These are pages 12 - 15. It covers several experiments of historical nature. You don’t need to know the names/details of experiments but do need to understand the results/significance.

It’s mostly reading today.

EMAIL ME if you have questions.

Experimental Evidence of Matter Waves

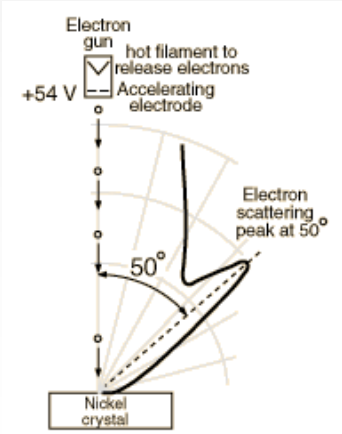
Clint Davisson (1881-1958)
Lester Germer (1896-1971)

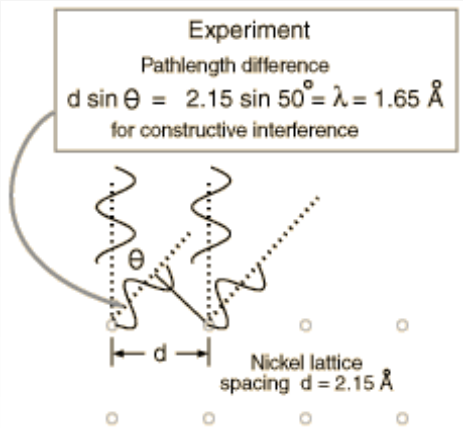
Clinton Joseph Davisson (22 October 1881 – 1 February 1958), was an American physicist. In 1927 while working for Bell Labs he confirmed the De Broglie hypothesis that that all matter has a wave-like nature through the discovery of electron diffraction. He shared the Nobel Prize in Physics in 1937 with George Paget Thomson for the discovery of electron diffraction.

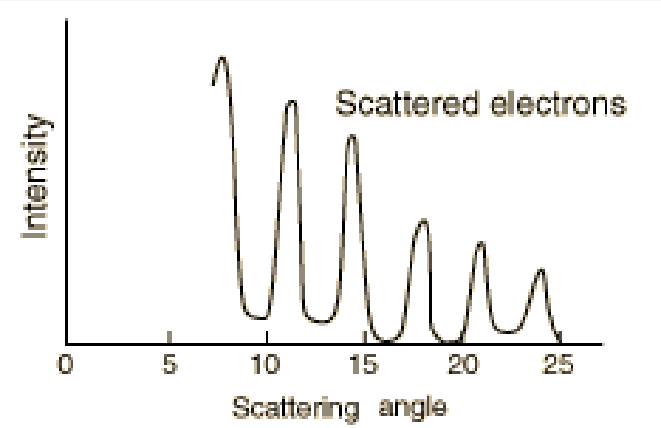
Trying to prove that electrons would diffract and interfere, showing they have wave properties.

Experimental Evidence of Matter Waves

- **Experiment:** Davisson-Germer experiment (electron diffraction)
- **Method:** directed beam of electrons onto a crystal of nickel and measured number of electrons scattered at various angles



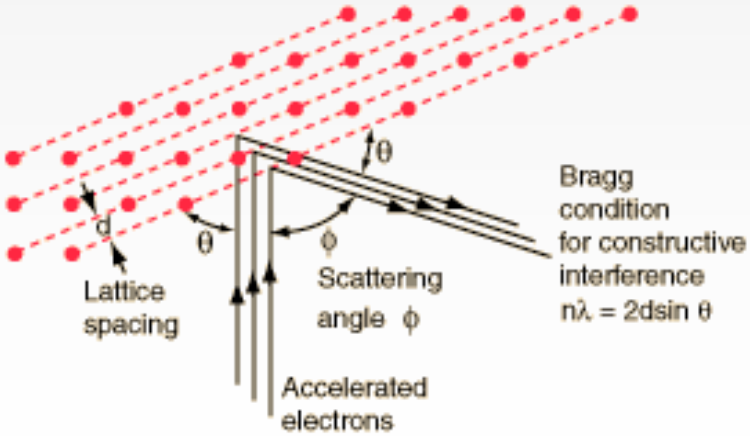




It worked! Electrons are also wavicles. (both wave and particle properties)

Experimental Evidence of Matter Waves

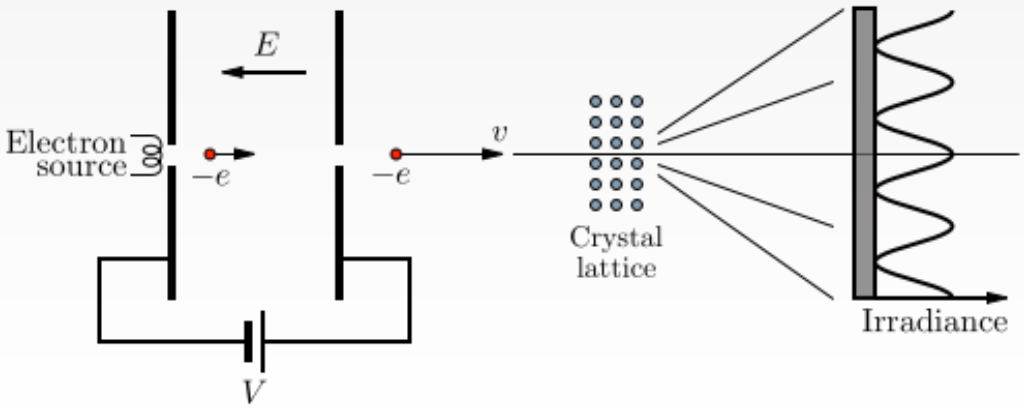
- **Results:** electrons in scattered beam are only detected at certain angles by the collector
- **Conclusion:** electrons are scattered from two layers of atoms and interfere with each other as waves do

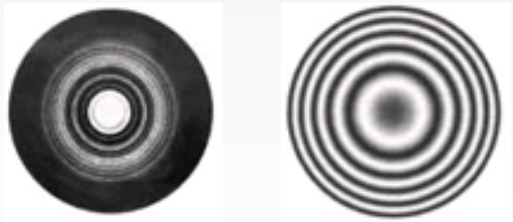


Another experiment for the same purpose.

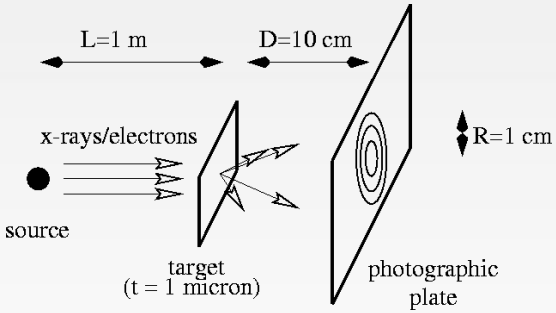
Experimental Evidence of Matter Waves

- **Experiment:** Electron Diffraction
- **Method:** A beam of electrons is sent at a target and results are observed on a fluorescent screen.





Experimental Evidence of Matter Waves

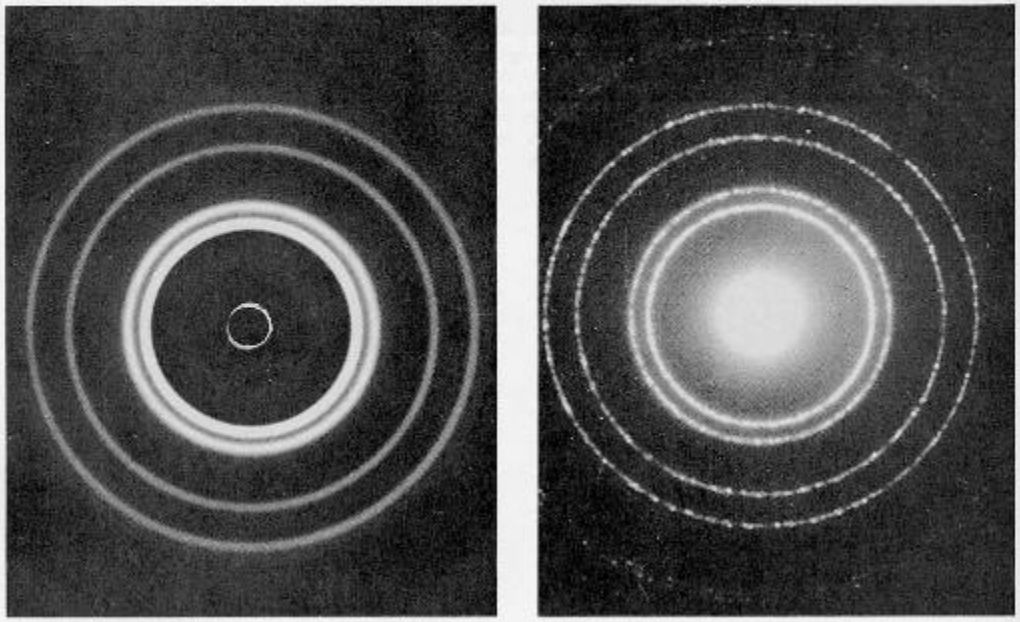


Thomson Experiment (1925-1927)

X-ray diffraction on the left, electron diffract on right, almost the same pattern.

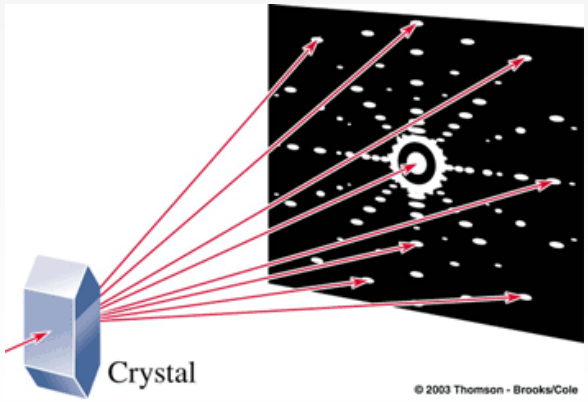
Matter Waves

The diffraction pattern on the left was made by a beam of x rays passing through thin aluminum foil. The diffraction pattern on the right was made by a beam of electrons passing through the same foil.



Experimental Evidence of Matter Waves

- **Results:** A pattern of bright and dark fringes is observed
- **Conclusion:** electrons are acting as waves in that they are diffracting and interfering.



You do need to know which are wave and which are particle behaviors/proof of each

Wave-Particle Duality

	Wave Nature	Particle Nature
Light	Diffraction Interference Doppler Effect	Photoelectric Effect Compton scattering
Matter	Electron Diffraction Matter Waves	Collisions (e.g. Alpha particle scattering)

Compare the energy of photons and particles.

Photon Energy

Particle Energy

Photon Energy	Particle Energy
$E = hf = pc$	$E = mc^2$ (rest mass and rest energy)
	$K = \frac{1}{2}mv^2$

Kinetic Energy and Wavelength

$K = \frac{1}{2}mv^2$ p=mv v=p/m $K=\frac{1}{2}m(p/m)^2$ $K=\frac{1}{2}\frac{p^2}{m}$

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

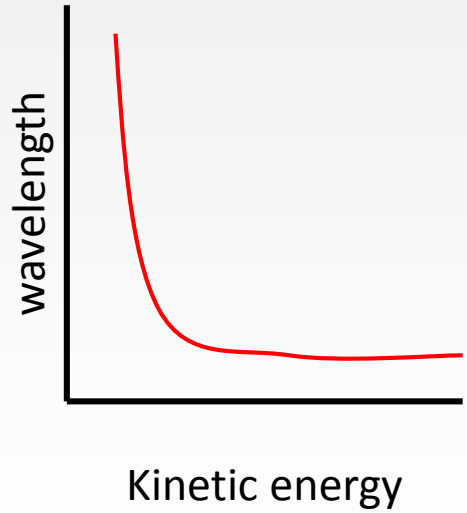
$$p = \sqrt{2mK}$$

$$K = \frac{h^2}{2m/^2}$$

$K\ a\ \frac{1}{/^2}$ and $/ = \frac{1}{\sqrt{K}}$

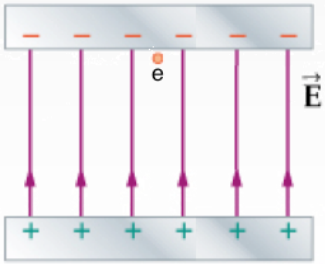
$$/ = \frac{h}{p} = \frac{h}{mv}$$

if K - , then v - , p - , / ¯



An electron is accelerated through a potential difference of 1.00 kV. What is its resulting de Broglie wavelength?

Warning – electrostatics is back, think about the energy gained by accelerating through a potential difference.



An electron is accelerated through a potential difference of 1.00 kV. What is its resulting de Broglie wavelength?

$$E_o = E_f$$

$$Ue = K$$

$$qV = \frac{1}{2} mv^2$$

$$v = \sqrt{\frac{2qV}{m}} = \sqrt{\frac{2(1.60 \times 10^{-19}\ C)(1.00 \times 10^{3}\ V)}{9.11 \times 10^{-31}\ kg}} = 1.87 \times 10^{7}\ m/s$$

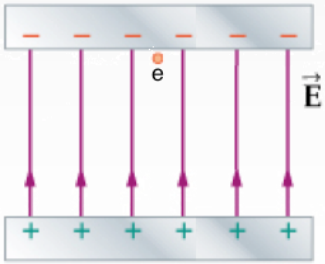
$$/ = \frac{h}{mv} = \frac{6.63 \times 10^{-34}\ Js}{(9.11 \times 10\text{-}31\ kg)(1.87 \times 10^{7}\ m/s)} = 3.9 \times 10^{-11}\ m$$

OR

$$E_o = E_f$$

$$U_e = K$$

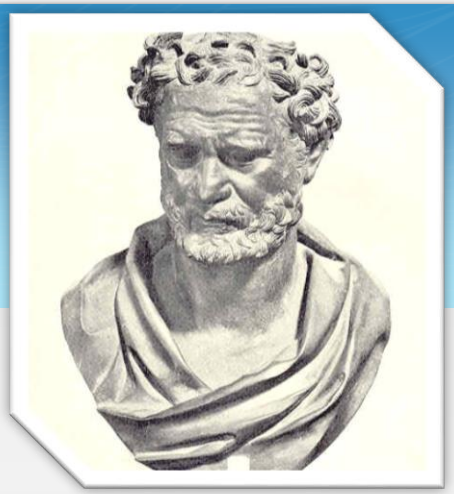
$$qV = \frac{h^2}{2m\lambda^2}$$



Atomic Structure

You don’t have to memorize the early models of the atom. They show us how science is refined over time.

Atomic Structure

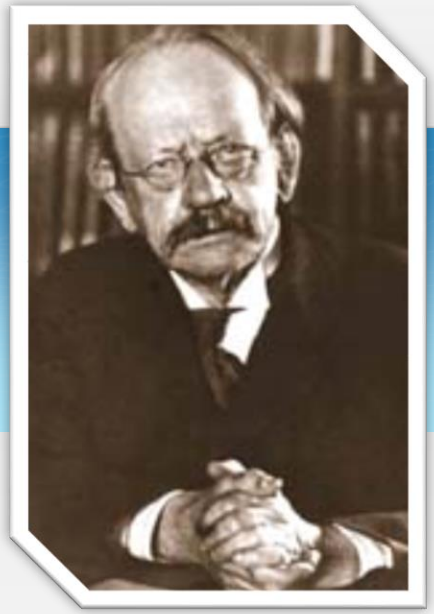


Democritus

Proposed that if matter was cut in ½ and then cut is ½ continuously, one would eventually reach indestructible or “atomos” matter.

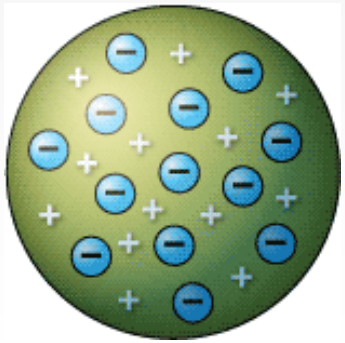
Atomic Structure

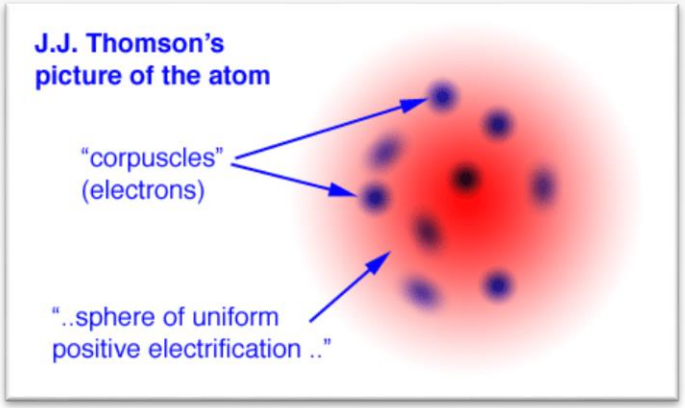
Discovered light negative particles which he called electrons



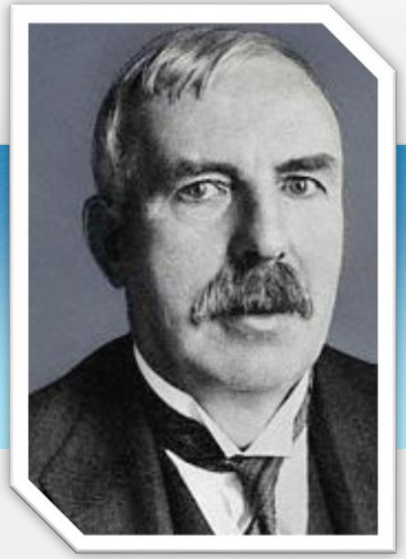
Thomson

- Proposed that atoms consist of a uniform distribution of positive and negative charges.





Atomic Structure

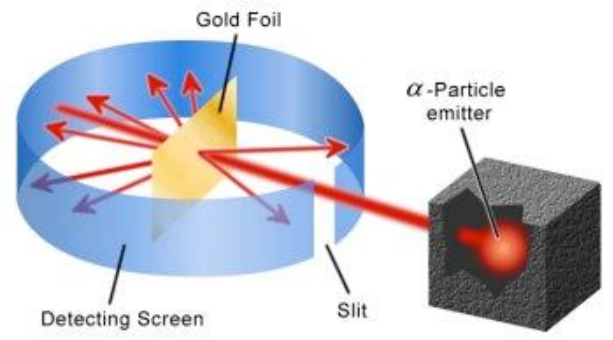


Rutherford

- **Nuclear Model of the Atom (Rutherford Model – Planetary Model):** Simple model in which electrons are kept in orbit around the nucleus as a result of the electrostatic attraction between the electrons and the nucleus.

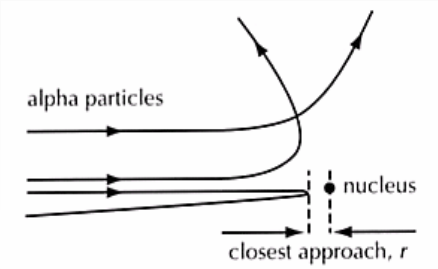
Evidence for Nuclear Model

- **Experiment:** Rutherford experiment (alpha scattering experiment) in 1909
- **Method:** Alpha particles from radioactive source are directed at thin gold foil. Scattered alpha particles are detected by a glow on a fluorescent screen.

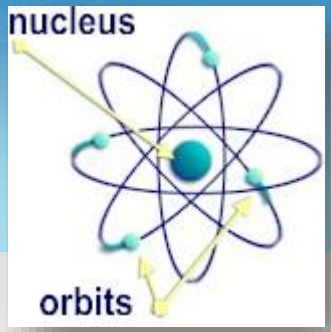


Evidence for Nuclear Model

- **Results:**
- Most particles went straight through or were deflected at small angles.
- A few were deflected at very large scattering angles.



Evidence for Nuclear Model



- **Conclusions:**
- Most of the atom is empty space since most particles go straight through.
- All positive charge and most of the mass are concentrated in a very small space called the nucleus.

Limitations of Nuclear Model

- **Limitation of the nuclear model of the atom**: According to classical physics, an orbiting electron is accelerating, and accelerating bodies radiate energy. This would mean that electrons would radiate energy as they orbit the nucleus. This contradicts observations for two reasons:

- Electrons would lose energy and spiral into the nucleus. This would destroy all matter.

- Electrons would radiate energy as light in a continuous spectrum of colors. This contradicts experimental observation since the emission spectra of atoms are observed to consist of only well-defined discrete wavelengths.

Evidence for Nuclear Model

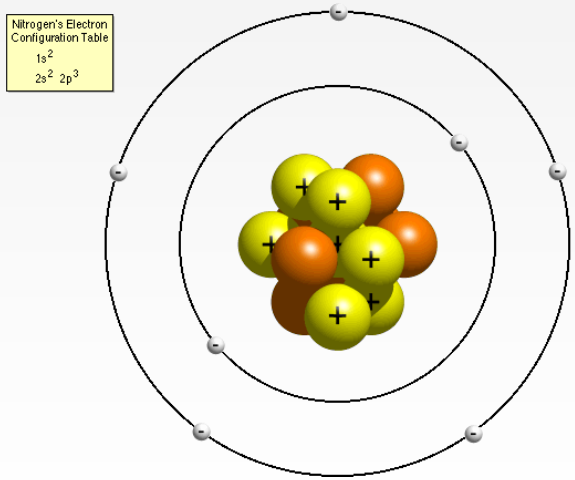
- **Conclusion**: Observations of atomic emission and absorption spectra indicate that:

- electrons do not radiate energy when in stable orbits. Stable orbits only occur at certain radial distance from the nucleus. Thus, electrons in these orbits have a well-defined discrete amount of energy.

- electrons only radiate or absorb energy only when they move (transition) between stable orbits. This energy is quantized and fixed by the energy differences between the allowed orbital levels.

Atomic Structure

- **Importance**: Atomic emission and absorption spectra provide evidence for the existence of atomic energy levels.

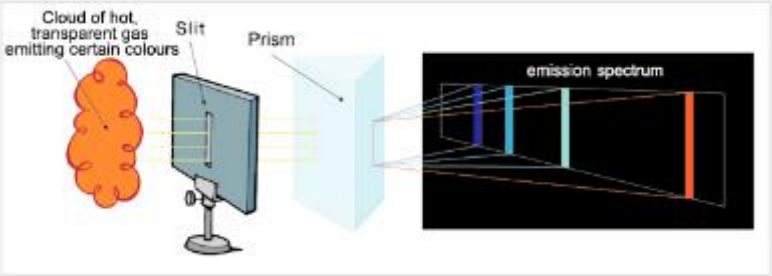


Niels Bohr

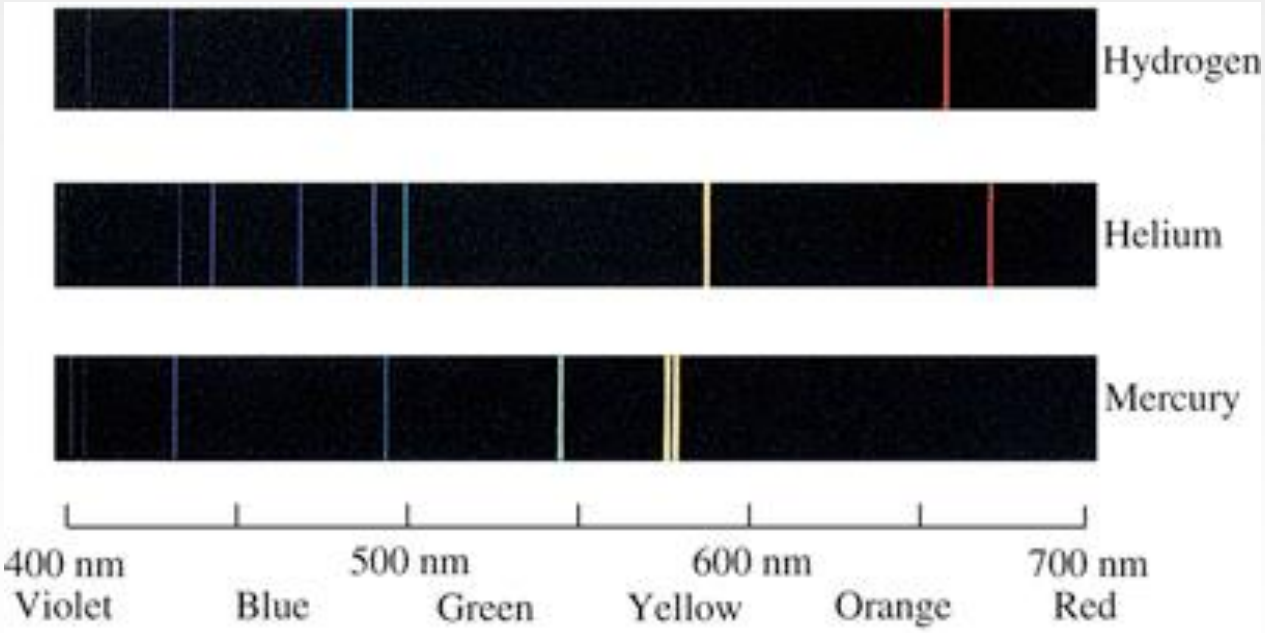
Remember the glowing gas tubes from last year? Those are the experiment to prove that atoms have discrete energy levels.

Production of Emission Spectra

- Low pressure gas is energized by applying a potential difference across it causing it to heat up.
- The hot gas emits light energy only at certain well-defined frequencies, as seen through a diffraction grating or prism.

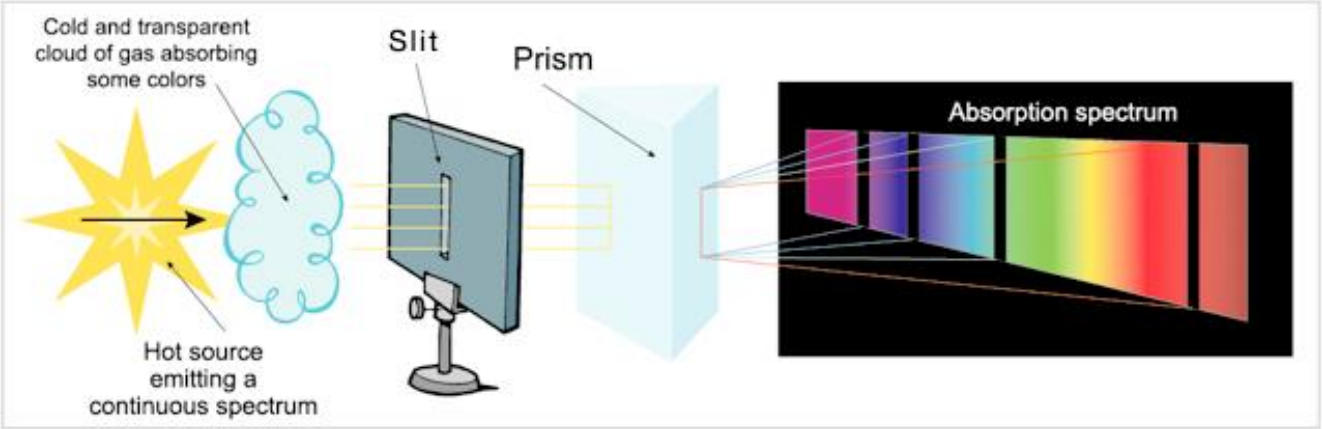


Emission Spectra



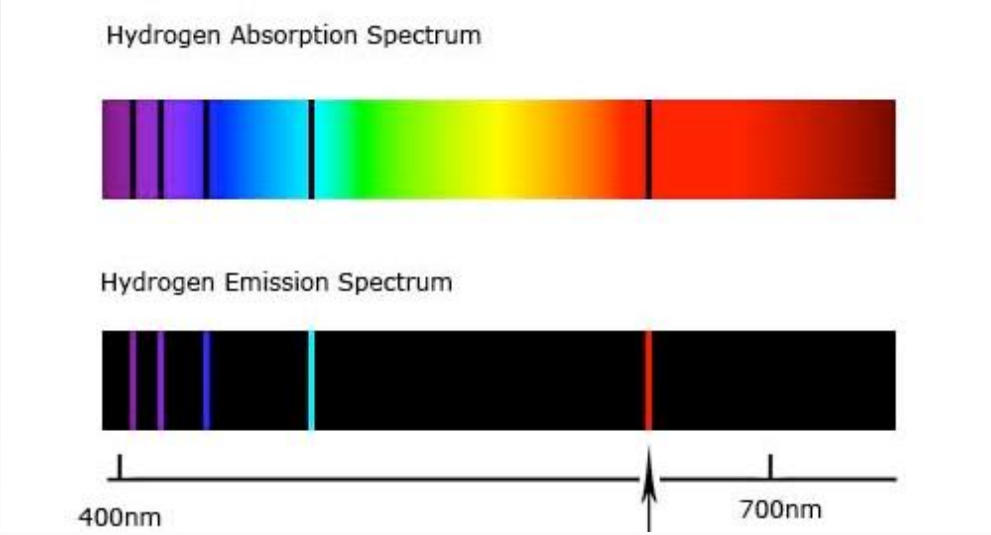
Production of Absorption Spectrum

- Light is shone through a cool low pressure gas.
- A diffraction grating or prism is used to determine what frequencies pass through the gas and which are absorbed.

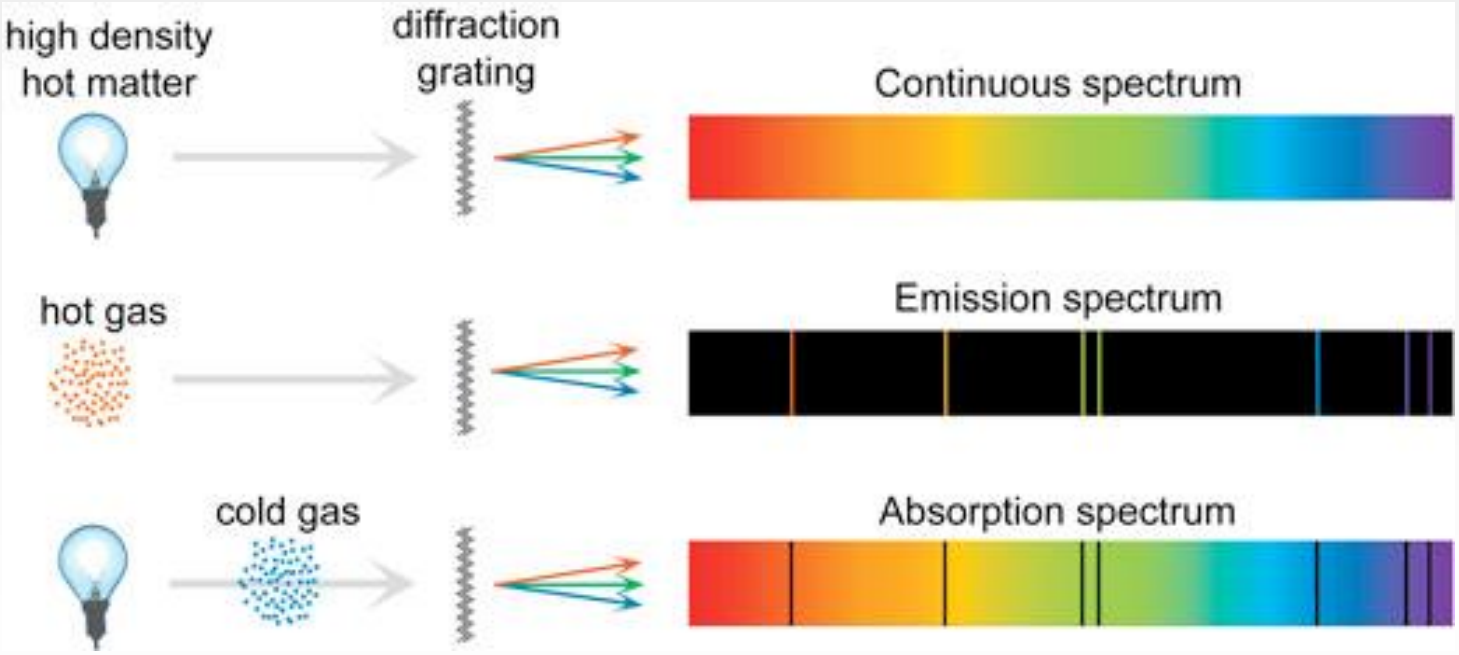


Absorption Spectra

- The **spectral lines** produced (emission or absorption) are characteristic of the particular element producing them.
- Note that emission and absorption spectral lines occur at the same locations for the same element.



Emission & Absorption Spectra



How do atomic spectra provide evidence for the quantization of energy in atoms?

- Electrons do not radiate energy when in stable orbits. Stable orbits only occur at certain radial distance from the nucleus. Thus, electrons in these orbits have a well-defined discrete amount of energy.
- Electrons only radiate or absorb energy only when they move (transition) between stable orbits. This energy is quantized and fixed by the energy differences between the allowed orbital levels.

We can see the colors for those going to n = 2, the balmer series. The other series are in UV and IR territory.