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Examiners' report

A LEVEL

CHEMISTRY B (SALTERS)

OCR Level 3 Advanced GCE in Chemistry B (Salters)

H433

For first teaching in 2015

H433/02 Summer 2025 series

Version 1

ocr.org.uk/science

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. A selection of candidate responses is also provided. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from Teach Cambridge.

Paper 2 series overview

H433/02 is one of the three examination components for GCE A Level Chemistry B. This component, entitled 'Scientific literacy in chemistry', links together different areas of chemistry within different contexts, some practical, some familiar and some novel. The paper also includes questions based on a pre-released Advance Notice Article, included as an insert with the question paper. To do well on this paper, candidates need to have studied the pre-release material and to have researched some of the unfamiliar contexts included in this document. They also need to be comfortable applying their knowledge and understanding to unfamiliar contexts and be familiar with a range of practical techniques that they should recognise from completing the practical elements of the course.

The most successful candidates demonstrated a knowledge and understanding of the subject material which clearly showed how much time and effort they had put into their studies and revision before sitting this examination.

In addition, it was very pleasing to see how well candidates engaged with both Level of Response questions. Many candidates achieved at least a Level 2 on both questions, and the more successful candidates achieved a mark at Level 3 on Questions 2 (g) and 5 (a). There was also strong evidence that candidates had spent time with their teachers going through the Advance Notice Article 'Battery Tech Report: Lithium-ion versus Vanadium Redox Flow Batteries (VRFB)', many candidates not only produced excellent responses to the Level of Response question but then subsequently scored creditably across the remainder of Question 5.

What is especially pleasing to note is that candidates made good use of the time available and there were very few instances where it appeared that candidates did not have sufficient time to complete the question paper. Also, it is clear that teachers have taken note of previous reports where concern was raised about candidates not displaying their working in calculations, as across the paper, where calculations were set, the majority of candidates showed their working. In a significant proportion of cases where the final answer was not the expected answer, candidates were often given credit for showing their working as examiners were able to identify where errors were made and so could award credit by use of ECF (error carried forward)

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• approached the calculations in Question 1 (a) (iv) and 2 (e) (ii) in a systematic way, laying out their working and in doing so often scored the majority of the marks available for these two questions • demonstrated a sound knowledge of organic chemistry in Question 1 (a) (i), (ii), (iii), 1 (b) (ii) and (iii) • showed a sound knowledge and understanding of rates of reaction in Question 3, particularly in questions involving graphs • were able to produce well-articulated responses to both Level of Response questions and scored at least Level 2 on both questions.	• struggled to produce balanced chemical equations in Questions 1 (a) (v), 2 (c), 5 (b) (i), and 5 (b) (iii). • had difficulty in expressing their ideas about intermolecular forces in Questions 4 (a) (iii), 4 (a) (iv) and 4 (e) (ii), often confusing one type of interaction with another.

Question 1 (a) (iv)

(iv) The bond energy of the C–C*l* bond is 346 kJ mol^{-1}.

Calculate the **wavelength** (in m) of radiation which breaks this bond.

Give your answer to an **appropriate** number of significant figures.

Wavelength = ... m **[5]**

This calculation was well answered by the majority of candidates. They had obviously practised this type of calculation as part of their revision strategies and it was especially pleasing to note that in most instances the calculation was well structured with clearly identifiable steps. This was particularly useful where candidates did not arrive at the expected answer as examiners were able to award credit for correct steps in the calculation by the application of ECF (error carried forward).

Question 1 (a) (v) and (vi)

(v) Chlorine radicals catalyse the breakdown of ozone in the stratosphere.

Write equations to show how this occurs and give the overall equation.

Overall equation:

[2]

(vi) Why is the breakdown of ozone in the stratosphere harmful to humans?

.....

.....

..... **[2]**

In this pair of questions, the examiners were looking to see if candidates could provide evidence for how chlorine radicals in the stratosphere contributed to ozone depletion, and then identify a problem caused by this issue.

In part (v) most candidates were able to provide a correct pair of equations to illustrate a pair of propagation equations involving chlorine radicals and then to write the overall equation for the pair of equations that they had provided. A common error observed was where some candidates then gave a different overall equation that was not the sum of their two previous equations.

In part (vi) candidates should have stated that ozone absorbs UV rather than blocking/preventing UV from passing through the stratosphere. The latter was not accepted as a creditworthy response as ozone absorbs the UV which causes the ozone to break down into oxygen molecules and radicals, and so the most common mark for this question was 1. Candidates did recognise that UV causes problems such as skin cancer, damage to DNA, damage to crops, etc. and so many scored the second mark on this question.

Question 1 (b) (i)

(b) CH_3Cl reacts with ammonia to give an amine salt.

$CH_3Cl + NH_3 \rightarrow CH_3NH_3Cl$ **Equation 1.1**

Ammonia is acting as a nucleophile here.

(i) Explain what is meant by the term **nucleophile**.

.....

..... **[1]**

This question produced a variety of responses that suggested that candidates had an awareness of what a nucleophile is but were not able to recall the specific definition of this term. So, some candidates did not score this mark as they omitted the key term 'electron pair' as part of their description.

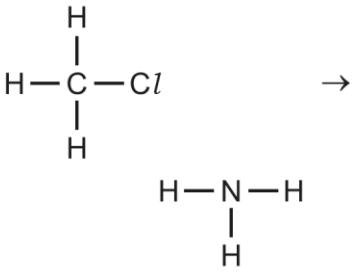
Assessment for learning

Teachers should try to make sure that key definitions from the specification are learnt and embedded into students' knowledge and vocabulary as they are often used to provide an introduction to the assessment of that topic, as illustrated in this set of questions.

Question 1 (b) (ii)

(ii) Show the mechanism of **Equation 1.1**.

Use curly arrows and show relevant lone pairs and the ionic products.



[2]

This question demonstrated that for most candidates, they knew what a nucleophile was as they added the lone pair of electrons to the nitrogen atom and then drew a correct curly arrow to the carbon atom. They usually scored the first mark by completing the diagram showing the correct movement of electrons in the C—Cl bond. Where some candidates missed out was in completing the diagram to show the ionic products of this reaction as they often went straight to the final substitution products of methylamine and hydrogen chloride, missing out the ionic intermediate(s) of the methyl ammonium ion and a chloride ion. Although the final products were correct they were not what the question had asked for and there was no mark for doing this.

