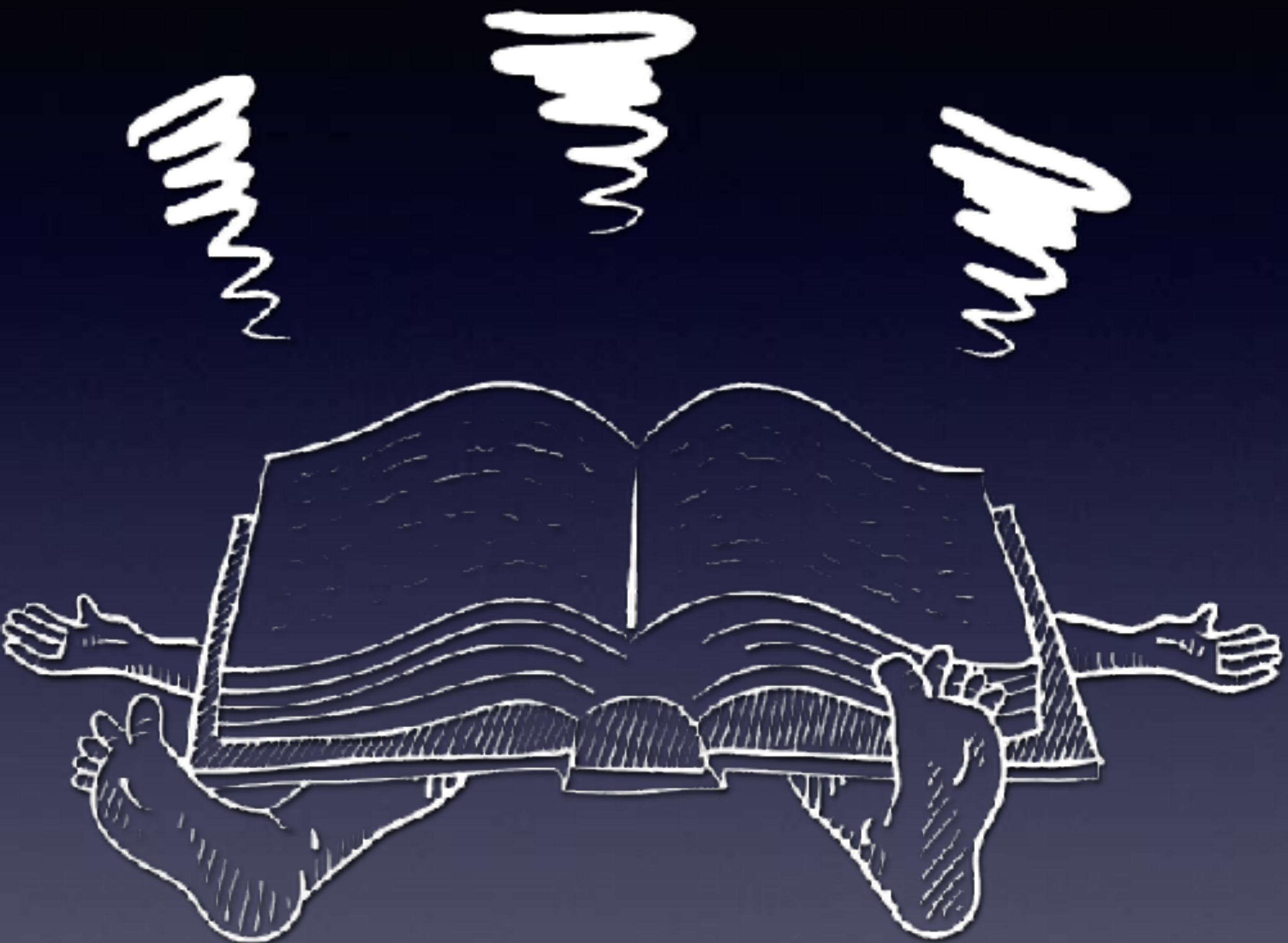


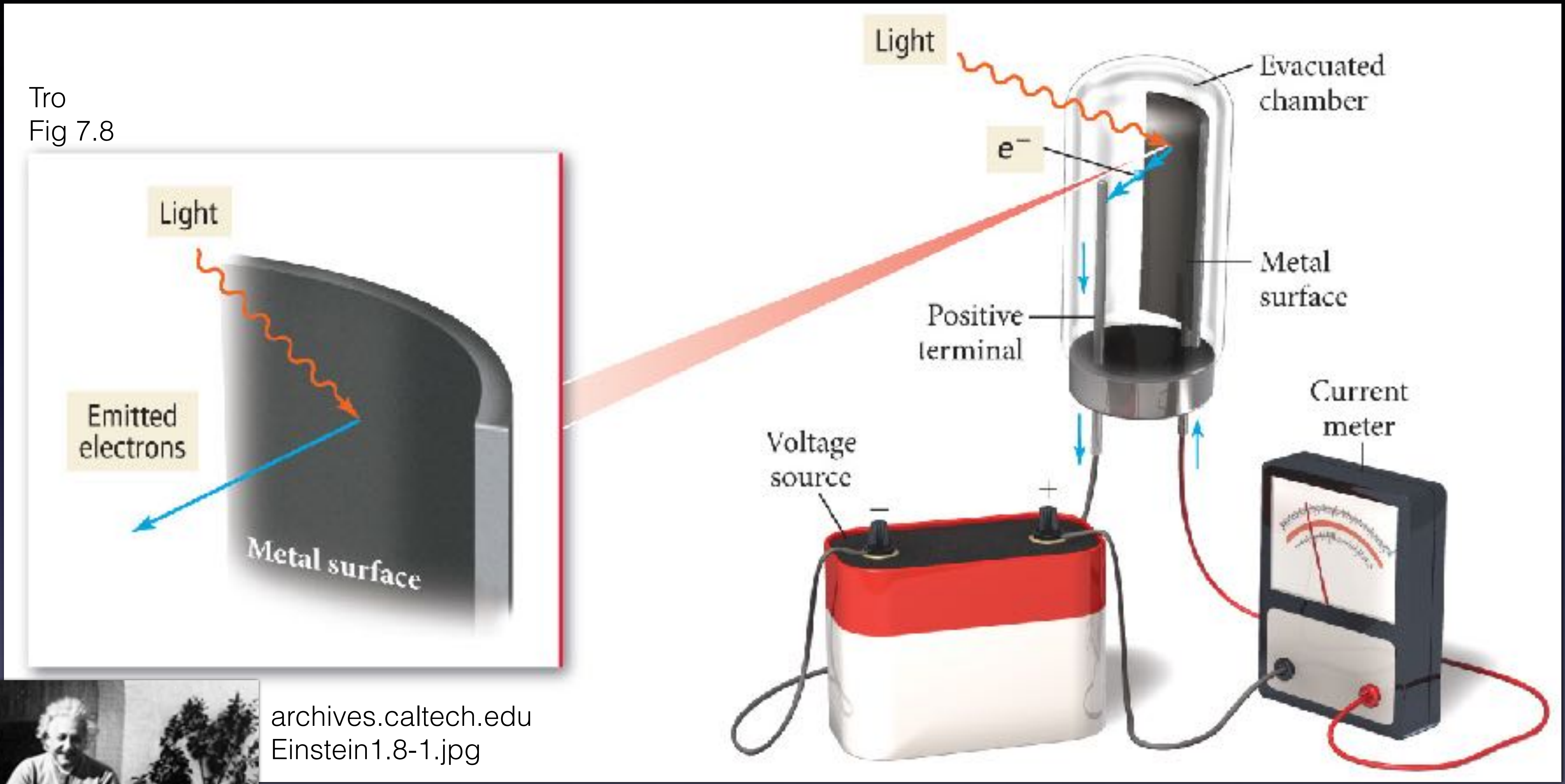
http://thumbs.dreamstime.com/z/too-much-homework-vector-23920513.jpg

