Baltic Chemistry Competition

2011
1st ROUND, PROBLEMS

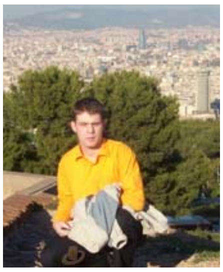
Solve all or some of the problems given on the next pages and write your full solutions in *MS Word, Excel* documents or *.pdf files. It is also acceptable if you scan your material and insert as picture in mentioned file formats.

If there are some explanations required, write them in English. Please, send your answers to: kimijas_olimpiades@inbox.lv **till 08.11.2010. at 3:00** (Latvian time; +2). Answers sent after this deadline will 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 will 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 found in BCC regulations.

Competition organizers and problem authors:



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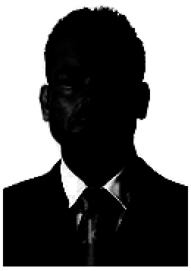

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Good luck with problem solving! ☺

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 (Lithuania)

Sulfur containing gases (8 points)

A 5.00 L closed container was filled with SO_2 (70% of total volume) and O_2 (30% of total volume) gases, the temperature inside the container was kept at 25°C.

$SO_2 + 0.5\ O_2 \rightleftarrows SO_3$ reaction occurs at 25°C.

1. *What will be the final volume of the O_2 in that container after the equilibrium is reached?*

1.00 L of water was added into the same container keeping it still closed.

2. *Write the reaction that occurs upon the addition of water? What is the pH of the resulting solution?*
3. *What would be the pH of the solution if the temperature inside the container (during the addition of the gases??) would be at 200°C? After adding water the solution is cooled to 25°C.*
4. *What would be the pH of the solution if the initial proportion of gases is 30 % (SO_2) and 70 % (O_2) of the total volume (at 25°C)?*
5. *Is it possible change concentration of hydrogen ions in solution to be two times higher or lower than in part 2 by changing temperature or initial proportion of gases? If so then how? Show the calculations.*

	$\Delta_f H^o$/ (kJ mol^{-1})	S_m^o/ (J mol^{-1} K^{-1})
SO_2	-296.83	248.22
SO_3	-395.72	256.76
O_2	0	205.138

All required constants can be found online or in handbooks. References should be given to the source of information.

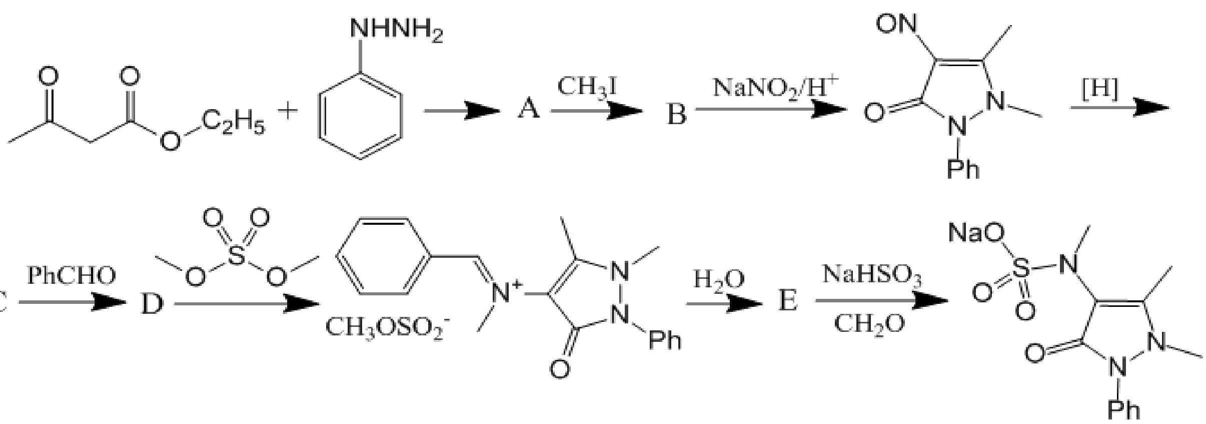
Problem 2 (Estonia)

Bless you! (10 points)

If too many drugs are provided against one illness, then it means that this illness cannot be healed.

