



TELEMATICS

GRADE 11

PHYSICAL SCIENCES CAPS

ENGLISH

REVISION

STOICHIOMETRY

Terms and symbols, Mass-mass calculations, Limiting reagents, Concentration of solutions, Molar gas volume, Volume-volume calculations, Empirical and Molecular formulae, Percentage yield, Percentage purity

CHEMISTRY CONTENT THAT WILL BE RE-EXAMINED IN GRADE 12

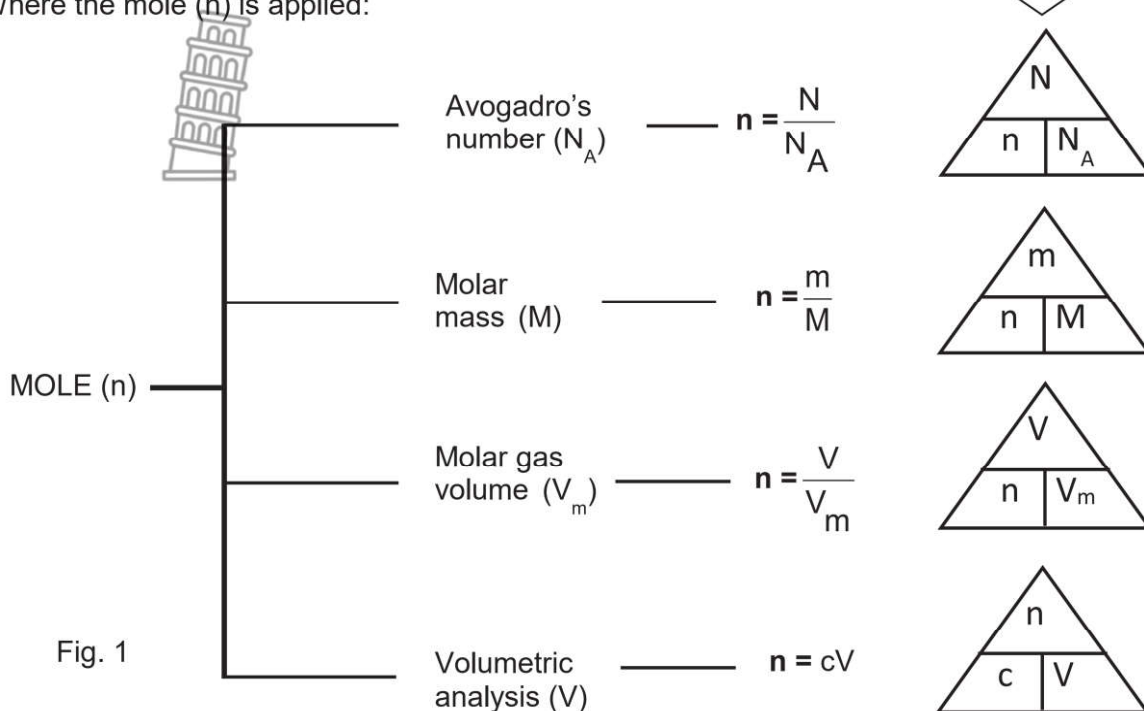
2017

PHYSICAL SCIENCES GRADE 11 TELEMATICS TEACHING PROGRAMME 2017
FISIESE WETENSKAPPE GRAAD 11 TELEMATIKA ONDERRIGPROGRAM 2017

Term 1				
Day	Date	Time	Grade	Topic
Wednesday	8 February	16:00 – 17:00	Grade 11	Mass-mass calculations
Monday	13 February	16:00 – 17:00	Grade 11	Massa-massa berekeninge
Wednesday	22 February	15:00 – 16:00	Grade 11	Molar gas volume
		16:00 – 17:00	Grade 11	Molêre gasvolume
Term 2				
Day	Date	Time	Subject	Topic
Wednesday	7 June	15:00 – 16:00	Grade 11	Concentration
Thursday	8 June	15:00 – 16:00	Grade 11	Konsentrasie
Term 3				
Day	Date	Time	Grade	Topic
Wednesday	2 August	16:00 – 17:00	Grade 11	Applications of the mol
Thursday	3 August	16:00 – 17:00	Grade 11	Toepassings van die mol
Tuesday	8 August	16:00 – 17:00	Grade 11	Vol.-vol. calculations, EF & MF
				Vol.-vol. berekeninge, EF & MF

LESSON 1: MASS – MASS CALCULATIONS

Where the mole (n) is applied:



In this lesson we will be using the formula: $n = \frac{m}{M}$.

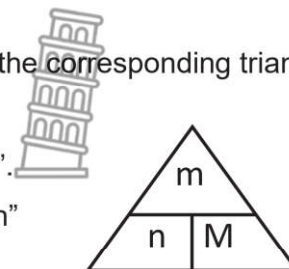
STUDY TIP (1): This formula is used in nearly every calculation in stoichiometry, especially in Grade 12 and at university.

The main uses of this formula are:

- To calculate moles (n) of a substance when the mass (m) is given.
 - To calculate mass (m) of a substance when the moles (n) are given.
- (The name, formula or symbol of the substance for which the moles (n) or the mass (m) is to be calculated is usually provided. Its molar mass (M) is obtained from the Periodic Table)

STUDY TIP (2): To change the subject of the formula in " $n = \frac{m}{M}$ ", use the corresponding triangle as follows:

- To make "m" the subject of the formula, place your finger on "m". What you will then see are the two adjacent blocks containing "n" and "M". When the symbols are like this it means they are multiplied. Thus you can write: $m = nM$.



- Similarly, to make "M" the subject of the formula, place your finger on "M" and what you now see is "m" over "n". This means division. Thus you can write: $M = \frac{m}{n}$

The meaning of each symbol in the formula, its unit of measurement and its definition is provided in Table 1 below.

