ATOMS, MOLECULES AND STOICHIOMETRY

- Atoms are small units of matter (molecules) which are known to consist of negatively, positively & neutrally charged particles respectively known as electrons, protons & neutrons.
- Symbol is the alphabetical representation of atoms which are entirely unique for every atom.
- A molecule is a group of ~~atoms~~ same and/or different atoms bonded in various ways.
- A molecular formula is the representation of a molecule on the basis of symbols of atoms and their number/amount in a molecule.

- For negatively charged ions, we use suffix ide

O^{--} - oxide N^{---} - Nitride

Cl^{-} - Chloride

- Atoms of different elements have different masses. When we perform chemical calculations, we need to know how heavy one atom is compared with ~~oth~~ another. The mass of a single atom is so small that it is impossible to weigh them directly. To overcome this, we have to weigh a lot of atoms. We then compare this mass with mass of the same number of 'standard' atoms. We defined atomic mass in terms of a standard unit. This unit is called the unified at. mass unit. Scientists have defined this in terms of isotope of Carbon 12 because it is most abundant carbon isotope and is solid, easy to handle & easily available.

Isotopes are ~~elements~~ atoms of same elements which have same number of p^+ but different number of n^0.

Unified atomic mass unit.

It is the mass of $1/12^{th}$ of an unbound neutral atom (in free state) of the carbon-12 isotope in its ground (lowest energy) state. The symbol for the mass is u. $1u = 1.66 \times 10^{-27}$ kg.

~~Relative atomic mass~~ $1u = 1/12 \times$ mass of one atom of C-12

Relative at. mass (Ar): is defined as the weighted average mass of atoms in a given sample of an element compared to the value of the unified at. mass unit. It is unitless because it is ratio.

$$\text{Relative at. mass- Ar} = \frac{\text{weighted average mass of atoms in a given sample of element}}{\text{unified at. mass unit}}$$

~~Relative~~

$$Ar[H] = \frac{\overset{\text{avg.}}{\text{mass}} \text{ of certain no. } (6.02 \times 10^{23}) \text{ H atoms}}{1/12 \times \text{mass of } 6.02 \times 10^{23} \text{ atoms of C-12}}$$

We take avg. mass because atoms can exist in various isotopes, so it's the avg. mass of all those isotopes.

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Relative ~~at~~ isotopic mass is the mass of a particular atom of an isotope compared to the value of unitified at. mass unit.

Relative isotopic mass = $\frac{\text{mass of a particular isotope}}{\text{unified at. mass unit.}}$

Isotopes are written as $^{235}_{92}U$

+ Relative molecular mass (Mr) is defined as the ratio of the weighted average mass of molecules of a molecular compound compared to the value of the unified at. mass unit.

Mr = $\frac{\text{weighted average mass of molecules}}{\text{unified at. mass unit.}}$

But we generally calculate it using the individual atoms e of elements in a molecule.

formula: C_2H_6
atoms present: 2 × C; 6 × H
add Ar values: (2 × Ar[C]) + (6 × Ar[H])
= Mr of ethane = (2 × 12.0) + (6 × 1.0)
= 30.0

Relative formula mass :

(Molecular formula is used for covalent compounds.)
(Formula unit is used for ionic compounds.)

for compounds containing ions, we use the term relative formula mass. It is the same as

formula : $Mg(OH)_2$
ions present $1 Mg^{2+}$; $2 \times (OH)^-$
add Ar values : $(1 \times Ar[Mg]) + (2 \times (Ar[O] + Ar[H]))$
Mr of $Mg(OH)_2 = (1 \times 24.3) + (2 \times (16.0 + 1.0))$.
$= 58.3$

Hydrated and anhydrous compounds

- Some compounds can form crystals which have water as a part of their structure. This is called water of crystallisation.
- A compound containing water of crystallization is called a hydrated compound. eg. hydrated copper (II) sulfate, $CuSO_4 . 5H_2O$
- A compound which dosen't contain water of crystallization is called an anhydrous compound. eg : anhydrous copper (II) sulfate, $CuSO_4$.
- There can be different degrees of hydration of a compound. It depends on nature of salt and the conditions it's kept in.
- When writing chemical formulae for hydrated compounds, we show water of crystallization separated from the main formula by a dot. The number of moles of water of crystallization can only exist in whole number.

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Anhydrous compounds can be converted into hydrated compounds by adding water.

$CuSO_4 + 5H_2O \longrightarrow CuSO_4.5H_2O$
$CuSO_4.5H_2O \xrightarrow{\Delta} CuSO_4 + 5H_2O$

To calculate hydrated compounds' Mr, we first do of salt then of water.

~~SO_2~~
~~Mg~~

1) SO_2
atoms present: 1×S; 2×O
Mr of Sulfur dioxide: (1× Ar[S]) + (2× Ar[O])
= (1 × 32) + (2×16)
= 64.0 //.

2) NaOH
~~a~~ ions present: 1×Na^+; 1×$(OH)^-$
Mr of Sodium Hydroxide: (1× Ar[Na]) + (1× (Ar[O] + Ar[H])
= (1× 23) + (1× (16 + 1))
= 40.0 //.

3) KNO_3
ions present: 1× K^+; 1× $(NO_3)^-$
Mr of Potassium nitrate: (1× Ar[K]) + (1×(Ar[N] + 3 Ar[O]))
= (1× 39) + (1× (14 + 3×16))
= 101.0 //.

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4) $MgCO_3$
ions present : $1 \times Mg^{2+}$; $1 \times (CO_3)^{2-}$
Mr. of Magnesium Carbonate : $(1 \times Ar[M]) + 1 \times (Ar[C] + 3 \times Ar[O])$
$= (1 \times 24) + (1 \times (12 + 3 \times 16))$
$= 84.0$ //.

5) $PbCl_2$
ions present : $1 \times Pb^{2+}$; $2 \times Cl^{-}$
Mr of Lead Chloride $(1 \times Ar[Pb]) + (2 \times Ar[Cl])$
$= (1 \times 207) + (2 \times 35)$
$= 277.0$ //.

6) $MgCl_2$
ions present : $1 \times Mg^{2+}$; $2 \times Cl^{-}$
Mr. of Magnesium Chloride : $(1 \times Ar[M]) + (2 \times Ar[Cl])$
$= (1 \times 24) + (2 \times 35)$
$= 94.0$ //.

7) $Mg(NO_3)_2$
ions present : $1 \times Mg^{2+}$; $2 \times (NO_3)^{-}$
Mr. of Magnesium nitrate : $(1 \times Ar[M]) + (2 \times (Ar[N] + 3\, Ar[O]$
$= (1 \times 24) + (2 \times (14 + 3 \times 16))$
$= 148.0$ //.

8) $Zn(OH)_2$
ions present : $1 \times Zn^{2+}$; $2 \times (OH)^{-}$
Mr. of Zinc Hydroxide : $(1 \times 65) + (2 \times (16 + 1))$
$= 99.0$ //.

9) $ZnSO_4$.

ions present: $1 \times Zn^{2+}$; $1 \times (SO_4)^{2-}$

Mr. of zinc sulfate : $(1 \times Ar[Zn]) + (1 \times (Ar[S] + 4 \times Ar[O]))$

$= (1 \times 65) + (1 \times (32 + 4 \times 16))$

$= 161.0$

10) H_2SO_4

~~ions~~ atoms present : $2 \times H^+$; $1 \times (SO_4)^{2-}$

Mr. of Sulfuric acid : $(2 \times Ar[H]) + (1 \times (Ar[S] + 4 \times Ar[O]))$

$= (2 \times 1) + (1 \times (32 + 4 \times 16))$

$= 98.0$

11) HNO_3

atoms present : $1 \times H$; $1 \times N$; $3 \times O$

Mr. of Nitric acid : $(1 \times Ar[H]) + (1 \times Ar[N]) + (3 \times Ar[O])$

$= (1 \times 1) + (1 \times 14) + (3 \times 16)$

$= 63.0$

12) $MgSO_4 \cdot 7H_2O$

~~atoms~~ ions present in $MgSO_4$: $1 \times Mg^{2+}$; $1 \times (SO_4)^{2-}$

Mr. of Magnesium sulfate : $(1 \times Ar.[Mg]) + (1 \times (Ar[S] + 4.Ar[$

$= (1 \times 24) + (1 \times (32 + 4 \times 16))$

$= 120.0$

atoms present in $7H_2O$: $14 \times H$; $7 \times O$

$= (14 \times Ar[H]) + (7 \times Ar[O])$

$= (14 \times 1) + (7 \times 16)$

$= 126.0$

$\therefore$ Mr. of hydrated Magnesium sulfate : $120 + 126$

$= 246.0$

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A EXERCISE FOR ATOMS, MOLECULES & STOICHIOMETRY..

13) $CaSO_4$
ions present : $1 \times Ca^{2+}$; $1 \times (SO_4)^{2-}$
Mr. of Calcium sulfate : $(1 \times Ar[Ca]) + (1 \times (Ar[S] + 4 Ar[O]))$
$= (1 \times 40) + (1 \times (32 + 4 \times 16))$
$= 136.0$ //.

14) Pb_3O_4 ~~$(PbO_2 . 2PbO)$~~ $(PbO_2 . 2PbO)$
ions present : ~~$3 \times Pb$~~ $(1 \times Pb^{4+}$; $2 \times O^{2-}) + (2 \times Pb^{2+} + 2 \times O^{2-})$
Mr. of Lead Tetroxide : $(1 \times Ar[Pb] + 2 \times Ar[O]) +$
$(2 \times Ar[Pb] + 2 \times Ar[O])$
$= (1 \times 207 + 2 \times 16) + (2 \times 207 + 2 \times 16)$
$= 685.0$ //.

15) P_2O_5
atoms present : $2 \times P$; $5 \times O$
Mr. of Phosphorous pentoxide : $(2 \times Ar[P]) + (5 \times Ar[O])$
$= (2 \times 31) + (5 \times 16)$
$= 142.0$ //.

16) Na_2CO_3
ions present ; $2 \times Na^+$; ~~$3 \times CO_3$~~ $1 \times (CO_3)^{2-}$
Mr. of Sodium Carbonate : $(2 \times Ar[Na]) + (1 \times (Ar[C] + 3 . Ar[O]$
$= (2 \times 23) + (1 \times (12 + 3 \times 16))$
$= 106.0$ //.

17) $Ca(OH)_2$

ions present : $1 \times Ca^{2+}$; $2 \times (OH)^{-}$

Mr. of Calcium Hydroxide : $(1 \times Ar[Ca]) + (2 \times (\overset{Ar[O]+Ar[H]}{\cancel{16+1}}))$

$= (1 \times 40) + (2 \times (16 + 1))$

$= 74.0$ //.

18) $CuCO_3$

ions present : $1 \times Cu^{2+}$; $1 \times (CO_3)^{2-}$

Mr. of Copper(II) carbonate : $(1 \times Ar[Cu]) + (1 \times (Ar[C] + 3 Ar[O]))$

$= (1 \times 63) + (1 \times (12 + 3 \times 16))$

$= 123.0$ //.

19) $CuSO_4$

ions present : $1 \times Cu^{2+}$; $1 \times (SO_4)^{2-}$

Mr. of Copper (II) sulfate : $(1 \times Ar[Cu]) + (1 \times (Ar[S] + 4 Ar[O]))$

$= (1 \times 63) + (1 \times (32 + 4 \times 16))$

$= 159.0$ //.

