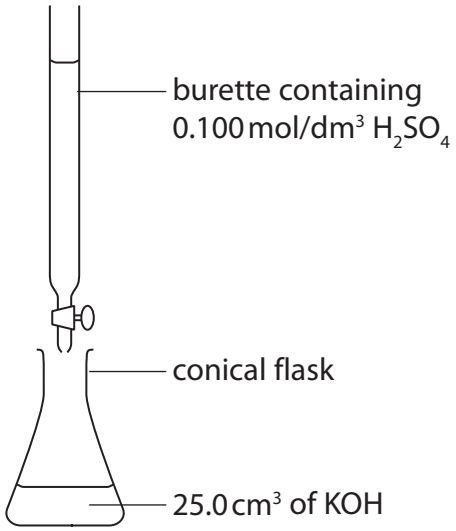
1 This apparatus can be used in a method to find the volume of sulfuric acid required to neutralise a solution of potassium hydroxide (KOH).



(a) What name is given to this method?

(1)

.....

(b) Which piece of apparatus should be used to measure the 25.0 cm³ of KOH?

(1)

☒ **A** beaker

☒ **B** measuring cylinder

☒ **C** pipette

☒ **D** syringe

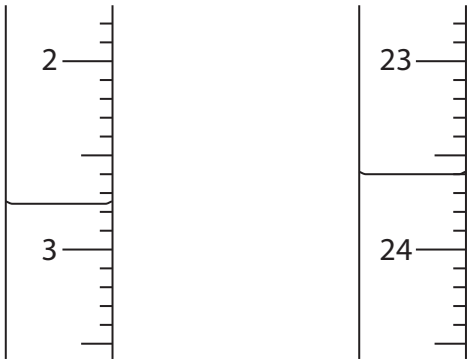
(c) State the colours that are seen if methyl orange is used as the indicator.

(2)

colour before adding the acid .....

colour after KOH is neutralised .....

(d) A student carries out the experiment. His burette readings are shown in the diagram.



Use the diagram to complete the table. Give the readings to the nearest 0.05 cm^3.

(3)

Burette reading after adding the acid	
Burette reading before adding the acid	
Volume in cm^3 of acid added	

(e) A second student did the experiment four times, using a different solution of potassium hydroxide. The table shows her results.

Volume in cm^3 of acid added	22.90	22.60	22.45	22.55
Concordant results (✓)				

Concordant results are those within 0.20 cm^3 of one another.

(i) Place ticks in the table to indicate which results are concordant with one another.

(1)

(ii) Use your ticked results to calculate the average (mean) volume of acid added.

(2)

average (mean) volume of acid = ... cm^3

(Total for Question 1 = 10 marks)

2 A group of students planned an experiment to find the temperature rise in a neutralisation reaction. This is their method.

- Use a measuring cylinder to add 25 cm^3 of an alkali to a 100 cm^3 beaker
- Record the temperature of the alkali
- Use a burette to add an acid to the alkali in 5.0 cm^3 portions
- Record the temperature of the mixture after adding each portion of acid
- Stop the experiment when the neutralisation is complete

(a) The teacher asked the students about their method.

Suggest an answer to each of her questions.

(i) Why would it be better to use a pipette instead of a measuring cylinder?

(1)

.....

.....

(ii) It would be better if a polystyrene cup were used instead of a beaker.

What property of polystyrene makes this an improvement?

(1)

.....

.....

(iii) What extra step should there be between adding each portion of acid and measuring the temperature?

(1)

.....

.....

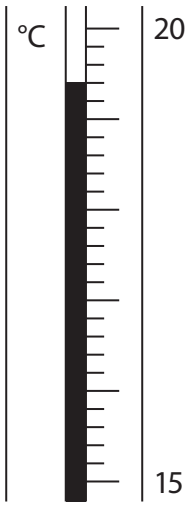
(iv) How would you know when the neutralisation was complete?

(1)

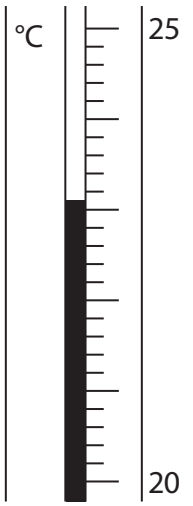
.....

.....

