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June 2016

GCE Chemistry 6CH05 01

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Introduction

This paper proved accessible to most candidates and provided them with the opportunity to demonstrate their knowledge and understanding of the key concepts in Unit 5 and the A level course as a whole. There was very little evidence of candidates having insufficient time to complete the paper.

The mean score for the multiple-choice questions in Section A was 15/20. Questions 1, 3 and 13 were the most straightforward, whilst questions 8, 10 and 18 were the most demanding.

The majority of candidates attempted the volumetric calculation with confidence and even if they made a slip it was possible to award them some marks as their working was set out clearly. Many candidates were able to deduce the steps for the synthetic route by giving correct reagents and intermediates. Candidates have improved their performance in the electrophilic substitution mechanism and only a few marks were lost due to slips and not thinking about the meaning of a curly arrow.

Some candidates did not read the questions carefully and their answers were incomplete or answering a similar question from a different paper. Candidates must continue to use the correct terminology in their answers as there was evidence of marks lost due to the use of imprecise language. Candidates should revise practical techniques carefully so they can describe them in a logical sequence. Candidates should also make sure that they know how to write balanced equations, particularly ionic equations.

Question 20 (a)

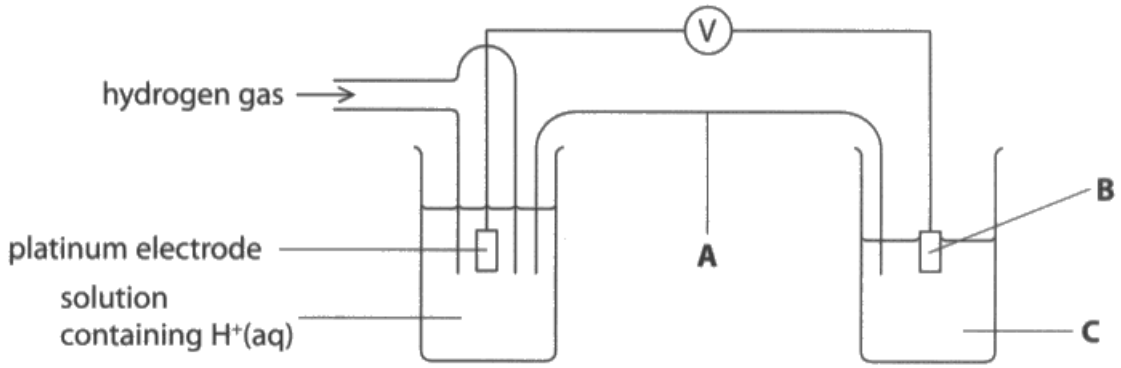
The vast majority of candidates selected the correct values to complete the table.

Question 20 (b)

The majority of candidates found this question straightforward, however, there were some who suggested using potassium hydroxide or potassium manganate(VII) in the salt bridge, a vanadium or graphite electrode and only included one of the vanadium ions in the solution in (i).

The three standard conditions were usually well-known, with just small numbers of candidates giving an incorrect temperature such as room temperature or 273 K or an incorrect concentration such as 1 mol.

(b) The standard electrode potential of $V^{3+}(aq) + e^- \rightleftharpoons V^{2+}(aq)$ is measured using the apparatus below.



(i) Identify, by name or formula, the substances needed in the salt bridge and the right-hand half-cell to measure the standard electrode potential.

(3)

A Salt bridge containing a solution of

excess vanadium ions (V^{3+})

B Electrode made of

vanadium

C Solution containing

V^{3+} ions

(ii) State the **three** standard conditions needed for this measurement.

(2)

1 298 K

2 1 atm pressure

3 1 mol concentration solution

ResultsPlus
Examiner Comments

This response scored 0 for (i). The use of vanadium for the electrode was a common error.

1 mark was awarded for (ii) as 1 mol is not a concentration unit.

ResultsPlus
Examiner Tip

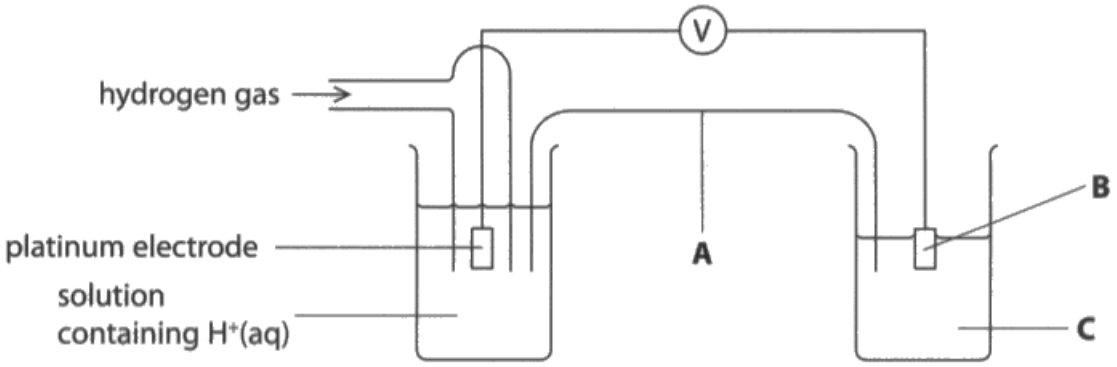
The best solution to use in a salt bridge is potassium nitrate as it will not react with any of the solutions in the beakers to form a precipitate.

When you are measuring the standard electrode potential of a system that does not involve a metallic element, you must use platinum as an inert electrode.

The solution must contain all the ions in the system you are measuring.

Take care when writing units.

(b) The standard electrode potential of $V^{3+}(aq) + e^- \rightleftharpoons V^{2+}(aq)$ is measured using the apparatus below.



(i) Identify, by name or formula, the substances needed in the salt bridge and the right-hand half-cell to measure the standard electrode potential.

(3)

A Salt bridge containing a solution of

KNO_3

B Electrode made of

Platinum

C Solution containing

V^{2+}

(ii) State the **three** standard conditions needed for this measurement.

(2)

1 atm pressure

concentration is 1 mol dm^{-3}

298k temperature

ResultsPlus
Examiner Comments

The salt bridge and electrode are correct in (i) so 2 marks were awarded.

All three conditions are correct in (ii) so 2 marks were awarded.

ResultsPlus
Examiner Tip

Remember to include all the ions, from the half-equation of the system you are using, in the solution.

Question 20 (c)

Many candidates gave excellent answers to this question by including all the relevant information and explaining it clearly. Other candidates found this item more challenging and they struggled to write a balanced ionic equation or calculate a correct E_{cell} value. They would benefit from more practise in these techniques. Some candidates worked out that iodide ions would reduce vanadium(V) to vanadium(IV) in acid solution and stopped there. They should have continued to show that iodide ions would not reduce vanadium(IV) to vanadium(III) to achieve full marks. Some candidates did not give the final oxidation state of vanadium, as asked, and just gave the formula of the ion, VO^{2+}. Many candidates did not relate the sign of E_{cell} to the feasibility of the reaction, seemingly requiring the examiner to make this connection.

*(c) A solution containing iodide ions, I^-, was added to an acidified solution containing vanadium(V) ions, VO_2^+.

Predict the oxidation state of the vanadium ions left at the end of the reaction. Justify your prediction by calculating the $E_{cell}^{\ominus}$ for any relevant reaction(s).

Write the ionic equation for any reaction(s) occurring. State symbols are not required.

(5)

$VO_2^+ + 2H^+ + e^- \rightarrow VO^{2+} + H_2O$ $\quad E^\ominus = +1.00$

$2I^- \rightarrow 2e^- + I_2$ $\quad E^\ominus = -0.54$

$E^\ominus_{cell} = +1.00 - 0.54$

$= +0.46$ reaction possible

$VO^{2+} + 2H^+ + e^- \rightarrow V^{3+} + H_2O$ $\quad E^\ominus = +0.34$

$E^\ominus_{cell} = +0.46 + 0.34$

$= +0.80$ reaction possible

$V^{3+} + e^- \rightarrow V^{2+}$ $\quad E^\ominus = -0.26$

$E^{\ominus}_{cell} = +0.80 - 0.26$

$= +0.54$ reaction possible

$V^{2+} + 2e^- \rightarrow V$ $E^{\ominus} = -1.18$

$E^{\ominus}_{cell} = +0.54 - 1.18$

$= -0.64$

reaction not possible

oxidation state of $V = 2$

(Total for Question 20 = 11 marks)

ResultsPlus
Examiner Comments

This response scored 1 mark for the E_{cell} value for the first reaction. The candidate could have scored another mark if they had written the overall ionic equation for the reaction. The remaining values are incorrect so no further marks could be awarded.

ResultsPlus
Examiner Tip

Read the question carefully and make sure that you answer all parts of it.

Revise how to calculate E_{cell} values.

*(c) A solution containing iodide ions, I^-, was added to an acidified solution containing vanadium(V) ions, VO_2^+.

Predict the oxidation state of the vanadium ions left at the end of the reaction. Justify your prediction by calculating the $E^{\ominus}_{cell}$ for any relevant reaction(s).

Write the ionic equation for any reaction(s) occurring. State symbols are not required.

(5)

$2I^- \rightarrow 2e^- + I_2 \quad (-0.54V)$

$VO_2^+ + 2H^+ + e^- \rightarrow VO^{2+} + H_2O \quad (+1.00V)$

$2VO_2^+ + 4H^+ + 2e^- + 2I^- \rightarrow 2VO^{2+} + 2H_2O + 2e^- + I_2$

Overall E_{cell} of Reaction is $+1.00 + (-0.54) = +0.46V$

∴ As E_{cell} is a positive Value the Reaction will occur. & Vanadium will have an oxidation state of 4^+ at the end

ResultsPlus

Examiner Comments

This is an example of a common response that scored 3 marks. The candidate has correctly given the overall equation, final oxidation state and E_{cell} value for the reduction of vanadium(V) to vanadium(IV) but they have not shown that vanadium(IV) cannot be reduced any further.

ResultsPlus

Examiner Tip

When you are asked to predict the final oxidation state of ions left in a reaction, you need to include a reason why they cannot change any further.

*(c) A solution containing iodide ions, I^-, was added to an acidified solution containing vanadium(V) ions, VO_2^+.

Predict the oxidation state of the vanadium ions left at the end of the reaction. Justify your prediction by calculating the $E^{\ominus}_{cell}$ for any relevant reaction(s).

Write the ionic equation for any reaction(s) occurring. State symbols are not required.

(5)

$2I^- \longrightarrow I_2 + 2e^- \quad E^{\ominus} = -0.54\,V$

$VO_2^+ + 2H^+ + e^- \longrightarrow VO^{2+} + H_2O \quad E^{\ominus} = +1.00\,V$

$2I^- + 2VO_2^+ + 4H^+ \rightarrow I_2 + 2VO^{2+} + 2H_2O \quad E^{\ominus}_{cell} = +0.46\,V$

$E^{\ominus}_{cell}$ is positive $\rightarrow$ reaction is feasible. So VO^{2+} is left for now.

$2I^- \longrightarrow I_2 + 2e^- \quad E^{\ominus} = -0.54\,V$

$VO^{2+} + 2H^+ + e^- \longrightarrow V^{3+} + H_2O \quad E^{\ominus} = +0.34\,V$

~~$I_2 + 2e^- \longrightarrow 2I^- \quad E^{\ominus} = +0.54\,V$~~

~~$2VO^{2+} + 4H^+ + I_2 \rightarrow$~~ $2VO^{2+} + 4H^+ + 2I^- \rightarrow 2V^{3+} + 2H_2O + I_2$

$E^{\ominus}_{cell} = -0.20\,V$

$E^{\ominus}_{cell}$ is negative $\Rightarrow$ VO^{2+} cannot be ~~oxidised~~ reduced furthur.

$\Rightarrow$ The solution is left with VO^{2+} ions at the end of equation.

ResultsPlus
Examiner Comments

This response scored 4 marks. The candidate has given the ionic equation for the reduction of vanadium(V) to vanadium(IV) ions, calculated the E_{cell} value, shown that vanadium (IV) cannot be reduced to vanadium(II) ions and clearly related the feasibility of the reactions to the sign of E_{cell}. However, they have just given the formula of the ions left in solution and not given the oxidation state of vanadium in these ions.

