TELEMATIC SCHOOLS PROJECT

2024 SUBJECT WORKBOOK
Grade 12

PHYSICAL SCIENCES

A joint initiative between the Western Cape Education Department and Stellenbosch University.

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BROADCAST SESSIONS

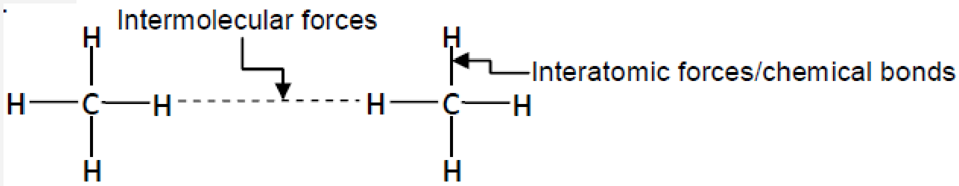
GRADE 12 PHYSICAL SCIENCES

Session	Date	Time	Topic
1	**10/04/2024**	**16h00-17h00**	**Organic molecules**
2	08/05/2024	16h00-17h00	Reaction rates
3	**15/07/2024**	**16h00-17h00**	**Acids and bases**

NOTE:

Intermolecular and interatomic forces (chemical bonds)

- Name and explain the different intermolecular forces (Van der Waal's forces):
  - (i) Dipole-dipole forces:
    Forces between two polar molecules
  - (ii) Induced dipole forces or London forces:
    Forces between non-polar molecules
  - (iii) Hydrogen bonding:
    Forces between molecules in which hydrogen is covalently bonded to nitrogen, oxygen or fluorine – a special case of dipole-dipole forces
- Describe the difference between intermolecular forces and interatomic forces (intramolecular forces) using a diagram of a group of small molecules; and in words.
  Example:



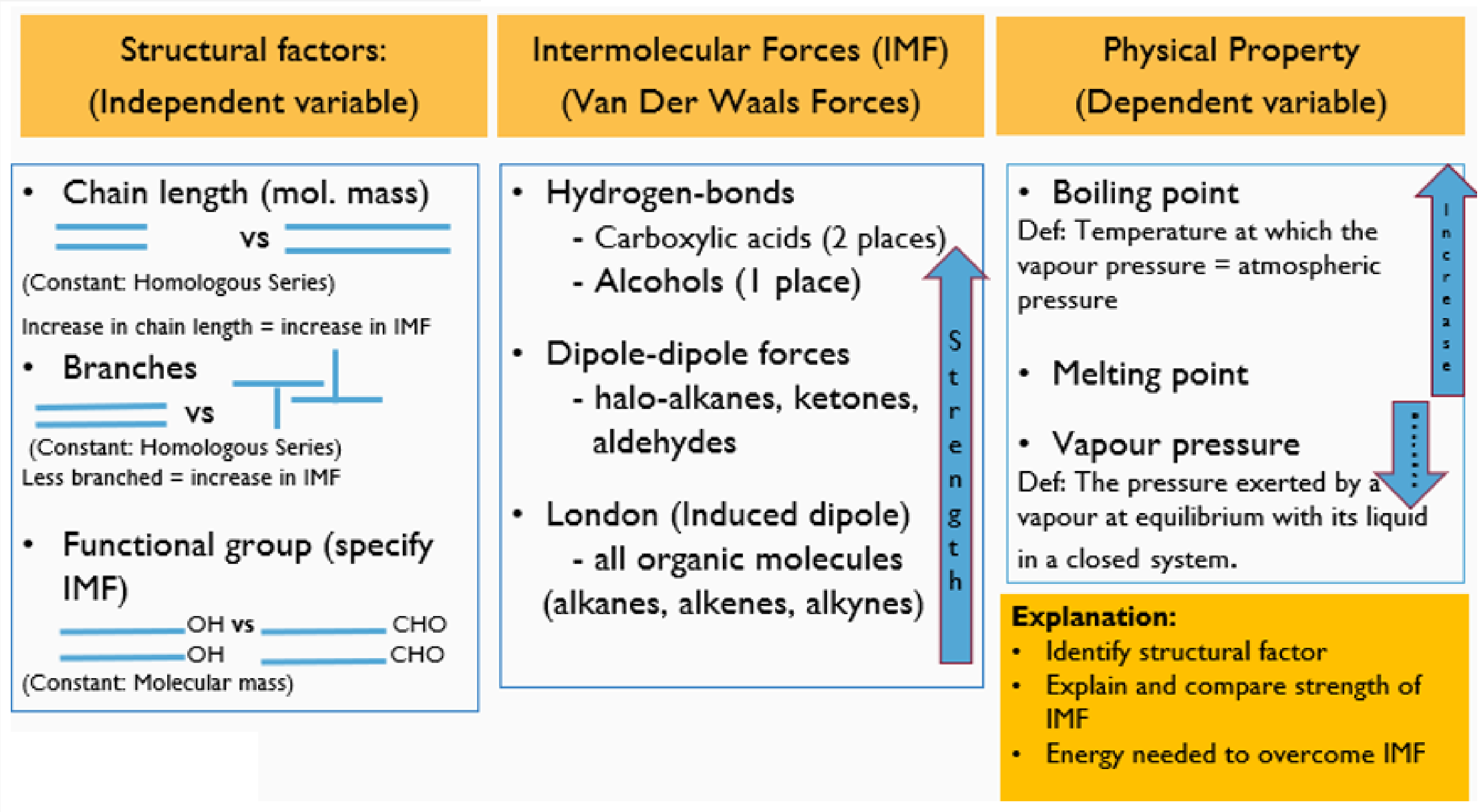
- State the relationship between intermolecular forces and molecular size. For non-polar molecules, the strength of induced dipole forces increases with molecular size.
- Explain the effect of intermolecular forces on boiling point, melting point and vapour pressure.
- Boiling point:
  The temperature at which the vapour pressure of a substance equals atmospheric pressure. The stronger the intermolecular forces, the higher the boiling point.
- Melting point:
  The temperature at which the solid and liquid phases of a substance are at equilibrium. The stronger the intermolecular forces, the higher the melting point.
- Vapour pressure:
  The pressure exerted by a vapour at equilibrium with its liquid in a closed system. The stronger the intermolecular forces, the lower the vapour pressure.

