Chemistry 12
August 2000 Provincial Examination

ANSWER KEY / SCORING GUIDE

CURRICULUM:

Organizers
1. Reaction Kinetics
2. Dynamic Equilibrium
3. Solubility Equilibria
4. Acids, Bases, and Salts
5. Oxidation – Reduction

Sub-Organizers
A, B, C
D, E, F
G, H, I
J, K, L, M, N, O, P, Q, R
S, T, U, V, W

Part A: Multiple Choice

<table>
<thead>
<tr>
<th>Q</th>
<th>K</th>
<th>C</th>
<th>CO</th>
<th>PLO</th>
<th>Q</th>
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Multiple Choice = 48 marks
### Part B: Written Response

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<td>T6, U11</td>
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**Written Response** = 32 marks

**Multiple Choice** = 48 (48 questions)

**Written Response** = 32 (10 questions)

**EXAMINATION TOTAL** = 80 marks

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**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:

\[ \text{CaCO}_3(s) + 2\text{HCl}_{(aq)} \rightarrow \text{CaCl}_2(aq) + \text{CO}_2(g) + \text{H}_2\text{O}(l) \]

A sample of some HCl was added to a sample of CaCO₃ in an open beaker. The total mass was monitored and the following data obtained:

<table>
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<tr>
<th>Time (min)</th>
<th>Total mass of beaker and contents (g)</th>
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<td>150.00</td>
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<tr>
<td>1.00</td>
<td>148.50</td>
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<td>4.00</td>
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<td>7.00</td>
<td>146.30</td>
</tr>
<tr>
<td>8.00</td>
<td>146.30</td>
</tr>
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</table>
a) Find the average rate of production of CO₂ in mol/s during the first 5 minutes. (2 marks)

Solution:

\[
\frac{(150.00 \text{ g} - 146.41 \text{ g})}{5.00 \text{ min}} = 0.718 \text{ g/min}
\]

\(\frac{0.718 \text{ g CO₂}}{44.0 \text{ g CO₂}} = 0.0163 \text{ mol}\)

Rate in \(\frac{\text{mol}}{\text{s}} = \frac{0.0163 \text{ mol}}{60 \text{ s}} = 2.72 \times 10^{-4} \frac{\text{mol}}{\text{s}}\)

\(\frac{1}{2}\) mark for subtraction
\(\frac{1}{2}\) mark for division

\(\frac{1}{2}\) mark

b) Give one reason why the rate of production of CO₂ would decrease with time. Explain, using collision theory. (1 mark)

Solution:

For Example:

Reason: [HCl] decreases
Explanation: Less frequent collisions

OR

Reason: Surface area of CaCO₃ decreases
Explanation: Less frequent collisions

\(\frac{1}{2}\) mark
2. Consider the following reaction:

\[
\text{Fe}^{3+}(aq) + \text{SCN}^- (aq) \rightleftharpoons \text{FeSCN}^{2+} (aq)
\]

yellow \hspace{1cm} \text{colourless} \hspace{1cm} \text{red}

When a few drops of 6.0 M NaOH is added to 25.0 mL of the above system, a precipitate of Fe(OH)₃ forms and the solution turns pale yellow.

a) Explain this colour change in terms of Le Châtelier’s Principle. \hspace{1cm} (2 \text{ marks})

Solution:

The reduced \([\text{Fe}^{3+}]\) causes a shift to the left to offset the stress. \hspace{2cm} \leftarrow 2 \text{ marks}

b) Describe the effect on the rate of the reverse reaction as the colour change occurs. \hspace{1cm} (1 \text{ mark})

Solution:

The rate of the reverse reaction decreases. \hspace{3cm} \leftarrow 1 \text{ mark}
3. Consider the following equilibrium:

$$3I_2(g) + 3F_2(g) \rightleftharpoons 2IF_2(g) + I_4F_2(g)$$

Initially, $2.00 \times 10^{-1}$ mol of $I_2$ and $3.00 \times 10^{-1}$ mol of $F_2$ are put into a 10.00 L flask.

At equilibrium, $[I_4F_2]$ is $2.00 \times 10^{-3}$ M. Calculate the $K_{eq}$.

