Egypt. J. Rad. Sci. Applic. **Vol. 32,** No.2, pp. 145-154 (2019)

Egyptian Journal of Radiation Sciences and Applications
http://ejrsa.journals.ekb.eg/

EGYPTIAN ATOMIC ENERGY AUTHORITY

Preparation and Quality Control of ^{113}Sn, ^{125}Sb and ^{60}Co Adsorbed in ZrSiW: Volume and Planar Reference Source for -Detector Calibration

H. El-Said[(1)#], S.E.A. Sharaf El-Deen[(2)], M.I. Aydia[(1)], M.R. El-Naggar[(3)], K.M. El-Azony[(1)]

[(1)]Radioactive Isotopes and Generators Department, Hot Labs Center, Atomic Energy Authority (AEA), Cairo, Egypt; [(2)]Nuclear Chemistry Department, Hot Labs Center, Atomic Energy Authority (AEA), Cairo, Egypt; [(3)]Radioactive Waste Treatment Department, Hot Labs. Center, Atomic Energy Authority (AEA), Cairo, Egypt.

NEUTRON activation of tin metal and cobalt chloride targets for production of ^{113}Sn and ^{125}Sb and ^{60}Co was carried out in Egypt's Second Research Reactor (ETRR-2). The ^{113}Sn, ^{125}Sb and ^{60}Co were loaded onto zirconium silicotungestate gel matrix from aqueous solution at pH 1 by the batch technique. The results obtained during the adsorption process of radionuclides were explained through the Visual MINTEQ program version 3. Then 1 and 0.1g of ^{113}Sn. ^{125}Sb and ^{60}Co-ZrSiW were packed into the volume and planar sealed sources, made of Chinese Artelon, respectively. The radioactivity levels of ^{113}Sn, ^{125}Sb and ^{60}Co were measured and found to be (2.96±0.26, 2.22±0.26, 0.74±0.074kBq) and (0.3±0.03, 026±0.03, 0.11±0.01kBq) for the volume and planar sealed source, respectively, on 27 June 2018. The efficiency curves for the two sealed sources were determined in the energy range 36-1332.5keV, which were measured at 5cm from the HPGe-detector to determine the radioactivity levels of unknown samples for the neutron activation method.

Keywords: Sealed Source; ^{125}Sb; ^{113}Sn; ^{60}Co; Efficiency calibration.

Introduction

Radionuclides have been extensively used for more than 50 years in medicine and industry. The use of unsealed sources of radionuclides is largely applied in the diagnostic and therapeutic purposes as well as the use of sealed sources in many fields (Enomoto et al., 1975; Pappalardo et al., 1996; Sahoo et al., 1996; Hino et al., 2000; Krazaniak & Coppel., 2002; Saniot et al., 2004; IAEA-TECDOC-1512, 2006). "A Sealed Source" means a radioactive material that is permanently bonded or fixed in a capsule or matrix designed to prevent the release and dispersal of the radioactive material under the most severe conditions, which are likely to be encountered in normal use and handling (Radiation Safety Policy Manual, 2005). Several radionuclides such as of the well-known sealed sources: ^{32}P, ^{60}Co, ^{63}Ni, ^{65}Zn, ^{90}Sr, ^{90}Y, ^{103}Pd, ^{106}Ru, ^{125}I, ^{133}Xe, ^{137}Cs, ^{144}Ce, ^{147}Pm, ^{166}Ho, ^{169}Yb, ^{192}Ir, ^{210}Po, and ^{241}Am are generally used (Enomoto et al., 1975; Sahoo et al., 1996; Hino et al., 2000; Krazaniak & Coppel, 2002; Saniot et al., 2004; Radiation Safety Policy Manual, 2005; IAEA-TECDOC-1512, 2006). Sealed sources are categorized by the IAEA according to their radioactivity in relation to a minimum dangerous source (where a dangerous source is the one that could cause a significant injury to humans). The ratio used is A/D, where A is the radioactivity of the source and D is the minimum dangerous activity.The radioactivity of the sealed sources is ranged from micro to thousand Curies depending on their use, where the latter type is used in industry and nuclear medicine (Mathew, 2002; IAEA-TECDOC-1512, 2006) while the former is commonly used in -detectors calibration such as ^{226}Ra (IAEA-TECDOC-1512, 2006).

[#]Corresponding author email: hasselsaid@gmail.com
Received 3/5/2019 ; Accepted 20/8/2019
DOI: 10.21608/ejrsa.2019.12489.1069

Different methods such as ion exchange and electro-deposition have been used for the preparation of sealed sources (Mostafa & El-Amir, 2007; El-Azony et al., 2009). In medicine ^{32}P, ^{60}Co, ^{90}Y, ^{103}Pd, ^{125}I, ^{133}X, ^{144}Ce, and ^{166}Ho are used in radiation therapy(teletherapy and brachytherapy) for the treatment of malignant diseases, bone density measurements and treatment of brain and prostate cancer (Enomoto et al., 1975; Sahoo et al., 1996; Hino et al., 2000; Krazaniak & Coppel, 2002, Mathew, 2002; Saniot et al., 2004; IAEA-TECDOC-1512, 2006; El-Azony et al., 2009).

