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Examiners' Report
June 2025

Int Advanced Level Chemistry WCH15 01

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Introduction

Introduction

Many candidates were well prepared and handled factual recall questions effectively but struggled more with extended questions requiring explanations of unfamiliar topics. This was particularly true for Q17(c)(i), about gas chromatography, and Q16(b), bond formation in benzene. The mean mark for this paper was 50.

Section A

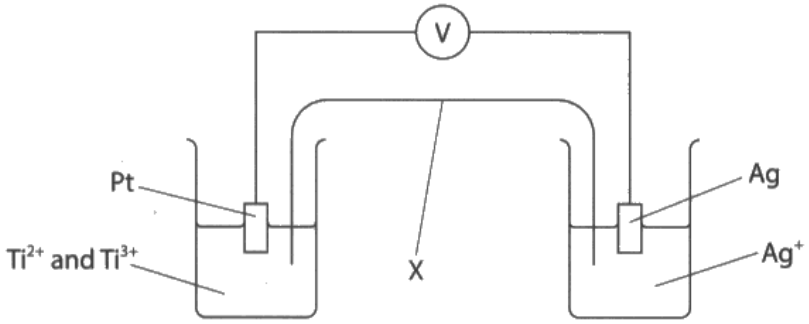
The average mark for the multiple-choice questions was 15. The most accessible questions were Q10 (polyamide repeat unit), Q11(a) (naming a nitrile functional group) and Q02(d) (oxidation number changes using roman numerals). The least scored questions were Q02(b) (redox titration calculation), Q13(b) (high resolution proton NMR splitting) and Q11(b) (naming mechanism type).

Question 14(a)

This question was well answered by many candidates. The mean mark was 1.33 from the 2 and over 56% of candidates scored 1 mark. M1 was most frequently awarded with most candidates able to name the salt bridge. M2 was less frequently scored, with some candidates giving answers that were insufficient and some losing the mark for mentioning electrons.

An example of a fully correct response.

14 This question is about the electrochemical cell shown.



(a) State the name and purpose of part **X**.

(2)

Allow ions to flow/move through the circuit (A salt bridge).

"Allow ions to flow/move" would have been insufficient for the mark but with the reference to the circuit scores the mark for M2. This candidate has included the name of part X almost as an afterthought, but scores M1.

Do not mention electrons in connection with the salt bridge – only ions.

Question 14(b)-(d)

Responses and success were mixed with this question.

For part (b) the most common error was to omit the solid state symbol on the platinum electrode. Some candidates had their species in the wrong order, often with the silver electrode next to the salt bridge. Brackets were not enforced and were rarely seen. A variety of notations were present between the aqueous Ti^{2+} and Ti^{3+} ions, rather than the expected comma.

Part (c) was the least well answered part of question 14, with the weakest answers referring to changes rather than increases or decreases in emf, concentrations and masses. Where candidates made a good attempt at an answer, the least frequently seen point was the lack of change at the platinum electrode – often leading to only 2 of the 3 marks being awarded.

An example of a fully correct answer.

$Pt(s) | Ti^{2+}(aq), Ti^{3+}(aq) // Ag^{+}(aq) | Ag(s)$

(b) The electrode system for the titanium ions is shown.

$Ti^{3+}(aq) + e^- \rightleftharpoons Ti^{2+}(aq) \qquad E^\ominus = -0.37V$

Calculate the $E^\ominus_{cell}$ value. Use your Data Booklet.

(2)

$E^\ominus_{cell} = E_R - E_O = +0.80 - (-0.37) = +1.17V$

(3)

The concentration of Ti^{3+} ions would increase, ~~the~~ and that of Ti^{2+} would decrease.
The concentration of Ag^+ ions would decrease and the Ag electrode would increase in size (mass) as Ag^+ is reduced to Ag. Pt electrode doesn't change.
The cell emf would decrease slightly.

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Examiner Comments

This candidate successfully draws the cell diagram. They then select the correct Eθ value from the data booklet and use it to calculate the Eθcell. When describing the changes in the cell the candidate describes the changes of concentration of all the ions, both electrodes and the cell emf.

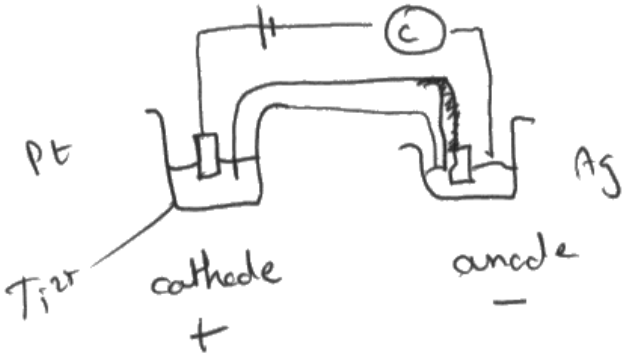
ResultsPlus
Examiner Tip

The candidate has underlined key words in the question to help them construct a full answer.

A less successful response.

(b) Draw a cell diagram for this system.

(2)



(c) The electrode system for the titanium ions is shown.

$$Ti^{3+}(aq) + e^- \rightleftharpoons Ti^{2+}(aq) \qquad E^\ominus = -0.37V$$

Calculate the $E^\ominus_{cell}$ value. Use your Data Booklet.

(2)

$E^\ominus_{cell} = E_{right} - E_{left}$

$= (-0.37V) - (+0.80)$

$= -1.17V$

$Ag = +0.80$

$Ti = -0.37$

(d) State the changes, if any, that would occur to the cell emf, the electrodes and the ion concentrations when current flows for several hours in this cell.

(3)

- As the current flows for several hours in the cell there will be certain changes occurring, when talking about cell emf it will have a change this is because the electrons are been transfered. Talking about the electrodes such as the anode and cathode one will become positive the other will become negative. Moreover, the ion concentrations will also change as ions are being transfered from one side to another.

ResultsPlus
Examiner Comments

This candidate has tried to redraw the diagram above instead of using cell notation. They do gain a mark for (c) as they selected the correct value from the data booklet – even though they have used this incorrectly. The response to (d) is far too vague, saying the concentrations or emf "change" will not score any credit, the candidate needs to state if it will increase or decrease.

ResultsPlus
Examiner Tip

Ensure you familiarise yourself with all of the key terms in the specification, including cell diagrams.

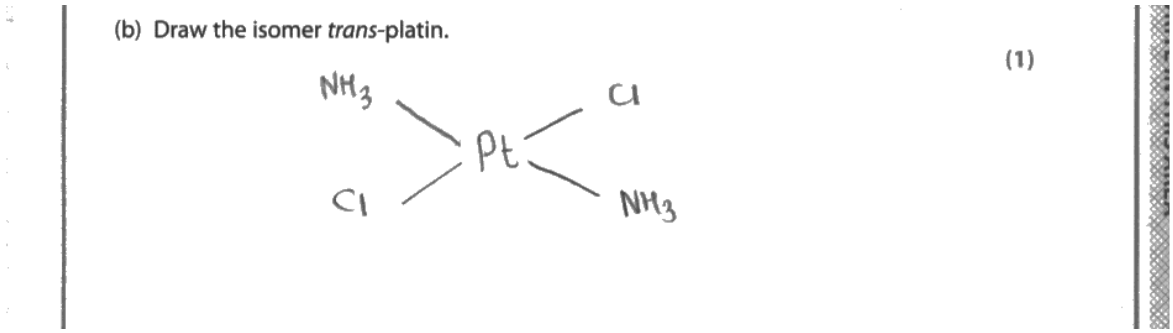
Question 15(a)

80% of candidates correctly gave the shape as square planar. The most common incorrect answer was tetrahedral, but octahedral and linear were also seen amongst others.

Question 15(b)

Only 45% of candidates gained the mark on this question. There were two types of common error. Firstly connectivity, where candidates did not show that the ammonia molecules were forming the dative covalent bond via the lone pair on the nitrogen atom and then the 3D representation. For this answer we did not allow mixtures of straight lines with wedges and dashes. Candidates were expected to show that the molecule was planar, either with four straight lines or with two wedges and two dashed lines. The wedges were required to be next to each other in the molecule. Less frequently seen errors included showing some of the charges on the ions, using Cl_2 molecules or giving the formula of ammonia as NH_2. Occasionally candidates drew the cis-form but these candidates usually also made one of the errors in connectivity or 3D drawing too.

An example of a common incorrect response.



ResultsPlus
Examiner Comments

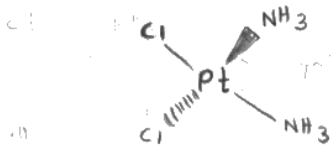
This response does not score due to the incorrect connectivity of the ammonia molecule. When drawing transition metal complexes, it is essential that the atom that had the lone pairs is shown to be forming the dative covalent bond.

ResultsPlus
Examiner Tip

Practice drawing out ligand interactions including the lone pair so candidates are aware that the connectivity is important.

An example of a response that failed to score due to the 3D drawing and isomer.

(b) Draw the isomer *trans*-platin. (1)



The second most common reason for candidates not to score this mark was to fail to represent a planar structure in 3D. Here the candidate has combined straight lines with both a wedge and a dashed line so the overall structure would not necessarily be planar. This candidate has also drawn the cis-form instead of the trans-isomer.

Look at correct 3D structures in your textbook to ensure you can draw them correctly. Revise the meaning of cis- and trans-isomers.

