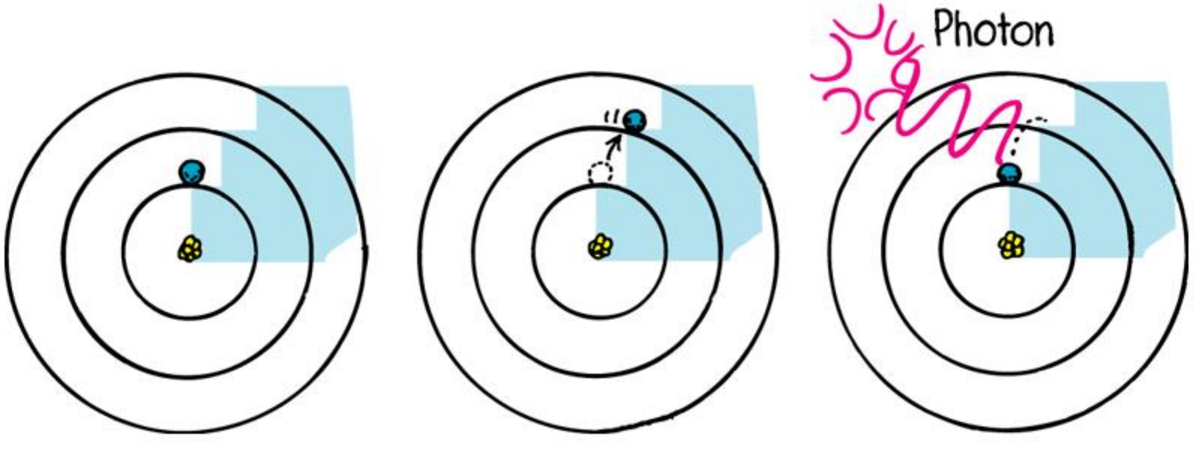
Chapter 30

Light Emission

Excitation & Light Emission

Electrons in atoms can be “excited” into higher energy levels. When the electrons return to their lower levels, the excess energy is given off as light.

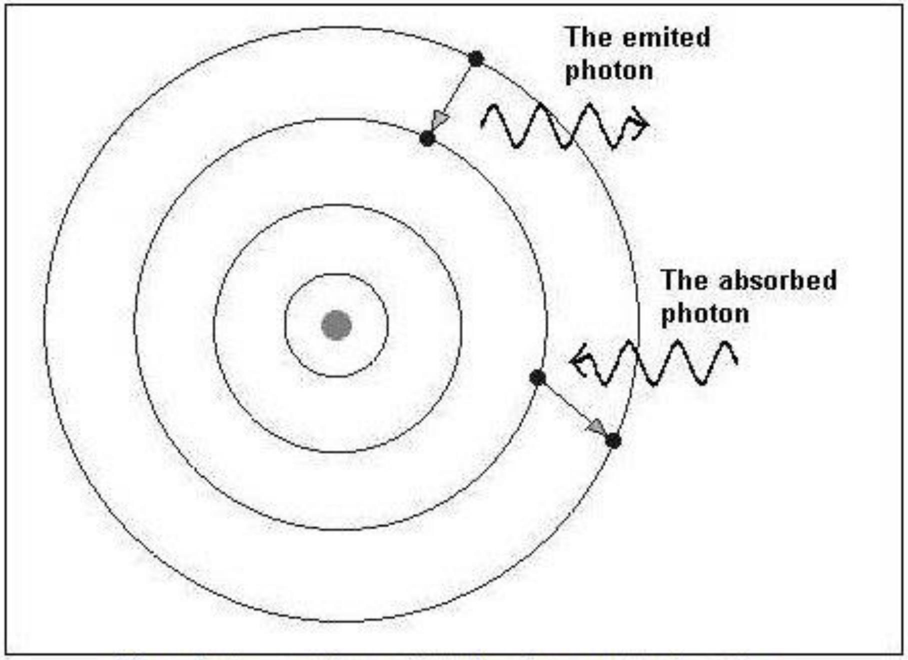


Energy in Light

Electrons in atoms can be "excited" into higher energy levels by thermal agitation, bombardment, or by absorbing a pulse of light called a *photon*.

