UCRL-17636

cy. 2

University of California

Ernest O. Lawrence Radiation Laboratory

g FACTOR OF THE 243-keV LEVEL IN ^{86}Y

William J. Treytl and E. Matthias

June 1967

TWO-WEEK LOAN COPY

This is a Library Circulating Copy which may be borrowed for two weeks. For a personal retention copy, call Tech. Info. Division, Ext. 5545

UCRL-17636 cy. 2

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

International Conference on Hyperfine Interactions
Detected by Nuclear Radiation, Asilomar,
August 25-30, 1967

UCRL-17636
Preprint

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

AEC Contract No. W-7405-eng-48

g FACTOR OF THE 243-keV LEVEL IN ^{86}Y

William J. Treytl and E. Matthias

June 1967

g-FACTOR OF THE 243-keV LEVEL IN ^{86}Y*

William J. Treytl† and E. Matthias

Lawrence Radiation Laboratory
University of California
Berkeley, California

June 1967

ABSTRACT

g-factor and half-life of the 243-keV 2- state in ^{86}Y have been measured. The values obtained are $g = -0.53 \pm 0.03$ and $t_{1/2} = 28.5 \pm 2.1$ nsec. The g-factor favors the configuration $[(p_{1/2})_\pi (d_{5/2})_\nu]_{2-}$.

INTRODUCTION

The decay properties of ^{86}Zr have been reported in recent studies.[1,2] In the most recent investigation,[2] a relatively complete decay scheme was proposed which, in addition to assigning energies, spins, and parities for the ^{86}Y levels populated, also postulated probable nucleon configurations for the levels. The decay scheme is given in Fig. 1. One difficulty was encountered with 2- level at 243 keV, which is the lowest excited ^{86}Y level populated by ^{86}Zr decay. In this decay sequence log ft values, conversion coefficients, and transition rates all argue strongly for straight-forward single-particle transitions. These considerations would support a $(\pi p_{1/2}\ \nu d_{5/2})_{2-}$ configuration for the 243-keV level, but according to the shell model, the closest available $d_{5/2}$ orbital should lie considerably higher than 243 keV. Other configurations are possible, but in such cases, one would not expect such good agreement with single-particle transition theory as was observed. For these reasons, no nucleon configuration was assigned to that level.

It was hoped that the determination of the g-factor of the 2-level would greatly clarify the configuration of this level. The known[2] half-life

of the 243 keV level ($T_{1/2}$ = 29 nsec) and the anisotropy of about -8% for the 28-243 keV cascade makes a spin precession experiment[3] in a large external magnetic field feasible.

EXPERIMENTAL

A magnetic field of about 41 kG was used. The detectors were 1 1/2" × 1" and 1 1/2"× 2" NaI(TL) crystals for the 28 keV and the 243 keV γ-rays respectively, mounted with 30 cm long quartz light pipes onto XP1020 photomultipliers. The two detectors were placed at an angle of $\theta_0 = 225°$, reading clockwise from γ_1 to γ_2. Time spectra were taken with the magnetic field pointing upward (C↑) and downward (C↓) with respect to the detector plane. The exponential decay was normalized out by forming the usual ratio[4,5]

$$R_i = 2(C_i\downarrow - C_i\uparrow)/(C_i\downarrow + C_i\uparrow)$$

for each channel number i. Since the 28 keV transition is of pure E1 character[2] and K > 2 terms vanish for pure L=1 transitions, the ratio R_i can be written in the form

$$R_i = a \cos 2(\omega_L t_i - \phi) + c \quad ,$$

where $\omega_L = g \cdot \frac{\mu_N}{\hbar} \cdot H$ is the Larmor precession frequency. The amplitude a

is connected with the angular correlation coefficients by the relation

$$a = \frac{3}{2} A_2/(1 + 1/2\ A_2) .$$

The phase ϕ determines the sign of the g-factor. A least-squares fit of the function R_i to the data yields the product $g \cdot H$ and its sign. Details of this type of data treatment have been described earlier.[4,5]

