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Radioactivity of the Baszkówka meteorite

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In January 1996 a fragment, and in May 1996 a cut slab of the Baszkówka meteorite, were delivered for the radioactivity analysis to the Dosimetry Department of the Central Laboratory for Radiological Protection (CLOR) in Warsaw. The measurement method was gamma spectrometry using HPGe (High Purity Germanium) detectors. The CLOR prepared volume calibration source identical to the cut slab of the meteorite delivered for analyses. The presence of ^{40}K and the cosmogenic radionuclides such as ^{54}Mn and ^{22}Na was detected in the Baszkówka meteorite. The results and measurement method are discussed.

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Analysis of the radioactivity of the Baszkówka meteorite was carried out on two samples:
— a fragment of mass 52.2 g;
— a cut slab of mass 474 g.

METHOD

The measurements were carried out by spectrometric analysis of gamma radiation using HPGe (High Purity Germanium) semiconductor detectors with a multichannel analyser.

The analysis allowed determination of the concentration of radionuclides in the samples in a gamma radiation energy scope from 40 to 1800 keV. The energy resolution of the applied spectrometer was about 2 keV for the radiation of ^{60}Co of energy 1333 keV. The samples analysed were put directly on the HPGe detectors having efficiencies 15 and 25%. The detectors were placed in low-background lead chambers reducing the external gamma radiation background by two orders of magnitude, particularly within the scope of typical gamma radiation from artificial radionuclides (up to about 1.4 MeV). The walls of the chamber consisted of three layers: 100 mm of lead externally; 1 mm of cadmium; and 2 mm of copper internally. This chamber also absorbs characteristic X-ray radiation excited within its material and the soft component of cosmic radiation.

The determination of the radionuclide concentration was carried out by measuring the area of photopeaks created by gamma radiation. SPECTRAN analysis software was used in the calculations. Individual measurements lasted 250 000 s. Though the detectors were located in low-background chambers, radically reducing the external background, the correction for the background radiation inside the chamber was taken into account due to the long several-day period of single measurement.

CALIBRATION

The spectrometer efficiency calibration was carried out by two means:

— a volume reference source of type *CBSS2* (produced in the Czech Republic) containing 10 radionuclides, covering the energy scope from 60 to 1840 keV and having a geometry similar to the meteorite fragment;

Table 1

Radioactivity of the Baszkówka meteorite

Radionuclide	Half-life [days]	Gamma radiation energy [keV]	Number of measurements	Average radionuclide concentration calculated on the day of impact (25.08.1994) [Bq/kg]
^{54}Mn	312.5	834.84	3	0.80±0.19
^{22}Na	950.4	1274.54	4	0.98±0.12
^{40}K	$4.66 \cdot 10^{11}$	1460.81	5	17.2±1.6

Average values of the concentration of radionuclides in the Baszkówka meteorite were calculated as weighted averages; the weight comprised standard deviations of the results particular determinations

— a volume source prepared in the Dosimetry Department of the CLOR on the basis of zirconium silicate containing natural radionuclides of the energy scope from 300 to 1760 keV having a geometry identical to the cut slab of the meteorite.

MEASUREMENT RESULTS

The results of the measurements of the Baszkówka meteorite are shown in Table 1.

The values of the concentration of the particular radionuclides are given with an error consisting of:

— error in the determination of the count number related to the photopeak area of the gamma radiation spectral line of the particular energy of the radionuclide determined (1-sigma);

— error of the spectrometer calibration (the determination of the detector efficiency for a given energy) taking into account reference source activity error and the difference in densities of the source and the measured sample;

— error in the measurement of the sample weight.

In case of the ^{40}K concentration measurement the error resulting from the determination of count number in the background potassium-40 spectral line photopeak (1460.81 keV) was taken into account.

The presence of ^{40}K and cosmogenic radionuclides such as ^{54}Mn and ^{22}Na was noted in the Baszkówka meteorite. The radionuclides occurring in lunar rocks and meteorites are given for comparison in Table 2 (Polański, 1979; Lipschutz *et al.*, 1993). The concentration of radionuclides in the Noblesville meteorite and the range of concentrations in H chondrites are given (Polański, 1979).

Measurements on the 52.2 g fragment of the Baszkówka meteorite were carried out in January and February 1996; only ^{40}K was determined. The larger slab (474 g) was analysed over the period of June–September 1996, when the concentrations of ^{40}K, ^{54}Mn and ^{22}Na were determined. As the analysis was carried out two years after the meteorite had fallen, the determination of other radionuclides using gamma radiation spectrometry was practically impossible. A theoretical possibility of determining the concentrations of ^{22}Na, ^{40}K, ^{54}Mn, ^{57}Co and ^{60}Co existed at the moment of impact (due to the half-life and spectrometer capabilities). Assuming that the initial activities of these radionuclides were similar to these of the Noblesville

Table 2

Radionuclides detected in lunar rocks and meteorities (Polański, 1979; Lipschutz *et al.*, 1993)

Radionuclide	Half-life [days]	Concentration in Noblesville meteorite [Bq/kg]	Scope of concentration in H chondrites [Bq/kg]
^{3}H	4510	–	–
^{7}Be	53.2	1.02±0.17	–
^{10}Be	5.5E8	0.32±0.02	–
^{14}C	20.93E5	–	–
^{22}Na	950.4	2.18±0.25	1.0–1.83
^{26}Al	2.7E8	0.87±0.05	–
^{32}P	14.29	–	–
^{36}Cl	1.1E8	0.38±0.02	–
^{37}Ar	34.5	–	–
^{40}K	4.66E11	11.33±1.15	–
^{45}Ca	165	–	–
^{46}Sc	83.8	0.13±0.02	0.08–0.25
^{44}Ti	3.7E5	–	–
^{48}V	16	0.33±0.17	0.25–0.67
^{49}V	330	–	–
^{51}Cr	27.7	0.45±0.08	0.83–2.17
^{54}Mn	312.5	1.65±0.18	1.0–1.83
^{55}Fe	1005	–	–
^{56}Co	78.5	0.13±0.03	0.08–0.25
^{57}Co	271	0.20 ±0.03	0.08–0.50
^{58}Co	71.3	0.03±0.02	0.03–0.42
^{60}Co	1925.5	0.02±0.01	0– > 1.67

meteorite and other H chondrites, it was only practically possible to determine the concentrations of ^{40}K, ^{22}Na and ^{54}Mn.

The concentrations of ^{22}Na [0.98±0.12 (Bq/kg)] and ^{54}Mn [0.80±0.19 (Bq/kg)] determined by the Central Laboratory for Radiological Protection lie in the lower range of values for the concentration of these radionuclides in other H chondrites. The concentration of ^{40}K [17.2±1.6 (Bq/kg)] is about 50% greater than that determined for the Noblesville meteorite.

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