Question 1 (c)

(c) The reaction between a haloalkane and hydroxide ions is a nucleophilic substitution reaction.

A student reacts 1-chlorobutane, 1-bromobutane and 1-iodobutane separately with aqueous sodium hydroxide.

Which will react fastest and why?

.....

.....

..... **[2]**

There were a variety of responses here, many of which were incorrect and illustrated some confusion about factors affecting the reactivity of haloalkanes. Most candidates correctly recognised that 1-iodobutane reacted the fastest and could explain why in terms of the C—I bond being the weakest of the C—Hal bonds possible and scored both marks. However, it was not unusual to see 1-chlorobutane being given as the answer and the explanation being linked to the greater polarity of the C—Cl bond.

Question 2 (c)

(c) The students add an aqueous solution of ammonia to a solution of $FeSO_4$.
A precipitate forms.

Give the colour of the precipitate and write an **ionic** equation for its formation.

Include state symbols.

Colour: .....

Ionic equation:

[3]

Candidates will have studied the reactions of iron(II) and iron(III) and their reactions with sodium hydroxide and ammonia as part of their practical work during any study of transition metal chemistry.

This question was trying to determine if they could recognise the oxidation state of the iron ion in $FeSO_4$ and thereby recognising the colour of the iron precipitate. From this they should have been able to derive an ionic equation for the formation of the precipitate.

Many candidates scored the first mark for stating that the precipitate would be a green colour but then struggled to produce a balanced ionic equation. Where they did attempt the equation, credit was given to those who included the correct state symbols for a precipitation reaction even if the equation was incorrect. The more successful candidates on this paper scored all 3 marks on this question.

Question 2 (d) (i) and (ii)

(d) The students read that ammonium ions are oxidised to NO_2^- by bacteria in the soil.

(i) Give the systematic name of NO_2^-.

..... **[1]**

(ii) The students add acid to $NaNO_2(s)$ in a test tube.
A colourless gas **A** (with nitrogen in the +2 oxidation state) and NO_3^- ions are produced.

Gas **A** turns to a brown gas **B** at the top of the test tube.

Suggest the **formula** of the brown gas **B**.

Suggest an **ionic** equation for the formation of **gas A** from acidified NO_2^- ions.

Formula of brown gas **B**: .....

Ionic equation:

[3]

This pair of questions was intended to assess candidates' knowledge and understanding of nitrogen chemistry.

In part d (i) the question proved to be quite a good discriminator as less successful candidates often identified the compound as nitrogen dioxide, while more successful candidates identified it as a nitrate ion, but some gave the wrong oxidation state. The most successful candidates on this paper correctly identified the ion as the nitrate(III) ion.

Part d (ii) addressed whether or not candidates could apply their knowledge in an unfamiliar context.

To do well on this question candidates needed to read the description of the reaction carefully. Information was provided that would allow them to identify the initial gas produced (NO), and that this undergoes an oxidation reaction at the top of the test tube. From this they should have been able to identify the brown gas as NO_2, and this was seen on many scripts and scored the first mark. A common incorrect gas given here was Br_2 where less successful candidates had recognised the colour and at least attempted to identify the gas.

Very few candidates scored both marks for the equation, but those who did attempt it could score 1 mark for recognising that the equation involved NO_2^- and H^+ ions from the acidified reaction mixture and that one of the products was NO.

The reaction is a complex disproportionation reaction that many students may not have come across during their study of Group V chemistry but should have encountered either through work on redox chemistry or when looking at chlorine compounds in Group VII chemistry.

Question 2 (e) (i)

(e) The students read that a sample of $N_2O(g)$ can be prepared by heating a mixture of the solids $NaNO_3$ and $(NH_4)_2SO_4$.

$2NaNO_3(s) + (NH_4)_2SO_4(s) \rightarrow 2N_2O(g) + 4H_2O(l) + Na_2SO_4(aq)$ **Equation 2.1**

(i) The students want to test **Equation 2.1** by measuring the volume of **dry** N_2O produced by heating $(NH_4)_2SO_4$ with $NaNO_3$.

Draw a labelled diagram of an apparatus they could use.

[4]

Very few candidates scored more than 2 marks on this question. This was not surprising, as not many centres would have carried out an activity where a dry gas needed to be collected. However, most candidates did recognise that they needed to use a suitable vessel to heat the dry solids in, e.g. boiling tube or conical flask, and that they needed a suitable method for measuring the volume of gas produced, e.g. gas syringe. Having looked at a significant number of scripts the Principal Examiner took the decision to allow candidates to score a mark for the use of an upturned measuring cylinder as a means of measuring the volume of gas, even if this was over water, as this would allow many candidates to score a mark for knowing to use some apparatus that was graduated to record a volume.

Question 2 (e) (ii)

(ii) The students heat 0.20 g of $(NH_4)_2SO_4$ with excess $NaNO_3$.

Calculate the volume of N_2O (in cm^3) that would be formed at 20 °C and 105 kPa.

Volume = ... cm^3 **[4]**

This was a well answered question by many candidates. They recognised that they needed to calculate the number of moles of ammonium sulfate, $(NH_4)_2SO_4$, and that they needed to calculate the volume by using pV = nRT. Marks were lost on this question either in failing to convert from m^3 to cm^3 in the final step or in giving the answer to an inappropriate number of significant figures.

It was not unusual to see candidates scoring at least 3 marks on this question, with the more successful candidates scoring all 4 marks.

Question 2 (f)

(f) Another oxide of nitrogen contains 37% nitrogen by mass.

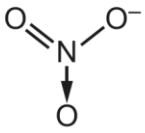
Calculate the formula of the oxide.

Formula = ... **[2]**

Another well answered question. Almost all candidates correctly recognised that the compound contained 63% oxygen and that they needed to determine the relative number of atoms of each element present in the compound to score the first mark. They then successfully calculated the simplest whole number ratio of the elements to deduce the formula of the compound correctly and scored the second mark too.

Question 2 (g)

(g)* An NO_3^- ion can be represented as shown:



A student says that NH_3 and NO_3^- have the same shape and bond angles.

Discuss this, drawing 'dot-and-cross' diagrams and giving chemical explanations for the shapes and bond angles.

