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<td>Question 4 (b) (ii)</td>
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<td></td>
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</tr>
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Introduction

These exemplar answers have been chosen from the summer 2018 examination series.

OCR is open to a wide variety of approaches and all answers are considered on their merits. These exemplars, therefore, should not be seen as the only way to answer questions but do illustrate how the mark scheme has been applied.

Please always refer to the specification https://www.ocr.org.uk/Images/171720-specification-accredited-a-level-gce-chemistry-a-h432.pdf for full details of the assessment for this qualification. These exemplar answers should also be read in conjunction with the sample assessment materials and the June 2018 Examiners' report or Report to Centres available from Interchange https://interchange.ocr.org.uk/Home.mvc/Index

The question paper, mark scheme and any resource booklet(s) will be available on the OCR website from summer 2019. Until then, they are available on OCR Interchange (school exams officers will have a login for this and are able to set up teachers with specific logins – see the following link for further information http://www.ocr.org.uk/administration/support-and-tools/interchange/managing-user-accounts/).

It is important to note that approaches to question setting and marking will remain consistent. At the same time OCR reviews all its qualifications annually and may make small adjustments to improve the performance of its assessments. We will let you know of any substantive changes.
Question 1 (a) (i)

1. This question refers to the elements in the first three periods (H→Ar) of the Periodic Table.
   
   (a) Select an element from the first three periods that fits each of the following descriptions.
   
   (i) The element that forms a 1− ion with the same electron configuration as helium.

Exemplar 1

1. This question refers to the elements in the first three periods (H→Ar) of the Periodic Table.

(a) Select an element from the first three periods that fits each of the following descriptions.

(i) The element that forms a 1− ion with the same electron configuration as helium.


Examiner commentary

This candidate has chosen lithium as forming an ion (Li+) with the same electron configuration as helium. The error lies with the 1− charge which fits with hydrogen instead (H+). The majority of candidates did choose hydrogen, with lithium the most common incorrect response.

Candidates are recommended to look closely at all of the information provided in the question.
Question 1 (a) (ii)

1 (a) (ii) The element with the highest first ionisation energy.

Exemplar 1 0 marks

(ii) The element with the highest first ionisation energy.

 Examiner commentary

Most candidates found this part difficult, with only the higher ability candidates choosing the correct response of ‘helium’.

Hydrogen and fluorine were common incorrect responses, as were the noble gases: neon and argon. Periodic trends are studied in the first module of the A Level course and the performance on this question suggests a lack of revision of content studied a long time ago.
Question 1 (a) (iii) The element in Period 3 which has the successive ionisation energies shown below.

<table>
<thead>
<tr>
<th>Ionisation number</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ionisation energy/kJ mol$^{-1}$</td>
<td>738</td>
<td>1451</td>
<td>7733</td>
<td>10541</td>
</tr>
</tbody>
</table>

Exemplar 1

(iii) The element in Period 3 which has the successive ionisation energies shown below.

<table>
<thead>
<tr>
<th>Ionisation number</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ionisation energy/kJ mol$^{-1}$</td>
<td>738</td>
<td>1451</td>
<td>7733</td>
<td>10541</td>
</tr>
</tbody>
</table>

Examiner commentary

Most candidates were aware that the large increase in ionisation energy signals a change in shell and magnesium was often correctly identified from the increase between the 2nd and 3rd ionisation energies.

In this response, the candidate has identified this large increase but has then chosen the next element, Al, rather than Mg. This candidate has also underlined 'Period 3'. This is good practice and would have prevented the common incorrect answers of the Group 2 elements Be and Ca from the wrong periods.
Question 1 (a) (iv)

1 (a) (iv) The element which forms a compound with fluorine that has octahedral molecules.

..............................

[1]

Exemplar 1 1 mark

(iv) The element which forms a compound with fluorine that has octahedral molecules.

..............................

[1]

Examiner commentary

This candidate has correctly selected sulfur, recalling $\text{SF}_6$ as an octahedral molecule from knowledge of molecular shapes encountered early in the course.

Incorrect responses were random, suggesting guesses. This was an easy recall question from the first year of the A Level course and candidates are encouraged to learn this material when preparing for the A Level examinations.
Question 1 (a) (v)

1 (v) An element which reacts with water to form an acidic solution. ................. [1]

Exemplar 1 1 mark

(v) An element which reacts with water to form an acidic solution. ...........

Examiner commentary

This candidate has correctly chosen chlorine, identifying that a mixture of acids (HCl and HClO) is formed from the reaction of chlorine with water. This is recall of content studied in the first year of the A Level course.

Hydrogen was a common incorrect response from the acidic properties of H\(^+\) ions. Li and Na were also commonly seen as elements that react with water but unfortunately these form an alkaline rather than acidic solution. As with 1(a)(i), it is important to read all of the information provided.
Question 1 (a) (vi)

1 (vi) The element X, which forms a compound with hydrogen, XH₃, with a molar mass of 34.0 g mol⁻¹.

…………………………... [1]

Exemplar 1 0 marks

(vi) The element X, which forms a compound with hydrogen, XH₃, with a molar mass of 34.0 g mol⁻¹.

