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Examiners' report

TWENTY FIRST CENTURY SCIENCE CHEMISTRY B

J258

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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 answers 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 OCR.

Paper 3 series overview

In general terms, the performance of candidates in these papers shows an improving trend. There were few spaces left in unattempted part questions. Candidates used all available space and remained engaged throughout the paper. They typically engaged with the contexts and processed the information given. Mathematical skills have also seen an improvement, with almost all candidates addressing instructions such as those to provide numerical answers to a specific number of significant figures or to a specified number of decimal places.

An area for development is practical skills. All practical questions were significantly less well answered than those that relied on knowledge. It appeared that many candidates had little familiarity with basic separation techniques and basic apparatus that it would be reasonable to expect them to know.

Other areas for focus include ensuring that candidates read questions carefully and address the task fully. This includes taking into account the number of marks available. In some questions, it was apparent that responses given did not address the question asked, for example discussing structure rather than properties in Question 1 (a) and discussing the whole graph rather than the last 20 years, in Question 3 (a).

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• read questions carefully in order to make sure the task and the information were understood before beginning to write • obeyed instructions such as 'give your answer to 3 significant figures' • showed knowledge of practical equipment and basic techniques such as separation techniques and stages in the method for making salts • made sure that they made enough separate points to address the mark allocation for each question.	• discussed points that were outside the demands of the questions, implying that they had not fully understood what they needed to do • gave multiple answers to calculations and did not clearly show which method was to be taken into account by the examiner • did not show their working so that partial credit could not be given if the answer was incorrect • repeated the same point in different words rather than making sure that they made enough clear, distinct points to address the question fully - repeating points often leads to contradictions so that marks cannot be given.

Question 1 (a)

1 Argon forms 1% of the air and is unreactive.

Argon is used as a replacement for nitrogen when nitrogen is too reactive.

(a) Argon is unreactive because it is in Group 0 of the Periodic Table.

State **one** other property of argon.

.... **[1]**

Most candidates were able to give a correct property of argon. The most common error was to make a point about the arrangement of electrons in the atom (for example 'argon has a full outer shell').

Question 1 (b)

(b) Chlorine is very reactive. Argon is unreactive.

Explain how the reactivity of these two elements are related to the arrangement of electrons in their atoms.

....

....

....

.... **[2]**

This was very well answered. Most candidates stated correctly that the unreactivity of argon is based on it having a full outer shell of electrons and that chlorine is reactive because it gains an electron.

Question 1 (c) (i)

(c) An element **X** has two electron shells with one electron in its outer shell.

(i) Which statements about **X** are **true**, and which are **false**?

Tick (✓) **one** box in each row.

	True	False
X is a metal.		
X is in the first period of the Periodic Table.		
X forms $\mathbf{X}^-$ ions.		
X loses one electron when it reacts.		

[2]

Most candidates gained at least 1 mark. The most common incorrect choice was that X is in the first period of the Periodic Table.

Question 1 (c) (ii)

(ii) Name **one** element that is more reactive than element **X**.

.... **[1]**

Almost all candidates chose a more reactive element than lithium (element X) from Group 1. Potassium and sodium were the most popular choices.

Question 1 (d)

(d) An argon atom has a mass number of 40.

Calculate the number of neutrons in its nucleus.

Use the Periodic Table.

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

Again, this was well answered. Almost all candidates were able to look up the atomic number of argon on the Periodic Table and use it to correctly calculate that argon contains 22 neutrons.

Question 2 (a) (i)

2 Formic acid is used to remove limescale from kettles.

(a) Formic acid is a carboxylic acid with the formula HCOOH.

(i) Draw the displayed formula of formic acid.

Show all the bonds.

[1]

This question proved challenging. The structure of the carboxylic functional group was not always shown correctly. The double bond between the carbon atom and oxygen atom was often omitted. Some drew the structure of ethanoic acid.

Question 2 (a) (ii)

(ii) The name of the carboxylic acid with the formula CH_3COOH is ethanoic acid.

What is the name of formic acid?

Tick (✓) **one** box.

Butanoic acid ☐

Methanoic acid ☐

Propanoic acid ☐

[1]

Most candidates correctly selected methanoic acid.

Question 2 (b)

(b) Ling and Taylor dip a piece of universal indicator paper into a solution of formic acid.

What pH value could the solution of formic acid be?

.... **[1]**

Again, this was well answered. Most candidates knew that formic acid has a pH below 7 and many gave a pH between 3 and 6, recognising that, as formic acid is a carboxylic acid, it is a weak acid. 7, 8 and 9 were the most common incorrect responses.

Question 2 (c) (i)

(c) Limescale contains calcium carbonate.

A solution of formic acid fizzes when it reacts with calcium carbonate.

(i) Name the gas that causes the fizzing.

.... **[1]**

Almost all candidates knew that the gas evolved is carbon dioxide. Some incorrectly identified the gas as hydrogen.

Question 2 (c) (ii)

(ii) A salt called calcium formate is also formed when formic acid reacts with calcium carbonate.

The formula of the calcium ion is Ca^{2+}. The formula of the formate ion is $HCOO^-$.

Write the formula of calcium formate.

.... **[1]**

Candidates found this question challenging. Most recognised that there was a 2:1 ratio involved in the formula, but fewer represented this correctly. Incorrect responses such as $CaHCOO_2$, Ca2HCOO and $CaHCOOH_2$ were commonly seen. This implies that the use of brackets around groups of atoms in a formula is not well understood.

Key point call out : writing formulae using brackets

Candidates find it challenging to write a formula for a compound that includes a multi-atom ion. The use of brackets is not well understood. They need to practise writing formulae such as $Ca(HCOO)_2$.

