Example Candidate Responses

Cambridge International AS & A Level

Cambridge International AS & A Level Chemistry

9701

Paper 5 – Planning, Analysis and Evaluation

Cambridge Advanced

CAMBRIDGE
International Examinations

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Contents

Introduction

The main aim of this booklet is to exemplify standards for those teaching Cambridge International AS and A Level Chemistry (9701), and to show how different levels of candidates' performance (high, middle and low) relate to the subject's curriculum and assessment objectives.

In this booklet candidate responses have been chosen to exemplify a range of answers. Each response is accompanied by a brief commentary explaining the strengths and weaknesses of the answers.

For each question, each response is annotated with a clear explanation of where and why marks were awarded or omitted. This, in turn, is followed by examiner comments on how the answer could have been improved. In this way it is possible for you to understand what candidates have done to gain their marks and what they will have to do to improve their answers. At the end there is a list of common mistakes candidates made in their answers for each question.

This document provides illustrative examples of candidate work. These help teachers to assess the standard required to achieve marks, beyond the guidance of the mark scheme. Some question types where the answer is clear from the mark scheme, such as short answers and multiple choice, have therefore been omitted.

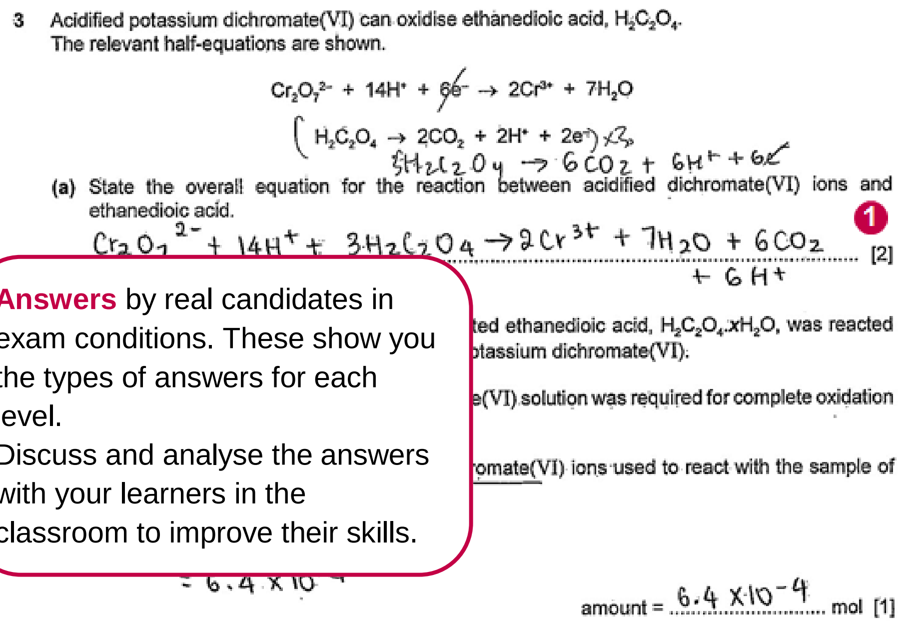
The questions, mark schemes and pre-release material used here are available to download as a zip file from Teacher Support as the Example Candidate Responses Files. These files are:

Question Paper 22, June 2016	
Question paper	9701_s16_qp_22.pdf
Mark scheme	9701_s16_ms_22.pdf
Question Paper 33, June 2016	
Question paper	9701_s16_qp_33.pdf
Mark scheme	9701_s16_ms_33.pdf
Question Paper 42, June 2016	
Question paper	9701_s16_qp_42.pdf
Mark scheme	9701_s16_ms_42.pdf
Question Paper 52, June 2016	
Question paper	9701_s16_qp_52.pdf
Mark scheme	9701_s16_ms_52.pdf

Past papers, Examiner Reports and other teacher support materials are available on Teacher Support at **https://teachers.cie.org.uk**

How to use this booklet

Example candidate response – high



3 Acidified potassium dichromate(VI) can oxidise ethanedioic acid, $H_2C_2O_4$.
The relevant half-equations are shown.

$Cr_2O_7^{2-}$ + $14H^+$ + ~~6~~e^- → $2Cr^{3+}$ + $7H_2O$

($H_2C_2O_4$ → $2CO_2$ + $2H^+$ + $2e^-$) ×3

$3H_2C_2O_4$ → $6CO_2$ + $6H^+$ + $6e^-$

(a) State the overall equation for the reaction between acidified dichromate(VI) ions and ethanedioic acid.

$Cr_2O_7^{2-}$ + $14H^+$ + $3H_2C_2O_4$ → $2Cr^{3+}$ + $7H_2O$ + $6CO_2$ + $6H^+$ [2]

①

ted ethanedioic acid, $H_2C_2O_4.xH_2O$, was reacted
otassium dichromate(VI).

e(VI) solution was required for complete oxidation

omate(VI) ions used to react with the sample of

= 6.4 x 10⁻⁴

amount = 6.4×10^{-4} mol [1]

Examiner comments

① This equation contains all the correct species from the half-equations given so one mark has been awarded. The

Answers by real candidates in exam conditions. These show you the types of answers for each level.
Discuss and analyse the answers with your learners in the classroom to improve their skills.

Examiner comments are alongside the answers, linked to specific part of the answer. These explain where and why marks were awarded. This helps you to interpret the standard of Cambridge exams and helps your learners to refine their exam technique.

How the candidate could have improved their answer

In **(a)** the candidate needed to remember that the key
loss in one half-equation must balance the electron ga

In **(b)(iii)** the candidate used the correct method but n
number of significant figures in the answer must corre
provided.

This explains how the candidate could have improved their answer and helps you to interpret the standard of Cambridge exams and helps your learners to refine exam technique.

Common mistakes candidates made in this question

(a) The skills needed to combine two half-equations and
tricky for many candidates. Good candidates often got c
them out, while weaker candidates failed to recognise th

(b) The first two parts of the calculation were generally c
the *Mr* calculation depended on the previous answer tog

This lists the common mistakes candidates made in answering each question. This will help your learners to avoid these mistakes at the exam and give them the best chance of achieving a high mark.

Assessment at a glance

Candidates for Advanced Subsidiary (AS) certification take Papers 1, 2 and 3 (either Advanced Practical Skills 1 or Advanced Practical Skills 2) in a single examination series.

Candidates who, having received AS certification, wish to continue their studies to the full Advanced Level qualification may carry their AS marks forward and take Papers 4 and 5 in the examination series in which they require certification.

Candidates taking the full Advanced Level qualification at the end of the course take all five papers in a single examination series.

Candidates may only enter for the papers in the combinations indicated above.

Candidates may not enter for single papers either on the first occasion or for resit purposes.

All components are externally assessed.

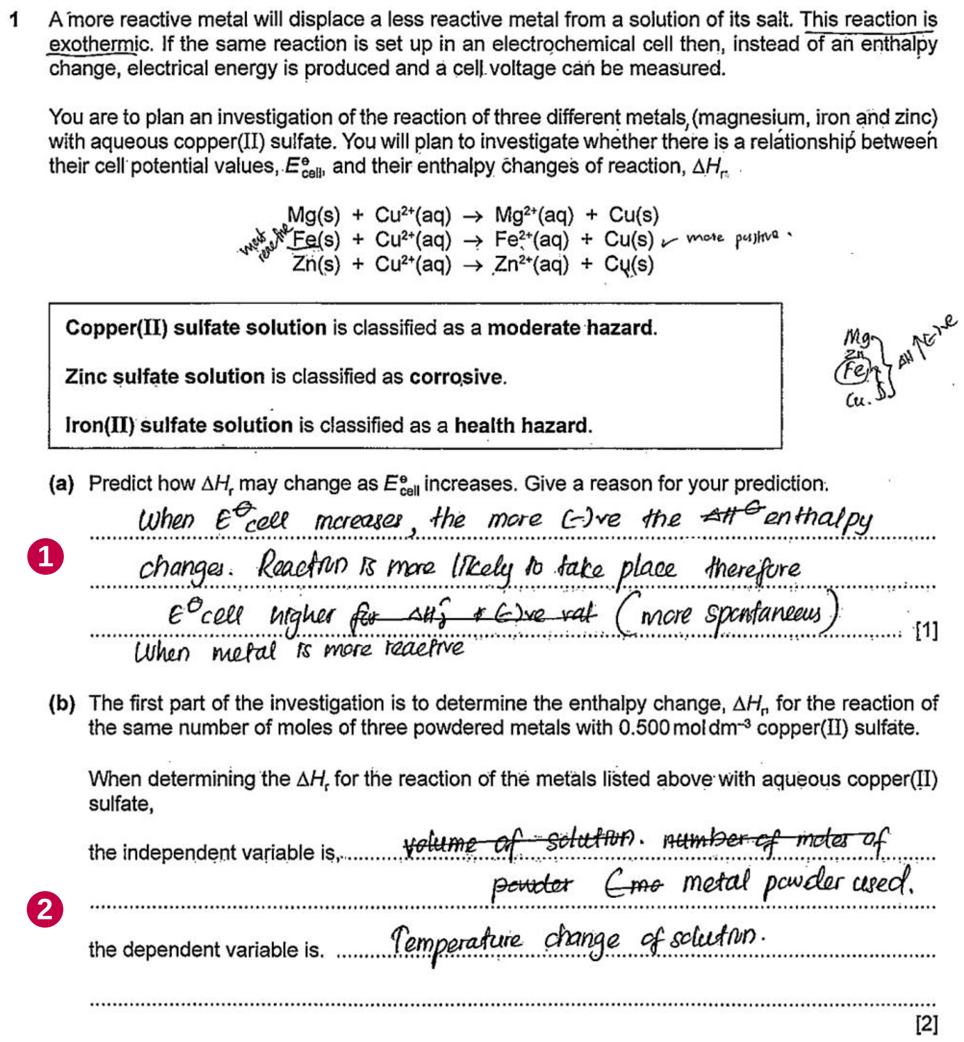
Component	Weighting	
	AS Level	A Level
Paper 1 Multiple Choice **1 hour** This paper consists of 40 multiple choice questions, 30 of the direct choice type and 10 of the multiple completion type, all with four options. All questions will be based on the AS Level syllabus content. Candidates will answer all questions. Candidates will answer on an answer sheet. [40 marks]	31%	15.5%
Paper 2 AS Level Structured Questions **1 hour 15 minutes** This paper consists of a variable number of questions of variable mark value. All questions will be based on the AS Level syllabus content. Candidates will answer all questions. Candidates will answer on the question paper. [60 marks]	46%	23%
Paper 3 Advanced Practical Skills **2 hours** This paper requires candidates to carry out practical work in timed conditions. Candidates will be expected to collect, record and analyse data so that they can answer questions related to the activity. The paper will consist of two or three experiments drawn from different areas of chemistry. Candidates will answer all questions. Candidates will answer on the question paper. [40 marks]	23%	11.5%
Paper 4 A Level Structured Questions **2 hours** This paper consists of a variable number of free response style questions of variable mark value. All questions will be based on the A Level syllabus but may require knowledge of material first encountered in the AS Level syllabus. Candidates will answer all questions. Candidates will answer on the question paper. [100 marks]	–	38.5%
Paper 5 Planning, Analysis and Evaluation **1 hour 15 minutes** This paper consists of a variable number of questions of variable mark value based on the practical skills of planning, analysis and evaluation. The context of the questions may be outside the syllabus content, but candidates will be assessed on their practical skills of planning, analysis and evaluation rather than their knowledge of theory. Candidates will answer all questions. Candidates will answer on the question paper. [30 marks]	–	11.5%

Teachers are reminded that the latest syllabus is available on our public website at **www.cie.org.uk** and Teacher Support at **https://teachers.cie.org.uk**

Paper 5 – Planning, Analysis and Evaluation

Question 1

Example candidate response – high



1 A more reactive metal will displace a less reactive metal from a solution of its salt. This reaction is exothermic. If the same reaction is set up in an electrochemical cell then, instead of an enthalpy change, electrical energy is produced and a cell voltage can be measured.

You are to plan an investigation of the reaction of three different metals, (magnesium, iron and zinc) with aqueous copper(II) sulfate. You will plan to investigate whether there is a relationship between their cell potential values, $E^{\ominus}_{cell}$, and their enthalpy changes of reaction, ΔH_r.

$$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$$
$$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$$ ✓ more positive.
$$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$$

most reactive

Copper(II) sulfate solution is classified as a **moderate hazard.**

Zinc sulfate solution is classified as **corrosive.**

Iron(II) sulfate solution is classified as a **health hazard.**

Mg
Zn
Fe
Cu.
ΔH (-)ve

(a) Predict how ΔH_r may change as $E^{\ominus}_{cell}$ increases. Give a reason for your prediction.