……………………………… [1]

Examiner commentary

Almost all candidates correctly responded with phosphorus and this was the easiest part of Question 1(a).

This candidate has opted for N from the formula of ammonia, NH₃. This is another example of not using all of the information provided in the question.
Question 1 (a) (vii)

1 (vii) An element which forms a compound with hydrogen in which the element has an oxidation number of $-4$.

............................

[1]

Exemplar 1

[(vii)] An element which forms a compound with hydrogen in which the element has an oxidation number of $-4$.

\[
\begin{align*}
\text{C} &\quad \text{H}_4 \\
\end{align*}
\]

[1]

Examiner commentary

This candidate has correctly selected carbon.

Good practice is seen by underlining $-4$ in the question and then checking the oxidation numbers above the formula of annotated formula of CH$_4$. 
Question 1 (a) (viii)

1 (viii) The element which has a density of $1.33 \times 10^{-3} \text{g cm}^{-3}$ at room temperature and pressure.


Exemplar 1

(viii) The element which has a density of $1.33 \times 10^{-3} \text{g cm}^{-3}$ at room temperature and pressure.

\[
\text{Examiner commentary}
\]

This candidate has interpreted the density as the mass in a volume and has correctly worked out the molecular mass as $1.33 \div 1/24$ which gives 31.92.

The candidate has then selected sulfur, with its atomic mass of 32.1, but unfortunately it is a solid. From the information, the element is gaseous and must be oxygen ($\text{O}_2$ at room temperature and pressure). This was a very difficult question requiring much interpretation and only the most able candidates selected oxygen. Sulfur was by far the commonest response.
Question 1 (b)

1 (b) Table 1.1 shows some properties of Period 3 chlorides.

<table>
<thead>
<tr>
<th>Group</th>
<th>1</th>
<th>2</th>
<th>14 (4)</th>
<th>15 (5)</th>
<th>16 (6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloride</td>
<td>NaCl</td>
<td>MgCl₂</td>
<td>SiCl₄</td>
<td>PCl₃</td>
<td>SCl₂</td>
</tr>
<tr>
<td>Electrical conductivity</td>
<td>Solid</td>
<td>poor</td>
<td>poor</td>
<td>poor</td>
<td>poor</td>
</tr>
<tr>
<td></td>
<td>Liquid</td>
<td>good</td>
<td>good</td>
<td>poor</td>
<td>poor</td>
</tr>
<tr>
<td>Melting point</td>
<td>high</td>
<td>high</td>
<td>low</td>
<td>low</td>
<td>low</td>
</tr>
</tbody>
</table>

Table 1.1

Explain the properties shown in Table 1.1 in terms of bonding and structure.

Exemplar 1

5 marks

Explain the properties shown in Table 1.1 in terms of bonding and structure.

Examiner commentary

This candidate has shown an excellent knowledge and understanding of structure and bonding.

The response is concise and very clear, comparing the different types of structure and the relative strengths of the particles within the structures. Extensive answers do not necessarily lead to more marks as correct responses can then often be contradicted.
Exemplar 2

3 marks

Explain the properties shown in Table 1.1 in terms of bonding and structure.

- NaCl and MgCl₂ are ionic compounds. Na loses 1 electron, and Mg loses 2 electrons to form compounds with a full outer shell. This means they do not have any delocalised electrons, and there are strong intermolecular forces (permanent dipole - permanent dipole), which require large amounts of energy to overcome. Giving the high melting points. SiCl₄, PCl₃ and SCl₂ are simple molecular compounds made by covalent covalent bonds. They have lower forces, which are weaker than the bonding in NaCl/MgCl₂, so require less energy to overcome when melted. NaCl and MgCl₂ are broken up, meaning they are able to move and carry charge. SiCl₄, PCl₃ and SCl₂ do not become mobile and... [5]

Examiner commentary

Compared with the previous exemplar, this response is less focussed and shows some classic confusion about structure and bonding.

The candidate has shown a good understanding of the simple molecular compounds (SiCl₄, PCl₃ and SCl₂) but the discussion of the ionic compounds (NaCl and MgCl₂) is very confused, with a mixture of ionic bonding, metallic bonding and intermolecular forces.
2 This question looks at reactions of hydrogen peroxide and of cobalt(II) ions.

(a) Aqueous hydrogen peroxide decomposes as shown in equation 2.1.

\[ 2\text{H}_2\text{O}_2(\text{aq}) \rightarrow 2\text{H}_2\text{O}(\text{l}) + \text{O}_2(\text{g}) \]  

Equation 2.1

The reaction is catalysed by manganese(IV) oxide, MnO\(_2\).

A student investigates the decomposition of a hydrogen peroxide solution as outlined below.

- The student adds 50.00 cm\(^3\) of H\(_2\)O\(_2\)(aq) to a conical flask.
- The student adds a small spatula measure of MnO\(_2\) and quickly connects the flask to a gas syringe.
- The student measures the volume of oxygen every 200 seconds.

