DETERMINATION OF MIXING FACTORS OF DAUGHTER RADIONUCLIDES IN THE URANIUM DECAY CHAIN

Soliyev T.I[1]., Muzafarov A.M[2]., Sherkulov U.D[1].
[1]Navoi state pedagogical institute45, street Ibn Sino, city Navoi, region Navoi,Uzbekistan,210100,
tursunboy.soliyev@bk.ru
[2]Navoi State University of Mining and Technology72, street Mahmud Tarobiy, city Navoi, regionNavoi,
Uzbekistan, 210100a.muzaffarov@ngmk.uz

ABSTRACT

This article presents the results of a theoretical study of determining the mixing factors of daughter radionuclides in the uranium decay chain. A theoretical calculation formula for the mixing of daughter radionuclides in the uranium decay chain is found, and based on this formula, the mixing distance between daughter radionuclides is calculated. A schematic view of the mixing of daughter radionuclides between subassemblies is constructed..

Key words:
uranium decay chains, decay factors, radioactive equilibrium, recoil energy, nuclear decay laws, nuclear atomic mass number, number of protons, daughter radionuclides, mixing distance.

DOI Number: 10.14704/nq.2022.20.11.NQ66274 **NeuroQuantology 2022; 20(11): 2722-2725**

1. INTRODUCTION

In uranium production, one has to deal with the radioactive element uranium. It is known from literature data [1-2] that natural uranium consists of three natural radionuclides - ^{238}U, ^{235}U and ^{234}U. Their quantitative ratio is ^{238}U-99.27%, ^{235}U-0.72%, ^{234}U-0.0053% and the specific activity of these radionuclides in mutual radioactive equilibrium is - 1.23•104 Bq/g, 4.9•104 Bq /g and 2.3•108 Bq/g, respectively [3-5].

The studies carried out in recent years show [7-9] that disruption of the radioactive balance between these radionuclides and radionuclides in the uranium decay chain negatively affects the quality of the finished uranium product and creates an additional background of ionizing radiation. There are many nuclear-physical factors that cause violations of the radioactive equilibrium between these radionuclides, such as the age of minerals, the migration coefficients of radionuclides, geochemical factors, recoil energies, geotechnological leaching conditions, etc. [10-13].

To determine the main factor of disruption of radioactive equilibrium between daughter radionuclides in the uranium decay chain from the above, it is advisable to conduct a theoretical study to determine the mixing factors of daughter radionuclides.

The purpose of this study is to conduct a theoretical study of determining the mixing factors of daughter radionuclides for solving urgent problems of nuclear physics and technology for obtaining finished uranium products.

2. LEVEL OF KNOWLEDGE OF THE PROBLEM:

An analysis of the literature of foreign and dmestic studies shows that the mixing factors of daughter radionuclides in the uranium decay chain have been little studied. Some reasons for the violation of the coefficient of radioactive equilibrium between radionuclides of the uranium decay chain are given in the literature. They can be assessed as follows - by studying the variety of nuclear-physical properties of chemical elements, studying the recoil energy, and the properties of daughter radionuclides.

Radionuclides in a closed system are in a state of radioactive equilibrium. Over time, in the nuclei of radioactive elements, nuclear transformations into the base of α - and β - decay occur. The ^{238}U nucleus on the basis of 8-mi α-decay and 6-ti β-decay turns into stable ^{206}Pb. It is known that the activity of 1 g of ^{238}U is 12500 Bq, and the activity of 1 g of ^{226}Ra is 3.7 × 1010 Bq [8–10].

There is information in foreign and domestic literatures that disturbances in the radioactive equilibrium between radionuclides can be associated with the age of minerals [11].

The main purpose of this study is to theoretically study and detail the laws of alpha decay occurring in the parent nucleus U and its daughter nuclei. On the basis of theoretical studies, to identify the reasons for the disruption of the radioactive balance between these radionuclides and to reveal the mechanisms of disruption of the radioactive balance in the uranium decay chain [13].

3. THEORETICAL PART OF THE INVESTIGATION.

As is known, during α-decay, the daughter radionuclides of the uranium chain receive recoil energies. This reaction can be written as follows[13]:

$$M_\alpha E_\alpha = M_{rec} E_{rec} \quad (1)$$

where $M_\alpha$and E_α – the mass and energy of the alpha particle, respectively, and $M_{rec}$and$E_{rec}$are the mass and energy of the decayed radionuclide. For alpha decay to be energetically possible, the following inequality must hold[13]:

$$M(A,Z) > M(A-4, Z-2) + M({}^4_2He) \quad (2)$$

That is, the mass (energy) of the parent nucleus must be greater than the sum of the masses (energies) of the formed nucleus and the α-particle. The excess energy of the parent nucleus during α-decay is released in the form of kinetic energies of particles[13]:

$$E_{full} = [\mathrm{M(A,Z)} - \mathrm{M(A-4,Z-2)} - \mathrm{M}({}^4_2He)]c^2 = E_\alpha + E_{rec.n} \quad (3)$$

Here $E_{rec \cdot n}$ is the kinetic energy of the pulsed nucleus, E_α is the binding energy of the α-particle.

If the decaying nucleus is in a relatively stable state, P_α and $P_{rec.n}$. the kinetic energy of the resulting daughter nucleus from the momentum equation, i.e.

$$E_{rec.n} = \frac{E_\alpha M_\alpha}{M_{rec.n}} \quad (4)$$

in accordance with

$$E_{full} = \left(1 + \frac{M_\alpha}{M_{rec.n}}\right) E_\alpha \quad (5)$$

$$E_\alpha = \left(\frac{M_{rec,n.}}{M_\alpha + M_{rec.n}}\right) E_{full} \quad (6)$$

Here $M_{rec.n.}$ is the momentum mass of the nucleus. [5]

During the alpha decay of a radionuclide, the reaction energy of the alpha particle released from the parent nucleus causes a change in its position. Because the alpha particle is one of the heaviest elementary particles having an electric charge equal to 2 and an atomic mass number equal to 4. move a certain distance from your location. To find the distance traveled by the daughter radionuclide due to alpha decay, the following formula is used [6].

$$\delta = \frac{(\mathrm{M}_\alpha + \mathrm{M}_\mathrm{U}) * ((\mathrm{M}_\alpha * \mathrm{E}_\mathrm{k}^\mathrm{U} * \mathrm{N}_\mathrm{A}) * (\mathrm{Z}_\mathrm{U}^{\frac{2}{3}} + \mathrm{Z}_\alpha^{\frac{2}{3}})}{(\mathrm{M}_\mathrm{U} * \mathrm{Z}_\mathrm{U} * \mathrm{Z}_\alpha * \rho)} \quad (7)$$

Here M_α and M_U are the mass of the alpha particle and the uranium nucleus (parent nucleus), $\mathrm{E}_\mathrm{k}^\mathrm{U}$ is the reaction energy of the radionuclide, Z_U and Z_α is the number of protons of the alpha particle and the uranium nucleus, respectively, ρ -is the density of the nucleus[6].

4. RESULTS AND DISCUSSION.

Using formula (7), we calculated how far the radionuclides have shifted as a result of the recoil energy of alpha decay [5]. The nuclear-physical characteristics of the alpha decay of radionuclides in the uranium decay chain and their displacement distance are given in Table 1.

Table 1. Nuclear-physical characteristics of the alpha decay of radionuclides in the uranium decay chain and their displacement distance

Radionuclide	**E_α(alpha-decay energy), MeV**	**E_T(recoil energy), MeV**	**Z**	**δ (nm) radionuclide displacement distance**
U-238	4,196	0,0700	92	17,1
U-234	4,777	0.0816	92	19,81
Th-230	4,688	0,0813	90	19.99
Ra-226	4,785	0,0846	88	21,02

Rn-222	5,490	0,0989	86	24,81
Po-218	6,002	0,1100	84	27,87
Po-214	7,692	0,1438	84	36,44
Po-210	5,305	0,1010	84	25,61
∑ δ(nm)				192,65

As can be seen from the results given in tab. 1, the displacement distance of the daughter radionuclide in column 5 is related to the radius and atomic mass number of the radionuclide. Using a theoretical method, we calculate the radius of any radionuclide using the following formula[12]:

$$R = R_0\sqrt[3]{A} \qquad (8)$$

R_0 is a constant value, the value of which is equal to R_0= (1.2 - l.4) F according to different methods for determining the core radius (1 Fermi=10^{-15}m). R_0 = 1.4F from experiments on the scattering of fast neutrons, R_0 = 1.3F from the results of alpha decay, and R_0 = 1.6F from the results of nuclear reactions under the action of charged particles. (8) - the formula shows that the radius of the uranium nucleus is $R=8.047\cdot10^{-15}$ m. one[12].

Distances of mixing of daughter radionuclides after one act are calculated on the basis of formula (7). Their calculated values are given in Table. 1, column 5. And the mixing of daughter radionuclides in the uranium decay chain between itself can be depicted schematically in Fig.1.

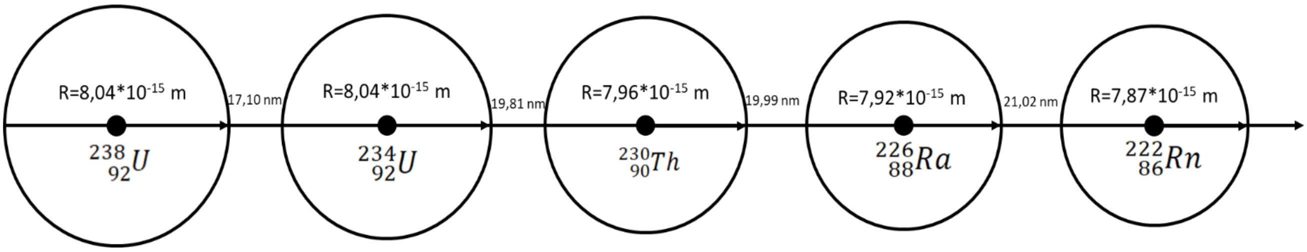

Fig.1. Principal schematic view of the mixing of daughter radionuclides of the uranium decay chain.

From fig. 1. it can be seen that the daughter radionuclides formed from the parent radionuclide receive recoil energies after each alpha decay and these daughter radionuclides are separated from the parent nucleus. Alpha decay of parent nuclei occurs with a certain intensity or up to several million times during a certain time. At each act, radionuclides are separated from each other by a distance of 17.10 nm for ^{238}U, 19.81 nm for ^{234}U, 19.99 nm for ^{230}Th, 21.02 nm for ^{226}Ra, 24.81 nm for ^{222}Rn, 24.81 nm for ^{218}Po 27.87 nm, for ^{214}Po at 36.44 nm and for ^{210}Po at 25.61 nm.

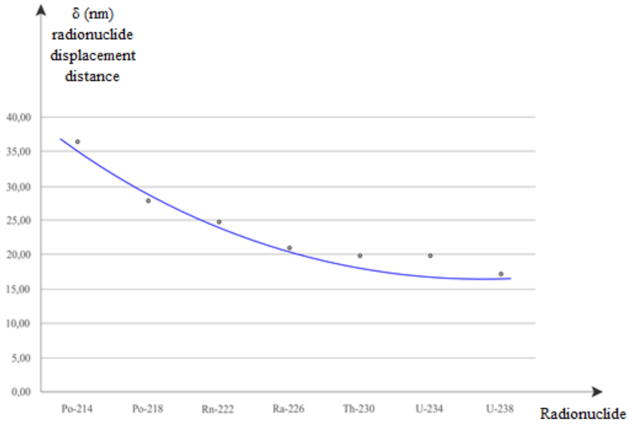

Figure 2. Dependence of the mixing distance on the number of atomic masses of radionuclides

As can be seen from Fig. 2. with an increase in the number of atomic masses of radionuclides, the mixing distance decreases. For the uranium decay chain, this value ranges from 17.10 to 36.44 nm. This fact states that the energy of alpha decay increases from 4.196 MeV to 7.692 MeV and the energy of alpha particle recoil to the daughter radionuclide also increases from 0.0700 MeV to 0.1438 MeV. The number of atomic masses of the radionuclide will change from 238 a.m.u up to 214 a.m.u

5. CONCLUSION

Thus, it was found that during alpha decay, the daughter radionuclide receives recoil energies from 4.196 MeV to 7.692 MeV and, depending on the atomic mass unit, this daughter radionuclide is displaced by a certain distance from the parent nucleus. On the basis of these facts, it can be concluded that the daughter radionuclides of the uranium decay chain, which form during alpha decays, are displaced at a certain distance from the parent nucleus due to the recoil energy and the radioactive equilibrium between the radionuclides is disturbed.

6. REFERENCES

[1] A. Akatov, Yu.Koryakovsky.Brief encyclopedia of uranium."Peterfond", 2013. - pp. 13-17.

[2].A.M. Muzafarov, G.S. Sattorov, G.N. GlotovOn the issue of violation of the coefficient of radioactive equilibrium between uranium isotopes // Gorniy Bulletin of Uzbekistan. 2011., № 1. (44). - pp. 57-60.

[3]A.M. Muzafarov. The method of preliminary scoring of the radioactivity of natural waters // Mountain Bulletin of Uzbekistan, 2017. № 1. (68). - pp. 147-149.

[4]A.M. Muzafarov, G.S. Sattarov Radioisotopes in natural waters of the Kyzylkum region // Mining Journal, Moscow, 2017. Special issue. - pp. 86-89.

[5].T.I.Soliyev, A.M.Muzafarov. Investigation of the causes of violations of the radioactive balance between radionuclides of the uranium decay chain» International journal multicultural and multireligious understanding.Germany. Volume 8. №6. June 2021. -PP. 95-101.

6. Bernard Bourdon, Simon Turner, Gideon M. Henderson, Craig C. Lundstrom. IntroductiontoU-seriesGeochemistry. 2021.- PP. 2-6.

7. A.M. Muzafarov, G.S. Sattarov Study of the isotopic composition of uranium by alpha-spectrometric method // Gorniy Bulletin of Uzbekistan. 2005., № 2. (21). – pp. 94-98..

8. G.M.Allaberganova, S.M.Turobjonov, A.M.Muzafarov, A.R.Jurakulov. Method for conducting of uranium isotopic analysis in various natural waters of uranium-bearing regions of Uzbekistan //International Journal of Academic Multidisciplinary Research (IJAMR). October 2019. – WashingtonDC, - PP. 52-55.

9.A.M. Muzafarov, G.S. Sattorov, O.F. Petukhov Study of the isotopic composition of uranium alpha - spectrometric method. // Mountain Bulletin of Uzbekistan. 2005., № 2. (21). – pp. 94-98..

10.O.A. Dzhabiev. Patterns of spatial distribution of uranium and radium on the northern flank of the Inkai deposit (Republic of Kazakhstan). //Problems of geology and subsoil development. Section 3 . Deposits of minerals. Methods of prospecting and exploration of mineral deposits. Geoinformationsystemsingeology. – pp. 177-179

11.V.I. Andreev, V.A. Rashidov, P.P. Fistrov “Radioactive equilibrium in volcanic rocks and post-volcanic formations” // Proceedings of the conference dedicated to the Day of the Volcanologist “Volcanism and Related Processes” Petropavlovsk-Kamchatsky IViS FEB RAS, 2012. - pp. 98-102

12.A.A. Abramov, G.A. Badun "Fundamentals of radiochemistry and radioecology" // Moscow - Baku. 2011. - pp. 28-34

13.T.I. Soliev, A.M. Muzafarov, K.A. Badalov Investigation of the factors of violations of radioactive equilibrium between radionuclides of the uranium decay chain. //Scientific Bulletin of SamSU. № 5, 2021. - pp. 162-167.