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)
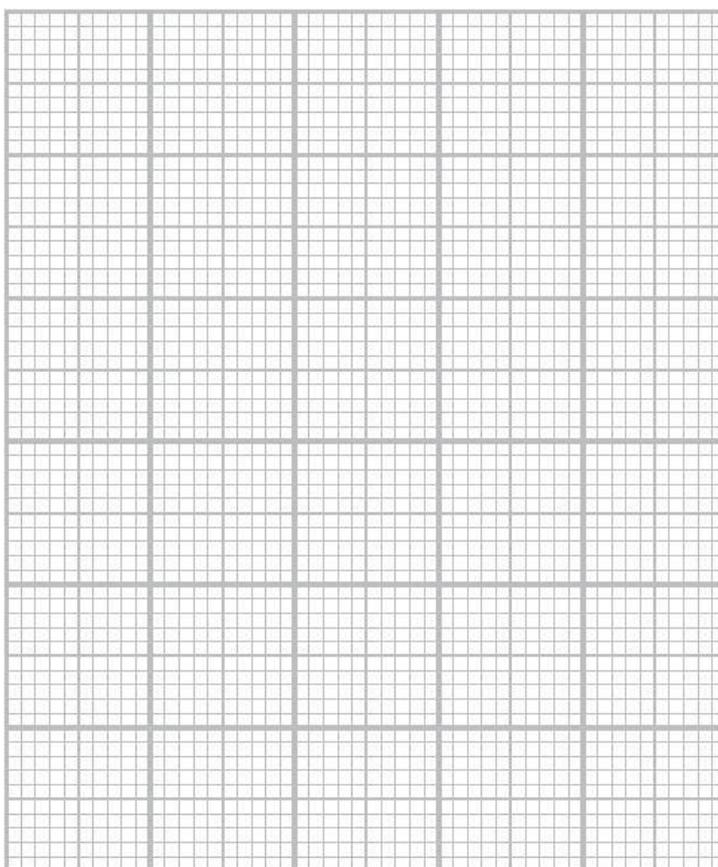
Q2.

This question is about acids and bases.

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)

(3)

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$_2$SO$_4$(aq).

[Ionic product of water K_w = 1.00 × 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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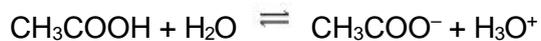
(Total for question = 5 marks)

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.
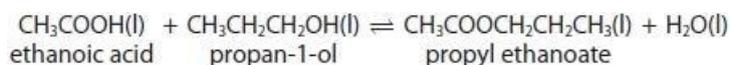
(1)

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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

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

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

- 6.0 cm³ of ethanoic acid (0.105 mol), 6.0 cm³ of propan-1-ol (0.080 mol) and 2.0 cm³ 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 cm³ using distilled water
- 25.0 cm³ 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 cm³ 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 cm³ 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.

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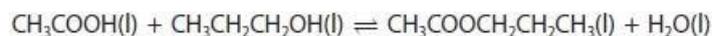
(1)

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

(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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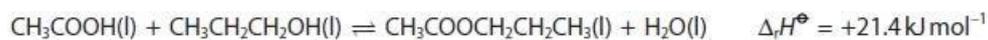...

(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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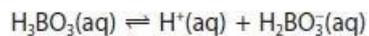
(Total for question = 19 marks)

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$_2$SO$_4$	−115
ethanoic acid, CH$_3$COOH	−56

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

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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
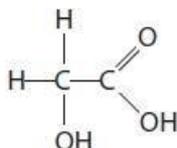
(1)

(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.
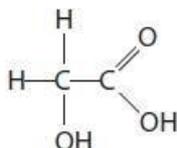
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$CH_2OHCOOH + CH_3COOH \rightarrow$...+
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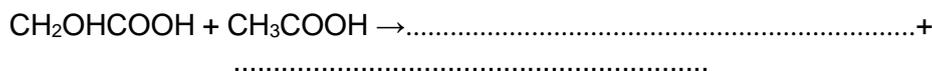
(Total for question = 3 marks)

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)

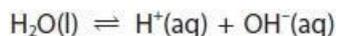...