20) $Ca(HCO_3)_2$

ions present : $1 \times Ca^{2+}$; $2 \times (HCO_3)^{-}$

Mr. of Calcium Bicarbonate : $(1 \times (\cancel{\ } Ar[Ca]) + (2 \times (Ar[H] + Ar[C] + 3 Ar[O]))$

$= (1 \times 40) + (2 \times (1 + 12 + 3 \times 16))$

$= 162.0$ //

~~21) $CuSO_4 \cdot 5H_2O$~~

21) $CuSO_4 \cdot 5H_2O$

ions in copper sulfate : $1 \times Cu^{2+}$; $1 \times (SO_4)^{2-}$

Mr. of copper sulfate : $(1 \times Ar[Cu]) + (1 \times (Ar[S] + 4\, Ar[O]))$

$= (1 \times 63) + (1 \times (32 + 4 \times 16))$

$= 159.0$

atoms in $5H_2O$: $10 \times H$; $5 \times O$

Mr. of $5H_2O$: $(10 \times Ar[H]) + (5 \times Ar[O])$

$= (10 \times 1) + (5 \times 16)$

$= 90.0$

$\therefore$ Mr. of hydrated copper sulfate $= 159 + 90 = 249.0$

22) $Fe_2(SO_4)_3$

ions in ferric sulfate : $2 \times Fe^{3+}$; $3 \times (SO_4)^{2-}$

Mr. of ferric sulfate : $(2 \times Ar[Fe]) + (3 \times (Ar[S] + 4 \times Ar[O]))$

$= (2 \times 56) + (3 \times (32 + 4 \times 16))$

$= 400.0$

23) $Na_2CO_3 \cdot 10H_2O$

ions in Sodium carbonate : $2 \times Na^{+} + 1 \times (CO_3)^{2-}$

Mr. of sodium carbonate : $(2 \times Ar[Na]) + (1 \times (Ar[C] + 3 \cdot Ar[O]))$

$= (2 \times 23) + (1 \times (12 + 3 \times 16))$

$= 106.0$

atoms in $10H_2O$: $20 \times H$; $10 \times O$

Mr. of $10H_2O$: $= (20 \times Ar[H]) + (10 \times Ar[O])$

$= (20 \times 1) + (10 \times 16)$

$= 180.0$

$\therefore$ Mr. of hydrated sodium carbonate $= 106 + 180 = 286.0$

24) $FeSO_4 . 7H_2O$

ions in ferrous solphate : $1 \times Fe^{2+}$; $1 \times (SO_4)^{2-}$

Mr. of ferrous sulphate : $(1 \times Ar[Fe]) + (1 \times (Ar[S] + 4 Ar[O]$

$= (1 \times 56) + (1 \times (32 + 4 \times 16))$

$= 152.0$

atoms in $7H_2O$: $14 \times H$; $7 \times O$

Mr. of $7H_2O$ = : $(14 \times Ar[H]) + (7 \times Ar[O])$

$= (14 \times 1) + (7 \times 16)$

$= 126.0$

$\therefore$ Mr. of hydrated ferrous sulphate $= 152 + 126$

$= 278.0$

Accurate relative at. masses.

A mass spectrometer can be used to measure the mass of each isotope present in an element. It also compares how much of each isotope is present - the relative abundance (isotopic abundan

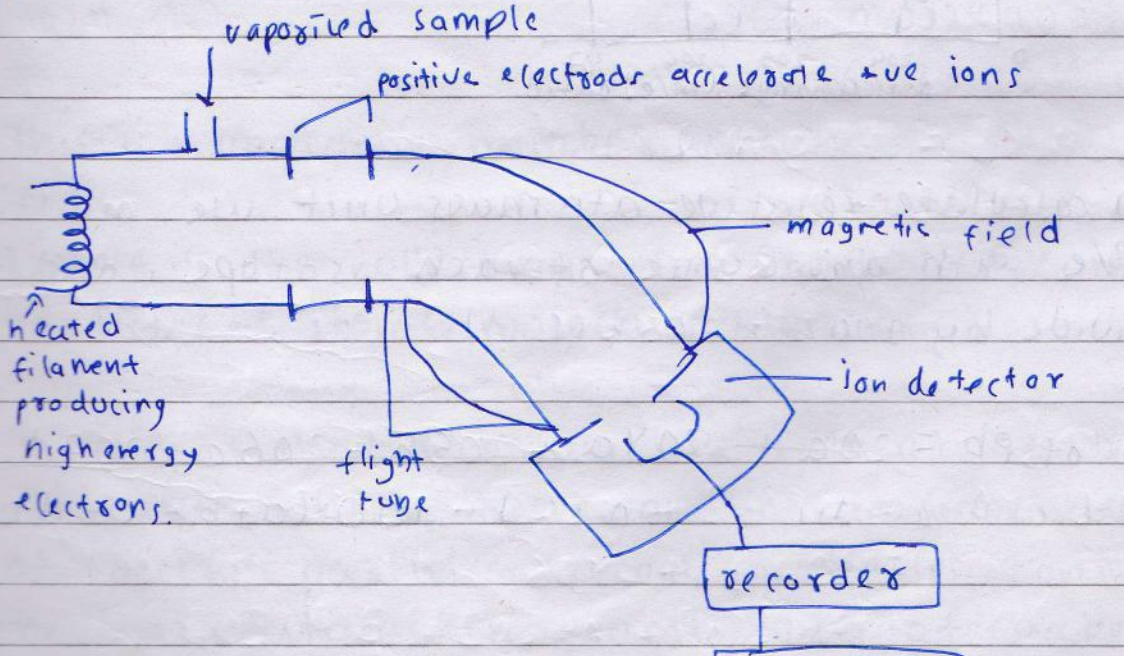


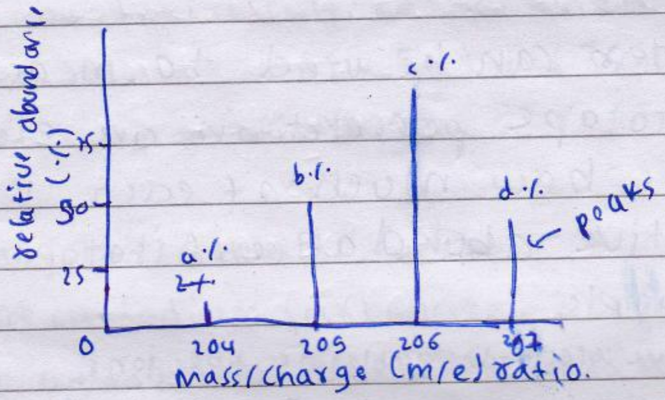
Fig. simple mass spectrometer.

Five main steps ~~vaporized~~ in mass spectrometer.

- Vaporization
- Ionization
- Acceleration
- Deflection
- Detection

Mass spectrometer calculates relative isotopic mass and ~~its~~ relative abundance of different isotopes.

In the computer we see a diagram called mass spectrum.



To calculate relative at. mass unit we multiply m/e with abundance of each isotope. add them and divide by 100.

$$Ar \text{ of } Pb = \cancel{20a +} \frac{204a + 205b + 206c + 207d}{100 \; (a+b+c+d)}$$

Amount of substance :-

- The quantity of matter is measured in mole.
- 1 mole = 6.02×10^{23} particles.
- One mole is the collection of 6.02×10^{23} particles (atoms, molecules, protons, quarks.)
- One mole never depends on mass. It only depends on amount (number of substance).
- One mole of Hydrogen ~~has 6~~ is 6.02×10^{23} H atoms
- The mole is also called Avogadro constant/ Avogadro number and is represented by L or N_A

$1p^+ = 1.66 \times 10^{\cancel{-23}\,-24}$ g
1 atom of C-12 has $6p^+$ and $6n^0$
∴ Mass of 1 atom of C-12 $= 12 \times (1.66 \times 10^{\cancel{-23}\,-24}\,g)$
$= 1.992 \times 10^{-23}$ g.
∴ No. of atoms in a 12 g sample $= \dfrac{12}{1.992 \times 10^{-23}}$
$= 6.02 \times 10^{23}$ atoms.
∴ This is avogadro's number.

- 1 mole is the collection of 6.02×10^{23} specific particles (atoms, molecules, ions etc.)

∴ 1 mole of that substance is amount of that substance which has exactly the same number of specific particles (atoms, molecules, ions) as there are atoms in exactly 12g of Carbon-12 isotope.

~~Collection~~ 1 mol of KCl = 6.02×10^{23} KCl formula units.
Eg:- 1 mol of Hydrogen = 6.02×10^{23} H atoms
1 mol of CO_2 = 6.02×10^{23} CO_2 molecules

- Avogardo's constant is independent of mass.
- 1 mol of CO_2 is heavier than 1 mol of H

Molar mass (M)

- It's unit is g/mol
- It is the mass of 1 mol of a substance.
- Molar mass of Na is the mass of 6.02×10^{23} sodium atoms.

1 atom of Na = $23 p^+$

~~Molar~~ mass of 1 atom = $23 \times (1.66 \times 10^{-24})$ g

∴ Molar mass of sodium = $(6.02 \times 10^{23}) \times (23) \times (1.66 \times 10^{-24})$

= ~~23 g/mol~~ 23 g

- It's value is equal to that to the relative atomic mass unit.
- M [Ca] = 40 g/mol ⇓ 6.02×10^{23} atoms of Ca

Ar [Ca] = 40 ⇓ $40 \times (1.66 \times 10^{-24})$ g

$M[H_2O] = 18$ g/mol [Molar mass] [Of one mole]

$Mr[H_2O] = 18$ [Relative molecular mass]

$= (18 \times 1u)$ g

$= (18 \times 1.66 \times 10^{-24})$ g [Of one molecule]

i) $CaCO_3$

$Mr[CaCO_3] = \cancel{M[Ca] + M[C] + 3M[O]}$

$= \cancel{40 + 12 + 3 \times 16}$

$= Ar[Ca] + Ar[C] + 3 Ar[O]$

$= 100$

$M[CaCO_3] = 100$ g/mol

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ii) CO_2

$Mr[CO_2] = Ar[C] + 2 \times Ar[O]$

$= 12 + 2 \times 16 = 44$

$M[CO_2] = 44$ g/mol ॥

~~iii) CH_4~~

~~$Mr[CH_4]$~~

number of moles (mol) = mass in grams / molar mass

$n = m/M$

3. Find mass of each element in :

d) 10 mol of hydrogen molecules

~~Mass~~ = $m = nM$

$= 10 \times 2 =$ ~~10 g~~ 20 g ॥

g) 3/4 mol iron

$m = nM$

$= 3/4 \times 55.8 = 41.8$ g ॥

j) ~~h)~~ 0.1 mol neon

$m = nM$

$= 0.1 \times 20 = 2$ g ॥

4a) 58.5 g NaCl

$M[NaCl] = Ar[Na] + Ar[Cl]$

$= 23 + 35.4 = 58.4$ g/mol

∴ No. of moles ≈ 1 mol ॥

h) 499 g of $CuSO_4 . 5H_2O$

$M[CuSO_4 . 5H_2O] = Ar[Cu] + Ar[S] + 4 Ar[O] + 10 Ar[$

$5 . Ar[O]$

$= 243.5$ g mol^{-1}

No ≈ 2 moles ॥

The no. of particles equivalent to the relative at. mass or relative molecular mass of a substance in grams is called the Avogadro constant.

Significance of molecular formula.

→ Molecular formula represents one molecule of the given compound. It is a symbolic representation where symbols of elements and no. of atoms is included.
→ Represents simplest ratio of nos. of atoms. of different elements.
→ Represents one mole molecules of given compound
→ In $2H_2 + O_2 \rightarrow 2H_2O$, we can say.
2 moles of hydrogen molecules combine with one mole of oxygen molecule to form 2 moles of water molecule.

Percentage composition

SiO_2
→ $Ar[Si] = 28$
→ $2Ar[O] = 2 \times 16 = 32$
→ $Ar[SiO_2] = 28 + 32 = 60$
Percentage of Silicon = $28/60 \times 100 = 46.67\%$

Avogadro's hypothesis.

Equal volumes of all gases contain the same number of molecules under similar condition of temperature and pressure.
&
Under same condition of temp. and pressure same no. of molecoles ~~un~~ of all gases have equal volumes.
At room temp. (20°C) and pressure (1 atm) i.e. at r.t.p. one mole of every gas occupies 24.0 dm^3 volume which is called molar gas volume at r.t.p.
This value is experimentally determined.
But at s.t.p one mole of every gas will occupy 22.4 dm^3 volume. [0°C, 1 atm]

We can use molar gas volume, 24 dm^3 to find:
→ The volume of a given mass or no. of moles of gas
→ The mass or number of moles of a given volume of gas.

