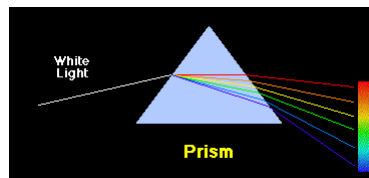


## Atoms Absorb & Emit Light—29 Jan

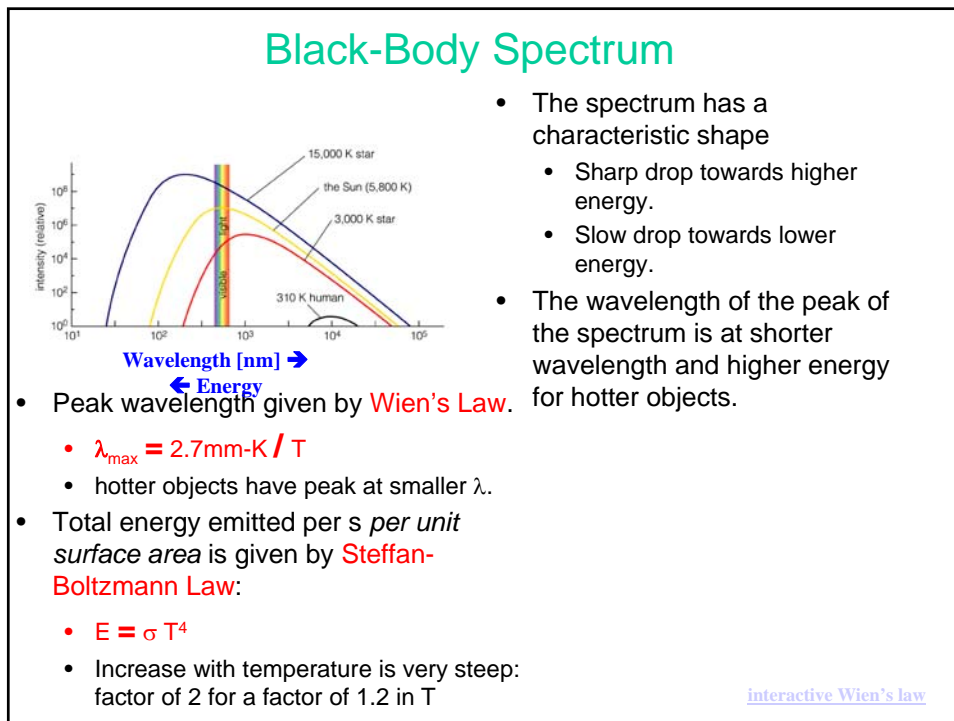
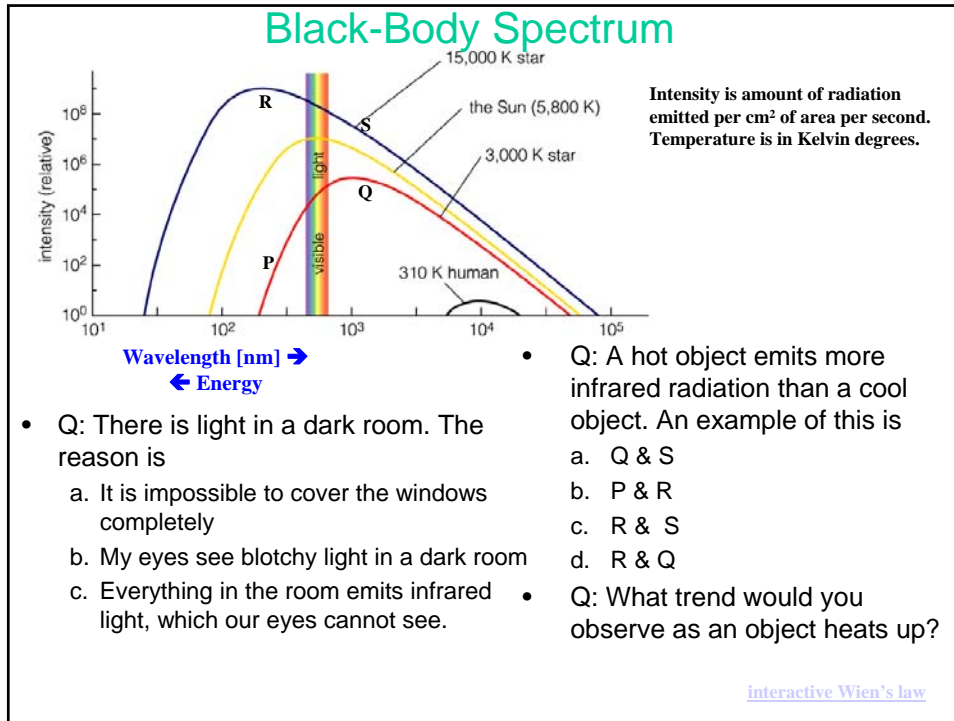
- Spectra
- Spectrum of thermal radiation
- The wavelength of the light that an element emits or absorbs is its fingerprint.
- Atoms emit and absorb light
  
