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# 26<sup>th</sup> CHEMISTRY OLYMPIAD OF THE BALTIC STATES

Riga, Latvia  
April 13<sup>th</sup>-15<sup>th</sup>, 2018

## PRACTICAL EXAMINATION



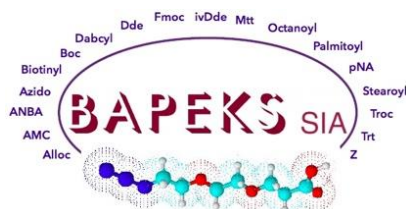
Riga Technical University  
<https://www.rtu.lv/en>



JSC OlainFarm  
<http://olainfarm.lv/>



Biosan  
<https://www.biosan.lv/en>



Bapeks  
<http://www.bapeks.com/>



Bauskas alus  
<https://bauskalus.lv/en/products/non-alcoholic-drinks>

“Back to where it all began”

Student code:

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# Kīmisko elementu periodiskā tabula

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 <b>H</b> Hydrogen 1.008	2 <b>He</b> Helium 4.0026	3 <b>Li</b> Lithium 6.94	4 <b>Be</b> Beryllium 9.0122	5 <b>B</b> Boron 10.81	6 <b>C</b> Carbon 12.011	7 <b>N</b> Nitrogen 14.007	8 <b>O</b> Oxygen 15.999	9 <b>F</b> Fluorine 18.998	10 <b>Ne</b> Neon 20.180	11 <b>Na</b> Sodium 22.990	12 <b>Mg</b> Magnesium 24.305	13 <b>Al</b> Aluminium 26.982	14 <b>Si</b> Silicon 28.085	15 <b>P</b> Phosphorus 30.974	16 <b>S</b> Sulfur 32.06	17 <b>Cl</b> Chlorine 35.45	18 <b>Ar</b> Argon 39.948
19 <b>K</b> Potassium 39.098	20 <b>Ca</b> Calcium 40.078	21 <b>Sc</b> Scandium 44.956	22 <b>Ti</b> Titanium 47.867	23 <b>V</b> Vanadium 50.942	24 <b>Cr</b> Chromium 51.996	25 <b>Mn</b> Manganese 54.938	26 <b>Fe</b> Iron 55.845	27 <b>Co</b> Cobalt 58.933	28 <b>Ni</b> Nickel 58.693	29 <b>Cu</b> Copper 63.546	30 <b>Zn</b> Zinc 65.38	31 <b>Ga</b> Gallium 69.723	32 <b>Ge</b> Germanium 72.630	33 <b>As</b> Arsenic 74.922	34 <b>Se</b> Selenium 78.971	35 <b>Br</b> Bromine 79.904	36 <b>Kr</b> Krypton 83.798
37 <b>Rb</b> Rubidium 85.468	38 <b>Sr</b> Strontium 87.62	39 <b>Y</b> Yttrium 88.906	40 <b>Zr</b> Zirconium 91.224	41 <b>Nb</b> Niobium 92.906	42 <b>Mo</b> Molybdenum 95.95	43 <b>Tc</b> Technetium (98)	44 <b>Ru</b> Ruthenium 101.07	45 <b>Rh</b> Rhodium 102.91	46 <b>Pd</b> Palladium 106.42	47 <b>Ag</b> Silver 107.87	48 <b>Cd</b> Cadmium 112.41	49 <b>In</b> Indium 114.82	50 <b>Sn</b> Tin 118.71	51 <b>Sb</b> Antimony 121.76	52 <b>Te</b> Tellurium 127.60	53 <b>I</b> Iodine 126.90	54 <b>Xe</b> Xenon 131.29
55 <b>Cs</b> Caesium 132.91	56 <b>Ba</b> Barium 137.33	57-71 Lanthanum 138.91	72 <b>Hf</b> Hafnium 178.49	73 <b>Ta</b> Tantalum 180.95	74 <b>W</b> Tungsten 183.84	75 <b>Re</b> Rhenium 186.21	76 <b>Os</b> Osmium 190.23	77 <b>Ir</b> Iridium 192.22	78 <b>Pt</b> Platinum 195.08	79 <b>Au</b> Gold 196.97	80 <b>Hg</b> Mercury 200.59	81 <b>Tl</b> Thallium 204.38	82 <b>Pb</b> Lead 207.2	83 <b>Bi</b> Bismuth 208.98	84 <b>Po</b> Polonium (209)	85 <b>At</b> Astatine (210)	86 <b>Rn</b> Radon (222)
87 <b>Fr</b> Francium (223)	88 <b>Ra</b> Radium (226)	89-103 Actinium (227)	104 <b>Rf</b> Rutherfordium (267)	105 <b>Db</b> Dubnium (268)	106 <b>Sg</b> Seaborgium (269)	107 <b>Bh</b> Bohrium (270)	108 <b>Hs</b> Hassium (277)	109 <b>Mt</b> Meitnerium (278)	110 <b>Ds</b> Darmstadtium (281)	111 <b>Rg</b> Roentgenium (282)	112 <b>Cn</b> Copernicium (285)	113 <b>Nh</b> Nihonium (286)	114 <b>Fl</b> Flerovium (289)	115 <b>Mc</b> Moscovium (290)	116 <b>Lv</b> Livermorium (293)	117 <b>Ts</b> Tennessine (294)	118 <b>Og</b> Oganesson (294)
6 Lanthanum 138.91	7 Actinium (227)	57 <b>La</b> Lanthanum 138.91	58 <b>Ce</b> Cerium 140.12	59 <b>Pr</b> Praseodymium 140.91	60 <b>Nd</b> Neodymium 144.24	61 <b>Pm</b> Promethium (145)	62 <b>Sm</b> Samarium 150.36	63 <b>Eu</b> Europium 151.96	64 <b>Gd</b> Gadolinium 157.25	65 <b>Tb</b> Terbium 158.93	66 <b>Dy</b> Dysprosium 162.50	67 <b>Ho</b> Holmium 164.93	68 <b>Er</b> Erbium 167.26	69 <b>Tm</b> Thulium 168.93	70 <b>Yb</b> Ytterbium 173.05	71 <b>Lu</b> Lutetium 174.97	103 <b>Lr</b> Lawrencium (266)

