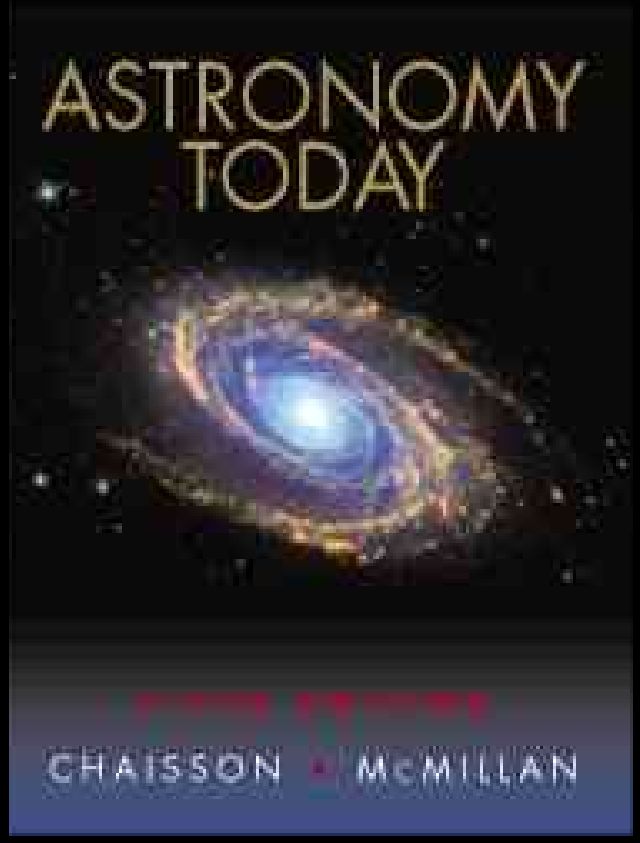


Lecture PowerPoint

Chapter 4

Astronomy Today,

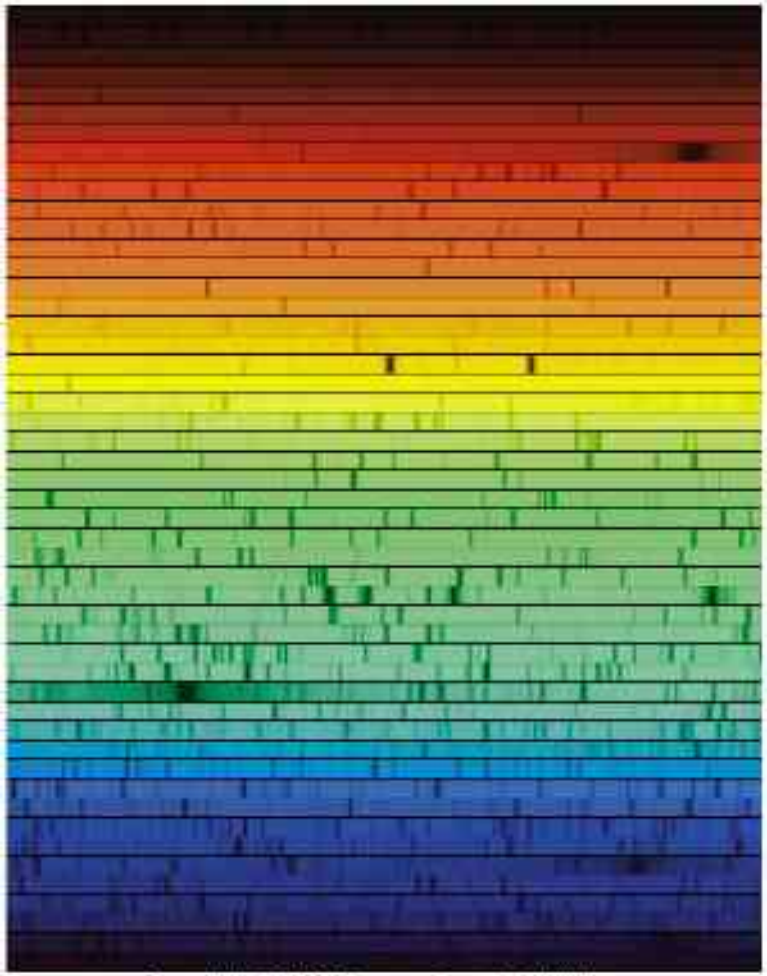
5th edition

Chaisson

McMillan

Chapter 4

Spectroscopy



Units of Chapter 4

Spectral Lines

The Formation of Spectral Lines

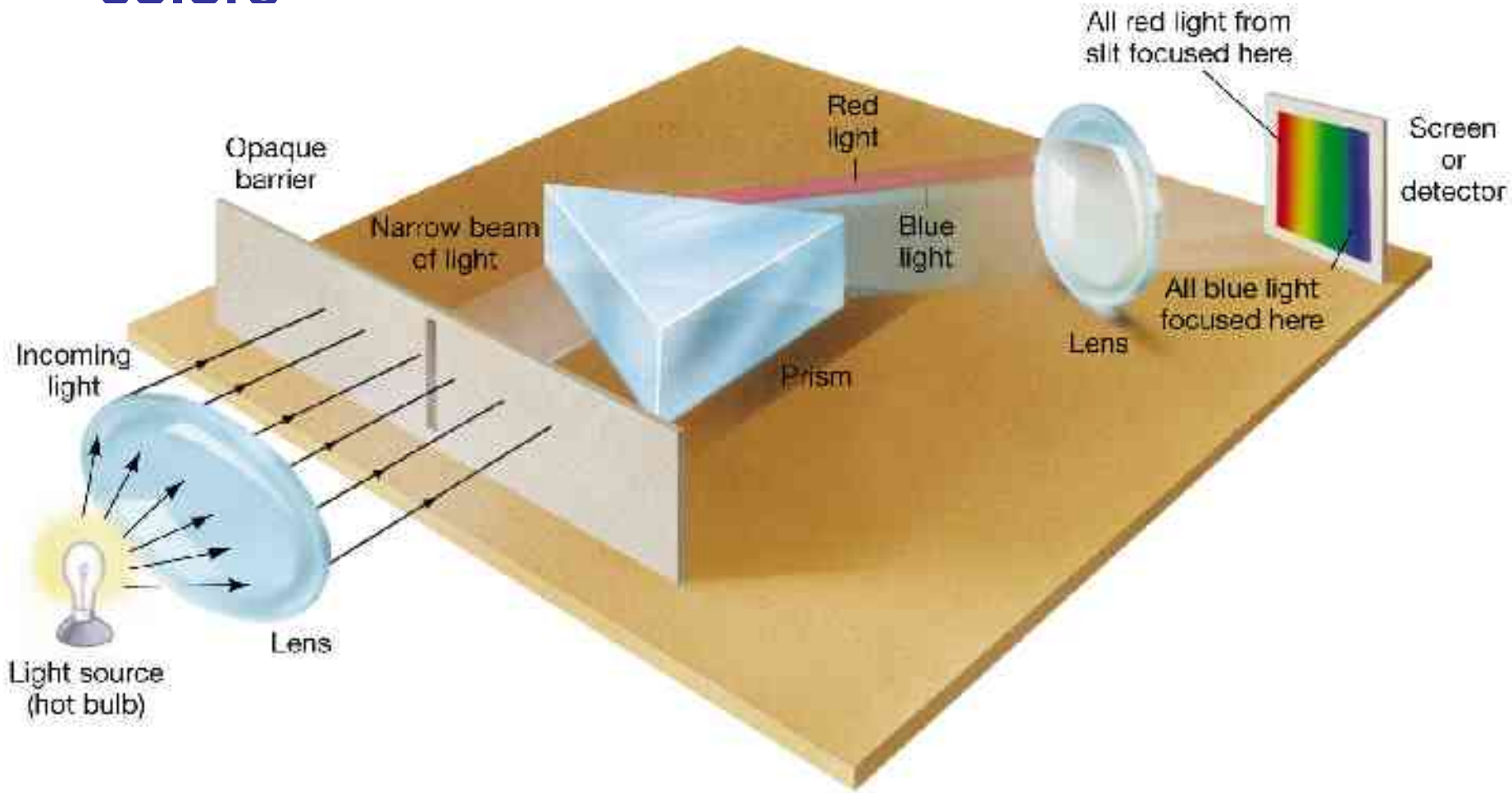
- The Energy Levels of the Hydrogen Atom
- The Photoelectric Effect

