



Examiners' Report

June 2024

IAL Chemistry WCH15 01

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Introduction

The paper was accessible to most candidates and provided a full range of marks. Some candidates scored very high marks and were well prepared for the examination, showing excellent learning and teaching has taken place. Many had a sound knowledge of the specification and could demonstrate this in their explanations and descriptions. However, a minority of candidates found the questions challenging and need to express their understanding of chemistry more clearly. The calculations were generally well attempted with the main errors being in the rearrangement of formulae. There were no reports of candidates running out of time and the majority of candidates provided responses to the last question, indicating that the paper was not unduly long. The mean mark for the paper was 45, the same as last year's paper in the June series.

Section A

The mean mark on the multiple-choice questions was 13.

The highest scoring questions were Question 12(a) (Grignard metal), Question 9(a) (percentage atom economy) and Question 3 (Roman numeral oxidation numbers and redox titration). Over 85% of candidates chose the correct answers for these items.

The least accessible question was Question 11(b) (impurity in aspirin), with only 13% getting the answer correct. Question 10(b)(i) (structure of a dipeptide), and Question 11(a) (liquid for testing melting point) also presented difficulties.

Question 14 (a)(i)

Over 80% of candidates achieved a mark here. Any answer relating to reduction was accepted but those that mentioned "redox" or "equilibrium" were ignored. Several "oxidation" answers were seen showing a lack of understanding of basic redox chemistry. A very small number gave disproportionation, endo or exothermic or reversible and the occasional organic reaction type.

An example of a correct answer.

14 This question is about cell reactions involving chromium.

Use your Data Booklet when answering this question.

- (a) (i) Name the type of the forward reaction that is shown in the right-hand electrode systems in the Data Booklet.

Reduction Reaction



This candidate scored the mark.

An example of an answer that did not score.

14 This question is about cell reactions involving chromium.

Use your Data Booklet when answering this question.

- (a) (i) Name the type of the forward reaction that is shown in the right-hand electrode systems in the Data Booklet.

standard electrode potentials



This was a common incorrect answer, along with half-cell reactions.

Question 14 (a)(ii)

Less than 25% of candidates achieved a mark here, though this was expected to be simple recall of a statement on the specification. Many answers overlapped with answers given for Question 14(a)(i), though a variety of incorrect answers were seen.

The expected answer.

- (ii) Name the series formed when the right-hand electrode systems are placed in order, most negative first.

Electrochemical series.



This answer is the correct answer as per the specification and scored the mark.

An unexpected answer.

- (ii) Name the series formed when the right-hand electrode systems are placed in order, most negative first.

Reduction Potential Series



This answer also scored the mark, though it is not the answer given on the specification.

An example of an incorrect answer.

- (ii) Name the series formed when the right-hand electrode systems are placed in order, most negative first.

reactivity series



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Examiner Comments

This answer did not score. Though the electrochemical series does have similarities with the reactivity series, the answer "reactivity series" does not give enough precision to gain credit.



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Examiner Tip

Read through the specification as part of your revision, highlighting the key terms and definitions you should know.

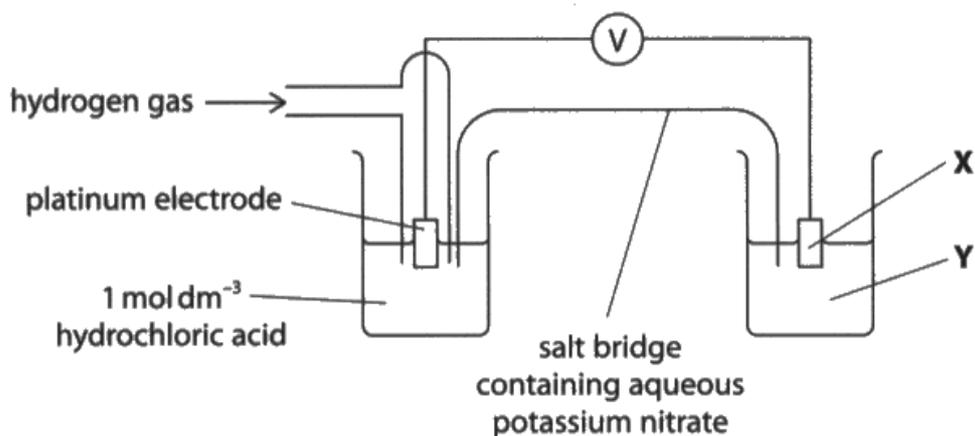
Question 14 (b)

There were 6 marks available here, but the mean achieved by all candidates was 1.8. Looking at candidates answers, the most commonly scored mark was (i) for X. Y was less frequently achieved, with many candidates omitting the concentrations of the two ions. The second most frequently awarded mark was the rescue mark for part (ii), where candidates just stated that one of the conditions were not standard. Only the best candidates appreciated that the Cr^{2+} would be oxidised in air. This was also true in part (iii) and so the solution would become more green due to the changing concentrations and the positive E_{cell} value when the cell was left running.

The poor outcomes on this question indicate that candidates do not fully appreciate the factors that affect electrochemical cells or why they produce current. More time may be needed on this topic in the classroom.

A typical candidate response.

- (b) A student set up the following apparatus to measure the standard electrode potential for right-hand electrode system 8 in your Data Booklet.



- (i) Identify X and Y.

(2)

x: Platinum black

y: 1 mol dm⁻³ solution of Cr³⁺ and Cr²⁺ ions

- (ii) Give **two** reasons why the initial reading on the voltmeter may differ from the stated value given in the Data Booklet.

(2)

The experiment of the student may not be held under standard conditions.

The reaction may require a high activation energy

(iii) The voltmeter is removed and the cell is allowed to run for one hour.

Explain the changes that would occur in the right-hand half-cell during this time.

(2)

Cr^{3+} ions will be reduced to Cr^{2+} ions as electrons will flow from the anode, which is the left-hand cell, to the cathode. An equilibrium will be established, giving a high concentration of Cr^{2+} ions, as ~~concent~~ electrons increase.



Equilibrium shifts to the right.



The candidate gains both marks for part (i).

In part (ii), the candidate gains the rescue mark for "not standard conditions".

No credit is given in part (iii), the candidate has the equilibrium moving in the wrong direction.



Data given earlier in the question is often required in explanations later on. Read back over the start of the question and apply it to your answer.

An example of a correct answer for part (iii).

(iii) The voltmeter is removed and the cell is allowed to run for one hour.

Explain the changes that would occur in the right-hand half-cell during this time.

(2)

$E_{\text{cell}} = 0 + 0.41 = 0.41 \text{ V} > 0$ for oxidising Cr^{2+} ,
so it's thermodynamically feasible for Cr^{2+} oxidising to
form Cr^{3+} by losing e^- , ~~so~~ so K^+ travels from
salt bridge to the right hand ^{half} cell to neutralise
the charge.



