RIVER VALLEY HIGH SCHOOL

JC 2 PRELIM PRACTICAL EXAMINATION

H2 CHEMISTRY 9729

Paper 4

25 AUGUST 2020

2 HOURS 30 MINUTES

NAME _____

CLASS _____

INDEX NO. _____

INSTRUCTIONS TO CANDIDATES

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

Read these notes carefully.

Write your name, class and index number in the spaces at the top of this page.
Give details of the practical shift and laboratory where appropriate, in the boxes provided.
Write in dark blue or black pen.
You may use a 2B pencil for any diagrams or graph.
Do not use staples, paper clips, highlighters, 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.

Shift
Laboratory

For Examiner's Use	
s.f. / d.p.	
units	
total	55

This Question Paper consists of **23** printed pages and **1** blank page.

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

For Examiner's Use

1 Determination of a value for the solubility product, K_{sp}, of calcium iodate(V), $Ca(IO_3)_2$

Calcium iodate(V), $Ca(IO_3)_2$, is a colourless salt that occurs naturally as the mineral, lautarite. It is used in the manufacture of disinfectants, antiseptics, deodorants and as iodine supplement in chicken feed.

$Ca(IO_3)_2$ has low solubility in water. When a sample of this salt is mixed with water, the following equilibrium is established.

$$Ca(IO_3)_2(s) \ll Ca^{2+}(aq) + 2IO_3^-(aq)$$

You are to perform an experiment to determine the solubility product, K_{sp}, of $Ca(IO_3)_2(s)$.

$Ca(IO_3)_2(s)$ is added to a specific volume of aqueous potassium iodate(V), KIO_3, with known concentration. The mixture is then filtered after leaving to stand for some time.

The total amount of $IO_3^-(aq)$ is determined as described below.

Excess potassium iodide, KI, is added to an acidified solution of the filtrate, liberating iodine.

Reaction 1 $IO_3^-(aq) + 5I^-(aq) + 6H^+(aq) \rightarrow 3I_2(aq) + 3H_2O(l)$

The liberated iodine is then titrated with a standard solution of sodium thiosulfate.

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

(a) Write an expression for the solubility product, K_{sp}, of calcium iodate(V).

.....

1	

(b) The following procedure is used to prepare a saturated solution of calcium iodate(V) in aqueous potassium iodate(V), **FA 1**.

You do not need to perform this part of the experiment.

1. Using a measuring cylinder, transfer 100.0 cm^3 of 0.0100 mol dm^{-3} KIO_3 to a clean, dry beaker.
2. Add 2 spatulas of solid $Ca(IO_3)_2$ to the same beaker.
3. Stir the mixture thoroughly. There should be undissolved solid $Ca(IO_3)_2$ present. Leave the mixture to stand for several minutes to allow equilibrium to be reached.
4. Filter the mixture through a dry filter paper into a dry conical flask to collect the filtrate, **FA 1** for titration in **(c)**.

For Examiner's Use

(c) You are provided with

FA 1 filtrate from **(b)**, a saturated solution of $Ca(IO_3)_2$ in KIO_3(aq)

FA 2 0.100 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$

FA 3 aqueous solution of potassium iodide, KI

FA 4 dilute sulfuric acid, H_2SO_4

Starch indicator

Titration of filtrate, FA 1

1. Pipette 25.0 cm^3 of **FA 1** into a conical flask.
2. Using a measuring cylinder, add about 10 cm^3 of **FA 4** to the conical flask.
3. Using another measuring cylinder, add about 10 cm^3 of **FA 3** to the conical flask.
4. Add **FA 2** from the burette into the conical flask until a pale yellow solution is obtained.
5. Add about 5 drops of starch indicator and continue adding **FA 2** until the blue-black colour just disappears.
6. Record your titration results, to an appropriate level of precision, in the space below.
7. Repeat the titration as many times as necessary until consistent results are obtained.

