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Abstract

The structure of some even – even Pt isotopes have been studied within the framework of the interacting boson model. The B(E2), B(M1) and Q(I) values of the above nuclei have been calculated. The numerical results obtained for Pt have been compared with the previous experimental and theoretical values obtained on the basis of the interacting boson model (IBA-2).

Key Words: Interacting boson model, quadrupol moment, electromagnetic transitions.

1. Introduction

The interacting boson approximation has been rather successful at describing the collective properties of several medium and heavy nuclei. The interacting boson model (IBM) introduced Arima and Iachello [1] and Casten [2] has enjoyed considerable success in recent years. In this model, the low-energy states of even-even nuclei are described in terms of interactions between s(J=0) and d(J=2) bosons. The corresponding Hamiltonian is diagonalized in this boson space by employing some rather powerful and efficient group theory methods.

In the original version of the interacting boson model, the Pt isotopes are regarded as an illustration of the transition from the O(6) symmetry to the SU(3) symmetry [3]. There is also a lot of work [4,5] for the Pt isotopes in the interacting boson model (IBM-2).

2. The Model

For a given nucleus, the boson numbers N_υ and N_π are found by counting neutrons and protons from the nearest closed shells. The vector space of IBM-2 is then just the product of all possible states $(s,d)^{N_\upsilon}$ with those of $(s,d)^{N_\pi}$, where in each factor the set of states is the same as in IBM-1 [6]. In this analysis we have used the following Hamiltonian [7]:

$$H = \varepsilon(\tilde{n}_{d\upsilon} + \tilde{n}_{d\pi}) + \kappa.Q_\upsilon.Q_\pi + \tilde{\kappa}(Q_\upsilon.Q_\upsilon + Q_\pi.Q_\pi) + V_{\upsilon\upsilon} + V_{\pi\pi} + M_{\upsilon\pi}. \tag{1}$$

Here ε is the d-boson energy,κ is the strength of the quadrupole interaction between neutron and proton bosons.

In the IBA-2 model, the quadrupole moment operator is given by [8]

$$Q_\rho = (s_\rho^+ \bar{d}_\rho + d_\rho^+ s_\rho)^{(2)} + \chi_\rho (d_\rho^+ d_\rho)^{(2)}, \tag{2}$$

where $\rho = \upsilon, \pi$. χ_ρ is the quadrupole deformation parameter for neutrons ($\rho = \upsilon$) and protons ($\rho = \pi$). The last term $M_{\upsilon\pi}$ is the Majorana interaction, which has the form

$$M_{\upsilon\pi} = \frac{1}{2}\xi_2 (s_\upsilon^+ d_\pi^+ - d_\upsilon^+ s_\pi^+)^{(2)}.(\tilde{s}_\upsilon \tilde{d}_\pi - \tilde{d}_\upsilon s_\pi)^{(2)} - \sum_{k=1,3} \xi_k (d_\upsilon^+ . d_\pi^+)^{(k)}.(\tilde{d}_\upsilon . \tilde{d}_\pi)^{(k)}. \tag{3}$$

The term $\tilde{\kappa}(Q_\upsilon.Q_\upsilon + Q_\pi Q_\pi)$ is a quadrupole interaction among similar bosons. This part of the interaction introduces a triaxial component into the IBM-2 Hamiltonian when χ_υ and χ_π have opposite signs. This is the main difference between this Hamiltonian and the usual IBA-2 Hamiltonian

$$H = \varepsilon(\tilde{n}_{d\upsilon} + \tilde{n}_{d\pi}) + \kappa.Q_\upsilon.Q_\pi + V_{\upsilon\upsilon} + V_{\pi\pi} + M_{\pi\upsilon}, \tag{4}$$

where the terms $V_{\upsilon\upsilon}$ and $V_{\pi\pi}$ are the neutron - neutron and proton - proton d-boson interactions only.

3. Electromagnetic Transitions and Quadrupole Moments

The general one-body E2 transition operator in the IBM-2 is

$$T(E2) = e_\upsilon.Q_\upsilon + e_\pi.Q_\pi, \tag{5}$$

where Q_ρ is in the form of equation (2). For simplicity, the χ_ρ has the same value as in the Hamiltonian [9]. This is also suggested by the single j-shell microscopy. In general, the E2 transition results are not sensitive to the choice of e and e_π, whether $e_\upsilon = e_\pi$or not.

In the IBM-2, the M1 transition operator up to the one-body term is

$$T(M1) = \sqrt{\frac{3}{4\pi}}(g_\upsilon.L_\upsilon + g_\pi.L_\pi). \tag{6}$$

The g_υ and g_π are the boson g-factors that depends on the nuclear configuration. They should be different for different nuclei.

The quadrupole moments for the I^+ spin are given by

$$Q_I = \frac{3\kappa^2 - I(I+1)}{(I+1)(2I+3)}.Q_0. \tag{7}$$

4. Results and Discussion

In this calculation, we use the following criteria to determine the effective charges. e_π is a constant throughout the whole isotopic chain and the e_υ changes with neutron number. This is true if the neutron (proton) interaction does not depend on the proton (neutron) configurations. The values of e_π and e_υ are determined by fitting to the six B(E2, $0_1 \rightarrow 2_1$) and B(E2, $2_2 \rightarrow 2_1$) in ^{194}Pt. They are given in Table 1.

Table 1. Effective charge used in E2 transition calculations (e_π=0.174 eb).

	^{188}Pt	^{190}Pt	^{192}Pt	^{194}Pt	^{196}Pt	^{198}Pt
e_υ(eb)	0.128	0.109	0.131	0.138	0.143	0.144

For platinum 188 to 198, the χ_ρ parameter is taken in the usual way that χ_π keeps constant, χ_υ changes smoothly with neutron-boson number. Other parameters such as ε, $\kappa, \kappa^{'}$ are chosen separately for each nucleus. One notices that ε is almost a constant, and the change in κ and $\kappa^{'}$ is smooth. Meanwhile, we keep ξ_2= 0 for simplicity, and $\xi_3 = \quad -0.083$ MeV as constant for the whole isotopic chain to give an overall improvement. The parameters used are shown in Table 2.

Table 2. Parameters for the Hamiltonian for platinum isotopes (χ_π= -0.88, ξ_3=-0.083 MeV).

	ε (MeV)	χ_υ	κ(MeV)	$\kappa^{'}$(MeV)
^{188}Pt	0.475	0.448	- 0.163	- 0.027
^{190}Pt	0.456	0.536	- 0.142	- 0.038
^{192}Pt	0.453	0.592	- 0.143	- 0.044
^{194}Pt	0.450	0.745	- 0.144	- 0.047
^{196}Pt	0.459	0.794	- 0.167	- 0.043
^{198}Pt	0.484	0.937	- 0.184	- 0.029

In phenomenological studies g_υ and g_π are treated as parameters and are kept constant for a whole isotopic chain, and they are determined by fitting the g-factors of the 2_1^+ states.

The other calculated values are given in Table 3.4.5. In general, it can be seen from the tables that calculated results are in better agreement with the previous experimental and theoretical data.

Table 3. E2 transitions for the platinum isotopes (unit e^2b^2).

Nucleus	I_i	I_f	This Work	Experimental	Theoretical [b]
^{188}Pt	2_1	0_1	0.532	$0.520(94)^a$	0.52
	2_2	0_1	0.002	–	0.0017
	2_2	2_1	0.741	–	0.723
	4_1	2_1	0.744	–	0.723
^{190}Pt	2_1	0_1	0.351	$0.350(44)^a$	0.35
	2_2	0_1	0.016	–	0.014
	2_2	2_1	0.432	–	0.40
^{192}Pt	2_1	0_1	0.390	$0.382(12)^a$	0.382
				$0.367(4)^c$	
				$0.42(2)^d$	
	2_2	0_1	0.018	$0.0044(5)^d$	0.011
	2_2	2_1	0.491	$0.46(5)^d$	0.41
^{194}Pt	2_1	0_1	0.337	$0.332(12)^a$	0.332
				$0.332(2)^e$	
	2_2	0_1	0.015	$0.0014(2)^f$	0.0131
	2_2	2_1	0.396	$0.423(15)^g$	0.303
	4_1	2_1	0.457	$0.449(22)^g$	0.462
	4_2	2_1	0.001	–	0.0009
	4_2	4_1	0.220	$0.87(43)^g$	0.14
^{196}Pt	2_1	0_1	0.285	$0.280(8)^a$	0.280
				$0.276(1)^e$	
	2_2	2_1	0.321	$0.318(23)^h$	0.316
	4_1	2_1	0.396	$0.409(22)^h$	0.379
	4_2	2_1	0.002	$0.003(1)^i$	0.0012
	4_2	4_1	0.148	$0.193(97)^h$	0.130
^{198}Pt	2_1	0_1	0.215	$0.212(10)^a$	0.212
	2_2	0_1	0.004	$0.0003(1)^i$	0.0036
	2_2	2_1	0.270	$0.262(38)^i$	0.262
	4_1	2_1	0.282	$0.2700(23)^i$	0.276

[a] [10], [b] [9], [c] [11], [d] [12], [e] [13], [f] [14], [g] [15], [h] [4], [i] [3]

Table 4. M1 properties of the some even-even platinum isotopes (g in μN).

Nucleus		This Work	Experimental	Theoretical [b]
^{192}Pt	g_{2_1}	0.321	$0.284(20)^a$	0.335
	g_{2_2}	0.329	$0.36(7)^a$	0.353
			$0.324(46)^c$	
	g_{4_1}	0.338	$0.40(28)^a$	0.336
			$0.4(3)^d$	
^{194}Pt	g_{2_1}	0.310	$0.302(16)^a$	0.336
			0.320^c	
	g_{2_2}	0.352	$0.343(32)^a$	0.357
			$0.324(26)^c$	
^{196}Pt	g_{2_1}	0.344	$0.346(13)^a$	0.339
			$0.326(14)^c$	
	g_{2_2}	0.351	$0.375(75)^a$	0.355
			$0.30(6)^c$	
	g_{4_1}	0.349	$0.375(75)^a$	0.340
			$0.30(15)^c$	
^{198}Pt	g_{2_1}	0.337	$0.344(28)^a$	0.343
	g_{2_2}	0.346	$0.36(7)^a$	0.354
	g_{4_1}	0.345	$0.36(6)^a$	0.342

^{a}[16], ^{b}[9], ^{c}[17], ^{d}[18]

Table 5. Electric quadrupole moments (unit b).

Nucleus	J_i	This Work	Experimental	Theoretical [a]
^{188}Pt	2_1	+ 0.07	–	+ 0.08
	2_2	-0.06	–	-0.07
	4_1	+0.18	–	+0.19
^{190}Pt	2_1	+ 0.55	–	+ 0.54
	2_2	-0.54	–	-0.53
	4_1	+0.53	–	+0.53
^{192}Pt	2_1	+ 0.58	$+ 0.63(6)^b$	+0.59
			$+0.55(21)^c$	
	2_2	-0.59	–	-0.60
	4_1	+0.58	–	+0.59
^{194}Pt	2_1	+ 0.66	$+ 0.48(14)^b$	+0.68
			$+0.84(16)^d$	
	2_2	+0.54	$+0.5(5)^e$	-0.67
	4_1	+0.55	$+0.5(10)^e$	+0.69
^{196}Pt	2_1	+ 0.48	$+ 0.78(6)^d$	+0.43
			$+0.56(21)^f$	
	2_2	-0.37	$-0.23(+0.20;-0.34)^g$	-0.42
	4_1	+0.36	$+0.32(+0.25;-0.27)^g$	+0.47
^{198}Pt	2_1	+ 0.43	$+ 0.42(12)^h$	+0.27
			$+1.22(50)^f$	
	2_2	-0.29	–	-0.24
	4_1	+0.38	–	+0.37

^{a}[9], ^{b}[16], ^{c}[11], ^{d}[3], ^{e}[15], ^{f}[19], ^{g}[20], ^{h}[13]

In the quadrupol moment, qualitatively, with κ= 0 for the ground state band, the positive $Q_{2^+}$and Q_{4^+}mean a negative Q_0. For the gamma band, κ= 2 a negative Q_{2^+} means a negative Q_0. The negative Q_0 implies that the nucleus has an oblate shape.

The overall agreement is surprisingly good in view of the interacting boson approximation.

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