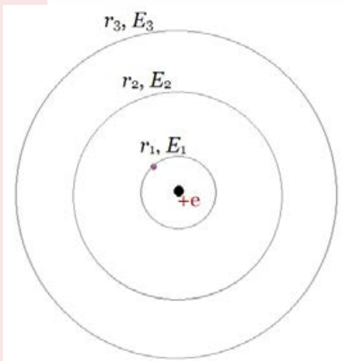
Ritz 公式 Rydberg–Ritz combination principle

$$\tilde{v} = R_H \left[\frac{1}{m^2} - \frac{1}{n^2} \right] = T(m) - T(n)$$

$$T(m) = \frac{R_H}{m^2}$$ 称为光谱项

W. Ritz
(1878-1909)

Bohr原子模型三部曲



Niels Bohr (1913). "On the Constitution of Atoms and Molecules, Part I". *Philosophical Magazine* 26: 1–24.

Niels Bohr (1913). "On the Constitution of Atoms and Molecules, Part II Systems Containing Only a Single Nucleus". *Philosophical Magazine* 26: 476–502. http://web.ihep.su/dbserv/compas/src/bohr13b/eng.pdf.

Niels Bohr (1913). "On the Constitution of Atoms and Molecules, Part III Systems containing several nuclei". *Philosophical Magazine* 26: 857–875.

 Niels Bohr

7 October 1885 – 18 November 1962

The Nobel Prize in Physics 1922

"for his services in the investigation of the structure of atoms and of the radiation emanating from them"

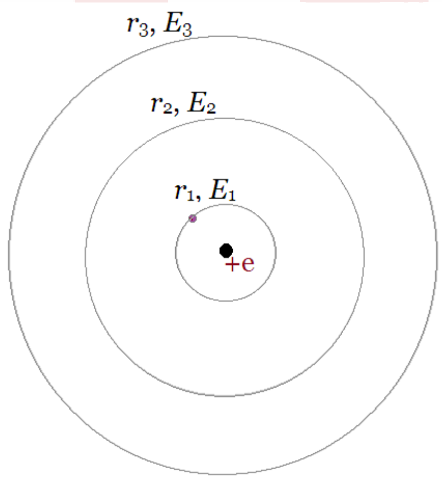
§ 1.5.3 H原子光谱和Bohr原子模型—Bohr氢原子理论

(1) 定态假设　　经典轨道+定态条件

Max Planck
(1858-1947)

经典轨道：H原子中的电子围绕原子核作圆周运动(Rutherford原子核式模型)。

定态条件：为了避免“原子塌缩”，借鉴了Planck的能量量子化观点。



$$E = T + V = -\frac{1}{2}\frac{e^2}{4\pi\varepsilon_0 r}$$

假设H原子的能量也是量子化的。

$$E_n = -\frac{1}{2}\frac{e^2}{4\pi\varepsilon_0 r_n}$$

H原子核外电子只能在一系列具有确定能量的分立的圆周轨道上运动。

定态条件：　并且假设在这些轨道上运动时不辐射电磁波。

Bohr将这样一些稳定的轨道称为定态。

§ 1.5.3 H原子光谱和Bohr原子模型—Bohr氢原子理论

(2) 频率条件

如何产生光谱辐射？

从Ritz 公式出发 $\tilde{\nu} = T(m) - T(n)$

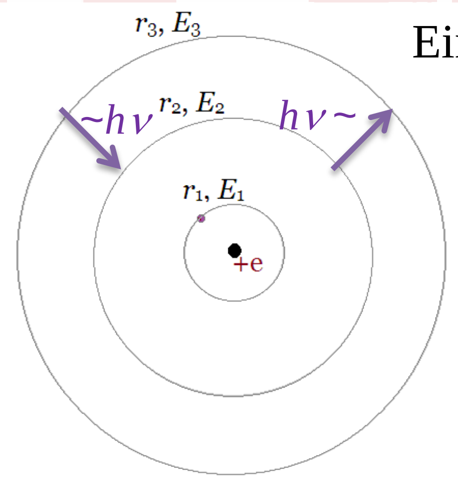
$$T(n) = \frac{R_H}{n^2}$$

$$hc\tilde{\nu} = h\nu = hcT(m) - hcT(n)$$

$$E_n = -hcT(n)$$

Einstein的光量子 $= E_n - E_m$

定态m的能量　　定态n的能量



定态跃迁：原子能量的改变是从一个定态跃迁(突然变到)到另一个定态。

跃迁过程放出(或吸收)一个光子，其能量：

$$h\nu = |E_m - E_n|$$

Bohr频率规则 $\boxed{\nu = |E_m - E_n| / h}$

J. J. Balmer
(1825-1898)

W. Ritz
(1878-1909)

A. Einstein
(1879-1955)

§ 1.5.3 H原子光谱和Bohr原子模型—Bohr氢原子理论

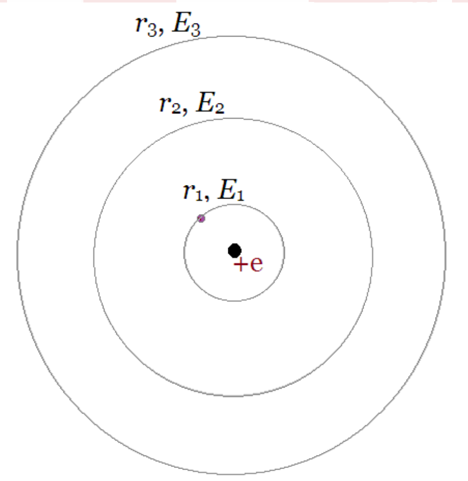
(3) 角动量量子化 （H原子）

$$L = L_n = n\hbar = n\frac{h}{2\pi}, \qquad n = 1, 2, 3, \ldots$$

?

N. Bohr
(1885-1962)

Bohr对应原理

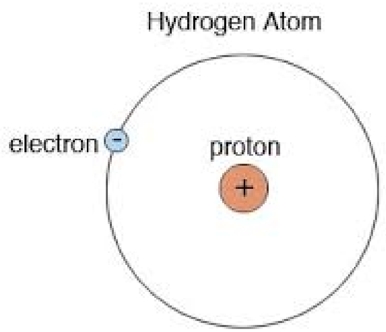


经典规律和量子规律虽然在形式上和内容上均有不同之处，看起来似乎是矛盾的。但这种矛盾只是它们应用在不同条件和场合下才出现，它们在各自的应用领域中均是正确的，因此，经典的和量子的物理量之间应该有一一对应的关系，在极限条件下，彼此趋于一致，即量子规律转化为经典规律，这叫做对应原理。

§ 1.5.3 H原子光谱和Bohr原子模型—Bohr氢原子理论

H原子辐射频率

经典理论 $$f = \frac{e}{2\pi}\sqrt{\frac{1}{4\pi\varepsilon_0 m_e r^3}}$$



Bohr量子理论

从Rydberg经验公式出发，结合定态假设

H原子定态能量 $$E_n = -hcT(n) = -hc\frac{R_H}{n^2}$$

$$E_n = -\frac{1}{2}\frac{e^2}{4\pi\varepsilon_0 r_n}$$

$$r_n = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{2R_H hc}n^2$$

H原子的定态能量和轨道半径都是正整数n的函数，即是量子化的

n =1,2,3,… 称为量子数

Bohr频率规则

$$\nu = \left|E_m - E_n\right| / h = \left[\left(-hc\frac{R_H}{n^2}\right) - \left(-hc\frac{R_H}{m^2}\right)\right] / h \qquad (\text{设} m < n)$$

$$= R_H c\left(\frac{1}{m^2} - \frac{1}{n^2}\right) = R_H c\frac{(n+m)(n-m)}{m^2 n^2}$$

当n很大时，邻能级间跃迁的频率 ($n = m+1 \to \infty$)

$$\nu = R_H c\frac{(n+n-1)(n-n+1)}{(n-1)^2 n^2} \approx R_H c\frac{2}{n^3}$$

§ 1.5.3 H原子光谱和Bohr原子模型—Bohr氢原子理论

按照Bohr对应原理，在大量子数极限下，量子计算与经典计算一致

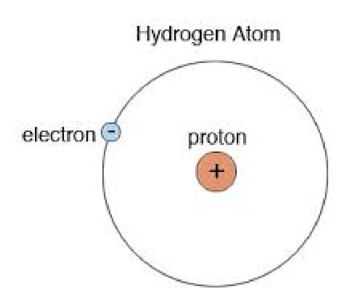
有 $$\frac{e}{2\pi}\sqrt{\frac{1}{4\pi\varepsilon_0 m_e r^3}} = R_H c \frac{2}{n^3}$$ $\Rightarrow$ $$r = \sqrt[3]{\frac{1}{4\pi\varepsilon_0}\frac{e^2}{16\pi^2 R_H^2 c^2 m_e}}n^2$$

又 $$r_n = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{2R_H hc}n^2$$

得到 $$R_H = \frac{m_e e^4}{(4\pi\varepsilon_0)^2 4\pi\hbar^3 c}$$

§ 1.5.3 H原子光谱和Bohr原子模型—Bohr氢原子理论

将 $R_H = \dfrac{m_e e^4}{(4\pi\varepsilon_0)^2 4\pi\hbar^3 c}$ 代回 $r_n = \dfrac{1}{4\pi\varepsilon_0}\dfrac{e^2}{2R_H hc}n^2$



得到 $$r_n = \frac{4\pi\varepsilon_0\hbar^2}{m_e e^2}n^2$$

又 $$\frac{1}{2}m_e v^2 = \frac{1}{2}\frac{e^2}{4\pi\varepsilon_0 r} \Rightarrow v = \sqrt{\frac{e^2}{4\pi\varepsilon_0 m_e r}}$$

所以，角动量 $$L = m_e v r = m_e\sqrt{\frac{e^2}{4\pi\varepsilon_0 m_e r}}\cdot r = \sqrt{\frac{e^2}{4\pi\varepsilon_0}m_e r} = \sqrt{\frac{e^2}{4\pi\varepsilon_0}m_e\frac{4\pi\varepsilon_0\hbar^2}{m_e e^2}n^2}$$
$$= n\hbar$$

