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EDEXCEL A LEVEL CHEMISTRY: QUESTIONS BY TOPIC

Acid-Base Equilibria (12)

A Level Chemistry Topic 12

14 questions · 171 marks · Mark schemes included

Pearson Edexcel A Level Chemistry (9CH0), June 2017 - June 2025

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HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic; within each sub-topic they run from the lowest mark tariff to the highest.

Click any sub-topic heading or question row below to jump straight to it.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

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QUESTIONS

14 questions · 171 marks · grouped by sub-topic



SUB-TOPIC 12(a)

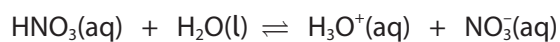
BRØNSTED-LOWRY ACIDS AND PH OF STRONG ACIDS AND BASES

3 questions in this sub-topic · 26 marks · lowest tariff first



5 This question is about acids and bases.

(a) The reaction of nitric acid with water can be represented by the equation shown.



Which is a conjugate acid–base pair for the reaction?

(1)

	Acid	Conjugate base
☐ A	HNO_3	H_2O
☐ B	NO_3^-	HNO_3
☐ C	H_3O^+	H_2O
☐ D	H_2O	H_3O^+

(b) State the expression that defines the pH of a solution.

(1)

(c) What is the concentration of $\text{OH}^-(\text{aq})$ ions, in mol dm^{-3} , in a solution of $\text{Ba}(\text{OH})_2(\text{aq})$ with $\text{pH} = 9.50$ at 298 K?

(1)

- ☐ A 3.16×10^{-10}
- ☐ B 3.16×10^{-5}
- ☐ C 6.32×10^{-5}
- ☐ D 3.16×10^4

(Total for Question 5 = 3 marks)



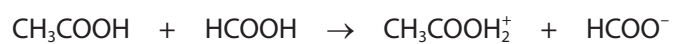
1 This question is about acids and bases.

(a) State what is meant by a Brønsted–Lowry acid.

(1)

(b) Identify the acid–base conjugate pairs in this reaction.

(1)



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(c) Write the expression that defines the pH of a solution.

(1)

(d) Calculate the concentration of hydrogen ions, in mol dm^{-3} , in a solution with a pH of 2.76

(1)

(e) Explain why the pH of a $1 \times 10^{-8} \text{ mol dm}^{-3}$ solution of nitric acid, HNO_3 , is not 8.

[Ionic product of water, $K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$]

(2)

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(Total for Question 1 = 6 marks)



6 This question is about acids and bases.

(a) State what is meant by a Brønsted-Lowry base.

(1)

(b) Write the ionic equation for the reaction between magnesium oxide and an acid.
State symbols **are** required.

(2)

(c) Calculate the concentration of hydrogen ions, in mol dm^{-3} , in a solution with a pH of 9.43

(1)

(d) The pH of two salt solutions, **J** and **K**, are

solution **J** pH = 5

solution **K** pH = 9

The solutions are equimolar.

Which acids and bases could form the salts in solutions **J** and **K**?

(1)

	Acid and base forming the salt in solution J	Acid and base forming the salt in solution K
☐ A	HCl(aq) and NH ₃ (aq)	CH ₃ COOH(aq) and NaOH(aq)
☐ B	HCl(aq) and NaOH(aq)	CH ₃ COOH(aq) and NH ₃ (aq)
☐ C	CH ₃ COOH(aq) and NaOH(aq)	HCl(aq) and NaOH(aq)
☐ D	CH ₃ COOH(aq) and NH ₃ (aq)	HCl(aq) and NH ₃ (aq)

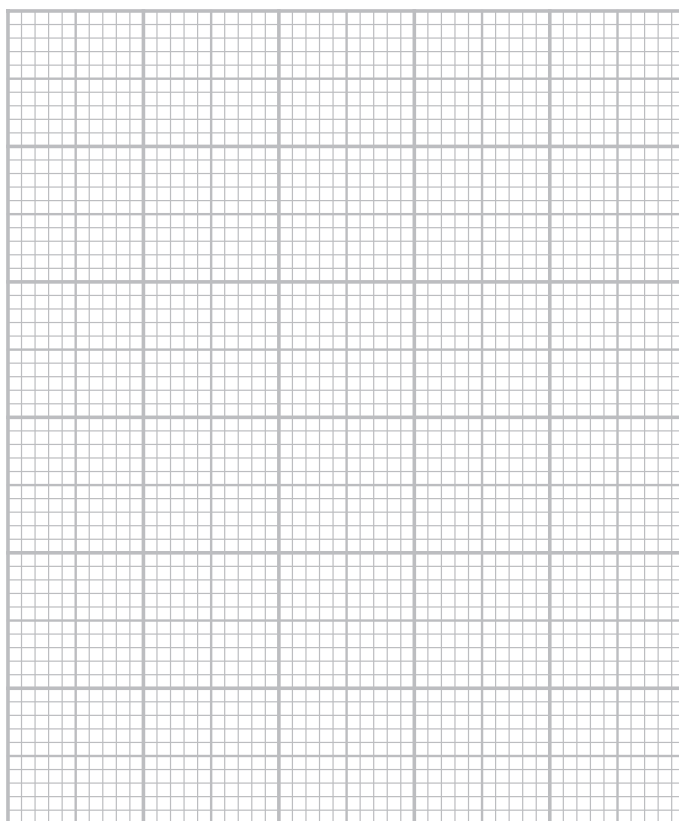


(e) The ionic product of water, K_w , varies with temperature as shown.

Temperature / °C	$K_w / \text{mol}^2 \text{dm}^{-6}$
0	0.11×10^{-14}
10	0.29×10^{-14}
20	0.68×10^{-14}
30	1.47×10^{-14}
40	2.92×10^{-14}
50	5.48×10^{-14}

- (i) Determine the value of K_w at 45 °C by plotting a suitable graph.
You must show your working on the graph.

(3)



K_w at 45 °C = ...



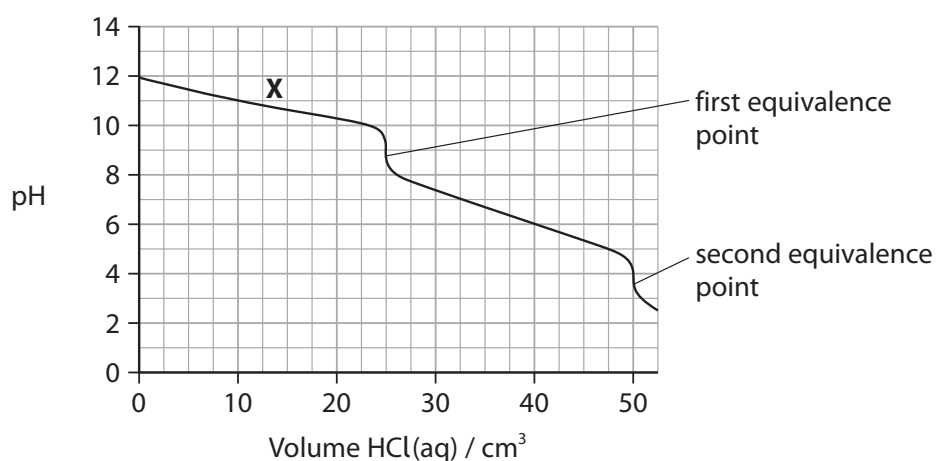
(ii) The ionic product of water at 30 °C is $1.47 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$.

Calculate the pH of water at this temperature.

(3)

(f) Hydrochloric acid, with a concentration of $0.100 \text{ mol dm}^{-3}$, is added to 25.0 cm^3 of $0.100 \text{ mol dm}^{-3}$ 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



- (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 = 17 marks)



SUB-TOPIC 12(b)

WEAK ACIDS AND KA

5 questions in this sub-topic · 60 marks · lowest tariff first



2 This question is about acids and bases.

(a) What is the order of **decreasing** pH for $0.100 \text{ mol dm}^{-3}$ solutions of these three acids?

(1)

- ☐ A $\text{CH}_3\text{COOH} > \text{CH}_2\text{ClCOOH} > \text{HCl}$
- ☐ B $\text{HCl} > \text{CH}_3\text{COOH} > \text{CH}_2\text{ClCOOH}$
- ☐ C $\text{CH}_2\text{ClCOOH} > \text{CH}_3\text{COOH} > \text{HCl}$
- ☐ D $\text{HCl} > \text{CH}_2\text{ClCOOH} > \text{CH}_3\text{COOH}$

(b) A solution of methanoic acid, HCOOH , has a concentration of $0.240 \text{ mol dm}^{-3}$ and a pH of 2.20.

Calculate the value of $\text{p}K_{\text{a}}$ for methanoic acid.

(3)

(c) Which of these mixtures would form a buffer solution with a pH **below** 7?

(1)

- ☐ A NaOH(aq) and excess HCl(aq)
- ☐ B NaOH(aq) and excess $\text{CH}_3\text{COOH(aq)}$
- ☐ C excess NaOH(aq) and HCl(aq)
- ☐ D excess NaOH(aq) and $\text{CH}_3\text{COOH(aq)}$



(d) Bromothymol blue, methyl orange and phenolphthalein are indicators used in titrations.

Which, if any, of these indicators could be used for a titration of ammonia, $\text{NH}_3(\text{aq})$, with ethanoic acid, $\text{CH}_3\text{COOH}(\text{aq})$?

(1)

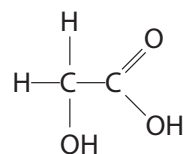
- ☐ **A** bromothymol blue
- ☐ **B** methyl orange
- ☐ **C** phenolphthalein
- ☐ **D** none of these three indicators

(Total for Question 2 = 6 marks)



- 8 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 $1.5 \times 10^{-4} \text{ mol dm}^{-3}$.

The structure of glycolic acid is



- (a) A solution of glycolic acid of concentration 0.1 mol dm^{-3} has a pH of 2.4

What is the approximate pH of the resulting solution after it has been diluted by a factor of 100?

(1)

- ☒ A 1.4
- ☒ B 2.4
- ☒ C 3.4
- ☒ D 4.4

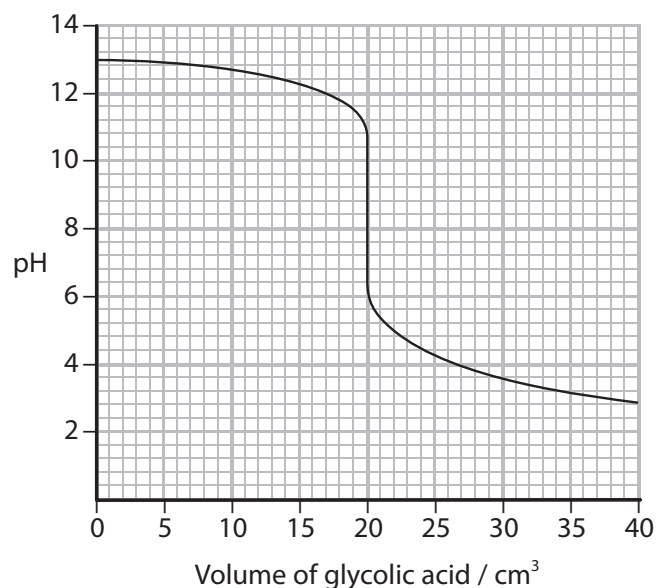
- (b) Another solution of glycolic acid has a pH of 2.0

Calculate the concentration of this solution.

(3)



- (c) 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

(d) Glycolic acid has an acid dissociation constant of $1.5 \times 10^{-4} \text{ mol dm}^{-3}$ compared with a value of $1.7 \times 10^{-5} \text{ mol dm}^{-3}$ for ethanoic acid.

(i) Give a possible explanation as to why the value of K_a for glycolic acid is approximately ten times larger than that of ethanoic acid.

(2)

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(ii) Complete the equation to show the conjugate acid-base pairs that would be produced when pure samples of glycolic acid and ethanoic acid are mixed.

(1)



(Total for Question 8 = 12 marks)



8 This question is about acids and bases.

- (a) Devise an experiment to determine the acid dissociation constant, K_a , for a solution of ethanoic acid, CH_3COOH , of unknown concentration.

