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

THE CANADIAN CHEMISTRY CONTEST
for high school and CEGEP students

IYC 2011 International Year of CHEMISTRY

PART B – EXTENDED RESPONSE SECTION (90 minutes)

In this section you should respond to **TWO** questions only, writing in the form of scientific essays (for number 1, 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 molar mass of an unknown weak acid and the K_a of the acid.

Describe a titration experiment to determine the molar mass and the acid ionization constant (K_a) of a solid, weak monoprotic acid. For this experiment, you are provided with a total of 2.00 g of the solid acid, one litre of a solution of NaOH which was prepared using approximately 4 g of NaOH in distilled water, 100.0 mL of a 0.0500 mol L^{-1} solution of oxalic acid dihydrate ($H_2C_2O_4 \bullet 2H_2O$) for standardizing the NaOH solution, a 50.0 mL burette, a pH meter and all standard laboratory equipment.

You should include an introductory paragraph which outlines the experiment and associated theory and includes an explanation of the terms: standardized solution, monoprotic and diprotic acids and acid ionization constant.

Provide a procedure which indicates the required steps, the results that need to be collected and an outline of the required calculations. You may want to write a concluding paragraph outlining any problems you may encounter and potential improvements you would make for future experiments.

2) Intermolecular Forces

In the mid-1800s, James Prescott Joule and William Thomson (later known at Lord Kelvin) discovered that most gases get colder when they are allowed to expand suddenly into a larger volume. This discovery was named the Joule-Thomson effect and it prompted many scientists, including Johannes van der Waals (1837-1923) and Fritz London (1900-1954) to dedicate a large part of their career to study intermolecular forces. Outline your understanding of the importance of intermolecular forces to the study of chemistry. You should use specific examples to identify and explain different types of intermolecular forces in different molecules as well as discuss the relative strength of different types of intermolecular forces and the relationship of the strength of intermolecular forces to the properties of a substance. Be sure to explain why the Joule-Thomson effect provides evidence of intermolecular forces.

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3) Challenging the Weight of Chemistry

On December 13, 2010, the International Union of Pure and Applied Chemistry (IUPAC) announced that the representation of atomic weights on the Periodic Table was about to change, starting with 10 elements including: hydrogen, lithium, boron, carbon, nitrogen, oxygen, silicon, sulfur, chlorine and thallium. This change was spearheaded by the Secretary of IUPAC's Commission on Atomic Weights and Isotopic Abundances, a Canadian associate professor from the University of Calgary, Michael Wieser. The Commission argued that relative atomic masses are not constants in nature because isotopic abundances change depending on the geological conditions in different locations on Earth. Therefore, the atomic mass of an element should appear on the periodic table as an interval of values (e.g. up to now lithium's atomic mass as indicated on the periodic table is 6.941, from now on, the mass will appear as 6.938; 6.997). How significant a change to chemistry do you think this is? Identify at least 5 specific examples of ways this modification to the periodic table will change the way high school students tackle topics in chemistry. In what ways and to what degree do you think the addition of the interval of atomic masses will change work in chemistry outside of the high school classroom?

4) The effects of nitrogen dioxide and ozone on air quality.

Nitrogen dioxide and ozone levels contribute significantly to Air Quality Index Rating guidelines published by Environment Canada. Motorized vehicles are major contributors to the concentrations of both gases. Some specific information about the chemistry of both pollutants can be gleaned from the reactions below:

(1) $N_2\,(g) + O_2\,(g) \rightarrow 2NO\,(g)$ (production of NO inside vehicle engines)

(2) $2NO\,(g) + O_2\,(g) \rightarrow 2NO_2\,(g)$ (hot NO reacts with oxygen gas in air as it is emitted from vehicle exhaust)

(3) $NO_2\,(g) + h\nu \rightarrow NO\,(g) + O\,(g)$ (NO_2 absorbs ambient sunlight and decomposes)

(4) $O\,(g) + O_2\,(g) + M \rightarrow O_3\,(g) + M$ (free oxygen atoms react with oxygen gas in air if some of the energy of the reactants is absorbed by a relatively inert molecule "M" when the collision occurs)

In addition, nitrogen monoxide (NO) can react to destroy ozone (see equation 5). Nitrogen monoxide is always present to some extent in smoggy air because reactions 1 - 4 occur at different rates.

(5) $NO\,(g) + O_3\,(g) \rightarrow NO_2\,(g) + O_2\,(g)$

In the atmospheric layer extending approximately 10 km above the Earth's surface, the concentration of ozone (O_3) is about 0.01 ppm (parts per million by volume); in the atmospheric layer extending from about 10 – 50 km above the Earth's surface, the concentration of ozone is about 10 ppm.

Use your general understanding and the information given above to:

i) Explain the implications of the presence of ozone in different layers of the atmosphere.
ii) Discuss the effects of nitrogen dioxide and ozone on air quality.