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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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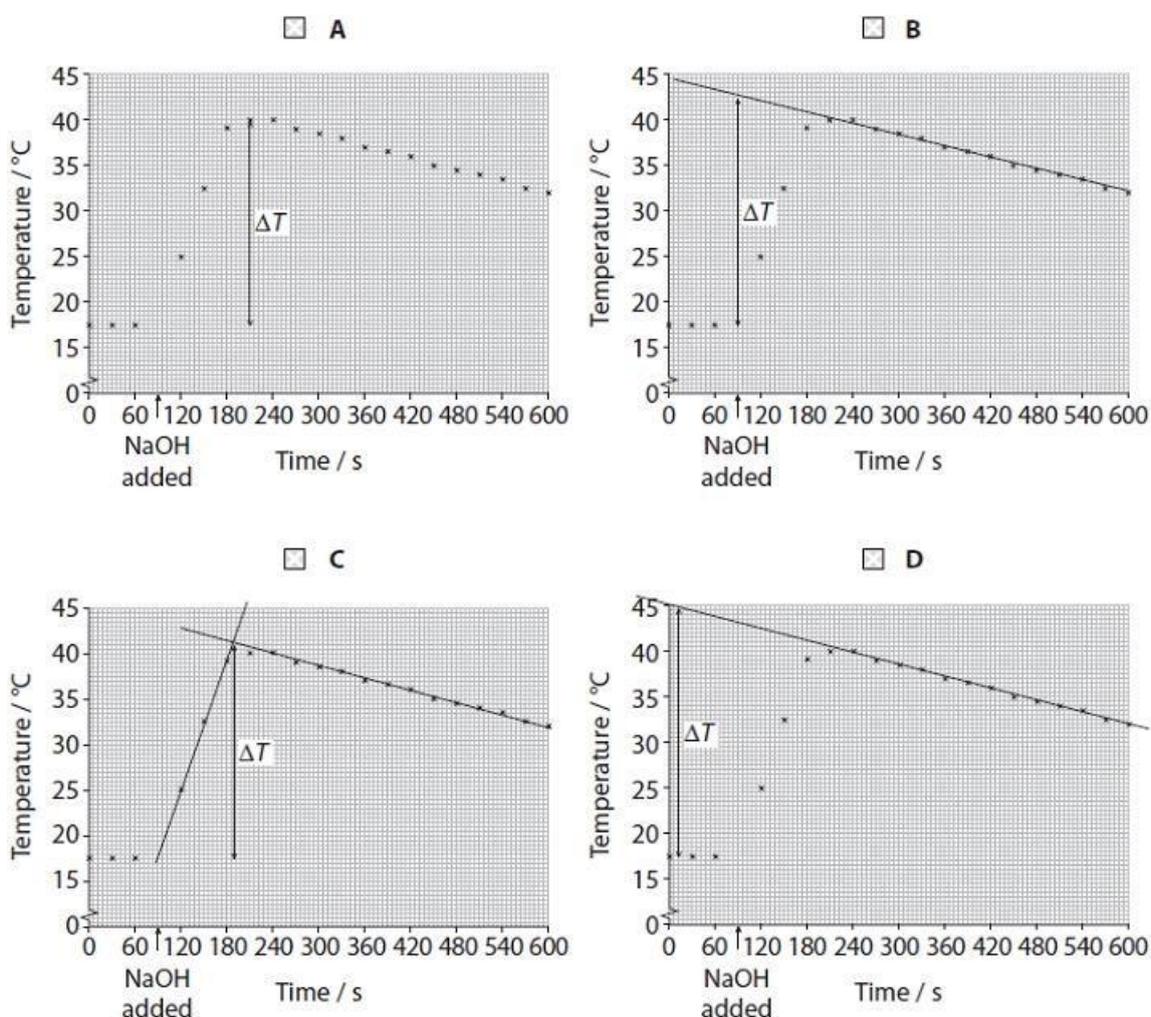**(Total for question = 5 marks)**

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)