H

NANYANG JUNIOR COLLEGE
JC2 PRACTICAL PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME	

CLASS	2	1				TUTOR				
CENTRE NUMBER	S					INDEX NUMBER				

CHEMISTRY

9729/04

Paper 4 Practical

18 August 2022

2 hour 30 minutes

Candidates answer on the Question Paper

Additional Materials: As listed in the Confidential Instructions

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Give details of the practical shift and laboratory, where appropriate, in the boxes provided.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the Question Paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.
Qualitative Analysis Notes are printed on pages 19 and 20.

Shift
Laboratory

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

				For Examiner's Use	
1(a), (b)(i) [7]		2(d) [4]		**1**	/ 17
1(b)(ii)-(v) [6]		2(e), (f) [3]		**2**	/ 16
1(c) [4]		3(a),(c)-(d) [5]		**3**	/10
2(a) [5]		3(b) [5]		**4**	/ 12
2(b), (c) [4]		4(a) & (b)-(c) [12]		**Total**	/55

This document consists of **18** printed pages and **2** blank pages.

[Turn over

Answer **all** the questions in the spaces provided.

1 An investigation of the chemistry of some vanadium ions

FA 1 is a solution of a dilute acid.
FA 2 contains vanadate(V) ions, VO_3^-, of concentration 0.50 mol dm^{-3}.

Ammonium vanadate(V), NH_4VO_3, is a crystalline solid that is slightly yellow in colour. It has a relatively low solubility in water at room temperature.

Vanadium, like all transition metals, is able to exhibit variable oxidation states in its compounds.

You are provided with a solution, **FA 2**, which was produced by reacting NH_4VO_3 with aqueous sodium hydroxide. In this reaction, the anion remains unreacted.

(a) Write an equation for the reaction between ammonium vanadate(V) and sodium hydroxide to produce **FA 2**.

Describe how, using a simple chemical test, you can confirm that this reaction occurred during the preparation of **FA 2**.

DO NOT carry out this test.

equation .....

test .....

..... [1]

$NH_4VO_3 + NaOH \rightarrow NaVO_3 + H_2O + NH_3$ or $NH_4^+ + OH^- \rightarrow H_2O + NH_3$
Gas evolved turns damp red litmus paper blue. NH_3 is evolved.
1 mark for both equation and test

Relevant standard electrode potential data of some species are given in Table 1.1.

Table 1.1

$V^{3+}(aq) + e^-$ green	$\rightleftharpoons$	$V^{2+}(aq)$ purple	$E^{\ominus} = -0.26$ V
$VO^{2+}(aq) + 2H^+ + e^-$ blue	$\rightleftharpoons$	$V^{3+}(aq) + H_2O(l)$ green	$E^{\ominus} = +0.34$ V
$VO_2^+(aq) + 2H^+ + e^-$ yellow	$\rightleftharpoons$	$VO^{2+}(aq) + H_2O(l)$ blue	$E^{\ominus} = +1.00$ V
$Zn^{2+} + 2\ e^-$	$\rightleftharpoons$	Zn	$E^{\ominus} = -0.76$ V
$MnO_4^-(aq) + 8H^+(aq) + 5e^-$	$\rightleftharpoons$	$Mn^{2+}(aq) + 4H_2O(l)$	$E^{\ominus} = +1.51$ V

(b) (i) When **FA 2** is acidified and reacted with zinc powder, VO_3^- ions are reduced stepwise.

Carry out the following tests. Carefully record your observations in Table 1.2.

Test and identify any gases evolved.

Table 1.2

tests		observations
1	Using a measuring cylinder, transfer 1 cm^3 of **FA 2** into a boiling tube. To this same boiling tube, use a measuring cylinder to add 4 cm^3 of **FA 1** and stir the mixture. This is solution **W**. Retain solution **W** for use in test 2.	• colourless solution turns yellow on acidification • beaker felt warm
2	To solution **W** in the boiling tube, add a spatula of zinc powder using a metal spatula. Swirl the mixture gently and record your observations. Continue to add more zinc powder one spatula at a time with swirling, until about 4 spatulas of zinc powder is added. Record all colour changes observed throughout the initial **10 minutes**.	• Yellow solution turns green [mixture of yellow VO_2^+ and blue VO^{2+}] • Green solution turns blue (OR bluish-green OR greenish blue) [more VO^{2+} formed] • Blue solution turns green (OR dark green) [V^{3+} formed] • Green solution turns purple (OR violet OR blue) [V^{2+} formed] • boiling tube felt warm • Effervescence of H_2 gas which extinguished lighted splint with a 'pop' sound. (not a marking point as it is not observable)
When no further changes are seen, decant the reaction mixture into a test-tube. This is solution **X** which contains one of the reduction product of the vanadium ion originally present in **W**. Retain solution **X** for use in test 3.		
3	Pour 1 cm^3 of **X** into a test-tube. Observe this solution for at least **5 minutes**.	• Solution turns blue-green/blue/green

[6]

- 8-9 pts - [6]; 6-7 pts – [5]; 5 pts – [4]; 4 pts – [3]; 3 pts – [2]; 2 pts – [1]

(ii) State the ion formed when **FA 1** is added to **FA 2** in test 1. Write an ionic equation for this reaction.

ion formed .....

ionic equation.....[1]

VO_2^+
$VO_3È(aq) + 2H^+(aq) \rightarrow VO_2^+(aq) + H_2O(l)$ [1]

(iii) Suggest which ion is responsible for the final colour observed in test 2. Explain your answer in terms of the $E_ɻ$ values given in Table 1.1.

ion……

explanation…….