SESSION 1 | PHYSICAL PROPERTIES OF ORGANIC MOLECULES

NOTE:

- This presentation will focus on the Physical Properties of Organic molecules. To understand the concepts that will be covered in this lesson, it is important that you have a thorough knowledge of the nomenclature of all the homologous series of organic molecules.
- Examination questions on this topic will in many cases be presented as the results of an experiment in the form of a table or graph. The results of multiple experiments may be included in the same table or graph. You should be able to identify which combination of experiments may be used in a **fair test**. The skill of interpreting results in tables and graphs need practice.
- The following mind map (summary) simplifies the required knowledge to enable you to answer questions on physical properties of organic molecules. Make sure you understand the mind map.
- In some questions you will be required **to identify the structural factor** applicable in the experiment and **explain it's influence on the strength of the IMF** and then mention the **effect** of this **on the physical property** applicable. Comparing the **energy required per unit time** to overcome the IMF might also be required in your explanation. Read these questions carefully and let the marks awarded guide you to the expected answer for the explanation.

MIND MAP/ SUMMARY:



WORKED EXAMPLE:

Question 1

The boiling points of straight-chain alkanes and straight-chain alcohols are compared in the table.

NUMBER OF CARBON ATOMS	BOILING POINTS OF ALKANES (°C)	BOILING POINTS OF ALCOHOLS (°C)
1	- 162	64
2	- 89	78
3	- 42	98
4	- 0,5	118

1.1 Explain the increase in boiling points of the alkanes, as indicated in the table. (3)

1.2 Explain the difference between the boiling points of an alkane and an alcohol, each having THREE carbon atoms per molecule, by referring to the TYPE of intermolecular forces. (4)

1.3 Does the vapour pressure of the alcohols INCREASE or DECREASE with an increase in the number of carbon atoms? (1)

1.4 How will the boiling point of 2-methylpropane compare to that of its chain isomer?
Write down HIGHER THAN, LOWER THAN or EQUAL TO. Give a reason for the answer by referring to the structural differences between the two compounds. (2)
[10]

ANSWER:

1.1
- Structure: From 1 C to 4 C atoms - The chain length/molecular size/molecular mass/ surface area increases. ✓
- Intermolecular forces: Increase in strength of intermolecular forces. ✓
- Energy: More energy needed to overcome intermolecular forces. ✓ (3)

1.2
- Alkanes have London forces. ✓
- Alcohols have hydrogen bonding (in addition to London forces and dipole dipole forces). ✓
- Hydrogen bonding are stronger intermolecular forces than London.
  OR More energy needed to overcome intermolecular forces in alcohols✓
- Alcohols have higher boiling points than alkanes. ✓ (4)

1.3 Decrease✓ (1)

1.4 Lower than ✓
2-methylpropane is more branched/has a smaller surface area than butane/chain isomer. ✓ OR Butane/chain isomer is less branched /has larger surface area than 2-methylpropane (2)
[10]

REVISION:

Question 2

The table below shows five organic compounds represented by the letters A to E.

A	CH_4
B	CH_3CH_3
C	$CH_3CH_2CH_3$
D	$CH_3CH_2CH_2CH_3$
E	CH_3CH_2OH

2.1 Is compound B SATURATED or UNSATURATED? Give a reason for the answer. (2)

Consider the boiling points of compounds A to E given in random order below and use them, where applicable, to answer the questions that follow.

