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Q1.Write about Characteristic and Bremsstrahlung radiation.

ANS: ***Characteristic Radiation***

Production:

The type of interaction that produces characteristic radiation, also illustrated above (in the "Kinetic" paragraph), involves a collision between the high-speed electrons and the orbital electrons in the atom. The interaction can occur only if the incoming electron has a kinetic energy greater than the binding energy of the electron within the atom. When this condition exists, and the collision occurs, the electron is dislodged from the atom. When the orbital electron is removed, it leaves a vacancy that is filled by an electron from a higher energy level. As the filling electron moves down to fill the vacancy, it gives up energy emitted in the form of an x-ray photon. This is known as characteristic radiation because the energy of the photon is characteristic of the chemical element that serves as the anode material. In the example shown, the electron dislodges a tungsten K-shell electron, which has a binding energy of 69.5 keV. The vacancy is filled by an electron from the L shell, which has a binding energy of 10.2 keV. The characteristic x-ray photon, therefore, has an energy equal to the energy difference between these two levels, or 59.3 keV.

Actually, a given anode material gives rise to several characteristic x-ray energies. This is because electrons at different energy levels (K, L, etc.) can be dislodged by the bombarding electrons, and the vacancies can be filled from different energy levels. The electronic energy levels in tungsten are shown below, along with some of the energy changes that give rise to characteristic photons. Although filling L-shell vacancies generates photons, their energies are too low for use in diagnostic imaging. Each characteristic energy is given a designation, which indicates the shell in which the vacancy occurred, with a subscript, which shows the origin of the filling electron. A subscript alpha (a) denotes filling with an L-shell electron, and beta indicates filling from either the M or N shell.

Tungsten Spectrum:

The spectrum of the significant characteristic radiation from tungsten is shown below. Characteristic radiation produces a line spectrum with several discrete energies, whereas Bremsstrahlung produces a continuous spectrum of photon energies over a specific range. The number of photons created at each characteristic energy is different because the probability for filling a K-shell vacancy is different from shell to shell.

BREMSSTRAHLUNG

Production Process

The interaction that produces the most photons is the Bremsstrahlung process. Bremsstrahlung is a German word for "braking radiation" and is a good description of the process. Electrons that penetrate the anode material and pass close to a nucleus are deflected and slowed down by the attractive force from the nucleus. The energy lost by the electron during this encounter appears in the form of an x-ray photon. All electrons do not produce photons of the same energy.

Spectrum:

Only a few photons that have energies close to that of the electrons are produced; most have lower energies. Although the reason for this is complex, a simplified model of the Bremsstrahlung interaction is shown below. First, assume that there is a space, or field, surrounding the nucleus in which electrons experience the "braking" force. This field can be divided into zones, as illustrated. This gives the nuclear field the appearance of a target with the actual nucleus located in the center. An electron striking anywhere within the target experiences some braking action and produces an x-ray photon. Those electrons striking nearest the center are subjected to the greatest force and, therefore, lose the most energy and produce the highest energy photons. The electrons hitting in the outer zones experience weaker interactions and produce lower energy photons. Although the zones have essentially the same width, they have different areas. The area of a given zone depends on its distance from the nucleus. Since the number of electrons hitting a given zone depends on the total area within the zone, it is obvious that the outer zones capture more electrons and create more photons. From this model, an x-ray energy spectrum, such as the one shown below, could be predicted.

The basic Bremsstrahlung spectrum has a maximum photon energy that corresponds to the energy of the incident electrons. This is 70 keV for the example shown. Below this point, the number of photons produced increases as photon energy decreases. The spectrum of x-rays emerging from the tube generally looks quite different from the one shown here because of selective absorption within the filter.

A significant number of the lower-energy photons are absorbed or filtered out as they attempt to pass through the anode surface, x-ray tube window, or added filter material. X-ray beam filtration is discussed more extensively in a later chapter. The amount of filtration is generally dependent on the composition and thickness of material through which the x-ray beam passes and is generally what determines the shape of the low-energy end of the spectrum curve.

