**Journal of Physics and Chemistry of Materials** **Research Paper**
Vol.7, Issue.4, pp.01-04, December (2020) **E-ISSN:** 2348-6341

# Nature of Masses Formed During Pair Production Reaction

**Saddam Husain Dhobi**

Department of Physics, Tribhuvan University, Kathmandu-44600, Nepal
Laboratory, Innovative Ghar Nepal, Lalitpur-44700, Nepal
Robotics Academy of Nepal, Lalitpur-44700, Nepal

*Author's Mail Id: saddam@ran.edu.np Tel.: +977-9808100285*

**Available online at: www.isroset.org**

Received: 18/Nov/2020, Accepted: 03/Dec/2020, Online: 31/Dec/2020

***Abstract***—The formation of the masses from the energy of photons after photon enters the atom due to velocity reduction. These formed masses are not ordinary masses that is it doesn't have a nucleus, proton, and electron. The masses formed during this phenomenon are composed of Fermion or Boson or D-Particles and these particles are separated from each other from mass due to dipole formation in a strong suitable field near the nucleus. Also, the properties are quite similar to the properties of an elementary particle. The phenomena take place very fast, less than $10^{-19}$ second, and adjustable to follow the principle of the mass of conservation of energy, in a discrete form with a non-homogenous field present in an atom.

***Keywords:*** Fermion, Boson, D-Particle, Dipole, Strong Field, Nucleus, Non-homogenous Field, Atom, Electron, Proton, etc.

## I. INTRODUCTION

The scattering with alpha particles at a certain angle of incidence given with differential scattering cross-section given as

$$\frac{d\sigma}{d\Omega} = \frac{I_\theta \times A}{d\Omega \times I_0 \times N_A \times \rho \times x_f}$$

Where $N_A$ is Avogadro's number, $x_f$ is the thickness of the target foil, A is the atomic mass target foil, dΩ is the solid angle of the detector, $I_0$ is the un-attenuated intensity of the alpha particle beam and $I_\theta$ intensity [1]. Also, the differential scattering cross-section is given as

$$\sigma(\theta)d\Omega = \frac{\text{Particles scattered at angle } \theta \text{ in a solid angle } d\Omega \text{ per unit time}}{\text{particles incident per unit area per unit time (incident flux)}}$$

Here, σ (θ) dΩ is area and total cross-section area is given as,

$$\sigma(\theta) = \frac{Z^2 z^2 e^4}{16E^2} cosec^4\left(\frac{\theta}{2}\right)$$

E is the kinetic energy of the incident particle, θ is the angle between the incident and scattered beams, $cosec^4\left(\frac{\theta}{2}\right)$

And is coefficient calculated before the experiment. Rutherford calculated cross-section for scattering during the collision as,

$$\frac{d\sigma}{d\Omega} = \left(\frac{k}{4E}\right)^2 \times \frac{1}{\sin^4\left(\frac{\theta}{2}\right)}$$

Where $k = \frac{zz'e^2}{4\pi\epsilon_0}$ is an appropriate Coulomb factor between the α-particle and the target nucleus with initial kinetic energy E [2]. Pair production only possible with incidence energy $h\nu > 2mc^2 \approx 1.02\ MeV$. The probability of pair production increase with increases in incidence energy while in the case of Compton Effect the phenomena are reverse.

Pair production in varying the field behaves as a tunneling process and the production rate is given by Schwinger formula is given as

$$N = \frac{(eE)^2}{4\pi^3} e^{-\pi\frac{m^2}{eE}},$$

Where m is the mass of the electron, e is a positive elementary charge [3], [4], [5] and this equation is also called Sauter-Schwinger pair production for no perturbative effect.
The cross-section during pair production phenomena is given by asymptotic as [6],

$$\sigma_{e^-e^+} = \frac{\frac{28}{9}(Z^2\alpha^3(\hbar c)^2)}{(m_e c^2)^2}\left[\log\left(\frac{183}{Z^{\frac{1}{3}}}\right) - \frac{2}{7}\right]$$