Question 2 (d)

(d) Calcium carbonate is insoluble in water. Calcium formate is soluble in water.

Sam wants to make some calcium formate crystals.

This is the method:
- stir calcium carbonate with a solution of formic acid
- stop adding calcium carbonate when no more reacts
- leave the mixture to crystallise.

An extra step is needed to make pure calcium formate crystals.

Name the extra step **and** explain why it is needed.

Extra step ....

....

Explanation ....

.... **[2]**

The main idea here is that the separation process is trying to collect pure calcium formate crystals. The crystals formed in this procedure would contain unreacted calcium carbonate solid unless it is removed BEFORE crystallisation. The extra step is to use filtration before crystallisation. The most common incorrect response was to state that the mixture should be filtered AFTER crystals have formed. This would not produce pure crystals. Similarly, many candidates discussed evaporating the solution. Again, this would not produce pure calcium formate crystals. This question was not successfully answered and implies that some candidates do not have sufficient practical experience.

Exemplar 1

Extra step Heat it using a bunser burner

Explanation It will leave you with all the pure crystals **[2]**

This is an example of a response that states that heating will produce pure crystals. This was a very common incorrect answer. This candidate has not gone through the method carefully in order to recognise that the solution would be mixed with unreacted solid.

Question 2 (e) (i)

(e) **(i)** Umi and Zayn have a dilute solution of calcium formate.

They want to make **dry** crystals of calcium formate.

Name **one** separation technique they must use.

.... **[1]**

The correct answer, evaporation, was given by some, but not all, candidates. Many stated 'filtering' implying that they have a misconception that filtering removes a soluble compound from a solution.

Misconception

Many candidates incorrectly stated that filtration separates crystals from a solution.

Question 2 (e) (ii)

(ii) They use 20.0 g of calcium carbonate and get 7.8 g of pure calcium formate.

Chemists calculate that 10.0 g of calcium carbonate should make 13.0 g of calcium formate.

Calculate the percentage yield of calcium formate.

Use the formula: percentage yield = $\frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$

Percentage yield of calcium formate = ... % **[3]**

This was well answered. The most common error was to use 13.0 g as the theoretical yield in the calculation rather than doubling it to get 26.0 g.

Question 3 (a)

3 There are links between our increased use of energy from fossil fuels and the concentration of carbon dioxide in the atmosphere.

Fig. 3.1 shows the world's usage of energy from fossil fuels from 1800 to 2019 in watt-hours (Wh).

Fig. 3.1

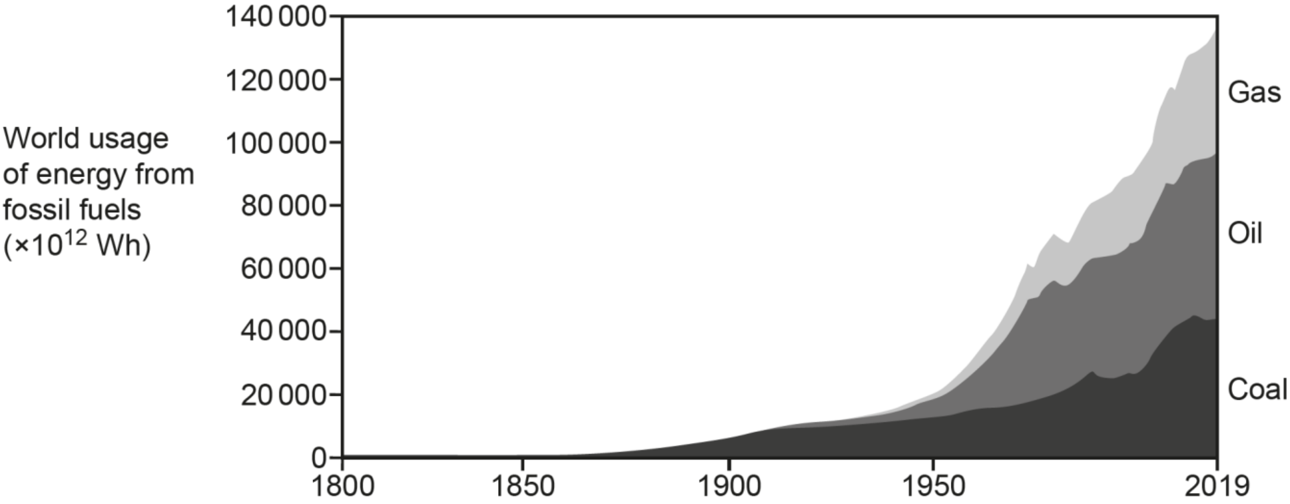
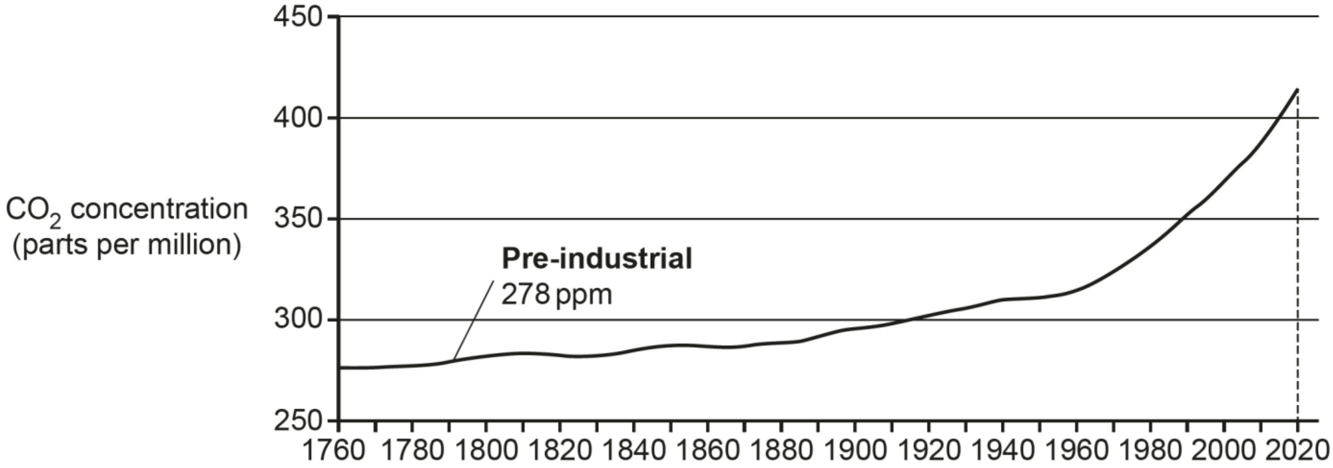