Table 1: Concepts that will be used in this lesson:

Concept	Symbol	Unit of measurement	Definition
mole	n	mol	Amount of substance that contains exactly the same number of elementary particles as there are carbon atoms in 12 g of carbon-12
mass	m	g	A measure of the amount of matter in an object OR A measure of the amount of matter an object consists of.
Molar mass	M	$\text{g}\cdot\text{mol}^{-1}$	The mass in gram of 1 mole of a substance

The following statement is ALWAYS TRUE:

"If the equation for a chemical reaction is balanced correctly, and the mass of one of the substances is known, then the theoretical mass of each of the other substances in the equation can be calculated using the formula: $n = \frac{m}{M}$ "

STUDY TIP (3): The theoretical mass is the mass that is obtained by doing a calculation. The

actual mass is the mass obtained by experiment. Percentage yield = $\frac{\text{Actual mass}}{\text{Theoretical mass}} \times 100\%$

ACTIVITY 1

EXAMPLES

1.1 Calculate the (theoretical) mass of:

1.1.1 0,25 moles of Mg

1.1.2 0,5 moles of NaOH.

1.2 Calculate the (theoretical) moles of:

1.2.1 Boron in 22 g of B

1.2.2 Calcium oxide in 5,6 g of CaO

$$M(\text{Mg}) = 24 \text{ g}\cdot\text{mol}^{-1} \quad M(\text{NaOH}) = (23 + 16 + 1) \text{ g}\cdot\text{mol}^{-1} = 40 \text{ g}\cdot\text{mol}^{-1}$$

STUDY TIP (4): A short way of writing the molar mass of a substance X is: $M(X)$. Thus the molar mass of Na is written as: $M(\text{Na})$. Similarly, $m(\text{Na})$ means the mass of Na, $n(\text{B})$ means the mole of boron and $V(\text{H}_2)$ means the volume of H_2 .

STUDY TIP (5): The molar mass of a molecule or an ionic compound is the SUM of the molar masses of each atom in its formula. Examples:
 $M(\text{H}_2\text{O}) = M(\text{H}) + M(\text{H}) + M(\text{O}) = 1+1+16=18 \text{ g}\cdot\text{mol}^{-1}$.
 Similarly $M(\text{CaCO}_3) = M(\text{Ca})+M(\text{C})+3M(\text{O}) = 40+12+3(16)= 100 \text{ g}\cdot\text{mol}^{-1}$

$$M(\text{B}) = 11 \text{ g.mol}^{-1} \quad M(\text{CaO}) = (40 + 16) = 56 \text{ g.mol}^{-1}$$

ANSWERS

$$1.1.1 \quad m(\text{Mg}) = nM = (0,25)(24) = 6 \text{ g}$$

$$1.1.2 \quad m(\text{NaOH}) = nM = (0,5)(40) = 20 \text{ g}$$

$$1.2.1 \quad n(\text{B}) = \frac{m}{M} = \frac{22}{11} = 2 \text{ mol}$$

$$1.2.2 \quad n(\text{CaO}) = \frac{m}{M} = \frac{5,6}{56} = 0,1 \text{ mol}$$

1.3 A chemical reaction represented by the equation below takes place in sufficient $\text{O}_2(\text{g})$:



1.3.1 What does the symbol (g) mean?

1.3.2 What does "sufficient $\text{O}_2(\text{g})$ " mean?

1.3.3 Is the equation balanced? Explain your answer.

1.3.4 Name this chemical reaction.

1.3.5 If 8 g of $\text{CH}_4(\text{g})$ reacted with the $\text{O}_2(\text{g})$, calculate:

(a) The $n(\text{CH}_4(\text{g}))$ that were used.

(b) The (theoretical) mass of $\text{O}_2(\text{g})$ that reacted with the $\text{CH}_4(\text{g})$.

(c) The (theoretical) mass of $\text{CO}_2(\text{g})$ that was produced.

ANSWERS

1.3.1 Gaseous phase

1.3.2 There is enough $\text{O}_2(\text{g})$ to react completely with the $\text{CH}_4(\text{g})$ OR The reaction can take place to completion.

1.3.3 Yes. There is one C-atom on the LHS and one C-atom on the RHS of the equation. There are four H-atoms on the LHS and 4 H-atoms on the RHS. There are four O-atoms on the LHS and four O-atoms on the RHS.

NOTES: An equation is balanced if the NUMBER OF ATOMS of each element in the reaction is the same on both sides of the arrow " \rightarrow ".

1.3.4 Combustion (reaction)

$$1.3.5 \quad (a) \quad n = \frac{m}{M} = \frac{8}{16} = 0,5 \text{ mol}$$

(b) Method 1: (Using $n = \frac{m}{M}$)

$$n(\text{O}_2(\text{g})) \text{ that reacted with the 8 g of } \text{CH}_4(\text{g}) = (2)n(\text{CH}_4(\text{g}))$$

$$= (2)(0,5) = 1 \text{ mol}$$

$$\therefore m(\text{O}_2(\text{g})) = nM = (1)(16+16) = (1)(32) = 32 \text{ g}$$

Method 2: Using proportionality and the balanced equation

From the LHS of the balanced equation:

1 mole of $\text{CH}_4(\text{g})$ reacts with 2 moles of $\text{O}_2(\text{g})$

i.e. 16 g of $\text{CH}_4(\text{g})$ reacts with 64 g of $\text{O}_2(\text{g})$

$$\therefore 8 \text{ g of } \text{CH}_4(\text{g}) \text{ reacts with } \frac{8}{16} \times 64 \text{ g of } \text{O}_2(\text{g}) = 32 \text{ g of } \text{O}_2(\text{g})$$

NOTES: Method 1 is the recommended method.

