International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

http://ijpsat.ijsht-journals.org
Vol. 29 No. 2 November 2021, pp.481-483

Some Characteristics of Decay Processes

A.U. Abdurakhimov[1], H.M. Nishonov[2]

[1,2]Candidate of physical and mathematical sciences, associate professor,
Andijan State University, Uzbekistan

Abstract – The article deals with proton and two-proton radioactivity, two-neutron radioactivity and other types of decays. This article also analyzes nuclei (as well as artificial ones) that spontaneously emit electrons. It is also shown that the decay has a probabilistic character. A number of characteristics of decay processes are also given - decay constant, half-life, constancy of half-life, decay probability.

Keywords – Radioactivity, Decay, Half-Life, Law, Radiation, Decay Activity, Atomic Nucleus.

I. Introduction

Decays are observed in nuclear processes, with the atomic nucleus passing from one state to another. The transition of the nucleus from one state to another is accompanied by the emission of α-alpha, β-beta and γ-gamma rays. Such nuclei are radioactive. Radioactivity (from Lat. Radio- radiate, radius- ray and activus-effective) is the ability of atomic nuclei to spontaneously (spontaneously) turn into other nuclei with the emission of particles.

II. The main part

Radioactive transformations include: alpha decay, all types of beta decay (with the emission of an electron, positron, or with the capture of an orbital electron), spontaneous nuclear fission, proton and two-proton radioactivity, two-neutron radioactivity and other types of decays. In the case of β-decay, the long lifetime of nuclei is due to the nature of the weak interaction causing β-decay. Strong interaction is responsible for other types of radioactive processes. The deceleration of such processes is associated with the presence of potential barriers (Coulomb and centrifugal), which impede the escape of particles from the nucleus.

The processes of emission of delayed p-protons and n-neutrons, as well as delayed spontaneous fission of nuclei, are associated with radioactivity. In these processes, β-decay is a preliminary stage that delays the emission of nuclear particles. Radioactive decay is often accompanied by gamma radiation emitted as a result of electromagnetic transitions between different quantum states of the same nucleus [1].

The discovery of radioactivity dates back to 1896, when the French physicist A. Becquerel discovered the emission of uranium from an unknown penetrating radiation, which he called radioactive. Radio, was soon discovered thorium activity, and in 1898. French physicists M. and P. Curie discovered two new radioactive elements - polonium and radium.

The works of the English physicist E. Rutherford and M. Curie established the presence of three types of radioactive radiation - α, β and γ rays. E. Rutherford and the English physicist F. Soddy pointed out that the emission of α-rays is accompanied by the transformation of chemical elements, for example, the transformation of radium into radon.

In 1913. American scientist C. Faience and F. Soddy independently formulated the so-called displacement rule, which characterizes the movement of a nuclide in the periodic table of elements during α- and β-decays. The term "γ-decay" does not exist.

The decaying nucleus is called the parent, and the nucleus of the decay product is called the daughter. As a result of the analysis of the results of radioactive decays experimentally, the rules of displacement for radioactive decays were discovered:

at α-decay: $_{Z}X^{A} \leftrightarrow {}_{Z-2}Y^{A-4} + {}_{2}He^{4}$ (1)

with β-decay: $_{Z}X^{A} \leftrightarrow {}_{Z+1}Y^{A} + {}_{-1}e^{0}$ (2)

Here X is the chemical symbol of the mother nucleus, Y is the daughter, $_{2}He^{4}$ is the nucleus isotope of helium, $_{-1}e^{0}$ is the designation of an electron: its charge is -1 (in units elementary charge e), and the mass number is zero, since the mass an electron is 1836 times less than a proton [2].

The displacement rules are consequences of two conservation laws that are fulfilled during radioactive decays - the conservation of the electric charge and the mass number: the sum of the charges (as well as the mass numbers) of the decay products is equal to the charge (mass number) of the original nucleus.

The decay of radium with the release of radon and an alpha particle illustrates these rules:

$$_{88}Ra^{226} \rightarrow {}_{86}Rn^{222} + {}_{2}He^{4} \qquad (3)$$

Alpha decay reduces the mass number by 4, and the charge number by 2, that is, it moves the element two cells to the left in the Mendeleev system. Beta decay does not change the mass number, but increases the charge number by 1, that is, it moves the element one cell to the right in the Mendeleev system.

There are nuclei in nature and (even more of them can be created artificially), which spontaneously emit electrons, according to the following reaction scheme:

$$Z^{A} \rightarrow (Z+1)^{A} + \beta^{-} \qquad (4)$$

The energy released during this reaction is equal to:

$$E = M_n(Z^A) - M_n[(Z+1)^A] - m(e) = M_a(Z^A) - Zm(e) - M_a[(Z+1)^A] + (Z+1)m(e) - m(e) = M_a(Z^A) - M_a[(Z+1)^A] \qquad (5)$$

where subscript n is the mass of the nucleus, and subscript a is the mass of the atom. There are also artificial radioactive substances that emit positrons:

$$Z^{A} \rightarrow (Z-1)^{A} + \beta^{+} \qquad (6)$$

Writing down, as above, the balance of mass and energy, we find that the released energy is equal to:

$$E = M_a(Z^A) - M_a[(Z-1)^A] - 2m(e) \qquad (7)$$

If a positron is emitted, then capture can also occur electron (usually from the K-shell), leading to the same nucleus according to the following scheme [3]:

$$Z^{A} + \beta^{-} \rightarrow (Z-1)^{A} \qquad (8)$$

Obviously, the energy released during the capture of an electron is equal to

$$E = M_a(Z^A) - M_a[(Z-1)^A] \qquad (9)$$

i.e. more energy released during the emission of a positron by 2 masses

electron. If the decay process is energetically possible, ie E >0, then it should be expected that it will occur, although in some cases the probability may be small due to nuclear selection rules [4].

The processes of radioactive decay are characterized by an exponential law of decreasing in time the average number of radioactive nuclei.

$$N = N_0 e^{-\lambda t} \qquad (10)$$

where N is the number of nuclei in a given volume of matter at time t = 0,

N is the number of nuclei in the same volume by the time t, λ is the constant decay process. The constant λ has the meaning of the probability of nuclear decay in 1 sec: it equal to the fraction of nuclei that decay in 1 sec. The quantity 1 / λ is called the average the lifetime of the radioactive isotope. For characteristics stability of nuclei with respect to decay use the concept of half-life $T_{1/2}$ (the time interval for which the number of radioactive nuclei is reduced by an average of half).

Relationship between the values of λ and $T_{1/2}$:

$$T_{1/2} = \ln 2 / \lambda \qquad (11)$$

The number of decays of the nuclei of a given sample per unit of time is called the activity of the substance. The half-lives of various naturally radioactive elements vary widely. For uranium it is 4.5 billion years, for radon it is 3.825 days, and for radium it is Ra (one of the isotopes of polonium) $1.5\text{x}10^{-4}$s. Some artificially obtained radioactivity half-life of active elements is in the millions and fractions of a second. The constancy of the half-life T (or λ) for a given radioactive element means that these quantities are characteristics of huge sets of atomic nuclei.

Radioactive decay is a statistical process, that is, the decay of a given nucleus is a random event with one or another probability. If dN nuclei decayed from the available number N over time (it is assumed that dN is large enough. Otherwise, using dN / N it is impossible to determine the decay probability), the relative decrease dN / N of the number of nuclei occurring per unit time, i.e. $(dN / N) / dt$ represents the probability of a single nucleus decay.

This definition of probability exactly coincides with the meaning of constant decay constant λ by the formula $\lambda = \frac{dN/N}{dt}$. Thus, by definition, the decay constant is the probability of decay of one nucleus per unit time. Let us further assume that this quantity is independent of time. Physically, this means that for the radioactive decay of one nucleus it is unimportant how long a given nucleus has "lived" and that λ is a constant characterizing all nuclei of a given type. It can be said that such a definition of the decay constant leads to the law of radioactive decay (10), which is thus a statistical law. In connection with the concept of half-life, sometimes there is an incorrect the idea that if the half-life is T, then the period of complete decay is supposedly $2T$. This is certainly not the case. If after time T half of the initial number of nuclei ($N_0 / 2$) remains, then after time $2T$ half of half of N_0 remains, i.e. 1/4 of the initial number, after T is half of $N_0 / 4$, i.e.

$N_0 / 8$, etc. [5].

III. Conclusion

The discovery of radioactivity has had a tremendous impact on the development of science and technology.

More than 10 Nobel Prizes in physics and chemistry have been awarded for work related to the study and application of radioactivity, including Antoine Becquerel, Pierre and Marie Curie-Sklodowska, Enrico Fermi, Ernest Rutherford, Frederic and Irene Joliot-Curie, De Georg Hevesy, Otto Hahn, Edwin Macmillan, Glenn Theodore Seaborg, Willard Libby [6].

References

[1] B. M. Yavorsky, A. A. Detlaf. Physics Handbook. Publishing house "Science", Moscow, 1965, pp. 743-749.

[2] B.M. Yavorsky, A. A. Pinsky. Fundamentals of Physics. T 2, Publishing house "Science", Moscow, 1974, pp. 372-380.

[3] G. Bethe, F. Morrison. Elementary theory of the nucleus. Publishing house "IL" Moscow, 1958, pp. 25-26.

[4] L. Eisenbud, E. Wigner. Kernel structure. Publishing house "IL" Moscow, 1959, pp. 13-16.

[5] Abdurakhimov AU, Nishanov Kh.M., Rakhmatillaev.R. Kinematics of the atomic nucleus, elementary particles and resonances. Science and world. International scientific journal, No. 05 (93), 2021, p. 8 - 13.

[6] Physical encyclopedic dictionary. Ch. ed. A.M. Prokhorov. Ed. count D. M. Alekseev, A. M. Bonch-Bruevich, A. S. Borovik-Romanov and others.

[7] M. "Sov. Encyclopedia ", 1984, pp. 605-606.