STRIPPING REACTIONS ON THE Zr^{90} *AND* Zr^{91} *NUCLEI*

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The values of the transferred angular momenta, parities, and possible spins of the ground and excited states of the Zr^{90} and Zr^{91} nuclei are determined by comparing the experimental proton angular distributions in stripping reactions with the theory.

THE angular distributions of protons in the reactions $Zr^{90,91}$ (d, p) $Zr^{91,92}$ were investigated using the extracted beam of 13.6-Mev deuterons from the cyclotron of the Physics Institute of the Ukrainian Academy of Sciences.

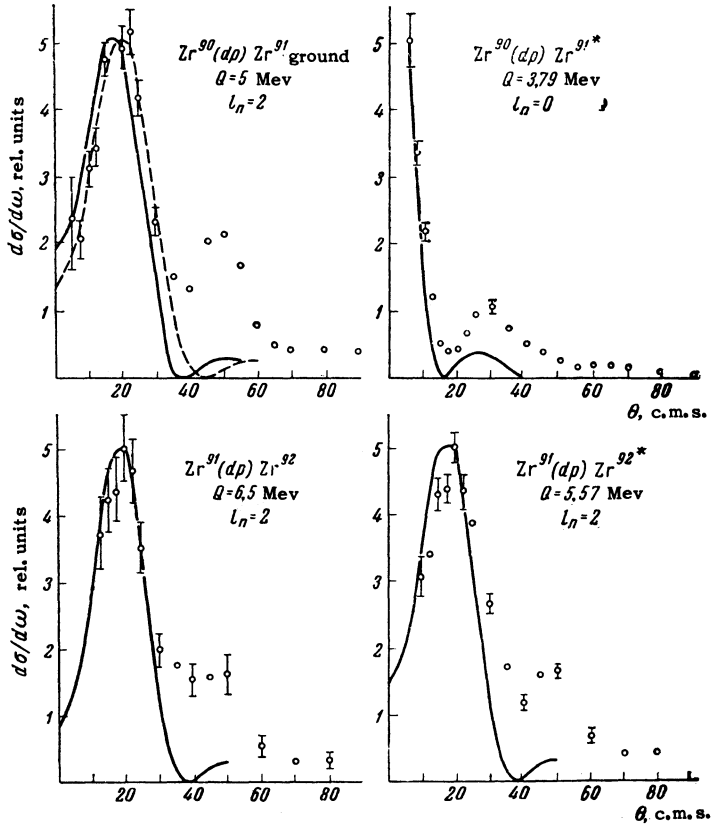
The geometry and experimental procedure were described earlier.[1] The present experiment differed in that a polystyrene absorber was placed ahead of the chamber to cut off the deuteron. The Zr^{90} target was a polystyrene film containing finely powdered enriched $Zr^{90}O_2$.

The angular distributions obtained are shown in the figure. The solid curves are calculated by the Butler theory.[2]

The spin, orbital-momentum, and energy-level data obtained by comparison with experiment, and also the radii r_0 used in the calculations, are listed in the table.

The values of Q, 5 Mev for Zr^{90} (d, p) Zr^{91} and 6.5 Mev for Zr^{91} (d, p) Zr^{92}, agree with the data of reference 3.

According to the level scheme proposed by Klinkenberg, when the number of neutrons exceeds 50 the states $d_{5/2}$, $g_{7/2}$, $h_{11/2}$, $d_{3/2}$, and $s_{1/2}$ begin to be filled. Nilsson's calculations give for the spherical case a somewhat different filling order, namely $d_{5/2}$, $g_{7/2}$, $s_{1/2}$, $d_{3/2}$, and $h_{11/2}$. The spin and parity $5/2^+$ which our experiments yield for



Reaction	J_{init}	Energy of the level of the final nucleus, Mev	l_n	J^{π}_{fin}	r_0, Fermi units
Zr^{90} (d, p) Zr^{91}	0	0	2	$3/2^+$, $5/2^+$	7.16 (6.15)*
		1.21	0	$1/2^+$	7.16
Zr^{91} (d, p) Zr^{92}	$5/2$	0	2	0^+, 1^+—5^+	7.19
		0.93	2	$0^+, 1^+, 2^+, 3^+, 4^+, 5^+$	7.19

*The number in the parentheses is the radius for the dotted curve, Fig. 1a.

the ground[6] state of Zr^{91} agree with the data that Brun et al. obtained by measuring the spin directly, and with the values of the spin predicted by the shell model ($d_{5/2}$). The spin and parity $1/2^+$ of the first-excited state (with energy 1.21 Mev) does not fit in any of the schemes referred to above. To explain the obtained value of the spin within the framework of Nilsson's calculations for the spherical case,[5] it is necessary to assume that the state $g_{7/2}$, which should lie between $d_{5/2}$ and $s_{1/2}$, either was not registered by us or does not exist at all. In Klinkenberg's scheme even the states $g_{7/2}$, $h_{11/2}$ and $d_{3/2}$ would have to be regarded as unregistered or nonexistent.

On the other hand, Dzhelepov and Peker[7] give for the 1.21-Mev level of Zr^{91} a value $J^{\pi} = 5/2^+$, which is also difficult to interpret from the point of view of the shell model. We note that in the case of the reaction Sr^{88} (d, p) Sr^{89} it was observed[8] that for the first excited state of Sr^{88} the 51-st neutron is also captured in the $s_{1/2}$ state. Such a coincidence can hardly be accidental.

According to Dzhelepov and Peker,[7] $J^{\pi} = 2^+$ for the 0.93-Mev level of Zr^{92}. If the spin and parity of the ground state of Zr^{91} are $5/2^+$, then according to the selection rules this state can be formed in stripping reactions[2] by transfer of angular momenta 0, 2, and 4. The fact that only the momentum $l_n = 2$ is observed signifies that $l_n = 0$ is forbidden by the selection rules of the shell model. The possibility that the transitions to the ground states of the final nuclei are forbidden was pointed out by Bethe and Butler.[9] We know of no other examples for transitions into excited states.

In conclusion, the authors take this opportunity to thank A. P. Klyucharev for providing the metal target of enriched Zr^{91} and to the cyclotron crew for ensuring uninterrupted operation of the apparatus.

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