Anton Chekhov

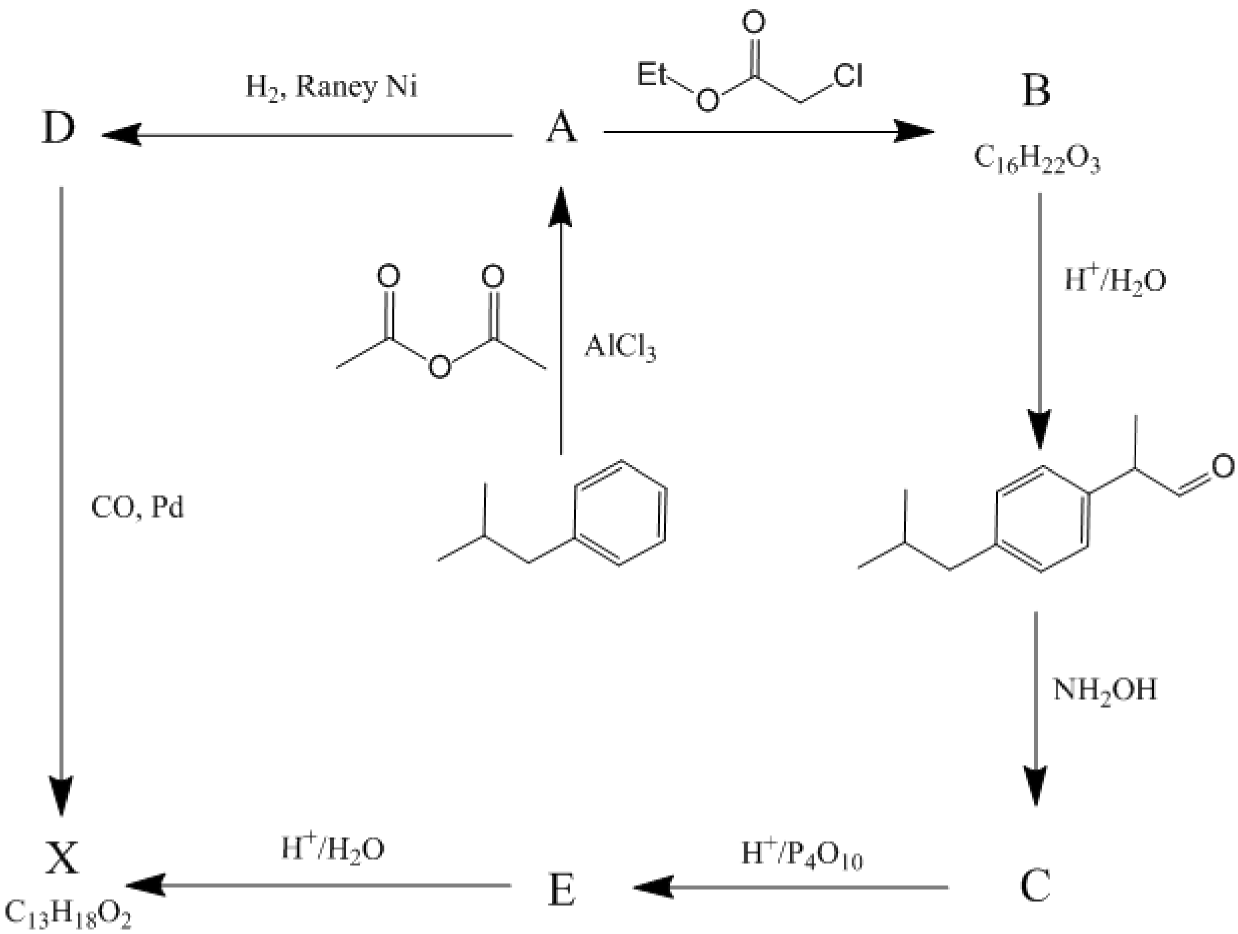
Scheme 1



Write the structures for compounds A-E.

Do you agree that in case when nitrogen atom carries three different substituents it is chiral, because of its lone electron pair that plays the role of the forth substituent? Why?