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Examiner Comments

This response is unusual as it scores both marks for part (iii). The candidate uses the half equation given in the question and applies it to the running cell.

Question 14 (c)(i)

Candidates struggled with this question. Many could not choose the correct equations to allow them to continue to do the calculations – a number included 7 rather than 5. Another common issue was not using all possible combinations of reactions in their answer (i.e. only the odd E_{cell} was calculated). Moreover, candidates often compared standard electrode potentials rather than calculating E_{cell} . Quite often, it was clear that a candidate did not understand that the E_{cell} value determined feasibility and this limited their score.

Over 40% of candidates did not gain any marks at all and the average mark was one. More time may be required covering the redox reactions in the specification given the poor achievement on this question. Candidates are expected to use electrode potentials, either given or from the data booklet to explain the feasibility of reactions.

An example of an excellent answer.

- (c) (i) Explain, by calculating $E_{\text{cell}}^{\ominus}$ values, why Fe(II) is used to reduce Cr(VI) to Cr(III) but zinc is used to reduce Cr(VI) to Cr(II). (4)

Numbers chosen of the right-hand electrode systems from the Data Booklet

5, 8, 21, 28

Explanation

Fe(II) can reduce Cr(VI) to Cr(III) as $E_{\text{cell}}^{\ominus} = +1.33 - (0.77) = +0.56\text{V}$
as positive so feasible. ~~Fe~~ Zinc can also reduce Cr(VI) to
Cr(III) as $E_{\text{cell}}^{\ominus} = +1.33 - (-0.76) = +2.09\text{V}$ as positive so feasible.
But Fe(II) can't reduce Cr(III) to Cr(II) as $E_{\text{cell}}^{\ominus} = -0.41 - 0.77$
 $> -1.18\text{V}$ which is negative. However zinc can
reduce Cr(III) to Cr(II) as $E_{\text{cell}}^{\ominus} = -0.41 - (-0.76) = +0.35\text{V}$.
So zinc used to reduce Cr(VI) to Cr(II) instead
of Fe(II)



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Examiner Comments

This candidate gains all 4 marks. The correct equation numbers have been chosen and then used to calculate the four E_{cell} values required.

An example of an answer that scored 1.

- (c) (i) Explain, by calculating $E_{\text{cell}}^{\ominus}$ values, why Fe(II) is used to reduce Cr(VI) to Cr(III) but zinc is used to reduce Cr(VI) to Cr(II).

(4)

Numbers chosen of the right-hand electrode systems from the Data Booklet

28, 8, 21, 5

Explanation

The E^{\ominus} of reducing Cr(VI) to Cr(III) is +1.33. The E^{\ominus} of oxidising Fe(II) is -0.77. The E^{\ominus} of reducing Cr(III) to Cr(II) is -0.41.

The $E^{\ominus}_{\text{cell}}$ of Cr(VI) to Cr(III) is bigger than 0, $E^{\ominus}_{\text{cell}}$ of Cr(VI) to Cr(II) is

The E^{\ominus} of oxidising zinc is +0.76. } Smaller than 0.

The $E^{\ominus}_{\text{cell}}$ of Cr(VI) to Cr(II) is greater than 0.



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Examiner Comments

This candidate gains a mark for the four correct equation numbers, but then does not calculate any E_{cell} values as asked for in the question.



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Examiner Tip

Underline essential parts of the answer in the question. This candidate has missed that E_{cell} values are required.

Question 14 (c)(ii)

The majority of candidates did not gain a mark here. Many gave answers that related to standard conditions or cell components and missed the H^+ in the standard electrode potential equation 28.

An example of a correct answer.

(ii) State the essential condition required for these reactions to occur.

H^+ ions to be present.



This candidate has recalled that acid is required for the reaction to occur – or they may have taken the clue from the standard electrode potentials chosen for the previous part.



When using the data book, look for any information that you have not yet used for previous parts.

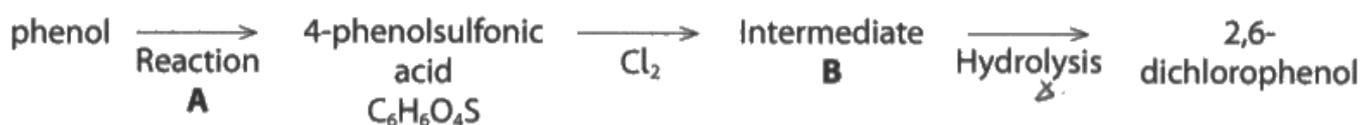
Question 15 (a)(i)

This question was well answered with over 75% of candidates gaining the mark and a variety of correct answers were seen, including the formula (though rarely named) for oleum, and the name and formula for sulfuric acid, often with the "fuming" before. Though dilute acid could not score, the "concentrated" was not an absolute requirement. SO_2 was ignored but occasionally seen and incorrect answers usually just involved SO_3 alone. Some candidates lost the mark for giving the answer "concentrated sulfuric acid (aq)".

An example of a correct answer.

...analysis of intermediate compound B removed the sulfonic acid group.

The reaction scheme is shown.



- (a) (i) The sulfonation of phenol is similar to the sulfonation of benzene. Suggest the reagent(s) required for Reaction A. Δ .

(1)

SO_3 and conc. H_2SO_4



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Examiner Comments

This candidate has a fully correct answer and gains the mark. We can see understanding in the inclusion of both the SO_3 and "conc.".



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Examiner Tip

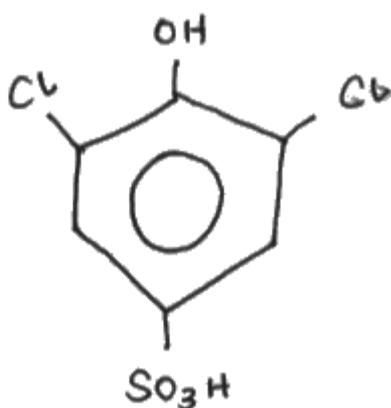
Write out a list of reagents required for different reactions as part of your revision.

Question 15 (a)(ii)

Only 20% of candidates gained the mark here. Many had most of the structure correct but lost the mark due to imprecise bonding of the sulfonic acid group. Other candidates drew this part correctly but attached it to the wrong carbon atom on the benzene or omitted the phenol or either chlorine atom from their intermediate structure. Other near misses included SO_3 (omitting the hydrogen atom), adding the sulphonic acid group to C3 or replacing the OH at C1 and just a small number omitted the arene ring altogether.

An example of a response that did not score.

(ii) Deduce the structure of intermediate compound B.



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Examiner Comments

Though the formula of this intermediate is correct, it is not clear from the candidate's structure that the benzene ring is attached to the sulfur atom. A fully displayed diagram may have resolved this ambiguity.



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Examiner Tip

Be precise when drawing structures. You need to show which atom is bonded to other parts of the structure.

