This is a Class 1 exam

Lebanon Evangelical School
for Boys and Girls — Loueizeh - Baabda

Stage Exam 04

20-25JUN2025

Do NOT write in this box. Your MARK will be placed here.

Subject :	Chemistry
Class :	12M and 12E
Teacher :	Mrs. Mirella Freige
Duration :	2 hours

Graph paper needed

You are to answer the questions to this exam on : Lined paper

Your name :		*Time taken to complete exam*
Your Class :		
Exam Room :		
How many sheets, including cover sheet :		

- Do not open this paper until the teacher in charge instructs you to do so.
- The most important thing to remember in taking an exam is NEVER PANIC.
- If you are caught cheating in this exam, you will be awarded zero for ALL exams that are taken on this day.

Exercise I (7 points) Kinetics of the Reaction of Magnesium with Hydrochloric Acid

Magnesium metal reacts with hydrochloric acid solution ($H_3O^+ + Cl^-$) according to a slow and complete reaction as shown by the equation below:

$$Mg_{(s)} + 2\ H_3O^+_{(aq)} \rightarrow Mg^{2+}_{(aq)} + H_{2(g)} + 2\ H_2O_{(l)}$$

In order to study the kinetic of this reaction the following experiment is carried out at constant temperature.

A volume V_1=100 mL of a hydrochloric acid solution (S_1) of molar concentration C_1= 0.20 $mol.L^{-1}$ is introduced into an Erlenmeyer flask.
At instant t = 0, a mass m = 0.15 g of powdered magnesium is added to the Erlenmeyer flask and the chronometer is set to function.
The volume V, of the released hydrogen gas H_2, is measured at different instants t, and then the numbers of moles of hydrogen gas are deduced at these instants. The obtained values are given in document-1.

t (s)	20	40	60	80	100	120
$n(H_2)x10^{-5}$ (mol)	50	90	123	152	176	195

Document-1

Given: $M_{(Mg)} = 24 g.mol^{-1}$

1. Preparation of The Acid Solution

A bottle of an aqueous hydrochloric acid solution (S_0) is labelled with the following indications: 32.3% by mass of the acid, density d = 1.13 $g.mL^{-1}$, $M_{(HCl)}$ =36.5 $g.mol^{-1}$.

1.1. Show that the molar concentration C_0 of the solution (S_0) is close to 10 $mol.L^{-1}$.

1.2. The solution (S_1), with a concentration C_1 = 0.20 $mol.L^{-1}$, is prepared from the solution (S_0).

1.2.1. Calculate the volume V_0 withdrawn from (S_0) to prepare 200 mL of solution (S_1).

1.2.2. Choose, from document-2, the most precise glassware for the preparation of (S_1)

- Volumetric pipets: 5 mL and 10 mL
- Graduated pipets: 2 mL and 5 mL
- Volumetric flasks:200 mL, 250 mL and 500 mL
- Graduated cylinders: 5 mL and 10 mL

Document-2

2. Kinetic Study

2.1. Determine the limiting reactant.

2.2. Specify whether the time t = 120s represents the end of the reaction.

2.3. Plot the curve that represents the variation of the number of moles of H_2 gas as a function of time, $n(H_2) = f(t)$ within the time interval [0 ; 120s].
Take the following scale: abscissa: 1cm for 10s ; ordinate: 1cm for 20×10^{-5} mol.

2.4. Deduce, graphically, the variation of the rate of formation of H_2 as a function of time.

2.5. The preceding experiment is repeated with one modification: the solution (S_1) is replaced by a hydrochloric acid solution (S_2) of concentration C_2, where $C_2 > C_1$.

Given the following propositions:

2.5.1. The end of the reaction is reached faster.

2.5.2. The number of moles of hydrogen gas produced at the end of the reaction increases.

If the proposition is correct, justify it. If the proposition is false, correct it.

Exercise II (6 points) **Sodium Hydroxide NaOH**

The aim of this exercise is to study the behavior of sodium hydroxide in distilled water and then determine the percentage by mass of sodium hydroxide in a solid drain opener.

