Q1. This question is about several Brønsted–Lowry acids and bases.

(a) Define the term *Brønsted–Lowry* acid.

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(1)

(b) Three equilibria are shown below. For each reaction, indicate whether the substance immediately **above** the box is acting as a Brønsted–Lowry acid (**A**) or a Brønsted–Lowry base (**B**) by writing **A** or **B** in each of the six boxes.

(i) CH_3COOH + H_2O ⇌ CH_3COO^- + H_3O^+

(1)

(ii) CH_3NH_2 + H_2O ⇌ $CH_3NH_3^+$ + OH^-

(1)

(iii) HNO_3 + H_2SO_4 ⇌ $H_2NO_3^+$ + HSO_4^-

(1)

(c) A 25.0 cm^3 sample of 0.0850 mol dm^{-3} hydrochloric acid was placed in a beaker. Distilled water was added until the pH of the solution was 1.25.

Calculate the total volume of the solution formed. State the units.

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(3)

(d) At 298 K, the value of the acid dissociation constant (K_a) for the weak acid HX in aqueous solution is 3.01×10^{-5} mol dm^{-3}.

(i) Calculate the value of pK_a for HX at this temperature.
Give your answer to 2 decimal places.

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(1)

(ii) Write an expression for the acid dissociation constant (K_a) for the weak acid HX.

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(1)

(iii) Calculate the pH of a 0.174 mol dm^{-3} solution of HX at this temperature.
Give your answer to 2 decimal places.

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(3)

(e) An acidic buffer solution is formed when 10.0 cm^3 of 0.125 mol dm^{-3} aqueous sodium hydroxide are added to 15.0 cm^3 of 0.174 mol dm^{-3} aqueous HX.
The value of K_a for the weak acid HX is 3.01×10^{-5} mol dm^{-3}.

Calculate the pH of this buffer solution at 298 K.
Give your answer to 2 decimal places.

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(6)

(Total 18 marks)

Q2. Ammonia and ethylamine are examples of weak Brønsted–Lowry bases.

(a) State the meaning of the term *Brønsted–Lowry base*.

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(1)

(b) (i) Write an equation for the reaction of ethylamine ($CH_3CH_2NH_2$) with water to form a weakly alkaline solution.

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(1)

(ii) In terms of this reaction, state why the solution formed is **weakly** alkaline.

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(1)

(c) State which is the stronger base, ammonia or ethylamine. Explain your answer.

Stronger base .....

Explanation .....

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(Extra space) .....

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(3)

(d) Give the formula of an organic compound that forms an alkaline buffer solution when added to a solution of ethylamine.

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(1)

(e) Explain qualitatively how the buffer solution in part (d) maintains an almost constant pH when a small amount of hydrochloric acid is added to it.

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(2)
(Total 9 marks)

Q3. When iron(II) sulfate is used for killing weeds in lawns, it is often mixed with the fertiliser ammonium sulfate. Ammonium sulfate also makes the soil acidic.

(a) Write an equation to show how the ammonium ion behaves as a Brønsted–Lowry acid in water.

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(1)

(b) Compounds such as ammonium sulfate react on warming with sodium hydroxide solution as shown in the equation below.

$$(NH_4)_2SO_4 + 2NaOH \longrightarrow Na_2SO_4 + 2NH_3 + 2H_2O$$

Use this information to describe a simple test, other than smell, to show that ammonia is evolved. State what you would observe.

Test .....

.....

Observation .....

(2)
(Total 3 marks)

Q4. In which one of the following reactions is the role of the reagent stated correctly?

	Reaction	**Role of reagent**
A	$TiO_2 + 2C + 2Cl_2 \rightarrow TiCl_4 + 2CO$	TiO_2 is an oxidising agent
B	$HNO_3 + H_2SO_4 \rightarrow H_2NO_3^+ + HSO_4^-$	HNO_3 is a Brønsted-Lowry acid
C	$CH_3COCl + AlCl_3 \rightarrow CH_3CO^+ + AlCl_4^-$	$AlCl_3$ is a Lewis base
D	$2CO + 2NO \rightarrow 2CO_2 + N_2$	CO is a reducing agent

(Total 1 mark)

Q5.

Summarised directions for recording responses to multiple completion questions			
A (i), (ii) and (iii) correct only	**B** (i) and (iii) correct only	**C** (ii) and (iv) correct only	**D** (iv) alone correct

Brønsted-Lowry acid-base reactions include

(i) $OH^- + CH_3Cl \rightarrow CH_3OH + Cl^-$

(ii) $NH_3 + HCl \rightarrow NH_4^+ + Cl^-$

(iii) $KF + PF_5 \rightarrow K^+ + PF_6^-$

(iv) $H_2O + H_2O \rightarrow H_3O^+ + OH^-$

(Total 1 mark)

Q1. The acid dissociation constant, K_a, for ethanoic acid is given by the expression

$$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]}$$

The value of K_a for ethanoic acid is 1.74×10^{-5} mol dm^{-3} at 25 °C.

(a) A buffer solution is prepared using ethanoic acid and sodium ethanoate. In the buffer solution, the concentration of ethanoic acid is 0.186 mol dm^{-3} and the concentration of sodium ethanoate is 0.105 mol dm^{-3}.

Calculate the pH of this buffer solution.
Give your answer to 2 decimal places.

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(3)

(b) In a different buffer solution, the concentration of ethanoic acid is 0.251 mol dm^{-3} and the concentration of sodium ethanoate is 0.140 mol dm^{-3}.

A sample of hydrochloric acid containing 0.015 mol of HCl is added to 1000 cm^3 of this buffer solution.

Calculate the pH of the buffer solution after the hydrochloric acid has been added.
You should ignore any change in total volume.
Give your answer to 2 decimal places.

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(5)
(Total 8 marks)

Q2. A solution of chlorine in water is acidic. Swimming pool managers maintain pool water at a constant pH by using a buffer. They do so by adding sodium hydrogencarbonate and sodium carbonate.

(a) Hydrogen carbonate ions (HCO_3^-) act as a weak acid in aqueous solution. Write an equation for this equilibrium.

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(1)

(b) Use the equation in part (a) to explain how a solution containing sodium hydrogencarbonate and sodium carbonate can act as a buffer when small amounts of acid or small amounts of alkali are added.

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(3)

(Total 4 marks)

Q3. When 1.00 mol dm^{-3} solutions of salicylic acid and sodium hydroxide are mixed a buffer solution can be formed. Salicylic acid is a monoprotic acid that can be represented by the formula HA.

(a) Select a mixture from the table below that would produce a buffer solution. Give a reason for your choice.

Mixture	Volume of 1.00 mol dm^{-3} salicylic acid solution / cm^3	Volume of 1.00 mol dm^{-3} sodium hydroxide solution / cm^3
X	25	75
Y	50	50
Z	75	25

Mixture .....

Reason .....

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(2)

(b) Another mixture, formed by adding 50 cm^3 of 1.00 mol dm^{-3} salicylic acid solution to 25 cm^3 of 1.00 mol dm^{-3} sodium hydroxide solution, can be used to determine the pK_a of salicylic acid. State **one** measurement that must be made for this mixture and explain how this measurement can be used to determine the pK_a of salicylic acid.

Measurement .....

Explanation .....

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(3)

(Total 5 marks)

Q4. This question is about alkalis and carboxylic acids.

In this question, all data are quoted at 25 °C.

(a) Carboxylic acids are weak acids.

State the meaning of the term **weak** as applied to carboxylic acids.

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(1)

(b) Write an equation for the reaction of propanoic acid with sodium carbonate.

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(1)

(c) Calculate the pH of a 0.0120 mol dm^{-3} solution of calcium hydroxide.
The ionic product of water $K_w = 1.00 \times 10^{-14}$ mol^2 dm^{-6}.
Give your answer to 2 decimal places.

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(3)

(d) The value of the acid dissociation constant K_a for benzenecarboxylic acid (C_6H_5COOH) is 6.31×10^{-5} mol dm^{-3}.

