Radium micro-precipitates using alpha spectrometry and total alpha counting measurement

T. Hosseini^{*}, A. A. Fathivand

National radiation protection department Iranian nuclear Regulatory Authority, Tehran, Iran

ABSTRACT

Background: This study consists of two parts. The first part deals with both qualitative and quantitative analysis of ²²⁶Ra using alpha spectrometry measurement method. In the second part, the percent age of radioactive equilibrium between ²²⁶ Ra and its daughter products were determined by alpha spectrometry and total alpha measurement system after elapsed time of 15 days from precipitation.

Materials and Methods: Twelve ²²⁶Ra samples as barium-radium sulfate in form of microprecipitate on millipore and Whatman #42 filters were prepared. An alpha spectrometer with surface barrier detector and a total alpha measurement system consists of scintillation crystal assembly ZnS (Ag) were used for counting.

Results: The minimum detection limit of alpha spectrometry and total alpha counting for ²²⁶Ra measurements in samples for counting time equal to 10000 seconds, were found to be 3.7 mBq and 15.8 mBq respectively. Results from total alpha counting showed that radioactive equilibrium between ²²⁶Ra and its daughter products reached to about 92% \pm 3.5, where as, in the case of alpha spectrometry radioactive equilibrium, it was destroyed due to vacuum during counting the sample. Also in case of alpha spectrometry, the optimum sample to detector distance, was found to be 0.5 centimeter.

Conclusion: From this study it was concluded that micro-precipitation can be used as a proper method for sample preparation and alpha spectrometry micro- precipitates simultaneously of ²²⁴Ra and ²²⁶Ra in these precipitates, prepared from different samples. Besides it is not time consuming and sources can be measured immediately after sample preparation.

Key words: Radium, micro-precipitate, millipore and Whatman filters, alpha spectrometry, to-tal alpha counter.

INTRODUCTION

2²⁶Ra and ²²⁴Ra the members of uranium-238 and thorium-232 series respectively are alpha emitter radionuclides and do not add directly to gamma activity of the environment. But since they are chemically similar to calcium, they are therefore, absorbed from the soil by plants and are passed up the food chain to man. Then they are accumulated in the skeleton of individuals and cause particular biological effects. Therefore, determination of ²²⁴Ra and ²²⁶Ra in environmental samples and foodstuffs seems to be very important for human health especially in high natural radioactivity areas.

There are different kinds of measurement methods to determine 226 Ra content in natural samples. Some of these methods are gamma spectrometry, emanation of radon gas (Lucas 1977), total alpha counting, solid state nuclear track detectors (Sohrabi *et al.*1995) and alpha spectrometry (Sill 1981, Lozano 1999). Among these methods alpha spectrometry, due to its lower detection limit, is preferred for determination of 226 Ra in trace amounts. In this study

Corresponding author:

T. Hosseini. National Radiation Protection Department Iranian Nuclear Regulatory Authority, Tehran, Iran P.O.Box: 14155-4494, Fax: +98 21 8009502. *E-mail: thosseini@msn.com*

twelve ²²⁴Ra and ²²⁶Ra micro-precipitates were prepared as sources according to the technique reported by Sill (1983) and counted by alpha spectrometry and total alpha counter system.

MATERIALS AND METHODS

Specific amounts (100 µl) of a diluted ²²⁶Ra standard solution (11.887±3.65% Bq/ml) (Amersham), 5ml citric acid (93 g/l) and 2ml lead carrier solution (100mg Pb⁺²/ml) were added to 400ml distilled water. Three ml of Barium-133 tracer solution (3.191±2.95% Bq/ml) was used for calculation of chemical yield. The pH of solution was changed to 9 by addition of ammonia solution. Then, 9M sulfuric acid solution was added until the pH was changed to 1. In this situation radium and lead was precipitated as Ra/PbSO₄ (Kim, *et al.* 2001).

The sulfate precipitate was dissolved in alkaline 0.25M EDTA (Ethylene Diamine Tetraacetic Acid, disodium salt) solution. The micro-coprecipitate of radium was prepared by addition of very small amounts of barium carrier (50 μ g Ba²⁺) to the above solution and decreasing pH to 4.2 with 3M sulfuric acid (Lim *et al.* 1989, Sill 1983). In this pH, barium and radium precipitated in form of Ra/BaSO₄ but lead remained in the solution. After 30 minutes the micro-precipitate was filtered on a millipore or Whatman filter.

Twelve samples were prepared by using Whatman #42 and millipore 0.45 μ m filters. The thickness of micro- precipitates was about 25 μ g/cm². All filters were counted by alpha spectrometry measurement system and total alpha counter system.

Measurement systems: Alpha spectrometry measurement system consists of a surface barrier detector, model PI450251 with 450 mm² area, 25 keV resolution (FWHM) and 100 microns depletion dept; a vacuum chamber model 7400A (canberra) and a MCA (Multi Channel Analyzer) model 35 plus (Canberra).

Total alpha measurement system consists of scintillation crystal assembly, RD - 13 (Alpha) [A layer of ZnS (Ag) crystals adhered to a lucite light pipe which is 3/4 inch in thickness and 2.49 inches in diameter (Eberline)] and a mini scalar model MS - 3 (Eberline).

RESULTS AND DISCUSSION

The alpha spectrums of radium precipitates on Whatman #42 and millipore filters immediately after preparation are shown in figure 1 and 2 respectively. Analysis of spectrums shows that compared to Whatman #42, millipore filter has better resolution (FWHM = 80 keV) and much less tailing. So, it was found that millpore filter is much more suitable than whatman filter to prepare sources to be counted by alpha spectrometry system, since peaks due to presence of different radionuclides can be isolated better.

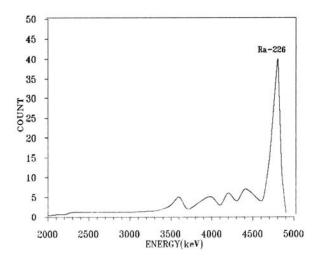


Figure 1. Alpha particle spectrum of ²²⁶Ra microprecipitate on Whatman filter immediately after preparation.

In order to obtain an appropriate distance between our samples and detector, the filters were counted in different sample to detector distances. Obtained results show that as the sample to detector distance increases, the counting efficiency decreases, so for our samples the optimum sample to detector distance at which both efficiency and resolution were good, was obtained to be 0.5 cm.

In order to study radioactive equilibrium between ²²⁶Ra and its daughter products in the samples on millipore filters, one of the filters with known activity was analyzed by alpha spectrometry in different elapsed times after preparation. Immediately after filtration only ²²⁶ Ra peak was seen in the spectrum, where as, in the subsequent spectrums the area of radium daughter products' peaks grew. Considering the long half-life of ²²⁶Ra, the increase of ²²⁶Ra peak area in subsequent countings is assumed to be due to ²²⁶Ra daughter products.

Theoretically 15 days after filtration, radioactive equilibrium should be about 93.5%, but we found it to be about 83%. It seems that vacuum process makes a part of radon gas come out from filter, which then the equilibrium destroys. In order to check this idea, after radioactive equilibrium was achieved in the precipitate, the filter was fully covered by a thin aluminium foil. The alpha spectrometry of this covered filter (with previous condition) showed radioactive equilibrium up to about 90%. So, from obtained results it was concluded that alpha spectrometry is not a good method to determine radioactive equilibrium in micro precipitates, unless special spray is used to fix and cover the precipitate. In

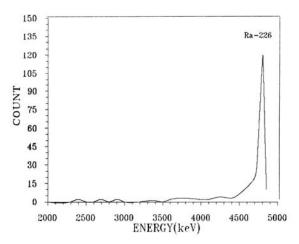


Figure 2. Alpha particle spectrum of ²²⁶Ra microprecipitate on millipore filter immediately after preparation.

this study the percent age of radioactive equilibrium between 226 Ra and its daughter products was equal to $92\% \pm 3.5$.

Results from alpha spectrometry of samples suggest that micro precipitation, as a sample preparation method is quite suitable for determination of ²²⁶Ra in different samples. By this method it is possible to measure ²²⁶Ra immediately after preparation of filter samples. The minimum detection limits of alpha spectrometry and total alpha counting system for ²²⁶Ra measurements in our geometry and counting time equal to 10000 seconds were found to be 3.7 and 15.8 MBq respectively.

Radium precipitate, in the form of sulfate, may contain the other naturally occurring radium isotopes (i.e. ²²⁴Ra and ²²⁸Ra), which affect the measurement of ²²⁶Ra. Among these radioisotopes ²²⁸ Ra is a beta emitter so it doesn't affect ²²⁶Ra measurement. But the effect of ²²⁴Ra on ²²⁶Ra peak was determined by preparing samples of ²²⁴Ra precipitate (from ²³²Th solution) and calculating the percent of ²²⁴Ra peak (about 4.6%), which lies on ²²⁶Ra region [E_a (Ra226) = 4.78 MeV and E_{a (Ra224)} = 5.69 MeV]. It means that if sample contains ²²⁴Ra and ²²⁶Ra, 4.6% of ²²⁴Ra peak region will lies in ²²⁶Ra peak's region. This addition should be diminished while analyzing samples for ²²⁶Ra contents. Figure 3 shows the spectrum of ²²⁴Ra micro - precipitate 24 hours after filtration.

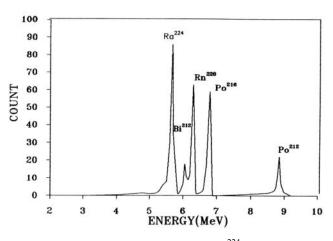


Figure 3. Alpha particle spectrum of ²²⁴Ra microprecipitate on millipore filter.

CONCLUSION

Measurement of ²²⁴Ra and ²²⁶Ra contents in micro-precipitate samples were studied by alpha spectrometry and total alpha counting measurement methods. It was shown that it is possible to prepare micro-precipitate of radium in sulfate form from various environmental and food samples and measure it immediately after filtration process, without waiting to achieve radioactive equilibrium between radium and its daughter products. Also it is a fast method to measure radium in different samples. Analysis of alphaparticle spectrums of radium micro-precipitates on both millipore and Whatman # 42 filters showed that the former is more suitable for radium determination. For our samples the optimum sample to detector distance, which gives us both good efficiency and resolution, was found to be 0.5 cm. The percent of ²²⁴Ra peak's region which lies in ²²⁶Ra peak's region, due to its tailing, was found to be 4.6% of ²²⁴Ra peak's that should be diminished while analyzing ²²⁶Ra in the samples.

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