Examiners' Report
June 2016

IAL Chemistry WHC06 01

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Introduction

This paper provided a good balance of standard and higher demand questions, the latter often requiring students to apply their knowledge and understanding to unfamiliar scenarios. It was similar in style and standard to previous Unit 6 papers for this specification. A range of skills and knowledge was assessed. The levels of difficulty allowed good discrimination between the different grades, while allowing well-prepared students at all levels to demonstrate their abilities. This paper is primarily designed to assess practical knowledge as far as this is possible within a written paper, but students were much more comfortable when dealing with theoretical concepts than with laboratory techniques. Thus calculations were often completed confidently and were often well-presented, with the logical steps easy to follow, while all too often practical procedures were muddled or incorrect. It was evident that, even at this level, students do not take sufficient care in reading questions and context material before framing their responses.

Question 1 (a) (1)

(i) Write the formula of the complex ion that is present at the **end** of Test **A**.

(1)

$[Zn(OH)_2(H_2O)_4]^{2+}$

ResultsPlus
Examiner Comments

This answer scored (0). Reason: Although the types of each ligand are correct, the numbers of each ligand are the wrong way round and the overall charge on the complex ion is incorrect.

ResultsPlus
Examiner Tip

Check all ligands and that the overall charge is correct.

$[Zn(OH)_4(H_2O)_2]^{2-}$ would have been a correct response.

(i) Write the formula of the complex ion that is present at the **end** of Test **A**.

(1)

$[Zn(OH)_6]^{4-}$

ResultsPlus
Examiner Comments

This response scored (0) – as per the 'Reject' column of the Mark Scheme.

ResultsPlus
Examiner Tip

This complex has four, rather than six, OH^- ligands.

Question 1 (a) (ii)

(ii) Write the formula of the complex ion that is present at the **end** of Test **B**.

(1)

$[Zn(NH_3)_6]^{2+}$

ResultsPlus
Examiner Comments

This response scored (0).

ResultsPlus
Examiner Tip

This complex ion has four, rather than six, ammonia ligands.

(ii) Write the formula of the complex ion that is present at the **end** of Test **B**.

(1)

$[Zn(NH_3)_4]^{2+}$

ResultsPlus
Examiner Comments

This correct formula scored the available mark.

ResultsPlus
Examiner Tip

Learn the correct number of ligands to include in the formulae of complex ions encountered in the specification.

Question 1 (b) (i)

(i) Write an ionic equation, including state symbols, for the formation of the green precipitate in Test **C**.

(1)

$$Cr^{3+}_{(aq)} + 3OH^-_{(aq)} \rightarrow Cr(OH)_{3\,(s)}$$

ResultsPlus
Examiner Comments

This correct equation, including the appropriate state symbols, scored the available mark.

ResultsPlus
Examiner Tip

Check carefully whether or not state symbols are required when you are asked to write an equation.

(i) Write an ionic equation, including state symbols, for the formation of the green precipitate in Test **C**.

(1)

$$[Cr(H_2O)_6]^{3+} + 3OH^- \rightarrow Cr(H_2O)_3(OH)_3 + 3H_2O$$

ResultsPlus
Examiner Comments

This response scored (0) as, although the species are all correct, the state symbols have unfortunately been omitted.

ResultsPlus
Examiner Tip

Always read the question carefully to check whether or not state symbols are required in your answer.

Question 1 (b) (ii)

(ii) Give the oxidation numbers, including signs, of the d-block element in Test **C**.

(2)

Before the addition of hydrogen peroxide ....+3....

At the end of Test **C** ....+6....

ResultsPlus
Examiner Comments

This response scored two marks, as both the oxidation numbers are correct.

ResultsPlus
Examiner Tip

When writing oxidation numbers, don't forget that the charge is written before the number (e.g. +3 rather than 3+).

(ii) Give the oxidation numbers, including signs, of the d-block element in Test **C**.

(2)

Before the addition of hydrogen peroxide .... $[\overset{(+3)}{Cr}(OH)_4(H_2O)_2]^-(aq)$

At the end of Test **C** .... $\overset{(+6)}{Cr}O_4^{2-}(aq)$

ResultsPlus
Examiner Comments

This response scored both marks.The correct oxidation numbers of Cr have both been clearly annotated above the correct species.

ResultsPlus
Examiner Tip

Only the correct oxidation numbers of Cr were required to answer this question.

Question 2 (a) (i)

(a) (i) Show that the 25.0 cm³ of equilibrium mixture contains 0.0960 mol of CH_3COOH.

(3)

$42.4\times10^{-3} \times 0.5 = 0.0212$ mol of NaOH

$0.0212 - (10\times10^{-3})\left(\frac{5}{25}\right) = 0.0192$ mol of CH_3COOH in 5cm³

$0.0192 \times 5 = 0.096$ mol

ResultsPlus
Examiner Comments

This answer scored all three marks by the second route in the Mark Scheme.

ResultsPlus
Examiner Tip

Always show each step clearly in your answer to a calculation question.

(a) (i) Show that the 25.0 cm³ of equilibrium mixture contains 0.0960 mol of CH_3COOH.

(3)

n NaOH in 5cm³ = 0,0424 × 0,5 = 0,0212

n NaOH in 25cm³ = 0.0212 × 5 = 0.106 mol

n H_2O = 1 × 0,01 = 0.01 mol

eq. mol of CH_3COOH = 0.106 − 0,01 = 0.0960 mol

ResultsPlus
Examiner Comments

This answer scored all three marks by the first route in the Mark Scheme.