'Dot-and-cross' diagrams

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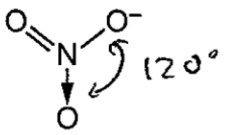
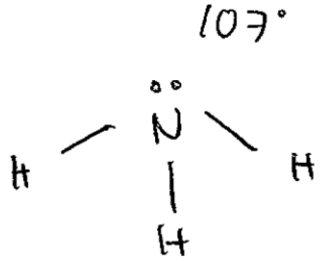
..... **[6]**

Exemplar 1

6

(g)* An NO_3^- ion can be represented as shown:





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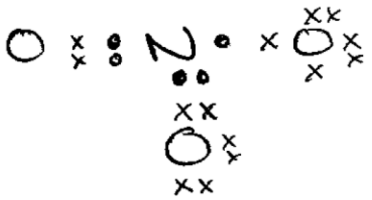
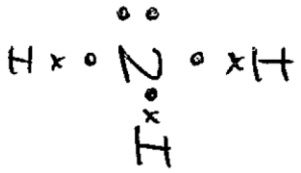
'Dot-and-cross' diagrams





The studen is wrong, they do not have the same bond angle. NH_3 has a 107 degrees bond angle trigonal ~~planar~~ pyramidal shape and NO_3^- has a 120° trigonal planer shape. NO_3^- has two double bonds to oxygen and one single bond, so it has no lone pairs, the oxygens are more electronegative than nitrogen, ~~so but~~ but as there are no lone pairs on the nitrogen the bond angle is 120. In NH_3, the nitrogen only can ~~form single~~ bonds with hydrogen therefore it has a lone pair on, due to electron repulsion theory, the areas of electron [6]

Extra answer space if required.

density repel eachother to move as far apart as possible to minimise repulsion, resulting in a 107° bond angle.

The first of the two Level of Response questions on this paper was looking at two nitrogen species, ammonia and the nitrate(V) ion, at a fundamental level. Candidates were asked to use ideas about electronic structure to compare the two compounds, by drawing suitable dot-and-cross diagrams and to use suitable theory to support their explanations.

The exemplar shown here was typical of a number of responses where the candidate had produced a good explanation in terms of the numbers of electron density regions surrounding the central nitrogen atom in each species, correctly identifying the bond angle in each species, and giving the correct shapes. All of which supported their diagram for ammonia perfectly and was a good match to the Level 2 descriptor. However, in order to move this response to Level 3 they needed to have also drawn the dot-and-cross diagram for the nitrate(V) ion correctly, and in this case it can be seen that two of the oxygen atoms surrounding the central nitrogen atom are electron deficient. Had this candidate taken a moment to check their diagram I am certain that they would have identified this error and corrected it, which would have resulted in them achieving a mark of 6 at Level 3.

Question 3 (a)

3 Some scientists investigate the reaction of nitrogen monoxide with chlorine.

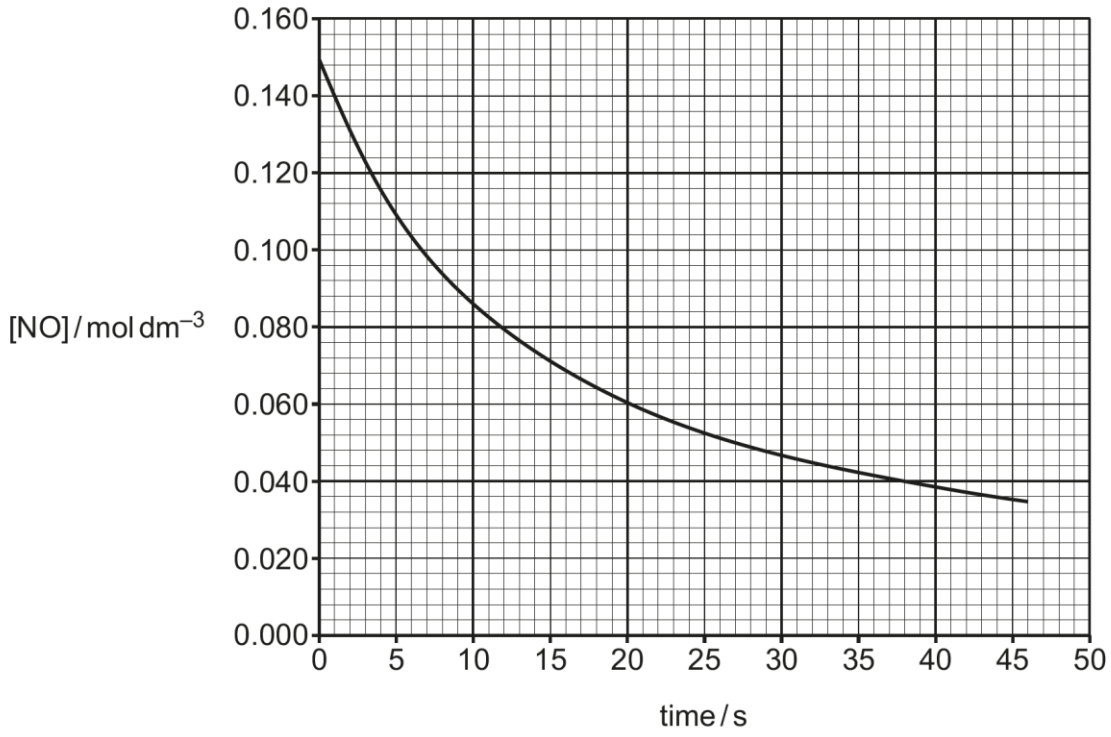
The reaction is:

$2NO(g) + Cl_2(g) \rightarrow 2NOCl(g)$ **Equation 3.1**

The scientists wish to determine the order of the reaction with respect to NO.

They start their experiment by mixing a known concentration of NO with a large excess of Cl_2.

They then measure the concentration of NO over time and plot a graph of [NO] against time.



(a) Explain why a large excess of Cl_2 is required.

.....

..... **[1]**

This question was intended to provide a straightforward introduction to a question about rates of reaction.

In the stem of the question there is information to guide students, and the intended response here should have been a recognition that although the concentration of chlorine may change slightly as the reaction progresses, because it is in a large excess the overall change should be negligible. To all intents and purposes the concentration will remain constant.

However, candidates seemed to have missed the fact that the scientists had been altering the concentration of the NO in the reaction and following the reaction by measuring how the rate changed as the concentration of NO changed. Therefore, it is the NO that is the limiting reagent in this reaction rather than chlorine, which is what many students stated as their answer to this question.

Question 3 (b)

(b) Use the graph to work out the **initial** rate of the reaction in mol dm^{-3} s^{-1}.

Show your working on the graph.

Initial rate = ... mol dm^{-3} s^{-1} **[2]**

This question was well answered by most candidates. Candidates knew that they needed to draw a tangent to the curve at time = 0, and that it should not go above the curve. Having drawn an appropriate tangent, they then calculated the gradient from this in order to determine the initial rate of reaction. Many candidates score full marks on this question.

Question 3 (c) (i)

(c) The scientists measure the initial rates of reaction for other NO concentrations.

Their results are shown in **Table 3.1**.

Table 3.1

[NO] / mol dm^{-3}	[NO]^2 / (mol dm^{-3})^2	Initial rate / mol dm^{-3} s^{-1}
8.59×10^{-2}	7.38×10^{-3}	3.28×10^{-3}
6.10×10^{-2}	3.72×10^{-3}	1.65×10^{-3}
4.75×10^{-2}	.....	1.00×10^{-3}
3.89×10^{-2}	1.51×10^{-3}	0.67×10^{-3}

The scientists plot initial rate against [NO] and discover this does **not** give a straight line.

(i) What can the scientists conclude from this?

.....

..... **[1]**

There was some evidence to suggest that candidates may have come back to this question after they had answered Question 3 (c) (iv) as many stated that the reaction could not be first order but that it had to be second order. This is incorrect at this point, as the only thing that can be deduced from the shape of the graph is that it is NOT a first order reaction (the candidates are told in the stem of the question that the graph is not a straight line). Had they left out the information about the reaction being second order then they would have scored this mark.

Question 3 (c) (ii), (iii) and (iv)

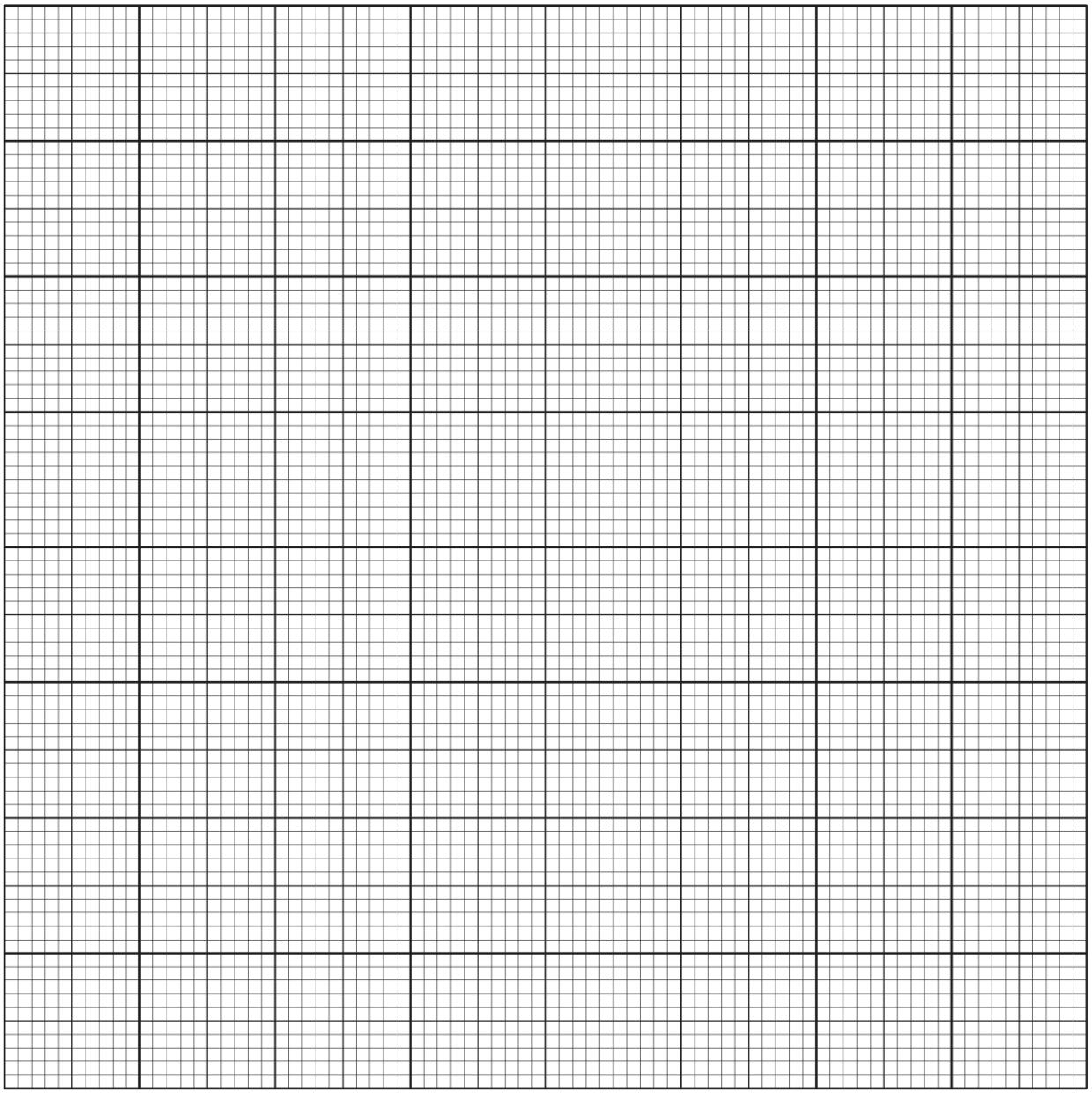
(ii) Fill in the missing value in **Table 3.1**. **[1]**

(iii) Plot a graph of initial rate against $[NO]^2$.

Use the data in **Table 3.1**.

Include the origin.

Draw the line of best fit.



[4]

(iv) Explain why the graph shows that the reaction is second order with respect to NO.

.....

..... **[1]**

The next set of three questions were all related to help students to process some experimental data and to draw an appropriate conclusion based upon the results of the experiment.

In part c (ii) candidates had to calculate a missing value from the results table by entering the value in column 1 of the results table and squaring it. Most candidates did this successfully and rounded the value obtained correctly to score this mark. There were a few candidates who did not round the value correctly, but provided that they used this in the next step they only lost one mark.

In part c (iii) candidates were asked to plot a graph of the results using the grid provided. Many candidates did this successfully and scored all 4 marks, however, there were a significant number of candidates who got their axes the wrong way round. Provided that they plotted the points accurately and drew a suitable straight line of best fit (that should have passed through the origin) then they scored 3 of the 4 marks.

Finally in part c (iv) candidates were asked why the graph showed that the reaction was second order with respect to NO. They should have been able to state that because it was a straight line through the origin that it was second order because the initial rate was directly proportional to $[NO]^2$. While the more successful candidates recognised this relationship, less successful candidates struggled and often left this answer blank.

Question 3 (d) (i), (ii) and (iii)

(d) The scientists find that the reaction is first order with respect to Cl_2.

(i) Complete the rate equation for the reaction.

Rate = k ×

[1]

(ii) Give the units of the rate constant, k.

..... **[1]**

(iii) Explain why the value of the rate constant **cannot** be calculated from data in this question.

.....

..... **[1]**

The next three parts of this question were looking at the processing of the data and trying to identify if candidates were aware of the limitations of the results presented so far.

In part d (i) they are told that the reaction is first order with respect to Cl_2, and to use this information to complete the rate equation. It is pleasing to note that this mark was scored by the majority of candidates.

In part d (ii) they then had to take their rate equation and use it to determine the units for the rate constant. Most candidates attempted to do so, but this produced a variety of answers. The more successful candidates did correctly derive the units and scored this mark, but a commonly seen error was where candidates gave the units as $mol^2\,dm^{-6}\,s^{-1}$, which has the wrong superscripts for the moles and decimetre parts of the value. It was clear that candidates knew that they needed to use the values derived from the rate equation but in re-arranging this they transposed the numerator and denominator to arrive at this expression.

Finally in part d (iii) candidates were asked to explain why the rate constant could not be calculated using the data provided so far and it is pleasing to be able to say that the vast majority of students correctly stated that the rate constant could not be calculated as they did not possess any values for the concentration of chlorine.

Question 3 (d) (iv)

(iv) The scientists conclude that a possible mechanism is as shown below, with **step 2** being rate-determining.

$NO + Cl_2 \rightarrow NOCl_2$ **Step 1**

$NOCl_2 + NO \rightarrow 2NOCl$ **Step 2**

Give the meaning of rate-determining step and explain why the scientists conclude that **Step 2** is the rate-determining step.

Meaning .....

.....

Explanation .....

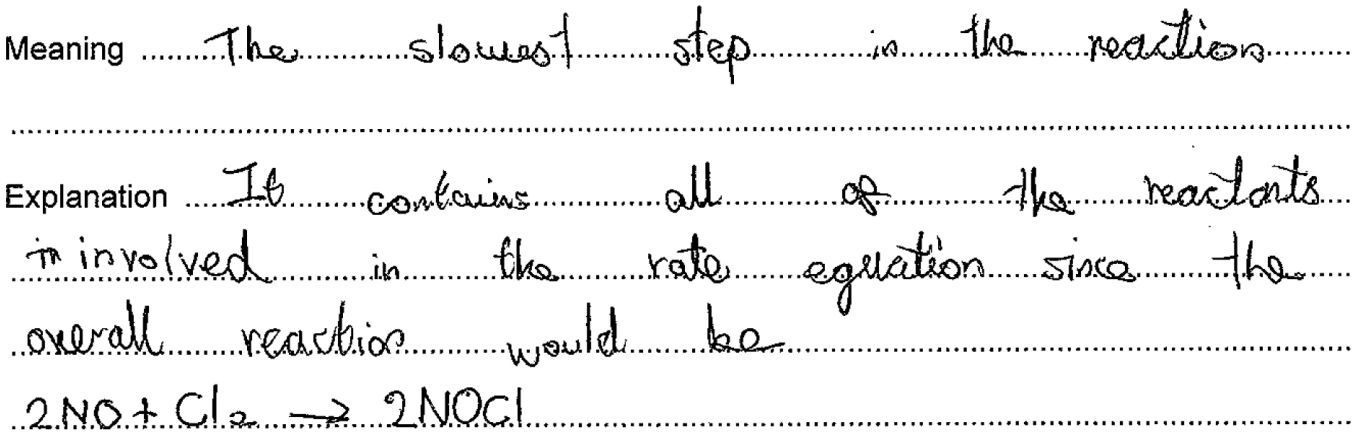
.....

.....

.....

[3]

Exemplar 2



This question highlighted an area of possible student misconception. Many were able to correctly state the meaning of the term 'rate-determining step' but were then unable to explain how this could be identified in the context of the reaction outlined. Most incorrect responses were stating that step 2 was the slowest step because it involved 2 molecules of NO reacting with 1 molecule of Cl_2. If we look at the equation for step 2, chlorine does not appear in this equation and so this approach is incorrect.

Where candidates were going wrong was in not appreciating that rates can only be determined from experimental data, and not from balanced chemical equations. Therefore they should have been talking about how the concentrations of NO and Cl_2 in step 1 determined how quickly $NOCl_2$ was formed as this is an intermediate in the overall reaction, and that once this is produced step 2 can only begin to occur in the presence of excess NO, as NO appears in both steps of the process.

An alternative answer was identified in the mark scheme in the guidance column which this exemplar illustrates. The candidate shows some understanding of the nature of a multi-step process in that they have stated what the overall reaction would be if step 1 and step 2 were combined, and states correctly that the overall rate equation has to involve all of the species contained in the overall equation.

This question proved to be a good discriminator when looking at identifying top grade candidates.

Misconception

Candidates struggled to score on this question as there appears to be a misconception regarding balanced chemical equations and rate equations.

Candidates did not appreciate that rate equations can only be derived from direct experimental observations and measurements and do not depend upon the stoichiometry of the chemical reaction.