Assume you have access to a pH meter and a solution of sodium hydroxide of similar concentration to the acid.

Include how to determine K_a from your results.

(5)



(b) 500 cm^3 of a buffer solution of $\text{pH} = 4.70$ 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 = $1.74 \times 10^{-5}\text{ mol dm}^{-3}$]

(3)



- (c) Calculate the pH of the solution formed when 51.2 cm^3 of $0.927 \text{ mol dm}^{-3}$ NaOH(aq) is mixed with 40.4 cm^3 of $0.370 \text{ mol dm}^{-3}$ $\text{H}_2\text{SO}_4\text{(aq)}$.

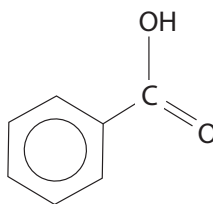
[Ionic product of water $K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$]

(6)

(Total for Question 8 = 14 marks)



6 Benzoic acid is a weak acid found in cranberries.



C_6H_5COOH – benzoic acid

(a) Which of these answers identifies the types of species present when benzoic acid is mixed with nitric acid?

$[K_a \text{ of benzoic acid} = 6.3 \times 10^{-5} \text{ mol dm}^{-3}; \quad K_a \text{ of nitric acid} = 40 \text{ mol dm}^{-3}]$

(1)

	C_6H_5COOH	+	HNO_3	$\rightleftharpoons$	$C_6H_5COOH_2^+$	+	NO_3^-
☐ A	acid		base		acid		base
☐ B	acid		base		base		acid
☐ C	base		acid		base		acid
☐ D	base		acid		acid		base

(b) The ionic salts sodium benzoate and potassium benzoate are both used as food preservatives.

Explain why the melting temperature of sodium benzoate is higher than the melting temperature of potassium benzoate.

(2)

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(c) The value of K_a for benzoic acid = $6.28 \times 10^{-5} \text{ mol dm}^{-3}$.

(i) Write the expression for the acid dissociation constant, K_a , of benzoic acid.

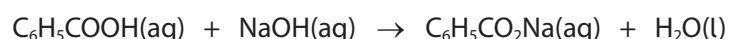
(1)

(ii) Calculate the mass of benzoic acid needed to prepare 250 cm^3 of a solution with a $\text{pH} = 3.51$

(4)



(d) Weak acids such as benzoic acid can be neutralised by sodium hydroxide solution.



- (i) Which of these could be used to show the end-point of a titration of benzoic acid with sodium hydroxide solution?

(1)

- ☐ A bromothymol blue
- ☐ B litmus
- ☐ C methyl orange
- ☐ D phenolphthalein

- (ii) Another weak acid found in cranberries is quinic acid, $\text{C}_6\text{H}_7(\text{OH})_4\text{COOH}$. It is neutralised by sodium hydroxide solution in a similar way to benzoic acid.

A 25.0 cm^3 sample of 0.500 mol dm^{-3} quinic acid solution was neutralised under standard conditions in a polystyrene cup using 25.0 cm^3 of 0.800 mol dm^{-3} of sodium hydroxide solution. This resulted in a temperature rise of 2.9°C .

Calculate the standard enthalpy change of neutralisation, $\Delta_{\text{neut}}H^\ominus$, of quinic acid in kJ mol^{-1} .

[Assume the density of both solutions is 1.0 g cm^{-3} .

specific heat capacity of solution formed = $4.18\text{ J g}^{-1}\text{ }^\circ\text{C}^{-1}$]

(3)

- (iii) The standard enthalpy change of neutralisation of the weak acid HCN by sodium hydroxide is $-11.7 \text{ kJ mol}^{-1}$ while that of the strong acid HCl is $-57.9 \text{ kJ mol}^{-1}$.

Explain the difference between these values.

(2)

(Total for Question 6 = 14 marks)



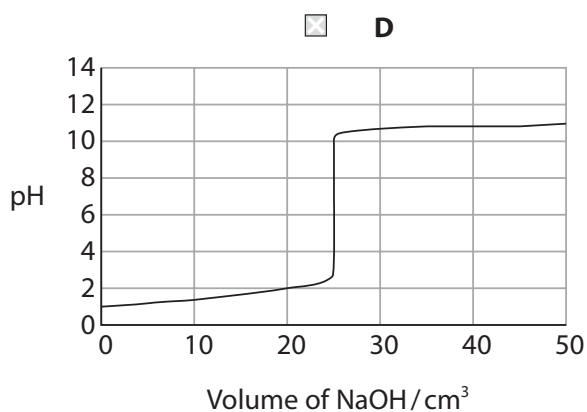
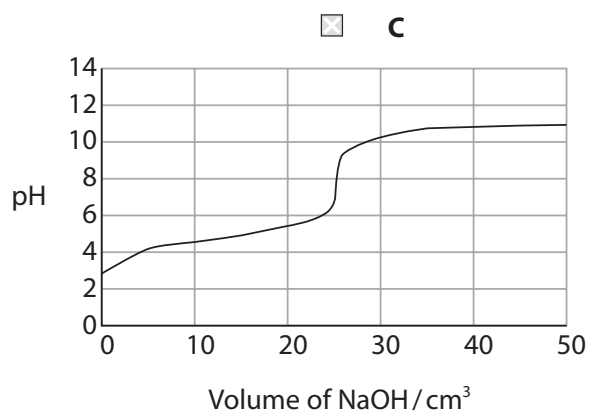
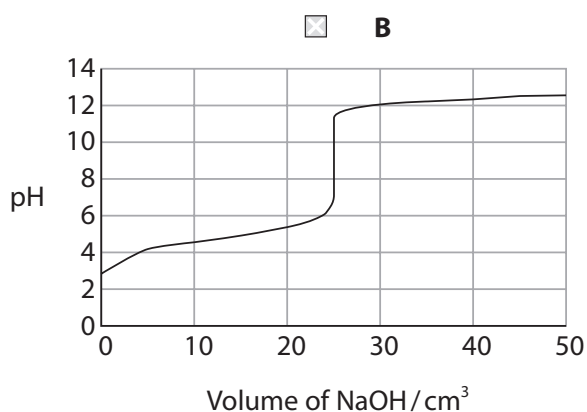
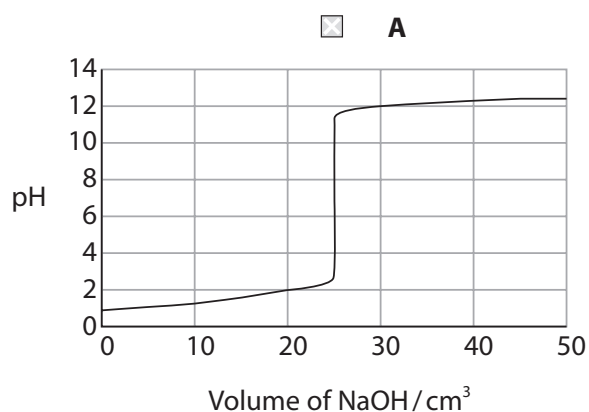
4 This question is about acids, bases and buffers.

(a) State what is meant by a Brønsted–Lowry acid.

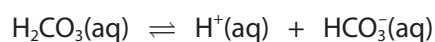
(1)

(b) Which could be the titration curve when $0.100 \text{ mol dm}^{-3} \text{ NaOH(aq)}$ is added to 25.0 cm^3 of $0.100 \text{ mol dm}^{-3} \text{ CH}_3\text{COOH(aq)}$?

(1)



- (d) One of the systems controlling the pH of blood is the carbonic acid–hydrogencarbonate buffer system.



- (i) Write the expression for the acid dissociation constant, K_a , for carbonic acid.
State symbols are not required.

(1)

- (ii) A blood sample taken from an individual was analysed.

Calculate the pH of the blood sample.

Use your expression for K_a and the values shown.

K_a for carbonic acid = $4.50 \times 10^{-7} \text{ mol dm}^{-3}$

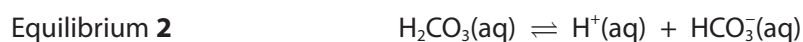
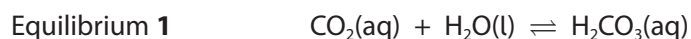
$[\text{HCO}_3^-] = 0.0240 \text{ mol dm}^{-3}$

$[\text{H}_2\text{CO}_3] = 0.00200 \text{ mol dm}^{-3}$

(3)



(e) The relevant equilibria that maintain the pH of blood are shown.



- (i) When a person exercises vigorously the concentration of carbon dioxide (aq) in the blood increases.

Explain how this increase in the concentration of carbon dioxide affects the pH of the blood.

Refer to the equilibria in your answer. No calculation is required.

(2)

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- (ii) Explain how the carbonic acid–hydrogencarbonate buffer system in Equilibrium 2 acts to restore the pH of the blood after a person has exercised.

(2)

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(Total for Question 4 = 14 marks)



SUB-TOPIC 12(c)

TITRATION CURVES AND INDICATORS

2 questions in this sub-topic · 31 marks · lowest tariff first



7 This question is about weak acids.

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

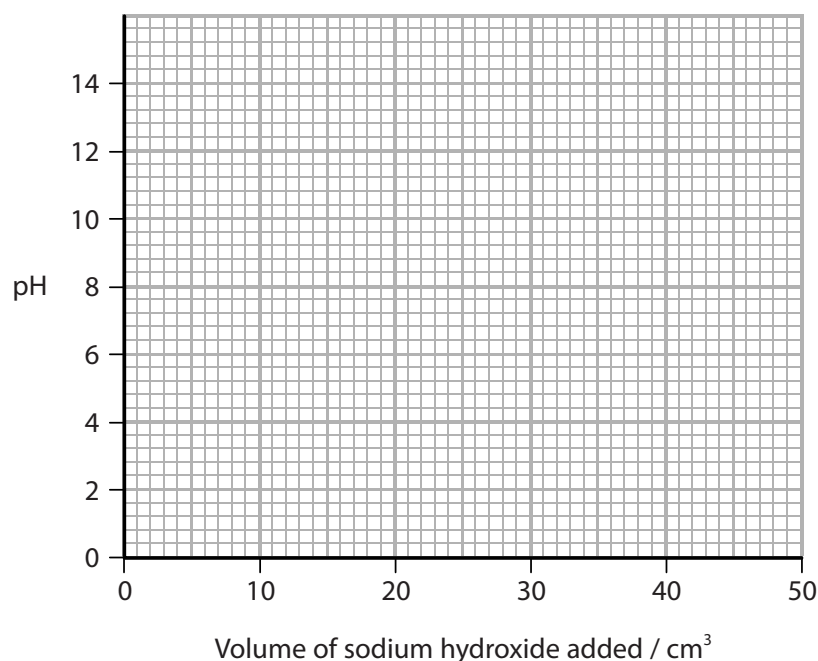
Calculate the pH of the solution formed, showing all your working.

(5)

- (b) (i) Propanoic acid, $\text{CH}_3\text{CH}_2\text{COOH}$, is a weak acid.

On the grid below, sketch the change in pH during the addition of 50.0 cm^3 of $0.100 \text{ mol dm}^{-3}$ sodium hydroxide solution to 25.0 cm^3 of $0.100 \text{ mol dm}^{-3}$ propanoic acid solution.

(4)



- (ii) Explain how you would use the graph in (b)(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 7 = 11 marks)



8 This question is about weak acids.

- (a) An aqueous solution of a weak acid, $\text{HA}(\text{aq})$, with a concentration of $0.0712 \text{ mol dm}^{-3}$, has a $\text{pH} = 3.25$ at room temperature.

Calculate the value of K_{a} for the weak acid $\text{HA}(\text{aq})$.

(2)

- (b) The value of K_{a} may be determined from experimental data, using a titration curve.

Ethanoic acid, $\text{CH}_3\text{COOH}(\text{aq})$, with a concentration of $0.0500 \text{ mol dm}^{-3}$, has a pH of 3.03 at room temperature.

A 20.0 cm^3 sample of the acid was titrated with sodium hydroxide solution, $\text{NaOH}(\text{aq})$, with a concentration of $0.0500 \text{ mol dm}^{-3}$.

