Lester B. Pearson School Board

Commission scolaire Lester-B.-Pearson

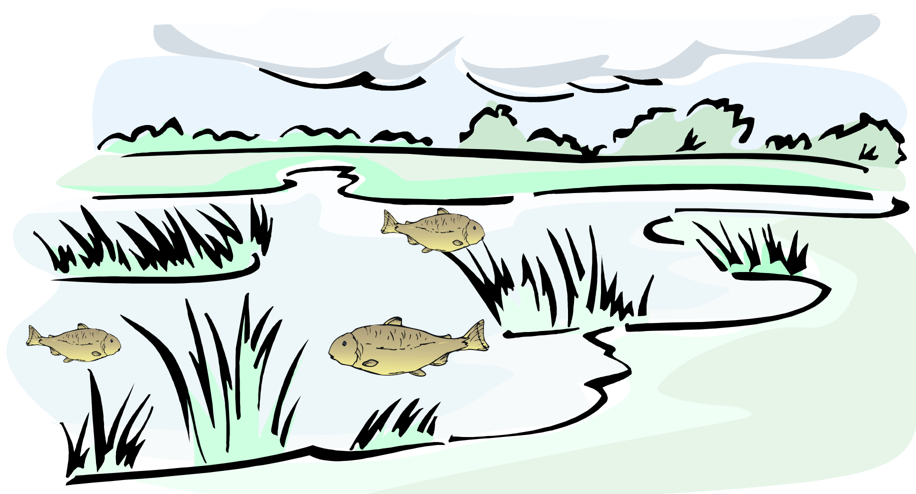
JUNE 2012

CHEMISTRY

Secondary 5

551-504

Theory Examination



Administration and Marking Guide

Note

This examination is reserved for end-of-year (June) evaluation purposes until September 2013.

DESIGN TEAM

Central Quebec School Board

COORDINATION

Laurette Barker, Central Quebec School Board

VALIDATION

Michael Quinn, Sir Wilfrid Laurier School Board

LINGUISTIC REVISION

Kevin O'Donnell, Société GRICS

EDITING

Barbara Choquette, BIM, Société GRICS

LAYOUT AND COMPUTERIZATION

Diane Nadeau, BIM, Société GRICS

ILLUSTRATIONS

Serge Hanna, BIM, Société GRICS
www.clipart.com

TABLE OF CONTENTS

GENERAL INFORMATION

TITLE OF THE EXAMINATION

Chemistry — 551-504 ▪ CHE-500.A03

CYCLE AND OPTION

Secondary Cycle Two Year Three (Secondary 5)
Chemistry Theory Examination

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 15 minutes must be allotted, if needed.*)

PERMITTED MATERIALS

The following materials are permitted during the examination:

- Calculators without graphic displays*
- Writing instruments
- Rulers

** To ensure fairness for all students, the graphic calculator or any type of calculator that can store information should not be permitted during the examination. The use of a memory aid, cellphone, MP3 player, camera, etc. is prohibited.*

EXAMINATION DOCUMENTS

- *Administration and Marking Guide*
- *Question Booklet*
- *Answer Booklet* (All student work must be completed here.)

DETERMINATION OF FINAL MARK

The examination is out of 85 marks and can be converted to a score out of 100. The mark awarded for each question is not percentage values.

PRESENTATION OF THE EXAMINATION

GENERAL DESCRIPTION

- This document provides all the necessary information concerning the evaluation of competencies for the Chemistry option at the end of Secondary Cycle 2, Year 3. This theory examination was developed by a group of teachers, coordinated by MaST (Mathematics and Science and Technology Committee) and formatted by the Société GRICS.

- This theory examination requires students to analyze phenomena and applications in Chemistry. Students will have to solve problems, on their own, by using their knowledge of gases, energy changes in reactions, reaction rates, chemical equilibrium and measurement techniques that are general concepts in the *Chemistry* program.

