Atoms Absorb & Emit Light

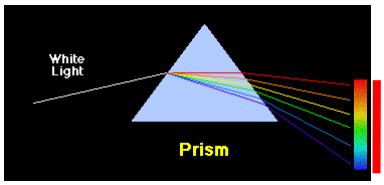
- Spectra
- The wavelength of the light that an element emits or absorbs is its fingerprint.
- Atoms emit and absorb light

- First Test is Thurs, Feb 1st
  - About 30 multiple choice questions
    - Some require working with models such as phases of Venus & zodiac (Fig 2.12).
  - Click on Study Guide & 2005 Test on Syllabus.
  - Class of 30th is not on test
- Homework: Higher of 2 attempts is used.

- How to study
  - Identify Big Ideas
  - Practice models & examples
  - Do 2005 test
  - Go over homework & clicker questions
  - Go to office hours (Brian Thomas after each class in atrium)
- Missouri "Show Me" Club
  - Mon 29th, 7:00-8:00pm, 1415 BPS
- Homework 3 is ready on angel.
  - Due at 6:00am on Tues, 30th.

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

- 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.

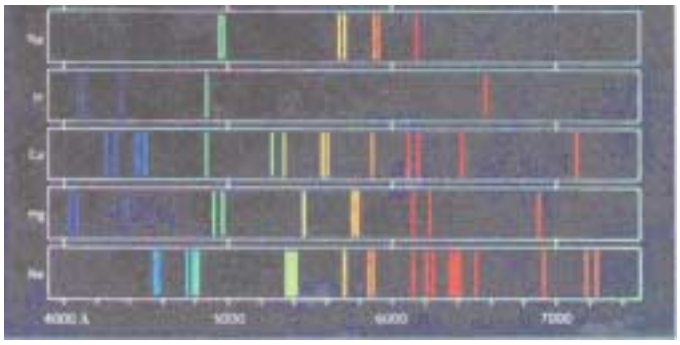
Emission spectrum of hydrogen

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.

Sodium
Hydrogen
Calcium
Mercury
Neon



Emission spectra of hot gasses

What is the absorption spectrum of H?

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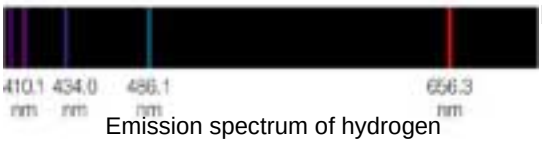

Emission spectrum of hydrogen

- 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.

↑ Emission spectrum of hydrogen
↓ Absorption spectrum of hydrogen

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- Q1 Would hydrogen gas absorb light at 500nm?
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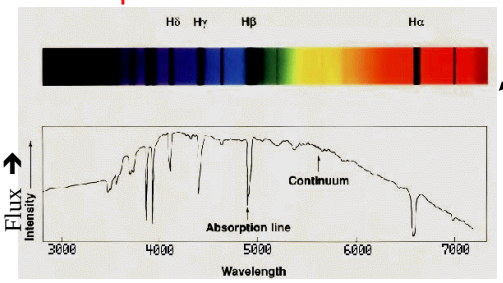
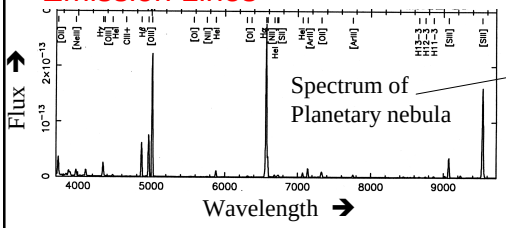
Astrophysical examples

- Absorption Lines



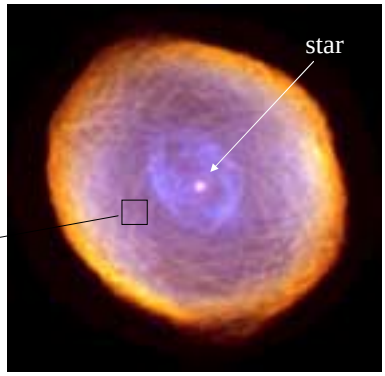
Spectrum of a star

- Emission Lines



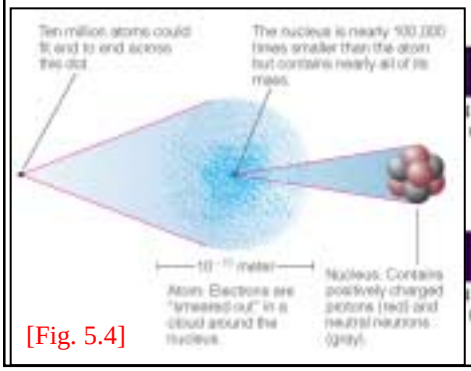
Spectrum of Planetary nebula

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

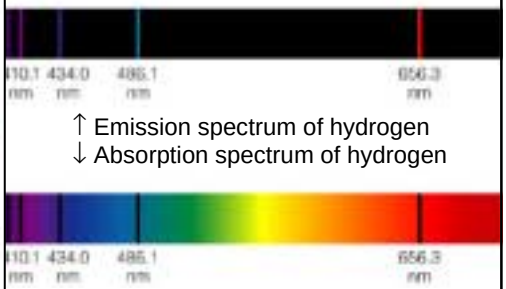


How do atoms absorb & emit light?

