

Compton Shifting with Scattering Angle and Masses of Order 10-31kg To 1-0-27kg

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Compton Shifting with scattering angle and masses of order $10^{-31}kg$ to $10^{-27}kg$

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Abstract

The objective of this work is to study and observed the Compton shift of elementary particles masses lies in between $10^{-31}kg$ to $10^{-27}kg$ within the angle between 0 radians to 3 radians. The observation shows Compton shifting ranges from $10^{-11}m$ to $0.5 \times 10^{-18}m$. This nature of shifting is the same for all the considered masses for the same angle of scattering. Therefore this scattering is suitable for other elementary particles that lie in between considered masses. Hence the validity of Compton shifting can be used for other elementary particles scattering as elementary particles masses in between $10^{-31}kg$ to $10^{-27}kg$ as having similar nature or original Compton scattering of electron-photon interaction.

Keywords: Compton Shifting, Scattering Angle, Elementary Particle's, Electron Photon Interaction, etc.

1. Standard Model and Elementary Particles with characteristics

Elementary particles are defined as the minor units of matter and classified into three major distinct groups: quarks model, leptons model, and bosons model. The quark model has six quark types (up and down quark, charm and strange quark, top, and bottom quark). All quark has their mass, charge, and color, but all are distinct (particles from antiparticles). All lepton models include electron and electron neutrino, muon and muon neutrino, tau and tau neutrino.

The standard model described the interaction of elementary particles with all existence forces like electromagnetic force, strong force, weak force, and gravitational force. For example, among the elementary particle gauge bosons (W and Z) are mediated by the weak force, gluons mediate the strong nuclear force while photon mediates the electromagnetic force.

Fermions are the particle that follows Fermi-Dirac Statistics, which are half-odd integer spin like 1/2, 3/2, 5/2, etc., and obeys Pauli Exclusion Principle. There are 12 fundamental fermions without their constituent particle and divided into two categories, Quarks and Lepton. No two fermions have the same quantum numbers. The repulsion for fermions or compelling attraction for bosons, or exchange force generally [1].

Standard Model (SM) categories boson's elementary particles based on integer spin (including zero spins), unlike fermions. In SM, all mesons are considered bosons and are responsible for the electroweak force. Interaction between bosons are massive W^+ , W^- and Z^0 , and the charge-changing are weak interaction in between (W^+ and W^- bosons); also, the neutral particle is weak interactions in between (Z^0 boson) [2].

Bosons have an integer spin, including zero spin and don't Pauli's Exclusion Principle and occupy the same quantum state. Boson follows Bose-Einstein's statistics with intermediate vector bosons like photons, gluons, weak bosons (particles W and Z), and mesons [3].

In the quantum mechanical case, bosonic particles are indistinguishable, and particles are labeled with integer spin: 0, 1, 2, etc., while for fermion particles are distinguishable and particle is not marked with integer spin 1/2, 3/2, etc. The distribution of the fermion and boson are

$$\langle n_i \rangle = \frac{1}{e^{\beta(\epsilon_i - \mu)} + 1} \text{ [Fermion - Dirac]}$$

$$\langle n_i \rangle = \frac{1}{e^{\beta(\epsilon_i - \mu)} - 1} \text{ [Bose - Einstein]}$$

Where ϵ_i is the energy of i th- state, $= \frac{1}{kT}$ M is the chemical potential. According to SM, all elementary particles are either bosons or fermions, and spin identifies them [4]

Among different experiments and theories, the photoelectric effect is one theory with an experiment that shows energy quantized and absorption of energy from photon and emission of energy during transmission from material shows photon nature. Moreover, the Compton effect support this theory and develop a relation shown in equation (1), which also indicates that intensity and scattered wavelength are independent while scattering angle and incidence wavelength are dependent on each other as

$$\lambda_s = \lambda_0 + \frac{h}{m_0c}(1 - \cos\theta) \dots \dots \dots (1)$$

Where m_0 is the rest mass of the electron, $\frac{h}{m_0c}$ is constantly called Compton wavelength of the electron and θ is scattering angle, the simple phenomena of Compton scattering shown as below,

