

### **RIVER VALLEY HIGH SCHOOL** JC 2 PRELIM PRACTICAL EXAMINATION

## H2 CHEMISTRY 9729 Paper 4

# 19 AUGUST 2021

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.





This Question Paper consists of **20** printed pages and **1** blank page.

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

#### 1 Determine the solubility product, K<sub>sp</sub>, of calcium iodate(V), Ca(IO<sub>3</sub>)<sub>2</sub>

Calcium iodate is used in the manufacture of disinfectants, antiseptics, and deodorants. Its solubility in water is low. When calcium iodate(V) is mixed with water, the following equilibrium is established.

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

The total amount of  $IO_3^-(aq)$  in the saturated salt solution is determined using iodometry.

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) You are provided with
  - **FA 1** a saturated solution of Ca(IO<sub>3</sub>)<sub>2</sub> in KIO<sub>3</sub>(aq)
  - FA 2 0.200 mol dm<sup>-3</sup> sodium thiosulfate,  $Na_2S_2O_3$
  - FA 3 aqueous solution of potassium iodide, KI
  - **FA 4** dilute sulfuric acid, H<sub>2</sub>SO<sub>4</sub>

Starch indicator

#### Titration of filtrate, FA 1

- 1. Pipette 25.0 cm<sup>3</sup> of **FA 1** into a conical flask.
- 2. Using a measuring cylinder, add about 10 cm<sup>3</sup> of **FA 4** to the conical flask.
- 3. Using another measuring cylinder, add about 10 cm<sup>3</sup> 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 on Page 3.
- 7. Repeat the titration as many times as necessary until consistent results are obtained.

#### Results

Titration	<mark>  1</mark>	<mark>2</mark>
Final burette reading / cm <sup>3</sup>	<mark>18.95</mark>	<mark>18.95</mark>
Initial burette reading/ cm <sup>3</sup>	<mark>0.00</mark>	<mark>0.00</mark>
Volume of <b>FA 2</b> used / cm <sup>3</sup>	<mark>18.95</mark>	<mark>18.95</mark>



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2	
3	
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(b) (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.

Average volume of **FA 2** used = 18.95 cm<sup>3</sup>



(ii) Use the volume of **FA 2** obtained in (b)(i) to calculate the amount of  $IO_3^-(aq)$  present in 25.0 cm<sup>3</sup> of **FA 1**.

Amount of  $S_2O_3^{2-} = 0.200 \times \frac{18.95}{1000}$ = 0.00374 mol IO  $_3^- = 3I_2 = 6S_2O_3^{2-}$ amount of IO $_3^-$  in 25.0 cm<sup>3</sup> of **FA 1** = 0.00374 ÷ 6 = 6.32 × 10<sup>-4</sup> mol

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#### Planning

The solubility of calcium iodate(V), at a particular temperature, can be defined as:

For Examiner's Use

the mass of calcium iodate(V) that will dissolve in and just saturate  $1000 \text{ cm}^3$  of solvent at that temperature.

A saturated solution is one in which no more solid can dissolve at a particular temperature. In a saturated solution with undissolved solid, the following equilibrium is established.

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

Like most salts, solubility of calcium iodate(V) increases when the temperature of the solution increases.

(e) Plan a procedure to determine the solubility of calcium iodate(V) in water.

You may assume that you are provided with:

- deionised water
- solid calcium iodate(V), Ca(IO<sub>3</sub>)<sub>2</sub>
- filter funnel and filter paper
- water bath
- thermometer
- the apparatus and equipment normally found in a school or college laboratory.

Your plan should include

- calculation of the mass (approximate) of Ca(IO<sub>3</sub>)<sub>2</sub> that will dissolve in 100 cm<sup>3</sup> of deionised water to give a saturated solution [molar mass of Ca(IO<sub>3</sub>)<sub>2</sub> = 390 g mol<sup>-1</sup>; solubility of Ca(IO<sub>3</sub>)<sub>2</sub> at 20 °C  $\approx$  6.15  $\times$  10<sup>-3</sup> mol dm<sup>-3</sup>]
- practical details of how you would
  - prepare a saturated solution in 100 cm<sup>3</sup> of deionised water in a 250 cm<sup>3</sup> conical flask,
  - maintain the temperature of the mixture,
  - separate the saturated solution from the undissolved solid,
  - obtain the mass of **dry** solid,
  - ensure that an **accurate** and **reliable** value of solubility of calcium iodate(V) in water is obtained.
- details of how the results would then be used to obtain the solubility of Ca(IO<sub>3</sub>)<sub>2</sub> in water at 20 °C.

Approximate mass of Ca(IO<sub>3</sub>)<sub>2</sub> that can dissolve in 100 cm<sup>3</sup> of deionised

- Measure 100.0 cm<sup>3</sup> of deionised water using a 100.0 cm<sup>3</sup> measuring cylinder and add it to a 250 cm<sup>3</sup> conical flask. Place the conical flask in a thermostatically-controlled water bath at 20 °C. Place a thermometer into the flask to monitor the temperature of the water.
- 2. Weight <u>accurately</u> the mass of 1.0 g of Ca(IO<sub>3</sub>)<sub>2</sub> in a weighing bottle. Using a spatula, add small amounts of pre–weighed Ca(IO<sub>3</sub>)<sub>2</sub> to the deionised water in the conical flask and stir continuously the mixture with a glass rod. Continue adding Ca(IO<sub>3</sub>)<sub>2</sub>, with stirring, until some undissolved solid remains. Allow 10 min for the mixture to reach equilibrium.
- Using an electronic balance, weigh <u>accurately</u> a dry filter paper. Record the mass as m<sub>1</sub>. Using a dry filter funnel and the same dry filter paper, filter the mixture immediately.
- Place the filter paper and its contents from (3) under an infra-red lamp for 30 mins.
- 5. Cool and weigh the filter paper and its contents.
- Repeat the dry-cool-weigh process from (4) and (5) until the difference in mass is ≤ ±0.05g. Record the final mass of residue and filter paper as m<sub>2</sub>.
- 7. Mass of Ca(IO<sub>3</sub>)<sub>2</sub> residue =  $m_2 m_1$
- Reweigh accurately the weighing bottle with residual Ca(IO<sub>3</sub>)<sub>2</sub> to determine mass of Ca(IO<sub>3</sub>)<sub>2</sub> transferred to conical flask.

Mass of Ca(IO<sub>3</sub>)<sub>2</sub> in filtrate =  $(x - y) - (m_2 - m_1)$ 

Solubility of Ca(IO<sub>3</sub>)<sub>2</sub> in water =  $\frac{(x-y)-(m_2-m_1)}{100} \times 1000$ 

Mass of Ca(IO <sub>3</sub> ) <sub>2</sub> + weighing bottle / g	x x
Mass of residual Ca(IO <sub>3</sub> ) <sub>2</sub> + weighing bottle / g	<mark>y</mark>
Mass of Ca(IO <sub>3</sub> ) <sub>2</sub> added / g	$\frac{x-y}{y}$

[Total: 20]

## 2 Determination of acid concentration and enthalpy change of neutralisation using calorimetry

For Examiner's Use

When an acid is added into an alkali, an exothermic reaction takes place and the temperature of the mixture increases. Maximum heat is given out when stoichiometric amounts of  $H^+$  and  $OH^-$  are added together.

**FA 5** is an aqueous solution prepared by mixing *equal volumes* of y mol dm<sup>-3</sup> hydrochloric acid, HC*I*, and y mol dm<sup>-3</sup> sulfuric acid, H<sub>2</sub>SO<sub>4</sub>.

**FA 6** is 2.00 mol  $dm^{-3}$  sodium hydroxide, NaOH.

In this question, you are to follow the neutralisation of known volume of **FA 5**, by measuring the highest temperature obtained as different volumes of **FA 6** are added.

