Paper 3 – Advanced practical skills

Question 1(a)

For Examiner's Use

1 You are to determine the enthalpy change of neutralisation of hydrochloric acid by aqueous sodium hydroxide and also the concentration of the aqueous sodium hydroxide. These can be found by measuring the temperature change when solutions of the acid and alkali are mixed.

FA 1 is aqueous sodium hydroxide, NaOH.
FA 2 is 2.00 mol dm^{-3} hydrochloric acid, HCl.

(a) Method

- Fill a burette with **FA 1**. **[Care: FA 1 is corrosive]**
- Support the plastic cup in a 250 cm^3 beaker.
- Use a measuring cylinder to transfer 25 cm^3 of **FA 2** into a 100 cm^3 beaker.
- Use a measuring cylinder to add 35 cm^3 of distilled water to the acid in the beaker.
- Measure and record, in the table below, the initial temperature of the mixture in the beaker.
- Run 5.0 cm^3 of **FA 1** from the burette into the plastic cup.
- Add the mixture of acid and water from the 100 cm^3 beaker to the **FA 1** in the plastic cup.
- Stir carefully and measure the highest temperature obtained.
- Record this temperature in the table.
- Rinse the plastic cup with water.
- Repeat the experiment using 25 cm^3 of **FA 2**, 30 cm^3 of distilled water and 10.0 cm^3 of **FA 1** as shown for experiment **2** in the table.
- Carry out experiments **3** to **7** in the same way.
- Complete the table for each experiment.

Results

experiment number	**1**	**2**	**3**	**4**	**5**	**6**	**7**
volume of **FA 2** / cm^3	25	25	25	25	25	25	25
volume of water / cm^3	35	30	25	20	15	10	5
volume of **FA 1** / cm^3	5.0	10.0	15.0	20.0	25.0	30.0	35.0
initial temperature of acid mixture / °C							
highest temperature / °C							
temperature change / °C							

[7]

I	
II	
III	
IV	
V	
VI	
VII	

Mark scheme

Question	Sections	Indicative material	Mark	
1 (a)	PDO Recording	**I** Thermometer readings for all experiments recorded to 0.0 or 0.5°C. (At least one recorded to 0.5°C.)	1	
	ACE Interpretation	**II** Calculation of all temperature changes correct.	1	
	MMO Quality	Award **III** for a temperature rise followed by constant temperature (within 0.5°C).	1	
		Award **IV** and **V** for a **maximum** rise within 0.5°C of supervisor.	1	
		Award **IV** for a **maximum** rise within 1.0°C of supervisor.	1	
		Award **VI** and **VII** for the experiment **3** temperature rise within 0.5°C of supervisor.	1	
		Award **VI** for the experiment **3** temperature rise within 1.0°C of supervisor.	1	[7]

General comment

In the examples for this paper, separate candidates may have been used for each question part therefore answers may not necessarily follow on from previous example candidate responses for that grade.

Almost all candidates completed the seven experiments and were able to calculate the rise in temperature correctly. However, some weaker candidates read the thermometer incorrectly (2.00 °C instead of 20.0 °C) and a large number did not record the thermometer readings to the expected level of precision. Good candidates achieved the expected constant temperature rise in the latter experiments. Weaker candidates, who are likely to have carried out a thermometric titration which produces a drop in temperature after the end point is reached, did not achieve this. Generally the accuracy marks tended to be Centre dependent although there were good results from individual candidates where others from the Centre had performed poorly. However, the majority of candidates gained at least three out of the five accuracy marks available.

Example candidate response – grade A

1 You are to determine the enthalpy change of neutralisation of hydrochloric acid by aqueous sodium hydroxide and also the concentration of the aqueous sodium hydroxide. These can be found by measuring the temperature change when solutions of the acid and alkali are mixed.

For Examiner's Use

FA 1 is aqueous sodium hydroxide, NaOH.
FA 2 is 2.00 mol dm^{-3} hydrochloric acid, HC*l*.

(a) Method

- Fill a burette with **FA 1**. **[Care: FA 1 is corrosive]**
- Support the plastic cup in a 250 cm^3 beaker.
- Use a measuring cylinder to transfer 25 cm^3 of **FA 2** into a 100 cm^3 beaker.
- Use a measuring cylinder to add 35 cm^3 of distilled water to the acid in the beaker.
- Measure and record, in the table below, the initial temperature of the mixture in the beaker.
- Run 5.0 cm^3 of **FA 1** from the burette into the plastic cup.
- Add the mixture of acid and water from the 100 cm^3 beaker to the **FA 1** in the plastic cup.
- Stir carefully and measure the highest temperature obtained.
- Record this temperature in the table.
- Rinse the plastic cup with water.
- Repeat the experiment using 25 cm^3 of **FA 2**, 30 cm^3 of distilled water and 10.0 cm^3 of **FA 1** as shown for experiment **2** in the table.
- Carry out experiments **3** to **7** in the same way.
- Complete the table for each experiment.

Results

experiment number	1	2	3	4	5	6	7
volume of **FA 2** / cm^3	25	25	25	25	25	25	25
volume of water / cm^3	35	30	25	20	15	10	5
volume of **FA 1** / cm^3	5.0	10.0	15.0	20.0	25.0	30.0	35.0
initial temperature of acid mixture / °C	28.0	28.0	28.0	28.0	28.0	28.0	28.0
highest temperature / °C	30.5	33.5	36.0	39.0	39.0	39.0	39.0
temperature change / °C	2.5	5.5	8.0	11.0	11.0	11.0	11.0

11.0
8.0

δ = 0.0 6.0

[7]

I	✓
II	✓
III	✓
IV	✓
V	✓
VI	✓
VII	✓

7

Examiner comment – grade A

This answer was typical in that full marks were gained for the accuracy with which the experiment was carried out. Thermometer readings are expected to be taken to the nearest 0.5 °C, without interpolation, and for at least one of the readings to be at 0.5 °C.

Example candidate response – grade C

For Examiner's Use

1 You are to determine the enthalpy change of neutralisation of hydrochloric acid by aqueous sodium hydroxide and also the concentration of the aqueous sodium hydroxide. These can be found by measuring the temperature change when solutions of the acid and alkali are mixed.

FA 1 is aqueous sodium hydroxide, NaOH.
FA 2 is 2.00 mol dm^{-3} hydrochloric acid, HCl.

(a) Method

- Fill a burette with **FA 1**. **[Care: FA 1 is corrosive]**
- Support the plastic cup in a 250 cm^3 beaker.
- Use a measuring cylinder to transfer 25 cm^3 of **FA 2** into a 100 cm^3 beaker.
- Use a measuring cylinder to add 35 cm^3 of distilled water to the acid in the beaker.
- Measure and record, in the table below, the initial temperature of the mixture in the beaker.
- Run 5.0 cm^3 of **FA 1** from the burette into the plastic cup.
- Add the mixture of acid and water from the 100 cm^3 beaker to the **FA 1** in the plastic cup.
- Stir carefully and measure the highest temperature obtained.
- Record this temperature in the table.
- Rinse the plastic cup with water.
- Repeat the experiment using 25 cm^3 of **FA 2**, 30 cm^3 of distilled water and 10.0 cm^3 of **FA 1** as shown for experiment **2** in the table.
- Carry out experiments **3** to **7** in the same way.
- Complete the table for each experiment.

Results

experiment number	1	2	3	4	5	6	7
volume of **FA 2** / cm^3	25	25	25	25	25	25	25
volume of water / cm^3	35	30	25	20	15	10	5
volume of **FA 1** / cm^3	5.0	10.0	15.0	20.0	25.0	30.0	35.0
initial temperature of acid mixture / °C	26.5	26.5	26.5	26.5	26.5	26.5	26.5
highest temperature / °C	29.5	32.0	34.5	37.5	37.5	37.5	42.5
temperature change / °C	3.0	5.5	8.0	11.0	11.0	11.0	16.0

[7]

8.0 11.0

I	✓
II	✓
III	✗
IV	✓
V	✓
VI	✓
VII	✓

Examiner comment – grade C

Much of this answer was very good and many candidates gaining a grade C were equally competent in this section. A mark was lost owing to the much higher temperature rise in experiment 7. The candidate would have benefited from repeating it.

