Cambridge Assessment International Education

Example Responses – Paper 3

Cambridge International AS & A Level Chemistry 9701

For examination from 2022

Cambridge Pathway

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Introduction

The main aim of this booklet is to exemplify standards for those teaching Cambridge International AS & A Level Chemistry 9701.

This booklet contains responses to all questions from June 2022 Paper 34, which have been written by a Cambridge examiner. Responses are accompanied by a brief commentary highlighting common errors and misconceptions where they are relevant.

The question papers, mark schemes and instructions are available to download from the School Support Hub.

9701 June 2022 Question Paper 34

9701 June 2022 Mark Scheme 34

Past exam resources and other teaching and learning resources are available from the School Support Hub.

Question 1

Quantitative analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show the precision of the apparatus you used in the data you record.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

1 Calcium carbonate reacts with hydrochloric acid to release carbon dioxide.

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

The concentration of the hydrochloric acid can be determined by reacting it with calcium carbonate and measuring the volume of carbon dioxide formed.

FB 1 is hydrochloric acid, HCl.
FB 2 is calcium carbonate, $CaCO_3$.

(a) Method

- Fill the tub with tap water to a depth of approximately 5 cm.
- Fill the 250 cm^3 measuring cylinder **completely** with water. Hold a piece of paper towel firmly over the top, invert the measuring cylinder and place it in the water in the tub.
- Remove the paper towel and clamp the inverted measuring cylinder so the open end is in the water just above the base of the tub.
- Using the 50 cm^3 measuring cylinder, transfer 50 cm^3 of **FB 1** into the flask. Check that the bung fits tightly into the neck of the flask, clamp the flask and place the end of the delivery tube into the inverted 250 cm^3 measuring cylinder.
- Remove the bung from the neck of the flask. Tip all the **FB 2**, from the container, into the acid in the flask and replace the bung immediately. Remove the flask from the clamp and swirl it to mix the contents.
- Replace the flask in the clamp. Leave for several minutes, swirling the flask occasionally.

You may wish to start Question 3 while the gas is being produced.

- When the reaction stops producing gas, record the final volume of gas in the measuring cylinder.

Keep the flask and contents for use in 1(c)(i).

volume of gas = ...110.......... cm^3 [2]

Accuracy marks depend on the supervisor's volume of gas collected so the marks are centre- or lab-dependent.

Examiner comment

An example was a supervisor's volume of 120 cm^3 and the volume given as 110.0 cm^3. While the value is within 10 % of the supervisor's and should be awarded 2 marks, only 1 marks could be awarded. The calibrations on a 250 cm^3 measuring cylinder (at 2 cm^3) do not allow it to be read to the level of accuracy given in this response.

(b) Calculations

(i) Calculate the amount, in mol, of carbon dioxide collected in the measuring cylinder. (Assume that 1 mol of gas occupies 24.0 dm^3 under these conditions.)

0.11 / 24 =

amount of CO_2 = ...4.58 x 10^{-3}.... mol [1]

Examiner comment

Candidates should be aware that the molar gas volume is given in the 'Important values, constants and standards' section of the question paper.

(ii) Use your answer to **(b)(i)** and the equation on page 2 to calculate the concentration, in mol dm^{-3}, of hydrochloric acid in **FB 1**. Show your working.

4.58 x 10^{-3} x 2 x 1000 / 50 = 0.183

concentration of HC*l* = ...0.183.... mol dm^{-3}
[2]

(c) (i) A student thinks that the mass of **FB 2** should be measured.

Explain, by observing the contents of the flask, why this is not necessary.

When the reaction finished there is still white solid left in the flask.

This shows that the calcium carbonate is in excess (so it is not

necessary to find the mass added). [2]

Examiner comment

Candidates who referred to the unreacted solid as 'precipitate' could not be awarded both marks. It is important for candidates to use chemistry-specific language correctly.

(ii) In this experiment some carbon dioxide is lost before the bung is replaced.

Suggest a change that could be made to minimise the loss of gas. Explain how this change minimises the loss of gas.

