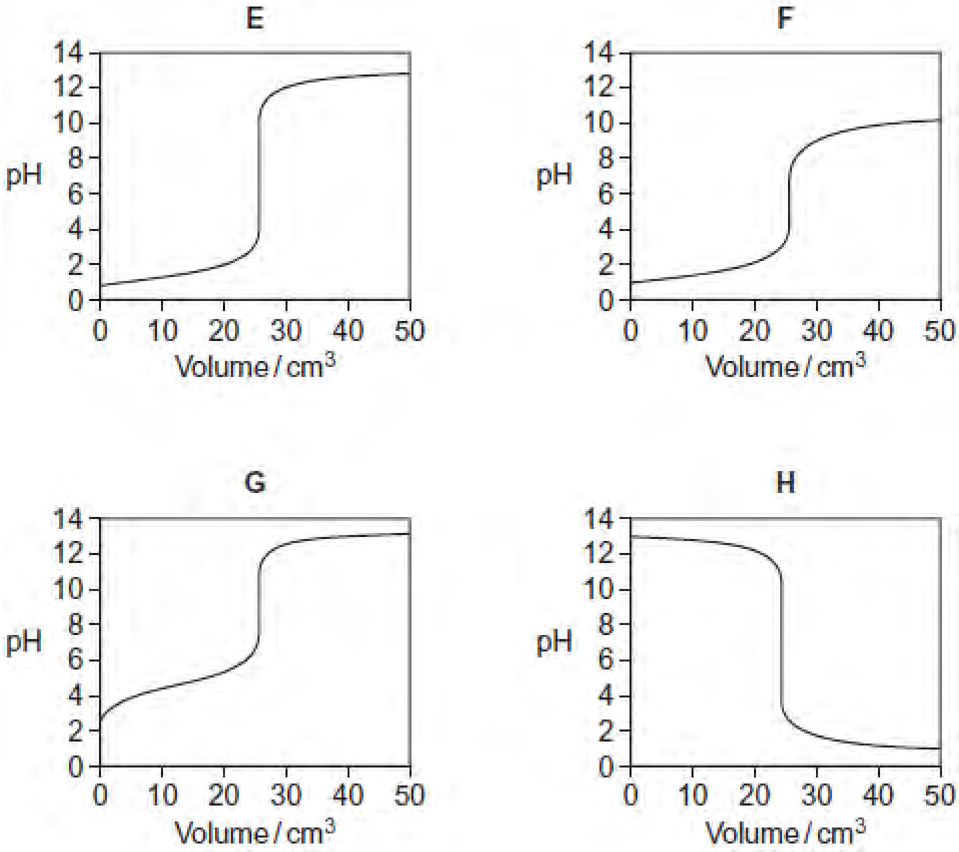
Q1. Titration curves, labelled **E**, **F**, **G** and **H**, for combinations of different aqueous solutions of acids and bases are shown below.

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)

