Q1. This question is about Brønsted-Lowry acids of different strengths.

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

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(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)

Q2. 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 ....

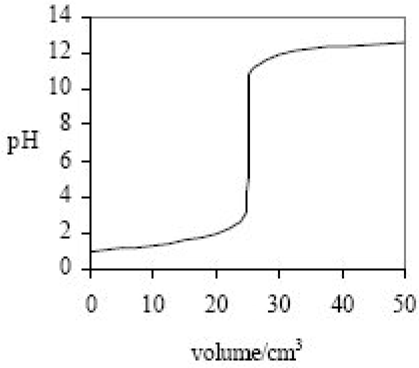
....

Observation ....

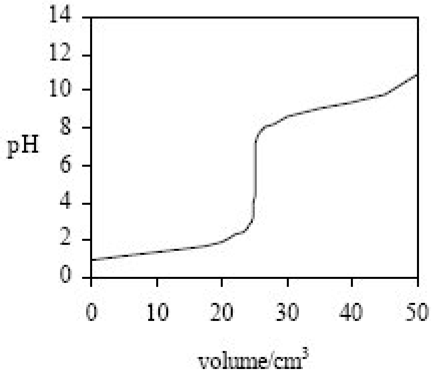
(2)
(Total 3 marks)

Q3. Indicators and pH curves can be used to determine the end point in a titration.

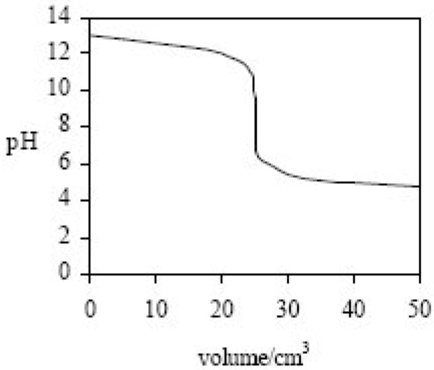
(a) The pH curves labelled **J, K, L** and **M** for combinations of different acids and bases are shown below. All solutions have a concentration of 0.1 mol dm^{-3}.



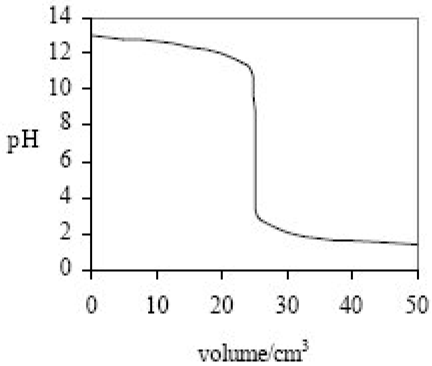
J



K



L



M

(i) Select from **J**, **K**, **L** and **M** the curve produced by the addition of

ammonia to 25 cm^3 of hydrochloric acid ....

ethanoic acid to 25 cm^3 of sodium hydroxide ....

sodium hydroxide to 25 cm^3 of hydrochloric acid ....

(ii) A table of acid–base indicators and the pH ranges over which they change colour is shown below.

Indicator	**pH range**
Thymol blue	1.2 – 2.8
Bromophenol blue	3.0 – 4.6
Methyl red	4.2 – 6.3
Cresolphthalein	8.2 – 9.8
Thymolphthalein	9.3 – 10.5

Select from the list above an indicator which could be used in the titration which produces curve **J** but not in the titration which produces curve **K**.

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(4)

(b) The acid dissociation constant, K_a, for the weak acid, ethanoic acid, has a value of 1.74×10^{-5} mol dm^{-3} at 25 °C.

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

(i) Write an expression for the term pH.

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(ii) Calculate the pH of a 0.15 mol dm^{-3} solution of ethanoic acid. Give your answer to
2 decimal places.

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(4)
(Total 8 marks)

Q4. Ethanoic acid is manufactured in industry from methanol and carbon monoxide in a multi-step process involving hydrogen iodide. Ethanoic acid is obtained from the reaction mixture by fractional distillation. Methanoic acid is a useful by-product of this process.

The K_a value of an organic acid can be determined by using the pH curve obtained when the acid is titrated against sodium hydroxide. The pH of the solution formed when exactly half of the acid has been neutralised is equal to the pK_a value of the acid. The K_a value of the acid can be used to confirm its identity.

A chemist used a pH curve to determine the pK_a value of acid **Y**, formed during the manufacture of ethanoic acid. The chemist transferred 25.0 cm^3 of a solution of acid **Y** into a beaker using a pipette, and measured the pH of the acid solution using a pH meter which could be read to one decimal place. A solution of sodium hydroxide of concentration 0.100 mol dm^{-3} was added from a burette in small portions. The pH of the mixture was recorded after each addition of the sodium hydroxide solution. The chemist's results are given in the table below.

Volume of sodium hydroxide solution added / cm^3	pH
0.0	3.0
2.0	3.4
4.0	3.5
8.0	3.7
12.0	4.3
16.0	4.1
20.0	4.3
22.0	4.7

Volume of sodium hydroxide solution added / cm^3	pH
23.5	5.1
24.0	5.5
24.5	11.8
25.0	12.1
26.0	12.3
27.0	12.4
28.0	12.5
30.0	12.5

(a) Use the results given in the table above to plot a graph of pH (y-axis) against volume of sodium hydroxide solution added. Use the points to draw the pH curve, ignoring any anomalous results.

(6)

(b) Use your graph from part (a) to determine the

(i) volume of sodium hydroxide solution at the end-point of the titration

.... cm^3

(ii) volume of sodium hydroxide solution needed to neutralise half the acid

.... cm^3

(iii) pH of the half-neutralised mixture. Give your answer to one decimal place.

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(3)

(c) Use the pH of the half-neutralised mixture from part (b) (iii) to calculate the value of the acid dissociation constant, K_a, of the acid **Y**. Show your working.

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(2)

(d) The table below shows the K_a values for some organic acids.

Acid	K_a / mol dm^{-3}
Methanoic acid	1.6×10^{-4}
Ethanoic acid	1.7×10^{-5}
Iodoethanoic acid	6.8×10^{-4}
Propanoic acid	1.3×10^{-5}

Use your answer from part (c) to identify acid **Y** from this table.

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(1)

(e) For the pipette and the burette, the maximum total errors are shown below. These errors take into account multiple measurements.

pipette	± 0.05 cm^3
burette	± 0.15 cm^3

Estimate the percentage error in using each of these pieces of apparatus. You should use your answer to part (b) (i) to estimate the percentage error in using the burette.

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(1)

(f) Calculate the difference between the K_a value from part (c) and the K_a value of the acid you identified as the acid **Y** in the table in part (d).

Express this difference as a percentage of the value given in the table in part (d). (If you could not complete the calculation in part (c), you should assume that the K_a value determined from the graph is 1.9×10^{-4} mol dm^{-3}. This is not the correct value.)

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(1)

(g) Other than by using a different pH meter, state **one** way in which the accuracy of the pH readings could be improved.

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(1)

(h) State why there was little change in the pH value of the mixture when between 8 cm^3 and 20 cm^3 of alkali were added.

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(1)
(Total 16 marks)