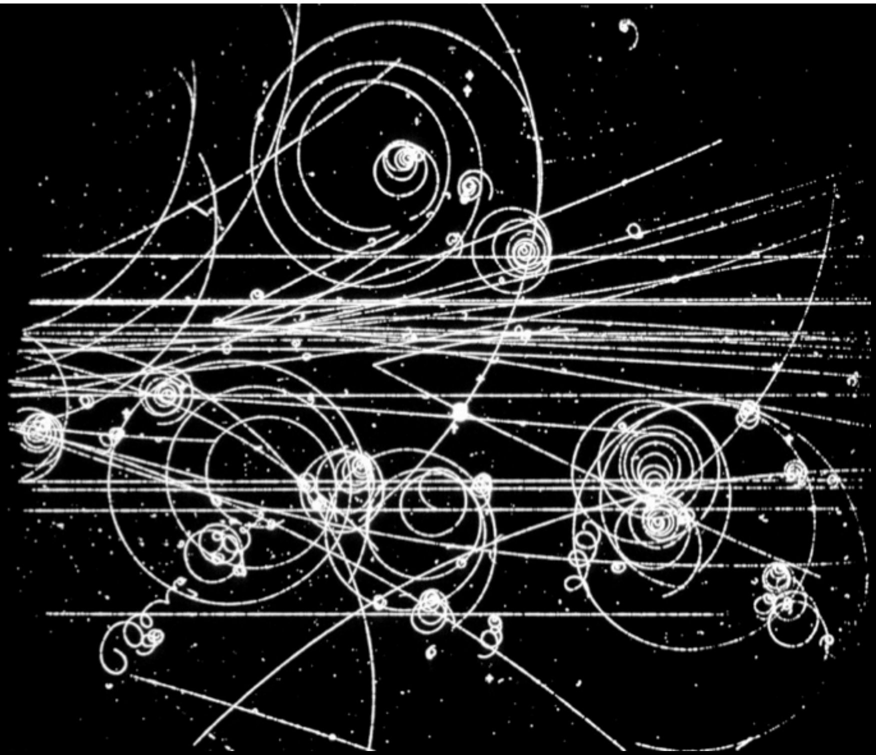
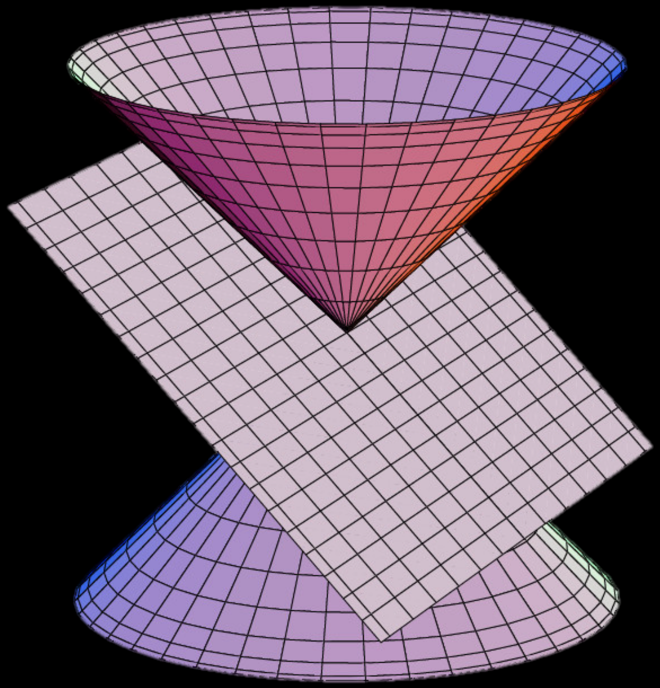
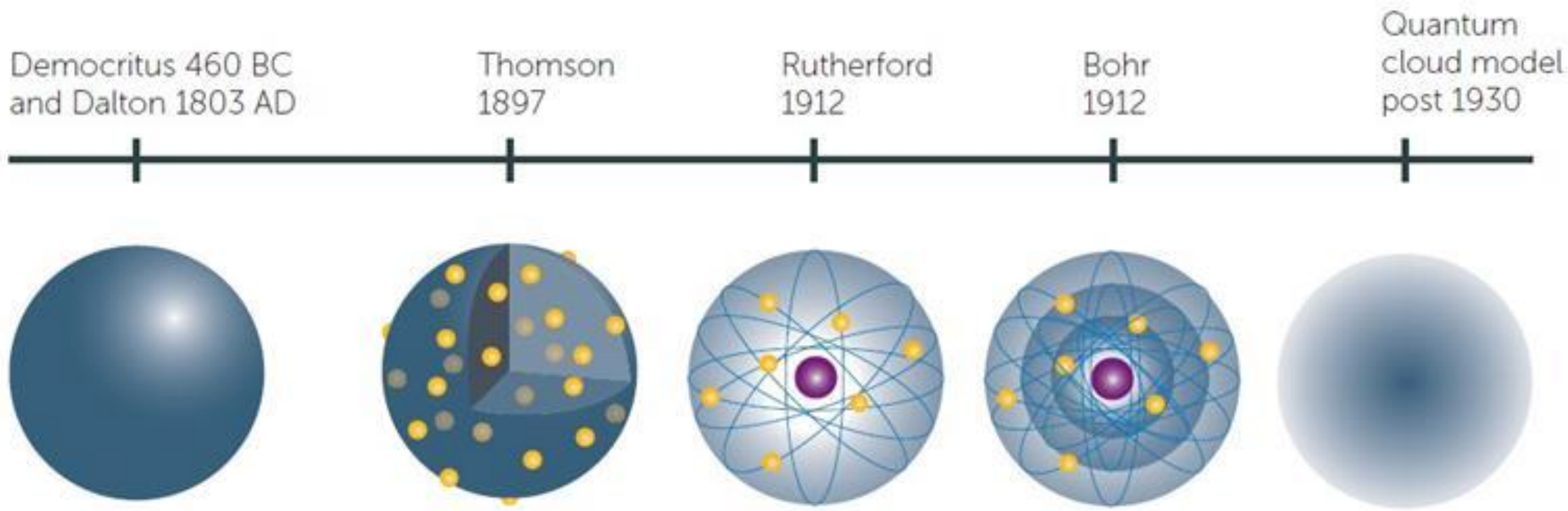




Modern Physics (Phys. IV): 2704

Professor Jasper Halekas
Van Allen 70
MWF 12:30-1:20 Lecture

Models of the Atom

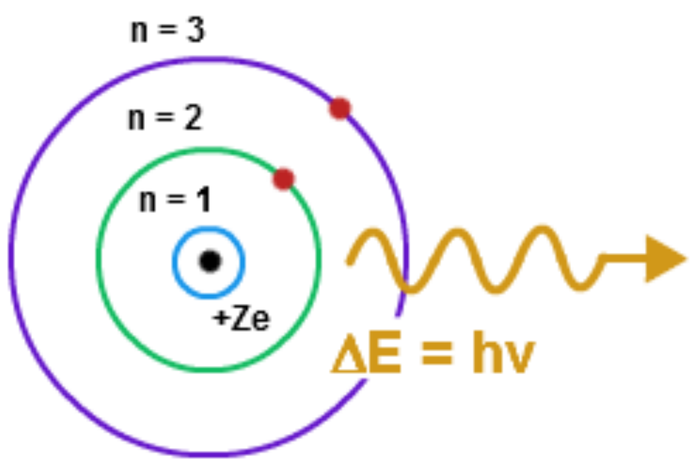


Bohr Model

L = nħ = nh/(2π)