Given: Molar mass of sodium hydroxide M = 40g/mol.
The study is performed at 25°C where $K_W = 10^{-14}$.

1. Study of the Behavior of Sodium Hydroxide in Distilled Water

Available is a solution (S) of sodium hydroxide ($Na^+ + OH^-$) with a concentration $C = 6\times10^{-3}$ mol/L and a pH of 11.78.

1.1. Show that sodium hydroxide is a strong base.

1.2. Write its dissociation equation in distilled water.

2. Determination of the Percentage by Mass of Sodium Hydroxide in the Drain Opener

Procedure of the experiment:

- A solution (S_b) of volume V = 500 mL of the drainer opener is prepared by dissolving a mass m = 0.7 g of the drain opener in distilled water.
- A volume V_b = 20 mL is taken from the solution (S_b) and placed in a beaker containing about 30 mL of distilled water.
- The pH electrode of the pH-meter is immersed in the solution in the beaker, then a hydrochloric acid solution ($H_3O^+ + Cl^-$) of molar concentration $Ca = 4 \times 10^{-2}$ mol/L is added progressively.
- Based on the titration results, the equivalence point is reached upon the addition of V_{aE} = 15.5 mL of the acidic solution.

2.1. List the materials needed to prepare the solution (S_b).

2.2. Name the glassware used to :

2.2.1. Withdraw the volume V_b.
2.2.2. Add progressively the acidic solution.

2.3. Write the equation of the titration reaction.

2.4. Based on the chemical species present in the solution in the beaker, justify the neutrality of the solution obtained at equivalence.

2.5. Determine the molar concentration C_b of the solution (S_b).

2.6. Determine the percentage by mass of sodium hydroxide in the drain opener.

2.7. Plot the shape of the curve pH = f (Va) passing through the following three remarkable points: Va = 0 mL; Va = 15.5 mL and Va = 25 mL.
Va is the volume of the acidic solution added.
Take the following scale : 1 cm for 1 pH unit; 1 cm for 2 mL.

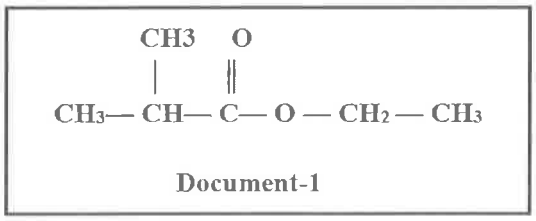
Exercise III (7 points) Isobutyric Acid Ethyl Ester

Isobutyric acid ethyl ester is a sweet tasting compound. It is prepared by an esterification reaction between an acid (A) and an alcohol (B).
Outside of the human body, it has been detected in several different foods, such as apples, figs.

The aim of this exercise is to identify the acid (A) and the alcohol (B) and to study the effect of some factors on the esterification reaction yield.

1. Study the Structure of Isobutyric Acid Ethyl Ester

The condensed structural formula of isobutyric acid ethyl ester is given in **Document-1**:



Document-1

1.1. Recopy the condensed structural formula of isobutyric acid ethyl ester and circle its functional group.

1.2. Give the systematic name of isobutyric acid ethyl ester.

1.3. Isobutyric acid ethyl ester is obtained from the reaction between a carboxylic acid (A) and an alcohol (B). Identify the acid (A) and the alcohol (B).

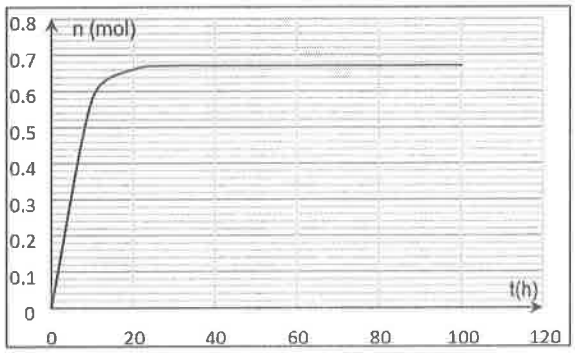
2. Synthesis of Isobutyric Acid Ethyl Ester

