ANALITIČKA KEMIJA - SEMINAR

- osnove statistike
- kemija vodenih otopina
- gravimetrijske metode analize
- **taložne titracije**

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akademska godina: 2026./27.

1. Otopina srebrova nitrata pripravljena je otapanjem 13,5920 g $AgNO_3$ u litri vode. Koliko miligrama NaCl reagira s 1,00 mL ove otopine?

$m(AgNO_3) = 13{,}5920\ \text{g}$ $\qquad$ $V(AgNO_3) = 1{,}00\ \text{mL} = 1{,}00 \cdot 10^{-3}\ \text{L}$

$V(H_2O) = 1\ \text{L}$

$$c(AgNO_3) = \frac{m(AgNO_3)}{M(AgNO_3)\,V(H_2O)} = 0{,}0800\ \text{mol L}^{-1}$$

$$AgNO_3 + NaCl \rightleftharpoons AgCl(s) + NaNO_3$$

$$n(NaCl) = n(AgNO_3) = c(AgNO_3)\,V(AgNO_3) = 8{,}00 \cdot 10^{-5}\ \text{mol}$$

$$m(NaCl) = n(NaCl)\,M(NaCl) = 4{,}68 \cdot 10^{-3}\ \text{g} = 4{,}7\ \text{mg}$$

2. Izračunajte koncentraciju otopine srebrova nitrata: a) ako u 40,00 cm^3 otopine taloženjem nastane 0,4468 g AgCl; b) ako je 30,00 cm^3 $AgNO_3$ ekvivalentno s 0,3000 g čistog KSCN.

a) $V(AgNO_3) = 40{,}00\ cm^3 = 40{,}00 \cdot 10^{-3}\ dm^3$ $\qquad$ $m(AgCl) = 0{,}4468\ g$

$$AgNO_3 + Cl^- \rightleftharpoons AgCl(s) + NO_3^-$$

$$n(AgCl) = \frac{m(AgCl)}{M(AgCl)} = 3{,}12 \cdot 10^{-3}\ mol$$

$$n(AgNO_3) = n(AgCl)$$

$$c(AgNO_3) = \frac{n(AgNO_3)}{V(AgNO_3)} = 0{,}0779\ mol\ dm^{-3}$$

b) $V(\mathrm{AgNO_3}) = 30{,}00\ \mathrm{cm^3} = 30{,}00 \cdot 10^{-3}\ \mathrm{dm^3}$ $m(\mathrm{KSCN}) = 0{,}3000\ \mathrm{g}$

$$n(\mathrm{KSCN}) = \frac{m(\mathrm{KSCN})}{M(\mathrm{KSCN})} = 3{,}09 \cdot 10^{-3}\ \mathrm{mol}$$

$$n(\mathrm{KSCN}) = n(\mathrm{AgNO_3})$$

$$c(\mathrm{AgNO_3}) = \frac{n(\mathrm{AgNO_3})}{V(\mathrm{AgNO_3})} = 0{,}1029\ \mathrm{mol\ dm^{-3}}$$

3. Kolika je koncentracija otopine $\mathrm{AgNO_3}$ ako 36,60 mL ove otopine reagira s 0,2460 g čistog NaCl?

$V(\mathrm{AgNO_3}) = 36{,}60\ \mathrm{mL} = 36{,}60 \cdot 10^{-3}\ \mathrm{L}$ $m(\mathrm{NaCl}) = 0{,}2460\ \mathrm{g}$

$$\mathrm{AgNO_3} + \mathrm{NaCl} \rightleftharpoons \mathrm{AgCl(s)} + \mathrm{NaNO_3}$$

$$n(\mathrm{NaCl}) = \frac{m(\mathrm{NaCl})}{M(\mathrm{NaCl})} = 4{,}21 \cdot 10^{-3}\ \mathrm{mol} = n(\mathrm{NaCl})$$

$$c(\mathrm{AgNO_3}) = \frac{n(\mathrm{AgNO_3})}{V(\mathrm{AgNO_3})} = 0{,}1150\ \mathrm{mol\ L^{-1}}$$

4. Otopljeno je 0,5482 g uzorka nečistog barijeva klorida i titrirano Mohrovom metodom. Utrošeno je 35,25 mL otopine $AgNO_3$ koncentracije 0,1208 mol L^{-1}. Koliki je maseni udio $BaCl_2 \cdot 2H_2O$ u uzorku?

