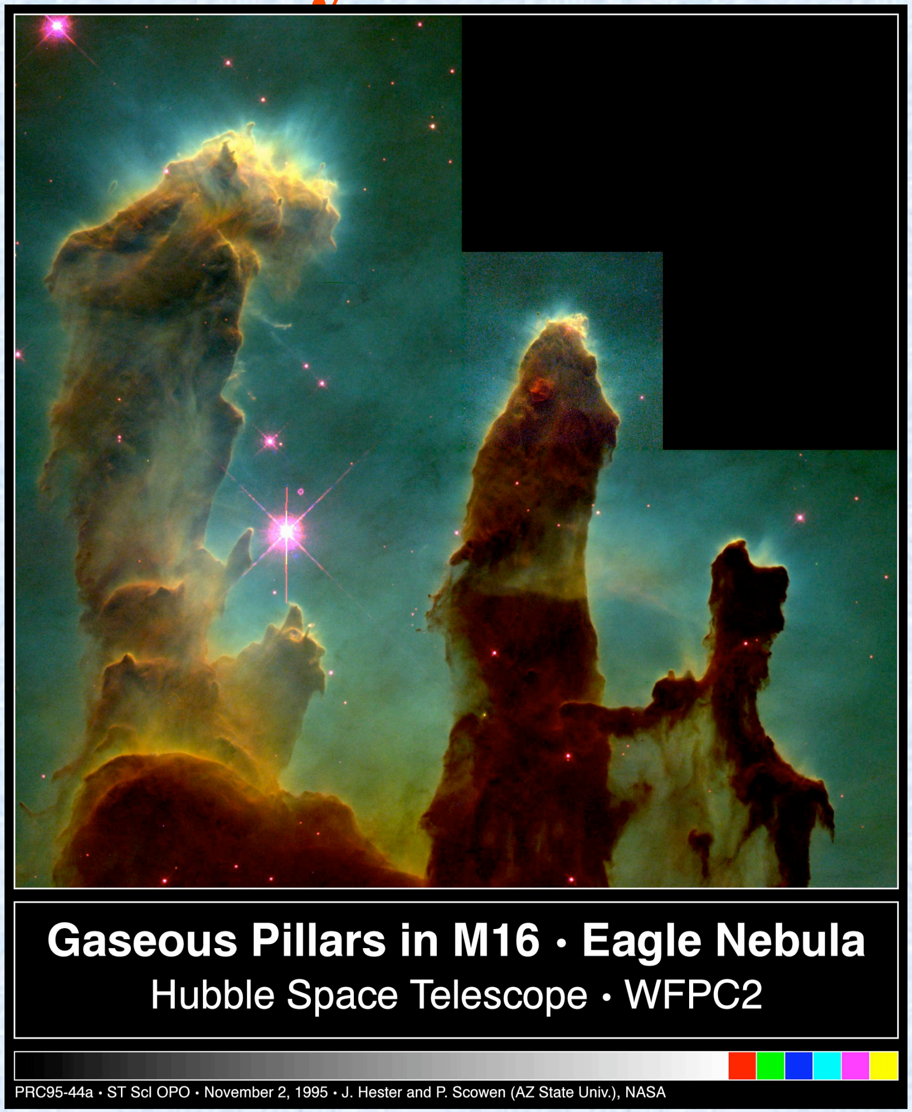
Astronomy 1 – Winter 2011



Lecture 8; January 24 2011

Previously on Astro 1

- **Light as a wave**
- **The Kelvin Temperature scale**
- **What is a blackbody?**
  - **Wien's law**: λ_{max} (in meters) = (0.0029 K·m)/T.
  - The **Stefan-Boltzmann law**: $F = \sigma T^4$.
  - Cosmic microwave background

Stargazing event

- **When: March 7 (and 8 if necessary)**
- **Where: Broida Rooftop**
- **How: sign up with Bill or Sagar. Maximum 50/night. First come first served. If the first night is full we'll do the second.**

Today on Astro 1

- **What are photons?**
  - light can have particle-light properties. The particles of light are called photons: $E = h\nu = hc/\lambda$
- **Why is the sky is blue and sunsets red?**
  - Interaction between light and atmosphere
- **What are stars and interstellar gas made of?**
  - The same elements we see on Earth, mostly Hydrogen, He, Oxygen, Carbon
- **What causes spectral lines?**
  - **Atomic structure**

Question 8.1 (iclickers!)

- If all stars are considered perfect blackbodies, then it should follow that all stars
  - A) of the same composition emit the same energy flux
  - B) of the same size emit the same energy flux
  - C) traveling at the same speed emit the same energy flux
  - D) of the same temperature emit the same energy flux

Light is also a particle: Planck's Law

$$E = \frac{hc}{\lambda}$$ or $$E = h\nu$$

E = Energy of a photon
h = Planck's constant = 6.625×10^{-34} J s
c = speed of light
λ = wavelength of light
ν = frequency of light

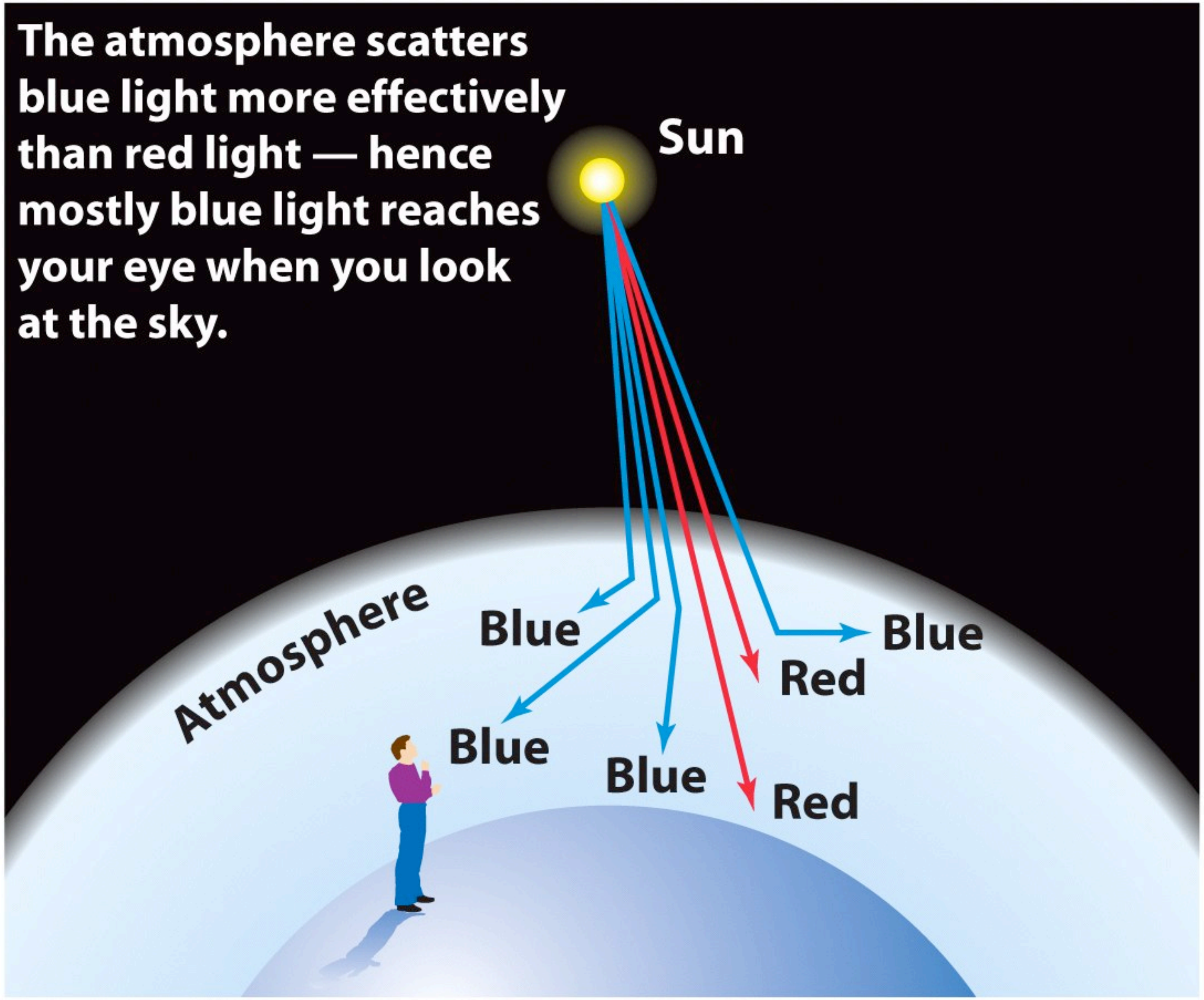
Example: DNA molecules are easily broken when hit with ultraviolet light at 260 nm (why you get cancer from sunburns). How much energy does a single photon at this wavelength have?

$$E = \frac{hc}{\lambda} = \frac{(6.625 \times 10^{-34}\, Js)(3.00 \times 10^{8}\, m/s)}{2.60 \times 10^{-7}\, m} = 7.64 \times 10^{-19}\, J$$

Question 8.2 (iclickers!)

