Задача 0-6-1

$T - ?$

$a = 1{,}2 Å$

$E_l = \frac{\hbar^2}{2I} (l+1) l$

$E_1 - E_0 = \frac{\hbar^2}{I}$

$kT = \frac{\hbar^2}{I} = \frac{\hbar^2}{\mu a^2} = \frac{2\hbar^2}{m a^2}$

Откуда $T = \frac{2\hbar^2}{m k a^2} = 4{,}2\ K$

Задача 0-6-2

$\mathcal{E} = 12{,}5\ эВ$

$\mathcal{E}^-_{min}$ рассеяния - ?

$$E_1 = -\frac{me^4}{2\hbar^2}\cdot\frac{1}{1} = -R_y = -13{,}6\ эВ$$

$$E_2 = -\frac{me^4}{2\hbar^2}\cdot\frac{1}{4} = -3{,}4\ эВ \hookrightarrow \Delta E_{12} = 10{,}2\ эВ$$

$$E_3 = -\frac{me^4}{2\hbar^2}\cdot\frac{1}{9} = -1{,}51\ эВ \hookrightarrow \Delta E_{13} = 12{,}09\ эВ$$

$$E_4 = -\frac{me^2}{2\hbar^2}\cdot\frac{1}{16} = -0{,}85\ эВ \hookrightarrow \Delta E_{14} = 12{,}75\ эВ$$

$$\mathcal{E}^-_{min} = \mathcal{E} - \Delta E_{13} = 12{,}5 - 12{,}09 = 0{,}41\ эВ$$

4.29

$(p\bar{p})$

из $2p \to 1s$ $E_{21} = 10{,}1$ кэВ

$\Delta\varepsilon - ?$

$$\varepsilon_n = -\frac{\mu e^4}{2\hbar^2 n^2}\frac{m_e}{m_e}, \text{ где } \mu = \frac{m_p}{2}$$

$$\varepsilon_n = -R_y \frac{m_p}{2m_e}\frac{1}{n^2} = -13{,}6\,\frac{1836}{2}\,\frac{1}{n^2} = -12{,}5\,\frac{1}{n^2}\text{ кэВ}$$

$$\Delta\varepsilon_{куд} = 12{,}5\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = 9{,}4 \text{ кэВ}$$

Откуда $\Delta\varepsilon = E_{21} - \Delta\varepsilon_{куд} = 0{,}7$ кэВ.

4.38

$Z < 50$

$T_e - ?$

$_{30}Zn$

$_{47}Ag \quad E_\gamma = 21,6$ кэВ

$$E = \hbar\omega = R_y (Z-\sigma)^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

Для K_α - электронов

Серебро $E = R_y (Z-\sigma)^2 \left(\frac{1}{1^2} - \frac{1}{2^2}\right)$

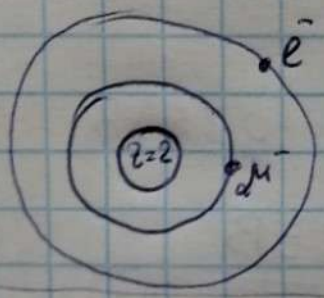
$$\sigma = Z - \sqrt{\frac{4E}{3R_y}} = 47 - \sqrt{\frac{4 \cdot 21,6 \cdot 10^3}{13,6 \cdot 3}} \approx 1$$

Zn: $\hbar\omega_{Zn} = 13,6(Z-1)^2 = 13,6 \cdot 29^2 = 11,4$ кэВ

$T_e = E_\gamma - E_{ион} = 21,6 - 11,4 = 10,2$ кэВ

4.45

$m_\mu c^2 = 106,6$ МэВ



$3_p \to 2_s$ E_{32} - ?

λ_{32} - ?

$$r_\mu = \frac{\hbar^2}{m_\mu z e^2} \frac{m_e}{m_e} = r_Б \frac{m_e}{z m_\mu} =$$

$$= 0,53 \cdot 10^{-8} \frac{0,511}{2 \cdot 106,6} = 1,27 \cdot 10^{-11} \text{ см} \ll r_Б$$

$$\frac{1}{\lambda_{32}} = R_\infty \left(\frac{1}{2^2} - \frac{1}{3^2} \right) = \frac{5}{36} R_\infty =$$

$$= \frac{5}{36} 109737 = 1,52 \cdot 10^4 \text{ см}^{-1}$$

$$\lambda_{32} = 656 \text{ нм}$$

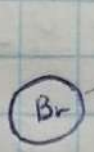
$$\mathcal{E}_{32} = \frac{hc}{\lambda_{32}} = 1,89 \text{ эВ}$$

5.16

HBr

$\Delta = \frac{1}{\lambda} = 17\ см^{-1}$

d - ?



$I = \mu d^2 \approx m d^2$

$\Delta E_l = \frac{\hbar^2}{I}(l+1) = \frac{\hbar^2}{I}$

$\Delta E = \frac{\hbar^2}{m d^2} = \frac{hc}{\lambda} = hc\frac{1}{\lambda}$

$d^2 = \frac{\hbar^2}{mhc(\frac{1}{\lambda})} = \frac{\hbar}{2\pi mc\Delta} = 1,97 \cdot 10^{-16}\ см^2$

$d \approx 1,4 \cdot 10^{-8}\ см$

5.25

$\lambda = 4{,}61$ мкм

$A_0 - ?$

$T - ?$ $(n = 1)$

$$\overline{E} = \overline{E}_{кин} + \overline{E}_{пот}$$

$$\overline{E}_k = \overline{E}_n = \frac{\mu \omega^2 \overline{x^2}}{2}$$

$$\overline{E} = \frac{\hbar\omega}{2}$$

$$\overline{x^2} = \overline{A_0^2 \cos^2 \omega t} = \frac{A_0^2}{2} \hookrightarrow \frac{\hbar\omega}{2} = 2 \cdot \frac{\mu\omega^2}{2} \frac{A_0^2}{2}$$

Откуда $A_0 = \sqrt{\frac{\hbar}{\mu\omega}}$

$$\mu = \frac{m_0 m_c}{m_0 + m_c} = 11{,}45 \cdot 10^{-24} \text{ г}$$

$$\omega = \frac{2\pi c}{\lambda} \hookrightarrow A_0 = \sqrt{\frac{\hbar}{\mu\omega}} = \sqrt{\frac{\hbar\lambda}{2\pi c \mu}} \simeq 4{,}7 \cdot 10^{-10} \text{ см}$$

$$kT \geq \hbar\omega \hookrightarrow T \geq \frac{2\pi\hbar c}{k \cdot \lambda} \simeq 3100 \text{ K}$$

5.51

$H^{35}Cl$

^{35}Cl, ^{37}Cl

$\frac{\Delta\lambda}{\lambda}$ - ?

$\mu_{35} = \frac{1 \cdot 35}{1+35} = 0{,}9722 m_p$

$\mu_{37} = \frac{1 \cdot 37}{1+37} = 0{,}9737 m_p$

$\Delta\mu = 0{,}0015 m_p$

$\lambda = \frac{hc}{\Delta\varepsilon_{кол}} = \frac{hc}{\hbar\sqrt{\frac{k}{\mu}}} = 2\pi c\sqrt{\frac{\mu}{k}} \propto \sqrt{\mu}$

$\frac{\Delta\lambda}{\lambda} = \frac{1}{2}\frac{\Delta\mu}{\mu} = \frac{1}{2}\frac{0{,}0015}{0{,}9737} = 7{,}7 \cdot 10^{-4}$