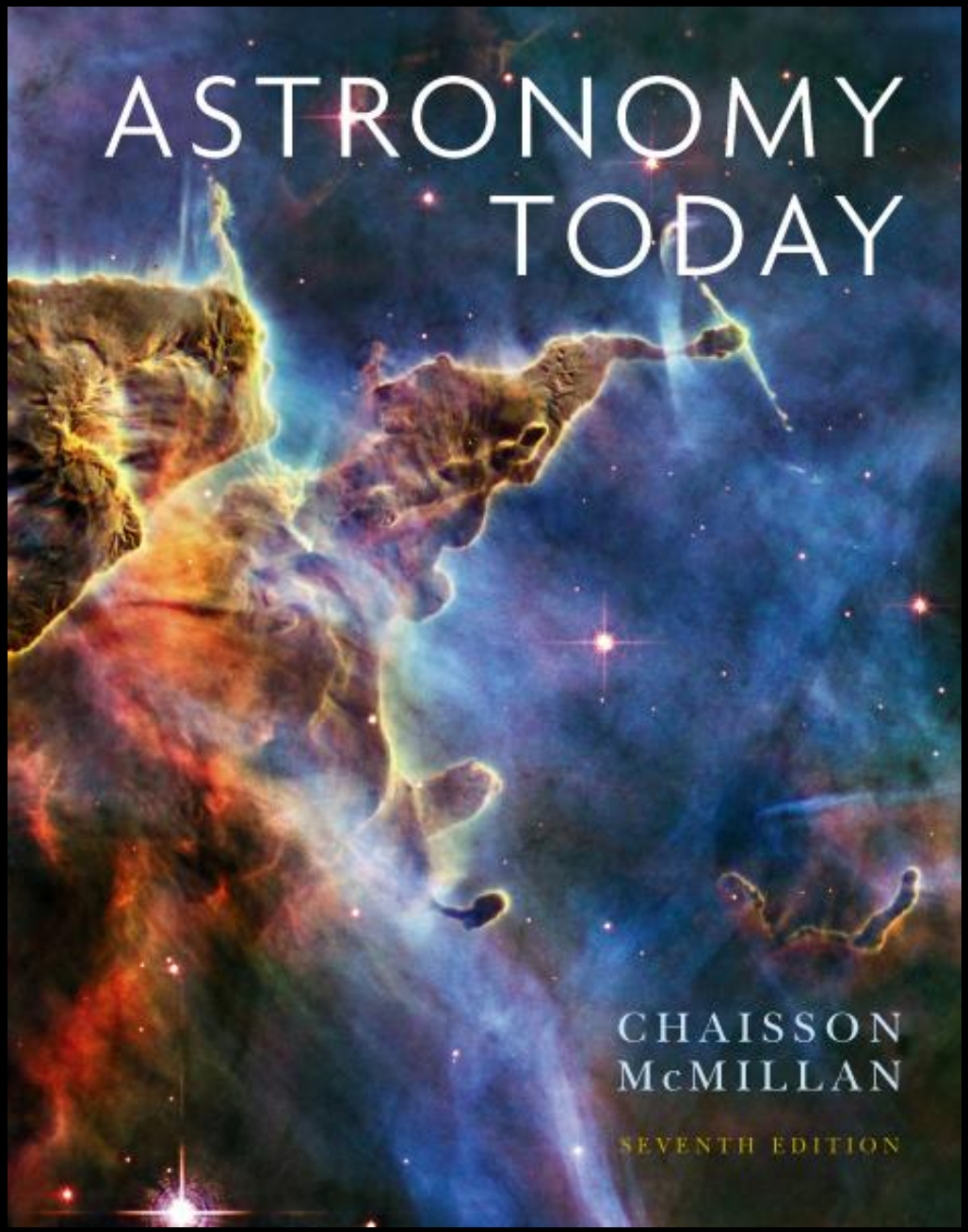


Lecture Outlines

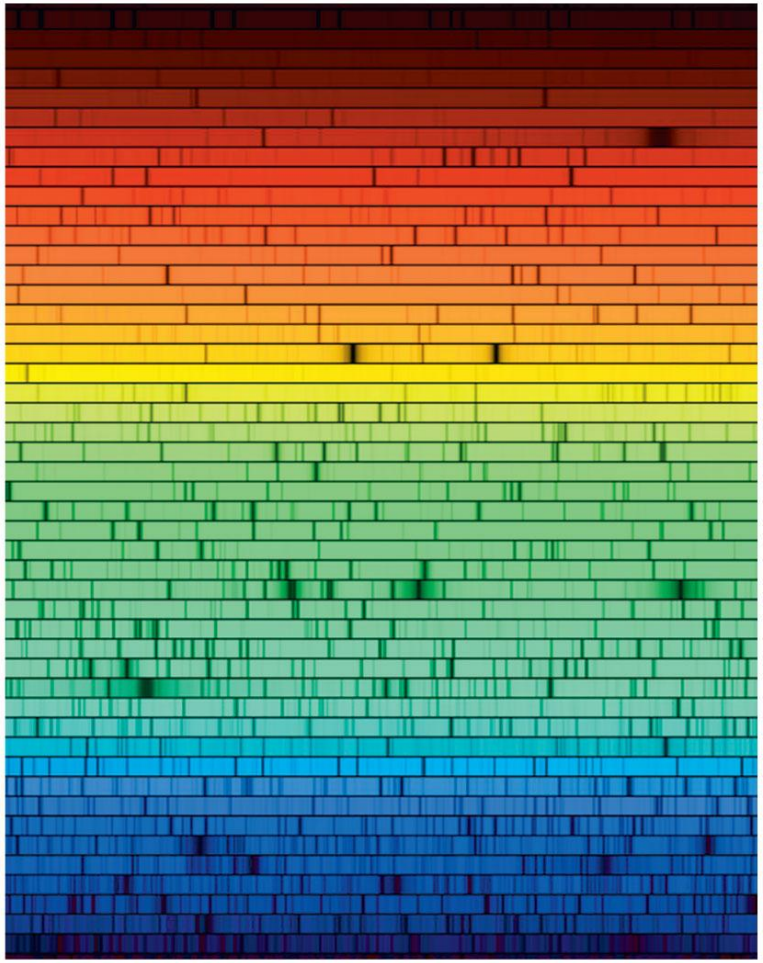
Chapter 4

Astronomy Today

7th Edition

Chaisson/McMillan

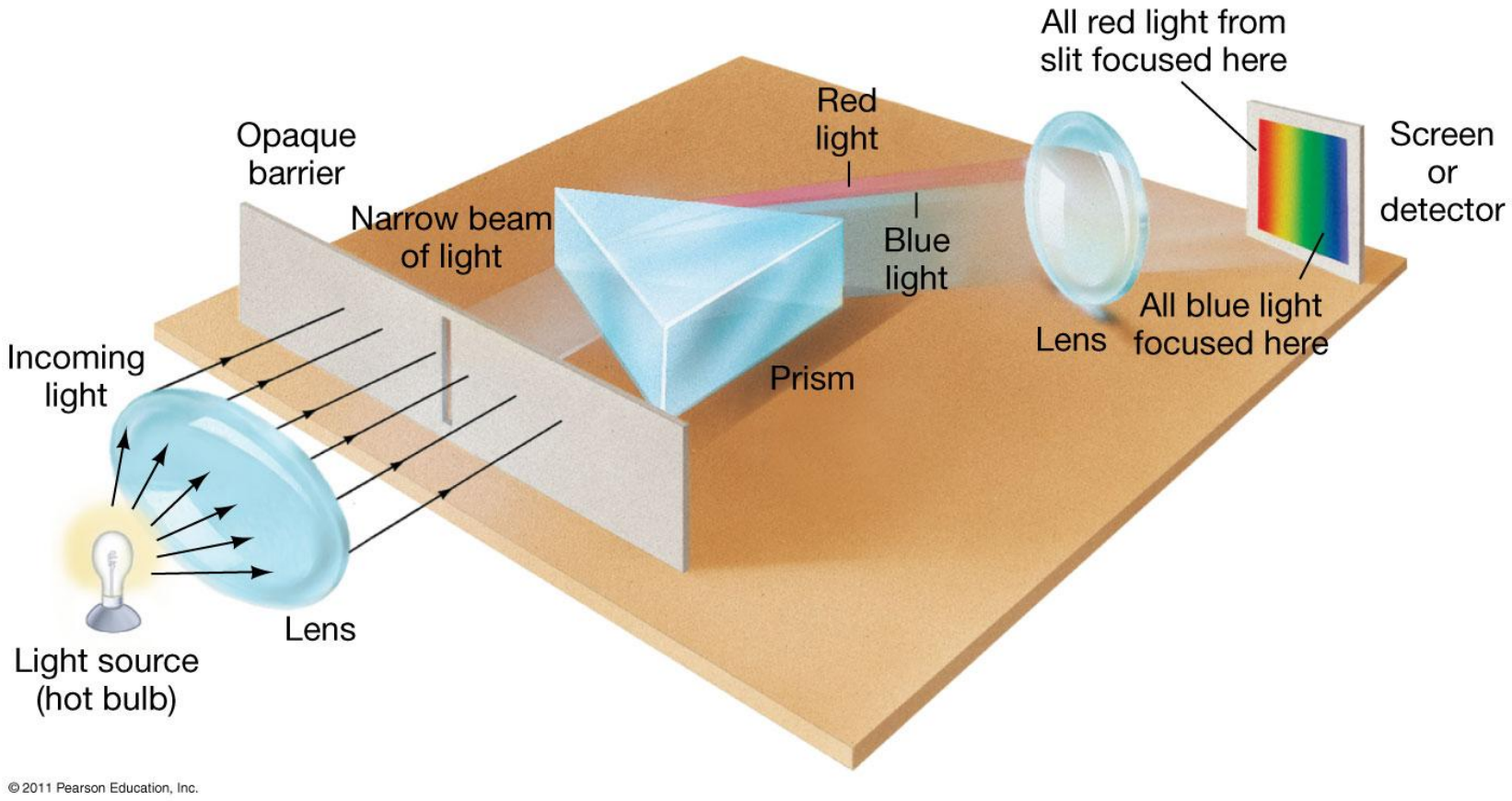
Chapter 4
Spectroscopy



Units of Chapter 4

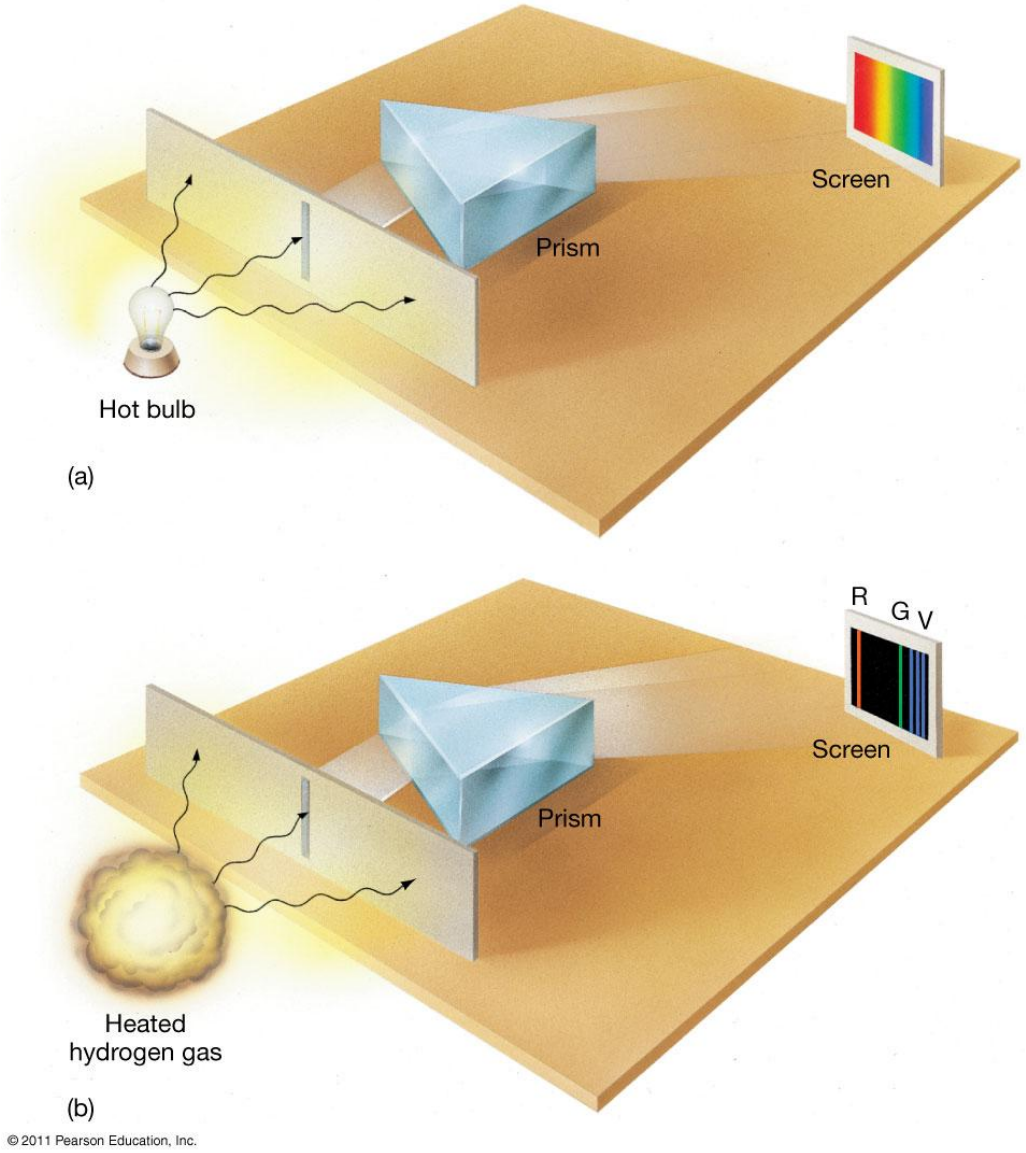
4.1 Spectral Lines