在大量子数极限下，得到了角动量量子化

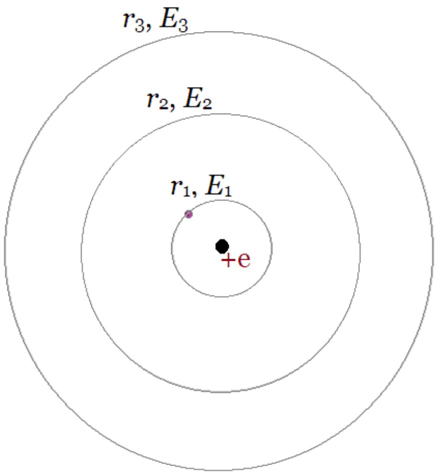
$$L = n\hbar \qquad \text{其中} \quad \hbar = \frac{h}{2\pi}$$

假设在小量子数下，即n小的时候也成立。

(3) 角动量量子化 （H原子）

$$L = L_n = n\hbar = n\frac{h}{2\pi}, \qquad n = 1, 2, 3, \ldots$$

N. Bohr
(1885-1962)



H原子的大小

从角动量量子化出发

$$\left.\begin{array}{l} L = m_e vr = n\hbar \\ \frac{1}{2}m_e v^2 = \frac{1}{2}\frac{e^2}{4\pi\varepsilon_0 r} \end{array}\right\} \quad r_n = \frac{4\pi\varepsilon_0\hbar^2}{m_e e^2}n^2 \quad = n^2 a_0$$

复合常数

$$\boxed{\frac{e^2}{4\pi\varepsilon_0} = 1.44eV\cdot nm}$$

$$\boxed{\hbar c = 197eV\cdot nm}$$

$$\boxed{m_e c^2 = 0.511MeV}$$

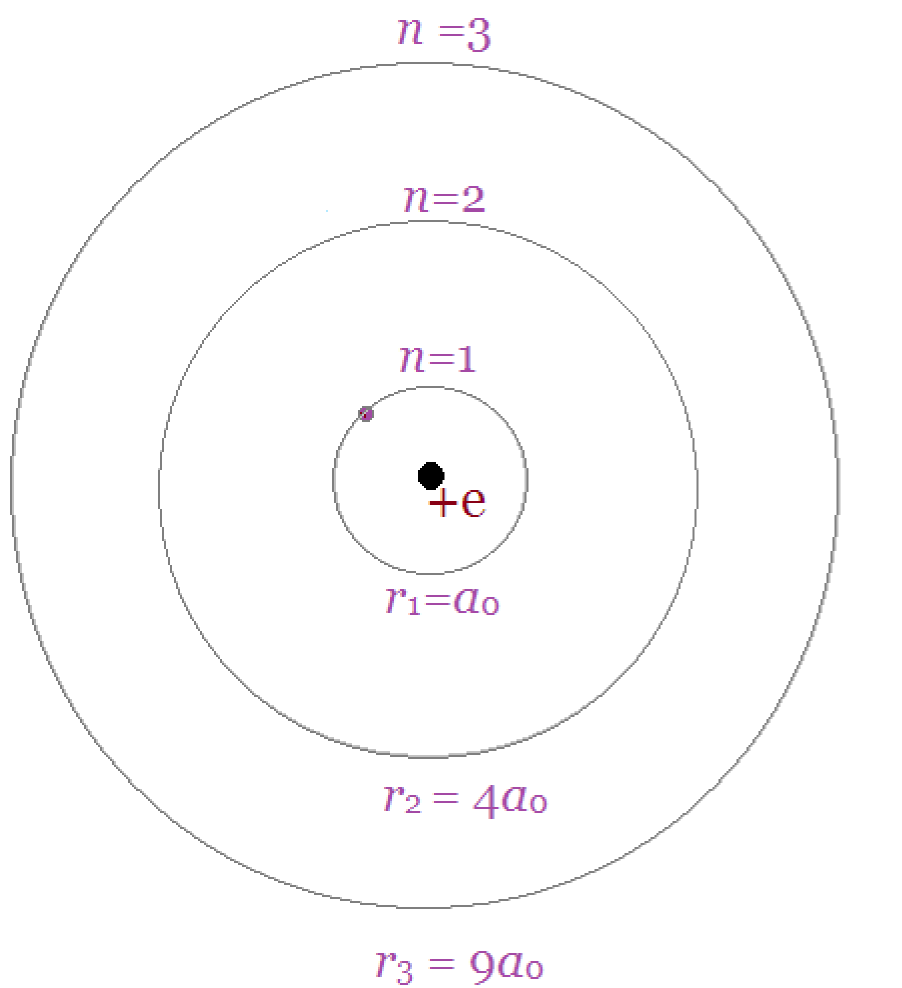
其中 $a_0 = \frac{4\pi\varepsilon_0\hbar^2}{m_e e^2} = \frac{4\pi\varepsilon_0}{e^2}\frac{(\hbar c)^2}{m_e c^2}$

$$= \frac{1}{1.44eV\cdot nm}\frac{(197eV\cdot nm)^2}{0.511\times10^6 eV}$$

$$\approx 0.053nm = 0.53\times10^{-10}m = 0.53\,\mathring{A}$$

称为玻尔半径。

H原子的大小



➤确定的原子大小：10^{-10}m

H原子的电子运动的速度大小

$$r_n = \frac{4\pi\varepsilon_0\hbar^2}{m_e e^2} n^2 \quad \text{代入} \quad v = \sqrt{\frac{e^2}{4\pi\varepsilon_0 m_e r}}$$

得

$$v = v_n = \frac{e^2}{4\pi\varepsilon_0 n\hbar} = \frac{\alpha c}{n}$$

其中 $\alpha = \dfrac{e^2}{4\pi\varepsilon_0\hbar c} = \dfrac{1}{137}$ 称为精细结构常数。

所以，电子的运动速度 $v << c$，因而不用考虑相对论。

H原子的定态能量

$$r_n = \frac{4\pi\varepsilon_0\hbar^2}{m_e e^2} n^2 \quad \text{代入} \quad E = -\frac{1}{2}\frac{e^2}{4\pi\varepsilon_0 r}$$

得 $$E_n = -\frac{1}{2}\frac{e^2}{4\pi\varepsilon_0 r_n} = -\frac{1}{2}\frac{e^2}{4\pi\varepsilon_0}\frac{m_e e^2}{4\pi\varepsilon_0\hbar^2 n^2} = -\frac{1}{(4\pi\varepsilon_0)^2}\frac{m_e e^4}{2\hbar^2 n^2}$$

$$= -hcR_\infty \frac{1}{n^2} \qquad n = 1, 2, 3, \ldots$$

里德伯常数的理论公式 $$R_\infty = \frac{1}{(4\pi\varepsilon_0)^2}\frac{m_e e^4}{4\pi\hbar^3 c}$$

$$\boxed{E_n = -\frac{1}{2} m_e \alpha^2 c^2 \frac{1}{n^2}}$$

§ 1.5.3 H原子光谱和Bohr原子模型—Bohr氢原子理论

$$E_n = -\frac{1}{2} m_e \alpha^2 c^2 \frac{1}{n^2}$$

H原子的能级和能级图

H原子的能级

基态：能量最低的n=1的状态

基态能量：

$$E_1 = -\frac{1}{2} m_e \alpha^2 c^2 \frac{1}{1^2}$$

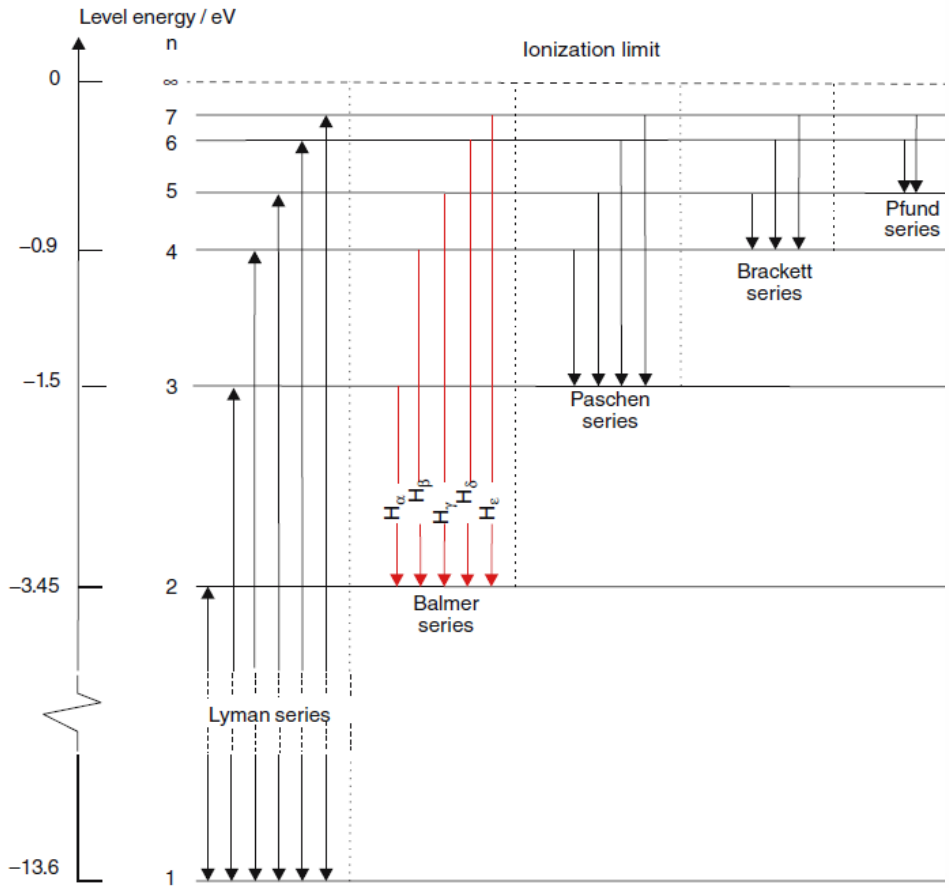
$$= -\frac{1}{2} \times \left(\frac{1}{137}\right)^2 \times 0.511 \times 10^6 eV$$

