An Update on Building 88 Alpha Spectrometer

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1 Update on Alpha Spectrometer

An extra supply of un-activated ORTEC detectors was located in building 88 and two suitable 150 mm^2 A-series detectors were used to replace the contaminated 450 mm^2 A-series detector used in the device previously. The advantage of smaller detectors is that they will give a slightly better energy resolution at the cost of counting efficiency. In a low counting application such as this, the resolution is not quite as important as the counting efficiency. For a 450 mm^2 detector at a height of 1.2 cm (roughly the 10th slot in the chamber) above a circular source with diameter of one inch, efficiency is 11.22%. For a 150 mm^2 detector, efficiecy is 4.31%. Efficiencies were arrived upon based on the following formula presented by Conway [1] for a circular detector parallel to a circular source with G being the geometrical effiencey.

$$G = \frac{R_d}{R_s}\int_0^\infty \frac{J_0(as)J_1(R_d s)J_1(R_s s)}{s} exp(-sh)\,\mathrm{d}s \tag{1}$$

R_d is the detector radius, R_s is the source radius, and h is the height from the detector to the source, and a is the offset of the centers of the source and detector. The above equation was integrated numerically in Mathematica to find the geometrical detector efficiencies. A 150 mm^2 detector was used since it was barely contaminated but a larger detector would be better for our applications. The ideal detector would be an ORTEC ULTRA-AS 450 mm^2 costing roughly $1000. The problem of recoil contamination was addressed by negatively biasing the sample plate. Sill and Olsen [2] state that a negative bias as well as careful control of pressure can greatly reduce the amount of recoil contamination present in the detectors. With the current pump, pressure could not be kept at the recommended 300 $mTorr$ but a pump with electronic pressure control could address this problem. It is worth looking at to reduce recoil

introduced by calibration sources or if counting is done on samples with high levels of ^{228}Th or ^{222}Rn. Of the two located 150 mm^2 detectors, one was found to be slightly contaminated. Without a proper AmGd calibration source, the clean detector, serial number 15-577C, by using a ^{226}Ra source with the dirty detector, serial number 20-784J (Figure 1). A spectrum was obtained and the dirty detector was calibrated. FWHM was found to be about 55 KeV. This number could likely be improved with a better electronic set-up and possibly with a new detector. ^{252}Cf and ^{241}Am sources were counted with both the clean and dirty detectors and a shift of roughly four channels was seen with every peak in the 4500-5500 KeV region (Figures 2 and 3). A shift was applied to the dirty calibration to get the calibration with the clean detector. Although this method will not give a perfect calibration across the whole spectrum, it is close enough to be able to identify peaks in the gold spectrum. Resolution with the clean detector appeared slightly better than the dirty detector.

2 Background in Spectrometer and Counting of Gold Deposition

A 1-inch by 1-inch glass substrate similar to the one the gold was deposited on was then counted for 90 hours (Figure 5). 45 counts were seen giving a rate of $1.39\times10^{-4}\pm2.07\times10^{-5}$ Bq. Then, a 1-inch by 1-inch glass substrate with 6.485 mg of gold deposited on the surface was then counted. This is roughly a 5000 Angstrom thick layer of gold, much thinner than the stopping distance of a 5000 keV alpha particle in gold. This deposition was counted for 120 hours and 66 decays were counted for a rate of $1.53\times10^{-4}\pm1.88\times10^{-5}$ Bq (Figure 6).

In the presentation given to the UCB Bolometer R&D group, an upper limit of the full spectrum alpha radioactivity of gold was given of 845 Bq/Kg. Upon further review, the method used an imperfect approach. A new value of 170.6 Bq/Kg for the upper limit on the radioactivity of gold was obtained using the following method.

Assuming that the total rate of radioactive decay R_t observed by the detector is the background rate, R_b, plus the source rate, R_s

$$R_s = R_t - R_b \tag{2}$$

With standard deviation given by

$$\delta R_s = \sqrt{\delta {R_t}^2 + \delta {R_b}^2} \tag{3}$$

With the values given above for R_t and R_s, we see that

$$R_s = 1.39 \times 10^{-5} \pm 2.80 \times 10^{-5} Bq \tag{4}$$

This value is only the counts seen by the detector however. A geometrical correction using (1) must be made for the actual rate of decay. (1) is limited to finding the geometrical efficiency for a circular source only. To get a more accurate geometrical efficiency for the square source used, the geometrical efficiencies for a circle inscribed in a 1-inch by 1-inch square and a circle with a 1-inch by 1-inch square inscribed inside of it were averaged giving a rough geometrical efficiency of 3.7% for the 1-inch by 1-inch glass substrate. Applying this correction yields a new value of

$$CR_s = 3.68 \times 10^{-4} \pm 7.42 \times 10^{-4} Bq \tag{5}$$

Finally, this value can be converted to Bq per $KgAu$ to give the value of

$$Rate = 56.6 \pm 114 \frac{Bq}{Kg} \tag{6}$$

Obviously, the error in this rate is vastly to high to draw any conclusions about how radioactive gold is. Much longer counting times, a larger detector, and cleaning the chamber to remove any alpha contamination would do yield a better value for the radioactivity of gold.

References

[1] John T. Conway, Generalizations of Ruby's formula for the geometric efficiency of a parallel-disk source and detector system, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Volume 562, Issue 1, 15 June 2006, Pages 146-153, ISSN 0168-9002, 10.1016/j.nima.2006.02.197. (http://www.sciencedirect.com/science/article/pii/S0168900206004906)

[2] C.W. Sill, D.G. Olson, Sources and Prevention of Recoil Contaminations of Solid State Alpha Detectors An. Chem., 42, 1596 (1970).