Spectroscope: Splits light into component colors



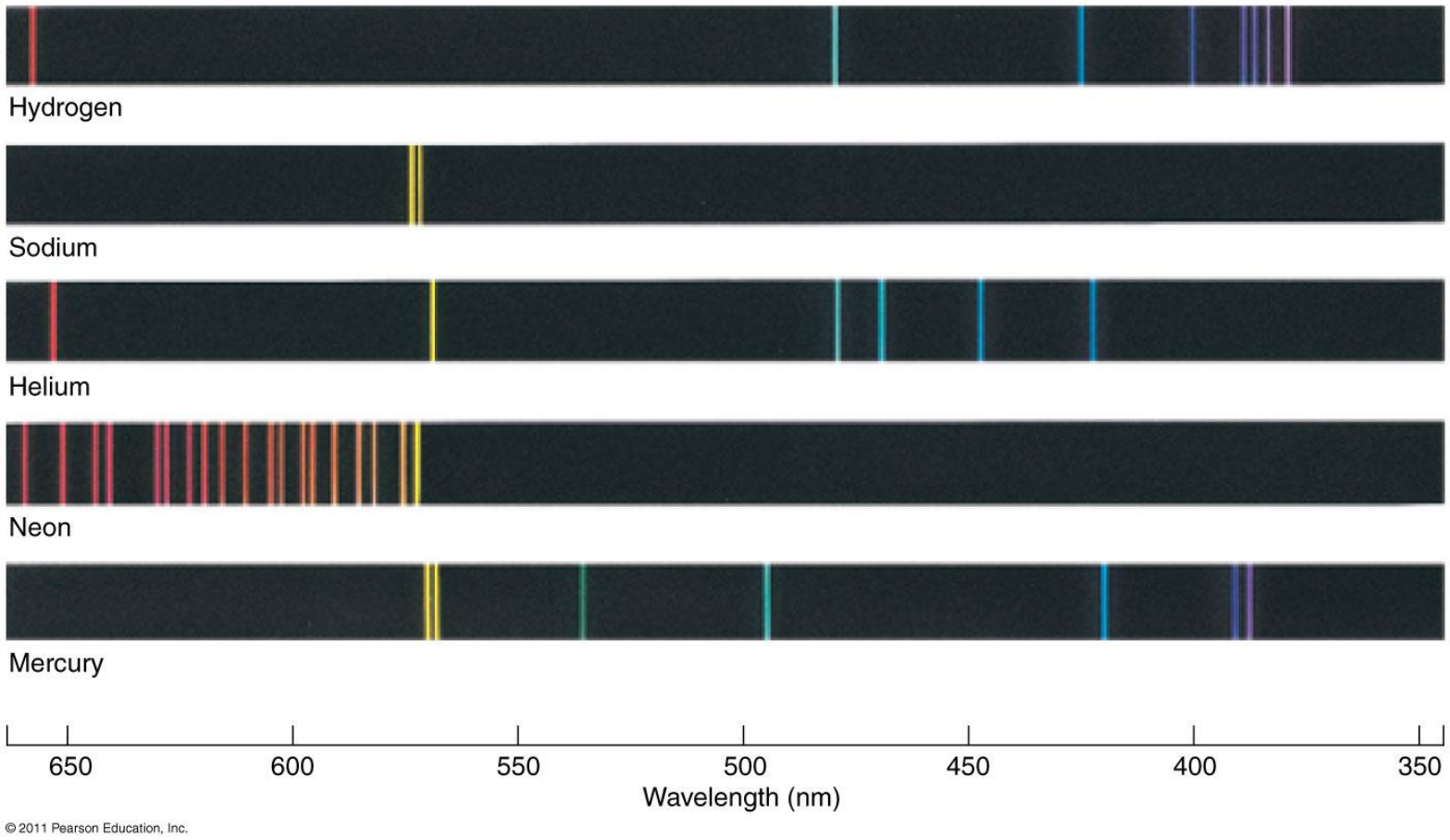
4.1 Spectral Lines

Emission lines:
Single frequencies emitted by particular atoms



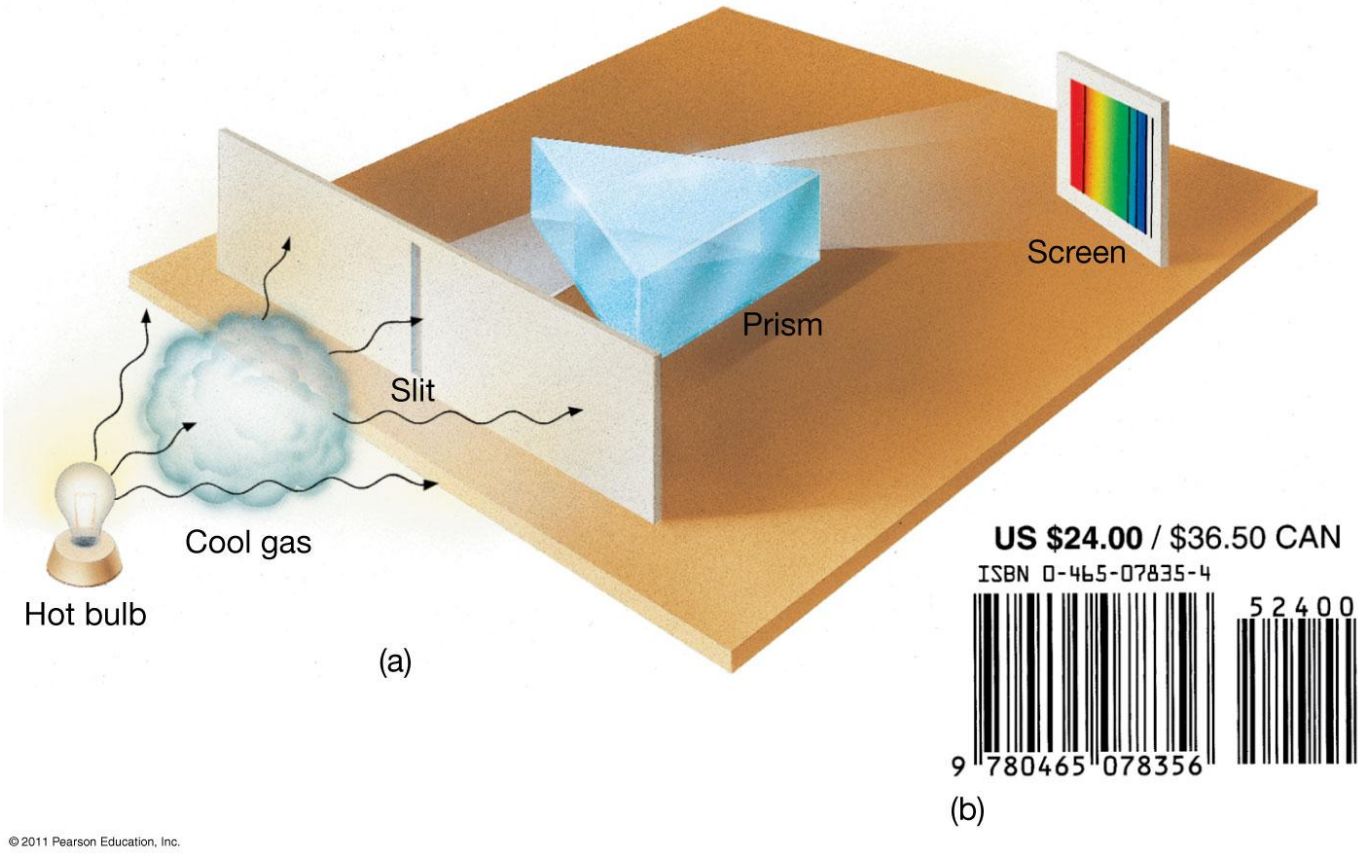
4.1 Spectral Lines

Emission spectrum can be used to identify elements



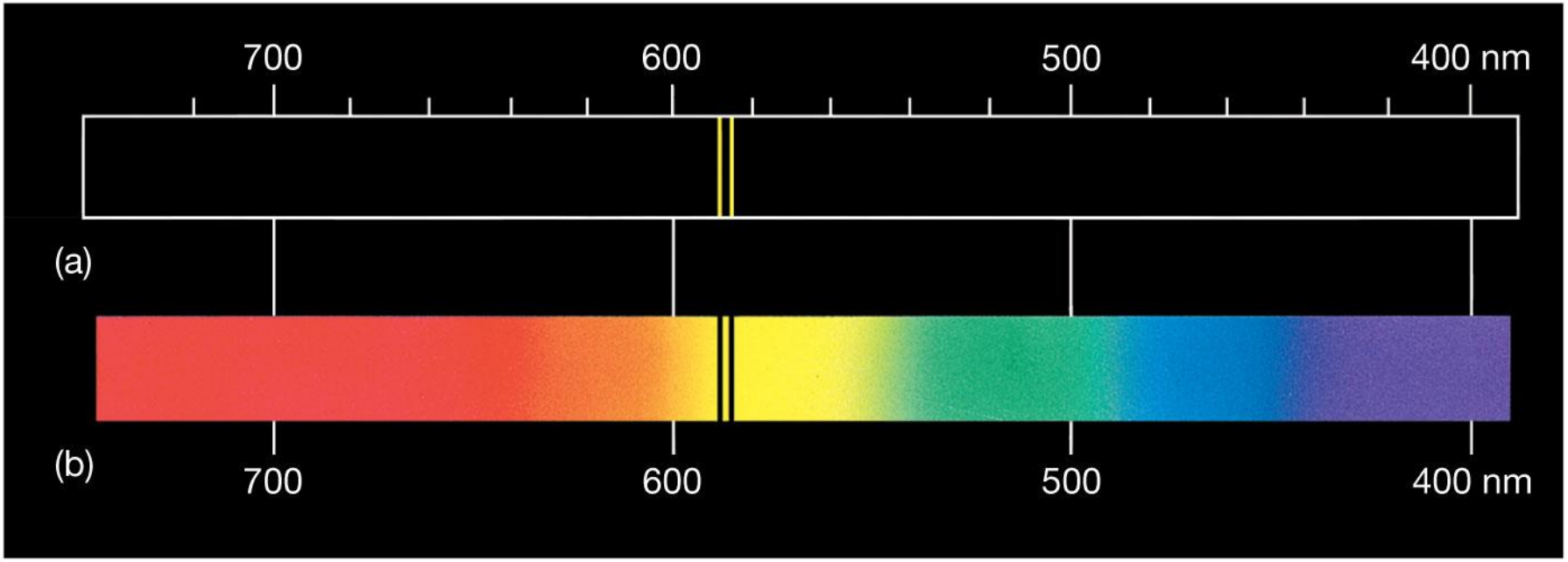
4.1 Spectral Lines

Absorption spectrum: If a continuous spectrum passes through a cool gas, atoms of the gas will absorb the same frequencies they emit



4.1 Spectral Lines

An absorption spectrum can also be used to identify elements. These are the emission and absorption spectra of sodium:



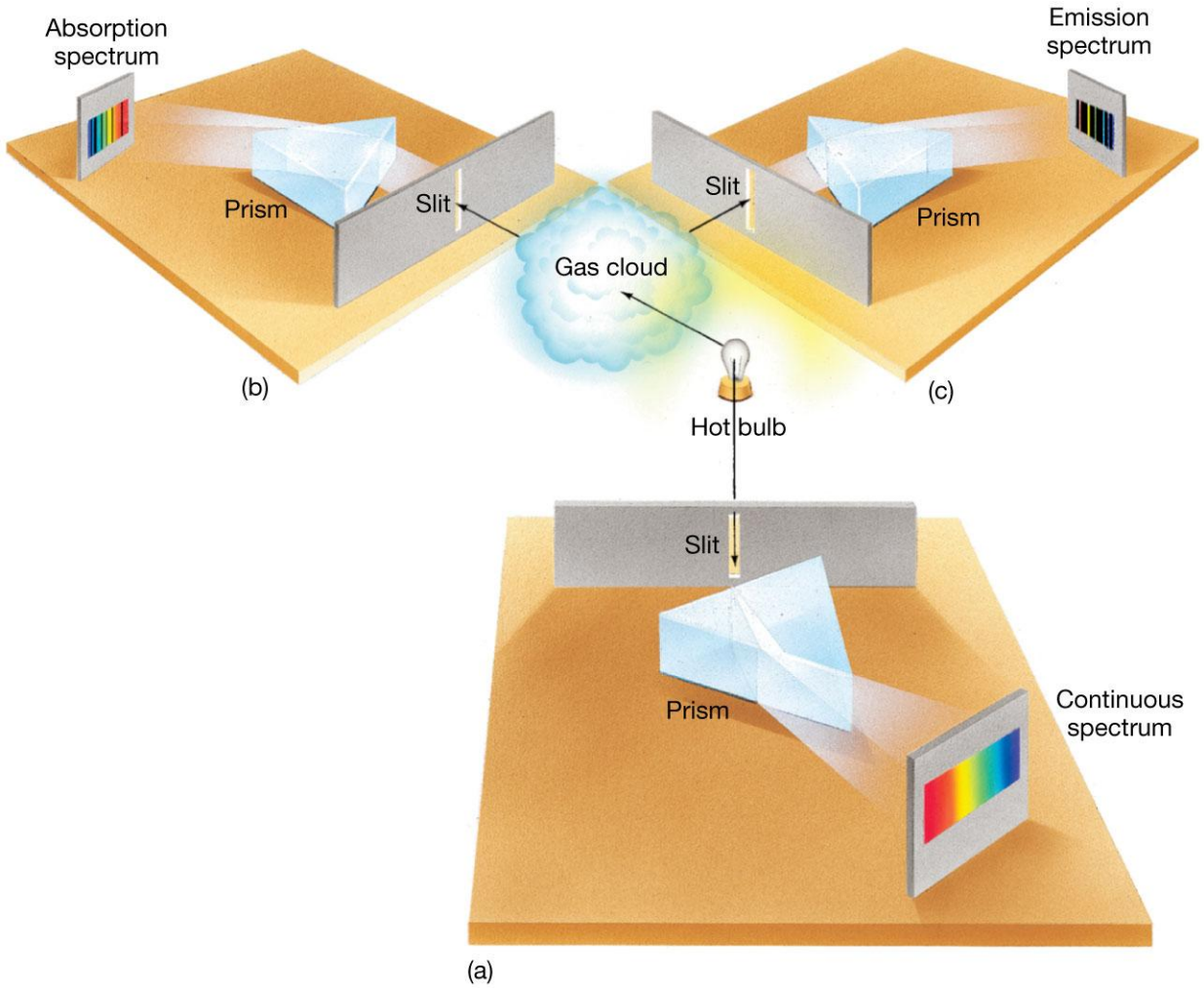
4.1 Spectral Lines

Kirchhoff's laws:

- **Luminous solid, liquid, or dense gas produces continuous spectrum**
- **Low-density hot gas produces emission spectrum**
- **Continuous spectrum incident on cool, thin gas produces absorption spectrum**

4.1 Spectral Lines

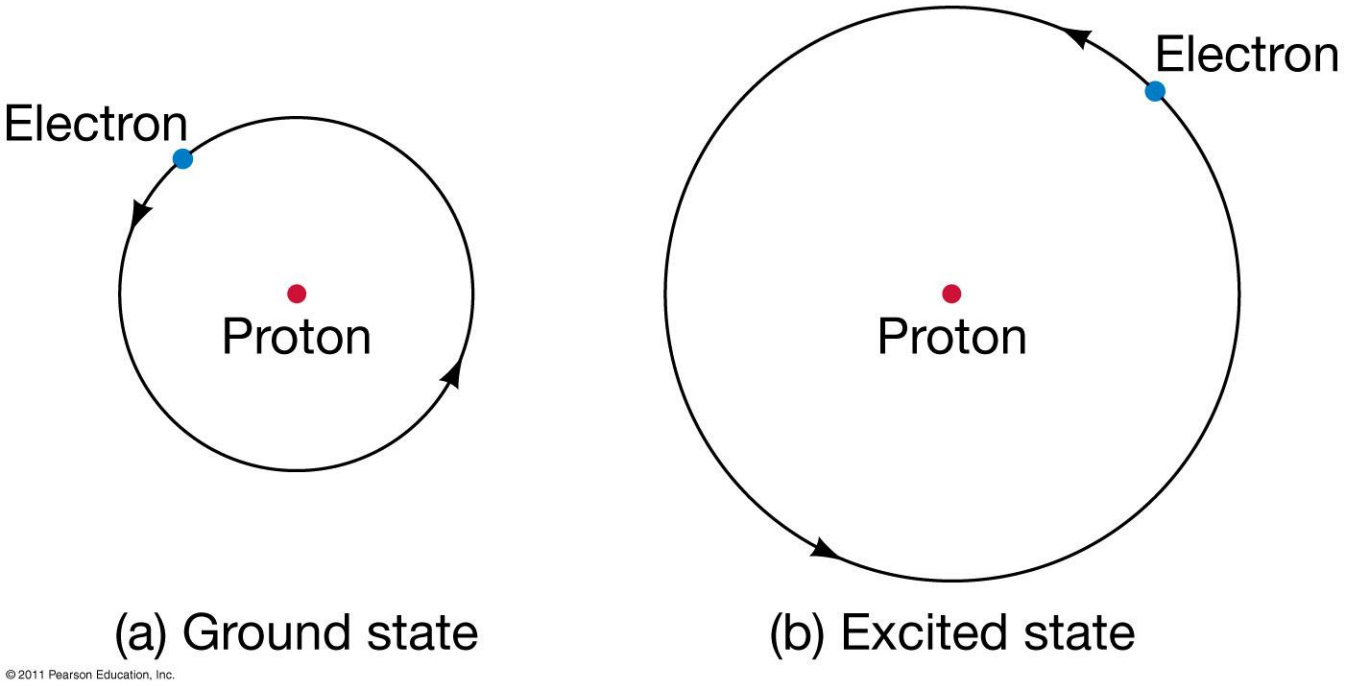
Kirchhoff's laws illustrated



4.2 Atoms and Radiation

Existence of spectral lines required new model of atom, so that only certain amounts of energy could be emitted or absorbed

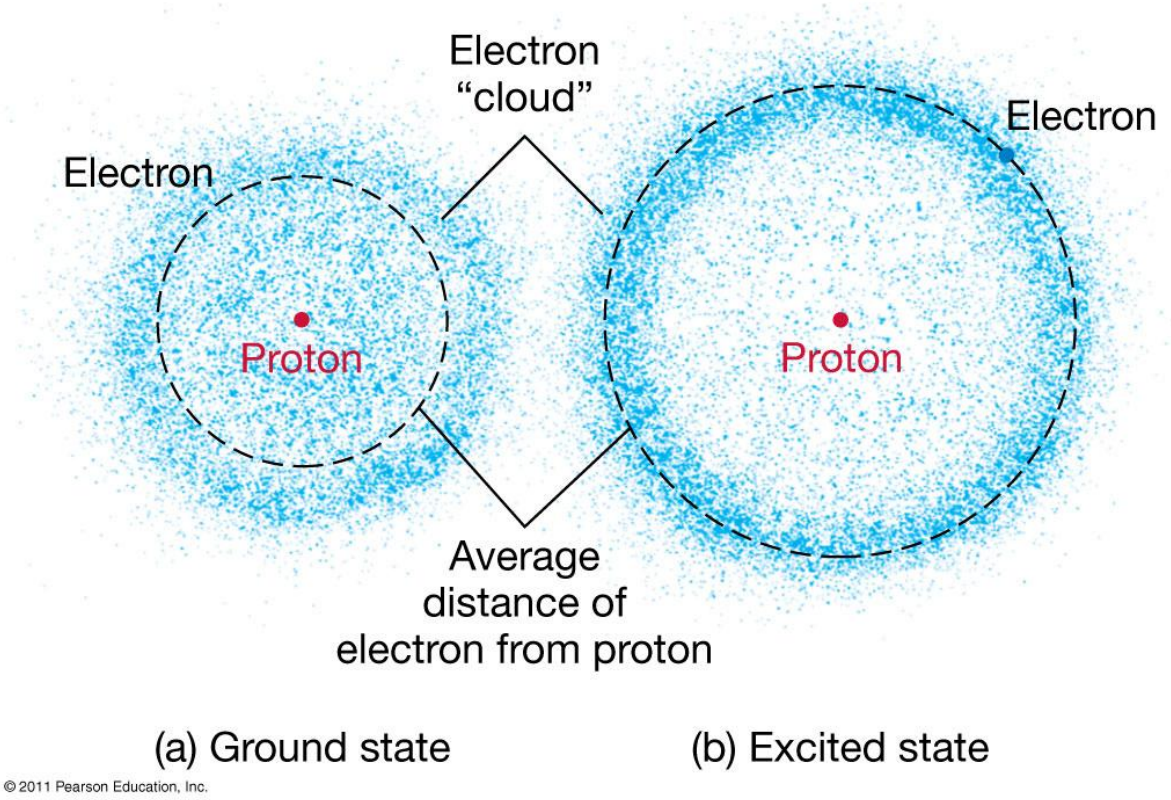
Bohr model had certain allowed orbits for electron



