



NAME

CT GROUP

20S

CHEMISTRY

9729/04

Paper 4 Practical

18 August 2021

2 hours 30 minutes

Candidates answer on the Question Paper

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 17 and 18.

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.

Shift
Laboratory

For Examiner's Use	
1	
2	
3	
4	
Total	

This document consists of **18** printed pages.

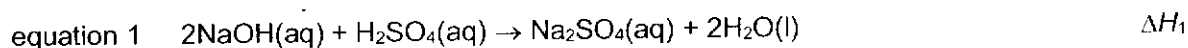
1 Determination of the values for the enthalpy changes associated with several chemical reactions and concentration of aqueous sodium hydroxide

FA 1 is aqueous sodium hydroxide, NaOH

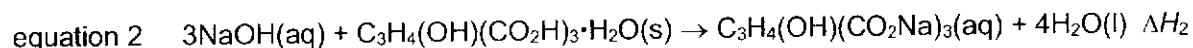
FA 2 is 1.00 mol dm⁻³ sulfuric acid, H₂SO₄

FA 3 is citric acid crystals, C₃H₄(OH)(CO₂H)₃·H₂O

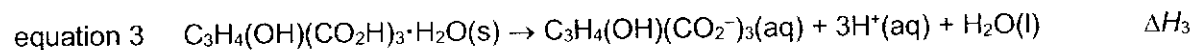
Sodium hydroxide and sulfuric acid react according to equation 1. The enthalpy change for the reaction is ΔH_1 .



Sodium hydroxide and citric acid crystals react according to equation 2. The enthalpy change for the reaction is ΔH_2 .



In this question, you will perform experiments to determine the values for ΔH_1 and ΔH_2 . You will use your values of ΔH_1 and ΔH_2 to calculate a value for the enthalpy change shown in equation 3.



In **1(c)**, you will use data provided to determine the concentration of sodium hydroxide in **FA 1**.

- (a) You will follow the instructions to perform experiments 1 and 2. Record your results in the space provided on page 3.

Experiment 1

- Using a measuring cylinder, transfer 50.0 cm³ of **FA 1** into a Styrofoam cup. Place this cup inside a second Styrofoam cup, which is placed in a 250 cm³ glass beaker.
- Stir and measure the temperature of this **FA 1**, T_{FA1} .
- Using another measuring cylinder, measure 20.0 cm³ of **FA 2**.
- Stir and measure the temperature of this **FA 2**, T_{FA2} .
- Add the **FA 2** from the measuring cylinder to the **FA 1** in the Styrofoam cup.
- Using the thermometer, stir the mixture continuously until it reaches its maximum temperature. Record this temperature, T_{max} .

Experiment 2

- Weigh the capped bottle containing **FA 3**.
- Using a measuring cylinder, transfer 50.0 cm³ of **FA 1** into the other clean Styrofoam cup. Place this cup inside the used Styrofoam cup, which is placed in a 250 cm³ glass beaker.
- Stir and measure the temperature of this **FA 1**, T_{FA1} .
- Add all the **solid FA 3** to the **FA 1** in the Styrofoam cup.
- Using the thermometer, stir the mixture continuously until it reaches its maximum temperature. Record this temperature, T_{max} .
- Reweight the empty bottle and its cap.

In an appropriate format in the space below,

- record all measurements of temperature,
- record all measurements of mass,
- calculate the values for the average of T_{FA1} and T_{FA2} , T_{ave} , and ΔT_{max} for experiment 1,
- calculate the mass of **FA 3** added and ΔT_{max} for experiment 2.

$$T_{ave} = \frac{(50 \times T_{FA1}) + (20 \times T_{FA2})}{70}$$

[3]

(b) Given that:

- sodium hydroxide is used in excess in experiments 1 and 2;
- M_r of $C_3H_4(OH)(CO_2H)_3 \cdot H_2O$ is 210.0;
- specific heat capacities of the Styrofoam cup, lid and thermometer are negligible;
- specific heat capacity of the mixture is $4.18 \text{ J g}^{-1} \text{ K}^{-1}$;
- density of the mixture is 1.00 g cm^{-3} ,

- (i) calculate the heat change, q_1 , for Experiment 1 and hence determine a value for the enthalpy change ΔH_1 shown in equation 1.

$q_1 = \dots\dots\dots$

$\Delta H_1 = \dots\dots\dots$

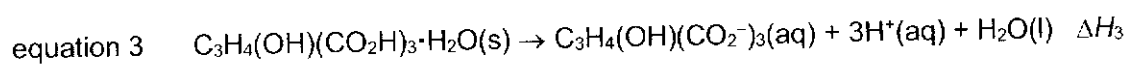
[2]

- (ii) calculate the heat change, q_2 , for Experiment 2 and hence determine a value for the enthalpy change ΔH_2 shown in equation 2.

$$q_2 = \dots\dots\dots$$

$$\Delta H_2 = \dots\dots\dots [2]$$

- (iii) Use your values of ΔH_1 and ΔH_2 to determine a value for the enthalpy change ΔH_3 shown in equation 3. Show your working clearly.



$$\Delta H_3 = \dots\dots\dots [2]$$

(iii) Using your graph, determine the concentration of sodium hydroxide in FA 1.

concentration of sodium hydroxide in FA 1 = [2]

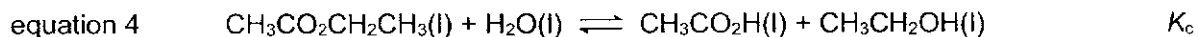
[Total: 14]

1

2 Planning

The hydrolysis of an ester is catalysed by either an acid or alkali. In the presence of an acid catalyst, the reaction is reversible and reaches equilibrium in about 48 hours.

Ethyl ethanoate hydrolyses to give ethanoic acid and ethanol as shown in equation 4.



- (a) To determine the equilibrium constant, K_c , it is necessary to determine the amounts of ethyl ethanoate, water, ethanoic acid and ethanol present in the equilibrium mixture. One way of doing this is described below.

Known amounts of ethyl ethanoate and an acid catalyst are mixed in a sealed reagent bottle. After sufficient time, the whole equilibrium mixture is diluted with deionised water. Titration with a standard solution of sodium hydroxide determines the total amount of acid in the mixture: both ethanoic acid and the acid catalyst.

Since the amount of acid catalyst does not change, it is possible to deduce the amount of ethanoic acid and hence the amounts of each of the other components in the equilibrium mixture.

Using these data, a value for K_c may then be determined.

Plan a procedure to collect sufficient data to allow you to determine a value for K_c in equation 4 at 40 °C.

You should plan to make an initial reaction mixture containing

- 5.00 g of ethyl ethanoate,
- 5.00 cm³ of 2.00 mol dm⁻³ hydrochloric acid.

You may assume that you are also provided with:

- 1.50 mol dm⁻³ sodium hydroxide,
- the equipment and materials normally found in a school or college laboratory.

In your plan you should include brief details of:

- the apparatus you would use,
- the procedure you would use to prepare the equilibrium mixture,
- the procedure you would use to determine the total amount of acid in the equilibrium mixture,
- the measurements you would make.

In your plan, you will titrate the **whole** equilibrium mixture so only **one** titration can be carried out.

- (b) Describe how you would use your results obtained in 2(a) to calculate the amounts in moles of
- all the components in your initial reaction mixture,
 - ethanoic acid present in this mixture at equilibrium,
 - all the other components in this mixture at equilibrium.

You may assume that 1.00 cm^3 of hydrochloric acid contains 1.00 cm^3 of water and that the density of water is 1.00 g cm^{-3} .

M_r $\text{CH}_3\text{CO}_2\text{CH}_2\text{CH}_3$, 88.0; H_2O , 18.0.

You do **not** need to show how a K_c value is calculated.

[4]

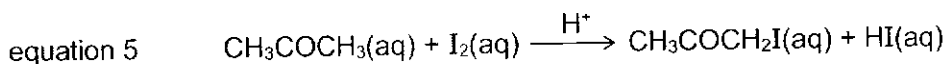
- (c) Explain how diluting the equilibrium mixture before titrating it with sodium hydroxide ensures the accuracy of the amount of ethanoic acid present at equilibrium.

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

[Total: 11]

3 Investigation of the kinetics of an acid-catalysed reaction between propanone and iodine

The reaction between propanone and iodine in aqueous solution is catalysed by hydrogen ions:



In this experiment you are to investigate how the rate of the reaction is affected by changes in the concentration of iodine.

You are provided with the following chemicals:

FA 4 is 0.0100 mol dm⁻³ sodium thiosulfate, Na₂S₂O₃

FA 5 is aqueous iodine, I₂

FA 6 is hydrochloric acid, HCl

FA 7 is propanone, CH₃COCH₃

FA 8 is sodium hydrogen carbonate, NaHCO₃

(a) (i) Preparation and titration of the reaction mixture

Notes:

- Please cap **FA 5** and **FA 7** after use.
- You should **keep the reaction mixture stoppered** except when removing aliquots.
- You will perform each titration **once** only. Great care must be taken that you do not overshoot the end-point.
- Once you have started the stopwatch, it must continue running for the duration of the experiment. You must **not** stop it until you have finished this experiment.
- You should aim to transfer your first aliquot within the first three minutes of starting the reaction.
- You should aim **not** to exceed a maximum reaction time of **20 minutes** for this experiment.

In Table 3.1 provided on page 11, record for each aliquot

- the time of transfer, *t*, in minutes and seconds,
- the decimal time, *t_d*, in minutes to 0.1 min, for example, if *t* = 3 min 22 s then *t_d* = 3 min + 22/60 min = 3.4 min,
- the burette readings and the volume of **FA 4** added.

1. Fill a burette with **FA 4**.
2. Using measuring cylinders, add 50.0 cm³ of **FA 5** and 25.0 cm³ of **FA 6** to the conical flask labelled **reaction mixture**.
3. Using a measuring cylinder, add 25.0 cm³ of **FA 7** to the same conical flask. Start the stopwatch. **Insert the stopper** and swirl the mixture thoroughly to mix its contents.
4. Using a measuring cylinder, add 20.0 cm³ of **FA 8** to a second conical flask.
5. Transfer a 10.0 cm³ aliquot (portion) of the reaction mixture to a 10 cm³ measuring cylinder, using a dropping pipette.
6. **Immediately** transfer this aliquot into the conical flask containing **FA 8** and vigorously swirl the mixture. Read and record the time of transfer in minutes and seconds, to the nearest second, when the aliquot is added.
7. **Immediately** titrate the I₂ in the conical flask with **FA 4** until the solution is pale yellow. Add 1 cm³ of starch indicator into this solution and continue titrating until the point when the solution just turns colourless. Record your titration results.
8. Wash out the conical flask with water.
9. Repeat steps 4 to 8 until a total of **five** aliquots have been titrated and their results recorded.

Table 3.1

aliquot	t		t_d / min	final burette reading / cm^3	initial burette reading / cm^3	volume of FA 4 / cm^3
	min	s				
1						
2						
3						
4						
5						

[3]

(ii) Plot a graph of the volume of FA 4 added, on the y-axis, against decimal time, t_d , on the x-axis on the grid in Fig. 3.1.

Draw the most appropriate best-fit graph taking into account all of your plotted points. Extrapolate (extend) your graph to $t_d = 0.0 \text{ min}$.

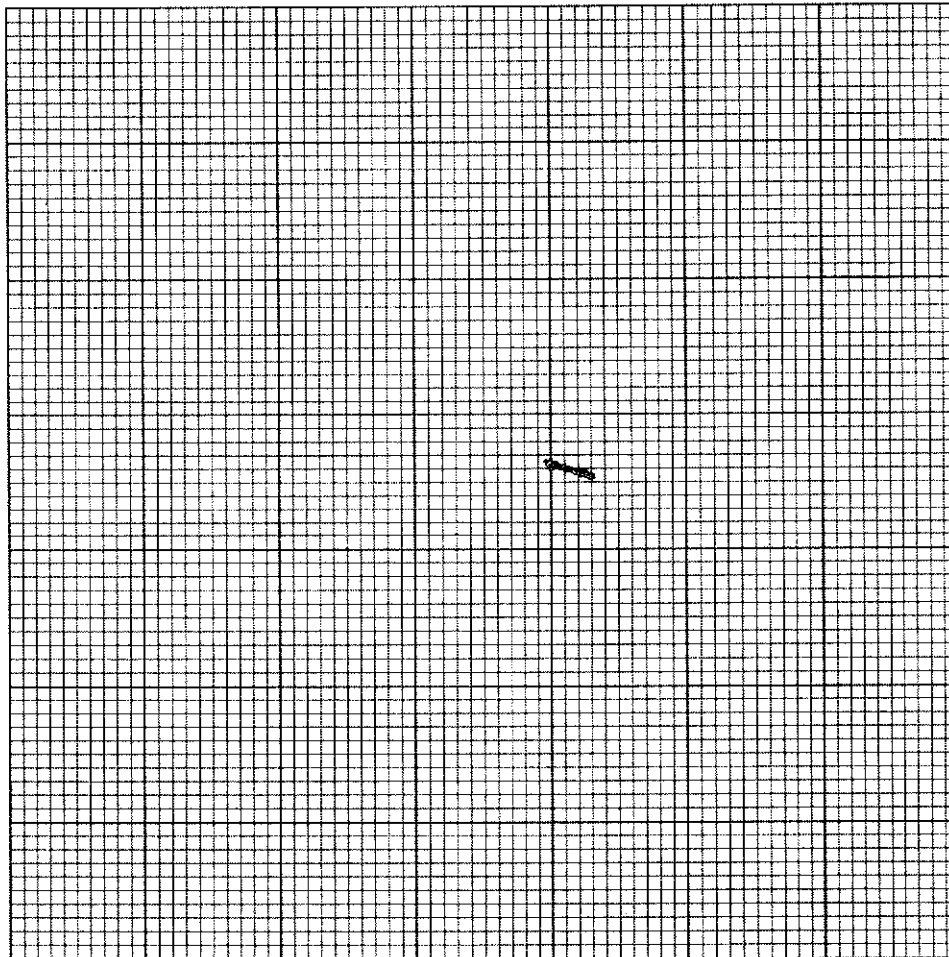


Fig. 3.1

[3]

(b) The initial rate of change of the concentration of iodine, **FA 5**, $[I_2]$, can be determined from the gradient of the graph in Fig. 3.1 at time $t_d = 0.0$ min.

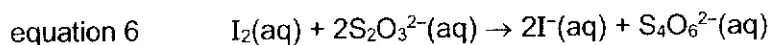
(i) Determine the gradient of graph at time $t_d = 0.0$ min, showing clearly how you did this.

gradient = $\text{cm}^3 \text{min}^{-1}$ [2]

(ii) Use your gradient to determine the rate of change of the amount of $S_2O_3^{2-}$ ions required in mol min^{-1} .

rate of change of the amount of $S_2O_3^{2-}$ required = mol min^{-1} [1]

(iii) Sodium thiosulfate and iodine react as shown in equation 6.



Determine the change in amount of I_2 per minute and hence deduce the rate of change of $[I_2]$ at $t_d = 0.0$ min, in $\text{mol dm}^{-3} \text{min}^{-1}$.

rate of change of $[I_2]$ at $t_d = 0.0$ min = $\text{mol dm}^{-3} \text{min}^{-1}$ [4]

(iv) What is the order of reaction with respect to $[I_2]$? Use evidence from your graph in Fig. 3.1 to support your answer.

.....
[1]

- (c) Suggest a modification to the chemicals used in the procedure to investigate the order with respect to [propanone]. Explain briefly how you will use your results from this new experiment, **together** with your previous results, to confirm that it is first order with respect to [propanone].

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

[Total: 16]

4 Identification and investigations of some reactions of FA 9

Solid FA 9 is a hydrated salt containing one cation and one anion from the Qualitative Analysis Notes on pages 17 – 18.

You are provided with solid **FA 9** in a capped bottle, and with solution **Y**, which you are not required to identify.

In addition to having access to the usual bench reagents, you are also provided with aqueous potassium iodide, KI.

You will also need access to the **FA 8** solution you used earlier.

- (a) Place four spatulas full of solid **FA 9** into a small beaker, and add approximately 40 cm³ of deionised water. Stir the solution thoroughly to ensure all the solid has dissolved. This is **FA 9 solution**.

Carry out the following tests. Carefully record your observations in Table 4.1.

Unless otherwise stated, the volumes given below are approximate and should be estimated rather than measured. You only need to carry out tests for gases when instructed to do so.

Table 4.1

tests		observations
1.	Test the FA 9 solution you prepared using Universal Indicator paper.	
2.	To 1 cm depth of FA 9 solution in a test-tube, add aqueous sodium hydroxide slowly, with shaking, until no further change is seen.	
3.	To 1 cm depth of FA 9 solution in a test-tube, add aqueous ammonia slowly, with shaking, until no further change is seen.	
4.	(i) To 1 cm depth of FA 9 solution in a test-tube, add a further 2 cm depth of FA 8 dropwise, with shaking.	
	(ii) Transfer 1 cm depth of the resultant mixture to a clean test-tube. Add aqueous sodium hydroxide slowly, with shaking, until no further change is seen. Then, add dilute nitric acid dropwise until no further change is seen.	

tests		observations
5.	<p>Add 1 cm depth of FA 9 solution to a test-tube.</p> <p>Add an equal volume of aqueous silver nitrate.</p>	
6.	<p>(i) Using a graduated plastic dropper, add 3 cm³ of FA 9 solution to a boiling tube.</p> <p>Add 9 drops of solution Y to the tube. A precipitate is formed. Do not add too much solution Y as the precipitate will dissolve.</p> <p>Carefully warm the contents of the boiling tube and test any gas produced with moist litmus paper. Be careful not to let any liquid be propelled out of the tube.</p> <p>Allow the boiling tube and its contents to cool, note its appearance and label this solution as FA 10, to be used in test 6(ii).</p>	
	<p>(ii) Add 1 cm depth of aqueous potassium iodide to a test-tube.</p> <p>Using a plastic dropper, add FA 10 dropwise, with shaking, until no further change is seen.</p>	

[7]

(b) (i) Identify the cation in **FA 9**.

cation [1]

(ii) Suggest an identity for the anion in **FA 9**.

anion [1]

(iii) A further test has to be carried out after adding aqueous silver nitrate in test 5 to confirm the identity of the anion in **FA 9**.

State the reagent you would use and the observation you will expect in this test.

reagent:

observation:

[1]

(c) Account for the chemistry behind the observations in test 4(i).

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

[2]

(d) Using your answer to (b)(ii) and by considering your observations in test 6,

(i) state the *role* of solution Y in the reaction between FA 9 solution and solution Y.

role of solution Y [1]

(ii) explain, in terms of the chemistry involved, how one of the observations in test 6 supports your answer to (d)(i). You are not required to identify solution Y.

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

[1]

[Total: 14]

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 aqueous anions

<i>anion</i>	<i>reaction</i>
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, $\text{Cl}^-(\text{aq})$	gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$)
bromide, $\text{Br}^-(\text{aq})$	gives pale cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$)
iodide, $\text{I}^-(\text{aq})$	gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$)
nitrate, $\text{NO}_3^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
nitrite, $\text{NO}_2^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil; NO liberated by dilute acids (colourless $\text{NO} \rightarrow$ (pale) brown NO_2 in air)
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	SO_2 liberated with dilute acids; gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in dilute strong acids)

(c) Test for gases

<i>gas</i>	<i>test and test result</i>
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

<i>halogen</i>	<i>colour of element</i>	<i>colour in aqueous solution</i>	<i>colour in hexane</i>
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



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2021 C2 H2 CHEMISTRY PRELIM PAPER 4
SUGGESTED SOLUTIONS

1(a) Sample answer:

	experiment 1	experiment 2
$T_{FA1} / ^\circ\text{C}$	29.4	29.2
$T_{FA2} / ^\circ\text{C}$	29.6	-
$T_{\text{max}} / ^\circ\text{C}$	38.2	35.0
$T_{\text{ave}} / ^\circ\text{C}$	29.5	-
$\Delta T_{\text{max}} / ^\circ\text{C}$	8.7	5.8

mass of capped bottle and FA3 = 7.56 g

mass of capped bottle and residual FA3 = 5.50 g

mass of FA3 added = 2.06 g

Records temperature / $^\circ\text{C}$ and mass / g

Correct headers and units (included in the header or with each entry in the table) [1]

All temperatures recorded to 0.1 $^\circ\text{C}$, and mass to 0.01 g [1]

Correctly calculates T_{ave} and ΔT_{max} for experiment 1 and ΔT_{max} for experiment 2 and mass of FA3 added is about 2.1-2.2 g. [1]

In general, the recording of data is well done – the requisite data was captured, and the precision used was appropriate. There was a wide variety of formats but they were generally acceptable. It is highly recommended that recordings should be grouped in a systematic manner, so that data can be retrieved quickly for calculations.

The most common omission was the absence of ΔT_{max} for experiment 1 and experiment 2, though they may be determined in the calculation of q_1 and q_2 . Candidates were not penalized for this, but it is a good experimental practice to record and process all the necessary data coherently, especially when the question asks for it.

The instructions requested for candidates to weigh the bottle, the contents and the cap, but some candidates either failed to include the mass of the cap before, or after emptying the bottle. This caused the measurement of the mass of solid used to be inaccurate. This is a reminder to be systematic in your experimental procedures.

1(b)(i) $q_1 = mc\Delta T = (50.0 + 20.0) \times 4.18 \times \Delta T_{\text{max}}$ J (accept kJ) [1]

$$n_{\text{H}_2\text{SO}_4} = 1.00 \times 20/1000 = 0.02 \text{ mol}$$

$$\Delta H_1 = -\frac{q_1}{0.02} \text{ J mol}^{-1} \text{ (accept kJ mol}^{-1}\text{)} [1]$$

The quantity, q_1 , refers to the amount of energy transferred to the mixture by the (exothermic) chemical reaction. This quantity is measured in joules or kilojoules, and does not have a sign.

The mass, m , refers to the total mass of mixture present, i.e. 70.0 g, which is calculated using the total volume of mixture multiplied by density of mixture.

ΔT_{max} refers to the temperature change of the mixture, i.e. the difference between T_{max} and T_{avg} .

The enthalpy change of reaction, ΔH_1 , is the amount of heat given out per mole of the reaction in equation 1, i.e. when 2 mol of NaOH reacts with 1 mol of H_2SO_4 . To find ΔH_1 , in this case, we divide q_1 by the amount of H_2SO_4 since it is the limiting reagent. ΔH_1 is negative because this is an exothermic reaction, i.e. the temperature of the reaction mixture increases. The appropriate sign has to be incorporated into the calculation at this point.

1(b)(ii) $q_2 = mc\Delta T = 50.0 \times 4.18 \times \Delta T_{max}$ J (accept kJ) [1]

$n(\text{citric acid}) = \text{mass added} \div 210 = c$ mol

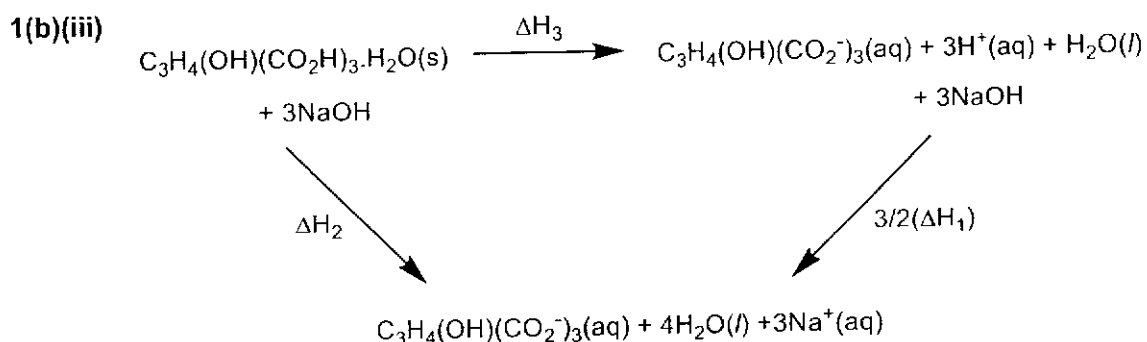
$\Delta H_2 = -\frac{q_2}{c}$ J mol⁻¹ (accept kJ mol⁻¹) [1]

All comments about q_1 are applicable to q_2 .

In addition, the mass, m , refers to the mass of mixture, i.e. 50.0 g, which is calculated using the volume of mixture multiplied by density of mixture. It does not include the mass of the solid as we assumed that the volume of mixture remains constant at 50.0 cm³ after adding the solid.

An extension question to think about, before turning to the last page to check your answer.

Q: Another student mixed 50.0 cm³ of 1.00 mol dm⁻³ sodium hydroxide with an excess amount of citric acid solid using the procedure for experiment 2. Explain why using **excess citric acid solid** would make his value for ΔH_2 incorrect.



$$\Delta H_3 = \Delta H_2 - \frac{3}{2} \times \Delta H_1$$

- Correctly constructs energy cycle or uses equations in working [1]
Correctly applies Hess' Law [1]

Constructing this Hess cycle requires an addition of stoichiometric amounts of NaOH on both sides of equation 3. This allows ΔH_1 and ΔH_2 to be incorporated into the complete cycle.

- ΔH_1 depicts the reaction between 2 mol of NaOH and 1 mol of H_2SO_4 while the Hess cycle depicts the reaction of 3 mol of NaOH. Hence, we need to multiply ΔH_1 by 3/2 in the cycle.
- In the statement of Hess's law, the sign of ΔH_1 was changed because the direction of the arrow was reversed.

- 1(c)(i) Draws two best-fit straight lines, extend both lines until they cross and V_{FA1} at point of intersection is $34.5 \pm 0.5 \text{ cm}^3$. [1]

The best-fit lines are generally well-drawn.

Do note that the graphs were obtained by plotting the temperature change of seven separate solutions containing different proportions of NaOH and H_2SO_4 . This is not a thermometric titration.

As such, best-fit lines, rather than curves, were expected. Candidates should follow the instructions in the question which says 'draw two best-fit straight lines'.

An extension question to think about, before turning to the last page to check your answer.

Q: Explain why in these experiments the change in temperature, ΔT , is proportional to the amount of water formed.

- 1(c)(ii) At the point of intersection, volumes/ amount of NaOH and H_2SO_4 reacted are exact / neither NaOH and H_2SO_4 are in excess. [1]
The maximum amount of water is formed so the maximum amount of heat is evolved and ΔT is maximum. [1]

Or words to the effect

Most students mistook the experiment for a thermometric titration, and failed to recognize that at the point of intersection, neither NaOH nor H_2SO_4 are in excess. It was not sufficient to say that the NaOH or H_2SO_4 is fully neutralized, because there is always a complete reaction of either NaOH or H_2SO_4 at each point of the graph.

Most students were also unable or did not explain why ΔT is maximum at the point of intersection. A clear reference to the concept of the enthalpy change of neutralization was required to earn credit. The maximum amount of heat was evolved because the most amount of water was produced by the given proportion of NaOH and H_2SO_4 .

