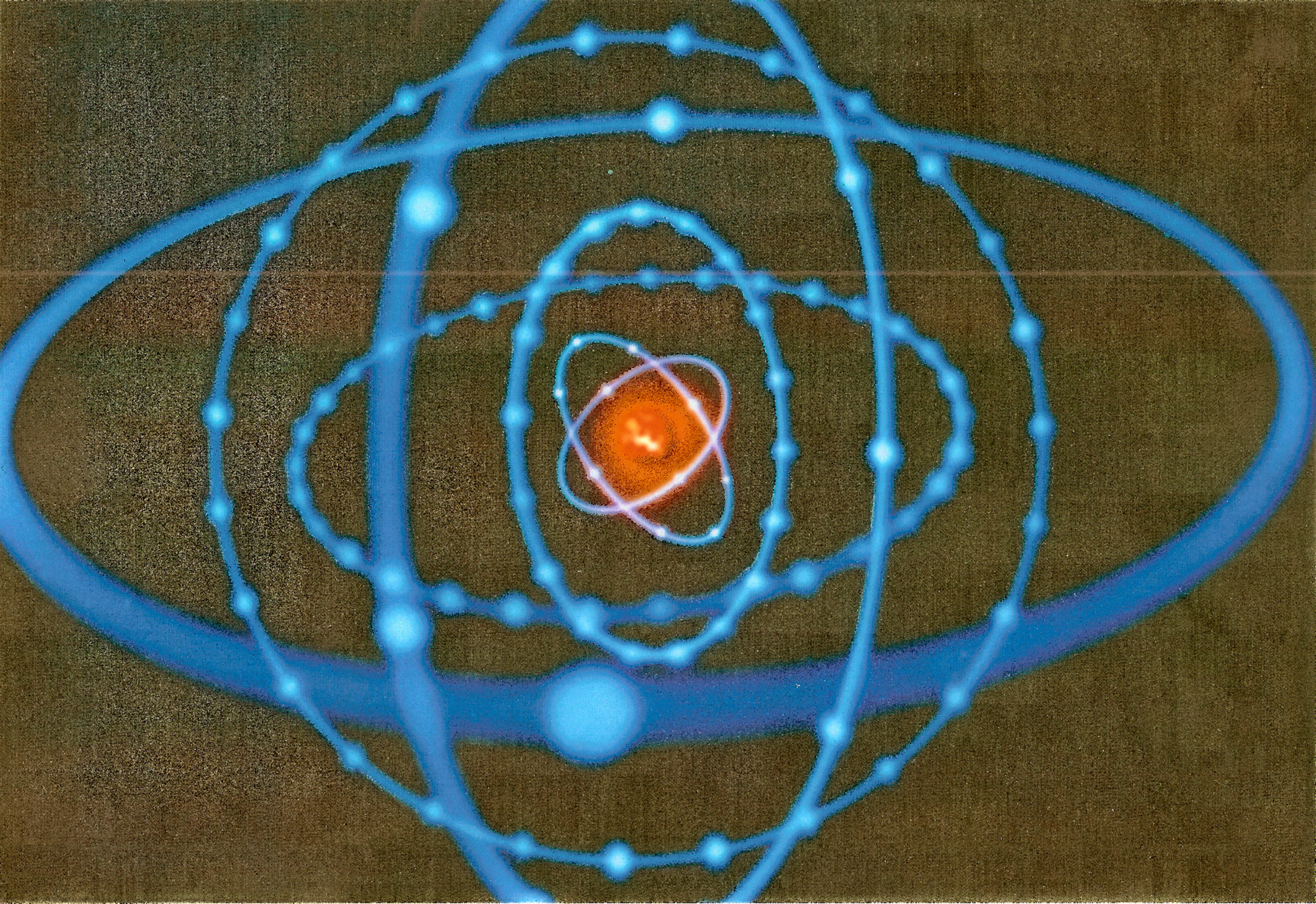


The Bohr atom.

Foot Ch. 1.3. Exercises: 1 - 6 (**H1**)

Postulates

Angular momentum - classically

Results in a quantized one-electron (H-like) system

$$r_n = a_0 \frac{n^2}{Z}, \quad a_0 = 0,53 \text{ Å}.$$

$$v_n = \alpha \cdot c \cdot \frac{Z}{n}, \quad \alpha \approx \frac{1}{137}.$$

$$E_n = -R \cdot \frac{Z^2}{n^2}, \quad R = 109677 \text{cm}^{-1} \text{ for H}$$

$$\frac{1}{\lambda} = E_{n_1} - E_{n_2} = R \cdot Z^2 (\frac{1}{n_1^2} - \frac{1}{n_2^2}). \quad \text{Rydberg formula}$$

$$1 \text{ eV} = 8066 \text{ cm}^{-1}$$

Spectral series:
Lyman, Balmer, Paschen, Brackett, Pfund, Humphreyes.....

