EPJ A
Hadrons and Nuclei

EPJ.org
your physics journal

Eur. Phys. J. A **46**, 69–72 (2010) DOI: 10.1140/epja/i2010-11028-7

Alpha decay half-life of ^{147}Sm in metal samarium and Sm_2O_3

J. Su, Z.H. Li, L.C. Zhu, G. Lian, X.X. Bai, Y.B. Wang, B. Guo, B.X. Wang, S.Q. Yan, S. Zeng, Y.J. Li, E.T. Li, S.J. Jin, X. Liu, Q.W. Fan, J.L. Zhang, X.Y. Jiang, J.X. Lu, X.F. Lan, X.Z. Tang and W.P. Liu

EDP SCIENCES Società Italiana di Fisica Springer

Eur. Phys. J. A **46**, 69–72 (2010)
DOI 10.1140/epja/i2010-11028-7

THE EUROPEAN PHYSICAL JOURNAL A

Regular Article – Experimental Physics

Alpha decay half-life of ^{147}Sm in metal samarium and Sm_2O_3

J. Su, Z.H. Li[a], L.C. Zhu, G. Lian, X.X. Bai, Y.B. Wang, B. Guo, B.X. Wang, S.Q. Yan, S. Zeng, Y.J. Li, E.T. Li, S.J. Jin, X. Liu, Q.W. Fan, J.L. Zhang, X.Y. Jiang, J.X. Lu, X.F. Lan, X.Z. Tang, and W.P. Liu

China Institute of Atomic Energy, P.O. Box 275(10), Beijing 102413, PRC

Received: 1 June 2010 / Revised: 11 August 2010
Published online: 11 September 2010 – © Società Italiana di Fisica / Springer-Verlag 2010
Communicated by A.A. Korsheninnikov

Abstract. In order to investigate the possible influence of metallic environment on the alpha decay process, we have measured the ^{147}Sm activities in the hosts of metal samarium and Sm_2O_3. The ^{147}Sm half-life was found to be $(1.06 \pm 0.01) \times 10^{11}$ y in metal samarium and $(1.07 \pm 0.01) \times 10^{11}$ y in Sm_2O_3, respectively. No significant change has been observed within the experimental uncertainty. The absolute half-life presented here is consistent with the recommended value.

1 Introduction

A possible influence of the quasi-free electron cloud in metallic environment on the α-decay process has attracted an intense interest in recent years. It was predicted [1, 2] that the α-decay rate could be enhanced by a factor greater than two in the metal hosts. Contrary to these predictions, the theoretical calculation with quantum-mechanical tunneling arguments indicated that the change of α-decay rate in metals is negligibly small [3]. It was attributed to the fact that the reduction in Coulomb barrier arising from electron screening can be canceled in principle by the decrease in the α-decay energy due to the extension of the screened potential into the inner part of the decaying nucleus. On the other hand, a recent study revealed that the electron screening potential in the inner part is smaller than in the external region since it is considered to be related with the energy of the α-particle, and the difference leads to a few percent increase of the α-decay rate in the metallic environment [4].

For investigating such a conjectural metal host effect, the α-decay of ^{221}Fr has been measured in several materials [5], the result shows that the half-lives of ^{221}Fr in metals Au/W are slightly shorter by 0.30(17)/0.42(21)% respectively, as compared to that in the insulator Si.

We report here an independent measurement of the ^{147}Sm half-life in metallic environment. ^{147}Sm is a natural and pure α-emitter with relative low Q_α (2.31 MeV), and the electron screening potential of the samarium metal for the $D(d,p)T$ reaction was measured to be about 300 eV [1]. Furthermore, the decaying nuclei are homogeneously distributed in the sample, so the doubts related to the ion implantation depth can be obviated spontaneously. For the sake of comparison, we correspondingly performed the measurement for the insulator Sm_2O_3 sample. The details of the experiment setup and data analysis are described in what follows.

