Atomic Physics

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0.1 Bohr Model

1. 定态条件：氢原子中的一个电子绕原子核作圆周运动，电子只能处于一些分立的轨道上，它只能在这些轨道上绕核转动，且不产生辐射。

2. 频率条件：当电子从一个定态轨道跃迁到另一个定态轨道时，会以电磁波的形式放出 (或吸收) 能量 $h\nu$，其值由能级差决定:

$$h\nu = E_{n'} - E_n \ , \tag{1}$$

3. 角动量量子化

$$L = n\hbar \ , n = 1, 2, 3, \tag{2}$$

4. 对应原理

推导

$$\begin{aligned} F &= m_e \frac{v^2}{r} \ , \\ \frac{1}{4\pi\epsilon_0}\frac{e^2}{r^2} &= \frac{m_e v^2}{r} \ , \\ v^2 &= \frac{1}{4\pi\epsilon_0}\frac{e^2}{m_e r} \ . \end{aligned}$$

$$m_e v r = n\hbar \ ,$$

$$v = \frac{n\hbar}{m_e r} \ .$$

$$\frac{1}{4\pi\epsilon_0}\frac{e^2}{m_e r} = \frac{n^2\hbar^2}{m_e^2 r^2} \ ,$$

$$r = \frac{4\pi\epsilon_0\hbar^2}{m_e e^2} n^2 \ , \tag{3}$$

$$r_n = \frac{1}{4\pi\epsilon_0}\frac{e^2}{2Rhc} n^2 \ . \tag{4}$$

$$\begin{aligned} E = T + V &= \frac{1}{2}m_e v^2 - \frac{e^2}{4\pi\epsilon_0 r} \ , \\ &= \frac{1}{2}\frac{e^2}{4\pi\epsilon_0 r} - \frac{e^2}{4\pi\epsilon_0 r} \ , \\ &= -\frac{1}{2}\frac{e^2}{4\pi\epsilon_0 r} \ , \\ &= -\frac{1}{2}\frac{e^2}{4\pi\epsilon_0} \times \frac{m_e e^2}{4\pi\epsilon_0 n^2\hbar^2} \ , \end{aligned}$$

$$E_n = -\frac{m_e e^4}{(4\pi\epsilon_0)^2 \cdot 2n^2\hbar^2} \ . \tag{5}$$

$$\tag{6}$$

电子作圆周运动的频率

$$f = \frac{v}{2\pi r} = \frac{1}{2\pi r}\sqrt{\frac{e^2}{4\pi\epsilon_0 m_e r}} = \frac{e}{2\pi}\sqrt{\frac{1}{4\pi\epsilon_0 m_e r^3}} \tag{7}$$

$$\hbar c = 197 \ \mathrm{fm \cdot MeV} = 197 \ \mathrm{nm \cdot eV} \ , \tag{8}$$

$$\frac{e^2}{4\pi\epsilon_0} = 1.44 \ \mathrm{fm \cdot MeV} = 1.44 \ \mathrm{nm \cdot eV} \ , \tag{9}$$

$$m_e c^2 = 0.511 \ \mathrm{MeV} = 511 \ \mathrm{keV} \ , \tag{10}$$

$1\ \mathrm{fm} = 10^{-6}\ \mathrm{nm} = 10^{-15}\ \mathrm{m}$。精细结构常数

$$\alpha \equiv \frac{e^2}{4\pi\epsilon_0 \hbar c} \approx \frac{1}{137}\ . \tag{11}$$

$$r_1 \equiv a_1 = \frac{4\pi\epsilon_0\hbar^2}{m_e e^2} = \frac{(\hbar c)^2}{m_e c^2 e^2/4\pi\epsilon_0} = \frac{(197)^2}{0.511\times 10^6 \times 1.44}\,\mathrm{nm} \approx \frac{0.039\times 10^6}{0.73\times 10^6}\,\mathrm{nm} \approx 0.053\,\mathrm{nm}\,. \tag{12}$$