- First test is Thurs, Feb 5.
  - About 30 multiple choice questions
    - Some require working with models such as phases of Venus & zodiac (Fig 2.12).
  - You may use one cheat sheet. 8½" x 11", front and back.
  - Click on Study Guide & 2005 Test on Syllabus.
    - Material covered on Q2, 3, & 28 from 2005 will not be on the test.
  - Missouri (Show me) Club
    - Tues, Feb 3, 7:00-8:00pm, room 1415.
  - Covers material through Tues, 27 Jan.

## Spectroscopy

- Spectrograph. Instrument that measures how bright the light is at each individual wavelength.
  - Prism spreads light by color
  - Grating does the same



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



## Light is the atom's fingerprint

- Each element emits a unique set of spectral lines, its fingerprint
  - A spectrum of starlight reveals what elements are in the star.
- A hot gas emits light only at certain discrete wavelengths.
  - Hydrogen emits light at 656.3nm (red), 486.1nm (cyan), 434.0nm (blue), 410.2nm (violet), etc. No light in between.
  - Other elements emit a different pattern of wavelengths
- Contrast: A black object emits light at all wavelengths in a range.

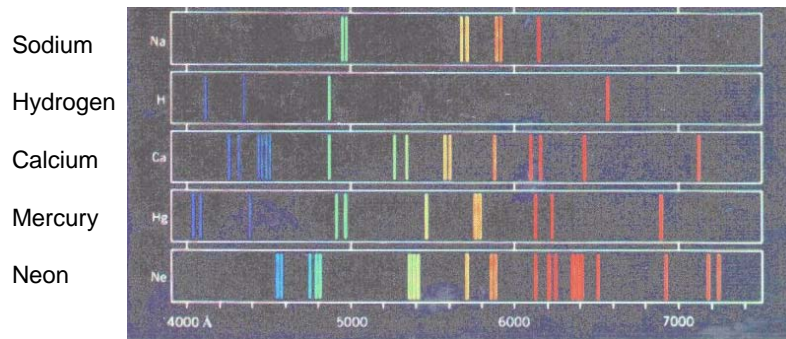


Emission spectrum of hydrogen

Demo:  
Is this H?

## Light is the atom's fingerprint

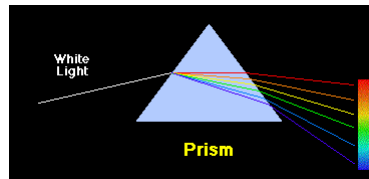
- A hot gas emits light only at certain discrete wavelengths.
  - Hydrogen emits light at 6563Å (red) , 4861Å (cyan), 4340Å (blue), 4102Å (violet), etc. No light in between. (6563Å =656.3nm)
- Contrast: A black object emits light at all wavelengths in a range.



Emission spectra of hot gasses

## Mystery element

- Each element emits a unique set of spectral lines, its fingerprint
  - A spectrum of starlight reveals what elements are in the star.

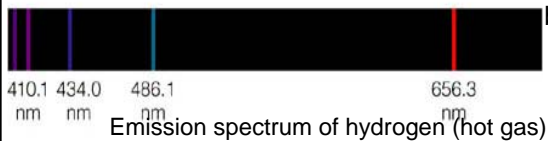


Detector measures brightness of light at each point in vertical direction.

demo

## What is the absorption spectrum of H?

- A hot gas emits light only at certain discrete wavelengths.
  - Hydrogen emits light at 656.3nm (red), 486.1nm (cyan), 434.0nm (blue), 410.2nm (violet), etc. No light in between.
  - Other elements emit a different pattern of wavelengths
- Recall “a perfectly black object emits a thermal spectrum.” Is H black at all wavelengths?
- Q1 Would hydrogen gas absorb light at 500nm?
  - a. Yes, emission spectrum is black at that wavelength.
  - b. No, its emissivity is 0 at that wavelength.



