Examiners' Report

June 2016

IAL Chemistry WCH05 01

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Introduction

This paper included questions that assessed candidates across the ability range and generated some excellent responses. There was little evidence that candidates ran out of time with most scripts having fully attempted answers.
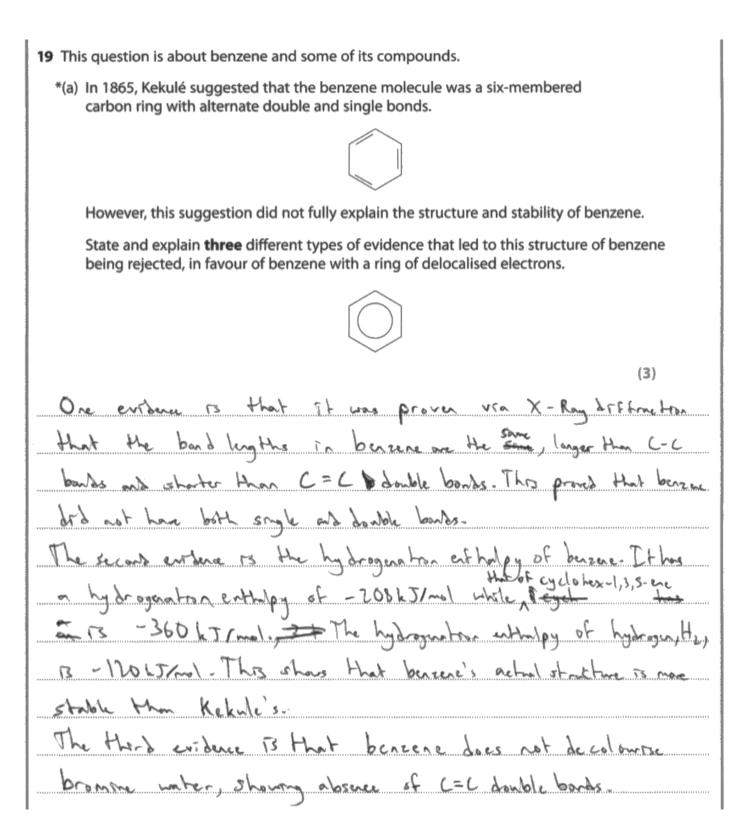
The mean score for the multiple-choice questions in Section A was 13.8. Questions 2, 7 and 12 were found to be the most straightforward, whilst questions 9 and 15 were found to be the most challenging.

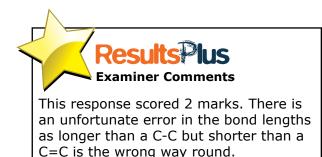Knowledge of organic reactions was good and the organic mechanism was very well known.

Some of the work shown in the numerical questions was excellent, but in some cases calculations were difficult to follow as candidates gave no written explanation of their numbers. This was particularly noticeable on the long calculation in question 20d where the large number of steps required careful consideration.
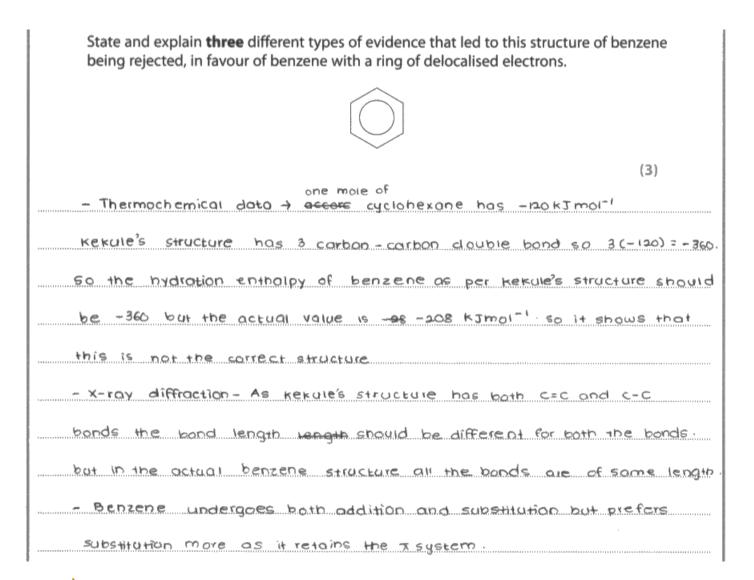
Question 19 (a)

There were many excellent answers to this question, with most candidates giving answers concerning the equal carbon-carbon bond lengths in benzene, the reaction by electrophilic substitution rather than electrophilic addition and explaining the structure using enthalpy of hydrogenation. Some candidates lost marks by inadequate explanations, for example using 'lower' when they should have said 'less exothermic'. There were quite a number of candidates who used the 'enthalpy of hydration' when they meant 'hydrogenation'.
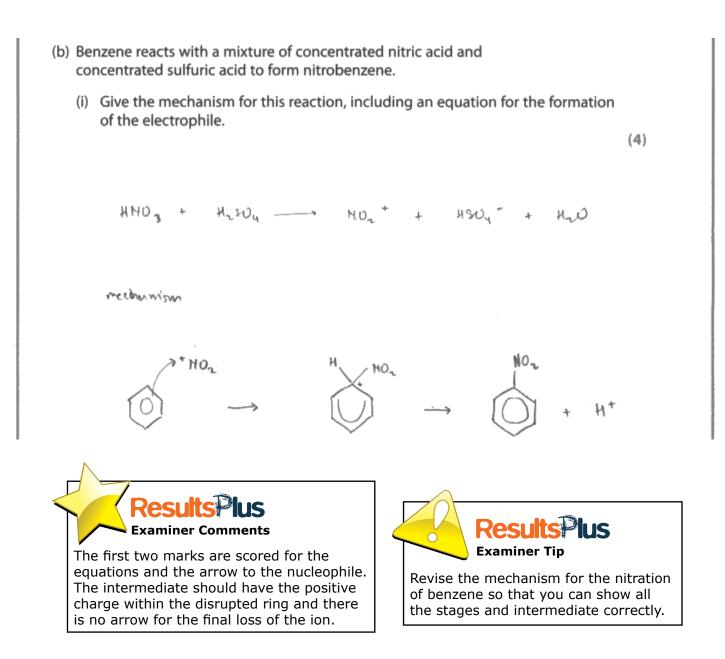
19 This question is about benzene and some of its compounds.