Question 15(c)

Over 68% of candidates failed to score for this item. They could have responded in two ways, either referring to the position of the equilibrium in human cells or the size of ligand and therefore strength of the bond. Many candidates who would have gained M1 for stronger bonds or being a better ligand unfortunately referred to chlorine, rather than chloride and therefore were not awarded the mark. Only the most able candidates gained both marks here.

An example of a response that scored both marks.

(c) In human cells, the two chloride ions are replaced by water molecules in a ligand exchange reaction as shown.

$$PtCl_2(NH_3)_2 + 2H_2O \rightleftharpoons [Pt(NH_3)_2(H_2O)_2]^{2+} + 2Cl^-$$

Suggest why this occurs.

(2)

Cl^- ions may have more entropy than H_2O molecules, therefore making ΔS_{system} positive, making the reaction more entropically favourable for H_2O ligands to replace Cl^- ligands. In human cells, there is a greater concentration of H_2O molecules, shifting the position of equilibrium to the right, causing more $[Pt(NH_3)_2(H_2O)_2]^{2+}$ to form. It is also more kinetically stable as it can be hydrated by water as it is an ion and will dissolve.

ResultsPlus
Examiner Comments

This candidate starts off on completely the wrong track, responding about entropy which is irrelevant in this context. The second sentence is relevant and correct, however, and the candidate gains marks for stating that the concentration of water is greater and that the equilibrium position will shift. The final sentence is also ignored, as candidates are not expected to speculate on kinetic stability with no appropriate data.

ResultsPlus
Examiner Tip

Think about your answer before starting writing. The irrelevant material here is ignored but if it had been relevant and incorrect the marks may have been lost.

An example of an alternative response that scores 2 marks.

(c) In human cells, the two chloride ions are replaced by water molecules in a ligand exchange reaction as shown.

$$PtCl_2(NH_3)_2 + 2H_2O \rightleftharpoons [Pt(NH_3)_2(H_2O)_2]^{2+} + 2Cl^-$$

Suggest why this occurs.

(2)

water Ligands are Smaller than Chloride Ligands & can form a stronger Bond with the platinum.

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Examiner Comments

This candidate has responded using the sizes of the ligands and strength of bonds.

ResultsPlus
Examiner Tip

Where candidates are asked to "suggest" there are usually multiple possible scoring answers. It is helpful for candidates to be aware of this when practising past paper questions – they may be able to come up with multiple scoring answers.

Question 15(d)i

79% of candidates gained the mark for bidentate here. Multidentate and polydentate did not score; multidentate being too vague and there not being sufficient bonds for polydentate to be correct.

Question 15(d)ii

The mark scheme was relaxed slightly to ensure candidates who did not express their ideas clearly could still score. Though the answer should be in terms of entropy changes of the system, any increase in entropy was allowed for M1.

M2 was expected to be in terms of numbers of particles but moles and reactants/products were allowed. Some good candidates lost M2 for using the word "molecules" when some of the species are ions. A few candidates scored the rescue mark for talking about stronger bonds but the majority of candidates correctly answered about entropy and gained M1. 48% of candidates gained both marks here.

An example of an excellent response scoring both marks.

(ii) Explain, by considering the equation shown, why this process is thermodynamically feasible.

$$Pt(Cl)_2(NH_3)_2 + DNA \rightarrow [Pt(NH_3)_2(DNA)]^{2+} + 2Cl^-$$

(2)

The product side has 3 moles while reactants side has 2 moles. The products formed have one more mole and therefore more disorder. DNA forming dative bond has a positive ΔS_{system} as it is more stable with respect to the reactants. So, the equation is thermodynamically feasible.

This candidate clearly understands the concept of entropy and can explain their answer clearly.

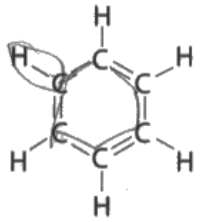
Practise explaining concepts verbally to ensure written responses are succinct.

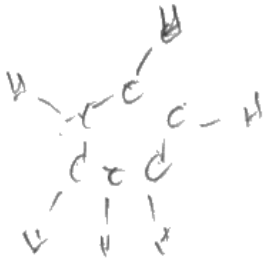
Question 16(a)i

This question was deliberately easy and the mark was gained by 95% of candidates. Those that did not score usually gave 6 as the number to balance the hydrogen molecules.

An example of a correct answer.

16 In 1865, Kekulé proposed a cyclic structure for benzene, C_6H_6.

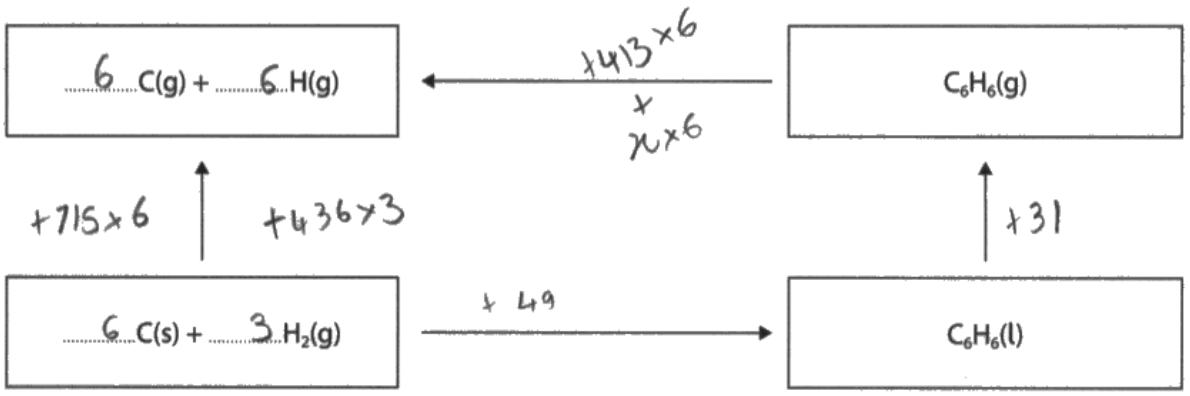




(a) An incomplete Hess cycle is shown.

(i) Complete the cycle by adding balancing numbers.

(1)



This candidate has correctly answered in the cycle. All the extra annotations were ignored as working for (a)(ii).

Using the framework provided by questions may help with later calculations, especially when the directions of arrows are shown.

Question 16(a)ii

Over 40% of candidates failed to score on this item, while a third of the cohort gained both marks. Many candidates who did not manage to correctly formulate the expression gained M2 by transferred error (TE). Some candidates failed to include the 6C-C bonds in their expression at all so could not calculate a value. Some candidates divided their final answer by 9 and others ended with a negative answer so did not qualify for TE.

An example of a response gaining M2 for transferred error.

(ii) Calculate the mean carbon-carbon bond enthalpy in benzene, using your completed cycle and the data shown.

(2)

$C_6H_6(l)$ $\Delta_f H = +49.0\,kJ\,mol^{-1}$

$C(s) \rightarrow C(g)$ $\Delta_{at}H = +715\,kJ\,mol^{-1}$

$H_2(g) \rightarrow 2H(g)$ $\Delta_{at}H = +436\,kJ\,mol^{-1}$

$C_6H_6(l) \rightarrow C_6H_6(g)$ $\Delta_r H = +31\,kJ\,mol^{-1}$

Bond enthalpy C—H = $+413\,kJ\,mol^{-1}$

let x be the bond enthalpy of C-C

bond enthalpy C-C = -(1308) + 49.0 + 31

• $[(413 \times 6) + 6x] = -1308 + 49 + 31$

• $6x - 2478 = -1228$

• $6x = 1250$

$x = +208$ (3s.f.)

∴ bond enthalpy C-C = $+208\,kJ\,mol^{-1}$

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Examiner Comments

This candidate has not got the correct expression so cannot score M1. However, they have 6 C-C bonds in their expression and divide their value by 6 to get a positive answer so they gain M2 by TE.

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Examiner Tip

Always check your answers to make sure they are chemically possible – bond enthalpies are always positive (endothermic).

Question 16(a)iii

Some candidates attempted to answer this question without using the data, so they could not gain M1 immediately. Many candidates appreciated that the values were different but did not say which was higher and give an explanation. Statements such as "benzene is more stable" were common but this is not an explanation for the difference. Many answers referred to bond lengths rather than bond strengths and these explanations were ignored. 67% of candidates did not gain any credit for this question which was unexpected.

A response scoring both marks.

(iii) Explain why the bond enthalpy value calculated in (a)(ii) is not the exact mean of the carbon-carbon double bond and carbon-carbon single bond enthalpies that would be expected from the Kekulé structure.

Bond enthalpy C—C = +347 kJ mol^{-1}

Bond enthalpy C=C = +612 kJ mol^{-1}

(2)

According to kekulé's structure mean bond enthalpy is 479.5 kJmol^{-1} which is less than 506.7 kJmol^{-1} because in benzene there is a delocalised π ring and all C-C bonds are equal in length.

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Examiner Comments

This candidate has calculated the average bond enthalpy for the Kekulé structure and then compared it to their previous answer. They have then explained the reason for the difference, completing their answer.

