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ABSTRACT

On the basis of the experimental study of the ^{188}Re and ^{188}Ir decays to ^{188}Os, some remarkable features, such as the nature of the lowest K = 2 band, the 0+ states and the beta decay modes to quasiparticle states, are discussed.

†Work performed under the auspices of the U. S. Atomic Energy Commission.

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The decay of ^{188}Re and ^{188}Ir was studied with use of electron spectrometers, Ge(Li) detectors, and coincidence and angular correlation apparatus. Conversion coefficients of almost all transitions were determined from electron and gamma-ray intensities. The decay scheme, as shown in Fig. 1, was proposed on the basis of 1) energy and intensity balances, 2) multipolarities of the transitions, and 3) genetic relations among the transitions. In addition to this experimental information, the theoretical gamma-ray intensity ratio from a level to the levels within a rotational band was also taken into account to avoid unreasonable placement of transitions, although the band mixing often changes such quantities. Comparison of gamma ray spectra from both sides of parents was very useful and interesting. We will discuss some of the remarkable features observed in this study.

1) The Lowest K = 2 Band

This band is interpreted as the gamma vibrational state of an axially symmetric rotor, which is intrinsically different from the ground state band.

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On the other hand, in the asymmetric rotor model it is regarded as a kind of rotational state of an asymmetric rotor generated by a rotation with respect to the nearly-symmetric axis. In other words, the wavefunction of the K = 2 state is intrinsically the same as the ground state. The beta decay of ^{188}Re (1-) to the $^{1}2+$ and $^{2}2+$ states provides the most crucial test to distinguish between these models. From the ft value ratio for the 0+ and $^{1}2+$ states the ^{188}Re state turns out to be a pure K = 1 state.

We represent in general the wavefunctions of the first and the second 2+ states as follows:

$$|^{1}2+\rangle_m = \sqrt{\frac{5}{8\pi^2}} \frac{1}{\sqrt{1+\xi^2}} [D^2_{m0}|\Psi_0\rangle + \xi \frac{1}{\sqrt{2}} \{D^2_{m2}|\Psi_2\rangle + D^2_{m-2}|\Psi_{\tilde{2}}\rangle\}],$$

$$|^{2}2+\rangle_m = \sqrt{\frac{5}{8\pi^2}} \frac{1}{\sqrt{1+\xi^2}} [\frac{1}{\sqrt{2}} \{D^2_{m2}|\Psi_2\rangle + D^2_{m-2}|\Psi_{\tilde{2}}\rangle\} - \xi D^2_{m0}|\Psi_0\rangle] ,$$

where $|\Psi_0\rangle$ and $|\Psi_2\rangle$ are intrinsic wavefunctions associated with the K = 0 and K = 2 bands, respectively, ξ is the band mixing amplitude, approximately given by

$$\xi \approx \frac{\sqrt{2}}{3p\sqrt{p}} , \quad p \equiv E(^{2}2+)/E(^{1}2+) ,$$

and $|\Psi_{\tilde{2}}\rangle$ stands for the time reversed state of $|\Psi_2\rangle$.

The ratio of the ft values for the first and second 2+ states is

$$\frac{ft(1- \rightarrow {}^{2}2+)}{ft(1- \rightarrow {}^{1}2+)} = \left[\frac{\sqrt{2}\langle 111\text{-}1|20\rangle + \xi\,\Gamma\langle 1111|22\rangle}{-\sqrt{2}\,\xi\,\langle 111\text{-}1|20\rangle + \Gamma\langle 1111|22\rangle}\right]^2$$

$$= \left(\frac{0.577 + \xi\,\Gamma}{-0.577\,\xi + \Gamma}\right)^2 ,$$

where $\Gamma \equiv \frac{\langle \Psi_2 \| G_\beta \| \Phi_1 \rangle}{\langle \Psi_0 \| G_\beta \| \Phi_1 \rangle}$.

The quantity Γ means the intrinsic retardation amplitude of the K = 2 band compared with that of the ground-state band. In the BM model, $|\Psi_0\rangle$ and $|\Psi_2\rangle$ refer to the $n_\gamma = 0$ and 1 vibrational modes, respectively. In this case, it is expected that the beta transition from the K = 1 parent state to the K = 2 band may be fairly retarded compared with the beta transition to the ground band, because the former transition involves a change in $n_\gamma (\Delta n_\gamma = 1)$. Similar phenomena are well known for spherical nuclei, where the beta transition from a parent nucleus of 1+ spin to the first 2+ state is retarded. On the other hand, in the framework of the DF model $|\Psi_2\rangle = |\Psi_0\rangle$, so that the relative decay rates depend simply on the geometrical factors (the Clebsch-Gordan coefficients).

