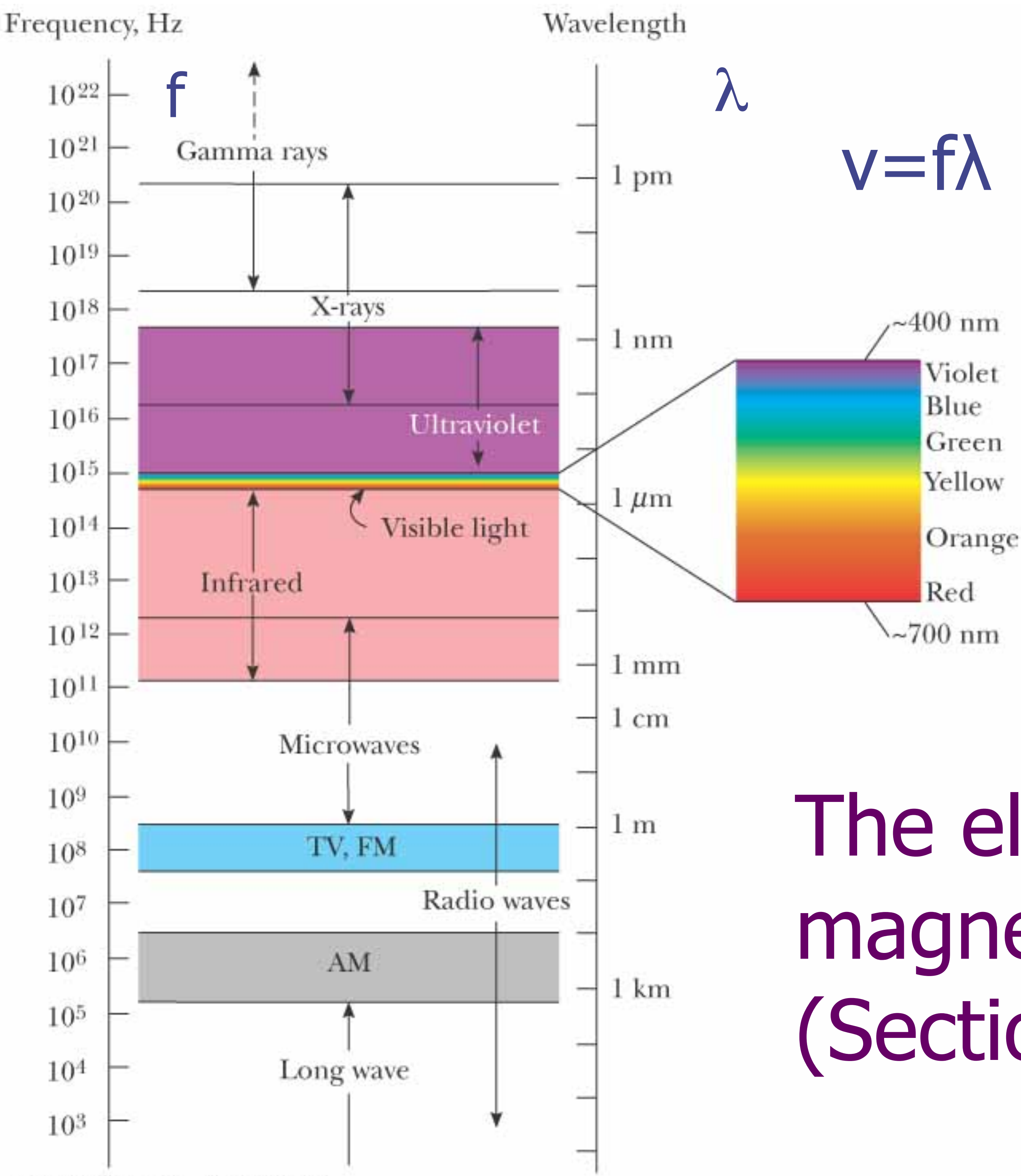
Chapter 8: Energy Quantization

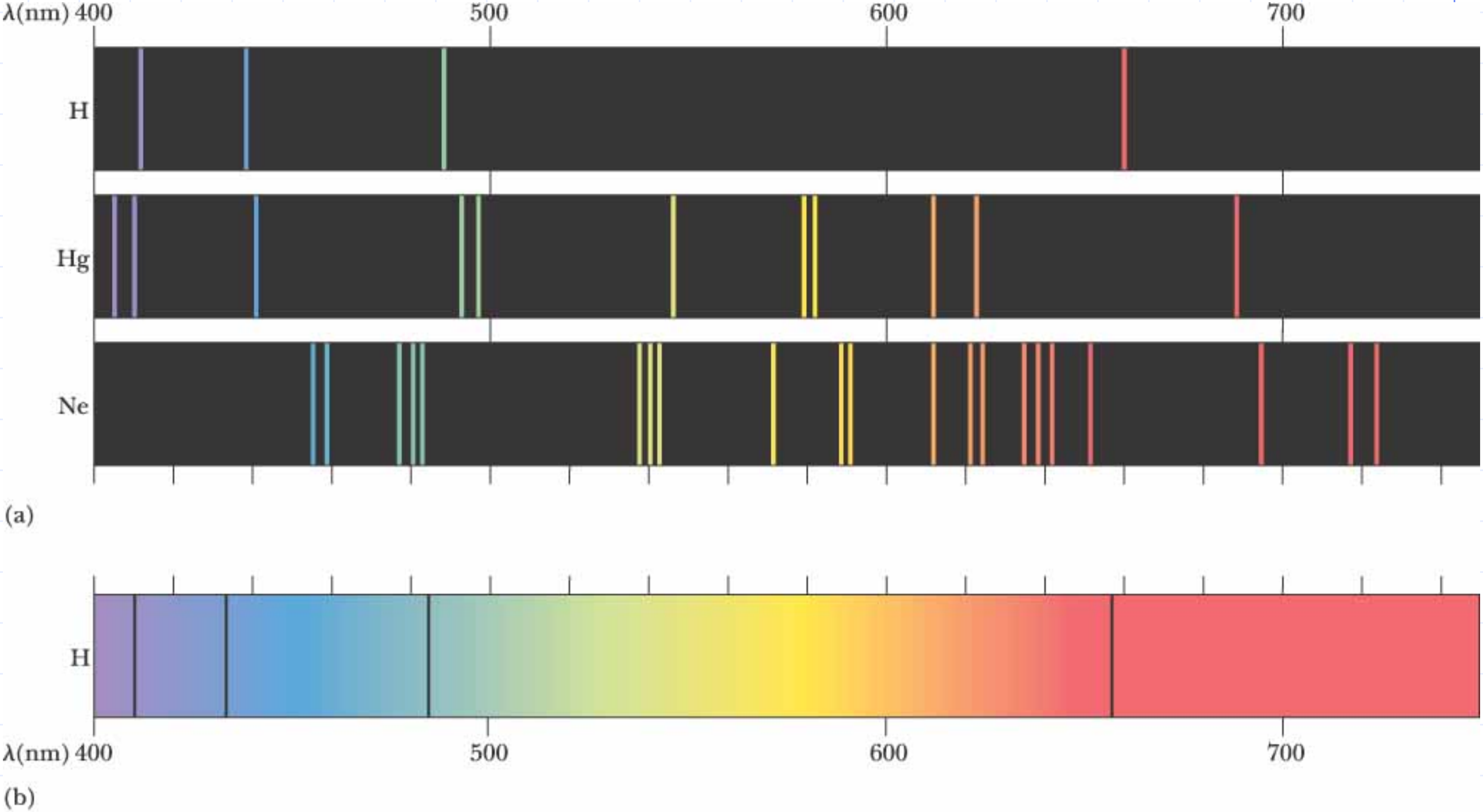
- We will begin by considering the Bohr model of the atom. It uses some principles of quantum mechanics in an attempt to explain “mysterious” emission features of gases
- Also a macroscopic object emits a continuous black-body spectrum related to its temperature - first hint of quantized (discrete) energy (Planck)
- However, at the end of the 19th century, spectra which consisted of discrete ``lines” were observed for low pressure gas which was excited by an electric discharge.



