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Examiners' Report
June 2023

International Advanced Level Chemistry WCH11 01

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Introduction

The paper was accessible to most candidates and provided the full range of marks. Candidates who had a sound knowledge of the chemistry covered in this unit and could produce clear explanations scored high marks. The calculations were generally well attempted with the main errors being in the use of significant figures and failing to use information from questions or the Periodic Table.

There were no reports of candidates running out of time and the majority of candidates provided responses to the last question, indicating that the paper was not unduly long. The mean mark for the paper was 42. Section A had an average of just under 12 marks. Candidates of all abilities gained marks on Q04 (electrons in boxes), Q09 (empirical formula calculation) and Q15 (free radical substitution in alkanes). Some questions were more challenging for the majority of candidates, namely Q01 (polarisation in molecules) and Q18(b) (reacting masses calculation). Five marks were available for simply stating definitions and it was disappointing to see the number of marks lost across all ability ranges, usually as a result of imprecise language.

Question 19 (a)(i)

This question was straightforward for those candidates that could recall the principles of mass spectrometry.

Some candidates who failed to score this mark described the ions produced rather than the method of production.

(i) State how atoms are ionised in the mass spectrometer.

(1)

An electron gun fires an electron which knocks off an electron in the atom forming an ion.

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Examiner Comments

Even though this candidate has not used "bombard" to describe the action of the electron gun, the sense is clear and the mark is awarded.

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Examiner Tip

In multi-stage processes, such as mass spectrometry, learn the key points of each step.

Question 19 (a)(ii)

Many responses showed that candidates were unsure of the difference between the accelerator and deflector in a mass spectrometer and stated that a magnetic field was responsible for accelerating the ions.

The acceleration process was not as well known as the ionisation step. When an electric field was correctly stated, candidates sometimes added incorrect information to their answers eg positively charged or a single plate, leading to the loss of the mark.

(ii) State how the ions formed are accelerated.

(1)

The ions formed are accelerated by the electric field formed by the negative plates.

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Examiner Comments

How the electric field is formed is not required in the answer – just the electric field is sufficient.

ResultsPlus
Examiner Tip

Take care when adding extra information that the mark already gained is not lost by an incorrect statement.

Question 19 (a)(iii)

This question required candidates to recall the different components of an atom in addition to their behaviour.

It is important for candidates to read questions carefully to ensure that all aspects are addressed. Two marks are allocated to this question, and two responses are required. The question is constructed in such a way as to help candidates to recognise that they must explain **both** why isotopes have the same chemical reactions as well as why their ions are deflected differently.

(iii) Explain why isotopes of an element have the same chemical reactions but their ions are deflected differently in a mass spectrometer.

(2)

Isotopes have the same chemical reactions as they have the same electronic configuration, so the same no. of outer shell electrons. Isotope deflect differently as they have different no. of neutrons, so they have different mass.

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Examiner Comments

This example of a response which scores both marks would only have scored one mark if the "different mass" had not been included.

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Examiner Tip

An awareness of the number of marks available often helps in constructing a successful answer.

This response only answers one part of the question.

(iii) Explain why isotopes of an element have the same chemical reactions but their ions are deflected differently in a mass spectrometer.

(2)

They have different mass to charge ratio (m/z)
The ones with smaller (m/z) ratio have a bigger deflection whilse the one with larger (m/z) ratio has a smaller deflection

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Examiner Comments

Only the deflection of the ion due to differing mass is mentioned. There is no explanation of the similar reactivity so this response scores only one mark.

ResultsPlus
Examiner Tip

Note the number of marks available in a question.

Question 19 (b)(i)

Some well learned and accurately remembered definitions were seen which scored two marks. However, most candidates did not score both marks and many gained no marks. The most common errors were:

- not including a **mean** mass of the **atom**.
- not having the specific carbon – **12** isotope, or not stating that **1/12** of the mass was the reference point.

(i) State what is meant by relative atomic mass.

(2)

Relative atomic mass is the ~~mass~~ weighted average mass of an atom compared to a C-12 isotope.

ResultsPlus
Examiner Comments

This response scores only one mark as the 1/12 has been omitted for the second mark.

(i) State what is meant by relative atomic mass.

(2)

Relative atomic mass is a mass of an element ~~in respect~~ relative to 1/12th of the mass of a Carbon 12 atom.

ResultsPlus
Examiner Comments

It is the **mean or average** mass of the atom which is needed for the first mark.

ResultsPlus
Examiner Tip

Learn definitions carefully.

Question 19 (b)(ii)

One of the two marks available for a correct answer was for stating the answer to **four** significant figures.

(ii) A sample of chlorine contains 75.53% of ^{35}Cl and 24.47% of ^{37}Cl.

Calculate the relative atomic mass of this sample of chlorine, giving your answer to **four** significant figures.

(2)

$$A_r = A_{35}f_1 + A_{37}f_2$$

$$= \left(35 \times \frac{75.53}{100}\right) + \left(37 \times \frac{24.47}{100}\right)$$

$$= 26.4355 + 9.0539$$

$$= 35.4894$$

$$\approx \underline{35.49}$$

ResultsPlus
Examiner Comments

This answer shows good practice in giving the correct numerical answer and then correctly rounding to four significant figures.

ResultsPlus
Examiner Tip

Underlining your final answer makes it very clear.

(ii) A sample of chlorine contains 75.53 % of ^{35}Cl and 24.47 % of ^{37}Cl.

Calculate the relative atomic mass of this sample of chlorine, giving your answer to **four** significant figures.

(2)

$$RAM = \frac{(75.53 \times 35) + (24.47 \times 37)}{100}$$

$$= 35.4894$$

ResultsPlus
Examiner Comments

This answer is numerically correct to four decimal places. The final answer should have been rounded to four significant figures – 35.49 – to score the second mark.