- The examination consists of 19 questions in three parts:

    - Part A: Multiple Choice Questions
    - Part B: Constructed Response Questions
    - Part C: Extended Constructed Response Questions
    - A total of 3 marks have been allocated to the consistent use of significant figures in all final statements of Questions 8, 9, 10, 13, 14, 16, 17, 18 and 19 of the examination. To avoid penalizing the student twice, this error in significant figures should not be considered as a minor error within the marking of the question itself.
    - Examples of appropriate procedures are provided.

SUBJECT-SPECIFIC COMPETENCIES EVALUATED

- The questions evaluate the students' acquisition of knowledge, as well as the understanding, application and use of this knowledge. The four evaluation criteria to be considered in this examination are as follows:

    - Mastery of subject-specific knowledge targeted in the progression of learning
    - Accurate interpretation of the problem
    - Revelant use of knowledge of physics
    - Appropriate formulation of explanations

CONCEPTS COVERED IN THE EXAMINATION

General Concept	Compulsory Concept
Gases	Physical properties of gases • Kinetic theory of gases • General gas law • Ideal gas law • Dalton's Law • Molar volume of a gas
Energy Changes in Reactions	Energy diagram Activation energy Enthalpy change Molar heat of reaction
Reaction Rate	Factors that influence reaction rate Rate law
Chemical Equilibrium	Factors that influence the state of equilibrium Le Chatelier's Principle Equilibrium constant Relationship between pH and the molar concentration of hydronium and hydroxide ions
Measurement Techniques	Interpreting the results of measurement

WEIGHTING TABLE

Content / Question	Gases	Energy Changes in Reactions	Reaction Rates	Chemical Equilibrium	Measurement Techniques
Weighting	**31%**	**21%**	**21%**	**21%**	**6%**
Number of Questions	5	4	4	4	2

SCORING OF THE EXAMINATION

Marking Guide

GUIDELINES FOR CORRECTING QUESTIONS

The marking scale for correcting the answers to the examination questions is presented below, along with explanations of the terms used in the scale.

It is **IMPORTANT** that the teacher read this information carefully before correcting the examination.

Questions usually consist of two parts: the **procedure** used to solve the problem and the **answer**. Thus, a question should be corrected in two steps.

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 the steps presented 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, then evaluate the answer. If the answer is incorrect, identify the type of error made according to the rubric provided for each question.

No marks are allotted for a correct answer when the procedure used is inappropriate.

The application of significant figures should be considered during the correction of this examination

A total of 3 marks have been allocated to the consistent use of significant figures in all final statements for Questions 8, 9, 10, 13, 14, 16, 17, 18 and 19 of the examination.

To avoid penalizing the students twice, an error in significant figures should NOT be considered as a minor error within the marking of each question.

Marking Guide

Part A
Multiple Choice Questions
Questions 1 to 7

Question 1 B

Question 2 A

Question 3 B

Question 4 A

Question 5 C

Question 6 D

Question 7 B

Part B
Constructed Response Questions
Questions 8 to 15

Question 8

Example of an appropriate procedure

Solution

The percentage of oxygen (O_2) is equal to the partial pressure of a gas divided by the total pressure of a system x 100.

$$\frac{P_{O_2}}{P_T} \times 100 = \frac{106\,\text{kPa}}{75\,\text{kPa} + 150\,\text{kPa} + 106\,\text{kPa}} \text{ x } 100 = 32\%$$

The percentage of oxygen in the gas mixture is 32%.

Answer:

☑ **NO,** this gas mixture does not correspond to the Earth's atmosphere.

Explanation:

The percentage of oxygen in the mixture is greater than the percentage of oxygen in the Earth's atmosphere.

Note: Accept the calculation of the percentage of Nitrogen or Argon as an appropriate procedure.

- Percentage of Argon in the mixture: 23%
- Percentage of Nitrogen in the mixture: 45%

Marking Scale

4 marks	Appropriate procedure, correct answer, and appropriate explanation.
3 marks	Appropriate procedure but incorrect answer because of a minor mistake such as a calculation error, transcription error, or an incorrect or missing unit of measurement. Appropriate explanation that corresponds to answer found.
2 marks	Appropriate procedure but incorrect answer because of a major mistake in the application of a formula, law or rule.
1 mark	Partially appropriate procedure (e.g. only found total pressure).
0 marks	Inappropriate procedure or did not show the procedure, regardless of the final answer.

