



# 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.”

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## THE CANADIAN CHEMISTRY CONTEST 2008 for high school and CEGEP students (formerly the National High School Chemistry Examination)

### 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.

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#### 1. Water hardness

When rainwater passes through the Earth's crust it dissolves minerals such as calcium and magnesium salts from rocks. These salts are not usually removed in water treatment plants, so they can contribute to the hardness of water. In this essay you should consider the reactions of soap with hard and soft water, different types of hardness, and the advantages and disadvantages of hard water. You should also discuss some of the different methods of removing hardness, such as boiling, distillation, addition of washing soda (sodium carbonate) and the use of ion exchange materials. It is important to include equations, preferably fully balanced, for all the reactions you discuss.

#### 2. Alternatives to gasoline

As gasoline becomes increasingly expensive to buy at the pump, manufacturers are beginning to develop technologies that allow cars to be run on alternative energy sources. In this essay you should discuss some of these alternatives, which may include one or more of the following: hydrogen fuel cells, electrical batteries, diesel derived from crude oil, compressed natural gas, methanol, diesel derived from animal and/or vegetable fats, ethanol (from corn or sugar cane). You might also like to consider hybrid cars and/or cars run on mixed fuels or on “flex fuel”. You should compare the energy sources you choose with conventional gasoline technology, and discuss the advantages and disadvantages of each, with particular reference to cost, availability of “top-up” stations, pollution and renewability. You need to be as specific as possible about the chemical technology involved in each case.

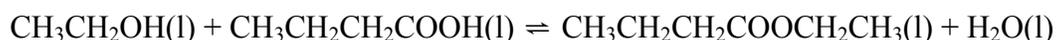
/questions continued overleaf

### 3. Isomers

In this essay you should discuss what is meant by the term *isomer*, and consider some different types of isomers. These should include constitutional isomers (chain isomers, position isomers and functional group isomers), optical isomers (chirality), and geometric (*cis-trans*) isomers. Some examples of compounds that you might like to consider are those represented by the formulae C<sub>4</sub>H<sub>10</sub>, C<sub>4</sub>H<sub>9</sub>Cl, C<sub>2</sub>H<sub>6</sub>O, CH<sub>3</sub>CH(OH)COOH and CH<sub>3</sub>CH=CHCH<sub>3</sub>, but you need not restrict yourself to these examples, or even to organic compounds. It is important in this essay that you draw clear structures of the molecules you are discussing, and that you give the compounds unambiguous IUPAC names. You might also like to consider some of the physical and chemical properties exhibited by different isomers.

### 4. Experiment design: Determination of an equilibrium constant

In this question you are required to design an experiment to determine the equilibrium constant of the following reaction at 25°C and 1 atmosphere pressure (101.325 kPa):



The reaction system requires several days to equilibrate under the specified conditions, even in the presence of hydrochloric acid catalyst.

In your response you should give an expression for the equilibrium constant, and outline your experimental procedure, giving details of the apparatus and materials you would need for performing the experiment in a high school laboratory. It is important to specify any precautions that might be required to maintain safety and comfort in the work area. You should indicate what readings you would take and how you would use these readings to calculate a result. You should consider any problems that you might encounter when performing your experiment and how these factors might give rise to errors in the final value obtained. You might also like to discuss how your experiment could be improved in order to overcome these problems.

Some information about the compounds in the reaction mixture is given below:

**Ethanol:** CH<sub>3</sub>CH<sub>2</sub>OH, *M*<sub>r</sub> = 46.07, density = 0.789 g cm<sup>-3</sup> at 25°C, flammable, boiling point = 78.5°C, miscible with water and with many organic liquids, absorbs moisture rapidly from air.

**Butanoic acid:** CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>COOH, *M*<sub>r</sub> = 88.11, boiling point = 163.5°C, density = 0.958 g cm<sup>-3</sup> at 25°C, miscible with water and ethanol, p*K*<sub>a</sub> = 4.83, extremely unpleasant odour.

**Concentrated hydrochloric acid** (reagent grade), contains 38.0% HCl by mass, density = 1.19 g cm<sup>-3</sup> at 25°C.

**Ethyl butanoate,** CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>COOCH<sub>2</sub>CH<sub>3</sub>, *M*<sub>r</sub> = 116.16, density 0.879 g cm<sup>-3</sup> at 20°C, boiling point = 120-121°C, miscible with alcohol, pineapple aroma.