Fig. 3.2 shows the carbon dioxide (CO_2) concentration in the atmosphere from 1760 to 2020.

Fig. 3.2



(a) Casey thinks that the change in carbon dioxide concentration in the last **20 years** is due to burning coal.

Explain why Casey is **wrong**. Use evidence from both graphs in your answer.

....

....

....

....

.... **[3]**

The question included 'in the last 20 years' in bold type. Most responses ignored this and instead talked more generally about trends shown across the whole graph. Many responses gave correct points about the increase in carbon dioxide concentration and linked this to the idea that not only coal is being used as an energy source, but also oil and gas. Fewer discussed the change in the use of coal over the twenty year period.

Question 3 (b)

(b) The world's usage of energy from fossil fuels in 2019 was approximately $135\,000 \times 10^{12}$ Wh.

A solar panel generates 1350 kWh per year.

Calculate the number of solar panels that would have been needed to meet the world's usage of energy from fossil fuels in 2019.

Give your answer in **standard form**.

Number of solar panels = ... **[3]**

Most candidates answered this correctly and were able to present their values in standard form. The most common error was not noticing that the two values in the question were given in different units, Wh and kWh, and so a unit conversion was necessary. A response without a unit conversion, 1×10^{14} was given 2 marks.

Question 3 (c)

(c) Gabi says that the concentration of carbon dioxide in 2020 has increased by approximately 50% since pre-industrial times.

Explain why Gabi is correct.

Use data from **Fig. 3.2** and a calculation in your answer.

....

.... **[3]**

The most successful responses stated a value for concentration in 2020 (the accepted range was 415+/-5 ppm) and then used the stated value on the graph of 278 to show mathematically that is was a 50% increases. There are a number of ways this may be demonstrated, e.g. by showing that half of 278 is equal to the increase or by calculating 150 % of 278 and comparing that to the 2020 value.

The most common error was to ignore the information on the graph which stated that the pre-industrial value was 278 ppm but instead to use a different value. This does not show secure data processing skills. Another common error was to work out a 50% increase but then not show clearly that this is equivalent to the 2020 value.

Question 3 (d) (i)

(d) The greenhouse effect is caused by carbon dioxide in the atmosphere.

(i) Describe the greenhouse effect.

....

....

....

....

.... **[3]**

Responses here were often confused and contradictory. Most candidates knew that greenhouse gases absorb radiation (although the type was often incorrectly stated). Radiation from the Sun was often mentioned in the context that the greenhouse gases directly absorb UV radiation, rather than the idea that this radiation is first absorbed by the Earth and then re-emitted as IR. Some candidates thought that the greenhouse effect is entirely due to absorption of infra-red radiation from the Sun. Few stated that absorbed radiation is re-emitted in all directions. It was not uncommon to see incorrect responses that included reference to the ozone layer or the idea that the greenhouse gases form a layer which reflects radiation back to Earth.

Key point call out: greenhouse effect

The narrative in the specification that links to this learning objective is not well known by candidates and is an important focus point for the future. See specification section C1.3.

Question 3 (d) (ii)

(ii) Describe **three** potential effects of an increase in the greenhouse effect on the Earth's climate.

1. ....

2. ....

3. ....

[3]

This was well known, although candidates often gave three effects that were too similar to be given more than 1 mark. For example, melting of ice caps and rise in sea levels are the same idea. The most successful responses clearly stated three different effects, for example rising global temperatures, more extreme weather patterns and a rise in sea levels. Some responses incorrectly stated that there would be more 'natural disasters'. This was not marked as correct as 'natural disasters' could include events such as earthquakes which are not climate-related. Some incorrectly thought that climate change causes tsunamis.

Question 4 (a) (i)

4 **(a)** There are two main isotopes of oxygen, ^{16}O and ^{18}O. The table shows information about the atomic structure of ^{16}O.

	^{16}O
Number of protons	8
Number of neutrons	8
Number of electrons	8

(i) Why do atoms of each isotope have the same number of electrons?

....

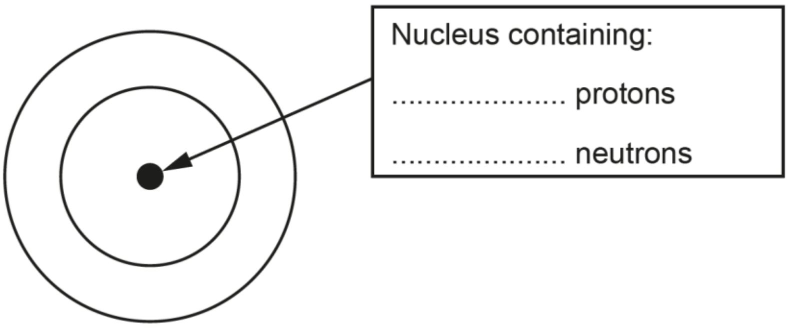
.... **[1]**

Most candidates knew what isotopes were, but did not always articulate their answers clearly. 'Because they are the same element' or 'if they had different protons they would be a different element' were common responses that were not given marks. The most successful responses referred to isotopes having the same proton number and that the number of electrons in an atom equals the number of protons.

