PHYS 3313 – Section 001
Lecture #15

Monday, Mar. 17, 2014
Dr. Jaehoon Yu

- Atomic Excitation by Electrons
- X-ray Scattering
- Bragg's Law
- De Broglie Waves
- Bohr's Quantization
- Electron Scattering
- Wave Motion

Announcements

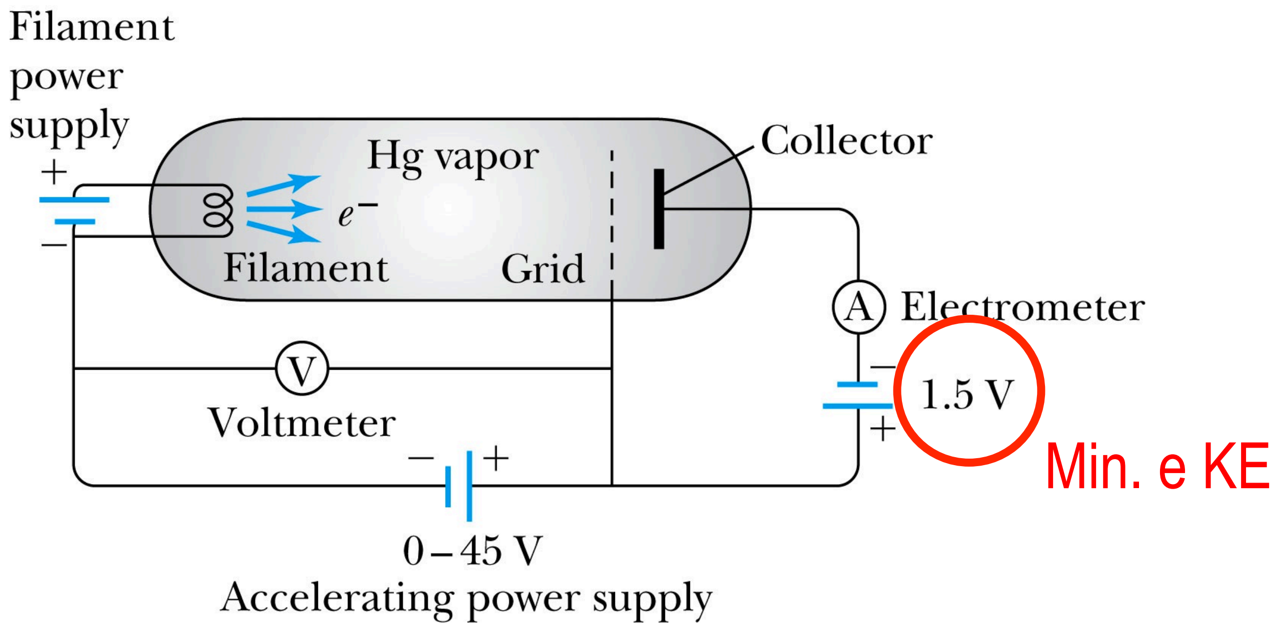
- Mid-term exam results
  - Class average: 59/105
  - Equivalent to 56/100
  - Top score: 95/105
- Mid-term grade discussions
  - In Dr. Yu's office, CPB342, Wednesday, Mar. 19
  - 12:45pm – 1:30pm: Last names A – L
  - 1:30pm – 2:20pm: Last names M – Z
- Special colloquium on April 2, triple extra credit
- Colloquium this Wednesday at 4pm in SH101

Research Projects

1. Each of the 10 research groups picks one research topic
2. Study the topic as a group, looking up references
   - Original theory or Original observation
   - Experimental proofs or Theoretical predictions + subsequent experimental proofs
   - Importance and the impact of the theory/experiment
3. Each member of the group writes a 10 page report, including figures (must not copy!!)
   - 10% of the total grade
   - Can share the theme and facts but you must write your own!
   - Due Mon., April 28, 2014
4. The group presents a 10min power point talk
   - 5% of the total grade
   - Date and time posted on the web page

Atomic Excitation by Electrons

- Franck and Hertz studied the phenomenon of ionization KE transfer from electrons to atoms.