- (c) Method 1: Using $n = \frac{m}{M}$
 $n(\text{CO}_2(\text{g}))$ that was produced from the 8 g of $\text{CH}_4(\text{g}) = n(\text{CH}_4(\text{g}))$
 $= 0,5 \text{ mol}$
 $\therefore m(\text{CO}_2(\text{g})) \text{ produced} = nM = (0,5)(12+16+16) = (0,5)(44) = 22 \text{ g}$

Method 2: Using proportionality and the balanced equation

From the balanced equation:

1 mole of $\text{CH}_4(\text{g})$ produces 1 mole of $\text{CO}_2(\text{g})$

i.e. 16 g of $\text{CH}_4(\text{g})$ produces 44 g of $\text{CO}_2(\text{g})$

$$\therefore 8 \text{ g of } \text{CH}_4(\text{g}) \text{ reacts with } \frac{8}{16} \times 44 \text{ g of } \text{O}_2(\text{g}) = 22 \text{ g of } \text{CO}_2(\text{g})$$

ACTIVITY 2

Express all answers correct to the second decimal place.

2.1 Calculate the (theoretical) mass of:

- 2.1.1 (a) 0,1 moles of C (b) 1,25 moles of S (c) 0,3 moles of Al

ANSWERS: (a) 1,20 g (b) 40 g (c) 8,10 g

- 2.1.2 (a) 0,83 moles of NH_3 (b) 1,7 moles of NaHCO_3 (c) 0,01 moles of $(\text{COOH})_2 \cdot 2\text{H}_2\text{O}$

ANSWERS: (a) 14,11 g (b) 142,80 g (c) 1,26 g

2.2 Calculate the number of moles of:

- 2.2.1 (a) Helium in 5 g of He (b) Aluminium in 5,21 g of Al (c) Silicon in 3,5 g of Si

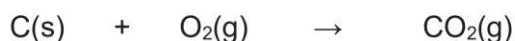
ANSWERS: (a) 1,25 mol (b) 0,19 mol (c) 0,13 mol

- 2.2.2 (a) Carbon dioxide in 11 g of CO_2

(b) Sodium carbonate decahydrate in 10 g of $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$

ANSWERS: (a) 0,25 mol (b) 0,04 mol

2.3 The chemical reaction that takes place during a braai is given by the following equation :



- 2.3.1 What does the symbol (s) mean?
 2.3.2 Write down the name of the product of this reaction?
 2.3.3 Is the equation balanced? Explain your answer.
 2.3.4 Name the chemical reaction taking place.

ANSWERS: 2.3.1 solid (phase) 2.3.2 carbon dioxide 2.3.3 Yes. There is one C-atom on the LHS and RHS of the equation. There are two O-atoms on the LHS and RHS of the equation. 2.3.4 combustion

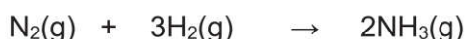


- 2.3.5 If 3 g of C(g) react with the O₂(g), calculate:

- (a) The n(C(g)) that were used.
 (b) The (theoretical) mass of O₂(g) that reacted with the C(g).
 (c) The (theoretical) mass of CO₂(g) that was produced.

ANSWERS: 2.3.5: (a) 0,25 mol (b) 8 g (c) 11 g

- 2.4 1,4 g of N₂(g) are mixed with 0,6 g of H₂(g) and NH₃(g) is formed. The balanced equation for the chemical reaction taking place is:



- 2.4.1 Calculate the (theoretical mass) of NH₃(g) that is produced.
 2.4.2 If 1,62 g of NH₃(g) are formed, calculate the percentage yield of NH₃(g)

ANSWERS: 2.4.1: 1,7 g 2.4.2: 95,29%

How to find the limiting reagent? Method 1:
 Using mass: Use the given masses to find the moles of any reactant. In example 2.4 on page 6, we use N₂. Now we test if it is the limiting

reagent: $n(\text{N}_2) = \frac{1,4}{28} = 0,05 \text{ mol}$. Since it reacts

with 3 moles of H₂, $m(\text{H}_2) = nM = (3)(0,05)(2) = 0,3 \text{ g}$ which is less than the 0.6 g given. H₂ is thus in excess. ∴ N₂ is the limiting reagent. If there was a smaller mass of H₂, e.g. 0,2 g, then H₂ would be the limiting reagent.

LESSON 2: MOLAR GAS VOLUME (V_m)

In this lesson we will be using the formula: $n = \frac{V}{V_m}$

STUDY TIP (1): In Lesson 1 we used mass (m) to find moles (n) and vice versa. In this Lesson we use volume (V) to find moles (n) and vice versa. Once we have moles (n), we can determine mass (m).

The main uses of this formula are:

- To calculate moles (n) of a substance when the volume (V) is given.
 - To calculate volume (V) of a substance when the moles (n) are given.
- (The value for molar gas volume (V_m) is provided on data sheets in a question paper)



STUDY TIP (2): To change the subject of the formula in " $n = \frac{V}{V_m}$ ", use the corresponding

triangle in Fig.1 on Page 2 and then follow the procedure in STUDY TIP (2) on Page 2.

The meaning of each symbol in the formula, its unit of measurement and its definition are provided in Table 2 below.

Table 2: Concepts that will be used in this lesson:

Concept	Symbol	Unit of measurement	Definition
mole	n	mol	Amount of substance that contains exactly the same number of elementary particles as there are carbon atoms in 12 g of carbon-12
volume	V	dm ³	The space a gas occupies
Molar gas volume	V _m	dm ³ .mol ⁻¹	The volume a gas occupies at STP (standard temperature and pressure)

Standard temperature (T) has a value of 273 K (0°C).

Standard pressure (p) has a value of 1,013x10⁵ Pa.

Whenever there is reference to STP it means that T = 273 K and p = 1,013x10⁵ Pa.

STUDY TIP (3): All gases occupy a volume (V_m) of 22,4 dm³ at STP. When you use molar gas volume V_m, volume (V) must be expressed in

STUDY TIP (4): To convert cm³ to dm³ divide by 1000.

Example: $500 \text{ cm}^3 = \frac{500 \text{ cm}^3}{1000 \text{ cm}^3} \times 1 \text{ dm}^3 = 0,5 \text{ dm}^3$

NOTE: $\frac{1 \text{ dm}^3}{1000 \text{ cm}^3} = 1$. ∴ the value 500 cm³ remains the same but it is only expressed in an equivalent other form.

