Chapter 4 *Spectroscopy*

Spectral Lines

The Formation of Spectral Lines

The Energy Levels of the Hydrogen Atom

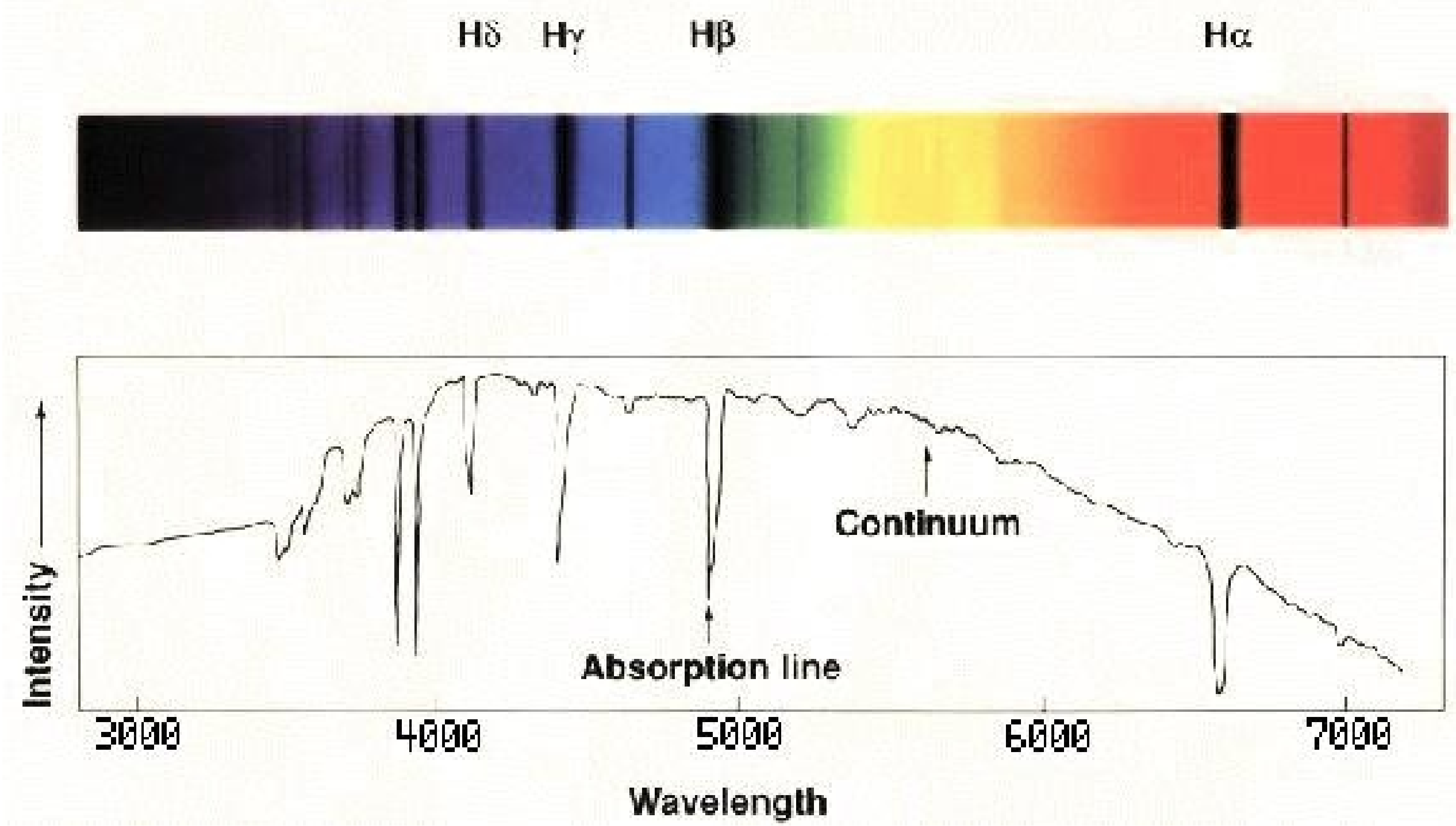
The Photoelectric Effect

Molecules (skip)

Spectral-Line Analysis

4.1 Spectral Lines

Spectrum: a graphical depiction of light intensity as a function of wavelength, frequency, or energy.



4.1 Spectral Lines

Spectroscope: **splits light into component colors**

Picture of Spectrograph

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:

Picture of 3
Spectrographs
pointed at a gas cloud.

4.1 Spectral Lines

Emission spectrum **each element has a characteristic spectrum.**

Picture of emission
spectra
for 5 elements.

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:

Picture of two circular e-
orbits around a proton.

4.2 The Formation of Spectral Lines

Emission energies correspond to energy differences between allowed levels.

Modern model has electron "cloud" rather than orbit:

Picture of electrons as a "cloud".

4.2 The Formation of Spectral Lines

Picture of energy levels in
the Bohr model for the Hydrogen atom.

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

4.2 The Formation of Spectral Lines

Light particles (photons) each have energy *E*:

$$E = hf$$

Here, *h* is Planck's constant:

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

Photon *Energy* can also be related to wavelength, e.g.,

$E = hc/\lambda = 1240\ eV/\lambda$ (nm)

4.2 The Formation of Spectral Lines

Absorption: a photon hits the atom and its energy is used to boost an e^- to a higher energy level ... an *excited* state

Deexcitation or decay: the e^- shifts to a lower energy level and the atom emits a photon

Ionization: the atom receives so much energy that the e- is "kicked off" of the atom.

4.2 The Formation of Spectral Lines

Ways to decay.

Picture showing different transitions between energy
levels.

4.2 The Formation of Spectral Lines

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

Picture of two atoms with more than 1 e-

Ionization changes energy levels

4.2 The Formation of Spectral Lines

Emission lines can be used to identify atoms:

Picture of red nebula
with
spectrum beneath it.

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

Picture of Spectra for molecular and atomic H.

4.4 Spectral-Line Analysis

Information from spectral lines:

- Chemical composition – from line strength, presence of lines
- Temperature – from line strengths, presence of lines
- Radial velocity: - doppler shifting of all lines

Picture showing H
emission
line spectrum redshifted
and blueshifted.

4.4 Spectral-Line Analysis

Line broadening can be due to Doppler shifting

- from thermal motion
- from rotation

Picture of atoms moving along the line of sight.

4.4 Spectral-Line Analysis

Spectral Types - based on the presence of lines.

Fig. 17-10 from textbook.

4.4 Spectral-Line Analysis

Line broadening caused by higher gas pressure on the surface of the star.

Fig. 17.18 b, and c.

4.4 Spectral-Line Analysis

Fig. 17.20

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