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Application of New Mass-Energy Concept in Computation of Q - Values of Nuclear Fission and Fusion Reactions

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ABSTRACT
In the past century, it is crucial to note that the Einstein's mass-energy theory has been continuously evolving in energies computations of massive particles. However this research work, Present the computational analysis and graphical difference between Einstein's relativistic theory (mc^2), Bahjat mass-energy relation (mbc) and new mass-energy concept (mvc) when employed in calculations of the Q-values of nuclear fission and fusion reactions. The new mass-energy concept with energy converting factor vc, where v = 1.8 x $10^8 ms^{-1}$ and Bahjat mass-energy relation with energy conversion bc, where b = 0.6× $10^8 ms^{-s}$ are to be applied on massive particle rather than c^2 which would have been applied perfectly on Photon or massless particles. The computational analysis depicted that, the new mass-energy concept (mvc) used in nuclear reactions fail below the predictions of Einstein's relativistic mass-energy theory mc^2. Additionally, these results suppress the Bahjat mass-energy relation mbc due to the difference in the energy conversion factor. In this regard, the new mass-energy concept mvc is recommended in studying atomic structures and any area related to massive particle that employed Einstein's relativistic mass-energy theory.

Keywords:
Q-Value,
Nuclear Reaction,
Fission,
Fusion,
Blackbody,
Planks Transcendental equation,
Einstein (mc^2),
Bahjat (mbc).

INTRODUCTION

The concept of relativistic mass-energy relation has undergo continuous evolution over the past century, initially Einstein's theory posited that matter and fields are two distinct realities with matter representing mass and field representing energy. However, the theory also suggests that the majority of energy is contained within matter while the surrounding field represent smaller amount of energy. Mass –energy theory shows that we can no longer differentiate between field and matter (Leong and Chin, 2005). The concept of relativistic mass, which has been questioned by particle physicists, suggests that the increase in a particle's energy or mass with velocity may result from changes in the particle's internal structure (Jammer, 2000). The relativistic mass-energy relationship has also been criticized for overestimating nuclear energy, prompting the suggestion of a new conversion factor, different from c^2 for calculating nuclear energy (Bahjat, 2008). The energy dissipation and stopping power of charged particles as they traverse through matter have been of significant interest for many years, given their broad applicability in nuclear physics (Ahlan and Khalda, 2022).

Theory

The theory of Einstein relativistic mass-energy from Newtonian mechanics:

The theory was derived from Newtonian mechanics (Ammalai, 2022). Matter are constituent of mass attributed with volume.. Light is massless and volume less but characterized by a speed of $3 \times 10^8 ms^{-1}$, beyond the speed of matter (Ammalai and Antonio, 2023) The Einstein mass-energy equivalence demonstrates relativistic energy. In the theory of special relativity (Ammalai, 2023a; Ammalai, 2023b; Ammalai, 2023c). The relativistic momentum is concerned with the motion of a particle whose velocity approaches the speed of light (Perez and Ribisi, 2022)

Rest Mass-energy equivalence($E = m_0c^2$)

Newton's second law of motion depicted the following

$$F = \frac{dp}{dt} = \frac{d(mv)}{dt} = m\frac{dv}{dt} + v\frac{dv}{dt} \quad (1)$$

Kinetic energy is equal to work done

$$dK = dW = Fds \quad (2)$$

Equation (1) was taken into (2)

$$dK = Fds = \left(m\frac{dv}{dt} + v\frac{dv}{dt}\right)ds \quad (3)$$

Derivative of equation (3) was taken with respect to time, t as

$$dK = Fds = m\frac{ds}{dt}dv + v\frac{ds}{dt}dv \quad (4)$$

$as\ ,\frac{ds}{dt} =$

Considering that, the term c^2dm allows the hypothesis of variable mass as it actually occurs at high speed. Also, c^2dm is equal to the kinetic energy.