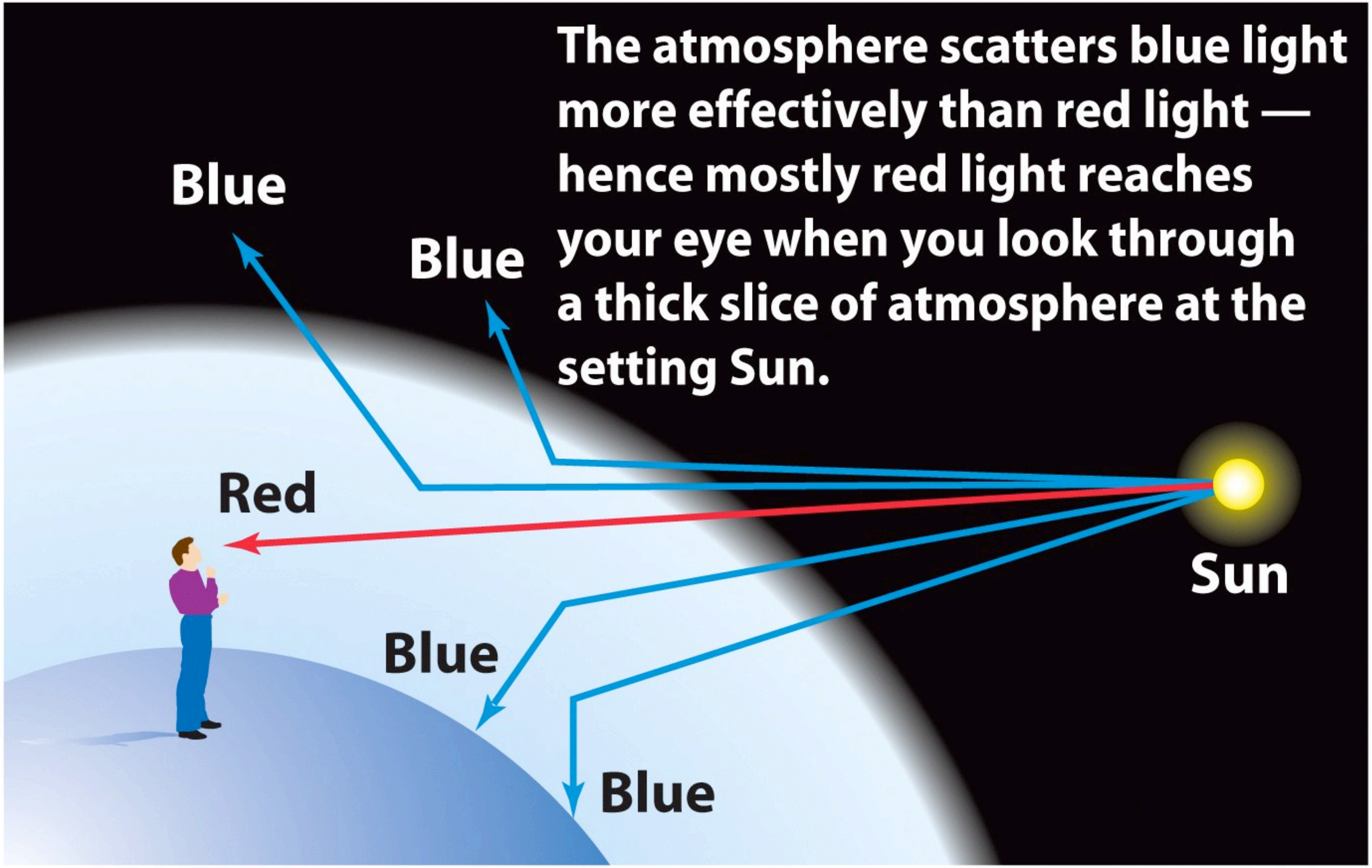
- In what way does a photon of blue light not differ from a photon of yellow light in a vacuum
    - A) wavelength
    - B) color
    - C) energy
    - D) speed

Why is the sky blue and the sunset red?



Why the sky looks blue

Box 5-4a
Universe, Eighth Edition



Why the setting Sun looks red

Box 5-4b
Universe, Eighth Edition

Spectra as the “fingerprints” of nature

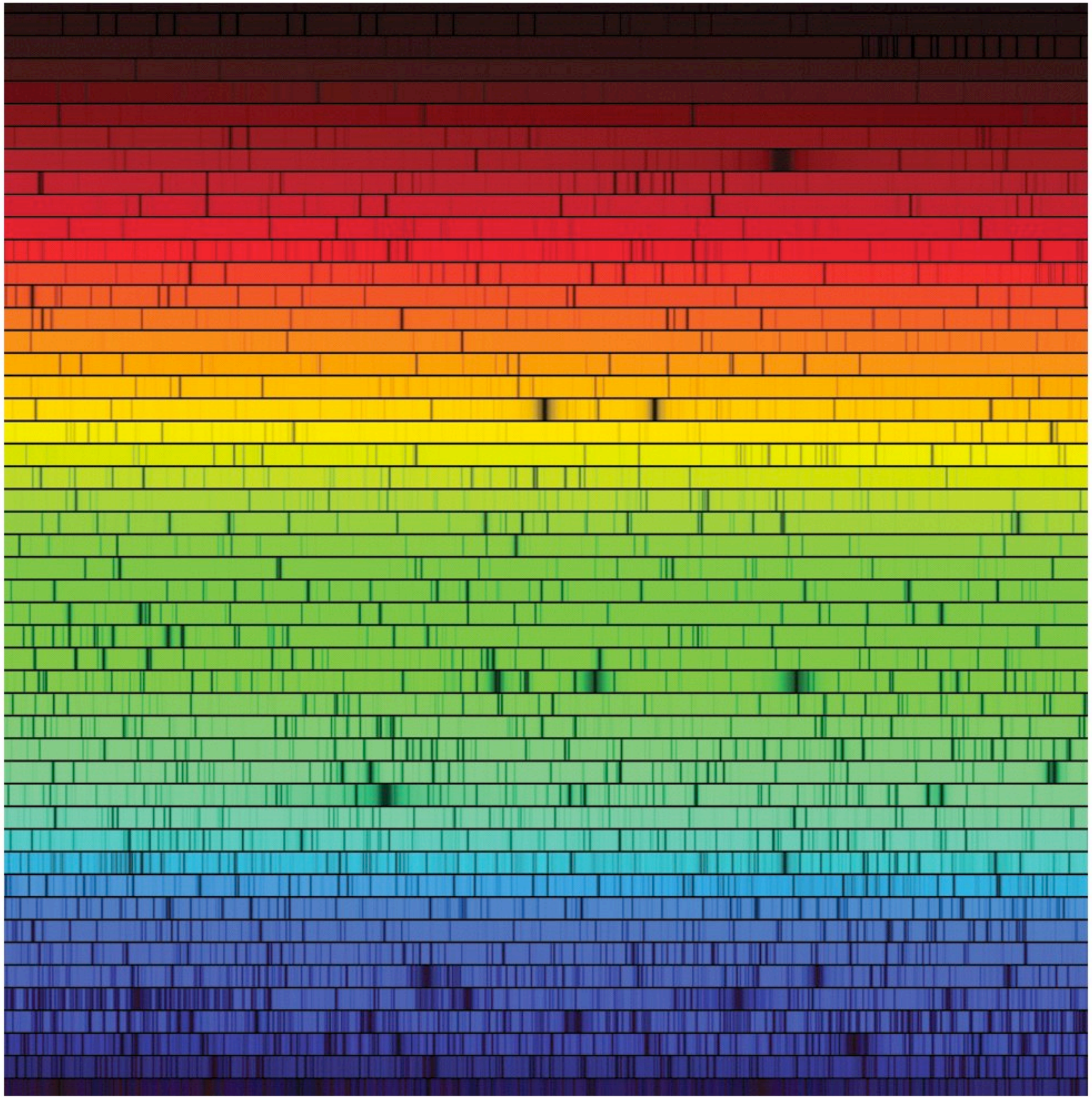


Figure 5-13
Universe, Eighth Edition

The Sun's Spectrum

In 1814 Joseph von Fraunhofer magnified the solar spectrum seen through a prism, and found hundreds of dark lines.