① When $E^{\ominus}$cell increases, the more (-)ve the ~~ΔH~~$^{\ominus}$ enthalpy changes. Reaction is more likely to take place therefore $E^{\ominus}$cell higher ~~for ΔH (-)ve val~~ (more spontaneous) when metal is more reactive [1]

(b) The first part of the investigation is to determine the enthalpy change, ΔH_r, for the reaction of the same number of moles of three powdered metals with 0.500 mol dm^{-3} copper(II) sulfate.

When determining the ΔH_r for the reaction of the metals listed above with aqueous copper(II) sulfate,

② the independent variable is, ~~volume of solution~~. ~~number of moles of powder~~ ~~(mo~~ metal powder used.

the dependent variable is. Temperature change of solution.

[2]

Examiner comments

① The candidate makes a correct prediction and explains that both ΔH_r and $E^{\ominus}_{cell}$ are related to the reactivity of the metal.

Mark for (a) = 1/1

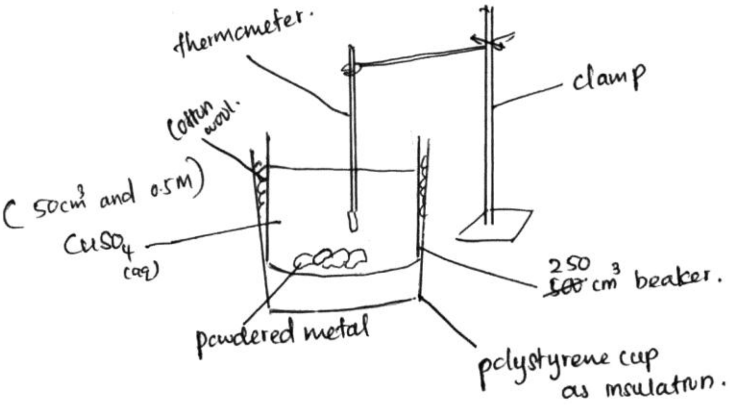
② The candidate completes both sentences correctly.

Mark for (b) = 2/2

Example candidate response – high, continued

You are provided with a sample of powdered metal and 50.0 cm³ of 0.500 mol dm^{-3} aqueous copper(II) sulfate.

(c) **(i)** Draw a fully labelled diagram to show how the apparatus should be set up to allow you to determine the increase in temperature of aqueous copper(II) sulfate.
You should use apparatus normally found in a school or college laboratory.



③

[1]

(ii) State the measurements you would make in your experiment.

final temperature and initial temperature of solution in beaker.

mass / volume of solution ~~after addition of sample~~.

number of moles of metal added (mass of metal added). ④ [2]

(iii) Other than eye protection, state **one** precaution you would take to make sure that the experiment proceeds safely.

Reactions are exothermic wear gloves when handling apparatus ⑤ [1]

Examiner comments

③ The diagram has been drawn clearly and, importantly, shows the thermometer bulb placed in the solution inside a polystyrene cup. The diagram is very well labelled.

Mark for (c) (i) = 1/1

④ The irrelevant measurements have been ignored here.

Mark for (c) (ii) = 2/2

⑤ 'Wear gloves' earns the mark here. The candidate was not asked for a reason but gives one. As there was no indication what the final temperature may become, their reasoning has been accepted.

Mark for (c) (iii) = 1/1

Example candidate response – high, continued

(iv) For the reaction with magnesium, calculate the mass of magnesium, in g, you would use so that it is in a small excess. You must show your working.
[A_r: Mg, 24.3]

⑥ # of moles of $CuSO_4$ present $= \frac{50}{1000} \times 0.5$

$= 0.025$ mol.

mass To react exactly (g) $= \frac{0.025}{1\cancel{24}} \times 24.3$

$= 0.6075$g

mass of Mg = 0.8 g [2]

⑦ **(v)** Explain why the metal used should be in powdered form rather than in strips.

Higher surface area so reaction rate is higher (time taken small) when powdered metal used. Also ensure reaction completion. [1]

⑧ **(vi)** The aqueous copper(II) sulfate and metal mixture should be stirred continuously. Explain why.

To allow reactants to mix well and allow even heat distribution in the solution [1]

(d) In one experiment, the increase in temperature when excess magnesium powder is added to 50.0 cm³ of 0.500 mol dm⁻³ aqueous copper(II) sulfate is 58.5 °C.

Calculate the enthalpy change for this reaction, ΔH_r, in kJ mol⁻¹.
Assume the specific heat capacity, c, of the reaction mixture is 4.18 J g⁻¹ K⁻¹.
Assume 1.0 cm³ of 0.500 mol dm⁻³ aqueous copper(II) sulfate has a mass of 1.0 g.
Include a sign in your answer.

$$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$$

$\Delta\theta = 58.5$

$1cm^3 \rightarrow 1g$.

$m = 50$ g

$\Delta\theta = 58.5$

⑨

$Q = mc\Delta\theta$

$= 50 \times 4.18 \times 58.5$

$= 12,230$ J

Mg:

0.025 mol $\rightarrow 12.2$

1 mol $\rightarrow x$

$x = 488$

$\Delta H_r =$ ~~12.2~~ -488 kJ mol⁻¹ [2]

Examiner comments

⑥ A correct calculation and the mass in g given is an acceptable excess.

Mark for (c) (iv) = 2/2

⑦ A correct explanation of why powdered magnesium is better than a strip of the metal in terms of a higher surface area producing a higher reaction rate.

Mark for (c) (v) = 1/1

⑧ A correct explanation of why the mixture should be stirred.

Mark for (c) (vi) = 1/1

⑨ The candidate shows their working and includes a sign. Unfortunately, only the first mark is awarded (for calculating E = mc∆T) and not the second mark as the candidate rounded too early.

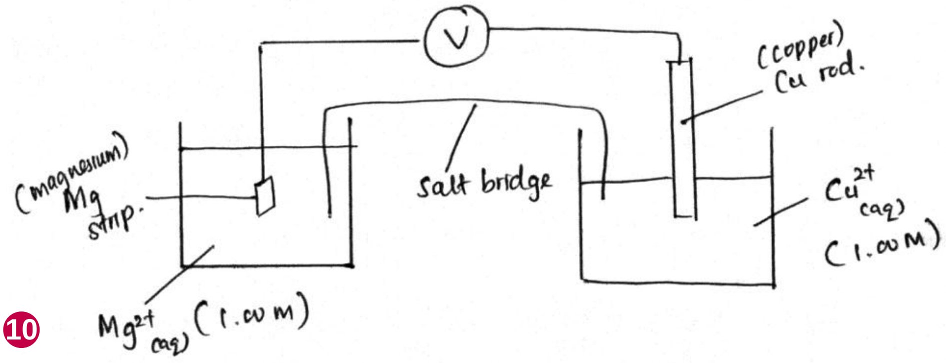
Mark for (d) = 1/2

Example candidate response – high, continued

(e) The second part of the investigation involves determining the cell potential, $E^\ominus_{cell}$, for the three electrochemical cells.

cell reaction
$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$
$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$
$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$

Draw a diagram of the apparatus you would use to measure the $E^\ominus_{cell}$ for the magnesium/copper cell. Your labels should include the **names** of the metals and the **names** and **concentrations** of the solutions you would use.



⑩

[3]

(f) Explain why the enthalpy change determination and cell potential determination should be carried out at the same temperature as each other.

⑪ Temperature needs to be standardised, so that temperature doesnt become the factor that affects $E^\ominus$cell. All condition except the once that are measured should be kept constant. [1]

(g) Accepted $E^\ominus_{cell}$ values are shown for the cell reactions.

⑫

	cell reaction	$E^\ominus_{cell}$/V	ΔH_r	
1	$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$	+2.72	~~-12.2~~	-486
2	$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$	+1.10	~~-8.3~~	-250
3	$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$	+0.78	~~-4.4~~	-130

Use your prediction in **(a)**, your answer to **(d)** and data from the table to predict ΔH_r values for reactions 2 and 3.
Complete the table with these values. [1]

Examiner comments

⑩ The candidate has followed all the instructions successfully. Ideally, the units of concentration should be mol dm^{-3}, but the old fashioned ‘M’ for molar is allowed.

Mark for (e) = 3/3

⑪ The candidate is able to explain that either variable would be dependent upon temperature, thus compromising the idea of a ‘fair test’.

Mark for (f) = 1/1

⑫ The candidate uses their prediction in (a) and their answer to (d) successfully.

Mark for (g) = 1/1

Total marks awarded = 17 out of 18

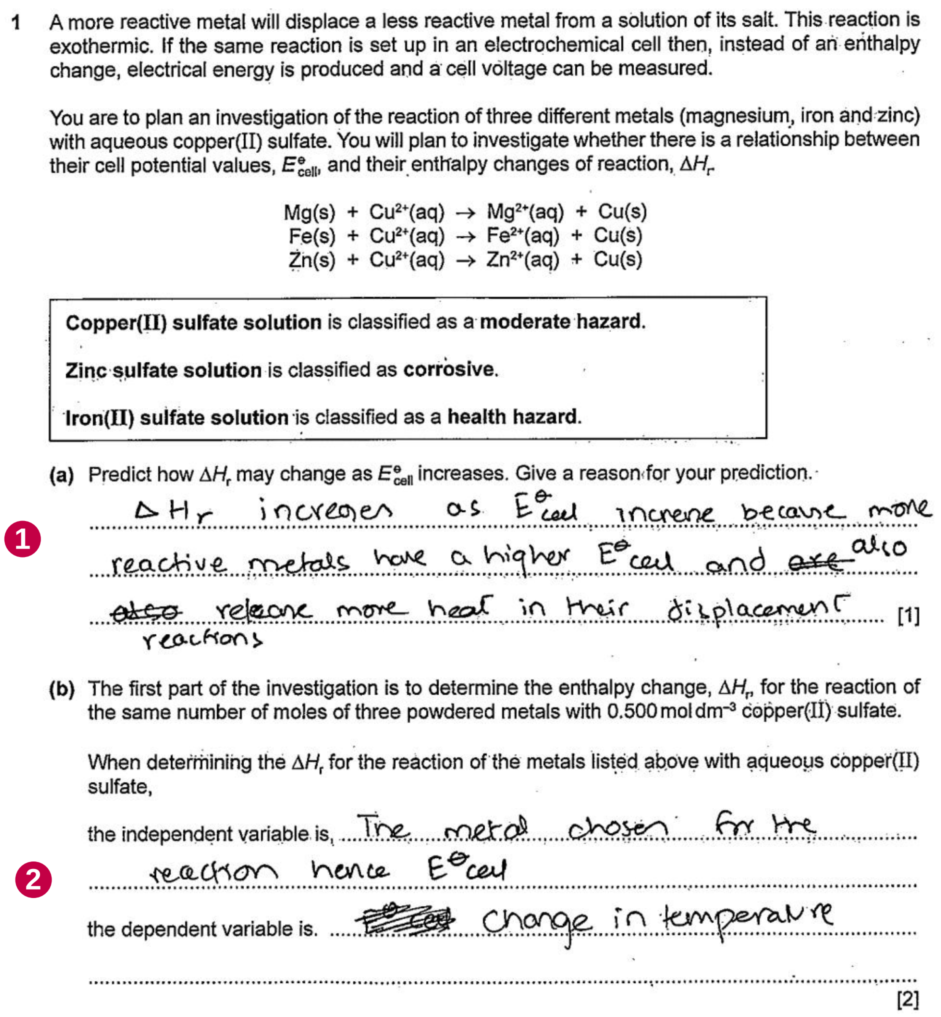
How the candidate could have improved their answer

In part **(d)**, the candidate should ideally have left their answer for the first mark (50.0 × 4.18 × 58.5 = 12 226.5 (J)) in their calculator and used it for the final calculation, rather than rounding the number too early.

Mark awarded = **(a) 1/1**
Mark awarded = **(b) 2/2**
Mark awarded = **(c) (i) 1/1, (ii) 2/2, (iii) 1/1, (iv) 2/2, (v) 1/1, (vi) 1/1**
Mark awarded = **(d) 1/2**
Mark awarded = **(e) 3/3**
Mark awarded = **(f) 1/1**
Mark awarded = **(g) 1/1**

Total marks awarded = 17 out of 18

Example candidate response – middle



1 A more reactive metal will displace a less reactive metal from a solution of its salt. This reaction is exothermic. If the same reaction is set up in an electrochemical cell then, instead of an enthalpy change, electrical energy is produced and a cell voltage can be measured.

You are to plan an investigation of the reaction of three different metals (magnesium, iron and zinc) with aqueous copper(II) sulfate. You will plan to investigate whether there is a relationship between their cell potential values, $E^{\ominus}_{cell}$, and their enthalpy changes of reaction, ΔH_r.

$$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$$
$$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$$
$$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$$

Copper(II) sulfate solution is classified as a **moderate hazard.**

Zinc sulfate solution is classified as **corrosive.**

Iron(II) sulfate solution is classified as a **health hazard.**

(a) Predict how ΔH_r may change as $E^{\ominus}_{cell}$ increases. Give a reason for your prediction.

