# THE $g$-FACTOR OF THE $21/2^+$ STATE IN $^{91}$Nb

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The $^{89}$Y($\alpha$, $2n\gamma$)$^{91}$Nb reaction was used to populate excited states in $^{91}$Nb. The rotation of the angular distribution of the 357 keV gamma-transition from the $21/2^+$ state was measured in an external magnetic field. The IPAD method was used. By applying $\tau = (1.33 \pm 0.14)$ ns for the lifetime of the $21/2^+$ state at 3467 keV, the value of the $g$-factor $1.18 \pm 0.18$ was derived.

## 1. Introduction

The properties of the $N = 50$ isotones have been succesfully described by the shell model treating $^{88}$Sr as an inert core and the valence protons as being restricted to the $2p_{1/2}$ and $1g_{9/2}$ orbits [1-6]. In such configuration space the three valence protons in $^{91}$Nb can have the $p_{1/2}(g_{9/2})^2$, $(p_{1/2})^2\, g_{9/2}$ and $(g_{9/2})^3$ configurations. Of the three configurations, the last is the only one for which such a spin value as 21/2 can be obtained in the framework of the pure shell model.

The level scheme as well as electromagnetic properties of the $^{91}$Nb nucleus have recently been studied in several experiments [7-12]. Nearly all levels belonging to the $(g_{9/2})^3$ and all of the $p_{1/2}\,(g_{9/2})^2$ proton configurations have been found [10].

For the $13/2^-$ state at 1985 keV the $g$-factor was determined by Feastermann et al. [11] and their experimental result was interpreted in terms of the $|\pi(g_{9/2})^2\, p_{1/2}, 13/2\rangle$ configuration. Recently Schneider et al. [12] have measured the half-life of the lowest $21/2^+$ state at 3467 keV in $^{91}$Nb with the pulsed-beam direct-timing method. The result is $T_{1/2} = (0.92 \pm 0.10)$ ns. In their work both the experimental and theoretical E2 transition rates were derived and it was suggested that the $21/2^+ \rightarrow 17/2^+$ transition in $^{91}$Nb might not be very sensitive to configuration admixtures. It was hoped that the measurements of the $g$-factor for the $21/2^+$ state could furnish some further information concerning the configuration of this state.

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## 2. *Experimental*

The measurements were performed on the alpha beam of the U-120 cyclotron in the Institute of Nuclear Physics in Cracow. The experimental conditions were similar to those described elsewhere [13]. Alpha particles with an energy of 26.5 MeV bombarded a target with $^{89}$Y. The target used in the present experiment consisted of thin natural $^{89}$Y 2 mg/cm$^2$ foil with Bi backing of 200 mg/cm$^2$ to stop the alpha beam. The target was placed within the pole pieces (8 mm diam.) of an electromagnet whose magnetic field was applied perpendicularly to the reaction plane. The intensity of the field in the target place was measured with a well calibrated Hole probe.

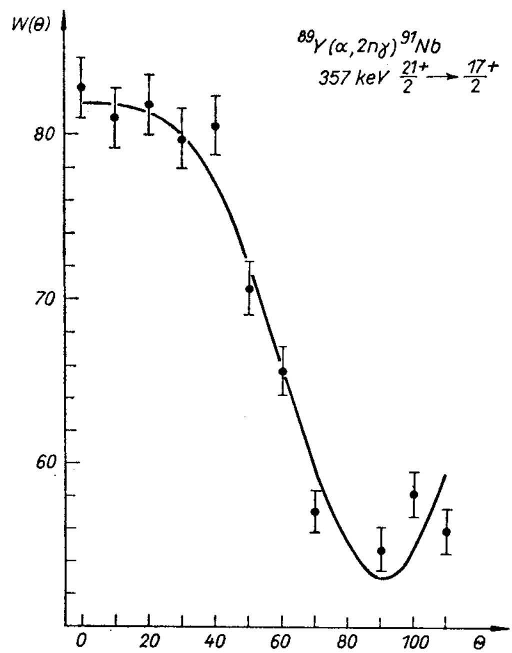


Fig. 1. Angular distribution for the 357 keV $\gamma$-line deexcitating the $21/2^+$ state at 3467 keV in $^{91}$Nb

The IPAD experiments were performed for three values of the magnetic field, i.e. for 9.5, 11.2 and 12.15 kGs the directions of which were automatically reversed every two minutes during the measurements.

The angular distribution of the 357 keV $\gamma$-ray deexciting the $21/2^+$ level at 3467 keV was measured by a 13 cm$^3$ Ge(Li) detector mounted on a turn-table at a distance of 90 mm from the target. An NaJ(Tl) counter placed at 90° to the beam direction acted as a monitor. The intensities of the $\gamma$-ray measured with the movable detector were further corrected for absorption in the target (see paragraph 3); the correction factors were calculated from the known Y and Bi thicknesses. These factors were also verified using a radioactive source placed at the beam position after the experiment. An example of the angular distribution measured for the 357 keV transition is shown in Fig. 1.

### 3. *Data analysis*

The measurements of the angular distribution of the 357 keV gamma-transition for the two opposite directions of the external magnetic field provided two sets of data: $N^{+}(\theta)$ and $N^{-}(\theta)$. As has been mentioned earlier, the magnetic field direction during the experiment was changed very frequently. Owing to the monitor detector, moreover, it was certain that the $N^{+}(\theta)$ and $N^{-}(\theta)$ values were properly normalized. Then, after the normalization at each angle for time and beam intensity and the absorption in the target, they could be fitted with the two $W^{\pm}(\theta)$ functions which are given by two following expressions

$$W^{\pm}(\theta) = b_0[1+\sum b'_k \cos k(\theta \pm \Delta_k \theta)] \tag{1}$$

where

$$b'_k = \frac{b_k}{1+(k\omega\tau)^2}$$

and

$$\Delta_k \theta = \vartheta + \frac{1}{k} \text{ arc tg } k\omega\tau.$$

The angle $\vartheta$ denotes rotation of the beam axis according to the field direction. This effect is due to the bending of the $\alpha$ beam in the stray magnetic field.

In the present work, however, instead of analysing the experimental data with these $W^{\pm}(\theta)$ functions, the values of new functions $R(\theta)$ and $W_{+}(\theta)$ were calculated from $N^{+}(\theta)$ and $N^{-}(\theta)$ quantities, where

$$R(\theta) = 2\frac{N^{+}(\theta)-N^{-}(\theta)}{N^{+}(\theta)+N^{-}(\theta)} \tag{2}$$

and

$$W_{+}(\theta) = k(\theta)N^{+}(\theta)+k(\theta)N^{-}(\theta). \tag{3}$$

An example of the experimental $R(\theta)$ function is shown in Fig. 2. The coefficients $k(\theta)$ are the normalization coefficients which involve for each angle the time and beam intensity differences and the absorption in the target. The present way of handling the data provides a more reliable method to obtain the $\omega\tau$ value, since one can avoid the normalization of the experimental $N^{+}(\theta)$ and $N^{-}(\theta)$ peak intensities at every angle $\theta$ in the calculation of the $R(\theta)$ curve. The normalization is crucial in the case of $W^{\pm}(\theta)$ curves, when they are used to provide the $\omega\tau$ value, whereas it can be dispensed with in the $R(\theta)$ function which, as will be shown below, depends directly on $\omega\tau$.

The normalization had to be taken into account in the $W_{+}(\theta)$ curve calculated in the present work, or when $W(\theta)$ was measured without the external magnetic field in the same experimental conditions in which the $R(\theta)$ curve was obtained. It was observed in the testing fits that an increase of the errors on the experimental $W^{+}(\theta)$ points (i.e. on the experimental $W^{+}(\theta)$ and $W^{-}(\theta)$) by a factor of two did not cause a similar increase of the error on $\omega\tau$ when the fit was made with the $R(\theta)$ and $W_{+}(\theta)$ functions. On the other-hand the $\omega\tau$ error obtained was two times larger when the fit was made with the functions given by Eq. (1) to the $W^{\pm}(\theta)$ values. This shows that the normalization would cause a greater effect on $\omega\tau$ if the analysis was made with $W^{\pm}(\theta)$ functions.

The computer fits were made with a MULT program [14]. The program permits to perform a simultaneous fit of two types of mathematical functions to the appropriate experimental points. Inserting in the expression (2) the functions (1) one obtains

$$R(\theta) = \frac{\sum\limits_{k\ \mathrm{even}} b_k' \sin k\theta \sin k\Delta_k\theta}{1+\sum\limits_{k\ \mathrm{even}} b_k' \cos k\theta \cos k\Delta_k\theta}. \tag{4}$$

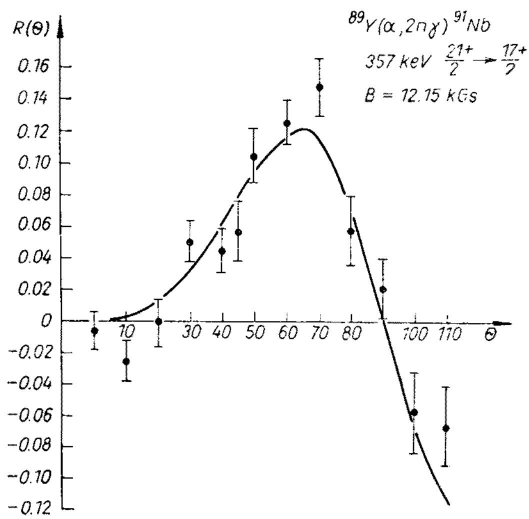


Fig. 2. Measured $R(\theta) = 2\frac{N^{+}(\theta)-N^{-}(\theta)}{N^{+}(\theta)+N^{-}(\theta)}$ at $B_0 = 12.15$ kGs external magnetic field. The solid line represents a common fit (see text)

Limiting the summation at $k = 4$ and taking into account the fact that the angle $\vartheta$ due to the beam bending is of the order of one degree, the $R(\theta)$ function can be written as

$$R(\theta) = 4\,\frac{b_2' \sin 2\theta + 2b_4' \sin 4\theta}{1+b_2' \cos 2\theta + b_4' \cos 4\theta}\,(\vartheta+\omega\tau). \tag{5}$$

The $W_{+}(\theta)$ function was then given by the following expression

$$W_{+}(0) = W_0(1+b_2' \cos 2\theta + b_4' \cos 4\theta). \tag{6}$$

The values of the angle $\vartheta = 0.0183$, 0.0216 and 0.0234 were calculated by numerical integration over the magnetic field profiles $f(s)$ obtained for the $B_0 = 9.5$, 11.2 and 12.15 kGs fields applied. This angle was calculated using the following formula

$$\vartheta = 6.942\times 10^{-3}\,\frac{B_0[\mathrm{kGs}]}{\sqrt{E_\alpha[\mathrm{MeV}]}}\int\limits_0^\infty f(s)ds. \tag{7}$$

Besides this rotation of the beam axis according to the field direction there is also a shift of the beam spot. This latter effect was also taken into account in the $N^{\pm}(\theta)$ peak intensities measured at every angle $\theta$.

The weighted average of the $g\tau$ product obtained from the experimental data for the three external fields is

$$g\tau = 1.567 \pm 0.167.$$

Applying the lifetime $\tau = (1.33 \pm 0.14)$ ns gives the following value of the $g$-factor of the $21/2^+$ state

$$g = 1.18 \pm 0.18.$$

## 4. *Discussion*

The assumption of the pure $(g_{9/2})^3$ shell model configuration for the $21/2^+$ state in $^{91}$Nb would lead to a $g$-factor for this state equal to the Schmidt limits, i.e. 1.5085, according to the additivity relation [15]. The known $g$-factors for the $(g_{9/2})^n$ configurations in the $^{88}$Sr region obtained from the experimental magnetic moments measured for the states $8^+$ in $^{90}$Zr, $9/2^+$ in $^{93}$Nb and $8^+$ in $^{92}$Mo deviate from the Schmidt value [15]. Of those three $g$-factors, the one for $^{90}$Zr, $g = 1.364 \pm 0.019$, is considered to correspond to almost pure configuration of $(g_{9/2})^2$ while for the $(g_{9/2})^3$ configuration the value of $g = 1.371$ was obtained from the measured magnetic moment of the $9/2^+$ ground state of $^{93}$Nb [16].

The present $g$-factor, $g = 1.18 \pm 0.18$, for the $21/2^+$ state in $^{91}$Nb seems to be lower than that value. However, there is a relativly high uncertainty, which is due to the large error in the mean lifetime of this state and the necessity to employ the integral PAD method.

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