*(a) In 1865, Kekulé suggested that the benzene molecule was a six-membered carbon ring with alternate double and single bonds.

However, this suggestion did not fully explain the structure and stability of benzene.

State and explain **three** different types of evidence that led to this structure of benzene being rejected, in favour of benzene with a ring of delocalised electrons.

(3)

One evidence is that it was proven via X-Ray diffraction that the bond lengths in benzene are the same, larger than C-C bonds and shorter than C=C double bonds. This proved that benzene did not have both single and double bonds.

The second evidence is the hydrogenation enthalpy of benzene. It has a hydrogenation enthalpy of -208kJ/mol while that of cyclohex-1,3,5-ene is -360 kJ/mol. The hydrogenation enthalpy of hydrogen, H₂, is -120kJ/mol. This shows that benzene's actual structure is more stable than Kekule's.

The third evidence is that benzene does not decolourise bromine water, showing absence of C=C double bonds.

State and explain **three** different types of evidence that led to this structure of benzene being rejected, in favour of benzene with a ring of delocalised electrons.

(3)

one mole of
– Thermochemical data → accept cyclohexane has –120 kJ mol⁻¹

Kekule's structure has 3 carbon-carbon double bond so 3(–120) = –360.

So the hydration enthalpy of benzene as per Kekule's structure should

be –360 but the actual value is –as –208 kJmol⁻¹. So it shows that

this is not the correct structure.

– X-ray diffraction– As kekule's structure has both C=C and C-C

bonds the bond length length should be different for both the bonds.

but in the actual benzene structure all the bonds are of same length.

– Benzene undergoes both addition and substitution but prefers

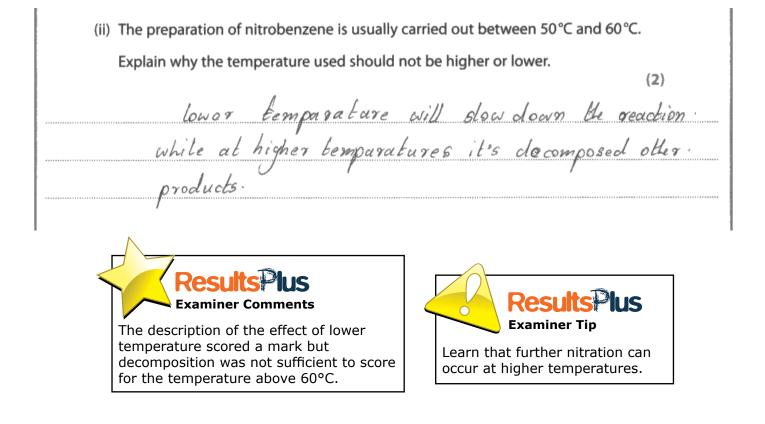substitution more as it retains the π system.

Question 19 (b)(i)

The mechanism in this question is very well known and there were many excellent answers. Some marks were lost by missing signs in the equation and for poorly drawn intermediates with inaccurate horseshoes showing the disrupted ring of electrons.

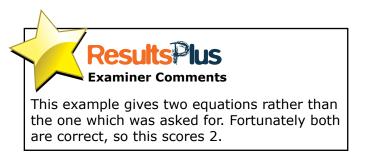(b) Benzene reacts with a mixture of concentrated nitric acid and concentrated sulfuric acid to form nitrobenzene.

  (i) Give the mechanism for this reaction, including an equation for the formation of the electrophile.

(4)

$$HNO_3 + H_2SO_4 \longrightarrow NO_2^+ + HSO_4^- + H_2O$$

mechanism

Question 19 (b)(ii)

This question was answered well overall although some candidates said the reaction would stop at a lower temperature, rather than become too slow. Others thought that the product would decompose at a higher temperature.

(ii) The preparation of nitrobenzene is usually carried out between 50°C and 60°C.

Explain why the temperature used should not be higher or lower.

(2)

lower temparature will slow down the reaction while at higher temparatures it's decomposed other products.

ResultsPlus
Examiner Comments

The description of the effect of lower temperature scored a mark but decomposition was not sufficient to score for the temperature above 60°C.

ResultsPlus
Examiner Tip

Learn that further nitration can occur at higher temperatures.

Question 19 (c)(i)

This question required a correct organic product to be identified in an equation for the first mark and then the rest of the equation to balance for the second. The first mark was commonly scored, but candidates found balancing the equation much more difficult as they were not aware that HBr was the second product.

*(ii) Explain why phenol reacts with bromine under much milder conditions than those required for the reaction between benzene and bromine.

(2)

The OH group in phenol donates its electrons to the delocalised π system increasing the electron density of the ring and making it more susceptible to attack requiring milder conditions. Benzene does not have OH group so requires forcing conditions.

ResultsPlus
Examiner Comments

A typical example of a candidate who knew the structure of the organic product, but did not produce a balanced equation as 3HBr is missing from the product side. This response scored 1 mark.

ResultsPlus
Examiner Tip

All equations must be balanced.

The lone pair of electrons from oxygen is added to the ring of delocalised electrons in the benzene. This increases the charge density of the system and makes it more susceptible to reactions. The phenol is more reactive than benzene and so doesn't need harsher conditions.
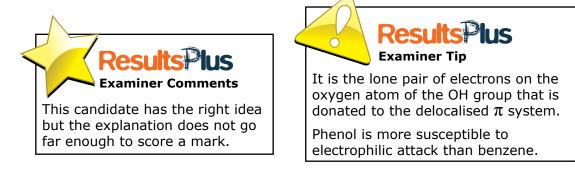
ResultsPlus
Examiner Comments

This example gives two equations rather than the one which was asked for. Fortunately both are correct, so this scores 2.

ResultsPlus
Examiner Tip

If you give more than one answer, check to make sure they are all correct as a mistake in one will lose the marks.

