31 Atomic Physics

Outline

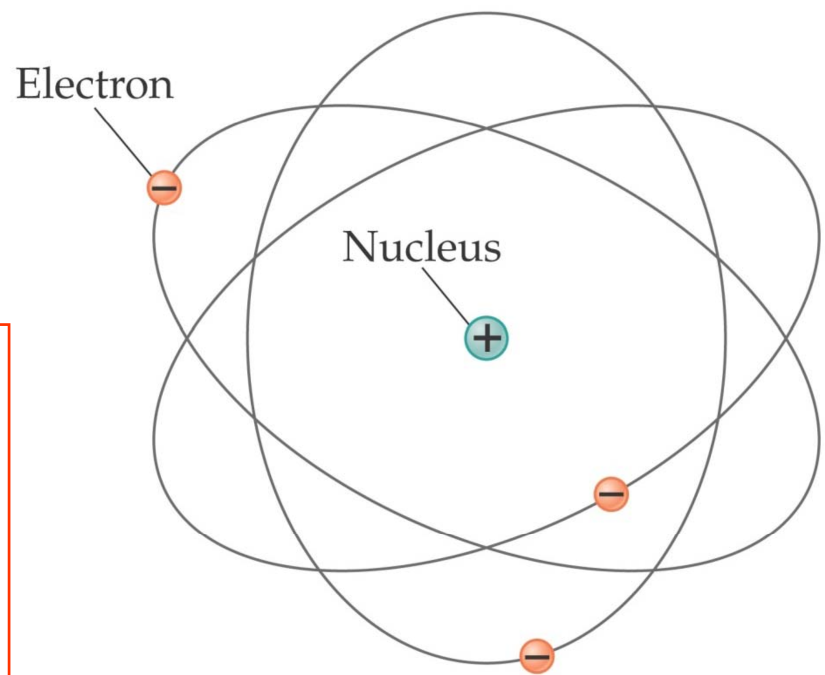
31-1 Early Models of the Atom

The "solar system" model has been applied to the atom : electrons orbit a small, positively charged nucleus.

The electrons move in centripetal motion, and the force is provide by the Coulomb force.

Electron Energies include:

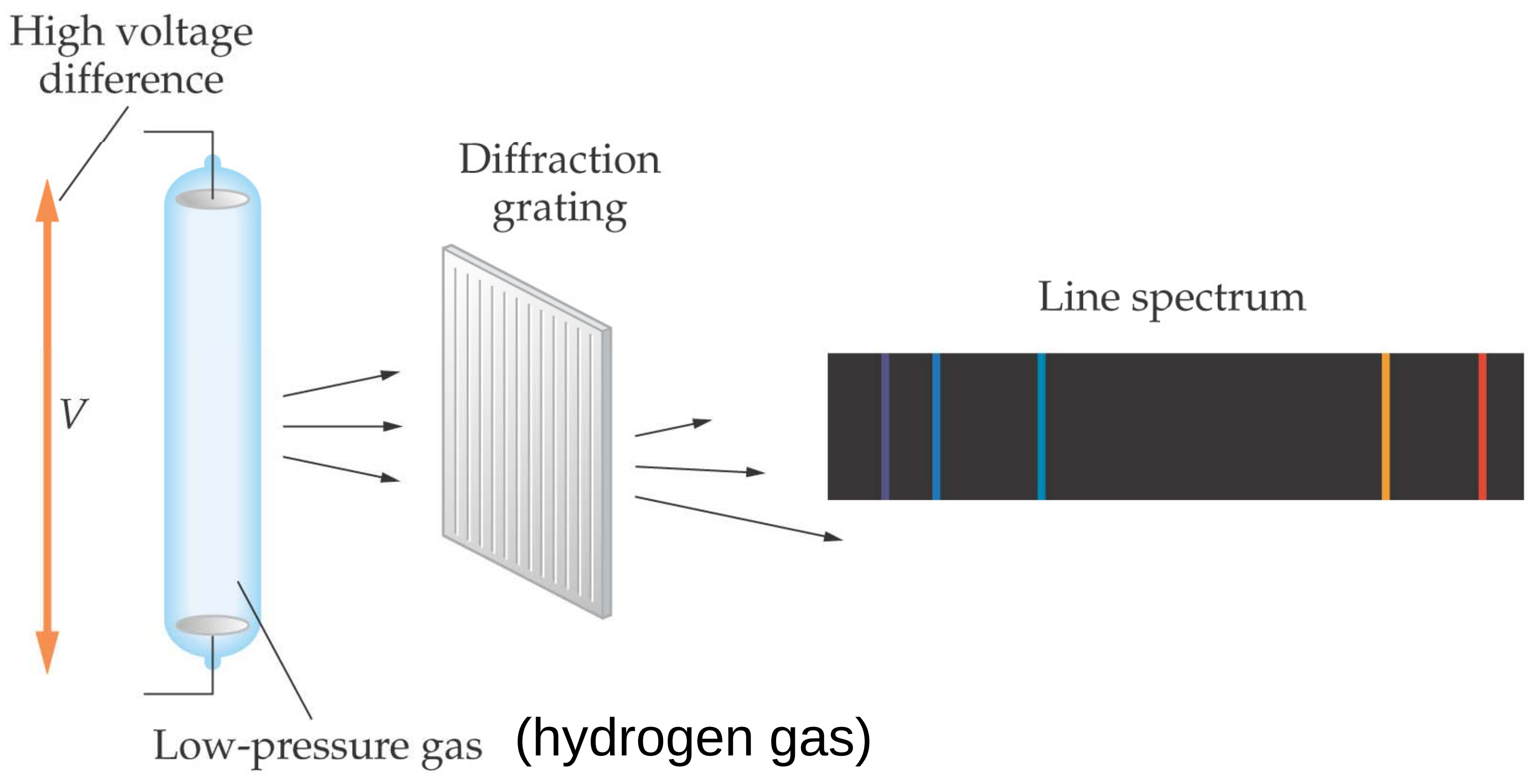
- Electric Potential energy.
- Kinetic energy.



- Spectrum (photon) can be created when electron jumps from one orbit to other orbit.
- The photon wavelength is determined by hf.

31-2 The Spectrum of Atomic Hydrogen

The creation of spectral lines: Emission spectrum.



(hydrogen gas)

Figure 31-3 The Line Spectrum of an Atom

There are two types of spectral lines:

Emission spectrum: bright lines. Direct radiation from hot gas.

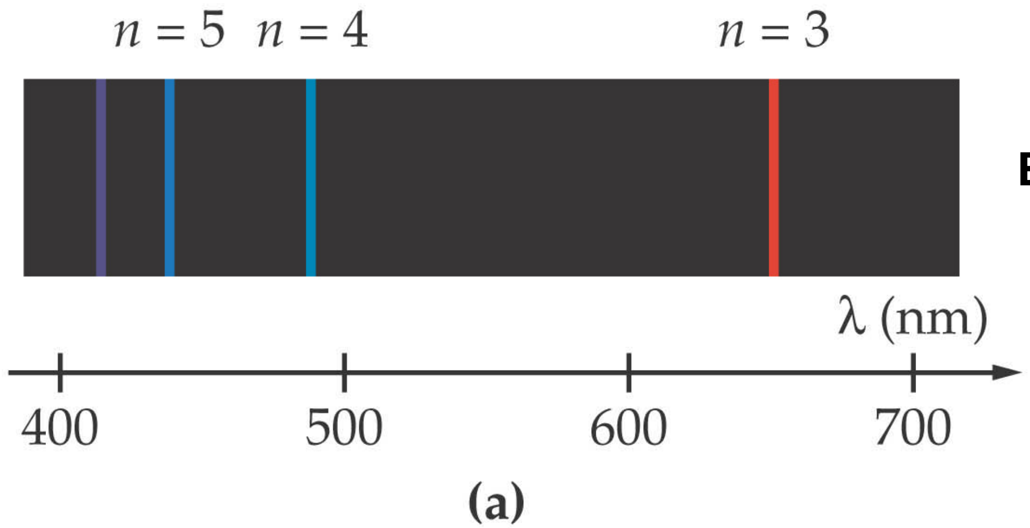
Absorption Spectrum: dark lines. Absorption of gas atom when white light goes through the gas.