① ΔH_r increases as $E^{\ominus}_{cell}$ increase because more reactive metals have a higher $E^{\ominus}_{cell}$ and ~~are~~ also ~~also~~ release more heat in their displacement reactions [1]

(b) The first part of the investigation is to determine the enthalpy change, ΔH_r, for the reaction of the same number of moles of three powdered metals with 0.500 mol dm^{-3} copper(II) sulfate.

When determining the ΔH_r for the reaction of the metals listed above with aqueous copper(II) sulfate,

② the independent variable is, The metal chosen for the reaction hence $E^{\ominus}_{cell}$

the dependent variable is. ~~E_{cell}~~ change in temperature

[2]

Examiner comments

① The candidate makes a correct prediction and explains that reactivity would be the reason.

Mark for (a) = 1/1

② The candidate gives the correct answers.

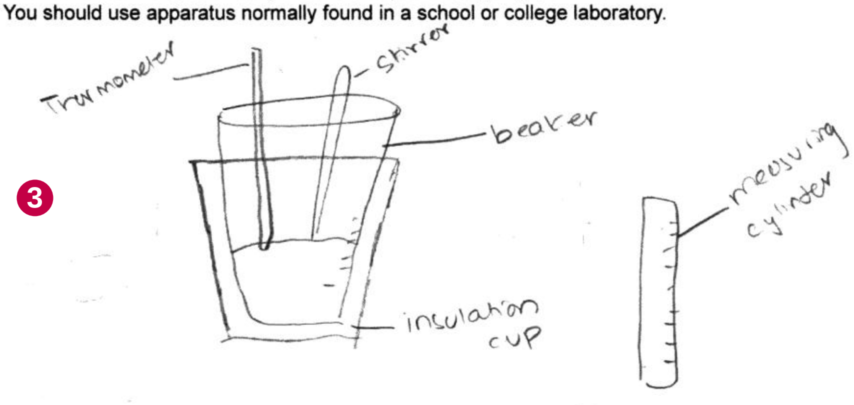
Mark for (b) = 2/2

Example candidate response – middle, continued

You are provided with a sample of powdered metal and 50.0 cm^3 of 0.500 mol dm^{-3} aqueous copper(II) sulfate.

(c) **(i)** Draw a fully labelled diagram to show how the apparatus should be set up to allow you to determine the increase in temperature of aqueous copper(II) sulfate.
You should use apparatus normally found in a school or college laboratory.

③



[1]

(ii) State the measurements you would make in your experiment.

④ The initial temperature of CuSO4 and the final temperature after adding the powered metal

[2]

(iii) Other than eye protection, state **one** precaution you would take to make sure that the experiment proceeds safely.

⑤ Use a large beaker so the contents dont spill out if the reaction is too vigourous.

[1]

Examiner comments

③ The diagram has been drawn clearly and, importantly, shows the thermometer bulb placed in the solution in an insulated cup. The diagram is very well labelled. The mark is awarded here, but the drawing would have been better presented in 2D, rather than as a 3D ‘picture’.

Mark for (c) (i) = 1/1

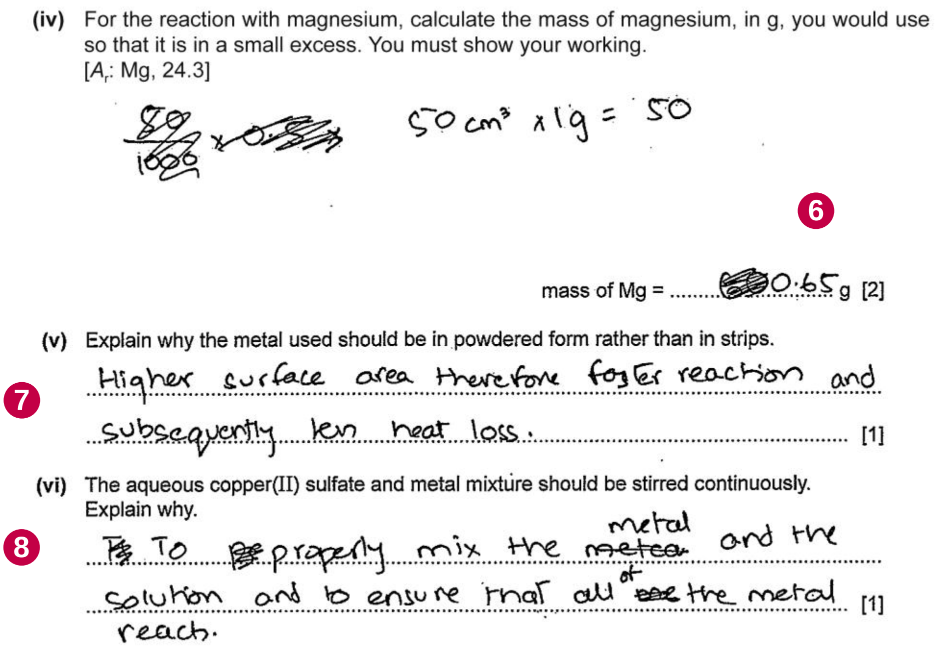
④ The candidate correctly states that the initial and final temperatures should be measured. For the second mark, they should have also stated that the mass of metal should be measured.

Mark for (c) (ii) = 1/2

⑤ The candidate incorrectly states that a larger beaker should be used. They should have stated, ‘Wear gloves’.

Mark for (c) (iii) = 0/1

Example candidate response – middle, continued



(iv) For the reaction with magnesium, calculate the mass of magnesium, in g, you would use so that it is in a small excess. You must show your working.
[A_r: Mg, 24.3]

~~$\frac{80}{1000}$ × 0.[illegible]~~ 50 cm³ × 1g = 50

⑥

mass of Mg = ~~[illegible]~~ 0.65 g [2]

(v) Explain why the metal used should be in powdered form rather than in strips.

⑦ Higher surface area therefore faster reaction and subsequently less heat loss. [1]

(vi) The aqueous copper(II) sulfate and metal mixture should be stirred continuously. Explain why.

⑧ ~~Te~~ To ~~[illegible]~~ properly mix the metal ~~metea~~ and the solution and to ensure that all of ~~eae~~ the metal reach. [1]

Examiner comments

⑥ The full calculation is not shown here, but the candidate has given a mass in g in an acceptable excess.

Mark for (a) = 1/2

⑦ The candidate explains correctly why powdered magnesium is better than a strip of the metal: it has a higher surface area which produces a higher reaction rate and therefore heat loss is reduced.

Mark for (c) (v) = 1/1

⑧ The candidate states that the reason for continual stirring is to enable all the metal to react. This is incorrect, as the question tells candidates that the metal is in excess. The candidate should have explained that stirring distributes the increase of temperature evenly throughout the solution.

Mark for (c) (vi) = 0/1

Example candidate response – middle, continued

(d) In one experiment, the increase in temperature when excess magnesium powder is added to 50.0 cm³ of 0.500 mol dm⁻³ aqueous copper(II) sulfate is 58.5 °C.

Calculate the enthalpy change for this reaction, ΔH_r, in kJ mol⁻¹.
Assume the specific heat capacity, c, of the reaction mixture is 4.18 J g⁻¹ K⁻¹.
Assume 1.0 cm³ of 0.500 mol dm⁻³ aqueous copper(II) sulfate has a mass of 1.0 g.
Include a sign in your answer.

$$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$$

⑨

$$Q = mc\Delta\theta$$

$$Q = 50 \times 4.18 \times 58.5$$

$$Q = 12226.5$$

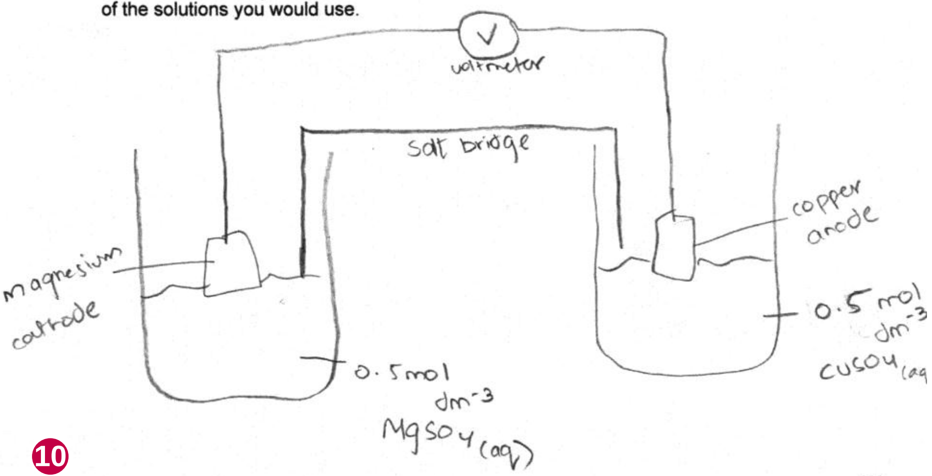
$$\frac{12226.5}{50 \times 0.5} = 489.06$$

ΔH_r = − 0.489 kJ mol⁻¹ [2]

(e) The second part of the investigation involves determining the cell potential, E°_{cell}, for the three electrochemical cells.

cell reaction
$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$
$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$
$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$

Draw a diagram of the apparatus you would use to measure the E°_{cell} for the magnesium/copper cell. Your labels should include the **names** of the metals and the **names** and **concentrations** of the solutions you would use.



[3]

Examiner comments

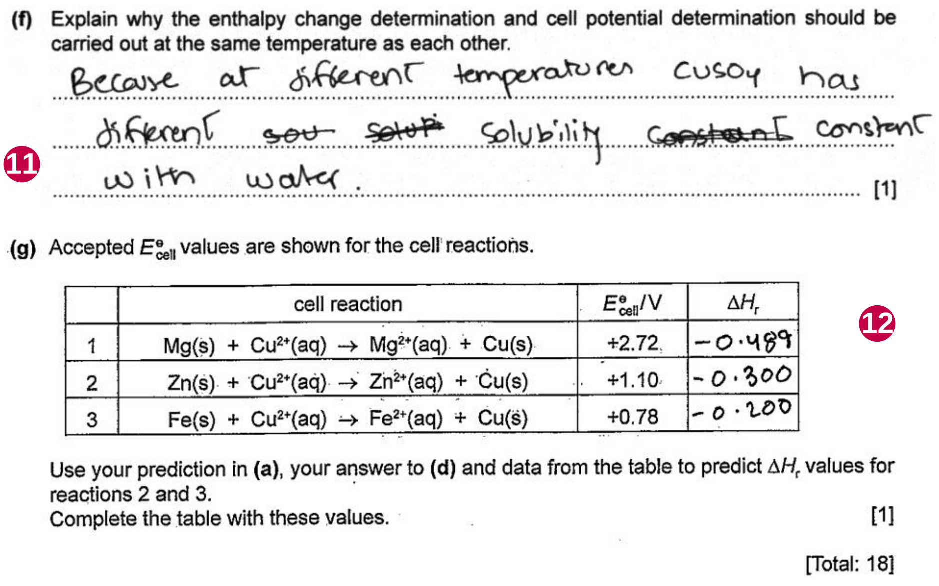
⑨ The candidate shows their working and includes a sign. Unfortunately, only the first mark is awarded (for calculating E = mcΔT) and not the second mark. The second part of the calculation is incorrect by a factor of 3. The candidate should have divided by 0.05 (dm³) rather than 50 (cm³) before converting J mol⁻¹ into kJ mol⁻¹.

Mark for (d) = 1/2

⑩ The candidate has only labelled the metals and solutions successfully here. The diagram should have shown the salt bridge entering both solutions, and the concentrations of the solutions should have been stated as 1(.00) mol dm⁻³.

Mark for (e) = 1/3

Example candidate response – middle, continued



(f) Explain why the enthalpy change determination and cell potential determination should be carried out at the same temperature as each other.

⑪ Because at different temperatures CuSO4 has different ~~sou~~ ~~solut~~ solubility ~~constant~~ constant with water. [1]

(g) Accepted $E^\ominus_{cell}$ values are shown for the cell reactions.

	cell reaction	$E^\ominus_{cell}$/V	ΔH_r
1	$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$	+2.72	−0.489
2	$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$	+1.10	−0.300
3	$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$	+0.78	−0.200

⑫

Use your prediction in **(a)**, your answer to **(d)** and data from the table to predict ΔH_r values for reactions 2 and 3.
Complete the table with these values. [1]

[Total: 18]

Examiner comments

⑪ The candidate's reasoning is incorrect here. They should have explained that either variable would be dependent upon temperature, therefore compromising the idea of a 'fair test'.

