KAZAN FEDERAL UNIVERSITY
INSTITUTE OF PHYSICS

ALPHA SPECTROSCOPY

PASSING OF α-RADIATION THROUGH MATTER

Kazan
2013

UDK 539.164
BBK 22.38

Approved by
the Editorial Board of Kazan Federal University
the methodical commission of the Institute of Physics
Protocol № 9 from 18 December 2013

the Solid State Physics Department meeting
Protocol № 5 from 19 November 2013

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Dulov E.N., *Alpha spectroscopy. Passing of alpha radiation through matter.* An educational guide to a general laboratory practicum on nuclear physics / Dulov E.N., Voronina E.V., Tagirov L.R., Bikchantaev M.M. – Kazan: Kazan Federal University publishing house, 2013. – 13 p.: 7 ill.

Destination:

The methodical guide is intended for students of the Institute of Physics, Institute of Geology and Petroleum Technologies, as a support to the general physical practicum to the courses «Physics of particles and atomic nuclei», «Nuclear physics» and «Physics».

Introduction

Alpha decay (α-*decay*) is a spontaneous escaping of an α-*particle* (^{4}He atomic nuclei) from a nucleus, which occurs mainly for heavy nuclei. Single nucleons have binding energies, even in heavy nuclei, of about 8 MeV and cannot generally escape from the nucleus. In many cases, however, it is energetically possible for a bound system of a group of nucleons to be emitted, since the binding energy of this system increases the total energy available to the process. The probability of such escaping decreases rapidly with the number of nucleons required. The most significant decay process is the emission of ^{4}He nucleus; *i.e.*, a system of 2 protons and 2 neutrons. Contrary to other light nuclei, this so-called α-particle has extraordinarily large binding energy – 7 MeV/nucleon.

Figure 1 shows the potential energy of an α-particle as a function of its separation from the centre of nucleus. Beyond the nuclear force range ($r>R$) the α-particle feels only Coulomb potential V_c which increases the potential energy closer to the nucleus up to 30-40 MeV. In the range $r<R$, strongly attractive nuclear force prevails.

The range of lifetimes of α-radioactive nuclei is extremely large, from 10 ns to 10^{17} years. At the same time, the range of energies of emitted α-particles is very narrow, 2-9 MeV.

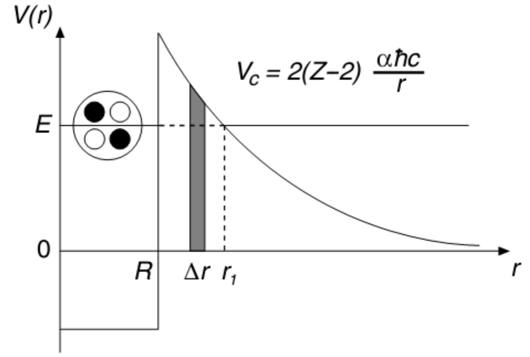

Figure 1. Potential energy of an α-particle depending on separation r from the centre of daughter nucleus. The probability that it tunnels through the Coulomb barrier can be calculated as a superposition of the tunneling process through thin walls of thickness Δr.

Most of the α-emitting nuclei are heavier than lead nucleus with the exception of some rare earth elements ($Z\approx60$).

An example of α-unstable nuclide with a long lifetime, ^{238}U, is shown in Fig. 2. Since uranium compounds are common in granite mineral, uranium and its radioactive daughters are a part of the stone walls of buildings. They, therefore, contribute to the environmental radiation background. This is particularly true for the inert gas radon, ^{222}Rn, which escapes from the walls and is inhaled into lungs. The α-decay of ^{222}Rn is responsible for about 40% of the average natural human radiation exposure.

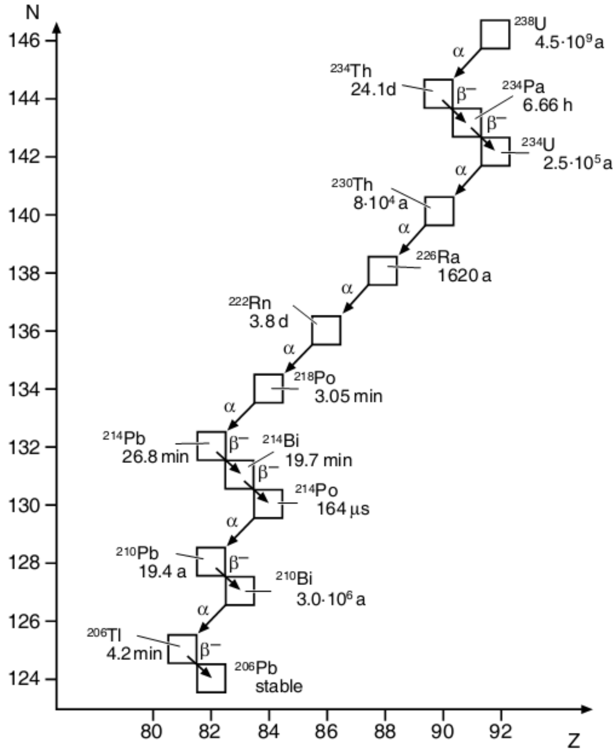

Figure 2. Illustration of ^{238}U decay chain. N and Z denote numbers of neutrons and protons, correspondingly. This is one of three decay chains occurring in nature.

Energies of the emitted α-particles are in strong relation with corresponding lifetimes. This for the first time was reflected in empirical equation (1911) called *Geiger-Nuttall law*:

$$\lg E = A \lg T_{1/2} + B\,, \qquad (1)$$

where A, B – some empirically determined coefficients, which depend on selected measurement units.