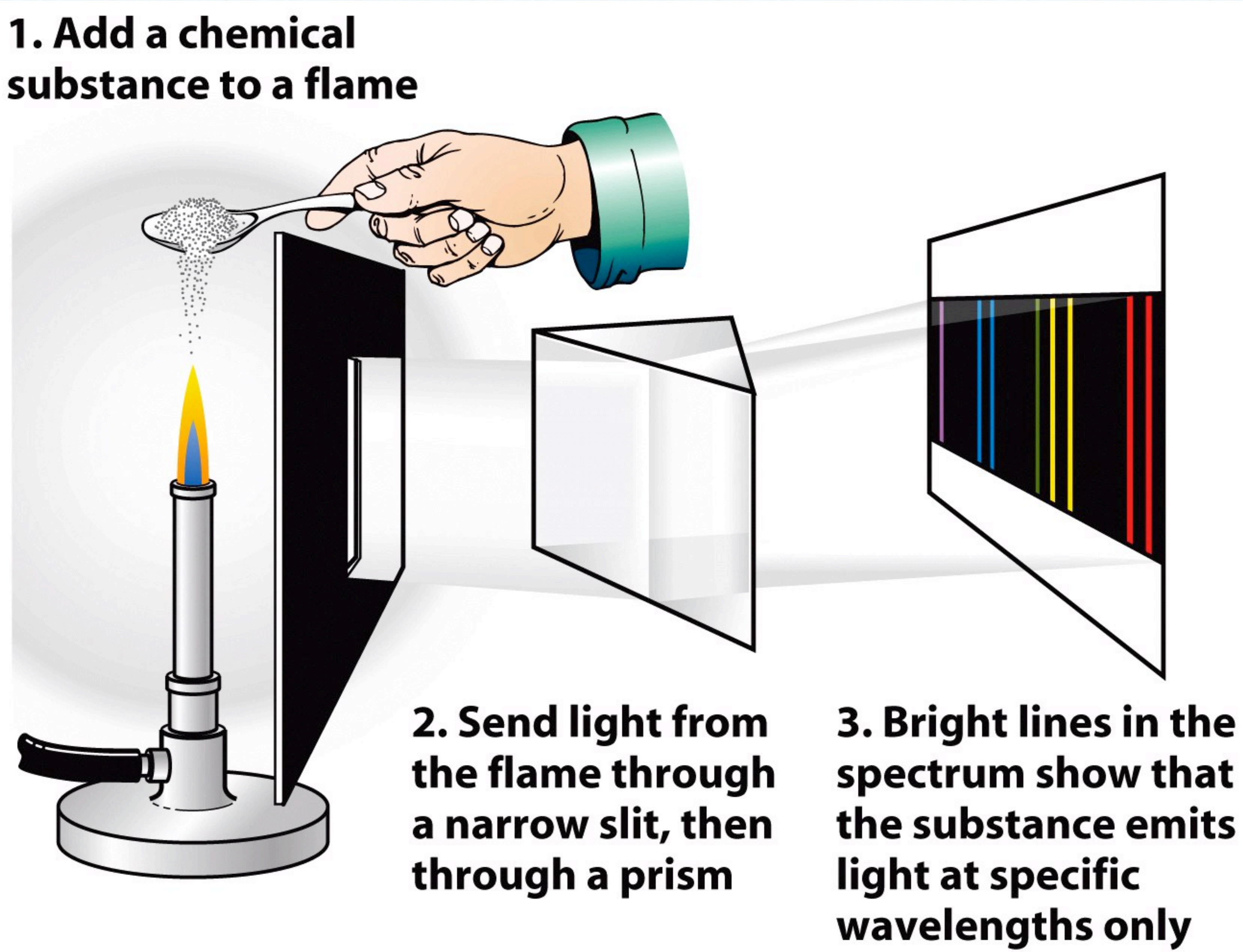


Figure 5-14
Universe, Eighth Edition

Kirchoff’s Laws

1. A hot, dense object such as a blackbody emits a **continuous spectrum** covering all wavelengths.
2. A hot, transparent gas produces a spectrum that contains bright (**emission**) lines.
3. A cool, transparent gas in front of a light source that itself has a continuous spectrum produces dark (**absorption**) lines in the continuous spectrum.