ResultsPlus
Examiner Tip

Read the question carefully to make sure that you have included answers to all parts.

Question 21 (a) (i)

Many candidates found this item difficult. Some mis-read the question and thought that it referred to high resolution proton nmr spectra so they wrote about different splitting patterns. Some thought that there would be a different number of peaks in the spectra and others tried to work out the chemical shift values. Candidates who worked out the peak ratios usually scored 2 marks.

(i) Explain how the **low** resolution proton nmr spectra of these two amino acids differ.

(2)

They will have the same number of peaks but each of the peaks will have a different splitting pattern. Sizes of peaks will be different in different positions.

ResultsPlus
Examiner Comments

This answer scored 0. The candidate has stated that the sizes of the peaks will be different but has not explained how they will be different. The comment about the splitting patterns is irrelevant as this question is about low resolution proton nmr spectra where the splitting is not seen.

ResultsPlus
Examiner Tip

Questions using the command word 'explain' require you to give reasons for your answers.

(i) Explain how the **low** resolution proton nmr spectra of these two amino acids differ.

(2)

- There will be both 4 different peaks at these two nmr spectra.
- But in spectrum for 2-aminopropanoic acid, the height ratio of the 4 peaks is = 1 : 1 : 2 : 3.
- in spectrum for 3-aminopropanoic acid, the height ratio of the 4 peaks ~~or~~ is = 1 : 2 : 2 : 2.

ResultsPlus
Examiner Comments

This answer scored 2 marks. The candidate has shown clearly how the spectra differ due to the different ratios of the peaks by giving the actual values.

ResultsPlus
Examiner Tip

When you are asked for a difference between two things, refer to both in your answer.

Question 21 (a) (ii)

The majority of candidates gained a mark for an acceptable reason why 3-aminopropanoic acid is not chiral, with most of them stating that there is no carbon atom with four different atoms or groups attached. Some just stated that there is no chiral carbon atom, without explaining what this means. A few candidates thought that 3-aminopropanoic acid is chiral.

(ii) Explain whether or not 3-aminopropanoic acid is chiral.

(1)

It is a chiral carbon because it contains 4 different functional groups.

ResultsPlus
Examiner Comments

This candidate must have looked at the structure of 2-aminopropanoic acid as there is no carbon atom in 3-aminopropanoic acid that has four different groups. This response scored 0.

ResultsPlus
Examiner Tip

Read the question carefully and make sure that you refer to the correct structure.

(ii) Explain whether or not 3-aminopropanoic acid is chiral.

(1)

It is not chiral as no one carbon has bonds with three different functional groups

ResultsPlus
Examiner Comments

This response scored 0 as the candidate has referred to three different groups instead of four.

ResultsPlus
Examiner Tip

Revise optical isomerism.

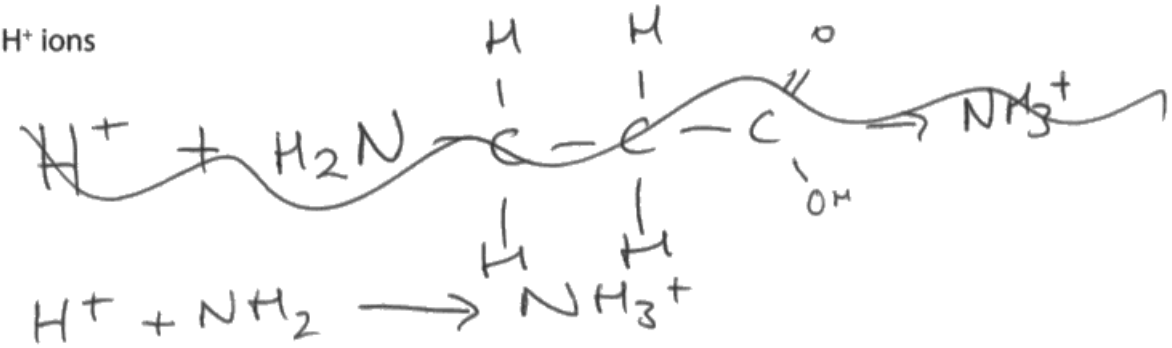
Question 21 (a) (iii)

Many candidates scored 2 marks for this item, with the most common errors being the omission of water as a product in the second equation and not including the charges at the correct ends of the molecules. A small number of candidates just gave the two products without writing equations so they scored 1 mark if the two structures were correct. A few candidates used the wrong amino acid but were awarded 1 mark if both equations were correct.

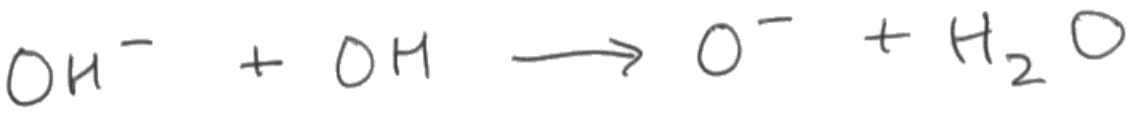
(iii) Write ionic equations for the reaction of 3-aminopropanoic acid with

(2)

H^+ ions



OH^- ions



ResultsPlus
Examiner Comments

This response scored 0. The candidate has tried to take a short cut by just including the functional groups that react. This is not an acceptable way of writing equations.

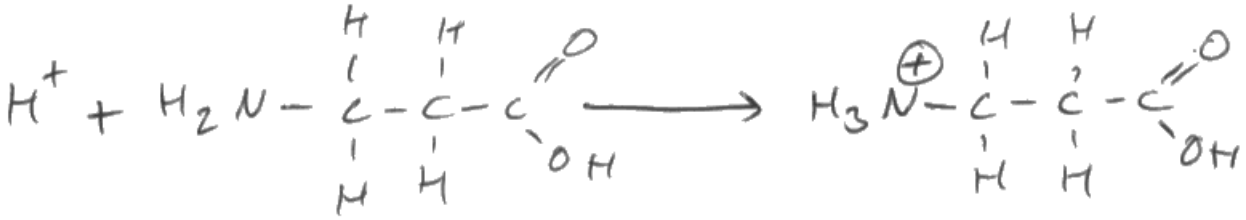
ResultsPlus
Examiner Tip

Write equations in full.

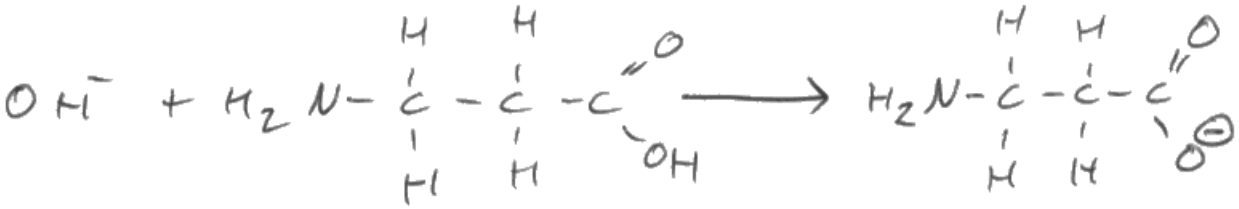
(iii) Write ionic equations for the reaction of 3-aminopropanoic acid with

(2)

H^+ ions



OH^- ions



ResultsPlus
Examiner Comments

This is an example of a common response that scored 1 mark. The candidate has given the structures of the two products but has not balanced the second equation by adding water as a product.

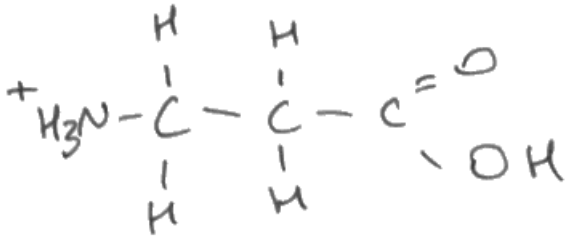
ResultsPlus
Examiner Tip

All equations must be balanced.

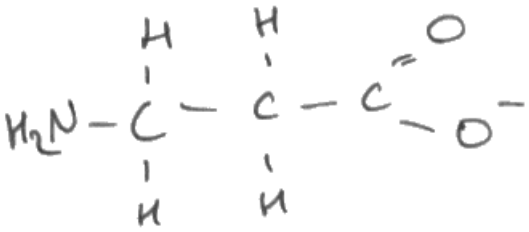
(iii) Write ionic equations for the reaction of 3-aminopropanoic acid with

(2)

H^+ ions



OH^- ions



ResultsPlus

Examiner Comments

This response scored 1 mark for the two correct products.

ResultsPlus

Examiner Tip

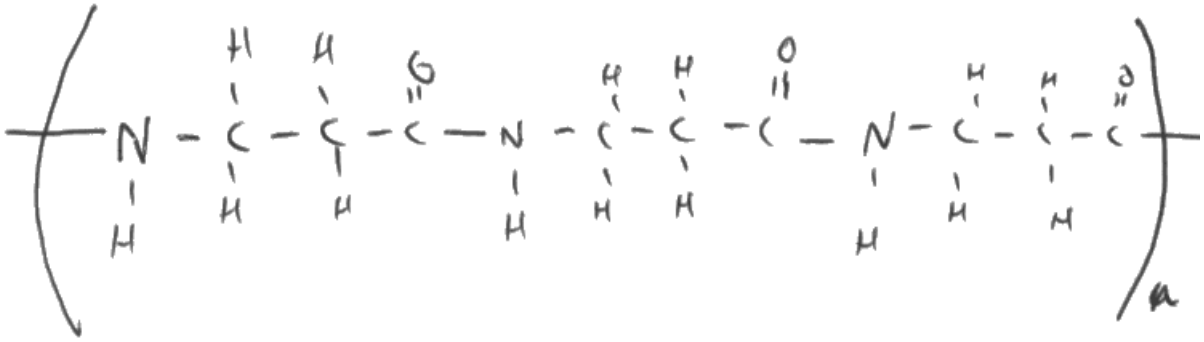
The question asks you to write ionic **equations** so you can only score full marks if you follow this instruction.

Question 21 (a) (iv)

This item was well-answered by many candidates. Some candidates drew a dipeptide instead of two repeat units. Other common errors included: not drawing two repeat units, omitting the extension bonds, including an extra oxygen in the amide group and using 2-aminopropanoic acid.

(iv) Draw two repeat units of the polymer formed when 3-aminopropanoic acid polymerizes.

(1)



ResultsPlus
Examiner Comments

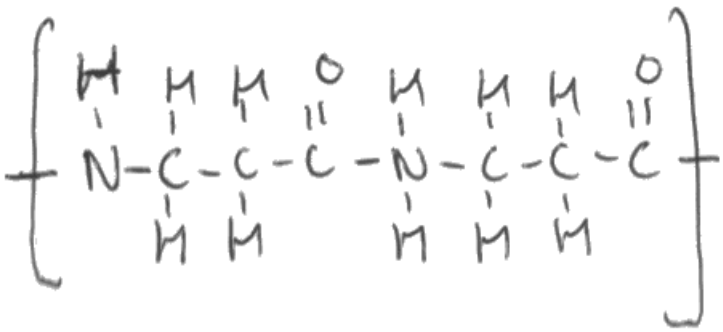
This response scored 0. The candidate has drawn three repeat units instead of two.

ResultsPlus
Examiner Tip

Read the question carefully.

(iv) Draw two repeat units of the polymer formed when 3-aminopropanoic acid polymerizes.

(1)



ResultsPlus
Examiner Comments

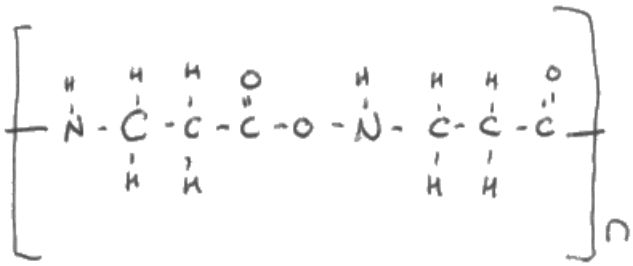
This response scored 0. The candidate has carelessly drawn an extra hydrogen on the nitrogen in the centre of the structure.

