Kinetic reaction between hydrochloric acid and iron

A hydrochloric acid solution (**HCl**) attacks iron (**Fe**) according to the following reaction:

$$2\,H^+_{(aq)} + Fe_{(s)} \rightarrow Fe^{2+}_{(aq)} + H_{2\,(g)}$$

The aim of this exercise is to study the kinetic of this reaction.

<u>Given</u>: Molar mass of iron=56g/mol

Molar volume of the gas in the experiment conditions $V_m = 24\ L.mol^{-1}$

I- Primary study

At time t=0 we add Va =40ml of hydrochloric acid solution of concentration Ca=0.5 $mol.l^{-1}$

In a beaker containing a mass m=2g of iron powder ,the volume of the reacted medium is constant.

1-Show that H^+ is the limiting reactant.

2-Determine **at t=∞** the concentration of Fe^{2+} ions.

3-Show that : $[H^+]_t = [H^+]_0 - \frac{V_{H_2}}{480}$, VH_2 is the volume expressed in ml of hydrogen gas

Formed at each instant.

II-Kinetic study of the reaction

The results of this experiment are given in the following table :

t (s)	0	100	200	300	400	500	600	800	1000
V_{H2} (mL)	0	80	132	154	168	178	183	188	192
$[H^+]$ ($mol.L^{-1}$)	x	0,333	0,225	0,179	0,150	0,129	0,119	y	0,100

1-Give the value of x and calculate that of y in the above table.

2-Draw on a paper graph the curve $[H^+] = f(t)$. take the following scale :

x-axis : 1cm=100sec **y-axis : 1cm=0.05 $mol.l^{-1}$**

3-Interpret graphically the evolution of the rate of disappearance of H^+ ions with time.

4-Determine the concentration of Fe^{2+} at t=100 sec.

5- Find the time at which **50 %** of H^+ are left.

6-Give the relation between the rate of formation of Fe^{2+} ions and that of the disappearance of H^+ ions at each instant t.

7- Is the time =1000s the end time of the reaction ? explain.

Exercise : 1

A Commercial Vinegar solution of concentration C_o = 5 mol/l and V = 250 ml is an aqueous solution of acetic acid ($C_2H_4O_2$) and trace of chemicals

Given : M $C_2H_4O_2$ = 60 g/mol

1- Calculate the mass needed to prepare the solution S_0 of $C_2H_4O_2$.

2. - Describe the procedure of preparation of $C_2H_4O_2$ solution and list the materials used.

3. From the commercial $C_2H_4O_2$ solution (S_0), it is required to prepare a solution(S) of C = 0.2 mol/l

Choose from the sets below, the convenient one that should be used to perform the required dilution. Justify your answer

Set 1	Set 2	Set 3
250 mL volumetric flask 200 mL beaker 5 mL volumetric pipette	100mL volumetric flask 50 mL beaker 5 mL volumetric pipette	150mL volumetric flask 50 mL beaker 10 mL graduated pipette

4- Describe the procedure of preparing the diluted solution.

Exercise : 2

Kinetic of the Reaction Between Hydrochloric Acid and Magnesium

Magnesium reacts, at room temperature, with the H_3O^+ ions of an aqueous solution of hydrochloric acid by a slow reaction according to the following equation:

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

A mass of 2 g of magnesium is introduced into a volume V = 100 mL of a hydrochloric acid solution of concentration C = 0.11 mol.L^{-1}. The change of the reacting system is followed in terms of time, by determining the number of moles of hydrogen gas, n(H_2), released at different instants. results are given in the following table:

-Given :**Molar mass in g.mol^{-1}: M(Mg) = 24 and V_m = 24 mol/L.**

Preliminary Study

t (min)	0	2	4	6	8	10	14	18	22	26	30	34
n (H_2) (10^{-3} mol)	0	0.85	1.6	2.2	2.9	3.4	4.2	4.7	4.9	5.1	5.2	5.3

1.1- Show that the concentration of H_3O^+ ions, in the reacting medium, at t = 10 min, is equal to 4.2×10^{-2} mol.L^{-1}.

