that differ from $\delta(T_0)$ by a factor not larger than 10 (Fig. 1b). We then get $(\Delta T_c - \Delta T_e)/\Delta T_e$ ~ 13%, i.e., the discrepancy is small.

It follows from these estimates that a study of the dependence of this singularity on the purity of the metal at helium temperatures is hindered by the difficulty of obtaining the required range of sample purity necessary to keep the singularity in this region at all times. In order to estimate in this case the role of the usual scattering mechanisms accompanied by umklapp it is obviously necessary to broaden the temperature interval (to ~14°K), as will be done in the future. This is also necessary to ascertain the possibility of observing another interesting singularity - a minimum of resistivity, which should be observed in thin samples [4].

In conclusion we thank B. I. Verkin for continuous interest in the work, R. N. Gurzhi for a valuable discussion of the measurement results, and O. G. Shevchenko for help with the experiments.

[1] R. E. Peierls, Quantum Theory of Solids, Oxford, 1955.

[2] B. N. Aleksandrov and I. G. D'yakov, JETP 43, 852 (1962), Soviet Phys. JETP 16, 603 (1963).

[3] B. N. Aleksandrov, Dissertation, Low-temp. Physico-techn. Inst. Ukr. Acad. Sci. 1964.

[4] R. N. Gurzhi, JETP 47, 1414 (1964), Soviet Phys. JETP 20, 953 (1965).

[5] De Vroomen and C. Van Baarle, Physica 23, N8, 1957.

[6] Low Temperature Physics, Handbuch d. Physik, Springer, 1956.

[7] E. S. Borovik, V. G. Volotskaya, and N. Ya. Fogel', JETP 45, 46 (1963), Soviet Phys. JETP 18, 34 (1964).

SHELL EFFECTS IN THE CROSS SECTION OF THE REACTION $Zn^{67}(\gamma p)$

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Study of the energy and angular distributions of photoprotons emitted by nuclei having one or two protons in excess of the $1f_{7/2}$ filled shell, corresponding to the magic nucleus with Z = 28, has pointed to the existence of shell effects [1,2]. The contribution from the individual shells is apparently also manifest in the cross section of the (γp) reaction [3]. It is of interest to obtain more accurate data with respect to the connection between the photoproton cross section and the shell structure of the nucleus.

We have chosen for this purpose the nucleus Zn^{67}, which has two protons in the state $2p_{3/2}$ in excess of the filled $1f_{7/2}$ shell. Data on the angular distribution of the photoprotons from natural zinc, where the main role is played by Zn^{64} [2], show that the contribution of the direct photoeffect amounts to more than 30% of the photoproton yield. The ratio of the nucleon binding energies in Zn^{64} and Zn^{67}, taking into account the different density of the

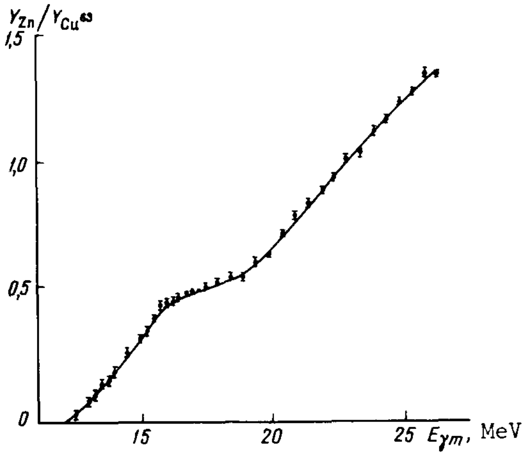

Fig. 1

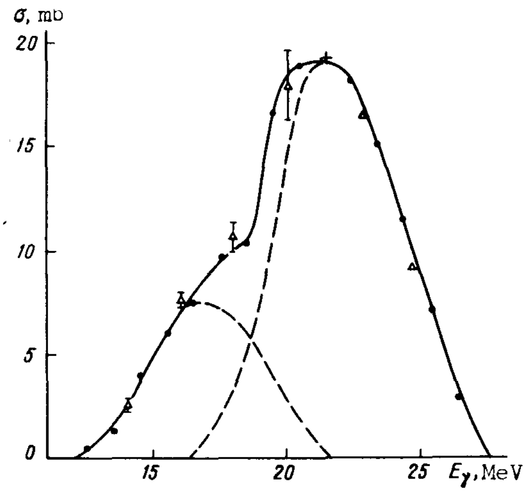

Fig. 2. Cross section of the reaction $Zn^{67}(\gamma p)Cu^{66}$ vs. E_γ. • -- cross section calculated with 1 MeV interval, △ -- with 2 MeV interval. The dashed curves are drawn under the assumption that the form of the cross section for proton emission from the $1f_{7/2}$ shell (position of the maximum and half-width) is the same as in the case of the reaction $Ni^{62}(\gamma p)$ [6].

levels of the final nuclei, makes the probability of evaporation of protons from Zn^{67} much lower than from Zn^{64}. We can therefore conclude that the yield of the reaction $Zn^{67}(\gamma p)$ is due essentially to the direct photoeffect.

