Announcements

- Homework 6 is due TODAY March 10, this Friday.
- Homework 7 is due March 22, the Wednesday after the spring break.
- Have a wonderful spring break!

Last time

- Bohr model

Today's class

- Line spectra

in-class quiz (5 min)

An unknown single-electron atom has its longest wavelength at which absorption in ground state occurs is 4.86 nm. What is the atom?

A. H (Z=1)

B. He^{+} (Z=2)

C. Li^{2+} (Z=3)

D. Be^{3+} (Z=4)

E. B^{4+} (Z=5)

in-class quiz (5 min)

minimum energy 1 → 2 transition

An unknown single-electron atom has its longest wavelength at which absorption in ground state occurs is 4.86 nm. What is the atom?

$$\Delta E = \frac{hc}{\lambda} = \frac{1240\ eV \cdot nm}{4.86\ nm} = 255.1\ eV$$

$$E_n = -\frac{Z^2}{n^2} R_y, \quad R_y = 13.6\ eV$$

$$\Delta E = E_2 - E_1 = -Z^2\left(\frac{1}{2^2} - \frac{1}{1^2}\right) R_y$$

$$255.1\ eV = -Z^2\left(\frac{1}{4} - 1\right) \cdot 13.6\ eV$$

$$Z^2 = 25$$

A. H (Z=1)

B. He^{+} (Z=2)

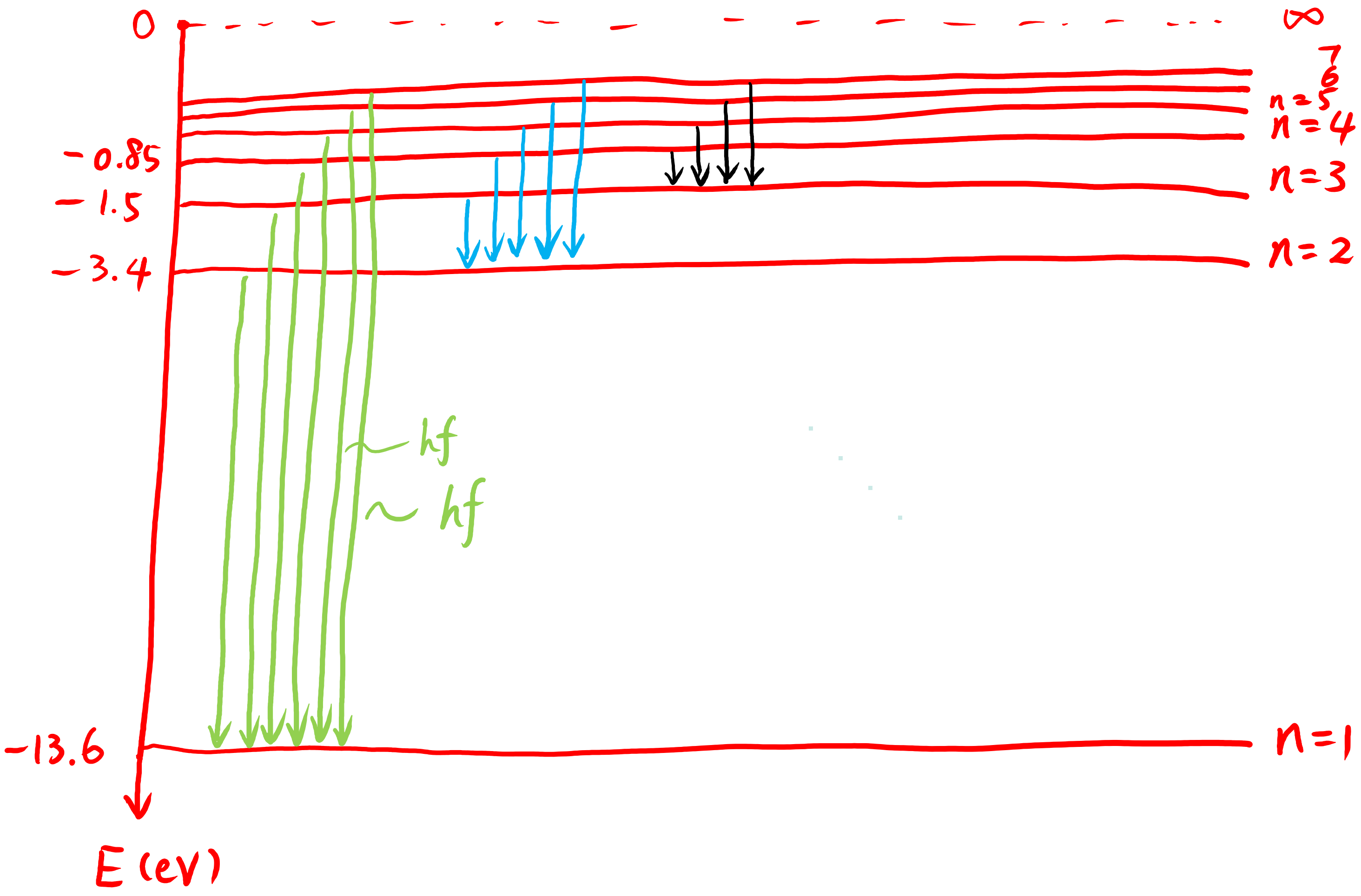
C. Li^{2+} (Z=3)

D. Be^{3+} (Z=4)

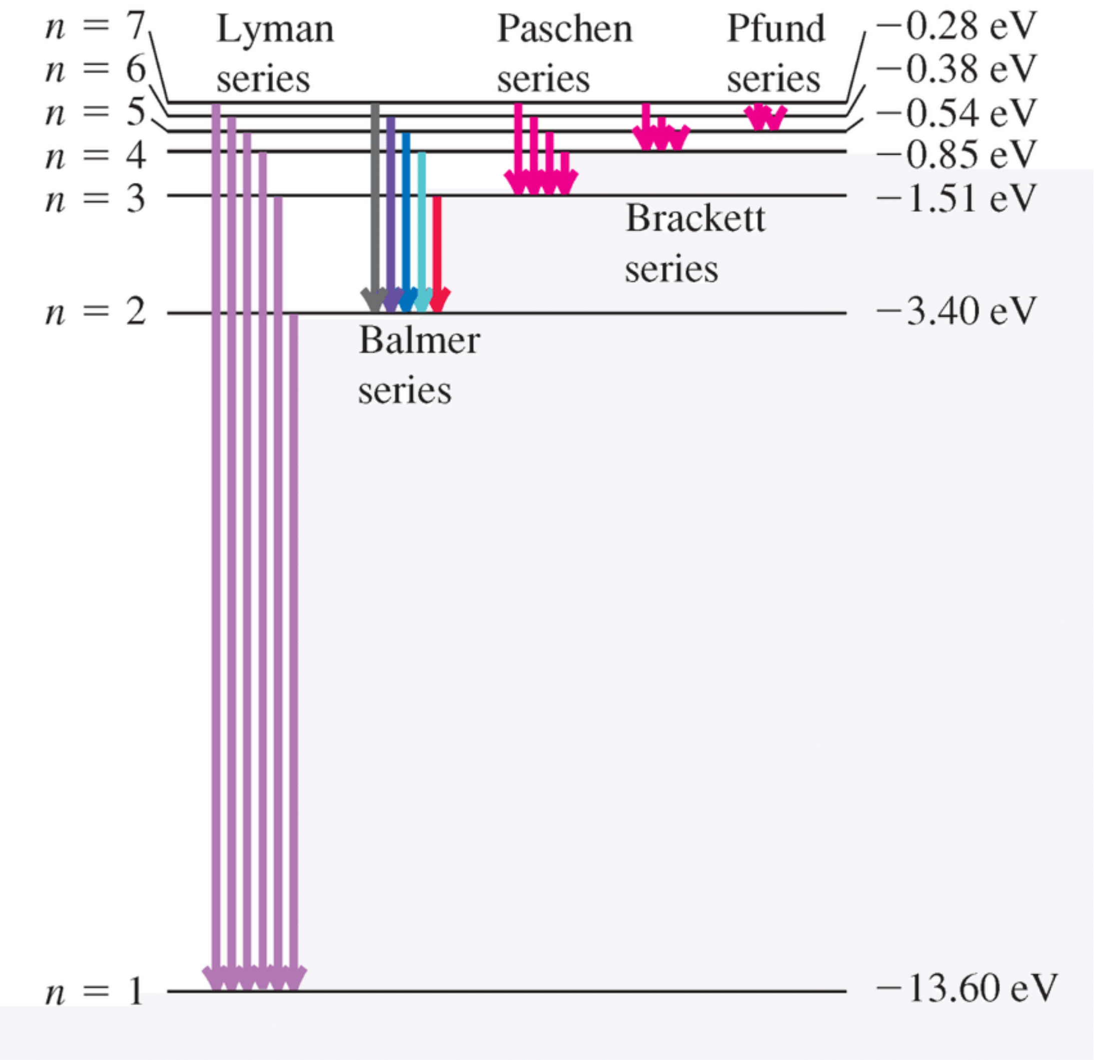
E. B^{4+} (Z=5)

Bohr model

$Z = 1$ Hydrogen $E_n = -\frac{R_y}{n^2}$



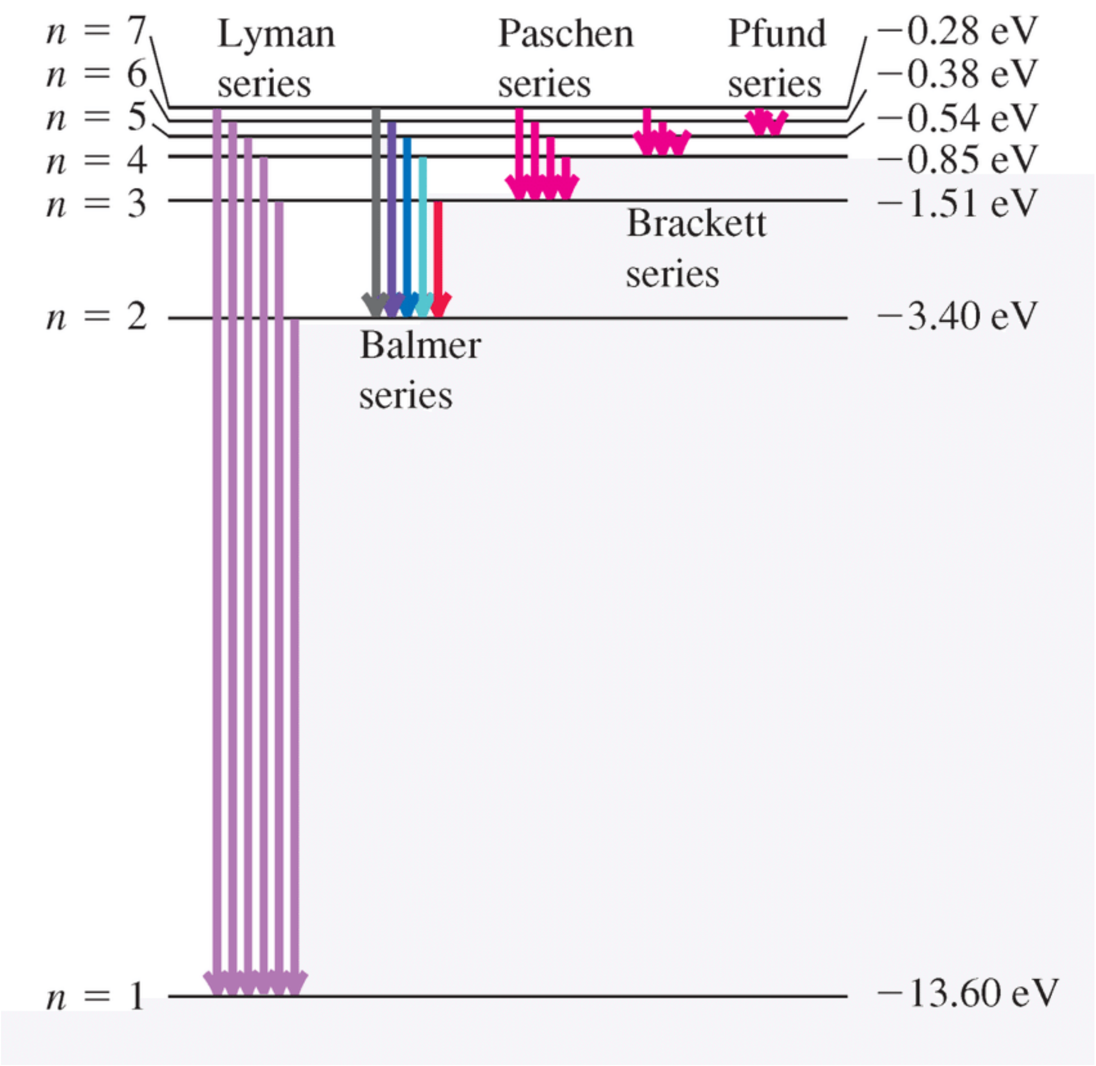
Line spectra



$E_{n_i} - E_{n_f} = hf$

emission $\Delta E > 0$, $n_i > n_f$

in-class exercise (5 min)



The wavelength range for the visible spectrum is 400 – 700 nm. Which is the series overlaps in the visible range? Once you identify the series, please list all wavelengths that are in the visible range. Hint: hc=1240 eV·nm.

$\Delta E = \frac{hc}{\lambda}$, $\Delta E = \frac{1240\,eV\cdot nm}{400\,nm} = 3.1\,eV$, $\Delta E = \frac{1240\,eV\cdot nm}{700\,nm} = 1.77\,eV$

Balmer: 3→2 $\Delta E = -1.51\,eV - (-3.40\,eV) = 1.89\,eV$

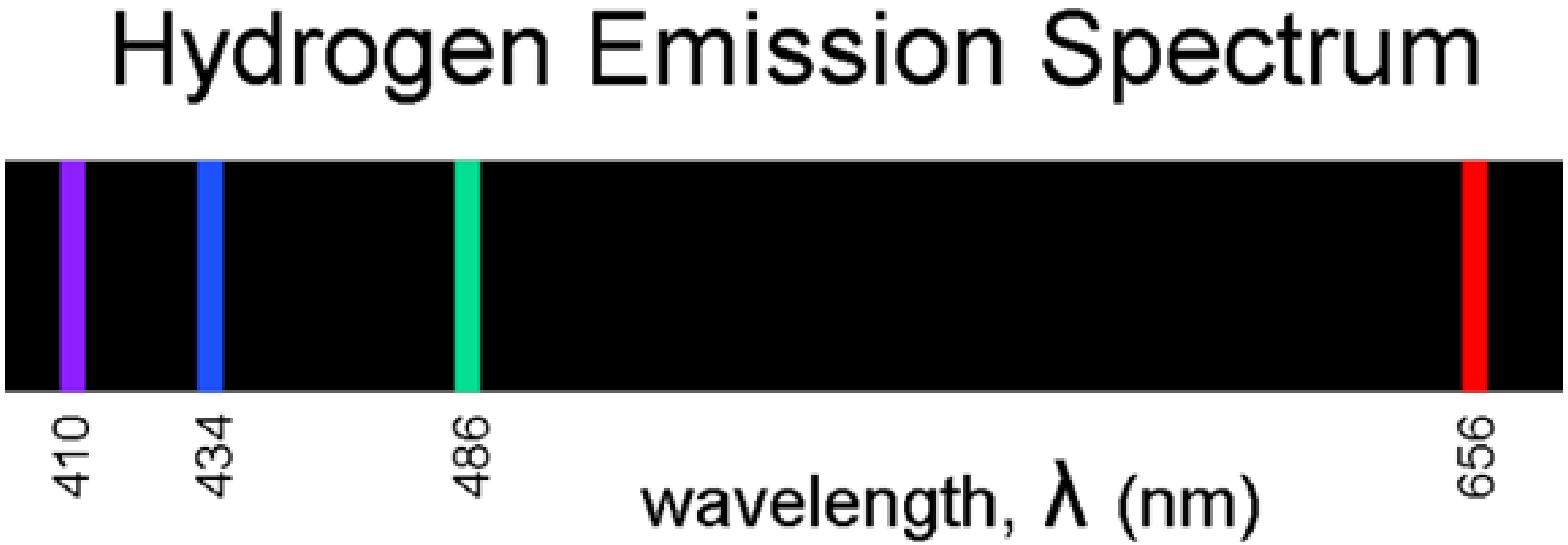
$\lambda = \frac{hc}{\Delta E} = 656\,nm$

4→2 $-0.85\,eV \rightarrow -3.40\,eV \Rightarrow 2.55\,eV$

$\lambda = 486\,nm$

5→2 $2.86\,eV \Rightarrow \lambda = 434\,nm$

6→2 $-0.38\,eV - (-3.40\,eV) = 3.02\,eV \Rightarrow \lambda = 410\,nm$


Hydrogen Emission Spectrum
410
434
486
656
wavelength, λ (nm)

Bohr model

$n_i > n_f$

Emission

$E_i = -\frac{R_y}{n_i^2}$

$E_f = -\frac{R_y}{n_f^2}$

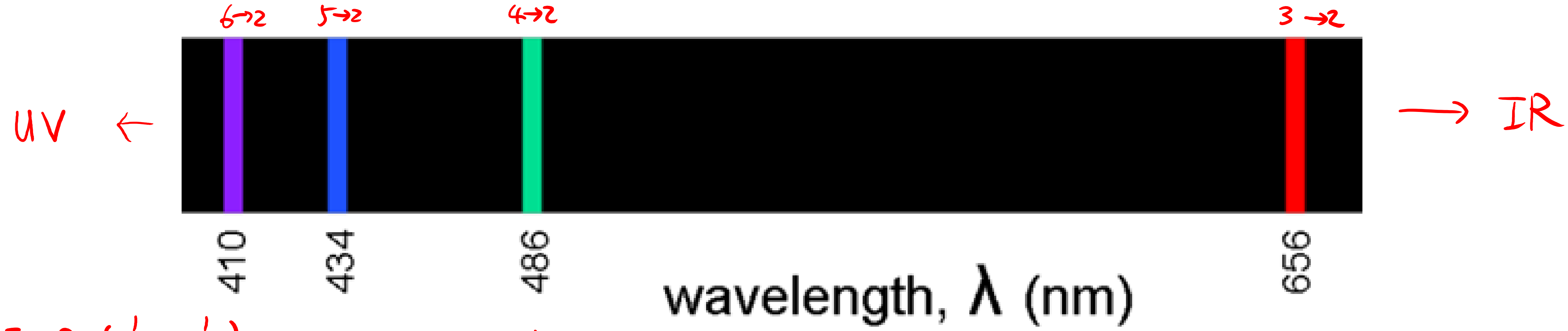
$\Delta E = E_i - E_f = hf$

$-\frac{R_y}{n_i^2} - \left(-\frac{R_y}{n_f^2}\right) = hf$

$R_y\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = hf$

$= \frac{e^4 m}{8\varepsilon_0^2 h^2}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

Hydrogen Emission Spectrum



$$\Delta E = R_y \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

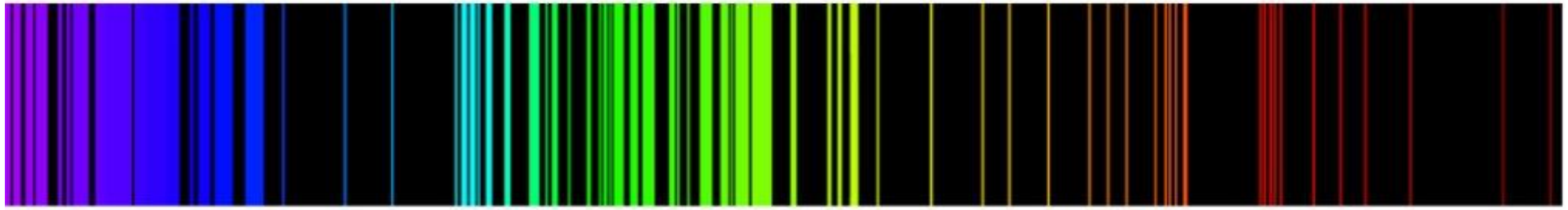
$3 \to 2$ $\quad R_y\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = 0.139\,R_y$ $\quad \lambda = \frac{hc}{\Delta E} = \frac{1240\,\text{eV}\cdot\text{nm}}{0.139 \times 13.6\,\text{eV}} = 656\,\text{nm}$

$4 \to 2$ $\quad R_y\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = 0.188\,R_y$ $\quad \lambda = 485\,\text{nm}$

$5 \to 2$ $\quad R_y\left(\frac{1}{2^2} - \frac{1}{5^2}\right) = 0.21\,R_y$ $\quad \lambda = 434\,\text{nm}$

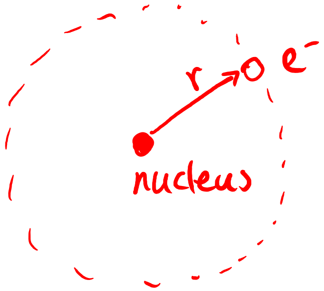
$6 \to 2$ $\quad R_y\left(\frac{1}{2^2} - \frac{1}{6^2}\right) = 0.22\,R_y$ $\quad \lambda = 414\,\text{nm}$

Hydrogen Emission Spectrum



Iron

Reduced mass



nucleus mass M, electron mass m

reduced mass μ

$$\frac{1}{\mu} = \frac{1}{M} + \frac{1}{m}$$

$$\mu = \frac{Mm}{M+m}$$ check unit

$M \gg m$

$\mu \sim m$ very close in value

Non-relativistic regime

$n=1$ orbit

$r_1 = a_0$

quantization $L = n\hbar \xrightarrow{n=1} \hbar$

$L = mvr = mva_0 = \hbar$

$v = \frac{\hbar}{ma_0}$, $a_0 = \frac{\hbar^2}{me^2} \cdot 4\pi\varepsilon_0$

$$\frac{v}{c} = \frac{\hbar}{mca_0} = \frac{\hbar}{mc} \cdot \frac{me^2}{\hbar^2 \cdot 4\pi\varepsilon_0} = \frac{1}{\hbar c} \frac{e^2}{4\pi\varepsilon_0} = \frac{1}{137}$$