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Examiners' report

CHEMISTRY B (SALTERS)

H433
For first teaching in 2015

H433/02 Summer 2019 series

Version 1

www.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. 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 can be downloaded from OCR.

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.

Candidate performance overview

Candidates who did well on this paper generally demonstrated the following characteristics

- Used information about redox and electrochemistry in Q3, used ideas related to rates of reaction in Q4(a) and 4(e).
- Demonstrate knowledge and understanding relating to practical techniques in 1(d), 1(f), 2(d), and 3(c)(i).
- Produced clear and concise answers to the Level of Response questions, 2(d) and 5(f).
- Performed standard calculations showing clear working and, where appropriate, conversion to the required number of significant figures in questions 1(c), 2(b)(i), 2(e)(ii), 3(c)(v), 4(d), and 5(b).

Candidates who did less well on this paper, generally demonstrated the following characteristics

- Struggled to identify the products of the hydrolysis reaction in 1(f), often could not identify the reducing agent in 3(d)(ii) and so gave an incorrect observation for 3(d)(iii).
- Gave responses in 2(d) that identified the need for a titration to be conducted but struggled to explain how the results obtained could be processed.
- Found it difficult to apply their knowledge in novel situations, and so scored low marks in Question 5(f).
- Often struggled to structure their responses to mathematical questions.

Note

From this series students have been provided with a fixed number of answer lines and an additional answer space. The additional answer space will be clearly labelled as additional, and is only to be used when required. Teachers are encouraged to keep reminding students about the importance of conciseness in their answers. Please follow this link to our SIU (https://www.ocr.org.uk/administration/support-and-tools/siu/alevel-science-538595/)

Question 1 (a)

1 Twaron™ is a polymer used to make body armour.

The polymer strands are made using the reaction in **Fig. 1.1**.

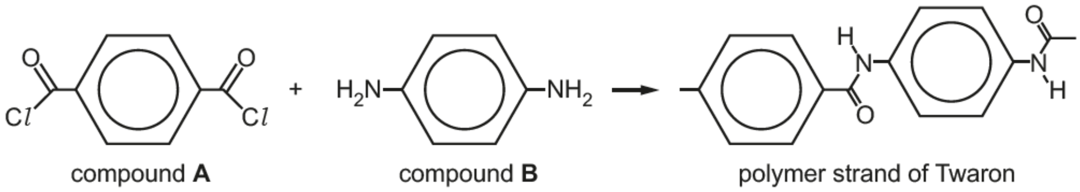


Fig. 1.1

(a) Name the **functional groups** in compounds **A** and **B**.

A ....

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

This was a good question to get candidates' confidence raised, most candidates correctly identified that A contained an acyl chloride functional group, and that B contained an amine functional group. The terms primary or secondary were ignored when marking this question. Some candidates also included the benzene ring in both compounds. The only commonly seen incorrect response was the identification of the NH_2 group as an amide group.

Question 1 (b)

(b) Suggest the $O{=}\hat{C}{-}Cl$ bond angle in compound **A**.

Explain your answer.

....

....

....

....

....

....

.... **[3]**

This was generally a well answered question. The three marking points were treated independently such that a candidate who gave an incorrect bond angle could still score the other marks if they correctly identified the number of electron groups surrounding the central carbon atom correctly and used this to explain the idea of electrons repelling one another to achieve a position of minimum repulsion.

Question 1 (c)

(c) Compound **A** can be made by the reaction in **Fig. 1.2**.

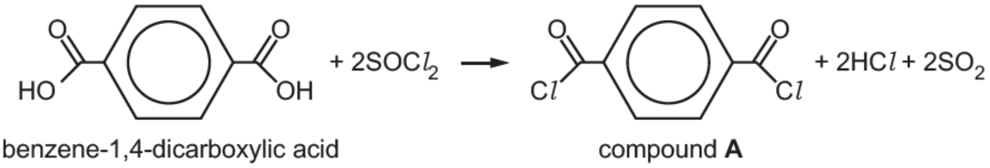


Fig. 1.2

Calculate the mass of compound **A** that can be made from 32 g of benzene-1,4-dicarboxylic acid if the yield is 67%.

Give your answer to the nearest whole number.

mass of compound **A** = ... g **[2]**

A number of candidates lost the second mark for this question due to not converting their answer to the nearest whole number as instructed in the stem of the question.

Many candidates correctly calculated that the mass produced would be 26.2g, scoring one mark, but then did not convert to 26g as the nearest whole number value. Other common errors included calculating the Mr value for benzene-1,4-carboxylic acid as 142, or that for compound A as 179, both of which derive from omitting the carbon atoms that form the carbonyl group at either end of each molecule.

A candidate who correctly calculated the Mr of benzene-1,4-dicarboxylic acid and hence the number of moles present in 32g scored 1 mark, even if they used 179 for A and gave their final answer to one or more decimal places.

Where a candidate had incorrectly calculated the number of moles by using 142, but had then used the correct Mr for A, they could still score 1 mark if they had given their final answer to the nearest whole number.

Both of these routes were seen regularly and were marked accordingly to allow candidates to gain some credit for demonstrating what they knew.

Question 1 (d)

(d) A synthetic route for making compound **B** is shown in **Fig. 1.3**.

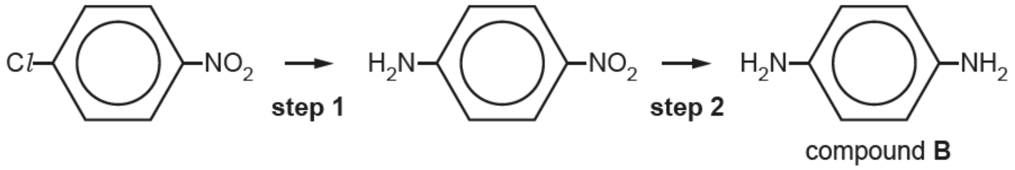


Fig. 1.3

Use your chemical knowledge and the Data Sheet to suggest possible reagents for **steps 1** and **2**.

Step 1 ....

Step 2 ....
[2]

The majority of candidates scored at least one mark here by identifying that the reagents needed for step two were tin and concentrated hydrochloric acid. Higher attaining candidates also recognised that for step 1 ammonia gas or (concentrated) solution was needed.

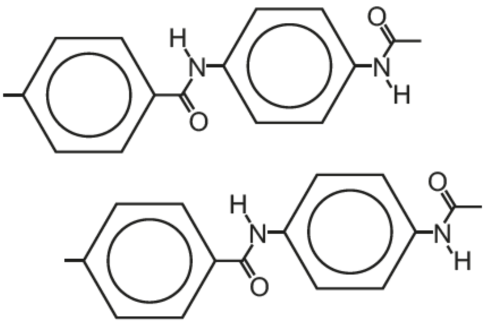
Question 1 (e) (i) and (e) (ii)

(e) The polymer strands link together by intermolecular bonds when they are spun to form Twaron. This gives the fabric its tough quality.

(i) Name the strongest intermolecular bonds that can form between the chains.

.... **[1]**

(ii) Mark the positions of the intermolecular bonds by drawing dotted lines on the diagram below.



[1]

This pair of questions allowed the majority of candidates to score two marks. They successfully identified that the intermolecular bonds present would be hydrogen bonds and were able to successfully indicate where they would be formed between the two chains of Twaron polymer.

Question 1 (f) (i) and (f) (ii)

(f) A Twaron polymer strand is hydrolysed.

(i) State the conditions that could be used to hydrolyse the polymer.

.... **[1]**

(ii) Draw the formulae of the **two** organic products of hydrolysis in the boxes.

[2]

There were two possible routes that candidates could have identified for carrying out the procedure in the question. So there was scope for errors to be made that needed to be accounted for in the mark scheme.

In (i) we were looking for the reagents AND reaction conditions necessary to bring about the hydrolysis reaction. For this, what was required was a solution of (moderately concentrated) acid or alkali and heat/reflux. The strength of the acid or alkali was not required but it is worth noting that the use of concentrated sulfuric acid was not allowed, as this would have dehydrated the polymer rather than hydrolysing it. Then in (ii) we hoped that candidates would be able to draw appropriate diagrams to illustrate the products of their hydrolysis reaction.

As with 1(e)(i) and (ii) there was a route that gave candidates 1 mark in (f)(ii) for drawing correct structures of both of the unionised products of the hydrolysis reaction.

Question 2 (a)

2 Strontium carbonate is used in fireworks to colour the flames red.

(a) The red colour comes from lines of specific frequency in the atomic emission spectrum of strontium.

Explain how these lines are formed.

....

....

....

....

....

.... **[3]**

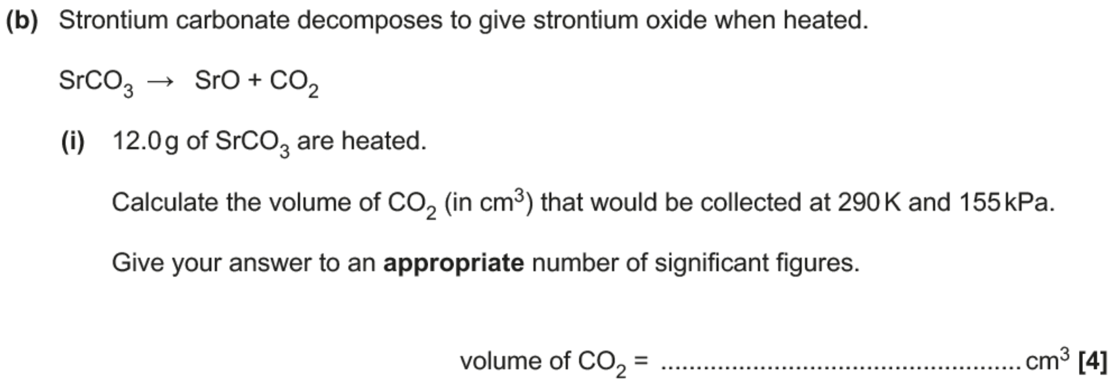
Many candidates scored at least 2 marks here, with higher ability candidates scoring all 3 marks.

Candidates were able to outline the three components, i.e. excitation of ground state electrons, returning to ground state from the excited state releasing energy/light of a particular frequency, and either quoting $E = h\nu$ linked to the frequency emitted, or identified that the frequency was proportional to the energy gap between the quantised energy levels within the strontium atom.

Marks were often lost for stating that the atoms absorbed electromagnetic radiation (e.g. light) in order to excite and promote the electron. This was not allowed as we were looking at the use of strontium in fireworks where the energy source would be heat (thermal), although the term energy used on its own was allowed. Marking point two was usually scored; the majority of candidates knew that the coloured line(s) (on a black background) were produced as a result of the electron being in an unstable state and returning to its ground state energy level, emitting a light / a photon of a frequency associated with the red colour observed.

