<table>
<thead>
<tr>
<th>Question number</th>
<th>Answer</th>
<th>Marks</th>
<th>Guidance</th>
</tr>
</thead>
</table>
| 1 (a)           | N in Cu(NO$_3$)$_2$ oxidation state: +5  
N in NO$_2$ oxidation state: +4  
Oxidation product: oxygen | 1  
1  
1 | You know Cu is +2 here since the formula of copper(II) nitrate is given to start. Since oxygen is normally −2 and in O$_2$ the oxygen is zero, then oxygen must have been oxidised. |
| 1 (b)           | [Cu(H$_2$O)$_6$]$^{2+}$ octahedral | 1  
1 | When a transition metal compound is added to water, a hexaaqua complex ion is formed. |
| 1 (c)           | Cu(H$_2$O)$_4$(OH)$_2$ OR Cu(OH)$_2$  
[Cu(H$_2$O)$_6$]$^{2+}$ + 2NH$_3$ → Cu(H$_2$O)$_4$(OH)$_2$ + 2NH$_4^+$ | 1  
1 | Accept: copper(II) hydroxide since the identity is asked for. Using two equations, this would be:  
NH$_3$ + H$_2$O → NH$_4^+$ + OH$^-$  
[Cu(H$_2$O)$_6$]$^{2+}$ + 2OH$^-$ → Cu(H$_2$O)$_4$(OH)$_2$ + 2H$_2$O |
| 1 (d)           | [Cu(NH$_3$)$_4$(H$_2$O)$_2$]$^{2+}$ deep blue  
Cu(H$_2$O)$_4$(OH)$_2$ + 4NH$_3$ → [Cu(NH$_3$)$_4$(H$_2$O)$_2$]$^{2+}$ + 2H$_2$O + 2OH$^-$ | 1  
1  
1 | This is an example of partial ligand substitution. |
| 1 (e)           | [CuCl$_4$]$^{2-}$ yellow-green tetrahedral | 1  
1  
1 | Learn the colours of these transition metal complexes. |
| 1 (f) (i)       | 1s$^2$ 2s$^2$ 2p$^6$ 3s$^2$ 3p$^6$ 3d$^{10}$ | 1 | Remember the 4s electron is lost first. |
| 1 (f) (ii)      | a reducing agent | 1 | |
### 24 Reactions of inorganic compounds in aqueous solutions

#### Practice questions

**AQA Chemistry**

<table>
<thead>
<tr>
<th>Practice questions</th>
<th>2 (a)</th>
<th>2 (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Forms blue or pink precipitate.</strong></td>
<td>Co(H₂O)₄(OH)₂</td>
<td>Fe³⁺ has a larger charge and smaller size than Fe²⁺.</td>
</tr>
<tr>
<td>Precipitate dissolves in excess ammonia.</td>
<td>[Co(NH₃)₆]²⁺</td>
<td>The Fe³⁺ polarises a ligand water molecule to a greater extent.</td>
</tr>
<tr>
<td>Forms yellow or pale brown ‘straw’ coloured solution.</td>
<td>Darkens on standing in air.</td>
<td>The solution of Fe³⁺ contains more H⁺ ions.</td>
</tr>
<tr>
<td>[Co(NH₃)₆]³⁺ formed.</td>
<td>[Co(NH₃)₆]³⁺ formed.</td>
<td>green precipitate with Fe²⁺</td>
</tr>
<tr>
<td>Due to oxidation by O₂ in air.</td>
<td>Due to oxidation by O₂ in air.</td>
<td>FeCO₃</td>
</tr>
<tr>
<td>This sometimes looks lilac.</td>
<td>Accept turns brown.</td>
<td>brown or red/brown precipitate with Fe³⁺</td>
</tr>
<tr>
<td>Accept: Co(OH)₂.</td>
<td>Accept: more hydrolysis occurs, or Fe³⁺ weakens the OH bond more.</td>
<td></td>
</tr>
</tbody>
</table>

**2 (b)** Fe³⁺ has a higher charge/size ration scores two marks, or Fe³⁺ has a higher charge density scores two marks. However, if you refer to either atoms or molecules and not ions you lose both marks.

Accept: more hydrolysis occurs, or Fe³⁺ weakens the OH bond more.

If you give the hydrolysis equation, then you can get a mark for the equation and then a mark for stating that in Fe³⁺ the equilibrium lies further to the right.

Fe³⁺ is more acidic in aqueous solution so it can react with carbonates and give off carbon dioxide (acid + carbonate → salt + water + carbon dioxide). The Fe²⁺ is not acidic enough to react in this way.
### 3 (a) Reaction 1
Ammonia (NH₃) (solution) / NaOH

\[
\begin{align*}
[Cu(H₂O)_6]^{2+} + 2NH₃ &\rightarrow [Cu(H₂O)_4(OH)_2]^+ + 2NH₄^+ \\
\text{OR } [Cu(H₂O)_6]^{2+} + 2OH^- &\rightarrow [Cu(H₂O)_4(OH)_2]^+ + 2H₂O
\end{align*}
\]

1

**General principles in marking this question**
- Square brackets are not essential
- Penalise charges on individual ligands rather than on the whole complex
- Reagent and species can be extracted from the equation
- Ignore conditions such as dilute, concentrated, excess
- Reagent must be a compound NOT just an ion
- Equations must start from \([Cu(H₂O)_6]^{2+}\) except in 4(b)
- Mark reagent, species and equation independently

2

### 3 (b) Reaction 2
Ammonia (conc/xs)

\[
[Cu(H₂O)_4(OH)_2]^+ + 4NH₃ → [Cu(H₂O)_2(NH₃)_4]^{2+} + 2H₂O + 2OH^-
\]

1

**Product 1, balanced equation 1**

2

**Note that the equation must start from the hydroxide \([Cu(H₂O)_4(OH)_2]^+\)**

### 3 (c) Reaction 3
Na₂CO₃ / any identified soluble carbonate / NaHCO₃

\[
[Cu(H₂O)_6]^{2+} + CO₃^{2-} → CuCO₃ + 6H₂O
\]

1

**Do not allow NaCO₃ or any insoluble carbonate but mark on**

2

**Product 1, balanced equation 1**

### 3 (d) Reaction 4
HCl (conc/xs) / NaCl

\[
[Cu(H₂O)_6]^{2+} + 4Cl^- → [CuCl₄]^{2-} + 6H₂O
\]

1

**Allow any identified soluble chloride**

2

**Product 1, balanced equation 1**
<table>
<thead>
<tr>
<th>No.</th>
<th>Question</th>
<th>Reaction</th>
<th>Marks</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 (a)</td>
<td>W is CuCl$_4^{2-}$</td>
<td>[Cu(H$_2$O)$_6$]$^{2+}$ + 4Cl$^-$ → CuCl$_4^{2-}$ + 6H$_2$O</td>
<td>1</td>
<td>Yellow-green/yellow/green</td>
</tr>
<tr>
<td>4 (b)</td>
<td>X is Cu(H$_2$O)$_4$(OH)$_2$</td>
<td>[Cu(H$_2$O)$_6$]$^{2+}$ + 2NH$_3$ → Cu(H$_2$O)$_4$(OH)$_2$ + 2NH$_4^+$</td>
<td>1</td>
<td>Blue precipitate/solid</td>
</tr>
<tr>
<td>4 (c)</td>
<td>Y is [Cu(NH$_3$)$_4$(H$_2$O)$_2$]$^{2+}$</td>
<td>Cu(H$_2$O)$_4$(OH)$_2$ + 4NH$_3$ $\rightarrow$ [Cu(NH$_3$)$_4$(H$_2$O)$_2$]$^{2+}$ + 2H$_2$O + 2OH$^-$</td>
<td>1</td>
<td>Deep/dark/royal blue solution</td>
</tr>
<tr>
<td>4 (d)</td>
<td>Z is CuCO$_3$</td>
<td>[Cu(H$_2$O)$_6$]$^{2+}$ + CO$_3^{2-}$ $\rightarrow$ CuCO$_3$ + 6H$_2$O</td>
<td>1</td>
<td>Green solid/precipitate</td>
</tr>
<tr>
<td>4 (e) (i)</td>
<td>Cu$^{2+}$(aq) + Fe(s) $\rightarrow$ Cu(s) + Fe$^{2+}$(aq)</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4 (e) (ii)</td>
<td>Any two correct points about copper extraction from two of these three categories:</td>
<td></td>
<td>2</td>
<td>Do not allow reference to electricity alone or to temperature alone. Allow avoids depletion of (copper ore) resources. Not just greenhouse gases. Must mention CO$_2$ or CO.</td>
</tr>
</tbody>
</table>