1. Introduction

The Photoelectric effect

In the photoelectric effect, electrons are emitted from a material when light is incident on its surface. Ordinarily an electron is bound to the material and cannot escape from it unless energy is supplied. The light must supply each emitted electron with sufficient energy to escape from the surface. To be emitted from the surface, an electron must receive a minimun amount of energy Φ, called the work function of the surface. The value of the work function depends on the material and on the condition of the surface. For example, the work function for aluminium (with a clean, unoxidized surface) is 4.2 eV.

The Photon

Albert Einstein (1879-1955) proposed a corpuscular, or particle, theory of light: Monochromatic light of frequency ν propagating in vacuum consists of a stream of particles or quanta, which we now call photons. Each photon travels at speed c and has a discrete amount or quantum of energy:

$$E = h\nu \qquad (1)$$

where h is Planck's constant. Further, when a photon interacts „one on one“ with an electron, the electron acquires all of the energy of the photon, which then exists no longer. All of the features of the ***photoelectric effect*** can be simply explained by using the photon concept. Consider each of the properties listed above that could not be understood with the wave picture of light.

- To escape from the surface of a material, an electron must gain an energy at least equal to the work function Φ.
- An electron receives a definite amount of energy $h\nu$ by absorbing a photon.
- The maximum kinetic energy, K_{max} equals, by conservation of energy, the energy $h\nu$ absorbed from the photon, less the minimum energy Φ required to escape from the surface. Thus

$$K_{max} = h\nu - \phi \qquad (2)$$

which is known as Einstein's photoelectric equation.

- Since an electron absorbs a photon and acquires the energy all at once, there need ne no appreciable time delay between the incident of light and the emission of electrons. An electron can be emitted immediately.

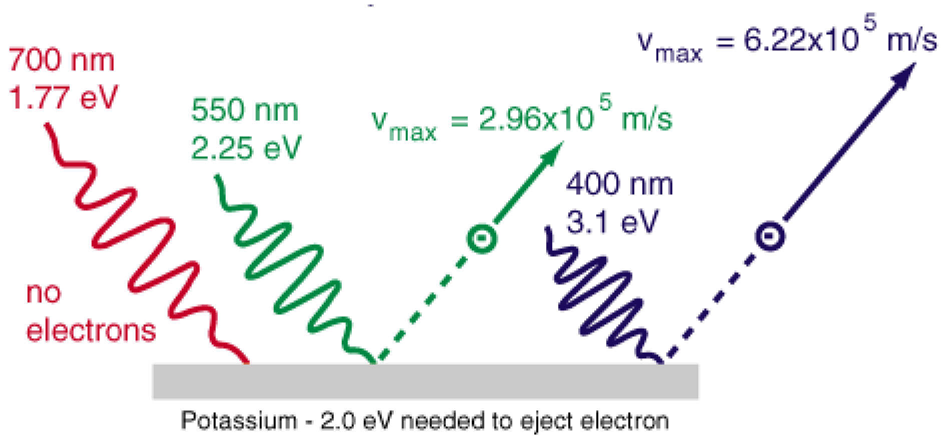


Figure 1: The photoelectric effect.

The Compton Effect

In 1923 A.H.Compton (1892-1962) found that the frequency of some of the x-rays scattered by electrons was not the same as the frequency of the incident x-rays. The frequency change on scattering is called the **Compton effect**. Compton showed that the interaction can be interpreted as a colision of two particles, a photon and an electron. The final state is determined by applying the conservation laws for energy and momentum.

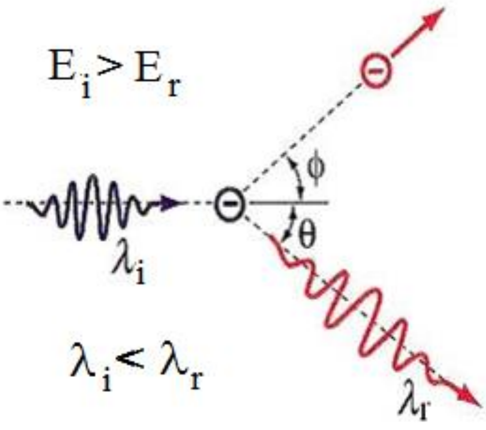
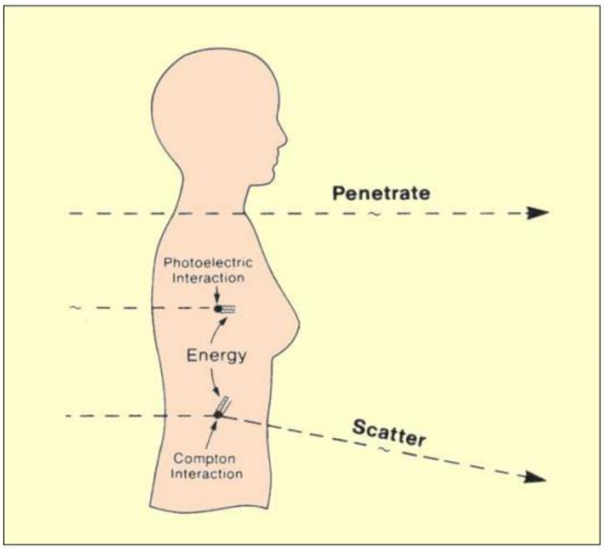


Figure 2: The Compton effect.

2. The interaction of Photons with Atoms

X-ray Scattering and Absorption by Atoms

Imaging with X-rays depends on the relative numbers of photons, emitted from an X-ray tube, that traverse a patient's body undeviated by interactions with atoms of the body. This fraction depends on the efficiency with which X-ray photons are absorbed or scattered within the body. We can describe each of several processes in terms of collisions between atoms, which have both a finite size and an internal structure, and photons. The collisions can be one in which the photon loses no energy but merely alters its direction. This is the ***elastic scattering***. Alternatively the photon can loose some or all of its energy to an atom, whose internal structure is disrupted in the process. This is ***inelastic scattering and absorption***. The processes, which we describe in this section, are of great importance to both X-ray and γ-ray methods of imaging. In general, for a given atom and a given incident photon energy, the efficiencies of both inelastic and elastic processes vary with the photon energy and the atomic number of the atom. In medical diagnostic imaging we are concerned with the interaction between X-rays, γ-rays and biological tissues that contain a wide of variety of atoms. In general, the amount of radiation transmitted through the patient decreases exponentially with the path length of the beam through the patient. There are two important general points to understand. First, the various attenuation mechanisms are independent and each one adds independently to the overall attenuation coefficient. Second, the magnitude of each contribution depends in a predictable manner on the atomic number of the atoms and the energy of the incident radiation.



Photons Entering the Human Body Will Either Penetrate, Be Absorbed, or Produce Scattered Radiation

The photoelectric effects

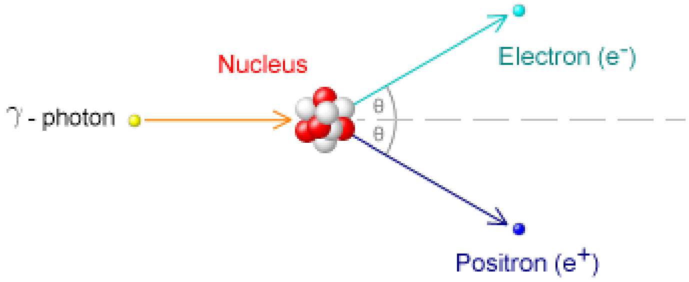
Absorbed **X and γ** photons cause the photoelectric effect on the electrons in the **inner** orbitals and result is production of excited cations and primary electrons. Secondary X photons are emitted by relaxation of cations and its are absorbed in tissue while high speed electrons can induce new excitations. The interaction is **more probable** for lower energies photons (**20 – 80 keV**) and for **heavier** atoms (bigger Z; Z is atomic number).

Elastic incoherent scattering of photon – Compton's effect

Collision of photon with atom results in ejection of electron from outer shell. The scattered photon has lower energy and different direction. The result of this type of interaction is production of excited cations, primary electrons and scattered photons. Scattered photons exit the body and electrons can induce new excitations and ionizations. The interaction is more probable for photons with energy much higher from the ionization energy of electron in atom **(> 80 keV**) and for **easier atoms.**

Pair production

γ- photon energy higher than 1 MeV near the heavy nucleus may transforms into the pair of particles: *electron – positron.*



Literature:

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