

Examiners' Report
June 2014

GCE Chemistry 6CH05 01

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Introduction

This paper was a reasonable balance of standard and higher demand questions, the latter often requiring candidates to apply their knowledge and understanding in unfamiliar situations. Despite this being an A2 paper and having a synoptic element, for the most part, candidates seemed far better prepared for the straightforward type of question. Calculation work was usually carried out confidently and generally well-presented, with the logical steps easy to follow. In multi-step calculations there are still candidates who round intermediate values for use in the subsequent stages of the problem; while this practice is not itself penalised, it leads to inaccurate final values and is a frequent source of transcription error. The questions that required specific knowledge of reagents and substances used in standard laboratory procedures scored low marks; just over half of all candidates could name a drying agent and only a quarter could identify a solid that could be used to absorb carbon dioxide. Even in standard questions, candidates often showed little regard for correct chemical vocabulary, treating distinct technical terms as interchangeable. Candidates also need to be aware of the need for the text of a question to be read closely; it was all too common for candidates to overlook clear indications in the stem of a question about the required answer.

Multiple Choice Section Data

This was the highest scoring section of the paper with a mean score across all candidates of 61.8% and it discriminated better at the higher than the lower end of the entry, with A grade candidates typically scoring over 80% while E grade candidates scored around 55%. Over 80% of candidates gave the correct answer to questions 1, 8 and 14a while less than 40% of candidates gave the correct answer to questions 12 and 6b.

Question 19 (a) (i)

The importance of excluding water from the apparatus was poorly understood with many candidates suggesting that water would react with compound A.

Question 19 (a) (ii)

Most candidates were able to suggest a suitable solid drying agent, and it was pleasing to see that many were aware that the substance needed to be anhydrous, although this detail was not required to score the mark.

Anhydrous sodium hydrogencarbonate calcium carbonate or
silica gel



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Examiner Comments

The candidate has given two answers, one correct but the other wrong. If more than one answer is given, all must be correct.

Question 19 (a) (iii)

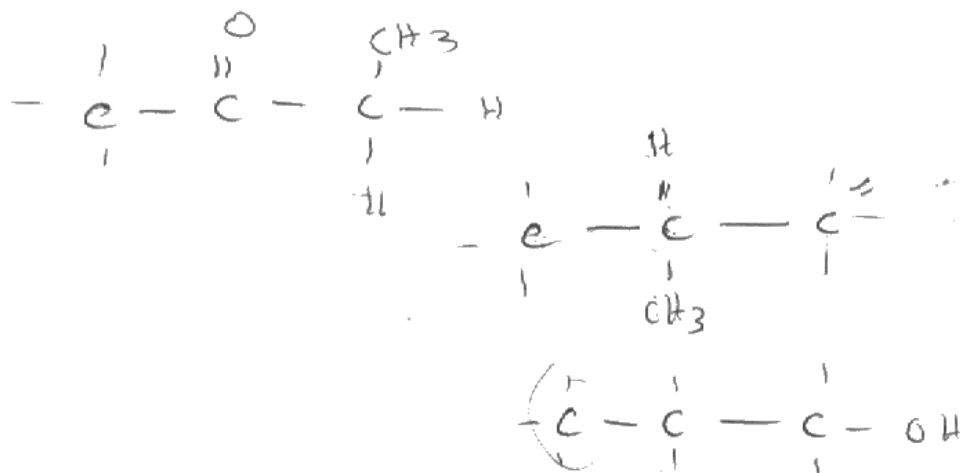
Identifying a substance that could be used to absorb carbon dioxide was beyond a majority of candidates. Many suggested calcium carbonate but some put forward some very unlikely materials.

Question 19 (a) (iv-bi)

There were many excellent answers to the calculation, concisely presented and with clear indication of the method. The most common errors involved confusion about the amount of hydrogen indicated by the water produced; some candidates forgot to double the amount of water while a few doubled it twice. There were a significant number of candidates who seemed unfamiliar with this type of calculation, although many of these were able to score the first and last marks. Most candidates correctly identified the molecular ion on the mass spectrum and were able to deduce the molecular formula. Some candidates then returned to their calculation with varying degrees of success.