Question 15 (a)(iii)

Over a third of candidates gained all three marks here. This type of question reoccurs frequently on WCH15 and the marks allowed and mark scheme are standardised, so these candidates had obviously been doing their past papers. Where candidates didn't score all the marks, M1 was the most frequently awarded followed by M2. Some candidates omitted the overlap with the **electrons** on the ring so couldn't score M2.

An example of a common response.

(iii) Explain why the reaction of chlorine with phenol occurs under milder conditions than the reaction of chlorine with benzene.

(3)

As lone pair on O atom of OH on phenol overlaps with delocalised π electrons of benzene ring, so higher electron density and electrons more readily available than benzene.



This candidate gains the first 2 marks but doesn't mention what type of reaction will proceed from the increased electron density.



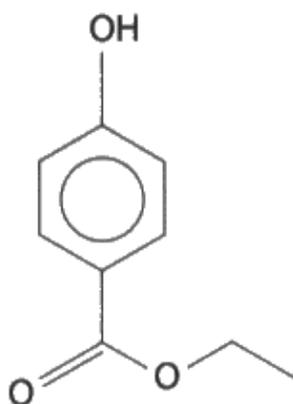
Review previous mark schemes to see what points are required in commonly reoccurring questions.

Question 15 (b)

Over half of candidates gained this mark. Incorrect answers mainly involved C=O groups, such as carbonyl, ketone, carboxylic acid, though ether, aldehyde, alkyl were seen and a few students gave components of the phenyl group. Some interesting spellings were seen – both Easter and Esther made occasional appearances.

An example of a correct answer.

(b) An alternative synthesis of 2,6-dichlorophenol starts with compound **C**.



compound **C**

Compound **C** is chlorinated and hydrolysed and then the CO₂ group is removed (decarboxylation) to form 2,6-dichlorophenol.

Other than phenol, name the functional group present in compound **C**.

ester



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Examiner Comments

This candidate has correctly identified the functional group.



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Examiner Tip

Remember that functional groups can involve more than two atoms!

Question 15 (c)

Over 70% of candidates gained credit here, though many did not gain full marks. Marks were often lost for imprecise answers, using words like "yield", "safety", "cost" and "rate and reaction". Marks were most frequently awarded for percentage yield, atom economy, number of steps and reaction conditions (often because candidates mentioned temperature or pressure). The most able candidates gave an extensive list of considerations and so scored all the marks available.

An example of a well structured answer.

(c) Identify **three** factors that organic chemists would take into account when considering alternative methods for an organic synthesis.

(3)

Percentage yield - how more/less economic
new alternative is.

Conditions: How harder/easier it is to
achieve conditions for alternative reaction

Safety: Are there any safety issues/toxic
byproducts to an alternative method?



This candidate has 3 clear points in their answer, and has then expanded on them so they are able to score all 3 marks.



Using the question and marks available is an excellent way to structure your answer. Bullet points or separate paragraphs will never be penalised on short answer questions.

An example of a vague answer.

- Safety of reaction / less hazards
- ~~to~~ atom economy / yield
- ~~efficiency~~ / rate of reaction



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Examiner Comments

This candidate limits their achievement with the lack of precision in their answer. "Yield", "safety" and "rate of reaction" were all ignored on their own as the candidate is not linking these key words to the question.



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Examiner Tip

Answer using as much detail as possible. Vague answers won't score as many marks.

Question 15 (d)(i)

Over 75% of candidates failed to score here, indicating that they had not retained understanding from their AS modules. Many assumed that hydrogen atoms were being removed from the molecule to form the peaks and so did not score. It is important that candidates review the earlier modules when sitting the A2 exams as there will be synoptic questions. Here candidates were expected to recall the two isotopes of chlorine and their relative abundancies using the spectrum ratios as a prompt. M2 was more regularly awarded than M1, with candidates indicating which chlorine isotopes were present in each peak. A concerning regular mistake was that some candidates stated that ^{36}Cl was present.

A rare answer scoring both marks.

(i) Explain the relative intensities of the peaks at m/z values of 162, 164 and 166.

(2)

~~$m/z = 162$ peak is because of $\text{C}_6\text{H}_5\text{Cl}_2\text{O}^+$, which can remove any of the hydrogen atom, so relative intensity highest.~~

Cl has two isotopes: ^{35}Cl and ^{37}Cl , ratio 3:1.

so $m/z = 162$ is because of two ^{35}Cl , 164 corresponds to

$^{35}\text{Cl}^{37}\text{Cl}$, 166 is ~~^{37}Cl~~ $^{37}\text{Cl}^{37}\text{Cl}$, so relative intensity is

9:6:1



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Examiner Comments

This is an example of a candidate who scores both marks. The candidate has appreciated they are on the wrong path and crossed out their initial answer, replacing it with a fully correct response.



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Examiner Tip

Review your notes on the AS modules as part of your revision for the A2 exams – there will be synoptic questions where this knowledge is expected.

Question 15 (d)(ii)

Most correct answers here mentioned the carbon-13 isotope. Few identified deuterium as being the source of the M+1 peaks. Among the incorrect responses, again a few candidates mentioned the presence of ^{36}Cl or even $^{35.5}\text{Cl}$ which is concerning. Fewer than 15% of candidates gained the mark here, showing that candidates may not have been challenged in class with questions requiring reasoning and application of earlier concepts to their A2 understanding.

An example of a correct response.

(ii) Suggest why there is a corresponding set of peaks at m/z values of 163, 165 and 167.

(1)

This is caused by the isotope C-13 of carbon which is present in small amounts.



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Examiner Comments

This candidate scored the mark. They have correctly identified the isotope most likely to cause the M+1 peaks.

Question 16 (a)

Just over half of candidates gained any credit here. Common errors leading to M1 not being awarded included not balancing their equation for water on the right hand side, including the charge for the hydroxide ligand in their complex and including NaOH as the reagent, but then not including the spectator ions. Where NH₃ was used, a significant number of candidates thought ligand substitution took place rather than the precipitation reaction. For M2 a surprising number of candidates gave the state symbol for water as (aq).

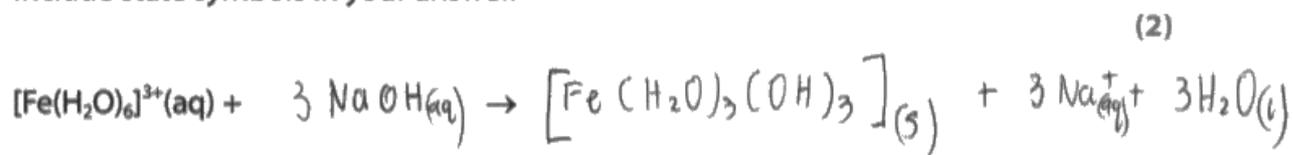
A correct response including spectator ions.

16 Metal ions occur naturally in river water but near industrial plants the concentrations can reach toxic levels. Wastewater from a stainless steel electropolishing plant contains dangerous concentrations of transition metal ions as aqueous complexes.