ResultsPlus
Examiner Tip

Check your work to avoid careless errors.

(iv) Draw two repeat units of the polymer formed when 3-aminopropanoic acid polymerizes.

(1)



ResultsPlus
Examiner Comments

This response scored 0 for a fairly common error of including an extra oxygen in the amide group.

ResultsPlus
Examiner Tip

Learn the structure of an amide group.

Question 21 (b) (i)

The reagents and conditions for the formation of the diazonium compound were generally well-known. The common errors included: using sodium nitrate instead of sodium nitrite, giving incorrect formulae and giving an incorrect temperature or range of temperatures. It was not uncommon to see a temperature of 5°C and heat under reflux. This additional incorrect statement would negate the condition mark.

(i) Give the reagents and condition for **Step 1**.

(2)

Sodium nitrate and hydrochloric acid,
heat to 55°C

ResultsPlus
Examiner Comments

This response scored 0. The candidate has just written sodium nitrate instead of sodium nitrate(III) or sodium nitrite. The temperature is incorrect and looks as if the candidate has confused this reaction with the nitration of benzene.

ResultsPlus
Examiner Tip

Learn the reagents and conditions for the reactions in the specification.

(i) Give the reagents and condition for **Step 1**.

(2)

$NaNO_2$ and concentrated HCl

ResultsPlus
Examiner Comments

This answer scored 0 as the formula of sodium nitrite is incorrect. It should be $NaNO_2$.

ResultsPlus
Examiner Tip

If you use formulae, they must be correct.

(i) Give the reagents and condition for **Step 1**.

(2)

Sodium nitrite & conc. HCl & Heat under reflux

ResultsPlus
Examiner Comments

This response scored 1 mark. The reagents are correct but this reaction needs a low temperature, not heat.

ResultsPlus
Examiner Tip

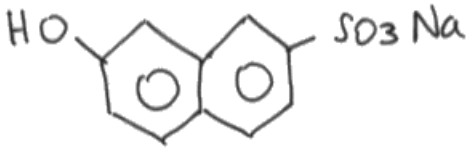
Learn the correct condition for each reaction.

Question 21 (b) (ii)

Many candidates were able to apply their knowledge of azo dye formation to this example of Sunset Yellow. Some candidates included an extra OH group or methyl group on the benzene ring.

(ii) Draw the structure of the reagent needed for **Step 2**.

(1)



ResultsPlus
Examiner Comments

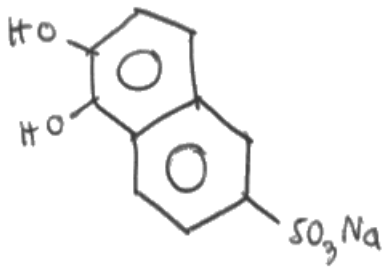
This answer scored 0 as either the OH and SO_3Na group is in the wrong position on the benzene ring.

ResultsPlus
Examiner Tip

Look carefully at the structure of the azo dye given and make sure that you keep all the substituents on the benzene in the same positions.

(ii) Draw the structure of the reagent needed for **Step 2**.

(1)



ResultsPlus
Examiner Comments

This answer scored 0 as there is an additional OH group on the top benzene ring.

ResultsPlus
Examiner Tip

It is a good idea to draw the structure with the same orientation as the one given in the question.

Question 21 (b) (iii)

Many candidates did not realise that the double bond between the two nitrogen atoms has restricted rotation in the same way as C=C. Some candidates thought that there were two different groups attached to each nitrogen atom, whereas the second group is effectively a lone pair of electrons. Quite a lot of candidates thought that the benzene rings restrict rotation. Some candidates did not understand geometric isomerism and discussed structural or optical isomerism.

(iii) Explain why Sunset Yellow can exist as geometric isomers.

(1)

The benzene ring acts like a double bond and rotation is restricted around the ring

ResultsPlus
Examiner Comments

This is an example of a common incorrect answer, scoring 0. The benzene rings are attached to the nitrogen atoms by single bonds and these bonds can rotate.

(iii) Explain why Sunset Yellow can exist as geometric isomers.

(1)

This is because the N=N can have the groups attached as cis or trans, showing geometric isomerism.

ResultsPlus
Examiner Comments

This canidate has realised the N=N is important in giving geometric isomers but has not explained why.

ResultsPlus
Examiner Tip

It is the lack of rotation around a bond that can give rise to geometric isomers.

(iii) Explain why Sunset Yellow can exist as geometric isomers.

(1)

There is barrier to rotation or restricted rotation due to benzene ring.
There is restricted rotation around ~~C=C bond~~ N=N
C=C bond and each atom has 2 different groups
attached to it.

ResultsPlus
Examiner Comments

This response also scored 0. The candidate is familiar with geometric isomerism around C=C but they have not applied that to this example.

ResultsPlus
Examiner Tip

Read the question carefully and apply your knowledge to the specific example given.

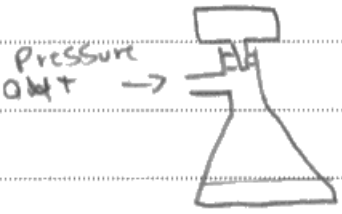
Question 21 (b) (iv)

Although there were some excellent descriptions of recrystallisation, there were many that were poor as they had the steps in the wrong order and they were contradictory. Candidates should revise practical techniques such as this one carefully and make sure that they understand what is happening at each stage. Some candidates just added ethanol to the impure sample without mentioning that the solid needs to be dissolved in the minimum amount of hot ethanol. Another common error was just to add the solution or the crystals to an anhydrous salt to dry them. However, the use of an anhydrous salt in a desiccator to dry slightly damp crystals is a good technique. Some candidates thought that Sunset Yellow was a liquid, even though the question stated that it is a solid, so described distillation and solvent extraction.

*(iv) Describe the essential steps of the method that you would use to prepare a pure, dry sample of the solid Sunset Yellow from an impure sample of the food colouring. You may assume that ethanol is a suitable solvent for this method.

minimal (4)

Firstly ~~w~~ using filter Paper wash the Solid with^ethanol.
Then using a low Pressure device which looks like



Pour the liquid Solution through the top
~~Block the filtered solid in the top~~, drawn air out of the side and
wait until all the ethanol with dissolved impurities is in the
flask. Then leave the remaining solid to dry.

ResultsPlus
Examiner Comments

This response scored 0. The candidate has some idea about the process but none of the points are completely correct. They also do not know the correct name for the apparatus used.

ResultsPlus
Examiner Tip

Use the correct names for apparatus.

Learn how to recrystallise an impure solid.

*(iv) Describe the essential steps of the method that you would use to prepare a pure, dry sample of the solid Sunset Yellow from an impure sample of the food colouring. You may assume that ethanol is a suitable solvent for this method.

(4)

- ~~Firstly~~ Firstly dissolve the impure Sunset Yellow, in the minimum amount of hot solvent to ensure the yield is maximum. Next filter the solution whilst still hot, to remove any insoluble impurities. Next leave the filtered solution to crystalize, and Finally wash the Sunset Yellow crystals with cold water, to remove any soluble impurities

ResultsPlus
Examiner Comments

This response has scored 2 marks. The first two points from the mark scheme are correct. The candidate has mentioned leave it to crystallize but should have mentioned cooling. They have also not filtered the mixture to separate the crystals and a method of drying them.

ResultsPlus
Examiner Tip

The question asked for a dry sample of Sunset Yellow so a method of drying the crystals should be mentioned.

*(iv) Describe the essential steps of the method that you would use to prepare a pure, dry sample of the solid Sunset Yellow from an impure sample of the food colouring. You may assume that ethanol is a suitable solvent for this method.

(4)

- Place impure sample (of known mass) in ethanol. Small amount of ethanol used to ensure saturation.
- Heat ~~solution~~ mixture.
- Filter hot solution to remove the insoluble impurities.
- Cool solution, get crystallisation of pure sample.
- Filter the cool solution.
- Wash the solid with a little amount of cold ethanol (excess can redissolve solid).
- Dry using filter papers.

ResultsPlus
Examiner Comments

This response scored 3 marks. The candidate has placed the impure sample in a small amount of ethanol and then heated it. This is not sufficient for the mark. The impure sample must be dissolved in the minimum amount of hot ethanol. The remaining steps are correct.

Question 21 (b) (v)

The majority of candidates scored a mark for measuring the melting temperature of the sample and comparing it with the Data Book value. Some candidates just mentioned measuring the melting temperature but did not mention the comparison or stating that it would be sharp, so they did not score a mark. A small number of candidates mentioned various types of spectroscopy and a few mentioned measure the boiling temperature.

(v) Suggest how you could check that a sample of Sunset Yellow is pure.

(1)

Check it is a pure sample by heating it and measuring its melting point using a thermometer.

ResultsPlus
Examiner Comments

This response scored 0. Just measuring the melting point is not sufficient.

ResultsPlus
Examiner Tip

A pure substance will have a sharp melting temperature and it will be close to the Data Book value.

(v) Suggest how you could check that a sample of Sunset Yellow is pure.

(1)

Chromatography.

ResultsPlus
Examiner Comments

Just chromatography is not sufficient, so this response scored 0.

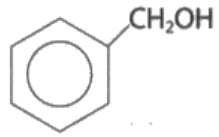
ResultsPlus
Examiner Tip

State what the chromatography will show if the sample is pure, for example, it will only produce one spot on the chromatogram.

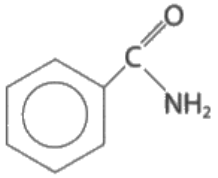
Question 21 (c)

There were many excellent responses for the synthesis of benzamide from phenylmethanol. Some candidates were less successful and tried different reactions that would not work, for example converting benzoic acid into benzoyl chloride by the addition of hydrochloric acid, or converting benzoic acid into benzamide in one step by adding ammonia. Some candidates confused benzamide with phenylamine, ignoring the C=O bond and they tried to reduce nitrobenzene using tin and hydrochloric acid.

(c) Explain how a chemist could use phenylmethanol to synthesise a sample of benzamide in three steps.



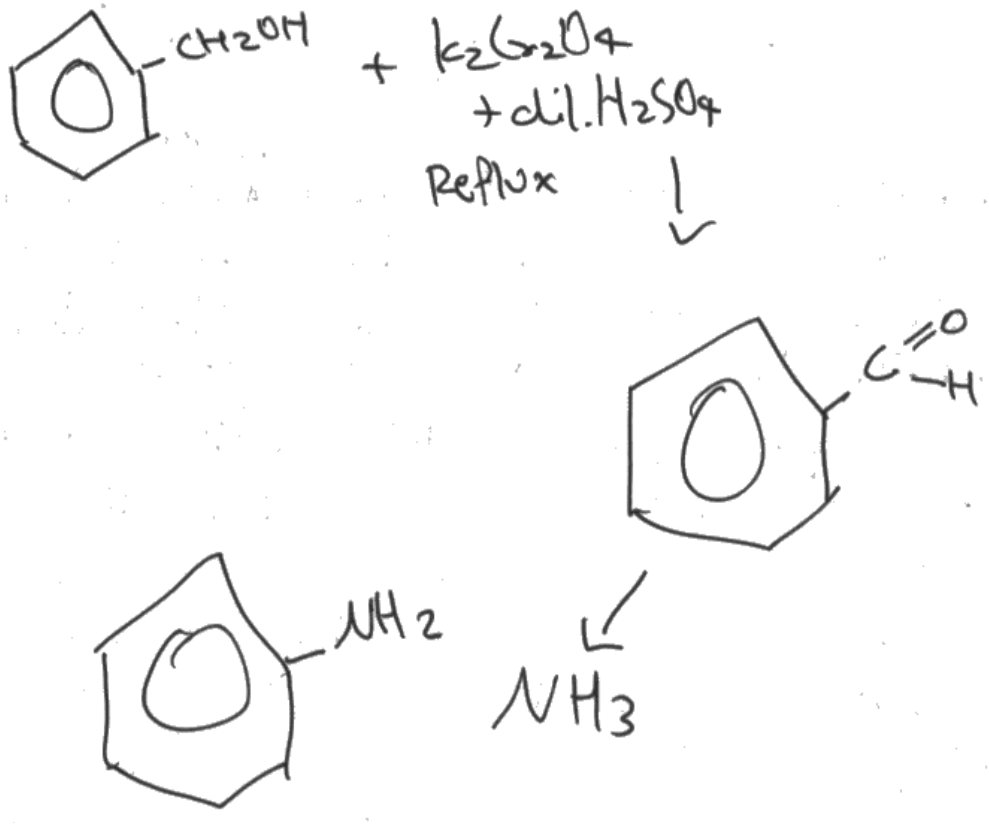
phenylmethanol



benzamide

Include the reagents for the steps in the synthesis and draw the structures of **all** the intermediates.