1.2- Find the limiting reactant.

1.3- Determine the volume of the hydrogen gas evolved at the end of the reaction.

1- <u>Kinetic Study</u>

2.1- Plot, on a graph paper, the curve representing the change of the number of moles of hydrogen versus time: n (H_2) = f (t) in the time interval [0-34 min].

Take the following scale: **1 cm for 2 min in abscissa**

and 1 cm for 5.0×10^{-4} mol in ordinate.

2.2- The rate of formation of hydrogen at the instant t = 7 min, $3{,}1\times10^{-4}$ mol.min^{-1}.
Choose, by justifying without calculation, between the two following values: 6.2×10^{-4}mol.min^{-1} and
8.0×10^{-5} mol.min^{-1}, the one that corresponds to the rate of formation of hydrogen at t = 18 min.

2.3- Determine the average rate of (H_3O^+) during the interval of time t= 6 min & t = 10 min.

r

Exercice 1 (10 pts) **Study of a Slow Reaction**

In an aqueous medium, methanoic acid (HCOOH) reacts slowly and completely with bromine (Br_2) according to the **reaction 1** represented by the following equation:

$$Br_{2\,(aq)} + HCOOH_{(aq)} + 2\,H_2O_{(l)} \rightarrow 2\,H_3O^+_{(aq)} + 2\,Br^-_{(aq)} + CO_{2\,(g)}$$

The aim of this exercise is to study the kinetic of this reaction.

1. **Preparation of a Solution (S_1) of Methanoic Acid**
   In order to prepare a solution (S_1) of methanoic acid of concentration $C_1 = 2.0 \times 10^{-2}$mol.L^{-1}, asolution (S_o) of methanoic acid previously available in the laboratory is diluted 50 times.
   Choose, from **document-1**, the most suitable glassware to prepare 100 mL of the solution (S_1).Justify your answer.

- Volumetric flasks: 100 mL, 500 mL	-Volumetric pipet: 10 mL	- Precision balance
- Graduated pipet: 10 mL	- Beaker: 100 mL	- Graduated cylinder: 25 mL

Document- 1

2. **Preliminary Study**

   At instant t = 0 s, a volume V_1 = 50 mL of the methanoic acid solution (S_1) of concentration $C_1 = 2.0 \times 10^{-2}$mol.L^{-1} is mixed with a volume V_2 = 50 mL of bromine solution (S_2) of concentration $C_2 = 2.6 \times 10^{-2}$mol.L^{-1}. **Reaction 1** takes place at temperature **T** maintained constant.

   2.1. Verify that the initial molar concentration of methanoic acid, $[HCOOH]_o = 1.0\times 10^{-2}$mol.L^{-1} and that of the bromine is $[Br_2]_o = 1.3 \times 10^{-2}$mol.L^{-1}.
   2.2. Determine the limiting reacting.
   2.3. Show that the molar concentration of bromine **remained** in the solution at time t of **reaction 1** is given by the following relation: $[Br_2]_t = [Br_2]_o - [HCOOH]_t$

3. **Kinetic Follow-up**
   By an appropriate method, one determines the molar concentration of bromine at different instants. The results obtained are grouped in the table of **document-2**.

t (s)	0	50	100	150	250	350	450	550	700	900
$[Br_2]$ (10^{-3} mol.L^{-1})	13.0	10.5	9.0	8.0	6.4	5.0	3.8	3.3	3.1	3.0

Document-2

   3.1. Plot the curve representing the variation of the concentration of bromine as a function of time:$[Br_2] = f(t)$ in the interval of time [0 – 900s]
   Take the following scales: In abscissa: 1cm for 100 s
   In ordinates: 1cm for 1×10^{-3} mol. L^{-1}
   3.2. For each of the two following propositions, justify the correct one and correct, by justifying, the false one.
   3.2.1. The reaction is ceased at t = 900s.
   3.2.2. The rate of disappearance of Br_2 is at instant t = 50 s is 2.3×10^{-4} mol.l^{-1}.s^{-1} , the rate of the reaction at t= 50 s is 4.6×10^{-4} mol.l^{-1}.s^{-1} .