In Fig. 2 is shown the relation between the ft value ratio and the energy ratio p with parameter Γ. As mentioned before, the DF model requires $\Gamma = 1$. Apparently, the experimental values reveal great deviation from the DF prediction.

A similar discussion can be made on the gamma transition rates from the K = 1 states. If we take the asymmetric rotor model, the B(M1) ratio from any K = 1, I = 1 state should approximately follow the simple expression

$$\frac{B(M1,\ 1+ \rightarrow {}^{2}2+)}{B(M1,\ 1+ \rightarrow {}^{1}2+)} = \left| \frac{\langle I111|22\rangle}{\sqrt{2}\ \langle I11\text{-}1|20\rangle} \right|^2 = 3$$

The small band mixing between the ground and the K = 2 bands changes these values only slightly. On the other hand, as seen in Table I, the experimental values are quite different from this prediction, showing the dependence on the individual initial state. These facts mean that the intrinsic state of the K = 2 band is different from the ground state, which contradicts with the basic idea of the asymmetric rotor model.

2) Beta Decays to Quasiparticle States

As far as we assume the independent quasiparticle model, the beta decay can take place only when either the quasiproton or the quasineutron in the parent odd-odd state changes its charge and configuration. In other words one of two quasiparticle configurations in the final even-even state should be the same as the initial state. Furthermore, if we impose the K selection rule for the beta decay, the number of two-quasiparticle states that are populated by the decay of ^{188}Re and of ^{188}Ir should be limited as follows. 1) ^{188}Re can populate only two states: K = 0+ {n[512]↓ - n[512]↓} and K = 1+ {n[510]↑ - n[512]↓}; while ^{188}Ir can populate those states: K = 1+ {n[510]↑ - n[512]↓}, K = 2+ {n[510]↑ + n[512]↓}, K = 3+ {n[510]↑ - n[514]↓}, K = 1+ {p[402]↓ - p[400]↑}, K = 2+ {p[402]↓ + p[400]↑} and K = 1+ {p[402]↓ - p[402]↑} (this explains the fact that there are only few quasiparticle states commonly populated by both parents); 2) there is no population of negative parity states either from ^{188}Re or from ^{188}Ir. This explains the remarkable experimental fact that we do not see many negative-parity states in the decay of ^{188}Re and ^{188}Ir, both of which have negative parity so that they could feed negative-parity states by allowed beta decay, if any. Experimentally, there is no negative-parity state well populated by ^{188}Re except for the 1463-keV 2- state. This 1463 keV 2- state may be interpreted as a K = 2- collective state because its energy is so low, and therefore must be composed of many two-quasiparticle states some of which are responsible for the beta decay from the parent nuclei. As for the ^{188}Ir decay we observed only one negative-parity state at 2350 keV in addition to the 1463 keV state.

3) Decoupled Rotational Bands

From the decay scheme of Fig. 1 it seems to be difficult to identify a rotational band for each intrinsic excited state. Two-quasiparticle states are located so close to each other, the Coriolis coupling among those states is supposed to destroy the regular rotational pattern. One of the most significant effects should be coupling between the state of $K = \Omega_1 + \Omega_2$ and the state of $K = \Omega_1 - \Omega_2$ in the case of $\Omega_2 = 1/2$. This is compared to the decoupling phenomena in odd-A nuclei. The n[510]↑ ± n[512]↓ states (K = 1+ and 2+) can be decoupled. Also we have another example: p[402]↓ ± p[400]↑ (K = 1+ and 2+). All these can be populated by the decay of ^{188}Ir. The irregularity of rotational bands, which are exhibited by the 1+ and 2+ states above 2 MeV may be partly due to this Coriolis admixture. However, because of missing 3+ states, we cannot correctly identify these states.