By measuring the maximum temperature rise for different mixtures of the two reagents, you are to determine the following:

- the value of y, concentration of the acids present in FA 5
- the enthalpy change of neutralisation,  $\Delta H_{neut}$ , for the reaction

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(I)$$

#### (a) **Procedure**:

- 1. Fill the burette to the  $0.00 \text{ cm}^3$  mark with **FA 6**.
- Place the polystyrene cup in a 250 cm<sup>3</sup> beaker and use a 50 cm<sup>3</sup> measuring cylinder to transfer 25.0 cm<sup>3</sup> of FA 5 into the cup. Record the steady temperature of FA 5 in Table 1 provided on page 9.
- 3. Read through the following instructions before starting the experiment.
- 4. Run 3.00 cm<sup>3</sup> of **FA 6** from the burette into the cup, stir the solution carefully with the thermometer and record the maximum temperature,  $T_x$  (where x is the total volume of **FA 6** added).
- 5. **Immediately** run a further 3.00 cm<sup>3</sup> of **FA 6** from the burette into the cup, stir and record the maximum temperature as before. Continue the addition of **FA 6**, in 3.00 cm<sup>3</sup> portions, until a total of 36.00 cm<sup>3</sup> of **FA 6** have been run from the burette.
- 6. Record all temperatures in Table 1.
- 7. Fill in the units for the final column of **Table 1**.
- 8. Complete the table by calculating  $\Delta T$  and (total volume of mixture  $\times \Delta T$ ) for each measurement.

Volume of FA 6 added / cm <sup>3</sup>	Total volume of mixture in cup / cm <sup>3</sup>	Tempe T <sub>x</sub>	erature / °C	$\Delta T$ $(T_x - T_0)/ \ ^{\circ}C$	Total volume of mixture × ∆ <b>T</b> / <mark>cm<sup>3</sup> °C</mark>
0.00	25.0	<b>T</b> 0	<mark>29.6</mark>	0.0	0.00
3.00	28.0	<b>T</b> <sub>3</sub>	<mark>32.2</mark>	<mark>2.6</mark>	<mark>72.8</mark>
6.00*	31.0	<b>T</b> <sub>6</sub>	<mark>34.6</mark>	<mark>5.0</mark>	<mark>155</mark>
9.00	34.0	<b>T</b> 9	<mark>36.6</mark>	<mark>7.0</mark>	<mark>238</mark>
12.00*	37.0	<b>T</b> <sub>12</sub>	<mark>38.4</mark>	<mark>8.8</mark>	<mark>326</mark>
15.00*	40.0	<b>T</b> <sub>15</sub>	<mark>39.6</mark>	<mark>10.0</mark>	<mark>400</mark>
18.00*	43.0	<b>T</b> <sub>18</sub>	<mark>38.8</mark>	<mark>9.2</mark>	<mark>396</mark>
21.00	46.0	<b>T</b> <sub>21</sub>	<mark>37.8</mark>	<mark>8.2</mark>	<mark>377</mark>
24.00	49.0	<b>T</b> <sub>24</sub>	<mark>37.0</mark>	<mark>7.4</mark>	<mark>363</mark>
27.00	52.0	<b>T</b> <sub>27</sub>	<mark>36.4</mark>	<mark>6.8</mark>	<mark>354</mark>
30.00*	55.0	<b>T</b> <sub>30</sub>	<mark>35.8</mark>	<mark>6.2</mark>	<mark>341</mark>
33.00	58.0	<b>T</b> <sub>33</sub>	<mark>35.2</mark>	<mark>5.6</mark>	<mark>325</mark>
36.00*	61.0	<b>T</b> <sub>36</sub>	<mark>34.8</mark>	<mark>5.2</mark>	<mark>702</mark>

Table 1

(b) On the grid provided on the next page, plot (total volume of mixture  $\times \Delta T$ ) against the volume of **FA 6** added.

Draw two straight lines through the plotted points to find the equivalence point for the titration



Graph of (total volume of mixture  $\times \Delta T$ )/ cm<sup>3</sup> °C against volume of FA 6 added/ cm<sup>3</sup>

- (c) Using the graph in (b), determine the volume of FA 6 added at the equivalence point of the titration.
   Volume of FA 6 added at equivalence point = 15.50 cm<sup>3</sup>
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- (d) Using your results from (c),
  - (i) calculate the concentration of the  $H^+$  ions in **FA 5**.