ResultsPlus
Examiner Tip

Show each step clearly in your answer to calculation questions.

Question 2 (a) (ii–v)

(ii) Deduce the number of moles of each of the other components in the equilibrium mixture.

(3)

I	0.153	0.556	0	0
C	−x	−x	+x	+x
E	0.057	0.4600	0.0960	0.0960

x = 0.0960

Equilibrium moles of C_2H_5OH = 0.0960 mol

Equilibrium moles of $CH_3COOC_2H_5$ = 0.0570 mol

Equilibrium moles of H_2O = 0.4600 mol

(iii) Give the expression for the equilibrium constant, K_c, for the reaction

$$CH_3COOC_2H_5(l) + H_2O(l) \rightleftharpoons C_2H_5OH(l) + CH_3COOH(l)$$

(1)

$$\frac{[C_2H_5OH][CH_3COOH]}{[H_2O][CH_3COOC_2H_5]}$$

(iv) The equilibrium constant, K_c, is defined in terms of the concentrations in the equilibrium mixture. However, in this case, K_c can be calculated using moles rather than concentrations.

Calculate the value of K_c from the data in parts (a)(i) and (a)(ii).

Give your answer to **three** significant figures.

(2)

$$\frac{(0.0960)(0.0960)}{(0.46)(0.0570)}$$

$K_c =$ [illegible]

(v) Explain why it is possible, in this case, to calculate K_c using moles rather than concentrations.

(1)

because the mols are one to one ratio,

same volumes

ResultsPlus
Examiner Comments

Q2(a)(ii) three marks were awarded, as all three mole values are correct.

Q2(a)(iii) scored one mark for the correct K_c expression.

Q2(a)(iv) scored two marks for a correct calculation, with the final answer to 3 S.F.

Q2(a)(v) scored one mark as 'one to one mole ratio' is an allowed option in the Mark Scheme.

ResultsPlus
Examiner Tip

Practise determining the equilibrium moles in K_c calculations. Consider using an algebraic method.

(ii) Deduce the number of moles of each of the other components in the equilibrium mixture.

(3)

	$CH_3COOC_2H_5$	H_2O	C_2H_5OH	CH_3COOH
I	0.153	0.556	0	0.
C	0.0960.	0.0960.	0.0960	0.0960.
E.	0.057	0.46.	0.0960	0.0960.

0.106 − 0.960 = 0.01

Equilibrium moles of C_2H_5OH = 0.0960. mol

Equilibrium moles of $CH_3COOC_2H_5$ = 0.057. mol

Equilibrium moles of H_2O = 0.46. mol

(iii) Give the expression for the equilibrium constant, K_c, for the reaction

$$CH_3COOC_2H_5(l) + H_2O(l) \rightleftharpoons C_2H_5OH(l) + CH_3COOH(l)$$

(1)

$$K_c = \frac{[C_2H_5OH][CH_3COOH]}{[CH_3COOC_2H_5][H_2O]}$$

(iv) The equilibrium constant, K_c, is defined in terms of the concentrations in the equilibrium mixture. However, in this case, K_c can be calculated using moles rather than concentrations.

Calculate the value of K_c from the data in parts (a)(i) and (a)(ii).

Give your answer to **three** significant figures.

(2)

$$K_c = \frac{0.0960 \times 0.0960}{0.46 \times 0.057} = 0.351487$$

$K_c =$ 0.351

(v) Explain why it is possible, in this case, to calculate K_c using moles rather than concentrations.

(1)

The units cancel out. ~~and~~ ~~the~~

ResultsPlus
Examiner Comments

Q2(a)(ii) three marks were awarded, as all three mole values are correct.

Q2(a)(iii) scored the available mark for a correct K_c expression.

Q2(a)(iv) scored two marks as the calculation is correct, with the final answer rounded to 3 S.F.

Q2(a)(v) scored zero, as this response is an 'IGNORE' in the Mark Scheme.

ResultsPlus
Examiner Tip

When answering questions such as Q2(a)(ii), consider setting out your answer in a table format – as is the case here.

Question 2 (b) (i)

(b) The experiment was repeated by a student whose value for K_c differed from the value calculated in (a)(iv).

The student made several suggestions to explain this.

State and explain how, if at all, each suggestion would affect the K_c value obtained by the student, compared with that from (a)(iv).

(i) **Suggestion 1** – The concentration of the sodium hydroxide solution used by the student was less than 0.500 mol dm^{-3}.

(2)

How the student's value of K_c compared with that from (a)(iv) It would be lower.

Explanation If NaOH conc was reduced, moles of NaOH would have reduced and therefore the moles of $CH_3COOC_2H_5$ and H_2O would be lower at equilibrium, therefore Kc would reduce

ResultsPlus
Examiner Comments

This response scored zero overall.

Neither scoring point has been correctly addressed.

ResultsPlus
Examiner Tip

The key point here is that a larger titre value for the sodium hydroxide solution would be recorded, leading the student to over-estimate the moles of acid present in the equilibrium mixture.

(b) The experiment was repeated by a student whose value for K_c differed from the value calculated in (a)(iv).

The student made several suggestions to explain this.

State and explain how, if at all, each suggestion would affect the K_c value obtained by the student, compared with that from (a)(iv).

(i) **Suggestion 1** – The concentration of the sodium hydroxide solution used by the student was less than 0.500 mol dm^{-3}.

