

**SUPPLEMENT****Definition of Mole**

An amount of substance containing 6×10^{23} particles (atoms, molecules, ions) of that substance is called a mole (often abbreviated to mol).

A mole of the element Magnesium is 6×10^{23} atoms of Magnesium.

A mole of the element Iodine is 6×10^{23} molecules of Iodine (I_2).

A mole of the compound water is 6×10^{23} molecules of water (H_2O).

A mole of the compound Sodium chloride is 6×10^{23} formula units of NaCl, where one formula unit consists of one Sodium ion and one Chloride ion.

Definition of Avogadro constant

An amount of substance containing 6×10^{23} particles (atoms, molecules, ions) of that substance is called a mole.

The number 6×10^{23} is called Avogadro's constant (after the famous Italian scientist Amedeo Avogadro) →



Just as a dozen is to 12, Avogadro constant is to 6×10^{23} .



Calculating Molar mass

Molar mass = mass of 1 mole, expressed in terms of g

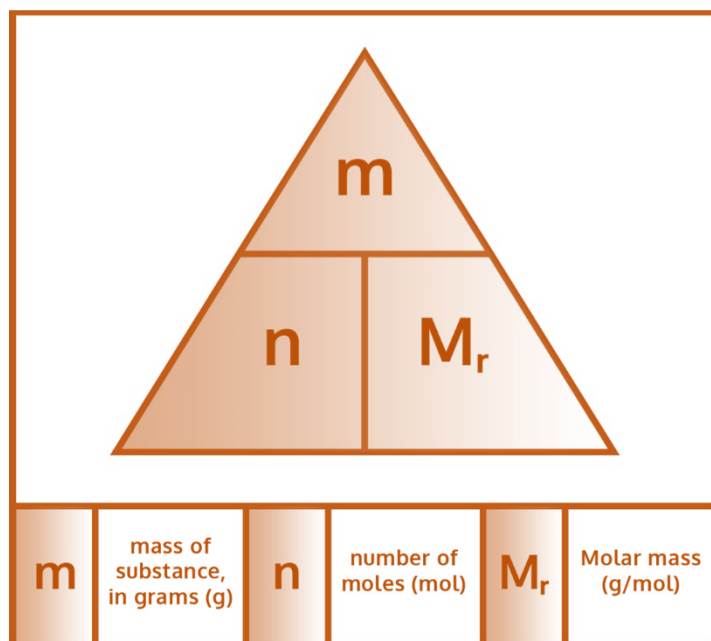
Note:

The molar mass is calculated in the same way as the M_r .

Molar mass has units (g / mol) unlike M_r .

Molar mass of O_2 molecule: $2 \times 16 = 32 \text{ g}$	Molar mass of H_2O molecule: $2 \times 1 + 16 = 18 \text{ g}$
Molar mass of $NaCl$: $23 + 35.5 = 58.5 \text{ g}$	Molar mass of $CuSO_4 \cdot 5H_2O$: $64 + 32 + 4 \times 16 + 5 \times 18 = 250 \text{ g}$

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**Calculating number of moles, n, from mass**

$$n = \frac{m}{M_r}$$

$$m = n \times M_r$$

**QUESTION 1**

Calculate the number of moles of Aluminium in 13.5 g of Aluminium.

SOLUTION:

Mass of Al = 13.5 g

M_r of Al = 27 g

$$n(\text{Al}) = \frac{13.5}{27} = 0.5$$

**QUESTION 2**

Calculate the mass of 0.35 mol of NaCl.

SOLUTION:

Molar mass of NaCl = $23 + 35.5 = 58.5$ g

$n(\text{NaCl}) = 0.35$

mass of NaCl = $0.35 \times 58.5 = 20.475$ g

QUESTION 3

Calculate the number of moles of magnesium oxide, MgO, in 80 g of the compound.

(Ar: O = 16; Mg = 24)

SOLUTION:

Molar mass of MgO = $24 + 16 = 40$ g

Mass of MgO = 80 g

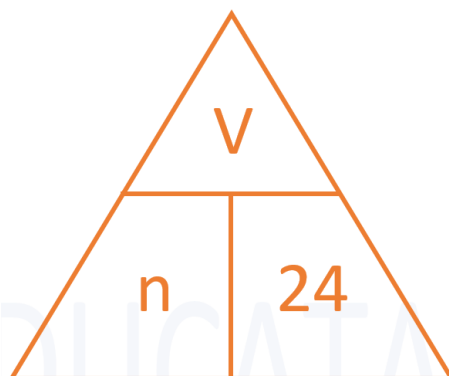
$$n(\text{MgO}) = \frac{80}{40} = 2$$

**Calculating number of moles, n , of a gas from its volume, V**

The volume of **ONE mole** of any gas at room temperature and pressure (rtp) is 24 dm^3 .

