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K. A. Kabylbekov, Kh. K. Abdrakhmanova,
P. A. Saidakhmetov, T. S. Sultanbek, B. Sh. Kedelbaev

M. Auezov South Kazakhstan state University, Shymkent, Kazakhstan.
E-mail: kenkab@mail.ru, khadi_kab@mail.ru

CALCULATION AND VISUALIZATION OF ISOTOPES SEPARATION PROCESS USING MATLAB PROGRAM

Abstract. The article presents the MATLAB program for calculation and visualization of the separation process of isotopes ${}^{1}_{1}H,\ {}^{2}_{1}H\ and\ {}^{3}_{1}H;\ {}^{235}_{92}U\ and\ {}^{238}_{92}U;\ {}^{12}_{12}C\ and\ {}^{14}_{12}C;\ {}^{20}_{10}Ne\ and\ {}^{22}_{10}Ne$.

There is a brief theory of motion of a charged particle in the magnetic field. Due to action of the magnetic field the charged particles with different masses move along circles of different radius. To solve the system of differential equations of the second order it is converted into the system of differential equations of the first order and previously m-file is created under the name Lorenz.m, which is addressed from the command line. The equations are solved by using the procedure ode 45 of the MATLAB system. The calculation results are presented by diagrams where the isotopes with various specific charges move along trajectories with different revolution radii. It is said that isotopes are separated due to specific charges. The more is the mass number of an isotope the greater is its revolution radius.

Key words: isotope, specific charge, mass-spectrometer, velocity selector, revolution, radius of the trajectory.

Introduction. Nowadays all educational institutions of Kazakhstan are provided with computer hardware and software, interactive boards and internet. Almost all teachers have completed language and computer courses for professional development. Hence the educational institutions have all conditions for using computer training programs and models for performing computer laboratory works. During several years we have been conducting the work on organization computer laboratory works on physics with use of resources of the Fizikon Company [1, 2] which are developed at Al-Farabi Kazakh National University by V.V.Kashkarov and his group. Some of worksheet templates for computer laboratory works are introduced in educational process of our university and schools of the Southern Kazakhstan [3-29]. Students of the physics specialties 5B060400 and 5B011000 successfully master the discipline "Computer modeling of physical phenomena" which is the logical continuation of the disciplines "Information technologies in teaching physics" and "Use of electronic textbooks in teaching physics". The aim of this discipline is to study and learn the MATLAB program language [30] system, acquaintance with its huge opportunities for modeling and visualization of physical processes. The present article is devoted to organization of the laboratory work «Calculation and visualization of isotopes separation process » by using the package of MATLAB applied programs.

Methods. Let's consider the problem of space separation of nuclei with identical charges q, but of different masses m (mixture of isotopes). From the source (ordinarily it is the velocity selector) the particles escape in the direction of Y axis perpendicularly to the magnetic field. The magnetic field $\boldsymbol{B}$ is parallel to Z axis. Particles escape from the selector with initial velocity, identical in magnitude and in direction, and enter into a transversal magnetic field. (The operation of the velocity selector is described in our article [4].) Here we just note that to have isotopes entering the magnetic field with identical speeds, irrespectively of their specific charges, they must pass through crossed electric and magnetic fields. In that case their speed does not depend on anything, except the ratio of the electric field to the magnetic induction, i.e. $\upsilon = E/B$).

It is necessary to carry out calculation and visualization of the motion trajectory of nuclei with identical charges but different masses, i.e. isotopes in the mixture.

The charged particles escaping the velocity selector are under the action of the Lorentz force:

$$\vec{F} = q\vec{E} + q\left[\vec{\upsilon}\vec{B}\right] \quad (1)$$

At the action of the Lorentz force the charged particle entering the magnetic field at right angle moves along the circle with radius R.

$R = \dfrac{m\upsilon}{qB}$ is the revolution radius, $T = 2\pi\dfrac{m}{qB}$ is the revolution period, here m is the mass of the particle, q is the charge of the particle.