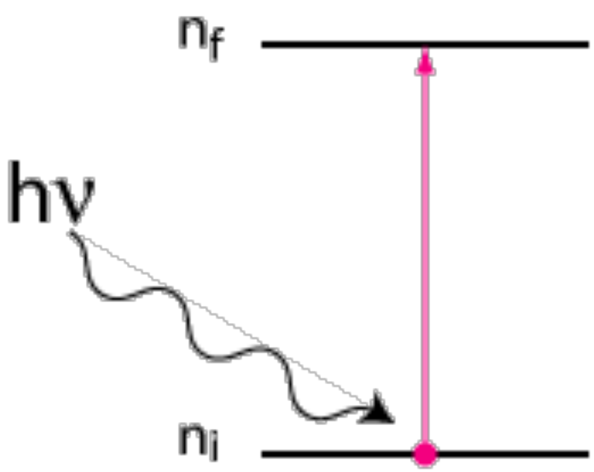
$$E = -\frac{Z^2 m e^4}{8 n^2 h^2 \varepsilon_0^2} = \frac{-13.6 Z^2}{n^2} eV \qquad r = \frac{n^2 h^2 \varepsilon_0}{Z \pi m e^2} = \frac{n^2 a_0}{Z}$$

$$a_0 = 0.0529 nm = Bohr\ \ radius$$



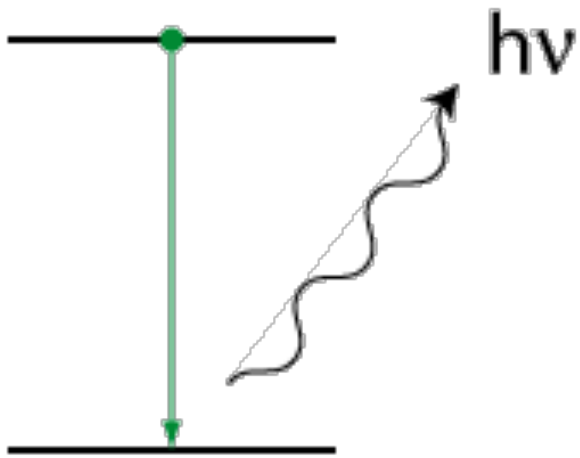
Bohr model only provides quantitatively accurate predictions for atoms with one electron!

Emission and Absorption



Absorption

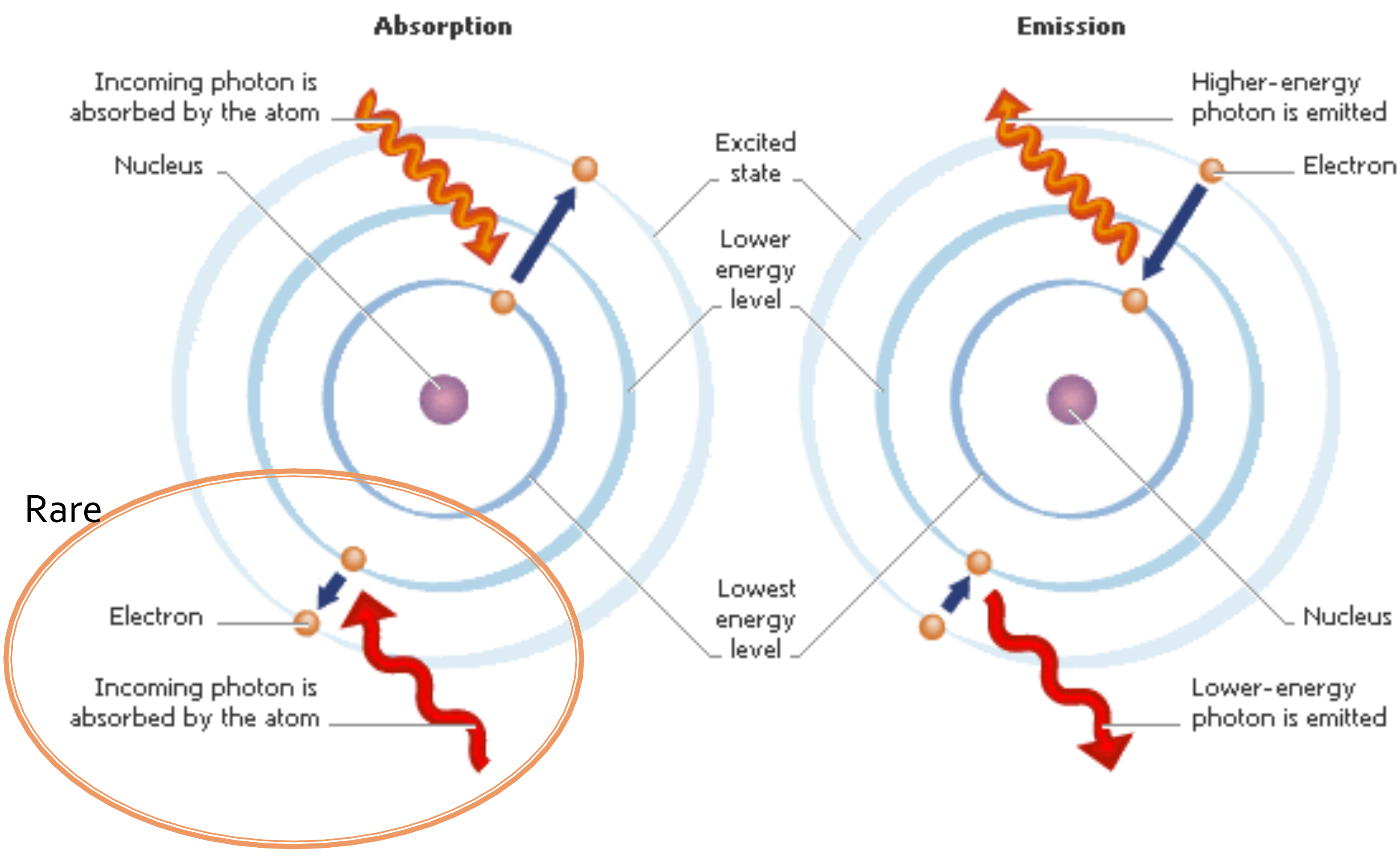
When atom absorbs energy of photon to promote electron to higher energy orbital.



Emission

When atom emits energy as photon as electron falls from higher energy orbital to lower energy orbital.

Emission and Absorption



Concept Check

- Which of these could **not** represent the energy of a photon emitted by an excited hydrogen atom?