Chemical precipitation can be used to remove these ions from the water.

(a) Complete the equation for the reaction of a laboratory reagent with aqueous Fe³⁺ ions to produce a precipitate.

Include state symbols in your answer.



This candidate gains both marks but has made extra work for themselves by including the sodium ions on both sides. However, the equation is balanced and all the state symbols are correct.



Double check your equations to make sure they are balanced for atoms and charges.

An unusual response.

16 Metal ions occur naturally in river water but near industrial plants the concentrations can reach toxic levels. Wastewater from a stainless steel electropolishing plant contains dangerous concentrations of transition metal ions as aqueous complexes.

Chemical precipitation can be used to remove these ions from the water.

(a) Complete the equation for the reaction of a laboratory reagent with aqueous Fe^{3+} ions to produce a precipitate.

Include state symbols in your answer.

(2)



This candidate has used ammonia as their laboratory reagent. The products are correct and balanced, but they have omitted the state symbols that are required for the second mark. The candidate has underlined all parts of the question excluding the command to include state symbols, so it is possible they did not read this part of the question.



Read the whole question twice before answering to ensure you understand what is required before you begin your answer.

Question 16 (b)(i)

Just under half of all candidates gained three marks here. Where marks were lost, they were evenly distributed over all three marking points.

Incorrect answers for M1 often gave the charge on the whole complex (1-) rather than calculating the charge for the nickel ion, using the final charge and the combined charges on the ligands, though 3+, 3- and 5+ were all also seen regularly.

Bidentate was well known, though the spelling proved challenging and some licence was given. Incorrect answers for M2 included Hexadentate as a popular wrong answer and some described the chemistry of the ligand (anion, thionyl).

A few candidates were misled by the diagram to give a coordination number of 3, though the vast majority counted the six bonds. Common incorrect shapes were trigonal planar (from misreading the diagram), pyramidal, tetrahedral or hexahedral.

This response scores all available marks.

(i) Complete the table for the complex.

Charge on nickel ion	2+
Type of ligand	bidentate
Co-ordination number of the nickel ion	6
Shape of metal complex around the nickel ion	octahedral



This candidate has correctly deduced the charge on the nickel ion, identified the type of ligand, the coordination number and the shape of the complex.

An example of a typical response.

Charge on nickel ion	-3
Type of ligand	polydentate ligand
Co-ordination number of the nickel ion	6
Shape of metal complex around the nickel ion	octahedral



This candidate only scores 1 of the marks available (M3, for the coordination number and the shape of the complex). Polydentate was not allowed as the ligand specifically forms two coordinate bonds and the term bidentate is specifically mentioned on the specification, so M2 is not awarded. The candidate appears to have calculated the combined charge of the ligands instead of the central ion, so no M1.



Use the charge of the complex and the charge on the ligand to work back to the charge on the central ion.

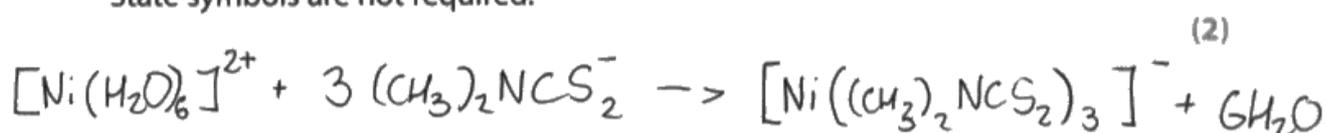
Question 16 (b)(ii)

Over half of candidates did not gain any credit here and the question was poorly answered. The usual reasons for not scoring M1 for the equation were an incorrect formula for the complex ion in the product (usually because the '3' was missing or the inclusion of Na) or not balancing the water molecules correctly. M2 was often not scored because the candidate mentioned molecules or just stated more products than reactants. Where mole quantities were mentioned, these were usually correct.

An example of a fully correct answer.

- (ii) Explain, using a balanced equation, why the formation of the dimethyldithiocarbamate complex from an aqueous solution of nickel ions is thermodynamically feasible.

State symbols are not required.

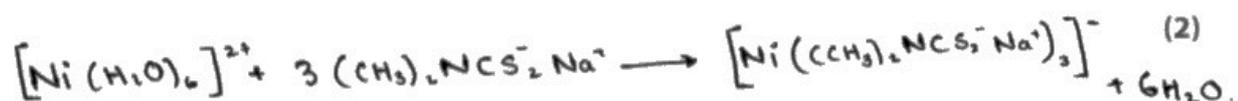


there are more moles of products than moles of reactants so entropy increases. Therefore the reaction is feasible



This candidate scores both marks. The equation is fully correct, showing the ligand exchange and is balanced. The explanation refers to moles which is allowed. The numbers were not necessary here as they are given by the diagram, and the candidate notes the entropy increasing.

A response highlighting common errors.



Number of molecules increase from 4 to 7, so total entropy increases and reaction is thermodynamically feasible.



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Examiner Comments

This candidate has included sodium within the complex so cannot score M1. They have referred to molecules in their explanation so cannot score M2.



ResultsPlus
Examiner Tip

Refer back to earlier diagrams (where available) when writing your formulae.

Question 16 (b)(iii)

Over a third of candidates scored 2 or more marks here. Though the maths was often correct in process, many used the M_r of the ligand as the total M_r so limited themselves to 2 marks by TE. The majority of candidates correctly converted the mass units, and the most common mistake was dividing by 3 once moles had been calculated due to there being three ligands in the complex before then dividing by 5 – the number of litres of water – in the final step as many candidates used the alternative route in their answer.

A fully correct response.

- (iii) When a 5 dm³ sample of wastewater was treated with excess **acidified** sodium dimethyldithiocarbamate, 245.0 mg of the dry precipitate H⁺[Ni((CH₃)₂NCS₂)₃]⁻ was formed.

Calculate the concentration, in mol dm⁻³, of nickel ions in the sample.

[Molar mass of dimethyldithiocarbamate ion = 120.2 g mol⁻¹]

(3)

$$\begin{aligned} \text{Moles of } \text{H}^+[\text{Ni}((\text{CH}_3)_2\text{NCS}_2)_3]^- &= \frac{245 \times 10^{-3}}{3 \times 120.2 + 58.7 + 1} \\ &= 0.0005829 \text{ mol} \end{aligned}$$

$$\text{Mol ratio} = 1:1$$

$$\begin{aligned} \text{Concentration} &= \frac{0.0005829}{5} = 0.00011658 \text{ mol dm}^{-3} \\ &\approx 0.0001166 \text{ mol dm}^{-3} \end{aligned}$$



ResultsPlus
Examiner Comments

Though candidates often give their answers in standard form (as seen on their calculators), this answer is fully correct and scores all 3 marks. The candidate has calculated the M_r of the precipitate correctly, divided the mass from the question by the M_r and then calculated the concentration per dm³.