During the experiment, 40.0 cm^3 of sodium hydroxide solution was slowly added to the ethanoic acid.

A pH probe connected to a data logger was used to monitor the pH throughout the experiment.

- (i) Calculate the pH of the sodium hydroxide solution.
Give your answer to one decimal place.

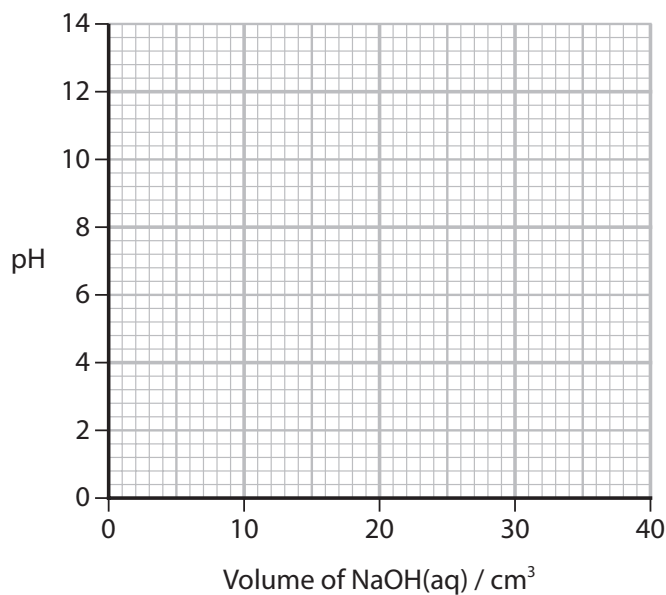
$$[K_{\text{w}} = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}]$$

(1)



- (ii) Draw a titration curve, on the axes shown, to show the change in pH throughout the experiment.

(3)



- (iii) Give an estimate of the pH value at the half-equivalence point.
Show your working on the titration curve.

(1)

- (iv) Calculate a value for K_a of ethanoic acid using your answer to (b)(iii).
You **must** show your working.

(3)



- (c) Another method used to monitor the titration is to use a pH meter without a data logger. The pH is measured and recorded after the addition of each 1.00 cm^3 portion of NaOH(aq) .

A student assessed the two methods and concluded that using the data logger was a more effective way to carry out the experiment.

Give **three** reasons that support this conclusion.

(3)

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(d) A solution containing propanoic acid and sodium propanoate forms a buffer.

- (i) 2.30 g of sodium propanoate is dissolved in propanoic acid solution.
This forms a buffer with $\text{pH} = 4.2$ and a volume of exactly 100 cm^3 .

Calculate the concentration of the propanoic acid, in mol dm^{-3} , in this buffer.

$[K_a(\text{propanoic acid}) = 1.34 \times 10^{-5} \text{ mol dm}^{-3} \quad M_r(\text{CH}_3\text{CH}_2\text{CO}_2\text{Na}) = 96.0]$

(4)

- (ii) Explain why there is no significant change in pH when a small amount of hydrochloric acid, HCl(aq) , is added to this buffer.

(3)

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(Total for Question 8 = 20 marks)



SUB-TOPIC 12(d)

BUFFER SOLUTIONS

4 questions in this sub-topic · 54 marks · lowest tariff first



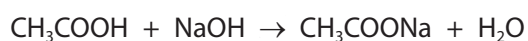
9 This question is about buffer solutions.

- (a) 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)

- (b) Another 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} .



Calculate the pH of this buffer solution.

$[K_a \text{ for ethanoic acid} = 1.74 \times 10^{-5}\text{ mol dm}^{-3}]$

(5)

(Total for Question 9 = 7 marks)



9 This is a question about buffer solutions.

(a) A buffer solution always

(1)

- ☒ A keeps the pH less than 7.
- ☒ B contains equimolar amounts of acid and its conjugate base.
- ☒ C keeps the pH constant if small quantities of acid or base are added.
- ☒ D resists changes in pH if small quantities of acid or base are added.

(b) 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 $0.800 \text{ mol dm}^{-3}$ to form this buffer solution.

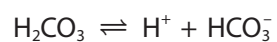
Give your answer to an appropriate number of significant figures.

$[K_a \text{ for ethanoic acid} = 1.74 \times 10^{-5} \text{ mol dm}^{-3}]$

(5)



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



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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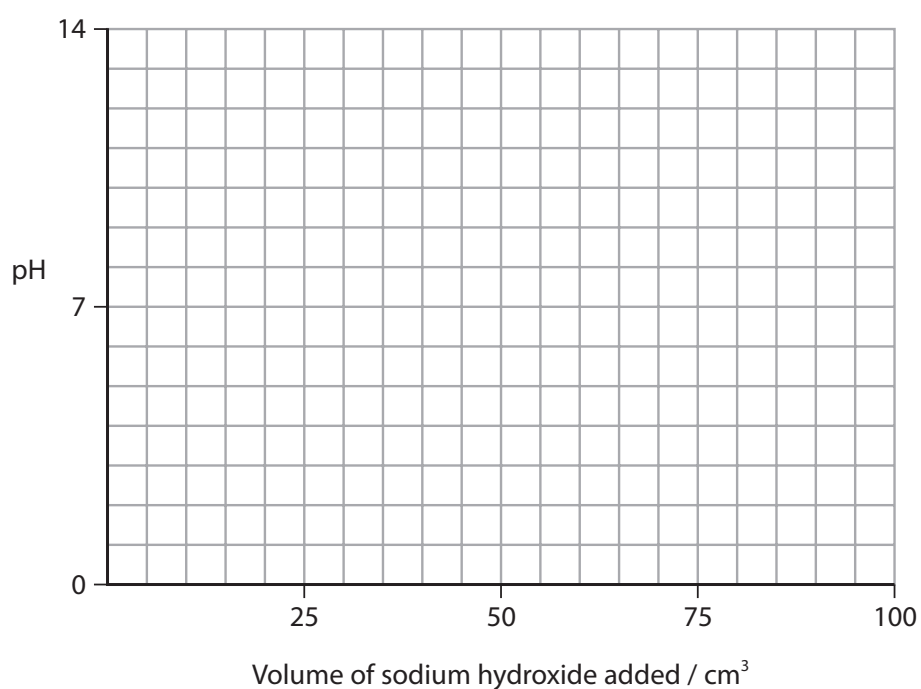


(d) A weak acid-strong base titration curve can be used to demonstrate buffer action.

- (i) Draw a titration curve for the addition of 100 cm^3 of sodium hydroxide solution of concentration 0.100 mol dm^{-3} to 40.0 cm^3 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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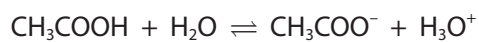
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(Total for Question 9 = 15 marks)



7 This question is about acids and buffer solutions.

(a) Ethanoic acid, CH_3COOH , is a monobasic acid.



Give a reason why only the proton from the carboxylic acid group, and not from the methyl group, is donated to a water molecule.

(1)

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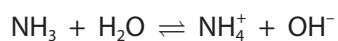
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(b) The reaction of ammonia with water can be represented by



Which is the acid-conjugate base pair?

(1)

	Acid	Conjugate base
☐ A	NH_3	OH^-
☐ B	NH_3	NH_4^+
☐ C	H_2O	OH^-
☐ D	H_2O	NH_4^+

- (c) A commercial nitric acid solution, $\text{HNO}_3(\text{aq})$, has a concentration of 15.9 mol dm^{-3} .
A 15.0 cm^3 sample was made up to 100 cm^3 by adding deionised water.

Calculate the pH of this diluted solution.

(2)



(d) Propanoic acid is a weak acid.

- (i) Calculate the pH of a $0.100 \text{ mol dm}^{-3}$ solution of propanoic acid at 298 K.
Give your answer to an appropriate number of significant figures.

$$[K_a = 1.35 \times 10^{-5} \text{ mol dm}^{-3} \text{ at } 298 \text{ K}]$$

(3)

- (ii) State **two** assumptions that you made in the calculation in d(i).

(2)

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- (e) 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} .

$$[K_a = 1.52 \times 10^{-5}\text{ mol dm}^{-3}\text{ at }298\text{K}]$$

- (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 $\text{C}_3\text{H}_7\text{COOH}$ as the formula for butanoic acid.

(2)

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(Total for Question 7 = 15 marks)



8 This question is about acids and bases.

- (a) A student devised a method to determine the acid dissociation constant, K_a , of ethanoic acid, CH_3COOH , using a solution of the acid of unknown concentration.

The student's outline procedure is shown.

Step 1 Titrate 25.0 cm^3 of the ethanoic acid solution with a solution of ammonia of known concentration, using phenolphthalein to find the end-point.

Step 2 Add a further 25.0 cm^3 of the same ethanoic acid solution to the mixture from Step 1.

This gives a solution where the acid has been half-neutralised.

Step 3 Record the pH of the solution from Step 2.

- (i) Explain why this procedure would give invalid results.

(3)

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- (ii) State how Step 1 should be amended to give valid results.

(1)

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- (iii) Show that when the solution has been half-neutralised, the acid dissociation constant is given by the expression

$$K_a = 10^{-\text{pH}}$$

(3)



- (b) Calculate the mass of sodium ethanoate needed to be dissolved in 250 cm^3 of 0.520 mol dm^{-3} ethanoic acid to form a buffer solution with $\text{pH} = 4.48$

$[K_a \text{ for ethanoic acid} = 1.74 \times 10^{-5}\text{ mol dm}^{-3}]$

(5)



- (c) A student mixes 50.0 cm^3 of 0.900 mol dm^{-3} NaOH(aq) with 20.0 cm^3 of 0.400 mol dm^{-3} $\text{H}_2\text{SO}_4\text{(aq)}$.

Calculate the pH of the resultant solution.

[Ionic product of water, $K_w = 1.00 \times 10^{-14}\text{ mol}^2\text{ dm}^{-6}$]

(5)

(Total for Question 8 = 17 marks)



MARK SCHEMES

official Pearson Edexcel mark schemes



Question Number	Answer	Mark
5(a)	The only correct answer is C (acid H_3O^+, conjugate base H_2O) <i>A is not correct as H_2O is not the conjugate base of HNO_3</i> <i>B is not correct because the NO_3^- is the conjugate base and HNO_3 is the acid</i> <i>D is not correct because the H_2O is the conjugate base and H_3O^+ is the acid</i>	(1)

Question Number	Answer	Additional Guidance	Mark
5(b)	An answer that makes reference to the following point: $(\text{pH} =) -\log_{10} [\text{H}^+(\text{aq})]$ or $(\text{pH} =) -\log_{10} [\text{H}_3\text{O}^+(\text{aq})]$	Allow log / lg for $\log_{10}$ Ignore missing (aq) Do not award $-\log$ conc H^+ Do not award round brackets / no brackets for concentration, but allow round brackets around the square brackets e.g. $-\log_{10} ([\text{H}^+(\text{aq})])$	(1)

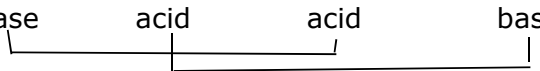


Question Number	Answer	Mark
5(c)	The only correct answer is B (3.16×10^{-5}) <i>A is not correct because this is the value for the H^+ concentration</i> <i>C is not correct as the value for the concentration has been doubled</i> <i>D is not correct because $10^{4.5}$ has been used instead of $10^{-4.5}$</i>	(1)

(Total for Question 5 = 3 marks)