……

……[2]

- V^{2+}
- VO_2^+ will first be reduced to VO^{2+} by Zn.
  $E^{\ominus}_{cell} = +1.00 – (–0.76) = +1.76$ V, > 0, hence reaction is feasible
- VO^{2+} will then be further reduced by Zn to V^{3+}.
  $E^{\ominus}_{cell} = +0.34 – (–0.76) = +1.10$ V, > 0, hence reaction is feasible
- V^{3+} will also be further reduced by Zn to V^{2+}.
  $E^{\ominus}_{cell} = –0.26 – (–0.76) = +0.50$ V, > 0, hence reaction is feasible

Hence the ion responsible for the final colour is likely to be V^{2+}.

4 pts – [2]; 2 pts – [1]

(iv) Suggest an explanation for your observations in test 3.

explanation……

……[1]

aerial oxidation by O_2 from V^{2+} to V^{3+} or VO^{2+} [1]

(v) When aqueous sodium hydroxide was added dropwise till excess into a solution containing the complex ion $[V(H_2O)_6]^{3+}$, a brown precipitate is observed.

State the type of reaction and write an equation to explain the observation.

.....

.....[2]

$[V(H_2O)_6]^{3+} + 3OH^- \rightarrow [V(H_2O)_3(OH)_3] + 3H_2O$ [1]

The ion of vanadium in **Y** has a high charge density. Hence, it undergoes hydrolysis to produce H^+, which reacts with NaOH to give an insoluble hydroxide of vanadium. **OR**
Acid-base reaction with OH^- to form an insoluble hydroxide of vanadium. [1]

Do **not** allow explanations in terms of ligand exchange.

(c) The identity of **FA 1** could be hydrochloric acid, nitric acid or sulfuric acid.

(i) Devise a test that will positively identify hydrochloric acid, nitric acid, and sulfuric acid respectively. For each of the possible acids, you should indicate the expected observations in the table below. Your tests should be based on the Qualitative Analysis Notes on pages 19–20 and should use only the bench reagents provided.

	tests	expected observations
1	To 1 cm depth of dilute HCl in a test-tube, add aqueous silver nitrate dropwise.	White ppt formed [1]
2	To 1 cm depth of dilute nitric acid in a boiling tube, add 1 cm depth of aqueous sodium hydroxide and a piece of aluminium foil. Heat the resulting mixture.	Gas evolved turns moist red litmus paper blue. [1]
3	To 1 cm depth of dilute sulfuric acid in a test-tube, add aqueous barium chloride dropwise. Then, add excess dilute hydrochloric acid.	White ppt formed; white ppt remains insoluble in excess dilute HCl. [1]

[3]

(ii) Perform your tests on **FA 1** to confirm its identity.

Any test requiring heating MUST be performed in a boiling tube.

FA 1…… [1]

H_2SO_4 [1]

[Total: 17]

2 Investigation on how rate of reaction is affected by the concentration of iodide ions

In acidic solutions iron(III) ions are reduced by iodide ions to form iron(II) ions. The iodide ions are oxidised to iodine.

$$2Fe^{3+}(aq) + 2I^{-}(aq) \downarrow 2Fe^{2+}(aq) + I_2(aq)$$

The rate of this reaction can be investigated by using starch indicator, which turns blue-black in the presence of iodine. Sodium thiosulfate is added to the reaction mixture to react with iodine as it is formed. The blue-black colour is seen when all the thiosulfate has reacted.

$$I_2(aq) + 2S_2O_3^{2-}(aq) \downarrow 2I^{-}(aq) + S_4O_6^{2-}(aq)$$

You will investigate how the rate of reaction is affected by changing the concentration of the iodide ions.

FA 3 is 0.0500 mol dm^{-3} potassium iodide, KI.
FA 4 is 0.0500 mol dm^{-3} acidified iron(III) chloride, $FeCl_3$.
FA 5 is 0.00500 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.
FA 6 is starch indicator.

Read through the whole method before starting any practical work.

(a) Method

Prepare a table on page 8 for your results. You will need to include the volume of **FA 3**, volume of water, reaction time and rate of reaction for each of five experiments.