Isobutyric acid ethyl ester can be prepared starting from carboxylic acid (A) and alcohol (B) according to the following equation:

Carboxylic acid (A) + Alcohol (B) ⇌ Isobutyric Acid Ethyl Ester + Water

An equimolar mixture (M) containing 1.0 mol of carboxylic acid (A) and 1.0 mol of the alcohol (B) is heated to reflux for several hours in the presence of a few drops of sulfuric acid as a catalyst.

Document-2 represents the change in the number of moles of the ester formed with time.



Document-2

2.1. Give the importance of heating this reacting mixture.

2.2. Justify, based on **Document-2**, that the system has reached equilibrium state.

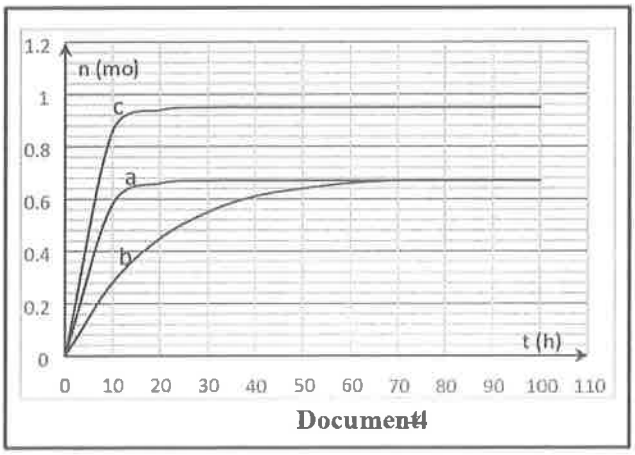
2.3. Determine the yield of this synthesis reaction.

2.4. We realize other reacting mixtures given in the table of **Document-3**.

Reacting mixture	Number of moles of (A)	Number of moles of (B)	Catalyst	Corresponding curve
M	1.0 mol	1.0 mol	H_2SO_4	a
M′	1.0 mol	1.0 mol		b
M″	1.0 mol	5.0 mol	H_2SO_4	c

Document-3

Document-4 shows the curves that represent the variation of n(ester) with time in each mixture.



Document-4

Referring to **Document-3** and **Document-4:**

2.4.1. Deduce the effect of the use of a catalyst on the equilibrium state.

2.4.2. Suggest a way to increase the yield of the esterification reaction. Justify.

Exercise I (7 points)

1. (S_0) : $H_3O^+ + Cl^-$: 32.3% $d = 1.13\ g/mL$ $M_{HCl} = 36.5\ g/mol$.

1.1. $C_0 = \frac{n_{solute}}{V_{solution}} = \frac{m_{solute} \times d_{solution}}{M_{solute} \times m_{solution}}$

$C_0 = \frac{32.3 \times 1.13 \times 10^3}{36.5 \times 100} = 9.99 \simeq 10\ mol/L$. (0.75)

1.2.1. During dilution, number of moles of solute is conserved:

$n_0 = n_1 \Rightarrow C_0 \times V_0 = C_1 \times V$

$\Rightarrow V_0 = \frac{0.2 \times 200}{10} = 4\ mL$. (0.5)

1.2.2. Graduated pipette: 5 mL (to take 4 mL) (0.25)
. Volumetric flask : 200 mL. (0.25)

2.1. $Mg + 2H_3O^+ \longrightarrow Mg^{2+}_{(aq)} + H_{2(g)} + 2H_2O$

$n_{0\,Mg} = \frac{m}{M} = \frac{0.15}{24} = 0.0062\ mol = 6.2 \times 10^{-3}\ mol$.

$n_{0\,H_3O^+} = C_1 \times V_1 = 0.2 \times 100 \times 10^{-3} = 20 \times 10^{-3}\ mol$.