During the Compton scattering phenomena, the absorption of an incoming photon with four-momentum k and polarization vector Λ with $p_i$ and $p_f$ are the four-momenta of the initial and the final electrons respectively, the differential cross-section for photon polarizations is given as

 

$$\frac{d\sigma_c}{d\Omega_k}\frac{1}{r_0^2} = \left[\frac{\gamma'}{\gamma^2}\frac{1+\cos^2\theta}{2\sqrt{AB}} + \frac{\gamma'^2}{4\gamma^2}\left[\frac{\gamma'}{\gamma A}+\frac{\gamma}{\gamma' B}-\frac{2}{\sqrt{AB}}+\left(1-\sqrt{\frac{A}{B}}\right)\frac{\gamma}{A}(1-p)\sin^2\theta - \left(1-\sqrt{\frac{B}{A}}\right)\frac{\gamma'}{B}(1-p')\sin^2\theta - \frac{p\gamma}{AB}\left\{\frac{2\gamma}{\gamma'}\sqrt{AB}+A\left(\frac{\gamma^2}{\gamma'^2}+\frac{\gamma}{\gamma'}\right)-B\left(\frac{\gamma'}{\gamma}+1\right)-2\sqrt{AB}\right\}\right]\right]G$$

Where $\gamma = \frac{\hbar\omega}{mc^2}$ and $\gamma' = \frac{\hbar\omega'}{mc^2}$ are initial and final energies of photon related to energy-momentum conservation law [7],

$$p+\frac{1}{\gamma} = \frac{\gamma'}{\gamma^2}+\left(\frac{\gamma'}{\gamma}\right)\left\{1-\sqrt{1-p}-\sqrt{1-p'}\cos\theta\right\}, G = \left[1+p\gamma+\frac{p'\gamma'\sqrt{1-p}\cos\theta}{\sqrt{1-p'}}\right]^{-1}\sqrt{1-p'}$$

Also, θ is the scattering angle, and

$$A = \left(1+\frac{p\gamma}{2}\right)^2, B = \left(1-\frac{p'\gamma'}{2}\right)^2, p' = \frac{\omega_p^2}{\omega'^2}, and\ r_0^2 = \left(\frac{e^2}{mc^2}\right)^2$$

## II. RELATED WORK

The scattering of light is directly related to the structure factor on assuming that no internal multiple scattering, this is called Rayleigh–Debye–Gans. The description of optical particle size and morphology analysis is given the characterization of the system [8]. Scattering of α-particles of gold foil measured with Rutherford differential scattering cross-section was experimentally determined as $(7.81 \pm 5.35) \times 10^{-25} cm^2$ which is precious and omitted the errors. The mass formation during the pair production phenomena takes place in the field strength from where scattering takes place. The coupling of the electron-photon vertex is modified in the plasma medium and the three cross-section processes are Compton scattering, electron-positron pair annihilation, and production in a plasma. The probabilities of the formation of masses take place in this cross-sectional area when the interaction takes place for a nuclear reaction. In the case of Bethe–Heitler cross-section the production of lepton pairs take place with accounted the lepton masses and the target mass in the field of a longitudinally polarized nucleon.

The spin structure of the nucleon and asymmetry in longitudinally polarized, these inelastic scattering of elementary particles (leptons, proton, deuterium, and neutron targets) [9]. The dependency of spin, for splitting functions, have been calculated recently, but the demonstrated are still not sufficient for accuracy. The Muon Collider or Neutrino Factory is the Bethe-Heitler lepton-pair-production process,

$$\gamma + A \rightarrow A^{+} + \mu^{+}\mu^{-}$$

Here $\gamma$ have high energy photon interactions with a nucleus A, the conversion of energy into masses take place, and in nucleus field, this go-to particle to produce muons pair. The phenomena of muon-pair production similar to electron-positron pair production [10-15]. Diquark model calculated for a proton with the help of amplitudes of virtual Compton scattering show proton built up by quarks and diquarks [16]. Photons with high energy like 1TeV produced by inverse Compton scattering of the relativistic electrons but more than 1TeV produced by the cascade emission as the argument shows by strong Bethe-Heitler [17]. The quantization of mass in space is described with experimental data, like baryonic interior in terms of ordinary space-time background [18].