Many candidates also identified that the frequency of light emitted was proportional to the gap between energy levels OR made correct use of $E=h\nu$. However, lower ability candidates often did not score this mark as they struggled to link these ideas correctly.

Question 2 (b) (i)



(b) Strontium carbonate decomposes to give strontium oxide when heated.

$SrCO_3 \rightarrow SrO + CO_2$

(i) 12.0 g of $SrCO_3$ are heated.

Calculate the volume of CO_2 (in cm^3) that would be collected at 290 K and 155 kPa.

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

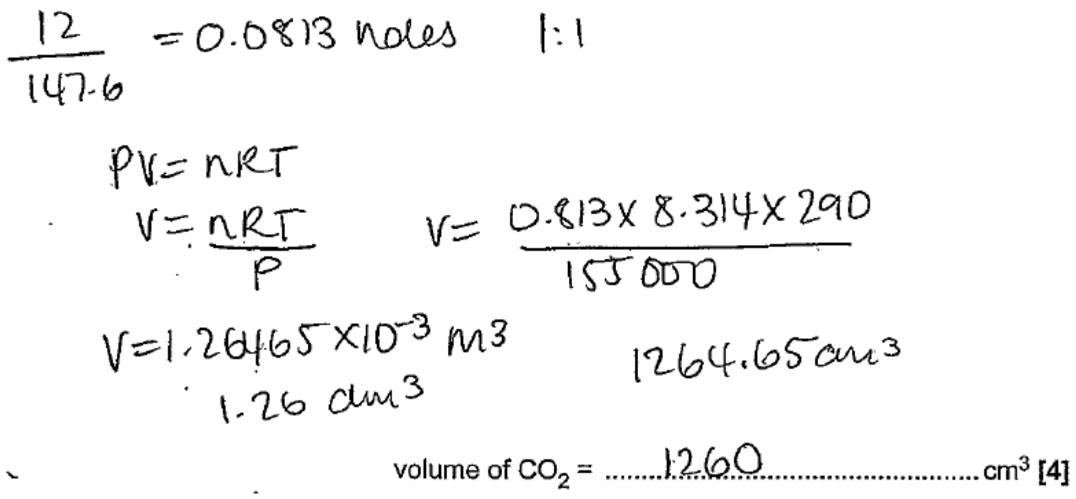
volume of CO_2 = ... cm^3 **[4]**

This was the first multi-step calculation on this paper, requiring candidates to demonstrate their maths skills by manipulating an expression they should have been familiar with, and also to convert units within the identified values. Finally, they had to give their answer to an appropriate number of significant figures, which in this case was three.

In order to arrive at an appropriate value candidates had to calculate the number of moles of strontium carbonate used in the reaction. They then had to identify that they needed to use the ideal gas equation and re-arrange this making *V* the subject of the equation. The mark for this could be given from a clearly laid out calculation where "*V* =" may have been used. Next they had to convert from kPa to Pa for the pressure. Finally, they had to convert from m^3 to cm^3 giving their final value to 3 significant figures. Exemplar 2 shows a well laid out response of this calculation, illustrating how showing what is being calculated makes the candidate's working easy to follow. This can help candidates gain error carried forwards marks in the event of arriving at an incorrect answer.

Many candidates only scored three marks on this calculation rather than the full 4 marks. Errors included not converting the final value to three significant figures. Others made a single error in scaling from kPa to Pa, e.g. dividing by 1000 rather than multiplying by 1000, or from m^3 to cm^3, e.g. by multiplying by 10^3 rather than 10^6, however provided that their working was clearly laid out these errors were only penalised once. It was pleasing to note that there were very few scripts where candidates had not attempted the calculation, and also that very few scripts contained an incorrect answer that was unsupported by evidence of the working carried out.

Exemplar 1



$\frac{12}{147.6}$ = 0.0813 noles 1:1

PV = nRT

$V = \frac{nRT}{P}$ $V = \frac{0.813 \times 8.314 \times 290}{155\,000}$

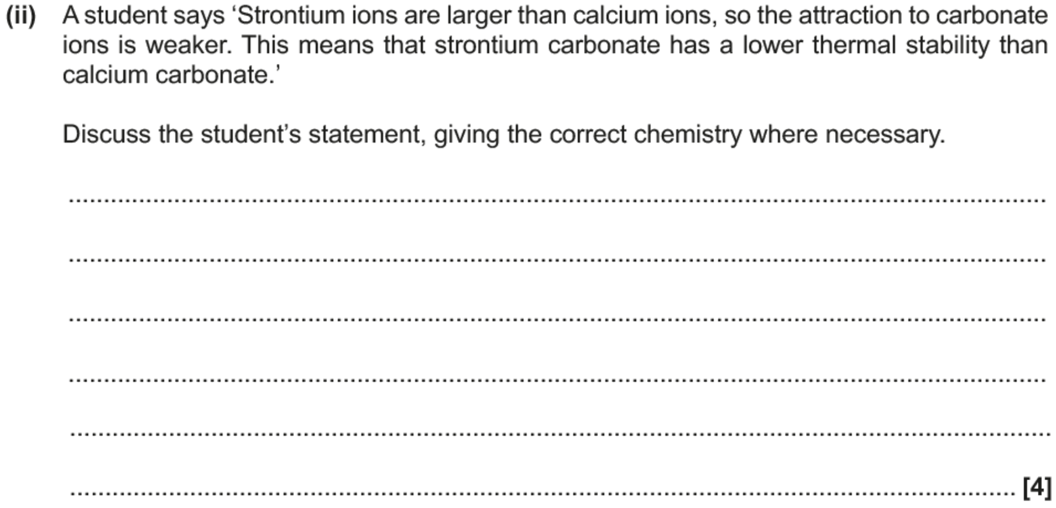
$V = 1.26465 \times 10^{-3}$ m3

1.26 dm3

1264.65 cm3

volume of CO_2 = ...1260...................... cm^3 **[4]**

Question 2 (b) (ii)



(ii) A student says 'Strontium ions are larger than calcium ions, so the attraction to carbonate ions is weaker. This means that strontium carbonate has a lower thermal stability than calcium carbonate.'

Discuss the student's statement, giving the correct chemistry where necessary.

....

....

....

....

....

.... **[4]**

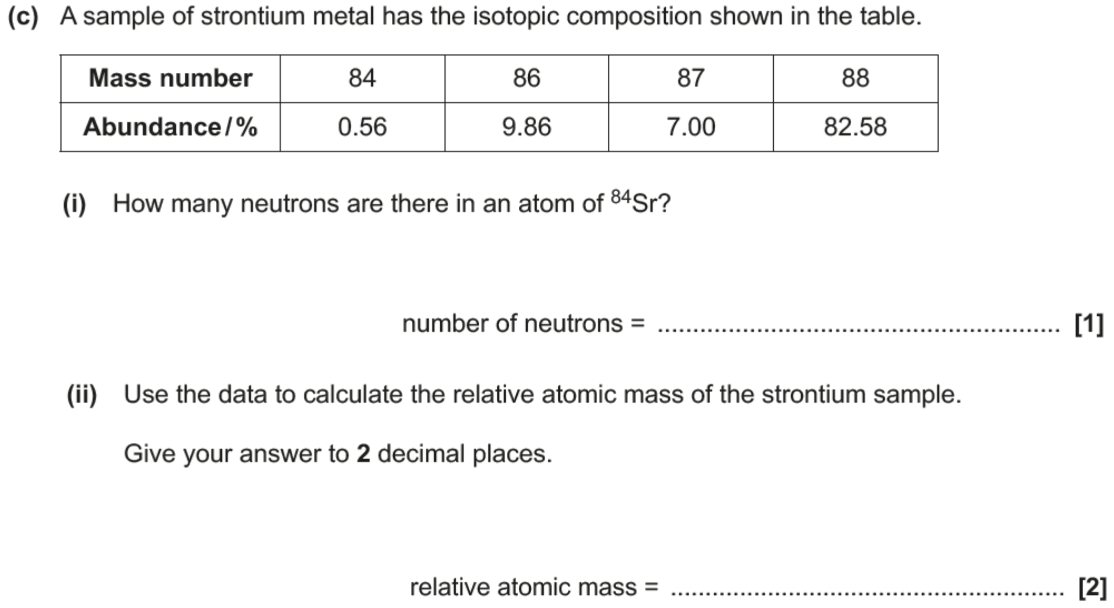
This question was designed to assess whether or not candidates could explain a trend in a property of the elements in Group 2, thermal stability.

The first mark was an easy mark in that all that was required was for students to identify that the first part of the statement was correct, but that from then on they had to explain why the rest of the statement was incorrect.

Many had clearly learnt the trend for this property for the Group and correctly stated that as you descend Group 2 the thermal stability of the compounds increases. After this, some candidates struggled to explain why this trend exists. They often stated that strontium ions have a higher charge density compared to calcium, which resulted in them having a stronger attraction to the carbonate ions, thus requiring a greater amount of energy to overcome the electrostatic attraction between the ions.

The correct explanation is that the strontium ions have a lower charge density as the ion is larger than calcium and so the nuclear charge is distributed over a larger volume. Therefore the lower charge density has less of a distortion effect on the carbonate ion and so the ionic bond formed is more stable.

Question 2 (c) (i) and (c) (ii)



(c) A sample of strontium metal has the isotopic composition shown in the table.

Mass number	84	86	87	88
Abundance / %	0.56	9.86	7.00	82.58

(i) How many neutrons are there in an atom of ^{84}Sr?

number of neutrons = ... **[1]**

(ii) Use the data to calculate the relative atomic mass of the strontium sample.

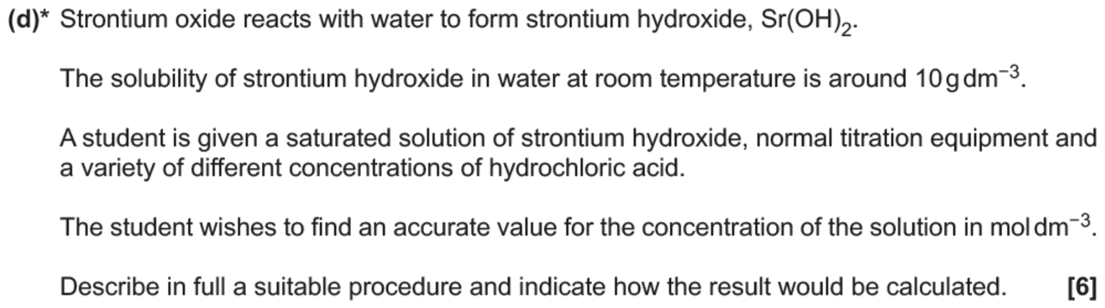
Give your answer to **2** decimal places.

relative atomic mass = ... **[2]**

In (c)(i) the vast majority of candidates correctly calculated that the number of neutrons present was 46.

