Calculation of energy levels of ^{232}Th, $^{232-238}$U for the $K^{\pi}=0^{+}$ ground state bands

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From the semiempirical formalism of Sood, energy levels of the $K^{\pi}=0^{+}$ ground state band in ^{232}Th, $^{232-238}$U even nuclei have been calculated. By ascribing appropriate values of N, better agreement is obtained with experimental data.

The rotational energy equation for the $K^{\pi}=0^{+}$ ground state bands of doubly even nuclei, expressed as an infinite power series by Nathan *et al.*,[1] was rewritten by Sood[2] in the form

$$E_I = AI(I+1)\left\{1-\left[\frac{B}{A}\right]I(I+1)\times\left[1-\left[\frac{C}{B}\right]I(I+1)+\left[\frac{D}{C}\right]I^2(I+1)^2+\cdots\right]\right\}, \quad (1)$$

where $A=h^2/2\mathcal{J}$ is the well-known rotational constant parameter and $B,C,D,\ldots,$ are the coefficients of successive order correction terms. Assuming $(C/B)=(D/C)=N(B/A)$, Sood's semiempirical formalism (SSEF) leads to the equation

$$E_I = AI(I+1)\left[\frac{1+(N-1)\left[\frac{B}{A}\right]I(I+1)}{1+N\left[\frac{B}{A}\right]I(I+1)}\right], \quad (2)$$

where $(B/A)=(10-3R)/(200-18R)$, $R=E_4^*/E_2^*$, E_4^* and E_2^* being the energies of the second and the first excited levels of the ground state rotational band. The constant N obtained from empirical consideration by Sood[2] was

$$N=a-bI\ , \quad (3)$$

with

$$a=2.85,\quad b=0.05\ .$$

Equation (3) seems to work well in describing the energies of the ground state $K^{\pi}=0^{+}$ bands in the rare earth region. Sood[3] has suggested that N may be varied to get agreement for the actinides ^{232}Th, $^{232-238}$U. In the present work, the best values of N were obtained as follows:

(i) in the linear Eq. (3), the constant a was varied from 2.800 to 3.000 in steps of 0.005 and b was fixed as $(\frac{1}{30})$;

(ii) for each N thus obtained, E_I was calculated by Eq. (2).

The following values of N were found to be the most appropriate to calculate E_I which compare favorably well with experimentally known energies:

^{232}Th: $N=2.990-(I/30)$,

^{232}U: $N=2.980-(I/30)$,

^{234}U: $N=2.980-(I/30)$,

^{236}U: $N=2.850-(I/30)$,

^{238}U: $N=2.815-(I/30)$.

Data for experimental energies were taken from the most recent compilation of Nuclear Data Sheets.[4-6]

In Fig. 1, the calculated energies for the ground state

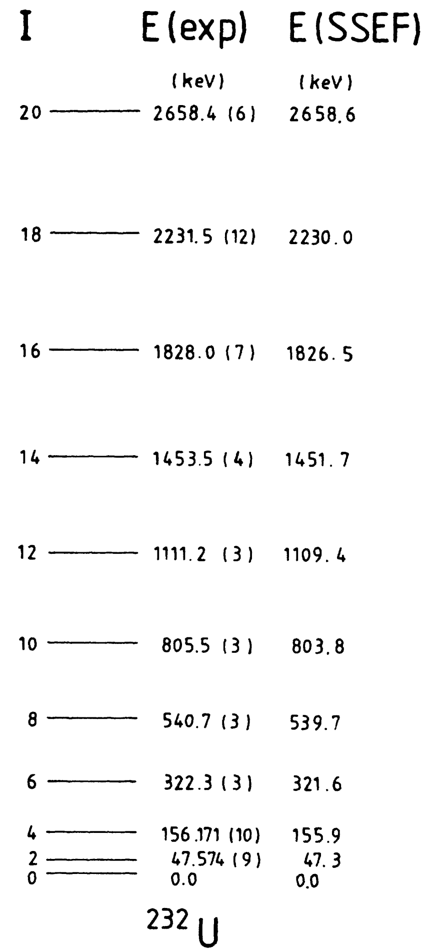

FIG. 1. Experimental and SSEF calculated energy levels of ^{232}U.

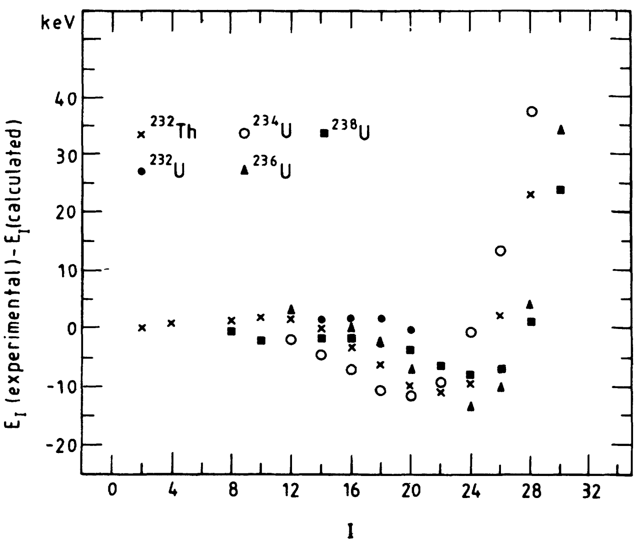

FIG. 2. E_I(experimental)$-E_I$(calculated) by SSEF vs I for ^{232}Th, $^{232-238}$U.

rotational band of ^{232}U are compared with experimental values, and in Fig. 2, the deviations $\delta E_I = E_I$(experimental)$-E_I$(calculated) are represented for ^{232}Th, $^{232-238}$U. As we can see, the experimental energy

TABLE I. Values of $\Sigma\delta E_I/\Sigma E_I$(experimental).

Spin range	Nucleus	$\Sigma\delta E/\Sigma E_I$(experimental)
2–28	^{232}Th	2.6×10^{-3}
2–20	^{232}U	8.7×10^{-4}
2–28	^{234}U	4.0×10^{-3}
2–30	^{236}U	2.9×10^{-3}
2–30	^{238}U	1.9×10^{-3}

level for the 20^+ state in ^{232}U is 2658.4(6) keV (Ref. 7), in excellent agreement with the calculated value of 2658.6 keV.

The gradient in the equation defining N is the same for ^{232,234}U and relatively less for ^{236,238}U. Overall deviations defined by $\Sigma\delta E_I/\Sigma E_I$(experimental) are given in Table I.

The fact that the E_{26} (3808 keV), E_{28} (4297 keV) levels have not been measured precisely explains the highest overall deviation in ^{234}U.

In summary, we observe that in the actinide region, the value of N can be evaluated for each of the nuclei to describe energy levels of the $K^\pi=0^+$ ground state band comparable to experimentally known energies. It is hoped that experiments may be planned to populate high spin states in ^{232}U to verify energies calculated from the N value suggested in this work.

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