**Metals**

- Alkali metals
- Alkaline earth metals
- Lanthanoids (Lanthanides)
- Actinoids (Actinides)
- Transition metals
- Post-transition metals

**Nonmetals**

- Other nonmetals
- Noble gases

**States of Matter**

- C** Solid
- Hg** Liquid
- H** Gas
- Rf** Unknown

For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

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## General information

This exam contains 11 pages for practical exam tasks (including the answer sheets). There are a total of 2 Tasks:

- Problem 1 - Determining the concentration of sodium hypochlorite solution;
- Problem 2 - Synthesis of cyclohexanone and its isolation as a 2,4-dinitrophenylhydrazone derivative

Follow safety rules while working in laboratory! It is forbidden to eat and drink in lab. While you are in lab you must wear lab suit and protective glasses. Gloves are not mandatory, but you can ask for them.

Write your code on each answer sheet.

You will have a total of 5 hours to complete two practical tasks. You must begin as soon as the “**Start Command**” is given.

You must start the practical examination with Problem 1 – determination of NaOCl concentration. This task will be held in analytical chemistry lab on 3<sup>rd</sup> floor. Write **sample number** on the answer sheet. After your calculations are finished show your results to lab assistant.

The second practical task (Problem 2) will be held in organic chemistry labs on 4<sup>th</sup> floor. After you finish Problem 1 – take your lab report and go to other lab as designated by lab assistant.

Some of the plastic and glass equipment will be used more than once. Wash them carefully.

All answers should be written in answer boxes provided. Answer written in other places will not be graded. You can use other side of page as a draft paper.

When it is necessary, provide your calculations in the answer boxes. You will get full marks for correct answers (numbers and units) only if the calculations will be shown.

You must stop your work immediately (including filling answer sheets) when the “**Stop Command**” is announced.

Do not leave laboratory before lab assistant allows to do it.

Chemicals and labwares, unless noted, are not supposed to be refilled or replaced. Chemical and labwares will be refilled or replaced without penalty only for the first incident. Each further incident will result in the deduction of 1 point from your 40 practical exam points.

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## PROBLEM 1 (18 POINTS)

### Determining the concentration of sodium hypochlorite

In order to perform the problem 2 – the oxidation of the cyclohexanol, you will need to know the concentration of the aqueous sodium hypochlorite solution. In this problem the concentration of the sodium hypochlorite solution will be determined by titration.

