PEARSON EDEXCEL A-LEVEL CHEMISTRY · 9CH0

CHEMISTRY



EXAM QUESTION PACK

TOPIC 12: ACID-BASE EQUILIBRIA

SCORE	PERCENTAGE
/242	%

STEMUP

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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. The reaction between concentrated sulfuric acid and pure ethanoic acid is

$$CH_3COOH + H_2SO_4 \rightleftharpoons CH_3COOH_2^+ + HSO_4^-$$

The Brønsted-Lowry acids in this equilibrium are

☒ **A** CH_3COOH and H_2SO_4

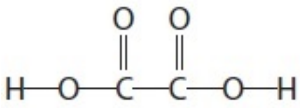
☒ **B** CH_3COOH_2 + and HSO_4^-

☒ **C** H_2SO_4 and $CH_3COOH_2^+$

☒ **D** CH_3COOH and HSO_4^-

(Total for Question = 1 mark)

Q3. Ethanedioic acid, $H_2C_2O_4$, is a dicarboxylic acid which occurs in many plants, for example in rhubarb leaves, and is used as a rust remover and strong descaler. The structure of ethanedioic acid is shown below.



Ethanedioic acid is a much stronger acid than carboxylic acids such as ethanoic acid, having a pK_a of 1.38. The hydrogenethanedioate ion, $HC_2O_4^-$, is a weaker acid than ethanedioic acid, having a pK_a of 4.28, although slightly stronger than ethanoic acid.

(a) (i) Write an equation for the reaction of the hydrogenethanedioate ion with water to form an

acidic solution. Include state symbols in your equation.

(2)

(ii) Write the expression for the acid dissociation constant, K_a, of the weak acid, $HC_2O_4^-$.

(1)

(iii) A solution containing hydrogenethanedioate ions behaves as a typical weak acid. Use your answer to (a)(ii) and the pK_a of the hydrogenethanedioate ion to calculate the pH of a 0.050 mol dm^{-3} solution of sodium hydrogenethanedioate, $NaHC_2O_4$.

(3)

(b) (i) State **two** approximations used in the calculation of pH in (a)(iii).

(2)

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*(ii) Explain why the calculation of the pH of a solution of sodium hydrogenethanedioate gives a more accurate value than a similar calculation for ethanedioic acid.

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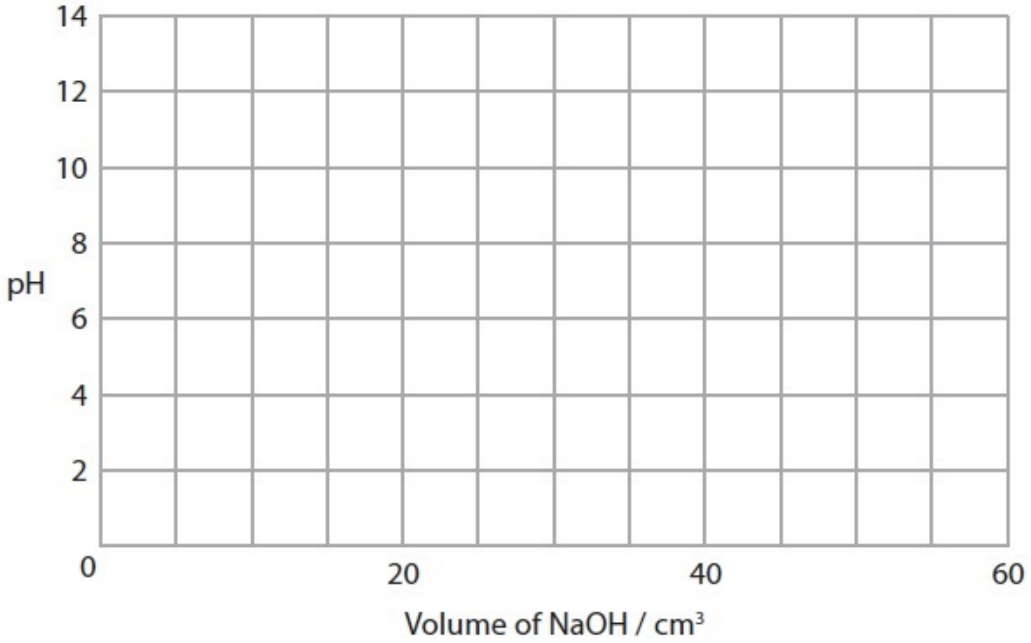
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(c) 25 cm^3 of a 0.050 mol dm^{-3} solution of sodium hydrogenethanedioate was titrated with a sodium hydroxide solution of the same concentration.

(i) On the axis below, sketch the curve for this titration.

(3)



*(ii) When 25 cm^3 of a 0.050 mol dm^{-3} solution of **ethanedioic acid** is titrated with sodium hydroxide solution of the same concentration using phenolphthalein as the indicator, the end point is 50 cm^3.

When methyl yellow indicator is used, the colour changes at around 25 cm^3.

Using the information given at the start of the question and quoting data from page 19 of your data booklet, suggest why these volumes are different.