0 °C	- 162 °C	- 42 °C	- 89 °C	78 °C

2.2 Write down the boiling point of:

2.2.1 Compound **C** (1)

2.2.2 Compound **E** (1)

2.3 Explain the difference in boiling points of compounds C and E by referring to the TYPE of intermolecular forces present in EACH of these compounds. (3)

2.4 Does vapour pressure INCREASE or DECREASE from compounds A to D? Fully explain the answer. (4)

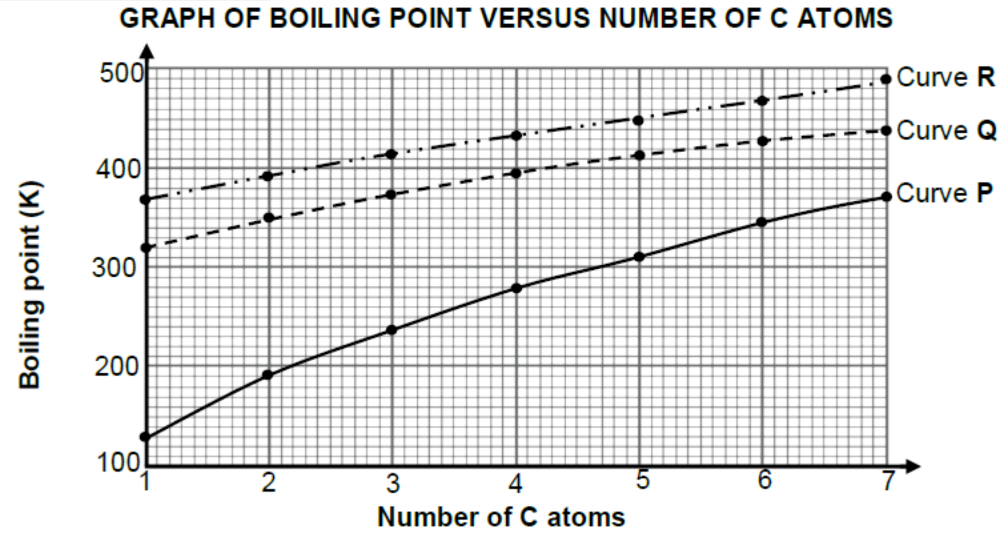
2.5 How will the vapour pressure of 2-methylpropane compare to the vapour pressure of compound D? Write down only HIGHER THAN, LOWER THAN or EQUAL TO. (1)

[12]

REVISION:

Question 3

The relationship between boiling point and the number of carbon atoms in straight chain molecules of alkanes, carboxylic acids and alcohols is investigated. Curves P, Q and R are obtained.



3.1 Define the term boiling point. (2)

3.2 For curve P, write down a conclusion that can be drawn from the above results. (2)

3.3 Identify the curve (P, Q or R) that represents each of the following:

3.3.1 Alkanes (1)

3.3.2 Carboxylic acids (1)

2.3 Explain the answer to QUESTION 3.3.2 by referring to the:
- Types of intermolecular forces present in alkanes, carboxylic acids and alcohols
- Relative strengths of these intermolecular forces
- Energy needed (5)

[11]

Question 4

The boiling points of different organic compounds are given below.

	COMPOUND	BOILING POINT (°C)
A	HCOOH	101
B	CH_3COOH	118
C	CH_3CH_2COOH	141
D	$CH_3CH_2CH_2COOH$	164

4.1 Define the term boiling point. (2)

4.2 Which ONE of the compounds, **A** or **B** or **C**, has the highest vapour pressure? Refer to the data in the table to give a reason for the answer. (2)

4.3 The boiling point of compound **B** is now compared with of compound **X**.

	COMPOUND	BOILING POINT (°C)
B	CH_3COOH	118
X	$CH_3CH_2CH_2OH$	98

4.3.1 Besides the conditions used to determine boiling points, give a reason why this is a fair comparison. (1)

4.3.2 Is compound **X** a PRIMARY, SECONDARY or TERTIARY alcohol? Give a reason for the answer. (2)

4.3.3 Fully explain the difference between the boiling points by referring to the types of intermolecular forces present in each of these compounds. (4)

[11]

REVISION:

Question 5

i. Name the six factors that determine the rate of a chemical reaction.

ii. Name the two requirements according to the COLLISION THEORY for an effective collision between two molecules.

Grade 12 learners use the reaction between a sodium thiosulphate solution ($Na_2S_2O_3$) and a hydrochloric acid solution (HCl) to investigate the factors that affect reaction rates.