Scheme 2



Write the structures for compounds A-E, X.

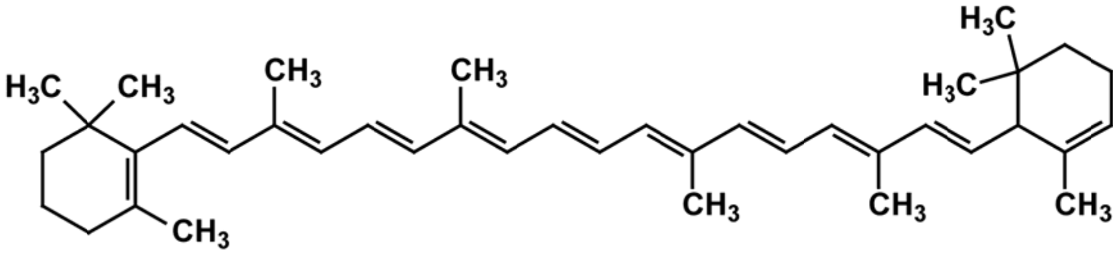
Write down the structures for all of the compound B stereoisomers and assign configurations at their stereocenters.

Problem 3 (Latvia)

Quantum organic chemistry (4 points)

β-Carotene is an organic compound that is classified as a terpenoid. It is a strongly-colored red-orange pigment, abundant in plants and fruits. As a carotene with beta-rings at both ends, it is the most common form of carotene. It is a precursor (inactive form) of vitamin A. β-Carotene contains a conjugated chain of 22 carbon atoms with an average internuclear separation of 144 ppm. The π electrons in this conjugated chain are delocalized and, to a rough approximation, they can be considered to be particles in a one dimensional box of 3.17 nm (that is 22x14 pm)length. Each carbon atom contributes to one π electron.

1. *Calculate the difference in energy between the highest occupied π electron energy level (HOMO) and the lowest unoccupied level (LUMO).*
2. *Calculate the wavelength of radiation that would be absorbed in producing a transition between these two states.*



Problem 4 (Estonia)

Chemistry of radioactive particles (8 points)

Part 1 – Radioactive decay equations

Radioactive decays are classified by rules of Fajans and Soddy into two groups: α- and β-decays:

$^{A}_{Z}X \rightarrow \, ^{A-4}_{Z-2}Y + \, ^{4}_{2}He$ α-decay,

$^{A}_{Z}X \rightarrow \, ^{A}_{Z+1}Y + \, ^{0}_{-1}e$ β^{-}-decay,

$^{A}_{Z}X \rightarrow \, ^{A}_{Z-1}Y + \, ^{0}_{+1}e$ β^{+}-decay.

Complete following equations and, if it is possible, determine the type of radioactive decay.

$^{1}_{0}n \rightarrow ...... + \, ^{0}_{-1}e$	$^{99}_{43}Tc \rightarrow ...... + ...$	$^{204}_{82}Pb \rightarrow ...... + \, ^{4}_{2}He$
$^{8}_{4}Be \rightarrow ...... + \, ^{4}_{2}He$	$^{113}_{48}Cd \rightarrow ...... + \, ^{0}_{-1}e$	$^{206}_{81}Tl \rightarrow ...... + ...$
$^{14}_{6}C \rightarrow \, ^{14}_{7}N + ...$	$^{109}_{53}I \rightarrow ...... + \, ^{0}_{-1}e$	$^{210}_{83}Bi \rightarrow \, ^{206}_{81}Tl + ...$
$^{40}_{19}K \rightarrow ...... + \, ^{0}_{-1}e$	$^{144}_{60}Nd \rightarrow ...... + \, ^{4}_{2}He$	$^{222}_{86}Rn \rightarrow \, ^{218}_{84}Po + ...$
$^{68}_{31}Ga \rightarrow \, ^{68}_{30}Y + ...$	$^{148}_{62}Sm \rightarrow \, ^{144}_{60}Nd + ...$	$^{226}_{88}Ra \rightarrow ...... + ...$

Part 2 – Measuring radioactivity

For measuring activity of radioactive particles SI measurement units, becquerels (Bq), are used. One bequerel corresponds to one dps (decay per second). Measurement units as dpm (decays per minute), Bq/kg or Bq/mL are derived from Bq that way to show the number of decays per mass or volume of radioactive material. Besides SI units non-Si unit, curie (Ci), is also used for describing radioactivity. One curie is equal to 3.70×10^{10} Bq and originally it was defined as activity of 1.00 grams of radium-226.

