Polarization effects produced as a result of inelastic scattering of protons near 20 MeV with excitation of the different 2^+, 4^+ and 6^+ states in ^{90,92}Zr and ^{92,94}Mo nuclei

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On the basis of experiments on inelastic scattering of polarized protons with energy of about 20 MeV, we show that the analyzing power of $A(\theta)$ is sensitive to the excited states in ^{90,92}Zr and ^{92,94}Mo nuclei.

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In this paper we formulate conclusions arrived at by us in studying polarization effects in the inelastic scattering of protons, primarily on the ^{90,92}Zr and ^{92,94}Mo nuclei examined here, which we reported in advance elsewhere.[1]

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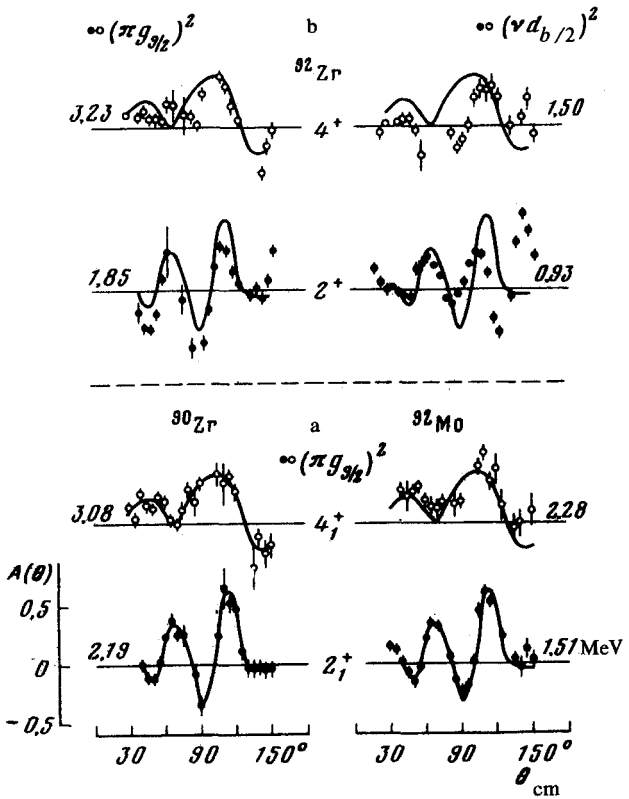

FIG. 1. Angular dependences of the analyzing power of $A(\theta)$ in the (p,p') process at $E_p = 20$ MeV with excitation of the indicated levels of ^{90}Zr and ^{92}Mo nuclei (a) and ^{92}Zr nucleus (b). The smooth curves for the 2_1^+ (2.19 MeV) and 4_1^+ (3.08 MeV) states of ^{90}Zr, which are drawn through the experimental points, are used as reference curves for comparison of the $A(\theta)$ dependences of other 2^+ levels (filled circles) and 4^+ levels (open circles), respectively.

This paper is a continuation of preceding investigations.[2,3] The experiments were performed by using the cyclotron of the Center for Nuclear Studies in Saclay. The polarization of the proton beam was about 80% on the average and the proton energy was 20 MeV.

From a comparison of the angular dependences of the analyzing power $A(\theta)$, which correspond to the same values of I^π, we can see the following (Fig. 1). The $A(\theta)$ dependences are sufficiently similar for the 2^+ levels: 2.19-MeV level of ^{90}Zr, 1.51-MeV level of ^{92}Mo, and 1.85-MeV level of ^{92}Zr. The 4^+ levels, in turn, also demonstrate the same similarity of $A(\theta)$: 3.08-MeV level of ^{90}Zr, 3.23-MeV level of ^{92}Zr, and 2.28-MeV level of ^{92}Mo. The indicated $A(\theta)$ dependences of the first group of 2^+ and 4^+ levels differ strongly from those of the second group: 2^+, 0.93-MeV and 4^+, 1.50-MeV levels of ^{92}Zr, respectively. But, as is well known from numerous studies, in particular Refs. 4–7, the first group of the 2^+ and 4^+ levels is determined by the dominating two-proton configuration $(g_{9/2})^2$ and the second group is determined by

