



Measurement of the gamma-ray probability per decay of ^{42}K

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Received 18 October 1999; accepted 15 February 2000

Abstract

In the present work, the gamma-ray emission probabilities per decay of ^{42}K transitions have been measured. The activity measurement was carried out in a 4π (PC) β - γ coincidence system. The gamma-ray measurements were performed in a HPGe system. All the uncertainties involved were treated rigorously, by means of covariance analysis. The value of the 1524 keV gamma-ray intensity per decay of ^{42}K obtained in the present work was (0.1813 ± 0.0014) . This result is compared to the data from other authors. © 2001 Elsevier Science Ltd. All rights reserved.

1. Introduction

The accurate knowledge of the gamma-ray emission probability per decay of radionuclides is important in several applications. In the case of ^{42}K , the importance lies mainly in medical applications and as a high energy calibration point for gamma-ray spectrometers.

^{42}K decays by beta transition, 18% populating the excited states of ^{42}Ca and 82% to the ground state (Fig. 1) (Lagoutine et al., 1984). The main gamma-ray energy is 1524 keV with 18% intensity.

A few values of the 1524 keV gamma-ray intensity per decay of ^{42}K can be found in the literature as follows: $18.8\% \pm 0.6\%$ (Lederer and Shirley, 1978), $18.08\% \pm 0.09\%$ (Miyahara et al., 1990) and $17.9\% \pm 0.5\%$ (Lagoutine et al., 1984). Some of these values are more than one standard deviation apart, due to some discrepancies in the data. For this reason, we have

undertaken the measurement of this intensity using $4\pi\beta$ - γ coincidence and HPGe spectrometric techniques.

2. Experimental methods

2.1. Source preparation

The ^{42}K sample has been obtained by means of the $^{41}\text{K}(n,\gamma)^{42}\text{K}$ reaction in a thermal neutron flux of $1.5 \times 10^{13} \text{ cm}^{-2} \text{ s}^{-1}$ obtained near the core of the IPEN 2 MW research reactor. The sample consisted of 4 mg K_2CO_3 powder sealed in a quartz tube. After 8 h of irradiation, the powder was dissolved into 15 ml HCl 0.16 N solution.

The sources to be measured in the $4\pi\beta$ - γ system were prepared by dropping known aliquots of the solution on a $20 \mu\text{g}/\text{cm}^2$ thick COLLODION film. This film had been previously coated on both sides with a $10 \mu\text{g}/\text{cm}^2$ gold layer in order to turn the film conductive. A drop of a seeding agent (CYASTAT SN) was used in order to improve the deposit uniformity and

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Table 1
Partial uncertainties in the gamma emission probability per decay^a

Irradiation ^c	$4\pi\beta\text{-}\gamma^b$	Attenuation	Geometry	Dead time	Counting statistic	HPGe efficiency
1	0.16	0.25	0.40	0.31	0.35	0.59
2 a	0.50	0.25	0.40	0.11	0.31	0.59
b	0.50	0.25	0.40	0.38	0.34	0.59
3 a	0.18	0.25	0.40	0.11	0.31	0.59
b	0.18	0.25	0.40	0.34	0.33	0.59
Correlation factor	1 or 0	1	1	0	0	1

^a The uncertainties are stated as one standard deviation (i.e. coverage factor $k = 1$).

^b The correlation factor is 1 for the same and 0 for different irradiations.

^c a, b refer to different sample batches from the same irradiation.

the sources were dried in a desiccator. The accurate source mass determination was performed using the pycnometric technique (Campion, 1975). Due to the low specific activity of the solution, flame sealed ampoules were prepared for gamma ray spectroscopy measurements.

2.2. $4\pi\beta\text{-}\gamma$ Coincidence measurements

The system used for absolute standardization of ^{42}K sources consisted of a gas-flow proportional counter with 4π geometry (β -channel) coupled with a pair of $3'' \times 3''$ NaI(Tl) scintillation counters (γ -channel) operating in coincidence. The proportional counter was operated with +2050 V bias. The lower discrimination level was set around 2 keV.

The activity is given by the well-known relationship (Baerg, 1973):

$$\frac{N_\beta N_\gamma}{N_C} = N_0(1 + k_e) \quad (1)$$

where

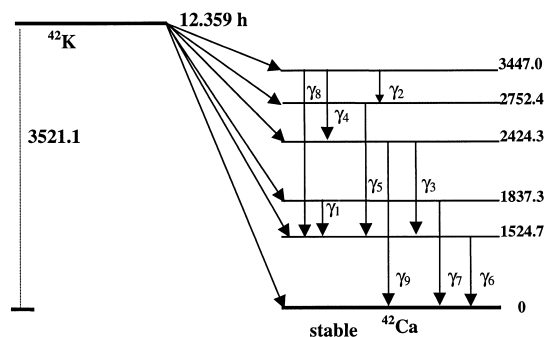


Fig. 1. Decay scheme of ^{42}K (Lagoutine et al., 1984). The energies are in keV.

$$k_e = \frac{(1 - \varepsilon_\beta)}{\varepsilon_\beta} C, \quad \varepsilon_\beta = \frac{N_C}{N_\gamma} \quad \text{and} \quad C = \left(\frac{\alpha_i \varepsilon_{ec} + \varepsilon_{\beta\gamma}}{1 + \alpha_i} \right)$$

In this equation, N_0 corresponds to the source activity, ε_β is the detection efficiency for beta particles, ε_{ec} is the detection efficiency for conversion electrons and α_i is the total conversion coefficient of branch i . The values of N_β , N_γ and N_C have been corrected for background, dead time, decay, and accidental coincidences. The Cox–Isham formalism has been used (Cox and Isham, 1977). The constant C was determined using the efficiency extrapolation method described by (Baerg, 1973).

A total of 18 sources from three irradiations have been measured in the coincidence system. The efficiency parameter N_C/N_γ in Eq. (1) was varied from 97.9 to 99.7 by using external absorbers made of $40 \mu\text{g}/\text{cm}^2$ thick COLLODION films, $200 \mu\text{g}/\text{cm}^2$ aluminum foils, over and under the sources. Fig. 2 shows the extrapolation curve obtained with sources from one of the three irradiations. The extrapolation effi-

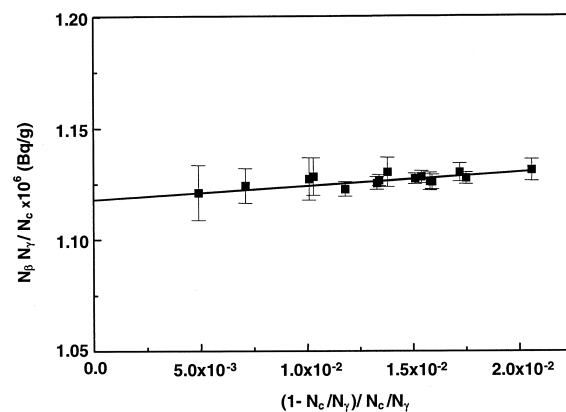


Fig. 2. Extrapolation curve of $N_\beta N_\gamma / N_C$ as a function of $(1 - N_C/N_\gamma) / (N_C/N_\gamma)$ for the 3rd irradiation.

Table 2

Gamma emission probability per decay of ^{42}K obtained in each irradiation with total uncertainties and correlation matrix

Irradiation	Gamma emission probability	Total uncertainty ^a (%)	Correlation matrix					
1	0.1798	0.90	1000					
2 a	0.1832	0.96	656	1000				
b	0.1820	1.04	608	819	1000			
3 a	0.1814	0.84	750	702	651	1000		
b	0.1821	0.91	695	651	603	786	1000	
Average	0.1813	0.79						

^a One standard deviation.

Table 3

Gamma ray emission probability per decay of ^{42}K in comparison with other authors

Gamma-ray energy (keV)	This work	Browne and Firestone (1986)	Lagoutine et al. (1984)	Mackin and Love (1958)	Miyahara et al. (1990) and Firestone and Shirley (1996)
1524.70	0.1813(14)	0.188(6)	0.179(5)	0.184(5)	0.1808(9)

ciency curve was obtained by linear least square fitting using code LINFIT (Dias, 1999), which incorporates covariance matrix methodology. Each source was measured six to ten times for periods between 500 and 2000 s each.

3. Gamma spectrometry measurements

The ^{42}K ampoules were measured in a HPGe spectrometer with an active volume of 99.7 cm³ and intrinsic efficiency of 20%. This spectrometer has been calibrated in the energy range between 244 and 1836 keV by measuring sealed ampoules of ^{60}Co , ^{88}Y , ^{133}Ba and ^{152}Eu standardized at our laboratory. These standards are traceable to standards sources supplied by the International Atomic Energy Agency (IAEA).

The source to detector distance was around 17.2 cm. At this distance, the cascade-summing effects were considered to be negligible. Dead time and pile-up corrections were applied by measuring a reference pulser peak near the upper end of the gamma spectrum simultaneously with the sources. The area of the peak was evaluated by summing all MCA counts in the interval $[C - 3\delta, C + 3\delta]$, where C is the peak centroid and δ is the FWHM (Full Width at Half Maximum). The net counts were obtained by considering the background in a region of width δ at both sides of the gamma-ray peak. The ^{42}K gamma-ray data were accumulated for more than 5×10^4 s, and Bremsstrahlung

effects were suppressed with the aid of a perspex slab 15 mm thick, over the detector front-face.

4. Results and discussion

The partial uncertainties and correlation factors involved in the determination of the gamma-ray emission probability per decay of ^{42}K for each measurement are listed in Table 1. Table 2 shows the values of gamma-ray emission probability per decay determined for each irradiation together with the final uncertainty. The average value calculated by means of a least-square fit procedure and the correlation matrix are also presented.

In Table 3, our final result of gamma-ray emission probability per decay of 1524 keV is compared with the data from other authors. As can be seen, our result agrees well with these data, especially with the one presented by Miyahara et al. (1990), which is a value obtained from absolute measurements. This value is also shown in the evaluation published by Firestone and Shirley (1996).

Acknowledgements

The authors are grateful to Mrs. Eliane Pocobi for samples preparations and to the IEA-R1 reactor staff for helping during the sample irradiation.

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