(i) Write an expression for the acid dissociation constant K_a for benzenecarboxylic acid.

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(1)

(ii) Calculate the pH of a 0.0120 mol dm^{-3} solution of benzenecarboxylic acid. Give your answer to 2 decimal places.

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(Extra space).....

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(3)

(iii) A buffer solution with a pH of 4.00 is made using benzenecarboxylic acid and sodium benzenecarboxylate.

Calculate the mass of sodium benzenecarboxylate (M_r = 144.0) that should be dissolved in 1.00 dm^3 of a 0.0120 mol dm^{-3} solution of benzenecarboxylic acid to produce a buffer solution with a pH of 4.00

The value of the acid dissociation constant K_a for benzenecarboxylic acid (C_6H_5COOH) is 6.31×10^{-5} mol dm^{-3}.

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(Extra space) .....

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(5)

(e) Two solutions, one with a pH of 4.00 and the other with a pH of 9.00, were left open to the air.

The pH of the pH 9.00 solution changed more than that of the other solution.

Suggest what substance might be present in the air to cause the pH to change. Explain how and why the pH of the pH 9.00 solution changes.

Substance present in air .....

Explanation .....

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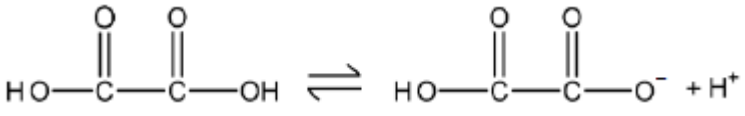
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(3)
(Total 17 marks)

Q5. Ethanedioic acid is a weak acid.

Ethanedioic acid acts, initially, as a monoprotic acid.



(a) Use the concept of electronegativity to justify why the acid strengths of ethanedioic

acid and ethanoic acid are different.

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(6)

(b) A buffer solution is made by adding 6.00×10^{-2} mol of sodium hydroxide to a solution containing 1.00×10^{-1} mol of ethanedioic acid ($H_2C_2O_4$).
Assume that the sodium hydroxide reacts as shown in the following equation and that in this buffer solution, the ethanedioic acid behaves as a monoprotic acid.

$$H_2C_2O_4(aq) + OH^-(aq) \longrightarrow HC_2O_4^-(aq) + H_2O(l)$$

The dissociation constant K_a for ethanedioic acid is 5.89×10^{-2} mol dm^{-3}.

Calculate a value for the pH of the buffer solution.
Give your answer to the appropriate number of significant figures.

pH = ...

(5)

(c) In a titration, the end point was reached when 25.0 cm^3 of an acidified solution containing ethanedioic acid reacted with 20.20 cm^3 of 2.00×10^{-2} mol dm^{-3} potassium manganate(VII) solution.

Deduce an equation for the reaction that occurs and use it to calculate the original concentration of the ethanedioic acid solution.

Equation .....

Calculation

Original concentration = ... mol dm^{-3}

(4)

(Total 15 marks)

Q1. Water dissociates slightly according to the equation:

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

The ionic product of water, K_w, is given by the expression

$$K_w = [H^+][OH^-]$$

K_w varies with temperature as shown in the table.

Temperature / °C	K_w / mol^2 dm^{-6}
25	1.00×10^{-14}
50	5.48×10^{-14}

(a) Explain why the expression for K_w does **not** include the concentration of water.

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(2)

(b) Explain why the value of K_w increases as the temperature increases.

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(2)

(c) Calculate the pH of pure water at 50 °C.
Give your answer to 2 decimal places.

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(3)

(d) Calculate the pH of 0.12 mol dm^{-3} aqueous NaOH at 50 °C.
Give your answer to 2 decimal places.

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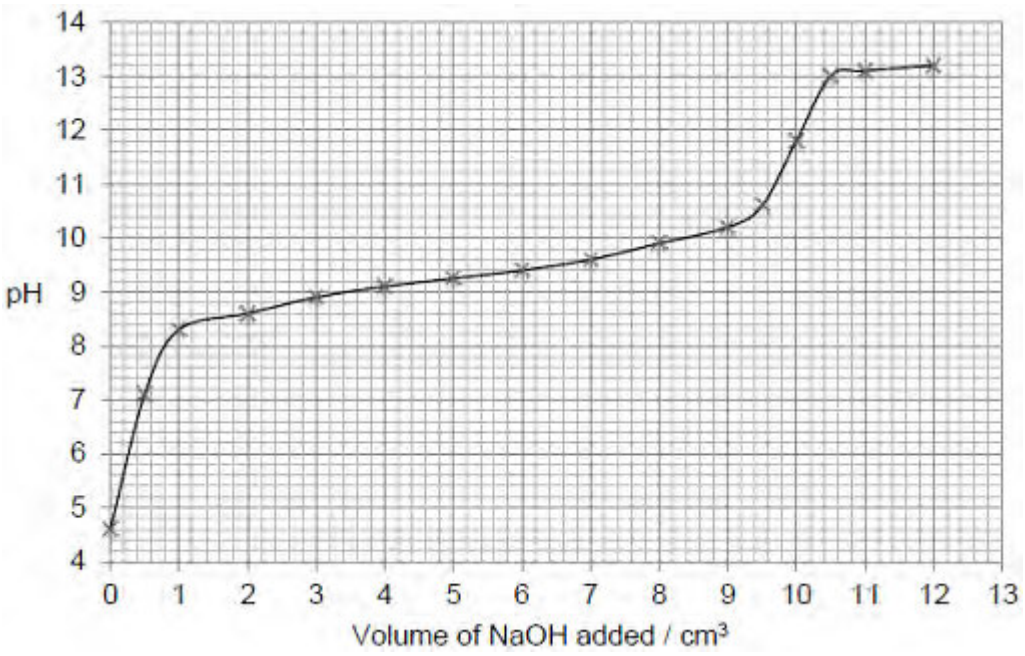
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(3)
(Total 10 marks)

Q2. Ammonium chloride, when dissolved in water, can act as a weak acid as shown by the following equation.

$$NH_4^+(aq) \rightleftharpoons NH_3(aq) + H^+(aq)$$

The following figure shows a graph of data obtained by a student when a solution of sodium hydroxide was added to a solution of ammonium chloride. The pH of the reaction mixture was measured initially and after each addition of the sodium hydroxide solution.



(a) Suggest a suitable piece of apparatus that could be used to measure out the sodium hydroxide solution.
Explain why this apparatus is more suitable than a pipette for this purpose.

Apparatus .....

Explanation .....

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(2)

(b) Use information from the curve in the figure above to explain why the end point of this reaction would be difficult to judge accurately using an indicator.

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(2)

(c) The pH at the end point of this reaction is 11.8.

Use this pH value and the ionic product of water, $K_w = 1.0 \times 10^{-14}$ mol^2 dm^{-6}, to calculate the concentration of hydroxide ions at the end point of the reaction.

Concentration = ... mol dm^{-3}

(3)

(d) The expression for the acid dissociation constant for aqueous ammonium ions is

$$k_a = \frac{[NH_3][H^+]}{[NH_4^+]}$$

The initial concentration of the ammonium chloride solution was 2.00 mol dm^{-3}.

Use the pH of this solution, before any sodium hydroxide had been added, to calculate a value for K_a

K_a = ... mol dm^{-3}

(3)

(e) A solution contains equal concentrations of ammonia and ammonium ions.

Use your value of K_a from part **(d)** to calculate the pH of this solution. Explain your working.

(If you were unable to calculate a value for K_a you may assume that it has the value 4.75×10^{-9} mol dm^{-3}. This is **not** the correct value.)

pH= .....

(2)
(Total 12 marks)

Q3. This question involves calculations about two strong acids and one weak acid.
All measurements were carried out at 25 °C.

(a) A 25.0 cm^3 sample of 0.0850 mol dm^{-3} hydrochloric acid was placed in a beaker and 100 cm^3 of distilled water were added.
Calculate the pH of the new solution formed.
Give your answer to 2 decimal places.

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(2)

(b) HX is a weak monobasic acid.

(i) Write an expression for the acid dissociation constant, K_a, for HX.

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(1)

(ii) The pH of a 0.0850 mol dm^{-3} solution of HX is 2.79
Calculate a value for the acid dissociation constant, K_a, of this acid.
Give your answer to 3 significant figures.

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(3)

(c) A 25.0 cm^3 sample of 0.620 mol dm^{-3} nitric acid was placed in a beaker and 38.2 cm^3 of 0.550 mol dm^{-3} aqueous sodium hydroxide were added.
Calculate the pH of the solution formed.
Give your answer to 2 decimal places.

The ionic product of water $K_w = 1.00 \times 10^{-14}$ mol^2 dm^{-6} at 25 °C.

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(6)

(Total 12 marks)

Q4. What is the pH of a 0.020 mol dm^{-3} solution of a diprotic acid which is completely dissociated?

A 1.00 ⬭

B 1.40 ⬭

C 1.70 ⬭

D 4.00 ⬭

(Total 1 mark)

Q5. This question is about alkalis and carboxylic acids.

In this question, all data are quoted at 25 °C.

(a) Carboxylic acids are weak acids.

State the meaning of the term **weak** as applied to carboxylic acids.

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(1)

(b) Write an equation for the reaction of propanoic acid with sodium carbonate.

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(1)

(c) Calculate the pH of a 0.0120 mol dm^{-3} solution of calcium hydroxide.
The ionic product of water $K_w = 1.00 \times 10^{-14}$ mol^2 dm^{-6}.
Give your answer to 2 decimal places.

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(3)

(d) The value of the acid dissociation constant K_a for benzenecarboxylic acid (C_6H_5COOH) is 6.31×10^{-5} mol dm^{-3}.

(i) Write an expression for the acid dissociation constant K_a for benzenecarboxylic acid.

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(1)

(ii) Calculate the pH of a 0.0120 mol dm^{-3} solution of benzenecarboxylic acid.
Give your answer to 2 decimal places.

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(Extra space).....

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(3)

(iii) A buffer solution with a pH of 4.00 is made using benzenecarboxylic acid and sodium benzenecarboxylate.

Calculate the mass of sodium benzenecarboxylate (M_r = 144.0) that should be dissolved in 1.00 dm^3 of a 0.0120 mol dm^{-3} solution of benzenecarboxylic acid to produce a buffer solution with a pH of 4.00

The value of the acid dissociation constant K_a for benzenecarboxylic acid (C_6H_5COOH) is 6.31×10^{-5} mol dm^{-3}.

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(5)

(e) Two solutions, one with a pH of 4.00 and the other with a pH of 9.00, were left open to the air.

The pH of the pH 9.00 solution changed more than that of the other solution.

Suggest what substance might be present in the air to cause the pH to change.
Explain how and why the pH of the pH 9.00 solution changes.

Substance present in air .....

Explanation .....

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(3)
(Total 17 marks)

Q1. What is the pH of a 0.020 mol dm^{-3} solution of a diprotic acid which is completely dissociated?

A 1.00 ⬭

B 1.40 ⬭

C 1.70 ⬭

D 4.00 ⬭

(Total 1 mark)

Q2. The acid dissociation constant, K_a, of a weak acid HA has the value 2.56×10^{-4} mol dm^{-3}.

What is the pH of a 4.25×10^{-3} mol dm^{-3} solution of HA?

A 5.96 ⬭

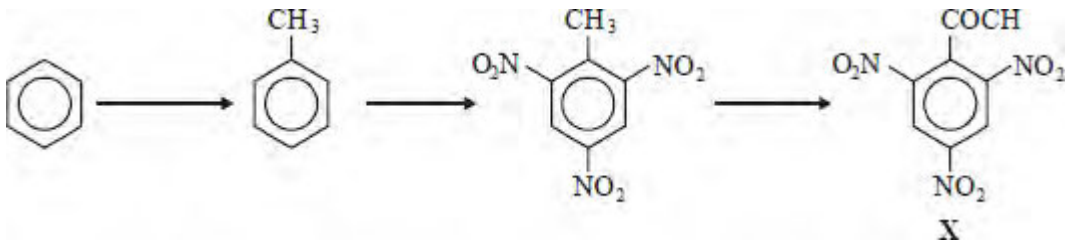
B 3.59 ⬭

C 2.98 ⬭

D 2.37 ⬭

(Total 1 mark)

Q3. This question is based on the reactions and compounds shown in the scheme below.



X

A 0.100 mol dm^{-3} solution of **X** is found to have a pH of 2.50. The value of K_a in mol dm^{-3} is

A 3.16×10^{-2}

B 3.16×10^{-3}

C 1.00×10^{-4}

D 1.00×10^{-5}

(Total 1 mark)

Q4. Use the information about the following solutions to answer the question below.

Solution F: This is a mixture of 1 mol of propanoic acid, 1 mol of methanol and 2 mol of water.

Solution G: This was originally the same mixture as solution **F** but it has been left to reach equilibrium.

Compared to the pH of solution **F**, the pH of solution **G** will be

A considerably lower.

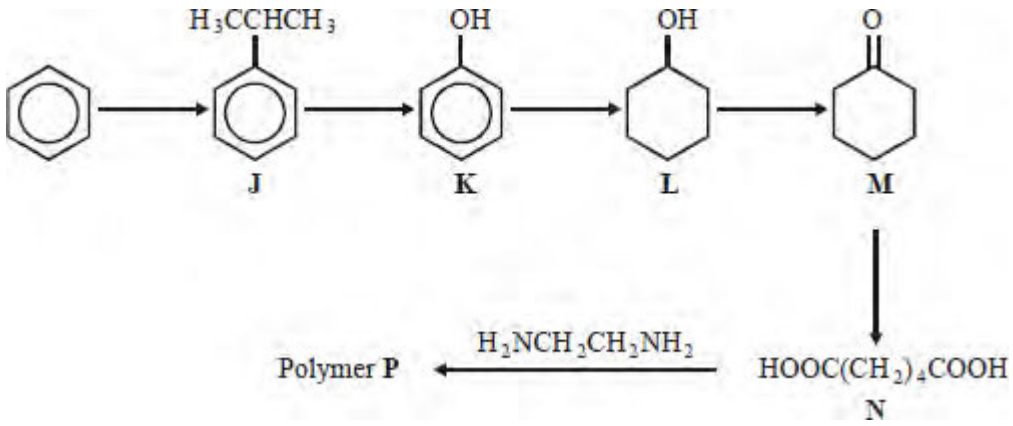
B slightly lower.

C slightly higher.

D exactly the same.

(Total 1 mark)

Q5. This question is about the following reaction scheme which shows the preparation of polymer **P**.



K is a weak acid with a pK_a of 9.95. The pH of a 0.10 mol dm^{-3} solution of **K** is

A 4.48

B 4.98

C 5.48

D 5.98

(Total 1 mark)

Q6. In which one of the following reactions is the role of the reagent stated correctly?

	Reaction	**Role of reagent**
A	$TiO_2 + 2C + 2Cl_2 \rightarrow TiCl_4 + 2CO$	TiO_2 is an oxidising agent
B	$HNO_3 + H_2SO_4 \rightarrow H_2NO_3^+ + HSO_4^-$	HNO_3 is a Brønsted-Lowry acid
C	$CH_3COCl + AlCl_3 \rightarrow CH_3CO^+ + AlCl_4^-$	$AlCl_3$ is a Lewis base
D	$2CO + 2NO \rightarrow 2CO_2 + N_2$	CO is a reducing agent

(Total 1 mark)

Q7. Use the information below to answer this question.

A saturated solution of magnesium hydroxide, $Mg(OH)_2$, contains 0.1166 g of $Mg(OH)_2$ in 10.00 dm^3 of solution. In this solution the magnesium hydroxide is fully dissociated into ions.

Which one of the following is the pH of a solution of magnesium hydroxide containing 4.0×10^{-5} mol dm^{-3} of hydroxide ions at 298 K?
($K_w = 1.0 \times 10^{-14}$ mol^2 dm^{-6} at 298 K)

A 9.6

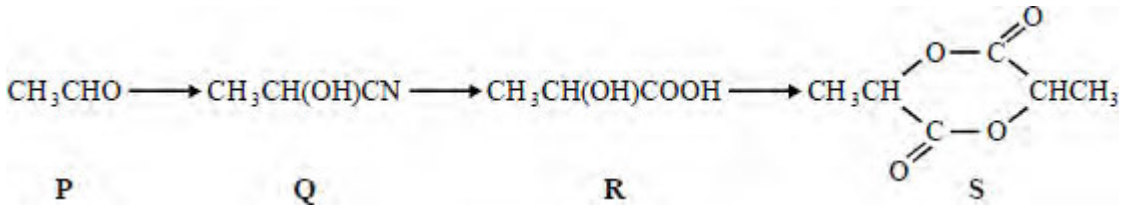
B 9.5

C 8.6

D 8.3

(Total 1 mark)

Q8. This question refers to the reaction sequence below.



HCN is a weak acid with a pK_a value of 9.40. If a 0.010 mol dm^{-3} solution of HCN was used in the first step, the concentration of cyanide ions, in mol dm^{-3}, would be

A 2.0×10^{-6}

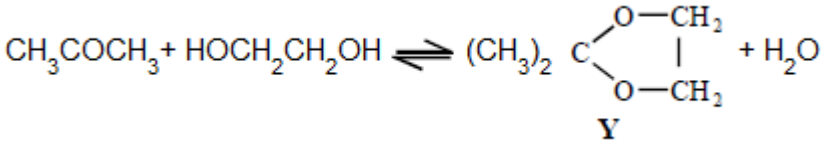
B 6.4×10^{-5}

C 2.0×10^{-5}

D 3.1×10^{-1}

(Total 1 mark)

Q9. This question is about the reaction between propanone and an excess of ethane-1,2-diol, the equation for which is given below.



Y

In a typical procedure, a mixture of 1.00 g of propanone, 5.00 g of ethane-1,2-diol and 0.100 g of benzenesulphonic acid, $C_6H_5SO_3H$, is heated under reflux in an inert solvent. Benzenesulphonic acid is a strong acid.

If 0.100 g of the strong monoprotic acid, benzenesulphonic acid, was dissolved in 100 cm^3 of water, the pH of the solution would be

A 0.20

B 1.20

C 2.20

D 3.20

(Total 1 mark)

Q10. An aqueous solution contains 4.0 g of sodium hydroxide in 250 cm^3 of solution.
(K_w = 1.00 × 10^{-14} mol^2 dm^{-6})

The pH of the solution is

A 13.0

B 13.3

C 13.6

D 13.9

(Total 1 mark)

Q11. The equation and rate law for the reaction of substance P with substance Q are given below.

$$2P + Q \rightarrow R + S$$

$$rate = k[P]^2[H^+]$$

Under which one of the following conditions, all at the same temperature, would the rate of reaction be slowest?

	[P] / mol dm^{-3}	pH
A	0.1	0
B	1	2
C	3	3
D	10	4

(Total 1 mark)

Q12. Addition of which one of the following to 10 cm^3 of 1.0 M NaOH would result in the pH being halved?

A 10 cm^3 of water

B 100 cm^3 of water

C 5 cm^3 of 1.0 M HCl

D 10 cm^3 of 1.0 M HCl

(Total 1 mark)

Q13. A solution of sodium ethanoate has a pH of 8.91 at 25 °C. The hydrogen ion and hydroxide ion concentrations in this solution are

A $[H^+] = 1.00 \times 10^{-9}$ mol dm^{-3} $[OH^-] = 1.00 \times 10^{-5}$ mol dm^{-3}

B $[H^+] = 1.00 \times 10^{-9}$ mol dm^{-3} $[OH^-] = 8.13 \times 10^{-6}$ mol dm^{-3}

C $[H^+] = 1.23 \times 10^{-9}$ mol dm^{-3} $[OH^-] = 1.00 \times 10^{-5}$ mol dm^{-3}

D $[H^+] = 1.23 \times 10^{-9}$ mol dm^{-3} $[OH^-] = 8.13 \times 10^{-6}$ mol dm^{-3}

(Total 1 mark)

Q14. A weak acid HA dissociates in aqueous solution as shown below

$$HA(aq) \rightleftharpoons H^+(aq) + A^-(aq) \qquad \Delta H = +20 \text{ kJ mol}^{-1}$$

Which one of the following changes will result in a decrease in the pH of an aqueous solution of the acid?

A addition of a little aqueous sodium hydroxide solution

B raising the temperature of the solution

C dissolving a little of the sodium salt, NaA, in the solution

D adding a platinum catalyst to the solution

(Total 1 mark)

Q15. The pH of 0.001 M NaOH at 25°C is

A 13

B 11

C 9

D 3

(Total 1 mark)

Q16. Which one of the following could be true in an aqueous solution of sodium hydroxide?

A $[H^+] = (OH^-]$

B $pH = -\log_{10} [OH^-]$

C pH = 1.2

D pH = 12.8

(Total 1 mark)

Q17. Which one of the following is the change in units of pH which occurs when 10.0 cm^3 of a 1.0 M solution of a strong monoprotic acid are made up to 1.0 dm^3 with water?

A 1

B 2

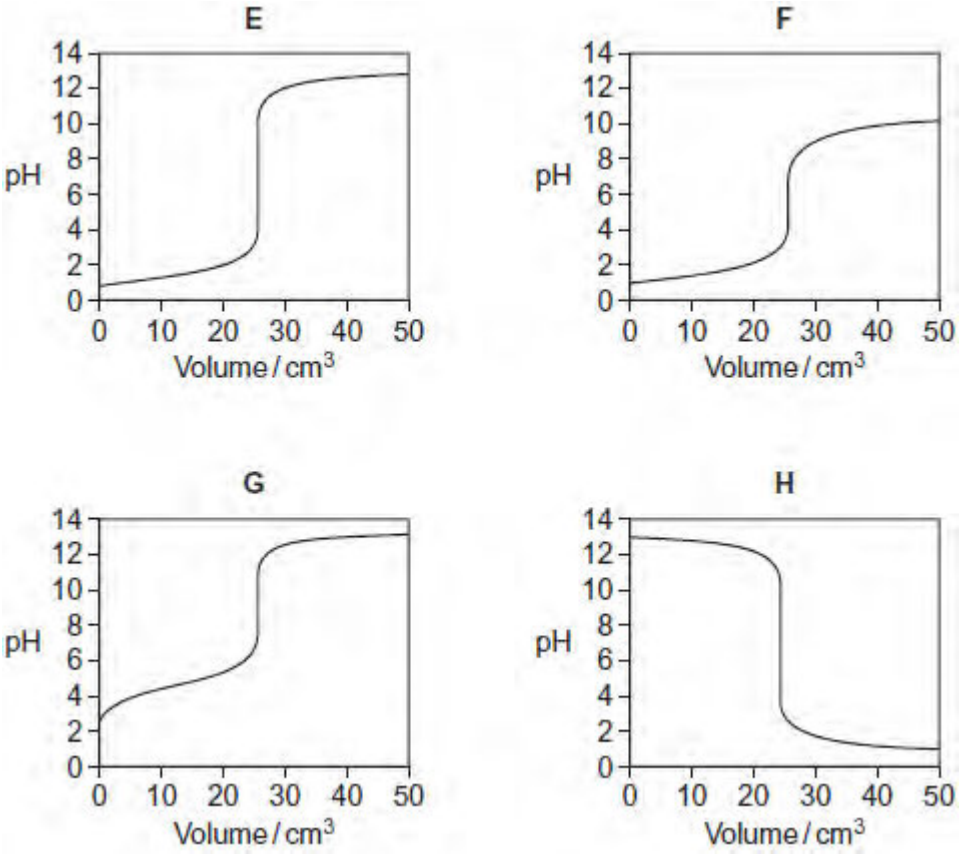
C 3

D 5

(Total 1 mark)

Q1. Titration curves, labelled **E**, **F**, **G** and **H**, for combinations of different aqueous solutions of acids and bases are shown below.

All solutions have concentrations of 0.1 mol dm^{-3}.



(a) In this part of the question, write the appropriate letter in each box.

From the curves **E**, **F**, **G** and **H**, choose the curve produced by the addition of

(i) sodium hydroxide to 25 cm^3 of ethanoic acid ☐

(1)

(ii) ammonia to 25 cm^3 hydrobromic acid ☐

(1)

(iii) hydrochloric acid to 25 cm^3 of potassium hydroxide ☐

(1)

(b) The table shows information about some acid-base indicators.

Indicator	**pH range**	**Lower pH colour**	**Higher pH colour**
pentamethoxy red	1.2−3.2	violet	colourless
naphthyl red	3.7−5.0	red	yellow
4−nitrophenol	5.6−7.0	colourless	yellow
cresol purple	7.6−9.2	yellow	purple

(i) Which indicator in the table could be used for the titration that produces curve **E** but **not** for the titration that produces curve **F**?

Tick (✓) **one** box.

pentamethoxy red ☐

naphthyl red ☐

4−nitrophenol ☐

cresol purple ☐

(1)

(ii) Give the colour change at the end point of the titration that produces curve **H** when naphthyl red is used as the indicator.

.....

(1)

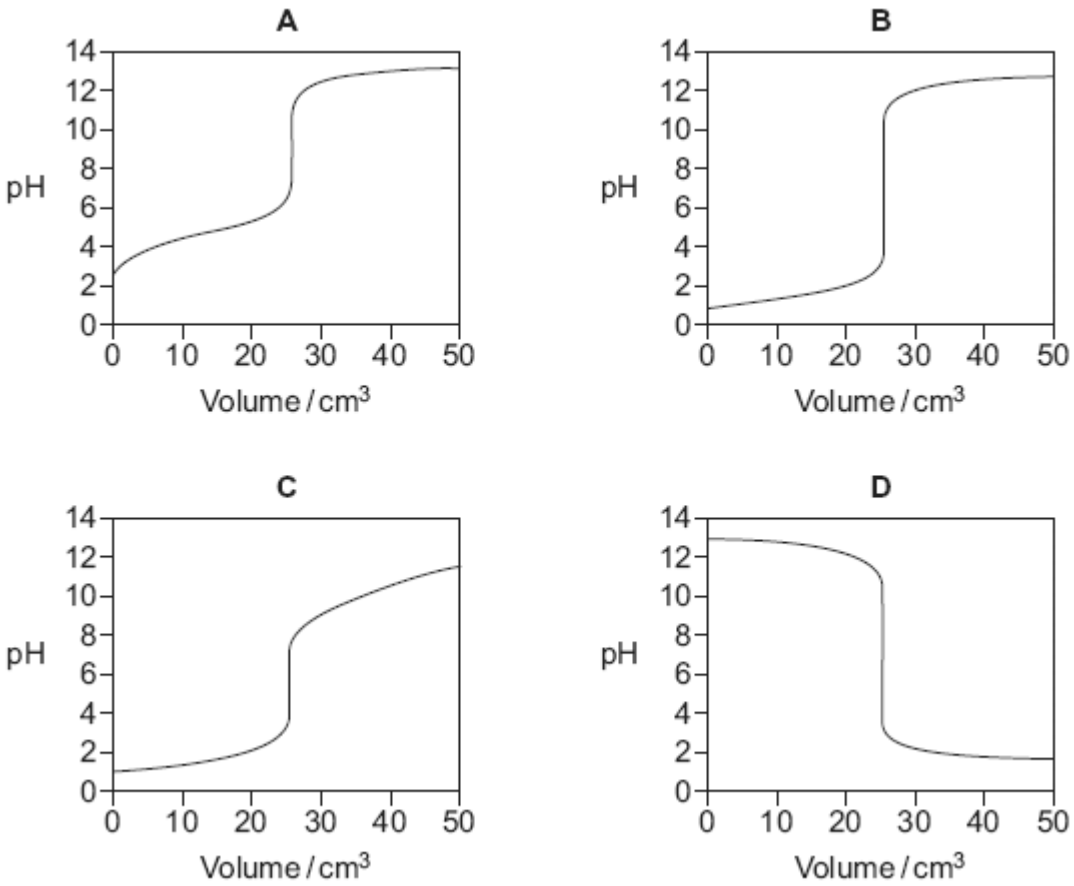
(iii) A beaker contains 25 cm^3 of a buffer solution at pH = 6.0
Two drops of each of the four indicators in the table are added to this solution.

State the colour of the mixture of indicators in this buffer solution.
You should assume that the indicators do **not** react with each other.

.....

(1)
(Total 6 marks)

Q2. Titration curves labelled **A**, **B**, **C** and **D** for combinations of different aqueous solutions of acids and bases are shown below.
All solutions have a concentration of 0.1 mol dm^{-3}.



(a) In this part of the question write the appropriate letter in each box.

From the curves **A**, **B**, **C** and **D**, choose the curve produced by the addition of

ammonia to 25 cm^3 of hydrochloric acid ☐

sodium hydroxide to 25 cm^3 of ethanoic acid ☐

nitric acid to 25 cm^3 of potassium hydroxide ☐

(3)

(b) A table of acid.base indicators is shown below.
The pH ranges over which the indicators change colour and their colours in acid and alkali are also shown.

Indicator	**pH range**	**Colour in acid**	**Colour in alkali**
Trapaeolin	1.3 – 3.0	red	yellow
Bromocresol green	3.8 – 5.4	yellow	blue
Cresol purple	7.6 – 9.2	yellow	purple
Alizarin yellow	10.1 – 12.0	yellow	orange

(i) Select from the table an indicator that could be used in the titration that produces curve **B** but **not** in the titration that produces curve **A**.

.....

(1)

(ii) Give the colour change at the end point of the titration that produces curve **D** when cresol purple is used as the indicator.

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(1)
(Total 5 marks)

Q3. When 1.00 mol dm^{-3} solutions of salicylic acid and sodium hydroxide are mixed a buffer solution can be formed. Salicylic acid is a monoprotic acid that can be represented by the formula HA.

(a) Select a mixture from the table below that would produce a buffer solution. Give a

reason for your choice.

Mixture	Volume of 1.00 mol dm^{-3} salicylic acid solution / cm^3	Volume of 1.00 mol dm^{-3} sodium hydroxide solution / cm^3
X	25	75
Y	50	50
Z	75	25

Mixture .....

Reason .....

.....

.....

(2)

(b) Another mixture, formed by adding 50 cm^3 of 1.00 mol dm^{-3} salicylic acid solution to 25 cm^3 of 1.00 mol dm^{-3} sodium hydroxide solution, can be used to determine the pK_a of salicylic acid. State **one** measurement that must be made for this mixture and explain how this measurement can be used to determine the pK_a of salicylic acid.

Measurement .....

Explanation .....

.....

.....

(3)
(Total 5 marks)

Q4. In order to obtain a pH curve, you are provided with a conical flask containing 25.0 cm^3 of a 0.100 mol dm^{-3} carboxylic acid solution and a burette filled with 0.100 mol dm^{-3} sodium hydroxide solution. You are also provided with a calibrated pH meter.

(a) State why calibrating a pH meter just before it is used improves the accuracy of the pH measurement.

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(1)

(b) Describe how you would obtain the pH curve for the titration.

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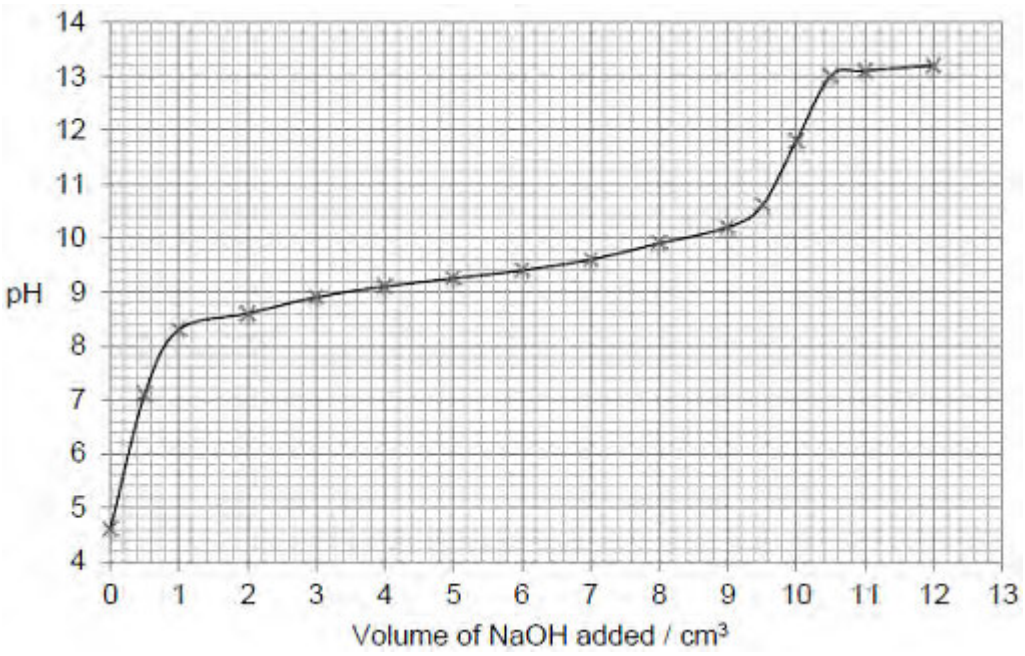
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(5)
(Total 6 marks)

Q5. Ammonium chloride, when dissolved in water, can act as a weak acid as shown by the following equation.

$$NH_4^+(aq) \rightleftharpoons NH_3(aq) + H^+(aq)$$

The following figure shows a graph of data obtained by a student when a solution of sodium hydroxide was added to a solution of ammonium chloride. The pH of the reaction mixture was measured initially and after each addition of the sodium hydroxide solution.



(a) Suggest a suitable piece of apparatus that could be used to measure out the sodium hydroxide solution.
Explain why this apparatus is more suitable than a pipette for this purpose.

Apparatus .....

Explanation .....

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(2)

(b) Use information from the curve in the figure above to explain why the end point of this reaction would be difficult to judge accurately using an indicator.

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(2)

(c) The pH at the end point of this reaction is 11.8.

Use this pH value and the ionic product of water, $K_w = 1.0 \times 10^{-14}$ mol^2 dm^{-6}, to calculate the concentration of hydroxide ions at the end point of the reaction.

Concentration = ... mol dm^{-3}

(3)

(d) The expression for the acid dissociation constant for aqueous ammonium ions is

$$k_a = \frac{[NH_3][H^+]}{[NH_4^+]}$$

The initial concentration of the ammonium chloride solution was 2.00 mol dm^{-3}.

Use the pH of this solution, before any sodium hydroxide had been added, to calculate a value for K_a

K_a = ... mol dm^{-3}

(3)

(e) A solution contains equal concentrations of ammonia and ammonium ions.

Use your value of K_a from part **(d)** to calculate the pH of this solution. Explain your working.

(If you were unable to calculate a value for K_a you may assume that it has the value 4.75×10^{-9} mol dm^{-3}. This is **not** the correct value.)

pH= .....

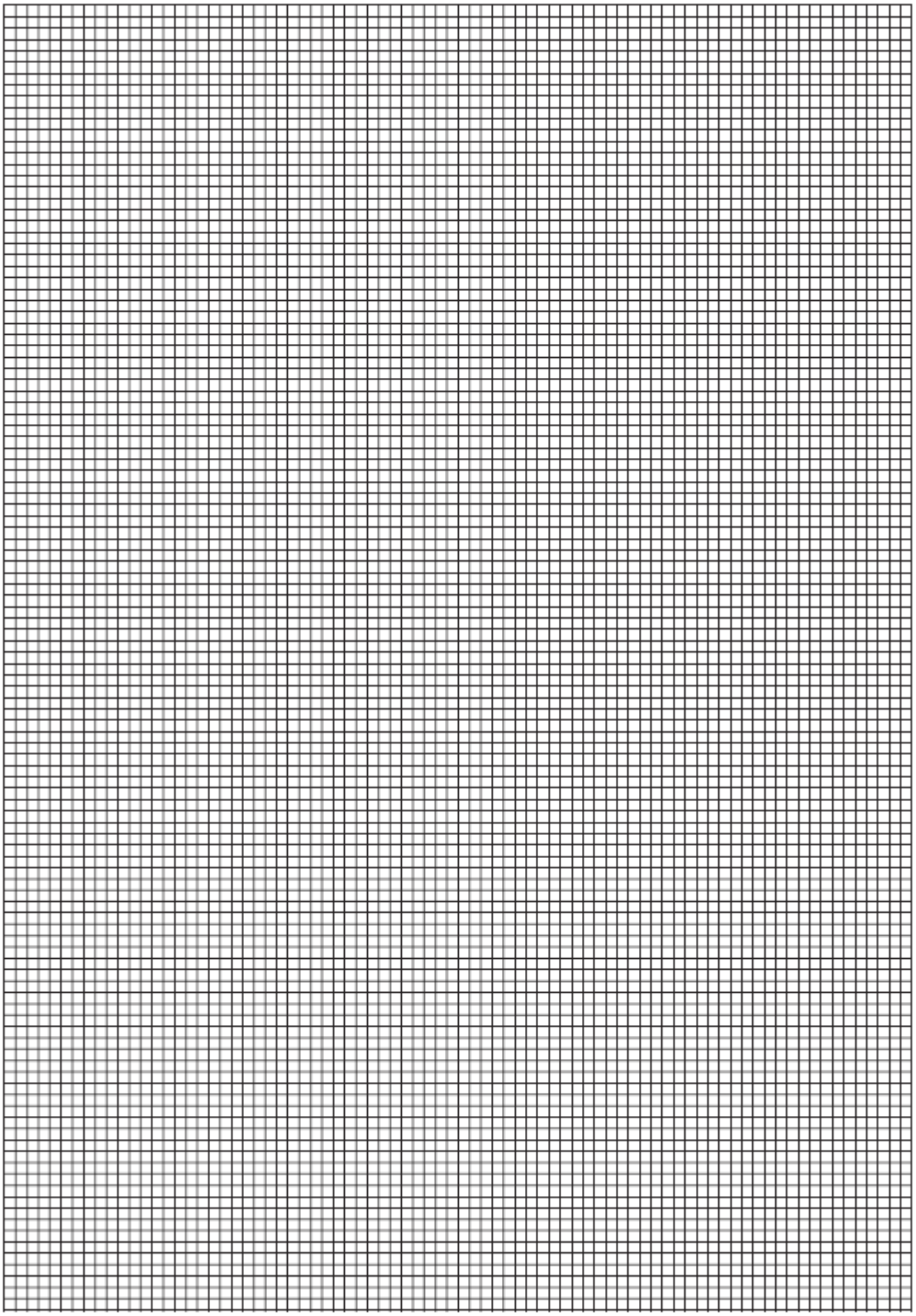
(2)
(Total 12 marks)

Q6. In an experiment to determine the acid dissociation constant (K_a) of a weak acid, 25.0 cm^3 of an approximately 0.1 mol dm^{-3} solution of this acid were titrated with a 0.10 mol dm^{-3} solution of sodium hydroxide.
The pH was measured at intervals and recorded. The table below shows the results.

Volume of NaOH / cm^3	0.0	1.0	2.0	3.0	4.0	5.0	10.0	15.0
pH	5.1	7.8	8.1	8.7	8.4	8.5	8.9	9.3

Volume of NaOH / cm^3	20.0	22.0	23.0	24.0	25.0	26.0	27.0	28.0
pH	9.7	10.0	10.2	11.0	11.3	11.4	11.5	11.6

(a) On the grid below, plot the values from the table above on a graph of pH (y-axis) against volume of NaOH.
You should start your y-axis at pH 4.0.
Draw a curve that represents the curve of best fit through these points. Ignore any anomalous points.



(4)

(b) Deduce the volume of the sodium hydroxide solution that would have been added at the half-neutralisation point of this experiment. This is the point where half the amount of the weak acid has been neutralised.

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(1)

(c) When half of the weak acid has been neutralised, the pH of the mixture at this point is equal to the pK_a of the weak acid.

Use your answer to part (b) and your graph to determine the pK_a of the weak acid and, hence, its K_a value.

pK_a .....

K_a .....

(2)

(d) State the pH value for the anomalous point on your graph.
Suggest **one** reason for this anomaly. Assume that the reading on the pH meter is correct.

pH .....

Reason for anomaly .....

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(1)

(e) Suggest how the experimental procedure could be slightly modified in order to give a more reliable value for the end-point.

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(1)
(Total 9 marks)

Q1. Water dissociates slightly according to the equation:

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

The ionic product of water, K_w, is given by the expression

$$K_w = [H^+][OH^-]$$

K_w varies with temperature as shown in the table.

Temperature / °C	K_w / mol^2 dm^{-6}
25	1.00×10^{-14}
50	5.48×10^{-14}

(a) Explain why the expression for K_w does **not** include the concentration of water.

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(2)

(b) Explain why the value of K_w increases as the temperature increases.

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(2)

(c) Calculate the pH of pure water at 50 °C.
Give your answer to 2 decimal places.

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(3)

(d) Calculate the pH of 0.12 mol dm^{-3} aqueous NaOH at 50 °C.
Give your answer to 2 decimal places.

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(3)
(Total 10 marks)

Q2. This question is about alkalis and carboxylic acids.

In this question, all data are quoted at 25 °C.

(a) Carboxylic acids are weak acids.

State the meaning of the term **weak** as applied to carboxylic acids.

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(1)

(b) Write an equation for the reaction of propanoic acid with sodium carbonate.

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(1)

(c) Calculate the pH of a 0.0120 mol dm^{-3} solution of calcium hydroxide.
The ionic product of water $K_w = 1.00 \times 10^{-14}$ mol^2 dm^{-6}.
Give your answer to 2 decimal places.

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(3)

(d) The value of the acid dissociation constant K_a for benzenecarboxylic acid (C_6H_5COOH) is 6.31×10^{-5} mol dm^{-3}.

(i) Write an expression for the acid dissociation constant K_a for benzenecarboxylic acid.

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(1)

(ii) Calculate the pH of a 0.0120 mol dm^{-3} solution of benzenecarboxylic acid.
Give your answer to 2 decimal places.

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(Extra space).....

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(3)

(iii) A buffer solution with a pH of 4.00 is made using benzenecarboxylic acid and sodium benzenecarboxylate.

Calculate the mass of sodium benzenecarboxylate (M_r = 144.0) that should be dissolved in 1.00 dm^3 of a 0.0120 mol dm^{-3} solution of benzenecarboxylic acid to produce a buffer solution with a pH of 4.00

The value of the acid dissociation constant K_a for benzenecarboxylic acid (C_6H_5COOH) is 6.31×10^{-5} mol dm^{-3}.

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(5)

(e) Two solutions, one with a pH of 4.00 and the other with a pH of 9.00, were left open to the air.

The pH of the pH 9.00 solution changed more than that of the other solution.

Suggest what substance might be present in the air to cause the pH to change.
Explain how and why the pH of the pH 9.00 solution changes.

Substance present in air .....

Explanation .....

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(3)
(Total 17 marks)

Q3. This question involves calculations about two strong acids and one weak acid.
All measurements were carried out at 25 °C.

(a) A 25.0 cm^3 sample of 0.0850 mol dm^{-3} hydrochloric acid was placed in a beaker and 100 cm^3 of distilled water were added.
Calculate the pH of the new solution formed.
Give your answer to 2 decimal places.

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(Extra space) .....

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(2)

(b) HX is a weak monobasic acid.

(i) Write an expression for the acid dissociation constant, K_a, for HX.

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(1)

(ii) The pH of a 0.0850 mol dm^{-3} solution of HX is 2.79
Calculate a value for the acid dissociation constant, K_a, of this acid.
Give your answer to 3 significant figures.

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(Extra space) .....

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(3)

(c) A 25.0 cm^3 sample of 0.620 mol dm^{-3} nitric acid was placed in a beaker and 38.2 cm^3 of 0.550 mol dm^{-3} aqueous sodium hydroxide were added.
Calculate the pH of the solution formed.
Give your answer to 2 decimal places.

The ionic product of water $K_w = 1.00 \times 10^{-14}$ mol^2 dm^{-6} at 25 °C.

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(Extra space) .....

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(6)

(Total 12 marks)

Q4. This question is about the pH of some solutions containing potassium hydroxide and ethanoic acid.

Give all values of pH to 2 decimal places.

(a) (i) Write an expression for pH.

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(1)

(ii) Write an expression for the ionic product of water, K_w

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(1)

(iii) At 10 °C, a 0.154 mol dm^{-3} solution of potassium hydroxide has a pH of 13.72. Calculate the value of K_w at 10 °C.

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(Extra space) .....

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(2)

(b) At 25 °C, the acid dissociation constant K_a for ethanoic acid has the value 1.75×10^{-5} mol dm^{-3}.

(i) Write an expression for K_a for ethanoic acid.

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(1)

(ii) Calculate the pH of a 0.154 mol dm^{-3} solution of ethanoic acid at 25 °C.

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(Extra space) .....

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(3)

(c) At 25 °C, the acid dissociation constant K_a for ethanoic acid has the value 1.75×10^{-5} mol dm^{-3}.

(i) Calculate the pH of the solution formed when 10.0 cm^3 of 0.154 mol dm^{-3} potassium hydroxide are added to 20.0 cm^3 of 0.154 mol dm^{-3} ethanoic acid at 25 °C.

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(Extra space) .....

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(4)

(ii) Calculate the pH of the solution formed when 40.0 cm^3 of 0.154 mol dm^{-3} potassium hydroxide are added to 20.0 cm^3 of 0.154 mol dm^{-3} ethanoic acid at 25 °C.

At 25 °C, K_w has the value 1.00×10^{-14} mol^2 dm^{-6}.

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(4)
(Total 16 marks)

Q1. A solution of chlorine in water is acidic. Swimming pool managers maintain pool water at a constant pH by using a buffer. They do so by adding sodium hydrogencarbonate and sodium carbonate.

(a) Hydrogen carbonate ions (HCO_3^-) act as a weak acid in aqueous solution. Write an equation for this equilibrium.

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(1)

(b) Use the equation in part (a) to explain how a solution containing sodium hydrogencarbonate and sodium carbonate can act as a buffer when small amounts of acid or small amounts of alkali are added.

