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Abstract

Full Text

PHYSICS

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HYPERFINE STRUCTURE OF PARAMAGNETIC RESONANCE. NUCLEAR SPIN AND MAGNETIC MOMENT OF THE 5.3-YEAR RADIOACTIVE ISOTOPE Eu^{152}

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From the hyperfine structure of paramagnetic resonance, the nuclear spin and magnetic moment of the 5.3-year radioactive isotope Eu^{152} have been determined: $I(\text{Eu}^{152}) = 3$, $|\mu_{152}| = 2.03$ nuclear magnetons.

In works ^(1,2) the hyperfine structure of the paramagnetic resonance of Eu^{2+} , caused by the nuclei of the stable isotopes Eu^{151} and Eu^{153} , was investigated.

In the present work we investigated paramagnetic resonance in a powdered SrS phosphor activated with europium and containing the 5.3-year radioactive isotope Eu^{152} . The latter was obtained by irradiating the natural mixture of the isotopes Eu^{151} (47.77%) and Eu^{153} (52.23%) with thermal neutrons. In this irradiation, an appreciable yield is obtained of the radioactive isotope Eu^{152} , formed from Eu^{151} by the reaction $\text{Eu}^{151} (n, \gamma) \text{Eu}^{152}$.

No appreciable accumulation of other radioactive isotopes, Eu^{154} and Eu^{155} , formed in the pile by the reactions $\text{Eu}^{153} (n, \gamma) \text{Eu}^{154}$ and $\text{Eu}^{154} (n, \gamma) \text{Eu}^{155}$, occurs because of the unfavorable ratios of the effective neutron cross sections for Eu^{153} , Eu^{154} , and Eu^{155} ^(3,4). The initial mixture of the isotopes Eu^{151} and Eu^{153} was irradiated with a neutron flux of $4 \cdot 10^{13}$ for 39 days.

As a result of the irradiation, a mixture of the isotopes Eu^{151} , Eu^{152} , and Eu^{153} was obtained, whose relative contents, as was shown by our paramagnetic-resonance experiments described below, were respectively 29%, 17%, and 54%.

A sample of the SrS phosphor activated with this mixture of europium isotopes was obtained by a method developed by Z. A. Trapeznikova. This method is as follows: into a mixture of 2 g SrCO_3 , 1.5 g S, and 0.35 g SrCl_2 , a solution of EuCl_2 was introduced, after which the mixture was dried and calcined in air at a temperature of 1150°C for 20 min. The concentration of europium in the phosphor was $\sim 10^{-4}$.

Paramagnetic resonance in this sample was investigated at a frequency of 9343

Mc/s with the aid of a superheterodyne radio spectroscopy described in ⁽⁵⁾. The observed spectrum is shown in Fig. 1. It consists of three series of hyperfine-structure components caused by the nuclei Eu^{151} , Eu^{152} , and Eu^{153} ; the spectrum belongs to one electronic transition $M = 1/2 \leftrightarrow -1/2$ (lines corresponding to other electronic transitions are not observed because of their anisotropic broadening in the powder).

Series I consists of the most intense lines, belonging to the isotope Eu^{153} ; series II—of lower intensity—to Eu^{151} ; and series III—of the lowest intensity—to the radioactive isotope Eu^{152} .

In the figure, solid lines show the well-resolved components of the spectrum; dashed lines show components belonging to the isotope Eu^{152} , which are overlapped in the observed spectrum by components from

of the isotope Eu^{151} . The magnetic field was measured by means of proton resonance. The positions of the lines are indicated in Fig. 1 in proton-resonance frequencies (in Mc).

As is seen from Fig. 1, the number of components in each of series I and II is 6, which corresponds to the nuclear spins of Eu^{151} and Eu^{153} , $I = 5/2$, while the total splittings in these series, as was already reported ^(1,2), give for the ratio of the magnetic moments of the Eu^{151} and Eu^{153} nuclei the value $\mu_{151}/\mu_{153} = 2.24$.

As for series III, belonging to the radioactive isotope Eu^{152} , not all components in it are resolved owing to their overlap with the lines of the stable isotope Eu^{151} . The lines 14.096; 14.160; 14.290 and 14.416 Mc are completely resolved. The relative distances between these lines show that the nuclear spin of Eu^{152} is equal to $I = 3$. In this case the remaining 3 lines, which should be observed at the frequencies 14.225; 14.354; 14.480 Mc, are overlapped, respectively, by the lines 14.218; 14.353 and 14.488 Mc of the isotope Eu^{151} , since the distances between these corresponding lines are smaller than the linewidth (12 kc on the proton-resonance frequency scale). This overlap is confirmed by the fact that the intensities of the lines 14.218; 14.354 and 14.488 Mc in the observed spectrum are greater than the intensities of the other lines of the isotope Eu^{151} .

Any other values of the nuclear spin of Eu^{152} , except $I = 3$, are excluded, since otherwise additional lines should have been observed, sufficiently well resolved from the lines of the stable isotopes. The value $I = 6$ was probable, since in this case the additional lines should have been located close to the lines of the isotope Eu^{153} and could have been overlapped by the latter.

However, a detailed analysis of the observed spectrum shows that the value $I = 6$ is also excluded. This is confirmed by two circumstances.

For $I = 6$ there should have existed a line at 14.128 Mc. This presumed line would have been sufficiently well resolved in the spectrum from the 14.139 Mc line of the isotope Eu^{153} , since it would have been separated from it by a distance of 11 kc, almost equal to the linewidth. It may be noted that the lines 14.083 and 14.096 Mc, separated from one another by 13 kc, are well resolved in the

Fig. 1. Hyperfine structure of paramagnetic resonance in SrS · Eu^{151,152,153} in the electronic transition $M = 1/2 \leftrightarrow -1/2$

Figure 1: Fig. 1. Hyperfine structure of paramagnetic resonance in SrS · Eu^{151,152,153} in the electronic transition $M = 1/2 \leftrightarrow -1/2$

observed spectrum. Careful study of the 14.139 Mc line showed the absence of the presumed line. A comparison of the relative intensities of the spectral lines also indicated the absence of additional lines, except for the lines corresponding to spin $I = 3$.

Thus, it may be considered established that the nuclear spin of Eu¹⁵² is equal to 3.

The frequencies of the observed spectrum are described by formula (2):

$$h\nu = g\beta H + Am' + \frac{1}{2} \frac{A^2}{g\beta H_0} \{I(I+1) - m^2\}. \quad (1)$$

Comparison of the observed frequencies with this formula gives the following values for the g -factor and the hyperfine-structure constant A_{152} : $g = 1.992 \pm 0.001$; $A_{152}^* = 0.064 \pm 0.002$ Mc (on the proton-resonance frequency scale); $A_{152} = (13.9 \pm 0.1) \cdot 10^{-4} \text{ cm}^{-1}$. It should be noted that for the hyperfine-structure constants A_{151} and A_{153} the values obtained are $A_{151} = (29.4 \pm 0.1) \cdot 10^{-4} \text{ cm}^{-1}$; $A_{153} = (13.1 \pm 0.1) \cdot 10^{-4} \text{ cm}^{-1}$, which are somewhat smaller than the values determined for the phosphor SrS · Eu in (1,2). Since the hyperfine splitting depends on the electric field of the crystal, this

Fig. 1. Hyperfine structure of paramagnetic resonance in SrS · Eu^{151,152,153} in the electronic transition $M = 1/2 \leftrightarrow -1/2$.

The discrepancy is probably connected with certain differences in the crystalline structure of these specimens.

A considerable difference in the values of the hyperfine-structure constants (about 15%) had previously been found (2) in SrS · Eu and CaF₂ · Eu. However, in all cases the ratio A_{151}/A_{153} was the same, i.e., it did not depend on the crystalline structure.

The total hyperfine splitting for a given isotope is equal to $2AI$, and, since the constant A is proportional to the ratio of the magnetic moment μ of the nucleus to its spin I , the total splitting is proportional to μ . Therefore, from the observed spectrum one can directly determine the ratio of the magnetic moments of the nuclei Eu¹⁵¹ (or Eu¹⁵³) and Eu¹⁵². This ratio is:

$$\mu_{152}/\mu_{151} = 1.77 \pm 0.02.$$

Using for μ_{151} the known value of 3.6 nuclear magnetons ⁽⁶⁾, we obtain for the magnetic moment of the Eu¹⁵² nucleus:

$$\mu_{152} = 2.03 \text{ nuclear magnetons.}$$

The relative signs of the moments μ_{151} and μ_{152} remain undetermined. They can be determined by comparing the hyperfine splitting in different electronic transitions ⁽²⁾.

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CITED LITERATURE

1. B. Bleaney, W. Low, Proc. Phys. Soc., **A 68**, 55 (1955).
2. A. A. Manenkov, A. M. Prokhorov, DAN, **107**, 402 (1956).
3. D. Hughes, *Neutron Investigations on Nuclear Reactors*, IL, 1954.
4. R. J. Hayden, J. H. Reynolds, M. G. Ingram, Phys. Rev., **75**, 150 (1949).
5. A. A. Manenkov, A. M. Prokhorov, *Radiotekhn. i elektronika*, **1**, No. 4, 469 (1956).
6. P. F. A. Klinkenberg, Rev. Mod. Phys., **25**, 63 (1952).

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