**Solution:**

<table>
<thead>
<tr>
<th></th>
<th>$I_2$</th>
<th>$F_2$</th>
<th>$IF_2$</th>
<th>$I_4F_2$</th>
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</thead>
<tbody>
<tr>
<td>$[I]$</td>
<td>0.0200</td>
<td>0.0300</td>
<td>0.00200</td>
<td>0.00200</td>
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<tr>
<td>$[C]$</td>
<td>-0.0060</td>
<td>-0.0060</td>
<td>+0.00400</td>
<td>+0.00200</td>
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<tr>
<td>$[E]$</td>
<td>0.0140</td>
<td>0.0240</td>
<td>0.00400</td>
<td>0.00200</td>
</tr>
</tbody>
</table>

\[
K_{eq} = \frac{(IF_2)^2(I_4F_2)}{(I_2)^3(F_2)^3}
\]

\[
K_{eq} = \frac{(0.00400)^2(0.00200)}{(0.0140)^3(0.0240)^3}
\]

\[
= 8.44 \times 10^2
\]
4. a) Write the complete ionic equation for the reaction between NaBrO$_3$ and AgNO$_3$. (1 mark)

Solution:

\[
\text{Na}^+_{(aq)} + \text{BrO}_3^-_{(aq)} + \text{Ag}^+_{(aq)} + \text{NO}_3^-_{(aq)} \rightarrow \text{Na}^+_{(aq)} + \text{NO}_3^-_{(aq)} + \text{AgBrO}_3_{(s)} \quad \leftarrow 1 \text{ mark}
\]

b) What is the maximum [NaBrO$_3$] that can exist in equilibrium with 2.0 M AgNO$_3$?

Solution:

\[
\begin{align*}
\text{AgBrO}_3_{(s)} & \rightleftharpoons \text{Ag}^+ + \text{BrO}_3^- \\
2.0 & \quad x
\end{align*}
\]

\[
K_{sp} = [\text{Ag}^+]\text{[BrO}_3^-] \\
5.3 \times 10^{-5} = (2.0)(x) \quad \leftarrow \frac{1}{2} \text{ marks}
\]

\[
x = [\text{BrO}_3^-] = [\text{NaBrO}_3] = 2.6 \times 10^{-5} \text{ M} \quad \leftarrow 1 \frac{1}{2} \text{ marks}
\]
5. a) Define the term Brønsted-Lowry conjugate acid-base pair.  

Solution:

*For Example:*

A pair of chemical species which differ by the presence of a proton on the acid which is absent from the base.  

\[ \text{Acid: } 
\text{Base: } \]

\( \left\{ \right. \) ← 1 mark

b) Give an example of a conjugate acid-base pair.  

Solution:

*For Example:*

Acid: \( \text{H}_2\text{O} \)

Base: \( \text{OH}^- \)

\( \left\{ \right. \) ← 1 mark
6. Consider the acids HCl and HF.

   a) Only one of the following reactions occurs. Complete the equation for the reaction which does occur.  
      (1 mark)
      
      i) \( \text{HCl} + \text{F}^- \xrightarrow{?} \) __________________________
      ii) \( \text{HF} + \text{Cl}^- \xrightarrow{?} \) __________________________

      Solution:
      \[
      \text{HCl} + \text{F}^- \rightarrow \text{HF} + \text{Cl}^- \quad \leftarrow \quad \frac{1}{2} \text{ mark for selection of correct reaction and}
      \quad \frac{1}{2} \text{ mark for completing equation}
      \]

   b) For the reaction that occurs, are reactants or products favoured? Explain.  
      (1 mark)

      Solution:
      \textit{For Example:}
      Products are favoured \( \left( \frac{1}{2} \text{ mark} \right) \) because HCl is stronger than HF \( \left( \frac{1}{2} \text{ mark} \right) \)

   c) Explain why the other reaction will not occur.  
      (1 mark)

      Solution:
      \textit{For Example:}
      \( \text{Cl}^- \) will not accept a proton. \quad \leftarrow \quad 1 \text{ mark}
7. Calculate the $\left[H_3O^+\right]$ of 0.10 M HNO$_2$.  

(3 marks)

**Solution:**

\[
\begin{array}{c|c|c|c|c}
\text{HNO}_2 & \text{H}_2\text{O} & \rightleftharpoons & \text{H}_3\text{O}^+ & \text{NO}_2^- \\
[\text{I}] & 0.10 \text{ M} & 0 & 0 & \\
[\text{C}] & -x & +x & +x & \\
[\text{E}] & 0.10 - x & x & x & \\
\end{array}
\]

\[
K_a = 4.6 \times 10^{-4} = \frac{\left[H_3O^+\right]\left[NO_2^-\right]}{[\text{HNO}_2]} \hspace{1cm} \left(1 \frac{1}{2} \text{ marks}\right)
\]

\[
= \frac{(x)(x)}{(0.10 - x)} \hspace{1cm} \left(1 \frac{1}{2} \text{ marks}\right)
\]

assume $0.10 - x \approx 0.10$

\[
= \frac{(x)(x)}{0.10} \hspace{1cm} \left(1 \frac{1}{2} \text{ marks}\right)
\]

\[
x = \left[H_3O^+\right] = 6.8 \times 10^{-3} \text{ M} \hspace{1cm} \left(1 \frac{1}{2} \text{ marks}\right)
\]
8. Write the formula equation and the net ionic equation for the reaction between 0.10 M $\text{H}_2\text{SO}_4$ and 0.10 M $\text{Sr(OH)}_2$. (3 marks)

Solution:

Formula equation:

$$\text{H}_2\text{SO}_4(aq) + \text{Sr(OH)}_2(aq) \rightarrow \text{SrSO}_4(s) + 2\text{H}_2\text{O}(l)$$

$\leftrightarrow 1 \frac{1}{2}$ marks

Net ionic equation:

$$2\text{H}^+(aq) + \text{SO}_4^{2-}(aq) + \text{Sr}^{2+}(aq) + 2\text{OH}^-(aq) \rightarrow \text{SrSO}_4(s) + 2\text{H}_2\text{O}(l)$$

$\leftrightarrow 1 \frac{1}{2}$ marks
9. During the production of magnesium metal from sea water, magnesium ions are first precipitated from sea water as magnesium hydroxide.

   a) The magnesium hydroxide is then neutralized by hydrochloric acid, producing magnesium chloride. Write the neutralization reaction. (1 mark)

   Solution:

   \[
   \text{Mg(OH)}_2(s) + 2\text{HCl}_{(aq)} \rightarrow \text{MgCl}_2_{(aq)} + 2\text{H}_2\text{O}(l)
   \]  ← 1 mark

   b) The salt produced, magnesium chloride, is dried, melted and undergoes electrolysis. Write the reaction occurring at each electrode. (2 marks)

   Solution:

   Anode: \(2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-\)  ← 1 mark

   Cathode: \(\text{Mg}^{2+} + 2\text{e}^- \rightarrow \text{Mg}\)  ← 1 mark

   c) It is **not** possible to use electrolysis to remove Mg from a 1.0 M MgCl\(_2\) solution. Why? (1 mark)

   Solution:

   For Example:

   Water is a stronger oxidizing agent than Mg\(^{2+}\).  ← 1 mark
10. In the process of extracting tin from a sample of ore, the tin is removed as Sn\(^{2+}\) ions. A titration requires 21.43 mL of 0.0170 M K\(_2\)Cr\(_2\)O\(_7\) to reach the equivalence point with the Sn\(^{2+}\) in a 0.750 g sample of the ore.

\[
3\text{Sn}^{2+} + \text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ \rightarrow 3\text{Sn}^{4+} + 2\text{Cr}^{3+} + 7\text{H}_2\text{O} 
\]

Using the reaction, calculate the percent mass of tin in the ore sample. \(4\) marks

**Solution:**

\[
\text{mol Cr}_2\text{O}_7^{2-} = \left(0.0170 \text{ mol/L Cr}_2\text{O}_7^{2-}\right)\left(0.02143 \text{ L}\right) = 3.643 \times 10^{-4} \text{ mol Cr}_2\text{O}_7^{2-} \quad \leftarrow 1 \text{ mark}
\]

\[
\text{mol Sn}^{2+} = 3.643 \times 10^{-4} \text{ mol Cr}_2\text{O}_7^{2-}\left(\frac{3 \text{ mol Sn}^{2+}}{1 \text{ mol Cr}_2\text{O}_7^{2-}}\right) = 1.093 \times 10^{-3} \text{ mol Sn}^{2+} \quad \leftarrow 1 \text{ mark}
\]

\[
\text{mol Sn} = \text{mol Sn}^{2+} = 1.093 \times 10^{-3} \text{ mol Sn} \quad \leftarrow 1 \text{ mark}
\]

\[
\text{g Sn} = 1.093 \times 10^{-3} \text{ mol Sn}\left(\frac{118.7 \text{ g Sn}}{1 \text{ mol Sn}}\right) = 1.297 \times 10^{-1} \text{ g Sn} \quad \leftarrow 1 \text{ mark}
\]

\[
\% \text{ Sn} = \frac{1.297 \times 10^{-1} \text{ g Sn}}{0.750 \text{ g Sn ore}} \times 100\% = 17.3\% \quad \leftarrow 1 \text{ mark}
\]

END OF KEY