Question (4) (a) (ii)

(ii) Complete the diagram for an ^{18}O atom.

Use crosses (x) to represent electrons.



[2]

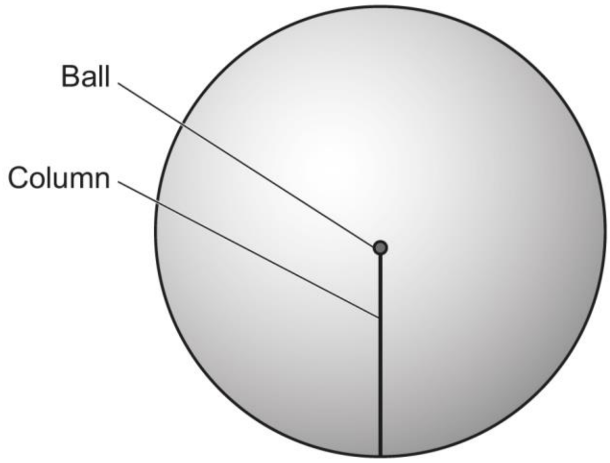
This was well answered, but some candidates reversed the number of protons and neutrons. Some omitted the electrons from the diagram, implying that they had not fully read the question instructions.

Question 4 (b)

(b) The radius of an atom is approximately 1×10^4 times the radius of its nucleus.

A student imagines a ball with a radius of 0.5 cm on top of a column, as shown.

- The ball represents the nucleus.
- The height of the column represents the radius of the atom.



Calculate the height of the column.

Give your answer in **metres**.

Height = ... m **[3]**

Many responses were correct. Most candidates multiplied by 10^4. The conversion from cm into m was not always shown, leading to many candidates achieving 2 of the 3 available marks.

Question 5 (a) (i)

5 Alex has a bottle of mineral water.

The label says:

Concentration of ions (mg/dm^3)	
Bicarbonate 150	
Calcium 40.5	Nitrate 3.1
Chloride 6.1	Sodium 5.6
Magnesium 10.7	Sulfate 5.3

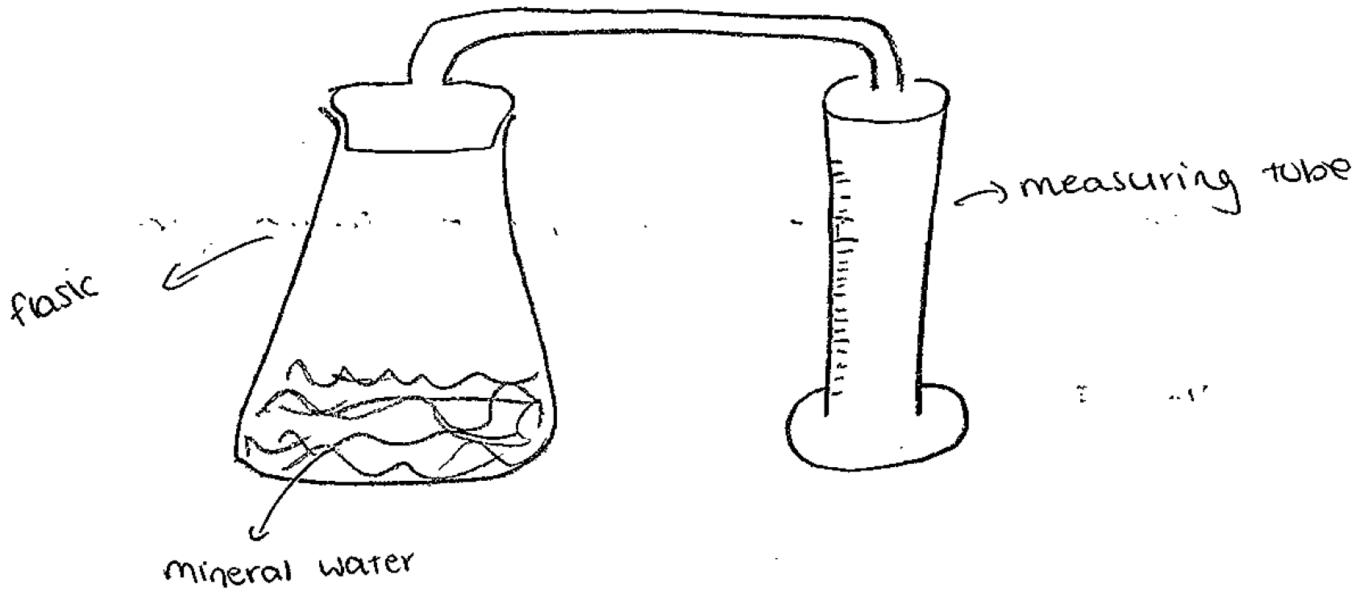
(a) Alex increases the concentration of the mineral water by decreasing its volume.

(i) Draw a labelled diagram of the equipment that Alex uses.

[2]

This question was often incorrectly answered. Very few candidates drew an apparatus to show evaporation being used correctly. The mark scheme demanded that an appropriate, labelled vessel (an evaporating basin or beaker) was shown assembled over a heat source. It was common to see filtration or distillation apparatus shown. In common with 2 (d), it appears that many candidates have insufficient practical experience to fully engage with the practical questions. It was common to see unworkable apparatus which included syringes, conical flasks, burettes or other apparatus that is irrelevant to any separation process.

Exemplar 2



This candidate's response was typical of incorrect answers commonly seen. It is unclear what separation process is being represented, the apparatus shows no workable technique and the apparatus shown is not used for any recognised separation technique.

Question 5 (a) (ii)

(ii) Alex adds sodium hydroxide solution to some of the concentrated mineral water.

The calcium ions form a white precipitate.

Complete the **balanced symbol** equation for the reaction.

$Ca^{2+}(aq) + 2OH^{-}(aq) \rightarrow$ ....

[2]

This question was not well answered. Most responses did not show a formula that was close to that of calcium hydroxide. Few candidates added an (s) state symbol. Many responses showed ions or incorrect oxide formulae.

Question 5 (b)

(b) Alex tests the concentrated mineral water for calcium by doing a flame test.

Suggest why the flame they see is yellow and **not** red.

....

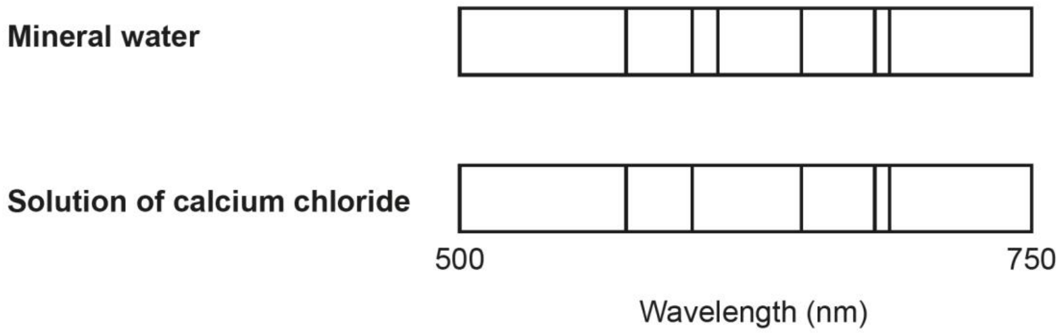
.... **[1]**

The fact that sodium is often responsible for a yellow colour in a flame was well known.

Question 5 (c) (i)

(c) An industrial laboratory uses an instrumental method of analysis to test some mineral water.

Some results are shown:



(i) What instrumental method of analysis is the laboratory using?

.... **[1]**

The instrumental method is spectroscopy. Most candidates knew this but some gave incorrect terms such as 'spectrum' or 'spectroscope' rather than name the technique.

Question 5 (c) (ii)

(ii) Give **two** conclusions that you can make about the presence of minerals in **this** mineral water.

1 ....

....

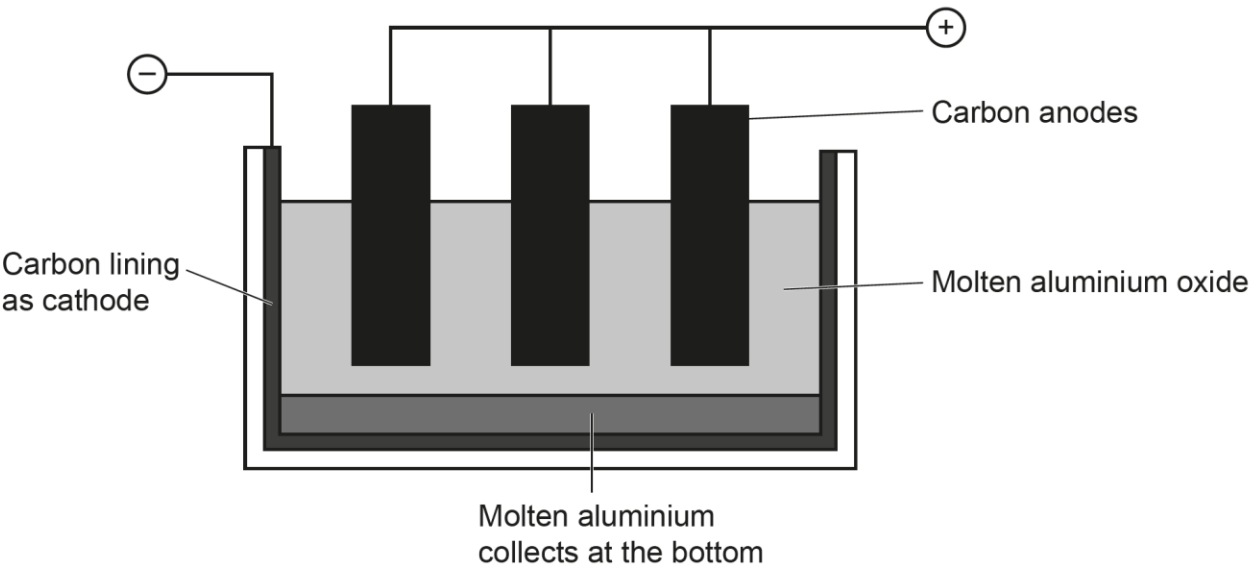
2 ....

.... **[2]**

From the spectrum, all the lines in calcium chloride line up with those of the mineral water with one additional line. This can be interpreted as the same mineral (calcium) being present in both, with one additional mineral in the mineral water. Candidates often stated the idea that both contained a common mineral, but many said that the 'mineral water contains lots of ions'. While this is true (from the table), this is not shown by the spectrum itself.

Question 6 (a)

6 Aluminium is made by the electrolysis of molten aluminium oxide, Al_2O_3.



(a) Why is the aluminium oxide molten?

....

.... **[1]**

Most candidates correctly stated that the aluminium oxide needs to be molten to allow ions to move, hence to conduct electricity. The most common misconception was that electrons move.