The volume of gas is the volume of container in which it's kept.
$1\ dm^3 = 1000\ cm^3$

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MOLAR MASS EXERCISE

1. Calculate the percentage by mass of

a) carbon and hydrogen in pentene, C_5H_{10}

$5Ar[C] = 5 \times 12 = 60$

$10 Ar[H] = 10 \times 1 = 10$

$Mr[C_5H_{10}] = 60 + 10 = 70$

Percentage of carbon $= \frac{60}{70} \times 100\% = 85.71\%$

Percentage of hydrogen $= \frac{10}{70} \times 100\% = 14.28\%$

b) nitrogen, hydrogen and oxygen in ammonium nitrate

$2Ar[N] = 2 \times 14 = 28$

$4Ar[H] = 4 \times 1 = 4$

$3Ar[O] = 3 \times 16 = 48$

$Mr[NH_4NO_3] = 28 + 4 + 48 = 80$

Percentage of Nitrogen $= \frac{28}{80} \times 100\% = 35\%$

Percentage of Hydrogen $= \frac{4}{80} \times 100\% = 5\%$

Percentage of Oxygen $= \frac{48}{80} \times 100\% = 60\%$

c) iron, oxygen and hydrogen in iron (II) hydroxide

$Ar[Fe] = 56$

$2Ar[O] = 2 \times 16 = 32$

$2Ar[H] = 2 \times 1 = 2$

$Mr[Fe(OH)_2] = 56 + 32 + 2 = 90$

Percentage of iron $= \frac{56}{90} \times 100\% = \cancel{65.56\%}\ 62.22\%$

Percentage of oxygen $= \frac{32}{90} \times 100\% = 35.56\%$

Percentage of hydrogen $= \frac{2}{90} \times 100\% = 2.22\%$

d) carbon, hydrogen and oxygen in ethanedioic acid $C_2H_4O_2$

$2Ar[C] = 2 \times 12 = 24$

$4Ar[H] = 4 \times 1 = 4$

$2Ar[O] = 2 \times 16 = 32$

$Mr[C_2H_4O_2] = 24 + 4 + 32 = 60$

Percentage of carbon $= \frac{24}{60} \times 100\% = 40\%$

Percentage of hydrogen $= \frac{4}{60} \times 100\% = 6.67\%$

Percentage of Oxygen $= \frac{32}{60} \times 100\% = 53.33\%$

2. State the mass of each element in:

a) 0.5 mol chromium

$m = nM = 0.5 \times Mr[Cr] = 0.5 \times 52 = 26\,g$

b) $1/7$ mol iron

$m = nM = 1/7 \times Mr[Fe] = 1/7 \times 55.8 = 7.9\,g$

c) $1/3$ mol carbon

$m = nM = 1/3 \times Mr[C] = 1/3 \times 12 = 4\,g$

d) $1/4$ mol magnesium

$m = nM = 1/4 \times Mr[Mg] = 1/4 \times 24 = 6\,g$

e) $1/7$ mole nitrogen molecules
$m = nM = 1/7 \times Mr[N] = 1/7 \times 28 = 4g$

f) $1/4$ mole oxygen molecules
$m = nM = 1/4 \times Mr[O] = 1/4 \times 32 = 8g$

3. Calculate the amount of each element in
$\cancel{n = m/M =}$

a) 46 g sodium
$n = m/M = 46/Mr[Na] = 46/22.9 \approx 2$ moles

b) 130 g Zinc
$n = m/M = 130/Mr[Zn] = 130/65 = 2$ moles

c) 10 g calcium
$n = m/M = 10/Mr[Ca] = 10/40 = 1/4$ moles

d) 2.4 g magnesium
$n = m/M = 2.4/Mr[Mg] = 2.4/24 = 1/10$ moles

e) 13 g chromium
$n = m/M = 13/Mr[Cr] = 13/52 = 1/4$ moles

4. Find mass of each element in:

a) 10 mole lead
$m = nM = 10 \times Mr[Pb] = 10 \times 207 = 2070g$

b) 0.1 mole iodine molecules
$m = nM = 0.1 \times Mr[I] = 0.1 \times 253 = 25.3g$

c) $\frac{1}{6}$ mol copper

$m = nM = \frac{1}{6} \times Mr[Cu] = \frac{1}{6} \times 63 = 10.5\ g$

d) 10 mol hydrogen molecules

$m = nM = 10 \times Mr[H] = 10 \times 2 = 20\ g$

e) 0.25 mol calcium

$m = nM = 10 \times Mr[Ca] = 10 \times 40 = 400\ g$

f) 0.25 mol bromine molecules

$m = nM = 0.25 \times Mr[Br] = 0.25 \times \cancel{80}\ 160 = \cancel{20g}\ 40g$

g) $\frac{3}{4}$ mol iron

$m = nM = \frac{3}{4} \times Ar[Fe] = \frac{3}{4} \times 55.8 = 41.8\ g$

h) 0.20 mol zinc

$m = nM = 0.2 \times Ar[Zn] = 0.2 \times 65 = 13\ g$

i) $\frac{1}{2}$ mol chlorine molecules

$m = nM = \frac{1}{2} \times Mr[Cl] = \frac{1}{2} \times 71 = 35.5\ g$

j) 0.1 mol neon

$m = nM = 0.1 \times Ar[Ne] = 0.1 \times 20.17 = 2.01\ g$

5. State amount of substance (mol) in:

a) 58.5 g sodium chloride

$Mr[NaCl] = Ar[Na] + Ar[Cl] = 23 + 35.5 = 58.5\ g$

$n = m/M = 58.5/58.5 = 1$ mole

b) 26.5 g anhydrous sodium carbonate

$Mr[Na_2CO_3.\cancel{10H_2O}] = 2Ar[Na] + Ar[C] + 3Ar[O]$
$\cancel{+20Ar[H]} + \cancel{10Ar[O]}$
$= 2\times23 + 12 + 3\times16 + \cancel{20\times1} \cancel{+10\times16}$
$= \cancel{286}$ g // 106 g //

$n = m/M = 26.5/\cancel{286}_{106} = \cancel{0.09 mol}$ // $1/4$ mol //

c) 50 g calcium carbonate

$Mr[CaCO_3] = Ar[Ca] + Ar[C] + 3Ar[O]$
$= 40 + 12 + 3\times16 = 100$ g //

$n = m/M = 50/100 = 1/2$ mol //

d) 15.9 copper (II) oxide

$Mr[CuO] = Ar[Cu] + Ar[O]$
$= 63.5 + 16 = 79.5$

$n = m/M = 15.9/79.5 = 1/5$ mol //

e) 8 g sodium hydroxide

$Mr[NaOH] = Ar[Na] + Ar[O] + Ar[H]$
$= 23 + 16 + 1 = 40$ g //

$n = m/M = 8/40 = 1/5$ mol //

f) 303 g potassium nitrate

$Mr[KNO_3] = Ar[K] + Ar[N] + 3Ar[O]$
$= 39 + 14 + 3\times16 = 101$ g //

$n = m/M = 303/101 = 3$ mol //

g) 9.8 g sulfuric acid

$Mr[H_2SO_4] = 2Ar[H] + Ar[S] + 4Ar[O]$
$= 2\times1 + 32 + 4\times16 = 98$ g //

$n = m/M = 9.8/98 = 1/10$ mol //

h) 499 g copper (II) sulphate 5-water

$Mr[CuSO_4 \cdot 5H_2O] = Ar[Cu] + Ar[S] + 4Ar[O] + 10Ar[H] + 5Ar[O]$

$= 63.5 + 32 + 4\times16 + 10\times1 + 5\times1$

$= 249.5$ g.

$n = m/M = 499/249.5 = 2$ mol.

6. Given Avogadro's constant is 6×10^{23} mol^{-1}, calculate no. of atoms in ~~35.5 g chlorine~~.

a) 35.5 g chlorine

$Ar[Cl] = 35.5$ g

$n = m/M = 35.5/35.5 = 1$ mol $= 6\times10^{23}$ Cl atoms.

b) 27 g aluminium

$Ar[Al] = 26.9 \approx 27$

$n = m/M = 27/27 = 1$ mol $= 6\times10^{23}$ Al atoms.

c) 3.1 g phosphorus

$Ar[P] = 31$.

$n = m/M = 3.1/31 = 1/10$ mol $= 1/10 \times (6\times10^{23})$

$= 6\times10^{22}$ P atoms.

d) 336 g iron

$Ar[Fe] = 55.8$

$n = m/M = 336/55.8 = 6.02$ mol $= 6.02 \times (6\times10^{23})$

$= 3.6\times10^{24}$ Fe atoms.

e) 48 g magnesium

$Ar[Mg] = 24$

$n = m/M = 48/24 = 2$ mol $= 2\times(6\times10^{23})$

$= 1.2\times10^{24}$ Mg atoms.

f) 1.6 g oxygen

Ar [O] = 16 ..

$n = m/M = 1.6/16 = 1/10 \text{ mol} = 1/10 \times (6 \times 10^{23})$

$= 6 \times 10^{22}$ O atoms..

g) 0.4 g oxygen

Ar [O] = 16 ..

$n = m/M = 0.4/16 = 1/40 \text{ mol} = 1/40 \times (6 \times 10^{23})$

$= 1.5 \times 10^{22}$ O atoms..

h) 216 g silver

Ar [Ag] = 108 ..

$n = m/M = 216/108 = 2 \text{ mol} = 2 \times (6 \times 10^{23})$

$= 1.2 \times 10^{24}$ Ag atoms..

MOLAR GAS VOLUME...

+ 1 mole of H_2O contains 2 moles of Hydrogen and 1 mole of oxygen.
+ Similarly, 180 g of $C_6H_{12}O_6$ contains 72g of carbon, 12 g of Hydrogen and 96 g of Oxygen.

Stoichiometry

+ Measure of quantitative relationship between the products and reactants of a given chemical reaction in terms of their relative ratios of moles.
+ Fundamental mathematical principle used to describe the law of conservation of mass, which states matter can't be created nor destroyed, but only converts from one ~~per~~ form to another.

+ Equations tell us what substances react and what amounts of them react together.

$2NaHCO_3 \longrightarrow Na_2CO_3 + CO_2 + H_2O$ (first balance)

2 moles 1mol 1mol 1mol (stoichiometry)

= 2 × 84g 106g 44g 18g (mass)

= 168g

2 : 1 : 1 : 1 ratio.

$Mg + H_2SO_4 \longrightarrow MgSO_4 + H_2$

- Already balanced
- 1 mole 1 mole 1 mole 1 mole
- 24.3 g 98 g 120.3 g 2 g
- Ratio : 1 : 1 : 1 : 1

$HCl + CaCO_3 \longrightarrow CaCl_2 + CO_2 + H_2O$

- $2HCl + CaCO_3 \longrightarrow CaCl_2 + CO_2 + H_2O$
- 2 moles 1 mole 1 mole 1 mole 1 mole
- 73 g 100 g 111 g 44 g 18 g
- Ratio : 2 : 1 : 1 : 1 : 1

Thus when 40 g of HCl and 40 g of $CaCO_3$ react, some HCl dosen't react.

The amounts of substances undergoing reaction are stoichiometric amounts.

- The reactant which is present in deficient amount less that stoichiometric amount demanded by balanced eq^n and consumed completely in reaction is called limiting reactant or reagent.
- Reactant which is left unreacted at the end of the reaction is excess reactant.

4 g of H_2 reacts with 4 g of O_2

- $2H_2 + O_2 \longrightarrow 2H_2O$
- 2 moles 1 moles 1 mole
- 4 g 32 g 36 g

Thus oxygen is limiting agent.

- Product formation is always determined by amount of limiting agent

32 g of oxygen reacts with H_2, forms 36 g water.
4 g of oxygen reacts with H_2, forms $\frac{36}{32}$ g w

$\frac{36}{32} \times 4$ g = 4.5 g

How much amount of H_2 will be left unreacted.