A. 13.6*3/4 eV
B. 13.6*1/4 eV
C. 13.6*8/9 eV
D. 13.6*3/16 eV

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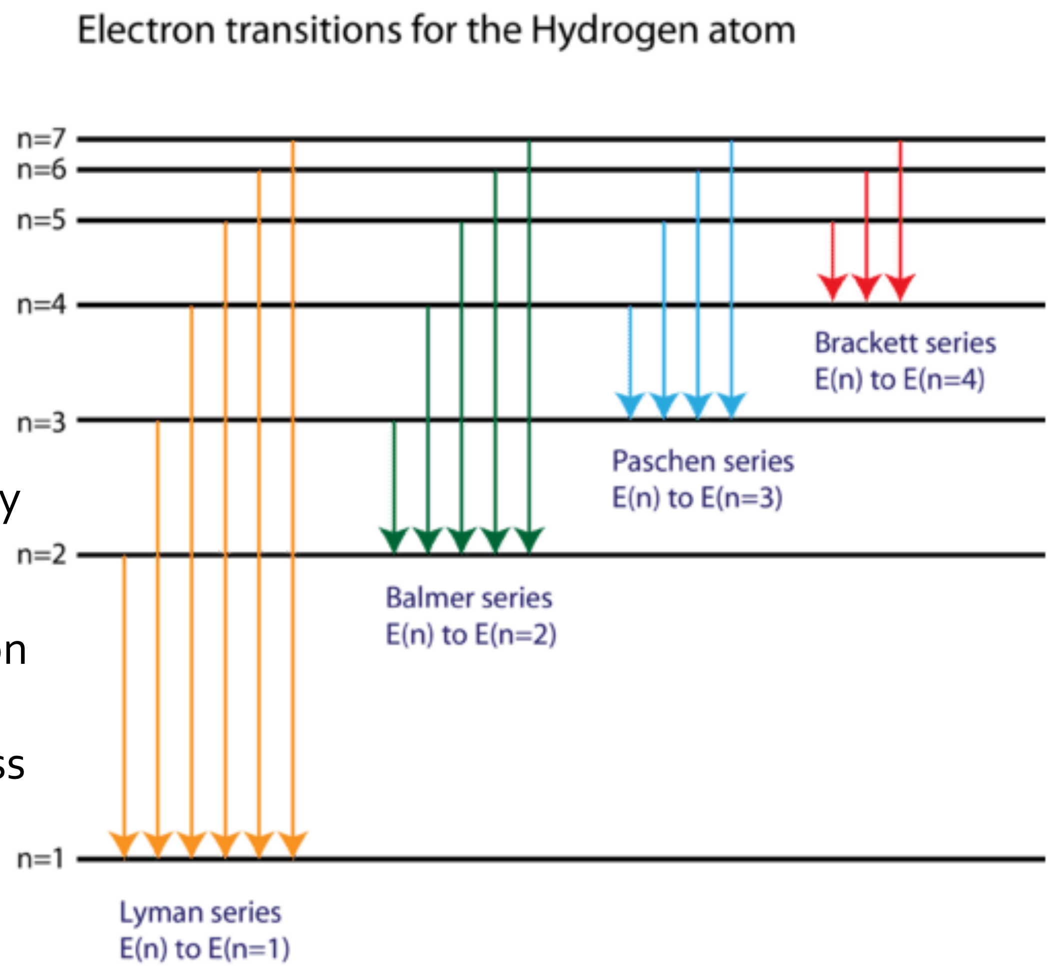
Hydrogen Energy Levels



Emission occurs after atom excited - can occur from any state to any other

Normally absorption only occurs for Lyman series (unless atom starts not in ground state)

