HIGH-K STATES IN ^{180}Re*

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The ^{180}Re nucleus has been studied at high angular momentum using the ^{174}Yb(^{11}B,5n) reaction at the Australian National University, with the CAESAR array for γ-ray detection and the Super-E solenoid for electron-conversion measurements. A $\tau = 13 \pm 1$ μs, 6-quasiparticle isomer and two intrinsic states and their associated bands have been established. The validity of the K quantum number is discussed.

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1. Introduction

In the last few years there have been several attempts to measure and interpret the high-spin structure of ^{180}Re [1–3], yet significant problems persist. The doubly odd nucleus ^{180}Re exists close to the edge of the rare-earth

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region of the periodic table where nuclei are known to have well-deformed prolate shapes. Also nuclei in that region have high-K orbitals close to the Fermi surface (where K is the projection of the angular momentum on the symmetry axis). Broken-pair states at high excitation energies are able to compete favourably with collective nuclear rotation [4] in the generation of angular momentum. The non-collective states can be classified by their quasiparticle number, *i.e.* the number of unpaired nucleons taking part in the excitation. In Ref. [1], studies of ^{180}Re provided evidence for a 6-quasiparticle isomer whose half-life was not measured. The present work establishes this isomer and its half-life, as well as two new rotational bands associated with it.

2. Experiment

The nucleus ^{180}Re was populated up to spin $\sim$30 $\hbar$ with a 71 MeV, ^{11}B beam from the 14UD pelletron accelerator at the Australian National University. The ^{11}B beam was incident on a self-supporting ^{174}Yb target of thickness 5 mg/cm^2. The emitted γ rays were detected using the CAESAR array which consists of six Compton-suppressed Ge detectors and two unsupressed planar LEPS. The latter are used for improved efficiency in identifying low-energy γ rays and X-rays. Conversion-electron measurements were undertaken using the Super-E electron spectrometer [5].

3. Results

A partial level scheme of ^{180}Re, depicting 4- and 6-quasiparticle bands, is shown in figure 1. A γ-ray spectrum for the $K^\pi = 22^+$ band is shown in figure 2. A key part of the level scheme is the placement of a 54 keV transition, depopulating the $K^\pi = 15^-$ bandhead. Also important is the conversion coefficient for the 457 keV transition from the 6-quasiparticle isomer, for which $\alpha_K = 0.0084(10)$, establishing its E1 character. The theoretical value for a 457 keV, E1 transition is $\alpha_K = 0.0076$. Evaluation of the configurations of the bands was done by comparing the experimentally determined $\mid g_K - g_R \mid / Q_0$ values, from γ-ray branching ratios, with theoretical estimates from the Nilsson model. See Table I for results.

The mean-life of the 6-quasiparticle isomer is determined to be 13$\pm$1 μs, with the predominant decay going by a 457 keV, 4-fold K-forbidden E1 transition. About 30% of the isomer decay proceeds by other pathways, which are not shown in figure 1. The 457 keV transition has a Weisskopf hindrance factor of $F_{\rm W} = 6 \times 10^9$, or, since E1 transitions are typically hindered by a factor of 10^4, we may say that the effective K-hindrance is 6×10^5. The latter estimate corresponds to a hindrance per degree of K-forbiddenness of

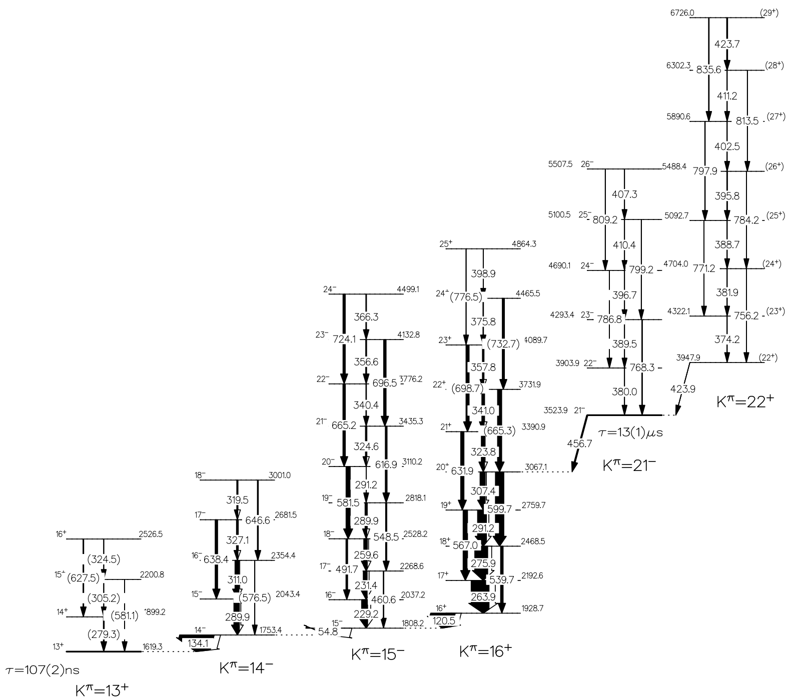

Fig. 1. Partial level scheme for ^{180}Re showing the high-K bands, including the new $K^\pi = 21^-$ and $K^\pi = 22^+$ bands.

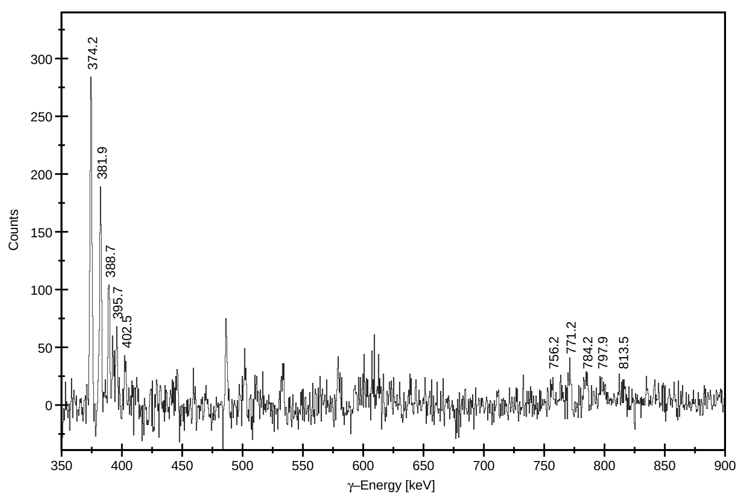

Fig. 2. Transitions in the $K^\pi = 22^+$ band, gated by the 424 keV transition in prompt coincidence.

$f_\nu = (F_{\rm W})^{1/\nu} \approx 30$. This is a substantial value, approximately the same as, for example, for the E1 decay of the 8-quasiparticle isomer in ^{178}W [6]. Even though ^{180}Re is likely to be softer than ^{178}W to axially asymmetric distortions, on account of its lower number of valence nucleons, nevertheless the K quantum number retains an important role in its high-spin structure.

TABLE I

Experimental and calculated $\mid g_K - g_R \mid /Q_0$ values for the K^π=21$^-$ and 22$^+$ bands in ^{180}Re.

K^π	Main configuration[a]		$\mid g_K - g_R \mid /Q_0$	
	ν	π	Expt.	Calc.
21$^-$	7/2$^-$ 9/2$^+$ 5/2$^-$	5/2$^+$ 9/2$^-$ 7/2$^+$	0.045±0.009	0.036±0.007
22$^+$	7/2$^-$ 9/2$^+$ 7/2$^+$	5/2$^+$ 9/2$^-$ 7/2$^+$	0.033±0.003	0.032±0.009

[a]Configurations: *neutrons*(ν): 7/2$^-$[514]; 9/2$^+$[624]; 5/2$^-$[512]; 7/2$^+$[633]; *protons*(π): 5/2$^+$[402]; 9/2$^-$[514]; 7/2$^+$[404]. In the theoretical calculations, an intrinsic quadrupole moment of $Q_0 = 5.6 \pm 0.5$ e.b and a gyromagnetic ratio of $g_R = 0.30 \pm 0.05$ taken from Ref. [1] have been used.

4. Summary

Two new high-K, 6-quasiparticle bands have been found in ^{180}Re and assigned as $K^\pi = 21^-$ and $K^\pi = 22^+$. These bands decay through the $K^\pi = 21^-$ isomer, measured to have a 13 μs mean-life. The γ-ray branching ratios and associated $\mid g_K - g_R \mid /Q_0$ values have been used to specify the quasiparticle configurations of the states. The decay properties of the isomer indicate the important role of the K quantum number.

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