When the accelerating voltage is below 5 V

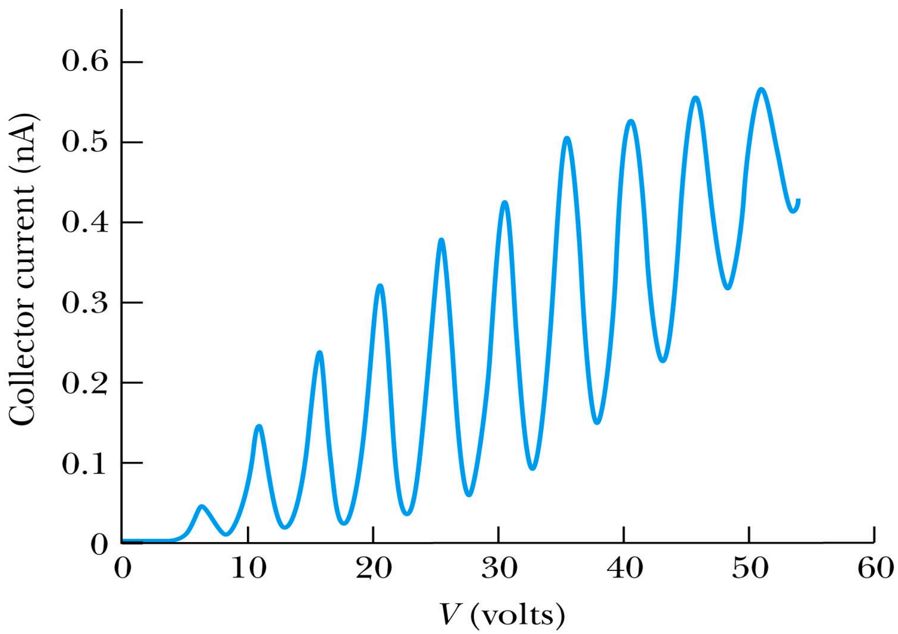
→ electrons did not lose energy going through the mercury vapor

When the accelerating voltage is above 5 V, 10V, etc..

→ sudden drop in the current

Atomic Excitation by Electrons

- Ground state has E_0 to be considered as 0.
  First excited state has E_1.
  The energy difference $E_1 - 0 = E_1$ is the **excitation energy**.

