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Xenon gamma-detector applicability for identification and characterization of radioactive waste

S. N. Pyae*, V. M. Grachev, V. V. Dmitrenko, S. E. Ulin, K. F. Vlasik, Z. M. Uteshev, A. E. Shustov, A. S. Novikov, D. V. Petrenko, I. V. Chernysheva

National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Kashirskoe shosse 31,Moscow, 115409, Russia

Abstract

In this paper described applicability of xenon gamma detector for identification and characterization of radioactive waste was researched. Standard calibration gamma ray sources were used to determine real physical and technical characteristics of xenon gamma spectrometer. Samples of radioactive waste were measured by xenon gamma detector for identification and characterization.

Keywords: xenon gamma detector, radioactive waste, gamma ray spectrometer

1. Introduction

For the characterization of large amounts of different types of waste generated during the installation of industrial uranium-graphite reactors and other nuclear and radiation hazardous objects, one must use nondestructive methods and the gamma rays spectrometer with high sensitivity and high energy resolution. In addition they must provide reliable detection and identification of radioactive waste, as well as have the radiation resistance and thermal stability, high operational reliability.

In the Radiation laboratory of MEPhI, the xenon gamma spectrometer (XGS) was developed, which is a new gamma detector type offering unique opportunities for scientific and applied researches in various fields. The

* Corresponding author. Tel.: +7-926-192-5384;
E-mail address: pyaesonenyein@mail.ru

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detector energy resolution is 2% for the γ-ray energy of 662 keV, which is 3–4 times better than the resolution of scintillation gamma detectors based on NaI or CsI [1].

The objective of this study was to determine real physical and technical characteristics of xenon gamma spectrometer and capability of its characterization of radioactive waste. In the present work described measuring samples of radioactive waste by XGS, the composition of isotopes contained in the samples of wastes and their activity.

2. Description of Xenon Gamma Spectrometer

The xenon gamma-detector is cylindrical pulsed ionization chamber with a Frisch grid, filled with compressed xenon(~50 atm). The XGS sensitive volume is 200 cm^3 at an end-cap area of 11 cm^2. The ratio of the effective ionization chamber volume to the total volume is 83%. The schematic of the spectrometer and its main physical characteristics are shown in Fig. 1.

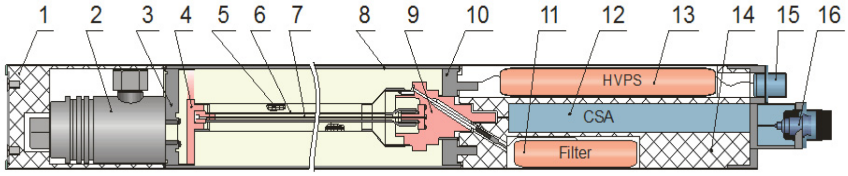

Fig. 1. Schematic of xenon gamma detector. 1 - Teflon insulator; 2 - gas valve; 3 - flange; 4 - ceramic support for the grid; 5 - Frisch grid; 6 - anode; 7 - grounded metal thread; 8 - detector case of (cathode); 9 - ceramic insulator; 10 - flange; 11 - HV filter; 12 - charge-sensitive amplifier (CSA); 13 - high-voltage power supply; 14 - Teflon insulator; 15 - low-voltage connector for high voltage power supply; 16 – output CSA.

General characteristics XSC: Energy range - 0.02 - 3 MeV; xenon density - 0.4 g / cm^3; xenon pressure at 23° C- 50 atm; sensitive volume - 200 cm^3; weight - 1 kg and dimensions - Ø4 × 35cm.

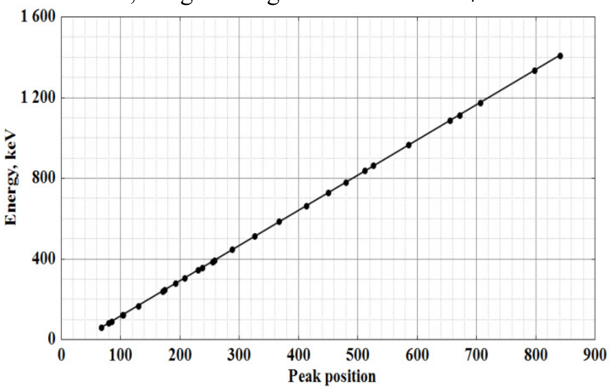

Fig. 2. Peak position vs. gamma ray energy.

The dependence of the peak position of full energy absorption versus the gamma rays energy for the XGS is shown at Fig. 2. Deviation of the measured values from the straight line does not exceed 1%, which demonstrates the good linearity installation XGS for the characterization of radioactive waste. Experimental errors are very small to show in figure.