Example candidate response – grade E

1 You are to determine the enthalpy change of neutralisation of hydrochloric acid by aqueous sodium hydroxide and also the concentration of the aqueous sodium hydroxide. These can be found by measuring the temperature change when solutions of the acid and alkali are mixed.

For Examiner's Use

FA 1 is aqueous sodium hydroxide, NaOH.
FA 2 is 2.00 mol dm^{-3} hydrochloric acid, HC*l*.

(a) Method

- Fill a burette with **FA 1**. **[Care: FA 1 is corrosive]**
- Support the plastic cup in a 250 cm^3 beaker.
- Use a measuring cylinder to transfer 25 cm^3 of **FA 2** into a 100 cm^3 beaker.
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- Measure and record, in the table below, the initial temperature of the mixture in the beaker.
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- Stir carefully and measure the highest temperature obtained.
- Record this temperature in the table.
- Rinse the plastic cup with water.
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- Carry out experiments **3** to **7** in the same way.
- Complete the table for each experiment.

Results

experiment number	1	2	3	4	5	6	7
volume of **FA 2** / cm^3	25	25	25	25	25	25	25
volume of water / cm^3	35	30	25	20	15	10	5
volume of **FA 1** / cm^3	5.0	10.0	15.0	20.0	25.0	30.0	35.0
initial temperature of acid mixture / °C	19	19	19	19	19	19	19
highest temperature / °C	23	25	27	29	28	28	28
temperature change / °C	4	6	8	10	9	9	9

[7]

(7) (11)
δ = 1·0 1·0

I	X
II	✓
III	✓
IV	✓
V	X
VI	✓
VII	X

4/7

Examiner comment – grade E

In this answer the candidate needed to show more precision in the thermometer readings and the experimental results differed from those of the Supervisor. Although there was no change in temperature rise in the final three experiments they were 1.0 °C lower than the maximum, which should not have occurred as the same number of moles of water would have been formed.

Question 1(b)

(b) On the grid below plot the temperature **change** (*y*-axis) against the volume of **FA 1** (*x*-axis). Using these points, draw two straight lines that intersect.

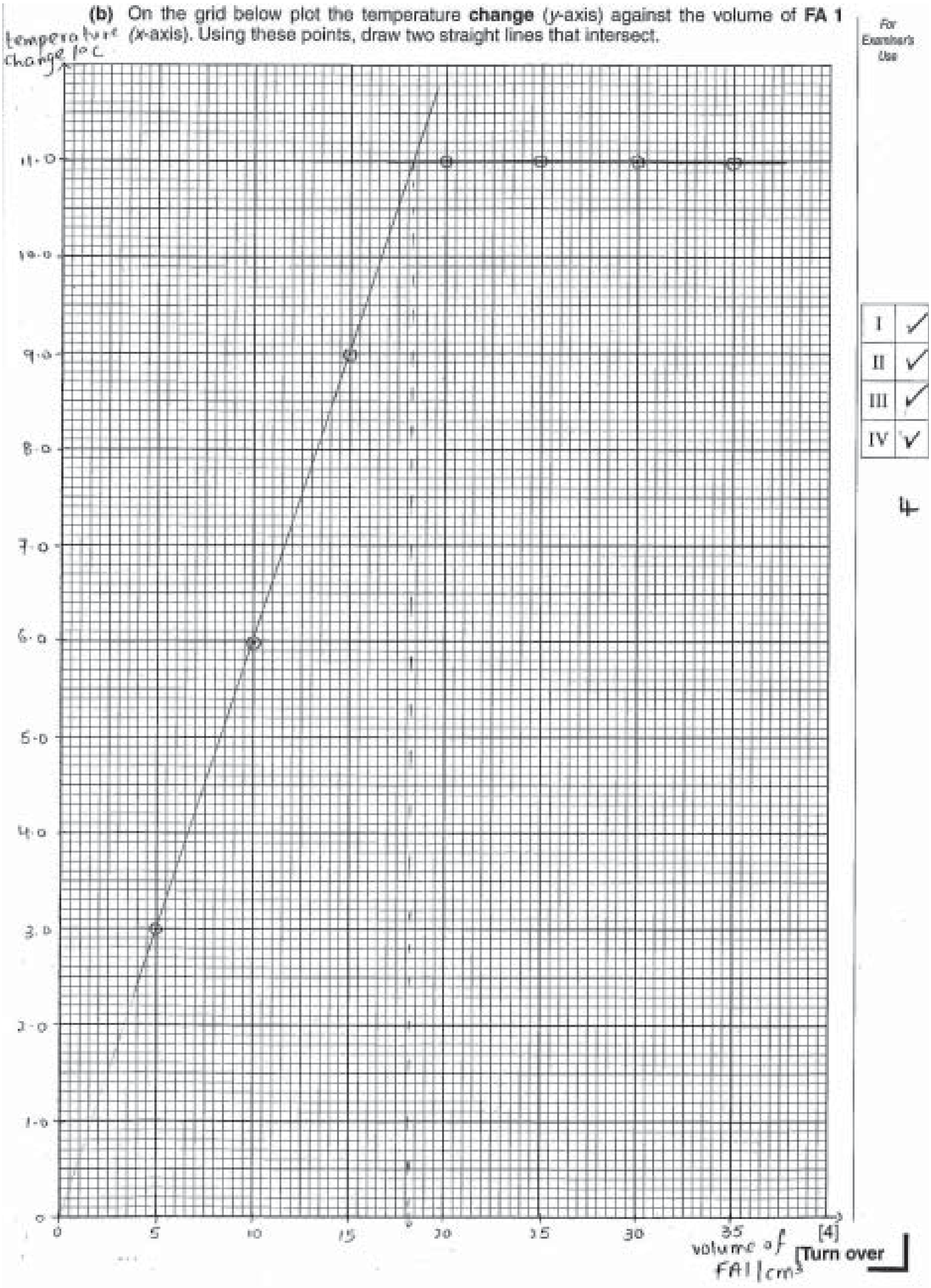
Mark scheme

(b)	PDO Layout	I	Axes correct and labelled: temperature change/ T change/ΔT and volume/vol/V (of) sodium hydroxide/NaOH/**FA 1** **and** correct units /°C or (°C) or 'in °C'; /cm^3 or (cm^3) (allow NaOH in cm^3)	1	
		II	Scales chosen so that graph occupies at least half the available length for *x*- and *y*-axes.	1	
		III	Plotting – all points accurate to within half a small square and in the correct square.	1	
		IV	Draws two straight lines of best fit which intersect.	1	[4]

General comment

A large majority of candidates chose scales so that at least half the available squares were used, and plotted all points correctly. However, some chose difficult scales so that plotting and then reading the intercept was difficult for both candidate and examiner. A few did not label the axes or did not record units in any of the forms specified in the syllabus. The mark most commonly withheld was for the two best fit intersecting straight lines: a number of candidates left more points to one side of the line than the other. The use of (0,0) may have assisted some candidates to improve the line for the increase in temperature rise. If candidates realise that one of their results is anomalous they should circle or otherwise indicate this decision on the graph so that the point is not considered by examiners when awarding marks for best fit lines.