#### Reagents

- 0.100 M  $\text{Na}_2\text{S}_2\text{O}_3$  aqueous solution
- 10% KI aqueous solution
- 5%  $\text{CH}_3\text{COOH}$  aqueous solution
- 1% starch aqueous solution
- Distilled water
- The sample to be analyzed (aqueous solution of sodium hypochlorite)

#### Glassware and equipment

- 100.0 mL measuring flask
- 5.00 mL pipette
- 10.00 mL pipette
- 100 mL conical flasks
- Burette
- Pipette for the starch solution
- Kipp dispensers for KI and  $\text{CH}_3\text{COOH}$  solutions:
  - 1 mL nominal for KI solution
  - 10 mL nominal for  $\text{CH}_3\text{COOH}$  solution

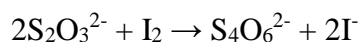
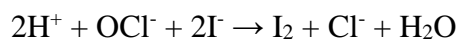
#### Analytical procedure

- 1) Transfer the sample (5.00 mL) into the 100.0 mL measuring flask and dilute it with distilled water to the mark.
- 2) Transfer part of the obtained solution (10.00 mL) into the conical flask, add 10 % KI solution (2 mL) and 5 % acetic acid solution (10 mL).

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- 3) Titrate the obtained mixture with 0.100 M Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> solution until a pale yellow colour. Add 1% starch solution (1-2 mL) and continue the titration until the colour disappears. The blue colour should not reappear for at least 30 seconds.

**During the analysis the following reactions occur:**



**Results of the titrations**

**Sample Nr .** \_\_\_\_\_

Nr.	Volume of Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> (aq.)		
1			
2			
3			

<b>Calculations:</b>	<i>Points:</i> <i>(filled by</i> <i>jury)</i>
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**Calculations (continued if necessary):**

**The concentration of the NaOCl in the sample Nr \_\_\_\_\_ is:**

\_\_\_\_\_

**Comments and signature by lab assistant:**

**Total points for Problem 1:**

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## PROBLEM 2 (22 POINTS)

### The synthesis of cyclohexanone and its isolation as a 2,4-dinitrophenylhydrazone derivative

**Introduction.** Cyclohexanone is the starting material in the synthesis of nylon, and it is manufactured in industry in large quantities. One of the most economical and nature friendly methods is the oxidation of cyclohexanol by sodium hypochlorite. The oxidation reaction is conducted in water and in industry cyclohexanone is isolated by steam distillation. In this problem you will synthesize cyclohexanone and part of it you will isolate as its derivative.

#### Reagents:

Aqueous solution of sodium hypochlorite (concentration to be determined by titration)  
Acetic acid  
Cyclohexanol  
Na<sub>2</sub>CO<sub>3</sub>  
NaCl  
Methyl tert-butyl ether (MTBE)  
2,4-Dinitrophenylhydrazine reagent (EtOH/H<sub>2</sub>O/ H<sub>2</sub>SO<sub>4</sub> solution)  
Ethanol  
Toluene  
Distilled water  
Cyclohexanone 2,4-dinitrophenylhydrazone standard

#### Glassware and equipment:

Magnetic stirrer hotplate  
Water bath  
Two-neck round-bottom flask, 250 mL  
Dropping / separating funnel, 100 ml  
Thermometer  
Measuring cylinders, 100 mL, 20 mL, 10 mL  
Beakers, conical flasks  
Dephlegmator (Vigreux column)  
Büchner funnel, Bunsen flask  
Petri dish  
Spatula  
Glass rod  
Funnels  
Universal indicator  
Drying oven, 60 °C (for communal use)  
Balance (for communal use)  
TLC plates, glass capillary tubes, TLC jar.

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### The oxidation of cyclohexanol

- Clamp the 250 mL two-neck round-bottom flask and put it in the water bath on the magnetic stirred hotplate. Pour in 5.2 mL of cyclohexanol ( $d=0.962 \text{ g/cm}^3$ ). (*The necessary amount of cyclohexanol is precisely measured and provided to each student*). Attach the 100 mL dropping funnel to one neck of the flask, attach the thermometer to the other. Heat the water bath to 40-45 °C.
- Pour the calculated volume of aqueous NaOCl solution in the 100 mL beaker. NaOCl should be taken in excess – **1.5 equiv. per 1 equiv. of cyclohexanol**. The concentration of NaOCl should be calculated from the titration.  
Slowly add glacial acetic acid (5 mL,  $d = 1.049 \text{ g/cm}^3$ ) to the NaOCl solution, while slowly stirring with the glass rod. (*Should be done in the fume hood! Do not breathe the vapour!*) Transfer the resulting mixture into the dropping funnel.
- Slowly add the oxidative mixture from the dropping funnel to the cyclohexanol over a period of 15 minutes, while stirring. Keep the internal temperature of the reaction mixture between 40-50 °C. After the addition, keep stirring at 45 – 50 °C for 15 min. Usually, to achieve this, the water bath must be heated to 60-70 °C.
- Change the hot water in the water bath to cold water, and, while stirring, add sodium carbonate until pH 7-8 (roughly 1-2 g). In order to decrease the solubility of the product in water, the mixture should be saturated with NaCl.
- Cool the mixture to 15-20 °C and transfer it to the separating funnel. Extract the mixture twice with 6-8 mL of methyl *tert*-butyl ether (MTBE). Combine the organic extracts and measure the volume.