Why spectrum is the fingerprint of an atom and why it is discontinuous?

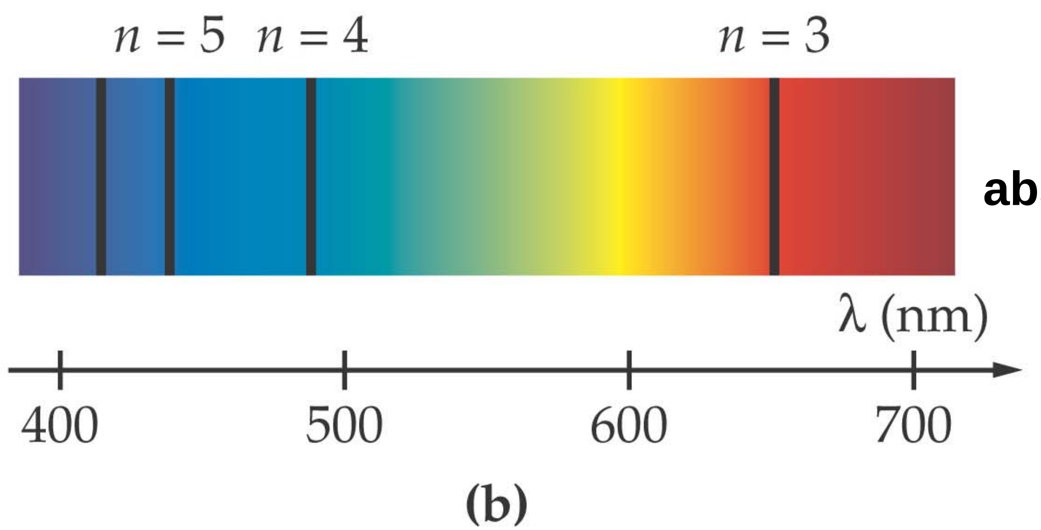
1) Since the electron of each atom has its specific energy level in its orbits that is discontinuous;

2) When the electron jump from one energy level to another energy level, it gives off or absorbs photons: $|\Delta E| = hf$.

Figure 31-4 The Line Spectrum of Hydrogen

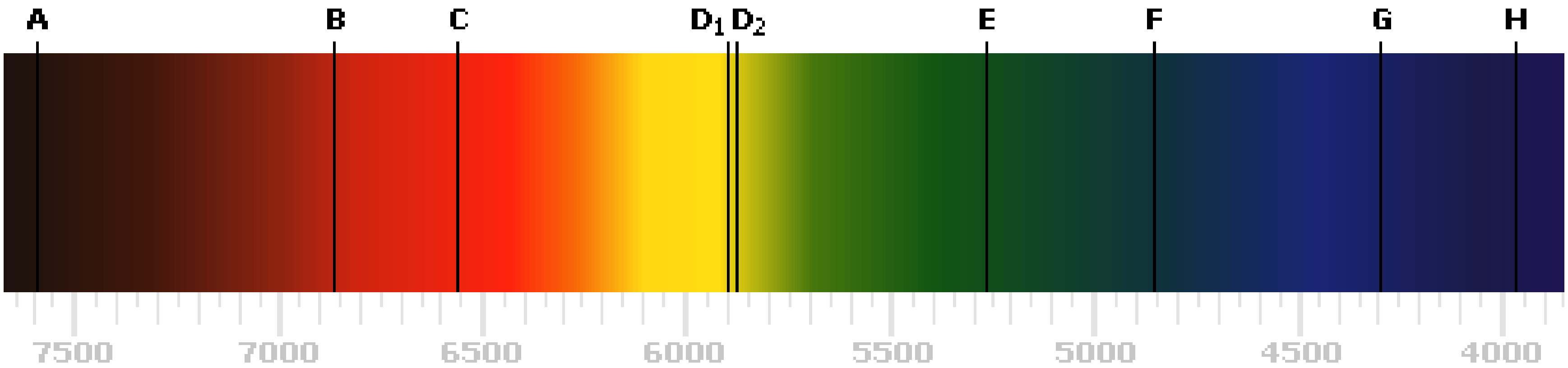


Emission spectrum lines (a);



absorption spectrum lines (b).