Mark for (f) = 0/1

⑫ The candidate answers correctly.

Mark for (g) = 1/1

Total marks awarded = 10 out of 18

How the candidate could have improved their answer

(c) (i) The diagram could have been improved by drawing it in 2D rather than as a 3D 'picture'.

(c) (ii) For the second mark, the candidate should also have stated that the mass of metal should be measured.

(c) (iii) The candidate should have stated 'Wear gloves'.

(c) (iv) The calculation should have been given in full.

(c) (vi) The candidate should have explained that stirring distributes the increase of temperature evenly throughout the solution.

(d) For the second mark, the candidate should have divided by 0.05 (dm^3) rather than 50 (cm^3) before converting $J\ mol^{-1}$ into $kJ\ mol^{-1}$.

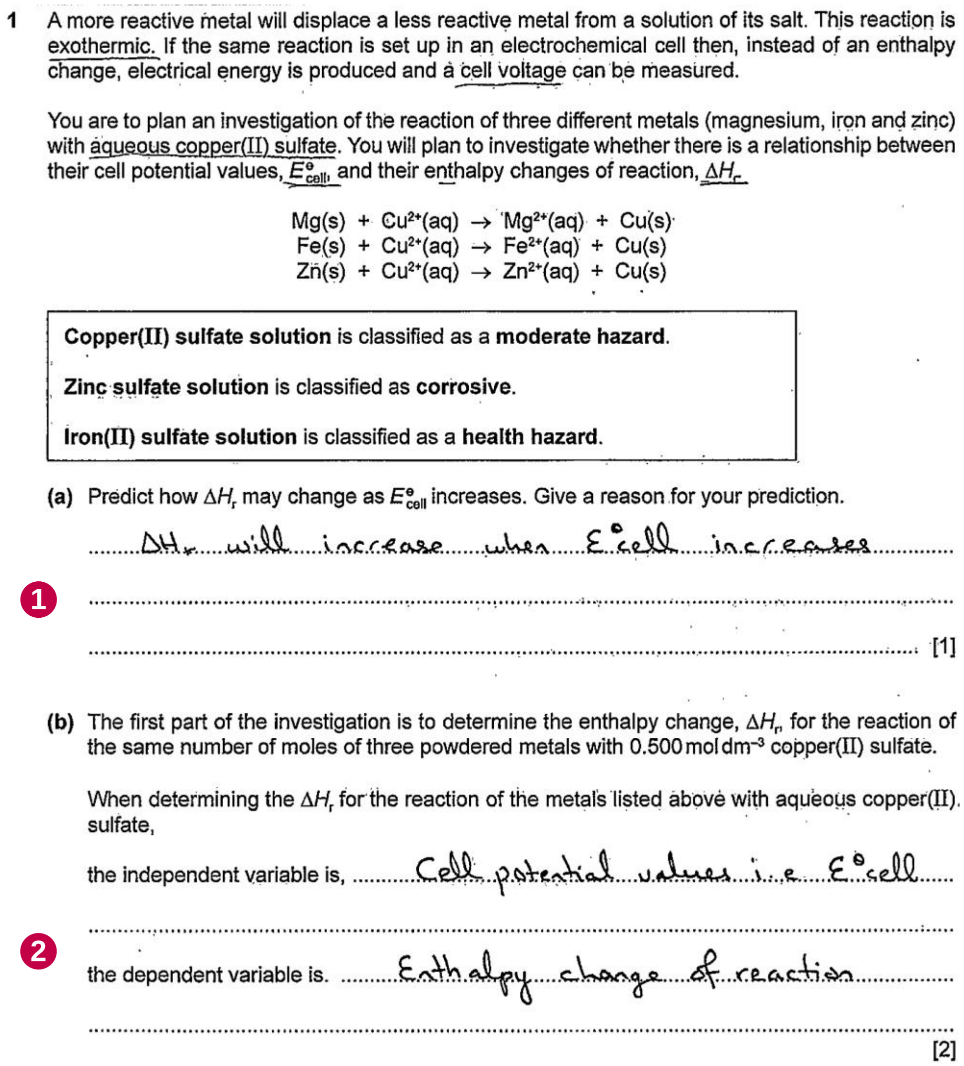
(e) For the first mark, the diagram should have shown the salt bridge entering both solutions. For the third mark, the concentrations of the solutions should have been stated as 1(.00) $mol\ dm^{-3}$.

(f) The candidate should have explained that either variable would be dependent upon temperature, therefore compromising the idea of a 'fair test'.

Mark awarded = **(a) 1/1**
Mark awarded = **(b) 2/2**
Mark awarded = **(c) (i) 1/1, (ii) 1/2, (iii) 0/1, (iv) 1/2, (v) 1/1, (vi) 0/1**
Mark awarded = **(d) 1/2**
Mark awarded = **(e) 1/3**
Mark awarded = **(f) 0/1**
Mark awarded = **(g) 1/1**

Total marks awarded = 10 out of 18

Example candidate response – low



1 A more reactive metal will displace a less reactive metal from a solution of its salt. This reaction is exothermic. If the same reaction is set up in an electrochemical cell then, instead of an enthalpy change, electrical energy is produced and a cell voltage can be measured.

You are to plan an investigation of the reaction of three different metals (magnesium, iron and zinc) with aqueous copper(II) sulfate. You will plan to investigate whether there is a relationship between their cell potential values, $E^{\ominus}_{cell}$, and their enthalpy changes of reaction, ΔH_r.

$$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$$
$$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$$
$$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$$

Copper(II) sulfate solution is classified as a **moderate hazard**.

Zinc sulfate solution is classified as **corrosive**.

Iron(II) sulfate solution is classified as a **health hazard**.

(a) Predict how ΔH_r may change as $E^{\ominus}_{cell}$ increases. Give a reason for your prediction.

ΔH_r will increase when E°cell increases

① [1]

(b) The first part of the investigation is to determine the enthalpy change, ΔH_r, for the reaction of the same number of moles of three powdered metals with 0.500 mol dm^{-3} copper(II) sulfate.

When determining the ΔH_r for the reaction of the metals listed above with aqueous copper(II) sulfate,

the independent variable is, Cell potential values i.e E°cell

② the dependent variable is. Enthalpy change of reaction

[2]

Examiner comments

① The candidate gives no explanation for their correct prediction. They should have explained that the reactivity of the metal is the reason.

Mark for (a) = 0/1

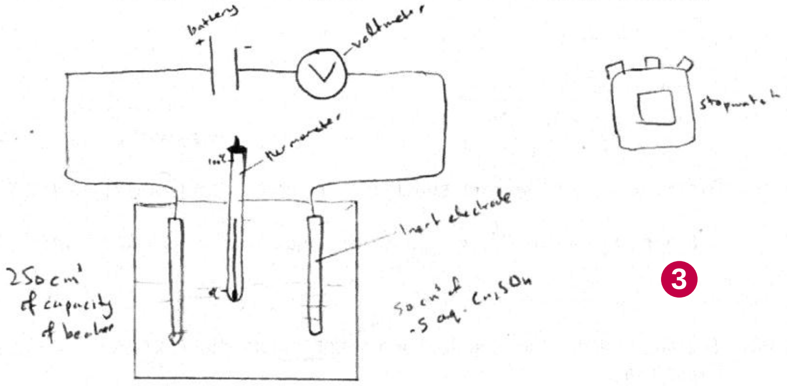
② The candidate identifies only the dependent variable correctly here.

Mark for (b) = 1/2

Example candidate response – low, continued

You are provided with a sample of powdered metal and 50.0 cm^3 of 0.500 mol dm^{-3} aqueous copper(II) sulfate.

(c) **(i)** Draw a fully labelled diagram to show how the apparatus should be set up to allow you to determine the increase in temperature of aqueous copper(II) sulfate.
You should use apparatus normally found in a school or college laboratory.



③

[1]

(ii) State the measurements you would make in your experiment.

④

Initial and final temperature

The cell voltage

The time taken [2]

(iii) Other than eye protection, state **one** precaution you would take to make sure that the experiment proceeds safely.

~~Make sure there is constant power supply without any intruption.~~ Wear protective gloves as $ZnSO_4$ is corrosive [1]

Examiner comments

③ The candidate has drawn an incorrect diagram.

Mark for (c) (i) = 0/1

④ The candidate states correctly that the initial and final temperatures should be measured. For the second mark, they should also have stated that the mass of metal should be measured.

Mark for (c) (ii) = 1/2

Mark for (c) (iii) = 1/1

Example candidate response – low, continued

⑤

(iv) For the reaction with magnesium, calculate the mass of magnesium, in g, you would use so that it is in a small excess. You must show your working.
[A_r: Mg, 24.3]

$n = c \times v$

$= \frac{.5 \times 50}{1000}$

$= 0.025$

$\text{mass} = n \times M_r$

$= 0.025 \times 24$

$= 0.6\,g$

mass of Mg = ...0.6...... g [2]

⑥

(v) Explain why the metal used should be in powdered form rather than in strips.

Rate of reaction increases with increase in surface area [1]

⑦

(vi) The aqueous copper(II) sulfate and metal mixture should be stirred continuously.
Explain why.

So that constant heat is provided to all the reactants [1]

(d) In one experiment, the increase in temperature when excess magnesium powder is added to 50.0 cm³ of 0.500 mol dm⁻³ aqueous copper(II) sulfate is 58.5 °C.

Calculate the enthalpy change for this reaction, ΔH_r, in kJ mol⁻¹.
Assume the specific heat capacity, *c*, of the reaction mixture is 4.18 J g⁻¹ K⁻¹.
Assume 1.0 cm³ of 0.500 mol dm⁻³ aqueous copper(II) sulfate has a mass of 1.0 g.
Include a sign in your answer.

$$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$$

$1\,cm^3 = 1\,g$

$50\,cm^3 = 50\,g$

$\Delta H = mc\Delta\theta$

$= -\frac{50}{1000} \times 4.18 \times 58.5$

$= -12.2\,kJ$

⑧

ΔH_r = ...-12.2...... kJ mol⁻¹ [2]

Examiner comments

⑤ The first calculation is correct (one mark) but the candidate has missed '.3' from the relative atomic mass of magnesium so the second mark cannot be awarded.

Mark for (c) (iv) = 1/2

⑥ The candidate explains correctly that powdered magnesium is better than a strip of the metal because its higher surface area produces a higher reaction rate.

Mark for (c) (v) = 1/1

⑦ The candidate incorrectly states that the reason for continual stirring is to provide heat to all reactants. They should have explained that stirring distributes the increase of temperature evenly throughout the solution.

Mark for (c) (vi) = 0/1

⑧ The candidate shows their working and includes a sign. Unfortunately, only the first mark can be awarded (for calculating E = mcΔT). For the second mark the candidate should have divided 12.2 kJ by 0.05 (dm^3) and 0.5 mol dm^{-3}.

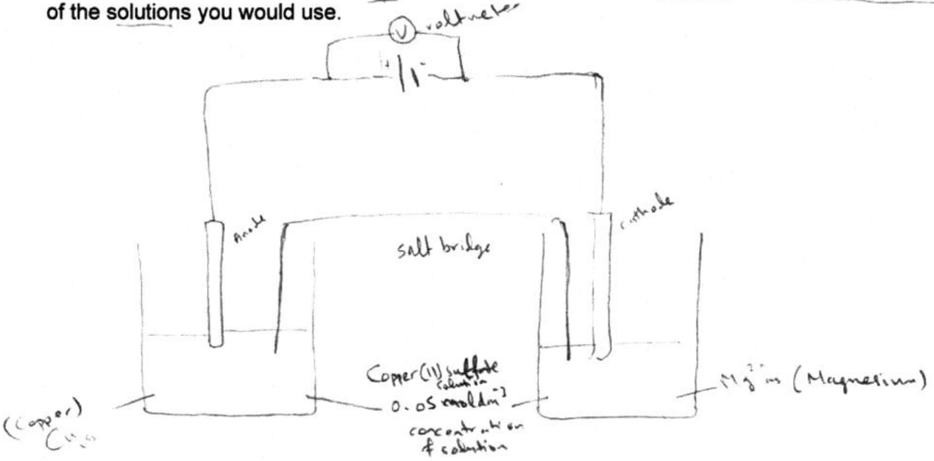
Mark for (d) = 1/2

Example candidate response – low, continued

(e) The second part of the investigation involves determining the cell potential, $E^\ominus_{cell}$, for the three electrochemical cells.

cell reaction
$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$
$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$
$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$

Draw a diagram of the apparatus you would use to measure the $E^\ominus_{cell}$ for the magnesium/copper cell. Your labels should include the **names** of the metals and the **names** and **concentrations** of the solutions you would use.