$m(\mathrm{uzorak}) = 0{,}5482\ \mathrm{g}$ $\qquad$ $V(\mathrm{AgNO_3}) = 35{,}25\ \mathrm{mL} = 35{,}25 \cdot 10^{-3}\ \mathrm{L}$

$c(\mathrm{AgNO_3}) = 0{,}1208\ \mathrm{mol\ L^{-1}}$

$$2\,\mathrm{AgNO_3} + \mathrm{BaCl_2 \cdot 2H_2O} \rightleftharpoons 2\,\mathrm{AgCl(s)} + \mathrm{Ba(NO_3)_2} + 2\,\mathrm{H_2O}$$

$$n(\mathrm{AgNO_3}) = c(\mathrm{AgNO_3})\, V(\mathrm{AgNO_3}) = 4{,}26 \cdot 10^{-3}\ \mathrm{mol}$$

$$n(\mathrm{BaCl_2 \cdot 2H_2O}) : n(\mathrm{AgNO_3}) = 1 : 2$$

$$n(\mathrm{BaCl_2 \cdot 2H_2O}) = \frac{1}{2}\, n(\mathrm{AgNO_3}) = 2{,}13 \cdot 10^{-3}\ \mathrm{mol}$$

$$m(\mathrm{BaCl_2 \cdot 2H_2O}) = n(\mathrm{BaCl_2 \cdot 2H_2O})\, M(\mathrm{BaCl_2 \cdot 2H_2O}) = 0{,}5201\ \mathrm{g}$$

$$w(\mathrm{BaCl_2 \cdot 2H_2O}) = \frac{m(\mathrm{BaCl_2 \cdot 2H_2O})}{m(\mathrm{uzorak})} \cdot 100\% = 94{,}87\%$$

5. Koliko cm^3 otopine srebrova nitrata, koncentracije 0,1080 mol dm^{-3}, je potrebno za titraciju 0,3400 g uzorka u kojem je udio $BaCl_2 \cdot 2H_2O$ 20,70%?

$m(\text{uzorak}) = 0{,}3400\ \text{g}$ $\qquad$ $c(AgNO_3) = 0{,}1080\ \text{mol dm}^{-3}$

$w(BaCl_2 \cdot 2H_2O) = 20{,}70\% = 0{,}2070$

$$2\,AgNO_3 + BaCl_2 \cdot 2H_2O \rightleftharpoons 2\,AgCl(s) + Ba(NO_3)_2 + 2\,H_2O$$

$$w(BaCl_2 \cdot 2H_2O) = \frac{m(BaCl_2 \cdot 2H_2O)}{m(\text{uzorak})}$$

$$m(BaCl_2 \cdot 2H_2O) = w(BaCl_2 \cdot 2H_2O)\, m(\text{uzorak}) = 0{,}0704\ \text{g}$$

$$n(\mathrm{BaCl_2 \cdot 2H_2O}) = \frac{m(\mathrm{BaCl_2 \cdot 2H_2O})}{M(\mathrm{BaCl_2 \cdot 2H_2O})} = 2{,}88 \cdot 10^{-4}\ \mathrm{mol}$$

$$n(\mathrm{AgNO_3}) : n(\mathrm{BaCl_2 \cdot 2H_2O}) = 2 : 1$$

$$n(\mathrm{AgNO_3}) = 2n(\mathrm{BaCl_2 \cdot 2H_2O}) = 5{,}76 \cdot 10^{-4}\ \mathrm{mol}$$

$$c(\mathrm{AgNO_3}) = \frac{n(\mathrm{AgNO_3})}{V(\mathrm{AgNO_3})}$$

$$V(\mathrm{AgNO_3}) = \frac{n(\mathrm{AgNO_3})}{c(\mathrm{AgNO_3})} = 5{,}34 \cdot 10^{-3}\ \mathrm{dm^3} = 5{,}34\ \mathrm{cm^3}$$

6. Koliki je maseni udio NaCl u otopini soli (gustoće 1,081 g mL^{-1}) ako 10,0 mL ove otopine titracijom potroši 48,50 mL otopine $AgNO_3$, koncentracije 0,4520 mol L^{-1}?

