Q1.

This question is about pH.

Pure water dissociates slightly.

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq) \qquad \Delta H = +57 \text{ kJ mol}^{-1}$$

The equilibrium constant, $K_c = \dfrac{[H^+][OH^-]}{[H_2O]}$

The ionic product of water, $K_w = [H^+][OH^-]$

(a) Explain why $[H_2O]$ is not shown in the K_w expression.

_____

_____

(1)

Table 1 shows how K_w varies with temperature.

Table 1

Temperature / °C	**K_w / mol² dm⁻⁶**
10	2.93×10^{-15}
20	6.81×10^{-15}
25	1.00×10^{-14}
30	1.47×10^{-14}
50	5.48×10^{-14}

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

_____

_____

_____

_____

(2)

(c) Give the expression for pH.

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

Explain why water is neutral at 50 °C

Expression _____

Calculation

pH _____

Explanation _____

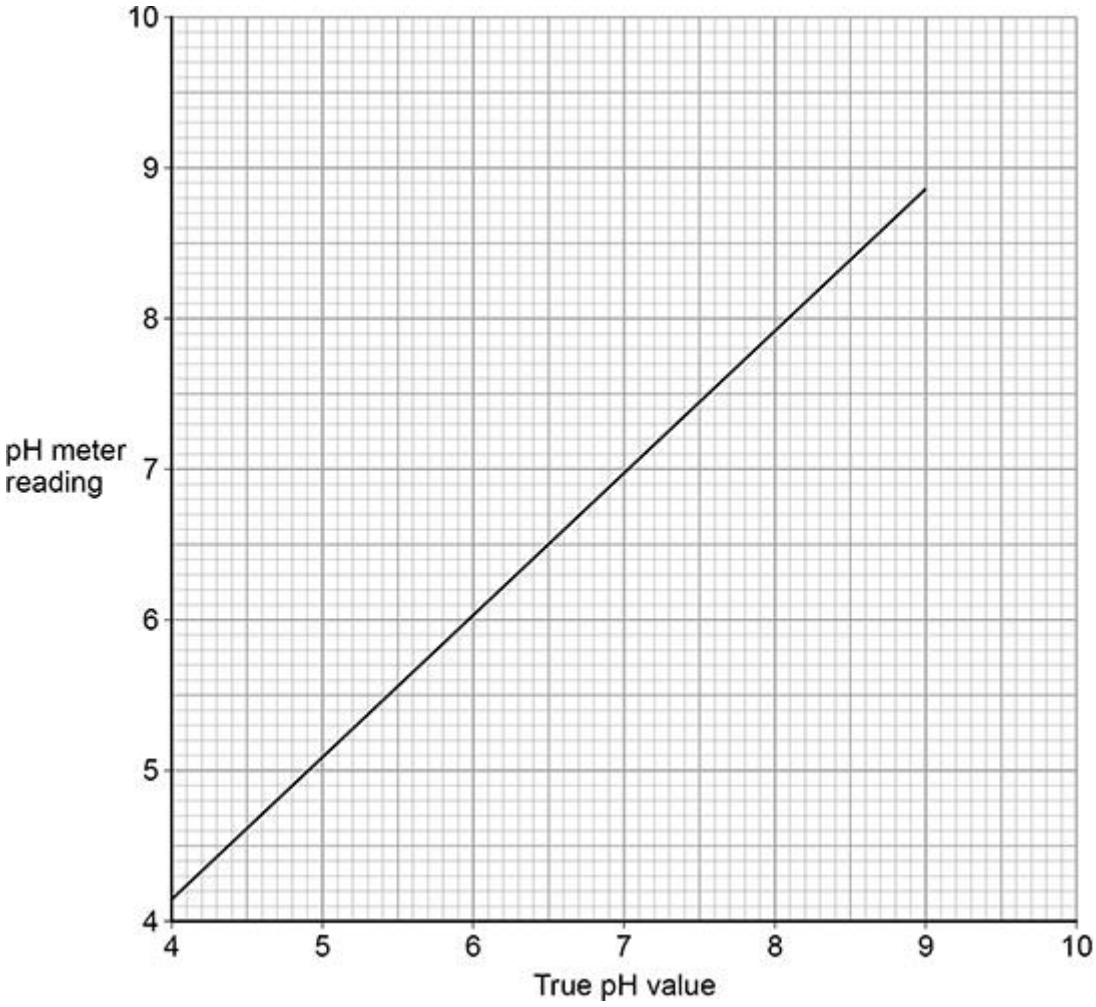
_____

(4)

