Decay Properties of Low-Lying States in ^{192}Pt and ^{192}Os

Amir A. Mohammed-Ali

Physics Department
Science College, Karbala University

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Abstract

The β^- and (β^+ + E.C.) decays of ^{192}Ir to the levels of ^{192}Pt and ^{192}Os respectively have been investigated. HPGe detector was employed for the measurements of the γ-ray energies and relative intensities allowing the log*ft* values, spins and parities deduced.

Two new transitions and one new level at 1439 keV for ^{192}Pt and one level at 737 keV for ^{192}Os are suggested. The energy level scheme of ^{192}Os and ^{192}Pt has been established on the basis of energy sum considerations. Comparisons are made with predictions of the interacting boson model calculated on the basis of an O(6) for ^{192}Pt and SU(3) → O(6) transition for ^{192}Os.

Introduction

The low lying levels of ^{192}Pt and ^{192}Os populated in the β^- and (β^+ + E.C.) decays of ^{192}Ir ($T_{1/2}$ = 73.8 d) have been investigated theoretically [1-7] and experimentally by many workers [4, 8-12].

In brief, the main problems in the early work are as follows. Gehrke[9] studied the decay of ^{192}Ir with Ge(Li) detector. The existence of transitions at 329, 420, 694 and 704 keV were identified, and the 909 keV level in ^{192}Os was suggested on the basis of energy sum considerations. Moreover, it was observed that the relative γ-ray intensities in most case differ from those of Plasks et al[8]. Prasad et al[10] also studied the decay of ^{192}Ir using Ge(Li) detector and NaI(Tl)-NaI(Tl) sum coincidence spectrometer. They proposed the establishment of an 1118 keV level in ^{192}Os and confirmed the existence of gamma energies at 177.6,467.6, 694 and 1201 keV in ^{192}Pt. The observation for the first time of transitions at 784.6, 921 and 1201 keV, which depopulate 4^+, 3^+ and 4^+ level respectively to the ground state, deserve further attention as the angular momentum change involved in each transition is rather large. Yoshizawa et al[11] mainly provided relative intensities for the strong gamma rays from ^{192}Ir decay in view of their usefulness for the efficiency calibration in 200-1400 keV energy region. They have shown that the peaks at 624, 784 and 921 keV observed in their singles spectra were due summing of cascading gamma rays.Eid and Stewart[4] have made an extensive study of the ^{192}Ir decay in singles and coincidence modes using HPGe and Compton suppression system. They measured the intensities of 624, 784, 905, 921 and 1201 keV weak gamma rays. A spin value of 4^+ was assigned to the level at 1201 keV at ^{192}Pt by all previous workers[8-11]. But Eid and Stewart ruled out 4^+ spin and assigned firm 2^+ spin to the 1201 keV level by taking into account : I) log*ft* = 8.18, II) the decay by mixed (E2+M1) 416.5 keV gamma transition to the 4^+ state via the 1201 keV gamma transition.Finally, Mehta et al[12] have determined the spins and parities of the few excited states and miltipole mixing ratio in many gamma transition of ^{192}Pt and ^{192}Os from γ–γ directional correlation measurements using HPGe-HPGe detector combinations. A spin 4^+ to 1201 keV level in ^{192}Pt was reaffirmed on the basis of single and directional correlation measurements.

Taking into consideration the above mentioned discrepancies the decay of ^{192}Ir was reinvestigated. In the present work, the energies and intensities of the gamma-ray emitted in β^- and (β^+ + E.C.) decay for ^{192}Ir have been measured afresh employing HPGe efficient detector with by for the best resolution in single mode.

Experimental Methods and Results

The ^{192}Ir ($T_{1/2}$ = 73.8 d) radioactive source was found in the Iraqi Reactor, the activity was about 10μCi. Three different singles spectra were taken, ranging between 2-3 days depending upon the counting statistics, with HPGe detector (energy resolution 2.1 keV FWHM at 1332 keV peak of ^{60}Co). Background spectra were also taken each time under the same geometrical conditions and subtracted from the corresponding spectra of ^{192}Ir. In one further case a 2*cm* Pb absorber was placed in front of the detector to suppress intense low energy γ-rays which are sources of sum peaks. The source to detector distance was kept 25*cm*. The efficiency curve for HPGe detector in the energy region 80-1400 keV was generated as shown in Fig.(1).