(2)

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(Total for Question = 15 marks)

Q4. The dissociation constant of water, K_w, increases with increasing temperature. When the temperature increases, water

☒ **A** remains neutral.

☒ **B** dissociates less.

☒ **C** becomes acidic.

☒ **D** becomes alkaline.

(Total for Question = 1 mark)

Q5. Which of the following statements is true about **all** substances that form acidic solutions in water?

☒ **A** They are corrosive.

☒ **B** They are liquids.

☒ **C** They contain hydrogen atoms.

☒ **D** They form $H^+(aq)$ ions.

(Total for Question = 1 mark)

Q6. An aqueous solution of ethanoic acid is gradually diluted. Which of the following statements is **incorrect**?

☒ **A** The pH decreases.

☒ **B** The value of K_a is unchanged.

☒ **C** The concentration of ethanoic acid molecules decreases.

☒ **D** The proportion of ethanoic acid molecules which dissociates increases.

(Total for Question = 1 mark)

Q7.

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)

Q8. Methyl orange and phenolphthalein are both acid-base indicators. In the titration of a strong acid against a weak alkali

☒ **A** methyl orange is a suitable indicator but phenolphthalein is not.

☒ **B** phenolphthalein is a suitable indicator but methyl orange is not.

☒ **C** both phenolphthalein and methyl orange are suitable indicators.

☒ **D** neither phenolphthalein nor methyl orange is a suitable indicator.

(Total for Question = 1 mark)

Q9.

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 ☒.

This question is about acids and bases.

What is the order of **decreasing** pH for 0.100 mol dm^{-3} solutions of these three acids?

(1)

☒ **A** $CH_3COOH > CH_2ClCOOH > HCl$

☒ **B** $HCl > CH_3COOH > CH_2ClCOOH$

☒ **C** $CH_2ClCOOH > CH_3COOH > HCl$

☒ **D** $HCl > CH_2ClCOOH > CH_3COOH$

(Total for question = 1 mark)

Q10.

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)

Q11.

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

.....

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).

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(Total for question = 19 marks)

Q12.

Adipic acid, $HOOC(CH_2)_4COOH$, is a dicarboxylic acid used in the production of polymers. It can be made by the reaction of buta-1,3-diene with carbon monoxide and water.

$$CH_2CHCHCH_2(g) + 2CO(g) + 2H_2O(l) \rightarrow HOOC(CH_2)_4COOH(s)$$

(a) (i) Use the Data Booklet to complete the table below.

(2)

	$CH_2CHCHCH_2(g)$	$CO(g)$	$H_2O(l)$	$HOOC(CH_2)_4COOH(s)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	+109.9			–994.3
$S^{\ominus}$ / J mol^{-1} K^{-1}	278.7			250.0

(ii) Use data from the table to calculate the standard enthalpy change, in kJ mol^{-1}, when adipic acid is formed from buta-1,3-diene, carbon monoxide and water.

(2)

(iii) Use data from the table to calculate the standard entropy change of the system, in J mol^{-1} K^{-1}, when adipic acid is formed from buta-1,3-diene, carbon monoxide and water.

(2)

(iv) Use your answers to (ii) and (iii) to calculate $\Delta S_{surroundings}$ and ΔS_{total} for the reaction at 298 K.

(3)

(v) It was suggested that **decreasing** the temperature of the reaction to less than 298 K would produce a greater yield of adipic acid.

Explain, in terms of the effect on ΔS_{system}, $\Delta S_{surroundings}$ and hence ΔS_{total}, whether this would be the case.

(3)

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(b) Infrared spectroscopy can be used to follow the progress of reactions. During the reaction to produce adipic acid, suggest **one** peak which diminishes and **one** peak which appears.

Use information from the Data Booklet to identify two such possible peaks, giving their wave numbers and the bonds involved.

(2)

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(c) Adipic acid is used as an additive in some fruit jellies. Suggest what effect the adipic acid will have on the flavour of the jelly.

(1)

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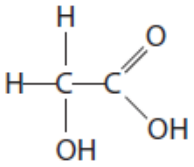
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(Total for question = 15 marks)

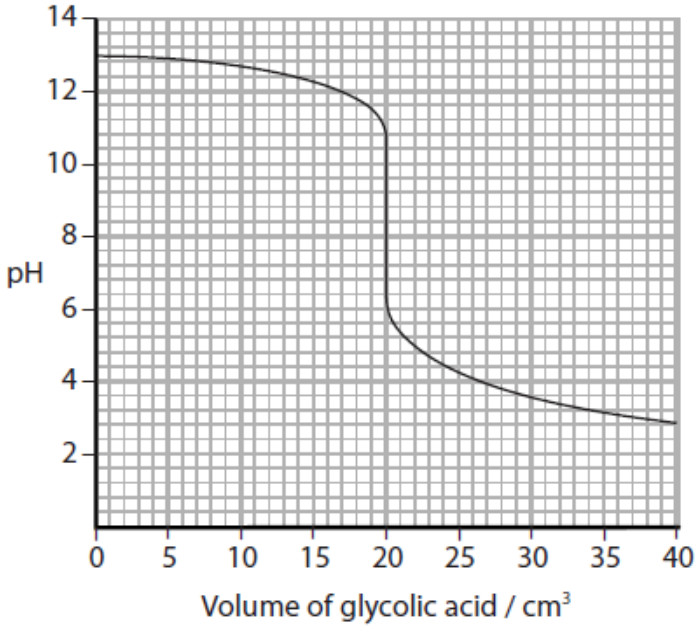
Q13.

