COMPARISON MEASUREMENTS OF THE CONCENTRATION OF DAUGHTER PRODUCTS OF EMANATIONS IN AIR

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The concentrations of radioactive aerosols are usually measured by a comparison method. The comparison sources used for measurement of the content of α emitters in air are ^{239}Pu sources. In concentration measurements of natural radioactive aerosols formed by the daughter products of radon and thoron, the discrepancy between the isotopic (spectral) composition of the test sample and the comparison source may lead to several errors.

Special sources of radium (^{226}Ra) [1] and radioactive thorium (^{228}Th) [2] have recently come into use in attempts to reduce these errors; these sources are made in such a manner that the decay products are retained along with the long-lived parent substance. The use of special techniques in preparing such sources, which essentially prevent the emanation of inert gases from the source, leads to a radioactive equilibrium between the short-lived daughter products of the emanation decay and the long-lived parent substance.

Difficulties arise in calibrating such sources because of the presence of α-, β-, and γ-emitting isotopes in them, which force one to measure the activity of one isotope against a background of the others. Moreover, such sources may contain radioactive impurities in a quantity which must also be determined during the calibration.

We used a 4π flow counter operating in the proportional region to calibrate ^{226}Ra and ^{228}Th sources [3]. An improvement in the amplifier* of this apparatus permits its use to separately count α's and β's when nuclides emitting both are present in a source.

In studying this apparatus we carried out experiments to justify measurement of α's and β's from a source containing nuclides emitting both. The following procedure was followed: the α yield from a ^{239}Pu source deposited on a steel substrate was measured in a 2π geometry; then a pycnometric method was used to deposite 0.06801 g of a solution of ^{90}Sr + ^{90}Y, whose specific activity was determined by means of a 4π counter to be $1.02 \cdot 10^5 \pm 1\%$ disintegrations/sec · g; a source prepared in this manner was used to record the dependence of the count rate N on the voltage U applied to the counter. The experimental results are shown in Fig. 1. This figure shows that two plateau regions can be singled out: 1800-2350 V for the α's and 3200-3450 for the β's. The plateau slopes are less than 0.5% per 100 V. The β plateau shows that α's do not overload the amplifier and that the apparatus may be used to measure β's against an α background.

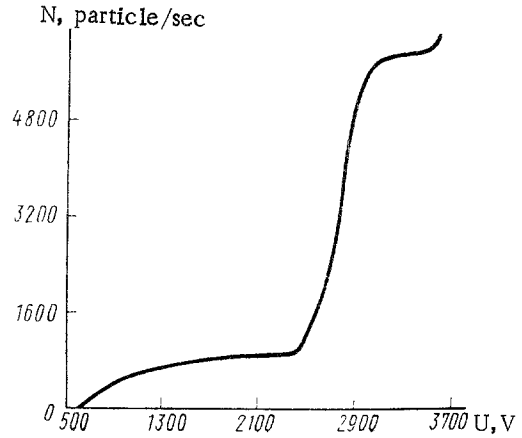

Fig. 1

Table 1 shows the external yield of α's from the ^{239}Pu source and the total yield of α's and β's from the ^{239}Pu + ^{90}Sr + ^{90}Y source.

The β back-scattering coefficient τ from the steel substrate was measured and found to be 0.48. Table 2 shows the good agreement between the measurements of the number of α's and β's from sources of pure α and β emitters and from a mixture of such sources.

*The amplifier was improved by V. I. Albul and I. S. Fedchenko.

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TABLE 1

Source	Number of α's per second (into 2π)	Number of β's + α's per second (into 2π)	Number of β's + α's per second (into 2π)	
			according to measurement with source (with an account of τ)	according to calculation based on solution activity
^{239}Pu	906 ±3	–	–	–
^{239}Pu + ^{90}Sr + ^{90}Y	906 ±3	6065 ±30	3490 ±35	3470 ±35

TABLE 2

Source	Number of α's per second (into 2π)		Number of α's + β's per second (into 2π)	Number of β's per second (into 2π)	
	no correction for reflection	with correction for reflection (τ_α = 0.02)		no correction for reflection	with correction for reflection (τ_β = 0.48)
^{228}Th	3040 ±15	2980 ±20	4780 ±30	1740 ±35	1180 ±30

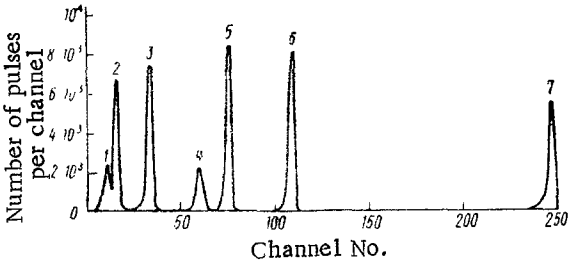

Fig. 2. α-Spectrum of a nonemanating ^{228}Th source. 1, 2) ^{228}Th; 3) ThX; 4) ThC; 5) Th; 6) ThA; 7) ThC'.

Accordingly, the apparatus with the 4π flow counter, which may be used for a separate count of α's and β's from sources containing α- and β-emitting nuclides, may be used successfully to calibrate ^{226}Ra and ^{228}Th sources used as comparison standards for comparison measurements of the concentration of the daughter products of radon and thoron in aerosols.

Table 2 shows the measured number of α's and β's from one of the nonemanating ^{228}Th sources.

No corrections were made for α and β absorption in the film covering the source or for self-absorption in the source material because of the smallness of these corrections.

The ^{228}Th source contains five α- and two β-emitting isotopes in radioactive equilibrium. If there are no radioactive impurities in the source, the following equality should hold:

$$N_\beta = 2/5\, N_\alpha. \quad (1)$$

For every case we have N_β = 1180 particles/sec and N_α = 2980 particles/sec, from which it follows that, within the experimental error (~ 1%), Eq. (1) holds. The spectrum of a ^{228}Th source was recorded by means of a semiconductor α spectrometer (Fig. 2); it showed that there are no impurities of other radioactive substances in the source and that all the isotopes are in radioactive equilibrium with ^{228}Th, according to the decay scheme for radioactive thorium.

In the nonemanating ^{226}Ra sources, in the absence of radioactive impurities, there is also a strict radio between the number of α's and β's:

TABLE 3

Isotopes of the eight sources	No. N_α of α's per sec	No. N_β of β's per sec	$N_\alpha/2N_\beta$	$2N_\alpha/5N_\beta$
^{228}Th	5270	2170	—	0,97
^{228}Th	5390	3460	—	1,08
^{226}Ra	2540	1690	0,75	—
^{226}Ra	2450	1670	0,73	—
^{226}Ra	4470	2770	0,81	—
^{226}Ra	640	400	0,80	—
^{226}Ra	1680	1890	0,42	—
^{226}Ra	1750	1960	0,45	—

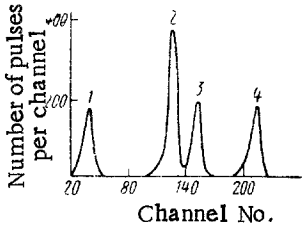

Fig. 3. 1) ^{226}Ra; 2) ^{210}Po; 3) ^{222}Rn; 4) RaA.

$$N_\beta = 1/2\, N_\alpha \tag{2}$$

since this source contains two α- and four β-emitters in equilibrium. Violation of Eqs. (1) and (2) implies that there are α- and β-emitters in the sources. We had to deal with this situation in measuring the activity of available nonemanating ^{226}Ra sources.

The final experimental results, shown in Table 3, show that there is an impurity of β-emitting isotopes in the ^{226}Ra sources.

Analysis of the spectral composition of the ^{226}Ra sources carried out by means of a semiconductor α spectrometer showed that there is also a ^{210}Po impurity in the sources. This would seem to lead to an excess of α's, so that the ratio $N_\alpha/2N_\beta$ should be greater than unity. It also follows from Table 3, however, that we have $N_\alpha/2N_\beta < 1$ for all the sources measured. This implies that there is an impurity of RaD and RaE in the initial radioactive ore used for preparing the radium sources; as a result of β decay, they form ^{210}Po.

As an example, Fig. 3 shows the α spectrum of ^{226}Ra source No. 7 (the first three peaks, 1, 3, and 4) in which the ^{210}Po impurity (peak 2) makes up 50% of the activity of the radium source.

This procedure for calibrating sources by means of an apparatus with a 4π flow counter, involving separate measurement of α's and β's along with the use of a semiconductor α spectrometer, can be used for highly accurate measurements of the activity of nonemanating sources.

The use of sources thus calibrated for subsequent comparison measurements will in turn lead to a significant reduction of the error involved in measuring the concentration of daughter products of emanations in air.

LITERATURE CITED

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3. N. F. Zhdanova and I. I. Turuntsova, Tr. In-tov Komiteta Standartov, No. 89 (149) (1967).