It is also known as molar gas volume and is generally denoted by the letter V or V_m .

$$1 \text{ dm}^3 = 1000 \text{ cm}^3$$



$$n = \frac{V}{24}$$

$$V = n \times 24$$

**QUESTION 1**

Calculate the number of moles of ammonia gas, NH_3 , in a volume of 72 dm^3 of the gas measured at rtp.

SOLUTION:

Volume of Ammonia gas = 72 dm^3

$$n(\text{NH}_3) = \frac{72}{24} = 3$$

**QUESTION 2**

Calculate the volume of carbon dioxide gas, CO_2 , occupied by 5 moles of the gas measured at rtp.

SOLUTION:

$$n(\text{CO}_2) = 5$$

$$\text{Volume of CO}_2 \text{ gas} = 5 \times 24 = 120 \text{ dm}^3$$

QUESTION 3

Calculate the number of moles of Hydrogen gas, H_2 in a volume of 150 cm^3 of the gas measured at rtp.

SOLUTION:

$$\text{Volume of H}_2 \text{ gas} = 150 \text{ cm}^3 = \frac{150}{1000} \text{ dm}^3 = 0.150 \text{ dm}^3$$

$$n(\text{H}_2) = \frac{0.150}{24} = 0.00625$$



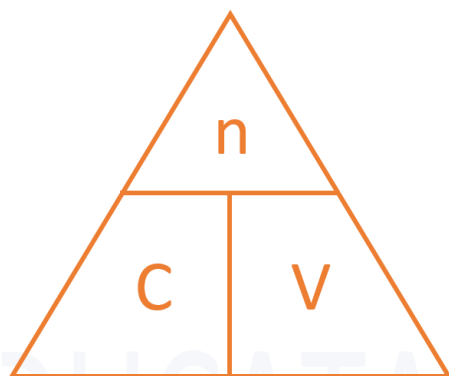
Calculating concentrations of solutions

The concentration of a solution can be expressed in terms of g/dm^3 or mol/dm^3 .

In Chemistry, it is often denoted using square brackets.

For example, $[\text{HCl (aq)}]$ denotes concentration of aqueous HCl.

$$1 \text{ dm}^3 = 1000 \text{ cm}^3$$



$$C = \frac{n}{V}$$

$$n = C \times V$$

NOTE:

Only aqueous solutions will be assessed in the examination.

Questions on the gas laws and the conversion of gaseous volumes to different temperatures and pressures will not be set.



QUESTION 1

Calculate the concentration in g/dm^3 or mol/dm^3 of a solution of sodium hydroxide, NaOH , which was made by dissolving 10 g of solid sodium hydroxide in water and making up to 250 cm^3 .

(A_r : $\text{H} = 1$; $\text{O} = 16$; $\text{Na} = 23$)

SOLUTION:

$$\text{Volume of solution} = 250 \text{ cm}^3 = \frac{250}{1000} \text{ dm}^3 = 0.250 \text{ dm}^3$$

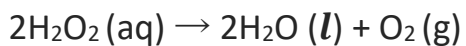
$$\text{Concentration of solution in g/dm}^3 = \frac{10}{0.250} = 40 \text{ g/dm}^3$$

$$\text{Molar mass of NaOH} = 23 + 16 + 1 = 40 \text{ g}$$

$$n(\text{NaOH}) = \frac{10}{40} = 0.25$$

QUESTION 2

Hydrogen peroxide, H_2O_2 , decomposes into water and oxygen in the presence of a catalyst, manganese (IV) oxide.



A student studies the rate of decomposition of hydrogen peroxide.

The student uses 20 cm^3 of 0.1 mol/dm^3 hydrogen peroxide and 1.0 g of manganese (IV) oxide.

Calculate the number of moles of hydrogen peroxide used in this experiment.