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

The structure of glycolic acid is



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



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

Justify your selection.

(3)

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

(1)

☒ **A** 0.080

☒ **B** 0.100

☒ **C** 0.125

☒

D 0.250

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

(1)

☒ **A** 2.8

☒ **B** 6.0

☒ **C** 8.3

☒ **D** 11.0

(Total for question = 5 marks)

Q14.

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)

Q15.

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)

Q16.

In liquid ammonia the following equilibrium is present.

$$NH_2^- + NH_4^+ \rightleftharpoons 2NH_3$$

Identify the Brønsted-Lowry base(s).

- ☒ **A** NH_2^- only
- ☒ **B** NH_4^+ only
- ☒ **C** NH_2^- and NH_3
- ☒ **D** NH_4^+ and NH_3

(Total for question = 1 mark)

Q17.

Ammonia reacts with water in a reversible reaction. Which are the Brønsted-Lowry bases?

☒ **A** H^2O and OH^-

☒ **B** NH_3 and OH^-

☒ **C** NH_4^+ and H_2O

☒ **D** NH_4^+ and NH_3

(Total for question = 1 mark)

Q18.

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 ☒.

This question is about acids and bases.

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 CH_3COOH(aq)

☒ **C** excess NaOH(aq) and HCl(aq)

☒ **D** excess NaOH(aq) and CH_3COOH(aq)

(Total for question = 1 mark)

Q19.

Which of the following mixtures would form the best buffer solution with pH 5 for use in a school laboratory?

☒ **A** Ethanoic acid and sodium ethanoate

☒ **B** Hydrochloric acid and sodium chloride

☒ **C** Sodium hydroxide and sodium methanoate

☒ **D** Ammonium chloride and ammonia

(Total for question = 1 mark)

Q20.

Which of the following mixtures would form the best buffer solution with pH 9 for use in a school laboratory?

☒ **A** Ethanoic acid and sodium ethanoate

☒ **B** Sodium chloride and sodium hydroxide

☒ **C** Hydrocyanic acid and sodium cyanide

☒ **D** Ammonium chloride and ammonia

(Total for question = 1 mark)

Q21.

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 ☒.

This is a question about buffer solutions.

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.

(Total for question = 1 mark)

Q22.

This is a question about buffer solutions.

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

$$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

Explain how this buffer system helps to control the pH of blood when extra carbon dioxide is present due to strenuous exercise.

(3)

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(Total for question = 3 marks)

Q23.

This question is about buffer solutions.

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

$$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$$

Calculate the pH of this buffer solution.

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

(5)

(Total for question = 5 marks)

Q24.

This question is about acids and buffer solutions.

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

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

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

(4)

(ii) Explain why the pH of the buffer solution hardly changes when a few drops of sodium hydroxide solution are added to it.

Include an equation or equations in your answer.

Use C_3H_7COOH as the formula for butanoic acid.

(2)

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(Total for question = 6 marks)

Q25.

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)

Q26.

Calculate the pH of a solution of HCl, of concentration 0.25 mol dm^{-3}.

☒ **A** −0.60

☒ **B** 0.25

☒ **C** 0.60

☒ **D** 1.39

(Total for question = 1 mark)

Q27.

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)

Q28.

(i) Give the expression for pH.

(1)

(ii) Calculate the pH of 0.0540 mol dm^{-3} hydrochloric acid, HCl(aq), and of 0.0540 mol dm^{-3} methanoic acid, HCOOH(aq).
Give your answers to two decimal places.

(4)

Q29.

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)

Q30. This question is about the reactions of butanoic acid, $CH_3CH_2CH_2COOH$. It has a foul smell and behaves like a typical carboxylic acid.

(a) (i) The addition of sodium carbonate solution is often used as a chemical test to distinguish carboxylic acids, like butanoic acid, from other compounds, such as aldehydes.

Explain why old stocks of aldehydes often react with sodium carbonate solution.

(1)

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(ii) How would the result of this test distinguish between a carboxylic acid and an old stock of an aldehyde?

(1)

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(iii) Write the balanced chemical equation, including state symbols, for the reaction of sodium carbonate solution with butanoic acid.

(2)

*(iv) Infrared spectroscopy is a good physical method to distinguish carboxylic acids from other organic compounds. Give the wavenumbers of **two** characteristic absorptions for a carboxylic acid. Indicate the bond responsible for each absorption. Suggest why one of the absorptions is broad.

(3)

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(v) High resolution nuclear magnetic resonance spectroscopy is a suitable physical method to use alongside infrared spectroscopy to identify butanoic acid. State the total number of peaks and suggest the splitting pattern for each peak that you would expect for butanoic acid, $CH_3CH_2CH_2COOH$.

