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 2009
for high school and CEGEP students

PART B – EXTENDED RESPONSE SECTION (90 minutes)

In this section you should respond to **TWO** topics only, writing in the form of scientific essays (or, for Question 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. Group 14

The properties of the elements of Group 14 (formerly known as Group IV) were an important piece of evidence cited by Mendeleev in his periodic classification of the elements. In this essay you should discuss the properties of these elements (from carbon to lead) with particular reference to how they illustrate trends down a group of the Periodic Table. Although it is appropriate to consider atomic scale properties such as atomic and ionic radii, ionization energies, electron affinities and electronegativity, your essay will be more interesting if you discuss the structure and bonding of the elements and how these factors are related to macro-scale physical properties such as molar volume, melting points and boiling points. You might also wish to discuss the formulae and chemical properties of the elements and their compounds (e.g. oxides, chlorides and hydrides).

2. Ethanol

Ethanol (also known as ethyl alcohol), C_2H_5OH, has traditionally been used in alcoholic beverages, but it has recently been promoted as a gasoline additive. In this essay you should give details of the fermentation process for making ethanol from carbohydrates, and discuss the advantages and disadvantages of using this process for making gasoline additives. You may like to consider the possibility of using alternative manufacturing processes, such as those using ethene, ethyne, synthesis gas ($CO + H_2$), or methane as starting materials, for example. You could also discuss other uses of ethanol, such as in beverages, as a solvent in the lab, or in the pharmaceutical and cosmetic industries. It is important to include balanced chemical equations in any reactions that you discuss.

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3. WHMIS

WHMIS (Workplace Hazardous Materials Information System) is implemented by a combination of federal and provincial legislation. The main purpose of the federal WHMIS legislation is to require the suppliers of hazardous materials used in the workplace to provide health and safety information about their products as a condition of sale. The main purpose of the provincial WHMIS legislation is to require employers to obtain health and safety information about hazardous materials in the workplace and to pass this information on to workers. The different classes of materials covered by WHMIS legislation are defined as:

1. Class A Compressed Gas
2. Class B Flammable and Combustible Material
3. Class C Oxidizing Material
4. Class D Poisonous and Infectious Material
5. Class E Corrosive Material
6. Class F Dangerously Reactive Material

In this essay you should give specific examples of each class of material, discussing the nature of the hazard and what precautions you should take when handling such materials.

4. Experiment Design: Preparation of Buffer Solutions

Buffer solutions are important in many industrial processes and in biological systems, because they resist changes in pH when acids or alkalis are added to them. Buffers can generally be prepared by mixing solutions of an acid with its conjugate base: the proportions required to obtain a particular pH can be calculated using the Henderson-Hasselbalch equation:

$$\mathrm{pH} = \mathrm{p}K_\mathrm{a} + \log \frac{[\text{conjugate base}]}{[\text{acid}]}$$

In this exercise you should describe how you would prepare a 100.00 mL sample of buffers with pH values of (a) 6.50, and (b) 11.50, given apparatus that is commonly available in a school laboratory, plus the following solutions:

Potassium dihydrogen phosphate (0.100 mol L^{-1}), hydrochloric acid (0.100 mol L^{-1}), and sodium hydroxide (0.100 mol L^{-1}). Distilled water is also available.

$$\mathrm{p}K_\mathrm{a}\,(H_3PO_4) = 2.1;\ \ \mathrm{p}K_\mathrm{a}\,(H_2PO_4^-) = 7.2;\ \ \mathrm{p}K_\mathrm{a}\,(HPO_4^{2-}) = 12.4$$

You should show the stoichiometric equations and the calculations you need to determine the volumes of solutions to be mixed. You should also specify exactly what pieces of apparatus you require to prepare the buffers. You could also indicate what you might expect to happen to the pH if you were to (1) test your buffers by adding hydrochloric acid solution, (2) test your buffer by adding sodium hydroxide solution, and (3) dilute your buffer to twice the volume before testing its pH.