2004/2005 õa keemiaolümpiaadi lõppvooru ülesannete lahendused
10. klass

1. a) I – Ag, hõbe; **II** – Al, alumiinium, **III** – Zn, tsink

b) $Ag + 2HNO_3 = AgNO_3 + NO_2 + H_2O$

$2Al + 6HCl = 2AlCl_3 + 3H_2\uparrow$

$2Al + 2NaOH + 6H_2O = 2Na[Al(OH)_4] + 3H_2\uparrow$

või $2Al + 6NaOH + 6H_2O = 2Na_3[Al(OH)_6] + 3H_2\uparrow$

$Zn + 2HCl = ZnCl_2 + H_2\uparrow$

$Zn + 4HNO_3 = Zn(NO_3)_2 + 2NO_2 + 2H_2O$

$Zn + NaOH + 2H_2O = Na[Zn(OH)_3] + H_2\uparrow$

või $Zn + 2NaOH + 2H_2O = Na_2[Zn(OH)_4] + H_2\uparrow$

c) Hõbe on passiivne metall. Al ja Zn on kaetud oksiidide tiheda kaitsekihiga, vastavalt Al_2O_3 ja ZnO.

2. a) i) Aine **D** saab olla elemendi **A** oksiid.

$M_r(\mathbf{A}) = 16 \cdot \frac{47}{53} = 14{,}1$

Pole tõenäoline, et ainukesteks saadusaineteks on NO ja NH_3.

$M_r(\mathbf{A}) = 32 \cdot \frac{47}{53} = 28{,}3$ **A** – Si, räni

D – SiO_2, ränidioksiid (liiv)

ii) A – Si, räni

B – N_2, lämmastik

C – Si_3N_4, räninitriid

E – H_2O, vesi

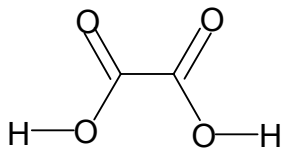
b) i) $3Si + 2N_2 \xrightarrow{CuO} Si_3N_4$

ii) $Si_3N_4 + 6H_2O = 3SiO_2 + 4NH_3$

iii) $2NH_3 + H_2SO_4 = (NH_4)_2SO_4$

c) Räni saamise protsess on väga kulukas.

3. a)



b) $(COOH)_2 + 2NaOH = (COONa)_2 + 2H_2O$

c) i) $M[(COOH)_2 \cdot 2H_2O] = (12{,}011 \cdot 2 + 16{,}00 \cdot 6 + 1{,}008 \cdot 6)$ g/mol = 126,07 g/mol

ii) $0{,}1\ dm^3 \cdot 0{,}05000\ mol/dm^3 \cdot 126{,}07\ g/mol = 0{,}63035\ g \approx 630{,}4\ mg$

d) $c(NaOH) = \frac{2}{1} \cdot 0{,}05000\ mol/dm^3 \cdot \frac{10\ cm^3}{10{,}20\ cm^3} = 0{,}09804\ mol/dm^3$

e) $\%(NaOH) = \frac{0{,}09804\ \text{mol/dm}^3 \cdot 1\,\text{dm}^3 \cdot 40{,}0\ \text{g/mol}}{5{,}2\,\text{cm}^3 \cdot 1{,}54\ \text{g/cm}^3} \cdot 100 \approx 49$

4. a) i) A – Fe, raud

ii) $CaCO_3 = CaO + CO_2\uparrow$

iii) $2Fe + O_2 = 2FeO$

b) i) R – Fe sool; **M** – Ca sool

ii) $M(\mathbf{X}) = 55{,}8 \cdot \frac{36{,}5}{63{,}5} = 32{,}1$

iii) $M(\mathbf{X}) = 40{,}1 \cdot \frac{44{,}4}{55{,}6} = 32{,}0$

c) Y – P, fosfor
Q – C, süsinik
Z – Si, räni
X – S, väävel
R – FeS, raud(II)sulfiid
B – FeO, raud(II)oksiid
D – P_4O_{10}, tetrafosfordekaoksiid
E – CO, süsinikmonooksiid
G – SiO_2, ränidioksiid
J – CaO, kaltsiumoksiid
L – CO_2, süsinikdioksiid
M – CaS, kaltsiumsulfiid

