DISCUSSION FOR PAPER 4

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

1 Determination of the kinetics of the reaction between iodide ions and peroxodisulfate ions

FA 1 is 0.0200 mol dm⁻³ potassium peroxodisulfate, K₂S₂O₈.

FA 2 is 1.00 mol dm⁻³ potassium iodide, KI.

FA 3 is 0.00500 mol dm⁻³ sodium thiosulfate, Na₂S₂O₃.

starch indicator.

Equation 1 represents the reaction between peroxodisulfate ions, $S_2O_8^{2-}$, and iodide ions, I^- .

equation 1 $S_2O_8^{2-}(aq) + 2I^{-}(aq) \rightarrow 2SO_4^{2-}(aq) + I_2(aq)$

When starch is added to the reaction mixture, a blue-black colour is immediately seen due to the formation of an iodine-starch complex.

If a small amount of sodium thiosulfate, $Na_2S_2O_3$, is also present in the reaction mixture, the formation of the blue-black colour is delayed. The $Na_2S_2O_3$ reacts with I_2 as shown in equation 2.

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

You will perform a series of five experiments. Then you will graphically analyse your results in order to determine the order with respect to the concentration of the peroxodisulfate ions, $[S_2O_8^{2-}]$.

For each experiment, you will note the volume of **FA 1** added, V_{FA1} , and the time taken, *t*, for the reaction mixture to turn blue-black.

In each experiment, you will add a fixed amount of sodium thiosulfate, **FA 3**, to each of your experiments. You will need to ensure that the same total volume of reaction mixture is used by adding deionised water as required.

You will then calculate values for

- 1/*t*,
- lg(1/t),
- lg(*V*_{FA1})

Prepare a table in the space provided on page 4 in which to record, to an appropriate level of precision:

- all volumes, except the volumes of FA 2, FA 3 and starch indicator,
- all values of *t*,
- all calculated values of 1/t, Ig(1/t), Ig(V_{FA1}) to 3 significant figures.

For

Examiner's

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(a) Experiment 1

- 1. Fill the burette labelled **FA 1**, with **FA 1**.
- 2. Run 20.00 cm³ of **FA 1** into a 100 cm³ beaker labelled **Beaker A**.
- Using appropriate measuring cylinders, add the following to the second 100 cm³ beaker labelled **Beaker B**:
 - 20.0 cm³ of **FA 2**
 - 10.0 cm³ of **FA 3**
- 4. Add 10 drops of starch indicator to **Beaker B**.
- 5. Add the contents of **Beaker A** to **Beaker B** and start timing immediately.
- 6. Stir the mixture thoroughly using the glass rod and place the beaker on a white tile.
- 7. Stop timing as soon as the solution turns blue-black.
- 8. Record the time taken, *t*, to the nearest 0.1 s in your table.
- 9. Wash out both beakers thoroughly with water and shake dry. Rinse and dry the glass rod.

Experiments 2 to 5

Repeat experiment 1 four times, adding 18.00, 14.00, 10.00 and 6.00 cm³ respectively, of **FA 1** at point 2.

In each case, you will need to ensure that the **same total volume** of the reaction mixture is used by adding deionised water as required using the second burette provided.

Record all required volumes, time taken and calculated values in your table.

Results	Burette (2.d.p.)	Burette (2.d.p.)	Nearest 0.1s	3.s.f.		
Expt	<u>V_{FA1}/ cm³</u>	<u>V_{water}/ cm³</u>	<u>t/ s</u>	<u>1/t / s⁻¹</u>	<u>lg(1/t)</u>	Ig(V _{FA1})
1	20.00	0.00	13.4	0.0746	-1.13	1.30
2	18.00	2.00	14.9	0.0671	-1.17	1.26
3	14.00	6.00	19.4	0.0515	-1.29	1.15
4	10.00	10.00	27.3	0.0366	-1.44	1.00
5	6.00	14.00	48.3	0.0207	-1.68	0.778

[1] single table with correct headers and units

[1] correct precision of recording.

