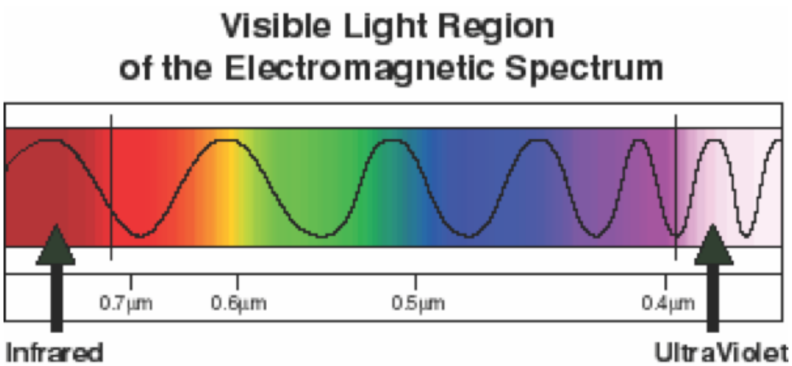
Energy of waves

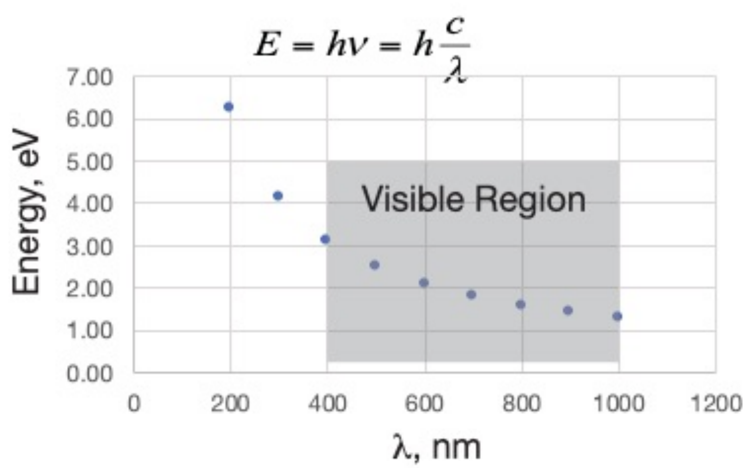
The Visible Spectrum

White light consists of a spectrum of colors, each with its own specific wavelength

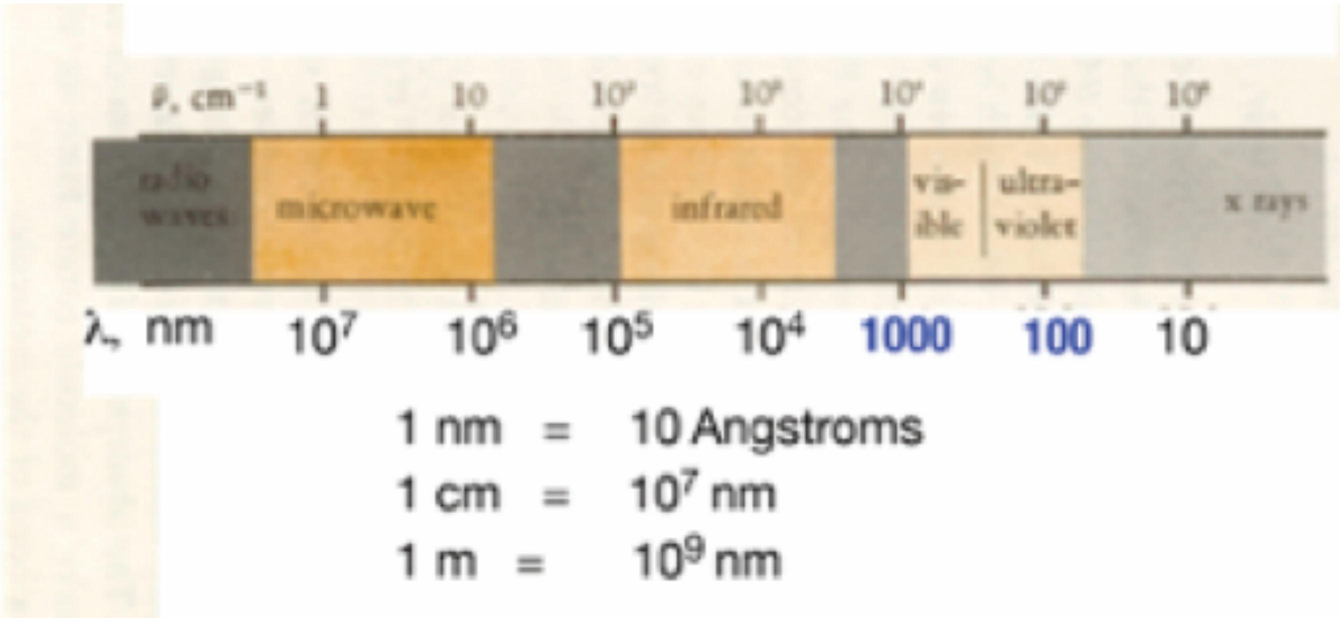


Application of the Planck's equation (Eq. 1) converts the wavelength of light into eV (units of energy) as shown on the right.