d) i) $10FeO + 4P = 10Fe + P_4O_{10}$

ii) $FeO + C = Fe + CO$

iii) $2FeO + Si = 2Fe + SiO_2$

iv) $CaO + FeS = FeO + CaS$

5. a) i) $Cl^- + AgNO_3 = AgCl\downarrow + NO_3^-$

ii) Y – Cl, kloor
Q – $AgNO_3$, hõbenitraat
Z – AgCl, hõbekloriid

b) 100 g kristallhüdraadis on $n(O) = 100\ \text{g} \cdot 0{,}36 \cdot \frac{1\,\text{mol}}{16\ \text{g}} = 2{,}25$ mol

$n(H) = 100\ \text{g} \cdot 0{,}045 \cdot \frac{1\,\text{mol}}{1{,}0\ \text{g}} = 4{,}5$ mol

c) Kuna ülesandes on öeldud, et vesinik kuulub ainult veemolekulide koostisse, saame $n(H_2O) = ½\ n(H) = 2{,}25$ mol. Saadud vee hulk on võrdne hapniku hulgaga. Kuna $n(H_2O) = n(O)$, siis sellest järeldub, et hapnik kuulub samuti ainult neutraalsete veemolekulide koostisse ja aniooni koostises hapnikku pole. Seega moodustub anioon ainult elemendist **Y** (Cl^-).

Kuna metall **X** on kolmelaenguline, siis kristallhüdraadi brutovalem peab olema $\mathbf{X}Cl_3 \cdot nH_2O$. Siit

$n(\mathbf{X}) = \frac{n(Cl)}{3} = 100\ \text{g} \cdot 0{,}40 \cdot \frac{1\,\text{mol}}{35{,}5} \cdot \frac{1}{3} = 0{,}3756$ mol

$M(\mathbf{X}) = 100\ \text{g} \cdot 0{,}195 \cdot \frac{1}{0{,}3756} = 51{,}9$

X – Cr, kroom

Kristallhüdraadi brutovalem on: $CrCl_3 \cdot 6H_2O$

d) Metalli koordinatsiooniarv on kuus. Hõbedaioonidega astuvad reaktsiooni ainult välissfääri ioonid. Seega peavad isomeeride valemid olema järgmised:

A – $[Cr(H_2O)_6]Cl_3$

B – $[Cr(H_2O)_5Cl]Cl_2 \cdot H_2O$

C – $[Cr(H_2O)_4Cl_2]Cl \cdot 2H_2O$

6. a) **A** – H_2O, vesi, divesinikmonooksiid

B – CO_2, süsinikdioksiid

Z – O_2, hapnik

C – HCl, vesinikkloriid

D – H_2, vesinik

E – Cl_2, kloor

b) $n(C) = 180\ g \cdot 0{,}4 \cdot \frac{1\ mol}{12\ g} = 6\ mol$

$n(H) = 180\ g \cdot 0{,}067 \cdot \frac{1\ mol}{1\ g} = 12\ mol$

$n(O) = 180\ g \cdot 0{,}533 \cdot \frac{1\ mol}{16\ g} = 6\ mol$

Q – $C_6H_{12}O_6$, glükoos

c) $6H_2O + 6CO_2 = C_6H_{12}O_6 + 6O_2$

d) $m(H_2O) = 1{,}00 \cdot 10^{25} \cdot \frac{1\ mol}{6{,}02 \cdot 10^{23}} \cdot 18\ g/mol = 299\ g$

$V(lahus) = V(H_2O) = 299\ g \cdot \frac{1\ dm^3}{1000\ g} = 0{,}299\ dm^3$

$n(HCl) = 1{,}5 \cdot 10^{21} \cdot \frac{1\ mol}{6{,}02 \cdot 10^{23}} = 0{,}00249\ mol$

$c(HCl) = \frac{0{,}00249\ mol}{0{,}299\ dm^3} = 0{,}0083\ mol/dm^3$ (kaks tüvenumbrit)