4 g of oxygen and 0.5 g H_2 must react
∴ H_2 left unreacted = 4 − 0.5 = 3.5 g

18 g Calcium reacts with 8 g oxygen

$$2Ca + O_2 \longrightarrow 2CaO$$
80g 32g 112g

Given ratio = 18 : 8
~~Act~~ Required ratio = 20 : 8
∴ Calcium is limiting agent.
~~18 g Ca gives 112 g CaO~~
80 g Ca gives 112 g CaO
18 g Ca gives $\frac{112}{80} \times 18$ = 25.2 g CaO

∴ Product mass = 25.2 g
∴ ~~Unreacted mass = 7.2 g~~
∴ Unreacted mass = 0.8 g

7.3 g HCl with 7.4 g $Ca(OH)_2$

$$2HCl + Ca(OH)_2 \longrightarrow CaCl_2 + 2H_2O$$
73 g 74 g 111 g 36 g

∴ The ratios are equal, so no limiting reactant and 11.1 g product formed.

1 mol $CaCO_3$ with 1.5 mol HCl

$$2HCl + CaCO_3 \longrightarrow CaCl_2 + H_2O + CO_2$$
73 g 100 g 111 g 18 g 44 g
2 moles 1 mole 1 mole 1 mole 1 mole

Required ratio = $1 : \frac{1}{2}$ ~~1 : 0.5~~ 1 : 2
Actual ratio = ~~1 :~~ ~~1 : 1.5~~ ~~1 : 0.67~~ 1 : 1.5
∴ HCl is limiting agent
∴ Moles of $CaCO_3$ that reacts = $1 \times \frac{1.5}{2} = 0.75$ g

∴ $CaCO_3$ not reacted = 0.25 g
∴ 0.75 mol of CO_2 is produced.
∴ Volume of CO_2 at rtp = $0.75 \times 24 = 18\, dm^3$

100 molecules of N_2 reacts with 150 molecules of H_2

$$N_2 + 3H_2 \longrightarrow 2NH_3$$
~~1 mole 3 mole~~
~~2m~~ 1 molecule 3 molecules
∴ Required ratio = 1 : 3, Reaction ratio = 1 : 1.5
∴ Hydrogen is limiting agent.

STOICHIOMETRY...

1. Calculate concentration in mol dm^{-3}

a) 3.65 g HCl in 2 dm^3 of solution
1 mol HCl = 36.5 g
$^1/_{10}$ mol HCl = 3.65 g
∴ Concentration = $^1/_{10} \div 2$ = 0.05 mol dm^{-3}

b) 73.0 g HCl in 2 dm^3 of solution
1 mol HCl = 36.5 g
2 mol HCl = 73.0 g
∴ Concentration = 2 ÷ 2 = 1 mol dm^{-3}

c) 49.0 g H_2SO_4 in 2.00 dm^3 of solution
1 mol H_2SO_4 = 98 g
$\cancel{2}^{0.5}$ mol H_2SO_4 = 49 g
∴ Concentration = $2 \div \cancel{2}^{0.5} = \cancel{1}^{4}$ mol dm^{-3}

d) 49.0 g H_2SO_4 in 250 cm^3 of solution
1 mol H_2SO_4 = 98.0 g
0.5 mol H_2SO_4 = 49.0 g
250 cm^3 = 0.25 dm^3
∴ Concentration = 0.5/0.25 = 2 mol dm^{-3}

h) 53.0 g of Na_2CO_3 in 2.5 dm^3 of solution
1 mol Na_2CO_3 = 106 g
0.5 mol Na_2CO_3 = 53.0 g
∴ Concentration = 0.5/2.5 = 0.2 mol dm^{-3}

Titration is an experimental technique used to determine concentration of unknown solution by using standard solution in the presence or absence of an indicator.

e) 2.80 g KOH in 500 cm^3 of solution
1 mol KOH = 56.1 g.
0.05 mol KOH = 2.8 g.
∴ 500 cm^3 = 0.5 dm^3
∴ Concentration = 0.05/0.5 = 0.1 mol dm^{-3}

f) 2.80 g KOH in 4 dm^3 of solution
1 mol KOH = 56.1 g
0.05 mol KOH = 2.8 g
∴ Concentration = 0.05/4 = 0.0125 mol dm^{-3}

g) 5.3 g Na_2CO_3 in 200 cm^3 solution
1 mol Na_2CO_3 = 106 g
0.05 mol Na_2CO_3 = 5.3 g
200 cm^3 = 0.2 dm^3
∴ Concentration = 0.05/0.2 = 0.25 mol dm^{-3}

2. Calculate amount in moles of solute in :-

a) 250 cm^3 NaOH solution where M = 1 mol dm^{-3}
250 cm^3 = 0.25 dm^3
∴ No. of moles = 0.25 mol

d) 2 dm^3 of 1.25 M H_2SO_4
∴ No of moles = 1.25 x 2 = 2.5 moles

h) 1500 cm^3 of KOH solution with 0.750 M
1500 cm^3 = 1.5 dm^3
∴ No of moles = 1.5 x 0.75 = 1.125 mol

b) 500 cm^3 NaOH where 0.25 M
500 cm^3 = 0.5 dm^3.
∴ No. of moles = 0.5 x 0.25 = 0.125 mol

c) 250 cm^3 of $Ca(OH)_2$ with 0.02 M

250 cm^3 = 0.25 dm^3

∴ No of moles = 0.02 × 0.25 = 0.005 mol

e) 125 cm^3 of aq. ~~nitric acid~~ HNO_3 with 0.4 M

125 cm^3 = 0.125 dm^3

∴ No of moles = 0.125 × 0.4 = 0.05 mol

f) 200 cm^3 of NH_3 solution with 0.125 M

200 cm^3 = 0.2 dm^3

∴ No of moles = 0.2 × 0.125 = 0.025 g mol

g) 123 cm^3 of aq. HCl with 3 M

123 cm^3 = 0.123 dm^3

∴ No of moles = 0.123 × 3 = 0.369 mol

3. What mass of solute must be used.

a) 500 cm^3 of 0.1 M $H_6C_4O_4(aq)$ from $H_6C_4O_4(s)$

500 cm^3 = 0.5 dm^3

No of moles = 0.5 × 0.1 = 0.05 mol

1 mol $H_6C_4O_4$ = 118 g

∴ Mass = ~~5.9~~ 118 × 0.05 = 5.9 g

e) 500 cm^3 of 0.1 M $Na_2B_4O_7$ from $Na_2B_4O_7 \cdot 10H_2O$

500 cm^3 = 0.5 dm^3

No of moles = 0.5 × 0.1 = 0.05 mol

1 mol $Na_2B_4O_7 \cdot 10H_2O$ = 381.2 g

∴ Mass = 0.05 × 381.2 = 19.06 g

Note: Standard solution has known concentration while that with unknown is unknown solution. Titration is an experimental technique used to determine concentration of unknown solution by using standard solution in presence or absence of indicator.

b) $250 cm^3$ of 0.2 M $Na_2CO_3 (aq)$ from $Na_2CO_3 (s)$

$250 cm^3 = 0.25 dm^3$

No of moles $= 0.25 \times 0.2 = 0.05$ mol

1 mol $Na_2CO_3 = 106$ g

$\therefore$ Mass $= 0.05 \times 106 = 5.3$ g

c) $750 cm^3$ of 0.1 M $H_2C_2O_4$ from $H_2C_2O_4 2H_2O$

$750 cm^3 = 0.75 dm^3$

No of moles $= 0.75 \times 0.1 = 0.075$ mol

1 mol $H_2C_2O_4 . 2H_2O = 126$ g

$\therefore$ Mass $= 0.075 \times 126 = 9.45$ g

d) $2.5 dm^3$ of 0.2 M $NaHCO_3 (aq)$ from $NaHCO_3 (s)$

No. of moles $= 2.5 \times 0.2 = 0.5$ mol

1 mol $NaHCO_3 = 84$g

$\therefore$ Mass $= 0.5 \times 84 = 42$g

4. What volumes of solutions are required to give stated vols.

a) $2.00 dm^3$ of 0.5 M $H_2SO_4 (aq)$ from 2 M $H_2SO_4 (aq)$

No. of moles of dilute sol. $= 2 \times 0.5 = 1$ mol

No. of moles of conc. sol $= 1$ mol

$\therefore$ Volume of conc. sol $= 1/2 = 0.5 dm^3$

b) $1.00 dm^3$ of 0.75 M $HCl (aq)$ from 10 M $HCl (aq)$

No. of moles of dilute sol $= 1 \times 0.75 = 0.75$ mol

No. of moles of conc. sol $= 0.75$ mol

$\therefore$ Volume of conc. sol $= 0.75/10 = 0.075 dm^3$

Note: Law of dilution states that the no. of moles of solute before and after dilution remains constant.

Dillution is process of preparing solutions of lower concentration from solutions of higher concentration. carried out by adding H_2O to solution of higher concentration.

c) $250 cm^3$ of $0.25 M$ $NaOH(aq)$ from $5.5 M$ $NaOH(aq)$
$250 cm^3 = 0.25 dm^3$
No. of moles of dil. solution $= 0.25 \times 0.25 = 0.0625$ mol
No. of moles of conc. solution $= 0.0625$ mol
$\therefore$ Volume of conc. solution $= \cancel{5.5/0.0625}$ $0.0625/5.5 = 0.0114 dm^3$.

d) $500 cm^3$ of $1.25 M$ $HNO_3(aq)$ from $3.25 M$ $HNO_3(aq)$
$500 cm^3 = 0.5 dm^3$
No. of moles of dil. solution $= 0.5 \times 1.25 = 0.625$ mol
No. of moles of conc. solution $= 0.625$ mol
$\therefore$ Volume of conc. solution $= 0.625/3.25 = 0.19 dm^3$

e) $250 cm^3$ of $2M$ $KOH(aq)$ from $2.6 M$ $KOH(aq)$
$250 cm^3 = 0.25 dm^3$.
No. of moles of dil solution $= 0.25 \times 2 = 0.5$ mol
No. of moles of conc solution $= 0.5$ mol
$\therefore$ Volume of conc. solution $= 0.5/2.6 = 0.19 dm^3$

5. 1 mol H_2SO_4 will neutralize

a) $500 cm^3$ of $NaOH(aq)$ of $4 M$. True or False.
$500 cm^3 = 0.5 dm^3$
No. of moles of NaOH $= 4 \times 0.5 = 2$ mol~~es~~ [1:2]
$H_2SO_4 + 2NaOH \longrightarrow Na_2SO_4 + 2H_2O$
~~Ratio = 1:2~~ Molar ratio = 1:2
$\therefore$ True

b) $1 dm^3$ of $KOH(aq)$ of $1 M$.
No. of moles of KOH $= 1 \times 1 = 1$ mol [1:1]
$H_2SO_4 + 2KOH \longrightarrow K_2SO_4 + 2H_2O$
Molar ratio = 1:2
$\therefore$ False

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c) $400 cm^3$ of NaOH (aq) of 5 M.
$400 cm^3 = 0.4 dm^3$
No. of moles of NaOH = $0.4 \times 5 = 2$ mol [1 : 2]
$H_2SO_4 + 2NaOH \longrightarrow Na_2SO_4 + 2H_2O$
Molar ratio = 1 : 2
∴ True.

d) $500 cm^3$ of Na_2CO_3 (aq) of 1 M
$500 cm^3 = 0.5 dm^3$
No. of moles of Na_2CO_3 = $1 \times 0.5 = 0.5$ mol [2 : 1]
$H_2SO_4 + Na_2CO_3 \longrightarrow Na_2SO_4 + H_2O + CO_2$
Molar ratio = 1 : 1
∴ False.

e) $2 dm^3$ of Na_2CO_3 (aq) of 0.5 M
No. of moles of Na_2CO_3 = $0.5 \times 2 = 1$ mol [1 : 1]
$H_2SO_4 + Na_2CO_3 \longrightarrow Na_2SO_4 + H_2O + CO_2$
Molar ratio = 1 : 1
∴ True.

f) $4 dm^3$ of KOH of 0.25 M.
No. of moles of KOH = $4 \times 0.25 = 1$ mol [1 : 1]
$H_2SO_4 + 2KOH \longrightarrow K_2SO_4 + 2H_2O$
Molar ratio = 1 : 2
∴ False.