(2)

How the student's value of K_c compared with that from (a)(iv) Kc will be greater than Kc ~~is~~ value in (a)(iv)

Explanation This is because less concentration leads to more volume to be used so ~~titre~~ titre will increase and the number of moles of CH_3COOH will increase. Therefore, Kc will increase, as more products are formed.

ResultsPlus
Examiner Comments

Two marks were awarded.

This response scored M1 for the statement of a greater K_c value.

M2 was awarded for the idea of a larger number of moles of ethanoic acid being calculated.

ResultsPlus
Examiner Tip

This question shows the necessity for clear and logical argument when faced with an unfamiliar scenario.

Question 2 (b) (ii)

(ii) **Suggestion 2** – The mixture had been left in a warm part of the laboratory and the equilibrium had been reached at a temperature above room temperature.

(2)

How the student's value of K_c compared with that from (a)(iv) Kc would decrease.

Explanation ~~Ag~~ Since the reaction is ~~endo~~ endothermic, when ~~temp in~~ temperature increases Kc decreases.

ResultsPlus
Examiner Comments

This response scored one mark overall. Note that the scoring points, M1 and M2, were marked independently.

M1 was not awarded as the K_c value increases, rather than decreases, at higher temperatures.

M2 was awarded, however, for the statement that the reaction is endothermic.

ResultsPlus
Examiner Tip

This question required application of the knowledge that the value of K_c increases when the temperature is raised on a reaction which is endothermic in the forward direction.

(ii) **Suggestion 2** – The mixture had been left in a warm part of the laboratory and the equilibrium had been reached at a temperature above room temperature.

(2)

How the student's value of K_c compared with that from (a)(iv) Kc will be greater

Explanation For an endothermic reaction the equilibrium constant increases as temperature increases.

ResultsPlus
Examiner Comments

This response scored two marks overall.

M1 was awarded for the statement that the "K_c will be greater".

M2 was awarded for including in the answer that the reaction is endothermic.

ResultsPlus
Examiner Tip

Both scoring points have been addressed concisely in this response.

Question 2 (c) (i)

(c) A second student repeated the original experiment using exactly the same method. However, when using the pipette and the burette, the readings were taken from the **top** of the meniscus.

(i) How, if at all, will this affect the volume of the equilibrium mixture delivered from the pipette? Justify your answer.

(1)

The actual ~~vals~~ volume will be ~~greater~~ ~~the~~ less than expected.

ResultsPlus
Examiner Comments

Although it has been stated that the volume delivered will be less than expected, there also needs to be a justification mentioning that the reading should have been taken from the bottom of the meniscus.

ResultsPlus
Examiner Tip

Try to visualise being in the laboratory and reading the volume of solution in a pipette.

(c) A second student repeated the original experiment using exactly the same method. However, when using the pipette and the burette, the readings were taken from the **top** of the meniscus.

(i) How, if at all, will this affect the volume of the equilibrium mixture delivered from the pipette? Justify your answer.

(1)

The volume delivered will not be accurate ~~becaus~~ because the reading is supposed to be taken from ~~to~~ the bottom of the meniscus.

ResultsPlus
Examiner Comments

This response scored zero.

Although this student realises that the volume should have been read from the bottom of the meniscus, the fact that the volume delivered will be less also needs to be stated for the available mark. Just stating that "the volume delivered will not be accurate..." is not sufficient.

ResultsPlus
Examiner Tip

Always check carefully that all the requirements of each question are addressed.

Question 2 (c) (ii)

(ii) How, if at all, will this affect the volume of sodium hydroxide solution delivered from the burette? Justify your answer.

(1)

A greater volume will be delivered from the burette because the reading should be taken from the bottom of the meniscus.

ResultsPlus
Examiner Comments

This incorrect response does not score. It has not addressed the fact that a burette titre is calculated from the difference between two readings.

ResultsPlus
Examiner Tip

Again, try to visualise carrying out a titration and how you would determine the volume of sodium hydroxide solution delivered from a burette.

(ii) How, if at all, will this affect the volume of sodium hydroxide solution delivered from the burette? Justify your answer.

(1)

The volume will ~~be~~ not be affected because when titre value is calculated by substracting, the error will be cancelled.

ResultsPlus
Examiner Comments

This response scored the available mark as the candidate realises that the volume delivered is unaffected because the error effectively 'cancels out' (since the burette is read twice in order to calculate the titre value).

ResultsPlus
Examiner Tip

Always remember that a titre value is obtained by subtracting the initial reading from the final burette reading.

Question 2 (c) (iii)

(iii) One of the student's titres was 42.60 cm^3 of sodium hydroxide solution.
The burette has a maximum uncertainty of ±0.05 cm^3 for each reading.

Calculate the percentage uncertainty in this titre.

(1)

$\%$ uncerty $= 2 \times \frac{0.05}{42.6} \times 100$

$= 0.23\%$

Percentage uncertainty = 0.23 %

ResultsPlus
Examiner Comments

This response scored the available mark. The answer is correctly rounded, to 2 S.F.

ResultsPlus
Examiner Tip

This question tested the fact that the titre volume is calculated from two burette readings (final and initial).

(iii) One of the student's titres was 42.60 cm^3 of sodium hydroxide solution.
The burette has a maximum uncertainty of ±0.05 cm^3 for each reading.

Calculate the percentage uncertainty in this titre.

