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NEAR-THRESHOLD SINGULARITIES OF THE YIELD OF DIRECT PHOTONUCLEAR REACTIONS

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The present research was undertaken for the purpose of studying direct photonuclear reactions in the gamma-quantum energy region close to the nucleon-emission threshold. Studies of this kind may yield information on relatively "pure" transition in the nucleus with excitation of a small number of degrees of freedom.

The yield of the reaction (γ, p) was measured for two nuclei: the proton-shell even-even nickel isotope Ni^{64} and the nucleus Cr^{53}. The large positive value of the proton and neutron binding energy difference (2.82 MeV for Ni^{64} and 3.19 MeV for Cr^{53} [1] leads to suppression of the emission probability of "evaporation" protons, making it possible to regard the indicated reactions as direct. A nickel sample weighing 0.884 g, enriched with Ni^{64} to 90.3%, and a chromium oxide sample containing 2.0 g of the metal, enriched with Cr^{53} to 84.3%, [1)] were placed in the beam of gamma quanta from a synchrotron with maximum energy $E_{\gamma m}$ = 35 MeV at a distance 25 cm from the internal target of the accelerator (a vertical platinum wire of 0.3 mm diameter). The effective thickness of the target was governed mainly by the pitch of the electron-beam helix, which amounted to 1 μ. The activity induced in the samples was recorded with flow-through counters [2]. The half-life of the final Co^{63} nucleus, 34.8 sec, was determined in preliminary measurements [3]. The stability of the energy $E_{\gamma m}$ was verified in accord with [4] before and after the irradiation of the samples; the statistical error in the determination of $E_{\gamma m}$ was on the average 1.3 keV. In the measurement of the yield of the reaction $Ni^{64}(\gamma, p)Co^{63}$ the background was connected mainly with the contribution of the reaction $Ni^{64}(n, \gamma)Ni^{65}$ with T = 154 min.

In several measurements, as an added check, we used the reaction $Cu^{63}(\gamma, n)Cu^{62}$.

The results of the measurement of the (γp) yield averaged over $E_{\gamma m}$ in the interval 10 - 100 keV are shown in Fig. 1. The excess of the observed reaction threshold above the true threshold amounts to 1.5 ± 0.1 MeV for the reaction $Cr^{53}(\gamma, p)U^{52}$ and 2.6 ± 0.2 MeV for the reaction $Ni^{64}(\gamma, p)Co^{53}$. The cross section of the last reaction is $\sigma = 1 \times 10^{-29}$ cm^2 at $E_{\gamma m}$ = 16.2 MeV. For the reaction $Ni^{64}(\gamma, p)Co^{63}$ we performed careful measurements of individual sections of the yield curve in narrower intervals of $E_{\gamma m}$. Figure 2 shows one of the sections in the region of $E_{\gamma m}$ = 16.35 MeV, investigated in three series of measurements (A, B, C) for one year. Each point combines the results of 15 - 20 measurements in the interval $E_{\gamma m}$ = 1.4 keV. The yield errors are rms. A second section of the same curve in the region of $E_{\gamma m}$ = 16.70 MeV is shown in Fig. 3a. The change in $E_{\gamma m}$ during one measurement cycle (∿3 hrs)

[1)] The samples were obtained from the USSR State Stock of Stable Isotopes.

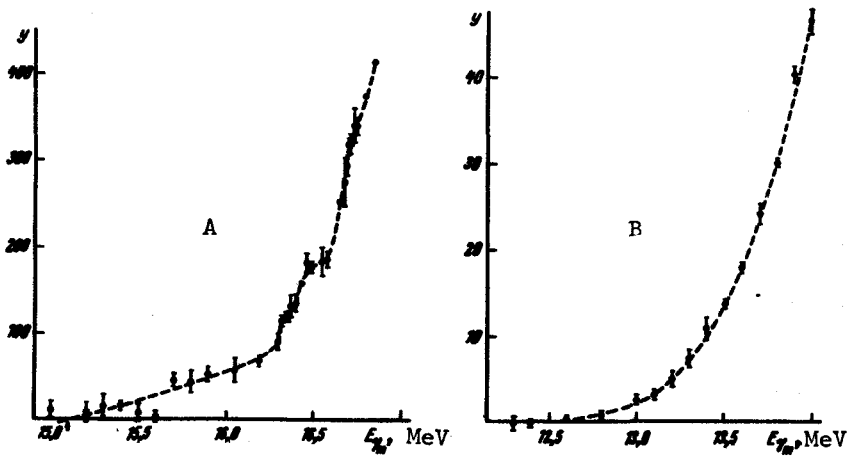

Fig. 1. Yield of reactions $Ni^{64}(\gamma, p)Co^{63}$ (A) and $Cr^{53}(\gamma, p)U^{52}$ (B) near the threshold, averaged over $E_{\gamma m}$ in the interval 10 - 100 keV

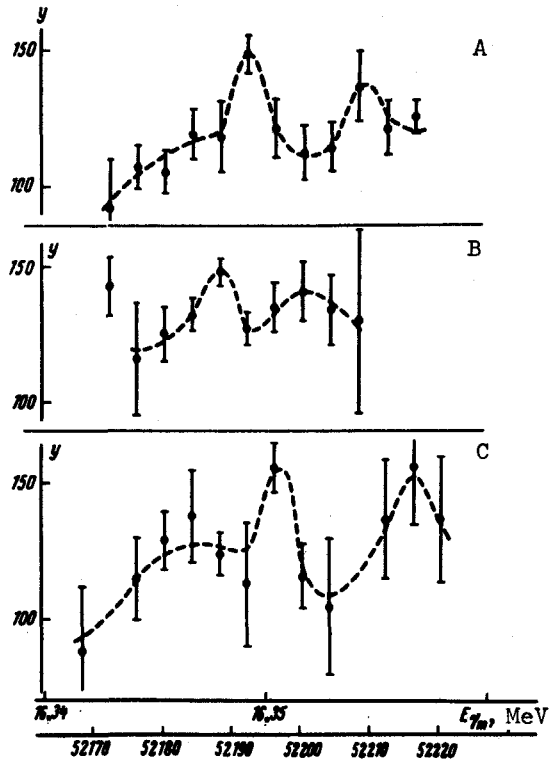

Fig. 2. Yield of reaction $Ni^{64}(\gamma, p)Co^{63}$ in the region $E_{\gamma m}$ = 16.35 MeV.

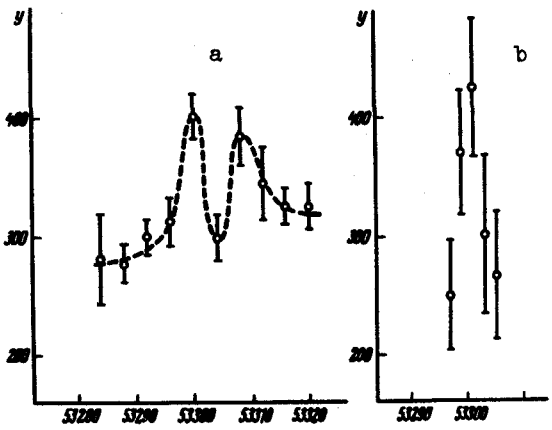

Fig. 3. Yield of reaction $Ni^{64}(\gamma, p)Co^{63}$ in the region $E_{\gamma m}$ = 16.70 MeV: a - summary data obtained during one month; b - results of one cycle of measurements.

has a monotonic character [4]. A more accurate form of the yield curve is therefore obtained from the results of individual cycles (Fig. 3b). In this case, however, the accuracy of the yield measurement is insufficient (the statistical errors are shown).

The results demonstrate that the yield curve of the reaction $Ni^{64}(\gamma, p)Co^{63}$ has in the region close to the reaction threshold not only a rising part but also a part consisting of individual narrow (~1 keV) peaks. A χ^2 estimate yields for the probability that χ^2 exceeds the value calculated assuming a smoothed yield curve, respectively p = 0.001, 0.2, and 0.05 for the data of A. B. and C of Fig. 2 and p = 0.0001 for Fig. 3.

As is well known, the continuous character of the gamma-quantum spectrum does not admit of the existence of peaks in the photonuclear-reaction yield curve regardless of the

form of the cross section. To explain the anomalous yield of the reaction $Ni^{64}(\gamma, p)Co^{63}$ it is necessary to propose the presence, besides the bremsstrahlung spectrum of the gamma quanta, also of a narrow (on the order of 1 keV) gamma line with energy close to the kinetic energy of the accelerated electrons, and with an intensity equal to the intensity of the bremsstrahlung spectrum in the region 0.2 - 0.4 MeV from the upper boundary.

No such additional line could be observed in the hitherto-performed measurements of the bremsstrahlung spectrum, since these measurements were performed either with an energy resolution not better than 100 keV, or in steps $\Delta E_{\gamma m}$ much larger than the width of the proposed line.

In a study of the yield of photonuclear reactions, this line can appear in the gamma spectrum only in those cases when the cross section near the threshold consists of individual narrow peaks. Apparently the large difference between the densities of the single-particle levels of the shell even-even nucleus Ni^{64} and the odd-odd Cr^{53} causes the unusual structure of the yield curve to be observed only for the first of these nuclei. The appreciable shift of the start of the yield curve of the reaction $Ni^{64}(\gamma, p)Co^{63}$ relative to the threshold, compared with the reaction $Cr^{53}(\gamma, p)V^{52}$, is apparently due to the same factor.

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INVESTIGATION OF REACTIONS OF EXCITED IODINE ATOMS WITH THE AID OF A PHOTODISSOCIATION LASER

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The photodissociation iodine laser operating with CF_3I molecules in the near infrared ($\lambda = 1.315\ \mu$) can be used as a convenient device for the investigation of the kinetics of reactions of atomic iodine. As is well known [1], in the photolysis of CF_3I there are produced only excited atoms I* (the state $5^2P_{1/2}$).

The radiative lifetime of the state $^2P_{1/2}$ is about 0.1 sec. It is therefore possible to choose conditions (low pressures or low pump levels) such that the entire atomic iodine is in the excited state[1)] during a sufficiently long time interval ($\Delta t \sim 10^{-3}$ sec). In the generation regime, however, from the instant of formation of the laser field, owing to stimulated transitions, the working volume contains both excited atoms I* and unexcited ones I. Thus, an investigation of the photolysis of CF_3I in the generation regime and without generation makes it possible to separate, to a certain degree, reactions in which the atoms

[1)] This follows, in particular, from experiments with a Q-switched iodine laser [2].