- Recorded volumes to 2.d.p (nearest 0.05 cm³)
- all t to nearest 0.1s
- 1/t, lg(1/t), lg(V_{FA1}) correctly calculated to 3.s.f.

[1] 5 sets of data + correct volumes of deionised water

• V_{FA1} as stated in the question

• V_{FA1} + V_{water} = 20.00 cm³

Accuracy:

Deviation in ratio of time for 10.00 cm³ FA 1 / time for 20.00 cm³ FA 1 btw Supervisor and student's titre, δ :

δ ≤ 0.10 [1]

(b) (i) Plot a graph of lg(1/t) on the y-axis against $lg(V_{FA1})$ on the x-axis. Draw the best-fit straight line taking into account all of your plotted points.





- [1] Draw a line of best fit (min. of 3 points that lie close to the line are required within one small square in both x & y direction)
 Do not exceed this mark if:
 - Do not award this mark if:
 - there is clearly a better line that could have been drawn through the points)
 - the line is drawn through points "bunched" in less than 20 imes 20 small squares | Over

(ii) Calculate the gradient of the line to three significant figures, showing clearly how you did this. Hence, deduce the order of the reaction with respect to [S₂O₈²⁻].
 *Show your coordinates and mark out your triangle on your graph!
 Coordinates chosen MUST lie exactly on the line

Gradient = $\frac{y_2 - y_1}{x_2 - x_1} = \frac{(-1.10) - (-1.71)}{1.32 - 0.75}$ = 1.07 [1] construction lines drawn on the graph. • The hypotenuse of the constructed "triangle" should cover <mark>at least half of the length of the line</mark> drawn by the candidate • correctly reads the coordinates to nearest $\frac{1}{2}$ small square [1] calculates gradient correctly • using the values read from the graph $1/t \propto rate$, $V_{FA1} \propto [S_2O_8^{2-1}]$. Rate = $k' [S_2 O_8^{2} - 1^n]$ $1/t = k'(V_{FA1})^n$ $lq(1/t) = lq k' + nlq(V_{FA1})$ $lq(1/t) = nlq(V_{FA1}) + lq k'$ (y=mx+c graph) n= gradient of line. Order of reaction w.r.t. $[S_2O_8^{2-}] = 1$ [1] [1] correct conclusion of order (must be integer e.c.f. from gradient). Marks are not awarded if incorrect chemistry is used to conclude order. (Eg. First order because a straight line with positive gradient is obtained.) Gradient = Order = [3]

7

Common errors for graph:



*You should choose a scale that is convenient to read as long as plotted points occupy at least ½ the given grid in both directions.

2. Incorrect plotting of points.



⇒ most of the time caused by candidates failing to mark out the scale for every 10 small squares.

(c) (i) A student thought that the experiment could be made more accurate by having longer reaction times. To do this, he repeated Experiment 1 with the same volumes but using 0.100 mol dm⁻³ sodium thiosulfate instead of FA 3. He found that the reaction never turned blue-black. Explain why.

```
FA 3 [Na_2S_2O_3] = 0.00500 \text{ mol } dm^{-3}
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Sodium thiosulfate is in excess. All the iodine reacts with the thiosulfate hence no iodine present to turn solution blue-black.

[1]

(ii) Other than errors involving measurements of volume and time, suggest an additional source of error in these experiments and what improvement could be made to reduce this error.



(d) (i) The experimental method can be modified to enable the rate of reaction with respect to [□] to be investigated.

Equation 1
$$S_2O_8^{2-}(aq) + 2I^{-}(aq) \rightarrow 2SO_4^{2-}(aq) + I_2(aq)$$

In the first line in Table 1.1 below, the volumes of **FA 1**, **FA 2**, **FA 3** and deionised water used in **Experiment 1** are recorded.

Complete the following table, suggesting volumes for each of the reagents that could be used in one further experiment to investigate how the rate of reaction varies with a change in volume of potassium iodide, **FA 2**.

Do not carry out this experiment.

Experiment	V _{FA1} / cm ³	V _{FA2} / cm ³	V _{FA3} / cm ³	V _{water} / cm ³
1	20	20	10	0
6	20	15	10	5

Table 1.1

[1] only V_{FA2} and V_{H2O} changes, the rest of the volumes remain constant.

 $V_{FA2} + V_{H2O} = 20 \text{ cm}^3$

(ii) The overall order for the reaction in equation 1 is second order. Using your answer in **1(b)(ii)**, write a rate equation for the reaction.

<u>Rate = k[S₂O₈²⁻][I⁻]</u> [1] ecf from (b)(ii).

[Total: 15]

[1]

[1]

2. Determination of the percentage of mass of copper in FA 4

When excess of potassium iodide, KI, is added to the solution of Cu^{2+} ions, iodine, I₂, and a precipitate of CuI is produced. The I₂ turns the solution brown.

equation 3
$$2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$$

I2 has a relatively low solubility in water. However, the presence of an excess of I- ions in the reaction mixture allows the soluble tri-iodide ion, I₃, to form as shown by equation 4. This ensures that the I_2 formed as shown in equation 3 is fully dissolved.

equation 4
$$I_2 + I^- \rightarrow I_3^-$$

The I₃⁻ ions formed may be titrated against a standard solution of Na₂S₂O₃ as shown in equation 5.

 $I_{3^{-}}$ + $2S_{2}O_{3^{2^{-}}} \rightarrow S_{4}O_{6^{2^{-}}}$ + $3I^{-}$ equation 5

FA 4 is a solid compound containing Cu²⁺.

FA 6 is 0.100 mol dm⁻³ sodium thiosulfate, Na₂S₂O₃.

You are also provided with

FA 2, 1.00 mol dm⁻³ potassium iodide, KI, Starch indicator.

In this experiment, you will first prepare a solution of Cu²⁺(aq) using the **FA 4** provided. You will then perform a titration to determine the percentage by mass of copper in FA 4. You may assume that the no other components in FA 4 take part in any of the reactions mentioned.

(a) (i) Preparation of FA 5 from FA 4

- 1. Weigh the weighing bottle containing **FA 4** and record this mass in Table 2.1.
- 2. Tip the **FA 4** into the 250 cm³ beaker. Reweigh the weighing bottle including any residual FA 4 and record this mass in Table 2.1.
- 3. Calculate the mass of FA 4 used for the preparation of FA 5.

Ta

Table 2.1	(3.d.p.)
Mass of FA 4 and weighing bottle / g	10.482
Mass of weighing bottle and residual FA 4 / g	5.487
Mass of FA 4 used / g	4.995

- 4. Add approximately 150 cm³ of deionised water to the beaker and stir until the FA 4 has dissolved.
- 5. Transfer the solution and washings into a 250 cm³ volumetric flask.
- 6. Make up to the mark with deionised water.