*Place **FA 2** in an ignition tube and prop it (upright) against the (inner) wall of the flask. Add the acid carefully (so the tube stays in place). Insert the bung then shake the flask (so the tube falls) and the reaction starts.* [1]

[Total: 8]

Examiner comment

- Candidates should read the task carefully so they provide suitable responses: ways of decreasing the solubility of the carbon dioxide formed do not answer the question.
- Many candidates who suggested using a closed system did not indicate how this would work so could not be awarded the mark.
- Marks were given to candidates who suggested feasible ways of decreasing the rate of reaction so less gas was lost prior to inserting the bung.

Question 2

2 In this experiment you will use a thermometric method to determine the concentration of a sample of alkali. You will mix varying volumes of acid with a fixed volume of the alkali and measure the temperature rises that occur.

You will use your experimental data to calculate the enthalpy change for the neutralisation of the acid with alkali.

FB 3 is aqueous sodium hydroxide, NaOH.
FB 4 is 2.20 mol dm^{-3} hydrochloric acid, HC*l*.

(a) Method

- Support the cup in the 250 cm^3 beaker.
- Use the thermometer to measure the initial temperature of **FB 3**.

initial temperature of **FB 3** = ...27.0.......... °C

- Fill a burette with distilled water.
- Fill the other burette with **FB 4**. Label this burette **FB 4**.
- For **Experiment 1**, use the 10 cm^3 pipette to transfer 10.0 cm^3 of **FB 3** into the cup.
- Add 9.00 cm^3 of distilled water from the burette into the same cup.
- Add 1.00 cm^3 of **FB 4** from the other burette into the same cup.
- Stir the mixture and use the thermometer to measure the maximum temperature obtained.
- Record the maximum temperature in the table.
- Empty and shake dry the cup ready for use in **Experiment 2**.
- Repeat the method using 10.0 cm^3 of **FB 3** for each experiment and the volumes of water and **FB 4** shown in the table. In each case, measure and record the maximum temperature.

Table 2.1

experiment	volume water / cm^3	volume **FB 4** / cm^3	maximum temperature / °C
1	9.00	1.00	29.5
2	7.00	3.00	32.0
3	5.00	5.00	34.0
4	3.00	7.00	34.0
5	1.00	9.00	34.0
6	6.00	4.00	33.5
7	4.00	6.00	34.0

I	
II	
III	
IV	
V	

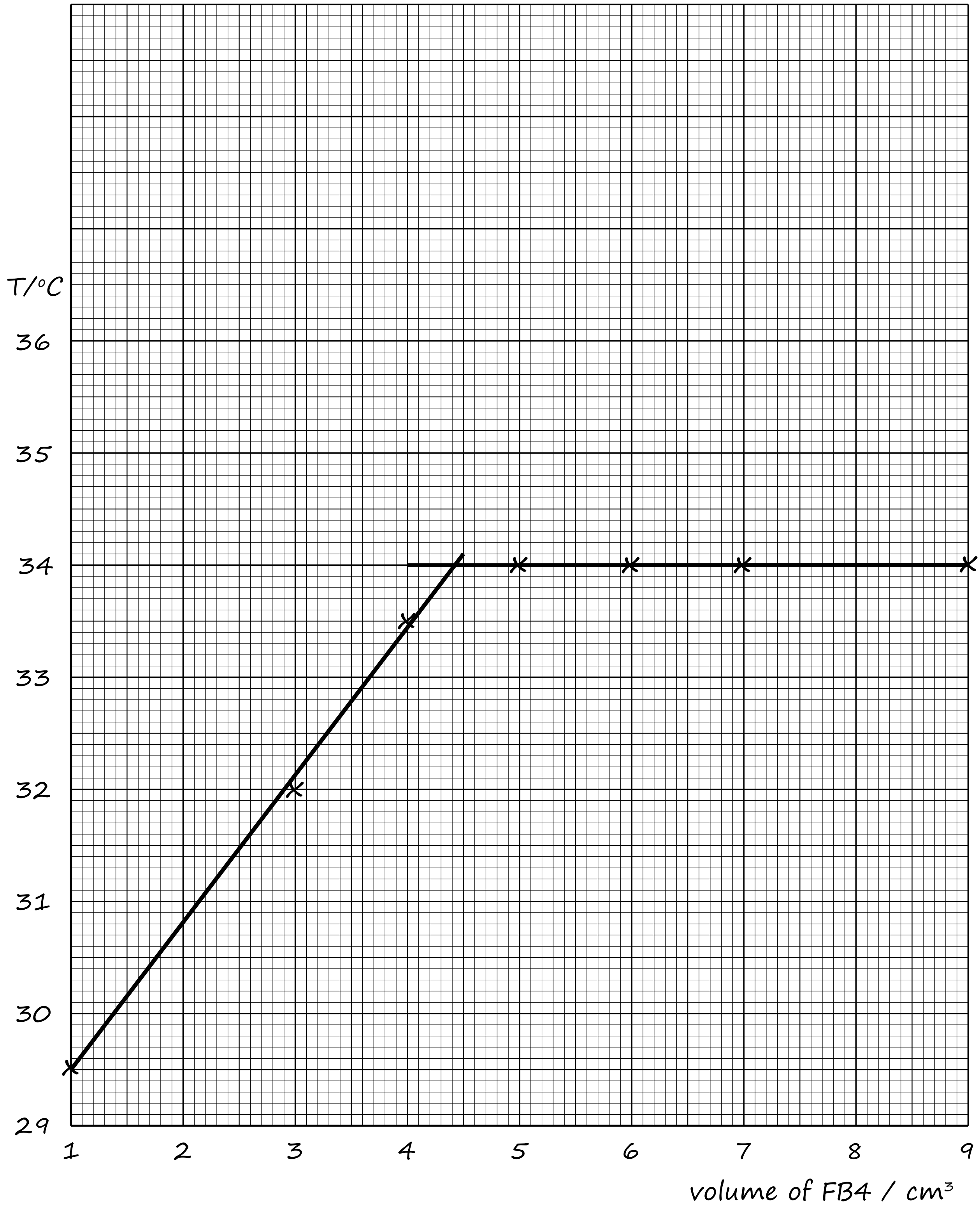
Carry out **two** further experiments which will enable you to determine more precisely the volume of **FB 4** that gives the highest maximum temperature.