**** Significant figures are evaluated.***

Question 9

Example of an appropriate procedure

Solution

Step 1
Mass of unknown gas
6.06 g – 4.30 g = 1.76 g

Step 2
Temperature conversion
18°C + 273 K = 291 K

Step 3
Volume conversion

$$\frac{1225\ \text{mL}}{1000\ \text{mL}} = 1.225\ \text{L}$$

Step 4
Find the molar mass (M)

$$PV = \frac{mRT}{M} \quad \text{Then} \quad M = \frac{mRT}{PV} = \frac{(1.76\ \text{g} \bullet 8.31\ \text{kPa} \bullet \text{L/mol} \bullet \text{K} \bullet 291\ \text{K})}{(102\ \text{kPa} \bullet 1.225\ \text{L})} = 34.1\ \text{g/mol}$$

Step 5
Molar mass of H_2S = 34.1 g/mol

Answer

The unknown gas is **H_2S.**

Marking Scale

4 marks	Appropriate procedure and correct answer.
3 marks	Appropriate procedure but incorrect answer because of a minor mistake such as a calculation error, transcription error, or an incorrect or missing unit of measurement.
2 marks	Appropriate procedure with a major error (e.g. forgot to convert temperature and volume OR incorrect molar mass calculation).
1 mark	Partially appropriate procedure with a major error (e.g. only found the mass of the gas sample).
0 marks	Inappropriate procedure or did not show the procedure, regardless of the final answer.

**** Significant figures are evaluated.***

Question 10

Example of an appropriate procedure

Solution

$\Delta H_{Rxn} = \Delta H_{(\text{bonds broken})} - \Delta H_{(\text{bonds formed})}$