ResultsPlus
Examiner Tip

Pay attention to the units given in the question and the units required for the answer.

A common response.

relative mass of anhydrous calcium sulfate = 120.2 g mol⁻¹

$$\frac{2.45}{1000} = \frac{0.245 \text{ g}}{120.2} \times \frac{5}{\text{mol}} \times \frac{\text{M}}{\text{cm}^3} \quad (3)$$
$$= \frac{2.0382 \times 10^{-3}}{5}$$
$$= \underline{4.077 \times 10^{-4}}$$



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Examiner Comments

This candidate has not calculated the correct M_r for the precipitate and has instead used the molar mass for the ligand. This information was intended to help the candidates calculate the M_r of the precipitate, but candidates often did not use this value in the context of the whole question. The candidate scores 2 marks by TE as they correctly divide the mass by their M_r and then calculate the concentration per dm^3 .



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Examiner Tip

Use information given in the context of the whole question. Here the M_r still needs to be calculated.

Question 17 (a)

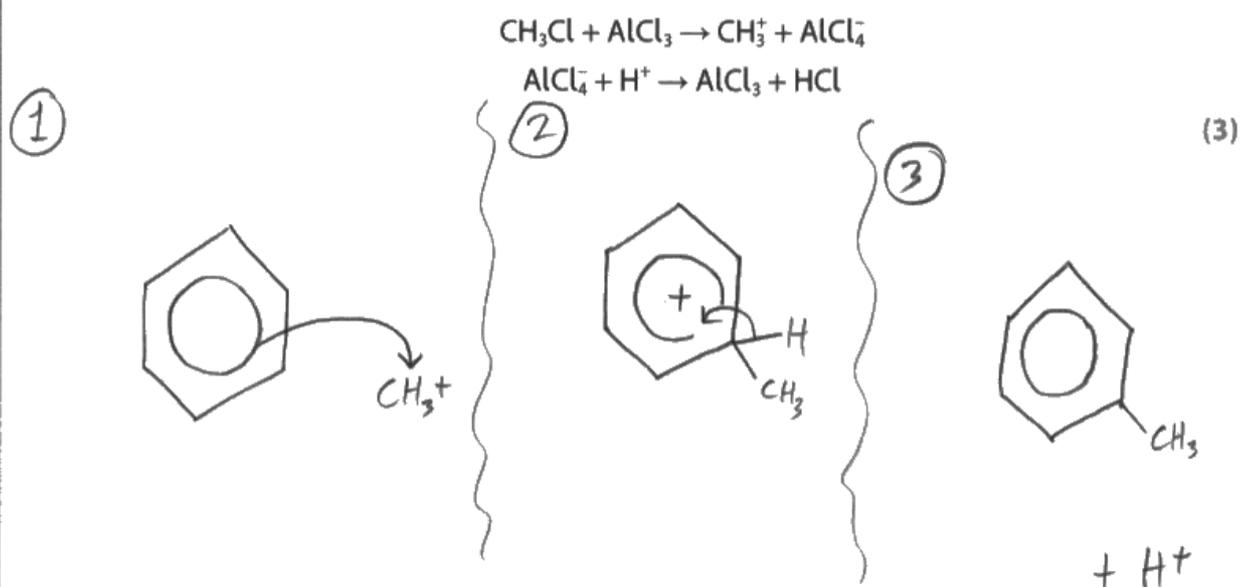
Over half of all candidates achieved all three marks here. Common mistakes included the arrow in step 1 not being aimed at the C, incorrect electrophiles, positive charges on the intermediate on the CH₃ and sloppy placement of the horseshoe.

An example of a fully correct answer.

- (a) The first step of the synthesis is the formation of methylbenzene, from benzene and chloromethane.

Draw the mechanism of this reaction.

Equations for the formation of the electrophile and regeneration of the catalyst are shown.



ResultsPlus
Examiner Comments

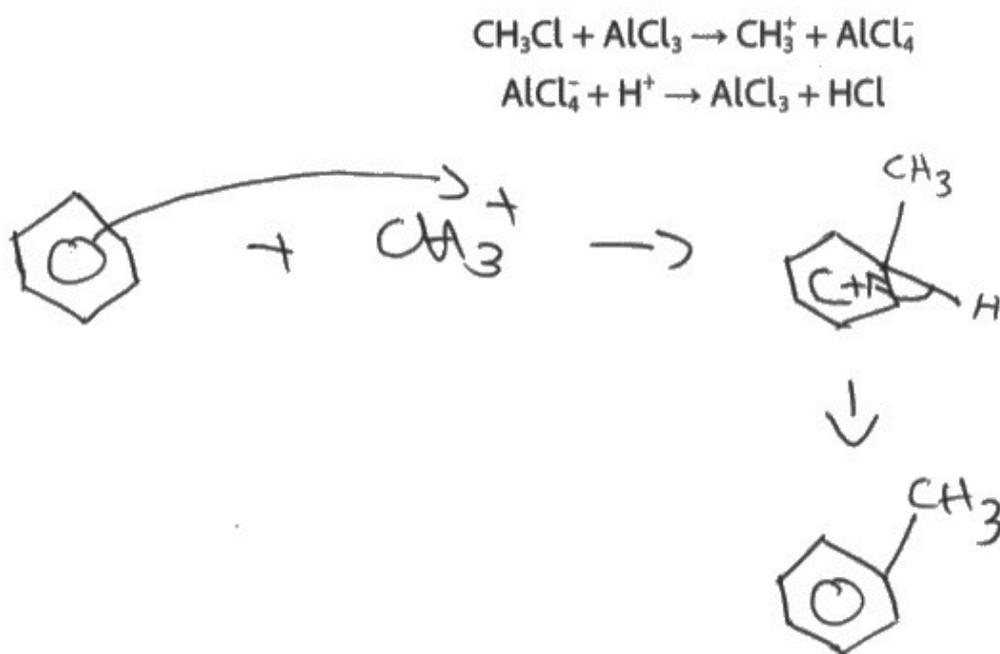
This candidate scores all 3 marks. There is no need for the dividing lines or numbers on the mechanism. The only improvement this candidate could make would be to ensure that their curly arrow doesn't make contact with their horseshoe from the intermediate ion. Though the horseshoe showing the delocalisation must cover at least 3 carbons, it can also be too large and here covers the area required for the curly arrow.



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Examiner Tip

Ensure all your lines are distinct and don't overlap.

An answer showing some common errors.



This candidate makes two errors in their mechanism. M1 is not awarded as the arrow needs to go to the carbon showing how the methyl ion is going to be connected to the benzene. Technically the positive charge should be on the carbon, though this was not penalised. M2 is also not awarded here as the positive charge is outside of the horseshoe showing the delocalisation. M3 is awarded for the correct curly arrow and final product.



