^{68}Zn(d,p)^{69}Zn reaction at 7.5 MeV[†]

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The ^{68}Zn$(d,p)^{69}$Zn reaction has been studied with an incident deuteron bombarding energy of 7.5 MeV. A total of 48 levels below $E_x = 4.8$ MeV have been identified in ^{69}Zn.

[NUCLEAR REACTIONS ^{68}Zn(d,p), (d,d), $E_d = 7.5$ MeV; measured $\sigma(E_p, \theta)$, Q. ^{69}Zn deduced levels, J, π, l_n. Enriched target.]

The ^{68}Zn$(d,p)^{69}$Zn reaction has been used many times[1-6] to study the energy-level structure of ^{69}Zn, as have the ^{70}Zn$(p,d)^{69}$Zn reaction[7] and the ^{68}Zn$(n,\gamma)^{69}$Zn reaction,[8,9] but there were many unresolved levels. In the present work, 48 levels below 4.722 MeV were identified; 13 for the first time.

The MIT-ONR Van de Graaff accelerator was used to obtain the deuteron beam and the reaction products were momentum-analyzed using the MIT multiple-gap spectrograph. In addition to the 7.5 MeV deuteron exposure for the ^{68}Zn(d,p) study, a 7.5 MeV deuteron elastic scattering experiment was done to determine optical-model parameters for the incident channel. To obtain the effective target thicknesses, 3.0 MeV deuteron elastic scattering measurements were used and the cross sections normalized to the Rutherford cross sections.

The target was prepared by evaporating enriched Zn supplied by the Oak Ridge National Laboratory on to a Formvar backing. An isotopic mass analysis of the ^{68}Zn target material gave 0.3% ^{64}Zn, 0.25% ^{66}Zn, 0.12% ^{67}Zn, 99.3% ^{68}Zn, and 0.05% ^{70}Zn. The measured thickness of the target plus backing was 11 μg/cm^2.

The Q value for the ground state transition was found to be 4243 ± 10 keV in agreement with the value of 4259 ± 10 keV found by Ehrenstein and Schiffer.[1] Forty-eight levels in ^{69}Zn were identified up to $E_x = 4.722$ MeV (see Table I). The excitation energies are arithmetic averages of values determined for a number of reaction angles and are expected to be accurate to about ±5 keV for the lowest levels increasing to ±10 keV for the highest levels. For $l_n = 0$ transitions the values of $(d\sigma/d\Omega)_{\max}$ given in Table I are the measured differential cross sections at the most forward angle ($\theta = 7.5°$). The elastic scattering cross section for the 7.5 MeV deuterons incident on the ^{68}Zn target was analyzed using the optical-model code ABACUS.[10] Using the search routine that varied all the parameters, in order to obtain an over-all least-squares fit to the experimental data, we found: $V = 118.3$ MeV, $r_0 = 1.0$ fm, $a = 0.812$ fm, $W = 0.0$ MeV, $W^1 = 13.15$ MeV, $r_0^1 = 1.415$ fm, $a^1 = 0.683$ fm, and $r_{0c} = 1.3$ fm. The DWBA calculations were performed using the zero-range code JULIE.[11,12]

Of the previously reported levels below 4.722 MeV, seven were not seen in this work: 1.986, 2.544, 2.740, 3.457, 3.539, 4.125, and 4.291 MeV (assigned J^π of $\frac{1}{2}^-$ or $\frac{3}{2}^-$, $(\frac{5}{2})^+$, $(\frac{5}{2}^+)$, $\frac{5}{2}^+$, $\frac{1}{2}^+$, $\frac{3}{2}^+$, and $\frac{3}{2}^+$, respectively[1,5]). With the exception of the

