| Class | Adm No |
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Candidate Name: ____________________

H

millennia institute

# 2023 Preliminary Examination
## Pre-University 3

**H2 CHEMISTRY** **9729/04**

Paper 4 Practical **30 August 2023**

**2 hours 30 minutes**

Candidates answer on the Question paper.

**READ THESE INSTRUCTIONS FIRST**

**Do not turn over this question paper until you are told to do so.**

Write your name, class and admission number in the spaces at the top of this page.
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.

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.

| Question | 1 | 2 | 3 | **Total** |
| --- | --- | --- | --- | --- |
| Marks | 18 | 24 | 13 | **55** |

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

**1 To determine the effect of concentration changes on the rate of a reaction**

**FA 1**, 0.0200 mol $dm^{-3}$ aqueous potassium iodate(V), $KIO_3$

**FA 2**, 0.0200 mol $dm^{-3}$ aqueous sodium hydrogen sulfite, $NaHSO_3$

**FA 3**, 0.0600 mol $dm^{-3}$ aqueous sulfuric acid, $H_2SO_4$

**FA 4** is starch solution

In this experiment, the Landolt-Iodine clock reaction is illustrated by the following equations.

$IO_3^- + 3HSO_3^- \rightarrow I^- + 3SO_4^{2-} + 3H^+$ **equation 1**

$IO_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_2O$ **equation 2**

$3I_2 + 3HSO_3^- + 3H_2O \rightarrow 6I^- + 3SO_4^{2-} + 9H^+$ **equation 3**

Any $I_2$ produced in equation 2 while $HSO_3^-$ ions still remain in the solution is rapidly reduced to $I^-$ in equation 3. Once all the $HSO_3^-$ ions have been used up, $I_2$ will accumulate in the solution. When this happens, the iodine can no longer be converted back to iodide ions. The presence of iodine can be confirmed from the blue-black colour produced upon addition of starch.

**Overview of experiment**

You will carry out **five** similar experiments, 1 to 5 with varying concentrations of $IO_3^-$. In each experiment, you will be required to prepare two solutions – **solution A** and **solution B**.

**Note:**

- **Solution B** should only be prepared once for all five experiments, while **solution A** must be prepared five times.
- Perform the experiments in order, from experiment 1 to 5.
- The measuring apparatus used to prepare **solutions A** and **B** must be kept separate at all times.

For each experiment, you will record the time taken, *t*, for the solution to turn blue-black. The rate of the reaction is given to be, $\boldsymbol{r} = \frac{initial\ [HSO_3^-]}{\boldsymbol{t}}$ mol $dm^{-3}$ $s^{-1}$.

You will record in a table in the space provided on **page 4**, the following values for **each** of the five experiments.

- all volumes of **FA 1** and deionised water used to prepare **solution A**,
- values of ***t***, to the **nearest second**,
- calculated values of initial $[IO_3^-]$ in the reaction mixture to 3 significant figures, and
- calculated values of ***r***, to 3 significant figures.

**Note:** volumes used to prepare solution **B** need not be recorded.

**(a)** **(i) Preparing solution B**

1. Using a pipette, transfer 25.0 $cm^3$ of **FA 2** to the 250 $cm^3$ volumetric flask.
2. Using an appropriate measuring cylinder, transfer to the same volumetric flask
   - 50.0 $cm^3$ of **FA 4**, then,
   - 50.0 $cm^3$ of **FA 3**.
3. Make up the solution to 250 $cm^3$ with deionised water and **mix thoroughly**. This is solution **B**.

**(ii) Preparing solution A**

1. Fill a burette with **FA 1**.
2. Fill another burette with deionised water.
3. Transfer 10.00 $cm^3$ of **FA 1,** followed by 10.00 $cm^3$ of deionised water into a 100 $cm^3$ conical flask. This is solution **A**.

**(iii) Experiment 1**

1. Using an appropriate measuring cylinder, measure out 10.0 $cm^3$ of **solution B**.
2. Add **solution B** from the measuring cylinder into the conical flask containing **solution A**. Swirl and start the stopwatch immediately upon mixing.
3. Stop the stopwatch when the end-point is reached.
4. Record this value of ***t***, to the nearest second.

At the end of experiment 1, wash the conical flask and allow it to stand to drain on a paper towel.

