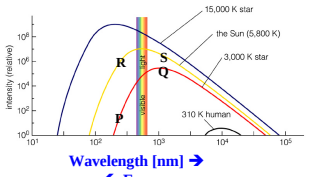
Atoms Absorb & Emit Light–January 28

- First test is next Wed
  - Covers atoms & light.
  - Does not cover telescopes (Mon).
  - Practice test on angel.
  - "Missouri Club" (Show me)
    - Mon, 31 Jan, 7:00-8:00pm, 1415 BPS (next door)
- Clicker scores
  - What counts are the scores starting with 4th classes.
  - Absent means you did not click for that day. If you did not click during classes 1-3, your grade is not hurt.
  - Ignored questions are not averaged properly. Will be fixed soon.
- **Atoms emit and absorb light**

Black-Body Spectrum

[Fig. 5.10]



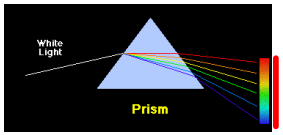
- Peak wavelength given by Wien's Law.
  - $\lambda_{max} = 0.0027 \text{m-K} / T$
  - hotter objects have peak at smaller λ.
- Total energy emitted per s *per unit surface area* is given by Steffan-Boltzmann Law:
  - $E = \sigma T^4$
  - Increase with temperature is very steep: factor of 2 for a factor of 1.2 in temperature

1. There is light in a dark room. The plausible reason is
   a. It is impossible to cover the windows completely
   b. My eyes see blotchy light in a dark room
   c. Everything in the room emits infrared light, which our eyes cannot see.
2. A hot object emits more infrared radiation than a cool object. An example of this is
   a. Q & S
   b. P & R
   c. R & S
   d. R & Q
3. S1: A hot star always emits more light than a cool star. S2: The sun is pretty bright at infrared wavelengths of 10,000nm.
   a. S1 is true; S2 is true.
   b. S1 is true; S2 is false.
   c. S1 is false; S2 is true.
   d. S1 is false; S2 is false.

interactive Wien's law

Light is the atom's fingerprint –Spectroscopy

- Spectrograph. Instrument that measures how bright the light is at each individual wavelength.
  - Prism spreads light by color
  - Grating does the same
- Each element emits a unique set of spectral lines, its fingerprint
  - A spectrum of starlight reveals what elements are in the star.

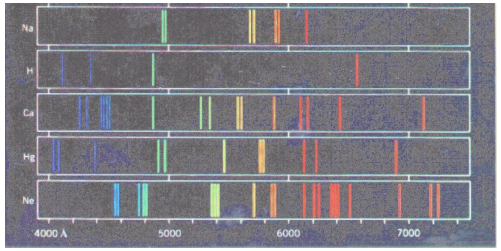


Detector measures brightness of light at each point in vertical direction.

demo

Light is the atom's fingerprint

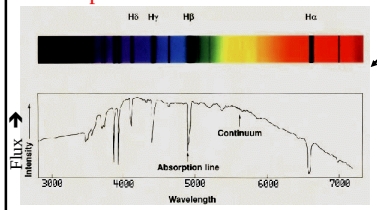
Sodium
Hydrogen
Calcium
Mercury
Neon



demo

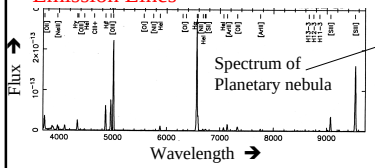
Astrophysical examples

- Absorption Lines



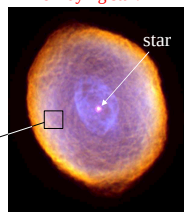
Spectrum of a star

- Emission Lines



Spectrum of Planetary nebula

IC 418 – shell of gas blown off dying star.

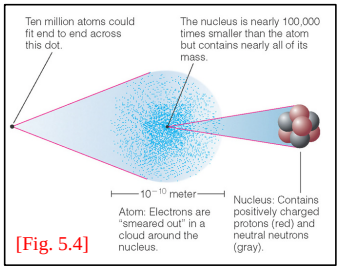


Questions on readings

- Atoms emit & absorb light

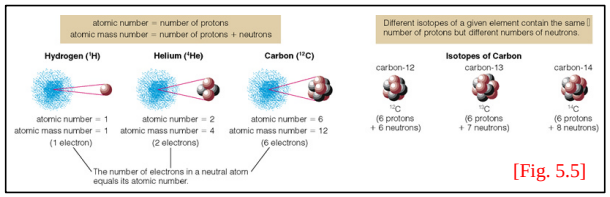
1. Which is an example of an atom
   a. Water
   b. Air
   c. Carbon dioxide
   d. Helium
2. When an oxygen atom absorbs light
   a. One of its electrons gains energy
   b. One of its protons gain energy
   c. One of its electrons loses energy
   d. One of its protons loses energy

Atoms



[Fig. 5.4]

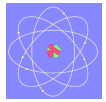
- Electrons in orbit around nucleus.
- Nucleus =
  - Protons (+ charge)
  - Neutrons (no charge)
- Different chemical elements distinguished by different numbers of protons.