- 1(c)(iii) At the point of intersection, $V_{FA1} = V_{NaOH} = v \text{ cm}^3$
 $V_{H_2SO_4} = 50 - v \text{ cm}^3$

$$n(H_2SO_4) = 1.00 \times (50 - v)/1000$$

$$n(NaOH) = 2 \times n(H_2SO_4) \quad [1]$$

$$[NaOH] \text{ in FA1} = \frac{n(NaOH)}{v} \times 1000 \text{ mol dm}^{-3} \quad [1]$$

This question was generally well done.

2

General comments:

Many candidates found this question on chemical equilibrium challenging. A large number of plans were poorly described and unlikely to yield any results if carried out. On the other hand, candidates who read the information in the question carefully and wrote their answers according to the given outline, bullet points and requirements were usually able to come up with coherent plans.

Candidates are reminded to write legibly and present their answers clearly. For example, number the experimental steps in part (a) and write mathematical expressions in part (b). Candidates should not give answers that are not required. For example, the question did not require a justification of the quantities used (since the quantities are given) and treatment of results is not considered a part of the experimental procedure in (a).

- (a) The marks in the six boxes are awarded as follows:

Appropriate apparatus: electronic balance, burette/micropipette,
 thermostatically controlled water bath 3 × [½]

Leave mixture in sealed bottle (or sealed conical flask)
 for at least 48 hr 2 × [½]
 Do not accept beaker and test-tube

Dilute equilibrium mixture (in a conical flask) with rinsing / Add water (directly)
 to mixture in conical flask and titrate whole mixture 2 × [½]
 Mark is lost if water is added to initial mixture or repeats titration or eqm mixture
 is placed in burette instead of conical flask

Titrate quickly with NaOH [½]

Use suitable indicator (phenolphthalein/ thymol blue/ thymolphthalein) * Do not
 accept methyl orange
 and correct colour change (colourless to pink/ yellow to blue/ colourless to
 blue) 2 × [½]

Record masses (allow TARE) and initial and final burette readings 2 × [½]

Preparation of initial mixture

1. Use an electronic balance to weigh accurately 5.00 g of ester into a reagent bottle*.
Record: mass of empty bottle, mass of bottle + ester.
2. Using a burette, add 5.00 cm³ of HCl.
3. Insert the stopper and shake the bottle to mix the contents.
4. Leave the bottle in a thermostatically controlled water bath set at 40°C for 48 hours to reach equilibrium.

Titration of equilibrium mixture

5. Fill a burette with NaOH. Record the initial burette reading.
6. Transfer the equilibrium mixture into a 250 cm³ conical flask.
7. Rinse the reagent bottle with 50 cm³ of deionised water. Transfer all washings into the conical flask.
8. Add 2 to 3 drops of phenolphthalein indicator.
9. Quickly titrate the acids with NaOH until the solution changes from colourless to pink.
10. Record the final burette reading.

* Allow conical flask with stopper for initial mixture. Dilution and titration can be done in the same conical flask without transfer or rinsing (remove step 6, step 7 only need to add deionised water; no rinsing is needed).

Preparation of initial mixture:

Candidates should follow the instruction to prepare the initial mixture using 5.00 g of ethyl ethanoate and 5.00 cm³ of hydrochloric acid. These quantities will be needed in the calculation of K_c . They must be measured with precise apparatus.

The 5.00 g of ester is measured with an electronic balance. Many candidates did not read the state symbols in equation 4 and thought the ester is a solid. Do not think that only solids can be measured with an electronic balance. To avoid having to account for the residual liquid left in a weighing bottle, the ester can be weighed in the reagent bottle directly.

Hydrochloric acid should also be added directly into the reagent bottle from a burette. Measuring it with a burette into a measuring cylinder, then transferring into the reagent bottle is redundant. Such 'multiple transfers' is erroneous as the volumes used would not be accurate.

Hydrochloric acid provides both the acid catalyst and the water needed for hydrolysis. Candidates who added water to the initial mixture are penalised for not following instructions given in the question. Part (b) is made more difficult as the additional amount of water must be included in the calculations.

The initial mixture must be allowed to reach equilibrium in a closed system. In the given outline, it is clearly stated that a 'sealed reagent bottle' is used. Many candidates tried using a whole range of apparatus from volumetric flasks to beakers and test-tubes. A beaker cannot be properly sealed and a test-tube is too small for proper mixing (in this case). Both are not accepted.

Since the plan is to determine a value for K_c at 40 °C, the mixture must be placed in a thermostatically controlled water bath for at least 48 hours (duration is stated at the start of the question). It is important to ensure a constant temperature. Heating with a Bunsen burner or hotplate is not accepted. Time need not be exact so it is not necessary to measure it with a stopwatch.

Titration of equilibrium mixture:

In the given outline, the whole equilibrium mixture must be diluted before titrating with sodium hydroxide. The reason for dilution is explained below. The volume of water used need not be precise. It should not be too large (e.g. 250 cm³) such that swirling becomes difficult or the conical flask may overflow during the titration!

Errors seen included: wrongly diluting the initial mixture instead, preparing a 250 cm³ diluted solution and titrating an aliquot (e.g. 25.0 cm³), placing the diluted mixture in the burette and sodium hydroxide in the conical flask.

While it is important to repeat the titration to obtain consistent results, it is more important to follow the instructions in the question. Candidates who did not follow the instruction to only carry out one titration made the calculations in (b) more complex for themselves.

Since the whole mixture must be titrated (i.e. all the acids must be neutralised), the mixture should be placed in the conical flask (not burette).

There is no instruction given to dilute the sodium hydroxide. Again, candidates who failed to read the question carefully made the calculations in (b) more complex.

The equilibrium mixture contains both a strong acid (HCl) and a weak acid (ethanoic acid). The pH at the (second) equivalence point is greater than 7. Hence, methyl orange is not a suitable indicator. Do not use universal indicator in titrations!

During the titration, ethanoic acid is neutralised so the position of equilibrium will shift right (based on Le Chatelier's principle). To minimise any shifts in position of equilibrium, the mixture was diluted to slow down the rate of reaction (both forward and backward). In addition, the titration must be done quickly to accurately determine the amount of ethanoic acid present in the equilibrium mixture. There is no need to maintain the temperature of sodium hydroxide and the equilibrium mixture at 40 °C during the titration. In practice, this is hard to achieve. The dilution and quick titration is sufficient to ensure results are accurate.

Finally, make sure you include the measurements you would make in your plan (see last bullet point). Many candidates did not describe the mass measurements. Of those who did, only a small number were able to do so clearly. Consider presenting the mass measurements in the form of a table. Take note that we record initial and final burette readings (these are your raw measurements), not burette volumes or titres (these are processed data).

2(b)

Initial mixture

mass of H₂O = 5 g (since 5 cm³ of HCl is used)

$n(\text{H}_2\text{O}) \text{ initial} = 5 / 18 = \mathbf{0.278 \text{ mol}}$ [1]

$n(\text{ester}) \text{ initial} = 5 / 88 = \mathbf{0.0568 \text{ mol}}$ [½]

$n(\text{HCl}) = 2.00 \times 5.00/1000 = \mathbf{0.0100 \text{ mol}}$ [½]

Let volume of NaOH needed to react with the acids = V dm³

$n(\text{NaOH}) \text{ used} = 1.50 \times V = 1.5V \text{ mol} = \text{total moles of acid}$

Equilibrium mixture

$n(\text{CH}_3\text{CO}_2\text{H}) \text{ in equilibrium mixture} = \mathbf{1.5V - 0.01 \text{ mol}}$ [½]

$n(\text{CH}_3\text{CH}_2\text{OH}) = n(\text{CH}_3\text{CO}_2\text{H}) = 1.5V - 0.01 \text{ mol}$ [½]

$n(\text{ester}) = \mathbf{0.0568 - n(\text{CH}_3\text{CO}_2\text{H})} = 0.0668 - 1.5V \text{ mol}$ [½]

$n(\text{H}_2\text{O}) = \mathbf{0.278 - n(\text{CH}_3\text{CO}_2\text{H})} = 0.288 - 1.5V \text{ mol}$ [½]

Two misconceptions were commonly seen: 'Amount' does not refer to concentration. It refers to number of moles (stated in the question!). It is incorrect to say a certain reagent is limiting or in excess since the reaction does not go to completion. At equilibrium, all the reagents and products are present (none are used up). The amount do not change as the rate of forward and backward reactions are now the same.

When describing the calculations, use mathematical expressions. Do not write the steps in prose form. They are usually incomplete and extremely difficult to follow!

Follow the bullet points. They are ordered to guide your thinking process.

Many candidates did not know how to use the information given (after the bullet points in (b)) to calculate the initial amount of water. Those who added water to the initial mixture are penalised here if they did not include the (additional) amount of water added. Water added to dilute the equilibrium mixture should not be included as the mixture is already at equilibrium.

The volume of sodium hydroxide is measured with a burette so the units should be in cm³. However, you may define the volume as 'V dm³' to simplify the expressions. Candidates who diluted sodium hydroxide are penalised if they used an incorrect concentration in their calculations.

Many candidates who titrated an aliquot (instead of the whole mixture) failed to perform the necessary scaling to correctly calculate the amount of ethanoic acid present in the whole mixture. A common mistake is to subtract the amount of HCl added to the initial mixture from the total amount of acid in the aliquot. A small number of candidates mixed up ethyl ethanoate, ethanoic acid and ethanol and gave incorrect answers.

2(c)

Diluting the mixture lowers the concentration of the components and catalyst and slows down the rate of reaction [½], preventing the position of equilibrium from shifting [½] during the titration.

Many candidates found this challenging. Some suggested dilution will reduce the concentration of acids and decrease the titre so that it is within the capacity

of burette. Others suggested the titre will increase and reduce the percentage error. Both showed misconceptions in basic stoichiometry concepts. It is common to use water to rinse any reagents from the sides of the conical flask during titration. Adding water lowers the concentration but the number of moles in the flask and hence titre will not be affected!

- 3(a)(i) Correct precision for burette readings and volume of **FA 4** (to nearest 0.05 cm³)
and
 Gives t_d to 0.1 min [1]

Calculates t_d correctly

1 – 2 s = 0.0 min	21 – 26 s = 0.4 min	45 – 50 s = 0.8 min
3 – 8 s = 0.1 min	27 – 32 s = 0.5 min	51 – 56 s = 0.9 min
9 – 14 s = 0.2 min	33 – 38 s = 0.6 min	57 – 59 s = 1.0 min
15 – 20 s = 0.3 min	39 – 44 s = 0.7 min	

and

Calculates volume of **FA 4** correctly [1]

Records **five** sets of data **within 20 min**

and

First data taken within 1 to 4 min

and

Well-spaced time intervals within 2 to 6 min [1]

Since the table was provided, the recording of data was generally well done – most students were able to record burette readings to nearest 0.05 cm³ and decimal time to 1 d.p. The five chosen times should be evenly spread out to get a better spread of data points for use in graphical analysis later.

- 3(a)(ii) Axes correct way round + correct labels + units + scale [1]

*Sensible linear scale must be chosen so that plotted points occupy **at least half** the graph grid in **both** x and y directions.

Students need **not** include the origin (0,0) in their graph. However, the x-axis should start from 0, as the question clearly stated to extend your graph to 0 min. E.g. of sensible scale – every 10 small squares is 2 or 2.5 or 4 or 5 units.

Check **all** points are correctly plotted to within ½ small square. [1]

Any wrongly plotted or missing point(s) will lose this mark. Choosing whole numbers for t_d (e.g. 3.0, 6.0, etc.) would make plotting of points relatively faster, and result in fewer mistakes made.

Draws **best-fit straight** line (a good distribution of points on each side of the line if these points do not lie on the line)

and

At least **four** points within $\pm 0.50 \text{ cm}^3$ of the straight line (accuracy mark). [1]

Do not allow mark if clearly anomalous points are included

When drawing a best-fit straight line, ensure there are equal number of points on both sides of the best-fit line and the points on different sides of the line are preferably about the same distance from the line.

If one point is very far from the other points, then it would make no sense to include it when drawing the line of best-fit. In this case, you should consider the point to be anomalous, annotate and ignore it when drawing the best-fit line.

Many candidates attempted to force a curve when the data clearly showed a straight line. This led to inconsistencies across their answers. As a matter of scientific principle and integrity, you should report your data as it is.

3(b)(i) Shows clearly the two chosen points (either on the graph or in working) [1]

Calculates gradient correctly with correct negative sign [1]

3(b)(ii) rate of change of $n(\text{S}_2\text{O}_3^{2-})$
= gradient $\times 10^{-3} \times 0.01$ [1]

3(b)(iii) Amt of I_2 per min
= rate of change of $n(\text{S}_2\text{O}_3^{2-}) \div 2$ (mole ratio: $2\text{S}_2\text{O}_3^{2-} \equiv \text{I}_2$) [1]

rate of change of $[\text{I}_2]$
= Amt of I_2 per min $\div 10/1000$ (i.e. volume of aliquot) [1]

Shows working in **all** calculations in 1(b)(i), 1(b)(ii), 1(d)(iv), 3(b)(i), 3(b)(ii), 3(b)(iii).

All calculations must be relevant although they may not be complete or correct.

and

correct **negative sign** in **all** final answers in 3(b)(i), 3(b)(ii), 3(b)(iii) [1]

Any calculation not attempted loses this mark.

Shows appropriate significant figures (3 or 4 sf) in **all** final answers in 1(b)(i), 1(b)(ii), 1(b)(iii), 1(d)(iv), 3(b)(i), 3(b)(ii), 3(b)(iii)

and

appropriate units in **all** answers in 1(b)(i), 1(b)(ii), 1(b)(iii) (J or kJ for q , J mol^{-1} or kJ mol^{-1} for ΔH); 1(d)(iv) (mol dm^{-3}). [1]

Any calculation not attempted loses this mark.

Final answers refer to those written on the line provided. **If** this is absent, consider final answer in working.

The last two marks are assessed across Questions 1 and 3. Any calculation not attempted loses these 2 marks. Any quantity that is not calculated does not allow the examiner to assess your ability to show appropriate significant figure or units in your final answer.
You are advised to have proper time management throughout the exam so that you can attempt all calculations parts.

3(b)(iv) Zero order.

A **straight-line** graph OR graph with **constant gradient** is obtained [$\frac{1}{2}$] which means that **rate is constant while concentration of I_2 decreases** OR **rate is independent of $[I_2]$** during reaction. [$\frac{1}{2}$]

Your answer needs to have an idea of linear/straight line **and its significance** to be awarded full credit (A curve drawn in (a)(ii) automatically loses this mark).

The y-axis of the graph is volume of thiosulfate titrated, which is proportional to the amount of iodine present in the aliquot, and hence correlates to the concentration of iodine (reactant), which is decreasing with time.

In this concentration-time graph, the gradient represents the rate of reaction. If the gradient is constant, it means that the reaction is zero order with respect to iodine.

3(c) Repeat the experiment by doubling the concentration of propanone instead.
OR

Repeat the experiment with 12.5 cm^3 of propanone and 12.5 cm^3 of water instead.

(double or half [propanone]) OR (suggest a different volume of propanone and vol. of propanone + vol. of water equals 25 cm^3) **[1]**

On the **same axis**, plot the graph using the results from this repeated experiment. Calculate the gradient of this new line. If the gradient is doubled / halved that of (b)(i), then it is first order wrt propanone. **[1]**

OR

Can use a simple sketch of graph to illustrate doubled / halved gradient

Since you are required to compare your new results with your previous results, you have to vary the **concentration** of propanone **only**, while keeping the concentrations of other reactants the same.

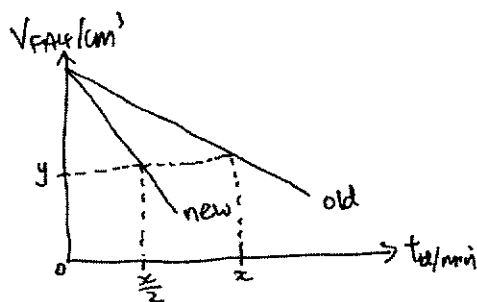
The first answer (doubles [propanone]) actually requires a solution different from FA 7 to be available. Simply doubling the volume of FA 7 will NOT double [propanone].

If you use the same FA 7 in your second experiment, you can only use a lower volume of propanone and top up the difference with water.

In any case, you keep concentrations of other reactants the same by using the same volume for that reactant and making sure total volume used is constant (at 100 cm^3).

You will expect to get the same downward sloping straight line for your new experiment, just with a different gradient.

e.g. if doubled [propanone], graph obtained would be as below:



There are two conceptual **errors** shown by students who suggested to limit propanone and use iodine in large excess. Firstly, you would be unable to compare your new results with the previous results, as both concentrations of propanone and iodine have been changed. Secondly, since iodine is in large excess, its concentration would remain relatively constant throughout the experiment, hence your five titres will be relatively the same (in theory, the titres would be constant, which means you would get a horizontal straight line).

We are unable to perform an experiment in which propanone is limiting and iodine in large excess as we do not have a suitable method (in our current lab settings) to monitor the changes in the concentration of propanone.

4(a) FA 9 is aluminium chloride

General comments:

- This question was generally well attempted, particularly the reporting of observations. Do be more careful about reading the pre-ambule to the Table carefully. Here, tests for gases evolved were **only required when instructed**. This is not usual, but highlights how important it is to read the question carefully rather than make assumptions based on habit.
- There was evidence that some candidates' poor practical skills may have hampered the accuracy of some of their observations, including not ensuring that test-tubes were thoroughly cleaned before starting a Test, which caused some of the ppts to appear yellow rather than white.
- Note that a 'solution' should not be described as 'white'. If you observe a cloudy mixture, then it is likely due to the presence of a white ppt.
- Also note the difference between 'evolution' of a gas (not necessarily able to 'see' the gas, except through its effect on something else like a lighted splint or litmus paper) and 'effervescence' (implies bubbles are seen).
- Test 4: the effervescence observed in observations 5 and 9 are both due to carbon dioxide.
- In general, answers in pencil were ignored.

test		observations	obs
1.	Indicator paper	turns orange, pH 3 / pH 4 Note that the corresponding pH must be given as it is the point of the indicator paper.	1
2.	FA 9 + NaOH	white ppt, soluble in excess $A^{3+}(aq) + 3OH^{-}(aq) \rightarrow A(OH)_3(s)$ $A(OH)_3(s) + OH^{-}(aq) \rightarrow A(OH)_4^{-}(aq)$	2
3.	FA 9 + NH ₃	white ppt, insoluble in excess Note that it may be difficult to see that this ppt ($A(OH)_3$) <u>does not</u> dissolve in excess aq. ammonia. One way to verify when in doubt is to let the mixture settle and compare the bottom of the tube to that in Test 2. You will see a cloudy mixture in Test 3 versus clear solution in Test 2.	3
4. (i)	FA 9 + NaHCO ₃	white ppt (slight) effervescence (upon shaking) Some candidates did not report the effervescence. Note that the instruction say to add FA 8 "dropwise, with shaking" and the bubbles tend to appear upon shaking. There were quite a number of candidates who mentioned that "the gas produced gave a white ppt in limewater" despite the fact that <u>limewater was not provided</u> (see the note above Table 4.1 in the question paper that says 'you only need to carry out tests for gases when instructed to do so'). This was ignored when marking since the gas was indeed CO ₂ . However, in the case where the test for gas was contradictory to the gas identity, the observation was penalised.	4 5
4. (ii)	Mixture from 4(i) + NaOH,	(white) ppt dissolves Note that you were meant to use the mixture from 4(i) for this test, which means you are starting the test with the white ppt <u>already</u> formed. Thus, the phrasing 'white ppt forms' should not be used for the section with NaOH being added. $A(OH)_3(s) + OH^{-}(aq) \rightarrow A(OH)_4^{-}(aq)$	6

	then HNO ₃	<p>white ppt reappears/forms upon adding dil. HNO₃ then dissolves/soluble in excess acid with effervescence</p> <p>Note that the ppt is only observable upon careful dropwise addition of the acid. Furthermore, the instructions said to add dilute nitric acid until no further change was seen, thus the effervescence was expected to be reported here too.</p> <p>HNO₃ removes the OH⁻ and caused A(OH)₃ ppt to be formed again. With excess acid, A(OH)₃ is neutralised to give A³⁺ ions. When all the A(OH)₃ is neutralised, excess HNO₃ reacts with FA 8 (NaHCO₃) to give CO₂.</p>	7 8 9
5.	FA 9 + AgNO ₃	<p>white ppt forms</p> <p>Note that the white ppt (AgCl) appears immediately and is very white. Any other colour observed here (e.g. cream or pale yellow) will likely be due to contaminated glassware, and such colours were rejected.</p> <p>A typical test would ask you to add aq. NH₃ to check the solubility of the ppt to confirm its identity. This was not done here but asked as a question in (b)(iii) instead.</p>	10
6. (i)	<p>FA 9 + solution Y</p> <p>Heat and test gas produced</p>	<p>(ppt is white)</p> <p>moist (blue) litmus (turns red then) is bleached (ignore references to ppt remaining/dissolving upon heating as both are possible observations here)</p> <p>Solution Y is aqueous NaOCl. The OCl⁻ ion is not strong enough to oxidise Cl⁻ at room temperature, but can do so with some heating.</p> <p>Any reference to the smell of the gas were ignored here given the difficulty in smelling with the mask on, although many candidates correctly identified a pungent smell. As the quantities of gas evolved were low, no colour was expected to be seen, though such references in candidates' answers were ignored.</p> <p>It is a good practice to use both the red and blue litmus papers when you are not sure of the identity of the gas.</p>	11

	Cool	<p>FA 10 is a cloudy mixture OR white ppt (reappears) OR FA 10 is a colourless solution</p> <p>Note that the appearance of FA 10 depends on how much ppt was formed originally and how long candidates heated the boiling tube contents. While any of the above suggested observations were accepted, it is important that candidates gave one since the question asked to 'note its appearance'. Also note that it is important to <u>align your observations to the specific instructions</u>, especially in this Test, as the observation for the heated contents and the cooled contents might be different.</p>	12
6. (ii)	KI + FA 10 (chlorine water formed in 6(i))	<p>solution turns yellow/orange-brown, then brown/darkens with more FA 10</p> <p>(ppt seen in FA 10 from Test 6(i) may or may not dissolve)</p> <p>Since the instructions asked to add the KI(aq) to the test-tube first, answers cannot imply that KI solution was yellow (it is colourless!). Also, the instructions asked for FA 10 to be added dropwise, so candidates should report the gradual darkening of the solution formed.</p> <p>Some strange colour combinations were rejected here: "xyellow-red" (not a colour, use 'orange' instead), "xbrick-red" (reserved for Fehling's test), "xblood-red" (reserved for complex of Fe(III) with SCN⁻).</p>	13 14

[7] all 14 obs correct, or all except 9 or 14 (only one of these two missing)

[6] 12 - 13 obs correct

[5] 10 - 11 obs correct

[4] 8 - 9 obs correct

[3] 6 - 7 obs correct

[2] 4 - 5 obs correct

[1] 3 obs correct

[0] 0 - 2 obs correct

4(b)(i) cation: A³⁺

The identity of the cation can be deduced from Tests 1, 2 and 3.

4(b)(ii) anion: Cl^- (if obs 10 recorded as white ppt)

accept Br^- if obs 10 recorded as cream ppt (mark already lost in part (a))

Do not accept I^-

The identity of the anion can be deduced from correct observations in Tests 5 and 6.

4(b)(iii) reagent: aqueous NH_3

observation : (white) ppt dissolves (if they suggested Cl^-)

: (cream) ppt partially dissolves (if they suggested Br^-)

This question was generally well attempted. Both reagent and observations must correspond to each other and be correct in order to earn the point. Vague answers or answers in which additional reagents were suggested were penalised.

A number of candidates confused the confirmation test for the chloride anion with the test for halogenoalkanes (incorrectly suggesting to add nitric acid first then aqueous ammonia).

4(c) (1) A^{3+} solution is acidic due to the high charge density of the cation, which allows it to polarise the water ligands in the $[\text{A}(\text{H}_2\text{O})_6]^{3+}$ complex, hence

(2) hydrolysis occurs producing H^+ which can then react with basic HCO_3^- in an acid-base reaction

OR

HCO_3^- causes an acid-base reaction that deprotonates some of the water ligands on the $[\text{A}(\text{H}_2\text{O})_6]^{3+}$ complex

(3) with enough base, this causes the formation of a white ppt of $\text{A}(\text{OH})_3$

(4) The effervescence seen is carbon dioxide gas liberated from the protonation of HCO_3^- .

[2] All 4 points

[1] 2-3 points

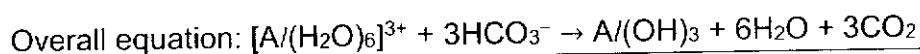
[0] 1 point

Four points were required for full credit. No half marks were awarded. This question was generally poorly attempted.

A number of candidates incorrectly thought that the white ppt was "aluminium carbonate", but carbonates are not stable in the presence of acidic cations such as A^{3+} , Cr^{3+} and Fe^{3+} .

Another common trend was to refer to the hydrogen carbonate ion (HCO_3^-) interchangeably with the carbonate ion (CO_3^{2-}). Although both have basic

properties, they are actually different species (they are conjugate acid-base pairs) and should not be interchanged freely.
Points (3) and (4) should clearly relate the observation to the identity of species formed.



4(d)(i) Role of Y: oxidising agent

Note that the question asked you to use your answer to (b)(ii) in order to assign a role to solution Y. You deduced the identity of the anion in (b)(ii), which means the role of solution Y has got something to do with the chloride ion. As such, references to precipitation/removal of the aluminium cation were not accepted.

4(d)(ii) The bleached litmus proves that chlorine was made, which means that the chloride ion was oxidised to chlorine by solution Y.

OR

FA 10 contains an oxidising agent able to oxidise I⁻ (in aq. KI) to iodine, as seen by the appearance of the brown colour. This oxidising agent is likely chlorine, which means solution Y oxidised the chloride in **FA 9** to chlorine in **FA 10**.

Note that strong answers should clearly identify chlorine as having been formed by adding solution Y, through an observation that confirms its presence, that is, the bleaching of moist litmus paper.

Some candidates believed that solution Y was still present in **FA 10** and was thus responsible for the oxidation of the iodide ion into iodine. This line of thinking would completely ignore the presence of the chloride ion in **FA 9** and the use of Test 6(i) in forming **FA 10**, and was therefore not given credit. Remember that the question asked to use the answer to (b)(ii) and your observations in Test 6.

[As a side note, adding solution Y directly to KI does not result in the same observations as seen in Test 6(ii), as solution Y is not a strong enough oxidising agent.]

Answers to **extension questions** in Q1

The dissolving of any excess citric acid solid would cause a heat change. ΔT_{max} , q and hence, his value for ΔH_2 would be incorrect.

$$\Delta H_{neut} = - \frac{m \times c \times \Delta T}{n(H_2O)} \Rightarrow \Delta T = - \frac{\Delta H_{neut}}{50 \times c} \times n(H_2O)$$

ΔH_{neut} , c and total volume are constant hence ΔT , is directly proportional to the amount of water formed.