2020/2021. õa keemiaolümpiaadi lahtise võistluse ülesanded
Vanem rühm (11. ja 12. klass)
2. oktoober 2021
Lahendused

1. Analoogfotograafia — Kokku 10 p

Allikas: Gerge T. Eaton, Photographic Chemistry.

a) $2AgBr = 2Ag + Br_2$ (1)

b) $K_3[Fe(CN)_6]$ = kaaliumheksatsüanoferraat(III) või kaaliumheksatsüanidoferraat(III) (1)
$Ag_4[Fe(CN)_6]$ = hõbeheksatsüanoferraat(II) või hõbeheksatsüanidoferraat(II) (1)

c) (**1**) $\mathbf{4}Ag + \mathbf{4}K_3Fe(CN)_6 + \mathbf{6}Pb(NO_3)_2 = Ag_4Fe(CN)_6 + \mathbf{3}Pb_2Fe(CN)_6 + \mathbf{12}KNO_3$ (2)
(**2**) $Ag_4Fe(CN)_6 + \mathbf{2}Na_2S = \mathbf{2}Ag_2S + Na_4Fe(CN)_6$ (1)
(**3**) $Pb_2Fe(CN)_6 + \mathbf{2}Na_2S = \mathbf{2}PbS + Na_4Fe(CN)_6$ (1)

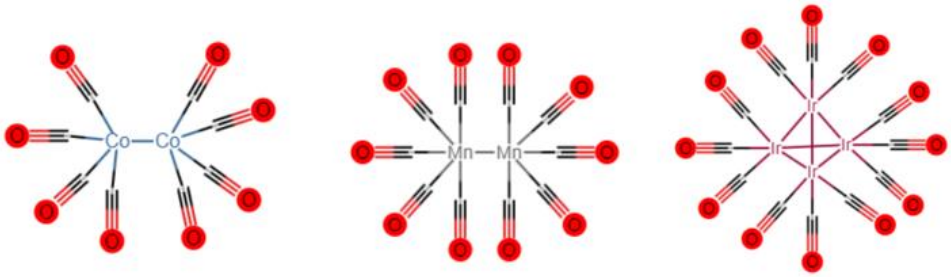
d) (**4**) $\mathbf{4}Ag + \mathbf{4}K_3Fe(CN)_6 = Ag_4Fe(CN)_6 + \mathbf{3}K_4Fe(CN)_6$ (2)
(**5**) $Ag_4Fe(CN)_6 + \mathbf{8}Na_2S_2O_3 = Na_4Fe(CN)_6 + \mathbf{4}Na_3Ag(S_2O_3)_2$ (1)

2. Metallide karbonüülühendid — Kokku 10 p

a) $a = 8$, $b = 5$, ja $c = 4$ (3)

b) o.a.(V) = −1, o.a.(Mn) = −1, o.a.(Fe) = −2 (3)

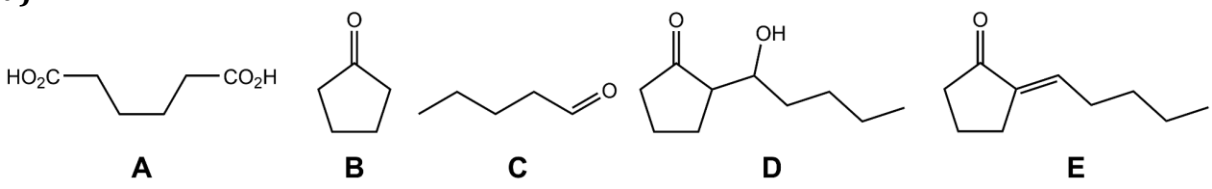
c) (3)



