CHARGE DISTRIBUTION OF FRAGMENTS IN NUCLEAR DISINTEGRATIONS

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The charge distributions of fragments with Z = 4 — 8 produced in the disintegration of Ag and Br nuclei by 9-Bev protons, are investigated. The analysis is carried out for small and large energy transfers to the nucleus, for various directions of emission of the fragments, and for cases involving the emission of two or more fragments in a single disintegration. The fragment charge distributions are found to be practically the same in all indicated cases. A discussion of the obtained data is presented.

THE charge distribution of spallation products of Ag and Br has been investigated for different bombarding energies in a number of papers.[1-6] A comparison of the obtained results reveals the absence of any marked dependence of the charge distributions on the energy of the incoming particles. This result seems to be surprising since a number of quantities characterizing the spallation process (cross sections, multiplicities, angular distributions, and others) are known to depend on the energy of the incoming particle.

In this connection it is of interest to investigate directly the charge distribution of the fragments for a given energy of the incoming particles but for different conditions of the outgoing particles. Such conditions of interest are the magnitude of the energy transfer to the nucleus, or the direction of the outgoing particles with respect to the incoming particle, or the multiplicity of the reaction. This interest is due to the known dependence on the bombarding energy of these characteristics of the spallation process. Such an investigation was undertaken with 9-Bev protons. At this energy the spallation cross section is relatively large (100 mb), which allows one to accumulate a sufficiently large body of data to perform a statistically significant analysis.

The charge of the fragments was determined by measuring the total area of their tracks in P-9ch emulsion. This was done on a special semiautomatic optical photometric setup. The distribution of track areas was determined for each kind of disintegration (see Table I). The distributions of fragments with a charge of more than 3 were compared by means of two methods: (a) the method of statistical verification of hypotheses (calcula-

Table I. Results of the comparison of the distribution of the fragments in different disintegrations according to total track area.

Characteristics of the disintegrations		Number of analyzed fragments		Mean value of the total track area*		Value of the probability p from the comparison of two distributions***	
		Run I	Run II	Run I	Run II	Run I	Run II
Total number of light charged particles in the disintegration**	⩽12	159	102	0,60	1.46	0,51	0.18
	>12	134	90	0.60	1.48		
Number of fragments N_f with $Z \geqslant 4$ in the disintegration	1	262	209	0,60	1,47	0.48	0,8
	⩾2	112	187	0,60	1.45		
Emission direction of the fragments with respect to the incoming protons	$N_f = 1$ ⩽90°	150	130	0,59	1.49	—	0,6
	$N_f = 1$ >90°	58	56	0,60	1,49		
	$N_f \geqslant 2$ ⩽90°	112	95	0,63	1.49	—	0,4
	$N_f \geqslant 2$ >90°	63	51	0,61	1.46		

*The mean values of the total track area of the fragments is given in arbitrary units for track lengths ⩾ 16 μ in Run I and ⩾ 38 μ for Run II.
**Only for disintegrations with one fragment.
***p is the probability that the difference between two observations due to statistics is not smaller than the observed difference.

Table II. Charge distribution of the fragments in the different disintegrations.

Characteristics of the disintegrations*		Number of fragments Be	B	C	N	$Z \geq 8$
$N_f = 1$	$n \leq 12$	76	24	4	2	0
	$n > 12$	68	22	9	4	0
	forward	102	34	11	4	0
	backward	42	12	2	2	0
	total	144	46	13	6	0
$N_f \geq 2$	forward	67	29	14	1	1
	backward	45	17	1	0	0
	total	112	46	15	1	1

*N_f is the number of fragments, and n is the number of the other charged particles in the disintegration.

tion of χ^2) and (b) comparison of the mean value of the track area in the distributions. Both methods showed that the distributions of track area, and thus the distributions of charge of the fragments, were practically indistinguishable for the following cases:

(1) for disintegrations which differ in the energy transfer to the recoiling nucleus from the incoming particle;

(2) for disintegrations which differ in the number of fragments;

(3) for disintegrations in which the fragments are emitted forward or backward relatively to the incoming particle.

In Table II are given the charge distributions of the fragment from the different disintegration types.

It must be mentioned that the above conclusions relate only to fragments within the range of the charge between 4 and around 8 and only to those which have an emission energy of ≥ 2 Mev per nucleon. At present one cannot say anything definite about the distribution of fragments with lower energy or with higher charge. However, it should be kept in mind that their relative contribution to the spallation process is not large, about 7%. Therefore the obtained results can be of more general importance and could be of significance for the understanding of certain aspects of the mechanism of production of higher charge fragments in the nuclear spallation process.

First, it becomes clear why the form of the charge distribution of the fragments does not change as a function of the energy of the incoming particles.

This situation could obtain if the relative probabilities of the production of fragments with different charge is independent of such factors as the temperature of the nucleus, and the angular and energy distribution of the cascade nucleons in the development of the cascade within the nucleus. The given results indicate that this apparently actually is true.

Secondly, in the given range it is unlikely that, as has been sometimes assumed, there exist several mechanisms (like, e.g., knock-on, evaporation, fission) each of which contributes a definite fraction to the total spallation cross section. To the contrary, the production of fragments evidently takes place by means of only one mechanism, independently of the energy of the incoming particle.

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