Increasing of the decay energy E by 10% corresponds to decreasing of the half-life time $T_{1/2}$ by a factor of $\sim 10^3$.

Regularities of α-decay leaded to a simple model (1925, Gamow theory), where α-particle was considered as a quantum particle or a wave packet (Fig. 3) penetrating Coulomb barrier by means of the *tunnel effect*. The tunnel effect, or *tunneling*, is a quantum mechanical phenomenon where a particle tunnels through a barrier that is classically could not surmount. The nearest analogy to the tunnel effect in classical physics is the partial transmission and reflection of an electromagnetic wave traveling from low to high refractive index medium (Fig. 3).

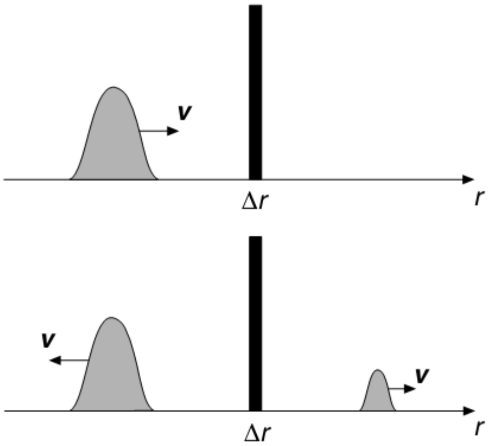

Figure 3. Illustration of the tunneling probability of a wave packet with the energy E and velocity v faced with a potential barrier of the height V and the thickness Δr.

If we divide the Coulomb barrier into thin potential walls and look at the quantum-mechanical probability p of the α-particle to tunnel through one of these (Fig. 1), then the transmission is given by:

$$p = e^{-2k\Delta r}, \qquad (2)$$

where $k = \sqrt{2m(V-E)}/\hbar$.

The Coulomb barrier can be thought of as a barrier composed of a large number of thin potential walls of different heights. Then, the cumulative transmission P can be described accordingly by:

$$P = e^{-2G}. \qquad (3)$$

The Gamow factor G can be expressed by the integral:

$$G = \frac{1}{\hbar}\int_R^{r_1}\sqrt{2m\left(V_C(r)-E\right)}dr, \qquad (4)$$

where R is the nucleus radius and r_1 is a separation from the nucleus center where the kinetic energy of the α-particle equals to zero (Fig. 1). Note that conserved mechanical energy (sum of the potential energy and kinetic energy) of the α-particle is shown in Fig. 1 as a horizontal line crossing the potential barrier curve. At the right point of intersection the mechanical energy equals to the Coulomb potential energy $V(r_1)$ and, therefore, the kinetic energy is zero.

Taking into account that $R \ll r_1$, and assuming $R \approx 0$ we have a simple analytical approximation to the Gamow factor (4):

$$G \propto Z/\sqrt{E}. \qquad (5)$$

The probability λ of the α-decay per unit time (decay constant) is, therefore, proportional to: the probability of finding such an α-particle in the nucleus, the number of collisions $(v_0/2R)$ of the α-particle with the barrier and the transmission probability. Here $v_0 \approx 0.1c$ is the velocity of the α-particle in nucleus. Finally, an analytical expression for Geiger-Nuttall law is obtained as follows:

$$\ln\lambda = \frac{aZ}{\sqrt{E}} + b, \qquad (6)$$

where a, b – some dimensional combinations of physical constants. The ratio $aZ/\sqrt{E}$ is dimensionless, because of equation (3), hence, the $(\ln\lambda - b)$ combination is also must be dimensionless.

Note that the analytical solution (6) is not directly obtainable from the empirical Geiger-Nuttall law (1), but they both are in good agreement with the experimental data.

Principles of measurements

With a semiconductor counter, the energy of α radiation can be determined. α particles transfer their energy to the semiconductor through inelastic collisions, thus giving rise to electron-hole pairs. The number of these charge carriers is proportional to the energy of the α particles. The charge carriers are separated in an electric field and collected at the semiconductor contacts with opposite polarity. A preamplifier integrates their current and generates a voltage pulse which is proportional to the α energy. The pulse height analysis is made by means of a multichannel analyzer (MCA) which is connected to a computer (PC).

Silicon-semiconductor counter

Large area silicon diodes of the type p-i-n, operating in reverse direction, are often used as semiconductor counters. Their leakage currents are so small that even at room temperature an electric field can be applied to collect the charge carriers generated by irradiation. α-radiation is detected in the depletion layer via energy transfer to electrons in the semiconductor.

Energy-rich α particles transfer their energy mainly via inelastic collisions with the electrons of the semiconductor. In a single collision, the α particle loses only a small amount of energy, and many collisions are required to slow it down considerably. Its energy is completely "consumed" after it passes a certain path length R, which depends on the energy. In a 100-μm thick silicon layer, for example, α particles with energies of up to 15 MeV are completely stopped (see Fig. 2). The depletion layer of the semiconductor must be thicker than this range.

The energy transferred to the semiconductor gives rise to pairs consisting of occupied states in the conduction band and unoccupied states in the valence band of the crystal (electron-hole pairs). At the same time, lattice vibrations (phonons) are excited. Therefore, the mean energy E_0 for generating electron-hole pair in silicon at room temperature is about 3.6 eV, although the gap E_g between the conducting band and the valence band is only 1.1 eV.

As the generation of an electron-hole pair always requires the same energy E_0, the number N_α of electron-hole pairs is proportional to the energy E_α absorbed. If an electric field is applied, the charge carriers are separated and drift to the semiconductor contacts. The current of the charge carriers is integrated and converted into a voltage signal $U_\alpha \propto E_\alpha$ in a preamplifier.