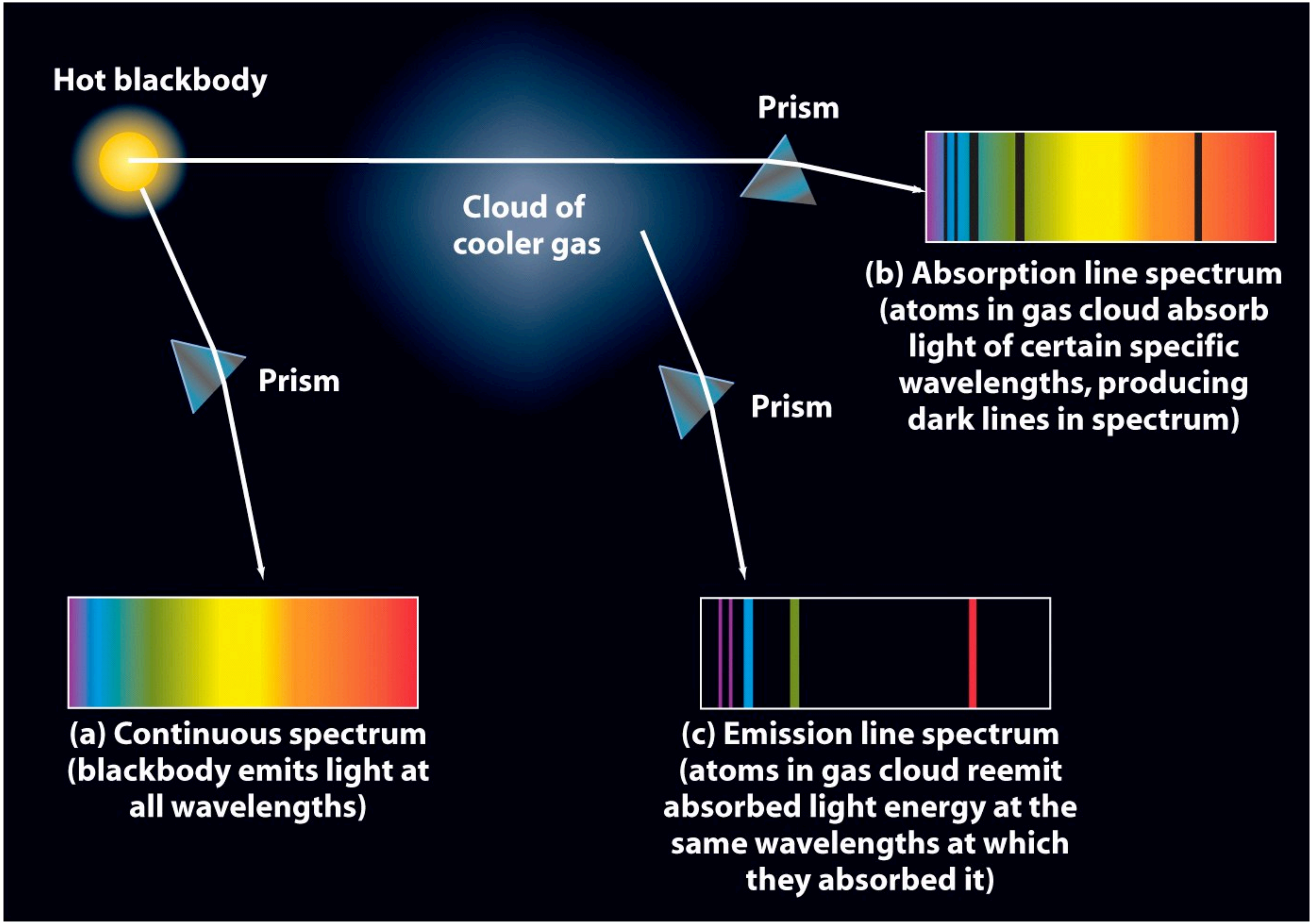


Figure 5-16
Universe, Eighth Edition

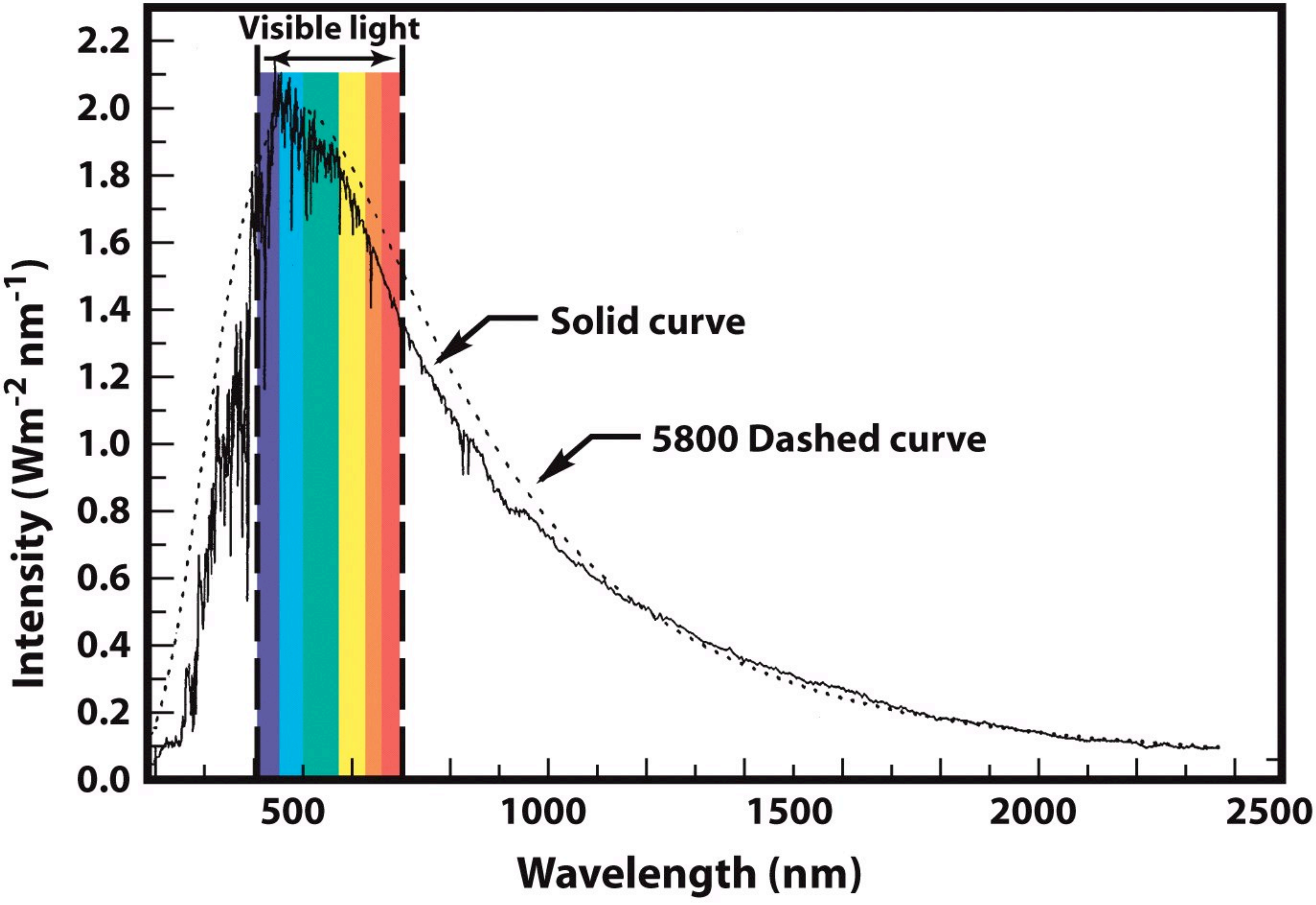


Figure 5-12
Universe, Eighth Edition

The energy output of the sun.

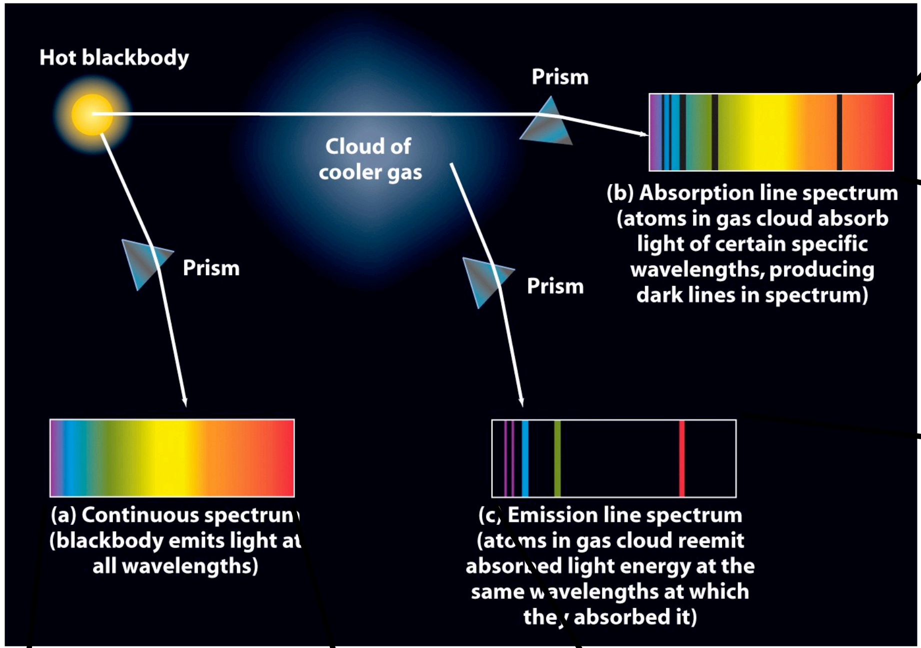
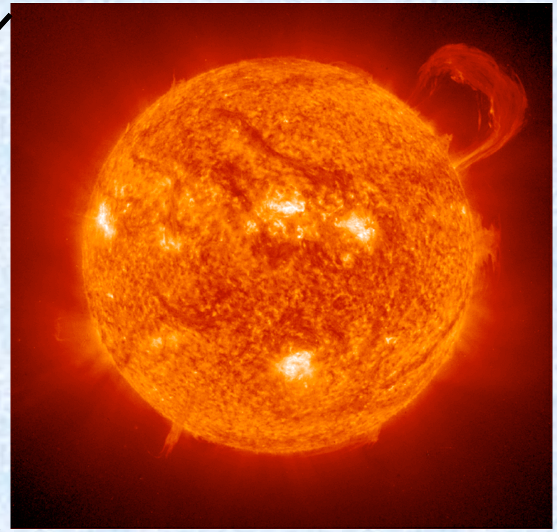


Figure 5-16
Universe, Eighth Edition



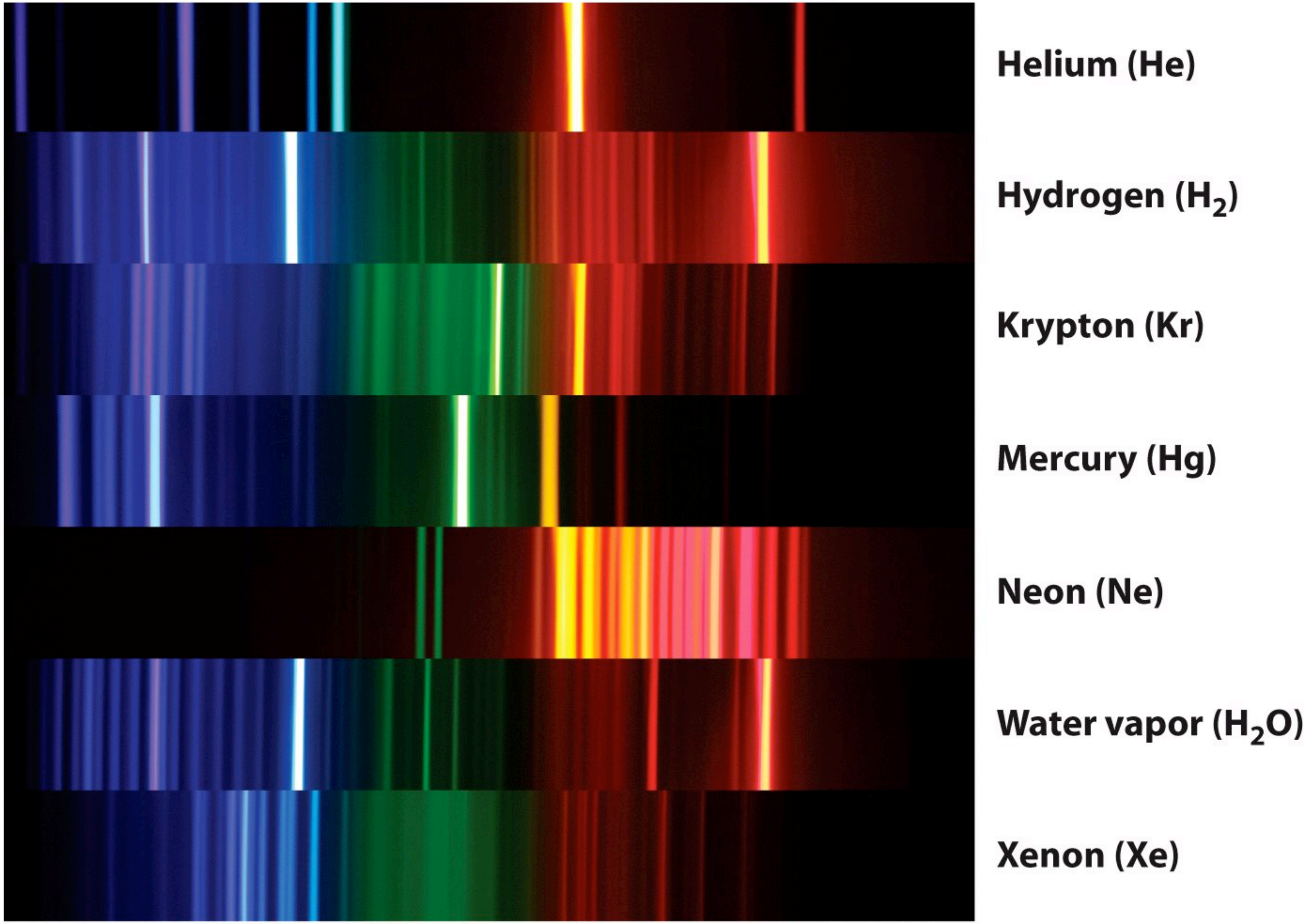


Figure 5-15
Universe, Eighth Edition

Figure 5-18
Universe, Eighth Edition

The glowing gas cloud in this Hubble Space Telescope image lies 210,000 light-years away in the constellation Tucana (the Toucan). Hot stars within the nebula emit high-energy, ultraviolet photons, which are absorbed by the surrounding gas and heat the gas to high temperature. This heated gas produces light with an emission line spectrum. The wavelength of red light emitted by the nebula is 656 nm, characteristic of hydrogen gas