Question 19 (c)(i)

This item required the use of data from the mass spectrum shown in part (c) as well as the isotopic abundance stated in Q19(b)(ii).

Many candidates found this challenging and tried to achieve the stated m/z values by varying the numbers of chlorines in the molecule.

(i) There are three peaks in the region of $m/z = 101–105$.

Complete the table to show the ions responsible for these peaks.

(2)

m/z	Formula of ion	Relative peak height
101	$^{31}P\,^{35}Cl\,^{35}Cl$	9
103	$^{31}P\,^{37}Cl\,^{35}Cl$	6
105	$^{31}P\,^{37}Cl\,^{37}Cl$	1

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Examiner Comments

This example shows clearly the three ions responsible for the peaks in the mass spectrum but this candidate has neglected to show the positive charge on each ion. This frequent omission has been penalised only once so scores one mark overall.

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Examiner Tip

In questions on mass spectra, charges on ions are always required.

Question 19 (c)(ii)

Those candidates who knew and understood how to calculate the ratios of probabilities completed this correctly. Those who had not met this idea simply restated the 3:1 ratio of isotopes which did not score. A few candidates explained a 9:3:1 ratio, giving no valid explanation of the double probability of the peak at 103, so they were able to score 1 mark for explaining the peaks with intensities of 9 and 1.

(ii) Show that the relative peak heights given in the table are consistent with the isotopic ratio of ^{35}Cl to ^{37}Cl being 3 : 1.

(2)

$^{35}Cl\ ^{35}Cl\ ^{31}P = \frac{3}{4} \times \frac{3}{4} \times 1 = \frac{9}{16}$

$^{35}Cl\ ^{37}Cl\ ^{31}P = 2 \times \left(\frac{3}{4} \times \frac{1}{4} \times 1\right) = \frac{6}{16}$

$^{37}Cl\ ^{37}Cl\ ^{31}P = 2 \times \left(\frac{1}{4} \times \frac{1}{4} \times 1\right) = \frac{1}{16}$

$\frac{9}{16} : \frac{6}{16} : \frac{1}{16}$

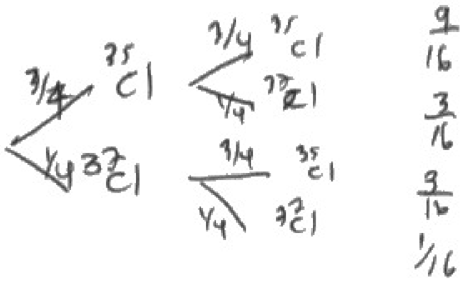
$9 : 6 : 1$ (ans)

ResultsPlus
Examiner Comments

This is an example of a very clear response. Candidates who had some idea of the application of the isotopic ratios to the relative peak height sometimes neglected to multiply the ^{35}Cl:^{37}Cl ratio by 2. In these cases a mark was available for two correct answers.

This shows a different explanation which scores two marks.

(ii) Show that the relative peak heights given in the table are consistent with the isotopic ratio of ^{35}Cl to ^{37}Cl being 3:1. **(2)**



$^{35}Cl_2$: $^{35/37}Cl$: $^{37}Cl_2$

$\frac{9}{16} : \frac{6}{16} : \frac{1}{16}$

∴ since ^{35}Cl has 75% and ^{37}Cl has 25%.

the ratio of $^{35}Cl : ^{37}Cl$ is 3:1

ResultsPlus
Examiner Comments

This type of "flow diagram" approach was not seen often but clearly shows that the peak of intensity 6 can be explained by the two different arrangements of the ^{35}Cl and ^{37}Cl isotopes.

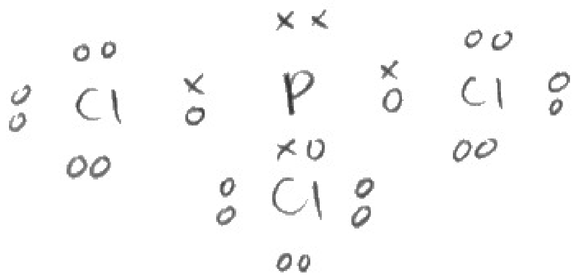
Question 19 (d)

A good number of correct, clearly drawn molecules were seen in Q19(d)(i), although the most common errors were to omit the lone pair on the P atom or not to complete the chlorine outer shells.

Recalling the idea of repulsion was commonly seen and most candidates realised it was the electron pairs which were repelling each other, rather than the chlorine atoms. Trigonal pyramidal was the most common shape given but there were quite a few answers with trigonal bipyramid and tetrahedral too – candidates should think about what these shapes look like to see that it is an impossibility for this molecule. Some answers included lp-lp repulsion, which cannot occur in this molecule as there is only one lone pair.

(d) (i) Draw a dot-and-cross diagram of a PCl_3 molecule.
Show outer electrons only.

(2)

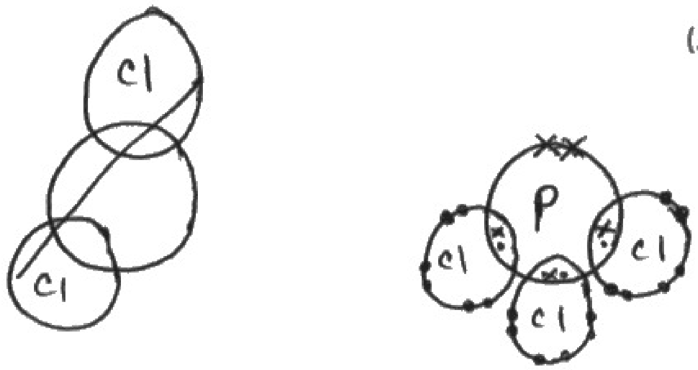


ResultsPlus
Examiner Comments

This has been drawn clearly and scores both marks. Note that circles showing the outer shell do not have to be included.

