THE CHEMICAL INSTITUTE OF CANADA
L'INSTITUT DE CHIMIE DU CANADA

"Chemists, engineers and technologists working together."
"Les chimistes, les ingénieurs et les technologistes travaillant ensemble."

THE CANADIAN CHEMISTRY CONTEST 2010
for high school and CEGEP students

PART B – EXTENDED RESPONSE SECTION (90 minutes)

In this section you should respond to **TWO** questions only, writing in the form of scientific essays (or, for number 4, an experimental description) including any appropriate equations, formulae and diagrams. Some suggestions are made about the direction(s) you could take, but these are not exclusive. Each essay/experiment is of equal value, and the quality of **both** responses will be considered in the final competition: you should therefore allocate approximately equal time to each of the subjects you choose. The judging of the responses will be based on both factual accuracy and presentation. A clear, concise and well-organized piece of written work will be rated more highly than a long rambling one that contains the same information.

1. Experiment design: determining the rate law of the decomposition of hydrogen peroxide using a heterogeneous or a homogeneous catalyst

For this experiment, you will provide **one of two** procedures for how you would determine the rate law for the decomposition of hydrogen peroxide. Hydrogen peroxide is unstable and slowly disproportionates to form water and oxygen gas according to the equation:

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

This reaction happens spontaneously but slowly over time. It can be catalyzed by a number of methods to make rate law determination possible in the laboratory. Two of these methods include catalysis by solid manganese (IV) oxide and catalysis by aqueous potassium iodide.

You are given a 10% solution of hydrogen peroxide by mass, distilled water, pyrolusite (solid manganese (IV) oxide), 0.10 mol L^{-1} aqueous potassium iodide and all of the apparatus commonly found in a high school chemical laboratory including, but not limited to, a 50.0 mL Erlenmeyer flask, gas measuring apparatus, microstirrer bar, magnetic stir plate, 10.0 mL graduated cylinder. Write a clear procedure for how to determine the rate law of the reaction using **either:**

1) heterogeneous catalysis **OR**
2) homogeneous catalysis

In your introduction be sure to explain how catalysis increases the rate of a reaction, how heterogeneous catalysis differs from homogeneous catalysis and how the order of a reaction with respect to a reactant is determined in an experiment. Create a table for all data you would collect.

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2. My favourite element(s)

Next year, 2011, will be the international year of Chemistry as declared by the United Nations. 2011 marks the 100^{th} year of awarding Marie Curie the Nobel Prize in Chemistry for her discoveries of the elements radium and polonium. Understanding the periodic table and the elements is fundamental to the study of chemistry. For this question you are asked to select and discuss, one, two or up to three of your "favourite elements" in the periodic table. In your discussion demonstrate your knowledge of these elements by identifying such things as their uses, chemical properties, physical properties, importance for technological development and significance in today's society. In your discussion, you should demonstrate an understanding of the ionization energy, atomic radius, reactivity and electron affinity of your element(s). You should also mention compounds and/or ions of interest that involve the elements and the uses of those compounds and/or ions.

3. Valence Shell Electron Pair Repulsion (VSEPR) theory

VSEPR theory is a chemical model used to predict the shape of molecules and it was first proposed by Ronald Gillespie, a professor at McMaster University in Hamilton, Ontario and Ronald Nyholm. For this question, you are asked to explain the concepts involved in VSEPR theory and explain how the theory predicts molecular shapes. You should list the different molecular shapes in an organized way and provide examples of molecules that would have the given molecular shape (suggested examples include XeF_4, BF_3, H_2O, ClF_3, CH_4, IF_5, BeF_2, PCl_5, XeF_2, SO_2, NH_3, SF_6, SF_4). Finally, provide a few examples of how molecular shape influences the chemistry of molecular substances in terms of polarity, chemical and physical properties.

4. The effect of changes in atmospheric gases on the chemistry of the oceans.

Ocean acidification was a term coined in 2003, to describe the effect that many environmentalists attribute to the increasing levels of CO_2 entering the ocean's ecosystem from the air. The average concentration of CO_2 in the atmosphere has increased from 280 ppm to 380 ppm in the past 200 years. Possible effects of ocean acidification include decreasing ocean biodiversity due to pH changes and difficulty of calcifying organisms in making calcium carbonate with available calcium and carbonate ions:

$$Ca^{2+}(aq) + CO_3^{2-}(aq) \rightleftharpoons CaCO_3(s) \qquad K_{sp} = 3.8 \times 10^{-9} \qquad \text{at } 25°C \qquad (1)$$

As shown in reaction (2) below, dissolved carbon dioxide dissociates into protons and bicarbonate ions (HCO_3^-). The protons produced in this equilibrium can then react with dissolved carbonate to form more bicarbonate ions, as shown in reaction (3). If too much carbon dioxide is dissolved in the oceans, the carbonate ion concentration will drop below the saturation level of $CaCO_3$, and the coral which is made up of $CaCO_3$ will start to dissolve.

$$H_2O(l) + CO_2(g) \rightleftharpoons H^+(aq) + HCO_3^-(aq) \qquad (2)$$

$$H^+(aq) + CO_3^{2-}(aq) \rightleftharpoons HCO_3^-(aq) \qquad (3)$$

Use your understanding of equilibria to discuss one or more of the following effects on the chemistry of oceans:

i) The concentration of carbonate ions in oceans. Calculate the concentration of carbonate ions in a saturated solution of calcium carbonate at 25°C given equation (1) (show your calculations). Explain clearly how increasing CO_2 levels in the atmosphere would cause coral to dissolve.

ii) The pH of the ocean seawater is presently around 8.1. Explain how the pH of seawater would be affected if atmospheric CO_2 increases.

iii) Which oceans are most likely to show the first signs of dissolving coral, given that the solubility of CO_2 decreases as the temperature rises.

In your discussion, demonstrate an understanding of Le Châtelier's Principle, solubility, pH and the potential environmental impacts of ocean acidification. Be sure to use the equilibrium reactions (1, 2 and 3 above).