The target was a zinc sample enriched with Zn^{67} and weighing 156 mg (39.8% Zn^{67} and 6.0% Zn^{64}) [1]. The yield of the reaction $Zn^{67}(\gamma p)$ was measured as a function of the maximum γ-quantum energy $E_{\gamma m}$ of the 30-MeV Physics Institute synchrotron, by recording the β activity of the final Cu^{66} nucleus (T = 5.1 min) with two end-window counters (BFL-25). The activity due to the reaction $Zn^{67}(\gamma p)$ was separated from the activity due to the reaction $Zn^{64}(\gamma n)$ by analyzing the decay curve with an M-20 electronic computer, using the least-squares method. The yield of the reaction $Zn^{64}(\gamma, pn)$ was estimated to be less than 1% of the yield of the investigated reaction. The monitor was the reaction $Cu^{63}(\gamma n)Cu^{62}$. The ratio of the yield of the reactions $Zn^{67}(\gamma p)$ and $Cu^{63}(\gamma n)$ is plotted in Fig. 1 as a function of the energy $E_{\gamma m}$ (rms errors are indicated).

The curve showing the cross section of the reaction $Zn^{67}(\gamma p)$, calculated from the relative yield curve by the photon-difference method [4] under the assumption that the cross section of the reaction $Cu^{63}(\gamma n)$ corresponds to the data of [5], is shown in Fig. 2. The cross section of the reaction $Zn^{67}(\gamma p)Cu^{66}$ at the maximum, for E_γ = 21.5 MeV, is 19.0 mb. The integral cross section is equal to 118 MeV-mb. If we assume that the cross section of the (γp) reaction on the $1f_{7/2}$ shell has the same form as the cross section for the nickel nucleus with filled $1f_{7/2}$ shell, then we can obtain data on the contribution of the two p-shell protons to the cross section of the reaction $Zn^{67}(\gamma p)$. We use the results obtained for the reaction $Ni^{62}(\gamma p)$ [6]. As seen from Fig. 2, the contribution from the protons in excess of the shell has a maximum at E_γ = 17.0 MeV. The integral cross section amounts to 0.31 of the total integral cross section of the reaction. The distance between the p and f levels is found to be 5 MeV.

Comparing the data on the cross section with the angular distributions of the photoprotons from zinc, measured at E = 20.8 and 23.3 MeV [2], we find that the maximum in the cross section at E = 17.0 MeV corresponds to a considerable proton anisotropy (b/a ~ 0.4), but the maximum at E = 22.0 MeV corresponds to a practically isotropic proton distribution. It is of interest to note that for photoprotons with energy $E_p \geq 5$ MeV from copper [3] two peaks were obtained in the cross section at energies E_γ = 12.5 and 16.5 MeV, in place of one braod peak in the case of zinc. In this connection, more accurate data on the cross section of photoproton emission from copper are most desirable.

The reaction $Zn^{68}(\gamma p)$ was investigated earlier [7]. The cross section at the maximum for E_γ = 22 MeV, equal to 11.7 mb, is smaller than for Zn^{67}, in accord with the previously observed decrease of the cross section of the direct photoeffect with increasing number of neutrons at a specified value of Z [8].

Thus, the reactions at low energies like the reactions (p, 2p) and (e, e'p) can be used at high energies to determine the proton binding energies in the internal shells of nuclei, provided the bombarded nuclei are appropriately chosen.

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[1] E. M. Leikin, R. M. Osokina, and B. S. Ratner, Nuovo Cimento Suppl. 3, 105 (1956).
[2] R. M. Osokina and B. S. Ratner, JETP 32, 20 (1957), Soviet Phys. JETP 5, 1 (1957).
[3] B. S. Ratner, JETP 46, 1157 (1964), Soviet Phys. JETP 19, 783 (1965).
[4] B. S. Ratner, Preprint A-114, Phys. Inst. Acad. Sci., 1965.
[5] A. L. Berman and K. L. Brown, Phys. Rev. 96, 83 (1954).
[6] J. Carver and W. Turchinetz, Proc. Phys. Soc. 73, 585 (1959).
[7] El. Sioufi, P. Erdos, and P. Stoll, Helv. Phys. acta 30, 264 (1957).
[8] Kuo Ch'i-ti and B. S. Ratner, JETP 39, 78 (1960), Soviet Phys. JETP 12, 1098 (1961).

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EXCITED STATES OF THE He^4 NUCLEUS

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Excited states of the He^4 nucleus were observed by many authors [1-3]. A hypothesis has been recently advanced that alongise the well established levels with energies 19.94 (0^+) and