⑨

[3]

(f) Explain why the enthalpy change determination and cell potential determination should be carried out at the same temperature as each other.

A relationship between $E^\ominus$cell and $\Delta H^\ominus_r$ could be established

⑩

[1]

(g) Accepted $E^\ominus_{cell}$ values are shown for the cell reactions.

	cell reaction	$E^\ominus_{cell}$/V	ΔH_r
1	$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$	+2.72	
2	$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$	+1.10	6.05
3	$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$	+0.78	3.2

⑪

Use your prediction in **(a)**, your answer to **(d)** and data from the table to predict ΔH_r values for reactions 2 and 3.
Complete the table with these values. [1]

[Total: 18]

Examiner comments

⑨ This diagram is incorrect. It should have shown a circuit with a voltmeter and without a cell. The metals should have been labelled and the concentrations of the solutions should have been stated as 1(.00) mol dm^{-3}.

Mark for (e) = 0/3

⑩ The candidate's reasoning is incorrect here. They should have explained that either variable would be dependent upon temperature, therefore compromising the idea of a 'fair test'.

Mark for (f) = 0/1

⑪ The candidate was unable to do this. They should have shown the zinc reaction having a less negative voltage than –12.2 and the iron reaction less negative value than the zinc reaction.

Mark for (g) = 0/1

Total marks awarded = 6 out of 18

How the candidate could have improved their answer

(a) The candidate should have explained that the reactivity of the metal was the reason.

(b) The candidate should have identified the independent variable as the metal used.

(c) (i) A 2D diagram showing a labelled thermometer placed into labelled aqueous copper(II) sulfate inside a polystyrene cup should have been drawn.

(c) (ii) The candidate should also have stated that the mass of metal should be measured.

(c) (vi) The candidate should have explained that stirring distributes the increase of temperature evenly throughout the solution.

(d) The candidate should have divided 12.2 kJ by 0.05 (dm^3) and 0.5 $mol\,dm^{-3}$.

(e) To improve (and secure the first mark), the diagram should have shown a circuit with a voltmeter and without a cell. To secure the second mark, the candidate should have labelled the metals. To secure the third mark, the concentrations of the solutions should have been stated as 1(.00) $mol\,dm^{-3}$.

(f) The candidate should have explained that either variable would be dependent upon temperature, therefore compromising the idea of a 'fair test'.

(g) The candidate should have shown the zinc reaction having a less negative voltage than –12.2 and the iron reaction less negative value than the zinc reaction.

Mark awarded = **(a) 0/1**
Mark awarded = **(b) 1/2**
Mark awarded = **(c) (i) 0/1, (ii) 1/2, (iii) 1/1, (iv) 1/2, (v) 1/1, (vi) 0/1**
Mark awarded = **(d) 1/2**
Mark awarded = **(e) 0/3**
Mark awarded = **(f) 0/1**
Mark awarded = **(g) 0/1**

Total marks awarded = 6 out of 18

Common mistakes candidates made in this question

(a) Making a correct prediction but omitting an explanation.

(c) (i) Drawing 3D 'pictures' instead of 2D diagrams.

(c) (vi) Assuming that stirring will make all of the metal react, despite the information in the question stating that the metal was in excess.

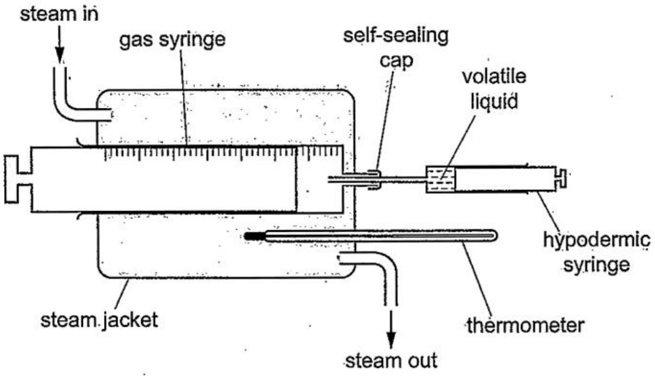
(d) Omitting a negative sign for the enthalpy change.

(e) Including a cell, and not fully labelling their diagrams as requested.

Question 2

Example candidate response – high	**Examiner comments**

2 The relative molecular mass, M_r, of volatile liquids can be determined using the apparatus below.



A known mass of volatile liquid is injected into the gas syringe using a hypodermic syringe. The injected volatile liquid vaporises and the volume of vapour is recorded.

The experiment can be repeated using different samples of the same volatile liquid. The following mathematical relationship can be used to calculate the relative molecular mass if the experiment is carried out at 100 °C and 1.01×10^5 Pa.

$$V = \left(\frac{3.07 \times 10^4}{M_r}\right) \times m$$

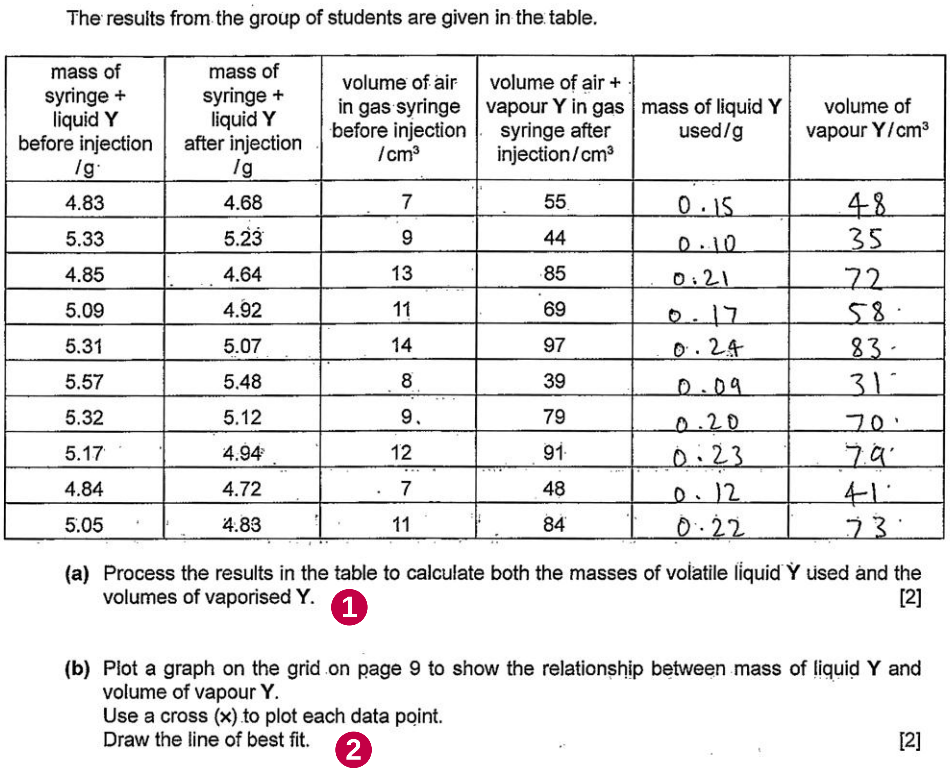
m is the mass of the volatile liquid in g.
V is the volume of the volatile liquid in cm^3 when vaporised.

A graph of V against m can be plotted.

A group of students is given a volatile liquid hydrocarbon, **Y**, and asked to find its relative molecular mass in a series of experiments using this procedure.

- A 100 cm^3 gas syringe is placed in a steam jacket.
- Approximately 5 cm^3 of air is pulled into the gas syringe.
- The temperature is allowed to reach a constant 100 °C.
- Once the air in the gas syringe has stopped expanding, its volume is recorded.
- The hypodermic syringe is filled with liquid **Y**.
- The total mass of the hypodermic syringe and liquid **Y** is recorded.
- A little liquid **Y** is injected into the hot gas syringe.
- The total mass of the hypodermic syringe is recorded again.
- The maximum volume of air and vapour in the gas syringe is recorded.
- The mass of liquid **Y** injected into the gas syringe is calculated and recorded.

Example candidate response – high, continued



The results from the group of students are given in the table.

mass of syringe + liquid **Y** before injection /g	mass of syringe + liquid **Y** after injection /g	volume of air in gas syringe before injection /cm^3	volume of air + vapour **Y** in gas syringe after injection/cm^3	mass of liquid **Y** used/g	volume of vapour **Y**/cm^3
4.83	4.68	7	55	0.15	48
5.33	5.23	9	44	0.10	35
4.85	4.64	13	85	0.21	72
5.09	4.92	11	69	0.17	58
5.31	5.07	14	97	0.24	83
5.57	5.48	8	39	0.09	31
5.32	5.12	9	79	0.20	70
5.17	4.94	12	91	0.23	79
4.84	4.72	7	48	0.12	41
5.05	4.83	11	84	0.22	73

(a) Process the results in the table to calculate both the masses of volatile liquid **Y** used and the volumes of vaporised **Y**. [2] ①

(b) Plot a graph on the grid on page 9 to show the relationship between mass of liquid **Y** and volume of vapour **Y**.
Use a cross (**x**) to plot each data point.
Draw the line of best fit. [2] ②

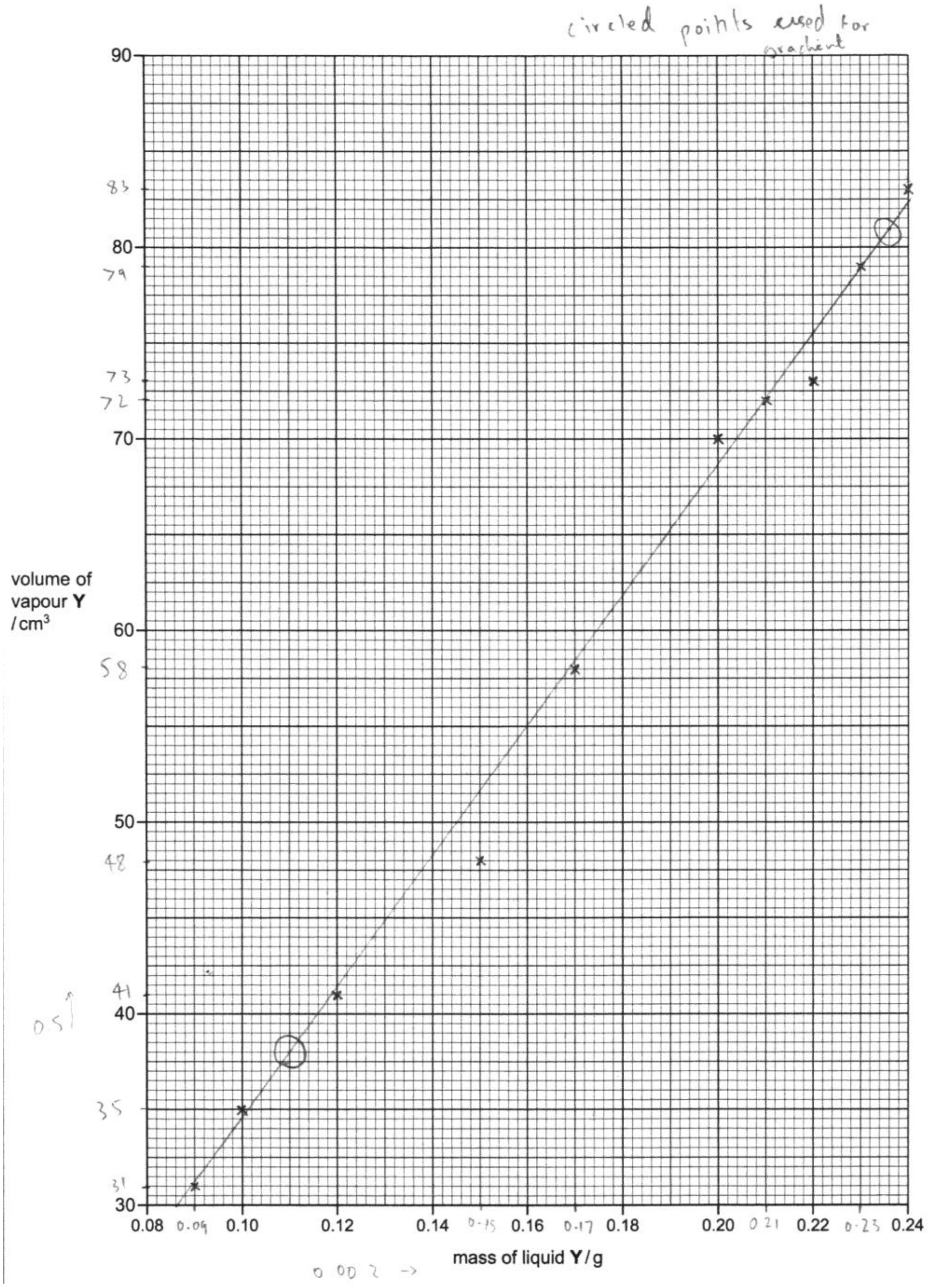
Examiner comments

① The candidate answers this successfully.