When the incoming photon energy matches the energy difference between an electron's energy levels, the photon (and its energy) is "absorbed."

A photon is emitted when the electron "de-excites" and drops back down.



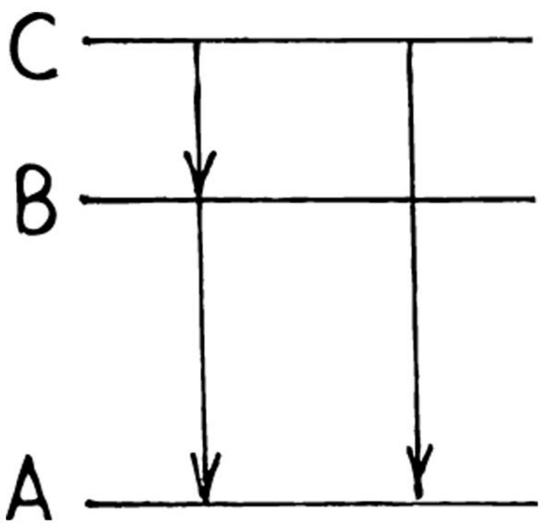
The electron emits or absorbs the energy changing the orbits.

Energy in Light

The energy of a photon (in Joules) is: $E_{ph} = hf$,

where f is the frequency of the light (in Hertz) and

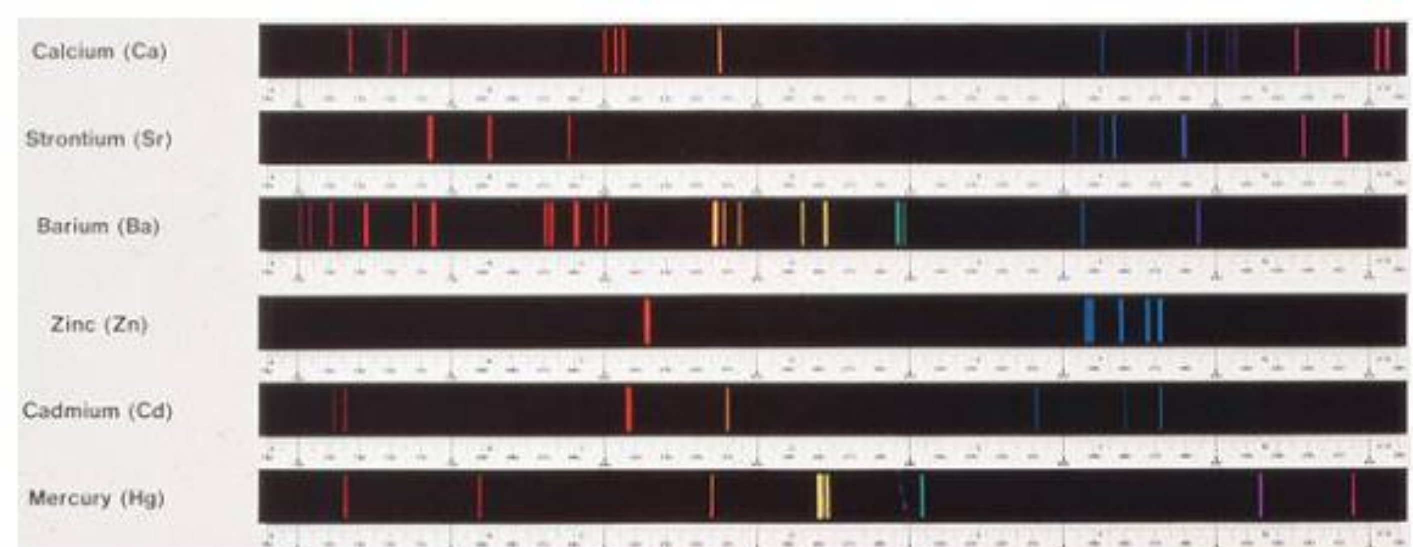
$h = 6.626\text{x } 10^{-34}$ J-s = "Planck's constant."