Nomenclature videos available under Modules link on Canvas

Previously in Molecularity…

The photoelectric effect

Tro
Fig 7.8

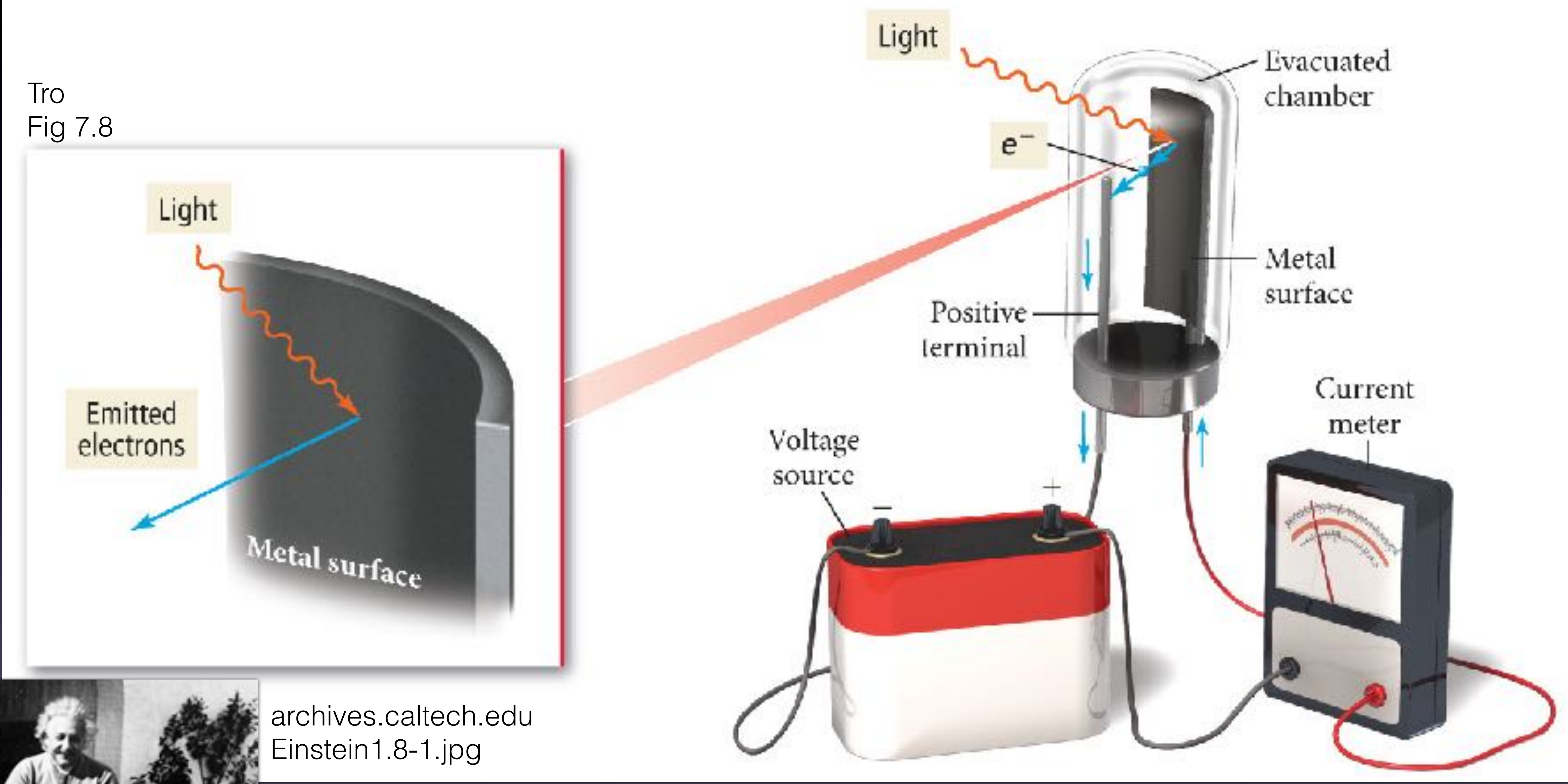


archives.caltech.edu
Einstein1.8-1.jpg

Conclusion:
Energy of light is related to its color
Power is related to its intensity

The photoelectric effect

Tro
Fig 7.8



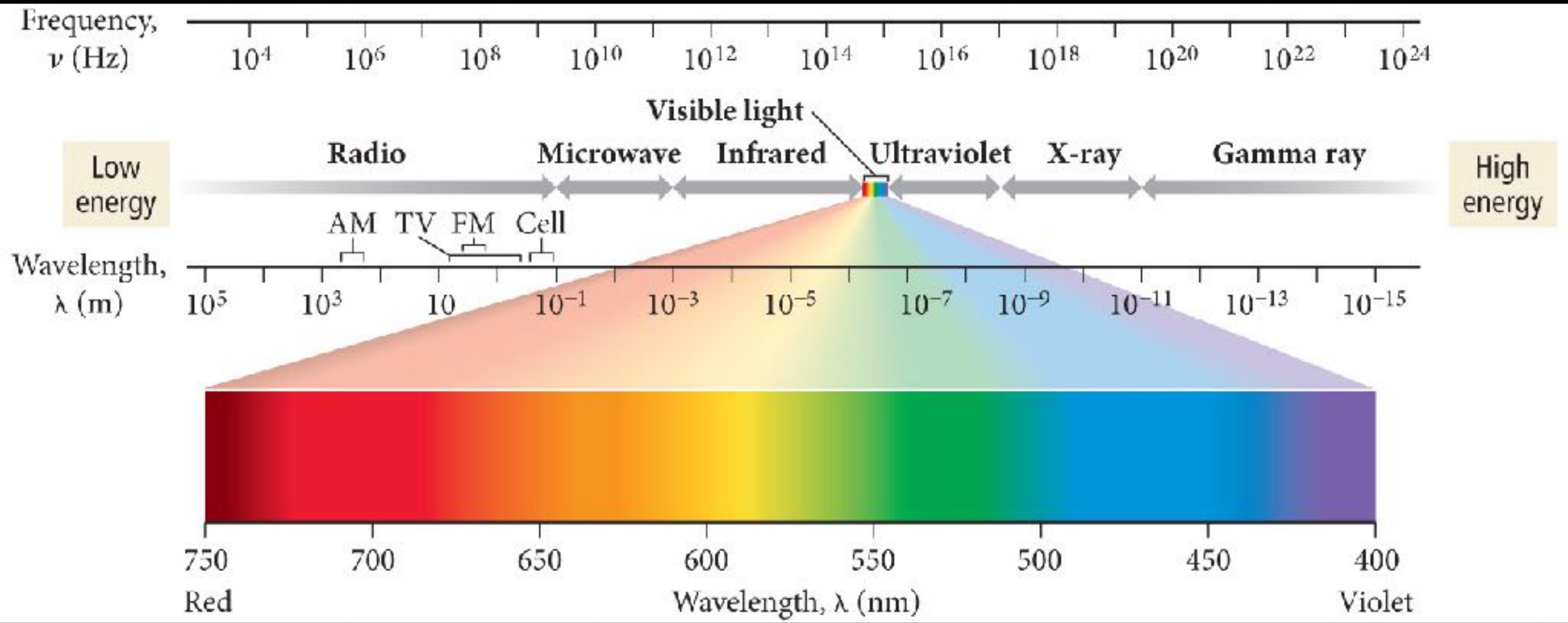
archives.caltech.edu
Einstein1.8-1.jpg

Φ is the **work function** of the metal (J or eV)

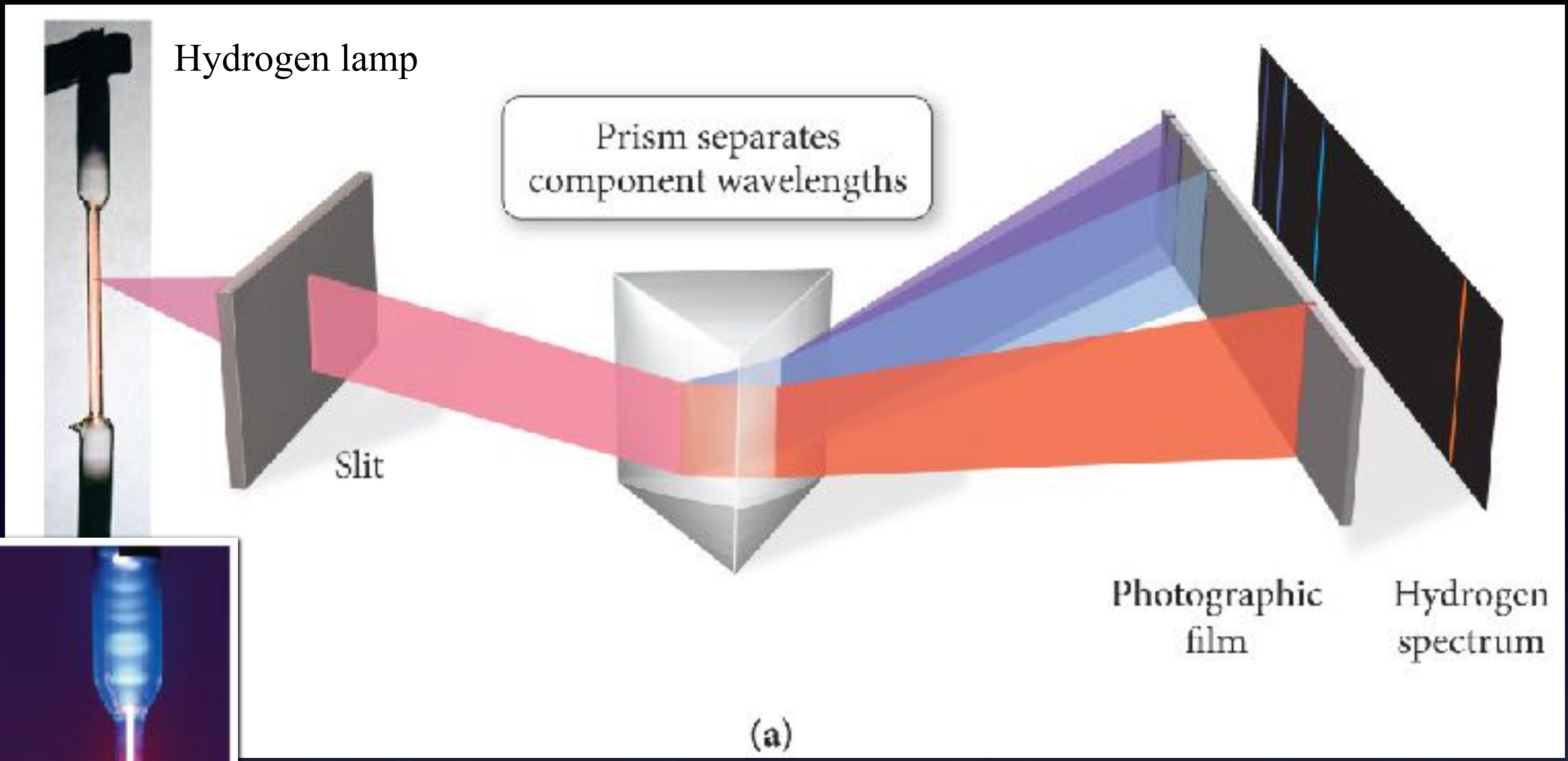
$E_{light} > \Phi_{metal}$ current observed

