**PHOTOELECTRIC EFFECT**

The photoelectric effect refers to the emission of electrons from the surface of a metal in response to incident light. Energy contained within the incident light is absorbed by electrons within the metal, giving the electrons sufficient energy to be removed out of / emitted from, the surface of the metal by overcoming the binding energy. [1]

**APPLICATION OF PHOTOELECTRIC EFFECT FOR THE PRODUCTION OF X-RAYS**

X-ray photons are created by the interaction of energetic electrons with matter at the atomic level. Photons (energy packets) transfer their energy to electrons contained in matter. Photoelectric interactions usually occur with electrons that are firmly bound to the atom, that is, those with a relatively high binding energy. Photoelectric interactions are most probable when the electron binding energy is only slightly less than the energy of the photon. [2] This interaction is possible only when the photon has sufficient energy to overcome the binding energy and remove the electron from the atom.

A portion of the energy is used to overcome the electron's binding energy (the Work Function) and to remove it from the atom. The remaining energy is transferred to the electron as the Kinetic energy. Since the interaction creates a vacancy in one of the valence orbits, typically the K or L, an electron moves down to fill in. The drop in energy of the filling electron often produces a different type of energy packets known as Characteristic x-ray photon.

**PRODUCTION OF X-RAYS**

X-Rays for medical diagnostic procedures are produced by accelerating electrons with a high voltage and allowing them to collide with a metal target. The electrons are liberated from the heated filament and accelerated by a high voltage towards the metal target. The X-rays are produced when the electrons collide with the atoms and nuclei of the metal target.

The Second mechanism by which x-rays are produced is through transitions of electrons between atomic orbits in the Bohr’s Atomic Model. Such transitions involve the movement of electrons from outer orbits to fill the vacancy of inner-most orbit. When a high energy electron is accelerated into a metal target, some electrons knock the K-shell electrons out of orbit. An electron from a higher energy orbit or shell will jump down to replace the lost electron. Since the K-shell requires a lower state of energy, radiation energy is given in the form of an x-ray photon. In making such transitions, electrons emit photons of x-radiation with discrete energies given by the differences in energy states at the beginning and the end of the transition.

The Third Mechanism by which x-rays are produced is by Synchrotron Radiation. Synchrotron radiation is emitted by charged particles traveling on a curved path along a Magnetic Field. Synchrotron radiation produces radiations by centripetal acceleration. The wavelength of this radiation is a function of the energy of the charged particles and the strength of the magnetic field bending the charged particles. The spectrum of the radiation is continuous and is characterized by its critical wavelength, which divides the spectrum into two parts with equal power.

**BREMSSTRAHLUNG RADIATION**

[X-rays](https://radiopaedia.org/articles/x-rays) are produced by high-energy electrons bombarding a target having high proton number. When bombarding electrons penetrate into the target, some electrons travel very close to the nucleus due to the attraction of its positive charge and are influenced by its electric pull. During this interaction, some of the energy will be lost and photons shall be generated as per the law of Conservation of Energy. [3]

The lost energy is emitted as X-ray photons, specifically Bremsstrahlung radiation. Bremsstrahlung can have any energy ranging from zero to the maximum KE of the bombarding electrons, depending on how many the electrons are influenced by the electric pull, therefore forming a continuous spectrum. The intensity of Bremsstrahlung radiation is proportional to the square of the atomic number of the target, the number of unit charges of the bombarding particle and inversely with the mass of the bombarding particle.

**BREMSSTRAHLUNG RADIATION AS OPPOSED TO PROTON BOMBARDEMENT**

When an electron passes near the nucleus, due to electrostatic attraction of opposite charges between nucleus and electron, its path is deflected. In these interactions, a negatively charged electron is attracted toward the positively charged nucleus and it loses some of its velocity. [3] Energy lost during this process is emitted as a form of X-ray photons. Bremsstrahlung Radiations (or Braking radiation) are generated usually when the incident beam interacts with the material and it is slowed down by the electric field (Coulomb field) of the atomic nuclei which results on a partially or complete conversion of the Kinetic energy into Electromagnetic radiation. [4]

The closer the electron approaches the nuclei, the greater is the electrostatic attraction on the electron, the braking effect, and the greater is the energy of the resulting Bremsstrahlung photon. When the electrons from the filament strike the target, x-ray photons are created if they either hit a target nucleus directly or their path takes them close to the nucleus. If such an electron hits the nucleus of a target atom, all its kinetic energy is transformed into a single x-ray photon.

[5] Bombardment with ions of sufficient energy (usually MeV protons) produced by an ion accelerator, will cause inner shell ionization of atoms in a specimen. [6] This is known as Proton Bombardment which results into Proton Induced X-ray Emission (PIXE). PIXE is a non destructive multi elemental technique that can analyze medium and heavy trace elements on thick samples. Outer shell electrons drop down to replace inner shell vacancies and X-rays of a characteristic energy of the element are emitted. An energy dispersive detector is used to record and measure these X-rays.

Thus, we can say that Bremsstrahlung method uses electron braking or incident electron path deflection induced X-Ray while Proton Bombardment uses high speed and high energy proton induced ionization for X-Rays. The Bremsstrahlung method produces continuous x-rays while Proton Bombardment produces x-ray photons that have only certain energies related to specific electron shells and so are ‘characteristic’ to that target metal. [7]

**X-RAYS VS. THE GAMMA RAYS**

The key difference between gamma rays and X-rays is how they are produced. Gamma rays originate from the nucleus of a radionuclide after radioactive decay whereas X-rays are produced when electrons strike a target or when electrons are rearranged within an atom.

X-rays are produced by an x-ray generator using electrons and gamma radiation is the product of radioactive atoms post-radioactive nucleus undergoing [alpha or beta radiation](http://pediaa.com/difference-between-alpha-beta-and-gamma-radiation/), the nucleus is left in an “excited” state. The nucleus then loses the excess energy by emitting a gamma photon.

There are three primary differences between X-ray and gamma rays. X-rays and gamma rays can be characterized by frequency, wavelength, and velocity. X-rays have a larger wavelength (and hence a smaller frequency) than gamma. X-ray photons carry more energy than gamma photons. Therefore, gamma rays have a stronger ionizing ability. X-rays have less penetrating power compared to gamma rays.

**SOFT X-RAYS VS. HARD X-RAYS**

Soft X-rays differ from Hard X-rays because of their properties of longer wavelength, less penetrating, low voltage production, resulting out of slow moving electrons, generated at low potential difference.[8]

 Soft X-rays have lower penetrating depths and so when incident on any matter are absorbed completely. Hence, they transfer all their energy to the valence electrons. This results in Radiation Sickness at a very high dose. But at lower doses of Soft X-Rays, patient may be susceptible to Radiation based Cancer.[8]

Hard X-Rays have great penetrating depth and when they are incident on any matter, they travel completely and can be displayed on screen placed. No radiation damage of the sample, which can pin in commensurations or destroy the chemical compound to be analyzed. High momentum transfers are naturally accessible due to the high momentum of the incident wave. However, they are used primarily in Radiation Therapy to treat Cancerous Tumor and Malignant Cells.

Thus we can conclude that Soft X-rays even though having lower energy can prove to be detrimental due to their complete transfer of energy. A pastille dose is enough to produce erythema and a high dose can cause a painful blister. Also there may be effects of skin discoloration. Unscreened and uncontrolled X-rays can prove to be more detrimental and harmful at any dosage.

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