$v = f\lambda = c$

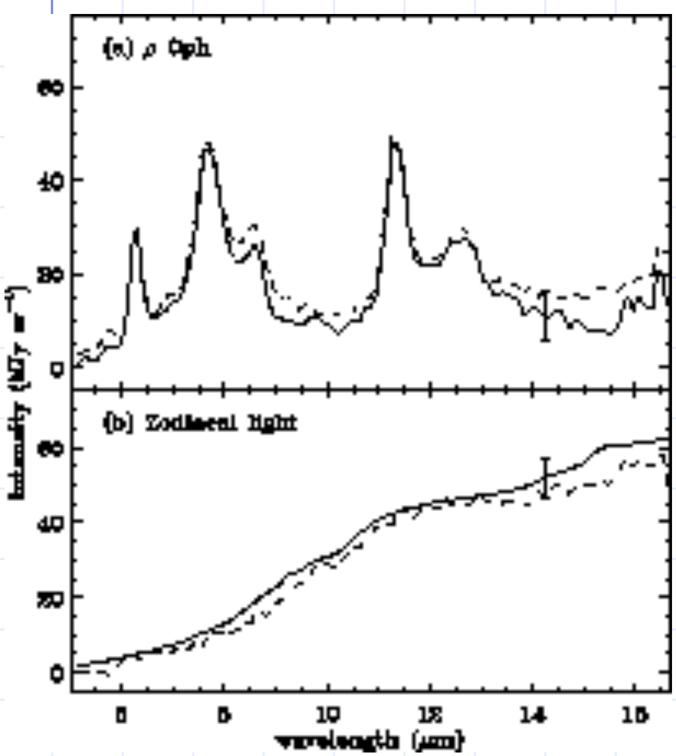
The electro-magnetic spectrum (Section 23.4)

Atomic emission and absorption lines

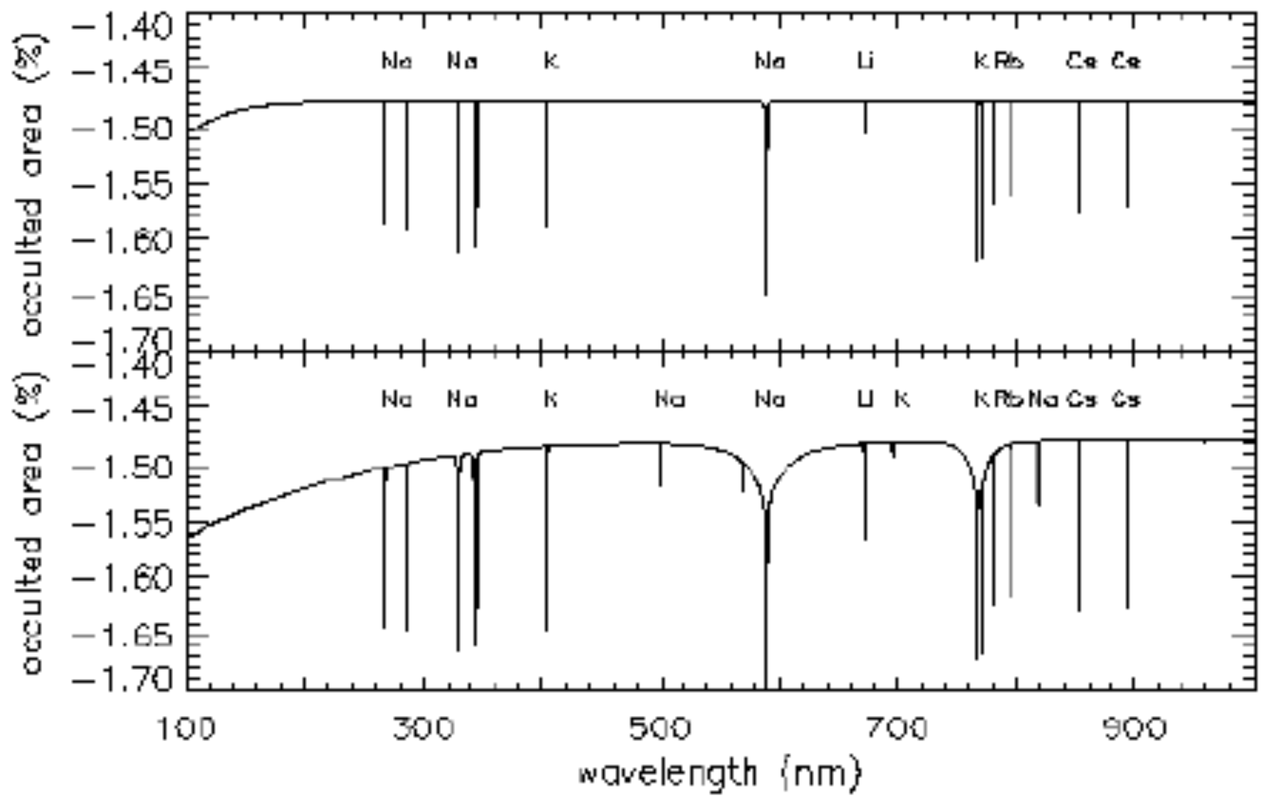


Astrophysical Spectra as examples

- Gaseous nebula

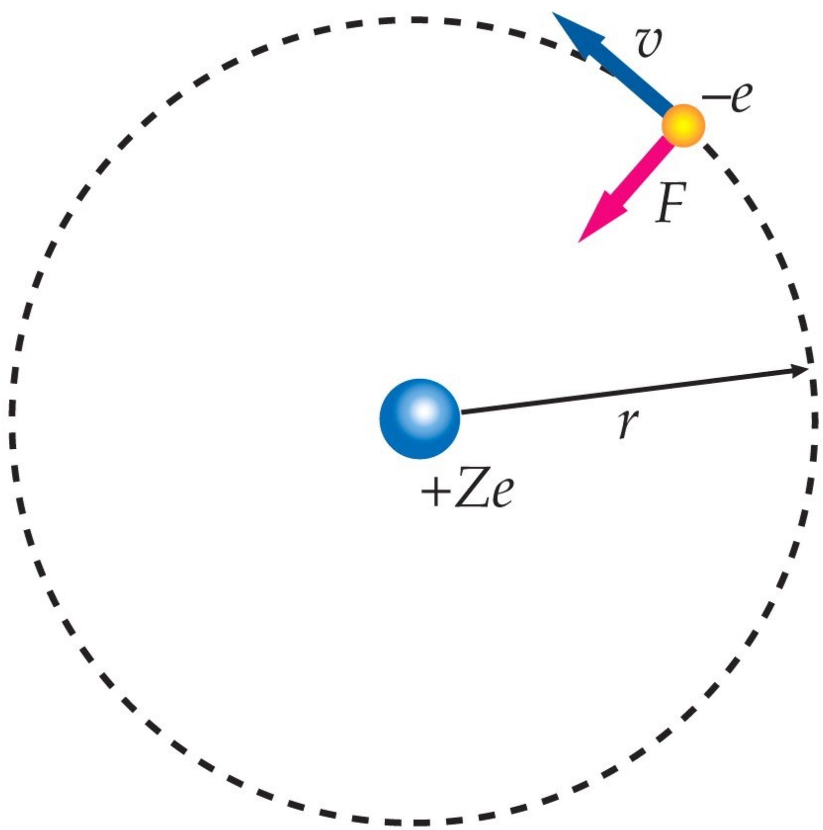


- Extrasolar planet model

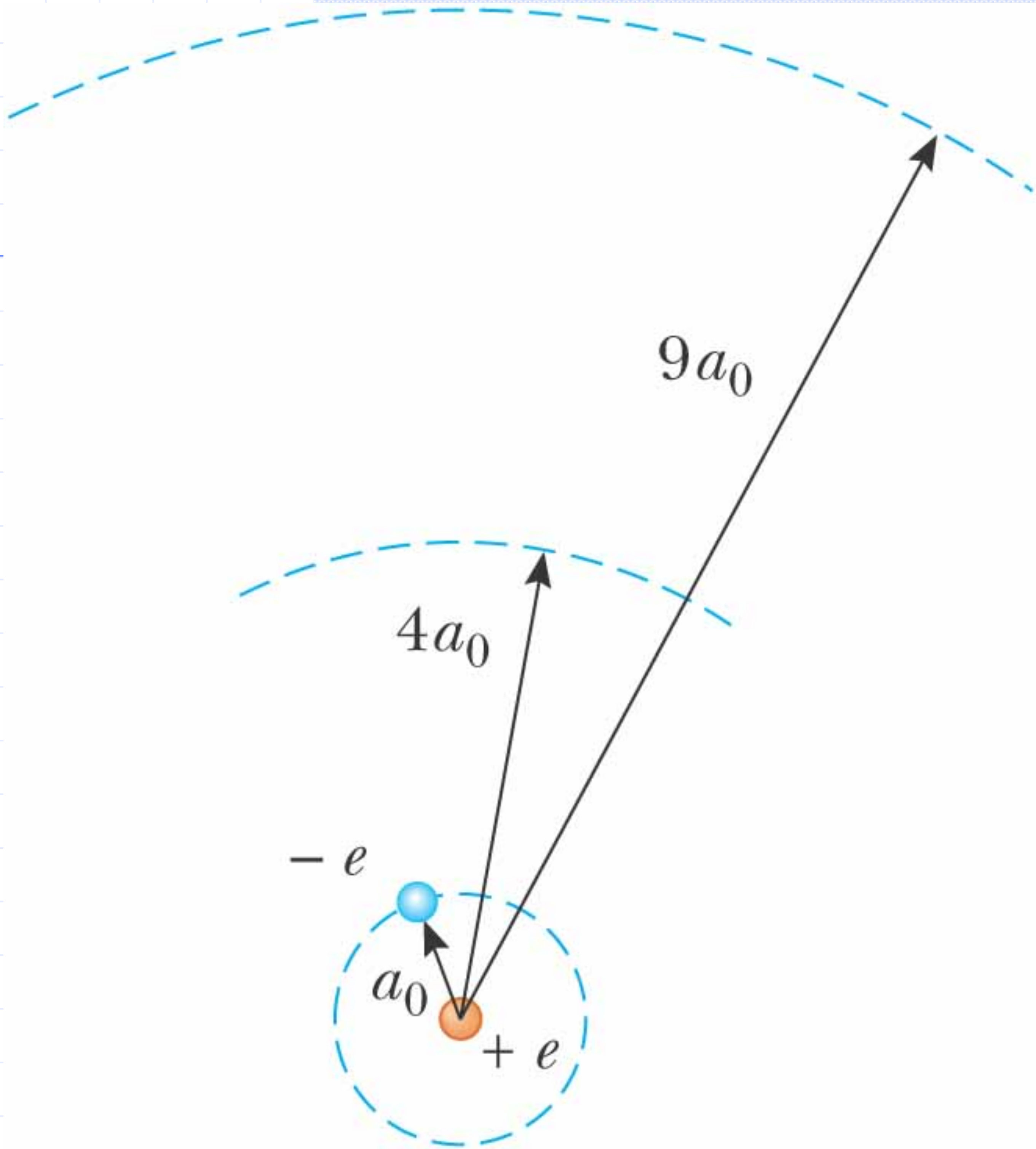


- These features were a mystery and were also the driving force behind the development of quantum mechanics
- Many models were put forth to attempt to explain the discrete spectra, but before the development of the Schrödinger Equation
- One that still has attractive features is the Bohr model
- Bohr knew that the hydrogen atom consisted of an electron and a proton
- He postulated that (1) the electron was held in an circular orbit about the proton

Bohr model of the hydrogen atom



$$F = \frac{kZe^2}{r^2} = \frac{mv^2}{r}$$



9a0
4a0
− e
a0
+ e

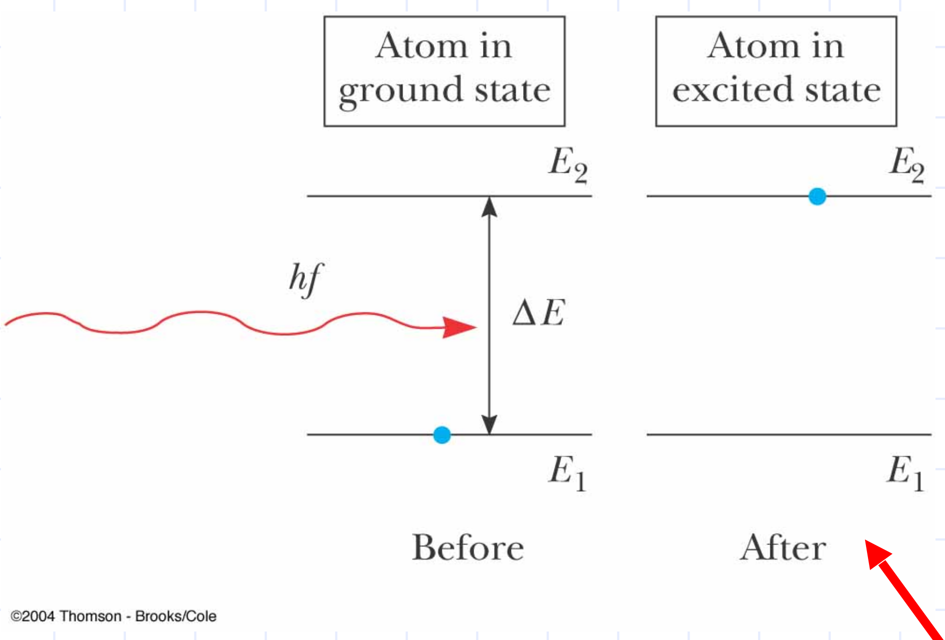
- While useful, the Bohr model fails in a number of important ways:

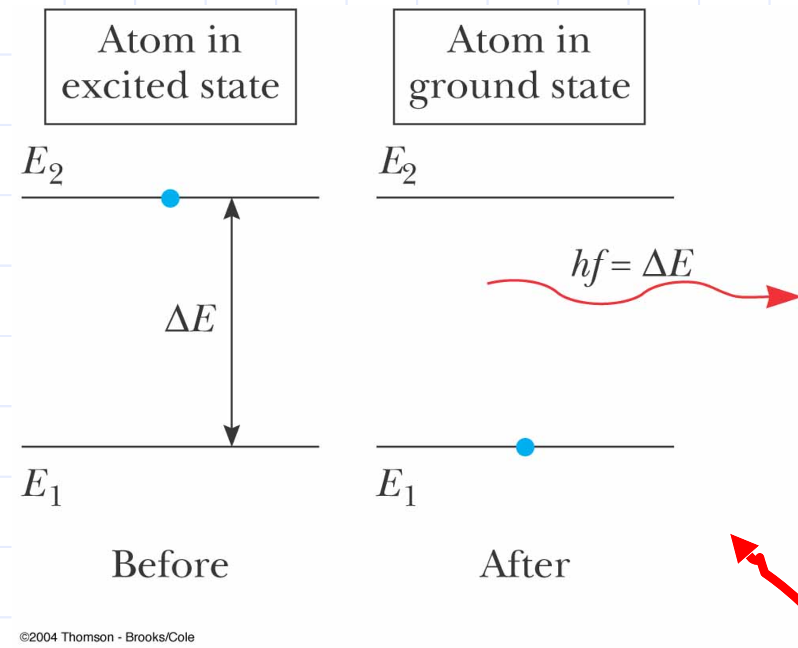
1. While the electron is most likely to be found at certain radii, which in the language of quantum mechanics is the expectation value $<r_n>$, they must be treated as waves and therefore do not have fixed radial distances. In fact, the electrons do not travel in circular orbits, but can be found anywhere in the 3D space around the proton
   - electrons have radial KE as well as rotational KE
   - also if r was precisely known, then uncertainty in $p \rightarrow \infty$ (Heisenberg Uncertainty Principle)

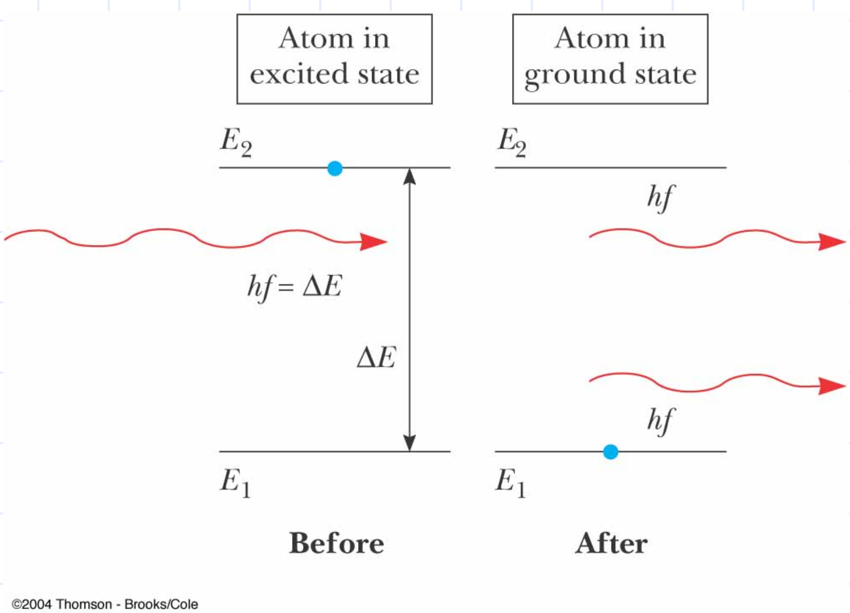
2. The Bohr model cannot be applied to atoms with more than one-electron
   → however, it does give reasonable results for highly excited states (large n, or Rydberg states) – since the classical limit is being approached
3. The quantization of angular momentum has no theoretical basis in the Bohr model
   → only justified to give agreement with experiment
   → quantum mechanics actually predicts angular momentum quantization (sec. 11.11)

- Therefore, for an accurate description of an atom, we need to apply the Schrödinger equation (a 2nd-order partial diff. equation)

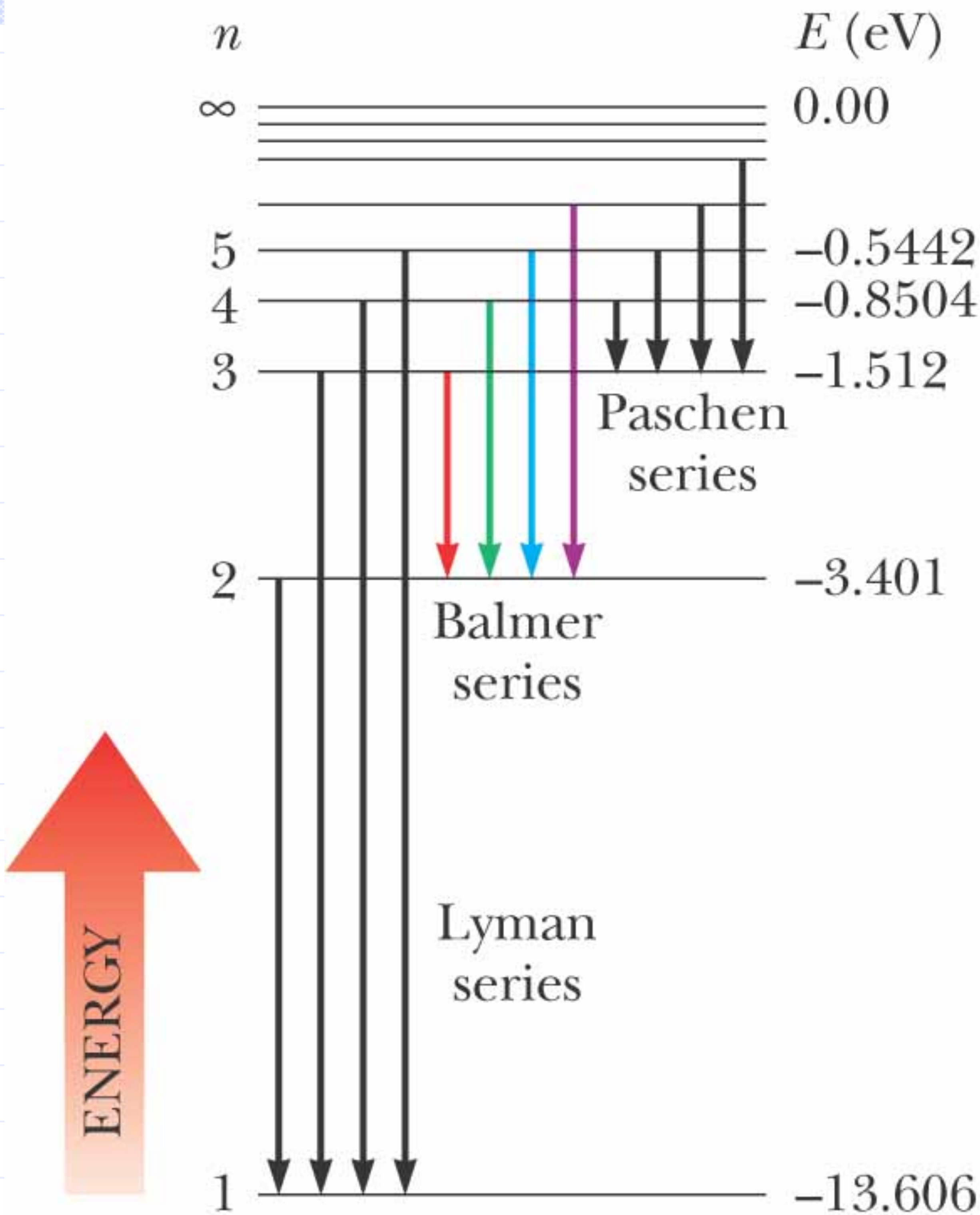
Emission and absorption processes





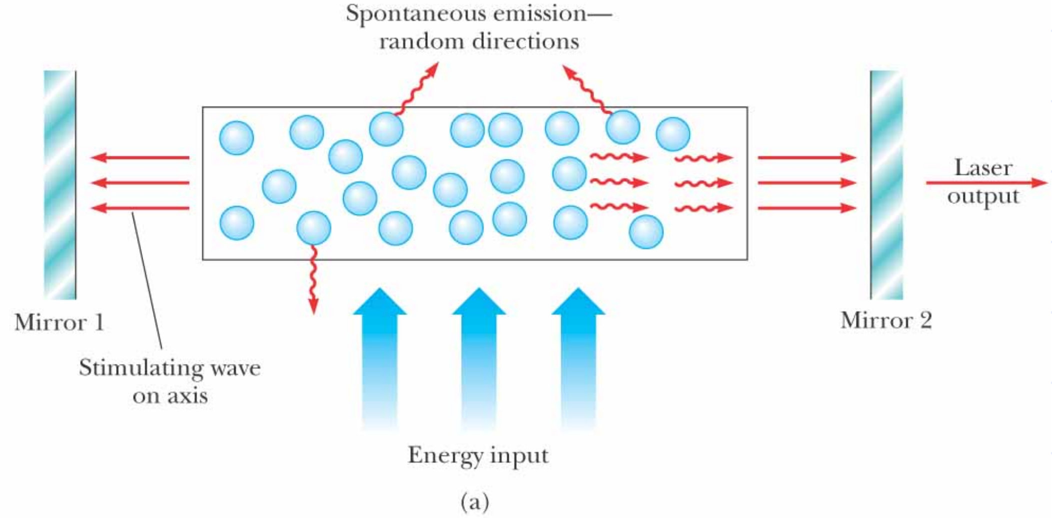


- Absorption
- Stimulated emission
- Spontaneous emission

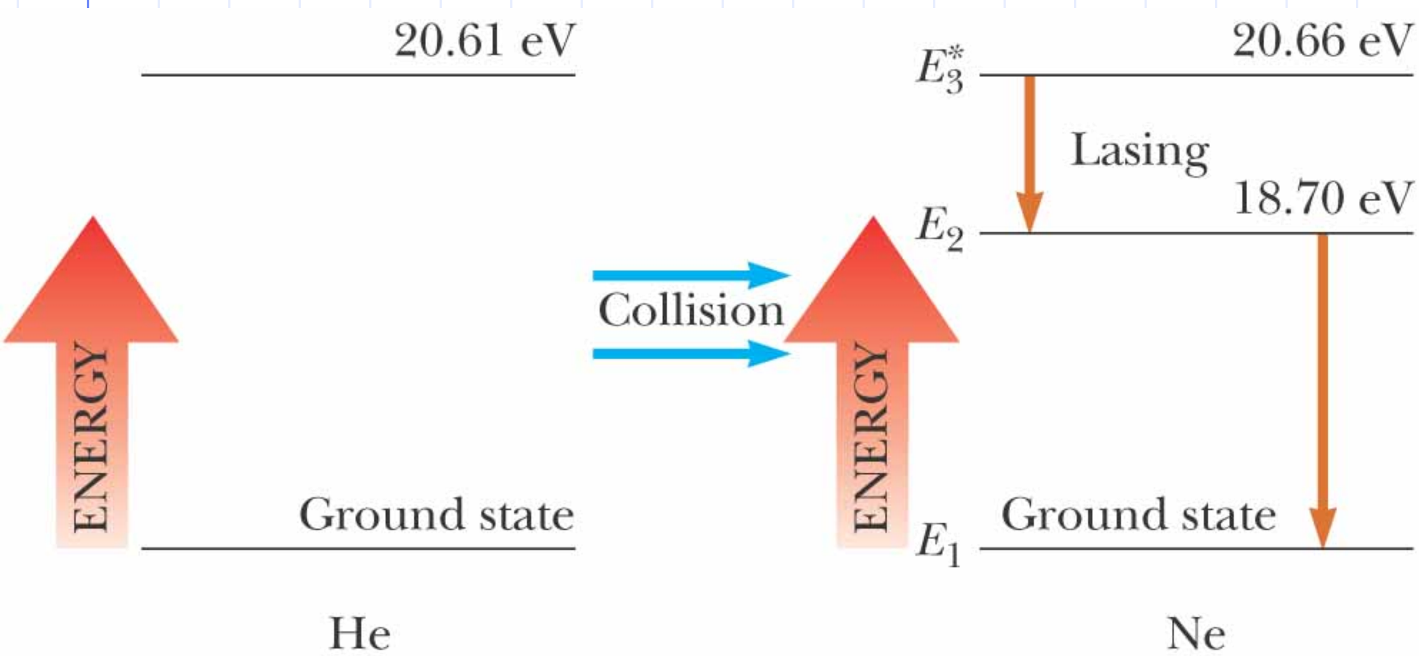


n
E (eV)
∞
0.00
5
–0.5442
4
–0.8504
3
–1.512
Paschen series
2
–3.401
Balmer series
Lyman series
ENERGY
1
–13.606

Laser



Spontaneous emission—
random directions
Laser
output
Mirror 1
Mirror 2
Stimulating wave
on axis
Energy input
(a)



20.61 eV
ENERGY
Ground state
He
Collision
ENERGY
E3*
20.66 eV
Lasing
18.70 eV
E2
E1
Ground state
Ne