Question Number	Acceptable Answers	Additional Guidance	Mark
1(a)	(a Brønsted-Lowry acid is a) proton donor	Allow donates / gives away protons / H^+ (ions) / hydrogen ions Allow releases / loses protons / H^+ / hydrogen ions Do not award 'donates H_3O^+ (ions)'	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
1(b)	correct acid-base pairs identified and linked	<u>Examples of acid-base pairs</u> $\text{CH}_3\text{COOH} + \text{HCOOH} \rightarrow \text{CH}_3\text{COOH}_2^+ + \text{HCOO}^-$ base 2/B2 acid 1/A1 acid 2/ A2 base 1/B1 or $\text{CH}_3\text{COOH} + \text{HCOOH} \rightarrow \text{CH}_3\text{COOH}_2^+ + \text{HCOO}^-$ base acid acid base  or $\text{CH}_3\text{COOH} + \text{HCOOH} \rightarrow \text{CH}_3\text{COOH}_2^+ + \text{HCOO}^-$ base / B acid / A conjugate conjugate acid / CA base / CB Allow any clear identification of acid and base and connection between the correct pairs	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
1(c)	(pH =) $-\log[\text{H}^+(\text{aq})]$ or (pH =) $-\log[\text{H}_3\text{O}^+(\text{aq})]$	Allow $\log_{10}$ / lg for log Ignore missing (aq) Do not award $-\log$ conc H^+ Do not award round brackets / no brackets for concentration but allow round brackets around the square brackets e.g. $-\log([\text{H}^+(\text{aq})])$	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
1(d)	calculation of $[\text{H}^+(\text{aq})]$	<u>Example of calculation</u> $[\text{H}^+(\text{aq})] = 10^{-\text{pH}} = 10^{-2.76}$ $= 1.7378 \times 10^{-3} / 1.738 \times 10^{-3} /$ $1.74 \times 10^{-3} / 1.7 \times 10^{-3} / 0.0017378 /$ $0.001738 / 0.00174 / 0.0017 \text{ (mol dm}^{-3}\text{)}$ Ignore units even if incorrect Correct answer to 2 or more SF with no working scores (1)	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
1(e)	An explanation that makes reference to the following points: $[\text{H}^+]$ / $[\text{H}_3\text{O}^+]$ / concentration of hydrogen ions from water is $1(.0) \times 10^{-7} \text{ (mol dm}^{-3}\text{)}$ (1) - so total $[\text{H}^+]$ is greater than $1(.0) \times 10^{-7} \text{ (mol dm}^{-3}\text{)}$ / is $1.1 \times 10^{-7} \text{ (mol dm}^{-3}\text{)}$ or the pH cannot be more than 7 / alkaline (for an acid) or concentration of hydrogen ions from water is not negligible / cannot be ignored or 10^{-8} is only the concentration of ions from the acid, it doesn't include those from the water (1)	Penalise reference to nitric acid as a weak acid in M2 only Allow $[\text{H}^+]$ from water = $\sqrt{1(.00) \times 10^{-14}} / \sqrt{K_w}$ Allow this shown as part of a calculation Allow $[\text{H}_3\text{O}^+]$ / concentration of hydrogen ions for $[\text{H}^+]$ Allow $[\text{H}^+]$ is greater than $1 \times 10^{-8} \text{ (mol dm}^{-3}\text{)}$ Allow $[\text{H}^+]$ cannot be less than $[\text{OH}^-]$ / $[\text{OH}^-]$ cannot be more than $[\text{H}^+]$ Allow the addition of nitric acid to water decreases pH by increasing $[\text{H}^+]$ Allow pH is 6.96 Allow pH 8 / >7 is alkaline Allow acid must have pH below 7 Do not award $10^{-14}/10^{-8} = 10^{-6}$ so pH = 6 for M2 only Allow water also dissociates to form H^+ ions	(2)

(Total for Question 1 = 6 marks)

Question Number	Answer	Additional Guidance	Mark
6(a)	An answer that makes reference to the following point: (a Brønsted-Lowry base is a) proton acceptor	Allow accepts protons / H^+ (ions) / hydrogen ions Do not award additional references to reacting with OH^- / alkali	(1)

Question Number	Answer	Additional Guidance	Mark
6(b)	- balanced equation (1) - state symbols (1)	<u>Example of equation</u> $\text{MgO(s)} + 2\text{H}^+(\text{aq}) \rightarrow \text{Mg}^{2+}(\text{aq}) + \text{H}_2\text{O(l)}$ Allow multiples Conditional on M1 or near miss e.g. Mg^+ Allow a fully balanced equation with correct state symbols for 1 mark e.g. $\text{MgO(s)} + 2\text{HCl(aq)} \rightarrow \text{MgCl}_2(\text{aq}) + \text{H}_2\text{O(l)}$ e.g. $\text{MgO(s)} + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{MgSO}_4(\text{aq}) + \text{H}_2\text{O(l)}$ e.g. uncanceled spectator ions from the acid with (aq) Do not award M1 for $\text{Mg}^{2+}(\text{s}) + \text{O}^{2-}(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{Mg}^{2+}(\text{aq}) + \text{H}_2\text{O(l)}$ But M2 can be awarded for correct state symbols	(2)

Question Number	Answer	Additional Guidance	Mark
6(c)	calculation of $[H^+(aq)]$	<u>Example of calculation</u> $[H^+(aq)] = 10^{-pH} = 10^{-9.43}$ $= 3.7154 \times 10^{-10} / 3.715 \times 10^{-10} / 3.72 \times 10^{-10} /$ $3.7 \times 10^{-10} \text{ (mol dm}^{-3}\text{)}$ Do not award 3.71×10^{-10} Ignore units even if incorrect Ignore SF except 1 SF Correct answer with no working scores (1)	(1)

Question number	Answer	Mark
6(d)	The only correct answer is A (solution J: $HCl(aq)$ and $NH_3(aq)$, solution K: $CH_3COOH(aq)$ and $NaOH(aq)$) B is incorrect because the salt formed from a strong acid (HCl) and a strong base ($NaOH$) will have pH 7 while that formed from a weak acid (CH_3COOH) and a weak base (NH_3) will have pH close to 7 C is incorrect because the salt formed from a weak acid and a strong base will have a pH of about 9 while that formed from a strong acid and a strong base will have pH 7 D is incorrect because the salt formed from a weak acid and a weak base will have a pH of about 7 while that formed from a strong acid and a weak base will have pH of about 5	(1)



Question Number	Answer	Additional Guidance	Mark
6(e)(i)	- axes the correct way round, labelled, including units and suitable scale with points covering at least half the paper in both directions (1) - points plotted correctly ($\pm 1/2$ small square) and smooth curve (1) - value of K_w at 45°C (1)	<u>Example of graph</u> Allow $K_w / 10^{-14} / \text{mol}^2 \text{ dm}^{-6}$ as units on y axis Allow $K_w \times 10^{-14} / \text{mol}^2 \text{ dm}^{-6}$ $4.0 \times 10^{-14} (\text{mol}^2 \text{ dm}^{-6})$ Allow 3.8 to $4.2 \times 10^{-14} (\text{mol}^2 \text{ dm}^{-6})$ with no working TE on their working from their graph If they have converted K_w to $\text{p}K_w$, drawn a graph with correctly labelled axes and line of best fit then they can access all three marks as long as their final answer is K_w	(3)

Question Number	Answer	Additional Guidance	Mark
6(e)(ii)	- deduction of expression relating K_w and $[H^+(aq)]$ (1) - calculation of $[H^+(aq)]$ (1) - calculation of pH (1)	Example of calculation $(K_w = [H^+(aq)][OH^-(aq)]$ but $[H^+(aq)] = [OH^-(aq)]$ so $K_w = [H^+(aq)]^2$ $[H^+(aq)]^2 = 1.47 \times 10^{-14}$ $[H^+(aq)] = \sqrt{1.47 \times 10^{-14}}$ (so $[H^+(aq)] = 1.2124 \times 10^{-7} \text{ (mol dm}^{-3}\text{)}$) $pH = -\log 1.2124 \times 10^{-7}$ $= 6.9163 / 6.916 / 6.92 / 6.9$ Do not award 1SF or final answer of 7 or answer incorrectly rounded to 6.91 pH TE on $[H^+]$ Correct answer with no working scores (3) Allow alternative methods	(3)

Question Number	Answer	Additional Guidance	Mark
6(f)(i)	- phenolphthalein (1) - pH at equivalence point / 9 is very close / ± 1 to pK_{in} / 9.3 or pH range is (completely) within the (first) vertical jump in the titration curve / between the range of (pH) 8.5 - pH9.5 (1)	Allow recognisable spellings Allow indicator will change colour in the vertical section of the curve / at the end / equivalence point Accept correct reference to the pH range for phenolphthalein from the data book (8.2-10.0) if there is a connection to the graph Do not allow colourless to pink/red if the colour change of phenolphthalein is mentioned	(2)

Question Number	Answer	Additional Guidance	Mark
6(f)(ii)	equation	<u>Example of equation</u> $\text{NaHCO}_3 + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{O} + \text{CO}_2$ or $\text{HCO}_3^- + \text{H}^+ \rightarrow \text{H}_2\text{O} + \text{CO}_2$ Allow $\text{NaHCO}_3 + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{CO}_3$ Allow multiples Ignore state symbols even if incorrect	(1)

Question Number	Answer	Additional Guidance	Mark
6(f)(iii)	(solution at X) contains a large amount of / reservoir of carbonate ions / CO_3^{2-} and hydrogencarbonate ions/ HCO_3^- (1) - carbonate ions / CO_3^{2-} react with added hydrogen ions / H^+ / acid or $\text{CO}_3^{2-} + \text{H}^+ \rightarrow \text{HCO}_3^-$ (1) - hydrogencarbonate ions / HCO_3^- react with added hydroxide ions / OH^- / alkali or $\text{HCO}_3^- + \text{OH}^- \rightarrow \text{CO}_3^{2-} + \text{H}_2\text{O}$ (1)	Allow there is a large amount of Na_2CO_3 and NaHCO_3 Allow solution at X contains a reservoir of an acid and its conjugate base Allow Na_2CO_3 reacts with added hydrogen ions / H^+ / acid to form NaHCO_3 or $\text{CO}_3^{2-} + \text{HCl} \rightarrow \text{HCO}_3^- + \text{Cl}^-$ or $\text{A}^- + \text{H}^+ \rightarrow \text{HA}$ Allow NaHCO_3 reacts with added hydroxide ions (to form $\text{Na}_2\text{CO}_3 + \text{H}_2\text{O}$) Allow hydroxide ions react with hydrogen ions to form water and hydrogencarbonate ions dissociate to replace / form hydrogen ions or $\text{OH}^- + \text{H}^+ \rightarrow \text{H}_2\text{O}$ and $\text{HCO}_3^- \rightarrow \text{CO}_3^{2-} + \text{H}^+$ or $\text{HA} + \text{OH}^- \rightarrow \text{A}^- + \text{H}_2\text{O}$ Allow $\rightleftharpoons$ in equations Ignore state symbols	(3)

(Total for Question 6 = 17 marks)



Question Number	Answer	Mark
2(a)	The only correct answer is A ($\text{CH}_3\text{COOH} > \text{CH}_2\text{ClCOOH} > \text{HCl}$) <i>B is incorrect because HCl is the only strong acid, so would have the lowest pH</i> <i>C is incorrect because CH_2ClCOOH is stronger than CH_3COOH as the Cl atom stabilises the anion</i> <i>D is incorrect because the stronger the acid the lower the pH, hence these are in reverse order</i>	(1)

Question Number	Answer	Additional Guidance	Mark
2(b)	- calculation of $[\text{H}^+]$ - use of K_a expression to calculate K_a - calculation of $\text{p}K_a$	Example of calculation $[\text{H}^+] = 10^{-2.20} = 6.3096 \times 10^{-3} \text{ (mol dm}^{-3}\text{)}$ $K_a = (6.3096 \times 10^{-3})^2 / 0.240$ $= 1.6588 \times 10^{-4}$ $\text{p}K_a = -\log [1.6588 \times 10^{-4}] = 3.7802$ ignore SF except 1SF ignore units allow TE throughout correct answer with no working scores 3	(3)

Question Number	Answer	Mark
2(c)	The only correct answer is B (NaOH(aq) and excess CH₃COOH(aq)) <i>A is incorrect because the solutions would not form a buffer</i> <i>C is incorrect because the solutions would not form a buffer</i> <i>D is incorrect because the solutions would not form a buffer</i>	(1)

Question Number	Answer	Mark
2(d)	The only correct answer is D (none of these three indicators) <i>A is incorrect because both acid and base are weak so pH range at equivalence is too narrow for bromothymol blue to change colour</i> <i>B is incorrect because both acid and base are weak so pH range at equivalence is too narrow for methyl orange to change colour</i> <i>C is incorrect because both acid and base are weak so pH range at equivalence is too narrow for phenolphthalein to change colour</i>	(1)