Results

<table>
<thead>
<tr>
<th>Time/s</th>
<th>Volume of O(_2)/cm(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>200</td>
<td>15</td>
</tr>
<tr>
<td>400</td>
<td>28</td>
</tr>
<tr>
<td>600</td>
<td>36</td>
</tr>
<tr>
<td>800</td>
<td>41</td>
</tr>
<tr>
<td>1000</td>
<td>46</td>
</tr>
<tr>
<td>1200</td>
<td>48</td>
</tr>
<tr>
<td>1400</td>
<td>50</td>
</tr>
</tbody>
</table>

(i) Process the results as outlined below.

- On page 5, plot a graph of volume of O\(_2\) against time.
- Use your graph to find the rate of the reaction, in cm\(^3\)s\(^{-1}\), at t = 500 s.

Show your working on the graph and in the space below.

\[ \text{rate} = \frac{\text{change in volume of O}_2}{\text{change in time}} \text{ cm}^3\text{s}^{-1} \] [5]
(i) Process the results as outlined below.

- On page 5, plot a graph of **volume of O₂** against **time**.
- Use your graph to find the rate of the reaction, in cm³ s⁻¹, at **t = 500 s**.

Show your working on the graph and in the space below.

\[
\text{gradient} = \frac{47.5 - 17}{880 - 100} = 0.03910 \ldots = 0.039 \text{ cm}^3 \text{s}^{-1}
\]

rate = \(0.039\) cm³ s⁻¹ [5]
Examiner commentary

The candidate has drawn a well-plotted graph. The tangent has been accurately drawn and there is clear working to calculate the rate from the gradient of the tangent.

Most candidates found the plotting (3 marks) the easiest part of this question. The most common error was not to draw a tangent at 500 s and to simply read off the volume at 500 s as the rate.
Question 2 (a) (ii)

2 (ii) The student allows the reaction in equation 2.1 to proceed until no more gas is evolved. The volume of O₂ in the syringe is now 55 cm³, measured at RTP.

Calculate the initial concentration of the H₂O₂.

Give your answer to two significant figures.

\[ \text{initial concentration of } \text{H}_2\text{O}_2 = \ldots \ldots \ldots \ldots \ldots \text{mol dm}^{-3} \] [3]

Exemplar 1

(ii) The student allows the reaction in equation 2.1 to proceed until no more gas is evolved. The volume of O₂ in the syringe is now 55 cm³, measured at RTP.

Calculate the initial concentration of the H₂O₂.

Give your answer to two significant figures.

\[ \text{Moles } \text{O}_2 : \ \frac{55}{24 \text{cm}^3} = 2.20916 \]

\[ \times \ \frac{2}{1} \text{ ratio} \]

\[ = 0.004583 \text{ moles } \text{H}_2\text{O}_2 \]

\[ \div (55 \text{ cm}^3) \]

\[ = 0.00816 \text{ moles } \text{H}_2\text{O}_2 \]

\[ \text{initial concentration of } \text{H}_2\text{O}_2 = \ldots \ldots \ldots \ldots \ldots \text{mol dm}^{-3} \] [3]

Examiner commentary

This is a clear response that successfully calculates the initial concentration of H₂O₂ from the moles of O₂ and H₂O₂. Notice that the candidate has underlined two in the significant figure requirement but has then given their answer to two decimal places instead.
Question 2 (b)

(b) Hydrogen peroxide can act as an oxidising agent or as a reducing agent.

Some standard electrode potentials are shown below.

\[
\begin{align*}
2\text{H}^+ (aq) + \text{O}_2 (g) + 2e^- & \rightleftharpoons \text{H}_2\text{O}_2 (aq) & E^0 = +0.68 \text{V} \\
\text{H}_2\text{O}_2 (aq) + 2\text{H}^+ (aq) + 2e^- & \rightleftharpoons 2\text{H}_2\text{O} (l) & E^0 = +1.77 \text{V} \\
\text{VO}^{2+} (aq) + 2\text{H}^+ (aq) + e^- & \rightleftharpoons \text{V}^{3+} (aq) + \text{H}_2\text{O} (l) & E^0 = +0.34 \text{V} \\
\text{MnO}_4^- (aq) + 8\text{H}^+ (aq) + 5e^- & \rightleftharpoons \text{Mn}^{2+} (aq) + 4\text{H}_2\text{O} (l) & E^0 = +1.51 \text{V}
\end{align*}
\]

Use this information to write an equation for a reaction in which hydrogen peroxide acts as a reducing agent.

Exemplar 1

2 marks

(b) Hydrogen peroxide can act as an oxidising agent or as a reducing agent.