ACTIVITY 1

EXAMPLES

1.1 Calculate the (theoretical) number of moles of:

1.1.1 H₂(g) that occupy a volume of 100 cm³ at STP.

1.1.2 O₂(g) that occupy a volume of 1125 cm³ at STP.

1.2 Calculate the (theoretical) volume:

1.2.1 Occupied by 0,24 moles of CO₂ at STP

1.2.2 Occupied by 1,3 moles of Cl₂(g) at STP

ANSWERS (expressed correct to the second decimal place.)

1.1.1 $n = \frac{V}{V_m} = \frac{0,1}{22,4} = 0,0045 = 0,01 \text{ mol}$

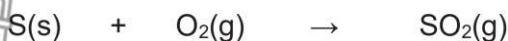


$$1.1.2 \quad n = \frac{V}{V_m} = \frac{1,125}{22,4} = 0,05 \text{ mol}$$

$$1.2.1 \quad V = nV_m = (0,24)(22,4) = 5,38 \text{ dm}^3$$

$$1.2.2 \quad V = nV_m = (1,3)(22,4) = 29,12 \text{ dm}^3$$

1.3 When S burns in O₂(g), SO₂(g) is formed :



1.3.1 What is the colour of the flame?

1.3.2 If 4480 cm³ of O₂(g) reacted with the S(s) at STP, calculate:

- (a) The (theoretical) mass of S(s) that burned in the O₂(g)
 (b) The (theoretical) volume of SO₂(g) that was collected at STP.

ANSWERS

1.3.1 Blue

$$1.3.2 \quad (a) \quad n(\text{O}_2(\text{g})) \text{ that reacted with the S(s)} = \frac{V}{V_m} = \frac{4,480}{22,4} = 0,2 \text{ mol} = n(\text{O}_2(\text{g}))$$

$$\therefore m(\text{O}_2(\text{g})) \text{ that burned in the O}_2(\text{g}) = nM = (0,2)(32) = 6,4 \text{ g}$$

$$1.3.2 \quad (b) \quad V(\text{SO}_2(\text{g})) \text{ collected at STP} = nV_m = (0,2)(22,4) = 4,48 \text{ dm}^3$$

ACTIVITY 2

Express all answers correct to the second decimal place.

2.1 Calculate the (theoretical) volume occupied by:

2.1.1 (a) 0,2 moles of N₂(g) at STP (b) 1,25 moles of NH₃(g) at STP

ANSWERS: (a) 4,48 dm³ (b) 28 dm³

2.2 Calculate the (theoretical) number of moles of:

2.2.1 (a) Argon in 1050 cm³ of Ar(g) (b) Bromine in 500 cm³ of Br₂(g)

ANSWERS: (a) 0,05 mol (b) 0,02 mol

$$\text{Percentage purity} = \frac{\text{Actual volume}}{\text{Theoretical volume}} \times 100\%$$

2.3 The chemical reaction below shows that NaNO₃ is thermally unstable.



2.3.1 What do the underlined words mean?

2.3.2 What does the symbol “Δ” mean?

2.3.3 A sample of NaNO₃(s) of mass 4,25 g was heated and 500 cm³ of O₂(g) was collected at STP. Calculate:


ANSWERS:

2.3.1: NaNO₃ decomposes when it is heated

2.3.2: The reactants are heated

- (a) The theoretical volume of $O_2(g)$ that was formed.
 (b) The percentage purity of the $NaNO_3(s)$.

ANSWERS

2.2.3 (a)  $n(NaNO_3(s)) = \frac{m}{M} = \frac{4,25}{85} = 0,05 \text{ mol}$

$$n(O_2(g)) \text{ produced} = (1/2)n(NaNO_3(s)) = 0,025 \text{ mol}$$

$$V(O_2(g)) = n(V_m) = (0,025)(22,4) = 0,560 \text{ dm}^3$$

(b) Percentage purity = $\frac{\text{Actual volume}}{\text{Theoretical volume}} \times 100\%$
 $= \frac{0,500}{0,560} \times 100\% = 89,29\%$

OR

$$n(NaNO_3) \text{ that forms } 500 \text{ cm}^3 O_2(g) = (2) \left(\frac{0,5}{22,4} \right) = 0,044643 \text{ mol}$$

$$m(NaNO_3(s)) \text{ that decomposed} = nM = (0,044643)(85) = 3,794655 \text{ g}$$

$$\text{Percentage purity} = \frac{\text{Actual mass}}{\text{Theoretical mass}} = \frac{3,794655}{4,25} \times 100\% = 89,29\%$$

LESSON 3: CONCENTRATION

In this lesson we will be using the formula: $c = \frac{n}{V}$

STUDY TIP (1): In Lesson 1 we used mass (m) to find moles (n) and vice versa. In Lesson 2 we used volume (V) of a gas to find moles (n) and vice versa. Once we have moles (n), we can also determine mass (m). In Lesson 3 we will use moles (n) to find concentration (c) and vice versa. Once we have moles (n), we can also determine mass (m).

The main uses of this formula are, (when volume (V) is given):

- To calculate moles (n) of a substance when the concentration (c) is given.
- To calculate concentration (c) of a substance when the moles (n) are given.

(This formula is used widely in Acids and Bases)


STUDY TIP (2): To change the subject of the formula in " $c = \frac{n}{V}$ ", use the corresponding triangle 

in Fig.1 on Page 2 and then follow the procedure in STUDY TIP (2) on Page 2.

The meaning of each symbol in the formula, its unit of measurement and its definition are provided in Table 3 below.

STUDY TIP (3): To convert cm^3 to dm^3 divide by 1000. Refer to Study Tip (4) in Lesson 2 for more details.

Table 3: Concepts that will be used in this lesson:

Concept	Symbol	Unit of measurement	Definition
mole	 n	mol	Amount of substance that contains exactly the same number of elementary particles as there are carbon atoms in 12 g of carbon-12
volume	V	dm^3	The space a substance occupies
Concentration (Molarity)	c	$\text{mol}\cdot\text{dm}^{-3}$	The number of moles of a substance dissolved in a specific volume of water. (Also called molarity)

Other formulae can be used to express concentration. The one we use is called molarity. The molarity of a solution is its concentration expressed in $\text{mol}\cdot\text{dm}^{-3}$.