$R_{Mg} = \frac{n_0}{coeff} = \frac{6.2 \times 10^{-3}}{1} = 6.2 \times 10^{-3}$

$R_{H_3O^+} = \frac{n_0}{coeff} = \frac{20 \times 10^{-3}}{2} = 10 \times 10^{-3}$

$R_{Mg} < R_{H_3O^+}$

$\Rightarrow Mg$: limiting reactant.

(0.75)

2.2. According to stoichiometry:

$$\frac{n_{Mg\ reacting}}{1} = \frac{n_{H_2}\ (\text{obtained at the end of the reaction})}{1}$$

$\Rightarrow n_{H_2\ obtained\ at\ \infty} = 6.2 \times 10^{-3}$ mol.

Based on doc-1, $n_{(H_2)}$ obtained at $t = 120s = 195 \times 10^{-5}$ mol

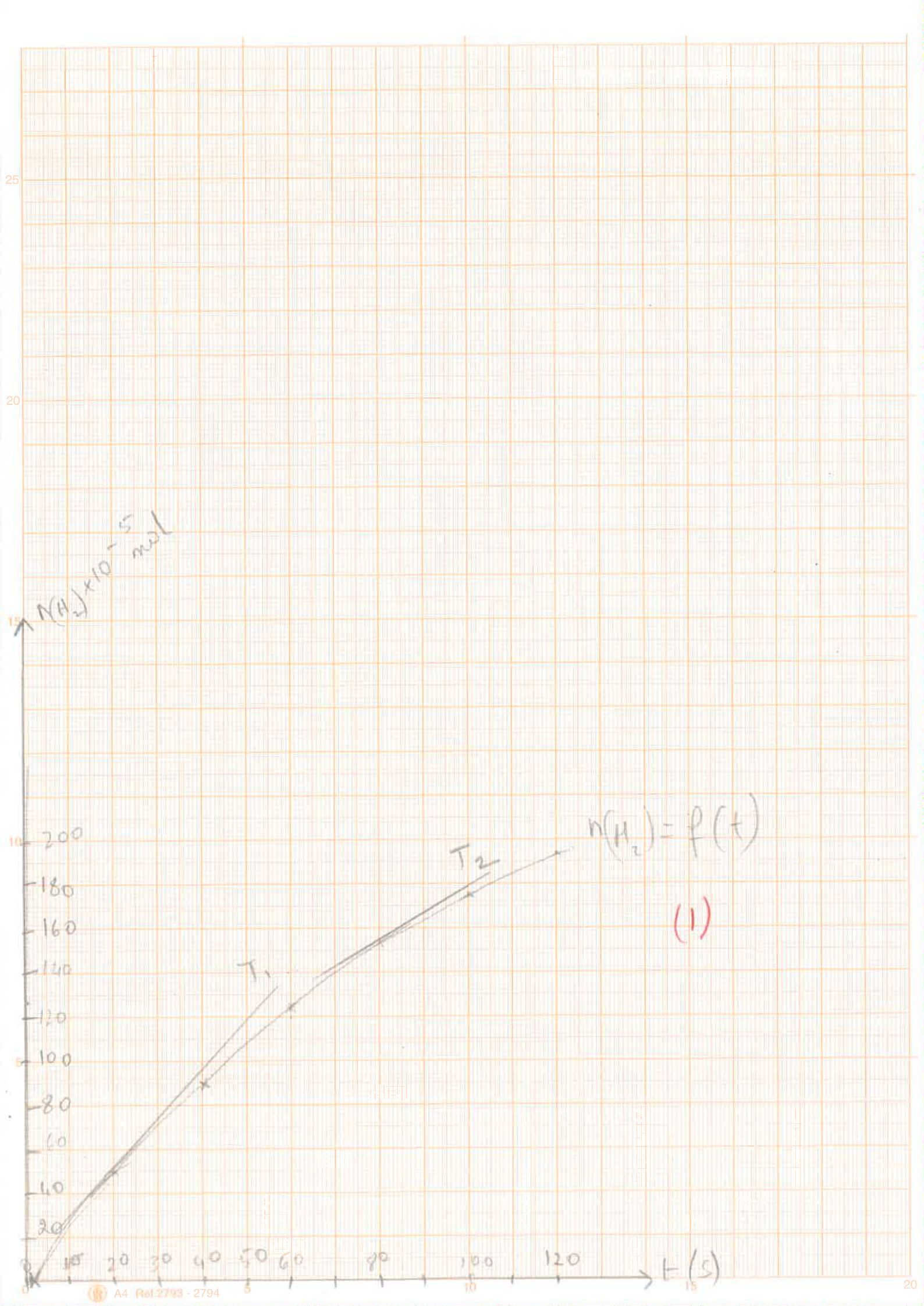
So, $n_{H_2}(t=120s) < n_{H_2}(\infty) \rightarrow t = 120s$ doesn't represent the end of the reaction. (0.75)