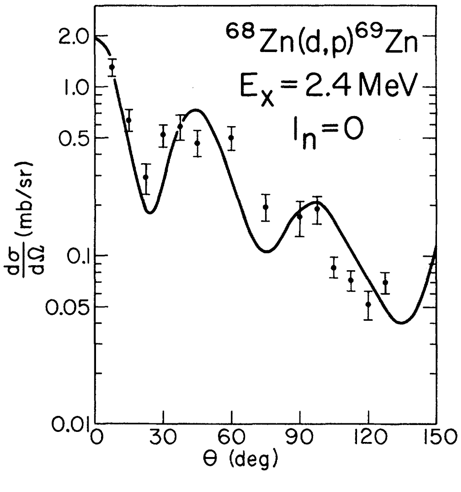

FIG. 1. Angular distribution of the $E_x = 2.400$ MeV transiton in ^{69}Zn. The solid curve is a distorted-wave Born-approximation fit to the experimental data.

TABLE I. The levels of ^{69}Zn up to $E_x = 4.722$ MeV determined from the ^{68}Zn$(d,p)^{69}$Zn reaction.

Level No.	E_x (MeV)	$(d\sigma/d\Omega)_{\max}$ (mb/sr)	l_n	J^π
1	0.0	0.3	1	$\frac{1}{2}^-$
2	0.440	0.45	4	$\frac{9}{2}^+$
3	0.530	0.14	3	$\frac{5}{2}^-$
4	0.835	0.80	1	$\frac{3}{2}^-$
5	0.868	1.0	2	$\frac{5}{2}^+$
6	0.967			
7	1.002			
8	1.136			
9	1.224			
10	1.338 [a]			
11	1.436 [a]			
12	1.629	0.4	2	$\frac{5}{2}^+$
13	1.696	1.8	0	$\frac{1}{2}^+$
14	1.786 [a]			
15	1.831		1 [b]	$\frac{3}{2}^{-}$ [c]
16	1.941			
17	2.256			
18	2.268	0.35	0	$\frac{1}{2}^+$
19	2.281			$\frac{1}{2}^{+}$ [d]
20	2.400	1.3	0	$\frac{1}{2}^+$
21	2.504 [a]	0.16	1	$\frac{1}{2}^-, \frac{3}{2}^-$
22	2.580	0.27	1	$\frac{1}{2}^-, \frac{3}{2}^-$
23	2.607 [a]			
24	2.625 [a]			
25	2.663	1.6	0	$\frac{1}{2}^+$
26	2.828	0.28	0	$\frac{1}{2}^+$
27	2.905	0.25	2	$\frac{5}{2}^+$
28	2.919 [a]	0.35	1	$\frac{1}{2}^-, \frac{3}{2}^-$
29	2.950		2 [b]	$(\frac{5}{2})^{+}$ [b]
30	3.014	0.90	2	$\frac{5}{2}^+$
31	3.061	0.54	0	$\frac{1}{2}^+$
32	3.091 [a]			
33	3.120 [a]			
34	3.134 [a]			
35	3.194		2 [b]	$(\frac{5}{2})^{+}$ [b]
36	3.338			
37	3.385	1.7	0	$\frac{1}{2}^+$
38	3.438		(0) [b]	$(\frac{1}{2}^+)$ [b]
39	3.671			
40	3.913			
41	3.978 [a]			
42	4.089			
43	4.193 [a]			
44	4.262			
45	4.518			
46	4.620			
47	4.661 [a]			
48	4.722			

[a] Previously unreported levels.
[b] Reference 1.
[c] Reference 5.
[d] Reference 8.

2.504- and 2.919-MeV levels (reported here for the first time) and the 2.400-MeV level, we confirmed previous l_n assignments for ^{69}Zn. Barchuk *et al.*,[8] Zabegai *et al.*,[4] Ehrenstein and Schiffer,[1] and Thomson[5] all assign $l_n = 2$ and $J^\pi = \frac{5}{2}^+$ to the 2.400-MeV level; however, our angular distribution was forward-peaked and suggests $l_n = 0$ and $J^\pi = \frac{1}{2}^+$ (see Fig. 1).

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