the longitudinal coordinate z

$$f_{av} \approx {}^{1}/_{2} r_0 E_0 H_0 \{(\omega_0^2 - \omega^2)\,\omega c \,/\, [(\omega_0^2 - \omega^2)^2 + \gamma^2\omega^2]\} \sin 2hz.$$

In order to achieve cumulative acceleration of particles it is necessary that in those regions of space where sin 2hz changes sign the factor $\{\dots\}$ should either change sign or have a different magnitude. (In estimating the average force we can, as before, restrict ourselves in certain cases to a consideration of the effect on the forced vibrations, since the possible excitation of characteristic oscillations gives no average contribution not only in the presence of real damping or of a spread in the phases of excitation of free oscillations, but also as a result of the fact that the characteristic oscillations have a frequency different from the frequency of the magnetic field of the wave.) In the case of a more complicated, say sinusoidal, spatial variation of the resonance parameters, we can easily demonstrate the fact that the space average of the accelerating force is different from zero by making use of solutions of the Mathieu equation, or by assuming for the sake of simplicity that the variations of the resonant frequency are small and by restricting ourselves to the first approximation. The cumulative contribution in the latter case will be determined by integrals of terms of the type $\sin\{2\pi(2/\lambda - 1/l)z + \varphi\}$ in the case when the spatial period l of the frequency variation is equal to one half of the wavelength of the radiation λ. Such zonal damping of the reverse acceleration by local constant external fields or by a local choice of the regime of dissipation will enable us to obtain continuous acceleration of plasma particles over long paths within the stationary field of a standing wave of large amplitude.

The simplest choice of the spatial variation of the oscillation parameters may be made by means of increasing or decreasing the axial magnetic field in those "quarter wavelength" regions in which it is required to alter the direction or the magnitude of the acceleration. This field will give rise to spatially-periodic variation of the amplitudes and the phases of the forced oscillations either because of a change in the cyclotron resonance frequencies, or because of a change in the characteristic plasma resonances (these changes may occur due to a change in plasma density when it is compressed in the regions of increased magnetic field) etc. Such a "corrugated field" may also help the focusing of the beam of particles undergoing acceleration.

In the method of acceleration under discussion the effective accelerating field intensity acting on the electrons may be made sufficiently large compared to the amplitude of the electric wave field. The efficiency of acceleration can also be increased by a transition from a linear resonator to a circular resonator utilizing repeated traversals of the wave field.

It is evident that similar devices may be used not only for the acceleration of plasma, but also for retarding and for turning back charged particles leaking out of storage systems.

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CONCERNING THE PRODUCTION OF COMPOUND NUCLEI IN THE INTERACTION BETWEEN ATOMIC NUCLEI

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Submitted to JETP editor September 16, 1958

J. Exptl. Theoret. Phys. (U.S.S.R.) **36**, 621-623 (February, 1959)

It is natural, when investigating the interaction between multiply-charged ions and nuclei of various elements, to inquire about the extent to which these reactions proceed by complete fusion of the colliding nuclei with subsequent evaporation of neutrons. A useful criterion for such a reaction are the curves of the cross section of a reaction involving the emission of a specified number of

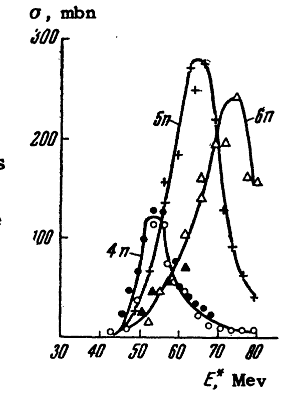

FIG. 1. Dependence of the cross sections of the reactions Au(N, (4–6)n) on the excitation energy of the compound nucleus Em^{211}.

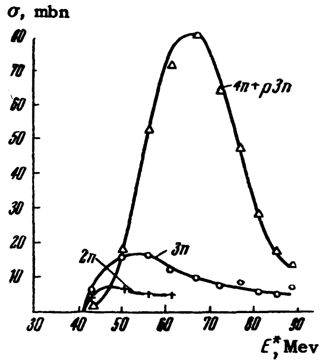

FIG. 2. Dependence of the cross sections of the reactions V(N, xn) on the excitation energies of the compound nucleus Zn^{65}.

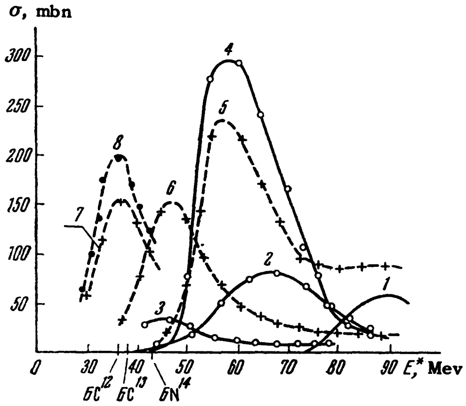

FIG. 3. Comparison of the energy relations of the cross sections of evaporation reactions on multiply-charged protons, resulting in compound nuclei. o – data of this paper, • – data of reference 5, + – data of reference 6. Curve 1 – $V(N^{15}, 5n)$, 2 – $V(N^{14}, p3n + 4n)$, 3 – $V(C^{12}, 2n)$, 4 – $V^{51}(C^{13}, 3n)$, 5 – Cu^{65} (p, p3n + 4n), 6 – Cu^{65}(p3n), 7 – Cu^{63}(p2n), 8 – Cu^{63}(p2n).

neutrons vs. the energy of excitation of the compound nucleus.