$\Delta H_{(\text{bonds formed})}$ = 4(C–Cl) = 4(397 kJ/mol) = 1588 kJ/mol

= 2(H–H) = 2(436 kJ/mol) = 872 kJ/mol

1588 kJ/mol + 872 kJ/mol = 2460 kJ/mol

$\Delta H_{(\text{bonds broken})}$ = 4(C–H) = 4(413 KJ/mol) = 1652 kJ/mol

= 2(Cl–Cl) = 2(243 KJ/mol) = 486 kJ/mol

1652 kJ/mol + 486 kJ/mol = 2138 kJ/mol

ΔH_{Rxn} = 2138 kJ/mol + (–2460 kJ/mol) = –322 kJ/mol

Answer

The heat of reaction is **–322 kJ/mol.**

Marking Scale

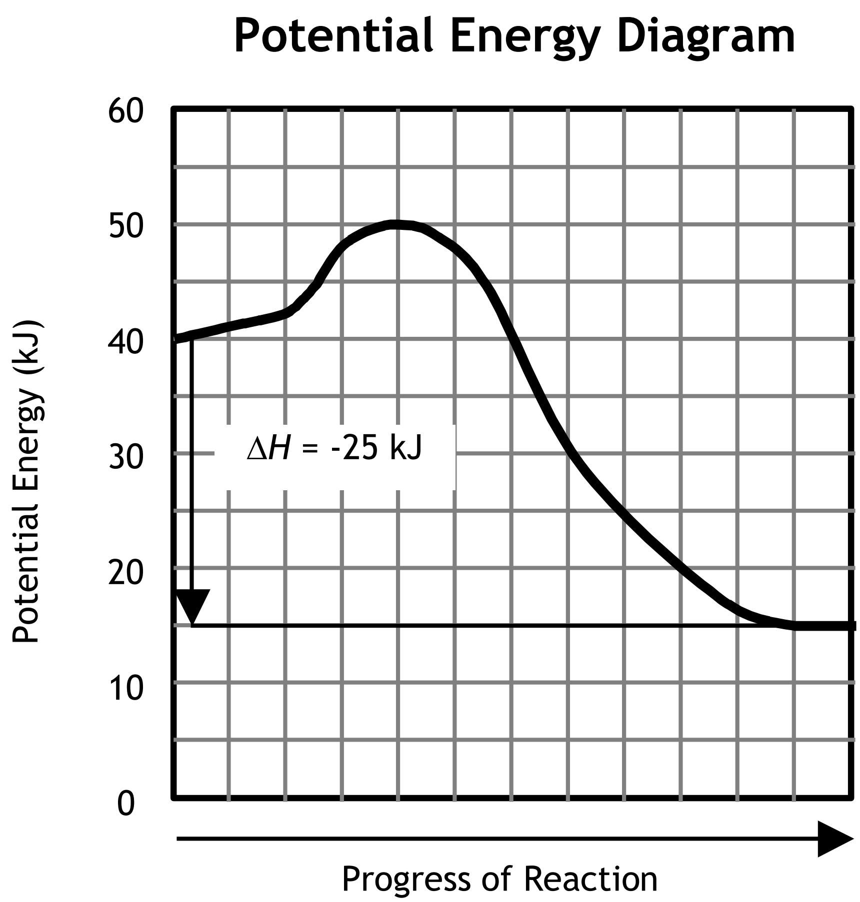
4 marks	Appropriate procedure and correct answer
3 marks	Appropriate procedure but incorrect answer because of a minor mistake such as a calculation error, transcription error, or an incorrect or missing unit of measurement.
2 marks	Appropriate procedure with a major error (e.g. using incorrect bond enthalpy) correctly calculates $\Delta H_{(\text{bonds formed})}$ and $\Delta H_{(\text{bonds broken})}$.
1 mark	Partially appropriate procedure with a major error e.g.partial calculation of one ΔH.
0 marks	Inappropriate procedure or did not show the procedure, regardless of the final answer.

**** Significant figures are evaluated.***

Question 11

Example of an appropriate procedure

Solution



Answer

ΔH is −**25 kJ.**

Marking Scale	
4 marks	Appropriate procedure and correct answer.
3 marks	Appropriate procedure but incorrect answer because of a minor mistake such as an axis mislabelled or not labelled, arrow in wrong direction.
2 marks	Appropriate and correct procedure with a major error (e.g. Graph indicates an exothermic reaction, but incorrect calculation of ΔH OR incorrect value for the potential energy at the end of the reaction).
1 mark	Partially appropriate and correct procedure.(e.g. Reaction shown as endothermic, but axes are correct and ΔH indicated in the correct direction.
0 marks	Inappropriate diagram or no answer provided.

Question 12

Example of an appropriate answer

Answer

Placing it upright: this reduces the surface area between the wine and the oxygen. Therefore, there are fewer collisions between the wine and the oxygen molecules, which slows the reaction.

Keeping it in a cool place: keeping it at a lower temperature reduces the kinetic energy of the molecules. Therefore, few collisions will have enough energy to produce an effective collision leading to a chemical reaction.

Marking Scale

4 marks	Appropriate response and correct explanation using the collision theory.
3 marks	Appropriate response but incomplete answer because of a minor mistake, such as one factor correctly explained and the other factor partially explained (e.g. omits surface area OR kinetic energy).
2 marks	Appropriate procedure with a major error (e.g. one factor correctly explained and the other factor has a major error OR two factors partially explained).
1 mark	Partially appropriate response with a major error (e.g. one factor partially explained).
0 marks	Inappropriate response.