$\rho(\text{otopina}) = 1{,}081\ \text{g mL}^{-1} = 1081\ \text{g L}^{-1}$ $\qquad$ $c(AgNO_3) = 0{,}4520\ \text{mol L}^{-1}$

$V(\text{NaCl}) = 10{,}00\ \text{mL} = 10{,}00 \cdot 10^{-3}\ \text{L}$

$V(AgNO_3) = 48{,}50\ \text{mL} = 48{,}50 \cdot 10^{-3}\ \text{L}$

$$AgNO_3 + NaCl \rightleftharpoons AgCl(s) + NaNO_3$$

$$c(AgNO_3) = \frac{n(AgNO_3)}{V(AgNO_3)}$$

$$n(AgNO_3) = c(AgNO_3)\, V(AgNO_3) = 0{,}0219\ \text{mol L}^{-1}$$

$$n(\mathrm{NaCl}) = n(\mathrm{AgNO_3})$$

$$c(\mathrm{NaCl}) = \frac{n(\mathrm{NaCl})}{V(\mathrm{NaCl})} = 2{,}1922\ \mathrm{mol\ L^{-1}}$$

$$\rho(\mathrm{otopina})\ w(\mathrm{NaCl}) = c(\mathrm{NaCl})\ M(\mathrm{NaCl})$$

$$w(\mathrm{NaCl}) = \frac{c(\mathrm{NaCl})\ M(\mathrm{NaCl})}{\rho(\mathrm{otopina})} = 0{,}1185 = 11{,}85\%$$

7. Otopljeno je 0,2851 g uzorka koji sadrži magnezijev klorid. Otopini uzorka dodano je 50,00 cm^3 otopine srebrova nitrata koncentracije 0,1045 mol dm^{-3}, a titracijom suviška srebrovih iona utrošeno je 9,10 cm^3 otopine kalijevog tiocijanata koncentracije 0,1205 mol dm^{-3}. Izrazite sadržaj $MgCl_2$ u uzorku.

$m(\text{uzorak}) = 0{,}2851\ \text{g}$ $\qquad V(AgNO_3) = 50{,}00\ \text{cm}^3 = 50{,}00 \cdot 10^{-3}\ \text{dm}^3$

$c(AgNO_3) = 0{,}1045\ \text{mol dm}^{-3}$

$$2\,AgNO_3 + MgCl_2 \rightleftharpoons 2\,AgCl(s) + Mg(NO_3)_2$$

$c(\text{KSCN}) = 0{,}1205\ \text{mol dm}^{-3}$ $\qquad V(\text{KSCN}) = 9{,}10\ \text{cm}^3 = 9{,}10 \cdot 10^{-3}\ \text{dm}^3$

$$Ag^+ + KSCN \rightleftharpoons AgSCN(s) + K^+$$

$$n(AgNO_3)_{\text{ukupno}} = c(AgNO_3)\,V(AgNO_3) = 5{,}23 \cdot 10^{-3}\ \text{mol}$$

$$n(\mathrm{AgNO_3})_{\text{suvišak}} = n(\mathrm{Ag^+}) = n(\mathrm{KSCN}) = c(\mathrm{KSCN})\, V(\mathrm{KSCN}) = 1{,}10 \cdot 10^{-3}\ \mathrm{mol}$$

$$n(\mathrm{AgNO_3})_{\text{za reakciju}} = n(\mathrm{AgNO_3})_{\text{ukupno}} - n(\mathrm{AgNO_3})_{\text{suvišak}} = 4{,}13 \cdot 10^{-3}\ \mathrm{mol}$$

$$n(\mathrm{MgCl_2}) : n(\mathrm{AgNO_3})_{\text{za reakciju}} = 1 : 2$$

$$n(\mathrm{MgCl_2}) = \frac{1}{2}\, n(\mathrm{AgNO_3})_{\text{za reakciju}} = 2{,}07 \cdot 10^{-3}\ \mathrm{mol}$$

$$m(\mathrm{MgCl_2}) = n(\mathrm{MgCl_2})\, M(\mathrm{MgCl_2}) = 0{,}1966\ \mathrm{g}$$

$$w(\mathrm{MgCl_2}) = \frac{m(\mathrm{MgCl_2})}{m(\text{uzorak})} \cdot 100\% = 68{,}96\%$$