- 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



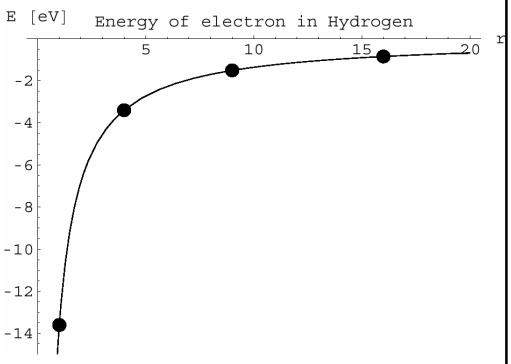
[Fig. 5.4]



↑ Emission spectrum of hydrogen
↓ Absorption spectrum of hydrogen

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.



r is distance between electron & nucleus

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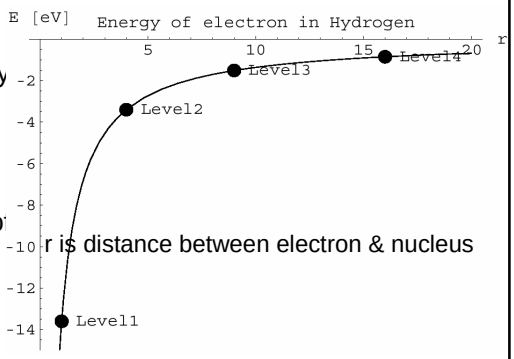
- Q2. How much energy does electron need to climb from Lev 1→2? a: 14eV, b: 10eV, c: 3 eV.

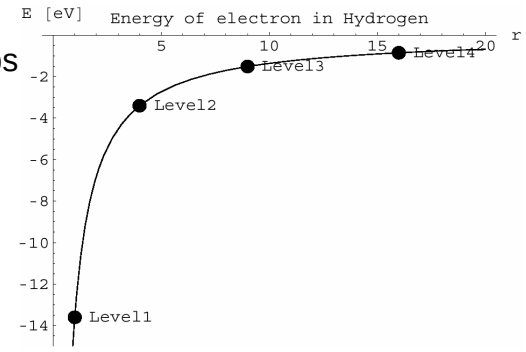


r is distance between electron & nucleus

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.

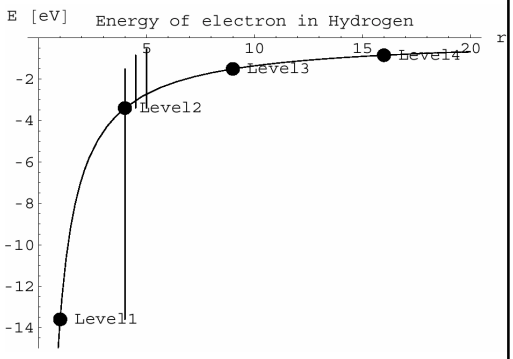
- Q3: An atom with electron in L3 emits photon. Where does energy of photon come from?
  a. Electron supplies energy by dropping to a lower level
  b. Electron supplies energy by going to a higher level.
  c. Nucleus gives up some energy
  d. Energy is created.



Niels Bohr's quantization

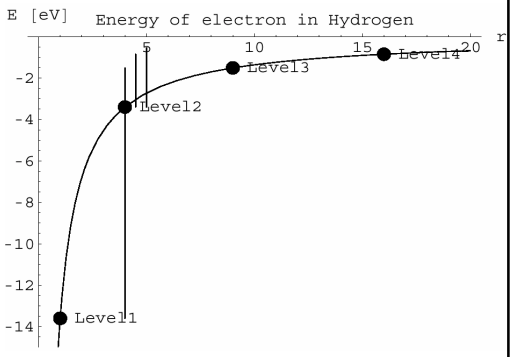
- Big question in 1900: Why does hydrogen emit & absorb light at discrete wavelengths? at discrete energies?
- Bohr's "quantization" rule:
  - Electron can only be in a level for which angular momentum L=n h,
    - h is Planck's constant
    - n = 1, 2, 3, 4, etc
  - These are "levels" in plot.
- Bohr's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

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



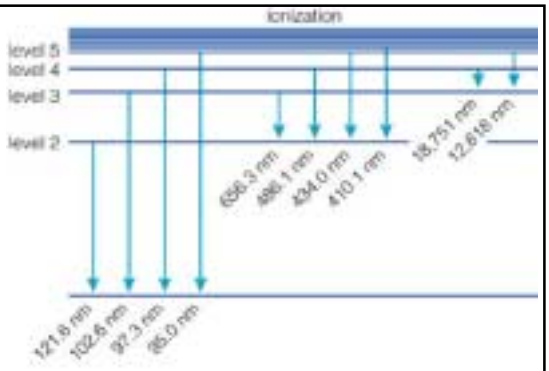
Other lines of H

- Visible emission line of H
  - Red line is jump 3→2
  - Cyan line is jump 4→2
  - Blue line is jump 5→2
- Q4: Why did we not see lines that can account for jump 2→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.

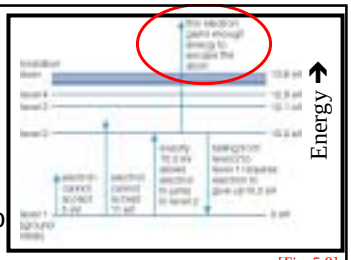


Other lines of H

- "Balmer" series.
  - Transitions between level 2 and higher levels are visible.
- Lyman series
  - 1↔higher is in ultraviolet.
- Paschen series
  - 3↔higher is in infrared.
- Brackett
  - 4↔higher is in infrared.



Ionization



[Fig. 5.8]

- Very energetic photon
  ➔ electron acquires escape velocity.
  - Atom has same nucleus, but one less electro
    - 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.

Recombination

- Ion recaptures a free electron ➔ photon is emitted.