# GENERAL CONCEPTS OF RADIATION

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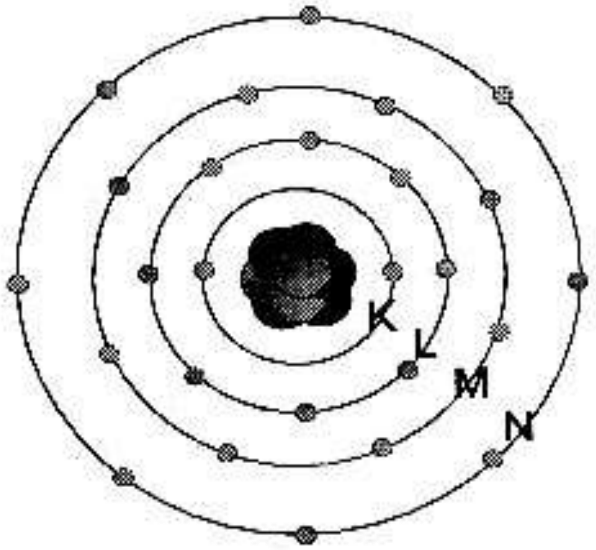
## Structure of matter:

**Atom:** The smallest unit of matter composed of negatively charged electrons, positively charged protons and neutral neutrons.




| Shell | Maximum permissible electrons |
|---|---|
| K | 2 |
| L | 8 |
| M | 18 |
| N | 32 |
| O | 50 |
| P | 72 |
| Q | 98 |



The total charge of electrons is equal to protons and hence the atom is electrically neutral.

**Nucleus:** The centre of atom containing neutrons and protons and hence almost whole mass of the atom.

**Electrons:** Fast moving negatively charged particles outside the nucleus.

**Forces in atom:** Since the similarly charged particles repel each other, it is essential that there must be a <u>nuclear force</u> that exceeds this electrostatic repulsive force to which the protons are continuously subjected to so that the nucleus remains intact.

Similarly the negatively charged electrons are subjected to a constant electrostatic attractive force of centrally placed positively charged protons. Therefore in order to remain outside from the nucleus, the electrons outcome this attractive pulls by way of their <u>high kinetic energy</u> as they revolve around the nucleus with a very high velocity.

**Shell:** Moving electrons are arranged outside the nucleus in different energy levels or shells namely K, L, M N, N, O, P and Q. There is a certain limit of the number of electrons which can remain in a particular shell.

**Binding energy:** The energy required to remove an electron from the atom is termed as the binding energy of that electron.

Binding energy of the electron in the shell nearer to the atom's nucleus is higher than the electron in the shell further from the nucleus because of the stronger electrostatic attractive force of the nucleus.

Binding energy of the electron increases with the atomic number of the atom because of stronger electrostatic pull due to more number of protons.

Any vacancy occurring within electron shell (due to forced ejection of electron) will be promptly filled by electron cascading from lower energy levels (shells further from the nucleus) and the difference in the binding energy between the original and final energy level of the electron is released as the photon of the energy.

(This photon is considered an x-ray if its energy level exceeds 100 eV).

**Radiation (Radiant energy):** The propagation or transfer of energy through space is termed as radiation. It is basically of two types.

(i) **Particulate or corpuscular radiations:** These radiations are composed of subatomic particles of the matter and may either be electrically charged or neutral *e.g.* alpha, beta particles, protons, electron, neutrons etc.



***Beta particles.*** These are high velocity electrons with an electrical charge of -1. Beta radiation is a by-product of the natural radioactive decay of radioactive substances and is also abundant in the high velocity stream of electrically charged particles with are emitted by the sun. An electron's mass is about 1/2000th the mass of a proton.

- *Moving electrons are termed as* ***<u>beta (β) rays</u>*** *if emitted by radioactive nuclei. These may be called as* ***<u>cathode rays</u>*** *if these are accelerated by any other method as in x-ray tubes.*

**Alpha particles.** These are helium ions having an electrical charge of +2. Alpha radiation is a by-product of the natural radioactive decay of radioactive substances.

(ii) **Electromagnetic radiations (EMR):** It does have a wave nature as well as particulate nature (sounds strange!!!).

**EMR as a wave**

- EMR, when propagating through space and interacting with other EMR, displays characteristics which are unique to waves, such as interference and diffraction. This behavior defines the radiation's wavelengths and frequencies. It has great spectrum of wave lengths (λ) and frequencies (μ) which determine its distinguishing physical properties.

- The ability to be polarized further characterizes electromagnetic radiation as being a transverse wave.

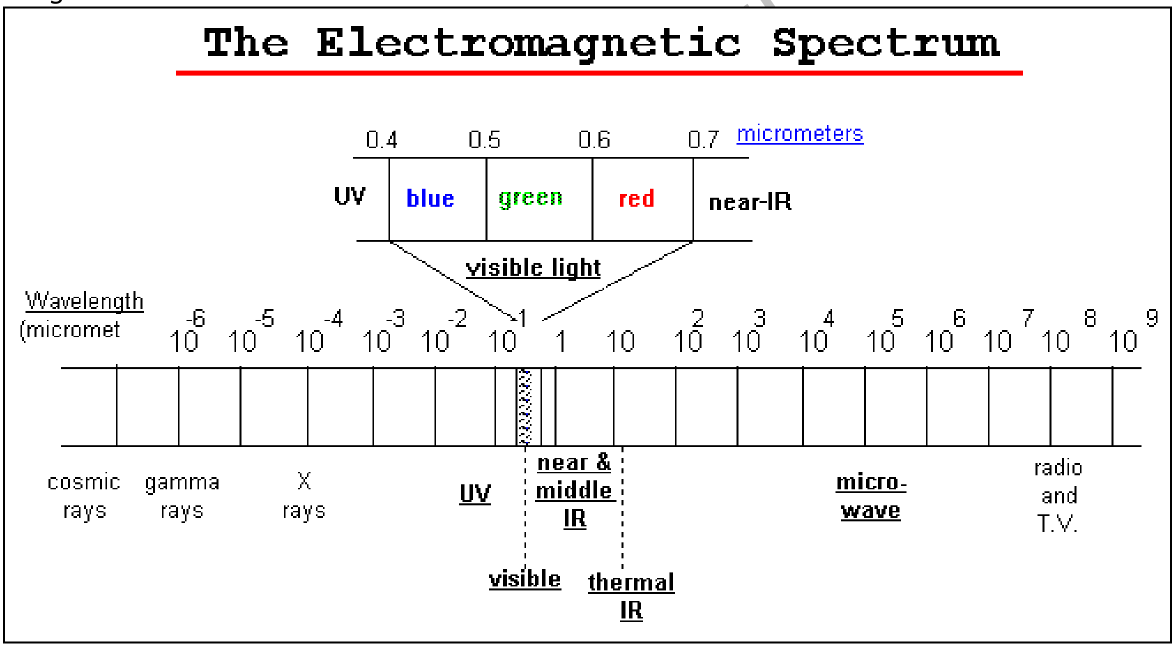
*The velocity of all kinds of EMR is constant at 3 x $10^{10}$ cm/s in vacuum (equal to that of light). However, in medium transparent to EMR, the velocity is slightly lesser.*

**EMR as a particle**

- When interacting with matter, behaviour such as the *photoelectric effect (To be discussed later)* clearly characterizes EMR composed of zero-mass particles.
- It has been seen that the energy is carried by EMR in the form of discrete bundles or quanta which do not posses any mass.
- These quanta are often simply referred to as **photons** *(because they were first investigated as an optical (light) phenomena)***.**
- The energy transferred/carried by photons is greater if EMR wavelength is shorter.

**Therefore, it is concluded that in general, electromagnetic radiation behaves as a wave when moving through space, but it behaves as a particle when it interacts with matter.**

***Ionization or Ionizing Radiation****: when radiation is capable of removing one more electrons from the atoms after interaction, this is called as ionization. The radiation is then termed as ionizing radiation.*




Electromagnetic radiation has a variety of names; one kind differing from another only in its frequency (and consequently wavelength) and the amount of energy carried by the radiation. The designated wavelengths (or frequency) of many types of EMR however, often overlap.

*E.g.* wavelength of high energy (Hard) X-rays overlaps with gamma rays and wavelength of low energy (Soft) X-rays overlap with the range of extreme ultraviolet.

***The EMR visible to human eye is light.***

**X-rays:** X-rays are a form of high energy ionizing electromagnetic radiations with relatively high frequency and low wavelength produced by conversion of kinetic energy of electron into EMR

**Physical properties of X-rays:**

1. Their wavelength range is from 0.1 to 0.5 A with energy levels of 25 – 125 KeV in the diagnostic X-rays range for medical application.
2. They travel in straight line with speed of light.
3. These rays can not be focused by a lens like light rays.
4. They do not possess mass or charge and therefore are unaffected by electric or magnetic field.
5. Because of their high energy these rays are capable to penetrate material which readily absorb and reflect visible light.
6. X-rays interact with matter, are absorbed or scattered and liberate minute heat on passing on passing through it. Thicker and denser is the material more is the absorption and scattering.
7. X-rays affect photographic film.
8. X-rays produce Phosphorescence/ Fluorescence in certain crystalline materials e.g. Calcium tungstate, Zinc Cadmium sulphide.
9. Interaction with living tissue cause both somatic and genetic damage.
10. Interactions with gases cause ionization and the gas/ air is made electrically conductive.
11. X rays may be diffracted by passage through a crystal or by reflection (scattering) from a crystal, which consists of regular lattices of atoms that serve as fine diffraction gratings. The resulting interference patterns may be photographed and analyzed to determine the wavelength of the incident X-rays or the spacings between the crystal atoms, whichever is the unknown factor.