June 2014
Chemistry
Secondary 5
Theory Examination

ANYONE WHO RECEIVES A COPY OF THIS EXAMINATION HAS
UNDERTAKEN TO USE IT ON THE MORNING OF THE FOLLOWING DATE:

Wednesday JUNE 11, 2014 a.m.

NOTE: This date was established by the Directors of English Education Network (DEEN) and the Mathematics and Science and Technology Committee (MaST).
DIFFUSION

2014

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Feedback Questionnaire

Site for the electronic format: http://bimonline.qc.ca.
General Information

Discipline
Chemistry

Subject-Specific Competencies

- Makes the most of his/her knowledge of chemistry.
- Communicates ideas relating to questions involving chemistry, using the language associated with science and technology.

Time Allotted

3 hours

An additional 5 minutes per hour may be allotted if needed.

Provided Documents

For the Teacher
- Administration and Marking Guide

For the Student
- Student Booklet
- Answer Booklet

Authorized Materials

The following materials are permitted during the examination:

- Calculators with or without graphic displays*
- Writing instruments
- Rulers

* Calculators with or without graphic displays designed mainly to perform mathematical calculations are authorized during official exams. Before the exam starts, data and programs stored in the calculator's memory must be deleted. Calculators equipped with formal calculation software are not authorized for the exams. These models are allowed under the sole condition that the formal calculation functions are deactivated during the exam. Computers, tablet computers, electronic organizers and calculators with an alphanumeric keyboard (QWERTY or AZERTY) are not authorized. All calculator peripherals, such as instruction manuals and memory expansion devices, are forbidden. It is strictly forbidden to use memory expansion cards or chips, as well as data or program libraries. Communication between calculators is not allowed during the exam. Using a calculator containing stored data or programs will be considered as cheating. Students cannot share their calculator with a peer.

[Adapted from MELS Information Document, Science and Technology, Applied Science and Technology, June/August/January 2013, and provided as a recommendation.]
Presentation of the Examination

Structure

This exam requires students to analyze phenomena and concepts in chemistry. Students will solve problems by themselves using their knowledge of gases, energy changes in chemical reactions, reaction rates, chemical equilibrium and measurement techniques. These are the general concepts of the chemistry program.

This exam consists of 25 questions, divided into two sections:

- Part A: Multiple-Choice Questions
- Part B: Constructed-Response Questions

This exam must be completed individually.

Note: Significant figures will be evaluated in questions 14 and 15.

Types of Questions and Percentage Values for General Concepts Evaluated

<table>
<thead>
<tr>
<th>General Concept</th>
<th>Gases (28%)</th>
<th>Energy Changes in Reactions (28%)</th>
<th>Reaction Rate (12%)</th>
<th>Chemical Equilibrium (32%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section of Exam</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part A (Multiple Choice) (40%)</td>
<td>1, 2, 3</td>
<td>4, 5</td>
<td>6, 7</td>
<td>8, 9, 10</td>
</tr>
<tr>
<td>Part B (Constructed Response) (60%)</td>
<td>11, 12, 13, 14</td>
<td>15, 16, 17, 18, 19</td>
<td>20</td>
<td>21, 22, 23, 24, 25</td>
</tr>
</tbody>
</table>
## Elements Targeted

