L. V. GROSHEV, A. M. DEMIDOV, V. A. IVANOV, V. N. LUTSENKO

and V. I. PELEKHOV

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L. V. GROSHEV, A. M. DEMIDOV, V. A. IVANOV, V. N. LUTSENKO and V. I. PELEKHOV

ENERGY LEVELS OF Gd^{156} AND Gd^{158}

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In recent years, in many works the schemes of the low-lying levels of even-even gadolinium isotopes have been studied in detail. These isotopes attract attention because here it is possible to trace the behavior of levels of different nature under a sharp change in nuclear deformation in the region where the number of neutrons passes through $N = 90$.

Information on the levels of Gd^{156} and Gd^{158} can also be obtained by studying the radiation arising in the de-excitation of a nucleus after capture of a thermal neutron ([1,2]). Such a study gives new possibilities for investigating the levels of even-even nuclei.

It is known that in radiative neutron capture, high-energy γ rays are due to transitions from the initial state formed upon capture of a thermal neutron to lower nuclear levels. This circumstance makes it possible reliably to introduce levels at excitation energies from zero to 2-3 MeV, with angular momenta differing from that of the initial state by $\Delta I = 0, \pm 1$.

Furthermore, in radiative neutron capture, as a result of cascade de-excitation of the nucleus, appreciable population occurs for most levels lying at energies below ~ 1.5 MeV.

The possibility of comparing internal-conversion electron spectra and γ-ray spectra measured with high resolution makes it possible to establish the characteristics of γ transitions and, in particular, to identify $0^+ \to 0^+$ transitions and monopole transitions with large matrix elements.

We have studied the spectra of γ rays and internal-conversion electrons for Gd^{156} and Gd^{158}, formed in the $(n\gamma)$ reaction. The measurements were carried out on enriched isotopes Gd^{155} and Gd^{157}. The γ-ray spectra were measured with a magnetic Compton spectrometer ([3]), and the spectra of internal-conversion electrons on a special magnetic spectrometer ([4]). The spectra obtained make it possible to construct schemes of γ transitions for Gd^{156} and Gd^{158}.

From transitions out of the initial state we established in Gd^{156} and Gd^{158} the presence of a large number of levels up to excitation energy ~ 3 MeV. In the

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present work we restrict ourselves to consideration of only the very lowest levels with excitation energy below 1.5 MeV (see Fig. 1).

In Fig. 2 the upper part of the γ spectrum of Gd^{158} is shown as an example. In the spectrum a transition with energy 7857 keV from the initial state to the first excited level is reliably established (see the right inset). From the energy of this transition the neutron binding energy in Gd^{158} was determined. It is equal to (7937 ± 5) keV. In the same way, for the neutron binding energy in Gd^{156} the value (8531 ± 5) keV was obtained.

In the spectrum of Fig. 2 the greatest interest is presented by γ transitions with energies 6960 and 6911 keV to the levels 978 and 1025 keV. These levels are strongly populated—

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during the cascade de-excitation of the Gd^{158} nucleus and decay with the emission of intense lines lying in the lower part of the spectrum. Analysis of the decay scheme of the 978 and 1025 keV levels and determination of the multipolarities of the γ transitions (see Fig. 1) leads to the conclusion that these levels have characteristics 1^- and 2^-, respectively.

Fig. 3. Comparison of the spectra of γ rays (a) and internal-conversion electrons (b) of Gd^{156} in the energy range 900—1200 keV

It should be noted that in the spectra of γ rays and internal-conversion electrons of Gd^{158} at an energy of ~ 1 MeV there are also intense transitions which were not included in the scheme shown in Fig. 1. This circumstance indicates that at an energy of ~ 1 MeV there are also other levels, strongly populated as a result of cascade de-excitation of the nucleus. In particular, from the difference between the energies of two very intense E1 transitions with energies of 964 and

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778 keV, one may suppose the existence of a 1044 keV level with characteristic 3^-. This level also appears in the radioactive decay of Tb^{158}*.

* R. A. Naumann —private communication.

The presence in Gd^{158} of levels with negative parity at an excitation energy of ~ 1 MeV is of undoubted interest. Their appearance is most probably associated with the breaking of a pair of nucleons and the transition of one nucleon to another state. This assumption is confirmed by the theoretical calculations of Galacher and Solovjev.*

In Gd^{156}, levels with negative parity have also been found. Their energies are 1273 and 1316 keV. The 2^- characteristic for the 1316-keV level was also established in work ([5]).

Figure 3 shows a section of the spectra of γ rays and internal-conversion electrons for Gd^{156} in the energy interval 900–1200 keV. Comparison of these spectra shows that, in the case of the 1011- and 1041-keV transitions, the conversion coefficients are considerably larger than for the E2 transitions of 960, 1065, and 1159 keV. Several assumptions can be made to explain such large coefficients.

1) The transitions are of type M2 or E4. The existence of transitions of such multipolarity at an energy of ~ 1 MeV is unlikely, since much more intense competing transitions of lower multipolarity should be present.

2) The indicated lines correspond to transitions between levels with identical angular momenta and parities. In this case, the increase in the conversion coefficient is associated with the contribution to conversion from a monopole transition.

3) The internal-conversion electron lines under consideration are not monochromatic, but correspond to two transitions of close energy, one of the transitions being of the type $0^+ \to 0^+$. For the 1041-keV line, it was shown in work ([6]) that it corresponds to transitions located in two places.

In constructing the scheme of Fig. 1 we assumed that the 1011-keV line corresponds to a $0^+ \to 0^+$ transition, and the 1041-keV line to the transition 2^+ (1130 keV) $\to 2^+$ (89 keV). If it is assumed that the 1011- and 1130-keV levels belong to the β-vibrational band, then, according to theoretical calculations, large matrix elements are expected for the $0^+ \to 0^+$ transition and the monopole transition between levels with characteristics 2^+. The 1130-keV level was also found in work ([6]).

In Gd^{158} a 1427-keV transition is observed, which also has a very large conversion coefficient. We assume that it corresponds to a $0^+ \to 0^+$ transition.

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* C. J. Galacher, V. P. Solovjev —private communication.

Note: Figure translations are in progress. See original paper for figures.