Fig.(2) shows single spectrum and table (1) gives the relative intensities of γ-ray measured following the β^- and (β^+ + E.C.) decay of ^{192}Ir to ^{192}Pt and ^{192}Os. Two new γ-rays at 518 and 1439 keV are reported with intensities related to I(316.5keV)=100 being 0.003 and 0.0013. The intensities of γ rays are compared with the work of Eid and Stewart[4].

The present results are consistent with the result of Eid and Stewart[4] for most parts. The analysis of singles spectra enable a total of 50 gamma rays to be identified with computer code SAMPO 80 [13].

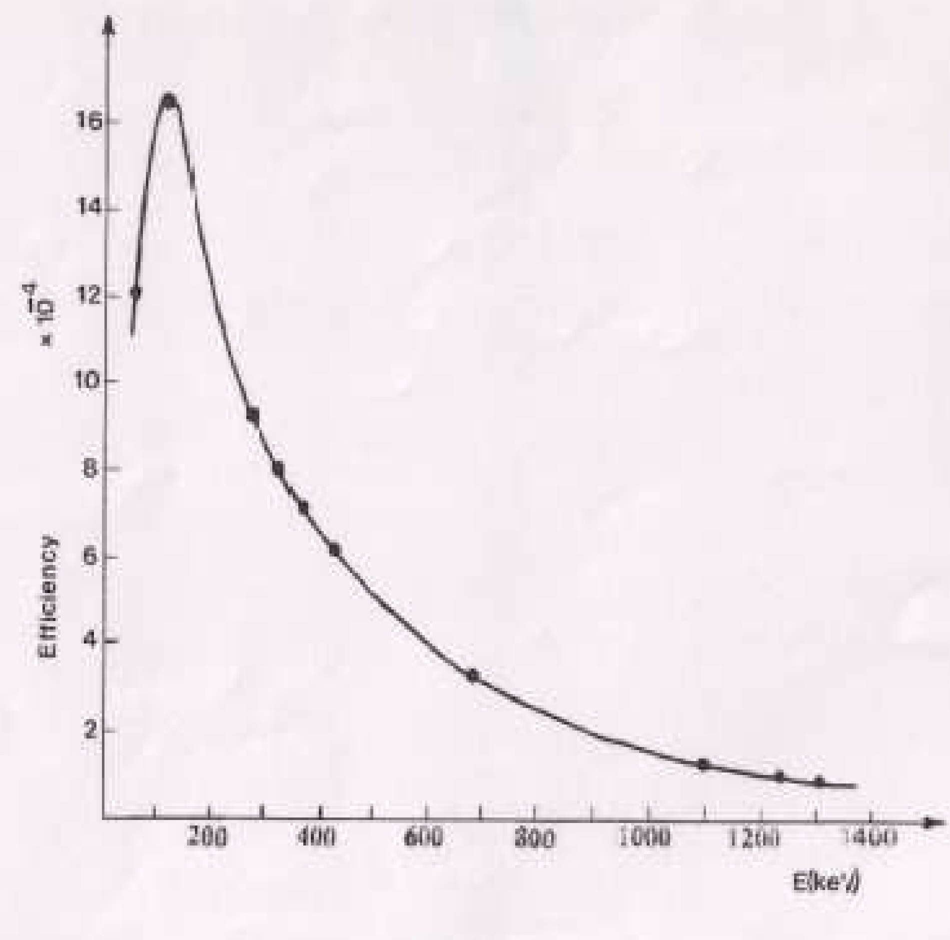

Figure 1. The absolute efficiency energy relationship for the HPGe detector

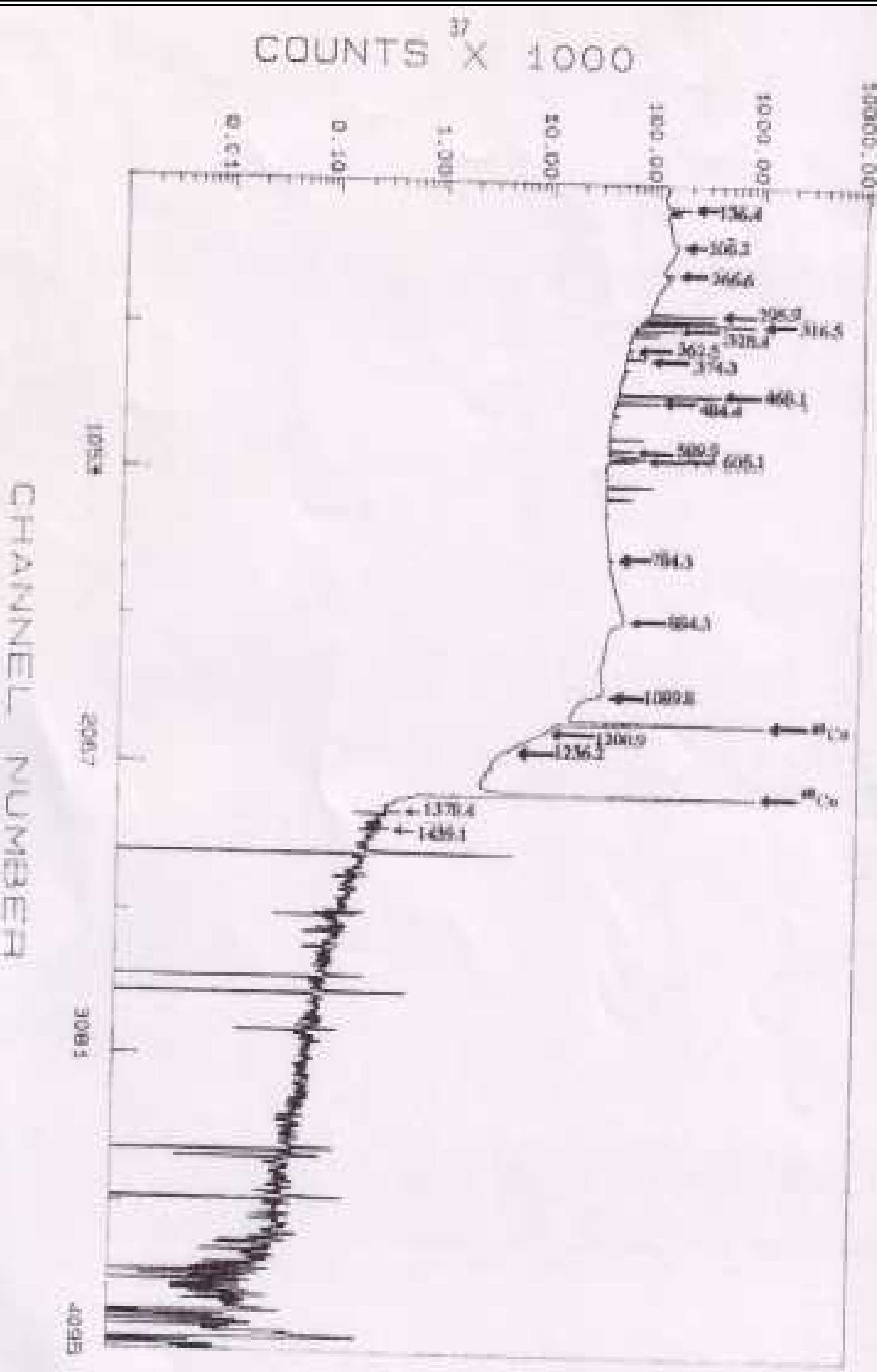

Figure 2. γ-ray singles spectrum of [illegible] (peak energies in keV).

Table 1. Relative Intensities of γ-rays emitted from the decay of ^{192}Ir.

Energy (keV)	Intensity related to I(316.5) =100 Present Work	Eid[4]
110.90(Os)	0.006(1)	0.011(4)
136.40(Pt)	0.180(2)	0.209(8)
156.30(Os)	0.010(3)	0.015(4)