(b) The diagrams show the readings on the thermometer before and after one of the students added a portion of acid.



before adding acid



after adding acid

Write down the thermometer readings and calculate the temperature change.

(3)

Temperature before adding acid ..... °C

Temperature after adding acid ..... °C

Temperature change ..... °C

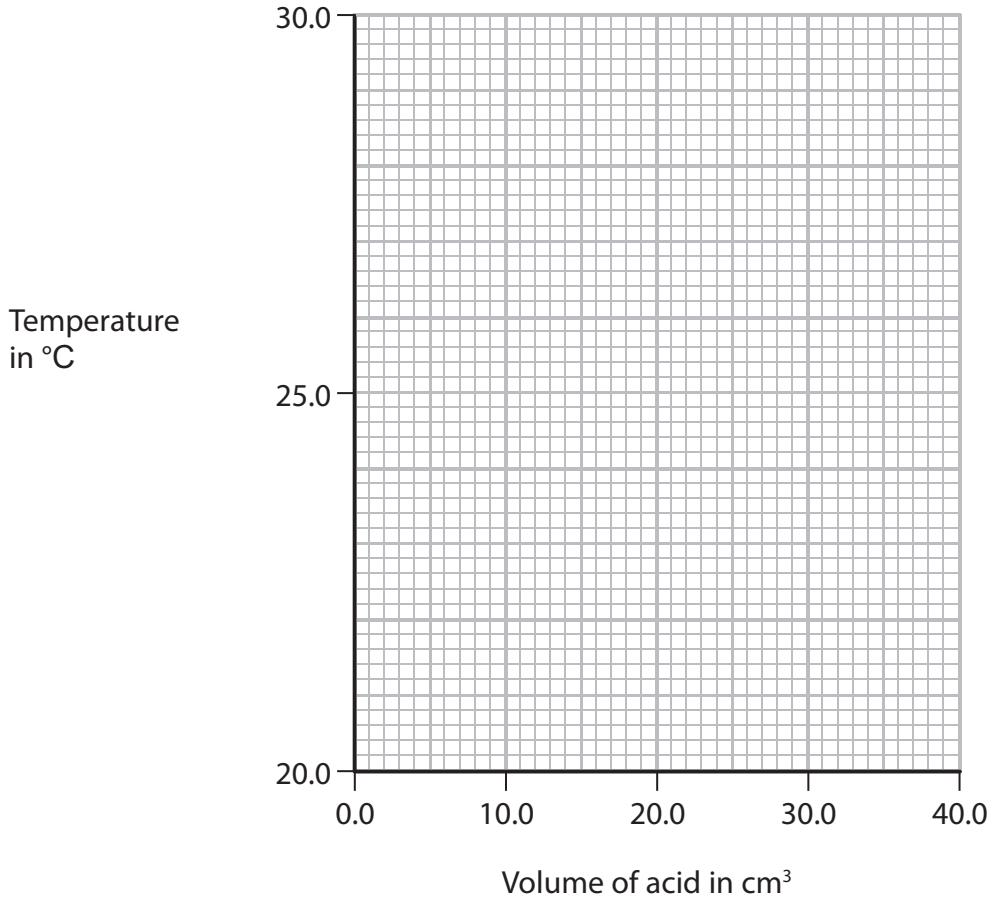
(c) One student obtained these results from an experiment in which she added a total of 40.0 cm^3 of hydrochloric acid to 25 cm^3 of sodium hydroxide solution.

Volume of acid in cm^3	0.0	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0
Temperature in °C	21.0	22.3	24.4	26.2	27.8	27.8	27.5	26.7	26.2

(i) Plot a graph of these results on the grid below.

Draw a straight line of best fit through the first five points and another straight line of best fit through the last four points. Make sure that the two lines cross.

(4)



(ii) The point where the lines cross indicates the volume of acid needed to exactly neutralise the alkali, and also the maximum temperature reached.

Use your graph to record these values.

(2)

Volume of acid ..... cm^3

Maximum temperature ..... °C

(d) A second student used the same method and found that 30.0 cm^3 of acid were needed to neutralise 25 cm^3 of alkali.

He obtained a temperature rise of 5.5 °C in his experiment.

Calculate the heat energy change in this experiment using the expression:

heat energy change = total volume of mixture × 4.2 × temperature change

(2)

Heat energy change = ... J

(e) A third student calculated that the heat energy change in her experiment was 1800 J. This heat energy was released by the neutralisation of 25 cm^3 of 1.50 mol/dm^3 sodium hydroxide solution.

(i) Calculate the amount, in moles, of sodium hydroxide neutralised.

(2)

Amount = ... mol

(ii) Calculate the molar enthalpy change, in kJ/mol, for the neutralisation of sodium hydroxide.

(2)

Molar enthalpy change = ... kJ/mol

(Total for Question 2 = 19 marks)

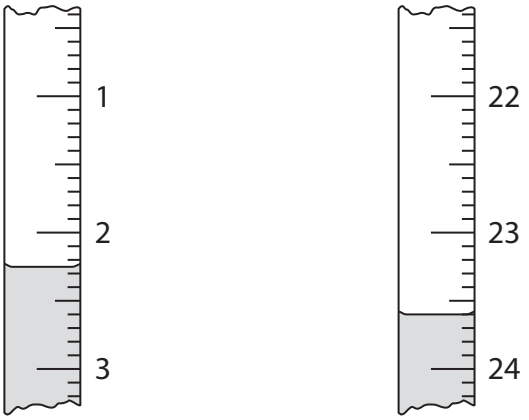
3 A student prepares a solution of the soluble salt lithium sulfate, using the neutralisation reaction between sulfuric acid and the alkali lithium hydroxide.

To make sure that she obtains a pure solution of the salt, she first carries out a titration to find the volumes of sulfuric acid and lithium hydroxide that react exactly together.

She uses this method in the titration.

- use a pipette to add 25.0 cm^3 of dilute sulfuric acid to a conical flask
- add a few drops of phenolphthalein indicator
- fill a burette with lithium hydroxide solution
- add the lithium hydroxide solution from the burette until the indicator just changes colour

(a) The diagram shows the burette readings in the experiment before and after adding the lithium hydroxide solution.



Use these readings to complete the table, giving all values to the nearest 0.05 cm^3.

(3)

Burette reading in cm^3 after adding alkali	
Burette reading in cm^3 before adding alkali	
Volume in cm^3 of alkali added	

(b) The student repeats the experiment using a different concentration of sulfuric acid
The table shows her results.

Burette reading in cm^3 after adding alkali	25.05	25.65	24.85	26.10
Burette reading in cm^3 before adding alkali	0.75	1.70	1.35	2.40
Volume in cm^3 of alkali added	24.30	23.95	23.50	23.70
Titration results to be used (✓)				

The average (mean) volume of alkali should be calculated using only concordant results.

Concordant results are those volumes that differ from each other by 0.20 cm^3 or less.

(i) Identify the titration results to be used by placing ticks (✓) in the table where appropriate.

(1)

(ii) Use the titration results you ticked in (i) to calculate the average (mean) volume of alkali added.

(2)

average volume = ... cm^3

(c) In a titration using solutions of the same acid and alkali but of different concentrations, she recorded these results.

volume of sulfuric acid = 25.0 cm^3

concentration of sulfuric acid = 0.107 mol/dm^3

average (mean) volume of lithium hydroxide solution = 22.85 cm^3

The equation for the reaction is

$$2LiOH + H_2SO_4 \rightarrow Li_2SO_4 + 2H_2O$$

(i) Calculate the amount, in moles, of H_2SO_4 in 25.0 cm^3 of 0.107 mol/dm^3 sulfuric acid.

(2)

amount of H_2SO_4 = ... mol

(ii) Calculate the amount, in moles, of LiOH in the 22.85 cm^3 of lithium hydroxide solution.

(1)

amount of LiOH = ... mol

(iii) Calculate the concentration, in mol/dm^3, of LiOH in the lithium hydroxide solution.

(2)

concentration of LiOH = ... mol/dm^3

(d) To prepare the solution of lithium sulfate, the student mixes together the volumes of acid and alkali obtained from the titration results.

She then tests a sample of the lithium sulfate solution formed by adding a few drops of barium chloride solution.

(i) Describe the observation she makes.

(1)

.....

.....

(ii) State the name of the substance responsible for this observation.