4.2 Atoms and Radiation

Emission energies correspond to energy differences between allowed levels

Modern model has electron "cloud" rather than orbit



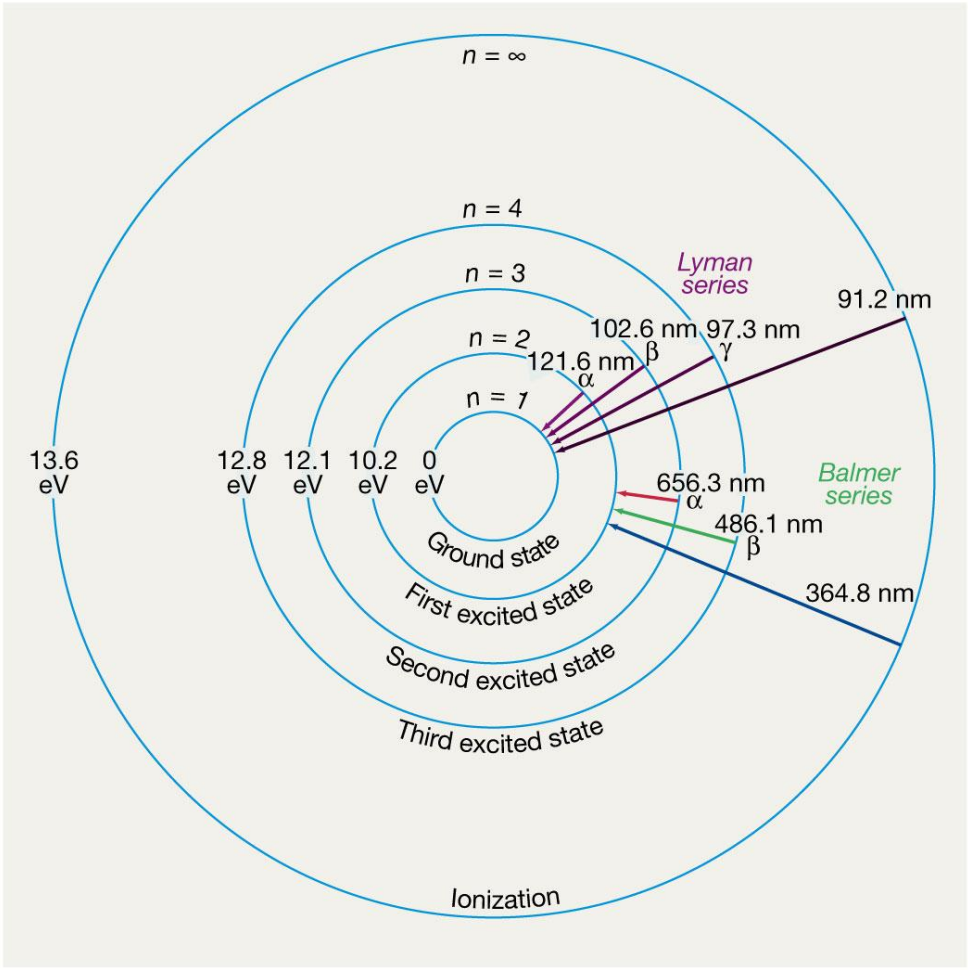
More Precisely 4-1: The Hydrogen Atom

Energy levels of the hydrogen atom, showing two series of emission lines:

The energies of the electrons in each orbit are given by:

$$E_n = 13.6\left(1 - \frac{1}{n^2}\right)\text{ eV}.$$

The emission lines correspond to the energy differences



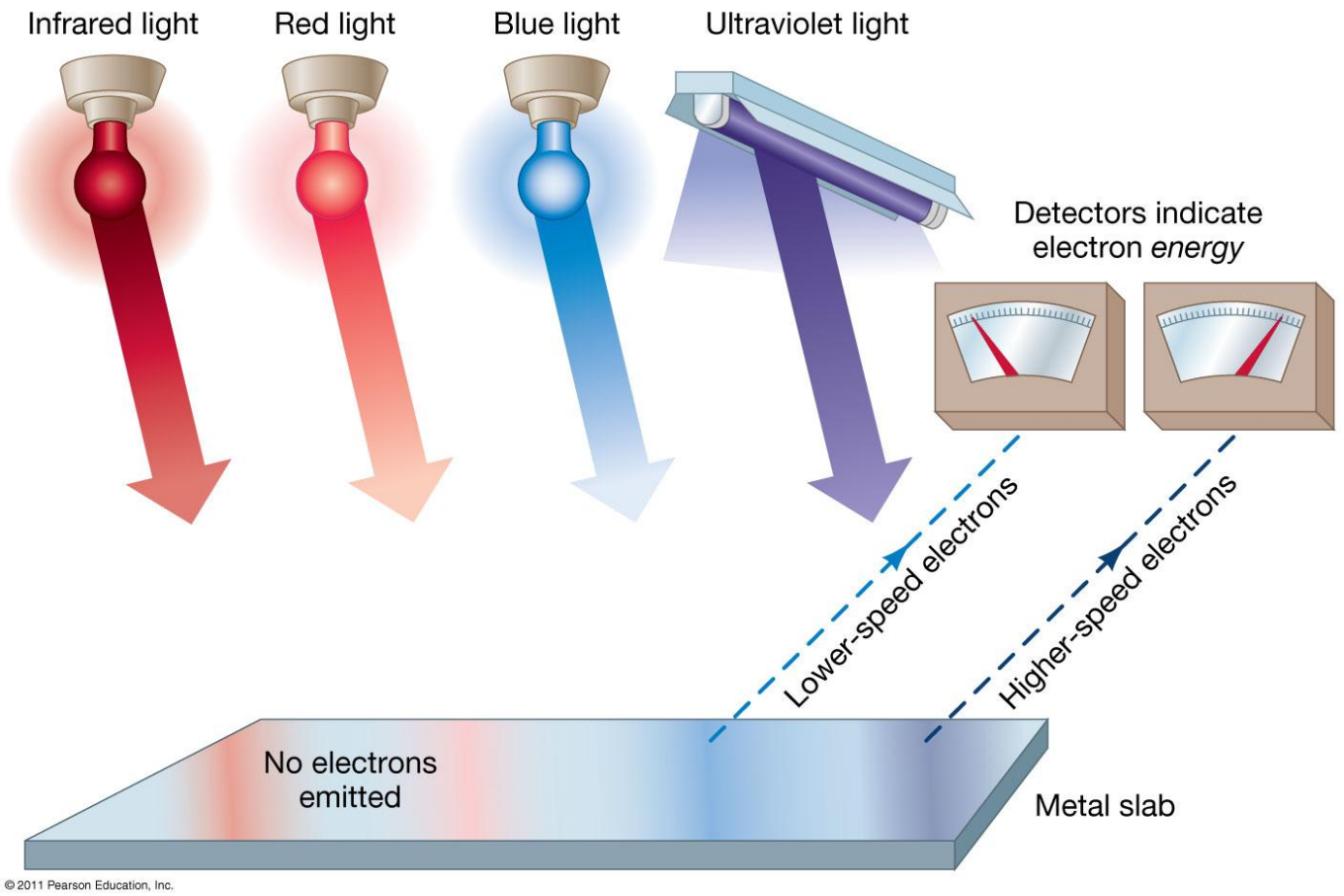
Discovery 4-1: The Photoelectric Effect

The photoelectric effect:

- **When light shines on metal, electrons can be emitted**
- **Frequency must be higher than minimum, characteristic of material**
- **Increased frequency—more energetic electrons**
- **Increased intensity—more electrons, same energy**

Discovery 4-1: The Photoelectric Effect

Photoelectric effect can only be understood if light behaves like particles



4.2 Atoms and Radiation

Light particles each have energy *E*:

$$E = hf$$

Here, *h* is Planck's constant:

$$h = 6.63 \times 10^{-34} \text{ joule seconds } (\text{J} \cdot \text{ s})$$

4.3 The Formation of Spectral Lines

Absorption can boost an electron to the second (or higher) excited state

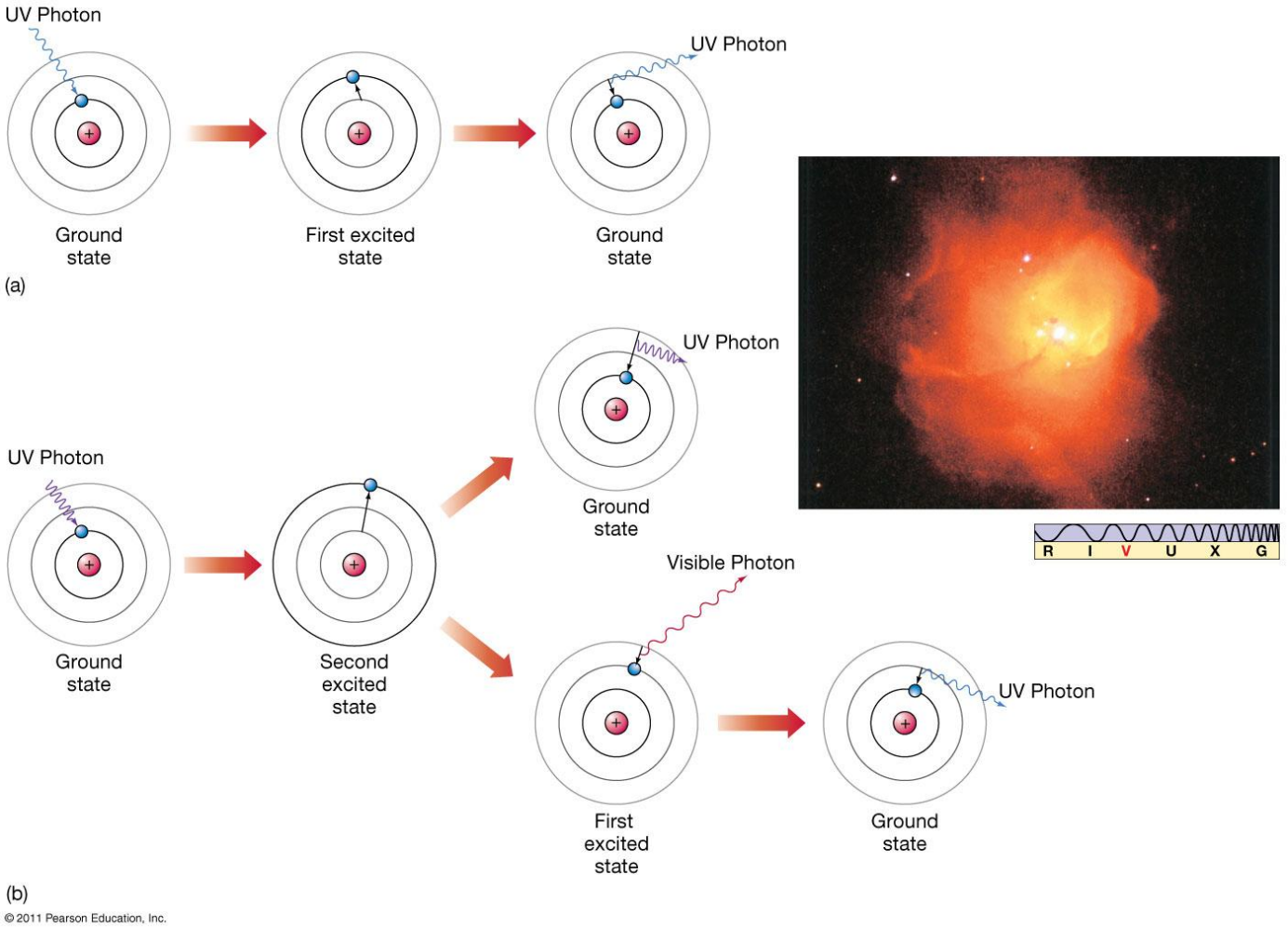
Two ways to decay:

1. **Directly to ground state**
2. **Cascade one orbital at a time**

4.3 The Formation of Spectral Lines

(a) Direct decay

(b) Cascade

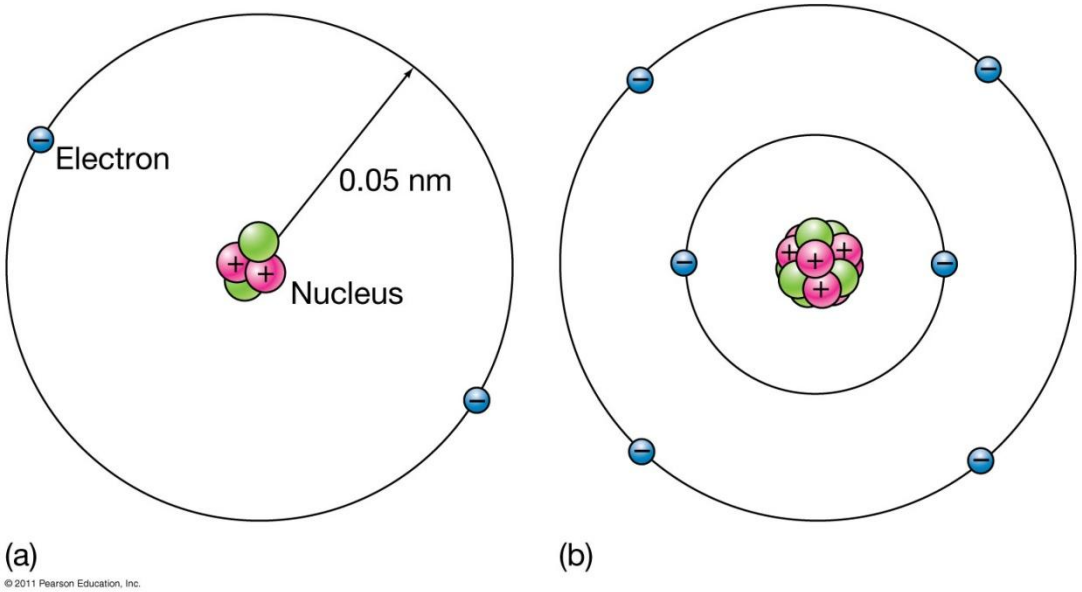


4.3 The Formation of Spectral Lines

Absorption spectrum: **Created when atoms absorb photons of right energy for excitation**

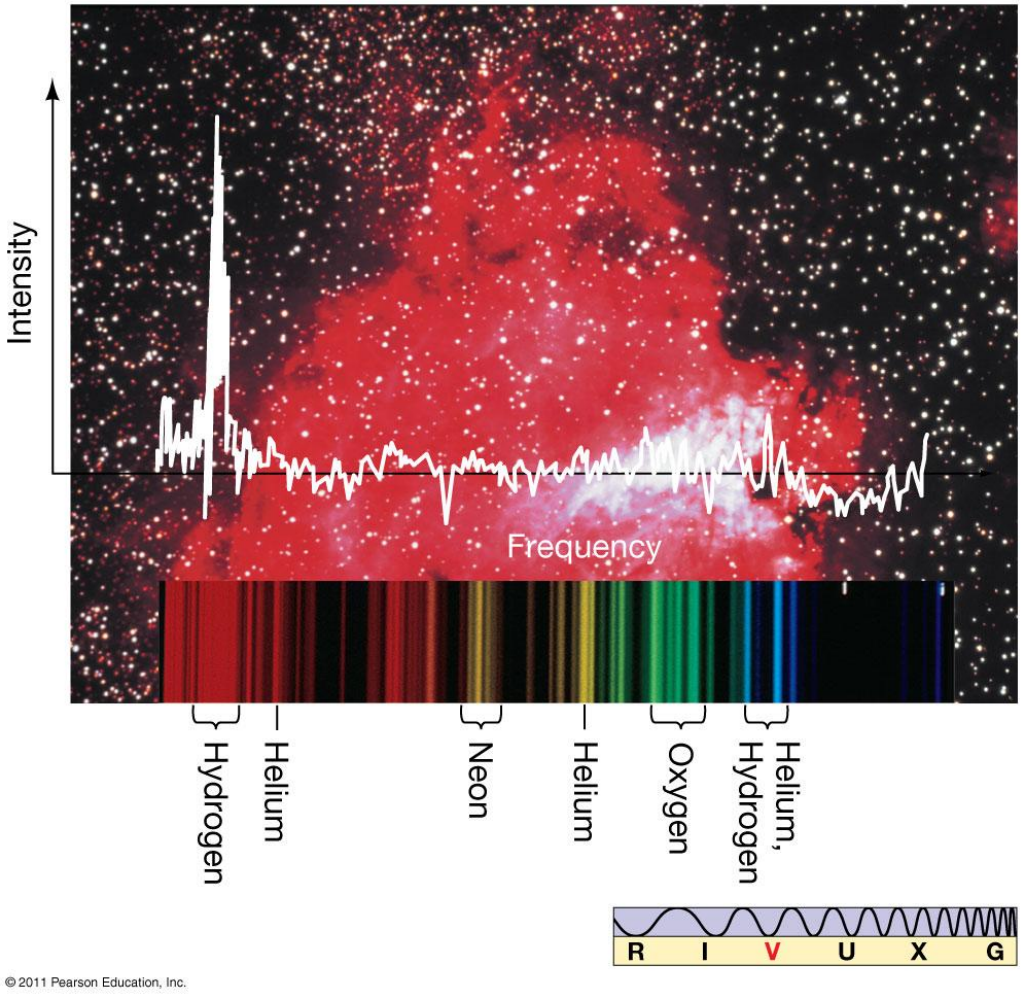
Multielectron atoms: **Much more complicated spectra, many more possible states**