Multichannel pulse-height analysis

The voltage signals are further processed in a multichannel analyzer, the central component of which is an analog-digital converter. The analog-digital converter measures the pulse height U_α and converts the measuring value into a proportional digital value k_α. More precisely, k_α corresponds to a pulse-height interval, the width of which depends on the resolution of the analog-digital converter. The computer allocates a storage location for the each digital value and counts the events at each storage location. As a result, a histogram is obtained representing the pulse-height distribution. The histogram can be displayed graphically on the computer screen or printed as a table. For a quantitative evaluation, an energy calibration is required since the coefficients of the proportionalities $E_\alpha \propto U_\alpha \propto k_\alpha$ are unknown beforehand.

Energy losses in matter

The energy loss of energy-rich α radiation in a matter is mainly determined by inelastic collisions of the α particles with electrons. The direction of flight remains practically unchanged by the collisions, that is, the trajectory of an α particle is almost a straight line. In a single collision, the α particle loses only a small amount of energy, and many collisions are required to slow it down considerably. Usually, the energy loss dE of the α particle per path element dx in the moderating material is considered for quantitative description. A fast α particle looses less energy in a collision than a slow one because it remains in the interaction region for a shorter time interval, and thus can transfer less energy to the scatterer. The energy loss therefore depends on the energy. The energy of the α particle is consumed after it has passed the path length:

$$R = \int_{E_0}^{0} \frac{dx}{dE} \cdot dE \,.$$

This range is a measure for the initial energy E_0 of the α particle. Empirically, the relation between E_0 and R is given by the *Geiger* law:

$$R \propto E_0^{3/2} \,.$$

For air:

$$R[cm] = 0.46 E_0^{3/2} [MeV]$$

is a good approximation. In the experiment, the energy E of the α particles from an ^{241}Am source is measured in a vacuum chamber. On a fixed path length x_0 and with varying air pressure p, the α particles lose as much energy as they would lose at standard pressure p_0 on the path length in air:

$$x = \frac{p}{p_0} \cdot x_0 \,.$$

Variation of the pressure p by means of a ventilation valve therefore provides an easy way of varying the effective path length x of the α particles in air.

The quantitative description of the energy loss was obtained firstly by Bohr and then generalized for relativistic charged particles by Bethe and Bloch. For a non-relativistic α particle with the energy E the energy loss dE per path element dx is described by the original Bohr equation (SI units):

$$\frac{dE}{dx} = -\frac{nZe^4 M}{2\pi\varepsilon_0^2 m} \frac{1}{E} \ln\left(\frac{4mE}{MI} \right)$$

with M – mass of the α particle, m – electron mass, e – electronic charge, ε_0 – permittivity of free space, I – means ionization energy, Z and n – ordinal number and volume concentration of all atomic electrons (including bonded electrons) of moderating material, respectively.

Note, that the Bohr equation coincides with the empirical Geiger law when logarithm function in the Bohr formula is approximated by the square root function.

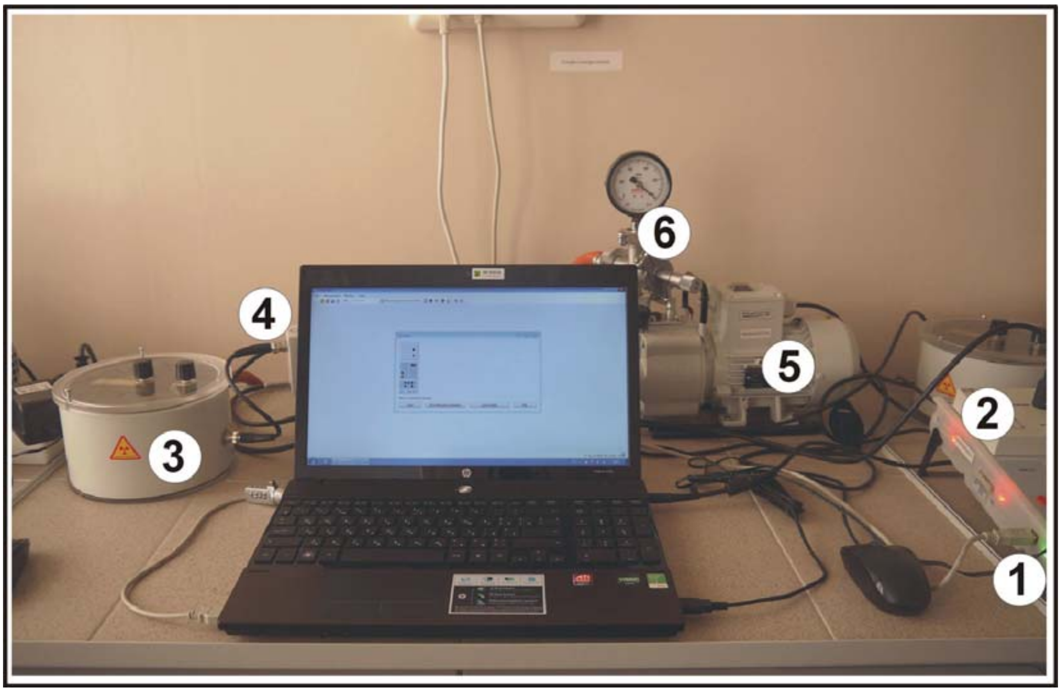

Figure 4. Experimental setup. 1 – CassyLab2 data acquisition unit; 2 – multichannel analyzer module; 3 – vacuum chamber; 4 – charge-sensitive preamplifier; 5 – vacuum pump; 6 – needle leak valve and the pressure gauge.

Setup

Experimental setup is shown in Fig. 4. Universal CassyLab2 data acquisition unit **1** with the module **2** of the multichannel analyzer MCA and the appropriate software is used. Alpha-radioactive source and the silicon-semiconductor detector are set in the vacuum chamber **3**. Detector is connected to the input of CassyLab2 data acquisition unit **2** (Fig. 4) via charge-sensitive preamplifier **4**. Vacuum pump **5** with the pressure gauge and pressure regulator **6** are used with the vacuum chamber. Notebook installed with specified software is used to display and process the data.

The vacuum chamber with controls is also shown in Fig. 5. Radioactive sources are preinstalled inside the chamber. **Do not open them**.

The semiconductor counter is light-sensitive: avoid direct illumination of the vacuum chamber, especially by daylight lamps, to prevent distortion of the measuring results.

Figure 5. The vacuum chamber. The radioactive source and particle detector are mounted inside the chamber. 1 – vacuum chamber; 2 – vacuum rotating shaft for ^{241}Am source; 3 – vacuum rotating shaft for “unknown” source; 4 – charge sensitive preamp.

Carrying out the experiment

Preparation

Before operations make sure that all units of the setup are available and connected according to the scheme above.

- Switch on the notebook, power supply of the CassyLab2 unit.
- Run CassyLab2 by clicking the icon on the desktop.
- In the window “Cassy” select “measurements channel” by the upper square selection of the left column (multichannel analyser). In such a manner the pulse height analysis (PHA) hardware module of CassyLab2 or the multichannel analyzer mode is activated (2**,** Fig. 4).
- Load settings file for this work from “Main Menu” → “Help” → “Experiment Examples” → “Alpha spectroscopy of radioactive samples”. The window will appears which offers to save current settings. These settings contain amplifier gain, number of channels, scale labels and other installation specific settings appropriate to measurements of alpha spectra. **Do not save current setting when offered to do so**.
- Make sure that the vacuum inlet on the backside of the vacuum chamber is closed. It is necessary to make hermeticity test of the vacuum line before the experiment. Closed state corresponds to vertical position of the tap lever.
- Make sure the needle leak valve (6, Fig. 4) is closed. The valve is intended to regulate environmental air access to the vacuum line and, therefore, to accurate regulation of pressure in the vacuum chamber (3, Fig. 4).

Vacuum chamber evacuation

Because of high ionization capabilities of α-particles and, therefore, their short free path length even in air at normal condition (<10 cm), the α-spectroscopy needs to be performed in vacuum.

- Switch the vacuum pump on (5, Fig. 4).
- Close the tap on the vacuum chamber cautiously by rotating it in clockwise direction. The closed state corresponds to

the vertical position of the tap lever.

- Make sure that the radioactive source ^{241}Am is opposite to the detector. Zero angle (shaft 2, Fig. 5) on the cap of the vacuum chamber corresponds to correct orientation of the source.
- The equipment may be used in different exercises, for example, in observation of Rutherford scattering and measurement of energy losses in metallic foils. If the cassette with the foil absorber is installed inside the vacuum chamber, then set the position of the absorber by rotating shaft 3, Fig. 5, which provides path of the α particles form the source to the detector without obstacles.
- If the cassette with the foil scatterer is installed inside the vacuum chamber (sample holder which manipulated by shaft 2, Fig. 5), then ask advisor to remove it. **Do not open the vacuum chamber without assistance.**
- Switch the vacuum pump on. Make sure all suction connections are hermetic. In the correct case the pressure-gauge (6, Fig. 4) indicates continuous decreasing of the pressure down to approximately 0 mBar. If residual pressure is greater than 10 mBar, ask advisor to solve the problem.
- Open the tap on the vacuum chamber cautiously by rotating it in the counterclockwise direction. Open state corresponds to horizontal orientation of the tap lever. Evacuation of the vacuum chamber will be started.
- Press the cap of the vacuum chamber (3, Fig. 4) for tight coupling to facilitate start of the chamber evacuation. As soon as the pressure decreases by 100 mBar, release the cap.
- Pump out the vacuum chamber down to a pressure below 10 mBar. This process takes 1-3 minutes approximately.
- Close the tap on the vacuum chamber cautiously by rotating them in the clockwise direction. Now the vacuum chamber is isolated from the vacuum pump and atmosphere. The vacuum pump can be switched off.
- Open the needle leak valve (6, Fig. 4) by rotating them in the counterclockwise direction. Make sure the pressure-gauge shows increasing value and ensure the vacuum main line has atmospheric pressure, 1000 mBar. This operation is important for safety reasons. Pressure difference between the vacuum line and atmosphere will cause grease oil extrusion from the pump to the vacuum line. This makes possible lack of the grease and breakage of the pump in a worst case, and grease oil to get in the vacuum chamber in the best case.
- Switch the vacuum pump off.

Energy calibration

Spectroscopic equipment allows observation of the pulse heights distribution (PHD, pulse height is usually a discretized value, n_A, in the present work) from a detector. PHD is supposing proportionality of the pulse height and the particle energy. The proportionality coefficient for the spectrometer can be found by measurement of calibration spectrum with a known radioactive source.

