Determination of full energy peak efficiency of HPGe for volume source by daughters of $^{222}$Rn

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**Abstract**

In this work, detection efficiency of HPGe detector is determined by daughters of $^{222}$Rn radioactive gas in Marinelli geometry as a volume source. The accurate configuration of HPGe is simulated by MCNPX code and the efficiency curve of a gaseous volume source is obtained by tally $\Phi$. The results of experiment and simulation is compared.

**Introduction**

In the framework of low-level activity measurements of noble gases, detection limits as low as possible are required. This is achieved using dedicated "low-level" spectrometers and using large volume samples. The HPGe detector represents one of the fundamental instruments in noble gas measurements. Operating these systems require an accurate knowledge of detection efficiency. Big volume sources like Marinelli geometries can provide the best detection limits. The establishment of the efficiency calibration curve is particularly complex because the calibration procedure needs standard volume sources which are not always accessible and it's production has some difficulties.

In order to determine activity of radionuclide with HPGe detectors, one must know the absolute full-energy peak efficiency at the desired gamma-ray energy [1].

**Experiment**

We used a coaxial HPGe with the diameter and length 60.6 mm and 66.9 mm respectively. The spectrometer had Be entrance window. It's relative efficiency at 1.33 MeV was 40 %. The spectrometer was put in Pb shield with 10 cm thickness.

As we do not have a calibrated gas source, we decided to use flow-through $^{222}$Rn source which were developed by Pylon. This source features reliable rate of emanation, high accuracy and ease of use. More over, It provides a convenient means of generating calibrated quantities of either radon gas. The source material is in a dry powder form which reliably emanates 100% of the gas produced [2]. We used Marinelli geometry for activity measurement of $^{222}$Rn daughters. Fig. 1 shows the configuration of HPGe and Marinelli.

For collecting the gas, Marinelli was put in the line which the gas was flowed. The Marinelli had 2 valves for being in the line of flow-through gas source. It was 10 minutes in the line with opened valves and after that, the valves were closed. During this 10 minutes, according to the flow rate of gas, 1 l/min, the Marinelli was filled with total activity of 13.45±0.54 Bq/lit of $^{222}$Rn in the environment pressure. The Marinelli had a volume of 1 lit, so the activity of $^{222}$Rn was 13.45 Bq. Fig. 2 shows the Marinelli.

The time which the valves were closed, was considered as zero time which we assumed that there was just $^{222}$Rn nucleus in the Marinelli. As the half life of $^{222}$Rn (3.8235 d) and it's daughters is very short, during the counting time, one must consider the activity of it's daughters. So the number of daughter nucleuses of $^{222}$Rn after the zero time was obtained by solving the differential equation of growth and decay as below in MATLAB. In this equation $i$ was related to each nucleus.

$$dN_i = \frac{(-\lambda_i)222Rn}{dt} + (\lambda_{i+1}222Rn - \lambda_i)210Pb$$

$\lambda_i$ is the characteristic decay constant of isotope $i$ which is shown in fig. 1. Air is included in Marinelli. Detection efficiency of mono-energy volume source is obtained by tally $\Phi$.

**Simulation**

The accurate configuration of HPGe is simulated by MCNPX code [4]. A Marinelli geometry is considered as a volume source on top of the detector. The configuration is shown in fig. 1. Air is included in Marinelli. Detection efficiency of mono-energy volume source is obtained by tally $\Phi$.

**Results**

Table 1 shows the activity of 2 daughters of $^{222}$Rn after counting time of 50000 s.

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Activity (Bq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb-214</td>
<td>12.62</td>
</tr>
<tr>
<td>Bi-214</td>
<td>12.59</td>
</tr>
</tbody>
</table>

The results of experiment and simulation are shown in fig. 5. The selected points are in good agreement with the simulation curve. So, we can use the simulated efficiency curve for determination of efficiency of detector in various energies. The decay scheme of $^{222}$Rn is shown in fig.3. The $^{222}$Rn spectrum was collected within 50000 s which is shown in fig. 4.

**References**