$$dK = mvdv + v^2dm \quad (5)$$

where, dK = Kinetic energy

$$c^2dm = mvdv + v^2dm \quad (6)$$

Making $\frac{dm}{m}$, the subject of relation in equation (6), the following equation results:

$$\frac{dm}{m} = \frac{v}{c^2-v^2}dv \quad (7)$$

Integrating equation (7) we obtain:

$$\int_{m_0}^{m}\frac{dm}{m} = \int_0^v \frac{v}{c^2-v^2}dv \quad (8)$$

$$[ln(m)]_{m_0}^{m} = -\frac{1}{2}[(c^2-v^2)]_0^v \quad (9)$$

$$ln\, m - ln\, m_0 = -\frac{1}{2}(c^2-v^2) + \frac{1}{2}lnc^2 \quad (10)$$

$$ln\frac{m}{m_0} = \frac{1}{2}ln\frac{c^2}{c^2-v^2} \quad (11)$$

$$\frac{m}{m_0} = \sqrt{\frac{c^2}{c^2-v^2}} \quad (12)$$

$$m = m_o\left(\frac{1}{1-\frac{v^2}{c^2}}\right)^{-1/2} \quad (13)$$

where m is the relativistic mass of the particle, m_o is the rest mass of the particle, v is the velocity of the particle and c is the speed of light (Ammalai, 2023b).

The relativistic momentum

$$P = mv \quad (14)$$

Equation (13) were substituted into equation (14)

$$P = m_ov\left(\frac{1}{1-\frac{v^2}{c^2}}\right)^{-1/2} \quad (15)$$

Since the relativistic energy was given as ($E = mc^2$) Equation (15) becomes:

$$E = m_0c^2\left(\frac{1}{1-\frac{v^2}{c^2}}\right)^{-1/2} \quad (16)$$

The relationship between the relativistic energy and the relativistic momentum becomes:

$$E^2 = m_0^2c^4\left(\frac{1}{1-\frac{v^2}{c^2}}\right)^{-1} \quad (17)$$

$$E^2 = \frac{m_0^2c^2(v^2-v^2+c^2)}{1-\frac{v^2}{c^2}} \quad (18)$$

$$E^2 = \frac{m_0^2c^2v^2-m_0^2c^2v^2+m_0^2c^4}{1-\frac{v^2}{c^2}} \quad (19)$$

$$E^2 = \left(m_ov\left(\frac{1}{1-\frac{v^2}{c^2}}\right)^{-1/2}\right)^2 c^2 + \frac{m_0^2c^2(c^2-v^2)}{\frac{c^2-v^2}{c^2}} \quad (20)$$

From the above expression of equation (20), the energy-momentum relation is obtained

$$E^2 = P^2c^2 + m_0^2c^4 \quad (21)$$

If particle is at rest, then $P = 0$ thus, the rest energy is becomes $E = m_oc^2$.

The Relativistic Mass-energy equivalence($E = mc^2$) was derived by employing equation (13) above by squaring both sides to obtain

$$m^2c^2 - m^2v^2 = m_0^2c^2 \quad (22)$$

Where, $m_0^2c^2$ is the rest mass energy of the particle

By differentiating the equation with respect to time we obtain

$$2mc^2\frac{dm}{dt} - 2mv\frac{d(mv)}{dt} = 0 \quad (23)$$

From equation (23), the following result is obtained:

$$c^2\frac{dm}{dt} = v\frac{d(mv)}{dt} \quad (24)$$

$$\frac{dE}{dt} = Fv = v\frac{d(mv)}{dt} = c^2\frac{dm}{dt} \quad (25)$$

$$dE = c^2dm \quad (26)$$

The kinetic energy of the particle K is given as:

$$\int_0^K dE = \int_{m_0}^{m} c^2dm \quad (27)$$

$$K = c^2(m - m_0) \quad (28)$$

The total energy of the particle is the sum of its kinetic energy and the rest mass-energy m_0c^2

Total Energy (E) = Kinetic Energy (K) + Rest Mass-Energy m_0c^2

$$E = c^2(m - m_0) + m_0c^2 \quad (29)$$

Hence, $\mathrm{E = mc^2}$ (Ammalai, 2023c) (30)

With energy conversion factor, $c^2 = 9 \times 10^{16}m^2/s^2$, where $c = 3 \times 10^8 m/s$ and would have been perfectly applied on massless particle or photon (Bahjat, 2008; Ngari *et al,* 2023)

Bahjat Mass-Energy concept(mbc)

