Pearson

Examiners' Report
June 2017

GCE Chemistry 9CH0 03

ResultsPlus

edexcel

Edexcel and BTEC Qualifications

Edexcel and BTEC qualifications come from Pearson, the UK's largest awarding body. We provide a wide range of qualifications including academic, vocational, occupational and specific programmes for employers. For further information visit our qualifications websites at www.edexcel.com or www.btec.co.uk.

Alternatively, you can get in touch with us using the details on our contact us page at www.edexcel.com/contactus.

ResultsPlus

Giving you insight to inform next steps

ResultsPlus is Pearson's free online service giving instant and detailed analysis of your students' exam results.

- See students' scores for every exam question.
- Understand how your students' performance compares with class and national averages.
- Identify potential topics, skills and types of question where students may need to develop their learning further.

For more information on ResultsPlus, or to log in, visit www.edexcel.com/resultsplus. Your exams officer will be able to set up your ResultsPlus account in minutes via Edexcel Online.

Pearson: helping people progress, everywhere

Pearson aspires to be the world's leading learning company. Our aim is to help everyone progress in their lives through education. We believe in every kind of learning, for all kinds of people, wherever they are in the world. We've been involved in education for over 150 years, and by working across 70 countries, in 100 languages, we have built an international reputation for our commitment to high standards and raising achievement through innovation in education. Find out more about how we can help you and your students at: www.pearson.com/uk.

June 2017

Publications Code 9CH0_03_1706_ER

Introduction

This is the first opportunity for candidates to sit paper 3 from the Pearson Edexcel Level 3 Advanced GCE in Chemistry. The paper tests understanding from across all parts of the specification and many of the questions are synoptic in nature. In addition, a central core of the paper covers the indirect assessment of practical skills. Questions in this context assess conceptual and theoretical understanding of experimental methods that will draw on candidates' experiences of the core practicals.

The main differences between this paper and the style of assessment used in the previous specification are:

- a much longer exam paper;
- a wider breadth of content;
- the indirect assessment of practical skills;
- greater emphasis on extended writing questions;
- greater emphasis on unstructured calculations;
- no multiple-choice questions;
- questions that will target mathematical skills at Level 2 or above.

The paper counts as 40% of the total qualification and covers all three assessment objectives, AO1, AO2 and AO3 as outlined in the specification. It provides an opportunity for candidates to demonstrate knowledge of chemical principles and apply them to a wide range of both familiar and unfamiliar contexts, both quantitatively and qualitatively. It also will challenge candidates to show that they can analyse, interpret and evaluate information, often data or observations from a practical context.

During this session, many of the scripts they saw at the higher levels impressed the examination team. It seemed that stronger candidates coped with the increased demand, in terms of the content covered by a single paper, and the changes in question style outlined.

Particular strengths included:

- the ability to process data from an enthalpy experiment in question 4(b);
- use of skeletal formulae;
- use of data from mass spectra;
- some organic mechanisms e.g. the nucleophilic substitution mechanism in question 8 (a);
- the ability to discriminate between transition metals and metals such as zinc and scandium in question 7(a).

However, the performance of candidates was less effective in other areas of the paper. These included:

- the knowledge of the reactions of copper and chromium in question 1;
- the ability to apply knowledge of a known mechanism to an unfamiliar context e.g. in question 8(b);
- the ability of some candidates to make significant progress in unstructured calculations;
- justifying how the results of experimental work may change under different circumstances.

As a result, it is important for candidates to experience a wide range of practical work in preparation for this paper, and for them to ensure they reflect on both the procedures followed and the content covered in such work.

Question 1 (a) (i)

In general, the chemistry of the transition metals was not well known, and the answers to this question illustrated that. Many ignored or did not appreciate the phrase ‘amphoteric’ or the fact the hydrochloric acid was dilute and assumed this reaction was a ligand substitution involving chloride ions. Even those who realised it was a reaction with H^+ ions found it difficult to balance the equation correctly. In one sense, this type of question is not particularly demanding but it does show the importance of making sure the breadth of the course is appreciated as well as the depth.

(i) Write an **ionic** equation for the reaction of solid chromium(III) hydroxide with dilute hydrochloric acid, showing the formula of the complex ion formed. Include state symbols in your answer.

(2)

$$Cr(OH)_3(H_2O)_3 + 3H^+ \rightarrow [Cr(H_2O)_6]^{3+} + 3H_2O$$

ResultsPlus
Examiner Comments

Although the correct chromium complex is shown, 3 additional waters are evident on the left hand side, and no state symbols are shown, despite the guidance in the question.
Hence this example was not worth any credit.

ResultsPlus
Examiner Tip

Make sure you learn the reactions of chromium as outlined in the specification, as they can be difficult to work out when required, without recall to fall back on.

Question 1 (a) (ii)

Most students appreciated the colours of the species involved in the reaction but lost marks by not using terms such as ‘solution’ and ‘precipitate’.

This is a vital distinction to make when describing such reactions.

(ii) Describe the changes you would **see** when the reaction in (a)(i) is carried out.

(2)

As it reacts with sodium hydroxide, the colour change would be from yellow to brown

ResultsPlus
Examiner Comments

This example did not gain any marks. The candidate has not described physical states seen in the reaction and the colours given are incorrect.

ResultsPlus
Examiner Tip

Remember to include descriptions such as solution and precipitate when appropriate, and not just describe change in colour.

Question 1 (a) (iii)

Candidates seemed to find this equation a bit more straightforward than the reaction in Q1(a)(i), though missing state symbols were again common. Other common errors included missing charges on the complex ion, and use of NaOH, rather than OH^- in the question. Those who started with $[Cr(OH)_3(H_2O)_3](s)$ often failed to balance the equation correctly.

(iii) Write an **ionic** equation for the reaction of solid chromium(III) hydroxide with dilute sodium hydroxide solution, showing the formula of the complex ion formed. Include state symbols in your answer.

(2)

$$Cr(OH)_3(s) + OH^-(aq) \rightarrow [Cr(OH)_6]^{3-}(aq).$$

ResultsPlus
Examiner Comments

This example made one slip, the omission of the '3' before the hydroxide ion.
Hence it gained 1 mark for the correct state symbols.

ResultsPlus
Examiner Tip

Double check equations to make sure they balance.

Question 1 (a) (iv)

This question was often correct, though a minority simply stated 'green' and so missed the mark.

(iv) State the final appearance of the reaction mixture in (a)(iii).

(1)

Green precipitate

ResultsPlus
Examiner Tip

Remember, you can distinguish between a precipitate and a solution by the fact that although both may be coloured, a solution will still let light pass through.

ResultsPlus
Examiner Comments

The colour is correct, but not the state, so no marks were given for this answer.

Question 1 (b) (i)

The descriptions seen in this question were far better than those in (a), and candidates regularly used the terms 'solution' and 'precipitate' correctly.

In addition, most answers distinguished between the shades of blue observed, and so could score both marks.

(i) Describe what you would **see** during this experiment.

(2)

pale blue solution to form blue precipitate, when in excess the & blue precipitate darkens to dark blue.

ResultsPlus
Examiner Comments

In this case, the candidate has not recognised that the precipitate dissolves to form a dark blue solution, so only scores 1 of the 2 marks.

ResultsPlus
Examiner Tip

Use colour coding in your revision notes for the transition metal topic, when writing out the formulae of complexes.
This will help to act as a memory trigger.

Question 1 (b) (ii)

Despite the success of many candidates in part (b)(i), which implied that most had carried out this reaction, far fewer could recall the species involved and so write a balanced equation. In weaker responses they simply tried to write an equation for the reaction of copper sulfate with ammonia, while others tried to replace the water molecules with six ammonia ligands.

(ii) The reaction between aqueous copper(II) sulfate and **excess** aqueous ammonia is an example of a **ligand substitution** reaction.

Write an equation for the ligand substitution reaction that occurs, showing the formulae of the complex ions involved. State symbols are not required.

(2)

$$[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+} + 4H_2O + 2OH^-$$

ResultsPlus
Examiner Comments

The right hand side of the equation is incorrect as it shows an additional 2 hydroxide ions.

It scores 1 mark for the correct reactants.

ResultsPlus
Examiner Tip

When carrying out qualitative practical chemistry, make sure you write an equation in your notes for each reaction you can describe.

Question 2 (a)

Most candidates seemed familiar with distillation apparatus and were quick to notice the incorrect direction of water flow, often justifying the need for change in terms of the efficiency of cooling. The replacement of the funnel proved more difficult, with a minority suggesting the whole apparatus should be sealed to prevent escape of volatile compounds. Those that did recognise the need to close the set-up on the left hand side did not always specify what they would use (e.g. bung, stopper etc.), and so missed the mark. Thermometers were regularly mentioned but nearly always in the context of determining the boiling temperature, which was not relevant in this case.

(a) Identify the **two** changes that must be made to the apparatus before heating the pear-shaped flask, giving a reason for each change.

(4)

H_2O/water must be put into the condenser from the bottom not the top to ensure the whole condenser is full of water. A thermomater must be added to monitor the temperature and funnel removed incase it gets knocked over.

ResultsPlus
Examiner Comments

In this case, the need to change the water direction is justified, so scores marks 1 and 2.
The thermometer here is used to measure the temperature, rather than seal the apparatus so no additional credit is given.

ResultsPlus
Examiner Tip

Remember that when using distillation to remove products of oxidation as they are formed, it is more important to recognise the need to seal the apparatus at the side with the reaction flask to prevent escape of volatile compounds, than it is to record the boiling temperature.

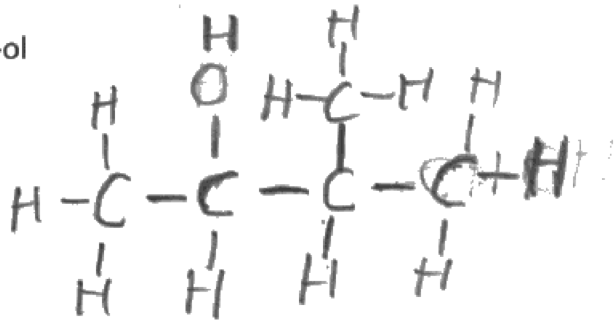
Question 2 (b)

Understanding and use of skeletal formulae seemed embedded and this question was well answered consequently. The most common error was the use of 'CH3' in the structures.

