1 A student investigates the reaction of aqueous sodium hydroxide with two different aqueous solutions of hydrochloric acid, solution X and solution Y.

She carries out two experiments.

Experiment 1

- Using a measuring cylinder, she pours 20 cm^3 of aqueous sodium hydroxide into a conical flask and records its temperature.
- Using a burette, she adds 5 cm^3 of solution X to the conical flask.
- She stirs the mixture with the thermometer and records the temperature.
- She adds further 5 cm^3 volumes of solution X and stirs with the thermometer.
- She records the temperature after each addition of solution X.
- She stops when a total of 40 cm^3 of solution X has been added.

Experiment 2

- She empties the burette and rinses it first with water and then with solution Y. She then fills the burette with solution Y.
- She repeats the experiment using solution Y.

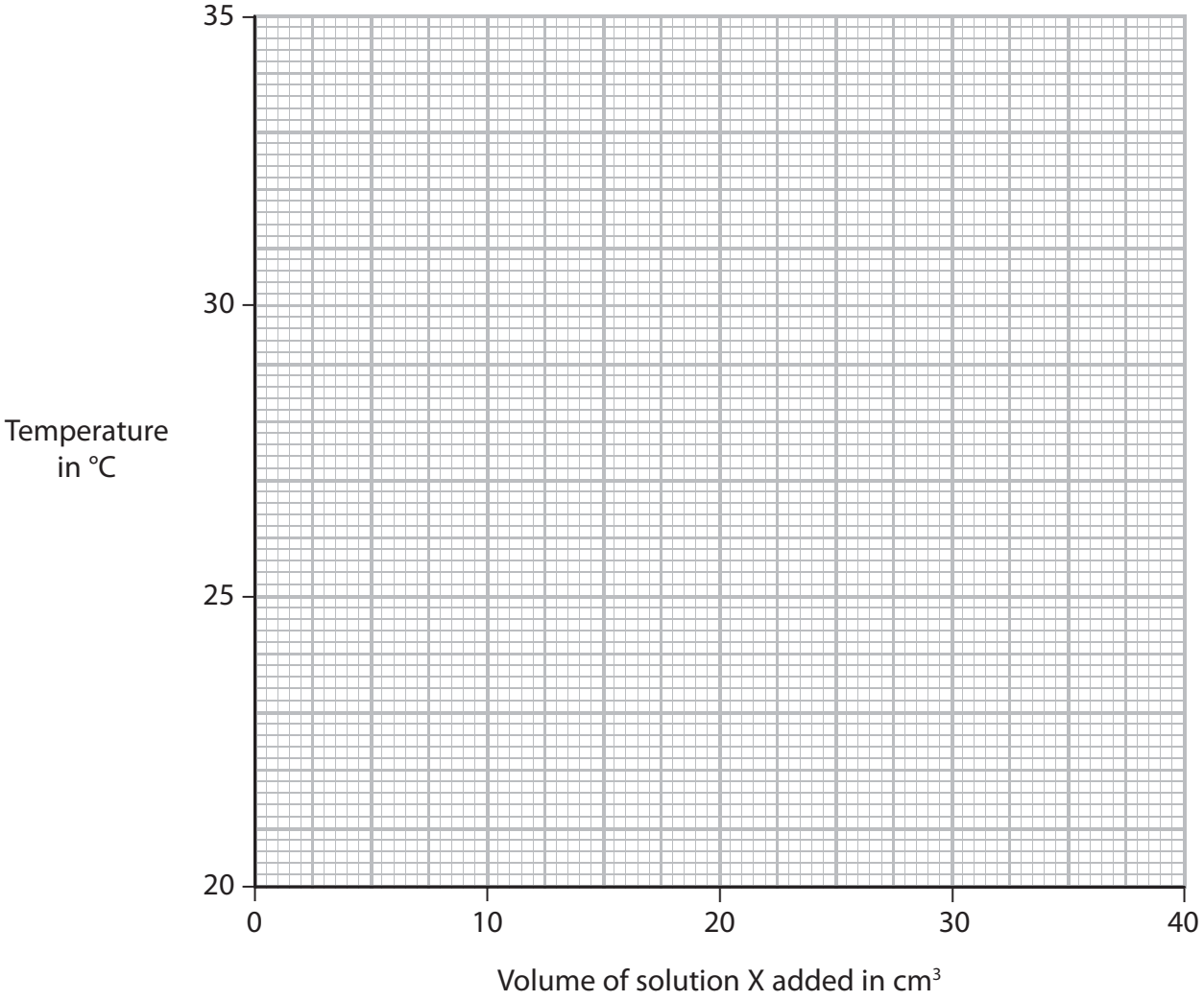
The table shows the results she obtains in Experiment 1.

Experiment 1 – Solution X	
Volume in cm^3 of solution X added	**Temperature in °C**
0	23.0
5	27.0
10	31.0
15	32.2
20	30.6
25	28.9
30	27.3
35	25.6
40	24.0

(a) Plot the results for Experiment 1 on the grid.
Draw a straight line of best fit through the first three points and a second straight line of best fit through the last six points.

Make sure that the two straight lines cross.

(4)



(b) (i) Use the graph to determine the volume of solution X that will produce the maximum temperature rise when added to 20 cm^3 of the aqueous sodium hydroxide.

(1)

volume of solution X = ... cm^3

(ii) Use the graph to determine the maximum temperature rise.

(1)

maximum temperature rise = ... °C

(c) Why did the student rinse the burette first with water, and then with solution Y, before performing Experiment 2?

(2)

water .....

.....

solution Y .....

.....

(d) The maximum temperature rise in Experiment 2 was less than that in Experiment 1. Suggest a reason why.

(1)

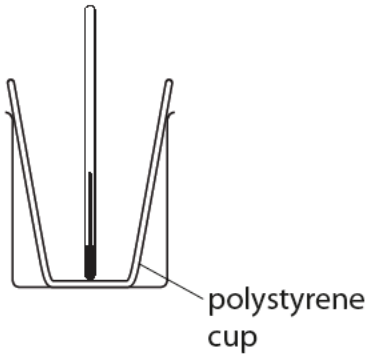
.....

.....

.....

(Total for Question 1 = 9 marks)

2 A student investigates the reactions between acids and alkalis. He uses this apparatus to measure the temperature change in the reaction between dilute hydrochloric acid (HCl) and aqueous sodium hydroxide (NaOH).



This is his method.

- add 25 cm^3 of dilute hydrochloric acid to the polystyrene cup and record the steady temperature
- add some aqueous sodium hydroxide and stir the mixture
- record the maximum temperature of the mixture

The student repeats the experiment using different volumes of aqueous sodium hydroxide.

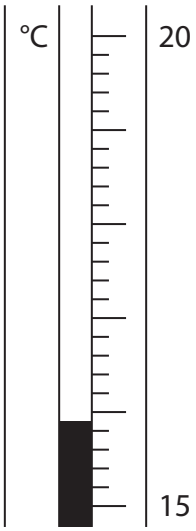
(a) What is the advantage of using a polystyrene cup rather than a glass beaker?

(1)

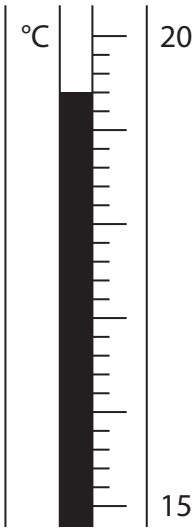
.....

.....

(b) These are the thermometer readings from one experiment.



before adding
aqueous sodium hydroxide



after adding
aqueous sodium hydroxide

Use these readings to complete the table.

(3)

temperature in °C after adding aqueous sodium hydroxide	
temperature in °C before adding aqueous sodium hydroxide	
temperature change in °C	

