Isospin splitting of giant dipole resonance and the cross section of the reaction $^{64}Zn(\gamma,n)^{63}Zn$

S. S. Verbitskiĭ, A. M. Lapik, B. S. Ratner, and A. N. Sergievskiĭ

Institute of Nuclear Research, USSR Academy of Sciences
(Submitted 2 February 1978)
Pis'ma Zh. Eksp. Teor. Fiz. **27**, No. 5, 315–319 (5 March 1978)

The cross section of the reaction $^{64}Zn(\gamma, n)^{63}Zn$ was investigated for the high-energy component of the neutron spectrum ($\epsilon_n \geq 3.7$ MeV). An analysis of the results indicates that the interpretation of the structure observed in the cross section of the $^{64}Zn(\gamma, n)^{63}Zn$ as a manifestation of isospin splitting is in error.

PACS numbers: 25.20.+y, 24.30.Cz

The influence of isospin conservation on the properties of the cross sections of the photonuclear reactions has been considered in a number of theoretical and experimental studies. According to the isospin selection rules, the isovector electric dipole resonance in nuclei with $T \neq 0$ consists of two components with $T=T_0(T_<)$ and $T=T_0+I(T_>)$, whose energy differs by an amount $\Delta E=E_>-E_<=UT_>/T_<$, where U is the "symmetry" energy.[1] A number of investigations of the cross section of the reactions (p, γ), (γ, n), (γ, p) and others in the region of medium-weight atoms were carried out to verify these data. From this point of view, the most thorough studies were made of the reactions on the ^{64}Zn nucleus.[2–6] Thus, it was established in[2] that the cross section of the reaction $^{63}Cu(p, \gamma)\,^{64}Zn$ (as well as a number of other reactions of this type with nuclei having $A \sim 60$ and $A \sim 90$) reveal two peaks, which apparently pertain to the resonances $T_<$ and $T_>$. An energywise close structure was observed in the cross section of the reaction $^{64}Zn(\gamma,n)\,^{63}Zn$,[3,6] and this gave grounds for regarding this structure likewise as a manifestation of isospin splitting. It should be noted that the identification of the resonances $T_<$ and $T_>$ is made difficult by the absence of distinguishing features of these resonances. Some light can be cast by investigations during which the energy of the neutron emitted in the (γ, n) reaction is fixed. The point is that the decay of the resonance $T_>$ via the neutron channel is allowed only to final-nucleus states with isospin $T_0+1/2$, which lie relatively high, i.e, this decay is accompanied by emission of low-energy neutrons.

One of the tasks of the present investigation, in which we measured the cross section of the reaction $^{64}Zn(\gamma, n)\,^{63}Zn$ for the high-energy component of the neutron spectrum, consisted in checking the correctness of the aformentioned identification of the structure in the cross section.

The yield curve of the $^{64}Zn(\gamma, n)\,^{63}Zn$ reaction at the minimal value of the energy of the emitted neutrons $\epsilon_{min}=3.7$ MeV was investigated with the synchrotron of our Institute from the threshold to the energy limit of the bremsstrahlung spectrum $E_{\gamma m}=26.3$ MeV, in steps of 0.1–0.2 MeV. The neutrons were registered with a previously described[7–9] spectrometer based on stilbene crystals. The target was 142 g of powered zinc oxide enriched to 99% with the ^{64}Zn isotope[1)], placed in an organic-glass cassette. To determine the influence of the reaction $^{16}O(\gamma, n)\,^{15}O$ due to the oxygen contained in the target, measurements were made with the cassette filled with water. The contribution of the background to the reaction yield ranged from 4 to 22%, depending on the energy $E_{\gamma m}$. The number of measurements of the yield at each value of $E_{\gamma m}$ was 10–11. The yield curves of the reaction $^{64}Zn(\gamma, n)\,^{63}Zn$, after subtracting the background and introducing various corrections, including corrections for the registration efficiency with allowance for the shape of the energy spectrum of the