Mark for (a) = 2/2

② The candidate answers this successfully.

Mark for (b) = 2/2

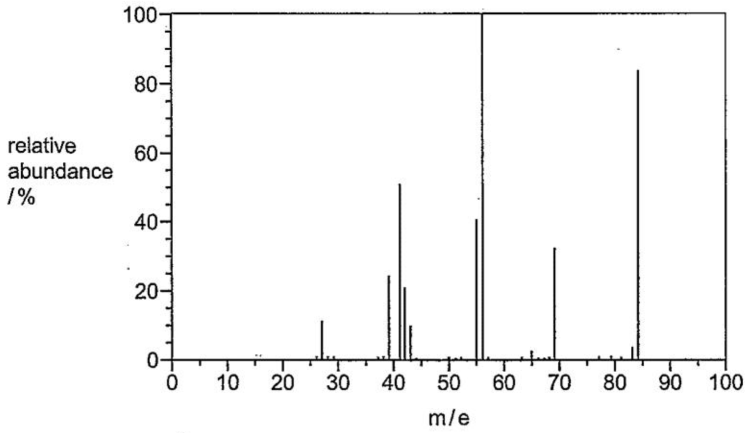
Example candidate response – high, continued	**Examiner comments**
	

Example candidate response – high, continued	Examiner comments
(c) Liquid **Y** evaporates easily, even at room temperature. This can cause anomalous results giving points below the line of best fit. **(i)** Explain how such anomalies occur. ③ The liquid Y evaporates from the hypodermic syringe between when the mass readings are taken. [1]	③ The candidate's reasoning is correct. Mark for (c) (i) = 1/1
(ii) With reference to the experimental procedure, explain how this source of error could be minimised. ④ The mass of hypodermic syringe + Y should recorded as quickly as possible after injecting the liquid. The hypodermic syringe could also be cooled (in an ice water bath for example) so that Y doesn't evaporade ~~too~~ much [1]	④ The candidate's reasoning is correct. Mark for (c) (ii) = 1/1
(d) **(i)** Determine the gradient of your graph. State the co-ordinates of both points you used for your calculation. Record the value of the gradient to **three** significant figures. co-ordinates 1 (0.236 , 81) co-ordinates 2 (0.110 , 38) ⑤ gradient = $\frac{81 - 38}{0.236 - 0.110}$ $= 341.2$ gradient = 341 $cm^3 g^{-1}$ [2]	⑤ The candidate correctly states the co-ordinates used in the calculation. They also correctly calculate the change in *y*-axis values and divide this by the change in *x*-axis values. Mark for (d) (i) = 2/2
(ii) Use the gradient value in **(i)** and the mathematical relationship on page 7 to calculate the experimentally determined relative molecular mass of **Y**. $V = \left(\frac{3.07 \times 10^4}{M_r}\right) \times m$ gradient $= \frac{3.07 \times 10^4}{M_r}$ $M_r = \frac{3.07 \times 10^4}{341.2}$ $= 89.95$ ⑥ experimentally determined M_r of **Y** = 90 [2]	⑥ The candidate shows full working and calculates the correct answer. Mark for (d) (ii) = 2/2

Example candidate response – high, continued

(e) Compound **Y** is a hydrocarbon that contains 85.7% carbon by mass.

The diagram shows the mass spectrum of compound **Y**.



Use all the information given to determine the molecular formula of **Y**.

%	C	H
	85.7	14.3
dividing by Ar	$\frac{85.7}{12}$	$\frac{14.3}{1}$
	= 7.14	14.3
Simplest ratio	1	: 2

⑦

molecular formula of **Y** C_6H_{12} [2]

[Total: 12]

∴ Empirical formula = CH_2

mass of molecular formula = n × mass of empirical formula

84 ~~[illegible]~~ = n × (12 + 2)

n = $\frac{84}{14}$

n = ~~[illegible]~~ 6

~~[illegible]~~ mass of molecular ion = 84

~~molecular form~~ $CH_2 \times 6 = C_6H_{12}$

~~∴ C_6H_{12}~~

Examiner comments

⑦ The candidate calculates that the empirical formula is CH_2. They also realise that, as the information on the mass spectrum indicated the molecular ion had an m/e value of 84, the relative molecular mass would be 84. Therefore, they are able to divide 84 by the mass of the empirical formula (14) to find that six 'lots' of the empirical formula made up the molecular formula.

Mark for (e) = 2/2

Total marks awarded = 12 out of 12

How the candidate could have improved their answer

All this candidate's answers were correct.

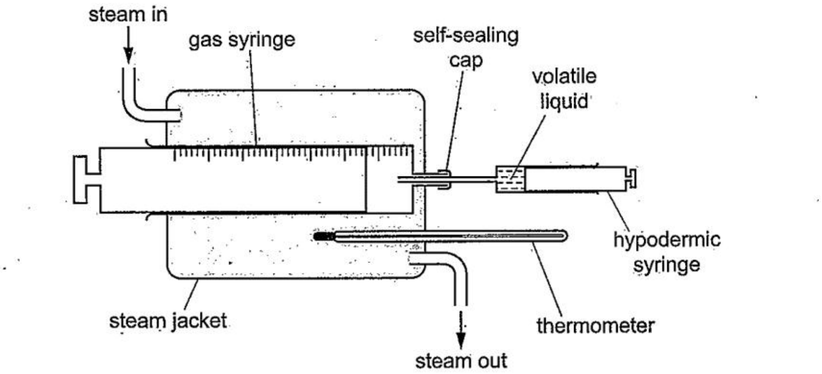
Mark awarded = **(a) 2/2**
Mark awarded = **(b) 2/2**
Mark awarded = **(c) (i) 1/1, (ii) 1/1**
Mark awarded = **(d) (i) 2/2, (ii) 2/2**
Mark awarded = **(e) 2/2**

Total marks awarded = 12 out of 12

Example candidate response – middle

Examiner comments

2 The relative molecular mass, M_r, of volatile liquids can be determined using the apparatus below.



A known mass of volatile liquid is injected into the gas syringe using a hypodermic syringe. The injected volatile liquid vaporises and the volume of vapour is recorded.

The experiment can be repeated using different samples of the same volatile liquid. The following mathematical relationship can be used to calculate the relative molecular mass if the experiment is carried out at 100 °C and 1.01×10^5 Pa.

$$V = \left(\frac{3.07 \times 10^4}{M_r}\right) \times m$$

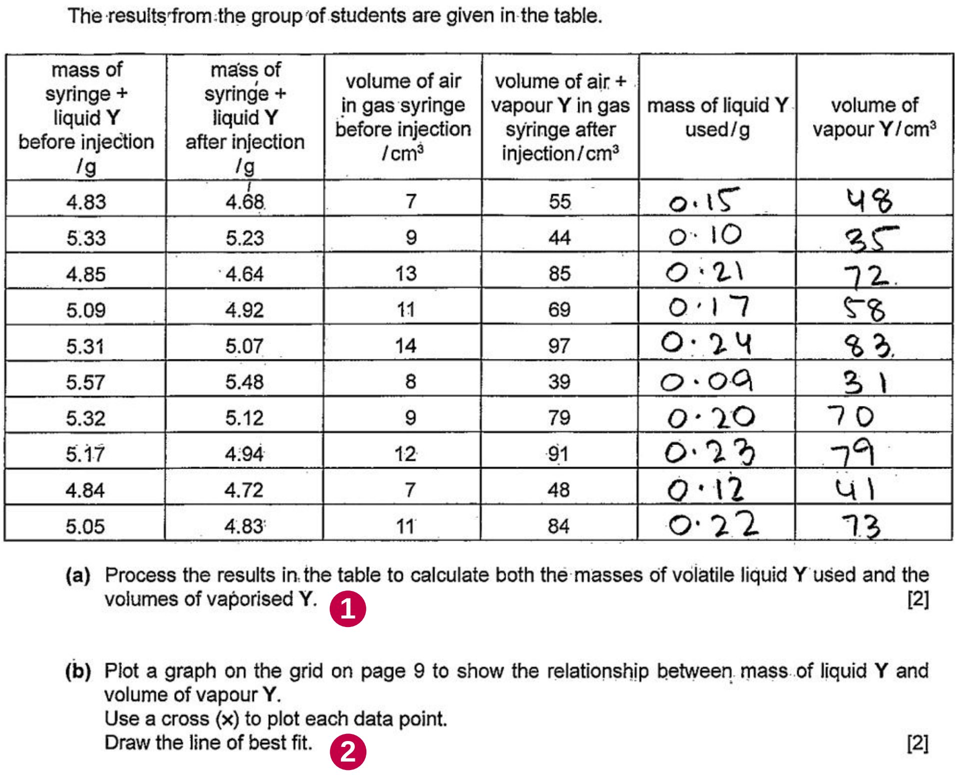
m is the mass of the volatile liquid in g.
V is the volume of the volatile liquid in cm^3 when vaporised.

A graph of V against m can be plotted.

A group of students is given a volatile liquid hydrocarbon, **Y**, and asked to find its relative molecular mass in a series of experiments using this procedure.

- A 100 cm^3 gas syringe is placed in a steam jacket.
- Approximately 5 cm^3 of air is pulled into the gas syringe.
- The temperature is allowed to reach a constant 100 °C.
- Once the air in the gas syringe has stopped expanding, its volume is recorded.
- The hypodermic syringe is filled with liquid **Y**.
- The total mass of the hypodermic syringe and liquid **Y** is recorded.
- A little liquid **Y** is injected into the hot gas syringe.
- The total mass of the hypodermic syringe is recorded again.
- The maximum volume of air and vapour in the gas syringe is recorded.
- The mass of liquid **Y** injected into the gas syringe is calculated and recorded.

Example candidate response – middle, continued



The results from the group of students are given in the table.

mass of syringe + liquid **Y** before injection /g	mass of syringe + liquid **Y** after injection /g	volume of air in gas syringe before injection /cm^3	volume of air + vapour **Y** in gas syringe after injection /cm^3	mass of liquid **Y** used /g	volume of vapour **Y** /cm^3
4.83	4.68	7	55	0.15	48
5.33	5.23	9	44	0.10	35
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5.57	5.48	8	39	0.09	31
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5.17	4.94	12	91	0.23	79
4.84	4.72	7	48	0.12	41
5.05	4.83	11	84	0.22	73

(a) Process the results in the table to calculate both the masses of volatile liquid **Y** used and the volumes of vaporised **Y**. ① [2]

(b) Plot a graph on the grid on page 9 to show the relationship between mass of liquid **Y** and volume of vapour **Y**.
Use a cross (×) to plot each data point.
Draw the line of best fit. ② [2]

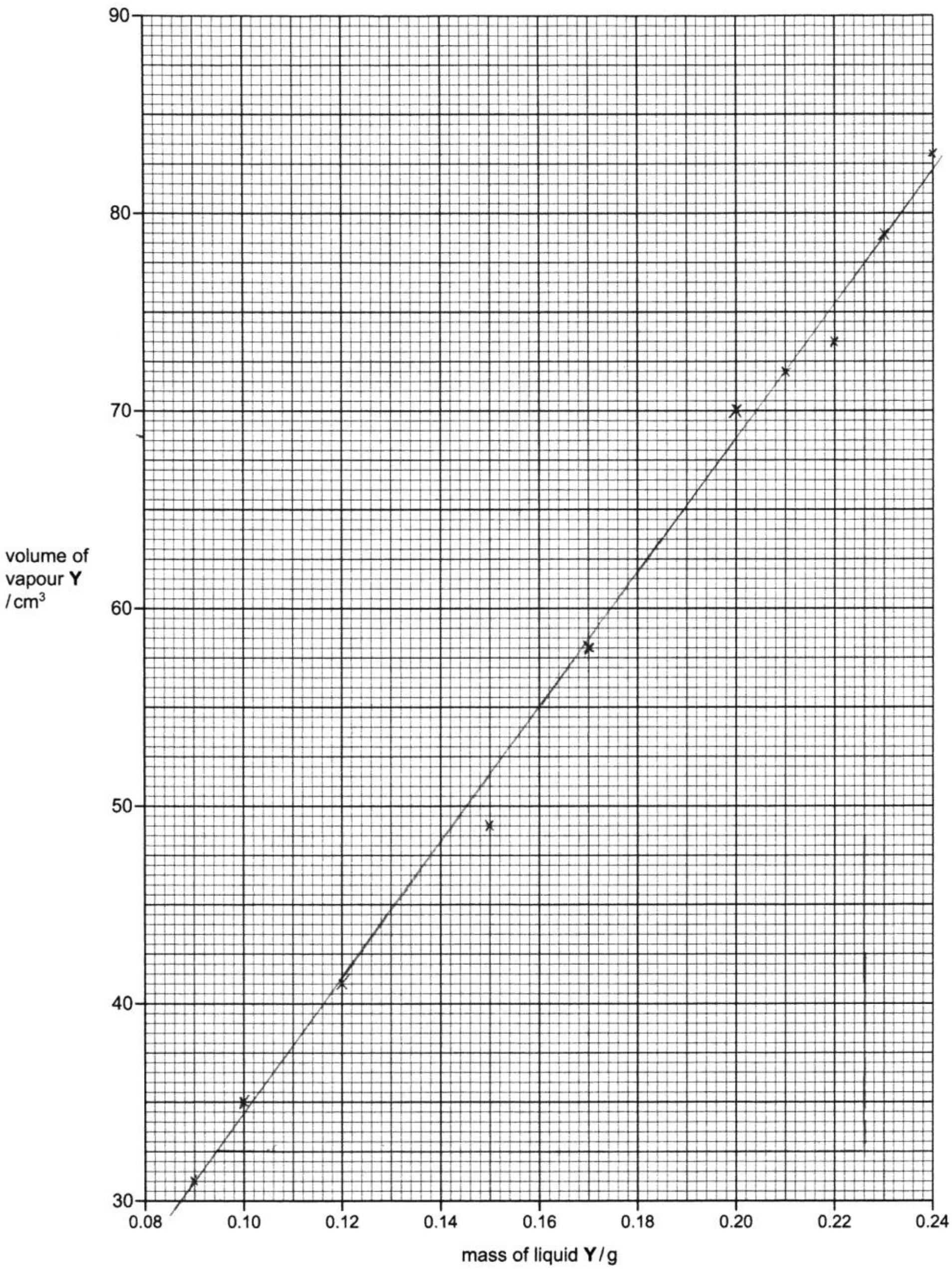
Examiner comments

① The candidate answers this correctly.

