объединенный
институт
ядерных
исследований
дубна

E4-81-637

S.Cwiok, I.N.Mikhailov, R.G.Nazmitdinov,
W.Nazarewicz *

CALCULATED SPECTRUM OF STRETCHED γ-RAYS FROM THE HIGH-SPIN STATES IN ^{118}Te

Submitted to "Physics Letters"

* Institut of Physics, Technical University,
Koszykowa 75, PL-00-622, Warsaw, Poland

1981

In the last ten years the nuclear states with large angular momenta have been investigated most extensively. The unresolved γ-ray spectra in the transitional nuclei around $A \approx 120$ measured by using the modern techniques [1,2] reveal some irregularities pertinent to the details of nuclear structure at $A \gtrsim 30\,h$. In these papers we report the calculations of the γ-ray spectrum in ^{118}Te showing that these irregularities originate from the changes in the nuclear average field with the increase of nuclear spin.

Having in mind that the high-spin part of the γ-ray spectrum from (HI, xn) reaction is unresolved, we set up the calculation for the intensity of γ-radiation $\bar{n}_\gamma(E_\gamma)$ averaged over an energy interval Δ around E_γ with the weight function $\rho_\Delta(E_\gamma)$. We suppose that the bulk of γ-emission is composed of the stretched E2-transitions from the states belonging to the yrast-line or lying near it. Then

$$\bar{n}_\gamma(E_\gamma) = \sum_I n_\gamma(I)\rho_\Delta(E_\gamma - E(I)), \tag{1}$$

where the summation runs over the angular momenta of yrast states ($I = \mathrm{mod}2$); $E(I)$ being the energy difference of the adjacent yrast-states and $n_\gamma(I)$ being the number of transitions $I \to I-2$ per cascade. The weight function $\rho_\Delta(E_\gamma - E(I))$ is normalized so that

$$\int_0^\infty \rho_\Delta(E_\gamma - E)dE = 1\,. \tag{2}$$

Taking a Lorentz distribution for $\rho_\Delta(E_\gamma - E)$ one comes to

$$\bar{n}_\gamma(E_\gamma) = \frac{\Delta}{2\pi}\sum_{I=2}^{I_{cr}} \frac{n_\gamma(I)}{(E_\gamma - E(I))^2 + (\Delta/2)^2}\,. \tag{3}$$

To estimate the number of transitions $n_\gamma(I)$, we assume that the side-feeding of the yrast-line is given by the population function $g(I)(\sum_I g(I) = 1)$ according to the formula

$$g(I) = c\begin{cases} 2I+1, & I \le I_{cr} \\ 0, & I > I_{cr} \end{cases}\,. \tag{4}$$

Then for the function $n_\gamma(I)$ one obtains

$$n_\gamma(I) = c \sum_{I' \geq I} g(I') = \frac{(I_{cr}+I+1)(I_{cr}-I+2)}{(I_{cr}+1)(I_{cr}+2)} . \quad (5)$$

The transition energy E(I) may be related to the angular frequency of rotation ω corresponding to a given yrast-state. One has

$$E(I) = 2h\omega(I), \qquad \omega(I) = I / \mathcal{J} . \quad (6)$$

where $\mathcal{J}$ is the moment of inertia.

For the calculation of the transition energy E(I) in the cascade transition we use the model which is essentially the same as in ref. [3]. The basic elements of the model are: (i) the cranking equation for the single-particle energies in the field rotating with the angular velocity ω, and (ii) the shell-correction method by Strutinsky which allows one to determine the equilibrium deformation of a rotating nucleus with the angular momentum I corresponding to ω. As in ref. [3] we use the formalism of a statistical minimization of the Gibbs-Routhean function at given values of ω and the temperature which, in principle, provides the description of transitions from the state lying high above the yrast-line. Here the temperature formalism is used mostly as a tool to simplify the calculational procedure. For simplicity we do not take into account the pairing correlations which are not essential in the region of $I \gtrsim 25h$.

The three-axial Woods-Saxon potential with parameters of ref. [4] is taken for the average field. The potential contains three deformation parameters β_2, β_4, γ related to the coefficients of multipole expansion as follows.

$$\beta_{20} = \beta_2 \cos\gamma ,$$

$$\beta_{2\pm2} = \frac{\beta_2}{\sqrt{2}} \sin\gamma , \quad (7)$$

$$\beta_{40} = \frac{\beta_4}{6}(5\cos^2\gamma + 1), \qquad \beta_{4\pm2} = \frac{\beta_4}{6}\sqrt{\frac{15}{2}} \sin 2\gamma ,$$

$$\beta_{4\pm4} = \frac{\beta_4}{6}\sqrt{\frac{35}{2}} \sin^2\gamma .$$

The parametrization in eq. (7) maintains the symmetry properties of the shape with respect to the transformations $\gamma \to \gamma + \frac{\pi}{3} n$ ($n = \pm 1, \pm 2, \pm 3$) which are known for the quadrupole deformation.

Figure 1 shows the yrast-line in ^{118}Te calculated at the temperature $t = 0.2$ MeV (see also ref. [5]). This corresponds to the excitation energy above the yrast-line $U \sim 0.5$ MeV. Such a small value of U does not affect the large-scale structure effects which could not be studied by using the up-to-date experimental data. As is seen, the yrast-line splits into the three bands. The low-spin part of it corresponds to the oblate shape, which is typical for the magic nucleus: in the case of ^{118}Te the number of protons is close to the "magic" number Z=50. Here, the deformation energy for the nonrotating nucleus has strongly marked minimum neither at the oblate shapes ($\gamma = \pm 60°$) nor at the prolate shape ($\gamma = 0°$). At $I \geq 30\hbar$ the shell effects favour the prolate shape leading to the prolate rotating configurations (the second band in Fig.1). At still higher spins ($I \gtrsim 46\hbar$) the yrast-configurations become three-axial (the third band in Fig.1).

The calculated γ-ray spectrum in ^{118}Te is shown in Fig.2. The cut-off parameter I_{cr} in (4) and (5) is chosen to be $I_{cr} = 72$ which corresponds to the experimentally measured multiplicity in ref. [2]. The function $\bar{n}_\gamma(E_\gamma)$ has irregularities related to the differences in the shape of yrast-configurations in different spin regions. The maxima in $\bar{n}_\gamma(E_\gamma)$ appear at the spin at which the bands cross. As is known, the band-crossing leads to the irregularity in the ω-dependence of the moment of inertia. This, in turn, leads to the increase in $\bar{n}_\gamma(E_\gamma)$ which is seen in the schematic drawing in Fig.3. The intensity of transitions corresponding to a given interval of E_γ is proportional to the corresponding interval rotational frequency $\hbar\omega = \frac{1}{2} E_\gamma$. The steep increase of the moment of inertia in the neigbourhood of a band-crossing leads to the maximum in the function $\bar{n}_\gamma(E_\gamma)$.

The calculated $\bar{n}_\gamma(E_\gamma)$ reproduces rather well the experimental data reported in ref. [2]. Both the experiment and the theory say that $\bar{n}_\gamma(E_\gamma)$ has two maxima. The calculated positions of the maxima are close to the experimental findings. The small disagreements between the theory and experiment may be understood as coming from the neglect of pairing effects: the inclusion of such effects must decrease the moment of inertia at small and moderate spins which will result in shifting the curve $\bar{n}_\gamma(E_\gamma)$ to large values of E_γ.

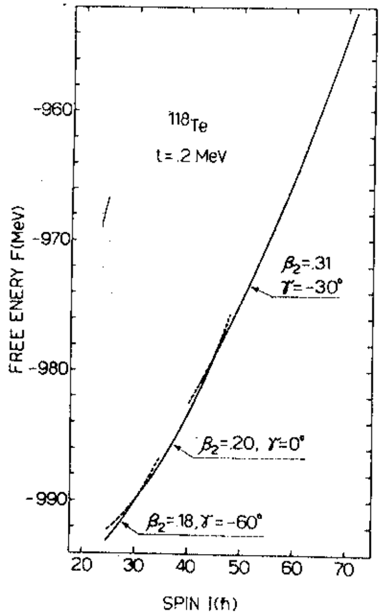

Fig.1. The yrast-line of ^{118}Te.

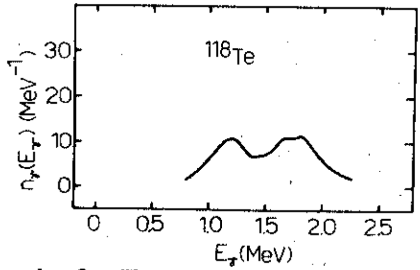

Fig.2. The calculated γ-ray spectrum $\bar{n}_\gamma(E_\gamma)$ of ^{118}Te as a function of energy E_γ.

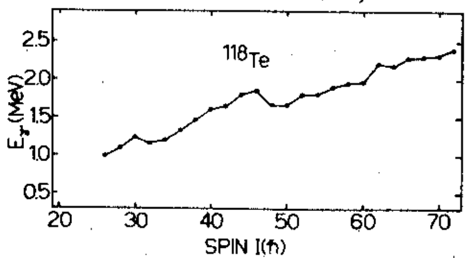

Fig.3. The γ-ray energy dependence on the angular momenta of ^{118}Te.

REFERENCES

1. Deleplangue M.A. et al. Phys.Rev.Lett., 1978, 40, 629; Diamond R.M., Stephens F.S. Nuclei at High Angular Momentum, Ann.Rev.Nucl.Part.Sci., 1980, 30, p. 85.
2. Simon R.S. et al. Nucl.Phys., 1979, A313, p. 209.
3. Ignatyuk A.V. et al. Nucl.Phys., 1980, A346, p. 191.
4. Dudek J., Werner T. J. of Phys., 1978, 64, p. 1543. Dudek J. et al. J. of Phys., 1979, 65, p. 1359.
5. Andersson G. et al. Nucl.Phys., 1976, A268, p. 205.

Received by Publishing Department
on October 12 1981.