SOLUTION:

$$V(\text{H}_2\text{O}_2) = 20\text{ cm}^3 = 20 \times 10^{-3}\text{ dm}^3$$

$$[\text{H}_2\text{O}_2] = 0.1\text{ mol/dm}^3$$

$$n(\text{H}_2\text{O}_2) = C \times V = 0.1 \times 20 \times 10^{-3} = 0.002$$

ASSESSMENT



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CONCENTRATIONS OF SOLUTIONS





MOLE RATIO

Mole ratio = ratio in terms of moles

Mole ratio denotes the stoichiometry of a reaction.

A balanced chemical equation represents the mole ratio / stoichiometric ratio in which the reactants react to form products.

State symbols represent the physical states of the reactants and products under reaction conditions.

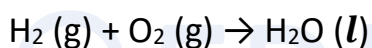
s → solid

l → liquid

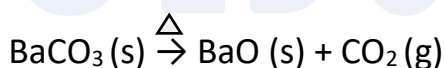
g → gas

aq → aqueous

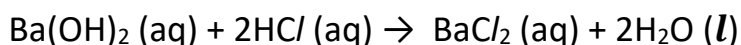
Examples:



1 mol of H₂ gas reacts completely with 1 mol of O₂ gas to form 1 mol of water (liquid).



1 mol of solid Barium carbonate decomposes completely upon heating to form 1 mol of solid Barium oxide and 1 mol of Carbon dioxide gas.



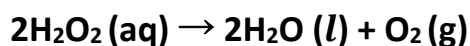
1 mol of aqueous Barium hydroxide reacts completely with 2 mol of aqueous Hydrochloric acid to form 1 mol of aqueous Barium chloride and 2 mol of water.

Using mole ratios

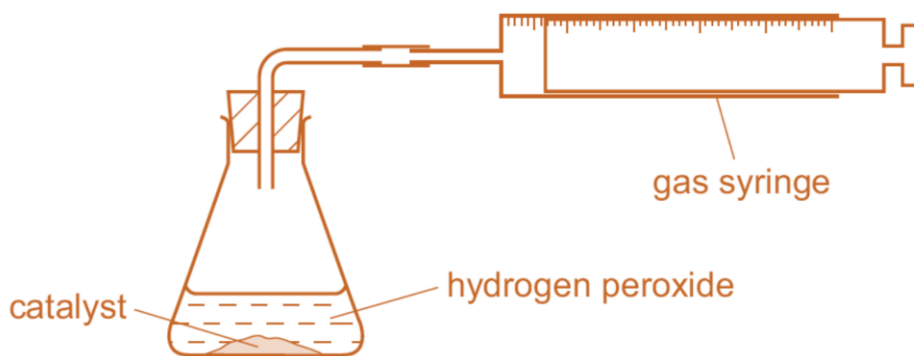


QUESTION 1

Hydrogen peroxide, H_2O_2 , decomposes into water and oxygen in the presence of a catalyst, manganese (IV) oxide.



A student studies the rate of decomposition of hydrogen peroxide using the apparatus shown.



The student uses 20 cm^3 of 0.1 mol/dm^3 hydrogen peroxide and 1.0 g of manganese (IV) oxide.

The student measures the volume of oxygen given off at regular time intervals until the reaction stops.

(a) Calculate the number of moles of hydrogen peroxide used in this experiment.

SOLUTION:

$$V(\text{H}_2\text{O}_2) = 20 \text{ cm}^3 = 20 \times 10^{-3} \text{ dm}^3$$

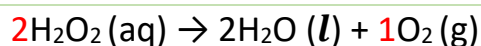
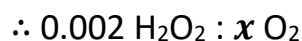
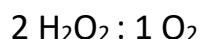
$$[\text{H}_2\text{O}_2] = 0.1 \text{ mol/dm}^3$$

$$n(\text{H}_2\text{O}_2) = C \times V = 0.1 \times 20 \times 10^{-3} = \mathbf{0.002} \checkmark$$



QUESTION 1 continued

(b) Use your answer to (a) and the equation to calculate the number of moles of oxygen produced in the reaction.

**SOLUTION:****Mole ratio**

$$x = \frac{0.002}{2} = 0.001 \checkmark$$

(c) Calculate the volume (at rtp) of oxygen produced.

SOLUTION:

$$y = 0.001 \times 24 = 0.024 \text{ dm}^3 \checkmark$$

(d) Deduce the volume of oxygen that would be produced if 20 cm³ of 0.2 mol/dm³ hydrogen peroxide was used instead of 20 cm³ of 0.1 mol/dm³ hydrogen peroxide.