(d) (i) Draw a dot-and-cross diagram of a PCl_3 molecule.
Show outer electrons only.

(2)



(ii) Explain the shape of a PCl_3 molecule.

(3)

There are 3 bond-pair electrons on phosphorus atom and 1 lone-pair electron on phosphorus atom. So, to minimise the stronger lonepair – bondpair; ~~rep~~ bondpair-bondpair repulsion and to maximise the separation, the bond angle is 107.5° and the shape is said to trigonal pyramidal.

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Examiner Comments

In Q19(d)(i) the candidate has clearly crossed through the diagram that is not to be marked and replaced it with a correct diagram.

In Q19(d)(ii) the response includes all three marking points and the additional information of the number of bonding/lone pairs and the bond angle is also correct.

ResultsPlus
Examiner Tip

If you make a mistake in your answer then the part that you are discarding should be crossed through clearly.

Question 20 (a)(i)

This question provided an opportunity for candidates to demonstrate their ability to construct a balanced ionic equation. They needed to be aware that mineral acids and metal salts can be considered to be 100% ionised in aqueous solution so removal of the chloride (spectator) ions from each side of the equation gives the correct answer. The most common error involved a failure to check the balance of charges on either side of the equation ('H+' instead of '$2H^+$' and/or 'Ba^+' in place of 'Ba^{2+}')

(i) Write the ionic equation for this reaction.
State symbols are not required.

$BaCO_{3(s)} + 2H^+ + \cancel{2Cl^-} \rightarrow Ba^{2+} + \cancel{2Cl^-} + CO_{2(g)} + H_2O$ **(1)**

$BaCO_3 + 2H^+ \rightarrow Ba^{2+} + CO_2 + H_2O$

ResultsPlus
Examiner Comments

This response scores both marks. The aqueous chloride ions on both sides of the equation have been clearly cancelled. Note that this candidate has removed the state symbols from the final answer as they are not required.

ResultsPlus
Examiner Tip

In presenting an ionic equation in an answer, check that charges and species balance.

Question 20 (a)(ii)

In most cases, candidates demonstrated an ability to calculate formula masses from given values of the relevant atomic masses. However, some seemed unaware that atom economy is usually expressed as a percentage.

This response illustrates the advantage of clearly showing working in an answer.

(ii) Calculate the atom economy by mass for this preparation of barium chloride.

[A_r values: H = 1.0 C = 12.0 O = 16.0 Cl = 35.5 Ba = 137.3]

(2)

Mr $(BeCl_2)$: 137.3 + 12 + 12 = 161.3.

Mr $(BeCl_2 + CO_2 + H_2O)$ = 161.3 + 12 + 16 + 16 + 1 + 1 + 16

= 223.3.

atom economy $\frac{Mr\ (BeCl_2)}{Mr\ (products)} = \frac{161.3}{223.3} = 72\%$

ResultsPlus
Examiner Comments

This response shows two mistakes. The metal cation is shown as Be throughout but the *Ar* value for Ba is clearly used so this "slip" is ignored. Unfortunately the second mistake, transposing the *Ar* value for C with that of Cl, leads to an incorrect value for the *Mr* of the required product. M1 is not scored. The candidate has clearly used this incorrect value in evaluating the total mass of the products. Since it is also clear from the working that the correct expression has been used to find the atom economy, M2 can be awarded.

ResultsPlus
Examiner Tip

Clearly showing steps in a calculation can often lead to partial credit being gained.

Question 20 (a)(iii)

In order to explain the difference between the melting temperatures of the Period 6 chlorides caesium chloride and barium chloride, the question states that responses should consider the **ions** involved. References to atomic radii, electronegativity, intermolecular forces etc therefore gained no credit. The ionic charges were often correct to score the first mark, but there was sometimes confusion between ionic charge and nuclear charge. There were a significant number of answers which explained the attraction of the electrons to the nucleus, confusing ionic attraction and bond strength with nuclear charge and ionisation energies. Most candidates realised that bonds needed to be broken to melt, but the bonds stated were not specific enough or sometimes incorrect and so could not score the 3rd and 4th marks.

This is an example of a response that addresses correctly all four marking points.

(iii) Barium chloride has a melting temperature of 962 °C.
Caesium chloride has a melting temperature of 646 °C.

Explain, by considering the ions involved, the difference between the melting temperatures of these Period 6 chlorides.

(4)

Ba^{2+} is smaller than Cs^+ since it has a greater number of protons. Ba^{2+} also has a greater charge compared to Cs^+. And so, Ba^{2+} has a greater charge density. So, the ionic attraction between the Ba^{2+} and Cl^- is greater and stronger than between Cs^+ and Cl^-; ~~so, more en and hence the~~ Hence, more energy is needed to break the stronger electrostatic force of attraction between the Ba^{2+} and Cl^- ions.

ResultsPlus
Examiner Comments

The first sentence refers to the difference in size of the ions and also indirectly to the difference in charge. The ionic bonding is clearly indicated and the need for a greater amount of energy to break these is also clear.

ResultsPlus
Examiner Tip

Take care to distinguish between atoms, ions and molecules in answers.

(iii) Barium chloride has a melting temperature of 962 °C.
Caesium chloride has a melting temperature of 646 °C.

Explain, by considering the ions involved, the difference between the melting temperatures of these Period 6 chlorides.