(Total Question 2 = 6 marks)



Question Number	Answer	Mark
8(a)	The only correct answer is C <i>A is not correct because this is for a 100-fold increase in concentration</i> <i>B is not correct because this is for no change in concentration</i> <i>D is not correct because this is for a 10000-fold decrease in concentration</i>	(1)

Question Number	Answer	Additional Guidance	Mark
8(b)	- calculation of $[H^+]$ (1) - expression relating K_a, $[H^+]$ and $[CH_2OHCOOH]$ (1) - calculation of $[CH_2OHCOOH]$ (1)	<u>Example of calculation</u> $[H^+] = 10^{-pH} = 0.01 / 1 \times 10^{-2} / 10^{-2} \text{ (mol dm}^{-3}\text{)}$ $K_a = \frac{[H^+]^2}{[CH_2OHCOOH]}$ or $[CH_2OHCOOH] = \frac{[H^+]^2}{K_a}$ Allow [HA] in M2 and M3 $[CH_2OHCOOH] = \frac{0.01^2}{1.5 \times 10^{-4}}$ $= 0.667 / 0.67 \text{ (mol dm}^{-3}\text{)}$ Ignore SF except 1 SF Ignore units Correct answer with no working scores (3)	(3)

Question Number	Answer	Additional Guidance	Mark
8(c)(i)	- named indicator (1) - matching colour change (1) - pH range (of indicator) / quoted range lies (completely) in the vertical region (on the titration curve) or - indicator will change colour in the vertical / straight / steep region of the graph or - pH range of indicator and pH range of vertical region of the graph stated, as long as they overlap (1)	<u>Examples of indicators and colour changes</u> phenol red – red to orange / yellow phenolphthalein ((in ethanol)) – red / pink to colourless (do not allow purple or clear) bromothymol blue – blue to yellow M2 is conditional on a correct indicator in M1 Do not allow unsuitable indicators e.g. litmus Stand alone mark Allow $pK_{in} (\pm 1)$ is in the vertical jump or pK_{in} is nearest to the pH at the end / equivalence point or indicator will change colour at the end / equivalence point or (because it is a) titration of a weak acid with a strong base	(3)



Question Number	Answer	Mark
8(c)(ii)	The only correct answer is C <i>A is not correct because used the volumes the wrong way round</i> <i>B is not correct because not used the volume of glycolic acid from the graph</i> <i>D is not correct because used a 1:2 mole ratio</i>	(1)

Question Number	Answer	Mark
8(c)(iii)	The only correct answer is C <i>A is not correct because this is the pH of glycolic acid</i> <i>B is not correct because this is the pH at the end of the vertical jump in the curve</i> <i>D is not correct because this is the pH at the start of the vertical jump</i>	(1)

Question Number	Answer	Additional Guidance	Mark
8(d)(i)	An explanation that makes reference to the following points: - the O of the (extra) OH / hydroxyl group (in the 2 / alpha position / CH₂OH) withdraws / attracts electrons (1) - stabilises the anion / CH₂OHCOO⁻ ion or weakens O-H bond in acid so hydrogen ion / H⁺ lost more easily (1)	Allow reference to intramolecular hydrogen bonding Allow hydrogen ion / H⁺ more easily dissociates	(2)



Question Number	Answer	Additional Guidance	Mark
8(d)(ii)	$(\text{CH}_2\text{OHCOOH} + \text{CH}_3\text{COOH} \rightarrow)$ $\text{CH}_2\text{OHCOO}^- + \text{CH}_3\text{COOH}_2^+$	Both correct for the mark Allow formulae in either order Allow formulae in brackets with charge outside Allow displayed formulae Do not allow $\text{CH}_3\text{C}(\text{OH})_2^+$	(1)

(Total for Question 8 = 12 marks)



Question Number	Answer	Additional Guidance	Mark
8(a)	An answer that makes reference to the following points: Titration - titrate (ethanoic acid /weak acid) with strong base / sodium hydroxide (1) Then follow the three points for Method 1 or Method 2 Method 1 - measure pH at regular intervals (1) - plot pH against volume (of strong base) (1) - use graph to find pH at half-equivalence point (1) OR Method 2 - use phenolphthalein indicator to find end-point (1) - then add same volume of acid to mixture (at end-point) (1) - measure pH of resultant mixture (with pH meter) (1) Determining K_a (at half neutralisation $\text{pH} = \text{p}K_a$ so) $K_a = 10^{-\text{pH}}$ (1)	Stand alone Allow any indication of a titration Allow acid added to base or base added to acid In both methods, ignore reference to making a standard solution / calibration of the pH probe or meter / practical details of carrying out the titration Allow plot a titration / pH curve Allow use graph to find pH at volume when half neutralised Allow thymol blue / thymolphthalein indicators Ignore colour change even if incorrect Allow repeat titration (with same volumes but without indicator) then add original volume of acid to mixture (at end-point) or use same volume of acid and half the volume of base Do not award pH at end point is 7 Stand alone Allow $[\text{H}^+] = 10^{-\text{pH}}$ and $K_a = [\text{H}^+]$	(5)



Question Number	Answer	Additional Guidance	Mark
8(b)	EITHER - calculation of $[H^+(aq)]$ (1) - calculation of ratio of [acid]/[salt] or [salt]/[acid] or correct values substituted into expression for ratio (1) - calculation of volume of acid required and salt required (1) OR - calculation of $\log [acid]/[salt]$ using Henderson-Hasselbalch (1) - calculation of ratio of [acid]/[salt] (1) - calculation volume of acid required and salt required (1)	<u>Example of calculation</u> $[H^+(aq)] = 10^{-4.70} = 1.9953 \times 10^{-5} \text{ (mol dm}^{-3}\text{)}$ $[acid]/[salt] = 1.9953 \times 10^{-5} / 1.74 \times 10^{-5}$ $= 1.1467 : 1 / 1 : 0.872$ or $[salt]/[acid] = 1.74 \times 10^{-5} / 1.9953 \times 10^{-5}$ $= 0.872 : 1 / 1 : 1.1467$ $(1.1467 / 2.1467) \times 500 = 267 \text{ cm}^3 \text{ acid}$ $500 - 267 = 233 \text{ cm}^3 \text{ salt}$ $4.7595 - 4.70 = 0.05945$ $10^{0.05945} = 1.1467 : 1$ $(1.1467 / 2.1467) \times 500 = 267 \text{ cm}^3 \text{ acid}$ $500 - 267 = 233 \text{ cm}^3 \text{ salt}$ Allow $270 \text{ cm}^3 \text{ acid}$ and $230 \text{ cm}^3 \text{ salt}$ Ignore SF except 1 SF but allow 2 / 2.0 / 2.00 x 10^{-5} for M1 in 'EITHER' Allow TE from M1 throughout Correct answer with no working scores (3)	(3)



Question Number	Answer	Additional Guidance	Mark
8(c)	- calculation amount of $\text{H}_2\text{SO}_4(\text{aq})$ in mol (1) - calculation amount of $\text{H}^+(\text{aq})$ in mol / amount $\text{OH}^-(\text{aq})$ needed (1) - calculation amount of $\text{OH}^-(\text{aq})$ in mol (1) - calculation amount of excess $\text{OH}^-(\text{aq})$ in mol (1) - calculation $[\text{OH}^-]$ in resultant mixture (1) - calculation pH of resultant mixture (1)	<u>Example of calculation</u> $= (40.4/1000) \times 0.370 = 0.014948$ $0.014948 \times 2 = 0.029896 \text{ (mol)}$ $= (51.2/1000) \times 0.927 = 0.047462 \text{ (mol)}$ $= 0.047462 - 0.029896 = 0.017566 \text{ (mol)}$ $= 0.017566 / (91.6/1000) = 0.19177 \text{ (mol dm}^{-3}\text{)}$ $[\text{H}^+] = 1.00 \times 10^{-14} / 0.19177 = 5.2146 \times 10^{-14} \text{ (mol dm}^{-3}\text{)}$ $\text{pH} = -\log 5.2146 \times 10^{-14}$ $= 13.3$ or $14 - (-\log(0.19177)) = 13.3$ Final answer needs to be to at least 1dp Allow TE throughout but TE from M5 to M6 must give a $\text{pH} > 7$ Correct answer with no / some working scores 6 marks Ignore SF except 1 SF in M1 to M5	(6)

(Total for Question 8 = 14 marks)



Question Number	Answer	Mark
6(a)	The only correct answer is D (base acid acid base) <i>A is not correct because HNO_3 is the stronger acid</i> <i>B is not correct because HNO_3 is the stronger acid</i> <i>C is not correct because $\text{C}_6\text{H}_5\text{COOH}_2^+$ is the conjugate acid, and NO_3^- is the conjugate base</i>	(1)

Question Number	Answer	Additional Guidance	Mark
6(b)	An explanation that makes reference to the following points - as the sodium ion / Na^+ is smaller / has a smaller ionic radius (but has the same charge) (1) - so sodium benzoate has stronger ionic bonds / electrostatic forces between ions (so more energy required to break the bonds) (1)	Allow reverse argument Allow (the sodium ion's) charge density is greater / the (oppositely charged) ions are closer together Ignore sodium ion has 1 less shell Ignore atomic radius Ignore just 'sodium is smaller' Ignore Na^+ has less shielding Do not award sodium ions have a higher charge Allow stronger attraction between ions Allow just 'sodium benzoate has stronger bonds' if ion mentioned / formula given in M1 Ignore reference to polarising power of cation / distortion of anion Do not award attraction of electrons to nucleus / electronegativity Do not award M2 if reference to other types of bonding	(2)



Question Number	Answer	Additional Guidance	Mark
6(c)(i)	expression for K_a	Example of expression $K_a = \frac{[\text{C}_6\text{H}_5\text{COO}^-][\text{H}^+]}{[\text{C}_6\text{H}_5\text{COOH}]}$ Allow 6.28×10^{-5} instead of K_a Allow $[\text{H}_3\text{O}^+]$ for $[\text{H}^+]$ Ignore missing K_a Ignore state symbols, even if incorrect Do not award $K_a = \frac{[\text{H}^+]^2}{[\text{C}_6\text{H}_5\text{COOH}]}$ Do not award expression including $[\text{H}_2\text{O}]$ Ignore expression with HA / A⁻ instead of full formulae Do not award round brackets instead of []	(1)

Question Number	Answer	Additional guidance	Mark
6(c)(ii)	- calculation of concentration of H^+ ions (1) - calculation of concentration of benzoic acid (1) - calculation of moles of benzoic acid (1) - calculation of mass of benzoic acid (1) Alternative route for M2 to M4 - calculation of concentration of benzoic acid (1) - calculation of moles of benzoic acid (1) - calculation of mass of benzoic acid (1)	<u>Example of calculation</u> $10^{-3.51} = 3.0903 \times 10^{-4} \text{ (mol dm}^{-3}\text{)}$ This can be subsumed in M2 $6.28 \times 10^{-5} = (3.0903 \times 10^{-4})^2 \div [\text{C}_6\text{H}_5\text{CO}_2\text{H}]$ $[\text{C}_6\text{H}_5\text{CO}_2\text{H}] = (3.0903 \times 10^{-4})^2 \div 6.28 \times 10^{-5}$ $= 1.5207 \times 10^{-3} \text{ (mol dm}^{-3}\text{)}$ $= 1.5207 \times 10^{-3} \times (250 \div 1000)$ $= 3.8017 \times 10^{-4} \text{ (mol)}$ $= 3.8017 \times 10^{-4} \times 122 = 0.046381 / 4.6381 \times 10^{-2} \text{ (g)}$ Allow 46.381 mg $[\text{C}_6\text{H}_5\text{CO}_2\text{H}]_{\text{eqm}} = 1.5207 \times 10^{-3} = [\text{C}_6\text{H}_5\text{CO}_2\text{H}]_{\text{int}} - [\text{H}^+]$ $[\text{C}_6\text{H}_5\text{CO}_2\text{H}]_{\text{int}} = [\text{C}_6\text{H}_5\text{CO}_2\text{H}]_{\text{eqm}} + [\text{H}^+]$ $= 1.5207 \times 10^{-3} + 3.0903 \times 10^{-4}$ $= 1.82973 \times 10^{-3} \text{ (mol dm}^{-3}\text{)}$ $1.82973 \times 10^{-3} / 4 = 4.5743 \times 10^{-4} \text{ (mol)}$ $= 4.5743 \times 10^{-4} \times 122 = 0.055807 / 5.5807 \times 10^{-2} \text{ (g)}$ Allow 55.807 mg Allow TE throughout Allow intermediate values shown as fractions Ignore SF except 1SF Ignore units Final correct answer, with or without working scores 4 marks	(4)