$$\boxed{\approx -13.6eV}$$

激发态：n>1的状态

激发态能量：

$$E_n = \frac{E_1}{n^2}$$



H原子的能级图

§ 1.5.3 H原子光谱和Bohr原子模型—Bohr氢原子理论

$$E_n = -\frac{1}{2} m_e \alpha^2 c^2 \frac{1}{n^2}$$

H原子的能级和能级图

H原子的能级

$n \to \infty$时，$E_n \to 0$

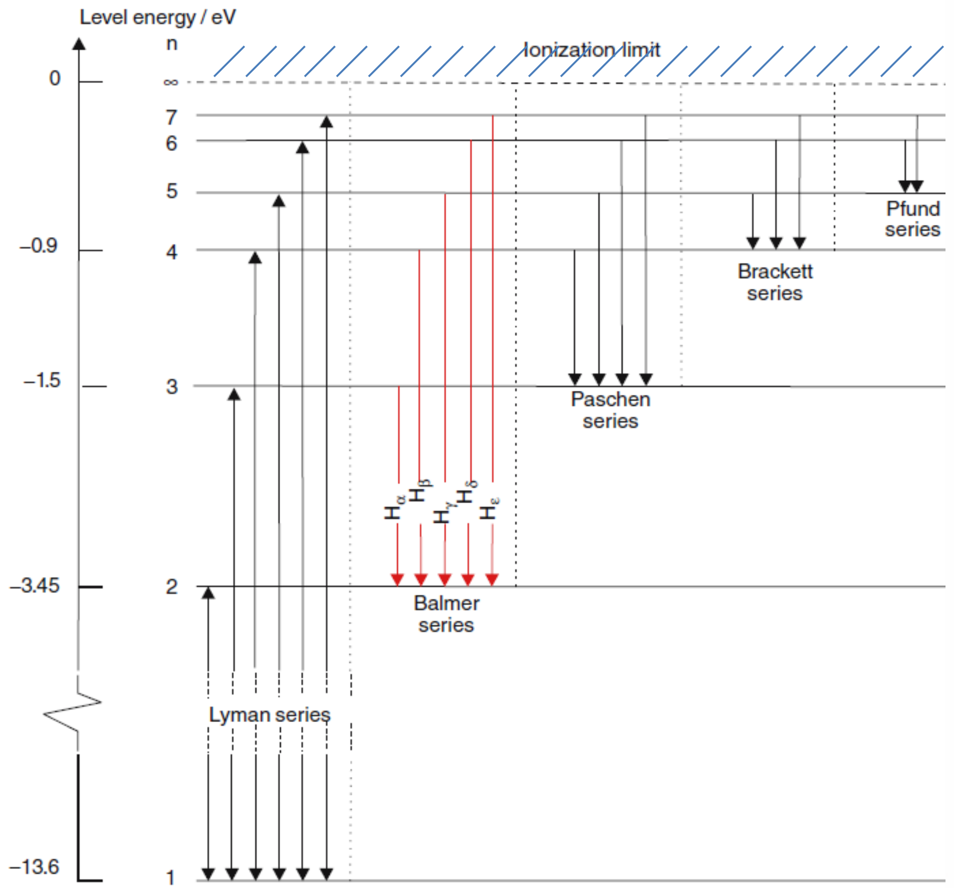
$$E = -\frac{1}{2} \frac{e^2}{4\pi\varepsilon_0 r}$$

$r \to \infty$

电子脱离原子核库仑场的束缚，成为自由电子，称为电离。

自由电子可以具有一定的动能T，而$r \to \infty$时，势能$V(r) = 0$，所以总能量 $E = T > 0$，轨道是双曲线的一支，动能可以为任意值，不是量子化的。

能级图上是$n \to \infty$时，$E_n \to 0$之上连续的正能量区。

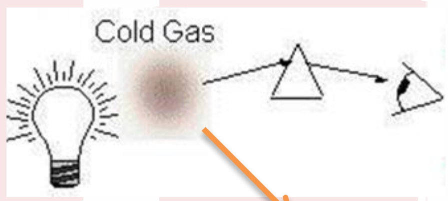


H原子的能级图

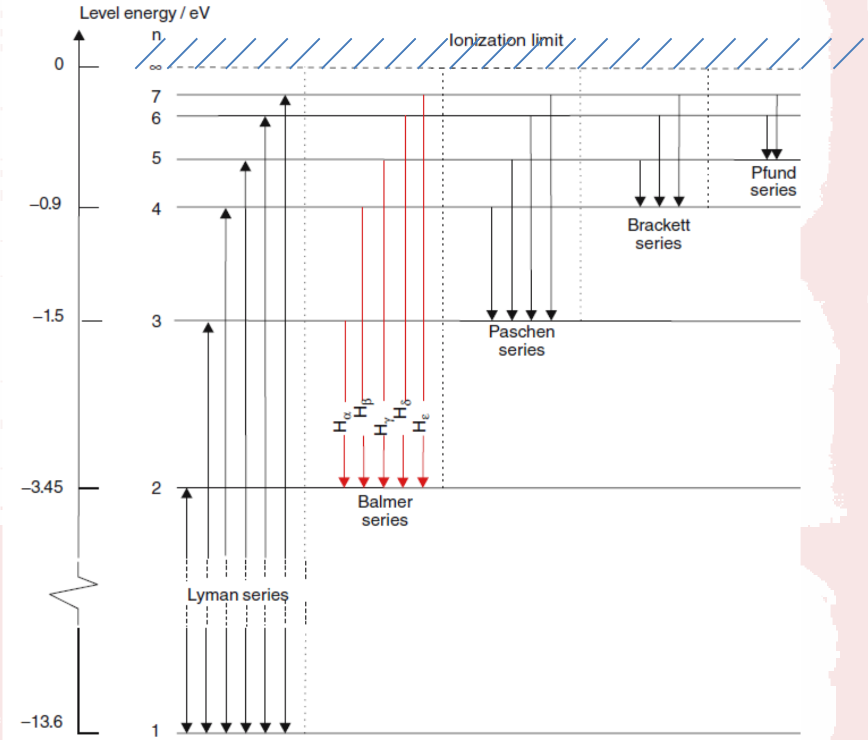
§ 1.5.3 H原子光谱和Bohr原子模型—氢原子光谱解释

H原子的光谱

冷气体原子的吸收光谱



温度T



H原子的能级图

大量H原子可以处在n=1, 2, 3, … 等不同的能级，例如N_1个H原子处在n=1能级、 N_2个H原子处在n=2能级、依次类推，服从Boltzmann统计分布。

$$N_i \propto \exp(-E_i / k_B T)$$

常温T=300K

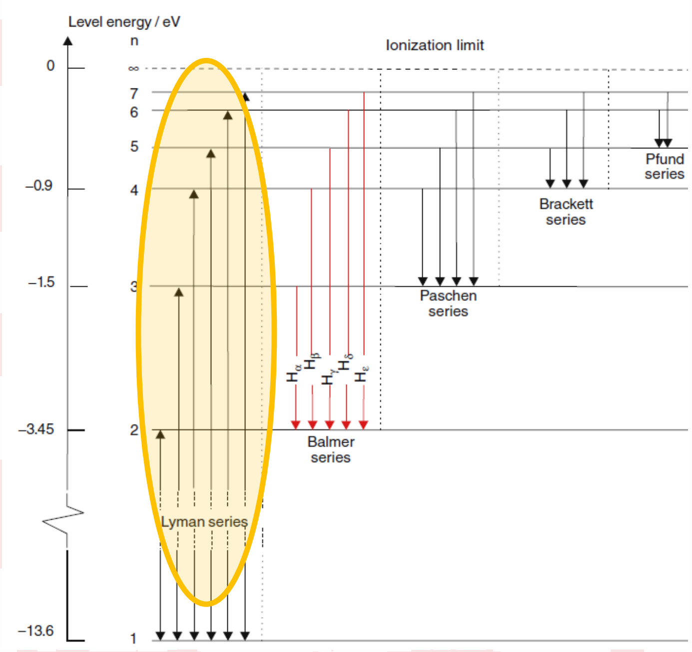
$$\frac{N_2}{N_1} \sim \frac{\exp(-E_2/k_BT)}{\exp(-E_1/k_BT)} = e^{-(E_2-E_1)/k_BT}$$

Boltzmann常数 k = 8.62×10^{-5} eV·K^{-1}

$$E_1 = -13.6eV \qquad E_2 = \frac{-13.6eV}{2^2} = -3.4eV$$

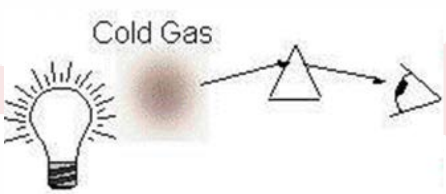
$$\frac{N_2}{N_1} \sim e^{-(-3.4eV+13.6eV)/(8.62\times10^{-5}eV\cdot K^{-1}\cdot 300K)}$$

$$= e^{-394.6} \sim 4.2\times10^{-172} = 0$$



H原子的能级图

常温下，一团冷气体的原子几乎全部处在基态。白光通过，一些H原子吸收光子跃迁到激发态。



只有莱曼线系 $$hc\tilde{\nu} = E_n - E_1 = -\frac{1}{2}m_e\alpha^2c^2\frac{1}{n^2} + \frac{1}{2}m_e\alpha^2c^2\frac{1}{1^2}$$

§ 1.5.3 H原子光谱和Bohr原子模型—氢原子光谱解释

$$\tilde{\nu}=(E_n-E_1)/hc=\frac{m_e\alpha^2 c}{2h}\left(\frac{1}{1^2}-\frac{1}{n^2}\right)$$

$$n=2,3,4,\ldots$$

比较经验公式

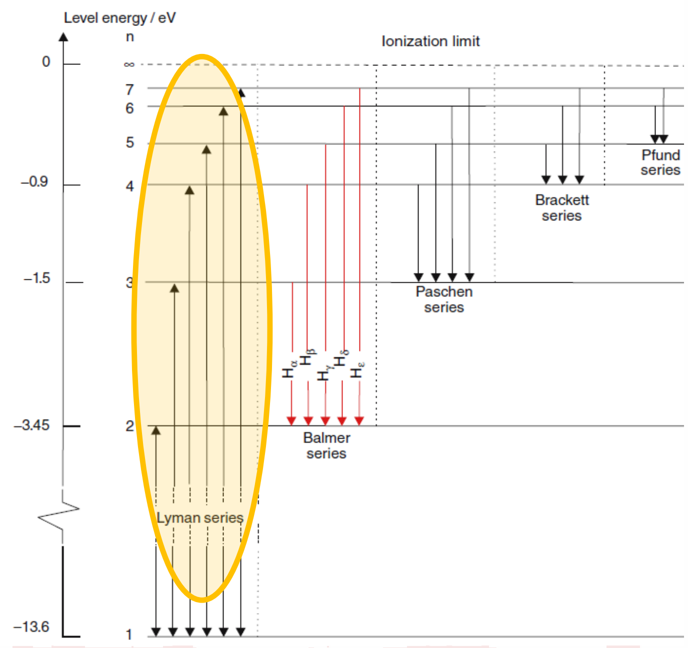
$$\tilde{\nu}=R_H\left[\frac{1}{1^2}-\frac{1}{n^2}\right]$$