2004/2005 õa keemiaolümpiaadi lõppvooru ülesannete lahendused
11. klass

1. a) $m(H_2O) = 55\ m \cdot 1{,}5\ m \cdot 0{,}05 \cdot 920\ kg/m^3 = 3795\ kg$

molaalne kontsentratsioon $m(ioonid) = 3{,}0\,K \cdot \frac{1\,mol}{1{,}86 \cdot K \cdot kg} = 1{,}613\ mol/kg$

$n(NaCl) = 1{,}613\,mol/kg \cdot \frac{1}{2} \cdot 3795\,kg = 3060{,}5\ mol$

$m(NaCl)$ $= 3060{,}5\ mol \cdot 58{,}44\ g/mol \cdot \frac{1\,kg}{1000\,g} = 178{,}8\ kg \approx$ **180 kg**

b) Kui lahustuvus on 30,0 g, siis 1 kg vee kohta on lahustunud 30<u>0</u> g.

$\Delta T = 2 \cdot 300\,g \cdot \frac{1\,mol}{58{,}44\,g} \cdot \frac{1}{kg} \cdot 1{,}86 \frac{K \cdot kg}{mol} = 19{,}09\ K \approx 19{,}1\ K$

$t^0_{külm} = 0\ ^0C - 19{,}1\ K =$ **$-19{,}1\ ^0C$**

2. a) i) A – NCl_3, lämmastiktrikloriid; kloronitriid
B – NBr_3, lämmastiktribromiid; brominitriid
C – NI_3, lämmastiktrijodiid; jodonitriid
D – NF_3, lämmastiktrifluoriid; fluoronitriid
E – CO_2, süsinikdioksiid
F – HCl, vesinikkloriid (soolhape)
G – NH_3, ammoniaak

ii) Me_3SiCl

iii) $n(NH_3) = \frac{446 - (14 + 3 \cdot 127)}{17} = 3$

Kompleksmolekuli valem on **$NI_3(NH_3)_3$**

b) i) $NH_4Cl + 3Cl_2 = NCl_3 + 4HCl$

ii) $(NH_2)_2CO + 6Cl_2 + H_2O = 2NCl_3 + CO_2 + 6HCl$

iii) $3NH_4Cl \xrightarrow{\text{elektrolüüs}} NCl_3 + 3H_2 + 2NH_3$

iv) $(Me_3Si)_2NBr + 2ClBr = NBr_3 + 2Me_3SiCl$

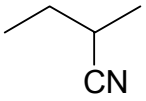
v) $3I_2 + 7NH_3 \cdot H_2O = NI_3 \cdot (NH_3)_3 + 3NH_4I + 7H_2O$

vi) $BN + 3IF \xrightarrow{\text{detonatsioon}} NI_3 + BF_3$

vii) $2NI_3 \xrightarrow{\text{vaskkatalüsaator}} N_2 + 3I_2$

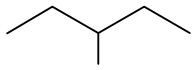
viii) $3F_2 + NH_3 = NF_3 + 3HF$

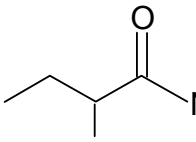
3. a) amiinid

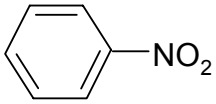
b) A – 

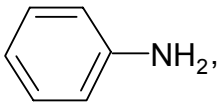
, 2-tsüanobutaan

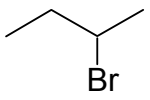
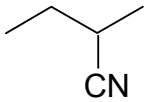
B – NaBr, naatriumbromiid

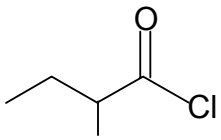
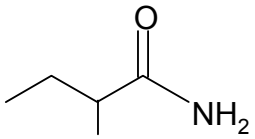
C –  , 2-metüülbutüülamiin

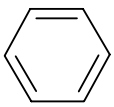
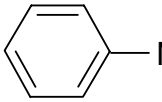
D –  , 2-metüülbutüülamiid