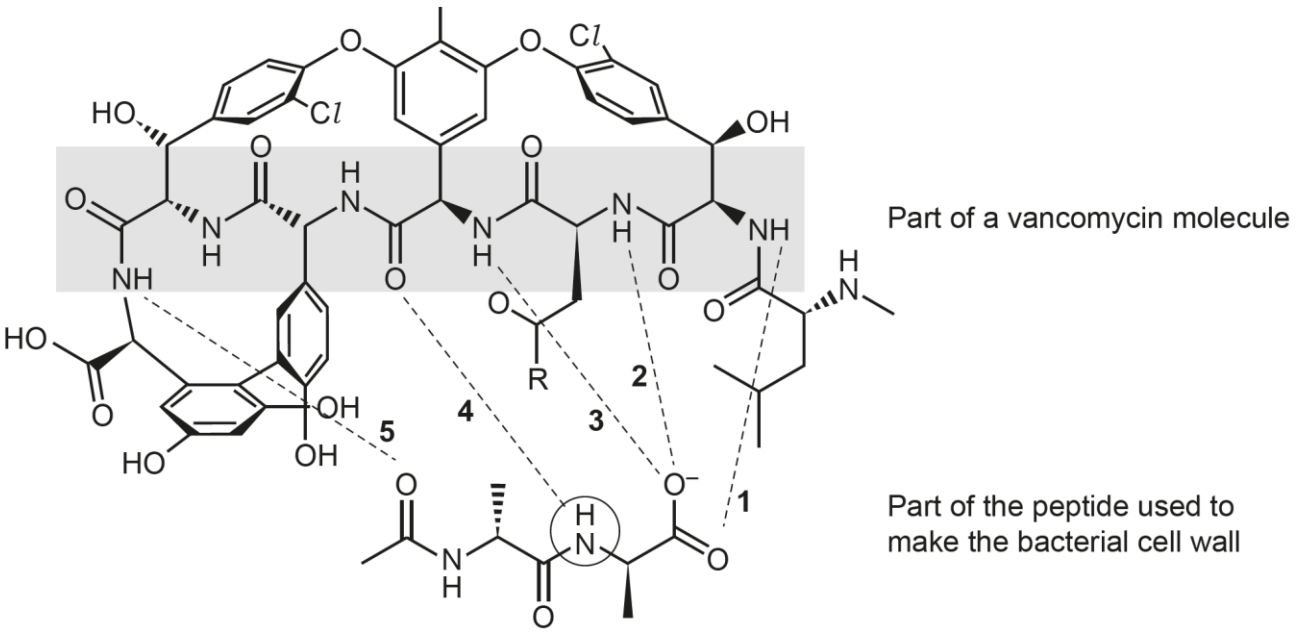
Question 4 (a) (i)

4 This question is about molecular recognition.

(a) Vancomycin is an antibacterial drug. It binds with peptides that bacteria use to make their cell walls. When the vancomycin binds, the process of making cell walls is disrupted, so the bacteria cannot grow.

Fig. 4.1 shows part of a vancomycin molecule bonded to part of the peptide.

Fig. 4.1



(i) Vancomycin has a polypeptide chain. The area shaded grey represents the primary structure. In order for vancomycin to function, the primary structure must be held in a definite shape. This enables intermolecular bonds **1**, **2**, **3**, **4** and **5** to form.

Describe how the primary structure is held in this definite shape in vancomycin.

.....

..... **[1]**

This was a particularly difficult questions for candidates. Many thought that the primary structure was held in place by peptide links as they had only looked at the shaded grey area of the diagram. What they had not appreciated was the information in the stem of the question informing them that the primary structure is held in a definite shape to help bonds 1 – 5 to form. This should have prompted them to look at the other parts of the chain where they could see that the side groups on the individual amino acids are also joined together by covalent bonds, and it is the bonds formed between the R-groups that hold the primary chain in its desired shape.

Question 4 (a) (ii)

(ii) The part of the **peptide** shown at the bottom of **Fig. 4.1** is made from a repeat of the same amino acid.

Give the structure of this amino acid.

[1]

Most candidates attempted this question, and many scored the mark for correctly drawing the structure of alanine. The only commonly seen error was not including a CH_3 group attached to the central carbon atom but including a hydrogen atom.

Question 4 (a) (iii)

(iii) Name the **type** of intermolecular bond shown by the numbers **1**, **4** and **5** and suggest why these bonds are weaker than bonds **2** and **3**, even though they are of similar length.

.....

.....

.....

.....

..... **[3]**

Many candidates struggled to score more than 1 mark on this question. They correctly identified that bonds 1, 4 and 5 were held together by hydrogen bonds to score the first mark.

Had they looked closely at the diagram they should have seen that bonds 1, 4 & 5 were attached to polar oxygen atoms as part of carbonyl groups on the bacterial cell wall, while bonds 2 & 3 were attached to a negatively charged oxide ion to score marking point two.

They also needed to state that the strength of the bonds is determined by the different oxygen species rather than the length of the bonds, i.e. that the attraction to the negative oxide ion is stronger than the attraction to the polar carbonyl oxygen atom, for the final mark.

Question 4 (a) (iv)

(iv) In the peptides from some bacteria, the circled NH in **Fig. 4.1** is replaced by an oxygen atom, O. These bacteria are resistant to vancomycin.

Suggest why vancomycin has less effect on these bacteria.

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..... **[2]**

Most candidates scored 1 mark for stating that bond 4 would not form but then did not simply state that this would result in a reduction in the number of intermolecular bonds formed between the vancomycin molecule and the bacterial cell wall. A commonly seen incorrect answer here was to state that because bond 4 would not form this produced weaker intermolecular bonds.

Question 4 (c)

(c) Molecular recognition occurs in the formation of proteins from messenger RNA.

Explain this process.

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..... **[3]**

It was clear to see from candidate responses that this topic had been covered in detail by most centres. Candidates were able to explain that mRNA contained triplet codes / codons along its chain, and that these codons were 'read' by the tRNA anti-codons / complementary anti-codons. tRNA molecules carried/collected a specific amino acid in a process that was repeated in order to produce an exact copy of the original protein chain. There was sufficient scope within the mark scheme to allow for examiners to award credit for answers that outlined this process in the correct sequence. So, most candidates scored at least 2 marks on this question.

Question 4 (e) (i)

(e) Dyes attach themselves to fibres by a variety of bonds.

(i) Acid dyes have $-SO_3^-$ groups. These groups form ionic bonds with nylon fabrics under acid conditions.

Explain how this occurs.

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..... **[2]**

This was well answered by many candidates.

They recognised that in acidic conditions the NH group within the polyamide chain of nylon, could be protonated to produce either $-NH_2^+$ groups or $-NH_3^+$ groups.