(5)



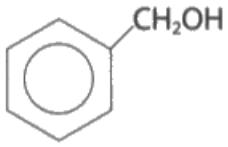
ResultsPlus
Examiner Comments

This response scored 0. The candidate starts correctly by trying to oxidise the alcohol but the formula of potassium dichromate is incorrect so the reagent cannot score a mark. They have stopped at benzaldehyde instead of continuing to benzoic acid. The last stage is incorrect.

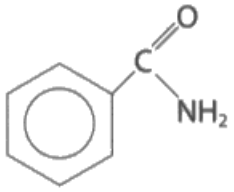
ResultsPlus
Examiner Tip

Learn the formulae of the common reagents.

(c) Explain how a chemist could use phenylmethanol to synthesise a sample of benzamide in three steps.



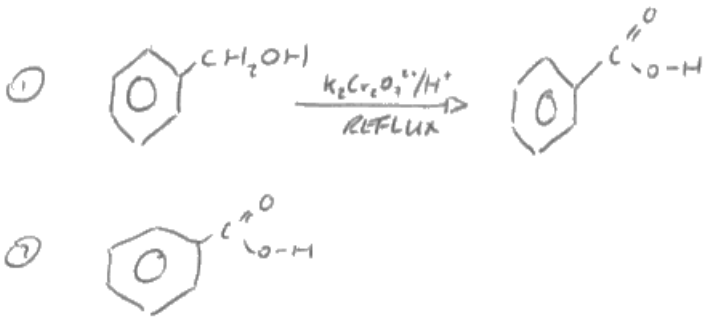
phenylmethanol



benzamide

Include the reagents for the steps in the synthesis and draw the structures of **all** the intermediates.

(5)



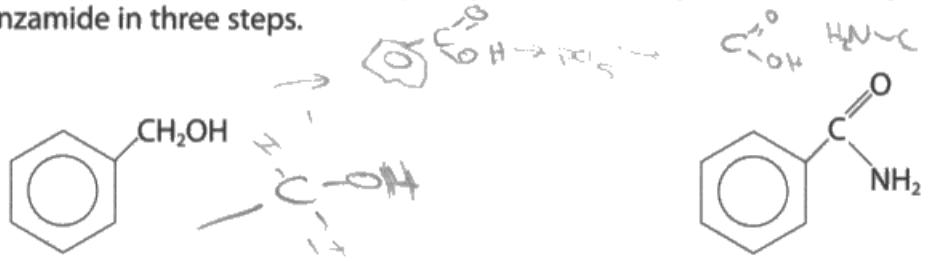
ResultsPlus
Examiner Comments

The candidate has started correctly by oxidising the phenylmethanol to benzoic acid. Unfortunately they cannot complete the synthesis so this response scored 2 marks.

ResultsPlus
Examiner Tip

Learn the reactions of organic compounds from the specification.

(c) Explain how a chemist could use phenylmethanol to synthesise a sample of benzamide in three steps.

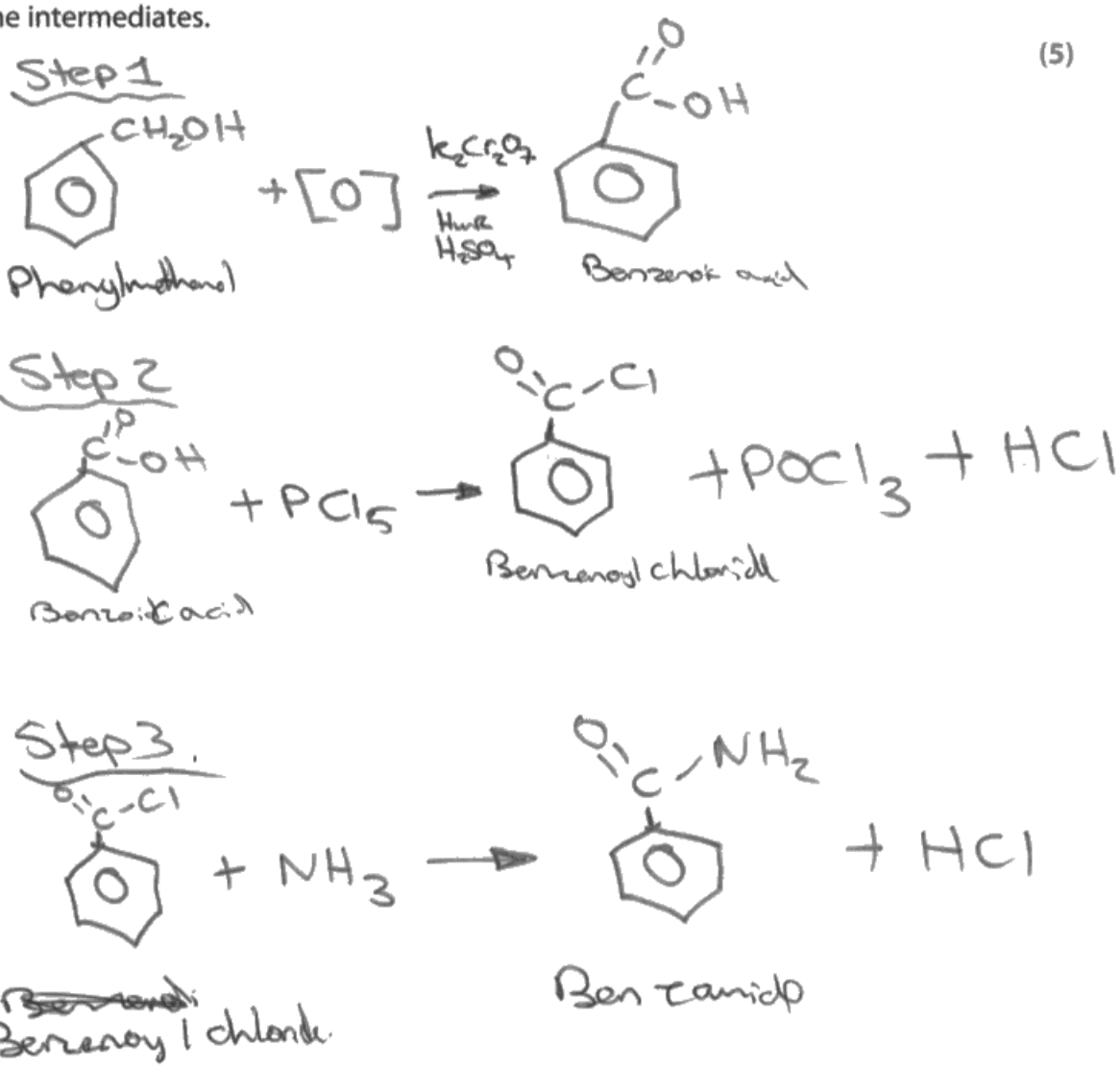


phenylmethanol

benzamide

Include the reagents for the steps in the synthesis and draw the structures of **all** the intermediates.

(5)



ResultsPlus
Examiner Comments

This is an example of an excellent answer that scored 5 marks. The candidate has given the reagents needed for each step and the structures of the intermediates.

ResultsPlus
Examiner Tip

Try to give clear steps for a synthetic route, as in this example.

Question 22 (a)

Many candidates could give the electronic configurations of Cu^{2+} and Zn^{2+} but a significant minority just removed 3d electrons from the atoms and left the 4s electrons. The explanation was often correct but some candidates need to think more carefully about the terminology as they used the terms orbital(s), shell and sub-shell interchangeably without showing any understanding of the differences between them. For example, some wrote that zinc only forms an ion with a full 3d orbital instead of full 3d orbitals. The candidates who wrote about the 3d sub-shell were more successful than those who wrote about the 3d orbitals.

(a) Complete the electronic configurations of the Cu^{2+} ions and Zn^{2+} ions and hence explain why copper is classified as a transition metal but zinc is not.

(2)

Cu^{2+} [Ar] $3d^9$

Zn^{2+} [Ar] $3d^{10}\ 4s^2$

Zn not classified as has all d obtals occupied e/ there are no valent electrons ~~for a electron pair to be accepte~~)

4s2 3d9 29 30

ResultsPlus
Examiner Comments

This response scored 0. The electronic configuration for the zinc ion is incorrect as there should not be any 4s electrons. The explanation is incomplete as it does not refer to a zinc ion and there is no mention of why copper is classified as a transition metal.

ResultsPlus
Examiner Tip

Make sure you understand the meaning of a transition metal and use correct terminology in your answer.

(a) Complete the electronic configurations of the Cu^{2+} ions and Zn^{2+} ions and hence explain why copper is classified as a transition metal but zinc is not.

(2)

Cu^{2+} [Ar] $3d^8\ 4s^1$

Zn^{2+} [Ar] $3d^{10}$

Copper can form ~~one or more~~ a stable ion with a partially filled 3d-subshell, whereas zinc cannot.

ResultsPlus
Examiner Comments

This response scored 1 mark. The electronic configuration of the copper ion is incorrect, however, the explanation refers to both copper and zinc so was awarded a mark.

ResultsPlus
Examiner Tip

Remember that transition metals form ions by losing the 4s electrons first.

(a) Complete the electronic configurations of the Cu^{2+} ions and Zn^{2+} ions and hence explain why copper is classified as a transition metal but zinc is not.

(2)

Cu^{2+} [Ar] $3d^9\ 4s^0$

Zn^{2+} [Ar] $3d^{10}\ 4s^0$

- Cu classified as a transition metal because one or more of its stable ions have partially filled d-orbitals.
- But Zn doesn't have any stable ions have partially filled d subshell. Zn^{2+} has full d-orbitals.

ResultsPlus
Examiner Comments

This is a correct answer worth 2 marks.

ResultsPlus
Examiner Tip

Give a full explanation, as in this example, using the correct terminology.

Question 22 (b)

Many candidates found this question difficult. If they realised that silver is formed then they should work out that the silver ions are reduced so the copper(I) ions are oxidised to copper(II).

(b) Some photochromic glasses contain silver(I) and copper(I) chlorides.

Explain, with the aid of an equation, why these photochromic glasses go darker in sunlight.

(2)

$AgCl \xrightarrow[UV]{Light} Ag^+ + Cl^-$

The silver ions have a dark colour so the more UV light the glasses are exposed to, the more Ag^+ is formed and the darker the lense becomes.

ResultsPlus
Examiner Comments

This response scored 0. The candidate has just shown silver chloride split up into silver and chloride ions so there is no redox reaction and the equation does not include copper(I) chloride.

ResultsPlus
Examiner Tip

Make sure that any equation you write includes all the reactants mentioned in the question.

(b) Some photochromic glasses contain silver(I) and copper(I) chlorides.

Explain, with the aid of an equation, why these photochromic glasses go darker in sunlight.

(2)

$$AgCl + Cu \xrightarrow{light} CuCl + Ag_{(s)}$$

light (UV) catalyses this process and produces $Ag_{(s)}$ which is dark.

ResultsPlus
Examiner Comments

This response scored 1 mark for the production of silver.

ResultsPlus
Examiner Tip

Read the question carefully. This question tells you to start with copper(I) chloride so that should be a reactant in the equation, not a product.

(b) Some photochromic glasses contain silver(I) and copper(I) chlorides.

Explain, with the aid of an equation, why these photochromic glasses go darker in sunlight.

