Yield of the mirror nuclei ^{3}H, ^{3}He and ^{7}Li, ^{7}Be in interactions of relativistic oxygen nuclei with protons

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(Submitted 31 January 1994)
Pis'ma Zh. Eksp. Teor. Fiz. **59**, No. 5, 316–318 (10 March 1994)

New experimental data have been obtained on the yield of the mirror nuclei ^{3}H, ^{3}He and ^{7}Li, ^{7}Be in ^{16}Op interactions at a momentum of 3.25A GeV/c.

In a recent study,[1] which was part of a series of studies on the interaction of relativistic oxygen nuclei with protons,[2–5] we reported data on the isotope composition of fragments of the projectile nucleus with charges $Z_f = 1$–7. The results were compared with predictions of the cascade-fragmentation evaporation model (CFEM).[5,6] Some significant discrepancies between experiment and the model were found in terms of the yields of isotopes of helium and carbon nuclei. We should point out that, on the whole, the CFEM gives a satisfactory description of the multiplicities of secondary particles, including multiply charged fragments.

In this letter we are reporting experimental results on inclusive characteristics of isospin doublets with mass numbers $A=3$ (^{3}H, ^{3}He) and $A=7$ (^{7}Li, ^{7}Be), based on an analysis of 4737 measured ^{16}Op interactions at a momentum of 3.25A GeV/c. The efficiency of the scan for topologies involving the formation of the mirror nuclei discussed below was close to 100%. Methodological questions concerning the analysis of the photographs from the one-meter hydrogen bubble chamber, which was used to obtain the experimental data, are discussed in detail in Refs. 1–4. For a reliable separation of fragments by mass, we studied secondary particles with a measured length $L \geqslant 40$ cm in the chamber, as in Ref. 1. For this type of selection, the mean relative error in the measurements of the momentum is $\leqslant 4\%$ at all values of the charge.

The total number of mirror nuclei (^{3}H, ^{3}He and ^{7}Li, ^{7}Be) found from the analysis of the momentum spectrum of the secondary fragments with charges $Z=1$–4, by the method described in Ref. 1, and the corresponding inclusive formation cross sections σ_{incl} are shown in Table I, along with calculations from the CFEM. The values shown

TABLE I.

	Number of fragments			
σ_{incl}, mb	^{3}H(394±25)	^{3}He(410±25)	^{7}Li(80±10)	^{7}Be(78±11)
Experiment	42.3±2.2	44.1±2.2	9.6±1.2	9.4±1.2
CFEM	35.6±0.7	50.3±0.9	13.7±0.5	19.6±0.5

here for the cross sections have been corrected for losses due to secondary interactions over distances up to 40 cm. These values were found through a normalization of the total number of measured events to the inelastic cross section for the ^{16}Op interactions.[7] The values of the cross sections for the isotopes ^{3}H and ^{7}Be agree well with the data reported in Refs. 8 and 9.

We see in Table I that the inclusive cross sections for the yield of mirror nuclei are the same, within the statistical errors. The CFEM predicts the following values for the ratio of cross sections for the yields of the mirror nuclei: $\sigma_{incl}(^3He)/\sigma_{incl}(^3H)=1.41\pm0.04$ and $\sigma_{incl}(^7Be)/\sigma_{incl}(^7Li)=1.43\pm0.06$. Although these ratios are again equal in the experimental results, the proton-excess nuclei have a higher emission probability in the model than experimentally.

The experimental data found here can be explained in a simple way on the basis of two-stage mechanisms for ^{16}Op collisions, as in the case of the CFEM, under the assumption that no additional charge is transferred to the residual excited nucleus (whose decay results in the formation of the observed fragments) in the stages of the development of the intranuclear cascade. A possible explanation here is that, since elastic and inelastic charge exchange occurs with a larger momentum transfer, the nucleons of the nucleus which have undergone charge exchange and which are participating in the cascade process are not captured by the residual thermalized nucleus, and Coulomb forces do not influence the formation of the observed fragments.