Spectrum of the Sun



A	extreme red	Made by terrestrial oxygen
B	red	Made by terrestrial oxygen
C	red	Made by solar hydrogen
D_1	yellow	Made by solar sodium
D_2	yellow	Made by solar sodium
E	green	Made by solar iron
F	blue	Made by solar hydrogen
G	violet	Made by solar iron and calcium group
H	extreme violet	Made by solar calcium

(In 1885) Swiss school teacher, Balmer developed an empirical formula for the calculation Hydrogen spectrum lines. This formula is expressed as:

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right), \qquad n = 3,4,5,\cdots (Balmer \quad series) \qquad 31-1$$

Unit: meter.

Where R is Rydberg constant:

$R = 1.097 \times 10^7 \ m^{-1}$

The collection of lines by the above formula is called Balmer series.

For example, n=5:

$$\frac{1}{\lambda} = (1.097 \times 10^7 m^{-1})\left(\frac{1}{2^2} - \frac{1}{5^2}\right)$$

$$so, \qquad \lambda = 4.341 \times 10^{-7} \quad m$$

Example 31-1 The Balmer Series

Find the longest and shortest wavelengths in the Balmer series of the spectral lines.

Solution:

1). The longest wavelength in Balmer series is n = 3,

$$\frac{1}{\lambda} = R(\frac{1}{2^2} - \frac{1}{n^2}) = (1.097 \times 10^7 m^{-1})(\frac{1}{2^2} - \frac{1}{3^2}),$$

$$\lambda = 653.3 \times 10^{-9} m = 653.3 \quad nm$$

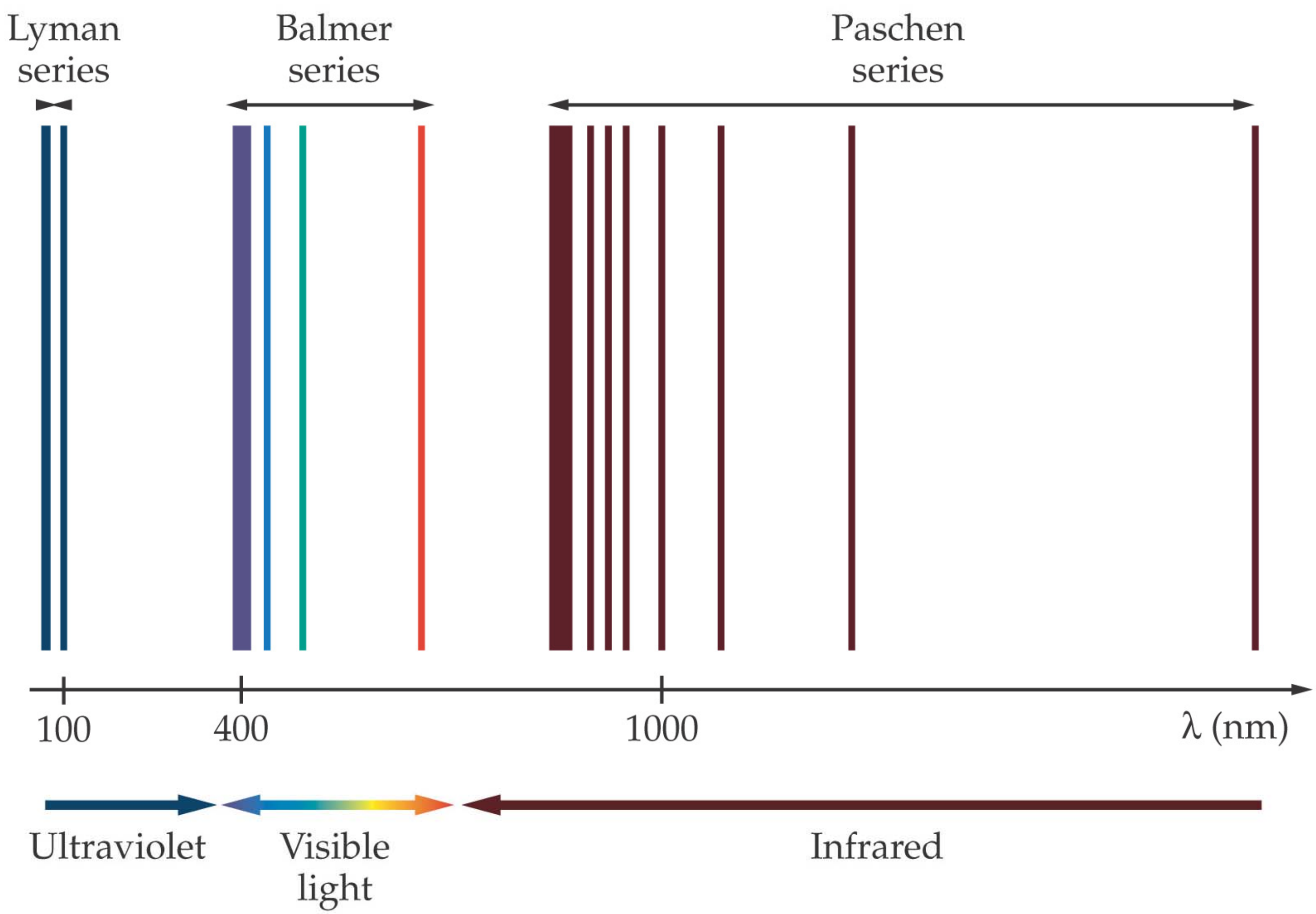
2). The shortest wavelength in Balmer series is n $\to \infty$,