Question 13

Example of an appropriate procedure

Solution

Step 1

pH = –log [H^+]

6.2 = –log [H^+]

[H^+] = $1 \times 10^{-6.2} = 6.3 \times 10^{-7}$ mol/L

Step 2

K_w = [H^+] [OH^-]

$1 \times 10^{-14} = (6.3 \times 10^{-7})$ (x)

x = 1.6×10^{-8} mol/L

Answer

The [OH^-] concentration is **1.6×10^{-8} mol/L.**

Marking Scale

4 marks	Appropriate procedure and correct answer.
3 marks	Appropriate procedure but incorrect answer because of a minor mistake such as a calculation error, transcription error, or an incorrect or missing unit of measurement.
2 marks	Appropriate procedure with a major error (e.g. incorrect application of formula).
1 mark	Partially appropriate procedure (e.g. only converts pH to concentration).
0 marks	Inappropriate procedure or did not show the procedure, regardless of the final answer.

**** Significant figures are evaluated.***

Question 14

Example of an appropriate answer

Solution

The concentration of F^- ion
$K_{sp} = [Sr^{2+}]\,[2F^-]^2$
$x = [Sr^{2+}] \qquad 2x = [F^-]$
$K_{sp} = (x)\,(2x)^2$
$K_{sp} = 4x^3$
$4.33 \times 10^{-9} = 4x^3$
$\sqrt[3]{\dfrac{4.33 \times 10^{-9}}{4}}$
$x = 1.03 \times 10^{-3}$ mol/L $= [Sr^{2+}]$
$2x = 2.06 \times 10^{-3}$ mol/L $= [F^-]$

Answer

The fluoride ion concentration is **2.06×10^{-3} mol/L.**

Marking Scale

4 marks	Appropriate procedure and correct answer.
3 marks	Appropriate procedure but incorrect answer because of a minor mistake such as a calculation error, transcription error, or an incorrect or missing unit of measurement.
2 marks	Appropriate procedure with a major error (e.g. solved for Sr concentration instead of F concentration).
1 mark	Incomplete procedure (e.g. only one correct step in the procedure).
0 marks	Inappropriate procedure or did not show the procedure, regardless of the final answer.

**** Significant figures are evaluated.***

Question 15

Example of an appropriate answer

Answer

The temperature and uncertainty of measurement indicated by this thermometer is **22 ± 1 °C**.

Other possible answer

The temperature and uncertainty of measurement indicated by this thermometer is **22 ± 4.5%**.

Marking Scale

2 marks	Appropriate response and correct answer.
1 mark	Appropriate response but incorrect answer because of a minor mistake such as an incorrect or missing unit of measurement or error involving significant figures or uncertainty.
0 marks	Inappropriate response or no answer given.

Part C
Extended Constructed Response Questions
Questions 16 to 19

Question 16

Example of an appropriate procedure

Step 1

Calculate moles of glucose

$$\frac{0.83\ \mathbf{mol}}{1\ \mathbf{L}}(0.100\ \mathbf{L}) = 0.083\ \mathbf{mol}$$

Step 2

Find number of moles of CO_2

$$0.083\ \mathbf{mol\ C_6H_{12}O_6}\left(\frac{6\ \mathbf{mol\ CO_2}}{1\ \mathbf{mol\ C_6H_{12}O_6}}\right) = 0.498\ \mathbf{mol}$$

Step 3

Find volume of CO_2

$$PV = nRT$$

$$V = \frac{nRT}{P} = \frac{(0.50\ \text{mol})\left(\frac{8.31\ \text{kPa} \bullet \text{L}}{\text{mol} \bullet \text{K}}\right)(298\ \text{K})}{101.3\ \text{kPa}}$$

$$= 12\ \text{L}$$

OR, using molar volume at SATP = 24.5 L/mol

$$\mathbf{0.}498\ \mathbf{mol}\left(\frac{\mathbf{24.5\ L}}{\mathbf{1\ mol}}\right)$$

$$= 12\ \mathbf{L}$$

Answer

The plant would have absorbed **12 L** of carbon dioxide.

Marking Scale

6 marks	Appropriate procedure and correct answer.
5 marks	Appropriate procedure but incorrect answer because of a minor mistake such as a calculation error, transcription error or missing or incorrect unit of measurement.
4 marks	Appropriate procedure but incorrect answer because of a major error.
3 marks	Does not apply.
2 marks	Appropriate procedure with several major errors.
1 mark	Incomplete procedure (e.g. only one correct step in the procedure).
0 marks	Inappropriate procedure or did not show the procedure, regardless of the final answer.