STUDY TIP (3): When you use molarity, volume (V) must ALWAYS be expressed in dm^3 .

DEFINITION: A standard solution is a solution whose concentration is known exactly. To make a standard solution of a substance, e.g. oxalic acid, a precise mass of oxalic acid and a precise volume of water must be used. The oxalic acid is then dissolved in a beaker and poured into a suitable measuring flask. Water is then added to the contents of the measuring flask until the concave meniscus reaches the mark on the neck of the flask. This standardised solution can now be used to standardise (determine the concentration of) an unknown solution in a titration.

ACTIVITY 1

EXAMPLES (Approximate answers correct to the second decimal place)

1.1 A standard solution of oxalic acid, $(\text{COOH})_2 \cdot 2\text{H}_2\text{O}$, of concentration $0,2 \text{ mol}\cdot\text{dm}^{-3}$ is to be prepared: Calculate the:

1.1.1 The number of moles of oxalic acid required to make 250 cm^3 of this solution.

1.1.2 The mass of oxalic acid that is needed to make 100 cm^3 of this solution

ANSWERS

1.1.1 $n(\text{oxalic acid}) = cV = (0,2)(0,250) = 0,05 \text{ mol}$

1.1.2 $n(\text{oxalic acid}) = cV = (0,2)(0,100) = 0,02 \text{ mol}$. $m(\text{oxalic acid}) = nM = (0,02)(126) = 2,52 \text{ g}$
 OR $m = cMV = (0,2)(126)(0,100) = 2,52 \text{ g}$

1.2 In a titration, 25 cm^3 of a standard oxalic acid solution of concentration $0,15 \text{ mol}\cdot\text{dm}^{-3}$ was neutralised by a sodium hydroxide solution of unknown concentration.

1.2.1 Give the meaning of the term neutralised and use the net reaction to motivate your answer.

1.2.2 Choose a suitable indicator from the table below to show the endpoint of the titration.

INDICATOR	WHAT IS IT USED FOR?	pH RANGE
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Bromothymol blue	Strong acid and Strong base	6,0 – 7,6
Methyl orange	Strong acid and weak base	3,1 – 4,4
Phenolphthalein	Strong base and weak acid	8,3 – 10,0

1.2.3 Explain your answer in question 1.2.2.

When the end point of the titration is reached, 20 cm³ of the sodium hydroxide was added.

1.2.4 State what is meant by the term endpoint.

1.2.5 Calculate the concentration of the sodium hydroxide solution.

ANSWERS

1.2.1 The H⁺ or H⁺(aq) or H₃O⁺ ions are removed from the solution by the OH⁻ ions to form water.

The net reaction taking place is: H⁺ + OH⁻ → H₂O

NOTES: The stage in a titration when neutralisation is reached is called the equivalence point. At this point the number of H⁺ ions are neutralised by an equal the number of OH⁻ ions.

1.2.2 Phenolphthalein

1.2.3 The reaction is between a weak acid (oxalic acid) and a strong base (NaOH). There is less H⁺ than OH⁻ in the solution. Thus at the equivalence point unreacted OH⁻ ions remain and cause the pH to be greater than 7.

OR

The product of the reaction between a weak acid (oxalic acid) and a strong base (NaOH) is a basic salt (CH₃COONa)₂ · 2H₂O. (CH₃COONa)₂ ionises in water to form OH⁻ ions (or NaOH) which makes the pH > 7.

1.2.4 The stage in a titration where the indicator changes colour.

1.2.5 METHOD 1: THIS IS THE RECOMMENDED METHOD.

Look at the balanced chemical equation: (COOH)₂ + 2NaOH → ...

The mole ratio: (COOH)₂:NaOH = 1:2 1 mole 2 mole →

$$n(\text{COOH})_2 = cV = (0,15)(0,025) = 0,00375 \text{ mol}$$

$$n(\text{NaOH}) = 2(0,00375) = 0,0075$$

$$\therefore c(\text{NaOH}) = \frac{n}{V} = \frac{0,0075}{0,020} = 0,38 \text{ mol.dm}^{-3}$$

METHOD 2:

$$\text{Or } \frac{c_a V_a}{c_b V_b} = \frac{n_a}{n_b} \text{ i.e. } \frac{0,15 \times 0,025}{c_b \times 0,020} = \frac{1}{2}$$

$$\therefore c_b = 0,38 \text{ mol.dm}^{-3}$$

ACTIVITY 2 (Express answers correct to the second decimal place where applicable)

2.1 A standard solution of NaOH(s), of concentration 0,4 mol.dm⁻³ is to be prepared: Calculate the:

2.1.1 The number of moles of NaOH(s) required to make 150 ml of this solution.

2.1.2 The mass of NaOH that is required to make 1 l of this solution

ANSWERS: 2.1.1 0,06 mol 2.1.2 16 g

2.2 In a titration, 25 cm³ of a standard hydrochloric acid solution of concentration 0,21 mol.dm⁻³ was neutralised by a sodium hydroxide solution of unknown concentration.

2.2.1 Give the meaning of the term neutralised and use the net reaction to motivate your answer.

2.2.2 Choose a suitable indicator from the table below to show the endpoint of the titration.

INDICATOR	USE	pH RANGE
Bromothymol blue	Strong acid and Strong base	6,0 – 7,6
Methyl orange	Strong acid and weak base	3,1 – 4,4
Phenolphthalein	Strong base and weak acid	8,3 – 10,0

2.2.3 Explain your answer in question 2.2.2.

At the end point of the titration 20 cm³ of the sodium hydroxide was used.

