THE EFFECT OF SOURCE THICKNESS AND DENSITY ON Ge(Li) DETECTION EFFICIENCY

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ABSTRACT

A study was carried out on the effect of different source thickness (0.5 cm, 0.75 cm, 1.0 cm and 1.25 cm) on a Ge(Li) detector's relative efficiency. The effect of sample density was also studied. It was found that for a particular energy of a gamma photon, the relative efficiency increases as the thickness decreases. For the range of mass (hence, density) studied it was found that the effect on the relative efficiency is very little.

1. INTRODUCTION

With the rising importance of nuclear based determinative technique, gamma-ray spectroscopy has grown to be one of the major tools involved. To accomplish this kind of spectroscopy, lithium drifted germanium detector, the Ge(Li), which was developed by Tavendale and Ewan (1963), has been widely used. The popularity of Ge(Li) detector is generally due to its much better resolution capability as compared to the traditional NaI (Tℓ) scintillation counter, although it shows poorer detection efficiency and need to be maintained at liquid nitrogen temperature.

Measurements of the detector's efficiency is a must and always precede any gamma spectroscopy using a Ge(Li) detector. Most workers depended on measured efficiency of the Ge(Li), due to the non-standard geometries of many Ge(Li) detectors, and also difficulty in defining their active volumes (Singh et al. 1971). Experimentally, relative efficiency of a deterctor may be obtained using standard or reference gamma sources (Mannhart et al. 1976).

Since most workers focus much emphasis on the efficiency-energy relationship, they tend to overlook the effect of sample or source geometry and density on the detection efficiency of a detector. One must realized that by disregarding these effects, they might possibly introduce or increase the systematical error in their results. The present study tried to show the relations of various sample thickness and densities on a Ge(Li) detector's efficiency . The standard source used was S16 from International Atomic Energy Agency (IAEA).

2. THEORITICAL CONSIDERATIONS

For the study a disc-shaped gamma source of radius r and thickness l was used. Figure 1 illustrates the arrangements in which the source was placed coaxially in contact with the Ge(Li) detector.

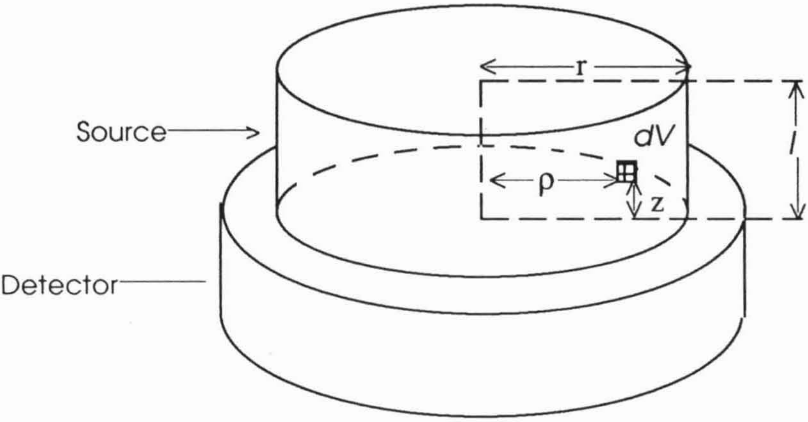

Figure 1

A volume element *dV*, placed at a distance ρ from the axis and *z* from the detector, is also shown.

For this arrangement, the countrate, C, of the gamma photons of energy E can be written as the integral of the product of the gamma activiti, G, and the efficiency, ε, of the detector for the volume element dV, over the whole volume of the disc source. Hence

$$C(E,r,l) = \int_V G(E,\rho,z)\ \varepsilon(E,\rho,z)\,dV \qquad (1)$$

In the determination of the relative efficiency of a detector for a fixed geometry of source and detector (as in this study), a homogeneous gamma source comprising of a mixed radionuclides can be used. The gamma activity emitted by the source for the photons of energy E is then given by

$$\begin{aligned} A(E,r,l) &= \int G(E,\rho,z)\,dV \qquad (2) \\ &= G(E)V, \end{aligned}$$

since $G(E,\rho,z)$ is constant over the whole volume of the source. The ratio of the detected to the emitted gamma is known as the relative efficiency. Thus the relative efficiency of the detector can be written as

$$\bar{\varepsilon}(E,r,l) = C/A \tag{3}$$

Using equations (1) and (2),

$$\bar{\varepsilon}(E,r,l) = 1/V \int \bar{\varepsilon}(E, \rho, z) \tag{4}$$

A graph of log $\bar{\varepsilon}$ versus E gives rise to the relative effeciency curve of a given source geometry and matrix. A linear relationship between log $\bar{\varepsilon}$ and log E is normally observed for energy from about 200 keV to 2 MeV (Ahmad, 1988). For this linear range we can write

$$\log \bar{\varepsilon}(E,r,l) = -m \log E + K(r,l)$$

or

$$\bar{\varepsilon}(E,r,l) = B(r,l)E^{-m}, \tag{5}$$

where m is the gradient of the graph and B(r,l) the geometrical factor, which by comparing equations (4) and (5) is given by

$$B(r,l) = 1/V \int \varepsilon(\rho, z)dV, \tag{6}$$

We could now write the detector's effeciency as

$$\varepsilon(E, \rho, z) = E^{-m} \varepsilon(\rho, z), \tag{7}$$

that is the product of an energy term and a geometrical factor term. Hence, from equation (5), for a gamma source of a given geometry (radius and thickness), if the values of B and m is known, the relative efficiency at any energy between 200 keV and 2 MeV can be calculated.