## What is the absorption spectrum of H?

- At wavelengths where H emits light, it also absorbs light.
- Recall “a perfectly black object emits a thermal spectrum.” Is H black at all wavelengths?
- Q1 Would hydrogen gas absorb light at 500nm?
  - a. Yes, emission spectrum is black at that wavelength.
  - b. No, its emissivity is 0 at that wavelength.

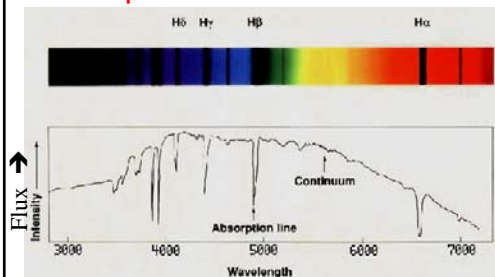


↑ Emission spectrum of hydrogen (hot gas)  
 ↓ Absorption spectrum of hydrogen (gas in front of black body)



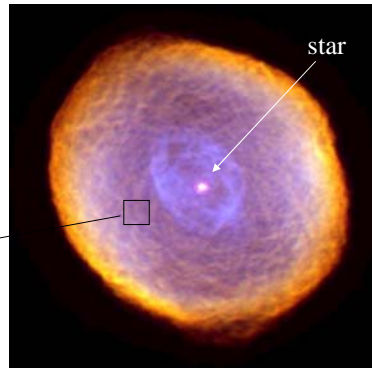
## Astrophysical examples

### Absorption Lines

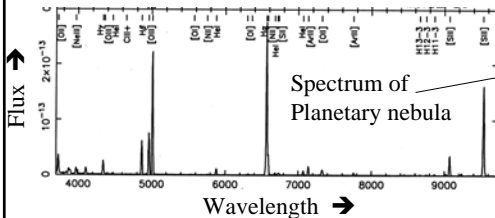


Spectrum of a star

“Planetary” nebula IC 418 – shell of gas blown off dying star.



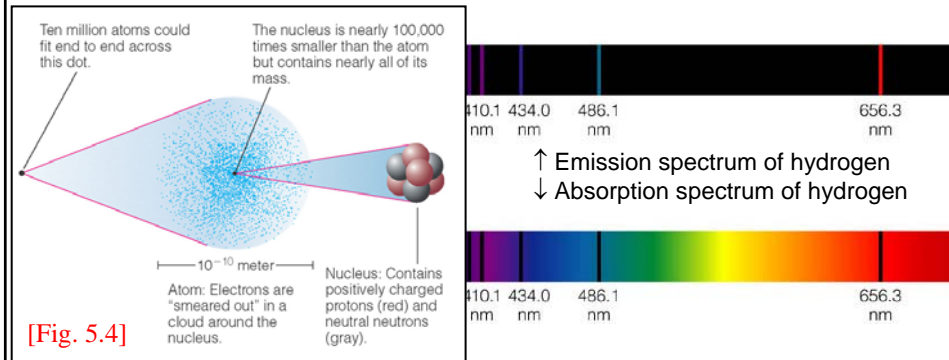
### Emission Lines



Spectrum of Planetary nebula

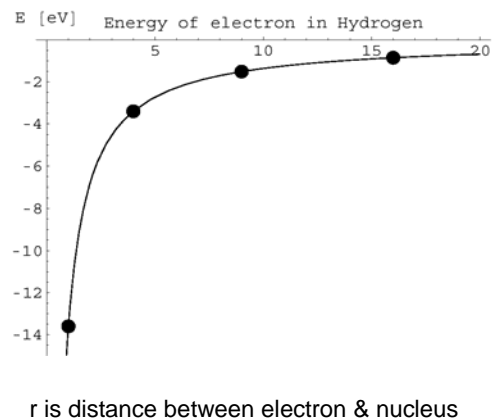
## How do atoms absorb & emit light?

- In an atom, electron(s) orbit a nucleus.
  - In H, one electron orbits nucleus
- How do photons (quanta of light) interact with atoms?
- Need to explain why atoms emit & absorb photons at discrete wavelengths



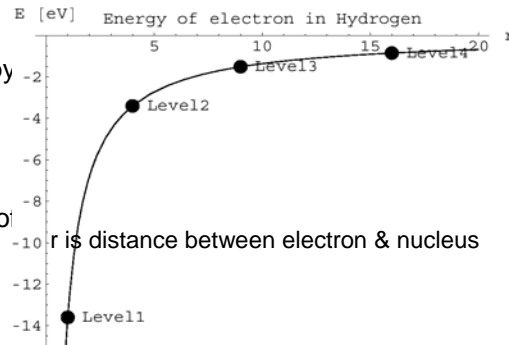
## How do atoms absorb & emit light?

- In an atom, electron(s) orbit a nucleus.
- Key idea: Energy
  - A photon carries energy
  - Electron in orbit has energy because it is moving and it is pulled by nucleus.
- Mental image
  - Electron is in a hole because of electric pull of nucleus. It takes energy to climb up the hole.



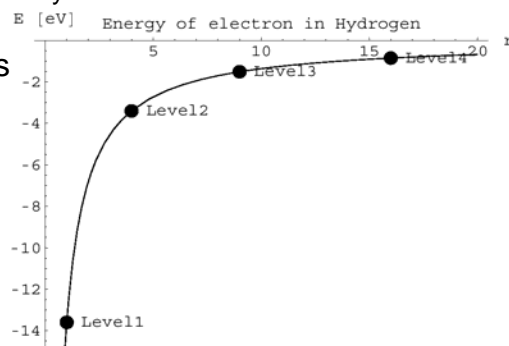
## How do atoms absorb & emit light?

- In an atom, electron(s) orbit a nucleus.
- Key idea: Energy
  - A photon carries energy
  - Electron in orbit has energy because it is moving and it is pulled by nucleus.
- Mental image
  - Electron is in a hole because of electric pull of nucleus. It takes energy to climb up the hole.
- Q. How much energy does electron need to climb from Level 1 → 2? a: 14eV, b: 10eV, c: 3 eV.



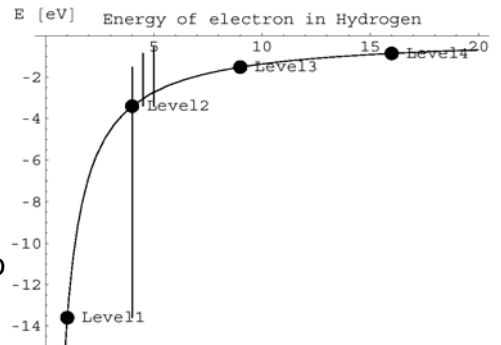
## How do atoms absorb & emit light?

- Key idea: Energy
  - A photon carries energy
  - Electron in orbit has energy because it is moving and it is pulled by nucleus.
- When atom absorbs photon, energy of photon promotes electron to higher energy.
- Q: An atom with an electron in L3 emits photon. Where does energy of photon come from?
  - Electron supplies energy by dropping to a lower level
  - Electron supplies energy by going to a higher level.
  - Nucleus gives up some energy
  - Energy is created.



## Niels Bohr's quantization

- Big question in 1900: Why does hydrogen emit & absorb light at discrete wavelengths? at discrete energies?
- Bohr's "quantization" rule:
  - Electron can only be in a level for which angular momentum  $L = n h$ ,
    - $h$  is Planck's constant
    - $n = 1, 2, 3, 4$ , etc
  - These are "levels" in plot.
- Bohr's rule showed path to quantum mechanics.



- Visible emission line of H
  - Red line is jump  $3 \rightarrow 2$
  - Cyan line is jump  $4 \rightarrow 2$
  - Blue line is jump  $5 \rightarrow 2$
- Electron cannot jump from level 4 to level 2.5 and emit some green light.

## Other lines of H

- Visible emission line of H
  - Red line is jump  $3 \rightarrow 2$
  - Cyan line is jump  $4 \rightarrow 2$
  - Blue line is jump  $5 \rightarrow 2$
- Q4: Why did we not see lines that can account for jump  $2 \rightarrow 1$ ?
  - a. This jump cannot occur.
  - b. Light of this wavelength is ultraviolet and not visible to the eye.
  - c. Light of this wavelength is infrared and not visible to the eye.