176.60(Pt)	0.008(3)	0.006(2)
210.07(Os)	0.4(1)	0.62(2)
206.2(Os)	2.5(2)	3.93(7)
212.7(Pt)	0.014(1)	0.014(4)
215.4(Os)	0.0031(2)	0.014(10)
266.6(Pt)	0.0015(1)	0.001(1)
280.1(Pt)	0.0065(11)	< 0.005
282.6(Os)	0.25(2)	0.317(9)
295.9(Pt)	34.44(31)	34.81(66)
308.46(Pt)	35.53(32)	36.34(73)
316.5(Pt)	100	100
323.6(Os)	0.0132(2)	0.014(4)
328.4(Os)	0.018(1)	0.023(1)
362.5(Pt)	0.012(1)	0.009(4)
374.3(Os)	0.9(1)	0.87(2)
416.8(Pt)	0.82(5)	0.77(2)
420.6(Os)	0.053(2)	0.078(4)
451.9(Pt)	0.021(1)	0.014(4)
457.5(Pt)	0.022(1)	0.017(5)
468.1(Pt)	66.7(5)	58.24(97)
476.9(Pt)	0.0024(3)	0.0013(5)
484.4(Os)	4.0(3)	3.62(7)
489.8(Os)	0.41(4)	0.49(5)
518.2(Pt)	0.011(7)	-------
589.9(Pt)	7.20(2)	5.47(9)
594.1(Pt)	0.0058(5)	0.0043(7)
605.1(Pt)	10.95(2)	10.39(18)
612.4(Pt)	7.71(14)	6.77(12)
623.7(Pt)	0.040(2)	0.037(2)
629.6(Os)	0.02(1)	0.02(1)
704.2(Os)	0.007(1)	0.006(2)
737.7(Os)	0.0028(4)	0.0015(1)
766.1(Pt)	0.0021(3)	0.0018(2)
772.8(Pt)	0.002(1)	0.0031(2)
784.3(Pt)	0.071(2)	0.073(2)
884.3(Pt)	0.420(6)	0.366(6)
904.9(Os)	0.022(5)	0.0034(10)
912.3(Os)	0.0033(5)	0.0064(33)