Question 19 (c)(ii)

Candidates clearly had a very good understanding of the chemistry in this question, with some excellent answers seen. However, there was quite a variety in the accuracy with which this was expressed. Candidates needed to be really precise in their descriptions of both the electrons and the increase in reactivity. Marks were lost on occasion through insufficient detail in the description of which electrons were being incorporated into the delocalised system of the benzene ring. It had to be clearly stated that these were a lone pair of electrons from the oxygen atom. There was also sometimes a lack of clarity about the nature of the increased reactivity, which required a description of either the susceptibility of the benzene ring to electrophilic attack or the increasing ability of phenol to act as a nucleophile.
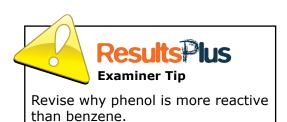
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(2)

The OH group in phenol donates its electrons to the delocalised π system increasing the electron density of the ring and making it more susceptible to attack requiring milder conditions. Benzene does not have OH group so requires forcing conditions.

ResultsPlus
Examiner Comments

This candidate has the right idea but the explanation does not go far enough to score a mark.

ResultsPlus
Examiner Tip

It is the lone pair of electrons on the oxygen atom of the OH group that is donated to the delocalised π system.

Phenol is more susceptible to electrophilic attack than benzene.

*(ii) Explain why phenol reacts with bromine under much milder conditions than those required for the reaction between benzene and bromine.

(2)

The lone pair of electrons from oxygen is added to the ring of delocalised electrons in the benzene. This increases the charge density of the system and makes it more susceptible to reactions. The phenol is more reactive than benzene and so doesn't need harsher conditions.
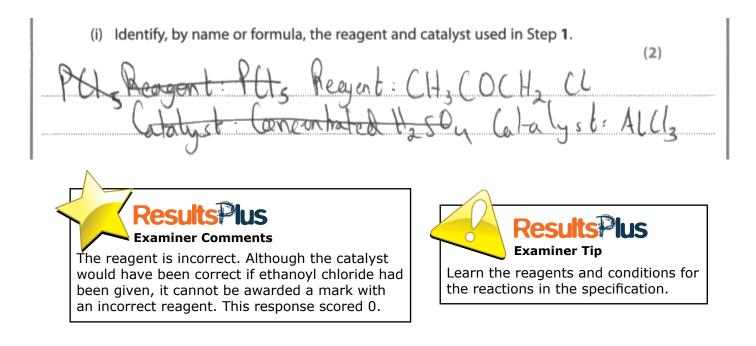
ResultsPlus
Examiner Comments

This example had a very nice description of the delocalisation of the lone pair of electrons into the benzene ring delocalised system, but the resulting increase in reactivity is not clearly described as making phenol more susceptible to electrophilic attack. This response scored 1 mark.

ResultsPlus
Examiner Tip

Revise why phenol is more reactive than benzene.

Question 19 (d)(i)

When the reagent was identified in this question, the catalyst was very often correctly recalled as well. The most common incorrect reagents were propanoyl chloride, chloroethane and chloropropanone, CH_3COCH_2Cl.

(i) Identify, by name or formula, the reagent and catalyst used in Step **1**.

(2)

PCl$_5$ Reagent: PCl$_5$ Reagent: CH$_3$COCH$_2$ Cl
Catalyst: Concentrated H$_2$SO$_4$ Catalyst: AlCl$_3$

ResultsPlus
Examiner Comments

The reagent is incorrect. Although the catalyst would have been correct if ethanoyl chloride had been given, it cannot be awarded a mark with an incorrect reagent. This response scored 0.

ResultsPlus
Examiner Tip

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

Question 19 (d)(ii)

The majority of candidates drew a correct structure which identified Compound X as 1-phenylethanol.

Question 19 (d)(iii)

The majority of candidates identified the reagent as lithium tetrahydridoaluminate(III). Sodium tetrahydridoborate(III) was also seen quite commonly.

Question 19 (d)(iv)

Question Introduction

One of the most common incorrect answers here was hydrochloric acid. This is only suitable for the substitution of an -OH group in a tertiary alcohol to form a chloroalkane. For a secondary alcohol another reagent, for example, phosphorus(V) chloride, is required.

Question 20 (a)

The vast majority of students selected the correct values to complete the table.
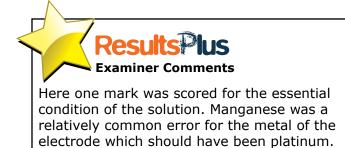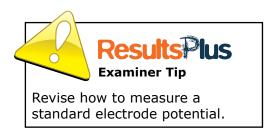
Question 20 (b)

There were some very good answers to this question, showing that candidates had a clear understanding of the measurement of a standard electrode potential. Common incorrect answers included the use of manganese as the electrode and just stating one of the ions in the solution.

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

The measurement is made at 298 K and 1 atm. State the other essential condition for solution C.

(4)

A Salt bridge containing a solution of...............KNO_3..................................

B Electrode made of ....platinum...

C Solution containing ....$1 \, mol \, dm^{-3} \, mn^{3+}$ and $1 \, mol \, dm^{-3} \, mn^{2+}$......

Essential condition ....298 K and 1atm,..............................

ResultsPlus
Examiner Comments

Here one mark was scored for the essential condition of the solution. Manganese was a relatively common error for the metal of the electrode which should have been platinum.

ResultsPlus
Examiner Tip

Revise how to measure a standard electrode potential.

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

The measurement is made at 298 K and 1 atm. State the other essential condition for solution **C**.

(4)

A Salt bridge containing a solution of ....filter paper dipped in nitric acid.........

B Electrode made of .....Manganese . ...

C Solution containing ....$Mn^{2+}(aq)$..

Essential condition ....$(1 mol\, dm^{-3} ,)$..

Question 20 (c)

Many candidates could work out the overall ionic equation for the reaction although some did not cancel the electrons, H^+ ions or water molecules. Some candidates did not read the question carefully and they selected an incorrect half-equation for the manganese ions. The majority of candidates scored a mark for calculating E_{cell} for the half-equations they used.

(c) Manganate(VII) ions, MnO_4^-, can be made by oxidizing manganese(II) ions with bismuthate(V) ions, BiO_3^-, in acid solution.

(i) Use the information in (a) to write the overall ionic equation for this reaction. State symbols are not required.

(2)

$$2MnO_4^{2-} + BiO_3^- + 6H^+ \rightleftharpoons Bi^{3+} + 3H_2O + 2MnO_4^-$$

(ii) Hence calculate $E^{\ominus}_{cell}$ for this reaction. Include a sign and units in your answer.

(1)

$$-0.56 + 1.60 = +1.04 \text{ V}$$

ResultsPlus
Examiner Comments

This candidate has chosen incorrect manganese ions for the synthesis of the manganate(VII) ions and consequently cannot score any marks in part (i). In part (ii) however, they have correctly calculated their value for that reaction, giving a sign and units, and so score this mark.

ResultsPlus
Examiner Tip

Read the question carefully and check that you have chosen the correct half-equations.

(i) Use the information in (a) to write the overall ionic equation for this reaction. State symbols are not required.

(2)

$$Mn^{2+} + 4H_2O \rightarrow MnO_4^- + 8H^+ + 5e^- \qquad E^\ominus = -1.51V$$

$$BiO_3^- + 6H^+ + 2e^- \rightarrow Bi^{3+} + 3H_2O \qquad E^\ominus = +1.60V$$

$$2Mn^{2+} + \cancel{8H_2O} + 5BiO_3^- + \overset{14}{\cancel{30}}H^+ \rightarrow 2MnO_4^- + \cancel{16}H^+ + 5Bi^{3+} + \overset{7}{\cancel{15}}H_2O$$

$$\Rightarrow \quad 2Mn^{2+} + 5BiO_3^- + 14H^+ \rightarrow 2MnO_4^- + 5Bi^{3+} + 7H_2O$$

(ii) Hence calculate $E^\ominus_{cell}$ for this reaction. Include a sign and units in your answer.

(1)

$$E^\ominus_{cell} = 1.60 - 1.51$$

$$= +0.09V$$

ResultsPlus
Examiner Comments

This is a fully correct response, scoring 2 marks for (i) and 1 mark for (ii). The half-equations required for working out the final equation have been given and electrons, excess hydrogen ions and water have been cancelled. The calculation in part (ii) is the expected answer.

ResultsPlus
Examiner Tip

Remember to cancel the electrons and any H^+ ions or H_2O molecules that are on both sides of the equation.

Question 20 (d)

This question required a large number of mathematical operations to be carried out successfully to score full marks. For each of the two titrations, the number of moles of manganate(VII) ions was calculated and then this was converted into the mass of iron in the original solution by multiplying by 5 to account for stoichiometry, by 20 to convert 25 cm^3 into the full 500 cm^3 and by the relative atomic mass of iron. Most candidates were able to make a start on the calculation and many excellent answers were seen which achieved full marks. It was often difficult to decipher, however, exactly what was being calculated. A structured and clearly labelled calculation allows examiners to award marks where errors have been made.

*(d) Iron(II) ions in solution are oxidized by the air to iron(III) ions.

The amounts of iron(II) and iron(III) ions in solution can be found by using titrations with acidified potassium manganate(VII) which only reacts with the iron(II) ions.

$$MnO_4^- + 5Fe^{2+} + 8H^+ \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$$

Reaction 1

- 25.0 cm³ portions of a solution **A**, containing a mixture of iron(II) and iron(III) ions, were acidified and titrated with potassium manganate(VII) solution of concentration 0.0195 mol dm⁻³.

- The mean titre was 16.80 cm³.

- About 150 cm³ of solution **A** was reacted with excess zinc, which reduced the iron(III) ions to iron(II) ions. The excess zinc was filtered off.

Reaction 2

- 25.0 cm³ portions of this reduced solution, which contained iron(II) ions but no iron(III) ions were acidified and titrated with potassium manganate(VII) solution of concentration 0.0195 mol dm⁻³.

- The mean titre was 18.20 cm³.

Calculate the **mass** of iron(II) ions and **the mass of** iron(III) ions in 500 cm³ of the original solution **A**.

(5)

Reaction 1

Moles of $KMnO_4$ = $\dfrac{16.8}{1000}$ × 0.0195

= 0.0003276 mol

Moles of Fe^{2+} in 500 cm³ = $\dfrac{(5)(0.0003276)(20)}{}$

= 0.03276 mol

Reaction 2

Moles of $KMnO_4$ = $\dfrac{18.2}{1000}$ × 0.0195

= 0.0003549 mol

Moles of Fe^{2+} in 500 cm³ = (6×5×20)(0.0003549)

= 0.21294 mol

Moles of Fe^{3+} in 500 cm³ = 0.21294 − 0.03276

= 0.18018

Mass of Fe^{2+} = (0.21294)(55.8) = 11.9 g

Mass of Fe^{3+} = (0.18018)(55.8) = 10.1 g

Here is an example of where 150 cm^3 of solution caused the candidates to multiply by 6, which was not correct. The candidate has not used this answer later in the calculation, however, so it was not penalised. At the bottom a subtraction has been done, but this is of the number of moles of manganate(VII) ions in the original titrations. This has been multiplied by the atomic mass of iron. The answers are one hundredth of that expected as the candidate has not multiplied by 5 to convert manganate(VII) ions to iron(II) ions or by 20 to give the number of moles in the original 500 cm^3 solution. Consequently this scored 3 marks.