In (c)(ii) there was evidence that candidates were not reading the question fully, as one mark was lost by candidates who gave an answer to one decimal place, or to three or more decimal places, rather than to the required number of two decimal places as instructed in the question.

Question 2 (d)



(d)* Strontium oxide reacts with water to form strontium hydroxide, $Sr(OH)_2$.

The solubility of strontium hydroxide in water at room temperature is around 10 g dm^{-3}.

A student is given a saturated solution of strontium hydroxide, normal titration equipment and a variety of different concentrations of hydrochloric acid.

The student wishes to find an accurate value for the concentration of the solution in mol dm^{-3}.

Describe in full a suitable procedure and indicate how the result would be calculated. **[6]**

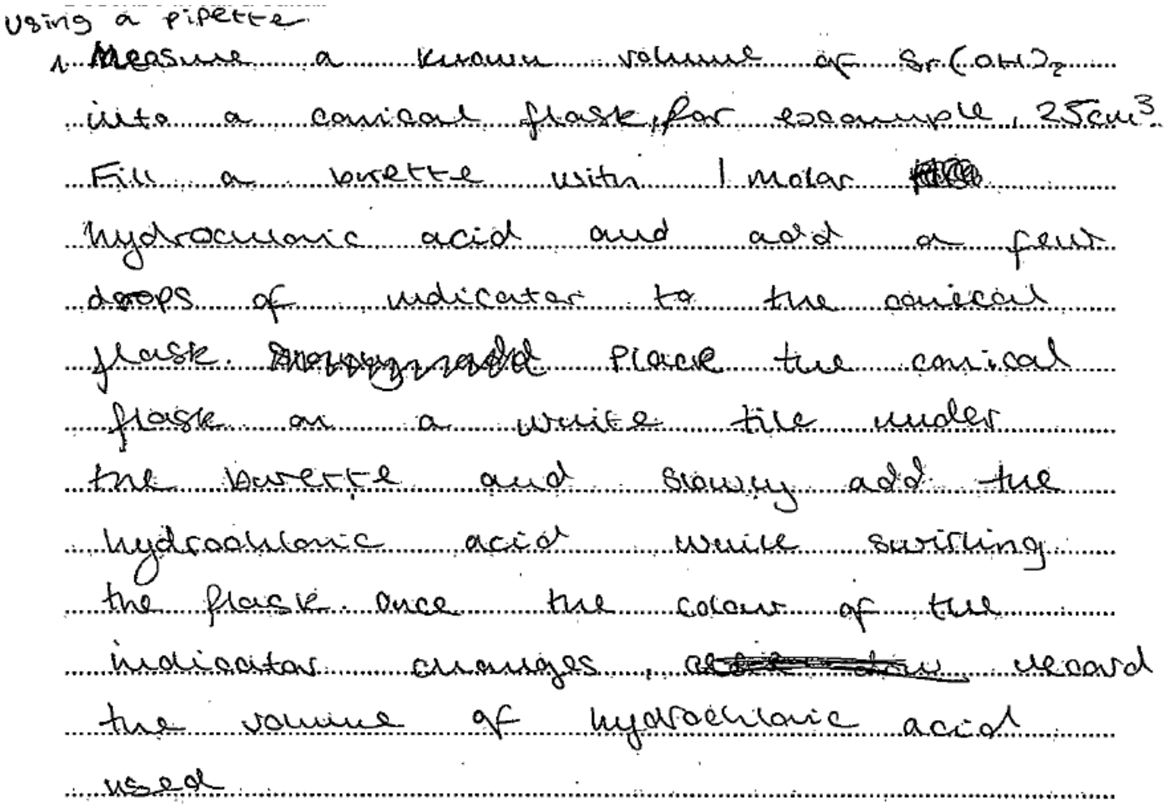
This was the first of the Level of Response questions on this paper. The topic chosen was based around a familiar practical procedure that all students should have carried out as part of the required practical element of the course. Candidates were provided with sufficient information to deduce that a titration was required but there was sufficient challenge in the task to allow for differentiation between candidates in the responses produced.

To access Level 3 a candidate had to use the solubility of the strontium hydroxide given in the question and convert this to a concentration value. Having done this, they needed to write (or use) a balanced symbol equation for the reaction in order to use the stoichiometry to derive an appropriate concentration of hydrochloric acid to use in their titration. They then needed to give details of the procedure they would use to collect the required data. Finally, they needed to give an explanation of how they would use the data to determine the accurate concentration of the saturated strontium hydroxide solution.

At Level 2 what was typically seen was a good description of the titrimetric method, including some fine detail, and a description of a workable calculation that would determine a value for the concentration of the strontium hydroxide solution. What was lacking was usually that the candidate had not made use of the solubility data and so had not identified an appropriate concentration of acid to use.

At Level 1 the most commonly seen response was a workable description of a titration that gave enough detail to allow for the candidate to collect concordant titres to use in a calculation. The details of the calculation were often omitted, or were very sketchy and showed that the candidate was unsure of how to carry out the required processing. Exemplar 2, a Level one response which scored two marks, illustrates this.

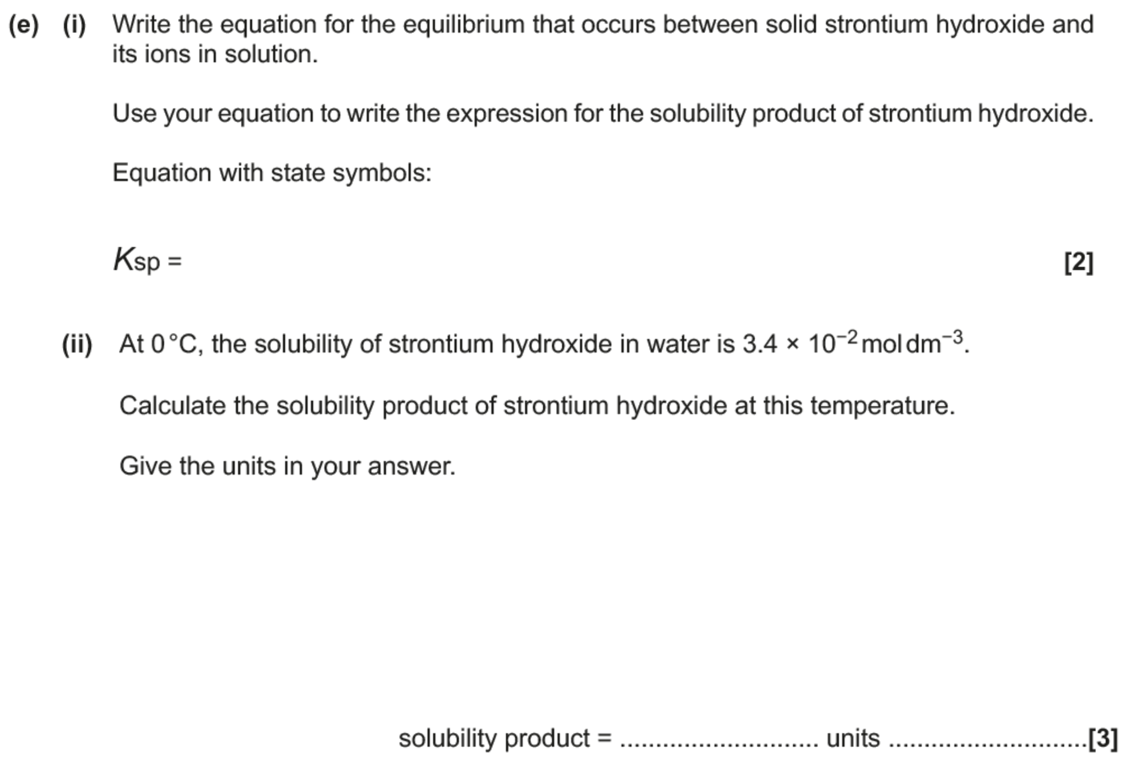
Exemplar 2



Using a pipette

1 Measure a known volume of $Sr(OH)_2$ into a conical flask, for example, 25cm^3. Fill a burette with 1 molar hydrochloric acid and add a few drops of indicator to the conical flask. Place the conical flask on a white tile under the burette and slowly add the hydrochloric acid while swirling the flask. Once the colour of the indicator changes, record the volume of hydrochloric acid used

Question 2 (e) (i) and (e) (ii)



(e) **(i)** Write the equation for the equilibrium that occurs between solid strontium hydroxide and its ions in solution.

Use your equation to write the expression for the solubility product of strontium hydroxide.

Equation with state symbols:

K_{sp} = **[2]**

(ii) At 0 °C, the solubility of strontium hydroxide in water is $3.4 \times 10^{-2}\,\text{mol}\,\text{dm}^{-3}$.

Calculate the solubility product of strontium hydroxide at this temperature.

Give the units in your answer.

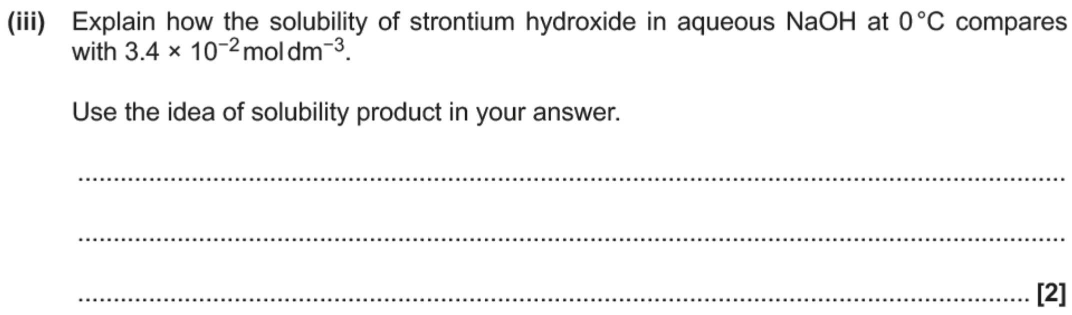
solubility product = ... units ....**[3]**

In (e)(i), most candidates scored the mark for the expression required for the solubility product, but a number of candidates did this without first of all writing an equation for the equilibrium. There were a significant number of others who did write out the expression but either did not give the appropriate state symbols or gave an incorrect state symbol for the strontium hydroxide ((aq) rather than (s)).

In (e)(ii), provided that candidates used their expression from (i) and realised that the concentration of hydroxide ions would be twice that of the strontium ions, they should have scored all three marks.

