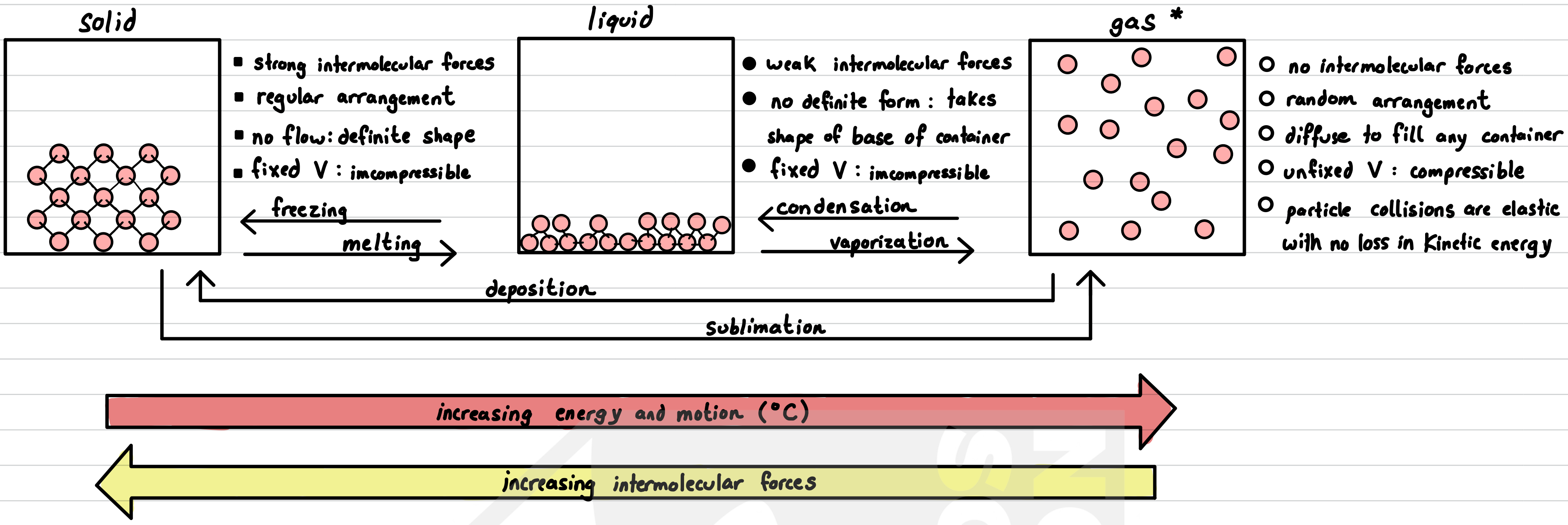
Ideal Gases

Matter exists in different **phases** depending on the amount of kinetic energy (temperature) particles have

Particle model of matter: describes how particles (can be individual atoms, molecules, compounds) move and interact in different phases

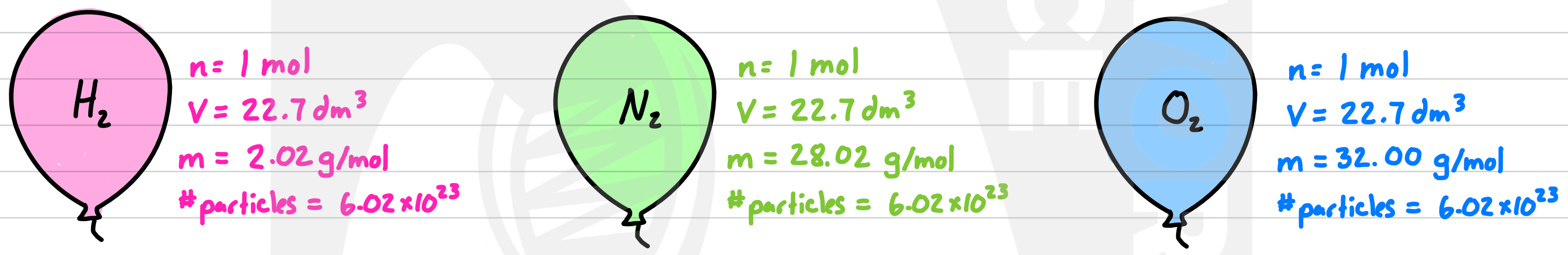


* these properties are true for 'ideal' gases but this is not true for all gases

Avogadro's Law: under Standard Temperature and Pressure (STP) equal volumes of different gases contain equal number of particles.

