Baltic Chemistry Competition

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Medical - Biological Research and Technologies
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2011
2ND ROUND, PROBLEMS

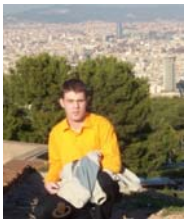
Solve all or some of the problems given on the next pages and write your full solutions in *MS Word, Excel* documents or *.pdf files. It is also acceptable if you scan your material and insert as picture in mentioned file formats.

If there are some explanations required, write them in English.Please, send your answers to:kimijas_olimpiades@inbox.lv**till 28.12.2010. at12:00** (Latvian time; UTC+2). Answers sent after this deadlinewill not be graded.

File name must consist from your name, last name(in English) and country, for example,*John_Black_England.doc* (or *.docx etc.). If you do not name the file as described, you will receive 3-point penalty. For all the correctly solved problems you can get the maximum of 30 points. The exact amount of points for each task is given at the top of each problem.

All the students who will be taking part in at least one round may participate in the final round, which will be held on the web on February 27th. During the final round you will have to solve the multiple-choice test. More information can be foundin BCC regulations.

Competition organizers and problem authors:



KasparsVeldre

PhD student, University of Latvia, Department of Chemistry

VladislavIvaništšev

PhD student, Tartu University, Institute of Chemistry

EgleMaksimaviciute

BSc student, Vilnius University, Department of Chemistry

FilipTopić

MSc student, Department of Chemistry, University of Zagreb

Peter Holzhauser

Czech Republic

Karina Kizjakina

PhD student, Virginia Polytechnic Institute and State University, Department of Chemistry

GlebŠiroki

BSc student, University of Cambridge

Maxim Mišin

BSc student, Estonia

GytisKulaitis

BSc student, University of St Andrews

VidmantasBieliunas

BSc student, Vilnius University, Department of Chemistry

Good luck with problem solving! ☺

If you have any questions, you can address them to us in English by sending them to: kimijas_olimpiades@inbox.lv
Feel free to ask!

Problem 1 (Latvia)

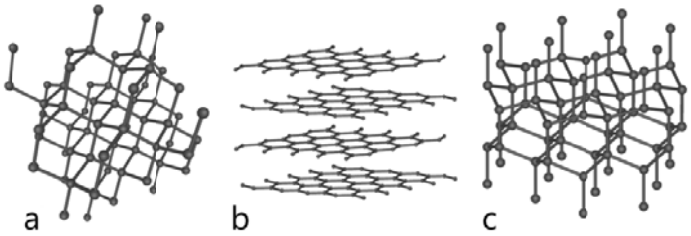
If you do not know – Ask google! (5 points)

One of the most interesting chemical elements nowadays is carbon, which is used in several ways; it is found in every home.In addition, it is 4th abundant chemical element in universe (after hydrogen, helium, and oxygen, by mass). It is known that carbon forms several solid phases, which can transform from each to another by changing conditions.

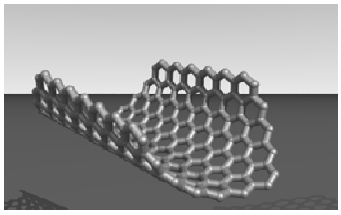
These phases are minerals diamond and graphite, meteorite mineral lonsdaleite, fullerenes (buckyballs) and buckytubes. Another phase is amorphous carbon, which is used for preparation of activated carbon that is special case of carbon with especially large surface area. Another material is linear acethylenic carbon or carbine,which is a short-lived intermediate during pyrolysis or phtotolysis reactions. Another modification whose structure is not completely knownuntil nowadays is glassy carbon, which is used in electrochemistry for production of high temperature and chemical resistance electrodes. It is an inert electrode for hydronium ion reduction (with reduction standard potential not equal to zero).

Answer questions given below. Please write your explanations in English. You can also use *Google Translate* for translation.