Clearly label your calculations. It will help if you become confused part way through the calculation and allow examiners to see how you came to your final answer and award marks for correct chemistry.

$$Fe^{3+} \longrightarrow Fe^{2+}$$

$\cancel{N_{Fe^{2+} \text{ initial}}}$

$N_{Fe^{2+} \text{ m reduced solution m } 25cm^3} = C \times V$
$= 0.0195 \times \dfrac{18.2}{1000} = \cancel{3.18375 \times 10^{-4} \text{mol}} \quad 3.55 \times 10^{-4} \text{ mol}$ //

$N_{Fe^{2+} \text{ m reduced solution m } 150cm^3} = \cancel{*} \cancel{3.18375 \times 10^{-4}} \times 6 = \cancel{2.1225 \times 10^{-3} \text{mol}} \quad 2.13 \times 10^{-3} \text{ mol}$ //
$\qquad\qquad\qquad\qquad\qquad\qquad\quad 3.55 \times 10^{-4}$

$N_{Fe^{2+} \text{ m original solution}} = 0.0195 \times \dfrac{16.8}{1000} = 3.28 \times 10^{-4} \text{ mol}$

change in no. of moles $= 3.55 \times 10^{-4} - 3.28 \times 10^{-4} = 2.74 \times 10^{-5} \text{ mol of } Fe^{3+}$

$m = 2.74 \times 10^{-5} \times 55.8 = \boxed{1.53 \times 10^{-3} g}$ // $\left| \begin{array}{l} m \text{ of } \\ Fe^{2+} \end{array} = 3.55 \times 10^{-9} \times 55.8 \right.$
$m \text{ of } Fe^{3+} \qquad\qquad\qquad\qquad\qquad = \boxed{0.0198 g}$ //

(Total for Question 20 = 13 marks)

Question 21 (a)

Most candidates were able to write something about the definition of a transition element and score the first mark. It was less common for them to appreciate that scandium forms only one ion, Sc^{3+}, which has no electrons in 3d-orbitals and therefore is not a transition element.

21 Chromium is in the d-block of the Periodic Table and it is a transition metal.

(a) Scandium is also in the d-block of the Periodic Table but it is not a transition metal.

Explain, by giving any relevant electronic configurations, why scandium is **not** a transition metal.

(3)

Scandium has ~~electr~~ electron configuration $[Ar] 3d^1 4s^2$. The only ion it forms is Sc^{3+}, which has electron configuration ~~E#~~ $[Ar]$. So its ~~ion~~ ion doesn't have a partially filled 3d orbital as all of its 3d orbitals are empty. For an element to be a transition metal they must ~~form~~ be able to form an ion with a partially filled 3d orbital.

ResultsPlus
Examiner Comments

This answer gained all 3 marks with a good description of the electronic structure of the scandium ion and a statement defining a transition metal.

ResultsPlus
Examiner Tip

Make sure that you use correct terminology. Some candidates confused orbitals with sub-shells and shells.
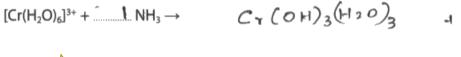
Question 21 (b)

This question was answered much less well than similar questions on previous papers involving hydroxide ions. The use of ammonia and the formation of ammonium ions seemed to confuse some candidates, although a good number knew the structure of the chromium(III) hydroxide formed.

(b) When a few drops of aqueous ammonia are added to an aqueous solution of chromium(III) ions, a green precipitate of chromium(III) hydroxide is formed.
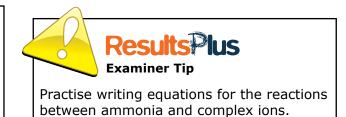
Complete the ionic equation for this reaction. State symbols are not required.

(2)

$[Cr(H_2O)_6]^{3+} + \underline{\quad 1 \quad} NH_3 \rightarrow$ $Cr(OH)_3(H_2O)_3 \quad + \quad NH_3$

ResultsPlus
Examiner Comments

This typical example gives the correct product but the candidate is clearly unsure about the involvement of the ammonia, so the equation is not correct.

ResultsPlus
Examiner Tip

Practise writing equations for the reactions between ammonia and complex ions.

Question 21 (c)

There were a significant number of fully correct answers, with candidates confidently identifying the oxidation states in the chromium ions. The first reaction was sometimes, nevertheless, described as not a redox reaction as it was only a reduction of chromium(VI) to chromium(III).

(c) Explain, in terms of oxidation numbers of chromium, whether or not each of these two reactions are redox.

$$\overset{+6}{Cr_2O_7^{2-}} + 14H^+ + 6Fe^{2+} \rightarrow 2\overset{3+}{Cr^{3+}} + 7H_2O + 6Fe^{3+} \qquad \textbf{Reaction 1}$$

$$2\overset{+6}{CrO_4^{2-}} + 2H^+ \rightarrow \overset{+6}{Cr_2O_7^{2-}} + H_2O \qquad \textbf{Reaction 2}$$

(2)

Reaction 1 is not redox since in $Cr_2O_7^{2-}$ Cr is +6 & in Cr^{3+} Cr is +3.

but in Reaction 2 the charge of Cr stays the same → CrO_4^{2-} Cr is +6 & in $Cr_2O_7^{2-}$ Cr is +6. So Reaction 2 is redox.

ResultsPlus
Examiner Comments

This candidate has identified all the relevant oxidation numbers but has the redox reactions incorrect so scores 0.

ResultsPlus
Examiner Tip

There is always a change in oxidation number during a redox reaction. The oxidation number of an element increases during oxidation and decreases during reduction.
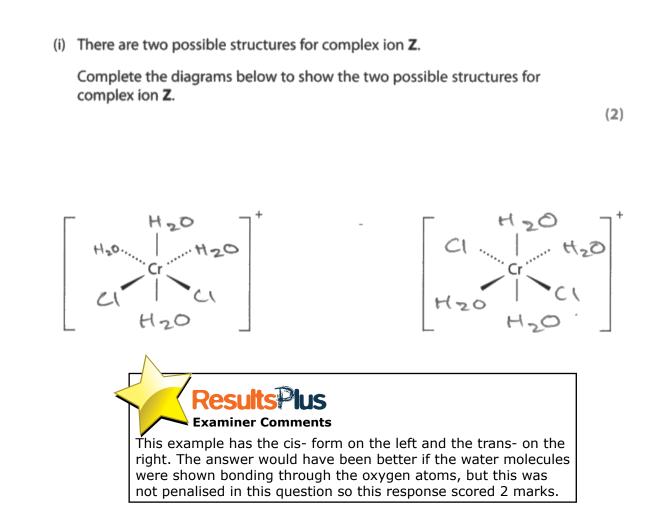
(c) Explain, in terms of oxidation numbers of chromium, whether or not each of these two reactions are redox.