X = water	Y = CO ₂	mass
3.60g	8.80g	moles Mr
$\frac{3.60}{18}$	$\frac{8.80}{44}$	
$\frac{1}{5} \times 2$	$\frac{1}{5} \times 12$	
$\frac{2}{5}$ moles	$\frac{12}{5}$ moles	
$\frac{2}{5} \times 100 = \frac{100}{9}\%$ (11.1%)	$\frac{12}{5} \times 100 = \frac{200}{3}\%$ (66.7%)	
$100 - \left(\frac{100}{9} + \frac{200}{3}\right) = \frac{200}{9}\%$ (22.2%)		
H	C	O
$\frac{100}{9}$	$\frac{200}{3}$	$\frac{200}{9}$
11.1	12	16
$\frac{100}{9}$	$\frac{50}{9}$	$\frac{25}{18}$
11.1	5.56	1.39
4	4	1
		C ₄ H ₈ O

$$M_r = 72$$



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Examiner Comments

This candidate used a percentage by mass method in the calculation. This approach was not on the mark scheme but is correct and scored full marks.



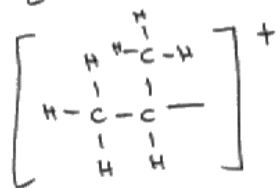
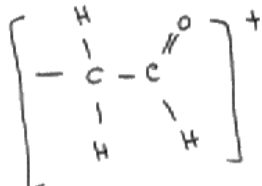
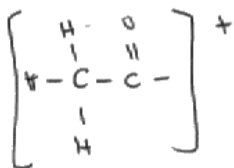
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Examiner Tip

In (b)(i) as well as the correct answer which gained full credit, the candidate has done some working on possible structures of compound A. Remember that if a molecular formula is required, structural formulae won't score.

Question 19 (b) (ii)

The candidates who drew displayed structures were less likely go wrong here. The most frequent errors were the omission of the positive charge and the inclusion of an extra hydrogen atom.

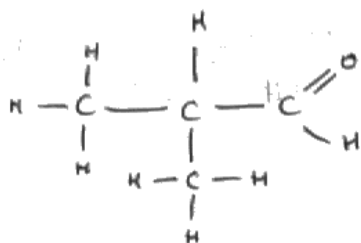


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Examiner Comments

A well-presented set of structures with the positive charges sensibly placed outside the brackets.

Question 19 (c)

Candidates who identified one of the two possible structures usually went on to score three marks, but there were still some who failed to clearly identify the three proton environments. Some candidates discussed splitting patterns in addition to analysis of the relative peak heights, but in some cases peak height and splitting were confused. The most common incorrect structure was butanone, an error which suggests that many candidates have an uncertain grasp of proton nuclear magnetic resonance spectra.



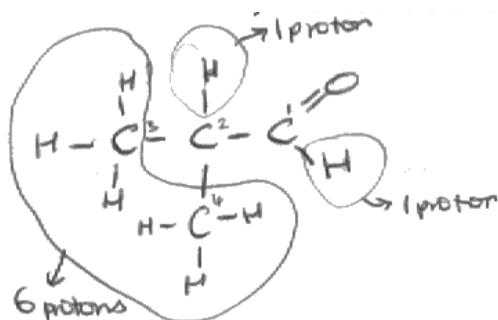
This is consistent with the nmr data as the structure has 3 hydrogen environments, with two of them containing only one hydrogen atom and then one containing 6 hydrogen atoms. Making the ratio 6:1:1

(Total for Question 19 = 16 marks)



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Examiner Comments

Although the structure is correct and the candidate has stated that there are three proton environments, it is not stated clearly enough where these are. Annotating the diagram would be the simplest way of doing this.



This is consistent with the NMR data because the ratio shows you there are 3 hydrogen environments which A has (they are circled) and it shows you one environment has 6 protons, one environment has 1 proton and another also has one proton.



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Examiner Comments

This type of approach was very popular with candidates and an excellent way of securing full marks.



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Examiner Tip

A labelled diagram is often quicker and clearer than an explanation in words.