E –  , nitrobenseen

F –  , fenüülamiin, aniliin

c) i) NaCN +  =  + NaBr

ii)  + NH_3 =  + HCl

iii)  + HNO_3 $\overset{H_2SO_4}{=\!=}$  + H_2O

4. a) i) $Al_2O_3 + 6NaOH + 3H_2O = 2Na_3[Al(OH)_6]$

ii) $Na_3[Al(OH)_6] + 3HCl = Al(OH)_3\downarrow + 3NaCl + 3H_2O$

iii) $2Al(OH)_3 \xrightarrow{^0t} Al_2O_3 + 3H_2O$

b) i) $Al^{3+} + 3e^- = Al$

ii) $4AlO_3^{3-} + 3C = 2Al_2O_3 + 3CO_2 + 12e^-$

iii) $2Al_2O_3 + 3C = 4Al + 3CO_2$

c) $I \cdot 7 \cdot 24 \cdot 3600\ s \cdot 0{,}95$ $8 \cdot 10^5\ g$

$3e^-$ = Al

96485 A·s 26,98 g/mol

$$\mathbf{I} = \frac{3}{1} \cdot 8 \cdot 10^5\ \text{g} \cdot \frac{1\,\text{mol}}{26{,}98\,\text{g}} \cdot 96485\,\frac{\text{A} \cdot \text{s}}{\text{mol}} \cdot \frac{1}{7} \cdot \frac{1}{24} \cdot \frac{1}{3600\,\text{s}} \cdot \frac{1}{0{,}950} = 14{,}93\ \text{kA} \approx \mathbf{14{,}9\ kA}$$

d) t·14,93 kA·0,95 10^6

$3e^-$ = Al

96485 A·s 26,98 g/mol

$$t = \frac{3}{1} \cdot 10^6\ \text{g} \cdot \frac{1}{26{,}98\,\text{g}} \cdot 96485\ \text{A} \cdot \text{s} \cdot \frac{1\,\text{h}}{3600\,\text{s}} \cdot \frac{1}{14938\,\text{A}} = 199{,}5\ \text{h}$$

$$\Sigma = 6{,}00\ \text{V} \cdot 14{,}9\ \text{kA} \cdot 199{,}5\ \text{h} \cdot \frac{1\,\text{EEK}}{1\,\text{V} \cdot \text{kA} \cdot \text{h}} \approx \mathbf{17800\ EEK}$$

5. a) $\mathbf{L_M(KClO_4)} = \frac{n(KClO_4)}{V} = \frac{1{,}30\,\text{g} - 0{,}59\,\text{g}}{138{,}6\,\text{g/mol}} \cdot \frac{1}{(0{,}0500 + 0{,}0003)\,\text{dm}^3} = 0{,}1018\ \text{M} \approx \mathbf{1{,}02 \cdot 10^{-1}\,M}$

b) $\mathbf{LK(KClO_4)} = [K^+] \cdot [ClO_4^-] = (0{,}1018\ \text{M})^2 = 0{,}01036\ \text{M}^2 \approx \mathbf{1{,}04 \cdot 10^{-2}\,M^2}$

c) i) $[H^+] = [ClO_4^-]$

$pH = -\lg[H^+]$

$[ClO_4^-] = [H^+] = 10^{-2}\ \text{M} = 0{,}01\ \text{M} = c(ClO_4^-)$

ii) $LK = [K^+][ClO_4^-]$

$[K^+] = L'_M(KClO_4)$; $[ClO_4^-] = [L'_M(KClO_4) + c(ClO_4^-)]$

$0{,}01036 = L'_M(KClO_4) \cdot [L'_M(KClO_4) + 0{,}01]$

$[L'_M(KClO_4)]^2 + 0{,}01 \cdot L'_M(KClO_4) - 0{,}01036 = 0$

$\mathbf{L'_M(KClO_4)} = 0{,}09672\ \text{M} \approx \mathbf{0{,}0967\ M}$

d) $m(1\ \text{dm}^3\ \text{lahust}) = 1000\ \text{cm}^3 \cdot 1{,}01\ \text{g/cm}^3 = 1010\ \text{g}$

