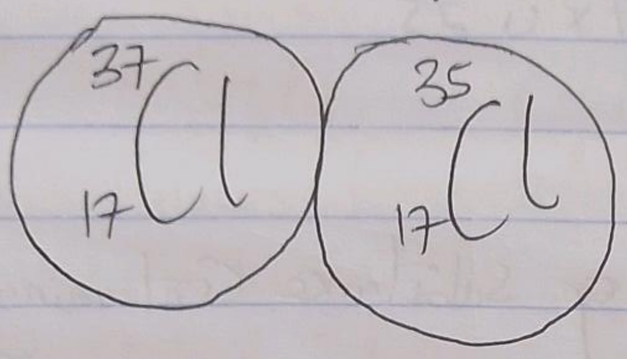
$N = A - P$

$= 12 - 6$

$= 6$

$^{12}_{6}C$

* Isotopy: Is the existence of an atom of the element with the same number of protons but different number of neutrons.



mass no m =

m = p + n

OR

Is the existence of an atom with the same mass number but different atomic numbers.

* Relative Atomic Mass [R.A.M]: Is the average mass of an atom in relative to 1/12th mass of carbon 12.

e.g Cl = 35.45

Carbon is the most abundant element.

Mathematically, $R.A.M = \frac{\sum \text{Istopic mass} \times \text{abundance}}{\sum \text{abundance}}$

E.g If chlorine has two Istopes ^{35}Cl (75%) and ^{37}Cl (25%) Calculate the Relative atomic mass [R.A.M]

Solution

$^{35}Cl = 75\%$

$^{37}Cl = 25\%$

$$R.A.M = \frac{35 \times 75}{100} + \frac{37 \times 25}{100}$$

$$= 35 \times 0.75 + 37 \times 0.25$$

$$= 35.5$$

* **Mole Concept:** Is the amount of substance containing 6.022×10^{23} particles/atoms/molecules.

Note: $6.022 \times 10^{23} \rightarrow$ Avogadro's Number $[N_A]$

$$\text{Mole} = \frac{\text{Mass}}{\text{Molar Mass}}$$

Exercise 3

Given N_A atom contains 3.011×10^{23} atoms. Calculate the no. of atoms of that solution.

Solution

1 mole of $N_A = 6.022 \times 10^{23}$

x mole of $N_A = 3.011 \times 10^{23}$

$$= \frac{1 \times 3.011 \times 10^{23}}{x 6.022 \times 10^{23}} = \frac{x 6.022 \times 10^{23}}{6.022 \times 10^{23}}$$

$$x = \frac{3.011 \times 10^{23}}{6.022 \times 10^{23}}$$

$$= 0.5 \text{ mole}$$

* Empirical formula: It is the simplest whole number ratio of atom of each element with a Compound.

Eg

$C_6H_{12}O_6 - CH_2O$

(Glucose)

6 : 12 : 6

1 : 2 : 1

Steps to determine Empirical Formula:

i) Obtain the Percentage Composition of mass of an element.
ii) Convert mass to moles of each element
iii) Divide all mole atom by the Supposed no. of moles.
iv) Round to the nearest whole numbers.

Eg A Compound Contains 40% C, 67% H and 53.5% O. Find the empirical formula.

Solution

C	H	O
40	67	53.5
12	1	16
= 3.33	67	3.33

Divide all sides by 3.33

$\frac{3.33}{3.33} \quad \frac{67}{3.33} \quad \frac{3.33}{3.33}$

1 2 1

∴ The empirical formula = CH_2O

* Molecular formula: Is the actual no. of atoms of each element in a compound or molecule.

Molecular Formular = n × Empirical Formula
Where n = Molar mass

Exercise:

A Compound has a molar mass of 180 g/mol. Find the molecular formulas. [Take empirical formula to be CH_2O].

Solution

$$n = \frac{180}{CH_2O} = \frac{180}{12+(1\times2)+16}$$

$$n = \frac{180}{30}$$

$$n = 6$$

Molecular formula = n × Empirical formula
$= 6 \times (CH_2O)$
$= C_6H_{12}O_6$

B: Study the law of chemical reaction.