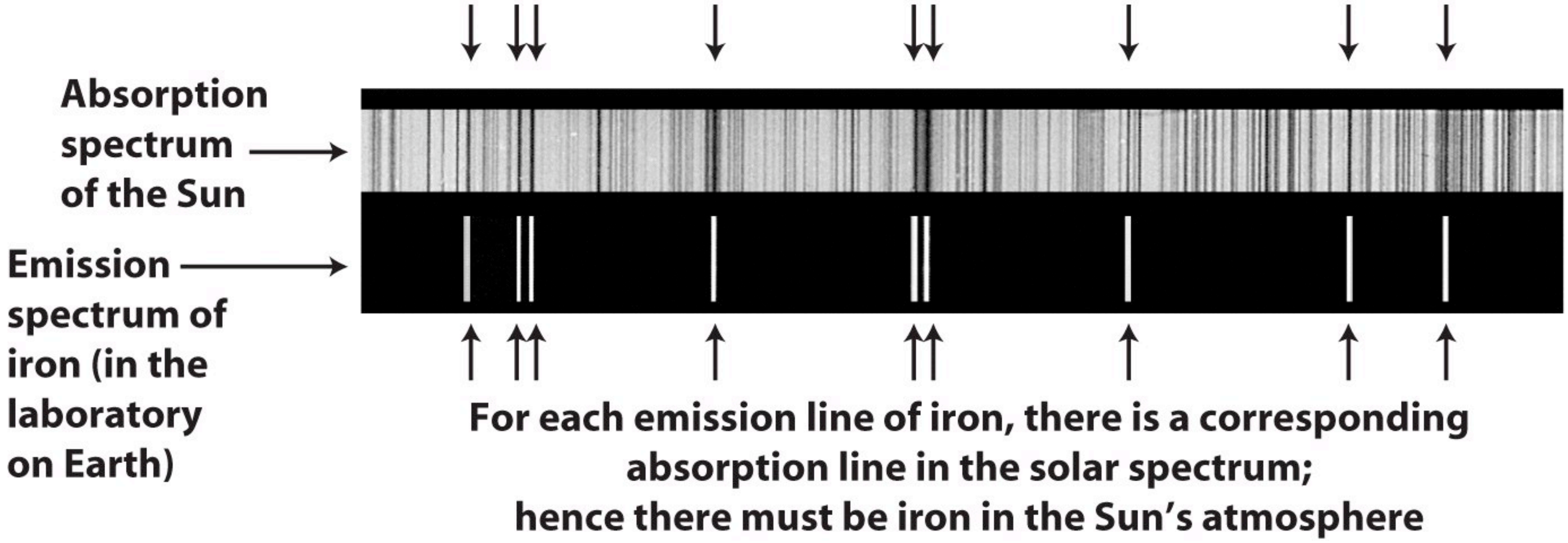
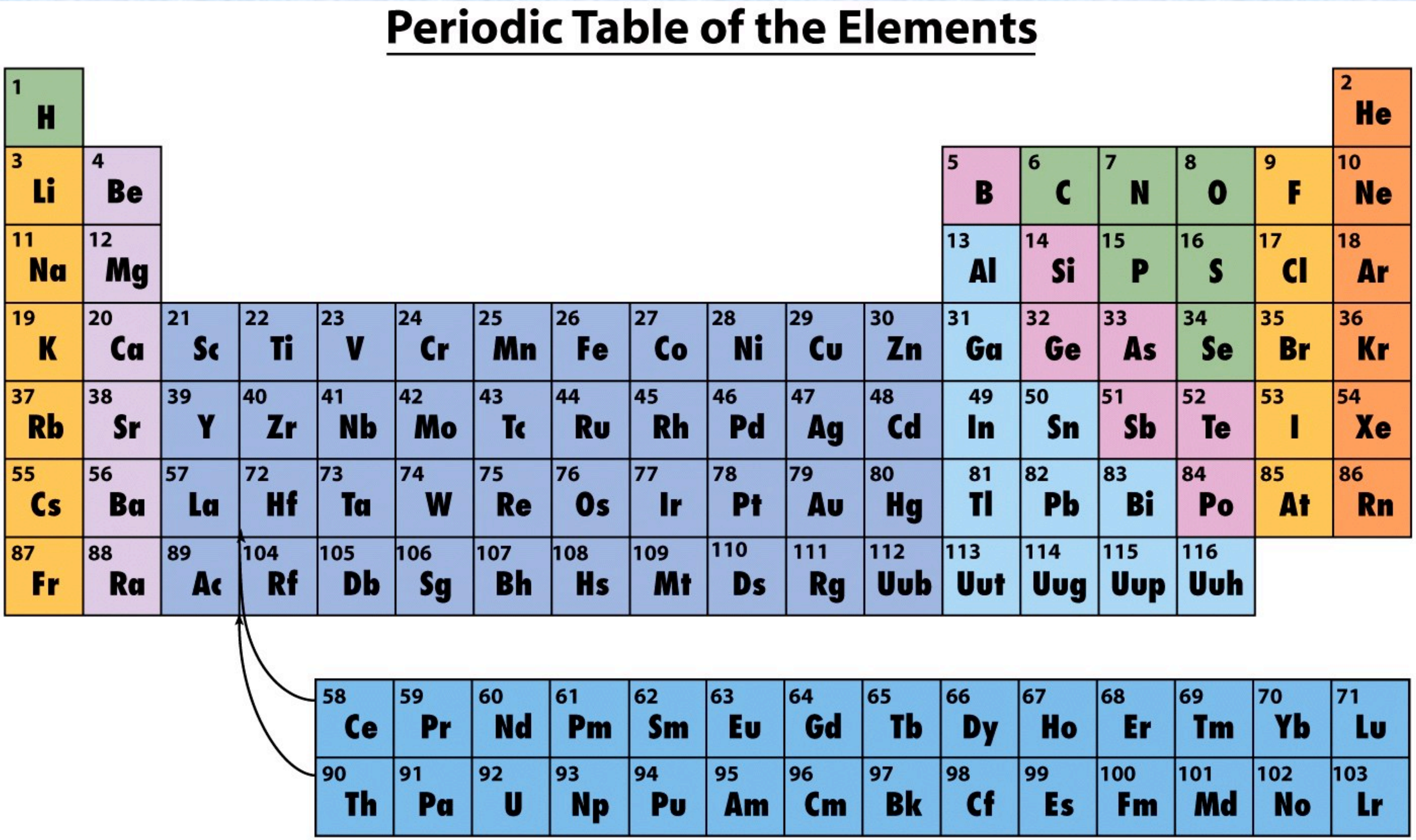


Figure 5-17
Universe, Eighth Edition



Box 5-5 part 2
Universe, Eighth Edition

Atomic number is the number of protons in an atom.

What causes spectral lines?
The structure of atoms

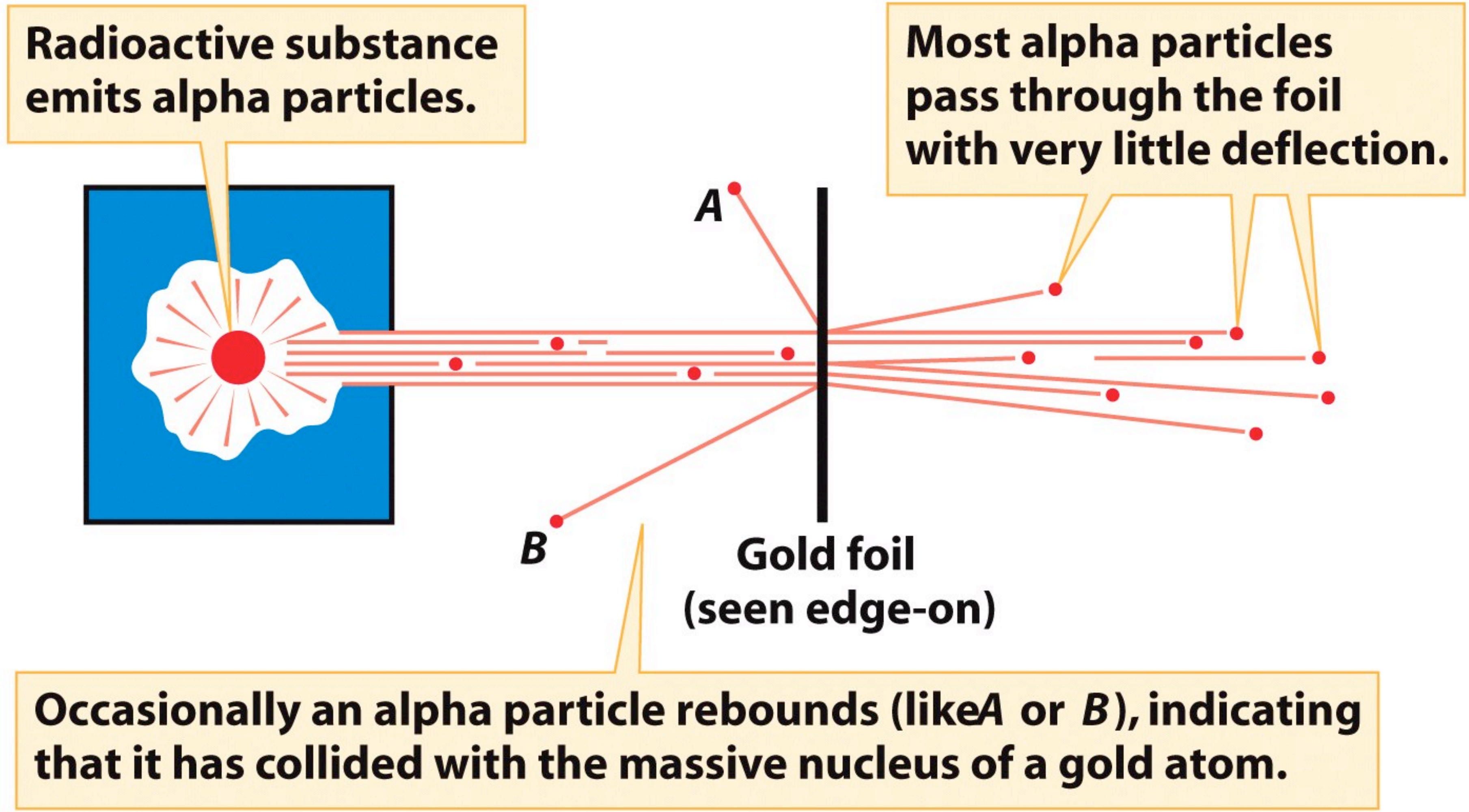


Figure 5-19
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Rutherford's Experiment