(2)

$$CuCl + AgCl \rightarrow Ag_{(s)} + CuCl_2$$

The sunlight provides UV radiation to help the copper(I) chloride breaks down the silver chloride to silver, which is a silver solid so causes the glasses to darken in sunlight

ResultsPlus
Examiner Comments

This is a good answer scoring 2 marks.

ResultsPlus
Examiner Tip

Write balanced equations using the reactants in the question and write a clear explanation based on the equation.

Question 22 (c)

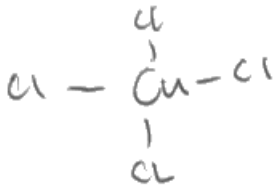
The tetrachlorocuprate(II) ion has a square planar shape in some crytalline solids and although the question told the candidates that this ion has the same shape as the cis-platin complex, they were also awarded a mark for a tetrahedral shape that they may have remembered from an aqueous solution. If they drew a tetrahedral shape, it had to be an attempt at a 3-dimensional shape with a wedge coming forwards and a dotted line or wedge going into the paper. The majority of candidates knew the type of bonding although some wrote ionic or metallic and a few candidates misread the question and gave the name of the shape or the bond angle.

(c) Copper forms a complex ion with the formula $[CuCl_4]^{2-}$. This has the same shape as $[Pt(NH_3)_2Cl_2]$.

Draw the shape of the $[CuCl_4]^{2-}$ ion and state the type of bonding between the ligands and the metal ion.

(2)

Shape



Bonding ..... metalwe bonding

ResultsPlus
Examiner Comments

This reponse scored 1 mark for the square planar shape. The bonding is incorrect.

ResultsPlus
Examiner Tip

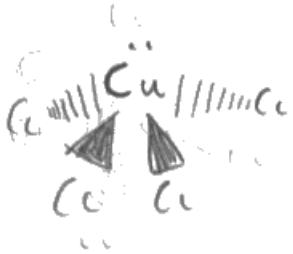
Remember that there is dative covalent bonding between a ligand and a metal ion.

(c) Copper forms a complex ion with the formula $[CuCl_4]^{2-}$. This has the same shape as $[Pt(NH_3)_2Cl_2]$.

Draw the shape of the $[CuCl_4]^{2-}$ ion and state the type of bonding between the ligands and the metal ion.

(2)

Shape



Square pyramidal.

Bonding Ionic

ResultsPlus
Examiner Comments

This response scored 0. The shape and the bonding are incorrect.

ResultsPlus
Examiner Tip

Learn the shapes of the complexes listed in the specification.

Question 22 (d) (iii)

Candidates are more familiar with explaining why solutions of transition metal ions are coloured so some of them struggled to explain why this solution is colourless. The majority of candidates did realise that it was related to the full 3d sub-shell of the copper(I) ion but a lack of precision in the use of scientific terminology meant that only a small minority scored the second mark. The common incorrect answers included: the d sub-shell does not split, the splitting has too large an energy gap, the light absorbed is outside the visible spectrum and a discussion about electrons not being able to be promoted to a higher energy level, without specifying which energy level.

(iii) Explain why the $[CuCl_2]^-$ ions are colourless.

(2)

A d-d electron transition still takes place as Cu^+ still has a partially ~~filled~~ filled d orbital. However, the frequency of light emitted is not within the visible region as the energy gap during the electron transition is too large. Thus, the ions are colourless.

ResultsPlus
Examiner Comments

This response scored 0. The candidate has remembered that colour may be related to d-d transitions, however, they have missed the point here as the copper(I) ion does have a full 3d sub-shell.

ResultsPlus
Examiner Tip

Make sure you understand how colour arises in transition metal ions and why some ions are colourless in solution.

(iii) Explain why the $[CuCl_2]^-$ ions are colourless.

(2)

The Cu^+ ion has a complete 3d orbitals and no electrons in its 4s orbital. This means that no splitting of orbitals and subsequent promotion of electrons can take place. So no light is absorbed for promotion of electrons, so no colour is observed.

ResultsPlus
Examiner Comments

This is an example of a common response that scored 1 mark. The candidate has realised that the copper(I) ion has complete 3d orbitals but thinks there is no splitting, which is incorrect.

ResultsPlus
Examiner Tip

The 3d sub-shell will still be split by the water ligands, however, there is no space for an electron to be promoted from a lower 3d orbital to a higher 3d orbital.

(iii) Explain why the $[CuCl_2]^-$ ions are colourless.

(2)

It is colourless because the Cu has an oxidation state of +1 so its electronic configuration is $[Ar]\,3d^{10}4s^0$ so it has a full 3d subshell so there can be no electron transitions in the d subshell so it is colourless.

ResultsPlus
Examiner Comments

This is an example of a response that scored 2 marks. The candidate has stated the electronic configuration and explained why the solution is colourless.

ResultsPlus
Examiner Tip

Try to give a clear explanation as in this example.

Question 22 (d) (i)-(ii)

Many candidates found it difficult to construct a correct equation for the reaction described in (i), even though there were five equations that were acceptable. A common error was to omit the hydrochloric acid or the chloride ions from it or to include hydrogen gas as a product. Candidates should remember to balance equations by considering the charges as well as the atoms. Most candidates could explain the meaning of disproportionation but the majority could not apply it to this example, with many stating that this was disproportionation. This indicates that they had learnt a definition but not understood it. They should have explained why the reaction was the reverse of disproportionation.

(d) The $[CuCl_2]^-$ ion is formed by boiling a solution of copper(II) chloride with copper turnings and concentrated hydrochloric acid.

(i) Write an equation for this reaction. State symbols are not required.

(1)

$CuCl_2 + HCl + Cu \longrightarrow [CuCl_2]^-$

(ii) State the meaning of the term **disproportionation** and explain whether or not this reaction to form the $[CuCl_2]^-$ ion is a disproportionation reaction.

(2)

Disproportionation is when a ~~reaction~~ molecule is oxidised and reduced at the same time.

ResultsPlus
Examiner Comments

This response scored 0 for both parts. The equation in (i) has the potential to be correct as all the correct species are given as reactants but H^+ ions are missing as a product and the equation is not balanced. This definition of disproportionation is not acceptable as it is not precise enough. The molecule is not oxidised and reduced but atoms within it.

ResultsPlus
Examiner Tip

Make sure you understand the meaning of disproportionation. It is better to write about the simultaneous oxidation and reduction of a single species rather than a particular type of particle.

(d) The $[CuCl_2]^-$ ion is formed by boiling a solution of copper(II) chloride with copper turnings and concentrated hydrochloric acid.

(i) Write an equation for this reaction. State symbols are not required.

(1)

$CuCl_2 + Cu + 2HCl \longrightarrow 2[CuCl_2]^- + 2H^+$

(ii) State the meaning of the term **disproportionation** and explain whether or not this reaction to form the $[CuCl_2]^-$ ion is a disproportionation reaction.

(2)

A disproportionation reaction is when an element in both oxidised & reduced at the same time. The reaction for $[CuCl_2]^-$ is not a disproportionation reaction as the Cu in both $CuCl_2$ & Cu start off with no oxidation state & then goes to $[CuCl_2]^-$ with an oxidation state of +1 so they're only been oxidised

ResultsPlus
Examiner Comments

(i) This scored 1 mark for a correct equation.

(ii) This scored 1 mark for the meaning of disproportionation. Element was allowed, although species would be better. The reason for this not being disproportionation is incorrect.

ResultsPlus
Examiner Tip

Make sure that you can work out oxidation numbers. The oxidation number of copper in $CuCl_2$ is +2.

(d) The $[CuCl_2]^-$ ion is formed by boiling a solution of copper(II) chloride with copper turnings and concentrated hydrochloric acid.

(i) Write an equation for this reaction. State symbols are not required.

(1)

$$CuCl_2 + Cu + 2HCl \Rightarrow 2[CuCl_2]^- + 2H^+$$

(ii) State the meaning of the term **disproportionation** and explain whether or not this reaction to form the $[CuCl_2]^-$ ion is a disproportionation reaction.

(2)

Disproportionation is when a species is simultaneously oxidised and reduced. This is not a disproportionation reaction as the species being the reduced is the copper in the $CuCl_2$ and the species being oxidised is the Cu. The Cu^{2+} and Cu are not the same species as they are not in the same oxidation state so it is not disproportionation

ResultsPlus
Examiner Comments

This is an excellent answer scoring 1 for (i) and 2 for (ii).

ResultsPlus
Examiner Comments

Give clear explanations, as in this example.

Question 22 (e) (i)

It was disappointing that less than half of the candidates scored a mark for this straightforward equation. Some candidates wrote a non-ionic equation, even though ionic is printed in bold in the question and others showed ions but included the spectator ions. Some did not balance the equation, either by omitting two hydroxide ions or forgetting to add water if they used the hexaaqua complex. A significant minority omitted one or more state symbols. Candidates would benefit from more practice in writing equations for the reactions in the specification.

(i) Write the **ionic** equation for the reaction of copper(II) sulfate solution with aqueous sodium hydroxide. Include state symbols.

(1)

$Cu^{2+}_{(aq)} + 2OH^-_{(aq)} \longrightarrow Cu(OH)_{2(aq)}$

ResultsPlus
Examiner Comments

This response scored 0. The candidate has written a correct ionic equation but the state symbol of copper(II) hydroxide is incorrect.

ResultsPlus
Examiner Tip

Use the information given in the question to help you to work out state symbols. You are told that copper(II) hydroxide is a precipitate, so the state symbol must be (s).

(i) Write the **ionic** equation for the reaction of copper(II) sulfate solution with aqueous sodium hydroxide. Include state symbols.

(1)

$Cu^{2+}_{(aq)} + OH^-_{(aq)} \longrightarrow [Cu(H_2O)_4(OH)_2]_{(s)}$

ResultsPlus
Examiner Comments

This response scored 0. The candidate has written an ionic equation and included state symbols, but the equation is not balanced. There should be two hydroxide ions and there are four water molecules on the right but none on the left.

ResultsPlus
Examiner Tip

All equations must be balanced.

This candidate has underlined the important words from the question to help them to remember what to include in the answer.

Question 22 (e) (ii)

This was a straightforward question that the majority of candidates got right. Common incorrect answers included: deprotonation, reduction and just substitution.

(ii) State the type of reaction occurring overall when excess aqueous ammonia is added to copper(II) sulfate solution.

(1)

Ligand exchange, (Acid base reaction)

ResultsPlus
Examiner Comments

This candidate has written the correct answer but then added an additional incorrect answer so no mark could be awarded.

ResultsPlus
Examiner Tip

If you write an additional incorrect answer, this will negate the mark that could have been awarded for the correct answer.

Question 22 (f) (i)

The majority of candidates could state what is meant by a bidentate ligand. Some candidates thought that there are two ligands attached to the metal ion and some just stated that the ligand has two lone pairs of electrons without describing what they do.

(i) State what is meant by the term **bidentate**.

(1)

If the ligand has 2 lone pairs

ResultsPlus
Examiner Comments

This response does not go far enough to be awarded a mark. It needs to state that the lone pairs are used to form bonds to the metal ion.

ResultsPlus
Examiner Tip

Give more detail in your answers.

(i) State what is meant by the term **bidentate**.

(1)

Has two sets of lone pairs that can form dative covalent bonds with metal ion.

ResultsPlus
Examiner Comments

This is an example of a good answer that scored 1 mark.

ResultsPlus
Examiner Tip

Give the full meaning of any terms you are asked about.

Question 22 (f) (ii)

Many candidates gave good answers that scored 2 marks. Some candidates had the right idea but lost a mark by using poor terminology, for example, referring the 4 molecules increasing to 7 molecules when there is a mixture of ions and molecules in the equation. A small minority just went as far as stating there is an increase in disorder and did not mention entropy in their answers.

(ii) Explain, in terms of entropy, why the reaction takes place.

(2)

dative covalent bonds

4 moles goes to 6 moles of products. Therefore there's an increased degree of disorder.

ResultsPlus
Examiner Comments

This response scored 0. There are 7 moles of particles, not 6, on the right of the equation. The disorder does increase but this is not sufficient for the second mark as there is no mention of entropy.

ResultsPlus
Examiner Tip

Check the number of particles carefully.

(ii) Explain, in terms of entropy, why the reaction takes place.