Experiment 1

1. Fill the burette with **FA 3**. Run 20.00 cm^3 of **FA 3** into the 100 cm^3 beaker.

2. Using appropriate measuring cylinders, transfer to the beaker:
   - 20.0 cm^3 of **FA 5**
   - 10.0 cm^3 of **FA 6**.

3. Stir the contents of the beaker using a glass rod.

4. Use the 10 cm^3 measuring cylinder to transfer 10.0 cm^3 of **FA 4** to the beaker. Start the stopwatch during this addition.

5. Mix the contents in the beaker by **thoroughly** stirring.

6. Stop the stopwatch when the solution **first** turns blue-black. Record the time to the nearest second.

7. Carefully wash out the beaker. Stand it upside down on a paper towel to drain.

Experiment 2

8. Fill the second burette with distilled water.

9. Run 10.00 cm^3 of **FA 3** into another 100 cm^3 beaker.

10. Run 10.00 cm^3 of distilled water into the beaker containing **FA 3**.

11. Using appropriate measuring cylinders, transfer to the beaker:
    - 20.0 cm^3 of **FA 5**
    - 10.0 cm^3 of **FA 6**.

12. Stir the contents of the beaker using a glass rod.

13. Use the 10 cm^3 measuring cylinder to transfer 10.0 cm^3 of **FA 4** to the beaker. Start the stopwatch during this addition.

14. Mix the contents in the beaker by **thoroughly** stirring.

15. Stop the stopwatch when the solution **first** turns blue-black. Record the time to the nearest second.

16. Carefully wash out the beaker. Stand it upside down on a paper towel to drain.

Experiments 3 – 5

17. Carry out three further experiments to investigate how the reaction time changes with different volumes of potassium iodide, **FA 3**.

    Remember
    - The combined volume of **FA 3** and distilled water must always be 20.00 cm^3.
    - Do **not** use a volume of **FA 3** that is less than 6.00 cm^3.
    - You should record all your results in a single table.

Results

The rate of reaction can be calculated as shown:

$$\text{rate} = \frac{1000}{\text{reaction time}}$$

Experiment	$V_{FA\ 3}$ / cm^3	V_{water} / cm^3	time / s	rate / s^{-1}
1	20.00	0.00	17	58.8
2	10.00	10.00	60	16.7
3	6.00	14.00	155	6.45
4	14.00	6.00	32	31.3
5	18.00	2.00	20	50.0

- Four (or more) experiments completed **AND** table with correct headings ($V_{FA\ 3}$, V_{water}, time, rate) and units. *Ignore date for this mark
- All times recorded to nearest second (minimum of 3 times) **AND** $V_{FA\ 3}$ and V_{water} recorded to the nearest 0.05 cm^3.
- Three additional experiments with $V_{FA\ 3}$ not less than 6.00 cm^3, not more than 20.00 cm^3 and no volume less than 2.00 cm^3 close to another volume. *Reject if further additional experiments carried out. Reject if all 3 additional experiments are between 20 and 10 cm^3.
- V_{water} chosen so that $V_{FA\ 3}$ + V_{water} = 20.00cm^3 for additional experiments carried out. *Reject if $V_{FA\ 3}$ = 0. Reject if no times recorded.
- Correctly calculates rate for all experiments and answer shown to 3 s.f.. Allow for a minimum of 3 experiments attempted.

5 pts – [3]; 3-4 pts – [2]; 2 pts – [1]

