Solving Problems In Nuclear Physics

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ABSTRACT

This article reveals the essence of solving problems in nuclear physics.

KEYWORDS

Nuclei, atom, energy, neutron, neutrino, proton, electron, mass, study, quantum, flux, velocity.

INTRODUCTION

Using a mass spectrometer, the masses of the nucleus are compared, and the difference in the masses of the helium atom in the normal and metastable states is also determined. In most cases, the mass of the nucleus is found from the Einstein equation \( E = mc^2 \).

The epegdiaapi that the nucleus spends on splitting into free nucleons is called the epegdiaapi of the nucleus bond. The relation between the atomic stem \( Z \) and the mass stem \( A \) with the nuclear mass \( M (Z, A) \) the epegdua expression is as follows:
\[ E = (ZM_\rho + (A - Z)M_n - M(Z_1A))c^2 \]

- \( M_\rho \) - free proton mass, \( M_n \) - mass of free neutron. The mass of these two nucleons is of great importance. The mass of the proton is found with great accuracy by measuring the charge-to-mass ratio. The mass of the neutron is determined based on the reactions in which the deiron is involved. If the mass of the \( M_d \) -deuteron is equal to its binding energy

\[ E_d = (M_p + M_n - M_d)c^2. \]

- \( M_\rho \) - it is known from experience that, \( M_d/M_\rho \) the ratio value is found as a result of mass spectrometric measurements, then the \( M_d \) value is determined. For this reason \( E_d \) - the size is measured, \( M_n \) easily calculate the size. The following reaction can be used to determine the binding energy \( E_d \). When a slow-moving neutron collides with water or paraffin (Figure 44), it is captured by protons, forming deuterium and emitting gamma radiation. This reaction is written as follows.

\[ ^1H + ^1n \rightarrow (^2H) \rightarrow ^2H + h\nu \]

The intermediate deuterium core is in the \( ^2H \) state. For it to go to the ground state, it must emit an \( h\nu \) gamma ray. \( h \) - Planck's constant. \( \nu \) - the frequency of the gamma ray quantum.

Knowing the \( \nu \) -frequency of \( \gamma \) -radiation, it is easy to determine its \( h\nu \) -energy.

The mass of the neutron is greater than the mass of the proton. The mass of the proton versus the mass of the electron \( M_p = (988,256 \pm 0.005)m_e \), \( Mn = (939,550 \pm 0.005)m_e \).

The release of energy as a result of the addition of light nuclei is called a fusion reaction. In the fusion reaction, the lighter atoms join and form a heavier nucleus, and when two deuterons collide with a higher energy, one of the deuterons absorbs the proton or neutron of the other, attaching it to itself. In the first case, an isotope of helium with a mass of 3 is formed. As a result of this reaction, an energy of 3.25 MeV is released. The reaction goes as follows:

\[ ^2D + ^2D \rightarrow ^3He + ^1n + 3,25 \text{ MeV} \]
If one of the colliding deuterons attaches a neutron to the other, the result is a tritium nucleus and an energy of 4 MeV is released. The appearance of a reaction: \( ^{2}\text{D} + ^{1}\text{D} \rightarrow ^{3}\text{T} + ^{1}\text{p} + 4 \text{ MeV} \)

For two nuclei to react, their nuclei must touch each other. But the nuclei have a positive electric charge, so they repel each other. As a result, energy must be transferred to the nuclei to overcome the force of electrostatic repulsion. The gas in which the synthesis reaction is observed is always stored at a high temperature. Only this time of the velocity of the thermal motion of the nucleus will be enough to overcome the force of mutual repulsion of the nuclei.

For the practical use of a synthesis reaction, the energy expended in the reaction must be less than the energy produced by the reaction. Such a case is appropriate for very light nuclei, that is, the nuclei of hydrogen and helium. As we move to heavier nuclei, their positive electric charge also increases. Ultimately, it takes a lot of energy to overcome the forces of mutual repulsion.

How much energy is needed for the synthesis reaction to proceed? It has enough energy of about 20 keV.

The atomic energy at room temperature is 0.025 eV. The value of this energy increases with increasing temperature. For the energy of an atom to reach 20 keV, it must be heated to 200 million degrees. Only at this temperature is the synthesis reaction observed.

By studying the neutral, highly penetrating radiation produced by the bombardment of a beryllium target with polonium \( \alpha \)-particles. Chadwick found that it produced recoil protons with a maximum energy of 5.7 MeV in hydrogen, and recoil ions with a maximum energy of 1.2 MeV in nitrogen. To show, applying the laws of conservation of energy and momentum, that this unknown radiation could not be a stream of gamma rays.

Decision

Considering the interaction of the gamma quantum with the nucleus, we conclude that the photoelectric effect could not have taken place, since the protons and nitrogen recoil ions had different energies. Solving the equations for the conservation of energy and momentum in the case of the Compton effect in a mass collision, we proceed

\[ h\nu = E \left( \frac{1}{2} + \frac{\nu}{\vartheta} \right), \]

where \( h\nu \) is the energy of the incident quantum, \( E \) and \( \vartheta \) are the energy and velocity of the recoil core; according to the recoil in hydrogen, it turns out that \( h\nu = 55 \text{ MeV} \), and according to the recoil in nitrogen, \( h\nu = 90 \text{ MeV} \), i.e. the answers contradict each other.
Difficulties in interpreting their experiences (see problem № 1). Chadwick eliminated it by assuming that the mentioned unknown radiation is a stream of neutrinos. Determine the mass of the neutron from these problems № 1, considering its collisions with the nuclei of hydrogen and nitrogen elastic.