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Examiner Tip

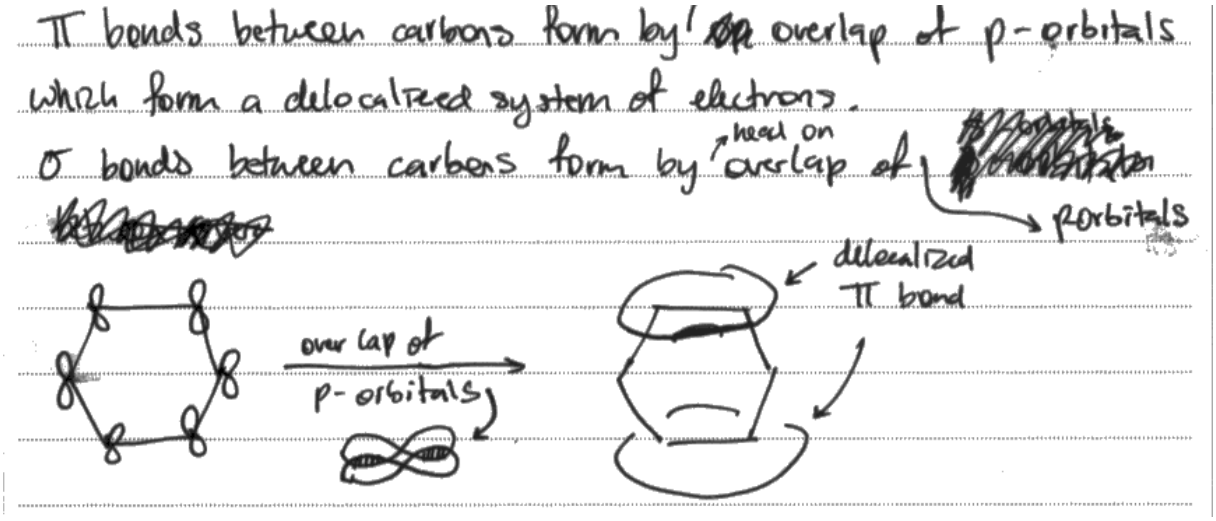
Always use any data given to you in the question.

Question 16(b)

This question was poorly answered and many candidates did not mention the two types of bonding. Over three quarters of the cohort failed to gain any marks for this question. The number of bonds formed was ignored and the answer was in relation to overlaps of orbitals. M1 was significantly easier that M2, as the orientation was not required. When attempting M2, many candidates stated that there was an overlap of p-orbitals above and below the ring, leading to an area of delocalisation so did not gain the mark for the formation of π-bonds.

Pi-orbitals were seen quite frequently and could not score. Some excellent diagrams were seen and these could gain both marks, though many were accompanied with text that would also gain both marks.

An example of an answer with diagrams.



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Examiner Comments

This candidate has used a diagram to illustrate their description. Though the text has several crossings out the meaning is clear. The diagram would have gained M2 without the first sentence.

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Examiner Tip

Labelled diagrams can be a useful way to explain your ideas.

Question 16(c)

The surprise with this question was the number of candidates who did not know the difference between chemical properties and physical properties. Many candidates gave two chemical properties and some a list of multiple properties, without distinguishing between physical and chemical. The most common mark awarded was that benzene does not decolourise bromine water for M1. For M2 the most common correct response was that all the carbon-carbon bonds are the same length, though those who stated "all the bonds in benzene are the same length" did not gain the mark. Many answers were seen relating to smoky flames and boiling point, neither of which gained a mark. Candidates that used their data booklets usually scored a mark for physical property. A significant minority of candidates referred to enthalpy of hydration instead of hydrogenation so couldn't gain M1 and answers that said benzene "needs a catalyst to react" didn't score without reference to the type/name/formula of catalyst. Just under half of the cohort gained credit on this question and all the correct answers in the mark scheme were seen.

An example of a common response.

(c) State one chemical property and one physical property of benzene which would **not** be shown by the compound with the Kekulé structure.

(2)

benzene is more stable due to As delocalised electrons so does not undergo electrophilic addition, and does not decolourise Br_2 water. Benzene has a lower enthalpy of hydrogenation and combustion than kekule.

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Examiner Comments

This candidate knows about some properties of benzene but not about chemical and physical properties. Only 1 mark is scored for this response. Note: "lower enthalpy of hydrogenation" would not have scored as the candidate has not included the word (or sign for) exothermic.

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Examiner Tip

Write out a table of properties for benzene, segregating them into columns for physical and chemical.

Question 17(a)

The mean mark for this part was 2.66 from the 5 available.

In (a)(i) a variety of structures were seen, not all skeletal and not all amines. Some did not even contain the correct number of carbon and hydrogen atoms.

For part (a)(ii) many candidates scored the mark, even when the structure drawn for (a)(i) was not a tertiary amine.

There was a TE from (a)(i) for this part so any correct hydrogen bond could score and most candidates gained at least one mark. The most common reasons for not gaining two marks were the bond angle not being linear and omitting the partial negative charge on the nitrogen atom.

Success was mixed on part (a)(iv), with many candidates unable to show how an amine acts as a base in an ionic equation. Molecular formulae were allowed, along with any structures and equilibrium signs and TE was given on the structure from (a)(i).

Question 17(b)

This question was generally well attempted and over 70% of the cohort gained both marks. The main reason for candidates not gaining full marks was significant figures (SF).

The question asks for a suitable number of SF and as the data is all to 3SF, 2SF or 3SF were accepted for the final answer.

An example of a response that lost the final mark due to significant figures.

(b) When trimethylamine oxidises, it forms trimethylamine *N*-oxide, C_3H_9NO.

Healthy humans have a concentration of 3.90×10^{-6} mol dm^{-3} trimethylamine *N*-oxide in their blood.

An average adult human has 5.00 dm^3 of blood.

Calculate the mass, in grams, of trimethylamine *N*-oxide in an average human's blood, giving your answer to a suitable number of significant figures.

(2)

$(3.90 \times 10^{-6}) \times 5.00 = 1.95 \times 10^{-5}$ mol

$1.95 \times 10^{-5} \times (12 \times 3 + 9 + 14 + 16)$

1.4625×10^{-3} g

This candidate starts their response well but has not read the question carefully. All the calculation is numerically correct but the candidate gives their answer to 5SF. As all the data in the question is to 3SF this is not a suitable number.

Read the question twice, underlining the important points to ensure you understand what you need to do.

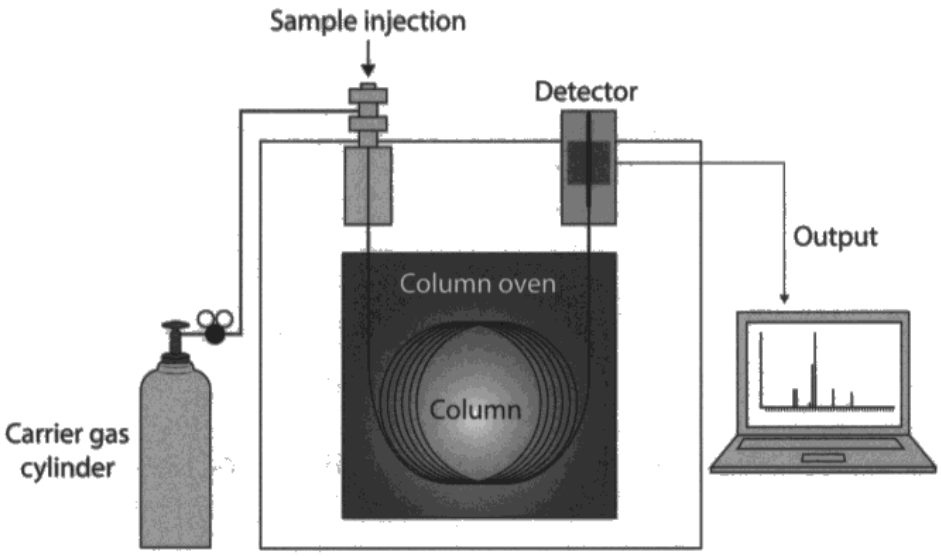
Question 17(c)i

This question was poorly answered with some candidates clearly not having been taught about the principles of gas chromatography (GC). Over 87% of candidates failed to score here. Many confused gas chromatography with mass spectrometry and referred to the compounds being separated by **size**, rather than due to the attraction of the species to the stationary phase. Where marks were awarded, they were evenly split between the two marking points. For M1, candidates were expected to state what the phases were in the context of GC. M2 was awarded when candidates could describe how the retention time relates to the attraction to the stationary phase. Stating "different" was insufficient for this mark.

An example of a common response.

(c) Trimethylamine is a major air pollutant originating from food waste, farm animals and vehicle exhausts. Trimethylamine levels need to be monitored as it can easily be absorbed through human skin.

Gas chromatography (GC) can be used to measure the level of trimethylamine in air, using the apparatus shown in the diagram.



(i) Briefly describe how trimethylamine will be **separated** from other chemicals present in the sample of air.

(2)

the trimethylamine is pumped through a column by the pressure of the gas in the gas cylinder. The ~~[illegible]~~ trimethylamine ~~and~~ will stay in the mobile phase a different duration than the other chemicals, so it will reach the detector a different time than the other chemicals. in the column.

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Examiner Comments

This candidate has obviously learnt about gas chromatography but does not include enough detail in their answer. For M1 they mention the gas but don't describe it as the mobile phase and there is no reference to the stationary phase. The candidate nearly gains the mark for M2 but uses the word different rather than longer or shorter and again does not refer to the attraction to the stationary phase.