Something to keep in mind is that the visible region corresponds from about 1 eV to about 4 eV. These values are easy to remember which, incidentally illustrates the usefulness of the eV as a unit of energy.



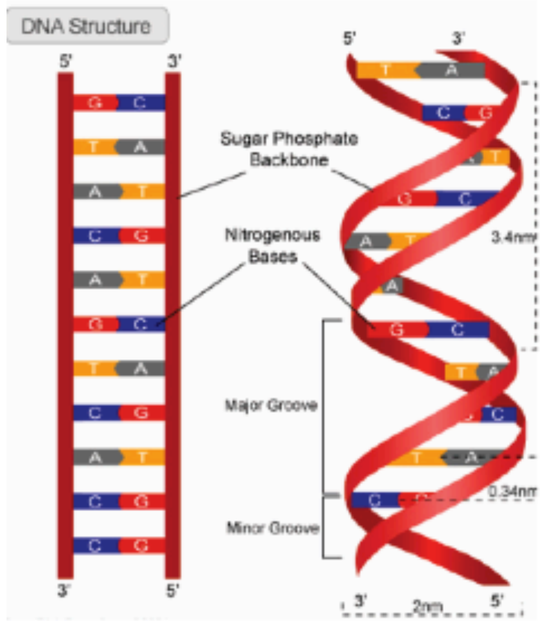
Beyond the Visible Spectrum



The wavelengths of light extend far into the long wavelength (for example radio waves and microwaves) and very short wavelengths (X-rays and gamma rays). In the above diagram, the visible region occupies only a narrow range. X-rays on the right can have wavelengths in the 0.1 nm (1 Angstrom range), while microwaves on the left can have a wavelength of several cm.

The interaction of waves with matter is wavelength specific, and is related to different phenomena, for example,

- *Scattering and absorption*: Why the sky is blue? - short wavelength are scattered more than long wavelengths. Alternatively we can say the longer wavelengths are more prone to be absorbed than short wavelengths.
- *Absorption and emission:* Absorption of light is fundemantal in understanding the physics of solar cells - this phenomenon is material specific, i. e. silicon. This is generally true, the absorption and emission of light is related to the electronic structure of matter. Crystals which have interact with light in rather specific ways, that is at specific energy levels. This concept will evolve into our analysis of the "blue shift" which is the main topic of this chapter.



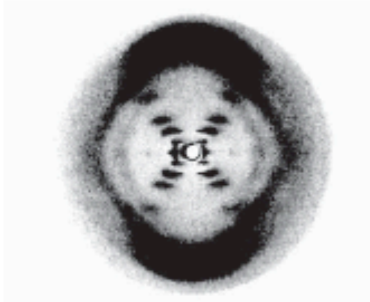


Figure 2.12 Franklin's x-ray picture of DNA. The regularity of this pattern indicated that DNA is a helix. The spacing between the strong bands at the top and bottom gave the spacing between elements of the helix (base pairs) as 3.4 Å. The spacing between neighboring lines in the pattern gave the overall repeat of the helix (the length of one helical turn) as 34 Å. (Source: Courtesy Professor M. H. F. Wilkins, Biophysics Dept., King's College, London.)

- *Diffraction*: Diffraction is a phenomenon where light reflected from a crystal (for example) produces constructive interference and destructive interference depending on the angle of incidence and reflection, producing bright spots. The arrangement of these spots on a plane conforms to the "symmetry" of the crystal while their angular spacing provide information regarding the spacing of crystal planes at the atomic scale. This phenomenon occurs when the wavelength of the X-rays is comparable to the length scale in the crystal that is being interrogated. The example of diffraction from DNA is given in the figure above. Note that the DNA molecule has three different length scales: in inter-molecular distance among the molecules that form the steps in the "ladder", the width of the ladder, and the spacing between the steps. Note that the molecular structure of the horizontal steps is such that the DNA can replicate itself by breaking the steps mid-way and mirroring with a RNA to construct repetitive DNAs.

Note that the width of ladder and the spacing between the steps is a few nm, which falls within the realm of X-ray diffraction, leading to the pattern shown in the figure. While the symmetry of the diffraction pattern is reflected in the symmetry of the diffraction pattern, the spacing of the spots from the center (which is related to the angle of diffraction - which will be given by the distance of the spot from the center divided by the distance of the diffracting crystal from the film which was shown in the figure.