2.2.4 State what is meant by the term endpoint.

2.2.5 Calculate the concentration of the sodium hydroxide solution.

ANSWERS

2.2.1 Refer to the answer 1.2.1 in Activity 1. The answers are the same.

2.2.2 Bromothymol blue

2.2.3 The reaction is between a strong acid (hydrochloric acid) and a strong base (NaOH). There are equal numbers of H⁺ and OH⁻ in the solution. Thus at the equivalence point the solution will be neutral with a pH = 7 or a pH = ± 7.

OR

The product of the reaction between a strong acid (hydrochloric acid) and a strong base (NaOH) is a neutral salt NaCl. NaCl ionises in water to form a neutral solution which makes the pH = 7 or a pH = ± 7.

2.2.4 Refer to the answer to 1.2.4 in Activity 1. The answers are similar.

2.2.5 c(NaOH) = 0,26 mol.dm⁻³

LESSON 4: APPLICATIONS OF THE MOLE

In this lesson you will apply the knowledge you acquired in Lessons 1 to 3 to answer questions on percentage yield and percentage purity. Refer to Lessons 1 to 3 for help.



ACTIVITY 1

EXAMPLES

1.1 4,5 g of MgO are dissolved in 100 cm³ of HCl of concentration 2 mol.dm⁻³. The following reaction takes place:




The excess HCl is neutralised by 21 cm³ of a 0,2 mol.dm⁻³ aqueous solution of NaOH. The reaction taking place is:

$$\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}$$

Calculate the percentage purity of the MgO.

Method

- STEP 1:  Calculate moles (n) at the start
 STEP 2: Calculate moles (n) in excess
 STEP 3: Calculate moles (n) that reacted (n(start) – n(excess) = n(reacted))
 STEP 4: Calculate the mass (m) that reacted
 STEP 5: Calculate the percentage purity or yield

ANSWER

- STEP 1: n(Start): $n(\text{HCl}) = cV = (2)(0,100) = 0,2 \text{ mol}$
 STEP 2: n(Excess): $n(\text{NaOH}) = cV = (0,2)(0,021) = 0,0042 = n(\text{HCl}) \text{ in excess}$
 STEP 3: n(Reacted): $n(\text{Reacted}) = n(\text{Start}) - n(\text{Excess})$
 i.e. $n(\text{HCl}) \text{ that reacted} = 0,2 - 0,0042 = 0,1958 \text{ mol}$
 Thus $n(\text{MgO}) \text{ that reacted} = \frac{1}{2} (0,1958) = 0,0979$
 STEP 4: m(Reacted): $m(\text{MgO}) = nM = (0,0979)(40) = 3,92 \text{ g}$
 STEP 5: Percentage purity = $\frac{\text{Actual mass}}{\text{Theoretical mass}} \times 100\%$

$$= \frac{3,92}{4,5} \times 100\% = 87,11\%$$

- 1.2 A 2 g sample of marble chips are dissolved in 50 cm³ of HCl of concentration 1,3 mol.dm⁻³. The reaction taking place is: $\text{CaCO}_3 + 2\text{HCl} \rightarrow \text{CaCl}_2 + \text{CO}_2 + \text{H}_2\text{O}$
 The excess HCl is neutralised by adding excess baking soda and 627,2 cm³ of CO₂(g) was collected at STP. The reaction taking place is: $\text{HCl} + \text{NaHCO}_3 \rightarrow \text{NaCl} + \text{CO}_2 + \text{H}_2\text{O}$
 Calculate the percentage purity of the marble chips.

ANSWER

- STEP 1: n(Start): $n(\text{HCl}) = cV = (1,3)(0,050) = 0,065 \text{ mol}$
 STEP 2: n(Excess): $n(\text{CO}_2) = \frac{V}{V_m} = \frac{0,6272}{22,4} = 0,028 = n(\text{HCl}) \text{ in excess}$
 STEP 3: n(Reacted): $n(\text{Reacted}) = n(\text{Start}) - n(\text{Excess})$
 i.e. $n(\text{HCl}) \text{ that reacted} = 0,065 - 0,028 = 0,037 \text{ mol}$
 Thus $n(\text{CaCO}_3) \text{ that reacted} = \frac{1}{2} (0,037) = 0,0185 \text{ mol}$
 STEP 4: m(Reacted): $m(\text{CaCO}_3) = nM = (0,0185)(100) = 1,85 \text{ g}$

STEP 5: Percentage purity = $\frac{\text{Actual mass}}{\text{Theoretical mass}} \times 100\%$

$$= \frac{1,85}{2} \times 100\% = 92,50\%$$

ACTIVITY 2

Answer the following questions. Approximate your answers correct to the second decimal place.

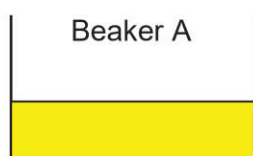
- 2.1 7,5 g of NaOH are dissolved in 250 cm³ of water. 10 cm³ of this solution are neutralised by 13,5 cm³ of nitric acid of concentration 0,50 mol.dm⁻³. The balanced equation for the reaction taking place is:
- $$\text{NaOH} + \text{HNO}_3 \rightarrow \text{NaNO}_3 + \text{H}_2\text{O}$$

Calculate the percentage purity of the NaOH.

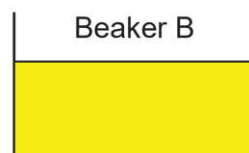
Answer: 90%

- 2.2 The molar mass of CuSO₄ .xH₂O is 250 g.mol⁻¹. Calculate the value of x. Answer: 5

2.3



50 cm³ of 0,5 mol.dm³ HCl



80 cm³ of 0,25 mol.dm³ HCl

- 2.3.1 Calculate the number of moles of HCl in beaker A.

The solution in Beaker A is poured into Beaker B.

- 2.3.2 Calculate the final concentration of the solution in B.