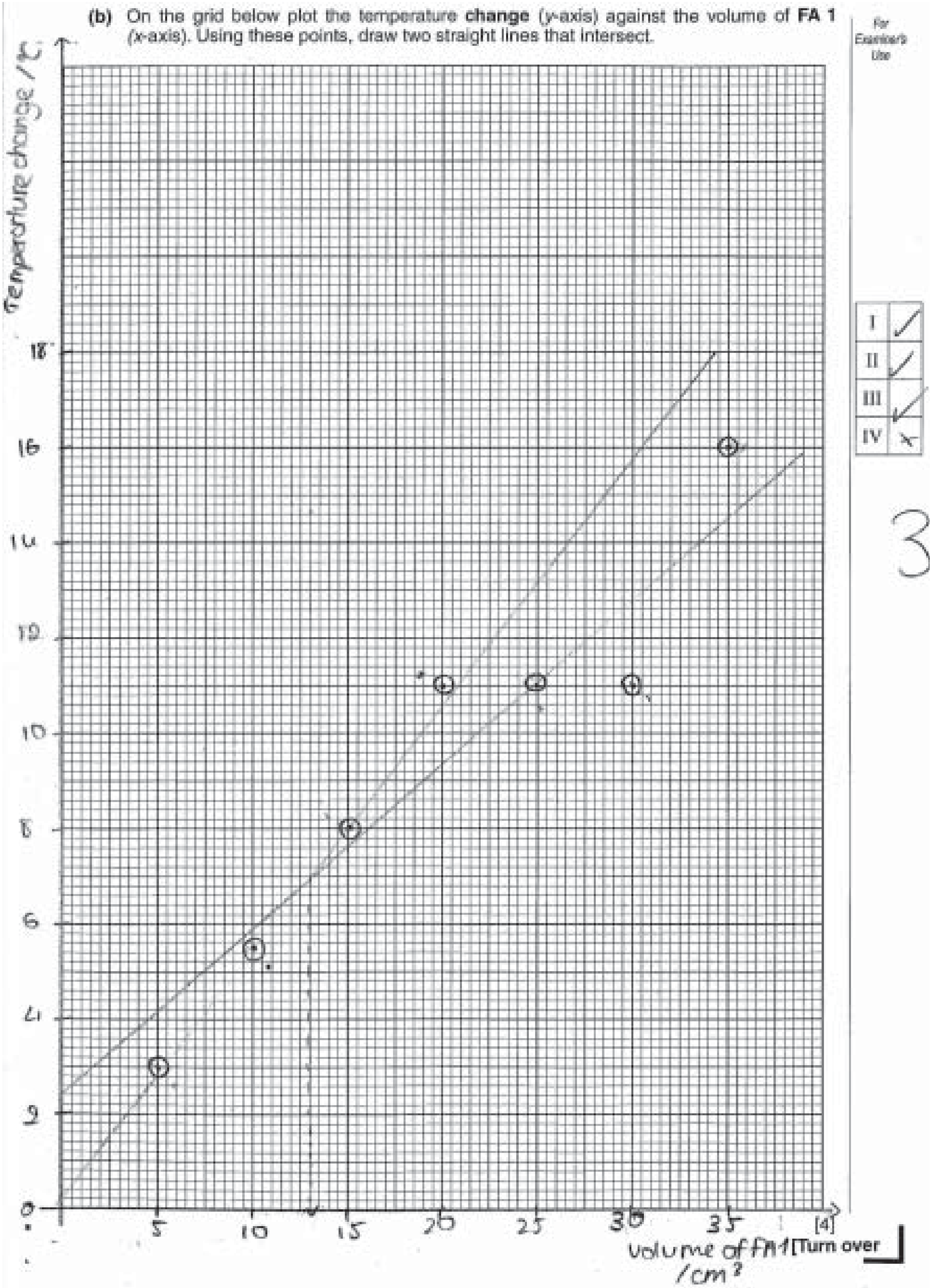
Example candidate response – grade A



Examiner comment – grade A

This excellent answer is typical of many grade A and B candidates. The drawing of a best fit line with positive gradient was made easier by obtaining excellent experimental results.

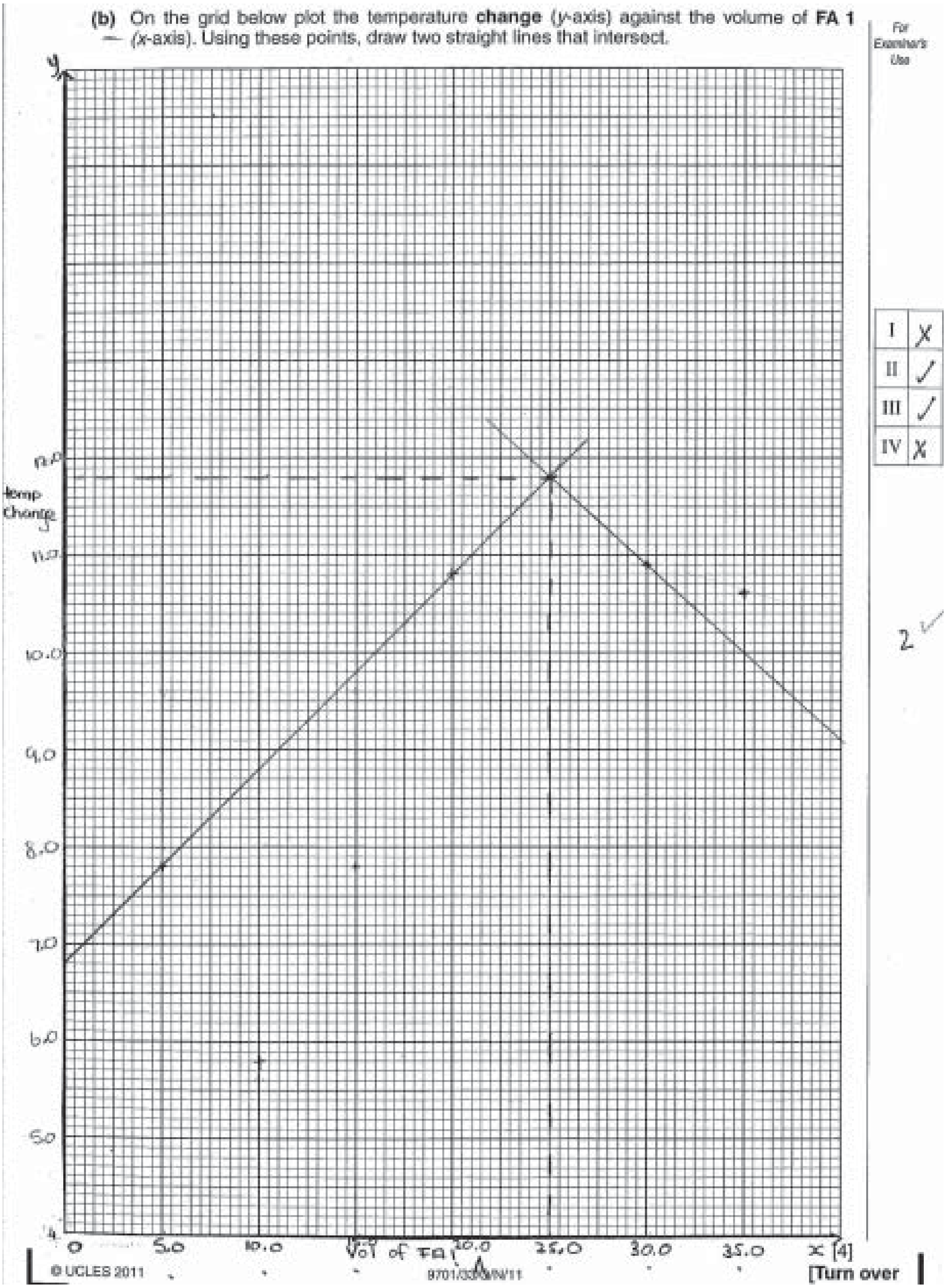
Example candidate response – grade C


(b) On the grid below plot the temperature **change** (*y*-axis) against the volume of **FA 1** (*x*-axis). Using these points, draw two straight lines that intersect.

Examiner comment – grade C

Had the anomalous result for experiment 7 been circled or labelled, and omitted from any attempt at a best fit line, the candidate may have been awarded full marks on this section. The line with the higher gradient is almost one of best fit: the candidate would have benefited from using (0,0) and ensuring points were lying either side of the line in equal measure. The line with the smaller gradient is one of best fit but the points are a long way off the line and the constant temperature rise portion has not been recognised.

Example candidate response – grade E


(b) On the grid below plot the temperature **change** (*y*-axis) against the volume of **FA 1** (*x*-axis). Using these points, draw two straight lines that intersect.