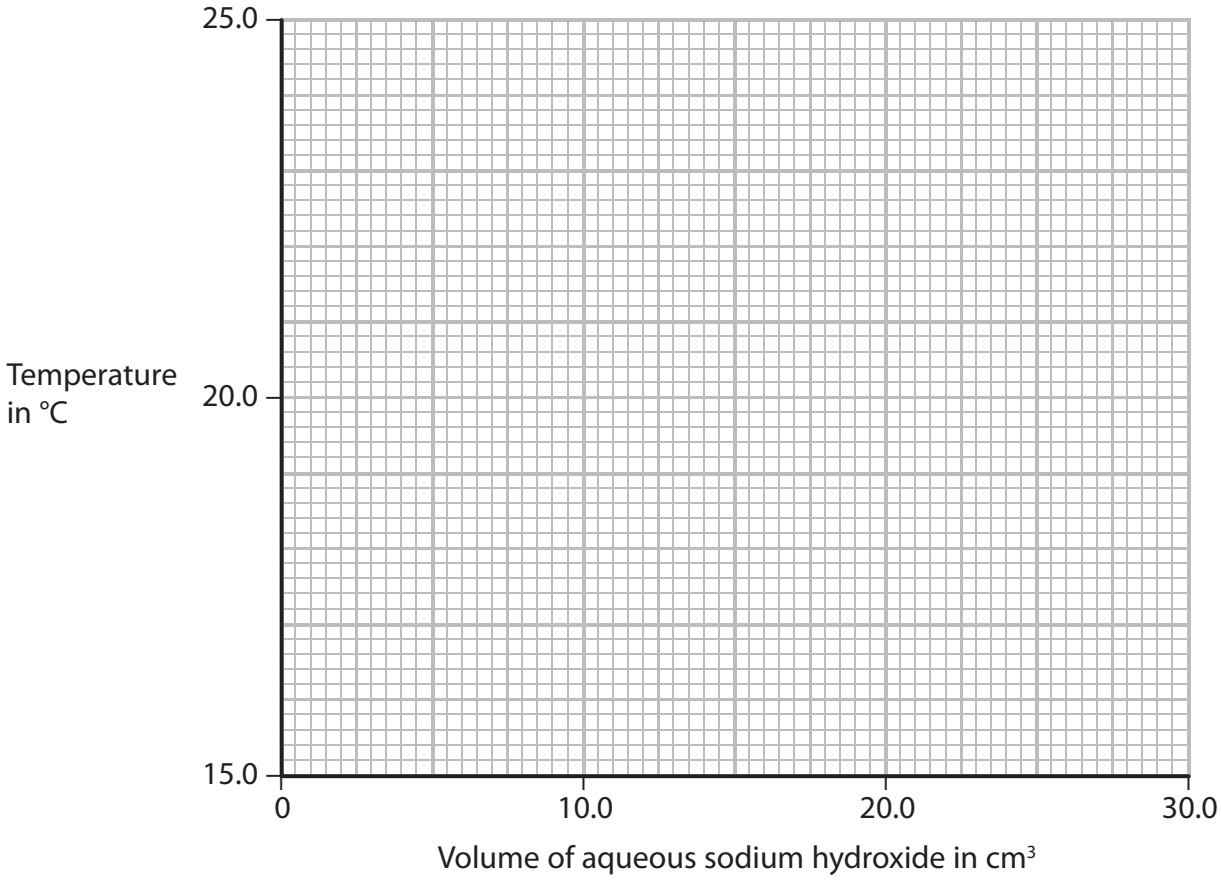
(c) The table shows the results of some experiments.

The initial temperature of both solutions in all the experiments is 17.6 °C.

Volume of aqueous sodium hydroxide added in cm^3	Temperature of mixture in °C
0.0	17.6
5.0	19.7
10.0	21.6
15.0	23.6
20.0	23.8
25.0	23.0
30.0	22.2

(i) Plot these results 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. Extend both lines so that they cross each other.

(4)



(ii) For the point where the lines cross, write down

(2)

the temperature of the mixture = ... °C

the volume of aqueous sodium hydroxide = ... cm^3

(d) In a similar experiment, using a different acid and alkali, the student records these results.

volume of dilute sulfuric acid = 25.0 cm^3

volume of aqueous potassium hydroxide = 22.7 cm^3

initial temperature of each solution = 18.9 °C

final temperature of mixture = 24.7 °C

Calculate the heat energy change during this reaction using this equation.

heat energy change = mass × 4.2 × temperature change

Assume that 1.0 cm^3 of each solution has a mass of 1.0 g.

(3)

heat energy change = ... J

(Total for Question 2 = 13 marks)

3 A student carries out a titration to find the concentration of some dilute sulfuric acid.

She is given

- a supply of the dilute sulfuric acid
- sodium hydroxide solution of concentration 0.150 mol/dm^3
- apparatus suitable for carrying out a titration
- phenolphthalein indicator

She uses this method to do the titration.

step 1 add 25. ^{3} of the sodium hydroxide solution to a conical flask

step 2 add ops of phenolphthalein indicator to the conical flask

step 3 fill a ette with the sulfuric acid

step 4 add the sulfuric acid to the conical flask until the phenolphthalein indicator just changes colour

(a) Name the piece of apparatus that the student should use to add the sodium hydroxide solution in step 1.

(1)

.....

(b) What is the colour change of the phenolphthalein indicator in step 4?

(1)

☒ **A** colourless to pink

☒ **B** pink to colourless

☒ **C** red to yellow

☒ **D** yellow to red

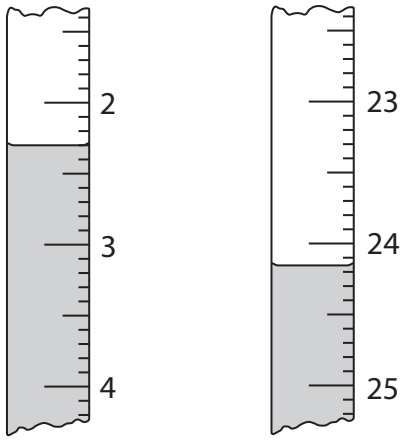
(c) Why is it better to use phenolphthalein indicator rather than universal indicator in this titration?

(1)

.....

.....

(d) The diagram shows the burette readings in one titration.



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

(3)

burette reading in cm^3 after adding acid	
burette reading in cm^3 before adding acid	
volume of acid added in cm^3	

(e) The student repeats the experiment using the same sodium hydroxide solution but another solution of sulfuric acid of a different concentration.