Table 1. Continued

Energy (keV)	Intensity related to I(316.5) =100 Present Work	Eid[4]
920.8(Pt)	0.010(1)	0.0095(9)
1061.9(Pt)	0.046(2)	0.63(2)
1089.8(Pt)	0.0011(3)	0.0018(5)
1147.3(Pt)	0.0025(3)	0.003(2)
1200.9(Pt)	0.0081(1)	0.0022(1)
1236.2(Pt)	0.0063(8)	0.009(1)
1378.4(Pt)	0.0011(3)	0.001
1413.8(Pt)	< 0.001	0.0013(1)
1439.1(Pt)	0.0013(4)	------

Interacting Boson Model(IBM)

In the IBM the spectroscopies of low energy collective properties of even-even nuclei are described in terms of a system of interacting **s** bosons (L=0) and **d** bosons (L=2). Furthermore, the model assumes that the structure of the low-lying level is dominated by excitations among the valence particles outside closed major shells. In the particle space the number of proton bosons N_π, and neutron bosons N_ν, is counted from the nearest closed shells, and resulting total boson number is a strictly conserved quantity. The underlying structure of the six dimensional unitary group SU(6) of the model leads to a simple Hamiltonian, capable of describing the three specific types of collective structure with classical geometrical analogs (vibrational SU(5)[14], rotational SU(3)[15], and γ-unstable O(6)[18]) and also transitional nuclei whose structures are intermediate. In the simplest form, IBM-1, no distinction is made between neutron and proton boson, the Hamiltonian H can be written explicity in terms of boson creation (d) and annihilation (d) operators [17] such that,

$$\mathbf{H = \varepsilon n_d + a_0 P^\dagger . P + a_1 L.L + a_2 Q.Q + a_3\ T_3 T_3 + a_4 T_4 T_4} \qquad (1)$$

where $\varepsilon=\varepsilon_d-\varepsilon_s$ is the boson energy, a_0,a_1,a_2,a_3 and a_4 designate the strength of the pairing, angular momentum, quadrupole, actupole and hexadecupole in interactions between the bosons.
The E2 operator T(E2) has the form [18],

$$\mathbf{T(E2) = \alpha_2\ [d^\dagger \times s + s^\dagger \times d]^{(2)} + \beta_2\ [d^\dagger \times d]^{(2)}} \qquad (2)$$

Where ($s^\dagger$,$d^\dagger$) and (s,d) are the creation and annihilation operators for s and d bosons respectively, while α_2 and β_2 are two parameters.

The O(6) Limit

In this limit the Hamiltonian in Eq.(1) namely[17],

$$\mathbf{H = a_0 P^\dagger . P + a_1 L.L + a_3\ T_3 T_3} \qquad (3)$$

The eigenvalues in this limit are given by [18] as,

$$\mathbf{E\ (N,\sigma,\tau,n_\Delta,I) = 1/4\ A\ (N-\sigma)(N+\sigma+4) + 1/6\ B\tau\ (\tau+1) + CL(L+1)} \qquad (4)$$

A, B and C are constants and the quantum numbers of (4) are give the following meaning: N is the total number of bosons, the SU(6) quantum number; σ is the O(6) quantum number, τ is the O(5) quantum number; ν_Δ is related to the number of zero coupled triplets of bosons, which further subdivided the levels; L is the angular momentum in O(3).
The E2 operator T(E2) of the O(6) limit has the form[18]

$$\mathbf{T(E2) = \alpha_2\ [d^\dagger\ x\ s + s^\dagger\ x\ d]^{(2)}} \qquad (5)$$