Examiner comment – grade E

The labels for the axes, though correctly placed, do not include units. Both 'best fit' lines have points lying to one side only. By starting the scale at 4.0 °C it was not possible for the candidate to use (0,0).

Question 1(c) and 1(d) – using the graph

(c) Reading from the intersection of the two lines on your graph,

the volume of **FA 1** is .... cm^3,

the temperature change is .... °C. [1]

The volume of **FA 1** at the intersection represents the volume of **FA 1** which neutralised 25.0 cm^3 of **FA 2**.

(d) The reaction between **FA 1** and **FA 2** is shown in the equation below.

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$$

This reaction is exothermic.

Use this information to explain the shape of the graph.

....

....

....

.... [2]

Mark scheme

(c)	ACE Interpretation	Reads to nearest ½ square to 1 or 2 dp volume of **FA 1** and temperature rise from intercept. Do **not** award if ΔT at intercept (or point) < max ΔT from table unless candidate has clearly indicated the max ΔT is anomalous.	1	[1]

(d)	ACE Conclusions	I	The temperature/temperature change increases as **more** reaction/more hydrochloric acid/sodium hydroxide reacts/as more water formed.	1	
		II	The temperature/temperature change stays constant/decreases when all acid/limiting reagent has reacted/excess NaOH is added.	1	[2]

General comment

Question 1(c)

The most common error in this section was that candidates did not show they had read the intercept to the nearest half square as many answers were given as whole numbers. Some candidates were unable to score the mark as the intercept was less than the maximum temperature rise recorded. However, there were many candidates who correctly gave the values of temperature change and volume to the level of precision shown in the graph.

Question 1(d)

Relatively few candidates gained both marks as the responses tended to describe the shape of the graph or the temperature rise without relating it to any reaction between the acid and alkali. More candidates gained the second mark which involved identifying that excess alkali was being added. A small minority of candidates wrote about bond breaking and making without specifying that more water was formed in successive experiments (until all the limiting reagent had reacted). Very few answered the question incorrectly in terms of equilibria or kinetics.

Example candidate response – grade A

(c) Reading from the intersection of the two lines on your graph,

the volume of **FA 1** is ....20.0.... cm^3,

the temperature change is ..11.0.. °C. ✓ [1]

The volume of **FA 1** at the intersection represents the volume of **FA 1** which neutralised 25.0 cm^3 of **FA 2**.

(d) The reaction between **FA 1** and **FA 2** is shown in the equation below.

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$$

This reaction is exothermic.

Use this information to explain the shape of the graph.

Since the reaction is exothermic, when the volume of FA1 increases, the temperature rise also increase. But when the minimum volume of FA1 needed to neutralise FA2 is reached, the temperature rise remains constant. [2]

Examiner comment – grade A

(c) The intersection was read correctly and the values recorded to the expected level of precision.

(d) The second mark was awarded as the answer incorporated the ideas of excess **FA 1**, neutralisation and constant temperature rise.

Example candidate response – grade C

(c) Reading from the intersection of the two lines on your graph,

the volume of **FA 1** is .....25..... cm^3,

the temperature change is ....10.... °C. [1]

The volume of **FA 1** at the intersection represents the volume of **FA 1** which neutralised 25.0 cm^3 of **FA 2**.

(d) The reaction between **FA 1** and **FA 2** is shown in the equation below.

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$$

This reaction is exothermic.

Use this information to explain the shape of the graph.

...When...25cm³...of...NaOH...was...added...to...the...solution...the...temperature...rise...of...10°C (greatest temperature rise). As...the...volume...of...NaOH...increased...the...temperature...rise...also...increased. Then...the...temperature...change...decreased. This...occurred...due...to...bonds...being formed. [2]

Examiner comment – grade C

(c) This answer lacked the precision expected from reading values from the graph.

(d) There was no explanation of the positive gradient line in terms of increasing rise in temperature and volume of alkali reacting. The link between bond making and the temperature change decreasing was not logical.

Example candidate response – grade E

(c) Reading from the intersection of the two lines on your graph,

the volume of **FA 1** is ..17.5.... cm^3,

the temperature change is ....9..... °C. X [1]

The volume of **FA 1** at the intersection represents the volume of **FA 1** which neutralised $25.0\,cm^3$ of **FA 2**.

(d) The reaction between **FA 1** and **FA 2** is shown in the equation below.

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$$

This reaction is exothermic.

Use this information to explain the shape of the graph.

Temperature increased slowly because not all the Hcm³ of HCL had been neutralised. ^ ^

.... [2]

Examiner comment – grade E

(c) The mark was not awarded as the reported temperature change was not to the expected level of precision although the volume was correct. Also the maximum temperature change had not been considered.

(d) The answer was partly correct but was not sufficiently developed to gain a mark. With two marks allocated to a question, candidates should aim to make two points in their answers. There was no comment made about the horizontal line portion of the graph.

Question 1(e)–(g)

(e) Calculate the amount of heat energy produced in the reaction. Use the temperature change from **(c)** in calculating your answer.

[Assume that 4.3 J are required to raise the temperature of 1 cm^3 of any solution by 1 °C]

heat energy produced = ... J [2]

(f) Calculate how many moles of hydrochloric acid are present in 25 cm^3 of **FA 2**.

mol of hydrochloric acid = ... [1]

(g) Use your answers to **(e)** and **(f)** to calculate the enthalpy change of neutralisation of hydrochloric acid by aqueous sodium hydroxide.

Give your answer in $kJ\,mol^{-1}$ and include the relevant sign.

Mark scheme

(e)	ACE Interpretation	I	Volume used in calculation is 65 cm^3	1	
		II	Heat energy change calculated using candidate's value for ΔT correct to 3 or 4 sf	1	[2]
(f)	ACE Interpretation		$\frac{25 \times 2}{1000}$ = **0.05**	1	[1]
(g)	ACE Interpretation	I	$\frac{\text{Candidate's answer to (e)}}{\text{Candidate's answer to (f)}}$	1	
	PDO Display	II	Correct calculation, conversion J to kJ and negative sign to 3 or 4 sf	1	[2]

General comment

Question 1(e)

The most common error in this section was using a volume other than 65 cm^3 in the calculation. However, the majority of candidates were able to gain the second mark for the calculation although some gave the answer to an excessive number of significant figures.

Question 1(f)

This section was correctly answered by almost all candidates.

Question 1(g)

Most candidates were able to gain the first mark. However, some could not be awarded the second mark owing to an inappropriate number of significant figures, no conversion of J to kJ, or, more commonly, writing ΔH or + for the sign.

Example candidate response – grade A

(e) Calculate the amount of heat energy produced in the reaction. Use the temperature change from **(c)** in calculating your answer.

[Assume that 4.3 J are required to raise the temperature of 1 cm^3 of any solution by 1 °C]

Energy = mcΔT
= 65 × 4.3 × 10.7
= 2990.65
= 2990 J (3sf)

heat energy produced = ...2990....J [2]

(f) Calculate how many moles of hydrochloric acid are present in 25 cm^3 of **FA 2**.

1000 cm^3 of FA2 contains 2.00 mol of HCl
25 cm^3 ———— $\frac{25 \times 2.00}{1000}$ = 0.05 mol

mol of hydrochloric acid = ...0.05.... [1]

(g) Use your answers to **(e)** and **(f)** to calculate the enthalpy change of neutralisation of hydrochloric acid by aqueous sodium hydroxide.

Give your answer in kJ mol^{-1} and include the relevant sign.

0.05 mol of HCl releases 2.99065 kJ
1 mol ———— $\frac{1 \times 2.99065}{0.05}$
= 59.813
= 59.8 (3sf)

enthalpy change of neutralisation = ...–.... ....59.8.... kJ mol^{-1}
sign *value* [2]

Examiner comment – grade A

These answers were clearly set out, using all the correct data, and correcting to a suitable number of significant figures in **(e)** and **(g)**. The value of the heat energy produced used in **(g)** had already been converted into kJ in the first step which was an acceptable alternative to the working shown in the mark scheme.

Example candidate response – grade C

(e) Calculate the amount of heat energy produced in the reaction. Use the temperature change from **(c)** in calculating your answer.