6. 5 mol NaOH will neutralize

a) $2 dm^3$ of HCl of 2 M
No. of moles of HCl = $2 \times 2 = 4$ mol [5 : 4]
$NaOH + HCl \longrightarrow NaCl + H_2O$
Molar ratio = 1 : 1
∴ False.

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b) $250 cm^3$ of HCl of $10M$

$250 cm^3 = 0.25 dm^3$

No. of moles of $HCl = 0.25 \times 10 = 5/2$ mol [2:1]

$NaOH + HCl \longrightarrow NaCl + H_2O$

∴ False.

c) $250 cm^3$ of H_2SO_4 of $10 M$

$250 cm^3 = 0.25 dm^3$

No. of moles of $H_2SO_4 = 0.25 \times 10 = 5/2$ mol [2:1]

$2NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + 2H_2O$

∴ Molar ratio = 2:1

∴ True.

d) $500 cm^3$ of H_2SO_4 of $5 M$

$500 cm^3 = 0.5 dm^3$

No. of moles of $H_2SO_4 = 0.5 \times 5 = 5/2$ mol [2:1]

$2NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + 2H_2O$

Molar ratio = 2:1

∴ True.

e) $2500 cm^3$ of HNO_3 of $2M$

$2500 cm^3 = 2.5 dm^3$

No. of moles of $HNO_3 = 2.5 \times 2 = 5$ mol [~~2:5~~ 1:1]

$NaOH + HNO_3 \longrightarrow NaNO_3 + H_2O$

Molar ratio = 1:1

∴ True.

f) $2 dm^3$ of HNO_3 of $2M$

No. of moles of $HNO_3 = 2 \times 2 = 4$ mol [5:4]

$NaOH + HNO_3 \longrightarrow NaNO_3 + H_2O$

Molar ratio = 1:1

∴ False.

7. 0.5 mol Na_2CO_3 will neutralize

a) 1 dm^3 of HCl of 1 M

No. of moles of HCl = 1×1 = 1 mol [1:2]

$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + H_2O + CO_2$

∴ Molar ratio = 1:2

∴ True.

b) 1 dm^3 of H_2SO_4 of 1 M

No. of moles of H_2SO_4 = 1×1 = 1 mol [1:2]

$Na_2CO_3 + H_2SO_4 \longrightarrow Na_2SO_4 + H_2O + CO_2$

Molar ratio = 1:1

∴ False.

c) 500 cm^3 of HCl of 1 M

500 cm^3 = 0.5 dm^3

No of moles of HCl = 0.5 × 1 = 1/2 mol [1:1]

$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + H_2O + CO_2$

Molar ratio = 1:2

∴ False.

d) 250 cm^3 of HNO_3 of 2M

250 cm^3 = 0.25 dm^3

No. of moles of HNO_3 = 0.25×2 = 1/2 mol [1:1]

$Na_2CO_3 + 2HNO_3 \longrightarrow 2NaNO_3 + H_2O + CO_2$

Molar ratio = 1:2

∴ False.

e) 200 cm^3 of H_2SO_4 of 2.5 M

200 cm^3 = 0.2 dm^3

No. of moles of H_2SO_4 = 0.2×2.5 = 1/2 mol [1:1]

$Na_2CO_3 + H_2SO_4 \longrightarrow Na_2SO_4 + H_2O + CO_2$

Molar ratio = 1:1

∴ ~~False~~ True.

f) 500 cm^3 of HNO_3 of 2M

500 cm^3 = 0.5 dm^3

No. of moles of HNO_3 = 0.5 × 2 = 1 mol [1:2]

$Na_2CO_3 + 2HNO_3 \rightarrow 2NaNO_3 + CO_2 + H_2O$

Molar ratio = 1:2

∴ True.

8. Sodium carbonate (anhydrous) is used as a primary standard in volumetric analysis. A solution of Na_2CO_3 of 0.1 M is used to standardise solution of HCl. 25 cm^3 of Na_2CO_3 required 35 cm^3 of acid for neutralization. Find acid's concentration.

25 cm^3 = 0.025 dm^3

No. of moles of Na_2CO_3 = 0.025 × 0.1 = 1/400 moles

$Na_2CO_3 + 2HCl \rightarrow 2NaCl + CO_2 + H_2O$

Molar ratio is 1:2, so number of moles of HCl must be 1/200 moles.

35 cm^3 = 0.035 dm^3

∴ Concentration of acid = 0.035 × 200 = 7 mol dm^{-3}.

9. A sample containing ammonium sulphate was warmed with 250 cm^3 of 0.8 M NaOH solution. After evolution of ammonia had ceased, excess NaOH solution was neutralized by 85 cm^3 HCl of 0.5 M. What mass of ammonium sulphate did the sample contain?

250 cm^3 = 0.25 dm^3

No. of moles of NaOH = 0.25 × 0.8 = 0.2 moles.

$(NH_4)_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O + 2NH_3 \uparrow$

$HCl + NaOH \rightarrow NaCl + H_2O$

$\therefore$ No. of moles of HCl $= 85/1000 \times 0.5 = 0.0425$ mol

$\therefore$ No. of moles of excess NaOH $= 0.0425$ mol [1:1]

No. of moles of reacted NaOH $= 0.2 - 0.0425 = 0.1575$ mol

No. of moles of $(NH_4)_2SO_4 = 0.1575/2 = 0.07875$ mol

M $[(NH_4)_2SO_4] = 2\times14 + 4\times2 + 32 + 4\times16 = 132\ g\,mol^{-1}$

$\therefore$ Mass of ammonium sulphate $= 0.07875 \times 132$

≈ 10.4 g.

10. 0.5 g impure ammonium chloride is warmed with excess NaOH solution. Ammonia liberated is absorbed in 25.0 cm^3 of 0.2 M H_2SO_4. Excess H_2SO_4 needs 5.64 cm^3 of 0.2 M NaOH solution for titration. Calculate percentage of ammonium chloride in original sample.

$$NH_4Cl + NaOH \longrightarrow NaCl + H_2O + NH_3\uparrow \quad [1:1]$$

~~M [NH4Cl]~~

$$H_2SO_4 + 2NaOH \longrightarrow Na_2SO_4 + 2H_2O \quad [1:2]$$

$M[NH_4Cl] = 14 + 4 + 35.5 = 53.5\ g\,mol^{-1}$

~~No. of moles of $NH_4Cl = 0.5/53.5 = 1/107$ mol~~

No. of moles of $H_2SO_4 = 25/1000 \times 0.2 = 0.005$ mol

No. of moles of ~~excess~~ NaOH $= 5.64/1000 \times 0.2 = 0.001128$ mol

No. of moles of excess $H_2SO_4 = 0.001128/2 = 0.000564$ mol [1:2]

No. of moles of absorbing $H_2SO_4 = 0.005 - 0.000564 = 0.004436$ mol

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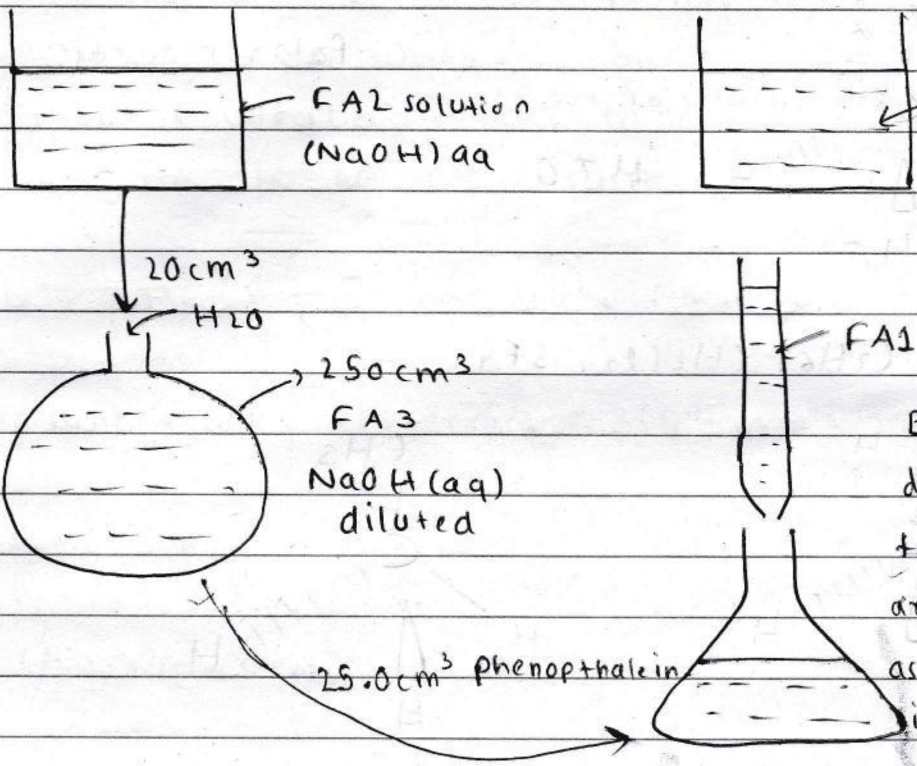
STOICHIOMETRY...



Endpoint is the stage during titration at which two reacting solutions are compeletely reacted as shown by the change in indicator colour.

Final reading /cm^3	27.00	26.80	26.70
Initial reading /cm^3	0.00	0.00	0.00
Volume of FA1 added /cm^3	27.00	26.80 ✓	26.70 ✓

i) Find volume of FA1 consumed in titration.

Volume of FA1 = $26.80 + 26.70 / 2 = 26.75\ cm^3$

ii) Calculate number of moles of HCl present in volume you obtain in (i)

Volume = $26.75 cm^3 = 0.02675\ dm^3$
Concentration = $1.00\ mol\ dm^{-3}$
∴ No. of moles = $1 \times 0.02675 = 0.02675$ mol

* Note: Equivalent point is stage during titration at which two reacting solutions are completely consumed according to their stoichiometry. This is theoretical point wheras endpoint is practical.

iii) Calculate no. of moles of NaOH present in 25.0 cm^3 of FA3.

$$NaOH + HCl \longrightarrow NaCl + H_2O$$

1 mol   1 mol

∴ Molar ratio = 1 : 1

∴ No. of moles of NaOH = 0.02675 mol

iv) Calculate no. of moles of NaOH present in ~~25.0 cm³~~ 250 cm^3 of FA3.

25 cm^3 of FA3 has 0.02675 mol of NaOH

∴ 250 cm^3 of FA3 has $0.02675 \times 10 = 0.2675$ mol.

v) Calculate concentration of FA2.

Volume of FA2 = 20 cm^3 = 0.02 ~~mo~~ dm^3

No. of moles = 0.2675 mol

∴ Concentration = $\frac{0.2675}{0.02}$ = 13.37 mol dm^{-3} ,,

When indicator changes colour, solution is already past equivalent point, as indicator only works in slightly acidic or slightly basic ~~poi~~ medium, and equivalent point is compeletely neutral. [pH-7], But after equivalent pt. one drop of acid from burrete makes flask sol. acidic and indicator colour changes. Thus, this end point comes after equivalent point. This difference between End Pt & Equ Pt is titration error.

Water of crystallization

Some compounds contain water molecules in their crystal structure.

$CuSO_4 . 5H_2O$, $BaCl_2 . 2H_2O$, $H_2C_2O_4 . 2H_2O$, $Na_2CO_3 . 10H_2O$

$$CuSO_4 . 5H_2O \xrightarrow{\Delta} CuSO_4 + 5H_2O$$

Hydrated — Anhydrous — Water of crystallization

1 mol — 1 mol — 5 mol

Number of moles of water moleculer associated with one mole of hydrated compound is called water of crystallization.