- 273 K or 0 °C
- 100 kPa or 1 atm

} 1 mol of gas occupies **22.7 dm^3**



$$n_{gas} = \frac{V}{V_m}$$

- n_{gas}: amount of ideal gas (mol)
- V: Volume of gas (dm^3 or L)
- V_m: gas molar volume (22.7 $dm^3 mol^{-1}$)

Example problems

(i) ~ Calculate volume of gas ~

Calculate the volume occupied by 16.00 g of O_2 at STP.

$n = 16.00\ g \times \frac{mol}{32.00\ g} = 0.500\ mol$

$V_m = 22.7\ dm^3 mol^{-1}$

$V = n \times V_m = (0.500\ mol)(22.7\ dm^3\ mol^{-1})$

$= $ **11.35 dm^3**

(ii) ~ Calculate mass of gas ~

Calculate the amount of grams of 5.43×10^4 mL of CH_4 at STP.

$V_m = 22.7\ dm^3 mol^{-1}$

$V = 5.43 \times 10^4\ mL \times \frac{1\ dm^3}{1000\ mL} = 54.3\ dm^3$

$n = \frac{V}{V_m} = \frac{54.3\ dm^3}{22.7\ dm^3 mol^{-1}} = 2.392\ mol\ CH_4 \times \frac{16.05\ g}{mol} = $ **38.4 g**

(iii) ~ Calculate number of atoms of gas ~

A sample of Cl_2 gas at STP occupies 17.1 L. Calculate the mass of Cl_2 and number of Cl atoms present in sample.

