Production of intermediate-mass fragments in the reaction $p+$Au in the proton energy range 2.6–7.5 GeV

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The cross sections $d\sigma/d\Omega$ for the production of fragments with charges $z_F = 5$–12 have been measured in the reaction $p + \mathrm{Au} \to A_F + X$ ($E_p = 2.6$–7.5 GeV in the laboratory frame of reference). The energy of the fragments was 1.2–10 MeV/nucleon; the detection angle was 88° in the laboratory frame. The functional dependence of the cross section on the fragment charge was approximated by the function $d\sigma/d\Omega \sim z_F^{-\tau(E_p)}$. The local minimum, which would be expected in $\tau(E_p)$ according to the model of a gas-liquid phase transition, was not observed.

Finn *et al.*[1] have proposed a mechanism for the production of intermediate-mass fragments ($A_F = 10$–30) as a condensation of an intensely heated nucleon gas. The approach of Refs. 1–5 is based on the theory of a gas-liquid phase transition which was developed by Fisher[6] for a classical van der Waals gas. The similarity between the

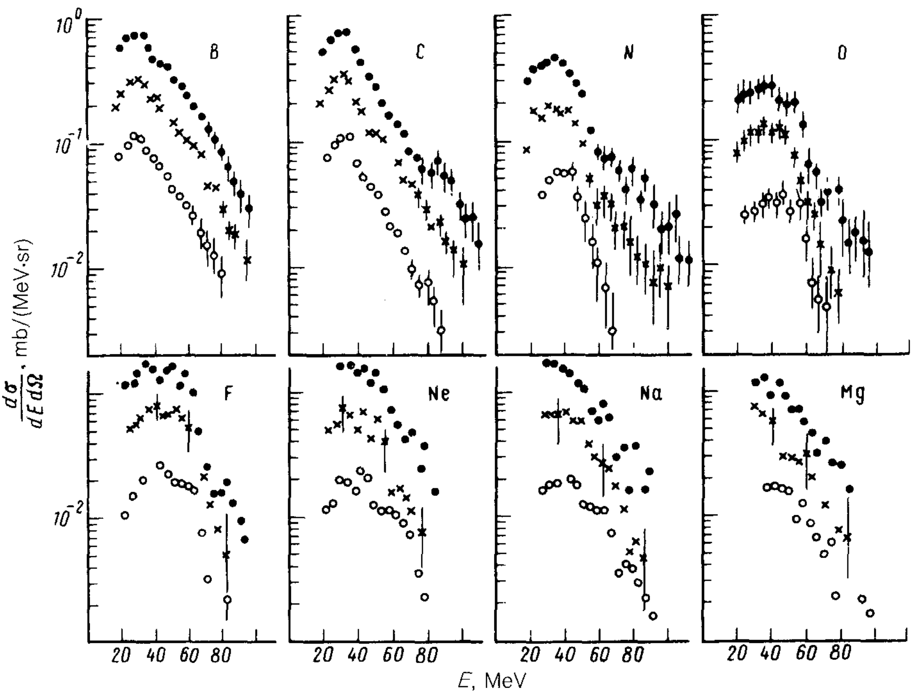

FIG. 1. Energy spectra of fragments with $z_F = 5$–12 detected in the reaction $p + \mathrm{Au}$ for several proton energies. ○—2.55 GeV (multiplied by 0.5); ×—4.18 GeV; ●—7.51 GeV (multiplied by 2).

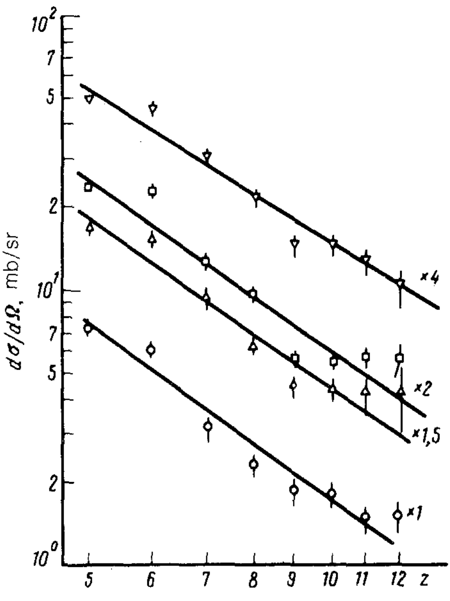

FIG. 2. Differential cross section for the emission of fragments in the reaction $p + \mathrm{Au}$ versus their charge for several proton energies. ○—2.55 GeV; Δ—3.36 GeV (multiplied by 1.5); □—4.18 GeV (multiplied by 2); ∇—7.51 GeV (multiplied by 4). The lines are values of the functions $z_F^{\ \tau}$.