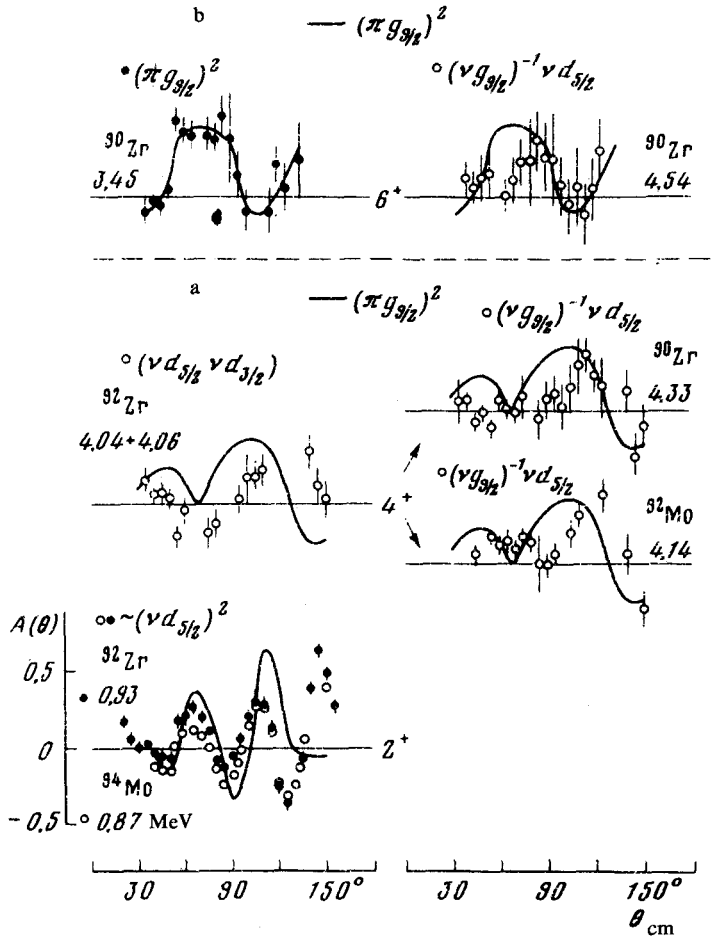

FIG. 2. Angular dependences of the analyzing power of $A(\theta)$ in the inelastic scattering of ~20-MeV protons due to excitation of the indicated energy states with $I^\pi = 2^+, 4^+$, and 6^+ of the ^{90,92}Zr and ^{92,94}Mo nuclei. The solid curves for the 2_1^+ (2.19 MeV), 4^+ (3.08 MeV) (see Fig. 1), and 6^+ (3.45 MeV) states of ^{90}Zr, which are drawn smoothly through the experimental points of $A(\theta)$, are used as reference curves for comparison with the $A(\theta)$ dependences of other levels with $I^\pi = 2^+, 4^+$, and 6^+, respectively.

the two-neutron configuration $(d_{5/2})^2$. The ^{92}Zr nucleus has 2^+ and 4^+ levels of both the first and second configurations. Of course, only some of these levels have absolutely pure configurations. Thus, although the 2^+, 1.85-MeV level of ^{92}Zr is characterized by the determining role of proton excitation $(g_{9/2})^2$, 2^+, it also contains an impurity composed of 25–30% neutron configuration $(d_{5/2})^2$, 2^+.[5,6]

As shown in Fig 2a, the $A(\theta)$ dependence for the 2_1^+, 0.93-MeV level of ^{92}Zr in turn is similar to that of the 2_1^+, 0.87-MeV level of ^{94}Mo (the data for ^{94}Mo were taken from Ref. 8). These 2_1^+ states in both nuclei, as is well known, are the result of the addition of two valence neutrons of the super magic neutron shell $N = 50$.

The difference of $A(\theta)$ between the 4^+, 1.50-MeV level of ^{92}Zr and the 3.08-MeV level of ^{90}Zr shown in Fig. 1b is also demonstrated by the sum of the two 4^+- and 4^+-MeV levels (4.04 +4.06) of ^{92}Zr in comparison with the same 3.08-MeV state of ^{90}Zr (Fig. 2a). But the 1.50-MeV level of ^{92}Zr, as indicated above, is determined by the two-neutron excitation with the $(d_{5/2})^2$ configuration and the 4^+, 4.04- and 4.06-MeV states of ^{92}Zr are characterized by the two-particle configuration of the valence neutrons $(d_{5/2}d_{3/2})$, which is fragmented between these two, closely spaced 4^+ energy levels.[6] It is interesting that such peculiarities (in comparison with the same 4^+, 3.08-MeV $(\pi g_{9/2})^2$ level of ^{90}Zr) also describe to a large extent the 4^+, 4.33-MeV state of ^{90}Zr and the 4.14-MeV state of ^{92}Mo (Fig. 2a) But these last two 4^+ states are also determined by neutron excitation of the closed neutron shell $N = 50$ in this case, rather than by neutron excitation of the valence shell. Each one of them is composed of almost 90% of the same neutron configuration $(g_{9/2})^{-1}d_{5/2}$.[7,9,10]

As for the levels with $I^\pi = 6^+$, the difference between the $A(\theta)$ dependences can also be seen in the case of their excitation with energies of 4.54 and 3.45 MeV in the same ^{90}Zr nucleus (Fig. 2b). The 4.54-MeV level of ^{90}Zr has the $(g_{9/2})^{-1}d_{5/2}$ neutron configuration[9] and the 6^+, 3.45-MeV state of ^{90}Zr is characterized by excitation of the valence protons $(\pi g_{9/2})^2$.[4,5]

The data of this work do not corroborate the recently expressed suppositions[11] about the significant effect of the resonance processes on $A(\theta)$ in the examined nuclei in the (p,p') reaction at these proton energies, but rather demonstrate, as a result of excitation of ^{90,92}Zr and ^{92,94}Mo, the role of the levels, which is due primarily to the proton and neutron shell structure of the nuclei.

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