$$\frac{1}{\lambda} = (1.097 \times 10^7 m^{-1})(\frac{1}{2^2} - \frac{1}{0^2}),$$

$$\lambda = 364.6 \times 10^{-9} m = 364.6 \quad nm$$

Equation 31-1 only calculate the Balmer Series spectral lines. There are other spectra:

Figure 31-5
The Lyman, Balmer, and Paschen Series of Spectral Lines



The formula that that gives the spectra in all wavelength series of hydrogen is

$$\frac{1}{\lambda} = R\left(\frac{1}{n'^2} - \frac{1}{n^2}\right), \qquad n' = 1, 2, 3, \cdots \quad n = n'+1, \quad n = n'+2, \qquad 31-2$$

Table 31-1
Common Spectral Series of Hydrogen

n'	Series name
1	Lyman
2	Balmer
3	Paschen
4	Brackett
5	Pfund

Exercise 31-1

Find (a) the shortest wavelengths in the Lyman series and (b) the longest wavelength in the Paschen series.

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Find (a) the shortest wavelengths in the Lyman series and (b) the longest wavelength in the Paschen series.

Solution:

1). Substitute n' =1 (Lyman) and n $\rightarrow \infty$ in equation 31-2:

$$\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{n^2}\right) = (1.097 \times 10^7 m^{-1})\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right),$$

$$\lambda = 91.16 \times 10^{-9} m = 91.16 \quad nm$$

2). Substitute n' =3 (Paschen) and n=4 in equation 31-2:

$$\frac{1}{\lambda} = R\left(\frac{1}{3^2} - \frac{1}{n^2}\right) = (1.097 \times 10^7 m^{-1})\left(\frac{1}{3^2} - \frac{1}{4^2}\right),$$

$$\lambda = 1875 \times 10^{-9} m = 1875 \quad nm$$

Summary

The formula that that gives the spectra in all wavelength series of hydrogen is

$$\frac{1}{\lambda} = R\left(\frac{1}{n'^2} - \frac{1}{n^2}\right), \qquad n' = 1, 2, 3, \cdots \qquad n = n'+1, \quad n = n'+2, \qquad 31-2$$

Table 31-1
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