Ensure you are precise in your writing of organic ions. The location of the charge is important. This candidate could have gained 2 marks if both charges were in the correct locations.

Question 17 (b)

45% of candidates did not score here and the mean mark was one. Of the candidates that did score marks, most candidates scored M3 as they identified that attack takes place from both sides and many were able to say that enantiomers formed for M1. Few candidates correctly articulated that the C=N area was planar. A common issue with this question was misunderstanding what was being asked. Because the question said to explain why one isomer is not formed, a lot of candidates went on to explain that isomers are not formed i.e. we do not get isomers at all. This may be an English comprehension problem but as many candidates could identify a chiral centre on the structure, it could be a misconception about chiral centres and enantiomers.

An example of a fully correct answer.

Explain, with reference to the mechanism, why this step in the reaction sequence will not produce a single isomer.

(3)

The reactant molecule is planar about $\begin{pmatrix} \text{H}-\text{C}=\text{N} \\ | \\ \text{benzene} \end{pmatrix}$, so CN^- can attack from either sides, forming a racemic mixture.



ResultsPlus
Examiner Comments

This answer is succinct and scores all 3 marks.



ResultsPlus
Examiner Tip

Using structures in your answer is an excellent way to communicate your explanation.

Question 17 (c)

Half of the candidates did not score here. M3 being dependent on M1 or M2 may have limited candidates achievement here but "reflux" or "heat" are the most common responses for any reaction conditions and would be insufficient for a mark at A2 level on their own. For M2, the most common mistake was the omission of water/dilute/aqueous. Alternative answers were mixed for M1 and there wasn't a common incorrect answer, with many reaction types and mechanisms seen.

A fully correct response.

State the type of reaction, and the reagent(s) and conditions required.

Type

Hydrolysis

Reagent(s)

dilute HCl (aq)

Conditions

Heat under reflux.



ResultsPlus
Examiner Comments

This candidate scores all 3 marks. Named strong acids were allowed for M2, provided they were dilute or aqueous.

An example of a response that does not score.



State the type of reaction, and the reagent(s) and conditions required.

Type

Oxidation reaction

Reagent(s)

H_2SO_4 [O]

Conditions

Heat under reflux



ResultsPlus
Examiner Comments

Oxidation reaction does not score M1, only hydrolysis was accepted. H_2SO_4 could have scored M2, but the acid is not stated as being dilute or aqueous so is insufficient. The [O] would have been ignored if the acid was credited.

M3 is dependent on M1 or M2 so no mark is awarded here, despite the answer being correct.



ResultsPlus
Examiner Tip

Revise all the reaction types on the specification and how they affect different species.

Question 18

The mean mark here was 2.6 and the full range of marks were seen. Few candidates were able to explain how a fuel cell worked and IP1 was the least frequently seen. Most candidates gained IP2 and IP3 for the half equations and most gained IP4/IP5 as they were able to correctly state an advantage and/or disadvantage of a fuel cell (mainly that water did not harm the environment and that hydrogen was difficult to store/transport or that it was explosive (a common mistake here was to confuse flammability with explosiveness)). Most candidates who suggested an alternative fuel cell were able to do so correctly for IP6, although a common incorrect answer here was an alkaline fuel cell and some gave reactive metals. This final point of the question was often omitted and candidates should be reminded to reread the question when they think they have completed their answer.

Teachers may need to spend some more time on explaining how fuel cells work. While candidates could recall the equations, they didn't understand the point of the reaction and some confused the acid and alkaline conditions. The difference between being explosive and flammable also needs to be emphasised.

An example of an excellent answer.

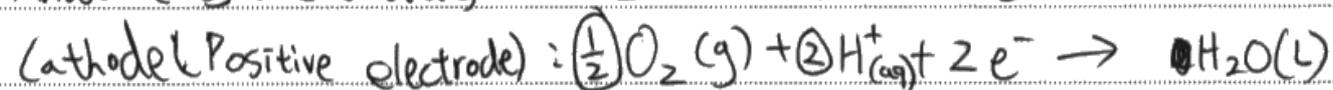
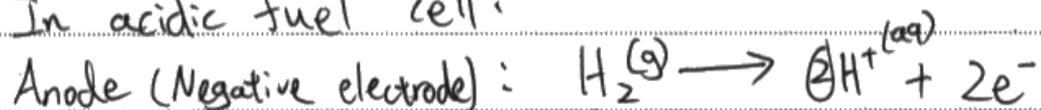
Explain how a fuel cell works, discussing their advantages and disadvantages.
Use the acidic hydrogen–oxygen fuel cell as an example.

Include, in your answer, half-equations for the electrode reactions and an example of another fuel suitable for use in fuel cells.

E^\ominus values and E^\ominus_{cell} values are not required.

(6)

In acidic fuel cell:



Fuel cell does not produce any pollutant to the environment as only H_2O is produced. It is also more efficient than traditional diesel fuel.

However, Transportation of $\text{H}_2(\text{g})$ is very expensive as well as dangerous as $\text{H}_2(\text{g})$ is highly flammable.

The ~~the~~ resources used to produce (extract) H_2 from might not be renewable.

Transportation expensive as it's a ~~gas~~ gas and it must be compressed.

Another example would be methanol-oxygen fuel cell.

For hydrogen oxygen fuel cell. H_2 oxidised at anode. Oxygen reduced at cathode, ~~and~~ They react and water is produced as well as emf which is used to power vehicles.



This candidate scores all 6 marks. All IPs are present, IP2 and IP3 first, then IP4 and IP5. IP6 is awarded for methanol and then IP1 for the final paragraph. 6IPs score 4 marks

The candidate's answer is structured, coherent and clear so 2 reasoning marks are awarded.

An example of a typical response.

Explain how a fuel cell works, discussing their advantages and disadvantages. Use the acidic hydrogen-oxygen fuel cell as an example.

Include, in your answer, half-equations for the electrode reactions and an example of another fuel suitable for use in fuel cells.

E^\ominus values and E^\ominus_{cell} values are not required.

(6)

~~acidic~~ in positive electrode ^(anode) the half-equation is $\text{H}_2 \rightarrow 2\text{H}^+ + 2\text{e}^-$. The 2 electrons goes to the other cathode and oxygen is present so $\frac{1}{2}\text{O}_2 + 2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2\text{O}$.
disadvantages more water is lost therefore it needs to be refueled while in alkaline ~~or~~ alkaline half cell they don't need refueling. alkaline ~~half~~ ^{solution} half cell equation is
at the anode $2\text{OH}^- + \text{H}_2 \rightarrow 2\text{H}_2\text{O} + 2\text{e}^-$ while at the cathode $\text{H}_2\text{O} + \frac{1}{2}\text{O}_2 \rightarrow 2\text{OH}^- + \text{H}^+$
advantage of acidic hydrogen-oxygen fuel is it is easier ~~advantage~~ ^{it gets} oxygen ^{from} ~~needs to be~~ ^{air} added everytime ~~it's used up~~ and has higher atom economy



ResultsPlus
Examiner Comments

This candidate gains IP2 and IP3 for the equations. The rest of the answer is confused and no further IPs are evidenced. 2IPs score 2 marks and no reasoning marks are awarded, so 2 marks total.