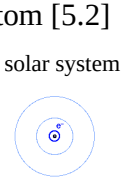


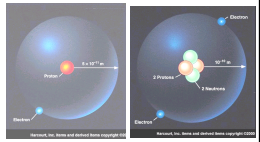
[Fig. 5.5]

The Bohr Atom [5.2]

- The atom as a miniature solar system







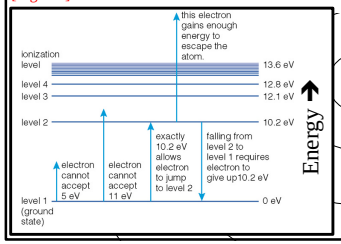
- But three special rules needed for Bohr Atom:
  - Electrons can only be in orbits at certain special radii.
  - Only one electron can be in a given orbit at one time.
  - Electron's energy stays constant while it is in orbit.

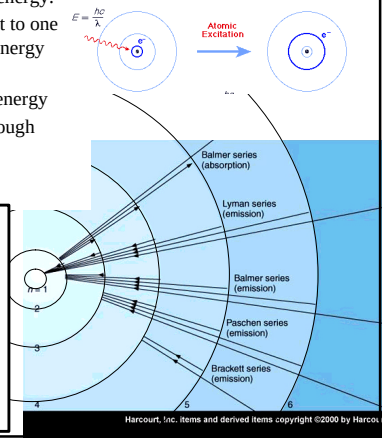
- Consequence of *quantum mechanics*.
  - Describes electrons as fuzzy probability distributions
    - not as discrete particles in discrete orbits
  - Too complicated! Bohr atom is almost right, so we'll use it pictures

Atomic Excitation

- Each Bohr orbit has its own distinct energy.
- For electron to move from inner orbit to one further out, it must gain exactly the energy difference between the orbits.
  - Can absorb photon with correct energy
  - Or can absorb kinetic energy through collisions.

[Fig. 5.8]

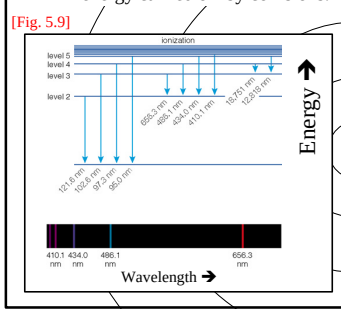


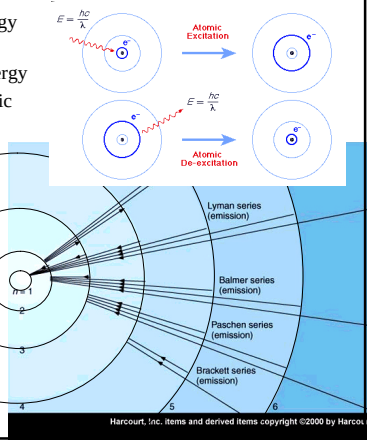


De-Excitation

- For electron to fall back in towards nucleus, it must *lose* exactly the energy difference between the orbits.
  - Can *emit* photon with correct energy
  - Or can *lose* energy through kinetic energy carried off by collisions.

[Fig. 5.9]



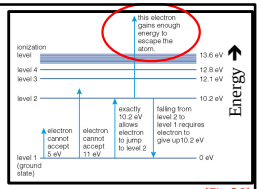


Ionization

- Very energetic photon
  ➔ electron acquires escape velocity.
  - Atom has same nucleus, but one less electron.
    - Atom is *ionized*.
  - Atom with all of its electrons is *neutral.* (neutral electrical charge)
- Elements heavier than hydrogen start out with several electrons
  - ➔ can be ionized several times
    - Example: oxygen ^{16}O
      - nucleus = 8 protons + 8 neutrons
      - O^0 or O I = nucleus with all 8 electrons.
      - O^+ or O II = nucleus with only 7 electrons.
      - O^{++} or O III = nucleus with only 6 electrons.

        etc.

Each have completely different spectra.



[Fig. 5.8]

Recombination

- Ion recaptures a free electron ➔ photon is emitted.

3. The spectrum of the outer parts of a planetary nebula is very different from that of a black body because the planetary nebula is
   a. very hot
   b. very cool
   c. not black
   d. black