* Stoichiometry: Deals with quantitative relationship between reactants and products in a chemical reaction. Helps to balance equations, Calculate amount of reactants needed and predict yields of products

Steps to Solving Stoichiometrics

i) Write the balanced equations.
ii) Identify the given and unknown quantities.
iii) Convert given quantities to moles.
iv) Use mole ratios.
v) Calculate moles of unknown
vi) Convert moles to desired Units.

E.g How many grams of H_2O are produced from 4g of H_2?

Solution

$$H_2 + O_2 \longrightarrow 2H_2O$$

2 moles of H_2 produces 2 moles of H_2O

4g of H_2 produces $2 \times (4 \times 12 + 16)$

$= 2 \times 18$

$= 36g$

* Electronic Configuration: Is the arrangement of electrons in an atom, showing how electrons are distributed in energy levels or orbitals.

S	p	d	f
2	6	10	14

1s
2s 2p
3s 3p 3d
4s 4p 4d 4f
5s 5p 5d 5f
6s 6p 6d 6f

Electronic Configuration of the First 20 elements

Elements	Electronic Configuration
Hydrogen (H)	
Helium (He)	
Lithium (Li)	
Beryllium (Be)	
Boron (B)	
Carbon (C)	
Nitrogen (N)	

8. oxygen (O)
9. Fluorine (Fl)
10. Neon (Ne)
11. Sodium (Na)
12. Magnesium (Mg)
13. Aluminum (Al)
14. Silicon (Si)
15. phosphorous (P)
16. Sulphur (S)
17. chlorine (Cl)
18. Argon (Ar)
19. Potassium (K)
20 Calcium (Ca)

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Topics Group ~~Elements~~ of elements [Chapter 8]

1) Hydrogen ✓
2) Nitrogen and phosphorus
3) Oxygen and Sulphur
4) The Halogens
5) Transition elements
6) Calcium and Aluminium

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Topic: Group Solution of Elements

Hydrogen: Is the smallest element, first on the periodic table and has one electron and no proton.
H_1 H_2 (Deuterium) and H_3 (Tritium or heavy hydrogen)

Reactions of Hydrogen

~~Preparation of Hydrogen~~:

1- Industrial preparation: Methane reacts with steam in a quantity of oxygen at a temperature of 900°

$$CH_4 + H_2O \xrightarrow[(Fe)]{\text{Catalyst}} CO + 3H_2 + H_2O \xrightarrow[\text{Catalyst of } 450^\circ]{Fe} CO_2 + 4H_2O$$

(g)

Methane Steam

2- Bossech process: Carbon reacts with steam

$$C + H_2O_{(g)} \longrightarrow CO + H_2$$

Steam

4B Another Industrial process is:

$$3Fe + 4H_2O \longrightarrow Fe_3O_4 + 4H_2$$

3. Electrolytic process: This is the process whereby Acidifying water Neutralizes using Cathode and anode. This is the purest form to obtain hydrogen, however it costs a lot.

4B. Water is self Ionizing $H_2O \rightarrow 4^- + OH^-$

In the electrolysis of water:

Anode: $4OH^- \rightarrow O_2 + 2H_2 + 4e^-$

Cathode: $4H^+ + 4e^- \rightarrow 2H_2$

4. Laboratory preparation: Any electropositive metals ~~with dilute acid~~ reacts with dilute acid.

$Zn + 2HCl \rightarrow ZnCl_2 + H_2$

$2Na + H_2SO_4 \rightarrow Na_2SO_4 + H_2$

The chemistry of Hydrogen: How Hydrogen form its Compound.

1. Hydrogen lose of its only electron: To form hydrogen proton. The proton cannot exist on its own, hence immediately after Ionization, it attaches itself to another element or molecule.

