Lecture 25: Measuring Light: Spectroscopy

Recommended Reading: Section 4.4 (again)

Key Ideas:

Every atom, ion, & molecule has a *unique* spectral signature:

- Reflects its internal electron orbital structure

Absorption & Emission of Photons

- Excitation & De-Excitation

Ionization:

- Eject electrons or add extra electrons.

Looking inside the Atom

Electrons cannot orbit just anywhere around a nucleus:

- Can only orbit in discrete *orbitals*.

Each orbital corresponds to a particular energy of the orbiting electron.

- If an electron does not have *exactly* the right energy, it cannot be in an orbital.

Details are dictated by Quantum Mechanics.

Hydrogen: The Simplest Atom

An atom of Hydrogen (^{1}H) is:

- Nucleus of 1 proton
- Orbited by 1 electron

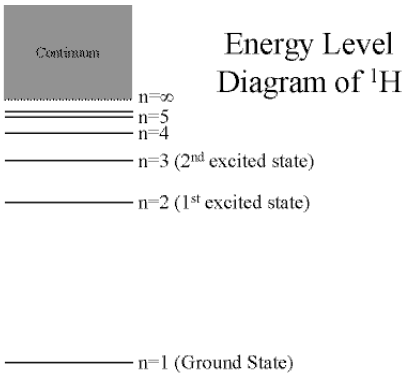
First orbital: "Ground State" (n=1)

- Lowest energy orbital

Higher orbitals: "Excited States" (n=2,3,...∞)

- Higher orbits around the nucleus.
- Come at specific, *exact* energies.

Energy Level Diagram of ^{1}H



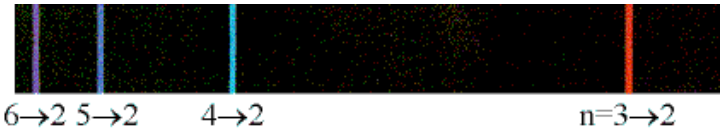
Energy Level Diagram of ^{1}H

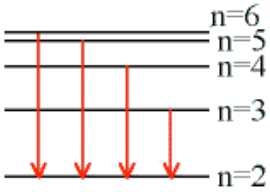
Emission Lines

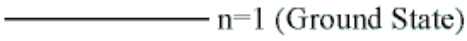
An electron jumps from a *higher* to a *lower* energy orbital

- Emits one photon with *exactly the energy difference* between the orbitals.
- Bigger Jumps emit Higher Energy (bluer) photons

^{123}Unobtainium



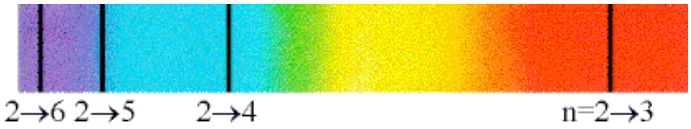


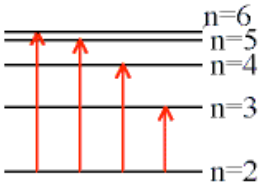


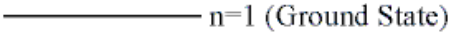
Absorption Lines

Electron absorbs a photon with *exactly* the energy needed to jump from a *lower* to a *higher* orbital.

- Only photons with the exact excitation energy are absorbed.
- All others pass through *unabsorbed*.







Ionization

If an electron absorbs enough energy from a photon or a collision, it can be *ejected*.

- Get a *positive ion* (net positive charge).

Can also *add* extra electrons:

- Get a *negative ion* (net negative charge)

Ions differ from their parent neutral forms:

- Different spectral line signatures.
- Different chemical properties.

Fingerprinting Matter

Atoms other than Hydrogen have different spectra:

- More complex electron orbital structures.
- More complex line spectra.

A *unique* spectrum for each element:

- Tell elements apart by their spectra.
- Isotopes show the same lines, but slightly shifted in wavelength.

See Figure 4.20d

In-Class Demonstration: Glowing Gases

Molecules

Molecules are even more complex:

- Compounds of two or more atoms
- Share some electrons in common orbitals

Results in very complex spectra:

- Broad “bands” of many lines together.
- Bands span large wavelength regions.

Get strong lines at infrared, microwave, and radio wavelengths.

The Importance of Spectroscopy

From the an object's spectrum, we can learn:

- Which atoms and molecules are present, and in what proportions.
- Which atoms are ionized, and in what proportions.
- How excited (or not) the atoms are, tells us the object’s state (e.g., hot or cold).

These data give us a nearly complete picture of the physical conditions in the object.