Half-Life of Nickel-63†

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The half-life of Ni^{63} was calculated to be 91.6±3.1 years from specific activity measurements. Liquid scintillation counting techniques were used to measure the disintegration rate.

INTRODUCTION

PREVIOUS reports[1–4] on the half-life of Ni^{63} have given values which vary from 61 to 125 years. (See Table I.) In this work we have obtained a value for the half-life using liquid-scintillation and mass-spectrometric techniques.

EXPERIMENTAL

A sample of nickel oxide, enriched in Ni^{62},[5] was irradiated in the Argonne CP-5 reactor at a flux of 6×10^{13} neutrons/cm² sec for a time-integrated flux of 3.7×10^{20} neutrons/cm². After allowing the shorter-lived activities to decay (about 4 months) the sample was dissolved in dilute HCl and purified by precipitation with Nioxime.[6] The Ni-Nioxime was dissolved and heated in HNO_3 to destroy the Nioxime. The HNO_3 was expelled by repeated evaporation with HCl. The Ni was finally dissolved in dilute HCl. The Ni concentration of this stock solution was determined colorimetrically by a dimethylglyoxime oxidizing agent method.[7]

For the preparation of counting samples, weighed aliquots of the stock solution were made slightly basic with NaOH and the Ni was extracted into a 1:1 solution of di(2-ethylhexyl) orthophosphoric acid (HDEHP) in xylene. Assay of the aqueous phase showed that less than 0.1% of the Ni remained there. Weighed aliquots of these Ni-HDEHP solutions were added to 250 μl of scintillator solution and sealed in thin-walled 7-mm-diam quartz tubing[8,9] for counting in a liquid scintillation spectrometer.[10] Two scintillator solutions with the following compositions were used.

a. 4 g *p*-terphenyl and 0.1 g POPOP in one liter of xylene.

b. 7 g PPO and 0.1 g POPOP in one liter of xylene.

Both solutions gave similar results. Three Ni-HDEHP solutions of different concentrations were prepared. Six counting samples, three in solution (a) and three in solution (b), were prepared from each Ni-HDEHP solution.

The samples were counted in single-channel and coincidence systems using a small Lucite light pipe to insure maximum light collection.[8,9]

The Ni was electroplated on tungsten filaments for mass spectrometry in the manner of McMullen *et al.*[4] The measurements were carried out in a 12-in., 60° mass spectrometer with a multiple-filament surface ionization source.

TABLE I. Reported half-life values for Ni^{63}.

Half-Life	Author	Method
Several hundred years	Friedlander[a]	Yield, neutron cross section
61 yrs	Wilson[b]	Yield, neutron cross section
85±20 yrs	Brosi *et al.*[c]	Yield, neutron cross section
125±6 yrs	McMullen *et al.*[d]	Specific activity, $4\pi\beta$ counting
91.6±3.1 yrs	This work	Specific activity, liquid scintillation counting

[a] See reference 1.
[b] See reference 2.
[c] See reference 3.
[d] See reference 4.

RESULTS

The abundance of the Ni isotopes was measured for the unirradiated and irradiated samples. The results for the unirradiated samples are:

Isotope	Atom percent abundance
58	0.59 ±0.02
60	1.41 ±0.02
61	0.132±0.006
62	97.75 ±0.03
64	0.121±0.007

Small amounts of masses 63 and 65 which were in the ratio of normal copper were observed in the unirradiated Ni. The calculated ratio of Ni^{63} to Ni^{62} in the irradiated sample was 0.00546±0.00013. This ratio includes a correction in the amount of mass 63 calculated from the isotopic ratio for normal copper and the amount of mass 65 observed. After applying this correction all of the data were consistent even though the correction varied from 10 to 20% of the amount of mass 63 due to the fractionation between Ni and Cu on the filament. Duplicate samples gave the same results.

† Based on work performed under the auspices of the U. S. Atomic Energy Commission.

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[10] Model 314, "Tri-Carb," Packard Instruments Company, LaGrange, Illinois.

The counting data were analyzed statistically by the "F" method[11] and found to be within a 95% confidence level. From the ratio of the extrapolated zero-bias integral counting rates in the single-channel and coincidence systems a value of 1.5 kev was obtained for the figure of merit, the energy required to be dissipated in the scintillator solution to produce on the average one electron at the photocathode.[9] For this value the observed extrapolated zero-bias integral counting rates were calculated to be 93 and 81% of the disintegration rate for single-channel and coincidence systems, respectively. A 95% confidence level error of 2% for the counting method was due to the uncertainty in the standards used to prove this method.[9]

The errors involved in the calculation of the half-life are listed below, with all errors quoted at the 95% confidence level.

(a)	Mass spectrometer	2.4%
(b)	Counting method	2.0%
(c)	Chemical analysis	1.0%
(d)	Counting statistics	<0.1%
(e)	Figure of merit	1.0%

These errors were propagated in the standard manner to give the final error in the calculation. The best value for the half-life of Ni^{63} is 91.6±3.1 yr with a 95% confidence level.

The beta spectrum appears to be that of pure Ni^{63}. A Kurie plot[12] was linear (above 7.5 kev) and gave an end-point energy of 67±2 kev for the maximum energy, which is in agreement with other published values.[13]

From the mass spectrometric data and the integrated flux a value of 14±1 barns was calculated for the $Ni^{62}(n,\gamma)Ni^{63}$ cross section. This agrees with other published values.[3,14] In this calculation we have neglected any appreciable capture cross section for Ni^{63}.

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Interpretation of Experiments on the Beta Decay of Eu^{152}†

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The 1483-kev beta decay of Eu^{152} has previously been interpreted in terms of the "modified B_{ij}" approximation. This decay has been reconsidered using more complete theoretical expressions and including the recent determination of the beta-circularly polarized gamma correlation along with the beta-gamma directional correlation and the beta spectral shape. The data indicate that the nuclear matrix element parameter ζ_1 lies between 0.5 and 1. For some suitable sets of matrix element parameters the quantities u and x are small in qualitative agreement with the "modified B_{ij}" approximation. However, other suitable sets of matrix element parameters may be found which are in disagreement with the approximation. The method of analysis described here is generally applicable to first forbidden beta decays with spin change 1 and the results from various types of experiments may be incorporated.

INTRODUCTION

THE theoretical expressions for the various observables, such as the spectral shape, beta-gamma directional correlation, and the beta-polarized gamma directional correlation in first-forbidden beta decay with spin change 1 are given by Kotani[1] in terms of the following nuclear matrix element parameters:

$$\zeta_1 = -(\xi - W_0/3)u - iC_V \int \boldsymbol{\alpha} \Big/ C_A \int B_{ij} - (\xi + W_0/3)x,$$

$$u = i \int \boldsymbol{\sigma} \times \mathbf{r} \Big/ \int B_{ij},$$

$$x = -C_V \int \mathbf{r} \Big/ C_A \int B_{ij},$$

where W_0 is the end-point energy of the betas in mc^2 units and ξ is a dimensionless parameter dependent

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