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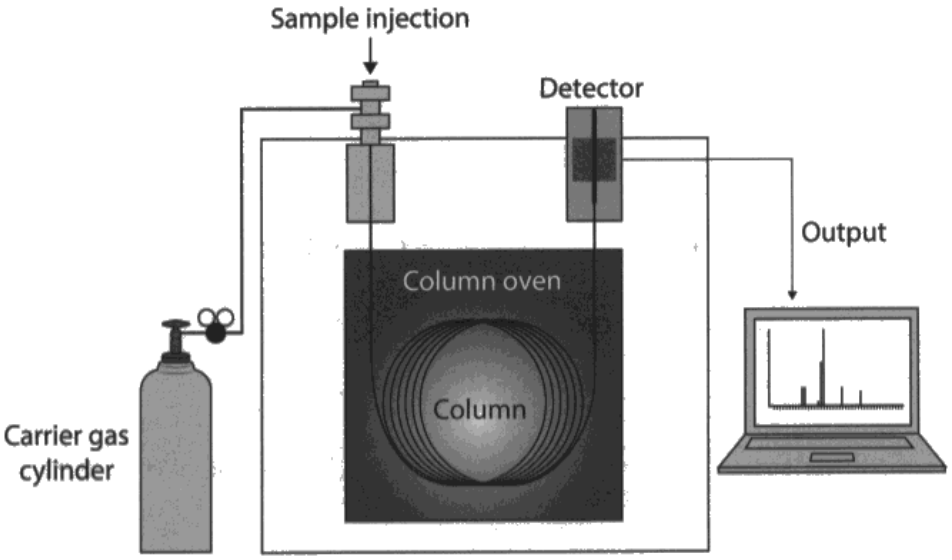
Examiner Tip

Ensure your answer contains sufficient detail, using the word " different " will rarely gain you credit at A-Level.

An example of a response that scores M1.

(c) Trimethylamine is a major air pollutant originating from food waste, farm animals and vehicle exhausts. Trimethylamine levels need to be monitored as it can easily be absorbed through human skin.

Gas chromatography (GC) can be used to measure the level of trimethylamine in air, using the apparatus shown in the diagram.



(i) Briefly describe how trimethylamine will be **separated** from other chemicals present in the sample of air.

(2)

The trimethylamine is pressurised and passed through the column with the mobile phase which is an inert gas, the column has a solid coating which is the stationary phase, the sample will be seperated based on its affection with the mobile and gas phase.

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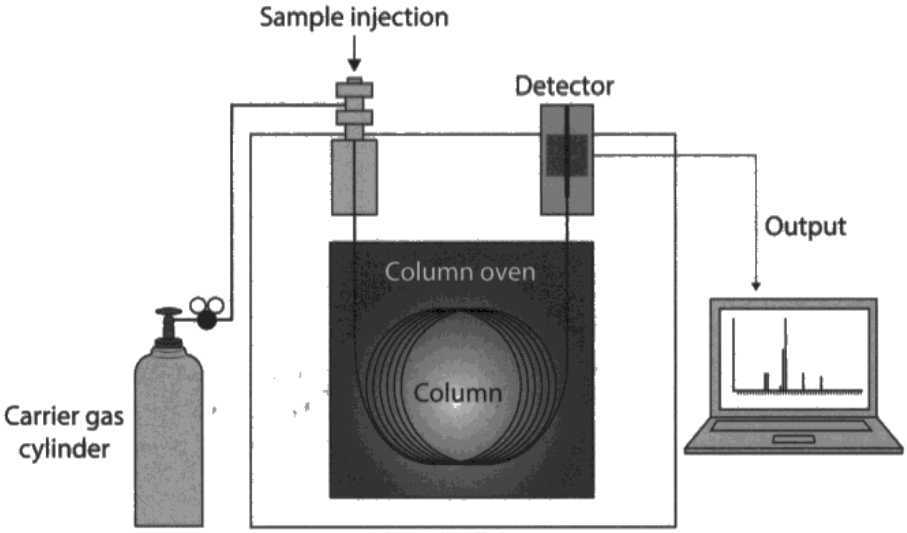
Examiner Comments

This candidate has clearly identified the two phases so gains the first mark. There is no mention of the length of time the components are in the column so M2 is not awarded.

An example of a response scoring both marks.

(c) Trimethylamine is a major air pollutant originating from food waste, farm animals and vehicle exhausts. Trimethylamine levels need to be monitored as it can easily be absorbed through human skin.

Gas chromatography (GC) can be used to measure the level of trimethylamine in air, using the apparatus shown in the diagram.



(i) Briefly describe how trimethylamine will be **separated** from other chemicals present in the sample of air.

(2)

- In GC, stationary phase is a gel and mobile phase is an inert gas.
- As trimethylamine has permanent dipoles due to hydrogen bonded to the nitrogen atom
- trimethylamine will spend more time on the stationary phase than mobile phase than other chemicals in air and will therefore, have a longer retention time than other chemicals

This candidate has a clear understanding of GC and has answered the question in detail to gain full marks.

Review the specification before the exam to ensure you have covered all aspects.

Question 17(c)ii

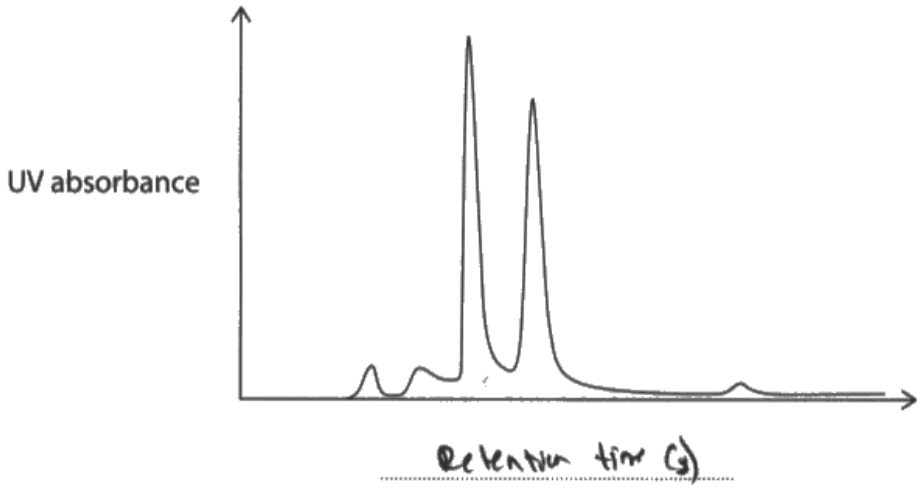
This question was surprisingly poorly answered, with over 54% of candidates not gaining the mark. Units of time were ignored and the word "retention" was not required. Common incorrect answers included wavelength/wavenumber, where candidates confused the graph with an infrared spectrum, Rf where candidates have studied other types of chromatography, plus distance and concentration. A variety of units were seen but all were ignored.

An example of a response that gained the mark.

(ii) High-performance liquid chromatography (HPLC) is used to measure levels of trimethylamine and trimethylamine *N*-oxide in blood and urine.

Label the x-axis on the chromatogram.

(1)



This candidate has studied gas chromatography and appreciates that the chromatogram x-axis should be labelled with time. The units were ignored, candidates are not expected to comment on how long it would take for the sample to pass through the column, even if the length of the column and gas flow rate were given.

Review the different types of data produced by different techniques, including chromatography.

Question 17(c)iii

This question is pure recall; candidates are expected to know that gas chromatography can be coupled to mass spectrometry. Only one third of the cohort gained the mark, however, showing that not enough time is spent on this part of the specification. A variety of techniques were seen, including infrared and NMR plus references to Rf values and other types of chromatography.

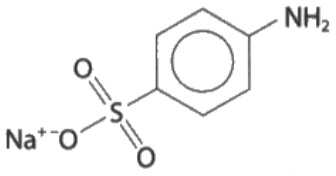
Question 18(a)

Candidates generally answered this question well, with over 48% of candidates gaining both marks. Common errors included extra hydrochloric acid added with nitrous acid (this was ignored) or using sodium nitrate instead of nitrite (this didn't score). A mixture of formulae and names were seen and temperatures below 10°C were allowed. Very few candidates mentioned an ice bath, indicating they may not have personal experience of the reagent.

An example of a good response.

18 Sunset yellow is a common food colouring.

Sunset yellow can be produced in a coupling reaction starting with compound **A**.



compound **A**

(a) State the reagents and conditions required for the formation of a diazonium ion from compound **A**.

(2)

Nitrous acid is needed as well as hydrochloric acid (HCl).
The reaction should be carried out at low temperatures, bellow 5 °C.

ResultsPlus
Examiner Comments

This candidate uses the name of the reagent required. The extra HCl is ignored. Low temperatures would not be sufficient but the reference to 5°C scores the second mark.

ResultsPlus
Examiner Tip

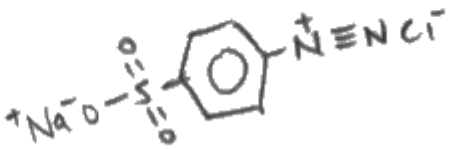
Review all the reagents and conditions required for the organic reactions, a single diagram can be used.

Question 18(b)

This question was well attempted but 53% of candidates did not gain the mark. Common errors included drawing the coupled product rather than the intermediate, putting the positive charge on the wrong nitrogen atom and a double bond between the nitrogen atoms rather than a triple bond. A minority of candidates also ignored the sulfate part of the molecule and drew a benzene attached to a diazonium group.

An example of a response that scored the mark.

(b) Draw the structure of the diazonium ion formed.



ResultsPlus
Examiner Comments

This candidate has drawn a fully correct benzenediazonium ion. The extra ions are ignored, though correct they are not required. The charge is on the nitrogen atom closest to the benzene ring and the sulfate group is correctly bonded.

ResultsPlus
Examiner Tip

Practice drawing intermediates in synthesis sequences.