A pH meter is calibrated using a calibration graph.
To create the calibration, the pH meter is used to measure the pH of separate solutions, each with a known, accurate pH.

Figure 1 shows the calibration graph.

Figure 1



(d) Use **Figure 1** to give the true pH value when the pH meter reading is 5.6

_____

(1)

(e) Suggest why the pH probe is washed with distilled water between each of the calibration measurements.

_____

_____

(1)

(f) The calibrated pH meter is used to monitor the pH during a titration of hydrochloric acid with sodium hydroxide.

Explain why the volume of sodium hydroxide solution added between each pH measurement is smaller as the end point of the titration is approached.

_____

_____

(1)

Figure 2 shows the pH curve for a titration of hydrochloric acid with sodium hydroxide solution.

Figure 2

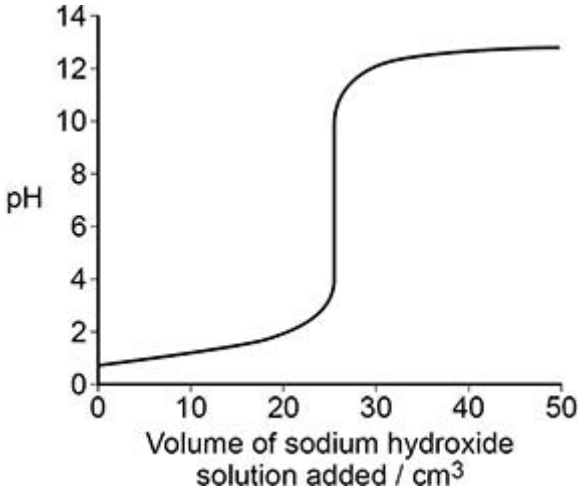


Table 2 shows data about some indicators.

Table 2

Indicator	pH range	Colour at low pH	Colour at high pH
Bromocresol green	3.8 – 5.4	yellow	blue
Phenol red	6.8 – 8.4	yellow	red
Thymolphthalein	9.3 – 10.5	colourless	blue

The student plans to do the titration again using one of the indicators in **Table 2** to determine the end point.

(g) State why all three of the indicators in **Table 2** are suitable for this titration.

_____

_____

(1)

(h) 36.25 cm^3 of 0.200 mol dm^{-3} sodium hydroxide solution are added to 25.00 cm^3 of 0.150 mol dm^{-3} hydrochloric acid.

Calculate the pH of the final solution at 25 ºC

$K_w = 1.00 \times 10^{-14}$ mol^2 dm^{-6} at 25 ºC

pH _____

(5)

(Total 16 marks)

Q2.

A mixture of methanoic acid and sodium methanoate in aqueous solution acts as an acidic buffer solution.

The equation shows the dissociation of methanoic acid.

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

Calculate the mass, in g, of sodium methanoate (HCOONa) that must be added to 25.0 cm^3 of 0.100 mol dm^{-3} methanoic acid to produce a buffer solution with pH = 4.05 at 298 K

For methanoic acid, $pK_a = 3.75$ at 298 K

Assume that the volume of the solution remains constant.

Mass _____ g

(Total 5 marks)

Q3.

Propanoic acid (C_2H_5COOH) is a weak acid.

The acid dissociation constant (K_a) for propanoic acid is 1.35×10^{-5} mol dm^{-3} at 25 °C

(a) State the meaning of the term weak acid.

_____

_____

(1)

(b) Give an expression for the acid dissociation constant for propanoic acid.