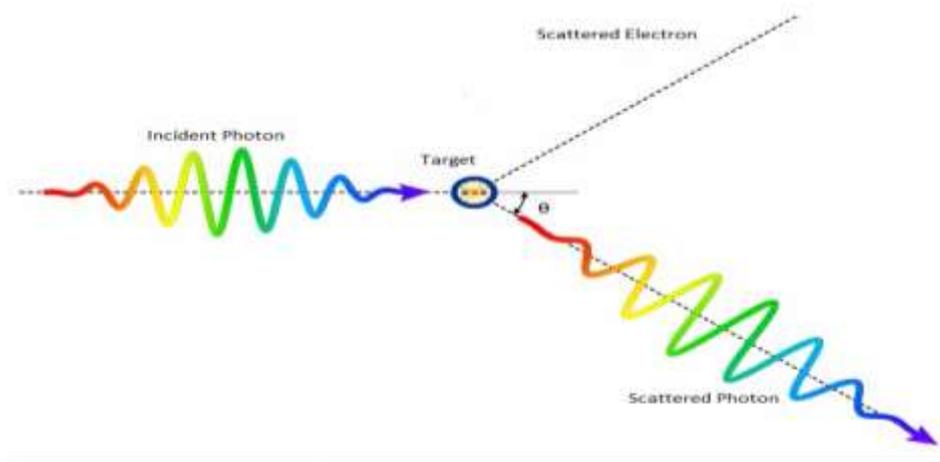


Figure 1: Compton scattering phenomena

Compton Effect is defined as a scattering of incidence photon by bounded or unbounded charge particle, and in this scattering, some photon energy is transformed to charge particle with which photon goes interaction. This theory derived from classical theory and used for

special relativity and quantum mechanics. This scattering help to understand the interactions of high energy physics theory in general, electromagnetic photon radiation with materials, like gamma rays interaction and X-ray production and Bremsstrahlung [5]. Compton length of the electron played a central part in several areas of physics and used to find the rest mass of an electron as described by Prasannakumar et al. [6], indirectly employed in the relativistic wave equation of Klein and Gordon, in the Dirac equation [7] as well as in the non-relativistic Schrodinger equation [8].

Compton scattering energy photon ranges up to a few MeV; therefore, it is one of the best studies for firmly bound atomic K-shell electrons, and some experimental data range between 0.279 to 1.0002 more detail in [9]. The interaction of matter and energy of X-rays (less than 1MeV) has different types of scattering like coherent (Rayleigh) scattering, incoherent (Compton) scattering, and photoelectric absorption [10]. In Rayleigh scattering, low-energy photons are considered; therefore, neither atom ionized nor electron goes to an excited state. On the other hand, in Compton scattering, the energy of a photon is high; therefore, atomic free-electron interact with incidence photons [11]. Thus, Compton scattering is observed in insufficient atomic numbers, while Rayleigh scattering is observed in higher atomic numbers [12].

Different experimental observations and theoretical development for non-relativistic kinematics show that physical parameters of Compton scattering are not appropriate. The change in wavelength in Compton scattering can be expressed as $\Delta\lambda = \lambda' - \lambda = \frac{2h}{mc} = 0.04852 \text{ \AA}$. For X-rays, the incidence for interaction and result shows that change in wavelength is about 4.852% when X-rays photon incidence with the energy of 12.41 keV. The experimental result shows that if the photon's energy is less than the rest energy (511KeV) of the photon, we can apply the Compton Effect for non-relativistic rather than relativistic cases

[13]. The contribution of Bose in quantum statistical physics also shows that light is accepted as particles, and the generalization of concept by Einstein leads the concept of bosonic particles and obeys Bose-Einstein statistics. The nature of photon (particle and wave) was compounded in 1924 by Broglie and forward as both nature in a single particle but not at an instant and develop the relation as $\lambda = h/p$ to study the wave-like properties, where λ wavelength and p is momentum, and later names as packet energy called quanta. In 1927 after discovering electron properties as wave-like nature by Davisson and Germer experimentally, the dual nature of photon (wave and particle) was accepted in the scientific world until a contradiction is going on [14].