Q2.Write about the factors that affect X-ray Quantity.

ANS: ***X-Ray Quantity***

X-ray photon quantity refers to the number of photons produced during an exposure.

Factors influencing x-ray quantity includes:

- ***Peak voltage (kVp)***: beam quantity is approximately proportional to the square of the tube potential

- ***Generator type/voltage waveform***: reducing ripple increases beam quantity
- ***Beam filtration:*** increasing filtration reduces beam quantity
- ***Distance from the beam:*** inverse square law
- ***Current (mA):*** beam quantity is directly proportional to current
- ***Exposure time (seconds):*** beam quantity is directly proportional to exposure time
- ***Anode material:*** beam quantity is directly proportional to the atomic number (Z) of the anode material

Q3.List and explain the five factors that affect subject contrast.

ANS: ***Subject Contrast:***

It refers to the difference in the intensity transmitted through the different parts of an object. For example, in an intraoral radiograph, enamel will attenuate x-rays more than dentin.

Subject contrast is affected by the following factors:

- ***Thickness difference:*** if the x-ray beam is attenuated by 2 different thicknesses of the same material, the thicker part will attenuate more x-rays than the thinner part.
- ***Density difference***: this is also known as the mass per unit volume. It is the most important factor contributing to subject contrast. A higher density material will attenuate more x-rays than a lower density material.

- ***Atomic number difference:*** A higher atomic number material will attenuate more x-rays than a lower atomic number material.
- ***Radiation quality or kVp:*** it has a great effect on subject contrast. A lower kVp will make the x-ray beam less penetrating. This will result in a greater difference in attenuation between the different parts of the subject, leading to higher contrast. A higher kVp will make the x-ray beam more penetrating. This will result in less difference in attenuation between the different parts of the subject, leading to lower contrast.

Q4.Define the following terms.

ANS: ***Collimator Filtration:***

A collimator is essentially an aperture diaphragm with the ability to adjust the size and shape of the X-ray field close to the tube port. Consisting of a set of lead shutters at right angles to each other, typically in a rectangular format, collimators are the most widely used beam-restrictor. The collimator assembly includes a housing, holding the collimator blades, a (visible) light fixture, and a mirror. Light is reflected by the mirror to follow the same direction as the X-ray beam. The mirror, while in the path of the X-ray beam, exhibits negligible attenuation to the X-ray beam. In this way, the visible light mimics the X-ray beam simplifying orientation of the X-ray assembly over the imaging area for imaging personnel. In a rectangular configuration, the collimator blades are x-y axis adjustable highly attenuating lead blades, creating a focused beam over the imaging target. Other configurations such as circular 'iris' designs are also used Adjustment of the collimator blades is typically controlled based on cassette size and location, so that the collimator blades match the cassette dimensions.

Image contrast:

Contrast is the difference in luminance or colour that makes an object (or its representation in an image or display) distinguishable. In visual perception of the real world, contrast is determined by the difference in the colour and brightness of the object and other objects within the same field of view. The human visual system is more sensitive to contrast than absolute luminance; we can perceive the world similarly regardless of the huge changes in illumination over the day or from place to place. The maximum contrast of an image is the contrast ratio or dynamic range.

Aperture diaphragm

The aperture diaphragm is likely the simplest restrictor used. It is composed of a flat sheet of metal, typically lead, with a hole cut in the center, and is attached to the X-ray tube window. Different diaphragms with varying sized holes must be switched into place based on the image required and the film size used. Though aperture diaphragms are cheap and simple to use, they detrimentally off-focus radiation because of proximity to the X-ray tube window. They also increase penumbra; geometric blur or the beam around its edges, again, due to its proximity to the X-ray tube window.

Q5.Write a note about Compton scattering and photoelectric effect.