Decision. The laws of conservation of energy and momentum in light collisions with hydrogen and nitrogen nuclei are expressed by the following equations:

\[
\frac{m_n \vartheta_0^2}{2} = E_n + \frac{m_n \vartheta_1^2}{2}, \quad m_n \vartheta_0 = \sqrt{2M_n E_n - m_n \vartheta_1},
\]

\[
\frac{m_n \vartheta_0^2}{2} + E_N + \frac{m_n \vartheta_2^2}{2}, \quad m_n \vartheta_0 = \sqrt{2M_N E_N - m_n \vartheta_2},
\]

where \(m_n\) is the mass of the neutron, \(M_n\) and \(M_N\) are the masses of the hydrogen and nitrogen nuclei, and \(E_n\) and \(E_N\) are their recoil energy, \(\vartheta_1\) and \(\vartheta_2\) are the neutron velocities after collision with the hydrogen and nitrogen nuclei.

Excluding from the equations \(\vartheta_1\), \(\vartheta_2\), and \(\vartheta_0\) we get:

\[
\frac{m_n+M_n}{m_n+M_N} = \frac{M_n E_N}{M_N E_n}.
\]

Substituting the experimental values \(E_n\) and \(E_N\), as well as \(M_n=1\) and \(M_N=14\), into the last ratio, we get \(m_n=0.81\approx1\).

Determine the difference in the binding energies of two mirror nuclei \(C^{13}_6\) and \(N^{13}_7\). Calculate also the difference in the energy of the Coulomb repulsion between the protons between the protons of these nuclei. To explain why the difference in the binding energies of the two above-mentioned mirror nuclei is equal to the difference in the Coulomb repulsion energies between the protons in the nuclei. When calculating the radius of the core, take equal to \(R=1.5 \times 10^{-13}\) A\(^{13}\) sm.

Decision. Using the formulas for the mass, we write

\[
M(C^{13}_6) = 6M(H^1) + 7m_n - \frac{\varepsilon_{cb}(C^{13})}{c^2}
\]

\[
M(N^{13}_7) = 7M(H^1) + 6m_n - \frac{\varepsilon_{cb}(N^{13})}{c^2}
\]

Therefore,

\[
M(N^{13}) - M(C^{13}) = M(H^1) - m_n + \frac{1}{c^2} [\varepsilon_{cb}(C^{13}) - \varepsilon_{cb}(N^{13})] \quad \text{and}
\]

\[
\Delta \varepsilon_{cb} = \varepsilon_{cb}(C^{13}) - \varepsilon_{cb}(N^{13}) = [M(N^{13}) - M(C^{13}) + m_n - M(H^1)]c^2 = 3.0 \text{ MeV}
\]

Based on the formula for the Coulomb repulsion energy of protons in a nucleus with charge \(Z_e\), we can write

\[
\varepsilon_{Kul}(N^{13}) = \frac{3}{5} \frac{c^2}{R_N} 7 \cdot 6, \quad \varepsilon_{Kul}(C^{13}) = \frac{3}{5} \frac{c^2}{R_e} 6 \cdot 5.
\]
Отсюда следует, что

\[ \Delta \varepsilon_{ku} = \varepsilon_{ku}(N^{13}) - \varepsilon_{ku}(C^{13}) = \frac{36c^2}{5 R} = 2.8 \text{ MeV}. \]

Since \( R_c = R_N = 1.5 \cdot 10^{-2}\text{A}^{1/3} = 3.7 \cdot 10^{-13} \text{ sm}. \)

The fact that \( \Delta \varepsilon \approx \Delta \varepsilon \) is explained by the approximate equality of the nuclear forces between the nucleons.

Isotope Be\(^7\) as a result, the K-capture turns into Li\(^7\), being in the main state. Determine the recoil energy of the latter, if the reaction energy \( Q \) is 0.87 MeV, and the rest mass of the neutrino is zero.

Decision. Let \( m \) be the mass of the lithium atom and \( p \) be the momentum of the recoil nucleus (it is also equal to the momentum of the neutron). We have \( \frac{p^2}{2m} + pc = Q \). Assuming \( \frac{p}{\sqrt{2m}} = x \), we have the following equation:

\[ x^2 + \sqrt{2mc^2} \cdot x - Q = 0, \]

Where from

\[ x = -\frac{1}{2} \sqrt{2mc^2} + \frac{1}{4} \cdot 2 \cdot mc^2 + Q. \]

Given that \( x^2 - E \), where \( E \)- the desired energy of the recoil core, we have \( E = mc^2 \left[ 1 + \frac{Q}{mc^2} - \sqrt{1 + \frac{2Q}{mc^2}} \right] \) and, decomposing the root into a series, we get

\[ E \approx \frac{1}{2} \frac{Q^2}{mc^2} = 58 \text{ MeV}. \]

Answer: \( E \approx \frac{1}{2} \frac{Q^2}{mc^2} = 58 \text{ MeV}. \)

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