$$Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 6Fe^{3+}$$ **Reaction 1**

$$2CrO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O$$ **Reaction 2**

(2)

Reaction 1 is a redox, since chromium is reduced ~~to~~ from +6 to +3

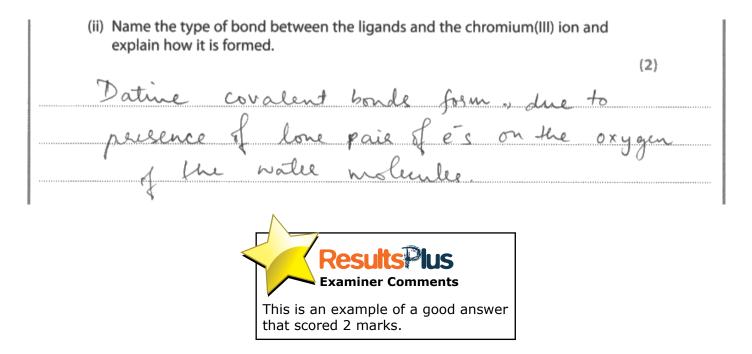Reaction 2 is not, oxidation number stays the same

Question 21 (d)(i)

There were a good number of correct answers to this question, but often candidates gave two equivalent ions, either both the cis- form with the two chloride ligands at 90° or both the trans- form with the chloride ligands 180° apart.

(i) There are two possible structures for complex ion **Z**.

Complete the diagrams below to show the two possible structures for complex ion **Z**.

(2)

ResultsPlus
Examiner Comments

This example has the cis- form on the left and the trans- on the right. The answer would have been better if the water molecules were shown bonding through the oxygen atoms, but this was not penalised in this question so this response scored 2 marks.

Question 21 (d)(ii)

Most candidates knew the bonds were dative covalent and very many of them could describe the origin of the lone pair of electrons on the ligand. However, a few suggested the electrons came from the chromium ion and some contradicted the named bond by describing covalent bonds or ionic bonds.

(ii) Name the type of bond between the ligands and the chromium(III) ion and explain how it is formed.

(2)

Dative covalent bonds form, due to presence of lone pair of e⁻'s on the oxygen of the water molecules

ResultsPlus
Examiner Comments

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

Question 21 (d)(iii)

As with the calculation in Q20(d), it was common to see calculations where it was not clear what the candidate was attempting to do. Candidates should be encouraged to explain all the steps in their working. Some candidates correctly calculated the ratio of Cr^{3+} : Cl^- as 1 : 2 but they then thought that there were two chloride ligands in the complex ion, rather than as free chloride ions in the solution.

(iii) The formula of the complex ion present in the solution is found by adding aqueous silver nitrate to the solution. This only reacts with the free chloride ions to form a precipitate of silver chloride.

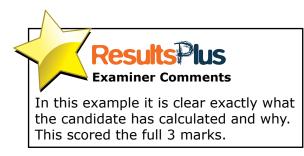$$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$$

The precipitate is then filtered, washed, dried and weighed.

In an experiment, 0.012 mol of one of the forms of chromium(III) chloride was used and 3.44g of silver chloride was formed.

Deduce the formula of the complex ion. You must show your working.

(3)

moles of AgCl = $\dfrac{3.44}{107.9+35.5}$

= 0.024 mol

molar ratio   chromium chloride : AgCl

0.012 : 0.024

1 : 2

2 mol AgCl formed for 1 chromium chloride(III)

∴ $[Cr Cl(H_2O)_5]^{2+}$

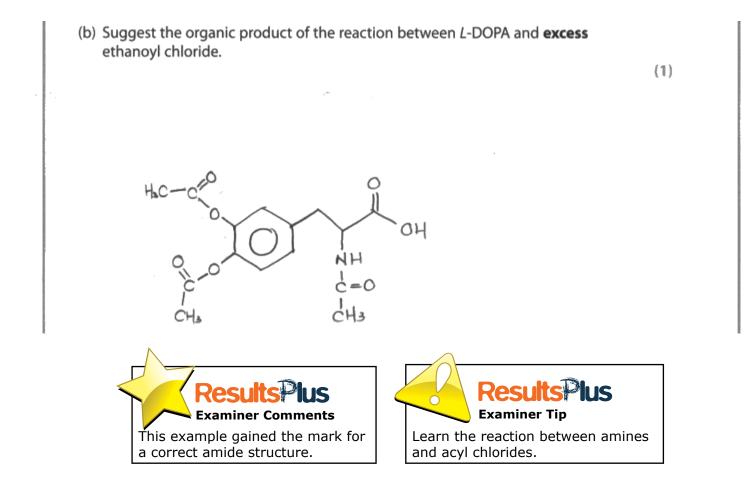as there are 2 free Cl⁻ ions to react with excess silver nitrate to form 2 AgCl.

Question 22 (a)

It was disappointing that only just over one third of candidates could give the correct molecular formula for *L*-DOPA. Candidates would benefit from more practice at working out molecular formulae from skeletal formulae.

Question 22 (b)

Relatively few candidates were able to score the mark on this question. Some only produced esters on the phenol groups in *L*-DOPA, whilst others converted the carboxylic acid group into an acid anhydride, which would not work directly. The specification expects candidates to know that amines react with ethanoyl chloride, although the reaction between phenol and ethanoyl chloride is not expected.

(b) Suggest the organic product of the reaction between *L*-DOPA and **excess** ethanoyl chloride.

(1)

ResultsPlus
Examiner Comments

This example gained the mark for a correct amide structure.

ResultsPlus
Examiner Tip

Learn the reaction between amines and acyl chlorides.

Question 22 (c)

There were a number of ways of scoring marks in this question. Many candidates used sodium carbonate and identified the carboxylic acid group by seeing effervescence. Some scored one mark for using phosphorus(V) chloride and observing misty fumes as this reaction occurs with any OH group and not just carboxylic acids. It was possible to add an alcohol and identify the acid by the presence of the fruity smell of an ester, but quite a few candidates who did this forgot that an acid catalyst is required.

Question 22 (d)

Many candidates were confused by the structure and drew polymer sections which were difficult to draw and decipher. The best answers had a diagram centred around the amide bridge which must be present as the question asks for two repeat units of the structure of a polyamide. Despite this a number of candidates tried to make a polyester using the phenol groups. Some candidates included an extra oxygen atom in the amide group. Most candidates would benefit from more practice at drawing structures of polyamides and polyesters.

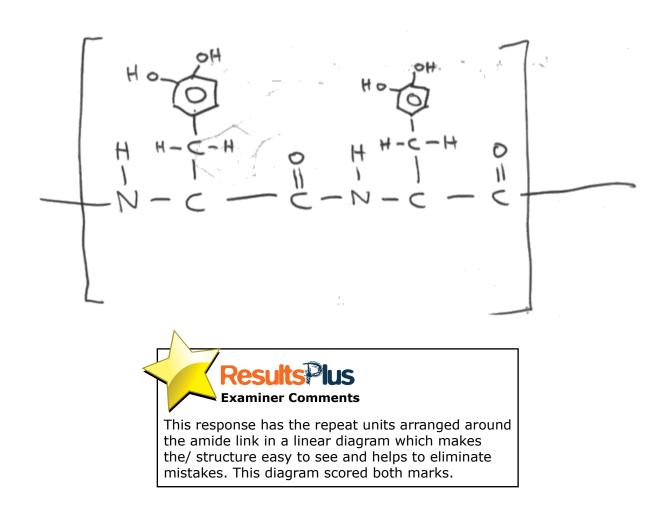(d) Molecules of L-DOPA can polymerize to form a polyamide by condensation.

Draw two repeat units of the polyamide formed from L-DOPA.

(2)

ResultsPlus
Examiner Comments

This structure has been arranged around the amide group in a linear diagram but unfortunately the candidate has missed an -H from the carbons at the bottom of the side chain, losing 1 of the 2 marks.

ResultsPlus
Examiner Tip

Check that all carbon atoms have 4 bonds.

(d) Molecules of L-DOPA can polymerize to form a polyamide by condensation.

Draw two repeat units of the polyamide formed from L-DOPA.

(2)

ResultsPlus
Examiner Comments

This response has the repeat units arranged around the amide link in a linear diagram which makes the/ structure easy to see and helps to eliminate mistakes. This diagram scored both marks.

Question 23 (a)(i)

This is a much practised question which is quite common in one form or another on WCH05 papers. Candidates had clearly prepared well for it, and many scored full marks. There are a number of errors candidates should try to avoid, including the incorrect use of splitting of a single d-orbital and the emission of light as the electron returns to the lower of the two sets of d-orbitals.

(a) (i) Explain why complex ions containing chromium(III) ions are coloured.

(4)

When ligands attach to the Cr^{3+} ions, they split the d-orbital of Cr^{3+} ion to two different energy levels. When light is shone to the complex, the electrons absorb energy from the light move to the higher energy level from the lower energy level. The frequency that is not absorbed is seen as colours by us which is ~~not ab~~ reflected due to not being absorbed.

ResultsPlus
Examiner Comments

This example scored 3 marks. The answer is almost entirely correct with a good description of the process, except that the candidate has split a singular d-orbital into two groups.

ResultsPlus
Examiner Tip

It is easier to discuss the d-subshell rather than orbitals to avoid errors such as this.

Question 23 (a)(ii)

There were many correct responses here suggesting that the d-subshell had been split to different extents. Other possible answers included that chromium ions replaced aluminium ions in rubies (to give it a red colour) or that other metal ions might also be present to give the different colours

(ii) Sapphires have the same type of structure as rubies.

Suggest why sapphires and rubies have different colours.

(1)

They have different ^number of e⁻ in their 3d subshells, therefore they absorb light to different extents.

ResultsPlus
Examiner Comments

One way to answer the question was to suggest that different splittings of the d-subshell or different metal ions would cause different colours. This response uses the different number of electrons in the d-subshell, which could be different metal ions or a different oxidation state of the same metal, as a source of the difference in colour, and was awarded 1 mark.

Question 23 (b)

It was disappointing that there was a lack of precision in many answers. Many candidates referred to intermolecular forces in diamond or could not describe the interaction between the layers in graphite. The layers were often referred to as being held together by delocalised electrons, confusing the structure with a metallic one. Candidates should be aware that AS content can be tested in A2 papers.

*(b) Carbon exists as diamond and graphite. Explain, in terms of structure and bonding, why diamond is much harder than graphite.

(3)

→ Both diamond and graphite has strong covalent bonds between adjacent molecules.

→ graphite has weak intermolecular forces between the layers

→ In diamond 1 carbon atom is attach to 4 other carbon atoms

ResultsPlus
Examiner Comments

This example describes the strong covalent bonds within the diamond structure and compares them to the weak intermolecular forces between the layers in graphite, although it would have been better to have identified the type of intermolecular force. The answer is rather spoiled, however, by referring to strong covalent bonds between adjacent molecules in diamond. This example was awarded 2 marks.

ResultsPlus
Examiner Tip

Revise structure and bonding thoroughly as questions involving this topic can be tested in AS and A2 papers.
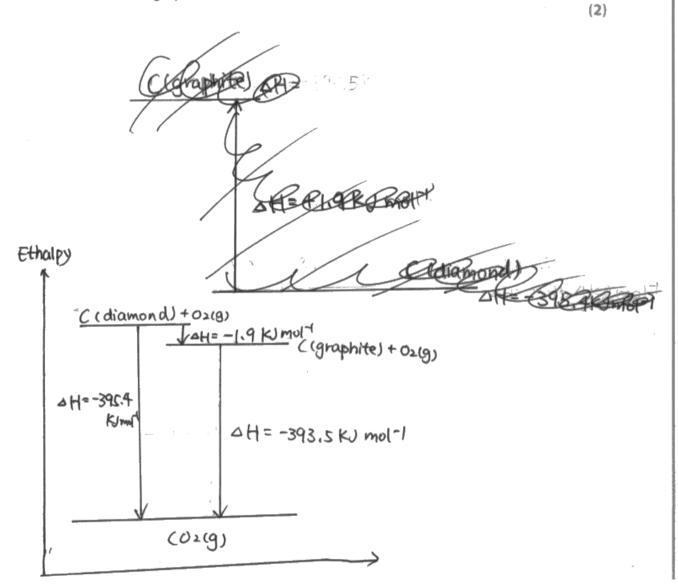
Question 23 (c)(i)

Candidates quite often scored the first mark in this question. They were much more unsure about enthalpy level diagrams, perhaps confused by having to do two things in the same question and so did not often score the second mark. Candidates would benefit from more practice in drawing enthalpy level diagrams.