(3)

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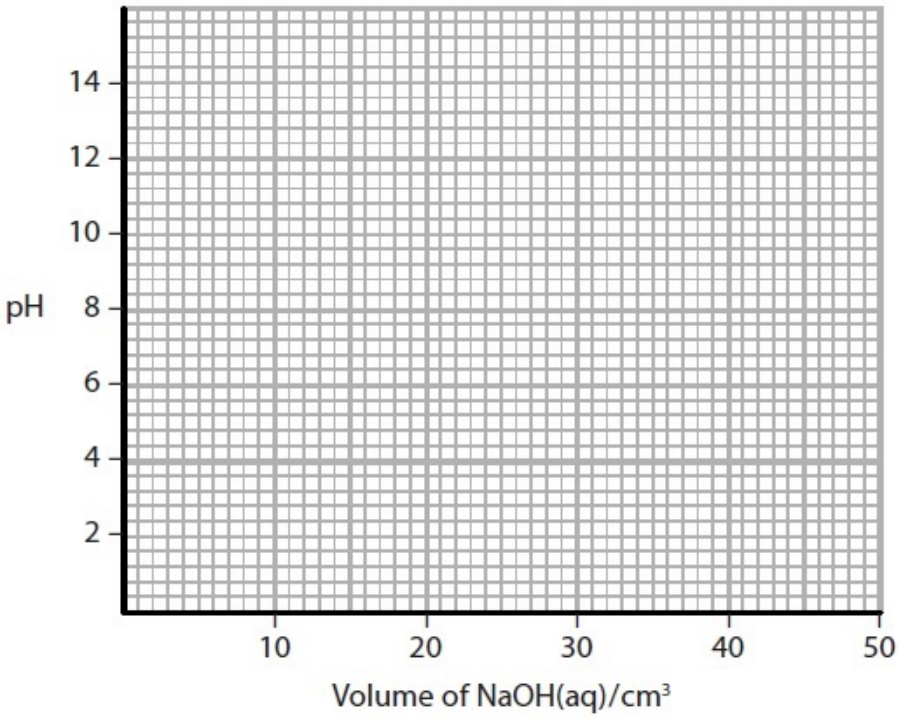
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(b) Sketch the titration curve obtained when 50 cm^3 of 0.10 mol dm^{-3} sodium hydroxide solution is added to 25 cm^3 of 0.10 mol dm^{-3} butanoic acid.

(4)



(c) (i) What would you see when phosphorus pentachloride, PCl_5, reacts with butanoic acid?

(1)

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(ii) Give the structural formula and name of the organic product of this reaction.

(2)

Structural formula

Name

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(d) (i) Give the name or formula of the organic product of the reaction between butanoic acid

and lithium tetrahydridoaluminate (lithium aluminium hydride).

(1)

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(ii) Water cannot be used as the solvent in this reaction because it reacts with lithium tetrahydridoaluminate. Suggest a suitable solvent.

(1)

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(iii) State the type of reaction that takes place between butanoic acid and lithium tetrahydridoaluminate. Justify your classification.

(2)

Type

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Justification

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(e) (i) Butanoic acid can be reacted with methanol to make methyl butanoate. State **two** conditions that help to speed up this reaction.

(2)

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(ii) Draw the **displayed** formula of methyl butanoate.

(1)

(iii) Identify another chemical, by name or formula, which could be added to methanol to make methyl butanoate.

(1)

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*(iv) Give **two** advantages and **one** disadvantage of using the reaction occurring in (e)(iii), compared to the reaction in (e)(i), when making methyl butanoate.

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Advantages

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Disadvantage

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(Total for Question = 28 marks)

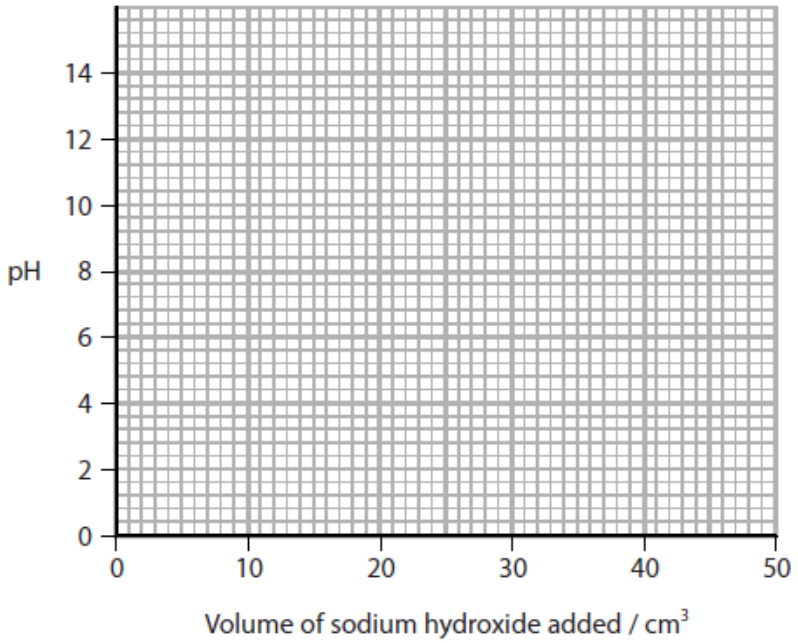
Q31.

