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Paper 01 Application of Core Principles of
Chemistry

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Introduction

Some candidates were very well prepared for this examination and scored high marks. Many candidates were able to demonstrate that they had a sound knowledge of the topics in the specification and could apply this to the questions with just a few errors or omissions. A significant minority of candidates found the paper very challenging and would benefit from much more preparation to ensure that they know the basic facts, can express their ideas clearly and carry out calculations, showing their working.

Section A

The mean mark for the multiple-choice questions was 13.1. The highest scoring questions were Q5 and Q13, with over 85% of candidates achieving these marks. The most challenging question was Q6, with 41% of candidates achieving this mark. It was surprising how frequently some candidates left one or more of the multiple choice questions unanswered.

Section B

Question 18

More than two-thirds of the candidates were able to draw a credit-worthy representation of the structure of diamond, despite relatively few attempting to draw a 3D structure. Drawing the bonds at right angles was a common mistake and some candidates attempting to draw extended structures made a slip by giving some carbons five bonds. Many candidates stated the correct shape and bond angle for diamond in (a)(ii) but did not mention **four** when explaining the **electron pair** repulsion. Fewer than half of the candidates drew credit-worthy structures for graphite in (b)(i) and many diagrams containing carbons with four bonds and some pentagonal and heptagonal arrangements of atoms were seen; 109.5° and 90° were common incorrect bond angles. Many candidates did not read the instructions carefully and gave more than one layer; responses with fewer than 13 or more than 19 carbon atoms were also seen.

More than three-quarters of the candidates could name the force between the layers in graphite and most understood that delocalised electrons explain the electrical conductivity of graphite. Some candidates lost the mark in (b)(iii), however, by stating that graphite contained a delocalised **electron**, implying the presence of just one in the entire structure. Another common mistake was to mention free electrons with no reference to their ability to move.

Although most candidates made sensible suggestions relating to the use of graphite as a shield on spacecraft, and many received credit for mentioning its high melting/boiling temperature, very few appreciated the directional transfer of heat. Candidates would benefit from exploring the concept of anisotropy when studying the properties of graphite. Common suggestions that did not receive

credit included the soft/slippery nature of graphite reducing friction upon re-entry and the flexibility of graphite layers making it easy to shape around spacecraft. More than half of the candidates scored the mark in (c) with fullerene being a common answer. Candidates should take care with the spelling of key terms such as this, however. Common incorrect answers included diamond, failing to read the question carefully, coal and charcoal. Amorphous carbon and carbon-60 were considered unclear responses that did not receive credit.

Question 19

The majority of candidates recognised the presence of both London forces and hydrogen bonding in ethanol and butan-2-ol though relatively few also included **permanent** dipole-dipole forces. While candidates generally attempted to apply their understanding of intermolecular forces to explain the limited solubility of butan-2-ol, many vague responses were seen referring to the polarity of butan-2-ol and/or water rather than specific intermolecular forces. Candidates commonly referred to hydrogen bonding **in** rather than **between** butan-2-ol and water and some incorrectly thought that hydrogen bonds could not form. Many candidates compared the solubility of butan-2-ol to ethanol and, although not required by the question, this did help lead them to the idea that the London forces in butan-2-ol are relatively strong.

The majority of candidates correctly described what is seen when sodium reacts with ethanol and approximately half gave a fully correct equation in (b)(ii); common mistakes included balancing the hydrogen incorrectly or omitting oxygen from the salt, giving C_2H_5Na and water as products.

Around two-thirds of candidates knew that ethanoic acid is produced when heating ethanol under reflux with acidified potassium dichromate(VI), however, the **chemical** test for a carboxylic acid was less well known with many candidates suggesting the use of PCl_5 , which also gives a positive result for an alcohol. Most of the candidates gave a correct structure for butanone in (c)(ii). The most common mistakes were to give the structure of butanoic acid, failing to recognise that this would be formed from butan-1-ol, or to include a hydrogen on the carbonyl carbon; candidates should take care to give the correct number of bonds to C, H and O atoms when drawing the structures of organic molecules. Many candidates understood how the IR spectra of butan-2-ol and butanone would differ with some, impressively, including correct wavenumber ranges even though this is not expected at AS. Some candidates did not refer to peaks/absorptions and, although not penalised in this examination, candidates should refer to specific bonds (eg O-H) rather than general groups of atoms (eg -OH / C-OH) when discussing IR spectra. Occasional confusion with mass spectrometry was also evident, with some candidates attempting to describe the expected differences in fragmentation patterns.