4) The Excited 0+ States

The well known 0+ states at 1087 and 1765 keV are interpreted as the two-phonon γ-vibrational state and the β-vibrational state. However, the most surprising fact is that the 1087 keV 0+ state has no 2+ state based on it, which should exist and be populated 50% as well as the 0+ state is, as far as we assume collective models. Therefore the conventional interpretation of this 0+ state seems to be quite doubtful.

These 0+ states are not populated by the ^{188}Ir decay. On the other hand, in the ^{188}Ir decay we found an almost pure E0 transition (1812 keV). This fact suggests the presence of 0+ state at 1812 keV or 2+ state at 1969 keV which deexcites to the 155 keV state via large E0 component. If the latter case is true, then this new state may be interpreted as the β-vibrational state.

Table I. B(M1) ratios from K = 1, I = 1 states to the $^{1}2+$ and $^{2}2+$ states in ^{188}Os.

Initial state (keV)	$B(M1,\ i \rightarrow {}^{2}2+)/B(M1,\ i \rightarrow {}^{1}2+)$
1620.7	>3.4
1843.3	37
2099.3	<1.2
2216.7	<0.037

FIGURE CAPTIONS

Fig. 1. Proposed decay scheme of ^{188}Re and ^{188}Ir.

Fig. 2. The ft value ratio $ft(1- \rightarrow {}^{2}2+)/ft(1- \rightarrow {}^{1}2+)$ versus $E({}^{2}2)/E({}^{1}2)$.