Some standard electrode potentials are shown below.

\[
\begin{align*}
2\text{H}^+ (aq) + \text{O}_2 (g) + 2e^- & \rightleftharpoons \text{H}_2\text{O}_2 (aq) & E^0 = +0.68 \text{V} \\
\text{H}_2\text{O}_2 (aq) + 2\text{H}^+ (aq) + 2e^- & \rightleftharpoons 2\text{H}_2\text{O} (l) & E^0 = +1.77 \text{V} \\
\text{VO}^{2+} (aq) + 2\text{H}^+ (aq) + e^- & \rightleftharpoons \text{V}^{3+} (aq) + \text{H}_2\text{O} (l) & E^0 = +0.34 \text{V} \\
\text{MnO}_4^- (aq) + 8\text{H}^+ (aq) + 5e^- & \rightleftharpoons \text{Mn}^{2+} (aq) + 4\text{H}_2\text{O} (l) & E^0 = +1.51 \text{V}
\end{align*}
\]

Use this information to write an equation for a reaction in which hydrogen peroxide acts as a reducing agent.

\[
\text{S}_{\text{H}_2\text{O}_2 (aq)} + 2\text{MnO}_4^- \rightarrow 2\text{Mn}^{2+} + 8\text{H}_2\text{O} + \text{SO}_4^{2-} + 5e^-
\]

Examiner commentary

The candidate shows clear cancelling of species that appearing on both sides of the equation (H+ and e−) to give the correct equation.

The working shows that the candidate has identified the relevant half equations from the key electrode potentials of 0.68 V and 1.51 V.

Overall, it was not possible to credit many otherwise correct equations as they contained balancing and cancelling errors.
**Question 2 (c) (i)**

2 (c) Cobalt(II) forms complex ions with water ligands and with chloride ligands.

- With water ligands, cobalt(II) forms a pink octahedral complex ion, \([\text{Co(H}_2\text{O})_6]^{2+}\).
- With chloride ligands, cobalt(II) forms a blue tetrahedral complex ion.

A student dissolves cobalt(II) sulfate in water in a boiling tube. A pink solution forms.

**Experiment 1**

The student places the boiling tube in a water bath at 100°C. Concentrated hydrochloric acid is added dropwise. The colour of the solution changes from pink to blue.

**Experiment 2**

The student places the boiling tube from experiment 1 in an ice/water bath at 0°C. The colour of the solution changes from blue to pink.

(i) Write the equilibrium equation for the reaction that takes place when the colour of the solution changes.

\[
[\text{Co(H}_2\text{O})_6]^{2+} + \text{HCl(aq)} \rightleftharpoons [\text{CoCl}_4]^{2-} + 6 \text{H}_2\text{O(l)}
\]  

**Exemplar 1**

0 marks

(i) Write the equilibrium equation for the reaction that takes place when the colour of the solution changes.

\[
[\text{Co(H}_2\text{O})_6]^{2+} + \text{HCl(aq)} \rightleftharpoons [\text{CoCl}_4]^{2-} + 6 \text{H}_2\text{O(l)}
\]

**Examiner commentary**

This equation includes HCl as the reagent but the candidate has not attempted to balance the equation. This will have contributed to the omitted H\(^+\) in the products. The response would have been clearer if Cl\(^-\) had been used as the reagent.

The state symbols for the complexes are incorrect but these would be ignored for this equation.
Question 2 (c) (ii)

(ii) Explain the observations and predict whether the formation of the blue colour is exothermic or endothermic. [2]

Exemplar 1

(ii) Explain the observations and predict whether the formation of the blue colour is exothermic or endothermic. 

The forward reaction (pink $\rightarrow$ blue) must be endothermic. 

This is because at a high temperature, the equilibrium shifts right (pink $\rightarrow$ blue). 

At a low temperature, it shifts left (pink $\leftarrow$ blue). [2]

Examiner commentary

This is an excellent response, identifying the correct type of enthalpy change and explaining this prediction from the direction of equilibrium shift with temperature.

Overall, the explanation was often incomplete, either omitting the direction of shift or the temperature.
Question 3 (a)

This question is about ethanedioic acid, (COOH)₂, and ethanedicate ions, (COO⁻)₂.

(a) The ethanedicate ion, shown below, can act as a bidentate ligand.

Fe³⁺ forms a complex ion with three ethanedicote ions. The complex ion has two optical isomers. Draw the 3D shapes of the optical isomers. In your diagrams, show the structure of the ethanedicote ligands and any overall charge. [3]

Exemplar 1 0 marks

Examiner commentary

Although this response uses wedges for the 3D structure, the (COO⁻)₂ are shown linked by C atoms rather than O atoms. There would have been more chance of success if the candidate had used the full structure of the (COO⁻)₂ ligands, as shown in the question.

Most candidates showed clear 3D diagrams of the optical isomers although the 3− overall charge was often incorrectly shown as 3+. 
Question 3 (b) (i)

3 (b) Ethanedioic acid, \((\text{COOH})_2\), is present in rhubarb leaves.

A student carries out a redox titration using aqueous cerium(IV) sulfate, \(\text{Ce}(\text{SO}_4)_2\text{(aq)}\), to determine the percentage, by mass, of ethanedioic acid in rhubarb leaves.

In the titration, \(\text{Ce}^{4+}\text{(aq)}\) ions oxidise ethanedioic acid in hot acid conditions:

\[
2\text{Ce}^{4+}\text{(aq)} + (\text{COOH})_2\text{(aq)} \rightarrow 2\text{Ce}^{3+}\text{(aq)} + 2\text{CO}_2\text{(g)} + 2\text{H}^+\text{(aq)}
\]

\(\text{Ce}^{4+}\text{(aq)}\) ions have a yellow colour. \(\text{Ce}^{3+}\text{(aq)}\) ions are colourless.