For the three energy levels shown, there are three distinct energy differences resulting in three distinct photon energies being emitted when an electron de-excites and drops back down.

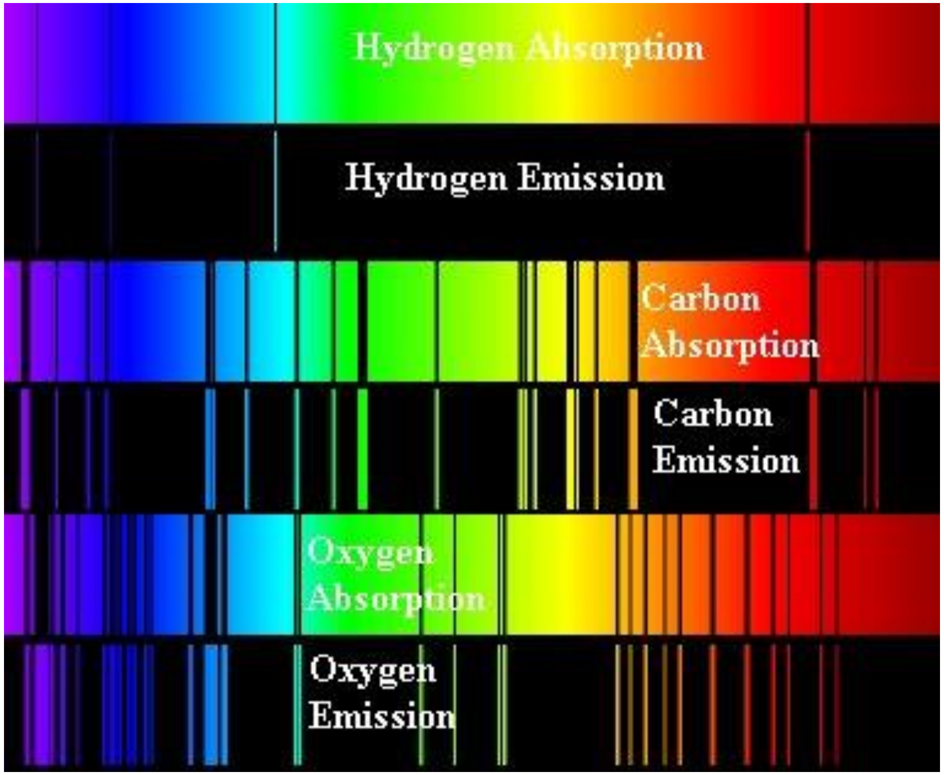
Emission Spectra

The distribution of wavelengths in the light emitted from a luminous object is called an emission spectrum. The distribution can be analyzed using a spectroscope. Different elements have different spectra. For example:



Absorption Spectra

A continuous spectrum (similar to that of white light), interrupted by dark lines that result from the absorption of light of certain frequencies by a substance though which the white light passes is called an absorption spectrum. It is essentially the "inverse" of an emission spectrum.



Types of Emission

Incandescence:

Light emitted due to high temperatures

(Ex.: Heater element; filament of a light bulb)

Fluorescence:

Light of lower frequency is emitted when excited electrons immediately de-excite after absorbing light at a higher frequency.