And the selection rules $\Delta\sigma = 0$, $\Delta\tau = \pm 1$

The SU(3) to O(6)Transitional Case

The description of nuclei which a behaviour in between pure rotor and γ-unstable, corresponding to SU(3)→O(6) transitional region, the Hamiltonian can be written in the form[17],

$$\mathbf{H = a_0 P^\dagger . P + a_1 L.L + a_2 Q.Q} \qquad (6)$$

The changes in electromagnetic transition rates can be seen from the ratio[19],

$$\mathbf{R = [B(E2:\ 2_2^+ \rightarrow 0_1^+)]\ /\ [B(E2:\ 2_2^+ \rightarrow 2_1^+)]}$$

Where by
R = 0 in O(6)
and
R = 7/10 in SU(3)

Decay Scheme

Based on the energy sum relations, the decay schemes of ^{192}Pt and ^{192}Os were deduced and are shown in Fig.(3). The numbers at the base of the arrows indicate the energy of transitions, and the new transitions together with new levels are shown as dashed lines.

Table (2 and 3) show the branching ratio (BR's), the log*ft* values for the β^- and (β^++E.C.) decay of ^{192}Ir and deduced spins and parities. The BR's were calculated from the total intensity balance between the intensity of the decay and feeding γ-rays for each level, using Q_{β^-} and $Q_{(\beta^+ + E.C.)}$ of 1457 and 1468 keV respectively[21,22]. The log*ft* values were calculated according to the relations and table given in Ref.(20), allowing spins and parities to be deduced, consistent with b decay selection rules.