Often, the samples are collected and measured in a granular form in order to determine the natural radioactivities. In neutron activation analysis, samples are bulky, grainular, or may have no uniform distribution of radioactive isotopes. Evaluation of the radioactivity requires an absolute reference source, which has geometrical shape and mass attenuation coefficient similar to the sample measured (Gustafsson, 2014) for adjusting the efficiency calibration. The gamma energy lines emitted from the absolute reference source must cover a wide range of energy (< 100 up to more than 1000keV) for adjusting the energy calibration.

Many sealed sources have been prepared using an ion exchange technique based on the adsorption of an element or more on a granularion exchanger material such as ^{65}Zn-permutitand ^{134}Cs-12-molybdocerate (IV) (El-Azony, 2009) ^{60}Co and ^{137}Cs-6-tungstocerate(IV) (Mostafa & El-amir, 2007).

In this study, the Visual MINTEQ (Gustafsson, 2014) as chemical speciation software packages has been used to explain and interpret the empirical results that obtained based on the distribution coefficients of ions between aqueous and solid phases because it can be extrapolated to systems of different ionic strengths, pH values, and component compositions (Koretsky, 2000; Bethke, 2008; Elmaghraby, 2016).

Antimony-125 ($T_{1/2}$= 2.758 y) is produced as a radioimpurity during the neutron activation of natural tin (^{nat}Sn (n, γ)$^{125}Sn \xrightarrow{\beta^-} {}^{125}Sb$) to produce the $^{113}Sn/^{113m}In$ generator (El-Said et al., 2018). Due to the suitability of^{1} ^{25}Sb, ^{113}Sn and ^{60}Co physical properties (half-lives and gamma energies) as shown in Table 1 (Aydia et al., 2018), the authors planed to use ^{125}Sb, ^{113}Sn and ^{60}Co in a sealed source together.

In a previous study (Aydia et al., 2018), zirconium silicotungstate (ZrSiW) was prepared by an inexpensive method and it is chemically stable gel matrix, and ^{113}Sn and ^{125}Sb were completely adsorbed on the ZrSiW matrix (El-Said et al., 2018).

The present study focuses on the findings of the previous study on the uptake of ^{113}Sn and ^{125}Sb on the ZrSiW gel matrix to prepare the sealed source of ^{113}Sn and ^{125}Sb-ZrSiW. Unfortunately, the - energy lines emitted from the ^{113}Sn and ^{125}Sb-ZrSiW are located in the range 36-671keV, which is insufficient to calibrate the -detector, sothe sealed source of ^{60}Co, ^{113}Sn and ^{125}Sb-ZrSiW, was prepared with a wide energy range (36-1332.5keV).

Experimental

Reagents

All reagents used were of analytical grade. Double distilled water (DDW) was used throughout this work. $ZrOCl_2.2H_2O$ from Sigma-Aldrich, $Na_2WO_4.2H_2O$, and Na_2SiO_3 from Fluka WO_3, ZrO_2, and SiO_2 were purchased from Merck.

Preparation of zirconium silicotungstate (ZrWSi)

ZrSiW gel was prepared by mixing 50ml of 0.04M sodium tungstate ($Na_2WO_4.2H_2O$) with 50ml of 0.28M sodium silicate (Na_2SiO_3), then the tungstate-silicate solution was added dropwise to 50 ml of 0.04M warmed zirconium oxychloride solution ($ZrOCl_2.8H_2O$, in 0.2M HCl) within 30min at pH 8. Then the precipitate was washed several times using bi-distilled water till a constant pH is reached .

Neutron irradiation and targets dissolution

Tin-113, ^{125}Sb and ^{60}Co radionuclides were prepared by thermal neutron irradiation of the corresponding target materials, tin metal and cobalt chloride, respectively, in the 22MW ETRR-2 Egypt's Research Reactor for 4h at a neutron flux of 1×10^{14} n.cm^{-2} s^{-1}. The irradiated tin target was dissolved using 6M HCl, gently heated and a few drops of 30% H_2O_2 solution were gradually added until complete dissolution and oxidation of Sn(II) to Sn(IV). Fresh solutions of ^{113}Sn were prepared by dilution.

TABLE 1. Decay mode of the radionuclides that used in the preparation of gamma standard sealed sources.

Radionuclide	Half-life	Decay mode					
		X-rays (keV)	I (%)	E (keV)	I (%)	E_β (keV)	I_β (%)
^{113}Sn	115.09 d	24.0	28.2	255.05	1.82	644.3*	98.3
		24.2	52.8	391.69	64		
		27.2	4.6				
		27.3	8.9				
		27.9	2.4				
^{125}Sb	2.7582 y	27.21	13.5	35.49	4.3	95.25	13.5
		27.47	25.2	176.31	6.8	124.5	5.8
		30.99	4.4	427.87	30	130.6	18.1
				463.36	10.5	303.3	40.3
				600.6	17.9	445.6	7.2
				606.72	5.0	621.9	13.6
				635.95	11.3		
^{60}Co	5.2714 y			1173.23	99.97	318.1	99.9
				1332.50	99.98		

A certain amount of the irradiated cobalt chloride was dissolved in hydrochloric acid then re-dissolved in double distilled water to obtain a clear solution.