Synthesis of ammonia

Ammonia is a colorless and irritating gas (pungent odor at low concentration, it burns eyes and lungs in itsconcentrated form).

1. Study of the Reaction.

Into a flask of volume V= 1L, we introduce 1 mol of N_2 and 3 mol of H_2 , a chemical equilibrium isestablished according to the following equation: $N_{2(g)} + 3\ H_{2(g)} \quad 2\ NH_{3(g)}$

Let α be the degree of conversion of N_2.

At different temperatures, the total number of mol of reactional mixture at equilibrium is calculated.The results are collected in the table in document-1-.

T(°C)	25	27	227	327	527	727
n_t (in mol)	2	2	2.32	2.7	3.46	3.8

Document-1-

1.1. Copy and complete the following table in terms of α .

	$N_{2\,(g)}$	$H_{2(g)}$	$NH_{3(g)}$
Initial state (mol)			
Equilibrium state (mol)			

1.2. Express the total number of mol of mixture at equilibrium in terms of α.

1.3. Write the expression of K_C in terms of α.

1.4. The rate of the reaction at equilibrium is zero.Could we say that the reaction stops ? Justify.

2. Study of the reaction at temperature 227 °C .

2.1. Referring **to document -1-** and at temperature 227 °C :

2.1.1. Calculate α at equilibrium. Deduce K_C.

2.1.2. Show that the percentage yield of the reaction is equal to 84%.

2.2. The experiment is repeated by introducing 1mol of $N_{2(g)}$ and 5 mol of $H_{2(g)}$.Choose, with justification, the correct answer :

The equilibrium constant K_C

-i- decreases -ii- increases -iii- remains constant

2.3. The experiment is repeated again ,by introducing 1 mol of $N_{2(g)}$, 3 mol of $H_{2\,(g)}$ and 2 mol of $NH_{3\,(g)}$. The number of mol of NH_3 at equilibrium is equal to 3.54 mol.

2.3.1. Determine the percentage yield of the reaction.

2.3.2. In what direction the equilibrium is shifted ?Justify.

~~**2.3.3.** Deduce the effect of adding NH_3 ,initially to the mixture, on the yield of~~ the reaction.

3. Study of the reaction at temperature 27°C

.Referring to document-1- :

3.1. What is the value of α at temperature 27 °C ? Conclude.

Specify if equilibrium constant K_C could be determined below

Exercise 1 (6 points) **Study of a Slow Reaction**

Hydrogen peroxide (H_2O_2) oxidizes iodide ions (I^-) in acidic medium in a slow reaction which takes place according to the following equation:

$$2\,I^-_{(aq)} + H_2O_{2\,(aq)} + 2\,H^+_{(aq)} \longrightarrow I_{2\,(aq)} + 2\,H_2O_{(l)}$$

The aim of this exercise is to study the kinetic of this reaction.

1. Preparation of a Hydrogen Peroxide (H_2O_2) Solution (S_1)

Available is a hydrogen peroxide solution (S_o) of concentration $C_o = 2.7$ mol.L^{-1}. It is required to prepare a hydrogen peroxide solution (S_1) of concentration $C_1 = 0.1$ mol.L^{-1}.
Choose, from the **document-1**, the most suitable set of glassware to realize this dilution. Justify.

Set A	Set B	Set C
Volumetric flask of 100 mL Volumetric pipet of 10 mL Beaker of 50 mL	Volumetric flask of 100 mL Graduated pipet of 10 mL Beaker of 50 mL	Volumetric flask of 100 mL Graduated cylinder of 10 mL Beaker of 50 mL

Document-1

2. Preliminary Study

In a beaker, one mixes:

- A volume $V_1 = 18$ mL of potassium iodide solution ($K^+ + I^-$) of concentration $C_1 = 0.1$ mol.L^{-1}
- A volume $V_2 = 9$ mL of sulfuric acid solution H_2SO_4 of concentration $C_2 = 1$ mol.L^{-1}.