K_a

(1)

(c) A student dilutes 25.0 cm^3 of 0.500 mol dm^{-3} propanoic acid by adding water until the total volume is 100.0 cm^3

Calculate the pH of this diluted solution of propanoic acid.

Give your answer to 2 decimal places.

pH _____

(4)

(d) A buffer solution with a pH of 4.50 is made by dissolving *x* g of sodium propanoate (C_2H_5COONa) in a solution of propanoic acid. The final volume of buffer solution is 500 cm^3 and the final concentration of the propanoic acid is 0.250 mol dm^{-3}

Calculate *x* in g
For propanoic acid, $K_a = 1.35 \times 10^{-5}$ mol dm^{-3}

x _____ g

(6)

(Total 12 marks)

Q4.

Which statement about pH is correct?

A The pH of a weak base is independent of temperature. ○

B At temperatures above 298 K, the pH of pure water is less than 7. ○

C The pH of 2.0 mol dm^{-3} nitric acid is approximately 0.30 ○

D The pH of 0.10 mol dm^{-3} sulfuric acid is greater than that of 0.10 mol dm^{-3} hydrochloric acid. ○

(Total 1 mark)

Q5.

A 0.10 mol dm^{-3} aqueous solution of an acid is added slowly to 25 cm^3 of a 0.10 mol dm^{-3} aqueous solution of a base.

Which acid–base pair has the highest pH at the equivalence point?

A CH_3COOH and NaOH ○

B CH_3COOH and NH_3 ○

C HCl and NaOH ○

D HCl and NH_3 ○

(Total 1 mark)

Q6.

Which is the concentration of NaOH(aq), in mol dm^{-3}, that has pH = 14.30?

$K_w = 1.00 \times 10^{-14}$ mol^2 dm^{-6} at 25 °C

A –1.16 ○

B 5.01×10^{-15} ○

C 2.00×10^{14} ○

D 2.00 ○

(Total 1 mark)

Q7.

This question is about different pH values.

(a) For pure water at 40 °C, pH = 6.67
A student thought that the water was acidic.

Explain why the student was incorrect.

Determine the value of K_w at this temperature.

