Physics 2D Lecture Slides
Oct 31

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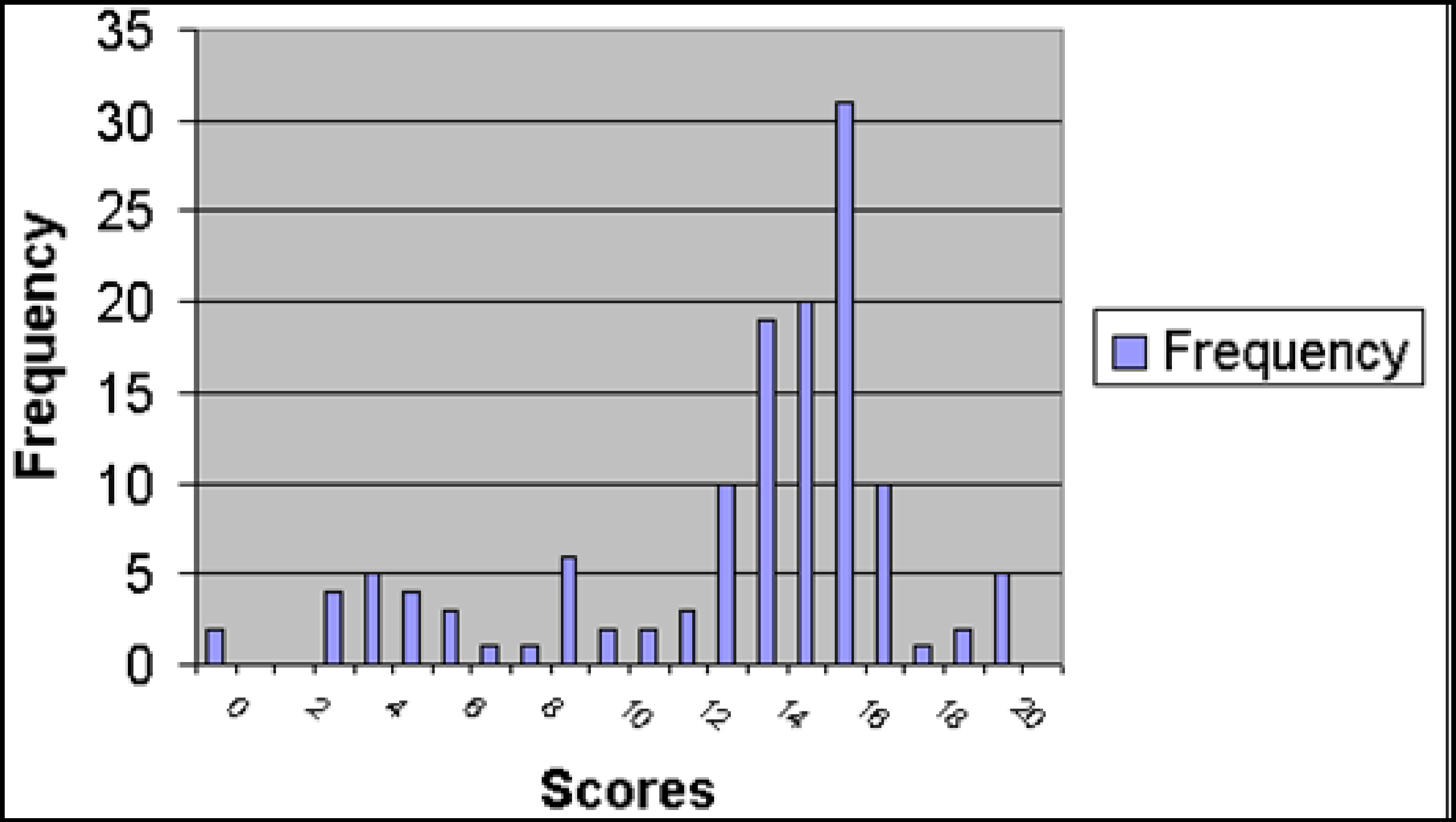
UCSD Physics

Quiz 4 : Good Show !



The 18 “Commandments” of this Universe

Saw what light does, Now examine matter

- Fundamental Characteristics of different forms of matter
  - Rest Mass (m)
  - Electric Charge (q)
    - Measurable
      - using some combination of **E** & **B fields interacting with the particle**

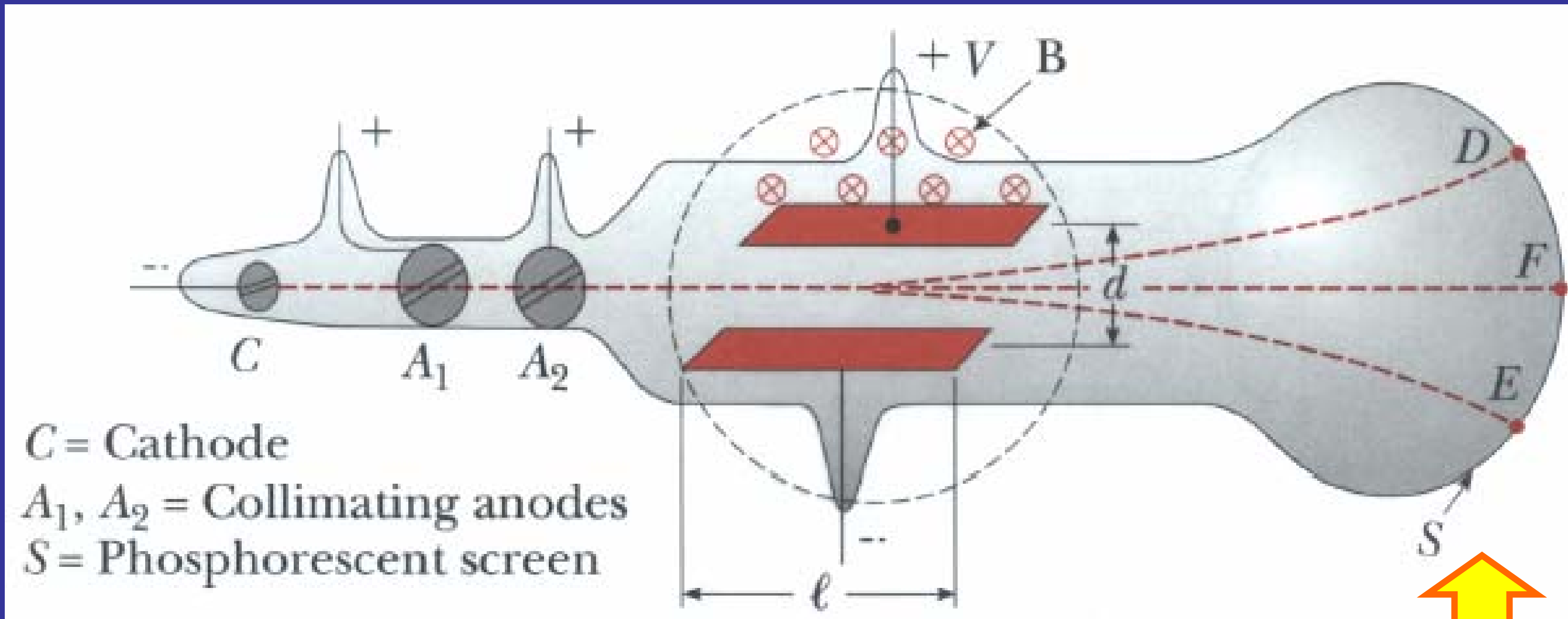
$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$$