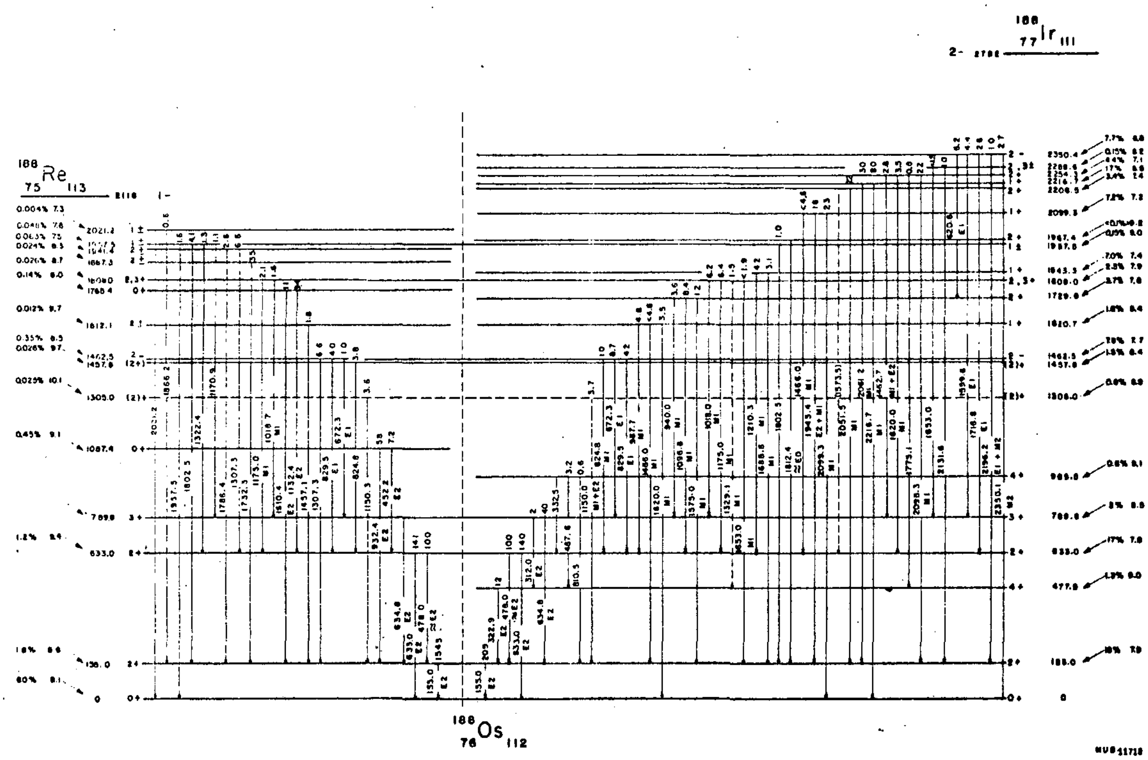

Fig. 1

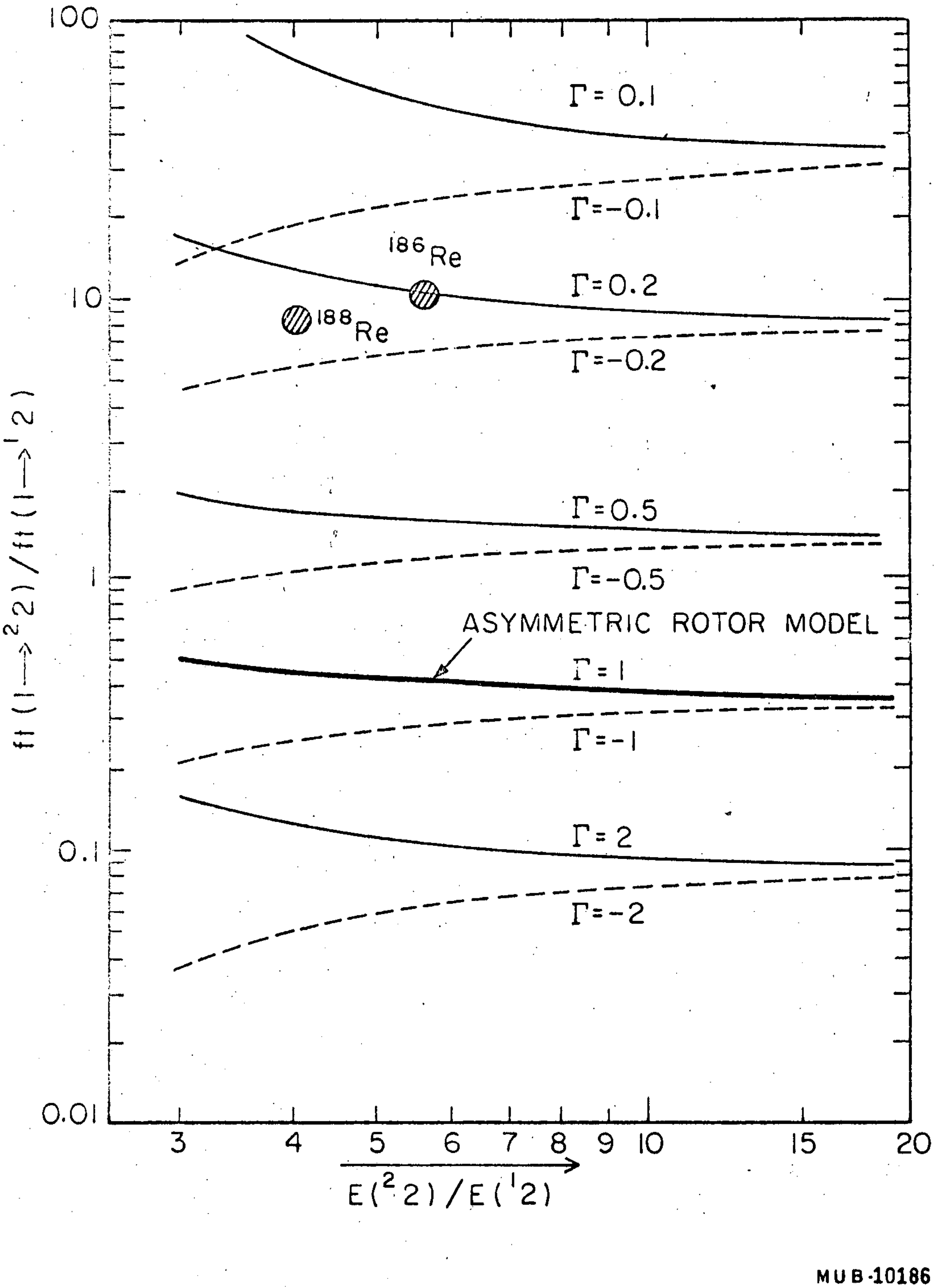
100
10
1
0.1
0.01
3
4
5
6
7
8
9
10
15
20
Γ = 0.1
Γ=-0.1
186Re
188Re
Γ=0.2
Γ=-0.2
Γ=0.5
Γ=-0.5
ASYMMETRIC ROTOR MODEL
Γ = 1
Γ=-1
Γ=2
Γ=-2
ft (1→22)/ft (1→12)
E(22)/E(12)
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Fig. 2