Explanation

_____

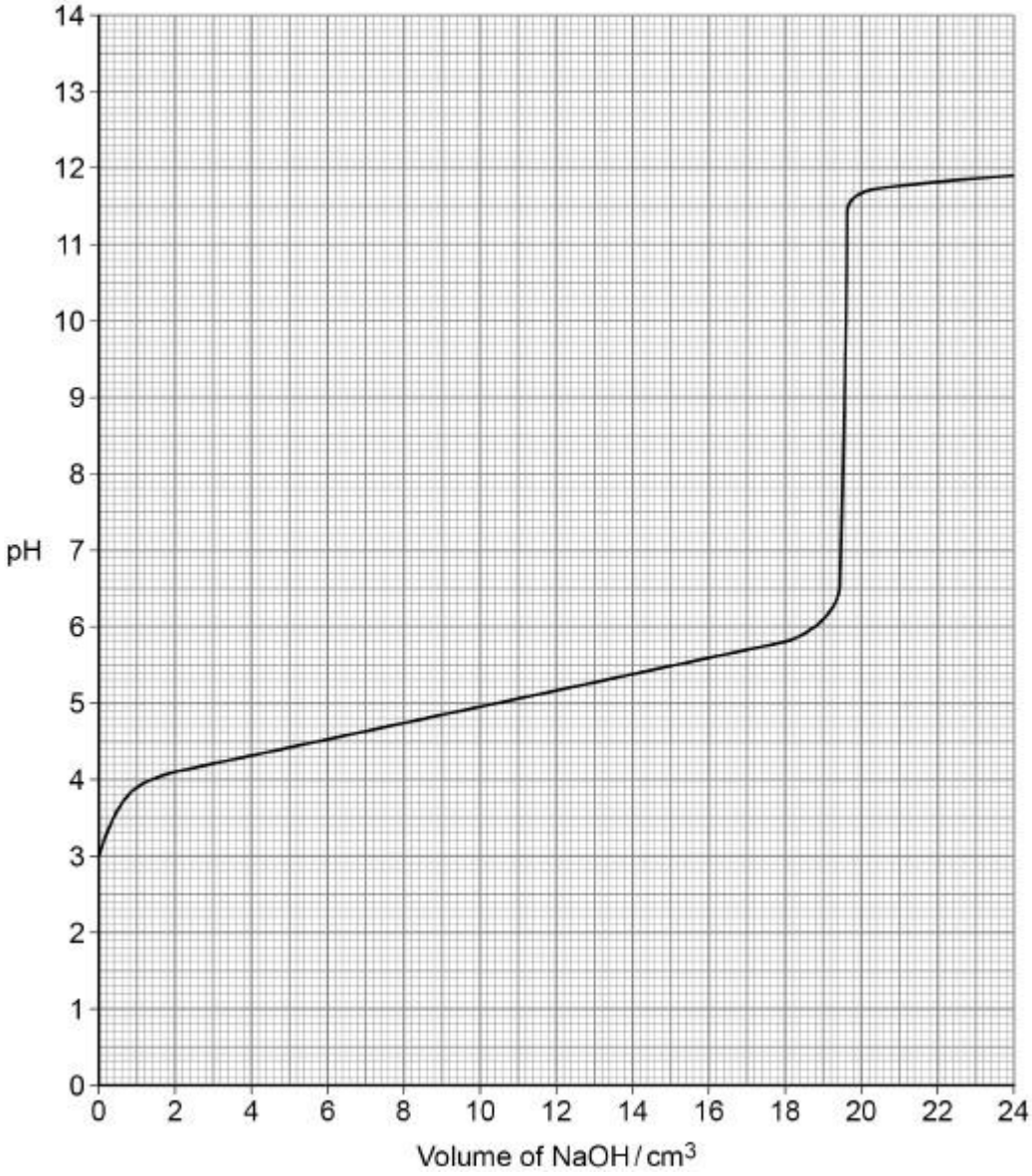
_____

K_w _____ $mol^2\ dm^{-6}$

(4)

(b) Sodium hydroxide solution was added gradually from a burette to 25 cm^3 of 0.080 mol dm^{-3} propanoic acid at 25 °C
The pH was measured and recorded at regular intervals.

The results are shown in the diagram.



Use the diagram above to determine the value of K_a for propanoic acid at 25 °C

Show your working.

K_a _____ mol dm^{-3}

(3)

(c) Suggest which indicator is the most appropriate for the reaction in part **(b)**? Tick (✓) **one** box.

Indicator	**pH range**	**Tick (✓) one box**
methyl orange	3.1 - 4.4	
bromothymol blue	6.0 - 7.6	
cresolphthalein	8.2 - 9.8	
indigo carmine	11.6 - 13.0	

(1)

(d) A student prepared a buffer solution by adding 0.0136 mol of a salt KX to 100 cm^3 of a 0.500 mol dm^{-3} solution of a weak acid HX and mixing thoroughly.

The student then added 3.00×10^{-4} mol of potassium hydroxide to the buffer solution.

Calculate the pH of the buffer solution after adding the potassium hydroxide.

For the weak acid HX at 25 °C the value of the acid dissociation constant, $K_a = 1.41 \times 10^{-5}$ mol dm^{-3}.

Give your answer to two decimal places.

pH _____

(6)

(e) A buffer solution has a constant pH even when diluted.

Use a mathematical expression to explain this.

(1)

(Total 15 marks)

Q8.

This question is about sulfuric acid and its salts.

(a) Draw the displayed formula of a molecule of H_2SO_4

(1)

(b) In aqueous solution, sulfuric acid acts as a strong acid. The H_2SO_4 dissociates to form HSO_4^- ions and H^+ ions.

The HSO_4^- ions act as a weak acid and dissociate to form SO_4^{2-} ions and H^+ ions.