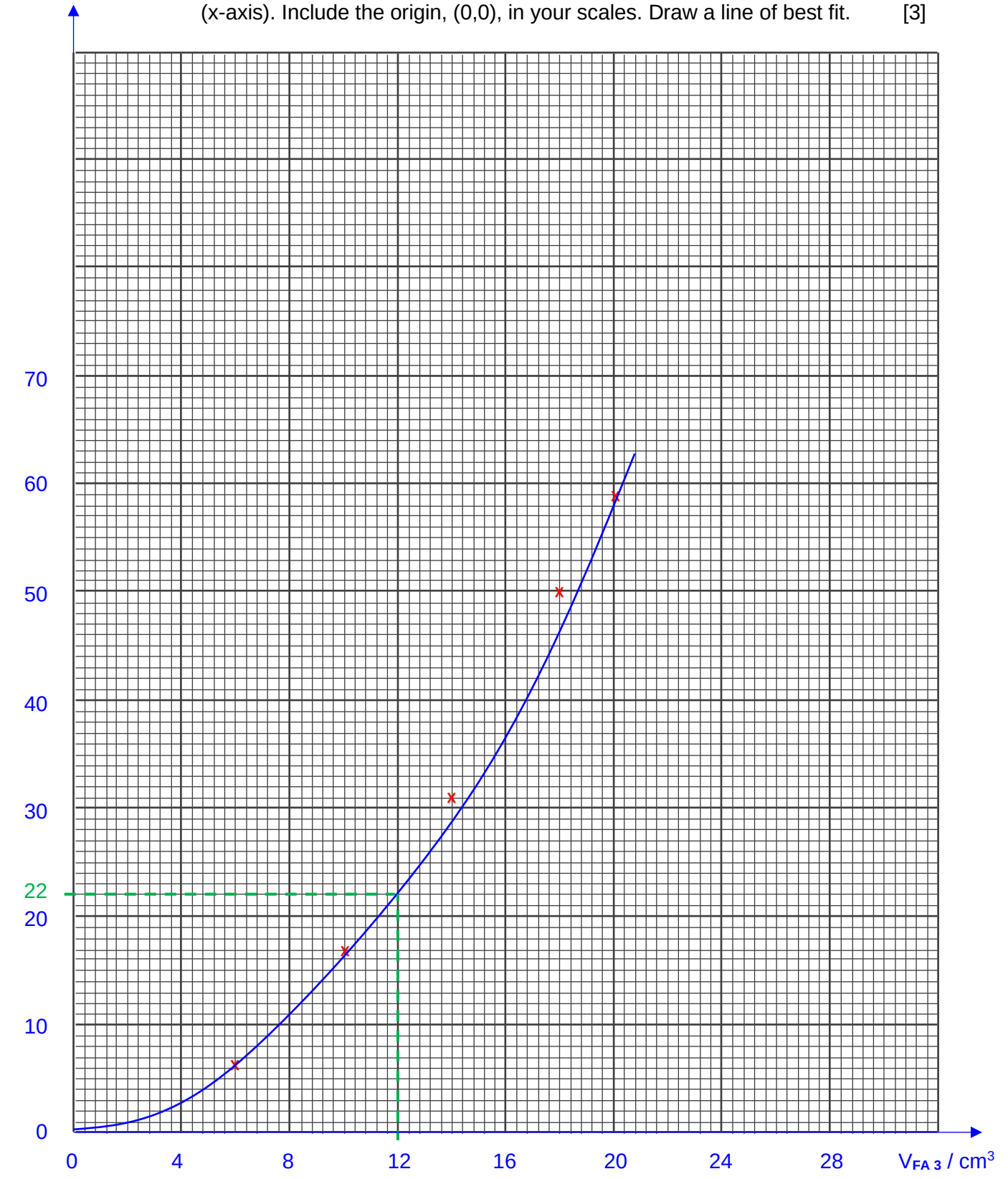
Calculate candidate's ratio $\frac{\text{time for } V_{FA\ 3} = 10}{\text{time for } V_{FA\ 3} = 20}$ to 2 d.p..

- 2 marks if ratio is between 3.50 and 4.50
- 1 mark if ratio is between 3.20 and 4.80
- 0 mark if ratio is otherwise

Candidate's ratio	

[5]

(b) Use the grid below to plot a graph of rate (y-axis) against volume of **FA 3** (x-axis). Include the origin, (0,0), in your scales. Draw a line of best fit. [3]



I	
II	
III	

[Turn over

- Linear scales that cover more than half the space in both directions including (0,0) **AND** axes correctly orientated and clearly labelled.
- Points plotted correctly. Points must be plotted to half a small square. If the point should be on a line it must on the line and if it should not be on the line it must not be so. 'Blobs' should be less than half a small square across and be correctly centred. *Reject if the scale is non-linear.
- Line of best fit drawn which ignores anomalous results identified by the candidate. The line may be a smooth curve or straight **AND** use a minimum of 3 points. *Ignore points which are circled or labelled as anomalous. Reject if a point has been shown at the origin and the line of best fit does not pass within 5 small squares of (0,0).

(c) **Use your graph** to calculate the time to the nearest second that the reaction would have taken if 12.00 cm^3 of **FA 3** had been used. **Show on the graph** how you obtained your answer.

At 12.00 cm^3 of **FA 3**, rate = 22 s^{-1}

time = $\frac{1000}{22}$ = 45.45 ≈ 45 s [1]

time = ... 45 ..... s [1]

- Correct lines drawn within 1 small square. *Allow if horizontal line drawn and some mark shown at 12.00 cm^3.
- Rate must be read to within correct half small square, compared with examiner-read value **AND** correctly calculates 1000/rate **AND** answer correct to nearest second *Reject if the portion of the scale used for the reading is non-linear.

(d) **(i)** Using data from **Experiments 1** and **2**, show by calculation that the volume of aqueous potassium iodide, **FA 3**, used was directly proportional to the concentration of iodide ions.

$[I_2]$ in reaction mixture in Experiment 1:
$\frac{20}{60} \times 0.0500 = 0.0167$ mol dm^{-3}

$[I_2]$ in reaction mixture in Experiment 2:
$\frac{10}{60} \times 0.0500 = 0.00833$ mol dm^{-3} [1]

$\frac{20}{10} = \frac{0.0167}{0.00833}$

Hence, the volume of KI(aq) is directly proportional to the $[I^-]$. [1]

[2]

(ii) Explain, by referring to your graph, how the rate of reaction is affected by an increase in the concentration of aqueous potassium iodide, **FA 3**.

