Uniting Elements, Strengthening Bonds, Shaping Tomorrow!

30th Baltic Chemistry Olympiad

Tartu, Estonia, May 4th–6th, 2024

Theoretical exam solutions

Student's code:

Problem	1	2	3	4	5	6
Points						

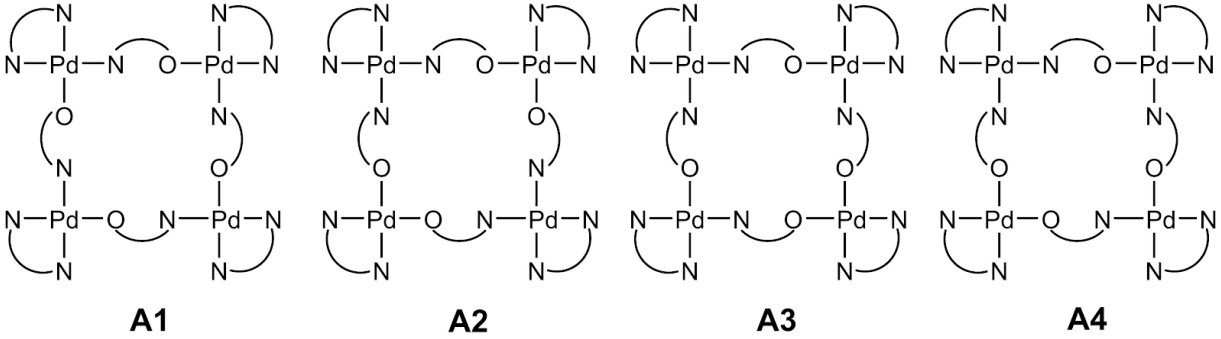
May 5th, 2024

Tartu, Estonia

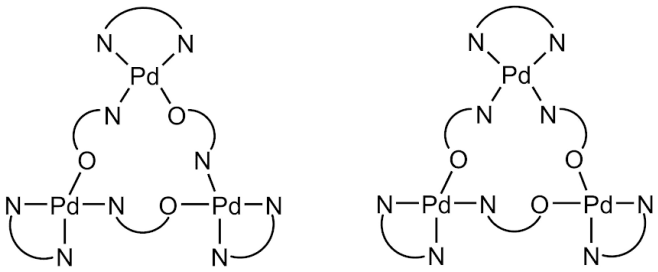
Problem 1. Polygonal chemistry. Author: Siim Kaukver

a) Dinitro(*N*,*N*,*N*′,*N*′-tetramethylethylenediamine)palladium(II) *(2 pts)*

b) Structures of **A1–A4** and **B1–B2**: *Each correct structure gives 3 points.* *(18 pts)*



A1 **A2** **A3** **A4**



B1 **B2**

c) a = **3**, b = **4** *(2 pts)*

d) First, ΔH has to be found using the Van't Hoff equation:

$$\ln\left(\frac{K_1}{K_2}\right) = -\frac{\Delta H}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

Substituting T_1 = 313 K, T_2 = 333 K, K_1 = 21.5 and K_2 = 32.1 and calculating, we get ΔH = 17.38 kJ·mol^{-1}. *(3 pts)*

A new equation can now be written to calculate K_3. It can be assumed ΔH is constant in the given temperature range. Whether K_3 is found via K_1 or K_2 makes no difference – both approaches are equally valid.

$$\ln\left(\frac{K_3}{K_1}\right) = -\frac{\Delta H}{R}\left(\frac{1}{T_3} - \frac{1}{T_1}\right)$$

By substituting known parameters and calculating, we get K_3 = **26.4**. *(3 pts)*

e) Equilibrium constant K for the reaction $3\mathbf{A} \rightleftharpoons 4\mathbf{B}$ can be written as $K = \frac{[\mathbf{B}]^4}{[\mathbf{A}]^3}$. *(1 pt)*

Let the ratio $\frac{[\mathbf{B}]}{[\mathbf{A}]}$ be equal to x. Hence, $K = [\mathbf{B}] \cdot x^3$. *(2 pts)*

Mass balance for Pd: $c_0 = 4 \cdot [\mathbf{A}] + 3 \cdot [\mathbf{B}]$. *(2 pts)*

By dividing the mass balance equation by [**B**], the following equation is obtained:

$\frac{c_0}{[\mathbf{B}]} = \frac{4}{x} + 3$, from which $[\mathbf{B}] = \frac{c_0 x}{3x+4}$. *(2 pts)*

Now, K can be expressed as: $K = [\mathbf{B}] \cdot x^3 = \frac{c_0 x^4}{3x+4}$. *(1 pt)*

Finding the exact solution is impossible under exam conditions, but a simplification can be made.

