THE LOW-LYING STATES OF ^{59}Co IN THE GENERALIZED SEMIMICROSCOPIC MODEL

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In a previous paper |1| we described the low-lying states of ^{49}Ti, ^{51}Cr and ^{57}Co with the generalized semimicroscopic model (GSMM) |2|. In this model, the states of a nucleus with odd-mass number A are approximated by linear combinations of the states of a hole coupled to an A+1 single-closed vibrating core and those of a particle coupled to an A-1 vibrating core. We faced certain difficulties in the detailed description of some peculiarities in ^{57}Co, so that it seems worthwhile to perform some calculations on ^{59}Co, the other cobalt isotope for which a reasonable amount of experimental data exist to make sense in comparison with theory. In this case, the basis states are those of a hole in the $1f_{7/2}$ shell coupled to the quadrupole phonons of ^{60}Ni and those of a particle which has available $1f_{5/2}$, $2p_{3/2}$ and $2p_{1/2}$ orbits, coupled to the quadrupole phonons of ^{56}Fe.

We used the following single-particle energies of the protons: $\varepsilon(f_{5/2})-\varepsilon(p_{3/2}) = 0.75$ MeV and $\varepsilon(p_{1/2})-$

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TABLE 1

Comparison of experimental |3| and calculated negative-parity states below 2 MeV and spectroscopic factors (2I+1)S in ^{59}Co.

I		Energy (MeV)		(2I+1)S		
Exper.	Calc.	Exper.	Calc.	(^{3}He,d)	(α,t)	Calc.
7/2	7/2	0	0	1.36	1.52	0.95
3/2	3/2	1.10	0.97	0.44	0.32	0.51
5/2, 9/2	9/2	1.19	1.04			0
3/2	3/2	1.29	1.74	1.36	1.04	0.95
(1/2)	1/2	1.43	1.32	0.74	0.58	0.56
$\geq$7/2	11/2	1.46	1.25			0
$\leq$7/2		1.48				
(7/2)	5/2	1.74	1.85			0.002
5/2, 7/2	7/2	2.06	1.93			0.57

$-\varepsilon(p_{3/2})$ = 1.05 MeV, taken from the experimental energy levels of ^{57}Ni, and $\varepsilon(f_{7/2})-\varepsilon(p_{3/2})$ = 2.57 MeV which was estimated from the proton separation energy. The phonon energies were set equal to the energy of the $^{1}2^{+}$ states of the corresponding vibrators, namely $\hbar\omega(^{58}\mathrm{Fe})$ = 0.805 MeV and $\hbar\omega(^{60}\mathrm{Ni})$ = 1.333 MeV. The corresponding quadrupole deformations were $\beta(^{58}\mathrm{Fe})$ = 0.25 and $\beta(^{60}\mathrm{Ni})$ = 0.20. In addition, the coupling constant of the cluster-field interaction was set equal to 0.9 times the value resulting from the radial wave functions corresponding to a Woods-Saxon potential with spin-orbit coupling. It has been found that the position of the $^{1}1/2$ and $^{1}3/2$ levels is very sensitive to the value of this coupling constant, which is the only free parameter. As for the remaining parameters, the vibrator charges were fixed at $(Z\beta/\sqrt{5})$, and the two usual values of the effective proton charge and gyromagnetic ratios |1| were used.

The calculated energy spectrum and spectroscopic factors compare favourably with the experimental ones |3| (table 1). In particular, the two low-lying 3/2 and the first 1/2 states are predicted with the correct nature as far as the experimental data on spectroscopic factors are concerned (see also table 2); the first 3/2 is mainly collective, whereas the second is predominantly of particle type. Table 3 shows the electromagnetic properties calculated with $e^{\mathrm{eff}} = e$, $g_R = 0$, $g_s^{\mathrm{eff}} = 3.5$. It is seen that they are fairly well described with this model, except the E2 transition probability from the $^{2}3/2$ level to the ground state.

TABLE 2.

Components X 10^3 of the negative-parity states in ^{59}Co below 2 MeV. Each state is indicated by its ordering number and spin. The base vectors are $|\ell_j,NR\rangle$, where ℓ_j labels the single-particle subshell, and N and R indicate the number of phonons and their total angular momentum, respectively. Only amplitudes contributing more than 4% are listed.

$1_{7/2}$	
$\|f_{7/2}, 00\rangle$	689
$\|f_{7/2}, 12\rangle$	612
$\|f_{7/2}, 24\rangle$	231
$\|f_{7/2}, 20\rangle$	206

$1_{9/2}$	
$\|f_{7/2}, 12\rangle$	705
$\|f_{7/2}, 24\rangle$	528
$\|f_{7/2}, 22\rangle$	-358

$1_{1/2}$	
$\|p_{3/2}, 12\rangle$	570
$\|p_{1/2}, 00\rangle$	530
$\|f_{5/2}, 12\rangle$	427
$\|f_{7/2}, 24\rangle$	335

$1_{5/2}$	
$\|f_{7/2}, 12\rangle$	635
$\|f_{7/2}, 24\rangle$	497
$\|f_{7/2}, 22\rangle$	385
$\|p_{3/2}, 12\rangle$	269
$\|f_{7/2}, 33\rangle$	250

$1_{3/2}$	
$\|f_{7/2}, 12\rangle$	704
$\|f_{7/2}, 22\rangle$	472
$\|p_{3/2}, 00\rangle$	357

$1_{11/2}$	
$\|f_{7/2}, 12\rangle$	718
$\|f_{7/2}, 24\rangle$	555
$\|f_{7/2}, 22\rangle$	262
$\|f_{7/2}, 36\rangle$	238

$2_{3/2}$	
$\|p_{3/2}, 12\rangle$	508
$\|p_{3/2}, 00\rangle$	-487
$\|f_{7/2}, 24\rangle$	361
$\|f_{7/2}, 22\rangle$	320
$\|p_{1/2}, 12\rangle$	312

$2_{7/2}$	
$\|f_{7/2}, 00\rangle$	535
$\|f_{7/2}, 22\rangle$	486
$\|p_{3/2}, 12\rangle$	303
$\|f_{7/2}, 12\rangle$	-299
$\|f_{7/2}, 20\rangle$	-287
$\|f_{7/2}, 32\rangle$	-268
$\|f_{7/2}, 24\rangle$	-220

TABLE 3

Comparison of calculated (first row) and experimental (second row) values of B(E2), B(M1), mixing δ and branching b ratios, electric quadrupole Q and magnetic dipole μ moments, and mean lifetimes τ for some low-lying negative-parity states in ^{59}Co.

Transition $^{\tau}I_i$	 $^{\tau'}I_f$	B(E2)$^{a)}$ [W.u.]	B(M1) [W.u.]	$\delta^{b)}$	$b^{b)}$ [%]
$^{1}3/2$	$^{1}7/2$	15.5			100
		13.0±2.6			100
$^{1}9/2$	$^{1}7/2$	25.7	0.28	-0.23	100
		12.9±1.2		-0.25±0.05	100
$^{1}11/2$	$^{1}9/2$	7.40	0.39	-0.02	12
					<10
$^{1}11/2$	$^{1}7/2$	16.2			88
		6.6±1.0			>90
$^{1}1/2$	$^{1}3/2$	14.9	0.01	-0.33	100
					100
$^{2}3/2$	$^{1}1/2$	6.84	0.36	-0.04	47
					0
$^{2}3/2$	$^{1}3/2$	15.0	0.02	-0.48	21
					7±4
$^{2}3/2$	$^{1}7/2$	2.13			32
		17.6±2.9			93±4
$^{1}5/2$	$^{1}3/2$	15.8	0.42	-0.12	15
					20±3
$^{1}5/2$	$^{1}7/2$	3.23	0.26	0.15	85
					80±3

Level $^{\tau}I$	Q [eb]	μ [μ_N]	$\tau^{a)}$ [ps].
$^{1}7/2$	0.495	4.177	
	0.39±0.6$^{c)}$	4.616±0.009$^{d)}$	
$^{1}3/2$	0.127	3.18	4.6
			>2.9

TABLE 3 (continued)

Level τ_I	Q [eb]	μ [μ_N]	$\tau^{a)}$ [ps]
$1_{9/2}$	0.251	3.575	0.097 0.05±0.02
$1_{11/2}$	0.392	4.056	1.06 1.1±0.3
$1_{1/2}$		-0.331	67.6
$2_{3/2}$	-0.110	1.61 1.64±0.12[e)]	0.56 0.59±0.02
$1_{5/2}$	0.084	2.55	0.016

[a)] Ref. |3|. [b)] K.L. Coop, I.G. Graham and E.W. Titterton, Nucl. Phys. A150 (1970) 346. [c)] T.R. Fischer, A.R. Poletti and B.A. Watson, Phys. Rev. C8 (1973) 1837.
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