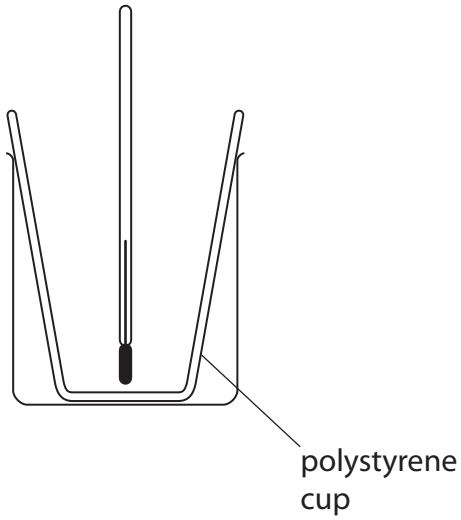
(1)

.....

(Total for Question 3 = 13 marks)

4 A student investigated the neutralisation of acids by measuring the temperature changes when alkalis were added to acids of known concentrations.

He used this apparatus to add different volumes of sodium hydroxide solution to a fixed volume of dilute nitric acid.



He used this method.

- measure the temperature of 25.0 cm^3 of the acid in the polystyrene cup
- add the sodium hydroxide solution in 5.0 cm^3 portions until a total of 30.0 cm^3 has been added

(a) State two properties of the sodium hydroxide solution that should be kept constant for each 5.0 cm^3 portion.

(2)

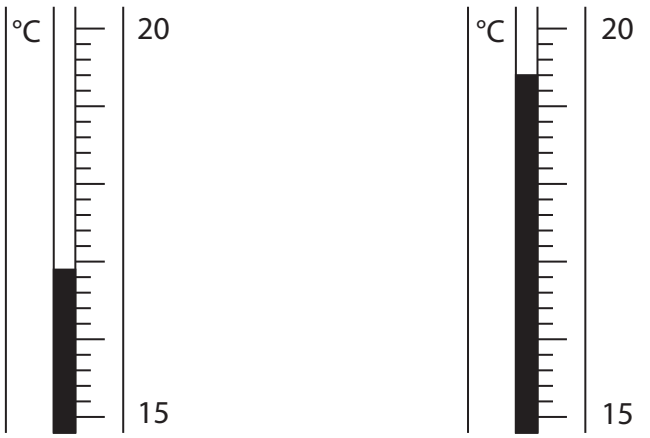
1 .....

.....

2 .....

.....

(b) The diagram shows the thermometer readings in one experiment.



before adding alkali

after adding alkali

Write down the thermometer readings and calculate the temperature change.

(3)

temperature after adding alkali ..... °C

temperature before adding alkali ..... °C

temperature change ..... °C

(c) The student carried out the experiment three times.

The table shows his results.

Volume of alkali added in cm^3	Temperature in °C		
	experiment 1	experiment 2	experiment 3
0.0	17.4	16.6	15.9
5.0	18.5	21.0	18.0
10.0	19.6	24.5	20.0
15.0	20.5	23.6	22.2
20.0	21.4	22.7	23.6
25.0	22.5	21.4	22.8
30.0	23.4	20.5	22.0

The teacher said that only the results for experiment 3 showed the expected increase and decrease in temperature.

(i) Why was there no temperature decrease in experiment 1?

(1)

☒ **A** The alkali was added too quickly

☒ **B** The starting temperature of the acid was too high

☒ **C** The acid concentration was half what it should have been

☒ **D** The volume of acid used was 50.0 cm^3 instead of 25.0 cm^3

(ii) Why were the temperature increases in experiment 2 much greater than expected?

(1)

