Canadian Chemistry Contest 2008
(for high school and CÉGEP students)

François Gauvin <gauvinf@cc.umanitoba.ca>
www.chemistry.ca
National Co-ordinator
Department of Chemistry, University of Manitoba
Winnipeg MB R3T 2N2

This year, the Chemical Institute of Canada (CIC) and the Canadian Chemistry Olympiad (CCO) will again co-ordinate their efforts in the organization of the 2008 Canadian Chemistry Contest (CCC). This event will be held on **Tuesday, April 22, 2008** and will combine the CIC Canadian Chemistry Contest and the CCO Olympiad Selection Examination. This examination was formerly known as the National High School Chemistry Examination (NHSCE).

Since 2007, the preparation of CCC involves the contribution of chemistry instructors from all over the country, under the supervision of the National Examiner, Mrs. Leslie Barton.

The Canadian Chemistry Contest is available in either English or French to all secondary schools and cégeps in Canada. CCC is intended for the top 10-15% of chemistry students. It consists of

- Part A: Multiple choice (60 min) and
- Part B: Essay questions (90 min), two (2) questions chosen from 3 or 4

The national winner of the 2008 Canadian Chemistry Contest will be awarded a prize of $800; other regional winners will receive $450, while regional second and third prizes will be $200 and $100 respectively. These prizes are awarded in six regions: Atlantic, Québec, Ontario, Manitoba-Saskatchewan-Nunavut, Alberta-NWT, and BC-Yukon. Financial support for these prizes is generously provided by the Canadian Society for Chemistry and the Canadian Society for Chemical Engineering.

It is important to note that this competition is based on the specific chemistry learning outcomes of the Pan-Canadian Protocol and not on any particular provincial curriculum. To ensure a good preparation, it is recommended to consult the Pan-Canadian Protocol website for more information *(http://www.cmec.ca/science/framework/)*. Former National High School Chemistry Examinations and CCC may also be consulted at *www.chemistry.ca.*

The CCO Olympiad Selection Examination consists of

- Part A: Multiple choice (60 min), same as the CCC
- Part C: Free response problems, designed to be more challenging (90 min)

Students interested in both competitions may write Parts A, B and C with a total time of four hours.

Information about these contests will be sent to schools in mid-March. If your school did not receive information about CCC in 2007, notify the National Co-ordinator at the address above to be added to the mailing list in your district. Further information is also available on our website. ■

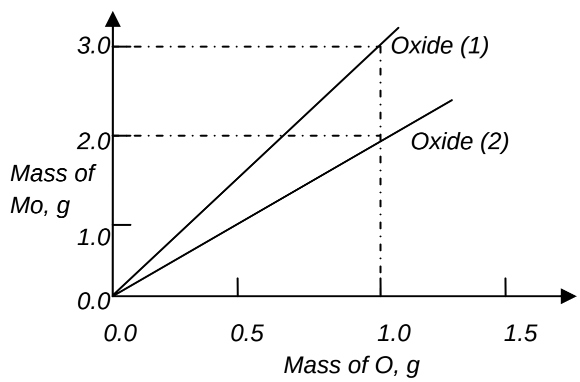
An empirical formula question from 2007 Canadian Chemistry Contest

Leslie Barton <barton@sympatico.ca>
Toronto French School (retired)
80 Weybourne Crescent
Toronto ON M4N 2R7

The following question from the 2007 Canadian Chemistry Contest[1] requires the calculation of the empirical formulae of two molybdenum oxides from data presented in graphical form. Students from different provinces always perform very differently in the contest exam, but I gather that fewer than 50% of the students chose the correct answer even in the best-performing province.

The question states:

A group of researchers did an experiment to determine the mass ratio of molybdenum to oxygen in two different oxides. They combined their results to give the graph shown below:



From these results it can be deduced that the formulae of the two metal oxides are:

Oxide	*A*	*B*	*C*	*D*	*E*
(1)	*MoO*	*Mo_2O*	*Mo_3O*	*MoO_2*	*MoO_3*
(2)	*Mo_2O_3*	*Mo_3O*	*Mo_2O*	*MoO_3*	*MoO_2*

Using the graph given in the question it can be established that, for oxide (1), 3.0 g of molybdenum react with 1.0 g of oxygen, whilst, for oxide (2), 2.0 g of molybdenum react with 1.0 g of oxygen. The empirical formulae can then be calculated in the usual way: I prefer to use a tabular method as shown below for oxide (1):

Oxide (1)	Mo	O
Mass, g	3.0	1.0
Molar mass, g mol^{-1}	96	16
Chemical amount, mol	0.03125	0.0625
Simplest ratio	$\frac{0.03125}{0.03125} = 1$	$\frac{0.0625}{0.03125} = 2$
Empirical formula	MoO_2	

A similar calculation can be done for oxide (2), which turns out to have a formula of MoO_3. The answer to this question was therefore D.

