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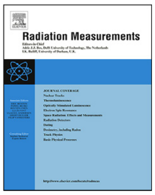

Unfolding alpha-particle energy spectrum from a membrane air filter containing radon progeny

R. Pöllänen*, T. Siiskonen

STUK - Radiation and Nuclear Safety Authority, P.O. Box 14, FI-00881 Helsinki, Finland

HIGHLIGHTS

- Novel analysis tools allow thorough alpha spectrum unfolding from air filters.
- Non-linear energy calibration and various peak shapes can be applied in the analysis.
- Coincidences with electrons, photons and beta particles can be taken into account.

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ABSTRACT

An alpha spectrum containing peaks of radon progeny and measured from a membrane air filter in a vacuum using a high-resolution spectrometer was thoroughly analyzed. The goal was to find solutions to several pending issues in spectrum analysis that are prerequisites for an accurate spectrum unfolding. These include non-linear energy calibration, detailed peak shape (tailing) and alpha-electron coincidences. Monte Carlo simulations were used to assess the coincidence phenomena and to provide input to peak fitting. The methodology applied here for radon progeny can be used for other alpha-particle emitting radionuclides possibly present in the filter.

1. Introduction

High-resolution alpha spectrometry can be applied for air filters without radiochemical sample processing (Pöllänen and Siiskonen, 2006). The filters, or other objects with flat and smooth surface, can be measured in a vacuum as such, provided that their dimensions are appropriate for the vacuum chamber. However, difficulties may arise in the spectrum analysis especially for thick (>>1 μm) or inhomogeneous sources causing notable peak widening and tailing. Lin et al. (2002) formulated that “any type of structure in the spectrum that is not included in the assumption of alpha peak shape will contribute to a bias in the peak area calculation”.

Difficulties may also arise with thin sources, such as a membrane air filter that was used in the present study due to physical characteristics of the decaying nuclei and the measurement electronics. Here an example was provided by short-lived alpha-particle emitting radon progeny (mainly ^{218}Po, ^{214}Po, ^{212}Po and ^{212}Bi) that was collected in the filter and, subsequently, measured in a vacuum. The resulting alpha spectrum was analyzed using novel software known as Adam which has numerous advanced features (Ihantola et al., 2011). Detailed characteristics of the spectrum were investigated highlighting problems and pitfalls in the spectrum unfolding.

2. Measurement data and preliminary analysis

The sampling was performed in a room where radon concentration is of the order of 100 Bq m^{-3} or more. Data acquisition was done in a vacuum chamber using the A1200-30AM (Canberra) silicon alpha detector and source to detector distance of 1 cm. Possible contamination was prevented by cautious filter handling and careful operation of the chamber. Details for the sampling and measurement are presented in Pöllänen et al. (2013) and are not repeated here. The resulting alpha spectrum is the same as that presented in the abovementioned reference (Fig. 4 therein, spectrum in the middle).

The preliminary analysis of the spectrum was performed using Adam by assuming linear energy calibration and equal shape for all

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* Corresponding author. Tel.: +358 9 75988425; fax: +358 9 75988433.
E-mail address: roy.pollanen@stuk.fi (R. Pöllänen).

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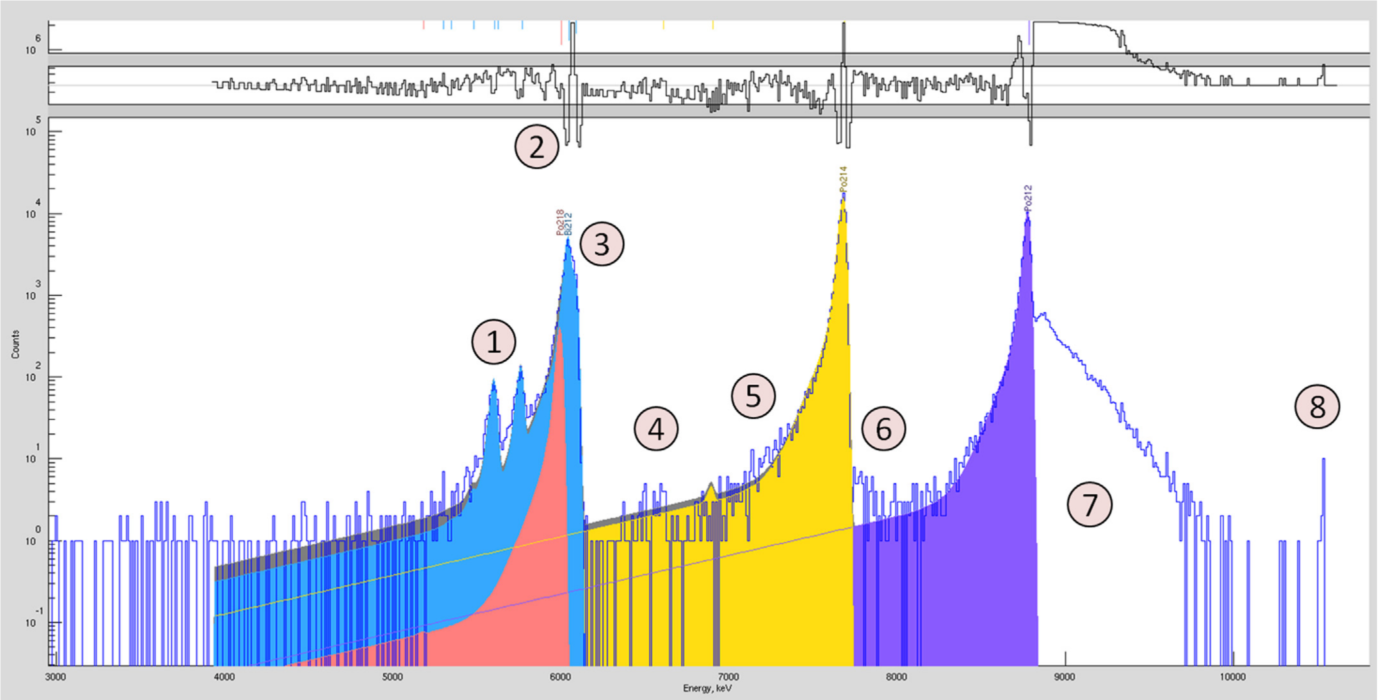

Fig. 1. Alpha spectrum measured in a vacuum from a membrane air filter where nuclides of radon progeny (from left to right ^{218}Po, ^{212}Bi ^{214}Po, and ^{212}Po) are present. Preliminary analysis of the spectrum was performed using the Adam program. See main text for the numbering.

alpha peaks (tied fitting for the peak families). The Gaussian distribution with three low-energy side exponentials was used for the peak shape. A snapshot of the analysis screen of Adam is presented in Fig. 1. The fitting area used in the analysis was 4–10.5 MeV.

Accurate emission data of alpha particles is a prerequisite for spectrum unfolding (Table 1). In addition, the emission of beta particles, electrons and low-energy photons is of special importance because of their possible coincidences with alpha particles

Table 1

The most important (with respect to the present work) nuclides that may be present in the air filter and their emission data (see http://www.nucleide.org/DDEP_WG/DDEPdata.htm for the data, notations, and uncertainties). Emission data for electrons (maximum energy for beta particles) and photons are presented only if they are of relevance considering the present work. Conversion electrons and Auger electrons from shell L are denoted as ec_L and e_{AL}, respectively. No long-range alphas are presented for ^{214}Bi because of their low emission probability. In addition, only the most relevant beta emissions are shown (the contribution of conversion electrons and auger electrons is small as well).

Nuclide	$t_{1/2}$	Alpha emissions			Beta/electron emissions			Photon emissions		
		Notation	E_α (keV)	Probability × 100	Notation	E_β (keV)	Electrons per 100 disintegrations	Notation	E_γ (keV)	Photons per 100 disintegrations
^{218}Po	3.071 min	$\alpha_{0,0}$	6114.68	99.9769						
		$\alpha_{0,1}$	5277.68	0.0011						
^{214}Po	162.3 μs	$\alpha_{0,0}$	7686.82	99.9895						
		$\alpha_{0,1}$	6902.6	0.0105						
		$\alpha_{0,2}$	6610.1	0.000058						
^{212}Po	0.300 μs	$\alpha_{0,0}$	8785.17	100						
^{212}Bi	60.54 min	$\alpha_{0,0}$	6090.14	9.7	$\beta^-_{0,0}$	2252.1	55.31	$\gamma_{1,0}$ (Tl)	39.858	1.07
		$\alpha_{0,1}$	6051.04	25.1	$\beta^-_{0,1}$	1524.8	4.50	$\gamma_{4,1}$ (Tl)	452.98	0.34
		$\alpha_{0,2}$	5768.29	0.61	$\beta^-_{0,2}$	739.4	1.44	$\gamma_{2,1}$ (Tl)	288.18	0.32
		$\alpha_{0,3}$	5625.7	0.060	$\beta^-_{0,3}$	631.4	1.90	$\gamma_{2,0}$ (Tl)	328.04	0.121
		$\alpha_{0,4}$	5606.60	0.43	$ec_{1,0\ L}$ (Tl)	24.511–27.200	19.06	$\gamma_{1,0}$ (Po)	727.330	6.65
		$\alpha_{0,6}$	5481.4	0.0050	$ec_{1,0\ M}$ (Tl)	36.154–39.469	4.46	$\gamma_{3,0}$ (Po)	1620.738	1.51
		$\alpha_{0,7}$	5344	0.00036	e_{AL} (Tl)	5.182–10.132	12.2	$\gamma_{2,1}$ (Po)	785.37	1.11
		$\alpha_{0,8}$	5302	0.000040				XL (Tl)	8.953–14.738	7.1
		[a]$\alpha_{1,0}$	9498.78	0.0024						
		[a]$\alpha_{4,0}$	10432.94	0.0010						
		[a]$\alpha_{5,0}$	10552.1	0.0106						
^{214}Bi	19.8 min	$\alpha_{0,0}$	5516	0.0082	$\beta^-_{0,0}$	3270	19.67			
		$\alpha_{0,1}$	5452	0.0116	$\beta^-_{0,9}$	1540	17.494			
		$\alpha_{0,2}$	5273	0.00125	$\beta^-_{0,11}$	1506	17.10			
		$\alpha_{0,3}$	5184	0.00013	$\beta^-_{0,12}$	1423	8.147			
		$\alpha_{0,4}$	5023	0.000045	$\beta^-_{0,4}$	1892	7.45			
		$\alpha_{0,5}$	4941	0.000052	$\beta^-_{0,21}$	1066	5.642			
^{211}Bi	2.15 min	$\alpha_{0,0}$	6622.4	83.56						
		$\alpha_{0,1}$	6278.5	16.16						

[a] Refers to long-range alpha particles.