Question Number	Answer	Mark
6(d)(i)	The only correct answer is D (phenolphthalein) <i>A is not correct because bromothymol blue does not change colour within the region of rapid change of pH of this weak acid-strong base titration</i> <i>B is not correct because litmus does not change colour within the region of rapid change of pH of this weak acid-strong base titration</i> <i>C is not correct because methyl orange does not change colour within the region of rapid change of pH of this weak acid-strong base titration</i>	(1)

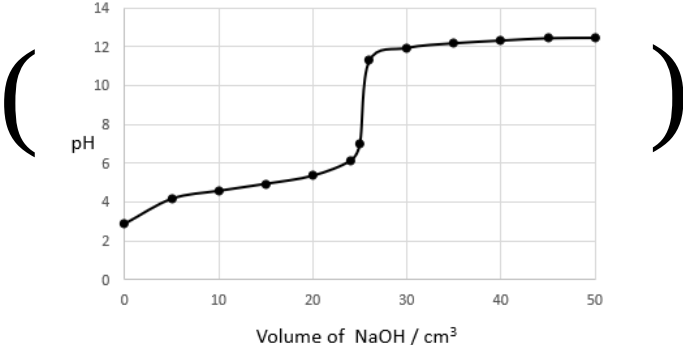
Question Number	Answer	Additional guidance	Mark
6(d)(ii)	- calculation of heat released - calculation of moles of quinic acid - calculation of standard enthalpy of neutralisation and value in kJ mol^{-1} and correct sign	<u>Example of calculation</u> (1) $50 \times 4.18 \times 2.9 = 606.1 \text{ (J)}$ Allow 0.6061 kJ Ignore any signs (1) $(25 \div 1000) \times 0.500 = 0.0125 \text{ (mol)}$ Ignore calculation of moles of NaOH (1) $\frac{-606.1}{0.0125 \times 1000} = -48.5 \text{ (kJ mol}^{-1}\text{)}$ Allow $-30.305 \text{ (kJ mol}^{-1}\text{)}$ as TE if M2 lost for only calculating mol NaOH Allow $-48500 \text{ J mol}^{-1}$ (units essential) Allow TE throughout Allow intermediate values shown as fractions Ignore SF except 1 SF Ignore missing / incorrect units in M1 and M2 Correct final answer with or without working scores (3) Penalise incorrect rounding once only e.g. 0.012 mol	(3)



Question Number	Answer	Additional Guidance	Mark
6(d)(iii)	An explanation that makes reference to the following points - HCN / the weak acid is only partially dissociated (but HCl is fully dissociated) (1) (so releases less energy when neutralised as) energy is needed to break H-C bond(s) (in order to completely dissociate) (1)	Allow ionise for dissociate throughout Allow HCN is not fully dissociated Allow HCN dissociates less than HCl Allow HCN produces a lower concentration of H^+ ions (from the same concentration of acid as HCl) Allow (some) energy is needed to complete the dissociation (of HCN) Allow (some) energy is needed to remove / separate all the H^+ ions Ignore references to enthalpy of hydration of ions Ignore just energy is needed to break bonds Do not award fewer H^+ ions so less NaOH needed for neutralisation Do not award incorrect bond broken If no other mark is awarded allow 1 for HCl is fully dissociated so no energy is required to break the H-Cl bond	(2)

(Total for Question 6 = 14 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
4(a)	An answer that makes reference to the following point: (a Brønsted-Lowry acid is a) proton donor / donator	Allow donates protons / H ⁺ (ions) / hydrogen ions	(1)

Question Number	Answer	Mark
4(b)	The only correct answer is B  <i>A is not correct because this is the titration curve of 0.100 mol dm⁻³ of a strong acid and 0.100 mol dm⁻³ of a strong base</i> <i>C is not correct because this is the titration curve of 0.100 mol dm⁻³ of a weak acid and 0.100 mol dm⁻³ of a weak base</i> <i>D is not correct because this is the titration curve of 0.100 mol dm⁻³ of a strong acid and 0.100 mol dm⁻³ of a weak base</i>	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
4(c)	An answer that makes reference to the following points: - hydrochloric acid is a strong acid - sulfuric acid is diprotic / can donate two H^+ ions / protons - the second ionisation of sulfuric acid is not complete / is suppressed by the first ionisation - propanoic acid is a weak acid / partially dissociated	(1) Allow HCl is (almost) fully dissociated / ionised in solution Allow $\text{HCl} \rightarrow \text{H}^+ + \text{Cl}^-$ Do not award reversible arrow (1) Ignore just H_2SO_4 is more strongly acidic than HCl Allow $\text{H}_2\text{SO}_4 \rightarrow 2\text{H}^+ + \text{SO}_4^{2-}$ Ignore reversible arrow (1) Allow this shown in an equation $\text{HSO}_4^- \rightleftharpoons \text{H}^+ + \text{SO}_4^{2-}$ (1) Allow $\text{CH}_3\text{CH}_2\text{COOH} \rightleftharpoons \text{CH}_3\text{CH}_2\text{COO}^- + \text{H}^+$ Ignore just propanoic acid is weakly acidic / weakest acid	(4)

Question Number	Acceptable Answer	Additional Guidance	Mark
4(d)(i)	An answer that makes reference to the following point: expression for K_a	$K_a = \frac{[\text{H}^+][\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]}$ Ignore state symbols Allow H_3O^+ for H^+ Do not award round brackets.	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
4(d)(ii)	- rearrangement or substitution of values into the equation (1) - calculation of $[\text{H}^+]$ (1) - calculation of pH (1)	<u>Example of calculation</u> $[\text{H}^+] = \frac{K_a \times [\text{H}_2\text{CO}_3]}{[\text{HCO}_3^-]}$ $[\text{H}^+] = \frac{(4.5 \times 10^{-7} \times 0.0020)}{0.024}$ $= 3.75 \times 10^{-8} \text{ (mol dm}^{-3}\text{)}$ Allow TE from an incorrect expression in 4(c)(i) for 1 mark $\text{pH} = -\log_{10} [\text{H}^+]$ $= -\log_{10} (3.75 \times 10^{-8}) = 7.426 / 7.43 / 7.4$ Standalone mark Allow TE on incorrect value Ignore SF except 1 SF	(3)

Question Number	Acceptable Answer	Additional Guidance	Mark
4(e)(i)	An answer that makes reference to the following points: - the position of the first and second equilibria are shifted to the right (to use up the CO₂) (so the) concentration of H⁺ / [H⁺] rises and (resulting in a) lower pH	(1) Allow reference to each specific equilibrium and a comment about more of the relevant products being produced if no mention of a shift to the right. (1) M2 dependent on M1 Ignore 'becomes more acidic' for lower pH	(2)

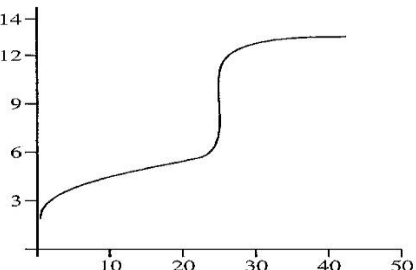
Question Number	Acceptable Answer	Additional Guidance	Mark
4(e)(ii)	An explanation that makes reference to the following points: - there is a (large) reservoir of HCO₃⁻ (and H₂CO₃) (when the H⁺ ion concentration / [H⁺] increases) the H⁺ ions / protons react with / the HCO₃⁻ to form more H₂CO₃ (so restoring the pH)	(1) Allow a large amount / high concentration (1) Allow Equilibrium 2 shifts to the left hand side (so restoring the pH) Allow H⁺ + HCO₃⁻ ⇌ H₂CO₃ Allow this equation with a forward arrow. Do not award the H⁺ ions neutralise the HCO₃⁻ Ignore any mention of OH⁻ ions shifting equilibrium 2 to the left.	(2)

(Total for Question 4 = 14 marks)



Question Number	Acceptable Answers	Additional Guidance	Mark
7(a)	- calculates moles of X^- / NaOH present in the mixture (1) - calculates moles of HX which remain unreacted (1) - calculates / shows ratio of [HX] to $[X^-]$ OR ratio of moles of HX : X^- (as total V cancels) (1) - re-arranges K_a or pK_a expression correctly and substitutes appropriate values (1) - final pH to 2 or 3SF (1)	<u>Example of calculation:</u> (moles of X^- = mol NaOH = $\frac{0.8(00) \times 10.5}{1000}$) $= 0.0084(0) / 8.4(0) \times 10^{-3}$ (mol) (moles of HX – mol NaOH = $\frac{0.92(0) \times 25.0}{1000} - 0.0084(0)$) $= 0.023(0) - 0.0084(0)$ $= 0.0146 / 1.46 \times 10^{-2}$ (mol) $[HX] = \frac{0.0146}{0.0355}$ and $[X^-] = \frac{0.0084(0)}{0.0355}$ $= 0.411$ and 0.237 (mol dm^{-3}) Allow use of the ratio of the moles as above (as total V cancels) $[H^+] = K_a \times \frac{[HX]}{[X^-]} = 5.25 \times 10^{-5} \times \frac{0.411}{0.237}$ $[H^+] = 9.10443038 \times 10^{-5}$ (mol dm^{-3}) pH = 4.04 Allow use of pH expression to get answer: pH = $pK_a - \log \frac{[HX]}{[X^-]}$ or $pK_a + \log \frac{[X^-]}{[HX]}$ ALLOW TE M5 for calculation of pH from any $[H^+]$ Correct answer with no working scores (5)	(5)



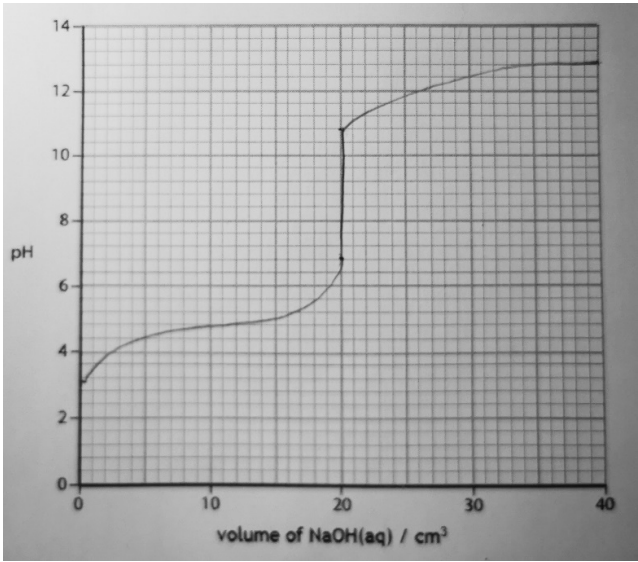
Question Number	Acceptable Answers	Additional Guidance	Mark
7(b)(i)	A sketch graph which shows the following: - a starting pH between 2 and 4 (inclusive) (1) - correct general shape and ends at pH = 12-13 (1) (any) vertical at 25 cm³ (1) - vertical between pH = 6 - 7 and pH = 10 - 12 (1)	 Vertical must be no more than 5 pH units within these ranges	(4)

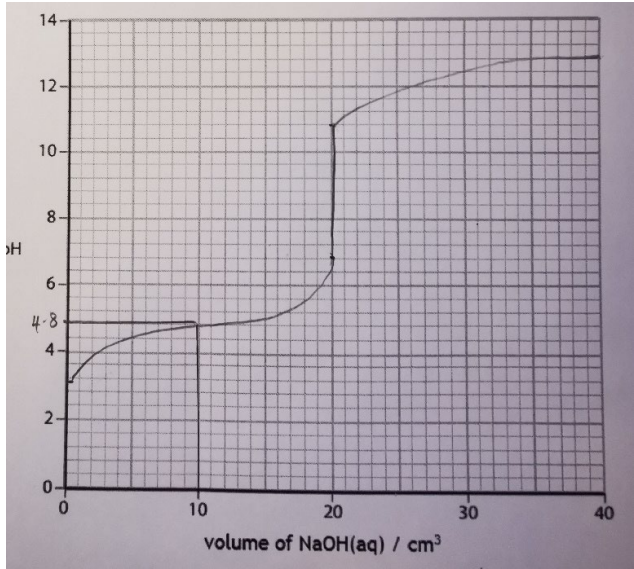
Question Number	Acceptable Answers	Additional Guidance	Mark
7(b)(ii)	An explanation that makes reference to the following points: (Read off) pH at half-neutralisation (point) / pH at 12.5 (cm³) OR pH at half-equivalence (point) (1) - As $\text{pH} = \text{p}K_a$ / $[\text{H}^+] = K_a / K_a = 10^{-\text{pH}}$ (1)	May be shown on the sketch graph ALLOW read equivalence vol, add same volume of (propanoic) acid and measure pH M2 dependent on mentioning half equivalent / 12.5 cm³	(2)

(Total for Question 7 = 11 marks)

Question Number	Answer	Additional Guidance	Mark
8(a)	- calculation of concentration of hydrogen ions (1) - calculation of K_a (1)	<u>Example of calculation</u> $[\text{H}^+] = 10^{-3.25} = 5.6234 \times 10^{-4} \text{ (mol dm}^{-3}\text{)}$ $(5.6234 \times 10^{-4})^2 \div 0.0712 = 4.4414 \times 10^{-6} \text{ (mol dm}^{-3}\text{)}$ Allow TE from M1 Final answer with no working scores 2 Ignore SF except 1SF If they round their answer to M1 to 5.6×10^{-4} they get an answer of $4.4045 \times 10^{-6} \text{ (mol dm}^{-3}\text{)}$	(2)

Question Number	Answer	Additional Guidance	Mark
8(b)(i)	calculation of pH	<u>Example of calculation</u> $[\text{H}^+] = 1.00 \times 10^{-14} \div [\text{OH}^-]$ $= 1.00 \times 10^{-14} \div 0.05$ $= 2.00 \times 10^{-13} \text{ (mol dm}^{-3}\text{)}$ $-\log(2.00 \times 10^{-13}) = 12.7$ Do not award answers with more than 1 decimal place (e.g. 12.70 scores 0) Correct answer with no or incorrect working scores 1	(1)

Question Number	Answer	Additional Guidance	Mark
8(b)(ii)	An answer that makes reference to the following points: - starting pH between 2.8 and 3.4 and pH at 40 cm³ between 12 and 12.8 no TE on answer to bi - vertical section at 20 cm³ and range of vertical section between 6-11, but must include 7-10 - curved shape including steep rise at the start (as example) between 0 and approx. 5 cm³	<u>Example of graph</u> 	(3)

Question Number	Answer	Additional Guidance	Mark
8(b)(iii)	An answer that makes reference to the following points: working shown, and value of pH at 10 cm³ consistent with graph in 8b(ii) Allow tolerance of ± 0.5 square	<u>Example of working on graph</u>  e.g. pH = 4.8	(1)

Question Number	Answer	Additional Guidance	Mark
8(b)(iv)	An answer that makes reference to the following points: • K_a expression for ethanoic acid or at half-neutralisation $[\text{CH}_3\text{COOH}] = [\text{CH}_3\text{COO}^-] / [\text{HA}] = [\text{A}^-]$ (1) • $[\text{H}^+] = K_a$ or $\text{pH} = \text{p}K_a$ (1) • Value of K_a (1)	$K_a = \frac{[\text{CH}_3\text{COO}^-][\text{H}^+]}{[\text{CH}_3\text{COOH}]}$ or $K_a = \frac{[\text{A}^-][\text{H}^+]}{[\text{HA}]}$ e.g. $K_a = 10^{-4.8} = 1.585 \times 10^{-5} \text{ (mol dm}^{-3}\text{)}$ Allow TE from 8biii	(3)



Question Number	Answer	Additional Guidance	Mark
8(c)	An answer that makes reference to three of the following points: Data logger likely to give most valid outcomes as - time period / volume between readings is (much) smaller / greater resolution / more data points / more frequent data-points (1) (percentage) errors in using measuring equipment reduced / (1) - data collection is faster (1) - produces continuous data / graph / processed data can be seen in real time (1) - automatic collection of data means less chance of human error / parallax error reduced (1) - data can be transferred (easily) to other software (e.g. spreadsheets) / stored (1)	Allow reverse arguments Ignore a general comment about accuracy e.g. more accurate	(3)



Question Number	Answer	Additional Guidance	Mark
8(d)(i)	- calculation of $[H^+]$ (1) - calculation of concentration of salt (1) - rearrangement of K_a to find $[CH_3CH_2COOH]$ (1) - calculation of $[CH_3CH_2COOH]$ (1)	<u>Example of calculation</u> $10^{-4.2} = 6.3096 \times 10^{-5} \text{ (mol dm}^{-3}\text{)}$ $(2.30 \div 96) \times 10 = 0.23958 \text{ (mol dm}^{-3}\text{)}$ $[CH_3CH_2COOH] = ([H^+] \times [CH_3CH_2COONa]) \div K_a$ $(6.3096 \times 10^{-5} \times 0.23958) \div 1.34 \times 10^{-5}$ $= 1.128 / 1.13 / 1.1 \text{ (mol dm}^{-3}\text{)}$ Ignore SF except 1 SF Allow TE throughout Correct answer without working scores 4 Do not award 1.12 (incorrectly rounded) Allow use of Henderson-Hasselbalch equation $pH = pK_a + \log_{10} \frac{[A^-]}{[HA]}$ M1: Rearrangement of HH equation $\log_{10} \frac{[A^-]}{[HA]} = 4.2 - 4.873 = -0.673$ M2 : Calculation of $\frac{[CH_3CH_2CO_2Na]}{[CH_3CH_2COOH]} = 10^{-0.673} = 0.2123$ M3: $[CH_3CH_2COONa] = (2.3 \div 96) \div 0.1 = 0.2396 \text{ (mol dm}^{-3}\text{)}$ M4: $[CH_3CH_2COOH] = 0.2396 \div 0.2123 =$ $1.128 / = 1.128 / 1.13 / 1.1 \text{ (mol dm}^{-3}\text{)}$ TE at all stages	(4)



Question Number	Answer	Additional Guidance	Mark
8(d)(ii)	An explanation that makes reference to the following points: • (large) reservoir of sodium propanoate / propanoate ions (and propanoic acid) (1) • (large reservoir of) propanoate ions accept protons from / react with HCl (1) • (small changes in [acid] and [salt] are negligible) so ratio of acid: salt remains (nearly) constant (and pH depends on this ratio) (1)	Allow a large amount / high concentration Accept (acid) eqm moves to left (forming CH₃CH₂COOH) $\text{CH}_3\text{CH}_2\text{CO}_2^- + \text{H}^+ \rightarrow \text{CH}_3\text{CH}_2\text{COOH}$ $\text{NaCH}_3\text{CH}_2\text{CO}_2 + \text{HCl} \rightarrow \text{CH}_3\text{CH}_2\text{COOH} + \text{NaCl}$ Do not award the H⁺ ions neutralise the propanoate	(3)

(Total for Question 8 = 20 marks)



Question Number	Answer	Additional Guidance	Mark
9(a)	$\text{HPO}_4^{2-} + \text{H}^+ \rightarrow \text{H}_2\text{PO}_4^-$ or $\text{HPO}_4^{2-} + \text{H}_3\text{O}^+ \rightarrow \text{H}_2\text{PO}_4^- + \text{H}_2\text{O}$ (1) $\text{H}_2\text{PO}_4^- + \text{OH}^- \rightarrow \text{HPO}_4^{2-} + \text{H}_2\text{O}$ (1)	Penalise non-ionic equations, e.g. using NaOH or HCl once only Equations must show reaction of ions with H^+ / H_3O^+ and OH^- Allow $\rightleftharpoons$ Ignore state symbols Allow $\text{H}_2\text{PO}_4^- \rightarrow \text{HPO}_4^{2-} + \text{H}^+$ and $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$	(2)



Question Number	Answer	Additional Guidance	Mark
9(b)	- calculation of the amount of NaOH / salt (1) - calculation of initial amount of acid (1) - calculation of the amount of acid left (1) - calculation of $[H^+]$ (1) - calculation of pH (1)	<u>Example of calculation</u> amount of NaOH = amount of salt formed $= 0.100 \times 20.0/1000 = 0.00200$ initial amount of acid = $0.150 \times 25.0/1000$ $= 0.00375$ amount of acid left = $0.00375 - 0.00200$ $= 0.00175$ total volume = $20.0 + 25.0 = 45.0 \text{ (cm}^3\text{)}$ $[\text{salt}] = 0.00200 \times 1000/45.0 = 0.0444 \text{ (mol dm}^{-3}\text{)}$ $[\text{acid}] = 0.00175 \times 1000/45.0 = 0.0389 \text{ (mol dm}^{-3}\text{)}$ $K_a = \frac{[H^+][\text{salt}]}{[\text{acid}]}$ so $[H^+] = K_a \frac{[\text{acid}]}{[\text{salt}]}$ $[H^+] = 1.74 \times 10^{-5} \times 0.0389/0.0444$ $= 1.52446 \times 10^{-5} \text{ (mol dm}^{-3}\text{)}$ Allow use of moles instead of concentrations pH = $-\log[H^+] = -\log(1.52446 \times 10^{-5})$ $= 4.817 / 4.82 / 4.8$ Allow TE for each step Ignore SF except 1 SF Correct answer without working score (5)	(5)



		Allow alternative methods, for example $\text{pH} = \text{p}K_{\text{a}} - \log \frac{[\text{acid}]}{[\text{salt}]}$ $\text{pH} = -\log 1.74 \times 10^{-5} - \log \frac{0.0389}{0.0444}$ pH = 4.817 / 4.82 / 4.8 scores M4 and M5 or $\text{pH} = \text{p}K_{\text{a}} + \log \frac{[\text{salt}]}{[\text{acid}]}$ $\text{pH} = -\log 1.74 \times 10^{-5} + \log \frac{0.0444}{0.0389}$ pH = 4.817 / 4.82 / 4.8 scores M4 and M5	
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(Total for Question 9 = 7 marks)



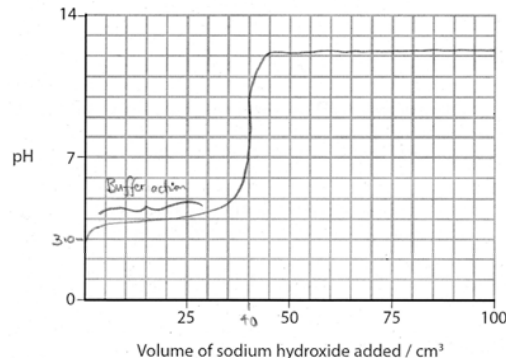
Question Number	Answer	Mark
9(a)	B is not correct because buffers do not always contain equal numbers of moles of the acid and its conjugate base C is not correct because a buffer does not prevent any change in pH	

Question Number	Answer	Additional Guidance	Mark
9(b)	(M1) calculation of $[H^+]$ (1) (M2) rearrangement of K_a and calculation of ethanoate concentration (1) (M3) calculation of the number of moles of ethanoate in the buffer volume (1) (M4) calculation of the mass of sodium ethanoate in the buffer volume (1) (M5) answer to 2/3 SF (1)	<u>Example of calculation</u> $[H^+] = 10^{-3.9} = 1.2589 \times 10^{-4} \text{ (mol dm}^{-3}\text{)}$ $[CH_3COO^-] = \frac{(1.74 \times 10^{-5} \times 0.800)}{1.2589 \times 10^{-4}} =$ $= 0.11057 \text{ (mol dm}^{-3}\text{)}$ $n = (0.11057 \times 0.05) = 5.5285 \times 10^{-3} \text{ (mol)}$ $m = (5.5285 \times 10^{-3} \times 82) = 0.453339 \text{ (g)}$ $m = 0.45 / 0.453 \text{ (g)}$ Award this mark only if there has been some attempt at calculation using an M_r TE at each stage If Henderson-Hasselbalch equation used (M1) for calculation of $pK_a = 4.759$ (M2) for rearrangement and calculation of ethanoate concentration Remaining marking points as above	(5)



Question Number	Answer	Additional Guidance	Mark
9(c)	An answer that makes reference to the following points: - carbon dioxide dissolved in the blood forms carbonic acid (and so this concentration increases) (1) - the equilibrium will shift to the right and produces more H^+/acid ions (1) - the (high) concentration of hydrogencarbonate ions suppress the ionisation of carbonic acid (to help to control pH) or the (large) reservoir/excess of hydrogencarbonate ions combine with the H^+ ions (to help to control blood pH) (1)	Can be shown in an equation Do not award 'CO_2 reacts with H^+ to form carbonic acid' Allow Carbonic acid (partially) dissociates to produce H^+ Do not award 'CO_2 reacts with H^+ so equilibrium shifts to the right to produce more H^+' Ignore general comments about the effects of adding acid and/or alkali to a buffer which do not relate to carbon dioxide	(3)



Question Number	Answer	Additional Guidance	Mark
9(d)(i)	- general shape of weak acid-strong base curve (1) - curve starts at pH of 3.0 and ends at pH of 12-13 (1) - vertical part of the curve at 40 cm³ (1) - labelling of area indicating buffer action (1)	Exemplar graph  Ignore missing initial rise in pH Vertical part must cover 3-5 pH units between 6 – 11 The curve should reach pH~12-13 by 10cm³ after vertical section The curve must start at zero and continue to 100 cm³ Allow buffering area to be labelled anywhere between ~5 and 35 cm³ inclusive	(4)

Question Number	Answer	Additional Guidance	Mark
9(d)(ii)	An answer that makes reference to - determine the pH at the point when half of the acid is neutralised (1) $K_a = 10^{-\text{pH}}$ / $K_a = 10^{-\text{p}K_a}$ (1)	Standalone marks Allow 'pH at half-equivalence point' Allow 'pH at half neutralisation point' Accept description in words such as inverse log of minus pH or value is $\text{p}K_a$ and so inverse log of minus value gives K_a Allow $\text{p}K_a = -\log K_a$ Ignore any calculation	(2)

(Total Question 9 = 15 marks)

Question Number	Answer	Additional Guidance	Mark
7(a)	An answer that makes reference to one of the following points the loss of a hydrogen from the O–H group is made possible by the delocalisation of charge of/stabilisation on the carboxylate ion or the loss of a hydrogen from a methyl group would produce a carbanion with no stabilisation or similar electronegativities of carbon and hydrogen means that there is a lack of C–H bond polarity or the enthalpy of hydration of the ions outweighs the energy needed to break the O–H bond	Allow the C–H bond is not polar but the O–H bond is/ O–H bond is more polar Do not award the O–H bond is weaker than the C–H bond	(1)

Question Number	Answer	Mark
7(b)	The only correct answer is C (H₂O and OH[–]) <i>A is not correct because ammonia is acting as a base and not an acid</i> <i>B is not correct because this is the base – conjugate acid pair</i> <i>D is not correct because water and the ammonium ion are not an acid-conjugate base pair</i>	(1)



Question Number	Answer	Additional Guidance	Mark
(7c)	(M1) calculation of concentration of diluted acid (1) (M2) calculation of pH (1)	<u>Example of calculation</u> $c = (15 \times 15.9 / 100) = 2.385 \text{ (mol dm}^{-3}\text{)}$ $\text{pH} = -\log(2.385) = -0.377 / -0.38 / -0.4$ TE on M1 provided answer is <7 Final answer without working scores (2) Ignore SF	(2)

Question Number	Answer	Additional Guidance	Mark
7(d)(i)	- expression for K_a (1) - calculation of $[\text{H}^+]$ (1) - calculation of pH to 2/3 SF (1)	<u>Example of calculation</u> $K_a = \frac{[\text{H}^+] \times [\text{A}^-]}{[\text{HA}]}$ $[\text{H}^+] = \sqrt{K_a \times [\text{HA}]} = \sqrt{(1.35 \times 10^{-6})} = 1.16... \times 10^{-3} \text{ (mol)}$ $\text{pH} = -\log(1.16... \times 10^{-3}) = 2.93/2.9$ TE on M2 provided answer <7 Final answer without working scores (3)	(3)

Question Number	Answer	Additional Guidance	Mark
7(d)(ii)	An answer which makes reference to the following points (assumption 1) $[C_2H_5COOH]_{initial} = [C_2H_5COOH]_{eqm}$ (1) (assumption 2) $[H^+] = [C_2H_5COO^-]$ (1)	ACCEPT assumptions in any order Allow HA for C_2H_5COOH Allow A^- for $C_2H_5COO^-$ Dissociation of propanoic acid is negligible Ignore propanoic acid is a weak acid ALLOW for M2 “Negligible $[H^+]$ from water” Ignore reference to standard conditions	(2)

Question Number	Answer	Additional Guidance	Mark
7(e)(i)	- calculation of acid concentration (1) - calculation of salt concentration (1) - calculation of hydrogen ion concentration (1) - calculation of pH (1)	<u>Example of calculation</u> $[Acid] = ((0.100 \times (20 \div 50)) = 0.04 \text{ (mol dm}^{-3}\text{)})$ $[A^-] = ((0.305 \times (30 \div 50)) = 0.183 \text{ (mol dm}^{-3}\text{)})$ $[H^+] = 1.52 \times 10^{-5} \text{ mol} \times (0.04 \div 0.183) = 3.322 \times 10^{-6} \text{ (mol dm}^{-3}\text{)}$ $pH = -\log(3.322 \times 10^{-6}) = 5.48/5.5$ Correct answer without working scores (4) Ignore SF except 1SF Allow M3 and M4 if just moles and no volumes are used Accept use of the Henderson-Hasselbalch equation	(4)



Question Number	Answer	Additional Guidance	Mark
7(e)(ii)	An answer which includes - suitable equation(s) (1) - The pH stays approximately constant because there is a large reservoir of undissociated acid and so the ratio of acid:salt does not change (1)	<u>Example equation</u> $\text{C}_3\text{H}_7\text{COOH} + \text{NaOH} \rightarrow \text{C}_3\text{H}_7\text{COONa} + \text{H}_2\text{O}$ OR $\text{C}_3\text{H}_7\text{COOH} + \text{OH}^- \rightarrow \text{C}_3\text{H}_7\text{COO}^- + \text{H}_2\text{O}$ Allow $\text{OH}^- + \text{H}^+ \rightarrow \text{H}_2\text{O}$ followed by $\text{C}_3\text{H}_7\text{COOH} \rightarrow \text{C}_3\text{H}_7\text{COO}^- + \text{H}^+$ Allow use $\rightleftharpoons$ of in all of above equations Allow (The pH stays approximately constant) as the hydroxide ions react to form water and butanoic acid dissociates to replace the hydrogen ions used up	(2)

(Total Question 7 = 15 marks)



Question Number	Answer	Additional Guidance	Mark
8(a)(i)	An explanation that makes reference to the following points: - as the weak acid (is being titrated with) a weak base (1) - as no rapid change in pH (to find volume at end-point) (1) - so end-point cannot be determined (1)	Accept pH changes gradually around the end point Allow there is no vertical section in the titration curve so a sharp colour change cannot be observed Allow phenolphthalein would not change colour/ pK_{in} is too high	(3)
Question Number	Answer	Additional Guidance	Mark
8(a)(ii)	(replace ammonia with) a strong base such as NaOH / KOH	Allow name or formula of strong base Allow use of a pH probe/pH meter Do not award change of indicator	(1)



Question Number	Answer	Additional Guidance	Mark
8(a)(iii)	An answer that makes reference to the following points: (method 1) K_a expression for ethanoic acid - statement that at half-neutralisation concentration of anion and acid are equal $K_a = [H^+] \quad (=10^{-pH})$ (method 2) - Henderson-Hasselbalch expression - statement that at half-neutralisation concentration of anion and acid are equal $pK_a = pH \quad (\text{so } K_a = [H^+] = 10^{-pH})$	(1) $K_a = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]} \quad \text{or } K_a = \frac{[A^-][H^+]}{[HA]}$ (1) $[CH_3COOH] = [CH_3COO^-] \text{ or } [HA] = [A^-]$ (1) Allow $pK_a = pH \quad (= -\log [H^+] = -\log K_a)$ Standalone mark Do not award $K_a = pK_a$ Penalise omission of square brackets once only Penalise use of () throughout for [] once only (1) $pH = pK_a + \log \left(\frac{[A^-]}{[HA]} \right) \text{ or } pH = pK_a + \log \left(\frac{[\text{salt}]}{[\text{acid}]} \right)$ or $pK_a = pH - \log \left(\frac{[A^-]}{[HA]} \right)$ (1) (1)	(3)



Question Number	Answer	Additional Guidance	Mark
8(b)	A calculation that makes reference to the following points: (M1) calculation of $[H^+]$ (M2) rearrangement of K_a expression (M3) calculation of $[CH_3COONa]$ in buffer OR Use of Henderson Hasselbalch for M1 to M3 (M1) rearrangement of H-H expression (M2) calculation of $[CH_3COONa] \div [CH_3COOH]$ (M3) calculation of $[CH_3COONa]$ ----- (M4) calculation of M_r of CH_3COONa (M5) calculate the mass of CH_3COONa needed	<u>Example of calculation</u> (1) $10^{-4.48} = 3.3113 \times 10^{-5} \text{ (mol dm}^{-3}\text{)}$ (1) $K_a = ([H^+][CH_3COONa]) \div [CH_3COOH]$ $[CH_3COONa] = K_a \times [CH_3COOH] \div [H^+]$ (1) $[CH_3COONa] = (1.74 \times 10^{-5} \times 0.52) \div 3.3113 \times 10^{-5}$ $= 0.27325 \text{ (mol dm}^{-3}\text{)}$ (1) $\log ([CH_3COONa] \div [CH_3COOH]) = 4.48 - 4.75945 = -0.27945$ (1) $[CH_3COONa] \div [CH_3COOH] = 10^{-0.27945} = 0.52547$ (1) $[CH_3COONa] = 0.52547 \times 0.52 = 0.27325 \text{ (mol dm}^{-3}\text{)}$ (1) 82 (1) $= (0.27325 \div 4 \times 82) = 5.6015 \text{ (g) / 5.6 (g)}$ Allow TE but not from an incorrect rearrangement for M3 Ignore SF except 1 SF Allow CH_3COO^- for CH_3COONa in M2 and M3 Correct answer with or without working scores (5)	(5)



Question Number	Answer	Additional Guidance	Mark
8(c)	A calculation that makes reference to the following points: - calculate amount of $\text{H}^+(\text{aq})$ in mol - calculate amount of $\text{OH}^-(\text{aq})$ in mol - calculate amount of excess $\text{OH}^-(\text{aq})$ in mol - calculate $[\text{OH}^-]$ in resultant solution - calculate pH of resultant solution	<u>Example of calculation</u> $= (20 \div 1000) \times 0.400 \times 2 = 0.016 \text{ (mol)}$ $= (50.0 \div 1000) \times 0.900 = 0.045 \text{ (mol)}$ $= 0.045 - 0.016 = 0.029 \text{ (mol)}$ $= 0.029 \div (70 \div 1000) = 0.41429 \text{ (mol dm}^{-3}\text{)}$ pH = $14 - (-\log(0.41429)) = 13.617 / 13.6$ or pH = $-\log(1 \times 10^{-14} \div 0.41429) = 13.617 / 13.6$ Do not award M5 for a pH less than 7 Ignore SF except 1 SF Ignore intermediate units even if incorrect Allow TE throughout	(5)

(Total for Question 8 = 17 marks)