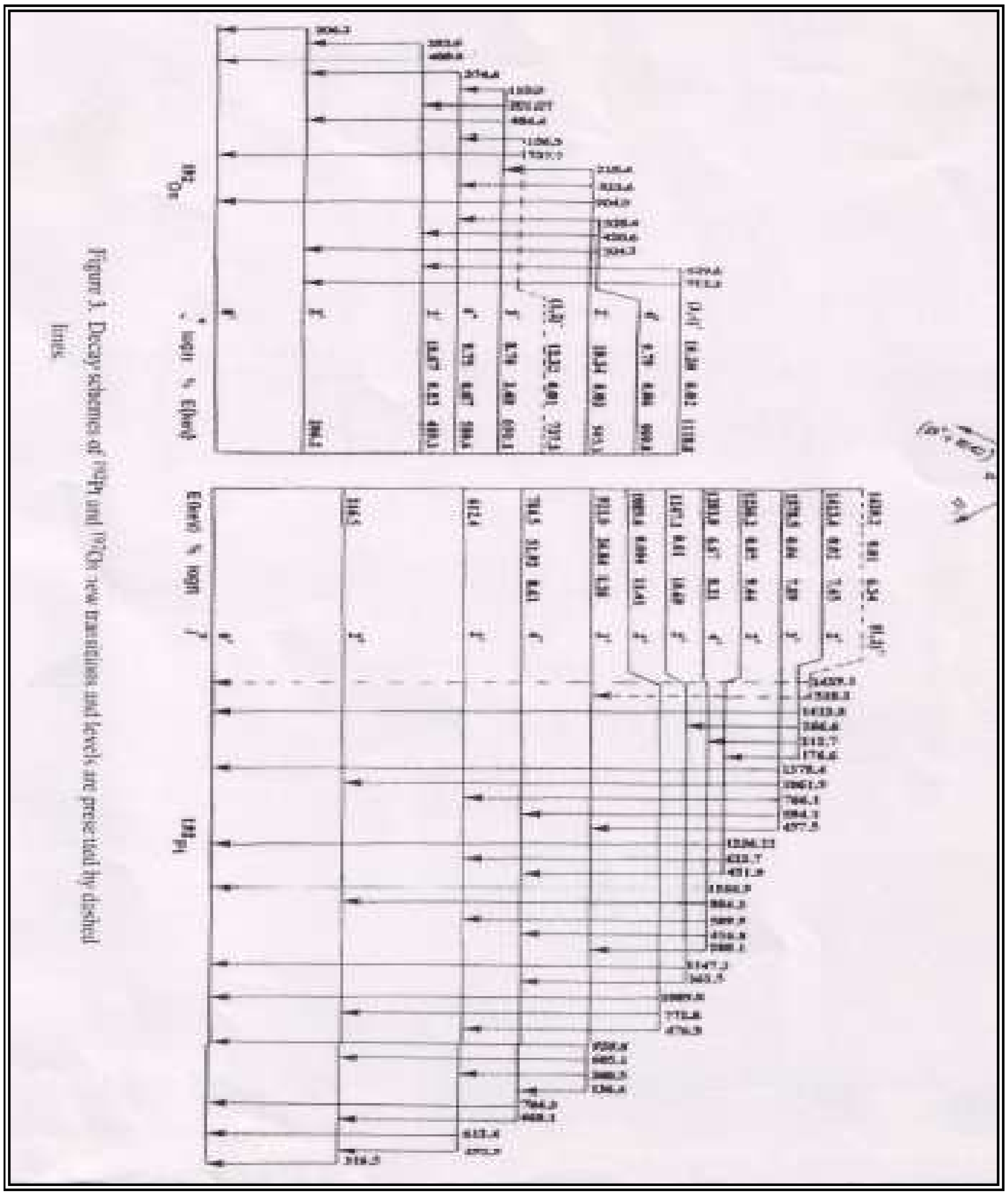

Figure 3. Decay schemes of ^{192}Pt and ^{192}Os: new transitions and levels are presented by dashed lines.

Table 2. Summay of the level properties in ^{192}Pt .

Energy level (keV)	E_β	B.R. %	Logft	Deduced J^π
316.5	11440.5	-----	-----	2^+
612.4	844.6	-----	-----	2^+
784.5	672.5	51.92	8.61	4^+
921.0	536.0	36.84	8.26	3^+
1089.6	367.4	0.004	11.41	2^+
1147.1	309.9	0.01	10.69	2^+
1201.0	256.6	6.67	8.21	4^+
1236.2	220.8	0.05	9.44	2^+
1378.5	78.5	0.06	7.89	3^+
1413.4	43.6	0.02	7.45	2^+
1439.2	17.8	0.01	6.34	$(1,2)^+$

Table 3. Summay of the level properties in ^{192}Os .

Energy level (keV)	E_{β^-}	B.R. %	Log*ft*	Deduced J^π
206.2	1261.8	-----	-----	2^+
489.3	978.7	0.15	10.67	2^+
580.6	887.4	0.67	9.75	4^+
690.8	777.2	3.48	8.70	3^+
737.3	730.7	0.01	12.32	$(1,2)^-$
905.3	562.7	0.03	10.34	2^+
909.8	558.2	0.06	9.79	4^+
1118.8	349.2	0.02	10.20	$(3,4)^+$

Decay scheme of ^{192}Pt

Most of the excited states were well established before and further confirmed in this work. The well established level at 1201 keV deserves some attention as there appears to be ambiguity about the nature of spin/parity assignment. A spin value of 4+ was assigned to level at 1201 keV by all previous workers[8-11], while Eid and Stewart[4] obtained 2^+ from IBM calculation and their measurements. The directional correlation measurements of the 416-468-316 gamma ray cascade by Mehta et al[12] suggest 4^+. The present work indicates a 4^+, consistent with log*ft* 8.21, which is also supported by the IBM.The new level at 1439.1 keV is suggested by observation of two new transitions at 518.2 and 1439.1 keV, which depopulate to the level at 921 keV and the ground state respectively. The 1439 keV level previously reported due to the decay of ^{192}Au[22], and never proposed in the decay of ^{192}Ir,was introduced in the present work, the log*ft* value of 6.34 is consistent with spin/parity of $(1,2)^+$ which agrees with results from ^{192}Au(1^-) decay.

Decay scheme of ^{192}Os

Even in such a small level scheme, it has been possible to throw light on previously suggested level. Although nine levels are suggested, eight were established previously[4,12] and are further confirmed from present work.

The newly suggested level at 737.7 keV by the observation of two γ ray transitions of energy 156.3 and 737.7 keV. These two transitions have been seen previously[4] but could not place in the decay scheme. The log*ft* value of 12.32 is consistent with a spin and parity of $(1,2)^-$.

Discussion

Casten and Cizewski[23] have performed the first study of Os/Pt transition region, using IBM-1. These authors consider nuclei in this mass region as representing smoothly developing departures from O(6) symmetries represented best by ^{192}Pt. The lighter mass even-even Os and Pt nuclei might be understood by breaking the O(6) symmetry with the introduction of a quadrupole-quadrupole interaction between bosons which introduce deformation to the nucleus.