2. Mathematical formulation to study the Compton shifting for the different mass of the elementary particle

Compton scattering and the Compton wave derivation: Considering Compton scattering as shown in figure 1, the conservation of energy in Compton scattering is given by

$$E_{\gamma} + E_e = E_{\gamma'} + E_{e'} \dots \dots \dots (2)$$

Here $E_{\gamma} = hf$ and $E_{\gamma'} = hf'$, before and after scattering and rest mass-energy of the electron is $E_e = m_e c^2$. From relativistic energy-momentum, the energy of $E_{e'} = \sqrt{(p_{e'}c)^2 + (m_e c^2)^2}$.

On substituting these values on equation (2), we obtained an expression of energy as,

$$hf + m_e c^2 = hf' + \sqrt{(p_{e'}c)^2 + (m_e c^2)^2} \dots \dots \dots (3)$$

Now the representation of equation (3) and conservation of momentum $p_{e'} = p_{\gamma} - p_{\gamma'}$ one can derive a relation,

$$2hf m_e c^2 - 2hf' m_e c^2 = 2h^2 f f' (1 - \cos\theta) \dots \dots \dots (4)$$

For, $E = pc = hf$ and $c = \lambda f$ the arrangement of equation (4) becomes

$$\lambda' - \lambda = \frac{h}{m_e c} (1 - \cos\theta) \dots \dots \dots (5)$$

It is similar to equation (1), on assuming $\Delta\lambda = \lambda' - \lambda$ and $\lambda_c = \frac{h}{m_e c} = 0.00249nm = 2.43pm$ is Compton wavelength as

$$\Delta\lambda = \lambda_c(1 - \cos\theta) \dots \dots \dots (6)$$

This equation (6) shows that shifting wavelength depends upon the scattering angle with the mass of the electron. For long wavelengths $\lambda \gg \lambda_c$ (i.e., $hf \ll m_e c^2$), the scattering is closely elastic. In term of energy, one can be derived and extend relation (6) as

$$E_{\gamma'} = \frac{m_e c^2}{(1 - \cos\theta)} \frac{(E_\gamma - E_{\gamma'})m_e c^2}{(1 - \cos\theta)E_\gamma} \dots \dots \dots (7)$$

Here E_γ is the energy of incident gamma rays and $E_{\gamma'}$ is scattered gamma rays at an angle θ for considered that $E_\gamma = E_{in}$ and $E_{\gamma'} = E_{out}$ equation (7) is modified as

$$E_{out} = \frac{E_{in}}{1 + \frac{E_{in}}{m_e c^2} (1 - \cos\theta)} \dots \dots \dots (8)$$

The energy difference $E_{in} - E_{out}$ denotes how much energy has been deposited to the electrons in the crystal by scattering [15]. The Compton wavelength of photons or gluons is described in the standard model (SM) of the elementary particle [16].

3. Result and Discussion

To study Compton shifting nature of elementary particles masses in between $10 \times 10^{-27} kg$ to $10^{-31} kg$, for this, we develop code from MATLAB. We consider the two variables here to study Compton shifting the nature one is masses, and the other is the angle. To study the Compton shifting for emitted particle electron for mass $3.11 \times 10^{-31} kg$, with

incidence photon energy which is higher than the threshold, are visualized below with different angle,