## III. METHODOLOGY

The conversion of energy into mass is shown with the help of photoproduction in which $e^+e^-$ pairs on a nucleus with atomic weight A and atomic number Z is given as,

$$\gamma + A \rightarrow e^{+} + e^{-} + A'$$

Similar other phenomena are coherent process, real and virtual photon loop, incoherent process, etc. In this, all phenomena the formation of massive particle take place from photon whose energies are energy some example of reaction for this phenomena are

$$\gamma + A \rightarrow e^{+} + e^{-} + A + \gamma, \gamma + p \rightarrow e^{+} + e^{-} + p,$$

$$\gamma + A \rightarrow \gamma^{*} + A \rightarrow e^{+} + e^{-} + A, \text{ etc.}$$

The creation of electron-positron pair creation in the interaction of a nuclear Coulomb field with a highly intense two-mode laser field, indicate the formation of a particle with various masses [19], [20].

**Description of mass formation during pair-production**

When a photon enters inside the target atom the velocity of the photon goes decreases and mass formation takes place. This formation is due to the opposing the nuclear field and the mass formed in this phenomena is not ordinary masses. Most of the formation in pair production phenomena are masses, properties are related to the properties of the elementary particles. The formed masses are positive and negative mainly for, conservation. The conservation of mass-energy relation help to understand the mechanism of the formation after the separation of the masses from single masses of the photon. The separation of positive and negative masses is due to the difference in the magnetic field of the nucleus and photon. The photon field means electric and magnetic fields together and the nucleus field means the field created or formed due to nucleons present in the nucleus and their phenomena.

 

Some of the masses formation during the phenomena was listed in the table below [1],

Table 1

| Particle | Q | Mass |
|---|---|---|
| e− | −1 | 0.51MeV/c$^2$ |
| μ− | −1 | 105.7MeV/c$^2$ |
| τ− | −1 | 1777MeV/c$^2$ |
| $\nu_e$ | 0 | <0.15eV/c$^2$ |
| $\nu_\mu$ | 0 | <0.15eV/c$^2$ |
| $\nu_\tau$ | 0 | <0.15eV/c$^2$ |
| u | 2/3 | 1.5 − 5 MeV/c$^2$ |
| d | −1/3 | 5 − 9 MeV/c$^2$ |
| s | −1/3 | 80 − 155 MeV/c$^2$ |
| c | 2/3 | 1 − 1.4 GeV/c$^2$ |
| b | −1/3 | 4 − 4.5 GeV/c$^2$ |
| t | 2/3 | 175 − 180 GeV/c$^2$ |

**Conservation of photon mass, positive and negative in pair production**

Let us consider $m_p$ be the mass of the photon, having energy $E_p$ , momentum $P_p$ goes for pair production phenomena. On entering the photon in the field of the nucleus, photons come rest and formed dipole in a strong magnetic field. The formation diploe of photon masses goes divide into two masses due to the difference of field. This means the negative the positive masses go to separate first from the cluster masses due to positive repulsion between photon formation masses and nucleus of and consider atom, and later negative mass. Let $m_p$ be the positive mass and $m_n$ be negative mass formed after dipole, then the conservation masses in this process are given as,

$$m_p \rightarrow m_p + m_n + \gamma \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

In general,

$$m_p \rightarrow \sum_{n=1}^{N} n(m_p + m_n) + \sum_{k=1}^{N'} k m_\gamma \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where n is the numbers of particles formed in the pair production phenomena, k is several gamma rays emitted from during the pair production phenomena.

Also, the conservation of momentum from equation (1) is given as

$$m_p v_p \rightarrow \sum_{n=1}^{N} n(m_p v_p + m_n v_n) + \sum_{k=1}^{N'} k m_\gamma v_\gamma \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where $v_p$ velocity of positive is masses after the formation and separation, $v_n$ is the velocity of negative masses after the formation of mass, and $v_\gamma$ is the velocity of a photon if it formed during the phenomena of formation of mass in the nuclear field.