The balanced equation for this reaction is :

$$Na_2S_2O_3\,(aq) + 2\,HCl\,(aq) \rightarrow H_2O\,(l) + SO_2\,(g) + 2\,NaCl\,(aq) + S\,(s)$$

The time from the moment EQUAL VOLUMES of the two solutions are mixed untill the appearance of a certain amount of turbidity (sulphur precipitation) is taken as an indication of the reaction rate

Consider **INVESTIGATION A** (Experiment 1 to 3):

	Temp (°C)	[$Na_2S_2O_3$] (mol.dm^{-3})	[HCl] (mol.dm^{-3})	Time (s)
Experiment 1	20	0,5	0,5	40
Experiment 2	20	0,9	0,5	25
Experiment 3	20	1,4	0,5	15

iii. For **INVESTIGATION A**, name the:

a) Dependent variable
b) Independent variable

iv. What is the scientific conclusion that can be drawn from **INVESTIGATION A**?

Consider **INVESTIGATION B** (Experiment 4 to 6):

	Temp (°C)	[$Na_2S_2O_3$] (mol.dm^{-3})	[HCl] (mol.dm^{-3})	Time (s)
Experiment 4	20	0,5	0,5	40
Experiment 5	30	0,5	0,5	20
Experiment 6	50	0,5	0,5	10

REVISION:

v. In which one of the experiments (4 to 6) in **INVESTIGATION B** is the reaction rate the fastest? Give a reason for your answer.

vi. Explain your answer in question 6.4.1 in terms of the collision theory.

ANSWERS:

i. Catalyst, Temperature, Gas pressure, State of division (Reaction surface), Nature of the reagents, Concentration of solutes.

ii. Molecules will undergo effective collisions if :

- The orientation of the collisions is correct.
- The molecule has enough energy.

iii. INVESTIGATION **A**:

a) Reaction Rate / Time

b) Concentration of $Na_2S_2O_3$

iv. ANY ANSWER THAT DESCRIBES THE CORRECT RELATIONSHIP : ✓✓

The reaction rate increases with an increase in concentration of the $Na_2S_2O_3$

v. Experiment 6

- Highest temperature / Fastest time
- Average kinetic energy the highest.

vi. More particles have enough activation energy (Maxwell-Boltzmann curve).

More effective collisions per second

SESSION 2 | REACTION RATE

REVISION:

Question 6

i. Define the term: CATALYST

ii. Draw the following graphs to indicate the effect of a catalyst on each type of graph :

a) 3.2.1 Potential energy – ▲t graph

b) 3.2.2 Maxwell-Boltzmann curve

c) 3.2.3 Reaction Rate –▲t graph

iii. Name the catalyst used in each of the following reactions :

a) 3.3.1 Esterification

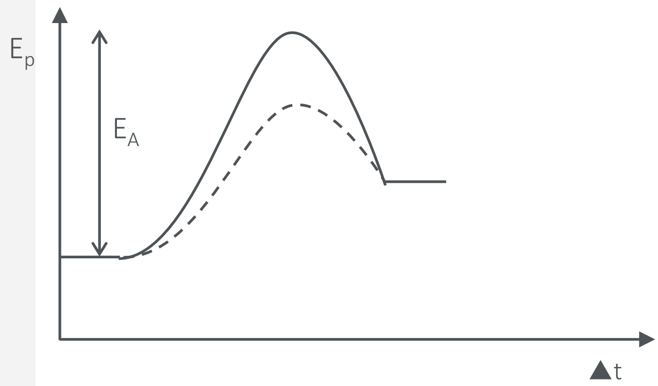
b) 3.3.2 Addition (Hydrogenation)

ANSWERS:

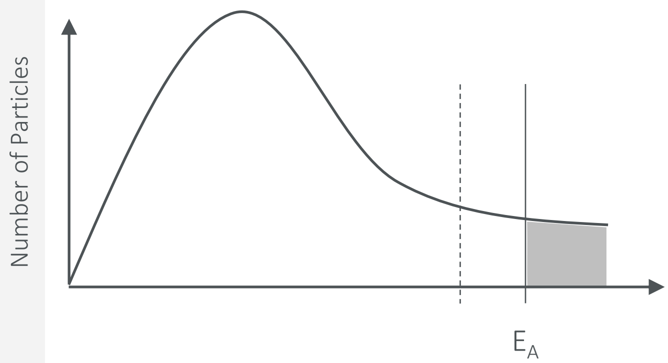
i. CATALYST: Chemical substance that lowers the potential energy of the activated complex and accelerates the reaction rate without participating in the reaction itself.

ii. GRAPHS

a)

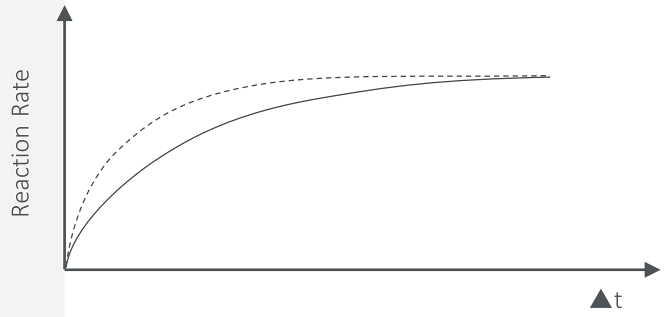


b)