The positive parity states have been interpreted in terms of the IBM-1. For the ^{192}Pt an initial attempt to fit the energy levels and B(E2) values, was made using the O(6) limit. Applying the transitional O(6)$\rightarrow$SU(3) Hamiltonian does not change the energy level values very much from those of the pure O(6) calculation, only very small improvement were obtained in the B(E2) values this is because the small values of a_2 primarily affect the magnitude of transition which are not allowed in the strict O(6) limit (implies violation of the $\Delta\tau = \pm 1$ selection rule).

The corresponding IBM parameters are given in table (4). As can be seen from table (4) the boson-boson interaction expressed by the QQ term, (dominant for SU(3) over pairing-pairing interaction characterizing of the O(6) symmetry), is not significantly different from zero. This implies that the observed energies of the states in^{192}Pt nucleus follow quite closely the predictions of the O(6) limit. It can be seen from Fig.(4) that the entire theoretical sequence of states has been well reproduced, and is in agreement with experimental results. One can also see that the B(E2) values are not strongly influenced by the introduction of the E2DD parameter (-0.055) which is zero in the O(6) limit. Table (5) shows a remarkable agreement between theory and experiment for transitions originating with the ground state. In other words, the ^{192}Pt nucleus preserves most of the characteristics of the rigorous O(6) limit.Previous studies indicated that it would be useful to describe the energy level in stable ^{192}Os nucleus by starting with O (6) limits and breaking the symmetry by introducing the strength of the boson-boson quadrupole-quadrupole interaction. Accordingly, an initial attempt to fit the energy levels and B(E2) values was made using the O(6) limit. Applying the transitional SU(3)$\rightarrow$O(6) Hamiltonian change the energy level values from those of the pure O(6) calculation. The P.P term has very little effect on this feature, the β band becomes above the γ band and the value of $a_0/a_4 \approx -1$[17]. The SU(3)$\rightarrow$O(6) predicted energy levels closer to experiment than pure O(6). The experiment results agree with IBM calculations are listed in table (4) and shown in Fig.(6).For the E2 transition probabilities, the situation appears to be less complex. Many transition probabilities have changed in away very characteristics of transition between an SU(3) and O(6) limit, so producing the good agreement with experiment shown in table(5).

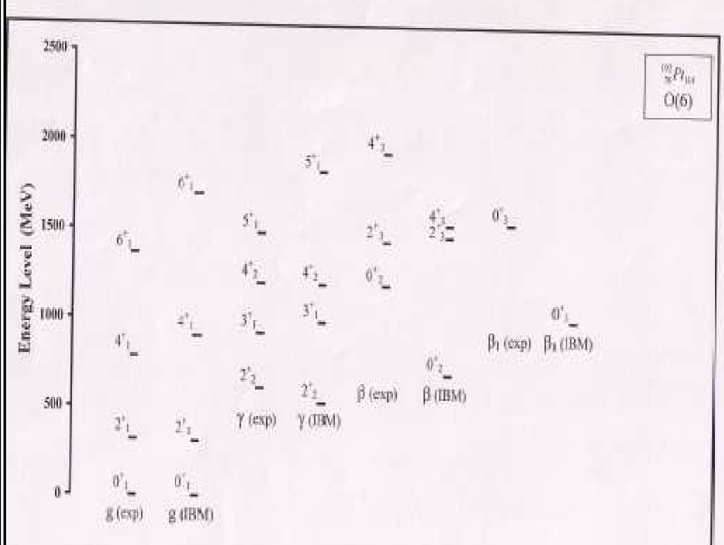

Fig.(4) Experimentally determined energy level in ^{192}Pt compared with IBM prediction