### The synthesis of cyclohexanone 2,4-dinitrophenylhydrazone

- Pour 70 mL (*calculated so that it would be in excess*) of the 2,4-dinitrophenylhydrazine reagent into a 100 mL beaker. While stirring, add a specific volume (approximately 1/5 of the total volume) of the obtained cyclohexanone solution in MTBE. Transfer the rest of the cyclohexanone solution into a 20 mL bottle and leave it aside
- Filter the obtained slurry, wash the precipitate on the filter with water, and after that with ethanol ( $2 \times 5 \text{ mL}$ ). Transfer the precipitate into a Petri dish and dry it in the drying oven at 60 °C (10-15 min). After drying, weigh the precipitate. Calculate the yield of the crude product. Leave couple of milligrams aside for the TLC analysis.
- Crystallization.** Transfer the obtained crude product into a 200 mL conical flask, connect the flask with dephlegmator and recrystallize the substance from ethanol. Approximately 75 mL of ethanol are needed for 1 g of the product. After recrystallization, filter the crystalline solid, dry it, weigh it and calculate the yield of the recrystallization.

### Thin Layer Chromatography

By performing the TLC analysis, compare the crude product, crystallized product and the given standard of cyclohexanone 2,4-dinitrophenylhydrazone. The samples (2-3 mg) should be dissolved in toluene. Use toluene as the eluent.



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Calculate the  $R_f$  of the obtained cyclohexanone 2,4-dinitrophenylhydrazone

### Answer sheets

<p>1. Write the reaction equations for the cyclohexanone synthesis and its reaction with 2,4-dinitrophenylhydrazine.</p>	<p><i>Points (filled by jury)</i></p>
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<p>2. Calculate the necessary volume of the aqueous NaClO solution:</p> <p>Concentration of the sodium hypochlorite: _____</p> <p>Necessary volume (mL): _____</p>	<p><i>Points</i></p>
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<p>3. The volume of the cyclohexanone solution after the extraction with methyl <i>tert</i>-butyl ether (MTBE) (mL)</p> <p style="text-align: right;">_____</p> <p>4. The volume of the solution taken for the reaction with 2,4-dinitrophenylhydrazine:</p> <p>_____</p>	
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<p>5. Calculate the <b>theoretical yield</b> of the product. Since the cyclohexanone was not isolated, you should calculate the yield of its 2,4-dinitrophenylhydrazone derivative</p>	<i>Points</i>
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<p>6. Estimate the yield for the oxidation reaction “cyclohexanol → cyclohexanone” based on the mass of the crude cyclohexanone 2,4-dinitrophenylhydrazone. Doing calculation please consider that:</p> <p>a) the formation of cyclohexanone 2,4-dinitrophenylhydrazone is quantitative;</p> <p>b) only a fraction of whole cyclohexanone solution in MTBE was used.</p> <p>Mass of the crude cyclohexanone 2,4-dinitrophenylhydrazone: _____ g</p> <p>Calculation:</p>  <p>Estimated yield for the oxidation reaction “cyclohexanol → cyclohexanone”: _____ %</p>	<i>Points</i>
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<p>7. Crystallization of cyclohexanone 2,4-dinitrophenylhydrazone</p> <p>Mass of the crude product: _____ g</p> <p>Mass of the crystallized product: _____ g</p> <p>Yield of the crystallization: _____ %</p>									
<p>8. Thin Layer Chromatography:</p> <table border="1" data-bbox="145 909 1305 1137"> <thead> <tr> <th>Sample name</th> <th>R<sub>f</sub></th> </tr> </thead> <tbody> <tr> <td> </td> <td> </td> </tr> <tr> <td> </td> <td> </td> </tr> <tr> <td> </td> <td> </td> </tr> </tbody> </table> <p>Conclusion:</p>	Sample name	R <sub>f</sub>							<i>Points</i>
Sample name	R <sub>f</sub>								
<p><b>Total points for the problem 2:</b></p>									