A New Definition of an Electronvolt

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A typical definition of an electronvolt is expressed by professor Serway in his physics textbook: "A unit of energy commonly used in atomic and nuclear physics is the electron volt, which is defined as *the energy that an electron (or proton) gains when passing through a potential difference of magnitude of 1 V.*" [1] The value of this unit was determined experimentally to be 1.602 176 634x10^{-19} Joules.

All definitions of the electronvolt, including the one above, give the impression that an electronvolt represent all the energy an electron acquires when accelerated by passing through an electric field. This paper will show that the energy gained by an accelerated electron is greater than the value of an electronvolt. Thus, a new and a more precise definition of the electronvolt is needed.

This paper will introduce a new, more accurate and a more intuitive definition, where "*An electronvolt represents* internal energy *of the mass that an electron acquires as it travels through an electric field generated by the potential difference of 1 volt.*"

When subtracting one internal energy from another, the difference must also be internal energy

According to physics textbooks, the kinetic energy of a slow moving electron is found from equation

$$m_0v^2/2 = mc^2 - m_0c^2 \quad (1)$$

or

$$KE = mc^2 - m_0c^2 \quad (2)$$

where mc^2 is the internal energy of the *accelerated electron* and m_0c^2 is the internal energy of the same *electron at rest.* [2]

What is on the right-hand side of the equation must also be on the left-hand side. On the right-hand side of the last equation, there are two internal energies. When we subtract one internal energy from the other, the difference must also be internal energy. However, in the above equation, the subtraction of two internal energies yields kinetic energy. It is like subtracting an orange from two oranges, where the result of subtraction is an apple instead of an orange.

Subtracting the internal rest energy of an electron before acceleration takes place from the internal energy of an electron after it passes through an electric field must yield the *internal energy* of the stuff the electron collects while passing through an electric field.

Because the kinetic energy of an electron (with the rest mass m_0) accelerated by 1 volt potential difference is equal to the energy value of an electronvolt, the above equation yields:

$$eV = mc^2 - m_0c^2 \quad (3)$$

The mass m in the term mc^2 indicates the mass of an accelerated electron, which is composed of the original mass of the electron m_0 plus the newly acquired mass m_a. An electronvolt is then

$$eV = (m_0+m_a)c^2 - m_0c^2 \quad (4)$$

or

$$eV = m_ac^2 \quad (5)$$

An electronvolt is equal to the internal energy of the mass difference of the total mass of an accelerated electron and its rest mass. This leads to a new and more intuitive understanding of the nature of an electronvolt.

New definition of an electronvolt

The term mc^2 (mass times the speed of light squared) represents the internal (or stored) energy of an object or a particle of mass m. This must be the case with the equation $eV=m_ac^2$. Hence:

An electronvolt represents internal energy of the mass that an electron acquires as it travels through an electric field generated by the potential difference of 1 volt.

More specifically, *an electronvolt represents* 1.602 176 634x10^{-19} *J of work the extra acquired mass of an electron can perform after the electron passes through the potential difference of 1 volt.*

Mass associated with an electronvolt

Equation $eV=m_ac^2$ states that an electronvolt is related to a certain mass m_a acquired by an accelerated electron. Because an eV is a known value, 1.602 176 634x10^{-19} J, the mass that is responsible for the amount of work an electronvolt can perform is:

$$m_a = m_{eV} = eV/c^2 \quad (6)$$

which yields

$$m_{eV} = 1.782\ 638\ 137\text{x}10^{-36} \text{ kg}$$

By gaining extra mass m_{eV} and internal energy $m_{eV}c^2$, along with kinetic energy, an accelerated electron with the rest mass m_0 also gains the speed v and the kinetic energy $m_0v^2/2$. Because the newly gained mass m_{eV} and the rest mass of the electron m_0 are part of one particle, *both traveling at the same speed*, the internal energy of the mass m_{eV} equals the kinetic energy of the electron with the rest mass m_0. In other words,

$$eV = m_{eV}c^2 = m_0v^2/2 \quad (7)$$

Because an electron gains an equal amount of energy for every applied volt, and because this energy represents the internal energy of the collected mass, *an electron passing through an electric field generated by potential difference of 1 V must gain the same amount of mass for every volt of applied potential difference*.

Energy, internal or kinetic, is the function of mass and speed. Mass m is the constituent of every energy equation. Thus, energy cannot exist without mass. So it must be with the energy of an accelerated electron.

Because an electron gains an equal amount of energy for every applied volt, it must also gain an equal amount of mass.