The student weighs 82.68 g of rhubarb leaves and extracts ethanedioic acid from the leaves.

The ethanedioic acid is added to dilute sulfuric acid to form a colourless solution which is made up to 250.0 cm\(^3\) with distilled water.

The student heats 25.00 cm\(^3\) of this solution to 70 °C and titrates this volume with 0.0500 mol dm\(^{-3}\) \(\text{Ce}(\text{SO}_4)_2\) from the burette.

The student repeats the titration to obtain concordant (consistent) titres.

**Titration results**
The trial titre has been omitted.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Final reading/cm(^3)</strong></td>
<td>24.30</td>
<td>47.80</td>
<td>23.65</td>
</tr>
<tr>
<td><strong>Initial reading/cm(^3)</strong></td>
<td>1.05</td>
<td>24.30</td>
<td>0.50</td>
</tr>
</tbody>
</table>

(i) This titration is self-indicating and the student does not need to add an indicator.

What colour change would the student observe at the end point?

Colour change from ........................................ to ......................................... [1]

**Exemplar 1** 0 marks

(i) This titration is self-indicating and the student does not need to add an indicator.

What colour change would the student observe at the end point?

Colour change from ........................................ to ......................................... [1]

**Examiner commentary**

Surprisingly, the colour change proved to be one of the more difficult questions on the paper and this candidate has given the common incorrect response with the colours the wrong way around.

This was an unfamiliar titration, but the colour change was analogous to that in a manganate titration.
Question 3 (b) (ii)

Calculate the percentage, by mass, of ethanedioic acid in the rhubarb leaves.

Give your answer to an appropriate number of significant figures.

percentage of ethanedioic acid = ........................................... % [6]

Exemplar 1  

(ii) Calculate the percentage, by mass, of ethanedioic acid in the rhubarb leaves.

Give your answer to an appropriate number of significant figures.

Examiner commentary

This candidate has not used the 1:2 stoichiometry and the calculated answer is twice the correct value. The response shows the merit of showing clear working, which allows error carried forward to be easily applied. With only one method step omitted, error carried forwards can still be applied, and the candidate still scores 5/6.

Notice that the question requires the final answer to be given to an appropriate number of significant figures. This reflects the least significant figures provided in the data, in this case three significant figures. Many candidates gave their final answer to fewer or more significant figures.
Question 4 (a) (i)

4  This question is about two compounds used in medicine.

  (a) Cis-platin, PtCl$_2$(NH$_3$)$_2$, is a complex of platinum which is used in cancer treatment.

  (i) What is the oxidation number of platinum in cis-platin?

        +2

Exemplar 1  0 marks

4  This question is about two compounds used in medicine.

  (a) Cis-platin, PtCl$_2$(NH$_3$)$_2$, is a complex of platinum which is used in cancer treatment.

  (i) What is the oxidation number of platinum in cis-platin?

        +4

Examiner commentary

Most candidates responded with the correct oxidation number of +2.

This candidate showed one of the common incorrect responses of +4 (the number of ligands). Others included 0 (the overall charge of the complex) or 2 (with no sign).

Candidates are reminded on the importance of the sign in assigning oxidation numbers.
Exemplar 1

(ii) cis-platin is prepared in a ligand substitution reaction which takes place in multiple steps.

The equation for the final step forming cis-platin is shown below.

\[
[\text{PtCl}_3(\text{NH}_3)]^{\text{2-}} + \text{NH}_3 \rightarrow \text{PtCl}_2(\text{NH}_3)_2 + \text{Cl}^{-}
\]

In the box, outline the mechanism for the formation of cis-platin from \([\text{PtCl}_3(\text{NH}_3)]^{\text{2-}}\). Use curly arrows and lone pairs where appropriate.

Examiner commentary

This question required candidates to apply their knowledge and understanding of curly arrows in an unfamiliar mechanism.

This candidate has drawn the correct structure of the complex (although the – charge is missing) and shows a curly arrow for the breaking of the Pt–Cl bond. The candidate has clearly shown the role of the lone pair in NH\(_3\) but has then added a negative charge for \(\text{NH}_3^-\). This was a common error, possible prompted by the missing negative charge on the \([\text{PtCl}_3\text{NH}_3]^-\) complex ion.
Question 4 (b) (i)

4  (b) Paracetamol is a solid organic compound used in tablets as a painkiller.

(i) Name the functional groups present in paracetamol.

……………………………………………………………

……………………………………………………………

[2]

Exemplar 1  1 mark

(b) Paracetamol is a solid organic compound used in tablets as a painkiller.

(i) Name the functional groups present in paracetamol.

……………………………………………………………

……………………………………………………………

Examiner commentary

The candidate has identified the phenol functional group, but then also added ‘(alcohol)’, which contradicts the previous correct response.

Candidates need to be careful that they do not present an extensive list of many functional groups in the hope that the correct groups are amongst them. Incorrect groups are marked first.
Question 4 (b) (ii)

A chemist prepares a solid sample of paracetamol from 4-nitrophenol in two stages:

\[
\begin{array}{c}
\text{4-nitrophenol} \\
\text{Stage 1:} \\
\text{Intermediate} \\
\text{Stage 2:} \\
\text{paracetamol}
\end{array}
\]

Describe a two-stage synthesis of 5.00 g of pure paracetamol from 4-nitrophenol. The overall percentage yield of paracetamol from 4-nitrophenol is 40.0%.

In your answer, include the mass of 4-nitrophenol required, the reagents and intermediate, and details of the purification of paracetamol.

Exemplar 1

Level 3, 6 marks

A chemist prepares a pure solid sample of paracetamol from 4-nitrophenol in two stages:

\[
\begin{array}{c}
\text{4-nitrophenol} \\
\text{Stage 1:} \\
\text{Intermediate} \\
\text{Stage 2:} \\
\text{paracetamol}
\end{array}
\]

Describe a two-stage synthesis of 5.00 g of pure paracetamol from 4-nitrophenol. The overall percentage yield of paracetamol from 4-nitrophenol is 40.0%.

In your answer, include the mass of 4-nitrophenol required, the reagents and intermediate, and details of the purification of paracetamol.

\[
\begin{align*}
\text{In stage 1, the } \text{NO}_2 \text{ group is reduced, changing the } \text{NO}_2 \text{ group to an } \text{NH}_2 \text{ group.}
\end{align*}
\]

To do this, react with \( \text{Sn (tin)} \) and concentrated \( \text{HCl} \) : The intermediate will be:

\[
\text{HO} - \text{NH}_2
\]

\[
n(\text{paracetamol}) = \frac{\Delta }{8(12) + 9 + 2(16) + 14} = \frac{5}{151}
\]

\[
= 0.033... \text{ mol}
\]

\[
n(4\text{-nitrophenol}) \text{ required} = \frac{0.033...}{0.4}
\]

\[
= 0.0827... \text{ mol}
\]
Examiner commentary

This candidate has produced an excellent response that addresses all aspects of the problem:

- The reagents for stage 1 and the intermediate
- Calculation of the mass of 4-nitrophenol with clear working
- A detailed description for the purification.

The description of purification includes most of the key details:

- Dissolving impure solid in minimum volume of hot solvent
- Cooling the solution, scratching with a glass rod and filtering the solid
- Drying the solid.

If using additional answer space, candidates are advised to write a message for the marker to go to the additional answer space. This candidate would have done better by writing a message rather than using an asterisk (*).

This excellent response gains all 6 marks.
Exemplar 2

Level 2, 4 marks

(ii)* A chemist prepares a pure solid sample of paracetamol from 4-nitrophenol in two stages:

4-nitrophenol → Intermediate → paracetamol

Describe a two-stage synthesis of 5.00 g of pure paracetamol from 4-nitrophenol. The overall percentage yield of paracetamol from 4-nitrophenol is 40.0%.

In your answer, include the mass of 4-nitrophenol required, the reagents and intermediate, and details of the purification of paracetamol.

Examiner commentary

This response is at Level 2. The key difference from the previous exemplar is in the description of purification. Details such as 'minimum volume of solvent', hot solvent, cooling and drying are all absent.

The response is structured, and the communication strand has been achieved.

This response has been credited with 4/6 marks.
Examiner commentary

This response is at Level 2. The candidate has provided some details of purification, has attempted the first stage of the calculation and has given the structure of the intermediate.

The response does lack structure and the communication strand has not been achieved.

This response has been credited with 3/6 marks.
Question 5 (a)

5 A student carries out two experiments in the laboratory based on succinic acid (butanedioic acid), (CH₂COOH)₂.

(a) Aqueous succinic acid can be neutralised by aqueous sodium hydroxide, NaOH(aq):

\[(\text{CH}_2\text{COOH})_2(\text{aq}) + 2\text{NaOH}(\text{aq}) \rightarrow (\text{CH}_2\text{COONa})_2(\text{aq}) + 2\text{H}_2\text{O}(l)\]

This reaction can be used to determine a value for the enthalpy change of neutralisation, \(\Delta_{\text{neut}}H\).

The student follows this method:
- Add 50.0 cm³ of 0.400 mol dm⁻³ succinic acid to a polystyrene cup.
- Measure out 50.0 cm³ of 1.00 mol dm⁻³ NaOH(aq), which is in excess.
- Measure the temperature of both solutions.
- Add the NaOH(aq) to the aqueous succinic acid in the polystyrene cup, stir the mixture, and record the maximum temperature.

**Temperature readings**

<table>
<thead>
<tr>
<th>Maximum temperature of mixture/°C</th>
<th>26.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial temperature of both solutions/°C</td>
<td>21.5</td>
</tr>
</tbody>
</table>

Calculate a value for the enthalpy change of neutralisation, \(\Delta_{\text{neut}}H\), in kJ mol⁻¹.