**(iv) Experiments 2 to 5**

1. Repeat step 3 in **(a)(ii)** and the procedures in **(a)(iii)** a further four times to perform experiments 2 to 5.
2. In step 3 in **(a)(ii),** you are to use different volumes of **FA 1** and deionised water to prepare a different **solution A** for each experiment. You should use a minimum volume of 2.00 $cm^3$ of **FA 1** and a maximum volume of 10.00 $cm^3$ of **FA 1**. By adding the appropriate volume of deionised water, ensure that the total volume of **solution A** is always 20.00 $cm^3$.

**(b)** The concentration of **FA 2** in the reaction mixture remains the same in each experiment.

**(i)** Calculate the amount of **FA 2**, $HSO_3^-$, in 250 $cm^3$ of **solution B**.

amount of **FA 2** in 250 $cm^3$ = ……………………………[1]

**(ii)** Calculate the amount of **FA 2**, $HSO_3^-$, in 10.0 $cm^3$ of **solution B** that was measured out for reaction.

amount of **FA 2** in 10.0 $cm^3$ = ……………………………[1]

**(iii)** Hence, determine the concentration of **FA 2**, $[HSO_3^-]$, in each reaction mixture.

[**FA 2**] = ………………………………[1]

**(c)** **Results**

[5]

**(d)** Plot a graph of rate, ***r***, on the *y*-axis against initial $[IO_3^-]$ on the *x*-axis.

Draw an appropriate line taking into account all of your plotted points.

[3]

**(e)** **(i)** The rate equation for the reaction is shown below.

$$r = k\,[H^+][HSO_3^-][IO_3^-]^x$$

Use your graph to deduce the order of reaction, ***x***, with respect to the concentration of $IO_3^-$ ions.

order of reaction, ***x*** = ...............................

explanation

..........................................................................................................

..........................................................................................................[2]

**(ii)** Hence, calculate the value of the rate constant, ***k***, given that the $[H^+]$ in each reaction mixture is 0.00800 mol $dm^{-3}$. State the units of ***k*** clearly.

***k*** = ....................................[2]

**(iii)** Using your graph, calculate the volume of **FA 1** needed to prepare **solution A** so that the reaction mixture turns blue-black after 40 seconds.

volume of **FA1** required = .................................[2]

**(f)** Student **Z** performed experiment 1 but she accidentally added less water to the conical flask in **(a)(ii)**. State and explain how the value of ***t*** obtained for student **Z** is likely to differ from another student who prepared the reaction mixture correctly.

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..........................................................................................................................................[1]

[Total: 18]

**2 To determine the percentage composition of $Na_2CO_3$ in a mixture**

**FA 5** is a solid mixture of $Na_2CO_3$ and NaC*l*

**FA 6** is a 0.100 mol $dm^{-3}$ aqueous solution of sulfuric acid, $H_2SO_4$

**FA 7** is methyl orange indicator

Sulfuric acid only reacts with $Na_2CO_3$ but not with NaC*l*, according to the equation shown.

$$H_2SO_4(aq) + Na_2CO_3(aq) \rightarrow Na_2SO_4(aq) + H_2O(l) + CO_2(g)$$

**(a) (i) Preparation of a standard solution, FA 8**

1. Weigh accurately 5.00 g of **FA 5** into a weighing bottle. Record your readings in an appropriate table on **page 9**.
2. Transfer the weighed **FA 5** to a small beaker. Add deionised water and stir the solution with a glass rod to dissolve all the solid.
3. Transfer the solution into a 250 $cm^3$ volumetric flask.
4. Rinse the beaker with deionised water and add the rinsing to the volumetric flask to ensure all **FA 5** have been transferred.
5. Make up the contents of the flask to the 250 $cm^3$ mark with deionised water.
6. Place the stopper in the flask and mix the contents thoroughly. This solution is **FA 8**.

**(ii) Titration**

1. Fill a burette with **FA 6.**
2. Pipette 25.0 $cm^3$ of **FA 8** into a conical flask.
3. Add to the flask 2-3 drops of methyl orange indicator and titrate with **FA 6** until the end point is reached.
4. Repeat the titration as necessary to obtain consistent results.

Record all measurements of mass and your titration results on **page 9**.

**(b) Results**

[6]

**(c) (i)** From your titration results, obtain a **suitable** volume of **FA 6** to be used in your calculations.

volume of **FA 6** = ………………………………[1]

**(ii)** Calculate the amount of $Na_2CO_3$ in 25.0 $cm^3$ of **FA 8.**

amount of $Na_2CO_3$ in 25.0 $cm^3$ of **FA 8** = ………………………………[1]

**(iii)** Calculate the amount of $Na_2CO_3$ in 250.0 $cm^3$ of **FA 8**.

amount of $Na_2CO_3$ in 250.0 $cm^3$ of **FA 8** = ………………………………[1]

**(iv)** Calculate the percentage by mass of $Na_2CO_3$ in **FA 5**.

% by mass = ………………………………[2]

**(d)** When preparing standard solutions, it is incorrect to use a dropper to remove some solution should the mark on the volumetric flask be exceeded.
Explain the effect of this incorrect method of preparation on the volume of **FA 6** used for titration and the percentage by mass of $Na_2CO_3$ calculated.

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………………………………………………………………………………………………...[2]

**(e) Planning**

When sodium hydrogencarbonate, $NaHCO_3$, is heated, it decomposes to form sodium carbonate, $Na_2CO_3$.

$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g) \qquad \Delta H_r$$

The enthalpy change of reaction, $\Delta H_r$, for the thermal decomposition of $NaHCO_3$ cannot be determined directly and so an indirect method is used.

By determining the enthalpy change of reaction between $Na_2CO_3$(s) and hydrochloric acid, $\Delta H_1$, and that between $NaHCO_3$(s) and hydrochloric acid, $\Delta H_2$, a value for $\Delta H_r$ for the thermal decomposition of $NaHCO_3$ can be obtained.

**Reaction between $NaHCO_3$(s) and hydrochloric acid, $\Delta H_2$**

$$NaHCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l) + CO_2(g) \qquad \Delta H_2 > 0$$

The reaction between $NaHCO_3$(s) and HC*l*(aq) is an endothermic process.

The maximum temperature change occurring during this reaction may be determined graphically. The maximum temperature change, $\Delta T$, obtained from the graph can be used to calculate the heat change, *q*, for this experiment. Using *q*, a value for $\Delta H_2$ may be determined.

**(i)** Outline how you would carry out an experiment to determine the maximum temperature change, $\Delta T$, **graphically** for the reaction between $NaHCO_3$(s) and HC*l*(aq) in order to determine a value for $\Delta H_2$.

Your answer should include details of:

- the apparatus used,
- calculations to determine the appropriate quantities of reagents used,
- the experimental procedure,
- the measurements taken to allow a suitable temperature-time graph to be drawn.

Assume that you are provided with:

- 150 $cm^3$ of 2.00 mol $dm^{-3}$ hydrochloric acid, HC*l*(aq),
- 10.0 g of solid sodium hydrogencarbonate, $NaHCO_3$(s),
- the equipment normally found in a school laboratory.

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……………………………………………………………………………………………………[6]

**(ii)** Sketch the graph you would expect to obtain in **(e)(i)**.

Indicate how the maximum temperature change, Δ***T***, can be determined on the graph.

[2]

**(iii)** Suggest one reason why the graphical method gives an accurate and reliable value for determining a value of **Δ*T***.

………………………………………………………………………………………………………

……………………………………………………………………………………………………...[1]

**(iv)** Student **Z** carried out two separate experiments and obtained the following values for $\Delta H_1$ and $\Delta H_2$.

$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$ $\Delta H_1 = -26.7 \text{ kJ mol}^{-1}$

$NaHCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l) + CO_2(g)$ $\Delta H_2 = +24.2 \text{ kJ mol}^{-1}$

Using these values of $\Delta H_1$ and $\Delta H_2$, construct an energy cycle to determine a value for the enthalpy change of reaction, $\Delta H_r$, for the decomposition of $NaHCO_3(s)$.

$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g) \qquad \Delta H_r$$

$\Delta H_r$ = ………………………………[2]

[Total: 24]

**3 Organic Qualitative Analysis**

**FA 9** is a solution containing an organic compound with the formula $\mathbf{C_4H_8O_2}$.

**FA 10** is a solution containing an organic compound with **two** functional groups.

Perform the tests described in the table below and record your observations clearly. Some observations have been recorded for you.

**Do not use Bunsen burner for heating. Use the hot water provided from the boiler.**

**(a)**

| | **tests** | **observations for FA 9** | **observations for FA 10** |
|---|---|---|---|
| **(i)** | Place about 2 cm depth of aqueous sulfuric acid in a test-tube.<br>To this test-tube, add 10 drops of **FA**, followed by 1 drop of aqueous potassium manganate(VII).<br>Warm the mixture in the hot water bath for five minutes. | | |
| **(ii)** | Place about 2 cm depth of aqueous silver nitrate in a test-tube.<br>To this test-tube, add 10 drops of aqueous sodium hydroxide, followed by aqueous ammonia until a clear solution is formed.<br>To this test-tube, add 10 drops of **FA**.<br>Warm the mixture in the water bath for two minutes. | | |
| **(iii)** | Place about 1 cm depth of deionised water in a test-tube. To this test-tube, add 10 drops of **FA** and add 10 drops of aqueous sodium hydroxide. Now add iodine solution dropwise, until a permanent yellow/ orange colour is obtained.<br>Warm the mixture in the water bath for two minutes. | | |

[6]

**(b)** In addition to the tests in **(a)**, a student carried out a further test and obtained the following observations.

| **test** | **observations for FA 9** | **observations for FA 10** |
|---|---|---|
| To 1 cm depth of **FA** in a test-tube, add 2,4-dinitrophenylhydrazine dropwise. | orange ppt formed | a small quantity of orange ppt formed |

Using all the observations in **(a)** and **(b)**, identify two functional groups present in **FA 9** and **FA 10**. Give evidence(s) to support your answer and state the type of reaction that took place.

| | | |
|---|---|---|
| **FA 9** | 1st functional group<br>…………………………<br>………………………… | evidence & type of reaction<br>………………………………………………………………<br>………………………………………………………………<br>………………………………………………………………<br>……………………………………………………………… |
| | 2nd functional group<br>…………………………<br>………………………… | evidence & type of reaction<br>………………………………………………………………<br>………………………………………………………………<br>………………………………………………………………<br>……………………………………………………………… |
| **FA 10** | 1st functional group<br>…………………………<br>………………………… | evidence & type of reaction<br>………………………………………………………………<br>………………………………………………………………<br>………………………………………………………………<br>……………………………………………………………… |

| | $2^{nd}$ functional group | evidence & type of reaction |
|---|---|---|
| | …………………………<br>………………………… | …………………………………………………………..……<br>…………………………………………………………..……<br>…………………………………………………………..…<br>…………………………………………………………..… |

[6]

**(c)** Suggest and draw one possible structure of **FA 9**.

[1]

[Total: 13]

**End of Paper 4**

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**Qualitative Analysis Notes**
*[ppt. = precipitate]*

**(a) Reactions of aqueous cations**

| *cation* | *reaction with* | |
|---|---|---|
| | NaOH(aq) | $NH_3$(aq) |
| aluminium, $Al^{3+}$(aq) | white ppt.<br>soluble in excess | white ppt.<br>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.<br>soluble in excess<br>giving dark green solution | grey-green ppt.<br>insoluble in excess |
| copper(II), $Cu^{2+}$(aq) | pale blue ppt.<br>insoluble in excess | blue ppt.<br>soluble in excess<br>giving dark blue solution |
| iron(II), $Fe^{2+}$(aq) | green ppt., turning brown on contact with air<br>insoluble in excess | green ppt., turning brown on contact with air<br>insoluble in excess |
| iron(III), $Fe^{3+}$(aq) | red-brown ppt.<br>insoluble in excess | red-brown ppt.<br>insoluble in excess |
| magnesium, $Mg^{2+}$(aq) | white ppt.<br>insoluble in excess | white ppt.<br>insoluble in excess |
| manganese(II), $Mn^{2+}$(aq) | off-white ppt., rapidly turning brown on contact with air<br>insoluble in excess | off-white ppt., rapidly turning brown on contact with air<br>insoluble in excess |
| zinc, $Zn^{2+}$(aq) | white ppt.<br>soluble in excess | white ppt.<br>soluble in excess |

### (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;<br>NO liberated by dilute acids<br>(colourless NO ⟶ (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;<br>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<br>(ppt. dissolves with excess $CO_2$) |
| chlorine, $Cl_2$ | bleaches damp litmus paper |
| hydrogen, $H_2$ | "pops" with 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, $I_2$ | black solid / purple gas | brown | purple |