 $n_{\text{NaOH}}$  in 15.50 cm<sup>3</sup> of **FA 6** =  $2.00 \times \frac{15.50}{1000}$ =  $3.10 \times 10^{-2}$  mol OH<sup>)</sup> = H<sup>+</sup> [H<sup>+</sup>] in FA 5 =  $(3.10 \times 10^{-2}) \div \frac{25.0}{1000}$ = 1.24 mol dm<sup>-3</sup>

(ii) Hence, the value of y.

Since **FA 5** is an aqueous solution prepared by mixing *equal volumes* of *y* mol dm<sup>-3</sup> hydrochloric acid, HC*l*, and *y* mol dm<sup>-3</sup> sulfuric acid, H<sub>2</sub>SO<sub>4</sub>;

mole ratio of H<sup>+</sup> from H<sub>2</sub>SO<sub>4</sub> : H<sup>+</sup> from HC/

2 : 1 concentration of HC*l* in **FA 5** =  $\frac{1}{3} \times (1.24) = 0.413$  mol dm<sup>-3</sup> Since *equal volumes* of both acids were mixed to obtain FA 5 Concentration of HC*l*(aq) before dilution = *y* = 2 × 0.413 = 0.827 mol dm<sup>-3</sup>

(e) (i) Using the graph in (b), calculate  $\Delta T_{max}$ . Total volume of mixture  $\times \Delta T_{max} = 420 \text{ cm}^3 \text{ °C}$  $\Delta T_{max} = \frac{420}{25.0+15.5} = 10.4 \text{ °C}$ 

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(ii) Hence, calculate the heat change for the reaction and the enthalpy change of neutralisation,  $\Delta H_{neut}$ , for the reaction

 $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$ 

[Assume that 4.18 J of energy is needed to raise the temperature of  $1 \text{ cm}^3$  of the solution by 1 K]

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 $\Delta H_{\text{neut}} = -\frac{1760}{0.0310} = -56.8 \text{ kJ mol}^{-1}$ 

(f) Suggest one possible modification that would minimise the error or limitation in this thermometric titration. Explain how the suggested modification improves the accuracy of the results.

Use a pipette instead of 50 cm<sup>3</sup> measuring cylinder to measure and transfer 25.0 cm<sup>3</sup> of FA 1 into the calorimeter. Pipette has a smaller absolute uncertainty, giving rise to lower percentage uncertainty in the volume of FA 1 measured.

Add FA 2 in smaller portions in the region of the intersection to obtain more data point. This will reduce the uncertainty about where the best fit lines cross each other.

Use a (liquid-in-glass) thermometer with a smaller scale division than 0.2 °C so that the temperature measurement has lower percentage uncertainty, thus more accurate. (Reject: more accurate thermometer/ digital thermometer/ thermocouple thermometer)

(g) On the grid provided below, plot a graph of  $\Delta T$  against the volume of **FA 6** added.

Draw two best fit lines through the plotted points to find the equivalence point for the titration.

Volume of **FA 6** added at equivalence point = ......15.50...... cm<sup>3</sup>

Briefly explain why the graph of  $\Delta T$  against the volume of **FA 6** added before equivalence point is not drawn as a best fit straight line.

(Before equivalence point,  $V_{FA6} \alpha$  nH<sub>2</sub>O produced  $\alpha$  heat evolved. NaOH is still limiting)

<u>V<sub>total</sub> increased as more FA 6 is added.</u>

Since heat evolved = mc $\Delta$ T = (V<sub>total</sub> × density) × c $\Delta$ T = (V<sub>total</sub> ×  $\Delta$ T) × constant, <u>the heat evolved will produce a lower temperature rise in</u> <u>an increasingly larger volume of mixture</u>. Thus, graph of  $\Delta$ T against V<sub>FA6</sub> is non-linear.

However,  $(V_{total} \times \Delta T)$  is directly proportional to the energy evolved and thus give a linear relationship in the graph from **(b)**.