SOLUTION:

$$n(\text{H}_2\text{O}_2) = C \times V = 0.2 \times 20 \times 10^{-3} = 0.004$$

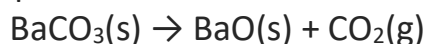
$$n(\text{O}_2) = \frac{0.004}{2} = 0.002$$

$$\text{Volume of O}_2 = 0.002 \times 24 = 0.048 \text{ dm}^3 \checkmark$$



QUESTION 2

Barium carbonate decomposes when heated.



(a) A student heated a 10.0 g sample of barium carbonate until it was fully decomposed.

Calculate the number of moles of barium carbonate the student used.

SOLUTION:

Mass of $\text{BaCO}_3 = 10.0 \text{ g}$

RFM or M_r of $\text{BaCO}_3 = 137 + 12 + 16 \times 3 = 197$

$$n(\text{BaCO}_3) = \frac{\text{mass}}{\text{RFM}} = \frac{10.0}{197} = 0.05076 \approx \mathbf{0.0508 \text{ (3 sf)}} \checkmark$$

(b) Calculate the volume of carbon dioxide gas produced at room temperature and pressure. Give your answer in dm^3 .

SOLUTION:**Mole ratio**

$1\text{BaCO}_3 : 1\text{CO}_2$

$\therefore 0.051\text{BaCO}_3 : 0.051\text{CO}_2$

1 mole of (any) gas at rtp : 24 dm^3

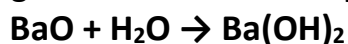
$\therefore 0.051 \text{ mol of CO}_2 : y \text{ dm}^3$

$$y = 0.051 \times 24 = \mathbf{1.224 \text{ dm}^3} \checkmark$$



QUESTION 2 continued

(b) The student added 2.00 g of the barium oxide produced to water.



Calculate the mass of barium hydroxide that can be made from 2.00 g of barium oxide. The M_r of Ba(OH)_2 is 171.

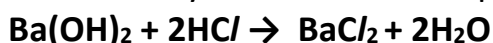
SOLUTION:

BaO	H ₂ O	→	Ba(OH) ₂
1 mol		→	1 mol
153 g		→	171 g
2.00 g		→	x g

$$x = \frac{2 \times 171}{153} = 2.24 \text{ g} \checkmark$$

(c) A 1.50 g sample of barium hydroxide was dissolved in water. The total volume of the solution was 100 cm³.

A 25.0 cm³ portion of the barium hydroxide solution was titrated against hydrochloric acid. The volume of hydrochloric acid required was 18.75 cm³.



Calculate how many moles of barium hydroxide were in the 25.0 cm³ portion used in the titration.

SOLUTION:

Mass of $\text{Ba(OH)}_2 = 1.50 \text{ g}$

RFM of $\text{Ba(OH)}_2 = 171$

$$n(\text{Ba(OH)}_2) = \frac{\text{mass}}{\text{RFM}} = \frac{1.50}{171} = 8.77 \times 10^{-3}$$

$$n(\text{Ba(OH)}_2) \text{ present in } 100 \text{ cm}^3 \text{ of solution} = 8.77 \times 10^{-3}$$

$$n(\text{Ba(OH)}_2) \text{ present in } 25 \text{ cm}^3 \text{ of solution}$$

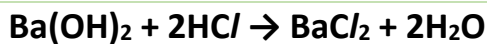
$$= \frac{8.77 \times 10^{-3}}{100} \times 25 = 2.19 \times 10^{-3} = 0.00219 \checkmark$$



QUESTION 2 continued

(d) Calculate the concentration of the hydrochloric acid used.

SOLUTION:



Mole ratio

1 Ba(OH)₂ : 2HCl

∴ 2.19×10^{-3} Ba(OH)₂ : x HCl

$$x = \frac{2.19 \times 10^{-3} \times 2}{1} = 4.38 \times 10^{-3}$$

$$n(\text{HCl}) = 4.38 \times 10^{-3}$$

$$\text{Volume of HCl used} = 18.75 \text{ cm}^3 = 18.75 \times 10^{-3} \text{ dm}^3$$

$$[\text{HCl}] = \frac{n}{V} = \frac{4.38 \times 10^{-3}}{18.75 \times 10^{-3}} = 0.2336 \approx \mathbf{0.234 \text{ mol/dm}^3} \checkmark$$



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THE MOLE CONCEPT





QUESTION-BANK



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