Examiners' Report
Principal Examiner Feedback

January 2023

Pearson Edexcel International Advanced Level
In Chemistry (WCH12) Paper 01: Energetics, Group Chemistry, Halogenoalkanes and Alcohols

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Introduction

While some excellent responses were seen to all questions, many students found it difficult to apply their knowledge in unfamiliar contexts and a significant proportion appeared to have a limited knowledge of the specification content. In general, the students were most confident in answering calculations and with identifying familiar organic structures, reagents, and products.

Section A

The mean score for the multiple-choice section was 10.1. The highest scoring questions were Q7, Q5 and Q3 with around three-quarters of the students achieving these marks. The most challenging question was Q14, with less than one-fifth selecting the correct answer.

Section B

Question 18

While many students realised the reaction in (a) was disproportionation, the overall level of understanding of the rules for calculating oxidation number was poor, with the totals of +2 and −2 commonly given for chlorine in the products; and many responses incorrectly showing changes in oxidation number for calcium. Many did not justify disproportionation in terms of simultaneous oxidation and reduction, or link oxidation and reduction to an increase and decrease in oxidation number respectively. Students were familiar with the atom economy calculation in (b), the highest scoring question on the examination. The calculations in (c) were less confidently handled, with many confusing the concentration by mass for moles in (c)(i) and incorrectly multiplying their answer by the molar mass of calcium hypochlorite. Unit conversions (from m^3 to dm^3, and from mg to kg) also proved difficult. In (c)(ii), many did not refer to the equation on the previous page to consider the molar ratio of calcium hypochlorite to chlorine, and a significant number failed to link the reference to **room temperature and pressure** to the molar volume of a gas at r.t.p. provided in the Data Booklet.

Question 19

Most students followed instruction in (a), giving skeletal formulae of tertiary alcohols. Those scoring the highest marks approached the question systematically, starting with five carbons in the chain before reducing its length. Less successful students often duplicated one of their structures, with 2,3-dimethylbutan-2-ol commonly omitted. Some gave tertiary alcohols containing an incorrect number of carbon atoms, or even cyclic alcohols, which consequently contained an incorrect number of hydrogen atoms. A significant number of students gave the skeletal alcohol group as −O (and not −OH). Students should be made aware that hydrogens attached to heteroatoms (atoms other than carbon) should be shown in skeletal formulae. As in past series, students struggled with applying the rules of IUPAC nomenclature in (b)(i), with many thinking the longest chain contained five carbons; other common mistakes included omitting "di" and/or using incorrect locant numbers.

Most students appreciated the effect of branching on boiling temperature in (b)(ii), avoiding the trap of comparing the number of electrons, however the best responses referred to the contact surface area between molecules. Only a minority made the connection to the strength of the London forces – the intermolecular forces responsible for the difference in boiling temperatures – necessary to explain their answer.

In (b)(iii), very few students were able to demonstrate a sound understanding of the role of intermolecular forces in the solubility of alcohols, with most simply referring to the type(s) of intermolecular force present in the separate compounds or making general comparisons about their strength. Only a small minority went on to compare the overall strength of the intermolecular forces broken and formed upon dissolving. Students should be aware that hydrogen-bonding is not always the strongest type of intermolecular force and that London forces can be stronger when molecules contain a large number of electrons or have a large contact surface area between the molecules. In the context of alcohol **B** dissolving in water, the London forces in **B** and the hydrogen-bonds in water (which must break) are stronger than the intermolecular forces formed between molecules of **B** and water. A large proportion of students gave vague responses, simply stating that "like dissolves like" or incorrectly referring to alcohol **B** as a non-polar molecule, which received no credit.

Many students appeared uncomfortable working with skeletal formulae in (c), instead converting the structures to structural and/or displayed formulae, often making mistakes in the process. The substitution product for Reaction **3** was the most common correct answer; it was surprising to see so many students give the aldehyde for Reaction **1**, despite this being a well-known reaction of alcohols and the question paper clearly stating **reflux**.

Question 20

It was surprising that less than half of the students were able to correctly identify the reagent for the simple addition reaction in (a), possibly indicating that they were not aware that Unit 2 may contain synoptic questions, which require knowledge and understanding from Unit 1. More than half of the students gave the correct structure of organic compound **W** in (b), however a significant number did not score after incorrectly displaying the C≡N bond, usually as C–N. The question did not specify a type of formula and those students who gave more than one answer often gave an incorrect structure.

Relatively few students scored both marks in (c)(i) as they failed to consider the total number of outer electrons (five from each nitrogen, plus one more from the negative charge) or appreciate that nitrogen (as for other Period 2 elements) cannot have more than eight electrons in its outer shell.

Although an unfamiliar reaction, students were expected to recognise the mechanism in (c)(ii) as the role of the azide ion was stated in the stem. Despite being prompted, many failed to include a lone pair on the azide nucleophile; other common errors included imprecise curly arrows and omitting the bromide ion by-product.

The conditions for the reaction of halogenoalkanes with ammonia to produce amines are clearly stated in the specification yet many students could not provide these in (d)(i), rarely mentioning either pressure (most referred to heating in a sealed tube) or an alcohol solvent. Many students stated "heat under reflux", demonstrating a clear lack of understanding of the conditions for this reaction. Only the keenest students were aware that the product in (d)(ii) was a primary amine, which could undergo further substitution, with most responses giving vague references to side-reactions.

Question 21

Those students who had learned the content and followed the rubric were able to score high marks on this extended response question on the thermal decomposition reactions of Group 1 and Group 2 nitrates. Some students failed to refer to **ions** in their responses and others tried to incorrectly explain the trend in terms of ionisation energy of the Group 2 element as opposed to polarisation of the nitrate anion by the metal cation. Producing correct equations proved challenging for many. In general, there was a clear distinction between students who had learned the content and those who had not.

Section C

Question 22

Most students failed to appreciate the equilibrium nature of the reaction in (a), and incorrectly said that excess steam was used to react with all the methane. In (a)(ii), some students did not realise the question was about equilibrium yield and the conditions used in industrial processes and, therefore, gave T_2 as the higher temperature for the exothermic reaction. Many students were able to combine the equations to derive the overall equation in (a)(iii), however it was not uncommon for the carbon monoxide to remain uncancelled.

Surprisingly few students were able to suggest a valid reason for removing the carbon dioxide in (b)(i), missing the point of the question and failing to appreciate that waste substances must often be processed in industry. Identifying the type of reaction in (b)(ii) proved to be the lowest scoring question on the examination, with only the most able students recognising the amine as a base and carbon dioxide as an acid. Many students ignored the emboldened text in (b)(iii), failing to provide a fully **displayed** formula.

In (c), many students did not present their responses clearly, leaving examiners to decide whether their responses related to an advantage or a disadvantage. Although most were able to provide an advantage related to rate or yield, relatively few gave a disadvantage in sufficient detail, making general references to cost without linking this to the energy required to generate the pressure or the equipment required to withstand it.

While most students seemed to understand how catalysed and uncatalysed reaction profiles would differ in (d)(i), few were able to correctly process the scale. Careless placement of arrows, starting and/or ending imprecisely, and the incorrect use of double-headed arrows resulted in many students scoring fewer marks than they might. Centres should reinforce that single-headed arrows should be used to represent enthalpy changes (and activation energies), which are directional in nature. A significant number of students either omitted or used incorrect labelling in their diagrams. Many students failed to answer the question asked in (d)(ii), choosing instead to describe the action of a catalyst. Stating that a catalyst can be reused did not address the issue of **sustainability** as the reaction cannot be carried out (successfully) without a catalyst.

The most common answer in (e)(i) was to increase rate, though more thoughtful students gave specific answers including to activate the catalyst or to break covalent bonds in the reactant molecules (however some confusion with breaking the hydrogen-bonds in ammonia was also seen). Although many students scored the mark in (e)(ii), for realising the exothermic nature of the reaction, very few appreciated that only a small amount of energy was needed to reach the relatively high temperature as the reaction is **highly** exothermic.

Part (f), where a reference to both the first and second reactions was required, was another question where students failed to express their answers clearly. Many referred to the position of equilibrium for the second reaction, even though this was shown as an irreversible reaction, and failed to explain how the nitrogen dioxide consumed (or the nitrogen monoxide formed) affected the position of equilibrium in the first reaction.

In (g)(i), the right-hand side of the enthalpy cycle was often correct, but ammonia was commonly missing on the left. Presumably, students were able to link the -32.6 to nitric acid but found it more difficult to compute -220.2 as the sum of the formation enthalpies of nitric acid and ammonia. The omission of state symbols, which were essential in the context of the question, was another common error. Many students were unable to use the Hess cycle to obtain a credit-worthy response in (g)(ii), even with transferred error, with a significant number of answers having the correct magnitude but wrong sign. As with several previous questions, a lack of specificity in (h) meant that many students did not receive credit for vague responses referring just to lower costs or less energy without qualification.

Summary

Based on their performance on this paper, students should:

- practise calculating the oxidation number of elements in compounds and ions, and explaining oxidation and reduction in terms of changes in oxidation number
- practise unit conversion in chemical calculations
- practise applying the rules of IUPAC nomenclature to alcohols (and other compounds relevant to the specification)
- improve their understanding of the role of intermolecular forces in the dissolving of organic compounds
- practise drawing organic compounds, particularly using skeletal formulae
- practise their recall of the specification content (eg the reagents and conditions for organic reactions)
- practise writing equations for reactions relevant to the specification (eg reactions of elements and compounds of Group 1 and Group 2)
- communicate their answers clearly to questions involving more than one aspect (eg an advantage and a disadvantage)
- use single headed arrows for enthalpy changes and activation energies in reaction profiles
- be specific wherever possible, eg when giving answers relating to increased cost or reduced energy in industrial processes

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