Question 19 (a)

Less than 25% of candidates scored the mark here, with many choosing extra boxes (usually explosive). Many labelled all the hazard symbols without identifying the relevant one.

An example of a correct answer.

- (a) Identify the hazard symbol(s) that should be displayed on a box of liquitabs, using ticks (✓).

(1)

			
oxidising	irritant ✓	explosive	flammable



ResultsPlus
Examiner Comments

This candidate has (correctly) labelled all the hazard symbols though this is not required and is ignored. They have then ticked the correct box so score the mark.



ResultsPlus
Examiner Tip

Read the question carefully so you don't waste time on unnecessary work.

A frequently seen incorrect response.

(a) Identify the hazard symbol(s) that should be displayed on a box of liquidabs, using ticks (✓).

(1)

			
	✓	✓	



ResultsPlus
Examiner Comments

Many candidates also ticked the explosive hazard symbol, though this is not an appropriate hazard symbol based on the information. It may be that candidate's understanding of English meant that the word "burst" was misinterpreted.



ResultsPlus
Examiner Tip

Look for the hazard terms in the text when asked to identify the correct symbol(s).

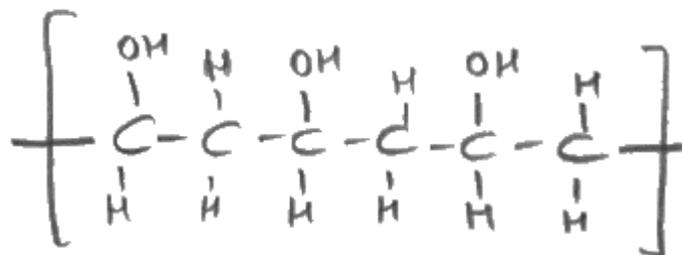
Question 19 (b)

One third of candidates scored 5 marks of the 6 here, with the mean mark being 4. The mark most frequently lost was in part (iii) where candidates didn't comment on their answer to part (ii). Other incorrect responses included drawing one, two or four repeat units, or drawing an alkane with hydrogens bonded to the extension bonds, or including extra or omitting hydroxyl groups. Candidates could gain TE on part (ii) with an incorrect structure, though other mistakes were also made with some only using one hydroxyl to divide by the full mass or miscalculating the mass of the repeat units. The majority of students could describe the formation of a hydrogen bond for part (iii).

An example of a correct answer.

(b) The capsule containing the detergent is often made from poly(ethenol) and its derivatives.

(i) Draw the structure of poly(ethenol), showing three repeat units.



- (ii) Use your structure from 19(b)(i) to calculate the percentage of hydroxyl groups by mass in the polymer.

(2)

$$\frac{(16+1) \times 3}{(12 \times 2 + 16 + 4) \times 3} \times 100 = \underline{\underline{38.6\%}}$$

- (iii) Explain why poly(ethenol) is soluble in water using your answers from 19(b)(i) and (ii).

(2)

There is

~~It~~ has a large amount of OH in the polymer.

Oxygen of each OH has a lone pair that can be used to dissolve in water through hydrogen bonding.



(i) This candidate scores 2 marks for the 3 repeat units with extension bonds. The brackets are ignored.

(ii) The candidate has then calculated the mass of the three hydroxyl groups and worked out their percentage of the whole structure's mass.

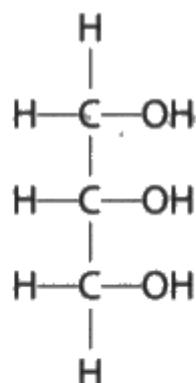
In part (iii) the candidate comments on the percentage calculated in part (ii) and describes the formation of a hydrogen bond.

Question 19 (c)(i)

As this is a familiar chemical, there should have been more correct answers but only 40% of candidates scored the mark. Most answers were correctly based on propan-ol, with some missing either the "tri" or the numbers. "Triolpropane" was common as was "tripropanol", with the occasional "prop" or "propyl" and "propan" was more common than propane. Almost half the students opted for a name based on hydroxypropanol so it may be worth checking textbooks to make sure the IUPAC name is used in school. It should be emphasised to candidates that alcohols take precedence over alkanes and their suffix will end the name.

An example of a correct answer.

(c) In liquid detergents, glycerol is added to the poly(ethenol).



glycerol

(i) Give the IUPAC name for this molecule.

~~1,2,3~~ propan-1,2,3-triol



ResultsPlus
Examiner Comments

This candidate scores the mark. Their initial response starts with the numbers, but that is neatly crossed out and the correct answer given. The omission of the "e" at the end of propane is allowed as a slip here.



ResultsPlus
Examiner Tip

Cross out answers with a single line so your original answer can still be seen.

Question 19 (c)(ii)

Nearly 90% of candidates did not score here, showing that many candidates have not thought about properties of materials since GCSE and struggle to apply their knowledge to unfamiliar scenarios. Where candidates did score, nearly all stated the polymer would be stronger.

An example of a response that scored.

(ii) Suggest **one** way that the properties of poly(ethenol) will be improved by the use of glycerol, apart from any effect on solubility.

(1)

form more H-bonds with itself, causing the packaging to be more sturdy and break ~~to~~ by accident less e.g. by children



"More sturdy" here is taken to be increasing the strength and the mark is awarded.

An example of a response that does not score.

The flammability can be reduced by adding more of glycerol and also the toxicity.



ResultsPlus
Examiner Comments

Neither reducing flammability or toxicity are going to be affected by adding glycerol, so this answer doesn't score. The candidate seems to be thinking about the hazard symbols from the earlier question, but neither of these properties are a problem when using the polymer as intended.



ResultsPlus
Examiner Tip

Reread the stem of the question to refresh your memory as you get to later parts of the questions.

Question 19 (c)(iii)

It was perfectly acceptable for candidates to carry out the steps in any order for this calculation and significant figures were not penalised except for 1SF. Over 45% of the cohort scored all four marks here, but some common errors were to divide 1000 by 1.19 (instead of 1000000) and to omit the division by 100 for the percentage. Some candidates were unable to rearrange the equation for density.

An example of a correct answer.

(iii) Glycerol is added to the polymer at 0.110%, by volume.

Calculate the number of moles of glycerol added to 1 tonne of poly(ethenol).

Data: 1 tonne = 1000 kg

density of glycerol: 1.26 g cm^{-3}

density of poly(ethenol): 1.19 g cm^{-3}

$$d = \frac{m}{V}$$

$$\begin{aligned} \text{Volume (polyethenol)} &= \frac{1000000}{1.19} = 840336 \text{ cm}^3 & (4) \\ &= 840.336 \text{ dm}^3 \end{aligned}$$

$$\frac{0.11}{100} \times 840.336 = 0.924 \text{ dm}^3$$

$$\text{mass} = 0.924 \times 1000 \times 1.26 = 1164.7 \text{ g}$$

$$n = \frac{1164.7}{92} = \underline{\underline{12.66 \text{ moles}}}$$



ResultsPlus
Examiner Comments

This response scores all 4 marks. The steps can be carried out in any order, though this response matches the mark scheme.



ResultsPlus
Examiner Tip

Lay out multistep calculations neatly down the page.

Question 19 (d)

The mean mark awarded here was 2, with many candidates failing to use all the information available. This was intended to be a harder question near the end of the paper and many candidates did not use their data booklets properly when identifying the peaks required. It is important that candidates either choose a single value or state a range within the range given in the data booklet, for example candidates did not score for stating "an aldehyde peak at 1700". Many candidates did not round their answers to the calculations to show how many atoms of hydrogen and carbon would be present in the molecule. Many candidates that gained full marks gave the unsaturated ketone structure rather than an ester.

An example of a fully correct response.

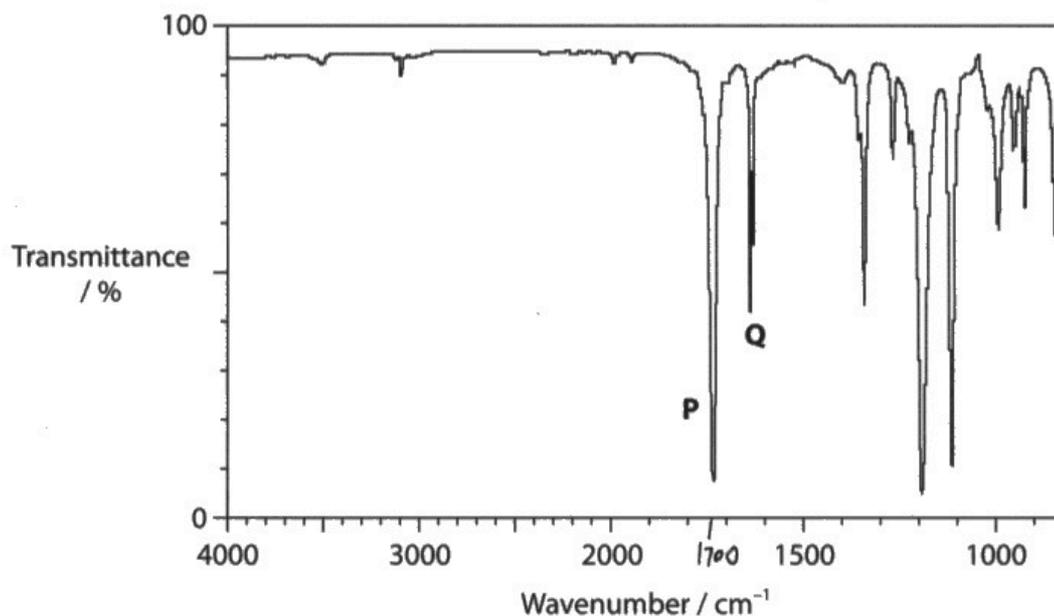
- (d) Poly(ethenol) is made from a polymer intermediate, rather than by polymerisation, as ethenol is unstable.

The polymer intermediate is prepared from a monomer, X.

When 1 mol of X is burned in excess oxygen, 95.6 dm³ of carbon dioxide (at r.t.p.) and 54.1 g of water are formed.

The infrared spectrum for the monomer is shown.

$$\frac{95.6}{24} = 3.98 \text{ mol}$$



Use the information to deduce the displayed structure of the monomer of the polymer intermediate.

You must show your working and quote the relevant wavenumber ranges from your Data Booklet.

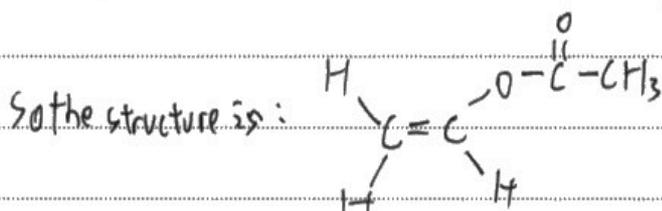
$$\text{CO}_2: \frac{95.6}{24} = 3.98 \approx 4 \text{ mol}, \quad \text{H}_2\text{O}: \frac{54.1}{18} = 3 \text{ mol}$$

1 mol of X produce 4 mol CO₂ and 3 mol water

Means it has a formula of C₄H₆O_x

peak P in IR: 1750-1720 cm⁻¹ means it has -C(=O)- group

peak Q in IR: 1669-1645 cm⁻¹, C=C presents





This candidate uses all the information to formulate their answer and gains the marks in the order given on the mark scheme.



Use **all** the information available to deduce an answer.

Question 19 (e)

Over half of candidates failed to score either mark here, despite this being an application of chemistry to real life and accessible to all. Of those that scored, many candidates recognised that the use of these bags was more hygienic or reduced cross contamination. Far fewer were able to identify that these bags would not need to be washed. The most common incorrect answer was that the bags were biodegradable which completely misses the point about the bags being soluble.

An example of a correct response.

(e) Some hospitals use poly(ethenol) laundry bags instead of reusable, washable polyester or nylon bags.

State **two** advantages of using soluble poly(ethenol) laundry bags.

(2)

An advantage would include that it decrease possibilities of infection if the bags where not washed properly. Another advantage is ~~is~~ that it would decrease time ~~is~~ and money spent to wash the poly(ethenol) laundry bags.



Both marks are awarded here.

An example of a typical response.

- Biodegradable
- ~~A~~ Will not pollute
- Easily manufactured



ResultsPlus
Examiner Comments

This candidate did not score any marks. The biodegradability of the polymer is irrelevant if it is going to dissolve in the washing machine. The ease of manufacture can't be commented on from the information provided.



ResultsPlus
Examiner Tip

Your answers should be relevant to the question.

Paper Summary

Candidates lost marks on both novel and familiar questions, showing that some of them need to spend more time doing past paper questions. Others need more challenge before the exam, being asked unfamiliar questions where they have to apply their understanding and have time to think about it and don't have immediate access to the mark scheme. Some candidates need to ensure their answers are more precise, both when drawing structures and explaining deductions.

To improve their performance, candidates need to:

- practise rearranging formulae for calculations, particularly those that are less familiar like parts per million and density
- read questions carefully to structure their answers, ensuring they don't miss any instructions or give answers that have already been excluded
- check equations are balanced in terms of both atoms and charges
- review key words and definitions from the specification
- review their own answers after re-reading the question, particularly on the 6-mark question.

Grade boundaries

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

<https://qualifications.pearson.com/en/support/support-topics/results-certification/grade-boundaries.html>