Mass dependence of the Rydberg constant for an element with nuclear mass *M* and massnumber *A*:

$$R_M = \frac{1}{1 + \frac{m}{M}} R_\infty = \frac{1}{1 + \frac{1}{1836 \cdot A}} R_\infty, \quad R_\infty = 109737 \text{ cm}^{-1}$$

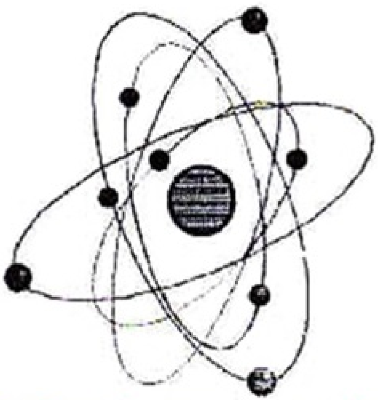
Bohr 1913.

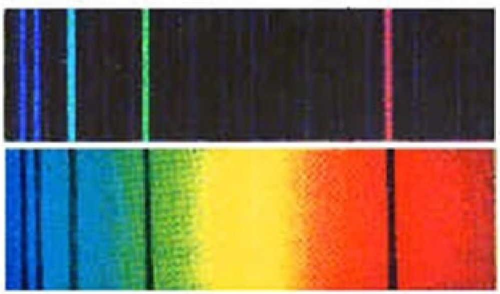
Pieces of the puzzle:

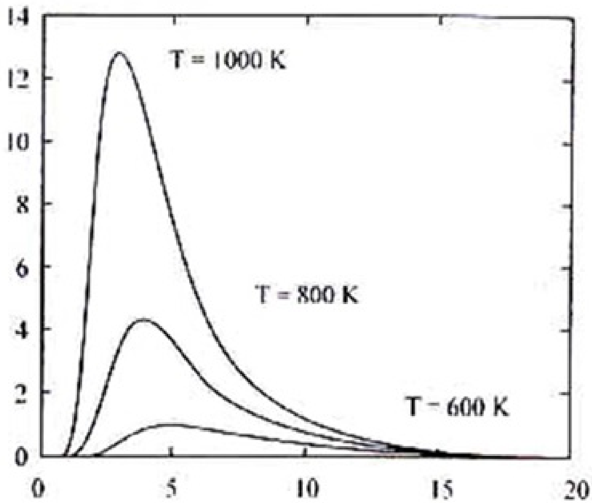
1. Rutherford's "impossible" planetary model of the atom

2. Planck/Einstein's description of light as photons

3. Atomic spectra with discrete emission and absorption lines







Bohr's postulates

P1 An electron may move around the nucleus in specific orbitals without loosing energy.

P2 To change from an orbit with energy E_1 to one with energy E_2 a photon with frequency f is either emitted or absorbed.

$$hf = |E_2 - E_1|$$

P3 The angular momentum L of an electron in a circular orbit can only assume certain, quantized values

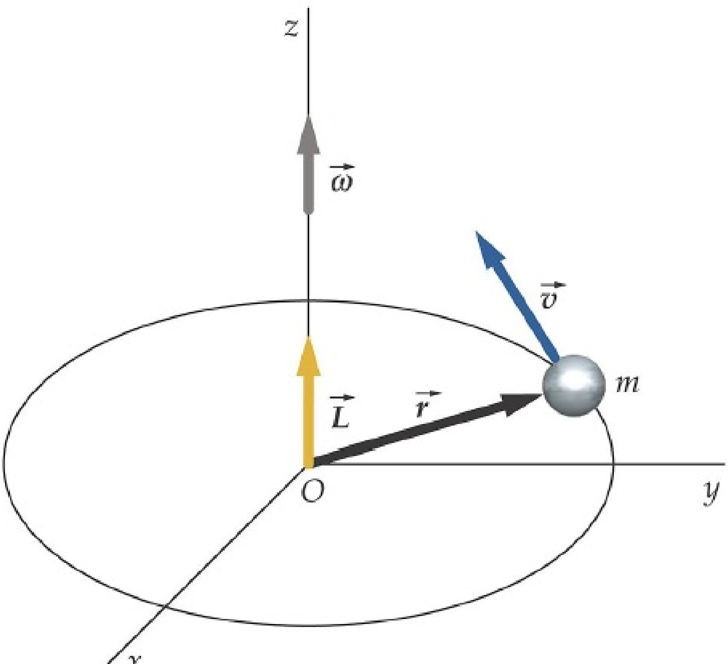
$$L = n \cdot \frac{h}{2\pi} \equiv n \cdot \hbar$$

where n is an integer, $n = 1, 2, 3...$

See e.g. Haken and Wolf, Ch 8., Foot Ch 1.

