Structure of ^{51}Cr

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(Received 28 February 1983)

Some comments are made on calculations with the generalized semimicroscopic model and a deformed configuration mixing shell model in the light of results obtained with a cluster-phonon model. Although the models yield a fairly good description of experimental data, a manifest discrepancy exists with these on the $B(E2;^{1}3/2 \rightarrow \text{g.s.})$ values predicted by the generalized semimicroscopic and cluster-phonon models. There is also a difference in expected values for the nuclear deformation.

[NUCLEAR STRUCTURE ^{51}Cr; calculated levels, $J, \pi, B(E2)$, $B(M1)$, q, μ, S, b, τ. Cluster-phonon model; particle-hole excitations.]

Some time ago a description of the properties of the low-lying negative-parity states of ^{51}Cr was performed with the generalized semimicroscopic model.[1] (Hereafter, this paper will be referred to as I.) An alternative description has been given by Ahalpara[2] with a deformed configuration mixing shell model. Calculated energy levels and electromagnetic properties with both models compared favorably with experimental data then available. Recently, Saha, Maynard, and Robertson[3] have suggested that more detailed intermediate coupling calculations would be very interesting in shedding more light on the structure of the low-lying levels of ^{51}Cr. We have performed such calculations with a cluster-phonon model[4] using the computational system NUCORE (Ref. 5) with and without the coupling of two phonons to 2h-1p excitations. A further refinement in the calculation takes into account anharmonicities of the quadrupole vibrating core.[6] Since the results are quite similar, we discuss only the latter. For the calculation of electromagnetic properties the following set of effective values for the charges and gyromagnetic ratios were used: $e_n = 0.15e$, $e_{vib} = Ze$, $g_R = 0.08$, and $g_s = -2.19\mu_N$, which are within the ranges used in I. Ahalpara[2] uses the larger value, $e_n = 0.64e$.

Some features of the present calculations deserve special attention. We use the following notation for the one-phonon components of the levels: $(J_h, l_j)J \otimes R\pi$ (2h-1p excitations) and $f_{7/2} \otimes R\pi$ (1h excitations.) For the zero-phonon components the notation $(J_h, l_j)I$ is used. $R\pi$ is the angular momentum and parity of the phonon, J_h is the resultant angular momentum of the two $f_{7/2}$ holed, J is the cluster angular momentum, I is that of the nucleus, and l_j stands for the particle orbitals.

In the low-lying levels, the nonzero seniority 2h-1p excitations practically replace the collective ones in such a way that those with two phonons contribute less than 4%. Further, the amplitudes of those with zero seniority also contribute less than 4% except in the case of the amplitude of the $(0, f_{5/2})\frac{5}{2}$ component in the $^{1}5/2$ level; nonetheless it is reduced to a value of 0.275. Consequently, the nature of the levels is not so pure as in I and the spectroscopic factors for the ^{50}Cr$(d,p)^{51}$Cr reaction tend to be smaller than the observed ones.[7] The structure of the $^{1}9/2$ and $^{1}11/2$ levels is practically the same, having comparable amplitudes of the zero-phonon $(6, p_{3/2})I$, and the one-phonon $f_{7/2} \otimes 2+$ components. The $^{1}13/2$ and $^{1}15/2$ levels also have an important contribution of the first component together with the $(6, p_{3/2})\frac{13}{2} \otimes 2+$ configuration in the former, and with the $(6, f_{5/2})\frac{15}{2}$ in the latter. In Ahalpara's model, all these levels belong to the $K = \frac{7}{2}$ ground-state band. On the other hand, the $^{2}3/2$, $^{2}5/2$, $^{3}7/2$, $^{1}9/2$, and $^{1}11/2$ levels can be considered as members of the one-phonon multiplet $f_{7/2} \otimes 2+$, a situation similar to that found in I. However, the rather strong configuration mixing does not allow a clear-cut classification of the levels. Actually, the nature of the ground state and that of the $^{3}7/2$ level are quite similar. In the group of levels $^{1}3/2$, $^{1}1/2$, $^{1}5/2$, and $^{2}7/2$ there is a major contribution from the zero-phonon $(2, p_{3/2})I$ state. It is to be noted that in the $^{1}5/2$ level the configuration mixing is of notorious importance: The four main components $(0, f_{5/2})\frac{5}{2}$, $(2, p_{3/2})\frac{1}{2} \otimes 2+$, $(2, f_{5/2})\frac{9}{2} \otimes 2+$, and $(2, p_{3/2})\frac{5}{2}$ contribute only between 4% and 10%. In the description of Ahalpara these levels belong to the excited $K = \frac{1}{2}$ band. All levels from the $^{2}17/2$ up to the 25/2's are purely collective with one- and two-phonon components.

