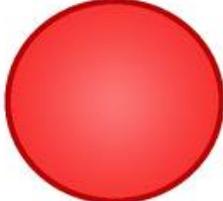


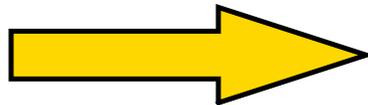
L04 - History of the Atomic Model

Part 1: Dalton to J.J. Thomson (Cathode Ray Tube)



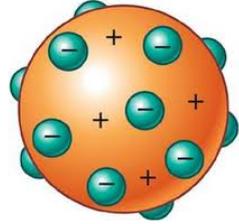
Dalton Model:

- All matter is made of small, indivisible particles called atoms.
- All atoms of an element are identical in size and mass.
- Atoms of different elements have different properties.



Evidence:

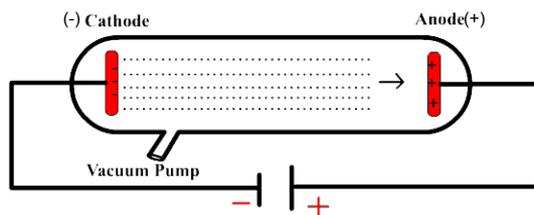
- J.J. Thomson discovered that all elements can produce a beam of negatively charged particles, suggesting that all atoms contained smaller particles that were identical.



J.J. Thomson Model:

- Sphere has a positive charge.
- Embedded in the sphere are negative charges (electrons).

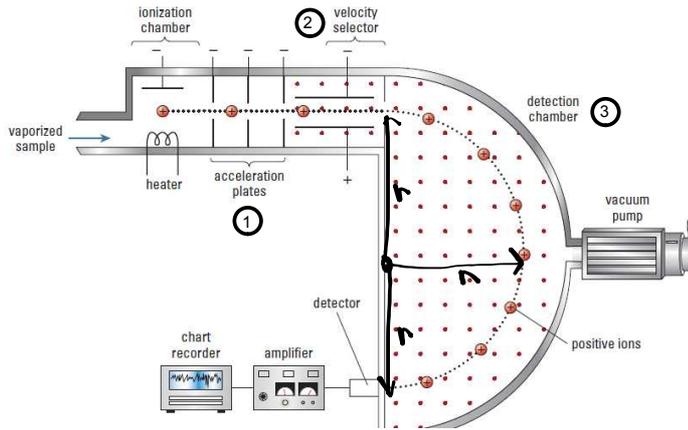
When a high enough voltage is applied to a vacuum tube, small negatively charged particles can be emitted from a Cathode of **any** material.



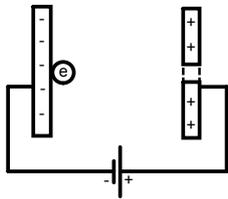
But are the negatively charged particles all the same...?

History of the Atomic Model

Part 1: Dalton to J.J. Thomson (Mass Spectrometer)



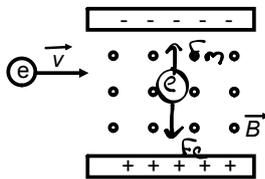
Part 1: Acceleration Plates



$$E_p \rightarrow E_k$$

$$q\Delta V \rightarrow \frac{1}{2}mv^2$$

Part 2: Velocity Selector

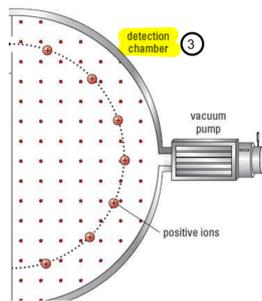


$$F_{up} = F_{down}$$

$$F_m = F_e$$

$$qv|\vec{B}| = q|\vec{E}|$$

Part 3: Detection Chamber



$$F_c = F_m$$

$$\frac{mv^2}{r} = qv|\vec{B}|$$

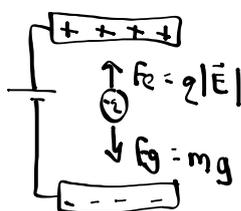
$$\frac{mv}{r} = q|\vec{B}|$$

$$\boxed{\frac{q}{m} = \frac{v}{r|\vec{B}|}}$$



Conclusion: All of these negative charges were identical, with the same charge-mass ratio!

Next: Millikan's *Oil Drop Experiment* showed that charge was quantized, and that the smallest fundamental charge was 1.60×10^{-19} C.