Question 18(c)

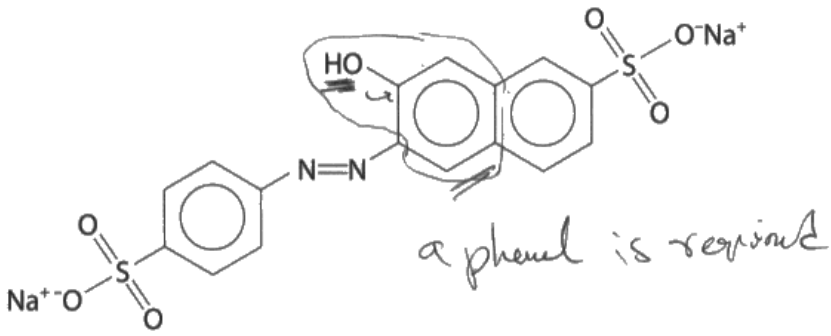
A variety of answers were accepted for this item, including circling the OH of phenol, circling one benzene ring with the phenol or circling the naphthalene structure with the phenol. (Note: candidates are not expected to know the term naphthalene). All of these were seen and over 61% of candidates gained the mark. Common errors included circling the azo group, the sulfate group or even half the structure.

An example of an accepted answer.

(c) The structure of sunset yellow is shown.

Use a circle to identify the functional group, other than the diazonium group, that is essential for the coupling reaction to occur.

(1)



ResultsPlus
Examiner Comments

This candidate has circled the benzene ring including the phenol group. Slightly wonky circles were, of course, accepted. This candidate has included the name of the group below but this was not required.

ResultsPlus
Examiner Tip

You need to be able to identify all the functional groups in the specification as well their names and uses.

Question 18(d)i

This was expected to be a simple recall mark but only 50% of candidates gained the mark. The most common incorrect answer was steam distillation, perhaps indicating that candidates have not done this experiment themselves, though many also stated they would compare the answer to a data booklet – showing that they are expecting certain questions to come up and not reading the questions carefully.

Question 18(d)ii

This question was well answered and over 51% of candidates gained full marks. The most common error was to incorrectly calculate the Mr of the compound, M2 and M3 could then be scored as TE. Truncation and incorrect rounding were also penalised in this question.

An example of a common error.

(ii) The yield, by mass, for the formation of sunset yellow is 67.9%.

Calculate the mass of sunset yellow produced from 5.00 g of compound **A**.

[M_r of sunset yellow = 452.2]

(3)

A ⟶ 181.1 (M_r)

A → sunset yellow

$\frac{5}{181.1} = 0.0276$ mol (A)

$0.0276 \times 0.679 = 0.0187$ mol (sunset yellow)

$0.0187 = \frac{x}{M_r}$

$x = 8.477$ gr

$x = 8.48$ gr

ResultsPlus
Examiner Comments

The candidate has incorrectly calculated the Mr so the moles are incorrect for M1.

M2 and M3 are then awarded as TE as the rest is correct, "gr" was ignored as the units were not required.

An example of a response with a truncation error.

(ii) The yield, by mass, for the formation of sunset yellow is 67.9%.

Calculate the mass of sunset yellow produced from 5.00 g of compound **A**.

[*M*, of sunset yellow = 452.2]

(3)

$\frac{5}{163} = 0.03$ mol

1:1

0.03 mol × 452.2 = 13.87

ResultsPlus
Examiner Comments

This candidate does not gain M1 as their moles have been rounded to 1 significant figure. M2 is given as a TE, however, for calculating the maximum mass. There is no attempt at M3.

ResultsPlus
Examiner Tip

Record your calculations to at least 3 significant figures throughout. Round them at the end if necessary.

Question 19

Very few blank responses were seen for this question, showing that candidates were familiar with the topic and willing to attempt the question. The mean mark for the question was 2.13 with the most frequently awarded indicative point (IP) being one (tetrahedral to octahedral). The next most frequently awarded IP was five, for ligand exchange, followed by IP4 for deprotonation. A surprising number of candidates gave the copper-ammine ion as $[Cu(NH_3)_6]^{2+}$ so could not gain IP3. $[Cu(NH_3)_4]^{2+}$ was also seen regularly, often with its shape stated as tetrahedral. IP6 was least frequently seen, with many candidates not giving any reason for the ligand exchange taking place or the colour changes being seen.

An example of a response that scores full marks.

***19** A solution containing tetrachlorocuprate(II) ions, $[CuCl_4]^{2-}$, is treated with dilute aqueous ammonia.

The ammonia solution is added gradually.

The following observations are made:

yellow solution → pale blue solution ($[Cu(H_2O)_6]^{2+}$) → pale blue precipitate ($[Cu(H_2O)_4(OH)_2]$) → deep blue solution ($[Cu(NH_3)_4(H_2O)_2]^{2+}$)

Explain the changes occurring in this sequence.

Your explanation should refer to the formulae, shapes and colours of the species present at each stage.

Detailed explanations of how the colours of transition metal complexes occur are not required.

(6)

The original yellow solution is due to $[CuCl_4]^{2-}$ with a tetrahedral shape due to 4 bonding pair of electrons.
By adding dil NH_3, $[CuCl_4]^{2-}$ is ~~oxidised~~ change of to $[Cu(H_2O)_6]^{2+}$ giving a pale blue solution. $[Cu(H_2O)_6]^{2+}$ has a octahedral shape with 6 bonding pairs of electrons as H_2O ligands are smaller, there is an increase in coordination number from 4 to 6 as 6 H_2O are able to bond and fit around Cu^{2+} ions, due to the ligand exchange ~~and change in oxidation no~~ there is a different gap between ~~split~~ energy levels of split d-orbitals in the complex, different wavelengths of light is absorbed and transmitted, giving a pale blue colour instead. By adding more dil NH_3, $[Cu(H_2O)_6]^{2+}$ is converted to $[Cu(H_2O)_4(OH)_2]$ due to deprotonation reaction $[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow [Cu(H_2O)_4(OH)_2] + 2NH_4^+$, giving a pale blue precipitate of $[Cu(H_2O)_4(OH)_2]$ with an octahedral shape. There is a change in colour due to the presence of $(OH)_2$ but no ~~ch~~ ligand exchange has taken place. $[Cu(H_2O)_4(OH)_2]$ is converted to $[Cu(NH_3)_4(H_2O)_2]^{2+}$ when excess NH_3 is added in ~~an~~ a ligand exchange reaction, forming deep blue solution of $[Cu(NH_3)_4(H_2O)_2]^{2+}$.

This complex also has an octahedral shape due to 6 bonding pairs of electrons present, but due to ligand exchange with 4 NH_3 ligands replacing 4 H_2O ligands, there is a change in colour of the complex from pale blue precipitate to deep blue precipitate.

ResultsPlus
Examiner Comments

This candidate gains IP1, IP2, IP6, IP5, IP4 and then IP3 (all on the first page). The answer is succinct with clear formulae and a logical structure. Full marks are awarded. The equation for the deprotonation reaction is also given and could score IP4 without the name of the reaction type.

ResultsPlus
Examiner Tip

This candidate has annotated the question with the ions responsible to help them structure their answer.

An example of a common response.

***19** A solution containing tetrachlorocuprate(II) ions, $[CuCl_4]^{2-}$, is treated with dilute aqueous ammonia.

The ammonia solution is added gradually.

The following observations are made:

+2

yellow solution → pale blue solution → pale blue precipitate → deep blue solution

Explain the changes occurring in this sequence.

Your explanation should refer to the formulae, shapes and colours of the species present at each stage.

Detailed explanations of how the colours of transition metal complexes occur are not required.

(6)

$[CuCl_4]^{2-}$ is a tetrahedral complex with a Cu^{2+} metal cations, making the solution yellow. As aqueous ammonia is added

$[Cu(H_2O)_6]^{2+}$ - Ligand exchange forming aq solution of Cu^{2+} ions

aqua. Complex

$[Cu(H_2O)_4(OH)_2]$ - pale blue precipitate from deprotonation

$[Cu(NH_3)_6]^{2+}$ - deep blue solution from ligand exchange

ResultsPlus
Examiner Comments

This candidate scores IP5 and IP4. IP1 is attempted but there is no "octahedral" so the indicative point is not given. The ammine ion is incorrect so no IP3. Not attempt at IP2 or IP6.

ResultsPlus
Examiner Tip

Refer back to the question to ensure you have answered fully.

Question 20(a)i

This question was well attempted and over 90% of candidates gained the mark. All annotations were allowed, though an asterisk was requested in the question, and some candidates chose to circle the chiral carbon instead. Some candidates also put the asterisk on top of the chiral carbon and this was allowed. A small minority of candidates lost the mark as their asterisk was halfway along the bond towards the acid group and it was not clear which carbon they had indicated.

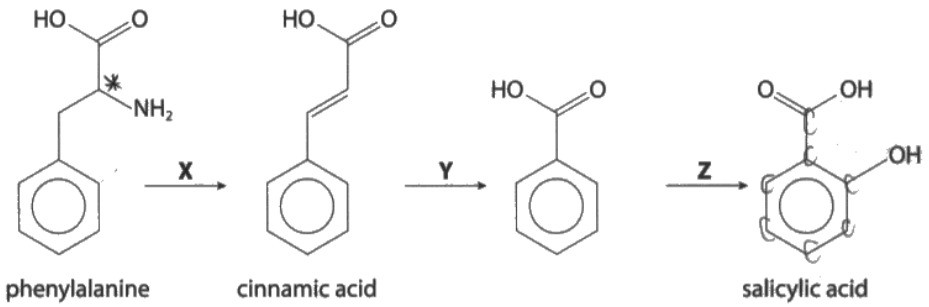
An example of the expected answer.

SECTION C

Answer ALL the questions. Write your answers in the spaces provided.