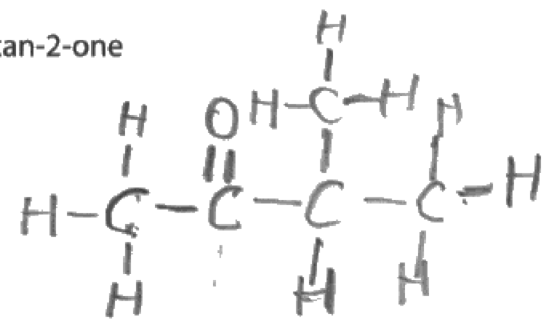
(b) Draw the **skeletal** formulae for 3-methylbutan-2-ol and 3-methylbutan-2-one.

(2)

3-methylbutan-2-ol



3-methylbutan-2-one



ResultsPlus
Examiner Comments

In this example the candidate has correctly drawn both structures but has ignored or misunderstood the command in **bold** to use skeletal formulae, so only scores 1 mark.

ResultsPlus
Examiner Tip

Look at the stem of the question for words or phrases in bold. They are there to help you focus your response.

Question 2 (c) (i)

The majority of answers were sufficient to score the mark here with the simple recognition that secondary alcohols cannot be oxidised to carboxylic acids.

A few simply stated 'because it is a secondary alcohol' which was deemed insufficient to score.

(i) Give a reason why 3-methylbutanoic acid cannot be formed in the reaction.

(1)

As you need to reflux it to get to carboxylic acid.

ResultsPlus
Examiner Comments

Here the candidate seems to be confusing the practical procedures one might use in the partial and complete oxidation of primary alcohols and as a result believes heating under reflux will form the carboxylic acid, so did not score.

ResultsPlus
Examiner Tip

Make sure that as well as remembering organic reactions, you can justify why they occur under a given set of conditions.

Question 2 (c) (ii)

Despite the mention of sulfuric acid in the stem, and the previous question making it clear that carboxylic acids do not form in the reaction, a surprising minority did not score the mark. Common wrong answers included a variety of organic acids or alcohols and $H_2Cr_2O_7$.

(ii) Deduce the **formula** of the compound that could cause the distillate to have a pH value of 2.

(1)

~~[illegible]~~ H_2SO_3

ResultsPlus
Examiner Comments

The formula for sulfuric (IV) acid is given, rather than sulfuric (VI) acid, so does not score.

ResultsPlus
Examiner Tip

Make sure you revise the names and formulae of the common inorganic acids studied previously at GCSE as they will be expected knowledge at A level.

Question 2 (c) (iii)

The writing of balanced equations continues to differentiate well between candidates, even for simple inorganic reactions such as this question. Candidates did not appreciate state symbols well, perhaps not considering the solubility of the sodium sulphate product nor the information in the question about the sodium carbonate solid added. The examination team were disappointed to regularly see $NaCO_3$ as the formula for sodium carbonate

(iii) Solid sodium carbonate is added to the distillate. The sodium carbonate disappears and fizzing occurs.

Write an equation, including state symbols, for the reaction that occurs between sodium carbonate and the compound you have identified in (c)(ii).

(2)

$NaCO_{3(s)} + a\,H_2SO_{4(aq)} \longrightarrow CO_{2(g)} + H_2O_{(l)} + NaSO_{4(aq)}$

ResultsPlus
Examiner Comments

The incorrect formula was such a fundamental error at this level that such responses did not score.

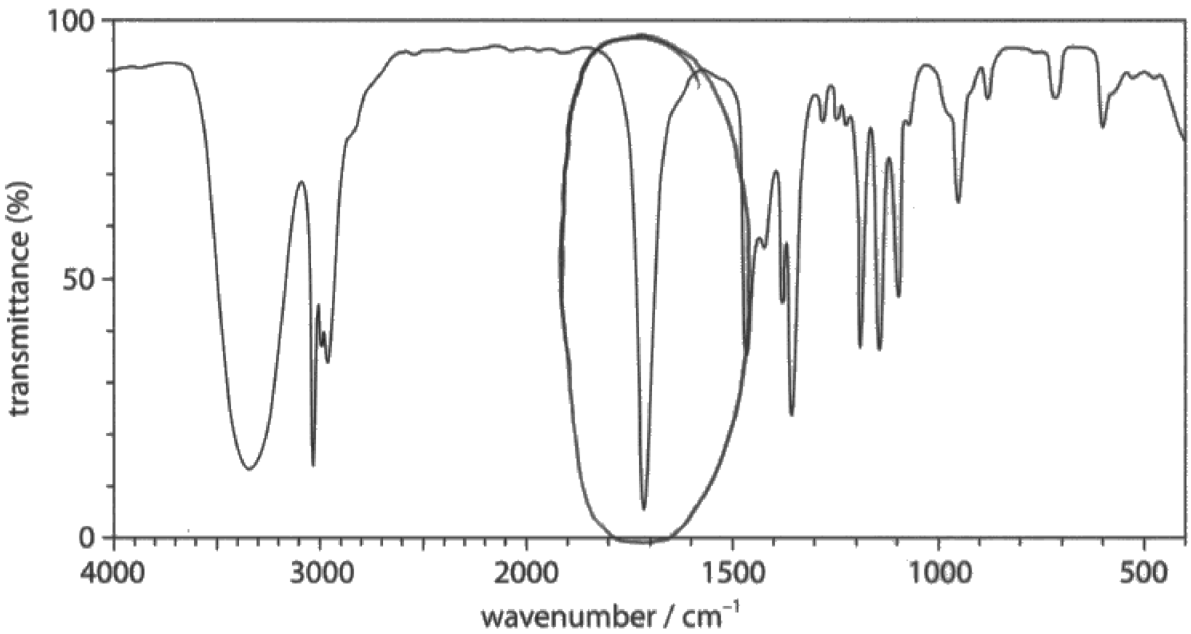
ResultsPlus
Examiner Tip

Learn the formula of common ions used in the course and practice using them, alongside solubility rules, throughout the two years of study.

Question 2 (d) (i)

Candidates almost all appreciated the need to comment on the peak at 1720 cm^{-1}, but fewer made the link between the peak and the carbonyl bond in the ketone. Some candidates simply tried to match peaks from the Data Booklet regardless of the structure of the ketone. Hence some answers claimed that peaks were due to alkene or alkyne groups.

(d) The organic mixture was separated from the aqueous layer and dried.
The infrared spectrum of the organic mixture is shown.



(i) By reference to any relevant peak(s), deduce how the infrared spectrum shows that the mixture contains 3-methylbutan-2-one.

(2)

There is a large peak around 1700 which would indicate the ketone functional group

ResultsPlus
Examiner Comments

In this case the relevant peak is identified but not linked to the bond that caused it, so only scores one of the two available marks.

ResultsPlus
Examiner Tip

When discussing IR spectra try to discuss specific bonds that cause the transmittance, rather than simply naming functional groups.

Question 2 (d) (ii)

Most candidates recognised that the broad peak at around 3400 cm^{-1} would disappear. However, although many realised this peak was due to the alcohol, only in the better responses could they justify their answer by referring to the removal of the alcohol in the distillation. Others misunderstood the separation role of the second distillation and thought that this was done to ensure any remaining alcohol was completely oxidised.

(ii) From the infrared spectrum, the student concludes that the mixture contains another organic compound.

The mixture is redistilled and the fraction that boils in the range 93–95 °C is collected. The boiling temperature of 3-methylbutan-2-one is 94 °C.

Predict any change(s) you would see in the infrared spectrum after redistillation, justifying your answer.

(2)

There would be no peak for the alcohol ~~at~~ between 3750 – 3200.

ResultsPlus
Examiner Comments

As in part (d)(i), the relevant peak is again identified. However, its disappearance is not justified so this only scores one of the two available marks.

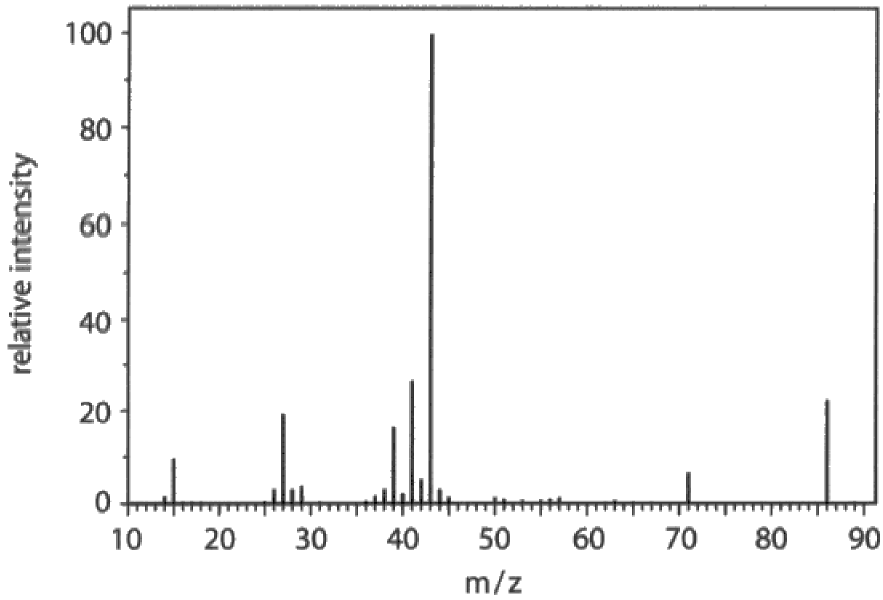
ResultsPlus
Examiner Tip

Look out for command words and make sure you know what they mean. In this case the prediction had to be **justified**, which means you have to give evidence/reasons to support your prediction.

Question 2 (e) (i)

This was well answered in the main. Those who failed to score seemed to have misinterpreted the question or ignored the 'how you would find' 'wording. Such candidates simply gave the value of 86 and did not score unless they included further clarification

(e) The mass spectrum of pure 3-methylbutan-2-one is shown.



(i) State how you would find the molar mass of 3-methylbutan-2-one from the mass spectrum.

(1)

Use the m/z value of the molecular ion peak at 87m/z

ResultsPlus
Examiner Comments

This response primarily failed to score because it did not say **how** to find the molar mass, but stated (incorrectly) what it was.

ResultsPlus
Examiner Tip

Read each question with care, to check you are attempting to answer what the question asks.