E=-13.6/49 eV

E=-13.6/36 eV

E=-13.6/25 eV

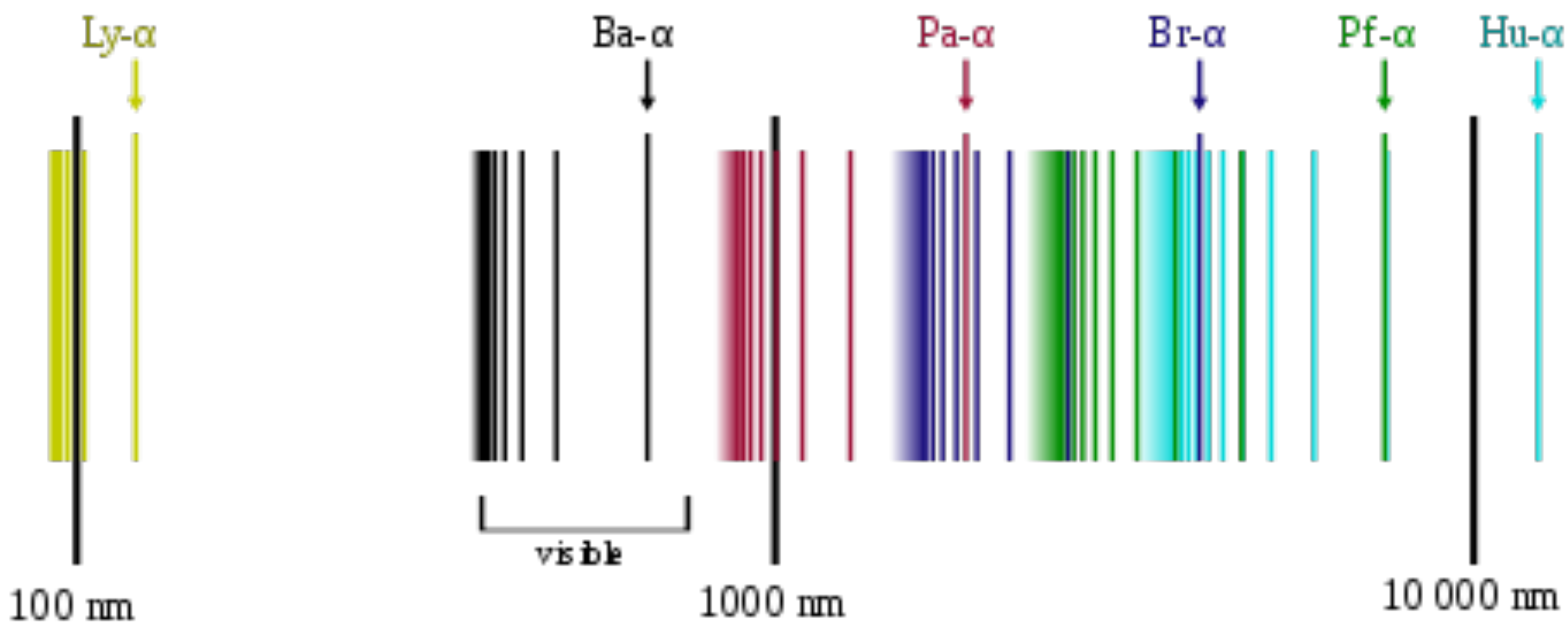
E=-13.6/16 eV

E=-13.6/9 eV

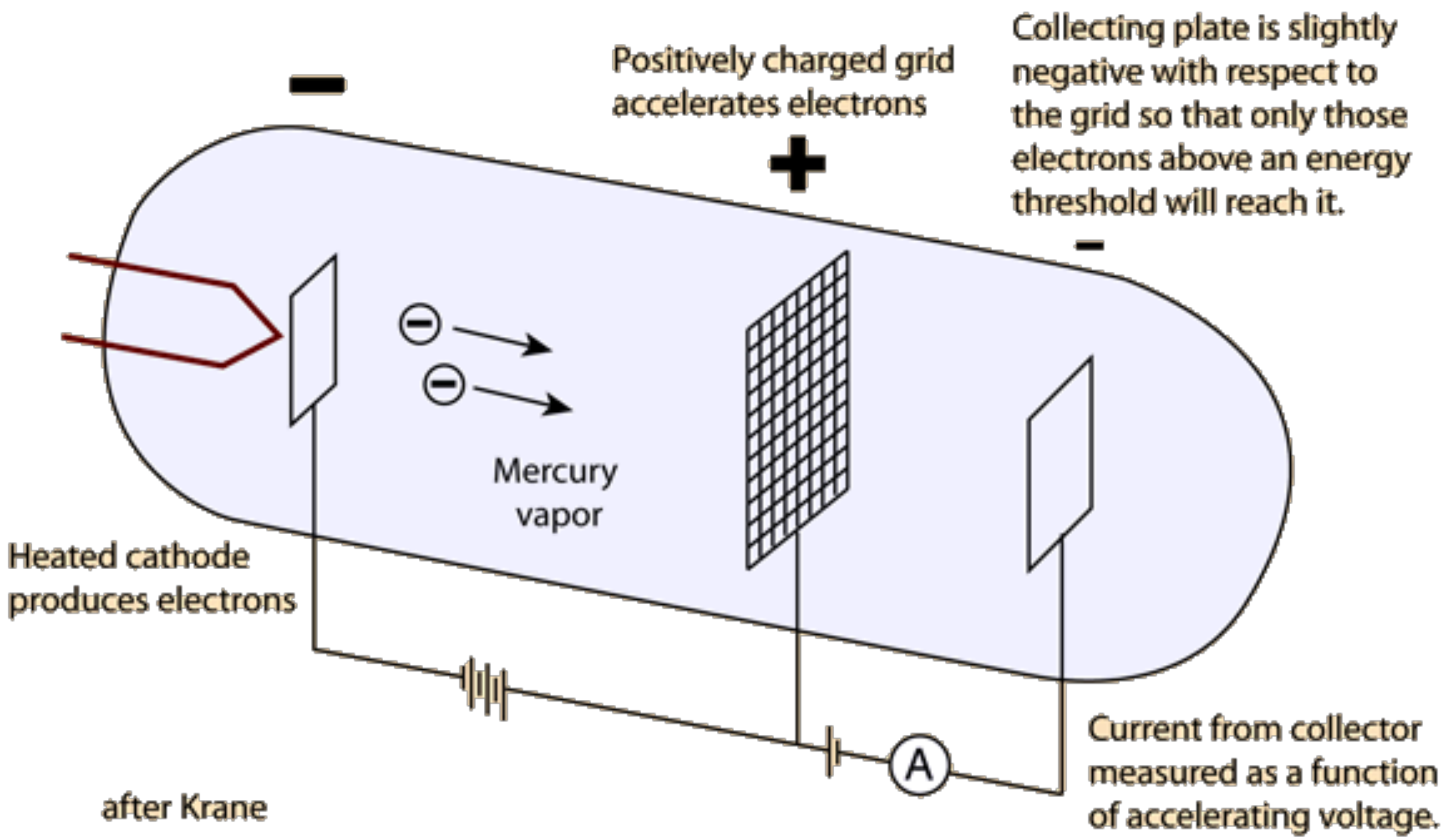
E=-13.6/4 eV

E=-13.6 eV

Hydrogen Emission Wavelengths



Franck-Hertz



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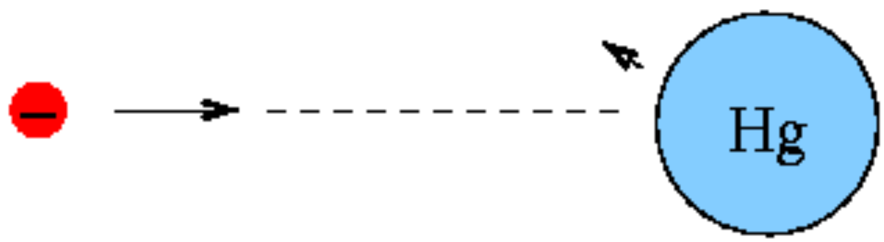
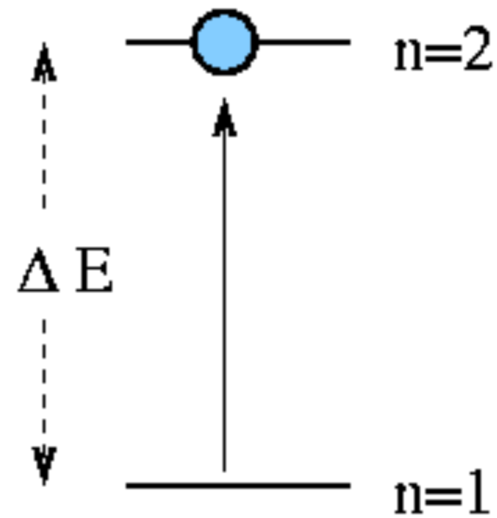


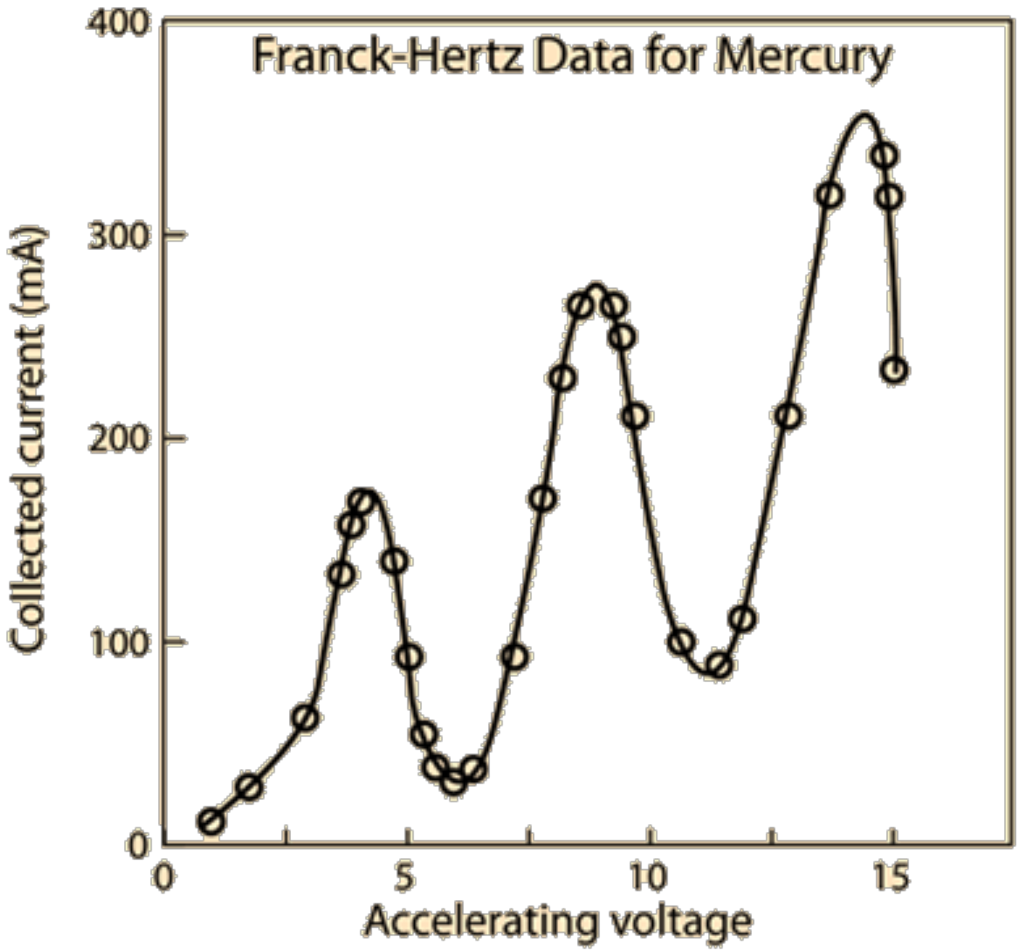
incoming electron has
kinetic energy

$KE = \Delta E$

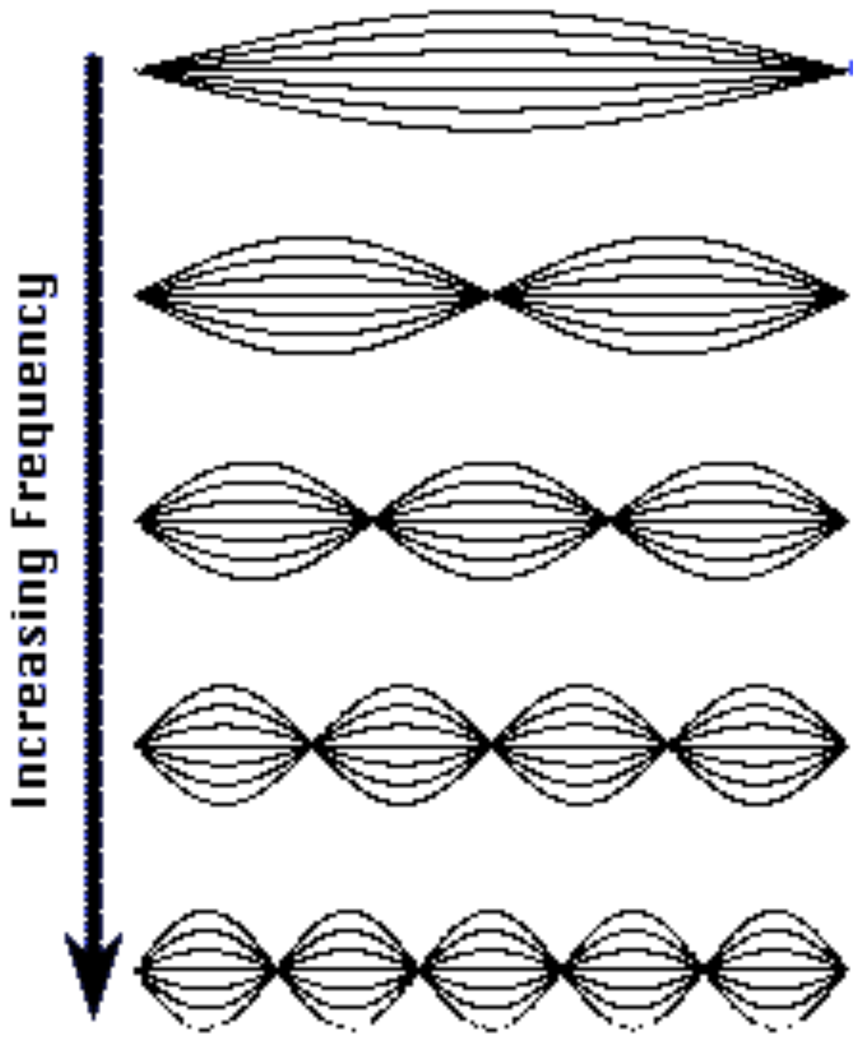


Hg energy level

Franck-Hertz

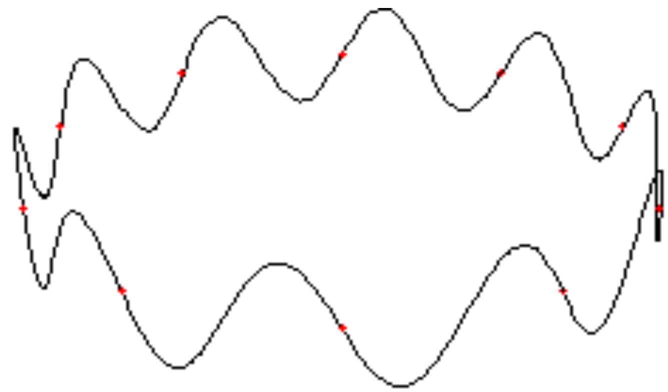


Standing Waves -> Quantization



Standing Waves on a Ring

Just like standing wave on a string, but now the two ends of the string are joined.



What are the restrictions on the wavelength?

A. $r = \lambda$
B. $r = n\lambda$
C. $\pi r = n\lambda$
D. $2\pi r = n\lambda$
E. $2\pi r = n\lambda/2$

$n = 1, 2, 3, \ldots$

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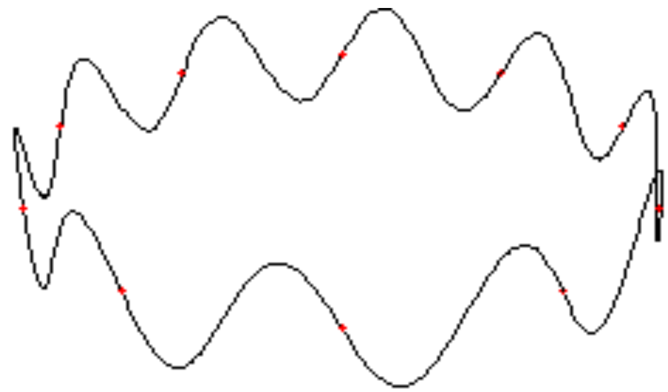

