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LEVEL DENSITIES AND γ STRENGTH FUNCTIONS IN ^{146,147}Sm NUCLEI*

S. Siem[a], M. Guttormsen[a], R. Chankova[a], A.C. Larsen[a]
J. Rekstad[a], A. Schiller[b], N.U.H. Syed[c,d]

[a]Department of Physics, University of Oslo
0316 Oslo, Norway
[b]NSCL, Michigan State University
East Lansing, Michigan 48824, USA
[c]Frank Laboratory of Neutron Physics, Joint Institute of Nuclear Research
141980 Dubna, Russia
[d]Department of Physics and Astronomy, Ohio University
Athens, Ohio 45701, USA

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The level density and radiative strength functions (RSF) for ^{146,147}Sm have been extracted and are here compared with the previously published results on ^{148,149}Sm. As one approaches the closed $N = 82$ neutron shell we see that the structures in the level density become more pronounced due to shell effects. Thermodynamic properties, like the temperature, have been derived within the micro-canonical framework. The pygmy resonance seen in the deformed rare earth nuclei was not seen in ^{146,147}Sm, as expected since the scissors-mode resonance is deformation dependent and these isotopes are close to spherical.

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1. Introduction

The nuclear level densities and radiative strength functions (RSF) are important input parameters in large network calculations of stellar evolution. These quantities have been studied for a wide range of nuclei. The experiments were carried out at the Oslo Cyclotron Laboratory, using the (^{3}He,α) and (^{3}He,^{3}He$'$)-reactions with the 45 MeV ^{3}He-beam delivered by the MC-35 cyclotron. Charged particles and γ-rays were recorded with the multi-detector system CACTUS, which includes a NaI γ-detector array with

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a total efficiency of ~ 15 %. The Oslo group has developed a technique [1] to measure with high precision the level density and radiative strength function (RSF) simultaneously in one and the same experiment. In this paper new data on ^{146,147}Sm are presented.

2. Level density and temperature

The extracted level densities of ^{146,147}Sm are plotted in the left panel of Fig. 1, and show a very pronounced step structure. The difference in the level density between the odd–even and even–even nucleus can be described as a simple energy shift due to pairing. In the right panel of Fig. 1, the level density of midshell ^{162}Dy is higher than the level densities of the more spherical ^{146,148}Sm isotopes. In the same way as the lowering of the ground state in even–even nuclei due to pairing leads to an energy shift in the level density, the shell-effects can also lead to an energy shift. In the case of a closed shell the particles need enough energy to cross the shell gap before having access to many levels, similar to overcoming the pair-gap in even–even nuclei. From looking at the energy shift as we approach the closed neutron shell of $N = 82$, we can get information on the size of the shell gap. The analysis of ^{144}Sm with 82 neutrons and the double magic nucleus ^{208}Pb is in progress.

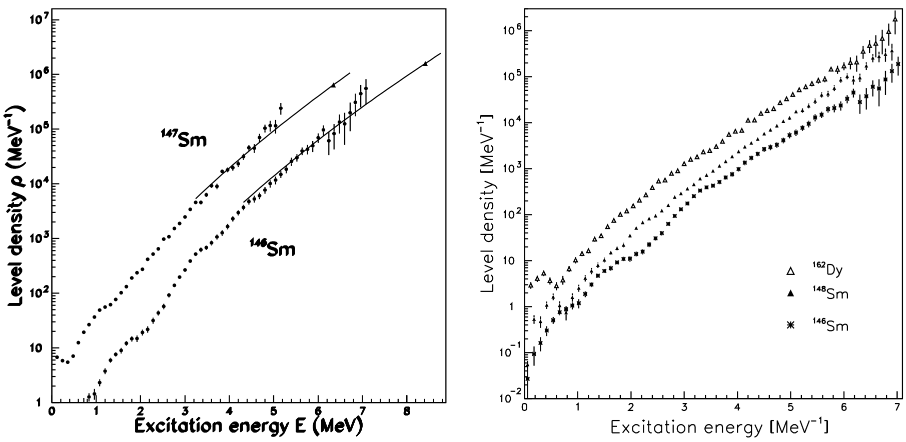

Fig. 1. The level density of ^{146,147}Sm, left panel. Right panel: level density of ^{162}Dy (open triangle), ^{148}Sm (filled triangle) and ^{146}Sm (asterisk).

After extracting the level density as a function of excitation energy, we can explore other thermodynamic properties of the nuclei. When using the micro-canonical ensemble the partition function is simply the multiplicity of nuclear states $\omega(E)$, which experimentally corresponds to the level density of accessible states. Thus, the entropy is defined as: $S(E) = k_{\rm B} \ln \omega(E)$, where $\omega(E) = \rho(E)/\rho_0$ and $k_{\rm B}$ is the Boltzmann constant. The micro-canonical temperature in units of MeV is given by: $T(E) = k_{\rm B}\left(\frac{\partial S}{\partial E}\right)^{-1}$. The deduced temperature spectra for ^{146,147}Sm are shown in Fig. 2. Due to the step structure of the level density we get very pronounced peaks in the temperature spectrum. When particle pairs are broken, new degrees of freedom open up *i.e.* a more than normal opening of new domains of the phase space, leading to an unusual increase in the entropy and thus the decrease in the temperature. We therefore interpret that the location of the break up of a nucleon pair happens in the region where the micro-canonical temperature curve has a negative slope.

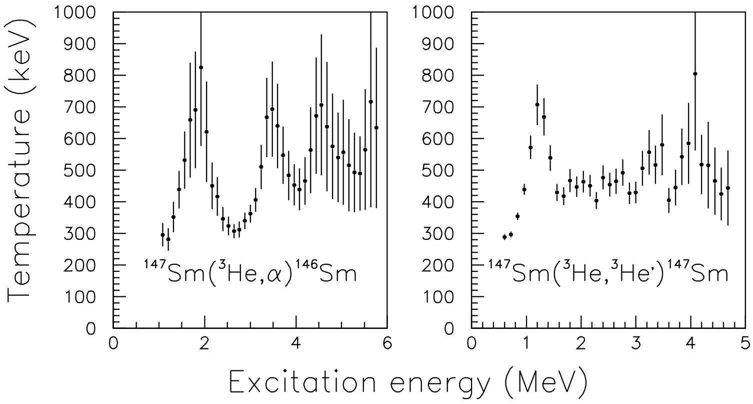

Fig. 2. The temperature curve for ^{146,147}Sm derived within the microcanonical ensemble.

3. The radiative strength function

A pygmy resonance at around 3 MeV has been observed in the RSF of several rare earth nuclei. This pygmy resonance is most pronounced in the well deformed ^{161,162}Dy, ^{166,167}Er and ^{171,172}Yb nuclei and less obvious in the almost spherical ^{148,149}Sm nuclei [2]. Recently, we have clearly established the M1 multipolarity of the pygmy resonance in ^{172}Yb [3]. This is in agreement with Ref. [4], which also found evidence of the M1 multipolarity of the pygmy resonance in ^{163}Dy. So the pygmy resonance can be described by the scissors mode, which is deformation dependent, and we expect it to disappear as we move towards the closed $N = 82$ shell where the nuclei are spherical. The radiative strength functions of ^{146,147}Sm are shown in Fig. 3. There might be a hint of a bump around 3.5 MeV in ^{147}Sm, but definitely none in ^{146}Sm. Both strength functions flatten out at low γ-ray energies, but with no strong enhancement of the RSF which was recently found in both Fe [5] and Mo nuclei [6]. There was observed an enhancement of more than a factor of 10 over common theoretical models for the soft ($E_\gamma < 2$ MeV) RSF.

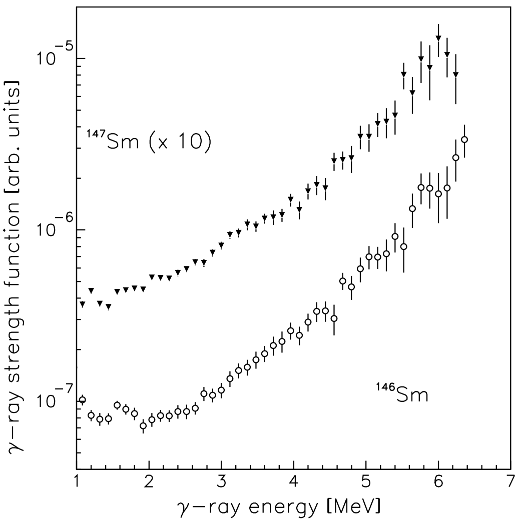

Fig. 3. The radiative strength function for ^{147}Sm (filled triangles) and ^{146}Sm (open circles). The ^{147}Sm values are multiplied by a factor 10.

4. Conclusions

In conclusion, as we approach the $N = 82$ shell closure the level density is decreasing and shows more pronounced step structures. The pygmy resonance with M1 multipolarity seen in the deformed rare earth nuclei is not present. The observed enhancement of more than a factor of 10 of the transition strength in the total RSF of Fe and Mo isotopes at low γ-ray energies, is not seen in the Sm nuclei.

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