(1)

$\%$ uncertainity $= \frac{\pm 2 \times 0.05}{42.60} \times 100$

$= \pm 0.235\%$

Percentage uncertainty = ... %

ResultsPlus
Examiner Comments

This response scored the available mark. The answer is correctly rounded, to 3 S.F.

ResultsPlus
Examiner Tip

The uncertainty doubles for values dependent on two readings.

Question 3 (a) (b)

(a) Student **A** followed the method exactly and obtained 0.021 mol of benzoic acid crystals.

Calculate the percentage yield of the benzoic acid obtained by Student **A**.

[Molar mass of ethyl benzoate = 150 g mol^{-1}]

(2)

Density = $\frac{\text{Mass}}{\text{volume}}$ → Mass = 1.05 × 6 = 6.3 g

Moles = $\frac{6.3}{150}$ = 0.042 moles

$\frac{0.021}{0.042}$ × 100 = 50%

Percentage yield = 50 %

(b) Student **B** dissolved just 1 g of sodium hydroxide instead of 2 g. This student carried on with the experiment.

Show, by calculation, that Student **B** did **not** have an excess of sodium hydroxide.

(2)

2g in 25cm³ 1g in 25cm³

Moles of ethyl benzoate = $\frac{6.3 g}{150}$ = 0.042 moles

NaOH = 40 g mol^{-1} → Moles in 1g of NaOH = $\frac{1}{40}$ = 0.025

0.025 moles less than 0.042 moles.

Moles of NaOH in 1g are (0.025 moles), which were less than moles of ethyl benzoate (0.042 moles) so not in excess.

ResultsPlus
Examiner Comments

Both parts (a) and (b) are correctly answered here.

ResultsPlus
Examiner Tip

All mathematical aspects of the answer have been clearly laid out by this student.

(a) Student **A** followed the method exactly and obtained 0.021 mol of benzoic acid crystals.

Calculate the percentage yield of the benzoic acid obtained by Student **A**.

[Molar mass of ethyl benzoate = 150 g mol^{-1}]

(2)

Density = $\frac{mass}{volume}$

mass of ethyl benzoate = 6 × 1.05

= 6.3 g

Mol of ethyl benzoate = $\frac{6.3}{150}$

= 0.042 mol

Expected mol of benzoic acid = 0.042 mol

Percentage yield = $\frac{0.021}{0.042}$ × 100

= 50

Percentage yield = 50 %

(b) Student **B** dissolved just 1 g of sodium hydroxide instead of 2 g. This student carried on with the experiment.

Show, by calculation, that Student **B** did **not** have an excess of sodium hydroxide.

(2)

Number of mol of NaOH = $\frac{1}{23+16+1}$

= 0.025 mol

Number of mol of NaOH requred is 0.042 mol

Therefore, NaOH is not in excess

ResultsPlus
Examiner Comments

Both parts (a) and (b) are correctly answered.

ResultsPlus
Examiner Tip

All aspects of these answers have been very clearly structured.

Question 3 (c)

(c) Student **C** dissolved 10 g of sodium hydroxide instead of 2 g. This student noticed the mistake and started the experiment again.

Explain why Student **C** did not need to start again.

(1)

~~An exc~~ 10g of NaOH provides an excess amount, ∴ all of the ethyl benzoate molecules would have reacted and the experiment is viable.

ResultsPlus
Examiner Comments

This response scored the mark for the idea of the NaOH being in excess.

ResultsPlus
Examiner Tip

There was no need to resort to further calculation in order to answer this question.

(c) Student **C** dissolved 10 g of sodium hydroxide instead of 2 g. This student noticed the mistake and started the experiment again.

Explain why Student **C** did not need to start again.

(1)

NaOH is in excess so increasing the ~~# mol~~ of concentration of NaOH doesn't matter.

ResultsPlus
Examiner Comments

The idea that the NaOH was already in excess is being tested here.

ResultsPlus
Examiner Tip

Adding more of a reagent already in excess has no effect on the outcome of the experiment.

Question 3 (d)

Name the procedure described in step 4 and 5, and explain why the benzoic acid prepared by Student **A** was purer than that obtained by Student **D**.

(1)

~~Cryst~~ Recrystallization because in student A's the ~~soluble and~~ insoluble impurities are removed by filtration.

ResultsPlus
Examiner Comments

Recrystallisation was the required procedure that had to be identified here.

ResultsPlus
Examiner Tip

Be able to identify a purification procedure from a description of the process.

Name the procedure described in step 4 and 5, and explain why the benzoic acid prepared by Student **A** was purer than that obtained by Student **D**.

(1)

Purification by ~~a~~ solvent extraction. The benzoic acid prepared by student A had less impurities as they were removed by this method.

ResultsPlus
Examiner Comments

Solvent extraction is incorrect. The procedure described was, in fact, recrystallisation.

ResultsPlus
Examiner Tip

Do not confuse the various purification techniques encountered in laboratory work.

Question 3 (e)

One reason why Student **E** obtained a greater mass of crystals than Student **A** was that the product was not benzoic acid.

Give the structural formula of the organic product that Student **E** obtained.

(1)

$C_6H_5COO^-Na^+$

ResultsPlus
Examiner Comments

This response scored the available mark.
NOTE: The charges do not need to be shown.

ResultsPlus
Examiner Tip

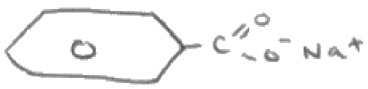
It is important to realise that the alkaline hydrolysis of an ester produces the salt of the carboxylic acid rather than the acid itself.