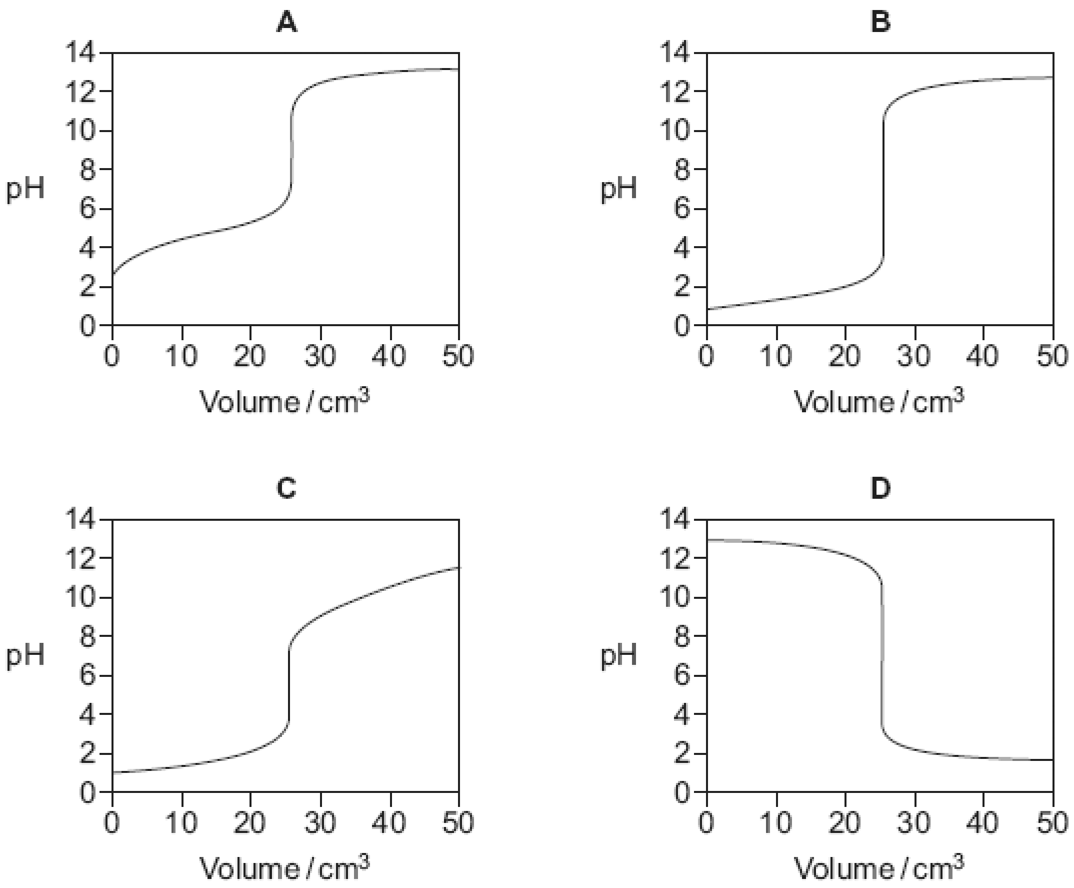
(iii) A beaker contains 25 cm^3 of a buffer solution at pH = 6.0
Two drops of each of the four indicators in the table are added to this solution.

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.

....

(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.

....

....

(1)

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

....

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....

....

....

....

....

....

....

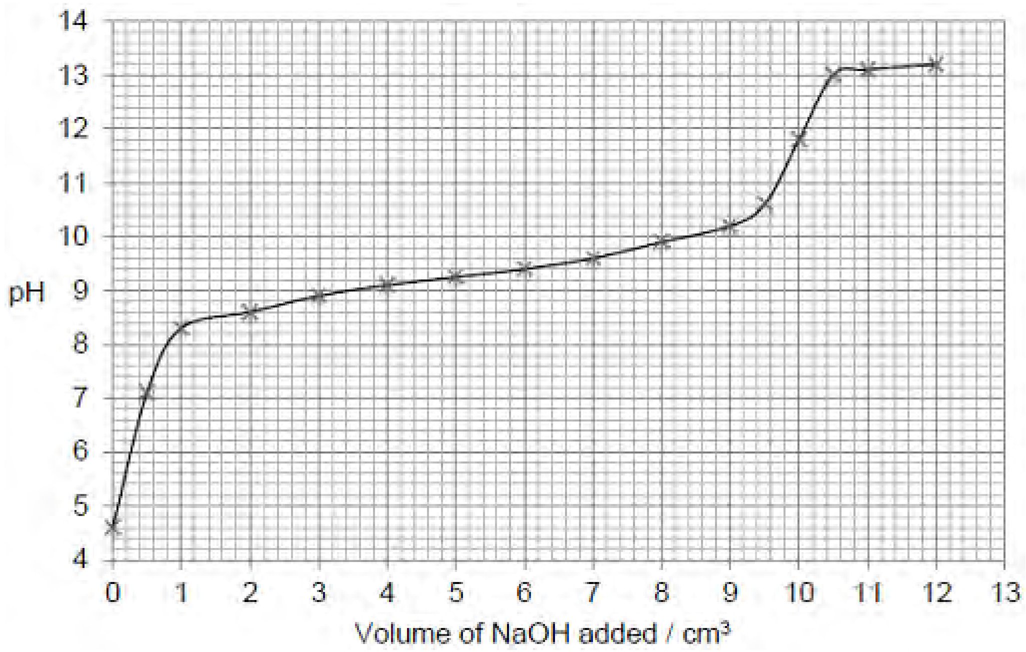
....

(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 ....

....

....

(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)

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.

....

(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 ....

....

....

(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)