Bahjat reported that, the Einstein's relativistic mass–energy theory$E = mc^2$ overestimates the nuclear energy. Therefore, the relativistic formula was suggested with a new conversion factor (b) other than $c^2$to help perfect the calculation of nuclear energy (Bahjat, 2008)

The new energy converting factor by Bahjat was expressed as $bc\ instead\ of c^2$ and the Einstein relativistic mass-energy $E = mc^2$ theory was transformed to

$E = mbc$, with energy converting factor $bc = 1.8 \times 10^{16} m^2/s^2$, where b is obtained as $0.6 \times 10^8 m/s$ and c remained the speed of light (Bahjat, 2008)

New mass-energy concept (mvc)

The new mass-energy concept $\mathrm{E = mvc}$ with energy converting factor of $\mathrm{vc} = 5.4 \times 10^{16} \mathrm{m}^2/\mathrm{s}^2$, where $\mathrm{v} = 1.8 \times 10^8 \mathrm{m/s}$. The method involved, Plank radiation law weins displacement law, Energy frequency relation, transcendental equation and computer program which employed Microsoft excel and origin 8.5 (Ngari *et al.,* 2024)

The result has shown a significance difference compared to Bahjat results (mbc) in terms of massive particle (Ngari *et al.*, 2023)

Nuclear Reaction

Following this discovery, the ancient dream of alchemist was again revived in the minds of scientist regarding the possibility of transforming one element into another from basic knowledge of atomic structure, it is clear that if the number of proton or neutron can be change in the nucleus, then it would be possible to bring about the transformation of the nucleus. If the proton number Z, is changed, then it is possible to change from one element into another. On the other hand, if the neutron number N is changed, then one isotope of an element will be transformed into another isotope of the same element (Ghoshal, 2000)

Nuclear fission reaction

This is the nuclear reaction in which heavy nucleus absorbs heat or is bombarded by high energy particle and produces energy by emitting daughter nuclei.

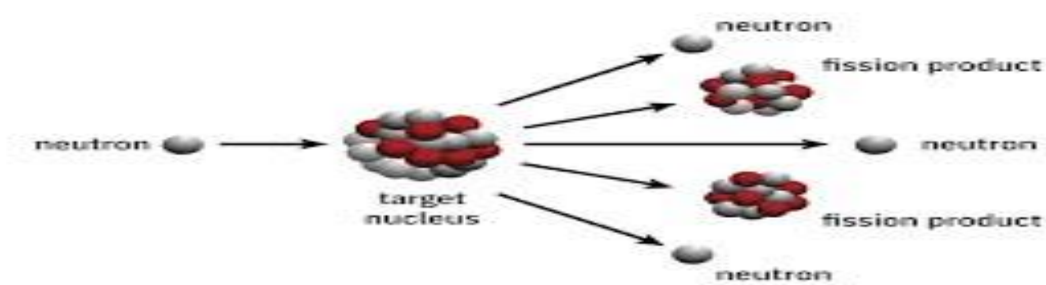

Figure 1: Nuclear fission Reaction (Nuclear Power.com, 2024)

Figure 1. illustrates the nuclear fission reaction, in which the nucleus of the parent nuclei (target) was fired by fast moving neutron to produced two daughter nuclei (fission product) and three neutrons accompanied with the release of energy.

Nuclear fusion Reaction:

This is a nuclear process whereby light nuclei comes together to form a heavy nuclei with release of huge amount of energy