One reason why Student **E** obtained a greater mass of crystals than Student **A** was that the product was not benzoic acid.

Give the structural formula of the organic product that Student **E** obtained.

(1)

$(C_6H_5COO^-Na^+)$



ResultsPlus
Examiner Comments

Both representations of sodium benzoate shown here are correct.

ResultsPlus
Examiner Tip

Any correct structural formula of sodium benzoate would have been accepted (see options in the Mark Scheme).

Question 3 (f)

(h) (i) Can the number of peaks in the low resolution proton nmr spectroscopy be used to distinguish between the three isomers **P**, **Q** and **R**?
Justify your answer.

(2)

No because they all have the same Number of hydrogen environments. This means that the $N^{\underline{o}}$ of peaks in the low resolution nmr would be the same for all.

ResultsPlus
Examiner Comments

This response would score the mark available, on two counts. Firstly, for the idea of incomplete recrystallisation and secondly, for stating that some product remains in solution.

ResultsPlus
Examiner Tip

Make sure that you fully understand purification processes, such as recrystallisation.

(f) Student **F** ran out of time and filtered the solution in **Step 5** before it had cooled properly. A low yield was obtained.

Explain why Student **F**'s failure to cool fully the solution resulted in **a low yield.**

(1)

• Most of benzoic acid are not ~~ca~~ recrystallised as they remain in the solution

ResultsPlus
Examiner Comments

This response scored the mark for the idea of some of the product remaining in solution.

Question 3 (g)

(i) Why are the melting temperatures of **Sample 1** and **Sample 2** different?

(1)

Sample 1 was more impure than Sample 2. Sample 1 contained more water than sample 2.

(ii) Suggest which isomer is present in these samples. Justify your answer.

(2)

Structural isomer P is present in these samples. Samples still contain some impurities which lower their melting point, which should be exactly 148°C but is 2–4°C less.

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Examiner Comments

Part (g)(i) scores one mark for the idea of Sample 1 being more impure than Sample 2. (The comment about the impurity being water was ignored.)

Part (g)(ii) scored two marks as isomer P has been correctly suggested (so scoring M1) and M2 was awarded for the idea that impurities lower the melting temperature of the sample.

ResultsPlus
Examiner Tip

It is important to remember that impurities lower the melting temperature of a solid, whereas they raise the boiling temperature of a liquid.

(i) Why are the melting temperatures of **Sample 1** and **Sample 2** different?

(1)

This is due to remaining impurities in sample 1 which lowered the melting temperature. Sample 2 is more pure.

(ii) Suggest which isomer is present in these samples. Justify your answer.

(2)

P - 2-nitrobenzoic acid is the isomer present.

This is because a small amount of impurities may still remain after recrystillization which causes the melting temperatu to be lower than its true pure value. It cannot be Q because impurities may not cause and increase in the melting temperature.

ResultsPlus

Examiner Comments

Part (g)(i) scored one mark for the idea of Sample 2 being more pure.

Part (g)(ii) scored two marks as isomer P has been suggested (so scoring M1) and M2 was awarded for the idea that impurities lower the melting temperature of a solid sample.

Question 3 (h) (i)

(f) Student **F** ran out of time and filtered the solution in **Step 5** before it had cooled properly. A low yield was obtained.

Explain why Student **F**'s failure to cool fully the solution resulted in **a low yield.**

(1)

Not all the crystals had formed (some were still dissolved in the solution).

ResultsPlus
Examiner Comments

This answer scored zero marks overall.

M1 was not awarded as there is no mention that both isomers P and Q would be expected to each have five peaks in their low-resolution NMR spectra. M2 was not awarded as it is not stated that isomer R would be expected to have only three peaks in its proton NMR spectrum.

ResultsPlus
Examiner Tip

In questions on low resolution proton NMR spectroscopy, there is no need to mention any expected splitting patterns.

(h) (i) Can the number of peaks in the low resolution proton nmr spectroscopy be used to distinguish between the three isomers **P**, **Q** and **R**?
Justify your answer.

(2)

~~Also~~ ~~They~~ P an Q would ~~all~~ produce 5 peaks in the relative ratio 1:1:1:1:1. R would produce 3 peaks. ~~in the ratio~~ P and Q cannot be distinguished but R can.

ResultsPlus
Examiner Comments

This answer scored both available marks.

M1 was awarded as it is stated that both isomers P and Q each have five peaks.

M2 was then awarded for mentioning that isomer R has only three peaks.

ResultsPlus
Examiner Tip

Practise identifying the total number of different proton environments in a variety of organic compounds.

Question 4 (a) (i)

(i) Write a balanced equation for this decomposition of ammonium vanadate(V). State symbols are not required.

(1)

$2NH_4VO_3 \longrightarrow V_2O_5 + 2NH_3 + H_2O$

ResultsPlus
Examiner Comments

This response scored the available mark as all species and balancing are correct.

ResultsPlus
Examiner Tip

When asked to construct an equation, check that all species are correct and that it is balanced.

(i) Write a balanced equation for this decomposition of ammonium vanadate(V). State symbols are not required.

$VO_2^+ - VO_2^+$

(1)

$2NH_4VO_3 + [O] \rightleftharpoons 2VO_2^+ + 2NH_3 + H_2O$

ResultsPlus
Examiner Comments

This response was incorrect. The vanadium-containing product should have been V_2O_5 (as stated in the question) rather than the VO_2^+ cation. Furthermore, [O] should not have been added to the left-hand side of the equation.