STUDY: What is the name of the phenomenon where hydrogen proton reacts with water: $H_2O + H^+ \rightarrow H_3O^+$

2. Toning electron from electropositive metals, thus becoming a negative ion: $H + e^- \rightarrow H^-$ [Hydride]

$Na + H \rightarrow NaH$ [Sodium hydride]

3. Forming Covalent compounds with anions [Electronegative elements]

4. Hydrogen bonding: It is a partial covalent bond, not a proper one

$H_2 + Cl_2 \rightarrow 2HCl$

$H_2 + F_2 \rightarrow 2H^+$

$H_2S \rightarrow 2 + 32 = 34$

$H_2O \rightarrow 2 + 16 = 18$

} Molar mass

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Electrochemistry (Mrs. Charity)

Electrochemistry is the study of Chemistry involving electrons and ions.

It is the study of chemical properties and reactions involving ions in solution including electrolysis and electric cell. It can also be defined as the study of the movement of electrons in system where chemical processes takes place.

* Electrolysis: Electrolysis is the production of chemical reactions by passing an electric current through an electrolyte. It is the process by which a Redox reaction is forced to take place by the passage of a direct current through an electrolyte in the molten or aqeous solution.

B An aqeous solution is a solution that its solvent is water.

Molten substance are substance that are in solid state but when heated becomes liquified.

* Electrolyte: Is a liquid that conducts electricity as a result of the presence of positive or negative ions. It is an ionic compound which when in molten or aqeous solution, conducts electricity and is decomposed to form the constitute elements.

Types: Strong, Weak, non-electrolyte.

* Electrode: Is a conductor that emits or collect electrons in a cell.
* Cathode: Is the negative electrode (Redox reaction takes place at the cathode).
* ~~Anode:~~ Cathode is attracted to the positive ions i-e the cations.

* Anode: Is the positive electrode (Redox reaction also takes place at the anode. Anode is attracted to the negative ions ie Anions.

NB: Electrons are produced at Anode and Consumed at ~~Cathode~~.

* Strong electrolyte: Ionizes completely in aqueous solution into free moving ion. Strong electrolytes are most of the Salts, the Compounds, Mainly Inorganic acids e-g HCl, e.t.c, alkanes, alkals.
Examples of strong electrolytes are aqeous Solution of Potassium hydroxide (NaOH), Sodium Sulphate, ~~Dilute~~, Dilute sulphuric acid, Copper Sulphate.

* Weak electrolyte: Are those compounds which are poor Conductors of ~~electrolysis~~ electricity when they are molten state or aqeous solution. They ionize Partially in aqeous

Solution and does not easily allow current pass through them. Examples; Ethanoic acid, Carbonic acid, boric acid, hydrocyanic acid and many other Organic acids, ammonia solution [Weak base] $\rightarrow NH_4O_3$, as well as Some salts e.g zinc, Calcium and mercury.

* Non-Electrolyte; Is a type of compound which does not allow the passage of current through itself either in molten or ageous solution. Examples; Distilled water, Benzene, Glucose and trichloromethane.

Faraday's Law of Electrolysis

The number of charges passing through a circuit is known as Quantity of Electricity (Q). The quantity of electricity is measured in Columbs (C). It is the quantity of electricity passing through a Conductor when a current of 1 Ampere flows in One Second.

$$Q = It$$

Where

Q = Quantity of electricity in Columbs.

I = Current in Ampere

t = time in Seconds

$$I = \frac{Q}{t}$$

$$t = \frac{Q}{I}$$

Another Unit of Quantity of electricity is Faraday. This means that Q can be measured in Columbs or Faraday

1 Faraday = 96500 columbs.

* Faradays 1st Law of electrolysis: States that the mass of a substance created during electrolysis is directly proportional to the quantity of electricity passing through it.

$$m \propto Q$$

$$m \text{ or } It$$

$$m = ZIt$$

Where Z is the Electro-chemical equivalent

Electrochemical equivalent of an ion can be defined as the mass of ion deposited by passage of 1 Ampere current for a Second.

Faradays first law is rigidly valued when the passage of electricity takes place mainly by electrolytic Conductance and its independent on temperature or pressure and the nature of the solvent.

* Faraday's 2nd Law of ~~Electrolysis~~: According to this law, it states that the number of moles of different ions produced by the same quantity of electricity is inversely proportional to their respective values.