Experimentally, the energy resolution of XGS defined as the full width of the absorption peak of the gamma line at its half maximum (FWHM) in the accumulated spectra using gamma-ray sources shown in Fig. 3. The energy resolution of XGS is about 2% at the gamma ray energy 662 keV (source Cs-137) [3]. Therefore, result is 3-4 times better than that of scintillation detector NaI .

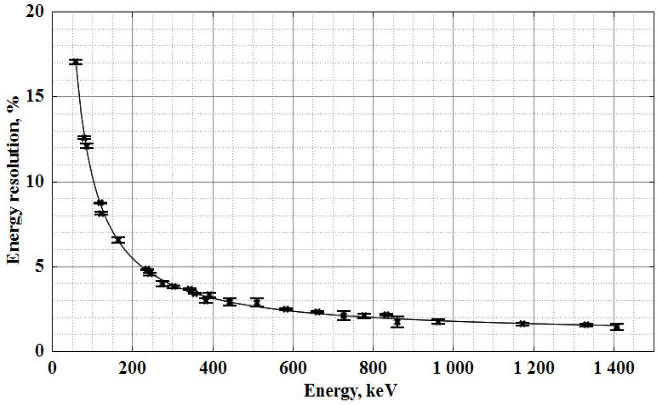

Fig. 3. Detector resolution vs. gamma ray energy

The efficiency of detection of gamma rays XGS was determined as the ratio of the number of particles detected XGS by peak of full energy absorption, to the number of particles emitted by gamma-ray source. In Fig. 4 shown the dependence of the detection efficiency XGS from gamma ray energy.

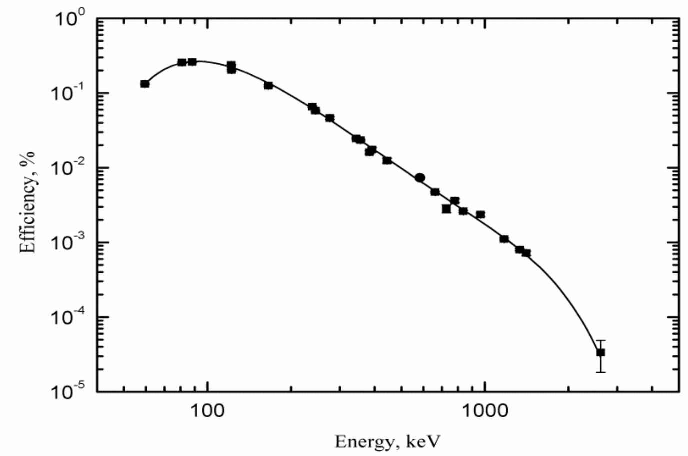

Fig. 4. Dependence of detector efficiency from gamma rays energy. Experimental errors are located within the experimental points.

In this figure one can clearly see that the detection efficiency of the XGS is 0.132±0.003% for gamma-ray energy E = 60 keV, 0.238±0.005% for gamma-ray energy E = 121.8 keV, 0.0047±0.001% for gamma-ray energy E = 662 keV.

3. Results

To study the metrological potential of xenon gamma detector for characterization samples of radioactive waste were measured. Three samples measured radioactive waste represented three different assays of the system for collecting radioactive waste. Each sample was placed in a glass bottle.

Fig. 5 - 7 shown the spectra of the samples radioactive waste, measured by xenon gamma detector. Analysis of measured by XGS gamma spectra indicates the presence of isotopes ^{241}Am, ^{134}Cs, ^{137}Cs, ^{152}Eu, ^{154}Eu and ^{60}Co in the samples of radioactive waste.

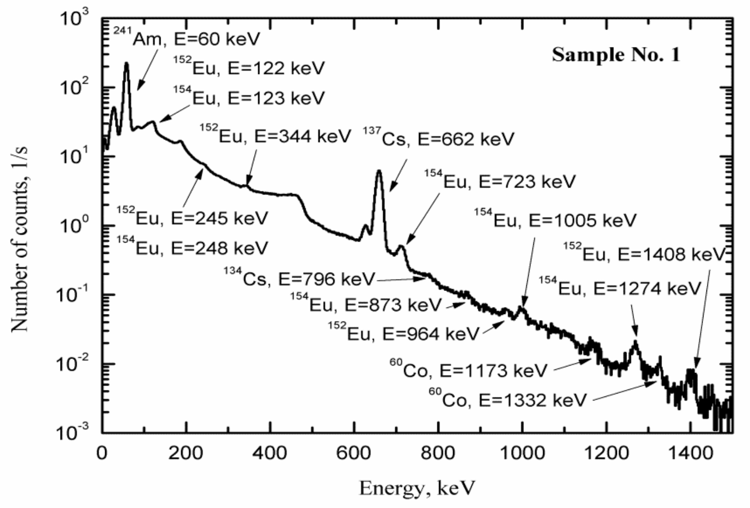

Fig. 5. Gamma-ray spectrum of radioactive waste (sample No. 1). Experimental errors are located within the experimental points.