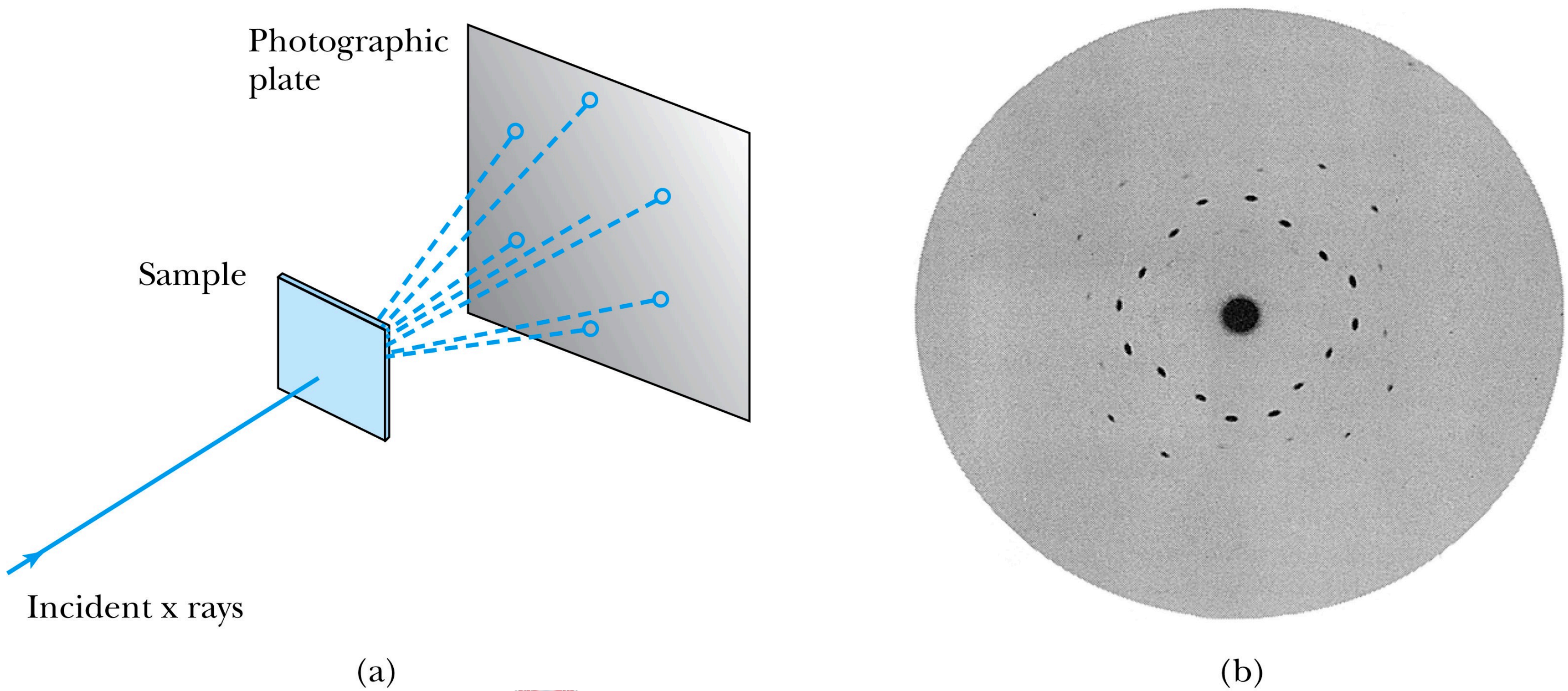


- Hg has an excitation energy of 4.88 eV in the first excited state
- No energy can be transferred to Hg below 4.88 eV because not enough energy is available to excite an electron to the next energy level

- Above 4.88 eV, the current drops because scattered electrons no longer reach the collector until the accelerating voltage reaches 9.76 eV and so on.

X-Ray Scattering

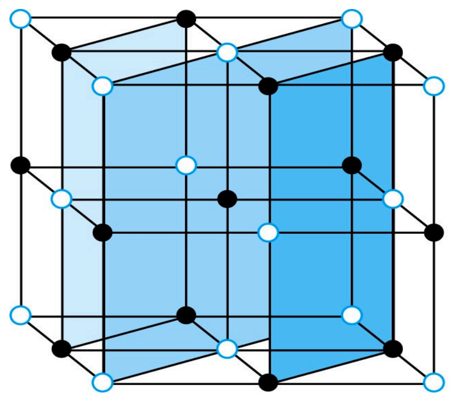
- Max von Laue suggested that if X rays were a form of electromagnetic radiation, interference effects should be observed. (Wave property!!)
- Crystals act as three-dimensional gratings, scattering the waves and producing observable interference effects.

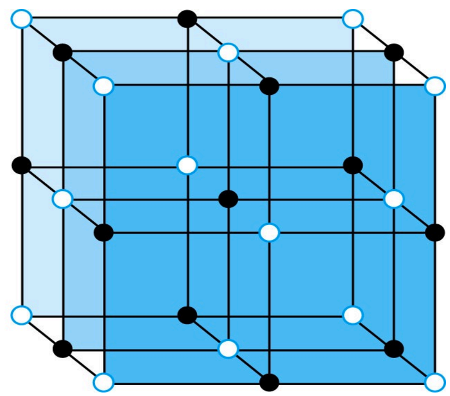


Bragg's Law

- William Lawrence Bragg interpreted the x-ray scattering as the reflection of the incident x-ray beam from a unique set of planes of atoms within the crystal.
- There are two conditions for constructive interference of the scattered x rays:

1) The angle of incidence must equal the angle of reflection of the outgoing wave. (total reflection)
2) The difference in path lengths between two rays must be an integral number of wavelengths.

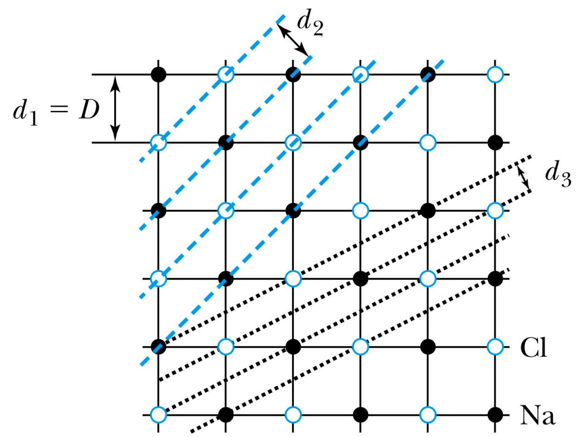


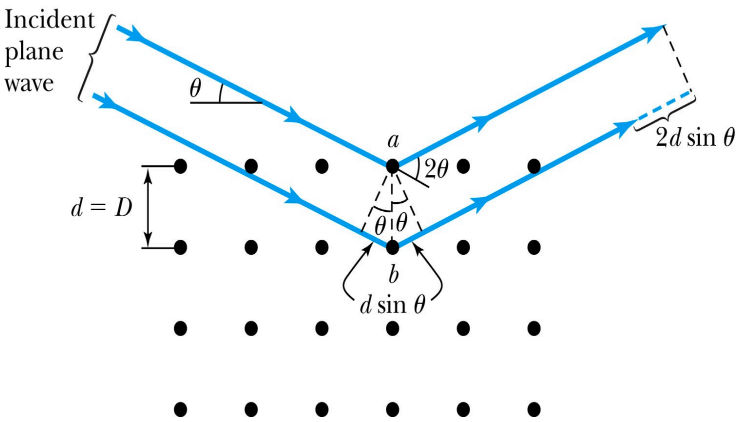


- **Bragg's Law:**

  $n\lambda = 2d \sin\theta$

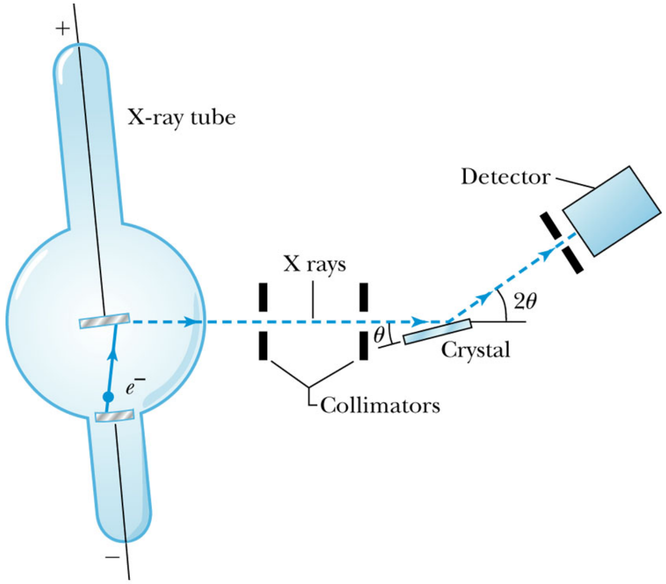
  (n = integer)

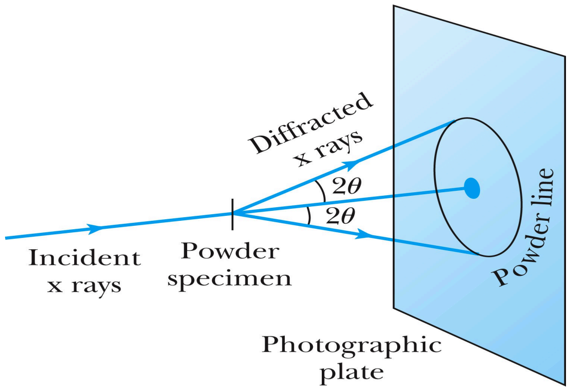




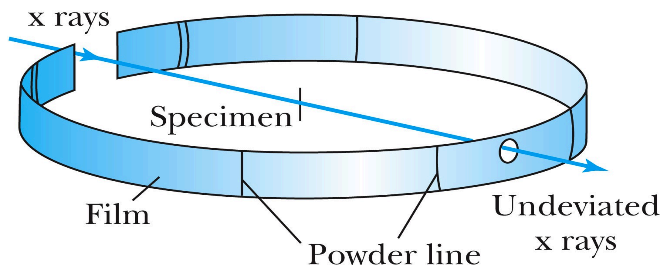
The Bragg Spectrometer

- A Bragg spectrometer scatters x rays from several crystals. The intensity of the diffracted beam is determined as a function of scattering angle by rotating the crystal and the detector.
- When a beam of x rays passes through the powdered crystal, the dots become a series of rings due to random arrangement.





(a)



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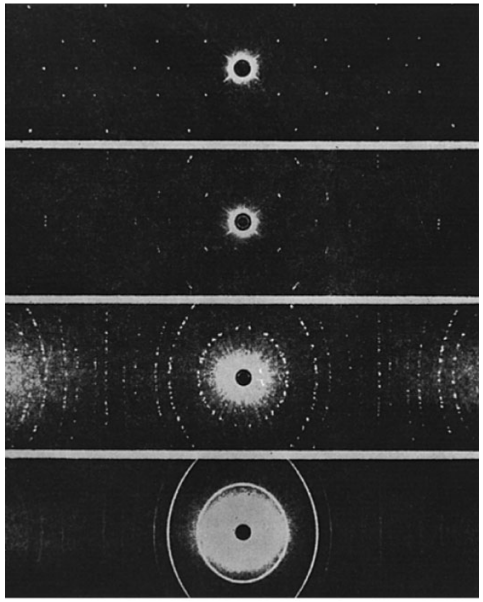

(c)

Ex 5.1: Bragg's Law

X rays scattered from rock salt (NaCl) are observed to have an intense maximum at an angle of 20° from the incident direction. Assuming n=1 (from the intensity), what must be the wavelength of the incident radiation?

- Bragg's law: $n\lambda = 2d \sin\theta$
- *What do we need to know to use this? The lattice spacing d!*
- *We know n=1 and $2\theta=20^o$.*
- *We use the density of NaCl to find out what d is.*

$$\frac{N_{molecules}}{V} = \frac{N_A \rho_{NaCl}}{M} = \frac{\left(6.02\times10^{23}\, molecules/mol\right)\cdot\left(2.16\, g/cm^3\right)}{58.5\, g/mol} =$$

$$= 2.22\times10^{22}\frac{molecules}{cm^3} = 4.45\times10^{22}\frac{atoms}{cm^3} = 4.45\times10^{28}\frac{atoms}{m^3}$$

$$\frac{1}{d^3} = 4.45\times10^{28}\frac{atoms}{m^3} \Rightarrow d = \frac{1}{\sqrt[3]{4.45\times10^{28}}} = 0.282nm$$

$$\lambda = 2d\sin\theta = 2\cdot0.282\cdot\sin10^o = 0.098nm$$

De Broglie Waves

- Prince Louis V. de Broglie suggested that mass particles should have wave properties similar to electromagnetic radiation ➔ many experiments supported this!
- Thus the wavelength of a matter wave is called the de Broglie wavelength:

$$\lambda = \frac{h}{p}$$

- This can be considered as the probing beam length scale
- Since for a photon, $E = pc$ and $E = hf$, the energy can be written as

$$E = hf = pc = p\lambda f$$