Question 20 (a) (i)

Relatively few candidates appreciated that the number of steps has a critical effect on the yield of a process and most scored a mark here by offering a number of possibilities, many of which were deemed irrelevant by the mark scheme. Some candidates did produce an acceptable alternative.

Question 20 (a) (ii)

This was a high scoring item, although some candidates came close to losing the mark by referring to the energy needed to *start* the reaction, a common misconception in rates. A common error was to list the properties of catalysts without explaining the environmental benefit. Here, as elsewhere on the paper, mention of green chemistry triggered generalised responses about global warming and the ozone layer.

provides a lower activation energy therefore
using less energy to overcome the original
high activation energy



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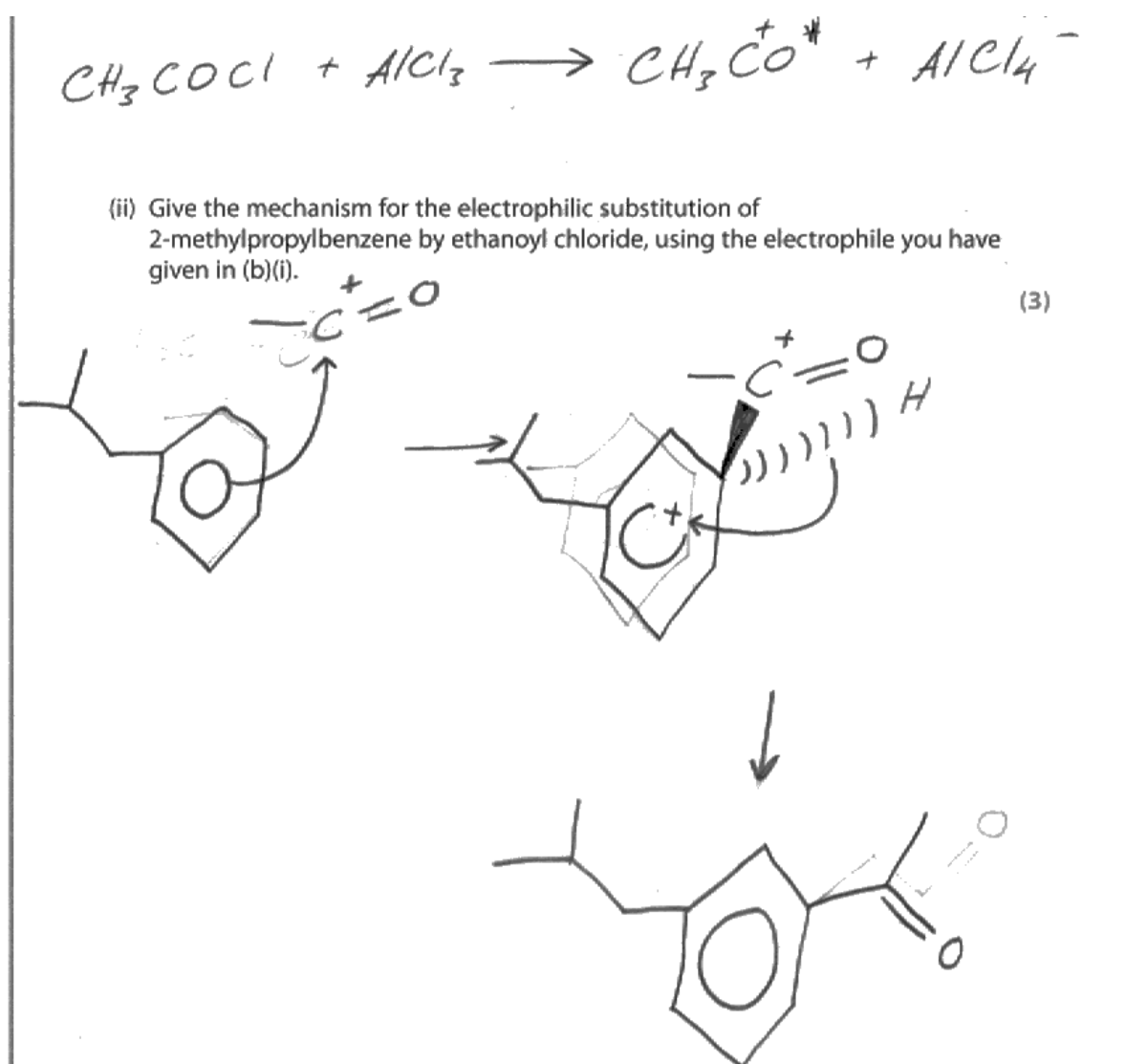
This response was allowed but the idea of overcoming the activation energy comes close to missing the point altogether.

Question 20 (b) (iii)

The basis of this question was familiar from recent series so most candidates realised that using ethanoyl chloride would result in the formation of hydrogen chloride. However, mention of the environment led to many responses describing the dangers of chlorine compounds in terms of the formation of chlorine radicals and the subsequent effect on the ozone layer.

Question 20 (b) (i-ii)

Despite its familiarity, the descriptions of the mechanism of electrophilic substitution were extremely varied in their quality, reflecting, in part at least, the understanding of the steps being described. Errors of detail were common, especially affecting the structure of the intermediate, but there were also chemically more serious mistakes such as the appearance of an additional positive charge, usually on the ethanoyl group. Candidates occasionally drew the ethanoyl group bonded to the benzene via the methyl group an error which would be less likely if displayed or skeletal structures were used rather than short structural formulae. In this particular question the presence of an alkyl group on the benzene ring brought an extra level of difficulty, even though the structure of the product was given.





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Examiner Comments

This mechanism lost a mark because the final product was 1,3 substituted rather than 1,4. Note that the Wheland horseshoe is correctly oriented towards the tetrahedral carbon but the positive charge is nearly placed outside the Wheland horseshoe rather than in the middle.



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Examiner Tip

The positive charge is spread over the benzene ring apart from the tetrahedral carbon so the position of the charge should reflect this. The three-dimensional representation of the tetrahedral carbon is fine but using dotted bonds is not as they indicate a transition state.

Question 20 (c) (i)

The great majority of candidates appreciated the importance of ease of separation but there was a good deal on the mechanism of heterogeneous catalysis, sometimes in place of the correct answer.

Question 20 (c) (ii)

The reagents needed for the hydrolysis of the nitrile group were reasonably well known although some candidates appeared to be trying to effect a substitution using a carboxylic acid. The use of phosphorus and iodine in reaction 1 was known by a minority of candidates although at least as many gained the mark by using HI.

Question 20 (c) (iii)

Selecting the carbonyl group as the important difference between these two molecules proved a significant challenge and many who did then gave the infrared range for the C=O of ketones rather than carboxylic acids.

Question 20 (d) (i)

Most candidates still score this mark by defining a chiral carbon atom rather than the fact that the molecule is non-superimposable on its mirror image. The mark was often lost through carelessness of expression, with superimposable molecules, molecules with four groups and carbon atoms bonded to four molecules were surprisingly common.

(1)

An a carbon A molecule which has a carbon atom
surrounded by four different groups



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Examiner Comments

An 'allow'. The carbon needs really to be bonded to rather than surrounded by four different groups.



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Examiner Tip

Using precise technical language is always an advantage.

Question 20 (d) (ii)

Most candidates could identify the chiral centre.

Question 20 (d) (iii)

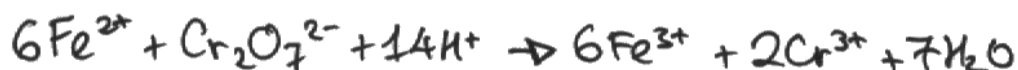
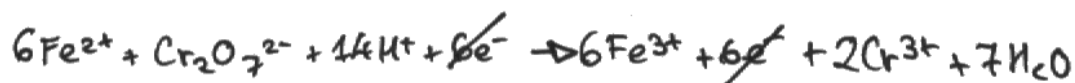
Candidates who failed to score this mark usually omitted 'equimolar' or one of the many allowed alternatives.

Question 20 (d) (iv)

The responses to this question illustrated the reluctance of many candidates to think logically about a problem and to express their ideas concisely. Many responses were generalised, mentioning atom economy, yield and side-effects without really addressing the specific question.