(2)

- Because in the reaction going from 4 moles of reactants to 7 moles of products moles increasing
- This means that ΔS_{system} is positive as it gets more disordered
- Entropy increases

ResultsPlus
Examiner Comments

This is an example of a good answer that scored 2 marks.

ResultsPlus
Examiner Tip

Give full explanations, as in this example.

Question 23 (a)

The majority of candidates knew that paracetamol contains an amide group. Incorrect answers included amine and ketone.

Question 23 (b) (i)

Many candidates could identify the matching conjugate acid-base pairs, although a significant minority just wrote acid or base on the lines and did not attempt to link the pairs using lines or numbers. A small minority wrote the formula of the conjugate acid or base on the line but did not state which was the acid or base.

(i) In a typical nitration of an arene, the electrophile is formed as shown below.

HNO_3 + H_2SO_4 → $H_2NO_3^+$ + HSO_4^- **Equation 1**

Base. acid acid. base

$H_2NO_3^+ \rightarrow H_2O + NO_2^+$ **Equation 2**

acid → donor
Base → acceptor

Identify the acid-base conjugate pairs in **Equation 1**. Write your answers on the dotted lines under the equation.

(1)

ResultsPlus
Examiner Comments

This candidate has correctly identified whether each species is an acid or a base but they have not linked them together as conjugate pairs so no mark was awarded.

ResultsPlus
Examiner Tip

You can link acid-base pairs by drawing a line between the matching pair, labelling them as acid 1 - base 1 or as acid and conjugate base.

(i) In a typical nitration of an arene, the electrophile is formed as shown below.

HNO_3 + H_2SO_4 → $H_2NO_3^+$ + HSO_4^- **Equation 1**

Base 2 Acid 1 Acid 2 Base 2

$H_2NO_3^+ \rightarrow H_2O + NO_2^+$ **Equation 2**

Identify the acid-base conjugate pairs in **Equation 1**. Write your answers on the dotted lines under the equation.

(1)

ResultsPlus
Examiner Comments

This response scored 0. The candidate has used the numbers 1 and 2 but has mixed them up. Sulfuric acid is not the conjugate acid of nitric acid. The acid and base with the same number must be a matching conjugate pair.

ResultsPlus
Examiner Tip

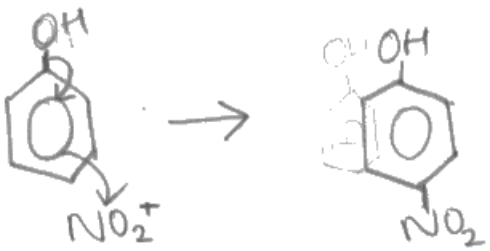
Think carefully about how to show a matching conjugate acid-base pair. If you are not sure about using numbers, use a line to link each pair.

Question 23 (b) (ii)

Many candidates drew clear mechanisms for the nitration of phenol and scored full marks. Some candidates just showed the nitration of benzene or gave the mechanism for the formation of 2-nitrophenol so they lost a mark. Most candidates drew the first curly arrow to the NO_2^+ ion correctly, but a significant number lost a mark for a poorly drawn intermediate as the 'horseshoe' was pointing to the wrong carbon atom, the positive charge was not inside the horseshoe or they left a positive charge on the NO_2 group as well as in the centre of the ring. Some candidates lost the last mark as they started the curly arrow from the hydrogen atom instead of the C-H bond.

(ii) Give a mechanism for the nitration of phenol by NO_2^+ to form 4-nitrophenol.

(3)



ResultsPlus
Examiner Comments

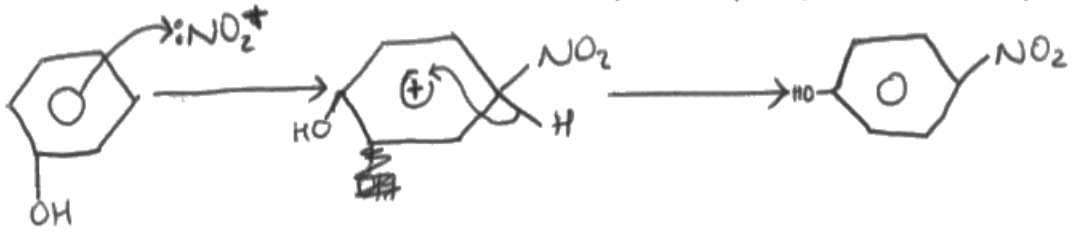
This response scored 0. Although the curly arrow from the ring to the NO_2^+ group is correct, it is negated by the additional incorrect curly arrow from the C-O bond to the ring.

ResultsPlus
Examiner Tip

Learn the mechanism for the nitration of benzene so that you can apply it to other molecules that contain a benzene ring.

(ii) Give a mechanism for the nitration of phenol by NO_2^+ to form 4-nitrophenol.

(3)



ResultsPlus
Examiner Comments

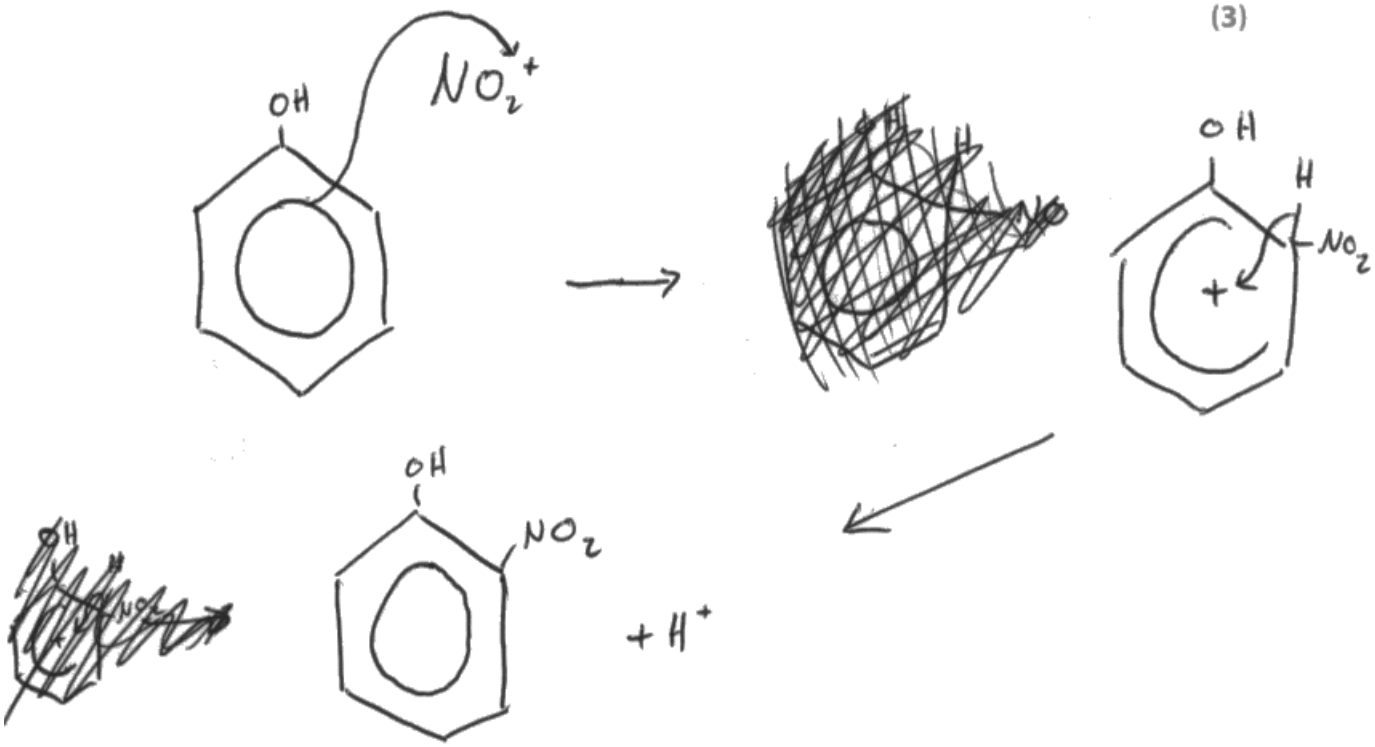
This response scored 1 mark. The first curly arrow is correct but it does not form a bond to a lone pair of electrons on the nitrogen atom, so this did not score the first mark. The 'horseshoe' in the centre is pointing to the wrong carbon atom - the open end should be facing the carbon atom with four bonds. The curly arrow from the C-H bond is correct.

ResultsPlus
Examiner Tip

Make sure that you understand the meaning of a curly arrow - it represents the movement of a pair of electrons so it cannot point towards a lone pair of electrons. Be careful how you draw the structure of the intermediate in this mechanism.

(ii) Give a mechanism for the nitration of phenol by NO_2^+ to form 4-nitrophenol.

(3)



ResultsPlus
Examiner Comments

This response scored 2 marks. The mechanism is correct but it shows the formation of 2-nitrophenol.

ResultsPlus
Examiner Tip

Read the question carefully and check to make sure that you start with the correct reactant and finish with the correct product.

Question 23 (b) (iii)

Many candidates gave clear explanations that scored 2 marks. Some candidates just referred to the OH group and didn't specifiy that it is the lone pair of electrons on the oxygen that overlap with the delocalised electrons in the benzene ring.

(iii) Explain why phenol is nitrated much more readily than benzene.

(2)

The on groups in the phenol makes make the OH phenol structure more reactive. This is due to the fact that

ResultsPlus
Examiner Comments

This answer is lacking in detail and scored 0.

ResultsPlus
Examiner Tip

Revise why phenol is more reactive than benzene.

(iii) Explain why phenol is nitrated much more readily than benzene.

(2)

The electron - donating OH group increases the electron density of the ring, making it more susceptible to electrophilic attack.

ResultsPlus
Examiner Comments

This response scored 1 mark for the idea that the ring will be more susceptible to electrophilic attack.

ResultsPlus
Examiner Tip

Remember that it is the lone pair of electrons on the oxygen of the OH group that is responsible for increasing the electron density of the ring.

Question 23 (b) (iv)

The majority of candidates knew that the conversion of a nitro group to an amine is a reduction reaction. Incorrect answers included hydrogenation and substitution.

(iv) State the type of reaction taking place in Step **2**.

(1)

Electrophilic substitution

ResultsPlus
Examiner Comments

This incorrect answer scored 0.

ResultsPlus
Examiner Tip

Learn the names of the types of reaction in the specification.

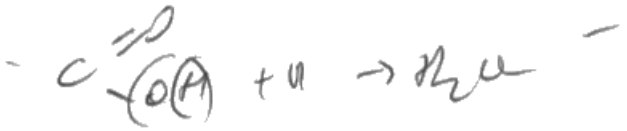
Question 23 (b) (v)

Many candidates scored a mark by suggesting ethanoyl chloride or ethanoic anhydride as the reagent for this reaction. A small number thought that ethanoic acid reacts with amines to produce amides. A few candidates lost marks by giving a correct name with an incorrect formula or vice versa. If both are given, both must be correct.

(v) Suggest a reagent for Step **3**.

(1)

ethanoic acid.



ResultsPlus
Examiner Comments

Ethanoic acid does not react with amines to form amides, so this response scored 0.

ResultsPlus
Examiner Tip

Revise the organic reactions in the specification.

(v) Suggest a reagent for Step **3**.

(1)

Acyl chloride - CH_3COCl

ResultsPlus
Examiner Comments

This candidate knows that acyl chlorides react with amines to form amides, but the general name 'acyl chloride' is not sufficient here, you must state the actual acyl chloride that is needed for this reaction. This response scored 0.

(v) Suggest a reagent for Step **3**.

(1)

CH_3COCl & methanoyl chloride

ResultsPlus
Examiner Comments

This response scored 0. The formula is correct but the name is incorrect.

ResultsPlus
Examiner Tip

If you give the name and formula of a substance, check to make sure that both are correct.

Question 23 (b) (vi)

This was one of the more challenging items on the paper. Many candidates did realise that there are hydrogen bonds between both molecules but few went on to explain that there will be intermolecular hydrogen bonding between 4-nitrophenol molecules but the intramoleular hydrogen bonding in 2-nitrophenol molecules will result in less intermolecular hydrogen bonding.