The motion equations in the projections on the X,Y,Z axes are the followings:

$$m\frac{d\upsilon_x}{dt} = q\left(\upsilon_y B_z - \upsilon_z B_y\right);\ m\frac{d\upsilon_y}{dt} = q\left(\upsilon_z B_x - \upsilon_x B_z\right);\ m\frac{d\upsilon_z}{dt} = q\left(\upsilon_x B_y - \upsilon_y B_z\right);$$

or

$$\frac{d\upsilon_x}{dt} = q\left(\upsilon_y B_z - \upsilon_z B_y\right)/m;\ \frac{d\upsilon_y}{dt} = q\left(\upsilon_z B_x - \upsilon_x B_z\right)/m;\ \frac{d\upsilon_z}{dt} = q\left(\upsilon_x B_y - \upsilon_y B_z\right)/m;$$

here $\dfrac{dx}{dt} = \upsilon_x$ (we denote it as υx = $z2$); $\dfrac{dy}{dt} = \upsilon_y$ (we denote it as υy = $z4$); $\dfrac{dz}{dt} = \upsilon_z$ (we denote it as υz = $z6$); also we introduce the following denotations $B_x = B(1)$, $B_y = B(2)$, $B_z = B(3)$. The initial conditions for these equations are: $x0=0$, $y0=0$, $z0=0$ (initial coordinates of particles); υx=0, υy=0.1, υz=0 (initial velocities of particles). The considered isotopes are proton ^1_1H , deuterium ^2_1H , tritium ^3_1H with masses in dimensionless units m=1, 2*m, 3*m respectively, and q=1 (proton charge).

For solving the differential equations (DE) we create the m-file with title Lorentz.m.

The listing of the m-file

```
function f=Lorenz(t,z)
global B % input the global variable
f=zeros(6,1);% building the matrix of dimension 6x1
f(1)=z(2);% x-component of the velocity
f(2)= 2*pi*(z(4)*B(3)-z(6)*B(2));% x-component of the force
f(3)=z(4);% y-component of the velocity
f(4)=2*pi*(z(6)*B(1)-z(2)*B(3));% y-component of the force
f(5)=z(6);% z-component of the velocity
f(6)=2*pi*(z(2)*B(2)-z(4)*B(1));% z-component of the force
end
```

Results. In the program for calculation and visualization of isotopes ^1_1H , ^2_1H , ^3_1H separation the magnitudes of the charge and mass are taken in dimensionless units, i.e. as ratio of the charge to the elementary charge and the ratio of the mass to the proton's mass, so q=1 and m=1.

In the command line we write

```
>> global B; % input the global variable
>> B=[0 0 1]; % input the elements of matrix (Bx=0, By=0, Bz =1)
>> x0=0; y0=0; z0=0; % input the initial coordinates of particles
>> vx=0;vy=0.1; vz=0; % input the initial velocities of particles
>> q=1; m=1; % input the charge and mass of the particle in dimensionless units
>> [t,R]=ode45('Lorenz',[0:10/1024:0.5],[x0 vx y0 vy z0 vz]); % solution of DE
>> plot3(R(:,1),R(:,3),R(:,5),x0,y0,z0,'o','MarkerSize',6);% drawing the trajectory
   in three-dimensional space (for q=1; m=1, 1/1 H )
>> view([0 0 100]) % drawing the trajectory on the plane
>> hold on% drawing the next picture
```

```
>> plot3(R(:,1)*2*m/q,R(:,3)*2*m/q,R(:,5)*2*m/q,x0,y0,z0,'o','MarkerSize',6);%
```
(for q=1; m=2, ${}_{1}^{2}H$)
```
>> plot3(R(:,1)*3*m/q,R(:,3)*3*m/q,R(:,5)*3*m/q,x0,y0,z0,'o','MarkerSize',6);%
```
(for q=1; m=3, ${}_{1}^{3}H$)
```
>> grid on% input the coordinate grid
>> gtext('m/q') % input the text at a chosen place
>> gtext('2*m/q') % input the text at a chosen place
>> gtext('3*m/q') % input the text at a chosen place
```
The result is presented in the figure 1.

Figure 1 shows that the charged particles with different specific charges move along different trajectories since their revolution radii depend upon their specific charges, thus, they are being separated.

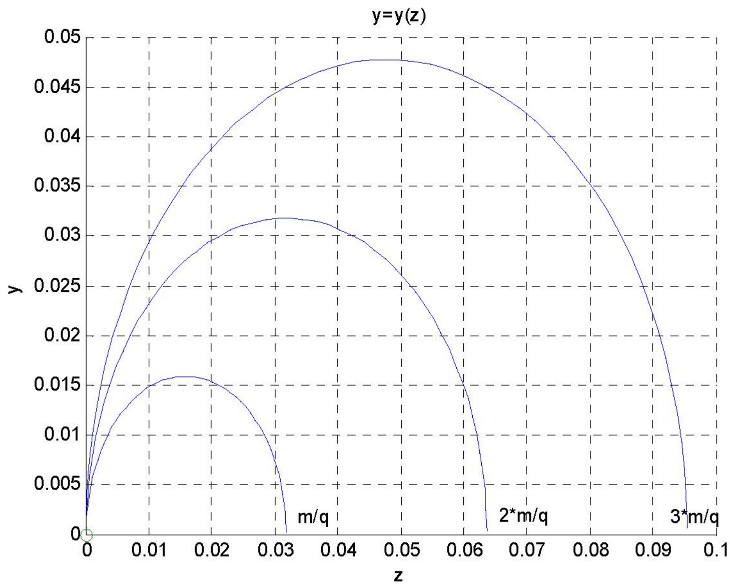

Figure 1 – The motion trajectories of isotopes ${}_{1}^{1}H$, ${}_{1}^{2}H$, ${}_{1}^{3}H$ on the plane

It should be noted that all isotopes enter the magnetic field with identical velocities. It is known that the revolution radius also depends upon the particle's velocity ($R = \frac{m\upsilon}{qB}$). To have isotopes entering the magnetic field with identical velocities it is necessary to pass them through the velocity selector. About the velocity selector used in mass-spectrometers we wrote in [4].

The program for calculation and visualization of isotopes ${}_{92}^{235}U$ and ${}_{92}^{238}U$.
```
>> global B; % input the global variable
>> B=[0 0 1]; % input the elements of matrix
>> x0=0; y0=0; z0=0; % input the initial coordinates of particles
>> vx=0;vy=0.1; vz=0; % input the initial velocities of particles
>> q=92; m=235; % input the charge and mass of the particle
>> [t,R]=ode45('Lorenz',[0:10/1024:0.5],[x0 vx y0 vy z0 vz]); % solution of DE
>> plot3(R(:,1)*235/q, R(:,3)*235/q, R(:,5)*235/q, x0,y0,z0,'o','MarkerSize',6),%
```
drawing the trajectory in three-dimensional space (for q=92; m=235, ${}_{92}^{235}U$)
```
>> view([0 0 100]) % drawing the trajectory on the plane
>> hold on% drawing the next picture
>> plot3(R(:,1)*238/q, R(:,3)*238/q, R(:,5)*238/q, x0,y0,z0,'o','MarkerSize',6);%
```
(for q=92, m=238)

```
>> grid on% input the coordinate grid
>> gtext('q/235') % input the text at a chosen place
>> gtext('q/238') % input the text at a chosen place
```

The result is presented in the figure 2.

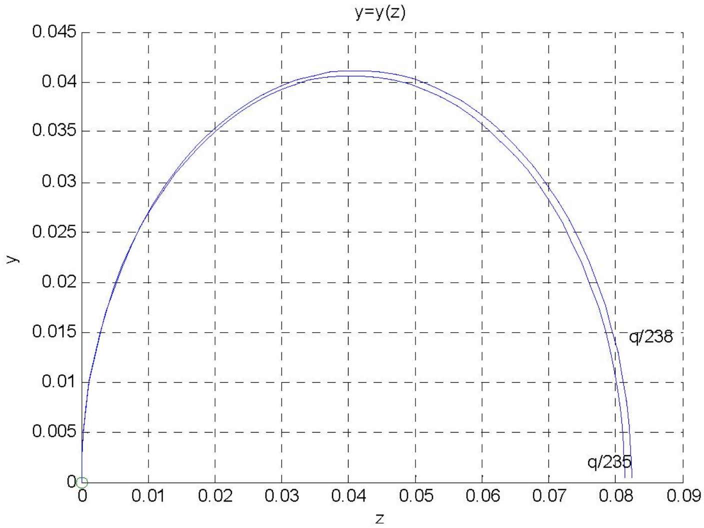

Figure 2 – The motion trajectories of isotopes ${}^{235}_{92}U$ and ${}^{238}_{92}U$ on the plane

