The ground state rotational bands in ^{150}Sm and ^{152}Sm

1972 J. Phys. A: Gen. Phys. 5 L69

(http://iopscience.iop.org/0022-3689/5/8/002)

J. Phys. A: Gen. Phys., Vol. 5, August 1972. Printed in Great Britain. © 1972.

LETTER TO THE EDITOR

The ground state rotational bands in ^{150}Sm and ^{152}Sm

A J HARTLEY, R CHAPMAN, G D DRACOULIS,
S FLANAGAN, W GELLETLY and J N MO
Schuster Laboratory, University of Manchester, Manchester M13 9PL, UK

MS received 3 July 1972

Abstract. The gamma rays from the ^{150}Nd (α, 4n) ^{150}Sm and ^{150}Nd (α, 2n) ^{152}Sm reactions have been studied in both singles and coincidence. The ground state rotational bands in ^{150}Sm and ^{152}Sm are populated up to the state with spin 10^+. It is found that the nuclear moment of inertia of ^{150}Sm is substantially lower than that of ^{152}Sm for the low spin states, but that it increases with spin and the moments of inertia converge for the high spin states. This supports earlier evidence that the change from spherical to deformed nuclei between $N = 88$ and $N = 90$ is gradual.

The change of nuclear properties associated with the onset of permanent nuclear deformation between $N = 88$ and $N = 90$ has long been of considerable interest. In this context, the samarium isotopes have been of particular interest since they undergo a transition in character from the closed-shell, spherical nucleus ^{144}Sm to the well-deformed nucleus ^{154}Sm. Calculations of the potential energy of deformation for these isotopes by Kumar and Baranger (1968), Kumar (1971) and Sorensen (1970) on the pairing-plus-quadrupole model show that the onset of permanent prolate deformation is fairly smooth. They indicate that ^{150}Sm ($N = 88$) and ^{152}Sm ($N = 90$) have deformed minima of potential energy, but that the energy of zero-point motion is comparable to the energy gain due to deformation showing that the two nuclei are transitional rather than deformed. On the basis of energy level systematics Sakai (1967) has suggested that quasirotational bands should appear in such nuclei. We have studied the quasi-rotational ground state bands in ^{150}Sm and ^{152}Sm using the reactions ^{150}Nd (α, 4n) ^{150}Sm and ^{150}Nd (α, 2n) ^{152}Sm. The reactions were observed to populate the ground state bands up to the $J^{\pi} = 10^+$ level in both nuclei.

Selfsupporting metallic targets of ^{150}Nd, enriched to 96·95% and approximately 1–2 mg cm^{-2} thick, were irradiated with α particles from the Manchester University heavy ion linear accelerator. The resulting in-beam gamma rays were studied with two Ge(Li) detectors of 25 cm^3 and 36 cm^3 active volume and an on-line PDP 9 computer. Gamma ray singles yields were measured as a function of α particle energy from 16·5 MeV to 38·4 MeV in order to assign gamma rays to particular final nuclei and to give an indication of spin assignments within each rotational band. Figure 1

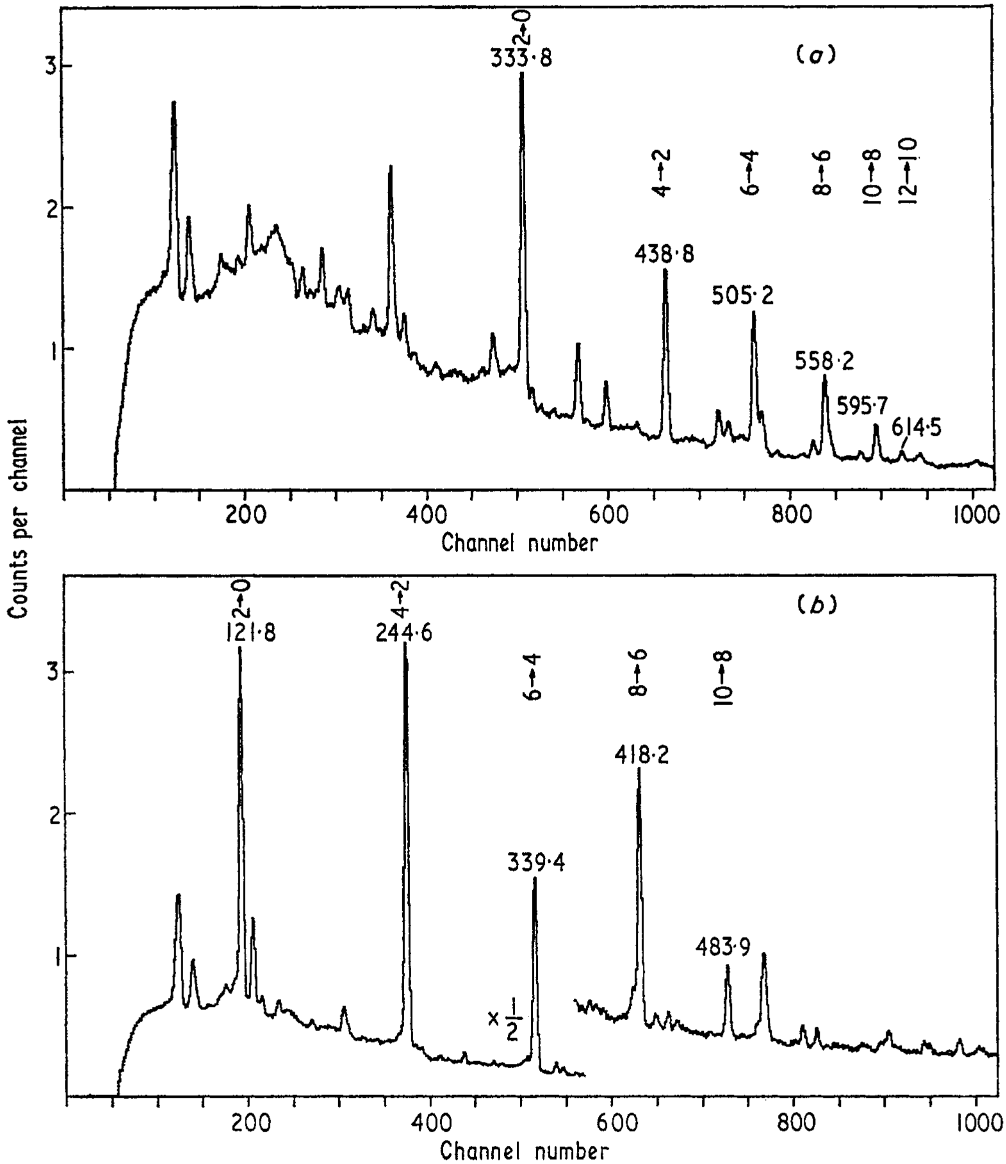

Figure 1. Singles γ ray spectra obtained from the ^{150}Nd (α, 2n) ^{152}Sm and the ^{150}Nd (α, 4n) ^{150}Sm reactions at (*a*) 22 MeV and (*b*) 38·4 MeV bombarding energy, the peaks of the reaction cross sections.

shows examples of the singles gamma ray spectra measured at the peak of each reaction cross section. The measured energies and relative intensities of the gamma rays assigned to the ground state bands in ^{150}Sm and ^{152}Sm are given in tables 1 and 2.

Gamma–gamma coincidence measurements (resolving time 40 ns FWHM) were recorded in an event-by-event mode on magnetic tapes. The coincidences established by setting gates on the peaks and subtracting background enabled the assignment of gamma rays to the ground state bands up to the 10^+ state in each nucleus. In

Table 1. The ground state rotational band in ^{152}Sm

Energy (keV)†	Relative γ ray intensity‡	A_2/A_0	A_4/A_0	Assignment
121·8	100	0·25 ± 0·04	−0·10 ± 0·07	$2^+ \to 0^+$
244·6	81	0·27 ± 0·06	−0·11 ± 0·09	$4^+ \to 2^+$
339·4	57	0·32 ± 0·06	−0·07 ± 0·09	$6^+ \to 4^+$
418·2	22	0·30 ± 0·07	−0·11 ± 0·10	$8^+ \to 6^+$
483·9	7	0·28 ± 0·06	−0·07 ± 0·09	$10^+ \to 8^+$

† The transition energies are accurate to ± 0·3 keV
‡ The relative intensities are accurate to ± 10%

Table 2. The ground state rotational band in ^{150}Sm

Energy (keV)†	Relative γ ray intensity‡	A_2/A_0	A_4/A_0	Assignment
333·8	100	0·27 ± 0·06	−0·01 ± 0·09	$2^+ \to 0^+$
438·8	91	0·29 ± 0·05	−0·04 ± 0·08	$4^+ \to 2^+$
505·2	88	0·27 ± 0·07	−0·03 ± 0·10	$6^+ \to 4^+$
558·2	67	0·31 ± 0·07	−0·08 ± 0·11	$8^+ \to 6^+$
595·7	28	0·32 ± 0·08	0 ± 0·12	$10^+ \to 8^+$
614·5	(8)			$(12^+ \to 10^+)$

† The transition energies are accurate to ± 0·3 keV
‡ The relative intensities are accurate to ± 10%

addition, there is less conclusive evidence for a 614·5 keV gamma ray in coincidence with the ground state band transitions in ^{150}Sm which has been assigned tentatively as the 12^+ to 10^+ transition.

Gamma ray angular distributions were measured and fitted with a Legendre polynomial expansion of the form $W(\theta) = A_0 + A_2 Q_2 P_2 (\cos\theta) + A_4 Q_4 P_4 (\cos\theta)$ where Q_2 and Q_4 are finite angle attenuation factors. The coefficients so deduced are shown in tables 1 and 2 and agree with the expectations for stretched E2 transitions depopulating rotational bands (Newton *et al* 1967).

The ground state band in ^{150}Sm was previously known tentatively up to the 6^+ state (Morinaga 1965, Buss and Smither 1970). In the case of ^{152}Sm our results support those obtained previously from conversion electron studies of the ^{150}Nd (α, 2n) ^{152}Sm reaction (Lonsjö and Hagemann 1966). In the latter study a 551 keV transition was tentatively assigned as the $12^+ \to 10^+$ transition. This gamma ray appears weakly in our singles spectrum but we have no further information about it because of its low intensity.

In figure 2 the nuclear moment of inertia for the two isotopes is plotted as a function of the square of the rotational frequency in the manner used previously for rotational bands in rare earth nuclei (Johnson *et al* 1971). The lifetimes and B(E2) values of the low-lying levels in the ground state bands in ^{148}Sm, ^{150}Sm, ^{152}Sm and ^{154}Sm have been measured (Diamond *et al* 1971, 1972, Fraser *et al* 1969, Sayer *et al* 1970). The results for ^{154}Sm (which include up to the 8^+ to 6^+ transition) are consistent with those

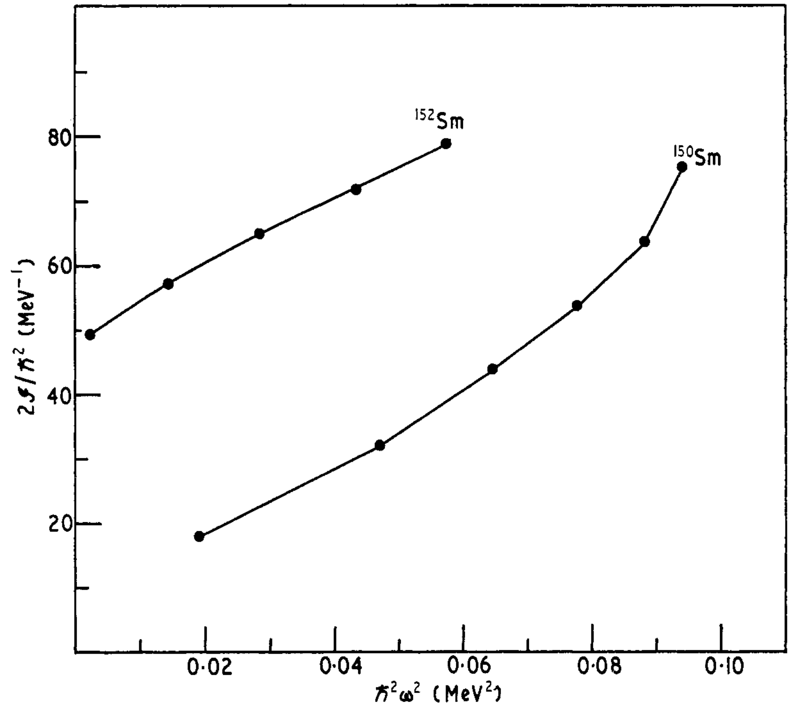

Figure 2. The nuclear moment of inertia against the square of the rotational frequency in ^{150}Sm and ^{152}Sm.

expected for a rigid rotor, while the results for ^{152}Sm (up to the 10^+ to 8^+ transition) are enhanced above the rigid rotor values and have been explained on the centrifugal stretching model, appropriate for a 'soft' nucleus. The results for ^{150}Sm and ^{148}Sm are limited to the 4^+ to 2^+ and 2^+ to 0^+ transitions, and are close to the vibrational values, as are the energies of the 4^+ and 2^+ states in these two nuclei.

The observation of a band of states with spin up to 12^+ in ^{150}Sm is not in itself evidence against the vibrational description in this nucleus, however the increase of the moment of inertia with increased spin converging to that of ^{152}Sm, as is indicated in figure 2, shows that ^{150}Sm is easily deformed at the higher spin values.

This effect has recently been observed for the corresponding $N = 88$ gadolinium nucleus (Løvhøiden *et al* 1972) and supports other evidence from quadrupole moment measurements (Gertzmann *et al* 1970) and particle transfer reactions (Chapman *et al* 1972 and references therein) that the change from a spherical to a deformed system between $N = 88$ and $N = 90$ is not abrupt.

References

Buss D J and Smither R K 1970 *Phys. Rev.* C **2** 1513–39
Chapman R, Mclatchie W and Kitching J E 1972 *Nucl. Phys.* A **186** 603–19
Diamond R M, Stephens F S, Nakai K and Nordhagen R 1971 *Phys. Rev.* C **3** 344–9
Diamond R M *et al* 1972 *Nucl. Phys.* A **184** 481–96
Fraser I A *et al* 1969 *Phys. Rev. Lett.* **23** 1051–4
Gertzmann H S *et al* 1970 *Nucl. Phys.* A **151** 273–81
Johnson A, Ryde H and Sztarkier J 1971 *Phys. Lett.* **34B** 605–8
Kumar K 1971 *Phys. Rev. Lett.* **26** 269–72
Kumar K and Baranger M 1968 *Nucl. Phys.* A **110** 529–54
Lonsjö O and Hagemann G B 1966 *Nucl. Phys.* **88** 624–40
Løvhøiden G, Hjorth S A, Ryde H and Harms-Ringdahl L 1972 *Nucl. Phys.* A **181** 589–608
Morinaga H 1965 *Nucl. Phys.* **75** 385–95
Newton J O *et al* 1967 *Nucl. Phys.* A **95** 357–76
Sakai M 1967 *Nucl. Phys.* A **104** 301–26
Sayer R O *et al* 1970 *Phys. Rev.* C **1** 1525–38
Sorensen B 1970 *Nucl. Phys.* A **142** 411–44