Angular momentum

$$\mathbf{L} = \mathbf{r} \times \mathbf{p}$$



Torque, τ.

$$\bar{L} = \bar{r} \times \bar{p}$$

$$\bar{\tau} = \bar{r} \times \bar{F} = \frac{d\bar{L}}{dt}$$

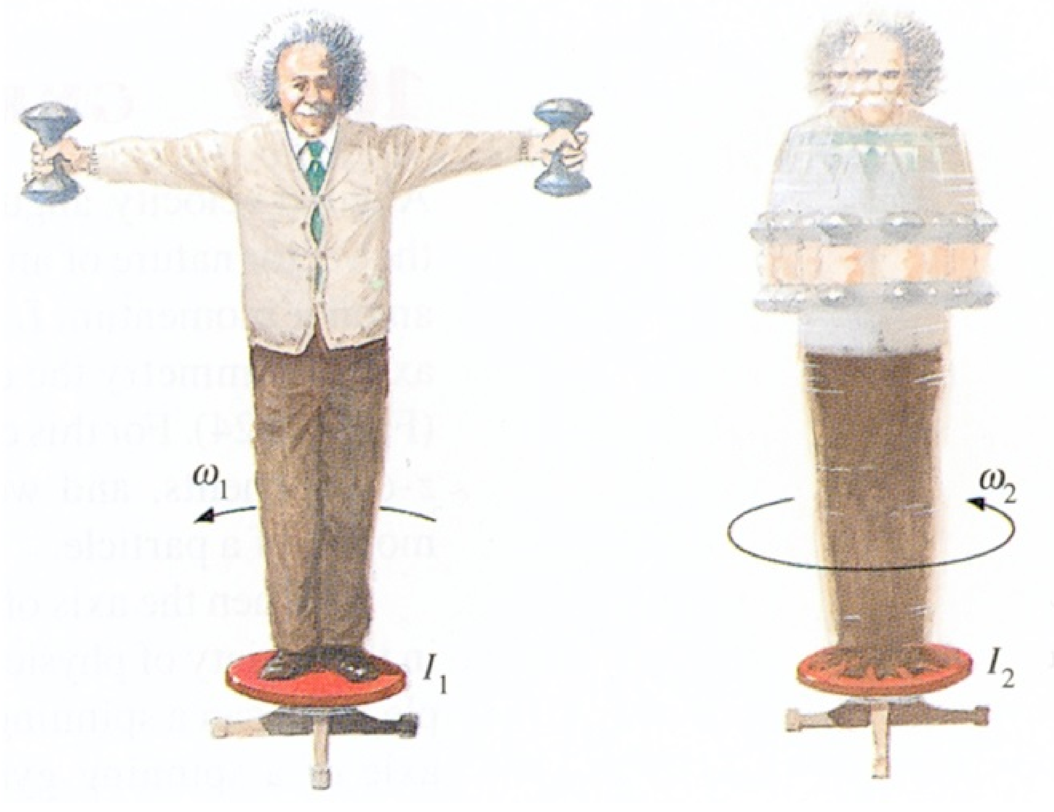
Angular momentum is conserved if

- **No external forces, $\tau = 0$**
- **Central forces, r // F**

Angular momentum

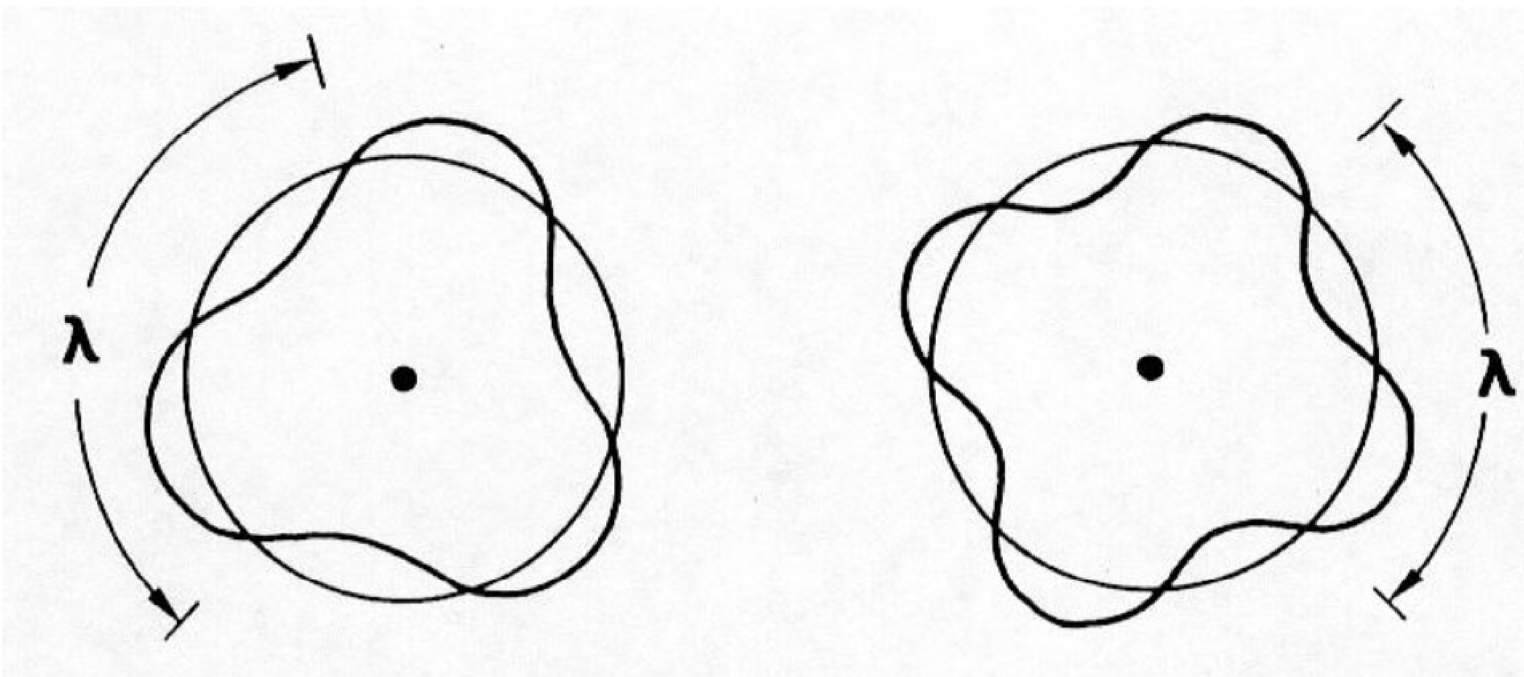
$$L = m \cdot v \cdot r = m \cdot \omega \cdot r^2$$

The total angular momentum is constant in an isolated system (no external torque)