$E_{light} < \Phi_{metal}$ current not observed

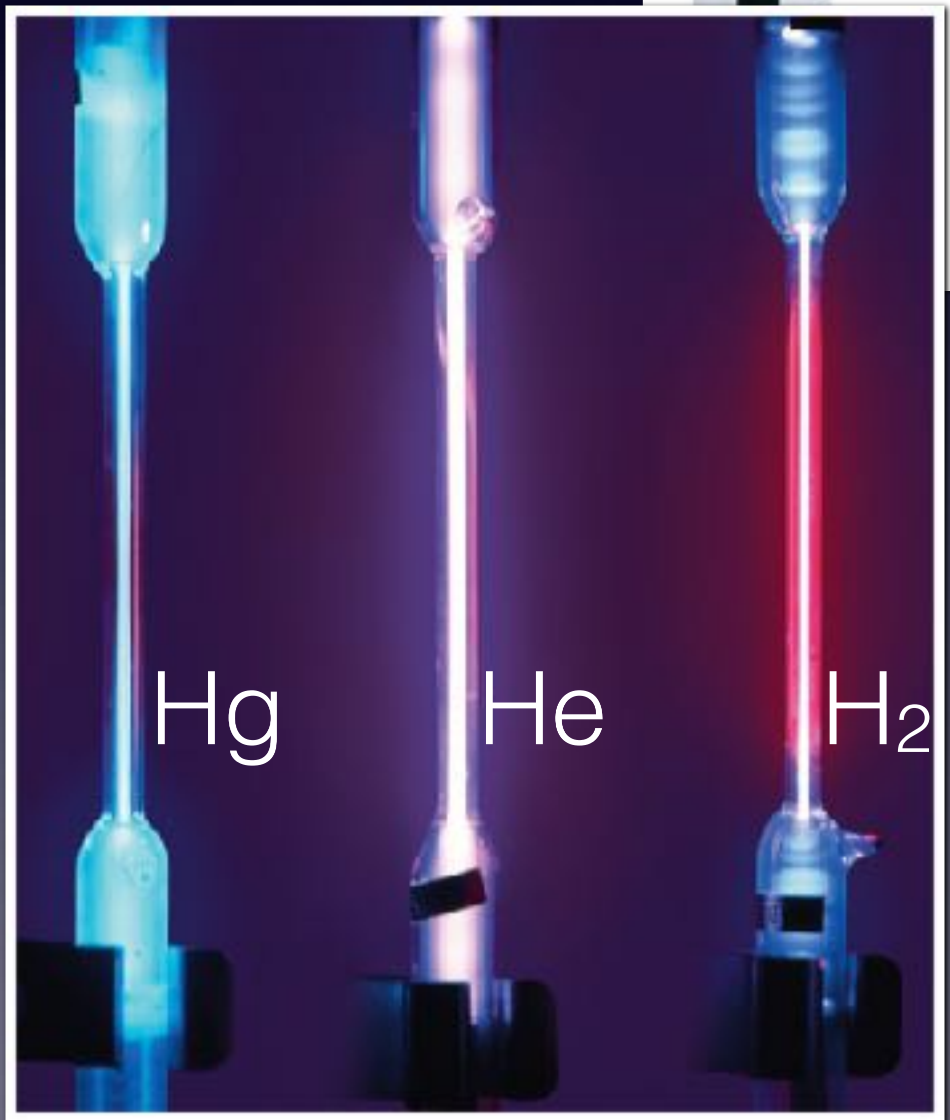
Tro, Fig 7.5



Frequency, ν (Hz)
10^4 10^6 10^8 10^10 10^12 10^14 10^16 10^18 10^20 10^22 10^24
Visible light
Low energy
Radio
Microwave
Infrared
Ultraviolet
X-ray
Gamma ray
High energy
AM
TV
FM
Cell
Wavelength, λ (m)
10^5 10^3 10 10^−1 10^−3 10^−5 10^−7 10^−9 10^−11 10^−13 10^−15
750 700 650 600 550 500 450 400
Red
Wavelength, λ (nm)
Violet



Tro, Fig 7.11a



Tro, Fig 7.10

$$\lambda = 364.56\,\text{nm}\left(\frac{n^2}{n^2-4}\right)$$

for hydrogen only

Glow discharge lamps

Where are we going today?

Ch1010-A17-A03 Lecture 3

- § 2.3 The Great Dane
- § 2.4 Matter as Waves

http://stevedeace.com/wp-content/uploads/2012/11/

upload.wikimedia.org
Rydberg%2C_Janne.jpg

$$\lambda = 364.56\,\mathrm{nm}\left(\frac{n^2}{n^2-4}\right)$$

$$\lambda = 364.56\,\mathrm{nm}\left(\frac{n^2}{n^2-2^2}\right)$$

$$\frac{1}{\lambda} = \frac{0.01097}{\mathrm{nm}}\left(\frac{1}{2^2}-\frac{1}{n^2}\right)$$

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Rydberg%2C_Janne.jpg

$$\lambda = 364.56\,\mathrm{nm}\left(\frac{n^2}{n^2-4}\right)$$

$$\lambda = 364.56\,\mathrm{nm}\left(\frac{n^2}{n^2-2^2}\right)$$

$$\frac{1}{\lambda} = \frac{0.01097}{\mathrm{nm}}\left(\frac{1}{2^2}-\frac{1}{n^2}\right)$$

For Balmer series, this number is 2.

What if this number was 3?

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Rydberg%2C_Janne.jpg

$$\frac{1}{\lambda} = \frac{0.01097}{\mathrm{nm}} \left(\frac{1}{3^2} - \frac{1}{n^2} \right)$$

Calculate λ when $n = 4$ …

Calculate λ when $n = 4$

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Rydberg%2C_Janne.jpg

$$\frac{1}{\lambda} = \frac{0.01097}{\mathrm{nm}}\left(\frac{1}{3^2} - \frac{1}{n^2}\right)$$

$$\frac{1}{\lambda} = \frac{0.01097}{\mathrm{nm}}\left(\frac{1}{9} - \frac{1}{16}\right)$$

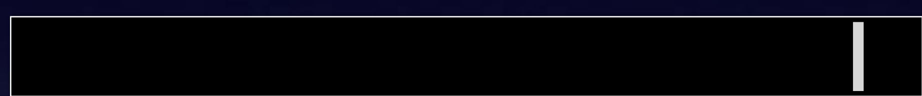
$$\frac{1}{\lambda} = \frac{0.01097}{\mathrm{nm}}\left(\frac{16-9}{16\times 9}\right)$$

$$\lambda = \frac{\mathrm{nm}}{0.01097}\frac{16\times 9}{16-9}$$

$$\lambda = \frac{\mathrm{nm}}{0.01097}\frac{16\times 9}{16-9}$$

$$\lambda \approx 1875\,\mathrm{nm}$$

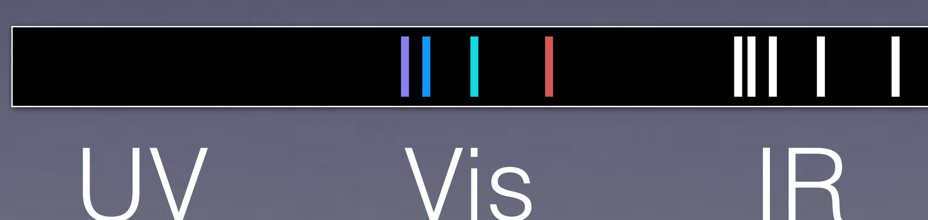
Paschen lines:



$$\frac{1}{\lambda} = \frac{0.01097}{\text{nm}} \left(\frac{1}{3^2} - \frac{1}{n^2} \right) \quad n = 4$$

$$\frac{1}{\lambda} = \frac{0.01097}{\text{nm}} \left(\frac{1}{3^2} - \frac{1}{n^2} \right) \quad n = 5$$