Assume that the density of all solutions and the specific heat capacity, \(c\), of the reaction mixture are the same as for water.

\[\Delta_{\text{neut}}H = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ ld
Question 5 (b) (i)

(b) Succinic acid is esterified by ethanol, \( \text{C}_2\text{H}_5\text{OH} \), in the presence of an acid catalyst to form an equilibrium mixture.

The equilibrium constant, \( K_c \), for this equilibrium can be calculated using the amounts, in moles, of the components in the equilibrium mixture, using expression 5.1.

\[
K_c = \frac{n((\text{CH}_2\text{COO})\text{C}_2\text{H}_5\text{H}_2) \times n(\text{H}_2\text{O})^2}{n((\text{CH}_2\text{COOH})_2) \times n(\text{C}_2\text{H}_5\text{OH})^2}
\]

Expression 5.1

A student carries out an experiment to determine the value of \( K_c \) for this equilibrium.

- The student mixes together 0.0500 mol of succinic acid and 0.150 mol of ethanol, with a small amount of an acid catalyst.
- The mixture is allowed to reach equilibrium.
- The student determines that 0.0200 mol of succinic acid are present in the equilibrium mixture.

(i) Which technique could be used to determine the equilibrium amount of succinic acid?

--------------------------------------------------------------------------------------------------------------------------------------------------------------- [1]

Exemplar 1 0 marks

(i) Which technique could be used to determine the equilibrium amount of succinic acid?

................................................................. [1]

Examiner commentary

This experiment is based on the experimental determination of \( K_c \) and the easiest way of determining the amount of an acid is by an acid–base titration.

This candidate’s answer of ‘pH meter’ is not a technique.
Question 5 (b) (ii)

5 (b) (ii) Write the equation for the equilibrium reaction that takes place.

Exemplar 1

(ii) Write the equation for the equilibrium reaction that takes place.

\[(\text{CH}_3\text{COOH})_2 + 2\text{H}_2\text{O} \rightleftharpoons (\text{CH}_3\text{COO})_2\text{H}_2 + 2\text{H}_2\text{O}\]

Examiner commentary

The candidate has identified the correct species but has not balanced H\(_2\)O on the right-hand side of the equation. This is a careless error that has cost the candidate a mark. Candidates are advised to carry out a final balancing check on equations.
Question 5 (b) (iii)

5 (b) (iii) Draw the skeletal formula of the ester present in the equilibrium mixture.

Exemplar 1

(iii) Draw the skeletal formula of the ester present in the equilibrium mixture.

Examiner commentary

The candidate has not used the information in the question. The formula of the ester is provided as (CH₂COOC₅H₁₁)₂ but the candidate has instead drawn out the structure of CH₃COOC₂H₅.
Question 5 (b) (iv)

5  (b) (iv) \( K_c \) is the equilibrium constant in terms of equilibrium concentrations.

Why can expression 5.1 be used to calculate \( K_c \) for this equilibrium?

.................................................................................................................................................................
..................................................................................................................................................................... [1]

Exemplar 1 0 marks

(iv) \( K_c \) is the equilibrium constant in terms of equilibrium concentrations.

Why can expression 5.1 be used to calculate \( K_c \) for this equilibrium?

..................................................................................................................................................................... [1]

Examiner commentary

Most candidates found this question difficult. This is a good response, showing good understanding. Other good answers identified that the units or volume would cancel.
Question 5 (b) (v)

5 (b) (v) Calculate the value of $K_c$ for this reaction.

Show your working.

$$K_c = \ldots$$ [3]

Exemplar 1 3 marks

(v) Calculate the value of $K_c$ for this reaction.

Show your working.

$$K_c = \frac{0.03 \times 0.6^2}{0.08 \times 0.09^2}$$

$$= \frac{0.03 \times 0.36}{0.08 \times 0.0081}$$

$$= \frac{0.0108}{0.00648} = 0.0109$$

$$K_c = \frac{0.667}{1} = 0.667$$

Examiner commentary

This candidate has analysed the information in the question to determine the moles of the components of the equilibrium mixture.

This candidate has used a table to show working and has calculated the correct $K_c$ value of 0.667. The clear working allows credit to be given for a sound method by error carried forward if there are errors in the calculation steps.
Question 6 (a) (i)

6 This question is about organic reactions.

(a) Compound A is formed when ethanal is mixed with OH\(^{-}\) (aq) ions, which act as a catalyst.

The balanced equation is shown in reaction 6.1 below.

\[
\begin{align*}
\text{H}_2\text{C}=\text{CH}_2 & \quad + \quad \text{H}_2\text{C}==\text{CH}_2 \\
\text{H}_2\text{C}==\text{CH}_2 & \quad \rightarrow \quad \text{H}_2\text{C}==\text{CH}_2\text{OH}
\end{align*}
\]

\text{Compound A}

(i) Give the systematic name for compound A.

......................................................................................................................................................... [1]

Exemplar 1 0 marks

(i) Give the systematic name for compound A.

......................................................................................................................................................... [1]

Examiner commentary

This response has correctly shown the position of the hydroxy group in the chain but unfortunately the aldehyde group has been confused with that of a carboxylic acid.

