NUKLEONIKA 2006;51(Supplement 2):S3–S5

Thermochromatographic separation of ^{206,208}Po from a bismuth target bombarded with protons

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Abstract The artificially produced isotopes of polonium are valuable tracers for radiochemical procedures for the determination of natural ^{210}Po. In this work, the isotopes of polonium (^{206}Po to ^{208}Po) were produced by activation of metallic bismuth targets with 40 MeV protons. The thick target yield of ^{206}Po was 16 MBq/μAh. Polonium was separated from bismuth by a thermochromatographic method under reduced pressure in static conditions. The bismuth target can be considered as the multiple-use material.

Key words thermochromatographic separation • radionuclides ^{206}Po and ^{208}Po • environment

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Received: 10 October 2005
Accepted: 30 November 2005

Introduction

Among the artificially produced isotopes of polonium the most important are: ^{208}Po and ^{209}Po, used as tracers in radiochemical procedures for the determination of natural ^{210}Po [3, 6]. They can be obtained by activation of lead or bismuth targets with accelerated particles. Since the production of long-lived ^{209}Po requires long activations (which results in a high cost of this isotope) we concentrated on ^{208}Po whose production requires less of the beam time. To produce ^{208}Po we have chosen the ^{209}Bi(p,2n)^{208}Po reaction. From the comparison of vaporization enthalpies of bismuth (152 kJ·mol^{-1} [5] or 177 kJ·mol^{-1} [2]) and polonium (103 kJ·mol^{-1} [5] or 59 kJ·mol^{-1} [2]), we expected a significant difference of vapour pressures and, consequently, an efficient separation of Po from Bi by means of thermochromatography.

Experimental

80 mg·cm^{-2} thick bismuth targets (total mass: 40 mg) were activated in the AIC-144 cyclotron of our Institute with a 40 MeV proton beam of 1 μA intensity.

The products of target activation and the progress of the separation process were measured by means of α and γ spectroscopy. The γ spectrometry tract consisted of a 35 cm^3 coaxial HPGe detector made at this Institute and of a multichannel analyser (SILENA, Italy). Its energy resolution was 2.5 keV at the 1332 keV peak of ^{60}Co. The α sources were measured in a SOLOIST chamber (ORTEC, USA) equipped with a 450 mm^2 silicon detector. The observed peaks were identified basing on the table data [1].

The activated target was cooled for 6 days until the short-lived activity decayed. Then, the target material

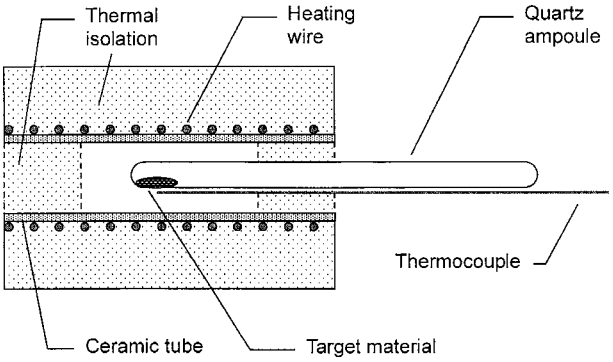

Fig. 1. Set-up for thermochromatography.

was divided into pieces and a 10 mg piece was placed in a 15 cm long, 4 mm I.D. quartz ampoule. The open end of the ampoule was sealed under argon at a pressure of 2400 Pa. The ampoule was placed in the furnace, and the temperature was raised in 5 min time intervals. After each heating step, the residual activity of the target was measured by means of gamma spectroscopy (the other parts of the ampoule were then shielded with 5 cm layer of lead). The data acquisition times were 30 s after each heating step. After finding the optimum conditions, i.e. the temperature at which polonium evolves rapidly but vaporization of the target material is still low, polonium was separated from bismuth thermochromatographically. The separation set-up is presented in Fig. 1.

Polonium collected on the cold parts of the tube was washed out with concentrated (ca. 10 M) HNO_3. The $^{206}Po/^{208}Po$ alpha source was made by internal electrolysis, i.e., the isotopes of Po were electrodeposited on a Ag foil from 0.5 M HCl in 363 K [4].

Results

In the reported energy range, the nuclear reactions $^{209}Bi(p,xn)$ result in production of the following isotopes of polonium: ^{206}Po ($t_{1/2}$ = 8.8 d), ^{207}Po ($t_{1/2}$ = 5.8 h), ^{208}Po ($t_{1/2}$ = 2.9 y), ^{209}Po ($t_{1/2}$ = 102 y). The isotopes ^{206}Po and ^{208}Po were detected in the α spectra. The isotope ^{206}Po and its daughter ^{206}Bi ($t_{1/2}$ = 6.24 d) were seen in the gamma spectra. The activity of the α emitter ^{209}Po, expected from the $^{209}Bi(p,n)$ reaction was not detected. The isotope ^{207}Bi ($t_{1/2}$ = 33.4 y), the daughter of ^{207}Po which decayed completely during the 6 days waiting period, was not detected in the gamma spectra during the 30 s data acquisition runs.

The γ emitters ^{206}Po and ^{206}Bi were used as tracers to control the progress of the thermochromatographic separation. The isotope ^{206}Po served also as a secondary reference source in the alpha-spectrometric determination of ^{208}Po.

Figure 2 shows the temperature dependence of the separation of Po isotopes and of vaporization of Bi. Evolution of Po increases rapidly when the temperature reaches 1273 K. With further increase of the temperature, the vaporization of the target material increases and reaches about 16% at 1373 K. According to these observations we established the optimum temperature for Po/Bi separation: 1325 K. After carrying out the

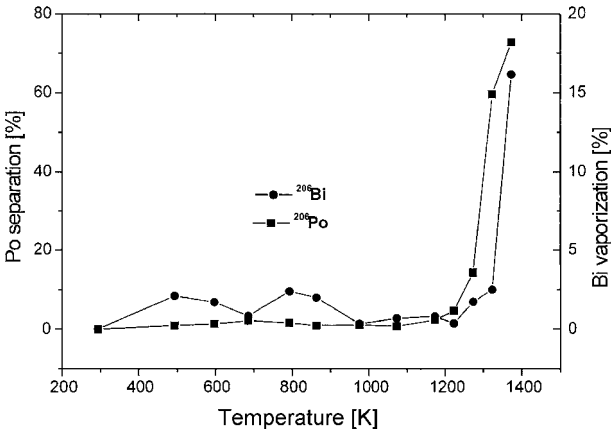

Fig. 2. Temperature dependence of Po/Bi separation.

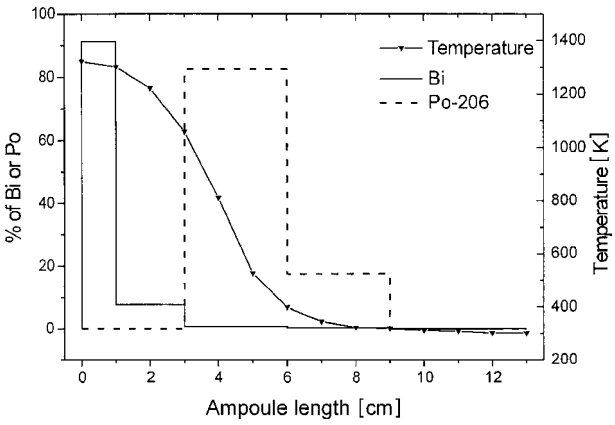

Fig. 3. Thermochromatographic spectrum of Po and Bi evolved during the separation process.

separation at this temperature during 20 min, the recovery yield of Po radioisotopes was > 97%. The separated polonium contained about 0.8% of the target material, i.e. about 0.08 mg of stable Bi. Figure 3 shows the chromatographic spectrum of the recovered polonium and evaporated bismuth.

The alpha spectrum of $^{206}Po/^{208}Po$ separated from the bismuth target, registered on the 35th day after the end of bombardment (EOB), is shown in Fig. 4.

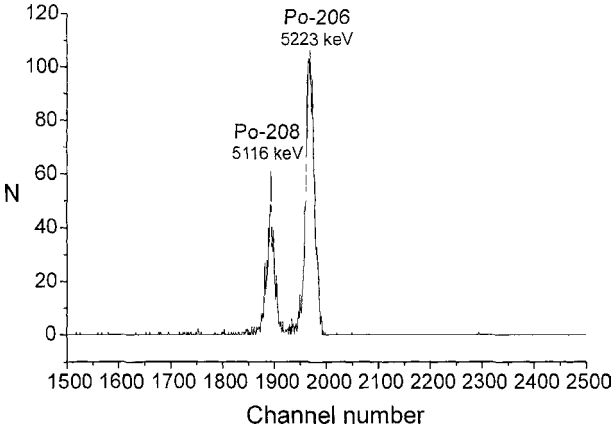

Fig. 4. Alpha spectrum of the separated Po, 35 days after EOB.

Discussion

The applied method of thermochromatographic separation of Po at reduced pressure in static conditions has the following advantages:

- simple apparatus,
- short separation times,
- the possibility of re-usage of the target material (after complete decay of ^{206}Bi).

As to the possibility of using ^{208}Po as a spike in the analysis of environmental samples, we have considered the potential interference of Bi in the following way: the typical amounts of the Po spike are 0.3 Bq per sample [6]. The activity of ^{208}Po separated from a single activation was ca. 50 kBq, which implies that it can be distributed among about 1.6E+5 samples. The resultant amounts of the contaminating Bi would be about 10 ng per sample. Such amounts of Bi should not interfere with the polonium-oriented analytical procedure.

Conclusion

The optimum temperature for the separation of Po from Bi is 1323 K at which the recovery of Po is high, and evaporation of the target material – relatively low. Further purification of ^{208}Po from Bi can be done by electrodeposition of Po on silver plates, followed by high-temperature desorption of polonium. This method will be a subject of our futher work.

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