Chemistry 12
August 2002 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>
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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 (13 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 reaction: 

\[ 2\text{H}_2\text{O}(l) \rightarrow 2\text{H}_2(g) + \text{O}_2(g) \]

The rate of production of \( \text{O}_2 \) is \( 1.2 \times 10^{-2} \) mol/s. How many seconds will it take to decompose 100.0 g \( \text{H}_2\text{O} \) ?

**Solution:**

*For Example:*

\[
\begin{align*}
\text{mol H}_2\text{O} &= 100.0 \text{ g} \times \frac{1 \text{ mol}}{18.0 \text{ g}} = 5.556 \text{ mol} \\
\text{mol O}_2 &= 5.556 \text{ mol H}_2\text{O} \times \frac{1 \text{ mol O}_2}{2 \text{ mol H}_2\text{O}} \\
&= 2.778 \text{ mol} \\
\text{time} &= \frac{\text{mol O}_2}{\text{rate}} = \frac{2.778 \text{ mol}}{1.2 \times 10^{-2} \text{ mol/s}} \\
&= 2.3 \times 10^2 \text{ s}
\end{align*}
\]

(Deduct \( \frac{1}{2} \) mark for incorrect significant figures.)
2. Define the term *catalyst*. (2 marks)

**Solution:**

*For Example:*

A catalyst is a substance that increases the rate of a chemical reaction and may be recovered at the end of the reaction. \[ \text{← 2 marks} \]
3. Describe the nature of *dynamic equilibrium.* (2 marks)

**Solution:**

*For Example:*

In a dynamic equilibrium, the forward reaction and reverse reaction continue to proceed at equal rates.

\[ \text{ } \]

\[ \text{ } \] \leftarrow 2 \text{ marks}
4. Consider the following:  

\[ \text{N}_2\text{O}_4(g) \rightleftharpoons 2\text{NO}_2(g) \quad K_{eq} = 9.5 \times 10^{-3} \]

Initially, 0.060 mol N\textsubscript{2}O\textsubscript{4} and 0.020 mol NO\textsubscript{2} are placed into a 2.00 L container. Use calculations to determine the direction in which the reaction proceeds in order to reach equilibrium.

**Solution:**

*For Example:*

\[
\begin{align*}
\text{[N}_2\text{O}_4] & = \frac{0.060 \text{ mol}}{2.00 \text{ L}} = 0.030 \text{ mol/L} \\
\text{[NO}_2] & = \frac{0.020 \text{ mol}}{2.00 \text{ L}} = 0.010 \text{ mol/L} \\
K_{\text{trial}} & = \frac{[\text{NO}_2]^2}{[\text{N}_2\text{O}_4]} = \frac{(0.010)^2}{(0.030)} = 3.3 \times 10^{-3} \\
K_{\text{trial}} & < K_{eq} \\
\therefore \text{ The reaction proceeds to the right.}
\end{align*}
\]

(Deduct 1/2 mark for incorrect significant figures.)
5. A 100.0 mL saturated solution of FeF$_2$ contains 0.0787 g of solute. Determine [Fe$^{2+}$] and [F$^-$] in the solution. (3 marks)

**Solution:**

*For Example:*

$$[\text{FeF}_2] = 0.0787 \text{ g} \times \frac{1 \text{ mol}}{93.8 \text{ g}} \times \frac{1}{0.1000 \text{ L}} = 8.39 \times 10^{-3} \text{ M}$$

FeF$_2$$_{(aq)}$ $\rightarrow$ Fe$^{2+}$$_{(aq)}$ + 2F$^-$_{(aq)} $\leftarrow$ 3 marks

$$[\text{Fe}^{2+}] = 8.39 \times 10^{-3} \text{ M}$$

$$[\text{F}^-] = 1.68 \times 10^{-2} \text{ M}$$

(Deduct $\frac{1}{2}$ mark for incorrect significant figures.)
6. Consider the following information and accompanying diagram:

In a titration experiment, \( \text{AgNO}_3(aq) \) was used to determine the \( [\text{Cl}^-] \) in a water sample and the following data were recorded:

<table>
<thead>
<tr>
<th>[ \text{AgNO}_3 ]</th>
<th>0.125 M</th>
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<tr>
<td>Volume of water sample containing ( \text{Cl}^- )</td>
<td>20.00 mL</td>
</tr>
<tr>
<td>Initial buret reading of ( \text{AgNO}_3 )</td>
<td>5.15 mL</td>
</tr>
<tr>
<td>Final buret reading of ( \text{AgNO}_3 )</td>
<td>37.15 mL</td>
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</tbody>
</table>

The equation for this reaction is

\[
\text{Ag}^+_{(aq)} + \text{Cl}^-_{(aq)} \rightarrow \text{AgCl}_{(s)}
\]

Using the above data, determine the \( [\text{Cl}^-] \) in the water sample. \( \text{(3 marks)} \)

**Solution:**

*For Example:*

Volume \( \text{AgNO}_3 \) used = 37.15 mL - 5.15 mL = 32.00 mL

\[
\text{mol Ag}^+ = 0.125 \text{ mol/L} \times 0.03200 \text{ L} = 0.00400 \text{ mol}
\]

\[
\text{mol Cl}^- = \text{mol Ag}^+ = 0.00400 \text{ mol}
\]

\[
[\text{Cl}^-] = \frac{0.00400 \text{ mol}}{0.02000 \text{ L}} = 0.200 \text{ M}
\]

(Deduct \( \frac{1}{2} \text{ mark} \) for incorrect significant figures.)
7. Consider the following equilibria:

<table>
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<tr>
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<th>CH₃COOH + OCN⁻ ⇌ HOCN + CH₃COO⁻</th>
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<tbody>
<tr>
<td>I.</td>
<td></td>
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<tr>
<td>II.</td>
<td>CH₃COOH + ClO⁻ ⇌ HClO + CH₃COO⁻</td>
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a) In equation I above, the reactants are favoured. Identify the stronger acid. 

Solution:

HOCN ← 1 mark

b) In equation II above, the products are favoured. Identify the stronger acid.

Solution:

CH₃COOH ← 1 mark

c) Consider the following reaction:

HOCN + ClO⁻ ⇌ OCN⁻ + HClO

Does this reaction favour reactants or products? Explain.

Solution:

For Example:

Products are favoured because HOCN is a stronger acid than HClO. ← 2 marks
8. At 60°C, the pH = 6.51 for pure water. Determine the value of $K_w$ at this temperature. (3 marks)

Solution:

For Example:

\[
\text{pH} = 6.51 \\
[H_3O^+] = 3.09 \times 10^{-7} \text{ M} = [OH^-] \\
K_w = [H_3O^+][OH^-] = (3.09 \times 10^{-7})(3.09 \times 10^{-7}) = 9.5 \times 10^{-14}
\]  

(Deduct $\frac{1}{2}$ mark for incorrect significant figures.)
9. Calculate the pH of 0.35 M H$_2$CO$_3$.

(4 marks)

Solution:

*For Example:*

\[
\begin{array}{c|cccc}
         & [\text{H}_2\text{CO}_3] & + & \text{H}_2\text{O} & \rightleftharpoons & [\text{H}_3\text{O}^+] + [\text{HCO}_3^-] \\
[I] & 0.35 & 0 & 0 & & \\
[C] & -x & +x & +x & & \\
[E] & 0.35 - x & x & x &
\end{array}
\]

\(\leftarrow 1\frac{1}{2} \text{ marks}\)

\[
K_a = \frac{[\text{H}_3\text{O}^+][\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} = 4.3 \times 10^{-7}
\]

\[
4.3 \times 10^{-7} = \frac{x^2}{0.35 - x}
\]

\[
x = [\text{H}_3\text{O}^+] = 3.88 \times 10^{-4} \text{ M}
\]

\[
\text{pH} = 3.41
\]

(Deduct \(\frac{1}{2}\) mark for incorrect significant figures.)
10. A strong acid–strong base titration has a pH = 7.0 at the equivalence point. A weak acid–strong base titration has a pH > 7.0 at the equivalence point.

a) What causes the difference in these pH values? (2 marks)

Solution:

For Example:

A strong acid–strong base titration produces a neutral salt while a weak acid–strong base titration produces a basic salt. \( \left\{ \text{2 marks} \right\} \)

b) Select one indicator which could be used for both titrations. (1 mark)

Solution:

For Example:

Phenolphthalein \( \left\{ \text{1 mark} \right\} \)
11. Balance the following redox equation: (4 marks)

\[ \text{ClO}_3^- + \text{S}_2\text{O}_3^{2-} \rightarrow \text{S}_4\text{O}_6^{2-} + \text{Cl}^- \] 
(photocopy)

Solution:

For Example:

\[
\begin{align*}
6e^- + 6\text{H}^+ + \text{ClO}_3^- &\rightarrow \text{Cl}^- + 3\text{H}_2\text{O} \\
3 \times (2\text{S}_2\text{O}_3^{2-} &\rightarrow \text{S}_4\text{O}_6^{2-} + 2e^-) \\
6\text{H}^+ + \text{ClO}_3^- + 6\text{S}_2\text{O}_3^{2-} &\rightarrow \text{Cl}^- + 3\text{H}_2\text{O} + 3\text{S}_4\text{O}_6^{2-}
\end{align*}
\]

\( 2 \) marks (1 for each half-reaction)
1 mark for balancing electrons
1 mark for addition

(Deduct \( \frac{1}{2} \) mark for incorrect significant figures.)
12. State two characteristics of the overall reaction in an electrochemical cell. (2 marks)

Solution:

*For Example:*

*Any two of the following for 1 mark each:*

- redox reaction
- spontaneous
- $E^\circ$ value
- exothermic

$\leftarrow 2 \text{ marks}$
13. Describe two chemically different methods of preventing the corrosion of iron. Explain how each method works. (3 marks)

Solution:

For Example:

- Coating with paint or oil prevents contact between iron and oxygen. \rightarrow 1\frac{1}{2} marks

- Attaching a more readily oxidized metal such as zinc—cathodic protection—turns the iron into a cathode, preventing oxidation. \rightarrow 1\frac{1}{2} marks