Questions

Q1.

This question is about acids and bases.

Identify the acid-base conjugate pairs in this reaction.

(1)

$$CH_3COOH + HCOOH \rightarrow CH_3COOH_2^+ + HCOO^-$$

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(Total for question = 1 mark)

Q2.

This question is about acids and bases.

State what is meant by a Brønsted-Lowry base.

(1)

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(Total for question = 1 mark)

Q3.

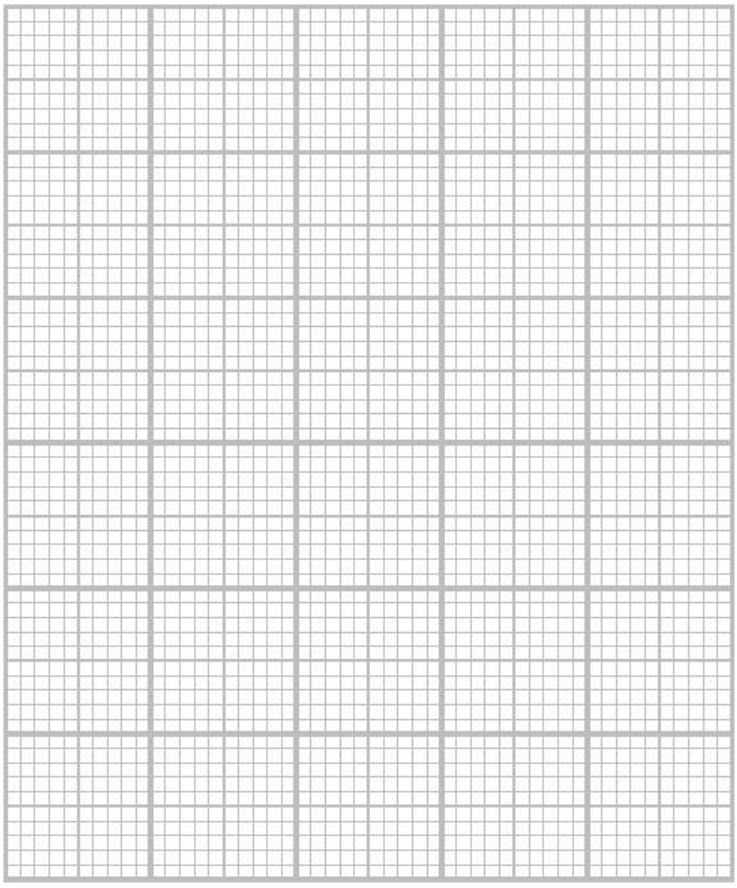
This question is about acids and bases.

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

Temperature / °C	K_w / mol^2 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)



(ii) The ionic product of water at 30 °C is 1.47×10^{-14} mol2 dm^{-6}.
Calculate the pH of water at this temperature.

(3)

(Total for question = 6 marks)

Q4.

This question is about acids and bases.

A solution of methanoic acid, HCOOH, has a concentration of 0.240 mol dm^{-3} and a pH of 2.20.

Calculate the value of pK_a for methanoic acid.

(3)

(Total for question = 3 marks)

Q5.

This question is about acids and bases.

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

(1)

(Total for question = 1 mark)

Q6.

Calculate the pH of the solution formed when

51.2 cm^3 of 0.927 mol dm^{-3} NaOH(aq) is mixed with

40.4 cm^3 of 0.370 mol dm^{-3} H_2SO_4(aq).

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

(6)

(Total for question = 6 marks)

Q7.

This question is about acids and bases.

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 $NH_3(aq)$	$CH_3COOH(aq)$ and $NaOH(aq)$
☒ **B**	$HCl(aq)$ and $NaOH(aq)$	$CH_3COOH(aq)$ and $NH_3(aq)$
☒ **C**	$CH_3COOH(aq)$ and $NaOH(aq)$	$HCl(aq)$ and $NaOH(aq)$
☒ **D**	$CH_3COOH(aq)$ and $NH_3(aq)$	$HCl(aq)$ and $NH_3(aq)$

(Total for question = 1 mark)

Q8.

This question is about acids and bases.

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)

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(Total for question = 5 marks)

Q9.

This question is about acids and buffer solutions.