- 7. Stopper and shake the flask to obtain a homogeneous solution. Label this solution FA 5.

(ii) Titration of FA 5 against FA 6

- 1. Fill a burette with **FA 6**.
- 2. Use a pipette to transfer 25.0 cm³ of **FA 5** into a 250 cm³ conical flask.
- 3. Use the 25 cm³ measuring cylinder to add 15 cm³ of **FA 2**, an excess of KI, to the conical flask. A white precipitate forms in a brown solution.
- 4. Run **FA 6** from the burette into this conical flask. Near the end-point, when the brown solution becomes pale, add 10 drops of starch indicator. The mixture will turn blue-black.
- 5. Continue adding **FA 6** slowly. The end-point is reached when the **solution** first becomes colourless. The white precipitate remains.
- 6. Record your titration results, to an appropriate level of precision, in the space provided.
- 7. Repeat points 2 to 6 in 2(a)(ii) until consistent results are obtained.



Titration results	(2.d	.p.)	
Titration number	1	2	
Final burette reading / cm ³	19.60	39.30	
Initial burette reading / cm ³	0.00	5.00	
Volume of FA6 used / cm ³	19.60	19.70	Consistent titre within 0.10cm ³
		V	

[1] table with correct headings ('burette' must be stated) and units. (Do not award if any final and initial burette readings are inverted or 50 is used as initial burette reading.)

[1] All burette readings are recorded to the nearest 0.05 cm³ + correct computation of titres & M_{FA4} + all mass measurements to 3.d.p.

[1] Has two <u>uncorrected</u> titres for end-point within 0.10 cm³ + <u>place</u> \checkmark under two selected titres within 0.10 cm³. (Do not award if additional titration is performed after consistent titres are obtained.)

[3]

titres

(iii) From your titrations, obtain a suitable volume of FA 6, V_{FA 6}, to be used in your calculations. Show clearly how you obtained this volume.

 $V_{FA 6} = \frac{19.60 + 19.70}{2} = 19.65 \text{ cm}^3$ - guote the selected titres in the average working - give correct final value to 2 d.p. [1] Accuracy: Deviation btw Supervisor and student's V/m, δ : $\delta \leq 0.03~\text{cm}^3\text{g}^{-1}$ [2] $0.03 < \delta \le 0.06 \text{ cm}^3 \text{g}^{-1}$ [1] $V_{FA 6} = 19.65 \text{ cm}^3$ [3]

(b) (i)

Calculate the amount of thiosulfate present in VFA 6.

Amount of $S_2O_3^{2-}=\frac{19.65}{1000}\times 0.100=$ 0.00197 mol [1] Amount of $S_2O_3^{2-}$ in $V_{FA 6} = 0.00197$ mol [1] (ii) Calculate the mass of copper in FA 4 that is used to prepare 250 cm³ of FA 5. [A_r: Cu, 63.5]

(iii) Hence, determine the percentage by mass of copper in the sample of **FA 4** used.

(c) Calculate the percentage error of V_{FA6} calculated in 2(a)(iii).

Average titre

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% error = \frac{\text{uncertainty}}{\text{quantity}} \times 100
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% error = $\pm \frac{2(0.05)}{19.65} \times 100 = \pm 0.509 \%$ [1]

[3]

[1] Shows working in <u>all</u> calculations AND

Shows appropriate significant figures (3sf) in <u>all</u> final answers in 1(b)(ii), 2(b)(i),(ii),(iii) and 2(c).

Any calculation not attempted loses this mark.

[1] Shows correct units in 2(a)(iii)[cm³], 2(b)(i) [mol], 2(b)(ii) [g], 2(b)(iii) [%], 2(c) [%]

Any calculation not attempted loses this mark.

[Total: 13]

3 Investigation of some inorganic reactions and the identity of an organic compound

(a) **FA 7** is an aqueous solution containing Fe³⁺ and one anion from the ions listed in the *Qualitative Analysis Notes*.

You are also provided with

FA 6, 0.100 mol dm⁻³ sodium thiosulfate, Na₂S₂O₃.

Hydrogen peroxide, H₂O₂.

Carry out the tests described in Table 3.1. Some of the observations have been completed for you. There is no need to carry out those tests. Carefully record your observations in Tables 3.1.

The volumes given below are approximate and should be estimated rather than measured. Test and identify any gases evolved. If there is no observable change, write **no observable change**.

	tests		observations
1	Add 2 cm depth of H_2O_2 into Add about a 2 cm depth of I same test-tube and shake t thoroughly.	a test-tube. F A 7 to the the mixture	Yellow <u>solution turns brown</u> (✓) then <u>turns</u> back to <u>yellow</u> . (✓) <u>Effervescence</u> (✓) observed.
	Observe the mixture until changes are seen.	no further	O₂ gas relights glowing splint. (✓)
	Test glo (Fe ³⁺)	ring gas wit wing splint	
	(Fe ³⁺) Add FA7		After some time
F			A C. MILLION

Table 3.1

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[3]



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(i) A possible mechanism for the reaction between H₂O₂ and FA 7 in test 1 from Table 3.1 is shown below.

step 1
$$[Fe(H_2O)_6]^{3+}(aq) + H_2O_2(aq) \rightleftharpoons [Fe(H_2O)_5(O_2H)]^{2+}(aq) + H_3O^+(aq)$$

step 2
$$[Fe(H_2O)_5(O_2H)]^{2+}(aq) \rightarrow OH^{-}(aq) + [Fe(H_2O)_5(O)]^{3+}(aq)$$

step 3 $[Fe(H_2O)_5(O)]^{3+}(aq) + H_2O_2(aq) \rightarrow [Fe(H_2O)_6]^{3+}(aq) + O_2(g)$

step 4 $H_3O^+(aq) + OH^-(aq) \rightarrow 2H_2O(I)$

Using evidence from your observations in Table 3.1 and the mechanism, deduce the role of $[Fe(H_2O)_6]^{3+}(aq)$ ions in this reaction.

[Fe(H₂O)₆]³⁺(aq) is a catalyst. [1]

<u>Yellow(\checkmark) [Fe(H₂O)₆]³⁺(aq) is reacted in step 1 (\checkmark) to form brown [Fe(H₂O)₅(O₂H)]²⁺(aq)/ intermediate(\checkmark).</u>

Then <u>vellow [Fe(H₂O)₆]³⁺(aq) regenerated in step 3 (\checkmark)</u>.

[3]

(ii) S₂O₃²⁻ ions undergo two chemical reactions with Fe³⁺ ions in test 2 from Table 3.1. One reaction involves the formation of a deeply coloured [Fe(S₂O₃)₂]⁻ complex.

Deduce the different roles played by $S_2O_3^{2-}$ ions in the two chemical reactions in test 2.

Ligand and reducing agent [1]

[1]

(iii) From the observations provided for test 3 in Table 3.1, elemental sulfur and a gas is produced after the reaction of $S_2O_3^{2-}$ ions and H⁺ ions.

Write **a balanced ionic equation** including state symbols for the reaction that occurred in test 3.

<u>S₂O₃²⁻(aq) + 2H⁺(aq) → S(s) + SO₂(g) + H₂O(l) [1]</u>

[1]

Devise and perform some simple tests to identify the anion in **FA 7**.

Your tests should be based on the *Qualitative Analysis Notes* on pages 23–24 and should use only the bench reagents provided.

Because **FA 7** is coloured, you may want to consider removing the Fe^{3+} present in **FA 7** so that it does not interfere with the anion tests.

Record the tests performed, the procedures used and the observations in the space below.

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

The anion is not a nitrate, nitrite or sulfide ion.

*Note those that indicate addition of NH₃ instead of NaOH,

White ppt will not be obtained if AgNO3 is after this. As NH3 is already in excess, AgCl will be dissolved in excess

tests	observations
To about 1 cm depth of FA 7 in a test-tube, <u>add excess</u> <u>NaOH</u> (aq) (✓)	Reddish brown ppt. formed insoluble in excess (✓)
Filter(✓) the mixture into a clean test-tube	<u>Reddish brown residue</u> <u>colourless filtrate</u>
To 1cm depth of the filtrate add in <u>equal volume of</u> <u>HNO₃(aq)</u> .	<u>White ppt.</u> (✓) <u>soluble in</u> <u>NH₃(aq) to form a colourless</u> <u>solution</u> (✓)
Then add few drops of <u>AgN</u> <u>O₃(aq)</u> (\checkmark) <u>followed by</u> <u>excess NH₃(aq)</u> (\checkmark)	



OR

tests	observations
To about 1 cm depth of FA 7 in a test-tube, <u>add</u> a few drops of <u>AgNO₃(aq)</u> (✓)	<u>White ppt.</u> formed (✓)
Filter(✓) the resulting mixture into a test-tube and wash the residue with some deionised water.	<u>White residue</u> <u>Yellow filtrate</u>
Use a spatula to transfer some residue into a clean test-tube. Add excess NH ₃ (aq) to the residue. (✓)	<u>White ppt. soluble in</u> <u>NH₃(aq) to form a colourless</u> <u>solution</u> (~)



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(v) Use your observations in 3(a)(iii) to deduce the identity of the anion in FA 7.

Anion <u>C/</u> [1]

[1]

[3]

(b) Y, C₄H₆O₂, is a cyclic 5-membered organic compound which contains only one functional group. When Y is heated with aqueous sulfuric acid, FA 8 is formed as the only organic product.

Carry out the following tests on **FA 8**. Carefully record your observations in Table 3.2.

The volumes given below are approximate and should be estimated rather than measured. Test and identify any gases evolved. If there is no observable change, write **no observable change**.

Care: FA 8 is flammable. Do not use Bunsen burner for heating. Use the hot water provided if heating is required.

(i)

	tests	observations	
1	To 1 cm depth of FA 8 in a test-tube, add a 1 cm depth of dilute sulfuric acid. Then add 1 drop of aqueous potassium manganate(VII).	Purple KMnO₄ <u>decolourised</u> . (✓)	
	Place the test-tube in a beaker of hot water for two minutes.		
	FA 8 with KMnO4		
2	To 2 cm depth of FA 8 in a test-tube, carefully add half a spatula measure of sodium hydrogen carbonate.	Effervescence observed (*) CO ₂ gas gives a white ppt. with limewater. (*)	



(b) (ii) Use your observations in Table 3.2 and the information provided to suggest the structure of **FA 8** and hence deduce the structure of **Y**.



[Total: 17]

4 Planning

Citric acid, C₆H₈O₇, can be found in citrus fruit such as lemons and limes.

You are required to determine the enthalpy change for the reaction between citric acid and sodium hydrogencarbonate, NaHCO₃.

equation 6 $C_6H_8O_7(aq) + 3NaHCO_3(aq) \rightarrow Na_3C_6H_5O_7(aq) + 3H_2O(I) + 3CO_2(g) \Delta H_6$

 ΔH_6 is the enthalpy change when 1.00 mol of citric acid reacts completely with NaHCO₃.

When citric acid is mixed with NaHCO₃, the reaction absorbs heat causing a drop in the temperature of the solution.

A series of experiments can be performed where increasing volumes of citric acid and decreasing volumes of NaHCO₃ are mixed and the **temperature drop**, ΔT , for each experiment is determined.

In each of the experiments using different volumes of citric acid and NaHCO₃, the total volume has to be kept constant. The maximum amount of heat is absorbed when all the citric acid present is exactly reacted with the NaHCO₃ present.

Plotting a graph of ΔT against the volume of citric acid used will give 2 lines of best–fit. Not T against volume

Extrapolation of the two lines will produce a point of intersection from which the enthalpy change for the reaction between citric acid and NaHCO₃ can be determined.

The volume of citric acid used should be at least 10.00 cm³ and the total volume of the reaction mixture should be kept constant at 50.00 cm³ for all experiments.

(a) Using the information given, you are required to write a plan to determine the enthalpy change of reaction between citric acid and NaHCO₃(aq), ΔH_6 .

You may assume that you are provided with:

- 250 cm³ of dilute citric acid of unknown concentration
- 250 cm³ of 1.50 mol dm⁻³ NaHCO₃(aq),
- the equipment normally found in a school or college laboratory.

In your plan you should include brief details of:

- the apparatus you would use,
- the quantities you would use, including suggested volumes of citric acid and NaHCO₃(aq),
- the procedure you would follow,
- the measurements you would make,
