# Chemistry 12
June 2003 Provincial Examination

**ANSWER KEY / SCORING GUIDE**

**CURRICULUM:**

<table>
<thead>
<tr>
<th>Organizers</th>
<th>Sub-Organizers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Reaction Kinetics</td>
<td>A, B, C</td>
</tr>
<tr>
<td>2. Dynamic Equilibrium</td>
<td>D, E, F</td>
</tr>
<tr>
<td>5. Oxidation – Reduction</td>
<td>S, T, U, V, W</td>
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</tbody>
</table>

## Part A: Multiple Choice

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

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<tr>
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<td>5</td>
<td>V2</td>
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</table>

Written Response = 40 marks

Multiple Choice = 60 (48 questions)
Written Response = 40 (12 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 in an open flask: (3 marks)

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

A 155.0 g sample of \( \text{CaCO}_3(s) \) is placed in the flask and \( \text{HCl(aq)} \) is added. The reaction consumes \( \text{HCl(aq)} \) at an average rate of 0.200 mol/min for 10.0 min. What mass of \( \text{CaCO}_3(s) \) remains?

Solution:

*For Example:*

Amount of \( \text{HCl} \) reacting = 0.200 mol/min \( \times \) 10.0 min = 2.00 mol \( \leftarrow \frac{1}{3} \text{ mark} \)

Moles of \( \text{CaCO}_3 \) reacting = 2.00 mol \( \text{HCl} \) \( \times \) \( \frac{1 \text{ CaCO}_3}{2 \text{HCl}} \) = 1.00 mol \( \text{CaCO}_3 \) \( \leftarrow \frac{1}{3} \text{ mark} \)

Mass of \( \text{CaCO}_3 \) reacting = 1.00 mol \( \text{CaCO}_3 \) \( \times \) \( \frac{100.1 \text{ g}}{1 \text{ mol}} \) = 1.00 \( \times \) \( 10^2 \text{ g} \) \( \leftarrow \text{ 1 mark} \)

Mass remaining = 155.0 g − 100. g = 55 g \( \leftarrow \text{ 1 mark} \)
2. a) Write the equation for Step 3 in the following reaction mechanism. (1 mark)

<table>
<thead>
<tr>
<th>Step 1</th>
<th>2NO → N₂O₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 2</td>
<td>N₂O₂ + H₂ → N₂O + H₂O</td>
</tr>
<tr>
<td>Step 3</td>
<td>?</td>
</tr>
<tr>
<td>Overall Reaction</td>
<td>2NO + 2H₂ → N₂ + 2H₂O</td>
</tr>
</tbody>
</table>

Solution:

Step 3: N₂O + H₂ → N₂ + H₂O ← 1 mark

b) Identify a reaction intermediate in the above mechanism. (1 mark)

Solution:

Either N₂O₂ OR N₂O ← 1 mark
3. Consider the following exothermic reaction:

\[
C_3H_8(g) + 5O_2(g) \underset{?}{\rightarrow} 3CO_2(g) + 4H_2O(g)
\]

Explain, in terms of increasing or decreasing entropy and enthalpy, whether or not the reaction will reach equilibrium. 

**Solution:**

*For Example:*

Entropy increases in the forward reaction. \(\leftarrow 1\) mark

Enthalpy decreases in the forward reaction. \(\leftarrow 1\) mark

Since both favour products, equilibrium will not be attained; or the reaction will go to completion. \(\leftarrow 1\) mark
4. Given the reacting system:

\[ H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \quad K_{eq} = 64 \]

Equal moles of H₂, I₂ and HI are placed in a 1.0 L container. Use calculations to determine the direction the reaction will proceed in order to reach equilibrium. (3 marks)

Solution:

For Example:

\[ H_2 + I_2 \rightleftharpoons 2HI \]

\[ \begin{array}{c|c|c|c} \text{[I]} & x & x & x \\ \end{array} \]

Trial \( K_{eq} = \frac{[\text{HI}]^2}{[\text{H}_2][\text{I}_2]} \)

\[ = \frac{(x)^2}{(x)(x)} = 1 \]

Since Trial \( K_{eq} < K_{eq} \), equilibrium is established by proceeding to the right. (1 mark)
5. After a 50.0 mL sample of a saturated solution of Ag₂SO₄ was heated to dryness, 7.2 × 10⁻⁴ g of solid Ag₂SO₄ remained. What is the value of $K_{sp}$ for Ag₂SO₄? (5 marks)

Solution:

For Example:

$$\text{Ag}_2\text{SO}_4(s) \rightleftharpoons 2\text{Ag}^+(aq) + \text{SO}_4^{2-}(aq)$$

$$[\text{Ag}_2\text{SO}_4] = \frac{7.2 \times 10^{-4} \text{ g}}{0.0500 \text{ L}} \times \frac{1 \text{ mole}}{311.9 \text{ g}} = 4.62 \times 10^{-5} \text{ M} \quad \leftarrow 1 \text{ mark}$$

$$[\text{Ag}^+] = 2 \times 4.62 \times 10^{-5} \text{ M} = 9.23 \times 10^{-5} \text{ M} \quad \leftarrow 1 \text{ mark}$$

$$[\text{SO}_4^{2-}] = 4.62 \times 10^{-5} \text{ M} \quad \leftarrow 1 \text{ mark}$$

$$K_{sp} = [\text{Ag}^+]^2 [\text{SO}_4^{2-}]$$

$$= (9.23 \times 10^{-5})^2 (4.62 \times 10^{-5})$$

$$= 3.9 \times 10^{-13} \quad \leftarrow 1 \text{ mark}$$

(Deduct $\frac{1}{2}$ mark for incorrect significant figures.)
6. a) Write an equation to represent the predominant reaction when \( \text{HC}_2\text{O}_4^- \) is mixed with \( \text{HSO}_4^- \). 