The chief distractor in this question was C, which some students presumably chose because they simply looked at the mass ratios shown on the graph, rather than performing the calculation to find the ratio of chemical amounts. Students may experience a "careless moment" because they feel under pressure to get the exam done in time, but they also appear to be exhibiting a sad lack of appreciation of the fact that the molar mass of oxygen is very much less than that of molybdenum, and of the effect this has on the mole ratio as compared to the mass ratio.

Notice how the numbers work out so neatly here because the molar mass of molybdenum just happens to be exactly six times that of oxygen. I had long played with the idea that copper has a molar mass four times that of oxygen – a fact I used to exploit when I was discussing the empirical formulae of the two copper oxides (determined using a modified version of the Nuffield method[2]). I was looking for another, similar coincidence, so I was really pleased when I found molybdenum!

I feel that it is also worth discussing in class how the graphs in this question illustrate two fundamental chemical laws, which were well-known to earlier chemists, long before they knew about atoms and moles. These laws are:

1. The Law of Constant Composition (also called the Law of Constant Proportions or Definite Proportions), which states that a pure chemical compound always contains elements in the same proportions by mass, irrespective of the method of preparation. This means that a graph of the masses of any two of the elements in different samples of the compound will be a straight line through the origin. The graph given in this question gives a straight line through the origin for each of the oxides, thus demonstrating this law.
2. The Law of Multiple Proportions, which states that where two elements can combine to form more than one compound, then the mass of one of the elements to a fixed mass of the other are in the ratio of small whole numbers. In the example given in this question, if we take a fixed mass, for example 1.0 g of oxygen, we can see that it combines with 3.0 g of molybdenum in oxide (1) and 2.0 g of molybdenum in oxide (2), so that the ratio of molybdenum to oxygen is 3/2:1 or 1.5 to 1.0. This is not, of course, a small whole number, however we can double both the numbers to give a mass ratio of 3:2, which does involve small whole numbers. This ratio would be maintained for any mass of oxygen one might choose, although it is somewhat difficult to see on the simplified graph given in the question.

Although these laws are often considered to be old-fashioned, they do demonstrate how, in days long past, chemists set about determining formulae using meticulous experimental work and a fascination with numbers. I feel that they are worth discussing, not only because of the historical connection, but also because they reinforce the concept of proportionality we teach.

References

1. The Chemical Institute of Canada Canadian Chemistry Contest for high school and cégep students, see *www.chemistry.ca/CCC,* was formerly known as the National High School Chemistry Examination.
2. See *Revised Nuffield Chemistry, Teachers' Guide II,* publ. Longman 1978, pages 504 to 507, and *Experiment sheet 45*. ■

Answers to Valentine's Day quiz.

[Students should be able to predict whether the melting point or boiling point would be high or low.]

Au – gold. Of course, its role in Valentine's Day does not need to be explained!
(metallic solid, melting point is 1065ºC)
http://www.answers.com/topic/list-of-elements-by-melting-point

C – diamond. Its role in Valentine's Day? It is a girl's best friend.
(purely covalent bonds, network solid, melting point is >3550ºC)
http://www.answers.com/topic/list-of-elements-by-melting-point

ZrO_2 – zirconium dioxide (or cubic zirconia). This is the cubic crystalline form of a mineral that is widely synthesized for use as a diamond simulant. Its role? It's a boy's wallet's best friend.
(ionic solid with very strong electrostatic forces between ions, melting point is 2680ºC)
CRC Handbook, 63rd edition, 1982-83, Chemical Rubber Company

C_2H_5OH– ethanol. It is found in wine. Its role in Valentine's Day? No comment.
(covalent bonds, hydrogen bonding and weak non-polar interaction between molecules, liquid, boiling point is 78.4ºC)
http://en.wikipedia.org/wiki/Ethanol

Ta – tantalum. Used for electrolytic capacitors in cell phones, which will be ringing everywhere with love messages.
(metallic solid, melting point of 2996ºC)
http://environmentalchemistry.com/yogi/periodic/Ta.html#Physical

$C_7H_8N_4O_2$ (on the green heart) – theobromine (also known as xantheose). It's a bitter alkaloid of the cacao plant, and is therefore found in your heart-shaped box of chocolates.
(covalent bond, solid with some intermolecular hydrogen bonding, melting point is 351ºC)
CRC Handbook, 63rd edition, 1982-83, Chemical Rubber Company

$C_{10}H_{18}O$ (on the yellow heart) – rose oxide or ((2S,4R)-2-(2-methyl-1-propenyl)-4-methyltetrahydropyran). It provides some of the odour contribution to the rose. Don't forget to send a dozen. (covalent bond, liquid with some non-polar intermolecular attractive forces, boiling point is 230ºC)
http://www.bama.ua.edu/~chem/seminars/student_seminars/spring06/papers-s06/hill-sem.pdf,
http://www.aacipl.com/msds_rose_oxide.pdf [JLH] ♥