This question is about weak acids.

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

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

(4)



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

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

(2)

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(Total for question = 6 marks)

Q32.

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)

Q33.

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.

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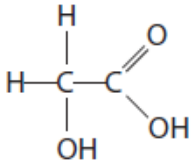
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(Total for question = 6 marks)

Q34.

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)

Q35.

The student made the following statement:

'The pH of pure water is always 7.0'

Is the student correct? Use the following information to justify your answer.

- $H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$
- $K_w = 1.0 \times 10^{-14}$ mol^2 dm^{-6} at 298 K
- ΔH is positive for the forward reaction in the equilibrium.

(3)

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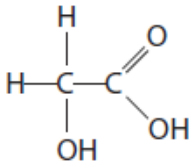
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Q36.

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)

Q37.

This is a question about buffer solutions.

A buffer solution with a pH of 3.90 is required.

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

Give your answer to an appropriate number of significant figures.

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

(5)

(Total for question = 5 marks)

Q38.

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

Boric acid can undergo further dissociation.

Which is the conjugate acid of the HBO_3^{2-} ion?

(1)

☒ **A** BO_3^{3-}

☒ **B** $H_2BO_3^-$

☒ **C** H_3BO_3

☒ **D** H_3O^+

(Total for question = 1 mark)

Q39.

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 ☒ .

This question is about acids and buffer solutions.

The reaction of ammonia with water can be represented by

$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$

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^+

(Total for question = 1 mark)

Q40.

Which one of the following indicators is most suitable for titrating ethanoic acid with 0.1 mol dm^{-3} sodium hydroxide?

(Refer to page 19 of your data booklet.)

☒ **A** Thymol blue (acid)

☒ **B** Bromothymol blue

☒ **C** Thymol blue (base)

☒ **D** Alizarin yellow R

(Total for question = 1 mark)

Q41.

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 ☒.

This question is about acids and bases.

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, $NH_3(aq)$, with ethanoic acid, $CH_3COOH(aq)$?

(1)

☒ **A** bromothymol blue

☒ **B** methyl orange

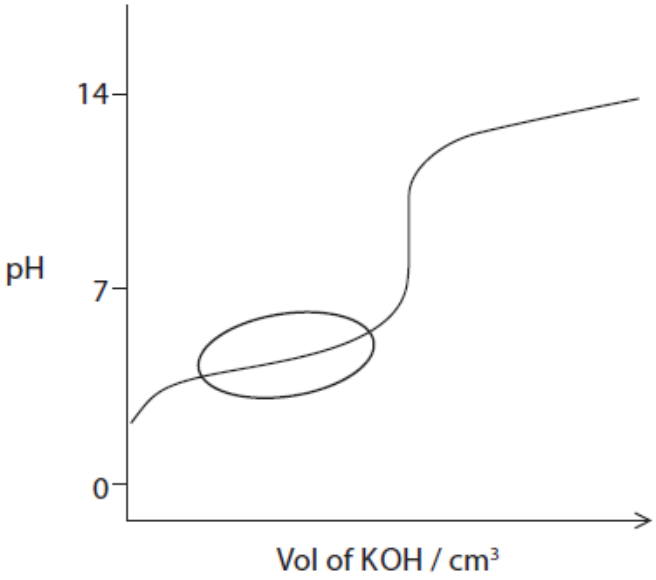
☒ **C** phenolphthalein

☒ **D** none of these three indicators

(Total for question = 1 mark)

Q42.

A student carried out a titration by adding 0.032 mol dm^{-3} potassium hydroxide solution to 25.0 cm^3 of 0.024 mol dm^{-3} propanoic acid. A sketch graph of pH against volume of potassium hydroxide solution added is shown below.



*(i) Describe and explain the behaviour of the solution formed in the region circled on the sketch graph.

(3)

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*(ii) Explain why the pH at the equivalence point of this titration is greater than 7.

(3)

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(iii) By considering the amount of excess alkali remaining, calculate the pH of the solution formed when 40 cm^3 of 0.032 mol dm^{-3} potassium hydroxide solution has been added to 25.0 cm^3 of 0.024 mol dm^{-3} propanoic acid.

$K_w = 1.0 \times 10^{-14}$ mol^2 dm^{-6} at 298 K

(5)

Q43.

This question is about acids and bases.

Write the expression that defines the pH of a solution.

(1)

(Total for question = 1 mark)

Q44.

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)

Q45.

What is the approximate pH of a buffer solution containing 0.20 mol of a weak acid, HA, (pK_a = 4.8) and 0.20 mol of the sodium salt of the acid, NaA, in a total volume of 1 dm^3 of solution?

☒ **A** 7.0

☒ **B** 5.8

☒ **C** 4.8

☒ **D** 3.8

(Total for question = 1 mark)

Q46.

