doi:10.2533/chimia.2012.136

Chimia 66 (2012) 136–137

43rd International Chemistry Olympiad

Ankara, Turkey

July 9–18, 2011

Two Bronze Medals for Switzerland at the 43rd International Chemistry Olympiad in Ankara, Turkey

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Abstract: At the 2011 International Chemistry Olympiad in Ankara, with 71 participating countries, Switzerland achieved two bronze medals thanks to two outstanding students.

Keywords: ICHO · International Chemistry Olympiad · Swiss Students

The 43rd International Chemistry Olympiad (IChO) 2011 was held at the Middle East Technical University (METU) in Ankara (Turkey) from the 9.–18. July 2011. 273 students from 71 countries took part in this competition.

Switzerland was represented by Michelle Frei (Kantonsschule Wettingen), Erwin Lam (Kantonsschule Solothurn), Ludovic Scyboz (Collège du Sud, Bulle) and Juris Reison (Institut Florimont, Genève) as students and Peter Ludwig (head mentor, ETH Zürich), Basile Wicky (mentor, EPFL) and Alain Vaucher (observer, ETH Zürich). Since Liechtenstein cooperates with the Swiss Chemistry Olympiad Association (SwissChO), Karin Birbaum (ETH Zürich / Roche) was their representative observer.

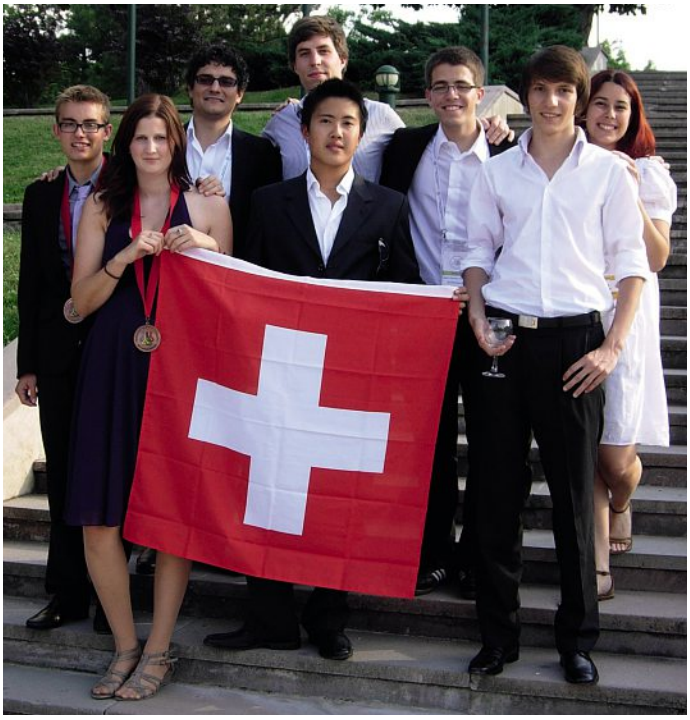
The IChO exam consists of two parts, a theoretical and practical one, each lasting five hours. The exam contained eight theoretical and three practical tasks. Tasks from the theoretical part with the worked-out solutions will be shown at the end of this article.

The IChO was won by Gong Zongping (China). He achieved 97.3 out of 100 points. Another Chinese student and a student from the Czech Republic achieved the maximum number of points, *i.e.* 60 points in the theoretical or 40 points in the practical part.

Michelle Frei and Ludovic Scyboz were both honoured with a bronze medal for their performance.

The IChO is an annual event for students in secondary education. Beside the competition with the exams, the students get the chance to meet other young people from around the world, to discover new cultures and religions. During the whole week, the students and the mentors are located at two different places and follow different programs. This is because the mentors see the exams in advance in order to translate them into their national languages. Discussing the marking scheme, translating the exam and arbitrating the final marking are the main functions of the mentors.

The organisation of the event was well done. There was a good mixture between scientific competition, historic and cultural attractions, and social events. The mentors had a guided tour to Istanbul, whereas the students could enjoy the attractions in Cappadocia.



The Swiss team at Ankara. From left to right: Ludovic Scyboz (Bronze medalist), Michelle Frei (Bronze medalist), Peter Ludwig, Basile Wicky, Erwin Lamm, Alain Vaucher, Juris Reison, the guide.

