GAMMA-SPECTROMETER FOR MEASUREMENT CHARACTERISTICS OF RADIONUCLIDES

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Describing and metrological characteristics of spectrometric stand intend for measurement characteristics of radionuclides and its identification are present. The results of measurements specific activity of any radionuclides using this spectrometer are present too.

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The spectrometric methods with the use of the scintillation and semi-conductor detectors are more and more applied at solving the problems connected with the quantitative analysis. In most of the measurements that are carried out the final goal is the data production of the specific activity, the concentration and the substance quantity. The identification of the radionuclides in the complex spectrum by one, but more often by several γ-lines is also an important problem. The γ-spectrometer, used for isotope radioactive analysis, must possess a rather high-resolution ability, great γ-quantum registration efficiency at the range ≈60 keV-2 MeV and have a small level of its own noise. The necessity to combine these demands in one device became the goal of this work.

GAMMA-SPECTROMETER HARDWARE

Primarily, for the radionuclide research we used spectrometer on the basis of the IBM PC 386(387) and ADC of the type 712 in CAMAC standard [1]. The Ge(Li) ДГДК with the volume 50 $см^3$ was used as a detector. The software allowed to carry out the spectra obtaining under MS DOS and realize the simple processing of the received data (to calculate the peak, and subtract the phone) Feature of the work with the CAMAC crate controller and limited quick-action of PC did not allow to assume high charges. Specifically, the counting error value reached 15-20 % at great charges of the spectrometric channel. Such counting errors must be taken into consideration by the programs on the specific activity determination. Besides, ADC of the 712 type has 10-bit precision that leads to necessity to change the amplification of the spectrometric channel during the work, and, hence, the calibration of the energy scales. Another configuration of the γ–spectrometer was introduced with the consideration of these remarks: PC386 was replaced by more powerful Pentium-133, instead ADC-712 the 16-bit ADC, on the AD976 basis produced by Analog Devices, is used. And there is no need in the CAMAC crate controller. The carried out substitution allowed working under the MS-DOS and Windows-98.

As a γ–radiation detectors were chosen: a semiconductor ДГДК-100 with the volume of 100 cm^3 and scintillation БДИС3-05 with scintillator NaJ(Tl) ∅ 63 mm × 63 mm. In addition, the spectrometer is equipped with the scintillation detector NaJ(Tl) ∅ 70 mm × 70 mm with well. It used during the work with the low-active samples in the 4π geometry. Such a spectrometer configuration provides a high resolution at the Ge(Li) detector use, which is necessary at the research of the isotopes with many γ–lines or at the research of isotopes mixture. The scintillation detector is used to the research of a single peak, for instance, in isotopes ^{15}O, ^{11}C, ^{18}F, ^{13}N, ^{188}Re. It has a sufficient energetic range of the registered γ-quanta and to have a spectrometer with a broadly varied registration efficiency that is especially useful at the measurement of the low-active and short-lived isotopes.

The spectrometric stand is equipped the end-window counter MCT-17 in order to have a β–radiation registration of the analyzed samples and a contribution rate of the β–activity into the irradiation dose. Besides, the β–activity control of the measured devices allows to detect the possible impurity of the sample targets, that can distort the γ-spectra after the activation, especially in low energy range. Spectrometers circuit is given at Fig. 1.

The main tendency of the measurements perfection is concluded in increasing of the device operating speed and improving the measurement results accuracy. The increase of the measurement accuracy is provided by reduce of the statistical errors, and of the operating speed – the device capability to work at great input charges.

The error of the impulse miscalculation is one of the main mistakes at the considerable input charges. It is the consequence of the fact that the measurement channel dead time is limited and the impulse distribution in time is submitted to the statistic law [2]. The spectrometric channel dead time is determined by the channel capability not to assimilate the next impulse during some time after the previous one. The value of this time is determined by the detector characteristics, the sharpener-amplifier characteristics, and the specification of the interaction between the ADC and PC.

The counting errors that are concerned limited time of charge absorption in the detector are observed at

charges more than 10^5 s^{-1}. The charge absorption time fluctuations and the terminal time of the impulse forming scheme occupation lead to the spectrum deformation and sometimes increase the error counting. Various scheme resolution of the rejecters that are deformed according to the signal form and the added impulses allow to reduce the spectrum deformation. The most essential contribution to the counting errors is carried in by the ADC and registration device [3]. Therefore, the main efforts were taken to optimize the work of this spectrometric channel module. The main approaches in this direction were: the ADC dead time reducing, the impulse forming scheme occupation time reducing, the spectrum correction with the high stable impulse generator. The dead time for the spectrometer (according to the scheme given at Fig. 1) was found by the two sources method by the formula

$$\tau = \frac{n_1 + n_2 - n_{12}}{2n_1 \cdot n_2},$$

where n_1, n_2 and n_{12} – are the charges from the first, second and both sources, accordingly. The average meaning $\tau = 30$ μs was received at the use of the БУС2-47 with shaping time 1,6 μs.

When evaluating the sample activity, the detector efficiency η is the essential factor. It was determined as a relationship between the quantity of quanta detected in the photopeak and the quantity of quanta radiated from the γ-source with a known activity. With such determination of the efficiency it was not necessary to evaluate in each case a solid angle being covered by the detector when changing the source position. To determine η we used the set of the standard sources composed of ^{22}Na, ^{137}Cs, ^{54}Mn, ^{241}Am, with γ-lines energy 511, 1275, 661, 834, 59.5 keV, respectively.

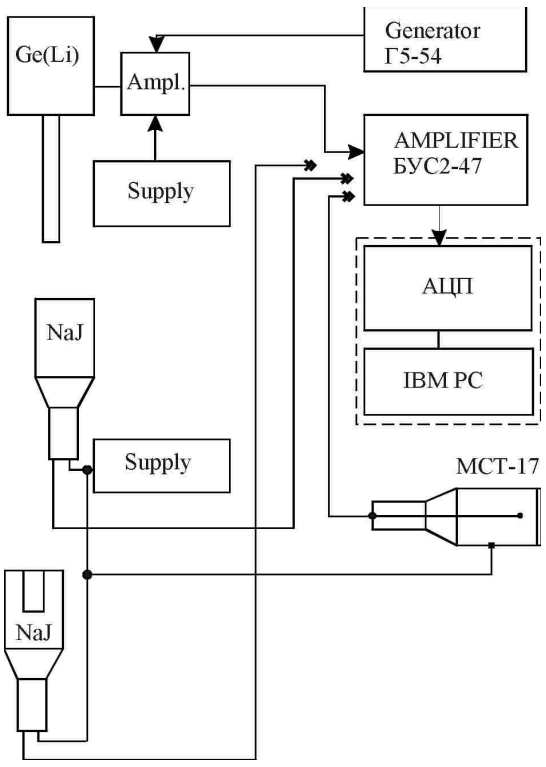

Fig. 1. *Spectrometers circuit*

The measurement results of the Ge(Li) detector efficiency dependence from γ-quanta energy at various distances from the detector are shown at Fig. 2.

Table 1 shows the efficiency in % of the БДИС3-05 detector with the scintillator NaJ ∅63 mm × 63 mm.

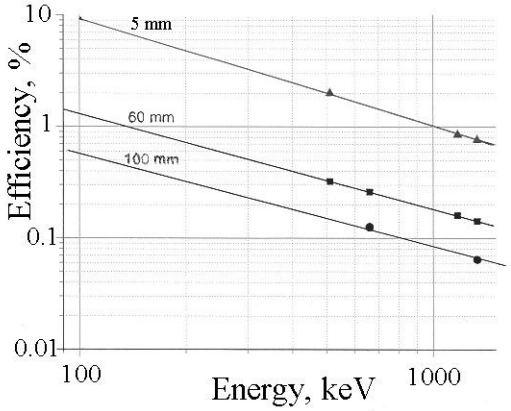

Fig. 2 *Detector efficiency as a function of γ-quantum energy at different distances from the source: 5,5 mm, 60 mm, and 100 mm*

The measured energetic resolution of the spectrometric channel with the semiconductor detector on lines Co^{60} is 1,2 %, and on the line Co^{57} (136 keV) – 1,8 %. These factors allow to divide γ-lines, and to identify, for instance, the radionuclides derivable at the Re and Mo irradiation. The energetic resolution on the line of 662 keV was measured for the scintillation detector, that the meaning of 8,5 % is received. The lower resolution than Ge(Li) will not be hinder for the correct specific activity determination due to the fact that the scintillation detector will be used mainly for the spectra set from the sources possessing single γ-lines.

Table 1

Energy, keV	Efficiency at various distance from the detector, %				
	0	13mm	23mm	34mm	43mm
60	23,4	14,7	10,1	6,9	5,0
511	9,3	5,3	3,7	2,7	2,1
662	9,0	4,7	3,2	2,2	1,7
835	7,1	3,5	-	-	-
1275	2,5	1,9	1,4	1,1	0,8

THE SOFTWARE AND DATABASE

The spectrometer software is written on the Borland C++, Delphi 4.0 languages and allows to work under the DOS and Windows-98 control. Unlike the software used previously the applied programs allow to determine the photo peak center, to subtract the phone and to estimate the counting amount under the peak with a high

accuracy. It is decided to divide the programs according to the spectrum accumulation and it's processing to have more flexibility in work. The database programs used to identify the isotopes are taken out into separate block. The spectra are accumulated either in the hand-mode (only once) or in the automatic one with the set time given beforehand and frequency. The data is kept in the file on the hard disk in format combined with the various program processing.

The program that allows producing the spectra visualization, the calibration of the energy scale and isotope identification according one or two γ-lines, was written for the operative work with the spectrum. Fig. 3 shows the view of the program-working window. If it is necessary this program counts the activity of the given isotope inquiring the spectrum set parameters of the working file and any characteristics of the applied detector.

The radionuclide activity A_0 at the instant of irradiation stopping was calculated by the formula

$$A_0 = \frac{A}{\eta \cdot I \cdot m \cdot k \cdot e^{-\lambda \cdot t}},$$

where η – is the efficiency of γ-quantum detection, I – is the average current falling onto the sample, A_0 – is the specific activity of the sample at the instant of stopping irradiation, m – is the target mass, k – is the coeffcient of γ-quantum multiplicity, A – is the number of γ-quanta detected in the time t after irradiation stopping, λ – is the radionuclide decay constant.

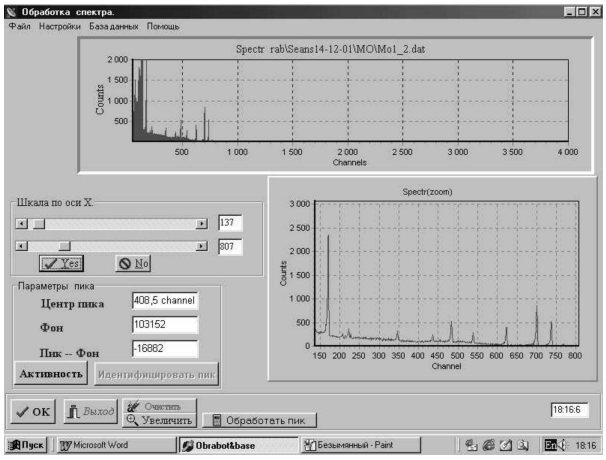

Fig. 3. *The view of the program working window*

Miscalculations were counted by the following formula:

$$N_0 = \frac{N}{1 - N_s \cdot (\tau / t_1)},$$

where N – is the number of photons in the photopeak detected by the detector, N_0 – is the real number of photons, Ns – is the total number of pulses in the spectrometric channel, τ – is the dead time of the spectrometer, t_1 – is the exposition time of spectrum.

The isotope identification is done by his γ-lines. The identification program sends the SQL-request to the database keeping the γ-lines energy meaning and the allowable error in the energy determination. The table, keeping the main characteristics of all isotopes that are in the base, satisfying the given selection criteria, is made on results of the request. The future selection conditions formed on the data basis of the half-life of the radionuclide and isotopic composition of target.

Such decision allows the stand operator to identify correctly radionuclides as their constitution conditions, are known.

Table 2

Isotope	Specific activity Bq/g.μA
^{11}C	$2.25 \cdot 10^6$
^{13}N	$3.3 \cdot 10^6$
^{15}O	$2.5 \cdot 10^6$
^{18}F	$1 \cdot 10^7$

The activity research of the various radionuclides for the medical application received on the linear accelerator was carried out as a result of the work on the spectrometric stand [4]. Table 2 shows the information about the specific activity of some isotopes generated on the linear accelerators NSC KIPT. Therefore, the described spectrometric stand provides the measurement of the various levels of γ-activity.

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REFERENCES

1. G.L. Bochek, A.N. Dovbnya, A.S. Zadvorny and all. Narabotka korotkozsuvuchih izitopov na yskoritele EPOS NSC KIPT dlya positron-emisionnoi tomografii // *Problems of Atomic Science and Tech*. 1999, №1. Issue: Nuclear Physics Researches (37), p. 66-67 (in Russian).
2. V.I. Gol'dansky, A.V. Kutsenko, M.I. Podgoretsky. *Statistika otschetov pri registratsii yadernyh shastits*. Moscow:"Fizmatgiz", 1959, 148 p. (in Russian).
3. V.B. Ivanov, Y.P. Sel'dyakov, V.I. Shepilov. Prosheti v amplitudnoy spectrometrii impulsov // *PTE,* 1979, №6, p. 14–29 (in Russian).
4. A.N. Dovbnya, N.P. Dikii, A.S. Zadvorny and all. Issledovanie vozmozhnosti poluchenia izotopov Re // *The Journal of Kharkiv National University,* 2001, №510. Issue 1 /13/, p. 87-90 (in Russian).