At instant t = 0 s, a volume $V_3 = 3$ mL of hydrogen peroxide solution H_2O_2 of concentration $C_3 =$ 0.1 mol.L^{-1} is added to the beaker.
In this mixture, sulfuric acid is in excess. ??

2.1. Calculate the initial concentrations of iodide ions $[I^-]_o$ and hydrogen peroxide $[H_2O_2]_o$ in the reaction mixture.

2.2. Show that hydrogen peroxide H_2O_2 is the limiting reactant.

3. Kinetic Study

By an appropriate method, the concentration of iodine $[I_2]$ at different instants is determined. The results are grouped in the table of **document-2**.

t (s)	100	200	300	400	500	600	650
$[I_2]$ (10^{-3} mol.L^{-1})	3.85	5.9	7.5	8.6	9.4	9.85	10

Document-2

3.1. Plot the curve representing the variation of the concentration of iodine as a function of time $[I_2] = f(t)$ in the interval of time [0 - 650 s].

Take the scales: In abscissa: 1 cm for 50 s ;

In ordinates: 1 cm for 1×10^{-3} $mol.L^{-1}$.

3.2. Show that t= 650s represents the end time of reaction.

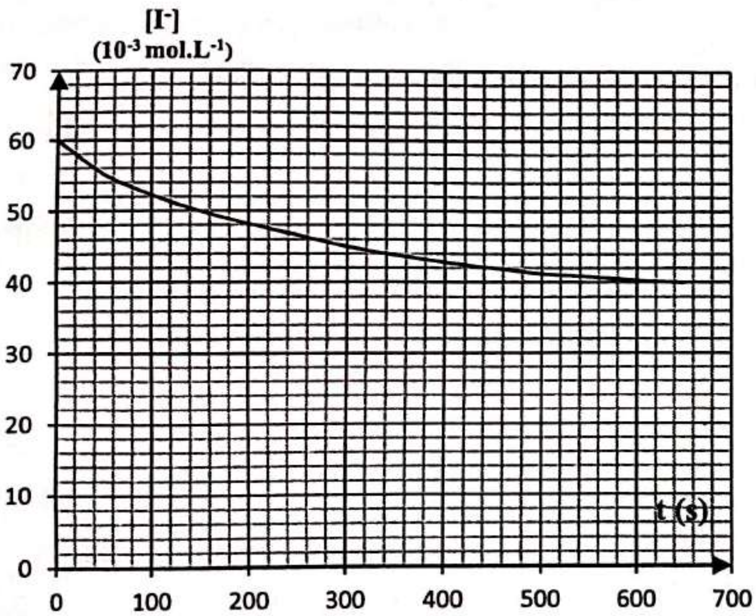
3.3. Determine graphically the half-life time of reaction $t_{1/2}$.

3.4. Justify the following statements:

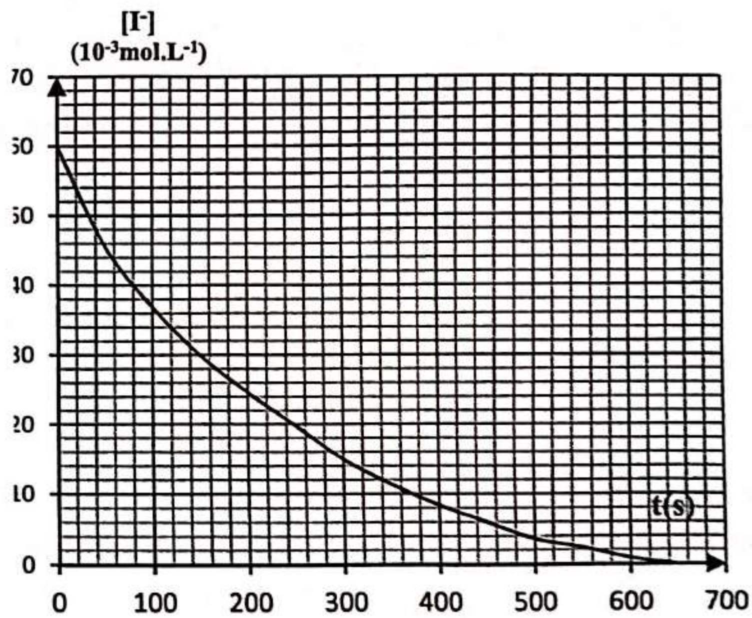
3.4.1. The initial rate of formation of I_2 is greater than its rate of formation at t = 300 s.

