TOPIC ONE: STOICHIOMETRY

1.1 Particulate matter and chemical change.

- atoms of different elements in fixed ratios (combine) to form compounds
- an element cannot be broken down into a simpler substance(s)
- the smallest part of an element = atom

mixtures are not chemically bonded tgt = retain individual properties
↳ homogeneous : same phase (state)
heterogeneous: different phase (ice + water)

compounds contain more than 1 element chemically combined in a fixed ratio.

SOLID ⇌ (melting / freezing) LIQUID ⇌ (evaporation / condensation) GASEOUS

sublimation → (SOLID to GASEOUS)
← deposition

1.2 The mole

- allows us to weigh elements / compds ("n")
- 6.02×10^{23} : one mole contains THIS amt of an atom/molecule
- mass (relative atomic mass) is compared to ^{12}C atom (Ar and Mr)
  ↳ mean of all naturally occurring isotopes relative to C-12

general term: (Ar) molar mass is in $g\,mol^{-1}$ · RAM has NO units (Mr) → you add up the Ar of all elements

- compounds - different chemical formula
  empirical formula: simplest whole no. ratio of atoms of each element in a substance
  molecular formula: actual whole no. ratio of atoms of each element " "
  ↳ need MOLAR MASS if you have empirical formula

chemical formula :

Valency 1	Valency 2	Valency 3
Ammonium NH_4^+	CO_3^{2-}	PO_4^{3-}
OH^-	SO_4^{2-}	
NO_3^-		
Hydrogen Carbonate HCO_3^-		
hydrogen sulphate HSO_4^-		

ionic equations - aqueous ions during reaction (aq. and − or +)
① Full eqn
② split into aq ions
③ removed uncharged.

e.g. $MgCl_2 \rightarrow Mg^{2+}$ and $2Cl^-$

$H_2SO_4 \rightarrow 2H^+$ n SO_4^{2-}

e.g. $Ba(NO_3)_2 + H_2SO_4 \rightarrow BaSO_4 + 2HNO_3$

$Ba^{2+} + 2NO_3^- + 2H^+ + SO_4^{2-} \rightarrow Ba^{2+} + SO_4^{2-} + 2H^+ + 2NO_3^-$

$Ba + SO_4 \rightarrow BaSO_4$

molar mass is the mass of 1 mole of an element / molecule / cpd

$$\text{moles} = \frac{\text{mass}}{\text{molar mass}} \qquad n = \frac{m}{Mr}$$

$$\text{moles} = \frac{\text{no. of particles}}{6.02 \times 10^{23}}$$

$$\text{no of particles} = \text{moles} \times 6 \times 10^{23}$$

empirical and molecular formula (example)

Mr = 88   54.5% C, 9.1% H   36.4% O

	C	H	O
mass	54.5	9.1	36.4
moles	÷ 12.01 = 4.5	÷ 1.01 = 9	÷ 16 = 2.25
÷ 2.25	2	4	1

empirical C_2H_4O ⇒ 12.01×2 + 4.04 + 16 ⇒ 44.06

molecular 88 ÷ 44 = 2 $C_{2\times2}H_{4\times2}O_{1\times2}$

$C_4H_8O_2$

combustion analysis: all C → CO_2 (get compd based off products)

all H → H_2O (2:1 ratio)

all O → obtained by subtracting C + H off initial mass of cpd)

e.g. 1g vitamin C, 1.5g CO_2, 0.408 g H_2O

	C	H	O
proportion of element in compound	12/44	2/16	

① divide by Mr of compound

(actual Mr) $\frac{1.5}{44}$ $\frac{0.408}{16}$

② × by the Mr of Element

$\frac{1.5}{44} \times 12$ $\frac{0.408}{16} \times 2$

mass : 0.409   0.0457

moles : ÷12 0.0341   ÷ 1 0.0452

$C_3H_4O_3$

1.3 reacting mass and volume

- moles of a gas → ONE MOLE OF ANY GAS (at stp) OCCUPIES THE SAME VOLUME ⇒ 22.7
  → $n = \frac{V_{gas}}{22.7}$ at 273 K, 1 atm (101 kPa)

e.g. 10g Iron (Fe_2O_3) → calculate mass of Fe and vol of CO_2 produced

$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

$n = \frac{10}{159.7} = 0.0626$ | 0.125 | 0.187

g | 0.125 × 55.85 | 0.187 × 22.7

6.98 | = 4.24 dm^3

- limiting reagents : when one reactant runs out ⇒ the reaction stops.

e.g. $Mg + 2HCl \rightarrow MgCl_2 + H_2$

① convert to moles — g = 5.0 | 10.0

n = 0.205 | 0.274

② ÷ coefficient — 0.205 > 0.137

∴ HCl is limiting

③ use moles of limit r. (0.274) → moles of H_2 formed = $\frac{.274}{2}$ = 0.137

0.137 × 22.4 = 3.07 dm^3

→ mg in excess 0.205 − 0.137 = 0.068 (m

0.068 × 24.31 = 1.65g.

reactions w/ gases

at STP: ONE MOLE OF ANY GAS OCCUPIES SAME VOLUME

$2SO_2 + O_2 \rightarrow 2SO_3$

rxn ratio 2 : 1 : 2

100 cm^3 : 50 cm^3 : 100 cm^3

but... what if... temperature isn't 273K and pressure is not 1 atm? ☹

use IDEAL GAS equation: $PV = nRT$ → kelvin; R → 8.31 (gas constant)

P: kPa / Pa; V: dm^3 / m^3

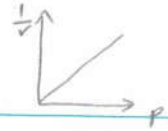
ie $PV = \frac{m}{Mr} RT$

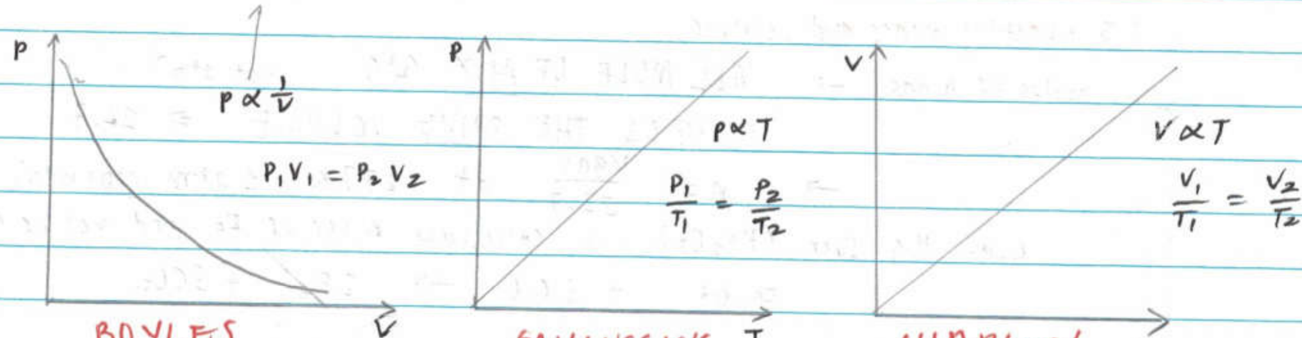
behaviour of gases → negligable volume
→ no forces btwn molecules
→ elastic collisions

→ if pressure doubles ... volume halves
if temperature doubles ... volume doubles
if temperature doubles ... pressure doubles

$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$ → in KELVIN!

high temp + low pressures = ideal gas falls apart.





BOYLES	GAY LUCSAC'S	CHARLES'
constant temp	constant vol	constant pressure
boils – without temp.	gay – part time	charles pressure #B 99

↳ real gases don't behave this way (low K, high Pa) LEAST ↗ (High K, low Pa) MOST ↗

↳ they move a lot slower + much closer together -- there is also attractive force btwn particles.

reactions with SOLUTIONS

- solid (solute) dissolved in solvent ⇒ solution made.

concentration = moles/volume

$n = c \times V\ (dm^3)$ unit of conc = $mol\,dm^{-3}$

- a standard solution is one of known concentration

titrations: determining the concentration/volume of an unknown solution using the standard solution of known concentration.