Misconception
Many candidates believe that electrons (rather than ions) move when a molten ionic compound conducts electricity.

Question 6 (b) (i)

(b) The half-equation for the reaction at the anode is

$$2O^{2-} \rightarrow O_2 + 4e^-$$

(i) Explain why the reaction is described as oxidation.

....

.... **[1]**

Most candidates knew that the equation shows loss of electrons. 'Oxygen is gained' was a common incorrect response. Although this is, sometimes, a correct definition of oxidation, in this case the equation does not show gain of oxygen.

Question 6 (b) (ii)

(ii) **Name** the species which is oxidised in the equation.

.... **[1]**

The oxidised species is the oxide ion. This loses electrons. A range of incorrect responses was seen. Many stated 'oxygen', but 'aluminium' or 'aluminium oxide' were other common responses.

Question 6 (b) (iii)

(iii) Explain why carbon dioxide is also produced at the anode.

....

.... **[1]**

Most candidates correctly stated that the carbon anodes react with the oxygen formed.

Question 6 (c)

(c) Write the **balanced half** equation for the production of aluminium at the cathode.

.... **[2]**

This question was not well answered. Some candidates gained 1 mark for giving the correct formula for the aluminium ion, Al^{3+}, but ions with many incorrect charges were seen. Few gave an equation with the format of a positive ion gaining electrons to form a neutral atom, it was common for positive ions with various charges to be shown on both sides of the equation.

Question 6 (d) (i)

(d) The overall equation for the electrolysis is

$Al_2O_3 \rightarrow 2Al + 1.5O_2$

(i) The relative formula mass of Al_2O_3 is 102.

Show how this is calculated.

Relative atomic mass (A_r): O = 16 Al = 27

[1]

This was well answered. The most common error was to add up the masses on the right hand side of the equation, hence showing 1.5x (16x2) + 2 x 27. This answer was not accepted as it does not show the method of calculating RFM correctly.

Question 6 (d) (ii)

(ii) Calculate the mass of aluminium, Al, that is made from 1.0 g of aluminium oxide, Al_2O_3.

Use the overall equation and the formula:

$$\text{number of moles} = \frac{\text{mass of substance (g)}}{\text{relative formula mass (g)}}$$

Give your answer to **2** significant figures.

Mass of aluminium = ... g **[4]**

Almost all candidates obeyed the instruction to give their answer to 2 significant figures. The most common error was to use '1.0' as the mass of aluminium rather than calculating that the mass of aluminium in the RFM is (2x27) = 54. Hence, the most common error was to divide 1.0 g by 102.

Question 6 (e)

(e) A solution of aluminium sulfate contains aluminium ions.

Amit says it should give aluminium at the cathode when it is electrolysed.

Explain why Amit is **wrong**.

....

....

....

.... **[2]**

Many candidates stated correctly that the solution contains water and that ions from water become involved in the electrolysis, but fewer stated clearly that hydrogen would be evolved at the cathode because aluminium is more reactive than hydrogen.

Question 6 (f)

(f) Explain why aluminium is **not** made by heating its oxide with carbon.

....

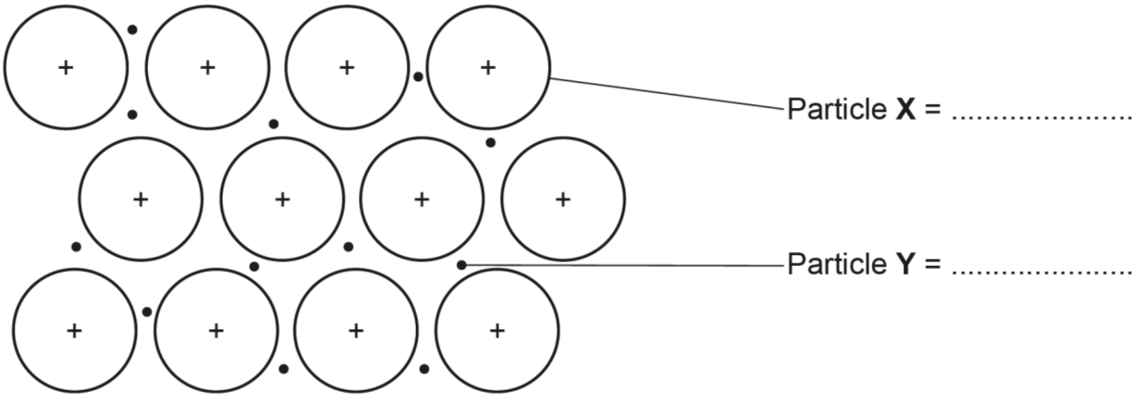
.... **[1]**

Many candidates said that 'aluminium cannot be displaced by carbon' which is close to repeating the question. Aluminium is a reactive metal was also not given a mark. The most successful responses stated that aluminium is more reactive than carbon.

Question 7 (a) (i)

7 Aluminium and iron are both metals used to make everyday objects.

(a) **(i)** Complete the diagram by identifying particle **X** and particle **Y**.



[2]

Almost all responses correctly identified Particle Y as electrons. Particle X was often mis-identified as a proton.

Question 7 (a) (ii)

(ii) Explain what happens to particle **X** and particle **Y** in the structure when a metal conducts electricity.

....

....

....

.... **[2]**

The idea that electrons move was well known, but fewer candidates stated clearly that the metal ions stay fixed in place. Many stated that ions move.

Assessment for learning

Questions 6 (a) and 7 (a) (i) and (ii) could be used to check understanding of the differences between the way that ionic compounds and metals conduct electricity. The common misconceptions between the movement of ions and electrons can then be addressed.