3.4.2. The concentration of iodide ions at t ½ is $[I^-]_{1/2} = 50\times10^{-3}$ $mol.L^{-1}$.

3.5. From the curves of **document-3,** specify the one that corresponds to the variation of the concentr of iodide ions as a function of time $[I^-] = g(t)$.



Curve a



Curve b

Document-3

Exercise 1 **Kinetic Study**

The aim of this exercise is to study the kinetics of the reaction between permanganate ions (MnO_4^-) and oxalic acid ($H_2C_2O_4$) in acidic medium, and the factors affecting the rate of this reaction.

The equation of the reaction is :

$$2MnO_4^- + 5H_2C_2O_4 + 6\,\overset{H^+}{\widehat{H_3O^+}} \rightarrow 2\,Mn^{2+} + 10\,CO_2 + 14\,H_2O$$

Three solutions are prepared to be used in this experiment:

- S_1: potassium permanganate solution ($K^+ + MnO_4^-$) of concentration $C_1 = 5.0 \times 10^{-3}$ mol.L^{-1}.
- S_2: oxalic acid solution ($H_2C_2O_4$) of concentration $C_2 = 5.0 \times 10^{-2}$ mol,L^{-1}
- S_3: concentrated sulfuric acid solution.

Given: MnO_4^- is considered the only colored species in the reaction medium.
Manganese salt used in this experiment dissolves readily in aqueous solutions to give Mn^{2+}.

1. Preparation of Solution S_1

Solution (S_1) is prepared from an initial concentrated solution (S_o) by diluting a sample of (S_o) 25 times.
Choose, from **document-1,** the most precise glassware to perform this dilution.

- Volumetric flask : 250 mL , 500 mL
- Volumetric pipet: 15, 20 mL
- Graduated pipet: 15, 20 mL
- Beaker: 50, 100 mL
- Buret: 50, 100 mL
- Graduated cylinder: 25 , 50 mL

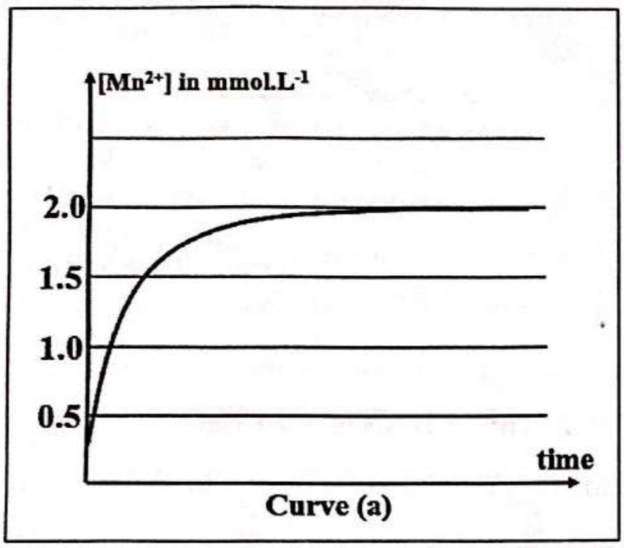
Document-1

2. Kinetic study:
Available are three beakers numbered from 1 to 3, each of the three beakers contained $V_1 = 40$ mL of S_1, $V_2 = 60$ mL of S_2, and few drops of S_3. **Document -2** shows additional information about these three beakers.