里德伯常数的理论公式

$$R_\infty=\frac{1}{(4\pi\varepsilon_0)^2}\frac{m_e e^4}{4\pi\hbar^3 c}=1.097,373,156\times10^7\,m^{-1}$$

光谱实验值

$$R_H=1.096,775,8\times10^7\,\mathrm{m}^{-1}$$



H原子的能级图

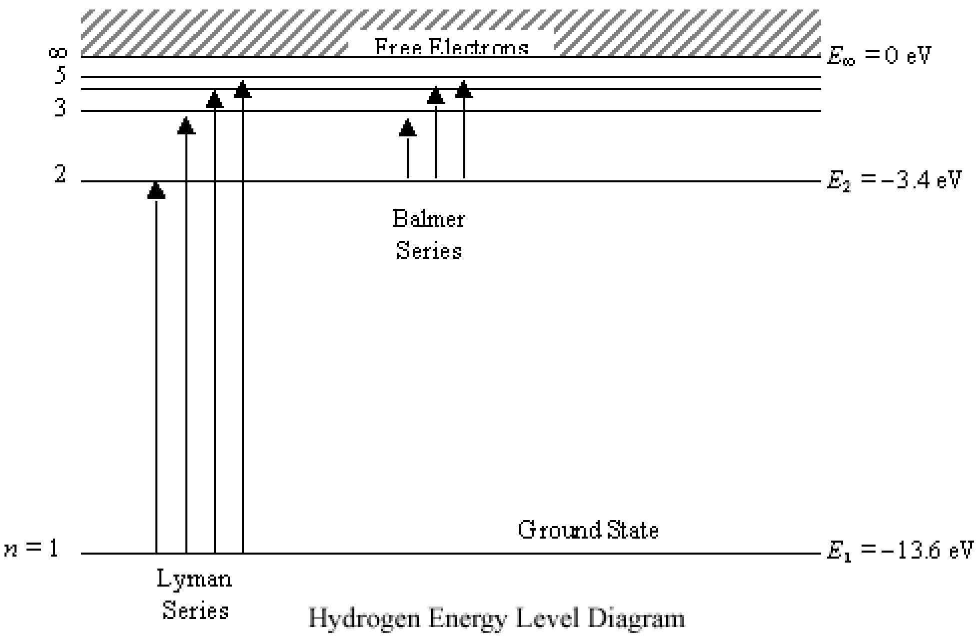
理论计算与实验值符合得非常好！

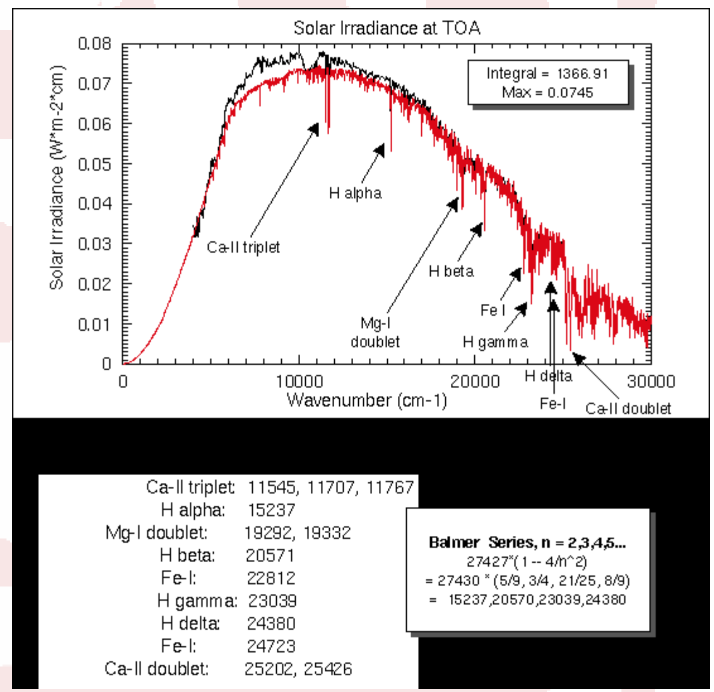
§ 1.5.3 H原子光谱和Bohr原子模型—氢原子光谱解释

太阳表面 T = 6000K

$$\frac{N_2}{N_1} \sim e^{-(-3.4eV+13.6eV)/(8.62\times10^{-5}\,eV\cdot K^{-1}\cdot 6000K)}$$

$$= e^{-19.73} \sim 2.7\times10^{-9}$$

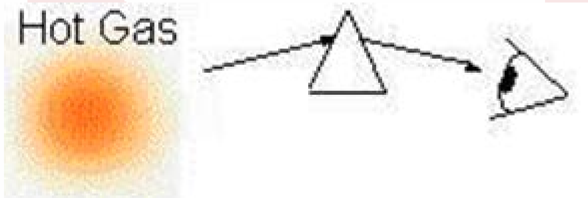




太阳光谱

§ 1.5.3 H原子光谱和Bohr原子模型—氢原子光谱解释

热气体原子的发射光谱

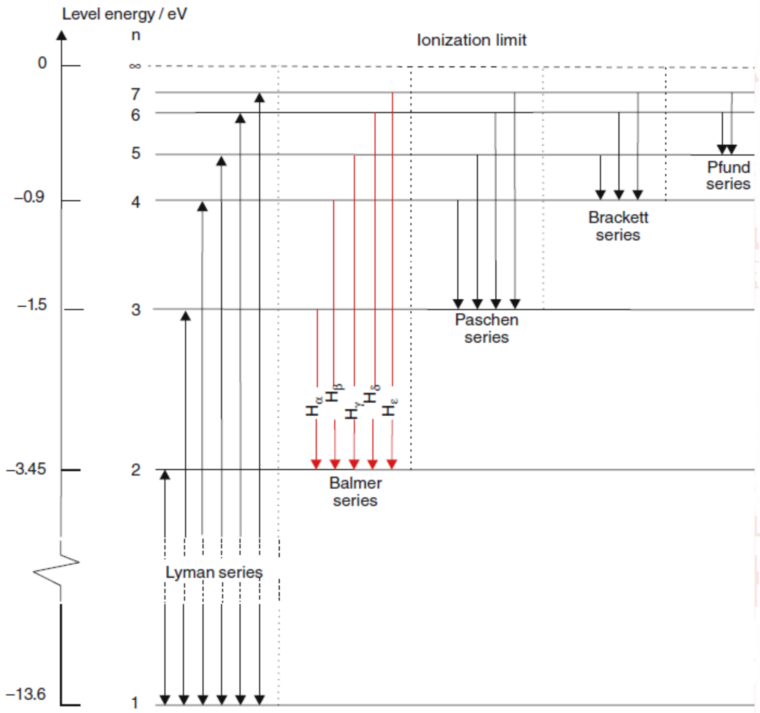


$$hc\tilde{\nu} = E_n - E_m \qquad (m < n)$$

$$= -\frac{1}{2} m_e \alpha^2 c^2 \frac{1}{n^2} + \frac{1}{2} m_e \alpha^2 c^2 \frac{1}{m^2}$$

$$\tilde{\nu} = \frac{m_e \alpha^2 c}{2h}\left(\frac{1}{m^2} - \frac{1}{n^2}\right)$$

$$= R_\infty \left(\frac{1}{m^2} - \frac{1}{n^2}\right)$$



§ 1.5.3 H原子光谱和Bohr原子模型—氢原子光谱解释

巴尔末线系 $(m=2)$

$$\tilde{\nu} = R_\infty \left[\frac{1}{2^2} - \frac{1}{n^2} \right], \qquad n = 3,4,5,\cdots$$

莱曼系 $(m=1)$

$$\tilde{\nu} = R_\infty \left[\frac{1}{1^2} - \frac{1}{n^2} \right] \qquad n = 2,3,4,\ldots$$

帕邢系 $(m=3)$

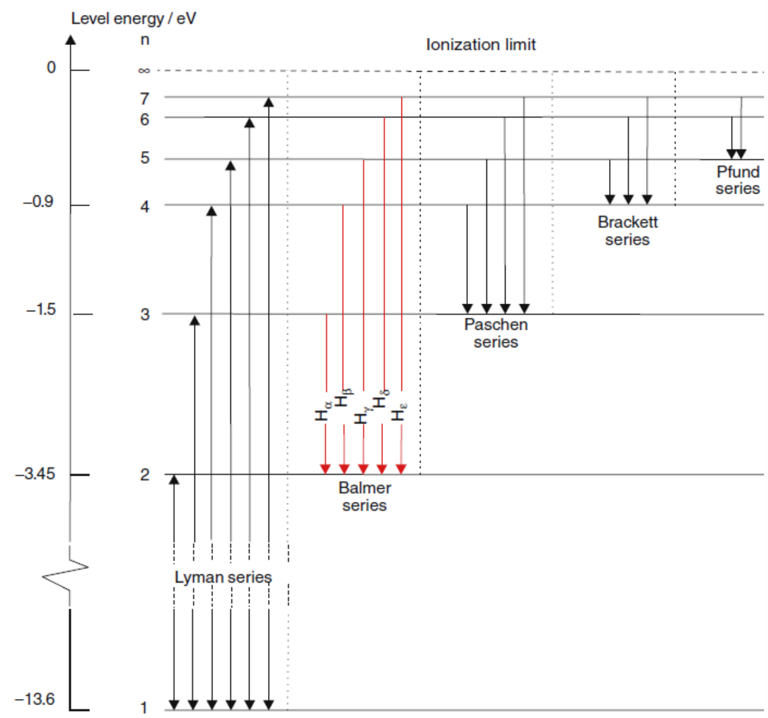
$$\tilde{\nu} = R_\infty \left[\frac{1}{3^2} - \frac{1}{n^2} \right] \qquad n = 4,5,6,\ldots$$

布喇开系 $(m=4)$

$$\tilde{\nu} = R_\infty \left[\frac{1}{4^2} - \frac{1}{n^2} \right] \qquad n = 5,6,7,\ldots$$

普丰特系 $(m=5)$

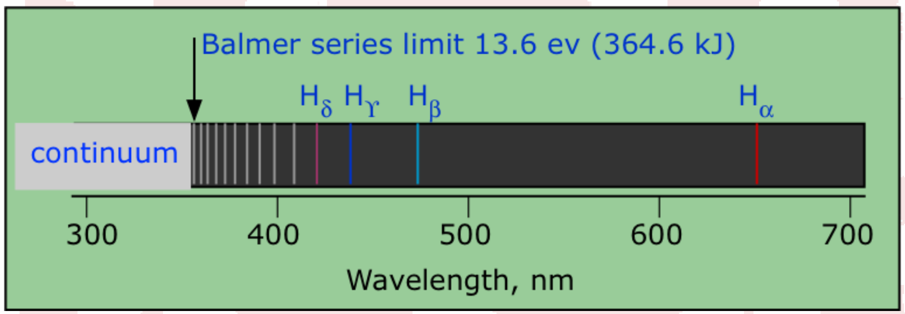
$$\tilde{\nu} = R_\infty \left[\frac{1}{5^2} - \frac{1}{n^2} \right] \qquad n = 6,7,8,\ldots$$

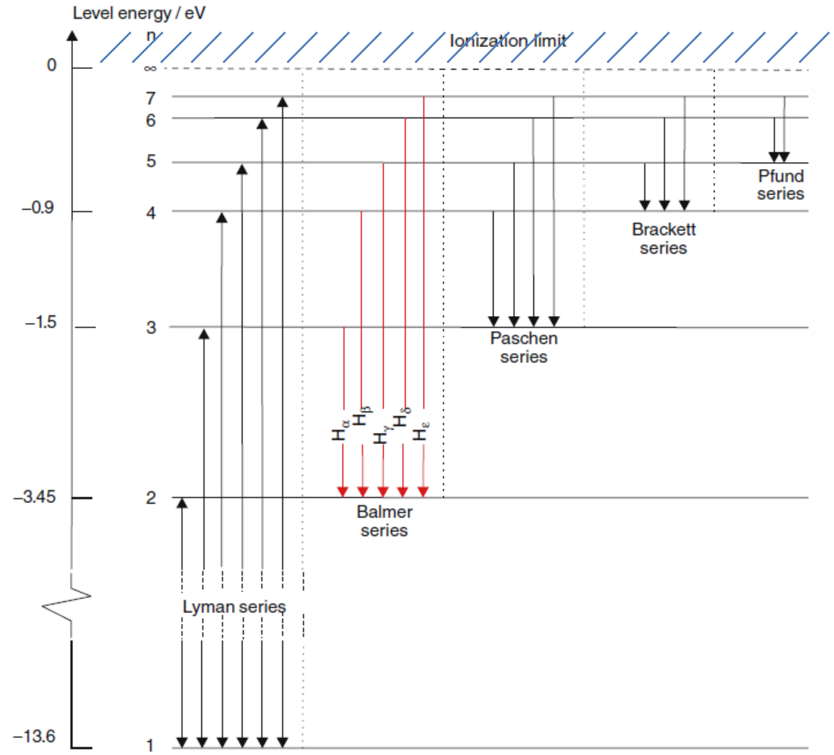


巴尔末线系 (m =2)

$$\tilde{v} = R_{\infty}\left[\frac{1}{2^2} - \frac{1}{n^2}\right], \qquad n = 3, 4, 5, \cdots$$

$$R_{\infty} = 1.097,373,156 \times 10^7\, m^{-1}$$





	3→2	4→2	5→2	6→2				
Name	H-α	H-β	H-γ	H-δ	H-ε	H-ζ	H-η	limit
Exp. (nm)	656.3	486.1	434.1	410.2	397.0	388.9	383.5	364.6
Theo. (nm)	656.1	486.0	433.9	410.1				364.5

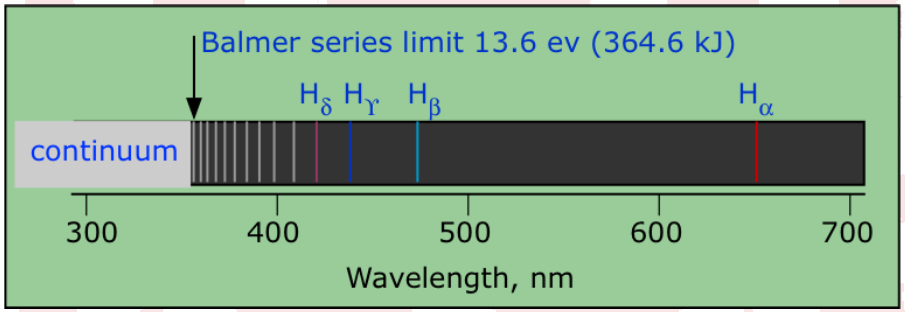
§ 1.5.3 H原子光谱和Bohr原子模型—氢原子光谱解释

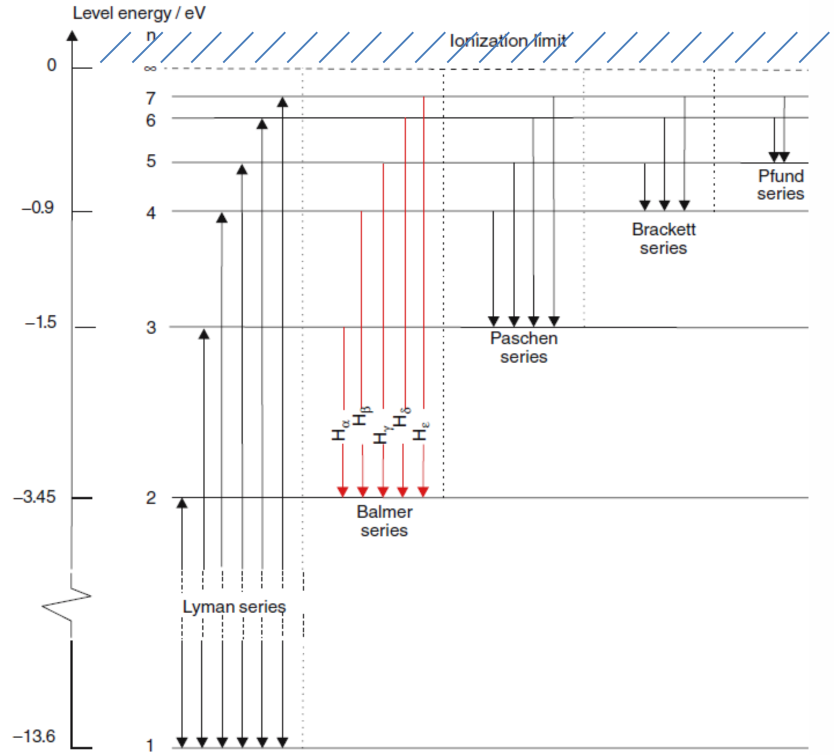
巴尔末线系的系限

$$n = \infty \rightarrow n = 2$$

$$\tilde{v}_{\infty} = R_{\infty}\left[\frac{1}{2^2} - \frac{1}{\infty^2}\right] = \frac{R_{\infty}}{2^2}$$

$$R_{\infty} = 1.097,373,156 \times 10^7\, m^{-1}$$





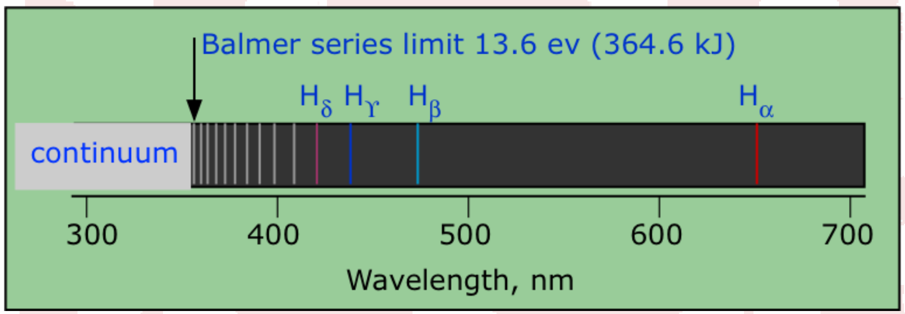
	$3\rightarrow2$	$4\rightarrow2$	$5\rightarrow2$	$6\rightarrow2$				$\infty\rightarrow2$
Name	H-α	H-β	H-γ	H-δ	H-ε	H-ζ	H-η	limit
Exp. (nm)	656.3	486.1	434.1	410.2	397.0	388.9	383.5	364.6
Theo. (nm)	656.1	486.0	433.9	410.1				364.5

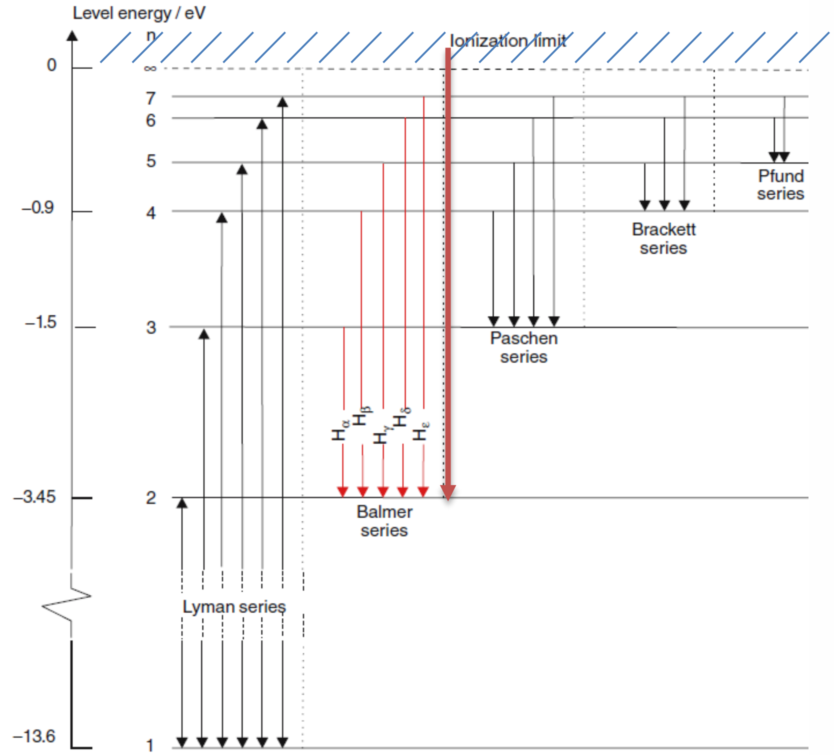
§ 1.5.3 H原子光谱和Bohr原子模型—氢原子光谱解释

系限外连续谱

连续态→ $n = 2$

$$\tilde{\nu} = \frac{1}{2} m_e v^2 + \frac{R_\infty}{2^2}$$





	3→2	4→2	5→2	6→2				∞ →2
Name	H-α	H-β	H-γ	H-δ	H-ε	H-ζ	H-η	limit
Exp. (nm)	656.3	486.1	434.1	410.2	397.0	388.9	383.5	364.6
Theo. (nm)	656.1	486.0	433.9	410.1				364.5

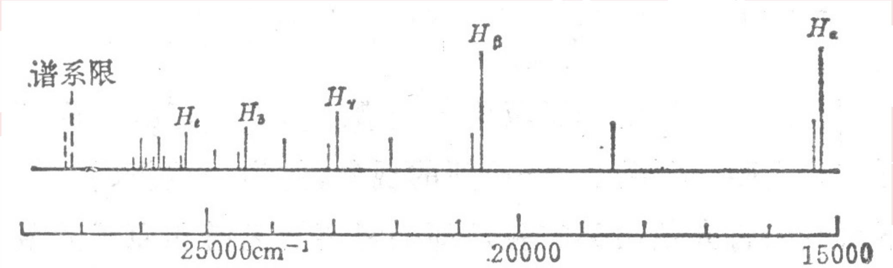
§ 1.6 氢原子理论的检验

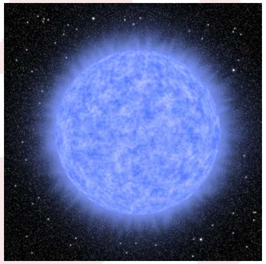
玻尔氢原子理论

① 解释了H原子的大小；
② 完美地解释了H原子光谱；
③ 理论上精确计算了里德伯常数。

E. C. Pickering
(1846-1919)

问题一 1897年，天文学家毕克林在观察船尾座ζ星(中国古天文名：弧矢增二十二)的星光光谱时发现了一个新的线系，称为毕克林线系。



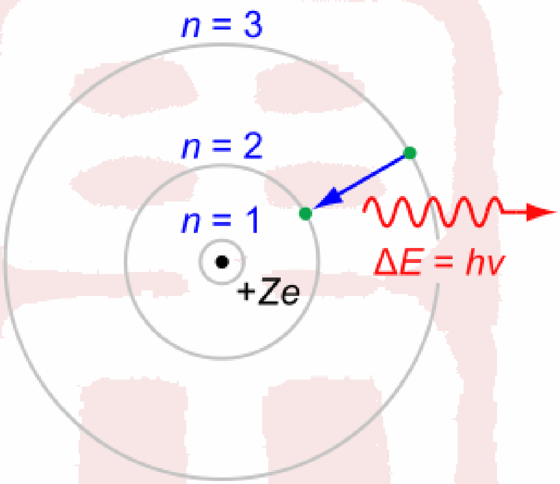


Zeta Puppis

$$\tilde{\nu} = R'\left(\frac{1}{2^2} - \frac{1}{k^2}\right)$$ 其中，$k = 2.5,\ 3,\ 3.5,\ 4, \ldots$

一直被当作H原子的一个光谱线系

Bohr将其归属于He的一价离子的光谱。



He^{+}，Li^{++}，Be^{+++}，都是类氢离子：

$+Ze$的原子核与核外的一个电子组成。

$$E_n = -\frac{1}{2} m_e c^2 \alpha^2 \frac{Z^2}{n^2} = Z^2 E_H, \qquad n = 1, 2, 3, \ldots$$

$$r_n = \frac{\hbar c n^2}{Z m_e c^2 \alpha} = \frac{r_H}{Z}, \qquad n = 1, 2, 3, \ldots$$

光谱波数 $$\tilde{\nu} = Z^2 R_\infty \left(\frac{1}{m^2} - \frac{1}{n^2} \right)$$

对于He^{+}

$$\tilde{\nu} = 2^2 R_\infty \left(\frac{1}{m^2} - \frac{1}{n^2} \right) = R_\infty \left(\frac{1}{(m/2)^2} - \frac{1}{(n/2)^2} \right)$$

§ 1.6 氢原子理论的检验 – 类氢离子光谱

Pickering series

$n = 5,\ 6,\ 7, \ldots \rightarrow m = 4$

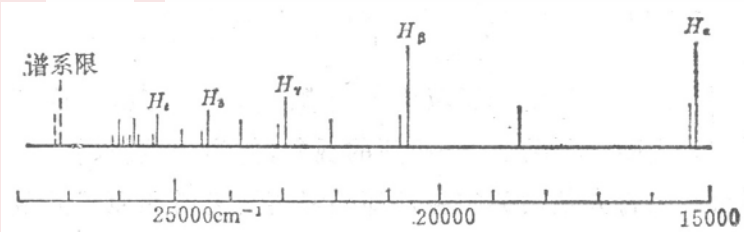
$$\tilde{\nu} = 2^2 R_\infty \left(\frac{1}{m^2} - \frac{1}{n^2} \right) = R_\infty \left(\frac{1}{(m/2)^2} - \frac{1}{(n/2)^2} \right)$$

$$\tilde{\nu} = R_\infty \left(\frac{1}{2^2} - \frac{1}{k^2} \right)$$

$k = n/2 = 2.5,\ 3,\ 3.5,\ 4, \ldots$

光谱观测

$$\tilde{\nu} = R' \left(\frac{1}{2^2} - \frac{1}{k^2} \right)$$



$$R' = R_{He^+} = 1.097,222,7 \times 10^7\ \mathrm{m}^{-1}$$

§ 1.6 氢原子理论的检验 – 原子核质量的影响

问题二　英国光谱学家福勒指出：R_∞与R_H差别大于万分之五，但当时的光谱实验精度已经好于万分之一。

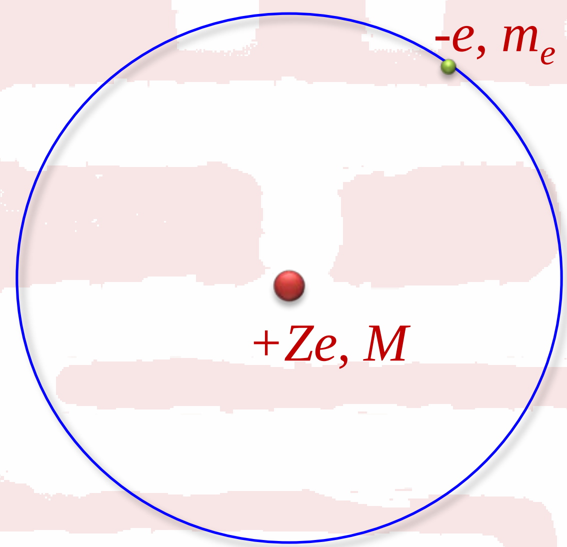
A. Fowler
(1868-1940)

实验值　$R_H = 1.096,775,8 \times 10^7\ \mathrm{m}^{-1}$

$R_{He^+} = 1.097,222,7 \times 10^7\ \mathrm{m}^{-1}$

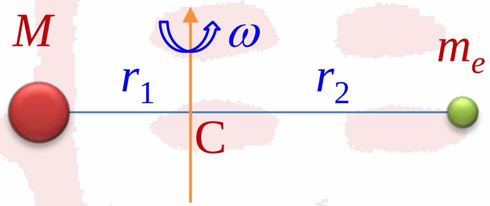
理论值　$R_\infty = 1.097,373,156 \times 10^7\ m^{-1}$

近似：$M >> m_e$



§ 1.6 氢原子理论的检验 – 原子核质量的影响

在质心系中



$$r = r_1 + r_2$$

$$Mr_1 = m_e r_2 \quad \Rightarrow \quad r_2 = \frac{M}{m_e} r_1$$

$$\Rightarrow \quad r_1 = \frac{m_e}{M + m_e} r = \frac{\mu}{M} r \qquad r_2 = \frac{M}{M + m_e} r = \frac{\mu}{m_e} r$$

其中 $\mu = \dfrac{m_e M}{M + m_e}$ 是电子和原子核的折合质量(约化质量)

电子和原子核以相同的角速度ω绕质心C运动，它们的线速度分别为

$$v_1 = r_1 \omega \qquad v_2 = r_2 \omega$$

则，电子和原子核在质心系中的总动能

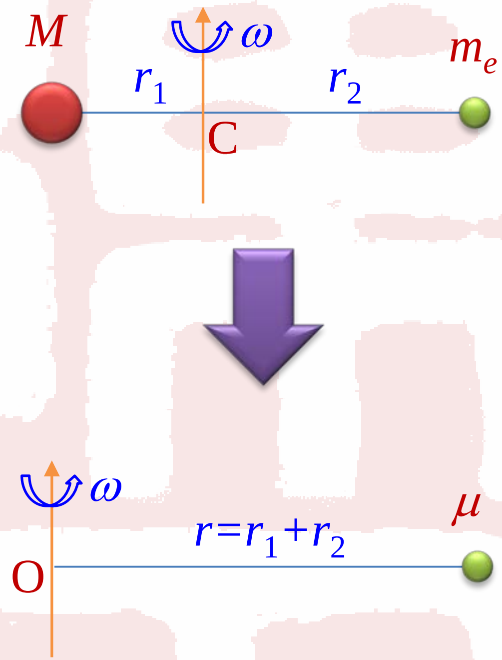
$$T = \frac{1}{2} M v_1^2 + \frac{1}{2} m_e v_2^2 = \frac{1}{2} M r_1^2 \omega^2 + \frac{1}{2} m_e r_2^2 \omega^2$$

$$= \frac{1}{2} \omega^2 r^2 \left[M \left(\frac{\mu}{M} \right)^2 + m_e \left(\frac{\mu}{m_e} \right)^2 \right] = \frac{1}{2} \mu r^2 \omega^2$$