e.g. $HCl + NaOH \longrightarrow NaCl + H_2O$

$25cm^3$ HCl, $0.1\ mol\,dm^{-3}$

$n(HCl) = cV = .10 \times 0.025 = 0.0025$ moles

rxn rio 1 : 1

0.0025 : 0.0025

21.5 cm^3 NaOH c

$n(NaOH)$ in $21.5\ cm^3 = 0.0025$

$c = \frac{0.0025}{0.0215} = .116\ mol\,dm^{-3}$

back titrations: 20g marble, dissolved in $0.25dm^3$ of $2.0mol\,dm^{-3}$ HNO_3 ⇒ $25cm^3$ of remaining acid needed $17.00dm^3$, $1.0\ mol\,dm^{-3}$ of NaOH for neutralisation

① moles of NaOH : $0.017 \times 1 = 0.017$ moles

② Eqn : $NaOH + HNO_3 \rightarrow NaNO_3 + H_2O$

③ rxn rto : NaOH 1 : 1 HNO_3 = 0.017 moles of HNO_3

moles of HNO_3 in OG solution = 0.25×2 = .5 moles.

$0.5 - 0.17 = 0.33$ moles. (of HNO_3 reacted.)

11.1 uncertainties

Random errors: · imprecise measurements
· far from "true" value
→ more precise equipment
→ repeat measurements

systematic errors: · poor design
· always deviate from "true" value
→ poor insulation / incorrect indicator / measuring device

accuracy: how close to a measured value

precision: how many SIGNIFICANT figures

random uncertainties: recorded to ONE s.f

measurements: include first uncertain figure e.g. 45.310 ± 0.001
NOT 45.31 ± 0.001
NOT 45.31 ± 0.01

Absolute uncertainty: random uncertainty estimated from equipment e.g. ± 0.001

percentage uncertainty: $\frac{\text{abs un}}{\text{measured value}} \times 100$

propogating errors

when adding/subtracting values = ADD absolute uncertainty

e.g. 22.3 ± 0.1 °C
27.3 ± 0.1 °C } temperature rise is 5°C ± 0.2 °C

when multiplying / dividing values = ADD percentage uncertainty

e.g. 1.00 ± 0.05 $mol dm^{-3}$
100 ± 0.1 cm^3 ↓
0.01 ± 0.0001

C×V = 0.01 moles

% uncertainty $\frac{0.05}{1} = 0.05$, 5%
$\frac{0.0001}{0.01} \times 100 = 1\%$ ⇒ 6%

0.01 moles ± 6%

% in 1 s.f if ≥ 2
% in 2 s.f if < 2

final answer = first uncertain figure's no. of s.f.

final uncertainty = 1 s.f!

significant figures when × or ÷ ⇒ same s.f as least precise data
when + or − ⇒ same d.p as least precise da

QUESTIONS TO NEVER GET WRONG

- empirical formula of a compound – 85.7% C, 14.3% H

  C $\frac{85.7}{12.01}$: H $\frac{14.3}{1.01}$

  7 : 14

  $\therefore CH_2$

- actual volume of hydrogen lower – why? ($Mg + HCl$)
  - ↳ some gas escaped
  - ↳ impure Mg.
  - ↳ gas syringe = stuck

- $BaCl_2$ added to $Fe(NH_4)_2(SO_4)_2$, 5.02×10^{-3} mol of $BaSO_4$ obtained.

  How many moles of SO_4 ions and Fe ions in the sample?

  Fe^{2+} and $2NH_4^+$ and $2SO_4^{2-}$

  $BaSO_4 \rightarrow$ all go to SO_4 $\therefore$ SO_4 must have 5.02×10^{-3}

  Fe only has 1 mole per every 2 mols of SO_4 $\therefore$ $\div 2$ of 5.02×10^{-3}

- Random uncertainty = REPEAT

  = more precise equipment

  ↳ systematic

- $CaCl_2$ (0.265g) and KNO_3 is dissolved in $50 cm^3$ water

  mixture titrated w/ $0.1 \, mol dm^{-3}$ $AgNO_3$ – produce AgCl. This used $38.5 cm^3$ of $AgNO_3$.

  → $CaCl_2 + 2AgNO_3 \rightarrow 2AgCl + Ca(NO_3)_2$

  → moles of silver nitrate → $0.1 \times 0.0385 = 3.85 \times 10^{-3}$

  → moles of $CaCl_2$ titrated.

  - $\frac{1}{2}$ of $AgNO_3$ = 1.925×10^{-3}
  - mass of $CaCl_2$ in sample ↑ $\times (40.08 + 35.45 \times 2)$

    ↳ 0.21363... g = 0.214g