$m(KClO_4) = 0{,}0967\ \text{mol} \cdot 138{,}6\ \text{g/mol} = 13{,}40\ \text{g}$

$m(HClO_4\ \text{lahust}) = 1010\ \text{g} - 13{,}40\ \text{g} = 996{,}6\ \text{g}$

$$\mathbf{L(KClO_4\ HClO_4\ lahuses)} = 13{,}4\,\text{g} \cdot \frac{1}{996{,}6\,\text{g}} \cdot 100\,\text{g} = 1{,}3445\ \text{g} \approx \mathbf{1{,}34\ g}$$

e) $m(KClO_4, 70\ \text{g}\ HClO_4\ \text{lahuses}) = 13{,}4\,\text{g} \cdot \frac{1}{996{,}6\,\text{g}} \cdot 70\,\text{g} \approx 0{,}94\ \text{g}$

$\mathbf{m(KClO_4, mittelahustunud)} = 1{,}30\ \text{g} - 0{,}94\ \text{g} = \mathbf{0{,}36\ g}$

6. a) i) $\overset{0}{\ }t$

$2\mathbf{D}(OH)_3 = \mathbf{D}_2O_3 + 3H_2O$

ii) $A_r(\mathbf{D}) = \frac{465{,}96 - 3 \cdot 16}{2} = 208{,}98$

iii) D – Bi, vismut

b) A – Cu, vask. Vaskhüdroksiid on valge pulber, mis kuumutamisel muutub mustaks.

B – Ni, nikkel. Selle järjenumber erineb vase järjenumbrist ühe võrra. Zn ei saa olla, sest Zn soolade lahused on värvitud.

C – Mn, mangaan. Ga oksüdatsiooniaste on III, mistõttu ei sobi.
E – Sb, antimon, mille määrab vismut.

c) $Cu^{2+} + 4H_2O + 2Cl^- = [Cu(H_2O)_4]Cl_2$
$Ni^{2+} + 6H_2O + 2Cl^- = [Ni(H_2O)_6]Cl_2$
$Mn^{2+} + 6H_2O + 2Cl^- = [Mn(H_2O)_6]Cl_2$

2004/2005 õa keemiaolümpiaadi lõppvooru ülesannete lahendused
12. klass

1. a) Normaalsoola **G** reageerimisel vesinikjodiidiga moodustuv binaarne sool peab olema $\mathbf{AI}_x$

$A_r(\mathbf{A}) = 126{,}9 \cdot \frac{40{,}25}{59{,}75} \cdot x = 85{,}48x$

Kui x = 1, siis

A – Rb, rubiidium

b) B – RbO_2, rubiidiumhüperoksiid

C – Rb_2O, rubiidiumoksiid

D – RbOH, rubiidiumhüdroksiid

E – Rb_2SO_4, rubiidiumsulfaat

F – $RbHCO_3$, rubiidiumvesinikkarbonaat

G – $RbCO_3$, rubiidiumkarbonaat

H – RbI, rubiidiumjodiid

I – RbH, rubiidiumhüdriid

X – O_2, hapnik

Q – H_2O_2, vesinikperoksiid

c) i) $Rb + O_2 = RbO_2$

ii) $RbO_2 + 3Rb = 2Rb_2O$

iii) $Rb_2O + H_2 = RbOH + RbH$

iv) $RbH + H_2O = RbOH + H_2$

v) $2RbO_2 + 2H_2O = 2RbOH + H_2O_2 + O_2$

vi) $2RbO_2 + H_2SO_4 = Rb_2SO_4 + H_2O_2 + O_2$

vii) $2H_2O_2 \xrightarrow{MnO_2} 2H_2O + O_2$

viii) $Rb_2SO_4 + Ba(OH)_2 = 2RbOH + BaSO_4\downarrow$

ix) $RbOH + CO_2 = RbHCO_3$

x) $2RbOH + (NH_4)_2CO_3 = Rb_2CO_3 + 2NH_3 + 2H_2O$

xi) $Rb_2CO_3 + 2HI = 2RbI + H_2O + CO_2$

2. a) $k = \frac{\ln 2}{\tau_{1/2}} = \frac{0{,}6931}{1{,}06 \cdot 10^{11}\ \text{aastat}} = 6{,}54 \cdot 10^{-12}\ \text{aasta}^{-1}$