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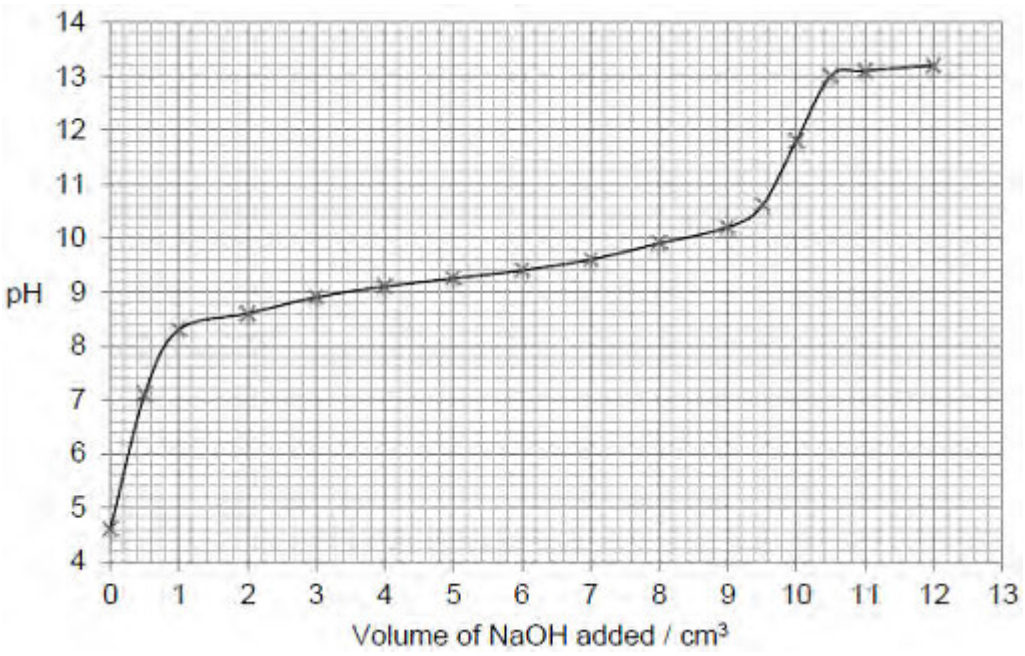
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(3)
(Total 4 marks)

Q2. Ammonium chloride, when dissolved in water, can act as a weak acid as shown by the following equation.

$$NH_4^+(aq) \rightleftharpoons NH_3(aq) + H^+(aq)$$

The following figure shows a graph of data obtained by a student when a solution of sodium hydroxide was added to a solution of ammonium chloride. The pH of the reaction mixture was measured initially and after each addition of the sodium hydroxide solution.



(a) Suggest a suitable piece of apparatus that could be used to measure out the sodium hydroxide solution.
Explain why this apparatus is more suitable than a pipette for this purpose.

Apparatus .....

Explanation .....

.....

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(2)

(b) Use information from the curve in the figure above to explain why the end point of this reaction would be difficult to judge accurately using an indicator.

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(2)

(c) The pH at the end point of this reaction is 11.8.

Use this pH value and the ionic product of water, $K_w = 1.0 \times 10^{-14}$ mol^2 dm^{-6}, to calculate the concentration of hydroxide ions at the end point of the reaction.

Concentration = ... mol dm^{-3}

(3)

(d) The expression for the acid dissociation constant for aqueous ammonium ions is

$$k_a = \frac{[NH_3][H^+]}{[NH_4^+]}$$

The initial concentration of the ammonium chloride solution was 2.00 mol dm^{-3}.

Use the pH of this solution, before any sodium hydroxide had been added, to calculate a value for K_a

K_a = ... mol dm^{-3}

(3)

(e) A solution contains equal concentrations of ammonia and ammonium ions.

Use your value of K_a from part **(d)** to calculate the pH of this solution. Explain your working.

(If you were unable to calculate a value for K_a you may assume that it has the value 4.75×10^{-9} mol dm^{-3}. This is **not** the correct value.)

pH= .....

(2)
(Total 12 marks)

Q3. This question is about Brønsted-Lowry acids of different strengths.

(a) State the meaning of the term *Brønsted–Lowry acid*.

.....

(1)

(b) (i) Write an expression for the acid dissociation constant K_a for ethanoic acid.

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(1)

(ii) The value of K_a for ethanoic acid is 1.75×10^{-5} mol dm^{-3} at 25 °C.

Calculate the concentration of ethanoic acid in a solution of the acid that has a pH of 2.69

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(4)

(c) The value of K_a for chloroethanoic acid ($ClCH_2COOH$) is 1.38×10^{-3} mol dm^{-3} at 25 °C.

(i) Write an equation for the dissociation of chloroethanoic acid in aqueous solution.

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(1)

(ii) Suggest why chloroethanoic acid is a stronger acid than ethanoic acid.

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(2)

(d) **P** and **Q** are acids. **X** and **Y** are bases. The table shows the strength of each acid and base.

Acids		**Bases**	
strong	weak	strong	weak
P	**Q**	**X**	**Y**

The two acids were titrated separately with the two bases using methyl orange as indicator.
The titrations were then repeated using phenolphthalein as indicator.
The pH range for methyl orange is 3.1 − 4.4
The pH range for phenolphthalein is 8.3 − 10.0

For each of the following titrations, select the letter, **A, B, C,** or **D**, for the correct statement about the indicator(s) that would give a precise end-point.
Write your answer in the box provided.

A Both indicators give a precise end-point.

B Only methyl orange gives a precise end-point.

C Only phenolphthalein gives a precise end-point.

D Neither indicator gives a precise end-point.

(i) Acid **P** with base **X** ☐

(1)

(ii) Acid **Q** with base **X** ☐

(1)

(iii) Acid **Q** with base **Y** ☐

(1)

(e) Using a burette, 26.40 cm^3 of 0.550 mol dm^{-3} sulfuric acid were added to a conical flask containing 19.60 cm^3 of 0.720 mol dm^{-3} aqueous sodium hydroxide. Assume that the sulfuric acid is fully dissociated.

Calculate the pH of the solution formed.

Give your answer to 2 decimal places.

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(Extra space) .....

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(6)

(Total 18 marks)

Q4. This question is about alkalis and carboxylic acids.

In this question, all data are quoted at 25 °C.

(a) Carboxylic acids are weak acids.

State the meaning of the term **weak** as applied to carboxylic acids.

.....

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(1)

(b) Write an equation for the reaction of propanoic acid with sodium carbonate.

.....

(1)

(c) Calculate the pH of a 0.0120 mol dm^{-3} solution of calcium hydroxide.
The ionic product of water $K_w = 1.00 \times 10^{-14}$ mol^2 dm^{-6}.
Give your answer to 2 decimal places.

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(Extra space).....

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(3)

(d) The value of the acid dissociation constant K_a for benzenecarboxylic acid

(C_6H_5COOH) is 6.31×10^{-5} mol dm^{-3}.

(i) Write an expression for the acid dissociation constant K_a for benzenecarboxylic acid.

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(1)

(ii) Calculate the pH of a 0.0120 mol dm^{-3} solution of benzenecarboxylic acid. Give your answer to 2 decimal places.

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(Extra space).....

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(3)

(iii) A buffer solution with a pH of 4.00 is made using benzenecarboxylic acid and sodium benzenecarboxylate.

Calculate the mass of sodium benzenecarboxylate (M_r = 144.0) that should be dissolved in 1.00 dm^3 of a 0.0120 mol dm^{-3} solution of benzenecarboxylic acid to produce a buffer solution with a pH of 4.00

The value of the acid dissociation constant K_a for benzenecarboxylic acid (C_6H_5COOH) is 6.31×10^{-5} mol dm^{-3}.

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(Extra space) .....

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(5)

(e) Two solutions, one with a pH of 4.00 and the other with a pH of 9.00, were left open to the air.

The pH of the pH 9.00 solution changed more than that of the other solution.

Suggest what substance might be present in the air to cause the pH to change. Explain how and why the pH of the pH 9.00 solution changes.

Substance present in air .....

Explanation .....

.....

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.....

.....

(3)
(Total 17 marks)

Q5. The acid dissociation constant, K_a, of a weak acid HA has the value 2.56×10^{-4} mol dm^{-3}.

What is the pH of a 4.25×10^{-3} mol dm^{-3} solution of HA?

A 5.96 ⬭

B 3.59 ⬭

C 2.98 ⬭

D 2.37 ⬭

(Total 1 mark)