ANSWERS:

c)



iii. Catalysts:

a) Sulfuric acid (H_2SO_4)

b) Platinum (Pt) / Nickel (Ni) / Palladium (Pd)

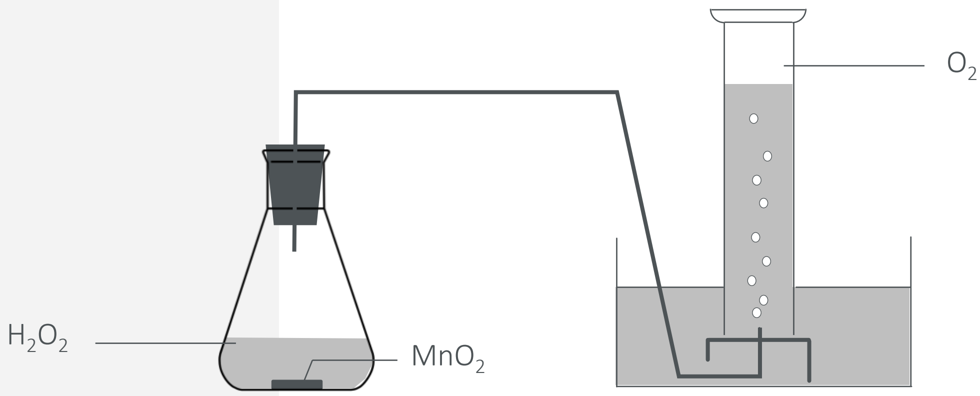
REVISION:

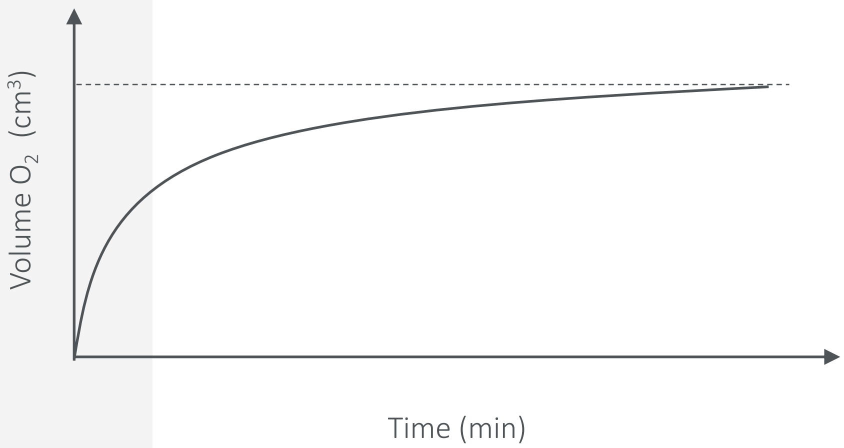
Question 7

Manganese dioxide (MnO_2) acts as a catalyst in the decomposition of hydrogen peroxide (H_2O_2) to form water and oxygen as products. The balanced equation is given :

$$2H_2O_2\,(aq) \rightarrow 2H_2O\,(l) + O_2\,(g)$$

One gram of MnO_2 powder was added to the hydrogen peroxide, with a concentration of 2 mol.dm^{-3} at a temperature of 25°C and the volume of oxygen, which is collected by means of the downward displacement of water, was measured. The sketch below illustrates the experiment and the graph shows the rate at which the gas was collected in a gas cylinder.





SESSION 2 | REACTION RATE

REVISION:

i. Define the term: CATALYST

Copy the GRAPH of time versus volume O_2 onto your answer set. The experiment is repeated twice with a change to one of the constant variables. The first experiment therefore now serves as the control experiment.

ii. Draw the possible curves expected on the same axis system if:

a) No catalyst is used. (Name the new graph A)

b) The experiment is repeated at a higher temperature. (Name this new graph B)

iii. What mass of MnO_2 will be left at the end of the experiment?

iv. Define the term: REACTION RATE

v. Name two more factors, apart from the factors already used in this question, which will influence the rate of a chemical reaction.

vi. Refer to the collision theory to explain how the presence of a catalyst increases the rate of a reaction.