§ 1.6 氢原子理论的检验 – 原子核质量的影响

总动能 $T=\frac{1}{2}\mu r^2\omega^2$

角动量 $L=Mv_1r_1+m_ev_2r_2=\mu\omega r^2=\mu(r\omega)r$



系统可以等效为：质量为μ的粒子、绕固定点、半径为r的圆周运动。

$$m_e \rightarrow \mu$$

$$E_n=-\frac{1}{2}\mu c^2\alpha^2\frac{Z^2}{n^2}$$

$$r_n=\frac{\hbar c n^2}{Z\mu c^2\alpha}=\left(\frac{m_e}{Z\mu}\right)n^2a_0$$

相应的里德堡常数

$$R_M = \frac{1}{(4\pi\varepsilon_0)^2}\frac{\mu e^4}{4\pi\hbar^3 c} = \frac{1}{1+m_e/M}R_\infty$$

对于H原子

$$R_H^{theo} = \frac{1}{1+m_e/M_H}R_\infty$$

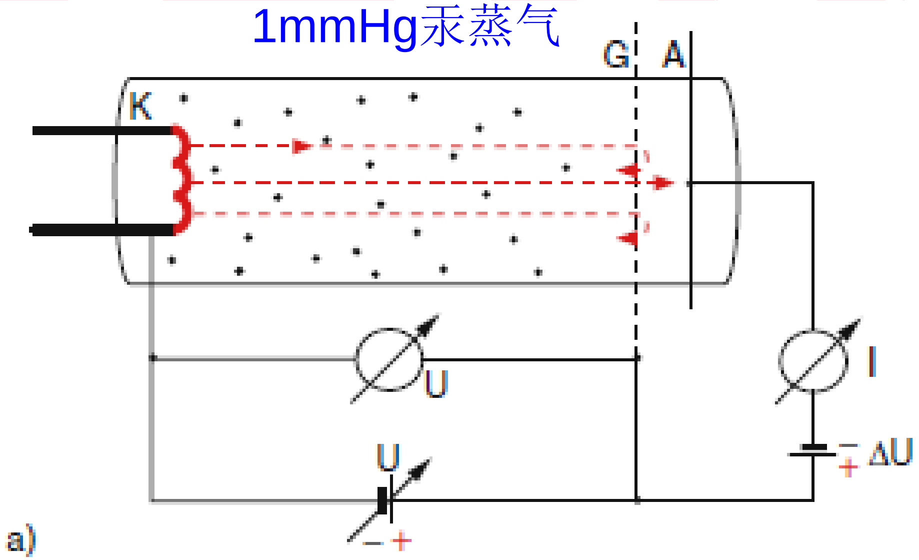
$$R_\infty = 1.097,373,156\times10^7\,m^{-1}$$

将 $m_e/M_{\mathrm{H}} \approx 1/1836.15$ 代入，得

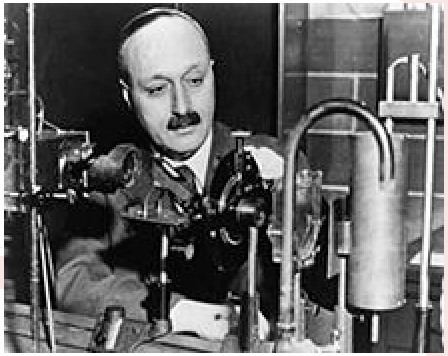
$$R_H^{theo} = 1.096,775,832\times10^7\,m^{-1}$$

实验值 $$R_H = 1.096,775,8\times10^7\,\mathrm{m}^{-1}$$

Franck-Hertz Experiment



[1]J. Franck and G. Hertz, Verh. Dtsch. Phys. Ges. 16, 457 (1914).
[2]J. Franck and G. Hertz, Verh. Dtsch. Phys. Ges. 16, 512 (1914).



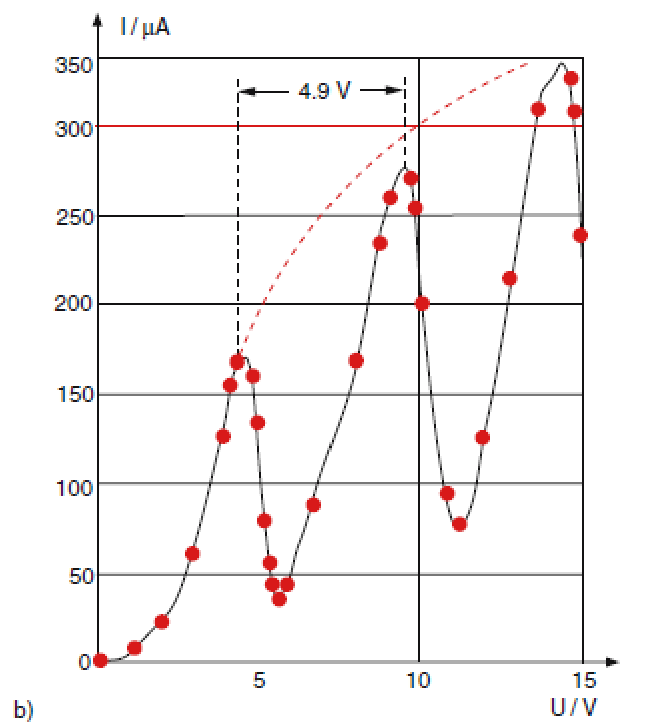
James Franck

1882 –1964

Gustav Ludwig Hertz
1887 –1975

The Nobel Prize in Physics 1925

§ 1.6 氢原子理论的检验 – Franck-Hertz实验



$i \propto V^{3/2}$

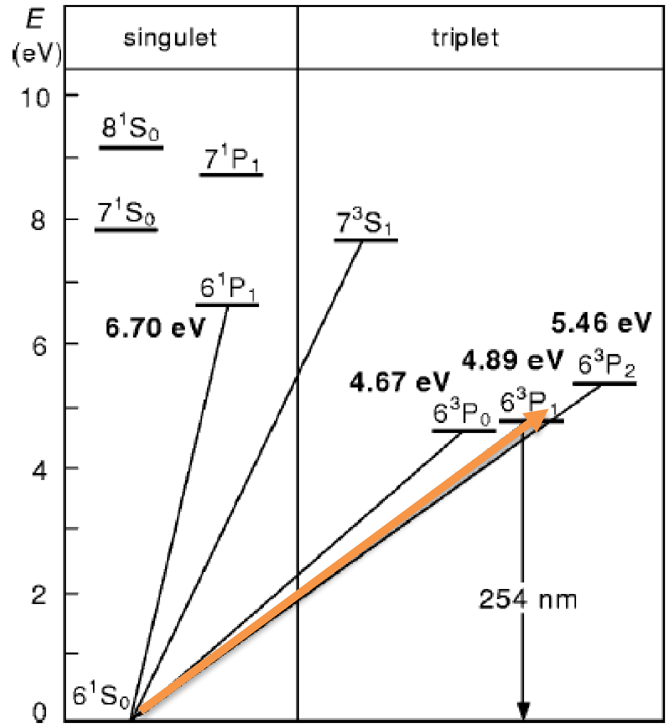


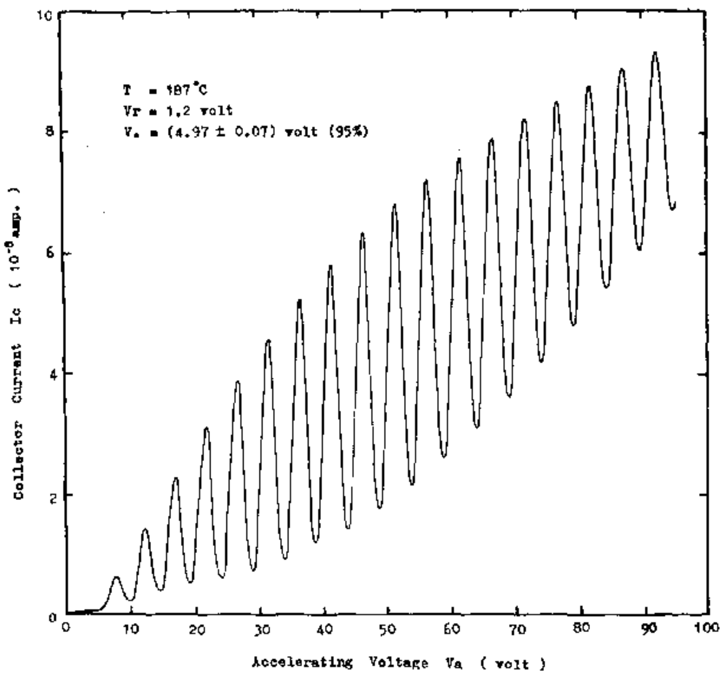
Fig. 2. Lowest energy levels in Hg (Ref. 10).

$$e^- \, (E_{kin}) + Hg \rightarrow Hg^* \, (E_a) + e^- \, (E_{kin} - E_a)$$

一个月后

$$\lambda = \frac{hc}{E} = \frac{1240eV \cdot nm}{4.89eV} \sim 254nm$$

§ 1.6 氢原子理论的检验 – Franck-Hertz实验



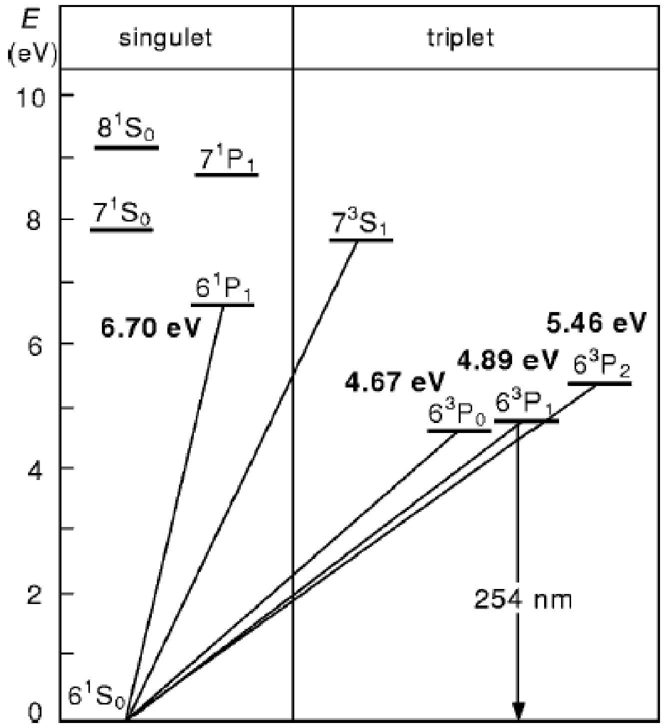
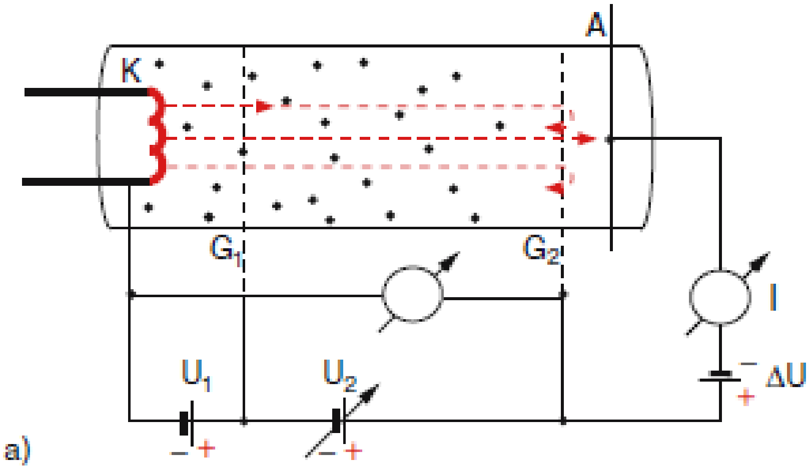
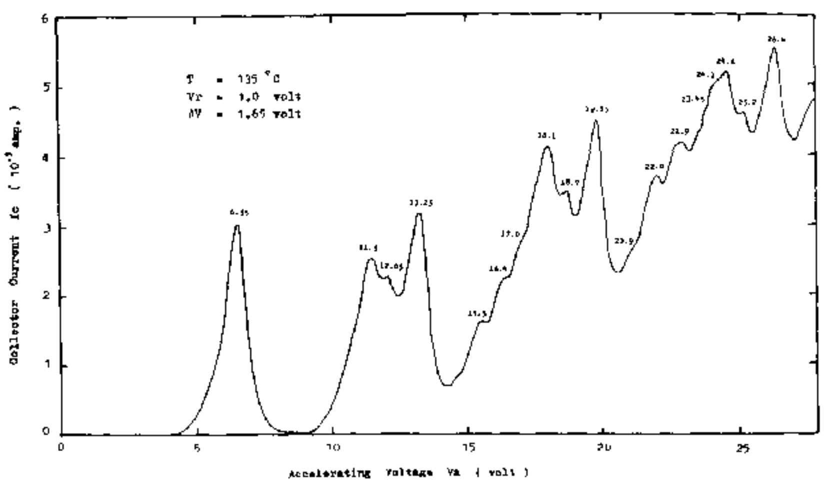


Fig. 2. Lowest energy levels in Hg (Ref. 10).





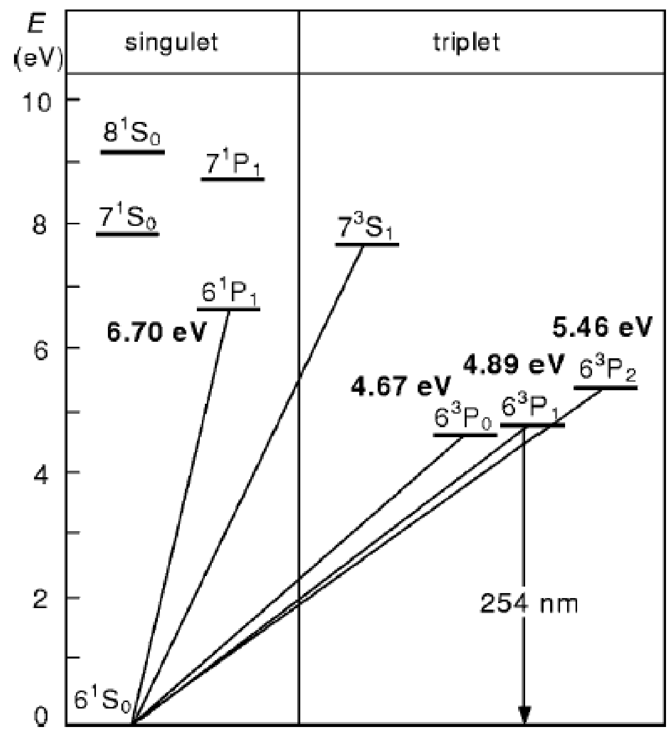
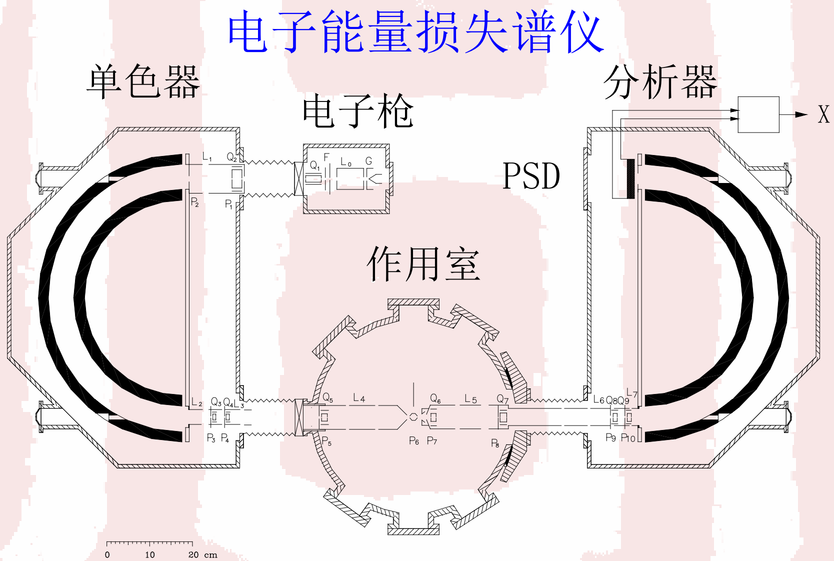
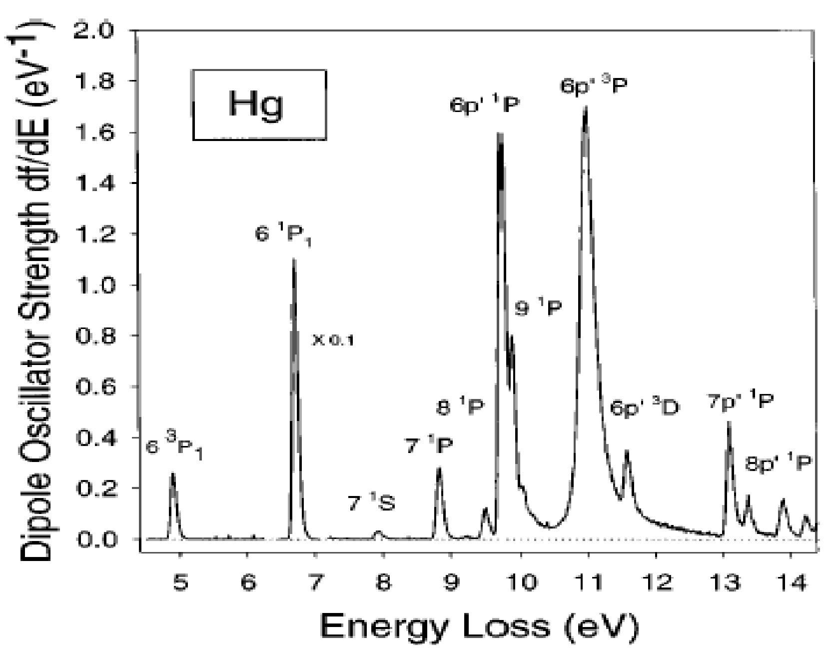


Fig. 2. Lowest energy levels in Hg (Ref. 10).

§ 1.6 氢原子理论的检验 – Franck-Hertz实验





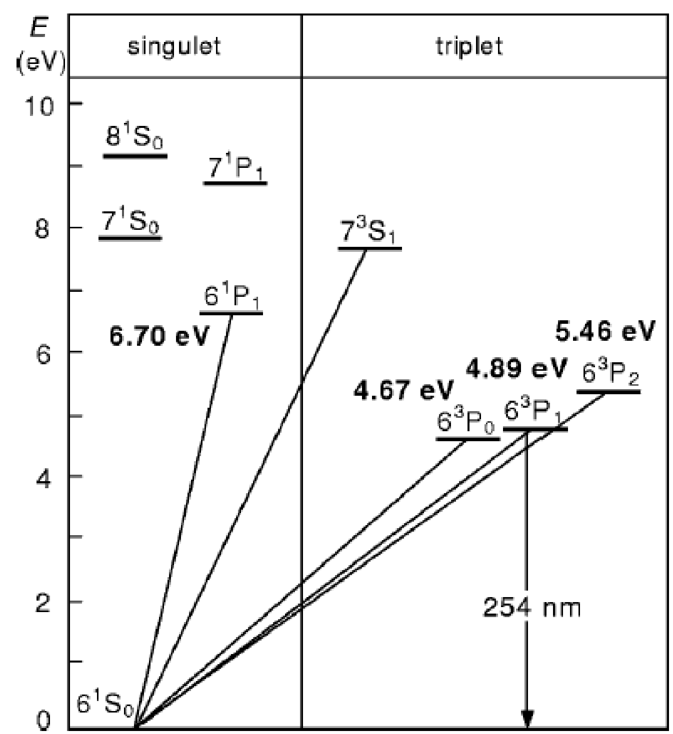


Fig. 2. Lowest energy levels in Hg (Ref. 10).

"Niels Bohr was indeed a keen football player and was the goalkeeper in the Danish team Akademisk Boldklub in the beginning of the 20th century," says Nicolaj Egerod. "But even though AB [as the club is commonly known] were, at the time, one of the best clubs in Denmark, he never made it to the national team. However, his brother Harald - a well-known scientist in his own right - who also played at AB, played for the Danish national team and was part of the team that won silver at the 1908 London Olympics."

Nils Refsdal suggests a possible reason why Niels never made it to the international stage: "According to AB, in a match against the German side Mittweida, one of the Germans launched a long shot and the physicist leaning against the post did not react, missing an easy save. After the game he admitted to his team-mates his thoughts had been on a mathematical problem that was of more interest to him than the game. He only played for the 1905 season."