(4)

In Barium chloride, Ba^{2+} has a charge of 2+, and Cl^- has a charge of -1. In Caesium chloride, Caesium has a charge of +1 and Cl^- has a charge of -1. The product of charges in Barium chloride (2×1=2) is greater than the Caesium chloride (1×1=1). There is stronger force of attraction between ions in Barium chloride than in Caesium chloride. More energy is required to break the force in Barium chloride. Hence, Barium chloride has a greater melting temperature than caesium chloride.

ResultsPlus Examiner Comments

This response does not address the difference in size of the ions but is correct in all other respects so scores three marks.

ResultsPlus Examiner Tip

Check the number of marks available for an item and take care that the correct number of points has been addressed in your answer.

Question 20 (a)(iv)

Differences in electronegativity values were usually calculated correctly as candidates had remembered that intermediate bonding depended on this. However, there was some confusion as to whether the larger difference led to more ionic or more covalent bonding. It is important that candidates understand what is meant by electronegativity so that they can interpret the differences correctly. There were many answers which did not score the 2nd mark as they categorised one as ionic and one as covalent, not appreciating that these are just the two extremes of the bonding scale.

(iv) Covalent and ionic bonding are the extremes of a continuum of bonding type.

Explain the difference in bonding between barium chloride and beryllium chloride, using the electronegativity values shown.

Element	Electronegativity
Ba	0.9
Be	1.5
Cl	3.0

(2)

The electronegativity difference of $BaCl_2$ is 2.1 and electronegativity difference of $BeCl_2$ is 1.5. So $BaCl_2$ is more polar than $BeCl_2$ as the ~~negat~~ electronegativity difference is greater.

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Examiner Comments

Both electronegativity differences are correctly evaluated and the comparative conclusion is also correct.

(iv) Covalent and ionic bonding are the extremes of a continuum of bonding type.

Explain the difference in bonding between barium chloride and beryllium chloride, using the electronegativity values shown.

Element	Electronegativity
Ba	0.9
Be	1.5
Cl	3.0

(2)

Beryllium chloride has more covalence character as their electronegativity difference is less ~~than~~ compared to barium chloride, which has more ionic character, due to more electronegativity difference.

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Examiner Comments

This response does not evaluate either electronegativity difference but both statements are correct and the comparative conclusion scores the second mark.

(iv) Covalent and ionic bonding are the extremes of a continuum of bonding type.

Explain the difference in bonding between barium chloride and beryllium chloride, using the electronegativity values shown.

Element	Electronegativity
Ba	0.9
Be	1.5
Cl	3.0

(2)

Electronegativity diff. between Ba and Cl (3-0.9)= 2.1
B " difference " Be and Cl (3-1.5)= 1.5
Barium chloride has an ionic bonding as its difference is greater than 1.5. BeCl has covalent bonding.

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Examiner Comments

This response was typical of those candidates who had not paid sufficient attention to the wording in the question. The idea that an electronegativity difference above a specific numerical value indicates ionic bonding does not fit with the idea that there is a gradual change from ionic to covalent across a wide range of electronegativity differences.

Question 20 (b)

This was well answered by many candidates with clearly set out, detailed calculations. M1 and M2 were commonly scored, but a good number of candidates failed to subtract the sulfate mass and hence identify the metal (M3 and M4). Some candidates sadly got the answer right (38.8) but then identified it as Rb, presumably confusing the atomic number of Rubidium for the mass number of Potassium, thus losing M4.

(b) Barium chloride reacts with Group 1 sulfates, M_2SO_4.

$$M_2SO_4(aq) + BaCl_2(aq) \rightarrow BaSO_4(s) + 2MCl(aq)$$

A solution is made by dissolving 7.98 g of a Group 1 sulfate in deionised water.

Excess aqueous barium chloride is added to this solution and the precipitate is filtered, dried and weighed.

The mass of the barium sulfate precipitate is 10.72 g.

Identify the Group 1 element.

[A_r values: Ba = 137.3 S = 32.1 O = 16.0]

$N = \frac{m}{M}$

(4)

mole no of $BaSO_4$ = $\frac{10.72}{137.3 + 32.1 + (16 \times 4)}$

= 0.0459 mol

mole no of M_2SO_4 = 0.0459 mol (1:1 ratio)

$N = \frac{m}{M}$

~~mr mdm = N × m = 0.0459 × 7.98~~

~~= 0.366282 g mol⁻¹~~

∴ ~~M_2 =~~ M = $\frac{7.98}{0.0459}$ = 173.9

∴ M_2 = 173.9 − (32.1 + 16×4)

= 77.8

The element is Rubidium.

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Examiner Comments

All steps in this calculation are correct following the alternative mark scheme. Unfortunately, despite stating that 77.8 is the value for M_2, the candidate has failed to divide by 2, and so identified M as Rubidium thus losing M4.

ResultsPlus
Examiner Tip

Showing your working clearly allows for the award of partial credit if your final answer is incorrect.

(b) Barium chloride reacts with Group 1 sulfates, M_2SO_4.

$$M_2SO_4(aq) + BaCl_2(aq) \rightarrow BaSO_4(s) + 2MCl(aq)$$

A solution is made by dissolving 7.98 g of a Group 1 sulfate in deionised water.

Excess aqueous barium chloride is added to this solution and the precipitate is filtered, dried and weighed.

The mass of the barium sulfate precipitate is 10.72 g.

Identify the Group 1 element.

[A_r values: Ba = 137.3 S = 32.1 O = 16.0]

(4)

mol of $BaSO_4 = \frac{10.72}{137.3+32.1+16\times4} = 0.0459$

mol ratio = $M_2SO_4 : BaSO_4 = 1:1$

mol of $M_2SO_4 = 0.0459$

$Mr = \frac{mass}{mol}$

$Mr = \frac{7.98}{0.0459} = 173.86$

Mr of $M_2SO_4 = 2x + 32.1 + 16\times4 = 2x + 96.1$

$2x + 96.1 = 173.86$

$2x = 77.76$

$x = \frac{77.76}{2}$

$x = 38.9$

∴ The element is Rubidium.

ResultsPlus
Examiner Comments

This is also a fully correct calculation until the final identification of the Group 1 metal.

(b) Barium chloride reacts with Group 1 sulfates, M_2SO_4.

$$M_2SO_4(aq) + BaCl_2(aq) \rightarrow BaSO_4(s) + 2MCl(aq)$$

A solution is made by dissolving 7.98 g of a Group 1 sulfate in deionised water.

Excess aqueous barium chloride is added to this solution and the precipitate is filtered, dried and weighed.

The mass of the barium sulfate precipitate is 10.72 g.

Identify the Group 1 element.

[A_r values: Ba = 137.3 S = 32.1 O = 16.0]

(4)

$n(BaSO_4) = \frac{10.72}{137.3 + 32.1 + 64} = 4.5930 \times 10^{-2}$ mol

$M_2SO_4 : BaSO_4 = 1:1$ in terms of moles.

$\therefore n(M_2SO_4) = n(SO_4^{2-}$ initially$) = 4.5930 \times 10^{-2}$ mol

$m(SO_4^{2-}) = 4.5930 \times 10^{-2} \times (32.1 + 64)$

$= 4.414$ g

$\therefore m(2M^{+}) = 7.98 - 4.414 = 3.566$ g

$\therefore$ molar mass of M $= \frac{3.566}{2 \times 4.5930 \times 10^{-2}} = 38.82$ g/mol

$\therefore$ M is Potassium as it has the closest molar mass of 39.1 $g\,mol^{-1}$ and also forms +1 ions.

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Examiner Comments

This is a fully correct example of a calculation following the first route on the mark scheme. The identification of the Group 1 metal is correct.

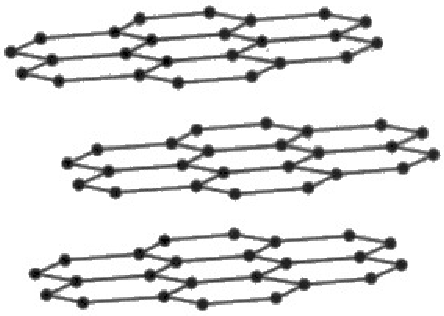
Question 21 (a)

In this question, credit was gained for describing those aspects of the giant covalent structure of graphite that enable it **both** to remain solid **and** to conduct electricity in a liquid mixture of bauxite and cryolite at 950°C. Some responses mentioned in detail the formation of the three covalent bonds between carbon atoms within the layers and the consequent delocalised nature of the remaining electron which leads to the ability of graphite to conduct electricity. In many cases the answer progressed no further and thus only one mark was scored.

In order to score M1 it was necessary for candidates to make clear the giant nature of the covalent layers or that **every** carbon was covalently bonded to its neighbour.

21 Graphite electrodes are used in the extraction of aluminium by the electrolysis of aluminium oxide, Al_2O_3, dissolved in a solvent (molten cryolite) at a temperature of 950 °C.

(a) Explain how the structure and bonding in graphite make it suitable for this application.
Refer to the diagram in your answer.



graphite

(3)

Graphite has a giant covalent lattice structure with many covalent bonds between carbon atoms throughout the structure. Therefore, a large amount of energy is required to overcome these strong bonds making graphite suitable for the high temperature conditions in extraction of Aluminimium. It has a high melting point.
Furthermore, each carbon atom forms only 3 bonds so there ~~is~~ ~~a free electron~~ are delocalised electrons which can carry a charge and conduct electricity.

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Examiner Comments

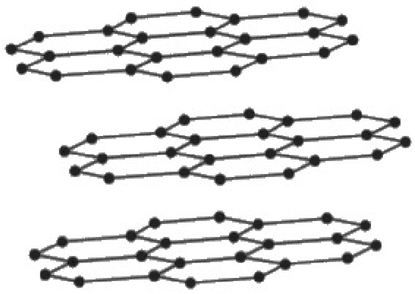
This response clearly links the structure and bonding in graphite to its use as a high-temperature electrode.

ResultsPlus
Examiner Tip

Read questions carefully, especially when explanations are needed.

21 Graphite electrodes are used in the extraction of aluminium by the electrolysis of aluminium oxide, Al_2O_3, dissolved in a solvent (molten cryolite) at a temperature of 950 °C.

(a) Explain how the structure and bonding in graphite make it suitable for this application.
Refer to the diagram in your answer.



graphite

In graphite, 1 carbon atom is covalently bonded to three other carbon atoms. So it has one free electron, which allows it coduct electricity by carrying charge ~~and use~~ ; ~~can~~ so can be used in ~~In graphite, the~~ making electrodes.
In graphite, the layers can slip and slide over one another, ~~so it~~ due to weak Van Der Waal's forces of attraction.

ResultsPlus
Examiner Comments

This response has not described the giant structure of the layers or linked this with the high melting point of graphite, thus neither of the first two marking points have been scored. Linking the free electron with the electrical conduction scores one mark. The reference to the ability of the layers to slide is not relevant to this application and so does not score.

ResultsPlus
Examiner Tip

When linking properties of materials to their structure and bonding, ensure that you have read the question carefully.

Question 21 (b)(i)

The difficult step in this calculation relating to the electrolysis of aluminium was the deduction of the ratio of aluminium to oxygen. The volume of carbon dioxide produced was then almost always correctly found.