1. State three different hybridizations what carbon atoms can have in chemical compounds! For each type of hybridization show an example with the lowest molecular mass and draw their Lewis structures, state bond angles!
2. Structures of three carbon modifications are shown in picture bellow. Identify these three structures and determine hybridization of carbon atoms in each structure.



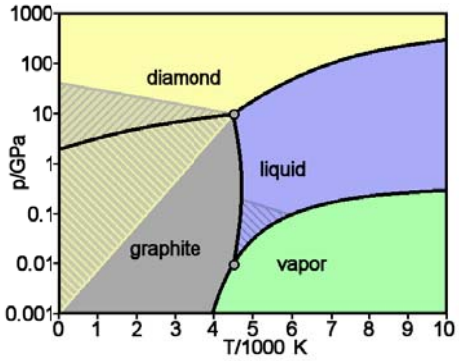
3. Explain the easiest way to prepare carbon in your school lab. Write chemical reaction for this process! Which modification of carbon will you obtain?
4. One modification of carbon has dangling bonds. It is one of the reasons that cause deviations in atomic spacing and noticeable variation in bond angles. Which carbon modification it is? Provide method for reducing the amount of dangling bonds?
5. A spherical carbon molecule was for the first time prepared in 1985 by scientists in Houston, Texas. It consists of covalently bonded carbon atoms. Carbon has 4 outer electrons. where stays 4^{th} electron if carbon forms three covalent bonds? What properties come from these electrons?
6. This material has the largest length-diameter ratio among all known materials; one molecule can achieve the length of 18 cm, while its diameter is only about 1 nm. What is this material? See also the figure below.



7. It is the hardest type of carbon and can be produced synthetically from the same material, which is obtained at low pressures. If pressure of 24GPa is applied to mentioned low

pressure material, it transforms to material which hardness is comparable with boron nitride, which is actually harder than diamond. What is it?

8. Phase diagram of carbon is shown below. At room temperature, diamond is not in the most stable form. Explain how diamonds can exist at room temperature, and do girls have to worry about their jewelry in an aspect of possible phase transition to graphite form? Can liquid carbon exist in conditions of 1atm pressure? State processes, which can happen if someone heats up solid carbon in 1atm pressure in anaerobic or aerobic conditions!



9. This carbon modification forms after heating silicon carbide in temperature above 1100°C followed by reduction, or it can be prepared via reaction of ethanol with sodium metal, followed by pyrolysis of ethoxide salt and product washing with water to remove sodium salts. What is the described carbon modification and what is carbon hybridization in this material?

10. This carbon modification is used for production of supercars, Formula One machines and bicycles (bicycle tubes). State which of mentioned carbon forms is used in this production and state the name of this material. State one positive and one negative property of this material!

Problem 2 (Estonia)

Compounds of sulfur (5 points)

Draw the structures for the given molecules: H_2SO_3, $SOCl_2$, H_2S, SO_3, clearly indicate molecular geometry.Mark those of them, which are polar.

Give an explanation to the fact that sulphur forms cycles S_n, but oxygen does not.

What is the difference between molecules $O_3$and SO_2? DrawLewisstructures (electron dot diagrams). Compare the multiplicity of the bonds in these structures.

Drawthestructuresfor the given molecules: S_4^{2+}, S_4, S_4^{2-}, clearly indicate molecular geometry and mark aromatic compounds.

Give and explanation why SF_4easily hydrolyses, while SF_6does not, even despite$\Delta_f$has negative values of −460 kJ for the reaction: $SF_6 + 3H_2O \rightleftharpoons 6HF + SO_3$.

Problem 3 (Lithuania)

Quantum observations due to laser cooling (10 points)

All the elementary particles can be divided into two groups: bosons and fermions. The main difference between them is that several bosons can occupy the same quantum state, whereas

fermions cannot due to Pauli exclusion principle. A decent chemist should already have understood (if he had not known it earlier) that electrons are fermions, because their spin is ½ just as the spin of neutrons and protons. The easiest way to determine whether composite particles, eg nuclei, atoms, are fermions or bosons, is to calculate the number of fermions in a particle. If it is even, then the particle is a boson, otherwise it is a fermion. Thus, the ^{4}He atom is a boson as well as the nucleus of ^{12}C.