As $3x >> 4$, it can be assumed that $3x + 4 \approx 3x$. Therefore, $K = \frac{c_0 x^4}{3x+4} \approx \frac{c_0 x^3}{3}$. *(3 pts)*

Finally, $x = \sqrt[3]{\frac{3K}{c_0}} = \sqrt[3]{\frac{3 \cdot 26.4}{1.154 \cdot 10^{-3}}} \approx \mathbf{41}$. *(1 pt)*

Note: the exact solution is x = 41.38, hence the simplification is justified.

Problem 2. Unknown amino acid. Author: Andreas Päkk

a) $n(\mathrm{N}) = n(\mathrm{NH_3}) = n(\mathrm{HCl}) - n(\mathrm{NaOH})$ *(1 pt)*

$n(\mathrm{N}) = 0.1350\ \mathrm{mol \cdot dm^{-3}} \cdot 0.04000\ \mathrm{dm^3} - 0.1500\ \mathrm{mol \cdot dm^{-3}} \cdot 0.01683\ \mathrm{dm^3} = 0.002875\ \mathrm{mol}$

$w(\mathrm{N}) = \frac{0.002875\ \mathrm{mol} \cdot 14.01\ \mathrm{g \cdot mol^{-1}}}{0.3425\ \mathrm{g}} \cdot 100\% \approx \mathbf{11.76\%}$ *(1 pt)*

b) Ammonium ions, which remain in the titrated solution, act as a weak acid:

$\mathrm{NH_4^+} \rightleftharpoons \mathrm{NH_3} + \mathrm{H^+}$

As the equilibrium is considerably shifted to the left, $[\mathrm{H^+}]_{eq} = [\mathrm{NH_3}]_{eq}$, therefore:

$$K_a = \frac{[\mathrm{NH_3}][\mathrm{H^+}]}{[\mathrm{NH_4^+}]} = \frac{[\mathrm{H^+}]^2}{[\mathrm{NH_4^+}]} \Rightarrow [\mathrm{H^+}] = \sqrt{K_a \cdot c(\mathrm{NH_4^+})} = \sqrt{K_a \cdot \frac{n(\mathrm{HCl}) - n(\mathrm{NaOH})}{V(\mathrm{HCl}) + V(\mathrm{NaOH})}}$$ *(2 pts)*

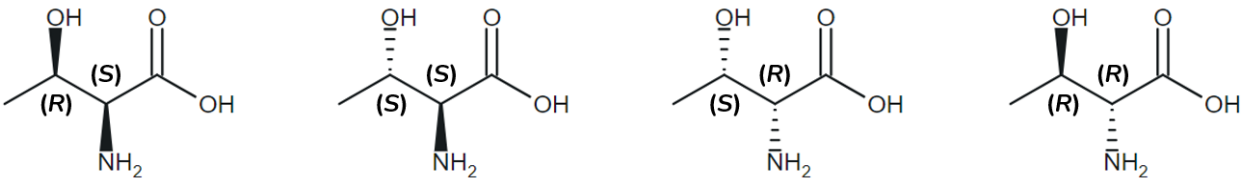
$$\mathrm{pH} = -\log[\mathrm{H^+}] = -\log\left(\sqrt{5.6 \cdot 10^{-10} \cdot \frac{0.002875\ \mathrm{mol}}{0.05683\ \mathrm{dm^3}}}\right) \approx \mathbf{5.27}$$ *(1 pt)*

c) Since **X** has two given dissociation constants, it can be assumed that there is only one ionizable amino group in its structure. The general formula of amino acids is R–CH($\mathrm{NH_2}$)COOH or R–CH($\mathrm{NH_3^+}$)$\mathrm{COO^-}$ (zwitterionic form), where the R group represents a specific side chain.