Question 20

In (a)(i), many marks were lost carelessly through giving the overall as opposed to the **ionic** equation and through incorrect balancing. While many candidates included half equations as working, some missed the point of the question giving a single half equation for the reduction of iodine only.

More than half of the candidates received no credit in (a)(ii) with alkane gases (eg ethane), ethanol and cyclohexene being common incorrect solvents where candidates failed to appreciate that ethanol is miscible with water and cyclohexene reacts with halogens. Some candidates seemed to misinterpret the question, giving starch or silver nitrate.

The majority of candidates scored one mark in (a)(iii) for recognising that iodine is reduced from 0 to -1 but many thought that sodium was oxidised or gave incorrect changes in oxidation state for sulfur, such as $+4$ to $+10$ (failing to divide by the number of atoms) or $+2$ to $+3$ (from rounding of 2.5). Candidates should be aware that the average oxidation number of an element in a species does not need to be an integer.

More than 80% of the candidates were able to draw credit-worthy skeletal formulae of the isomers of iodopropane though many demonstrated a poor understanding of bond length and bond angle. Less than 20% of the candidates scored the mark in (b)(ii) and a significant number of responses were left blank. In general, candidates did not make the link to the idea of **isotopes**, while some who did, made the mistake of referring to isomers. Other mistakes included the omission of **two** when referring to the isotopes of chlorine and bromine or incorrectly referring to isotopes of the halogenoalkanes. Some confusion relating to fragmentation being responsible for the additional peaks was evident, and many other incorrect responses relating to bond length, electronegativity, atomic radius and reactivity were seen. In (b)(iii), candidates were often able to identify the fragment and assign a positive charge although radicals and anions were occasionally seen. Candidates generally referred to fragmentation without making specific reference to the breaking of the C-I bond or confused fragmentation with the formation of the molecular ion by electron bombardment. Some who did refer to breaking of the C-I bond indicated heterolytic fission to form both a propyl cation and an iodide ion. Candidates should be aware that fragmentation of positive ions in a mass spectrometer does not lead to the formation of negatively charged ions.

Many candidates were able to give the colour and name of the precipitate in (c)(i) though some carelessly lost the mark for giving the formula rather than the **name** for silver iodide, and some incorrectly stated 'silver iodine' or 'silver iodate'.

Incorrect or missing state symbols was the main reason for losing the mark in (c)(ii), although some equations were complicated by the inclusion of additional species that candidates did not work through or cancel before giving the final ionic equation. Some candidates incorrectly gave the silver ion a charge of $+2$ and the formula of silver iodide as AgI_2 .

There were many carefully drawn mechanisms for (d). However, many candidates drew imprecise curly arrows and did not think about where they should start and

end. A curly arrow represents the movement of a pair of electrons so should start from a bond or lone pair of electrons and end at the atom that will be joined in the new bond. A significant number of candidates omitted either the charge or lone pair from the hydroxide ion and some showed a covalent bond in sodium hydroxide (ie Na-OH), which is incorrect. Although a correct dipole on the carbon-halogen bond is usually required, the difference in electronegativity between carbon and iodine is small and so was not needed in this example. The simplified nucleophilic substitution mechanism was all that was required for both marks; it is not necessary to distinguish between S_N1 and S_N2 mechanisms at AS. Although 1-iodopropane is a primary halogenoalkane, a correct S_N1 mechanism was allowed for both marks.

Around half of the candidates scored the marks in (e). A wide range of incorrect answers was seen in (e)(i) including 'nucleophilic elimination' where candidates did not appreciate that the hydroxide ion is acting as a base. When elimination was given, it was often spelt incorrectly. Typical incorrect answers to (e)(ii) included propanol and propane and some candidates appeared to incorrectly think that propene exists in two forms (prop-1-ene and prop-2-ene), which were both formed.

Section C

Question 21

Overall, candidates demonstrated a strong understanding of the origins of colour in a flame test. Marks lost usually related to ions rather than **electrons** being excited in the flame, and a significant number of candidates did not refer to **energy/photons** emitted as visible light during relaxation. Candidates who did not score misinterpreted the question, giving a description of how to carry out a flame test. In (a)(ii), 85% of candidates gave the correct colour with 'brick red' being the most common response. The majority of candidates understood why magnesium ions do not produce a flame colour though some incorrectly thought it was because the flame did not provide enough energy to excite the electrons. Despite being told the reactants and product in the question, nearly three-quarters of the candidates could not generate the correct equation in (b) with the formula of calcium hydrogencarbonate being frequently incorrect (eg $CaHCO_3$) and additional reactants and/or products included in an attempt to balance the equation. Candidates are advised to learn the formulae of common monatomic and polyatomic ions used within the specification.