2.3. On the Graph Paper.

2.4. Since the slope of the tangent T_2 < the slope of the Tang T_1.
(rate of formation of H_2 = ⊕ slope of the tangent on the curve)
so, the rate of formation of H_2 decreases with time (0.75)

2.5.1. True; the concentration of reactants is a Kinetic factor: when the conc. of a reactant increases the rate of the reaction increases.
$C_2 > C_1$ so, the end of the reaction will be reached faster. (1)

2.5.2. False; the number of moles of H_2 produced at the end of the reaction depends only on the limiting reactant Mg ⊕
so, $n_{H_2(\infty)}$ remains the same. (1)
⊕ and since



A4 Ref.2793 - 2794

Exercise II Sodium Hydroxide

(S): $Na^+ + OH^-$; $C = 6\times10^{-3}$ mol/L.
$pH = 11.78$.

1.

1.1. $pH = 11.78 \Rightarrow [H_3O^+] = 10^{-pH} = 10^{-11.78} \simeq 1.66\times10^{-12}$ mol/L

$K_w = [H_3O^+]\times[OH^-] \Rightarrow [OH^-] = \frac{10^{-14}}{1.66\times10^{-12}} = 6.02\times10^{-3}$ mol/L.
$\simeq 6\times10^{-3}$ mol/L.

$C_b = 6\times10^{-3} = [OH^-]$ then, sodium hydroxide is a strong base. (0.75)

1.2. $NaOH_{(s)} \longrightarrow Na^+_{(aq)} + OH^-_{(aq)}$ (0.25)

2.2.1. Materials needed for the preparation of (S_b) : (Dissolution)

- Scale
- Spatula
- Watch Glass
- Funnel
- 500 mL volumetric flask.
- Distilled water. (0.5)

2.2.1. V_b is taken with a 20mL volumetric pipette (0.25)

2.2.2. The acidic solution is added progressively from a graduated burette. (0.25)

2.3. Titration equation: $H_3O^+_{(aq)} + OH^-_{(aq)} \longrightarrow 2H_2O_{(\ell)}$ (0.75)

2.4. At equivalence, the species present in the solution are: H_2O: neutral, Na^+ ions and Cl^- ions which are spectator ions : don't affect the pH at equivalence
So, the medium at equivalence is neutral. (0.75)

2.5) $S_b \begin{cases} V_b = 20\ mL \\ C_b = ? \end{cases}$ $(H_3O^+ + Cl^-) \begin{cases} V_{bE} = 15.5\ mL \\ C_a = 4 \times 10^{-2}\ mol/L \end{cases}$

