ENERGY SPECTRUM OF CASCADE ALPHA PARTICLES IN PHOTOGRAPHIC EMULSION STARS PRODUCED BY HIGH-ENERGY PROTONS

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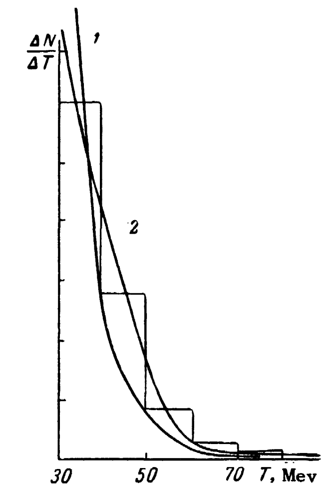
The energy spectrum of α particles with energies above 30 Mev and emitted in the disintegration of heavy photographic emulsion nuclei induced by 140, 200, 360 and 660 Mev protons has been computed. The calculations are based on the assumption of a single elastic collision between cascade nucleons and particles inside the nucleus. The calculated and experimental distributions are compared and found to be in good agreement if the kinetic energy of the α particle in the nucleus is assumed to equal 5-10 Mev.

In our previous work[1] we presented the results of calculations of the effective cross sections for the emission of α particles of energy greater than 30 Mev in the disintegration of emulsion nuclei induced by high energy protons. The calculations were based on the assumption of single elastic collisions between the secondary fast nucleons produced in the cascade stage of the disintegration process and clusters of nucleons of the α-particle type, which may exist in the nucleus as a temporary formation. Comparison with the corresponding experimental data allowed the determination of the relative time during which the nucleons remain in the group of α clusters for light emulsion nuclei (C, O, N) and in the peripheral region of heavy nuclei (Ag and Br). The probability for the production of α particles in the nucleus calculated in this way proved to be a decreasing function of the value assumed for the momentum of the α particles inside the nucleus.

In the present article we present a calculation of the energy spectrum of fast cascade α particles in order to obtain definite information on the value of the velocity of the α particles in the nucleus, since it is natural to expect that the shape of the energy distribution curve of the recoil particles will depend on their initial momentum.

The computational and experimental methods are quite analogous to those described earlier.[1,2] In order to obtain the energy spectrum of the emitted α particles, formulas[1] with the corresponding values of T (the lower limit of the kinetic energy of the recorded α particles) were used.

Shown in the figure is the experimental α-particle spectrum (with a lower limit of 30 Mev) obtained from the observation of stars produced in Ag and Br nuclei by protons of energy E_0 = 660 Mev. The α-particle spectra obtained in the experiments for proton energies of 140, 200, and 360 Mev have the same shape and therefore are not shown. The statistics of the observations are given in reference 2. The calculated results are shown in the same figure. The calculated and experimental distributions are reduced to the same total number of particles. In view of the fact that the energy spectra of the emitted α particles, calculated for α-particle kinetic energies in the nucleus of W = 5, 10, and 20 Mev, lie very close to one another, only the curves for W = 0 and W = 5 Mev are given in the figure. It is seen from the figure that the experimental data corresponds to the calculations based on elastic collisions of nucleons with moving α particles; the same good agreement is also obtained at E_0 = 140, 200, and 360 Mev.



Energy spectrum of α particles knocked out of Ag and Br nuclei by 660-Mev protons. The histogram represents the experimental data; curve 1 was calculated for W = 0 Mev; curve 2 was calculated for W = 5 Mev.

The choice of the particular value of the α-

particle momentum is not critical for the shape of the observed energy spectrum (at least if W remains between 5 and 20 Mev). Therefore attempts to choose some function for the momentum distribution of the α particles inside the nucleus in order to obtain good agreement between the calculated and experimental spectra serve no purpose. Thus, for example, a uniform momentum distribution within W = 0 to 20 Mev or a Gaussian distribution with the value e^{-1} corresponding to an energy of 5 or 10 Mev give practically the same good agreement with experiment.

A certain excess of high energy α particles above the calculated value can be attributed, at least in part, to an admixture of He^3 nuclei, which have a smaller energy for the same range. If we take the amount of He^3 nuclei as equal to 20%[3] and assume that the spectra for He^4 and He^3 are identical, then the correction to the experimental spectrum brings it closer to the calculated one. Moreover, a certain effect in this direction can result from the dependence of the α-particle mean free path in the nucleus on its kinetic energy.

Detailed calculations of the energy spectra of cascade α particles emitted from light emulsion nuclei lead approximately to the same results, since the distribution function of the emitted α particles is related to the concrete type of nucleus only by the shape of the energy spectrum of the cascade nucleons, which spectrum changes little from nucleus to nucleus. Comparison with experiment, however, is difficult, owing to the low accuracy of observation of stars from light nuclei. This was done for the disintegration of light nuclei induced by 360-Mev protons. In this case, too, the values W = 5 or 10 Mev proved to be most suitable. This result does not contradict the data of Cüer and Samman[4], who found that α particles in the C^{12} nucleus have a broad energy distribution with a mean value W = 6 Mev.

Comparing the data on the value of W obtained in the present work with that calculated from the expression for w (W) (see reference 1), where w is the probability for the production of an α particle, we can conclude that there is a strong tendency for the nucleons at the periphery of the heavy nuclei to produce α clusters which behave as a single entity in the cascade process of nuclear disintegration. Of course, the agreement between the calculated results and the experimental data is not yet sufficient to establish the absoluteness and uniqueness of the chosen model. The possibility of some other mechanism, for example, of the complex "pick-up" type (p, α) cannot be completely excluded.

For further verification of the correctness of the ideas we have developed to account for the occurrence of high energy α particles in nuclear disintegration, it is necessary to have additional criteria. Such a criterion can be the agreement between the calculated angular distribution of the cascade α particles and the expermental distribution, since it is difficult to expect that any two different mechanisms lead to the same angular and energy distributions over a wide energy range of incident nucleons. Extrapolation of the calculated curves to lower α-particle energies will probably not be successful, since the application of the model based on collisions between a single nucleon and an α particle is not suitable for low energies.

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