The most commonly seen error was where this had not happened, and so 3.4×10^{-2} was used for both the strontium and hydroxide ion concentrations. This results in a value of $3.93 \times 10^{-5}\,\text{mol}^3\,\text{dm}^{-9}$ which would score two marks, as the single error was only penalised once. Where a candidate had an incorrect expression for the solubility product in (i) and had used this, it was possible for them to score one mark for correctly derived units from their expression.

Question 2 (e) (iii)



(iii) Explain how the solubility of strontium hydroxide in aqueous NaOH at 0 °C compares with $3.4 \times 10^{-2}\,mol\,dm^{-3}$.

Use the idea of solubility product in your answer.

....

....

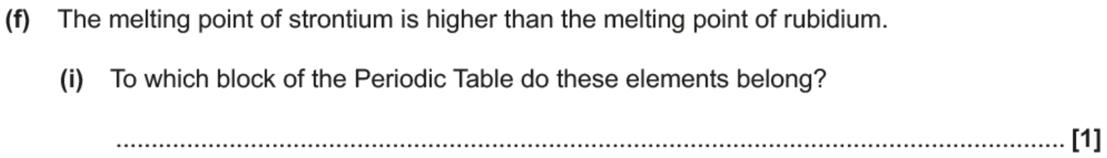
.... **[2]**

This question proved to be a good question to differentiate between candidates. It needed the candidate to recognise that K*sp* is a constant value and so whatever happens in the reaction mixture this has to remain unchanged.

Using the sodium hydroxide solution would result in a larger concentration of hydroxide ions being present, and so for K*sp* to remain constant the concentration of the strontium ions had to reduce, which would result in the solubility of the strontium hydroxide decreasing.

A second acceptable route through this question was if a candidate recognised that the increase in hydroxide ions meant that the equilibrium established would act to counter the change by moving to the left, and that this would result in the solubility of the strontium hydroxide decreasing.

Question 2 (f) (i)



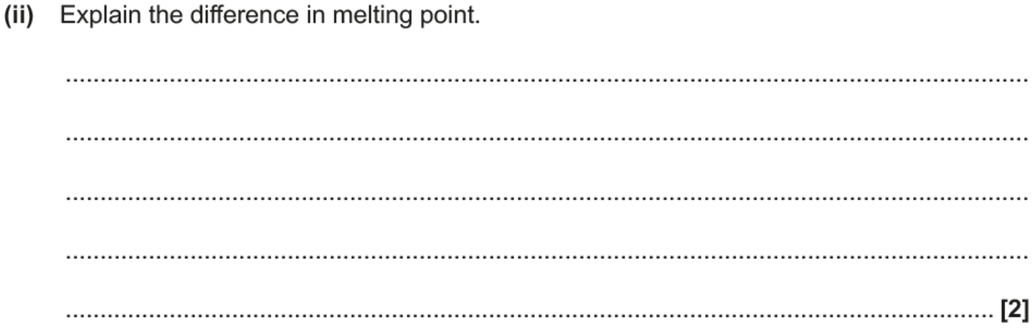
(f) The melting point of strontium is higher than the melting point of rubidium.

(i) To which block of the Periodic Table do these elements belong?

.... **[1]**

There were a couple of regularly seen errors in responses to this question, the most common of which was 5 on its own, or Period 5. This may be the correct row of the Periodic Table for these elements, but it is not the correct block.

Question 2 (f) (ii)



(ii) Explain the difference in melting point.

....

....

....

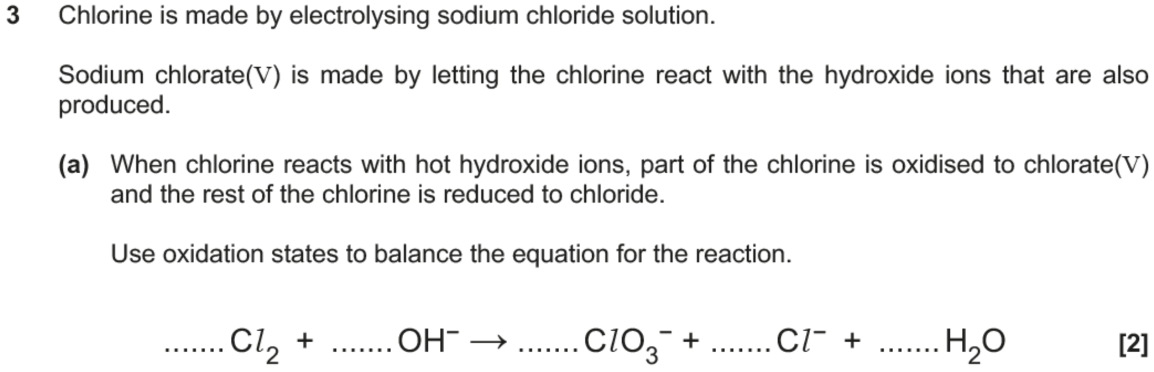
....

.... **[2]**

This question proved to be quite tricky for a number of candidates who tried to link the difference in melting point to reactivity and the ease with which the atoms would lose electrons to form compounds. A significant number of candidates tried to discuss the difference in melting point in terms of the differences in shielding resulting in strontium's nucleus having a stronger attraction for the valence electrons and so a higher melting point.

Unfortunately, these arguments were all incorrect as they had to realise that melting point is a physical property that is linked to the metallic structure of the elements. For this to happen, the elements' outer shells overlap, creating a delocalised area of electron density. Strontium can donate more electrons to the delocalised field than rubidium. This also means that the strontium ion, Sr^{2+}, will have a stronger attraction to the delocalised electrons and so will have a higher melting point than rubidium.

Question 3 (a)



3 Chlorine is made by electrolysing sodium chloride solution.

Sodium chlorate(V) is made by letting the chlorine react with the hydroxide ions that are also produced.

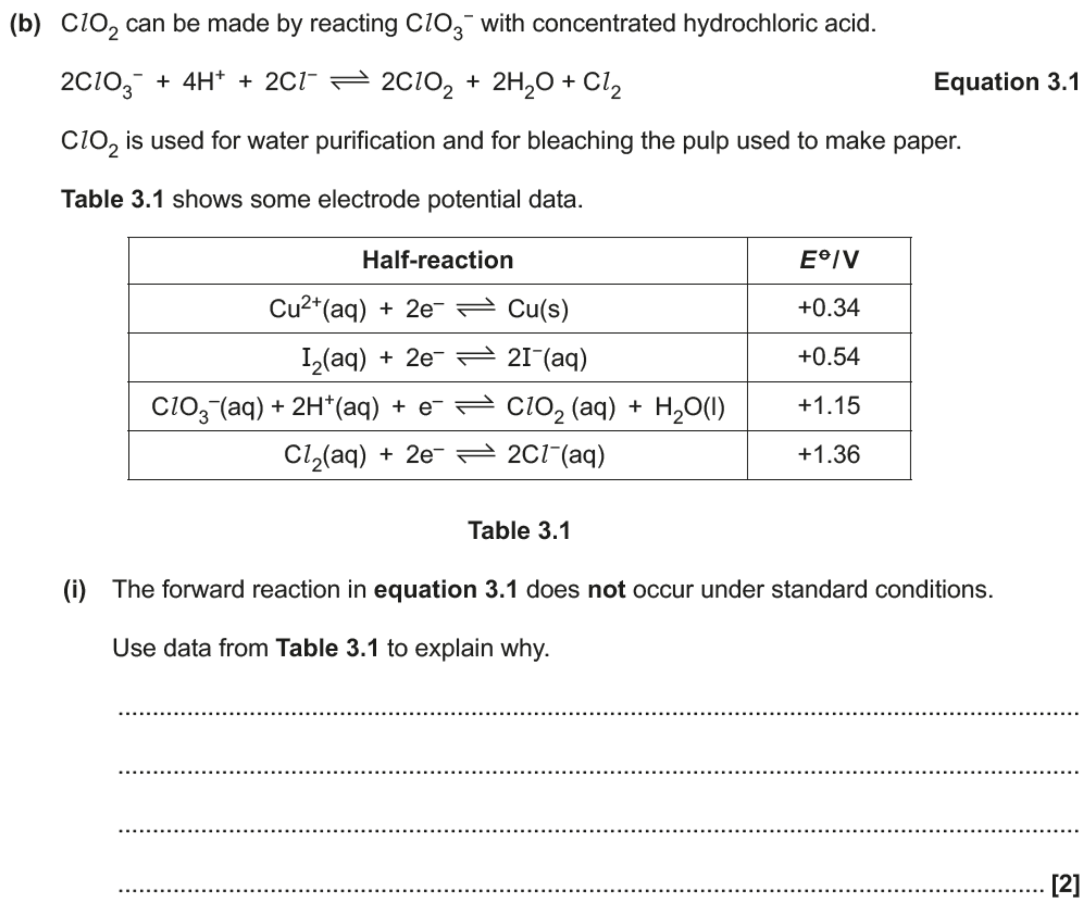
(a) When chlorine reacts with hot hydroxide ions, part of the chlorine is oxidised to chlorate(V) and the rest of the chlorine is reduced to chloride.

Use oxidation states to balance the equation for the reaction.

$$\ldots\ldots Cl_2 + \ldots\ldots OH^- \longrightarrow \ldots\ldots ClO_3^- + \ldots\ldots Cl^- + \ldots\ldots H_2O$$ **[2]**

This was a question that many lower attaining candidates left blank, as they struggled to use ideas about oxidation states to determine the changes evident in the disproportionation of the chlorine molecule. Some candidates did determine the need for six hydroxide ions producing three water molecules and providing the oxygen atoms required for the chlorate(V) ion to score one mark. However, they then thought that this was all that was required and did not consider the changes in the oxidation state of the chlorine atoms.

Question 3 (b) (i)



(b) ClO_2 can be made by reacting ClO_3^- with concentrated hydrochloric acid.

$2ClO_3^- + 4H^+ + 2Cl^- \rightleftharpoons 2ClO_2 + 2H_2O + Cl_2$ **Equation 3.1**

ClO_2 is used for water purification and for bleaching the pulp used to make paper.

Table 3.1 shows some electrode potential data.

Half-reaction	$E^\ominus$/V
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$	+0.34
$I_2(aq) + 2e^- \rightleftharpoons 2I^-(aq)$	+0.54
$ClO_3^-(aq) + 2H^+(aq) + e^- \rightleftharpoons ClO_2(aq) + H_2O(l)$	+1.15
$Cl_2(aq) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+1.36

Table 3.1

(i) The forward reaction in **equation 3.1** does **not** occur under standard conditions.

Use data from **Table 3.1** to explain why.

....

....