Also, the conservation of energy from equation (1) is given as

$$E_p \rightarrow \sum_{n=1}^{N} n(E_p + E_n) + \sum_{k=1}^{N'} k E_{p'} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where $E_p$ the energy of positive is masses after the formation and separation, $E_n$ is the energy of negative masses after the formation of mass, and $E_{p'}$ is the energy of photon if it formed during the phenomena of formation of mass in the nuclear field.

The formation of the positive, negative, and energy take place at an instant, while the escaping time from the nucleus is different. This difference times is due to the non-homogeneous field present in an atom, the non-homogenous field presence inside the atom is due to the revolution of the electron, internal mechanism of nucleons, and incidence field of the photon.

**Field involved in pair-production**

There are three parameters present in this phenomenon that manipulate the non-homogenous, among these three two, are from atoms and one from the external sources. The field in an atom is due to electron presence in the orbit of electron and nucleon present in the nucleus. Let $F_e$ is the field generated by electron around it, while $F_N$ in the field generated around the nucleus, while $F_p$ in the field generated by photons around it.

Since the field generated by them are different from each other and one field disturbed another field so, the resultant field is non-homogenous. Therefore, the resultant non-homogenous field when a photon of energy $E_P$ enter inside an atom have suitable energy for pair production is given as,

$$F = F_e + F_N + F_p \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

In general, for the multi-electron system, we have from (5),

$$F = \sum_{n}^{N} nF_e + \sum_{n}^{N'} nF_n + \sum_{n}^{N''} nF_p + F_p \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where, in equation (6) first term n is the number of electrons present in considering atom for pair production, in second term n represent the number of neutrons, and in third term n represent several protons.

## IV. RESULTS AND DISCUSSION

The equation (2), (3), and (4), show the mass, momentum, and energy conservation formed during pair production or nuclear reaction in which photon is converted into masses. This phenomena of formation of masses take place in the field of the nucleus of an atom with a very short time approximate $10^{-19} sec$ . After the formation of the mass separation into positive and negative parts in a strong field due to nucleons present in the nucleus. The masses formation doesn't have ordinary mass properties because it doesn't have nucleons, instead of these nucleons, it has bosons, fermions, and D-particles as these particles are the constituent of the electron. The formation of mass in such phenomena is take in a non-homogeneous field because of the nucleons present in the nucleus spinning throughout the time.

The field in which the formation of masses take place is given by equation (6), which is the resultant field formed by electron and nucleons (proton and neutron). This field resists the photon and decreases the velocity of a photon when enter into the atom and the mass of the photon goes heavier and heavier as it closure to a strong field.

Hence the formation of masses in pair production phenomena is due to field reduced velocity of the photon. The formation of mass is may composed of fermion, bosons, and D-particles which is different from the ordinary masses.

## V. CONCLUSION AND FUTURE SCOPE

The law of consideration of mass, energy, and momentum during the phenomena of formation of mass in pair production is verified by the above equations. The formed mass is due to the nuclear field but masses formed don't contain a nucleus. The nature of mass formed during this phenomena is different from ordinary masses and may compose of fermions, bosons, and D-particles. Therefore the resultant particle formed during the pair production is either fermion or bosons. The major role for the formation of such masses is due to the field interaction of photon and resultant nucleus. The formed masses in such ways varying from minimum to maximum because the speed of photons goes decrease as it approaches from weak field to strong field. Hence the masses formation in this phenomena varies with the energy of the photon and itself with the energy and speed in the nucleus field. The mass varying with speed play an important role in the formation of a resultant mass during pair production and formation of particles or photon during this phenomena.

## ACKNOWLEDGMENT

I would like to thanks all the members of Innovative Ghar Nepal, Motivation Funnel, and Robotic Academy of Nepal for kindly help during this research work.