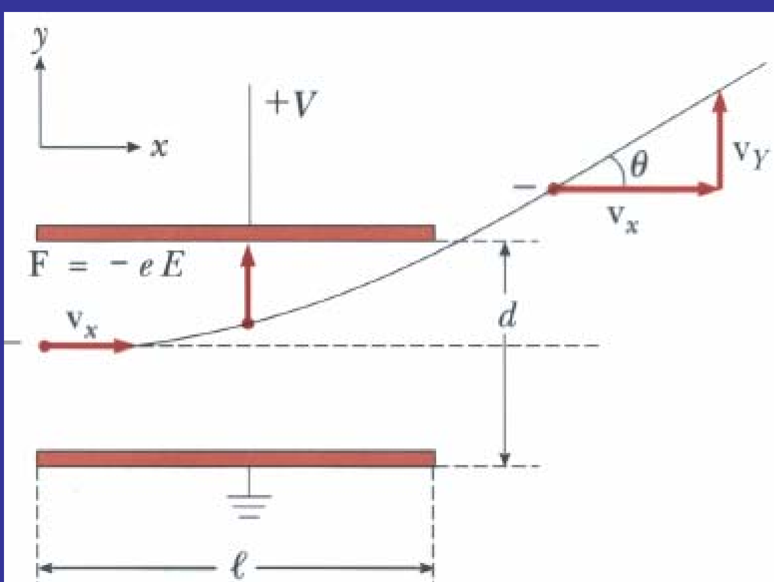
      - **Or E/B and some other macroscopic force**

e.g. Drag Force

The "magic" is that one is measuring tiny tiny numbers using Macroscopic devices

Thomson's Determination of e/m of the Electron

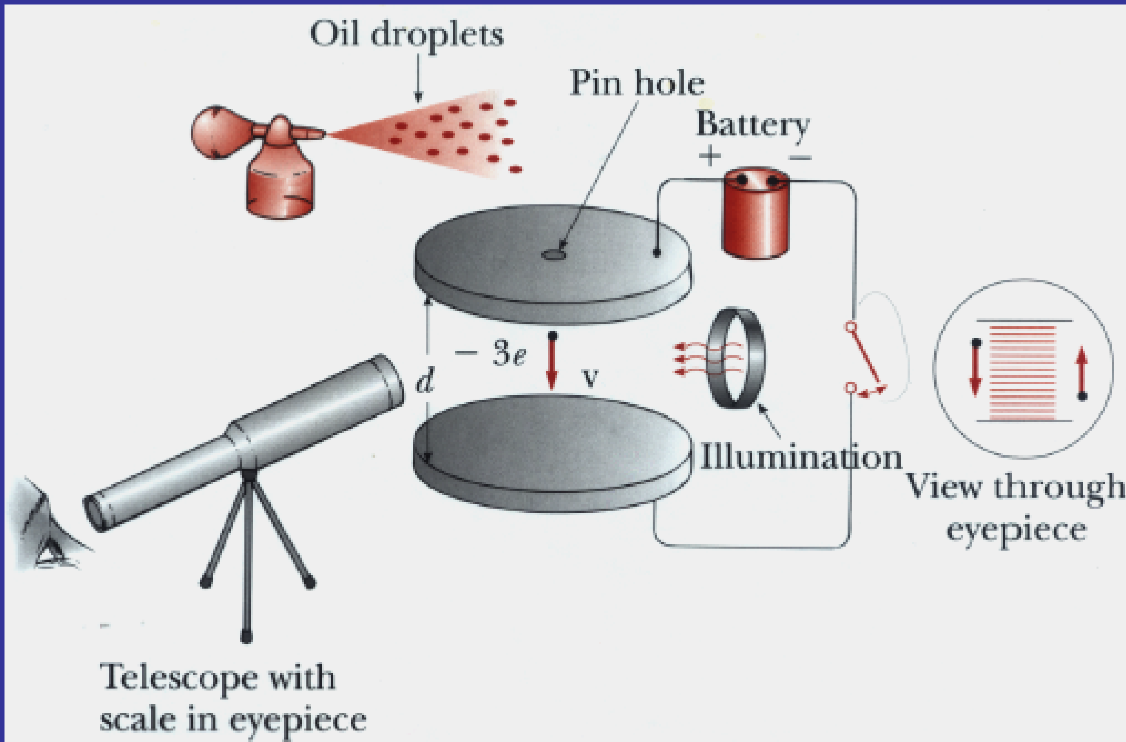


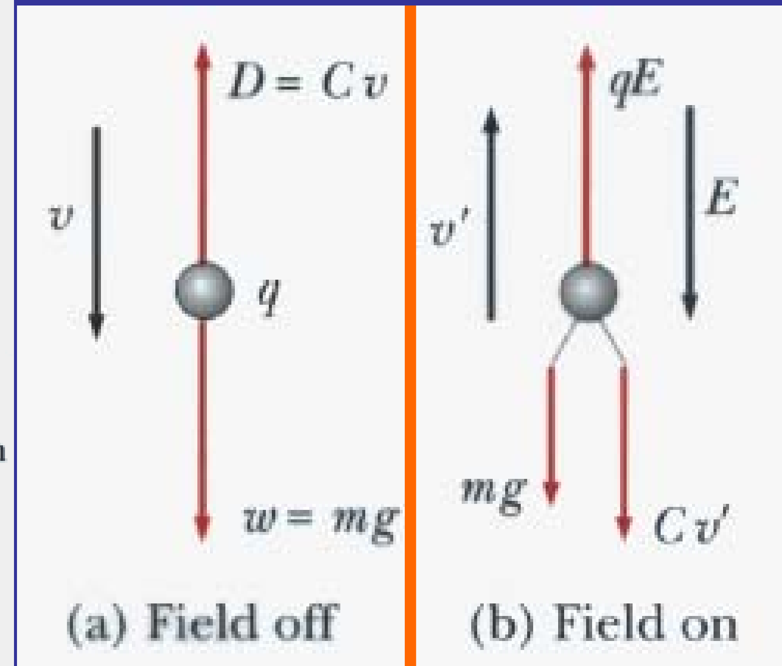


- In E Field alone, electron lands at D
- In B field alone, electron lands at E
- When E and B field adjusted to cancel each other's force → electron lands at F

→ $e/m = 1.7588 \times 10^{11}$ C/Kg

Millikan's Measurement of Electron Charge





Find charge on oil drop is always in integral multiple of some Q

$q_e = 1.688 \times 10^{-19}$ Coulombs

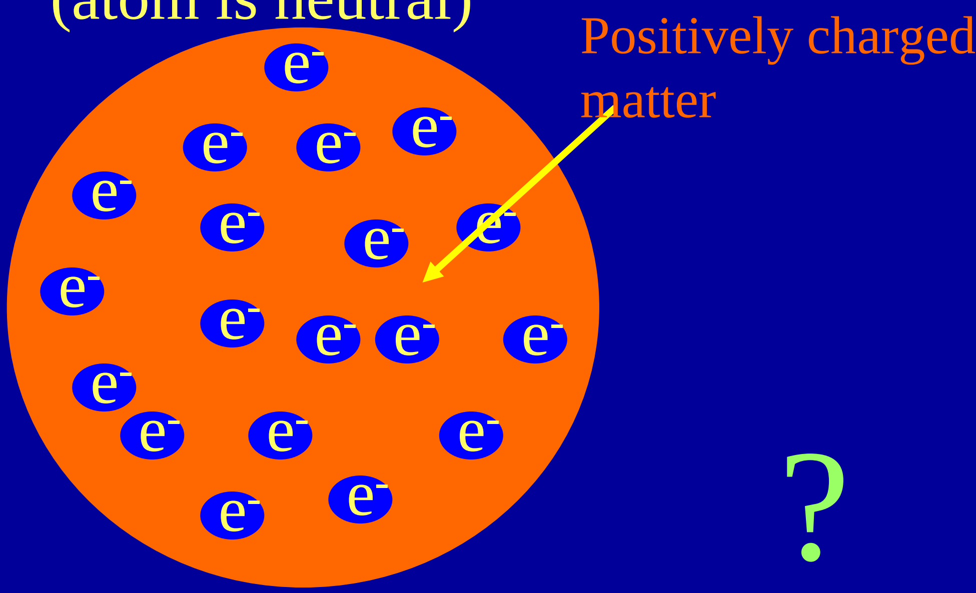
→ $m_e = 9.1093 \times 10^{-31}$ Kg

→ Fundamental properties (finger print) of electron

(similarly can measure proton properties etc)

Where are the electrons inside atoms?

Early Thought: "Plum pudding" model→ Atom has a homogenous distribution of Positive charge with electrons embedded in them (atom is neutral)