**Solution:**

*For Example:*

\[
\text{HC}_2\text{O}_4^- + \text{HSO}_4^- \rightleftharpoons \text{H}_2\text{C}_2\text{O}_4 + \text{SO}_4^{2-}
\]

\( \leftarrow 1 \text{ mark} \)

b) Justify your statement by comparing \( K_a \) values.

**Solution:**

*For Example:*

\[
K_a \text{HSO}_4^- > K_a \text{HC}_2\text{O}_4^- \]

\( \leftarrow 1 \text{ mark} \)

c) Identify a conjugate acid-base pair.

**Solution:**

*For Example:*

\[
\begin{align*}
\text{HSO}_4^- & \quad \text{and} \quad \text{SO}_4^{2-} \\
\text{OR} & \quad \text{HC}_2\text{O}_4^- \quad \text{and} \quad \text{H}_2\text{C}_2\text{O}_4
\end{align*}
\]

\( \leftarrow 1 \text{ mark} \)

d) Predict whether the equilibrium will favour the formation of reactants or products. Explain.

**Solution:**

*For Example:*

Reactants are favoured since \( K_a \text{HSO}_4^- < K_a \text{H}_2\text{C}_2\text{O}_4 \)

\( \leftarrow 2 \text{ marks} \)
7. Write an equation representing the ionization of water and state both ion concentrations that exist for pure water to have a pH = 7.20 .

(3 marks)

Solution:

For Example:

\[ \text{H}_2\text{O}(l) + \text{H}_2\text{O}(l) \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{OH}^-(aq) \] ← 1 mark

Since pH = 7.20, \( [\text{H}_3\text{O}^+] = 6.3 \times 10^{-8} \text{ M} \) ← 1 mark

\( [\text{H}_3\text{O}^+] = [\text{OH}^-] = 6.3 \times 10^{-8} \text{ M} \) ← 1 mark
8. Calculate the pH of 0.25 M NaHCO₃, a basic salt. (5 marks)

Solution:

*For Example:*

\[
\begin{array}{c|ccc}
[I] & \text{HCO}_3^- & + & \text{H}_2\text{O} & \rightleftharpoons & \text{H}_2\text{CO}_3 & + & \text{OH}^- \\
[C] & -x & +x & +x \\
[E] & 0.25 - x & x & x \\
\end{array}
\]

(assume \( x \) is negligible)

\[
K_b = \frac{1.0 \times 10^{-14}}{4.3 \times 10^{-7}} = \frac{[\text{H}_2\text{CO}_3][\text{OH}^-]}{[\text{HCO}_3^-]}
\]

\[
2.33 \times 10^{-8} = \frac{x^2}{0.25}
\]

\[
x = [\text{OH}^-] = 7.62 \times 10^{-5} \text{ M}
\]

\[
\text{pOH} = 4.12
\]

\[
\text{pH} = 9.88
\]

(Deduct \( \frac{1}{2} \) mark for incorrect significant figures.)
9. Explain why the action of a buffer solution is limited. (2 marks)

Solution:

For Example:

Buffer action depends on the presence of
• sufficient amounts ← 1 mark
• of weak acid and conjugate base ← 1 mark
in the buffer solution.
10. Balance the following redox equation: (4 marks)

\[ \text{H}_2\text{S} + \text{CrO}_4^{2-} \rightarrow \text{S}_8 + \text{Cr}^{3+} \quad \text{(acidic)} \]

**Solution:**

*For Example:*

\[
\begin{align*}
(8\text{H}_2\text{S} & \rightarrow \text{S}_8 + 16\text{H}^+ + 16\text{e}^-) \times 3 \\
(3\text{e}^- + 8\text{H}^+ + \text{CrO}_4^{2-} & \rightarrow \text{Cr}^{3+} + 4\text{H}_2\text{O}) \times 16 \\
24\text{H}_2\text{S} + 128\text{H}^+ + 16\text{CrO}_4^{2-} & \rightarrow 3\text{S}_8 + 48\text{H}^+ + 16\text{Cr}^{3+} + 64\text{H}_2\text{O} \\
24\text{H}_2\text{S} + 80\text{H}^+ + 16\text{CrO}_4^{2-} & \rightarrow 3\text{S}_8 + 16\text{Cr}^{3+} + 64\text{H}_2\text{O}
\end{align*}
\]

2 marks (1 mark for each half-reaction)

1 mark for the correct electron ratio

1 mark for the final balanced equation
11. An excess of copper solid is dropped into a solution which contains 
AgNO₃, Fe(NO₃)₃ and Zn(NO₃)₂. Write the equations for any reduction 
half-reactions that occur over time under standard conditions. (2 marks)

Solution:

For Example:

\[ \text{Ag}^+ + e^- \rightarrow \text{Ag} \leftarrow 1 \text{ mark} \]
\[ \text{Fe}^{3+} + e^- \rightarrow \text{Fe}^{2+} \leftarrow 1 \text{ mark} \]
12. Consider the following diagrams:

a) Predict what should happen to the Fe in Beaker A. (1 mark)

Solution:

_for example:_

Prediction: The iron is oxidized. ← 1 mark

b) Predict what should happen to the Fe in Beaker B. Explain. (2 marks)

Solution:

_for example:_

Prediction: Nothing happens to the Fe. ← 1 mark

Explanation: Zn is oxidized and protects the Fe.

OR

The Fe is cathodically protected by the Zn. ← 1 mark