☒ **A** The starting temperature of the acid was too high

☒ **B** The acid concentration was double what it should have been

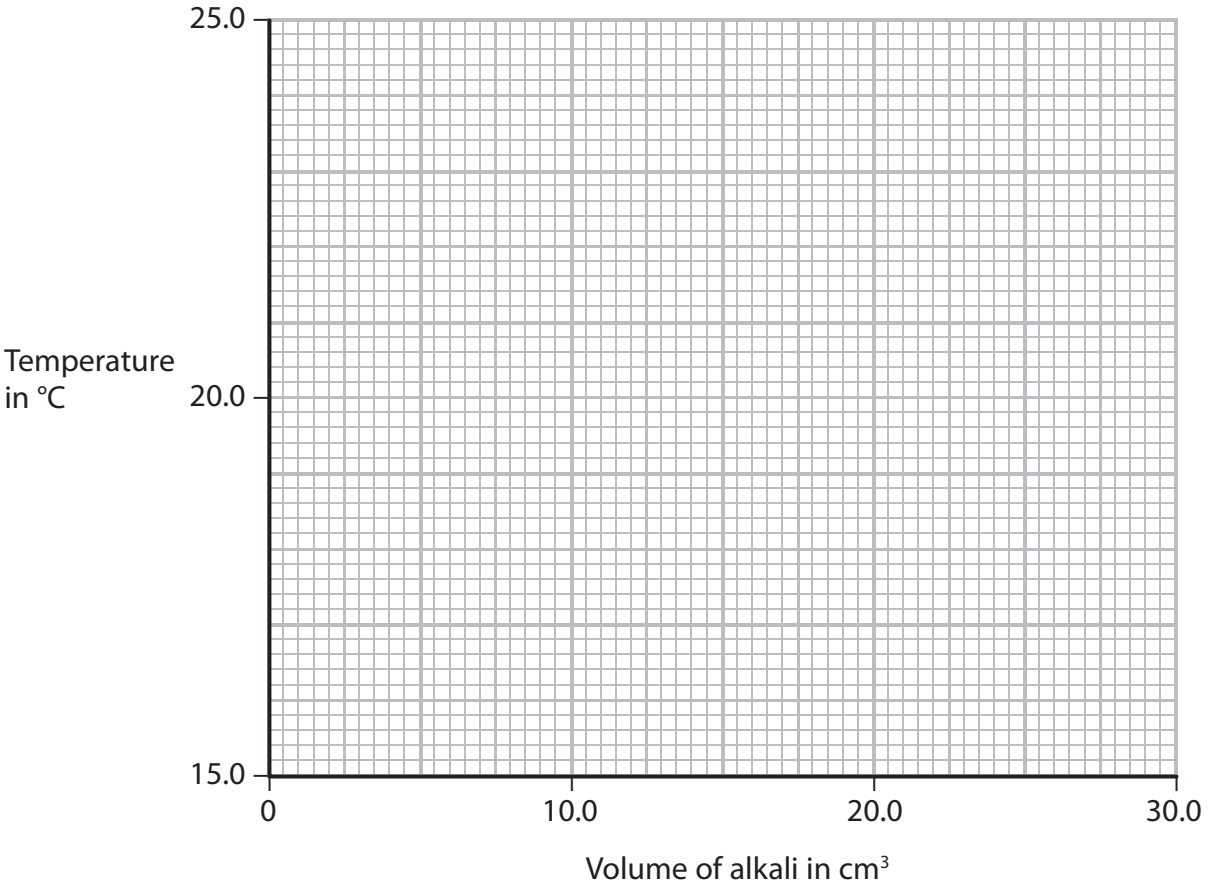
☒ **C** The volume of acid used was 50.0 cm^3 instead of 25.0 cm^3

☒ **D** The alkali was added in 10.0 cm^3 portions but were recorded as 5.0 cm^3 portions

(d) Plot the results of experiment 3 on the grid.

Draw a straight line of best fit through the first four points, and another straight line of best fit through the last three points. Make sure that the two lines cross.

(4)



(e) The point where the lines cross indicates the volume of alkali added to exactly neutralise the acid and also the maximum temperature reached.

Record these values.

(2)

volume of alkali..... cm^3

maximum temperature..... °C

(f) Another student used sulfuric acid instead of nitric acid in her experiments. She started with 25.0 cm^3 of sulfuric acid of concentration 0.650 mol/dm^3.

She added 0.500 mol/dm^3 sodium hydroxide solution until the acid was completely neutralised.

The equation for this reaction is

$$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$$

(i) Calculate the amount, in moles, of sulfuric acid used.

(2)

amount = ... mol

(ii) Calculate the amount, in moles, of sodium hydroxide needed to neutralise this amount of sulfuric acid.

(1)

amount = ... mol

(iii) Calculate the volume, in cm^3, of sodium hydroxide solution needed to neutralise this amount of sulfuric acid.

(2)

volume = ... cm^3

(Total for Question 4 = 18 marks)