In 2001, the Nobel Prize in Physics was given to Eric Cornell and Carl Wieman from University of Colorado at Boulder, and Wolfgang Ketterle from MIT for achieving the so-called Bose-Einstein condensate (BEC) - a state of matter, where quantum properties can be observed at macro scale. Currently, one of the many research trends in BEC is an effortto **observe** how the chemical reactions are happening in such state.

The first two scientists used the monatomic gas of ^{87}Rb atoms, the third - worked with monatomic gas of ^{23}Na atoms.

1. Why ^{87}Rb and ^{23}Na atoms are bosons, despitetheir mass numbers beingcertainly odd (noteven)? Can you state the simplest method fortelling if the atom is a boson?

The main problem of getting BEC is that the atoms have to be cooled down to temperatures near the absolute zero, because then we can assume that all the particles collapse into the lowest energy state and become indistinguishable.

Nowadays scientists usually use laser cooling. To understand how it works, first we have to remember that light is also made of matter (photons), which can hit an atom similarly as tennis balls can hit a bowling ball going in an opposite direction and eventually stop it. Suppose that we have confined atoms, which we want to cool down, in one dimension. Then, we need two lasers in total: one that hits the atoms going forward and the other thathits the atoms going back.

2. How many lasers do we need to cool atoms in three dimensions?
3. Calculate the average translational kinetic energy of a monoatomic ideal gas atom of ^{87}Rb and ^{23}Na at 25.00°C.

While cooling ^{87}Rb, scientists managed to achieve an impressive temperature of **170.0nK**. Due to the very weak interaction in BEC, the kinetic theory of gases still works pretty well at such temperatures.

4. What is the root mean square speed of rubidium atoms at such temperature?

To cool the atoms, the wavelength of the laser light is adjusted to correspond to the difference between the most possible excitation and the ground states. The commonly used wavelength of the laser beam used for cooling ^{87}Rb is 780.0nm at 25°C.

5. Calculate the corresponding energy of a laser beam of 780.0nm.
6. Which electron excitation does it correspond to?

In real laboratory laser cooling, the Doppler Effect has to be taken into account as well. Usually the frequency of the laser is lowered and then only the atoms going in opposite direction of the laser beam are slowed down.

7. Show how the formula for calculating the Doppler Shift in frequency used for laser cooling is derived:

$$f_{\text{laser}} = \frac{f_{\text{atom}}}{\left(1+\frac{v_{\text{atom}}}{c}\right)}$$

8. What is the change in frequency of the laser due to the Doppler Effect in this transition? This change is also called detuning.

Problem 4 (Latvia)

Chemistry of green compoinds(5 points)

Picture 1.

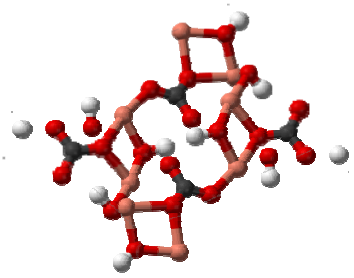
All situations described are fictional, except data about chemical analysis.

Three young chemists Radek, Ilya and Yusuf found green powdered crystalline materials near their homes. Radek visited graveyard in Vyšehrad fortification in Prague. Few monuments were covered with this green powder **A**(see picture 1). He scrapped 88.5 mg of sample and took home for analysis. He divided sample in two equal parts. One part he heated in crucible till all powder changed the color to black. After heating, he cooled it down till room temperature and determined mass of the black powder. It appeared to be 31.7 mg. Exhausted gases were absorbed in barium hydroxide solution (in excess). It resulted to formation of 19.7 mg of white precipitate, which dissolved in hydrochloric acid.

1. *Determine what is material **A**. Show your calculations!*

Radek's father was x-ray specialist at local university, so he invited son to his laboratory and they performed x-ray structure analysis for the rest of mentioned green powder. They determined crystalline structure and it appeared to be like in Picture 2.