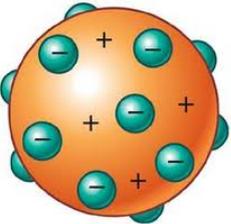
$$F_e = F_g$$

$$q|\vec{E}| = mg$$

$$q \frac{\Delta V}{\Delta d} = mg$$

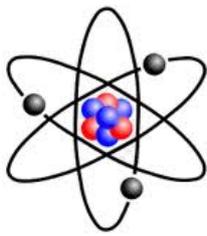
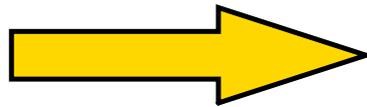
History of the Atomic Model

Part 2: J.J. Thomson to Rutherford (Gold Foil Scattering... or "Rutherford Scattering")



J.J. Thomson Model:

- Sphere has a positive charge.
- Embedded in the sphere are negative charges (electrons).



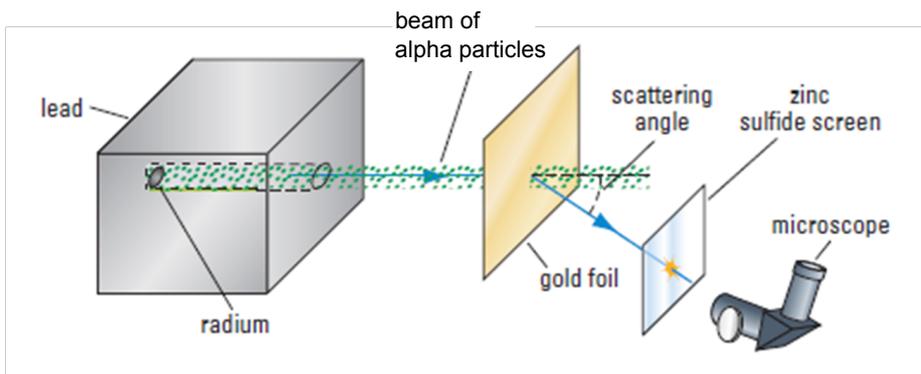
Rutherford Model:

- Small positively charged nucleus (1/10,000 the size on the entire atom).
- Most of the atom is empty space.
- Nucleus orbited by electrons (like a planetary model).

Evidence:

- Rutherford used radioactive substances and aimed the emitted particles at gold foil.
- Most passed through the foil, but 1 in 10,000 were deflected.

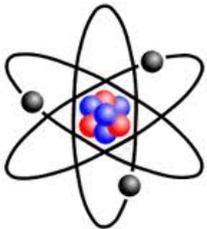
LINK: Colorado PhET: Rutherford Scattering



Conclusion: Small, positively charged nucleus, *orbited* by electrons. Also called the "*Planetary Model*".

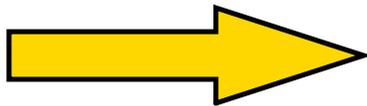
History of the Atomic Model

Part 3: Rutherford to Bohr (Absorption and Emission Spectra)



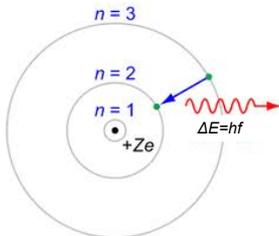
Rutherford Model:

- Small positively charged nucleus (1/10,000 the size on the entire atom).
- Most of the atom is empty space.
- Nucleus orbited by electrons (like a planetary model).



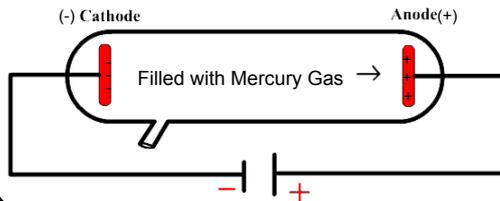
Evidence:

- Neils Bohr discovered that hydrogen atoms made to glow in a tube emitted very distinct colors of light.

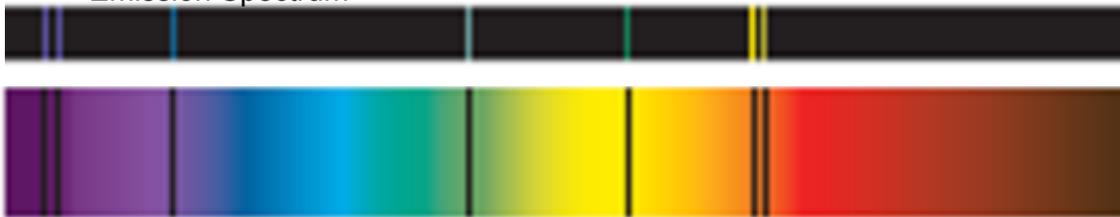


Bohr Model:

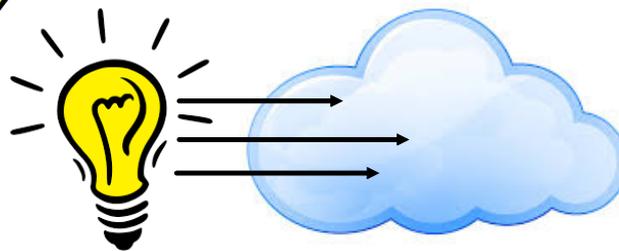
- Electrons exist in certain energy levels.
- When an electron passed to a lower energy level, they emit the energy as light (where different colors of light correspond to different energies).



Emission Spectrum

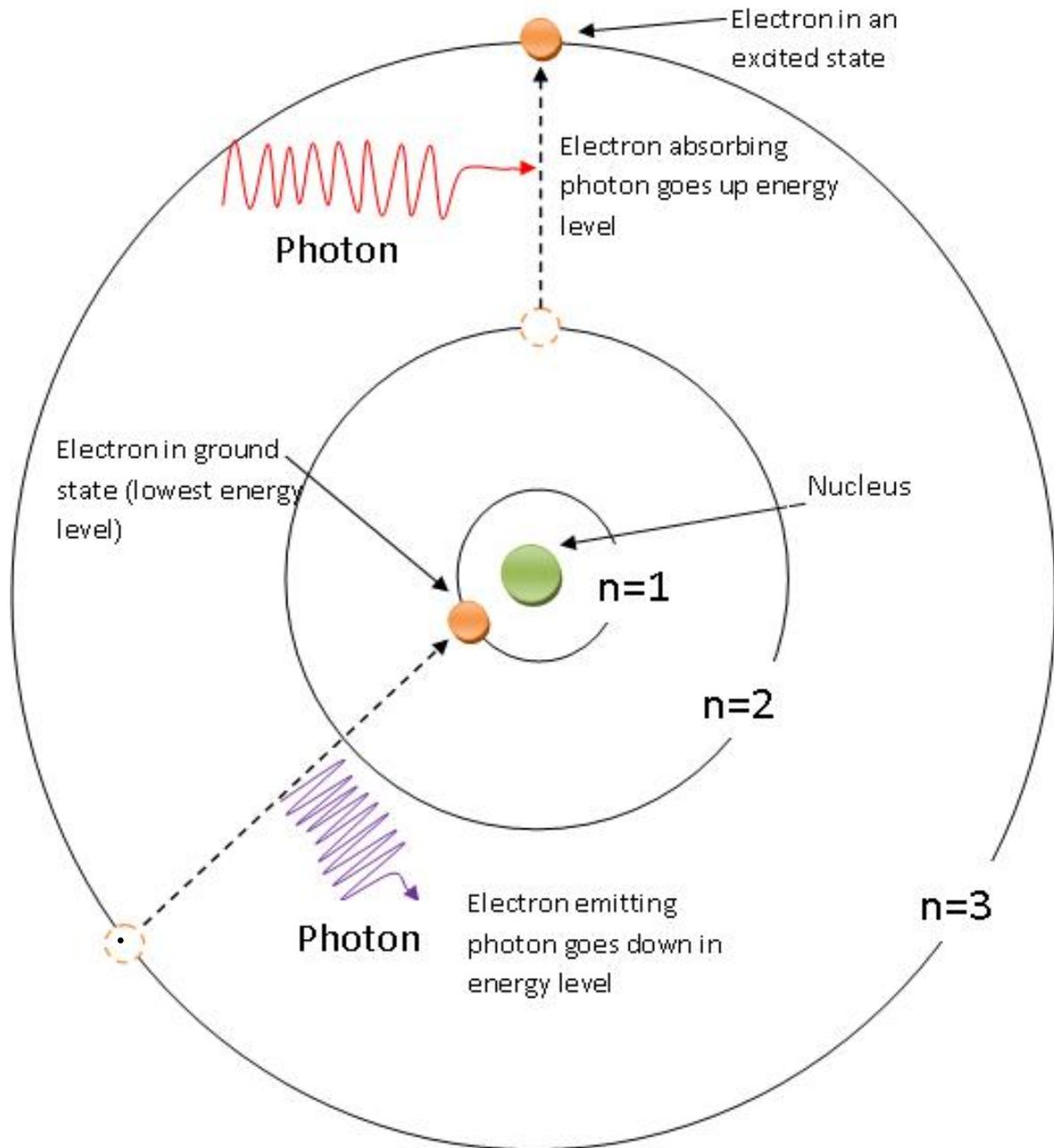


Absorption Spectrum



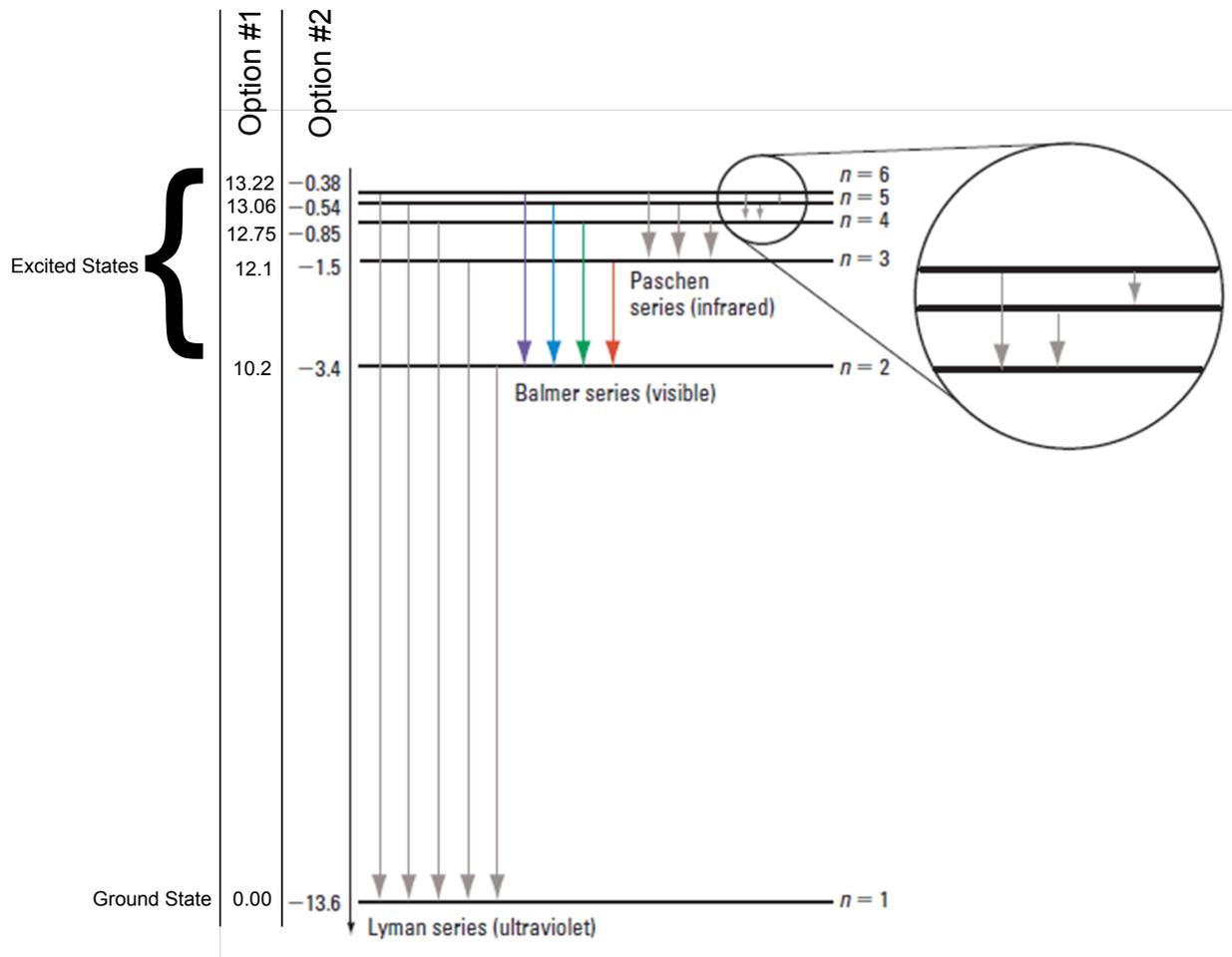
History of the Atomic Model

Part 3: Rutherford to Bohr (Discrete Energy Levels)



History of the Atomic Model

Part 3: Rutherford to Bohr (Sign Convention; *Hydrogen used as an example*)

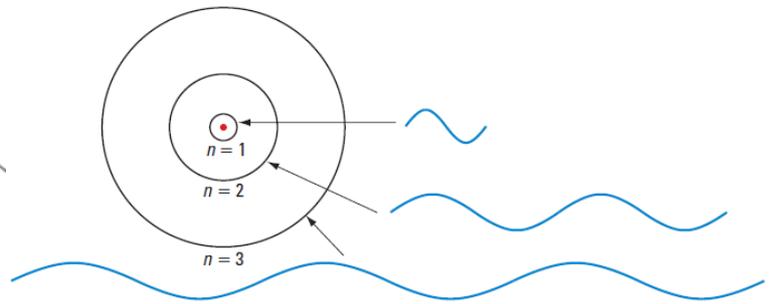
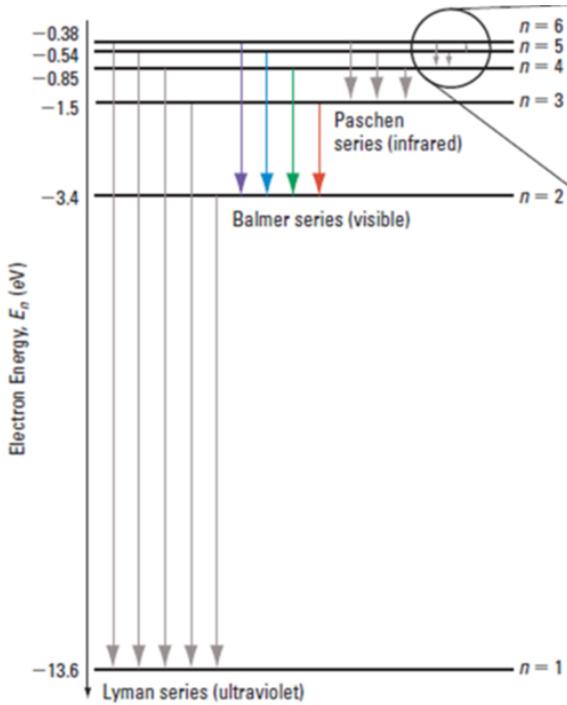


How much energy does it take to ionize a Hydrogen Atom?

• **13.6eV**

L04 - Quantum Mechanics

Question: Why can electrons only have certain energy orbits?



Answer: Electrons have *wave-particle* duality. They behave like a wave.



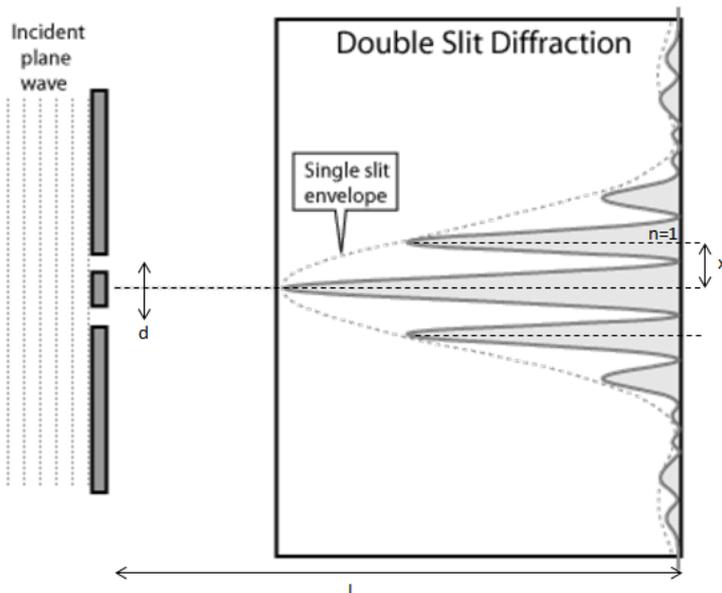
de Broglie's Explanation: If light has a wave and particle nature, maybe matter has both a wave and particle nature.

Electron

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

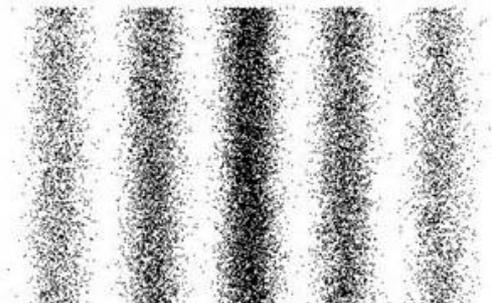
$$p = mv \quad \text{and} \quad p = \frac{h}{\lambda}$$

How could we test it? Double-slit experiment. Matter should interfere if it is a wave.



$$\lambda = \frac{d \sin \theta}{n}$$

$$\lambda = \frac{xd}{nl}$$



Q1: Calculate the wavelength of an electron moving at 1.00×10^4 m/s.

Note: Classically we believed that the radius of an electron was $\sim 2.82 \times 10^{-15}$ m.

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

$$p = mv \quad \text{and} \quad p = \frac{h}{\lambda}$$

$$\boxed{mv = \frac{h}{\lambda}}$$

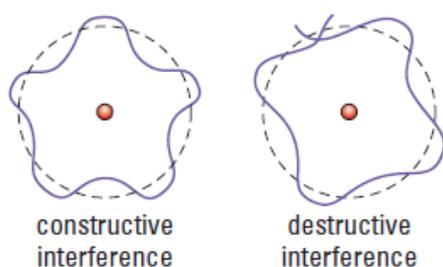
100% of time.

$$(9.11 \times 10^{-31})(1.00 \times 10^4) = \frac{(6.63 \times 10^{-34})}{\lambda}$$

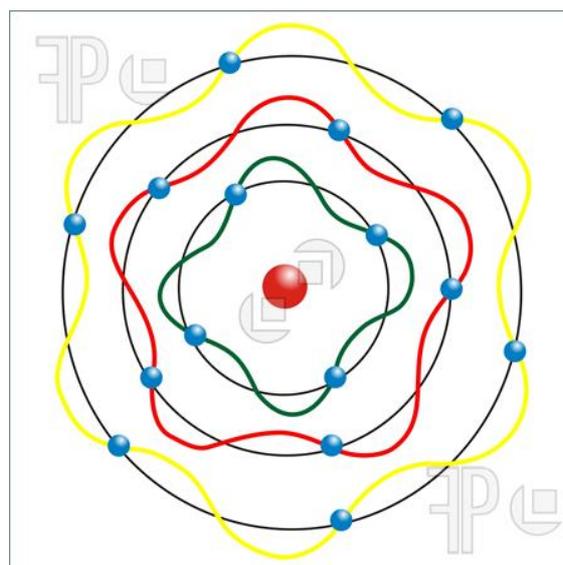
$$\boxed{\lambda = 7.28 \times 10^{-8} \text{ m}}$$

I could then $\lambda = \frac{d \sin \theta}{n}$ for double-slit diffraction.

So why do electrons have specific energies in Bohr's Model?

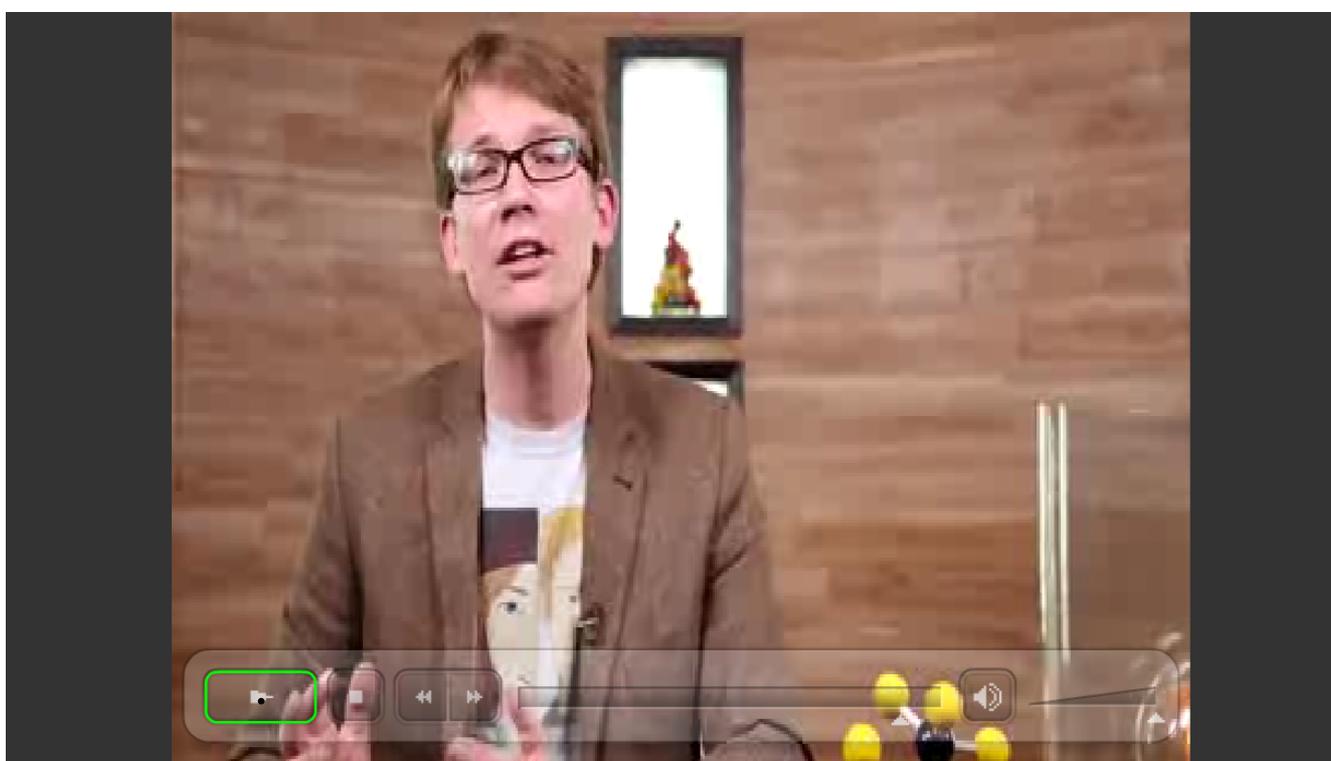


▲ **Figure 15.24** A standing wave is possible only if a whole number of electron wavelengths fit exactly along the circumference of an orbit.



Some physicists, including Einstein and Schrödinger, had difficulty accepting a quantum model that could predict only probabilities rather than clearly defined locations for electrons in an atom. As Niels Bohr noted, “Anyone who is not shocked by quantum theory has not understood a single word.” Despite its challenging concepts, quantum theory is the most comprehensive and accurate model of atoms and molecules yet developed.

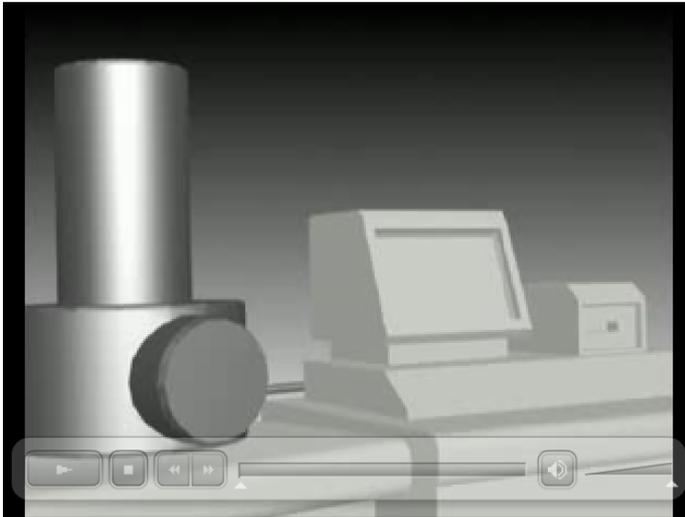
Probabilistic Location of Electron - Electron Clouds



Scanning Electron Microscope

A scanning electron microscope (SEM) is a type of electron microscope that images a sample by scanning it with a high-energy beam of electrons in a raster scan pattern.

Note: There is no sound for this video.



1. An electron beam is emitted from a tungsten filament cathode and accelerated.

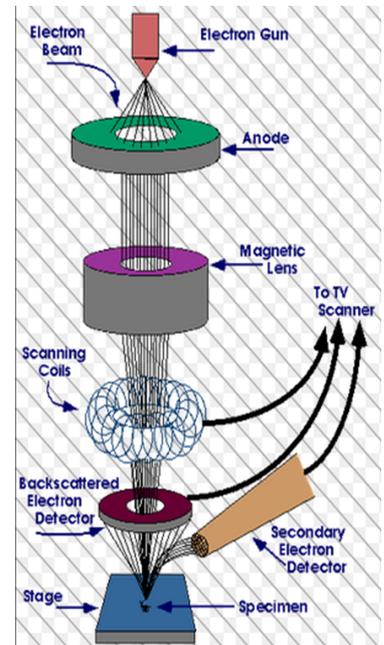
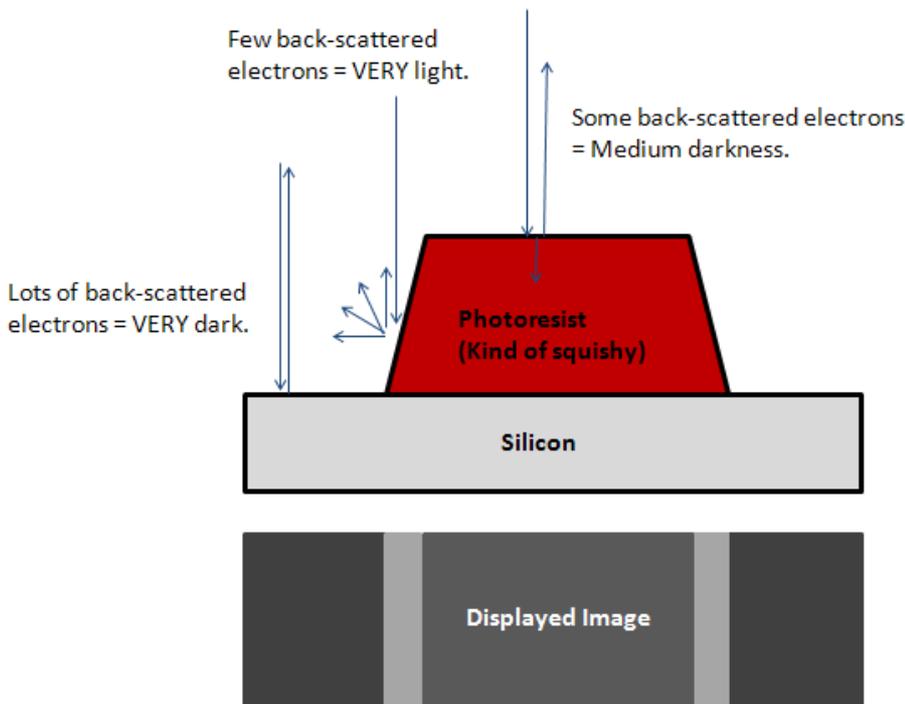
2. The electron beam is focused by the magnetic field of a series of condenser "lenses" (actually loops of wire with a current passed through them) to a spot about 2nm in diameter.

3. Some of the electrons, known as "back-scattered electrons", will bounce off the sample and reflect back to a detector.

If lots of back-scattered electrons are detected, the displayed image is dark.

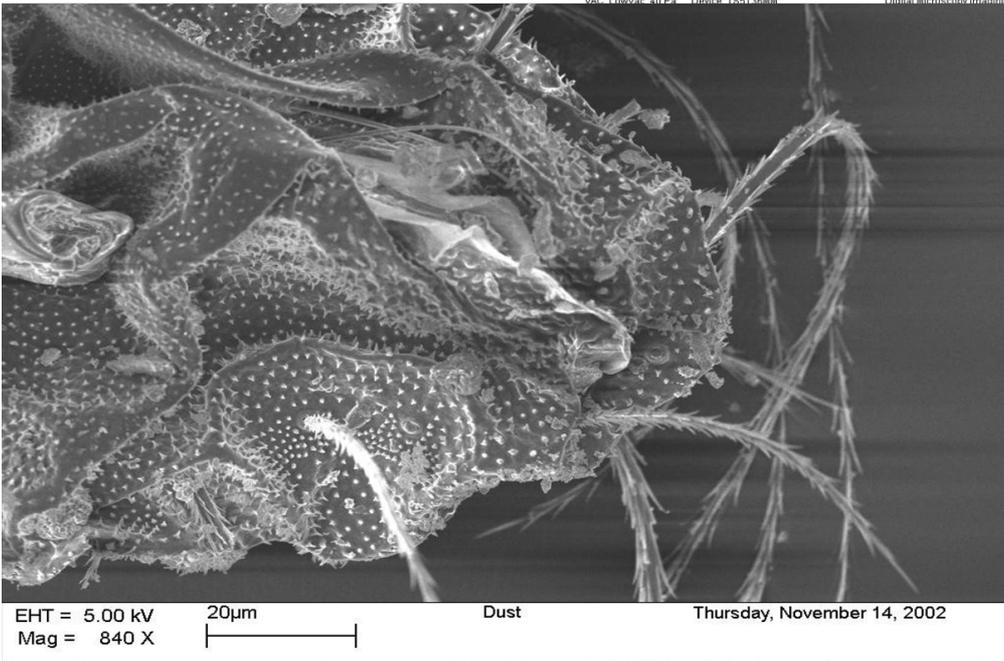
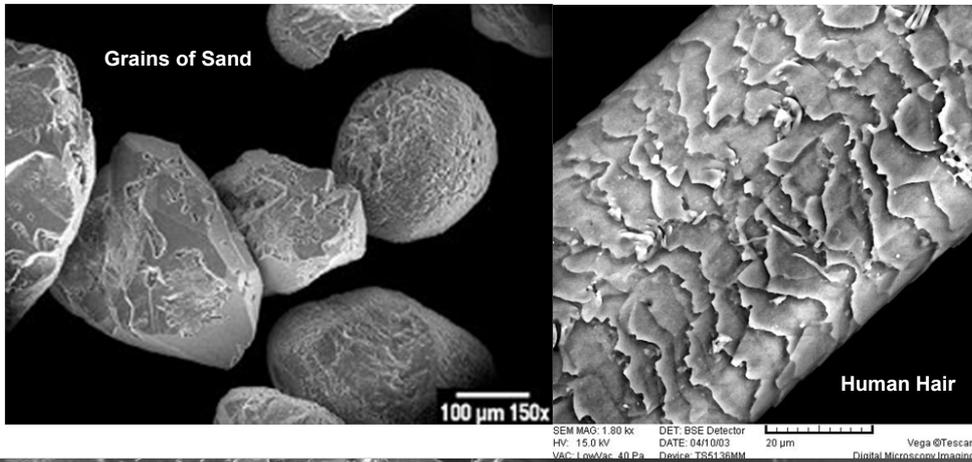
If few back-scattered electrons are detected, the displayed image is light.

What Does the Image Look Like?



That's Boring! Any better pictures?

Check out the next slide.



[Ah. Still bored. What else do you have?..](#)

Get ready for the best picture you've ever see.