(h)	The above experiment was repeated using citric acid instead of the acids in <b>FA 5</b> . The $\Delta T$ at the equivalence point was found to be a smaller value. Account for the difference.	
	citric acid	
	Enthalpy change of neutralisation for weak acid (citric acid) and strong base (sodium hydroxide) is less exothermic compared to that of strong acid (hydrochloric acid) and strong base.	39
	Citric acid, a <u>weak acid</u> , is <u>partially dissociated in water</u> whereas the acids in <b>FA 1</b> are <u>strong acids</u> and <u>fully dissociated</u> . <u>Some of the heat evolved</u> from neutralisation is absorbed to dissociate the citric acid molecules completely, resulting in a smaller $\Delta T$ at the equivalence point.	
		40

#### 3 Qualitative Analysis

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

At each stage of any test you are to record details of the following:

- colour changes seen;
- the formation of any precipitate and its solubility in an excess of the reagent added;
- the formation of any gas and its identification by a suitable test.

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

Rinse and reuse test-tubes where possible.

No additional tests for ions present should be attempted.

(a) Sandell's solution reacts in a similar way to Fehling's reagent.

You will need to heat Sandell's solution in a hot water bath when using it in tests.

FA 7, FA 8 and FA 9 are all solutions of carbohydrates.

- Sugars and starch are carbohydrates.
- Some sugars contain an aldehyde group so act as reducing agents.
- Other sugars do not contain an aldehyde group.

For

Examiner's Use For each test use 1 cm depth of the solution in a test-tube. Record all your observations in the table.

test	observations			
lesi	FA 7	FA 8	FA 9	
Add 2 or 3 drops of aqueous iodine.	blue-black/ dark blue colouration	yellow/ brown solution formed	yellow/ brown solution formed	
To prepare acidified potassium manganate(VII), add 2 drops of potassium manganate(VII) to 1 cm depth of an appropriate acid.	Solution remains purple / pink	Purple / pink MnO₄ <sup>–</sup> turns colourless	Solution remains purple / pink	
Add 2 or 3 drops of acidified potassium manganate(VII) and shake.				
Add a 3 cm depth of Sandell's solution and place the tube in the hot water bath for two minutes.	Solution remains blue/ No ppt formed.	brick red ppt	Solution remains blue/ No ppt formed.	

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(i) State the carbohydrate that could be starch.



(ii) State the carbohydrate that contains an aldehyde

Carbohydrate that contains aldehyde = FA 8

(iii) Suggest a different test, other than using Fehling's reagent, that could be carried out to identify the presence of an aldehyde group.

State the reagent(s) you would use and the expected observation if the result were positive.

#### Do not carry out your test.

reagent(s)	Tollens' reagent (warm) or acidified potassium dichromate or H <sup>+</sup> / K₂Cr₂O⁊, (warm)	
observation	Silver mirror/ Black ppt or Orange solution turn green	

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(b) FA 10 and FA 11 are two of the components of Sandell's solution. Each contains one cation and one anion. For all the tests, use 1 cm depth of each solution in a test tube.

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	observations			
Test	FA 10	FA 11		
Add a few drops of aqueous silver nitrate.	No ppt formed	Brown ppt formed		
Add a few drops of aqueous barium nitrate, then dilute nitric acid.	White ppt formed. Ppt is insoluble in dilute nitric acid	White ppt formed Ppt is soluble in excess dilute nitric acid to form a colourless solution.		
Add a few drops of aqueous iodine.	Cream ppt formed in brown solution.	yellow solution formed.		
Add a 1 cm depth of aqueous iron(II) sulfate.	No ppt formed/ Solution remains blue.	Green ppt formed. Green ppt turns brown on standing.		
Add a 1 cm depth of <b>FA 11</b> .	Blue ppt formed.			

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(ii) Identify the ions in **FA 10** and **FA 11**. If you are unable to identify any of the ions, write 'unknown'.

	FA 10	FA 11
cation	Cu <sup>2+</sup>	Unknown
anion	SO₄²-	<mark>OH⁻</mark>

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(iii) Suggest a simple chemical test that could be carried out to identify the presence of the anion in **FA 11**. **Do not carry out your test.** 

test Add NH₄⁺(aq) (and warm)

observation Colourless, pungent gas evolved that turns moist red litmus blue. Gas is NH<sub>3</sub>

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