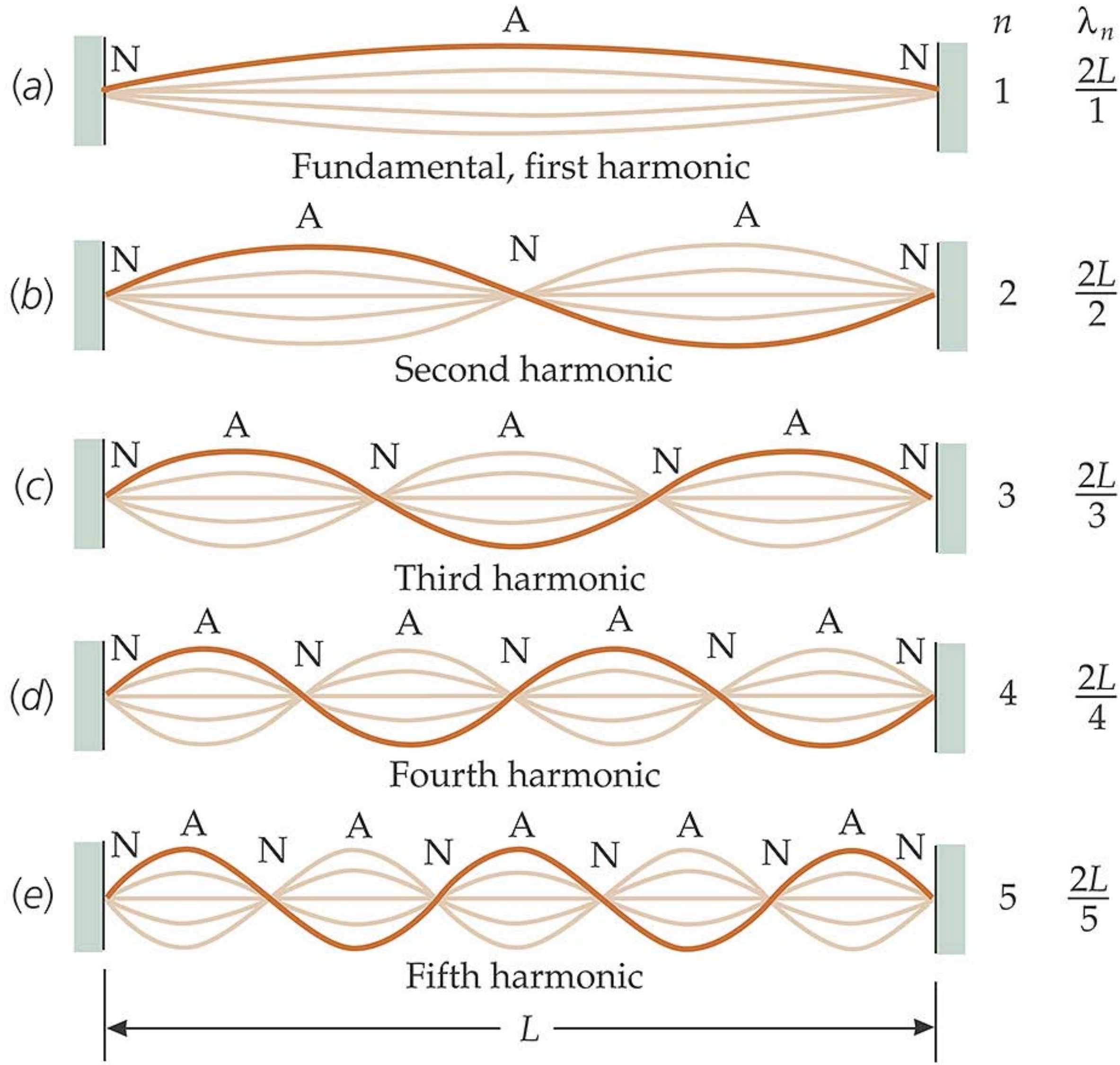


Interpretation of Bohr's 3:e postulate

$$L = mvr = n\frac{h}{2\pi} \Rightarrow 2\pi r = n \cdot \frac{h}{mv} = n \cdot \frac{h}{p} = n \cdot \lambda_{e^-}$$



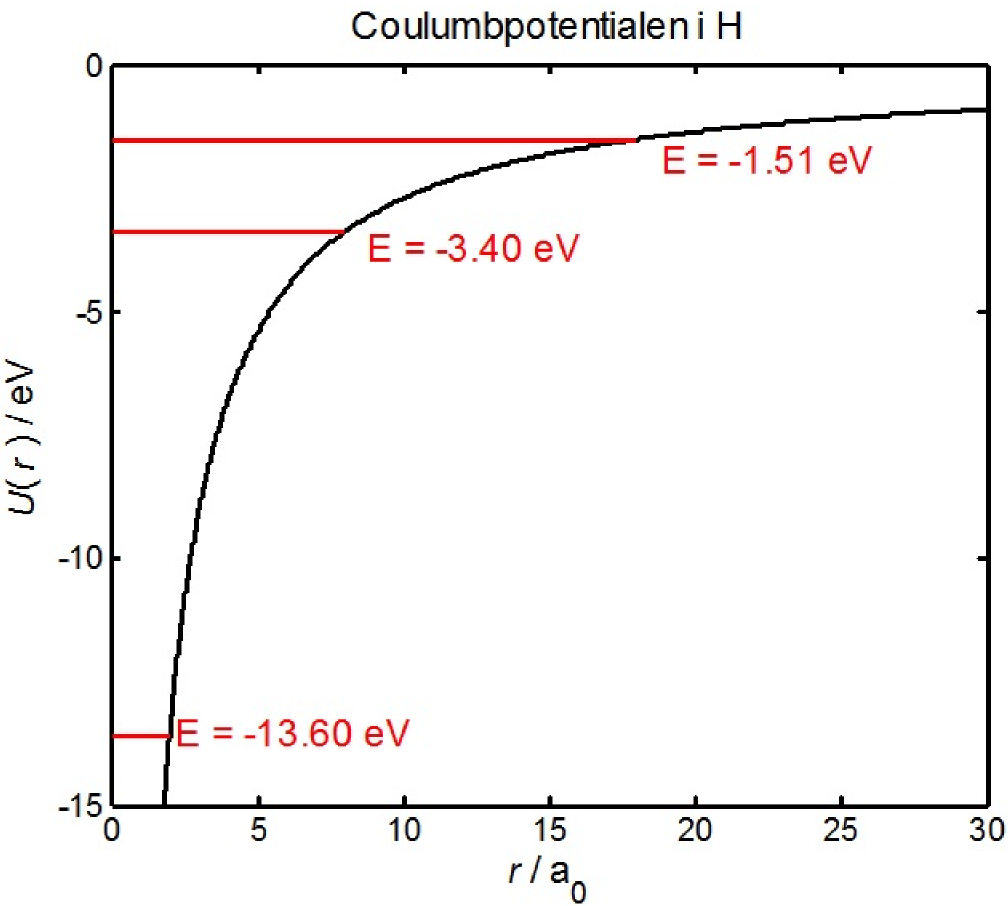
The circular electron orbit should be a integer number of deBroglie wavelengths