END OF CHAPTER EXERCISE

1ai) State meaning of relative atomic mass

→ Relative atomic mass is the mass of ~~an at~~ a number of atoms of an element compared to $1/12^{th}$ of the mass of an unbound, neutral, Carbon-12 isotope in its ground state. Mass of one mole of atoms of an element compared to unified atomic mass unit.

ii) $^{10}_{5}B$ (18.7%), $^{11}_{5}B$ (81.3%). Calculate relative atomic mass of Boron.

→ Relative atomic mass $= \frac{18.7 \times 10 + 81.3 \times 11}{100}$

$= 10.8$

b) B^{3+} can be formed by bombarding boron with e^-. Deduce no. of electrons in B^{3+}.

→ No. of electrons $= 5 - 3 = 2$

c)i) Boron is present in borates. Calculate relative molecular mass of $Fe(BO_2)_3$.

→ $M_r [Fe(BO_2)_3] = 55.8 + 3 \times 10.8 + 6 \times 16 = 184.2$

ii) Explain why accurate relative atomic mass is not a whole number.

→ It is not a whole number because percentage abundance are generally not in whole numbers ~~which~~, they are in random numbers which when multiplied and divided return non-whole values.

2ai) Hafnium forms hydrated peroxide $HfO_3 . 2H_2O$. Calculate its relative ~~atomic~~ molecular mass.

→ $Mr\ [HfO_3 . 2H_2O] = 178.5 + 3 \times 16 + 4 \times 1 + 2 \times 16 = 262.5$

ii) What is hydrated salt.

→ Hydrated salt is a salt which contains water of crystallization in its molecular lattice.

b) Hafnium isotope has 72 p^+ and 180 nucleon number. Write isotopic symbol.

→ $^{180}_{72}Hf$

ci) Give isotopic symbol for most abundant isotope of zirconium.

→ $^{90}_{40}Zr$

ii) Calculate relative atomic mass of zirconium.

→ Relative atomic mass $= \dfrac{90 \times 51.5 + 91 \times 11.2 + 92 \times 17.1 + 94 \times 17.4 + 96 \times 2.8}{100}$

$= 91.3$

iii) State meaning of relative isotopic mass.

→ Relative isotopic mass is the measured mass of a number of ~~isotopes of elemen~~ atoms of an isotope of an element compared to that of 1/12 th of the same number of carbon-12 isotope.

d) A sample of 15.2 g of tin (IV) oxide is mixed with 2.41 g of carbon and heated. Reaction is:

$$SnO_2 + 2C \longrightarrow Sn + 2CO$$

Show by calculation that reagent in excess is tin(IV) oxide.

$$SnO_2 + 2C \longrightarrow Sn + 2CO$$

150.7g   24g   118.7g   56g

$$\frac{24}{150.7} = \frac{2.41}{x}$$

$\therefore x = 15.1$

$\therefore$ Since 15.2 g SnO_2 is in the sample, but required is only 15.1 g, its in excess.

e) A sample zirconium is made by reacting 58.30 g of $ZrCl_4$, with excess magnesium.

$$ZrCl_4 + 2Mg \longrightarrow Zr + 2MgCl_2$$

Mass of zirconium produced is 20.52 g. Calculate percentage yield of zirconium.

$$ZrCl_4 + 2Mg \longrightarrow Zr + 2MgCl_2$$

233.2g   48.6g   91.2g   190.6 g

$$\cancel{\frac{233.2}{91.2}} \quad \frac{91.2}{233.2} = \frac{x}{58.30}$$

$\therefore x = 22.80$ g

$\therefore$ Percentage yield $= \frac{20.52}{22.80} \times 100\% = 90\%$

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3a) Rewrite eq^n to include state symbols.

→ $Na_2CO_3\ (s) + 2HCl\ (aq) \longrightarrow 2NaCl\ (aq) + CO_2(g) + H_2O(l)$

b) Calculate no. of moles of HCl required to react exactly with 4.15 g sodium carbonate.

$$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + CO_2$$
$$106\,g \quad 73\,g \quad\quad\quad 44\,g$$

$$\frac{73}{106} = \frac{x}{4.15}$$

$\therefore x = 2.86\,g$

$\therefore n[HCl] = \frac{2.86}{36.5} = 0.08$ mol

c) Define mole

→ Mole is the amount of matter of a substance. It is a standard unit of measure of no. of particles of a substance in chemistry. Its value is 6.02×10^{23} ~~moles~~.

d) $25\,cm^3$ Na_2CO_3 of 0.02 M is titrated with HCl. Volume of HCl is $12.50\,cm^3$.

i) Calculate no. of moles of Na_2CO_3 in solution.

→ No. of moles $= 0.02 \times \frac{25}{1000} = 5 \times 10^{-4}$ moles

ii) Calculate concentration of HCl

→ Volume of HCl $= 12.5/1000 = 0.0125\,dm^3$

No. of moles $= (5 \times 10^{-4}) \times 2 = 1 \times 10^{-3}$ moles

Concentration $= \frac{1 \times 10^{-3}}{0.0125} = 0.08\ mol\,dm^{-3}$

e) How many moles CO_2 produced when 0.2 mol Na_2CO_3 reacts with excess HCl.

$\frac{44}{106} = 1\,\cancel{x}$ $\quad \frac{n[Na_2CO_3]}{n[CO_2]} = \frac{1}{1}$

∴ No. of moles of CO_2 = 0.2 moles.

f) Calculate volume of this CO_2 at r.t.p.

→ Volume = 24 × 0.2 = 4.8 dm^3.

4. Hydrocarbon Z is composed of 80% carbon and 20% hydrogen.

a) Calculate empirical formula of Z.

→ Let Z be C_xH_y

Mass of Z = $12x + y$ g.

Mass of Carbon in Z = $\frac{4}{5}(12x+y)$ g.

Mass of Hydrogen in Z = $\frac{1}{5}(12x+y)$ g.

Mass of Carbon = $12x$

or, $\frac{4}{5}(12x+y) = 12x$

or, $48x + 4y = 60x$

or, $12x = 4y$

∴ $x : y = 1 : 3$

∴ Empirical formula : CH_3

b) Molar mass of Z is 30 $g\,mol^{-1}$. Deduce molecular formula.

→ Molecular formula : C_xH_{3x}

Mass of Z = $12x + 3x = 15x$ [1 mol]

or, $30 = 15x$

∴ $x = 2$

∴ Molecular formula : C_2H_6

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c) When $50 cm^3$ of hydrocarbon Y is burnt, it reacts with $300 cm^3$ O_2 to form $200 cm^3$ CO_2. Water is also formed. Construct eqⁿ for reaction and explain reasoning.

$$\boxed{C_xH_y + (x + y/4) O_2 \longrightarrow x CO_2 + y/2 H_2O}$$

$50 cm^3$ $300 cm^3$ $200 cm^3$

50g 0.2g $\frac{11}{30}$ g $\frac{299}{6}$ g

Volume of CO_2 = $0.2 dm^3$

No. of moles of CO_2 = $\cancel{0.2 \times 24}$ = $0.2/24 = 1/120$ mol

Volume of O_2 = $0.3 dm^3$

No. of moles of O_2 = $0.3/24 = 1/80$ mol

$O_2 / CO_2 = 1/80 \times 120 = 12/8 = 3/2$

$x + y/4 = 3$ $x = 2$

or $y/4 = 1$

$\therefore y = 4$

C_2H_4

~~Empirical formula = C_2H_4~~ Semi/empirical formula

$n(C_xH_y) = 6 n(O_2)$ ← As ~~carbon~~ hydrocarbon becomes gas when burnt

$= 6 \times 1/80$

$= 0.075$ mol

$$Y + O_2 \longrightarrow CO_2 + H_2O$$

$50 cm^3$ $300 cm^3$ $200 cm^3$

1 6 4

1 mole of Y and 6 moles of O_2 gives 4 moles of CO_2

Balancing eqⁿ we get,

$$Y + 6O_2 \longrightarrow 4CO_2 + 4H_2O$$

6

$n(C) = 4$, $n(H) = 4 \times 2 = 8$

$\therefore$ Hydrocarbon $Y \longrightarrow C_4H_8$

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d) Propane has formula C_3H_8. Calculate mass of $600 cm^3$ propane at rtp

$M[C_3H_8] = 3 \times 12 + 8 = 44 g mol^{-1}$
$600 cm^3 = 0.6 dm^3$.
$n[C_3H_8] = 0.6/24 = 0.025 mol$
$\therefore$ Mass of $C_3H_8 = 44 \times 0.025 = 1.1 g$.

5. When sodium reacts with $TiCl_4$, NaCl and Ti are formed.

a) Construct balanced eq^n for reaction.
→ $4Na + TiCl_4 \longrightarrow 4NaCl + Ti$

b) Calculate mass of Ti produced from 380 g $TiCl_4$. Give answer upto 3sf.
→ Molar ratio = 1 : 1
$M[TiCl_4] = 47.9 + 4 \times 35.5 = 189.9 g mol^{-1}$
$n[TiCl_4] = 380/189.9 = 2 mol$.
$n[Ti] = 2 mol$
$\therefore$ Mass of titanium $= 2 \times 47.9 = 95.8 g$.

c) Calculate mass of Ti produced from 46 g Na.
→ Molar ratio = 4 : 1
~~$M[TiCl_4] = 189.9 g mol^{-1}$~~
$M[Na] = 23 g$
$n[Na] = 46/23 = 2 mol$
$n[Ti] = 0.5 mol$ $[2/4]$
$\therefore$ Mass of titanium $= 0.5 \times 47.9 = 23.9 g$.

6. The reaction between NaOH and HCl is.

$HCl + NaOH \longrightarrow NaCl + H_2O$

In this reaction $15.0\ cm^3$ of HCl was neutralized by $20.0\ cm^3$ of 0.05 M NaOH

a) Calculate volume in dm^3 of

i) the acid ~~ii) +~~

+ Volume = $^{15}/_{1000} = 0.015\ dm^3$ ..

ii) the alkali

+ Volume = $^{20}/_{1000} = 0.0200\ dm^3$ ..

b) Calculate no. of moles of alkali

+ Volume = $0.0200\ dm^3$

Concentration = $0.05\ mol\ dm^{-3}$

∴ No. of moles = $0.05 \times 0.02 = 0.00100$ mol ..

c) Calculate no. of moles of acid and its concentration

+ Molar ratio = 1 : 1

∴ Number of moles = 0.00100 mol ..

∴ Concentration = $\frac{n}{V} = \frac{0.001}{0.015} = 0.0667\ mol\ dm^{-3}$ ..