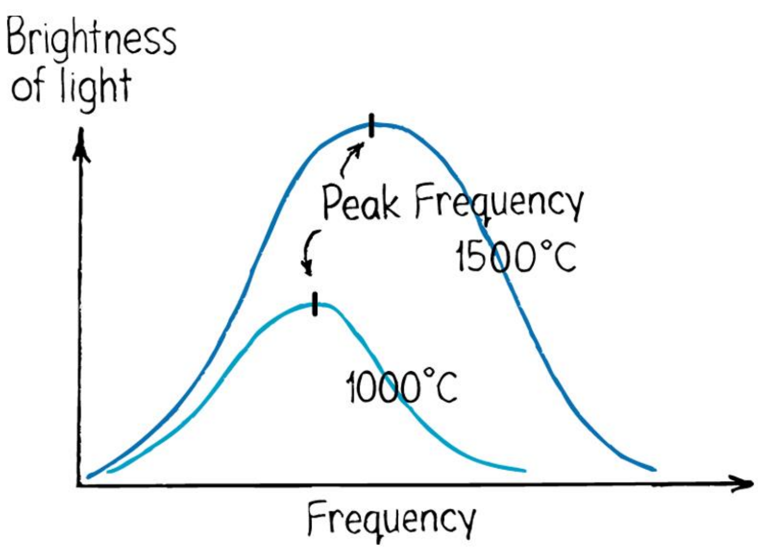
Phosphorescence:

Similar to fluorescence, except that the process can take much longer.

Incandescence

Incandescent light (also known as thermal radiation) is different from the light emitted by excited gases in that the excited gases emit discrete frequencies based on the energy level differences of the individual atoms.

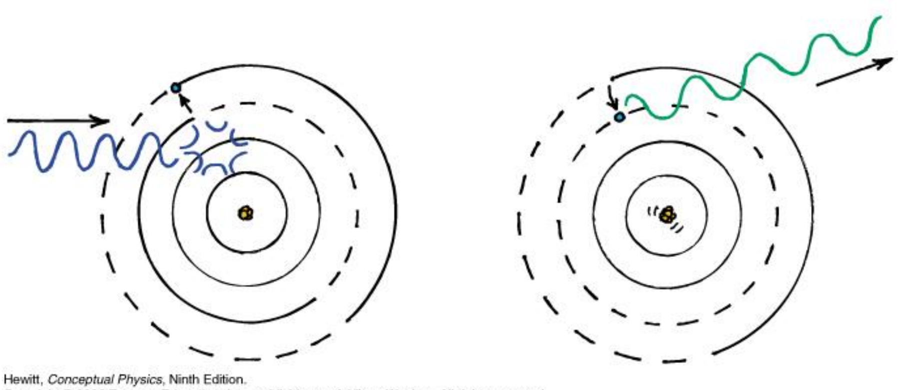
When the atoms are close together (as in a liquid or solid, the energy levels get "smeared out" resulting in the emitted light having an infinite number of frequencies. The "peak frequency" (the frequency of the most intense light) is directly proportional to the temperature of the object.



Fluorescence

As stated earlier, electrons can be excited into higher energy levels by the absorption of photons. Light is reemitted when excited electrons immediately return to their ground state.

The absorbed light can cause electrons to jump over one of more energy levels. If the electrons cascade back down one step at a time, the emitted light has lower energies.



Hewitt, *Conceptual Physics*, Ninth Edition.

Phosphorescence

Essentially the same thing as fluorescence, except that the afterglow can last for several seconds, minutes or even hours after the incoming light causing the excitations ceases.

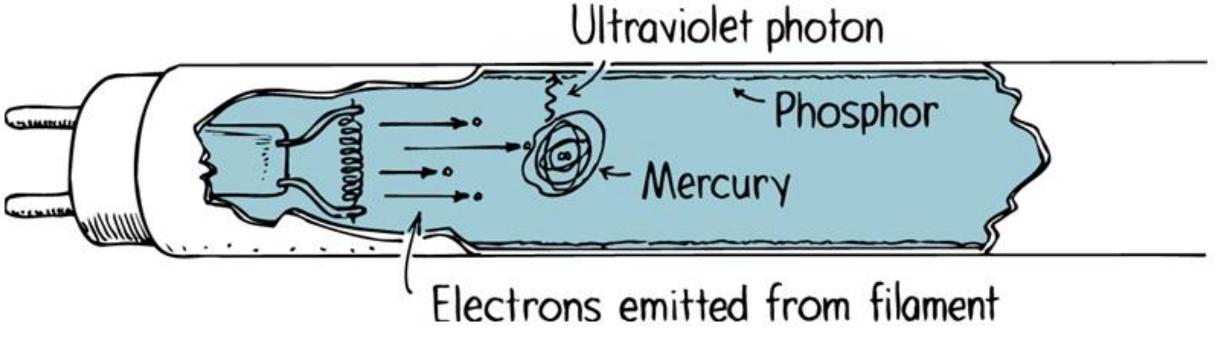
Electron boosted to higher energy levels get “stuck” in metastable states.