3. EXPERIMENTALS

Apparatus and Materials

For the study, an ORTEC Vertical Ge(Li) detector (10% efficiency and 2.2 keV resolution for Co^{60}) coupled to a Canberra 35-Plus Multichannel Analyser (MCA) was used. To minimise surrounding interference the Ge(Li) was kept in a special lead castle throughout the study.

The gamma source used was standard thorium ore (S16 from IAEA). Known amount of S16 was mixed and homogenised into common clay that was dried and pulverised earlier. The source emits gamma photon of various energies ranging from 77 keV to about 2 MeV.

Procedures

Study on the effect of denstiy on the detector's relative efficiency was carried out using the standard mixtures packed in round plastic containers of 4 cm diameter and 1 cm thickness. By using different magnitude of compression on the mixture in a particular container, sample sources of various mass, hence density were obtained, since each source's volume is the same as the container's. The mass ranged from about 10 gram to 19 gram. The relative efficiency was then checked using these sources, by placing coaxially in contact with the detector.

For the study on the effect of source thickness on the detector's efficiency, the standard mixture was filled in plastic containers of 4 cm diameter and various thickness (0.5 cm, 0.75 cm, 1.0 cm and 1.25 cm). Each time the same compression magnitude was used to ensure uniform density between the sources. To check the detector's efficiency, the source was placed in contact and coaxial with the Ge(Li).

4. RESULTS AND DISCUSSION

Figure 2 shows the relative efficiency at the energies of 844 keV and 1779 keV plotted against the respective mass of the source. It can be seen that no appericiable variation of relative efficiency was obtained for the various sample sources studied. Thus, within the rangeof this study, source mass (hence, density) has very little effect upon the detector's relative efficiency.

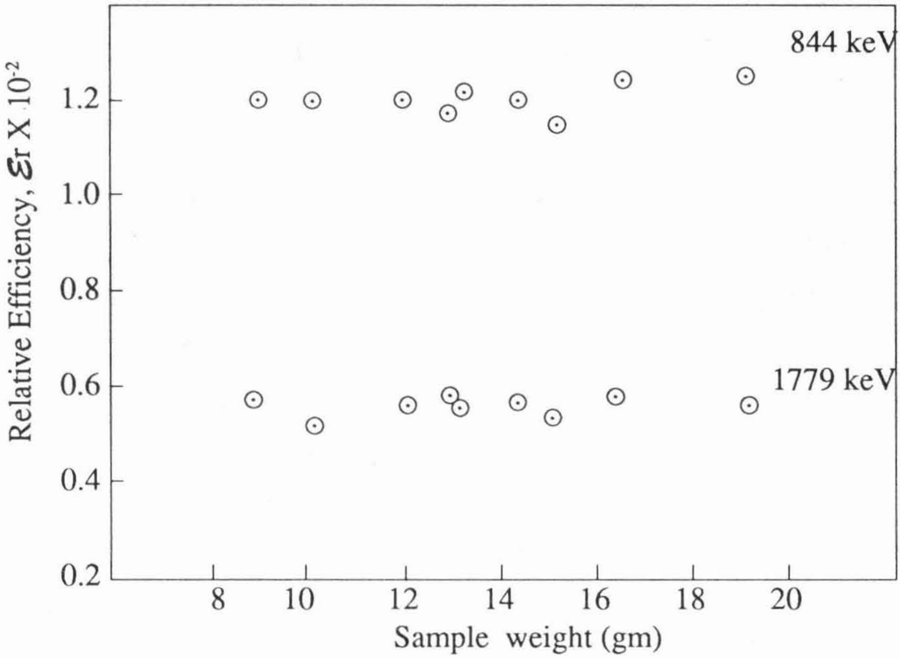

Figure 2 The variation of relative efficiancy of the detector with sample weight at 844 keV and 1778 keV

Figure 3 shows the results of the study on the effect of thickness on the deterctor's relative efficiency. The extrapolated relative efficiency for a thin disc source such as circular foil is also shown. From 200 keV up to around 2 MeV, the graphs are straight lines almost parallel to one another; with increasing relative efficiency as the sources thickness decrease. The gradients and intercepts of the plots ware calculated, and shown in Table 1. These values of intercepts and gradients are equivalent to B(r,l) and m of equation (5), respectively. Knowing these values and using equation (5), the detector's relative detection efficiency for that particular source geometry, at any gamma energy between 200 keV and 2MeV can be calculated.