7. Ammonium nitrate decomposes on heating to give nitrogen (II) oxide and water as follows.

$NH_4NO_3(s) \longrightarrow N_2O(g) + 2H_2O(l)$

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a) Deduce formula mass of ammonium nitrate.
→ Formula mass = $(14 + 4) + (14 + 3 \times 16) = 80.0\ g\ mol^{-1}$ //

b) How many moles of NH_4NO_3 are in 0.8g of it.
→ $M[NH_4NO_3] = 80\ g\ mol^{-1}$
Mass given = 0.8 g
∴ No. of moles = $^{0.8}/_{80} = 0.0100$ mol //

c) Calculate volume of N_2O produced from this mass NH_4NO_3.
→ Molar ratio = 1 : 1
$n(NH_4NO_3) = 0.01$ mol
$n(N_2O) = 0.01$ mol
∴ Volume of $N_2O = 24 \times 0.01 = 0.240\ dm^3$ //

8 a) $1.2\ dm^3$ of HCl gas wass dissolved in $100\ cm^3$ water

i) Calculate no. of moles of HCl gas.
→ Volume of gas = $1.2\ dm^3$
∴ No. of moles = $^{1.2}/_{24} = 0.0500$ mol //

ii) Calculate concentration of HCl formed.
→ $n(HCl) = 0.05$ mol
Volome of HCl = $100\ cm^3 = 0.1\ dm^3$.
∴ Concentration = $^{0.05}/_{0.1} = 0.500\ mol\ dm^{-3}$ //

b) $25\ cm^3$ of acid was titrated with NaOH of 0.2M to form NaCl and H_2O

$$NaOH + HCl \longrightarrow H_2O + NaCl$$

//

i) Calculate no. of moles of acid used.
→ Concentration = 0.5 mol dm^{-3}.
Volume = 25 cm^3 = 0.025 dm^3
∴ No. of moles = 0.5 × 0.025 = 0.0125 mol.

ii) Calculate volume of NaOH used.
→ Molar ratio = 1 : 1
∴ n(NaOH) = 0.0125 mol = n(HCl)
Molarity = 0.2 mol dm^{-3}.
∴ Volume of NaOH = 0.0125/0.2 = 0.0625 mol

9. 4.8 dm^3 of Cl gas was reacted with NaOH solution. Reaction takes place as:

$$Cl_2(g) + 2NaOH(aq) \longrightarrow NaCl(aq) + NaOCl(aq) + H_2O(l)$$

a) Calculate no. of moles of Cl_2 reacted.
→ Volume = 4.8 dm^3
∴ No. of moles = 4.8/24 = 0.200 mol.

b) Calculate mass of NaOCl formed.
Molar ratio [Cl_2 : NaOCl] = 1 : 1
n(NaOCl) = 0.2 mol
M[NaOCl] = 23 + 16 + 35.5 = 74.5 g mol^{-1}.
∴ Mass of NaOCl = 0.2 × 74.5 = 14.9 g.

c) NaOH was of ~~0.~~ 2 M. Calculate volume of NaOH required.
→ Molar ratio [Cl_2 : NaOH] = 1 : 2
n(NaOH) = 2 × 0.2 = 0.4 mol
∴ Volume of NaOH = ~~2/0.4 = 5 dm^3~~. 0.4/2 = 0.200 dm^3
= 200 cm^3.

d) Write ionic eq^n for the reaction.

→ $Cl_2 + 2Na^+ + 2OH^- \longrightarrow Na^+ + Cl^- + Na^+ + OCl^- + H_2O$

Cl $H^+ + OH^-$

10. Calcium oxide reacts with HCl as:

$CaO + 2HCl \longrightarrow CaCl_2 + H_2O$

a) Calculate mass of $CaCl_2$ formed when 28.05 g of CaO reacts with excess HCl.

→ Molar ratio [CaO : $CaCl_2$] = 1 : 1

M [CaO] = 40.1 + 16 = 56.1 g mol⁻¹

n [CaO] = 28.05/56.1 = 0.5 mol.

n [$CaCl_2$] = 0.5 mol

M [$CaCl_2$] = 40.1 + 2×35.5 = 111.1 g mol⁻¹

∴ Mass of $CaCl_2$ = 111.1 × 0.5 = 55.55 g.

b) Calculate mass of HCl that reacts with 28.05 g CaO.

→ Molar ratio [CaO : HCl] = 1 : 2

n (HCl) = 2 × 0.5 = 1 mol.

M [HCl] = 1 + 35.5 = 36.5 g mol⁻¹

∴ Mass of HCl = 36.5 × 1 = 36.5 g.

c) Calculate mass of water produced.

→ Molar ratio (CaO : H_2O) = 1 : 1

n (H_2O) = 0.5 mol

M [H_2O] = 2 + 16 = 18 g mol⁻¹

∴ Mass of H_2O = 18 × 0.5 = 9.00 g.

11. When NH_3 gas and HCl gas mix, they form a solid ammonium chloride.

a) Write a balanced eq^n for reaction with state symbols.
→ $NH_3 (g) + HCl (g) \longrightarrow NH_4Cl (s)$

b) Calculate molar masses of NH_3, HCl & NH_4Cl.
→ $M[NH_3] = 14 + 3 = 17 \ g \ mol^{-1}$
$M[HCl] = 1 + 35.5 = 36.5 \ g \ mol^{-1}$
$M[NH_4Cl] = 14 + 4 + 35.5 = 5\overset{3}{\cancel{8}}.5 \ g \ mol^{-1}$ "

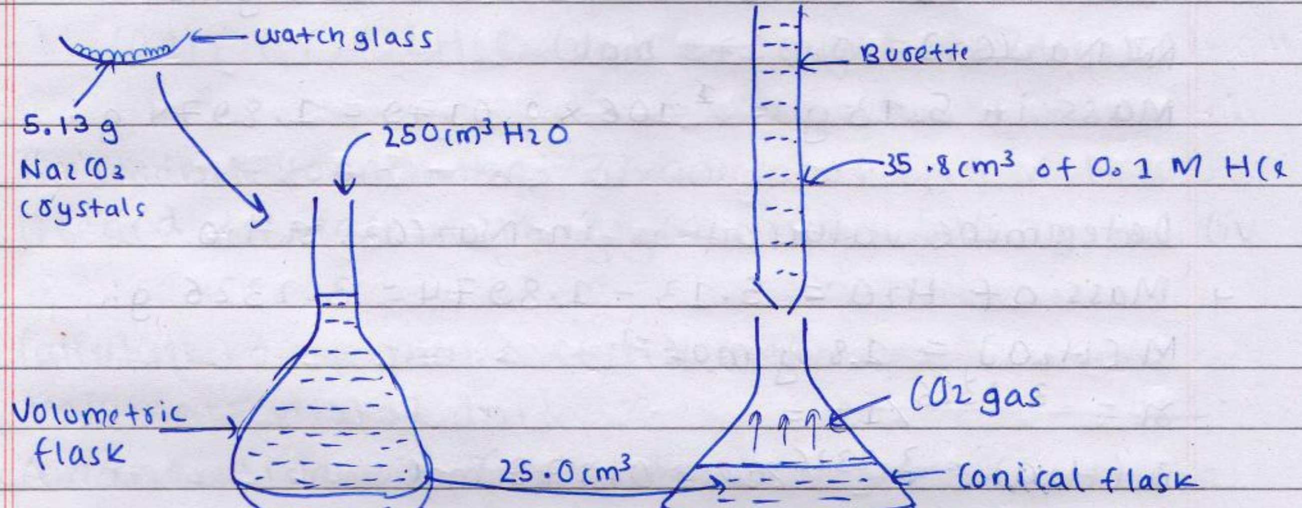
c) Calculate volumes of NH_3 and HCl at r.t.p to form 10.7 g of NH_4Cl
→ $M[NH_4Cl] = 5\overset{3}{\cancel{8}}.5 \ g \ mol^{-1}$
Given mass = 10.7g
$n[NH_4Cl] = 10.7/53.5 = 0.2\overset{00}{\cancel{12}}$ mol "
$n[NH_3] = n[\cancel{N}HCl] = n[NH_4Cl] = 0.2\overset{00}{\cancel{12}}$ mol
∴ Volume of $NH_3 = 0.2\overset{00}{\cancel{12}} \times 24 = 5\cancel{.08 \ dm^3}$ " $4.80 \ dm^3$
∴ Volume of $HCl = 0.2\overset{00}{\cancel{12}} \times 24 = 5\cancel{.08 \ dm}^3$ " $4.80 \ dm^3$

12. The mass spectrum of $CH_3CH_2CH_2CH_3$ is shown.

a) Identify fragments with mass charge ratios of

i) 15

Titration



Under similar condition of temperature and pressure equal volumes of all gases contain equal mole of molecules.

i) Write balanced eq^n for Na_2CO_3 and HCl reaction.

→ $Na_2CO_3 + 2HCl \longrightarrow 2NaCl + CO_2\uparrow + H_2O$

ii) Calculate amount in moles of HCl in $35.8\ cm^3$ of solution.

→ Volume $= 35.8\ cm^3 = 0.0358\ dm^3$

∴ No. of moles $= 0.1 \times 0.0358 = 3.58 \times 10^{-3}$ moles.

iii) Calculate amount in moles of Na_2CO_3 in the $25\ cm^3$ sol.

→ Molar ratio $(Na_2CO_3 : HCl) = 1:2$

∴ $n(Na_2CO_3) = 3.58 \times 10^{-3}/2 = 1.79 \times 10^{-3}$ moles.

iv) Calculate no. of moles of Na_2CO_3 in $250\ cm^3$ sol.

→ No. of moles $= 1.79 \times 10^{-3} \times 10 = 0.0179$ moles.

v) Calculate mass of Na_2CO_3 in 5.13 g of crystals.

→ $M[Na_2CO_3] = 2\times23 + 12 + 3\times16 = 106\ g\ mol^{-1}$

$N[Na_2CO_3] = 0.0179$ mol

∴ Mass in 5.13 g = $106 \times 0.0179 = 1.8974$ g.

vi) Determine value of n in $Na_2CO_3 . nH_2O$

→ Mass of $H_2O = 5.13 - 1.8974 = 3.2326$ g.

$M[H_2O] = 18\ g\ mol^{-1}$

∴ ~~$n = 3.2326/18 =$~~

$n(H_2O) = 3.2326/18 = 0.179$ mol.

0.0179 mol Na_2CO_3 has 0.179 mol H_2O

1 mol Na_2CO_3 has n mol H_2O

$$\frac{1}{0.0179} = \frac{n}{0.179}$$

∴ $n = 10.03$. [Never in fractional]

∴ Formula: $Na_2CO_3 . 10H_2O$.

3a) Compound containing Mg, Si and O is present in rock types in Italy. A sample weighing 5.27g was found to have Mg - 1.82 g, Si - 1.05 g, O - 2.40 g. Deduce empirical formula.

$Mg_xSi_yO_z$.

$(24x + 28y + 16z) \times n = 5.27$

$24nx = 1.82$ $\quad$ $28ny = 1.05$ $\quad$ $16nz = 2.40$

∴ $x = 1.82/24n$ $\quad$ ∴ $y = 1.05/28n$ $\quad$ ∴ $z = 2.40/16n$

$x : y = \frac{1.82}{24n} \times \frac{28n}{1.05} \approx 2 : 1$

$y : z = \frac{1.05}{28n} \times \frac{16n}{2.40} \approx 1 : 4$

∴ $x : y : z = 2 : 1 : 4$

∴ Empirical formula: Mg_2SiO_4.

b) $Mg(OH)_2$ was reacted with HCl (tablet of $Mg(OH)_2$)

$Mg(OH)_2\,(s) + 2HCl\,(aq) \longrightarrow MgCl_2 + 2H_2O\,(l)$

The student found that $32.00\ cm^3$ of 0.5 M HCl was needed to react with $Mg(OH)_2$ in 500 mg tablet.

i) Calculate no. of moles of HCl used.

→ Volume = $0.032\ dm^3$

Concentration = $0.5\ mol\,dm^{-3}$

∴ No. of moles = $0.5 \times 0.032 = 0.016$ moles.

ii) Calculate no. of mol of $Mg(OH)_2$ in the tablet.

→ Molar ratio $[Mg(OH)_2 : HCl] = 1 : 2$

∴ No. of moles = $0.016/2 = 0.008$ moles.

iii) Determine percentage by mass of $Mg(OH)_2$ in tablet.

→ $M[Mg(OH)_2] = 24 + 2\times16 + 2 = 58\ g\,mol^{-1}$

Mass in 0.08 moles = $58 \times 0.008 =$ ~~4.64 g~~ 0.464 g.

Mass in tablet = 0.500 g.

∴ Percentage by mass = $\frac{0.464}{0.500} \times 100 = 92.8\ \%$

1a) Give formulae of two simple zinc compounds that could react with dil. H_2SO_4 to produce zinc sulfate.

→ Zinc nitrate - $Zn(NO_3)_2$

Zinc oxide - ZnO

b) An experiment is done to find x in $ZnSO_4 . xH_2O$ reaction.

$ZnSO_4 . xH_2O(s) \longrightarrow ZnSO_4(s) + xH_2O(g)$

mass of empty tube - 74.25 g

mass of tube + hydrated salt - 77.97 g

mass of tube + salt after heating - 76.34 g

i) Why was tube heated, cooled and reweighed four times.

→ It was done so to ensure almost all the water molecules evapourate away and a constant value of mass can be obtained and checked.

ii) Calculate no. of moles of anhydrous salt formed.

