

原子物理第二次作业

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系别 _____ 班级 _____ 姓名 _____ 第 _____ 页

2-2.11 $r_n = r_1 \frac{n^2}{Z}$ $r_1 = a_1 = \frac{4\pi\epsilon_0\hbar^2}{me^2} = \frac{(hc)^2}{m_0c^2e^2} = \frac{(197.3)^2}{0.511 \times 10^6 \times 44} \text{ nm} \approx 0.053 \text{ nm}$

氢原子: $r_2 = n^2 r_1 = 4r_1 = 0.212 \text{ nm}$

He⁺ $r_1 = \frac{a_1}{Z} = 0.0265 \text{ nm}$ $r_2 = a_1 \frac{2^2}{Z} = 0.106 \text{ nm}$

L⁺: $Z=3$ $r_1 = \frac{a_1}{3} = 0.0176 \text{ nm}$ $r_2 = a_1 \frac{2^2}{3} = 0.0705 \text{ nm}$

电子在玻尔轨道上 $v_n = \frac{Z}{n} c \alpha$ $v_1 = \frac{c}{137} = 2.19 \times 10^6 \text{ m/s}$

∴ 对 H: $v_1 = \alpha c = 2.19 \times 10^6 \text{ m/s}$ $v_2 = \frac{\alpha c}{2} = 1.09 \times 10^6 \text{ m/s}$

对 He: $v_1 = 2\alpha c = 4.38 \times 10^6 \text{ m/s}$ $v_2 = \frac{2\alpha c}{2} = 2.19 \times 10^6 \text{ m/s}$

对 Li: $v_1 = 3\alpha c = 6.57 \times 10^6 \text{ m/s}$ $v_2 = \frac{3\alpha c}{2} = 3.28 \times 10^6 \text{ m/s}$

(2) $E_n = -\frac{1}{2} m_e (\alpha c \frac{Z}{n})^2$ 可得 $E_1 = \frac{1}{2} m_e (\alpha c Z)^2 = 13.6 Z^2 \text{ eV}$

1-1 13.6 eV He: 54.4 eV Li: 122.4 eV

(3) $\Delta E_{12} = \frac{\Delta E_{12}}{e} = 13.6 Z^2 (1 - \frac{1}{2^2})$ H: 10.2 V He: 40.8 V Li 91.8 V

共振线波长: $\lambda_{12} = \frac{hc}{\Delta E_{12}} = \frac{hc}{E_2 - E_1}$ H: $\lambda_{12} = \frac{1.24 \text{ nm} \cdot \text{keV}}{10.2 \text{ eV}} = 121.6 \text{ nm}$

He: $\frac{1.24 \text{ nm} \cdot \text{keV}}{40.8 \text{ eV}} = 30.4 \text{ nm}$ Li: $\lambda_{12} = \frac{1.24 \text{ nm} \cdot \text{keV}}{91.8 \text{ eV}} = 13.5 \text{ nm}$

2.4. 基态氢原子发出光子落到第一激发态

$E_k = \frac{1}{2} m_p v^2 = (H \frac{m_p}{m_H}) \Delta E_{12} = 20 \Delta E_{12} = 20.4 \text{ eV}$

$v = c \cdot \sqrt{\frac{2E_k}{m_p c^2}} = \sqrt{\frac{2 \times 20.4 \text{ eV}}{938 \text{ MeV}}} \times 3 \times 10^8 = 6.26 \times 10^4 \text{ m/s}$

2.7 $V_R = R Z^2 (1 - \frac{1}{2^2}) = \frac{3}{4} R Z^2$ $V_B = R Z^2 (\frac{1}{2^2} - \frac{1}{3^2}) = \frac{5}{36} R Z^2$

$\lambda = \lambda_B - \lambda_R = \frac{36}{5 R Z^2} - \frac{4}{3 R Z^2} = \frac{88}{15 R Z^2} = 133.7 \text{ nm}$

$Z^2 = \frac{88}{15 \times 1.097 \times 10^{-2} \times 133.7} \approx 4$ $Z = 2$

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2-10 (1) μ 子类似 H 原子 由 $\mu = \frac{207m_e M}{207m_e + M} = \frac{207 \times 1836}{207 + 1836} m_e = 186.0 m_e$

$$r_1 = \frac{4\pi\epsilon_0 \hbar^2}{186.0 m_e e^2} = \frac{a_1}{186.0} = \frac{0.053}{186} = 2.85 \times 10^{-4} \text{ nm}$$

$$(2) E_1 = -\frac{1}{2} \mu (2\pi c \frac{e}{\hbar})^2 = -186 \times 13.6 \text{ eV} = -2.53 \times 10^3 \text{ eV}$$

$$(3) \lambda = \frac{hc}{\Delta E} = \frac{hc}{E_\infty - E_1} = \frac{1.24 \times 10^3 \text{ nm} \cdot \text{eV}}{2.53 \times 10^3 \text{ eV}} = 0.49 \text{ nm}$$

2-11 $R_A = \frac{R_\infty}{1 + \frac{m_e}{M_A}} \quad \therefore \frac{R_H}{R_D} = \frac{1 + \frac{m_e}{M_D}}{1 + \frac{m_e}{M_H}} = 0.999728 = 1 + \frac{0.50020 m_e}{M_H}$

$$\therefore \frac{M_H}{m_e} = \frac{0.499528}{0.000272} = 1836.5 \approx 1.8 \times 10^3$$

8-1 $\Delta E = E_2 - E_1 = 13.6 - 3.4 = 10.2 \text{ eV}$

$$p = \frac{\bar{E}}{c} = \frac{10.2 \text{ eV}}{c} \quad \cancel{V = \frac{h\nu}{c}} \quad V = C$$

8-8 $m_W^2 r = \frac{e^2}{4\pi\epsilon_0 r^2} \quad W = \sqrt{\frac{e^2}{4\pi\epsilon_0 m_e r^3}} \quad r = \frac{4\pi\epsilon_0 \hbar^2}{m_e e^2} = a_1 = 0.053 \text{ nm}$

$$D = 4.1 \times 10^{16}$$

$$E = -\frac{e^2}{4\pi\epsilon_0 r} = -13.6 \text{ eV}$$

8-18 $\frac{1}{\lambda} = R \left(\frac{1}{2^2} - \frac{1}{n^2} \right) \quad R_{\text{He}^+} = 4R$

$$\left(\frac{1}{164.05 \times 10^{-9}} = \frac{4}{1.097 \times 10^{-7}} \left(\frac{1}{4} - \frac{1}{n^2} \right) \right) \quad n=3$$

$$\left(\frac{1}{121.52 \times 10^{-9}} = \frac{4}{1.097 \times 10^{-7}} \left(\frac{1}{4} - \frac{1}{n^2} \right) \right) \quad n=4$$

$$\left(\frac{1}{102.45 \times 10^{-9}} = \frac{4}{1.097 \times 10^{-7}} \left(\frac{1}{4} - \frac{1}{n^2} \right) \right) \quad n=5$$

$$\left(\frac{1}{102.53 \times 10^{-9}} = \frac{4}{1.097 \times 10^{-7}} \left(\frac{1}{4} - \frac{1}{n^2} \right) \right) \quad n=6$$

方法可以将其绘制于能级图上