20 Salicylic acid has been characterised as a plant hormone and is often used by students to prepare aspirin.

Salicylic acid is produced in plants, from phenylalanine via cinnamic acid, using enzymes.



phenylalanine cinnamic acid salicylic acid

(a) (i) Draw an asterisk (*) on the chiral carbon in phenylalanine.

(1)

The candidate has correctly identified the chiral carbon and marked it with an asterisk. Any other annotations on the structures were ignored as workings.

Use the notation asked for in the question when answering.

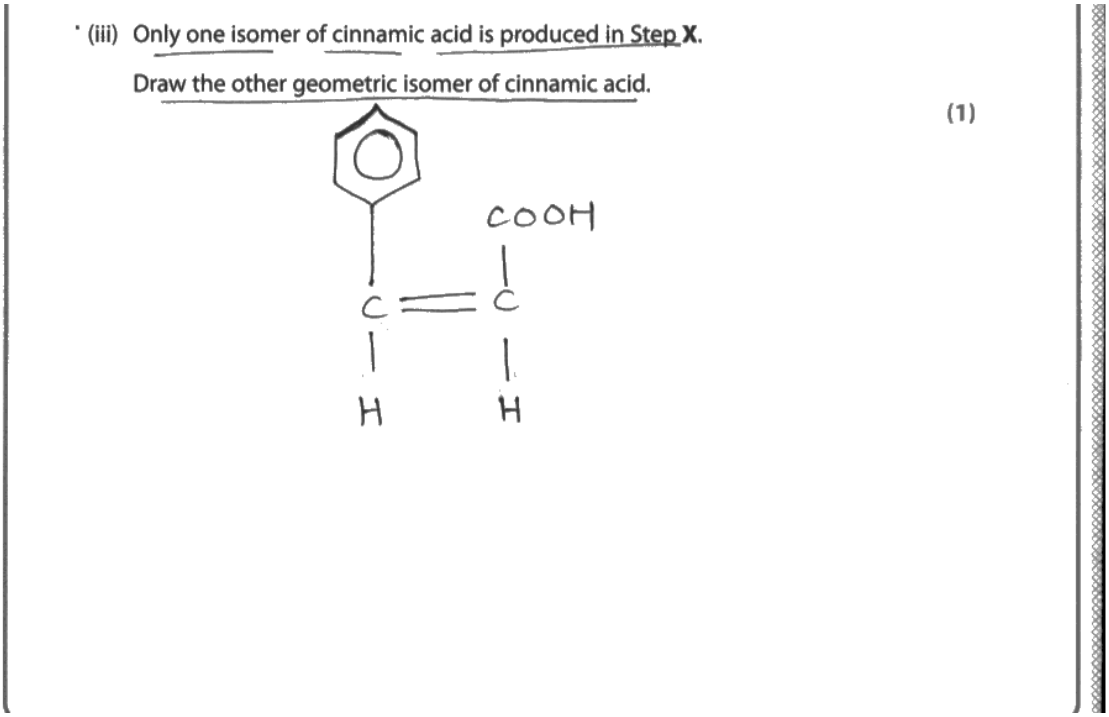
Question 20(a)ii

The expected answer here was elimination, though deamination is correct and was accepted. Only 35% of candidates gained a mark here with common incorrect answers being dehydrogenation, reduction and hydrolysis.

Question 20(a)iii

The most common error seen for this question was to redraw the cis-isomer. Other errors included adding an extra carbon to the chain or drawing an aldehyde instead of an acid. Incorrect connectivity of the acid hydroxyl was penalised and that cost some candidates the mark. Approximately 58% of the cohort gained the mark for this question.

An example of a correct answer.



ResultsPlus
Examiner Comments

All structures were allowed so this displayed structure gains the mark. Bond angles were ignored.

ResultsPlus
Examiner Tip

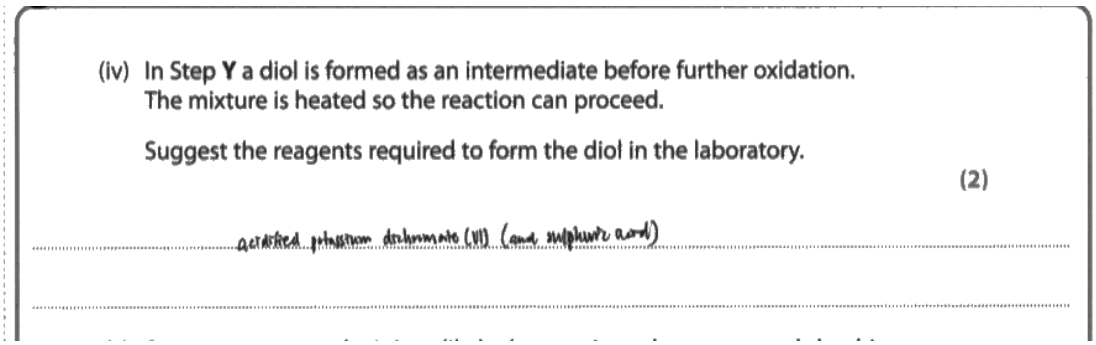
Practise converting structures from skeletal to displayed or the converse so you are familiar with recognising isomers in all depictions.

Question 20(a)iv

This question was well attempted but over 62% of candidates did not gain any credit here. Common errors were choosing an incorrect oxidising agent, such as dichromate or phosphoric acid and then combining it with hydrochloric acid. Many candidates who did opt for potassium manganate(VII) just stated it was acidified so could only gain one mark. The question asked for reagent**s** so more than one compound is required.

Potassium manganate and sodium hydroxide were accepted for two marks, though this combination is not given in the specification, as it is commonly seen in textbooks and does produce the required diol.

An example of a common incorrect answer.



(iv) In Step **Y** a diol is formed as an intermediate before further oxidation.
The mixture is heated so the reaction can proceed.

Suggest the reagents required to form the diol in the laboratory.

(2)

acidified potassium dichromate (VI) (and sulphuric acid)

ResultsPlus
Examiner Comments

This counts as a near miss, the candidate has unfortunately given dichromate(VI) instead of manganate(VII) but still gains the mark for the sulphuric acid.

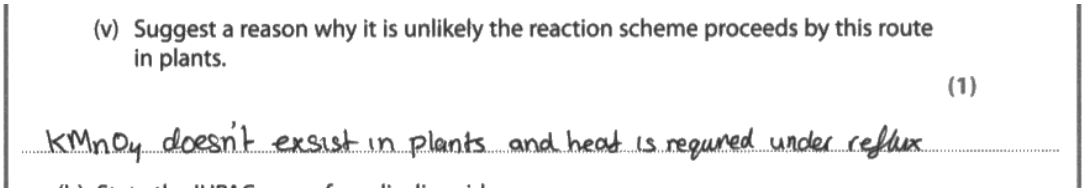
ResultsPlus
Examiner Tip

Test yourself on all the reagents for the different organic reactions using apps or revision cards.

Question 20(a)v

This question was aimed to make the candidates think and apply their learning to the context. 50% of candidates gained the mark, most of these answers related to the availability of reagents or conditions, eg stating that plants didn't contain oxidising agents or that plants can't moderate their temperature. Some candidates gave correct answers that related more to biology, eg that enzymes would be denatured by strong acids and these were also accepted. Incorrect answers were varied and included that the synthesis contains too many steps, has a low yield, takes too long or may produce other isomers.

An example of a response that scores the mark.


(v) Suggest a reason why it is unlikely the reaction scheme proceeds by this route in plants.

(1)

$KMnO_4$ doesn't exsist in plants and heat is requred under reflux

ResultsPlus
Examiner Comments

The temperature/conditions/reagents were ignored as it is their availability that was the marking point for this item. If candidates had already lost a mark for Q20(a)(iv) for using dichromate they were not penalised again here. Candidates should all be familiar with plants and their cells from their general knowledge and secondary education.

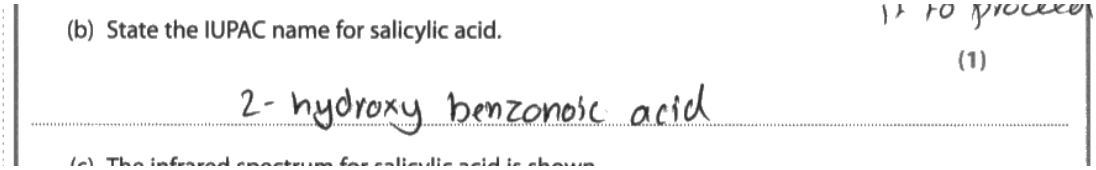
ResultsPlus
Examiner Tip

Be ready to apply your knowledge of Chemistry to unfamiliar contexts.

Question 20(b)

Over 63% of candidates did not gain this mark, which was unexpectedly high. Common errors here included giving the name as 3-hydroxy and including extra letters in the middle of benzoic. Benezenoic acid was allowed but benzanoic and benzonoic were regularly seen and not allowed.

An example of a response that did not score the mark.



This candidate has the numbering and sidechain correct but the name of the acid is incorrect so no mark is awarded.