Results

Supervisor's mean
Student's mean
Difference

2	
3	
4	
5	
6	

(c) **(i)** From your titrations, obtain a suitable volume of **FA 2** ($V_{FA\ 2}$) to be used in your calculations. Show clearly how you obtained this volume.

For Examiner's Use

$V_{FA\ 2}$ = ... | 7 |

(ii) Use the volume of **FA 2** obtained in **(c)(i)** to calculate the amount of IO_3^-(aq) present in 25.0 cm^3 of **FA 1**.

amount of IO_3^-(aq) present in 25.0 cm^3 of **FA 1** = ... | 8 |

(iii) Calculate the amount of IO_3^-(aq) in the mixture from **(b)** at equilibrium.

amount of IO_3^-(aq) in the mixture = ... | 9 |

(d) **(i)** Calculate the amount of IO_3^- ions from the dissolved $Ca(IO_3)_2$ in **(b)**.

For Examiner's Use

amount of IO_3^-(aq) from the dissolved $Ca(IO_3)_2$

= .....

10

(ii) Calculate the amount of Ca^{2+}(aq) in the mixture from **(b)** at equilibrium.

amount of Ca^{2+}(aq) in the mixture = ...

11

(e) Use your answer in parts **(c)(iii)** and **(d)(ii)** to calculate a value for the solubility product, K_{sp}, of $Ca(IO_3)_2$ and give its units in your answer.

For Examiner's Use

12	
13	

K_{sp} = ...

(f) In part **(b)** step 4, dry apparatus and dry filter paper are used in the preparation of **FA 1**. Suggest and explain the likely consequences on your mean titre value in part **(c)(i)** if the apparatus and filter paper were not dry.

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14	

(g) Another student prepared a solution of **FA 1** and performed the titration. He obtained a value for the solubility product, K_{sp}, of 7.96×10^{-7}. A literature value for this solubility product is 6.47×10^{-6} at 25 °C.

You should assume that apparatus of the same precision were used in both cases.

State a possible reason for the lower value of K_{sp} obtained by the student.

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15	

[Total: 15]

For Examiner's Use

2 To investigate the effect of concentration changes on the rate of reaction between iodate(V) ion and sulfate(IV) ion.

Iodate(V), IO_3^-, undergoes redox reaction with sulfate(IV), SO_3^{2-}, according to the equation below:

$$2IO_3^- + 5SO_3^{2-} + 2H^+ \rightarrow I_2 + 5SO_4^{2-} + H_2O$$

However, the iodine formed reacts immediately with sulfate(IV) ions to give iodide ions.

$$I_2 + SO_3^{2-} + H_2O \rightarrow 2I^- + SO_4^{2-} + 2H^+$$

When sulfate(IV) ions are completely consumed, the liberated iodine would react with starch solution to give the dark blue colour of the starch-iodine complex.

By measuring the time it takes for the solution to turn dark blue, it is possible to determine the effect of the concentrations of H^+ and IO_3^- on the initial rate of the reaction between IO_3^- and SO_3^{2-}.

FA 5 is 0.0160 mol dm^{-3} aqueous potassium iodate(V), KIO_3.

FA 6 is 0.100 mol dm^{-3} sulfuric acid, H_2SO_4.

FA 7 is 0.0400 mol dm^{-3} aqueous sodium sulfate(IV), Na_2SO_3.

You are to perform a series of three experiments, in which the concentration of either H^+, or IO_3^- is varied, and measure the time, ***t***, taken for the dark blue colour to appear.

For each experiment, you will require two solutions, **solution A** and **solution B**, in which **solution B** contains the same volume of **FA 7**.

In experiment 2, the volume of **FA 5** in **solution A** is varied. In experiment 3, the volume of **FA 6** in **solution B** is varied.

The total volumes of **solution A** and **solution B** are kept constant at 40 cm^3 and 35 cm^3 respectively by adding deionised water as required.

Prepare a table in the space provided on page **8** to record, for each experiment:

- all volumes used to prepare **solution A,** except volume of starch
- all volumes used to prepare **solution B,** except volume of **FA 7**
- all values of ***t***
- calculated values of the relative rate of reaction, 1/***t***, to 3 significant figures.

