Chemistry 12
April 2003 Provincial Examination

ANSWER KEY / SCORING GUIDE

CURRICULUM:

Organizers                     Sub-Organizers
1. Reaction Kinetics           A, B, C
2. Dynamic Equilibrium         D, E, F
5. Oxidation – Reduction       S, T, U, V, W

Part A: Multiple Choice

<table>
<thead>
<tr>
<th>Q</th>
<th>K</th>
<th>C</th>
<th>S</th>
<th>CO</th>
<th>PLO</th>
<th>Q</th>
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Multiple Choice = 60 marks (48 questions)
Part B: Written Response

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Written Response = 40 marks

Multiple Choice = 60 (48 questions)
Written Response = 40 (11 questions)

EXAMINATION TOTAL = 100 marks

LEGEND:

- **Q** = Question Number
- **K** = Keyed Response
- **C** = Cognitive Level
- **B** = Score Box Number
- **S** = Score
- **CO** = Curriculum Organizer
- **PLO** = Prescribed Learning Outcome
1. Consider the following reaction:

$$3\text{Cu}(s) + 8\text{HNO}_3(aq) \rightarrow 3\text{Cu(NO}_3)_2(aq) + 2\text{NO}(g) + 4\text{H}_2\text{O}(l)$$

A piece of copper is added to a nitric acid solution in an open beaker, allowing the $\text{NO}_x$ to escape. The following data was obtained:

<table>
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<th>TIME (min)</th>
<th>MASS OF BEAKER AND CONTENTS (g)</th>
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<td>200.00</td>
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<td>186.45</td>
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<td>8.0</td>
<td>184.80</td>
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</table>
a) Calculate the reaction rate for the time period 2.0 to 6.0 min.  

Solution:

*For Example:*

\[
\text{rate} = \frac{\text{mass change}}{\text{time change}} = \frac{195.45 \text{ g} - 188.15 \text{ g}}{(6.0 - 2.0) \text{ min}}
\]

\[
= \frac{7.30 \text{ g}}{4.0 \text{ min}}
\]

\[
= 1.8 \text{ g/min NO produced}
\]

(Deduct 1/2 mark for incorrect significant figures.)

b) Calculate the mass of copper consumed in the first 5 minutes.

Solution:

*For Example:*

\[
\text{moles NO produced} = \frac{200.00 \text{ g} - 189.90 \text{ g}}{30.0 \text{ g/mol}} = 0.3367 \text{ mol NO}
\]

\[
\text{moles Cu consumed} = 0.3367 \text{ mol NO} \times \frac{3 \text{ mol Cu}}{2 \text{ mol NO}} = 0.5050 \text{ mol Cu}
\]

\[
\text{mass Cu consumed} = 0.5050 \text{ mol Cu} \times \frac{63.5 \text{ g Cu}}{1 \text{ mol Cu}} = 32.1 \text{ g Cu}
\]
2. Using collision theory, explain why reactions between two solutions occur more rapidly than reactions between two solids. (2 marks)

**Solution:**

*For Example:*

- Particles must be able to collide to react.
- Only the particles on the surface of a solid are available for reaction. In a solution, all particles are available. \[\leftarrow 2 \text{ marks}\]
3. Consider the following reaction for the Haber Process for ammonia production:

\[ \text{N}_2(g) + 3\text{H}_2(g) \rightleftharpoons 2\text{NH}_3(g) \quad \Delta H = -92 \text{ kJ} \]

The system is normally maintained at a temperature of approximately 500°C.

a) Explain why 1000°C is not used. (1 mark)

**Solution:**

*For Example:*

Equilibrium will be shifted to the left, reducing the yield of \( \text{NH}_3 \). \( \leftarrow 1 \text{ mark} \)

b) Explain why 100°C is not used. (1 mark)

**Solution:**

*For Example:*

The rate of the reaction would be too low. \( \leftarrow 1 \text{ mark} \)
4. Consider the following equilibrium:

\[ \text{SO}_3(g) + \text{NO}(g) \rightleftharpoons \text{NO}_2(g) + \text{SO}_2(g) \]

In an experiment, 0.100 moles of \( \text{SO}_3 \) and 0.100 moles of \( \text{NO} \) are placed in a 1.00 L container. When equilibrium is achieved, \([\text{NO}_2] = 0.0414 \text{ mol/L}\). Calculate the \( K_{eq} \) value. 

**Solution:**

**For Example:**

\[
\begin{array}{c|cccc}
\text{ } & \text{SO}_3 & + & \text{NO} & \rightleftharpoons & \text{NO}_2 & + & \text{SO}_2 \\
\text{I} & 0.100 & 0.100 & 0 & 0 \\
\text{C} & -0.0414 & -0.0414 & +0.0414 & +0.0414 \\
\text{E} & 0.059 & 0.059 & 0.0414 & 0.0414 \\
\end{array}
\]

\[ K_{eq} = \frac{[\text{NO}_2][\text{SO}_2]}{[\text{SO}_3][\text{NO}]} \]

\[ = \frac{(0.0414)(0.0414)}{(0.059)(0.059)} \]

\[ = 0.50 \]
5. a) Write the net ionic equation for the reaction between $\text{Pb(NO}_3\text{)}_2(aq)$ and $\text{NaCl}_{(aq)}$.

\[(2 \text{ marks)}\]

\textbf{Solution:}

\textit{For Example:}

\[\text{Pb}^{2+}_{(aq)} + 2\text{Cl}^-_{(aq)} \rightarrow \text{PbCl}_2(s) \quad \leftarrow 2 \text{ marks}\]

b) Determine, with calculations, whether a precipitate will form when 15.0 mL of 0.050 M Pb(NO$_3$)$_2$ is added to 35.0 mL of 0.085 M NaCl.

\[(4 \text{ marks)}\]

\textbf{Solution:}

\textit{For Example:}

\[
\left[\text{Pb}^{2+}\right] = 0.050 \text{ M} \times \frac{15.0 \text{ mL}}{50.0 \text{ mL}} = 0.015 \text{ M}
\]

\[
\left[\text{Cl}^-\right] = 0.085 \text{ M} \times \frac{35.0 \text{ mL}}{50.0 \text{ mL}} = 0.0595 \text{ M}
\]

\[
\text{Trial } K_{sp} = [\text{Pb}^{2+}]\left[\text{Cl}^-\right]^2 = (0.015)(0.0595)^2 = 5.3 \times 10^{-5} \quad \leftarrow 1 \text{ mark}
\]

\[
K_{sp} \text{ for PbCl}_2 = 1.2 \times 10^{-5}
\]

Since Trial $K_{sp}$ > $K_{sp}$, a precipitate does form. \quad \leftarrow 1 \text{ mark}
6. An acid-base reaction occurs between $\text{HSO}_3^-$ and $\text{IO}_3^-$.

a) Write the equation for the equilibrium that results. (1 mark)

Solution:

For Example:

\[
\text{HSO}_3^- + \text{IO}_3^- \rightleftharpoons \text{SO}_3^{2-} + \text{HIO}_3
\]

b) Identify one conjugate acid-base pair in the reaction. (1 mark)

Solution:

For Example:

\[
\text{HSO}_3^- \text{ and } \text{SO}_3^{2-} \quad \text{OR} \quad \text{IO}_3^- \text{ and } \text{HIO}_3
\]

(1 mark)

(1 mark)

(1 mark)

(1 mark)

(1 mark)

(1 mark)

(1 mark)

(1 mark)

(1 mark)

(1 mark)

c) State whether reactants or products are favoured, and explain how you arrived at your answer. (2 marks)

Solution:

For Example:

Reactants are favoured.

\[
\text{HSO}_3^- \text{ is a weaker acid than } \text{HIO}_3 \quad \text{OR} \quad \text{IO}_3^- \text{ is a weaker base than } \text{SO}_3^{2-}
\]
7. At 10°C, $K_w = 2.95 \times 10^{-15}$.

a) Determine the pH of water at 10°C. (3 marks)

Solution:

For Example:

\[
K_w = 2.95 \times 10^{-15} = \left[H_3O^+\right]\left[OH^-\right] \quad \leftarrow 1 \text{ mark}
\]

Since $\left[H_3O^+\right] = \left[OH^-\right]$.

\[
\left[H_3O^+\right]^2 = 2.95 \times 10^{-15}
\]

\[
\left[H_3O^+\right] = 5.43 \times 10^{-8} \quad \leftarrow 1 \text{ mark}
\]

pH = 7.265 \quad \leftarrow 1 \text{ mark}

(Deduct 1/2 mark for incorrect significant figures.)

b) State whether water at this temperature is acidic, basic or neutral, and explain. (1 mark)

Solution:

For Example:

Since $\left[H_3O^+\right] = \left[OH^-\right]$, the water is neutral. \leftarrow 1 \text{ mark}
8. Calculate the pH of 0.50 M H₂S. (4 marks)

Solution:

For Example:

\[
\begin{array}{c|ccc}
 & H_2S & + & H_2O & \rightleftharpoons & H_3O^+ & + & HS^- \\
[I] & 0.50 & & 0 & & 0 \\
[C] & -x & & +x & & +x \\
[E] & 0.50 - x & & x & & x \\
\end{array}
\]

(assume \(x\) is negligible)

\[
K_a = 9.1 \times 10^{-8} = \frac{[H_3O^+][HS^-]}{[H_2S]} = \frac{(x)(x)}{(0.50)} \quad \leftarrow 1 \frac{1}{2} \text{ mark}
\]

\[x = [H_3O^+] = 2.13 \times 10^{-4} \quad \leftarrow 1 \text{ mark}\]

\[\text{pH} = 3.67 \quad \leftarrow \frac{1}{2} \text{ mark}\]
9. Consider the following experimental results:

\[
\begin{align*}
&\text{Ce}^{4+} + \text{Pd} \rightarrow \text{Pd}^{2+} + \text{Ce}^{3+} \\
&\text{In}^{3+} + \text{Cd} \rightarrow \text{no reaction} \\
&\text{Pd}^{2+} + \text{In}^{2+} \rightarrow \text{In}^{3+} + \text{Pd} \\
&\text{Cd}^{2+} + \text{Pd} \rightarrow \text{no reaction}
\end{align*}
\]

Use these results to complete the table of reduction half-reactions below.  

**Solution:**

*For Example:*

<table>
<thead>
<tr>
<th>Oxidizing Agents</th>
<th>Reducing Agents</th>
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</thead>
<tbody>
<tr>
<td>(\text{Ce}^{4+} + e^-)</td>
<td>(\text{Ce}^{3+})</td>
</tr>
<tr>
<td>(\text{Pd}^{2+} + 2e^-)</td>
<td>(\text{Pd})</td>
</tr>
<tr>
<td>(\text{Cd}^{2+} + 2e^-)</td>
<td>(\text{Cd})</td>
</tr>
<tr>
<td>(\text{In}^{3+} + e^-)</td>
<td>(\text{In}^{2+})</td>
</tr>
</tbody>
</table>

\(\leftarrow 3 \text{ marks}\)
10. Balance the following equation. (3 marks)

\[ \text{Cr}_2\text{O}_7^{2-} + \text{C}_2\text{O}_4^{2-} \rightarrow \text{Cr}^{3+} + \text{CO}_2 \] (acidic)

Solution:

For Example:

\[
\left(6\text{e}^- + 14\text{H}^+ + \text{Cr}_2\text{O}_7^{2-} \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O}\right) \times 1 \\
\left(\text{C}_2\text{O}_4^{2-} \rightarrow 2\text{CO}_2 + 2\text{e}^-\right) \times 3
\]

\[
14\text{H}^+ + \text{Cr}_2\text{O}_7^{2-} + 3\text{C}_2\text{O}_4^{2-} \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O} + 6\text{CO}_2
\]

\{ \rightarrow 3 \text{ marks} \}
11. Consider the following electrolytic cell which contains a porous barrier to prevent general mixing of solutions.

\[ \text{Pt} \quad \text{Cu} \]

\[ \text{Porous Barrier} \]

\[ \text{Power Supply} \]

\[ \text{e}^- \]

\[ \frac{1}{2} \text{ mark} \quad \text{Cathode} \]

\[ \frac{1}{2} \text{ mark} \quad \text{Anode} \]

\[ 1.0 \text{ M Sn(NO}_3\text{)}_2 \quad 1.0 \text{ M Cu(NO}_3\text{)}_2 \]

a) Label the anode and cathode in the space provided on the diagram above. (1 mark)

**Solution:**

*For Example:*

See diagram above.

b) Write an equation for the overall cell reaction. (2 marks)

**Solution:**

*For Example:*

\[ \text{Sn}^{2+} + \text{Cu}_{(s)} \rightarrow \text{Cu}^{2+} + \text{Sn}_{(s)} \] ← 2 marks

c) Calculate the minimum theoretical voltage required for this reaction under standard conditions. (1 mark)

**Solution:**

*For Example:*

0.48 V ← 1 mark

**END OF KEY**