The table shows her results.

burette reading in cm^3 after adding acid	27.65	27.80	27.75	27.40
burette reading in cm^3 before adding acid	0.50	1.50	1.00	1.00
volume of acid added in cm^3	27.15	26.30	26.75	26.40
titration results to be used (✓)				

The average (mean) volume of acid 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 concordant results by placing ticks (✓) in the table where appropriate.

(1)

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

(2)

average volume of acid = ... cm^3

(f) The student uses a similar method to find the concentration of a solution of phosphoric acid (H_3PO_4).

The equation for the reaction is

$$3NaOH + H_3PO_4 \rightarrow Na_3PO_4 + 3H_2O$$

The table shows her results.

volume of sodium hydroxide solution added to conical flask	25.0 cm^3
concentration of sodium hydroxide solution	0.180 mol/dm^3
average volume of phosphoric acid solution added from burette	28.30 cm^3

(i) Calculate the amount, in moles, of NaOH in 25.0 cm^3 of the sodium hydroxide solution.

(2)

amount of NaOH = ... mol

(ii) Calculate the amount, in moles, of H_3PO_4 in the phosphoric acid solution.

(1)

amount of H_3PO_4 = ... mol

(iii) Calculate the concentration, in mol/dm^3, of the phosphoric acid.

(2)

concentration of phosphoric acid = ... mol/dm^3

(Total for Question 3 = 14 marks)

4 The formula for hydrated iron(II) sulfate is $FeSO_4.xH_2O$

The value of x is a whole number between 1 and 10. It can be determined by carrying out a titration with 0.0200 mol/dm^3 potassium manganate(VII) ($KMnO_4$) solution as follows:

- dissolve a sample of $FeSO_4.xH_2O$ in water to make 250 cm^3 of solution
- measure out 25.0 cm^3 of this solution into a conical flask
- add the $KMnO_4$ solution using a burette until the end point is reached
- record the volume of solution added
- repeat the titration three more times

The table shows the results.

titration number	1	2		
volume in cm^3 of $KMnO_4$ solution added	22.80	22.10	22.50	22.20
concordant titration results (✓)				

(a) Concordant results are those within 0.20 cm^3 of each other.

Place ticks (✓) in the table to show the concordant results.

(1)

(b) Using the concordant results, calculate the average (mean) volume of $KMnO_4$ solution added. Give your answer to 2 decimal places.

(2)

average volume added = ... cm^3

(c) Which is the most suitable piece of apparatus to measure out 25.0 cm^3 of $FeSO_4$ solution?

(1)

☒ **A** beaker

☒ **B** gas syringe

☒ **C** measuring cylinder

☒ **D** pipette

(d) These results were obtained in another titration.

mass of $FeSO_4.xH_2O$ in 250 cm^3 of the $FeSO_4$ solution	5.56 g
average volume of $KMnO_4$ solution added to 25.0 cm^3 of solution	20.00 cm^3
concentration of the $KMnO_4$ solution	.0200 mol/dm^3

(i) Calculate the amount, in moles, of $KMnO_4$ in 20.00 cm^3 of solution.

(2)

amount of $KMnO_4$ = ... mol

(ii) In this reaction one mole of $KMnO_4$ reacts with five moles of $FeSO_4$

Calculate the amount, in moles, of $FeSO_4$ in 25.0 cm^3 of the $FeSO_4$ solution.

(1)

amount of $FeSO_4$ in 25.0 cm^3 = ... mol

(iii) Calculate the amount, in moles, of $FeSO_4$ in 250 cm^3 of this $FeSO_4$ solution.

(1)

amount of $FeSO_4$ in 250 cm^3 = ... mol

(iv) Using your answer from (d)(iii), calculate the mass, in grams, of $FeSO_4$ in the 5.56 g of $FeSO_4.xH_2O$.

[M_r of $FeSO_4$ = 152]

(1)

mass of $FeSO_4$ = ...g

(e) In another experiment it is found that 24.2 g of $FeSO_4.xH_2O$ contains 15.2 g of iron(II) sulfate ($FeSO_4$).

(i) Calculate the mass of water in 24.2 g of $FeSO_4.xH_2O$

(1)

mass of water = ... g

(ii) Calculate the amount, in moles, of H_2O in this mass of water.

(1)

amount of H_2O = ... mol

(iii) Calculate the amount, in moles, of $FeSO_4$ in 15.2 g of iron(II) sulfate.
[M_r of $FeSO_4$ = 152]

(1)

amount of $FeSO_4$ = ... mol

(iv) sing your answers to parts (ii) and (iii), calculate the value of x in $FeSO_4.xH_2O$.

(1)

value of x = ...

(Total for Question 4 = 13 marks)