<table>
<thead>
<tr>
<th>Question</th>
<th>General Concepts</th>
<th>Progression of Learning</th>
</tr>
</thead>
</table>
| 1        | Gases           | 1. Chemical properties of gases  
a. Reactivity  
i. Associates the use of certain gases in various applications with their chemical reactivity. |
| 2        | Gases           | 2. Physical properties of gases  
e. Avogadro’s hypothesis  
i. Uses Avogadro’s hypothesis to predict the number of molecules in equal volumes of gases subjected to the same temperature and pressure. |
| 3        | Gases           | 2. Physical properties of gases  
c. Ideal gas law  
ii. Applies the mathematical relationship between the pressure, volume and number of moles of a gas, the ideal gas constant and the temperature of a gas \( (pV = nRT) \).  
f. Molar volume of a gas  
i. Calculates the molar volume of a gas at standard temperature and pressure. |
| 4        | Energy Changes  | 1. Energy diagram  
b. Interprets the energy diagram of a chemical reaction. |
| 5        | Energy Changes  | 3. Enthalpy change  
a. Explains qualitatively the enthalpy change of substances during a chemical reaction. |
| 6        | Reaction Rates  | 1. Factors that influence the reaction rate  
i. Determines experimentally the factors that influence the reaction rate.  
b. Concentration  
i. Explains the effect of the concentration of the reactants on the reaction rate.  
d. Temperature  
i. Explains the effect of the temperature of the reactants on the reaction rate. |
| 7        | Reaction Rates  | 2. Rate law  
i. Describes the relationship between the concentration of the reactants and the reaction rate using algebraic expressions. |
| 8        | Chemical Equilibrium | 1. Factors that influence the state of equilibrium  
i. Explains qualitatively the state of dynamic equilibrium. |
| 9        | Chemical Equilibrium | 2. Le Chatelier’s Principle  
a. Predicts the direction of the shift in equilibrium of a system following a change in concentration, temperature or pressure. |
| 10       | Chemical Equilibrium | 3. Equilibrium constant  
a. Acidity and alkalinity constants  
iii. Associates the strength of acids and bases with the value of their acidity or alkalinity constant. |
| 11       | Gases           | 2. Physical properties of gases  
a. Kinetic theory  
i. Explains the macroscopic behaviour of a gas (e.g. compressibility, expansion, diffusion) using kinetic theory. |
| 12       | Gases           | 2. Physical properties of gases  
c. Ideal gas law  
ii. Applies the mathematical relationship between the pressure, volume and number of moles of a gas, the ideal gas constant and the temperature of a gas \( (pV = nRT) \). |
| 13       | Gases           | 2. Physical properties of gases  
c. Ideal gas law  
ii. Applies the mathematical relationship between the pressure, volume and number of moles of a gas, the ideal gas constant and the temperature of a gas \( (pV = nRT) \).  
d. Dalton’s law  
i. Applies the mathematical relationship between the total pressure of a mixture of gases and the partial pressures of the component gases \( (p_{total} = pA + pB + ppC + ...) \). |

1. The statements are taken from the Progression of Learning (MELS 2010).
<table>
<thead>
<tr>
<th>Question</th>
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</tr>
</thead>
</table>
| 14       | Gases            | 2. Physical properties of gases  
|          |                  | b. General gas law  |
| 15       | Energy Changes   | 4. Molar heat of reaction  
|          |                  | a. Determines the molar heat of a reaction using a calorimeter.  |
| 16       | Energy Changes   | 1. Energy diagram  
|          |                  | a. Produces an energy diagram representing the energy balance for a chemical reaction.  
|          |                  | 2. Activation energy  
|          |                  | a. Determines the activation energy for a reaction using its energy diagram.  
|          |                  | 3. Enthalpy change  
|          |                  | a. Determines the enthalpy change of a reaction, using its energy diagram.  |
| 17       | Energy Changes   | 4. Molar heat of reaction  
|          |                  | b. Determines the molar heat of a reaction using Hess’s Law or bonding enthalpies.  |
| 18       | Energy Changes   | 4. Molar heat of reaction  
|          |                  | a. Determines the molar heat of a reaction using a calorimeter.  |
|          |                  | b. Determines the molar heat of a reaction using Hess’s Law or bonding enthalpies.  |
| 20       | Reaction Rates   | 2. Rate law  
|          |                  | b. Determines the effect of a variation in the concentration of a reactant on the reaction rate, using the related algebraic expression.  |
| 21       | Chemical Equilibrium | 2. Le Chatelier’s Principle  
|          |                  | a. Predicts the direction of the shift in equilibrium of a system following a change in concentration, temperature or pressure.  
|          |                  | b. Predicts the effects of a shift in equilibrium on the concentrations of reactants and products.  |
| 22       | Chemical Equilibrium | 3. Equilibrium constant  
|          |                  | a. Acidity and alkalinity constants  
|          |                  | i. Writes as an algebraic expression the equilibrium constant for the dissociation of an acid or a base.  
|          |                  | ii. Experimentally determines the acidity or alkalinity constant of a system.  |
| 23       | Chemical Equilibrium | 3. Equilibrium constant  
|          |                  | b. Solubility product constant  
|          |                  | i. Writes as an algebraic expression the equilibrium constant for the dissociation of various substances in water.  
|          |                  | ii. Calculates the solubility product constant of a substance.  |
| 24       | Chemical Equilibrium | 4. Relationship between the pH and molar concentration of hydronium and hydroxide ions  
|          |                  | a. Describes the relationship between the pH and the molar concentration of hydronium and hydroxide ions.  
|          |                  | b. Applies the relationship between the pH and the molar concentration of hydronium ions ($pH = -\log_{10}[H^+]$).  |
| 25       | Chemical Equilibrium | 1. Factors that influence the state of equilibrium  
|          |                  | c. Concentration  
|          |                  | i. Explains the effect of a change in the concentration of a reactant or a product on a system’s state of equilibrium.  |

See QEP page 22
Procedure for Administering the Examination

- Distribute the *Student Booklets* and the *Answer Booklets*.