t = $\frac{\tau_{1/2}}{\ln 2} \cdot \ln\frac{100}{90} = \frac{1{,}06 \cdot 10^{11}\ \text{aastat}}{\ln 2} \cdot 0{,}1053$ = **1, 61·10^{10} aastat**

b) $c_t = c_0 \cdot e^{-k \cdot t} = 100\% \cdot e^{1{,}06 \cdot 10^{11}\ \text{aastat}} = 100\% \cdot e^{-6{,}54 \cdot 10^{-12}\ \text{aastat}^{-1} \cdot 5\ \text{aastat}}$ = **100%**

c) punktist **b)** järeldub, et 5 aasta möödudes preparaadi aktiivsus pole muutunud. Seega võib algaktiivsuseks lugeda 89,2 Bq/1g.

$$m(\text{Sm}) = 1\text{g} \cdot \frac{150{,}4 \cdot 2}{150{,}4 \cdot 2 + 3 \cdot 16} = 0{,}862\ \text{g}$$

$v = k \cdot N_0$, millest $N_0 = \frac{v}{k}$

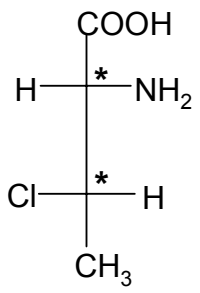
$$m(^{147}\text{Sm}) = \frac{89{,}2\ \text{tuuma}}{1\text{g} \cdot \text{s}} \cdot \frac{\tau_{1/2}}{\ln 2} \cdot (365{,}25 \cdot 24 \cdot 3600)\,\text{s} \cdot \frac{1\,\text{mol}}{6{,}02 \cdot 10^{23}\ \text{tuuma}} \cdot 147\text{g/mol} = 0{,}105\ \text{g}$$

%(^{147}**Sm)** = $\frac{0{,}105}{0{,}862} \cdot 100$ = **12,2**

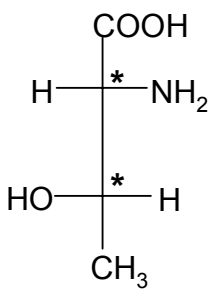
d) $N = v \cdot t$

N = $\frac{89{,}2\ \text{tuuma}}{1\text{g} \cdot \text{s}} \cdot 10\ \text{g} \cdot (5 \cdot 365{,}25 \cdot 24 \cdot 3600)\ \text{s}$ = **1,41·10^{12} tuuma**

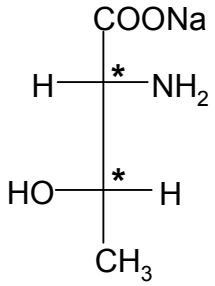
3. a)



X

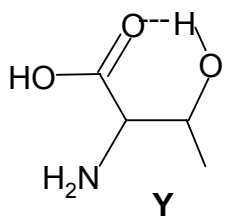


Y

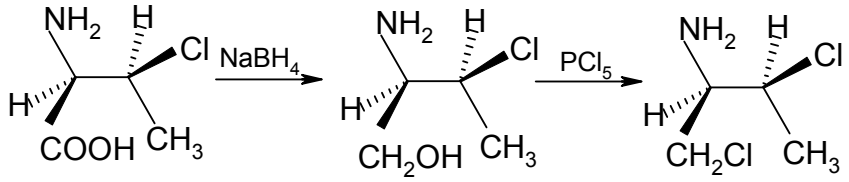


Z

b)



Y

c) 