Candidates are recommended to carefully check functional groups in an organic structure when naming the compound.
Question 6 (a) (ii)

What type of reaction has taken place?

................................................................................................................................................. [1]

Exemplar 1 1 mark

(ii) What type of reaction has taken place?

........................................... Nucleophilic addition ........................................... [1]

Examiner commentary

This candidate has correctly identified this unfamiliar reaction as being an addition reaction. As the reaction was unfamiliar, 'nucleophilic' was not required.
Question 6 (a) (iii)

6 (a) (iii) Reaction 6.1 takes place in two steps. OH\textsuperscript{-} ions act as a catalyst.

In step 1, ethanal reacts with OH\textsuperscript{-} ions to set up an acid–base equilibrium. In step 2, compound A is formed.

- Complete the equilibrium for step 1 and label the conjugate acid–base pairs as: A1, B1 and A2, B2.

\[
\begin{align*}
\text{CH}_3\text{CHO} + \text{OH}^- & \rightleftharpoons \text{___} + \text{___} \\
\text{___} & \text{___} \\
\end{align*}
\]

- Suggest the equation for step 2.

Exemplar 1

(iii) Reaction 6.1 takes place in two steps. OH\textsuperscript{-} ions act as a catalyst.

In step 1, ethanal reacts with OH\textsuperscript{-} ions to set up an acid–base equilibrium. In step 2, compound A is formed.

- Complete the equilibrium for step 1 and label the conjugate acid–base pairs as: A1, B1 and A2, B2.

\[
\begin{align*}
\text{CH}_3\text{CHO} + \text{OH}^- & \rightleftharpoons \text{___} + \text{___} \\
\text{___} & \text{___} \\
\end{align*}
\]

- Suggest the equation for step 2.

Examiner commentary

This candidate shows a correct response for challenging item.

Most candidates did gain some credit, especially as the mark scheme allowed just one acid–base pair to be correct for a mark. The mark for the overall equation was the most difficult, requiring candidates to link their equation for step 1 with the overall equation for this multi-step reaction provided as Equation 6.1 at the start of the question.
Question 6 (a) (iv)

A similar reaction takes place when propanone, \((\text{CH}_3\text{CO})_2\text{CO}\), is mixed with \(\text{OH}^-\) ions.

Draw the structure of the organic product of this reaction.  

Exemplar 1

(iv) A similar reaction takes place when propanone, \((\text{CH}_3\text{CO})_2\text{CO}\), is mixed with \(\text{OH}^-\) ions.

Draw the structure of the organic product of this reaction.

\[
\begin{align*}
\text{CH}_3 \quad & \quad \text{H} \\
\text{H} \quad & \quad \text{H} \\
\text{C} \quad & \quad \text{O} \\
\text{C} \quad & \quad \text{C} \\
\text{H}_3 & \\
\end{align*}
\]

Examiner commentary

This candidate has clearly drawn the correct structure for the organic product. For success, candidates needed to apply the information in Equation 6.1 to this new situation.

Most candidates found this part very difficult. Bearing in mind the difficulty, connectivity was not assessed in this case (although candidates should always strive for correct connectivity in their organic structures).
**Examiner commentary**

This candidate has produced a concise clear response that contains most of the required details:

- Types and names of mechanisms
- Equations for generation of electrophile and regeneration of catalyst
- Accurately positioned and directed curly arrows and charges/ dipoles

This response easily meets both scientific and communication strands of Level 3 and has been awarded 6/6 marks.
Exemplar 2

Level 2, 3 marks

(b) Many organic reactions use electrophiles as reagents.

Explain the role of electrophiles in organic chemistry.

Your answer should include one reaction of an aliphatic compound and one reaction of an aromatic compound, including relevant mechanisms.

Electrophiles............. accept........ lone........ pairs........ of........

...electrons............ This........ means........ they........ can........ form........

...compounds........... and........ make........ an........ organic........ product........

...more........ stable........ They........ can........ be........ used........ in........ electrophilic

...addition........ to........ add........ two........ organic........ molecules........

...together........ or........ to........ substitute........ one........ organic........ compound........

...for........ another........

HNO₃ + Benzeno........... is........ an........ electrophilic........ addition........

\[ \text{reaction: } \text{HNO}_3 + \text{C}_6\text{H}_6 \rightarrow \text{HNO}_2 + \text{NO}_3^- + \text{H}^+ \]

HCl + Alkane........... is........ an........ electrophilic........ reaction........

\[ \text{reaction: } \text{HCl} + \text{C}_2\text{H}_4 \rightarrow \text{HC} = \text{C}^- + \text{Cl}^- + \text{C}_2\text{H}_3^- \]

Examiner commentary

Compared with the previous exemplar, this response lacks clarity. Although the candidate has chosen two appropriate reactions, curly arrows have not always been accurately positioned. The equations have not been identified as being electrophilic addition and electrophilic substitution and there are no equations for generation of electrophile and regeneration of catalyst.

This response meets the scientific requirement for Level 2 but the lack of structure means that the communication strand has not been met. A mark of 3/6 has been awarded.
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