The modification in the nature of levels mentioned above is reflected in $B(E2)$ values as compared with those of I, which in turn influence the values of other electromagnetic properties. The most striking differences are found for the values of the electric quadrupole transition probabilities $^{1}11/2 \rightarrow {}^{1}9/2$, $^{1}15/2 \rightarrow {}^{1}11/2$, and $^{1}13/2 \rightarrow {}^{1}11/2$, as may be seen in Table I. From the relation between enhancement of $E2$ transition probabilities and deformation, one may conclude that the model in I implies somewhat larger deformations than the present one. On the other hand, the values calculated by Ahalpara would indicate a much greater deformation. Unfortunately, the question of deformation for these states cannot be decided upon due to the scarcity of experimental values. The only measured transition probability is $B(E2;^{1}11/2 \rightarrow {}^{1}7/2)$ and both models yield results

TABLE I. Experimental and calculated $B(E2)$ values for ^{51}Cr. The starred transitions involve levels belonging to the $K=\frac{1}{2}$ band in Ahalpara's model (Ref. 2).

Transition I_i	I_f	Expt.	$B(E2)$(W.u.) A[d]	AHK[e]	This work
^{1}3/2	^{1}7/2	0.064 ± 0.006[a]		4.4	2.7
^{1}1/2	^{1}3/2*	$< 7\times10^5$[a]	47.3	15.5	13.7
^{2}9/2	^{1}5/2*	$8.4^{+4.2}_{-5.3}$[c]	32.9		10.8
^{1}5/2	^{1}1/2*	$13.6^{+8.0}_{-5.5}$[b]	23.6	7.5	7.7
^{1}5/2	^{1}3/2*	$10.3^{+5.5}_{-4.4}$[b]	6.7	3.0	2.1
^{1}11/2	^{1}9/2		18.4	2.1	0.59
^{1}11/2	^{1}7/2	7.4 ± 3.4[c]	4.4	13.4	8.6
^{2}7/2	^{1}3/2*	$10.0^{+5.0}_{-5.7}$[c]	29.8	2.5	8.2
^{1}15/2	^{1}11/2	< 23[b]	9.5	24.9	3.1
^{1}13/2	^{1}11/2		15.0	9.2	0.46

[a] Reference 3.
[b] Quoted in Ref. 2.
[c] I. M. Szöghy, J. S. Forster, and G. C. Ball, Nucl. Phys. A201, 433 (1973).
[d] Reference 2.
[e] Reference 1.

which are in good agreement within experimental errors. The same is true for the half-life of the ^{1}11/2 level. In the group of levels which in Ahalpara's model belong to the $K=\frac{1}{2}$ band, it is seen in Table I that three known $B(E2)$ values are very well reproduced by the present model, whereas the corresponding results of Ahalpara are too high, thus suggesting that the approach would overestimate the deformation, as Ahalpara has already pointed out.[2]

The present model does not resolve the large discrepancy obtained in I, the half-life of the ^{1}3/2 level, 40 ps, which is a factor of 100 faster than that observed by Saha, Maynard, and Robertson,[3] (4.73 ± 0.49) ns. This results from the large value obtained for $B(E2;{}^1\text{3/2} \rightarrow \text{g.s.})$ which cannot be lowered to the experimental value (see Table I) even though it has been reduced by almost a factor of 2 from that obtained in I. The respective values are not quoted by Ahalpara, probably because in his model no mixing of states with different K takes place. It would be interesting if calculations for ^{51}Cr were made using the unified model developed by Heyde and collaborators[8]—which succeeded in discribing odd-mass indium isotopes—in order to investigate if these discrepancies can be removed.

The rest of the results do not merit any comment since no major improvement on the level sequence and electromagnetic properties is obtained over those of Refs. 1 and 2.

It is a great pleasure to express our indebtedness to the authorities of the Centro de Tecnología y Ciencias de Sistemas, Buenos Aires, for kindly granting us permission to use the computing facilities there.

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