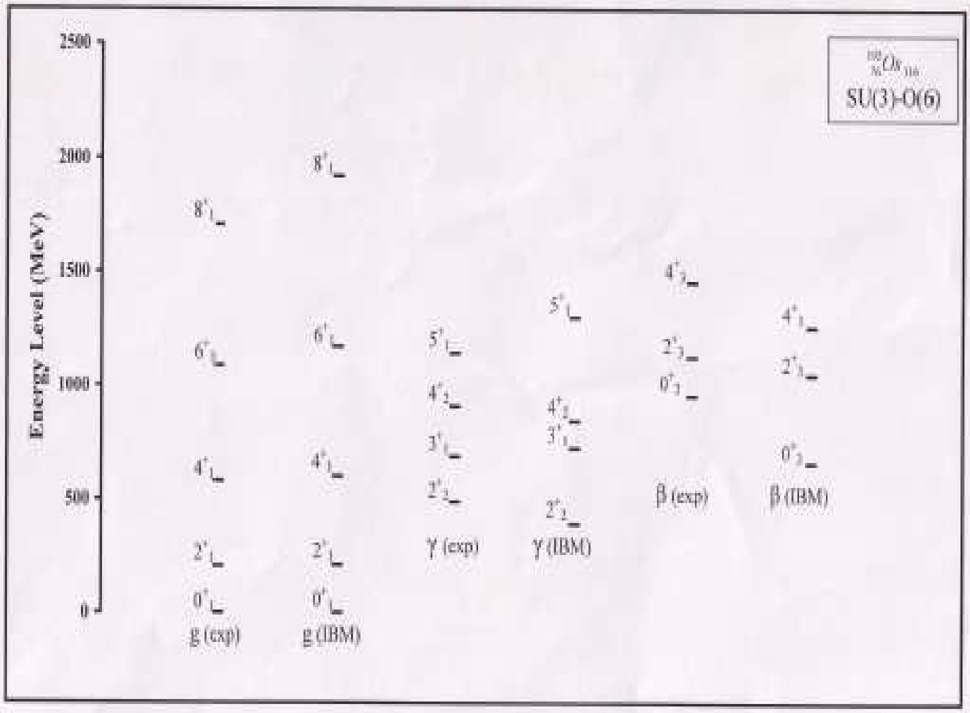

Fig.(5) Experimentally determined energy level in ^{192}Os compared with IBM prediction

Table 4. The parameters obtiand from programs IBM and IBMT.

Nucleus	p.p	L.L	Q.Q	$T_3.T_3$	E2SD	E2DD
^{192}Pt	0.065	0.034	0.0005	0.075	0.147	-0.055
^{192}Os	0.035	0.019	-0.0095	0.042	0.167	-0.0265

Table 5. Experimental B(E2) values ($e^2 b^2$) units in compersion with IBM.

a-^{192}Pt

Transition	B(E2)	
$I_i \rightarrow I_f$	Exp.[4]	IBM-1
$2_1^+ \rightarrow 0_1^+$	0.42 (2)	0.41
$2_2^+ \rightarrow 2_1^+$	0.46 (5)	0.56
$2_2^+ \rightarrow 0_1^+$	0.0044 (5)	0.0046
$4_1^+ \rightarrow 2_1^+$	0.62 (3)	0.56
$3_1^+ \rightarrow 4_1^+$	0.21 (3)	0.17
$3_1^+ \rightarrow 2_2^+$	0.43 (6)	0.43
$3_1^+ \rightarrow 2_1^+$	0.0046 (6)	0.0048

b-^{192}Os

Transition	B(E2)	
$I_i \rightarrow I_f$	Exp.[4]	IBM-1
$2_1^+ \rightarrow 0_1^+$	0.46 (1)	0.47
$2_2^+ \rightarrow 0_1^+$	0.038 (6)	0.01
$4_1^+ \rightarrow 2_1^+$	0.55 (6)	0.61
$4_2^+ \rightarrow 2_2^+$	0.18 (7)	0.34
$4_2^+ \rightarrow 4_1^+$	0.18 (7)	0.3
$4_2^+ \rightarrow 2_1^+$	0.001 (5)	0.007

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دراسة خواص مستويات الطاقة الواطئة لنظيري ^{192}Pt و ^{192}Os

عامر عبد الامير محمد علي

قسم الفيزياء

كلية العلوم – جامعة كربلاء

الخلاصة

تمت دراسة مستويات الطاقة لنظيري 192Pt و ^{192}Os من اضمحلال β^- و $(\beta^+ + E.C)$ لعنصر ^{192}Ir .
استخدم كاشف الجرمانيوم النقي لقياس طاقات اشعة كاما والشدة النسبية . تم قياس logft والبرم والتماثل .
انتقالين جديدين ومستوين جديدين 1439 KeV لنظير ^{192}Pt ومستوي جديد 737 KeV لنظير ^{192}Os تم اقترحهما .تم بناء مخططات الاضمحلال لنظيري ^{192}Pt و ^{192}Os بناء" على اعتبارات قواعد جمع الطاقة.
قورنت النتائج مع نموذج البوزونات المتفاعلة –1 حيث اعتبر نظير ^{192}Pt تابع للتحديد O(6) والنظير ^{192}Os انتقاليا" من O(6) $\rightarrow$ SU(3) .