- Have students read the examination questions and reference materials presented in the *Student Booklet*. Students must answer all questions in the *Answer Booklet* provided.

- Ensure that students work alone.

- Collect all *Student Booklets* and *Answer Booklets* at the end of the examination period.
Instructions for Marking the Examination

In order to determine what is expected of the students and to ensure a uniform understanding of the evaluation tools, it is suggested that teachers in each school form a marking committee to analyze the work of a sample of students.

Guidelines for correcting questions requiring an explanation, a justification, or a representation:

Analyze the student's work and determine if it is appropriate.

- An explanation, a justification or a representation is appropriate if most of the elements of the answer are correct and if appropriate terminology or symbolism is used.
- An explanation, a justification or a representation is partially appropriate if:
  - most of the elements of the answer are correctly indicated, but the terminology or symbolism used is not appropriate.
  - some elements of the answer are indicated, and some of the terminology or symbolism used is appropriate.
- An explanation, a justification or a representation is inappropriate if most of the elements of the answer are incorrect or missing, or if the terminology or symbolism used is inappropriate.

Guidelines for correcting questions requiring the use of formal mathematical solutions:

Step 1

Analyze the work to understand the procedure used by the student, and then decide if the procedure is appropriate or not.

A procedure is appropriate if most of the steps are relevant and could lead to the correct answer.

A procedure is partially appropriate if the steps presented do not lead to the correct answer, but include at least one step that is relevant and correct.

A procedure is inappropriate if none of the steps presented are relevant or if the student has not shown any work.

Step 2

If the procedure is deemed appropriate or partially appropriate, then evaluate the answer. If the answer is incorrect, identify the type of error(s) made.

The error is considered minor if it is an error in calculation or transcription, or if the unit of measurement is incorrect or missing.

The error is considered major if a law, rule, or formula has been applied incorrectly.

No marks are allotted for a correct answer when the procedure used is inappropriate, or no work is shown.

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<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question 1</td>
<td>D</td>
<td>4</td>
</tr>
<tr>
<td>Question 2</td>
<td>C</td>
<td>4</td>
</tr>
<tr>
<td>Question 3</td>
<td>B</td>
<td>4</td>
</tr>
<tr>
<td>Question 4</td>
<td>A</td>
<td>4</td>
</tr>
<tr>
<td>Question 5</td>
<td>C</td>
<td>4</td>
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<tr>
<td>Question 6</td>
<td>D</td>
<td>4</td>
</tr>
<tr>
<td>Question 7</td>
<td>B</td>
<td>4</td>
</tr>
<tr>
<td>Question 8</td>
<td>A</td>
<td>4</td>
</tr>
<tr>
<td>Question 9</td>
<td>C</td>
<td>4</td>
</tr>
<tr>
<td>Question 10</td>
<td>D</td>
<td>4</td>
</tr>
</tbody>
</table>
Part B  Constructed-Response Questions

Questions 11 to 25

NOTE:  
• The following examples of appropriate responses are guidelines and are **not exhaustive**. Teachers should use their professional judgement when correcting this exam.

• Significant figures will be evaluated in questions 14 and 15 only.

Question 11

*Examples of appropriate responses*

a)  The gas particles are not bound by forces of attraction and are always moving in every direction to occupy all available space. Therefore they can move across different membranes to the different areas available to them in the fish, including the bladder and blood.

**Marking Scale**

<table>
<thead>
<tr>
<th>Marks</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Uses appropriate point from the KMT and connects the explanation to the observation</td>
</tr>
<tr>
<td>1</td>
<td>Uses an appropriate point from the KMT without connecting it to the observation</td>
</tr>
<tr>
<td>0</td>
<td>Lists no appropriate points, or did not provide an answer</td>
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b)  The volume of the gas particles in the bladder is negligible and the particles are very far apart in gases. Therefore, the particles can be compressed closer together when subjected to a greater pressure. As the swim bladder is elastic, it then shrinks in size.

