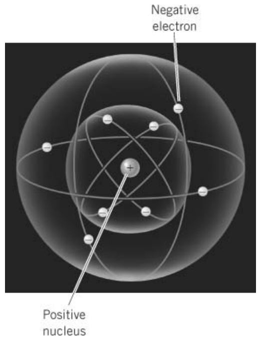
Chapter 30

Atom Physics

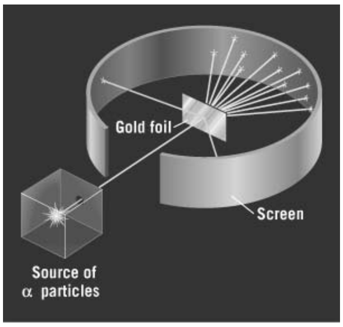


Model of an atom-the recent model

Nuclear radius – r ≈ 10^{-15} m

Electron's position radius r ≈ 10^{-10} m = 1 Å

In its natural state, an atom is electrically neutral.



A Rutherford scattering experiment.

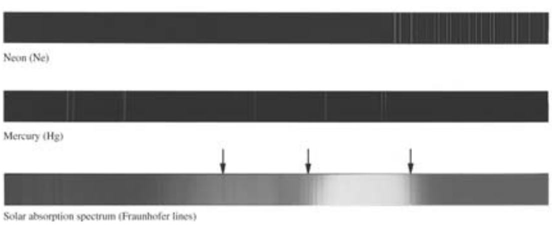
Positively charged alpha particles from radioactive source bombard a thin gold foil being reflected. Hence Thomson's plum-pudding model of atom has to be rejected since only concentrated positive charges can cause deflection due to F_E

Electrons must move around nucleus, else it will be electrically attracted to the positive nucleus. But accelerating electrons radiate and hence lose energy via EM wave radiation. So???

Conceptual Example 1 **Atoms are Mostly Empty Space**

In the planetary model of the atom, the nucleus (radius = 10^{-15}m) is analogous to the sun (radius = 7×10^{8}m). Electrons orbit (radius = 10^{-10}m) the nucleus like the earth orbits (radius = 1.5×10^{11}m) the sun. If the dimensions of the solar system had the same proportions as those of the atom, would the earth be closer to or farther away from the sun than it actually is?

The individual wavelengths emitted by two gases and the continuous spectrum of the sun.



The Line Spectrum of Hydrogen

R is Rydberg constant
R = 1.097 x 10^7 m^{-1}

Lyman series: transition to ground state

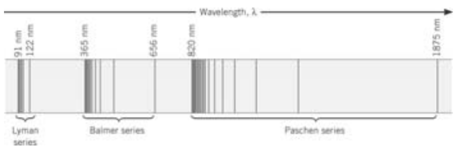
$$\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{n^2}\right) \qquad n = 2, 3, 4, \ldots$$

Balmer series: transition to 1st excited state

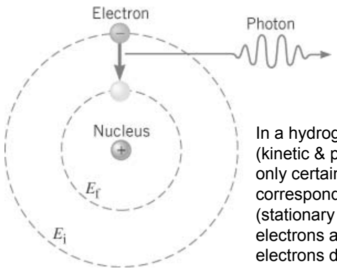
$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right) \qquad n = 3, 4, 5, \ldots$$

Paschen series: transition to 2nd excited state

$$\frac{1}{\lambda} = R\left(\frac{1}{3^2} - \frac{1}{n^2}\right) \qquad n = 4, 5, 6, \ldots$$



30.3 The Bohr Model of the Hydrogen Atom-explaining the observed experimental line spectrum



In the Bohr model, a photon is emitted when the electron drops from a larger, higher-energy orbit to a smaller, lower energy orbit.

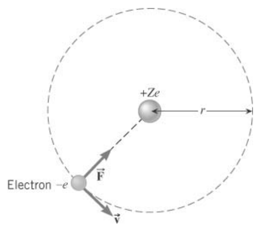
In a hydrogen atom, electrons' total (kinetic & potential) energy can have only certain allowed values corresponding different orbits (stationary state or orbits) of the electrons around the nucleus & that electrons do not radiate while orbiting

Photons are only emitted when electrons changes orbits from larges to smaller orbits. The energy of the photon is

$$\Delta E = E_i - E_f = hf = \frac{hc}{\lambda}$$

30.3 The Bohr Model of the Hydrogen Atom

THE ENERGIES AND RADII OF THE BOHR ORBITS



Assume the electrons are not radiating while orbiting the nucleus. The centripetal force is provided by the electrical force

$$F_{12} = \frac{kq_1q_2}{r^2}$$

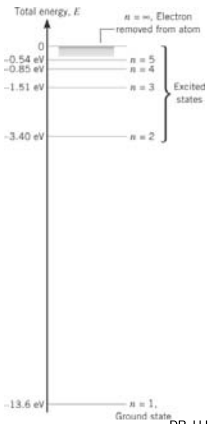
$$E = KE + EPE$$

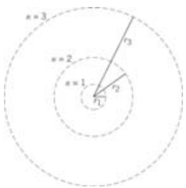
$$= \tfrac{1}{2}mv^2 - \frac{kZe^2}{r}$$

$$= -\frac{kZe^2}{2r}$$

30.3 The Bohr Model of the Hydrogen Atom

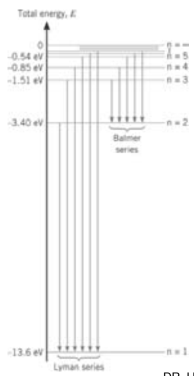
ENERGY LEVEL DIAGRAMS





30.3 The Bohr Model of the Hydrogen Atom

THE LINE SPECTRA OF THE HYDROGEN ATOM



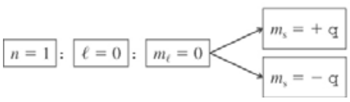
$$\frac{1}{\lambda} = \frac{2\pi^2 mk^2e^4}{h^3c}\left(Z^2\right)\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$n_i, n_f = 1, 2, 3, \ldots \quad n_i > n_f$$

30.5 The Quantum Mechanical Picture of the Hydrogen Atom

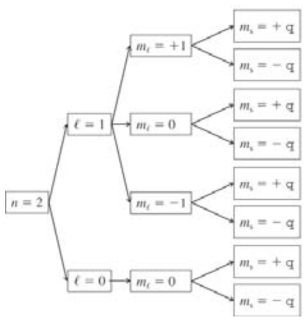
Example 5 **The Bohr Model Versus Quantum Mechanics**

Determine the number of possible states for the hydrogen atom when the principal quantum number is (a) n=1 and (b) n=2.



State			
n	ℓ	m_ℓ	m_s
1	0	0	+ q
1	0	0	− q

30.5 The Quantum Mechanical Picture of the Hydrogen Atom



State			
n	ℓ	m_ℓ	m_s
2	1	+1	+ q
2	1	+1	− q
2	1	0	+ q
2	1	0	− q
2	1	−1	+ q
2	1	−1	− q
2	0	0	+ q
2	0	0	− q

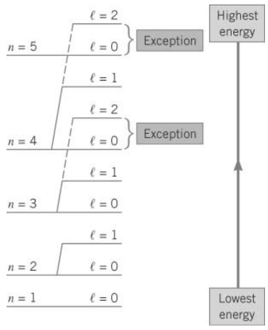
30.5 The Quantum Mechanical Picture of the Hydrogen Atom

Conceptual Example 6 **The Bohr Model Versus Quantum Mechanics**

Consider two hydrogen atoms. There are no external magnetic fields present, and the electron in each atom has the same energy. According to the Bohr model and to quantum mechanics, is it possible for the electrons in these atoms (a) to have zero orbital angular momentum and (b) to have different angular momenta?

DR JJ UiTM-Cutnell & Johnson 7th ed. 13

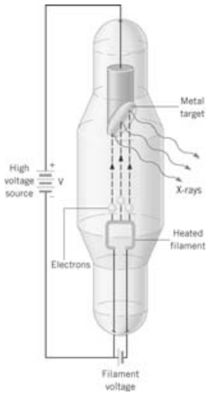
30.6 The Pauli Exclusion Principle and the Periodic Table of the Elements



Generally, the energy increases with increasing n. There are exceptions to the general rule.

DR JJ UiTM-Cutnell & Johnson 7th ed. 14

30.7 X-Rays

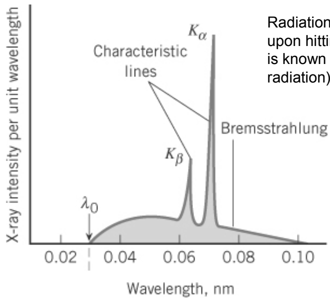


Electrons are emitted from a heated filament and accelerated through a large voltage.

When they strike the target (platinum or molybdenum, X-rays (photons when electrons undergo transition from higher energy states to lower energy states) are emitted.

DR JJ UiTM-Cutnell & Johnson 7th ed. 15

30.7 X-Rays



Radiation produced due to deceleration upon hitting the target is a continuum and is known as Bremsstrahlung (braking radiation)

The sharp peaks are called ***characteristic X-rays (X-ray photons)*** because they are characteristic of the target material. The K_α (from n=2 to n=1) and K_β (n=3 to n=1) lines involve transition of electrons from an excited state filling in the vacancy created in the K shell (n=1) after the electron from that shell is ejected by the incoming electrons.

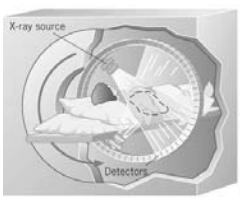
λ_0 is the cutoff wavelength which depends ONLY on the energy of the impinging electrons.

$$KE = eV = hf = \frac{hc}{\lambda_0}$$

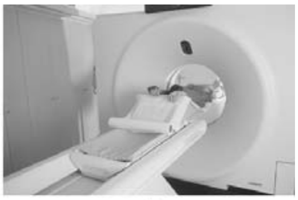
So, $\lambda_0 = \dfrac{hc}{eV}$

DR JJ UiTM-Cutnell & Johnson 7th ed. 16

30.7 X-Rays



(a)



(b)

DR JJ UiTM-Cutnell & Johnson 7th ed. 17