8. Nakon otapanja uzorka nekog klorida mase 0,4580 g u otopinu je dodano 35,85 mL otopine srebrova nitrata koncentracije 0,1240 mol L^{-1}. Titracijom suviška Ag^+ iona utrošeno je 9,50 mL otopine KSCN, koncentracije 0,1080 mol L^{-1}. Izračunajte udio klorida u uzorku.

$m(\text{uzorak}) = 0{,}4580\ \text{g}$ $\qquad$ $V(AgNO_3) = 35{,}85\ \text{mL} = 35{,}85 \cdot 10^{-3}\ \text{L}$

$c(AgNO_3) = 0{,}1240\ \text{mol L}^{-1}$

$$AgNO_3 + Cl^- \rightleftharpoons AgCl(s) + NO_3^-$$

$c(\text{KSCN}) = 0{,}1080\ \text{mol L}^{-1}$ $\qquad$ $V(\text{KSCN}) = 9{,}50\ \text{mL} = 9{,}50 \cdot 10^{-3}\ \text{L}$

$$Ag^+ + KSCN \rightleftharpoons AgSCN(s) + K^+$$

$$n(AgNO_3)_{\text{ukupno}} = c(AgNO_3)\, V(AgNO_3) = 4{,}44 \cdot 10^{-3}\ \text{mol}$$

$$n(\mathrm{AgNO_3})_{\text{suvišak}} = n(\mathrm{Ag^+}) = n(\mathrm{KSCN}) = c(\mathrm{KSCN})\, V(\mathrm{KSCN}) = 1{,}03 \cdot 10^{-3}\ \mathrm{mol}$$

$$n(\mathrm{AgNO_3})_{\text{za reakciju}} = n(\mathrm{AgNO_3})_{\text{ukupno}} - n(\mathrm{AgNO_3})_{\text{suvišak}} = 3{,}42 \cdot 10^{-3}\ \mathrm{mol}$$

$$n(\mathrm{Cl^-}) : n(\mathrm{AgNO_3})_{\text{za reakciju}} = 1:1$$

$$n(\mathrm{Cl^-}) = n(\mathrm{AgNO_3})_{\text{za reakciju}}$$

$$m(\mathrm{Cl^-}) = n(\mathrm{Cl^-})\, M(\mathrm{Cl}) = 0{,}1212\ \mathrm{g}$$

$$w(\mathrm{Cl^-}) = \frac{m(\mathrm{Cl^-})}{m(\text{uzorak})} \cdot 100\% = 26{,}47\%$$

9. Otopljeno je 1,600 g uzorka koji sadrži $CaBr_2 \cdot 6H_2O$ i nečistoću (koja ne reagira s $AgNO_3$). Otopini je dodano 52,00 cm^3 otopine srebrova nitrata, koncentracije 0,2000 mol dm^{-3}, a za titraciju suviška Ag^+ utrošeno je 4,00 cm^3 otopine KSCN, koncentracije 0,1000 mol dm^{-3}. Izračunajte udio $CaBr_2 \cdot 6H_2O$ u uzorku.

$m(\text{uzorak}) = 1{,}600\ \text{g}$ $\qquad V(AgNO_3) = 52{,}00\ \text{cm}^3 = 52{,}00 \cdot 10^{-3}\ \text{dm}^3$

$c(AgNO_3) = 0{,}2000\ \text{mol dm}^{-3}$

$$2\,AgNO_3 + CaBr_2 \cdot 6H_2O \rightleftharpoons 2\,AgBr(s) + Ca(NO_3)_2 + 6\,H_2O$$