In (c), many candidates just referred to barium sulfate as insoluble, which did receive credit. Candidates should have realised, however, that the question demanded a comparison and that barium sulfate does dissolve to some extent but is much less soluble than magnesium sulfate or calcium sulfate. Some candidates correctly referred to the trend in solubility of the group 2 sulfates, though some needlessly referred to lattice enthalpy, hydration enthalpy or trends in reactivity. The solubility of ionic compounds is a complex phenomenon, beyond AS, and

candidates should not expect to have to provide a detailed explanation for a one mark question.

In relation to the thermal stability of group 2 carbonates, the majority of candidates grasped the importance of ionic radius and polarisation though many were not precise enough in their answers, referring to elemental calcium and magnesium, as opposed to their **ions**, and referring to polarisation of the cations rather than the carbonate ion. Candidates should be aware that cations are polarising and anions polarisable. Very few candidates referred to the energy required to break the **C-O** bond with many incorrectly referring to the energy required to separate the cations and carbonate ions. Some candidates compared the degree of covalency in the ionic lattices of magnesium carbonate and calcium carbonate, which did not help to answer the question. A significant number of candidates incorrectly referred to molecules and/or London forces. Candidates should appreciate that group 2 carbonates are ionic and that ionic compounds have a giant structure; any reference to intermolecular forces is incorrect. Other vague responses that did not receive credit referred to trends in reactivity and/or thermal stability.

The calculation in (d)(ii) was done well by the majority of candidates with many clear and well-structured responses seen. A significant number of candidates correctly calculated the molar mass of the metal carbonate, but incorrectly stated radium as their final answer, confusing atomic mass with atomic number. A few candidates were penalised for rounding their answer to 1SF (eg 0.07 mols CO_2) and other careless rounding errors were seen, omitting trailing digits or rounding incorrectly (eg 0.067 for 0.068).

A significant number of candidates misinterpreted the question in (d)(iii), giving the equation for the formation of limewater from calcium oxide and water. When an attempt at the correct answer was seen, many responses did not include state symbols or gave $\text{CaCO}_3(\text{aq})$, failing to realise that the cloudiness observed when carbon dioxide is bubbled through limewater is due to the precipitation of calcium carbonate.

At AS, candidates are not expected to know the indicator of choice for a given acid-alkali titration and the majority gave either methyl orange or phenolphthalein. In general, the spelling of the latter was particularly poor. Candidates typically knew the colours associated with the indicators though sometimes gave the inverse colour change (eg colourless to pink for phenolphthalein). For methyl orange, the colour change was sometimes given as yellow to red, with candidates failing to realise that a red colour would indicate the end-point had been overshoot. Incorrect indicators, demonstrating a lack of understanding of acid-alkali titrations, included litmus, universal indicator and starch.

The calculation in (e)(ii) was answered well by many candidates, with many giving well-presented and clearly labelled working. A few candidates lost a mark due to incorrect rounding of an intermediate step (eg 2.225 to 2.22). While not penalised in this examination, candidates should avoid rounding at intermediate stages in multistep calculations and practise giving their final answer to a suitable number of significant figures. A significant number of candidates did not consider the information carefully, switching the volumes of calcium hydroxide solution and

hydrochloric acid and/or not scaling the amount of calcium hydroxide correctly to calculate the solubility in g dm^{-3} .

Summary

In order to improve their performance, candidates should:

- never leave multiple choice questions unanswered
- read the question carefully and make sure that you are answering the question that has been asked
- learn the meanings of all the key terms in the specification and practise spelling them correctly
- practise writing balanced equations for reactions in the specification, including state symbols
- practise writing ionic equations
- be careful with the precision of curly arrows in organic mechanisms
- make sure you understand the trend in thermal stability of the carbonates (and nitrates) of the elements in groups 1 and 2
- be careful when considering the colour change at the end-point of a titration
- show all your working for calculations, do not round prematurely and give your final answer to an appropriate number of significant figures.