ResultsPlus
Examiner Tip

This response showed the importance of gleaning as much information as possible from the wording of the question.

Question 4 (a) (ii)

(ii) How would the student confirm that this decomposition is complete?

(1)

• Test for presence of ammonia using glass rod dipped in concentrated HCl and look for white smoke

• If no more white smoke is produced, decomposition is complete

ResultsPlus
Examiner Comments

This answer scored the available mark for describing a suitable test to detect that no more NH_3 is being given off.

ResultsPlus
Examiner Tip

Make sure that a plausible practical method is suggested when answering questions of this type.

(ii) How would the student confirm that this decomposition is complete?

(1)

Using ~~a~~ red litmus paper, when it does not turn ~~the~~ from red to blue, the reaction has stopped.

ResultsPlus
Examiner Comments

This response scored the available mark for describing a suitable test to detect that no more NH_3 is being given off.

Question 4 (b)

(b) The student then reduces the vanadium(V) oxide to vanadium(III) oxide, V_2O_3, by passing hydrogen over the heated oxide.

Identify the hazard associated with this procedure.

(1)

Explosive.

ResultsPlus
Examiner Comments

This response did not score the available mark, as hydrogen has not specifically been identified as being explosive.

ResultsPlus
Examiner Tip

Avoid stating a hazard without identifying the substance responsible.

(b) The student then reduces the vanadium(V) oxide to vanadium(III) oxide, V_2O_3, by passing hydrogen over the heated oxide.

Identify the hazard associated with this procedure.

(1)

hydrogen is flammable

ResultsPlus
Examiner Comments

This response scored the available mark, as hydrogen has been identified as being flammable.

NOTE: For the award of the mark, the hydrogen specifically had to be identified (by name or formula) as being flammable.

ResultsPlus
Examiner Tip

When asked to identify a hazard, make sure that you describe a specific one, and don't just make a generic statement.

Question 4 (c)

(c) The student reacts 1.498 g of vanadium(III) oxide, $V_2O_3(s)$, completely with an **excess** of sulfuric acid, $H_2SO_4(aq)$, to make 250 cm^3 of a solution, T, containing aqueous vanadium(III) ions, $V^{3+}(aq)$.

(i) Calculate the concentration, in mol dm^{-3}, of vanadium(III) ions, $V^{3+}(aq)$, in the solution T.

(2)

Mol of $V_2O_3 = \frac{1.498}{(50.9 \times 2) + (16 \times 3)}$

$= 0.01$ mol

$0.01 = \frac{m(250)}{1000}$

$m = 0.04$ mol dm^{-3}

Concentration = 0.04 m

(ii) Give the **formulae** of **two** ions that would be present in high concentration in solution T, apart from vanadium(III) ions, $V^{3+}(aq)$ ions.

(1)

H^+ ions **and** SO_4^{2-} ions

ResultsPlus
Examiner Comments

Part (c)(i) scored one mark overall.

No M1 was awarded, as the moles of V^{3+} are incorrect, but (as per the Mark Scheme) M2 was awarded for a consequentially correct value of 0.04 mol dm^{-3} on the number of moles stated.

Part (c)(ii) scored the available mark for a correct response.

ResultsPlus
Examiner Tip

Remember that if you make a mistake when answering a calculation question, subsequent marks can still be awarded for the application of a correct method.

(c) The student reacts 1.498 g of vanadium(III) oxide, V_2O_3(s), completely with an **excess** of sulfuric acid, H_2SO_4(aq), to make 250 cm^3 of a solution, T, containing aqueous vanadium(III) ions, V^{3+}(aq).

(i) Calculate the concentration, in mol dm^{-3}, of vanadium(III) ions, V^{3+}(aq), in the solution T.

(2)

molar mass =

no of moles of vanadium oxide $= \frac{1.498}{149.8} = 0.01$ moles

$n = c\,v$

$c = \frac{0.01}{(25/1000)} = 0.4$ mol dm^{-3}

Concentration = 0.4 mol

(ii) Give the **formulae** of **two** ions that would be present in high concentration in solution T, apart from vanadium(III) ions, V^{3+}(aq) ions.

(1)

H^+ ions **and** SO_4^{2-} ions

$V_2O_3 + H_2SO_4 \rightarrow$

ResultsPlus

Examiner Comments

Part (c)(i) scored (0) as no M1 mark was awarded for the calculation of the moles of V^{3+} (as this should have been 2 x 0.01 = 0.02 mol) and then no transferred error mark for M2 could be given as the consequential answer should have been 0.04 mol dm^{-3} (and not a value of "0.4" mol dm^{-3}).

Part (c)(ii) scored (1) for a correct response.

ResultsPlus

Examiner Tip

Check all calculation steps thoroughly!

Question 4 (d) (i)

(i) These data suggest that a step-wise reduction of an acidified solution of VO_2^+(aq) ions, using sulfur dioxide, SO_2(aq), will initially produce VO^{2+}(aq) ions and then V^{3+}(aq) ions in solution.

By calculating the relevant $E^{\ominus}_{cell}$ values for any reactions that you predict will occur, show that such a step-wise reduction is possible.

(2)

Step One = $E^{\ominus}cell = 1 - 0.17$
$= +0.83 V$

Step Two = $E^{\ominus}cell = 0.34 - 0.17$
$= +0.17 V$

ResultsPlus
Examiner Comments

This answer was awarded both marks.