Candidates then correctly stated that these groups were than capable of forming ionic bonds to the SO_3^- groups present in the acid dye.

Question 4 (e) (ii)

(ii) Some dyes form instantaneous dipole–induced dipole bonds with certain fabrics.

Explain how instantaneous dipole–induced dipole bonds are formed.

.....

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..... **[3]**

This question was attempted by the majority of candidates but saw a full range of marks given.

Many candidates talked about the formation of instantaneous dipoles in individual atoms rather than in the dye molecules. Other responses described the formation of dipoles in covalent bonds which were more often descriptions associated with the formation of permanent dipoles rather than temporary dipoles.

Where candidates could often score was in describing the random movement of electrons which leads to areas of uneven charge distribution in molecules. They then often got confused and started to describe other types of intermolecular forces, which on occasion resulted in them making contradictory statements causing any creditworthy answers to be negated.

However, the more successful candidates on this paper recognised that when a molecule had formed an instantaneous dipole, that if it was in the proximity of another molecule the uneven charge distribution caused repulsion of the electron cloud in the neighbouring molecule. This created a temporary dipole and these oppositely charged species then attracted one another. Many often also stated that this type of intermolecular bond was the weakest of all forces between molecules.

Question 5 (a)*

5 This question refers to the Advance Notice Article Battery Tech Report: 'Lithium-Ion vs Vanadium Redox Flow Batteries (VRFB)' that is included as an Insert to this paper.

(a)* Explain why lithium has only one oxidation state in its compounds while vanadium has several.

Give electron configurations of atoms and several ions in your answer.

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..... **[6]**

This proved to be a very good question for many candidates with a score at Level 2 being scored regularly. Candidates had been studying the pre-release material and it became obvious that as part of their preparation they had studied the chemistry of vanadium and its compounds extensively.

In their answers to this question, they correctly identified that lithium was a group 1 element that could only form a single stable ion with an oxidation state of +1. To remove a further electron would involve removing an electron from the 1s sub-shell which was energetically unfeasible. They also recognised that vanadium was a transition (d-block) element and that the presence of partly filled d sub-shells meant that it could form multiple stable ions with a variety of oxidation states.

To be successful in this question candidates were required to demonstrate their knowledge of electron configurations by giving the full electron configuration for both elements, and then to write appropriate electron configurations for stable ions produced for each element.

At Level 3 this entailed giving the full electron configuration for both elements and then identifying all of the stable ions for each element and giving their electron configurations either in full or using the shorthand convention for the ions. They also needed to support their electronic structures with some relevant chemical knowledge as outlined above. Many candidates produced responses where they did this but occasionally lost the communication mark if they had made simple slips in the electron configurations of the vanadium ions e.g. reversing the order of the 3d and 4s sub-shells or removing electrons from the 3d sub-shell before removing them from the 4s sub-shell.

At Level 2 the mark scheme was loosened up slightly to allow candidates to score marks if they either did not identify all of the stable ions for vanadium or if they produced a partial account that focused on lithium but gave this in sufficient detail as identified in the guidance column of the mark scheme. This resulted in many candidates scoring 4 marks for demonstrating what they knew about either s-block elements or about d-block elements.

It was clear that candidates had prepared well for this question as there were very few responses that were left blank, or that did not reach at least Level 2.

Question 5 (b) (i) and (ii)

(b) **Table 5.1** shows some redox potentials.

Table 5.1

Redox system	$E^{\ominus}$/V
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	–0.76
$V^{3+}(aq) + e^- \rightleftharpoons V^{2+}(aq)$	–0.26
$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s)$	–0.14
$VO^{2+}(aq) + 2H^+(aq) + e^- \rightleftharpoons V^{3+}(aq) + H_2O(l)$	+0.34
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+0.80
$VO_2^+(aq) + 2H^+(aq) + e^- \rightleftharpoons VO^{2+}(aq) + H_2O(l)$	+1.00

(i) When the VRFB is delivering a current, V(V) is reduced to V(IV) and V(II) is oxidised to V(III).

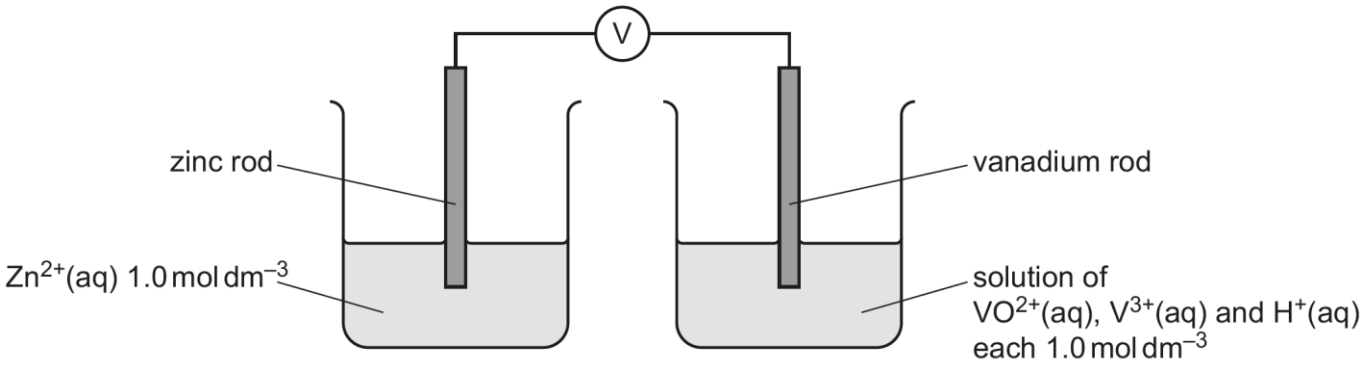
Write the ionic equation and give the $E^{\ominus}_{cell}$ for the overall reaction that occurs.

Include state symbols.

Ionic equation:

(ii) A student sets up a cell to measure the $E^{\ominus}_{cell}$ for VO^{2+}/V^{3+} against Zn^{2+}/Zn at 298 K.

Here is a diagram of the student's cell.



The student has made **two** mistakes in setting up the cell.

Describe these mistakes **and** how they should be corrected:

Mistake 1 .....

.....

Mistake 2 .....

.....