- 2.3.3 Calculate the mass of sodium carbonate that is required to neutralise the solution in Beaker B. ANSWERS: 2.3.1: 0,025 mol 2.3.2: 0,35 mol.dm⁻³ 2.3.3: 2,39 g

- 2.4 When 4,16 g of barium chloride are added to 1,42 g of sodium sulphate, a barium sulphate precipitate of mass 1,82 g is formed. The balanced chemical equation for the reaction taking place is: $\text{BaCl}_2 + \text{Na}_2\text{SO}_4 \rightarrow \text{BaSO}_4 + 2\text{NaCl}$

Calculate the percentage yield of barium sulphate.

ANSWER: 78,11%

- 2.5 92% of a fertilizer consists of NH₄Cl. A sample of mass x g of this fertilizer is dissolved in 100 cm³ of a 0,10 mol.dm⁻³ aqueous solution of sodium hydroxide (NaOH(aq)). The NaOH is in excess. The balanced chemical equation for the reaction taking place is:

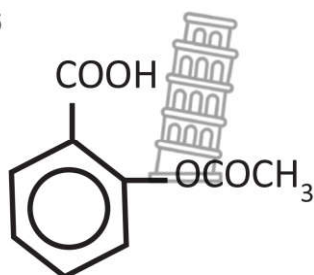


During a titration, 25 cm³ of the excess NaOH solution is titrated with a 0,11 mol.dm⁻³ HCl solution. At the endpoint it is found that 14,55 cm³ of the HCl neutralised the NaOH. The reaction taking place is: $\text{HCl}(\text{aq}) + \text{NaOH}(\text{aq}) \rightarrow \text{NaCl}(\text{aq}) + \text{H}_2\text{O}(\text{l})$

Calculate the mass of x, in grams, of the fertilizer used.

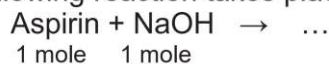
ANSWER: 0,21 g

2.6

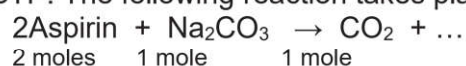


Aspirin: It is a monoprotic acid and $M(\text{Aspirin}) = 180 \text{ g}\cdot\text{mol}^{-1}$

An aspirin tablet of mass 300 mg is dissolved in ethanol and 41 cm^3 of a $\text{NaOH}(\text{aq})$ solution of concentration $0,01 \text{ mol}\cdot\text{dm}^{-3}$ is added. The following reaction takes place:



When excess Na_2CO_3 was then added, $13,776 \text{ cm}^3$ of CO_2 was collected at STP. The following reaction takes place:



2.6.1 State the role of the ethanol

2.6.2 Calculate the percentage purity of the aspirin.

ANSWER: 2.6.1 enables aspirin to react with $\text{NaOH}(\text{aq})$

2.6.2 98,4%

LESSON 5: VOLUME-VOLUME CALCULATIONS, EMPIRICAL AND MOLECULAR FORMULA.

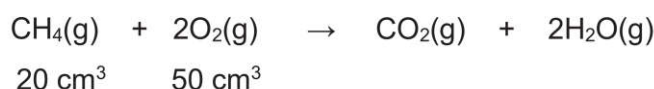
STUDY TIP (1): In volume-volume calculations involving gases at constant pressure p and temperature T , volume (V) values can be obtained from mole (n) values and vice versa, because under these conditions, $V \propto n$. This can easily be deduced from $pV = nRT$. If p and T are constant then $V \propto n$, because R is a constant.

ACTIVITY 1

EXAMPLE

How to find the limiting reagent? Method 2: Using volumes of gases: Find the volume of 1 mole of any reactant. In example 1.1 on this page, 1 mole of CH_4 is already given. Now we test if it is the limiting reagent: The given volume of CH_4 is 20 cm^3 . Since it reacts with 2 moles of O_2 , CH_4 will react with $2 \times 20 \text{ cm}^3 = 40 \text{ cm}^3$ of O_2 . Since there is 50 cm^3 , O_2 is in excess. $\therefore \text{CH}_4$ is the limiting reagent. If there was a smaller volume of O_2 , e.g. 30 cm^3 , then O_2 would be the limiting reagent.

1.1 Consider the following balanced chemical equation:



If there is initially 20 cm^3 of $\text{CH}_4(\text{g})$ and 50 cm^3 of $\text{O}_2(\text{g})$, and the reaction takes place at constant pressure p and temperature T , and reaches completion, determine:

1.1.1 The moles of $\text{CO}_2(\text{g})$ and $\text{H}_2\text{O}(\text{g})$ that are formed.

1.1.2 The theoretical volume of each of the gases in the equation after the reaction has reached completion.

Finding Limiting Reagent (continued): If you started with the volume of 50 cm^3 , 1 mole O_2 will have a volume of 25 cm^3 . Because there is only 20 cm^3 of CH_4 , CH_4 is still the limiting reagent.

STUDY TIP (2): First determine which reactant is the limiting reagent, and where applicable the volume of 1 mole of the limiting reagent. Then use the co-efficients in the balanced equation to deduce the volumes of all the gases in the equation. They must all be multiples of the volume of 1

mole of the limiting reagent. Do not forget to subtract on the LHS of the equation where applicable because reactants are used up in a reaction.

ANSWERS: 1.1.1 1 mole CO₂ 2 moles of H₂O

1.1.2 CH₄(g): 0 cm³; O₂(g): 10 cm³; CO₂(g): 20 cm³; H₂O(g): 40 cm³

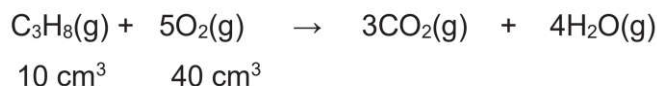
NOTES: First find the limiting reagent. It is CH₄(g). Then find the volume of 1 mole of the limiting reagent. It is 20 cm³. Using the co-efficients in the balanced equation you can now determine the volumes of each of the gases in the equation. Table 4 below summarises the process:

Table 4: Summary: How to obtain gas volumes at completion of a reaction.

