Physics for Pedestrians

Young India Fellowship [Term 1]

Philip Cherian

6th August, 2019

Ashoka University

Quiz 3!

Link:

tiny.cc/phquiz3

OR

https://drive.google.com/open?id=1M7loYozcPDVCSJpeQ3RST9H045ubFkUEuJYRSxgX4QU

Accelerated charges emit electromagnetic radiation (Light)

Planck Spectrum

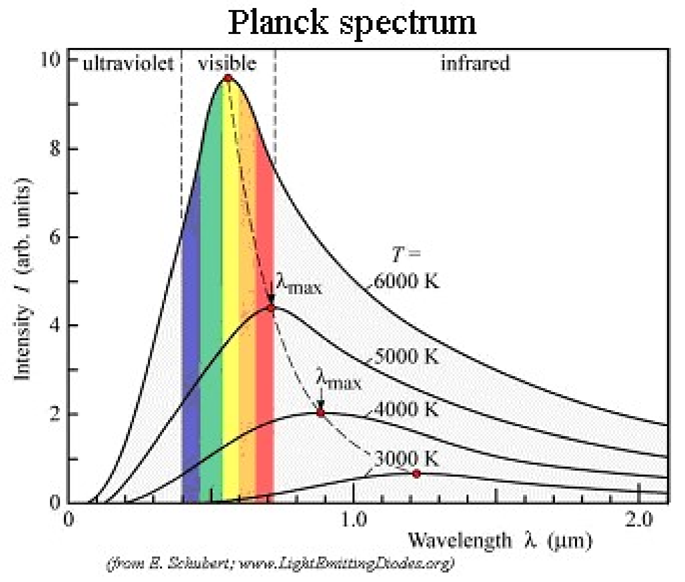

Figure 1: The Planck Spectrum for different temperatures.

Rutherford's Experiment

It was quite the most incredible event that has ever happened to me in my life. It was almost as incredible as if you fired a 15-inch shell at a piece of tissue paper and it came back and hit you.

– Rutherford

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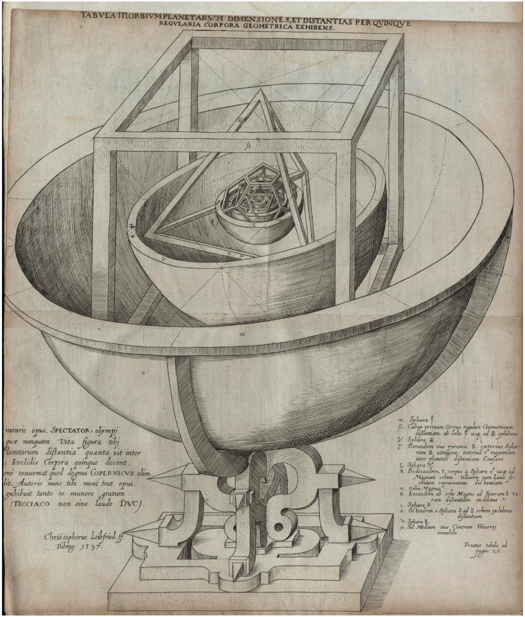
Kepler's Mysterium Cosmographicum



Two great revolutions in Physics

The Solar System

$$F_g = \frac{GMM_{\text{sun}}}{r^2} = \frac{D}{r^2}$$

$$D = GMM_{\text{sun}}$$

Orbits:

$$r = \frac{L^2/DM}{1 + \cancel{\epsilon\cos\theta}} = \frac{L^2}{DM}$$

Energy: Kinetic + Potential
(for circular orbits)

$$E = \frac{1}{2}mv^2 - \frac{D}{r}$$

The Atom

$$F_e = \frac{K_e q_1 q_2}{r^2} = \frac{D}{r^2}$$

$$D = K_e q_1 q_2$$

Atoms are “spherical”, so orbits

$$r = \frac{L^2}{DM}$$

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(for circular orbits)

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But...

Accelerated charges emit electromagnetic radiation (Light)!

So they lose energy.

$$E \downarrow \implies$$

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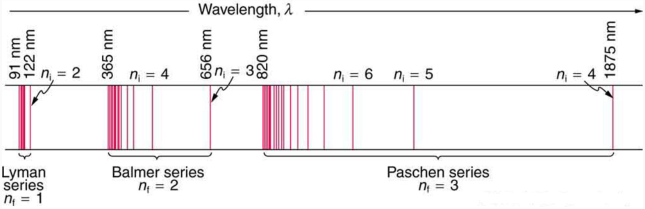
So they lose energy.

$$E \downarrow \implies -\frac{1}{r} \downarrow \implies \frac{1}{r} \uparrow \implies r \downarrow$$

The electron should fall into the atom, radiating a continuous spectrum of light. $\implies$ Classical atoms are not stable

As if that wasn't bad enough...



Atoms did not only radiate a continuous spectrum. Spectral lines, described empirically by Balmer and later Rydberg:

$$\frac{1}{\lambda} = R\left(\frac{1}{n^2} - \frac{1}{m^2}\right) \quad \text{(Dimensions of R?)}$$

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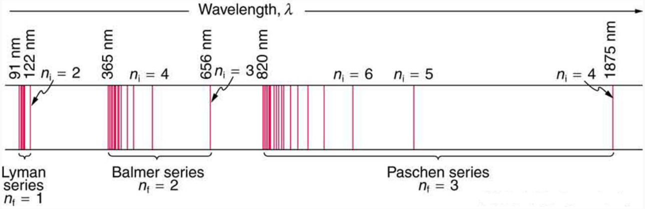

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$$R = 1.097 \times 10^7 \mathrm{m}^{-1} \text{(Rydberg constant)}$$

But why?

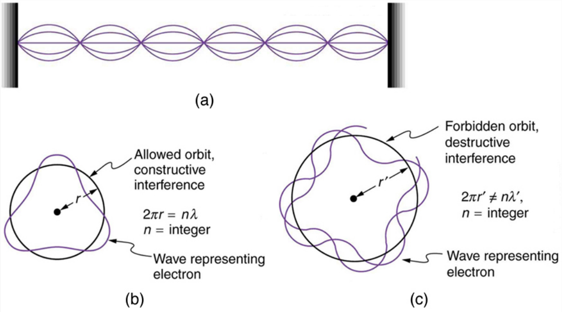
German Physicist Neils Bohr's Radical ideas:

1. **Maybe** there were some special orbits where atoms did not radiate! (Went against Newton's Physics)
2. Maybe the atoms absorbed and emitted discrete amounts of light energy jumping between these orbits. (Went against Maxwell's Electromagnetism)

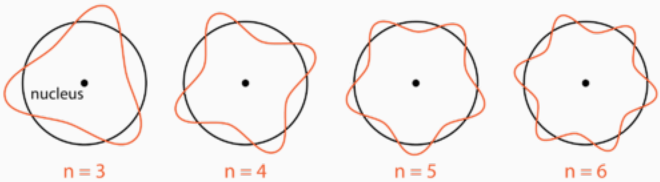
Light behaves like "particles", what about electrons?

Louis De Broglie proposed a hypothesis: if light (which acts so much like a wave) could behave like particles, perhaps other objects that we thought of as particles could behave like waves?

$$\text{(De Broglie Wavelength) } \lambda = \frac{h}{mv}$$

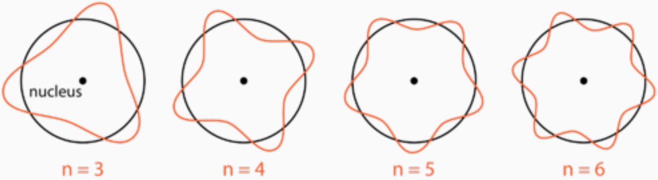


Angular momentum comes in lumps



$$2\pi r = n\lambda$$

Angular momentum comes in lumps



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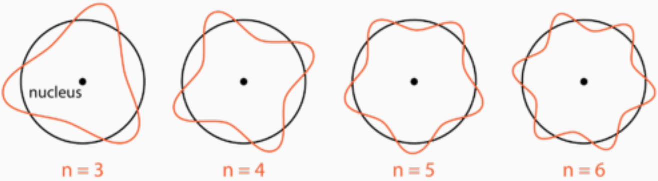


$$2\pi r = n\lambda$$

$$2\pi r = n\left(\frac{h}{mv}\right)$$

Angular momentum! $L = mvr = n\left(\frac{h}{2\pi}\right) = n\hbar$

Angular momentum comes in lumps of $\hbar$, $L = n\hbar$.

Solving the atom

From earlier, we know:

$$r = \frac{L^2}{DM}$$
$$r_n = \frac{n^2\hbar^2}{DM}$$

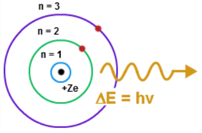
For $n = 1$, we'd find the "natural" unit of size of an atom's orbit, r_1:

$$r_1 = \frac{\hbar^2}{DM} \approx 0.5 \times 10^{-10} \text{ (0.5 Å)}$$

Discrete spectra?

From earlier, we know:

$$E_n = -\frac{D}{2r_n} = \frac{D^2 M}{2n^2\hbar^2}$$



But Einstein told us that light energy comes in packets of hf. Thus, if an electron jumps from some E_n to some E_m, the photon produced is

$$hf = h\frac{c}{\lambda} = E_n - E_m = \frac{MD^2}{2\hbar^2}\left(\frac{1}{m^2} - \frac{1}{n^2}\right)$$

$$\frac{1}{\lambda} = \frac{MD^2}{2hc\hbar^2}\left(\frac{1}{m^2} - \frac{1}{n^2}\right) \implies \boxed{R = \frac{MD^2}{2hc\hbar^2}}$$

BREAK!

(and Attendance)