Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

0607071901

CHEMISTRY **9701/52**

Paper 5 Planning, Analysis and Evaluation **May/June 2021**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS
- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working, use appropriate units and use an appropriate number of significant figures.

INFORMATION
- The total mark for this paper is 30.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **12** pages. Any blank pages are indicated.

IB21 06_9701_52/5RP

1 A student is asked to find the enthalpy change for the reaction between anhydrous magnesium sulfate and water.

$$MgSO_4(s) + 7H_2O(l) \rightarrow MgSO_4{\bullet}7H_2O(s)$$

This enthalpy change cannot be measured directly.

(a) Predict whether the enthalpy change for this reaction is positive or negative. Explain the reason for your prediction.

prediction ....

explanation ....

....
[1]

(b) The student decided to do two separate experiments.

Experiment 1
To find the enthalpy change of solution of anhydrous magnesium sulfate, $MgSO_4(s)$, 0.0250 moles of $MgSO_4(s)$ are dissolved in 50.0 cm^3 distilled water.

Experiment 2
To find the enthalpy change of solution of hydrated magnesium sulfate, $MgSO_4{\bullet}7H_2O(s)$, 0.0250 moles of $MgSO_4{\bullet}7H_2O(s)$ are dissolved in 50.0 cm^3 distilled water.

The results for **Experiment 1** are shown in the graph of temperature against time on page 3.

(i) Draw and extrapolate the cooling curve back to 180 seconds. Determine the temperature change during the reaction.

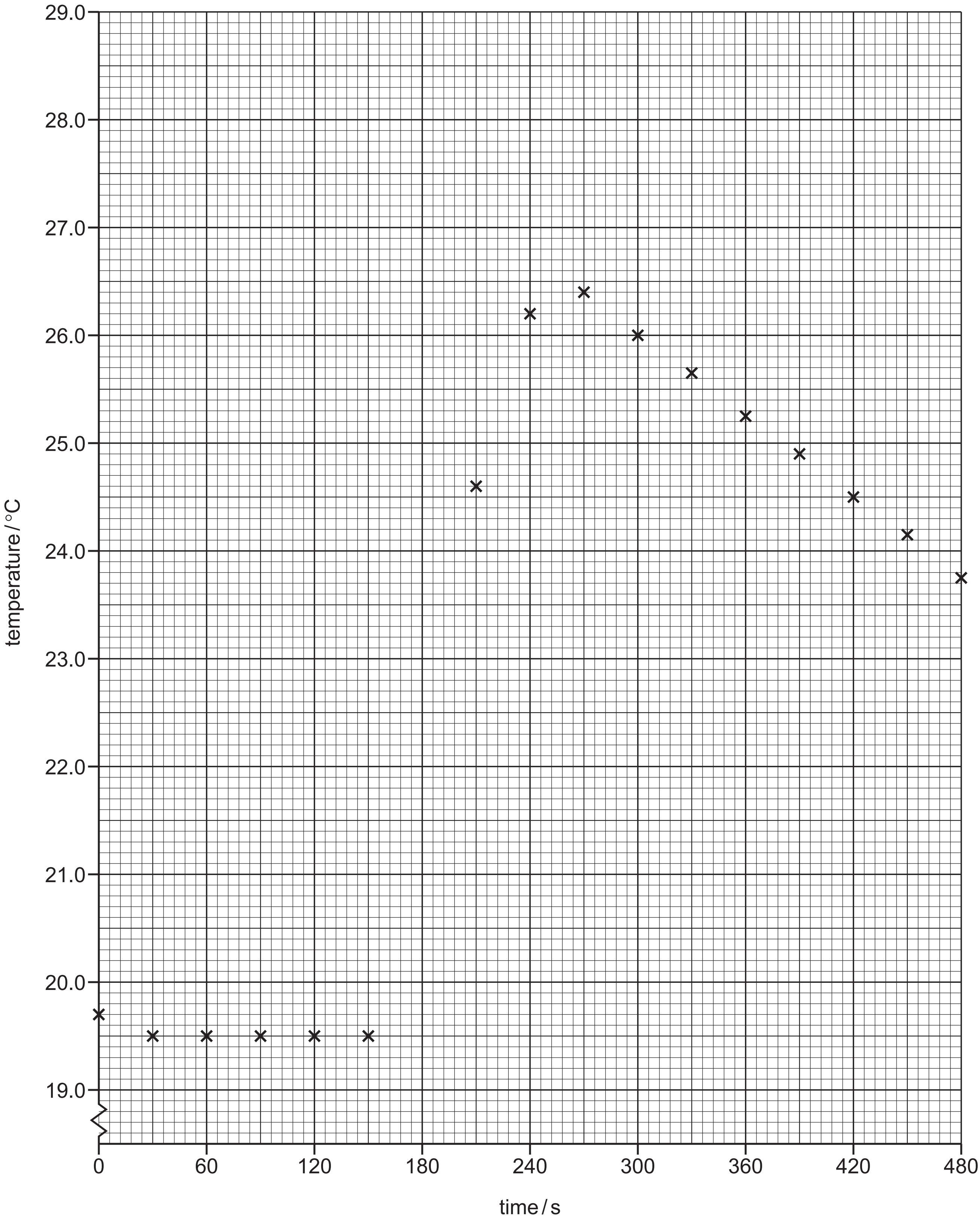
temperature change = ... °C [1]

(ii) The anhydrous magnesium sulfate was not added when the timing started.

Explain why.

....

.... [1]


29.0
28.0
27.0
26.0
25.0
24.0
23.0
22.0
21.0
20.0
19.0
temperature / °C
0
60
120
180
240
300
360
420
480
time / s

(iii) 3.01 g (0.0250 mol) of anhydrous magnesium sulfate is weighed.

Outline the next steps that should be taken in order to obtain the results in **Experiment 1**.

Write your answer using a series of numbered steps.

....

....

....

....

....

....

.... [4]

(c) (i) The student realised that when dissolving 0.0250 moles $MgSO_4 \cdot 7H_2O(s)$, the amount of water present in the compound alters the total volume of water used in **Experiment 2**.

Calculate the volume of distilled water needed to make the total volume of water 50.00 cm^3 in **Experiment 2**.

Give your answer to the nearest 0.05 cm^3.

Assume that 1.00 cm^3 of distilled water has a mass of 1.00 g.

[A_r: O, 16.0; H, 1.0]

volume of distilled water = ... cm^3 [1]

(ii) State which piece of apparatus should be used to measure the volume of distilled water in **(c)(i)**.

Explain your answer.

apparatus ....

explanation ....

[2]

(d) The temperature change when 0.0250 moles of $MgSO_4{\bullet}7H_2O(s)$ is added to the water is very small.

Suggest how the student should modify the experimental procedure to make the temperature change larger.

.... [1]

(e) (i) The energy released by 0.0250 moles of $MgSO_4(s)$, in **Experiment 1**, is 2125 J. The energy absorbed by 0.0250 moles of $MgSO_4{\bullet}7H_2O(s)$, in **Experiment 2**, is 477.5 J.

Calculate the enthalpy change, ΔH, for the reaction.

Include a sign in your answer. Give your answer to **one** decimal place.

$$MgSO_4(s) + 7H_2O(l) \rightarrow MgSO_4{\bullet}7H_2O(s)$$

enthalpy change, ΔH = ... $kJ\,mol^{-1}$ [2]

(ii) The student noticed that some $MgSO_4(s)$ in **Experiment 1** was left undissolved.

State and explain the effect this would have on the value of the enthalpy change for the reaction in **Experiment 1**.

effect ....

explanation ....
[1]

[Total: 14]

2 A student is asked to determine the acid dissociation constant, K_a, for butanoic acid, $CH_3CH_2CH_2COOH$.

$$K_a = \frac{[CH_3CH_2CH_2COO^-][H^+]}{[CH_3CH_2CH_2COOH]}$$

The student is told to measure the pH of eight buffer solutions containing $CH_3CH_2CH_2COOH$ and the salt sodium butanoate, $CH_3CH_2CH_2COO^-Na^+$. The salt provides butanoate ions, $CH_3CH_2CH_2COO^-$, as the base.

Each buffer solution contains a different ratio of $[CH_3CH_2CH_2COOH]$ to $[CH_3CH_2CH_2COO^-]$.

Each buffer solution is prepared by mixing different volumes of distilled water, 2.00 mol dm^{-3} $CH_3CH_2CH_2COOH$ and 2.00 mol dm^{-3} $CH_3CH_2CH_2COO^-Na^+$.

(a) Pure butanoic acid must be kept away from naked flames.

Explain why.

.... [1]

(b) **(i)** What is the maximum volume of a 2.00 mol dm^{-3} solution that can be prepared using 55.0 g of $CH_3CH_2CH_2COO^-Na^+(s)$?

[A_r: Na, 23.0; O, 16.0; C, 12.0; H, 1.0]

volume = ... cm^3 [1]

(ii) A student is given 55.0 g of $CH_3CH_2CH_2COO^-Na^+(s)$ in a beaker.

Describe the next steps the student should take to make a 2.00 mol dm^{-3} solution of the volume calculated in **(b)(i)**.

Give the name and capacity of any key apparatus which should be used.

Write your answer as a series of numbered steps.

....

....

....

....

....

....

....

....

.... [3]

(iii) Complete the table to show the volumes of $CH_3CH_2CH_2COO^-Na^+(aq)$ and distilled water that would be needed to provide the stated number of moles of $CH_3CH_2CH_2COOH$ and $CH_3CH_2CH_2COO^-$ for a 50.0 cm^3 buffer solution.

moles of $CH_3CH_2CH_2COOH$	volume of 2.00 mol dm^{-3} $CH_3CH_2CH_2COOH$ / cm^3	moles of $CH_3CH_2CH_2COO^-$	volume of 2.00 mol dm^{-3} $CH_3CH_2CH_2COO^-Na^+$ / cm^3	volume of distilled water / cm^3
0.050	25.0	0.005		
0.050	25.0	0.008		
0.050	25.0	0.010		
0.050	25.0	0.025		
0.030	15.0	0.050		
0.010	5.0	0.050		
0.006	3.0	0.050		
0.004	2.0	0.050		

[2]

(c) The pH of each buffer solution is measured.

The value of the pH is recorded in the table along with the number of moles of the $CH_3CH_2CH_2COOH$ and $CH_3CH_2CH_2COO^-$ in each 50 cm^3 solution of buffer.

(i) Complete the table. Give your values of $-\log\left(\frac{[\text{acid}]}{[\text{base}]}\right)$ to **two** decimal places.

moles of acid, $CH_3CH_2CH_2COOH$	moles of base, $CH_3CH_2CH_2COO^-$	ratio of [acid]/[base]	$-\log\left(\frac{[\text{acid}]}{[\text{base}]}\right)$	pH
0.050	0.005	10.00		3.82
0.050	0.008	6.25		4.01
0.050	0.010	5.00		4.12
0.050	0.025	2.00		4.70
0.030	0.050	0.60		5.04
0.010	0.050	0.20		5.52
0.006	0.050	0.12		5.74
0.004	0.050	0.08		5.91

[1]

(ii) Plot a graph of pH (*y*-axis) against $-\log\left(\frac{[\text{acid}]}{[\text{base}]}\right)$ (*x*-axis) on the grid on page 9.

Use a cross (×) to plot each data point. Draw a line of best fit. [2]

(iii) Circle the point on the graph you consider to be most anomalous.

Suggest **one** reason why this anomaly may have occurred during this experimental procedure. Assume no error was made in recording the pH.

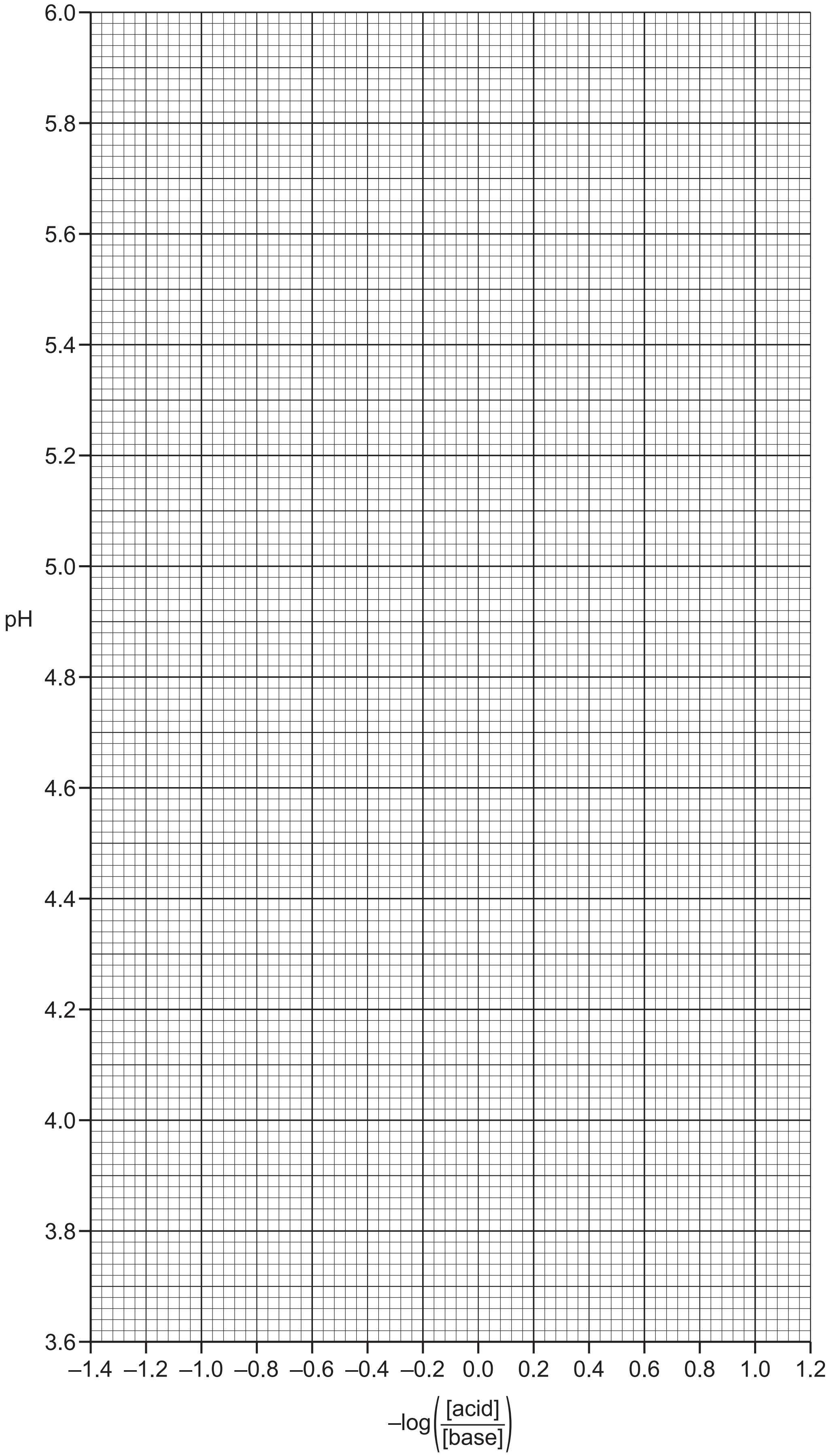
....

.... [2]

(iv) When the concentration of acid is equal to the concentration of base, pH = pK_a.

Use this information and your graph to find the value for the pK_a.

pK_a = ... [1]


6.0
5.8
5.6
5.4
5.2
5.0
pH
4.8
4.6
4.4
4.2
4.0
3.8
3.6
–1.4 –1.2 –1.0 –0.8 –0.6 –0.4 –0.2 0.0 0.2 0.4 0.6 0.8 1.0 1.2
–log([acid]/[base])

[Turn over

(v) Use your answer to **(c)(iv)** to calculate the value of K_a. State the units of K_a. Give your answer to **three significant figures**.

$pK_a = -\log K_a$

K_a = ...

units = ...
[2]

(d) The value of pK_a is lower when the experiment is repeated at a higher temperature.

What does this tell you about the enthalpy of dissociation of $CH_3CH_2CH_2COOH$?

Explain your answer.

....

.... [1]

[Total: 16]

BLANK PAGE

BLANK PAGE