[Assume that 4.3 J are required to raise the temperature of 1 cm^3 of any solution by 1 °C]

$1\,cm^3 = 1g$ $Q = mc\Delta T$

$= 50 \times 4.3 \times 10 = 2150J$

X ✓ ecf

heat energy produced = ...2150....... J [2]

(f) Calculate how many moles of hydrochloric acid are present in 25 cm^3 of **FA 2**.

$2.00\,mol = 1000cm^3$

$? = 25$

$\frac{25 \times 2}{1000} = 0.05\,mol$ ✓

mol of hydrochloric acid = ...0.05mol. [1]

(g) Use your answers to **(e)** and **(f)** to calculate the enthalpy change of neutralisation of hydrochloric acid by aqueous sodium hydroxide.

Give your answer in kJ mol^{-1} and include the relevant sign.

$\frac{2150 \times 1}{0.05} = \frac{43{,}000J}{1000} = 43kJ$

✓

enthalpy change of neutralisation = ...–.... ....43.... X kJ mol^{-1}

sign *value* sf [2]

Examiner comment – grade C

The use of an incorrect total volume of solution heated was a common error in **(e)** (the volume of water was omitted). Showing working is important when carrying out calculations as 'error carried forward' marks can be awarded. This was evident in the second part of **(e)** and the first part of **(g)**. The final answer was only given to two significant figures.

Example candidate response – grade E

(e) Calculate the amount of heat energy produced in the reaction. Use the temperature change from **(c)** in calculating your answer.

[Assume that 4.3 J are required to raise the temperature of 1 cm^3 of any solution by 1 °C]

1 cm^3 ⟶ 4.3J by 1°C

(25 + 17.5)cm^3 ⟶ 4.3J × (25+17.5) J by 1°C

1°C ⟶ 182.75

9°C ⟶ 182.75 × 9 / 1 = 1,644.75

heat energy produced = 1,644.75 J [2] × sf

(f) Calculate how many moles of hydrochloric acid are present in 25 cm^3 of **FA 2**.

1000cm^3 of HCl reacted with 2 moles of FA 2

25 cm^3 ⟶ 2 × 25 / 1000 = 0.05

mol of hydrochloric acid = 0.05 [1] ✓

(g) Use your answers to **(e)** and **(f)** to calculate the enthalpy change of neutralisation of hydrochloric acid by aqueous sodium hydroxide.

Give your answer in kJ mol^{-1} and include the relevant sign.

0.05 mol of HCl envolved 1,644.75 / 1000 kJ

1 mol of HCl will envolve (1,644.75 / 1000 × 1 / 0.05) ✓

enthalpy change of neutralisation = ∧ (sign) 32.895 (value) kJ mol^{-1} [2]

Examiner comment – grade E

Again, the volume of water added was not used in the first step of **(e)**. The final answers to both **(e)** and **(g)** were given to too many significant figures, and the latter was also missing the negative sign.

Question 1(h)

(h) Explain why the **total** volume of solution used was kept constant in each of the experiments.

....

....

.... [1]

Mark scheme

(h)	ACE Conclusions	So that rise in temperature is proportional to increase in energy produced/change in volume gives different change in temperature for same energy produced/ increase in volume requires increase in energy for same temperature rise.	1	[1]

General comment

The majority of candidates did not appear to understand this question and answered in terms of fair testing, keeping the concentration constant or other responses commonly associated with kinetics experiments. However, there were a few excellent answers where the candidates clearly linked temperature rise to energy produced. The three example candidate responses show typical errors which were made. The grade refers to the overall grade the candidate received for the whole paper.

Example candidate response – grade A

(h) Explain why the **total** volume of solution used was kept constant in each of the experiments.

To ensure uniform distribution of heat during each experiment. ✗

.... [1]

Examiner comment – grade A

While this answer involved 'heat' the link between temperature rise and heat energy produced was not made.

Example candidate response – grade C

(h) Explain why the **total** volume of solution used was kept constant in each of the experiments.

Since the volume of solution is directly proportional to the concentration of the ~~subs~~ solutions used, the volume should be kept constant so as not to change the concentration of the solutions. ✗ [1]

Example candidate response – grade C

Examiner comment – grade C

This answer was typical of many as, while chemically correct, it only involved the relationship of concentration with volume.

Example candidate response – grade E

(h) Explain why the **total** volume of solution used was kept constant in each of the experiments.

~~so we can vary~~

so no. of moles in the solution were kept constant. ✗

[1]

Examiner comment – grade E

This answer was incorrect and did not involve temperature rise and heat energy.

Question 1(i)

(i) Calculate the concentration, in mol dm^{-3}, of the aqueous sodium hydroxide, **FA 1**.

concentration of **FA 1** = ... mol dm^{-3} [2]

Mark scheme

(i)	PDO Display ACE Interpretation	I II	Number moles NaOH = number moles HC*l* (stated or clearly shown) Calculates or expression for Concentration = 0.05 (ecf from (f)) / answer to **(c)**/1000 If answer only, award mark if correct to 3 or 4 sf	1 1	 [2]

General comment

Many candidates gained both marks in this section though a significant number did not specify the mole ratio of the reactants which was an essential part of their working.

Example candidate response – grade A

(i) Calculate the concentration, in mol dm^{-3}, of the aqueous sodium hydroxide, **FA 1**.

From eqation HCl : NaOH ✓ ∴ concentration = 2.74 mol dm^{-3}

1 : 1

0.050 : 0.050

18.25 cm^3 of FA1 → 0.05 moles

1000 cm^3 of FA1 → $\frac{0.05}{18.25}$ × 1000 = 2.74 moles

concentration of **FA 1** = ...2.74... mol dm^{-3} [2] ✓

Examiner comment – grade A

Although the word mole was not used, the ratio was clearly shown, and the expression and calculation were fully correct.

Example candidate response – grade C

(i) Calculate the concentration, in mol dm^{-3}, of the aqueous sodium hydroxide, **FA 1**.

Since 1 mole of HCl reacts with 1 mole of NaOH. ✓

∴ 0.05 moles of NaOH are in 1 dm^3

∴ Concentration in mol dm^{-3} is 0.05 mol dm^{-3}

concentration of **FA 1** = ...0.05 X... mol dm^{-3} [2]

Examiner comment – grade C

The mole ratio was clearly presented. However, no working was shown for the second mark. Additionally, the answer given for the concentration of **FA 1** was incorrect and was not shown to a suitable number of significant figures.

Example candidate response – grade E

(i) Calculate the concentration, in mol dm^{-3}, of the aqueous sodium hydroxide, **FA 1**.

conc. = no of moles / volume used

= 0.05 / 25 = 2×10^{-3} mol /dm^3

concentration of **FA 1** = ...2×10^{-3}...... mol dm^{-3} [2]

Examiner comment – grade E

The mole ratio was not displayed and, while the volume from **(c)** was used in the calculation, the step to change the unit of volume from cm^3 to dm^3 was omitted.

Question 1(j)

(j) A student thought that the experiment was not accurate because the temperature changes measured were small.

Suggest a modification to the experimental method used in order to give larger changes in temperature.

....

.... [1]

Mark scheme

(j)	ACE Improvements	Use more **concentrated** solutions. (allow use **≤ 5** cm^3 water each time) Ignore all references to heat energy losses.	1	[1]

General comment

Only a minority of candidates gained this mark. The majority suggested increasing volumes of reagents, increasing the concentration of just one of the reagents, or gave methods of reducing heat energy losses. As in **1(h)** the three example candidate responses show typical errors which were made. The grade refers to the grade the candidates received for the whole paper.

Example candidate response – grade A

(j) A student thought that the experiment was not accurate because the temperature changes measured were small.

Suggest a modification to the experimental method used in order to give larger changes in temperature.

I would try to titrate HCl with a bigger concentration of NaOH like 4 M ✓ [1]

Examiner comment – grade A

This answer was partly correct as the need for greater concentration was recognised. However, both solutions would need to have greater concentrations.

Example candidate response – grade C

(j) A student thought that the experiment was not accurate because the temperature changes measured were small.