Give an equation to show each stage in the dissociation of sulfuric acid in aqueous solution.

Include appropriate arrows in your equations.

Equation 1

_____

Equation 2

_____

(2)

(c) A student is required to make 250 cm^3 of an aqueous solution that contains an accurately measured mass of sodium hydrogensulfate ($NaHSO_4$).

Describe the method that the student should use to make this solution.

(4)

(d) A solution that contains 605 mg of $NaHSO_4$ in 100 cm^3 of solution has a pH of 1.72

Calculate the value of K_a for the hydrogensulfate ion (HSO_4^-) that is behaving as a weak acid.
Give your answer to three significant figures.

State the units of K_a

K _____ Units _____

(6)

(e) Some sodium sulfate is dissolved in a sample of the solution from part **(d)**.

Explain why this increases the pH of the solution.

_____

_____

_____

_____

_____

_____

(2)

(Total 15 marks)

Q9.

Which indicator should be used in a titration to find the concentration of a solution of methylamine using 0.010 mol dm^{-3} hydrochloric acid?

A Thymol blue (pH range 1.2–2.8) ⬭

B Bromophenol blue (pH range 3.0–4.6) ⬭

C Phenol red. (pH range 6.8–8.4) ⬭

D Phenolphthalein (pH range 8.3–10.0) ⬭

(Total 1 mark)

Q10.

This question is about acidic solutions.

(a) The acid dissociation constant, K_a, for ethanoic acid is given by the expression

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

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

A buffer solution with a pH of 3.87 was prepared using ethanoic acid and sodium ethanoate. In the buffer solution, the concentration of ethanoate ions was 0.136 mol dm^{-3}

Calculate the concentration of the ethanoic acid in the buffer solution.

Give your answer to three significant figures.

Concentration of acid = _____ mol dm^{-3}

(3)

(b) In a different buffer solution, the concentration of ethanoic acid was 0.260 mol dm^{-3} and the concentration of ethanoate ions was 0.121 mol dm^{-3}

A 7.00×10^{-3} mol sample of sodium hydroxide was added to 500 cm^3 of this buffer solution.

Calculate the pH of the buffer solution after the sodium hydroxide was added.

Give your answer to two decimal places.

pH of buffer solution _____

(6)

(Total 9 marks)