Question 7 (b)

(b) Aluminium alloys are used as they are harder than pure aluminium.

One aluminium alloy contains 1% magnesium.

Explain why this aluminium alloy is harder than pure aluminium.

....

....

....

....

....

.... **[3]**

The impact of alloying on structure was not well known. Many candidates discussed how alloying 'mixes the properties' or 'magnesium is harder than aluminium so adding magnesium makes aluminium harder'. The most successful responses, which were seen from some candidates, discussed how different sized atoms disrupt the regular lattice structure of metals and stop the sliding of layers of atoms. A further common error was to discuss how alloying 'increases the intermolecular forces' within the structure.

Exemplar 3

Aluminium alloys are a mixture of different sized atom therefore it is harder for the layers to slide as atoms are more fixed into place. Whereas, pure aluminium contains atoms of the same size which can slide ~~making it~~ making it ~~more soft~~ less hard **[3]**

This response was given 2 marks. Notice that the candidate has clearly expressed two of the main ideas: the alloy contains atoms of different sizes and this prevents layers of atoms from sliding over each other, making the alloy harder than the pure metal. The response did not express the idea that the differently sized atoms result in a disruption to the regular arrangement of atoms in the pure metal. It was common for candidates to omit one of the key ideas. This may imply that they did not take full note of the 3 mark allocation for the question.

Question 7 (c) (i)

(c) A disadvantage of using iron is that it rusts.

Charlie has two pieces of iron.

Piece A has a coating of copper, and Piece B has a coating of zinc.

Charlie places both pieces in a beaker of water.

(i) Explain why neither piece will rust.

....

....

....

.... **[2]**

There was some confusion revealed in this question between barrier methods of rust prevention and sacrificial protection. This question stated that the iron had a coating. The important points to make here are that a coating acts as a barrier to prevent contact between the iron and the water and oxygen that cause rusting. Many candidates restated that the iron was 'coated' rather than emphatically explaining that a coating acts as a barrier. Candidates need to take care not to repeat the question. Many knew that rusting is caused by either water or oxygen, fewer mentioned both.

Question 7 (c) (ii)

(ii) Charlie scratches the two pieces deeply and puts them back in the water.

Explain why one of the pieces rusts but the other does not.

....

....

....

.... **[2]**

It was important in this question to state which piece will and which piece will not rust. Some candidates stated that copper is less reactive than iron and that zinc is more reactive, without clearly explaining how this impacts the rusting. Language was an issue for some candidates who said incorrectly that 'zinc rusts instead'. The term 'rust' may only be used for iron. Other metals are said to corrode.

Question 8 (a)

8 Carbon monoxide and nitrogen monoxide are two polluting gases produced by petrol engines.

(a) Describe how each of these polluting gases is produced in a petrol engine.

Carbon monoxide ....

....

Nitrogen monoxide ....

....

....

....

[3]

Most candidates knew how the gases formed but did not always give a precise description. The key idea for carbon monoxide formation is that it forms from incomplete combustion of the fuel. Many candidates stated partially correct descriptions such as 'one atom of carbon reacts with one atom of oxygen'. The formation of nitrogen monoxide was not well described. Many stated or implied that the nitrogen comes from the fuel itself or from combustion of the fuel, rather than from air. Few stated that the reaction occurs at high temperature.

Question 8 (b)

(b) In a catalytic converter, nitrogen monoxide and carbon monoxide react to form carbon dioxide and nitrogen.

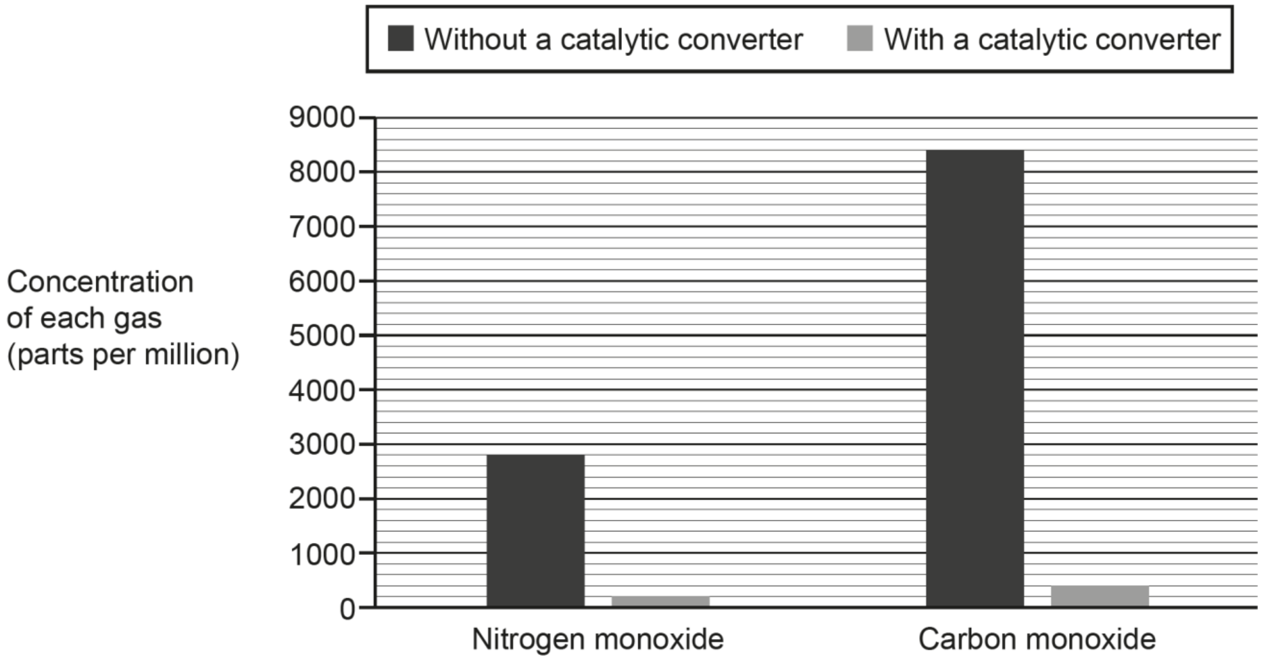
Write the **balanced symbol** equation for this reaction.