.....

.....

.....

.....

.....

.....[2]

Graph: (comment must refer to the shape of the line drawn)
Curve: as concentration / volume of iodide ions increases, rate increases more / not directly proportional as line is a curve / not a straight line [1]

Straight line: rate is proportional to concentration of iodide ions / proportional as line has a positive gradient [1]

*Reject directly proportional unless the straight line passes within 5 small squares of (0,0).

Reason: plotted points give line of increasing gradient [1]
*This mark is not available if a straight line was drawn.

(e) Thiosulfate ions can reduce iron(III) ions and also react with acid to form sulfur, sulfur dioxide and water.

(i) Write an ionic equation for the reaction between thiosulfate ions and hydrogen ions in aqueous solution. Include state symbols.

.....[1]
$S_2O_3^{2-}(aq) + 2H^+(aq) \downarrow S(s) + SO_2(aq/g) + H_2O(l)$ [1]

(f) Another student investigates the effect of iron(III) concentration on the rate of this reaction at a different temperature. The student carries out another experiment, **Experiment 6**, and the rate is compared to that of **Experiment 2**. In **Experiment 2**, the volumes used were:

reagent	volume / cm^3
FA 3	10.00
FA 4	10.0
FA 5	20.0
FA 6	10.0
distilled water	10.00

(i) Suggest the volumes the student could use for **Experiment 6**.

reagent	volume / cm^3
FA 3	10.00
FA 4	5.0
FA 5	20.0
FA 6	10.0
distilled water	15.00

[1]

- Volumes of **FA 3**, **FA 5** and **FA 6** are unchanged.
- $V_{FA\ 4} + V_{water} = 20\ cm^3$ *Reject if these volumes are unchanged from Experiment 2 values.

(ii) This student records a time of 178 s for **Experiment 2**.

The rate of reaction is directly proportional to the concentration of iron(III) ions.

Suggest how long it would take the reaction mixture proposed for **Experiment 6** in **(f)(i)** to turn blue-black. Assume that **Experiment 6** is carried out at the same temperature as **Experiment 2**.
Do not carry out Experiment 6.

$$\text{time} = 178 \times \frac{10}{\text{volume of FA 4}} = 178 \times \frac{10}{5.0} = 356 \text{ s}$$ [1]

time = ... 356 ..... s [1]

*Reject if $V_{FA\ 4} + V_{water} \neq 20\ cm^3$.

[Total: 16]

3 Planning

Baker's yeast is a useful enzyme which can be used to catalyse the decomposition of hydrogen peroxide.

$$H_2O_2 \rightarrow H_2O + \tfrac{1}{2}O_2$$

You are provided with

Apparatus:
- 1 × 100 cm^3 conical flask, fitted with rubber bung and rubber tubing
- 1 × gas syringe (possible capacities of 10, 20, 50 or 100 cm^3)
- stopwatch
- all other common laboratory equipment

Reagents:
- 100 cm^3 of yeast suspension
- 30 cm^3 of 3% (by weight) hydrogen peroxide
- distilled water

When 8.00 cm^3 of the yeast suspension, 4.00 cm^3 of H_2O_2 and 18.0 cm^3 of distilled water are mixed in one of the experimental runs, 10 cm^3 of oxygen gas was produced in 90 seconds.

Use the above information and the reagents provided to design an experiment to prove that the reaction is first order reaction with respect to yeast by a graphical method.

In your experiment, you should perform a total of five experimental runs (including the above run) to measure the volume of oxygen gas produced at regular intervals in each run.

(a) Suggest suitable volumes used for each reagent in the table below.

run	volume of yeast / cm^3	volume of H_2O_2 / cm^3	volume of water / cm^3
1	4.00	4.00	22.0
2	8.00	4.00	18.0
3	12.00	4.00	14.0
4	16.00	4.00	10.0
5	20.00	4.00	6.0

[2]

- total volume of yeast used in all 5 runs must be ≤ 100 cm^3
- volume of H_2O_2 is constant at 4.00 cm^3
- volume of water added accordingly to keep total volume constant

3 pts – [2]; 2 pts – [1]

Note: penalise 1 mark if volumes of yeast and H_2O_2 are not in 2 dp and/or volume of water is not in 1 dp

(b) In your plan, you should include brief details of:

- the calculations to determine the appropriate capacity of the gas syringe by assuming that the density of H_2O_2 is 1.00 g cm^{-3} and conditions are at r.t.p.,
- the apparatus you would use,
- the measurements you would make to determine the initial rate for each run and the order with respect to yeast.