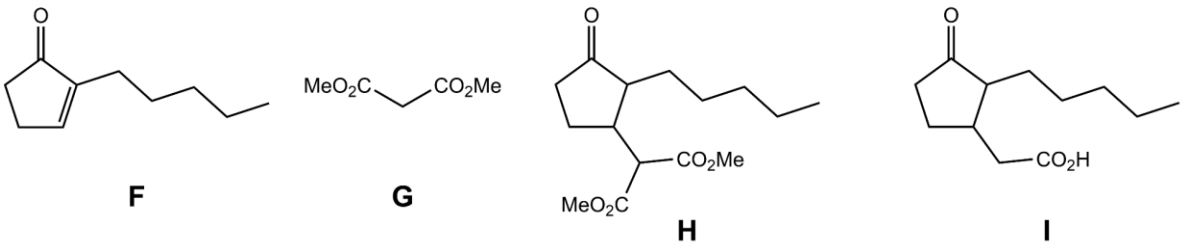
d) $g = 4$ (1)

3. Tehisparfüüm (IChO PP 1995) — Kokku 10 p

a) (9)

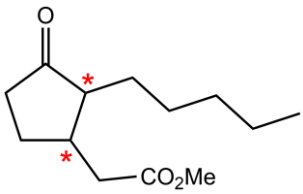


A **B** **C** **D** **E**



F **G** **H** **I**

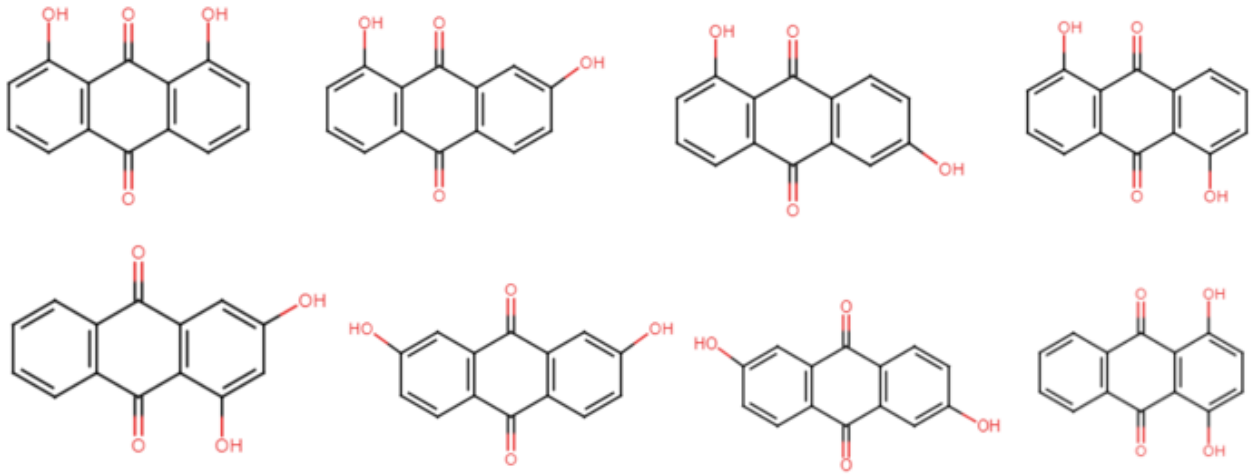
b)



(1)

4. Rabarber (IChO PP 1995) **Kokku 10 p**

a) (2)



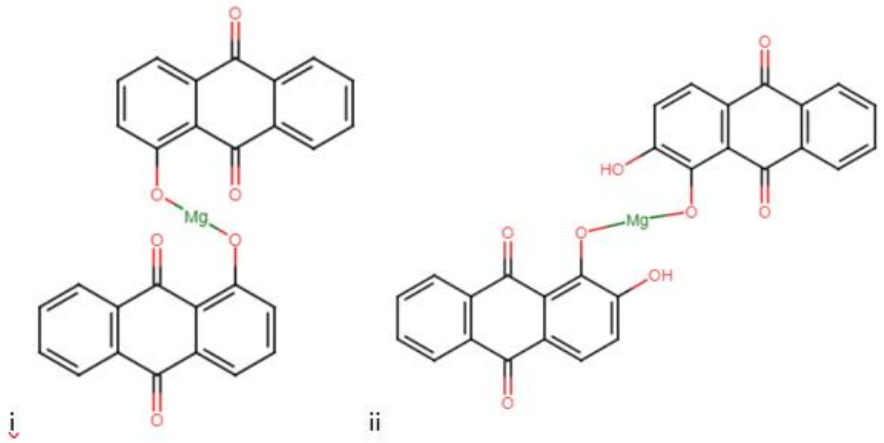
b) 10 (1)

