Examiners' Report
Principal Examiner Feedback

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Introduction

Although a proportion of candidates showed evidence of excellent understanding of a wide range of ideas, examiners noted that some students seemed unprepared for the breadth of content in the paper. Hence some questions, not necessarily at the end of the paper, were left blank. Even then, these omissions were not necessarily high demand questions. For instance question 14, although an extended response, required minimal application of ideas. However very few candidates had a detailed knowledge of the chemistry of cobalt, and the most common score for the question was 0.

Section A

The mean score for the section was 11.7. By far the most challenging questions were 3b and 8b. In 3b candidates didn't seem to appreciate that when equal amounts of each solution were mixed to form the electrolyte, the concentration with respect to each reactant would decrease by half. In 8b the need for the potassium iodide to be in excess was missed by the majority.
The most accessible questions were 1b, 2b, 3c, 6c and 9.

Question 10

Whilst most candidates could describe the shape as linear in (a)(i), few could explain the shape. Many discussed the idea of two ligands in the complex, but few related this to the number of bonding electron pairs, which is the key idea when deducing a complex shape. A minority of candidates did discuss the concept of 'minimising repulsion'. However too often this was a standalone statement rather than linked to the bond pairs or electrons.

In (a)(ii) most candidates realised that d electrons were the key to explaining the lack of colour in the complex. However, a lack of precision meant only the best candidates scored both marks. Attempts to describe the full d sub-shell in the silver ion proved challenging. Candidates persist in framing answers in terms of 'a full d orbital' putting credit at risk if they fail to make it clear that all the d orbital**s** were full. Others talked about the full d subshell in a silver **atom,** or gave a generic answer based on a full 3d sub-shell, rather than the specific 4d sub-shell in this case. Several candidates seemed to think the full d sub-shell meant that the splitting of the d orbitals could not take place, rather than the electron transition. Others believed that light was absorbed and transmitted but it was outside of the visible spectrum.
The most common incorrect product given in (b)(i) was the ammonium ion. Even those who correctly identified ammonia and water as the products could not aften balance the equation.
The structure of **Y** in (b)(ii) was more accessible. Some candidates seemed less confident with skeletal formula, so converted their response into structural and/or displayed formulae.

Whilst this is perfectly valid, it uses up valuable time, especially as the pre-cursor to **Y** was modelled in skeletal format in the stem.

The most common correct response in (c) simply showed the half-equation for the oxidation of zinc to zinc ions, though just less than 50 % of the cohort scored the mark.

Question 11

Only 40 % of the cohort correctly classified the amine in (a). Once again perhaps a better understanding of skeletal formulae would have helped candidates to recognise that three carbon atoms are attached to the nitrogen. Part (b) proved a useful discriminator. Many candidates recognised that pyridine would form hydrogen bonds with water, and although this was not always linked directly to the lone pair on the nitrogen atom, discussion of the lone pair was often seen. Fewer candidates discussed the basic properties of pyridine. Those who did often recognised the ability to accept a proton, but did not always link this to the resultant excess of hydroxide ions. Many candidates do now follow the guidance regarding curly arrows, lone pairs and dipoles and hence managed at least one of the first two marks in (c). However despite the guidance in the stem only the better candidates made full use of the link between this mechanism and that between ammonia and chloromethane, with many ignoring the formation of the intermediate.

Question 12

The majority of candidates knew where to split the polymer in (a) but only a minority managed to complete the structure of the two amino acids. In the main this was because extension bonds in the repeat unit were shown in the monomers as methyl groups, without an appropriate hydrogen or hydroxyl group. A small number used acyl chloride groups instead of carboxylic acid groups.

Just over 60 % of candidates could deduce both monomers correctly in (b), though a worrying number did not appreciate each monomer would have a carbon-carbon double bond.

In (c) nearly half of the cohort could correctly calculate the number of repeat units. Those who did not score both marks often made an error in working out the relative mass of the repeat unit, but were able to score a single mark as a transferred error.

Question 13

A clear majority correctly drew the ‘dot and cross’ diagram in (a), with the most common mistake being the omission of the lone pair on the arsenic atom. The calculation in (b) discriminated effectively. More able candidates could process the data using the Ideal Gas Equation with care, and mistakes due to the use of incorrect volumes seemed less frequent than in previous series. The use of the molar gas volume was evident to determine the amount of Arsine. This deserved some credit but gave a less precise answer which made deduction of the ratio, and hence final oxidation state more demanding. Some otherwise able candidates misunderstood which species were oxidised or reduced, and gave a final oxidation state of +5.

A disappointing feature of (b)(ii) was the number of candidates who made no attempt at any part of the calculation. The simple calculation to find the moles of cerium(IV) sulfate should not have been beyond any candidates at this level.

Question 14

This extended response question proved challenging for many, despite the relative low level of demand required. There was lots of evidence that candidates appreciated the types of reaction taking place, perhaps using the reactions of $[Cu(H_2O)_6]^{2+}$ as a model. However, sound knowledge of the expected observations and the ability to construct appropriate equations in the context of $[Co(H_2O)_6]^{2+}$ were far less noticeable.

The formation of a precipitate with sodium hydroxide solution was often discussed, but the colour of the precipitate or the initial solution was then omitted.

With ammonia, a significant number thought the formula of the complex would mirror that of the tetraamminediaqua copper(II) complex, whilst others were unaware of the colour of the solution formed.

With hydrochloric acid, better candidates could recall or deduce the equation based on the tetrachlorocopper(II) complex, but could not always recall it’s colour.

A number based their equations throughout on $CoSO_4$, rather than $[Co(H_2O)_6]^{2+}$, which given the wording of the question was an allowable approach. This possibly made the equation for the reaction with sodium hydroxide solution easier to access. However, those who used this strategy often could not balance their attempts when forming complex ions in the subsequent reactions.

Question 15
In (a) most candidates attempted to show the molecular formula of Q by calculating the amounts of CO_2 and H_2O formed. This is a valid technique given that this problem is a confirmation of a formula, rather than an attempt to determine the formula. However even though many managed to work through the problem using this starting point, it seemed that candidates were often using 'trail and error' or attempting to work back from the given formula, rather than any sort of systematic approach. Those who started the question by calculating the masses of carbon, hydrogen and therefore oxygen nearly always scored full marks. Such candidates completed the question efficiently, with examiners clearly able to see their route through the problem.

A systematic approach also benefitted candidates in (b). Such answers followed the guidance in the stem to consider the relative peak areas, chemical shifts and splitting patterns. Candidates who followed this advice were not always able to deduce the structure of Q but could often score credit by linking chemical shifts to key parts of the structure of Q and correctly justifying, for instance, the triplet and/or quartet peaks in terms of neighbouring hydrogen atoms.
The most frequent creditworthy statements linked the peak at approximately 7.4 ppm to the benzene ring, whilst the most challenging mark, apart from the structure of Q, was the ability to link the area under the curve for this peak to the presence of 5 hydrogen atoms or one side group on the ring.
Some candidates didn't use prior information from (a) effectively. Even though it was clear from the stem that Q did not contain any nitrogen atoms, a number of candidates persisted in suggesting that the structure contained amide or amine functional groups. These answers did not consider the chemical shifts and formulae of Q together to help rule out certain functional groups suggested by the Data Book.

Question 16
The reference to the Grignard reagent in the stem of (a) gave many candidates a hint of where to start though a number formed an inappropriate Grignard by using simple aliphatic halogenoalkanes.

Those who recognised the need to brominate the benzene ring nearly always included a sensible catalyst, but a few wasted time by including the mechanism. Care should be taken when presenting the structure of Grignard reagents as several were shown with the bromine attached to the ring instead of the magnesium. Those candidates who correctly deduced the structure of the Grignard reagent nearly always went on to react the reagent with a suitable compound containing a C=O bond, such as CO_2. However, the hydrolysis of the salt to form the final product was often omitted or included as part of a single step with the CO_2.

The mechanism in (b)(i) was more accessible for the majority of students. The equation to form the electrophile was well known and most errors were linked to a lack of precision, especially with the direction or starting point of curly arrows and the orientation of the incomplete ring in the intermediate.
Part (b)(ii) was a low demand question, requiring simple recall of the reagents needed to reduce the nitro group on the benzene ring. Just over 40 % scored the mark, which suggests some candidates need a more focused approach to revision to ensure they have a secure knowledge of all the organic reactions on the specification. Not only does this help in questions such as (b)(ii), it gives candidates a better chance when the have to apply such knowledge, for instance as part of a synthesis.

In part (b)(iii) it was pleasing to see that many candidates understood the need for temperature between 0 and 10°C. The was often justified in terms of the instability of the diazonium ion or the subsequent break down into a phenol.

The structure of the azo-dye in (b)(iv) was a useful discriminator. Around a quarter of candidates correctly determined the structure. Whilst some seemed to have little idea of the process, others just missed out due to the positioning of the side groups. Most commonly the OH group was shown on the second carbon from the nitrogen. Others had the side groups in the correct position but used a triple bond between the two nitrogen atoms.

Those candidates who attempted part (c) could often achieve some credit by correctly calculating the amount of lead benzoate, but a number of blank responses were seen. As in 13(b), at this level all candidates should be expected to attempt to find an amount in moles, even in an unstructured calculation. Examiners were pleased to see many of cohort using a range of successful strategies to determine x

Summary

In order to improve their performance, students should:

- practice using the valence shell electron repulsion theory to justify shapes of molecules **and** complex ions
- make sure you understand the difference between a full d orbital and a full d sub-shell when discussing d-block elements or ions
- try to use skeletal formulae whenever possible in organic chemistry – once you have mastered this skill it will mean you can answer many questions more efficiently and reduce the chance of minor errors such as the omission of hydrogen atoms in displayed formulae
- in unstructured calculations it can be challenging to know where to start, so 'if in doubt, mole it out' – that is look carefully at the data in the question to find an amount you can calculate using the equations learnt in Topic 1: Formulae, Equations and Amount of Substance to help get you going
- ensure you have a breadth of knowledge of the chemistry of **all** the transition metals proscribed by the specification
- use a systematic approach based of finding the masses of carbon, hydrogen and oxygen from combustion analysis data when confirming the formula of organic compounds
- organic synthesis requires a knowledge of organics chemistry from across the specification – produce your own summary diagrams or flow charts linking together functional groups, to help embed this knowledge

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