AN EXPERIMENTAL ATTEMPT TO DETECT TWO-PROTON DECAY OF Ne^{16}

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An experimental search for two-proton radioactivity is described. A Ni target was irradiated by ~ 150 MeV Ne^{20} ions in the internal beam of a 300 centimeter cyclotron. A special method was employed for recording Ne^{16} (the assumed two-proton emitter) produced in the four-neutron-transfer reaction. Not one case of two-proton decay was observed. The following explanations of this result may be suggested: 1) the cross section for production of the Ne^{16} nucleus is $\lesssim 1.8 \times 10^{-30}$ cm^2 (providing that its decay energy $E_{pp} > 1$ MeV and the lifetime is not smaller than 10^{-8} sec), or 2) the lifetime of Ne^{16} is smaller than 10^{-8} sec.

THE proton decay of radioactive nuclei has recently been the subject of experimental investigation. Already proton emitters have been produced with several different mass numbers[1-3] (see also the private communications of Preiss and Fink, and Friedman and Braid). Zel'dovich[4] and Gol'danskiĭ[5] have predicted that Ne^{16} is unstable against the simultaneous emission of two protons. The present note describes an experimental attempt to detect this nucleus.

We intended to obtain Ne^{16} as the result of a four-neutron-transfer reaction in the irradiation of Ni by Ne^{20} ions accelerated to 150 MeV: $Ne^{20} + Ni^{A} \rightarrow Ne^{16} + Ni^{A+4}$. On the basis of studies of neutron- and proton-transfer reactions,[6] we expected the cross section for this reaction to be at least 10^{-29} cm^2.

The technique used permitted detection of decays with a lifetime $\gtrsim 10^{-8}$ sec for protons of at least 0.5 MeV. The essence of the method consisted of driving a Ne^{16} nucleus into a nuclear emulsion and in the scanning to search for ion tracks terminating in a two-prong proton star. Reactions in the emulsion produced by scattered Ne^{20} ions can be easily distinguished by the presence of a recoil nucleus. The cyclotron magnetic field was essential for discrimination of the Ne^{16} nucleus from the large background of ions scattered in the target.

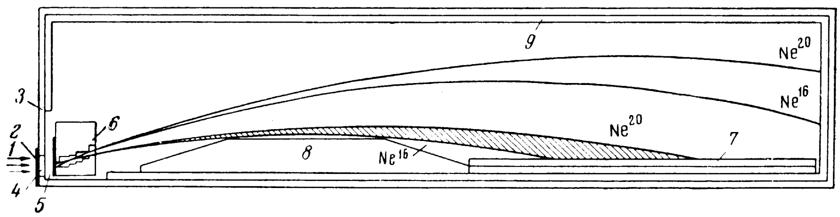
The experiments were performed in the internal beam of the JINR 300-centimeter heavy-ion cyclotron. A 4.5 μ nickel target was irradiated by ~ 150 MeV Ne^{20} ions. Type Ya-2 nuclear plates were used to record the particles. The experimental geometry is shown in the figure. The beam (1) passed through a 6.5 μ aluminum foil (2) which covered the entrance window of the chamber (4) and was incident on the target (5). Behind this was a collimator (6) which simultaneously served as a collector permitting the beam intensity to be monitored during the irradiation. The collimator was made mainly of aluminum in order to reduce the scattering of ions to a minimum. In order to decrease the exposure of the emulsion to x rays from the cyclotron, two tantalum plates 2 mm thick were placed in the middle of the collimator. The collimator transmitted only particles emitted from the target in the angular interval 13—22° with respect to the beam direction. The nuclear plate (7) was placed parallel to the ion beam. In order to decrease the neutron background, a copper shield (8) was placed between the target and the plate. The collimator, target, and plate were inside a copper chamber (3) lined with 2 mm of lead (9) for reduction of the x-ray background.

The calculated trajectories of Ne^{20} and Ne^{16} ions are shown in the figure (the magnetic field is perpendicular to the plane of the drawing). The part of the Ne^{16} ion beam which should be essentially free of scattered Ne^{20} ions is indicated by crosshatching. These trajectories were determined using theoretical values of the equilibrium charges of Ne^{20} and Ne^{16} and of the energy of Ne^{16}. The equilibrium charge was taken as 9.5, obtained from the formula given by Northcliffe[7]

$$Z_{eff}^2 / Z_0^2 = 1 - 1.85 \exp(-2v / v_K),$$

where Z_0 is the nuclear charge of the ion, v is the ion velocity, and v_K is the velocity of the K electrons in the ion.

In estimating the energy of the Ne^{16} ions we proceeded from what is presently known about



nucleon-transfer reactions. It was assumed that

$$E_{Ne^{16}} = E_{Ne^{20}}(16/20) + Q.$$

It is known that the energy distributions of the products of nucleon-transfer reactions are rather broad. This circumstance, together with the weak dependence of the radius of curvature in a magnetic field on the energy, permitted us to use an approximate evaluation of the Ne^{16} energy.

The angular dependence of the products of nucleon-transfer reactions[8] has a flatter variation with angle than the differential cross section for Rutherford scattering. For this reason the scattered beam, after passing through the collimator, should already be enriched in Ne^{16} nuclei. The magnetic field further separates Ne^{20} from the reaction products.

About 39 cm^2 of emulsion were scanned. Not one case of two-proton decay was observed.

The following explanations of this result are possible: 1) if the lifetime of Ne^{16} is greater than or equal to about 10^{-8} sec and the energy of the 2p decay is at least 1 MeV, the absence of the effect implies that the cross section for the reaction $Ni(Ne^{20}, Ne^{16})$ is less than or equal to about 1.8×10^{-30} cm^2; or 2) the lifetime of the Ne^{16} nucleus is less than 10^{-8} sec.

Jänecke[9] has recently calculated the lifetime of the Ne^{16} nucleus. According to his evaluations it does not exceed 10^{-19}sec.

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