SwissChO would like to thank all our sponsors and supporters and is looking forward to next year's competition which will take place in Washington D.C.

The future Olympiads will take place at the following locations: 2012 Washington D.C. (USA), 2013 Moscow (Russia), 2014 Hanoi (Vietnam), 2015 Spain, 2017 Thailand. (2016 is to be determined.)

Theoretical Task 3

At 0 K, the total energy of a gaseous diatomic molecule AB is approximately given by: $E = E_o + E_{vib}$, where E_o is the electronic energy of the ground state, and E_{vib} is the vibrational energy. Allowed values of the vibrational energies are given by the expression:

$$E_{vib} = (v + \frac{1}{2})\varepsilon \qquad v = 0, 1, 2, \ldots ; \qquad \varepsilon = \frac{h}{2\pi}\sqrt{\frac{k}{\mu}} ; \qquad \mu(AB) = \frac{m_A m_B}{m_A + m_B}$$

where h is Planck's constant, v is the vibrational quantum number, k is the force constant, and μ is the reduced mass of the molecule. At 0 K, it may be safely assumed that v is zero, and E_o and k are independent of isotopic substitution in the molecule.

a) Calculate the enthalpy change, ΔH, in $kJ \cdot mol^{-1}$ for the following reaction at 0 K.

$H_2(g) + D_2(g) \rightarrow 2\ HD(g)$

Deuterium D is an isotope of the hydrogen atom with mass number 2.

For the H_2 molecule, k is 575.11 $N{\cdot}m^{-1}$, and the isotopic molar masses of H and D are 1.0078 and 2.0141 $g{\cdot}mol^{-1}$, respectively.

Given: $\varepsilon(H_2) = 1.1546\ \varepsilon(HD)$, and $\varepsilon(D_2) = 0.8167\ \varepsilon(HD)$ at 0 K.

b) Calculate the frequency in s^{-1} of the infrared photons that can be absorbed by the HD molecule. (If you do not have the value for ε(HD) then use $8.000{\times}10^{-20}$ J for the calculation.)

c) The allowed electronic energies of H atoms are given by the expression

$E = -\frac{R_H}{n^2}$ n = 1, 2,... where R_H = 13.5984 eV, and 1 eV = $1.602{\times}10^{-19}$ J

i) The total energy of the H_2 molecule in its ground state is –31.675 eV, relative to the same reference as that of the hydrogen atom. Calculate the dissociation energy in eV of a hydrogen molecule in its ground state such that both H atoms are produced in their ground states.

ii) An H_2 molecule in the ground state dissociates into its atoms after absorbing a photon of wavelength 77.0 nm. Determine all possible electronic states of H atoms produced. In each case, what is the total kinetic energy in eV of the dissociated hydrogen atoms?

d) Calculate the electron affinity of the H_2^+ ion in eV if its dissociation energy is 2.650 eV. (If you do not have the value for the dissociation energy for H_2 then use 4.500 eV for the calculation.)

Answers to task 3:

a) $\Delta H = 0.6544\ kJ{\cdot}mol^{-1}$

b) $v = 1.1428{\times}10^{14}\ s^{-1}$

c) i) $\Delta E = 4.478$ eV; ii) $n_1 = 1$ and $n_2 = 1$, $n_1 = 1$ and $n_2 = 2$, $n_1 = 2$ and $n_2 = 1$

d) Electron affinity = –15.426 eV

Theoretical Task 6

Extraction of gold using sodium cyanide, a very poisonous chemical, causes environmental problems and gives rise to serious public concern about the use of this so-called 'cyanide process'. Thiosulfate leaching of gold has been considered as an alternative. In this process, the main reagent is ammonium thiosulfate, $(NH_4)_2S_2O_3$, which is relatively nontoxic. Although this process appears to be environmentally benign, the chemistry involved is very complex and needs to be studied thoroughly. The solution used for leaching gold contains $S_2O_3^{2-}$, Cu^{2+}, NH_3, and dissolved O_2. The solution must have a pH greater than 8.5 to allow free ammonia to be present.

According to the proposed mechanism, a local voltaic micro-cell forms on the surface of gold particles during the leaching process and operates as follows:

Anode:

$Au(s) + 2\ NH_3(aq) \rightarrow [Au(NH_3)_2]^+(aq) + e^-$

$[Au(NH_3)_2]^+(aq) + 2\ S_2O_3^{2-}(aq) \rightarrow [Au(S_2O_3)_2]^{3-}(aq) + 2\ NH_3(aq)$

Cathode:

$[Cu(NH_3)_4]^{2+}(aq) + e^- \rightarrow [Cu(NH_3)_2]^+(aq) + 2\ NH_3(aq)$

$[Cu(NH_3)_2]^+(aq) + 3\ S_2O_3^{2-}(aq) \rightarrow [Cu(S_2O_3)_3]^{5-}(aq) + 2\ NH_3(aq)$

a) Write the overall cell reaction for this voltaic cell.

b) In the presence of ammonia, O_2 oxidizes $[Cu(S_2O_3)_3]^{5-}$ back to $[Cu(NH_3)_4]^{2+}$. Write a balanced equation for this oxidation–reduction reaction in basic solution.

c) In this leaching process, the $[Cu(NH_3)_4]^{2+}$ complex ion functions as catalyst and speeds up the dissolution of gold. Write the net overall oxidation–reduction reaction for dissolution of the gold metal, which is catalysed by $[Cu(NH_3)_4]^{2+}$ complex ion.

d) Draw the coordination geometries of the metal in $[Au(NH_3)_2]^+$ and $[Au(S_2O_3)_2]^{3-}$ complex ions, indicating the coordinating atoms.

e) The formation constants, K_f, of $[Au(NH_3)_2]^+$ and $[Au(S_2O_3)_2]^{3-}$ complexes are $1.00{\times}10^{26}$ and $1.00{\times}10^{28}$, respectively. Consider a leaching solution, in which the equilibrium concentrations of the species are as follows:

$[S_2O_3^{2-}] = 0.100$ M; $[NH_3] = 0.100$ M; total concentration of gold(I) species = $5.50{\times}10^{-5}$ M. Calculate the percentage of gold(I) ion, which exists in the form of thiosulfate complex.

f) When the concentration of O_2 is not high enough and pH>10, $S_2O_3^{2-}$ reduces $[Cu(NH_3)_4]^{2+}$ to $[Cu(S_2O_3)_3]^{5-}$ with the formation of tetrathionate ion, $S_4O_6^{2-}$:

$2\ [Cu(NH_3)_4]^{2+}(aq) + 8\ S_2O_3^{2-}(aq) \rightarrow 2\ [Cu(S_2O_3)_3]^{5-}(aq) + S_4O_6^{2-}(aq) + 8\ NH_3(aq)$

In basic solution tetrathionate disproportionates to trithionate, $S_3O_6^{2-}$, and thiosulfate. Write a balanced equation for this disproportionation reaction.

g) When the O_2 concentration is too high it oxidizes $S_2O_3^{2}$ to yield trithionate and sulfate ions. Write a balanced equation for this reaction.

Answers to task 6:

a) $Au + [Cu(NH_3)_4]^{2+} + 5\ S_2O_3^{2-} \rightarrow [Au(S_2O_3)_2]^{3-} + [Cu(S_2O_3)_3]^{5-} + 4\ NH_3$

b) $4\ [Cu(S_2O_3)_3]^{5-} + 16\ NH_3 + O_2 + 2\ H_2O \rightarrow 4\ [Cu(NH_3)_4]^{2+} + 12\ S_2O_3^{2-} + 4\ OH^-$

c) $4\ Au + 8\ S_2O_3^{2-} + O_2 + 2\ H_2O \rightarrow 4\ [Au(S_2O_3)_2]^{3-} + 4\ OH^-$

d) $[H_3N\text{-}Au\text{-}NH_3]^+$; $[O_3S\text{-}S\text{-}Au\text{-}S\text{-}SO_3]^{3-}$

e) 99.0 % of Au(I) in the form of $[Au(S_2O_3)_2]^{3-}$

f) $4\ S_4O_6^{2-} + 6\ OH^- \rightarrow 5\ S_2O_3^{2-} + 2\ S_3O_6^{2-} + 3\ H_2O$

g) $2\ S_2O_3^{2-} + 2\ O_2 \rightarrow SO_4^{2-} + S_3O_6^{2-}$

The other problems can be found on *http://icho43.metu.edu.tr/*

Received: January 14, 2012