An aqueous solution of ammonium chloride, NH_4Cl, has a pH of less than 7 because

☒ **A** the ammonium ions donate protons to water molecules giving rise to oxonium ions, $H_3O^+(aq)$.

☒ **B** the chloride ions combine with hydrogen ions from water to form hydrochloric acid, HCl(aq).

☒ **C** an aqueous solution of ammonium chloride is unstable and evolves ammonia gas, $NH_3(g)$, leaving dilute hydrochloric acid.

☒ **D** the ammonium chloride reacts with carbon dioxide from the atmosphere giving ammonium carbonate, $(NH_4)_2CO_3(aq)$, and hydrochloric acid, HCl(aq).

(Total for question = 1 mark)

Q47.

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)

Q48.

Suggest the most likely pH for each of the following solutions.

(a) 5.0 mol dm^{-3} hydrochloric acid.

(1)

☒ **A** +5

☒ **B** +0.7

☒ **C** −0.7

☒ **D** −5

(b) 0.20 mol dm^{-3} strontium hydroxide, $Sr(OH)_2$

$K_w = 1.0 \times 10^{-14}$ mol^2 dm^{-6}

(1)

☒ **A** 13.3

☒ **B** 13.6

☒ **C** 14.0

☒ **D** 14.3

(c) A mixture of 20 cm^3 of 1.0 mol dm^{-3} nitric acid and 10 cm^3 of 1.0 mol dm^{-3} sodium hydroxide.

(1)

☒ **A** 0

☒ **B** 0.30

☒ **C** 0.48

☒ **D** 7

(Total for question = 4 marks)

Q49.

Select the correct pH for each of the following solutions.

(a) 2 mol dm^{-3} nitric acid.

(1)

☒ **A** −2

☒ **B** −0.3

☒ **C** +0.3

☒ **D** +2

(b) 0.10 mol dm^{-3} barium hydroxide, $Ba(OH)_2$. $K_w = 1.0 \times 10^{-14}$ mol^2 dm^{-6}.

(1)

☒ **A** 13.0

☒ **B** 13.3

☒ **C** 13.7

☒ **D** 14.3

(c) A mixture of 20 cm^3 of 1.0 mol dm^{-3} hydrochloric acid and 10 cm^3 of 1.0 mol dm^{-3} sodium hydroxide.

(1)

☒ **A** 13.0

☒ **B** 13.3

☒ **C** 13.7

☒ **D** 14.3

(Total for question = 3 marks)

Q50.

Methanoic acid, HCOOH, is present in ant stings.

A scientist analyzed 25.0 cm^3 of an aqueous solution of methanoic acid, solution **Z**, by titrating it with dilute sodium hydroxide, NaOH(aq).

- 20.0 cm^3 of sodium hydroxide was required to neutralize the methanoic acid
- The equation for the neutralization of methanoic acid is

$$HCOOH(aq) + NaOH(aq) \rightarrow HCOONa(aq) + H_2O(l)$$

(a) (i) Give the expression for K_w, the ionic product of water.

(1)

(ii) The concentration of the sodium hydroxide, NaOH(aq), used in the titration was 0.00750 mol dm^{-3}.

Calculate the pH of the sodium hydroxide solution.

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

(2)

(b) Use the equation for the reaction and the data from the titration to show that the concentration of the methanoic acid in solution **Z** was 6.00×10^{-3} mol dm^{-3}.

(2)

(c) Methanoic acid is a weak acid.

(ii) Explain the term **weak acid.**

(2)

Weak

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Acid

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(ii) The equation for the dissociation of methanoic acid in aqueous solution is shown below.

$$HCOOH(aq) \rightleftharpoons HCOO^-(aq) + H^+(aq)$$

Write the expression for the acid dissociation constant, K_a, for methanoic acid.

(1)

*(iii) At 298 K, the acid in ant stings has a concentration of 6.00×10^{-3} mol dm^{-3} and a pH of 3.01.

Calculate the value of K_a for methanoic acid at 298 K.

State clearly any assumptions that you have made.

(4)

Calculation:

Assumption(s):

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(Total for question = 12 marks)

Q51.

* An excess of magnesium was added to 100 cm^3 of 0.0540 mol dm^{-3} HCl(aq).
The same mass of magnesium, from the same sample, was added to 100 cm^3 of 0.0540 mol dm^{-3} HCOOH(aq).

Both reactions were carried out at the same temperature.
Compare and contrast the total volume of hydrogen evolved, and the rate at which it will be evolved, in the two reactions.

(6)

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Q52.

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 ☒.

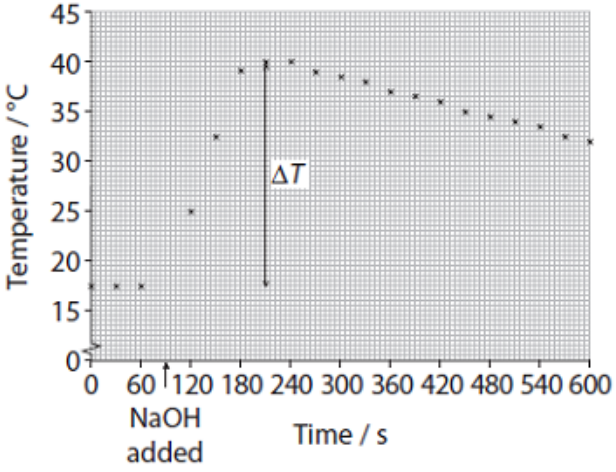
The standard molar enthalpy change of neutralisation is the enthalpy change when an acid and an alkali react under standard conditions to form one mole of water.