Baraboshkin et al.[1] obtained the excitation functions of the reactions $Au^{197}(N^{14}, xn)$ where x = 4, 5, and 6. New literature data[2] on branching in the α-decay and K-capture "forks," and more exact measurements of the energies of accelerated nitrogen ions have enabled us to refine somewhat these data. The excitation functions of the reactions that involve emission of 4, 5, or 6 neutrons in the interaction between accelerated nitrogen ions with gold nuclei, shown in Fig. 1, have a behavior that is characteristic of the production of a compound nucleus. The absolute values of the cross sections show that the reactions proceed in this manner with high probability. However, when the nitrogen-ion energies exceed 70 Mev, the compound Em^{211} nuclei are fissioned, a fact that makes difficult the study of deviations from the formation of compound nuclei at high excitation energies. It is obvious that it is necessary to employ for this purpose targets of lighter nuclei, for which the fission of compound nuclei has a low probability. Furthermore, there are indications[3] that the character of the interaction between multiply-charged ions and nuclei depends substantially on the region of mass numbers of the target nuclei. Irradiation of a lighter element by multiply charged ions will therefore simultaneously permit us to determine the extent to which reactions with formation of a compound nucleus occur at other regions of mass numbers, and to investigate possible deviations from this mechanism. For this purpose, we investigated interactions between accelerated ions of N^{14}, N^{15}, C^{12}, and C^{13} and nuclei of vanadium. The experiments were carried out in the following manners: stacks comprising 10 — 12 aluminum foils, 8μ thick with a spattered layer of 0.1 to 0.2 mg/cm^2 of vanadium were irradiated by monoenergetic beams in the internal test chamber of the cyclotron. The zinc and copper were separated from each foil after the exposure. The isotopes were identified by the half-lives of the beta-active products. The ion energies corresponding to each foil were determined from the range-energy curves obtained in reference 4.

Figure 2 shows the variation of the cross sections of the reactions with emission of 2, 3, and 4 neutrons on the excitation energy of the compound nucleus Zn^{65} ($V^{51} + N^{14} \rightarrow Zn^{65}$). In view of the fact that Zn^{61} has a very short half-life and is entirely converted into Cu^{61} during the time of chemical separation, it has been impossible to separate reactions with emission of 4 neutrons from the possible reaction whereby Cu^{61} is produced directly through the emission of 3 neutrons and 1 proton. The diagram shows therefore the summary cross section of both reactions.

Figure 3 shows analogous curves for the reactions, in which the emission of a various number of particle was investigated relative to the same reaction product Cu^{61}, obtained by irradiation with various ions. For comparison, the same diagram shows curves for the cross sections of several reactions investigated by Ghoshal[5] and Meadows.[6] If the distortion due to the presence of the Coulomb barrier at low energies is taken into account (BC^{12}, BC^{13}, and BN^{14} in the diagram), it is easy to see that the cross section vs. energy curve on Figs. 2 and 3 has a form characteristic of reactions with formation of a compound nucleus. A striking fact is that the curves for the emission of 2 and 3 neutrons do not break off on the high-energy side, but become almost parallel to the axis. While a similar behavior (see reference 6) of the cross sections is readily explained by the presence of direct collisions between the protons and the nuclei, in our case this may be an indication of the occurrence of some other reactions, say those connected with the so-called local heating.

In addition, it is seen from Fig. 3 that our curves corresponding to the evaporation of 2, 3, or 4 neutrons from the excited nuclei are shifted towards the high-energy side by approximately 8 or 10 Mev relative to the similar curves obtained in references 5 and 6. It is possible that this shift is caused by the large angular momentum acquired by the compound nucleus from the multiply-charged ion. However, we do not have enough accurate data to ascertain complete reliability of this shift, let alone to estimate its magnitude.

Without going into the details of the variation of the excitation function, as manifested by the presence of the foregoing segments of the curves and with their shifts, it can be apparently stated at present that when the target mass numbers range from 50 to 200 the interaction with multiply-charged ions proceeds to a considerable extent via production of compound nuclei.

The authors are indebted to Prof. G. N. Flerov for guidance of this research. The authors are grateful to diploma students A. A. Pleve and V. A. Fomichev for aid in the measurements and for processing the results.

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Translated by J. G. Adashko
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CONCERNING THE ρ^0 MESON

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Submitted to JETP editor October 22, 1958

J. Exptl. Theoret. Phys. (U.S.S.R.) **36**, 623-624 (February, 1959).

In the compound model of elementary particles, based on the Fermi-Yang idea,[2] the pion is represented as a system comprising a nucleon in strong interaction with an antinucleon.[2,3] However, along with a triplet of pions, the same "bare" particles can form an isotopic singlet[4]

$$\rho^0 = (\langle p\bar{p}\rangle + \langle n\bar{n}\rangle) / \sqrt{2}. \qquad (1)$$

The fact that no such particle has yet been observed experimentally necessitates a special explanation. Okun'[3] has proposed that the mass of the ρ^0 meson is sufficiently large. On the other hand, Perel'man has remarked recently[5] that $M_{\rho^0} \approx M_{\pi^0}$.

We wish to note that, in view of the difference in the isotopic spins, the forces that bind the nucleon and antinucleon into π^0 and ρ^0 mesons will also be different. For example, in the symmetrical variant, the interaction potential $V = a\tau_1\tau_2$ equals a when $t = 1$ and $-3a$ when $T = 0$. In this case the existence of a π meson would exclude the existence of a ρ^0 meson. Addition of a term independent of T to the potential cannot change this conclusion, since these forces are small.

The mass differences calculated by Perel'man pertain to particles having equal isotopic spins. In particular, the quantity $\Delta M = 12.7\ m_e$ is the mass difference between $\pi^\pm$ and π^0 mesons. Allowance for the magnetic interaction, which has an opposite sign but a somewhat smaller magnitude, brings the calculated mass difference closer to the experimental value $M = 9\,m_e$.

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Translated by J. G. Adashko
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