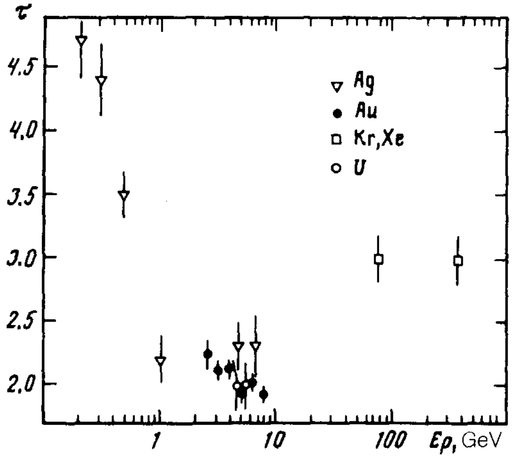

FIG. 3. The parameter τ as a function of the proton energy. ●—Data from the present study (Au target); ∇—data of Refs. 12–16 (Ag target); □ data of Ref. 2 (Kr, Xe target); O—data of Ref. 11 (U target).

phase diagrams of a nucleon gas and of a classical gas[7] suggests[1–3] a power-law dependence of the fragment production cross section on the fragment charge z_F (or mass): $\sigma(z_F) \sim z_F^{-\tau}$.

As in the condensation of a classical gas, the parameter τ should have a minimum value near the critical point on the gas-liquid diagram. Corresponding predictions are made by percolation theory.[8] In an effort to determine the behavior of τ as a function of the energy of a proton beam, we measured the differential cross sections $d^2\sigma/dEd\Omega$ for the production of fragments with $z_F = 5$–12 in the reaction $p + \text{Au} \to A_F + X$. This experiment was carried out in the internal beam of the synchrophasotron of the Joint Institute for Nuclear Research at six proton energies E_p: 2.55, 3.36, 4.18, 5.02, 5.85, and 7.51 GeV in the laboratory frame of reference. The fragments were detected at an angle of 88° in the laboratory frame by three-detector semiconductor telescope detectors. This procedure[9] provides a good charge resolution of the fragments and good measurements of their energies over the interval $E = 1.2$–10 MeV/nucleon. Figure 1 shows differential cross sections for fragment production; tables of cross sections were published in Ref. 10.

The differential cross sections are described by a quasi-Maxwellian function[11] corresponding to a diffuse Coulomb barrier, $(\langle k \rangle - \Delta)B \leqslant kB \leqslant (\langle k \rangle + \Delta)B$ of the fragment in a target nucleus:

$$\frac{d^2\sigma}{dEd\Omega} \sim \int_{\langle k \rangle - \Delta}^{\langle k \rangle + \Delta} (E - kB)^{1/2} \exp\left(\frac{E - kB}{T}\right) dk. \qquad (1)$$

Here $B = e^2 z_F (z_T - z_F)/r_0[A_F^{1/3} + (A_T - A_F)^{1/3}]$ is the nominal Coulomb barrier, Δ is its spreading, k is an integration variable, $\langle k \rangle$ is the effective Coulomb barrier, T is the effective temperature, and $z_{F(T)}$ and $A_{F(T)}$ are the charge and mass numbers of the fragment (or target nucleus), respectively. Function (1) can be used to reconstruct the low-energy part of the fragment spectrum, which was not measured but which is necessary for calculating the value of $d\sigma/d\Omega$ through an integration of the cross section $d^2\sigma/dEd\Omega$ over the energy. Figure 2 shows values of $d\sigma/d\Omega$ for several energies of the impinging protons, along with an approximation of the experimental data by the function $d\sigma/d\Omega \sim z_F^{-\tau(E_p)}$.

Figure 3 shows a compilation of data on the values of $\tau(E_p)$. It should be kept in mind here that since the points at $E_p > 80$ GeV^2 were obtained at a detection angle of 34°, it is not completely correct to directly compare them with other data at this point.

Our data on the parameter τ can be described by $\tau(E_p) = (2.24 \pm 0.01) - (0.0453 \pm 0.0004)E_p$.

In summary, these results do not exhibit a local minimum in the values of the parameter τ in the reaction $p + \text{Au}$ over the interval of impinging-proton energies studied.

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