The program for calculation and visualization of isotopes ${}^{12}_{12}C$ and ${}^{14}_{12}C$.

```
>> global B; % input the global variable
>> B=[0 0 1]; % input the elements of matrix
>> x0=0; y0=0; z0=0; % input the initial coordinates of particles
>> vx=0;vy=0.1; vz=0; % input the initial velocities of particles
>> q=12; m=12; % input the charge and mass of the particle
>> [t,R]=ode45('Lorenz',[0:10/1024:0.5],[x0 vx y0 vy z0 vz]); % solution of DE
>> plot3(R(:,1)*12/q,R(:,3)*12/q,R(:,5)*12/q,x0,y0,z0,'o','MarkerSize',6), ),%
   drawing the trajectory in three-dimensional space (for q=12; m=12, 12/12 C)
>> view([0 0 100]) % drawing the trajectory on the plane
>> hold on% drawing the next picture
>> plot3(R(:,1)*14/q,R(:,3)*14/q,R(:,5)*14/q,x0,y0,z0,'o','MarkerSize',6);%
   (for q=12, m=14)
>> grid on % input the coordinate grid
>> gtext('q/m=12/12') % input the text at a chosen place
>> gtext('q/m=12/14') % input the text at a chosen place
```

The result is presented in the figure 3.

The program for calculation and visualization of isotopes ${}^{20}_{10}Ne$ and ${}^{22}_{10}Ne$.

```
>> global B; % input the global variable
>> B=[0 0 1]; % input the elements of matrix
>> x0=0; y0=0; z0=0; % input the initial coordinates of particles
>> vx=0;vy=0.1; vz=0; % input the initial velocities of particles
>> q=10;m=20; % input the charge and mass of the particle
>> [t,R]=ode45('Lorenz',[0:10/1024:0.5],[x0 vx y0 vy z0 vz]); % solution of DE
>> plot3(R(:,1)*20/q,R(:,3)*20/q,R(:,5)*20/q,x0,y0,z0,'o','MarkerSize',6), ),%
   drawing the trajectory in three-dimensional space (for q=10; m=20, 20/10 Ne)
>> view([0 0 100]) % drawing the trajectory on the plane
```

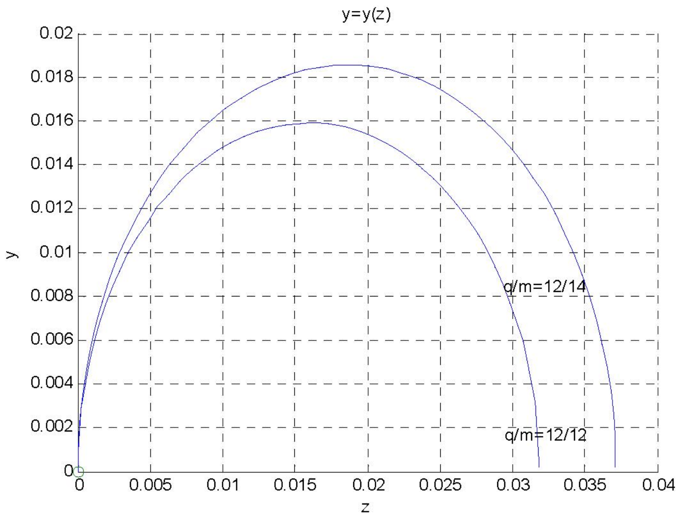

Figure 3 – The motion trajectories of isotopes $^{12}_{12}C$ and $^{14}_{12}C$ on the plane

```
>> hold on% drawing the next picture
>> plot3(R(:,1)*22/q,R(:,3)*22/q,R(:,5)*22/q,x0,y0,z0,'o','MarkerSize',6); );%
   (for q=10, m=22)
>> grid on % input the coordinate grid
>> gtext('q/m=10/20') % input the text at a chosen place
>> gtext('q/m=10/22') % input the text at a chosen place
```

The result is presented in the figure 4.

The program given above allows visualizing the motion trajectory of the charged particle in a magnetic field. For this purpose it is necessary to increase only the time of calculation and to take one of the components of the particle's velocity υx or υy if the charge enters the magnetic field at right angle to the direction of the magnetic induction or both components if the charged particle enters the magnetic field at a certain angle to the direction of the magnetic field.

In the given programs we have limited the time of calculation so that the particle passes a semi-circle and it has only one vy component of its velocity.

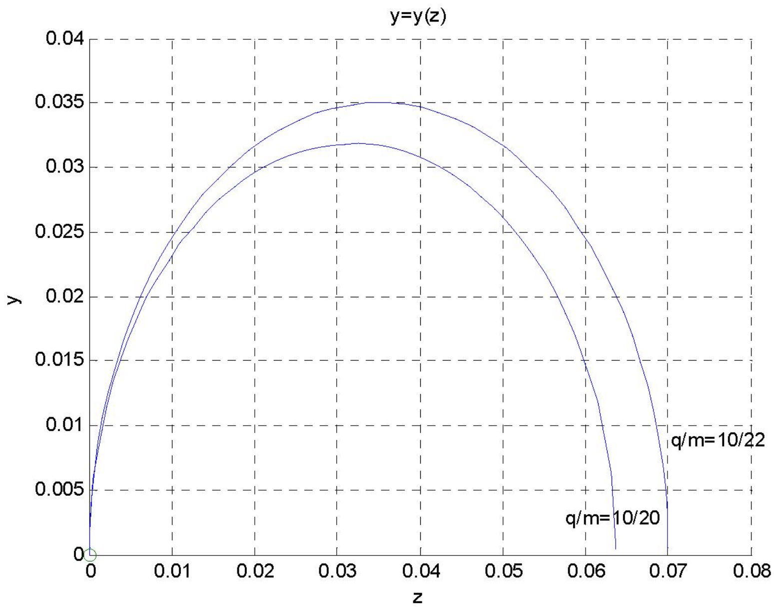

Figure 4 – The motion trajectories of isotopes $^{20}_{10}Ne$ and $^{22}_{10}Ne$ on the plane

Conclusion. The article offers the programs for calculation and visualization of the separation process of isotopes ${}^{1}_{1}H$, ${}^{2}_{1}H$, ${}^{3}_{1}H$; ${}^{235}_{92}U$, ${}^{238}_{92}U$; ${}^{12}_{12}C$, ${}^{14}_{12}C$; ${}^{20}_{10}Ne$, ${}^{22}_{10}Ne$. The mathematical model of motion of charged particles in the magnetic field is developed using the package of MatLab applied programs. To solve the system of differential equations of the second order it is converted into the system of differential equations of the first order and previously m-file is created under the name Lorenz.m, which is addressed from the command line. The equations are solved by using the procedure ode45 of the MatLab system. Results of calculations are presented in figures 1-4 in the form of motion trajectories of isotopes as a function of their specific charges. It is seen that isotopes with different specific charges are separated and move along different circular trajectories. The less is the specific charge the more is the revolution radius or the more is the mass number of the isotope the greater is its radius of revolution. The results of calculations and visualization are applied in electrical engineering.

REFERENCES

[1] CD of the open JSC "Phizicon". «The open hysics1.1».2001.

[2] http://elektronika.newmail.ru

[3] Kabylbekov K.A., Abdrakhmanova Kh.K., Abekova Zh.A., Abdraimov R.T., Ualikhanova B.S. Calculation and visualization of a system- an electron in a deep square potential well, with use of the software package of MATLAB // Proceeding of the III International Scientific and Practical Conference «Topical researches of the World Science» (Iune 28, 2017, Dubai, UAE). July 2017. Vol. 1, N 23. P. 7-13.

[4] Kabylbekov K., Saidullaeva N., Spabekova R., Omashova G., Tagaev N., Bitemirova A., Berdieva M. Model of a blank form for computer laboratory work on research of the speed selector // Journal of Theoretical and Applied Information Technology. 15th July 2017. Vol. 95, N 13. P. 2999-3009. JATIT & LLS. Indexada en Scopus.

[5] Kabylbekov K., Omashova G., Spabekova R., Saidullaeva N., Saidakhmetuv P. Junusbtkova S Management and organization of computer laboratory work in physics education // Espacios. Año 2017. Vol. 38 (N° 45). Pág. 35. Indexada en Scopus, Google Schollar.

[6] Kabylbekov K.A., Saidakhmetov P.A., Arysbaeva A.S. Worksheet template for organization the independent performance of computer laboratory works // Proceedings of the National Academy of Sciences of the Republic of Kazakhstan, Series of Physics and Mathematics. 2013. N 6. P. 82-89.

[7] Kabylbekov K.A., Saidahmetov P.A., Baidullaeva L.E., Abduraimov R. A technique of use of computer models for photo-effect and Compton effect studying, worksheet template for organization the performance of computer laboratory works // Proceedings of the National Academy of Sciences of the Republic of Kazakhstan. Series of Physics and Mathematics. 2013. N 6. P. 114-121.

[8] Kabylbekov K.A., Saidahmetov P.A., Turganova T.K., Nurullaev M.A., Baidullaeva L.E. Model of a lesson on converging and diverging lenses // Proceedings of NAN RK. Series physical-mat. 2014. N 2. P. 286-294.

[9] Kabylbekov K.A., Ashirbaev H.A., Saidahmetov P.A., Rustemova K.Zh., Baidullaeva L.E. Worksheet template for organization the performance of computer laboratory work on study the diffraction of light // Proceedings of the National Academy of Sciences of the Republic of Kazakhstan. Series of Physics and Mathematics. 2015. N 1(299). P. 71-77.

[10] Kabylbekov K.A., Ashirbaev H.A., Takibaeva G.A., Saparbaeva E.M., Baidullaeva L.E., Adineeva Sh.I. Worksheet template for organization the performance of computer laboratory work on study the motion of charged particles in a magnetic field // Proceedings of the National Academy of Sciences of the Republic of Kazakhstan. Series of Physics and Mathematics. 2015. N 1(299). P. 80-87.

[11] Kabylbekov K.A., Ashirbaev H.A., Saidakhmetov P.A., Baigulova Z.A., Baidullaeva L.E. Worksheet template for organization the performance of computer laboratory work on study the Newton's ringes // Proceedings of the National Academy of Sciences of the Republic of Kazakhstan. Series of Physics and Mathematics. 2015. N 1(299). P. 14-20.

[12] Kabylbekov K.A., Ashirbaev H.A., Sabalakhova A.P., Dzhumagalieva A.I. Worksheet template for organization the performance of computer laboratory work on study the phenomenon of light interference // Proceedings of the National Academy of Sciences of the Republic of Kazakhstan, Series of Physics and Mathematics. 2015. N 3(301). P. 131-136.

[13] Kabylbekov K.A., Ashirbaev H.A., Sabalakhova A.P., Dzhumagalieva A.I. Worksheet template for organization the performance of computer laboratory work on study the Doppler-effect // Proceedings of the National Academy of Sciences of the Republic of Kazakhstan, Series of Physics and Mathematics. 2015. N 3(301). P. 155-160.

[14] Kabylbekov K.A., Ashirbaev H.A., Arysbaeva A.S., Dzhumagalieva A.I. Worksheet template for organization the performance of computer laboratory work on study physical phenomena // Modern high technologies. M., 2015. N 4. P. 40-43.

[15] Kabylbekov K.A., Saidakhmetov P.A., Ashirbaev Kh.A., Omashova G.Sh., Berdalieva J. Worksheet template for organization the performance of computer laboratory work on study electromagnetic oscillations // Proceedings of the National Academy of Sciences of the Republic of Kazakhstan. Series of Physics and Mathematics. 2016. N 1(305). P. 111-116.

[16] Kabylbekov K.A., Saidakhmetov P.A., Omashova G.Sh., Berdalieva J., Dzhumagalieva A.I. Worksheet template for organization the performance of computer laboratory work on study the interaction between two infinitely long parallel current-carrying conductors // Proceedings of the National Academy of Sciences of the Republic of Kazakhstan. Series of Physics and Mathematics. 2016. N 1(305). P. 135-140.

[17] Kabylbekov K.A., Saidakhmetov P.A., Omashova G.Sh., Suttibaeva D.I., Kozybakova G.N. Worksheet template for organization the performance of computer laboratory work on study isobaric process // Proceedings of the National Academy of Sciences of the Republic of Kazakhstan. Series of Physics and Mathematics. 2016. N 2. P. 92-97.

[18] Kabylbekov K.A., Omashova G.Sh., Saidakhmetov P.A., Nurullaev M.A., Artygalin N.A. Worksheet template for organization the performance of computer laboratory work on study the Carnot cycle // Proceedings of the National Academy of Sciences of the Republic of Kazakhstan. Series of Physics and Mathematics. 2016. N 2. P. 98-103.

[19] Kabylbekov K.A., Saidakhmetov P.A., Ashirbaev H.A., Abdubaeva Ph.I., Doskanova A.E. Study of the work done by gas on computer model // The Herald of NAN PK. 2016. N 2. P. 83-88.

[20] Kabylbekov K.A., Saidakhmetov P.A., Omashova G.Sh., Serikbaeva G.S., Suyerkulova Zh.N. Worksheet template for organization the performance of computer laboratory work on study simple harmonic motions // Proceedings of the National Academy of Sciences of the Republic of Kazakhstan. Series of Physics and Mathematics. 2016. N 2. P. 84-91.

[21] Kabylbekov K.A., Madjarov N.T., Saidakhmetov P.A. An Independent design of research assignments for computer laboratory work on thermodynamics // Proceedings of the IX International scientific-methodical conference “Teaching natural Sciences (biology, physics, chemistry), mathematics and computer science”. Tomsk, 2016. P. 93-99.

[22] Kabylbekov K.A., Saidakhmetov P.A., Omashova G.Sh. Organization of computer laboratory work on study the inductor reactance in an ac circuit // Proceedings of NAN RK. 2017. N 1. P. 77-82.

[23] Kabylbekov K.A., Saidakhmetov P.A., Omashova G.Sh., Ashirbaev H.A., Abekova J.A. Organization of computer laboratory works on study of the isotherms of a real gas // Proceedings of the National Academy of Sciences of the Republic of Kazakhstan. Series of Physics and Mathematics. 2017. N 1. P. 77-83.

[24] Kabylbekov K.A., Saidakhmetov P.A., Omashova G.Sh. Organization of computer laboratory works on study of the phenomenon of beats // Proceedings of the National Academy of Sciences of the Republic of Kazakhstan. Series of Physics and Mathematics. 2017. N 2. P. 104-110.

[25] Kabylbekov K.A., Omashova G.Sh., Spabekova R.S., Saidakhmetov P.A., Serikbaeva G., Arysbaeva A.S. Worksheet template for organization the performance of computer laboratory work on study the isothermal process // Herald of the National Academy of Sciences of Kazakhstan. 2017. N 3. P. 199-207.

[26] Kabylbekov K.A., Omashova G.Sh., Spabekova R.S., Saidakhmetov P.A., Abdrakhmanova Kh.K., Arysbaeva A.S. Independent design of assignment for performance of a computer lab on study isochoric process // Proceedings of the National Academy of Sciences of the Republic of Kazakhstan. Series of Physics and Mathematics. 2017. N 3. P. 127-134.

[27] Kabylbekov K.A., Omashova G.Sh., Spabekova R.S., Saidakhmetov P.A., Serikbaeva G.S., Akturеeva G. Organization of computer laboratory works on study the turn-on and turn-off current of the power supply by using MATLAB software package // Proceedings of the National Academy of Sciences of the Republic of Kazakhstan. Series of Physics and Mathematics. 2017. N 3. P. 139-146.

[28] Kabylbekov K.A., Omashova G.Sh., Spabekova R.S., Saidakhmetov P.A., Serikbaeva G.S., Akturеeva G. Organization of computer labs for the study the velocity and height distribution of molecules from the Earth's surface by using MATLAB software package // Herald of RK NAS. 2017. N 3. P. 111-119.

[29] Kabylbekov K.A., Ashirbayev H.A., Abdrakhmanova Kh.K., Dzhumagalieva A.I., Kydyrbekova J.B. Organization of laboratory work on study the electric and magnetic fields by using MATLAB software package // Proceedings of the National Academy of Sciences of the Republic of Kazakhstan. Series of Physics and Mathematics. 2017. N 3(313). P. 206-212.

[30] Porsev S.V. Computer simulation of physical processes in the package MATLAB. M.: Hot Line-Telecom, 2003. 592 p.

К. А. Қабылбеков, Х. К. Абдрахманова, П. А. Саидахметов, Т. С. Сұлтанбек, Б. Ш. Кеделбаев

М. Әуезов атындағы Оңтүстің Қазақстан мемлекеттік университет, Шымкент, Казахстан

MATLAB ЖҮЙЕСІНДЕ «ИЗОТОПТАРДЫ АЖЫРАТУ ПРОЦЕСІН ЕСЕПТЕУ МЕН БЕЙНЕЛЕУ»

Аннотация. ${}^{1}_{1}H$, ${}^{2}_{1}H$, ${}^{3}_{1}H$; ${}^{235}_{92}U$, ${}^{238}_{92}U$; ${}^{12}_{12}C$, ${}^{14}_{12}C$; ${}^{20}_{10}Ne$, ${}^{22}_{10}Ne$ изотоптарын ажыратуды есептеу мен бейнелеудің програамалары ұсынылады. Зарядталған бөлшектердің магнит өрісінде қозғалысының қысқаша теориясы келтірілген. Изотоптарды ажыратудың математиалық моделі жасалып, ол MATLAB программалық ортасында іске асырылған. Екінші ретті дифференциялдық теңдеулер жүйесін шеші үшін олар бірінші реттік теңдеулер жүйесіне келтірілген және алдымен командалық қатардан қосылатын Lorenz.m атты m-файл функция жазылған. Теңдеулерді шеуде MATLAB жүйесінің ode45 процедурасы қолданылады. Есептеулер мен бейнелеулер нәтижелері суреттерде бөлшектердің траекториясы түрінде жазықтықта салынған. Изотоптардың бір-бірінен ажырауы изотоптардың меншікті зарядтары әртүрлі болуы айналу радиустарының әр-түрлі болуына байланысты. Изотоптың массалық саны артқан сайын оның магнит өрісіндегі айналу радиусы артатынын суреттерден көруге болады.

Түйін сөздер: изотоп, мешікті заряд, масс-спектрометр, жылдамдық селекторы, айналу, траектория радиусы.

К. А. Кабылбеков, Х. К. Абдрахманова, П. А. Саидахметов,
Т. С. Султанбек, Б. Ш. Кеделбаев

Южно-Казахстанский государственный университет им. М. Ауэзова, Шымкент, Казахстан

«РАСЧЕТ И ВИЗУАЛИЗАЦИЯ ПРОЦЕССА РАЗДЕЛЕНИЯ ИЗОТОПОВ» В СИСТЕМЕ MATLAB

Аннотация. В статье представлены программы MATLAB для расчета и визуализации процесса разделения изотопов ${}^{1}_{1}H$, ${}^{2}_{1}H$, ${}^{3}_{1}H$; ${}^{235}_{92}U$, ${}^{238}_{92}U$; ${}^{12}_{12}C$, ${}^{14}_{12}C$; ${}^{20}_{10}Ne$, ${}^{22}_{10}Ne$. Приведены краткие сведения из теории движения заряженной частицы в магнитном поле. Под действием магнитного поля заряженные частицы с различными массами движутся вдоль окружностей разных радиусов. Для решения системы дифференциальных уравнений второго порядка они приведены в систему уравнений первого порядка и предварительно создан m-файл под названием Lorenz.m, который вызывается с командной строки. При решении уравнений использована процедура ode45 системы MATLAB. Результаты расчетов представлены рисунками, где изотопы с разными удельными зарядами движутся вдоль траекторий с разными радиусами вращения. В этом случае говорят, что частицы разделяются из-за различия удельных зарядов. Чем больше массовое число изотопа тем больше его радиус вращения.

Ключевые слова: изотоп, удельный заряд, масс-спектрометр, селектор скорости, вращение, радиус траектории.

Information about the authors:

Kabylbekov K.A. – cand. phys.-math. sciences, associate professor of the department “Physics” of M. Auezov South Kazakhstan State University Shymkent, Kazakhstan, the correspondent member of KazNAS; kenkab@mail.ru; https://orcid.org/0000-0001-8347-4153

Abdrakhmanova Kh.K. – cand. chem. sciences, associate professor of the departments “Physics” of M. Auezov South Kazakhstan State University, Shymkent, Kazakhstan; khadi_kab@mail.ru; https://orcid.org/0000-0002-6110-970X

Saidakhmetov P. – M. Auezov South Kazakhstan State University, Shymkent, Kazakhstan; timpf_ukgu@mail.ru; https://orcid.org/0000-0002-9146-047X,

Sultanbek T. – M. Auezov South Kazakhstan State University, Shymkent, Kazakhstan; lazzat-kul@mail.ru; https://orcid.org/0000-0003-0782-7337

Kedelbayev B. – doct. chem. sciences, professor of the department “Chemistry” of M. Auezov South Kazakhstan State University, Shymkent, Kazakhstan; https://orcid.org/0000-0001-7158-1488