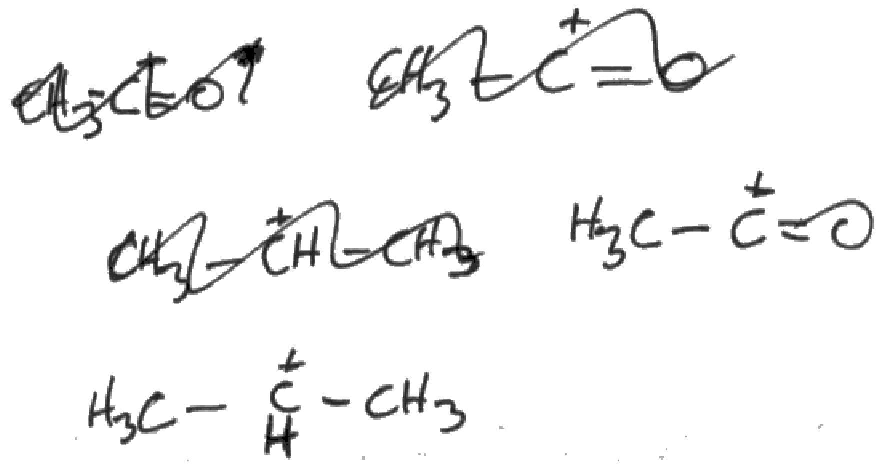
Question 2 (e) (ii)

Most candidates ensured their fragments were positively charged, so many scored both marks. However, some did carry out rearrangements to the ions or ignored the instruction in bold to use displayed formulae, so lost some credit.

(ii) The mass spectrum shows a peak at m/z = 43.

Draw the **displayed** formulae of two fragment **ions** that might be responsible for this peak.

(2)



ResultsPlus
Examiner Comments

This example shows both ions correctly but as structural formulae. As the question specifically wanted to test the skill of writing a displayed formula, as well as the fragmentation, this answer only scored 1 of the 2 marks.

ResultsPlus
Examiner Tip

When writing organic formulae, always check whether or not a question specifies the type of formula required in the answer.

Question 2 (f) (i)

Given its relatively straightforward nature, this question differentiated between candidates extremely well. Candidates had a lot to consider from counting carbon atoms to recognition that the other product was water. However, the most frequent error was in failing to use molecular formulae correctly, with candidates separating OH in the alcohol and/or writing structural formulae.

(f) The sample of purified 3-methylbutan-2-one is found to have a mass of 2.15 g.
This mass of 3-methylbutan-2-one represents a yield of 62.5% by mass.

(i) Write an equation, using **molecular** formulae, for the oxidation of 3-methylbutan-2-ol to 3-methylbutan-2-one.
Use [O] to represent the oxidising agent.

$CH_3CH(OH)CH(CH_3)CH_3$ **(2)**

$$C_5H_{12}O + [O] \rightarrow C_5H_{10}O + H_2$$

$C_5H_{12}O$

ResultsPlus
Examiner Comments

This candidate has used the correct formulae for the alcohol and oxygen on the left hand side. The right hand side has an incorrect product (hydrogen). Hence it scores 1 mark out of 2.

ResultsPlus
Examiner Tip

Practise writing equations for organic oxidation reactions. Use [O] rather than trying to include inorganic oxidising agents, but remember that such equations must balance.

Question 2 (f) (ii)

This twist on a percentage yield calculation proved relatively challenging for many. Many responses simply stopped after scaling up the mass of the product to 3.44 g, taking into account the 62.5% yield. Other common errors included using 65% as the yield, getting the molar masses of the alcohol and ketone the wrong way round, or working out the molar masses incorrectly.

(ii) Calculate the mass of 3-methylbutan-2-ol that the student uses at the start of the preparation.

(2)

$2.15\,g \div 86\,g\,mol^{-1} = 0.025\,mol$ at yield

$0.025 \div 0.625 = 0.04\,mol$ alcohol

$0.04\,mol \times 87\,g\,mol^{-1} = 3.48\,g$

ResultsPlus

Examiner Comments

The candidate has correctly determined the moles of ketone formed, appreciated the 1:1 ratio, and scaled up correctly to find the moles of alcohol needed. Unfortunately, the molar mass of alcohol is incorrect, so they did not score the second mark.

ResultsPlus

Examiner Tip

Lay out your working in calculations clearly. That way, if you do make a mistake it's easier for examiners to give you credit for what you have done, as well as transferred errors for work you do subsequently.

Question 3 (a)

Candidates found this difficult, even though it is a relatively low demand skill. The significance of **amino acid** was lost on many. Even those who appreciated that 'diaminohexanoic acid' was the main part of the name often did not count the carbon in the –COOH, so used '1,5-' as their prefix.

(a) Give the systematic (IUPAC) name for **lysine**.

(1)

1,6 di amino Hexanoic acid

ResultsPlus
Examiner Comments

The example does not score as one of the amino groups is numbered incorrectly.

ResultsPlus
Examiner Tip

Practice converting the common names of amino acids into IUPAC names.

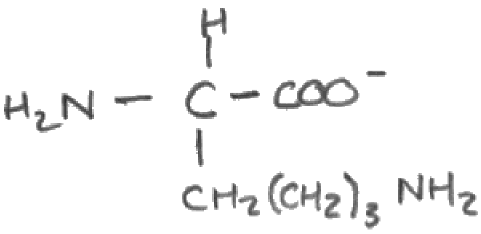
Question 3 (b)

This question differentiated reasonably effectively. In weaker responses, candidates could often draw the correct structure in alkaline conditions, but could not draw the ester. However, the protonation of **both** amine groups was often absent in the second structure, even for stronger candidates. This did not seem to be because they did not appreciate the possible reaction, as often one of the amine groups was protonated.

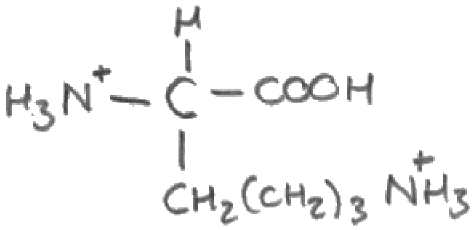
(b) Draw the **structure** of the organic product formed when **lysine** reacts with the following reagents:

(3)

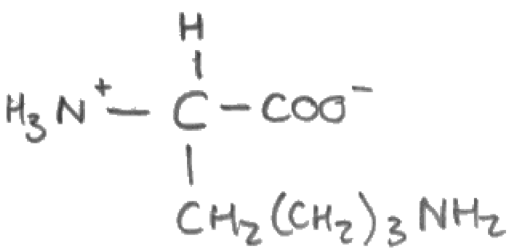
aqueous sodium hydroxide, NaOH(aq)



excess dilute hydrochloric acid, HCl(aq)



methanol, with warming, in the presence of a few drops of concentrated sulfuric acid.



ResultsPlus
Examiner Comments

This answers scores 2 of the 3 marks, as for the third structure the candidate has shown a zwitterion rather than the ester formed by reaction of the acid group with methanol.

ResultsPlus
Examiner Tip

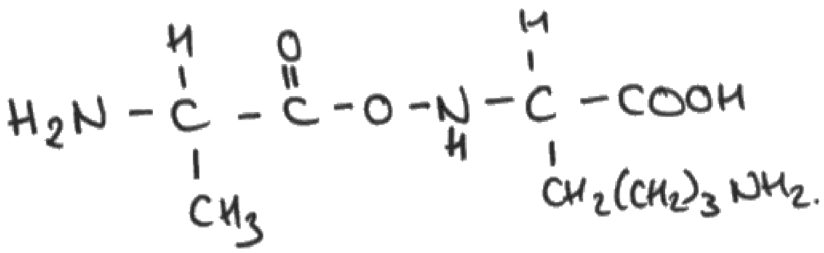
Remember when you study organic reactions you are learning how a functional group reacts, not a specific single compound. For example in this question, the third structure is testing your generic understanding of the reactions of the -COOH and –OH functional groups rather than specifically the chemistry of these amino acids. You need to spot the functional groups you study in unfamiliar compounds and apply the chemistry you have learnt.

Question 3 (c)

Many candidates could demonstrate the understanding of the peptide link and so answered this question successfully. Those who failed to score generally did so because they either introduced an additional oxygen atom into the link, or drew a section of a polypeptide/ protein consisting of the two units.

(c) Draw the structure of a dipeptide formed when one molecule of alanine reacts with one molecule of lysine.

(1)



ResultsPlus
Examiner Comments

This example fails to score as the peptide link is incorrect.

ResultsPlus
Examiner Tip

Be careful not to confuse an ester link with a peptide link.

Question 3 (d)

In better responses, candidates took notice of the emboldened phrase ‘acidic conditions,’ and were able to justify the greater attraction of lysine to the stationary phase in terms of its greater positive charge. The majority of other responses did score the ‘attraction’ mark, but tried to justify it with generally vague statements related to intermolecular forces or polarity. Disappointingly, a number of candidates seemed not to have developed an understanding of chromatography beyond the idea that ‘heavier molecules will take longer to move through the column’.

Explain why lysine leaves the chromatography column after alanine.

(2)

Lysine is a more polar compound than alanine because of the R group, so it will interact with the polar stationary phase to a greater extent than ~~for~~ alanine would which is less polar. Thus alanine carried by mobile phase more quickly.

(Total for Question 3 = 7 marks)

Lysine has a greater affinity for the stationary phase.

ResultsPlus
Examiner Comments

'Interact with the polar stationary phase to a greater extent' was sufficient for the 2nd mark - but the justification in terms of lysine being 'more polar' was not enough for the 1st mark.

ResultsPlus
Examiner Tip

Remember that under acidic or alkaline conditions amino acids protonate or deprotonate respectively to form ions. This will influence their properties under these conditions, such as the way they interact with a stationary phase in chromatography.

Question 4 (a)

Many candidates did not use the data already shown in the table as a model for the number of decimal places they should use. Hence a mark was often lost for the use of '1.6' for the mass of methanol.

The results of Student 1 are recorded in **Table 1**.

Mass of spirit burner plus methanol before burning / g	213.47
Mass of spirit burner plus methanol after burning / g	211.87
Mass of methanol burned / g	1.6000
Highest temperature of the water / °C	64.5
Initial temperature of the water / °C	22.0
Temperature change of the water / °C	42.5

Table 1

(a) Complete **Table 1**, giving the values to an appropriate number of decimal places.

(2)

ResultsPlus
Examiner Comments

This candidate tried to use the data as a model, but focussed on significant figures, rather than decimal places as guided in the question.

They did however score 1 mark for the correct precision for the temperature change data.

ResultsPlus
Examiner Tip

Use the guidance in the question to help decide when decimal places or significant figures are more important.

Question 4 (b)

More able candidates found this straightforward and often scored 2 marks. However some errors were common and these included:

incorrect balancing of oxygen using $2O_2$;
use of (aq) for the state symbol of methanol;
no written equation for 1 mole of methanol.

(b) Write the equation that represents the reaction that occurs when the standard enthalpy change of combustion of methanol, $CH_3OH(l)$, is measured. Include state symbols.

(2)

$$CH_3OH_{(l)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(l)}$$

ResultsPlus
Examiner Comments

This example scored 1 mark for the correct state symbols for the correct species but in an unbalanced equation.

ResultsPlus
Examiner Tip

Take care when balancing combustion equations with alcohols, as you need to take into account the single oxygen atom in the hydroxyl group, when you deduce how many moles of elemental oxygen molecules are required.

Question 4 (c)

This proved to be the most accessible unstructured calculation on the paper, with many candidates scoring 3 or 4 marks.

Common errors included:

- use of 1.6 g when calculating energy;
- missing signs on the value for the enthalpy change;
- final answer given to 5 significant figures.

(c) Use Student 1's result to calculate the enthalpy change of combustion of methanol in kJ mol^{-1}.
Give your answer to an appropriate number of significant figures.

Specific heat capacity of water = 4.18 J g^{-1} °C^{-1}
Density of water = 1.00 g cm^{-3}

(4)

$q = mc\Delta t$

$q = 150 \times 4.18 \times 42.5$

$= 26647.5$ J

moles of methanol = 1.60g ÷ (32)

= 0.05 moles.

$\Delta H = \frac{26647.5}{1000} \div 0.05$

$= -532.95$ kJ.mol^{-1}

ResultsPlus
Examiner Comments

This candidate scored the first 3 of the 4 marks available.
They lost credit because they gave their final answer to 5 significant figures, which is not appropriate given that the least precise data in the question was to 3 significant figures.

ResultsPlus
Examiner Tip

Use the least precise data in the question as a guide to the level of precision needed for your final answer.

Question 4 (d) (i)

Most candidates could calculate the percentage uncertainty correctly.

The most common way to not score was to round the final answer incorrectly, for instance giving an answer of 0.66% rather than 0.67%.

(d) Student 1 compared the experimental value for the enthalpy change of combustion of methanol obtained in part (c) with the standard value given on the internet.
The student's value was **less exothermic** than the standard value.

Student 1 decided to evaluate the uncertainty in the measurements made in this experiment.

(i) Student 1 used a 250 cm^3 measuring cylinder to measure the volume of 150 cm^3 distilled water. The uncertainty in this volume measurement is ±1 cm^3.

Calculate the percentage uncertainty in the volume of distilled water that Student 1 measured in the experiment.

(1)

$$\frac{\pm 1\,cm^3}{150\,cm^3} \times 100 = 0.6\%\ \text{uncertainty}$$

ResultsPlus
Examiner Comments

This candidate has the correct working but has rounded their final answer incorrectly, so did not score the 1 mark available.

ResultsPlus
Examiner Tip

Remember to check your rounding on the final answer in any calculation.

Question 4 (d) (ii-iii)

In part (d)(ii), most candidates could identify that the percentage uncertainty when using the smaller measuring cylinder six times was greater, and so less preferable to use.

This was often accompanied by the correct value for the percentage uncertainty, scoring 2 of the 3 marks.

Comments on the practicalities of using the two types of cylinder were far less frequent, so the award of 3 marks was relatively rare.

It was evident that candidates were familiar with this type of experiment and as a result, many could discuss at least two of the possible errors that may lead to an inaccurate value in part (d)(iii). Heat loss to the surroundings was by far the most common correct suggestion. Deviating from standard conditions was often cited as a reason, but was not given credit. Errors of the procedure were required, rather than external conditions under which the experiment was carried out.

(ii) Compare and contrast the use of a 250 cm^3 measuring cylinder to measure out the 150 cm^3 distilled water with the use of a 25 cm^3 measuring cylinder (uncertainty ±0.2 cm^3 for each volume measurement) six times to measure the same volume.

(3)

⇒ $\frac{0.2}{25}$ = 0.8% ⇒ 4.8%

⇒ The total uncertainty for using a 25cm^3 measuring cylinder is larger than the uncertainty for the 250cm^3 measuring cylinder.

⇒ Both measurements have an uncertainty of less than 1%.

⇒ using the 250cm^3 measuring cylinder is better as measuring larger volumes provides smaller uncertainty, more accurate.

(iii) Student 1 calculated the uncertainties in the remaining measurements. However, Student 1 realised that the measurement uncertainties did **not** explain the difference between the experimental value for the enthalpy change of combustion of methanol calculated in part (c) and the value obtained from the internet.

Other than human error, give **three** reasons for the difference in the values.

(3)

① copper calorimeter conducted heat energy away from the water to the surroundings.
② There was no lid on the copper calorimeter so heat energy can escape.
③ When flame was extinguished some unburnt fuel may have evaporated, lowering $\Delta_c H$ value.

ResultsPlus
Examiner Comments

In part (d)(ii), the percentage uncertainty is correctly calculated and identified as being greater than that of the larger cylinder used once, so this response scores 2 marks.
The loss of heat to the surroundings as well as the evaporation of the fuel are evident, scoring 2 marks in part (d)(iii).

ResultsPlus
Examiner Tip

When asked to give more than one reason for an answer, check to see that you are not giving the same answer more than once.
For instance 'heat loss to the air' and 'heat loss to the calorimeter' are essentially the same point so worth only 1 mark.

Question 4 (e)

Candidates seemed to find it hard to visualise any difference in the procedure followed when student 1 repeated the experiment. As a result, many answers suggested the value for the enthalpy of combustion would be the same. Those who did realise the temperature change would be lower could not always explain why, nor relate this with sufficient care to the effect on the enthalpy change. For instance, answers that just referred to the enthalpy change being 'lower' did not score without further clarification.

(e) Student 1 decided to repeat the experiment.

Student 1 used the copper calorimeter and water from the first experiment and recorded the initial temperature as 60.0 °C.
Student 1 burned **exactly** the same mass of methanol as in the first experiment.

Explain, with a reason, how the value for the enthalpy change of combustion of methanol from this experiment would differ, if at all, from the value obtained in the first experiment.

(2)

The enthalpy of combustion would be less exothermic due to the water being 60 °C at the start of the experiment and therefore will not have as big a temperature difference.

ResultsPlus
Examiner Comments

This candidate was careful to describe the change in the enthalpy of combustion as 'less exothermic' rather than just 'lower' so scored 1 mark.

Unfortunately they have not explained why the temperature difference was not as big, so just missed out on another mark.

ResultsPlus
Examiner Tip

When describing changes in enthalpy, try to use phrases like 'less exothermic' and 'more exothermic' rather than just 'greater' or 'smaller'.

Question 4 (f)

As in (f) it seemed that candidates could not always appreciate the similarities and differences in the two procedures. As a result, many candidates simply homed in on the increase in heating time, so assumed incorrectly that the enthalpy change calculated would be more exothermic. Those who did appreciate that the energy was proportional to the amount of fuel burned nearly always scored both marks.

(f) Student 2 followed the **original** instructions provided, but extinguished the flame after **four** minutes rather than after three minutes.

Explain how the value calculated by Student 2 for the enthalpy change of combustion of methanol compared with that obtained in Student 1's first experiment.

(2)

more methanol would have evapourated therefore mass of it burned increases and number of moles would increase, decreasing the value making it less exothermic

ResultsPlus
Examiner Comments

This answer scored 1 mark for the recognition that the enthalpy change would be less negative.
However, the reasoning was not enough to score the second mark.

ResultsPlus
Examiner Tip

In this type of 'explain' question, try to make a judgement on the value and then give reasons for your decision.

Question 4 (g)

This question was by far the best answered in this section, which seems a little surprising as it does not directly relate to the procedure.

However, this did not worry candidates who nearly all recognised the amount of calculated moles of methanol would be less, so the enthalpy change would be more exothermic.

While terms such as 'greater' were seen (and given credit), the preferable use of 'more exothermic' in part (g) was seen far more than the required term 'less exothermic' in part (e).

(g) Another student, Student 3, used the results from Student 1's first experiment to find the enthalpy change of combustion of methanol. Student 3 incorrectly used a value of 46.0 g mol^{-1} for the molar mass of methanol.

State and justify how this mistake would affect the calculated value for the enthalpy change of combustion of methanol.

(2)

The ΔH value would be much more exothermic.

ResultsPlus
Examiner Comments

This was an unusual example in that the candidate does not attempt to justify their choice.
In this question the 'state' mark was dependent on the justification, so this response was given 0 marks.

ResultsPlus
Examiner Tip

When asked to 'justify' an answer remember to give reasons or evidence for your choice.

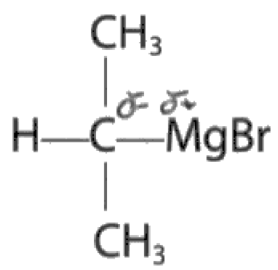
Question 5 (a) (b)

Some candidates perhaps overlooked part (a) since a number were blank. Those who did could not see past $C^{\delta+}$ used frequently in other parts of the specification. Many who had the required negative charge did not complete the dipole on magnesium to score the mark.

Writing the systematic name in part (b) was more discriminating than expected, with the most common being numbering of the methyl group, which was often given the positional prefix of 4. Other candidates drew the correct alcohol. However, they then named it using whatever portion of the chain was shown horizontally on their diagram, which did not always consist of 5 carbons. This was a shame at it seemed that they had done the more difficult task, then lost a mark for essentially an AS-level skill.

