UDC 530.1(075.8)

ONCE AGAIN ABOUT ADVANTAGES OF THE NEW METHOD OF ELECTROMAGNETIC ISOTOPES SEPARATION

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Received 3 June 2012, accepted 5 September 2012

The advantage of the new method of electromagnetic isotopes separation in the crossed electric and magnetic fields in comparison with an ordinary method with the presence of only magnetic field is shown in the paper. It is also shown that the theory of ordinary method of isotopes separation in the magnetic field of linear current, written in article of Bardakov V.M. etc. in ZTF, 2010, Vol. 80, No. 10, pp. 115-119, is built wrong.
KEY WORDS: electromagnetic field, isotope, separation, current, trajectory

ЕЩЕ РАЗ О ПРЕИМУЩЕСТВАХ НОВОГО МЕТОДА ЭЛЕКТРОМАГНИТНОГО РАЗДЕЛЕНИЯ ИЗОТОПОВ

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В работе показано преимущество нового метода электромагнитного разделения изотопов в скрещенных электрическом и магнитном полях по сравнению с обычным методом при наличии только магнитного поля. Также показано, что теория обычного метода разделения изотопов в магнитном поле линейного тока, изложенная в работе Бардакова В.М. и др. в ЖТФ, 2010, Т. 80, Вып. 10, С. 115-119, построена неверно.
КЛЮЧЕВЫЕ СЛОВА: электромагнитное поле, изотоп, разделение, ток, траектория

ЩЕ РАЗ ПРО ПЕРЕВАГИ НОВОГО МЕТОДА ЕЛЕКТРОМАГНІТНОГО РОЗДІЛЕННЯ ІЗОТОПІВ

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В роботі показана перевага нового метода електромагнітного розділення ізотопів у схрещених електричному та магнітному полях у порівнянні зі звичайним методом при наявності тільки магнітного поля. Також показано, що теорія звичайного метода розділення ізотопів у магнітному полі лінійного струму, викладена у роботі Бардакова В.М. та ін. у ЖТФ, 2010, Т. 80, Вип. 10, С. 115-119, побудована невірно.
КЛЮЧОВІ СЛОВА: електромагнітне поле, ізотоп, розділення, струм, траєкторія

Two works [1, 2] devoted to the theoretical research of a new method of electromagnetic separation of isotopes moving in constant electromagnetic field of a cylindrical capacitor and a linear current flowing along its axis (nonzero fields strengths H_α and E_r are inversely proportional to the distance r from the capacitor axis z; r, α and z are the cylindrical coordinate system) offered by the group of the Kharkov scientists (also including authors [1, 2]) that were published in 2007 year. In papers [1, 2] expressions for isotopes trajectories in the form of rather simple single integrals, which numeral integration enabled to present trajectories graphically and ipso facto to determine the experimental setup basic parameters, are obtained.

RESULTS AND DISCUSSION

On the face of it there can be a question: but isn't it simpler to separate isotopes in the same setup under only the magnetic field H_α (i.e. by $E_r = 0$)? In works [1, 2] this special case was not examined in detail. Authors considered that this, maybe, old method (further denoted M_O) is considerably worse than the new one (further denoted M_N). This assertion is easily proved by a limiting process $E_r \to 0$ (or $\eta = \dfrac{cE_r}{H_\alpha v_0} \to 0$) in isotopes path equations obtained within the bounds of M_N. Supposing $\eta = 0$ in the formulas (19-22) of [1], one obtain the isotope path equation in $\zeta\xi$ plane ($\zeta = \dfrac{z}{a}$, $\xi = \dfrac{r}{a}$, a is a distance of isotopes source from an axis)

$$\zeta(\xi) = -\kappa(1+\delta_z)\mathrm{e}^{\kappa(1+\delta_z)} \int\limits_{-\frac{\pi}{2}}^{\arcsin\left[\frac{\ln\xi}{\kappa(1+\delta_z)}-1\right]} d\theta \sin\theta\, \mathrm{e}^{\kappa(1+\delta_z)\sin\theta},\ 1 \le \xi \le \mathrm{e}^{2\kappa(1+\delta_z)}, \quad (1)$$