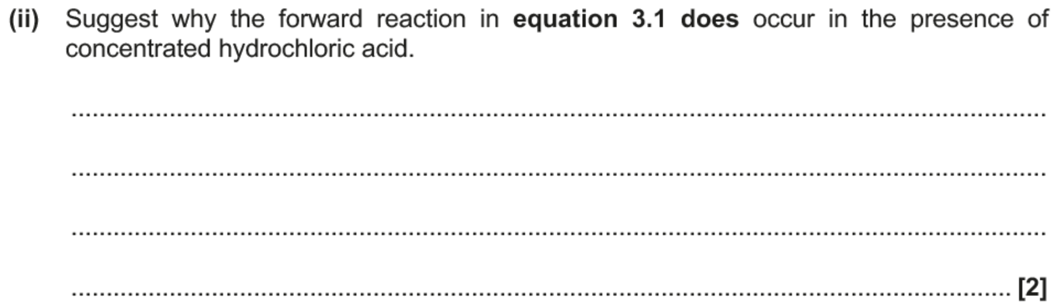
....

.... **[2]**

Many candidates found this question particularly challenging. In particular they often described the difference between the two relevant half-cells in simple terms such 'the chlorine half-cell is more than/larger than the chlorate half-cell'. This may be numerically correct but it is important to use the correct terminology and identify the polarity of each half-cell accordingly.

Marking point one was for identifying that the correct polarity, e.g. 'the Cl_2/Cl^- half-cell is more positive than the ClO_3^-/ClO_2 half-cell'. The second mark was for then stating what the effect of this would be and so why the forward reaction does not happen. Essentially, this meant that what was being looked for was the idea of the two relevant half-cells having been reversed, or the effect this would have on the equilibrium in equation 3.1, e.g. ClO_2 is oxidised and Cl_2 is reduced which is the reverse of the reaction outlined.

Question 3 (b) (ii)



(ii) Suggest why the forward reaction in **equation 3.1 does** occur in the presence of concentrated hydrochloric acid.

....

....

....

.... **[2]**

This question was more successfully answered by many candidates as they identified that the addition of concentrated hydrochloric acid introduced a larger concentration of H^+ or Cl^- ions. This would cause the position of the equilibrium in equation 3.1 to move to the right (and therefore the cell would no longer be under standard conditions) and so the forward reaction becomes favourable.

Question 3 (c) (i) and (c) (iii)

(c) A student investigates the reactions of some halogen compounds using the data in **Table 3.1**.

Half-reaction	***E*°/V**
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$	+0.34
$I_2(aq) + 2e^- \rightleftharpoons 2I^-(aq)$	+0.54
$ClO_3^-(aq) + 2H^+(aq) + e^- \rightleftharpoons ClO_2(aq) + H_2O(l)$	+1.15
$Cl_2(aq) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+1.36

Table 3.1

(i) The student uses a $Cu^{2+}(aq)/Cu(s)$ half-cell to confirm the *E*° of a $Cl_2(aq)/Cl^-(aq)$ half-cell.

Complete and label the diagram of the apparatus the student would set up.

Show state symbols.

Indicate how standard conditions are achieved.

[4]

(iii) State where the electrons move and which way they are moving when the cell delivers a current.

....

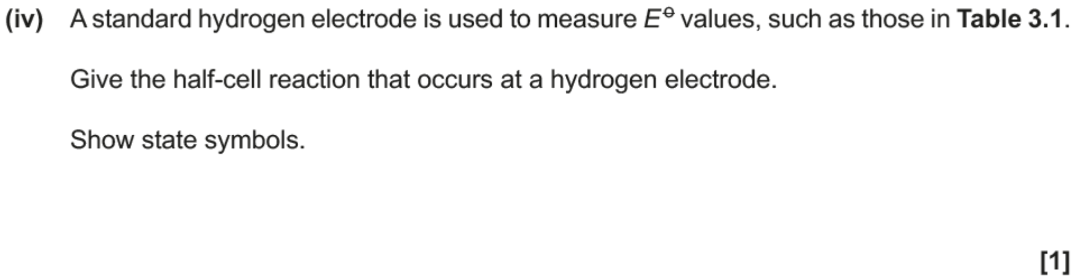
.... **[1]**

The first part of this question required candidates to complete the diagram to show how this electrochemical cell could be set up. Most candidates scored at least 3 marks here for correctly identifying and labelling a salt bridge and voltmeter, and giving the correct electrolytes and electrodes for each half-cell. Where they missed out on a mark was not giving the details required to identify that each cell had been constructed under standard conditions i.e. 1 mol/dm^3 for each solution and at a temperature of 298K.

In part (ii) they then needed to determine the E_{cell} value. Most candidates did this successfully, arriving at a value of 1.02V.

Finally, in part (iii), they were required to identify the direction of flow of the electrons when the cell is delivering a current. This could be a point that centres need to pay attention to as many candidates lost this mark. Although they correctly identified that the direction of flow would be from the copper half-cell to the chlorine half-cell, they either did not indicate that it happens through the wire, or stated that it went through the salt bridge which is incorrect.

Question 3 (c) (iv)



(iv) A standard hydrogen electrode is used to measure $E^\ominus$ values, such as those in **Table 3.1**.

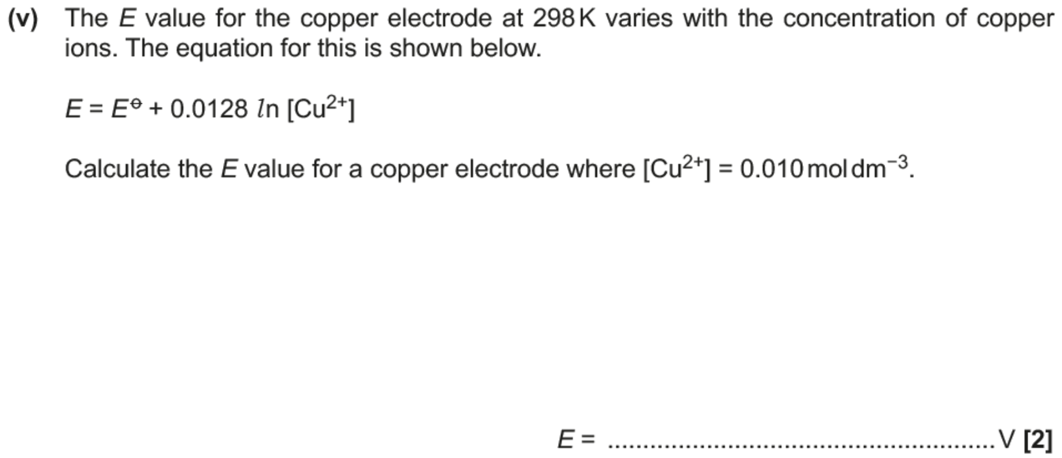
Give the half-cell reaction that occurs at a hydrogen electrode.

Show state symbols.

[1]

Most candidates correctly scored this mark. Where candidates did not score this mark it was because they had the electrons on the wrong side of their equation, i.e. being added to the $H_{2(g)}$ molecule rather than to the H^+ ions. The other common error was in not including the relevant state symbols as required in the question.

Question 3 (c) (v)



(v) The E value for the copper electrode at 298 K varies with the concentration of copper ions. The equation for this is shown below.

$E = E^\ominus + 0.0128\ ln\ [Cu^{2+}]$

Calculate the E value for a copper electrode where $[Cu^{2+}] = 0.010\ mol\ dm^{-3}$.

E = ... V **[2]**

This question threw up an omission by many candidates that cost them a mark. Many candidates correctly arrived at a value of 0.281V but did not include the + sign in front of this which was an essential part of the required answer. Other commonly seen errors included using +1.02 rather than +0.34 which gave a value of +0.96V for 1 mark, or using log_{10} rather than *ln* which gives a value of +0.31V again for 1 mark.

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

(d) From data in **Table 3.1**, the student knows that chlorine reacts with iodide ions in aqueous solution.

(i) Write an equation for the reaction that occurs.

[1]

(ii) **Name** the reducing agent in your reaction in **(d)(i)**.

.... **[1]**

(iii) What will be **seen** when the reaction in **(d)(i)** occurs?

.... **[1]**

For Question d(i), we did not allow the equation to be described as an equilibrium. The reason for this is that, under standard conditions, there is no possibility of iodine molecules reacting with chloride ions to reverse the accepted equation for this reaction.

In (ii), having written their equation, most candidates correctly identified the reducing agent as the iodide ion. We did not allow the formula to be used as the question specifically states **'Name..'** in bold within the question.

In (iii), purple or violet were not accepted as final colours for the iodine solution, as this is only seen in an organic solvent. Any given starting colours were ignored, but the identification of a precipitate was not allowed as the halogen would have been present dissolved in the aqueous solution. 'Brown liquid' was acceptable for 1 mark, 'it turns yellowy brown' was also acceptable for 1 mark, but 'a brown precipitate' was not allowed and scored 0 marks.

Question 3 (d) (iv)

(iv) Explain, in terms of electrons, why chlorine is more reactive than iodine.

....

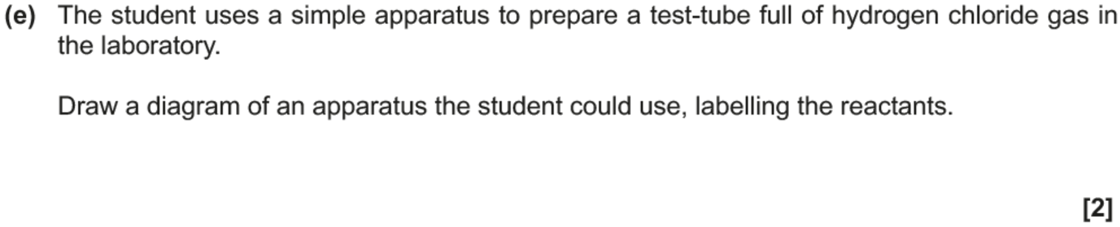
....

.... **[1]**

Many students started their answer by trying to use ideas about the electron configuration of the elements. They then tried to use this to explain the trend in reactivity in terms of the nuclear attraction between the protons in the nucleus and the valence shell electrons.

They were on the right track but what was needed was an appreciation that the halogens react by gaining an electron in order to complete their valence shell. This is more easily achieved by chlorine as the nucleus has a stronger attraction to electrons in other atoms (elements) and so can gain an electron more readily compared to iodine. 'Chlorine has a larger charge density compared to iodine and so can attract an additional electron more readily', was a correct answer that was seen from a number of candidates.

Question 3 (e)



(e) The student uses a simple apparatus to prepare a test-tube full of hydrogen chloride gas in the laboratory.

Draw a diagram of an apparatus the student could use, labelling the reactants.