Let us examine the correlations between the secondary-particle multiplicities and the yields of ^{3}H and ^{3}He nuclei, for which there is an adequate statistical base. Table II shows mean associative multiplicities of singly and doubly charged particles, and also of multiply charged fragments with a charge $Z\geqslant3$, in semi-inclusive reactions in which a single ^{3}H or ^{3}He nucleus is emitted. The corresponding numbers of events turned out to be 314 and 323, respectively. The multiplicities of the associated particles

TABLE II.

	^{3}H		^{3}He	
Particle	Experiment	CFEM	Experiment	CFEM
d	0.71±0.03	0.33	0.71±0.03	0.32
^{3}H	1.0	1.0	0.29±0.01	0.11
^{3}He	0.28±0.01	0.16	1.0	1.0
^{4}He	0.85±0.05	0.34	0.86±0.05	0.40
$A(Z\geqslant3)$	0.25±0.03	0.60	0.20±0.03	0.62

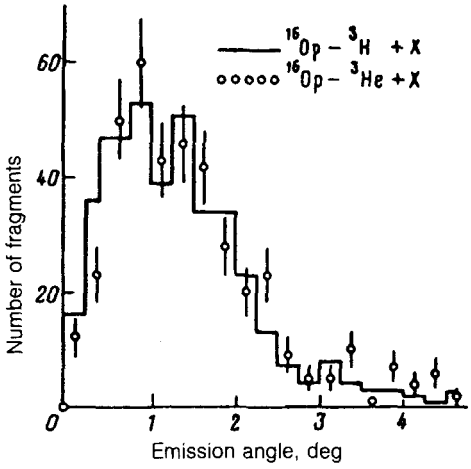

FIG. 1. Angular distributions of the mirror nuclei in the lab frame. Points—^{16}Op–$^{3}He+X$; Solid line—^{16}Op–$^{3}H+X$.

were determined (as in the case of the mirror nuclei) by sampling tracks with $L>40$ cm in the momentum interval 4.6–7.8 GeV/c for ^{2}H, >7.8 GeV/c for ^{3}H, <10.8 GeV/c for ^{3}He, and >10.8 GeV/c for ^{4}He. The losses due to secondary interactions were taken into account. For a sampling of this type, the error in the determination of the mean multiplicity due to the overlap of the momentum spectra of nearest isotopes is less than 5%. The mean multiplicity of fragments with $Z\geqslant 3$ in the selected events was determined from the scan data.

It can be seen from Table II that, experimentally, the mean multiplicities of the particles under consideration are identical for the two mirror nuclei within the statistical errors.

The CFEM prediction for the associative multiplicities of singly and doubly charged fragments is smaller by a factor of 2 or more than the experimental value, while for the multiply charged fragments with $Z\geqslant 3$ this prediction is, on the contrary, larger.

In addition to identical characteristics as discussed above, we find that the angular distributions of isospin doublets with $A=3$ coincide (Fig. 1).

The similarity of all the characteristics of the ^{3}H and ^{3}He mirror nuclei indicates that the process by which these nuclei form apparently occurs under identical physical conditions. The strong correlation observed between the yield of ^{4}He nuclei and the formation of the isospin doublet with $A=3$ in comparison with the model supports our earlier conclusion[5] that the presence of an α-particle cluster structure of the nucleus must be taken into account in models for high-energy hA collisions.

[1] V. V. Glagolev *et al.*, JETP Lett. **58**, 497 (1993).
[2] V. V. Glagolev *et al.*, JINR Reports P1-89-218 (Dubna, 1989).
[3] V. Vislitskiĭ, JINR Reports P1-90-306 (Dubna, 1990).
[4] B. U. Ameeva *et al.*, JINR Reports P1-91-545 (Dubna, 1991).
[5] A. S. Botvina *et al.*, Z. Phys. A **345**, 413 (1993).
[6] A. S. Botvina *et al.*, Nucl. Phys. A **507**, 649 (1990); Preprint 626, Institute of Nuclear Research, Academy of Sciences of the USSR, Moscow, 1989.

[7] A. S. Botvina *et al.*, JINR Preprint P1-92-45 (Dubna, 1992).
[8] F. P. Denisov and V. N. Mekhedov, *High-Energy Nuclear Reactions* (Atomizdat, Moscow, 1972).
[9] G. M. Raisbeck and F. Yiou, Phys. Rev. Lett. **35**, 155 (1975).

Translated by D. Parsons