Examples include “glow-in-the-dark” toys and T-shirts.

(Some animals exhibit *bioluminescence* in which they chemically excite molecules in their bodies that then emit light. However, this process in not well understood and is currently a topic of research.)

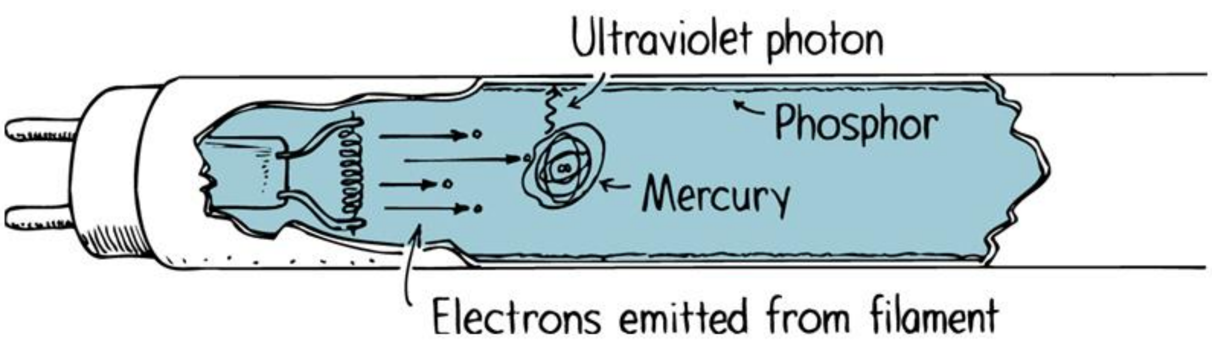
Fluorescent Lamps

Electrons “boiled” off a hot filament, vibrate back and forth at high speed back and forth by an AC voltage in a tube that contains argon gas and a small amount of mercury. The electrons collisions excite mercury atoms in the tube. The mercury atoms de-excite and emit UV light that is absorbed by the phosphorescent coating in the inner surface of the tube. These “phosphors” de-excite in the visible portion of the spectrum that combine to make white light.



Lasers

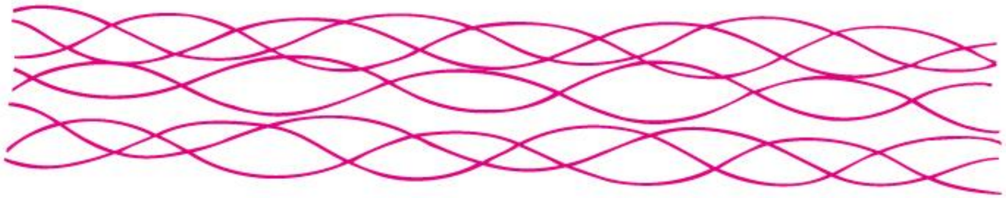
Electrons "boiled" off a hot filament, vibrate back and forth at high speed back and forth by an AC voltage in a tube that contains argon gas and a small amount of mercury. The electrons collisions excite mercury atoms in the tube. The mercury atoms de-excite and emit UV light that is absorbed by the phosphorescent coating in the inner surface of the tube. These "phosphors" de-excite in the visible portion of the spectrum that combine to make white light.



Coherent Light

Polychromatic (meaning "many color") light from a typical light source has many different wavelengths (and is *incoherent*):

Monochromatic (meaning "one color") light that is filtered is still *incoherent* because the light waves are out of phase:



Coherent light (like from a laser) has the same frequency, phase and direction: