

# Chapter 2

## 2.1: X-ray Characteristics:

X-radiation is a form of electromagnetic radiation. Most X-rays have a wavelength in the range of 0.01 to 10 nanometers, corresponding to frequencies in the range ( $3 \times 10^{16}$  Hz to  $3 \times 10^{19}$  Hz) and energies in the range 100 eV to 100 keV. X-ray wavelengths are shorter than those of UV rays and typically longer than those of gamma rays. In many languages, X-radiation is referred to with terms meaning Röntgen radiation, after Wilhelm Röntgen who is usually credited as its discoverer, and who had named it X-radiation to signify an unknown radiation.

X-rays with photon energies above 5–10 keV (below 0.2–0.1 nm wavelength) are called hard X-rays, while those with lower energy are called soft X-rays. Due to their penetrating ability, hard X-rays are widely used to image the inside of objects, e.g., in medical radiography and airport security. As a result, the term X-ray is metonymically used to refer to a radiographic image produced using this method, in addition to the method itself. Since the wavelengths of hard X-rays are similar to the size of atoms they are also useful for determining crystal structures by X-ray crystallography. By contrast, soft X-rays are easily absorbed in air and the attenuation length of 600 eV (~2 nm) X-rays in water is less than 1 micrometer. X-ray photons carry enough energy to ionize atoms and disrupt molecular bonds. This makes it a type of ionizing radiation, and therefore harmful to living tissue. A very high radiation dose over a short amount of time causes radiation sickness, while lower doses can give an increased risk of radiation-induced cancer. In medical imaging this increased cancer risk is generally greatly outweighed by the benefits of the examination. The ionizing capability of X-rays can be utilized in cancer treatment to kill malignant cells using radiation therapy. It is also used for material characterization using X-ray spectroscopy.

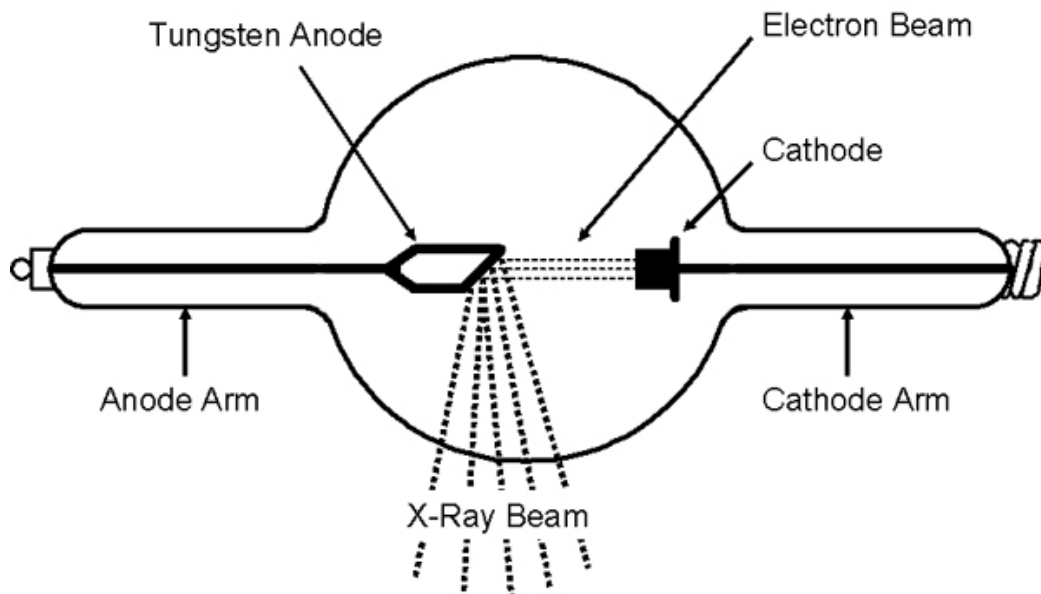
Hard X-rays can traverse relatively thick objects without being much absorbed or scattered. For this reason, X-rays are widely used to image the inside of visually opaque objects. The most often seen applications are in medical radiography and airport security scanners, but similar techniques are also important in industry (e.g. industrial radiography and industrial CT scanning) and research (e.g. small animal CT). The penetration depth varies with several orders of magnitude over the X-ray spectrum. This

allows the photon energy to be adjusted for the application so as to give sufficient transmission through the object and at the same time good contrast in the image.

X-rays have much shorter wavelength than visible light, which makes it possible to probe structures much smaller than what can be seen using a normal microscope. This can be used in X-ray microscopy to acquire high resolution images, but also in X-ray crystallography to determine the positions of atoms in crystals.

## **2.2: Mechanism of X-ray generation:**

The heart of an X-ray generator is the X-ray tube. Like any vacuum tube, the X-ray tube contains a cathode, which directs a stream of electrons into a vacuum, and an anode, which collects the electrons and is made of copper to evacuate the heat generated by the collision. When the electrons collide with the target, about 1% of the resulting energy is emitted as X-rays, with the remaining 99% released as heat. Due to the high energy of the electrons that reach relativistic speeds the target is usually made of tungsten .



**Figure (2.1) X-ray generation**

### **2. 3: Interaction of X-ray with matter:**

---

Since the quantum energies of X-ray photons are much too high to be absorbed in electron transitions between states for most atoms, they can interact with an electron only by knocking it completely out of the atom. That is, all x-rays are classified as ionizing radiation. This can occur by giving all of the energy to an electron (photoionization) or by giving part of the energy to the electron and the remainder to a lower energy photon (Compton scattering). At sufficiently high energies, the x-ray photon can create an electron positron pair.

### **2.4: Attenuation of X-ray beam through the matter:**

---

Attenuation is the removal of photons from a beam of x-rays as it passes through matter. Attenuation is caused by both absorption and scattering of the primary photons. The interaction mechanisms, in varying degrees, cause the attenuation. At low photon energies (less than 26 keV), the photoelectric effect dominates the attenuation processes in soft tissue. However, as previously discussed, the probability of photoelectric absorption is highly dependent on photon energy and the atomic number of the absorber. When higher energy photons interact with low Z materials (e.g., soft tissue), Compton scattering dominates. Rayleigh scattering occurs in medical imaging with low probability, comprising about 10% of the interactions in mammography and 5% in chest radiography. Only at very high photon energies (greater than 1.02 MeV), well beyond the range of diagnostic and nuclear radiology, does pair production contribute to attenuation.

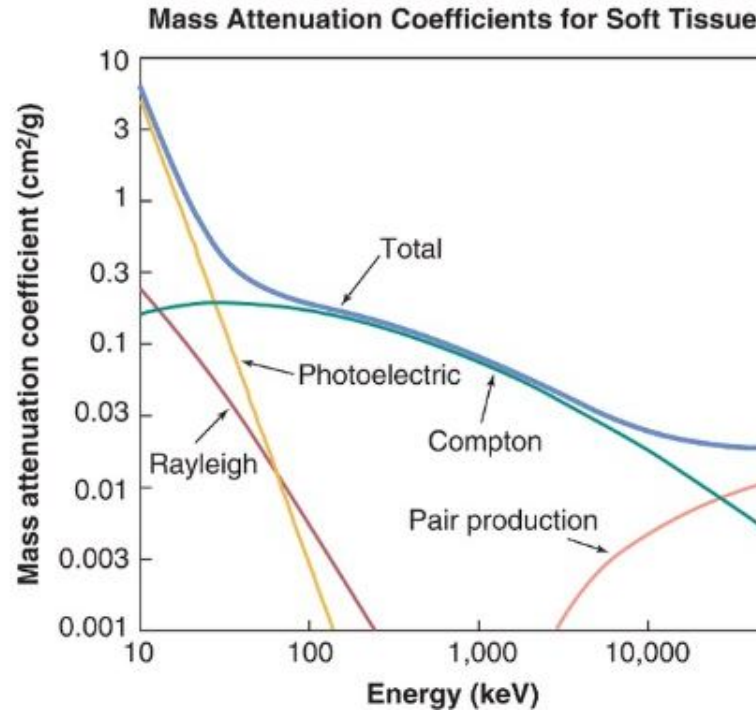


Figure (2.2) show Mass attenuation coefficients for soft Tissue

## 2.5: Exposure:

The term exposure: describe the ability of x-ray to ionize air.it is measured in Rontgen this unit is defined as the quantity of x-ray that produces 0.000258 c of charge collected per unit mass(kilograms) of air at standard temperature and pressure (STP).it essentially describes how much ionization is present the volume ,but it does not tell how much energy is absorbed by the tissues being irradiated

## 2.6: Absorbed radiation dose:

Often referred to describe the amount of energy absorbed per unit mass at specific point. it measured in grays(1 gray= 1 J/kg)or rad ( 1 rad=100 erg/gram). The conversion between rad and gray is 100 rad= 1 gray .absorbed dose essentially describes how much energy from radiation has been absorbed in small volume centered at a point; it doesn't describe where that radiation dose is absorbed as

reflects the relative radio sensitivity or risk of detriment to those tissues being irradiated.