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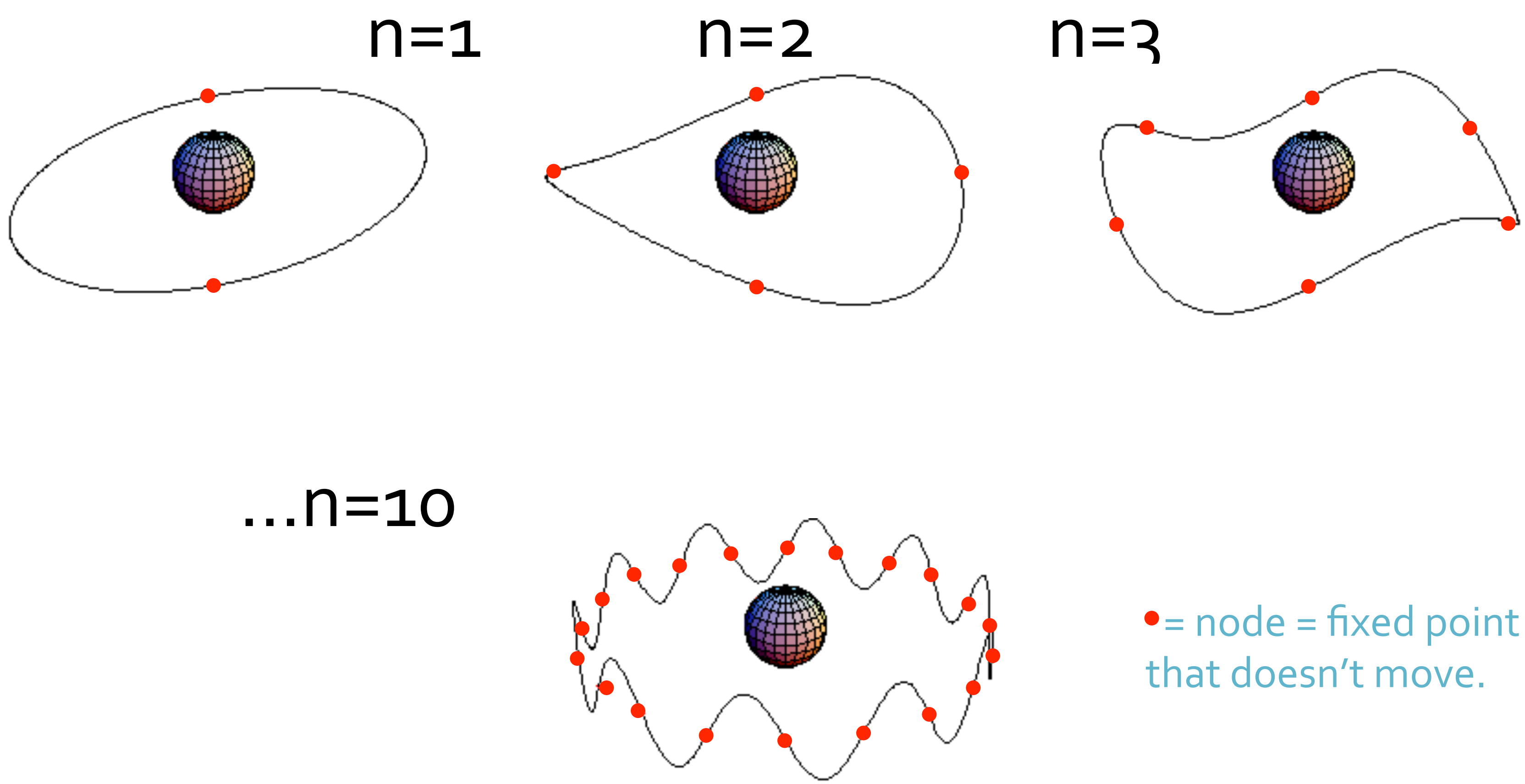
Standing De Broglie Waves



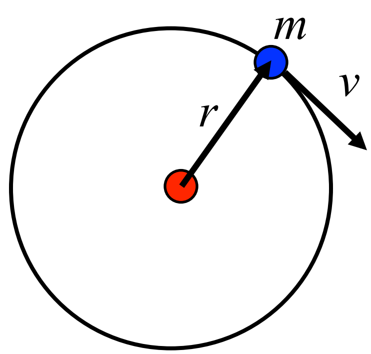
Angular Momentum

Given the deBroglie wavelength (λ**=h/p**) and the condition for standing waves on a ring (**$2\pi r = n\lambda$**), what can you say about the angular momentum L of an electron if it is a deBroglie wave?

A. $L = n\hbar/r$
B. $L = n\hbar$
C. $L = n\hbar/2$
D. $L = 2n\hbar/r$
E. $L = n\hbar/2r$

L = angular momentum = pr

p = (linear) momentum = mv



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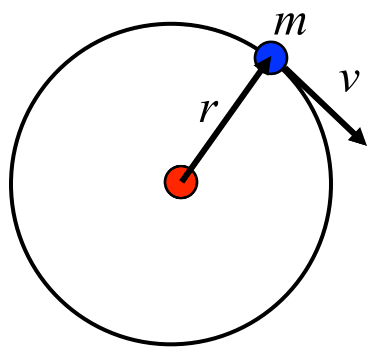


Serious Problem with Bohr / de Broglie Atomic Model

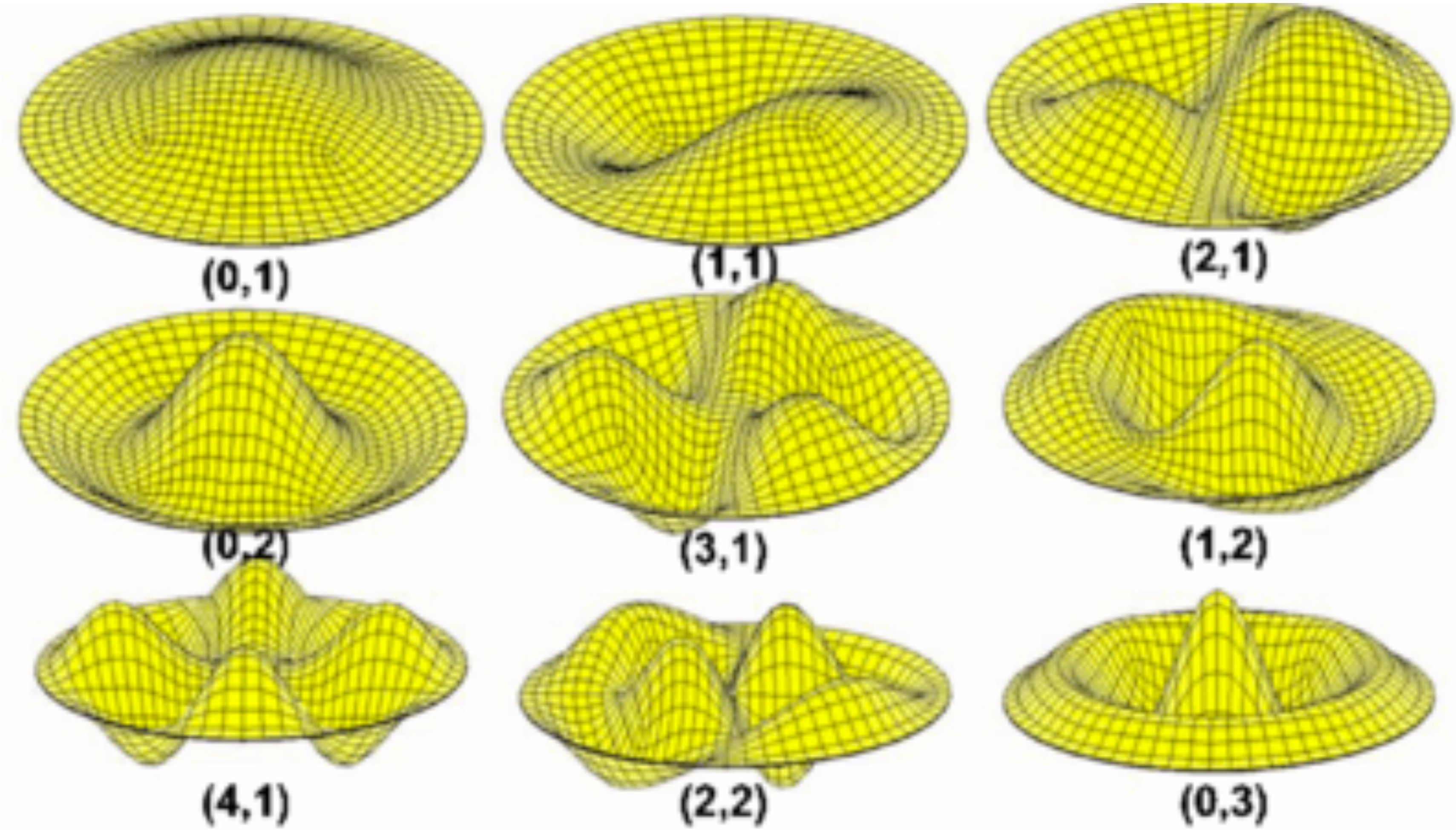
- Ground state of Bohr/de Broglie model has $n = 1$, corresponding to angular momentum $L = \hbar$
- Experiment clearly shows that the actual angular momentum of the electron for the ground state of hydrogen is $L = 0$!!

Another Serious Problem with Bohr Atomic Model

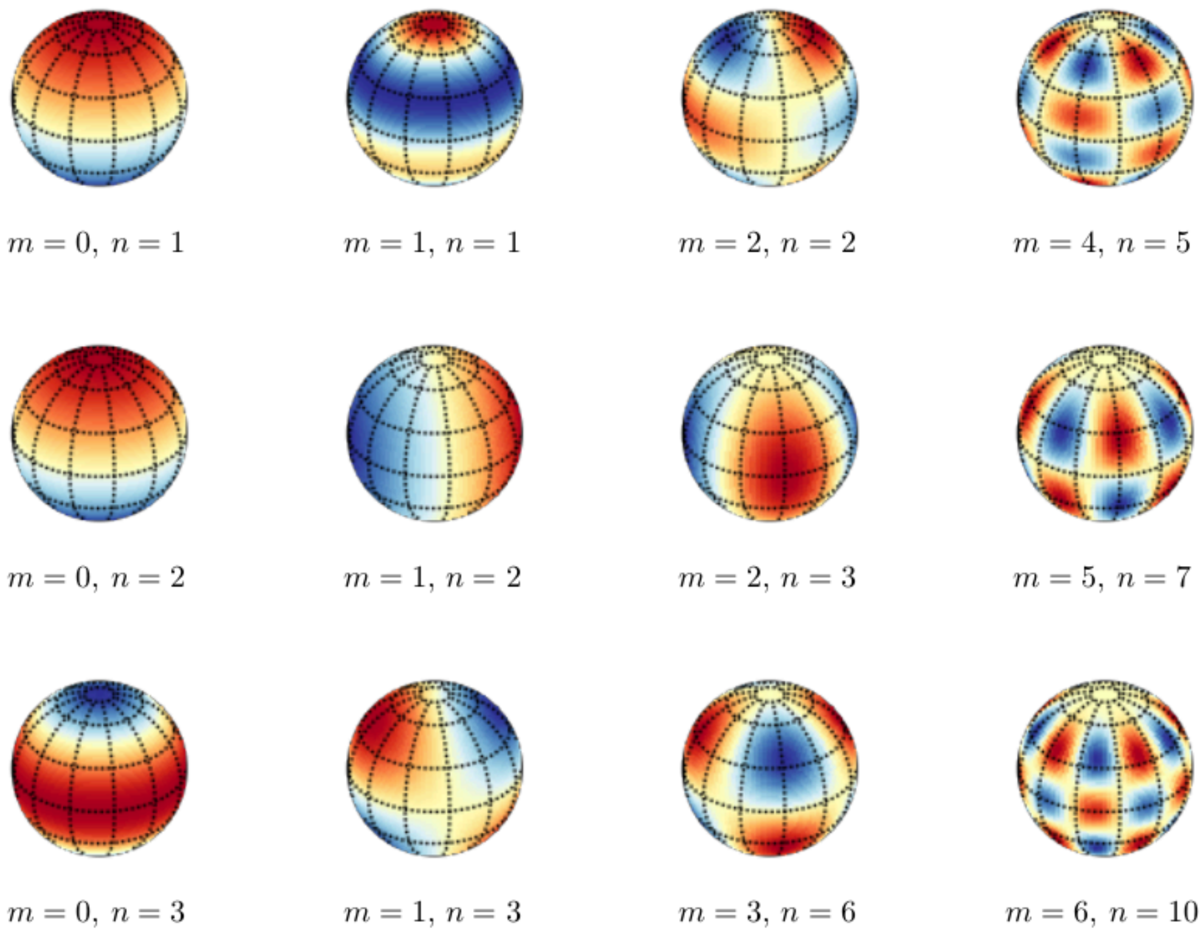
- If orbits are confined to a plane (say it's the x-y plane), then we know that $z = 0$, and we also know that $p_z = 0$.
  - This violates the uncertainty principle

- Our wave functions have to be fully three-dimensional, not one-d or two-d

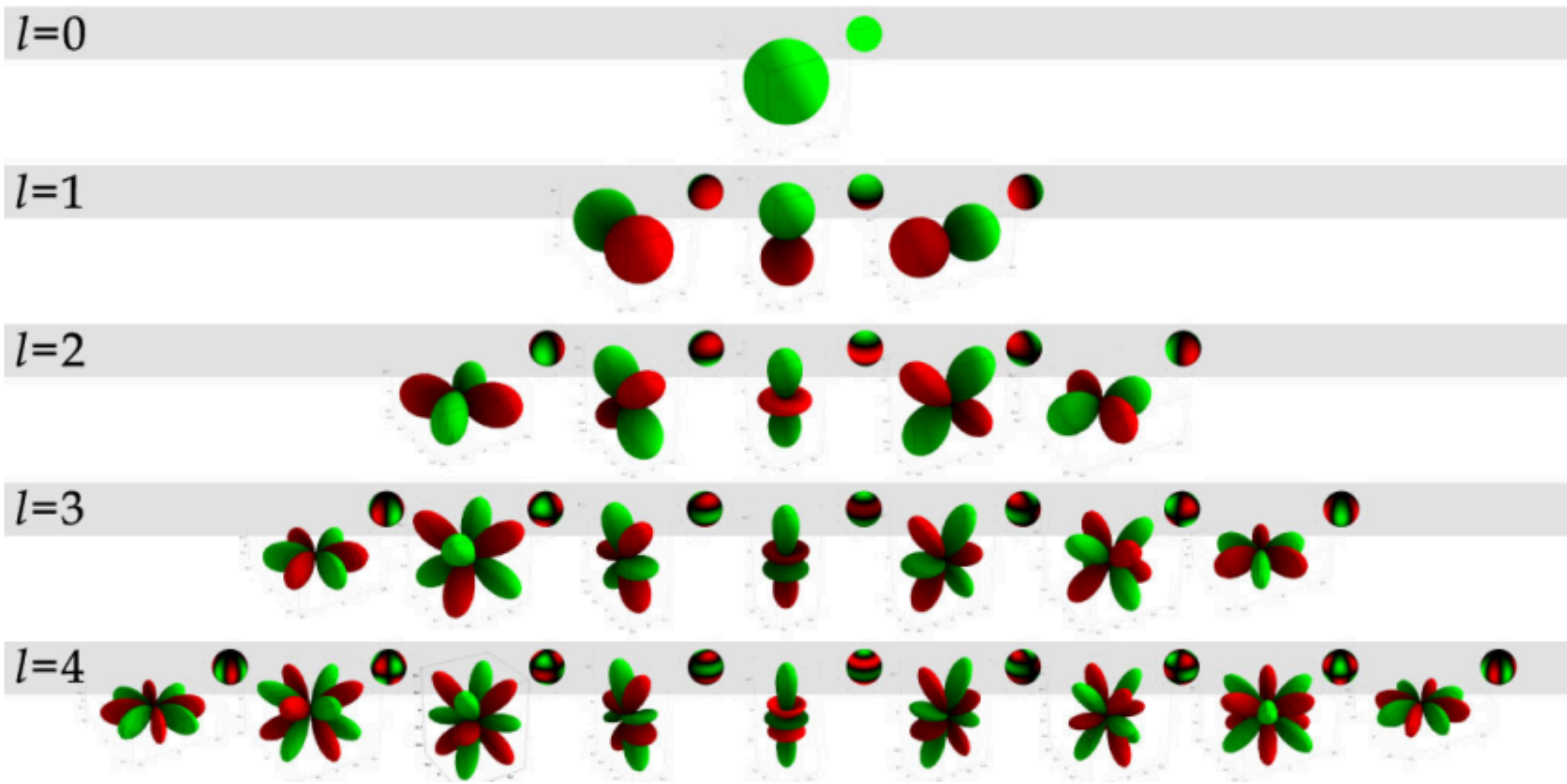
1-d -> 2d: Drumhead Modes



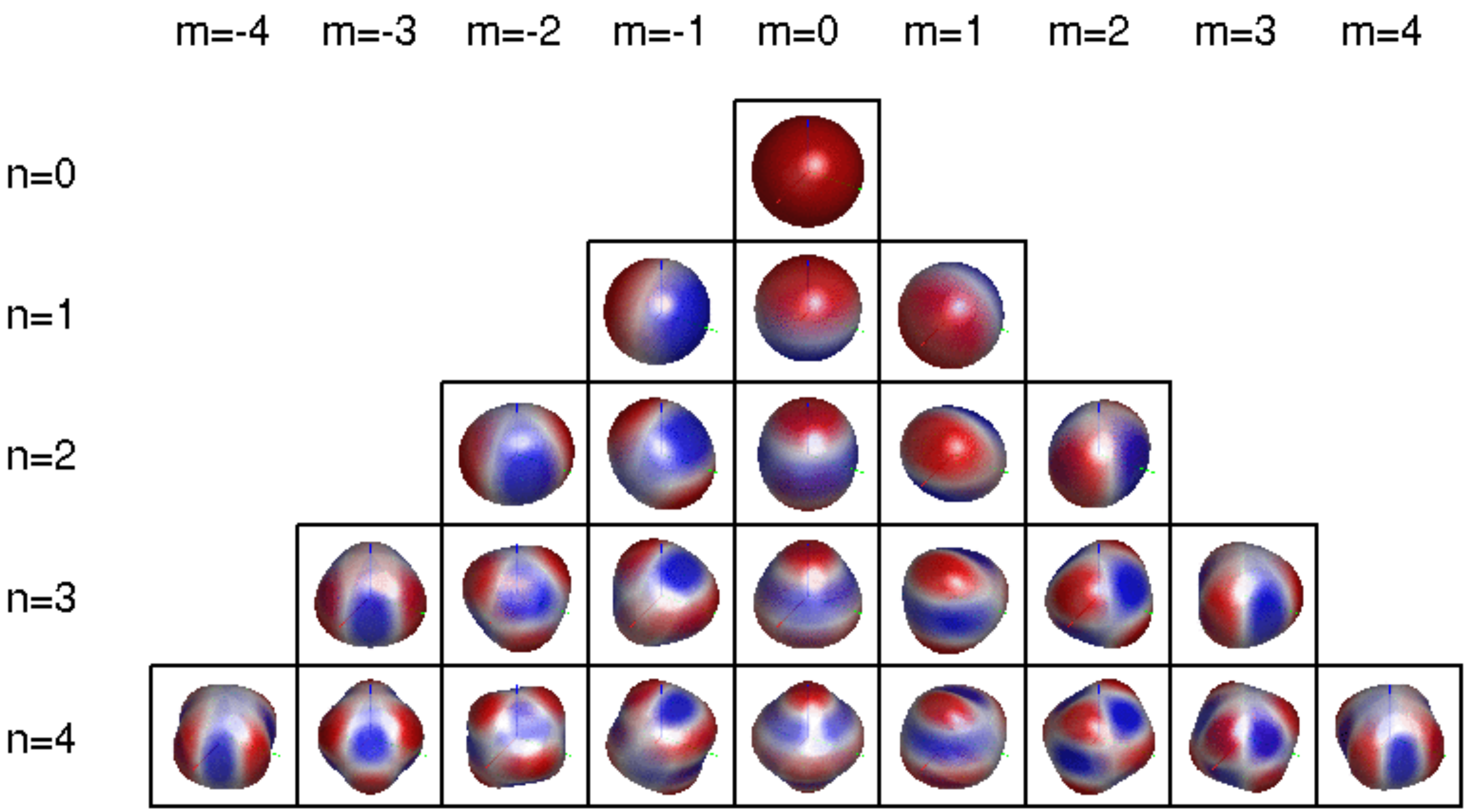
2d->3d: Spherical Harmonics



Another Way to Visualize Spherical Harmonics



Time-Dependent Complex Spherical Harmonics



Hydrogen Wave Functions