1) Calculate half-life of ^{226}Ra (in years) using definition of curium.

Later, half-life of radium-226 was determined more precisely and it appeared to be $T_{½}$ = 1620 years, but measurement unit Ci was not changed and it is still being used for approximate calculations.

2) Calculate mass or radium which has activity of 1 Ci.

Radium was discovered in 1902 by Pierre Curie and Marie Sklodowska-Curie. From 8000 tons of uranium ore waste they obtained 100 mg of radium chloride.

3) Calculate activity of obtained radium chloride in Bq per kilogram (Bq/kg).

In 1907 Marie Curie gifted 1.00 g of radium to Institute of Radium in Paris (now Institute of Curie), where it is still kept nowadays.

4) Calculate amount of radium (in moles) which was not decomposed in the time period from 1907 to2010.

5) Calculate mass of radium (in g) decomposed in this time period.

6) Calculate in what year practically all radium will be decomposed (99.99%).

Part 3 – Equipment for measuring radioactivity

Radioactivity of particles is measured by special equipment. Not all measuring devices are up-to-date so it is very hard to determine the correct value of radioactivity. With the aim to improve radioactivity measurement, instruments are calibrated using specially prepared specimens.

Such material is $^{35}_{16}S$ ($T_{½}$ = 87.9 days) with initial radioactivity 0.0100 μCi. In 200 days, radioactivity of this material, determined by Geiger counter, decreases to 2600 dcm.

1) Calculate actual radioactivity that $^{35}_{16}S$ will have in 200 days (in Bq).

2) Calculate sensitivity of Geiger counter (in %).

3) Calculate radioactivity value determined by this Geiger counter after 7 days for 100 mg 51-Cr sample ($T_{½}$ = 27.8 days).

4) Calculate mass fraction of 51-Cr in obtained sample (after 7 days).

Part 4 – Dangerousness of radioactive elements

At the moment of Earth formation, radioactive elements were part of several chemical compounds. Some scientists associate high temperatures in Earth core with the radioactive heat. Existence of radioactive elements with long half-lifes (for example: uranium-238 – $4.5 \cdot 10^9$ years; thorium-232 – $1.4 \cdot 10^{10}$ years; potassium-40 – $1.28 \cdot 10^9$ years; rubidium-87 – $6.75 \cdot 10^{10}$ etc.) is supporting this statement. Other elements with shorter half-lifes are formed at decay of uranium-238, thorium-232, and uranium-235. Radium, polonium, and radon are among those newly formed elements.

Due to effect of different waves from universe on the Earth atmosphere, radioactive carbon 14-C ($T_{½}$ = 5720 years) and tritium 3-H ($T_{½}$ = 12.4 years) are formed. Radioactive background exists at all times, and is formed from both natural and man-made radionuclides. For example, contents of radioactive isotope of potassium 40-K ($T_{½}$ = $1.275 \cdot 10^6$ years) in nature is equal to 0.0117%. All other isotopes of potassium are stable.

1) Calculate radioactivity of metallic potassium (m = 20 g), found in school laboratory.

2) State at least two reasons why potassium from school laboratory is considered to be safe.

Especially dangerous isotope is strontium-90, which replaces calcium in live organisms and accumulates in bones.

3) Explain why strontium-90 is so dangerous, name two illnesses caused by radioactive strontium.

As a fact, cigarette contains from 3 to 24 mBq of 210-Po. After entering human organism, most part of 210-Po accumulates in bones, teeth, and also in kidneys and liver.

4) Calculate time that is required for complete (99.99%) decomposition of 210-Po ($T_{½}$ = 138.4 days) after smoking one cigarette.