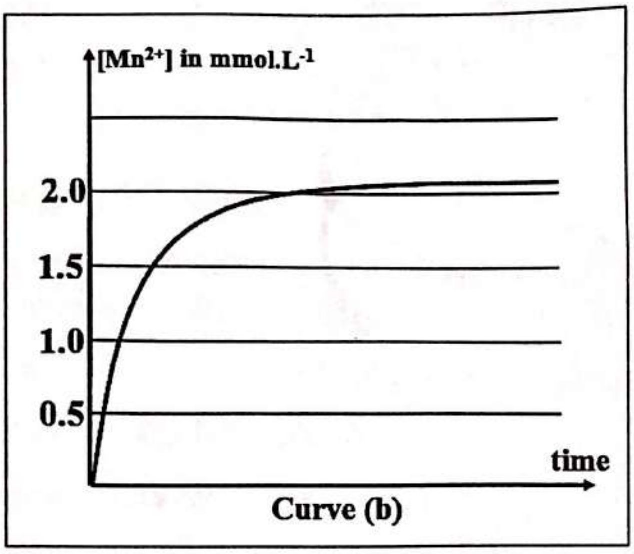
	Beaker 1	**Beaker 2**	**Beaker 3**
Other chemical content	-	-	Adding a mass (m) of manganese salt at t=0
Temperature	T	T'>T	T
Time interval of the reaction	$\Delta t_1 = 160$ s	Δt_2	Δt_3

Document-2

2.1. Calculate the concentrations of MnO_4^- and $H_2C_2O_4$ in the reaction mixture at t=0.
2.2. Specify the color of the reaction mixture in beaker (1) at t = 160 s.
2.3. Determine the maximum concentration of Mn^{2+} in beaker 1.
2.4. Verify if the two curves of **document-3** can represent the variation of [Mn^{2+}] over time in the reaction medium of **beaker 3.**



Curve (a)



Curve (b)

2.5. The rate of disappearance of MnO_4^- in beaker 1 at t = 80 s is $r(MnO_4^-)_{80} = 4{,}3 \times 10^{-5}$ mol.L^{-1}.s^{-1}.

2.5.1. Define the rate of disappearance of MnO_4^- at an instant t.

2.5.2. Deduce the rate of formation of CO_2 at this same instant.

2.6. At t = 100 s, the concentration of MnO_4^- in beaker 1 is found to be $[MnO_4^-]_{100} = 0.32$ mmol.L^{-1}. Choose, with justification, from the following values, the one that corresponds to $[MnO_4^-]_{100}$ in beaker 2.

a) 0.32 mmol.L^{-1} b) 0.27 mmol.L^{-1} c) 0.45 mmol.L^{-1}

2.7. The study of the reaction taking place in beaker 3 shows that $\Delta t_3 < 160$ s. Deduce the role of manganese ions (Mn^{2+}) in this reaction.

Exercise 1 **Luminol at the service of scientific police.**

Molecule of luminol

Luminol is an organic compound of molecular formula $C_8H_7N_3O_2$. Its reaction with certain oxidants leads to the emission of characteristic blue light. The most used oxidant is hydrogen peroxide ($H_2O_{2\,(aq)}$). The reaction between luminol and hydrogen peroxide is very slow; it takes several months....Otherwise it will be more rapid in the presence of a compound containing iron III ions.
Forensic investigators use luminol to detect trace amounts of blood at crime scenes, as it reacts with the iron in hemoglobin.

Translated from: http://la-science-rattrape-jack.

Document-1-

<u>**Given:**</u> M(luminol) = 177 g.mol^{-1}
The color of $MnO_4^-{}_{(aq)}$ is purple while that of $Mn^{2+}{}_{(aq)}$ is colorless.