$c(\text{KSCN}) = 0{,}1000\ \text{mol L}^{-1}$ $\qquad V(\text{KSCN}) = 4{,}00\ \text{cm}^3 = 4{,}00 \cdot 10^{-3}\ \text{dm}^3$

$$Ag^+ + KSCN \rightleftharpoons AgSCN(s) + K^+$$

$$n(AgNO_3)_{\text{ukupno}} = c(AgNO_3)\,V(AgNO_3) = 0{,}0104\ \text{mol}$$

$$n(\mathrm{AgNO_3})_{\text{suvišak}} = n(\mathrm{Ag^+}) = n(\mathrm{KSCN}) = c(\mathrm{KSCN})\, V(\mathrm{KSCN}) = 4{,}00 \cdot 10^{-4}\ \mathrm{mol}$$

$$n(\mathrm{AgNO_3})_{\text{za reakciju}} = n(\mathrm{AgNO_3})_{\text{ukupno}} - n(\mathrm{AgNO_3})_{\text{suvišak}} = 0{,}0100\ \mathrm{mol}$$

$$n(\mathrm{CaBr_2 \cdot 6H_2O}) : n(\mathrm{AgNO_3})_{\text{za reakciju}} = 1:2$$

$$n(\mathrm{CaBr_2 \cdot 6H_2O}) = \frac{1}{2} n(\mathrm{AgNO_3})_{\text{za reakciju}} = 5{,}00 \cdot 10^{-3}\ \mathrm{mol}$$

$$m(\mathrm{CaBr_2 \cdot 6H_2O}) = n(\mathrm{CaBr_2 \cdot 6H_2O})\, M(\mathrm{CaBr_2 \cdot 6H_2O}) = 1{,}5400\ \mathrm{g}$$

$$w(\mathrm{CaBr_2 \cdot 6H_2O}) = \frac{m(\mathrm{CaBr_2 \cdot 6H_2O})}{m(\text{uzorak})} \cdot 100\% = 96{,}24\%$$

10. Izračunajte množinsku koncentraciju Ag^+ i I^- iona te odgovarajuće p-vrijednosti prilikom titracije 50,00 cm^3 otopine KI, koncentracije 0,0050 mol dm^{-3}, otopinom $AgNO_3$, koncentracije 0,0100 mol dm^{-3}, nakon dodatka: a) 0,00; b) 5,00; c) 25,00 i d) 30,00 cm^3 $AgNO_3$ ($K_{sp}(AgI) = 8{,}5 \cdot 10^{-17}$ mol^2 dm^{-6}).

$V(\mathrm{KI}) = 50{,}00\ \mathrm{cm}^3 = 50{,}00 \cdot 10^{-3}\ \mathrm{dm}^3$ $\qquad$ $c(\mathrm{KI}) = 0{,}0050\ \mathrm{mol\,dm}^{-3}$

$K_{sp}(\mathrm{AgI}) = 8{,}5 \cdot 10^{-17}\ \mathrm{mol}^2\ \mathrm{dm}^{-6}$ $\qquad$ $c(\mathrm{AgNO_3}) = 0{,}0100\ \mathrm{mol\,dm}^{-3}$

$$\mathrm{AgNO_3} + \mathrm{KI} \rightleftharpoons \mathrm{AgI(s)} + \mathrm{KNO_3}$$

a) $V(\mathrm{AgNO_3}) = 0{,}00\ \mathrm{cm}^3$

$[\mathrm{Ag}^+] = 0{,}00\ \mathrm{mol\,dm}^{-3}$ $\qquad$ $[\mathrm{I}^-] = c(\mathrm{KI}) = 0{,}0050\ \mathrm{mol\,dm}^{-3}$

$$\mathrm{pI} = -\log\left(\frac{[\mathrm{I}^-]}{\mathrm{mol\,dm}^{-3}}\right) = -\log\left(\frac{0{,}0050\ \mathrm{mol\,dm}^{-3}}{\mathrm{mol\,dm}^{-3}}\right) = 2{,}30$$

b) $V(\mathrm{AgNO_3}) = 5{,}00\ \mathrm{cm^3} = 5{,}00 \cdot 10^{-3}\ \mathrm{dm^3}$

$$n_\mathrm{o}(\mathrm{I^-}) = n(\mathrm{KI}) = c(\mathrm{KI})\, V(\mathrm{KI}) = 2{,}5 \cdot 10^{-4}\ \mathrm{mol}$$

$$n(\mathrm{AgNO_3})_\mathrm{dodano} = c(\mathrm{AgNO_3})\, V(\mathrm{AgNO_3}) = 5{,}0 \cdot 10^{-5}\ \mathrm{mol}$$

$$n(\mathrm{I^-}) = n_\mathrm{o}(\mathrm{I^-}) - n(\mathrm{AgNO_3})_\mathrm{dodano} = 2{,}0 \cdot 10^{-4}\ \mathrm{mol}$$

$$[\mathrm{I^-}] = \frac{n(\mathrm{I^-})}{V(\mathrm{KI}) + V(\mathrm{AgNO_3})} = 0{,}0036\ \mathrm{mol\,dm^{-3}}$$

$$\mathrm{pI} = -\log\left(\frac{[\mathrm{I^-}]}{\mathrm{mol\,dm^{-3}}}\right) = -\log\left(\frac{0{,}0036\ \mathrm{mol\,dm^{-3}}}{\mathrm{mol\,dm^{-3}}}\right) = 2{,}44$$

$$[\mathrm{Ag^+}] = \frac{K_{\mathrm{sp}}(\mathrm{AgI})}{[\mathrm{I^-}]} = 2{,}36 \cdot 10^{-14}\ \mathrm{mol\,dm^{-3}}$$

$$\mathrm{pAg} = -\log\left(\frac{[\mathrm{Ag^+}]}{\mathrm{mol\,dm^{-3}}}\right) = -\log\left(\frac{2{,}36 \cdot 10^{-14}\ \mathrm{mol\,dm^{-3}}}{\mathrm{mol\,dm^{-3}}}\right) = 13{,}63$$

c) $V(\mathrm{AgNO_3}) = 25{,}00\ \mathrm{cm^3} = 25{,}00 \cdot 10^{-3}\ \mathrm{dm^3}$

$$n_{\mathrm{o}}(\mathrm{I^-}) = n(\mathrm{KI}) = c(\mathrm{KI})\,V(\mathrm{KI}) = 2{,}5 \cdot 10^{-4}\ \mathrm{mol}$$

$$n(\mathrm{AgNO_3})_{\mathrm{dodano}} = c(\mathrm{AgNO_3})\,V(\mathrm{AgNO_3}) = 2{,}5 \cdot 10^{-4}\ \mathrm{mol}$$

} točka ekvivalencije

$$[\mathrm{Ag^+}] = [\mathrm{I^-}] = \sqrt{K_{\mathrm{sp}}(\mathrm{AgI})} = 9{,}22 \cdot 10^{-9}\ \mathrm{mol\,dm^{-3}}$$

$$\mathrm{pAg} = \mathrm{pI} = -\log\left(\frac{9{,}22 \cdot 10^{-9}\ \mathrm{mol\,dm^{-3}}}{\mathrm{mol\,dm^{-3}}}\right) = 8{,}04$$

d) $V(\mathrm{AgNO_3}) = 30{,}00\ \mathrm{cm^3} = 30{,}00 \cdot 10^{-3}\ \mathrm{dm^3}$

$$n(\mathrm{AgNO_3})_{\mathrm{dodano}} = c(\mathrm{AgNO_3})\, V(\mathrm{AgNO_3}) = 3{,}0 \cdot 10^{-4}\ \mathrm{mol}$$

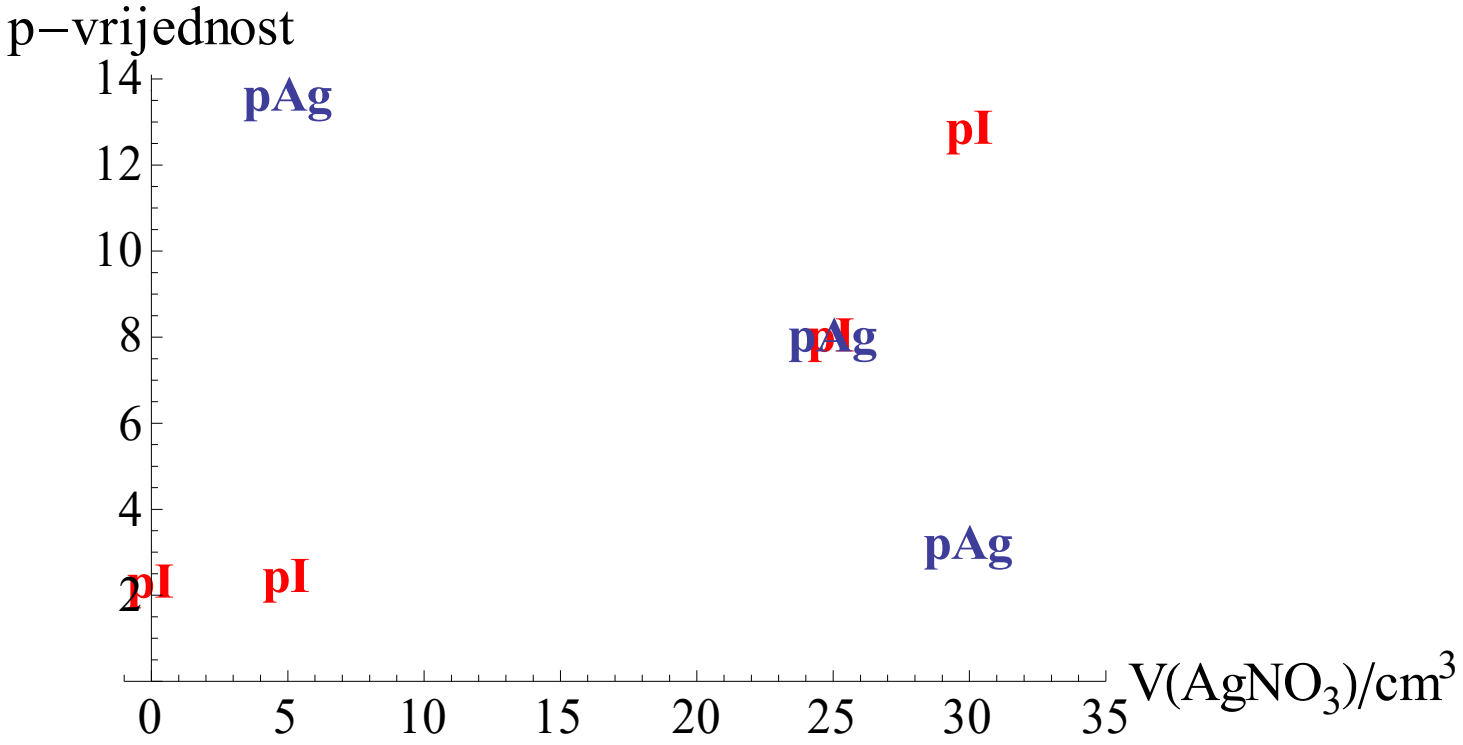
$$n(\mathrm{Ag^+}) = n(\mathrm{AgNO_3})_{\mathrm{dodano}} - c(\mathrm{KI})\, V(\mathrm{KI}) = 5{,}0 \cdot 10^{-5}\ \mathrm{mol}$$

$$[\mathrm{Ag^+}] = \frac{n(\mathrm{Ag^+})}{V(\mathrm{KI}) + V(\mathrm{AgNO_3})} = 6{,}25 \cdot 10^{-4}\ \mathrm{mol\,dm^{-3}}$$

$$\mathrm{pAg} = -\log\left(\frac{[\mathrm{Ag^-}]}{\mathrm{mol\,dm^{-3}}}\right) = -\log\left(\frac{6{,}25 \cdot 10^{-4}\ \mathrm{mol\,dm^{-3}}}{\mathrm{mol\,dm^{-3}}}\right) = 3{,}20$$

$$[\mathrm{I}^-] = \frac{K_{\mathrm{sp}}(\mathrm{AgI})}{[\mathrm{Ag}^+]} = 1{,}36 \cdot 10^{-13}\ \mathrm{mol\,dm^{-3}}$$

$$\mathrm{pI} = -\log\left(\frac{[\mathrm{I}^-]}{\mathrm{mol\,dm^{-3}}}\right) = -\log\left(\frac{1{,}36 \cdot 10^{-13}\ \mathrm{mol\,dm^{-3}}}{\mathrm{mol\,dm^{-3}}}\right) = 12{,}87$$



Ovisnost pAg i pI o volumenu $AgNO_3$