Determination of the distribution coefficient (K_d) values

The distribution coefficients for [^{113}Sn(IV) and ^{125}Sb] and^{60}Co(II)(1X10^{-4} M) ions in aqueous HCl acid solutions of zirconium silicotungstate gel matrix were individually determined by the batch equilibrium technique. The reaction mixtures consisted of 0.1g gel material and 10ml of different concentrations of HCl (0.002-1M) in 25ml glass vials. The samples were shaken 24h using shaker thermostat. The distribution coefficient values (ml/g) were calculated using Equation (1):

$$K_d = \frac{A_o - A_e}{A_e} \times \frac{V}{m} mL/g \qquad (1)$$

where, A_o and A_e are the counting rates of the aqueous phase before and after equilibration with the gel matrix, respectively. V is the total volume of the aqueous phase (ml), m is the weight of the gel matrix (g).

Loading of ^{113}Sn, ^{125}Sb and ^{60}Co radionuclides on ZrSiW gel matrix

The dissolved tin (^{113}Sn, ^{125}Sb) and cobalt (^{60}Co) were loaded using 1.2g ZrSiW matrix and equilibrated using 30ml of 10^{-2}M ^{113}Sn(VI) solution and 10ml of 10^{-3}M ^{60}Co(II) solution at pH 1, and shaken overnight using the shaker thermostat. The supernatant was decanted, drying the loaded gel (^{113}Sn, ^{125}Sb, ^{60}Co-ZrSiW) at 50^{o}C then, washed with distilled water. It was dried once again at 50^{o}C.

Preparation of ^{113}Sn, ^{125}Sb, ^{60}Co-ZrSiW in different shapes (volume and planar sealed source) for the - detector calibration

The preparation technique was applied earlier using chromo-nickel stainless steel 12X18H10T in the ^{192}Ir sealed source preparation (IAEA-TECDOC-1512, 2006). The holder discs were made of Chinese artelon for preparation the volume and planar sealed sources. The Chinese artelon has some advantages such as its lightness that leads to reducing the attenuation of γ-ray

(self-absorption of γ-ray), its resistance to acids and alkaline solutions, organic solvents, hard shocks and and the temperature up to 140°C. The sketch of capsules constituents is shown in Fig. 1. Calibrated amounts of ZrSiW matrix loaded with ^{113}Sn, ^{125}Sb and ^{60}Co were packed in the cavity of the capsule base on the volume and planar discs. The space above the packed ZrSiW matrix was filled with thermal silicon to the top of the capsule to fix the core material. Then, the capsule lid was compacted into the capsule base (Platonov et al., 2002; Shtrombakh et al., 2005). After 24h, the sealed sources were subjected to the quality control tests.

Quality control tests

Sealed sources were tested to adjust the radioactivity measurement using gamma analysis equipment such as high-puritygermanium detector connected with Multi-Channel Analyzer (MCA). Several tests were carried out such as leach-ability in water (Tompkins, 2003), immersion test (leak test) (ISO, 1999), wipe tests (surface contamination testing), impact test (Martinez, 2002) and accurate measurement of activity.

Radioactivity measurements

All radioactivity measurements were carried out using a gamma-spectrometer, which has a p-type coaxial HPGe detector (GX2518 model), Canberra, USA, with 29.4% efficiency and 1.66keV FWHM at 1332.5keV (^{60}Co). The detector is connected with a multichannel analyzer (MCA), power supply and amplifier that are contained in one unit (Inspector 2000 model, Canberra Series, made in USA). The relative efficiency curve was obtained using ^{152,154}Eu point source at 5 cm distance from the detector and this distance was used to determine the radioactivity of the sealed sources (^{113}Sn, ^{125}Sb, and ^{60}Co-ZrSiW), measured under the same conditions.

Methodology of energy and efficiency calibration of the gamma detector

The energy calibration is periodically carried out using the standard sources for the HPGe detector reported by Vucanac et al. (2008). After the identification of the energy using point source (^{152,154}Eu), the efficiency value was calculated taking into account the probability of disintegration for each energy line. These data are necessary for the efficiency calibration as illustrated by Equation (2):

$$\varepsilon_x = \frac{N}{t \times A \times p_x} \qquad (2)$$

ε_x is the efficiency at a specific energy line, N is the peak area (number of counts at that energy), A is the absolute activity of the standard [Bq], P_x is the probability of disintegration of the radionuclide at that energy.

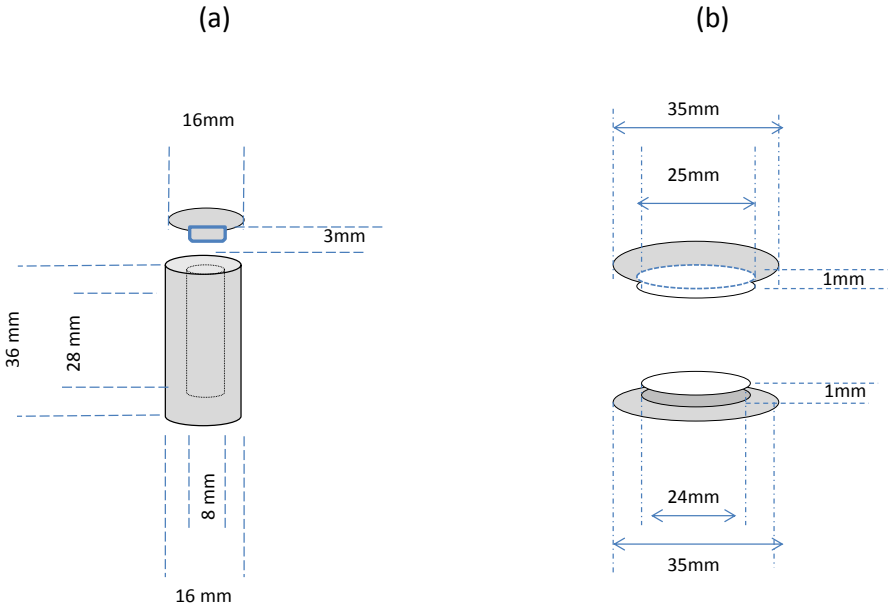

Fig. 1. A sketch of the volume (a) and planar (b) sealed source capsules used for preparation of ^{113}Sn, ^{125}Sb and ^{60}Co.