Record your measurements for these **two** experiments in the table. [5]

Examiner comment

- As thermometers are calibrated at 1 ºC, candidates should record readings to the nearest 0.5 ºC.
- The most useful extra experiments for candidates to select involved using volumes either side of those for the initial maximum temperature: these should give greater clarity of the volume of acid needed to neutralise the 10.0 cm^3 of alkali.
- Accuracy marks depended on the difference between the supervisor's and candidate's increase in temperature for 5.00 cm^3 acid added. Centres and venues should ensure their best practical chemists carry out the practical tasks and be prepared to repeat them if necessary.

(b) Plot a graph of the maximum temperature reached (*y*-axis) and the volume of **FB 4** used (*x*-axis).
The scale on the *y*-axis should include a temperature 2 °C above the highest maximum temperature reached. Circle any points you consider to be anomalous.



I	
II	
III	
IV	

Draw two straight lines of best fit on your graph. One line should show where the maximum temperature recorded was increasing. The other line should be after the highest maximum temperature. Extrapolate both lines so that they intersect.
Use your graph to determine the volume of **FB 4** that reacts with 10.00 cm^3 of **FB 3**.

volume of **FB 4** = ...4.4.............. cm^3 [4]

Examiner comment

- The scale for the y-axis cannot start at 0 °C if the plotting area is to be greater than half the grid in both directions. The scale must include room for the 2 °C above the highest maximum temperature recorded. Candidates should ensure that their points when plotted will extend to at least the minimum area.
- The centre of each cross or dot must be correctly positioned either on a line or within the correct half small square if it is supposed to be off the line. Candidates should use a sharp pencil to ensure accurate plotting.
- A small allowance was made where there were fewer than four points available for drawing a line of best fit. However, points needed be close to and balanced either side of a line of best fit and the line should not be capable of rotation. Although not relevant in this question, candidates should be aware that the line of best fit may be a smooth curve rather than a straight line. Candidates would benefit from practice in this skill.
- Candidates needed to make sure the value for the intersect reflected the scale used on the x-axis: an integer value here was not appropriate. In the example given, the mark would be awarded for 4.4 cm^3 (nearest 0.1 cm^3) or for a value in the range 4.41 – 4.46 cm^3. (Each candidate is marked according to the intersect on their graph. There is no one 'correct' value.)

(c) (i) Give your answers to **(c)(ii)**, **(c)(iii)**, **(c)(iv)** and **(c)(v)** to an appropriate number of significant figures. [1]

The mark was awarded for the suitable display of numerical answers to the rest of 2(c).