This response shows clearly all the steps needed to gain full credit.

(b) The half-equations for the electrolysis reactions are shown.

Negative electrode $2Al^{3+} + 6e^- \rightarrow 2Al$ $2Al^{3+} + 3O^{2-} \rightarrow 2Al + 1\frac{1}{2}O_2$

Positive electrode $3O^{2-} \rightarrow 1\frac{1}{2}O_2 + 6e^-$

The oxygen produced reacts with the graphite electrode.

$$C(s) + O_2(g) \rightarrow CO_2(g)$$

(i) Calculate the maximum volume, in dm^3, of CO_2, measured at r.t.p. which could be produced when 1.00 kg aluminium is extracted using this process.

[The molar volume of a gas is 24.0 dm^3 mol^{-1} at r.t.p.]

(4)

1 mol → 27 g => x = 37.037 mol
x → 1000 g

Al : O_2
2 : $\frac{3}{2}$ => 1 : $\frac{3}{4}$ → $\frac{3}{4} \cdot 37.037$ = 27.7778 mol

O_2 : CO_2
1 : 1 ∴ 1 mol → 24 dm^3
27.7778 mol → x

=> x = 667 dm^3

ResultsPlus
Examiner Comments

The correct mass of Aluminium in grams is used to find the moles reacted.

The deduction of both the ratio of aluminium to oxygen and then to carbon dioxide is clear.

The correctly evaluated final volume of CO_2 produced is underlined.

ResultsPlus
Examiner Tip

Showing all the steps in calculations enables some marks to be awarded even if some steps are incorrect.

Underlining key parts of the question helps to focus on the important data.

Question 21 (b)(ii)

The focus of this question was on the reduction in energy consumption by recycling aluminium cans. Many answers referred in general terms to recycling processes being superior to landfill and/or incineration. These would be appropriate in a discussion relating to plastics disposal but did not address the disparity in energy between the extraction of aluminium from the purified ore and recycling. This may have been due to a misreading of the question or perhaps familiarity with questions on plastics recycling, which have appeared in previous series.

Many candidates mentioned that metals would otherwise be incinerated which is very unlikely since aluminium burns at temperatures above 1600°C. Some responses mentioned reusing cans as equivalent to recycling which would be impractical.

A small minority of answers revealed a clear grasp of the advantages of recycling in terms of a massive reduction of energy use in electrolysis (both for melting the electrolyte and in the current supplied) and in terms of less mining and transport of the raw materials/ore. Some answers scored M2 by stating that 'less new aluminium is needed' which was an allowed response. Very few candidates pointed out that the cans only need to be melted to be reused which uses far less energy than extraction using electrolysis etc.

(ii) Every year in the United Kingdom, about 7.2 billion aluminium cans are recycled.

Suggest three ways this recycling reduces energy consumption.

(3)

~~Easer~~ ~~less~~ A high temperatrre is needed to extract Al from ore while recycling ~~ust~~ just needs to melt the Al so reduces heating energy.

The energy of mining and transporting the ore is saved. ~~and the amou as the transport of~~ ~~&~~ less product is lost ~~as~~ due to atom economy as in recycling it is 100% ∴ more efficient

prevent land needed in land fils, so reduces energy needed to maintain landfilts safely.

ResultsPlus
Examiner Comments

This is an example of a response which addresses all three marking points.

The first sentence scores M2 and M3, referring to the energy of extraction of Al from the ore and contrasting that with the reduced energy needed to melt the aluminium. M1 is then scored in the next sentence.

The reference to landfill does not score.

Question 22 (a)(i)

This item required candidates to define an unsaturated hydrocarbon. It had been included at the start of the question as an easy introduction but was aften not answered correctly.

(a) (i) State what is meant by a saturated hydrocarbon.

(2)

Saturated hydrocarbon are the hydrocarbon with carbon-carbon single bonds.

ResultsPlus
Examiner Comments

This response scored neither mark.

There is no definition of a hydrocarbon and the key idea that a saturated hydrocarbon has **only** C-C single bonds is not clear.

(a) (i) State what is meant by a saturated hydrocarbon.

(2)

• A compound with only carbon and Hydrogen atoms that has no double bonds.

ResultsPlus
Examiner Comments

This is an example of a response which scores both marks.

ResultsPlus
Examiner Tip

Learn definitions of standard terms carefully.

(a) (i) State what is meant by a saturated hydrocarbon.

(2)

Saturated hydrocarbon means a ~~Ra~~ hydrocarbon with no ~~carbon or of the carbon~~ carbon-carbon double bonds.

ResultsPlus
Examiner Comments

This response scores one mark only since the definition of a hydrocarbon is missing.

Question 22 (a)(ii)

Recall of the fact that fractional distillation separates molecules because of their different boiling temperatures was good, although there were a few melting temperatures included in answers which did not score. The temperature gradient and its relationship with the position in the column where molecules condense was less well explained and candidates sometimes described the density/chain, length/size of the hydrocarbon instead of its boiling temperature. There was evidence that some candidates had not taken account of the diagram provided and described cracking or laboratory fractional distillation.

This response shows clearly that the candidate understands the process.

(ii) Describe how the fractions in crude oil are separated during fractional distillation.

(2)

Oil is vapourised and passed into the column, ~~As~~ the tempretume in the column decreases as ~~you go~~ the gas flows to the top, different products with different boiling points condenses at a particular tempretun thus fractions are seperated.

ResultsPlus
Examiner Comments

The description of the temperature gradient in the column and the condensation at different points according to boiling temperatures scores both marks.

Question 22 (b)

The moles of butane were usually correctly calculated and most answers had a correctly rearranged equation.

The most common errors were:

- assuming the answer from the equation was in dm^3 or cm^3 rather than m^3 and therefore failing to use the correct conversion factor.
- not converting the pressure to Pa correctly.
- using 25 C instead of 298 K for the temperature.
- omission of the division by 120 for each dose.
- not stating the final answer to 2/3 significant figures.

This response shows the effect of rounding to 1 significant figure early in the calculation.

(b) Butane, C_4H_{10}, is found in the refinery gases fraction of crude oil.
It is used as a propellant in pharmaceutical inhalers.
An inhaler that provides a total of 120 doses contains 1.55 g of butane.

Calculate the volume, in cm^3, of propellant used for each dose at 25 °C and 100 kPa.

Use the ideal gas equation and give your answer to an appropriate number of significant figures.

[$pV = nRT$ $\quad R = 8.31\ JK^{-1}\ mol^{-1}$]

(5)

120 — 1.55
1 — x

$x = \frac{1.55}{120} = 0.01$

1 dose contains 0.01 g of butane.

mole of butane $= \frac{0.01}{58} = 1.72 \times 10^{-4}$

pressure = 100000 Pa

temp = 25 + 273
= 298 K

$V = \frac{1.72 \times 10^{-4} \times 8.31 \times 298}{100000}$

$= 4.26 \times 10^{-6}\ m^3$

$4.26 \times 10^{-6} \times 1000000$

$= 4.26\ cm^3$

ResultsPlus
Examiner Comments

The calculation of the mass of butane in each dose was done at the start of the process. This was acceptable since it could be done at any point but the rounding of the answer to 1 significant figure led to a significant error in the final answer.

1.55 / 120 = 0.01292 which should not have been rounded to 0.01. Although mathematically correct, this leads to an error of over 25% in the final answer.

All subsequent steps are correct and shown clearly and so this response scored 4 marks.

ResultsPlus
Examiner Tip

During multi-step calculations, leave intermediate values in the calculator even if rounded values are entered onto the script to show the working. Rounding should be saved for the final answer.

(b) Butane, C_4H_{10}, is found in the refinery gases fraction of crude oil.
It is used as a propellant in pharmaceutical inhalers.
An inhaler that provides a total of 120 doses contains 1.55 g of butane.

Calculate the volume, in cm^3, of propellant used for each dose at 25 °C and 100 kPa. V

Use the ideal gas equation and give your answer to an appropriate number of significant figures.

[$pV = nRT$ $R = 8.31\ J\ K^{-1}\ mol^{-1}$]

(5)

120 doses → 1.55g C_4H_{10}

∴ 1 dose → $\frac{1.55g}{120}$ = 0.0129 g C_4H_{10}

∴ $n = \frac{0.0129g}{4\times12+10} = 2.227\times10^{-4}$ mol

∴ $T = 25°C + 273 = 298\ K$

$P = 100\times10^3$ Pa

∴ $100\times10^3\ Pa \times V = 2.227\times10^{-4}\ mol \times 8.31\ J\ K^{-1}\ mol^{-1} \times 298\ K$

∴ $V = 5.51\times10^{-6}\ m^3$

$= 5.51\ cm^3$

ResultsPlus
Examiner Comments

This is a correct response with all steps clearly shown and the answer quoted to the correct number of significant figures.

Question 22 (c)(i)

This equation was well known but, despite the instruction to include state symbols, they were often omitted.

Question 22 (c)(ii)

The fact that biofuels are renewable and sustainable is widely appreciated by candidates and they clearly know that fossil fuels are in limited supply. Candidates are also very aware of carbon dioxide production when fossil fuels are burnt and that this leads to global warming; so many answers scored well here. However, some candidates' answers were spoiled by the incorrect mentioning of biofuels being biodegradable. 'Carbon neutral' is a phrase which was often seen when describing biofuels and it scored M2 but sometimes this was negated by an additional statement that the biofuels produced no carbon dioxide when burnt, which is incorrect. There were some very good descriptions of how the plants absorb the carbon dioxide as they grow to reduce the overall carbon footprint of biofuels, which was good to see.

This response is brief but scores both marking points.

(ii) Give **two** reasons why alternative fuels, such as bioethanol, are being developed to replace those produced from crude oil.

(2)

1) Because they are renewable energy

2) They are carbon neutral as they absorb CO_2 in the photosynthesis and produce CO_2 when burned.

ResultsPlus
Examiner Comments

The numbering of the points made in this response has helped the candidate to include **two** different points in their answer, as instructed in the question.

ResultsPlus
Examiner Tip

Check that you have included the correct number of points in your answer.

Question 22 (c)(iii)

This was a simple recall question on reforming of alkanes. There seemed to be some confusion between this and the cracking of alkanes.

Question 22 (c)(iv)

Many candidates showed that they were confident using skeletal formulae in equations.

Question 22 (d)(i)

With plenty of options, this question was generally well answered, with combustion being the most common answer, followed by oxidation then safety. Answers were often well written, making it clear that an alternative chemical reaction would occur. Vague answers such as oxygen will react / give other products did not score. Some candidates misinterpreted “exclude” as “include” and so talked about the benefit of oxygen in ensuring complete combustion and about avoiding knocking. Reaction of oxygen with steam was a regular incorrect offering and a common misconception is that oxygen is flammable or explosive in its own right.

(d) In steam cracking, a mixture of hydrocarbons and steam is heated to 850 °C for a very short time in the absence of oxygen.

(i) Give a reason why oxygen should be excluded during steam cracking.

(1)

The hydrocarbons will react with oxygen and undergo combustion if oxygen is not excluded.

ResultsPlus
Examiner Comments

This is an example of a clear response which scores the mark.

