

Brian Wecht, the TA, is away this week. I will substitute for his office hours (in my office 3314 Mayer Hall, discussion and PS session.

Pl. give all regrade requests to me this week (only)

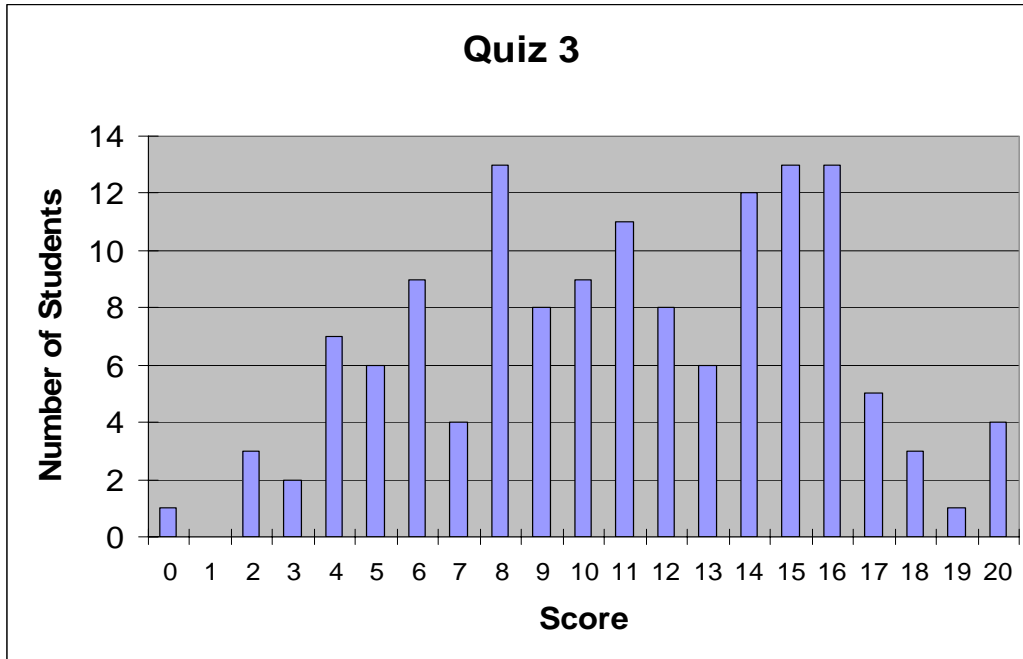
Quiz 4 is This Friday



Physics 2D Lecture Slides

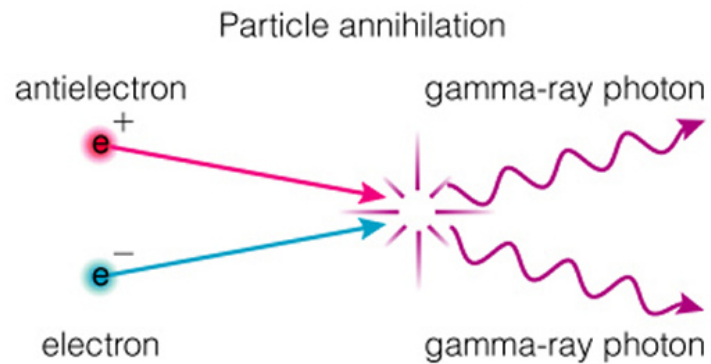
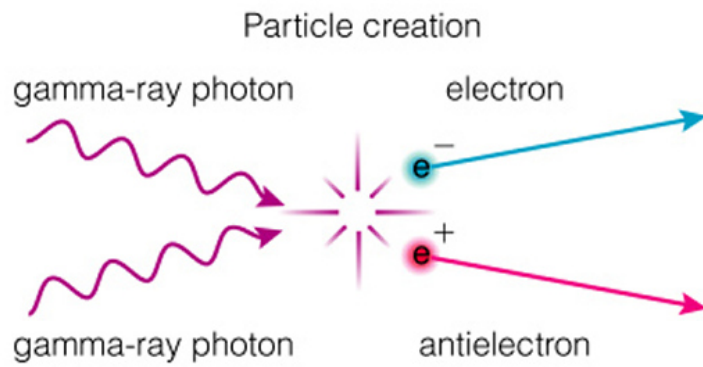
Lecture 13: Feb 2nd 2004

Vivek Sharma
UCSD Physics



Other forms of Interaction of Energy Exchange between Radiation and Matter

$E \rightleftharpoons mc^2 + mc^2$
Always same form of
Matter & Antimatter



Saw what light does, Now examine nature of matter

- Fundamental Characteristics of different forms of matter

- Rest Mass (m)
- Electric Charge (q)

Reading Assignment, one problem from here may be on the quiz

- Measurable

- using some combination of **E & B fields interacting with the particle**

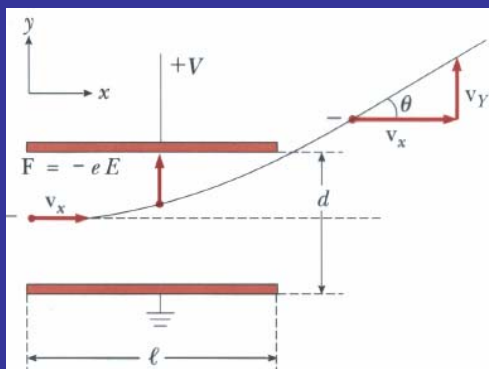
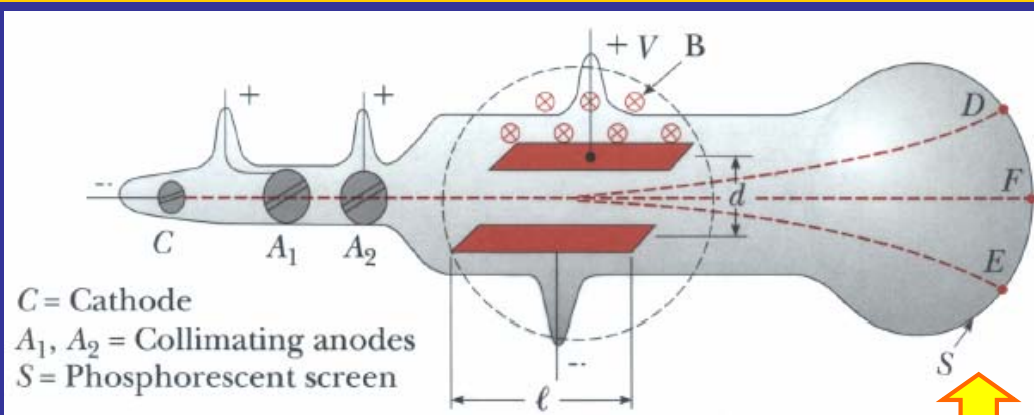
$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$$

- Or E/B or some other macroscopic force

e.g. Drag Force

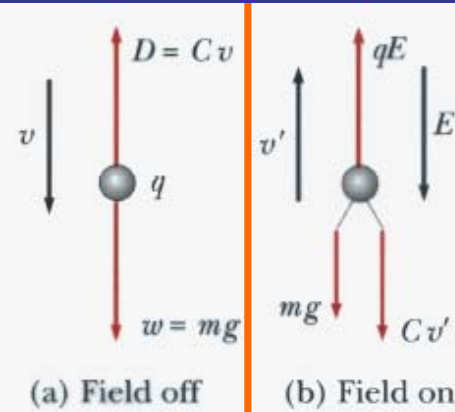
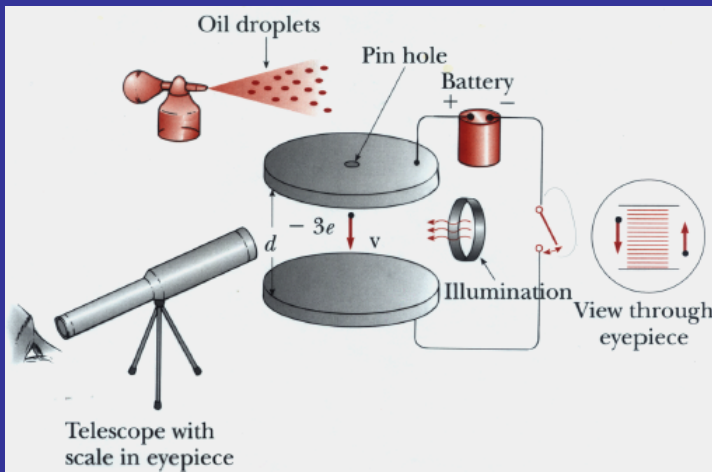
The “magic” is that one is measuring tiny tiny numbers using Macroscopic devices

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 \rightarrow electron lands at F
 $\rightarrow e/m = 1.7588 \times 10^{11} \text{ C/Kg}$

Millikan's Measurement of Electron Charge



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

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

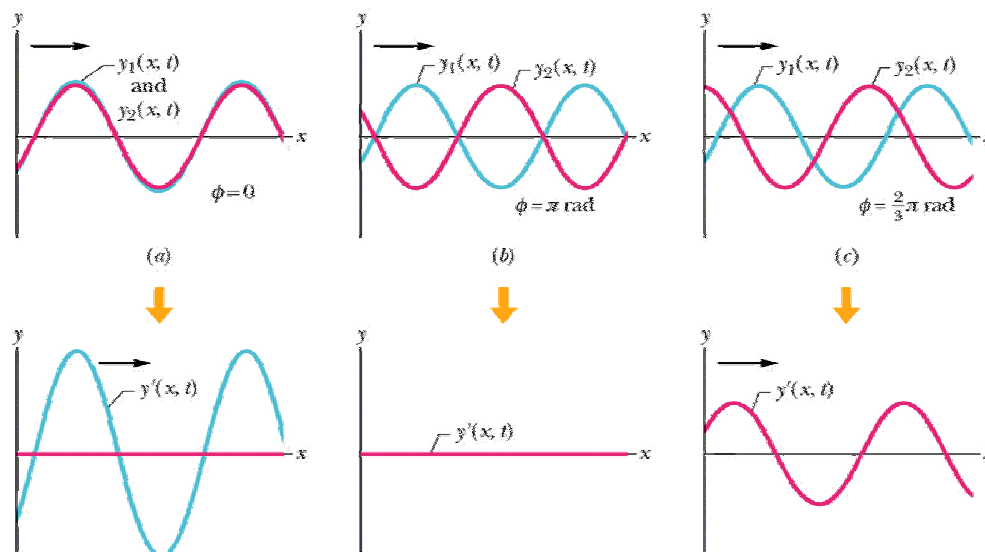
$$\rightarrow m_e = 9.1093 \times 10^{-31} \text{ Kg}$$

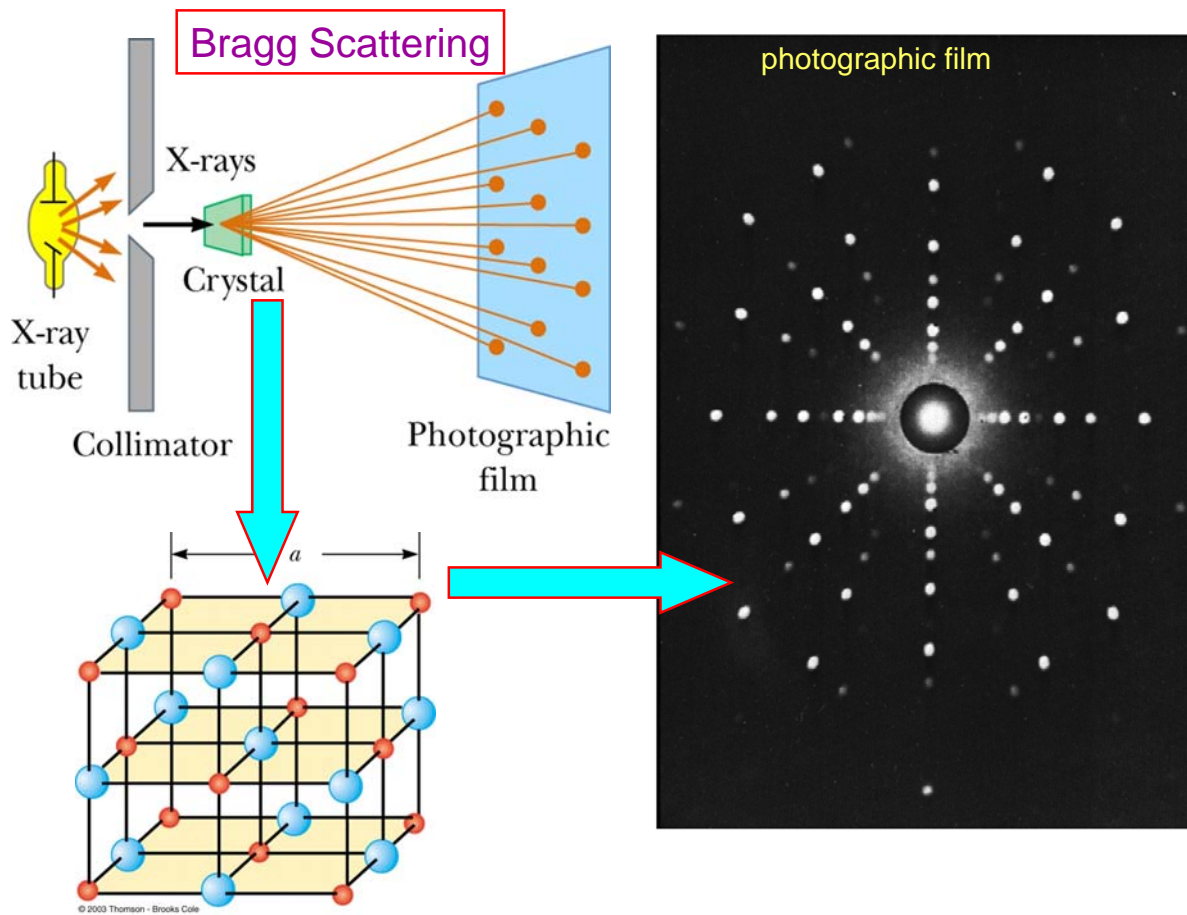
\rightarrow Fundamental properties (finger print) of electron
(similarly can measure proton properties etc)

Constructive Interference of Waves depends on Path length or Traversed (or corresponding phase difference)

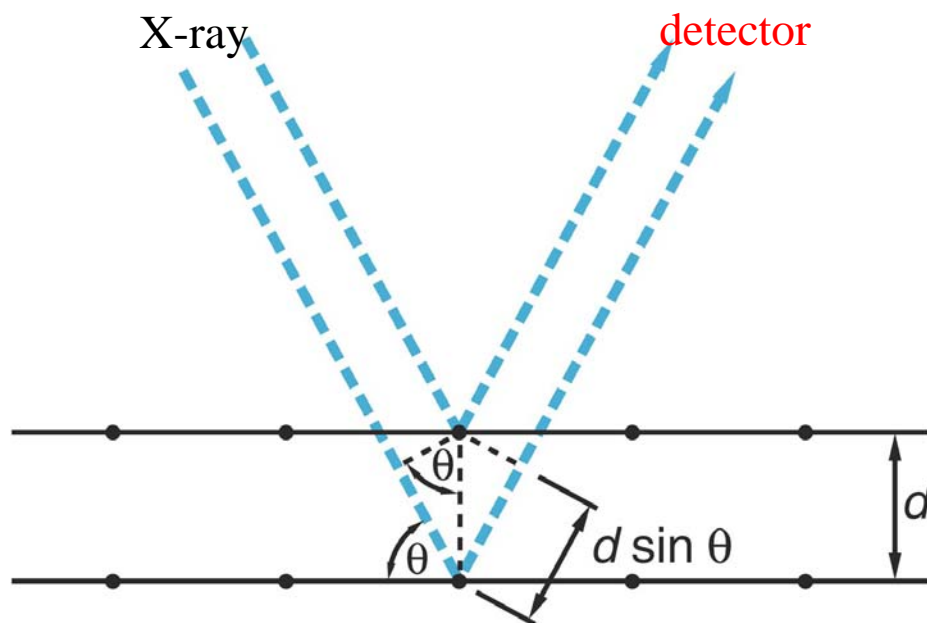
Two Identical waves $y_i(x, t) = y_{\max} \sin(k_i x - \omega_i t + \phi_i)$ travel along +x and interfere to give a resulting wave $y'(x, t)$. The resulting wave form depends on relative phase difference between 2 waves. Shown for $\Delta\phi = 0, \pi, \frac{2}{3}\pi$

Read Ch17-8 from Resnick et al held in Ereserve





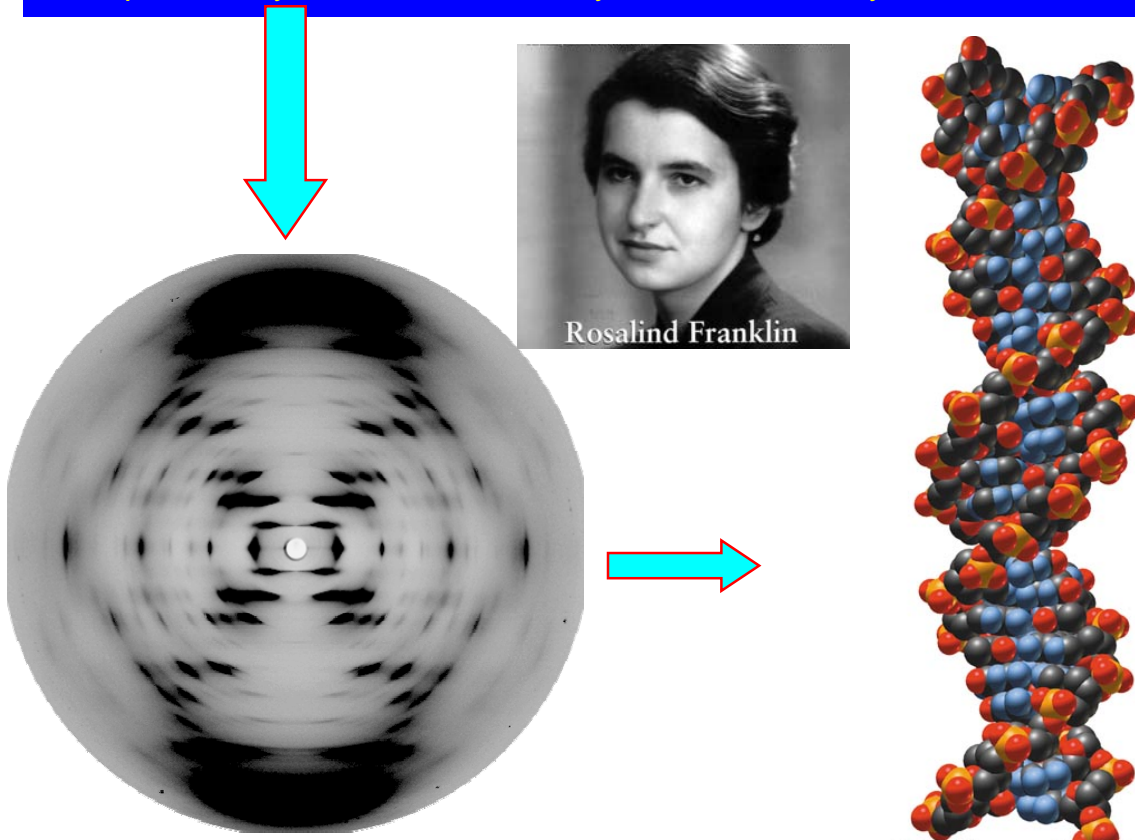
Bragg Scattering: Probing Atoms With X-Rays



Constructive Interference when net phase difference is $0, 2\pi$ etc
 This implied path difference traveled by two waves must be integral multiple of wavelength : $n\lambda = 2d \sin \theta$

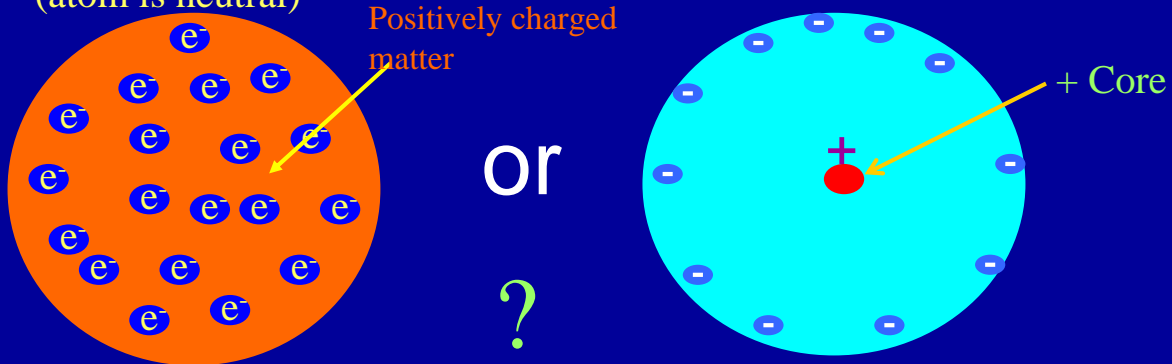
Summary : From X Ray (EM Wave) Scattering data, Size of the Atom was known to be about 10^{-10} m

Example : X-Ray Picture of a DNA Crystal and Discovery of DNA Structure !



Where are the electrons inside the atom?

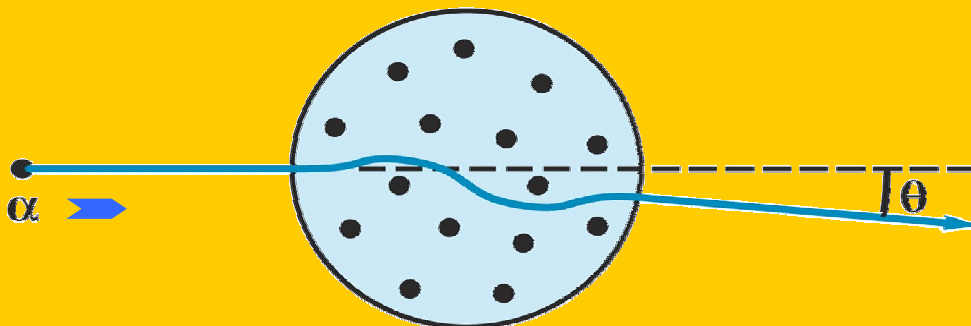
Early Thought: "Plum pudding" model \rightarrow Atom has a homogenous distribution of Positive charge with electrons embedded in them (atom is neutral)



- How to test these hypotheses? \rightarrow Shoot "bullets" at the atom and watch their trajectory. What Kind of bullets ?
 - Indestructible charged bullets \rightarrow Ionized He^{++} atom = α^{++} particles
 - $Q = +2e$, Mass $M_\alpha = 4\text{amu} \gg m_e$, $V_\alpha = 2 \times 10^7 \text{ m/s}$ (non-relativistic) [charged to probe charge & mass distribution inside atom]

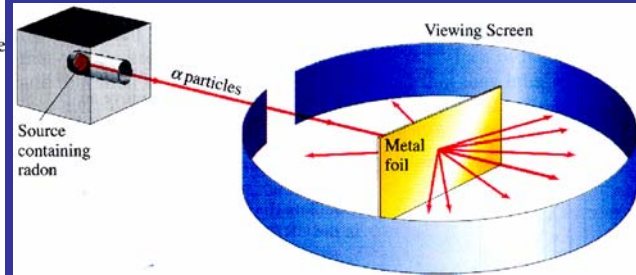
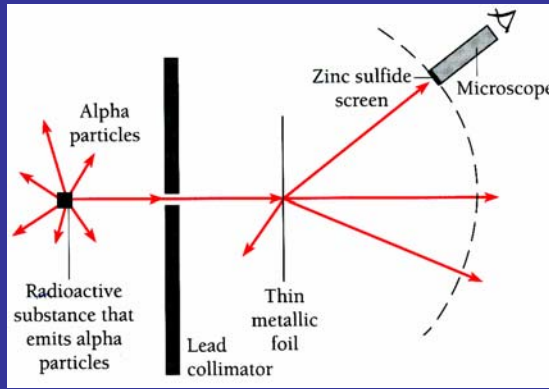
Plum Pudding Model of Atom

- 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)
 - $M_\alpha \gg M_e$ (like moving truck hits a bicycle)
 - \rightarrow predict α -rays will pass thru array of atoms with little scatter ($\sim 1^\circ$)

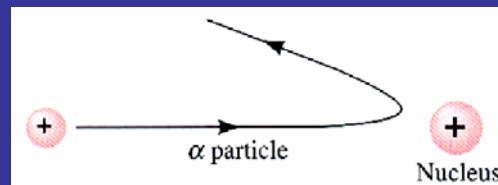


Need to test this hypothesis \rightarrow Ernest Rutherford

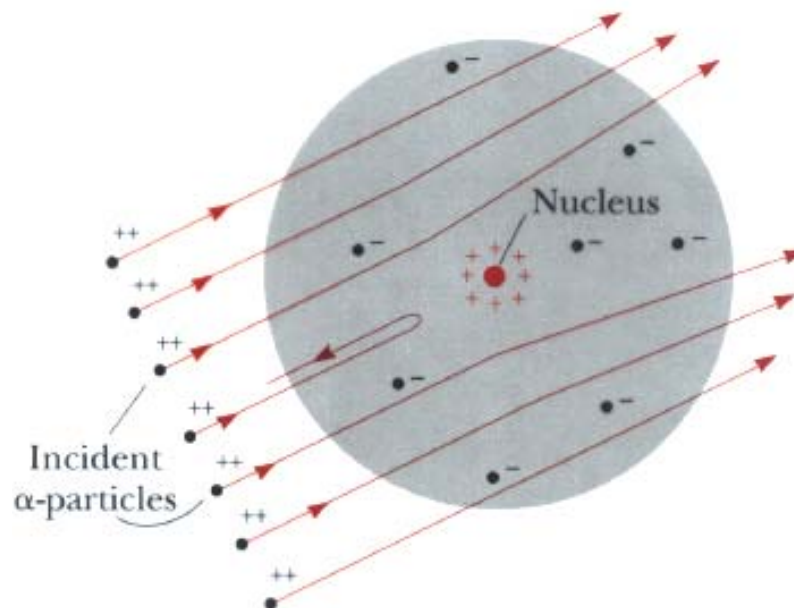
Probing Within an Atom with α Particles



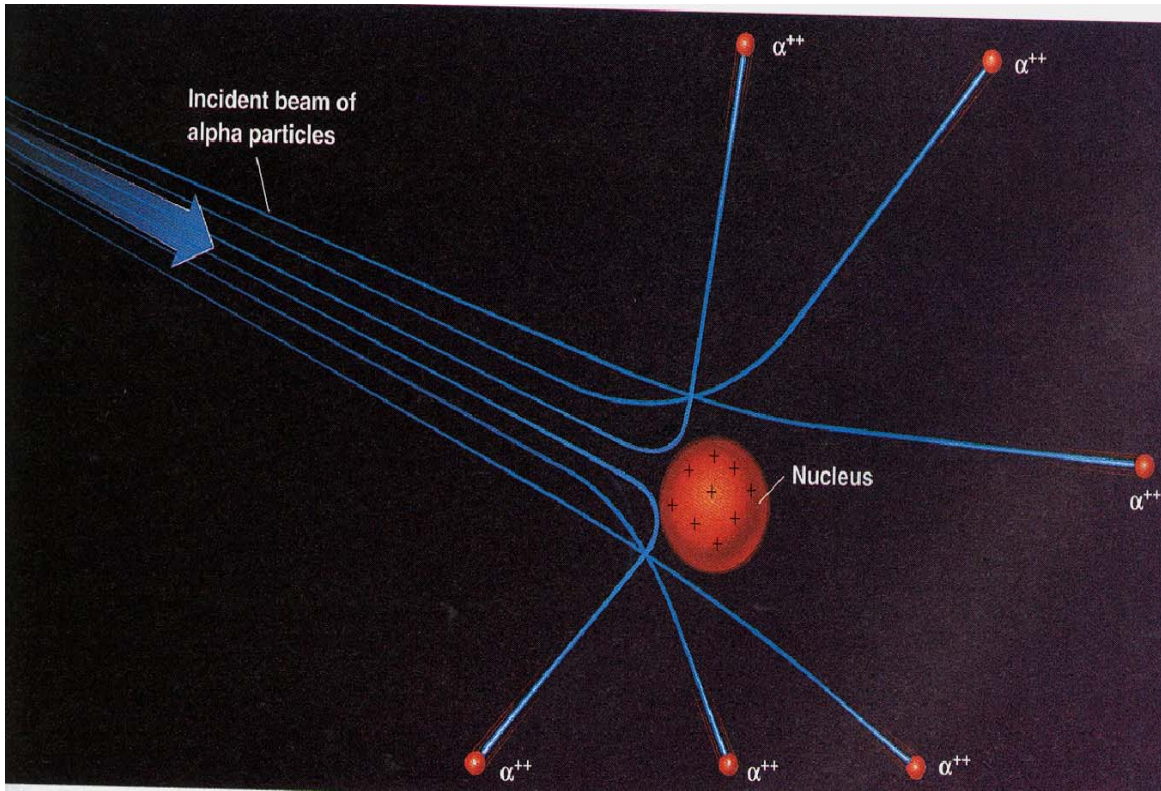
- Most α particles pass thru gold foil with nary a deflection
- SOME ($\cong 10^{-4}$) scatter at LARGE angles Φ
- Even fewer scatter almost backwards \rightarrow Why



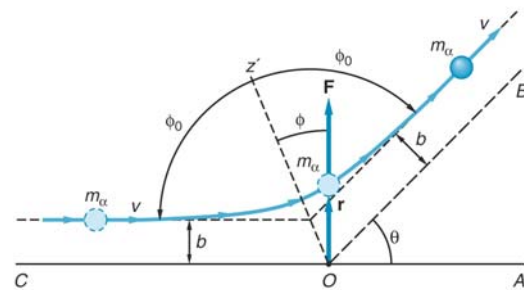
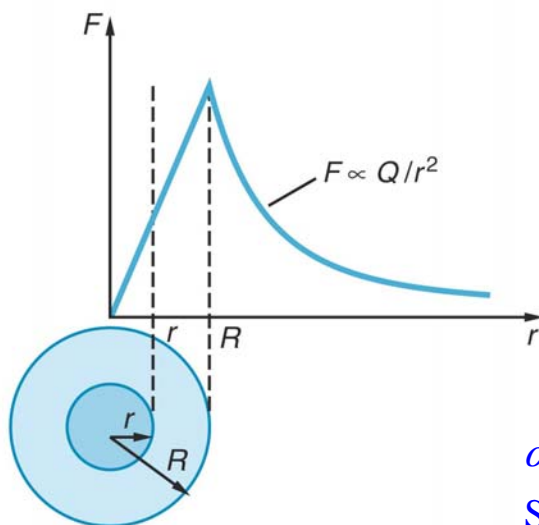
"Rutherford Scattering" discovered by his PhD Student (Marsden)



Rutherford Discovers Nucleus (Nobel Prize)



Force on α -particle due to heavy Nucleus

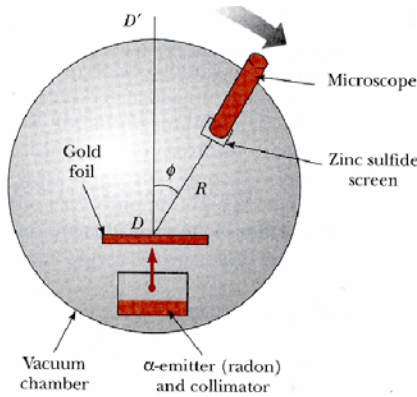


α particle trajectory is hyperbolic
Scattering angle is related to impact par.

- 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 $r = R$

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

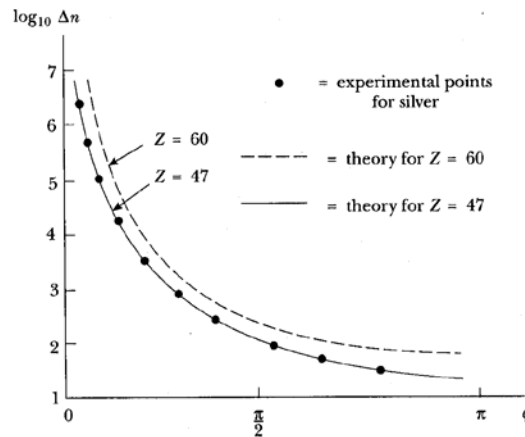
Rutherford Scattering: Prediction and Experimental Result



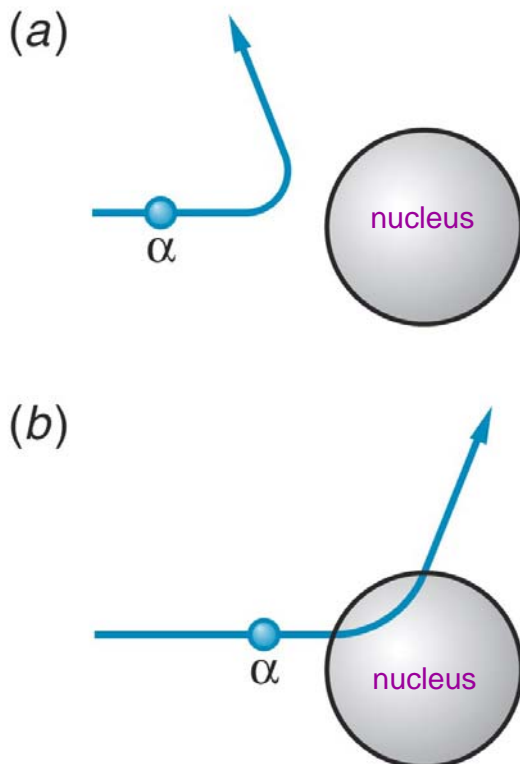
$$\Delta n = \frac{k^2 Z^2 e^4 N n A}{4 R^2 \left(\frac{1}{2} m_\alpha v_\alpha^2 \right)^2 \sin^4(\phi/2)}$$

• # 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 approach \propto r size of nucleus

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

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:

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

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

For $K_\alpha = 7.7 \text{ MeV}$, $Z_{\text{Al}} = 13$

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

Size of Nucleus = 10^{-15} m

Size of Atom = 10^{-10} m

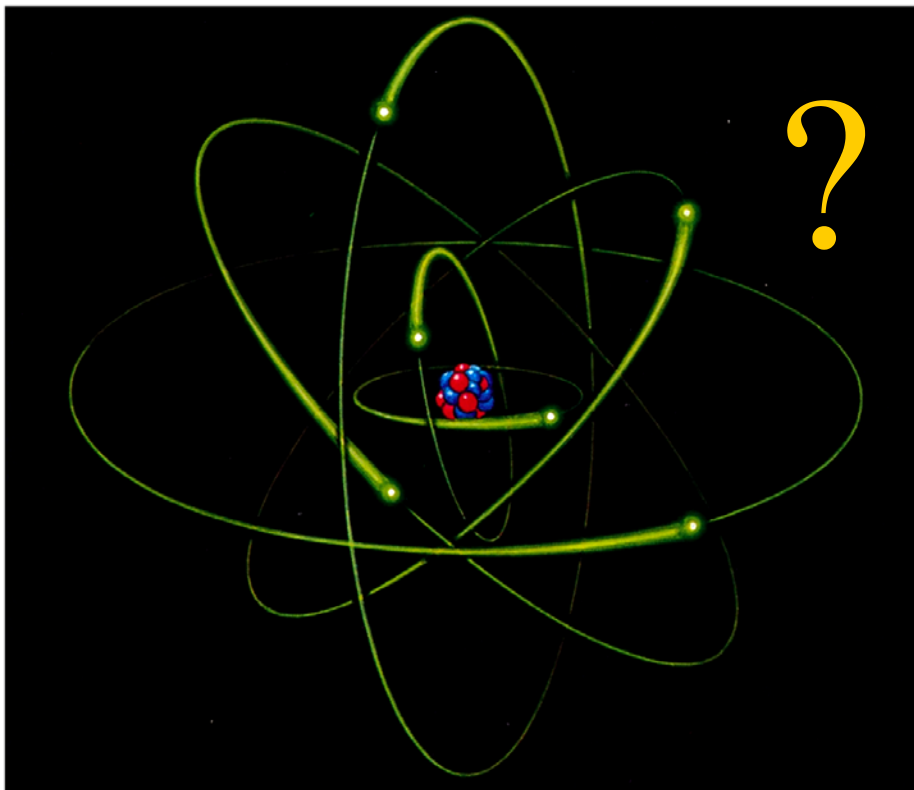
Size Matters !

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

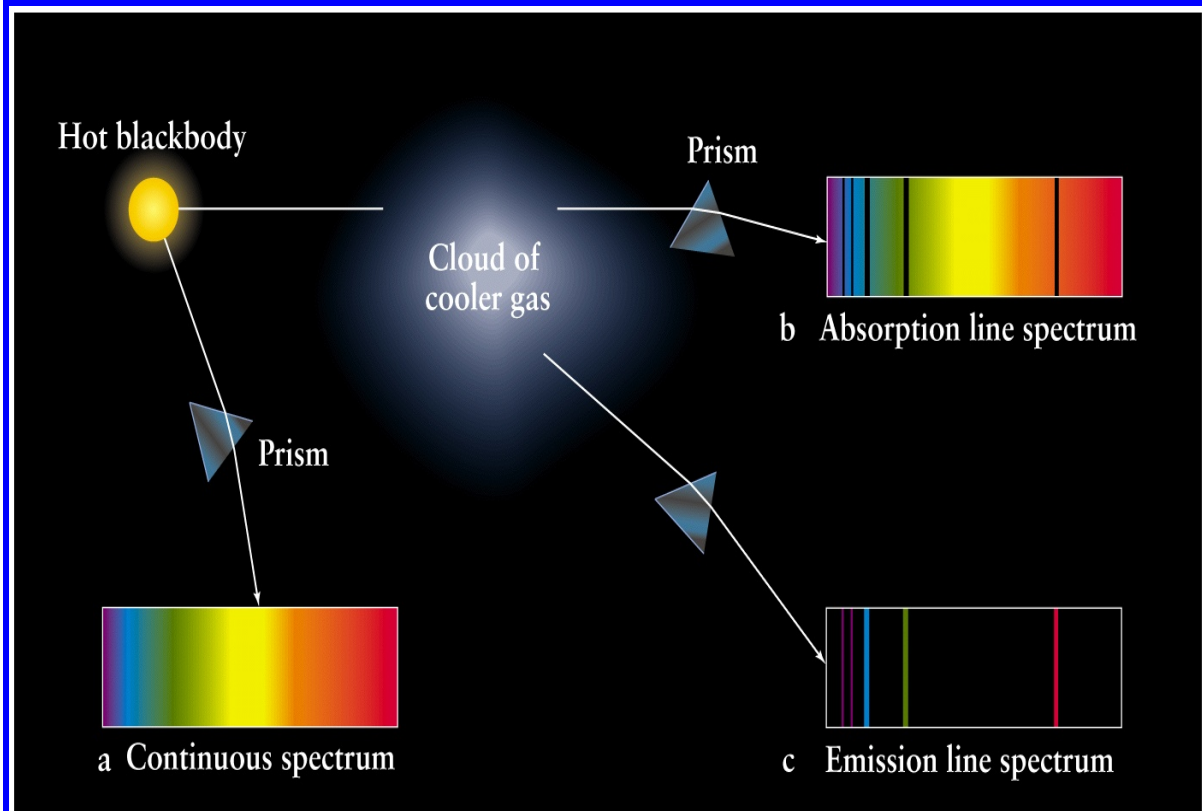
Size of Atom = $10^{-10}m$

- how are the electrons located inside an atom
- How are they held in a stable fashion
 - necessary condition for us to exist !
- All these discoveries will require new experiments and observations

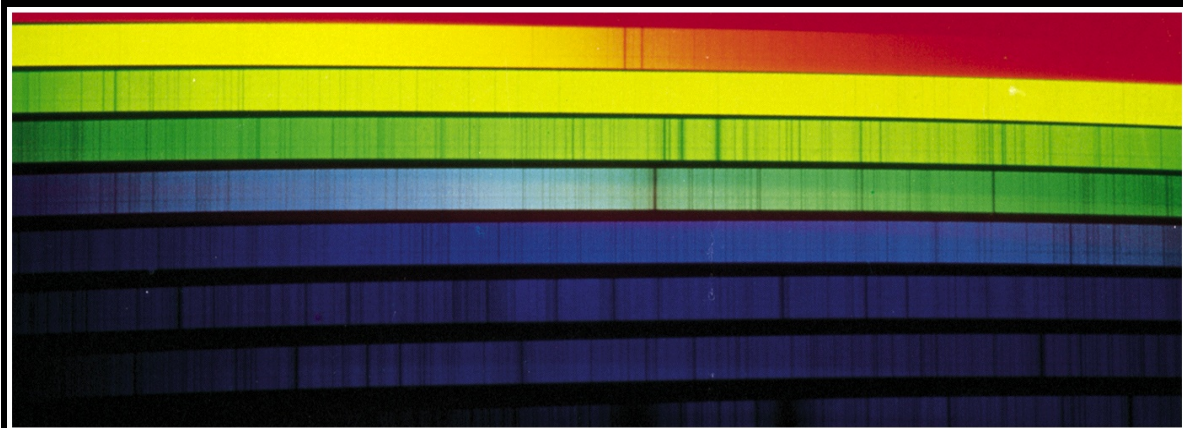
Rutherford Atom & Classical Physics



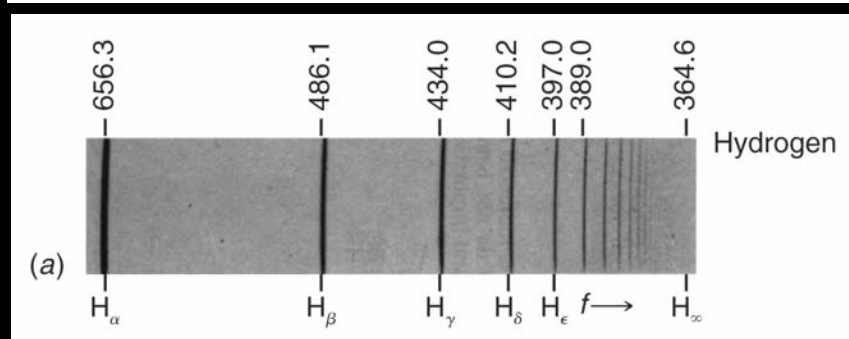
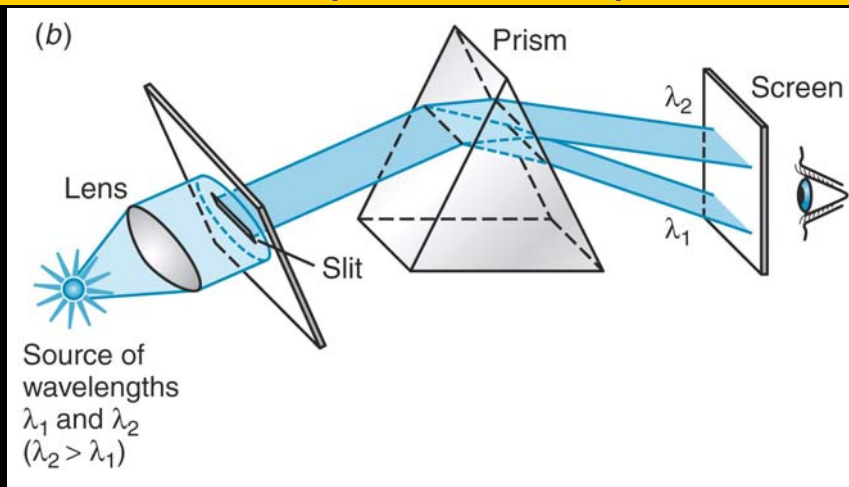
Continuous & Discrete spectra of Elements



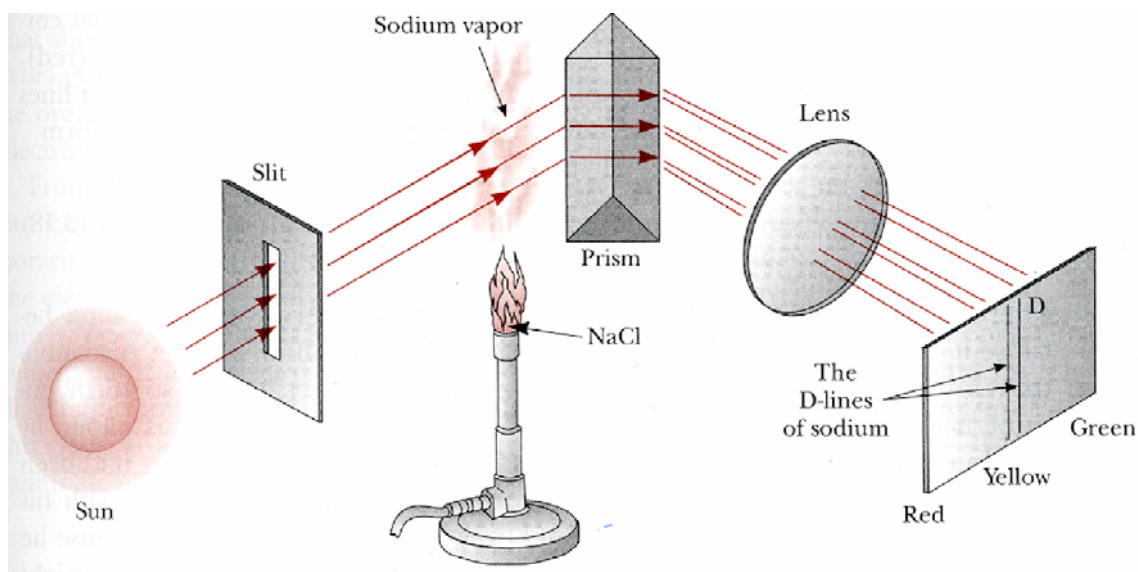
Visible Spectrum of Sun Through a Prism



Emission & Absorption Line Spectra of Elements



Kirchhoff' Experiment : "D" Lines in Na

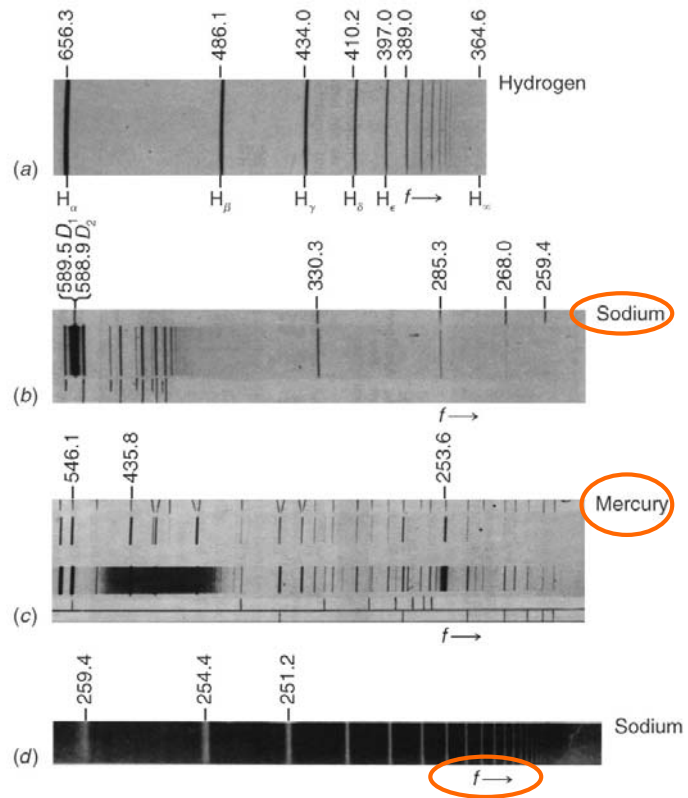


D lines **darken** noticeably when Sodium vapor introduced
Between slit and prism

Emission & Absorption 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



Atom: The Classical disaster

