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Relativistic Mass of the Neutron is Neglected in Nuclear Reactors

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Abstract

In fission reactions, neutron produced are known as fast neutrons having energy of 2MeV. With the help of amoderator, the velocity of neutrons is reduced to classical limits i.e. 0.025eV. The velocity of fast neutron is in the relativistic region. Thus the mass of neutrons must be more than rest mass 1.0086649156u due to relativistic variation. But in the determination of energy, mass is taken as just equal to rest mass. If the relativistic variation of mass is taken into account then the magnitude of energy theoretically predicted is less. It is experimentally supported as in fission of U^{235} and Pu^{239} that the energy emitted is found to be 20-40MeV less than theoretical predictions.

1.0 Initially fast neutrons are emitted in nuclear fission

The neutron was discovered by Chadwick [1] in 1932. O. Hahn and F. Strassmann **reported to** *Naturwissenschaften* the nuclear fission and a new element, barium was obtained [2]. The same i.e discovery of fission and barium was also confirmed [3-4] by Lise Meitner and O. R. Frisch. In the fission of U^{235}, various fission fragments are possible, but in first-ever nuclear fission, one of the fission fragments was barium. In nuclear fission, the energy of the neutron is nearly 2 MeV (velocity 1.954×10^{7} m/s). Such neutrons cannot cause further fission. Thus, with the help of moderators, their energy is reduced to 0.025eV (2185m/s). This energy and velocity is in the thermal range, and only slow neutrons can cause further fission of other atoms. These are called thermal neutrons.

2.0 The total kinetic energy(TKE) of fission fragments of U^{235} or Pu^{239} is 20-60 MeV less than predicted by $E = \Delta mc^2$.

The familiar fission reaction is

$${}_{92}U^{235} + {}_{0}n^{1} \rightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3\,{}_{0}n^{1} + Q$$

In laboratory, [5-8] it has been experimentally confirmed that when using thermal neutrons, the total kinetic energy of fission fragments that result from U^{235} or Pu^{239} is 20-60 MeV less than the Q value of the reaction predicted by $E = \Delta mc^2$. These observations are over 35 years old. In existing physics, these inconsistent observations are explained in the following ways.

(i) It is typically assumed that energy is lost in unobservable effects [5-8]. If so, then such unobservable effects may also be applicable to those cases where $E = \Delta mc^2$ is regarded as to hold good.

(ii) Also, attempts have been made to explain the total kinetic energy (or essentially total energy) of fission fragments by extending the successful liquid -drop model of Bohr and Wheeler [5-8].

(iii) Various other proposals are also given to explain the inconsistent experimental observations.

It simply highlights the gravity of inconsistent observations, and also can be explained with $E = \Delta mc^2$ if the relativistic masses of emitted neutrons and other fission fragments are considered. Further energy released for all fission reactions / fragments is not the same. This is typical with complex nature of nuclear fission. The Q value of the above reaction can be determined as ($E = \Delta mc^2$).

Mass of reactants = (235.0439299 +1.0086649156) amu = 236.0525948amu (1)

Mass of products = (143.922 953 + 88.917 630 +3.02599473) amu =235.8665777 amu (2)

Mass annihilated = Δm = 0.186017115 amu (3)

Energy released = 0.186017115 × 931.5MeV = 173.274MeV (4)

In the above calculations, the mass of neutrons is taken as rest mass.

3.0 Fast Neutrons: Energy in relativistic region

The neutrons which are emitted in the fission are fast neutrons, having energy nearly equal to 2MeV (3.2×10^{-13} J) . The mass of the neutron is 1.0086649156u, and with this energy (2MeV), the neutron moves with relativistic velocity.

If the velocity is in relativistic limits, then the mass of the particle increases [9-14] according to equation

$$M_{motion} = \frac{M_{rest}}{\sqrt{1 - \frac{v^2}{c^2}}} \qquad (5)$$

The relativistic mass of the neutron can be calculated from the equation of relativistic kinetic energy.

$$M_m = K / c^2 + M_r \qquad (6)$$

$M_m = 3.204\times10^{-13} / 9\times10^{16} + M_r$ (7)

$M_m = 0.002143883u + 1.0086649156u = 1.010808793amu$

In this case, the Q-value further decreases as the mass of products is higher.

Mass of reactants = 236.0525948amu (1)

Mass of products = (143.922 953 + 88.917 630 +**3.032426394**) amu = 235.873 0093 amu (8)

Δm = 0.179584606 amu (9)

Q = 167.28306 MeV (10)

Hence, when the relativistic mass of neutrons is considered, then energy emitted is 5.99 MeV less. Thus, such relativistic effects need to be studied for the other fission fragments, but the velocity or energy of other Ba^{141} and Kr^{92} is required to be known precisely for calculations and final conclusions. Here, the case of the neutron is discussed, as its energy and velocity are precisely known and used in the working of the moderator. Thus, calculations can be done with reasonable accuracy. In nuclear fission, energy is found to be 20-40 MeV than the predicted value, If the velocities of all fragments are precisely known, then it can be calculated. The incorporation of relativistic mass of the neutron implies the energy emitted will be less, which is also experimentally observed as mentioned above. It is further supported by the fact that the energy liberated is only 2% less than expected in uncontrolled fission (fission bomb exploded at Hiroshima), as reported by Robert Serber [14]. The relativistic variation in mass with velocity also holds good for fusion of the nuclei and other reactions, if velocity is in the relativistic region.

4.0 **Conclusions**

The relativistic mass is taken in account if the velocity is in relativistic limits 9-13]. In nuclear fission, the fast neutrons are emitted which have an energy of 2MeV or velocity of 1.95×10^7 m/s (relativistic limits). But while calculating the energy emitted in the reaction, the mass of the neutron is regarded as 1.0086649156 amu i.e. rest mass, whereas the actual mass must be 1.010808793u. If the relativistic mass is taken account, then energy emitted must be 5.99 MeV less. Also experimentally, the energy of fission fragments is observed to be 20-40 MeV less than the predicted value. Thus, such predictions appear to be experimentally consitent. If the relativistic masses (hence velocities) of other fragments are taken in account, then the amount of energy emitted can be further understood.

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