[2]

This pair of questions were attempted by almost all candidates. They had prepared well and could determine the voltage for the cell in part (i) and write an overall equation for the cell reaction. The only common error was in failing to follow the instructions in the question to include state symbols in the equation.

In part (ii) it was clear that candidates had been studying electrochemical cells and had been constructing them in the laboratory as they quickly recognised the errors in the diagram above. Most candidates scored both marks in part (ii) and it was not unusual to see candidates scoring 4 marks across these two questions.

Question 5 (b) (iii)

(iii) A student has powdered samples of the metals (silver, tin and zinc) shown in **Table 5.1**, and an acidic solution of $VO_2^+(aq)$.

The student wants to obtain a solution containing V^{3+} ions.

Explain why the student would use tin rather than silver or zinc.

Write the overall equation for the student's reaction.

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Overall equation:

[4]

Exemplar 3

Silver has an $E^{\ominus}$ above the reactions for $VO^{2+} \rightarrow V^{3+}$ meaning it wouldn't be able to reduce VO^{2+} and so V^{3+} wouldn't be formed. Zinc has an $E^{\ominus}$ more negative than the reaction for $V^{3+} \rightarrow V^{2+}$ meaning it would reduce the V^{3+} to give a solution of V^{2+} which isn't wanted. Tin has an $E^{\ominus}$ that is more negative than $VO^{2+} \rightarrow V^{3+}$ but less negative than $V^{3+} \rightarrow V^{2+}$. So it will reduce the VO_2^+ to V^{3+} but not past this, won't form V^{2+}

Overall equation:

$2VO_2^+_{(aq)} + 4H^+_{(aq)} + Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + 2VO^{2+}_{(aq)} + 2H_2O_{(l)}$

$2VO^{2+}_{(aq)} + 4H^+_{(aq)} + Zn_{(s)} \rightarrow 2V^{3+}_{(aq)} + 2H_2O_{(l)} + Zn^{2+}$ **[4]**

$2VO_2^+_{(aq)} + 8H^+_{(aq)} + 2Zn_{(s)} \rightarrow 2V^{3+} + 2Zn^{2+} + 4H_2O$

$VO_2^+_{(aq)} + 4H^+_{(aq)} + Zn_{(s)} \rightarrow V^{3+}_{(aq)} + Zn^{2+}_{(aq)} + 2H_2O_{(l)}$

This question differentiated well as it allowed the more successful candidates to demonstrate their knowledge and understanding of electrochemistry.

In the exemplar above it can be seen that this candidate has a solid knowledge of the fundamental ideas and can apply their knowledge to describe why tin is the most appropriate metal to use to produce a solution containing V^{3+} ions.

They constructed their answer using the table of electrode potentials and could explain the limitations of silver and zinc.

Silver was unsuitable because it has an E^{o} value that would allow VO_2^{+} to be reduced to VO^{2+} but was not sufficiently negative to allow VO^{2+} to be reduced to V^{3+}.

Zinc was unsuitable because it has an E^{o} value that would reduce the original VO_2^{+} solution from oxidation state 5 through to the desired V^{3+} but would then reduce this further to produce V^{2+}.

Having identified why these two elements were unsuitable they correctly identified that tin possesses an E^{o} value that would reduce the vanadium ions from VO_2^{+} to V^{+} but no further.

Where this candidate has gone wrong is that for some reason they tried to write a balanced equation using zinc rather than silver, which was unusual. It was more common to see accounts that were similar to this where they had identified the processes occurring correctly but had then used the wrong vanadium ion, VO^{2+}, in their equation.

Question 5 (c) (i) and (ii)

(c) The two types of battery have properties that are suited to different uses.

(i) From the article, give **two advantages** of Li-ion batteries over VRFBs as **batteries for electric vehicles**.

Advantage 1 .....

.....

Advantage 2 .....

.....

[2]

(ii) From the article, give **two advantages** of VRFBs over Li-ion batteries for large-scale use in **storing energy from an array of solar cells**.

Advantage 1 .....

.....

Advantage 2 .....

.....

[2]

This pair of questions were well answered by the majority of candidates and it was not unusual to see candidates scoring 4 marks here.

It was obvious that as part of their preparation they had discussed with their teachers the pros and cons of each type of battery and could give advantages for each battery.

Question 5 (d)

(d) Both types of battery have a separator in the middle.

Give the formulae of the particles that pass through the separators in each battery when they are in use.

Li-ion battery .....

VRFB .....

[1]

This was generally well answered by candidates. Most recognised that lithium ions, Li^+, moved across the separator in the Li-ion battery, and that H^+ ions were moving in the VRFB battery. Where a mark was lost here was when candidates occasionally indicated that in the VRFB battery vanadium ions were travelling across the separator which is unfeasible as they are in separate electrolyte tanks.

Question 5 (e) (i) and (ii)

(e) Solutions of vanadium compounds are coloured.

(i) Explain why they are coloured, selecting terms from the following list as required:

absorption **complementary** **emission** **transmission**

.....

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..... **[2]**

(ii) Explain why the colours are different.

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..... **[2]**

The final pair of questions was looking at some of the reasons for colour in transition metal compounds.

In part (i) candidates are told that they are to discuss why solutions of vanadium compounds are coloured. As there is no external energy source being used answers should have been in terms of the vanadium ions having the ability to absorb energy specific frequencies of light from visible light, and that we would see the frequencies (colours) NOT absorbed as they are transmitted through the solution.

Many candidates recognised that the vanadium ions were absorbing frequencies of radiation from visible light to score the first marking point. However, they then started to give descriptions of electrons being promoted from one energy level to another within the ions, and that as these decayed back to their ground state the ion emitted light in the form of the complementary colour to the frequencies absorbed. This second part to their answer did not score.

In part (ii) the question was trying to determine whether or not candidates appreciated that the frequencies of light absorbed were dependent upon the size of the energy gap created by the splitting of the d sub-shells, and that the size of this gap was influenced by the ligands complexed to the vanadium ion, and also to the oxidation state of vanadium in the complex. In this part of the question we only needed students to refer to the size of the energy gap once as part of their response in order to access both marks but failing to discuss the splitting of the d sub-shells and the magnitude of the energy gap meant that they were very unlikely to score any marks for this final question.

Most candidates scored at least 2 marks across this pair of questions as they correctly indicated that light was absorbed in e(i) and that the splitting of the sub-shells created an energy gap in e(ii)

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