.....[5]

Calculations to determine the maximum volume of oxygen gas produced in each experimental run

- Mass of 4.00 cm^3 of H_2O_2 = 1.00 x 4.00 x 0.03 = 0.1200 g
- Amount of H_2O_2 = 0.12 / 34.0 = 0.003529 mol
- Amount of O_2 gas = ½ (0.003529) = 0.001764 mol
- Volume of O_2 gas = 0.001764 x 24000 = 42.4 cm^3
- Hence minimum size of syringe to be used is the 50 cm^3 size if the reaction is allowed to go to completion.

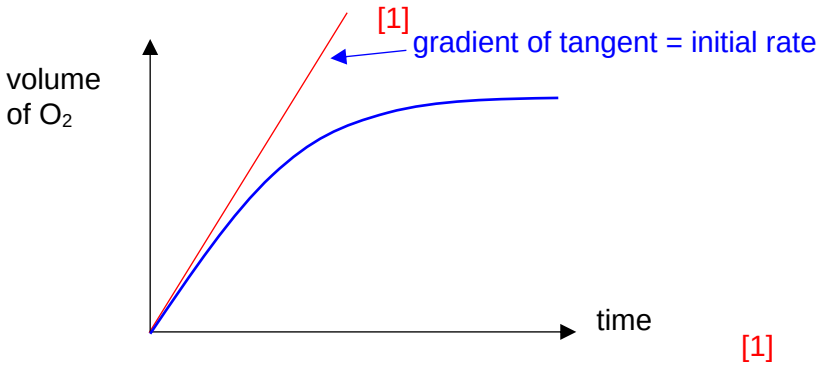
5 pts – [2], 2 pts – [1]

Procedure for measuring the volume of oxygen gas produced at fixed intervals

1. Connect the rubber tubing to the gas syringe. Record the initial reading on the syringe.
2. Using a burette/25 cm^3 measuring cylinder, measure 4.00 cm^3 of the yeast suspension and add into a 100 cm^3 conical flask.
3. Using a 25 cm^3 measuring cylinder, measure 22.0 cm^3 of the distilled water and add into the conical flask. (Burette should not be used as volume of water given to 1 d.p. in qn)
4. Using another burette/10 cm^3 measuring cylinder, measure 4.00 cm^3 of the H_2O_2 (into a 25 cm^3 beaker / boiling tube if burette used).
5. Pour the H_2O_2 into the conical flask quickly (hence no direct addition from burette allowed), stopper the conical flask with the rubber bung and start the stop watch immediately. Swirl the conical flask. (Alternatively, a dropping funnel may be used to ensure no gas escaped during addition).
6. Record the reading on the syringe every 30 seconds/1 minute (or other regular time intervals, until 5 readings are collected. (Procedure must state clearly when to stop recording.)
7. Repeat steps 2 – 6 for the next 4 experimental runs, changing the volumes according to the table given in (a).

- Measure volumes using M.C. / burette + use of c.f. to hold reaction mixture Capacity of M.C. should be specified and it should be suitable for use in 5 expts [1]
- Start stopwatch immediately upon adding H_2O_2 / yeast quickly + stopper flask + swirl (many students missed out this point hence BOD given for prelims) [1]
- Use of gas syringe + 30s/1min interval for min 5 readings + repeat expt for other runs [1]

(c) **(i)** Sketch the graph you would expect to obtain in run 2.

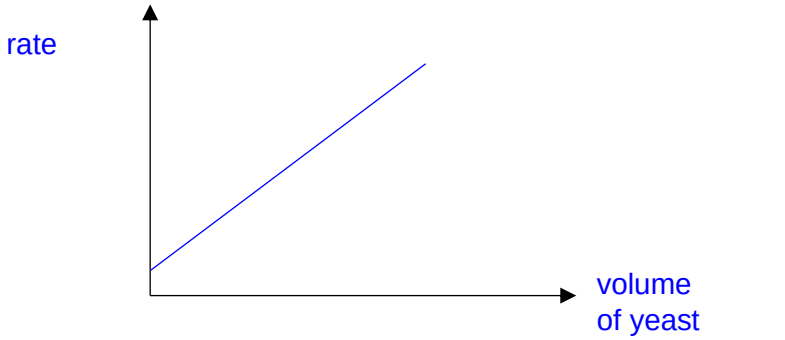


[1]

[1]

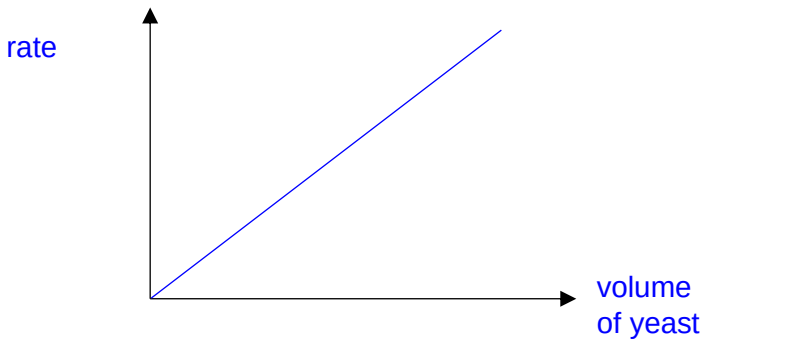
(ii) On the same graph in **(c)(i)**, show how you would obtain the initial rate in run 2. [1]

(d) Hence, sketch a suitable graph to show that the reaction is first order with respect to yeast.



