c. Increasing the detector-to-source distance results in longer counting times to achieve adequate precision in the counting statistics, as a result of the Inverse Square Law (see Expt. 2.5). What is the other way that the source-to-detector distance significantly affects the accuracy of the relative activity measurement?

EXPERIMENT 3.6. Activity of a Gamma Emitter (Absolute Method)

3.6.1. Purpose

The activity of the radioactive source used in Experiment 3.5 can be determined by the absolute method. The purpose of this experiment is to outline the procedure for this method. Here, the source to be measured will be called U1.

3.6.2. Procedure

1. Place a source U1 (of unknown activity) approximately 10 cm away from the face of the detector.
2. Measure the distance, s, from the middle of the source thickness to the front surface of the NaI(Tl) detector
3. Acquire a spectrum long enough to accumulate at least 10,000 counts in the photopeak, and note the elapsed live time, t_L.
4. Set a region of interest over the photopeak such that all the counts in the peak are included. Record the sum of the counts in the region of interest, Σ_{U1}.
5. Clear the spectrum, remove the source, accumulate background for the same live time, and sum the background, Σ_b, in the same region of interest.
6. Use the following formula to calculate the activity of U1. The units in equation (9) are disintegrations per second.

$$\text{Activity of } U_1 = \left(\frac{\Sigma_{U1} - \Sigma_b}{t_L}\right) \frac{1}{G\varepsilon_p f} \qquad (9)$$

Where

t_L is the live time in seconds,

ε_p is the intrinsic peak efficiency for the gamma-ray energy and detector size used (Fig. 3.7 and ref. 10),

f is the decay fraction of the unknown activity, which is the fraction of the total disintegrations in which the measured gamma ray is emitted (refs. 7 and 8 and Table 3.2)

G = [area of the detector (cm^2)] / [$4\pi s^2$], and

s is the source-to-detector distance in cm.

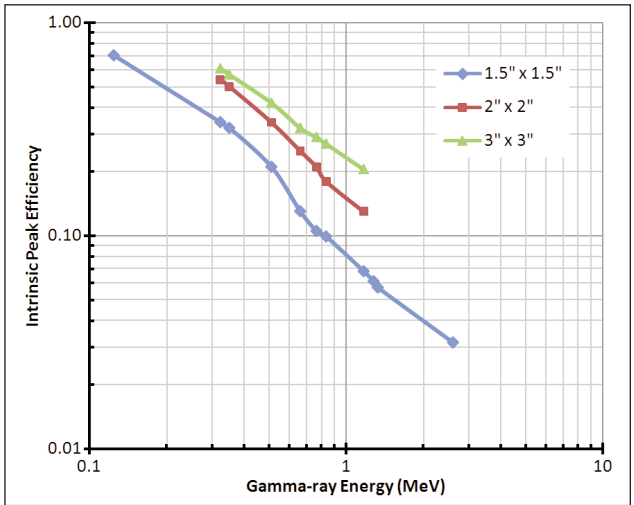

Fig. 3.7. Intrinsic Peak Efficiency of Various NaI(Tl) Crystals vs. Gamma-Ray Energy. Detector to Point-Source Distance is 9.3 cm for the 3-inch x 3-inch and 2-inch x 2-inch crystals and 10 cm for the 1.5-inch x 1.5-inch scintillator.

EXERCISE

a. Convert the activity in disintegrations per second from equation (9) to micro-Curies.

b. Check the nominal activity listed on the label affixed to the source. How closely does your measured activity match the nominal value listed?

c. What is the expected standard deviation in the measured activity due to the number of counts you recorded in the photopeak?

d. Intrinsic photopeak efficiencies are usually documented for a specific source-to-detector distance, and a point source located on the extended center line of the cylindrical scintillator crystal. Why?

e. Placing the source closer to the detector increases the counting rate. How does a smaller source-to-detector distance affect the accuracy of the measurement?

Table 3.2. Gamma Decay Fraction, (f), for some Common Isotopes.

Isotope	Gamma Energy (MeV)	f
^{137}Cs	0.662	0.851
^{51}Cr	0.320	0.0986
^{60}Co	1.173	0.9986
^{60}Co	1.333	0.9986
^{22}Na	1.275	0.9994
^{22}Na	0.511	1.78
^{54}Mn	0.835	0.9998
^{65}Zn	1.116	0.506