**** Significant figures are evaluated.***

Question 17

Example of an appropriate procedure

Step 1

Equation one remains the same

$\frac{1}{2}$ $N_{2(g)}$ + $O_{2(g)}$ + 33.9 kJ → $NO_{2(g)}$ (Δ*H* remains the same)

Step 2

Inverse equation 2

$NH_{3(g)}$ + 46.2 kJ → $\frac{1}{2}$ $N_{2(g)}$ + $\frac{3}{2}$ $H_{2(g)}$ (Δ*H* changes sign)

Step 3

Multiply equation three by $\frac{3}{2}$

$\frac{3}{2}$ $H_{2(g)}$ + $\frac{3}{4}$ $O_{2(g)}$ → $\frac{3}{2}$ $H_2O_{(l)}$ + 428.7 kJ (adjust Δ*H*)

Step 4

Calculate Δ*H*

$\frac{1}{2}$ $N_{2(g)}$ + $O_{2(g)}$ + 33.9 kJ → $NO_{2(g)}$

$NH_{3(g)}$ + 46.2 kJ → $\frac{1}{2}$ $N_{2(g)}$ + $\frac{3}{4}$ $H_{2(g)}$

$\frac{3}{2}$ $H_{2(g)}$ + $\frac{3}{4}$ $O_{2(g)}$ → $\frac{3}{2}$ $H_2O_{(l)}$ + 428.7 kJ

$NH_{3(g)}$ + $\frac{7}{4}$ $O_{2(g)}$ → $NO_{2(g)}$ + $\frac{3}{2}$ $H_2O_{(l)}$ + 348.6 kJ

Answer

The heat of reaction for this process is **-348.6 kJ.**

Marking Scale

6 marks	Appropriate procedure and correct answer.
5 marks	Appropriate procedure but incorrect answer because of a minor mistake such as a calculation error, transcription error or missing or incorrect unit of measurement (e.g. kJ/mol).
4 marks	Appropriate procedure but incorrect answer because of a major error (e.g.incorrect rearranging of one equation or incorrect sign).
3 marks	Does not apply.
2 marks	Appropriate procedure with several major errors (e.g. incorrect rearranging of more than one equation).
1 mark	Incomplete procedure (e.g. only one correct step in the procedure).
0 marks	Inappropriate procedure or did not show the procedure, regardless of the final answer.

**** Significant figures are evaluated.***

Question 18

Example of an appropriate procedure

a)

Step 1 Moles of $C_6H_{12}O_6$: $108\ g\left(\frac{mol}{180\ g}\right) = 0.6\ mol$

Step 2 Moles of CO_2: $\mathbf{0.6\ mol\ C_6H_{12}O_6}\left(\frac{\mathbf{6\ mol\ CO_2}}{1\ \mathbf{mol\ C_6H_{12}O_6}}\right) = 3.6\ \mathbf{mol\ CO_2}$

Step 3 Rate of production of CO_2 = $\frac{3.6\ mol}{600\ s} = 6.0 \times 10^{-3}\ \mathbf{mol \bullet s}^{-1}$

Answer

The rate of production of CO_2 is **6.0×10^{-3} mol/s.**

Marking Scale	
4 marks	Appropriate procedure and correct answer.
3 marks	Appropriate procedure but incorrect answer because of a minor mistake such as a calculation error, transcription error, or an incorrect or missing unit of measurement.
2 marks	Partially appropriate procedure with a major error (e.g. used mole ration incorrectly)
1 mark	Partailly appropriate procedure (e.g. only one correct step in the procedure).
0 marks	Inappropriate procedure or did not show the procedure, regardless of the final answer.

**** Significant figures are evaluated.***

Example of an appropriate response

The scientist must:

- **Gather information about how the reaction rate changes as the concentration of reactants changes. This will help determine the rate law expression.**

Examples of appropriate explanations:
The rate law expression is needed to predict reaction rates and can only be determined experimentally for reactions that occur in more than one step.