Molecules (skip)

Spectral-Line Analysis

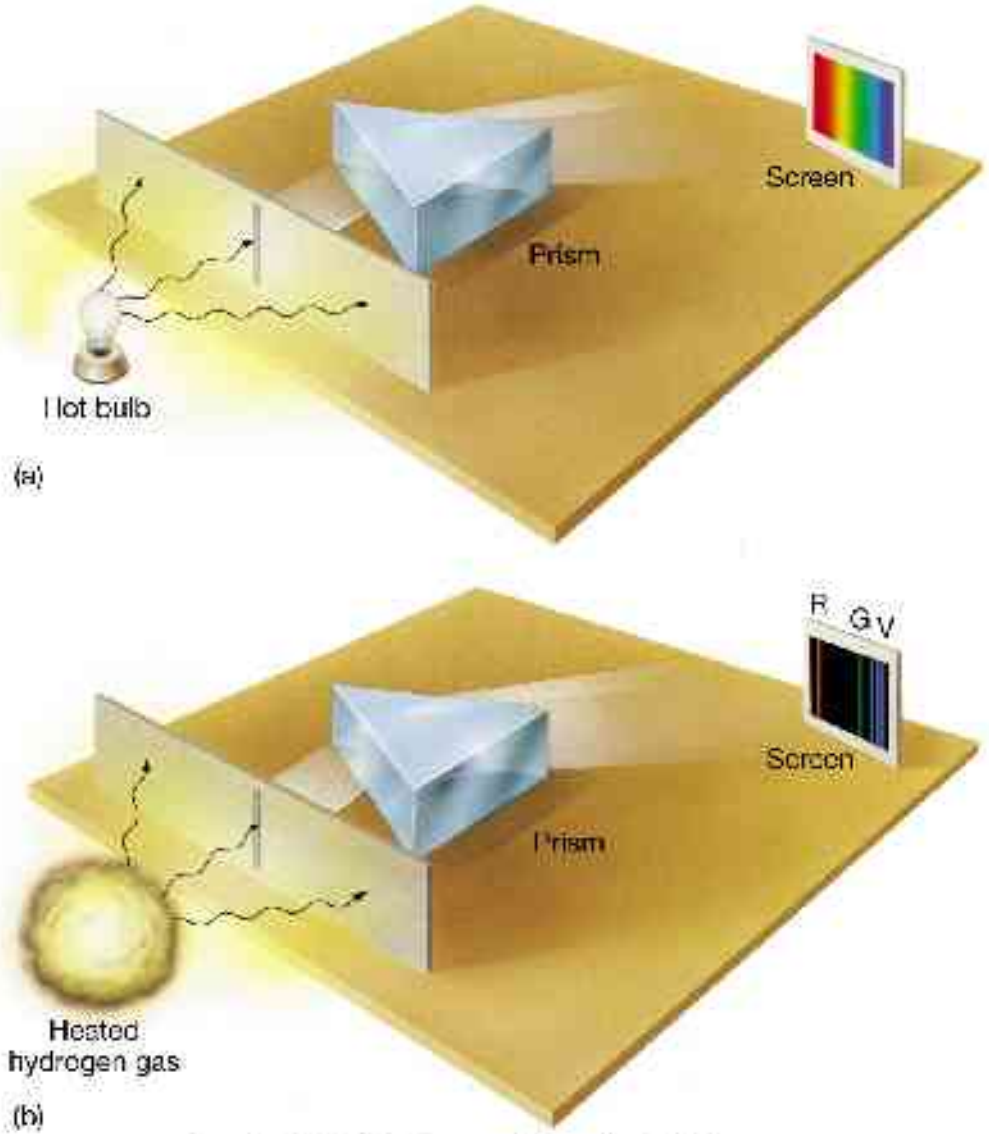
4.1 Spectral Lines

Spectroscope: splits light into component colors



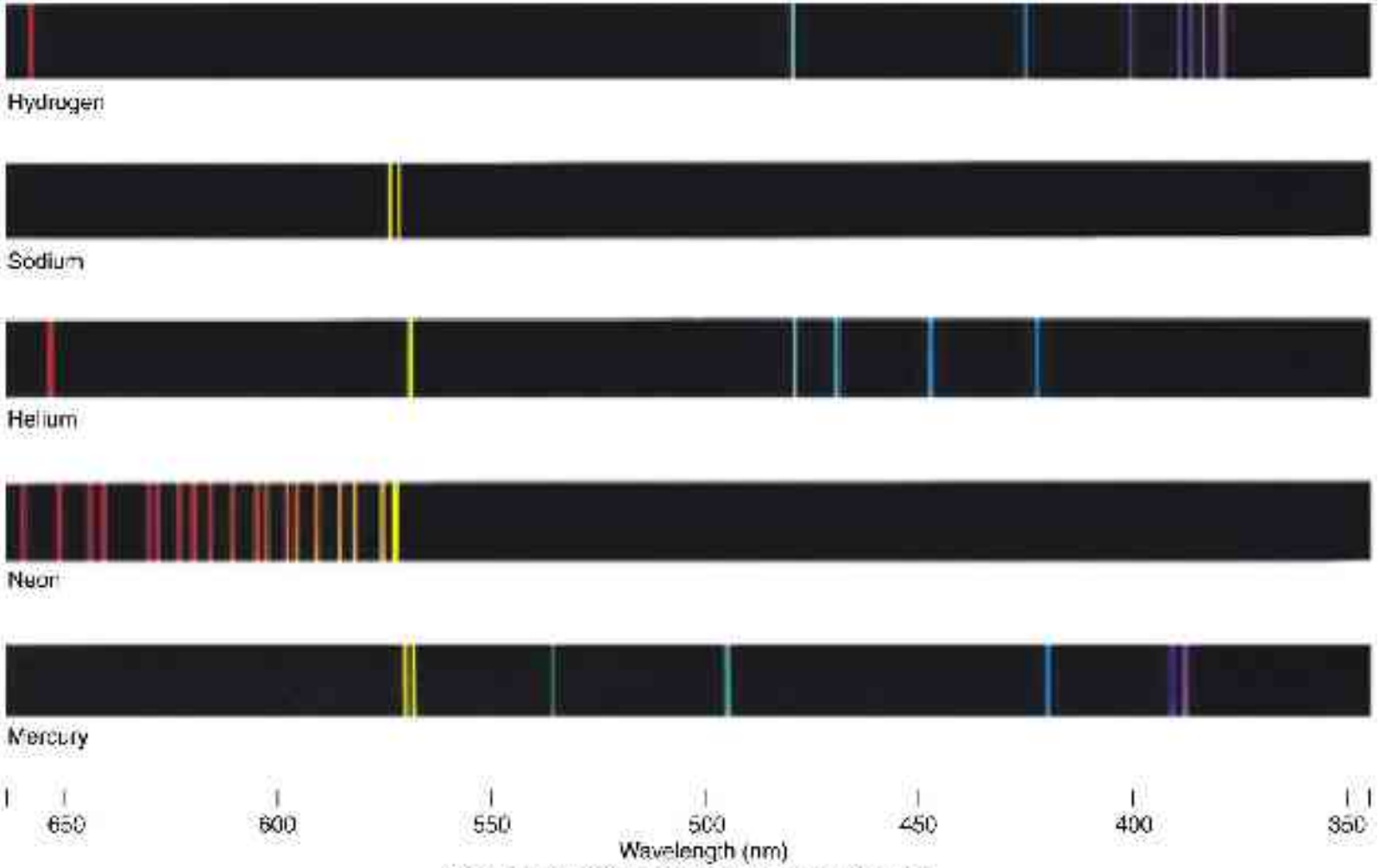
4.1 Spectral Lines

Emission lines:
single frequencies emitted by atoms undergoing de-excitation



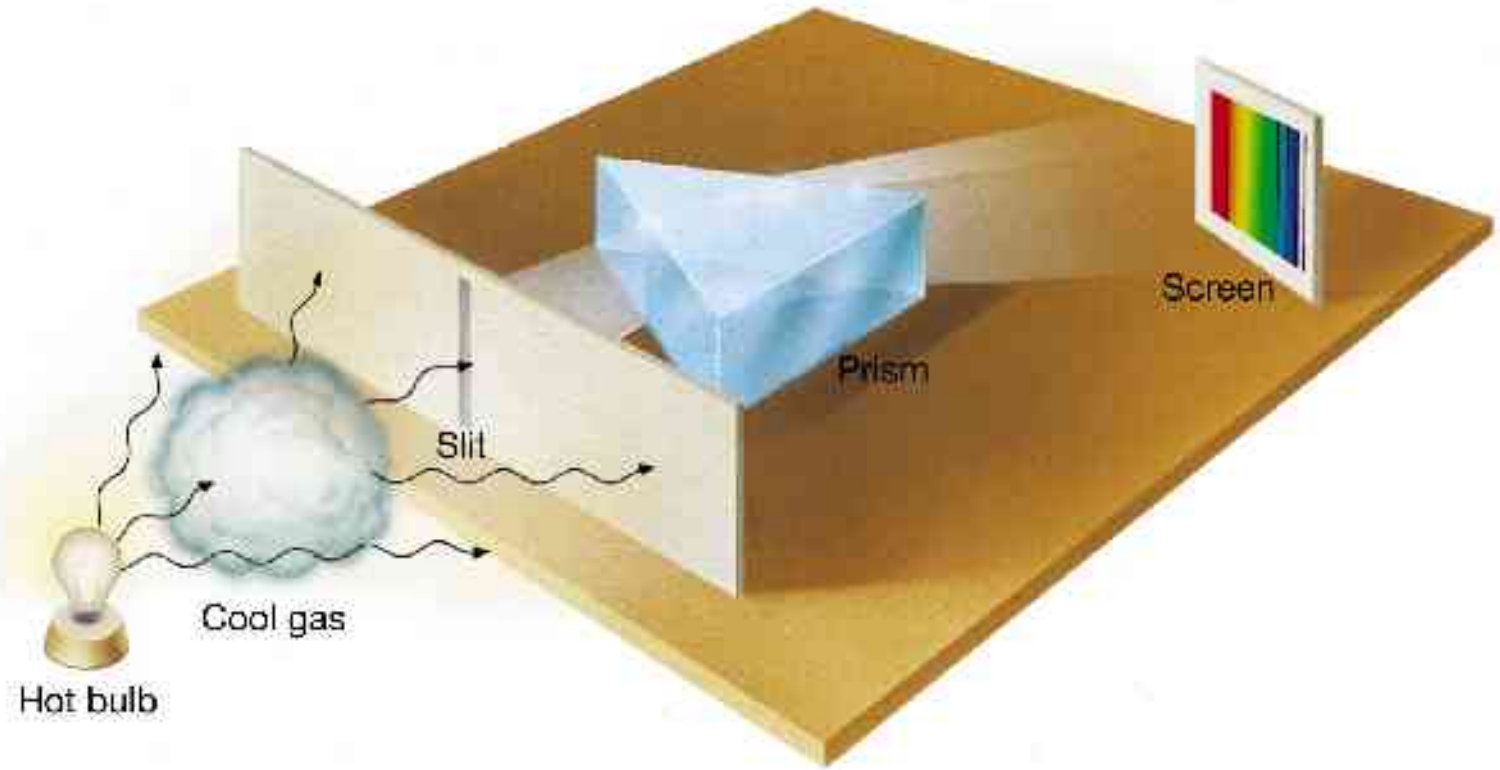
4.1 Spectral Lines

Emission spectrum can be used to identify elements:



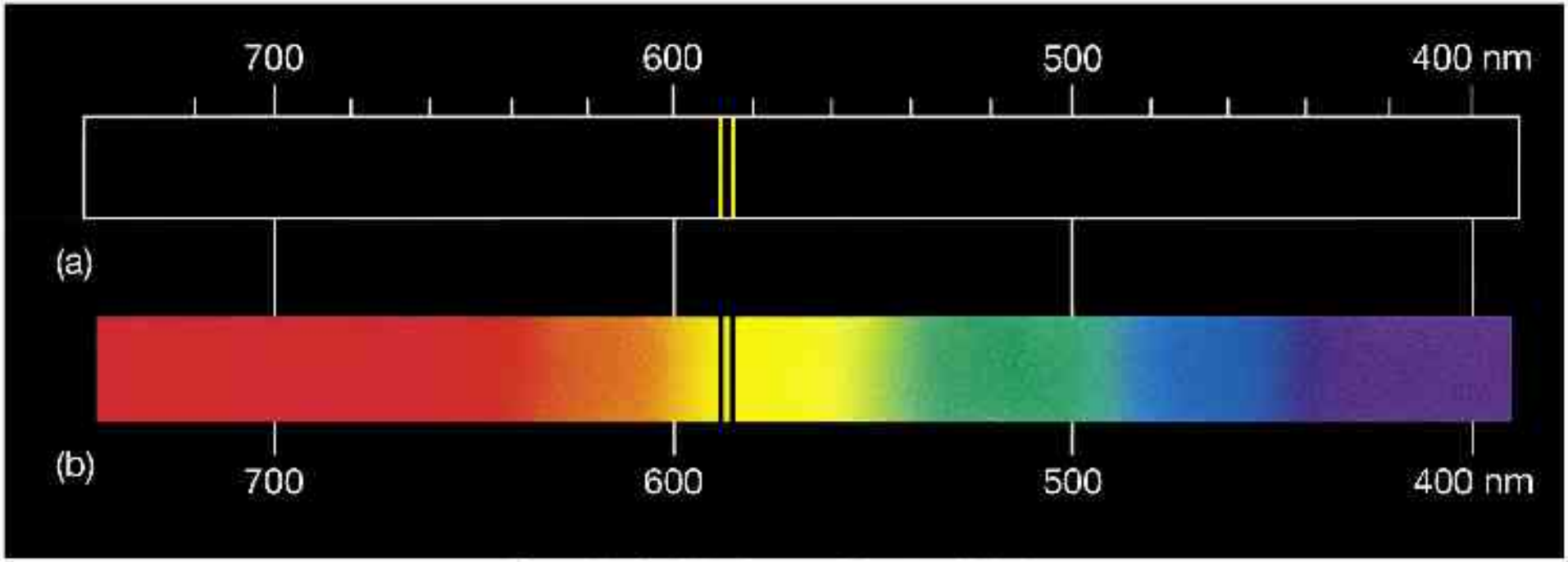
4.1 Spectral Lines

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:



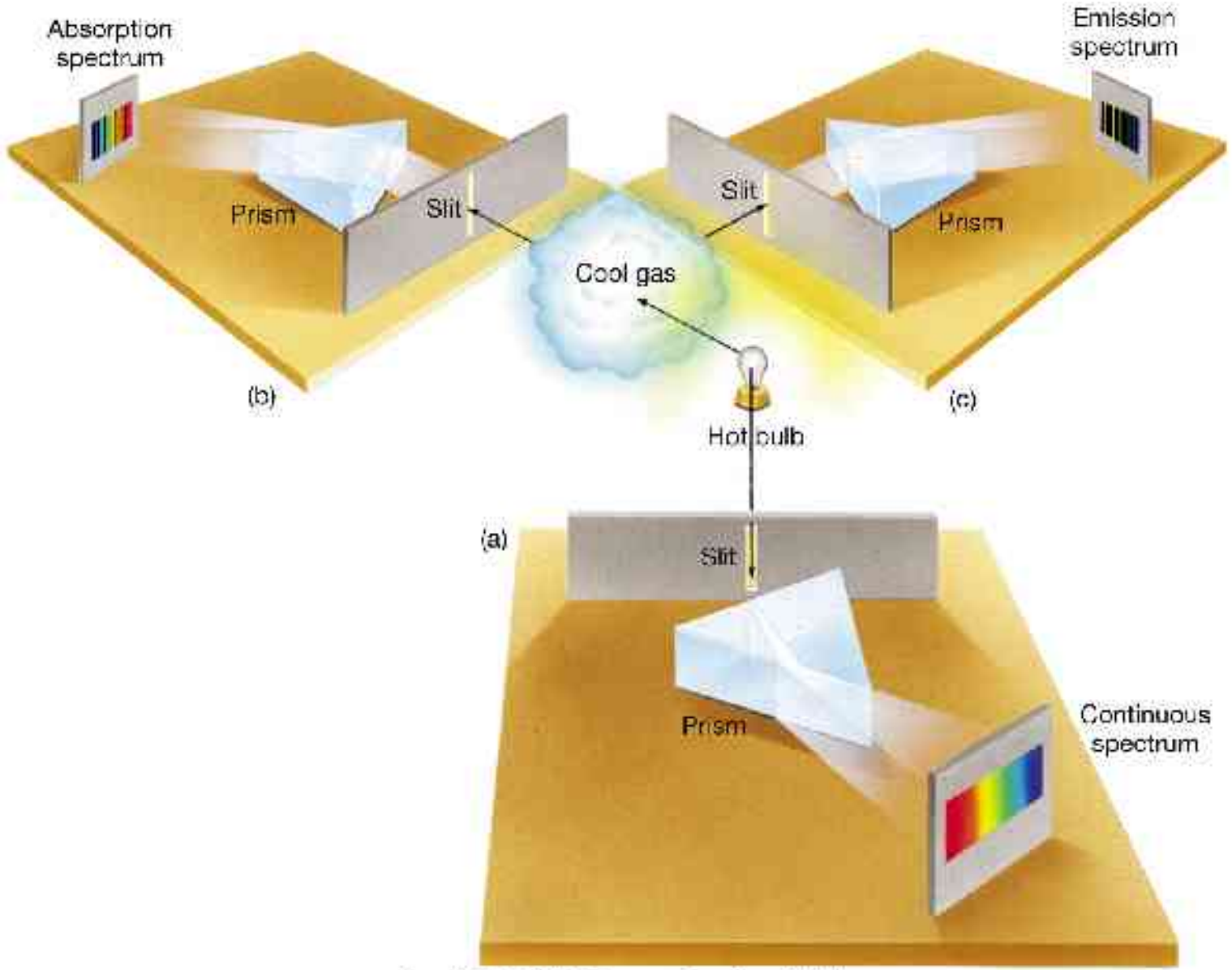
4.1 Spectral Lines

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

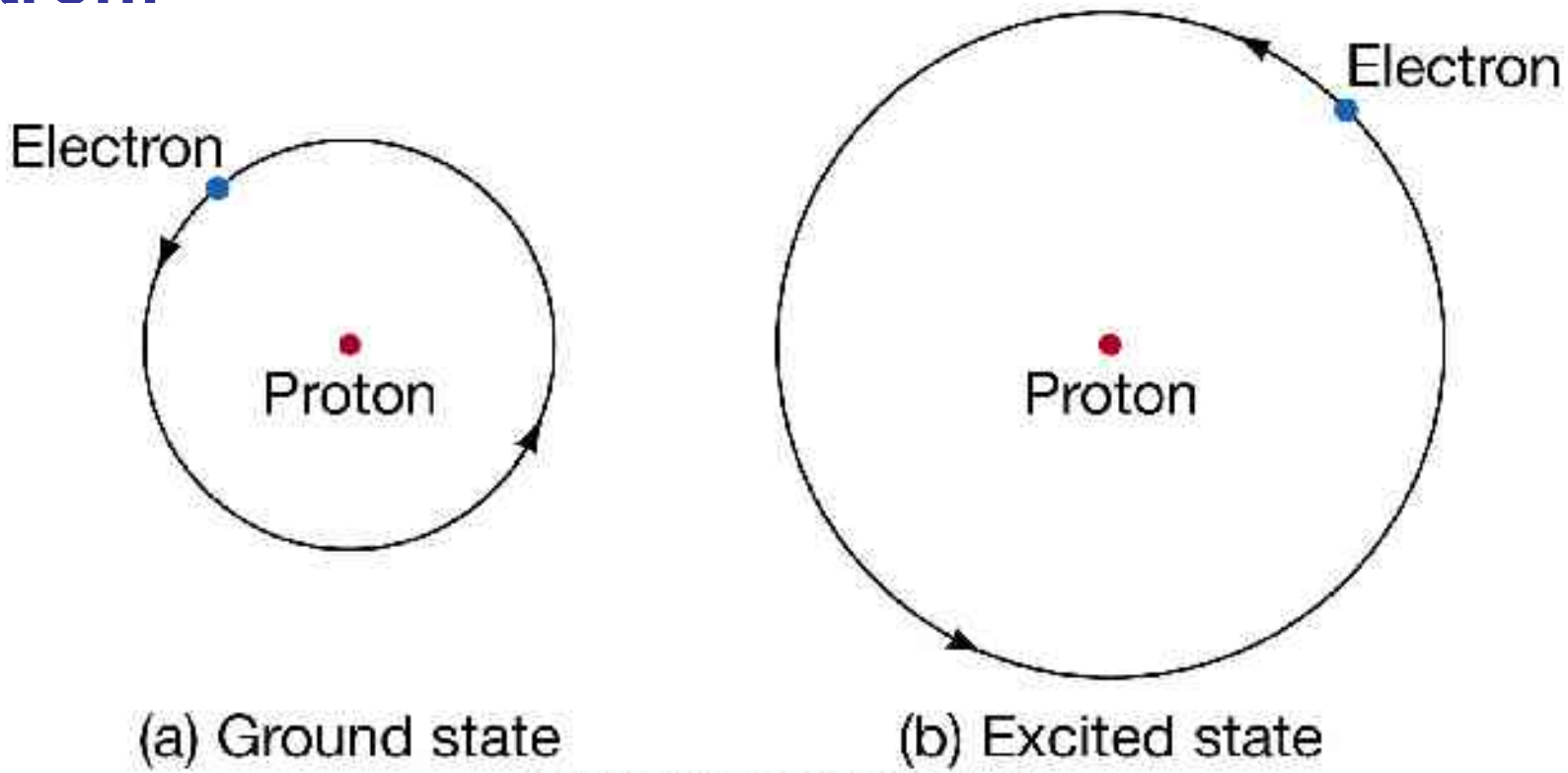
Kirchhoff's laws illustrated:



4.2 The Formation of Spectral Lines

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

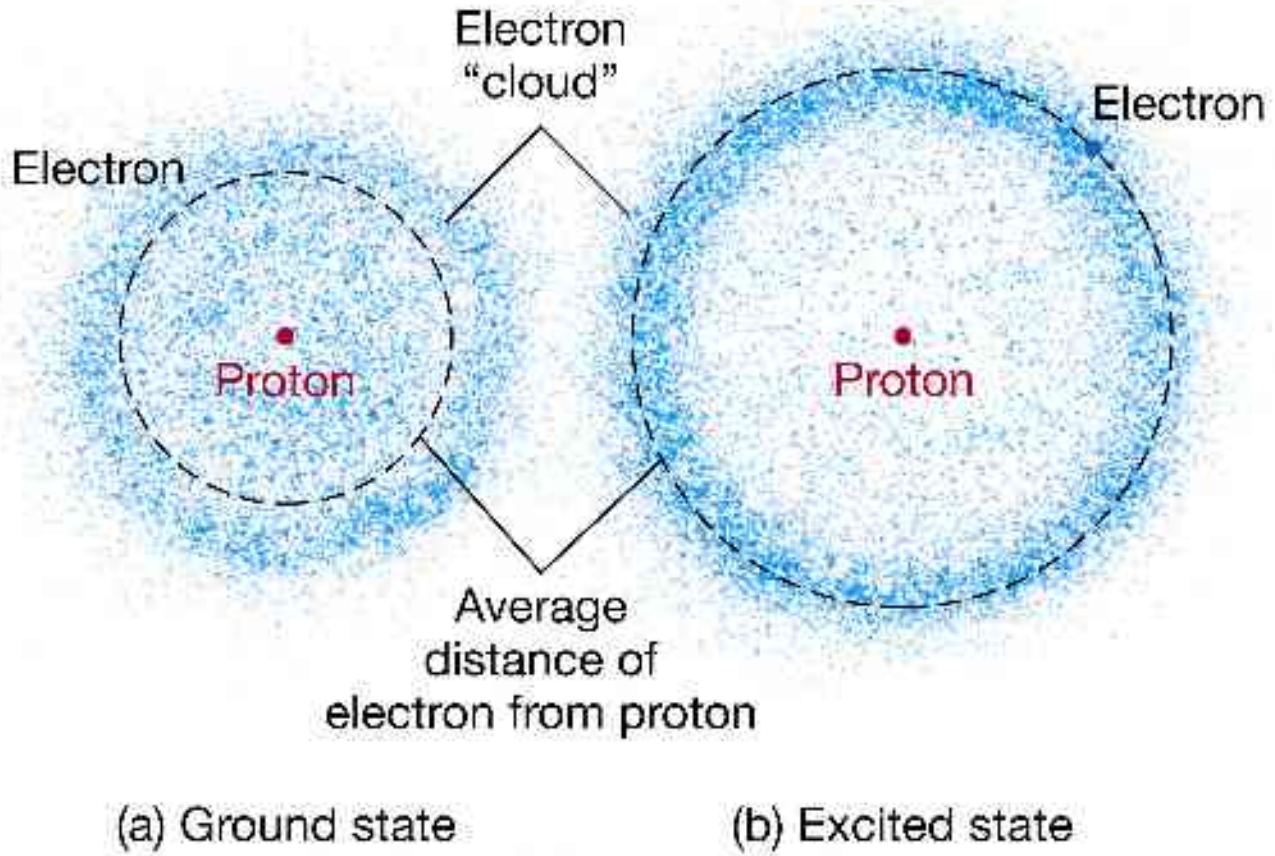
Bohr model had certain allowed orbits for electron:



4.2 The Formation of Spectral Lines

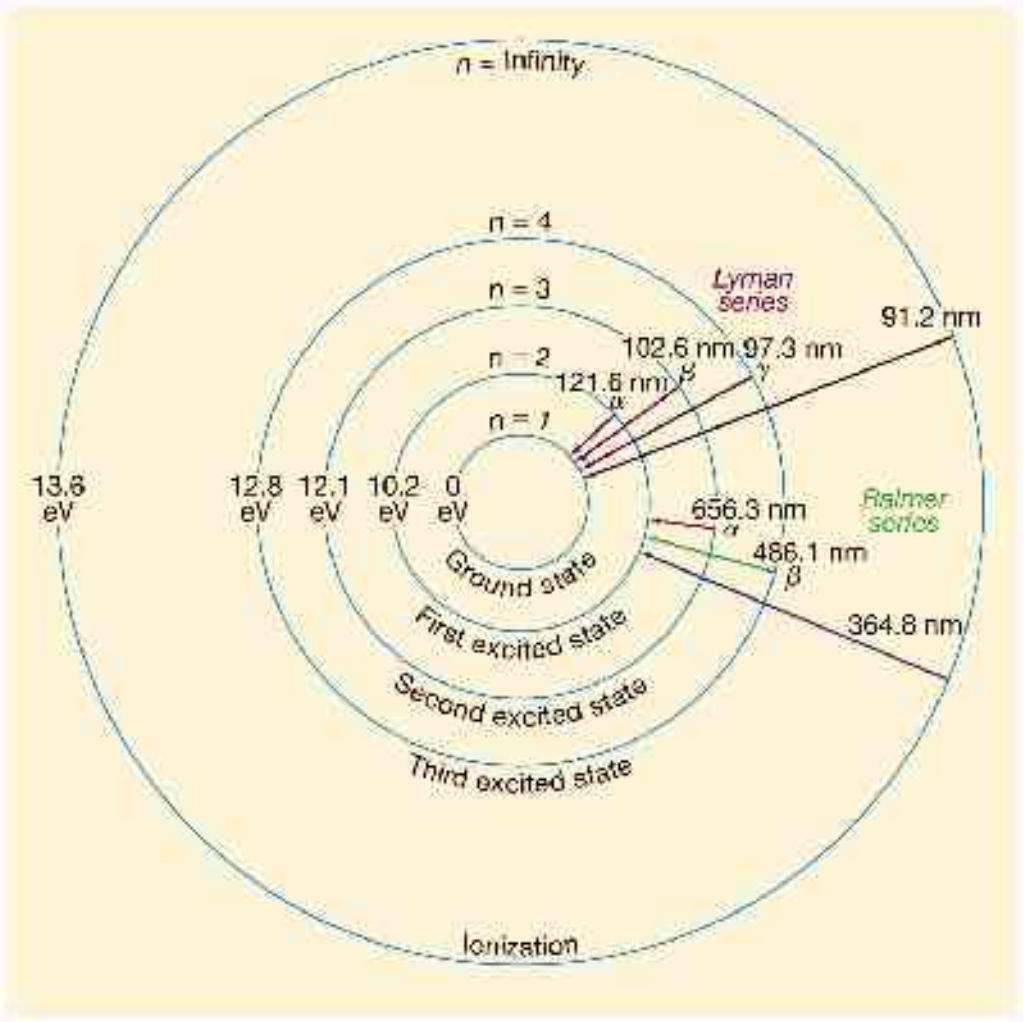
Emission energies correspond to energy differences between allowed levels.

Modern model has electron "cloud" rather than orbit:



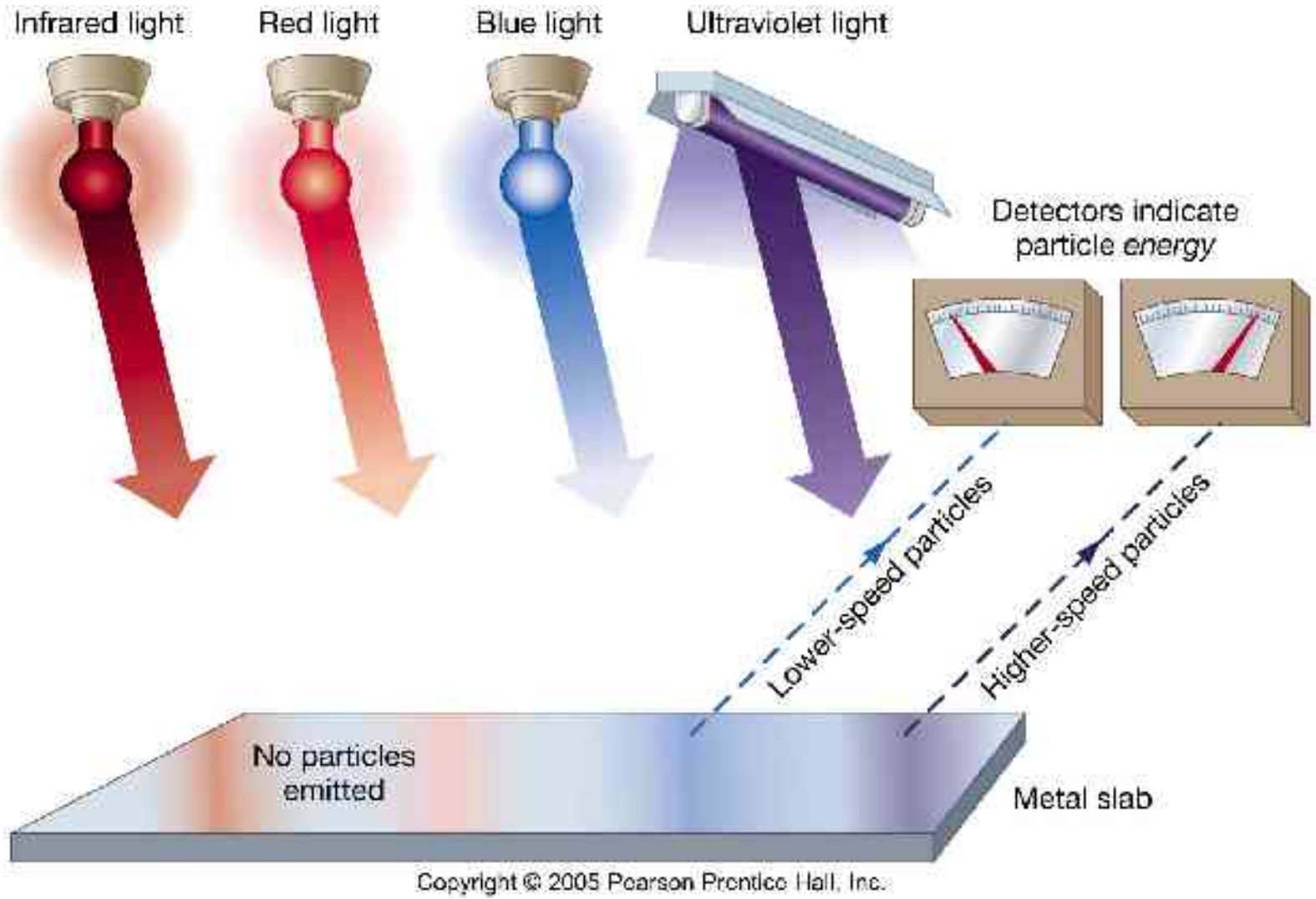
4.2 The Formation of Spectral Lines

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



4.2 The Formation of Spectral Lines

Photoelectric effect can be understood only if light behaves like particles



4.2 The Formation of Spectral Lines

Light particles each have energy *E*:

$$E = hf$$

Here, *h* is Planck's constant:

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

Photon *E* can also be related to wavelength, e.g.,
$E=hc/\lambda = 1240\ eV/\lambda$ (nm)

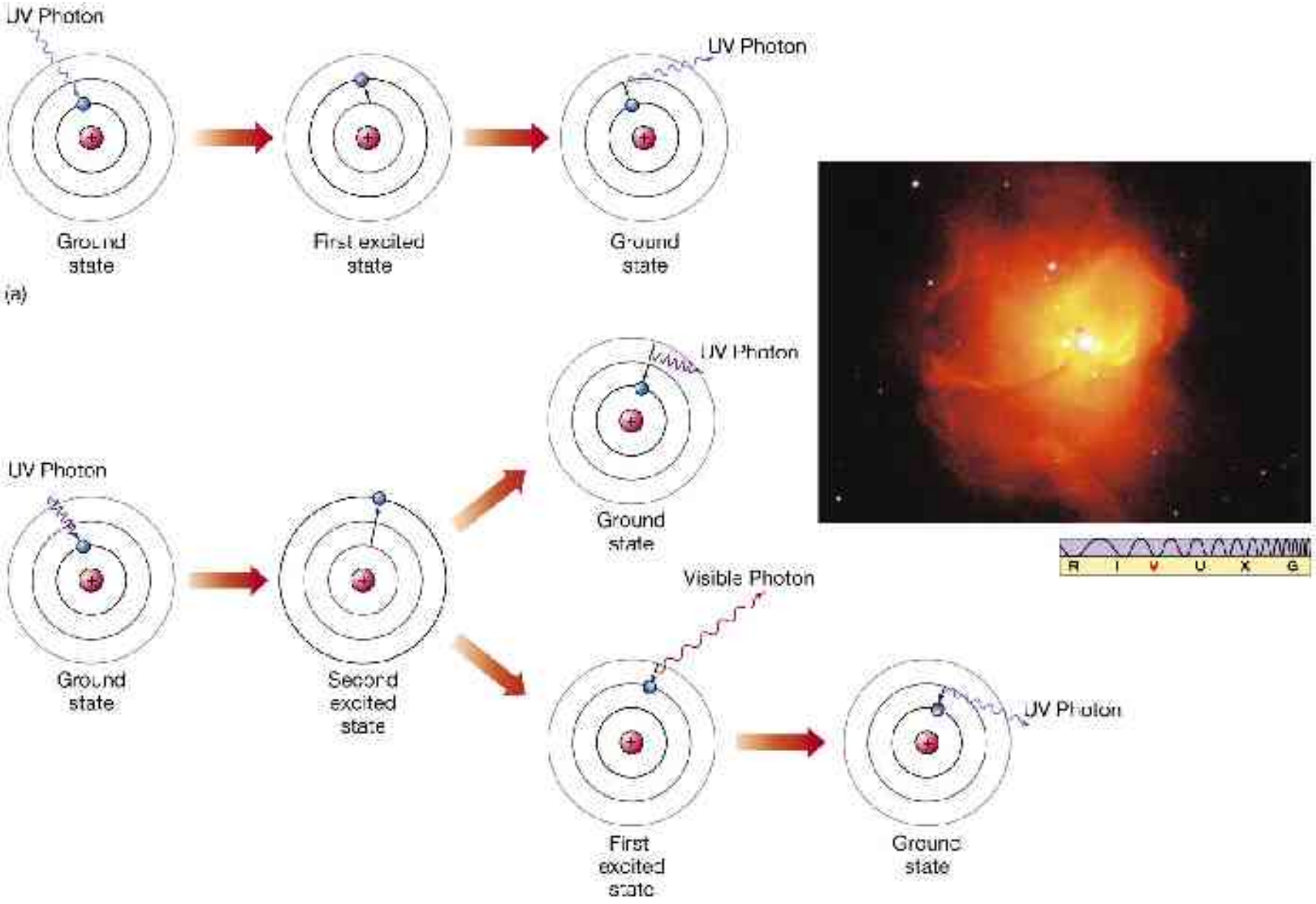
4.2 The Formation of Spectral Lines

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

Two ways to decay:

- to **ground state**
- **cascade** one orbital at a time

4.2 The Formation of Spectral Lines

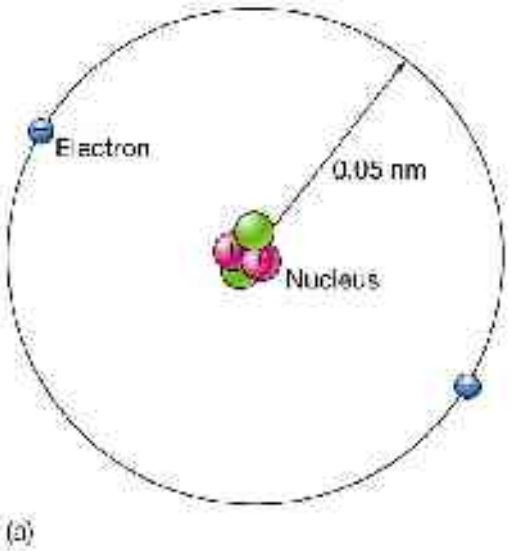


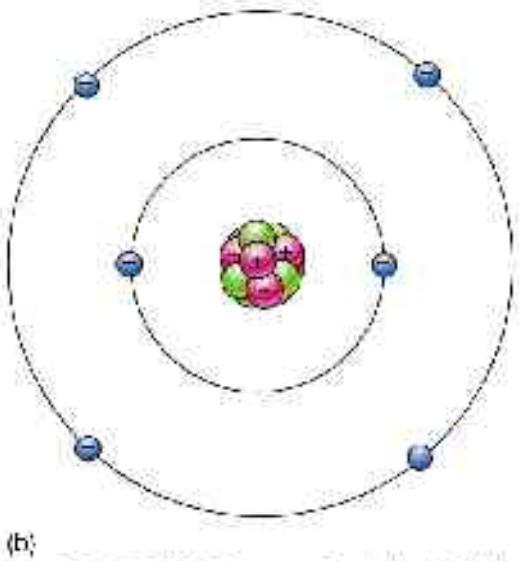
4.2 The Formation of Spectral Lines

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

Multielectron atoms: much more complicated spectra, many more possible states

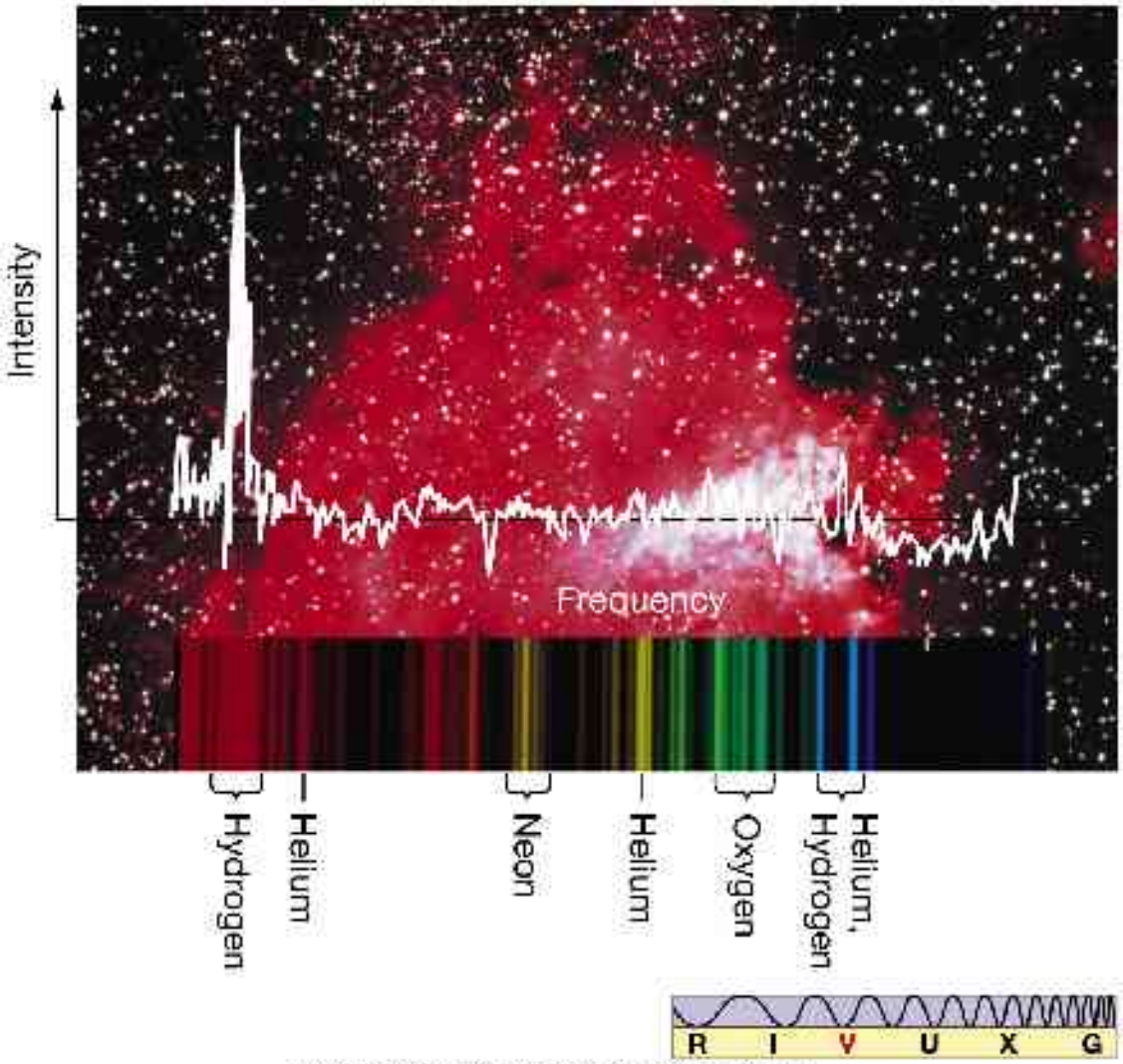
Ionization changes energy levels





4.2 The Formation of Spectral Lines

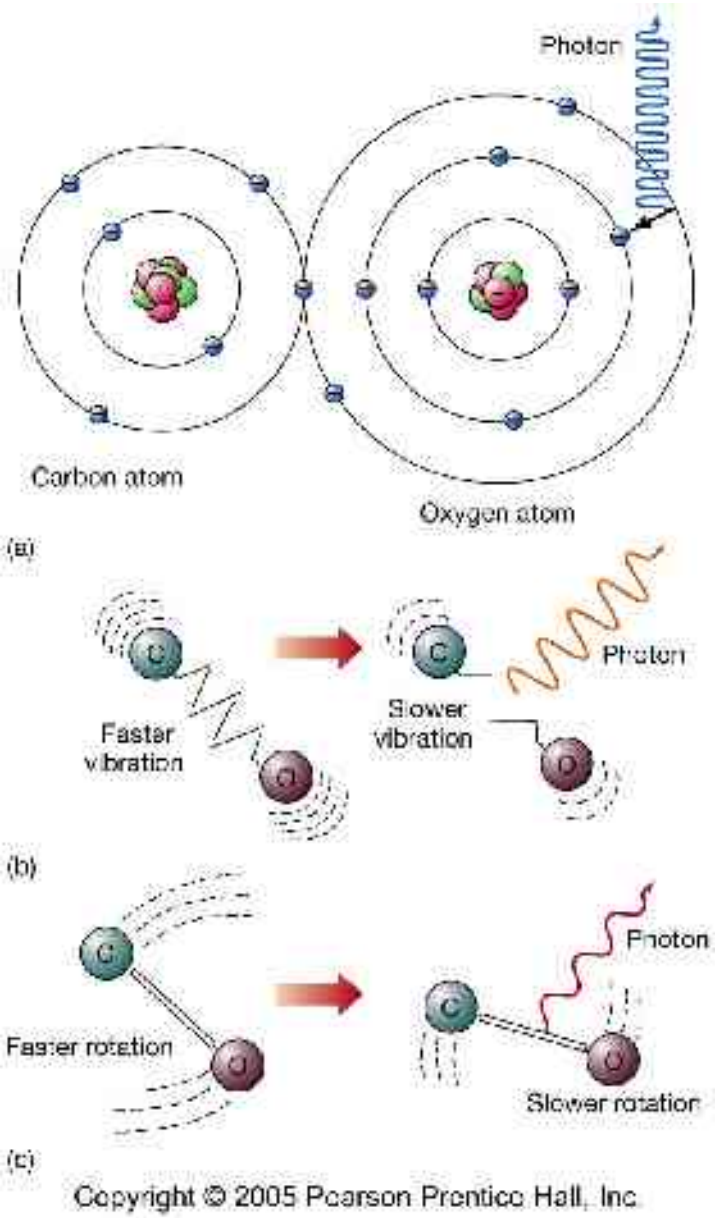
Emission lines can be used to identify atoms:



4.3 Molecules

Molecules can vibrate and rotate, besides having energy levels

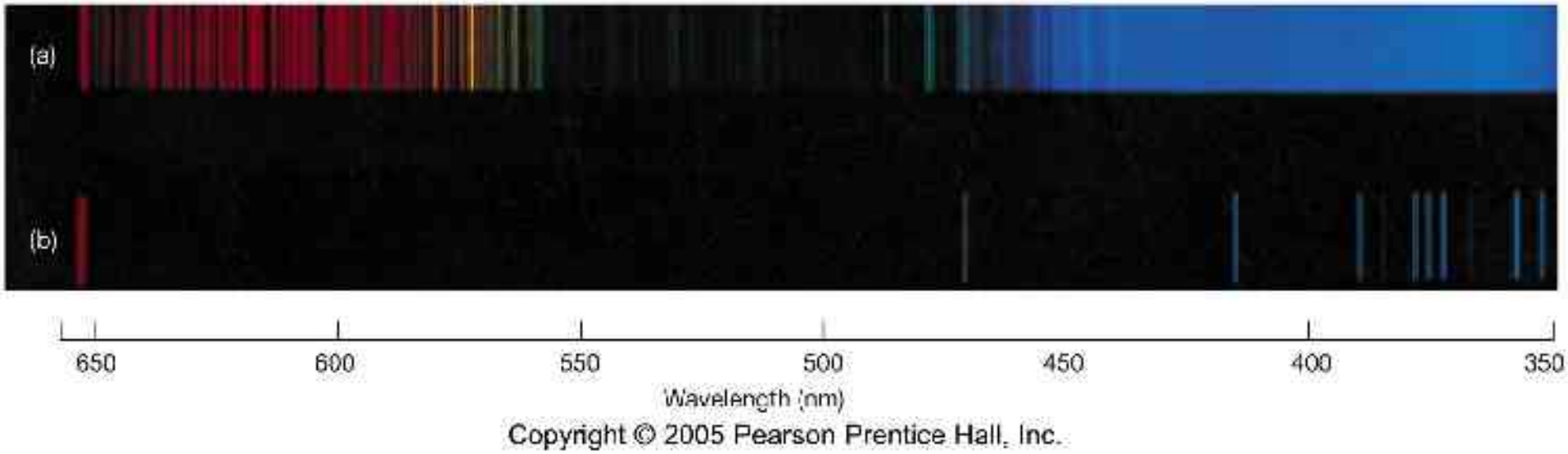
- **Electron transitions produce visible and ultraviolet lines**
- **Vibrational transitions produce infrared lines**
- **Rotational transitions produce radio-wave lines**



4.3 Molecules

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

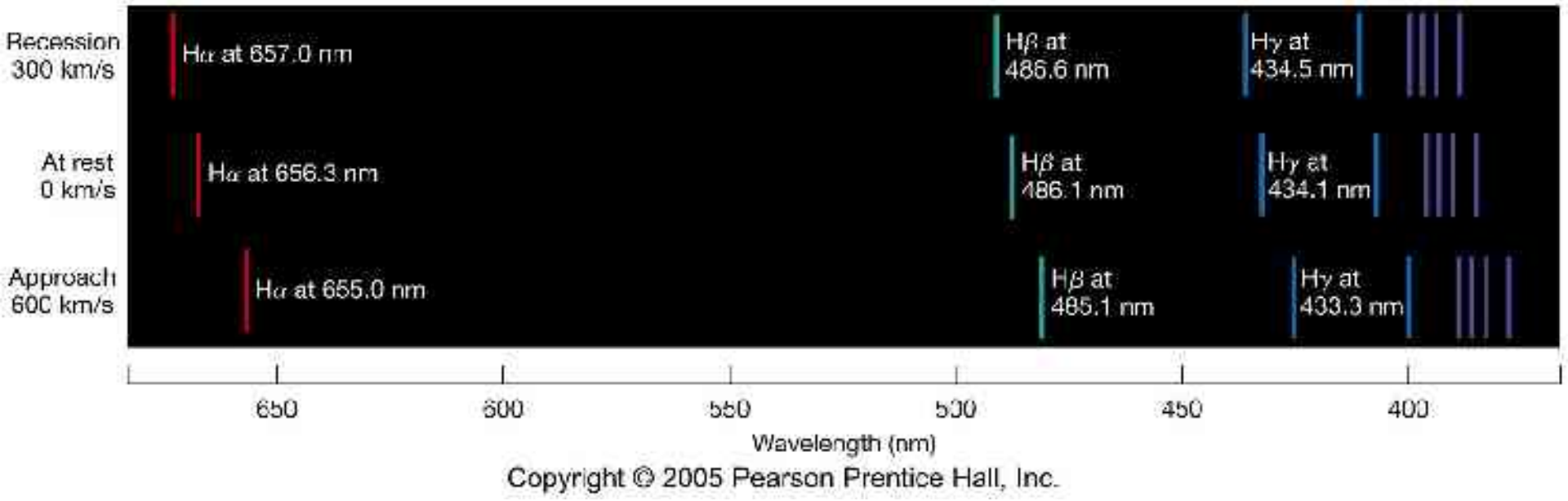
(a) Molecular hydrogen (b) Atomic hydrogen



4.4 Spectral-Line Analysis

Information that can be gleaned from spectral lines:

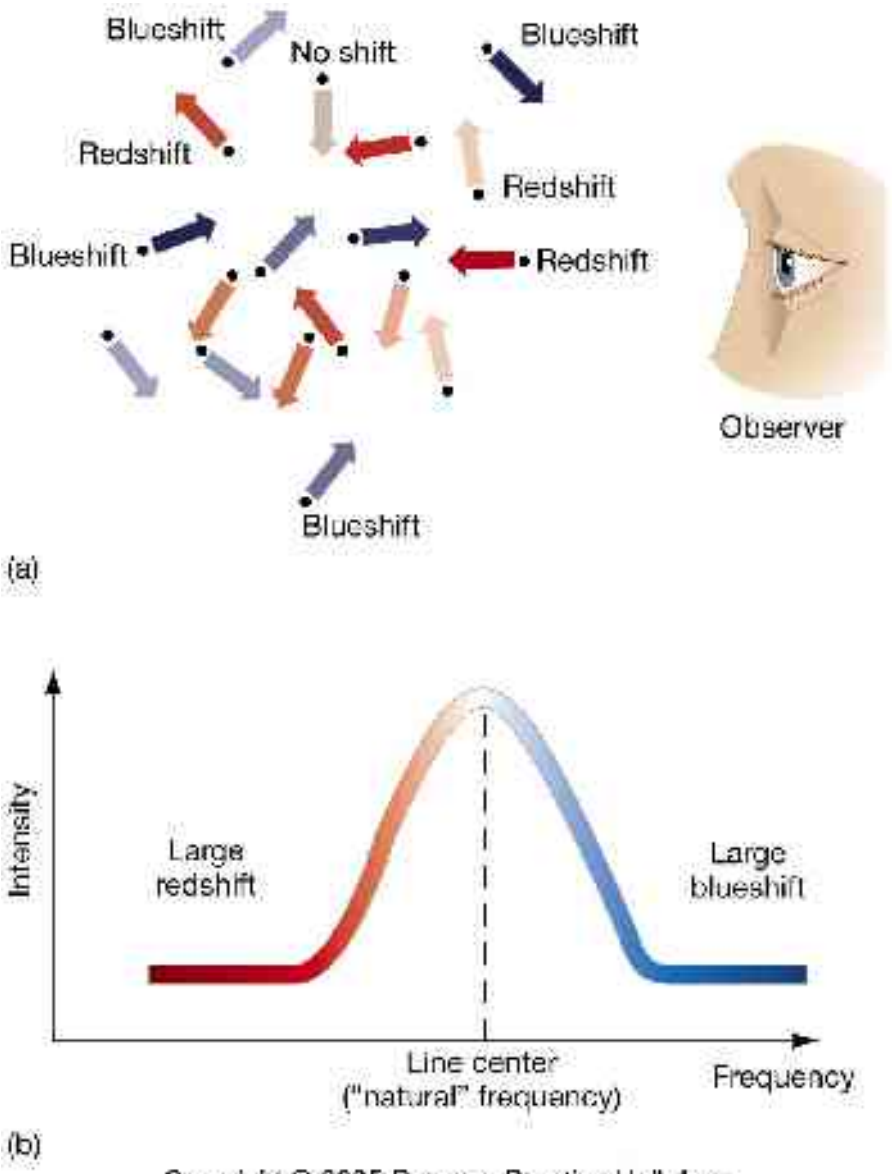
- **Chemical composition**
- **Temperature**
- **Radial velocity:**



4.4 Spectral-Line Analysis

Line broadening can be due to Doppler shift

- **from thermal motion**
- **from rotation**



4.4 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

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