Examiner comment

Candidates should look at the calibrations of the apparatus they use and the number of significant figures quoted in the concentrations or masses of reactants to decide on the number of significant figures to use in their answers. Using the information supplied for this task, candidates should have given all final answers to 2–4 sf. Those giving single figures or complete calculator displays could not be awarded the mark.

(ii) Calculate the amount, in mol, of hydrochloric acid in the volume of **FB 4** in **(b)**.
If you were unable to determine an answer to **(b)** use 4.10 cm^3 as the volume of **FB 4**.

(Using the 4.4 cm^3,) the amount of HCl =

2.2 x 4.4 / 1000 = 9.68 x 10^{-3}

amount of HC*l* = ...*9.68 x 10^{-3}*.... mol [1]

Examiner comment

Candidates may use the default value without penalty even if they record a volume of acid reacting from the graph.

(iii) Use your answer to **(c)(ii)** and the information on page 4 to calculate the concentration, in mol dm^{-3}, of sodium hydroxide in **FB 3**.

concentration of 9.68 x 10–3 x 1000 / 10 = 0.968

concentration of NaOH = ...*0.968*.... mol dm^{-3} [1]

(iv) Calculate the energy released when the volume of **FB 4** in **(b)** is neutralised by sodium hydroxide. Show your working.
(Assume that 4.18 J of energy changes the temperature of 1.0 cm^3 of solution by 1.0 °C.)

energy released = 20 x 4.18 x (34.0 – 27.5) = 543(.4) J

energy released = ...543(.4)...... J [2]

Examiner comment

Candidates needed to determine the total volume of solution in the cup: (alkali + [acid + water] = 10.0 + 10.00 cm^3). Hence 20 g is used in the equation q = mcΔT when calculating a value for the energy released as the density of aqueous solutions is close to 1.0 g cm^{-3} or 1.0 kg dm^{-3}.

(v) Use your answers to **(c)(ii)** and **(c)(iv)** to calculate the enthalpy change of neutralisation, in kJ mol^{-1}, for 1.0 mol of hydrochloric acid.

enthalpy change = (543.4 / 1000) x (1 / 9.68) x 10^{-3} = –56.1 kJ mol^{-1}

enthalpy change = ...–56.1...... kJ mol^{-1}

Examiner comment

Candidates should note the units displayed at the ends of the answer lines to ensure success in calculations where there are factors of 1000 to consider.

(d) **(i)** The theoretical value of the enthalpy change of neutralisation is –57.6 kJ mol^{-1}.

Calculate the percentage error in your value of the enthalpy change from **(c)(v)**.
Show your working.

(Assume that the conditions under which you carried out your experiment in **(a)** are identical to the conditions used to determine the theoretical value.)

(57.6 – 56.1) x 100 / 57.6 = 2.6 %

percentage error = ...2.6.......... % [1]

Examiner comment

- Candidates should be aware that the denominator in this type of calculation is always the theoretical value. As the task was to find the percentage error in the value in **(c)(v),** candidates had to use the difference between the theoretical and experimental values as the numerator (and also to take the signs into account).
- It was acceptable for candidates to calculate the percentage accuracy and subtract the answer from 100%.

(ii) Suggest **one** modification to the procedure used in **(a)** that would give a more accurate value for the enthalpy change of neutralisation.

Do **not** suggest any modifications to apparatus in your answer.

Measure the initial temperatures of the solutions for each experiment.

....

....

.... [1]

[Total: 17]

Examiner comment

Candidates needed to read the task carefully. 'Use a lid' was a common response which ignored the instructions given in this part.

Question 3

Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

- colour changes seen
- the formation of any precipitate and its solubility (where appropriate) in an excess of the reagent added
- the formation of any gas and its identification (where appropriate) by a suitable test.

You should record clearly at what stage in a test an observation is made.

Where no change is observed you should write 'no change'.

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

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

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

No additional tests should be attempted.

3 Half fill the 250 cm^3 beaker with water, heat until the water is nearly boiling and then turn off the Bunsen burner. This is your hot water bath for use in **(a)(i)**.

(a) You are provided with aqueous solutions **FB 5**, **FB 6**, **FB 7** and **FB 8**. The solutions are known to be hydrochloric acid, hydrogen peroxide, methanoic acid and sulfuric acid. All the solutions have the same concentration.