$V = 17.1\ dm^3$

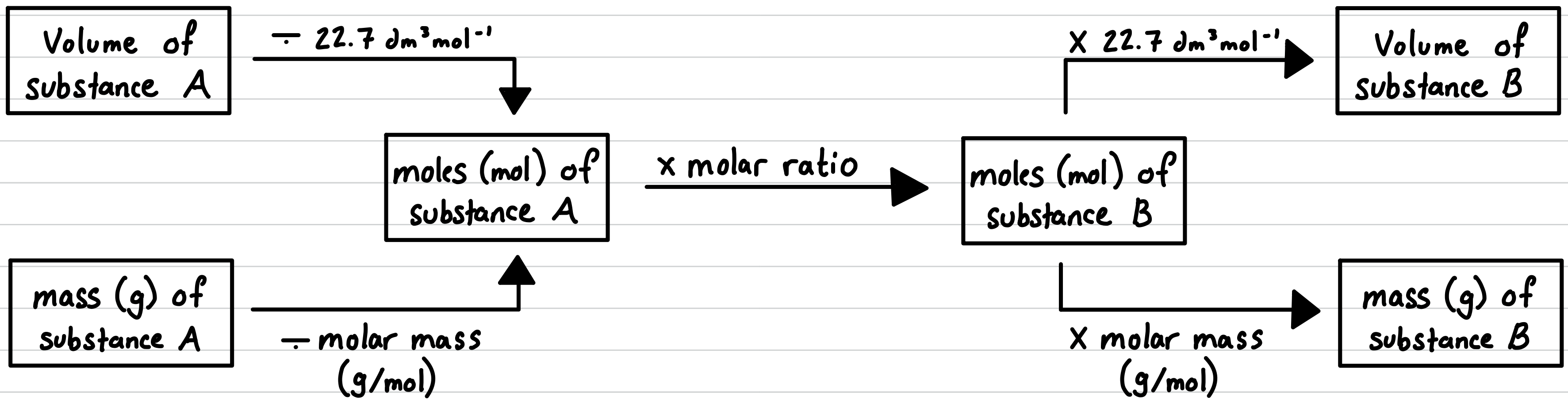
$V_m = 22.7\ dm^3$

$n = \frac{V}{V_m} = \frac{17.1\ dm^3}{22.7\ dm^3 mol^{-1}}$

$= 0.753\ mol \times \frac{70.9\ g}{mol} = $ **53.4 g**

$0.753\ mol \times \frac{6.02 \times 10^{23}\ Cl_2\ molecules}{1\ mol} \times \frac{2\ Cl\ atoms}{1\ Cl_2\ molecules} = $ **9.07×10^{23} Cl atoms**

Gas Stoichiometry



Example problems

(i) ~ Calculate volume of product from known mass of limiting reactant ~

3.54g of magnesium is reacted with excess hydrochloric acid. Calculate volume of hydrogen gas produced at STP.

1 - write a chemical equation: $Mg + HCl \rightarrow MgCl_2 + H_{2(g)}$

2 - balance the equation: $Mg + 2HCl \rightarrow MgCl_2 + H_{2(g)}$ (3.54g Mg; ? dm³ H_2)

3 - calculate mol of needed: $3.54\,g\,Mg \times \frac{mol\,Mg}{24.31\,g} \times \frac{1\,mol\,H_2}{1\,mol\,Mg} = 0.1456\,mol\,H_2$

4 - calculate vol of needed: $V = nV_m = (0.1456\,mol)(22.7\,dm^3mol^{-1}) = 3.31\,dm^3$

(ii) ~ Calculate volume of product from known volume of reactants ~

5dm³ of carbon monoxide and 2dm³ of oxygen gas react at STP.
What is the maximum volume of CO_2 that can be produced? What volume of excess reactant that remains?

1 - write a chemical equation: $CO + O_2 \rightarrow CO_2$

2 - balance the equation: $2CO + O_2 \rightarrow 2CO_2$

3 - calculate number of moles for each reactant: $5\,dm^3\,CO \times \frac{mol}{22.7\,dm^3} = 0.220\,mol$; $2\,dm^3\,O_2 \times \frac{mol}{22.7\,dm^3} = 0.0881\,mol$

4 - divide moles of reactants by coefficient: $0.220\,mol\,CO \div 2 = 0.11\,mol$; $0.0881\,mol \div 1 = 0.0881\,mol$ ∴ limiting

5 - convert mol of limiting to vol of product: $0.0881\,mol\,O_2 \times \frac{2\,mol\,CO_2}{1\,mol\,O_2} \times \frac{22.7\,dm^3}{mol} = 4\,dm^3$

6 - convert mol of limiting to vol of excess and find difference: $0.0881\,mol\,O_2 \times \frac{2\,mol\,CO}{1\,mol\,O_2} \times \frac{22.7\,dm^3}{mol} = 3.999\,dm^3$ will react
$5\,dm^3 - 3.999\,dm^3 = 1\,dm^3$ CO remaining

(iii) ~ Calculate volume of reactant from known mass of product ~

What volume in cm³ of oxygen gas is required in the complete combustion of C_3H_8 if 5.0g of water is produced?

1 - write a chemical equation: $C_3H_8 + O_2 \rightarrow CO_2 + H_2O$

2 - balance the equation: $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

3 - calculate mol of needed: $5.0\,g\,H_2O \times \frac{mol\,H_2O}{18.02\,g} \times \frac{5\,mol\,O_2}{4\,mol\,H_2O} = 0.347\,mol\,O_2$

4 - calculate vol of needed: $V = nV_m = (0.347\,mol)(22.7\,dm^3mol^{-1}) = 7.9\,dm^3 \times \frac{1000\,cm^3}{1\,dm^3} = 7900\,cm^3$