In addition, the ^{147}Sm-^{143}Nd method established by Lugmair [6] plays an important role in the dating of telluric, lunar and Martian rocks as well as meteorites. The half-life of ^{147}Sm was recommended to be 1.06×10^{11} y [7, 8]. It is in fairly good agreement with a measured value of $1.070(9) \times 10^{11}$ y in 2009 [9], yet clearly shorter than that of $1.17(2) \times 10^{11}$ y reported in 2003 [10]. The new measurements are needful for clarifying the discrepancy of experimental results.

2 Experimental setup and procedure

In order to get good statistics, the ^{147}Sm-enriched samarium in the form of metal (97.93%) and oxide powder (98.30%) bought from Oak Ridge National Laboratory were adopted to prepare samples. The material was deposited on a high pure quartz glass substrate by vacuum evaporation (metal) and sputtering (oxide), respectively. One metal and one oxide samples have been made, the samples were constrained at the central area of the substrates by a $\varnothing$7 mm diaphragm during the depositing process. The thicknesses of the ^{147}Sm samples were about 250 μg/cm^2 which was almost 700 atomic layers for metal samarium. Comparing to the ions implantation depth (about 20 atomic layers) in the measurement of ^{221}Fr α-decay half-life [5], our metal sample provided a more reliable metallic environment.

The uniformity of the samples were measured using the CR-39 track detectors. The CR-39 chips clung to the samples and were irradiated for about 100 hours, then were chemically etched in a 6.0 M NaOH solution at 70 °C for

[a] e-mail: zhli@ciae.ac.cn

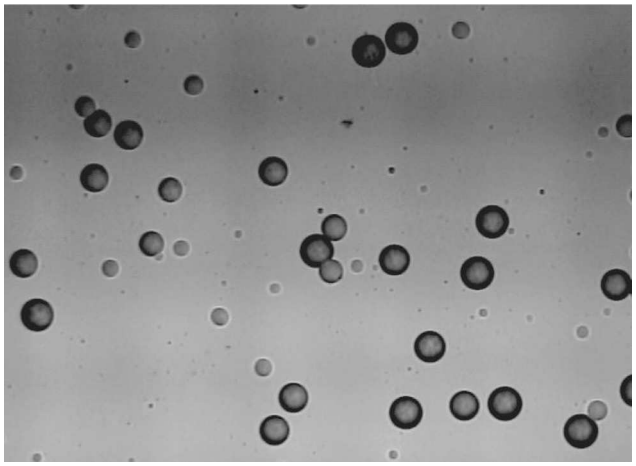

Fig. 1. Microphotograph of the track for the α-particles from the metal sample.

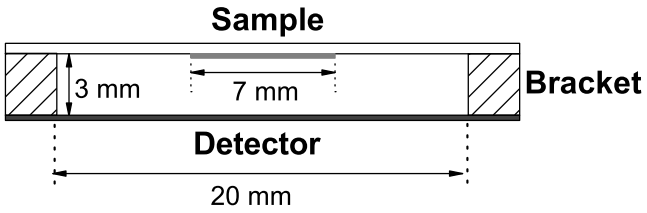

Fig. 2. Schematic view of the experimental setup.

24 hours. The etched CR-39 chips were observed using an optical microscope. The typical microphotograph is shown in fig. 1. The α-particle tracks were counted for 40 viewing frames which distributed uniformly on the irradiated region. No obvious deviations have been found within the statistical uncertainties ($\sim$ 20%) for both samples. The results show that the distribution of ^{147}Sm in the samples are relatively uniform.

The schematic view of the experimental setup is shown in fig. 2. A silicon surface barrier detector with a thickness of 300 μm was used to the detect the α-particles from the samples. The sample was coupled to the detector coaxially through a cylinder-shaped bracket made by high pure quartz glass. The effective detection area was limited by the inner diameter of the bracket (20 mm), and the distance from the sample to the detector was fixed by the height of the bracket (3 mm). The average solid angle was 4.40 ± 0.02 sr, determined with a Monte Carlo simulation by assuming that the sample thickness is uniform. The uncertainty results from the non-uniformity, uncertainties of the dimensions shown in fig. 2, and the eccentricity of sample.