Finally, from the study it was shown that the effect of sample geometry on a Ge(Li) detector efficiency is an important factor that cannot be neglected if one needs to produce an accurate and reliable results when using gamma spectroscopy. The effect of density, although very little also needs to be appreciated.

Table 1: Values of gradients, (m), and geometrical factors, B(r,l), for different sample thickness

Radius, r = 2 cm			
Thickness, (cm)	m	B(r,l)	Correlation Factor
1.25	-1.07	13.3	0.997
1.0	-1.09	16.2	0.997
0.75	-1.07	17.1	0.997
0.50	-1.08	19.7	0.995
Foil	-1.10	55.5	0.995

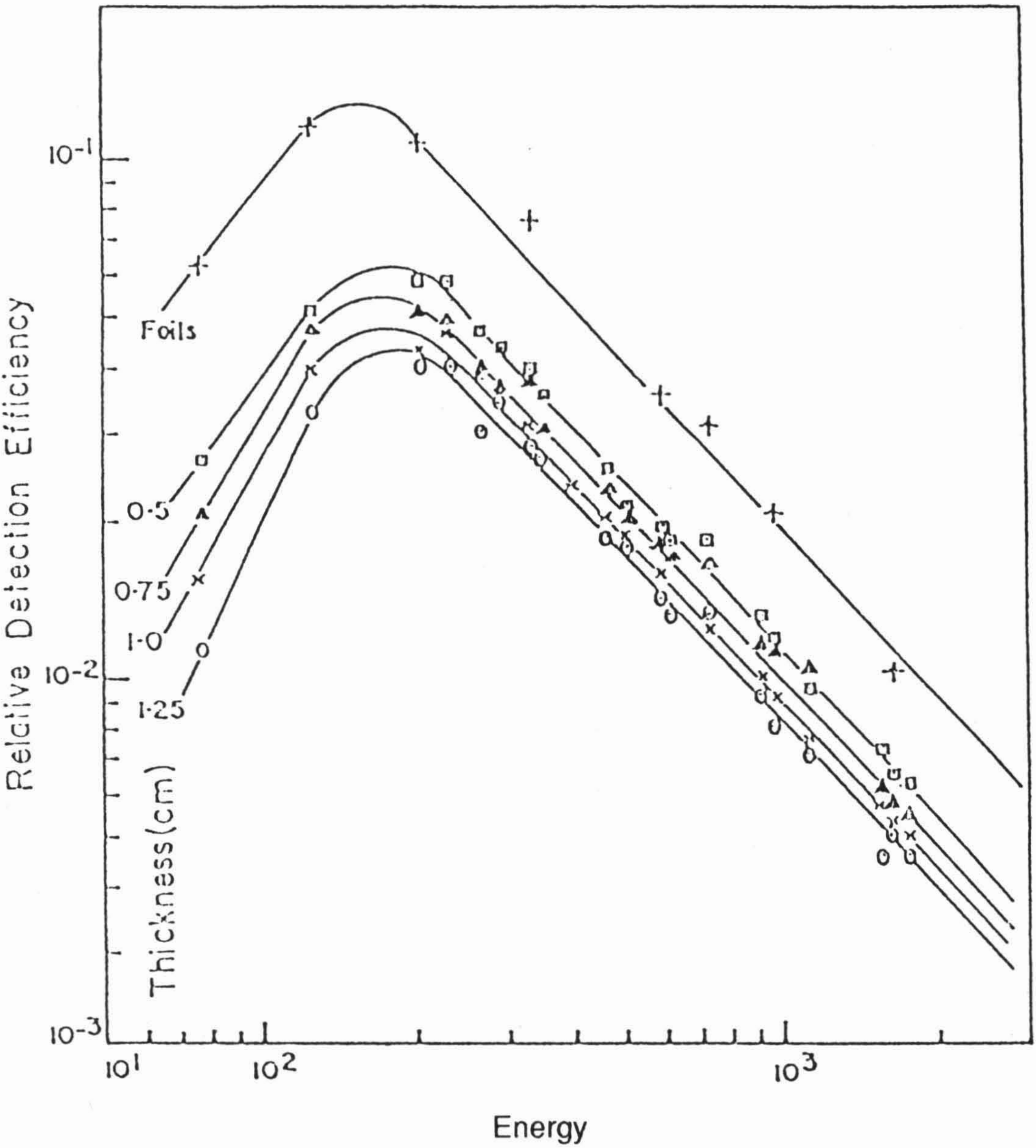

Figure 3: Variation in Gamma-ray Detection Efficiency of the Detector System as a Function of the Thickness of the Calibration Source, (Thorium Ore)

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