(c) (i) The standard enthalpy changes of combustion for diamond and graphite are shown below.

$$C(diamond) + O_2(g) \rightarrow CO_2(g) \quad \Delta H_c^{\ominus} = -395.4 \text{ kJ mol}^{-1}$$

$$C(graphite) + O_2(g) \rightarrow CO_2(g) \quad \Delta H_c^{\ominus} = -393.5 \text{ kJ mol}^{-1}$$

Calculate the enthalpy change for the conversion of diamond to graphite. Use your answer to draw an enthalpy level diagram for the combustion of diamond and graphite.

(2)

Question 23 (c)(ii)

The need to explain the factor required was missed by many candidates in this question, with many simply stating a factor. This was most often either change in entropy of the system or total entropy change.

(ii) Explain which factor, other than enthalpy change, must be considered to show which allotrope is thermodynamically more stable.

(1)

$\Delta S^{\ominus}_{Total}$

ResultsPlus
Examiner Comments

This response scored 0. The candidate has stated another factor but has not given a reason for it.

(ii) Explain which factor, other than enthalpy change, must be considered to show which allotrope is thermodynamically more stable.

(1)

ΔS_{system} must be considered as because the more ΔS_{system} is positive the more ΔS_{total} becomes positive and stability is higher.

ResultsPlus
Examiner Comments

This candidate has made an effort to explain why the change in entropy of the system is required and scored the mark.

ResultsPlus
Examiner Tip

Questions that ask for an explanation require a reason for your answer.

Question 23 (d)(i)

The reagents required for this transformation were well known, with all the allowable options seen. The conditions were not quite so well understood. Candidates should aim to state a clear range or a value rather than just 'less than' or 'more than', as this can be confused. Some candidates stated an acceptable low temperature but then negated the mark by stating heat under reflux as well.

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

(2)

Nitrous acid.

low temperature

ResultsPlus
Examiner Comments

Nitrous acid is acceptable so scores 1 mark, but a low temperature is not sufficient for the second mark.

ResultsPlus
Examiner Tip

State a temperature or a range of temperatures for the condition.

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

(2)

Temp. of Heads at 10°c

NaNO₂ & HCl to make HNO₂

ResultsPlus
Examiner Comments

This candidate uses the very top of the allowable temperature range and so scores 2 marks.

Question 23 (d)(ii)

This structure was well identified by many candidates, but some added extra functionality in to the benzene which lost them the mark.

(ii) Step **2** involves a reaction which is similar to the reaction of diazonium ions with phenol. Suggest the structure of the organic compound which reacts with the diazonium ion in Step **2** to form methyl red.

(1)

ResultsPlus
Examiner Comments

This is a typical incorrect answer with an unnecessary phenol group added to the benzene ring.

Question 23 (d)(iii)

The titration of a strong acid with either a strong or a weak alkali scored 1 mark, provided some justification was attempted. Many candidates were able to quote data from the Data Booklet, including the ranges over which the indicator changed colour, or the value of pK_{in}, but then some did not use these values to justify their choice.

(iii) Use information from page 19 of the Data Booklet to suggest the type of acid-alkali titration for which methyl red indicator would be most suitable. Justify your answer.

(2)

pH range for methyl red: 4.2 - 6.3
strong acid titrated against weak base
~~vertical se~~ pH range within the vertical section of
the titration graph, most of the vertical section in acid
condition

ResultsPlus
Examiner Comments

This candidate scored 2 marks with a justification for their choice based on the change of colour with the vertical portion of the titration curve.

Question 23 (e)(i)

This reaction had a number of possible correct equations and some options for the type of reaction, although the use of the word ligand was important. Candidates managed to score well for the type of reaction but the equation was often poorly attempted. Some candidates would benefit from more practice at writing equations for ligand exchange reactions.

(e) Prussian Blue contains the $[Fe(CN)_6]^{4-}$ ion.

    (i) The $[Fe(CN)_6]^{4-}$ ion is formed when aqueous potassium cyanide is added to an aqueous solution containing Fe^{2+} ions.

    Write the equation and state the type of reaction taking place when $[Fe(CN)_6]^{4-}$ is formed in this way.

(2)

$$\left[Fe(H_2O)_6\right]^{2+} \longrightarrow \left[Fe(CN)_6\right]^{4-} + 6H_2O.$$

Type of reaction..........Ligand   exchange...

ResultsPlus
Examiner Comments

Unfortunately this candidate has forgotten to include the cyanide ions on the reactant side of the equation, although they correctly identified the type of reaction and scored 1 mark.

ResultsPlus
Examiner Tip

Check that your equation is balanced.

Question 23 (e)(ii)

The majority of candidates could deduce the oxidation number of the iron 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.

- Always read the question carefully and check that you understand what is required.

- Then, after you have written your answer, re-read the question and your answer to ensure that you have fully answered the question.

- Use correct chemical terminology in your answers.

- Organic mechanisms need to be accurately drawn: ensure that 'curly arrows' are precisely located and that all intermediate structures are correct.

- Label each step of a calculation to show clearly what you are attempting to work out.

- In multi-step calculations, don't round numbers up or down until the final step.

Grade Boundaries

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

http://www.edexcel.com/iwantto/Pages/grade-boundaries.aspx

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