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EXPERIMENTAL DETERMINATION OF THE RADIOACTIVE EQUILIBRIUM COEFFICIENT BETWEEN RADIONUCLIDES OF THE URANIUM DECAY CHAIN

Abstract: *This paper describes an experimental method for determining the radioactive equilibrium coefficient between the uranium decay chain ^{226}Ra / ^{238}U and ^{234}U / ^{238}U and an analysis of the results obtained using this method. Geochemical, geotechnological, nuclear-physical and radiochemical factors affecting the radioactive imbalance between radionuclides of the uranium decay chain ^{226}Ra / ^{238}U and ^{234}U / ^{238}U have been identified.*

Key words: *uranium decay chain, radioactive equilibrium, radioactivity, radionuclide, experimental methods, radionuclide concentration, radioactive equilibrium distortion coefficient.*

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Introduction

ACTUALITY

The determination of the values of the radioactive equilibrium coefficient between radionuclides $^{226}Ra/^{238}U$ and $^{234}U/^{238}U$ in uranium ores allows to find answers to a number of questions about this ore, the conditions of its formation, which minerals it contains and its age [1-4].

Therefore, experimental determination of the radioactive equilibrium coefficient between radionuclides $^{226}Ra/^{238}U$ and $^{234}U/^{238}U$ in uranium ores, increase the accuracy of the results, create a database of results, compare the results with the results of other researchers, finding physical, radiochemical factors which affect the radioactive balance of radionuclides and finding the main cause of radioactive imbalance is the main current problem of nuclear physics [5-8].

OBJECTIVE OF THE RESEARCH:

Based on the above considerations, to develop a method for experimental determination of the radioactive equilibrium coefficient between radionuclides in uranium ores - $^{226}Ra/^{238}U$ and $^{234}U/^{238}U$, the composition of the experimental device, to get acquainted with the principle of its operation and to apply in practice the theoretical basis of determining the age of ores on the basis of the obtained results is the goal of the research.

OBTAINED RESULTS AND THEIR DISCUSSION

The radioactive equilibrium coefficient between uranium decay chain radionuclides $^{226}Ra/^{238}U$ and $^{234}U/^{238}U$ is determined based on their activity. The radioactive equilibrium coefficient between the radionuclides $^{226}Ra/^{238}U$ and $^{234}U/^{238}U$ in this decay chain is determined as follows:

$$K_{pм} = \frac{A_{Ra-226}}{A_{U-238}} = \frac{A_{U-234}}{A_{U-238}} = 1 \quad (1)$$

Here, A (^{226}Ra) is the activity of the radionuclide radium-226, A (^{234}U) is the activity of the radionuclide uranium-234, and A (^{238}U) is the activity of the radionuclide uranium-238.

The equilibrium activity of each radionuclide is calculated as follows:

$$A_x = \frac{m_x \cdot ln2 \cdot N_A}{T_x \cdot \mu_x} \quad (2)$$

Here A_x-is the specific activity of radionuclide, m_x-is the equilibrium mass of radionuclide, T_x is the half-life of radionuclide, μ_x-molar mass of radionuclide, N_A--Avogadro's number

From Equation (2), the equilibrium mass of radionuclide is determined as follows:

$$m_x = \frac{A_x \cdot T_x \cdot \mu_x}{ln2 \cdot N_A} \quad (3)$$

Based on formula (3), the equilibrium mass amounts of radionuclides are theoretically calculated.

It can be seen from formula (1) that radionuclides can be in equilibrium when the coefficient between radionuclides is 1. Nuclear-physical analysis of industrial products over many years shows that the value of the radioactive equilibrium coefficient varies between $^{226}Ra/^{238}U$ and $^{234}U/^{238}U$ radionuclides.

Experimental research device and its methodology

The uranium concentration in the selected samples was determined using an ARF-7 X-ray fluorescent analyzer. The concentration of radium in the sample was determined by gamma spectrometry using the device "PROGRESS-Gamma".

Samples containing radionuclides ^{226}Ra, ^{234}U, ^{238}U are crushed and pulverized. The powder is placed in a cuvette and placed in the measuring chamber of the ARF-7 X-ray fluorescent analyzer. The measurement time is around 30 minutes. In the ARF-7 analyzer, the total amount of uranium-238 in the sample is determined by placing it in a cuvette and activating it using X-ray fluorescent rays.

The 100 gram sample is ground and pressed into a cuvette. Using PROGRESS-Gamma, we record the gamma radiation emitted from the sample and determine the amount of ^{226}Ra. The energy range is measured in the range of 0.2 ÷ 2.8 MeV. Energy resolution is 9%.

Samples containing uranium radionuclides and other radioactive radionuclides were taken to measure the radioactive balance. The coefficient of radioactive equilibrium in 20 samples taken for the experiment was calculated.

For ^{226}Ra and ^{238}U, the radioactive equilibrium coefficient-mass at K_{ra} was calculated using the following formula:

$$K_{ra} = \frac{m(Ra)}{m(U) \cdot 0.34 \cdot 10^{-6}} \quad (4)$$

where, m(^{226}Ra) is the mass of radionuclide 226, m(^{238}U) is the mass of radionuclide 238U.

Table 1 below shows the values of the radioactive equilibrium coefficient between radionuclides ^{226}Ra and ^{238}U obtained experimentally.

Table 1

Sample serial number	Sample content Mass fraction of isotope ^{226}Ra (g / t)	Sample content Mass fraction of isotope ^{238}U (g / t)	Radioactive equilibrium coefficient K_{rr}
1	13,49	32	1,24
2	2,81	32	0,26
3	4,24	32	0,39
4	15,97	35	1,34
5	12,05	44	0,80
6	4,11	33	0,37
7	4,84	31	0,46
8	15,16	41	1,09
9	6,79	33	0,60
10	6,87	33	0,61
11	0,95	32	0,09
12	20,35	36	1,66
13	18,24	37	1,45
14	3,03	32	0,28
15	3,08	35	0,26
16	4,11	33	0,37

17	6,24	34	0,54
18	3,76	34	0,32
19	4,27	34	0,37
20	34,11	37	2,71

As can be seen from Table 1, the radioactive equilibrium coefficient will have different values in samples belonging to the same object but taken from different points. From these results we can conclude that the radioactive balance between uranium radionuclides is disturbed. In Table 1 we can see that the radioactive equilibrium coefficient between radionuclides ^{226}Ra and ^{238}U is different.

These different values can be attributed to the age of the radionuclides in the ore. It can be concluded that in the case of $K_{rm} > 1$, the activity of ^{226}Ra is higher than the activity of uranium, and the age of the ore is smaller. In the case of $K_{rm} < 1$, the opposite is true, which means that the ore was formed much earlier and that most of the ^{226}Ra in it has undergone radioactive decay.

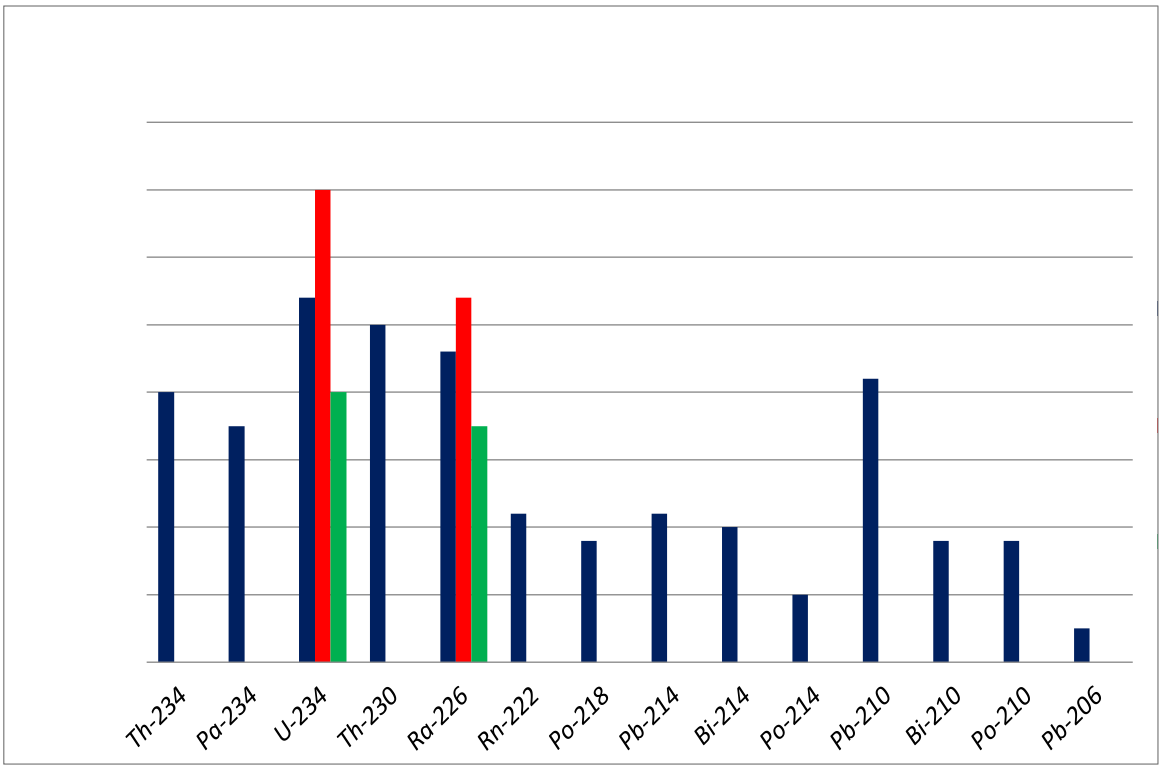

Figure 1. Changes in the values of the radioactive equilibrium coefficient between ^{26}Ra / ^{238}U and ^{234}U / ^{238}U radionuclides in uranium samples and products are given.

Conclusions

The results of the study showed that the radioactive balance between the radionuclides of the uranium decay chain is not always maintained. We can see this in the diagram in Figure 1. In this diagram, we have described in the diagram that the equilibrium amounts of blue-radionuclides are appropriate for the case where red is $K_{rm} > 1$ and for green-$K_{rm} < 1$.

From the results obtained, it was found that the value of the radioactive equilibrium coefficient varied in different samples. This is because uranium ores vary in age. It is also possible to develop a method for determining the age of the ore according to the radioactive equilibrium coefficient determined in the above studies. The application of this experimental evidence to individual cases will be the basis for future research.

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