Ethanoic acid, CH_3COOH, is a monobasic acid.

$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$

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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(Total for question = 1 mark)

Q10.

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

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

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)

Q11.

Boric acid, H_3BO_3, is a weak acid with antiseptic properties.

In aqueous solution, boric acid dissociates into ions in three stages.
The equation for the first dissociation is

$$H_3BO_3(aq) \rightleftharpoons H^+(aq) + H_2BO_3^-(aq)$$

pK_a for this dissociation is 9.24

(i) Calculate the pH of a 0.0500 mol dm^{-3} solution of boric acid from the pK_a value for the first dissociation.

(3)

(ii) State any assumptions you made in your calculation in (i).

(2)

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(Total for question = 5 marks)

Q12.

This question is about acids and bases.

State what is meant by a Brønsted-Lowry acid.

(1)

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(Total for question = 1 mark)

Q13.

This question is about acids and buffer solutions.

A commercial nitric acid solution, $HNO_3(aq)$, 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)

(Total for question = 2 marks)

Q14.

This question is about acids and buffer solutions.

Propanoic acid is a weak acid.

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

[K_a = 1.35 × 10^{-5} mol dm^{-3} at 298 K]

(3)

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

(2)

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(Total for question = 5 marks)

Q15.

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)

Q16.

In acid-base neutralisation reactions, there is a temperature change.

* The table shows the enthalpy changes of reaction when 1 mol of different acids are neutralised by sodium hydroxide solution, at 298 K.

Acid	Enthalpy change of reaction for 1 mol of acid / kJ mol^{-1}
hydrochloric acid, HCl	–58
nitric acid, HNO_3	–58
sulfuric acid, H_2SO_4	–115
ethanoic acid, CH_3COOH	–56

Comment on the relative enthalpy changes of reaction, using the data from the table and including any relevant equations.

(6)

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(Total for question = 6 marks)

Q17.

This question is about acids and bases.

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

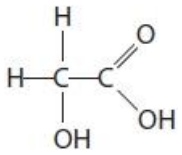
(1)

(Total for question = 1 mark)

Q18.

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



Glycolic acid has an acid dissociation constant of 1.5×10^{-4} mol dm^{-3} compared with a value of 1.7×10^{-5} 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)

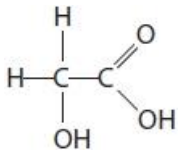
$CH_2OHCOOH + CH_3COOH \rightarrow$ ..... + ...

(Total for question = 3 marks)

Q19.

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



(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)

(Total for question = 4 marks)

Q20.

This question is about acids and bases.

Write the expression that defines the pH of a solution.

(1)

(Total for question = 1 mark)

Q21.

This question is about acids and bases.

Explain why the pH of a 1×10^{-8} mol dm^{-3} solution of nitric acid, HNO_3 , is not 8.

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

(2)

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(Total for question = 2 marks)

Q22.

This is a question about water.

An equation for the ionisation of water is

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$$

The expression for the ionic product of water is

$$K_w = [H^+(aq)]\,[OH^-(aq)]$$

The value of K_w at 310 K is 2.40×10^{-14} mol^2 dm^{-6}

(i) Calculate the pH of water at 310 K.
Give your answer to **two** decimal places.

(2)

(ii) Predict, with a reason, whether water is acidic, alkaline or neutral at 310 K.

(2)

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(iii) Predict, with a reason, the sign of the enthalpy change for the ionisation of water.

(1)

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(Total for question = 5 marks)

Q23.

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 ☒.

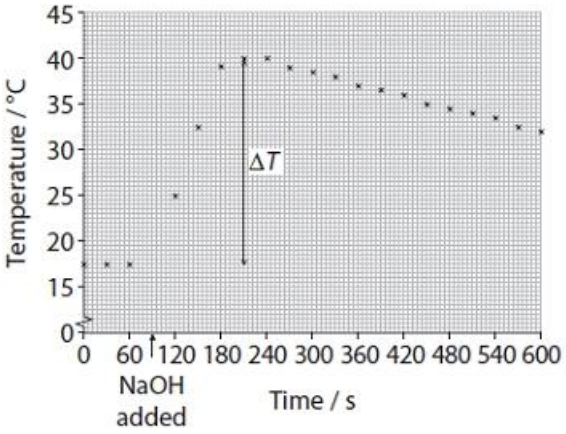
The standard molar enthalpy change of neutralisation is the enthalpy change when an acid and an alkali react under standard conditions to form one mole of water.

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

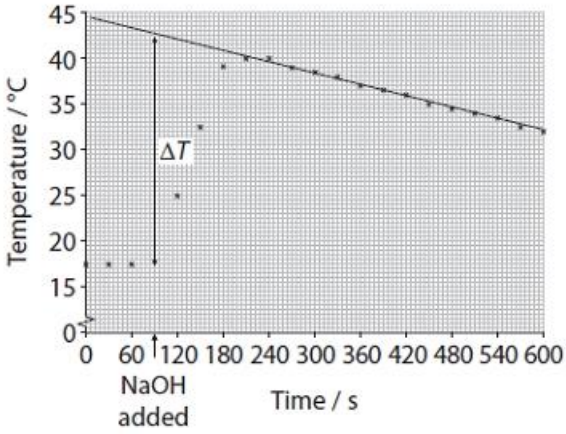
(i) Which graph shows the correct way that the maximum temperature rise should be determined?

(1)

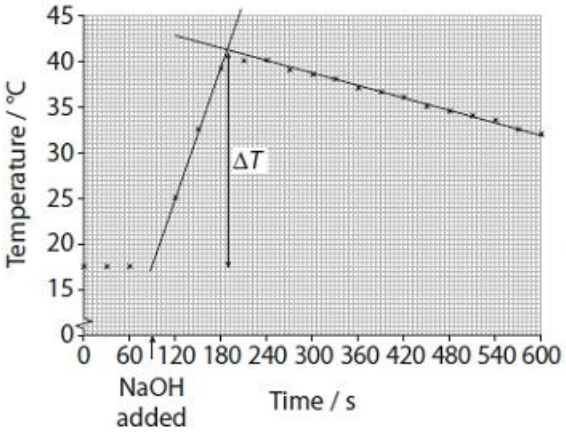
☒ **A**



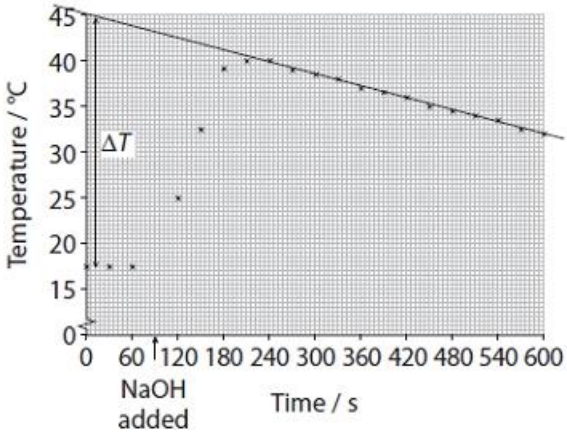
☒ **B**



☒ **C**



☒ **D**



(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)

Mark Scheme

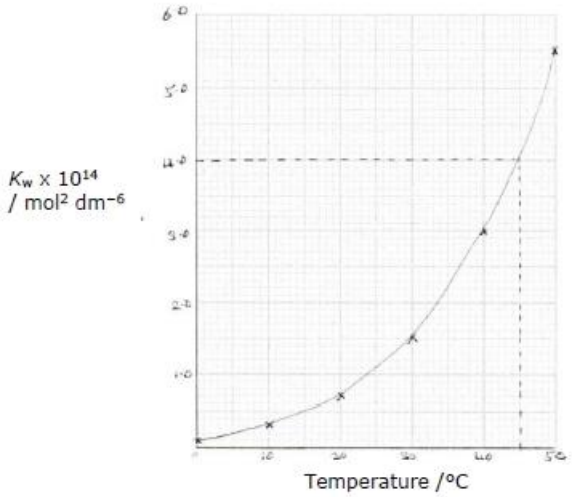
Q1.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• correct acid-base pairs identified **and** linked	Examples of acid-base pairs $CH_3COOH + HCOOH \rightarrow CH_3COOH_2^+ + HCOO^-$ base 2/B2 acid 1/A1 acid 2/ A2 base 1/B1 **or** $CH_3COOH + HCOOH \rightarrow CH_3COOH_2^+ + HCOO^-$ base acid acid base **or** $CH_3COOH + HCOOH \rightarrow CH_3COOH_2^+ + HCOO^-$ base / B acid / A conjugate acid / CA conjugate base / CB Allow any clear identification of acid and base **and** connection between the correct pairs	**(1)**

Q2.

Question Number	Answer	Additional Guidance	Mark
	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)**

Q3.

Question Number	Answer	Additional Guidance	Mark
(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 (±1/2 small square) **and** smooth curve **(1)** • value of K_w at 45°C **(1)**	Example of graph  Allow K_w / 10^{-14} /mol² dm^{-6} as units on y axis Allow K_w x 10^{-14}/mol² dm^{-6} 4.0 x 10^{-14} (mol² dm^{-6}) Allow 3.8 to 4.2 x 10^{-14} (mol² dm^{-6}) with no working TE on their working from their graph If they have converted K_w to pK_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
(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 $[H^+(aq)] = 1.2124 \times 10^{-7}$ (mol dm^{-3})) 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)**

Q4.

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

Q5.

Question Number	Answer	Additional Guidance	Mark
	• calculation of $[H^+(aq)]$	Example of calculation $[H^+(aq)] = 10^{-pH} = 10^{-9.43}$ $= 3.7154 \times 10^{-10}$ / 3.715×10^{-10} / 3.72×10^{-10} / 3.7×10^{-10} (mol dm^{-3}) 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)**

Q6.

Question Number	Answer	Additional Guidance	Mark
	• calculation amount of $H_2SO_4(aq)$ in mol **(1)** • calculation amount of $H^+(aq)$ in mol / amount $OH^-(aq)$ needed **(1)** • calculation amount of $OH^-(aq)$ in mol **(1)** • calculation amount of excess $OH^-(aq)$ in mol **(1)** calculation $[OH^-]$ in resultant mixture **(1)** calculation pH of resultant mixture **(1)**	Example of calculation $= (40.4/1000) \times 0.370 = 0.014948$ $0.014948 \times 2 = 0.029896$ (mol) $= (51.2/1000) \times 0.927 = 0.047462$ (mol) $= 0.047462 - 0.029896 = 0.017566$ (mol) $= 0.017566 / (91.6/1000) = 0.19177$ (mol dm^{-3}) $[H^+] = 1.00 \times 10^{-14}/0.19177 = 5.2146 \times 10^{-14}$ (mol dm^{-3}) $pH = -\log 5.2146 \times 10^{-14}$ $= 13.3$ **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 pH > 7 Correct answer with no / some working scores 6 marks Ignore SF except 1 SF in M1 to M5	**(6)**

Q7.

Question number	Answer	Mark
	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)**

Q8.

Question Number	Answer	Additional Guidance	Mark
	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)**	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	**(5)**
	• measure pH of resultant mixture (with pH meter) **(1)** **Determining K_a** • (at half neutralisation pH = pK_a so) $K_a = 10^{-pH}$ **(1)**	Stand alone Allow $[H^+] = 10^{-pH}$ **and** $K_a = [H^+]$	

Edexcel Chemistry A-level - Strong & Weak Acids - pH, pKa, Kw

Q9.

Question Number	Answer	Additional Guidance	Mark
	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 electronegativies 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)

Q10.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	Any one from: Catalyst / speeds up reaction / increases rate / increases rate of attainment of equilibrium / lowers activation energy	Ignore any mention of protonation or mechanism for catalysis Do not award additional incorrect types of reaction	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	• calculation of moles of H^+ in 25.0 cm^3 **(1)** • calculation of moles of H^+ in 250 cm^3 flask **(1)**	Ignore SF throughout 8(b)(i) to 8(c)(ii) except 1 SF, which should be penalised once only Example of calculation: (moles NaOH = 0.200 x $\frac{23.60}{1000}$) = 0.00472 (mol) (= mol H^+ in 25.0 cm^3) (= 10 x 0.00472) = 0.0472 (mol) (in 250 cm^3) Allow TE for M2 on moles of NaOH Correct answer with or without working scores 2 marks	**(2)**

Edexcel Chemistry A-level - Strong & Weak Acids - pH, pKa, Kw

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	• subtracts moles of H^+ in HCl from answer to (b)(i)	Example of calculation: 0.0472 – 0.00400 = 0.0432 (mol) Allow TE on answer to part (b)(i)	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(i)	• calculation of moles of CH_3COOH that have reacted	Example of calculation: (0.105 — 0.0432) = 0.0618 Allow TE on part (b)(ii) unless negative value	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(ii)	• calculation of equilibrium moles of $CH_3CH_2CH_2OH$ (1) • calculation of equilibrium moles of $CH_3COOCH_2CH_2CH_3$ (1) • calculation of equilibrium moles of H_2O (1)	Example of calculation: 0.0800 — 0.0618 = 0.0182 0.0618 0.111 + 0.0618 = 0.1728 Allow TE on answer to part (c)(i) unless negative value	(3)

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(i)	$(K_c =) \frac{[CH_3COOCH_2CH_2CH_3][H_2O]}{[CH_3COOH][CH_3CH_2CH_2OH]}$	IGNORE state symbols even if incorrect Do not award round brackets	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(ii)	An explanation that makes reference to the following points: • Same number of moles/molecules on both sides of the equation (1) • (so) volume / V cancels in K_c expression (1)	2 marks could be scored by a correct mathematical expression showing V or dm^3 cancel Allow same number of terms on top and bottom of K_c expression Allow units cancel out Allow "**all** divided by the same volume"	(2)

Edexcel Chemistry A-level - Strong & Weak Acids - pH, pKa, Kw

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(iii)	• calculates value of K_c **(1)** • final value of K_c quoted to 2 or 3 SF **(1)**	Example of calculation $K_c = \frac{(0.0618) \times (0.1728)}{(0.0432) \times (0.0182)} = 13.58241758$ = 14 / 13.6 (no units) Correct answer with no working gains full marks Ignore units No TE on wrong K_c expression	2

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)	An explanation that makes reference to the following points: • the equilibrium shifts to the left **or** the mixture absorbs carbon dioxide from the atmosphere **(1)** • so the mixture is (becoming more) acidic / the acid reforms **(1)**	Mark independently Allow no longer alkaline Do not award just "pH decreases"	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(f)	An explanation that makes reference to the following points: • carry out / repeat experiment **and** leave for longer than a week **(1)** • the titre value / K_c value will remain unchanged (if equilibrium has been established) **(1)**	Ignore pH probes / checking pH Allow repeat experiment **and** check titres within first week Allow moles / concentration are unchanged Ignore just "results unchanged"	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(g)	An answer that makes reference to the following points: • K_c value will be greater than that calculated in (d)(iii) **(1)** • because the (forward) reaction is endothermic **or** backward / reverse reaction is exothermic **(1)**	M2 depends on M1 Ignore References to the equilibrium position shifting to the right (with increasing temperature)	**(2)**

Q11.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• calculation of K_a **(1)** • calculation of $[H^+]$ **(1)** • calculation of pH **(1)**	Example of calculation $K_a = 10^{-pKa} = 10^{-9.24} = 5.7544 \times 10^{-10}$ (mol dm^{-3}) $[H^+] = \sqrt{K_a[H_3BO_3]} = \sqrt{5.7544 \times 10^{-10} \times 0.05}$ $= 5.364 \times 10^{-6}$ (mol dm^{-3}) TE on K_a $pH = -\log_{10}[H^+] = -\log_{10} 5.364 \times 10^{-6}$ $= 5.2705 / 5.271 / 5.27 / 5.3$ TE on $[H^+]$ provided pH is >2 and <7 Accept alternative methods, for example $[H^+] = \sqrt{K_a[H_3BO_3]}$ $pH = ½pK_a - ½\log[H_3BO_3]$ **(1)** $= ½9.24 - ½\log 0.05$ **(1)** $= 5.2705 / 5.271 / 5.27 / 5.3$ **(1)** Alternative method: $K_a = 10^{-pKa} = 10^{-9.24} = 5.7544 \times 10^{-10}$ (mol dm^{-3}) **(1)** $[H^+]^2 = K_a([H_3BO_3] - [H^+])$ $= 5.7544 \times 10^{-10} \times (0.05 - [H^+])$ $[H^+] = 5.135 \times 10^{-6}$ **(1)** pH = 5.29 **(1)** Ignore SF except 1SF Correct answer without working scores 3 marks	**(3)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: • $[H^+] = [H_2BO_3^-]$ **or** no H^+ from the (ionisation of) water / ionisation of water is negligible **or** H^+ is only from the acid **or** no H^+ from ionisation of $H_2BO_3^-$ **(1)** • ionisation / dissociation of the acid is negligible / very small / insignificant **or** $[H_3BO_3]_{initial} = [H_3BO_3]_{equilibrium}$ **or** $[H_3BO_3]_{equilibrium} = 0.05$ (mol dm^{-3}) **or** $[H^+]/[H_2BO_3] << [H_3BO_3]$ **or** $[H_3BO_3]$ / acid concentration remains constant **or** $[H_3BO_3]_{equilibrium} = [H_3BO_3]_{initial} - [H^+]$ used in calculation in (i)	Allow $[A^-]$ for $[H_2BO_3^-]$ / [HA] for $[H_3BO_3]$ Allow any of the expressions described in words Allow approximately equal to for = (in symbols or words) Ignore reference to standard conditions Do not award two marks from the same marking point Allow the effect of the third ionisation is negligible Ignore partial dissociation / not completely dissociated Do not award H_3BO_3 / [HA]is completely dissociated	(2)

Q12.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• (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)

Q13.

Question Number	Answer	Additional Guidance	Mark
	• (M1) calculation of concentration of diluted acid (1) • (M2) calculation of pH (1)	Example of calculation c=(15 x 15.9 / 100) = 2.385 (mol dm^{-3}) 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)

Q14.

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

Edexcel Chemistry A-level - Strong & Weak Acids - pH, pKa, Kw

Question Number	Answer	Additional Guidance	Mark
(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)**

Q15.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• 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)**	Example of calculation: (moles of X^- = mol NaOH = $\frac{0.8(00) \times 10.5}{1000}$) = 0.0084(0) / 8.4(0) x 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 x 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 × 10^{-5} (mol dm^{-3}) pH = 4.04 Allow use of pH expression to get answer: $pH = pK_a - \log \frac{[HX]}{[X^-]}$ or $pK_a + \log \frac{[X^-]}{[HX]}$	**(5)**

		ALLOW TE M5 for calculation of pH from any $[H^+]$ Correct answer with no working scores (5)	

Q16.

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>*</td><td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5–4</td><td>3</td></tr>
<tr><td>3–2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table></td><td>Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).
If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td><td></td></tr>
</table>

	The following table shows how the marks should be awarded for structure and lines of reasoning. **Number of marks awarded for structure of answer and sustained line of reasoning** Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout. — 2 Answer is partially structured with some linkages and lines of reasoning. — 1 Answer has no linkages between points and is unstructured. — 0	In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks. 3 and 4 indicative points would get 1 mark for reasoning and 0, 1 or 2 indicative points would score zero marks for reasoning.	**(6)**

	Comment: Look for the indicative marking points first, then consider the mark for the structure of answer and sustained line of reasoning. **Indicative content** **Hydrochloric acid and nitric acid** • (same value for) hydrochloric acid **and** nitric acid as they are strong / completely dissociated into ions (in solution) • reaction taking place is $H^+ + OH^- \rightarrow H_2O$ / $H_3O^+ + OH^- \rightarrow 2H_2O$	Allow correct formulae for names throughout the answer Ignore sulfuric acid as strong(est) acid Allow $HCl + NaOH \rightarrow NaCl + H_2O$ **and** $HNO_3 + NaOH \rightarrow NaNO_3 + H_2O$ Allow hydrochloric acid **and** nitric acid are both monoprotic / monobasic / provide 1 mol H^+ / produce 1 mol H_2O	

	Sulfuric acid • sulfuric acid is diprotic / dibasic **or** (1 mol of) sulfuric acid provides 2 mol H^+ / produces 2 mol H_2O • so value is (almost) twice that of hydrochloric acid / nitric acid **or** reverse argument **Ethanoic acid** • ethanoic acid is weak /partially dissociated into ions (in solution) / $CH_3COOH \rightleftharpoons CH_3COO^- + H^+$ / $CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$ • some energy is needed to break (O-H) bond(s) to release H^+ ions (so enthalpy change of neutralisation is less than for a strong acid) **or** enthalpy change of neutralisation includes the enthalpy of dissociation of ethanoic acid so it is less exothermic	Allow $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$ Allow ethanoic acid is the weakest acid Allow some energy is needed to ionise ethanoic acid	

Q17.

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

Q18.

Question Number	Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • the O of the (extra) OH / hydroxyl group (in the 2 / alpha position / CH_2OH) withdraws / attracts electrons **(1)** • stabilises the anion / CH_2OHCOO^- 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
(ii)	($CH_2OHCOOH + CH_3COOH \rightarrow$) • $CH_2OHCOO^- + CH_3COOH_2^+$	Both correct for the mark Allow formulae in either order Allow formulae in brackets with charge outside Allow displayed formulae Do not allow $CH_3C(OH)_2^+$	**(1)**

Q19.

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

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

Q20.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• (pH =) $-\log[H^+(aq)]$ **or** (pH =) $-\log[H_3O^+(aq)]$	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. $-\log([H^+(aq)])$	**(1)**

Q21.

Question Number	Acceptable Answers	Additional Guidance	Mark
	An explanation that makes reference to the following points:	Penalise reference to nitric acid as a weak acid in M2 only	**(2)**
	• $[H^+]$/ $[H_3O^+]$/ concentration of hydrogen ions from water is $1(.0) \times 10^{-7}$ (mol dm^{-3}) **(1)**	Allow $[H^+]$ from water = $\sqrt{1(.00)} \times 10^{-14}$ / $\sqrt{K_w}$ Allow this shown as part of a calculation	
	• so total $[H^+]$ is greater than $1(.0) \times 10^{-7}$ (mol dm^{-3}) / is 1.1×10^{-7} (mol dm^{-3})	Allow $[H_3O^+]$/ concentration of hydrogen ions for $[H^+]$ Allow$[H^+]$ is greater than 1×10^{-8} (mol dm^{-3}) Allow $[H^+]$ cannot be less than $[OH^-]$ / $[OH^-]$ cannot be more than $[H^+]$ Allow the addition of nitric acid to water decreases pH by increasing $[H^+]$	
	or the pH cannot be more than 7 / alkaline (for an acid)	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	
	or concentration of hydrogen ions from water is not negligible / cannot be ignored	Allow water also dissociates to form H^+ ions	
	or 10^{-8} is only the concentration of ions from the acid, it doesn't include those from the water **(1)**		

Q22.

Question Number	Answer	Additional Guidance	Mark
(i)	• square root of K_w at 310K to get $[H^+]$ **(1)** • calculation of pH to 2 decimal places **(1)**	Example of calculation: $[H^+] = (\sqrt{2.40 \times 10^{-14}}) = 1.549..\times10^{-7}$ (mol dm^{-3}) pH = $(-\log 1.549..\times10^{-7})$ = (6.809894379) = 6.81 Correct answer with no working scores (2) Allow TE from incorrect $[H^+]$ as long as answer is in the pH range 6.00 – 7.00 inclusive	**(2)**

Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: • **(M1)** neutral **(1)** • **(M2)** because $[H^+(aq)] = [OH^-(aq)]$ /equal amounts of H^+ and OH^- ions **(1)**	Acidic or alkaline scores (0) Allow both $[H^+]$ and $[OH^-]$ have increased equally (from 298 K to 310 K) M2 dependent on M1	**(2)**

Question Number	Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to the following point: • positive / + sign because K_w increases as the temperature increases	Allow 'positive because' bond breaking requires energy or equilibrium shifts to the right or there is greater/more ionisation/dissociation Ignore 'endothermic'	**(1)**

Q23.

Question Number	Answer	Mark
(i)	**The only correct answer is B** ***A** is not correct because there is no extrapolation to the largest temperature increase carried out* ***C** is not correct because the extrapolation is at the wrong time* ***D** is not correct because the extrapolation extends beyond the time of addition of alkali*	**(1)**

Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to • ethanoic acid is a weak(er) acid / only partially ionised/dissociated **(1)** • (some) **energy** is used to fully/completely ionise the ethanoic acid **(1)**	Allow hydrochloric acid is a strong(er) acid/fully ionised Do not award 'more NaOH will react so more energy given off'	**(2)**