Question 22 (d)(ii)

Although ethene can be burned, it is not used as a fuel. The C=C double bond in ethene makes it far more useful in polymerisation or as a feedstock for the production of halogenated compounds or ethanol.

(ii) Ethene is the major product.

State one use of ethene.

(1)

used in plastic bags and buckets.

ResultsPlus
Examiner Comments

This response did not score the mark since ethene is not used in plastic bags or buckets – it is however used to **make** polymers or plastics.

ResultsPlus
Examiner Tip

Be precise in your language.

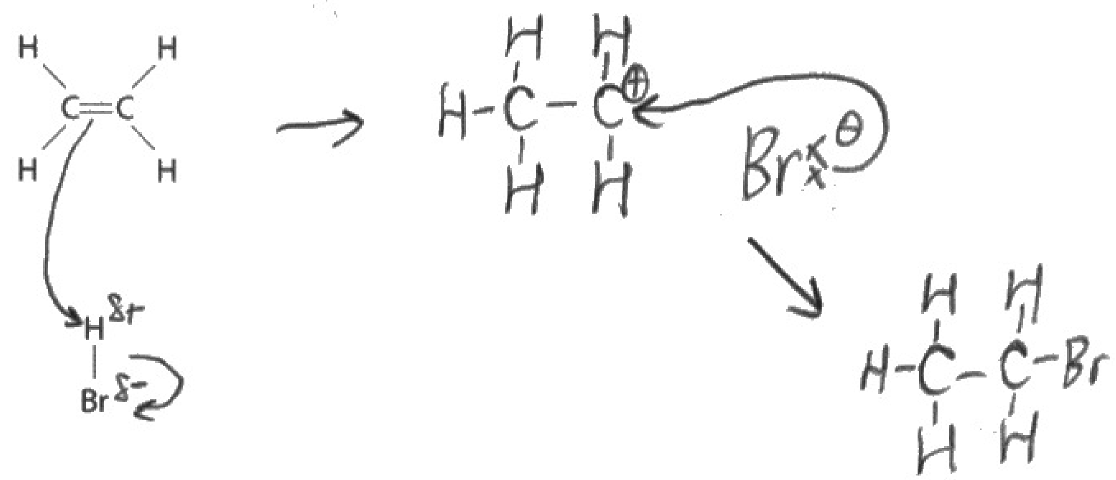
Question 22 (e)

The electrophilic addition mechanism is often the subject of questions in this unit and it was answered well by many candidates.

(e) Ethene reacts with hydrogen bromide to form bromoethane.

Draw the mechanism for this reaction.
Include curly arrows, and relevant lone pairs and dipoles.

(3)



ResultsPlus
Examiner Comments

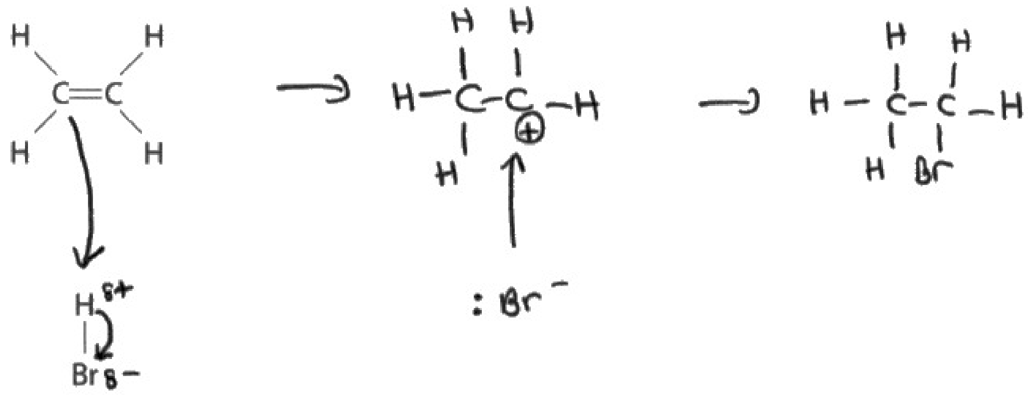
This response scores all three marks. All the curly arrows on the reactant molecules start at appropriate bonds and the dipole shown is correct. Both intermediates have correct structures and the curly arrow from the bromide ion comes clearly from the lone pair and not from the charge on the ion. Six marking points are correct.

This response showed an understanding of the mechanism but lost marks due to a lack of attention to the detail needed.

(e) Ethene reacts with hydrogen bromide to form bromoethane.

Draw the mechanism for this reaction.
Include curly arrows, and relevant lone pairs and dipoles.

(3)



ResultsPlus
Examiner Comments

Curly arrows in these mechanisms show the movement of a pair of electrons, either from a bond or from a non-bonded pair on an intermediate species.

Neither arrow on the reactant molecules is correct. Although, in both, the direction is correct, the curly arrow from the ethene molecule should start on the C=C double bond, not from the carbon atom. The bond fission arrow on the HBr molecule should start on the bond, not on the partially charged hydrogen. The dipole is shown correctly.

Both intermediate structures are correct but the starting point of the arrow from the bromide ion should be the lone pair as it is acting as a nucleophile.

Only three marking points were scored, which therefore scored only one mark.

ResultsPlus
Examiner Tip

Draw mechanisms carefully so that marks are not lost due to a lack of precision.

Paper Summary

Based on their performance on this paper, candidates should:

- Read questions carefully, particularly noting any words in bold.
- Note the number of marks available and structure their answer to include the correct number of different points.
- Draw curly arrows precisely in reaction mechanisms.
- Learn definitions of key terms in the specification.
- Ensure that in calculations you show your working, do not round values in intermediate steps and quote your final answer to an appropriate number of significant figures.

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