1. Verification of the Indication 110 V on a Bottle of Hydrogen Peroxide.

Hydrogen peroxide solution (S_0) 110 V means that 110 L of oxygen gas are released during the decomposition of 1 L of hydrogen peroxide solution at standard conditions of temperature and pressure(where V_m = 22.4 L.mol^{-1}). The decomposition reaction is: $2\ H_2O_{2(aq)} \longrightarrow O_{2(g)} + 2\ H_2O_{(l)}$

Document-2-

In order to verify the indication 110V ,the following procedure is followed:

- Solution (S_0) is diluted 10 times in order to prepare a solution (S) .
- 10 mL of (S) are titrated with acidified potassium permanganate solution $KMnO_4$ ($K^+_{(aq)}$+$MnO_4^-{}_{(aq)}$) of concentration 0.5 mol.L^{-1}.The volume of $KMnO_4$ solution added to reach equivalence is V_E= 7.84 mL.
- The equation of titration reaction is: $2\ MnO_4^-{}_{(aq)} + 5\ H_2O_{2(aq)} + 6\ H^+_{(aq)} \rightarrow 2\ Mn^{2+}{}_{(aq)} + 5\ O_{2(g)} + 8\ H_2O_{(l)}$

1.1 Indicate how equivalence point is detected in this titration.
1.2 Show that[H_2O_2] in solution (S) is 0.98 mol.L^{-1}.
1.3 Referring to document-2-,verify the indication 110 V on the bottle of hydrogen peroxide.

2. Preliminary Study of Reaction Between Luminol and Hydrogen Peroxide.

To study the kinetic of the slow reaction between luminol and hydrogen peroxide, three solutions are prepared where the total volume of the obtained mixture is 350 mL:

- solution(S_1) : 1 g of luminol, sodium hydroxide NaOH (s)in excess and distilled water.
- solution(S_2) : solution containing Fe^{3+} ions of concentration C .
- solution(S_3) : 0.5 mL of hydrogen peroxide solution 110 V (of concentration 9.8 mol.L^{-1}).

When solutions (S_1) and (S_2) are mixed in a beaker, a yellow color appears. By adding solution (S_3) to the beaker blue spots appear. The equation of reaction taking place (R_1) is:

$$2\ C_8H_7N_3O_{2(aq)} \ + \ 7\ H_2O_{2(aq)} \ + 4\ HO^-_{(aq)} \rightarrow 2\ N_{2(g)} + 2\ C_8H_7NO_4{}^{2-}{}_{(aq)} \ + \ 14\ H_2O_{(l)}$$

2.1. Identify the limiting reactant.

2.2. Show that at each instant "t" : $[H_2O_2]_t = 0.014 - \frac{V(N2)}{2.5}$ where $V(N_2)$ is in L (V_m=25 L.mol^{-1})

2.3. Referring to document-1-:

2.3.1. Indicate the role of solution (S_2).Pick up the sentence justifying your answer.

2.3.2. Why reaction (R_1) is interesting in criminology (scientific study of crime)?

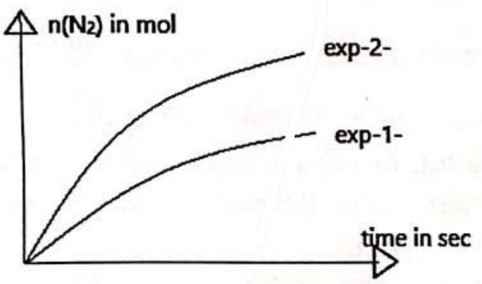
3. Kinetic Study of Reaction Between Luminol and Hydrogen Peroxide.

3.1. At time t=3.1 sec , the volume of nitrogen gas (N_2) is equal to 17.5×10^{-3} L.
What represents this time for the reaction? Justify your answer.

3.2. Determine the average rate of formation of N_2 between t=0 sec and t=3.1 sec .
Deduce the average rate of disappearance of H_2O_2.

3.3. The experiment is repeated with only one modification without change in the total volume of obtained mixture.Document-3- shows the modification and the curves of variation of number of mol of N_2 as function of time in the two experiments.

Experiment-1-	Experiment-2-
Solution of Fe^{3+} ions of concentration C	Solution of Fe^{3+} ions of concentration C_1> C



Document-3-

3.3.1. Referring to document-3-, specify the kinetic factor which is responsible for the difference in shape of the two curves.

3.3.2. Choose, with justification, the correct answer.
The half-life time (t½) of the reaction in experiment-1- is ....that in experiment-2-:

i- equal to ii- less than iii- greater than