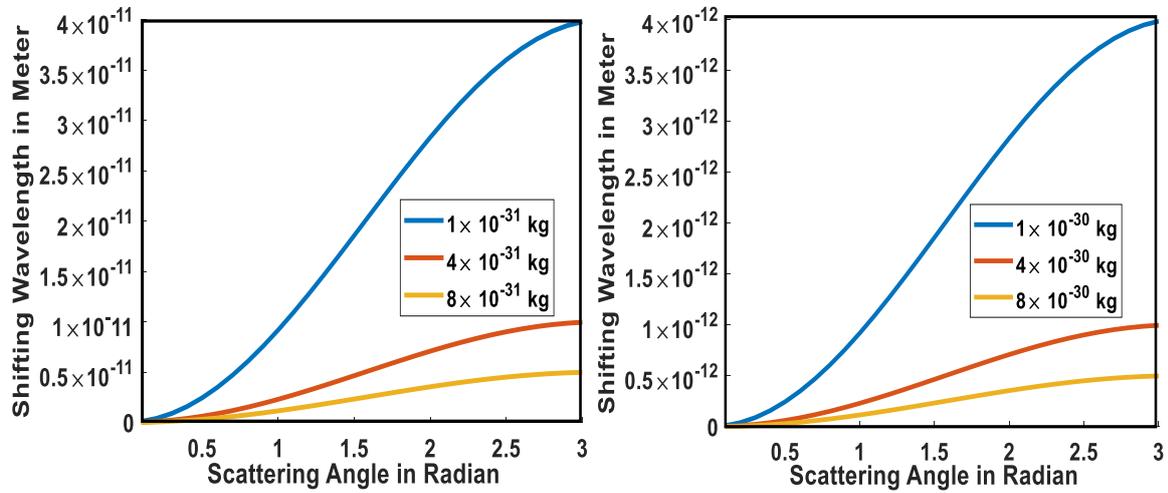


Figure 2: Shifting of wavelength with a scattered angle for masses of order $10^{-31}kg$ and $10^{-30}kg$.

For two constant mass of $10^{-31}kg$ and $10^{-30}kg$ the plot obtain on varying scattering angle, the Compton shifting ($\Delta\lambda$) is seen maximum within the range of the scattering 1 radian to 3 radians and found of order $10^{-11}m$ for the mass of order $10^{-31}kg$ while minimum shifting of wavelength takes place in scattering angle ranges 0.1 to 0.2 radian and found of the order of $10^{-14}m$ as shown in figure 2. The maximum shifting ($\Delta\lambda$) is seen maximum within the range of the scattering 1 radian to 3 radians and found of order $10^{-12}m$ for the mass of order $10^{-30}kg$ while minimum shifting of wavelength takes place in scattering angle ranges 0.1 to 0.2 radian and found of the order of $10^{-15}m$ as shown in figure 2. The shifting difference between maximum and minimum shifting is about $9.99 \times 10^{-12}m$ for $10^{-31}kg$ masses and $9.99 \times 10^{-13}m$ for $10^{-30}kg$.

The Compton shifting observation was obtained for elementary particles of a mass of order $10^{-29}kg$, as shown in figure 3. The maximum shifting ($\Delta\lambda$) is seen maximum within the range of the scattering 1 radian to 3 radians and found of order $10^{-13}m$ for the mass of order

$10^{-29}kg$ while minimum shifting of wavelength takes place in scattering angle ranges 0.1 to 0.2 radian and found of the order of $10^{-16}m$ as shown in figure 3. The shifting difference between maximum and minimum shifting is about $9.99 \times 10^{-14}m$.

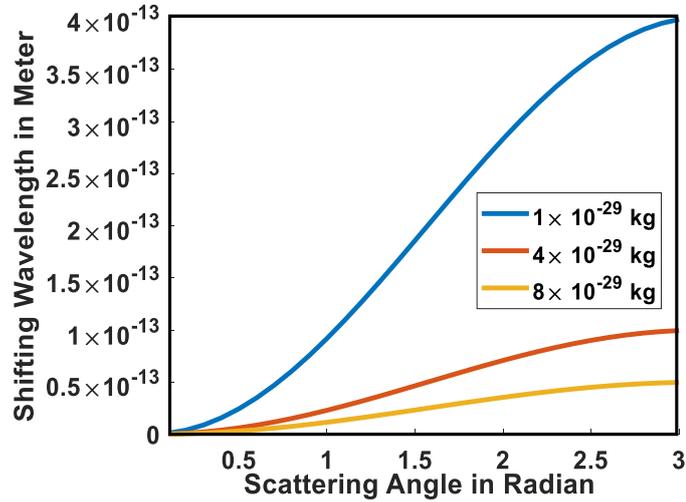


Figure 3: Shifting of wavelength with a scattered angle for masses of order $10^{-29}kg$.

The Compton shifting observation was obtained for elementary particles of a mass of order $10^{-28}kg$, as shown in figure 4. The maximum shifting ($\Delta\lambda$) is seen maximum within the range of the scattering 1 radian to 3 radians and found of order $10^{-14}m$ for the mass of order $10^{-28}kg$ while minimum shifting of wavelength takes place in scattering angle ranges 0.1 to 0.2 radian and found of the order of $10^{-17}m$ as shown in figure 4. The shifting difference between maximum and minimum shifting is about $9.99 \times 10^{-15}m$.

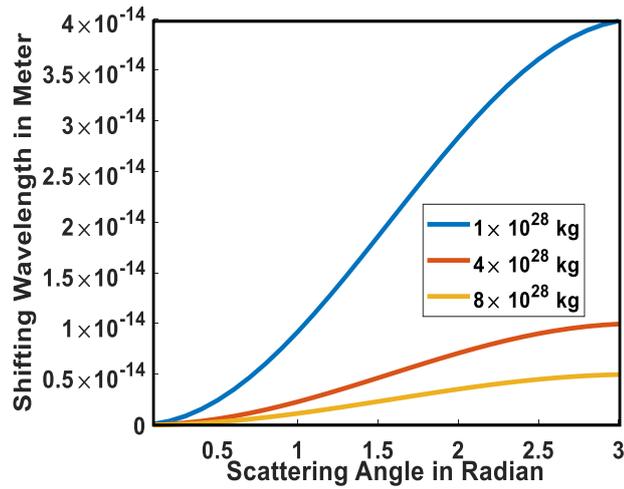


Figure 4: Shifting of wavelength with a scattered angle for masses of order $10^{-28}kg$

The Compton shifting observation was obtained for elementary particles of a mass of order $10^{-27}kg$, as shown in figure 5. The maximum shifting ($\Delta\lambda$) is seen maximum within the range of the scattering 1 radian to 3 radians and found of order $10^{-15}m$ for the mass of order $10^{-27}kg$ while minimum shifting of wavelength takes place in scattering angle ranges 0.1 to 0.2 radian and found of the order of $10^{-18}m$ as shown in figure 5. The shifting difference between maximum and minimum shifting is about $9.99 \times 10^{-16}m$.

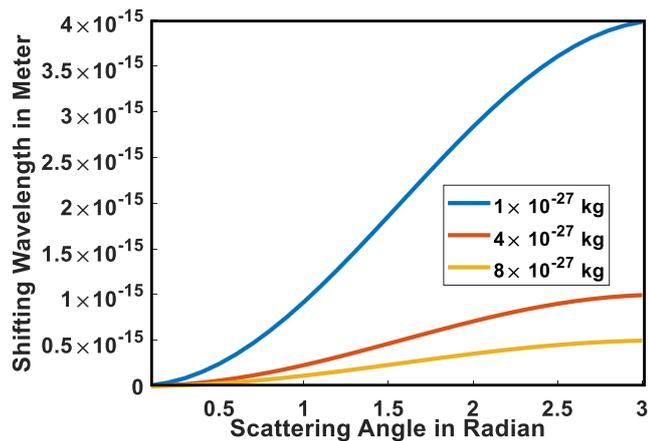


Figure 5: Plot of wavelength difference with scattered angle by fixing different masses of the same order $10^{-27}kg$.

The observation of Compton shifting with variation scattering angle θ (0 to π or 0 radians to 3 radians) for different elementary particles whose mass is less than the mass of electron are shown in figure 2 to figure 5. The maximum and minimum Compton shifting of different elementary masses within scattering angles 0 to 3 radian are listed in table 1.

Table 1: Subatomic ranges masses, maximum Compton shift, and maximum scattered angle.

| SN. | Subatomic masses (kg) | Maximum Compton shift (m) | Minimum Compton shift (m) |
|------------|----------------------------------|--------------------------------------|------------------------------------------|
| 1. | 1×10^{-31} | 4.4×10^{-11} | 1.1×10^{-13} |
| | 4×10^{-31} | 1.10×10^{-11} | 2.76×10^{-14} |
| | 8×10^{-31} | 5.50×10^{-12} | 1.38×10^{-14} |
| 2. | 1×10^{-30} | 4.40×10^{-12} | 1.10×10^{-14} |
| | 4×10^{-30} | 1.10×10^{-12} | 2.76×10^{-15} |
| | 8×10^{-30} | 5.50×10^{-13} | 1.38×10^{-15} |
| 3. | 1×10^{-29} | 4.40×10^{-13} | 1.10×10^{-15} |
| | 4×10^{-29} | 1.10×10^{-13} | 2.76×10^{-16} |
| | 8×10^{-29} | 5.50×10^{-14} | 1.38×10^{-16} |
| 4. | 1×10^{-28} | 4.40×10^{-14} | 1.10×10^{-16} |
| | 4×10^{-28} | 1.10×10^{-14} | 2.76×10^{-17} |
| | 8×10^{-28} | 5.50×10^{-15} | 1.38×10^{-17} |
| 5. | 1×10^{-27} | 4.40×10^{-15} | 1.10×10^{-17} |
| | 4×10^{-27} | 1.10×10^{-15} | 2.76×10^{-18} |
| | 5×10^{-27} | 5.50×10^{-16} | 1.38×10^{-18} |

The maximum and minimum Compton shifting of elementary particles masses from the order of $10^{-31}kg$ to $10^{-27}kg$ is ranged from $10^{-11}m$ to $10^{-16}m$ for maximum shifting and $10^{-13}m$ to $10^{-18}m$ for minimum shifting within consider scattering angle. On comparing Compton shift with visible photons, a vast difference is seen, i.e., the Compton shift of elementary particles of considers masses is the order of $10^{-18}m$ to $10^{-11}m$, while the wavelength of visible light is $10^{-7}m$. Therefore on comparing Compton shifting with the masses, the shift is observed in different elementary particles masses like for electron ($10^{-31}kg$), new elementary particles ($10^{-30}kg$ to $10^{-28}kg$), proton($10^{-27}kg$), and neutron($10^{-27}kg$).

4. Conclusion

The observation shows that Compton shifting depends on both elementary particles masses and scattering angle. The Compton shifting is decreased with increasing masses and increases with scattering angle. As we consider for the masses of the elementary particles of the order $10^{-31}kg$ to $10^{-27}kg$ the nature of shifting is the same for all and ranges in between maximum to minimum $10^{-11}m$ to $10^{-18}m$. The shifting is maximum for electrons range mass and minimum for proton and neutrons ranges masses, shifting the order of $10^{-11}m$ for electrons mass and $10^{-18}m$ for proton and neutron masses. Hence, it concluded that Compton shifting is valid for masses from $10^{-31}kg$ to $10^{-27}kg$ that is electron mass to proton and neutron.

Declaration statement

Availability of data and materials: Data are not taken from any sources. The data was generated using MATLAB software for this work based on the equation derived above; the plot above is drawn using MATLAB code

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