Suggest a modification to the experimental method used in order to give larger changes in temperature.

A thermometer which can measure temperature to two decimal places can be used. ✗ [1]

Examiner comment – grade C

This answer did not address the question as the same temperature rise would have occurred though it might have been recorded to a greater degree of precision.

Example candidate response – grade E

(j) A student thought that the experiment was not accurate because the temperature changes measured were small.

Suggest a modification to the experimental method used in order to give larger changes in temperature.

By not adding any distilled water. ✗

[1]

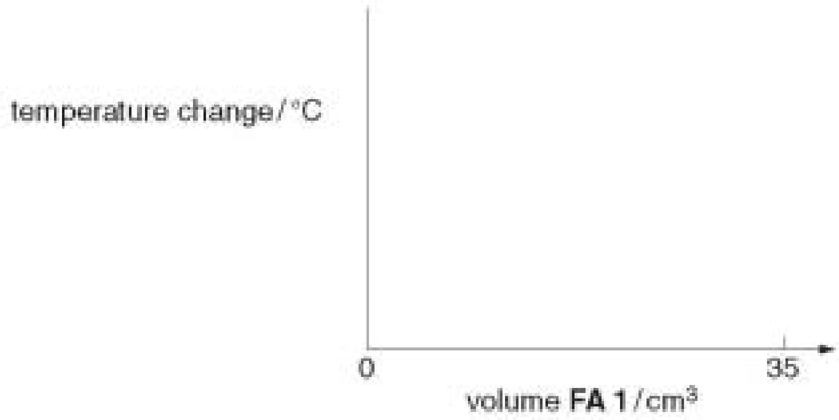
Examiner comment – grade E

Here again there was some understanding shown that greater concentrations would be required. However, more detail of the modification was necessary as the total volume of solution would not have been constant.

Question 1(k)

(k) Experiments **1** to **7** were repeated using 1.00 mol dm^{-3} sulfuric acid, H_2SO_4, instead of the 2.00 mol dm^{-3} hydrochloric acid, HC*l*.

On the axes below indicate an appropriate temperature scale and sketch the graph for the temperature changes you would expect.



[2]

Mark scheme

(k)	ACE Conclusions	I	Two straight intersecting lines (positive followed by zero gradient).	1	
		II	Same ΔT and V shown as in **(b)**.	1	[2]

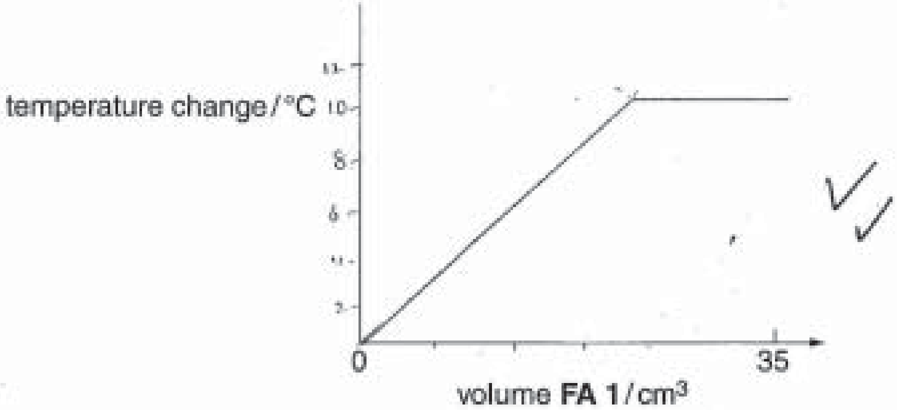
General comment

The majority of candidates gained the first mark in this section though a variety of responses were seen by Examiners including a few curves. Fewer gained the second mark either because there was no temperature scale shown or the intercept was not at the same values as those in **(b)**.

Example candidate response – grade A

(k) Experiments **1** to **7** were repeated using 1.00 mol dm^{-3} sulfuric acid, H_2SO_4, instead of the 2.00 mol dm^{-3} hydrochloric acid, HC*l*.

On the axes below indicate an appropriate temperature scale and sketch the graph for the temperature changes you would expect.



[2]

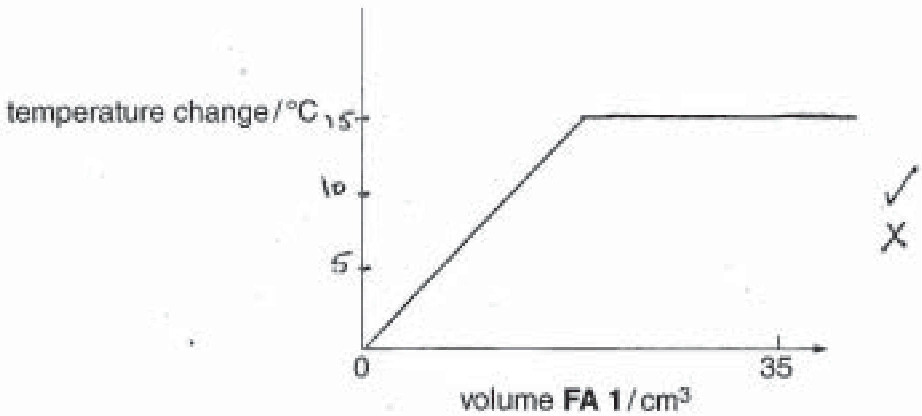
Examiner comment – grade A

This sketch showed the two lines with gradients similar to those in **(b)** and with the appropriate temperature change scale shown in detail.

Example candidate response – grade C

(k) Experiments **1** to **7** were repeated using 1.00 mol dm^{-3} sulfuric acid, H_2SO_4, instead of the 2.00 mol dm^{-3} hydrochloric acid, HC*l*.

On the axes below indicate an appropriate temperature scale and sketch the graph for the temperature changes you would expect.



[2]

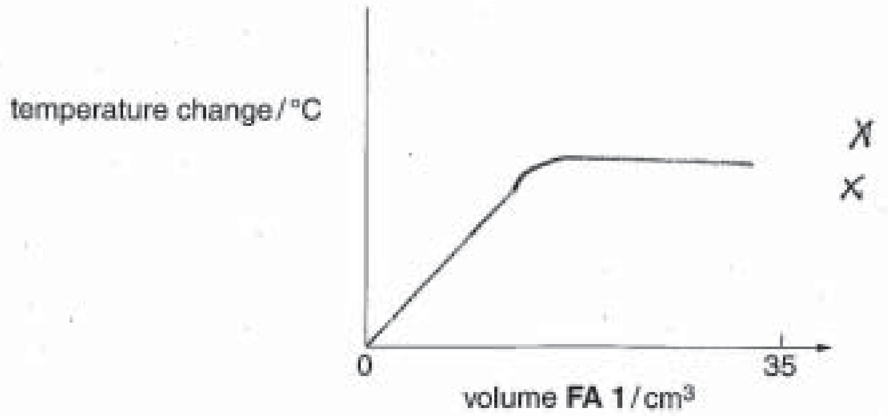
Examiner comment – grade C

The sketch of the two lines was clear and correct. However, the value for the temperature change in **(c)** was 9.0 °C , so the scale on the *y*-axis was incorrect. This implied that the information in the stem of the question allowing the concentration of hydrogen ions to be found had not been correctly used.

Example candidate response – grade E

(k) Experiments **1** to **7** were repeated using 1.00 mol dm^{-3} sulfuric acid, H_2SO_4, instead of the 2.00 mol dm^{-3} hydrochloric acid, HC*l*.

On the axes below indicate an appropriate temperature scale and sketch the graph for the temperature changes you would expect.



[2]

Examiner comment – grade E

Lines with similar gradients to those in **(b)** were drawn but they were not intersecting. There was no scale shown on the *y*-axis.

Question 2(a)

For Examiner's Use

2 Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the full name or correct formula of the reagents must be given.

(a) You are provided with three sodium salts **FA 3**, **FA 4** and **FA 5**. Each salt contains **one** of the ions carbonate, CO_3^{2-}, sulfite, SO_3^{2-} or sulfate, SO_4^{2-}.

(i) Using your knowledge of the reactions of these ions, suggest **one** reagent you could add to the solid to find out which ion is present in each of the solids.

....

(ii) Use the reagent you selected in **(i)** to identify which of these ions is present in **FA 3**, **FA 4** and **FA 5**.

Carry out suitable tests on a small amount of each solid and record the results of your experiments in an appropriate form in the space below.

I	
II	
III	
IV	
V	
VI	

Identify the anions in **FA 3**, **FA 4** and **FA 5**.

FA 3 contains the .... ion.

FA 4 contains the .... ion.

FA 5 contains the .... ion. [6]

Mark scheme

FA 3 is $Na_2S_2O_5$(s); FA 4 is Na_2CO_3(s); FA 5 is Na_2SO_4(s); FA 6 is $Pb(NO_3)_2$(s) and (aq)				
2 **(a)**	MMO Decisions	(i) I Any named mineral acid or formula or (acidified) potassium dichromate Do **not** allow any reagent suitable for testing cations or more than one reagent.	1	
	PDO Recording	(ii) II Tabulates evidence of 3 tests carried out with no repeat headings. **Only** consider observations with acid or dichromate.	1	
	MMO Collection	III Bubbles/effervescence in **FA 4**.	1	
		IV Slower effervescence in **FA 3** than **FA 4** or **FA 3** turns green **and FA 5** stays orange if dichromate used.	1	
	MMO Decisions	V Appropriate test with positive result used to test for either gas.	1	
	ACE Conclusions	VI All three ions correct from suitable observations. **FA3** is a sulfite. **FA4** is a carbonate. **FA5** is a sulfate. (or correct formulae)	1	[6]

General comment

(a) **(i)** Most candidates selected a suitable reagent with few choosing other than a named mineral acid.

(ii) A large majority set out an appropriate table for their observations and were able to access at least one mark for observations. It is important that candidates appreciate the difference between an observation, 'effervescence' and an inference, 'gas is evolved'. Not all of those using acid as their reagent went on to test the gas(es) produced which meant that there was insufficient evidence for the identification of the anions. However, the most discerning candidates reported the difference in the rate of effervescence when using acid with **FA 3** and **FA 4**.

Example candidate response – grade A

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations.**

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the full name or correct formula of the reagents must be given.

(a) You are provided with three sodium salts **FA 3**, **FA 4** and **FA 5**. Each salt contains **one** of the ions carbonate, CO_3^{2-}, sulfite, SO_3^{2-} or sulfate, SO_4^{2-}.

(i) Using your knowledge of the reactions of these ions, suggest **one** reagent you could add to the solid to find out which ion is present in each of the solids.

Dilute hydrochloric acid. ✓

(ii) Use the reagent you selected in **(i)** to identify which of these ions is present in **FA 3, FA 4** and **FA 5**.

Carry out suitable tests on a small amount of each solid and record the results of your experiments in an appropriate form in the space below.

Test	Observation with		
	FA 3	FA 4	FA 5
To a portion of the salt, Add 1 cm^3 of dilute hydrochloric acid.	A pungent smelling gas is evolved. The gas is SO_2	Rapid effervescence is observed. A gas turning lime water milky is evolved. The gas is CO_2 ✓	No visible reaction with dilute HCl. ✓

Table showing results of experiment

I	✓
II	✓
III	✓
IV	✗
V	✓
VI	✓

5

Identify the anions in **FA 3, FA 4** and **FA 5.**

FA 3 contains the SO_3^{2-} ion.

FA 4 contains the CO_3^{2-} ion.

FA 5 contains the SO_4^{2-} ion. ✓

[6]

Examiner comment – grade A

This was a good answer including the reporting of slower effervescence in the reaction between **FA 3** and hydrochloric acid than with **FA 4**. Although the gas evolved with **FA 3** was not tested with acidified potassium dichromate, the mark for the identities could be awarded as the choking odour of the gas and the fully correct limewater test with the gas from **FA 4** were clearly reported.

Example candidate response – grade C

2 Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations.**

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the full name or correct formula of the reagents must be given.

(a) You are provided with three sodium salts **FA 3**, **FA 4** and **FA 5**. Each salt contains **one** of the ions carbonate, CO_3^{2-}, sulfite, SO_3^{2-} or sulfate, SO_4^{2-}.

(i) Using your knowledge of the reactions of these ions, suggest **one** reagent you could add to the solid to find out which ion is present in each of the solids.

Add nitric acid to the salt containing CO_3^{2-} ✓
effervescence should be observed and CO_2 released

(ii) Use the reagent you selected in (i) to identify which of these ions is present in **FA 3**, **FA 4** and **FA 5**.

Carry out suitable tests on a small amount of each solid and record the results of your experiments in an appropriate form in the space below. ✓

~~OBSERVATION WITH HNO_3~~	FA3	FA4	FA5
	effervescence produced ✓ bubbles of gas observed. The gas SO_2 ~~turns limewater milky white produced~~	Reacts vigorously effervescence produced. A gas which turns lime water milky white produced	~~Does not~~ A white ppt obtained when barium chloride ✗ was added. It is insoluble in excess acid

Identify the anions in **FA 3**, **FA 4** and **FA 5**.

~~**FA 3** contains the ....CO_3^{2-}.... ion.~~ FA3 contains the SO_3^{2-}

FA 4 contains the ....CO_3^{2-}.... ion.

FA 5 contains the ....SO_4^{2-}.... ion. [6]

Examiner comment – grade C

Most of this answer was very good as the difference in the rates of effervescence was described as well as a valid test for one of the gases. The error was in using two reagents with **FA 5** contrary to the instruction in part **(ii)**.

Example candidate response – grade E

2 Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations.**

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the full name or correct formula of the reagents must be given.

(a) You are provided with three sodium salts **FA 3, FA 4** and **FA 5**. Each salt contains **one** of the ions carbonate, CO_3^{2-}, sulfite, SO_3^{2-} or sulfate, SO_4^{2-}.

(i) Using your knowledge of the reactions of these ions, suggest **one** reagent you could add to the solid to find out which ion is present in each of the solids.

HCl ✓

(ii) Use the reagent you selected in (i) to identify which of these ions is present in **FA 3, FA 4** and **FA 5**.

Carry out suitable tests on a small amount of each solid and record the results of your experiments in an appropriate form in the space below. ✗

Test	observation
You use FA_3 you add HCl drop by drop fill in excess then test gas with lime water on $Cr_2O_7^{2-}/H^+$	Gas given off. gas turns $K_2Cr_2O_7/H^+$ from orange to green
You use FA_4 you dilute with HCl drop by drop fill in excess then test gas with lime water on $Cr_2O_7^{2-}/H^+$	CO_2 given off it turns lime water milky ✓
you use FA_5 you dilute with HCl drop by drop fill in excess then test gas with lime water on $Cr_2O_7^{2-}/H^+$	No change

Identify the anions in **FA 3, FA 4** and **FA 5**.

FA 3 contains the SO_3^{2-} ion.

FA 4 contains the CO_3^{2-} ion. ✓

FA 5 contains the SO_4^{2-} ion.

[6]

Examiner comment – grade E

A suitable reagent was selected but its formula was repeatedly recorded in the table. There was no observation recorded that would lead to the inference of gas given off and this made two marks unavailable. However, both gas tests were given and the results recorded were correct as were the identities of the sodium salts.

Question 2(b)

(b) (i) You are provided with **FA 6** both as a solid and in aqueous solution. Complete the following table.

For Examiner's Use

test	*observations*
To a small spatula measure of **FA 4** in a test-tube, add enough distilled water to make a solution. Add 1 cm depth of **FA 6** solution.	
To a small spatula measure of **FA 5** in a test-tube, add enough distilled water to make a solution. Add 1 cm depth of **FA 6** solution.	
To 1 cm depth of **FA 6** solution in a test-tube, add aqueous sodium hydroxide.	
Carefully heat the solid **FA 6** in the test-tube provided. Note: **two** gases are released.	