5 Grignard reagents are used in organic synthesis as a way of increasing the length of the carbon chain in a molecule.

(a) The structure of the Grignard reagent formed by the reaction between 2-bromopropane and magnesium is



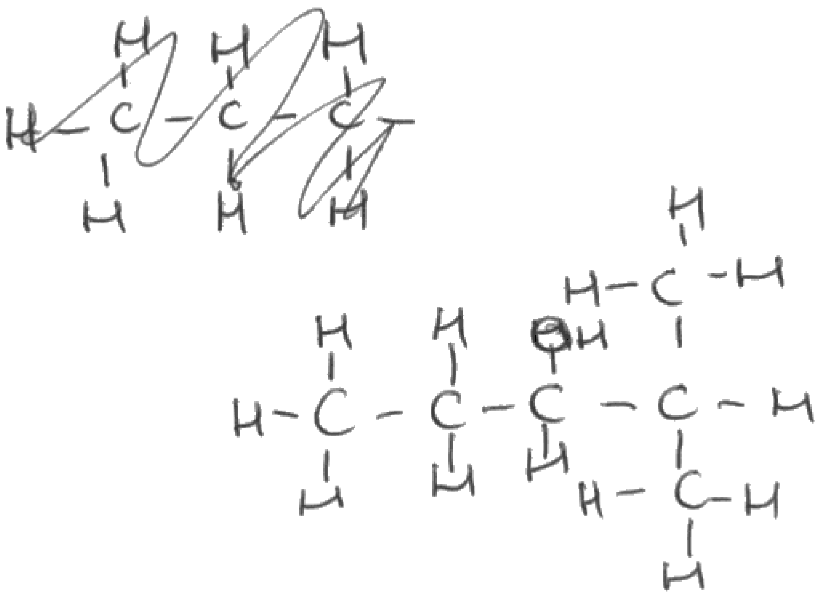
On the diagram, draw the permanent dipole involving the central carbon atom.

(1)

(b) The Grignard reagent in part (a) reacts with propanal.

(i) Draw the **fully displayed** formula of the final organic product of this reaction.

(1)



(ii) Name the organic product in (b)(i).

(1)

~~3 hydroxy~~ 2methyl pentan-2-ol

ResultsPlus
Examiner Comments

This example loses the naming mark in part (b) as they have numbered the positions of the methyl and alcohol group incorrectly.

ResultsPlus
Examiner Tip

Even though you probably study the rules for naming organic compounds quite early in your course, make sure you practise them at every opportunity throughout your studies.

Question 5 (c) (d)

Quite a few candidates seemed to guess an answer to part (c).

Some candidates did show great ingenuity in identifying propane in part (d), but the majority assumed it would be an alcohol or gave a structure containing MgOHBr.

(c) Identify, by using ticks, **two** boxes in the table to select appropriate terms that describe a Grignard reagent.

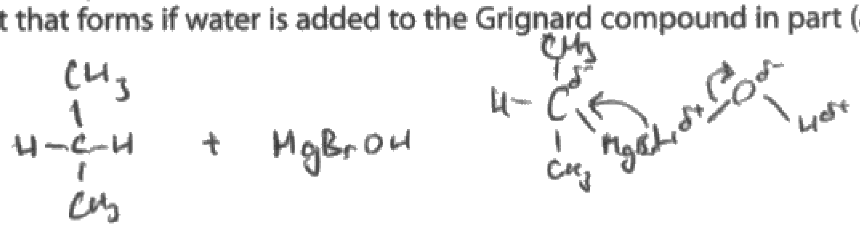
(2)

~~acid~~	
~~electrophile~~	✓
nucleophile	✓
~~oxidising agent~~	
~~reducing agent~~	

(d) The solvent used for Grignard reagents has to be completely **dry**.

By considering the dipole on the O—H bonds in water, predict the identity of the organic product that forms if water is added to the Grignard compound in part (a).

(1)



propane

ResultsPlus
Examiner Comments

This example uses the idea that MgOHBr is often produced when Grignard reagents react to deduce the product correctly.

ResultsPlus
Examiner Tip

Make sure you can deduce products from a range of reactions involving Grignard reagents. Use the idea of the inorganic product, MgOHBr, to help deduce the organic product.

Question 6 (a-d)

Many candidates were aware of the level of precision required for titres in (a), so scored both marks. Candidates did sometimes slip and quote a value of '23.2' for titration 3. In part (b) the best scripts did score the mark. Others tended to get the change of colour the wrong way round or described a change of 'pink to pale pink'. In practical terms, to the naked eye, solutions of Mn^{2+} ions of this concentration are colourless.

The calculation in part (c) also discriminated effectively. Most could pick up one or two marks for the amounts of MnO^{4-} of NO^{2-} respectively and some successfully managed to scale up the amount of NO^{2-} ions; a common error here was to assume the scaling factor was 250/25 rather than 250/average titre.

At this point only the more able candidates made further progress using a variety of creditworthy strategies. The most common was to calculate the molar mass of the hydrated salt. However, some failed to recognise that the amount of the hydrated salt was half the amount of the NO^{2-} ions.

Others used the more complex route of using the amount of hydrated salt to calculate the mass of all species present but water, then subtract these masses from the original mass of the hydrated salt. This enabled them to find the amount of water, which could then be compared to the amount of the salt to find x.

Most candidates managed to score at least 1 mark in part (d), the common mistakes being omission of charges on ions and not simplifying the equation by cancelling out species such as water molecules.

Method 1 – Titration

The student filled the burette with the solution made from $Mg(NO_2)_2{\cdot}\boldsymbol{x}H_2O$.

In each titration

- 25.0 cm^3 of 0.0200 mol dm^{-3} $KMnO_4$(aq) was transferred to a conical flask using a pipette.
- An excess of dilute sulfuric acid was added to the conical flask and the mixture heated.
- $Mg(NO_2)_2$(aq) was added from the burette until the end-point was reached.

The student's titration results are shown in the table (the rough titration results have **not** been included in the table).

Titration number	1	2	3
Final burette reading / cm^3	23.95	48.05	23.85
Initial burette reading / cm^3	0.80	24.50	0.65
Titre / cm^3	23.15	23.55	23.20
Concordant titres (✓)	✓		✓
Mean titre / cm^3	(23.175) ~~[illegible]~~ 23.18		

(a) Complete the table.

(2)

(b) Deduce the colour change that the student would see at the end-point in this titration.

(1)

From colourless to pink

(c) In the titration reaction, 2 mol MnO_4^- react with 5 mol NO_2^-.
Calculate the number of moles of NO_2^-, in the 250 cm^3 of solution prepared by the student and hence the value of **x** in $Mg(NO_2)_2.xH_2O$.
Give your answer to the nearest whole number.

(5)

moles MnO4 initial = $\frac{25}{1000} \times 0.02 = 5 \times 10^{-4}$

$\frac{5 \times 10^{-4}}{2} \times 5 = 1.25 \times 10^{-3}$ mol NO_2^- in 23.175 cm^3

so in 250 cm^3 = 0.01348 mol NO_2^-

Mr = $\frac{1.15}{0.01348}$ = 85.28

Mr $(Mg(NO_2)_2)$ = 116.3

116.3 − 85.28 = 31.02

Mr H_2O = 18

$\frac{31.02}{18}$ = 1.7 x = 2

(d) The half-equations for the reaction in the titration are

$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ × 2

$NO_2^- + H_2O \rightarrow NO_3^- + 2H^+ + 2e^-$ × 5

Use these half-equations to derive the overall ionic equation for the reaction between manganate(VII) and nitrate(III) ions in acidic conditions.
State symbols are not required.

(2)

~~$2MnO_4^- + 16H^+ + 5NO_2^- + 10H^+ \rightarrow 2Mn^{2+} + 8H_2O + 5NO_3^- +$~~

~~$2MnO_4^- + 16H^+ + 5NO_2 + H_2O \rightarrow 2Mn^{2+} + 8H_2O + 5NO_3^- + 10H^+$~~

$2MnO_4^- + 6H^+ + 5NO_2 \rightarrow 2Mn^{2+} + 7H_2O + 5NO_3^-$

ResultsPlus
Examiner Comments

Here the data is quoted to an appropriate level of precision and the average titre calculated correctly, so part (a) scores 2 marks. The colour change in part (b) is the wrong way round, so does not score.

In part (c) the candidate does not recognise that the amount of salt is half that of the NO^{2-} ions. This gives a molar mass of approximately 85, which, if carried forward would give a negative value for x, so is worth no further credit.

In part (d) the 2:5 ratio is evident, so scores 1. The number of water molecules is incorrect and a charge is missing from one of the ions, so the 2nd mark could not be given.

ResultsPlus
Examiner Tip

Label all your working clearly in unstructured calculations.
Then if you do make a mistake, the examiner can follow what you are trying to do.

Question 6 (e) (f)

In part (e) most candidates suggested that the amount or mass of magnesium carbonate would be less than expected.

However, this very often led to a judgement that x would also be lower.

In part (f) there seemed to be some confusion between the terms 'evaporate' and 'decompose', with some suggesting that magnesium carbonate might do both, so did not score.

A minority of candidates did not score because they referred to generic impurities in the residue rather than specific examples evident from the question, such as sodium carbonate. Only a small number of candidates made a judgement about the quality of the plan.

Method 2 – Precipitation

The student used the following procedure.

- Dissolve a known mass of $Mg(NO_2)_2 \cdot xH_2O$ in distilled water.
- Add an excess of aqueous sodium carbonate solution, $Na_2CO_3(aq)$, to obtain a precipitate of magnesium carbonate, $MgCO_3(s)$.

$$Mg^{2+}(aq) + CO_3^{2-}(aq) \rightarrow MgCO_3(s)$$

- Weigh a piece of filter paper.
- Filter the mixture from the above reaction through the pre-weighed filter paper.
- Wash the precipitate of $MgCO_3(s)$ with distilled water.
- Dry the filter paper and precipitate in a desiccator.
- Reweigh the filter paper and the precipitate.
- Calculate the value of ***x*** from the results obtained.

The student found that the value of ***x*** calculated using **Method 2** was different from that obtained using **Method 1**. This difference occurred despite having used a pure sample of the hydrated salt and without making any errors in technique during the experiment.

The student found out from a data book that the compound magnesium carbonate is very slightly soluble in water.

(e) Explain how, if at all, the very slight solubility of magnesium carbonate in water would affect the value calculated for ***x***.

(2)

it means that some $MgCO_3$ would be lost during washing and drying, so the mass used in calculations would be lower than reality so x would be larger.

(f) The student planned to obtain any dissolved magnesium carbonate by evaporating the filtrate, and then weighing the residue.

Criticise this student's plan.

(2)

it would include any impurities.

ResultsPlus

Examiner Comments

This candidate realises that the mass of magnesium carbonate would be less and correctly links this to the change in x, so scores 2 marks in part (e).
In part (f) the 'impurities' was not specific enough to gain credit.

ResultsPlus

Examiner Tip

When evaluating a plan or procedure try to make comments that apply specifically to that experiment.

Question 6 (g) (h)

Some candidates appeared to confuse Method 3 with the reaction between magnesium and oxygen to find the formula of magnesium oxide.

As a result, comments about lifting the crucible lid periodically were quite common in part (g).

Others realised that you had to determine when all the water had been removed, but suggested inappropriate techniques such as testing for water with cobalt chloride paper.

Near misses tended to include the idea of prolonged heating or of checking the mass, but not both.

Part (h) was often well answered, though just the phrase 'use a more accurate balance' was not enough to score a mark.

Method 3 – Thermal decomposition

NOTE: On heating, $Mg(NO_2)_2.xH_2O(s)$ loses its water of crystallisation and **then** undergoes further decomposition to give magnesium oxide, MgO.

The student used the following procedure.

- Weigh an empty crucible.
- Add some $Mg(NO_2)_2.xH_2O(s)$ and then reweigh the crucible plus contents.
- Heat the crucible plus contents and allow to cool.
- Weigh the crucible plus magnesium oxide residue.
- Use these data to calculate a value for ***x***.

The student's results are shown in the table.

Mass of crucible / g	18.02
Mass of crucible + $Mg(NO_2)_2.xH_2O$ / g	18.84
Mass of crucible + MgO residue / g	18.27

(g) Identify how the student should ensure that the hydrated salt was fully decomposed.

(1)

~~[illegible]~~ Test for NO_2 gas with damp litmus paper

Fully decomposed when further heating causes no more NO_2

(h) The student carried out an evaluation of the results obtained from **Method 3**

Identify **two** modifications to the method that would enable the student to lower the percentage uncertainty in the measurement of the mass of the solid residue.

(2)

Use a larger amount of ~~[illegible]~~ $Mg(NO_2)_2.xH_2O$ to minimise errors from the balance

Use a more accurate balance.

ResultsPlus

Examiner Comments

Although in part (g) the response uses the idea of more heating, it is not linked to the measurement of the mass over time, so does not score.
In part (h), using a larger mass of the salt scores 1 mark.

ResultsPlus

Examiner Tip

Remember that comments about 'repeating results' are linked to the reliability of the data, but will not influence the percentage uncertainty.

Question 7 (a)

The quality of extended responses in this question was generally good.

At the higher level of achievement, answers scoring 5 or 6 marks were common, any error tending to be the use of shortened electron configurations such as $[Ar]3d^{10}$. On occasion, imprecise terminology such as ‘Zn^{2+} has a full d orbital’ as a way of justifying why zinc is not classified as a transition metal hindered a candidate’s progress. Fortunately many went onto clarify this later in their answer with clear references to either ‘full subshells’, ‘d orbitals are full’ or clear reference to d^{10} in their answer. In a similar way, some answers used the imprecise term ‘d-shell’ throughout, and so lost 1 mark. Many good answers also went on to justify the lack of colour in Zn^{2+} and Sc^{3+} solutions, which was not required by the question. Fortunately, most of this additional information was correct; the only problem it may have created was to leave candidates with less time available for later questions. In the weakest answers, candidates did at least realise that zinc and scandium are not transition metals but then tried to define transition metals as **atoms** with an incomplete d subshell, making it difficult to then access the points needed to explain their choice of scandium and zinc.

7 This question is about the chemistry of elements in the *d*-block of the Periodic Table.

*(a) Many of the *d*-block elements are also classified as transition metals.

Explain why two of the *d*-block elements within Period 4 (scandium to zinc) are **not** classified as transition metals.

You should include **full** electronic configurations where relevant.

(6)

Transition metal elements are elements in the d-block which can form one or more stable ions with an incompletely filled d orbital. The elements within Period 4 that are d-block elements but not transition metals are zinc and scandium. Zinc can form Zn^{2+} ions, however, as its electron configuration is $[Ar]\ 3d^{10}\ 4s^2$ and electrons are lost from the 4s subshell when forming positive ions, the Zn^{2+} ion has a completely filled d-subshell so it cannot be classified as a transition metal. Scandium has an electron configuration of $[Ar]\ 3d^1\ 4s^2$. It forms Sc^{3+} ions which, like zinc, do not have an incompletely filled d subshell so scandium can not be classified as a transition metal.

ResultsPlus
Examiner Comments

This example showed evidence of 3 indicative points, scoring 2 marks for these points. Answers that make 3 or 4 relevant indicative points, in general, score 1 reasoning mark. This makes 3 marks in total.

The points made are:
successfully defines transition metal; recognises Sc and Zn are not transition metals; recognises the full d-subshell in the Zn^{2+} ions.

Unfortunately the electron configurations of the ions are not evident and there is no reference to the empty d-subshell in Sc^{3+}, only that it is 'not incompletely filled', which could of course mean full.

ResultsPlus
Examiner Tip

Make sure you are clear about the differences between orbitals, sub-shells and shells.

Question 7 (b)

The lack of structure in calculations at this level provided both a degree of challenge and differentiation by outcome.

In weaker responses, candidates benefitted by adopting a logical approach and in general looked to use the data to find the amounts of $Cr_2O_7^{2-}$ ions and Mn^{2+} ions, so scored the first two marks. Many also went on the find the whole number ratio between the reactants.

The better responses made further progress, using a variety of techniques to arrive at the correct outcome. These included use of oxidation numbers, deducing the numbers of electrons transferred by 3 moles of Mn^{2+} and calculations of the number of moles of electrons. Occasionally in the final step, candidates added the 2 electrons to Mn^{2+}, getting an oxidation state of 0, so missing the final mark.

(b) Under certain conditions, dichromate(VI) ions, $Cr_2O_7^{2-}$, can oxidise manganese(II) ions, Mn^{2+}.

In this reaction, dichromate(VI) ions are reduced to chromium(III) ions, in acidic conditions, according to the half-equation

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightleftharpoons 2Cr^{3+}(aq) + 7H_2O(l)$$

In an experiment it was found that 20.0 cm^3 of 0.100 mol dm^{-3} potassium dichromate(VI) was required to oxidise 30.0 cm^3 of 0.200 mol dm^{-3} manganese(II) sulfate solution.

Use these data to calculate the final oxidation state of the manganese.

(5)

moles of $Cr_2O_7^{2-}$ used = $\frac{20}{1000} \times 0.1$

$= 2 \times 10^{-3}$

∴ moles of electrons ~~uptaken~~ ~~released~~ uptaken = $2 \times 10^{-3} \times 6$

= 0.012 moles

moles of Mn^{2+} used = $\frac{30}{1000} \times 0.2 = 6 \times 10^{-3}$ moles.

$\frac{0.012}{6 \times 10^{-3}} = 2$

each Mn^{2+} releases 2 electrons.

oxidation number of manganese = +4

Mn^{4+}

ResultsPlus
Examiner Comments

In this example, worth full marks, the candidate uses the half equation and the amount of $Cr_2O_7^{2-}$ ions to deduce the moles of electrons gained. They then compare this to the moles of Mn^{2+} to deduce the electrons lost by each Mn^{2+} ion, and so find the correct oxidation state at the end of the reaction.

ResultsPlus
Examiner Tip

In an unstructured calculation based on quantitative chemistry, always start by calculating the amounts of substances present, using data from the question.

Question 7 (c)

As in Q7(b), in the weaker responses candidates found the unstructured nature of the problem very challenging and rarely scored more than one mark.

Often they were distracted by the idea of the cell and spent valuable time drawing a labelled diagram of the cell.

The data in the question was often ignored. Instead a significant minority of candidates looked up and attempted to use E_{cell} data. Sometimes this enabled candidates to narrow down the list of possible metals, and then by trial and error, identify X as magnesium, by working backwards from the atomic mass.

Such an approach could score credit but was not efficient in terms of time used.

Others successfully determined the amount of chromium, but did not realise the significance of the formula XSO_4, so could not deduce the mole ratio.

Those who did deduce the ratio invariably went on to score full marks.

(c) A student constructed an electrochemical cell as follows:

- a half-cell was made from a strip of chromium metal and a solution of aqueous chromium(III) sulfate
- a second half-cell was made from a piece of metal, **X**, and a solution of its sulfate, XSO_4(aq)
- the two half-cells were connected and a current allowed to pass for some time.

Results

- the chromium electrode increased in mass by 1.456 g
- the electrode made of metal **X** decreased in mass by 1.021 g.

Use these data to determine the identity of the metal, **X**.

(4)

$Cr = 52.0g$ $\qquad$ $Cr^{3+} + 3e^- \rightarrow Cr_{(s)}$ $\quad E^{\circ} = -0.74V$

∴ No of moles = $\frac{1.456}{52} = 0.028$ moles

~~∴ 0.028 × Molar mass of X = 1.021g~~

~~Molar mass of X =~~

~~$XSO_4 = X^{2+}$~~

~~∴ Mole ratio is 2 : 3 (Cr X)~~

XSO_4 ∴ ~~X~~ X^{2+}

∴ X is V^{2+}, Zn^{2+} or Mg^{2+}

~~X either V or Zn~~

~~2 Cr = 3X~~

~~$0.028 = \frac{0.028 \times 3}{2} = 0.042$~~

Mole ratio 2 : 3 (Cr X)

2 Cr = 3X

$0.028 = 0.028 \times \frac{3}{2} = 0.042$ moles

∴ $\frac{1.021}{x} = 0.042$

$x = \frac{1.021}{0.042} = 24.31$

∴ Molar mass of X = 24.3g

X is Mg

ResultsPlus
Examiner Comments

In this case the candidate has realised that X must form an X^{2+} ion, narrowing down their choice to 3 possibilities, possibly based on their ability to reduce Cr^{3+}.
However rather than trying to work backwards from the A_r values of each metal, as some did, they use the more efficient method of deducing the amount of X and then calculating A_r.

ResultsPlus
Examiner Tip

Even when you have a data booklet, if you are given data in the question, you are expected to use it in your answer.

Question 8 (a)

This question is on the nucleophilic substitution mechanism. Candidates were precise about the positioning of arrows.

The use of correct charges on the intermediate and the final arrow from the N-H bond suggested that such candidates understood the principle of the curly arrow. In weaker responses the final arrow often went incorrectly to the hydrogen, which perhaps indicates candidates having a 'rote learning' approach to mechanisms.

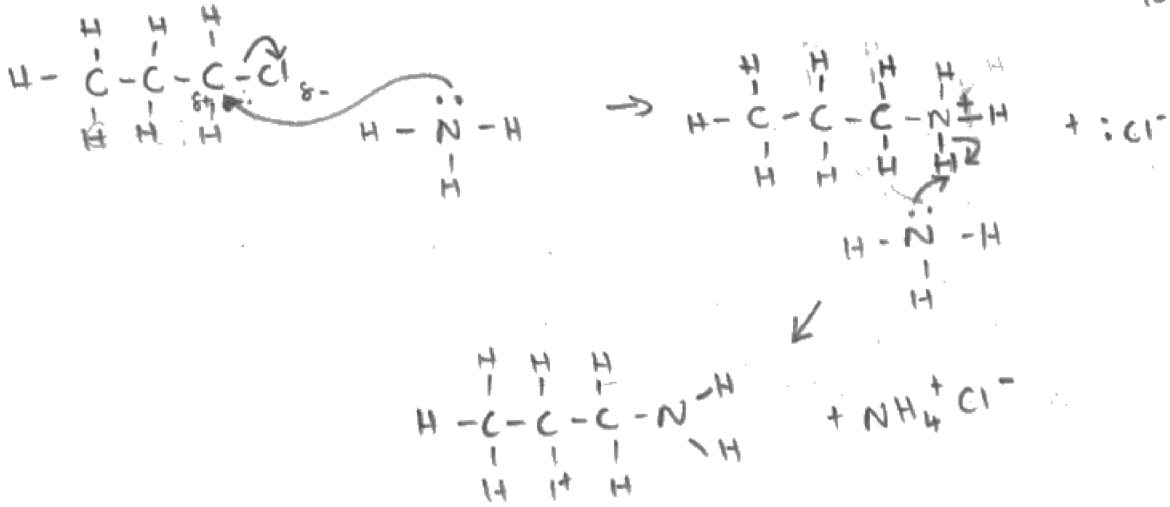
The majority of candidates used the SN2 mechanism.

8 The chemistry of organic compounds containing a chlorine atom is affected by the presence of other groups.

Consider the reaction of ammonia, NH_3, with $CH_3CH_2CH_2Cl$ and with CH_3CH_2COCl.

(a) Draw the mechanism for the reaction of $CH_3CH_2CH_2Cl$ with an **excess** of ammonia to form the primary amine. Include curly arrows and relevant lone pairs.

(3)



ResultsPlus
Examiner Comments

This example scored 2 marks out of 3. They have correctly shown the lone pair on ammonia and the first two curly arrows are correct.
The structure of the intermediate gets the second mark, but although the candidate realises that the intermediate must lose a hydrogen, perhaps they do not appreciate that the curly arrow represents a pair of electrons, as they try to donate two pairs of electrons to the hydrogen.

ResultsPlus
Examiner Tip

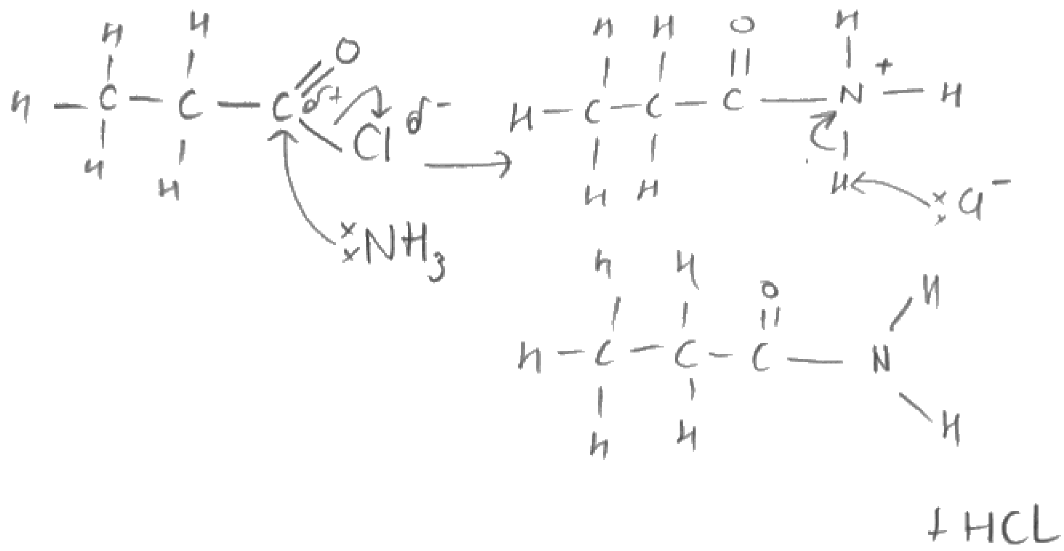
As well as learning the mechanisms, try to write out descriptions in words when you revise.
This will help you understand what the arrows represent, so might help you avoid getting curly arrows the wrong way round.

Question 8 (b)

Candidates struggled to apply their knowledge of nucleophilic addition in this question, and most who gained some credit did so by attempting to use a nucleophilic substation mechanism as in part (a).

(b) Predict the mechanism for the reaction of CH_3CH_2COCl with ammonia.
Include curly arrows and relevant lone pairs.

(3)



ResultsPlus
Examiner Comments

This example scored 2 marks, as the candidate shows all three steps of the SN2 mechanism, which although not correct was worth some credit in the context of this 'predict' question.

ResultsPlus
Examiner Tip

Try to apply the mechanisms you learn in different contexts.
For instance, here the carbonyl group is a pointer to the nucleophilic addition mechanism learnt when studying aldehydes and ketones.

Question 9 (a) (i)

The K_c expression was nearly always correct.

When the mark was not awarded it tended to be for use of 'I' and 'H' rather than 'I_2' and 'H_2'.

9 The gas phase reaction between hydrogen and iodine is reversible.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

(a) (i) Write the expression for the equilibrium constant, K_c, for this reaction.

(1)

$$K_c = \frac{[HI]^2}{[H][I]}$$

ResultsPlus
Examiner Comments

This candidate has used incorrect formulae for iodine and hydrogen so does not score.

ResultsPlus
Examiner Tip

Check that the formulae you use in a K_c expression match those in the balanced equation.

Question 9 (a) (ii)

Dealing with a ratio other than 1:1 in equilibria has always provided a degree of challenge and this was evident in part (ii). Most candidates managed to correctly deduce the numerator. However, far fewer could process the information to find the denominator. The most common incorrect responses were 'a^2' or '$(a-2y)^2$'.

(ii) If the starting concentration of both hydrogen and iodine was **a** mol dm^{-3} and it was found that 2**y** mol dm^{-3} of hydrogen iodide had formed once equilibrium had been established, write the K_c expression in terms of **a** and **y**.

(2)

~~$K_c = \frac{[a-2y]^2}{[2y][2y]}$~~

$$K_c = \frac{[2y]^2}{[a-2y][a-2y]}$$

ResultsPlus
Examiner Comments

Only the numerator is correct so this example scores 1 mark.

ResultsPlus
Examiner Tip

Practice finding concentrations at equilibrium for a variety of reactions, not just those with a 1:1 ratio.

Question 9 (b)

Most candidates successfully completed the table in part (i), and as a result plotted the graph with care. However, a minority did not extrapolate their line of best fir through (0,0) and so lost 1 mark. It was common to see gradients calculated correctly, within the acceptable range. On occasions, candidates lost marks because they simply chose a point from each axis to determine a gradient.

Others failed to show their working on the graph, and as a result it was not always clear to examiners how their value was derived. The determination of K_c in part (iv) discriminated effectively, and a significant minority managed to make the gradient the subject of the formula, even if they could not process the data any further.

A number ignored the stem of the question and tried to determine K_c inserting a pair of values from the table into the expression.

(b) The expression for the equilibrium constant in (a)(ii) can be rearranged as shown.

$$\mathbf{y} = \frac{\mathbf{a}\sqrt{K_c}}{2 + \sqrt{K_c}}$$

In an experiment, air was removed from a 1 dm^3 flask and amounts of hydrogen and iodine gases were mixed together such that their initial concentrations were both **a** mol dm^{-3}. This mixture was allowed to reach equilibrium at 760 K. The equilibrium concentration of iodine was then measured.

The experiment was repeated for various initial concentrations, **a** mol dm^{-3}, and the results recorded in the table.

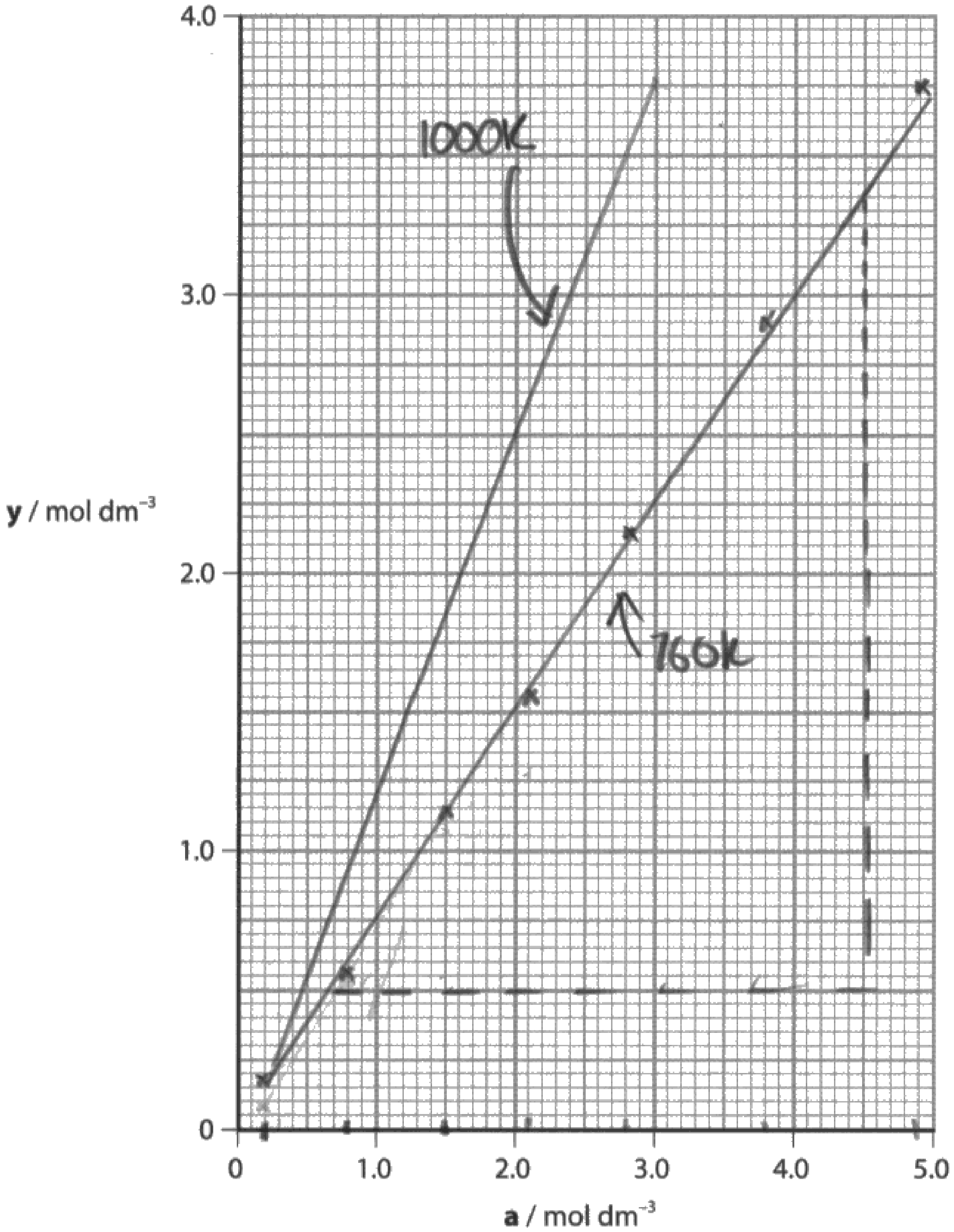
(i) Complete the table to give the two remaining values of **y** mol dm^{-3}, to **two** decimal places.

(1)

a / mol dm^{-3}	$[I_2]_{eq}$ / mol dm^{-3}	y / mol dm^{-3}
0.20	0.02	0.18
0.80	0.25	0.55
1.50	0.37	1.13
2.10	0.57	1.53
2.80	0.65	2.15
3.80	0.87	2.93
4.90	1.15	3.75

(ii) Plot a graph to show how **y** mol dm^{-3} varies with the initial concentrations of hydrogen and iodine, **a** mol dm^{-3}.

(2)



(iii) Determine the gradient of your graph.
Show your working on the graph.

(2)

$\frac{\Delta y}{\Delta x}$ $\frac{3.35 - 0.5}{4.5 - 0.7}$ $\frac{2.85}{3.8}$ = 0.75

mol dm⁻³
mol dm⁻³

(iv) Use your answer to (b)(iii) and the expression $\mathbf{y} = \frac{\mathbf{a}\sqrt{K_c}}{2+\sqrt{K_c}}$ to calculate the value of K_c.

(2)

$\left(\frac{2y}{a}\right)^2$ $y = \frac{a \times \sqrt{Kc}}{2 + \sqrt{Kc}}$ $y + 2$ $\frac{2y + \sqrt{Kc} \times y}{a}$

$Kc = 2.25$

$\frac{2y + \sqrt{Kc} \times y}{a} = \sqrt{Kc}$

2y ~~y(2+√Kc)~~

ResultsPlus
Examiner Comments

Here, the table is completed correctly and the data plotted with care.
However the line of best fit does not extend to (0,0), so a mark was lost.
Clear working is shown for the selection of co-ordinates to calculate the gradient in part (iii).
Unfortunately in part (iv) the candidate could not manage to make y/a the subject of the formula, so did not find K_c.

ResultsPlus
Examiner Tip

Always use as large a section of your graph as possible when finding a gradient.
Show your working clearly on the graph.

Question 9 (c)

The large number of potential hazards associated with the substances used in this experiment meant most scored the mark.

A number missed out because they focussed on the precautions they would take rather than the specific safety risk.

(c) Identify a safety issue associated with this experiment.

(1)

Storing hydrogen at high pressure

ResultsPlus
Examiner Comments

The idea of the high pressures was not enough to score a mark.

ResultsPlus
Examiner Tip

In a chemistry experiment always consider the risks associated with the substances being used.

Question 9 (d)

Candidates not spotting that a comment was required on both the rate and K_c was common. Those who did, often scored both marks. It was also quite common to see candidates try to explain their deductions, which was not required.

(d) One of the experiments in part (b) was repeated using the same molar quantities of hydrogen and iodine but in a 500 cm^3 flask instead of the 1 dm^3 flask.

Deduce the effect, if any, that this would have on the rate of reaction and on the value of K_c calculated.

(2)

This would ~~temperature~~ double the pressure, but K_c is only affected by temperature so no effect on K_c.

ResultsPlus
Examiner Comments

This example shows a candidate who correctly realises the pressure will increase and considers the effect this has on K_c.

However there is no discussion of rate, so they only score 1 mark.

ResultsPlus
Examiner Tip

Read even short questions with care to make sure you are answering all parts.

Question 9 (e) (i)

Most could explain the effect of a temperature increase on K_c, but a number failed to score both marks because they described the change in equilibrium position but did not relate it to the exothermic nature of the reaction.

(e) The equation for the reaction between hydrogen and iodine is

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H = -9.6 \text{ kJ mol}^{-1}$$

(i) Explain the effect, if any, on the value of K_c when the temperature is increased.

(2)

Kc will get bigger as the equilibrium would shift more in the endothermic direction producing more product

ResultsPlus

Examiner Comments

The change in K_c is incorrect, so no marks were awarded to this example.

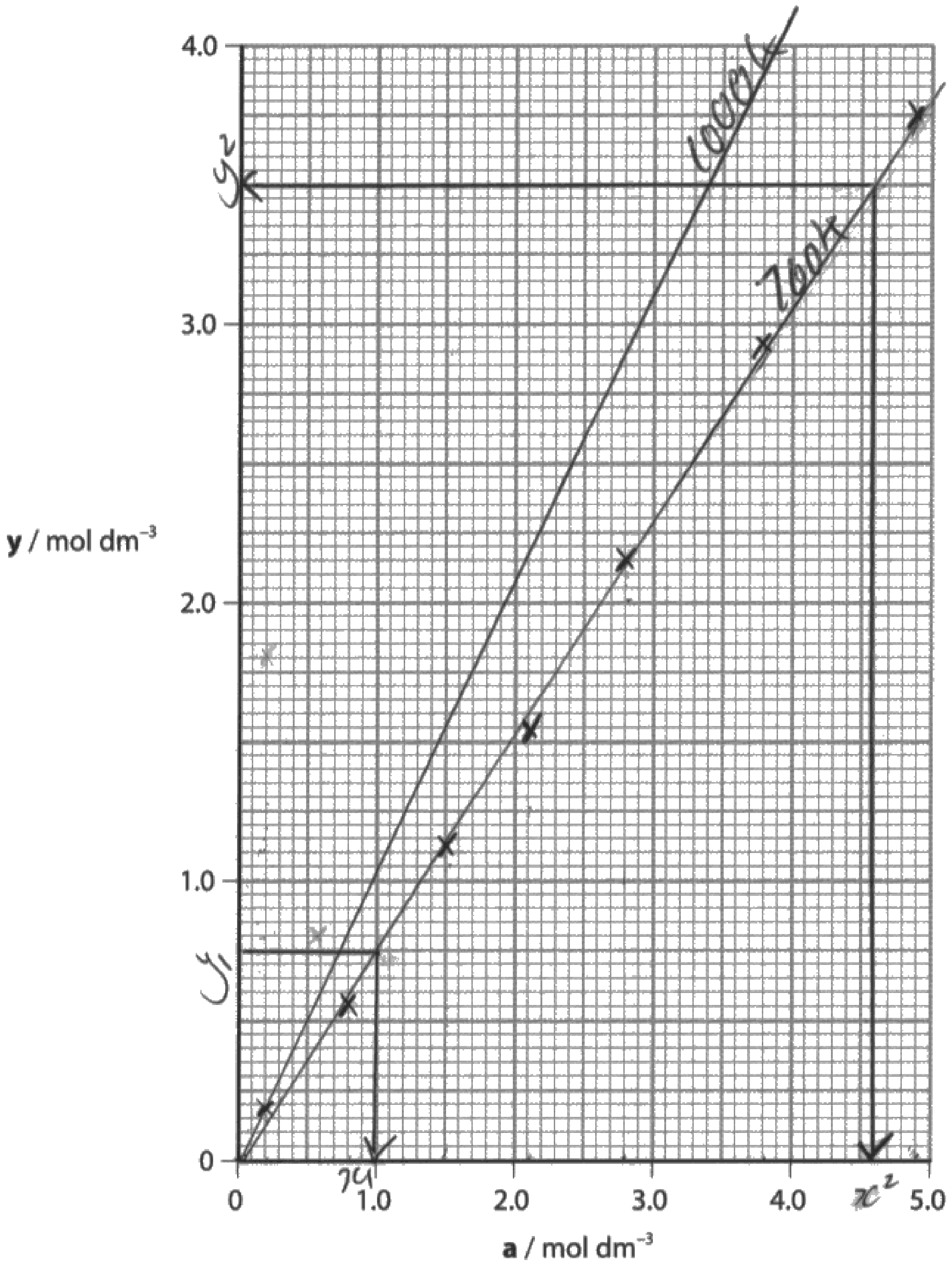
ResultsPlus

Examiner Tip

Make sure you can apply Le Chatelier's principle to both exo- and endothermic reactions and use the outcome to determine changes to K_c.

Question 9 (e) (ii)

Nearly all attempts here were either a steeper straight line or a less steep straight line.



(ii) On your graph in (b)(ii), draw and label the line you would expect if the experiment was carried out at 1000 K instead of 760 K.

ResultsPlus
Examiner Comments

Many candidates, such as this one, thought a steeper line indicated a greater value for the equilibrium constant.

ResultsPlus
Examiner Tip

Remember that questions in the same section e.g. (i), (ii) etc. often have linked ideas.

Paper Summary

Based on their performance on this paper, candidates are offered the following advice:

- Read the stem of each question carefully to ensure you focus your response more precisely on what the question is asking.
- Take care to revise all the reactions of transition metals highlighted in the specification.
- Make sure you write full descriptions of observations and equations when you carry out practical work on transition metals.
- Practise applying organic mechanisms to a wider variety of compounds than just the examples covered in your lessons.
- When revising, work together with peers to check for clarity in your written explanations, especially when justifying how changes in procedure or conditions might influence a practical outcome.
- Label each step clearly, when you practice unstructured calculations.
  This will help embed approaches that you can then try to apply to unfamiliar questions.

Grade Boundaries

Grade boundaries for this, and all other papers, can be found on the website on this link:

http://www.edexcel.com/iwantto/Pages/grade-boundaries.aspx