[1]

Note: When no yeast was added, H_2O_2 would still undergo decomposition on its own, albeit a slow reaction. Hence, rate > 0 when V(yeast) = 0.



[1]

Note: Would also accept rate = 0 when V(yeast) = 0 if we assume decomposition of H_2O_2 without yeast is negligible.

[1]

[Total: 10]

4 Determination of percentage purity of a sample of contaminated sodium carbonate

FA 7 is a solution of the contaminated sodium carbonate. You will first dilute **FA 7** and then titrate the diluted solution using hydrochloric acid.

$$2HCl(aq) + Na_2CO_3(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$$

FA 7 was prepared by dissolving 125 g of contaminated sodium carbonate, Na_2CO_3, in distilled water and making the solution up to 1 dm^3.
FA 8 is 0.100 mol dm^{-3} hydrochloric acid, HCl.
methyl orange indicator

(a) Method

Dilution

1. Fill the burette with **FA 7**.

2. Run between 13.00 and 13.50 cm^3 of **FA 7** into the 250 cm^3 volumetric (graduated) flask.
   Record the volume in the space below.

   volume of **FA 7** = 13.30 ..... cm^3

3. Fill the volumetric flask to the line with distilled water. Stopper the flask and shake it to ensure thorough mixing. This flask is **FA 9**.

Titration

4. Fill the burette with **FA 8**.

5. Use the pipette to transfer 25.0 cm^3 of **FA 9** into a conical flask.

6. Add 5 – 10 drops of methyl orange indicator.

7. Titrate the mixture in the conical flask until the end-point is reached.

8. Record your titration results in the space provided on page 17.

9. Repeat steps 5 to 8 until consistent results are obtained.

Titration results

	1	2
Final burette reading /cm^3	26.70	26.70
Initial burette reading /cm^3	0.00	0.00
Volume of **FA 8** used /cm^3	26.70	26.70

I	
II	
III	
IV	

Teacher's ratio	
Candidate's ratio	
difference	

- **FA 7** added is between 13.00 and 13.50 cm^3 inlcusive. Initial and final burette readings and titre unambiguously recorded in rough and accurate titrations.
- Headings and units correct for accurate titration and headings match readings.
- All accurate burette readings (initial and final) recorded to nearest 0.05 cm^3.
- Has two uncorrected, accurate titres within 0.10 cm^3. (do not award this mark if, having performed two titres within 0.10 cm^3, a further titration is performed that is more than 0.10 cm^3 from the closer of the two initial titres unless further titrations within 0.10 cm^3 of any other has also been carried out.)

Each point – [1]

Examiner to calculate, correct to 2dp, $\frac{\text{supervisor titre}}{\text{supervisor volume diluted}}$ and $\frac{\text{candidate titre}}{\text{candidate volume diluted}}$ and find the difference, δ.

- if $\delta \leq 0.04$ [2]
- if $0.04 < \delta \leq 0.06$ [1]

[6]

(b) From your accurate titration results, obtain a suitable volume of **FA 8** to be used in your calculations.
Show clearly how you obtained this value.

Volume of FA 8 = $\frac{26.70 + 26.70}{2} = 26.70$ cm^3 [1]

Candidate must average two (or more) titres that are all within 0.10 cm^3, quoted to 2dp rounded to the nearest 0.01 cm^3. Working must be shown or ticks must be put next to the two (or more) accurate readings selected.

25.0 cm^3 of **FA 9** required ..... 26.70 ..... cm^3 of **FA 8**. [1]

(c) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations. [1]

(i) Calculate the amount of hydrochloric acid present in the volume of **FA 8** calculated in **(b)**. Hence, calculate the amount of sodium carbonate present in 25.0 cm^3 of **FA 9**.

n(HCl) present in the volume of **FA 8** calculated in **(b)**

$= \frac{0.100 \times 26.70}{1000} = 2.67 \times 10^{-3}$ mol

amount of HCl = 2.67×10^{-3} mol

$n(Na_2CO_3)$ present in 25.0 cm^3 of **FA 9**

$= \frac{2.67 \times 10^{-3}}{2} = 1.335 \times 10^{-3} \approx 1.34 \times 10^{-3}$ mol [1] for both

amount of Na_2CO_3 = 1.34×10^{-3} mol [1]

(ii) Calculate the concentration, in mol dm^{-3}, of sodium carbonate in **FA 9**.