	CH ₄	O ₂	CO ₂	2H ₂ O
Moles at the Start / Formed	1 mole	2 moles	1 mole	2 moles
Volumes at the Start	20 cm ³	50 cm ³		
Limiting reagent	CH ₄			
Volumes Reacting / Formed	-(1x20 cm ³) = -20 cm ³	-(2x20 cm ³) = -40 cm ³	1x20 cm ³ = 20 cm ³	2x20 cm ³ = 40 cm ³
Volumes on completion of the reaction	(20 -20) cm ³ = 0 cm ³	(50 -40) cm ³ = 10 cm ³	20 cm ³	40 cm ³

ACTIVITY 2

2.1 Consider the following balanced chemical equation:



If there is initially 10 cm³ of C₃H₈(g) and 40 cm³ of O₂(g), and the reaction takes place at constant pressure and temperature, and reaches completion, determine:

2.1.1 The moles of CO₂(g) and H₂O(g) that are formed.

2.1.2 The theoretical volume of each of the gases in the equation after the reaction has reached completion.

ANSWERS: 2.1.1 3 moles of CO₂ and 4 moles of H₂O

2.1.2 C₃H₈(g): 2 cm³; O₂(g): 0 cm³; CO₂(g): 24 cm³; H₂O(g): 32 cm³

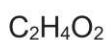
MOLECULAR FORMULA and EMPIRICAL FORMULA

Illustration to show the difference between a condensed structural formula, molecular formula and an empirical formula:

Ethanoic acid can be written in the following ways:



Condensed structural formula



Molecular formula



Empirical formula

It shows, to some extent, the STRUCTURE of the compound.

It shows the number of atoms of each element in a compound.

It is derived from the molecular formula in such a way that the Highest Common Factor (HCF) of the number of atoms of each element, together, is 1.

STUDY TIP (3): A molecular formula is written like a chemical formula. The same atoms are grouped together. The empirical formula is obtained from the molecular formula by dividing each of the numbers in the molecular formula by the HCF of all the numbers.

EXAMPLE

ACTIVITY 1

1.1 Consider H_2O_2 . It is the chemical formula of hydrogen peroxide. It is also the molecular formula of hydrogen peroxide. The HCF of 2 and 2, is 2. If you divide each 2 by 2 you obtain HO, which is the empirical formula of H_2O_2 . The HCF of each number 1 in H_1O_1 , is 1.

Steps to follow when determining the empirical formula of a substance:

- STEP 1: All quantities must be in moles. If not, convert %ages or masses to moles.
- STEP 2: Divide each number in STEP 1 by the SMALLEST of all the numbers.
- STEP 3: Round off each number in STEP 2 to the nearest whole number.
- STEP 4: Write down the empirical formula by using the whole numbers obtained in STEP 3.
- STEP 5: Check that the HCF = 1 for all the numbers obtained in STEP 4.

1.2. A molecule has the following percentage composition: 6,25% H and 93,7% O.
Determine it's:

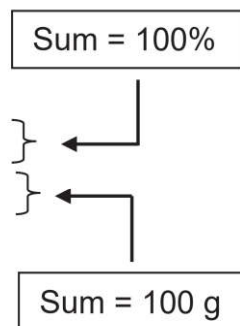
1.2.1 Empirical formula

1.2.2 Molecular formula if it's molar mass is 34 g.mol⁻¹

ANSWERS:

1.2.1

		H	O
STEP 1	Percentages	6,25%	93,75%
	Masses	6,25 g	93,75 g
	Moles	$\frac{6,25}{1}$	$\frac{93,7}{16}$
		6,25	5,856
STEP 2	Divide by 5,856	$\frac{6,25}{5,856} = 0,94$	$\frac{5,856}{5,856} = 1$
STEP 3	Round off	1	1
STEP 4	Empirical formula	HO	
STEP 5	CHECK if HCF=1	HCF of 1 and 1, is 1	



- 1.2.2 $M(\text{HO}) = 17 \text{ g.mol}^{-1}$. Let the molecular formula be X.
Then $M(\text{X}) = 34 \text{ g.mol}^{-1} = (2)(17\text{g.mol}^{-1})$. This means X has one more "OH".
 \therefore X is H_2O_2

ACTIVITY 2

- 2.1 Which one of the following is an empirical formula?
A: N_2O_4 B: N_2H_6 C: N_2O_5 D: $\text{C}_4\text{H}_8\text{O}_2$
- 2.2 If the empirical formula of a compound is CH_2 , it's molecular formula can be:
A: CH_4 B: C_2H_6 C: C_3H_6 D: C_4H_{10}
- 2.3 A compound consists of 40% carbon, 53,3% oxygen and 6,66% hydrogen. Determine its molecular formula.
- 2.4 Analysis of a nicotine sample shows that it contained 2,13 g of carbon, 0,248 g of hydrogen and 0,493 g of nitrogen. Determine its empirical formula.
- 2.5 A sample of nicotine that contains only carbon, hydrogen and nitrogen is burned in excess oxygen. A sample of mass 0,2340 g yielded 0,1826 g of H_2O and 0,6329 g of CO_2 . Determine the empirical formula of nicotine.
- 2.6 1,448 g sample of iron was heated in air and its final mass was found to be 2,001 g. Determine its molecular formula.
- 2.7 Caffeine has the following percentage composition: Carbon: 49,48%; Hydrogen: 5,19%; Oxygen: 16,48%; Stikstof: 28,85%. Determine its molecular formula if its molar mass is 194 g.mol^{-1}
- 2.8 An unknown compound of mass 0,40 g contains only hydrogen, nitrogen and oxygen. When it is heated it decomposes to form 0,22 g of nitrous oxide (N_2O) and 0,18 g of water. Determine its empirical formula.
- ANSWERS: 2.1: C; 2.2: C; 2.3: $\text{C}_2\text{O}_2\text{H}_4$; 2.4: $\text{C}_5\text{H}_7\text{N}$; 2.5: $\text{C}_5\text{H}_7\text{N}$; 2.6: Fe_3O_4 ; 2.7: $\text{C}_8\text{H}_{10}\text{N}_4\text{O}_2$
2.9: $\text{H}_4\text{N}_2\text{O}_3$



