**X-ray Investigation**

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**X-rays** are the same thing like visible light rays. Both are make a structure like of **electromagnetic energy** carried by some particles called photons. Difference between X-rays and visible light rays is the **energy level** of the individual photons. We can describe it as **wavelength** of the rays. The scattering and developing of **X-rays** gives additional support to the quantum view of electromagnetic radiation. X-rays are produced when rapidly moving electrons that have been accelerated through a potential difference of the order of 103 to 106 V strike a metal target. Bone x-ray uses a very small dose of ionizing radiation to produce pictures of any bone in the body.[1]

*Principle*- X-rays attenuated (blocked) by denser tissue develop a shadow on the image.

**Question** 1:-

**Answer** :- *Photoelectric effect*:- It occurs when matter emits electrons upon exposure to electromagnetic radiation, such as photons of light. Photoelectric effect posed a huge change into the study of optics. It gives a complete challenged to *classical wave theory of light* which is prevailing theory of time.

When a light source incident on metal, electron can be ejected from the surface of the metal. Electron emitted in this fashion are called *photoelectric effect*. This process are also called as *photoemission* and electrons that are ejected from the metal are called *photoelectrons*. But if you talk about the photoelectrons they are not different from electrons in term of their behaviour and properties.

Photoelectric effect can be introduced to wave particle duality and quantum mechanics. As according to the *Maxwell wave theory of light*, the more intense the incident light the greater the energy with which the electrons should be ejected from the metal. The average energy carried by an ejected electron should increase with the intensity of the incident light. Energy of the emitted electrons to be independent of the intensity of the incident radiation.

Photons that interacted with the electrons in the metal like discrete particle, rather than as continuous waves. For a incident the energy carried by each photons is:

E=hf

h – Planks’s Constant.

f- frequency

1. The kinetic energy of emitted photoelectrons should increase with the light amplitude.
2. The rate of electrons emission, which is proportional to the measured electric current, should increase as the light frequency is increase.

*X-ray production by photoelectric interaction*

When a moving electron strike a metal target and have potential difference than produced x-rays. There are three possible facts happed after of that

1. It deflection from it original directions.
2. It attenuate without the interaction.
3. It absorb the energy.

Photoelectric effect is a form of interaction of X-ray photon with the matter. A low energy photon interacts with the electron in the atom and removes it from the shell. The probability of these effect is the maximum when the energy of the incident photon is equal to or just higher than the electron in its shell and the electron is tightly bound. The electron that is removed is then called a photoelectron. The incident photon is completely absorbed all the energy in this process. This is one reason of attenuation of X-ray as its passes through the matter. In photoelectric emission the energy of a photon is alter into kinetic energy of an electron; in X-ray production the kinetic energy of an electron is converted into energy of a photon. The energy relation is exactly the same in both cases. In X-ray creation we can neglect the work function of the target because it is ordinarily very small in comparison to the other energies.

**Question** 2

**Answer**:- [3]*Bremsstrahlung* means baking radiation and discuss the radiation which is emitted when electrons are braked when they are fired at metal target. In the Bremsstrahlung process, a high speed electron traveling in a material is stopped or slow down by the forces of any atom it encounters. As a high speed electron approaches an atom, it will interact with the negative force from the electrons of the atom, and it may be slowed or completely stopped. If the electron is slowed down, it will exit the material with less energy. The law of conservation of energy tells us that this energy cannot be lost and must be absorbed by the atom or converted to another form of energy. The energy used to slow the will radiated as x-radiation of equal energy. The intensity of bremsstrahlung radiation is proportional to the square of the atomic number of the target (Z), the number of unit charges of the bombarding particle (z) and inversely with the mass of the bombarding particle (m): Z² z / m. It follows that light particles such as electrons and positrons bombarding targets of high atomic number are more efficient producers of bremsstrahlung radiation than heavier particles such as alpha particles or neutrons.

*Difference between Bremsstrahlung and proton bombardment*

[4][3]During Proton bombardment develop of solid target, a low frequency background develop. We used X-ray spectrographic techniques like *Proton Induced X-ray Emission* for deciding wheather element is made up of material and sample. In *Bremsstrahlung radiation*, because of the electric field electron from the nucleus will deflect from their actual path after encounter the atom The energy used to slow the electron is excessive to the atom and the energy will be radiated as x-radiation. While *proton bombardment* a hydrogen nucleus collide with another hydrogen nucleus and lose some of its positron, during this process charges inside the hydrogen become neutral and act as like a neutron. Bombardment with ions of sufficient energy (usually MeV protons) produced by an ion accelerator, which will be cause the inner shell ionization of atoms in a specimen. Outer shell electrons drop down to replace inner shell vacancy.