~~M ∝~~

$$\text{Moles} \propto \frac{1}{\text{Charge of ion}}$$

$$\frac{\text{Mass}}{\text{Molar mass}} \propto \frac{1}{\text{Charge of ion}}$$

$$\text{Mass} \propto \boxed{\frac{\text{Molar mass}}{\text{Charge of ion}}}$$

$Z = \frac{\text{Molar mass}}{\text{Charge of ion}}$ and is also known as Chemical equivalent of the element.

* The General formula that connects the 1st and 2nd law is $m = \frac{\text{molar mass} \times Q}{nF}$

$$m = \left(\frac{\text{molar mass}}{nF}\right) \times It$$

Where n = Number of ~~Protons~~ electrons

F = Faraday's Constant

No. of moles of product formed $= \frac{It}{nF}$

NB: Charge of 1 mole of $\bar{e}$ = 1F = 96500C.

Example:

$$AgCl \rightleftharpoons Ag^{+} + Cl$$

$$Ag^{+} + e \longrightarrow Ag_{(s)}$$

To discharge 1 mole of Ag^{+}, 1 mole of electron will be required

$$Cu^{2} + 3e^{-} \rightarrow Cu_{(s)}$$

To discharge 1 mole of Cu, 2 moles of e^{-} will be required

$$Al^{2+} + 3e^{-} \rightarrow Al_{(s)}$$

$$Au^{4+}$$

Example 1: A current of 5 Ampere is passed through a compound Voltameter for 10mins. If the electrochemical equivalent of copper is $3.27 \times 10^{-7} kg C^{-1}$. Determine the mass of copper deposition.

Solution

Current = 5 Ampere

Time = 10 mins = (10 x 60) = 600sec.

$m = ZIt$

$m = 3.27 \times 10^{-7} \times 5 \times 600$

$= 0.000981 kg$

$= 9.81 \times 10^{-4} kg$

Example 2: When a current of 2 Ampere pass through an

electrolytic solution for 3 hours. What is the total amount of charge passed through?

Solution

$I = 2$ Ampere

$t = 3$ hrs $(3 \times 60 \times 60) = 10800$ sec.

But $Q = It$

$Q = 2 \times 10800$

$= 21600$ C.

Example 3: How many Faraday's passes through a resista in a circuit carrying current of 5 Ampere for 1 hour?

Solution

$I = 5$ Ampere

$t = 1$ hour $(1 \times 60 \times 60) = 3600$ sec.

$Q = It$

$= 5 \times 3600$

$= 18000$ C

$1F = 96500$ C

$\therefore 18000\text{ C} = \frac{1F \times 18000\text{ C}}{96500\text{ C}}$

$= 0.187F$

or number of moles

Example 4: What is the mass of Copper formed at the Cathode when a current of 0.25 Ampere is passed through a ~~Copper Sulphate Solution~~ $CuSO_4$ for 1 hour. [R.A.M of Cu = 63.5).

Solution

$I = 0.25$ Ampere

$t = 1$ hour $(1 \times 60 \times 60) = 3600$ sec.

R.A.M of Cu = 63.5

$n = ?$

$$m = \frac{\text{molar mass} \times It}{nF}$$

$CuSO_4$

$Cu^{2+} + 2e^- \longrightarrow Cu_{(s)}$

To discharge 1 mole of Cu^{2+}, 2 moles of e^- is required

$$m = \left(\frac{63.5}{2 \times 96500}\right) \times 0.25 \times 3600$$

$$m = \frac{57,150}{193,000} = 0.296 \text{ g}$$

OR

To calculate the total no. of moles of Cu formed at the cathode?

$$\text{No. of moles of Cu Formed} = \frac{It}{nF}$$

$$= \frac{0.25 \times 3600}{2 \times 96500}$$

$$= 4.66 \times 10^{-3} \text{ mol}$$

Mass = mole × molar mass

$= 4.66 \times 10^{-3} \times 63.5$

$= 0.296 \text{ g}$

Applications/Uses of Electrolysis

i) Extraction of metals: Many metals are extracted in their pure forms through electrolysis e.g Alkali metals, Alkali earth metals, Magnesium, Aluminum e.t.c. Some non-metals can be extracted through electrolysis e.g oxygen, hydrogen are produced by electrolysis of water containing an electrolyte.

ii) Electroplating of metals: