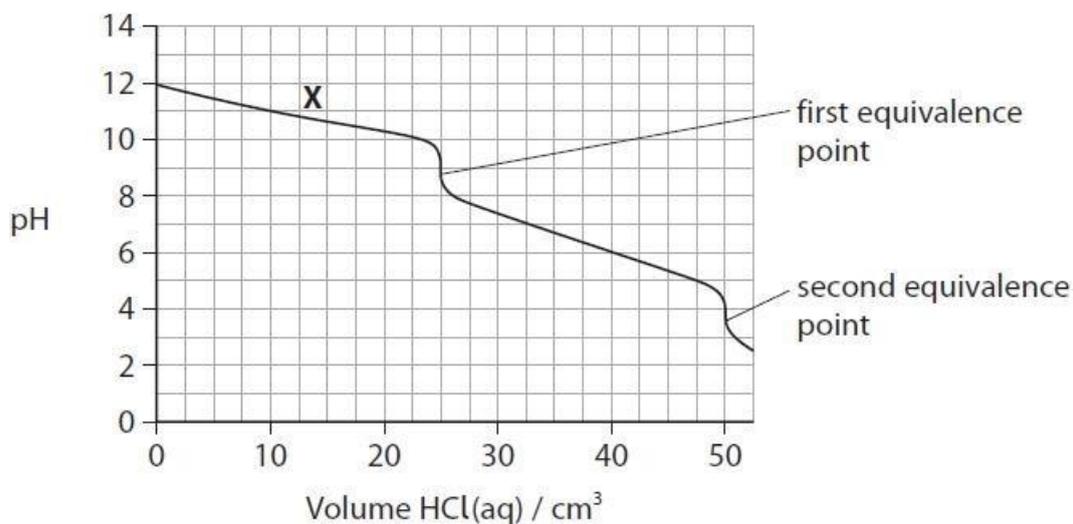## Questions

Q1.

This question is about acids and bases.
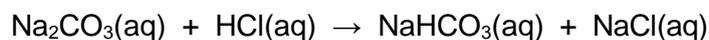
Hydrochloric acid, with a concentration of 0.100 mol dm^{-3}, is added to 25.0 cm^3 of 0.100 mol dm^{-3} aqueous sodium carbonate and the pH is measured.

The titration curve is shown.

The reaction takes place in two steps.
The equation for the reaction taking place in the first step is

$$Na_2CO_3(aq) \; + \; HCl(aq) \; \rightarrow \; NaHCO_3(aq) \; + \; NaCl(aq)$$

(i) Deduce a suitable indicator to identify the first equivalence point.

Justify your answer using values from the Data Booklet.

(2)

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(ii) Write the equation for the reaction taking place at the second equivalence point. State symbols are not required.

(1)

(iii) Explain how the solution at point **X** on the graph can act as a buffer solution.
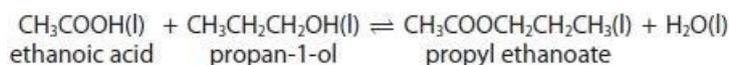
(3)

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(Total for question = 6 marks)

Q2.

This question is about an experiment to determine the equilibrium constant, K_c, for an esterification reaction producing propyl ethanoate. The equation for the reaction is

$$CH_3COOH(l) + CH_3CH_2CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_2CH_3(l) + H_2O(l)$$
$$\text{ethanoic acid} \quad \text{propan-1-ol} \quad \text{propyl ethanoate}$$

In an experiment to determine the equilibrium constant, K_c, the following steps were carried out.

• 6.0 cm^3 of ethanoic acid (0.105 mol), 6.0 cm^3 of propan-1-ol (0.080 mol) and 2.0 cm^3 of dilute hydrochloric acid were mixed together in a sealed boiling tube.
In this pre-equilibrium mixture, there is 0.111 mol of water
• The mixture was left for one week, at room temperature and pressure, to reach equilibrium
• The equilibrium mixture and washings were transferred to a volumetric flask and the solution made up to exactly 250.0 cm^3 using distilled water
• 25.0 cm^3 samples of the **diluted** equilibrium mixture were titrated with a solution of sodium hydroxide, concentration 0.200 mol dm^{-3}, using phenolphthalein as the indicator
• The mean titre was 23.60 cm^3 of 0.200 mol dm^{-3} sodium hydroxide solution.

(a) State the role of the hydrochloric acid in the esterification reaction.

(1)

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(b) (i) Calculate the total amount, in moles, of acid present in the **volumetric flask** in the equilibrium mixture.

(2)

(ii) The 2.0 cm^3 of dilute hydrochloric acid contained 0.00400 mol of H$^+$(aq) ions.
Use this and your answer to part (b)(i) to calculate the amount, in moles, of ethanoic acid present in the equilibrium mixture.

(1)

(c) (i) The initial mixture in the boiling tube contained 0.105 mol of ethanoic acid.

Use your answer to (b)(ii) to calculate the amount, in moles, of ethanoic acid that reacted to form the ester in the equilibrium mixture.

(1)

(ii) Use information given in the method, and your answer to (c)(i), to calculate the amounts, in moles, of propan-1-ol, propyl ethanoate and water that are present in the equilibrium mixture.

(3)

Moles of propan-1-ol at equilibrium

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Moles of propyl ethanoate at equilibrium

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Moles of water at equilibrium

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(d) (i) Write the expression for the equilibrium constant, K_c , for this reaction.

$$CH_3COOH(l) + CH_3CH_2CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_2CH_3(l) + H_2O(l)$$
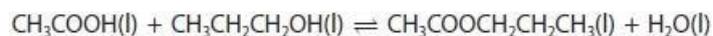
(1)

(ii) Explain why it is possible, in this case, to calculate K_c using equilibrium amounts in moles, rather than equilibrium concentrations.

(2)

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(iii) Calculate the value of K_c.
Give your answer to an appropriate number of significant figures.

(2)

(e) The pink colour of the phenolphthalein fades after the end-point of the titration has been reached.

Give a possible explanation for this observation.

(2)

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(f) Explain what you could do to confirm that one week is sufficient time for the mixture to reach equilibrium.

(2)

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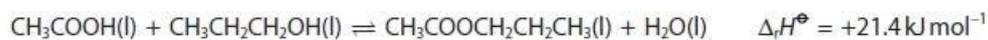..

(g) A student repeated the experiment, but left the mixture in a water bath at 40 °C until equilibrium was reached.

$$CH_3COOH(l) + CH_3CH_2CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_2CH_3(l) + H_2O(l) \qquad \Delta_r H^\ominus = +21.4 \, kJ \, mol^{-1}$$

Deduce the effect, if any, on this student's value for K_c compared with that obtained in part (d)(iii).

(2)

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(Total for question = 19 marks)

Q3.

2-Hydroxyethanoic acid, also known as glycolic acid, $CH_2OHCOOH$, is an alpha hydroxy acid used in some skincare products.
It has a K_a value of 1.5×10^{-4} mol dm^{-3}.

The structure of glycolic acid is

The titration curve for adding glycolic acid to 25.0 cm^3 of 0.100 mol dm^{-3} sodium hydroxide is shown.

(i) Use the information given in your Data Booklet to select a suitable indicator for this titration, including the colour change you would expect to see.

Justify your selection.

(3)

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(ii) What is the concentration of this glycolic acid in mol dm^{-3}?

(1)

☒ **A**   0.080

☒ **B**   0.100

☒ **C**   0.125

☒ **D**   0.250

(iii) The pH of the solution containing just sodium glycolate and water is

(1)

☒ **A**   2.8

☒ **B**   6.0

☒ **C**   8.3

☒ **D**   11.0

(Total for question = 5 marks)

Q4.

This is a question about buffer solutions.

One of the systems controlling the pH of blood is the carbonic acid-hydrogencarbonate buffer system.

$$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$
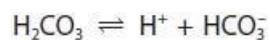
Explain how this buffer system helps to control the pH of blood when extra carbon dioxide is present due to strenuous exercise.

(3)

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(Total for question = 3 marks)

Q5.

This question is about buffer solutions.

A buffer solution was formed by mixing 20.0 cm^3 of sodium hydroxide solution of concentration 0.100 mol dm^{-3} with 25.0 cm^3 of ethanoic acid of concentration 0.150 mol dm^{-3}.

$$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$$
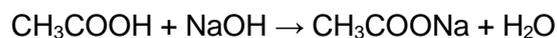
Calculate the pH of this buffer solution.

[K_a for ethanoic acid = 1.74 × 10^{-5} mol dm^{-3}]

(5)

(Total for question = 5 marks)

Q6.

This question is about weak acids.

(i) Propanoic acid, CH_3CH_2COOH, is a weak acid.

On the grid below, sketch the change in pH during the addition of 50.0 cm³ of 0.100 mol dm⁻³ sodium hydroxide solution to 25.0 cm³ of 0.100 mol dm⁻³ propanoic acid solution.

(4)
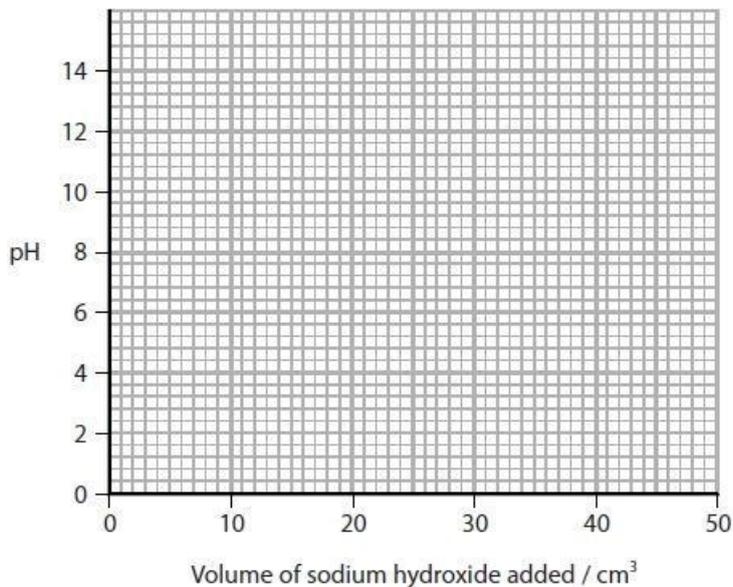
(ii) Explain how you would use the graph in (i) to obtain the value of the acid dissociation constant, K_a , for propanoic acid.

You are **not** expected to calculate this value.

(2)

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(Total for question = 6 marks)

Q7.

This question is about a titration experiment carried out by a group of students to determine the concentration of a solution of ethanoic acid using sodium hydroxide.

The sketch shows the pH changes during a titration of 25.0 cm^3 of ethanoic acid with sodium hydroxide of the same concentration.

The ideal indicator for this titration will change colour on the addition of a very small volume of sodium hydroxide solution at a titre value very close to the equivalence point of the reaction.

(i) Assess the suitability of methyl red as an indicator for this titration. Make use of the Data Booklet in answering this question.

(4)

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(ii) Complete the table, with a tick (✓) or a cross (X), to show whether or not the indicator would be suitable for use in this titration.

(1)

Indicator	pH range	Tick or Cross
Bromocresol purple	5.2 – 6.8	
Thymol blue	8.0 – 9.6	
Thymolphthalein	8.3 – 10.6	
Alizarin yellow R	10.1 – 13.0	

(Total for question = 5 marks)

Q8.

This is a question about buffer solutions.

A weak acid-strong base titration curve can be used to demonstrate buffer action.

(i) Draw a titration curve for the addition of

100 cm³ of sodium hydroxide solution of concentration 0.100 mol dm⁻³ to
40.0 cm³ of propanoic acid solution of concentration 0.100 mol dm⁻³
which has a pH of 3.0.
Show the part of the curve that demonstrates buffer action.

(4)
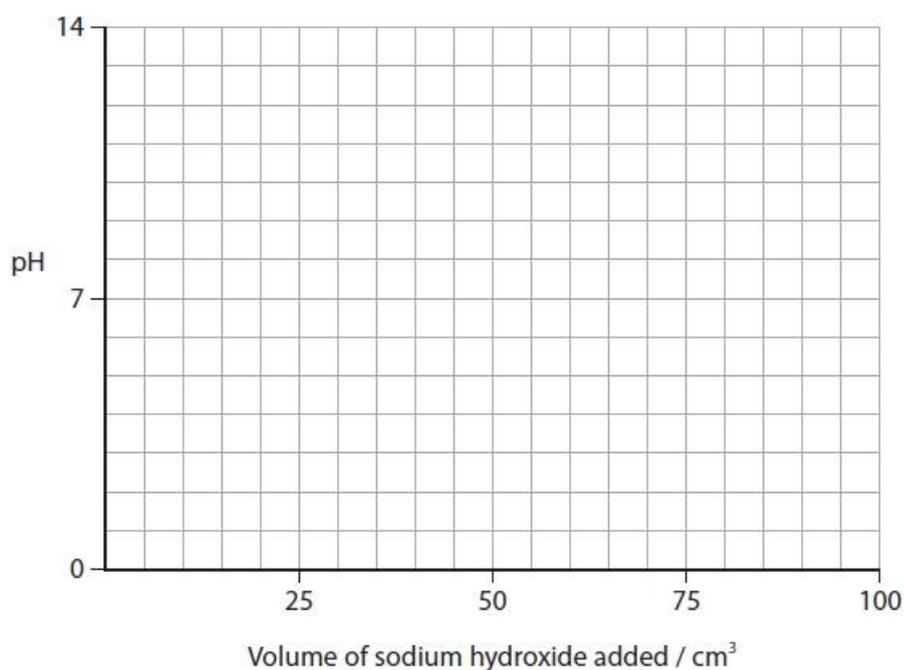
(ii) Describe, without calculation, how you would use your curve to determine the value of K_a for propanoic acid.

(2)

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(Total for question = 6 marks)

Q9.

Pineapple juice contains the weak acids citric acid ($C_6H_8O_7$) and ascorbic acid ($C_6H_8O_6$). The amount of each compound in a sample of 150 cm^3 of pineapple juice can be determined by titration.

Experiment **1** is designed to determine the total amount of acid. 10.0 cm^3 samples of pineapple juice are transferred to separate conical flasks and titrated with a solution of sodium hydroxide of known concentration.

The total amount of acid in the 150 cm^3 sample of pineapple juice is 8.00 × 10^{-3} mol.

(i) Give a reason why methyl orange would **not** be a suitable indicator to use in this titration.

(1)

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(ii) A student did not notice an air bubble in the tip of the burette **before** carrying out one of their accurate titrations. During this titration, the air bubble escaped.

Explain the effect this mistake would have on the value of this titre.

(2)

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(Total for question = 3 marks)

Q10.

Pineapple juice contains the weak acids citric acid ($C_6H_8O_7$) and ascorbic acid (C6H8O6). The amount of each compound in a sample of 150 cm^3 of pineapple juice can be determined by titration.

Experiment **1** is designed to determine the total amount of acid. 10.0 cm^3 samples of pineapple juice are transferred to separate conical flasks and titrated with a solution of sodium hydroxide of known concentration.

The total amount of acid in the 150 cm^3 sample of pineapple juice is 8.00 × 10^{-3} mol.

(b) Experiment **2** is carried out to determine the amount of ascorbic acid ($C^6H^8O^6$) in the pineapple juice.

An outline procedure for this experiment is given.

Step **1** 5.00 cm^3 of the pineapple juice is added to a conical flask.

Step **2** Deionised water, a small amount of HCl(aq), a few crystals of potassium iodide, KI, and 3 drops of starch solution are also added to the flask.

Step **3** The contents of the flask are swirled to ensure the KI dissolves fully.

Step **4** The resultant mixture is titrated with a solution of potassium iodate(V), KIO_3(aq), of concentration 0.00100 mol dm^{-3}.

The reactions that take place are

$$IO_3^-(aq) + 5I^-(aq) + 6H^+(aq) \rightarrow 3I_2(aq) + 3H_2O(l)$$

$$C_6H_8O_6(aq) + I_2(aq) \rightarrow C_6H_6O_6(aq) + 2H^+(aq) + 2I^-(aq)$$
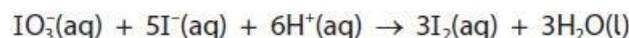
Only the ascorbic acid reacts with the iodine.

(i) The end-point of the titration is when the starch changes colour.

Explain how this occurs, including the colour change.

(3)

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(ii) The **total** amount of acid in the 150 cm^3 sample is 8.00×10^{-3} mol.

The mean titre in Experiment **2** using 5.00 cm^3 of pineapple juice is 9.50 cm^3.

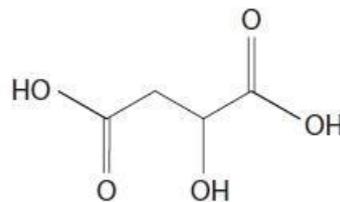Calculate the mass of **citric acid** in the 150 cm^3 sample.
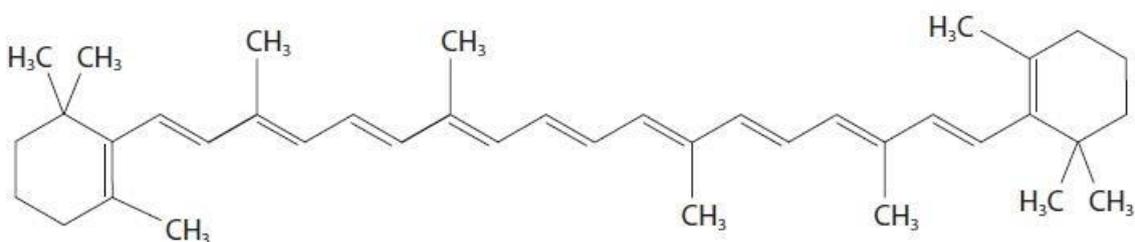
(5)

(c) While doing background research for the experiment, a student found that three other compounds, **D**, **E** and **F**, are often present in pineapple juice.
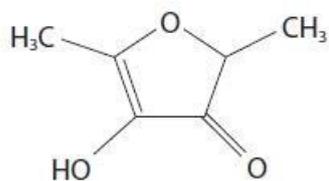
Compound **D**

Compound **E**

Compound **F**

Predict which one of these compounds is most likely to affect the result of Experiment **1** and hence predict the effect on the mass of citric acid calculated in (ii).

Justify your answer.

(3)

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(Total for question = 11 marks)

Q11.

This question is about the titration of a weak acid with a strong base.

A standard solution of ethanedioic acid, which is a weak, diprotic acid, can be used to determine the concentration of a sodium hydroxide solution. 25.0 cm³ of the ethanedioic acid solution, with concentration 3.80 g dm⁻³, was pipetted into a conical flask. A few drops of indicator solution were added. The ethanedioic acid was titrated with the sodium hydroxide solution which was in the burette. The titration was repeated and the following results were obtained.

[Molar mass of ethanedioic acid = 90.0 g mol−1]

	Titration 1	Titration 2	Titration 3	Titration 4
Final reading / cm³	18.00	17.60	35.30	27.70
Initial reading / cm³	0.00	0.00	17.60	10.05
Titre / cm³	18.00	17.60	17.70	17.65
Titre used to find the mean titre (✓)				
			Mean titre / cm³	

(i) In the appropriate row, tick (✓) those titre values that should be used to find the mean, and use these titres to calculate it.

 Write the value of the mean titre in the box provided in the table of results.

(2)

(ii) Ethanedioic acid is a weak acid. Name a suitable indicator for this titration and state the colour change at the end-point.

(2)

Name of indicator

....

Colour change at the end-point from

.... to ....

(iii) The equation for the reaction of ethanedioic acid with sodium hydroxide is

$$C_2H_2O_4 + 2NaOH \rightarrow C_2O_4Na_2 + 2H_2O$$
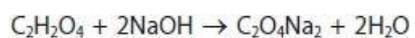
Calculate the concentration of the sodium hydroxide solution, in mol dm^{-3}.
Give your answer to **three** significant figures.

(4)

(Total for question = 8 marks)

Q12.

500 cm^3 of a buffer solution of pH = 4.70 is required.

Calculate the volume of 0.800 mol dm^{-3} sodium ethanoate solution and of 0.800 mol dm^{-3} ethanoic acid needed to make this buffer.

[K_a for ethanoic acid = 1.74 × 10^{-5} mol dm^{-3}]

(3)

(Total for question = 3 marks)

Q13.

This question is about acids and buffer solutions.

A buffer solution was made using 20.0 cm^3 of a butanoic acid solution, of concentration 0.100 mol dm^{-3} and 30.0 cm^3 of sodium butanoate solution, of concentration 0.305 mol dm^{-3}.

[K_a = 1.52 × 10^{-5} mol dm^{-3} at 298K]

(i) Calculate the pH of this buffer solution at 298 K.

(4)

(ii) Explain why the pH of the buffer solution hardly changes when a few drops of sodium hydroxide solution are added to it.
      Include an equation or equations in your answer.
      Use C$_3$H$_7$COOH as the formula for butanoic acid.

(2)

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(Total for question = 6 marks)

Q14.

This question is about weak acids.

A weak acid, HX, has a K_a value of 5.25×10^{-5} mol dm^{-3}. A solution was formed by mixing 10.5 cm^3 of 0.800 mol dm^{-3} dilute sodium hydroxide with 25.0 cm^3 of 0.920 mol dm^{-3} HX(aq).

Calculate the pH of the solution formed, showing all your working.

(5)

(Total for question = 5 marks)

Q15.

This is a question about buffer solutions.

A buffer solution with a pH of 3.90 is required.

Calculate the **mass**, in grams, of sodium ethanoate that should be added to 50.0 cm^3 of an ethanoic acid solution of concentration 0.800 mol dm^{-3} to form this buffer solution.

Give your answer to an appropriate number of significant figures.

[K_a for ethanoic acid = 1.74 × 10^{-5} mol dm^{-3}]

(5)

(Total for question = 5 marks)

Q16.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The standard molar enthalpy change of neutralisation is the enthalpy change when an acid and an alkali react under standard conditions to form one mole of water.

An experiment was carried out with a solution of ethanoic acid and sodium hydroxide solution of the same concentration.

(i) Which graph shows the correct way that the maximum temperature rise should be determined?

(1)
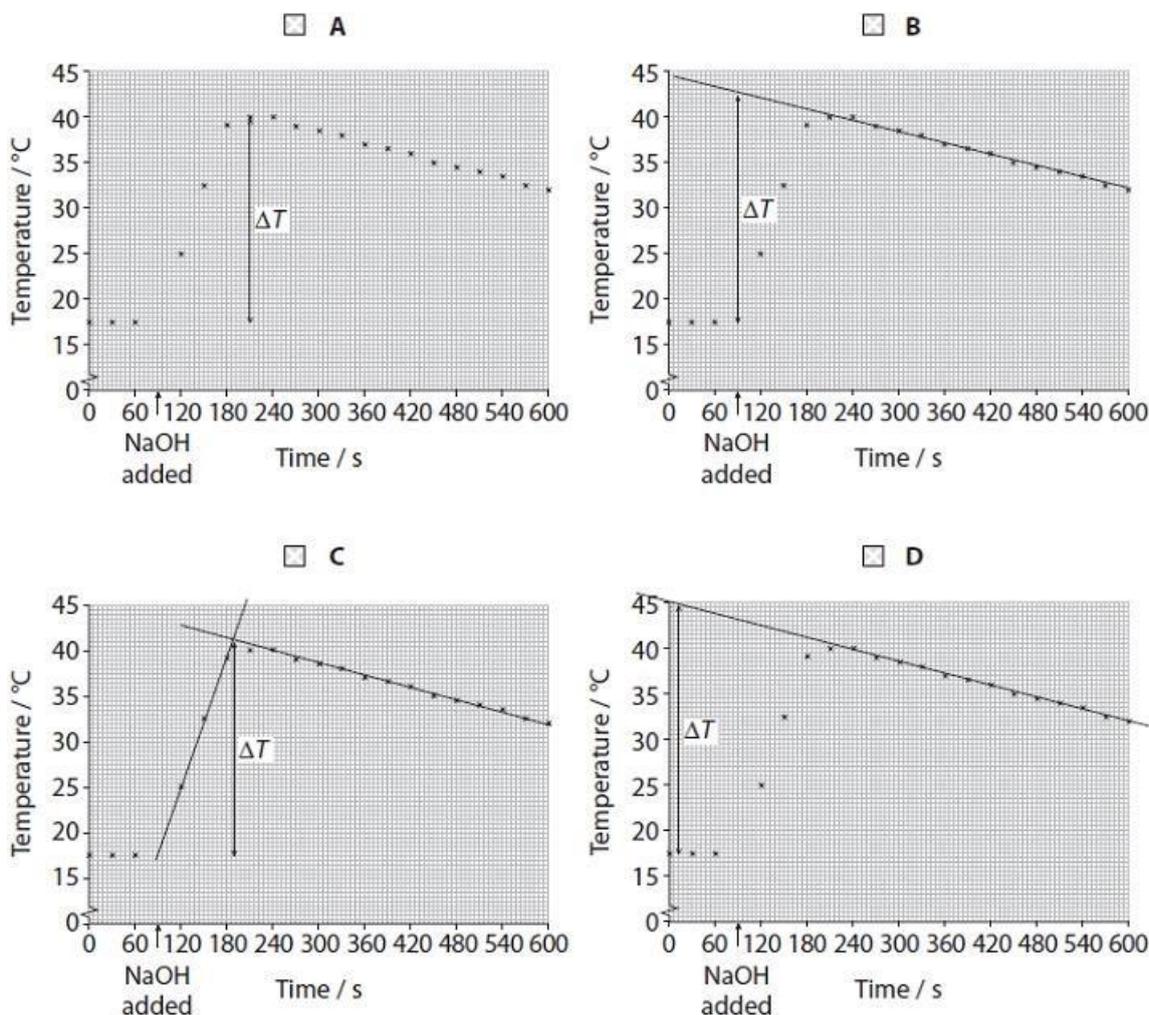
(ii) Explain why the data book value for the standard enthalpy change of neutralisation of ethanoic acid with sodium hydroxide is –55.2 kJ mol^{-1} but the value for hydrochloric acid is –57.1 kJ mol^{-1}.

(2)

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(Total for question = 3 marks)

Q17.

This question is about buffer solutions.

A buffer solution is formed from disodium hydrogenphosphate, containing HPO_4^{2-} ions, and sodium dihydrogenphosphate, containing $H_2PO_4^-$ ions.

Write the **ionic** equations involving HPO_4^{2-} and $H_2PO_4^-$ ions to show how this solution acts as a buffer solution.

(2)

(Total for question = 2 marks)