3B2v8.06a/w (Dec 5 2003).51c + model | ARI : 3390 | Prod.Type:FTP pp.1–3(col.fig.:NIL) | ED:BibhuPrasad PAGN:hashmath SCAN:v4soft

ARTICLE IN PRESS

Available online at www.sciencedirect.com

SCIENCE DIRECT®

ELSEVIER

Applied Radiation and Isotopes ▮ (▮▮▮▮) ▮▮▮–▮▮▮

Applied Radiation and Isotopes

www.elsevier.com/locate/apradiso

Technical note

A combined $^{148}Gd/^{244}Cm$ source for energy calibration of α-spectrometers

A.F. Novgorodov[a], N.A. Korolev[a], F. Roesch[b,*]

[a]*Joint Institute for Nuclear Research, RUS-141980 Dubna, Russian Federation*

[b]*Institute of Nuclear Chemistry, Johannes Gutenberg-University of Mainz, Fritz-Strassmann-Weg 2, 55128 Mainz, Germany*

Received 7 April 2005; received in revised form 1 June 2005; accepted 23 August 2005

Abstract

For high-resolution α-particle spectroscopy, detector calibration sources of highest performance are required concerning thickness and homogeneity. In addition, the α-emitting radionuclides must have adequate half-lives and α-emission energies. This paper describes a new type of α-emitting calibration source, represented by a mixture of ^{148}Gd and ^{244}Cm. This system covers an α-energy range from 3.18 MeV (^{148}Gd) to 5.76 and 5.80 MeV (^{244}Cm). The source has been prepared by electrolytic deposition and has good performance in terms of thickness and homogeneity.

© 2005 Published by Elsevier Ltd.

1. Introduction

For high-resolution α-particle spectroscopy, detector calibration sources of highest performance are required concerning thickness and homogeneity. Recent developments focus on chemical aspects of optimal preparation of layers for conventional α-emitters (Tsoupko-Sitnikov et al., 2000; Sanchez et al., 2002; Leprince and de Sanoit, 2002). However, there might be further improvements of calibration sources as regards the selection of unique α-emitter with adequate half-life and, in particular, α-particle energy. Here we describe a new type of α-emitting calibration source, consisting of a mixture of ^{148}Gd and ^{244}Cm. This system presents only two strong α-energies and covers a very broad α-energy range from 3.18 MeV (^{148}Gd) to 5.80 MeV (^{244}Cm).

State-of-the-art calibration sources for α-spectroscopy such as ^{226}Ra, $^{236,238–240}Pu$, etc. have several suboptimum properties. Among others, contamination of the detectors might occur due to recoil nuclei or fragmentation of the source material (aggregate recoil). Coating of the source surfaces with thin layers of specific materials might minimize these effects; however, the covering layer might decrease the energy resolution (up to 500–100 keV of the FWHM). Moreover, the α-energy range represented by these sources is rather narrow [^{226}Ra: $T_{1/2} = 1600$ a ($E_\alpha = 4601$ and 4784 MeV); ^{236}Pu: $T_{1/2} = 2.85$ a ($E_\alpha =$ 5721 and 5768 MeV); ^{238}Pu: $T_{1/2} = 87.74$ a ($E_\alpha = 5457$ and 5499 MeV); ^{239}Pu: $T_{1/2} = 2.41 \times 10^4$ a ($E_\alpha = 5143$ and 5156 MeV); ^{240}Pu: $T_{1/2} = 6563$ a ($E_\alpha = 5124$ and 5168 MeV)].

2. Materials and methods

The source proposed consists of a combination of two individual, α-emitting radionuclides in one uniform source. These radionuclides are ^{148}Gd and ^{244}Cm. Their decay data are summarized in Table 1. The proposed mixture provides a very reliable energy calibration, because it covers an α-energy range of almost 4 MeV. The ^{148}Gd decays to a stable, non-radioactive daughter (^{144}Sm), while the decay of ^{244}Cm results in the formation of ^{240}Pu, which has a rather long physical half-life of 6563 a. Thus, the radioactivity of ^{240}Pu created by the decay of ^{244}Cm is negligible compared to the radioactivity of the calibration source itself.

*Corresponding author. Tel.: +49 6131 392 5321; fax: +49 6131 392 4692.

E-mail address: frank.roesch@uni-mainz.de (F. Roesch).

0969-8043/$ - see front matter © 2005 Published by Elsevier Ltd.
doi:10.1016/j.apradiso.2005.08.012

UNCORRECTED PROOF

Table 1
Decay characteristics (Firestone et al. 1996) of the α-emitters involved

Initial radionuclides				Decay products			
Radionuclide	$T_{1/2}$ (a)	E_α (keV)	α-branch (%)	Radionuclide	$T_{1/2}$ (a)	E_α (keV)	α-branch (%)
^{148}Gd	74.6	3182.680(24)	100	^{144}Sm	Stable		
^{244}Cm	18.10	5804.77(5)	76.4(12)	^{240}Pu	6563	5123.45(23)	26.39(21)
		5762.16(3)	23.6(12)			5168.13(15)	73.51(36)
		Others	<0.03			Others	<0.1

2.1. Radionuclide availability

The ^{148}Gd was produced in (p, spall) processes of Ta targets at CERN, Geneva, in 2000. Following radiochemical separation of the massive tantalum target at the Institute of Nuclear Chemistry at the University of Mainz, Germany, in 2001, the gadolinium fraction of the neutron-deficient lanthanides was isolated (Novgorodov et al., 2002). Within 3 years, the initial content of ^{151}Gd ($T_{1/2} = 120$ d) and ^{153}Gd ($T_{1/2} = 241.6$ d) decayed, and only a pure fraction of ^{148}Gd remained. ^{244}Cm is commercially available.

2.2. Source preparation

The individual radionuclide solutions were mixed in different ratios (see below) and used for the source preparation. The sources were produced from small volumes of 1–3 ml of 0.1 N Na_2SO_4/0.01 N H_2SO_4 by electrolytic deposition on stainless steel (type 1810) cathode. The cathode current density was set to 80–100 mA/cm^2. The deposition time was 1–2 h. The chemical yield of this process was 95–99%. The quality of the prepared sources is demonstrated in Fig. 1, indicating the excellent energy resolution of the main α-groups. The FWHM are 14.8 keV for ^{148}Gd and 15.4 keV for ^{244}Cm.

2.3. Mixtures

According to the different branches of the individual α-emissions (cf. Table 1), the two radionuclides were mixed initially in an absolute activity ratio of ^{148}Gd:^{244}Cm of 1:1.3. This resulted in comparable peak areas of the $E_\alpha = 3183$ keV line of ^{148}Gd and the 5805 keV line of ^{244}Cm. The energy spectrum of the sources is presented in Fig. 1, representing the α-spectrum of a source of 300 Bq ^{148}Gd and 400 Bq ^{244}Cm. The area of the detector used was 1 cm^2. The distance between source and detector was 3 cm. The measurement time was 965 s.

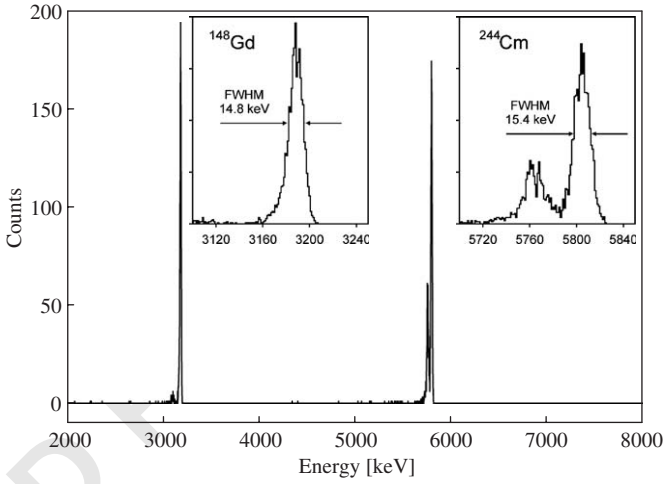

Fig. 1. α-spectrum of a source of 300 Bq ^{148}Gd and 400 Bq ^{244}Cm representing the whole range of α-energies between 2 and 8 MeV. The area of the detector used was 1 cm^2. The distance between source and detector was 3 cm. The measurement time was 965 s. The insets show the strongest lines on a magnified energy scale.

3. Discussion

The measured α-spectrum of the combined source of ^{148}Gd (300 Bq) and ^{244}Cm (400 Bq) clearly indicates the high resolution of the main α-particle groups of FWHM 14.8 keV for ^{148}Gd and 15.4 keV for ^{244}Cm and the broad range of about 4 MeV, covered by this unique mixture. It thus represents an almost ideal type of α-calibration source.

Provided the shelf life of this source is assumed to be three half-lives of the shorter-lived radionuclide ^{244}Cm, this source will be useful for more than 50 years. The recoil nuclei activity arising from ^{240}Pu hitting the detector surface during a regular calibration procedure (e.g. 900 s, 4000 Bq of ^{244}Cm, $\Theta = 3\%$) will correspond to 36 nBq. This will not cause any influence on subsequent determinations of real samples (e.g. ^{240}Pu or others from environmental probes), at least for more than 1000 calibration measurements for one detector. Moreover, the aggregate recoil will not affect the determination of plutonium and americium radioisotopes, because their α-energies are in-between the ones of the calibration source constituents.

UNCORRECTED

In conclusion, the combined ^{148}Gd and ^{244}Cm α-energy calibration sources might be widely used for routine detection of α-radiations both in fundamental investigations in nuclear physics and nuclear chemistry as well as in applied research such as environmental analysis.

References

Firestone, R.B., et al., 1996. Table of Isotopes, Appendix C-6. Wiley, New York.

Leprince, B., de Sanoit, J., 2002. A new design of ^{238}Pu activity sources for use in intercomparison exercises. Appl. Radiat. Isot. 57, 171–176.

Sanchez, A.M., Nuevo Sanchez, M.J., Rubio Montero, P., Mendez Vilas, A., 2002. Study of inhomogeneities in sources prepared for α-particle spectrometry using scanning probe microscopy. Appl. Radiat. Isot. 56, 31–36.

Novgorodov, A.F., Filosofov, D.V., Zhernosekov, K.P., Korobeinikov, A., Lebedev, N.A., Korolev, N.A., Beyer, G.-J., Rösch, F., 2002. Isolation of lanthanide and hafnium radioisotopes from a massive Ta-target irradiated with 1 GeV protons. COST Chemistry Action D18 "Lanthanide Chemistry for Diagnosis And Therapy" Workshop, Heidelberg, July 22–25, 2002, abstracts, p. 29.

Tsoupko-Sitnikov, V., Dayras, F., De Sanoit, J., Filossofov, D., 2000. Application of rotating disc electrode technique for the preparation of Np, Pu and Am α-sources. Appl. Radiat. Isot. 52, 357–364.

UNCORRECTED PROOF