Interaction of Radiation with Matter

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When anyone comes to the point of describing interactions of radiation (electromagnetic and acoustic) with matter, it is need to be considered whether the wavelength of the actual radiation would cause any interaction with the target object (e.g. human tissue) or even it would be totally absorbed. There are three wavelength ranges of radiation where absorption characteristics can be used for medical imaging: the X-ray range (used by CT, planar X-ray, PET, gamma cameras and SPECT), the radio frequency range (used by MRI) and the ultrasound range (used by Ultrasound equipment). If we consider a radiation interaction as a single system, in such case there are some quantities that remain the same after the interaction. These quantities are often called to be conserved in the interaction. Such conserved quantities include total energy, momentum and electric charge. In ionization we distinguish between *directly ionizing particles* (that are charged particles) and *indirectly ionizing* particles (uncharged particles). Directly ionizing are the alpha particles (helium nuclei), beta particles (electrons), protons and any other nuclei. Indirectly ionizing particles are the photons (in the adequate energy range) and neutrons. An atom becomes ionized when it ejects at least one electron. Under a certain energy limit, radiation is not able to induce ionization, therefore, radiation with higher energy than this limit is called ionizing and radiation with lower energy is called non-ionizing. There is a probability for an incident electron to cause the ejection from the K-shell electron in case of higher atomic numbers, and the vacancy is filled with an outer shell electron. During this process the energy difference of the two shells is emitted in the form of electromagnetic radiation that we call characteristic X-rays. It is called characteristic, since different but discrete energy X-ray photons are emitted according to the electron shells of the atom. The incident electron may only be repelled by the nucleus and while continuously accelerated in the electric field of the nucleus electromagnetic radiation is emitted in the X-ray spectrum. This is the so-called bremsstrahlung process. The difference between X-rays and g-rays are coming from their origin and not necessary observable in their energy. Both are forms of electromagnetic radiation and have a certain probability to go through different processes based on the energy. The energy of X-rays and g-rays in nuclear medicine applications regularly cause three kinds of interactions: the *Photoelectric effect, Compton scatter* and *Pair production.* One or more of these interactions are determining the final quality performance of nuclear medicine imaging systems.

References:

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