1. Which metal nitrate solution is coloured?
   A. Zn (NO₃)₂(aq)
   B. Ni (NO₃)₂(aq)
   C. Mg (NO₃)₂(aq)
   D. Sc (NO₃)₃(aq)
   (Total 1 mark)

2. What is the ligand in the complex K₃[Fe(CN)₆]?
   A. CN⁻
   B. Fe³⁺
   C. K⁺
   D. [Fe(CN)₆]³⁻
   (Total 1 mark)

3. Which process is responsible for the colour of a transition metal complex?
   A. The absorption of light when electrons move between s orbitals and d orbitals
   B. The emission of light when electrons move between s orbitals and d orbitals
   C. The absorption of light when electrons move between different d orbitals
   D. The emission of light when electrons move between different d orbitals
   (Total 1 mark)

4. Explain why copper is considered a transition metal while scandium is not.
   (Total 3 marks)
5. (a) (i) Draw the shape of the p_z orbital using the coordinates shown.

(ii) State the electron configuration of Fe^{3+}.

(iii) Define the term ligand.

(iv) Explain why the complex [Fe(H_2O)_6]^{3+} is coloured.
(v) The element selenium (Z = 34) has electrons in the 4s, 3d and 4p orbitals. Draw an orbital box diagram (arrow-in-box notation) to represent these electrons.

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

(1)

(Total 7 marks)

6. Which species could be reduced to form NO₂?
   A. N₂O
   B. NO₃⁻
   C. HNO₂
   D. NO

   (Total 1 mark)

7. Consider the following standard electrode potentials.
   
   \[
   \begin{align*}
   \text{Zn}^{2+} (aq) + 2e^- & \rightleftharpoons \text{Zn}(s) & E^\circ = -0.76 \text{ V} \\
   \text{Cl}_2 (g) + 2e^- & \rightleftharpoons 2\text{Cl}^- (aq) & E^\circ = +1.36 \text{ V} \\
   \text{Mg}^{2+} (aq) + 2e^- & \rightleftharpoons \text{Mg}(s) & E^\circ = -2.37 \text{ V}
   \end{align*}
   \]

   What will happen when zinc powder is added to an aqueous solution of magnesium chloride?
   
   A. No reaction will take place.
   B. Chlorine gas will be produced.
   C. Magnesium metal will form.
   D. Zinc chloride will form.

   (Total 1 mark)
8. Which statement about the electrolysis of molten sodium chloride is correct?

A. A yellow-green gas would be produced at the negative electrode.
B. A silvery metal is produced at the positive electrode.
C. Chloride ions are attracted to the positive electrode and undergo oxidation.
D. Sodium ions are attracted to the negative electrode and undergo oxidation.

(Total 1 mark)

9. The same quantity of electricity was passed through separate molten samples of sodium bromide, NaBr, and magnesium chloride, MgCl₂. Which statement is true about the amounts, in mol, that are formed?

A. The amount of Mg formed is equal to the amount of Na formed.
B. The amount of Mg formed is equal to the amount of Cl₂ formed.
C. The amount of Mg formed is twice the amount of Cl₂ formed.
D. The amount of Mg formed is twice the amount of Na formed.

(Total 1 mark)

10. Consider the following reaction:

\[
    \text{H}_2\text{SO}_3(aq) + \text{Sn}^{4+}(aq) + \text{H}_2\text{O}(l) \rightarrow \text{Sn}^{2+}(aq) + \text{HSO}_4^-(aq) + 3\text{H}^+(aq)
\]

Which statement is correct?

A. H₂SO₃ is the reducing agent because it undergoes reduction.
B. H₂SO₃ is the reducing agent because it undergoes oxidation.
C. Sn⁴⁺ is the oxidizing agent because it undergoes oxidation.
D. Sn⁴⁺ is the reducing agent because it undergoes oxidation.

(Total 1 mark)
11. Using the data below and data from Table 14 of the Data Booklet, predict and explain which metal, cadmium or chromium, may be obtained by electrolysis of separate aqueous solutions of Cd\(^{2+}\) (aq) ions and Cr\(^{2+}\) (aq) ions.

<table>
<thead>
<tr>
<th>Reaction</th>
<th>(E^\circ / \text{V})</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\text{Cd}^{2+}(aq) + 2e^- \rightarrow \text{Cd}(s))</td>
<td>–0.40</td>
</tr>
<tr>
<td>(\text{Cr}^{2+}(aq) + 2e^- \rightarrow \text{Cr}(s))</td>
<td>–0.91</td>
</tr>
</tbody>
</table>

(Total 2 marks)

12. The standard electrode potential for a half-cell made from iron metal in a solution of iron(II) ions, Fe\(^{2+}\) (aq), has the value –0.45 V.

(i) Define standard electrode potential.

(ii) Explain the significance of the minus sign in –0.45 V.

(Total 3 marks)
13. Fertilizers may cause health problems for babies because nitrates can change into nitrites in water used for drinking.

(i) Define oxidation in terms of oxidation numbers. (1)

(ii) Deduce the oxidation states of nitrogen in the nitrate, $\text{NO}_3^-$, and nitrite, $\text{NO}_2^-$, ions. (1)

(Total 2 marks)

14. An electrochemical cell is made from an iron half-cell connected to a cobalt half-cell:

The standard electrode potential for $\text{Fe}^{2+} (aq) + 2e^- \rightleftharpoons \text{Fe} (s)$ is $-0.45 \text{ V}$. The total cell potential obtained when the cell is operating under standard conditions is $0.17 \text{ V}$. Cobalt is produced during the spontaneous reaction.

(i) Define the term standard electrode potential and state the meaning of the minus sign in the value of $-0.45 \text{ V}$. (3)

(ii) Calculate the value for the standard electrode potential for the cobalt half-cell. (1)

(iii) Deduce which species acts as the oxidizing agent when the cell is operating. (1)
(iv) Deduce the equation for the spontaneous reaction taking place when the iron half-cell is connected instead to an aluminium half-cell.

(v) Explain the function of the salt bridge in an electrochemical cell.

(Total 9 marks)
1. B

2. A

3. C

4. Sc has no d electrons as an ion / Cu has d electrons; Cu compounds are coloured / Sc compounds are colourless; Cu has more than one oxidation state / Sc has only one oxidation state; Cu compounds can act as catalysts / Sc cannot act as catalysts; 3 max

5. (a) (i) dumbbell-shaped representation along the z-axis:

\[ \text{Sign of wave function not required.} \]

(ii) \(1s^22s^22p^63s^23p^63d^5\) / \(1s^22s^22p^63s^23p^63s^24s^03d^5\) / \([\text{Ar}]4s^03d^5\) / \([\text{Ar}]3d^6\);
Do not allow 2, 8, 13.

(iii) Lewis base / (species/ion/molecule) with lone pair and dative covalent/coordinate bond (to metal) / bonds with metal (ion)/ complex ion;

(iv) has partially filled d subshell/sublevel/orbitals; d orbitals are split (into two sets of different energies) colour due to electron transition between (split) d orbitals; frequencies of visible light absorbed by electrons moving from lower to higher d levels, colour due to remaining frequencies;
Allow wavelength as well as frequency. 3 max
Accept half-arrows or full arrows.
Do not penalize if additional sublevels are shown, if sublevels are not labelled or if no boxes are drawn (providing system of arrows correct).
Do not award mark if sublevels are incorrectly labelled.
Orbital diagram may also be represented with sublevels shown at different relative energy positions.

6. B

7. A

8. C

9. B

10. B

11. Cd$^{2+}$ is a stronger oxidizing agent than H$_2$O and will be displaced to produce Cd / OWTTE;
Cr$^{2+}$ is a weaker oxidizing agent than H$_2$O and H$_2$ will displace in preference to Cr / OWTTE;
Award [1 max] for stating Cd$^{2+}$ stronger oxidizing agent than H$_2$O and Cr$^{2+}$ weaker oxidizing agent than H$_2$O / OWTTE.

12. (i) the potential difference/voltage obtained when a half-cell is
connected to a standard hydrogen electrode; under standard conditions / 1.00 mol dm$^{-3}$ solutions, 298 K; 2

(ii) the electrons flow from the half-cell to the standard hydrogen electrode / the half-cell forms the negative electrode when connected to the standard half-cell / Fe is a better reducing agent than H$_2$ / Fe is above H$_2$ in electrochemical series; 1

Accept “the half reaction is not spontaneous”.

13. (i) increase in the oxidation number; 1

(ii) (NO$_3$)$^+$ 5 and (NO$_2^-$) + 3; 
Accept V and III. 
Do not penalize missing charges on numbers. 1

14. (i) the voltage obtained when the half-cell is connected to the standard hydrogen electrode; under standard conditions of 298 K and 1 mol dm$^{-3}$ solutions; electrons flow (in the external circuit) from the half-cell to the hydrogen electrode / the metal in the half-cell is above hydrogen in the ECS / Fe is a better reducing agent than H$_2$ / Fe is oxidized more readily than H$_2$; 3

(ii) –0.28 V; 1

(iii) Co$^{2+}$/cobalt(II) ion; 1

(iv) 2Al + 3Fe$^{2+}$ → 3Fe + 2Al$^{3+}$; 
Award [II] for correct reactants and products and [II] for correctly balanced, ignore states. 
Do not accept $\equiv$ 2

(v) to complete the electrical circuit / OWTTE; by allowing the movement of ions; 2