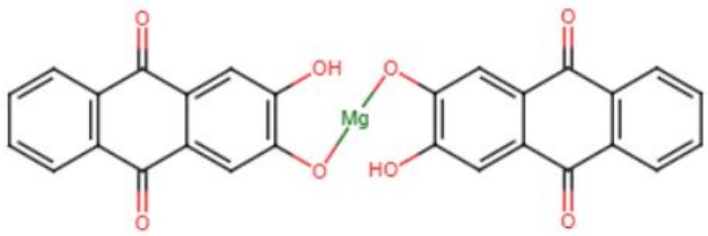
c) happeline keskkond iga ühendi jaoks (2)

d) **A > B** (0,5)

C > D (0,5)

e) (3)





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f) ühendites **B** ja **D** mõlemad C=O rühmad on keemiliselt ekvivalentsed, **A** ja **C** puhul aga üks neist moodustab vesiniksidet ühe –OH rühmaga. Seega karbonüülsed rühmad ei ole enam ekvivalentsed. (1)

5. Alkalimeetria (IChO PP1995) **Kokku 10 p**

a) **i)** $NH_4Cl + NaOH = NH_3 + NaCl + H_2O$ (0,5)

ii) $4NH_3 + 6CH_2O = (CH_2)_6N_4 + 6H_2O$ (1)

iii) $NH_3 + HCl = NH_4Cl$ (0,5)

b) $n(NH_3)_{üld} = 40{,}00\ cm^3 \cdot 0{,}1000\ M = 4{,}000\ mmol$ (0,5)

$n(NH_3)_{reag} = 4{,}000\ mmol - 15{,}40\ cm^3 \cdot 0{,}1000\ M = 2{,}460\ mmol$ (1)

$m(CH_2O) = 2{,}460\ mmol \cdot 6/4 \cdot 1\ mol/1000\ mmol \cdot 30{,}0\ g/mol = 0{,}1107\ g$ (0,5)

$w(CH_2O) = 0{,}1107\ g/0{,}300\ g \cdot 100\% =$ **36,9%** (1)

c) $n(HCO_2H) = 0{,}300\ g \cdot 1\ \%/100\ \%/46{,}0\ g/mol \cdot 1000\ mmol/mol = 0{,}0650\ mmol$ (0,5)

$n(NH_3)_{reag} = 4{,}000\ mmol - 15{,}40\ cm^3 \cdot 0{,}1000\ M - 0{,}0650\ mmol = 2{,}395\ mmol$ (0,5)

$m(CH_2O) = 2{,}395\ mmol \cdot 6/4 \cdot 1\ mol/1000\ mmol \cdot 30{,}0\ g/mol = 0{,}1078\ g$

$w(CH_2O) = 0{,}1078\ g/0{,}300\ g \cdot 100\% =$ **35,9%** (1)

d) $V_{üld} = (25{,}00 + 40{,}00 + 15{,}4)\ cm^3 = 80{,}4\ cm^3$

$c_B = c((CH_2)_6N_4) = (40{,}00 - 15{,}40)\ cm^3 \cdot 0{,}1000\ M \cdot 4/80.40\ cm^3 = 0{,}00765\ M$ (0,5)

$c_A = c(NH_4^+) = 0{,}300\ g/53{,}5\ g/mol \cdot 0{,}08040\ dm^3 - 0{,}00765\ M \cdot 4 = 0{,}0391\ M$ (0,5)

$(CH_2)_6N_4 + NH_4^+ = NH_3 + (CH_2)_6N_4H^+$ $K = 10^{-9{,}25} : 10^{-4.89} = 10^{-4{,}36}$

$K = 10^{-4{,}36} = x^2/(c_B - x)(c_A - x) \Rightarrow [NH_3] = x \approx 10^{-4{,}36/2} \cdot \sqrt{c_A c_B} = 0{,}000114\ M$ (0,5)

$pK_a = pK_w - pK_b = [NH_3][H^+]/[NH_4^+]$

$[H^+] = 10^{-9.25} \cdot 0{,}03145/0{,}000114 = 10^{-6.8}$ (0,5)

pH = **6.8** (1)