Ionization **changes energy levels**



4.3 The Formation of Spectral Lines

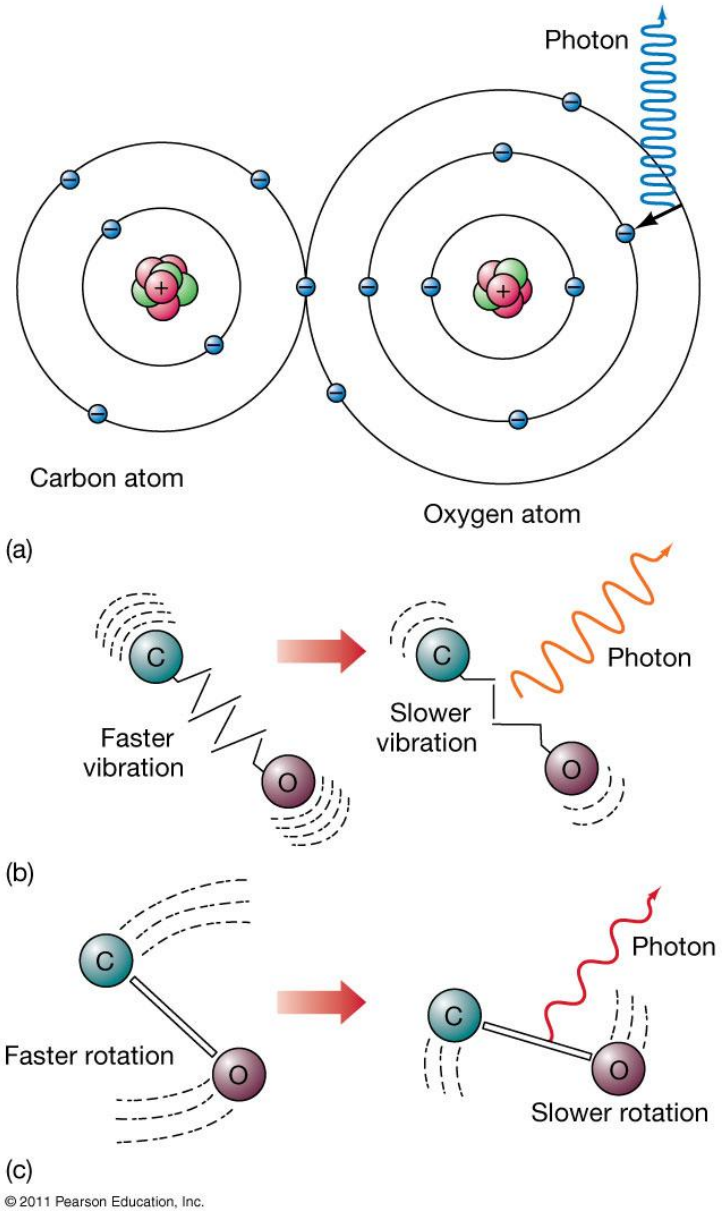
Emission lines can be used to identify atoms



4.4 Molecules

Molecules can vibrate and rotate, besides having energy levels

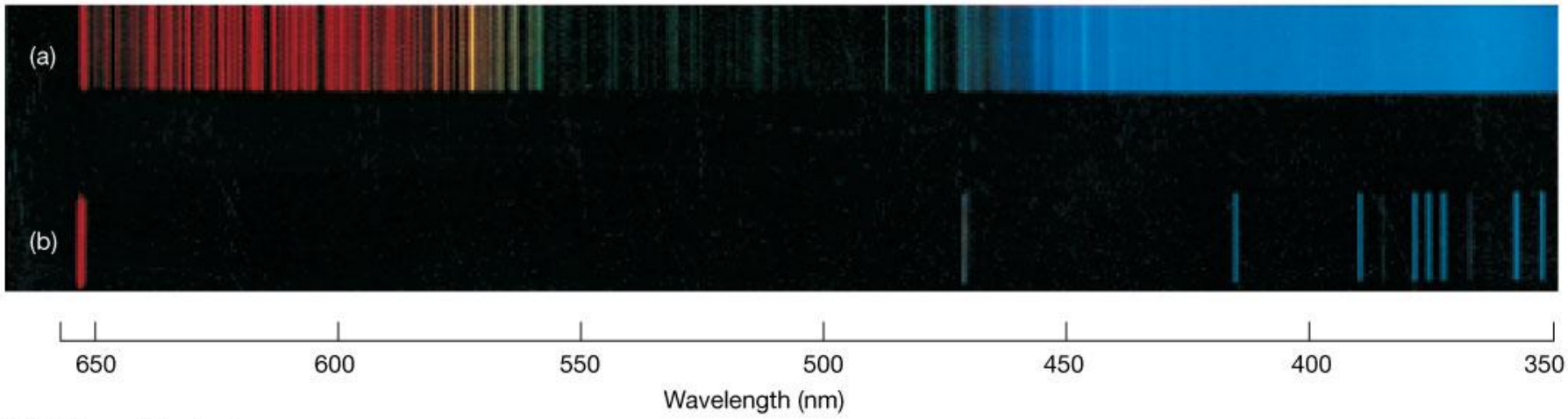
- **Electron transitions** produce visible and ultraviolet lines
- **Vibrational transitions** produce infrared lines
- **Rotational transitions** produce radio-wave lines



4.4 Molecules

Molecular spectra **are much more complex than atomic spectra, even for hydrogen**

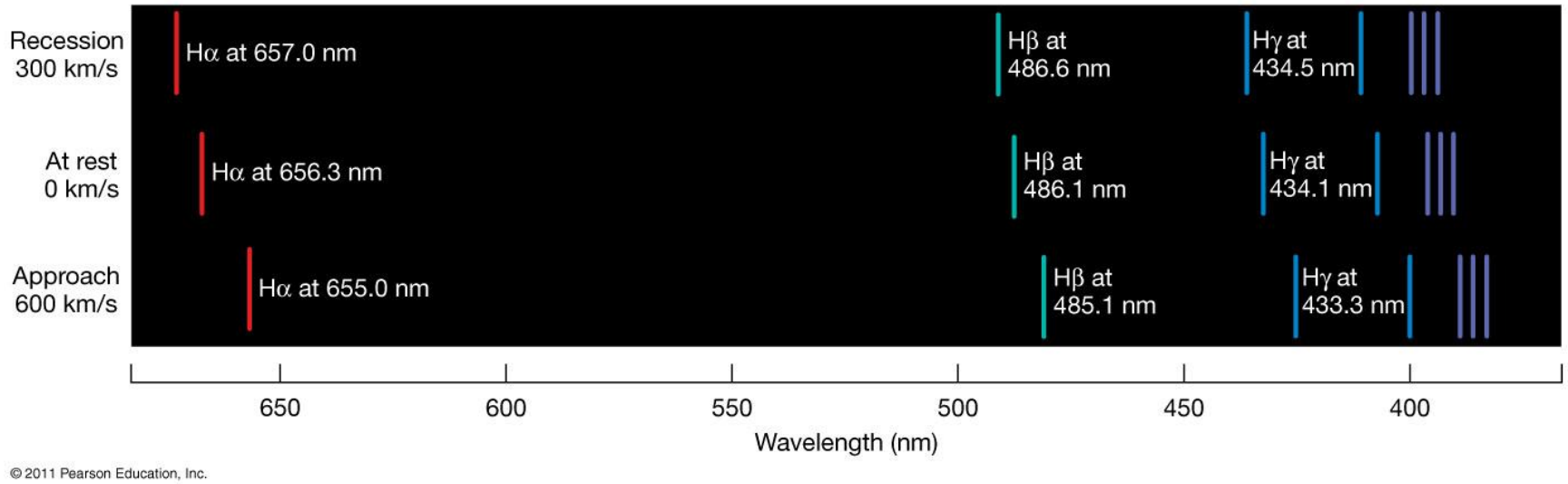
(a) Molecular hydrogen **(b) Atomic hydrogen**



4.5 Spectral-Line Analysis

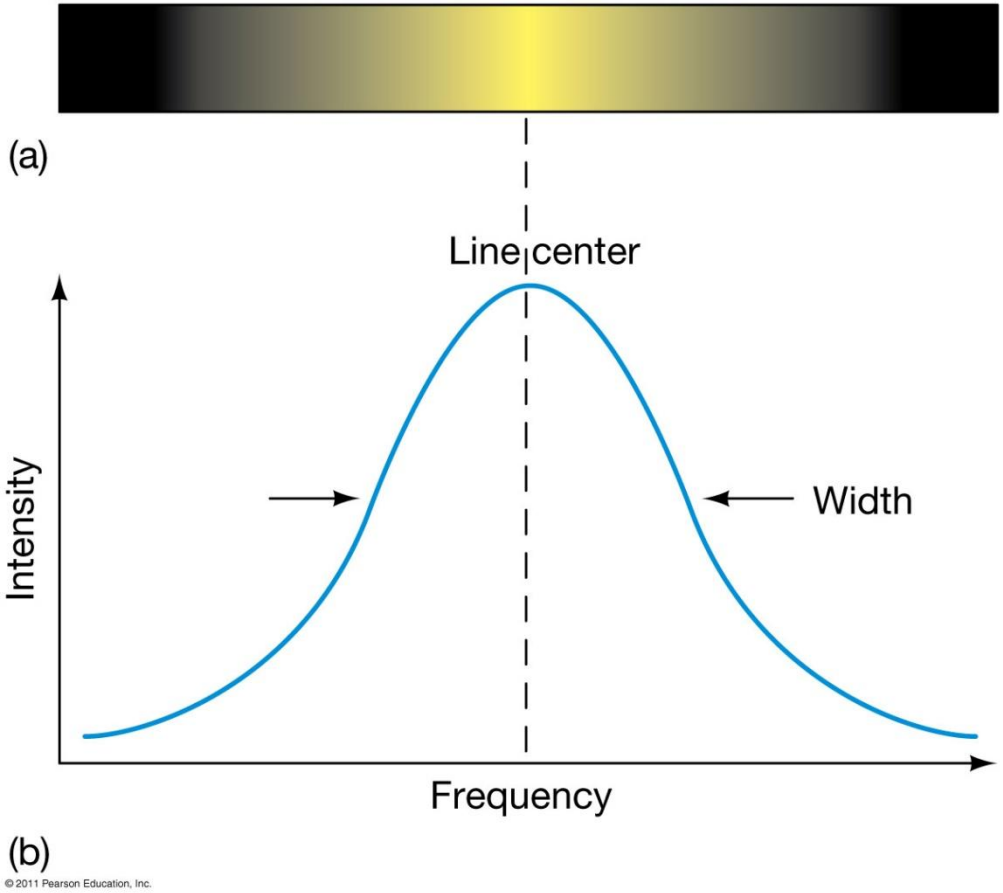
Information that can be gleaned from spectral lines:

- **Chemical composition**
- **Temperature**
- **Radial velocity**



4.5 Spectral-Line Analysis

Line broadening
can be due to a variety of causes



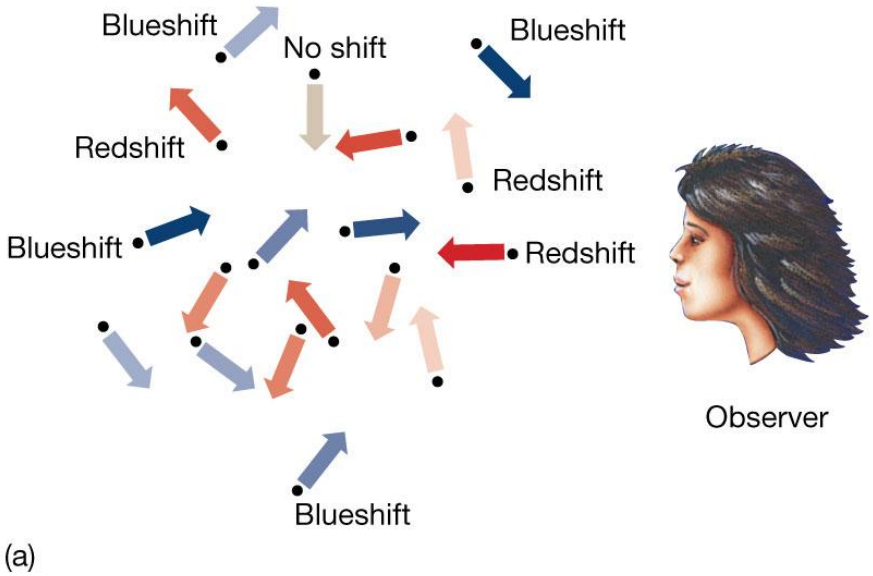
4.5 Spectral-Line Analysis

TABLE 4.1 Spectral Information Derived from Starlight

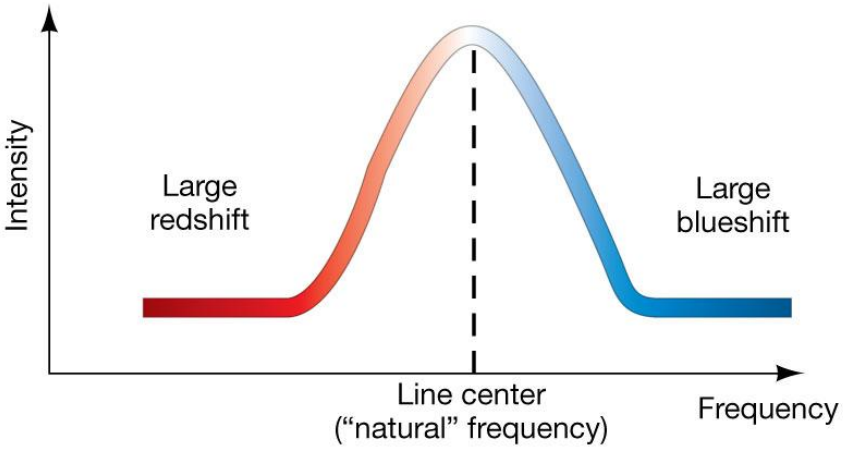
Observed Spectral Characteristic	Information Provided
Peak frequency or wavelength (continuous spectra only)	Temperature (Wien's law)
Lines present	Composition, temperature
Line intensities	Composition, temperature
Line width	Temperature, turbulence, rotation speed, density, magnetic field
Doppler shift	Line-of-sight velocity

4.5 Spectral-Line Analysis

The Doppler shift may cause thermal broadening of spectral lines



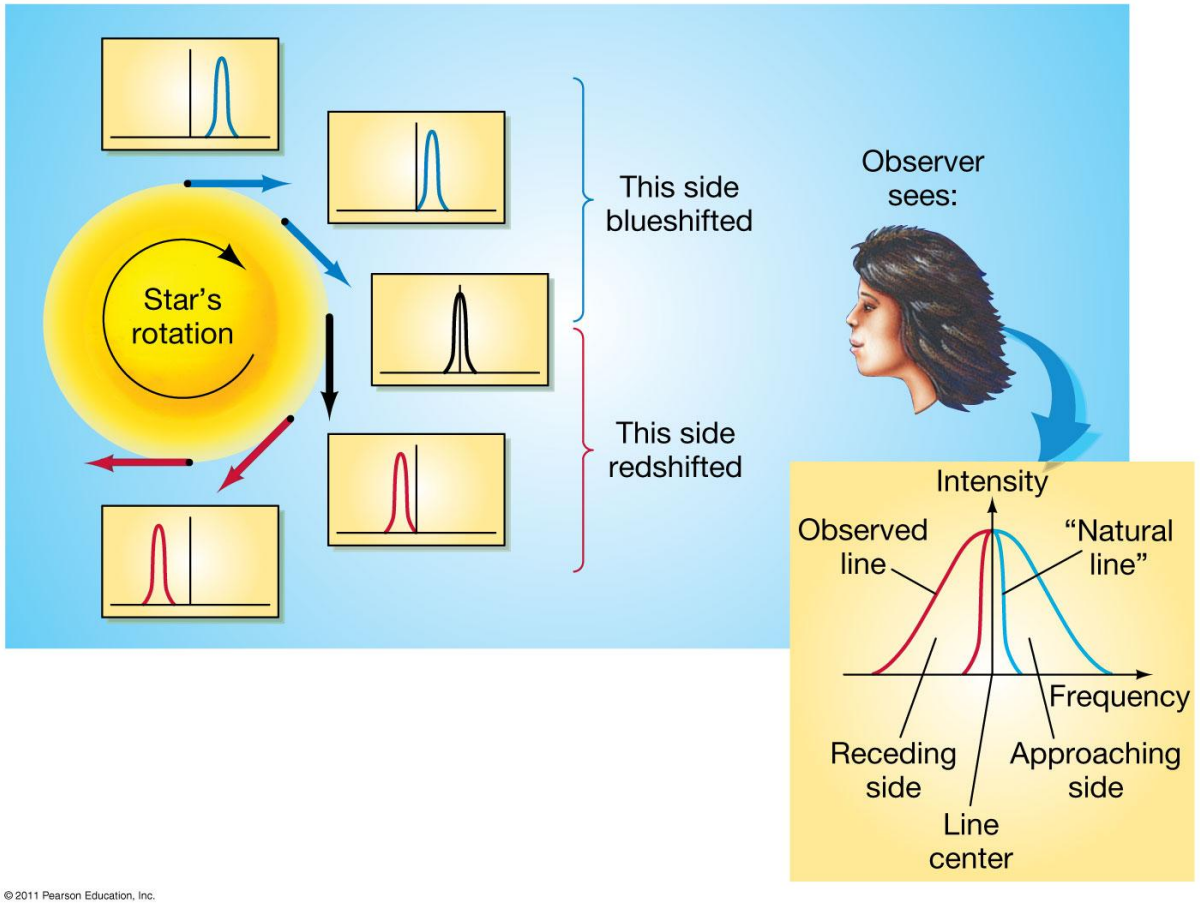
(a)



(b)

4.5 Spectral-Line Analysis

Rotation will also cause broadening of spectral lines through the Doppler effect



Summary of Chapter 4

- **Spectroscope splits light beam into component frequencies**
- **Continuous spectrum is emitted by solid, liquid, and dense gas**
- **Hot gas has characteristic emission spectrum**
- **Continuous spectrum incident on cool, thin gas gives characteristic absorption spectrum**

Summary of Chapter 4 (cont.)

- **Spectra can be explained using atomic models, with electrons occupying specific orbitals**
- **Emission and absorption lines result from transitions between orbitals**
- **Molecules can also emit and absorb radiation when making transitions between vibrational or rotational states**