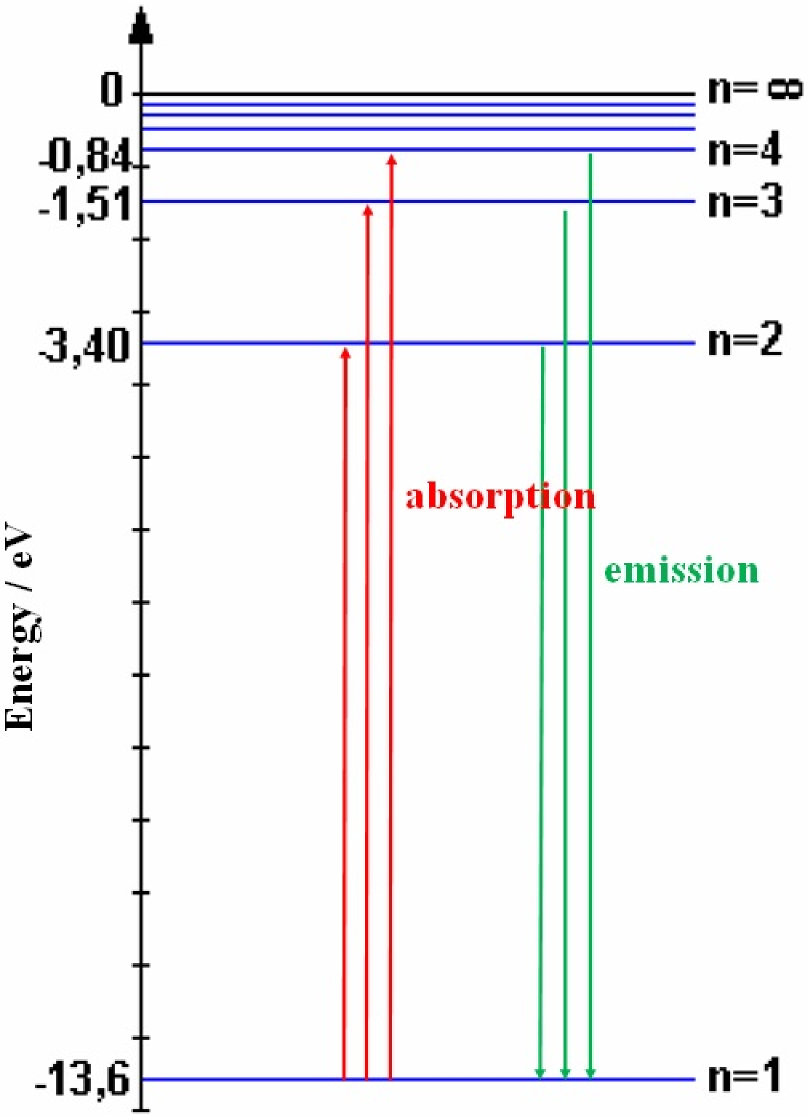
n
λn
(a)
A
N
N
1
2L/1
Fundamental, first harmonic
(b)
A
A
N
N
N
2
2L/2
Second harmonic
(c)
A
A
A
N
N
N
N
3
2L/3
Third harmonic
(d)
A
A
A
A
N
N
N
N
N
4
2L/4
Fourth harmonic
(e)
A
A
A
A
A
N
N
N
N
N
N
5
2L/5
Fifth harmonic
L

Quantized energy levels in the Coulomb potential in H

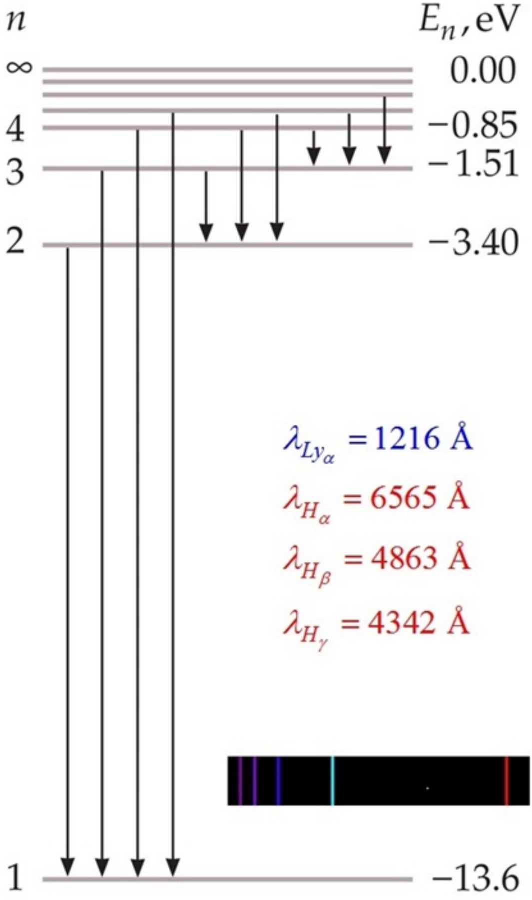
$$U(r) = -\frac{Ze^2}{4\pi\varepsilon_0 r}$$



Energy levels in H

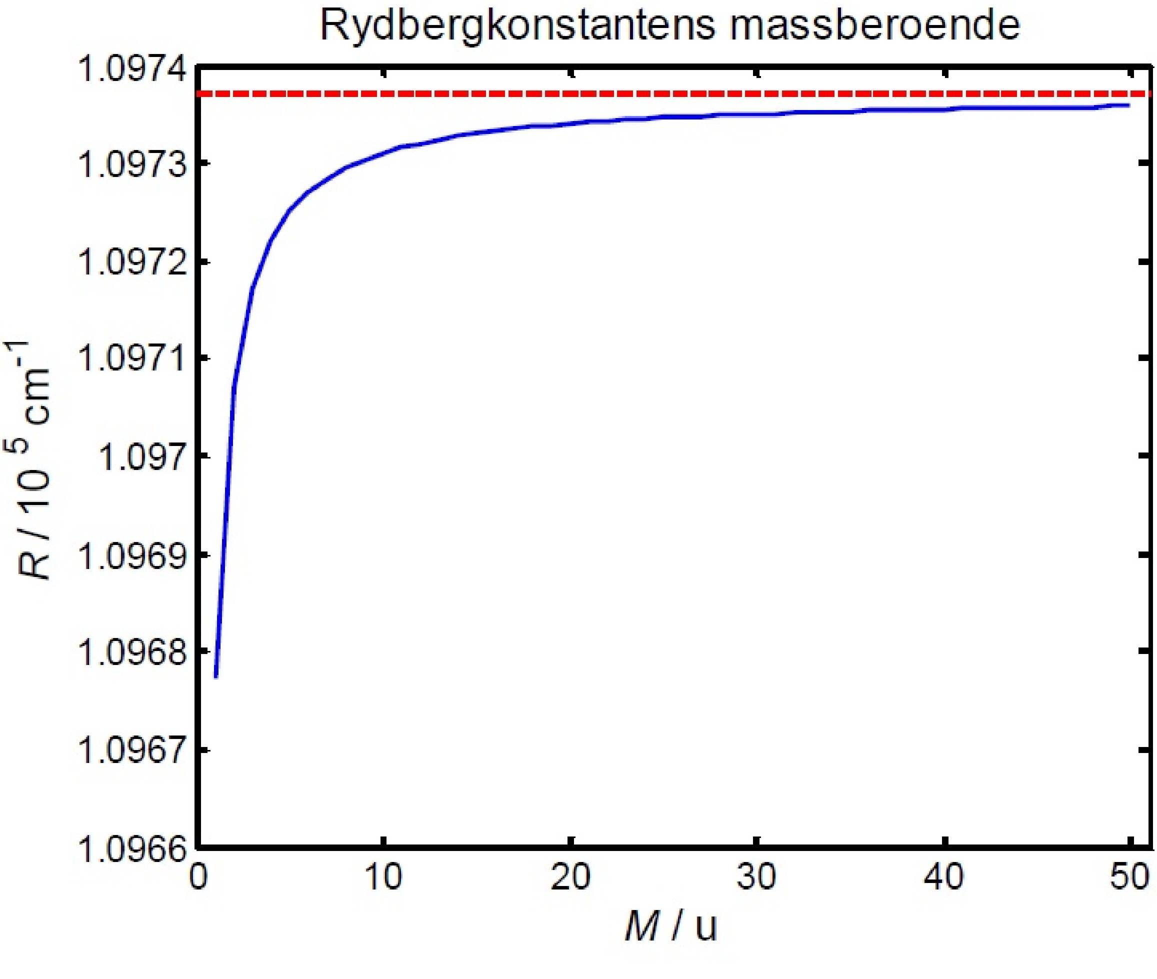


Spectral series in H



Rydbergskonstanten

$$R = \mu \cdot \frac{e^4}{8\varepsilon_0^2 h^3 c} \Rightarrow R_M = R_\infty \cdot \frac{M}{M+m}$$

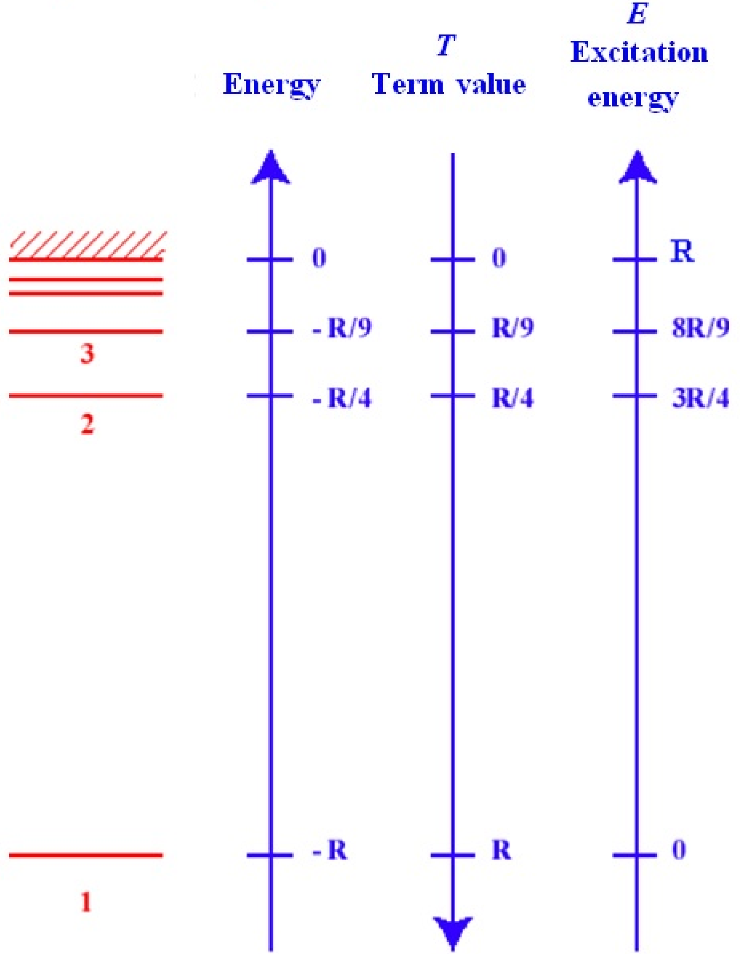


The Nobel Prize in Chemistry 1934

Harold C. Urey

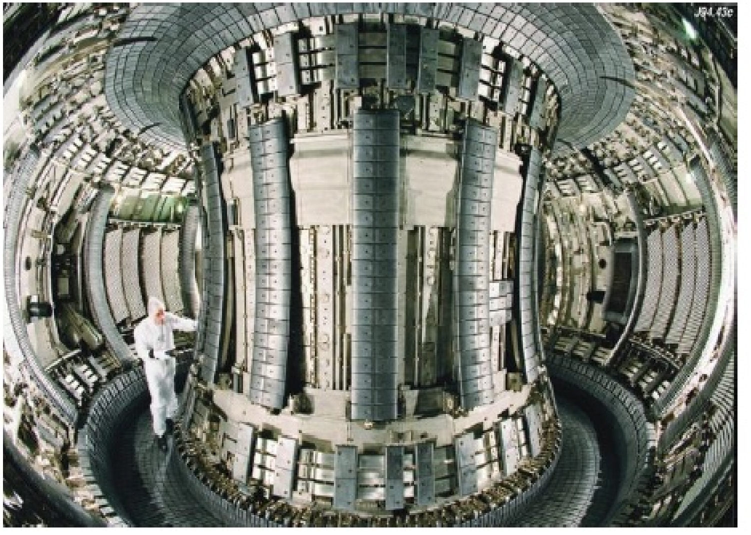
The Nobel Prize in Chemistry 1934 was awarded to Harold C. Urey *"for his discovery of heavy hydrogen"*.

Energy scales (Values for H)



Term value = Binding energy. $T = E_{ion} - E$

Hydrogen-like transitions in heavy elements



In fusion research energy losses due to radiation from highly ionized atoms are an important source of cooling that prevents ignition conditions

In this example we study H-like Kr, i.e. Kr^{+35}.

a) **What is the wavelength of the Lyman-α transition**

b) **What is the energy of the photon in units of 1 keV**

c) **How much energy is required to nock out the last electron**