.... **[2]**

Some candidates gave a fully correct equation. Common errors were to give incorrect formulae for some of the substances. 'N' as the symbol for nitrogen gas was a common error. Those who gave correct formulae usually balanced the equation correctly.

Question 8 (c) (i)

(c) The bar chart shows the relative concentrations of the two polluting gases produced by a petrol engine without and with a catalytic converter.



(i) The concentrations of the two polluting gases are given in parts per million.

Convert 9000 parts per million into a percentage (parts per hundred).

Percentage = ... % **[2]**

Candidates found this question challenging. Many recognised that a 10 000 or 10^4 conversion factor was necessary, but frequently multiplied rather than divided. Some expressed the ratio of 9000:1000000 and then cancelled down to reach the correct answer of a ratio of 0.9:100.

Question 8 (c) (ii)

(ii) Calculate the percentage **reduction** of nitrogen monoxide when a catalytic converter is used.

Give your answer to **1** decimal place.

Percentage reduction of nitrogen monoxide = ... % **[3]**

The first step was to read the graph to obtain the values of nitrogen monoxide with and without a catalytic converter. Most candidates did this correctly. A minority misread the question and gave values for carbon monoxide instead. Most correctly processed their values to reach a correct percentage reduction and most quoted this, as asked, to 1 decimal place. Candidates are improving in their attention to instructions in calculations about significant figures and decimal places.

Question 9 (a)

9 The Contact Process is used to produce sulfuric acid.

In the process, sulfur dioxide, SO_2, reacts with oxygen to make sulfur trioxide, SO_3.

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

The reaction is done at 200 kPa and 450 °C with a catalyst.

(a) An industrial company reacts 2 moles of SO_2 with oxygen and makes 1.99 moles of SO_3.

Calculate the percentage yield of SO_3.

Use the formula: percentage yield = $\frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$

Percentage yield of SO_3 = ... % **[2]**

For this question, it was not necessary to convert the molar values given into masses. Some candidates did so and this does not affect the marks given or the final answer. However, many who attempted to convert moles into masses made errors which meant that their final answer was incorrect.

Question 9 (b)

(b) Explain why a high pressure is needed to get the best yield of SO_3.

Use the symbol equation.

....

....

....

.... **[2]**

Many candidates used the symbol equation correctly to state that the equilibrium favours the side with the fewest moles of gas. This idea is a complex idea and yet was often well expressed. Incorrect responses sometimes referenced increased rate rather than yield.

Question 9 (c)

(c) The industrial company use a pressure of only 200 kPa.

Explain why a higher pressure is **not** used.

....

....

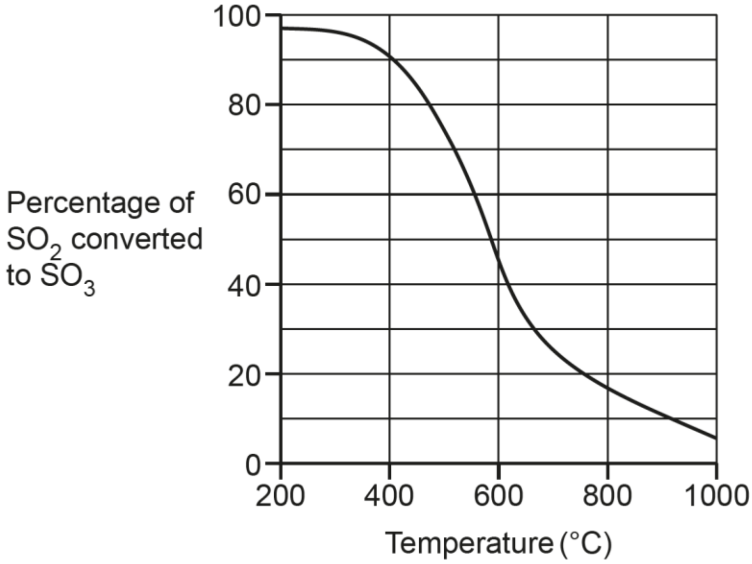
....

.... **[2]**

The limiting benefit of using very high pressures was not always well expressed. Many candidates who had correctly calculated the yield as being greater than 99% commented that the benefit of using a greater pressure was outweighed by the marginal possible improvement in yield. This is a very 'good' answer. Other correct responses included discussing the safety or energy costs of using very high pressures. Candidates should note that financial cost arguments are not accepted. 'It costs too much' is always ignored, although identified costs such as 'it costs too much because more energy is needed' are correct.

Question 9 (d)

(d) The graph shows the percentage of SO_2 converted to SO_3, at different temperatures.



Describe how the percentage of SO_2 converted to SO_3 changes with temperature.

....

....

....

.... **[2]**

Most candidates correctly interpreted the graph to say that yield decreases with an increase in temperature. This question was worth 2 marks. Fewer made a clear second point by discussing detail from the graph, such as the largest decrease in yield occurs between 400 and 700 °C. Many candidates incorrectly use the term 'proportional' for relationships where proportionality is not shown. 'Yield is inversely proportional to temperature' is incorrect. Candidates often have the misconception that a relationship in which one variable decreases as another increases is an inversely proportional relationship.

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