For Examiner's Use

(a) (i) Experiment 1

Preparation of solution A

- To a 50 cm^3 measuring cylinder, labelled **A**, add 5 cm^3 of starch and 5 cm^3 of **FA 5**. Make up the volume to 40 cm^3 with deionised water.

Preparation of solution B

- To a 50 cm^3 measuring cylinder, labelled **B**, add 20 cm^3 of **FA 6** and 5 cm^3 of **FA 7**. Make up the volume to 35 cm^3 with deionised water.

1. Transfer **solution A** into a 100 cm^3 beaker placed on a white tile.
2. Pour **solution B** rapidly into the beaker containing **solution A**, **starting a stopwatch as you do so**.
3. Stir the mixture using a glass rod.
4. Stop the stopwatch when the dark blue colour first appears. Record the time, ***t***, to the nearest 0.1 s.
5. Wash the beaker thoroughly with water and dry it.

(ii) Experiment 2

You will now repeat the experiment but prepare **solution A** by adding 5 cm^3 of starch and 10 cm^3 of **FA 5** into the measuring cylinder labelled **A**. Make up the volume to 40 cm^3 by adding deionised water.

(ii) Experiment 3

You will now repeat the experiment but prepare **solution B** by adding 10 cm^3 of **FA 6** and 5 cm^3 of **FA 7** into the measuring cylinder labelled **B**. Make up the volume to 35 cm^3 by adding deionised water.

(c) Results

Ratio 1

Ratio 2

16	
17	
18	
19	

(d) Using your results, show clearly how you determine the order of reaction with respect to

- IO_3^-

order of reaction with respect to IO_3^- = ……..

- H^+

order of reaction with respect to H^+ = …….. **20**

(e) Suggest a modification to improve the reliability of the relative rate obtained for these experiments.

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…… **21**

For Examiner's Use

(f) Student **A** carried out a series of experiments to determine the order of reaction with respect to SO_3^{2-}.

Instead of $\frac{1}{t}$, she defined the rate of reaction as follows:

$$\text{rate} = \frac{[SO_3^{2-}]_{\text{initial}}}{t}$$

It was found that the reaction is first order with respect to SO_3^{2-}.

(i) Using your results from **(c)**, calculate the rate of **experiment 1** using the above formula.

rate of **experiment 1** =…… **22**

(ii) Explain the effect on the rate of reaction if $V_{FA\ 7}$ is increased from 5 cm^3 to 10 cm^3 while keeping the total volume unchanged by adjusting the volume of deionised water used.

Assume all other conditions are kept constant.

23

(iii) Explain whether $\frac{1}{t}$ can be used as the relative rate when determining the order of reaction with respect to SO_3^{2-}.

24

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For Examiner's Use

(g) Another iodine clock reaction was studied.

To determine the value for activation energy, E_a, a series of experiments was performed, where the composition of the reaction mixture was kept constant but with different reaction temperatures. The same end-point (appearance of the dark blue colour) was timed.

The results of the experiments are given in **Table 2.1**.