- In the tab “Measurement” press → “Start/stop Measurement”. This operation will initiate measurement of the spectrum. Note that the same action is caused by <F9> key pressing.
- In the right side window called “Measuring Parameters” (this window is embedded in the main window “Cassy”) tune by the track bar named “Gain” the software amplification of the signal from detector, and repeat measurements until spectrum covers most of channels, like in Fig. 6. Typical value for the amplification coefficient is -3.
- When the tune is complete, delete all intermediate data.
- Measure spectrum of ^{241}Am during 5 minutes. Spectral composition of α particles of ^{241}Am caused by two energies of the emitted α particles, 5486 keV and 5443 keV, with intensity relation 84:13. Due to finite resolution of the silicon-semiconductor detector this two energies are unresolved (single line black curve on Fig. 6).
- When mouse cursor is over spectrum window click the right mouse button to get “Menu of Actions” with the spectrum. Select “Fit Function” → “Gaussian of equal

Width”. Then, hold the left button to mark the line of the spectrum.

- Read result of the processing in the line at the bottom of the window CassyLab2 (line center - μ, line width – σ).
- In the tab “Settings” perform the energy calibration of abscissa. Select in the Settings tree the item “Cassys” → “Input A_1” → “Channel n_A”.
- In the Group Box named “Energy Calibration” set the check mark in the line “Global for all channels” and type two calibration points in the corresponding windows. Enter for the first point: channel – “0”, energy – “0”. Enter for the second point channel – “μ”. Energy should be chosen from the drop-down menu window corresponding to the line of the calibration source.
- Select in the Settings tree the item Cassys → Display → Standard → $N_A(n_A)$, after that rename the *Ox* axis: E_A instead of n_A.

The spectrum should be redrawn in the energy scale.

Spectrum of “unknown” sample

When the energy scale is calibrated the spectrometer can be used to measure spectra of any samples. A set of spectral lines is a “fingerprint” for the radioactive nuclide. By means of this fact an unknown nuclide can be identified via its spectrum.

- By rotation the vacuum shaft (2, Fig. 4) place the “unknown” sample opposite to the silicon detector. The “unknown” sample must shield the detector from α particles of the calibration source ^{241}Am.
- Measure spectrum for 20 minutes. Another spectrum over the calibration spectrum must appear, something like red curve in Fig. 6.

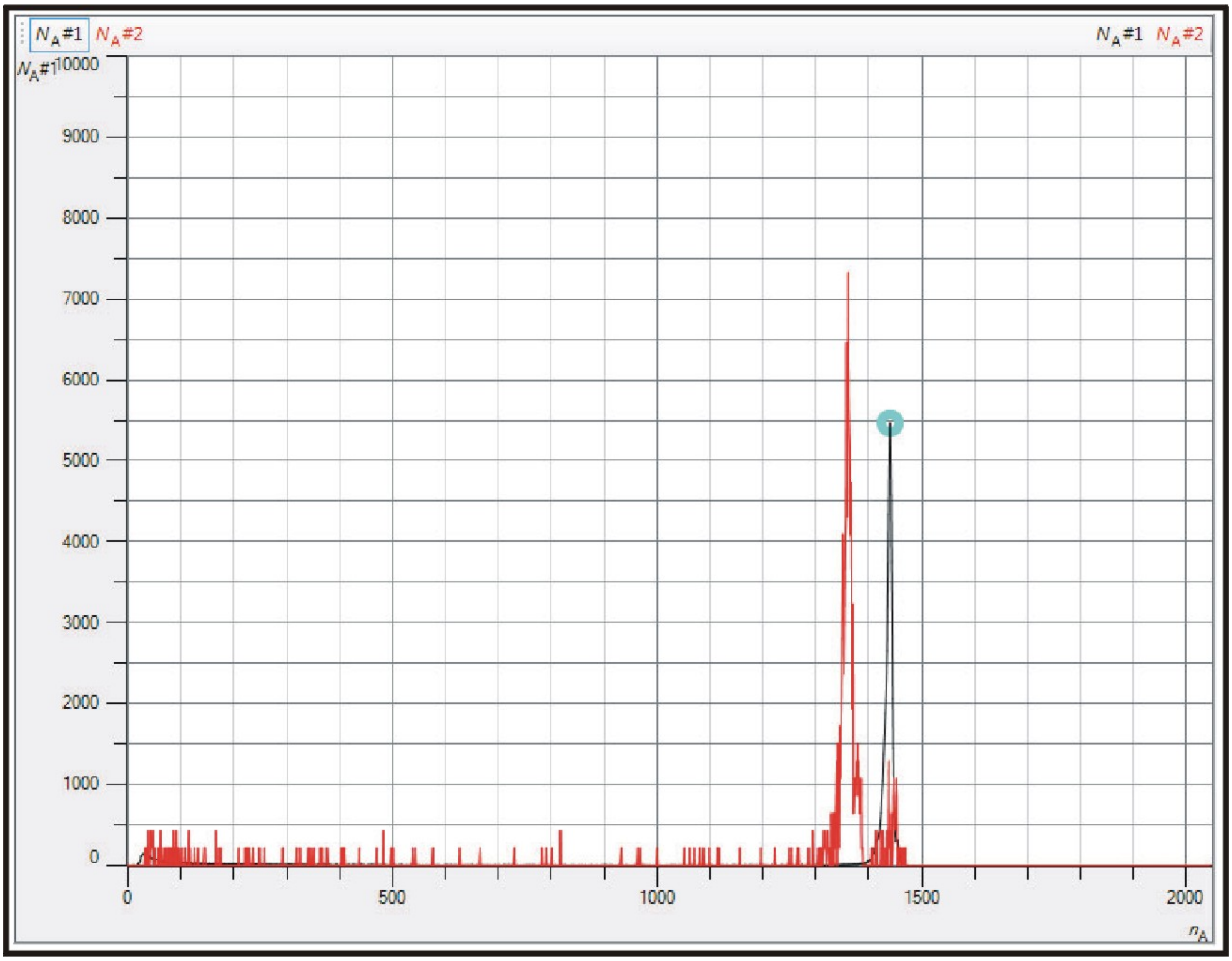

Figure 6. The alpha spectrum of ^{241}Am preparation and the spectrum of the “unknown” source.