→ Mass of hydrated salt = 77.97 - 74.25 = 3.72 g

Mass of anhydrous salt = 76.34 - 74.25 = 2.09 g

$M[ZnSO_4] = 65 + 32 + 4 \times 16 = 161\ g\ mol^{-1}$

∴ No. of moles = $2.09/161 = 0.0129$ moles

iii) Calculate no. of moles of water driven by heating

Mass of water = 3.72 - 2.09 = 1.63 g

$M[H_2O] = 18\ g\ mol^{-1}$

∴ No. of moles = $1.63/18 = 0.0905$ moles

iv) Calculate value of x in $ZnSO_4 . xH_2O$

→ $\frac{0.0129}{0.0905} = \frac{1}{x}$

∴ $x = 6.97 \approx 7$

∴ $ZnSO_4 . 7H_2O$

c) For many people, an intake of approximately 15 mg Zn per day is sufficient to prevent deficiencies. Zinc ethanoate crystals, $(CH_3CO_2)_2Zn.2H_2O$, may be used in such a way.

i) What mass of pure zinc ethanoate crystals ($M_r = 219.4$) will need to be taken to obtain 15 mg of Zinc.

$\frac{219.4}{65.4} = \frac{x}{0.015}$

$\therefore x = 0.0503 g.$ [50.3 mg]

$\therefore$ Mass of pure zinc ethanoate crystals = 0.0503 g.

ii) If this dose is taken in solution as $5 cm^3$ of aqueous zinc ethanoate, what would be concentration of solution used. Give answer in $mol\ dm^{-3}$.

Volume = $5 cm^3 = 5 \times 10^{-3} dm^3$.

No. of moles = $0.0503/219.4 = 2.29 \times 10^{-4}$ moles.

$\therefore$ Concentration = $\frac{2.29 \times 10^{-4}}{5 \times 10^{-3}} = 0.0459\ mol\ dm^{-3}$.

2. A student is given a sample of M_2CO_3 where M is a metal and A_r value of M is to be found.

a) Calculate mass of M_2CO_3

Mass of beaker + M_2CO_3 = 7.69 g

Mass of beaker = 5.99 g

$\therefore$ Mass of M_2CO_3 = 7.69 − 5.99 = 1.70 g.

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b) Student transfers this mass into a beaker and adds 50 cm^3 of 1.00 M HCl acid. A gas is produced. Name gas and describe a test for it.

→ $M_2CO_3 + HCl \longrightarrow MCl + CO_2\uparrow + H_2O$

The ~~gass~~ gas is carbon dioxide and a test for it can be to insert blue litmus paper (wet) which ~~for~~ becomes red if CO_2 is produced.

c) Then solution in beaker is transferred into volumetric flask and made up to 250 cm^3 with water. This is sol. G. 25.0 cm^3 of G is transferred to conical flask and methyl orange added. Burette is filled with 0.1 M NaOH. It is run through flask until end point is reached. What is colour change of methyl orange in this titration.

→

d) Complete the table.

cm^3	1	2	3
final burette reading	25.90	48.60	32.20
initial burette reading	0.00	23.30	6.90
Vol. of HCl	25.90	25.30 ✓	25.30 ✓

~~e) Calculate number of moles of~~

Vol. of NaOH is 25.30 cm^3

e) Calculate number of moles of NaOH in 0.1 M NaOH

→ Volume = 0.0253 dm^3

∴ No. of moles = 0.1 × 0.0253 = 0.00253 moles

f) Using eq^n below, calculate no. of moles of HCl in 25.0 cm^3 of G.

$NaOH + HCl \longrightarrow NaCl + H_2O$

→ No. of moles = 0.00253 moles.

g) Calculate no. of moles of HCl in 250 cm^3 of G

→ No. of moles = 0.00253 × 10 = 0.0253 moles.

h) Calculate no. of moles of HCl in original 50.0 cm^3 of 1 M HCl.

→ Volume = 0.05 dm^3

∴ No. of moles = 1 × 0.05 = 0.05 moles.

i) Calculate no. of moles of HCl reacted with M_2CO_3

→ No. of moles = 0.05 − 0.0253 ≐ 0.0247 moles.

j) Using eq^n below calculate no. of moles of M_2CO_3 that reacts with HCl.

$M_2CO_3 + 2HCl \longrightarrow 2MCl + CO_2 + H_2O$

→ No. of moles = 0.0247/2 = 0.01235 moles.

k) Calculate relative formula mass of M_2CO_3 and hence relative atomic mass of M.

→ Relative formula mass = 1.70/0.01235 = 137.65.

137.65 = 2 Ar[M] + 12 + 3 × 16

∴ Ar[M] = 38.8259 ≈ 38.8.

STOICHIOMETRY . . .

$Ca(OH)_2 + 2NH_4Cl \longrightarrow CaCl_2 + 2NH_3 + 2H_2O$

What mass of slaked lime is required to react completely with 5.35 g of NH_4Cl

$Ca(OH)_2 + 2NH_4Cl \longrightarrow CaCl_2 + 2NH_3 + 2H_2O$
74 g   107 g   111 g   34 g   36 g

$\frac{x}{5.35} = \frac{74}{107}$

$\therefore x = 3.7$ g

Find amount of salt and NH_3 produced.

~~3.7~~ 74 g $Ca(OH_2)$ gives 111 g salt and 34 g NH_3
3.7 g gives 5.55 g salt & 1.7 g NH_3
Volume of ammonia at r.t.p $= \frac{1.7}{17} = \frac{1}{10}$ mol
$= \frac{1}{10} \times 24 = 2.4\ dm^3$

Calculate max. mass of Na_2O_2 formed when 4.6 g Na is burnt in excess oxygen.

$2Na + O_2 \longrightarrow Na_2O_2$
46 g   32 g   78 g

Oxygen is excess agent.
46 g sodium gives 78 g Na_2O_2
$\therefore$ 4.6 g sodium gives 7.8 g Na_2O_2

Calculate mass of carbon that exactly reacts with 14g Tin oxide

$$SnO_2 + 2C \longrightarrow Sn + 2CO$$
$$150.7g \quad 24g \qquad 118.7g \quad 56g$$

$$\frac{150.7}{24} = \frac{14}{x}$$

$\therefore x = 2.22g$

56.2 g Si reacts exactly with 284 g Cl to form 340.2 g $SiCl_4$. Calculate stoichiometry of reaction

$$aSi + bCl_2 \longrightarrow cSiCl_4$$
$$a.28.1\,g \quad \cancel{b35}\; b.71\,g \qquad c.170.1\,g$$

$28.1a = 56.2$ $\qquad 71b = 284$ $\qquad 170.1c = 340.2$

$\therefore a = 2$ $\qquad \therefore b = 4$ $\qquad \therefore c = 2$

$\therefore 2Si + 4Cl_2 \longrightarrow 2SiCl_4$ is the actual equation.

Percentage Yield

In many chemical reactions, especially organic, not all reactants are changed into wanted products. This is because there are some other reactions going on at same time. Percentage yield tells us how much of a particular product you get from reactants compared with max. theoretical amount that you can get.

$$\text{Percentage yield} = \frac{\text{Actual yield}}{\text{Predicted yield}} \times 100$$

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A sample $AlCl_3$ is made by 18 g aluminium powder with excess chlorine. Mass of $AlCl_3$ produced is 71 g. Calculate percentage yield of $AlCl_3$

$2Al + 3Cl_2 \longrightarrow 2AlCl_3$

~~18g~~

54g   213g   267 g

$\frac{54}{267} = \frac{18}{x} \quad \therefore x = 89\,g$

$\therefore$ Percentage yield $= \frac{71}{89} \times 100 = 79.7\% \approx 80\%$

Empirical formula

- Ratio of number of atoms in molecules.
- Eg of H_2O_2, empirical formula is HO.
- Formula of ionic compound is always its empirical formula.
- Molecular formula of simple inorganic compounds is often same as empirical formula.

When 1.55 g phosphorous is completely combusted and 3.55 g Phosphorus oxide

= Molecular formula is representation of ~~the~~ actual ~~number of~~ a molecule of an element and/or compound showing actual no. of atoms of different elements present in it.

Empirical formula of a compound is the simplest whole number ratio of nos. of atoms of elements present in one molecule of that compound.

Deducing an empirical formula from data:

- Note mass of elements. [Element A – x g]
- Divide by molar mass. [x / Ar[A]]
- Divide by lowest figure.
- Convert into simplest whole no. ratio.

When 1.55 g Phosphorus is completely combusted and 3.55 g of an oxide of phosphorus is produced. Deduce empirical formula of this oxide. Ar[O] = 16, Ar[P] = ~~32~~ 31

	P	O
→	1.55 g	2 g
→	$1.55/31 = 0.05$ mol	0.125 mol
→	$\frac{0.05}{0.05} = 1$	$\frac{0.125}{0.05} = 2.5$
	2	5

$n\,P_xO_y$

$31nx = 1.55$

~~$31ny =$~~

$16ny$

$16ny = 2.00$

$\frac{31x}{16y} = \frac{1.55}{2.00}$

$\therefore \frac{x}{y} =$

P : O = 2 : 5 P_2O_5 [Empirical formula]

A hydrocarbon contains 85.7% carbon and 14.3% hydrogen by mass. Deduce empirical formula

	C	H
→	85.7%	14.3%
→		

CH = 13g

$C_{11.141}\,H_{1.859}$

Empirical and molecular formula are related as:-

Molecular formula = n × Empirical formula

where, $n = \frac{\text{Relative molecular wt.}}{\text{Empirical formula mass}}$

Hydrocarbons are compounds of C and H. Hydrocarbon Z is composed of 80% carbon and 20% Hydrogen. Find empirical formula. The molar mass of Z is 30 g/mol. Deduce molecular formula.

$M[C] = 12x$ $\quad\quad Z = C_xH_y$

$M[H] = y$

80% of Total mass (M) = $12x$

20% of Total mass (M) = y

$\frac{4}{5}M = 12x$, $\frac{1}{5}M = y$

$\frac{12x}{y} = \frac{4\cancel{M}}{\cancel{5}} \times \frac{\cancel{5}}{\cancel{M}}$

or, $\frac{x}{y} = \frac{4}{12}$

∴ $x : y = 1 : 3$

∴ Empirical formula = CH_3

$30 = n \times 15$

∴ $n = 2$

∴ Molecular formula = C_2H_6

Concentration of a solution

+ Amount of solute dissolved in a certain volume of a solution. (Number of moles of solute) / (Mass)
(not solvent)

$$\text{Concentration} = \frac{\text{Amount of solute (mol) / g}}{\text{Volume of solution } (dm^3)} \quad mol/dm^3 \;/\; g/dm^3$$

mol/dm^3 is commonly referred to as Molarity.

$1\ dm^3 = 1000\ cm^3$

[g/dm^3 / molar mass = mol/dm^3]

Find the concentration of :

a) ~~98g H_2SO_4~~ $500\ cm^3$ H_2SO_4 solution contains 98g of H_2SO_4.

b) $250\ cm^3$ of Na_2CO_3 solution contains 10 g of Na_2CO_3

c) $1\ dm^3$ of HCl solution contains 36.5 g HCl.

d) $25\ cm^3$ of KOH solution contains 3g of KOH.

a) $500\ cm^3 = 500/1000 = 1/2\ dm^3$

$n(H_2SO_4) = 1\ mol\ (98/98)$

concentration $= 1/1/2 = 2\ mol/dm^3$

b) $250\ cm^3 = 1/4\ dm^3$

$n(Na_2CO_3) = 10/106 = 5/53\ mol$

Concentration $= 5/53 / 1/4 = 0.4\ mol/dm^3$.

c) $n(HCl) = 36.5/36.5 = 1\ mol$

Concentration $= 1\ mol/dm^3$

d) $25\ cm^3 = 25/1000 = 1/40\ dm^3$

$n(KOH) = 3/56 = 3/56\ mol$

Concentration $= 3/56 / 1/40 = 2.14\ mol/dm^3$.