While this comes directly from established theories and the way the mass of an accelerated particle is calculated in contemporary physics, no textbook ever states this in these terms. Yet the acquired *mass and speed* are the hallmarks of all particle accelerations and the source of energy of all accelerated particles.

An eV does not represent total energy acquired by an electron accelerated by 1 V

Let us find the speed of an electron accelerated by a potential difference of 1 volt. According to NIST-CODATA 2018 [3], the values of the following three constants are:

Speed of light	$c = 299{,}792{,}458$ m/s
Electronsvolt	$eV = 1.602\ 176\ 634 \times 10^{-19}$ J
Electron mass at rest	$m_O = 9.109\ 383\ 701 \times 10^{-31}$ kg

The speed v of an electron accelerated by 1 volt can be found from the energy equation of the moving electron [2]:

$$mc^2 = m_0c^2 + m_0v^2/2 \tag{8}$$

which yields

$$m_0v^2/2 = mc^2 - m_0c2 \tag{9}$$

Since

$$mc^2 - m_0c^2 = eV, \tag{10}$$

then

$$eV = m_0v^2/2. \tag{11}$$

or

$$v = \sqrt{2eV/m_0} \tag{12}$$

The speed v is then: $v = 593{,}096$ m/s

Because the electron starts from zero speed, the total kinetic energy that an electron gains during its passage through an electric field, KE_G, must equal to the sum of the kinetic energy of the electron with its original rest mass m_0 plus the kinetic energy of the newly acquired mass m_a, both moving at the newly acquired speed v. Or,

$$KE_G = KE_0 + KE_{m_a} \tag{13}$$

which yields

$$KE_G = m_0v^2/2 + m_av^2/2 \tag{14}$$

or

$$KE_G = (m_0 + m_a)v^2/2 \tag{15}$$

Hence,

$$KE_G = 1.602\ \underline{179}\ 837 \times 10^{-19}\ \text{J}$$

The gained kinetic energy is greater than the value of an *eV*. The difference is equal to $0.000\ \underline{003} \times 10^{-19}$ J, which is the kinetic energy of the mass acquired KE_a by the accelerated electron.

The energy gained, E_G, by an electron accelerated by 1 V potential difference is equal to the sum of the internal energy of the newly acquired mass m_ac^2 plus the gained kinetic energy KE_G. That is,

$$E_G = eV + KE_G \tag{16}$$

or

$$E_G = m_ac^2 + (m_0 + m_a)v^2/2 \tag{17}$$

which yields

$$E_G = 3.204\ 377\ 918 \times 10^{-19}$$

Both the gained kinetic energy, KE_G, and the gained energy, E_G,of an electron after passing through the potential difference of 1 V are greater than the value of an electronvolt, $eV = 1.602\ \underline{176}\ 634 \times 10^{-19}$ J, confirming the conclusion that an *eV does not represent all of the energy gained by an accelerated electron* and invalidates its current definitions.

The two equations for the electronvolt give the same numerical value, that is,

$$eV = m_ac^2 = m_0v^2/2 = 1.602\ 176\ 634 \times 10^{-19}\ \text{J} \tag{18}$$

Equation $eV = m_0v^2/2$ tells us that the gained energy acquired by an electron comes from the newly gained speed v, and is a *part* of the total kinetic energy the electron gains during acceleration.

Equation $eV = m_ac^2$ tells us that the gained energy comes from the newly acquired mass, m_a.

Hence, the gained energy, *eV*, is the result of the gained mass or the gained speed, as the electron passes through the electric field generated by the potential difference of 1 V.

Importance of the new definition of the electronvolt

The new definition and the new equation $eV = m_ac^2$ show that when an electron is accelerated by passing through an electric field it gains speed and mass at the same time. In other words, the electron gains mass and speed through the interaction with the electric field and the electrons that generate this field.

Therefore, the new definition contradicts Einstein's theory that the increase in the speed v alone results in the increase in the mass of an electron, as expressed by equation $m = m_0/\sqrt{1 - v^2/c^2}$, where the mass of an electron in motion is equal to its mass at rest divided by the square root factor, and where the new generated speed v is the only cause of the increase in its mass.

References

[1] Raymond A. Serway, Physics for Scientists & Engineers, 3rd Edition, Saunders College Publishers, Chicago, 1990, p. 681

[2] Peter J. Nolan, *Fundamentals of College Physics*, Wm. C. Brown Publishers, Dubuque, IA, 2nd Edition, p. 879, 1995.

[3] http://physics.nist.gov/cgi-bin/cuu/Value?me|search_for=electron volt