Question 21 (a)

There were many excellent answers to this problem. The most common error was the omission of one of the scaling factors (usually the 10) in a(v). Many candidates struggled to write the half-equation for the oxidation of ethanol and some who used the reacting ratio as an aid here, reversed the ratio and derived an equation with two electrons rather than four. There were plenty of opportunities to go astray, the most surprising recurring error was to reverse the position of the iron ions in the equation in a(i).



(ii) Calculate the number of moles of potassium dichromate(VI) that remained unreacted after standing for several hours with solution R.

$$\text{Moles of Fe}^{2+} : \frac{23.85 \times 0.255}{1000} = \cancel{0.00608175} \quad (2)$$

6.08175×10^{-3}

6:1 ratio so $\div 6$

\rightarrow ~~1.013625~~

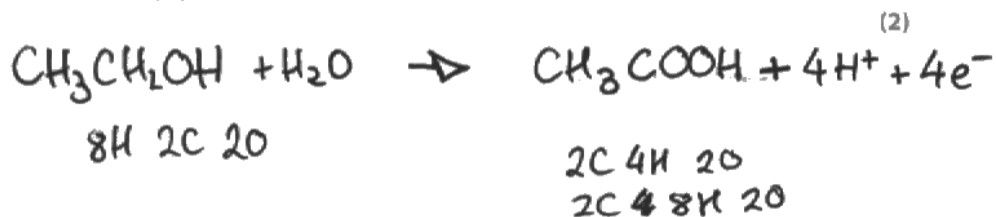
$$1.013625 \times 10^{-3} \text{ mol}$$

Moles of $\text{Cr}_2\text{O}_7^{2-}$ at beginning: $\frac{25 \times 0.200}{1000} = 5 \times 10^{-3}$ ⁽²⁾

$5 \times 10^{-3} - 1.013625 \times 10^{-3}$
 $= 3.986375 \times 10^{-3} \text{ mol}$
 reacted ($\approx 3.99 \text{ mol}$)
 $\times 10^{-3}$

(iv) Write an ionic half-equation for the oxidation of ethanol to ethanoic acid.

Use your equation, and the half-equation for the reduction of dichromate(VI) ions, to show that 3 mol of ethanol are oxidized by 2 mol of potassium dichromate(VI).



$\text{Cr}_2\text{O}_7^{2-}$ is reduced by 6e^- , $\text{CH}_3\text{CH}_2\text{OH}$'s oxidation produces 4e^- .
 $2 \times 6 = 12\text{e}^-$ $3 \times 4\text{e}^- = 12\text{e}^-$. As the numbers of electrons on both sides of the equation are equal, this is the correct ratio. ⁽³⁾

(v) Calculate the concentration of ethanol (in mol dm^{-3}) in solution Q.

$3.986375 \times 10^{-3} \text{ mol}$ of dichromate(vi)
~~3.98~~ 2:3 ratio
 $\rightarrow \times 1.5 = 5.9795625 \times 10^{-3} \text{ moles of ethanol}$
 in 25cm^3 of R
 $\rightarrow \times 10 = 5.9795625 \times 10^{-2} \text{ mol in } 25\text{cm}^3 \text{ Q}$
 $\times 40 \text{ g} \quad 5.979... : 25 \quad 2 \times 40$
 $\times 40 \text{ g} \quad 2.391825 : 1000$
 $\rightarrow \boxed{2.39 \text{ mol dm}^{-3}}$



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 Examiner Comments

A fully correct and nicely set out response.

Question 21 (b)

This was a challenging question made more difficult if the stem of the question was not studied with sufficient care. Thus many answers ignored the context of the question and stated that the indicator was acid-base or the purple colour was due to the presence of the manganate(VII) ion. However, a good number of candidates, recognising that the end-point of a titration is indicated by the first permanent appearance in the solution of a particular species, as with, for example, MnO_4^- in manganate(VII) titrations, correctly deduced that Fe^{2+} was the species required by the first mark. Good candidates were able to see that, by analogy with the familiar acid-base indicators, a redox indicator would have different colours in its oxidized and reduced forms.

Fe^{2+} causes the colour change. A redox reaction is involved when Fe^{2+} is added to barium diphenylamine sulfonate. Fe^{2+} is oxidised and loses an electron whereas barium diphenylamine sulfonate is reduced. This reduction effects the amount of delocalisation in the molecule and so causes it to change colour.



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Examiner Comments

Good candidates could score well on this question and this is a nice example of a thoughtful, concise response.

Question 21 (c)

There were many excellent answers to this question where candidates drew on their knowledge of alcohol oxidation to identify a possible flaw in the experimental technique and followed the subsequent logic impeccably. Once again, some failed to take note of the information in the stem and wrote at length about tolerances in titration apparatus and repeats or even transfer losses. A few candidates missed the point altogether and discussed the fermentation rather than the analysis.

As the ethanol can undergo partial oxidation to ethanal meaning the volume of potassium dichromate ~~used~~ reacted will be less than it should be as it requires less dichromate to only partially oxidise the ethanol. This means the volume of unreacted potassium dichromate will be higher than it should be so the measured concentration will be lower than the actual value.



ResultsPlus
Examiner Comments

A good example of a response covered by the 'EITHER' route in the mark scheme.

This could be because the potassium dichromate may react with/oxidise other substances that are in solution & e.g. solution & may contain other reactants to react with dichromate. Therefore the amount of $K_2Cr_2O_7$ that reacts may be more than it should. The measured concentration would therefore be higher than the actual concentration.



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Examiner Comments

This is a good example of the 'OR' route on the mark scheme. The candidate navigates neatly through the various potential pitfalls.

some of the ethanol evaporates when the mixture is allowed to stand, therefore less $\text{Cr}_2\text{O}_7^{2-}$ is reduced, ^{by the ethanol} therefore the titre value is higher. Therefore the measured concentration would be lower than the actual concentration.



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Examiner Comments

There is no credit for the first point but thereafter the answer is impeccable, dealing nicely with the potential confusion of titre and amount of dichromate(VI) used.

Question 22 (a)

Few candidates knew or could work out the nature of the interaction between water molecules and sodium ions, which was frequently described as ionic. Mention of the δ^- on the oxygen was very rare. Some candidates suggested a reaction forming sodium hydroxide.

Question 22 (b)

Few candidates progressed beyond repeating the stem of the question without considering the feature of an aluminium ion which allowed it to accept the lone pairs. There was much confusion about the nature of the interaction including a number of candidates stating that Al^{3+} would donate lone pairs to the F^- ion.

Aluminium has 3 electrons in the 3rd electron shell,
when it forms dative covalent bonds with F^- , F^- donates
a pair of electrons which can also go into the 3d orbital of
aluminium.



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Examiner Comments

Despite the 'also', which implies electrons already in the 3d orbitals, this was felt to be sufficient for the mark.

Question 22 (c) (i)

This is another familiar question that still produces a spread of marks. Many candidates lost a mark due to careless use of technical terms: orbital, subshell and shell were used interchangeably by many candidates, as were emitted and transmitted by some. A number of responses included very detailed but superfluous explanations of what causes the splitting of the 3d subshell. A number of candidates referred to the opposite colour being seen rather than the complementary colour. In addition to the usual confusion between the colour of complex ions and flame test colours, some candidates, having seemingly memorised a response, revealed a lack of understanding by references to the splitting of orbitals by the absorption of light and the emission of the complementary colour as the electrons return to the ground state.

Question 22 (c) (ii)

Unsurprisingly there were many correct responses to this question but once again careless use of orbital, subshell and shell often cost the mark. A number of candidates asserted that the filled orbitals prevented splitting rather than transitions, an error that was not penalised. Some candidates simply gave as their explanation that zinc was not a transition metal.

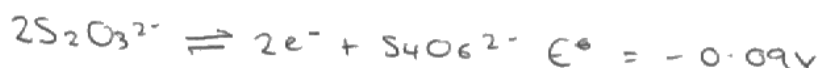
Question 22 (c) (iii)

Although many candidates referred, in their account, to the colours of transition metal complexes and to the effect of the ligands on the size of the energy gap, few applied the idea to this question. Most assumed that the strength of the interactions prevented either subshell splitting or the movement of electrons.

Question 22 (d)

The technical requirements of this question were well within the capabilities of competent candidates but marks were frequently lost through failure to complete the answer. Some stopped after the calculation of the first E_{cell} value and others stopped before writing the equations for the reactions. There was confusion between feasibility and whether a reaction would go (i.e. between thermodynamic and kinetic factors) which caused difficulties. A small number of candidates also attempted to discuss feasibility in terms of the magnitude of the E_{cell} value, often using a very large value of $E_{\text{cell}} = 0.4 \text{ V}$ as a cut-off. Many of the minority of candidates who attempted to use the anticlockwise rule became confused in their explanations and found it much more difficult to score the marks than those who used E_{cell} calculations.

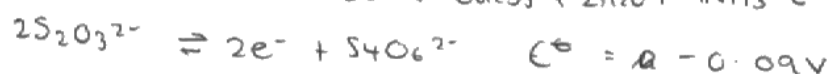
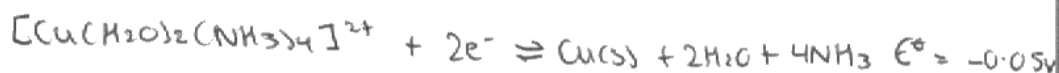
for Cu(II) ions dissolved in water:



$$\begin{aligned} \therefore E^\circ_{\text{cell}} &= 0.34 - 0.09 \\ &= +0.25\text{V} \end{aligned}$$

E°_{cell} & ΔS_{total} so ΔS_{total} is positive meaning reaction is thermodynamically feasible & reaction will occur!

for Cu(II) ions dissolved in ammonia:



$$\begin{aligned} \therefore E^\circ_{\text{cell}} &= -0.05 - 0.09 \\ &= -0.14\text{V} \end{aligned}$$

E°_{cell} is negative and so is ΔS_{total} so reaction is not thermodynamically feasible and so will not occur.



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Examiner Comments

The candidate has left out the equations so scores two marks for the very clearly presented E_{cell} calculations and the associated deductions.

Question 22 (e) (i)

Most candidates correctly deduced the coordination number of the complex. The common alternative was 2, presumably from the stoichiometry of the reaction.

Question 22 (e) (ii)

Common errors among responses using the correct method were the use of 4.82 in the final stage and a surprising number of incorrect values for the relative atomic mass of nickel, including the atomic number of nickel and the relative atomic mass of nitrogen. Otherwise candidates calculated the moles of complex and stopped.

Question 22 (f)

Few candidates realised the importance of nickel carbonyl being a gas and many discussed the dimethylglyoxime complex.

Question 22 (g)

Candidates frequently ignored the instruction at the start of this question to 'use the equilibria', answering in terms of often elaborate entropy calculations or discussions of the reaction between Tollens' reagent and aldehydes, often in the mistaken belief that the precipitate formed by the addition of alkali to silver nitrate was the silver mirror. Candidates who adopted the correct approach sometimes failed to identify clearly the equilibrium that they were discussing. There was little evidence of candidates referring back to the part of the passage where the preparation of Tollens' reagent was described.

The ammonia forms a complex ion with the silver which is Tollens' reagent, diammine silver (I). ~~This is the~~
The ammonia thus prevents the formation of the solid precipitate of Ag_2O as it reacts with the Ag^+ ions thus pushing equilibrium 1 to the left.



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Examiner Comments

This response scored 2 marks. The understanding of the equilibrium processes is good but the discussion omits any mention of equilibrium 2.

Paper Summary

On the evidence of their performance on this paper candidates are offered the following advice:

- Always read the question carefully and check that you understand what is required.
- Then, after you have written your answer, re-read the question and your answer to ensure you have fully answered the question.
- Always check organic formula you have written to ensure you have the correct number of bonds to each atom in the structure.
- In extended calculations, don't round intermediate values; keep the number in your calculator.
- Make sure you understand the precise meaning of chemical terms and can use them appropriately
- Practise questions where the context is unfamiliar.

Grade Boundaries

Grade boundaries for this, and all other papers, can be found on the website on this link:

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