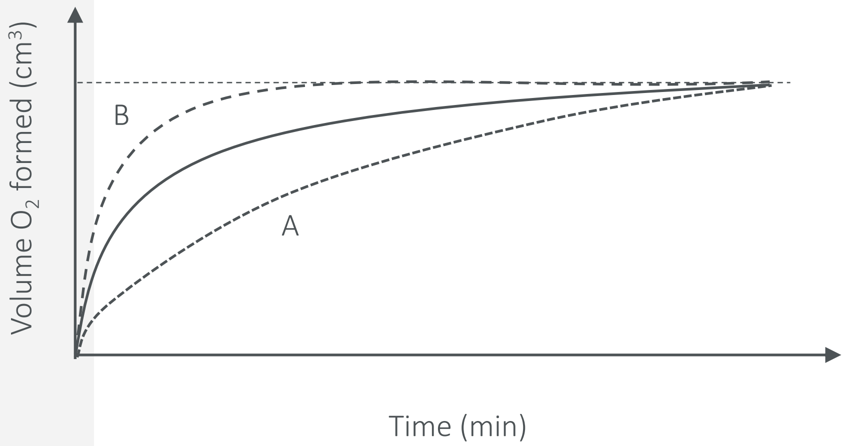
ANSWERS:

i. Chemical substance that lowers the potential energy of the activated complex and accelerates the reaction rate without participating in the reaction itself.

ii. GRAPHS

a) Start and End points same as original curve. Curve BELOW the original curve.

b) Start and End points same as original curve. Curve ABOVE the original curve.



ANSWERS:

iii. 1g MnO_2

iv. The change in concentration of reactants or products per unit time.

v. Concentration, Reaction surface (state of division), Nature of the reagents

vi. Catalyst lowers the activation energy.

More molecules possess enough energy for an effective collision.

More collisions occur in a shorter period of time.

Rate at which products are formed increases.

SESSION 2 | REACTION RATE

REVISION:

Question 8

i. Define the following terms:

a) Reaction rate

b) Activation energy

A Grade 12 learner uses the reaction of zinc with an excess of hydrochloric acid to investigate the factors that affect the rate of a chemical reaction. The balanced equation for the reaction is :

$$Zn\ (s) + 2HCl\ (aq) \rightarrow ZnCl_2\ (aq) + H_2(g)$$

The learners carry out five experiments during the investigation and summarize all data in the following table. Reaction 1 is the CONTROL EXPERIMENT.

Experiments	Mass (Zn)	State of Division (Zn)	Concentration (HCl)	Temperature (HCl)
1	1g	Ppebbles	0,5 mol.dm^{-3}	25 °C
2	1g	Ppebbles	0,8 mol.dm^{-3}	25 °C
3	1g	Ppebbles	0,5 mol.dm^{-3}	35 °C
4	1g	Powder	0,5 mol.dm^{-3}	25 °C
5	2g	Ppebbles	0,5 mol.dm^{-3}	25 °C

ii. Calculate the average reaction rate (in mol.s^{-1}) of reaction 1 if the reaction takes two minutes to complete.

iii. Name the INDEPENDENT VARIABLE between the following reactions :

a) Experiment 1 and Experiment 2

b) Experiment 1 and Experiment 3

c) Experiment 1 and Experiment 4

d) Experiment 1 and Experiment 5

SESSION 2 | REACTION RATE

ANSWERS:

i. DEFINITIONS:

a) The change in concentration of reactants or products per unit time.

b) The minimum energy required for a reaction to occur.

ii. n(Zn) = m ÷ M = 1 ÷ 65 = 0,015 mol

Average Reaction Rate= Δn ÷ Δt = 0,015 ÷ 120

Average Reaction Rate = 1,28 x 10^{-4} mol.s^{-1}

(Answer if rounded values were used : 1,25 x 10^{-4} mol.s^{-1})

iii. VARIABLES:

a) Concentration of the acid

b) Temperature of the reaction mixture

c) State of division of the zinc

d) NONE! (Mass of the reagent is not a factor)

SESSION 3 | ACIDS AND BASES

- **REVISION ACIDS & BASES**

ARRHENIUS THEORY

- ACIDS donate protons (H^+) to form H_3O^+.
- BASES donate hydroxide ions (OH^-).

LOWRY-BRØNSTED THEORY

- Acids donates protons (H^+).
- BASES accept protons(H^+).

Reactions of Acids & Bases

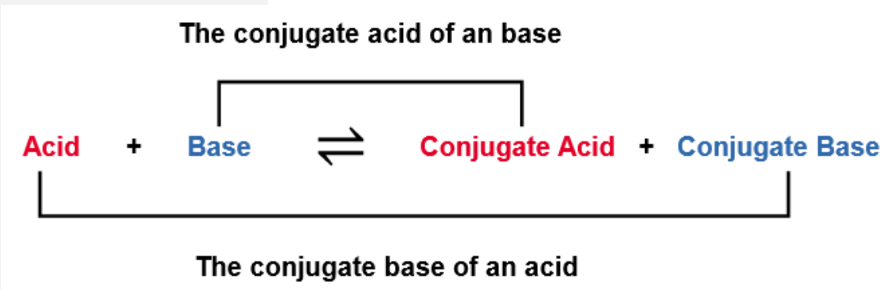
METAL OXIDE + ACID → SALT + H_2O

METAL HYDROXIDE + ACID → SALT + H_2O

METAL CARBONATE + ACID → SALT + H_2O + CO_2

Conjugate Acid-Base Pairs

- When an ACID donates a proton, a CONJUGATE BASE is produced.
- When a BASE accepts a proton, a CONJUGATE ACID is produced.