Mark for (a) = 2/2

② The candidate has not plotted the points correctly, but their line of best fit is good enough for the mark. The point at 0.22 g should have had a volume of 73(.0) cm^3 rather than 73.5 cm^3.

Mark for (b) = 1/2

Example candidate response – middle, continued	Examiner comments
	

Example candidate response – middle, continued

(c) Liquid **Y** evaporates easily, even at room temperature. This can cause anomalous results giving points below the line of best fit.

(i) Explain how such anomalies occur.

③ Some amount of liquid Y evaporates in the hypodermic syringe after injection. [1]

(ii) With reference to the experimental procedure, explain how this source of error could be minimised.

④ Make sure the liquid in the syringe is and comprenced as it can be so it is less likely to evaporate. [1]

(d) **(i)** Determine the gradient of your graph. State the co-ordinates of both points you used for your calculation. Record the value of the gradient to **three** significant figures.

co-ordinates 1 (0.094 , 32.5)

co-ordinates 2 (0.226 , 77.5)

⑤
$$\frac{y_2 - y_1}{x_2 - x_1} = \frac{77.5 - 32.5}{0.226 - 0.094} = 3409$$

gradient = 341 [2]

(ii) Use the gradient value in **(i)** and the mathematical relationship on page 7 to calculate the experimentally determined relative molecular mass of **Y**.

⑥
$$V = \frac{(3.07 \times 10^4)}{Mr} \times m$$

~~gradient =~~

$$Mr = \frac{3.07 \times 10^4}{gradient} = \frac{3.07 \times 10^4}{341} = 90.02$$

Examiner comments

③ The candidate's reasoning is incorrect here. They should have related the evaporation of liquid Y to the fact that the apparent mass would have been lower than the actual mass.

Mark for (c) = 0/1

④ The candidate's reasoning is incorrect here. They should have realised that the evaporation of liquid Y should be reduced and suggested a suitable method for doing this, e.g. using an ice-bath.

Mark for (c) (ii) = 0/1

⑤ The candidate correctly states the co-ordinates used in the calculation. They correctly calculate the change in *y*-axis values and divide this by the change in *x*-axis values.

Mark for (d) (i) = 2/2

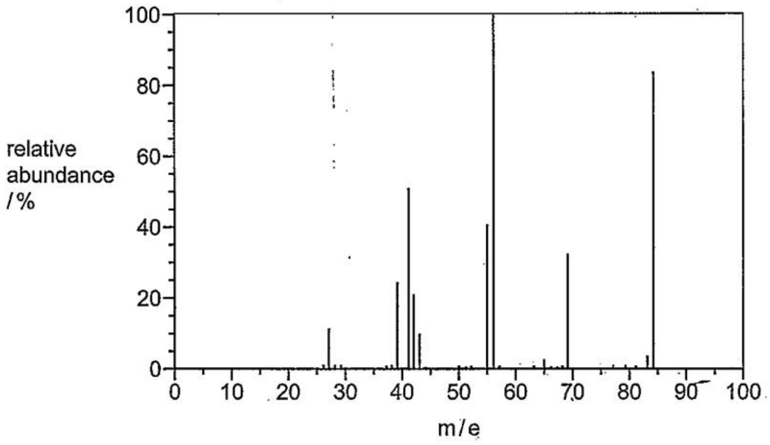
⑥ The candidate shows full working and successfully calculates the correct answer here.

Mark for (d) (ii) = 2/2

Example candidate response – middle, continued

(e) Compound **Y** is a hydrocarbon that contains 85.7% carbon by mass.

The diagram shows the mass spectrum of compound **Y**.



Use all the information given to determine the molecular formula of **Y**.

2 : 1·7 $90 \times \frac{85 \cdot 7}{100}$ 77·13

[illegible]   77·13/12 = 6·43

$90 \times \frac{100 - 77 \cdot 13}{100} = 20$

molecular formula of **Y** ......C_6H_6........... [2]

⑦

[Total: 12]

Examiner comments

⑦ The candidate is awarded one mark for determining that 85.7 per cent of the relative molecular mass, determined in part (d) (ii), is 77.13, and if this is divided by 12, the relative atomic mass of carbon, then this would give the number of carbon atoms as 6. However, they should have calculated that the empirical formula is CH_2. They would then have realised that, as the information on the mass spectrum indicates the molecular ion has an m/e value of 84, then the relative molecular mass would be 84. Therefore, they should have been able to divide 84 by the mass of the empirical formula (14) to find that six ‘lots’ of the empirical formula made up the molecular formula.

Mark for (e) = 1/2

Total marks awarded = 8 out of 12

How the candidate could have improved their answer

(c) (i) The candidate should have related the evaporation of liquid Y to the fact that the apparent mass would have been lower than the actual mass.

(c) (ii) The candidate should have realised that the evaporation of liquid Y should be reduced and then suggested a suitable method for doing this, e.g. use an ice-bath.

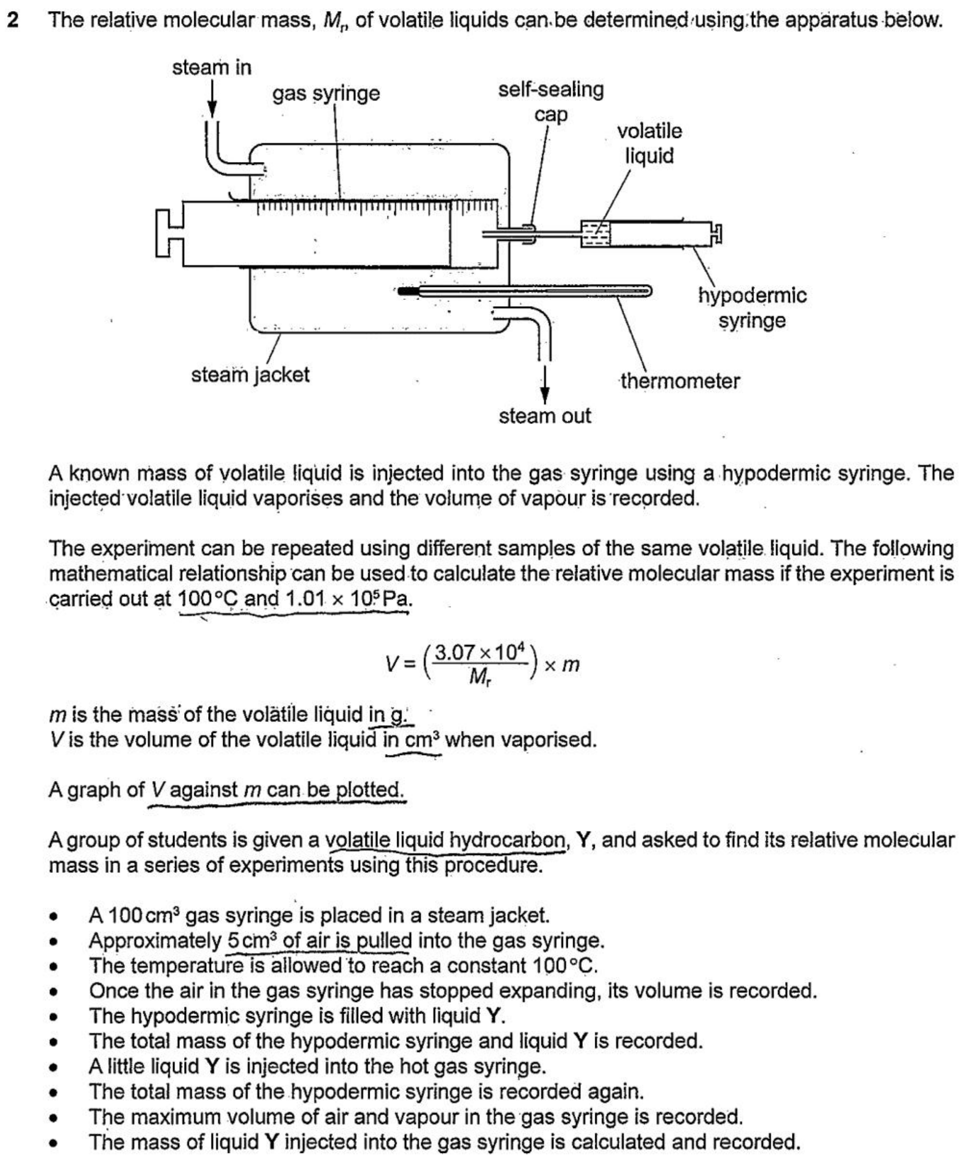
(e) The candidate should have calculated that the empirical formula was CH_2. The candidate should then have been able to realise that, as the information on the mass spectrum indicated the molecular ion had an m/e value of 84, then the relative molecular mass would be 84. Therefore, they should have been able to divide 84 by the mass of the empirical formula (14) to find that six ‘lots’ of the empirical formula made up the molecular formula.

Mark awarded = **(a) 2/2**
Mark awarded = **(b) 1/2**
Mark awarded = **(c) (i) 0/1, (ii) 0/1**
Mark awarded = **(d) (i) 2/2, (ii) 2/2**
Mark awarded = **(e) 1/2**

Total marks awarded = 8 out of 12

Example candidate response – low

Examiner comments



2 The relative molecular mass, M_r, of volatile liquids can be determined using the apparatus below.

A known mass of volatile liquid is injected into the gas syringe using a hypodermic syringe. The injected volatile liquid vaporises and the volume of vapour is recorded.

The experiment can be repeated using different samples of the same volatile liquid. The following mathematical relationship can be used to calculate the relative molecular mass if the experiment is carried out at 100 °C and 1.01×10^5 Pa.

$$V = \left(\frac{3.07 \times 10^4}{M_r}\right) \times m$$

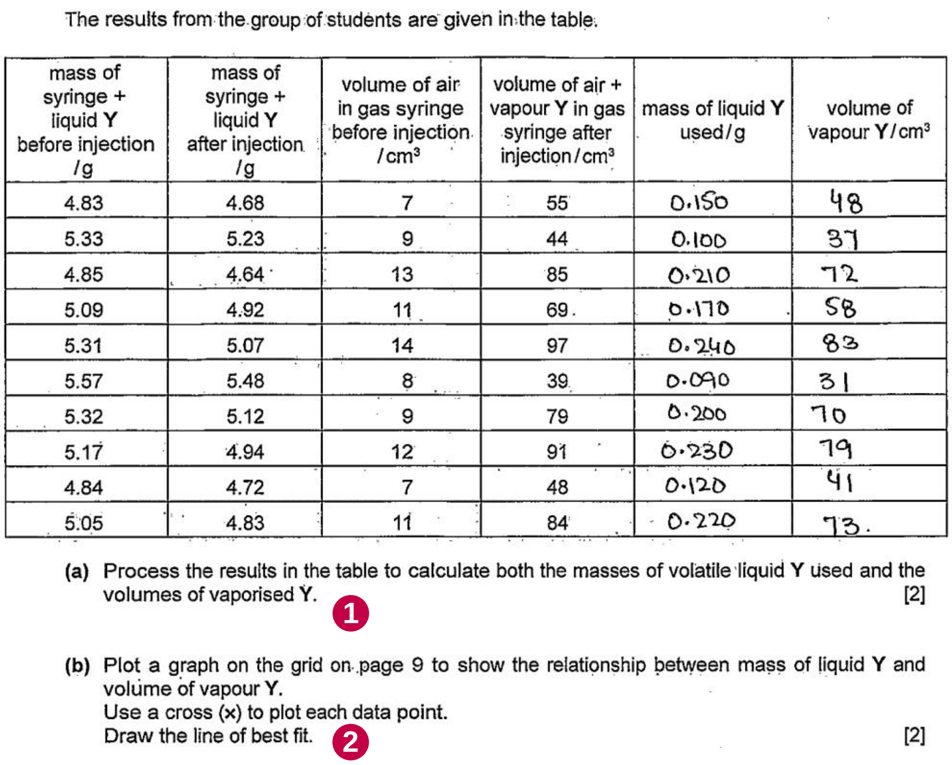
m is the mass of the volatile liquid in g.
V is the volume of the volatile liquid in cm^3 when vaporised.

A graph of *V* against *m* can be plotted.

A group of students is given a volatile liquid hydrocarbon, **Y**, and asked to find its relative molecular mass in a series of experiments using this procedure.

- A 100 cm^3 gas syringe is placed in a steam jacket.
- Approximately 5 cm^3 of air is pulled into the gas syringe.
- The temperature is allowed to reach a constant 100 °C.
- Once the air in the gas syringe has stopped expanding, its volume is recorded.
- The hypodermic syringe is filled with liquid **Y**.
- The total mass of the hypodermic syringe and liquid **Y** is recorded.
- A little liquid **Y** is injected into the hot gas syringe.
- The total mass of the hypodermic syringe is recorded again.
- The maximum volume of air and vapour in the gas syringe is recorded.
- The mass of liquid **Y** injected into the gas syringe is calculated and recorded.

Example candidate response – low, continued



The results from the group of students are given in the table.

mass of syringe + liquid **Y** before injection /g	mass of syringe + liquid **Y** after injection /g	volume of air in gas syringe before injection /cm^3	volume of air + vapour **Y** in gas syringe after injection /cm^3	mass of liquid **Y** used /g	volume of vapour **Y** /cm^3
4.83	4.68	7	55	0.150	48
5.33	5.23	9	44	0.100	37
4.85	4.64	13	85	0.210	72
5.09	4.92	11	69	0.170	58
5.31	5.07	14	97	0.240	83
5.57	5.48	8	39	0.090	31
5.32	5.12	9	79	0.200	70
5.17	4.94	12	91	0.230	79
4.84	4.72	7	48	0.120	41
5.05	4.83	11	84	0.220	73.

(a) Process the results in the table to calculate both the masses of volatile liquid **Y** used and the volumes of vaporised **Y**. [2]

①

(b) Plot a graph on the grid on page 9 to show the relationship between mass of liquid **Y** and volume of vapour **Y**.
Use a cross (**×**) to plot each data point.
Draw the line of best fit. ② [2]

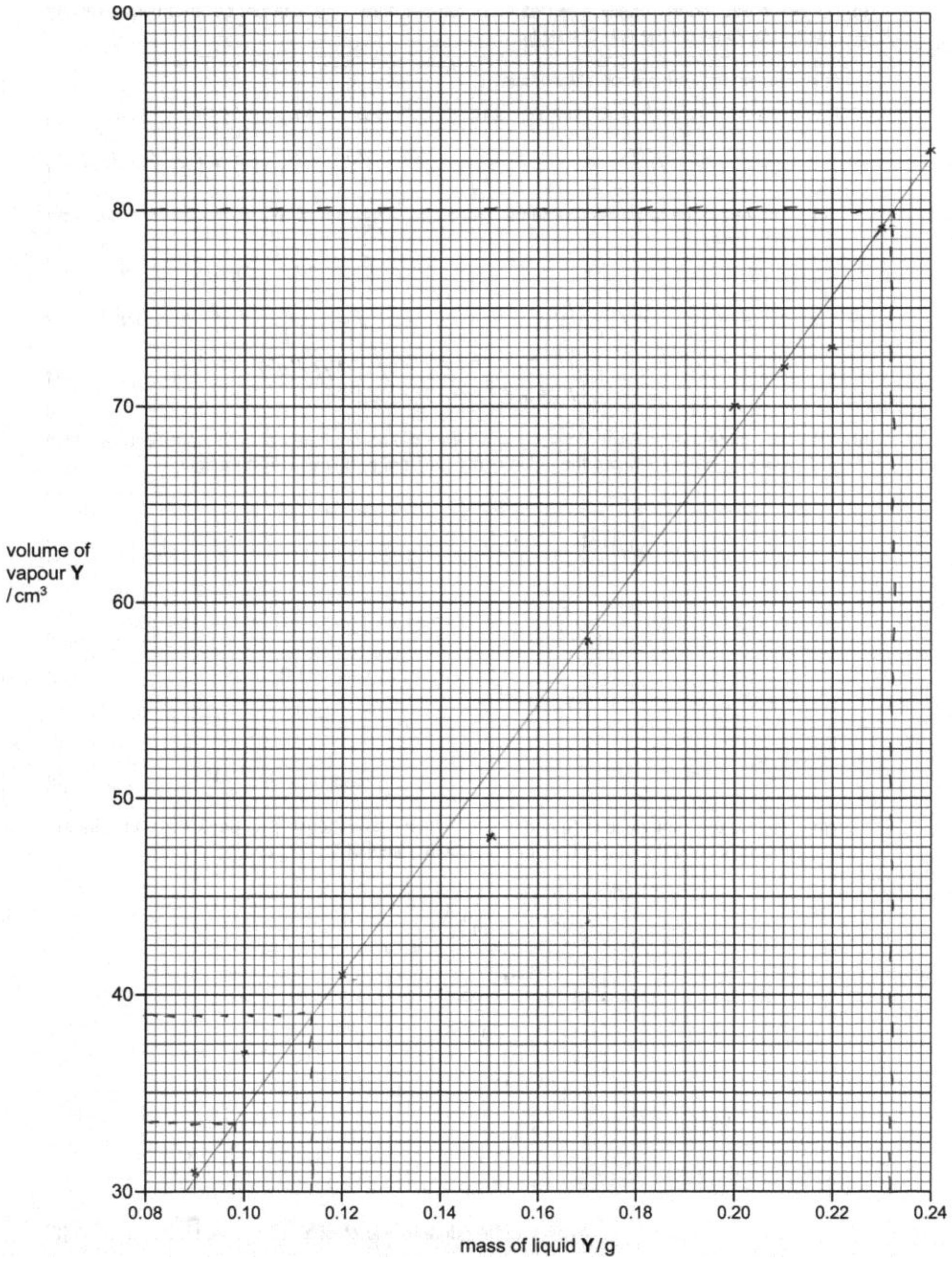
Examiner comments

① The candidate calculates the volumes correctly but gives too many decimal places in the mass column to earn the first mark. All the masses should have been given to two decimal places.

Mark for (a) = 1/2

② The candidate answers this correctly.

Mark for (b) = 2/2

Example candidate response – low, continued	Examiner comments
	

Example candidate response – low, continued

(c) Liquid **Y** evaporates easily, even at room temperature. This can cause anomalous results giving points below the line of best fit.

(i) Explain how such anomalies occur.

③ The liquid Y evaporates easily at room temperature hence its rate of diffusion will be greater than air and hence less dense. [1]

(ii) With reference to the experimental procedure, explain how this source of error could be minimised.

④ To minimise this error we should conduct experiment in controlled temperature and allow the liquid Y to make equilibrium with air of rate of diffusion. while measuring volume of Y and air in syringe. [1]

(d) (i) Determine the gradient of your graph. State the co-ordinates of both points you used for your calculation. Record the value of the gradient to **three** significant figures.

co-ordinates 1 0.232 , 80.

co-ordinates 2 0.114 , 39

⑤

$$\text{gradient} = \frac{80-39}{0.232-0.114}$$

gradient = 347 [2]

(ii) Use the gradient value in **(i)** and the mathematical relationship on page 7 to calculate the experimentally determined relative molecular mass of **Y**.

⑥

$$V \div \left(\frac{3.07\times10^4}{Mr}\right) \times V$$

$$\text{gradient} = \frac{3.07\times10^4}{Mr.}$$

$$\frac{347}{3.07\times10^4} = Mr.$$

experimentally determined M_r of **Y** = 0.0113 [2]

Examiner comments

③ The candidate's reasoning is incorrect here. They should have related the evaporation of liquid Y to the fact that the apparent mass would have been lower than the actual mass.

Mark for (c) (i) = 0/1

④ The candidate's reasoning is incorrect here. They should have realised that the evaporation of liquid Y should be reduced and suggested a suitable method for doing this, e.g. using an ice-bath.

Mark for (c) (ii) = 0/1

⑤ The candidate correctly states the co-ordinates used in the calculation. They correctly calculate the change in *y*-axis values and divide this by the change in *x*-axis values.

Mark for (d) (i) = 2/2

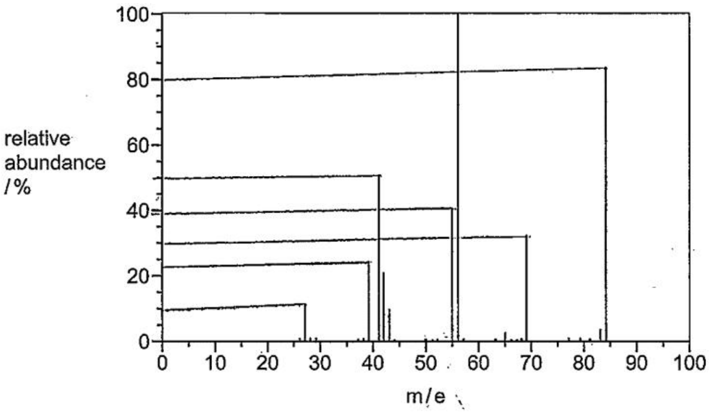
⑥ The candidate shows full working but uses the wrong method. They should have divided 3.07 × 104 by the gradient determined in (d)(i).

Mark for (d) (ii) = 0/2

Example candidate response – low, continued

(e) Compound **Y** is a hydrocarbon that contains 85.7% carbon by mass.

The diagram shows the mass spectrum of compound **Y**.



Use all the information given to determine the molecular formula of **Y**.

[illegible]

⑦

$$\frac{27\times10+41\times60+100\times5+69\times30+84\times80+85{\cdot}7\times12}{100}$$

181·5

molecular formula of Y ~~[illegible]~~ [2]

[Total: 12]

Examiner comments

⑦ The candidate's method is irrelevant. They should have calculated that the empirical formula is CH_2. The candidate should then have been able to realise that, as the information on the mass spectrum indicates the molecular ion has an m/e value of 84, then the relative molecular mass would be 84. Therefore, they should have been able to divide 84 by the mass of the empirical formula (14) to find that six 'lots' of the empirical formula made up the molecular formula.

Mark for (e) = 0/2

Total marks awarded = 5 out of 12

How the candidate could have improved their answer

(a) All masses should have been given to two decimal places.

(c) (i) The candidate should have related the evaporation of liquid Y to the fact that the apparent mass would have been lower than the actual mass.

(c) (ii) The candidate should have realised that the evaporation of liquid Y should be reduced and should have suggested a suitable method for doing this, e.g. using an ice-bath.

(d) (ii) The candidate should have divided 3.07×10^4 by the gradient determined in (d)(i).

(e) The candidate should have calculated that the empirical formula was CH_2. They should then have been able to realise that, as the information on the mass spectrum indicates the molecular ion has an m/e value of 84, then the relative molecular mass would be 84. Therefore, they should have been able to divide 84 by the mass of the empirical formula (14) to find that six 'lots' of the empirical formula made up the molecular formula.

Mark awarded = **(a) 1/2**
Mark awarded = **(b) 2/2**
Mark awarded = **(c) (i) 0/1, (ii) 0/1**
Mark awarded = **(d) (i) 2/2, (ii) 0/2**
Mark awarded = **(e) 0/2**

Total marks awarded = 5 out of 12

Common mistakes candidates made in this question

(a) Using too many decimal places.

(b) Mis-plotting points and drawing lines of best fit which did not have an approximately equal number of points each side of the line.

(c) (i) & (ii) Mixing up the gas syringe with the hypodermic syringe in their explanations.

(d) (i) Failing to use three significant figures in their answers.

(e) Not appreciating that the true relative atomic mass of Y could be gleaned from its mass spectrum.

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