The efficiency percentage values for each gamma energy line of ^{152,154}Eu were drawn to obtain a curve, which was used to determine the polynomial coefficients in an equation of the sixth degree. Then, the radioactivity levels of ^{113}Sn, ^{125}Sb and ^{60}Co in sealed sources (volume and planar sources) were determined using the same previous formula after calculating the efficiency for each gamma energy line and rearranging the previous formula to obtain Equation (3):

$$A = \frac{N}{t \times \varepsilon_x \times p_x} \qquad (3)$$

Result and Discussion

Figure 2 shows the gamma-ray spectrum of the metal tin target, which was measured one year after its irradiation for decay out the short-lived radionuclides by using High-pure Germanium detector connected to Multi-Channel Analyzer (MCA).The gamma-ray energies of ^{113}Sn and ^{125}Sb were detected by the following nuclear reactions:

$$^{112}Sn(n,\gamma)^{113}Sn_{(T1/2=115\ d)} \xrightarrow{\varepsilon+\beta^+} {}^{113m}In_{(T1/2=1.66\ h)} \rightarrow {}^{113}In_{(stable)} \quad (1)$$

$$^{124}Sn(n,\gamma)^{125}Sn_{(T1/2=9.64d)} \xrightarrow{\beta^-} {}^{125}Sb_{(T1/2=2.76} \xrightarrow{\beta^-} {}^{125}Te_{(stable)} \qquad (2)$$

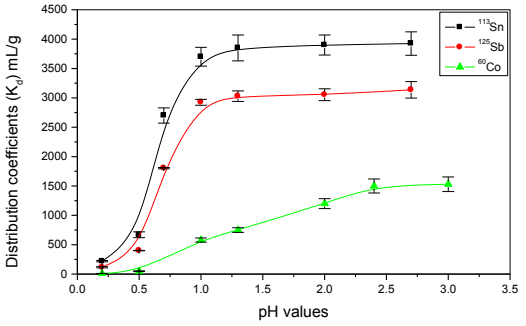

Fig. 2. Variation of Kd of ^{113}Sn(IV), ^{125}Sb(III), ^{60}Co(II) in an aqueous medium on the ZrSiW gel matrix as a function of pH.

The high distribution coefficients of ^{113}Sn (IV), ^{125}Sb (III) and ^{60}Co (II) were experimentally obtained (3700, 2925 and 580ml/g, respectively) by the batch technique at pH 1as shown in Fig. 2. The results obtained have been interpreted based on Visual MINTEQ 3.0 program that determines the studied elements concentrations of different aqueous species as a function of the pH as shown in Fig. 3 (a, b and c), which indicate the aqueous concentration of the dissolved species of tin, antimony and cobalt in cationic forms, Sn^{+4},$Sb(OH)_2^+$,$Sb(OH)_3$ and Co^{+2} with the concentrations 100. 78,22 and 100%, respectivelyat pH 1.The mechanism was carried out depending on the hydrolyticsorption or the cation exchange.

$$2R - H_{2(S)} + Sn^{4+}_{(L)} \rightarrow (R_2 - Sn)_{(S)} + 4H^+_{(l)}$$

$$R - H_{(S)} + Sb(OH)_2^+{}_{(L)} \rightarrow R - Sb(OH)_{2(S)} + H^+_{(l)}$$

$$R - H_{(S)} + Sb(OH)_{3(L)} \rightarrow R - Sb(OH)_{2(S)} + H_2O_{(l)}$$

$$R - H_{2(S)} + Co^{2+}_{(L)} \rightarrow R - Co_{(S)} + 2H^+_{(l)}$$

On the other hand, the ionic charge and radius of Sn^{+4}, Sb^{+3}, and Co^{+2} play an important role in the absorption mechanism onto the ZrSiW as a cation exchanger. The results confirm that the absorption of Sn^{+4}, Sb^{+3}, and Co^{+2} are based on their ionic charges +4 > +3> +2, and also their ionic radius 83, 90 and 88.5pm, respectively.

Radioactivity of Sealed sources (volume and planar)

In a previous work (El-Amir et al., 2013), a point source based on irradiated natural tin target was prepared. Most of the time, the samples of natural radioactive materials are collected and measured in a granular form. In neutron activation analysis, samples are grainular, and they may not be uniformly distributed from radioisotopes. The assessment of radioactivity requires an absolute reference source. The γ-energy peaks emitted from the absolute reference source must cover a wide range of energy for adjusting the energy calibration.