(vi) 2-nitrophenol has a melting temperature of 46 °C and 4-nitrophenol has a melting temperature of 114 °C.

Suggest, in terms of intermolecular forces, why these two compounds have different melting temperatures.

(2)

4-nitrophenol has more electrons, so more London forces, therefore more energy required to break these forces.

ResultsPlus
Examiner Comments

This candidate has not realised that 2-nitrophenol and 4-nitrophenol are structural isomers so they have the same number of electrons. This response scored 0.

ResultsPlus
Examiner Tip

Isomers have the same number of electrons.

(vi) 2-nitrophenol has a melting temperature of 46 °C and 4-nitrophenol has a melting temperature of 114 °C.

Suggest, in terms of intermolecular forces, why these two compounds have different melting temperatures.

(2)

4-nitrophenol is able to form hydrogen bonds whereas 2-nitrophenol is only able to form dipole-dipole interactions. As hydrogen bonds are stronger, 4-nitrophenol has a higher melting point

ResultsPlus
Examiner Comments

This response scored 0 as the candidate thought that only one of the isomers can form hydrogen bonds.

(vi) 2-nitrophenol has a melting temperature of 46 °C and 4-nitrophenol has a melting temperature of 114 °C.

Suggest, in terms of intermolecular forces, why these two compounds have different melting temperatures.

(2)

Although hydrogen bonding occurs in both compounds, there are greater London forces in 4-nitrophenol which require more heat energy to overcome.

ResultsPlus
Examiner Comments

This response scored 1 mark for stating that hydrogen bonding occurs in both compounds.

ResultsPlus
Examiner Tip

Remember that hydrogen bonding can be intermolecular or intramolecular.

(vi) 2-nitrophenol has a melting temperature of 46 °C and 4-nitrophenol has a melting temperature of 114 °C.

Suggest, in terms of intermolecular forces, why these two compounds have different melting temperatures.

(2)

They have the same number of electrons so Van der Waal forces are the same. However, in 2-nitrophenol, the $-NO_2$ group and -OH group form hydrogen bonds within the molecule, whereas in 4-nitrophenol, the groups are too far away so form hydrogen bonds between molecules. The hydrogen bonds between molecules are strong and require a lot of energy to overcome. H-bonds within molecules do not effect melting temperature.

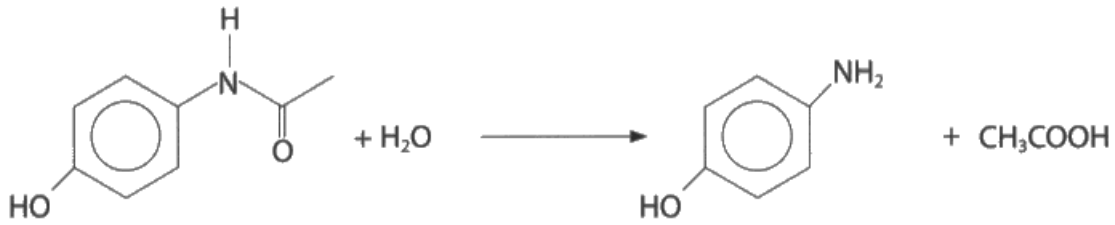
ResultsPlus
Examiner Comments

This is an example of an excellent answer that scored 2 marks.

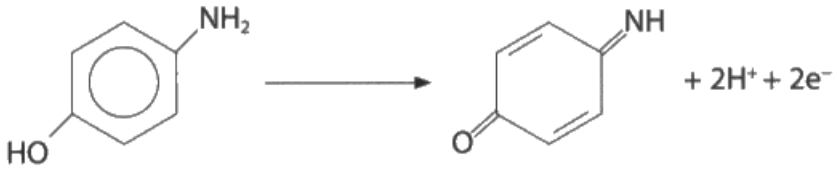
Question 23 (c)

It was very pleasing to see how well candidates answered this unfamiliar redox titration. They were able to apply their knowledge of other redox systems to this question and many scored full marks. Candidates who were less successful were unable to write the overall equation for the reaction, used an incorrect mole ratio, did not work out the number of moles of 4-aminophenol in 100cm^3 of solution or calculated an incorrect molar mass for paracetamol even though this was given in the question.

(c) Paracetamol can be hydrolysed to form 4-aminophenol and ethanoic acid.



The amount of 4-aminophenol produced can be determined using a redox titration. The half-equation for the oxidation of 4-aminophenol is given below.



The oxidizing agent is ammonium cerium(IV) sulfate and ferroin indicator is used to detect the end-point of the titration. During the reaction, the Ce^{4+} ions are reduced to Ce^{3+} ions.

(i) Write the overall equation for the reaction between Ce^{4+} ions and 4-aminophenol.

$Ce^{4+} + e^- \rightarrow Ce^{3+}$

(1)

(ii) In an experiment, 0.500 g of a tablet containing paracetamol was hydrolysed and the solution was made up to 100 cm^3.

20.0 cm^3 portions of the resulting solution were titrated with 0.100 mol dm^{-3} ammonium cerium(IV) sulfate solution.

The mean titre was 12.60 cm^3.

Calculate the percentage, by mass, of paracetamol in the tablet.

(5)

mol of ammonium cerium (IV) sulfate

$\frac{12.6}{1000} \times 0.1 = 1.26 \times 10^{-3}$ mol

therefore mol of paracetamol = 1.26×10^{-3}

$(1.26 \times 10^{-3}) \times 5 = 6.3 \times 10^{-3}$

mol in 100 cm^3 of solution

molar mass = 151

$151 \times (6.3 \times 10^{-3}) = 0.9513$

ResultsPlus
Examiner Comments

(i) This scored 0 as the candidate has omitted the double bond between the carbon and the nitrogen.

(ii) This scored 3 marks. The number of moles of Ce^{4+} is correct, but the candidate has used a mole ratio of 1:1 instead of 1:2 as shown in their equation. The multiplication by 5 is correct, as is that by 151. This gives a greater mass than that of the tablet so is obviously incorrect so the candidate did not go any further.

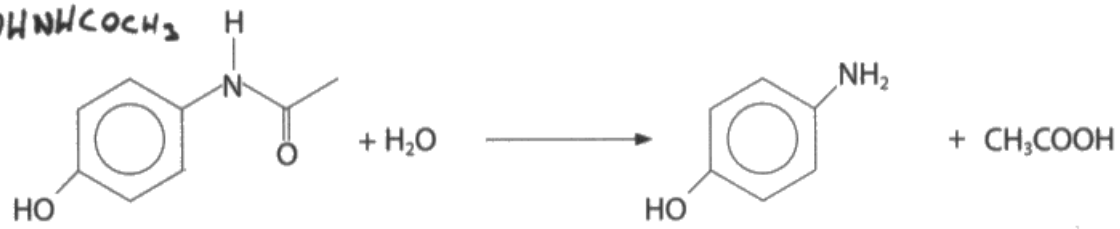
ResultsPlus
Examiner Tip

If you get an answer that will give you more that 100%, you have done something wrong in the calculation so go back and check to see if you can find your error or omission.

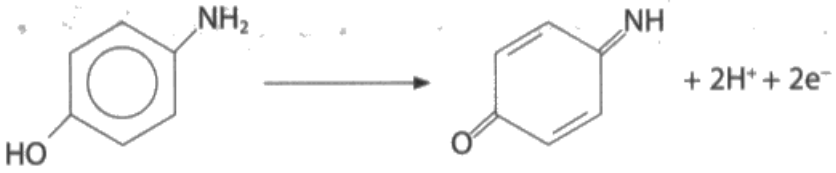
melting temperature.

(c) Paracetamol can be hydrolysed to form 4-aminophenol and ethanoic acid.

$C_6H_4OHNHCOCH_3$

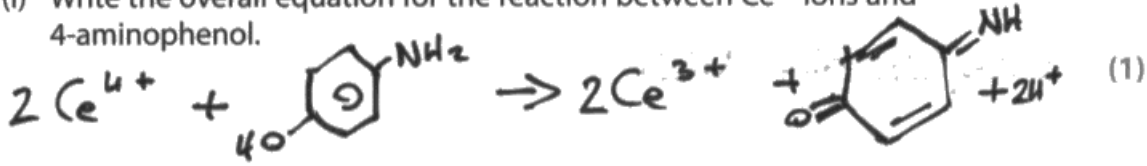


The amount of 4-aminophenol produced can be determined using a redox titration. The half-equation for the oxidation of 4-aminophenol is given below.



The oxidizing agent is ammonium cerium(IV) sulfate and ferroin indicator is used to detect the end-point of the titration. During the reaction, the Ce^{4+} ions are reduced to Ce^{3+} ions.

(i) Write the overall equation for the reaction between Ce^{4+} ions and 4-aminophenol.



(1)

(ii) In an experiment, 0.500 g of a tablet containing paracetamol was hydrolysed and the solution was made up to 100 cm^3.

20.0 cm^3 portions of the resulting solution were titrated with 0.100 mol dm^{-3} ammonium cerium(IV) sulfate solution.

The mean titre was 12.60 cm^3.

Calculate the percentage, by mass, of paracetamol in the tablet.

(5)

Mol Ammonium Cerium (IV) Sulfate = $\frac{12.60}{1000} \times 0.1$

$= 1.26 \times 10^{-3}$ mol

$\Rightarrow$ Mol 4 amino phenol = $\frac{1.26 \times 10^{-3}}{2} = 6.30 \times 10^{-4}$

$\Rightarrow$ Mol 4 aminophenol in $100 cm^3 = 6.30 \times 10^{-4} \times 5$

$= 3.15 \times 10^{-3}$ mol

$\Rightarrow$ Mol Paracetamol = 3.15×10^{-3} mol

Mr Paracetamol = 139

$\Rightarrow$ Mass Paracetamol = $139 \times 3.15 \times 10^{-3}$

= 0.438 g

$\therefore$ % by mass = $\frac{0.438}{0.500} \times 100 = 87.6\%$

ResultsPlus
Examiner Comments

(i) This scored 1 mark for the correct balanced equation.

(ii) The first three steps are correct but the candidate has calculated an incorrect molar mass so the fourth mark is not awarded. However, the fifth mark can be awarded for a transferred error.

ResultsPlus
Examiner Tip

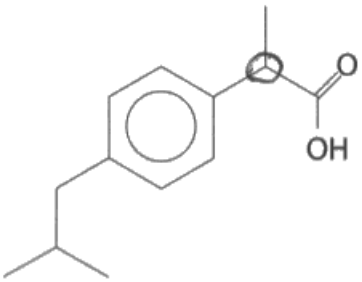
Explain your working clearly so you can be awarded most of the marks even if you make a slip in a calculation.

Question 23 (d) (i)

The majority of candidates could identify the correct chiral carbon atom in ibuprofen.

(d) (i) Identify the chiral carbon atom in ibuprofen with an asterisk (*).

(1)



ResultsPlus
Examiner Comments

This response scored 1 mark as the correct carbon atom is identified. The question asked for the identification with an asterisk, but the correct carbon atom circled was allowed.

ResultsPlus
Examiner Tip

If you do use a circle to identify the carbon atom, make sure that it only circles the chiral carbon atom and isn't too large, enclosing other carbon atoms as well.

Question 23 (d) (ii)

Many candidates misread the question and wrote a lot about the problems of producing a racemic mixture and that the unwanted isomer might be toxic, instead of concentrating on the problem of manufacturing a single isomer. Some candidates mentioned that the two isomers would need to be separated but did not comment on the difficulty of doing this. Some candidates thought that the use of plane polarised light would separate the isomers. More candidates scored the second mark as they suggested a suitable solution to the problem.

(ii) Suggest a problem in the manufacture of a single isomer of a chiral drug and describe a way that the pharmaceutical industry might overcome this problem.

(2)

A racemic mixture could be formed - the company would have to test if the product rotates the plane of plane-polarised light. If it does then it's a single isomer.

ResultsPlus
Examiner Comments

This response has missed the point of the question and scored 0.

ResultsPlus
Examiner Tip

Read the question carefully.