[2]

Describing this gas preparation was found challenging by the majority of candidates. Very few recognised that hydrogen chloride is a) denser than air, and b) highly soluble in water. Most opted to collect their gas by displacement over water which would not work. A correct method for collecting the gas by upward displacement of air from an open vessel, e.g. boiling tube, would have scored the second marking point.

The methods chosen to prepare the gas were at times inventive, e.g. use of an acyl chloride with water(plausible), the use of sodium chloride solution with phosphoric acid (dangerous), and adding H_2 to Cl_2 in the presence of sunlight. The first two might seem viable responses but the hydrogen chloride produced in both would have dissolved in the aqueous solution present. The correct standard method for producing hydrogen chloride is in dry conditions using concentrated sulfuric acid with solid sodium chloride. The gas produced is then delivered via downward delivery into an open vessel to prevent the build-up of pressure that may result in a small explosion.

Some students did identify the need for sulfuric acid and sodium chloride to be reacted together, but opted to use either, or both, of these reagents as aqueous solutions which negated the mark.

Question 4 (a)

4 Dinitrogen pentoxide, N_2O_5 is an oxide of nitrogen that is formed in the stratosphere by reactions such as those shown below.

$$NO_2 + O_3 \rightarrow NO_3 + O_2$$

$$NO_3 + NO_2 \rightleftharpoons N_2O_5$$

The dinitrogen pentoxide acts as a 'sink' for NO_2, stopping it breaking down ozone.

(a) A student says that oxides of nitrogen catalyse the breakdown of ozone in the stratosphere by the reactions shown below.

$$NO_2 + O_3 \rightarrow NO_3 + O_2$$

$$O_3 + NO_3 \rightarrow NO_2 + 2O_2$$

Discuss the student's choice of reactions, giving the correct chemistry if necessary.

....

....

....

.... **[2]**

This question generally scored one mark for the majority of candidates. They recognised that NO_2 was acting as a catalyst for the decomposition of ozone, as it is used up in step 1 but was reformed / regenerated as a product in step 2. However, they seemed to confuse the ideas here with the reactions that occur in the atmosphere involving chlorine radicals (from CFCs) and so often gave a single alternative reaction of $2O_3 \rightarrow 3O_2$ as their alternative correct reaction. The correct equations were seldom given.

Question 4 (b) (i) and (b) (ii)

(b) In the troposphere, dinitrogen pentoxide decomposes as shown below.

$2N_2O_5 \rightarrow 4NO_2 + O_2$ **Equation 4.1**

The table shows how the concentration of $2N_2O_5$ varies with time at 315 K.

Time / s	**$[N_2O_5]$ / mol dm^{-3}**
0	0.330
1000	0.210
2000	0.124
3000	0.078
4000	0.048

(i) Use the data in the table to plot a graph to determine the half-life for the reaction. Label the axes.

half-life = ... s **[4]**

(ii) How does the graph show that the reaction in **equation 4.1** is first order with respect to N_2O_5?

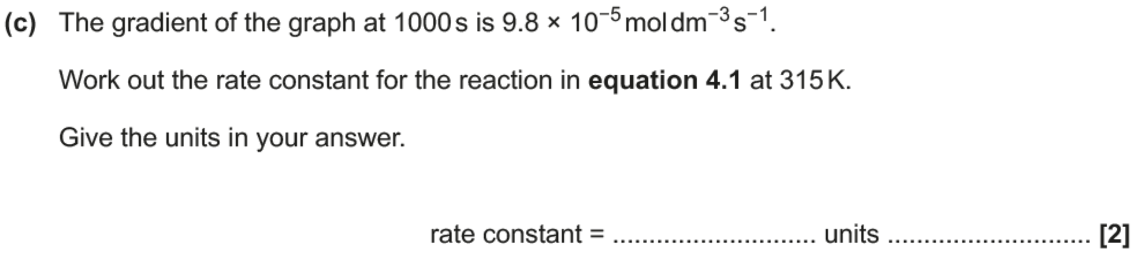
Draw construction lines on the graph to explain your answer.

.... **[1]**

This combination of questions was generally well answered by the majority of candidates, with many scoring full marks or at least scoring 4 of the 5 marks that were available.

The only commonly seen error was failing to label the axes correctly on their graph. There were a small number of candidates who scored all 4 marks for drawing their graph, but then gave an incorrect answer to (ii), often stating that the fact that the graph showed a curve with the concentration decreasing as time increased was evidence for a first order reaction.

Question 4 (c)



(c) The gradient of the graph at 1000 s is 9.8×10^{-5} mol dm^{-3} s^{-1}.

Work out the rate constant for the reaction in **equation 4.1** at 315 K.

Give the units in your answer.

rate constant = ... units .... **[2]**

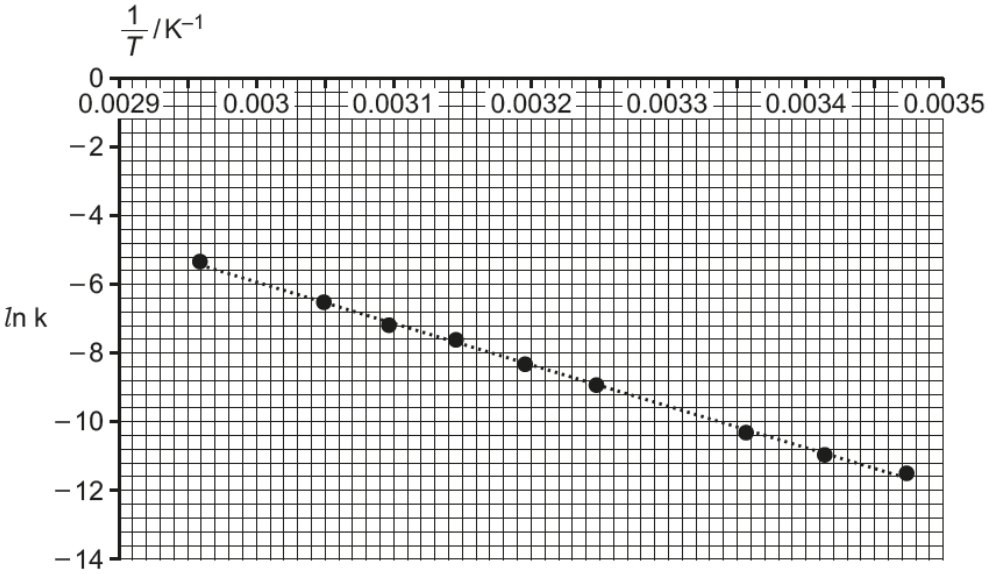
Having been told in (b)(ii) that the reaction is first order with respect to N_2O_5, candidates should have been able to deduce a suitable rate expression, i.e. Rate = k[N_2O_5], and then use it to determine the rate constant. However, because equation 4.1 tells them that the reaction uses 2 moles of N_2O_5, many candidates wrote the expression as Rate = k$[N_2O_5]^2$, and then derived their value and units from this expression.

Rather than simply penalising candidates fully for a recognisable error, it was decided that if they could derive appropriate units from this expression then we would allow the units marks to stand separately. This would be consistent with the marks given at 2(e)(ii) where a mark for derivation of units was previously allowed for a similar scenario. This allowed some candidates to access one mark where otherwise they would have scored 0 for a single error.

Question 4 (d)

(d) The reaction in **equation 4.1** was repeated with a fixed concentration of N_2O_5 at different temperatures.

A graph of ln k against $\frac{1}{T}$ for the reaction in **equation 4.1** is given below.



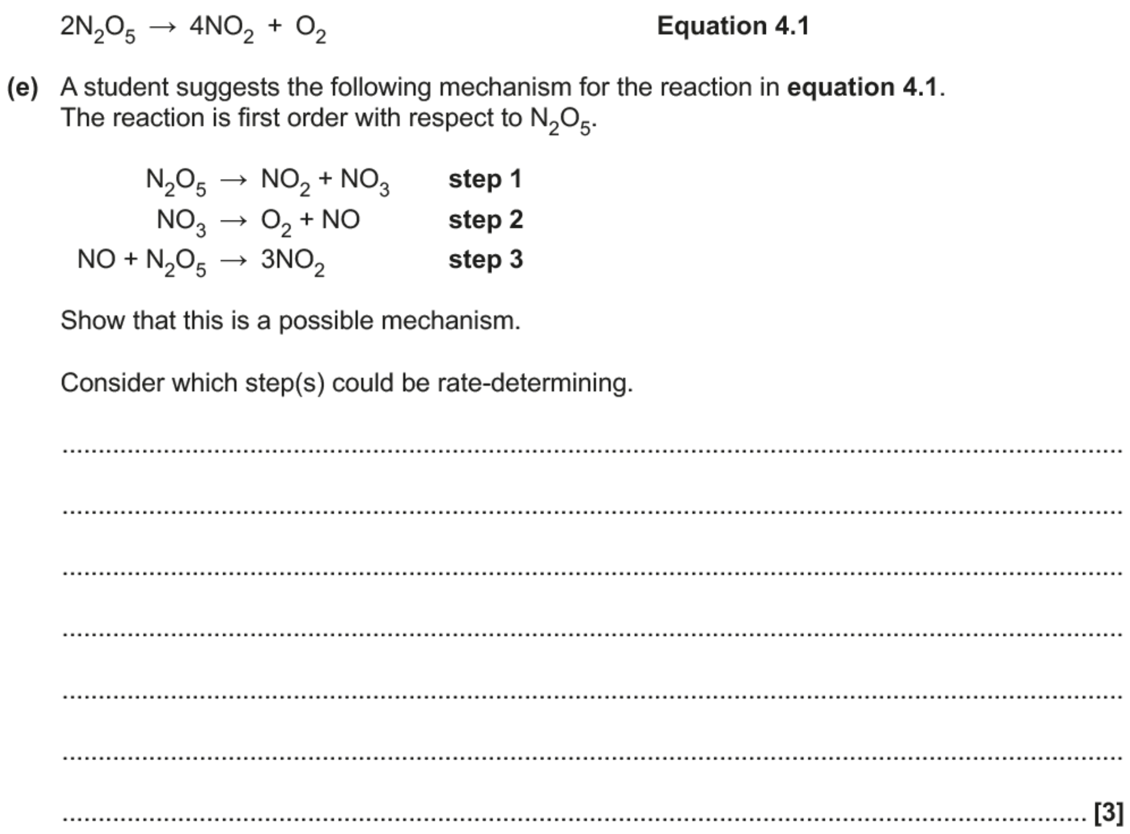
Use the graph to work out a value for the activation enthalpy (in kJ mol^{-1}) for the reaction.