Samples were produced by bombarding pressed arsenic targets with 160 MeV ^{16}O ions. The $^{75}As(^{16}O,5n)^{86}Zr$ reaction yielded ^{86}Zr in high isotopic purity. The Zr fraction was separated from the bombarded targets by standard radiochemical techniques.[2,6] The final ^{86}Zr samples were in 1 M HCl solution, in polyethylene containers of about 100 λ volume. It would have been preferable to take advantage of a diamagnetic cubic metallic lattice by dispersing the source in, for example, copper; however, the high absorption of the already weak 28 keV transition in such media rendered this approach inapplicable.

The low energy of the 28 keV transition presented other problems. Yttrium-86, the daughter of ^{86}Zr, is itself unstable and has a complex decay scheme,[7] with many higher energy γ rays. Consequently, as the daughter grew in, the number of events in the 28 keV window became predominantly compton events of the ^{86}Y decay. It was observed, in fact, that as samples aged, the apparant amplitude of the perturbation diminished. Accordingly, attempts were made to periodically remove daughter activities from the sample. These difficulties, which arise primarily from the low energy of the 28 keV

transition, could be circumvented by performing in-beam experiments, in which advantage is taken of the fact that following nuclear reactions induced by charged particle bombardment, product nuclei are strongly aligned in a plane perpendicular to the beam axis, which may be used as a reference axis. The resulting angular distribution can be rotated in a magnetic field applied perpendicular to the beam-detector plane. Using a pulsed beam, this rotation can be observed as a function of time. Further, recoil energies are sufficient to implant the product nuclei into a perturbation free metallic host. Experiments of this nature, which should give greatly improved results, are being contemplated.

RESULTS

The results of five separate experiments upon ^{86}Zr samples in 1 M HCl solution are summarized in Table I. A notable feature of these results is the variation in the percentage of the oscillation amplitude. We interpret this as the effect of daughter growth in the sample, which suggests that there is a level in ^{86}Sr whose lifetime falls within our experimental range. As seen in Table I, we obtain a weighted average for the g-factor of the 243 keV 2- level of ^{86}Y

$$g = -0.53 \pm 0.03.$$

The half-life of the 243 keV level was also remeasured. Excluding run 4, the average value of 28.5 ± 2.1 nsec agrees well with the previously reported figure of 29 ± 3 nsec.[2]

The question arises whether or not a paramagnetic correction, $\beta = H_{eff}/H_0$, has to be applied in this case. Yttrium forms only one stable oxidation state: Y(III), which corresponds to the krypton core and as such is diamagnetic. If the rearrangement of the electronic shell after EC-decay of the ^{86}Zr(IV), which is the only stable oxidation state for zirconium, goes faster than 10^{-8} sec, no paramagnetic correction is necessary. In a strongly ionic solution this is believed to be the case and we assume that within the present limits of error, no correction need to be applied to the g-factor. We note, however, that there is no proof for this assumption and the electron capture might actually lead to a mixture of oxidation states existing during the lifetime of the 243 keV level. The only way to clarify this question with confidence is to remeasure the g-factor with ^{86}Y in a diamagnetic metallic host.[4,5]

DISCUSSION

The main purpose of this work was to obtain information concerning the nuclear configuration of the 243 keV 2- level in ^{86}Y. The low lying intrinsic states of odd-odd nuclei are usually derived by coupling neutron (ν) and proton (π) states. In many cases, these same states may be found in neighboring odd-A nuclei. Hyde, et al.,[2] have suggested four possible configurations for the 243 keV level which could yield the proper spin and parity

I $[(p_{3/2})_\pi(7/2+)_\nu]_{2-}$

II $[(f_{5/2})_\pi(7/2+)_\nu]_{2-}$

III $[(f_{5/2})_\pi(g_{9/2})_\nu]_{2-}$

IV $[(p_{1/2})_\pi(d_{5/2})_\nu]_{2-}$.

If we assume that the ν configurations are the same as those of the ground states of the neighboring even Z-odd N nuclei exhibiting the proper spin and parity, and the π configurations are the same as for the neighboring even N-odd Z nuclei of appropriate spin and parity, we may interpolate from the experimental g-factors compiled by Lindgren[8] and calculate g-factors for the respective configurations. These values are shown in Table II. While the data available is somewhat sparse for some of the states, the calculated g factors should be reasonable predictions. The calculated value for configuration IV is -0.55, which is in quite good agreement with our experimental value. None of the other configurations can be said to agree with the observed result.

It is interesting to note that III is the configuration favored by in Ref. 2 on the basis of single-particle transition rates. Our results clearly support this configuration, and indicate that the $d_{5/2}$ neutron level lies somewhat lower in energy in the region just below the 50 neutron level than would be predicted by the simple shell model calculations.

Footnotes and References

*This work performed under the auspices of the U. S. Atomic Energy Commission.

†Present address: Naval Radiological Defense Laboratory, San Francisco, California.

1. Y. Awaya and Y. Tendow, J. Phys. Soc. Japan 19, 606 (1964).
2. E. K. Hyde, W. J. Treytl, A. Siivola, P. H. Sisson, and D. J. Horen, Phys. Rev. 142, 657 (1966).
3. R. M. Steffen and H. Frauenfelder, Perturbed Angular Correlations, Eds. E. Karlsson, E. Matthias, and K. Siegbahn (North Holland Pub. Co., Amsterdam, 1964), p. 1.
4. E. Matthias, D. A. Shirley, J. S. Evans, and R. A. Naumann, Phys. Rev. 140, B264 (1965).
5. E. Matthias, S. S. Rosenblum, and D. A. Shirley, Phys. Rev. 139,B532 (1965).
6. E. P. Steinberg, Natl. Acad. Sci.-Natl. Res. Council Publ. NAS-NS-3011.
7. B. Van Nooijen, W. Lounens, H. Van Krugten, and A. H. Wapstra, Nucl. Phys. 63, 241 (1965).
8. I. Lindgren, in Alpha-, Beta-, and Gamma-Ray Spectroscopy, Ed. K. Siegbahn (North Holland Publishing Co., Amsterdam, 1965) Appendix 4, p. 1621.
9. Y. E. Kim, D. J. Horen, and J. M. Hollander, Nucl. Phys. 31, 447 (1962).

Table I. Summary of experimental results.

Run No.	$\lambda \pm \Delta\lambda$	t cal (nsec/ch)	$t_{1/2}$ (nsec)	$\omega \pm \Delta\omega$	$\lvert a\rvert(\%)\pm\Delta a$	H(kg)	$g \pm \Delta g$
1	$5.44\times10^{-2}\pm4.35\times10^{-4}$	2.32	29.4±0.2	$2.33\times10^{-1}\pm1.36\times10^{-2}$	2.83±1.09	41.0	-0.512±0.032
2	$3.93\times10^{-2}\pm1.26\times10^{-3}$	1.65	29.1±0.8	$1.73\times10^{-1}\pm6.76\times10^{-3}$	6.21±1.24	41.0	-0.534±0.021
3	$1.86\times10^{-2}\pm1.33\times10^{-3}$	0.784	29.2±2.0	$8.22\times10^{-2}\pm1.39\times10^{-2}$	1.91±1.14	41.0	-0.534±0.082
4	$2.01\times10^{-2}\pm6.40\times10^{-4}$	1.11	38.2±1.2	$1.19\times10^{-1}\pm1.32\times10^{-2}$	1.59±0.92	41.5	-0.540±0.060
5	$2.92\times10^{-2}\pm6.59\times10^{-4}$	1.11	26.4±1.2	$1.17\times10^{-1}\pm5.34\times10^{-3}$	4.55±0.93	41.5	-0.531±0.024

weighted average: $\bar{t}_{1/2} = 28.5\pm2.1$ $\bar{g} = -0.529\pm0.029$

Table II. Estimated g-factors for various possible configuration of the 243-keV 2- level in ^{86}Y.

π state	g^a	ν state	g^a		Configuration	g
$p_{3/2}(^{81}Rb, ^{87}Rb, ^{79}Br, ^{81}Br)$	+1.40	$7/2+(^{79}Se)$	-0.31	I	$[(p_{3/2})_\pi(7/2+)_\nu]_{2-}$	-1.16
$f_{5/2}(^{83}Rb, ^{85}Rb)$	+0.50	"	"	II	$[(f_{5/2})_\pi(7/2+)_\nu]_{2-}$	-0.34
"	"	$g_{9/2}(^{83}Kr, ^{83}Kr, ^{87}Sr)$	-0.22	III	$[(f_{5/2})_\pi(g_{9/2})_\nu]_{2-}$	-0.82
$p_{1/2}(^{89}Y, ^{91}Y)$	-0.06	$d_{5/2}(^{95}Mo, ^{97}Mo, ^{99}Tc)$	-0.50	IV	$[(p_{1/2})_\pi(d_{5/2})_\nu]_{2-}$	-0.55

[a]Estimated from experimental values given in ref. 8 for isotopes within parantheses.

Figure Captions

Fig. 1. Decay scheme of ^{86}Zr, the 8+ and 5- levels from the work of Kim, et al.[9]

Fig. 2. Measurement of the time pattern of the angular correlation precessing in an external field of 41.0 kG, using a 1 M HCl liquid source.

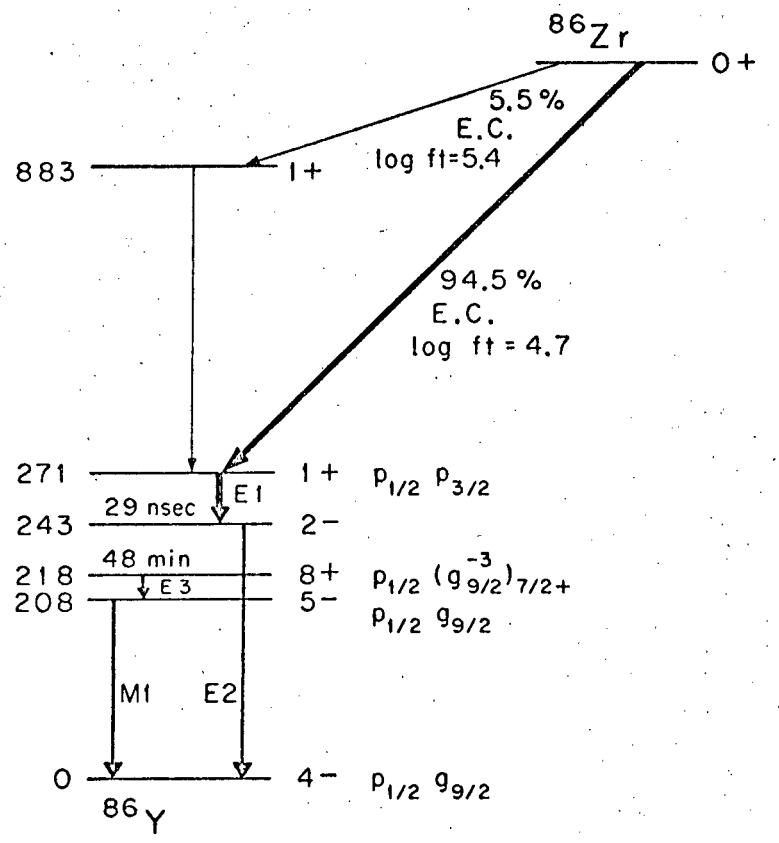
86Zr
0+
5.5 %
E.C.
log ft=5.4
883
1+
94.5 %
E.C.
log ft = 4.7
271
1+
p1/2 p3/2
E1
29 nsec
243
2−
48 min
218
8+
p1/2 (g9/2-3)7/2+
E3
208
5−
p1/2 g9/2
M1
E2
0
4−
p1/2 g9/2
86Y
MUB-7880A

Fig. 1

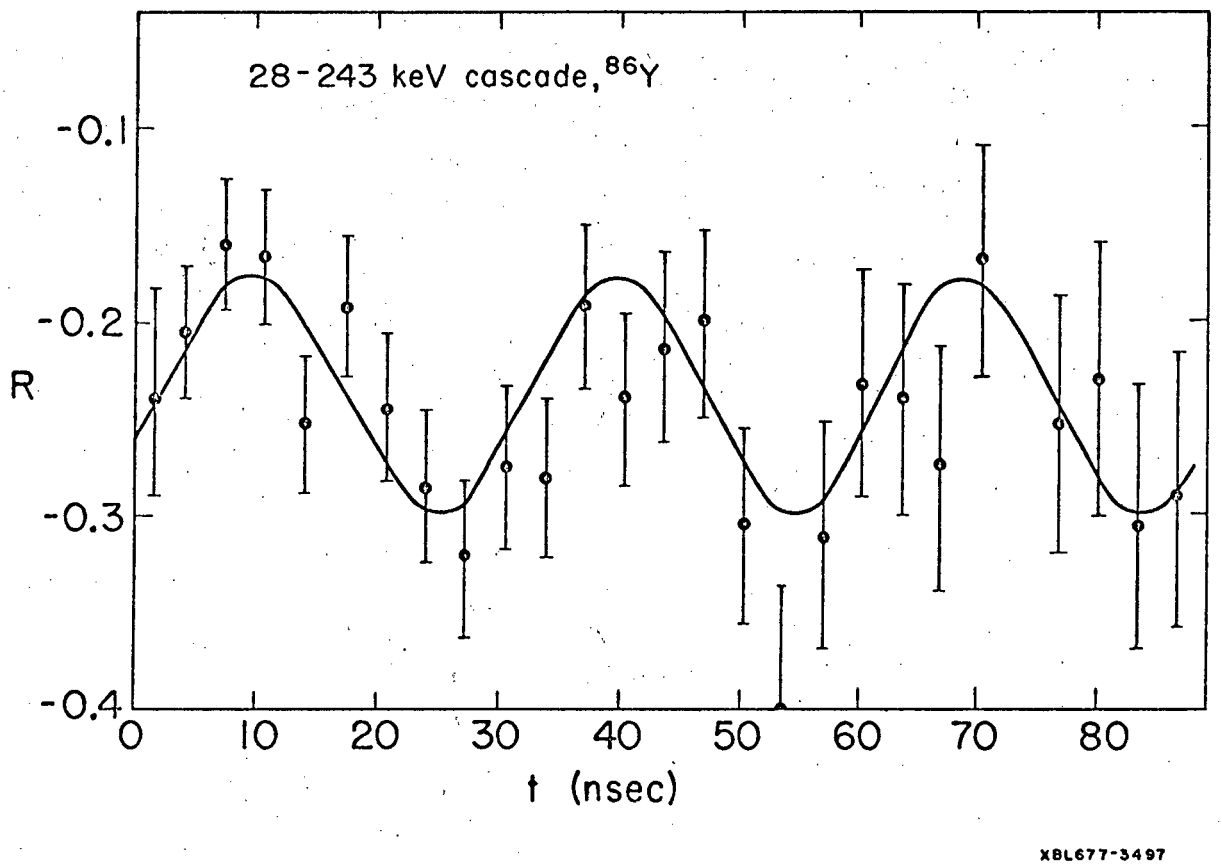
28-243 keV cascade, ^{86}Y
-0.1
-0.2
-0.3
-0.4
R
0
10
20
30
40
50
60
70
80
t (nsec)
XBL677-3497

Fig. 2

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.