(ii) Suggest a problem in the manufacture of a single isomer of a chiral drug and describe a way that the pharmaceutical industry might overcome this problem.

(2)

Chiral will produce two optically active stereoisomers due to attack from above a below plane.
The yield of the desired isomer would therefore be reduced.
To overcome this concentrations can be manipulated so a racemic mixture does not form

ResultsPlus
Examiner Comments

This response scored 1 mark for the idea of a lower yield of the desired isomer since a mixture of two isomers will be produced. Unfortunately just changing the concentrations will not prevent a racemic mixture from forming so the second mark could not be awarded.

ResultsPlus
Examiner Tip

Learn about some ways in which a single optical isomer can be produced.

(ii) Suggest a problem in the manufacture of a single isomer of a chiral drug and describe a way that the pharmaceutical industry might overcome this problem.

(2)

If they simple repeat the mixture to remove the unwanted isomer in a racemic mixture, the yield would be low & (<50%). They might overcome this by using a catalyst such as an enzyme, that only produce one of the stereoisomers, increasing yield and atom economy.

ResultsPlus
Examiner Comments

This is an example of a good answer that scored 2 marks. The candidate has read the question carefully and given a correct problem and a possible solution to the problem.

Question 23 (e)

The majority of candidates could suggest an environmental reason why the manufacturing process of ibuprofen was changed. The most common answers were that there would be less waste, a higher yield or less energy would be used. A few candidates just stated 'less pollution' but that was not specific enough to score a mark. Some candidates did not make their answer clear enough to know whether they were writing about the six-step or the three-step process.

(e) Ibuprofen was originally made in a six-step process but is now made in a three-step process.

Suggest a specific environmental reason why the manufacturing process was changed.

(1)

Less energy is used for processes as there are less processes, thus less fossil fuel will have to be burn to generate energy for reactions.

ResultsPlus
Examiner Comments

This is an example of an answer that scored 1 mark. More than one reason is given but they are both correct so the mark can still be awarded.

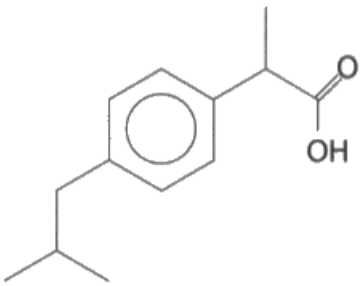
ResultsPlus
Examiner Tip

If you give more than the required number of answers, make sure they are all correct, otherwise you will lose a mark.

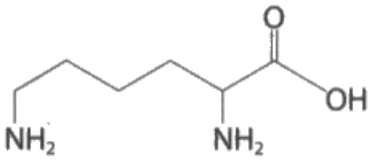
Question 23 (f)

It was pleasing to see how many candidates could draw the anion and cation formed from ibuprofen and lysine. Some candidates lost a mark as they showed the charges outside of brackets instead of by the group that has the positive or negative charges. A few candidates lost both marks if they put charges by the correct atoms and then put additional charges outside of brackets. Some candidates were more confused and tried to react the ibuprofen and lysine together then add charges to them.

(f) Ibuprofen is not very soluble in water. It can be made into an ionic, soluble salt by reacting it with lysine.



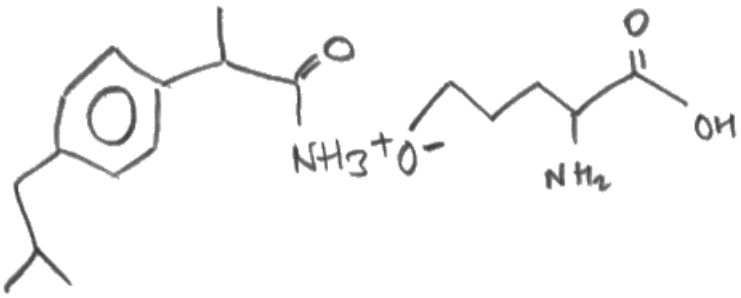
Ibuprofen



Lysine

Draw the structures of **both** the cation and the anion in the soluble salt formed when ibuprofen reacts with lysine.

(2)



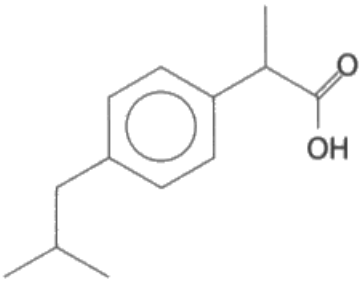
ResultsPlus
Examiner Comments

This response scored 0. The candidate has added NH_3^+ to ibuprofen and and extra O^- to lysine, which is incorrect.

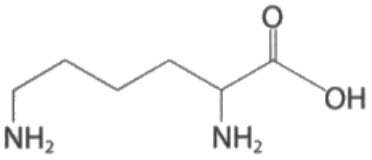
ResultsPlus
Examiner Tip

This question is an application of how zwitterions are formed by a proton transferring from the carboxylic acid functional group to an amine group.

(f) Ibuprofen is not very soluble in water. It can be made into an ionic, soluble salt by reacting it with lysine.



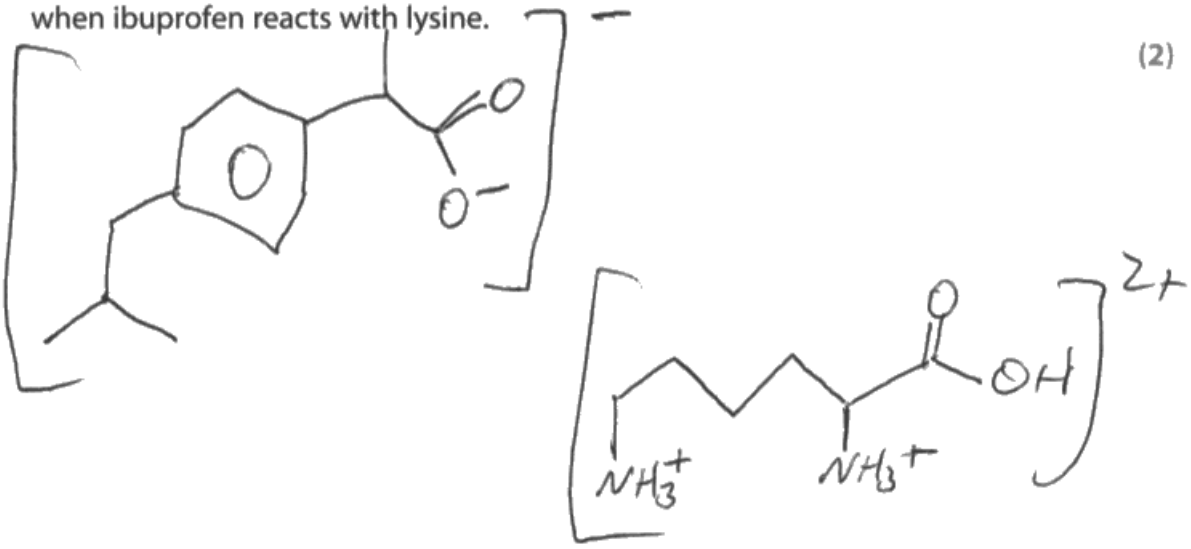
Ibuprofen



Lysine

Draw the structures of **both** the cation and the anion in the soluble salt formed when ibuprofen reacts with lysine.

(2)



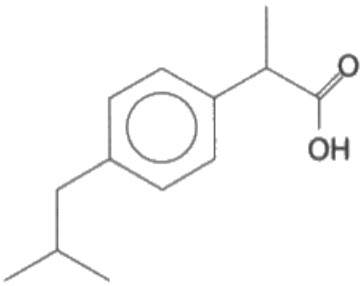
ResultsPlus
Examiner Comments

This candidate has put too many charges on the ions so scored 0. The charges should be placed alongside the appropriate atoms and it is acceptable to put the ions in brackets but these structures show double charges and are incorrect. A mark would have been allowed for the cation with both amine groups protonated.

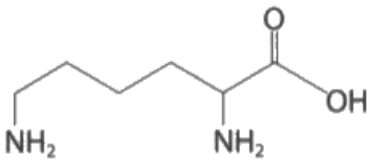
ResultsPlus
Examiner Tip

Check that you are not writing charges inside and outside of brackets.

(f) Ibuprofen is not very soluble in water. It can be made into an ionic, soluble salt by reacting it with lysine.



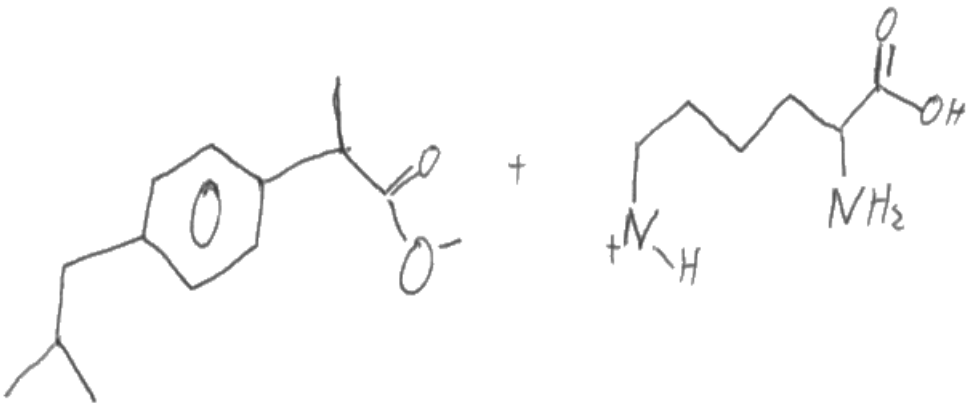
Ibuprofen



Lysine

Draw the structures of **both** the cation and the anion in the soluble salt formed when ibuprofen reacts with lysine.

(2)



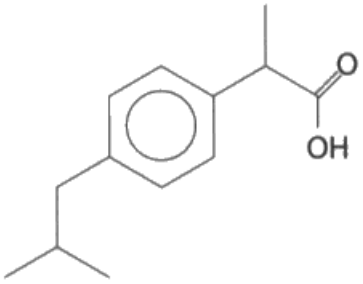
ResultsPlus
Examiner Comments

This response scored 1 mark. The anion is correct but the amine group should have gained a proton to form a positive ion, not lost a proton.

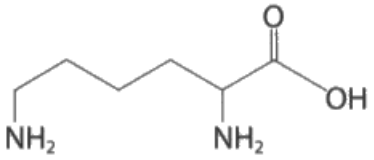
ResultsPlus
Examiner Tip

Revise how zwitterions are formed.

(f) Ibuprofen is not very soluble in water. It can be made into an ionic, soluble salt by reacting it with lysine.



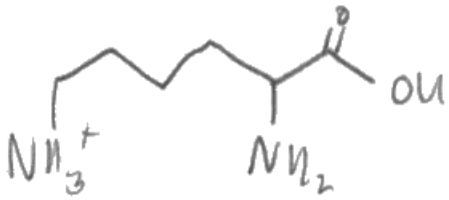
Ibuprofen

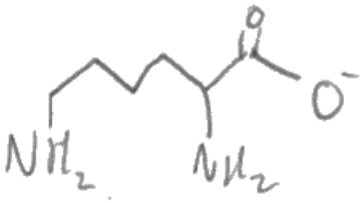


Lysine

Draw the structures of **both** the cation and the anion in the soluble salt formed when ibuprofen reacts with lysine.

(2)





ResultsPlus
Examiner Comments

This response scored 1 mark. The cation is correct but the anion should be formed from ibuprofen not lysine.

ResultsPlus
Examiner Tip

Read the question carefully. It tells you that ibuprofen reacts with lysine so it must form one of the ions.

Paper Summary

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

- Remember that AS content will be required when answering A2 question papers.
- Read the questions carefully and check that you understand what is required.
- After you have written your answer, re-read the question and your answer to ensure that you have fully answered the question.
- Use correct chemical terminology in your answer, for example, shell, sub-shell and orbitals do not all have the same meaning.
- Practise writing ionic equations.
- Revise the practical techniques, such as recrystallisation, and make sure that you can describe them in a logical order.

Grade Boundaries

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

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