**Question** 3:- Difference between X-ray and Gamma-ray

**Answer** :- Both X-Rays and gamma rays describe as waves in the electromagnetic spectrum. Due to the principle of wave-particle duality, these waves can also be idea of as a particle called photons.X-rays have longer wavelengths than gamma but sometimes waves of similar wavelengths may be referred to as X-rays or gamma. There is no agreed point on how to make difference between X-rays and gamma rays. However, they are different from their origin. In this sense, the main difference between X-rays and gamma rays is that **gamma rays are produced during nuclear decay by nuclei of atoms**, whereas **X-rays are produced by electrons**. For instance, for medical purposes,X-rays are produced by accelerating some electrons and then making them collide with a metal target.

* **X-rays** are produced when energetic electrons lose energy.
* **Gamma rays** are produced by radioactive nuclei.

**Energy:- X-ray** photons take more energy than **gamma** photons. Therefore, gamma rays have a stronger ionizing ability.

**Penetration:-X-rays** have less penetrating power compared to **gamma** rays.

**Wavelength** :-**X-ray** have a large wavelength than **Gamma** ray. But X-ray have smaller frequency than gamma. Gamma ray energy are always discrete from and X-ray have discrete and continuous energy.

Gamma rays originate from the nucleus of the atom by nuclear interactions, x-rays originate from extra-nuclear electron interactions. Gamma rays cause more harm to human body than the X- ray. Gamma ray are more danger for the human body as comparison to the X-ray because of there high penetrating and highly energetic ionizing radiation.

**Question** 4:-

**Answer** :- X-rays are of two types (i) Soft X-rays (ii) Hard X-rays

***(i) Soft X-rays***

X-rays having wavelength of 4 or above, have lesser frequency and hence lesser energy. They are called soft X - rays due to their low penetrating power. They are produced at comparatively low potential difference. Soft X-rays are usually filtered when doing a scan because they can't penetrate through a patient's body and add needless risk of radiation damage. They don’t damage to human tissue until unless we repeat the same process so many times.

***(ii) Hard X-rays***

 X-rays having low wavelength of the order of 1 have high frequency and hence high energy. Their penetrating power is high, therefore they are called hard X-rays. They are produced at comparatively high potential difference.

The wavelength of X-rays depends upon the kinetic energy of the electrons producing them and this kinetic energy depends upon the potential difference between the filament and the target. When a patient has an X-ray, they are usually scanned at a frequency of approximately 7×108 Hz because body tissues absorb this frequency the best. Hard X-rays are used in treatment of cancer and radiotherapy.

Soft X-rays cause more damage to human body as comparison to the hard X-rays because of the leaving of high energy radiation frequency. They have high absorption cross sections of C, N and O K-shells, the main organic matter constituents.

[5]The average radiation exposure during a couple of seconds of an abdominal X-ray [is 0.0014 Gy](http://books.google.co.uk/books/about/The_Pregnant_surgical_patient.html?id=xkxsAAAAMAAJ&redir_esc=y), it's a light dose, and it's locally administered, so it's not that bad. A radiation dose good for human body as low as 0.35 Gy but it could feel like you have the flu expect nausea and vomiting, headaches, fatigue, and fever. If the body is exposed to a higher dose, somewhere between 1-4 Gy, blood cells begin to die. odd sunburn if [exposed to 2 Gy or more of ionizing radiation](http://www.icrp.info/article/S0146-6453(01)00004-5/abstract). Between 4 and 8 Gy, however, a dose can be fatal but the route to death still varies on the level of the exposure. Between 8 to 30 Gy experience nausea and severe diarrhea within an hour, and they die between 2 days and 2 weeks after exposure. [6]

Reference:-

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5. Bertrand, L. *et al.* Mitigation strategies for radiation damage in the analysis of ancient materials. *Trends in Analytical Chemistry***66**

6. <https://www.nature.com/articles/srep10250>