SPECIAL ISSUE / 2004

BALKAN PHYSICS LETTERS

PROCEEDINGS OF THE 4TH INTERNATIONAL BALKAN SCHOOL ON NUCLEAR PHYSICS

September 22-29, 2004
Bodrum - TURKEY

OPTIMAL CONDITIONS FOR A ZnS(Ag) SCINTILLATION DETECTOR OPERATION

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ABSTRACT

The methods that use scintillation counting with ZnS(Ag) scintillation detector are widely used for gross alpha activity determination. Optimal counting conditions could be provided by properly setting of operating voltage and by this means, the long-term stability could be achieved. The common criteria for the selection of optimal counting conditions for a ZnS(Ag) scintillation detector do not consider simultaneously operating voltage and discrimination level variation. In presented method a relationship between voltage supply and discrimination level is derived for counting efficiency.

Keywords: ZnS(Ag) scintillation detector, gross alpha activity, counting conditions

Introduction

The important aspect of environmental protection and remediation is the assessment of the radiological quality of samples. Alpha-particle-emitting sources could be detected by the proportional counters, silicon surface-barrier, liquid scintillation and ZnS(Ag) scintillation detectors. The scintillation ZnS(Ag) detectors are the common choice for measurements of alpha-emitters. The advantages of these detectors are: long term stability, ruggedness, and relative easy sample preparation. The results of measurements by ZnS(Ag) scintillation detector could be used as an indicator for alpha-emission. In order to identify and quantify the presence of alpha-emitters in samples, further investigations are necessary.

For growing needs in environmental radioactivity monitoring the preliminary measurements with ZnS(Ag) scintillation detector are developed. The procedure for determination of the optimal conditions for operating of the ZnS(Ag) scintillation detector has been presented. This procedure contains two experimental steps. In the first step the wider range of counting conditions was considered, whereas in the second step the range was narrower The results obtained in the first step of the experiment were used for experimental set-up for the second step.

Determination of the optimal counting conditions

In setting up a nuclear counting system, it is often desirable to establish an operating point, which will provide maximum stability over long periods of time [1]. The reaching of the optimal counting conditions is possible by choosing the appropriate values of the high voltage supply and discrimination level. The optimisation of the specific device could be performed by figure of merit, FM, defined as $FM = E^2 / B$, where E is the counting efficiency and B is the background counting rate [2, 3].

The efficiency of ZnS(Ag) scintillation detector depends on high voltage supply and discrimination level (LLD) for the given device gain (preamplifier and amplifier). It is recommended not to use too high voltage supply, because the lifetime of the phototube is longer at the lower voltage supply However, the operating voltage should be taken above the threshold voltage of the plateau. It should be chosen where the counting rate has a minimum variation due to voltage supply and discrimination level drifts. This criterion involves the selection of the operating voltage at one third of the plateau length [2]. Maximum figure of merit is achieved by adjusting the operating voltage for a given discriminator setting or by adjusting the discriminator setting for given operating voltage [2].

The new approach for determination of the optimal counting conditions of ZnS(Ag) scintillation detector takes both criteria into account, simultaneously [4]. In this paper the results obtained by means of three different methods of determination of optimal counting conditions are presented [5,6].

Experimental set-up

The measurements were carried out by the ZnS(Ag) scintillation detector (Bicron 3M.125PP/3M-X) with photomultiplier tube (Canberra 2007). The maximum cathode to anode voltage for the PMT is 2000 V The discrimination level varies from 0 V to 10 V The alpha spectroscopic source used in this experiment is ^{239}Pu with the intensity of 1560 α s^{-1} in 2π (LMRI, No. 2796). The source-detector distance is 4.1 mm.

The characteristic curves were determined by measuring the alpha source by means of ZnS(Ag) scintillation alpha detector In the first step high voltage supply was between 600 V and 1500 V and the discrimination level was between 0.5 V and 9.5 V, whereas in the second step high voltage supply was between 800 V and 1400 V and the discrimination level was between 0.1 V and 2.0 V [5,6]. The statistics of one measurement was from 10 000 to 90 000 counts for each combination of voltage and discrimination level.

Results and discussion

Determination of the optimal conditions for ZnS(Ag) scintillation detector could be done by· plateau study, determination of figure of merit, determination of combination of efficiency and discrimination level for the certain operating voltage.

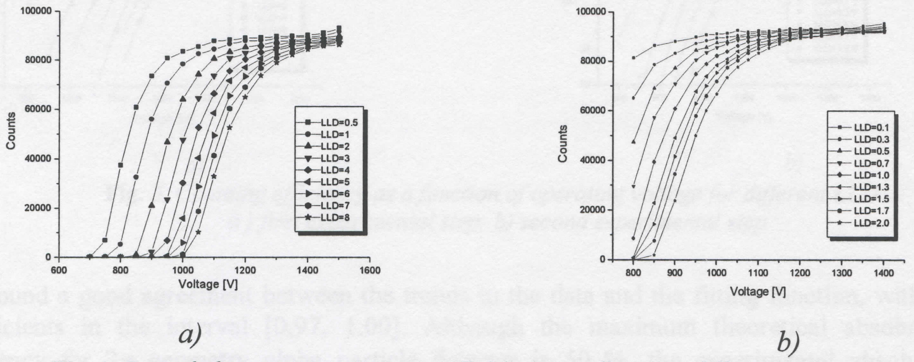

Fig. 1. *Typical characteristic curves in a ZnS(Ag) scintillation at different LLD settings a) first experimental step; b) second experimental step*

Figure 1 illustrates a typical characteristic curves for the ZnS(Ag) scintillation detector It was observed that the plateau became shorter by increasing the discrimination level. Thus, in the range of discrimination level from 2 V to 3 V, the plateau disappeared. This was also a limitation on the discrimination level value. The values for operating voltage and discrimination level obtained from Figure 1 are 1050 V and 0.5 V, respectively [5,6].

Figure 2. illustrates FM as a function of voltage and discrimination level in a ZnS(Ag) scintillation detector. From a graph we could observe flat zone, which take place in the discrimination level range from 0.3 V to 0.5 V for FM 2.0, with a small variation of the background and efficiency The value for operating voltage obtained from Figure 2. is 1000 V, since it should be selected in flat zone [5,6].

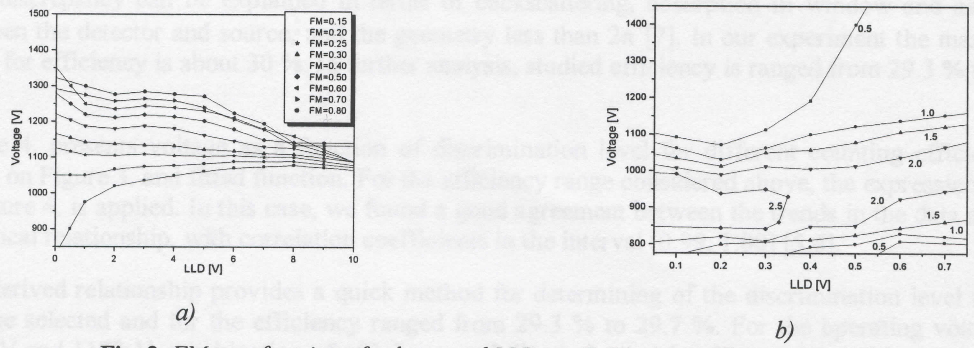

Fig. 2. *FM as a function of voltage and LLD in ZnS(Ag) scintillation detector*
a) first experimental step; b) second experimental step

Figure 3 presents counting efficiency as the function of the operating voltage for different discrimination level. The fitted functions for the ZnS(Ag) scintillation detector are also shown [5,6].

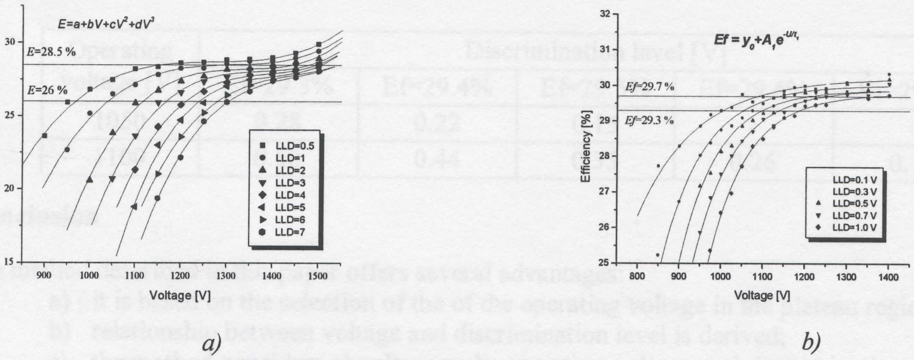

Fig. 3. *Counting efficiency as a function of operating voltage for different LLD.*
a) first experimental step; b) second experimental step

We found a good agreement between the trends in the data and the fitting function, with correlation coefficients in the interval [0.97, 1.00]. Although the maximum theoretical absolute detection efficiency for 2π geometry alpha particle detector is 50 %, the experimental absolute counting efficiency will be below this value.

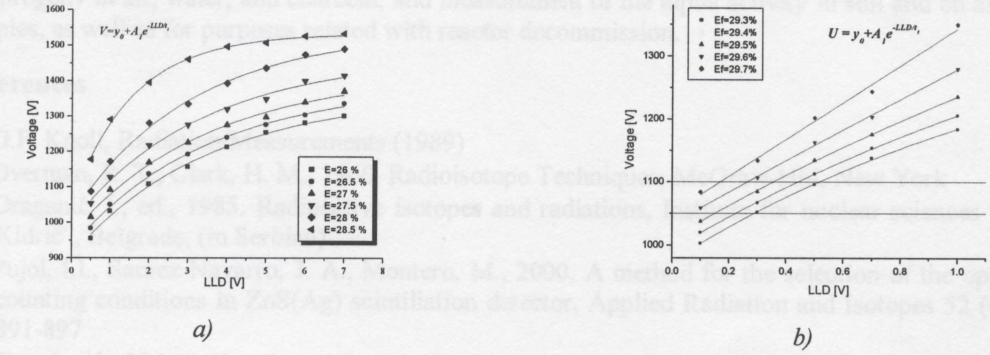

Fig. 4. Voltage as a function of LLD for the different counting efficiencies.
a) first experimental step; b) second experimental step

This discrepancy can be explained in terms of backscattering, absorption in window and air layer between the detector and source, and the geometry less than 2π [7]. In our experiment the maximum value for efficiency is about 30 %. In further analysis, studied efficiency is ranged from 29.3 % to 29.7 %.

Figure 4. presents voltage as a function of discrimination level for different counting efficiencies, based on Figure 3 and fitted function. For the efficiency range considered above, the expression given in Figure 4. is applied. In this case, we found a good agreement between the trends in the data and the empirical relationship, with correlation coefficients in the interval [0.99, 1.00] [5,6].

The derived relationship provides a quick method for determining of the discrimination level for the voltage selected and for the efficiency ranged from 29.3 % to 29 7 %. For the operating voltage of 1050 V and 1100 V, combination of efficiency and discrimination level are presented in the Table 1 Therefore, the optimal parameter values for our ZnS(Ag) scintillation detector are 1100 V for discrimination level 0.5 V or 1050 V for discrimination level 0.3 V [5,6]

Table 1. *Combination of efficiency and discrimination level for the operating voltage of 1050 V and 1100 V*

Operating voltage [V]	Discrimination level [V]				
	Ef=29.3%	Ef=29.4%	Ef=29.5%	Ef=29.6%	Ef=29 7%
1050	0.28	0.22	0.15	-	-
1100	0.50	0.44	0.35	0.26	0.17

Conclusion

The method described in this paper offers several advantages.

a) it is based on the selection of the of the operating voltage in the plateau region;
b) relationship between voltage and discrimination level is derived;
c) the method considers simultaneously operating voltage and discrimination level variation to reach the best counting conditions.

Using this method we determined the optimal counting conditions for our ZnS(Ag) scintillation detector· operating voltage 1100 V and discrimination level 0.5 V The aim of this experimental work was to develop a method for absolute measurements of a thick alpha source with ZnS(Ag) detector system. This method does not require the use of standards, special calibrations, or complicated radiochemical procedures. Applications of this method include the quantitative determination of radon and progeny in air, water, and charcoal, and measurement of the alpha activity in soil and on air filter samples, as well as for purposes related with reactor decommission.

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