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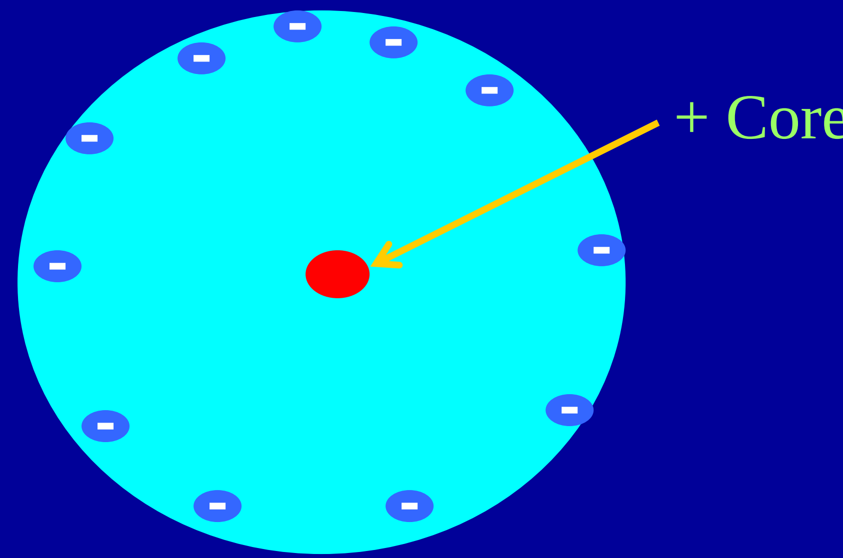
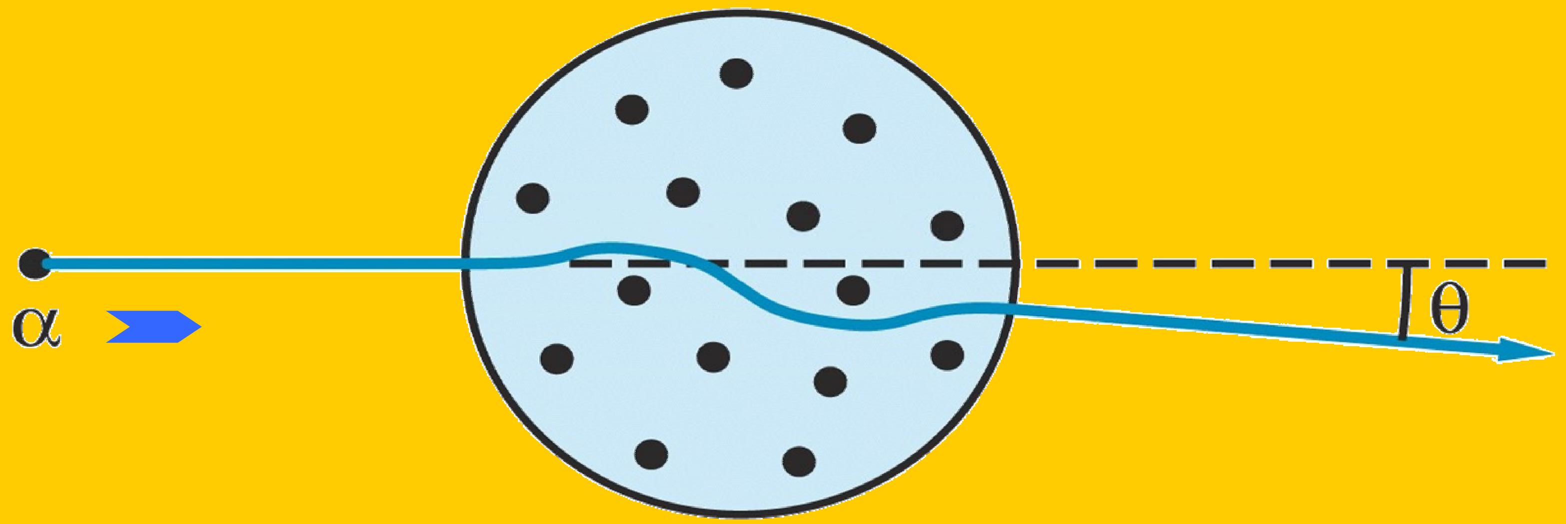


- How to test these hypotheses? → Shoot "bullets" at the atom and watch their trajectory. What Kind of bullets ?
  - •Indestructible charged bullets → Ionized He^{++} atom = α^{++} particles
  - •Q = +2e , Mass M_α=4amu >> m_e , V_α= 2 x 10^7 m/s (non-relavistic) [charged to probe charge & mass distribution inside atom]

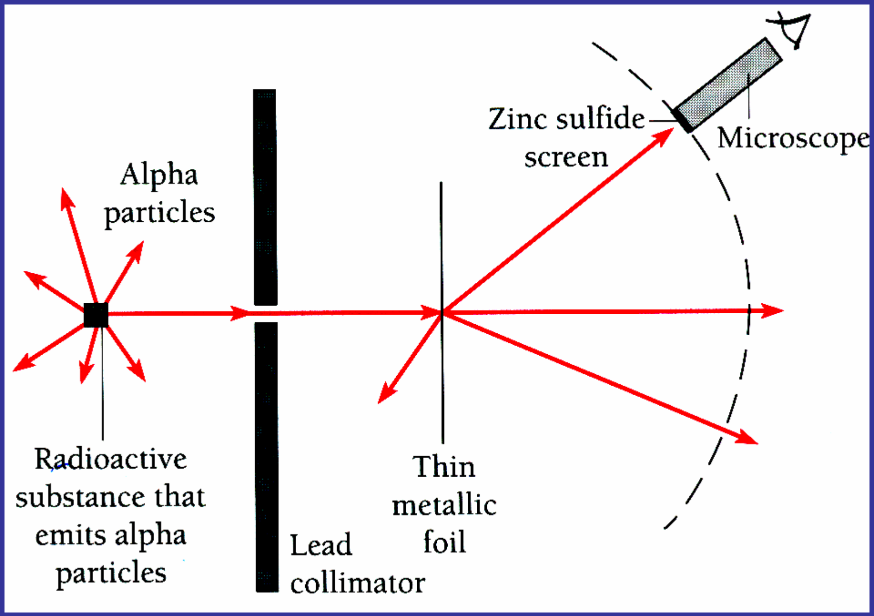
Plum Pudding Model of Atom

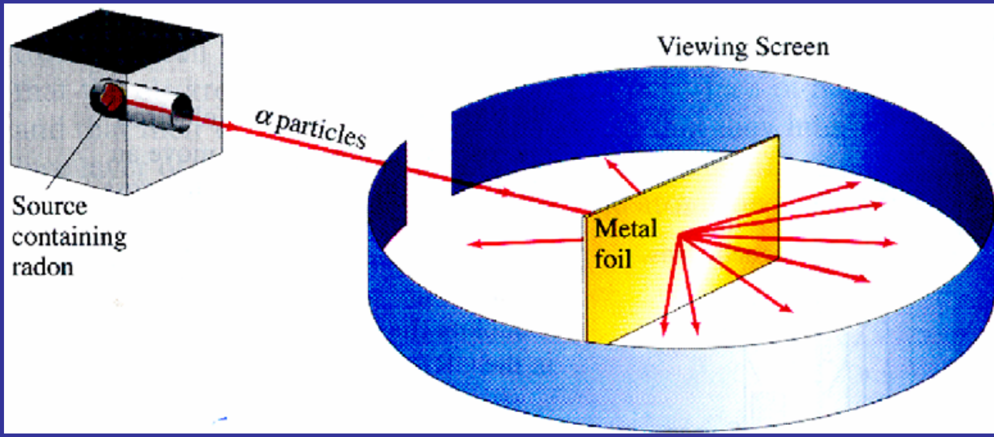
- Non-relativistic mechanics ($V_\alpha/c = 0.1$)
- In Plum-pudding model, α-rays hardly scatter because
  - Positive charge distributed over size of atom (10^{-10}m)
  - $M_\alpha >> M_e$ (like moving truck hits a bicycle)
  - → predict α-rays will pass thru array of atoms with little scatter (~1^o)



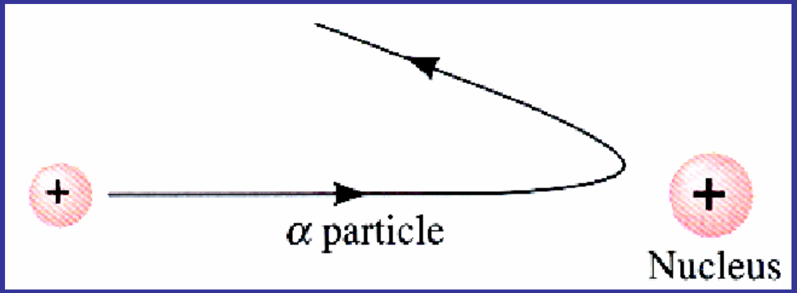
Need to test this hypothesis → Ernest Rutherford