E_a = ... kJ mol^{-1} **[3]**

This calculation was broken down into three recognisable steps where candidates could gain credit by marking them as independent steps. First of all they were required to calculate the gradient of the line drawn on the graph. Secondly, they had to multiply their value by R (8.314 J $mol^{-1}K^{-1}$) and then finally to convert their value from joules into kilojoules. By using this approach most of the candidates attempted this calculation scored at least two marks as they often scored marking points 2 and 3.

There were a few candidates who struggled to calculate the gradient of the line, inverting the numerator and denominator, but then continued with their calculation and scored either marking point 2 or 3. Others calculated the gradient correctly but then multiplied it by R and then divided it by 1/*T*. Others still chose a fixed point from the graph and used a single value of *ln*k and its corresponding value of 1/*T* to attempt to calculate a value for *Ea*. In each of these cases if it could be clearly identified that marking points 2 and 3 were evident then credit was given.

Question 4 (e)



$2N_2O_5 \rightarrow 4NO_2 + O_2$ **Equation 4.1**

(e) A student suggests the following mechanism for the reaction in **equation 4.1**.
The reaction is first order with respect to N_2O_5.

$N_2O_5 \rightarrow NO_2 + NO_3$ **step 1**
$NO_3 \rightarrow O_2 + NO$ **step 2**
$NO + N_2O_5 \rightarrow 3NO_2$ **step 3**

Show that this is a possible mechanism.

Consider which step(s) could be rate-determining.

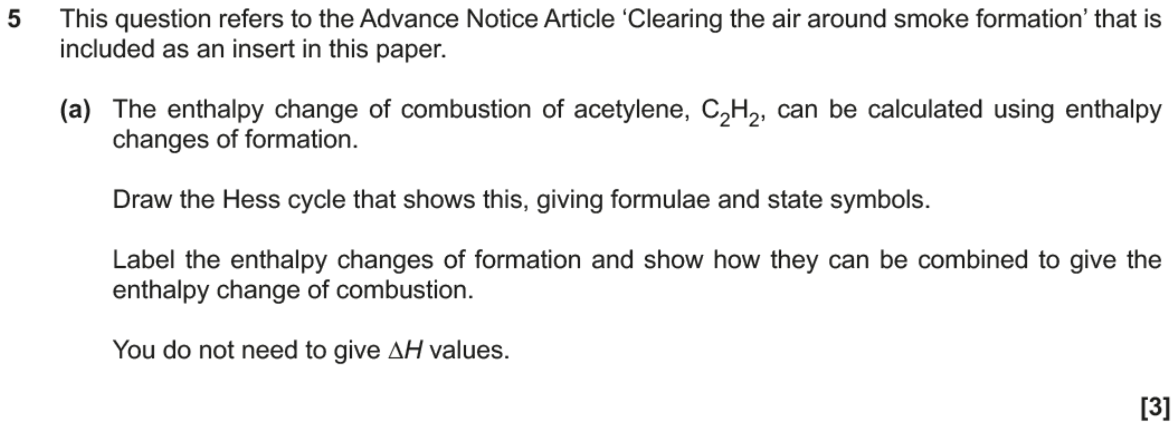
[3]

The first mark here was for identifying that the three steps outlined cancelled down to give the reaction shown in equation 4.1. Many candidates did this by adding the steps up to give a single equation and then crossed out substances that appeared on both sides of their equation to derive a final equation.

However, having done this, they then struggled to identify which step(s) was(were) the rate determining step(s) as they did not appreciate the significance of the statement in the stem of the question informing them that the reaction is first order with respect to N_2O_5. From this statement they should have been able to deduce that the rate determining step had to involve N_2O_5 as a reactant. Therefore it had to be either step 1 or step 3.

A significant number of responses did identify step 1 with a reason but said that step 3 could not be a rate determining step as it also contained NO as a reactant and there was no information available for NO in the rate equation.

Question 5 (a)



5 This question refers to the Advance Notice Article 'Clearing the air around smoke formation' that is included as an insert in this paper.

(a) The enthalpy change of combustion of acetylene, C_2H_2, can be calculated using enthalpy changes of formation.

Draw the Hess cycle that shows this, giving formulae and state symbols.

Label the enthalpy changes of formation and show how they can be combined to give the enthalpy change of combustion.

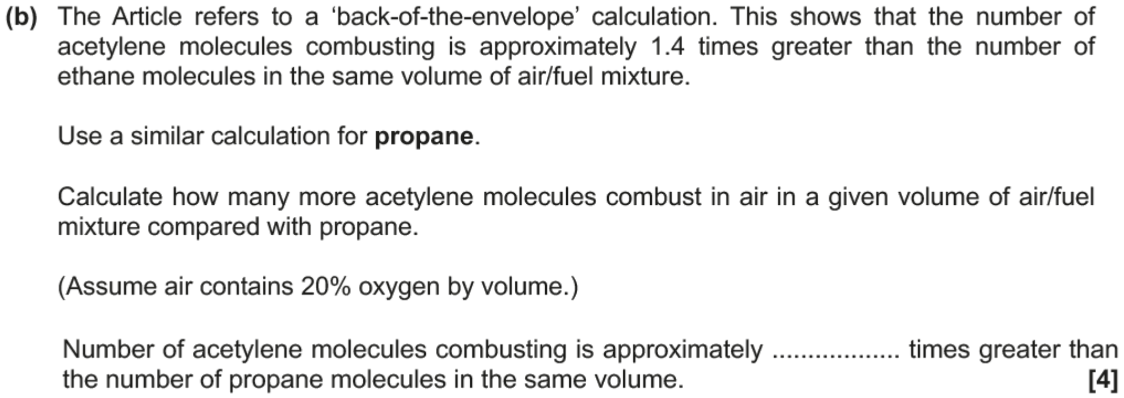
You do not need to give ΔH values.

[3]

The evidence from this question suggests that candidates need more practice drawing Hess's cycles as part of their revision and preparation for their examination. Very few candidates scored more than one mark in this question.

The most common error was the failure to include relevant state symbols for the reactants and products of the substances involved. This immediately meant that candidates could not score marking points one and two. However, even where a candidate did include state symbols, they usually did not label the reactions appropriately to indicate whether a step involved an enthalpy change of formation, or was the enthalpy change of combustion. They instead labelled the changes as ΔH_1, ΔH_2, etc. If they then used these symbols in a correct expression they could still score marking point three, which allowed most candidates to score one mark.

Question 5 (b)



(b) The Article refers to a 'back-of-the-envelope' calculation. This shows that the number of acetylene molecules combusting is approximately 1.4 times greater than the number of ethane molecules in the same volume of air/fuel mixture.

Use a similar calculation for **propane**.

Calculate how many more acetylene molecules combust in air in a given volume of air/fuel mixture compared with propane.

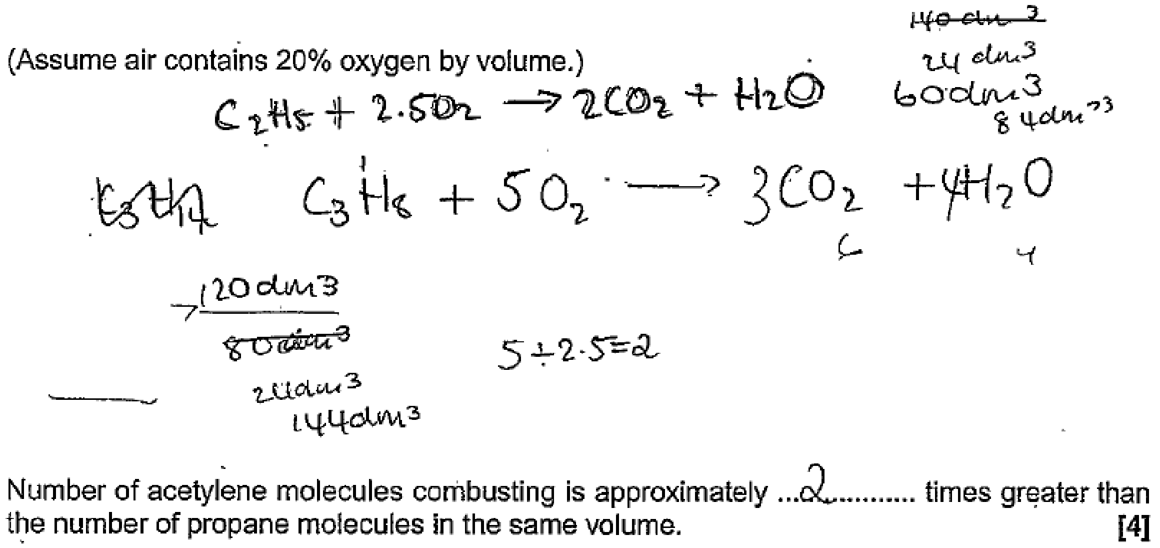
(Assume air contains 20% oxygen by volume.)

Number of acetylene molecules combusting is approximately .... times greater than the number of propane molecules in the same volume. **[4]**

Very few candidates scored full marks on this question as most candidates adopted a rather simple approach to the calculation. They recognised that the fully balanced equation for the combustion of propane when compared to the fully balanced equation for the combustion of acetylene showed a simple 2:1 ratio and so often suggested that the number of acetylene molecules combusting was 2 times greater than for propane.

Provided that the candidate had written down the equation for the combustion of propane and showed some evidence of using the acetylene equation then an answer of 2 times greater was given 3 marks. Exemplar 3 shows the most commonly seen response which took this approach.

Exemplar 3



(Assume air contains 20% oxygen by volume.)