Note: the order of **FB 5** to **FB 8** does **not** correspond to the order of identities given above.

(i) Carry out the following tests using a 2 cm depth of each reagent in a test-tube. Record your observations in Table 3.1.

test	*observations*			
	FB 5	**FB 6**	**FB 7**	**FB 8**
Test 1 Add a piece of magnesium.	rapid bubbling gas pops with a lighted splint	fast fizzing	slower bubbling	no visible change
Test 2 Add a few drops of acidified aqueous potassium manganate(VII). Place the test-tube in the hot water bath.	no visible change $KMnO_4$ stays purple	no reaction purple solution turns slihtly brown on heating	$KMnO_4$ turns slightly brown and is decolourised on heating	purple solution turns colourless slight fizzing

Table 3.1

[5]

Examiner comment

- Candidates needed to look at the tests listed, think about the possible outcomes and prepare for them before starting any practical exercise in qualitative analysis.
- Candidates should identify any gas formed by a suitable test. Those testing the gas with limewater had not considered which gas is formed in the reaction between a reactive metal and a dilute acid.
- Aqueous acidified potassium manganate(VII) is an oxidising agent, so candidates should consider which of the named solutions could be oxidised.
- 'No change' was also acceptable for the test using $KMnO_4$ and FB 6 as the water bath may not have been hot enough for sufficient chloride ions to be oxidised and a colour change to be seen.
- 'Colour changes seen' means candidates needed to describe the initial colour as well as the colour formed during the reaction.

(ii) Use your observations to complete the sentences. Explain your answer.

FB 7 is methanoic acid .

FB 8 is hydrogen peroxide. .

explanation There was no bubbling with FB 8 and Mg so it could not be an acid.

[2]

Examiner comment

Candidates needed to provide more explanation for the methanoic acid to be identified than for hydrogen peroxide. It is insufficient for them to write that effervescence was observed with magnesium as all the acids gave this result. The results of Test 2 distinguished methanoic acid from the other acids and the results of Test 1 distinguished it from hydrogen peroxide.

(iii) Carry out **one** additional test that allows you to distinguish between **FB 5** and **FB 6**.

Record your test and the result you obtained.

Test with aqueous silver nitrate: FB 5 no change, FB 6 white ppt.

FB 5 is sulfuric acid .

FB 6 is hydrochloric acid .

[2]

Examiner comment

- Candidates needed to give the full name or correct formula of any reagent selected for use. Those writing Ag^+ or $BaNO_3$ could not be awarded the mark. (Aqueous barium chloride or aqueous barium nitrate were also suitable for distinguishing between the sulfate and chloride ions.)
- As the majority of candidates tested for either chloride or sulfate ions, they did not need to use a second reagent or to carry out a second test. Those adding sulfuric acid to the barium sulfate precipitate lost the 'test' mark: using a sulfate to check the solubility of a sulfate or sulfite precipitate does not work.

(iv) Write an **ionic** equation for the reaction of magnesium with **FB 5**. Include state symbols.

$Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$ [1]

Examiner comment

- Candidates needed to check that they were writing an equation for the stipulated reaction.
- Almost all candidates correctly reported effervescence on adding magnesium to **FB 5**, which indicated **FB 5** was one of the acids. As an **ionic** equation is needed (and no precipitate was formed) candidates did not need to include the anion as it is a 'spectator ion'.
- Candidates need to include state symbols for all species in the (balanced) equation.

(v) Describe the observations that you would expect to see if the tests in **(a)(i)** were repeated using aqueous ethanoic acid.

observation with magnesium (slow) effervescence

observation with acidified aqueous potassium manganate(VII) no change

[2]

Examiner comment

Candidates should be aware that as ethanoic acid has no −CHO group it cannot be oxidised under the conditions given.

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(b) **FB 9** is an aqueous solution containing one cation from those listed in the Qualitative analysis notes.

Carry out tests that would identify the cation present in **FB 9**. Record your tests, observations and the identity of the cation.

+ NaOH(aq)	white ppt insoluble in excess
+ NH3(aq)	white ppt insoluble in excess

The cation is ....Mg^{2+}.......... . [3]

Examiner comment

Candidates writing 'Magnesium' gave an incomplete answer as a cation also has a charge.

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