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

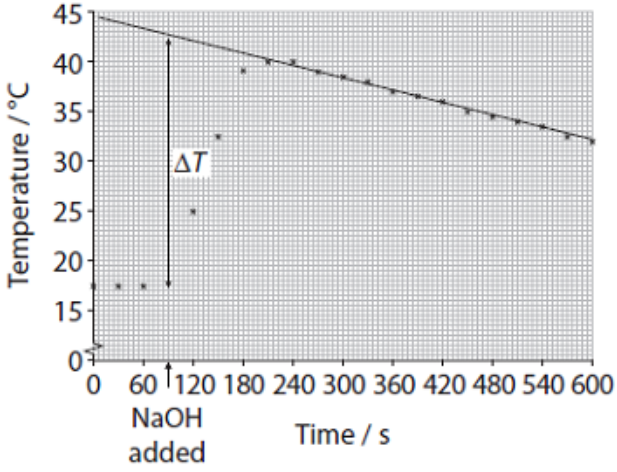
(i) Which graph shows the correct way that the maximum temperature rise should be determined?

(1)

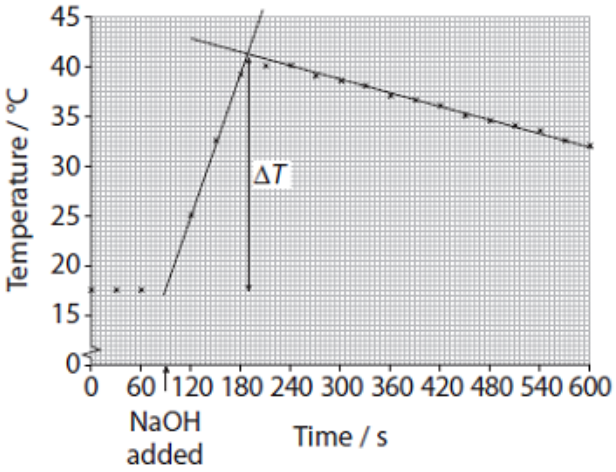
☒ A



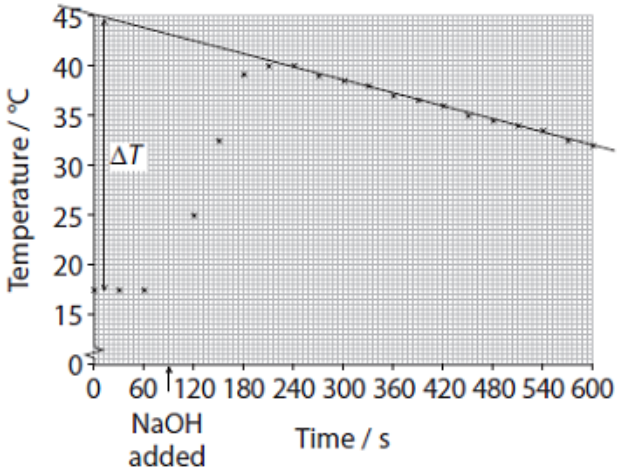
☒ B



☒ 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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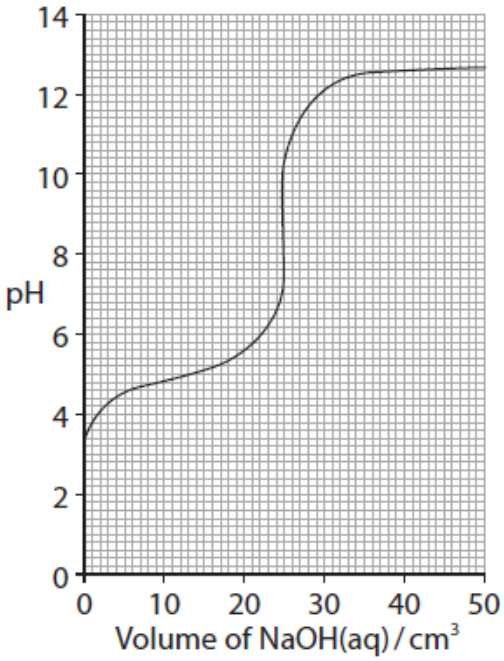
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(Total for question = 3 marks)

Q53.

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

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



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

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

(4)

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

(1)

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

(Total for question = 5 marks)

Q54.

This is a question about buffer solutions.

