Chapter 30

Light Emission

I. Emission and Absorption of Light

- The emission of light by atoms AND the absorption of light by atoms involves transitions of electrons among different energy states within the atom.
- The electrons in an atom can be only at certain distances from the nucleus (discrete radii), and as a result can only have discrete values of energy. Since only certain energy values are allowed, one says that the energy of the electrons are quantized.

![Bohr Theory of Atoms]

- The farther away the electron is from the nucleus, the more energy it has.
- Energy is absorbed when the electron makes a transition (also called a quantum jump) from a lower orbit (where the energy is less) to a higher orbit (where the energy is greater).
- Energy is emitted when the electron makes a transition from a higher orbit to a lower orbit.
II. Excitation (or Absorption of Radiation)
- The electron in the first orbit absorbs the incident radiation and as a result makes a quantum jump to the second orbit.
- The energy of the radiation absorbed must be equal to the difference in energies between the first and second orbit energy levels.

III. Emission of Radiation
- The electron in the second orbit makes a quantum jump (or transition) to the first orbit emitting the energy difference as radiation.
- The energy of the emitted radiation equals the energy difference between the first and second orbit energy levels.
IV. What is a photon?

- A photon is a "particle" of light. One may think of a light beam as consisting of a "particle beam".
- Each particle of light (photon) has an energy $E$ that is related to the frequency $f$ of the light wave associated with the light beam. Mathematically,

$$E_{\text{photon}} = h f_{\text{wave}}$$

where, $h = \text{Planck's constant} = 6.63 \times 10^{-34}$ Joule sec

"Particle picture" of light

V. Atomic Spectra

- Each kind of atom (or chemical element in the periodic table) has its own characteristic set of allowed energy levels. This characteristic set of energy values is like a fingerprint of the atom that may be used to identify the atom.
- Absorption spectrum: The set of energy values that an atom can absorb.
• **Emission Spectrum:** The set of energy values that an atom can *emit*.
• See figures 30.4, 30.8, and 30.9 in the textbook.

**VI. Incandescence**
• Radiant energy emitted by an object (like a tungsten filament in a light bulb) while at a high temperature, caused by electrons bouncing around over dimensions larger than the size of the atoms. This is blackbody radiation, where we learned that the frequency at which the highest energy is emitted is proportional to the absolute temperature of the substance.

**VII. Fluorescence**
• When a substance absorbs radiation of some energy (such as blue photons), holds the energy for a short time while the atoms re-adjust their positions slightly lowering their energy, and then re-emitting the energy at a lower value (such as green photons). That is, energy is absorbed and lower energy is emitted.

**VIII. Phosphorescence**
• Basically the same as fluorescence except that there is a much longer time delay between the absorption of the energy and the re-emission at lower energy.
This leads to after glow effect that lasts seconds or minutes.

IX. The LASER

- **LASER**: This is an acronym meaning **Light Amplification by Stimulated Emission of Radiation**.
- The first laser was built by Maiman in 1960 (not in 1958) as the author of the textbook points out.
- **Spontaneous Emission of Radiation**: This process refers to the case when an “excited atom” (with an electron in an orbit with a higher energy than the level it would ordinarily occupy) is left alone and emits the extra energy via electronic transitions to lower energy levels. That is,

![Diagram of excited and ground state of an atom]

- If all excited atoms are left alone, they will emit the extra energy in due time spontaneously!
• **Stimulated Emission of Radiation:** You actually do not have to wait for the excited atom to emit its extra energy. You can stimulate the atom to emit the extra energy by simply shooting a photon at it of the right energy. That is,

![Diagram of stimulated emission]

• Notice that you send in one photon and one excited atom and you end up with two photons and an atom in its "ground state" (de-excited). This process corresponds to **light amplification**!

• All lasers have:
  1. an **excitation source**. This could be a provided by an electric current, a flashlight, or another laser.
  2. an **active medium** where the laser light is generated. The active medium could be a solid, a liquid, or a gas.
  3. at least two **mirrors** to provide the feedback mechanism. One of the mirrors needs to be partially transmitting to let the laser light out.