The activity measurement was performed in a vacuum chamber surrounded by 10 cm thick lead shield for reducing the environmental background. Two same sets of detector-bracket were used to measure the α-activities of the metal and oxide samples, respectively. The two samples were measured simultaneously in the first 100 hours, and then the samples were exchanged for examining the consistency of the two detectors in the second 100 hours. Finally, the samples were dissolved into the standard nitric acid, respectively; the residual glass substrates were measured again to determine the background. The α-energy spectra obtained from the samples are shown in fig. 3 together with the corresponding backgrounds.

Monte Carlo simulations were performed for determining the energies of the α-particles emitting into the accepted solid angle, the stopping powers of α-particles in metal samarium and Sm_2O_3 were calculated by the program SRIM [11]. The results agree well with the measured spectra, as shown in fig. 3. Based on the simulations and measurements, the ^{147}Sm α-peaks were set to be 1.5 to 2.4 MeV for both samples, the α-particle amounts in the peaks with background subtracted are listed in table 1. The influence of the α-peak range was examined by expanding the range to 1.3–2.6 MeV, the result shows that the increment of the α-particle amount is less than 0.2%.

Assuming that the efficiency of the silicon detector is 100%, the total detection efficiency depends on the solid angle only. Then the activities of ^{147}Sm in two samples were determined as given in table 1. The α-decay of ^{148}Sm was ignored because of its long half-life (7.0×10^{15} y) and low abundance ($< 1\%$) in the samples.

For the determination of the ^{147}Sm number, the samples were dissolved with nitric acid, the solutions were weighed using an analytical balance with a precision of 0.1 mg. The number of ^{147}Sm in the sample, N_{147}, was determined by

$$N_{147} = mC_x X_{147}, \tag{1}$$

where m, C_x and X_{147} are the mass, samarium atomic concentration and ^{147}Sm atomic abundance of the sample solution, respectively. In the present work, C_x was determined via Isotope Dilution Mass Spectrometry (IDMS) recommended by ref. [12]. The sample and ^{154}Sm spike solutions, each about 3.0 g, were mixed together. The samarium isotopic ratios of the sample, spike and blend solutions were measured by the Multi Collector Inductively Coupled Plasma Mass Spectrometry (MC-ICP-MS). The concentration of the sample solution was given by

$$C_x = C_y \cdot \frac{m_y}{m_x} \cdot \frac{R_y - R_B}{R_B - R_x} \cdot \frac{\sum R_{ix}}{\sum R_{iy}}, \tag{2}$$

where C_y is the samarium atomic concentration in the spike solution, m_x and m_y the masses of sample and spike solutions in the mixture. R_x, R_y and R_B are the ^{154}Sm/^{147}Sm isotopic ratios in the sample, spike and blend solutions, R_{ix} and R_{iy} the ^{i}Sm/^{147}Sm isotopic ratios in the sample and spike solutions. X_{147} was then determined by

$$X_{147} = \frac{1}{\sum R_{ix}}. \tag{3}$$

It was found that the samarium atomic abundances given by Oak Ridge National Laboratory were well reproduced in the present measurements, as listed in table 2. It can be seen that the deviation of ^{147}Sm atomic abundance was less than 0.1%. This shows that our results are reliable.

The ^{147}Sm number of both samples was extracted with eq. (1), the results are also listed in table 1.

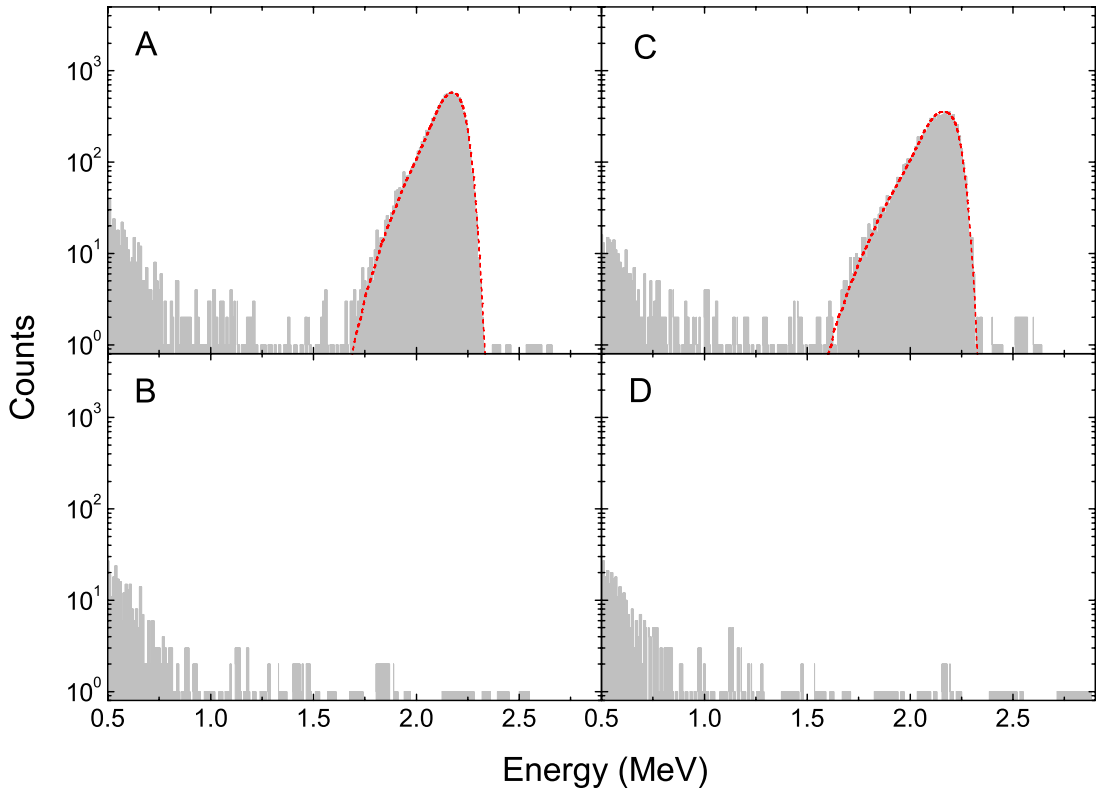

Fig. 3. Spectra taken for 100 hours: (A) metal samarium sample, (B) background for A, (C) Sm_2O_3 sample, (D) background for C. The dashed lines denote the corresponding simulation results.

Table 1. Measured activities and ^{147}Sm number in the two samples.

Sample	α-amount	Activity (Bq)	^{147}Sm number
Metal	21270	0.0843	4.07×10^{17}
Oxide	15465	0.0613	2.99×10^{17}

Table 2. The measured samarium atomic abundances X_m and reference ones X_r in metal and oxide samples.

Isotope	X_m^{metal}	X_r^{metal}	X_m^{oxide}	X_r^{oxide}
^{144}Sm	0.05	<0.10	0.05	0.05
^{147}Sm	97.84	97.93	98.23	98.30
^{148}Sm	0.84	0.84	0.86	0.85
^{149}Sm	0.51	0.50	0.37	0.36
^{150}Sm	0.17	0.17	0.11	0.11
^{152}Sm	0.37	0.35	0.22	0.21
^{154}Sm	0.22	0.21	0.14	0.12

Table 3. Uncertainty components of the half-life.

Components	$\Delta\, T_{1/2}/T_{1/2}$ (%)
Activity determination	
Statistical uncertainty	0.8
Detection efficiency	0.5
α-peak range	0.2
Background	0.1
^{147}Sm number determination	
IDMS analysis	0.5
^{147}Sm atomic abundance	0.1
Total	1.1

3 Determination of the ^{147}Sm half-life

The half-life of ^{147}Sm was determined by

$$T_{1/2} = \ln 2 \times \frac{N_{147}}{A_{147}}\,, \tag{4}$$

where A_{147} is the activity of ^{147}Sm in the sample.

Using the experimental data listed in table 1, the half-life of ^{147}Sm was determined to be $(1.06 \pm 0.01) \times 10^{11}$ y in metal samarium and $(1.07 \pm 0.01) \times 10^{11}$ y in Sm_2O_3. The two values are in good agreement with each other.

The uncertainties are from the statistics, detection efficiency, defined α-peak range, background, IDMS analysis and ^{147}Sm atomic abundance, as listed in table 3.

4 Conclusion

We have searched for a possible enhancement of the α-decay rate in metallic environment by measuring the half-life of ^{147}Sm in metal samarium and Sm_2O_3 samples, no significant change was observed within the experimental uncertainty. The result is not consistent with the prediction in refs. [1,2]. Due to the limited experimental precision in the present work, a change of less than 3% is difficult to be observed, so it still is a controversial issue whether a slight influence of metallic environment on the α-decay process exists or not [3,4].

The absolute half-life derived in this work is in good agreement with the recent experimental result [9] and recommended value [7,8]. Our experiment provides an independent examination of the existing data.

This work was supported by the National Natural Science Foundation of China under Grant Nos. 10735100, 10720101076, 10975193 and 10979026, and the National Basic Research Programme of China under Grant No. 2007CB815003.

References

1. F. Raiola, B. Burchard, Z. Fülöp, G. Gyürky, S. Zeng, J. Cruz, A.D. Leva, B. Limata, M. Fonseca, H. Luis, M. Aliotta, H.W. Becker, C. Broggini, A. D'Onofrio, L. Gialanella, G. Imbriani, A.P. Jesus, M. Junker, J.P. Ribeiro, V. Roca, C. Rolfs, M. Romano, E. Somorjai, F. Strieder, F. Terrasi, J. Phys. G: Nucl. Part. Phys. **31**, 1141 (2005).
2. K.U. Kettner, H.W. Becker, F. Strieder, C. Rolfs, J. Phys. G: Nucl. Part. Phys. **32**, 489 (2006).
3. N.T. Zinner, Nucl. Phys. A **781**, 81 (2007).
4. K. Czerski, P. Heide, A. Huke, A.I. Kilić, I. Kulesza, N. Targosz-Śleczka, Acta Phys. Pol. B **40**, 903 (2009).
5. H.B. Jeppesen, J. Byskov-Nielsen, P. Wright, J.G. Correia, L.M. Fraile, H.O.U. Fynbo, K. Johnston, K. Riisager, Eur. Phys. J. A **32**, 31 (2007).
6. G.W. Lugmair, Meteoritics **9**, 369 (1974).
7. G.W. Lugmair, K. Marti, Earth Planet Sci. Lett. **39**, 349 (1978).
8. E. der Mateosian, L.K. Peker, Nucl. Data Sheets **66**, 705 (1992).
9. K. Kossert, G. Jörg, O. Nähle, C.L.v. Gostomski, Appl. Radiat. Isotopes **67**, 1702 (2009).
10. N. Kinoshita, A. Yokoyama, T. Nakanishi, J. Nucl. Radiochem. Sci. **4**, 5 (2003).
11. J.F. Ziegler, SRIM version 2010.
12. F. Begemann, K.R. Ludwig, G.W. Lugmair, K. Min, L.E. Nyquist, P.J. Patchett, P.R. Renne, C.-Y. Shih, I.M. Villa, R.J. Walker, Geochim. Cosmochim. Acta **65**, 111 (2001).