**Marking Scale**

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<td>0</td>
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</table>

3. All marking scales adapted from MELS, 555-410, *Science and Technology, Marking Guide*, June 2012, and provided as a recommendation.
Question 12

Example of an appropriate procedure

1. \[ T = 25 \, ^\circ C + 273 = 298 \, K \]

2. 
   \[ n_{\text{HCl}} = C \times V \]
   \[ n_{\text{HCl}} = 3 \, \text{mol/L} \times (0.05 \, L) \]
   \[ n_{\text{HCl}} = 0.15 \, \text{mol of HCl} \]

3. 
   \[ 0.15 \, \text{mol HCl} \times \frac{1 \, \text{mol CO}_2}{2 \, \text{mol HCl}} = 0.075 \, \text{mol CO}_2 \]

4. 
   \[ PV = nRT \]
   \[ V = \frac{nRT}{P} \]
   \[ V = 0.075 \, \text{mol} \times \frac{8.31 \, \text{kPa} \, \text{L}}{\text{mol} \, \text{K}} \times \frac{298 \, K}{90 \, \text{kPa}} \]
   \[ V = 2.1 \, \text{L} \]

Note: Significant figures are not taken into consideration in this question.

Answer

The volume of the carbon dioxide gas collected was **2.1 L**.

**Marking Scale**

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<tr>
<td>3</td>
<td>Appropriate procedure, but incorrect answer due to a minor error, such as a calculation or transcription error, or an incorrect or missing unit of measure</td>
</tr>
<tr>
<td>2</td>
<td>Appropriate procedure, but incorrect answer due to a major error, such as the incorrect application of a law, formula or rule (e.g. did not use molar ratio)</td>
</tr>
<tr>
<td>1</td>
<td>Partially appropriate procedure</td>
</tr>
<tr>
<td>0</td>
<td>Inappropriate procedure, or did not provide a procedure, regardless of the answer</td>
</tr>
</tbody>
</table>
Question 13

Example of an appropriate procedure

1. \[ P_{H_2} = P_T - P_{Ar} \]
   \[ P_{H_2} = 15\,000\,\text{kPa} - 13\,500\,\text{kPa} \]
   \[ P_{H_2} = 1500\,\text{kPa} \]

2. \[ PV = nRT \]
   \[ n = \frac{1500\,\text{kPa} \times 50.0\,\text{L}}{8.31\,\text{kPa} \cdot \text{L/mol} \cdot \text{K} \times 288\,\text{K}} \]
   \[ n = 31.34\,\text{mol} \]

3. 2 moles of water produce 2 moles of hydrogen (1:1 ratio)
   Therefore at least 31.34 moles of water is required.

4. \[ m = n \times M \]
   \[ m = 31.34\,\text{mol} \times 18.02\,\text{g/mol} \]
   \[ m = 564.7\,\text{g} \]

Note: Significant figures are not taken into consideration in this question.

Answer

The minimum mass of water required is 564.7 g.

Marking Scale

4 marks  Appropriate procedure and correct answer
3 marks  Appropriate procedure, but incorrect answer due to a minor error, such as a calculation or transcription error, or an incorrect or missing unit of measure
2 marks  Appropriate procedure, but incorrect answer due to major error, such as the incorrect application of a law, formula or rule (e.g. uses total number of moles in cylinder instead of moles of hydrogen)
1 mark   Partially appropriate procedure
0 marks  Inappropriate procedure, or did not provide a procedure, regardless of the answer
Question 14

Example of an appropriate procedure

1. 
   \[ V_1 = 250.0 \text{ mL} \quad V_2 = ? \]
   \[ T_1 = 25.0 \text{ °C} = 298 \text{ K} \quad T_2 = 32.0 \text{ °C} = 305 \text{ K} \]
   \[ P_1 = 101.3 \text{ kPa} \quad P_2 = 70.3 \text{ kPa} \]
   \[ n = \text{the same for both} \]

2. 
   \[ \frac{P_1 V_1}{n_1 T_1} = \frac{P_2 V_2}{n_2 T_2} \]
   \[ V_2 = \frac{P_1 V_1 T_2}{P_2 T_1} \]
   \[ = \frac{(101.3 \text{ kPa})(250.0 \text{ mL})(305 \text{ K})}{(70.3 \text{ kPa})(298 \text{ K})} \]
   \[ V_2 = 369 \text{ mL} \]

Note: Significant figures are taken into consideration in this question.

Answer

The volume of the balloon was 369 mL.

Marking Scale

- 4 marks: Appropriate procedure and correct answer
- 3 marks: Appropriate procedure, but incorrect answer due to a minor error, such as a calculation or transcription error, or an incorrect or missing unit of measure, or an incorrect application of the rules of significant figures (e.g. temperature not converted to K)
- 2 marks: Appropriate procedure, but incorrect answer due to a major error, such as the incorrect application of a law, formula or rule
- 1 mark: Partially appropriate procedure (e.g. general gas law formula is used and some variables are substituted correctly)
- 0 marks: Inappropriate procedure, or did not provide a procedure, regardless of the answer
Question 15

Example of an appropriate procedure

1. 
   \[ m_{\text{H}_2\text{O}} = \rho V \]
   \[ m_{\text{H}_2\text{O}} = 1.0 \text{ g/mL} (1000 \text{ mL}) \]
   \[ m_{\text{H}_2\text{O}} = 1000 \text{ g} \]

2. 
   \[ Q_{\text{H}_2\text{O}} = mc\Delta T \]
   \[ Q_{\text{H}_2\text{O}} = 1000 \text{ g} (4.19 \text{ J/g \cdot °C})(0.50 \text{ °C}) \]
   \[ Q_{\text{H}_2\text{O}} = 2095 \text{ J} \]

3. 
   \[ Q_{\text{dissolution}} = Q_{\text{H}_2\text{O}} = 2095 \text{ J} \]

4. 
   \[ n_{\text{LiCl}} = \frac{m}{M} \]
   \[ n_{\text{LiCl}} = \frac{2.5 \text{ g}}{42 \text{ g/mol}} \]
   \[ n_{\text{LiCl}} = 0.060 \text{ mol} \]

5. 
   \[ \Delta H_{\text{dissolution}} = \frac{Q_{\text{dissolution}}}{n_{\text{LiCl}}} \]
   \[ \Delta H_{\text{dissolution}} = -\frac{2095 \text{ J}}{0.06 \text{ mol}} \]
   \[ \Delta H_{\text{dissolution}} = -34916.6 \text{ J/mol} \]
   \[ \Delta H_{\text{dissolution}} = -35 \text{ kJ/mol} \]

Note: Significant figures are taken into consideration in this question.

Answer

The molar heat of dissolution of lithium chloride is \(-35 \text{ kJ/mol}\).

Marking Scale

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Question 16

*Example of an appropriate response*

![Enthalpy Diagram for Decomposition of $A_2B_2$](image)

**Answer.**

The heat of reaction, $\Delta H$, for the decomposition of $A_2B_2$ is **+240 kJ/mol**.

The activation energy, $E_a$, for the decomposition of $A_2B_2$ is **375 kJ/mol**.

**Marking Scale**

- 4 marks: Appropriate procedure, complete graph and correct answers
- 3 marks: Appropriate procedure, but incorrect answer due to a minor error in either calculation or graph
- 2 marks: Appropriate procedure, but incorrect answer due to a major error in graph, such as not reversing the reaction
- 1 mark: Partially appropriate procedure
- 0 marks: Inappropriate procedure, or did not provide a procedure, regardless of the answer
Question 17

Example of an appropriate procedure

\[(\times 6)\quad \text{6 C}(s) + 12 \text{H}_2(g) \rightarrow 6 \text{CH}_4(g) \quad \Delta H = -456 \text{ kJ/mol}\]

(Reverse) \[\text{C}_6\text{H}_{13}\text{OH}(l) \rightarrow \text{6 C}(s) + 7 \text{H}_2(g) + \frac{1}{2} \text{O}_2(g) \quad \Delta H = +377 \text{ kJ/mol}\]

(No change) \[\text{H}_2(g) + \frac{1}{2} \text{O}_2(g) \rightarrow \text{H}_2\text{O}(g) \quad \Delta H = -242 \text{ kJ/mol}\]

\[\text{C}_6\text{H}_{13}\text{OH}(l) + 6 \text{H}_2(g) \rightarrow 6 \text{CH}_4(g) + \text{H}_2\text{O}(g) \quad \Delta H = -321 \text{ kJ/mol}\]

Note: Student should not use the following:

\[\text{C}(s) + \text{O}_2(g) \rightarrow \text{CO}_2(g) \quad \Delta H = -393 \text{ kJ/mol}\]

\[\text{H}_2(g) + \frac{1}{2} \text{O}_2(g) \rightarrow \text{H}_2\text{O}(l) \quad \Delta H = -285 \text{ kJ/mol}\]

Note: Significant figures are not taken into consideration in this question.

Answer

The heat of reaction, \(\Delta H\), for the "cracking" of hexanol is \(-321 \text{ kJ/mol}\).

Marking Scale

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<td>Appropriate procedure, but incorrect answer due to a major error, such as the incorrect application of a law, formula or rule (e.g. using either of the &quot;extra&quot; chemical equations in the table, OR not multiplying by 6 where appropriate, OR failing to change signs where appropriate)</td>
</tr>
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</table>
Question 18

Example of an appropriate procedure

1. \(( -19.7 \text{ kJ/g})(0.287 \text{ g}) = - 5.6539 \text{ kJ} \)
   \[
   Q_{\text{oil}} = - 5653.9 \text{ J}
   \]

2. \(- Q_{\text{oil}} = Q_{\text{H}_2\text{O}} \)
   \[- ( - 5653.9 \text{ J}) = Q_{\text{H}_2\text{O}} \]
   \[
   Q_{\text{H}_2\text{O}} = 5653.9 \text{ J}
   \]

3. \[
   Q_{\text{H}_2\text{O}} = mc\Delta T
   \]
   \[
   \Delta T = \frac{Q}{mc} = \frac{56539 \text{ J}}{(250 \text{ g})(4.19 \text{ J/ g} \cdot \degree\text{C})}
   \]
   \[
   \Delta T = 5.4 \degree\text{C}
   \]

4. \[
   \Delta T = T_f - T_i
   \]
   \[
   T_f = T_i + \Delta T
   \]
   \[
   T_f = 23.0 \degree\text{C} + 5.4 \degree\text{C}
   \]
   \[
   T_f = 28.4 \degree\text{C}
   \]

Note: Significant figures are not taken into consideration in this question.

Answer

The final temperature of the water is \textbf{28.4 \degree\text{C}}.

\[
\begin{array}{|c|c|}
\hline
\text{Marking Scale} & \\
\hline
4 \text{ marks} & \text{Appropriate procedure and correct answer} \\
3 \text{ marks} & \text{Appropriate procedure, but incorrect answer due to a minor error, such as a calculation or transcription error, or an incorrect or missing unit of measure (e.g. only finds } \Delta T) \\
2 \text{ marks} & \text{Appropriate procedure, but incorrect answer due to a major error, such as the incorrect application of a law, formula or rule (e.g. did not apply negative to } Q_{\text{H}_2\text{O}}) \\
1 \text{ mark} & \text{Partially appropriate procedure} \\
0 \text{ marks} & \text{Inappropriate procedure, or did not provide a procedure, regardless of the answer} \\
\hline
\end{array}
\]
Question 19

Examples of an appropriate procedure

\[ \text{C}_3\text{H}_8(\ell) + 5 \text{O}_2(\text{g}) \rightarrow 3 \text{CO}_2(\text{g}) + 4 \text{H}_2\text{O}(\ell) \]

\[ \begin{array}{cccc}
\text{H} & \text{C} & \text{C} & \text{H} \\
\text{H} & \text{H} & \text{H}
\end{array} + 5 \text{O}=\text{O} \rightarrow 3 \text{O}=\text{C}=\text{O} + 4 \text{H} \overset{\text{O}}{\text{O}}\text{H} \]

\[ 8(413) + 2(347) + 5(498) - [3 \times 2(745) + 4 \times 2(460)] = -1662 \]

**Note:** Significant figures are not taken into consideration in this question.

**Answer**

The molar heat for the combustion of propane is \(-1662 \text{ kJ/mol}\).

**Marking Scale**

- **4 marks**  Appropriate procedure and correct answer
- **3 marks**  Appropriate procedure, but incorrect answer due to a minor error, such as calculation or transcription error, or an incorrect or missing unit of measure
- **2 marks**  Appropriate procedure, but incorrect answer due to a major error, such as the incorrect application of a law, formula or rule
- **1 mark**   Partially appropriate procedure (e.g. only partially calculates bond enthalpy)
- **0 marks**  Inappropriate procedure, or did not provide a procedure, regardless of the answer
Question 20

*Examples of an appropriate procedure*

1. As the mass is doubled, the number of moles is doubled.

\[
C = \frac{n \times 2}{V \times \frac{1}{2}}
\]

\[
C = \frac{4 \times n}{V}
\]

2. New conditions: concentration of NH\(_3\) increases by a factor of 4.

\[
r \propto [\text{NH}_3]^2
\]

Factor of change for rate = \(4^2\)

\[= 16\]

**Answer**

The reaction rate will increase by a factor of **16**.

**Marking Scale**

- **4 marks**  Appropriate procedure and correct answer
- **2 marks**  Appropriate procedure, but incorrect answer due to a major error, such as the incorrect application of a law, formula or rule (e.g. not squaring the new concentration)
- **0 marks**  Inappropriate procedure, or did not provide a procedure, regardless of the answer
Question 21

Example of an appropriate response

<table>
<thead>
<tr>
<th>Modification</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Increase the pressure of the system.</td>
<td>An increase in pressure favours the side with fewer moles of gas (i.e. there are 4 moles on the left and 3 moles on the right because solids are not included).</td>
</tr>
<tr>
<td>2. Decrease the temperature.</td>
<td>A decrease in temperature favours the product side because the reaction is exothermic.</td>
</tr>
<tr>
<td>3. Remove some of the chlorine gas, Cl$_2$(g) produced.</td>
<td>A decrease in Cl$_2$(g) would drive the system to the right in order to replace it.</td>
</tr>
<tr>
<td>4. Increase the concentrations of either reactant.</td>
<td>An increase in Ga$_{\text{g}}$ or AsCl$_3$(g) would drive the system to the right in order to remove the excess.</td>
</tr>
</tbody>
</table>

Notes: Accept increase the concentration of Ga and AsCl$_3$ as two separate modifications. Accept a decrease in volume (which leads to an increase in pressure).

Marking Scale

<table>
<thead>
<tr>
<th>Marks</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Four correct answers with appropriate explanations</td>
</tr>
<tr>
<td>3</td>
<td>Three correct answers with appropriate explanations</td>
</tr>
<tr>
<td>2</td>
<td>Two correct answers with appropriate explanations</td>
</tr>
<tr>
<td>1</td>
<td>One correct answer with appropriate explanation</td>
</tr>
<tr>
<td>0</td>
<td>No correct answers</td>
</tr>
</tbody>
</table>
Question 22

Examples of an appropriate procedure

1. At 25 °C: pOH = 14.0 – 11.4 = 2.6

2. [OH⁻] = 10⁻¹ᵖOH = 10⁻².⁶ = 0.0025 M

3. 

<table>
<thead>
<tr>
<th></th>
<th>NH₃(aq)</th>
<th>H₂O(l)</th>
<th>NH₄⁺ (aq)</th>
<th>OH⁻ (aq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0.40 M</td>
<td>------</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>-0.0025 M</td>
<td>------</td>
<td>+0.0025 M</td>
<td>+0.0025 M</td>
</tr>
<tr>
<td>E</td>
<td>0.3975 M</td>
<td>------</td>
<td>0.0025 M</td>
<td>0.0025 M</td>
</tr>
</tbody>
</table>

4. 

\[ K_b = \frac{[NH_4^+][OH^-]}{[NH_3]} \]

\[ K_b = \frac{(0.0025 M)(0.0025 M)}{0.3975 M} \]

\[ K_b = 1.6 \times 10^{-5} \]

Note: Significant figures are not taken into consideration in this question.

Answer

The base dissociation constant, \( K_b \), of ammonia is \( 1.6 \times 10^{-5} \).

Marking Scale

<table>
<thead>
<tr>
<th>Marks</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Appropriate procedure and correct answer</td>
</tr>
<tr>
<td>3</td>
<td>Appropriate procedure, but incorrect answer due to a minor error, such as calculation or transcription error, or an incorrect or missing unit of measure</td>
</tr>
<tr>
<td>2</td>
<td>Appropriate procedure, but incorrect answer due to a major error, such as the incorrect application of a law, formula or rule (e.g. incorrect expression for ( K_b ))</td>
</tr>
<tr>
<td>1</td>
<td>Partially appropriate procedure (e.g. not calculating the pOH)</td>
</tr>
<tr>
<td>0</td>
<td>Inappropriate procedure, or did not provide a procedure, regardless of the answer</td>
</tr>
</tbody>
</table>
Question 23

Example of an appropriate procedure

1. \[ \text{CaF}_2(s) \rightleftharpoons \text{Ca}^{2+} \text{(aq)} + 2 \text{F}^{-} \text{(aq)} \]
   \[ x \quad 2x \]
   \[ K_{sp} = [\text{Ca}^{2+}] [\text{F}^{-}]^2 \]
   \[ K_{sp} = x(2x)^2 \]
   \[ K_{sp} = 4x^3 \text{ or } x = \left( \frac{K_{sp}}{4} \right)^{1/3} \]

2. \[ x = \left( \frac{3.45 \times 10^{-11}}{4} \right)^{1/3} \]
   \[ x = 2.0508 \times 10^{-4} \text{ M} \]

3. \[ [\text{F}] = 2x \]
   \[ [\text{F}] = 2(2.0508 \times 10^{-4} \text{ M}) \]
   \[ [\text{F}] = 4.1016 \times 10^{-4} \text{ M} \]

**Note:** Significant figures are not taken into consideration in this question.

**Answer**

The fluoride ion concentration at 25 °C is \( 4.10 \times 10^{-4} \text{ M} \).

**Marking Scale**

- **4 marks**  Appropriate procedure and correct answer
- **3 marks**  Appropriate procedure, but incorrect answer due to a minor error, such as calculation or transcription error, or an incorrect or missing unit of measure
- **2 marks**  Appropriate procedure, but incorrect answer due to a major error, such as the incorrect application of a law, formula or rule (e.g. only found value of \( x \), the \([\text{Ca}^{2+}]\))
- **1 mark**  Partially appropriate procedure
- **0 marks**  Inappropriate procedure, or did not provide a procedure, regardless of the answer
Question 24

*Example of an appropriate procedure*

a) For pH 2.4

1. \[ pOH = 14 - 2.4 = 11.6 \]

2. \[ [H^+] = 10^{-pH} = 4 \times 10^{-3} \text{ M} \]

*Note:* Significant figures are not taken into consideration in this question.

**Answer**

The pOH is **11.6**.

The \([H^+]\) is **4 \times 10^{-3} \text{ M}**.

<table>
<thead>
<tr>
<th><strong>Marking Scale</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>2 marks</td>
</tr>
<tr>
<td>1 mark</td>
</tr>
<tr>
<td>0 marks</td>
</tr>
</tbody>
</table>

b) For pH 4.6

1. \[ pOH = 14 - pH \]

   \[ = 14 - 4.6 = 9.4 \]

2. \[ [OH^-] = 10^{-pOH} \]

   \[ = 4.0 \times 10^{-10} \text{ M} \]

**Answer**

The \([OH^-]\) is **4.0 \times 10^{-10} \text{ M}**.

<table>
<thead>
<tr>
<th><strong>Marking Scale</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>2 marks</td>
</tr>
<tr>
<td>1 mark</td>
</tr>
<tr>
<td>0 marks</td>
</tr>
</tbody>
</table>
Question 25

*Example of an appropriate procedure*

a)

\[
K_c = \frac{[HI]^p}{[H_2][I_2]^2}
\]

\[
K_c = \frac{\left(\frac{12\text{ mol}}{2\text{ L}}\right)^2}{\left(\frac{10\text{ mol}}{2\text{ L}}\right)\left(\frac{4\text{ mol}}{2\text{ L}}\right)}
\]

\[K_c = 3.6\]

**Note:** Significant figures are not taken into consideration in this question.

**Answer**

The value of the equilibrium constant is **3.6**.

**Note:** *If students did not take the volume of the container into account, they will still obtain an answer of 3.6, but should only be awarded 1 mark.*

<table>
<thead>
<tr>
<th>Marking Scale</th>
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</thead>
<tbody>
<tr>
<td>2 marks</td>
</tr>
<tr>
<td>1 mark</td>
</tr>
<tr>
<td>0 marks</td>
</tr>
</tbody>
</table>

b)

**Answer**

The equilibrium constant will:

- [x] decrease
- [ ] increase
- [ ] remain unchanged.

The reaction is endothermic. As a result, a decrease in temperature will shift the equilibrium in the reverse direction and will decrease the value of the equilibrium constant, \(K_c\).

Therefore, the value of the equilibrium constant, \(K_c\), of the reaction will decrease.

<table>
<thead>
<tr>
<th>Marking Scale</th>
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<tbody>
<tr>
<td>2 marks</td>
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<tr>
<td>1 mark</td>
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<tr>
<td>0 marks</td>
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</table>
Feedback Questionnaire
(www.bimonline.qc.ca)

CHE-500.A06
Chemistry – Secondary 5

4 = Very satisfied  3 = Satisfied  2 = Not very satisfied  1 = Dissatisfied

<table>
<thead>
<tr>
<th>Teacher’s Guide</th>
<th>4</th>
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<td>Visual presentation (layout)</td>
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<tr>
<td>Time allotted for the examination</td>
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<tr>
<td>Procedure / Instructions</td>
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<td>Information regarding materials (provided, required, authorized)</td>
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<tr>
<td>Quality and use of the evaluation tools provided (rubrics, observable elements, etc.)</td>
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<td>In accordance with the QEP, Progression of Learning, Evaluation Framework</td>
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<tr>
<td>Other supporting reference materials (video, magazine, etc.)</td>
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</table>

If you have indicated Not very satisfied or Dissatisfied with any of the above, please comment and provide recommendations:

______________________________________________________________________________

______________________________________________________________________________

Overall assessment of the examination:

______________________________________________________________________________

______________________________________________________________________________

Comments or recommendations:

______________________________________________________________________________

______________________________________________________________________________

| School Board: ___________________________                          | Telephone / Email: ___________________________ |
| Name: ___________________________                             |                                           |

Please return to: BIM, GRICS, 5100, Sherbrooke Street East, Suite 300, 3rd floor, Montréal (Québec) H1V 3R9
Fax: 514 251-3920, email: bim@grics.ca