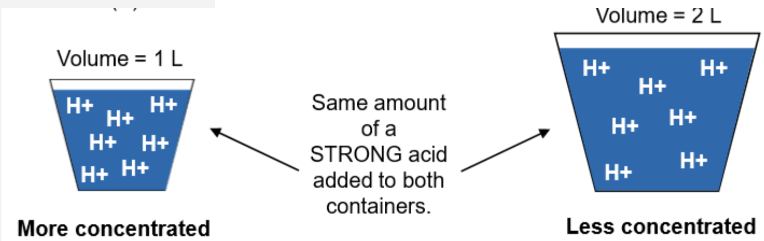
SESSION 3 | ACIDS AND BASES

ACID-BASE STRENGTH

- Strong acids ionise completely in solution to form a high concentration of H_3O^+ ions. Examples: Hydrochloric acid (HCl), Sulfuric acid (H_2SO_4), Nitric Acid (HNO_3)
- Weak acids ionise incompletely in solution to form a low concentration of H_3O^+ ions. Examples: Ethanoic acid (CH_3COOH) Hydrofluoric acid (HF) Phosphoric acid (H_3PO_4)
- Strong bases dissociate completely in solution to form a high concentration of OH^- ions. Examples: Sodium hydroxide (NaOH), Potassium hydroxide (KOH), Lithium hydroxide (LiOH)
- Weak bases dissociate incompletely in solution to form a low concentration of OH^- ions. Examples: Ammonium hydroxide (NH_4OH), Calcium hydroxide ($Ca(OH)_2$), Magnesium hydroxide ($Mg(OH)_2$)

CONCENTRATED ACIDS/BASES AND DILUTE ACIDS/BASES

- Concentrated acids/bases contain a large amount (number of moles) of acid/base in proportion to the volume of water.
- Dilute acids/bases contain a small amount (number of moles) of acid/base in proportion to the volume of water.



SESSION 3 | ACIDS AND BASES

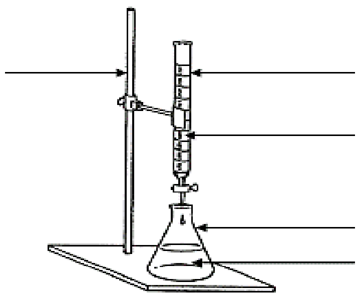
TITRATIONS

- Titrations is an experimental technique used to determine the concentration of an acid or a base using a standard solution.
- Using volumetric analysis, the **unknown concentration** of a solution (acid or base) may be determined.
- Use the equation: $c = \frac{n}{V}$
- Remember moles (n) can be calculated using mass of a substance (m) and its molar mass (M):

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

- Titration formula:

$$\frac{c_a V_a}{c_b V_b} = \frac{n_a}{n_b}$$



QUESTION 2

2.1	Sulphuric acid, H2SO4, ionises into two steps as follows:		
		I H2SO4(aq) + H2O(ℓ) → HSO_4^- (aq) + $H3O^+$(aq) Ka = 1 x 10^3	
		II HSO_4^-(aq) + H2O(ℓ) → SO_4^{2-}(aq) + $H3O^+$(aq) Ka = 1 x 10^{-2}	
	2.1.1	Define an acid in terms of the Lowry-Brønsted theory.	(2)
	2.1.2	Write down the NAME or FORMULA of the substance that acts as an ampholyte in the above equations. Give a reason for the answer.	(2)
	2.1.3	The conductivity of solutions of HSO_4^+(aq) and H_2SO_4(aq) are compared. Which solution will have a LOWER conductivity? Explain the answer.	(3)
2.2	The pH of a hydrochloric acid solution, HCℓ(aq), is 1,02 at 25 °C.		
	2.2.1	Calculate the concentration of the HCℓ(aq).	(3)
		This HCℓ solution reacts with sodium carbonate, Na_2CO_3, according to the following balanced equation:	
		2HCℓ(aq) + Na2CO3(aq) → 2NaCℓ(aq) + CO2(g) + H2O(ℓ)	
		50 cm^3 of the HCℓ solution is added to 25 cm3 of a 0,075 mol·dm^{-3} Na_2CO_3 solution.	
	2.2.2	Calculate the concentration of the EXCESS HCℓ in the new solution.	(8)

QUESTION 3

The K_a values for two weak acids, oxalic acid and carbonic acid, are as follows:

3.1 Define the term weak acid. (2)

3.2 Which acid, OXALIC ACID or CARBONIC ACID, is stronger? Give a reason for the answer. (2)

NAME	FORMULA	K_a
Oxalic acid	$(COOH)_2$	$5,6 \times 10^{-2}$
Carbonic acid	H_2CO_3	$4,3 \times 10^{-7}$