At equivalence, reactants react according to Stoichiometry: $n_{acid\ added\ at\ Equiv.} = n_{base\ present\ in\ the\ beaker}$

$$\Rightarrow C_a \times V_{aE} = C_b \times V_b$$

$$C_b = \frac{C_a \times V_{aE}}{V_b} = \frac{4 \times 10^{-2} \times 15.5}{20}$$

$$C_b = 0.031\ mol/L. \quad (0.75)$$

2.6) % by mass of sodium hydroxide in the drain opener

$$= \frac{m_{solute}}{m_{solution}} \times 100 = \frac{n_{solute} \times M_{NaOH}}{m_{solution}} \times 100$$

$$= \frac{C_b \times V_{solution} \times M_{NaOH}}{m_{solution}} \times 100 = \frac{0.031 \times 500 \times 10^{-3} \times 40}{0.7} \times 100$$

$$\% = 88.57\%. \quad (0.75)$$

2.7) * for $V_a = 0\ mL \rightarrow pH_{solution\ in\ the\ beaker} = pH_{(s)} = 14 + \log(0.031) = 12.49$. (0.25)

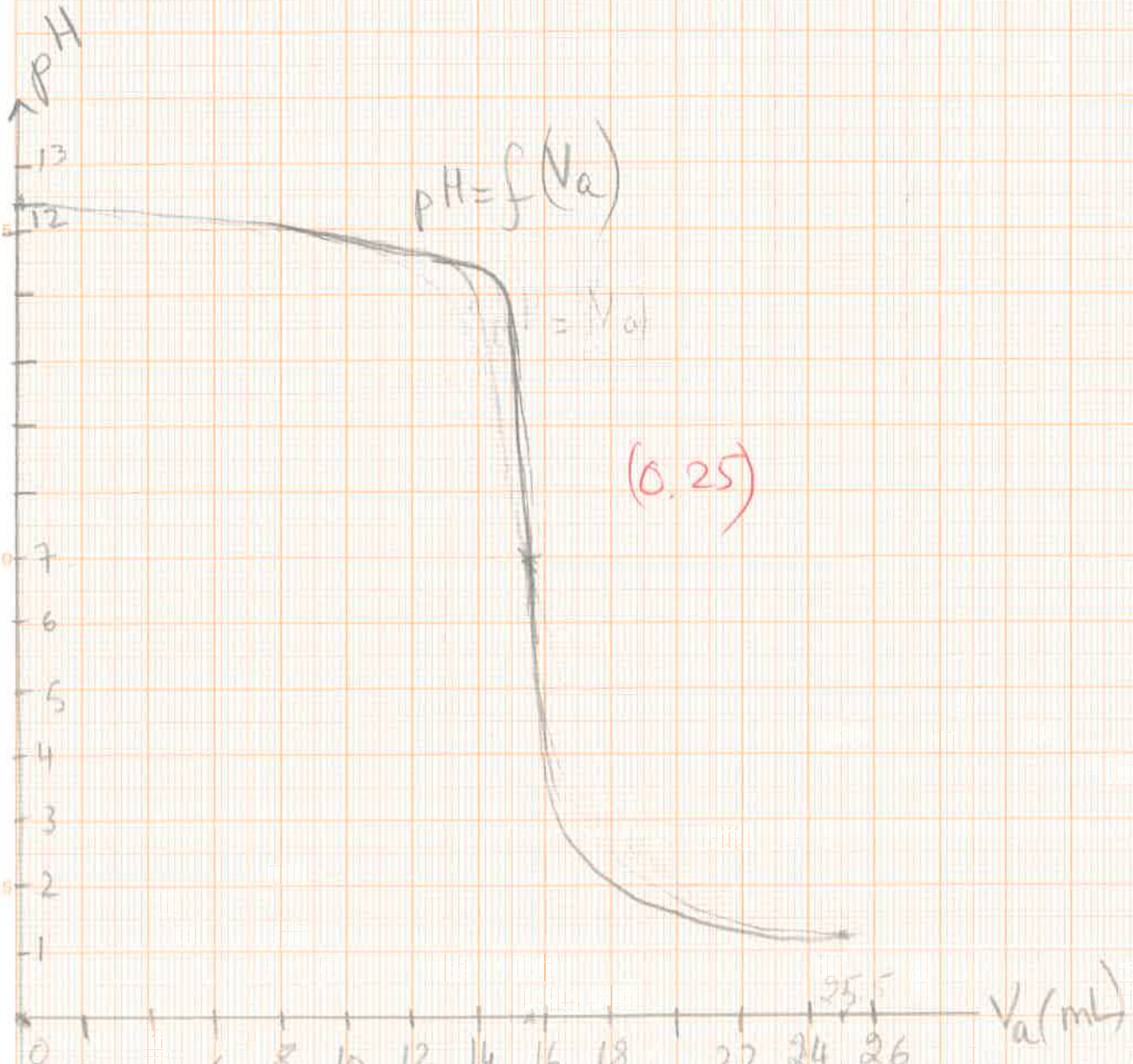
* $V_{aE} = 15.5\ mL \rightarrow pH_E = 7$. (0.25)