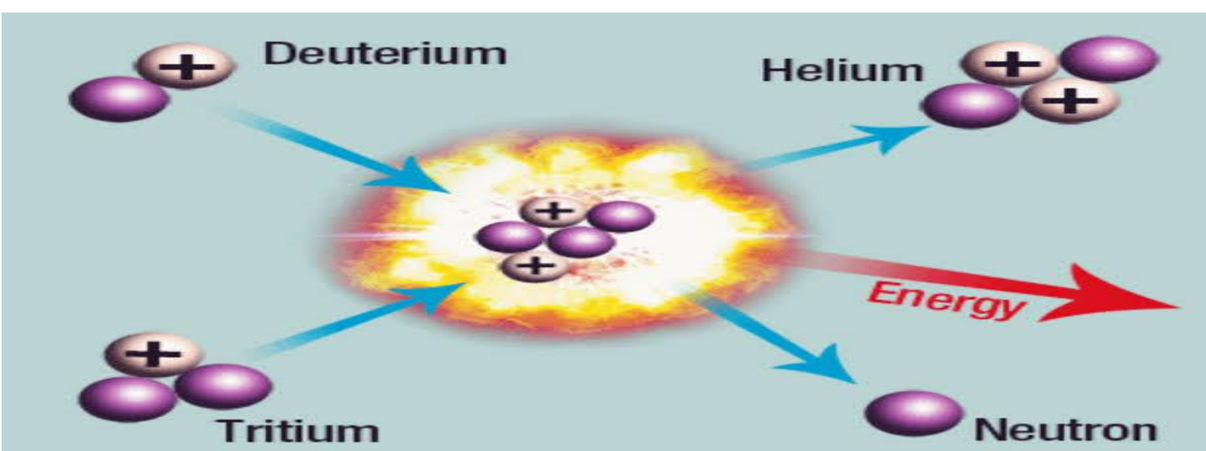

Figure 2: Nuclear fusion Reaction (Nuclear Power.com, 2024)

Figure 2 shows the fusion reaction of two light nuclei namely, deuterium and tritium and produced helium and a neutron accompanied the released of huge amount of energy.
$${}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n + Energy$$

Q-value of nuclear reactions

The first notable formula for determining the binding energy of the nucleus was derived by Von Weizsäcker and it is based on the basic premise that the nucleus may be considered as a droplet of incompressible matter. This droplet is kept together by the strong nuclear force, a basic short-range interaction between nucleons, which is assumed to be both spin-independent and charge-independent (Benzaid *et al,* 2020). The energy required to breakdown an atomic nucleus into its constituent nucleons is referred to as Nuclear Binding Energy. The cumulative mass of these individual nucleons often surpasses the mass of the atomic nucleus they create. This disparity in mass, known as the Mass Defect, corresponds to the energy needed to bind the nucleons together against the proton-proton repulsion, as explained by Einstein's classic mass-energy equivalence relation:

$$E = \Delta mc^2 \quad (31)$$

Where Δm is the mass difference, which can be used to calculate the binding energy in terms of the atomic number (Z), neutron number (N), and the corresponding masses of protons (m_p) and neutrons (m_n), in addition to the mass of the nucleus (m_{ucleus})

$$E_B = \left(Zm_p + Nm_n - m_{nucleus}\right)c^2 \quad (32)$$

The energy released in a nuclear reaction is termed its Q-value, which relies on the masses of the reactants and products. The Q-value can be either positive or negative: a positive Q-value implies an exothermic process, whereas a negative Q-value suggests an endothermic reaction. Mathematically, the Q-value is represented as:

$$Q = (Mass of the\ reactant - Mass\ of the\ Product)c^2$$ (Benzaid *et al,* 2020) (33)

MATERIALS AND METHODS

Methodology

The method employed Einstein's relativistic Mass-Energy conversion factor c^2, Bahjat Mass-Energy conversion factor bc and New Mass-Energy conversion factor vc in to Q-value empirical formula as given in equation (33) to transform the following equation (34) and (35) for computation and comparing of energies of Nuclear fission and fusion reactions using computer Program which employed Microsoft Excel and origin 8.5

$$Q = (Mass of the\ reactant - Mass\ of the\ Product)\text{bc} \quad (34)$$

$$Q = (Mass of the\ reactant - Mass\ of the\ Product)\text{vc} \quad (35)$$

RESULTS AND DISCUSSION

Table 1: The value of unified atomic mass unit (u) in mega electron volt (MeV) using Einstein's relativistic mass-energy relation, Bahjat mass-energy relation and the new mass-energy concept

Unified atomic mass unit (u)	Einstein $E = mc^2\ (MeV)$	Bahjat $E = mbc\ (MeV)$	New Mass-energy concept $E = mvc\ (MeV)$
1u	931.5	187.607	560.43

Table shows the energy equivalent of a unit mass from unified atomic mass unit (u) to Mega electron volt using Einstein's relativistic mass-energy relation, Bahjat mass-energy relation and the new mass-energy concept. Observation shows that the Bahjat mass-energy (mbc) is underestimated compared to Einstain's relativistic mass-energy theory (mc^2) and new mass-energy concept (mvc) and this is as result of tts energy converting factor (b) which was found less with a value of $0.6 \times 10^8 m/s$ Compared to Einstein $3 \times 10^8 m/s$ and the new mass-energy concept $1.8 \times 10^8 m/s$ (Ngari *et al.,* 2023).