Energy loss in air

The distance between radioactive source and detector inside vacuum chamber is greater than mean free path of α-particles in air. Varying residual pressure in the chamber it is a way to observe the energy losses of α-particles when passing through air.

- Remove the “unknown” sample from the path of ^{241}Am α-particles by rotating vacuum shaft 3, Fig. 4.
- Switch the vacuum pump on (5, Fig. 4). **The pump should remain be powered during all measurements described below**.
- Open the needle leak valve (6, Fig. 4) by rotating it in the counterclockwise direction.
- Open the variable leak valve until the pressure in the vacuum chamber is approximately 100 mbar.
- Delete the old measured values via the main menu of the CassyLab2 software.
- Start new measurement for the time approximately 1 min.
- When the detection time is over, evaluate centre of the peak.
- Increase the pressure in the vacuum chamber – at first in steps of about 100 mbar, and above 800 mbar by smaller steps. In each case record the α spectrum, and determine the α-particles energy.
- Collect measured energies E of the α particles depending on the pressure value p as shown in Table 1.

Table 1. Measured values of the α energy E as a function of the air pressure p, distance 5.2cm.

p / mbar	E / MeV
1	5.48
290	5.47
380	5.45
480	5.44
670	5.40
760	5.21
860	5.03
880	4.96
900	4.84
920	4.47
940	3.99
970	*

* - α counting rate is equal to zero

Evaluation and results

In the measured spectrum of the “unknown” sample determine position of the spectral lines through approximation of the each of them by Gaussian function. Treatment of the spectrum is performed in the same way like in the calibration stage. Try to identify α-radioactive nuclei of the sample (see the Appendix A). The first attempt of the isotope identification may be unsuccessful due to a reason described below.

In Table 2, the measured values of Table 1 are given with the air pressure p converted into the effective path length x in air. Figure 7 is a plot of these values.

Table 2. α-particles energy E as a function of the effective path length in air at the standard pressure.

x / cm	E / MeV
0.0	5.48
1.5	5.47
2.0	5.45
2.5	5.44
3.4	5.40
3.9	5.21
4.4	5.03
4.5	4.96
4.6	4.84
4.7	4.47
4.8	3.99
5.0	*

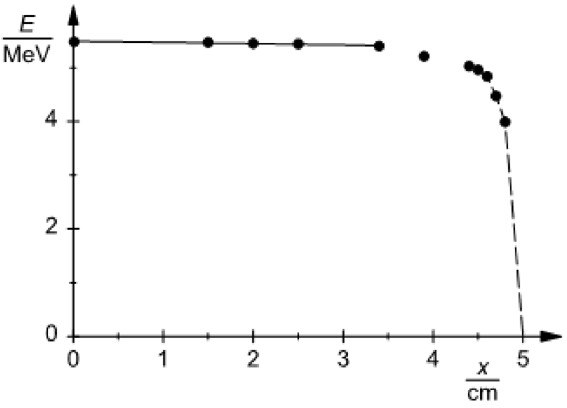

Figure 7. α-particles energy E as a function of the effective path length in air at the standard pressure.

As long as the path length in air is below 3.5 cm, the energy loss of the α-particles remains small. These small losses correspond to small energy changes region (the straight line drawn in Fig. 7). Assuming the energy dependence on the effective path to be linear in this region, the energy losses can be characterized by slope of the line or *the energy loss per unit path length*:

$$\frac{dE}{dx} = 23 \frac{\text{keV}}{\text{cm}}.$$

The range R of the α-particles can be estimated by extrapolating from the last data points to E=0:

$$R = 5.0 \text{ cm}.$$

The range R = 5.90 cm is obtained for the α-particles energy E = 5.477 MeV of ^{241}Am as an estimation from the Bohr formula and the Geiger empirical law. The estimation R = 5.0 cm corresponds to the α particles energy E = 4.9 MeV. This deviation is, among other things, due to the fact that the ^{241}Am preparation is coated with gold foil, and that the α particles leave the preparation with energy below 5.477 MeV.

Therefore, the data for the "unknown" source based on the calibration results should be revised. The simplest way to do the revision is a multiplication of energies obtained for the "unknown" source by a factor of (4.9 MeV/ 5.477 MeV) ≈ 0.895. For example, the left spectral line of the "unknown" source (Fig. 6, red curve) has the energy 5.15 MeV, obtained in assumption of the uncoated calibration source. This spectral line can be ascribed to ^{239}Pu isotope according to the reference data in Appendix A. Taking into account the correction factor 0.895, we have another value of the energy equal to 4.60 MeV, which is typical for ^{226}Ra isotope.

Note that in the present work the weak radioactive "unknown" sample has no coating.

Report

Process the spectra by the CassyLab2 software. Analyze the spectra obtained and determine position of the spectral peaks.

Save the results as graphs making screenshots or by exporting windows as images by means of the CassyLab2 software. Save the graphs in an external storage and use in the documentation of your work.

Represent the results in print including all estimations and graphs.

Treat the collected α-particles energy values depending on the residual pressure in the vacuum chamber. Calculate energy losses for the high-energy and low-energy particles in air. Compare the obtained data with the Bohr formula and the Geiger law. Represent the results in print including all estimations and graphs.

Safety notes

The following safety rules must nevertheless be kept to:

- **Prevent access to the preparations by unauthorized persons.**
- **Before using the preparations make sure that they are intact.**
- **For the purpose of shielding, keep the preparations in their safety vessel.**
- **To ensure minimum exposure time and minimum activity, take the preparations out of the safety vessel only as long as is necessary for carrying out the experiment.**
- **To ensure maximum distance, hold the preparations only at the upper end of the metal holder and keep them away from your body as far as possible.**

Self-test problems

1. Why does alpha decay occur most often in heaviest nuclides?
2. Why another combination of nucleons does not emit spontaneously instead of alpha particles?
3. What energies do correspond to long-lived nuclei, small or large?
4. What are the energies of alpha particles emitted in natural alpha decay?
5. What does quantum effect underly alpha-decay?
6. Estimate the size of region where an alpha particle exists in underbarrier state.
7. Assuming a nucleus consisting from alpha particles, estimate the binding energy per one alpha particle.
8. What advantages have semiconductor detectors in alpha spectroscopy?
9. Why does the alpha spectroscopy need to be performed in vacuum?

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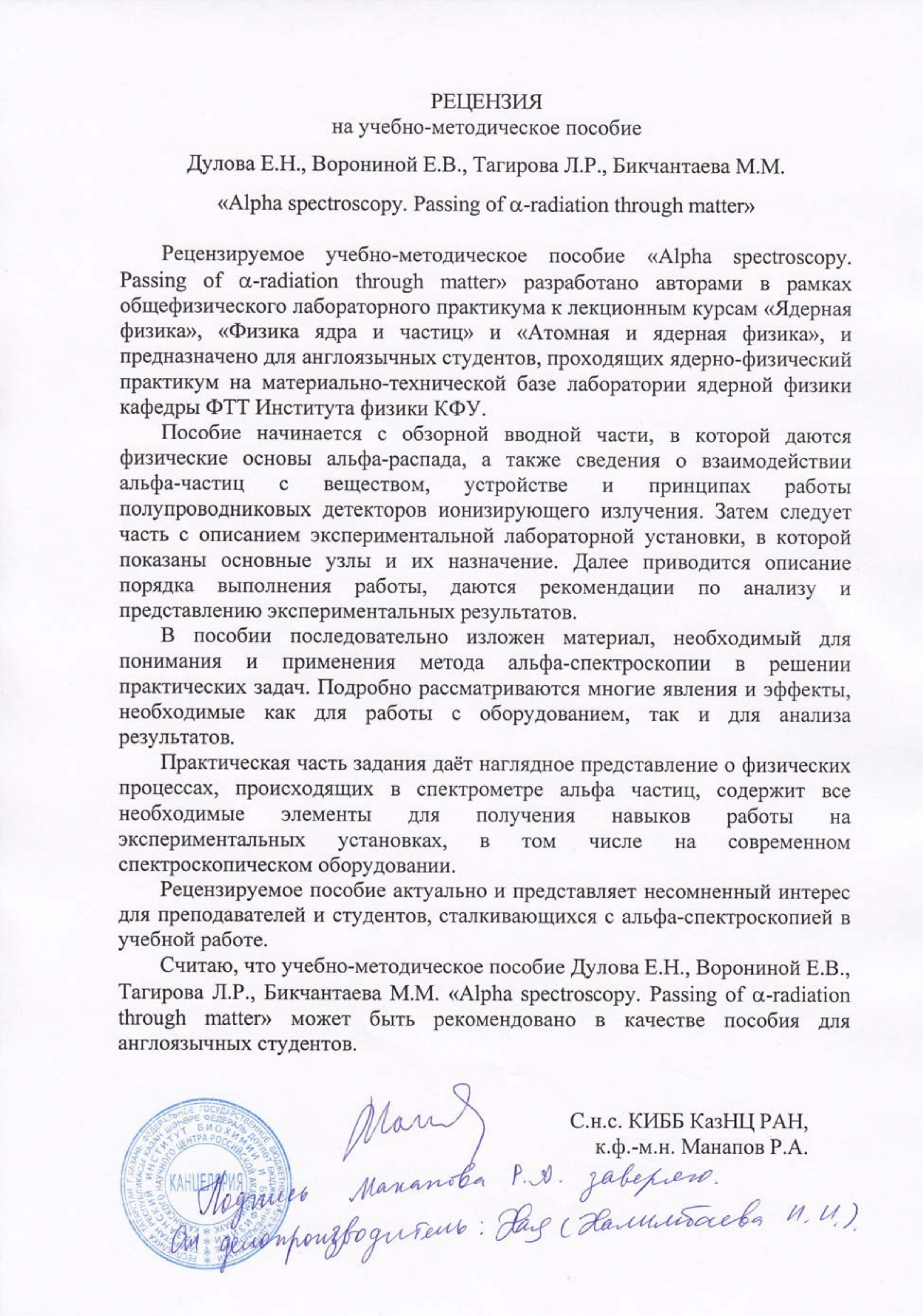
11.