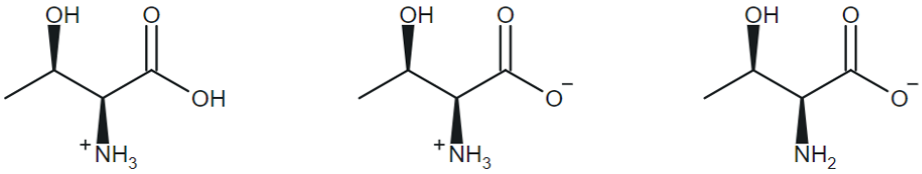
$M(\mathrm{R}) = \frac{1 \cdot 14.01\ \mathrm{g \cdot mol^{-1}} \cdot 100\%}{11.76\%} - M(\mathrm{C_2H_4NO_2}) = 45.07\ \mathrm{g \cdot mol^{-1}}$ *(1 pt)*

R corresponds to the hydroxylated carbon chain $\mathrm{CH_3CH(OH)}$–, thus the condensed structural formula of **X** is $\mathrm{CH_3CH(OH)CH(NH_2)COOH}$ or $\mathrm{CH_3CH(OH)CH(NH_3^+)COO^-}$ (Thr). *(1 pt)*

d) *Each correctly drawn stereochemical structure gives 1 point – in total 4 points.* ***Each pair*** *of correct configuration indications (S/R) gives 0,5 points – in total 2 points.*



e) *Each correctly drawn stereochemical ionic form gives 1 point – in total 3 points.*



H_2A^+ HA A^-

$\mathrm{pH} < \mathrm{p}K_{a1}$ $\mathrm{p}K_{a1} < \mathrm{pH} < \mathrm{p}K_{a2}$ $\mathrm{pH} > \mathrm{p}K_{a2}$

f) Two-step dissociation of **X**: *(2 pts)*

1. $H_2A^+ \rightleftharpoons H^+ + HA$ $\quad K_{a1} = \frac{[H^+][HA]}{[H_2A^+]} \Rightarrow [H_2A^+] = \frac{[H^+][HA]}{K_{a1}}$

2. $HA \rightleftharpoons H^+ + A^-$ $\quad K_{a2} = \frac{[H^+][A^-]}{[HA]} \Rightarrow [A^-] = \frac{K_{a2}[HA]}{[H^+]}$

At the isoelectric point $[H_2A^+] = [A^-]$, therefore: *(4 pts)*

$$\frac{[H^+][HA]}{K_{a1}} = \frac{K_{a2}[HA]}{[H^+]} \Rightarrow \frac{[H^+]}{K_{a1}} = \frac{K_{a2}}{[H^+]} \Rightarrow [H^+] = \sqrt{K_{a1}K_{a2}} = \frac{K_{a1}K_{a2}}{2}$$

$$pH = -\log[H^+] = \frac{-\log K_{a1} - \log K_{a2}}{2} = \frac{pK_{a1} + pK_{a2}}{2} = \frac{2.09 + 9.10}{2} \approx \mathbf{5.60}$$

Problem 3. Reverse engineering. Author: Ritums Cepītis

a) $\ln[A] = \ln[A]t - kt$, where $k = \frac{\ln(0.05) - \ln(1)}{30\ s} = \mathbf{0.1\ s^{-1}}$ *(2 pts)*

b) $k_{300} = 0.1\ s^{-1}$; $k_{2024} = 1.0\ s^{-1}$

$\ln\left(\frac{k_{300}}{k_{2024}}\right) = \frac{E_a}{8.314}\left(\frac{1}{2024} - \frac{1}{300}\right)$, where E_a = **6.7 kJ·mol⁻¹** *(3 pts)*

c) T_1 and t_2. *(2 pts)*

d) If T_1 is chosen, the answer is T_1 = **1230 K**. *(2 pts)*
If t_2 is chosen, the answer is t_2 = $\mathbf{3.79 \cdot 10^{-8}\ s}$. *(2 pts)*

e) The equations for the missing elementary steps: *(4 pts)*

A → A' + B	k_1
A' + B → A	k_{-1}
A' + B → B' + B + C	k_2
A' + B' → 2B	k_3

Mechanism correspondance to the given reaction law:

$$\frac{d(B')}{dt} = 0 = k_2[A'][B] - k_3[A'][B'] \Rightarrow [B'] = \frac{k_2[A'][B]}{k_3[A']} = \frac{k_2[B]}{k_3}$$

$$\frac{d(A')}{dt} = 0 = k_1[A] - k_{-1}[A'][B] - k_2[A'][B] - k_3[A'][B'] =$$
$$= k_1[A] - k_{-1}[A'][B] - k_2[A'][B] - k_2[A'][B'] =$$
$$= k_1[A] - [A'](k_{-1}[B] + 2 \cdot k_2[B])$$
$$\Rightarrow [A'] = k_1[A]$$

$$-\frac{d(A)}{dt} = k_1[A] - k_{-1}[A'][B] = k_1[A] - \frac{k_{-1}k_1[A]}{(k_{-1} + 2 \cdot k_2)} = \left(\frac{2 \cdot k_{-1}k_1}{k_{-1} + 2 \cdot k_2}\right)[A]$$

Problem 4. Have you heard about cerium? Author: Deimantas Šmigelskas

Part I. Minerals

a) There are 4 tetrahedral PO_4^{3-} ions and 4 Ce atoms in a unit cell which consists of **24** atoms in total. *(1 pt)*

b) **Th** isotopes are radioactive while La and Nd have stable isotopes. *(1 pt)*

c) $\Delta m = n(\mathrm{U}) \cdot M(\mathrm{U}) - n(\mathrm{Ce}) \cdot M(\mathrm{Ce}) = 4.53$ g

$97.91n = 4.53 \Rightarrow n = 0.0463$ *(1 pt)*

$$\frac{n}{n_0} = \frac{0.0463}{\frac{m(\mathrm{CePO_4})}{M(\mathrm{CePO_4})}} = \mathbf{0.71}$$ *(1 pt)*

d) $N_n(^{238}_{92}\mathrm{U}) = N_0 e^{-\lambda_\mathrm{U} t}$

Since there was no pre-existing lead in the mineral: $N_0 = N_n(^{238}_{92}\mathrm{U}) + N_n(^{206}_{82}\mathrm{Pb})$ *(1 pt)*

$$\frac{N_n(^{238}_{92}\mathrm{U})}{N_n(^{238}_{92}\mathrm{U}) + N_n(^{206}_{82}\mathrm{Pb})} = e^{-\lambda_\mathrm{U} t} \Rightarrow \ln\left(\frac{N_n(^{238}_{92}\mathrm{U})}{N_n(^{238}_{92}\mathrm{U}) + N_n(^{206}_{82}\mathrm{Pb})}\right) = -\lambda_\mathrm{U} t \Rightarrow$$

$$t = \frac{\ln\left(\frac{N_n(^{238}_{92}\mathrm{U})}{N_n(^{238}_{92}\mathrm{U}) + N_n(^{206}_{82}\mathrm{Pb})}\right)}{-\lambda_\mathrm{U}} = \frac{\ln\left(\frac{N_n(^{238}_{92}\mathrm{U}) + N_n(^{206}_{82}\mathrm{Pb})}{N_n(^{238}_{92}\mathrm{U})}\right)}{\lambda_\mathrm{U}} = \frac{\ln\left(1 + \frac{N_n(^{206}_{82}\mathrm{Pb})}{N_n(^{238}_{92}\mathrm{U})}\right)}{\lambda_\mathrm{U}}$$ *(2 pts)*

$$\lambda = \frac{\ln(2)}{t_{0.5}}$$

Moles of atoms can be used instead of the number of atoms and Pb mass is 206 because of $^{238}\mathrm{U} \rightarrow {}^{206}\mathrm{Pb}$ decay.

$$t = \frac{\ln\left(1 + \frac{n_n(^{206}_{82}\mathrm{Pb})}{n_n(^{238}_{92}\mathrm{U})}\right)}{\frac{\ln(2)}{t_{0.5}}} = \frac{\ln\left(1 + \frac{\frac{6.05\ \mathrm{g} \cdot 0.0001}{222\ \mathrm{g \cdot mol^{-1}}}}{2 \cdot \frac{6.05\ \mathrm{g} \cdot 0.0037}{524\ \mathrm{g \cdot mol^{-1}}}}\right)}{\ln(2)} \cdot t_{0.5} = 0.0453 \cdot t_{0.5} = \mathbf{2.02 \cdot 10^8\ years}$$ *(1 pt)*

e) 1 mol of CO_3^{2-} produces 1 mol of CO_2, which gives:

$n(\mathrm{CO_3^{2-}}) = \frac{m(\mathrm{CO_2})}{M(\mathrm{CO_2})} = 0.014224$ mol *(0.5 pts)*

$M(\mathrm{Ce_{0.48}La_{0.37}Nd_{0.1}Pr_{0.04}Sm_{0.01}CO_3F}) = \frac{m}{n(\mathrm{CO_3^{2-}})} = 219.235\ \mathrm{g \cdot mol^{-1}}$ *(0.5 pts)*

Mass balance: *(1.5 pts)*

$x \cdot M(\mathrm{La}) + y \cdot M(\mathrm{Nd}) = 219.235 - n(\mathrm{Ce}) \cdot M(\mathrm{Ce}) - n(\mathrm{Pr}) \cdot M(\mathrm{Pr}) - n(\mathrm{Sm}) \cdot M(\mathrm{Sm}) - n(\mathrm{C}) \cdot M(\mathrm{C}) - n(\mathrm{O}) \cdot M(\mathrm{O}) - n(\mathrm{F}) \cdot M(\mathrm{F})$ *(0.5 pts)*

$x \cdot M(\mathrm{La}) + y \cdot M(\mathrm{Nd}) = 65.827$ *(1 pt)*

Charge balance: *(0.5 pts)*

$3 \cdot [n(\mathrm{Ce^{3+}}) + n(\mathrm{La^{3+}}) + n(\mathrm{Nd^{3+}}) + n(\mathrm{Pr^{3+}}) + n(\mathrm{Sm^{3+}})] = 2 \cdot n(\mathrm{CO_3^{2-}}) + n(\mathrm{F^-})$

$(\mathrm{La^{3+}}) + n(\mathrm{Nd^{3+}}) = 0.47$ *(1 pt)*

The system of equations yields:

$$\begin{cases} x \cdot M(\mathrm{La}) + y \cdot M(\mathrm{Nd}) = 65.827 \\ x + y = 0.47 \end{cases} \Rightarrow (x; y) = (0.37; 0.1)$$

$Ce_{0.48}La_{0.37}Nd_{0.1}Pr_{0.04}Sm_{0.01}CO_3F$ *(1 pt)*

f) There are 6 atoms closely located to cerium in the same plane plus 3 above and 3 below the plane – in total 12 atoms, which means the coordination number of Ce is **12**. *(1 pt)*

g) $2CeO_2 + 8HCl \rightarrow 2CeCl_3 + 4H_2O + Cl_2$ *(1 pt)*

$$n(HCl) = 4 \cdot n(CeO_2) = 4 \cdot \frac{5.0 \cdot 10^3\ \text{kg} \cdot w(Ce)}{M(CeO_2) \cdot 100\%} = 45675.14\ \text{mol}$$

$$V(HCl) = \frac{n}{c} = 91350.27\ \text{dm}^3 \approx \mathbf{91\ m^3}$$ *(1 pt)*

h) β-cerium (a = 0.3681 nm, c = 1.1857 nm). DHCP structure can be subdivided into 6 rhombic prism unit cells each of which has 2 atoms inside it: *(3 pts)*

$$\rho = \frac{m(\text{atoms})}{V(\text{unit cell})} = \frac{2 \cdot \frac{M(Ce)}{N_A}}{\frac{\sqrt{3}}{2}a^2\frac{c}{2}} = \mathbf{6.69\ g{\cdot}cm^{-3}}$$

γ-cerium (a = 0.5161 nm). FCC unit cell contains 4 atoms of Ce: *(2 pts)*

$$\rho = \frac{m(\text{atoms})}{V(\text{unit cell})} = \frac{4 \cdot \frac{M(Ce)}{N_A}}{a^3} = \mathbf{6.77\ g{\cdot}cm^{-3}}$$

Thus, γ-cerium is more dense than β-cerium. *(0.5 pts)*

Part II. Cerium loves redox

i) $H^+ + [Ce(NO_3)_6]^{2-} + Fe(OH)_2 + Cu_2O \rightarrow Ce^{3+} + Fe^{3+} + Cu^{2+} + H_2O + NO_3^-$

Oxidation half-equations:

$2H^+ + Fe(OH)_2 \rightarrow Fe^{3+} + 2H_2O + e^-$ | · 4 *(0.5 pts)*

$2H^+ + Cu_2O \rightarrow 2Cu^{2+} + + 2e^-$ | · 1 *(0.5 pts)*

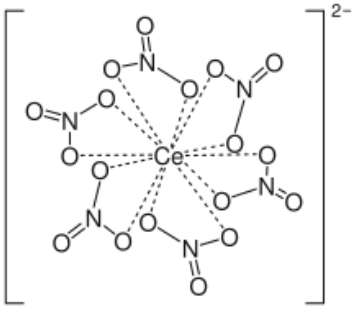
Reduction half-equation:

$[Ce(NO_3)_6]^{2-} + e^- \rightarrow Ce^{3+} + 6NO_3^-$ | · 6 *(0.5 pts)*

The sum of oxidation and reduction half-equations:

$\mathbf{10}H^+ + \mathbf{6}[Ce(NO_3)_6]^{2-} + \mathbf{4}Fe(OH)_2 + Cu_2O \rightarrow \mathbf{6}Ce^{3+} + \mathbf{4}Fe^{3+} + \mathbf{2}Cu^{2+} + \mathbf{9}H_2O + \mathbf{36}NO_3^-$ *(0.5 pts)*

j) The structrure of the anion of CAN: *(1 pt)*



k) *Each identified compound **A–C** gives 1 point.* *(3 pts)*

A must contain Ce and O. Hydrogen in water is a weak oxidizing agent, so Ce will be in +3 form, and out of Ce_2O_3, CeO(OH), $Ce(OH)_3$, or other non-polymeric formulas, $Ce(OH)_3$ gives the right answer. In the second reaction peroxide ion is consumed and water is produced, meaning that the HO_2^- ion has lost its hydrogen and replaced two OH^- ions in hydroxide resulting in **B**

$Ce(O_2)OH$ (Ce cannot be +4 here because no oxidation occurrs for cerium). However, anhydride $Ce_2(O_2)_2O$ formed after dimerization of $Ce(O_2)OH$ followed by H_2O abstraction is also a possible choice. Ce must be +4 in **C** due to oxidation and since all oxygens have the same oxidation number CeO_2 or $Ce(OH)_4$ are possible. The absence of stronger base to deprotonate OH^- leaves us with the choice of $Ce(OH)_4$.
Balanced reaction equations: *(3 pts)*

i) $2Ce + 6H_2O \rightarrow 2Ce(OH)_3 + 3H_2$

ii) $Ce(OH)_3 + HO_2^- \rightarrow Ce(O_2)OH + H_2O + OH^-$
or $2Ce(OH)_3 + 2HO_2^- \rightarrow Ce_2(O_2)_2O + 3H_2O + 2OH^-$

iii) $2Ce(O_2)OH + 3H_2O + OH^- \rightarrow 2Ce(OH)_4 + HO_2^-$
or $Ce_2(O_2)_2O + 4H_2O + OH^- \rightarrow 2Ce(OH)_4 + HO_2^-$

l) Ceria (CeO_2) plays a special role in heterogeneous catalysis. In the ideal cell of CeO_2, the structure consists of a **face-centered** cubic unit cell of cations with anions occupying the **tetrahedral** holes. In the structure, each cerium cation is coordinated by **8** nearest-neighbor oxygen anions, while each oxygen anion is coordinated by **4** nearest-neighbor cerium cations. Ceria can also be doped with other metal cations to alter electric conductivity. When cerium cations are replaced with lower oxidation state elements (M^{2+}/M^{3+}), the lattice oxygen atoms in CeO_2 are **removed**. The ceria crystal usually exhibits a few defects due to the co-existence of Ce^{4+} and **Ce^{3+}** ions. /…/ Because the metal surfaces are essentially saturated in CO when excess CO is present, the rate-limiting step for the reaction is **2** . /…/ *(3 pts)*

m) **I** – NO_x (NO, NO_2); **J** – O_2; **K** – O; **I** – Ce_2O_3; **M** – H_2. *(3 pts)*

n) **5.** $2CeO_2 \rightarrow O_{ad} + Ce_2O_3$ *(1 pt)*

6. $Ce_2O_3 + 0.5O_2 \rightarrow 2CeO_2$ *(1 pt)*

7. $Ce_2O_3 + H_2O \rightarrow 2CeO_2 + H_2$ *(1 pt)*

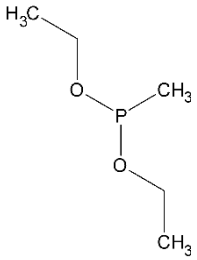
o) $Ce(5,5'\text{-}(Cl)_2\text{-salen})_2$ is a stronger oxidizing agent, because methoxy-substituted aromatic rings are more electron-rich, therefore, stabilizing central Ce(IV). *(1 pt)*

Problem 5. Poisonous chemicals. Author: Denis Sokol

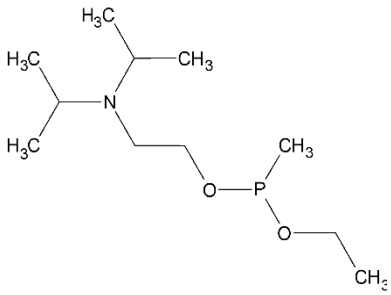
a) **A** – $[PCl_3CH_3]^+[AlCl_3I]^-$ *(4 pts)*

b) *Each correct structure gives 4 points – in total 12 points.* *(12 pts)*

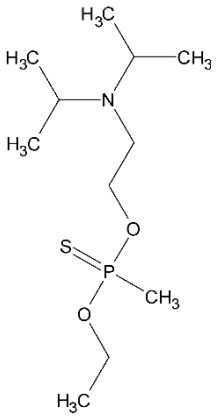
B –

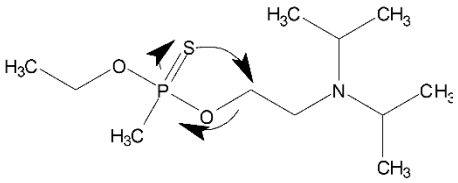


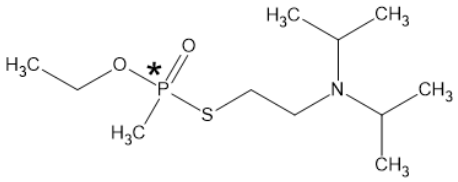
C –

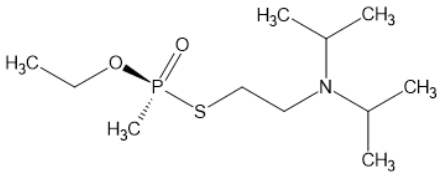
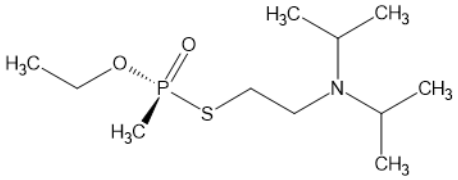


D –

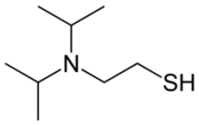
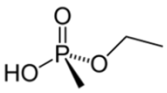


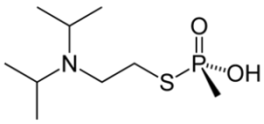
c)  *(4 pts)*

d)  *(2 pts)*

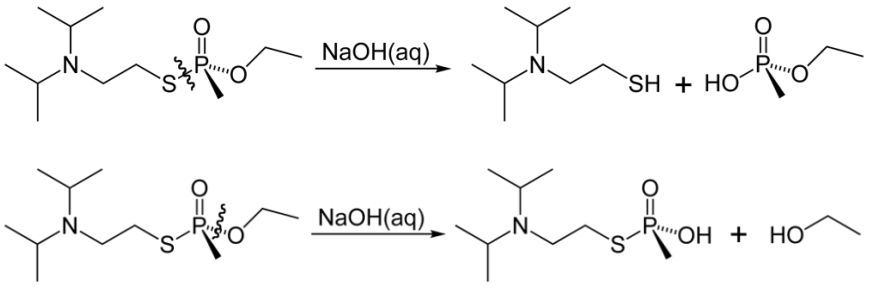
e) **2** isomers:  and  *(1 pt)*

f) *Each correct structure gives 2 points – in total 8 points.* *(8 pts)*

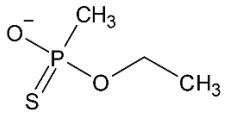
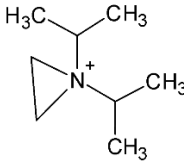
E –  **F** – 

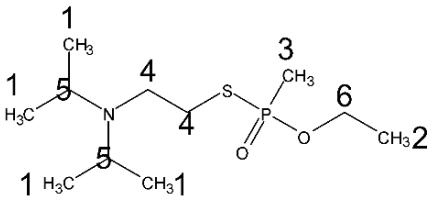
G –  **H** – 

Hydrolysis reactions with aqueous sodium hydroxide:



g) **G** *(2 pts)*

h) **I** –  **J** –  *(8 pts)*

i)  *(4 pts)*

j) Phosphorus *(4 pts)*

k) **qd**, **sept**, **s** (should be multiplate in a real spectrum), **d**, **t**, **d**. *(2 pts)*

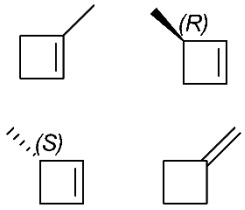
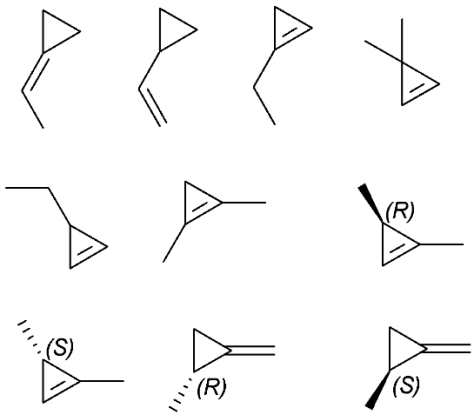
l) LD = $\frac{7\ \text{mg} \cdot 30\ \text{dm}^3}{1000\ \text{dm}^3} = 0.21\ \text{mg} = \mathbf{0.00021\ g}$ *(1 pt)*

m) LD = $\frac{0.00021\ \text{g}}{80\ \text{kg}} = \mathbf{2.62 \cdot 10^{-6}\ g \cdot kg^{-1}}$ *(1 pt)*

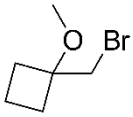
n) **3816** lethal doses. *(1 pt)*

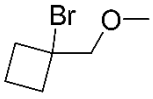
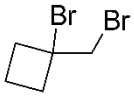
Problem 6. Simple organic chemistry. Author: Nauris Narvaišs

a) *Structure drawing is not required, only a numerical answer.* *(5 pts)*

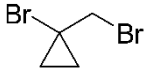
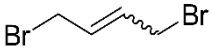
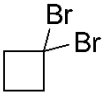
i) 1 *(1 pt)*	**ii) 4** *(2 pts)*	**iii) 10** *(2 pts)*
		

b) The structure of the symmetrical isomer:  *(3 pts)*

c) The main product:  *(3 pts)*

Other products:  *(1 pt)* or  *(0 pts)*

d) Structures of compounds **H1** and **B1**–**B3**: *Each correct structure gives 3 points.* *(12 pts)*

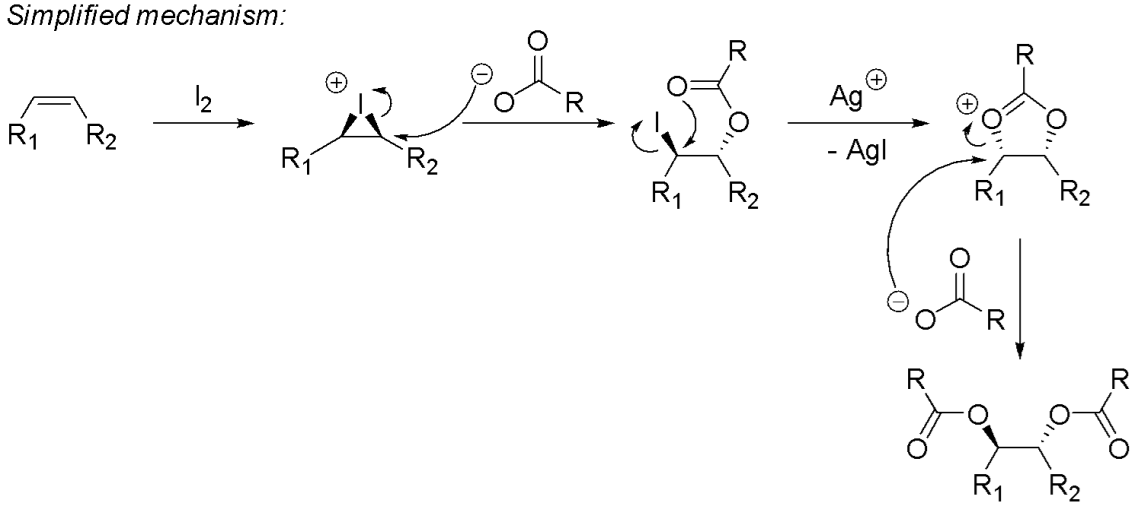
H1	**B1**	**B2**	**B3**
		 *(either cis or trans)*	

e) Number of possible stereoisomers and products: *1 point for each correct answer.* *(4 pts)*

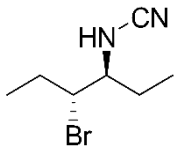
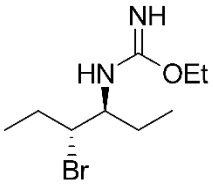
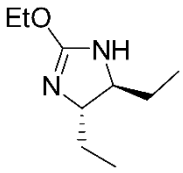
	i) (R1 = R2) ≠ H	**ii)** (R1 ≠ R2) ≠ H
Stereoisomers formed	**2**	**2**
Exist in total for product	**3**	**4**

f) *1 pt for formation of iodonium, 1 pt for attack on iodonium, 1 pt for cyclization, 1 pt for attack of second carboxylate. If mechanism is just 2 S_N2 reactions, then 2 pts total. If relative stereochemistry is incorrect or missing, then 1 pt deduction.*

Simplified mechanism:



g) Compounds **A1–A3**: *(9 pts)*

A1	**A2**	**A3**
		
If stereochemistry is incorrect or not specified 2 pts in total.	*3 pts*	*If stereochemistry is incorrect or not specified 2 pts in total.*

h) *1 pt for bromonium formation, 2 pts for rearrangement, 1 point for elimination. 0.5 pts for E_2 instead of E_1CB.*

Simplified mechanism: