

THE IBM-2 STUDY FOR SOME EVEN - EVEN PLATINUM ISOTOPES

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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 (IBM-2).

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).

The Model

For a given nucleus, the boson numbers N_π and N_ν 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 $(s, d)^{N_\nu}$ 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]:

$$H = \varepsilon(n_{d\nu}^{\sim} + n_{d\pi}^{\sim}) + \kappa Q_\nu \cdot Q_\pi + \kappa^{\sim} (Q_\nu \cdot Q_\pi + Q_\pi \cdot Q_\nu) + V_{\nu\nu} + V_{\pi\pi} + M_{\pi\nu} \quad (1)$$

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

In the IBM-2 model, the quadrupole moment operator is given by [8] $Q_\rho = (s_\rho^+ d_\rho^{\sim} + d_\rho^+ s_\rho)^{(2)} + \chi_\rho (d_\rho^+ d_\rho)^{(2)}$ (2)

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

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$$M_{\nu\pi} = \frac{1}{2} \xi_2 (s_{\pi}^+ d_{\nu}^+ - d_{\pi}^+ s_{\nu}^+)^{(2)} \cdot (s_{\nu}^{\sim} d_{\pi}^{\sim} - d_{\nu}^{\sim} s_{\pi}^{\sim})^{(2)} - \sum_{k=1,3} \xi_k (d_{\nu}^+ d_{\pi}^+)^{(k)} \cdot (d_{\nu}^{\sim} d_{\pi}^{\sim})^{(k)}$$

(3) The term $\kappa^{\sim} (Q_{\nu} \cdot Q_{\pi} + Q_{\pi} \cdot Q_{\nu})$ is a quadrupole interaction among similar bosons. This part of the interaction introduces a triaxial component into the IBM-2 Hamiltonian when χ_{ν} and χ_{π} have opposite signs. This is the main difference between this Hamiltonian and the usual IBM-2 Hamiltonian

$$H = \varepsilon(n_{d\nu}^{\sim} + n_{d\pi}^{\sim}) + \kappa Q_{\nu} \cdot Q_{\pi} + V_{\nu\nu} + V_{\pi\pi} + M_{\pi\nu} \quad (4)$$

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

Electromagnetic Transitions and Quadrupole Moments

The general one-body E2 transition operator in the IBM-2 is $T(E2) = e_{\nu} \cdot Q_{\nu} + e_{\pi} \cdot Q_{\pi}$ (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 $e\pi$, whether $e\nu = e\pi$ or not.

In the IBM-2, the M1 transition operator up to the one-body term is $T(M1) = \sqrt{\frac{3}{4\pi}} (g_{\nu} \cdot L_{\nu} + g_{\pi} \cdot L_{\pi})$ (6)

The g_{ν} 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

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

Results and Discussion

In this calculation, we use the following criteria to determine the effective charges. $e\pi$ is a constant throughout the whole isotopic chain and the $e\nu$ changes with neutron number. This is true if the neutron (proton) interaction does not depend on the proton (neutron) configurations. The values of $e\pi$ and $e\nu$ are determined by fitting to the six B(E2, 01 → 21) and B(E2, 22 → 21) in 194Pt. They are given in Table 1.

For platinum 188 to 198, the $\chi\rho$ parameter is taken in the usual way that $\chi\pi$ keeps constant, $\chi\nu$ changes smoothly with neutron-boson number. Other parameters such as ε , κ , $\kappa^{\sim}$ are chosen separately for each nucleus. One notices that e is almost a constant, and the change in k and $k^{\sim}$ is smooth. Meanwhile, we keep $\xi_2 = 0$ for simplicity, and $\xi_3 = -0.083$ MeV as constant for the whole isotopic chain to give an overall improvement. The parameters used are shown in Table 2.

In phenomenological studies g_{ν} 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.

In the quadrupol moment, qualitatively, with $\kappa=0$ or the ground state band, the positive Q2+ and Q4+ mean a negative Q0. For the gamma band, $\kappa=2$ a negative Q2+ means a negative Q0. The negative Q0 implies that the nucleus has an oblate shape. The overall agreement is surprisingly good in view of the interacting boson approximation.

Table 1. Effective charge used in E2 transition calculations ($e_{\pi}=0.174$ eb).

	^{188}Pt	^{190}Pt	^{192}Pt	^{194}Pt	^{196}Pt	^{198}Pt
$e_{\pi}(\text{eb})$	0.128	0.109	0.131	0.138	0.143	0.144

Table 2. Parameters for the Hamiltonian for platinum isotopes ($\chi\pi=-0.8$ $\xi_3=-0.083$ MeV)

ε (MeV)	χ_v	κ (MeV)	κ' (MeV)
^{188}Pt		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

Table 3. E2 transitions for the platinum isotopes (unit e_2 b 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(1)	0.382
	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
	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()	0.280
	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[13]

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

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
	g_{4_1}	0.338	0.40(28) ^a	0.336
^{194}Pt	g_{2_1}	0.310	0.302(16) ^a	0.336
	g_{2_2}	0.352	0.343(32) ^a	0.357
^{196}Pt	g_{2_1}	0.344	0.346(13) ^a	0.339
	g_{2_2}	0.351	0.375(75) ^a	0.355
	g_{4_1}	0.349	0.375(75) ^a	0.340
^{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	Jj	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	+	+0.59
	2 ₂	-0.59	-	-0.60
	4 ₁	+0.58	-	+0.59
¹⁹⁴ Pt	2 ₁	+ 0.66	+	+0.68
	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	+	+0.43
	2 ₂	-0.37	-0.23(+0.20)	-0.42
	4 ₁	+0.36	+0.32(+0.25)	+0.47
¹⁹⁸ Pt	2 ₁	+ 0.43	+	+0.27
	2 ₂	-0.29	-	-0.24
	4 ₁	+0.38	-	+0.37

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دراسة تركيب نوى Pt باستخدام نموذج البوزونات المتفاعله (IBM).

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الخلاصة

تم في هذا البحث دراسة التركيب النووي لبعض نوى البلاتين (Pt) باستخدام نموذج البوزونات المتفاعلة . تم حساب $B(E2)$, $B(M1)$ و $Q(I)$ للنوى أعلاه . وقورنت النتائج النظرية المحسوبة باستخدام IBM-2 مع القيم العملية المتوفرة فكانت مطابقة لها .