Table 2: Q- Value of Nuclear Fission Reaction

S/N	Nuclear Fission Reactions	$Q = \Delta mc^2$ (MeV)	$Q = \Delta mbc$ (MeV)	$Q = \Delta mvc$ (MeV)
1	${}^{17}_{8}O + {}^{1}_{1}H \rightarrow {}^{14}_{7}N + {}^{4}_{2}He$	1.19134	0.23995	0.716761
2	${}^{10}_{5}B + {}^{1}_{0}n \rightarrow {}^{7}_{3}Li + {}^{4}_{2}He$	2.98984	0.5618	1.798815
3	${}^{190}_{78}Pt \rightarrow {}^{186}_{76}OS + {}^{4}_{2}He$	3.25000	0.65456	1.955338
4	${}^{6}_{3}Li + {}^{1}_{0}n \rightarrow {}^{3}_{1}H + {}^{4}_{2}He$	4.78325	0.96336	2.877807
5	${}^{152}_{64}Gd + {}^{1}_{0}n \rightarrow {}^{149}_{62}Sm + {}^{4}_{2}He$	8.07611	1.62655	4.858931
6	${}^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$	10.4608	2,10683	6.293662
7	${}^{35}_{17}CL + 2{}^{1}_{0}n \rightarrow {}^{36}_{16}S + {}^{1}_{1}H$	10.5045	2.11564	6.319954
8	${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{232}_{90}Th + {}^{4}_{2}He$	11.1175	2.23909	6.688761
9	${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{81}_{35}Br + {}^{139}_{57}La + 16{}^{1}_{0}n$	85.0543	17.130	51.17228

10	${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{138}_{56}Ba + {}^{86}_{36}Kr + 12{}^{1}_{0}n$	123.663	24.906	74.40092
11	${}^{234}_{92}U + {}^{1}_{0}n \rightarrow {}^{136}_{54}Xe + {}^{88}_{38}Sr + 11{}^{1}_{0}n$	131.772	26.5393	79.27964
12	${}^{244}_{94}Pu + {}^{1}_{0}n \rightarrow {}^{136}_{54}Xe + {}^{96}_{40}Zr + 13{}^{1}_{0}n$	134.869	27.1631	81.14292

Table 3: of Q- Value of Nuclear Fusion Reaction

S/N	Nuclear Fusion Reactions	$Q = \Delta mc^2$ (MeV)	$Q = \Delta mbc$ (MeV)	$Q = \Delta mvc$ (MeV)
1	${}^{14}_{7}N + {}^{4}_{2}He \rightarrow {}^{17}_{8}O + {}^{1}_{1}H$	1.19232	0.24	0.71735
2	${}^{9}_{4}Be + {}^{1}_{1}H \rightarrow {}^{6}_{3}Li + {}^{4}_{2}He$	2.12563	0.42812	1.278869
3	${}^{209}_{83}Bi + {}^{1}_{1}H \rightarrow {}^{209}_{84}Po + {}^{1}_{0}n$	2.67619	0.53899	1.61011
4	${}^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He + {}^{1}_{0}n$	3.26957	0.65851	1.967112
5	${}^{97}_{42}Mo + {}^{2}_{1}H \rightarrow {}^{98}_{43}Tc + {}^{1}_{0}n$	3.95142	0.79583	2.377342
6	${}^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{3}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H}$	4.03339	0.81234	2.426659
7	${}^{75}_{33}\mathrm{As} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{78}_{35}\mathrm{Br} + {}^{1}_{0}\mathrm{n}$	5.15213	1.03765	3.09974
8	${}^{2}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{H}$	5.47536	1.10274	3.294209
9	${}^{9}_{4}\mathrm{Be} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{12}_{6}\mathrm{C} + {}^{1}_{0}\mathrm{n}$	5.70078	1.14815	3.429832
10	${}^{27}_{13}\mathrm{AL} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{31}_{15}\mathrm{P}$	9.66804	1.94717	5.816704
11	${}^{12}_{6}\mathrm{C} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{14}_{7}\mathrm{N}$	10.2723	2.06893	6.180252
12	${}^{3}_{2}\mathrm{He} + {}^{3}_{2}\mathrm{He} \rightarrow {}^{4}_{2}\mathrm{He} + 2{}^{1}_{1}\mathrm{H}$	12.8594	2.58991	7.736762
13	${}^{125}_{52}\mathrm{Te} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{127}_{53}\mathrm{I}$	13.0959	2.63766	7.87905
14	${}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$	17.5895	3.54258	10.58259
15	${}^{2}_{1}\mathrm{H} + {}^{3}_{2}\mathrm{He} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{1}\mathrm{H}$	18.3533	3.69642	11.04213