4. a) i) $Fe_2O_3 + 6H^+ = 2Fe^{3+} + 3H_2O$

ii) $Fe + 2H^+ = Fe^{2+} + H_2$

iii) $Fe^{3+} + PO_4^{3-} = FePO_4\downarrow$

iv) $Fe^{3+} + 3OH^- = Fe(OH)_3$

b) i) $[H^+]$ saadakse happe dissotsiatsiooni esimesest astmest. Ostwaldi lahjendusseadus ei anna nõutud täpsust. I ja II astme vahe on 5 suurusjärku, seetõttu II ja III astmest lisanduv H^+ hulk on tühine

$$[H^+]=\frac{-K_1+\sqrt{K_1^2+4c\cdot K_1}}{2}\Rightarrow\frac{-7{,}52\cdot10^{-3}+\sqrt{(7{,}52\cdot10^{-3})^2+4\cdot0{,}1\cdot7{,}52\cdot10^{-3}}}{2}=0{,}02392\ \text{M}$$

pH = 1,62

ii) H^+, happest < H^+, veest

pH ≈ 7 (ühe tüvenumbri täpsus)

c) $10^{-21,9} = 1{,}26\cdot10^{-22}$

i) $\mathbf{[Fe^{3+}]} = \frac{LK[Fe(OH)_3]}{(10^{-7})^3} = 3{,}98\cdot10^{-17}$ M ≈ $\mathbf{4\cdot10^{-17}}$ **M**

ii) $\mathbf{[Fe^3]} = \frac{LK(FePO_4)}{c_o\cdot\alpha} = \mathbf{3{,}77\cdot10^{-5}}$ **M**

5. a) A – Hg, elavhõbe

B – S, väävel

C – SO_2, vääveldioksiid

D – Na_2S, naatriumsulfiid

E – $Na_2S_2O_3$, naatriumtiosulfaat

F – HgO, elavhõbe(II)oksiid

G – Hg_2O, elavhõbe(I)oksiid

b) i) $HgS + O_2 = Hg + SO_2$

ii) $S + 2Na = Na_2S$

iii) $2Na_2S + 3SO_2 = 2Na_2S_2O_3 + S$

iv) $2Na_2S_2O_3 + I_2 = 2NaI + Na_2S_4O_6$

v) $KCN + Na_2S_2O_3 = KSCN + Na_2SO_3$

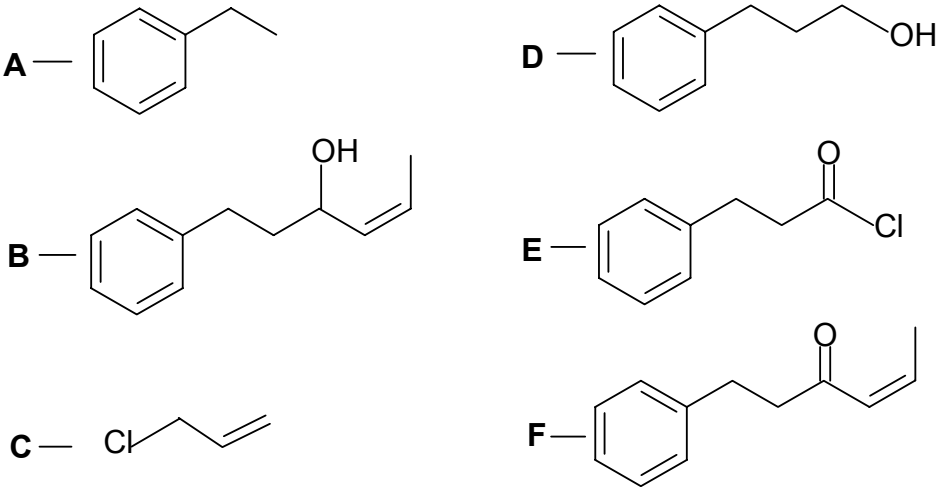
vi) $Hg(NO_3)_2 + 2NaOH = 2NaNO_3 + HgO\downarrow + H_2O$

vii) $Hg_2(NO_3)_2 + 2NaOH = 2NaNO_3 + Hg_2O + H_2O$

c) M(HgO) = 216,6 g/mol

$M(Hg_2O)$ = 417,2 g/mol

6. a)



b) i) $Br_2/h\nu$

ii) Mg

iii) OsO_4/ROH

iv) 1. B_2H_6, 2. $H_2O_2/NaOH$

v) $SOCl_2$

vi) $H_2/Pd\ (BaSO_4)$

c)