Accept any other appropriate response.

Marking Scale	
2 marks	Appropriate answer and explanation.
1 mark	Appropriate response but incorrect explanation or no explanation given..
0 marks	Inappropriate response or no answer given.

Question 19

Example of an appropriate procedure

Determine Ka of each solution:

Acid 1: Acetic acid

Initial Concentration of acetic acid:

$$\text{moles acetic acid} = \frac{\text{mass}}{\text{molar mass}}$$

$$n = \frac{0.90\ \text{g}}{60.1\ \text{g/mol}}$$

$$n = 0.015\ \text{mol}$$

$$c = \frac{n}{V}$$

$$c = \frac{0.015\ \text{mol}}{0.150\ \text{L}}$$

$$c = 0.10\ \text{mol/L}$$

$[H^+]$ at equilibrium

$[H^+] = 10^{-pH}$
$[H^+] = 10^{-2.9}$
$[H^+] = 0.00126\ \text{mol/L}$

Calculate K_a

As the $[H^+]$ at equilibrium represents a 1.26% change from the initial concentration of the acid, it can be assumed that the initial concentration of the acid≈equilbirium concentration

$$K_a = \frac{[H^+]\ [C_2H_3O_2^{1-}]}{[HC_2H_3O_2]}$$

$$= \frac{[0.00126]^2}{[0.1]}$$

$$= 1.6 \times 10^{-5}$$

Acid 2: Lactic Acid

ICE TABLE

Concentration(mol/L)	$HCH_3CH(OH)CO_2$	$\rightarrow$	H^+	+	$CH_3CH(OH)CO_2^{1-}$
Initial (C_i)	0.011		0		0
Change (ΔC)	–0.0012		+0.0012		+0.0012
Equilibrium (C_{eq})	0.0098		0.0012		0.0012

$$K_a = \frac{[H^+][CH_3CH(OH)CO_2^{1-}]}{[HCH_3CH(OH)CO_2]}$$

$$= \frac{0.0012^2}{0.0098}$$

$$= 1.5 \times 10^{-4}$$

Answer: The acid that is most effective for slowing bacterial growth is **lactic acid.**

Explanation: The strongest acid is most effective. The bigger the K_a, the stronger the acid. As lactic acid has the bigger K_a, it is more effective in solwing bacterial growth.

Marking Scale	
6 marks	Appropriate procedure and correct answer.
5 marks	Appropriate procedure but incorrect answer because of a minor mistake such as a calculation error or transcription error.
4 marks	Appropriate procedure but incorrect answer because of a major calculation or transcription error.
3 marks	Partially appropriate procedure with major error (e.g. did not calculate initial concentration).
2 marks	Partially appropriate procedure with more than one major error (e.g. omits the ICE table, includes water in the calculations, OR only produces ICE table).
1 mark	Does not apply.
0 marks	Inappropriate procedure or did not show the procedure, regardless of the final answer.

**** Significant figures are evaluated.***

Marking Guide for Significant Figures

Marking Scale	
3 marks	Appropriate and consistent use of significant figures for all questions.
2 mark	Appropriate use of significant figures for 6-7 questions.
1 mark	Appropriate use of significant figures for 3-5 questions.
0 marks	Appropriate use of significant figures for 0-2 questions.

Appendix

Feedback Questionnaire

Chemistry – Cycle 2, Year 3 (Secondary 5)
Theory Examination — June 2012

Circle the number that corresponds to your opinion.

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

Time allotted for this examination	4	3	2	1
Relevance of context to students' grade level	4	3	2	1
Level of difficulty	4	3	2	1
Evaluation tools	4	3	2	1
Overall quality of the *Administration and Marking Guide*	4	3	2	1

Comments:

____

____

____

____

____

____

List any errors or omissions:

____

____

____

____

____

Return to:
Katherine Davey
Educational Consultant, Secondary Science and Technology
Education Services Department
Lester B. Pearson School Board