M1 was awarded as a value of +0.83 (V) has been calculated and relates to Step 1, which is the reduction of VO_2^+ to VO^{2+}.

M2 was awarded as a value of +0.17 (V)has been calculated and relates to Step 2, which is the reduction of VO^{2+} to V^{3+}.

ResultsPlus
Examiner Tip

Remember that, for a proposed reaction to be feasible, its E_{cell} value must have a positive sign.

(i) These data suggest that a step-wise reduction of an acidified solution of VO_2^+(aq) ions, using sulfur dioxide, SO_2(aq), will initially produce VO^{2+}(aq) ions and then V^{3+}(aq) ions in solution.

By calculating the relevant $E^{\ominus}_{cell}$ values for any reactions that you predict will occur, show that such a step-wise reduction is possible.

(2)

$VO_2^+ / VO^{2+} = +1.00$ V

$SO_2 / SO_4^{2-} = -0.17$ V

Ecell = 1 − 0.17
= +0.83 V

∴ thermodynamically feasible.

$VO^{2+} / V^{3+} = +0.34$ V

$SO_2 / SO_4^{2-} = -0.17$ V

Ecell = 0.34 − 0.17
= +0.17 V

∴ thermodynamically feasible.

ResultsPlus
Examiner Comments

This answer was awarded both available marks.

M1 was awarded for the value of +0.83 (V) being calculated and, from reading the answer as a whole, relates to the reduction of VO_2^+ to VO^{2+}.

M2 was awarded for the value of +0.17 (V) being calculated and, from reading the answer as a whole, relates to the reduction of VO^{2+} to V^{3+}.

Question 4 (d) (ii)

(ii) When the student bubbles sulfur dioxide into a solution containing acidified VO_2^+(aq) ions, VO^{2+}(aq) ions are obtained, rather than V^{3+}(aq) ions.

Suggest why VO^{2+}(aq) ions are produced, rather than the V^{3+}(aq) ions predicted in (d)(i).

(1)

The reaction is not carried out ~~at~~ in standard condition or the reaction of reduction VO^{2+} to V^{3+} requires a lot of energy or has high activation energy. ~~to~~

ResultsPlus
Examiner Comments

This answer scores the available mark in two ways: firstly for the idea of departure from standard conditions, and also for the mention of a high activation energy.

ResultsPlus
Examiner Tip

Remember that a reaction with a positive E_{cell} value, although thermodynamically feasible, may not occur in practice due to kinetic inhibition (i.e. having a prohibitively high activation energy) or because of a departure from standard conditions.

(ii) When the student bubbles sulfur dioxide into a solution containing acidified VO_2^+(aq) ions, VO^{2+}(aq) ions are obtained, rather than V^{3+}(aq) ions.

Suggest why VO^{2+}(aq) ions are produced, rather than the V^{3+}(aq) ions predicted in (d)(i).

(1)

The activation energy is ~~higher~~ high for the reduction to V^{3+} aq. ions.

ResultsPlus
Examiner Comments

This answer scored the available mark for the mention of the proposed reaction having a high activation energy.

Question 4 (d) (iii)

(iii) Construct the overall equation for the reduction of acidified $VO_2^+(aq)$ ions to $VO^{2+}(aq)$ ions by aqueous sulfur dioxide, $SO_2(aq)$.
State symbols are not required.

(1)

$SO_2 + 2VO_2^+ \rightleftharpoons SO_4^{2-} + 2VO^{2+}$

ResultsPlus
Examiner Comments

This answer scored the mark available, as all the species and the balancing are correct.
NOTE: An equilibrium sign was allowed as an alternative to the full arrow(→) between the reactants and products in the equation (as mentioned in the Mark Scheme).

(iii) Construct the overall equation for the reduction of acidified $VO_2^+(aq)$ ions to $VO^{2+}(aq)$ ions by aqueous sulfur dioxide, $SO_2(aq)$.
State symbols are not required.

(1)

$2VO_2^+ + SO_2 \rightarrow 2VO^{2+} + SO_4^{2-}$

ResultsPlus
Examiner Comments

This answer scores the available mark as all species and the balancing are correct.

ResultsPlus
Examiner Tip

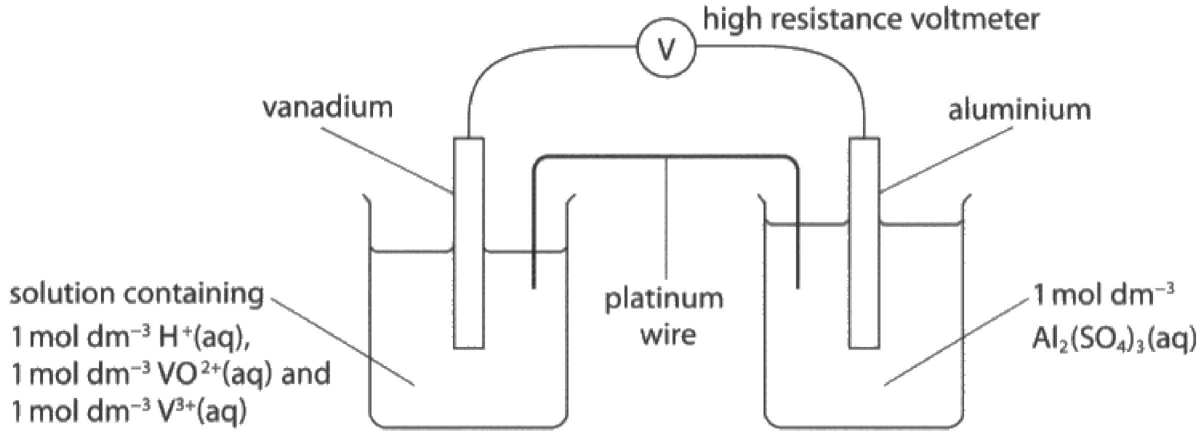
Remember to ensure that all electrons, hydrogen ions and water molecules have been cancelled out, as is appropriate here, when adding two equations together to obtain an overall equation.