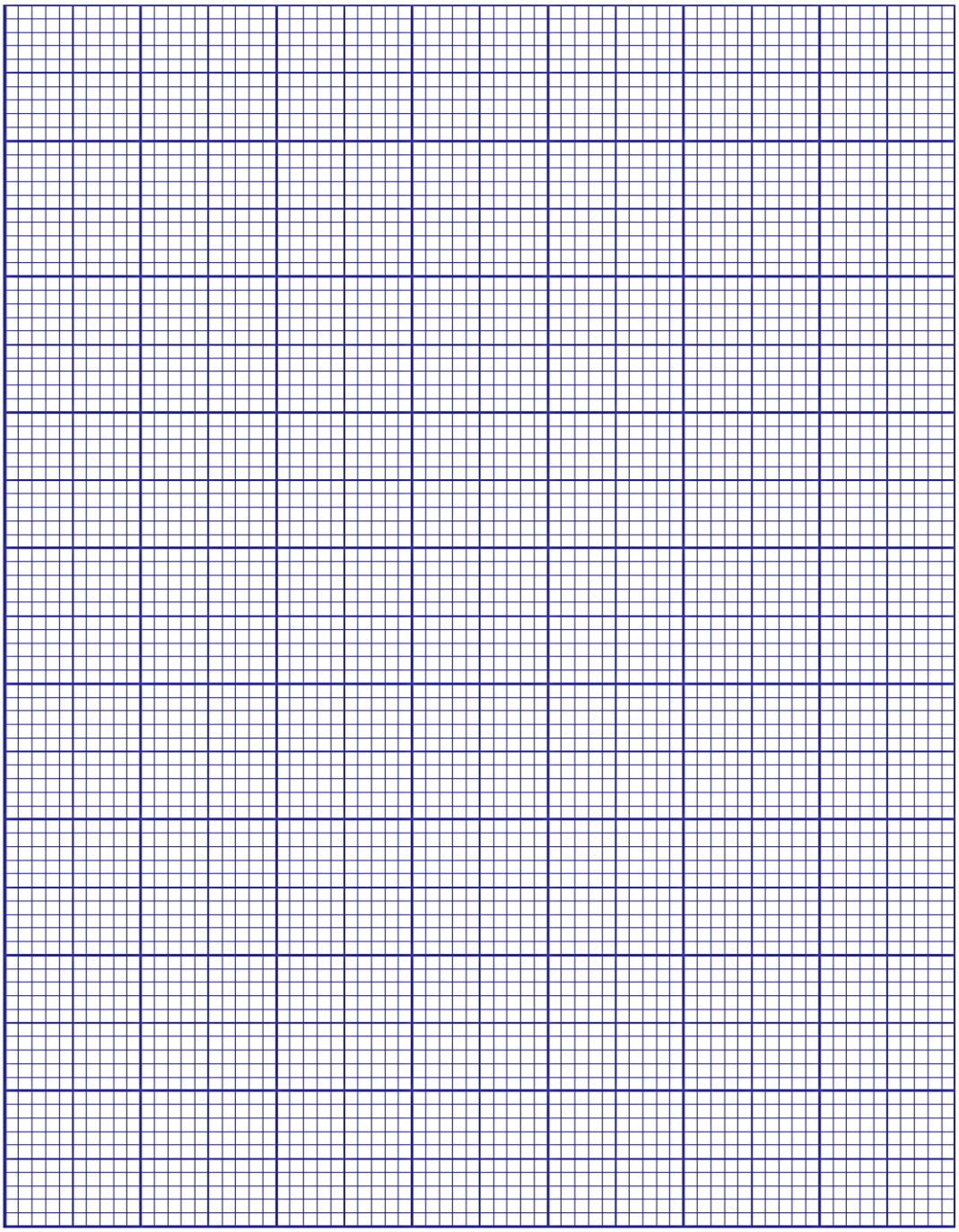
The activation energy for the reaction can be obtained from the following relationship derived using the Arrhenius Equation.

$$\ln\left(\frac{1}{t}\right) = \text{constant} - \left(\frac{E_a}{R}\right)\frac{1}{T}$$

Table 2.1

$\ln\left(\frac{1}{t}\right)$	$\frac{1}{T}$ / K^{-1}
–4.44	3.40×10^{-3}
–3.91	3.31×10^{-3}
–3.47	3.23×10^{-3}
–3.18	3.18×10^{-3}
–2.89	3.14×10^{-3}

(i) Plot, on the grid provided in page **13**, a graph of $\ln\left(\frac{1}{t}\right)$ on the *y*-axis against $\frac{1}{T}$ on the *x*-axis. Draw a line of best-fit taking into account all your plotted points.



25	
26	
27	

(ii) Calculate the gradient of the line, showing clearly how you did this.

gradient of line = ……..

28	

(iii) Determine a value for the activation energy, E_a. Show your working.

[R = 8.314 J K^{-1} mol^{-1}]

For Examiner's Use

E_a = ... | 29 |

(iv) Using **your graph**, calculate the temperature, in °C, of the reaction mixture that would result in the reaction mixture turning dark blue after 65.0 s. Show your working.

temperature = ... | 30 |

[Total: 15]

For Examiner's Use

3 Qualitative analysis of inorganic compounds

In this experiment, you are to perform a series of tests on the unknown samples provided and record your observations.

In tests where gaseous product(s) are expected, confirmatory test for gas(es) should be carried out.

Where reagents are selected for use in a test, the name or correct formula of the elements or compounds must be given.

You should also indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a boiling tube must be used unless stated otherwise.

No additional tests for ions present should be attempted.

(a) **FA 8** a solid containing one cation and one anion

FA 9 a solution containing one cation and one anion

Warm (do not boil) about 10 cm^3 of **FA 9** in a 100 cm^3 beaker. Stop warming the **FA 9**, add 3 spatulas of **FA 8** and stir the mixture.

Filter the mixture into a **dry** boiling tube. The filtrate will be used in the tests in **(b)**.

Record your observations in the space below.

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(b) Unless otherwise stated, use a 1 cm depth of the filtrate from **(a)** in separate test tubes for each of the following tests.

Test		Observations
(i)	To a portion of the filtrate from **(a)**, add aqueous ammonia till no more change is observed. To a portion of the resultant mixture, add dilute sulfuric acid till no more change is observed.	

(ii)	To a portion of **FA 3** in a large test tube, add a few drops of filtrate from **(a)**, followed by 3 cm height of **FA 2**. Shake for a few minutes.		
(iii)	To a portion of the filtrate from **(a)**, add aqueous sodium carbonate. To a portion of **FA 9**, add aqueous sodium carbonate.		
(iv)	To a portion of deionised water in a large test tube, dilute 5 drops of **FA 9**. Add aqueous silver nitrate, followed by aqueous ammonia.		

For Examiner's Use

32	
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34	
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(c) The cation in the filtrate is responsible for the observation in test **(b)(ii)** when a few drops of filtrate is added to **FA 3.**

(i) Identify the cation in the filtrate.

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(ii) Suggest the role of this cation in this reaction and explain how it account for the observation in test **(b)(ii)**.

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37	

(d) **(i)** Considering your results from **(b)**, suggest the chemical name of **FA 9**.

For Examiner's Use

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(i) Write two ionic equations, with state symbols, to account for your observation of any two reactions involving **FA 9**.

38	
39	
40	

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(e) The anion in the filtrate from **(a)** is a halide. The cation present in the filtrate can interfere with the observation for the anion tests.

Describe and explain how the halide from **(a)** can be separated from the cation using suitable bench reagent(s) prior to anion tests.

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42	

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[Total: 12]

For Examiner's Use

4 Planning

Dolomitisation is a geological process by which dolomite ($CaCO_3 \bullet MgCO_3$) is formed when magnesium ions replace calcium ions in limestone ($CaCO_3$). Depending on the extent of dolomitisation, the amount of dolomite in limestone varies.

$CaCO_3$ and $MgCO_3$ undergoes thermal decomposition.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

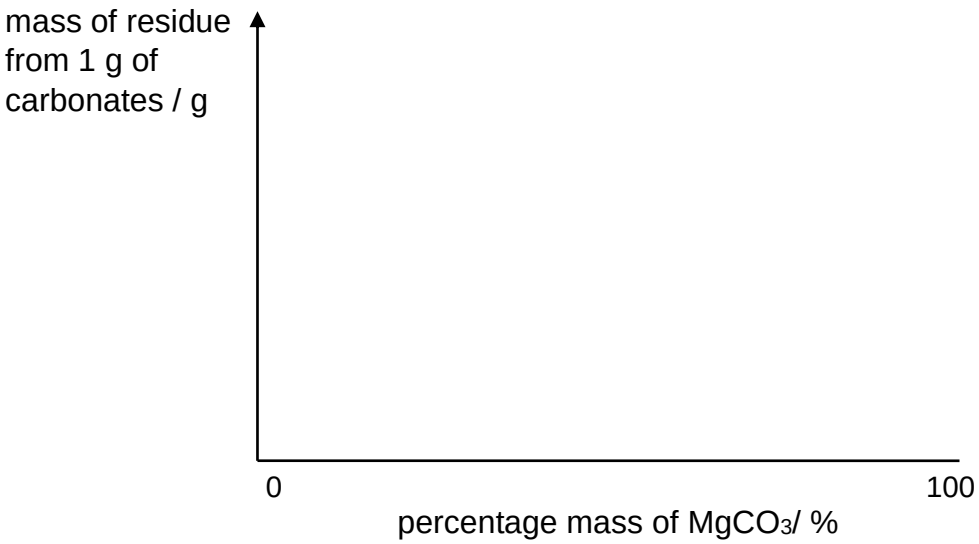
$$MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$$

The metal oxides formed can absorb moisture and carbon dioxide gas to form metal hydroxides or reform the metal carbonates.

Using an appropriate graph, the extent of dolomitisation of a limestone sample can be determined from the mass of its residue.

[A_r: Ca, 40.1; Mg, 24.3; O, 16.0; C, 12.0]

(a) Predict and sketch the graph you would expect on the axes below.



43	
44	

Explain your answer.

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(b) Given that 1.000 g of limestone sample contains 67.5% by mass of $CaCO_3(s)$, calculate the amount of magnesium carbonate and hence the percentage by mass of dolomite in the limestone sample.

For Examiner's Use

45	
46	

percentage by mass of dolomite = ……

(c) Calculate the minimum total mass of carbonates required to ensure the loss in mass is at least 0.400 g. State any assumptions that you have made in your calculations.

47	

minimum total mass of carbonates required = ……

For Examiner's Use

(d) Using the information given, plan a series of experiments to obtain the graph in **(a)**.

You are provided with

- pure powdered $CaCO_3(s)$
- pure powdered $MgCO_3(s)$
- apparatus commonly found in a school laboratory.

In your plan, you should include details of

(i) justification of specific quantities of reactants that you would use for each experiment such that the loss in mass is at least 0.400 g;

(ii) the preparation of the mixture of carbonates;

(iii) the heating and weighing so that thermal decomposition is completed;

(iv) the tabulation of the experimental results for one of the experiments.

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49	
50	
51	
52	

For Examiner's Use

For Examiner's Use

(e) **(i)** Hydrated copper(II) nitrate also undergoes thermal decomposition.

$$Cu(NO_3)_2 \bullet nH_2O(s) \rightarrow CuO(s) + 2NO_2(g) + \tfrac{1}{2}O_2(g) + nH_2O(g)$$

Draw an assembled apparatus you could use in a school laboratory to carry out the thermal decomposition of hydrated copper(II) nitrate. The apparatus should enable you to remove the toxic NO_2 gas and collect a dry sample of oxygen gas.

53	
54	

(ii) Suggest how would you check that NO_2 is removed effectively using the assembled apparatus in **(d)(i)**.

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[Total: 13]

END OF PAPER

9 Qualitative Analysis Notes

[ppt. = precipitate]

9(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

9(b) Reactions of anions

anion	*reaction*
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, Cl^-(aq)	gives white ppt. with Ag^+(aq) (soluble in NH_3(aq))
bromide, Br^-(aq)	gives pale cream ppt. with Ag^+(aq) (partially soluble in NH_3(aq))
iodide, I^-(aq)	gives yellow ppt. with Ag^+(aq) (insoluble in NH_3(aq))
nitrate, NO_3^- (aq)	NH_3 liberated on heating with OH^-(aq) and Al foil
nitrite, NO_2^- (aq)	NH_3 liberated on heating with OH^-(aq) and Al 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)

9(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

9(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_2	black solid / purple gas	brown	purple