2. *Identify each color (white, red, grey and pink) of atoms in picture 2 as chemical elements.*



Picture 2.Crystal structure of compound A

Picture 3.Yusuf's trip to King Solomon's Mines.

3. *Calculate crystallographic density of compound **A** if it is known that it crystallizes in monoclinic crystals with latticeparameters, a=9.50; b=11.98; c=3.24 Å and β=98.8°.*

Yusuf lives in Israel and visited King Solomon's Mines, where he also found some crystalline material **B**. He took 88.5 mg of the sample using the same method as Radek. Mass of obtained black powder was 613 mg while mass of white precipitate was 101 mg.

4. *Determine what is material **B**. Show your calculations!*
5. *Calculate crystallographic density of compound **A** if it is known that it crystallizes in monoclinic crystals with latticeparameters, a=5.01; 5.85; 10.36 Å and β=92.4°.*
6. *Material B was used in Kings Solomon's time for production of element **C**. What is element **C**? Write down all chemical reactions used in production of element **C** and write down chemical reaction that is used nowadays for element **C** purification!*
7. *Material **B** is related to material **A**as .. (chose one answer):*
   - *a. enantiomer,*
   - *b. ionization isomer,*
   - *c. allotrope,*
   - *d. polymorphic form,*
   - *e. pseudopolymorphic form,*
   - *f. cocrystal,*
   - *g. solid solution.*

Little Russian boy Ilya found his sample in mountains near the city of Perm. He found on internet that some people use such kind of stones as jewelry and believe that it protects them from diseases, lightning, and witchcraft.Therefore, he decided to make a gift to his mother for her birthday. After she received the gift, she decided to synthesize similar color substance at her laboratory in Perm

State University. In condensation reaction ofbenzaldehyde and dimethylanilineshe obtained the product,which was thenoxidized by manganese dioxide. Then she obtained green powder **D**thatwas very similar to son's found crystals.

8. *Write equations for all chemical proceses described.Name final product **D** using trivial and IUPAC nomenclature. What is common between compound **D** and Ilya's sample, do they have any chemical relation?*
9. *Draw structural formula for compound **D** and explain why it was colored!*
10. *State three possible applications of compound **D**, show literature references for that.*

Problem 5 (Lithuania)

Chemical rebuss(5 points)

A yellow and very poisonous chemical substance **A**is sometimes said to belong to the same group of binary polyatomic compounds as substances **L** and **M**. It can be prepared by reacting two concentrated acids **B** and **C**. Yellow gas **E** and water are produced as a byproduct. Although the mixture of these two acids has been known for quite some time, there reaction product **A** was described only in 1831. Alternative production method for **A** would be a reaction between gasses **E** and **D**, which doesnot produce any byproducts. However, this reaction is reversible at high temperatures. Gas **D** is produced by reacting a reddish transitional metal **I** with diluted acid **C**. If you use concentrated acid in this reaction you would get brown gas **N** instead of **D**. A blue salt **J**is produced in both cases. Gas **N** reacts with water to produce acids **C** and **F** simultaneously. Acid **F** upon reacting with acid **G** produces compound **H,** which in turn reacts with acid **B** to give compound **A** and acid **G**. Compound **H**canbe considered as an anhydride of both acids. Gas **E**is made in small quantities by reacting **B** with potassium permanganate. This gas can also be used to produce **L** in a reaction with a sodium salt of a weak acid **K**, which has a faint almond smell. Compound **M**is produced by thermal decomposition of a mercury (II) salt of acid **K** and it is symmetrical. Acid **G** upon reacting with barium chloride solution gives white precipitate. In air, gas **D**is oxidized to **N.**

1. Identify compounds **A-N**
2. A 2.0 L container was filled with 1molof gas **A** at 400K temperature. Calculate the concentrations of **A**, **D**, and **E** at the equilibrium point.
3. At which temperature themolar fraction of**A** equals to 0.01?