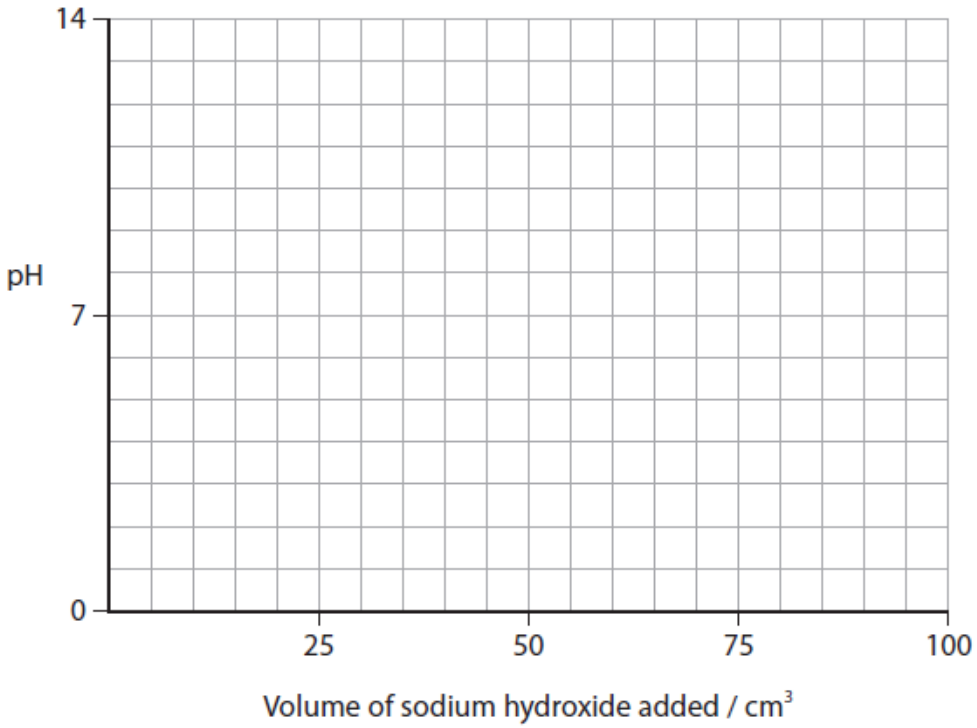
A weak acid-strong base titration curve can be used to demonstrate buffer action.

(i) Draw a titration curve for the addition of

100 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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(Total for question = 6 marks)

Q55.

The table gives the value of the acid dissociation constant, K_a, for three acids.

Acid	Formula	K_a / mol dm^{-3}
methanoic acid	HCOOH	1.60×10^{-4}
phenol	C_6H_5OH	1.28×10^{-10}
chloric(III) acid	$HClO_2$	1.00×10^{-2}

(a) What information about an acid is supplied by its K_a value alone?

(1)

☒ **A** the concentration of the acid

☒ **B** the extent of dissociation into ions of the acid

☒ **C** the hydrogen ion concentration of the acid

☒ **D** the pH of the acid

(b) When aqueous solutions of chloric(III) acid and methanoic acid are mixed together, an acid-base reaction takes place.

$$\underset{\text{.....}}{HClO_2(aq)} + \underset{\text{.....}}{HCOOH(aq)} \rightleftharpoons \underset{\text{.....}}{ClO_2^-(aq)} + \underset{\text{.....}}{HCOOH_2^+(aq)}$$

(i) Label one acid-base conjugate pair as **acid 1** and **base 1**.
Label the other acid-base conjugate pair as **acid 2** and **base 2**.

(1)

(ii) Explain, with the aid of an equation, the acid-base reaction that takes place when methanoic acid is mixed with phenol.

(2)

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Q56.

Acids can be classified as weak or strong acids.

(a) A mixture of concentrated sulfuric and nitric acids is used in the nitration of benzene.

The following equilibrium is set up:

$$H_2SO_4 + HNO_3 \rightleftharpoons H_2NO_3^+ + HSO_4^-$$

Which statement about this equilibrium is correct?

(1)

☒ **A** HNO_3 and $H_2NO_3^+$ are a conjugate acid-base pair

☒ **B** the nitric acid acts as an acid

☒ **C** the nitric acid acts as an oxidising agent

☒ **D** the sulfuric acid acts as a dehydrating agent

(b) Sulfuric acid ionises in two stages.

Stage 1: $H_2SO_4(aq) \rightarrow H^+(aq) + HSO_4^-(aq)$

Stage 2: $HSO_4^-(aq) \rightleftharpoons H^+(aq) + SO_4^{2-}(aq)$

(i) Explain, with reference to the equations, why the HSO_4^- ion is classified as a weak acid.

(2)

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(ii) A 0.100 mol dm^{-3} solution of sulfuric acid has a pH of 0.97.

Calculate the concentration of hydrogen ions in this solution.

(1)

(c) Ethanoic acid, CH_3COOH, is a weak acid.

A student prepares 600 cm^3 of a buffer solution by mixing 400 cm^3 of 0.500 mol dm^{-3} ethanoic acid solution with 200 cm^3 of 0.500 mol dm^{-3} sodium ethanoate solution, CH_3COONa.

Calculate the pH of the buffer solution produced.

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

(4)

Q57.

This question is about buffer solutions.

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

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