3.3 Oxalic acid ionises in water according to the following balanced equation:

$$(COOH)2(s) + 2H2O(\ell) \rightleftharpoons (COO)_2^{2-}(aq) + 2H3O^+(aq)$$

Write down the FORMULAE of the TWO bases in this equation. (2)

3.4 Learners prepare 2 dm^3 of a sodium hydroxide solution of concentration 0,1 $mol \cdot dm^{-3}$.

Calculate the pH of the solution. (4)

3.5 During a titration of the sodium hydroxide solution in QUESTION 3.4 with dilute oxalic acid, the learners find that 25,1 cm^3 of the NaOH(aq) neutralises exactly 14,2 cm^3 of the $(COOH)_2(aq)$.

The balanced equation for the reaction is as follows:

$$2NaOH(aq) + (COOH)_2(aq) \rightarrow (COO)_2Na_2(aq) + 2H_2O(\ell)$$

3.5.1 Calculate the concentration of the oxalic acid solution. (5)

The following indicators are available for the titration:

INDICATOR	pH RANGE
A	3,1–4,4
B	6,0–7,6
C	8,3–10,0

3.5.2 Which ONE of the indicators above is most suitable for this titration? (2)

Give a reason for the answer.

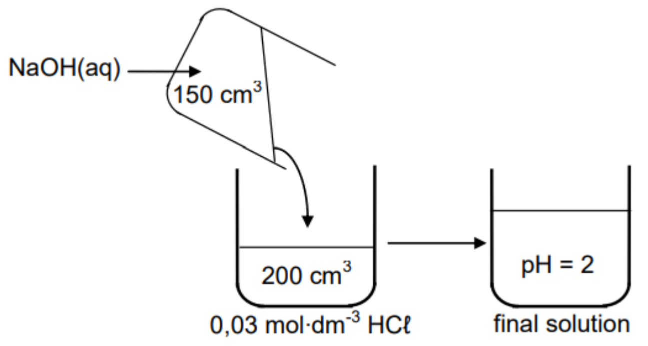
[17]

QUESTION 4

4.1	Define an acid in terms of the Lowry-Brønsted theory.	(2)
4.2	Carbonated water is an aqueous solution of carbonic acid, H_2CO_3. $H_2CO_3(aq)$ ionises in two steps when it dissolves in water.	
	4.2.1 Write down the FORMULA of the conjugate base of $H_2CO_3(aq)$.	(1)
	4.2.2 Write down a balanced equation for the first step in the ionisation of carbonic acid.	(3)
	4.2.3 The pH of a carbonic acid solution at 25 °C is 3,4. Calculate the hydroxide ion concentration in the solution.	(5)
4.3	X is a monoprotic acid.	
	4.3.1 State the meaning of the term monoprotic.	(1)
	4.3.2 A sample of acid X is titrated with a standard sodium hydroxide solution using a suitable indicator. At the endpoint it is found that 25 cm^3 of acid X is neutralised by 27,5 cm^3 of the sodium hydroxide solution of concentration 0,1 $mol{\cdot}dm^{-3}$.	
	Calculate the concentration of acid X.	(5)
	4.3.3 The concentration of H3O+ ions in the sample of acid X is 2,4 x 10^{-4} $mol{\cdot}dm^{-3}$.	
	Is acid X a WEAK or a STRONG acid? Explain the answer by referring to the answer in QUESTION 4.3.2.	(3)

QUESTION 5

5.1	Two acids, HX and HY, of EQUAL CONCENTRATIONS are compared. The pH of HX is 2,7 and the pH of HY is 0,7.
	5.1.1 Define an acid in terms of the Lowry-Brønsted theory.
	5.1.2 Which acid, HX or HY, is STRONGER? Give a reason for the answer.
	5.1.3 Acid HX ionises in water according to the following equation: $HX(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + X^-(aq)$ The K_a value for the reaction is $1,8 \times 10^{-5}$ at 25 °C. Is the concentration of the hydronium ions HIGHER THAN, LOWER THAN or EQUAL TO the concentration of HX? Give a reason for the answer.
5.2	Learners add 150 cm^3 of a sodium hydroxide solution, NaOH, of unknown concentration to 200 cm^3 of a 0,03 $mol{\cdot}dm^{-3}$ hydrochloric acid solution, $HC\ell$, as illustrated below. They find that the pH of the final solution is 2. Assume that the volumes are additive.



The balanced equation for the reaction is: $HC\ell(aq) + NaOH(aq) \rightarrow NaC\ell(aq) + H_2O(\ell)$ Calculate the:	
5.2.1 Concentration of the H_3O^+ ions in the final solution	(3)
5.2.2 Initial concentration of the NaOH(aq)	(7)