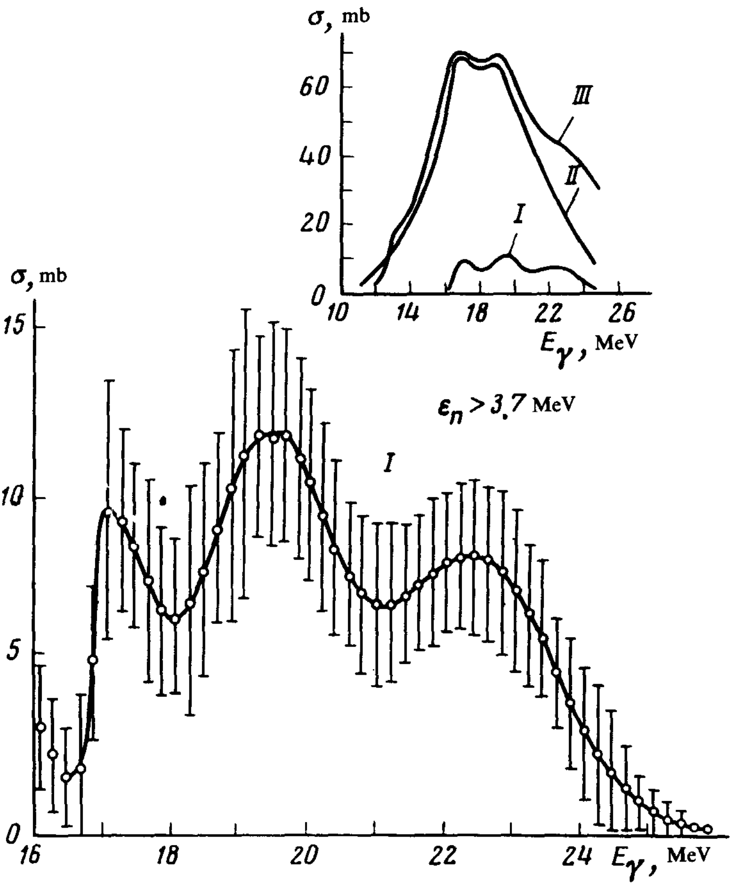

FIG. 1. Curve I) Cross section of the reaction $^{64}Zn(\gamma,n)\,^{63}Zn$ for neutrons with energy $\epsilon_n \geqslant 3.7$ MeV, obtained in the present study. Curve II) Cross section of the reaction $^{64}Zn(\gamma,n)\,^{63}Zn$ from[3]. Curve III) Total cross section of the reactions $^{64}Zn(\gamma,n)\,^{63}Zn$ and $^{64}Zn(\gamma,np)\,^{62}Cu$ from[6].

neutrons, were reduced with a BÉSM-6 computer by the method of statistical regularization[10] in order to obtain the cross section. The cross section were determined from the yield errors by the method described previously[7]

The cross section of the reaction $^{64}Zn(\gamma, n)\,^{63}Zn$ at $\epsilon_n \geqslant 3.7$ MeV is shown in Fig. 1 (curve 1), which shows also the cross section of the reaction $^{64}Zn(\gamma,n)\,^{63}Zn$[3] and the total cross section of the reactions $^{64}Zn(\gamma,n)\,^{63}Zn$ and $^{64}Zn(\gamma,np)\,^{62}Cu$,[6] which are accompanied by emission of neutrons of all energies. In the registration of the energetic neutrons, the contribution of the (γ, np) reaction is quite small because of its high effective threshold (assuming $\epsilon_{p\,\min} = 2$ MeV and $E_{0_{np}} = 18.5$ MeV, we obtain a threshold equal to 24.2 MeV). The cross section curve was normalized by extrapolating the neutron spectrum to the low-energy region and determing the fraction of the neutrons with $\epsilon_n \geqslant 3.7$ MeV.

From a comparison of the cross sections of the (γ,n) reactions for the energetic neutrons (I) and for the neutrons of all energies (III) we see that the maximum at $E \sim 17.0$ MeV and 19.0 MeV are present on both curves (we note incidentally that the maximum in the cross section of the (p,γ) reaction at $E = 15.8$ MeV is shifted by 1 MeV relative to the maximum in the reaction (γ,n). By plotting the difference of the cross sections II and I (Fig. 2) we obtain the cross section for the emission of neutrons with energy $\epsilon_n < 3.7$ MeV. On this curve there is no peak at $E_\gamma = 18.9$ MeV. The lower state of the final nucleus ^{63}Zn with $T = T_0 + 1/2$, to which the resonance $T_>$ can decay, has an energy $E = 5.42$ MeV.[11] The energy of the neutrons emitted in this case is $\epsilon_n = 18.9 - 11.9 - 5.4 = 1.6$ MeV. It follows therefore that the maximum at $E_\gamma = 18.9$ MeV in the cross section of the (γ,n) reaction cannot be ascribed to the resonance $T_>$.

Thus, our present results seem to indicate that there is no noticeable isospin splitting in the cross section of the reaction $^{64}Zn(\gamma, n)\,^{63}Zn$. This conclusion probably

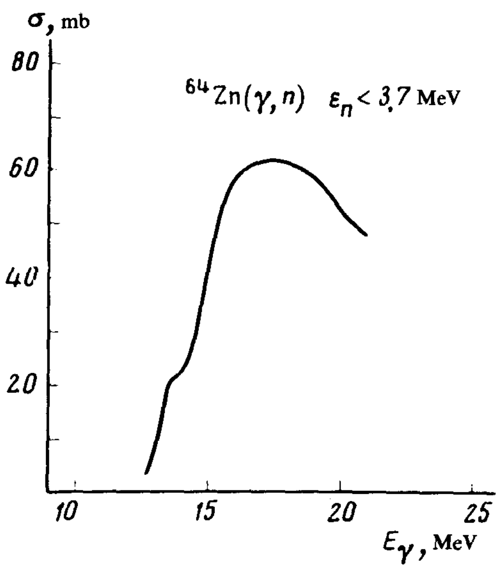

FIG. 2. Cross section for the emission of neutrons with energy $\epsilon_n < 3.7$ MeV in the reaction $^{64}Zn(\gamma,n)\,^{63}Zn$, obtained from the difference of the cross sections III and I of Fig. 1.

does not predict the observed isospin splitting in the (p,γ) reaction, for in the latter case there are no restrictions imposed by the slection rules. In addition, the (p,γ) reaction corresponds (in the inverse reaction) to a transition of the final nucleus to the ground state, which makes a small contribution to the photoabsorption cross section. A more detailed discussion of other results of the present investigation will be reported later.

[1)]Obtained from the State Stockpile of Stable Isotopes.

[1]R.O. Akyuz and S. Fallieros, Phys. Rev. Lett. **27**, 1016 (1971).
[2]P. Paul, J.F. Amann, and K.A. Snower, ibid. **27**, 1013 (1971).
[3]B.C. Cook, R.C. Morrison, and F.H. Schamber, ibid. **25**, **685** (1970).
[4]C.Y. Yamaguch, J. Phys. Soc. Japan **34**, 1123 (1973).
[5]G.E. Clark, R.C. Morrison, J.E.E. Baglin, and B.C. Cook, Nucl. Phys. **A213**, 358 (1973).
[6]P. Carlos, H. Beil, R. Bergere, J. Fagot, A. Lepretre, A. Vyssiere, and G.V. Solodukhov, Nucl. Phys. **A258**, 365 (1976).
[7]S.S. Verbitskiĭ, B.S. Ratner, A.N. Sergievskiĭ, Pis'ma Zh. Eksp. Teor. Fiz. **23**, 538 (1976) [JETP Lett. **23**, 492 (1976)].
[8]B.S. Ratner, A.N. Sergievsky, and S.S. Verbitsky, Nucl. Phys. **A285**, 71 (1977).
[9]S.S. Verbitskiĭ and B.S. Ratner, Kratkie soobshcheniya po fizike No. **1**, 40 (1977).
[10]V.G. Ivanchenko, Trudy FIAN SSSR **63**, 151 (1972).
[11]C.M. Fou, R.W. Zurmuhle, and J.M. Joyce, Nucl. Phys. **A97**, 458 (1967).