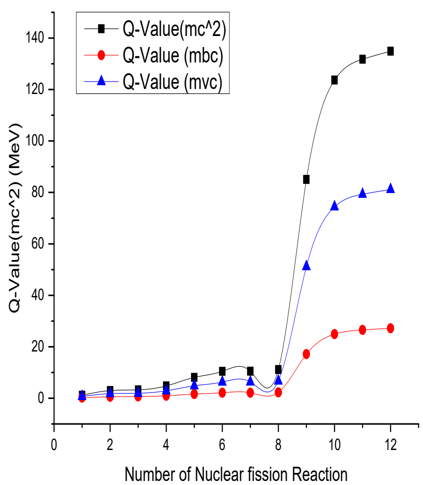

Figure 3: Graph of Fission Reaction

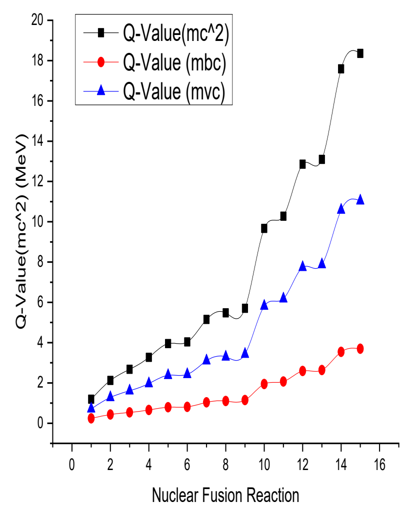

Figure 4: Graph of Fusion Reaction

Discussion

Figure 3 and 4 compares the results of Einstein (mc^2), Bahjat (mbc) and the new mass-energy concept (mvc) in calculation of Q-values of nuclear fission and fusion reactions. The Difference in energy of fission reaction shows that, heavy nuclei release more energy due to it excess neutron content in nuclear reactions compared medium and light nuclei in the reactions. Observation also shows that Einstein mass-energy (mc^2) is overestimated due to it energy converting component c^2 which is only attributed to massless particles or photon while the Bahjat mass-energy relation (mbc) is underestimated and the new mass-energy concept (mvc) rides between the Einstein and Bahjat mass-energy theories, also in Figure 4, the trend shows that, the fusion nuclear reactions are arranged in order of increase in energy. Observation also shows that Einstein mass-energy (mc^2) is overestimated, same as in the case of fission reactions and the new mass-energy concept (mvc) also ride between Einstein mass-energy theory and Bahjat mass-energy relation. Hence, Bahjat mass-energy (mbc) underestimates the study.

CONCLUSION

The Q-value results obtained using the new mass-energy concept fall below the prediction of Einstein relativistic theory, as they don't solely rely on speed of light. Additionally, these results surpass the Bahjat mass-energy relation due to difference in the energy conversion factor. It is therefore crucial to look into the new relativistic mass-energy concept in studying the interpretation of nuclear structure and the energy of particles that are relatively massive. Since Einstein's relativistic mass-energy theory has been manifesting continuously in many areas related to nuclear and particle physics, nuclear chemistry and cosmology. We also therefore, recommend the new mass – energy concept (mvc) for investigation of quarks confinement in which the strong force that binds the quarks together in particle such as, proton and neutron.

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