## REFERENCES

[1] E. P. Wang, "Rutherford Scattering of α-Particles", *Department of Physics, MIT*, pp.**1-10**, December **8**, **2004**.
[2] T. H. Kim, "Rutherford scattering of α-particles from gold foils", *Department of Physics, MIT*, pp.**1-3**, October **16**, **2008**.
[3] J. S. Schwinger, "On gauge invariance and vacuum polarization", Physical Review, **82,** pp. **664–679**, **1951**.
[4] F. Sauter. "Uber das Verhalten eines Elektrons im homogenen elektrischen Feld nach der relativistischen Theorie Diracs", *Zeitschrift fur Physics*, Vol. **69,** pp.**742– 764**, **1931**.
[5] W. Heisenberg and H. Euler, "Consequences of Dirac's theory of positrons", *Zeitschrift fur Physics*, Vol. **98,** pp.**714–732**, **1936**.
[6] C.W. Akerlof, "Electron-Positron Pair Production", *Department of Physics, University of Michigan*, pp.**1-2**, September **24**, **2012**.
[7] V. Krishan, "Compton Scattering, Pair Annihilation and Pair Production in a Plasma", *Highly Energetic Physical Processes and Mechanisms for Emission from Astrophysical Plasmas IAU Symposium*, Vol. **195**, pp.**1-5**, **1999**.
[8] C. M. Sorensen, "Light Scattering by Fractal Aggregates: A Review", *Aerosol Science and Technology*, Vol. **35**, pp.**648–687, 2001**.
[9] C.W. D Jager et al., "12th International Symposium on High Energy Spin Physics (SPIN '96)", *World Scientific,* Singapore, pp.**44**, **1997**.
[10] M.M. Alsharoa et al., "Recent progress in neutrino factory and muon collider research within the Muon Collaboration", *Physics Review Accelerator Beams,* Vol. **6**, pp.**1-10**, **2003**.
[11] R.J. Abrams et al., "International Design Study for a Neutrino Factory: Interim Design Report" arxiv, pp.**1-5,** December, **2011**.
[12] H. Bethe and W. Heitler, "On the Stopping of Fast Particles and on the Creation of Positive Electrons", *Proceedings of Royal Society London A,* Vol.**146**, Issue. **83,** pp.**23-45, 1934**,
[13] L.C. Maximon, "Simple Analytic Expressions for the Total Born Approximation Cross Section for Pair Production in a Coulomb Field", Journal of Research National Bureau of Standard, Vol. **72B**, Issue.**79**, pp.**12-30**, **1968**.
[14] J.W. Motz, H.A. Olsen and H.W. Koch, "Pair production by photons", *Review Modern Physics*, Vol.**41**, pp.**581-585, 1969.**
[15] A. Mastichiadis, R.J. Protheroe, and J.G. Kirk, "Spectral and temporal signatures of ultrarelativistic protons in compact sources I. Effects of Bethe-Heitler pair production", Astronomy and Astrophysics, Vol. **433**, pp.**765-777**, **2005.**
[16] P. Kroll, M. Schurmann, and P. A. M. Guichon, "Virtual Compton Scattering off Protons at Moderately Large Momentum Transfer", arxiv, pp.3-10, **2008**.
[17] Y. G. Zheng, C. Y. Yang, and S. J. Kang, "Bethe-Heitler cascades as a plausible origin of hard spectra in distant TeV blazars", Astronomy & Astrophysics, Vol. **585**, Issue.**A8**, pp.**1**-7, **2016**.
[18] P. Z. Kowski, "Elementary particles, the concept of mass, and emergent spacetime", Journal of Physics: Conference Series, **USA**, pp.**1-2**, **2015**.
[19] S. Augustin, and C. Muller, "Nonlinear Bethe–Heitler Pair Creation in an Intense Two-Mode Laser Field", *Journal of Physics: Conference Series*, **USA**, pp.**2-10**, **2014**.
[20] M. Heller, O. Tomalak, and M. Vanderhaeghen, "Soft-photon corrections to the Bethe-Heitler process in the $\gamma p \rightarrow l^+ l^- p$ reaction", *Physical Review D*, Vol. **97**, pp.**1-9**, **2018**.