



Examiners' Report Principal Examiner Feedback

October 2021

Pearson Edexcel International Advanced Level
In Chemistry (WCH15) Paper 01
UNIT 5: Transition Metals and Organic Nitrogen
Chemistry

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Publications Code WCH15_01_2110_ER

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Introduction

A significant proportion of the students were inadequately prepared for this examination with many blank responses seen for a number of the questions, including some of the multiple-choice questions.

Section A

The mean score for the multiple-choice section was 9.9. The highest scoring question was Q1(b) with 76% of students achieving this mark. The most challenging questions were Q1(c), Q4, Q14 and Q17, with less than one third of the students selecting the correct answer.

Section B

Question 18

Many students failed to link the pale green color to an iron (II) salt in (a), with others missing that the salt was hydrated. The instruction that working had to be shown was missed by many students, however, a good use of algebra to calculate the number of moles of water of crystallization was seen from some.

Many students did not appear to understand the term complex ion in (b), with common incorrect answers including just Fe^{2+} , a neutral complex such as $[\text{Fe}(\text{H}_2\text{O})_4\text{Cl}_2]$, or an iron(II) compound such as $\text{Fe}(\text{OH})_2$. The overall quality of the three-dimensional drawings in (c) was poor; students should practice this skill and centers should promote the use of molecular model kits to help students visualize the three-dimensional shapes of molecules and ions. Most students scored full marks in the empirical formula calculation in (d), though a small proportion carelessly used atomic numbers for relative atomic masses and/or the atomic symbol of fluorine for iron.

A very small proportion of students were able to approach the ionic equation successfully in (e). Where the question was attempted, the formula of complex ion C usually had an incorrect charge and most students tried to write an equation for a ligand exchange reaction. Most students recognized Reaction 2 as ligand exchange, though fewer were able to identify Reaction 3 as redox. A significant number of students identified one or both reactions as more than one type of reaction.

Question 19

While the majority of students realised that bromine water could be used to distinguish between the Dewar structure and benzene, a significant number did not score the second mark through failing to specify which compound would decolourise it. Part (b) was poorly answered, with most students constructing their answers around chemical shifts from the Data booklet, failing to consider the number of proton environments or incorrectly stating that benzene has peaks at both ~7 ppm and ~2 ppm.

A significant number of students did not refer to proton NMR at all, referring to ^{13}C NMR or IR spectra instead. Many students did not link X-ray diffraction to bond length in (c). Where this connection was made, failure to specify the type of bond or make clear which structure they were describing meant that less than a quarter of responses scored both marks. In part (d)(i), a large proportion of students did not seem to understand the terms 'enthalpy level diagram' or 'isomerise', often producing diagrams resembling reaction profiles and/or adding an enthalpy level below benzene (typically labelled with the numerical value for the enthalpy change of hydrogenation of benzene).

Less than 10% of students scored the mark in (d)(ii) as the connection between activation energy and bond strength was rarely made. Some students had the right idea, recognising the importance of the double bonds in the Dewar structure but incorrectly described C=C bonds as being weaker than C-C bonds. A general failure to read the question carefully or make the connection to delocalised pi-bonds and the thermochemical stability of benzene meant that very few students scored well in part (e). Surprisingly, many students did not recognise the relationship between -118 and -236 and a significant number referred to the energy required for hydrogenation, failing to appreciate the exothermic nature of the reactions. Around one third of the students gave the three correct isomers in (f)(i); a common mistake was to repeat the 1,2- or the 1,3-isomer, possibly thinking they were discrete from the '1,6-' or '1,5-' structures.

Some students found it difficult to translate the structural formula to skeletal formulae, with a significant number drawing aliphatic compounds despite the references to (methyl)benzene and arenes in the question stem. Few students scored well in (f)(ii), with many apparently thrown by the two peaks close in chemical shift on the ^{13}C NMR spectrum and a general difficulty in determining the number of carbon environments in an aromatic compound. More than one third of students scored 3 or 4 marks on the electrophilic substitution mechanism; common mistakes included adding a positive charge to the acyl group on the intermediate and poor positioning of curly arrows and/or the gap in the intermediate pi-bonds.

Question 20

The word catalyst led some students to active sites or other characteristics of heterogeneous catalysis, with many others referring to the incomplete d-orbitals of transition metal elements instead of the variable oxidation number in their **compounds**.

Fairly common misconceptions in (b)(i) included that monodentate ligands contain only one lone pair of electrons and that any one coordinated ligand must be monodentate. A significant number of students were unable to access both marks through omission of the term 'lone pair'. Only a small proportion of students could show the stereoisomer of complex Y with many simply drawing its mirror image, failing to appreciate that this was the same structure rotated clockwise by 90° . The large majority of students gave the reverse colour change in (c)(i), simply following the direction of the half-equation and not realising that the colour would change only when excess Ti^{3+} ions were added to the conical flask after all of the nitrate ions had been reduced.

The redox titration calculation was found to be challenging, with few students getting past the moles of titanium (III) and/or magnesium nitrate and even fewer appreciating the link between the mole ratio of reducing agent to oxidising agent and the change in oxidation number. Students would be well advised to use simple flow diagrams or storyboards to plan their route through unfamiliar and unstructured titration calculations. Further, when one part of a question leads into the next, marks can usually still be achieved from an incorrect or incomplete starting point and students should be encouraged to persevere. For example, students could have scored marks for a correctly derived ionic equation and E_{cell}^\ominus calculation without attempting the calculation in part (ii).

Around half of the students recognised that the flask was heated to speed up the titration reaction in part (v). A good number of students scored 2, 3 or 4 marks on the extended response question though many did not carefully read the instructions in the rubric. Only a small proportion of students thought to comment on the relevance of the incomplete d-orbitals of Ti^{3+} and many references to the advantage of using an indicator were too vague to receive credit. Students should be reminded to be precise when explaining the colour of a complex ion, for example: ligands split the energy of the d-subshell or d-orbitals (and not a single d-orbital); visible light is absorbed (and not adsorbed) when electrons are promoted; the colour observed is due to transmitted (and not emitted) wavelengths of light.

Question 21

Only a very small number of responses scored the mark in part (a), indicating that students are not comfortable with the meaning of curly half-arrows or the movement of electrons in radical reactions. A significant number ignored the instruction, adding half-arrows to both sides of the equation.

A good proportion of students correctly drew the first curly arrow in part (b), though relatively few were then able to come up with the movement of electrons required to generate the product shown.

In part (c), many students evidently found it difficult to deduce the charge on the metal ion in the gold complex and a significant number gave its shape as tetrahedral, failing to consider the bond angle provided. In part (i) of the methyl red synthesis, a surprisingly large proportion of students could not recall the reagents and conditions for the oxidation of an aldehyde to a carboxylic acid, especially as the original functional group was identified by name as well as by skeletal formula. Many students recognised the role of the tin and concentrated hydrochloric acid in part (ii) and were able to draw the structure of compound A; common mistakes included converting the carboxylic acid group to an acyl chloride or substituting a chlorine atom onto the benzene ring. Again, surprisingly, the reagents needed to produce the diazonium salt in part (iii) were slightly less well known. Part (iv) was poorly answered, with relatively few students appearing to recognise this nucleophilic substitution reaction or be able to correlate the structure of compound B with that of methyl red. Common mistakes were to substitute methyl and/or iodo groups onto the ring.

Part (e) was found to be particularly challenging, with relatively few students being able to correctly balance the equation or make significant progress with the percentage yield calculation. Deducing molecular formulae and molar masses from the skeletal formulae proved challenging, with missing hydrogens being the most common error. Many students failed to clearly present their working in the calculation, reducing their chance of securing transferred errors.

Again, the students found part (f) to be very challenging. Most students were confused by the different functional groups in coumarin 440 and were unable to link the **hydrolysis** with the ester group. Where this link was made, only the very best students considered the significance of a phenolic product in the presence of excess alkali. The condensation reaction was handled slightly better in part (ii), though many students were again distracted by the different functional groups and found it difficult to focus on the formation of an amide.

Summary

Based on their performance on this paper, students should:

- read the question carefully and make sure that they are answering the question that has been asked
- look for clues in the question stem (eg colours of transition metal compounds/ions)
- try to frame questions within the context of the specification content (eg hydrogenation enthalpies and benzene and delocalised pi-bonds)
- make sure that comparisons are made when required
- practise identifying proton and carbon environments in cyclic and aromatic compounds
- use simple flow diagrams/storyboards to plan their response to unstructured and unfamiliar titration calculations
- persevere with multi-stage questions as marks can still be achieved from incorrect or incomplete starting points
- be precise with terminology when explaining the colour of an aqueous complex ion
- pay careful attention to the placement of curly arrows, and look for clues from any structures shown in unfamiliar mechanisms
- present their working clearly in unstructured calculations

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