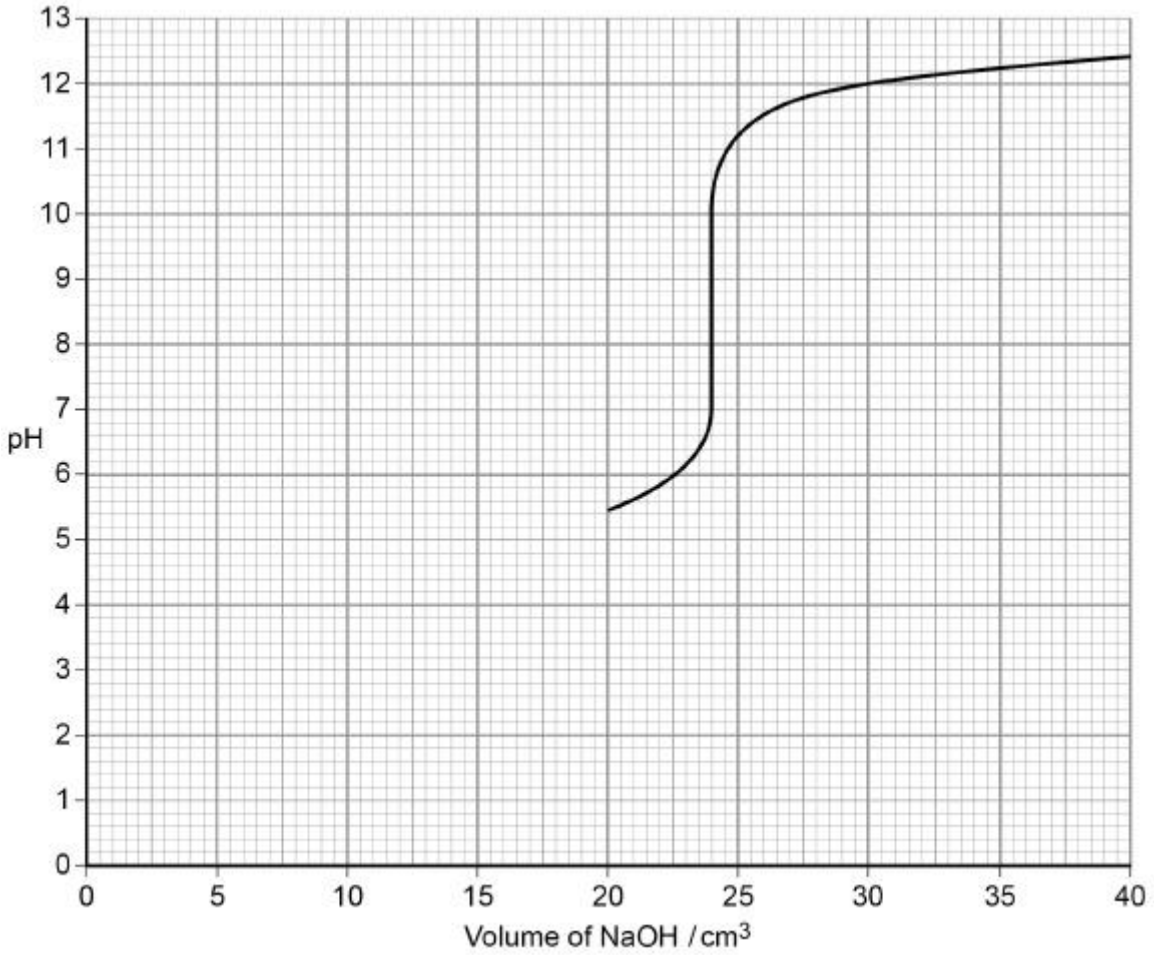
Q11.

A 0.100 mol dm^{-3} solution of sodium hydroxide was gradually added to 25.0 cm^3 of a solution of a weak acid, HX, in the presence of a suitable indicator.

A graph was plotted of pH against the volume of sodium hydroxide solution, as shown in the figure below.

The first pH reading was taken after 20.0 cm^3 of sodium hydroxide solution had been added.

The acid dissociation constant of HX, K_a, = 2.62×10^{-5} mol dm^{-3}



(a) The pH range of an indicator is the range over which it changes colour.

Suggest the pH range of a suitable indicator for this titration.

_____

(1)

(b) Give the expression for the acid dissociation constant of HX.

K_a =

(1)

(c) Calculate the concentration of HX in the original solution.

Concentration _____ mol dm^{-3}

(2)

(d) Calculate the pH of the solution of HX before the addition of any sodium hydroxide.

(If you were unable to calculate a value for the concentration of HX in part (c) you should use a value of 0.600 mol dm^{-3} in this calculation. This is not the correct value.)

pH of HX _____

(2)

(e) Calculate the pH of the solution when half of the acid has reacted.

pH of solution _____

(1)

(f) Plot your answers to part (d) and part (e) on the grid in the figure above.

Use these points to sketch the missing part of the curve between 0 and 20 cm^3 of NaOH solution added.

(2)

(Total 9 marks)

Q12.

2,4,6-Trichlorophenol is a weak monoprotic acid, with $K_a = 2.51 \times 10^{-8}$ mol dm^{-3} at 298 K.

What is the concentration, in mol dm^{-3}, of hydrogen ions in a 2.00×10^{-3} mol dm^{-3} solution of 2,4,6-trichlorophenol at 298 K?

A 5.02×10^{-11} ⬭

B 7.09×10^{-6} ⬭

C 1.26×10^{-5} ⬭

D 3.54×10^{-3} ⬭

(Total 1 mark)

Q13.

What is the pH of a 0.46 mol dm^{-3} solution of potassium hydroxide at 298 K?

(K_w = 1.0 × 10^{-14} mol^2 dm^{-6} at 298 K)

A 0.34 ⬭

B 13.66 ⬭

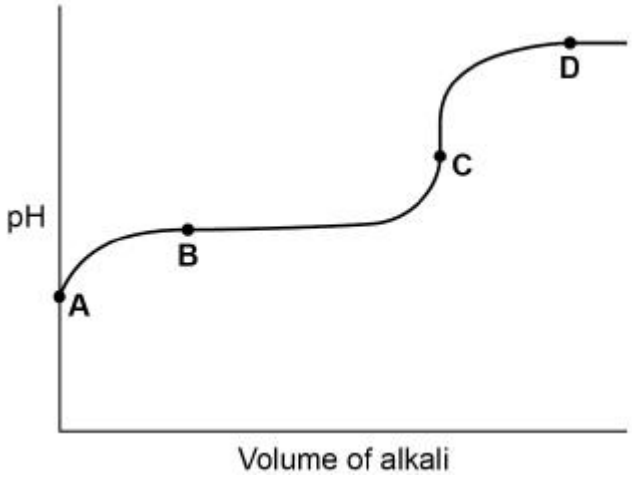
C 13.96 ⬭

D 14.34 ⬭

(Total 1 mark)

Q14.

The diagram shows a pH curve produced by adding a strong alkali to a weak acid.



Which point on the curve represents a solution that can act as a buffer?

A ⬭

B ⬭

C ⬭

D ⬭

(Total 1 mark)

Q15.

This question is about Brønsted–Lowry acids.

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

_____

_____

(1)

(b) What is meant by the term strong when describing an acid?

_____

_____

(1)

(c) At 298 K, 25.0 cm^3 of a solution of a strong monoprotic acid contained 1.45 × 10^{-3} mol of hydrogen ions.

Calculate a value for the pH of this solution.
Give your answer to 2 decimal places.

pH _____

(2)

(d) Calculate the pH of the solution formed after the addition of 35.0 cm^3 of 0.150 mol dm^{-3} NaOH to the original 25.0 cm^3 of monoprotic acid.

The ionic product of water K_w = 1.00 × 10^{-14} mol^2 dm^{-6} at 298 K.
Give your answer to two decimal places.

pH _____

(5)

(e) A buffer solution is made when 1.50 g of sodium hydroxide are added to 1.00 dm^3 of a 0.150 mol dm^{-3} solution of a weak acid HA.

For HA, the acid dissociation constant, K_a = 1.79 × 10^{-5} mol dm^{-3}.

Calculate the pH of this buffer solution.

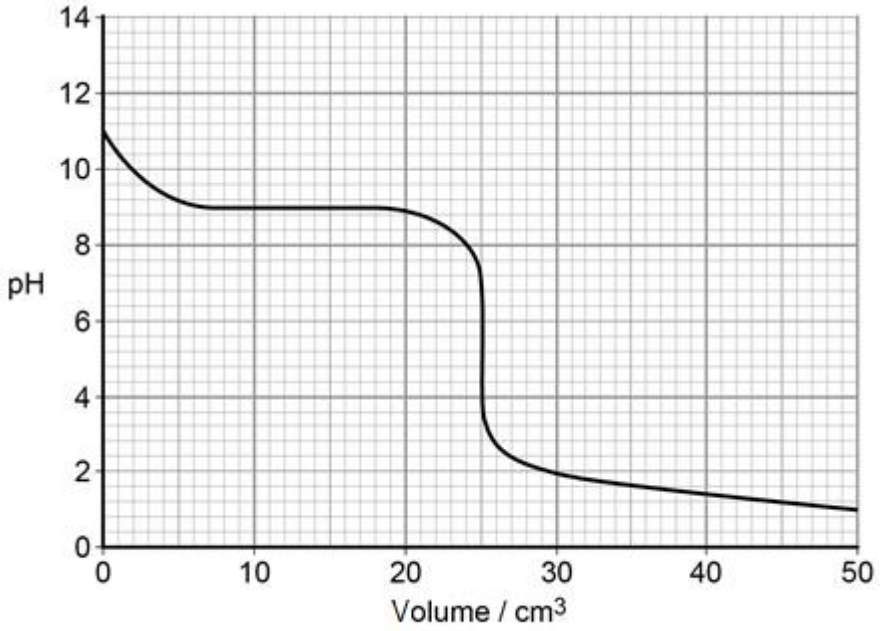
pH _____

(6)

(Total 15 marks)

Q16.

The graph was obtained from an experiment in which an acid was reacted with an alkali.



(a) Suggest possible formulae for an acid and an alkali that could be used to produce the curve shown in the graph.

Acid

_____

Alkali

_____

(2)

(b) Suggest briefly a practical procedure that a student could use to obtain data from which the curve in the graph could be plotted.

_____

_____

_____

_____

_____

_____

_____

(3)

(c) The student was provided with samples of three different indicators.

Suggest how the practical procedure in part **(b)** could be refined by the student to identify the most suitable indicator.

_____

_____

_____

_____

_____

(2)

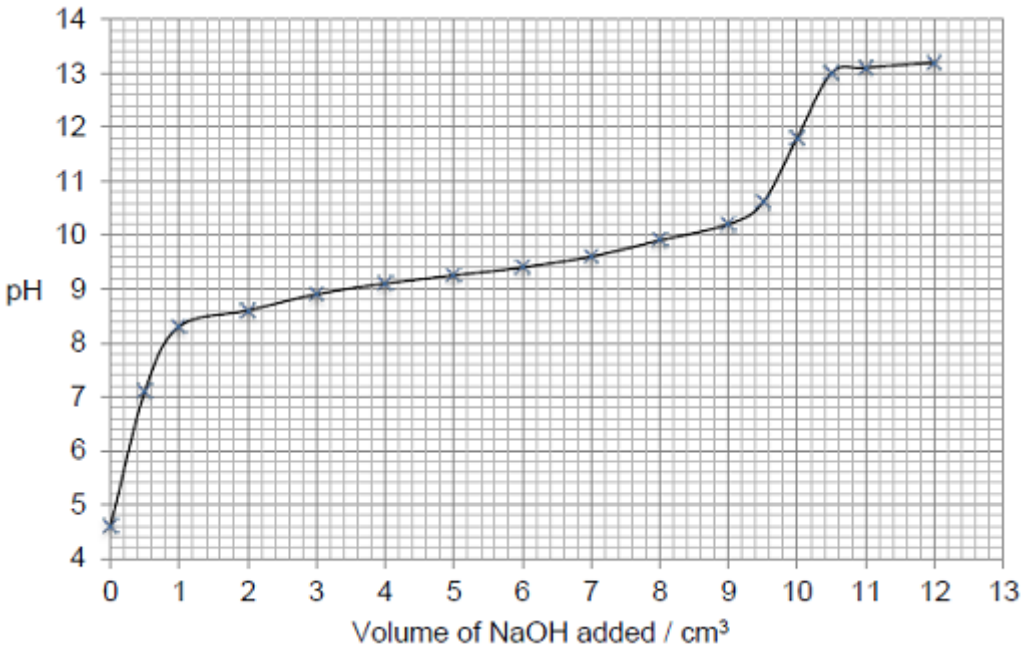
(Total 7 marks)

Q17.

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)

Q18.

The table shows the pK_a values for two acids.

Name of acid	pK_a
Propanoic acid	4.87
Butanoic acid	4.82

Which statement is correct?

A Propanoic acid is a stronger acid than butanoic acid. ⬭

B The value of K_a for propanoic acid is greater than that for butanoic acid. ⬭

C The value of K_a for propanoic acid is 1.35×10^{-5} mol dm^{-3} ⬭

D The value of K_a for butanoic acid is 6.61 × 104 mol dm–$^{-3}$ ⬭

(Total 1 mark)

Q19.

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)

Q20.

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)