Appendix A. Energies of α-particles for some nuclides

E, MeV	Source
1.83	Nd-144
2.14	Gd-152
2.23	Sm-147
2.46	Sm-146
2.50	Hf-174
2.73	Gd-150
3.18	Gd-148
3.18	Pt-190
3.957	Th-232
4.016	Th-232
4.15	U-238
4.196	U-238
4.367	U-235
4.397	U-235
4.416	U-235
4.445	U-236
4.494	U-236
4.557	U-235
4.568	Bi-210m
4.598	U-235
4.602	Ra-226
4.621	Th-230
4.688	Th-230
4.723	U-234
4.737	Pa-231
4.765	Np-237
4.770	Np-237
4.774	U-234
4.783	U-233
4.785	Ra-226
4.787	Np-237
4.811	Th-229
4.824	U-233
4.845	Th-229
4.856	Pu-242
4.896	Pu-241
4.901	Th-229
4.901	Pu-242
4.91	Bi-210m
4.95	Ac-227
4.951	Pa-231
4.946	Bi-210m
4.967	Th-229
5.012	Pa-231
5.053	Th-229
5.058	Pa-231
5.105	Pu-239
5.123	Pu-240
5.143	Pu-239
5.155	Pu-239
5.159	Pu-240
5.234	Am-243
5.264	U-232
5.276	Am-243
5.305	Po-210
5.307	Cm-245
5.321	U-232
5.343	Cm-246
5.343	Th-228
5.360	Cm-245
5.386	Cm-246
5.42	Bk-249
5.423	Th-228
5.443	Am-241
5.447	Ra-224
5.448	Bi-214
5.454	Pu-238
5.486	Am-241
5.490	Rn-222
5.499	Pu-238
5.512	Bi-214
5.53	Bk-247
5.540	Ra-223
5.608	Ra-223
5.677	Cf-251
5.688	Bk-247
5.686	Ra-224
5.709	Th-227
5.717	Ra-223
5.732	Ac-225
5.741	Cm-243
5.748	Ra-223
5.757	Th-227
5.764	Cm-244
5.785	Cm-243
5.794	Ac-225
5.806	Cm-244
5.812	Cf-249
5.818	U-230
5.830	Ac-225
5.852	Cf-251
5.868	At-211
5.889	U-230
5.978	Th-227
5.989	Cf-250
5.992	Cm-243
6.002	Po-218
6.031	Cf-250
6.038	Th-227
6.051	Bi-212
6.056	Cm-243
6.069	Cm-242
6.076	Cf-252
6.090	Bi-212
6.113	Cm-242
6.118	Cf-252
6.126	Fr-221
6.225	Th-226
6.278	Bi-211
6.28	At-219
6.288	Rn-220
6.34	Th-226
6.340	Fr-221
6.424	Rn-219
6.439	Es-254
6.551	Rn-219
6.56	Ra-222
6.622	Bi-211
6.63	Es-253
6.65	At-218
6.70	At-218
6.777	Po-216
6.818	Rn-219
7.022	Fm-255
7.07	At-217
7.14	Rn-218
7.145	Fm-254
7.200	Fm-254
7.28	Po-211m
7.384	Po-215
7.448	Po-211
7.687	Po-214
8.377	Po-213
8.785	Po-212
8.88	Po-211m
11.65	Po-212m

Note: the letter “m” at the end of radioactive isotope name (for example Bi-210m) means metastable nuclei.



РЕЦЕНЗИЯ

на учебно-методическое пособие

Дулова Е.Н., Ворониной Е.В., Тагирова Л.Р., Бикчантаева М.М.

«Alpha spectroscopy. Passing of α-radiation through matter»

Рецензируемое учебно-методическое пособие «Alpha spectroscopy. Passing of α-radiation through matter» разработано авторами в рамках общефизического лабораторного практикума к лекционным курсам «Ядерная физика», «Физика ядра и частиц» и «Атомная и ядерная физика», и предназначено для англоязычных студентов, проходящих ядерно-физический практикум на материально-технической базе лаборатории ядерной физики кафедры ФТТ Института физики КФУ.

Пособие начинается с обзорной вводной части, в которой даются физические основы альфа-распада, а также сведения о взаимодействии альфа-частиц с веществом, устройстве и принципах работы полупроводниковых детекторов ионизирующего излучения. Затем следует часть с описанием экспериментальной лабораторной установки, в которой показаны основные узлы и их назначение. Далее приводится описание порядка выполнения работы, даются рекомендации по анализу и представлению экспериментальных результатов.

В пособии последовательно изложен материал, необходимый для понимания и применения метода альфа-спектроскопии в решении практических задач. Подробно рассматриваются многие явления и эффекты, необходимые как для работы с оборудованием, так и для анализа результатов.

Практическая часть задания даёт наглядное представление о физических процессах, происходящих в спектрометре альфа частиц, содержит все необходимые элементы для получения навыков работы на экспериментальных установках, в том числе на современном спектроскопическом оборудовании.

Рецензируемое пособие актуально и представляет несомненный интерес для преподавателей и студентов, сталкивающихся с альфа-спектроскопией в учебной работе.

Считаю, что учебно-методическое пособие Дулова Е.Н., Ворониной Е.В., Тагирова Л.Р., Бикчантаева М.М. «Alpha spectroscopy. Passing of α-radiation through matter» может быть рекомендовано в качестве пособия для англоязычных студентов.

С.н.с. КИББ КазНЦ РАН,
к.ф.-м.н. Манапов Р.А.

КАНЦЕЛЯРИЯ

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ВЫПИСКА ИЗ ПРОТОКОЛА № 9

от 18 декабря 2013

заседания Учебно-методической комиссии Института физики КФУ

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СЛУШАЛИ: рекомендацию в печать методического пособия «Alpha spectroscopy – Passing of α-radiation through matter» (авторы: Дулов Е.Н., Воронина Е.В., Тагиров Л.Р., Бикчантаев М.М.)

ПОСТАНОВИЛИ: на основании положительной рецензии к.ф.-м.н., старшего научного сотрудника КИББ КНЦ РАН Манапова Р.А. рекомендовать вышеуказанное методическое пособие к опубликованию в электронном виде на сайте Института физики.

Председатель Учебно-методической комиссии
Института физики, профессор Таюрский Д.А.