- how the temperature drop, ΔT , is calculated to allow a suitable ΔT against the volume of citric acid graph to be drawn.



Volume of citric acid / cm ³	Volume of NaHCO3 (aq)/ cm ³	T ₁ / °C	T ₂ / °C	T _{initial} /°C	T _{min} / °C	∆T / °C	
10.00	40.0						
15.00	35.0						
20.00	30.0						
25.00	25.0						
30.00	20.0						
35.00	15.0						
40.00	10.0						
45.00	5.0						[

(b) Sketch on Fig 4.1 the graph you would expect to obtain from your results.Indicate clearly on your sketch how you would determine:

- V_{eq} , the volume of citric acid needed to just completely react with $(50 V_{eq})$ cm³ of NaHCO₃(aq).
- ΔT_{max}, the maximum temperature drop when stoichiometric amounts of citric acid and NaHCO₃(aq) are reacted.





[2]

- [1] gives correct straight line graph+ indicate ΔT_{max} correctly
- [1] indicates V_{eq} correctly

(c) Outline how you would use your answers from (b) to determine the enthalpy change of reaction between citric acid and NaHCO₃(aq), ΔH_6 .

equation 6 $C_6H_8O_7(aq) + 3NaHCO_3(aq) \rightarrow Na_3C_6H_5O_7(aq) + 3H_2O(I) + 3CO_2(g) \Delta H_6$

Express your answers in terms of ΔT_{max} and V_{eq} . It is not necessary to simplify the expression in your final answer.

You should assume that the specific heat capacity of the final solution is $4.18 \text{ J g}^{-1} \text{ K}^{-1}$ and its density is 1.00 g cm^{-3} .

Amount of NaHCO₃ in (50-V_{eq}) cm³ = $\left(\frac{50-V_{eq}}{1000} \times 1.50\right) mol$ [1] amount of citric acid in V_{eq} cm³ = $\left(\frac{50-V_{eq}}{1000} \times \frac{1.50}{3}\right)$ mol Heat change, q = mc Δ T = (50.0 × 1.00)(4.18)(Δ T_{max}) = 209 Δ T_{max} J = 0.209 Δ T_{max} kJ [1] ans. in J or kJ $\Delta H_{neut} = + \frac{(0.209\Delta T_{max})}{(\frac{50-V_{eq}}{1000} \times \frac{1.50}{3})}$ kJ mol⁻¹ [1] ecf + sign + units [3] [Total: 10]

Qualitative Analysis Notes

(a) Reactions of Aqueous Cations

a a tia n	Reaction with				
cation	NaOH(aq)	NH₃(aq)			
aluminium,	white ppt.	white ppt.			
A/ ³⁺ (aq)	soluble in excess	insoluble in excess			
ammonium, NH₄⁺(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)	grey–green ppt.	grey–green ppt. insoluble in excess			
$Cr^{3+}(aq)$	soluble in excess				
	giving dark green solution				
copper(II),	pale blue ppt.	blue ppt.			
Cu ²⁺ (aq)	insoluble in excess	soluble in excess			
	green opt turning brown on				
iron(II),	contact with air	contact with air			
Fe ²⁺ (aq)	insoluble in excess	insoluble in excess			
iron(III),	red-brown ppt.	red-brown ppt.			
Fe ³⁺ (aq)	insoluble in excess	insoluble in excess			
magnesium,	white ppt.	white ppt.			
Mg ²⁺ (aq)	insoluble in excess	insoluble in excess			
manganese(II)	off-white ppt. rapidly turning	off-white ppt. rapidly turning brown			
$Mn^{2+}(aq)$	brown on contact with air	on contact with air			
zinc,	white ppt.	white ppt.			
∠n= (aq)	soluble in excess	soluble in excess			

Anion	Reaction		
carbonate, CO ₃ ²⁻	CO ₂ liberated by dilute acids		
choride, C/⁻(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, NO₃⁻(aq)	NH_3 liberated on heating with $OH^-(aq)$ and A/ foil		
nitrite, NO₂⁻(aq)	NH_3 liberated on heating with $OH^-(aq)$ and A/ foil; NO liberated by dilute acids (colourless NO \rightarrow (pale) brown NO ₂ in air)		
sulfate, SO₄²⁻(aq)	gives white ppt. with Ba ²⁺ (aq) (insoluble in excess dilute strong acids)		
sulfite, SO ₃ ²⁻(aq)	SO ₂ liberated on warming with dilute acids; gives white ppt. with Ba ²⁺ (aq) (soluble in excess dilute strong acids)		

(c) Tests for Gases

gas	Test and test results		
ammonia, NH₃	turns damp red litmus paper blue		
carbon dioxide, CO2	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 acidified aqueous 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, I2	black solid/purple gas	brown	purple