The radionuclides of ^{113}Sn, ^{125}Sb and ^{60}Co were loaded onto zirconium silicotungstate (ZrSiW) by the batch technique and the volume and planar sealed sources were prepared by the packing of 1 and 0.1g of ^{113}Sn, ^{125}Sb and ^{60}Co-ZrSiW into the holders made of the Chinese Artelon as shown in Figs. 1-a and 1-b, respectively, then they were measured in 27June,2018. Figures 4 and 5 show typical gamma-spectra of ^{113}Sn, ^{125}Sb and ^{60}Co for the volume and planar sealed source, respectively. The spectra show only the peaks attributed to these radioisotopes. The absence of any radionuclide as an impurity confirms the success of the separation and preparation method of the sealed source. In addition to the importance of the radionuclidic purity for the gamma energy calibration, there

are several factors play an important role in the estimation of the radioactivity with a high accuracy of the unknown sample using the neutron activation method such as the geometric shape of the sealed source holder and the unknown sample holder, and accuracy of the efficiency curve of the sealed source, which was used to calculate the radioactivity values of the unknown sample. Figures 5 (a and b) shows the efficiency calibration curves, which were determined at 5 cm from the detector and processed by the polynomial fitting to obtain Equation (4) of the sixth degree:

$$y = A + Bx + B_2X^2 + B_3X^3 + B_4X^4 + B_5X^5 + B_6X^6 \quad (4)$$

where y is the efficiency (ε_x) at a any gamma-energy, B values are the polynomial coefficients, X is the gamma energy line (keV)

The efficiencies calibration for gamma energy lines of ^{113}Sn, ^{125}Sb, and ^{60}Co were determined by measuring the source on the HPGe-detector and using Equation (2) to calculate the efficiency for each gamma-line, then by compensation in Equation (3), the radioactivity levels were set for these radionuclides, which were found to be $2.96_{\pm 0.26}$ kBq ($0.08_{\pm 0.007}$Ci), $2.22_{\pm 0.26}$ kBq ($0.06_{\pm 0.007}$Ci), and $0.74_{\pm 0.074}$ kBq ($0.02_{\pm 0.002}$Ci), respectively as shown in Table 2. The results show that the radioactivity values of the planar source were less by about the tenth (1/10) of the volume sealed source values as shown in the Table 2 that compiles data of ^{123}Sn, ^{125}Sb and ^{60}Co radioactivity of the planar source, which was found to be $0.3_{\pm 0.03}$, $026_{\pm 0.03}$ and $0.11_{\pm 0.01}$ kBq, respectively.

Figure 6 (a and b) illustrates the two efficiency curves using the volume and planar sealed sources, respectively, and the results show that there is a slight difference between the values of the two curves. This may be due to the difference in the geometric shape of the two sealed sources, in addition to the inverse proportion relationship between the radioactivity and the efficiency. Therefore, the efficiency values of the volume source were less than the values that were obtained using the planar source at the same measured position (5cm)

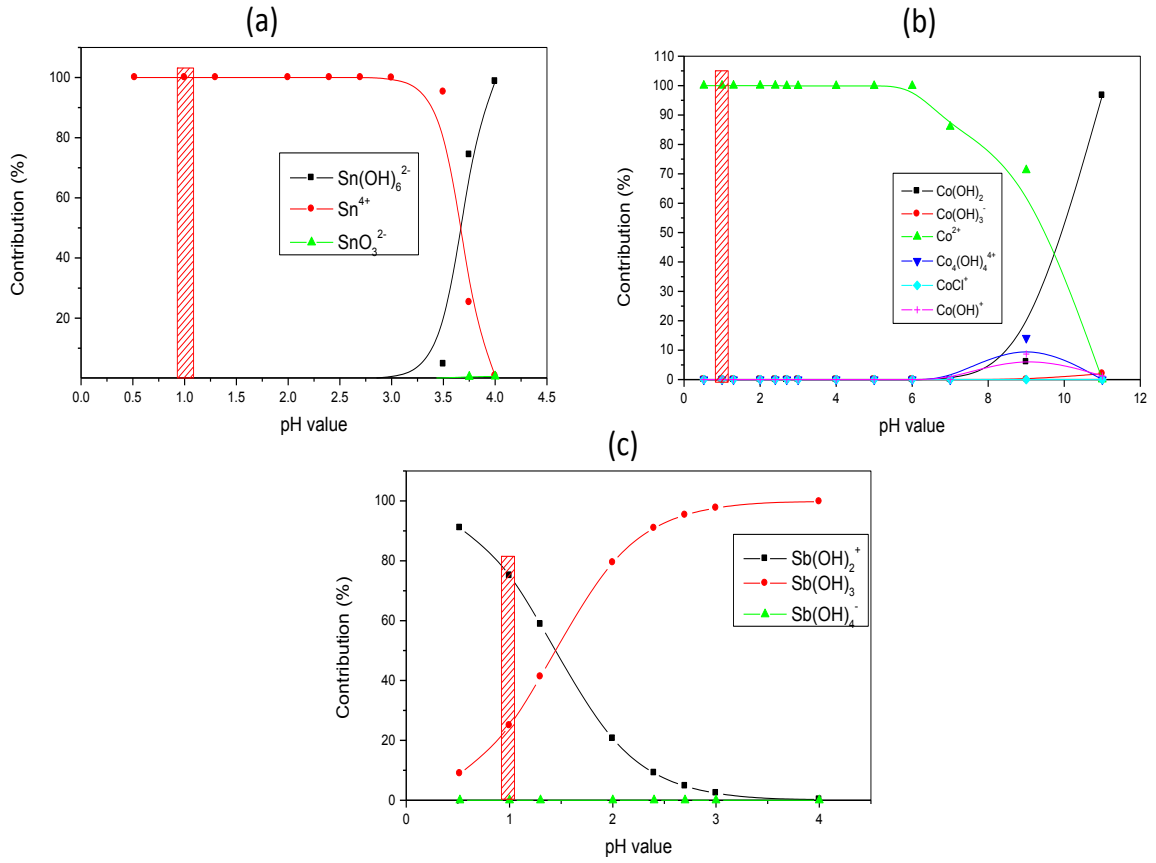

Fig. 3 (a, b and c). Variation concentration (%) of different species of Sn, Sb and Co, respectively as a function of pH in an aqueous solution (chloride medium) by using VISUAL MINTEQ Version 3.0, beta software.

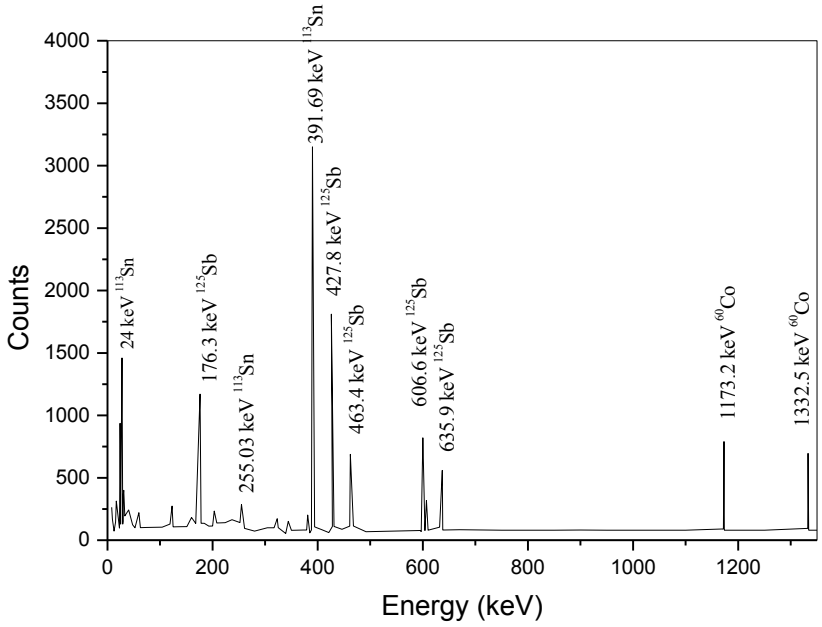

Fig. 4. γ-ray spectrum of the ^{113}Sn, ^{125}Sb and ^{60}Co-ZrSiW emitted from the volume sealed source that measured at 5cm from the detector.

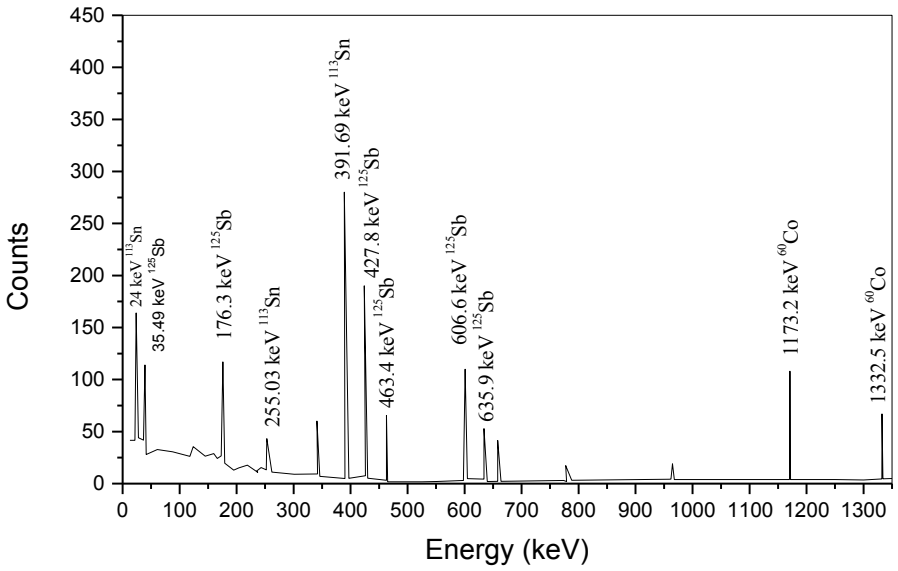

Fig. 5. γ-ray spectrum of the ^{113}Sn, ^{125}Sb and ^{60}Co-ZrSiW emitted from the planar sealed source that measured at 5cm from the detector.

TABLE 2. The determination of radioactivity of ^{113}Sn, ^{125}Sb, ^{60}Co-ZrSiW in the volume and planar sealed sources.

Sample	Matrix materia	Weight of radioactive ZrSiW	Radioactivity(μCi)		
			Sb-125	Sn-113	Co-60
Plannar source	ZrSiW	0.1	0.007±0.0008	0.008±0.00080	0.003±0.0003
Volume source		1	0.06±0.007	0.08±0.007	0.02±0.002

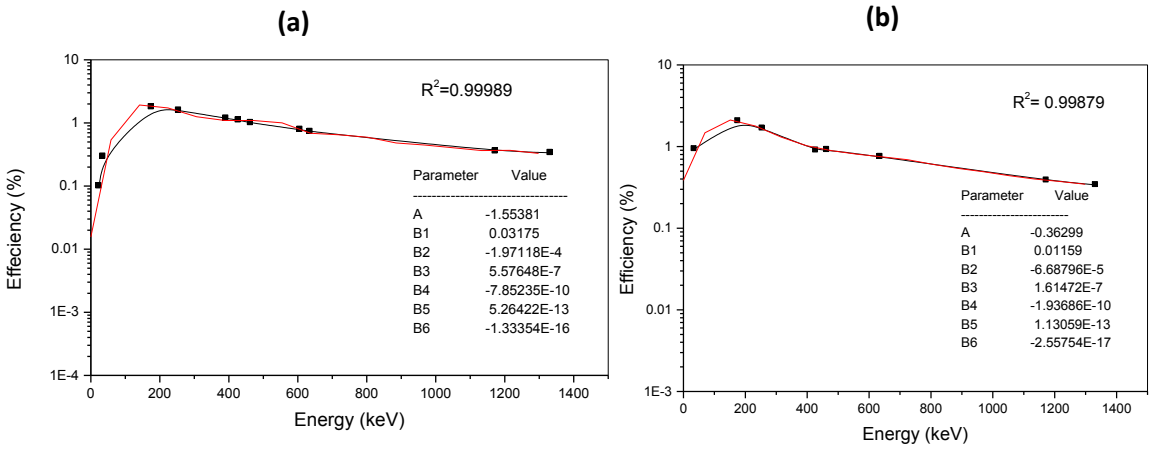

Fig. 6. Efficiency curve as a function of γ–energy at 5cm using (a) a volume sealed source (b) a planar sealed source of ^{113}Sn, ^{125}Sb , ^{60}Co-ZrSiW.

Conclusion

Sealed sources of ^{113}Sn, ^{125}Sb and, ^{60}Co-ZrSiW were prepared using the neutron activation technique. The prepared sealed sources could be used to measure an unknown sample, and this requires several demands such as the accuracy of the radioactivity values of the prepared sealed sources (^{113}Sn, ^{125}Sb and, ^{60}Co) that depend on using a known standard source (^{152,154}Eu), so as to determine the radioactivity values of the prepared sealed sources of ^{113}Sn, ^{125}Sb and, ^{60}Co. The prepared sealed sources have wide g-energy range (36-1332.5keV). In this study, the holder in the unknown sample and the standard source is made of Chinese Artelon and have the same geometric shape, which is a suitable material due to its low absorption of the emitted g-ray. The quality control tests were carried out on the prepared sealed sources (volume or planar) to examine its suitability for the gamma-energy calibration of the HPGe dector and for the determination the radioactivity of the unknown sample via estimating the efficiency calibration at 5cm that confirms its relevance for application. Calculating the efficiency of two different types in the geometric shape of this holder enables us to 10 assign the samples, which have high radioactivity and small-weight using neutron activation method.

References

Aydia M.I., El-Said, H., El-Sadek, A.A., El-Azony, K.M.. (2018) Preparation and characterization of zirconium silico ^{188}W-tungstate as a base material for ^{188}W/^{188}Re generator. *Appl. Radia. Isot.* **142**, 203-210.

Bethke, C.M. (2008) "*Geochemical and Biogeochemical Reaction Modeling*". New York: Cambridge University Press.

El-amir, M.A., El-Said, H., Ramadan, H.E. (2013) Potential use of an irradiatednatural tin target for preparation of a mixed sealead source based on 12-tungstocerate gel matrix for radiometric calibration purposes. *Radiochemistry,* **55**(2), 175-179.

El-Azony, K.M., El-Said, H., Mohty, A.A. (2009) Preparation of ^{65}Zn and ^{134}Cs sealed sources based on commercial organic and synthesized inorganic sorbents for calibration purposes of γ-detectors. *Appl. Radiat. Isot*. **67**, 984-989.

Elmaghraby, E.K. (2016) Internal efficiency calibration for bulk samples using a peak-by-peak cascade technique. *Int. J. Nucl. Energy Sci. Technol*. **10**(3), 234-244.

El-Said, H., El-Sadek, A.A., Aydia, M.I., El-Azony, K.M. (2018) Zirconium silicotungstate matrix as a prospective sorbent material for the preparation of ^{113}Sn/^{113m}In generator. *Radioanal. Nucl. Chem.* **317**, 1341-1347.

Enomoto, S., Senoo, M., Maeda, S. (1975) New method for preparation of a ceramic strontium-90 titanate β-ray source. *Int. J. Appl. Radiat. Isot.* **26**, 363.

Gustafsson, J.P. (2014) Visual MINTEQ 3.1. Sweden, Stockholm (KTH Royal Institute of Technology, Department of Land and Water Resource Engineering).

Hino, Y., Matui, S., Yamada, T., Takeuchi N., Onoma K., Iwamoto S., Kogure H. (2000) Absolute measurement of ^{166m}Ho radioactivity and development of sealed sources for standardization of γ-ray emitting nuclides. *Appl. Rad. Isot.* **52**(3), 545-549.

IAEA-TECDOC-1512 (2006) Production Techniques and Quality Control of Sealed Radioactive Sources of Palladium-103, Iodine-125, Iridium-192 and Ytterbium-169, IAEA-TECDOC-1512, Vienna.

ISO (International Organization for Standardization) (1999) Radiation Protection– Sealed Radioactive Sources–General Requirements and Classification, Second ed., ISO 2919.

Koretsky, C. (2000) The significance of surface complexation reactions in hydrologic systems: A geochemist's perspective. *Hydrol.* **230**, 71-127.

Krazaniak, M., Coppel, D. (2002) Conditions of use for sealed cobalt 60 sources. *Radiat. Phys. Chem.* **57**, 287-590.

Martinez, D.A., Abeyta, C.L., Leonard, L.E., Tompkins, J.A., Leonard, S.J. (2002) Development and Certification of a Special form Capsule for Sealed Sources to Facilitate Transportation and Storage as Special form Material, Los Alamos National laboratory-OSRP documents. LA-UR-02-433.

Mathew, C., Majali, M.A, Balakrishnan, S.A. (2002) A novel approach for the adsorption of iodine-125 on silver wire as matrix for brachytherapy source for the treatment of eye and prostate cancer. *Appl. Radiat. Isot.* **57**(3), 359-367.

Mostafa, M., El-Amir, M.A. (2007) Preparation of ^{137}Cs and ^{60}Co sealed sources based on inorganic sorbents for radiometric calibration purposes. *Colloids Surf.* **317**, 687-693.

Pappalardo, G., Sanoitc, J. de, Musumarra, A., Calvi, G., Marchetta, C. (1996) Feasibility study of aportable PIXE system using a ^{210}Po alpha source. *Physics Research,* 109-110.

Platonov, P.A., Shtrombakh, Ya.I., Chugunov, O.K., Lobanov, N.S., Aleksandrov, V.P., Alekseev, V.M., Semochkin, V.M., Denisov, V.A., Kochkin, V.N. (2002) Immobilization of radionuclides in irradiated reactor-graphite blocks. *Atomic Energy,* **92**, 475-481.

Radiation Safety Policy Manual, Montreal, Quebec (Canada) (2005) McGill Univ., Environmental Safety Office, Ed. 5.1.

Sahoo, P., Narasimhan, S.V., Kannan, (1996) Preparation of electrodeposited source for ^{65}Zn. Radioanal. *Nucl. Chem.* **204**(1), 3-14.

Saniot, J. de., Leprince, B., Bobin, Ch., Bouchard, J. (2004) Freeze-drying applied to radioactive source preparation. *Appl. Radiat. Isot.* **61**(6), 1391-1395.

Shtrombakh, Y.I., Platonov, P.A., Lobanov, N.S., Chugunov, O.K., Aleksandrov, V.P., Zinov'ev, O.A. (2005) Epoxy compounds for immobilizing radioactive wastes. *Atomic. Energ*. **98**, 331-333.

Tompkins, J.A. (2003) Control and Disposition of Sealed Sources: Relative to a Campus Setting, Los Alamos National laboratory-OSRP documents, LAUR-03-1016.

Vucanac, I., Djurasevic, M. , Kandic, A., Nadjerdj, L., Milosevic, Z. (2008) Experimental determination of the HPGe spectrometer efficiency curve. *Appl. Radiat. Isot.* **66**, 792-795.

تحضير و مراقبة الجودة للمصادر المرجعية الحجمي و المسطح للقصدير-113 والأنتيمون-125 و الكوبالت-60 المدمص على سليكو تنجستات الزركونيوم

حسن السيد أحمد[1]، سحر السيد شرف الدين[2]، محمد إسماعيل عايديه[1]، محمد راغب النجار[3]، خالد محمد صالح[1]

[1]قسم النظائر و المولدات المشعة - مركز المعامل الحارة - هيئة الطاقة الذرية - القاهرة - مصر، [2]قسم الكيمياء النووية - مركز المعامل الحارة - هيئة الطاقة الذرية - القاهرة - مصر، [3]قسم معالجة النفايات المشعة - مركز المعامل الحارة - هيئة الطاقة الذرية - القاهرة - مصر.

تم التنشيط النيتترونى لأهداف من القصدير وكلوريد الكوبالت فى مفاعل مصر البحثى الثانى (ETRR-2) لتحضير نظائرالقصدير-113 و الأنتيمون-125 و الكوبالت-60 على التوالى. وقد تم تحميل نظائرالقصدير-113 و الأنتيمون-125 و الكوبالت-60 على سليكو تنجستات الزركونيوم من المحاليل المائية عند أس هيدروجينى 1 بطريقة إتزان الطريحة. وقد تم تفسير النتائج التى تم الحصول خلال عملية الإدمصاص بإستخدام برنامج Visual MINTEQ الإصدار الثالث. وقد تم تصنيع المنابع المغلقة بتعبئة 1 و 0.1 جم سليكو تنجستات الزركونيوم المحملة بنظائرالقصدير-113 و الأنتيمون-125 و الكوبالت-60 على التوالى داخل كبسولات حجمية و مسطحة مصنوعة من مادة الأرتيلون الصينى. وقد تم قياس إشعاعية نظائرالقصدير-113 و الأنتيمون-125 و الكوبالت-60 ووجد أنها 0.26±2.96, 0.26±2.22, 0.074±0.74 و 0.03±0.3, 0.03±026, 0.01±0.11 كيلو بيكريل على التوالى. وقد تم تعيين منحنيات الكفاءة للمصدرين فى نطاق الطاقة 1332.5-36 كيلو إلكترون فولت وذلك بالقياس على بعد 5 سم من كاشف الجرمانيوم عالى النقاوة لتقدير الإشعاعية للعينات المجهولة بطريقة التنشيط االنيتترونى.