Question 4 (e)

Part 2

Having made solutions of VO^{2+}(aq) and V^{3+}(aq) ions, the students decide to measure the standard cell potential between the VO^{2+}(aq) / V^{3+}(aq) and Al^{3+}(aq) / Al(s) half-cells.

The students set up the apparatus below to measure this standard cell potential. The solutions were at 25 °C.



(e) Identify **three** mistakes in the way the cell has been set up and state what modifications should be made to correct them. Write your answers in the table below.

(3)

Mistake in set-up	Modification needed to correct mistake
Platinum wire	Use filter paper dipped in KNO_3.
1 mol dm^{-3} H^+ (aq) 1 mol dm^{-3} V^{3+} (aq)	Use only 1 mol dm^{-3} VO^{2+} (aq)
Aluminium electrode	Use platinum electrode

ResultsPlus
Examiner Comments

This response scored one mark (M1) for identifying the misplaced platinum wire and the description of a salt bridge that should be put in its place.

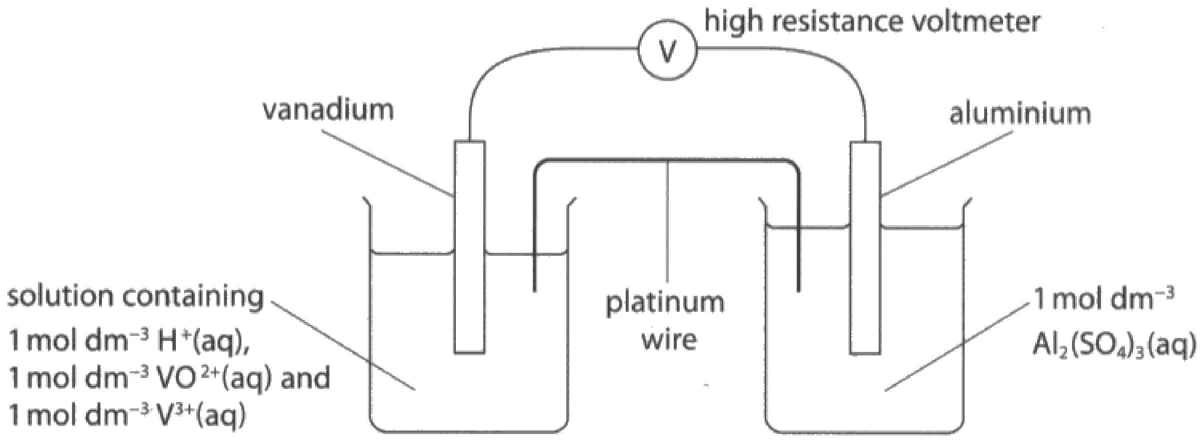
ResultsPlus
Examiner Tip

When carrying out experiments in the laboratory, find out the reasons for setting up the apparatus as directed.

Part 2

Having made solutions of $VO^{2+}(aq)$ and $V^{3+}(aq)$ ions, the students decide to measure the standard cell potential between the $VO^{2+}(aq)$ / $V^{3+}(aq)$ and $Al^{3+}(aq)$ / $Al(s)$ half-cells.

The students set up the apparatus below to measure this standard cell potential. The solutions were at 25 °C.



(e) Identify **three** mistakes in the way the cell has been set up and state what modifications should be made to correct them. Write your answers in the table below.

(3)

Mistake in set-up	Modification needed to correct mistake
~~short~~ the platinum wire as salt bridge	should use damped filter paper soaked in KNO_3
Vanadium electrode	should use platinum as electrode.
$Al_2(SO_4)_3$ solution	supposed to be $Al(NO_3)_3$

ResultsPlus

Examiner Comments

This scored three marks out of three.

M1 was awarded for realising that a salt bridge is needed, instead of the piece of platinum wire.

M2 was awarded for replacing the vanadium electrode with a platinum electrode.

M3 was awarded for replacement of the aluminium sulfate solution with aluminium nitrate solution.

ResultsPlus

Examiner Tip

Remember that 1 mol dm^{-3} aluminium nitrate solution, $Al(NO_3)_3$, has a concentration of $Al^{3+}(aq)$ at 1 mol dm^{-3}, whereas 1 mol dm^{-3} aluminium sulfate solution has a concentration of $Al^{3+}(aq)$ at 2 mol dm^{-3} as its formula is $Al_2(SO_4)_3$.

Paper Summary

Based on their perormance on this paper, candidates are offered the following advice.

To improve on this paper you should:

- Try to understand the reasons and underlying theory for all experimental procedures carried out in the laboratory
- Record and remember any observations that you make during qualitative tasks (e.g. analysis of unknown compounds)
- Practise drawing fully-labelled diagrams of any apparatus used
- Show clearly all steps in any calculations

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