* $V_a = 25\ mL > V_{aE}$ so, $pH \rightarrow pH_{solution\ added\ from\ the\ burette}$

$$pH \rightarrow pH_{acidic\ solution} = -\log[H_3O^+] = -\log C_a = -\log(4 \times 10^{-2})$$

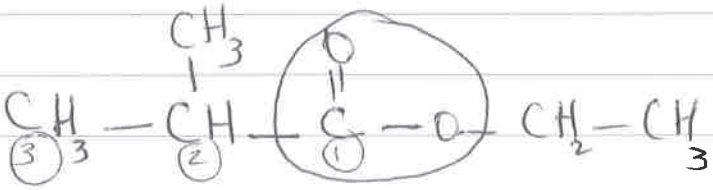
$$pH \rightarrow 1.39. \quad (0.25)$$

Curve $pH = f(V_a)$ on the graph paper.

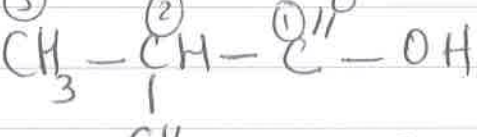


(0.25)

Exercise III

1.1.  (1/2)

1.2. Name: Ethyl 2-methylpropanoate (3/4)

1.3. Acid (A):  (3/4)

.. 2-methylpropanoic acid

Alcohol (B): $HO-CH_2-CH_3$: Ethanol. (3/4)

2.1. Heating increases the rate of the slow esterification reaction. (Temperature is a kinetic factor). (1/2)

2.2. Esterification reaction is a reversible reaction; referring to Document-2 and starting from t = 20 hrs, n(Ester) remains constant and doesn't change, then system has reached the equilibrium state. (1/2)

2.3. $n_{o(A)} = 1\,mol$ $\quad R_{(A)} = \frac{n_o}{coeff} = \frac{1}{1} = 1$

$n_{o(B)} = 1\,mol$ $\quad R_{(B)} = \frac{n_o}{coeff} = \frac{1}{1} = 1$

$\Rightarrow R(A) = R(B)$ → Initial mixture is stoichiometric.

Consider that the esterification reaction is complete.
According to stoichiometry:

$$\frac{n\,\text{Acid reacting}}{1} = \frac{n\,\text{Ester obtained}}{1} = 1\ \text{mol (Theoretical)}$$

(0.66 mol Acceptable)

According to Doc.-2, Experimental n(E) at equilibrium = 0.67 mol.

$$\text{Yield} = \frac{\text{Experimental } n(E)}{\text{Theoretical } n(E)} = \frac{0.67}{1} = 0.67. \quad (1)$$

(0.66 acceptable)

2.4.1. Comparing mixtures M and M':
Starting with the same equimolar mixture, a catalyst is added to Mixture M, from Doc.-4, the rate of the reaction in mixture M' (represented by curve a) is greater than the rate of the reaction in mixture M' (represented by curve b) where mixture M reaches the same equilibrium state as in mixture M' but in less time, so the catalyst increases the rate of esterification reaction to reach equilibrium faster. (1¼)

2.4.2. Using Documents 3 and 4 curve c reaches equilibrium state at a value: n(ester) = 0.96 mol which is greater than 0.66 mol and thus yield increases, therefore using a non-equimolar mixture as (M") increases the yield of an esterification reaction. (1)