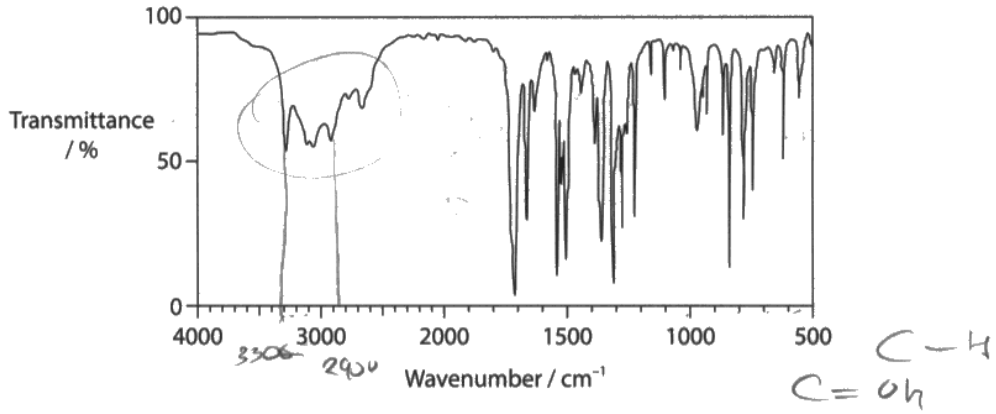
Practise naming compounds from past papers.

Question 20(c)

This question was occasionally left blank but more often candidates gave imprecise answers that did not allow them to gain credit. Over 42% of candidates did not gain any marks here, many of these answers gave correct wavenumbers (or ranges) but just did not refer to the bonds responsible. There were 5 different areas of the spectrum that could be referred to, with 4 different bonds – reference to stretching and bending were not required. In reference to C−H bending, it was common for candidates to give the value for 2 adjacent hydrogens (830 cm^{-1}). This was understandable as those lines in the data booklet are rarely used and they may not understand the equivalency of arene hydrogen atoms in terms of environment.

An example of a common response that did not score.

(c) The infrared spectrum for salicylic acid is shown.



Identify **two** wavenumbers on the spectrum and the bond responsible for each which show that an aromatic group is present in salicylic acid.

Use your Data Booklet.

(2)

The peak at 3300 - 2500 for the carboxylic acid and the peaks at 1600, 1580, 1500 and 1450 for the Arene.

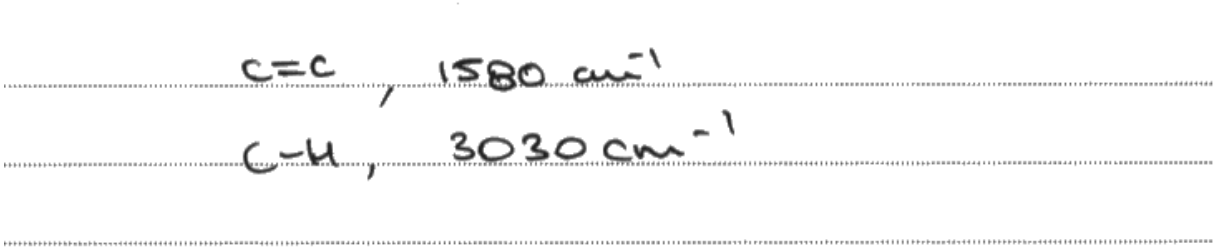
ResultsPlus
Examiner Comments

This candidate has identified numbers from the data booklet but the carboxylic acid range for O−H is incorrect as the group is a phenol. The candidate has also not identified which bond in the carboxylic acid would be responsible for this absorbance. The same is true for their second part of the answer, they have not identified which bond in the arene is responsible for absorbances at those wavenumbers. No marks awarded.

ResultsPlus
Examiner Tip

When using your data booklet ensure you include information from the headings (the type of bond).

An example of a response scoring 2 marks.



ResultsPlus
Examiner Comments

This response shows how little text is required to gain the marks for this question. Only the bond and the wavenumber/range are required.

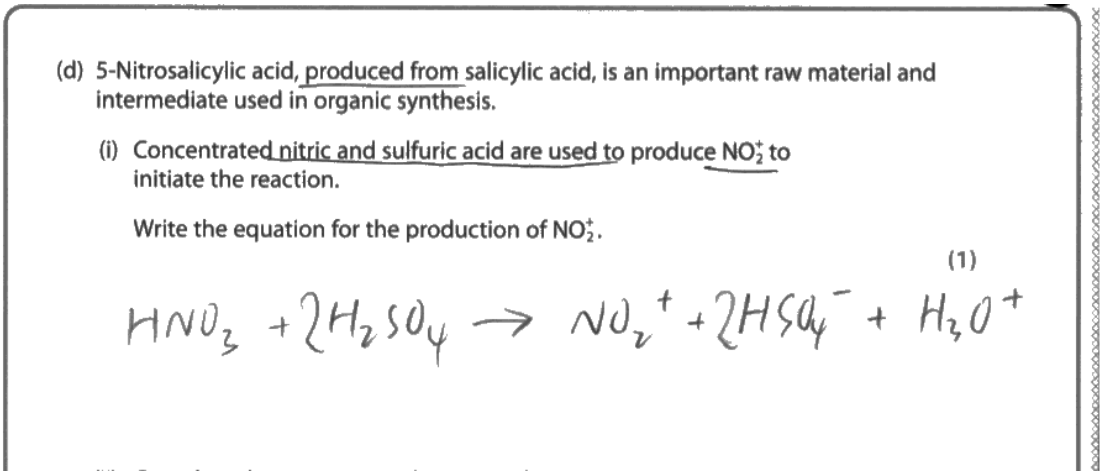
ResultsPlus
Examiner Tip

Practice using your data booklet, ensure you know what each line means.

Question 20(d)i

There were two equations that could be stated for this item, as well as 2 step reactions. Both were seen in equal measure. Over 64% of candidates gained a mark here. Many of the incorrect answers were not balanced, either in charge or atoms. Where state symbols were given, these were ignored as they were not required.

An example of the expected answer.



(d) 5-Nitrosalicylic acid, produced from salicylic acid, is an important raw material and intermediate used in organic synthesis.

(i) Concentrated nitric and sulfuric acid are used to produce NO_2^+ to initiate the reaction.

Write the equation for the production of NO_2^+.

(1)

$HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + 2HSO_4^- + H_3O^+$

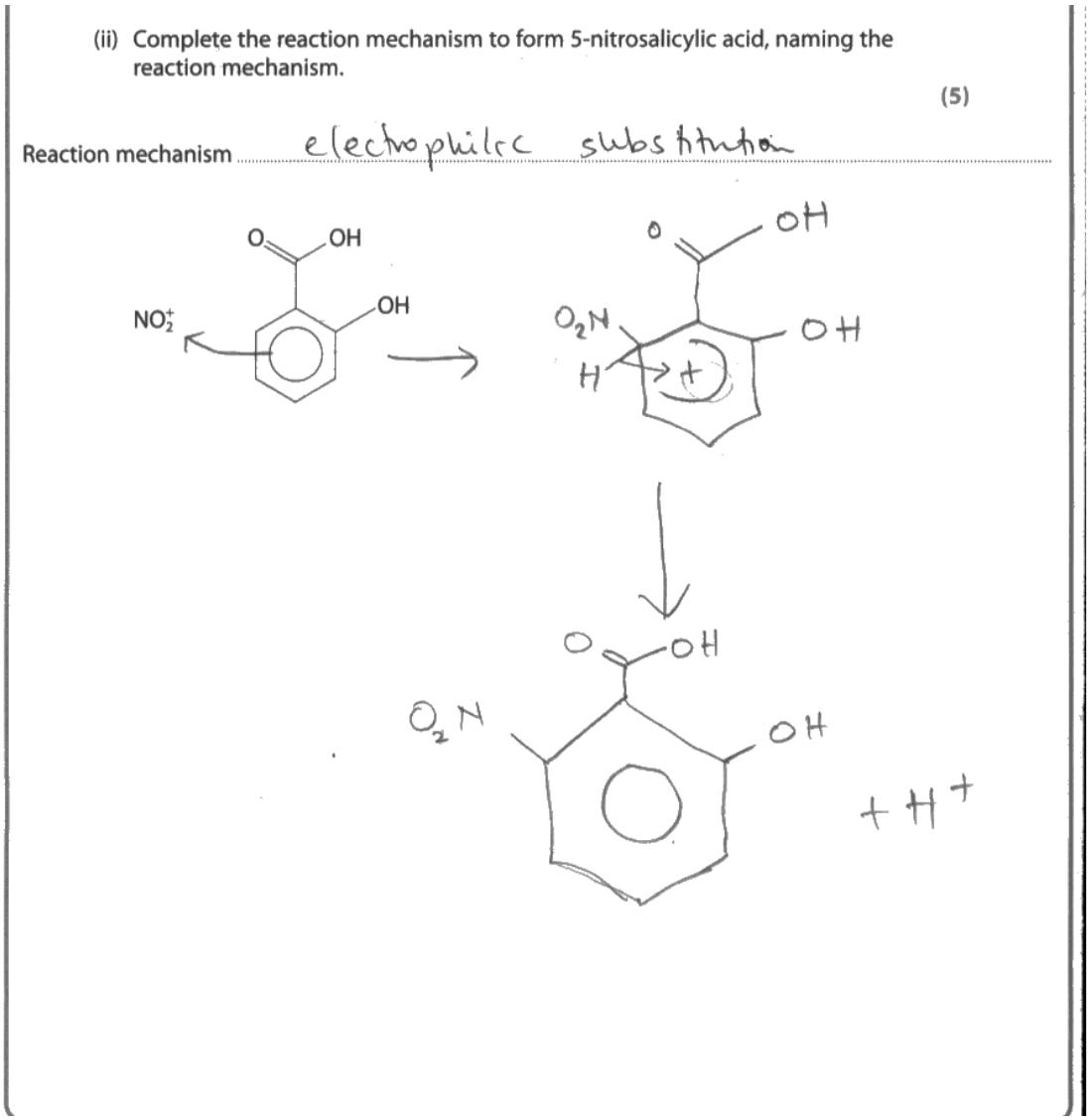
This candidate gained the mark for their response.

Check your equations are balanced for charge and atoms.

Question 20(d)ii

The modal mark for this question was 4 marks and over 40% of candidates gained 4 marks, often just making one mistake. The most common errors were in the position and connectivity of the nitro-group, with it often the bond from the benzene going to an oxygen and it is appearing in the 4- or 6- positions. Other regular errors were stating the reaction was electrophilic addition (rather than substitution) and arrows showing the hydrogen atom moving to the centre of the intermediate – rather than the bond. Some horseshoes inside the ring were far too large, nearly completing the circle and some positive charges were almost on carbon atoms rather than in the centre; these responses did not gain a mark for the intermediate. Occasionally arrows went from the NO_2^+ ion to the circle instead of showing the movement of the electrons.

An example of a common response.



ResultsPlus
Examiner Comments

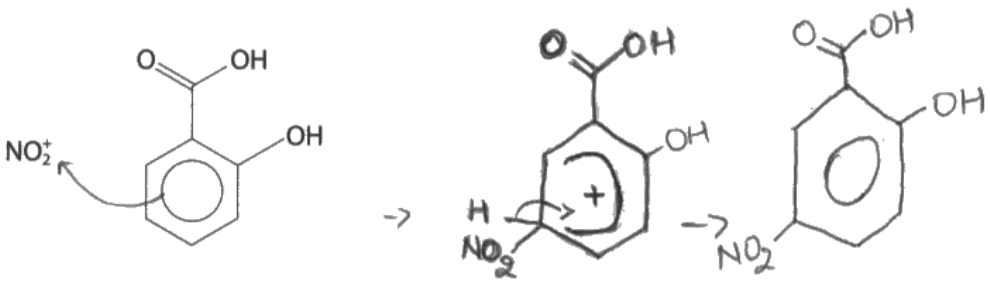
This candidate has made a good attempt at the answer but their final answer shows the 6-nitrosalicylic acid isomer so the final mark is lost.

ResultsPlus
Examiner Tip

Re-read the question after you have finished your response to check your answer is correct.

Another example of a common error.

Reaction mechanism Electrophilic substitution



ResultsPlus
Examiner Comments

This candidate has incorrect connectivity from the nitro-group to the benzene ring so lost a mark on this otherwise correct answer. Note: connectivity was not penalised on the intermediate, just the final structure.

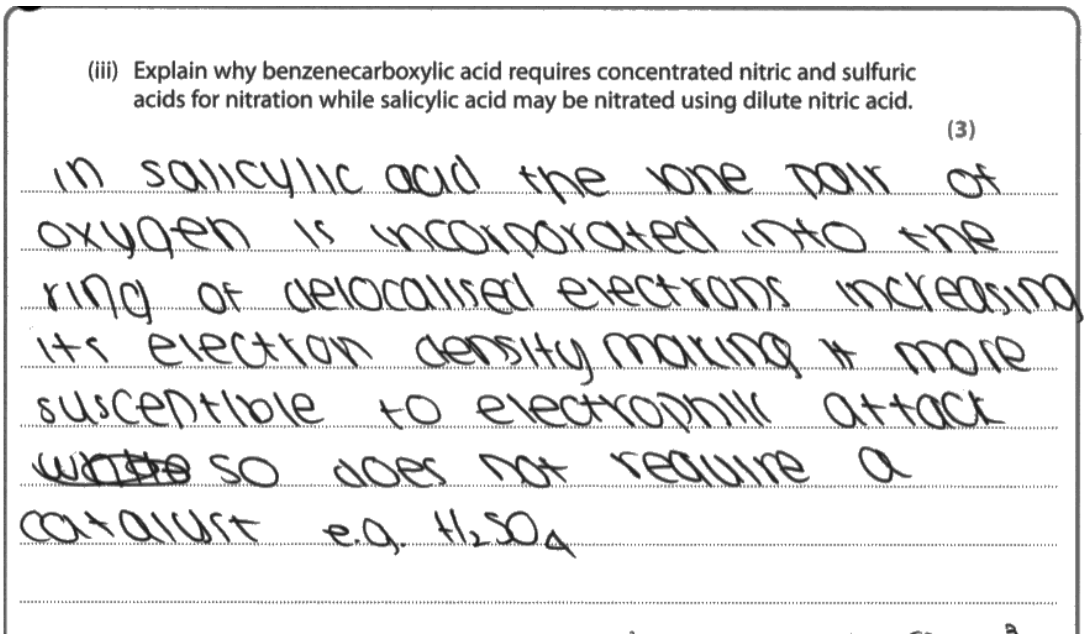
ResultsPlus
Examiner Tip

Check that the atom forming the bond is shown next to the bond on the structure.

Question 20(d)iii

Over 35% of candidates did not gain any credit here and the mean mark was 1.25. The most common mark awarded was for M2, increase in electron density. M1 was the least frequently given as many candidates did not specify which oxygen atom was donating the lone pair. With three oxygen atoms, and two hydroxyl groups (one in the acid) it was essential that candidates were specific. A minority of candidates stated the phenol would be more susceptible to nucleophilic attack.

An example of a common response.



(iii) Explain why benzenecarboxylic acid requires concentrated nitric and sulfuric acids for nitration while salicylic acid may be nitrated using dilute nitric acid.

(3)

in salicylic acid the one pair of oxygen is incorporated into the ring of delocalised electrons increasing its electron density making it more susceptible to electrophilic attack so does not require a catalyst e.g. H_2SO_4

ResultsPlus
Examiner Comments

This response scores 2 marks out of the three available. It is not clear which oxygen has its lone pair incorporated into the delocalised ring so M1 is not given.

ResultsPlus
Examiner Tip

Ensure it is clear which atom you are referring to in your answers.

An example of a fully correct answer.

(iii) Explain why benzenecarboxylic acid requires concentrated nitric and sulfuric acids for nitration while salicylic acid may be nitrated using dilute nitric acid. (3)

The lone pair of electrons on the oxygen, bonded to the benzene ring, overlaps with the delocalised π bond electrons in the ring increasing the rings electron density. Thus salicylic acid benzene ring has a greater attraction to the NO_2^+ electrophile compared to benzenecarboxylic acid. Thus it doesent require H_2SO_4 catalyst.

This candidate's response clearly identifies which oxygen atom is involved. They have described the susceptibility to electrophilic attack in terms of being attracted to the specific ion from the earlier parts of the question. All 3 marks are awarded.

Question 20(e)

There were two approaches to this question and both were seen in equal measure. The answer was not penalised for significant figures as the mass in the question is given as 1g. Over 78% of candidates gained both marks here and few blanks were seen, indicating that candidates did not have any issues with time when completing the paper.

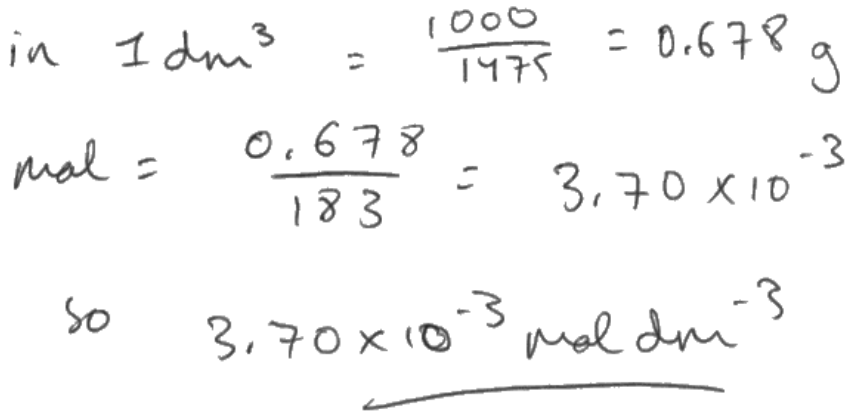
Method 1 from the mark scheme.

(e) 5-Nitrosalicylic acid has a solubility of 1 g in 1475 cm^3 of water.

Calculate the concentration of a saturated solution in mol dm^{-3}.

(2)

[5-nitrosalicylic acid M_r = 183]



ResultsPlus
Examiner Comments

This is an example of the first method from the mark scheme. The candidate's work is clearly laid out and they have underlined their final answer.

ResultsPlus
Examiner Tip

Underlining final answers is helpful to examiners.

An example of method 2.

$$\frac{1}{183} = 5.46 \times 10^{-3}$$

$$\frac{5.46 \times 10^{-3}}{\frac{1475}{1000}} = 3.7 \times 10^{-3} \text{ mol dm}^{-3}$$

This candidate has calculated the answer for M1 and then used this to calculate their final answer. Note: answers should always be expressed in decimal form.

Show all your working in calculations, in case you make an error inputting to your calculator.

Paper Summary

Based on their performance on this paper, candidates should:

- Read the question fully and carefully and make sure you follow the instructions.
- Underline key words in the questions to help you focus your answers.
- Practise drawing intermediates in organic syntheses.
- Show all your working in calculations and use at least 3 significant figures in your interim answers (more for molar masses).
- Check the question to see how many significant figures are required in your final answer.
- Practise drawing cell diagrams, including state symbols.
- Revise all reaction types, reagents and conditions for organic reactions.
- Practise drawing 3D diagrams of molecules and complex ions.
- Review physical and chemical properties of benzene.
- Ensure you can explain all the techniques in the specification (eg gas chromatography).

Grade boundaries

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