$C_2H_5 + 2.5O_2 \rightarrow 2CO_2 + H_2O$

~~140 dm3~~
24 dm3
600dm3
8 4dm3

C_3H_{14} $C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$

6 4

→ 120dm3

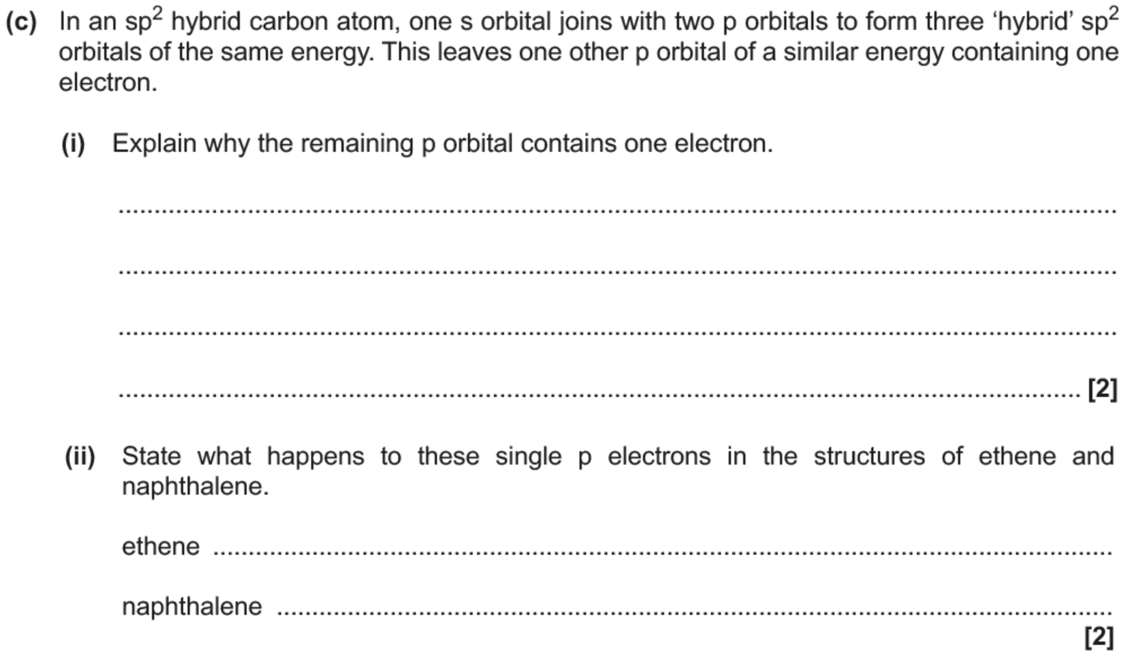
~~80dm3~~

5÷2.5=2

2ll dm3
144dm3

Number of acetylene molecules combusting is approximately ...2.......... times greater than the number of propane molecules in the same volume. **[4]**

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



(c) In an sp^2 hybrid carbon atom, one s orbital joins with two p orbitals to form three 'hybrid' sp^2 orbitals of the same energy. This leaves one other p orbital of a similar energy containing one electron.

(i) Explain why the remaining p orbital contains one electron.

....

....

....

.... **[2]**

(ii) State what happens to these single p electrons in the structures of ethene and naphthalene.

ethene ....

naphthalene ....
[2]

These two questions assessed candidates' knowledge and understanding of bonding in organic molecules with particular emphasis on double bonds in alkenes and in conjugated systems.

In part (i) candidates needed to be able to identify that the electrons involved in bonding in these systems came from the valence shell of the carbon atom. Therefore the first mark was for identifying that there were four electrons in the valence shell. Because there are three sp^2 hybrid orbitals the second mark was for then stating that three of the (valence) electrons would be used in the hybrid orbitals, therefore leaving one electron in an unhybridised p-orbital.

In part (ii) candidates needed to state what happens to the unpaired electron in an alkene or a conjugated system i.e. in ethene it forms the π bond, whereas in naphthalene it becomes delocalised (across the conjugated system).

Most candidates correctly identified what happens to the p-electron in the naphthalene structure, but often were not precise in their description of what happens in ethene, simply stating that it forms part of the double bond, and so did not score this mark.

Question 5 (d)

(d) **Fig. 2** in the Article shows the formation of naphthalene from benzene.

Suggest the first step in the formation of a larger PAH from naphthalene.

....

.... **[1]**

Where candidates had prepared well this was a well answered question as they readily identified that the first step was the abstraction (removal) of a hydrogen atom from naphthalene. However, there were some instances of responses that seemed to indicate that the candidates had not spent sufficient time on the article and so they gave more generalised responses such as 'bond breaking', addition of acetylene, or even leaving this blank.

Where a candidate correctly identified the first step and then followed it up with a suggested second step, this was ignored whether it was correct or not as the question only required them to identify the first step in the reaction. However, if they gave some indication of a process happening before the hydrogen atom is removed then this was marked as incorrect even if they gave the removal of hydrogen as a second step (e.g. addition of acetylene followed by hydrogen abstraction scored 0, both processes do occur in the growth of PAH molecules, but the order given is incorrect).

Question 5 (e) (i)

(e) The equation $C_4H_{10} + M \rightarrow C_3H_7 + CH_3 + M$, is given in the Article. M is a molecule.

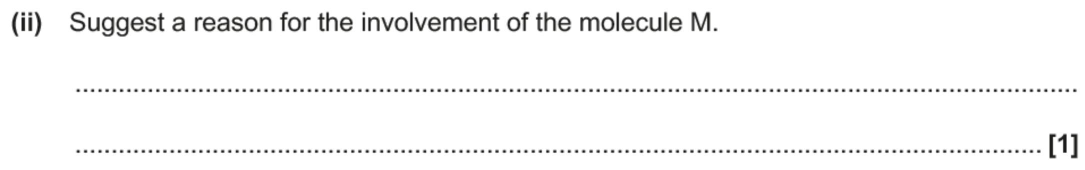
(i) Classify this reaction as *initiation*, *propagation* or *termination* with a reason.

....

.... **[1]**

This provoked a variety of responses from candidates. Many correctly identified the reaction as an initiation reaction, explaining this in terms of the production of two radicals where there were no radicals on the reactants side of the equation. However, there were a number of candidates who thought that this was a propagation reaction, as they thought that M was a radical. A smaller number identified the reaction as an initiation reaction but offered no explanation. To score this mark the correct identification and reason was required.

Question 5 (e) (ii)



(ii) Suggest a reason for the involvement of the molecule M.

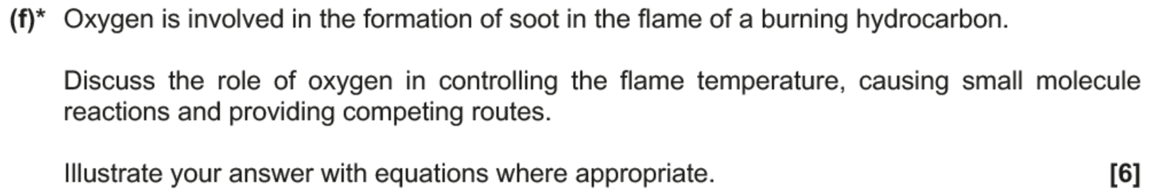
....

.... **[1]**

The most commonly seen answer here was that M was a catalyst as it was present on both sides of the equation. This was an incorrect response as the role of the molecule was to collide with the small alkane molecules in order to either break a bond homolytically to produce a radical, or to collide with the molecule in order to provide the energy needed for a bond to break. In both of these situations the common point was the necessity for M to collide with the other molecule.

There were a number of responses where the candidate had given partially correct descriptions but did not indicate the need for the molecules to collide with one another, e.g. M is needed to provide the energy needed for the reaction, M is needed to break a bond in the alkane/butane. Neither of these would score the mark as there is no reference to the molecules colliding.

Question 5 (f)



(f)* Oxygen is involved in the formation of soot in the flame of a burning hydrocarbon.

Discuss the role of oxygen in controlling the flame temperature, causing small molecule reactions and providing competing routes.

Illustrate your answer with equations where appropriate. **[6]**

The final question on the paper was the second Level of Response question. It is pleasing to note that there were very few scripts where no attempt had been made to answer this question. Even lower ability candidates who find this type of question particularly challenging made an attempt and often scored some marks at Level 1.

There were however very few scripts that progressed beyond Level 2. The main reason for this was that most candidates discussed the idea of flame temperature in terms of whether or not complete or incomplete combustion of the fuel had taken place. This was not a route that was deemed to be creditworthy given the context of the article and so if this was their only reason for suggesting why the flame temperature varied then it was not possible to reach to Level 3.

To access Level 3 candidates needed to give a detailed account of how oxygen controls flame temperatures by reference to the concentration (percentage) of oxygen present, or to the mole ratio of oxygen required by saturated or unsaturated hydrocarbons. For example, candidates could quote that acetylene burns at 3500°C in pure oxygen but only at 2000°C in air and could state that air is only 20% oxygen. Additionally by giving reference to the number of acetylene molecules that could burn compared to for example ethane molecules they would have been at a point of being able to access Level 3.

They also needed to give a detailed account about the small molecule reactions that occur that lead to the growth of PAH molecules via HACA, which many did by use of the appropriate equations contained in the article. Finally, they needed a detailed account of the competing reactions that could occur. These include production of soot from acetylene type molecules versus production of CO_2 when a higher proportion of oxygen molecules was present, or the idea that combustion of saturated molecules produces CO_2, but the combustion of unsaturated molecules leads to the production of acetylene and then to soot formation.

Even where candidates had avoided the idea of complete and incomplete combustion in controlling flame temperatures they often fell into the trap of describing this as an example of the competing reactions that could occur to produce either soot or CO_2, which again meant that Level 3 could not be accessed.

At Level 2 it was more common to see responses where candidates had addressed all three areas but often by giving an outline of the three areas. For example, they regularly quoted that the flame temperature was dependent on the amount of oxygen present by quoting the data for acetylene burning in air and in pure oxygen. They would then describe how oxygen was needed for the small molecule reactions needed to produce hydrogen atoms required for the growth of PAH molecules, or they would quote examples of the small molecule reactions from the article. Finally they would state that there were competing reactions occurring that decided whether or not soot or CO_2 would be produced but without expanding on this any further. Candidates at this level often gave a brief outline of two areas and may have expanded into greater detail in one area which would be a secure Level 2 but was insufficient to progress to Level 3.

At Level 1 many lower ability candidates accessed this by quoting the data for the flame temperature dependency for acetylene linked to pure oxygen and air, and then identified that one reaction produced soot, while another reaction produced CO_2. These responses were often contained very little detail. There were, however, a few responses where a candidate gave a detailed account of one area but did not address the other areas, possibly as a result of running out of time on the paper, but these were exceptional cases.

Exemplar 4

Oxygen is very important when causing small molecule reactions. oxygen reacts with CH to produce CO+H and CH_2 to produce CO_2 and 2H. This is crucial in the formation of soot as hydrogen atoms are produced which are needed to help abstract H atoms from the PAHs. Oxygen is also responsible for complete or incomplete combustion. If enough oxygen is in supply complete combustion occurs to form CO_2 and H_2O. Lack of oxygen causes incomplete combustion and the formation of C or CO and H_2O. * When molecules are exposed to ~~p~~ oxygen they burn with a much higher temperature then when exposed to just air (acetyle burns at 3500°C in O_2 and 2500°C in air) due to the fact air is approximately 20% oxygen. – The less oxygen, the lower the flame temperature.

Additional answer space if required

* Oxygen provides two competing routes – one to oxidise the fuel to CO_2 and H_2O and the other to the formation of soot from PAHs – the route taken depends on how unsaturated the molecule is

oxygen burns unsaturated fuels with a higher temperature than saturated fuels do

Exemplar 4 is a good example of a typical Level 2 response that addressed all three areas but was lacking in detail, and scored 4 marks.

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