6. Etüün **Kokku 10 p**

a) $\rho = \frac{m}{V} = \frac{n \cdot M}{V}$

$pV = nRT \therefore \frac{n}{V} = \frac{p}{RT}$

$M_{etüün} = (2 \cdot 12{,}01 + 2 \cdot 1{,}008)\ g \cdot mol^{-1} = 26{,}04\ g \cdot mol^{-1} \approx 0{,}026\ kg \cdot mol^{-1}$ (0,5)

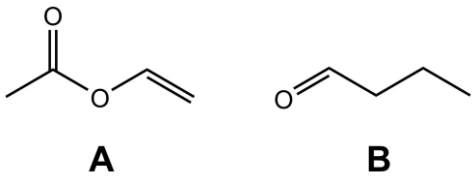
$T = 20\ °C = 293{,}15\ K,\ p = 1\ atm = 101325\ Pa$

$\rho_{etüün} = \frac{pM}{RT} = \frac{101325\ Pa \cdot 0{,}026\ kg \cdot mol^{-1}}{8{,}314\ J \cdot K^{-1} \cdot mol^{-1} \cdot 293{,}15\ K} \approx 1{,}08\ kg \cdot m^{-3} = 1{,}08 \cdot 10^{-3}\ kg \cdot dm^{-3}$ (0,5+1)

b) $2\ C_2H_2 + 5\ O_2 \rightarrow 4\ CO_2 + 2\ H_2O$ (1)

c) Kütteväärtuse saab leida tehtega: $\frac{16{,}25\ kJ \cdot 10^{-3} MJ \cdot kJ^{-1}}{300 \cdot 10^{-3}\ dm^3 \cdot 1{,}08 \cdot 10^{-3}\ kg \cdot dm^{-3}} = 50{,}15\ MJ \cdot kg^{-1}$ (1)

d) (2)



A **B**

e) Sobib ainult **NaOH**. (1)

f) Iga kahe polüvinüülalkoholi monomeeri kohta reageerib üks **B** molekul. Seega $m = \frac{n}{2}$. (1)

g) $a_x = \frac{1}{1-x} = \frac{1}{1-0{,}998} = 500$ (0,5)

$M_{monomeer} = (12{,}01 \cdot 2 + 16{,}00 + 1{,}008 \cdot 4)\ g/mol = 44{,}05\ g/mol$ (0,5)

$M_{polümeer} = M_{monomeer} \cdot a_x = 44{,}05\ g/mol \cdot 500 = 22025\ g/mol \approx 22\ kg/mol$ (1)

7. Vase sulam **Kokku 10 p**

a) $3Cu + 8HNO_3 = 3Cu(NO_3)_2 + 2NO + 4H_2O$ (2)

b) $n(Na_2EDTA \cdot 2H_2O) = n(EDTA) = \frac{0{,}773\ g}{372{,}24\ g/mol} = 0{,}00208\ mol$ (1)

$c(EDTA) = \frac{0{,}00208\ mol}{0{,}1000\ dm^3} =$ **0,0208 M** (1)

c) $n(EDTA) = n(\mathbf{M}+Cu) = 0{,}0208\ mol/dm^3 \cdot 0{,}01153\ dm^3 = 0{,}0002398\ mol$

$n(\mathbf{M}+Cu)_{proov} = 0{,}0002398\ mol \cdot 10 = 0{,}002398\ mol$ (1)

$n(\text{EDTA})' = n(\mathbf{M}) = c \cdot V = 0{,}0208\ \text{mol/dm}^3 \cdot 0{,}00426\ \text{dm}^3 = 0{,}00008861\ \text{mol}$

$n(\mathbf{M})_{\text{proov}} = 0{,}00008861\ \text{mol} \cdot 10 = 0{,}0008861\ \text{mol}$

$n(\text{Cu})_{\text{proov}} = n(\mathbf{M}+\text{Cu})_{\text{proov}} - n(\mathbf{M})_{\text{proov}} = 0{,}002398\ \text{mol} - 0{,}0008861\ \text{mol} =$ **0,00151 mol** (1)

d) $m(\text{Cu})_{\text{proov}} = n(\text{Cu})_{\text{proov}} \cdot M(\text{Cu}) = 0{,}00151\ \text{mol} \cdot 63{,}55\ \text{g/mol} = 0{,}0960\ \text{g}$

$w(\text{Cu}) = \frac{0{,}0960\ \text{g}}{0{,}1538\ \text{g}} \cdot 100\% =$ **62,4 %** (1)

e) Naatriumtiosulfaadi lahus moodustas vasega püsiva kompleksi ning EDTA reageeris seetõttu vaid metalli **M** kahevalentsete ioonidega. (1)

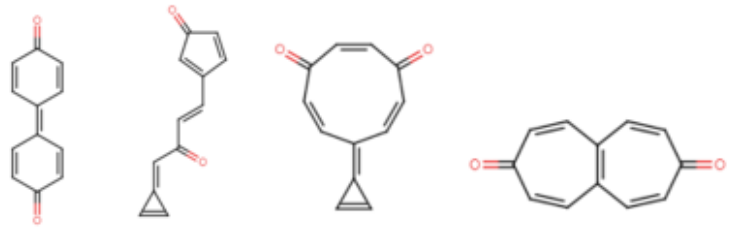
f) $m(\mathbf{M})_{\text{proov}} = m(\mathbf{M}+\text{Cu})_{\text{proov}} - m(\text{Cu}) = 0{,}1538\ \text{g} - 0{,}0960\ \text{g} = 0{,}0578\ \text{g}$ (1)

$M(\mathbf{M}) = m(\mathbf{M})_{\text{proov}} / n(\mathbf{M})_{\text{proov}} = 0{,}0578\ \text{g} / 0{,}0008861\ \text{mol} = 65{,}23\ \text{g/mol}$

Tegemist pole täiesti täpse molaarmassiga, sest vahepealseid tulemusi on ümardatud. Kõige paremini vastab see **tsingi molaarmassile (65,38)**, mis on ka kahevalentne metall (nagu ülesande tekstis kirjutatud). (1)

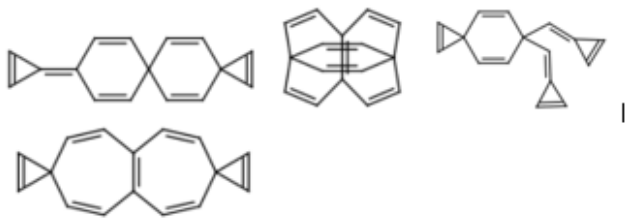
8. Osonolüüs — Kokku 10 p

a)

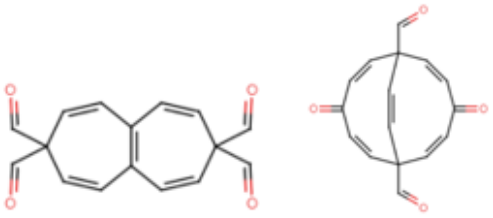


b)

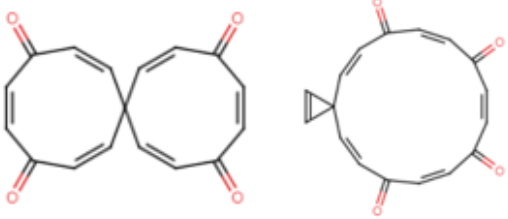
c)



d)



e)



9. Mõistatus **Kokku 10 p**

a) (**1**) $O_2 + 2Na = Na_2O_2$ **D**
(**2**) $O_2 + C = CO_2$ **E**
(**3**) $O_2 + S = SO_2$ **F**
(**4**) $2Na_2O_2 + 2CO_2 = 2Na_2CO_3 + O_2$ **G**
(**5**) $Na_2CO_3 + SO_2 = Na_2SO_3 + CO_2$ **H**
(**6**) $Na_2SO_3 + S = Na_2S_2O_3$ **I**
(**7**) $2Na_2SO_3 + O_2 = 2Na_2SO_4$ **J**
(**8**) $S + 2Na = Na_2S$ **K**
(**9**) $2S + C = CS_2$ **L**
(**10**) $Na_2S + CS_2 = Na_2CS_3$ **M**