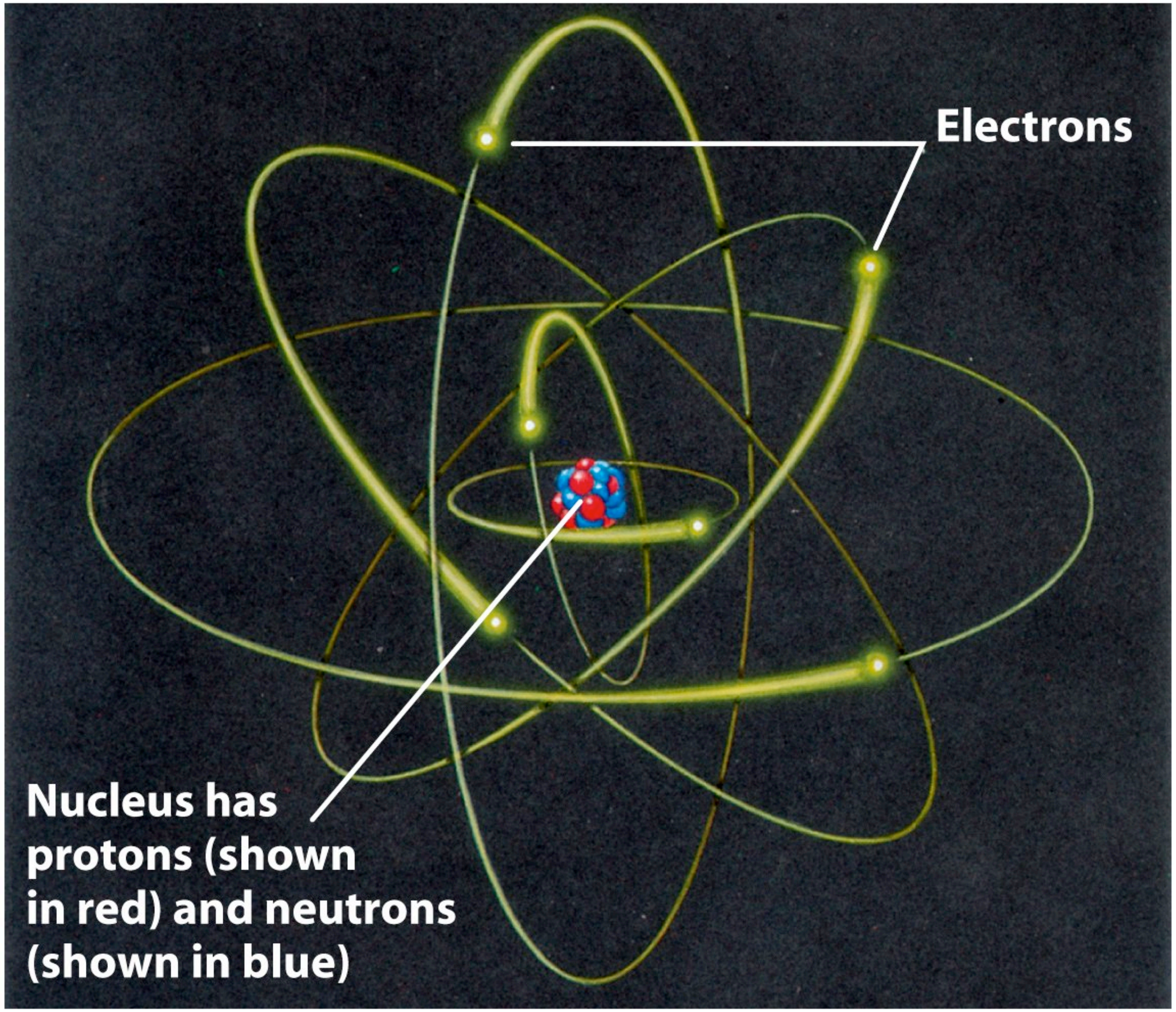


Figure 5-20
Universe, Eighth Edition

Rutherford's model of the atom.

Today we know this is not exactly correct – electrons do not orbit the nucleus, but the basic idea is right -- protons and neutrons exist in the nucleus, and electrons are outside of it.

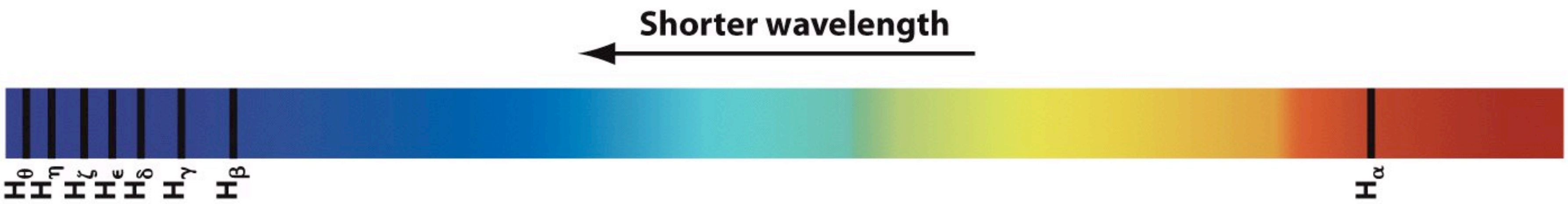


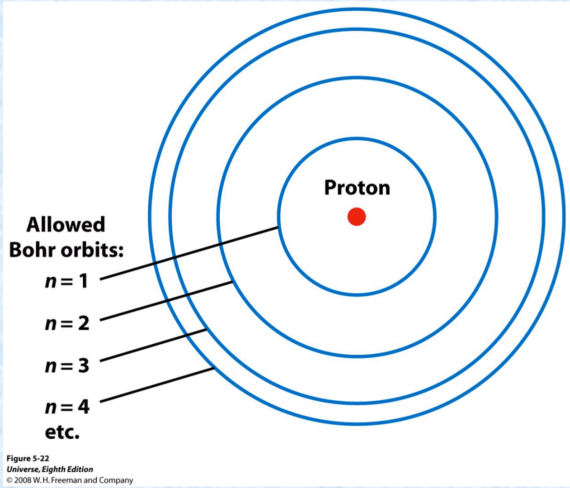
Figure 5-21
Universe, Eighth Edition

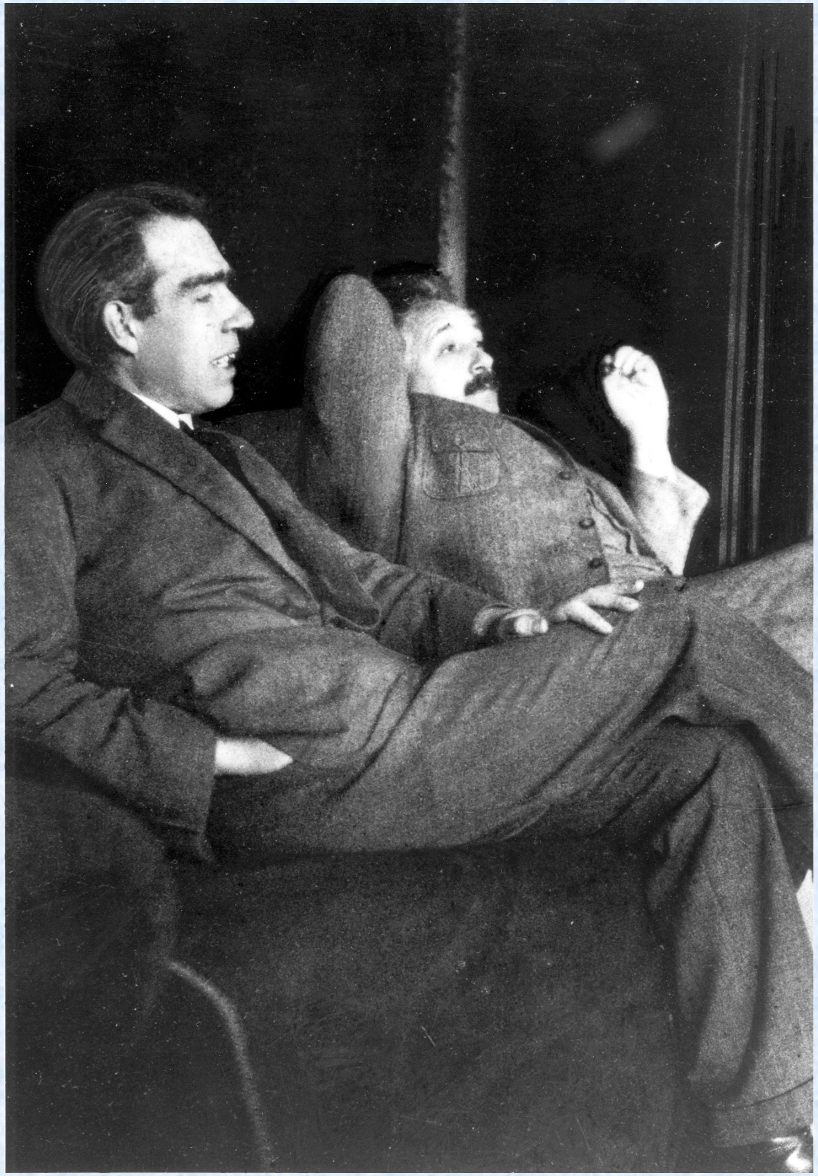
In 1885 Swiss schoolteacher Johann Jakob Balmer, by trial and error, created a formula that can predict where lines of hydrogen fall in the spectrum of a star.

We still call these Balmer lines.

$$\frac{1}{\lambda} = R\left(\frac{1}{4} - \frac{1}{n^2}\right)$$

R = Rydberg constant = 1.097×10^7 m^{-1}
n = any integer greater than 2





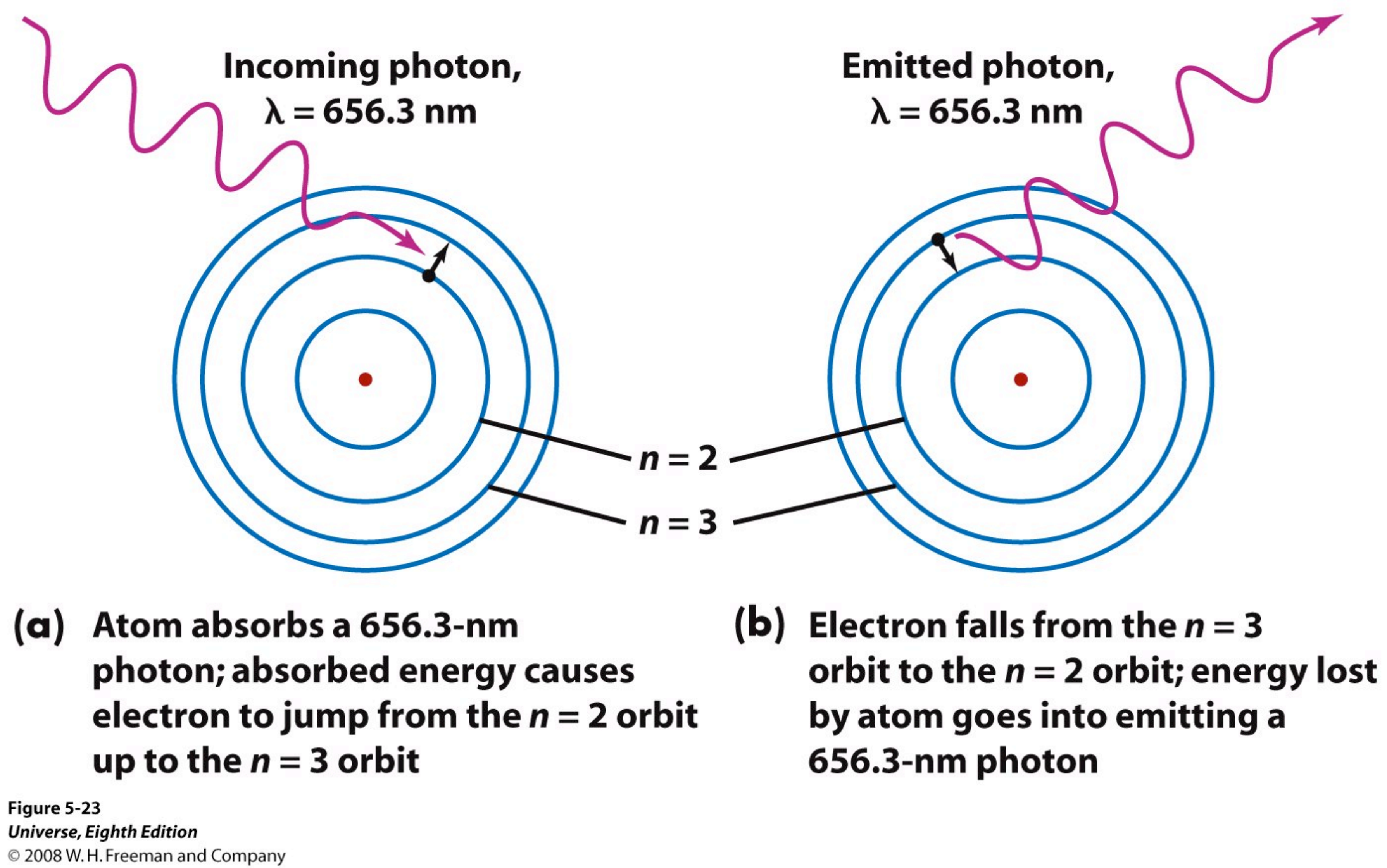
Niels Bohr
1885-1962

The Bohr model
of the atom

Was a postdoc with Rutherford.
In 1912, to explain discrete
nature of spectral lines,
hypothesized that electron orbits
are quantized (quantum
mechanics!).

Bohr and Einstein, 1925

The quantum nature of light is related to the quantum nature of atoms!



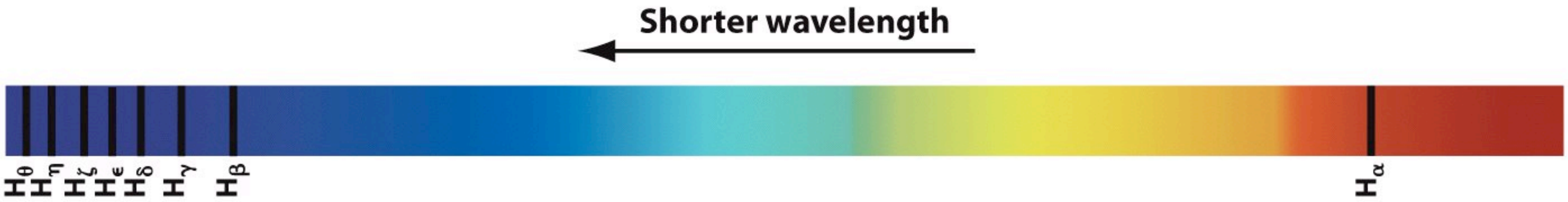


Figure 5-21
Universe, Eighth Edition

$$\frac{1}{\lambda} = R\left(\frac{1}{4} - \frac{1}{n^2}\right)$$

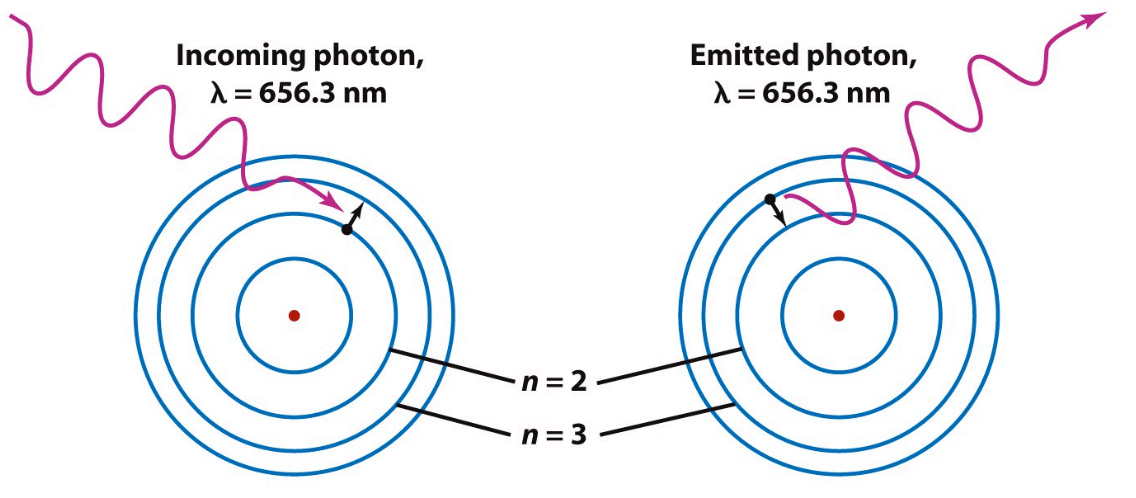
The Balmer series and fomula.

R = Rydberg constant = 1.097×10^7 m^{-1}

Bohr figured out the physical explanation for Balmer's formula – the spectra from stars depends on the structure of atoms!

$$\frac{1}{\lambda} = R\left(\frac{1}{N^2} - \frac{1}{n^2}\right)$$

N = lower orbital
n = higher orbital



(a) Atom absorbs a 656.3-nm photon; absorbed energy causes electron to jump from the *n* = 2 orbit up to the *n* = 3 orbit

(b) Electron falls from the *n* = 3 orbit to the *n* = 2 orbit; energy lost by atom goes into emitting a 656.3-nm photon

Figure 5-23
Universe, Eighth Edition

Electron Transitions in the Hydrogen Atom
The same wavelength occurs whether a photon is emitted or absorbed.

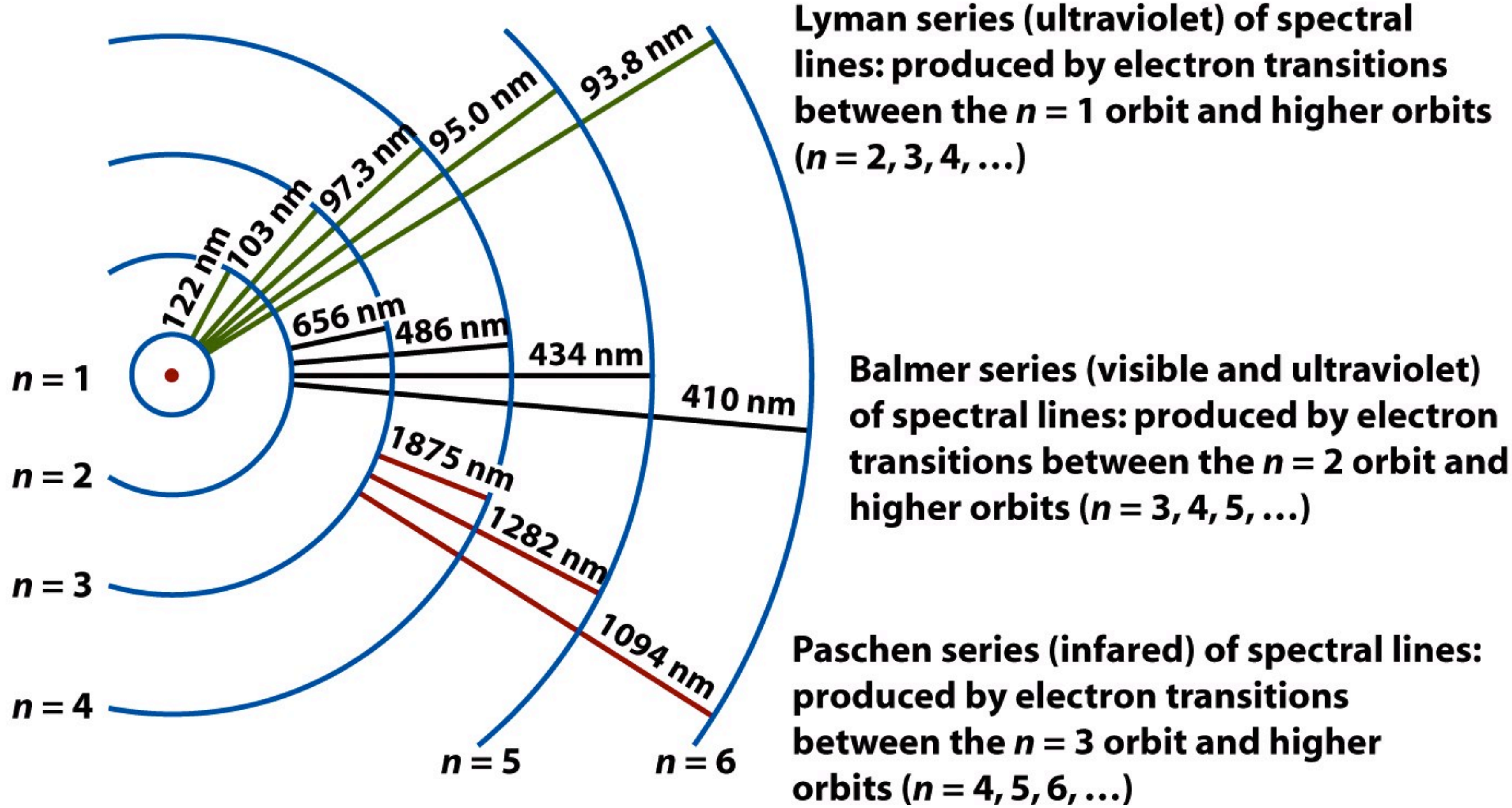


Figure 5-24
Universe, Eighth Edition

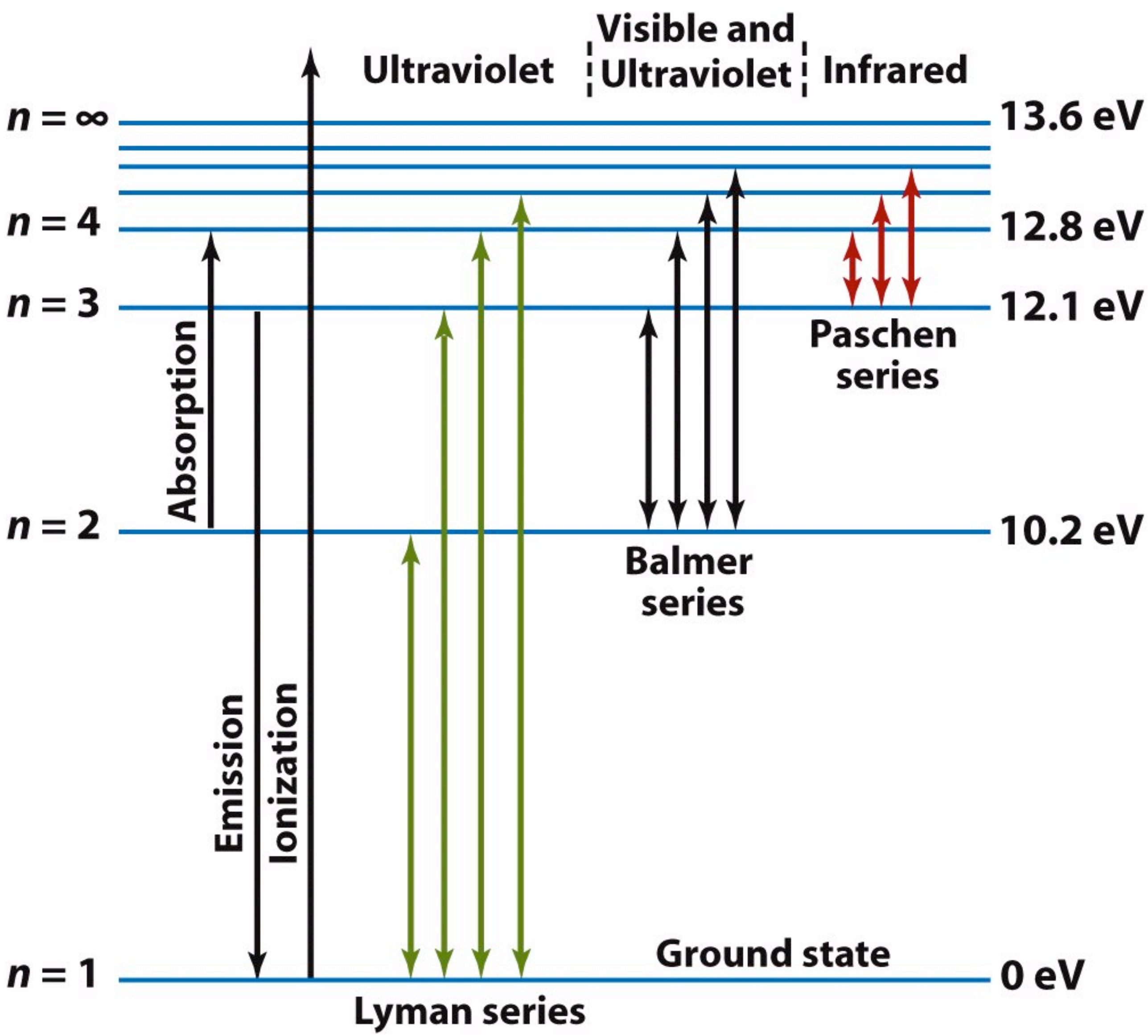


Figure 5-25
Universe, Eighth Edition

Question 8.3 (iclickers!)

- Most of the mass of ordinary matter resides in the
  - A) electrons and nuclei, shared equally
  - B) nuclei of atoms
  - C) electron around the nuclei of atoms
  - D) energy stored within the atom in electromagnetic forces

Summary

- **What are photons?**
  - light can have particle-light properties. The particles of light are called photons: $E = h\nu = hc/\lambda$
- **Why is the sky is blue and sunsets red?**
  - Interaction between light and atmosphere
- **What are stars and interstellar gas made of?**
  - The same elements we see on Earth, mostly Hydrogen, He, Oxygen, Carbon
- **What causes spectral lines?**
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The End

See you on wednesday!