ANS: ***Compton Effect:***

Compton effect or Compton scatter is one of principle forms of photon interaction. It is the main cause of scattered radiation in a material. It occurs due to the interaction of the photon (x-ray or gamma) with free electrons (unattached to atoms) or loosely bound valence shell (outer shell) electrons. The resultant incident photon is scattered (changes direction) and imparts energy to the electron (recoil electron). The scattered photon will have a different wavelength (observed phenomenon) and thus a different energy ($E=hc/\lambda$). Energy and momentum are conserved in this process. The Compton effect is a partial absorption process and as the original photon has lost energy, known as Compton shift (i.e. a shift of wavelength/frequency). The wavelength change of the scattered photon can be determined by $0.024 (1- \cos \theta)$, where θ is scattered photon angle. Thus, the energy of the scattered photon decreases with increasing scattered photon angle.

The Compton effect is the name given by physicists to the collision between a photon and an electron. The photon bounces off a target electron and loses energy. These collisions referred as elastic compete with the photoelectric effect when gamma pass through matter. It contributes to their attenuation.

The effect was discovered in 1922 by the amercan physicist Arthur H. Compton. Compton received the Nobel Prize in Physics in 1927. He demonstrated the particle nature of electromagnetic radiation. It was a sensational discovery at the time.

Compton collisions can be viewed as elastic collisions between a photon and an electron. These elastic collisions become predominant when the photon energy becomes large compared to the energy that holds the electron in an atom, its binding energy. For a light atom such as carbon, the Compton effect prevails on the photoelectric effect above 20 keV. For copper it is above 130 keV, and for lead 600 keV.

In this gamma energy range, which is rather extended , the phenomenon concerns all the electrons of the atom, whereas in the photoelectric effect these are the two electrons from the innermost K shell, which play a role. For an absorber, it is the density of electrons that is crucial in the range where Compton effect dominates. Lead has thus also an advantage over lighter materials, even if less important than for the photoelectric effect, which came at the fourth power of the high electrical charge of its nucleus.

Photoelectric Effect:

The photoelectric effect is the phenomenon that transforms visible light, infrared and ultraviolet rays into electricity in solar panels and cells of our cameras. It is also involved in the completely different field of radioprotection : by transforming penetrating X and gamma rays into electrons easy to stop, it protects us from the effects of these radiations.

The photoelectric effect is the most effective physical phenomenon in mitigating these radiations. The gamma or X photon, absorbed by interacting with an electron bound to an atom (*) disappears.

The shell structure of atoms plays a crucial role. The photon wrest an electron only if its energy exceeds the binding energy of the electron on its shell. The probability (called cross section) to remove an electron from this shell becomes non-zero beyond this threshold.

The photons of visible light whose energies are small can only eject the least bound electrons of the atom which are the most external. This property rapidly decreases, until the photon energy exceeds the binding energy of the atom first inner shell : the photon becomes able to extract electrons from this shell.

The probability of pulling out electrons from the new layer decreases in turn until the photon energy exceeds the binding energy of electrons from the second inner shell, which then become the main contributors. As and when its energy increases, the photon interacts in turn with deeper and deeper atom layers.

The two deepest K-shell electrons, the closest to the nucleus, constitute somehow the ultimate cartridge of the process . After a last jump, the cross section decreases inexorably. Meanwhile, the light photon has become an X or gamma ray. In this energy range, the electric charge Z of the nucleus occurs at the fourth power: the photoelectric effect for a lead atom (Z = 82) will therefor be 10,000 times stronger than for oxygen (Z = 8).

The decrease of the photoelectric effect with energy is impressive, although the fall is mitigated by the jumps due to the crossing of thresholds of the successive atomic shells.

In the case of light atoms like oxygen, the binding energy of the K-shell, is of the order of 1 keV. It is negligible for gamma having energies of tens or hundreds of keV. The electron them seem almost free. We are in the Compton effect range that prevails then on the photoelectric effect.