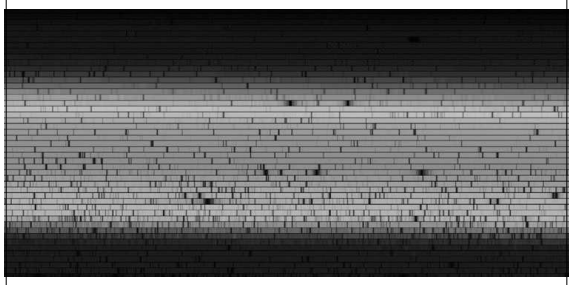
Chapter 6: Starlight and Atoms



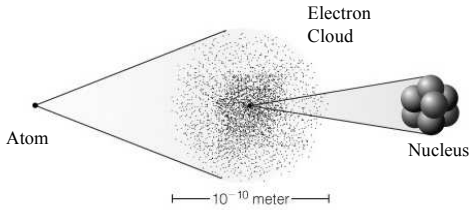
To study the largest objects in the universe, we must first understand the smallest objects in the universe!

Properties of Matter

- _____ of matter
- _____ of matter
- How _____ is stored in atoms

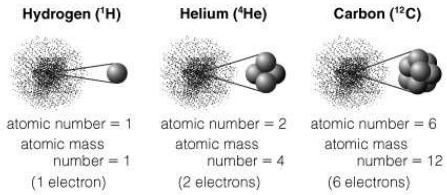
How do light and matter interact?

What is the structure of matter?



Atomic Terminology

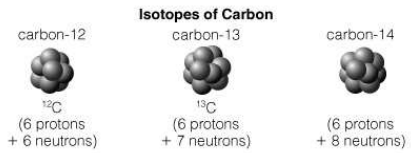
- Atomic Number = # of _____ in nucleus
- Atomic Mass Number = # of _____ + _____



- Molecules: consist of two or more _____ (H_2O, CO_2)

Atomic Terminology

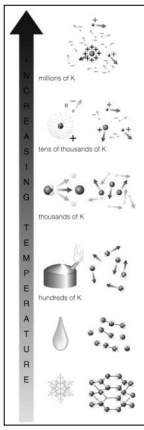
- Isotope: same # of protons but different # of _____. (^{4}He, ^{3}He)



What are the phases of matter?

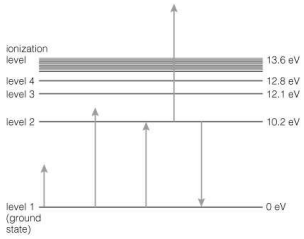
- Familiar phases:
  - Solid (ice)
  - Liquid (water)
  - Gas (water vapor)
- Phases of same material behave differently because of differences in _____ _____

Phase Changes



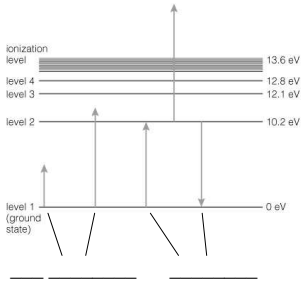
- _____: Breaking of rigid chemical bonds, changing solid into liquid
- _____: Breaking of flexible chemical bonds, changing liquid into gas
- _____: Breaking of molecules into atoms
- _____: Stripping of electrons, changing atoms into plasma

How is energy stored in atoms?



- Electrons in atoms are restricted to particular _____ _____ (electron shells)

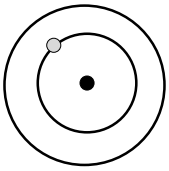
Energy Level Transitions



- An electron can only go from one level to another, not in between

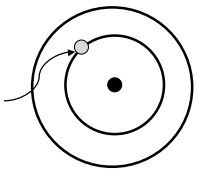
A Simple Atom

- Only 2 energy levels
  - Ground (E1)
  - Excited (E2)
- Right now electron is at E1



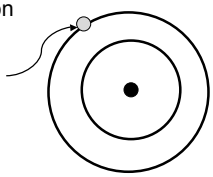
A Simple Atom

- Excitation
  - Electron _____ a photon and jumps from E1 to E2
  - Photon only absorbed if it has energy = (E2-E1)



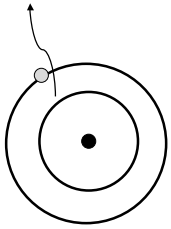
A Simple Atom

- Ionization
  - Electron _____ a photon and leaves!
  - Only works if electron is in higher energy levels

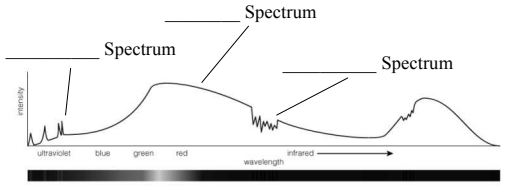


A Simple Atom

- De-excitation
  - Electron _____ a photon of energy (E2-E1)
  - Electrons like to be in the ground state

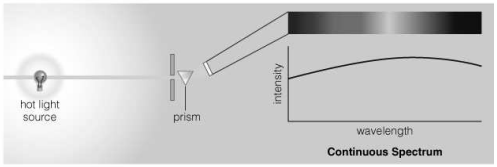


What are the three basic types of spectra?



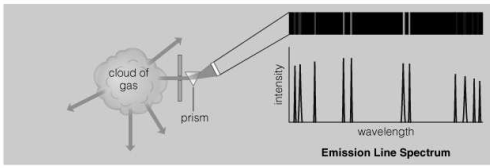
Spectra of astrophysical objects are usually combinations of these three basic types

_____ Spectrum



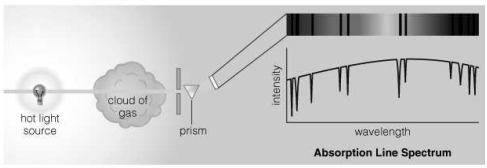
- All wavelengths, no breaks
- Rainbows!

_____ Spectrum



- Bright, individual lines
- Also called _____-____ spectrum
- Electrons are moving to **lower energy levels**, emitting photons of light

_____ Spectrum

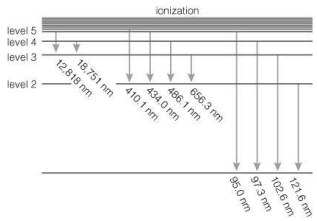


- Rainbow with dark lines on top
- Also called ____-____ spectrum
- Atoms in the cloud are absorbing photons, moving to **higher energy levels**

Kirchhoff's Laws

I. A hot, dense substance will give off _____ spectrum
II. A hot, low-density gas will give off an _____ spectrum
III. A cool, low-density gas in front of a continuous-spectrum source will give off an _____ spectrum

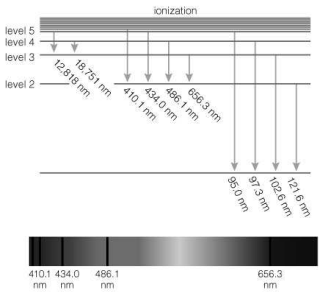
Chemical Fingerprints



Energy levels of Hydrogen

- Each type of atom has a unique set of energy levels
- Each transition corresponds to a unique photon energy, frequency, and wavelength

Chemical Fingerprints

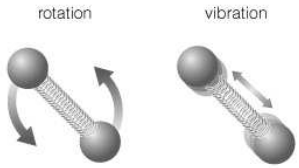


- Downward transitions produce _____ lines
- Upward transitions produce _____ lines

Chemical Fingerprints

- Each type of atom has a unique spectral fingerprint, due to _____ of _____ _____

Energy Levels of Molecules



- Molecules have additional energy levels because they can vibrate and rotate

Energy Levels of Molecules

Spectrum of Molecular Hydrogen (H_2)

- Spectra of molecules can be very complicated
  - Lots of energy modes
- Molecular transitions are typically in the IR

Light and Atoms Lecture Tutorial: page 63

- Work with a partner or two
- Read directions and answer all questions carefully. Take time to understand it **now**!
- Come to a consensus answer you all agree on before moving on to the next question.
- If you get stuck, ask another group for help.
- If you get **really** stuck, raise your hand and I will come around.

What can we learn from light?

- Temperature
- Energy
- Chemical Composition
- Speed towards or away from us

All from the spectrum!

Temperature and Radiation

- Why do different objects give off different forms of light?
- They have different _____!
  - Temperature depends on the motion of _____ & _____
  - Fast motion -> High temp.
  - Slow motion -> Low temp.

Temperature, Heat, or Thermal Energy?

- Temperature: _____ of thermal energy
- Heat: _____ of thermal energy

Two objects can be at the same temperature, but have different amounts of heat or thermal energy

Kelvin Temperature Scale

- Zero Kelvin (written 0 K) is absolute zero (-459.7ºF)
  - No heat energy
- Water freezes at 273 K, boils at 373 K.

K = ºC + 273.2

Temperature and Color

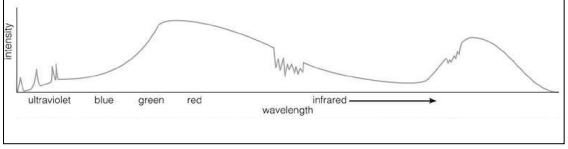
- Higher temp = higher E= higher f = shorter λ
- What color has shorter wavelength?
  - _____
  - Opposite of faucet handles…

400 nm 700 nm

Spectrum: Wavelength vs. Intensity

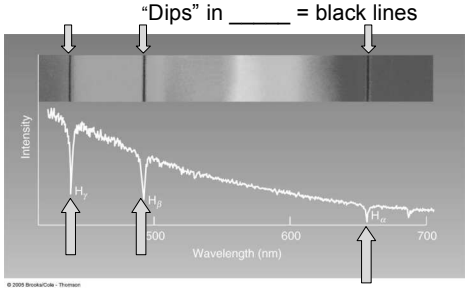
- Visible:

- Intensity vs. wavelength plot:



They show the same information

"Dips" in _____ = black lines



Dips in _____