$[Na_2CO_3]$ in **FA 9**

$= \frac{1.335 \times 10^{-3}}{\frac{25.0}{1000}} = 0.0534$ mol dm^{-3} [1]

or

$n(Na_2CO_3)$ in 250 cm^3 of **FA 9**

$= 1.335 \times 10^{-3} \times \frac{250}{25.0} = 1.335 \times 10^{-2}$ mol

$[Na_2CO_3]$ in **FA 9**

$= \frac{1.335 \times 10^{-2}}{\frac{250}{1000}} = 0.0534$ mol dm^{-3} [1]

concentration of Na_2CO_3 in **FA 9** = 0.0534 mol dm^{-3} [1]

(iii) Calculate the concentration, in mol dm^{-3}, of sodium carbonate in **FA 7**.

$[Na_2CO_3]$ in **FA 7**

$= \frac{0.0534 \times 250}{13.30} = 1.003 \approx 1.00$ mol dm^{-3} [1]

or

$n(Na_2CO_3)$ in 13.30 cm^3 of **FA 7**

= $n(Na_2CO_3)$ in 250 cm^3 of **FA 9**

= 1.335×10^{-2} mol

$[Na_2CO_3]$ in **FA 7**

$= \frac{1.335 \times 10^{-2}}{\frac{13.30}{1000}} = 1.003 \approx 1.00$ mol dm^{-3}

concentration of Na_2CO_3 in **FA 7** = 1.00 mol dm^{-3} [1]

(iv) Calculate the percentage purity by mass of sodium carbonate in the contaminated sample used to prepare solution **FA 7**.
(A_r: C, 12.0; O, 16.0; Na, 23.0)

Percentage purity by mass of Na_2CO_3 in the contaminated sample used to prepare solution **FA 7**

$= \frac{1.003 \times 106.0}{125} \times 100 = 85.11 \approx 85.1\%$ [1]

or

$n(Na_2CO_3)$ in 1 dm^3 of **FA 7**

$= 1.335 \times 10^{-2} \text{ x } \frac{1000}{13.30} = 1.003$ mol

Percentage purity by mass of Na_2CO_3 in the contaminated sample used to prepare solution **FA 7**

$= \frac{1.003 \times 106.0}{125} \times 100 = 85.11 \approx 85.1\%$

percentage purity by mass = 85.1 % [1]

[Total: 12]

Qualitative Analysis Notes
[ppt. = precipitate]

(a) Reactions of aqueous cations

cation	***reaction with***	
	NaOH(aq)	NH_3(aq)
aluminium, Al^{3+}(aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH_4^+(aq)	ammonia produced on heating	–
barium, Ba^{2+}(aq)	no ppt. (if reagents are pure)	no ppt.
calcium, Ca^{2+}(aq)	white ppt. with high [Ca^{2+}(aq)]	no ppt.
chromium(III), Cr^{3+}(aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu^{2+}(aq)	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution
iron(II), Fe^{2+}(aq)	green ppt., turning brown on contact with air insoluble in excess	green ppt., turning brown on contact with air insoluble in excess
iron(III), Fe^{3+}(aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, Mg^{2+}(aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn^{2+}(aq)	off-white ppt., rapidly turning brown on contact with air insoluble in excess	off-white ppt., rapidly turning brown on contact with air insoluble in excess
zinc, Zn^{2+}(aq)	white ppt. soluble in excess	white ppt. soluble in excess

(b) Reactions of anions

anion	***reaction***
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, C*l*È*(aq)*	gives white ppt. with $Ag^+(aq)$ (soluble in $NH_3(aq)$)
bromide, BrÈ(aq)	gives pale cream ppt. with $Ag^+(aq)$ (partially soluble in $NH_3(aq)$)
iodide, IÈ(aq)	gives yellow ppt. with $Ag^+(aq)$ (insoluble in $NH_3(aq)$)
nitrate, NO_3È(aq)	NH_3 liberated on heating with OHÈ(aq) and A*l* foil
nitrite, NO_2È(aq)	NH_3 liberated on heating with OHÈ(aq) and A*l* foil; NO liberated by dilute acids (colourless NO $\rightarrow$ (pale) brown NO_2 in air)
sulfate, $SO_4^{2-}(aq)$	gives white ppt. with $Ba^{2+}(aq)$ (insoluble in excess dilute strong acids)
sulfite, $SO_3^{2-}(aq)$	SO_2 liberated with dilute acids; gives white ppt. with $Ba^{2+}(aq)$ (soluble in dilute strong acids)

(c) Tests for gases

gas	***test and test result***
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	“pops” with a lighted splint
oxygen, O_2	relights a glowing splint
sulfur dioxide, SO_2	turns aqueous acidified potassium manganate(VII) from purple to colourless

(d) Colour of halogens

halogen	***colour of element***	***colour in aqueous solution***	***colour in hexane***
chlorine, Cl_2	greenish yellow gas	pale yellow	pale yellow
bromine, Br_2	reddish brown gas / liquid	orange	orange-red
iodine, I	black solid / purple gas	brown	purple