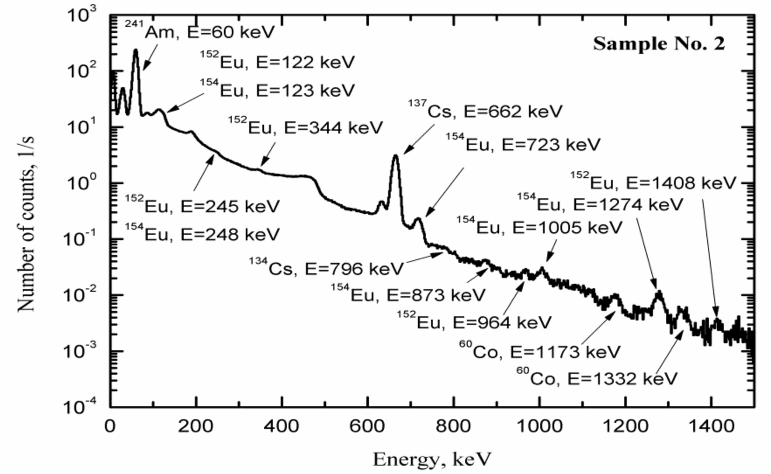

Fig. 6. Gamma-ray spectrum of radioactive waste (sample No. 2). Experimental errors are located within the experimental points.

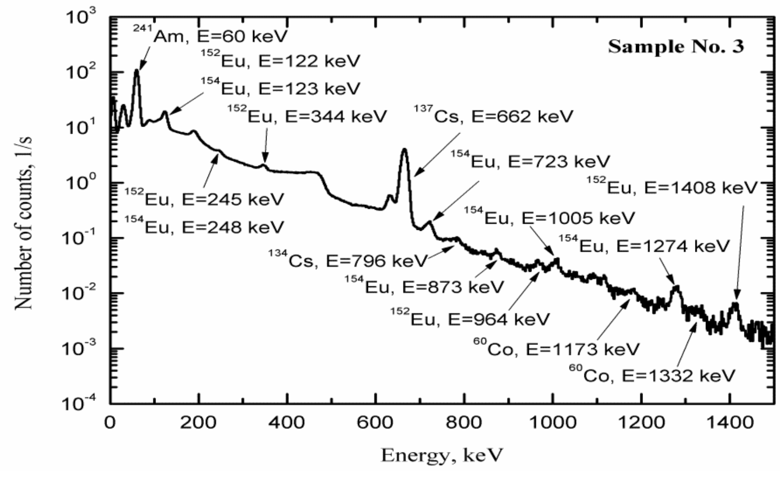

Fig. 7. Gamma-ray spectrum of radioactive waste (sample No. 3). Experimental errors are located within the experimental points.

As a result of the mathematical processing of the gamma spectra were obtained activities of the samples radioactive waste. Calculated values of the isotopes activity of samples waste are shown in Table 1.

Table. 1. Samples of radioactive waste activities registered by xenon gamma spectrometer.

Isotopes	Activity, Bq		
	Sample No. 1	Sample No. 2	Sample No. 3
^{241}Am	(1.09±0.03)×10^7	(1.24±0.04)×10^7	(5.29±0.16)×10^6
^{137}Cs	(5.59±0.22)×10^6	(2.85±0.11)×10^6	(3.67±0.15)×10^6
^{152}Eu	(3.11±0.22)×10^5	(2.33±0.16)×10^5	(2.58±0.18)×10^5
^{154}Eu	(3.17±0.25)×10^5	(2.31±0.18)×10^5	(4.04±0.32)×10^5
^{60}Co	(3.24±0.31)×10^4	(2.83±0.27)×10^4	(3.16±0.31)×10^4
^{134}Cs	(7.03±0.71)×10^3	(4.21±0.42)×10^3	(5.03±0.51)×10^3

4. Conclusion

Physical and technical characteristics of xenon gamma spectrometer with sensitive volume 0.2 liter were determined. Its energy resolution is 2.3% for the gamma-ray energy of 662 keV. This value is 3-4 times better than the energy resolution of the scintillation detectors. The measurement results of samples of radioactive waste show than xenon gamma detector with sensitive volume of 0.2 liters has good metrological capabilities for the identification and characterization of radioactive waste.

References

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