Probing Within an Atom with α Particles

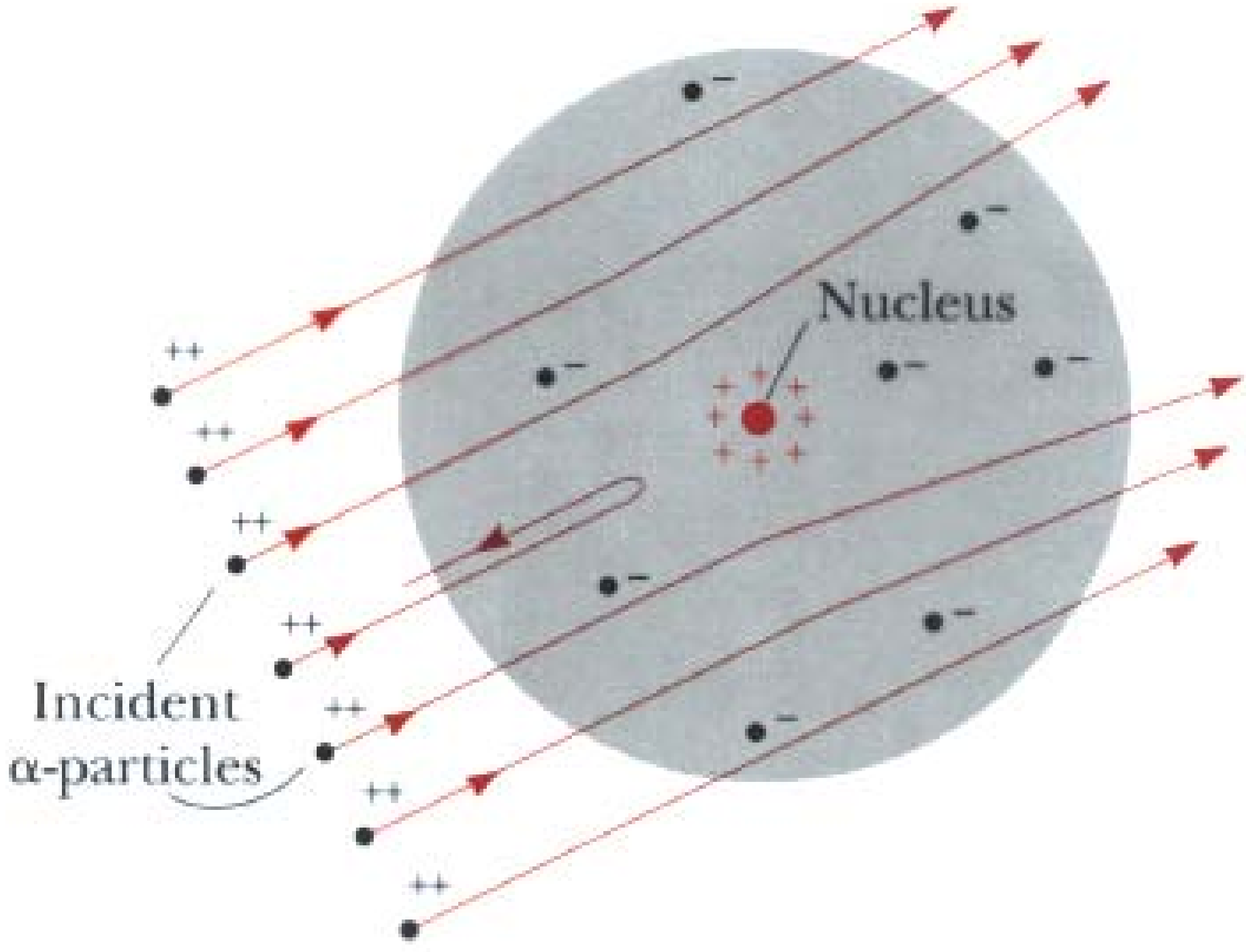




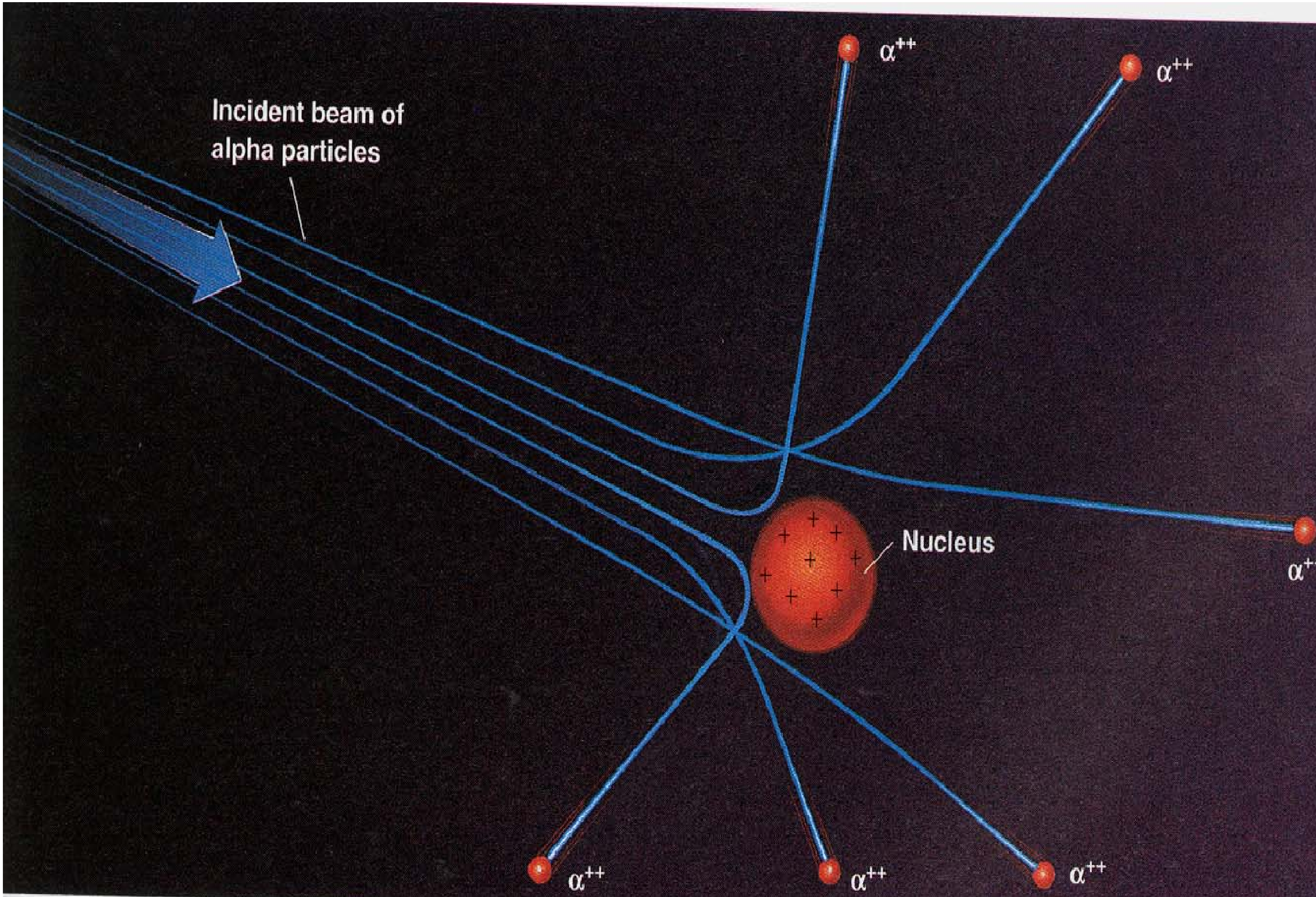
- Most α particles pass thru gold foil with nary a deflection
- SOME (≅10^{-4}) scatter at LARGE angles Φ
- Even fewer scatter almost backwards → Why



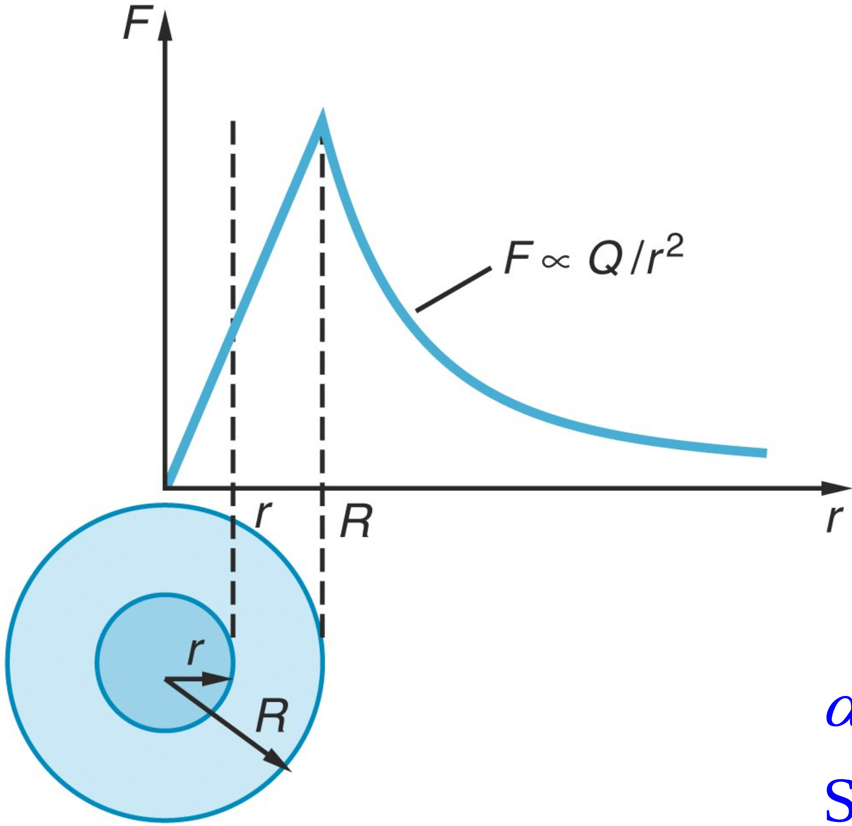
"Rutherford Scattering" discovered by his PhD Student (Marsden)

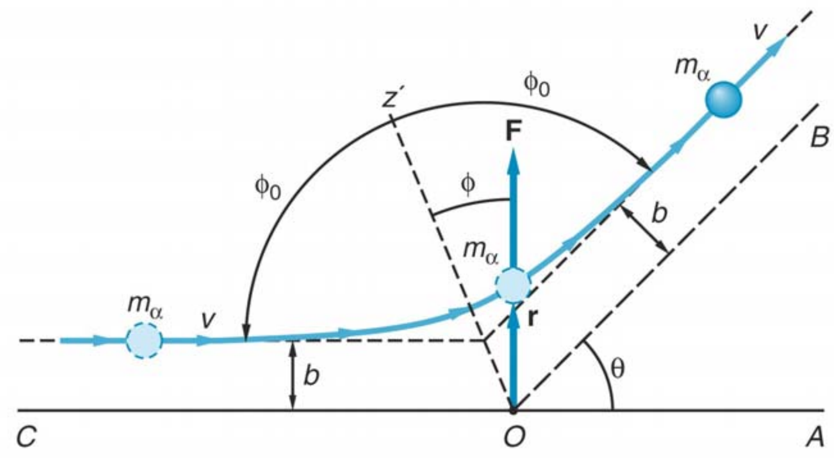


Rutherford Discovers Nucleus (Nobel Prize)



Force on α-particle due to heavy Nucleus





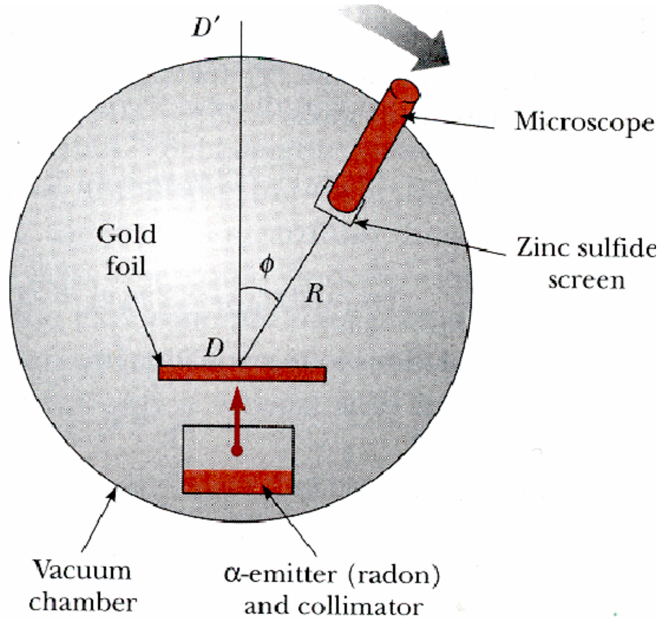
α particle trajectory is hyperbolic

Scattering angle is related to impact par.

$$\text{Impact Parameter } b = \left(\frac{kq_{\alpha}Q}{m_{\alpha}v_{\alpha}^{2}}\right)\left(\cot\frac{\theta}{2}\right)$$

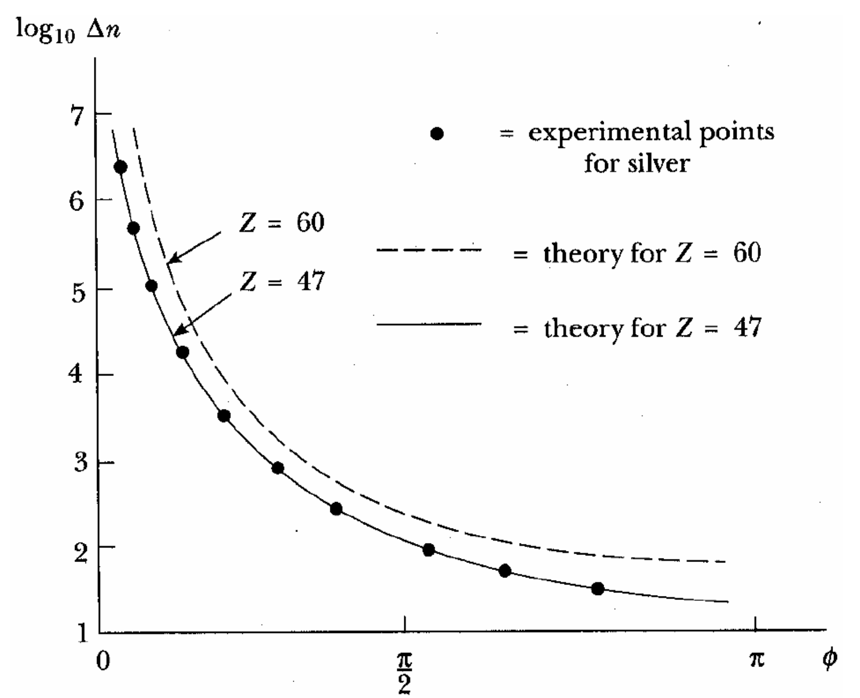
- Outside radius r =R, $F \propto Q/r^2$
- Inside radius r < R, $F \propto q/r^2 = Qr/R^2$
- Maximum force at radius r = R

Rutherford Scattering: Prediction and Experimental Result

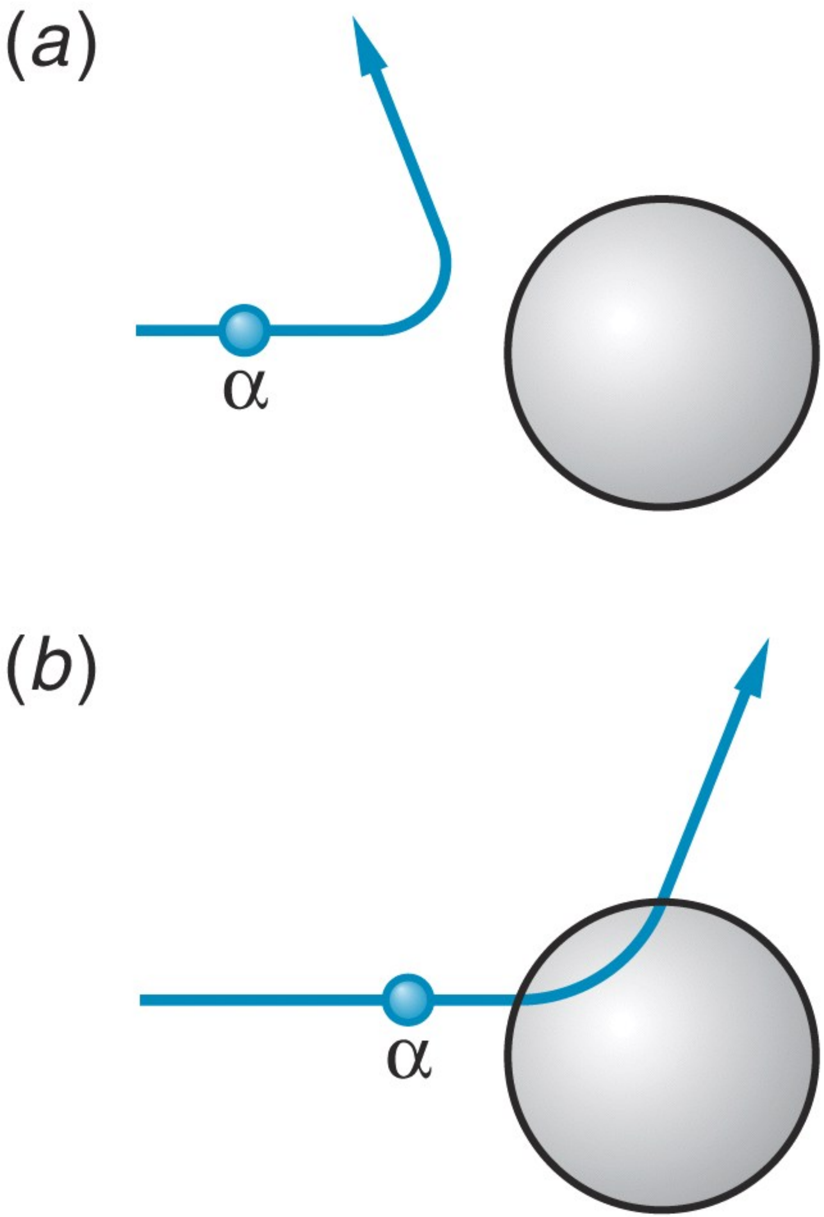


$$\Delta n = \frac{k^2 Z^2 e^4 NnA}{4R^2 \left(\frac{1}{2} m_\alpha v_\alpha^2\right)^2 Sin^4(\varphi/2)}$$

- # scattered Vs ϕ depends on :
  - n = # of incident alpha particles
  - N = # of nuclei/area of foil
  - Ze = Nuclear charge
  - K_α of incident alpha beam
  - A= detector area



Rutherford Scattering & Size of Nucleus



distance of closest appoach $\propto$ r size of nucleus

Kinetic energy of α = $K_\alpha = \frac{1}{2} m_\alpha v_\beta^2$

α particle will penetrate thru a radius r until all its kinetic energy is used up to do work AGAINST the Coulomb potential of the Nucleus:

$$K_\alpha = \frac{1}{2} m_\alpha v_\beta^2 = 8MeV = k\frac{(Ze)(2e)}{r}$$

$$\Rightarrow \qquad r = \frac{2kZe^2}{K_\alpha}$$

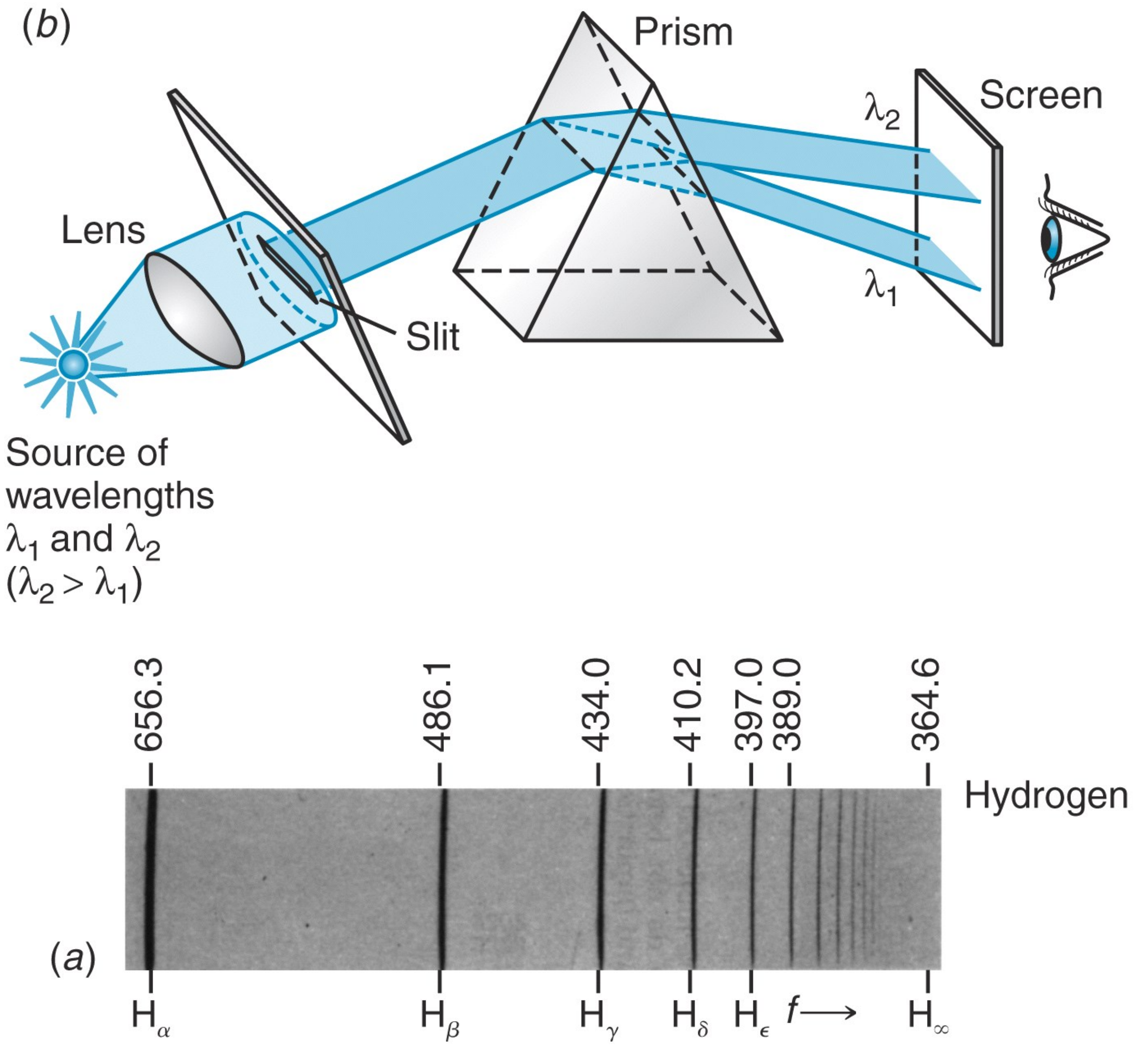
For K_α =7.7.MeV, $Z_{Al} = 13$

$$\Rightarrow \qquad r = \frac{2kZe^2}{K_\alpha} = 4.9 \times 10^{-15} m$$

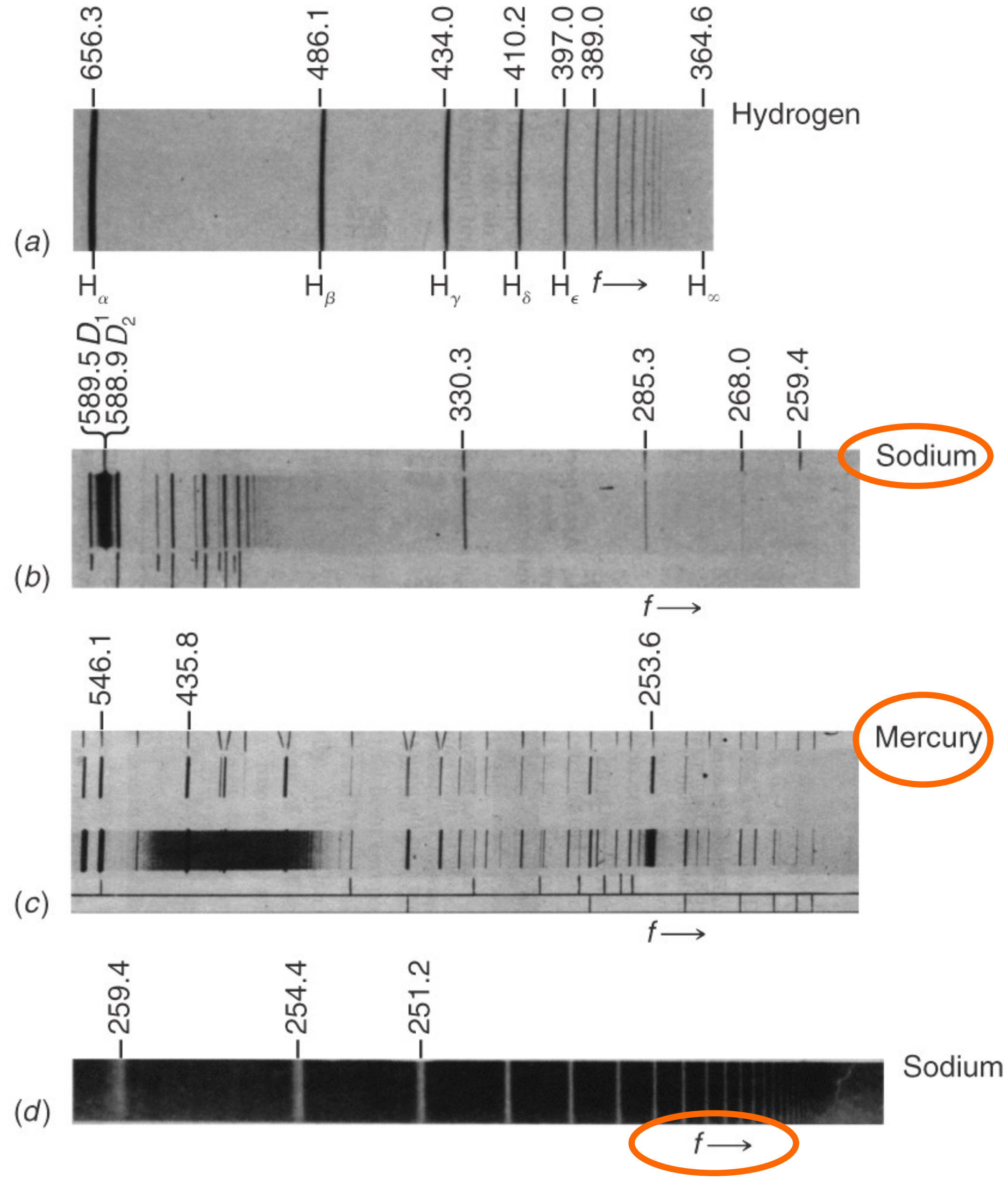
Size of Nucleus = $10^{-15} m$

Size of Atom = $10^{-10} m$

Spectrum of Light and Structure Within Atom



Emission Line Spectrum of Elements

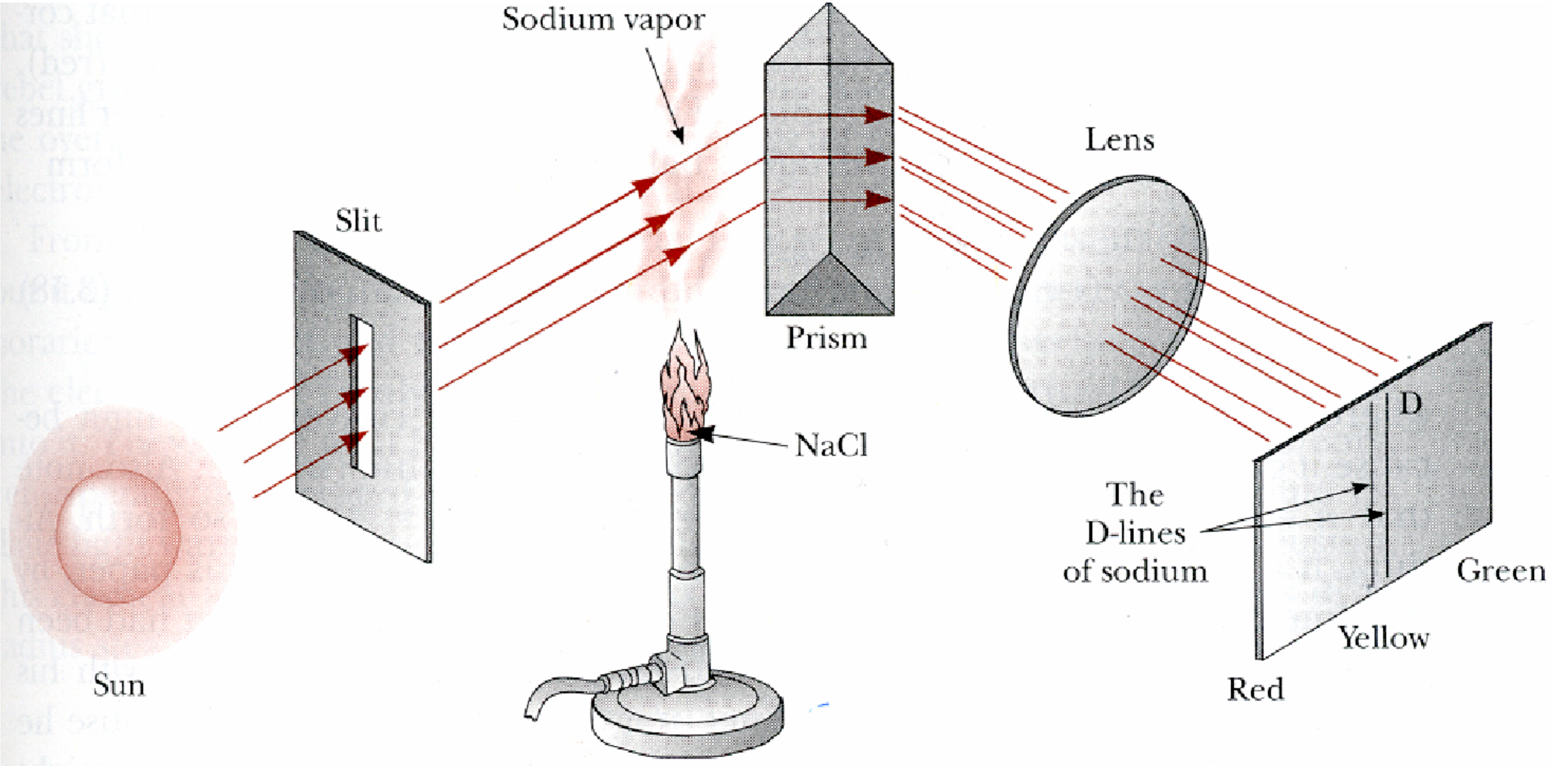


•Emission line appear dark because of photographic exposure

Absorption spectrum of Na

While light passed thru Na vapor is absorbed at specific λ

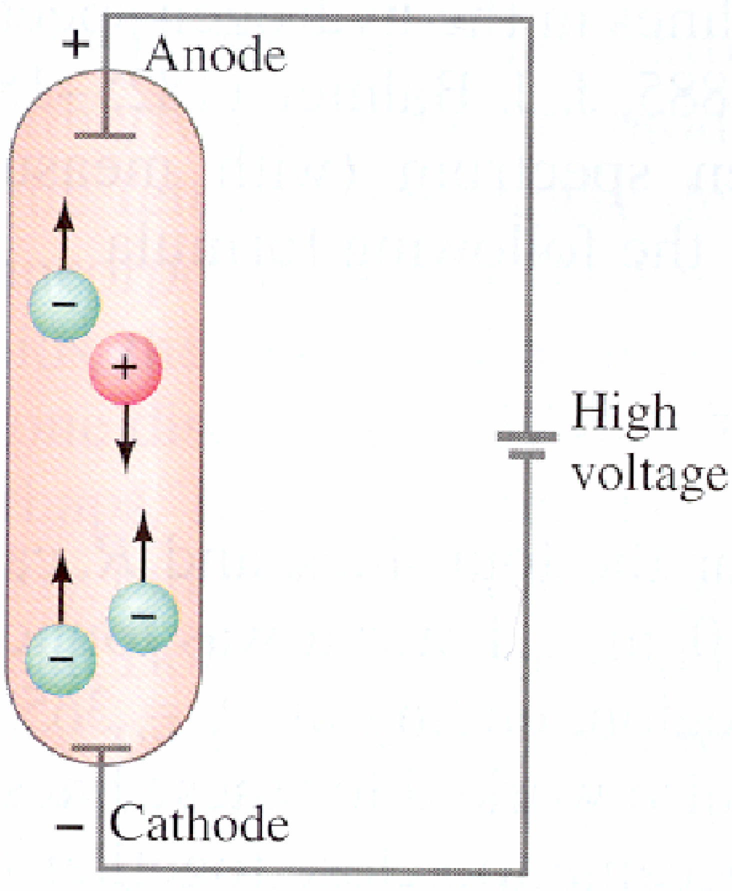
Kirchhoff' Experiment : "D" Lines in Na

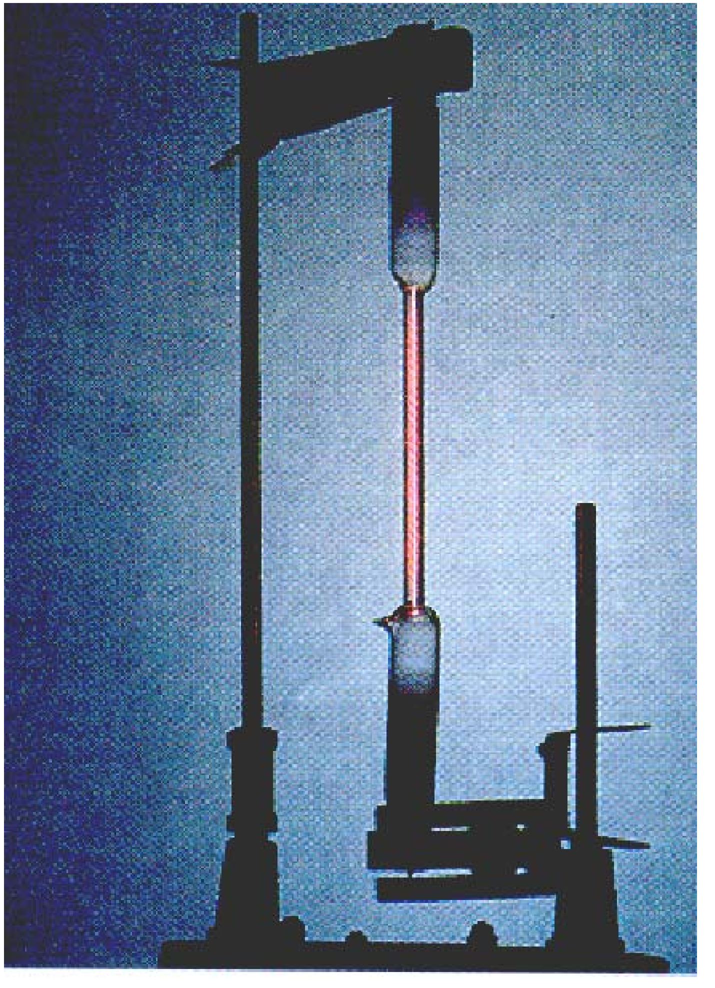


D lines darken noticeably when Sodium vapor introduced

Between slit and prism

Discharge Tube

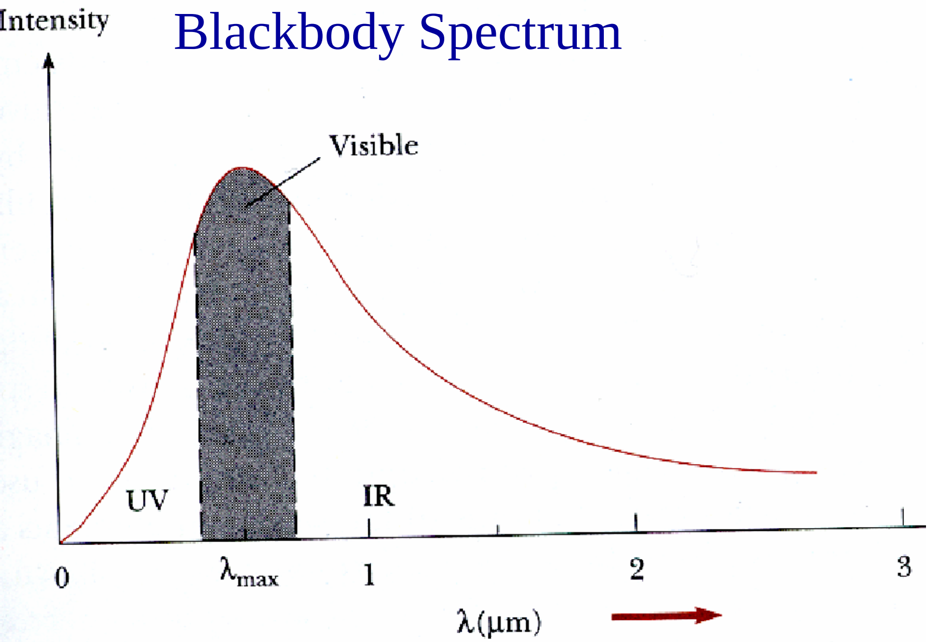




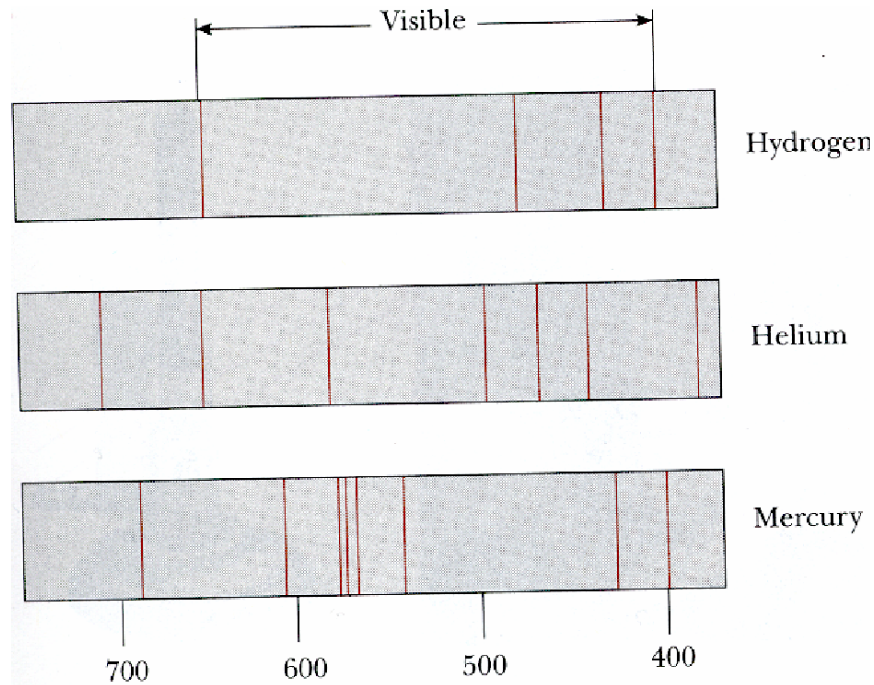
Spectrum of Light

Continuous

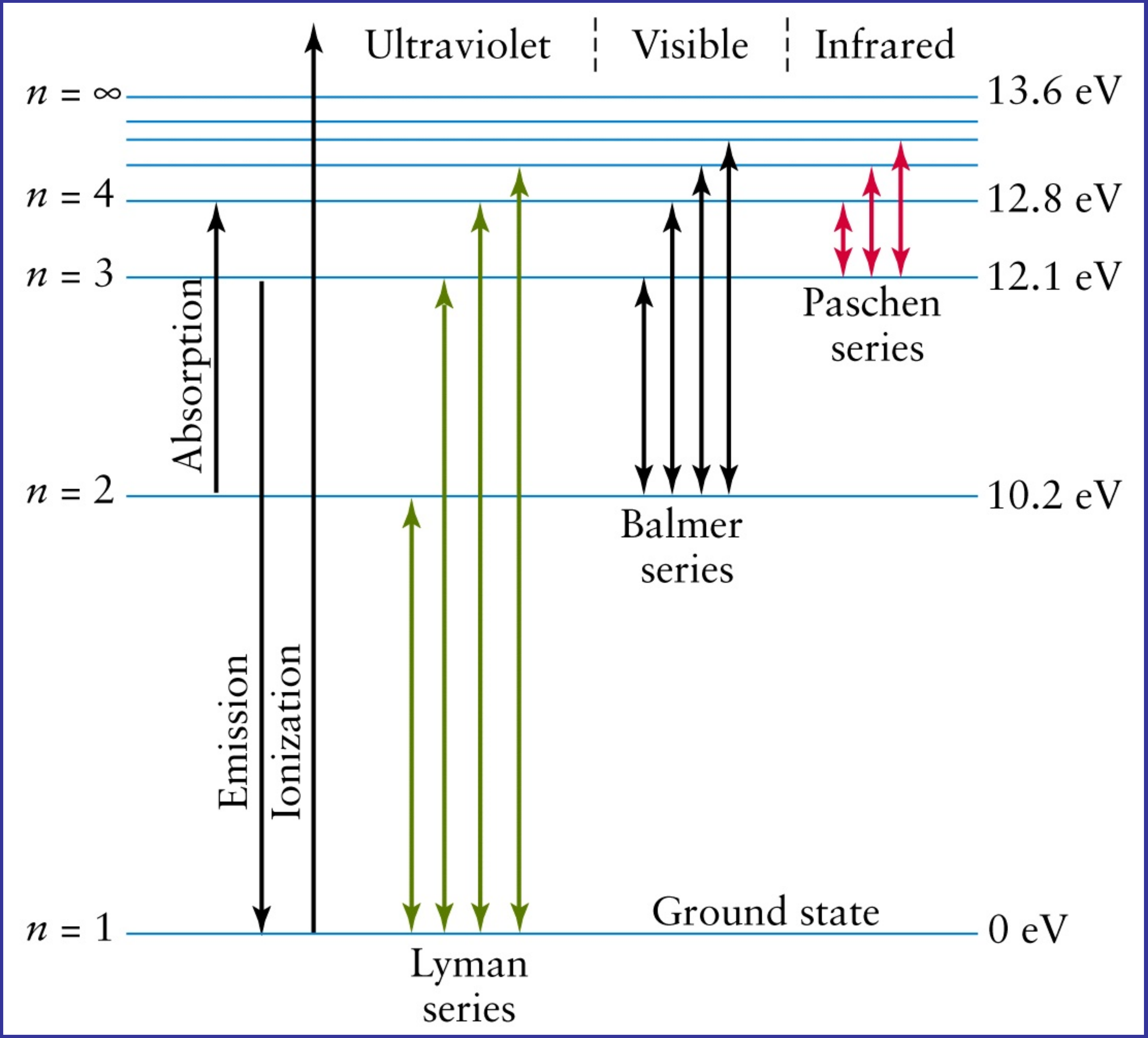
Blackbody Spectrum



Discrete Emission Line Spectrum of elements



Hydrogen Spectrum



Distribution of electron Inside Atoms ?

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