where $\kappa = \dfrac{mc^2 v_0}{2qJ}$, J is a linear current strength, m and q are isotope mass and charge, $\vec{v}_0 = \vec{e}_z v_0(1+\delta_z)$ is initial velocity of an isotope emitted from the source, $\delta_z = \dfrac{\delta v_z}{v_0}$, δv_z is the fluctuation of the initial velocity, and $|\delta_z| << 1$, $\xi_0 = 1$, and $\zeta_0 = 0$ are isotopes source coordinates, $\xi_2 = \mathrm{e}^{2\kappa(1+\delta_z)}$ is an isotope turning point transverse coordinate at its motion in the line of r growth, $\xi_z = \mathrm{e}^{\kappa(1+\delta_z)}$ is an isotope turning point transverse coordinate at its motion in the line of z growth (see [1] (13), (18)).

Using (1), one graphs trajectories of lithium isotopes and heavy in comparison with them uranium isotopes at the same parameters with M_N and assume $a = 3$ cm.

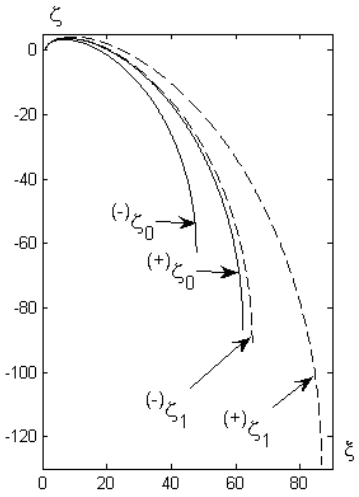

Fig. 1. Lithium isotopes trajectories

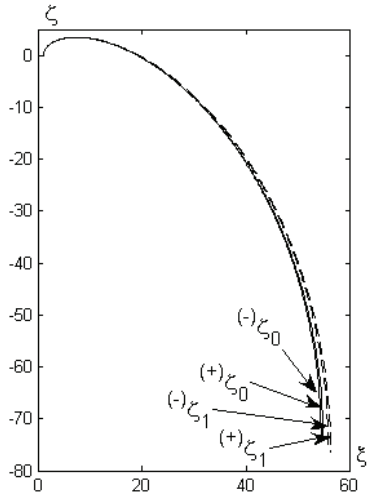

Fig. 2. Uranium isotopes trajectories

Graphs are built at the following parameters values:

^{6}Li: $\kappa = \kappa_0 = 2$; $\delta = 0{,}033$; curve ${}^{(-)}\zeta_0(\xi)$ at $\delta_z = -\delta$, curve ${}^{(+)}\zeta_0(\xi)$ at $\delta_z = +\delta$;

^{7}Li: $\kappa = \kappa_1 = \sqrt{\dfrac{m_1}{m_0}}\kappa_0 = 2{,}16$; $\delta = 0{,}033$; curve ${}^{(-)}\zeta_1(\xi)$ at $\delta_z = -\delta$, curve ${}^{(+)}\zeta_1(\xi)$ at $\delta_z = +\delta$;

^{235}U: $\kappa = \kappa_0 = 2$; $\delta = 9{,}03 \cdot 10^{-4}$; curve ${}^{(-)}\zeta_0(\xi)$ at $\delta_z = -\delta$, curve ${}^{(+)}\zeta_0(\xi)$ at $\delta_z = +\delta$;

^{238}U: $\kappa = \kappa_1 = \sqrt{\dfrac{m_1}{m_0}}\kappa_0 = 2{,}01277$; $\delta = 9{,}03 \cdot 10^{-4}$; curve ${}^{(-)}\zeta_1(\xi)$ at $\delta_z = -\delta$, curve ${}^{(+)}\zeta_1(\xi)$ at $\delta_z = +\delta$.

From a Fig. 1 we find that maximal transversal distance between the beams of separated lithium isotopes is $\Delta r_{10} = {}^{(-)}r_1 - {}^{(+)}r_0 = 2a = 6$ cm, longitudinal size of chamber $\Delta z = 90a = 270$ cm, chamber radius $R_{II} = 70a = 210$ cm. As it is obvious from a Fig. 2 approximately the same dimensions turn out at the uranium isotopes separation (only the distance between beams is half). Comparison with the proper dimensions in M_N leads to an essential difference in the setup transversal dimensions: in M_O a setup radius must be about 2 m, and in M_N ~20 cm. This is one of essential advantages of M_N. Moreover, M_N setup can be used for the decision of other physical problems (mass-spectrometer creation, electromagnetic traps etc.).

One notices that in M_O maximum distance between separated isotopes at its motion in radial direction is approximately equal to the difference of its turning points coordinates, each of which depends on the value of its own κ and is determined by formula (1)

$$ {}^{(+)}r = a\,\mathrm{e}^{2\kappa(1+\delta_z)}.$$

By this formula the minimum transversal setup radius, decreasing with κ decrease, is determined. However maximum transversal distance Δr_{10} between separated beams decreases with κ_1 and κ_0 decrease that reduces separation efficiency. As is obvious from expression for κ, it can be decreased either due to J growth, and it is difficult at the already large values of J (in a fig. 1 and 2 $J = 5$ kA) or due to isotopes initial velocity decreasing, that is not desirable

(in opinion of experimenters; in the fig. 1 $v_{01} \sim 4 \cdot 10^6$ cm/s, in the fig. 2 $v_{01} \sim 1{,}5 \cdot 10^6$ cm/s). Thus, M_N is much better than M_O!

Now about remarks on work [3] which describes the isotopes separation on M_O. Authors of this work did not give expression for the ion trajectory, limited with the remark that this problem «analytically cannot be solved and the ion trajectory can be found only by numerical calculations». But this assertion is refuted with the above mentioned expression (1) with the use of which the isotopes trajectories, presented on a fig. 1 and 2, are right built. For description of isotopes separation the authors of work [3] used equation (2) from this work as basic, which in the previous paragraph of that article is written in physically more transparent form

$$v_z = v_{z0} - u \ln \frac{r}{r_0} = u \left(\frac{v_{z0}}{u} - \ln \frac{r}{r_0} \right),$$

or, passing to our notations, one obtains

$$\frac{d\zeta}{dt} = \frac{v_{0z}}{\kappa a} \left(\kappa - \ln \frac{r}{a} \right), \quad \kappa = \frac{v_{0z}}{u} = \frac{mc^2 v_{0z}}{2Jq}.$$

It's easy to see that this equation determines the isotope turning point transversal coordinate at its motion along an axis z (without taking in account δ_z), namely $\xi_z \equiv \frac{r_z}{a} = \mathrm{e}^{\kappa}$, i.e. $v_z > 0$ at $\xi < \xi_z$, $v_z = 0$ at $\xi = \xi_z$ and $v_z < 0$ at $\xi > \xi_z$. Because, according to our calculations, isotope turning point transversal coordinate at its motion in the line of r growth equal to $\xi_2 = \mathrm{e}^{2\kappa}$ is greater than ξ_z then an isotope will not perform radial oscillations (see fig. 1 and 2), as authors of work [3] assert. As it is obvious from a fig. 1 and 2, isotopes separation near a coordinate ξ_z is insignificantly in comparison with a separation near a coordinate ξ_2, therefore separation theory M_O near a coordinate ξ_z, offered by the authors of work [3], does not have practical application. One can notice that work [3], as well as our work [1], is published in ZTF, however there are no references on our works there [3].

CONCLUSIONS

Definite advantage of new method of isotopes separation in the magnetic field of constant linear current flowing along the axis of cylindrical capacitor – separation chamber and the electrostatic field of the same cylindrical capacitor in comparison with the isotopes separation method in the same setup in the absence of the electrostatic field, whereupon the second (old) method is found practically inapplicable. Moreover, errors done in the process of construction and validation of the second (old) method of isotopes separation are found.

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