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.

.....

.....

.....

(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.

.....

.....

.....

.....

.....

.....

.....

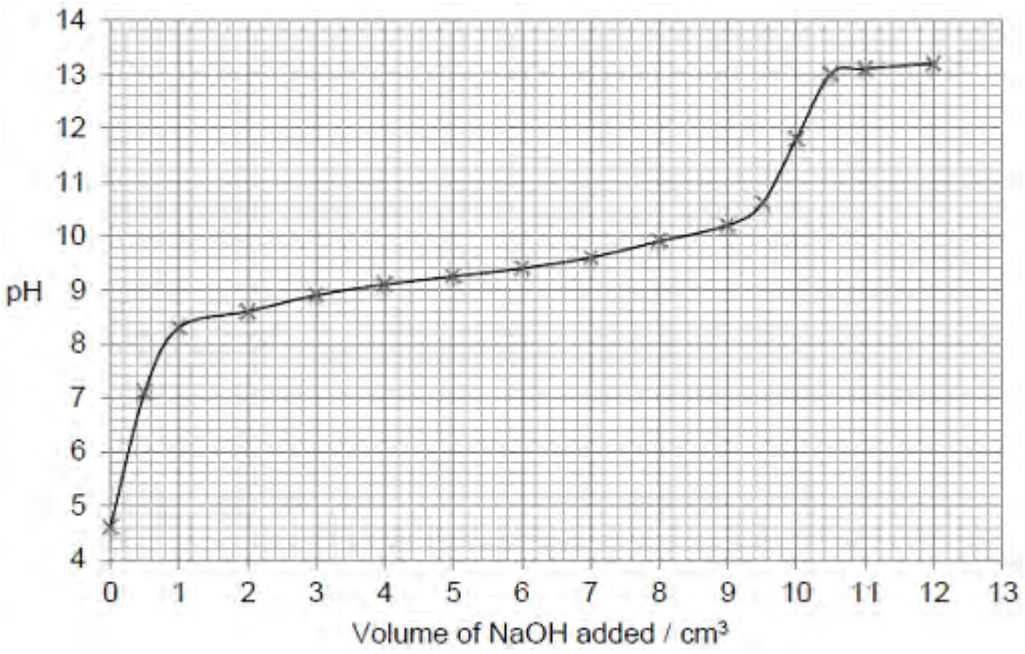
.....

(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 .....

.....

.....

(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.

.....

.....

.....

.....

.....

(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.

.....

.....

(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

.....

.....

.....

.....

.....

.....

(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.

.....

(1)

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

.....

.....

.....

.....

.....

(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.

.....

.....

.....

.....

.....

.....

.....

.....

(Extra space) .....

.....

.....

(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.

.....

.....

(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.

.....

.....

.....

.....

.....

.....

(Extra space).....

.....

.....

(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.

.....

.....

(1)

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

.....

.....

.....

.....

.....

.....

.....

.....

(Extra space).....

.....

.....

(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}.

.....

.....

.....

.....

.....

.....

.....

.....

.....

(Extra space) .....

.....

.....

.....

(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 .....

.....

.....

.....

.....

(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)