I	
II	
III	
IV	
V	
VI	

[6]

(ii) From the results of the tests in **(i)**, identify the cation present in **FA 6**.

Cation present in **FA 6** is .... [1]

(iii) Suggest and use another reagent to confirm the cation present in **FA 6**.

reagent ....

observation..[2]

[Total: 15]

Mark scheme

(b)	MMO Collection	(i) I **FA 4** + **FA 6** white ppt **and** **FA 5** + **FA 6** white ppt.	1	
		II **FA 6** + NaOH white ppt, soluble in excess sodium hydroxide.		
		III Brown gas		
		IV Gas relights glowing splint.		
		V Yellow residue or crackling/decrepitating.		
	ACE Conclusions	VI Gas identified as oxygen or as NO_2 from observations.		[6]
	ACE Conclusions	(ii) Lead/Pb^{2+} provided correct observations with **FA 6** + NaOH **and** **FA 6** + **FA 5** (sulfate).	1	[1]
	MMO Decisions	(iii) I Add HC*l* / H_2SO_4 / KI / K_2CrO_4 / NH_3*	1	
	MMO Collection	II white ppt/white ppt/yellow ppt/yellow ppt/white ppt insoluble in excess. * If not Pb^{2+} in (ii) but one of Al^{3+}, Ba^{2+}, Ca^{2+}, Zn^{2+} allow suitable reagent mark: K_2CrO_4 for Ba^{2+} and NH_3 for the other three. However, observation must be correct for $\mathbf{Pb^{2+}}$.	1	[2]

General comment

(b) (i) The majority of candidates were able to gain at least two marks in this section. The most commonly awarded marks were for the two white precipitates in the first two steps and the white precipitate soluble in excess aqueous sodium hydroxide. However, there are still candidates who report 'white solution' or 'cloudy white' instead of 'white precipitate'. The heating section was not as familiar to candidates and many possible observations were omitted. The mark most commonly awarded was for the brown gas though some were able to identify NO_2 and/or O_2 from a correct test with a positive result. The mark least awarded was for noting the solid turning yellow or for the sound made by the solid as it was heated.

(ii) Pb^{2+} was the cation most commonly identified though a few candidates did not have sufficient correct observations for this conclusion.

(iii) A large majority of candidates selected a suitable reagent, though a small number did not give its full name or formula so were unable to access the first mark. The second mark was frequently awarded as most candidates reported the correct observation for Pb^{2+} with their chosen reagent.

Example candidate response – grade A

(b) (i) You are provided with **FA 6** both as a solid and in aqueous solution. Complete the following table.

test	*observations*
To a small spatula measure of **FA 4** in a test-tube, add enough distilled water to make a solution. Add 1 cm depth of **FA 6** solution.	~~A white ppt was formed~~ The solid dissolves to give a colourless solⁿ A white ppt was formed ✓
To a small spatula measure of **FA 5** in a test-tube, add enough distilled water to make a solution. Add 1 cm depth of **FA 6** solution.	~~A white ppt was formed~~ The solid dissolves to give a colourless solⁿ A white ppt was formed ✓
To 1 cm depth of **FA 6** solution in a test-tube, add aqueous sodium hydroxide.	A white precipitate was formed ✓ The precipitate dissolves in excess of aqueous sodium ✓ hydroxide to give a colourless solution.
Carefully heat the solid **FA 6** in the test-tube provided. Note: **two** gases are released.	The solid decompose to give a yellow solid. ✓ A brown gas ✓ was evolved. Gas was NO_2 ✓ A second gas is evolved which bleaches damp red litmus paper. Gas was Cl_2. ✗

[6]

(ii) From the results of the tests in **(i)**, identify the cation present in **FA 6**.

Cation present in **FA 6** is ....Pb^{2+} ✓.......... [1]

(iii) Suggest and use another reagent to confirm the cation present in **FA 6**.

reagent ..Dilute sulphuric acid ✓..........

observation.....A white precipitate was formed. ✓..........[2]

Examiner comment – grade A

The observations using solutions in **(i)** are detailed and fully correct. The observations for heating solid **FA 6** were more detailed than seen in many scripts. Although NO_2 will bleach litmus paper so the inference of chlorine as the second gas is understandable, the thermal decomposition of nitrates is covered in the syllabus so should not be unfamiliar. Parts **(ii)** and **(iii)** were fully correct.

Example candidate response – grade C

(b) (i) You are provided with **FA 6** both as a solid and in aqueous solution. Complete the following table.

test	*observations*
To a small spatula measure of **FA 4** in a test-tube, add enough distilled water to make a solution. Add 1 cm depth of **FA 6** solution.	A white ppt is ~~given off~~ formed.
To a small spatula measure of **FA 5** in a test-tube, add enough distilled water to make a solution. Add 1 cm depth of **FA 6** solution.	A white ppt is formed ✓
To 1 cm depth of **FA 6** solution in a test-tube, add aqueous sodium hydroxide.	A white ppt is formed but in excess of NaOH (aq) the ~~solution~~ solid dissolves and turns colourless ✓
Carefully heat the solid **FA 6** in the test-tube provided. Note: **two** gases are released.	Pop sounds a given off ✓ with a ~~blow~~ brown glow around the test tube. It turns blue litmus red.

[6]

(ii) From the results of the tests in **(i)**, identify the cation present in **FA 6**.

Cation present in **FA 6** is ....Pb^{2+}.................. ✓ [1]

(iii) Suggest and use another reagent to confirm the cation present in **FA 6**.

reagent ..Aqueous Ammonia (NH_3 (aq)) ✓

observation....White ppt...[2]

Examiner comment – grade C

The formation of the white precipitates was correctly reported as was the solubility of the hydroxide precipitate in excess sodium hydroxide. 'Pop sounds given off' was taken to mean the heated solid was decrepitating and there was no reference to a lighted splint to indicate that it referred to a test for hydrogen gas. The 'brown glow around the test tube' was not sufficiently precise to be credited. 'It' should not be used as it is imprecise. The observations were used to correctly identify the cation in **(ii)** and the reagent selected was suitable in **(iii)**. However, use of aqueous ammonia involves testing with a small volume and then with excess and the solubility of the lead(II) hydroxide precipitate in excess ammonia was not investigated.

Example candidate response – grade E

(b) **(i)** You are provided with **FA 6** both as a solid and in aqueous solution. Complete the following table.

test	*observations*
To a small spatula measure of **FA 4** in a test-tube, add enough distilled water to make a solution. Add 1 cm depth of **FA 6** solution.	~~An effulate ppt is~~ solid dissolves and a ~~green~~ colourless solution is obtained. A white ppt is obtained when FA6 is added.
To a small spatula measure of **FA 5** in a test-tube, add enough distilled water to make a solution. Add 1 cm depth of **FA 6** solution.	solid dissolves to give a colourless solution. A milky white ppt is obtained when FA6 solution is added. ✓
To 1 cm depth of **FA 6** solution in a test-tube, add aqueous sodium hydroxide.	A white ppt is produced which is soluble in excess to form a colourless solution. ✓
Carefully heat the solid **FA 6** in the test-tube provided. Note: **two** gases are released.	Pungent smell of ammonia observed An orange, brownish gas vapour is observed of SO_2. ✗

[6]

(ii) From the results of the tests in **(i)**, identify the cation present in **FA 6**.

Cation present in **FA 6** is Pb^{2+} ✓ [1]

(iii) Suggest and use another reagent to confirm the cation present in **FA 6**.

reagent Addition of potassium dichromate ✗

observation A yellow ppt is observed. ✓ [2]

Examiner comment – grade E

Again the observations for the tests on the solution of **FA 6** in **(i)** were fully correct. Candidates should be discouraged from trying to identify gases by smell; a chemical test is safer and is more likely to be credited. The colour of the gas was incorrectly reported and the identity of SO_2 was inconsistent with the observation. The identity of the cation was correct in **(ii)** but the reagent chosen in **(iii)** did not show use of the Qualitative Analysis Notes. However, the observation was correct as the solubility of lead(II) chromate is so low that the equilibrium is shifted from dichromate to chromate.