General case…



$$\frac{1}{\lambda} = \frac{0.01097}{\text{nm}} \left(\frac{1}{3^2} - \frac{1}{n^2} \right)$$

upload.wikimedia.org
Rydberg%2C_Janne.jpg

$$\lambda = 364.56\,\mathrm{nm}\left(\frac{n^2}{n^2-4}\right)$$

$$\lambda = 364.56\,\mathrm{nm}\left(\frac{n^2}{n^2-2^2}\right)$$

$$\frac{1}{\lambda} = \frac{0.01097}{\mathrm{nm}}\left(\frac{1}{2^2}-\frac{1}{n^2}\right)$$

$$\frac{1}{\lambda} = \frac{0.01097}{\mathrm{nm}}\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)$$

upload.wikimedia.org
Rydberg%2C_Janne.jpg

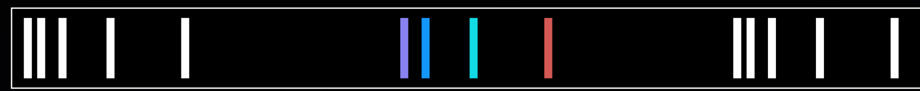
$$\lambda = 364.56\,\mathrm{nm}\left(\frac{n^2}{n^2-4}\right)$$

$$\lambda = 364.56\,\mathrm{nm}\left(\frac{n^2}{n^2-2^2}\right)$$

$$\frac{1}{\lambda} = \frac{0.01097}{\mathrm{nm}}\left(\frac{1}{2^2}-\frac{1}{n^2}\right)$$

$$\frac{1}{\lambda} = \frac{0.01097}{\mathrm{nm}}\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)$$

$$\mathbf{E} = 13.6\,\mathrm{eV}\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)$$



Lyman Balmer Paschen Bracket Pfund

$$\frac{1}{\lambda} = \frac{0.01097}{\mathrm{nm}} \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

aw energy level diagram here!!!

$$\mathbf{E} = 13.6\ \mathrm{eV} \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

$$\mathbf{E} = 2.18 \times 10^{-18}\,\mathrm{J} \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

We have some math,
but what does it all mean physically?

My expectations

- Given a particular series (i.e. given n_1) can you determine the **smallest** energetic transition? The **largest** energetic transition?
- Given a particular transition, could you determine the series? (i.e. Lyman, Balmer, Paschen, Bracket, Pfund, Humphries…)
- (After Tuesday) given either of the above, could you determine the one-electron atom (*e.g.* He^{+}, Li^{2+}, Fe^{25+}) emitting the light?
- (After Tuesday) draw energy level diagrams for these transitions.

The classical paradox of atoms…

$$\text{Potential Energy} \equiv \text{PE} = \frac{+q \ -q}{4\pi\epsilon_0 r} = \frac{-q^2}{4\pi\epsilon_0 r}$$

$$\text{Kinetic Energy} \equiv \text{KE} = \frac{1}{2}m_p v_p^2 + \frac{1}{2}m_e v_e^2$$

$$\text{Total Energy} = \text{KE} + \text{PE}$$

Lowest energy is the "ground state" when…

$$\text{PE} \longrightarrow 0 \ \text{ as r} \longrightarrow \infty \ \textbf{but} \ \text{PE} \longrightarrow -\infty \ \text{as r} \longrightarrow 0$$

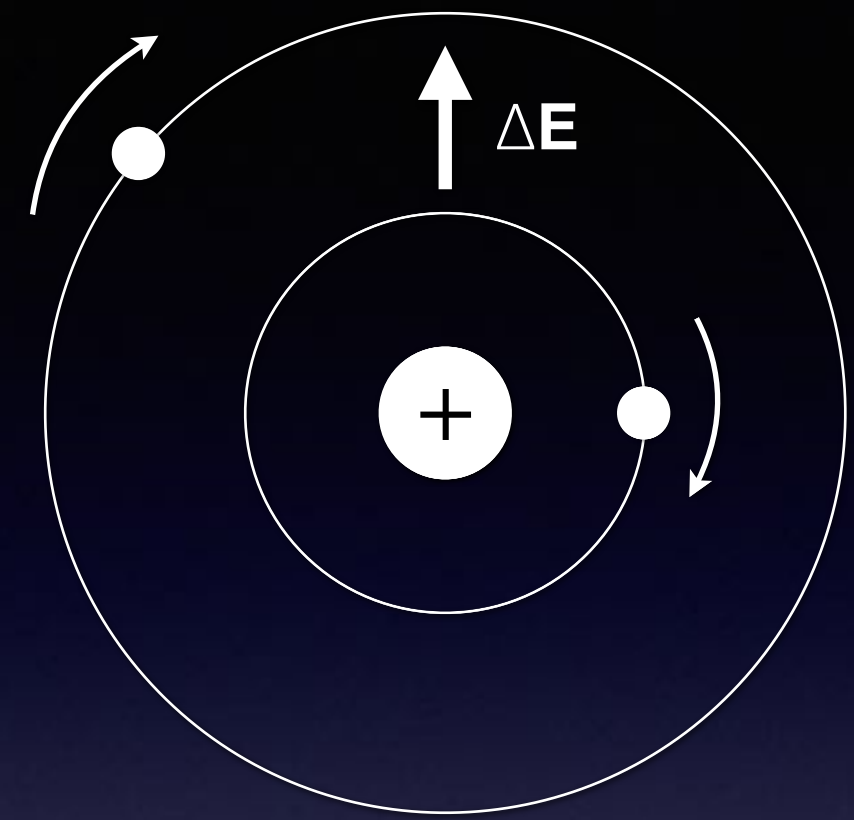
At lowest energy electron should crash into the nucleus!

Also, why does it radiate energy?

København, Danmark

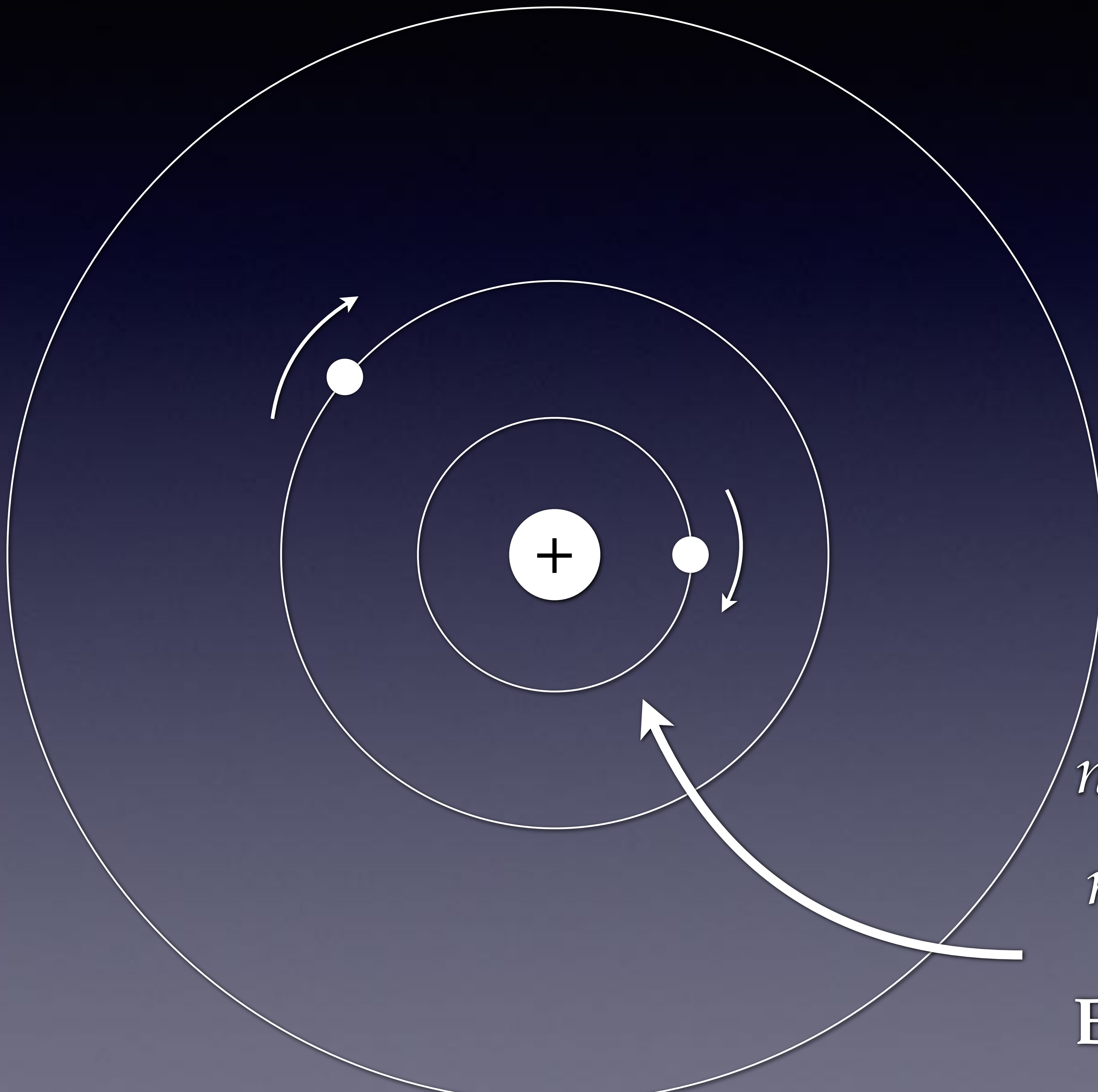
København
Danmark

Bohr's Theory:



- Atoms have well-defined e^- orbits.
- They don't radiate when in those orbits.
- Circular orbits: only specific orbits with specific angular momenta are allowed {quantization postulate}.
- Transitions in energy: electrons go from one orbit to the next.
- Absorption/emission of energy defined by quantized energy levels

Energy of Bohr-like orbitals



$$\mathbf{E}_\mathrm{n} = \frac{-13.6}{n^2}\mathrm{eV}$$

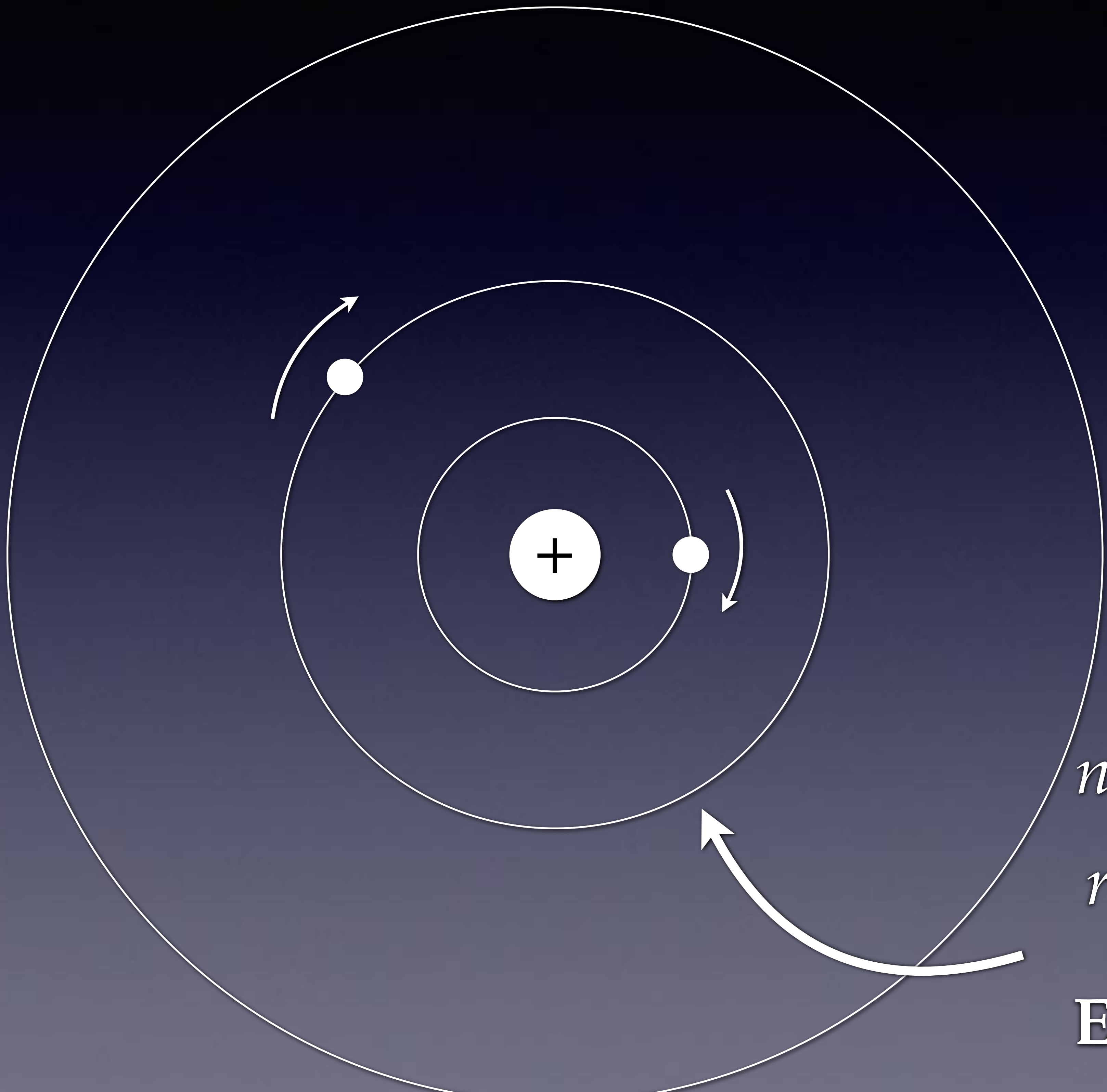
$$\mathrm{a}_0 = 0.0529\,\mathrm{nm}$$

$$n = 1$$

$$r = 1^2(0.0529\,\mathrm{nm})$$

$$\mathbf{E} = \frac{-13.6\,\mathrm{eV}}{1^2} = -13.6\,\mathrm{eV}$$

Energy of Bohr-like orbitals



$$\mathbf{E}_\mathrm{n} = \frac{-13.6}{n^2}\mathrm{eV}$$

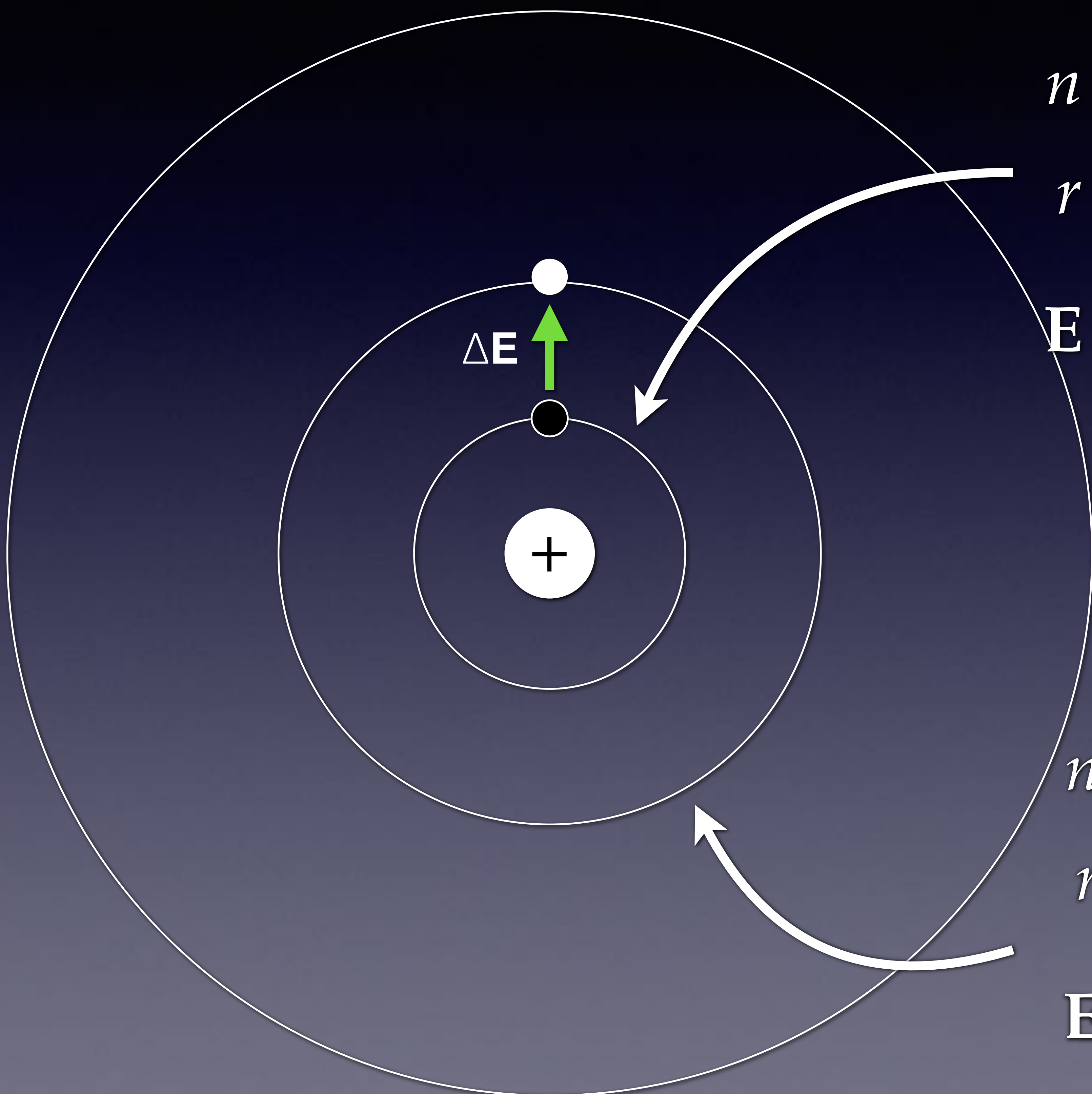
$$\mathrm{a}_0 = 0.0529\,\mathrm{nm}$$

$$n = 2$$

$$r = 2^2(0.0529\,\mathrm{nm})$$

$$\mathbf{E} = \frac{-13.6\,\mathrm{eV}}{2^2} = -3.4\,\mathrm{eV}$$

Transitions between orbitals



$$n = 1$$

$$r = 1^2(0.0529\,\text{nm})$$

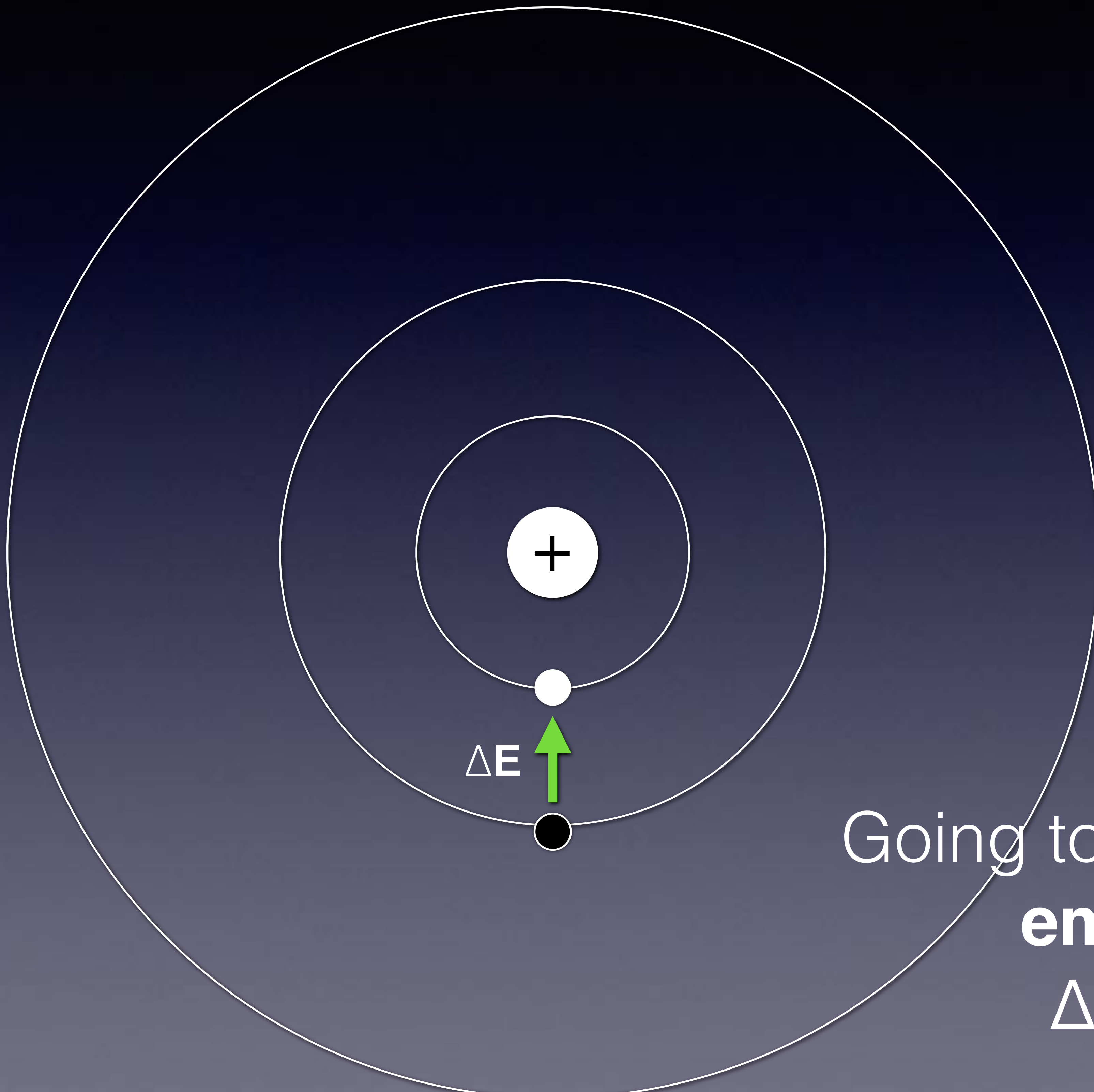
$$\mathbf{E} = \frac{-13.6\,\text{eV}}{1^2} = -13.6\,\text{eV}$$

$$n = 2$$

$$r = 2^2(0.0529\,\text{nm})$$

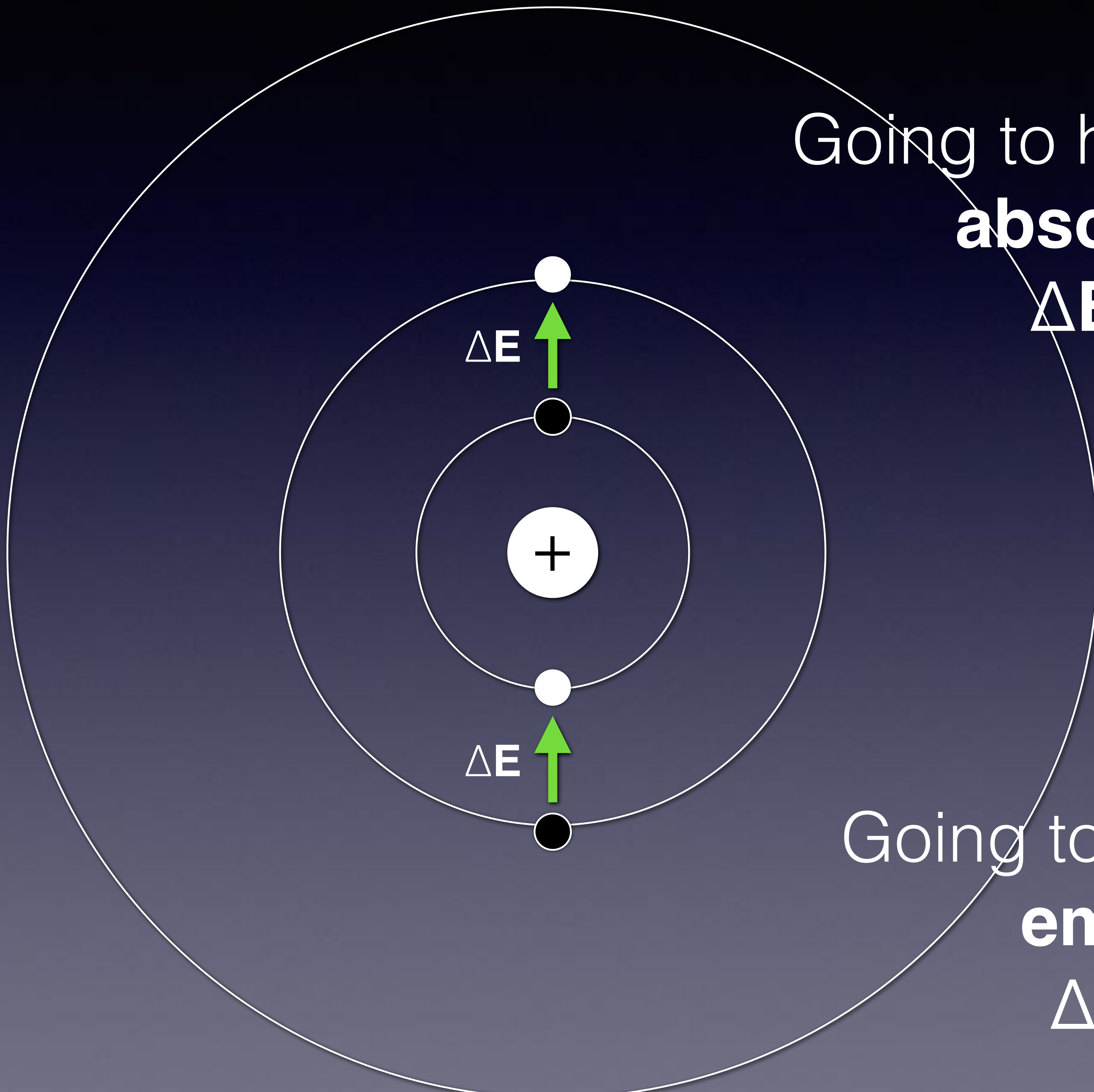
$$\mathbf{E} = \frac{-13.6\,\text{eV}}{2^2} = -3.4\,\text{eV}$$

Transitions: $\Delta \mathbf{E} = \mathbf{E}_{\text{final}} - \mathbf{E}_{\text{initial}}$



Going to lower energy level:
emitting energy
ΔE is negative

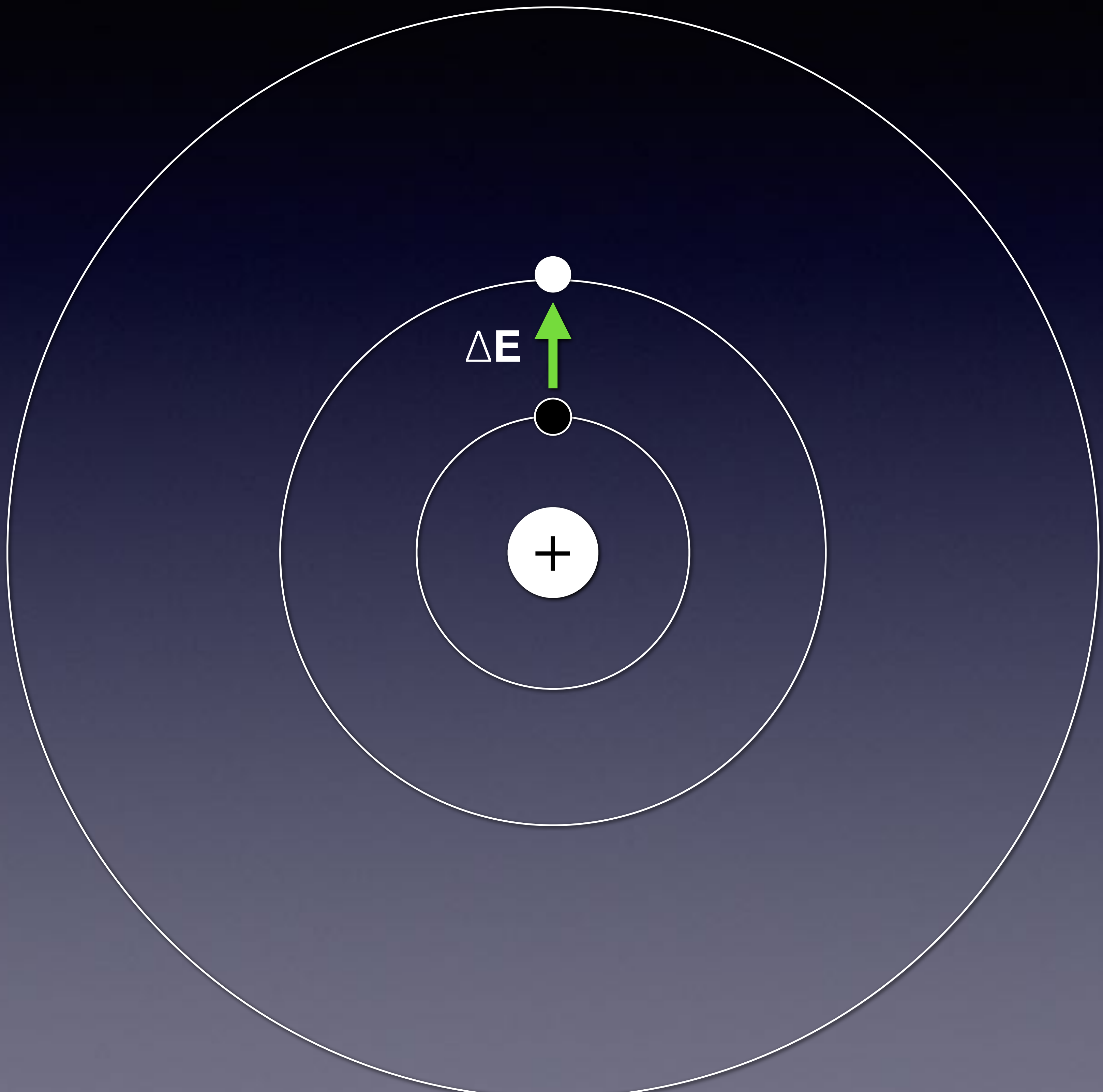
Transitions: $\Delta\mathbf{E} = \mathbf{E}_{\text{final}} - \mathbf{E}_{\text{initial}}$



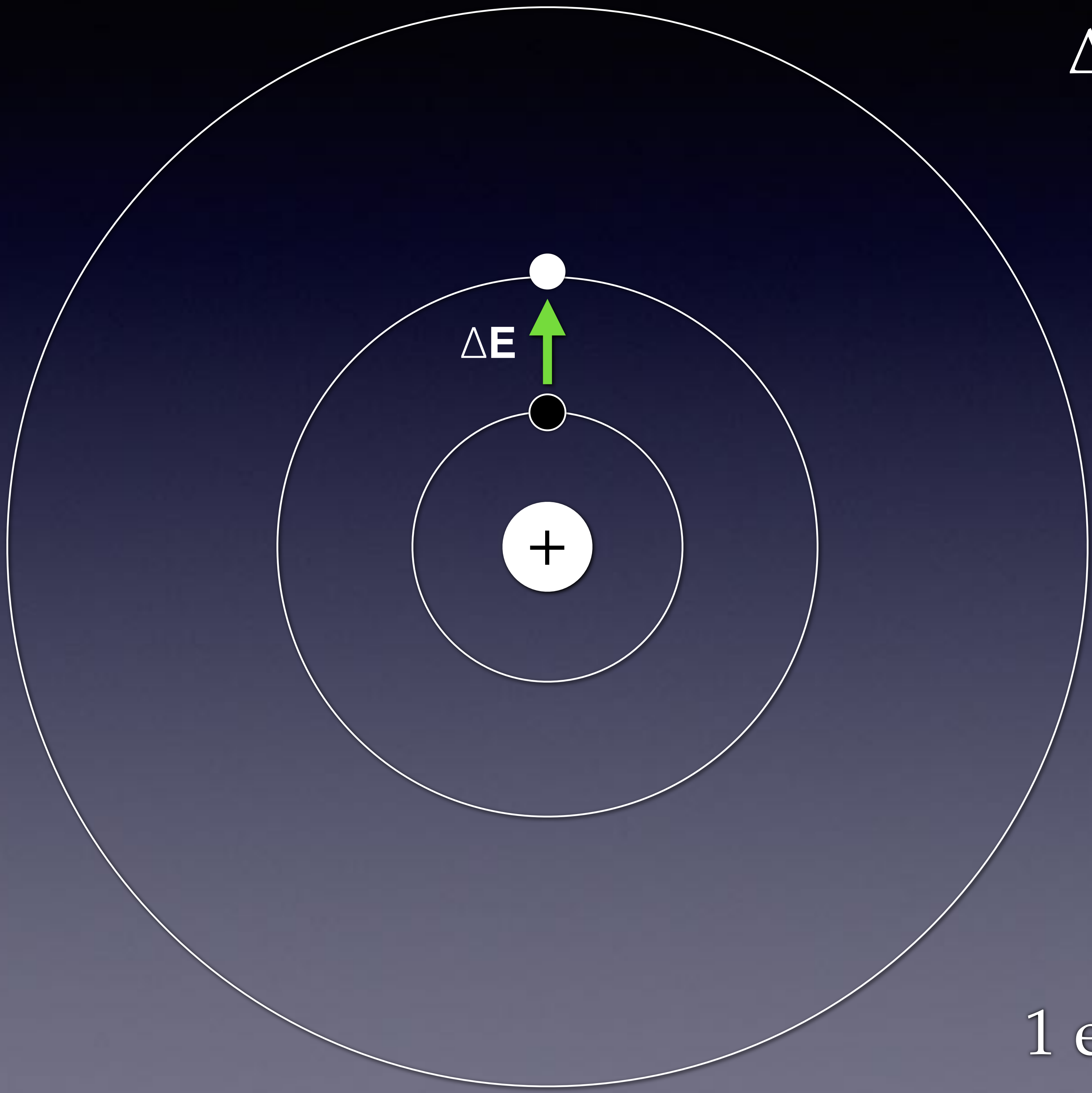
Going to higher energy level:
absorbing energy
ΔE is positive

Going to lower energy level:
emitting energy
ΔE is negative

What's the transition wavelength in nm?



What's the transition wavelength in nm?



$$\Delta \mathbf{E} = \mathbf{E}_{\text{final}} - \mathbf{E}_{\text{initial}}$$
$$= \mathbf{E}_{n=2} - \mathbf{E}_{n=1}$$
$$= -3.4\,\text{eV} + 13.6\,\text{eV}$$
$$= 10.2\,\text{eV}$$

$$\mathbf{E} = h\nu$$

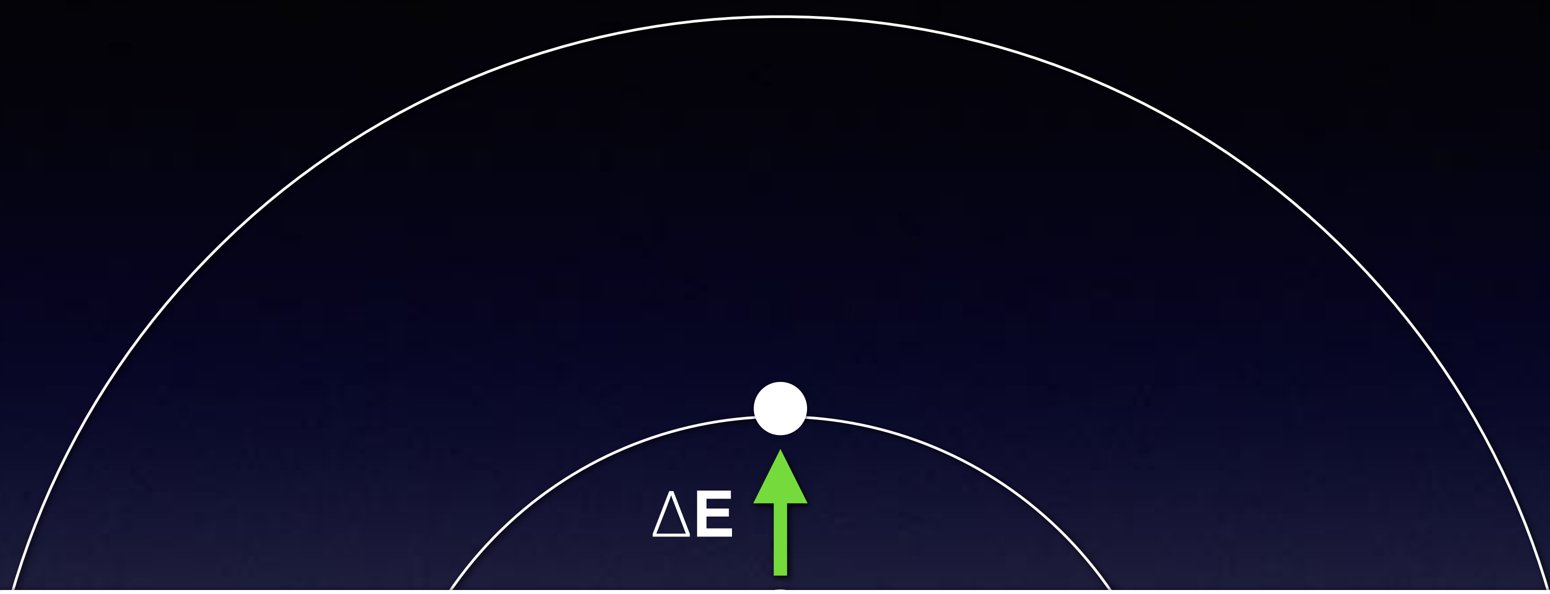
$$\mathbf{E} = \frac{hc}{\lambda}$$

$$h = 6.626 \times 10^{-34}\ \text{J s}$$

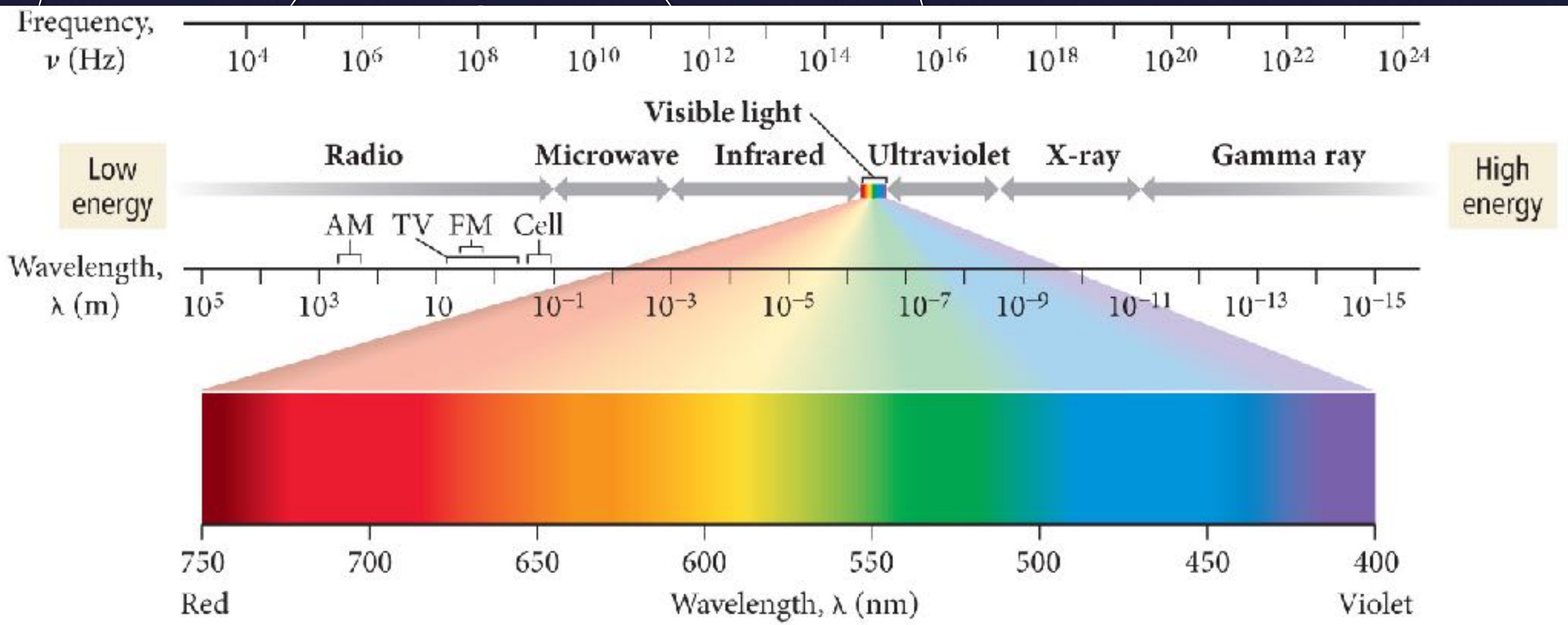
$$c = 2.998 \times 10^{8}\ \text{m s}^{-1}$$

$$1\ \text{eV} = 1.602 \times 10^{-19}\ \text{J}$$

What's the transition wavelength in nm?



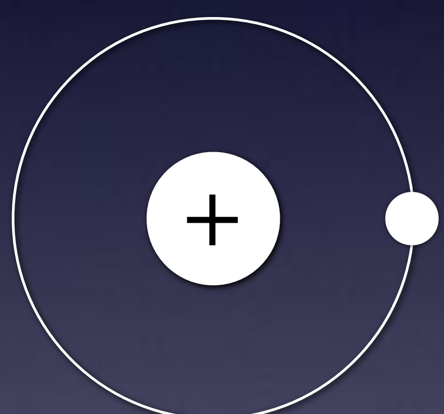
$$\begin{aligned}\Delta \mathbf{E} &= \mathbf{E}_{\text{final}} - \mathbf{E}_{\text{initial}} \\ &= \mathbf{E}_{n=2} - \mathbf{E}_{n=1} \\ &= -3.4\,\text{eV} + 13.6\,\text{eV} \\ &= 10.2\,\text{eV}\end{aligned}$$



Different Z…
…1 electron only

$$r = \frac{n^2(0.0529\,\mathrm{nm})}{Z}$$

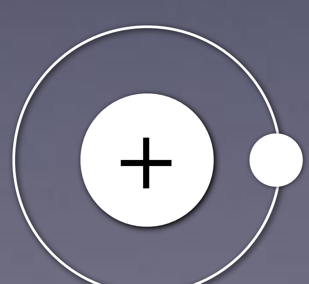
$$\mathbf{E} = \frac{-13.6\,\mathrm{eV}\,Z^2}{n^2}$$



He^+

$$r = \frac{1^2(0.0529\,\mathrm{nm})}{Z} = 0.0265\,\mathrm{nm}$$

$$\mathbf{E} = \frac{-13.6\,\mathrm{eV}\,Z^2}{1^2} = -54.4\,\mathrm{eV}$$



Li^{2+}

$$r = \frac{1^2(0.0529\,\mathrm{nm})}{Z} = 0.0176\,\mathrm{nm}$$

$$\mathbf{E} = \frac{-13.6\,\mathrm{eV}\,Z^2}{1^2} = -122\,\mathrm{eV}$$

…minute paper…

$$r = \frac{n^2(0.0529\,\mathrm{nm})}{Z}$$

$$\mathbf{E} = \frac{-13.6\,\mathrm{eV}\,Z^2}{n^2}$$

As n increases do radii spacing diverge, converge, or remain equally spaced?

As n increases do energy level spacing diverge, converge, or remain equally spaced?

Where did we go today?

Ch1010-A17-A03 Lecture 3

- § 2.3 The Great Dane
- § 2.4 Matter as Waves

Next time…

- § 2.4 Matter as Waves
- § 2.6 Waves, nodes, and gratuitous YouTube videos

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