3.7 Alpha-Particle Counting

3.7.1 *Introduction*

The use of 4π-proportional counters for alpha-particle counting has been treated in Section 3.5, pulse-ionization chambers and ZnS(Ag)-coated scintillation cells in Section 6.1.2.3, silicon surface-barrier detectors and diffused-junction detectors in Section 4.5.3, and liquid-scintillation counters in Sections 3.8, 4.3.8, and 6.1.2.2. The assay of alpha-particle-emitting sources by the methods of 2π proportional and defined-solid-angle counting is the subject of this section. Methods for the calibration of alpha-particle sources by defined-solid-angle counting have been reviewed by Brouns (1968).

3.7.2 *Standardization by 2π Proportional Counting*

The measurement of alpha-emitting radionuclides in 2π geometry requires essentially the measurement with one half of a 4π system, and all considerations in 4π proportional counting apply here equally well.

The source may, however, be electrodeposited or evaporated onto a polished-metal backing that behaves as a semi-infinite medium. Alpha particles, being more massive than electrons, are less easily scattered from the backing, so that the fraction of the alpha particles scattered into the 2π counter is far less than in the case of beta particles. Also, alpha particles are emitted in monoenergetic groups with much higher energies than beta particles, which are characteristically emitted in a spectrum of energies.

Nevertheless, to obtain accuracies comparable to those obtained in 4π counting, scattering and also source self-absorption must be evaluated. In general, such an evaluation can be readily made only for sources of uniform and known thickness.

3.7.3 *Backscattering*

Backscattering, in this section, refers specifically to the effect in which alpha particles, initially moving in the direction of the source mount, are deflected into the sensitive volume of the 2π detector. Many investigators [e.g., Deruytter (1962); Hutchinson *et al.* (1968)] have concluded that the number of backscattered alpha particles is between zero and five percent of the number emitted into 2π steradians, depending on the thickness and uniformity of the source, the atomic number of the mount and source material, and the energy of the alpha particles.

Walker (1965) and others have shown that backscattered alpha particles move predominantly into angles of less than 5° from the plane of the source mount, as a result of *multiple* small-angle scattering primarily due to the nuclear electrostatic field. Large-angle Rutherford scattering occurs in the order of a few times in 10^5 emitted alpha particles, and is, therefore, negligible for almost all 2π counting.

Backscattering increases with increasing atomic number, Z, of the scattering material, as demonstrated in Figure 32, for which 2 μg cm^{-2} collodion films impregnated with ^{210}Po were placed on polished source mounts of a number of materials. The backscattered fraction, f_b, of the total for "weightless" sources is given by:

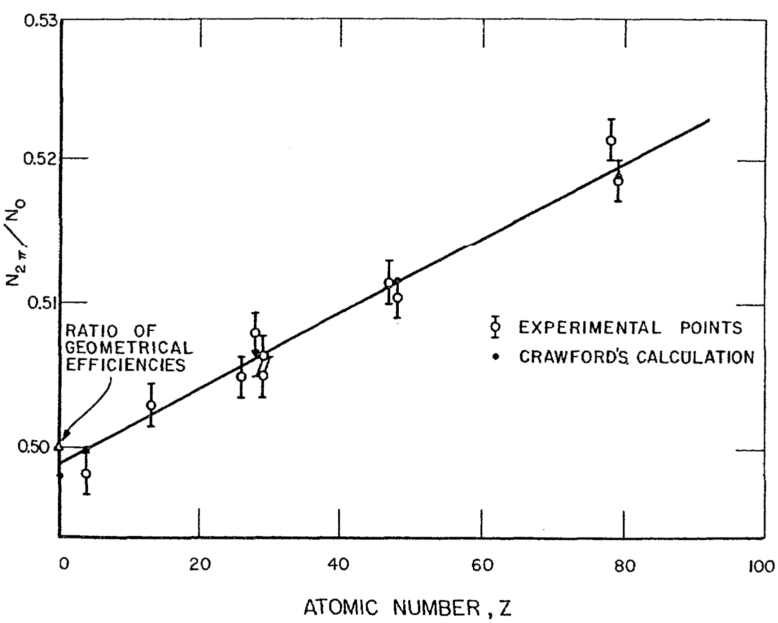

Fig. 32. Counting rate in the NBS 2π α-particle counter divided by N_0 for ^{210}Po sources impregnated in collodion on polished mounts plotted against Z, the atomic number of the backing material. The error bars represent plus and minus one standard error. The solid points are obtained from a relation developed by Crawford (1949). (From Hutchinson *et al.,* 1968)

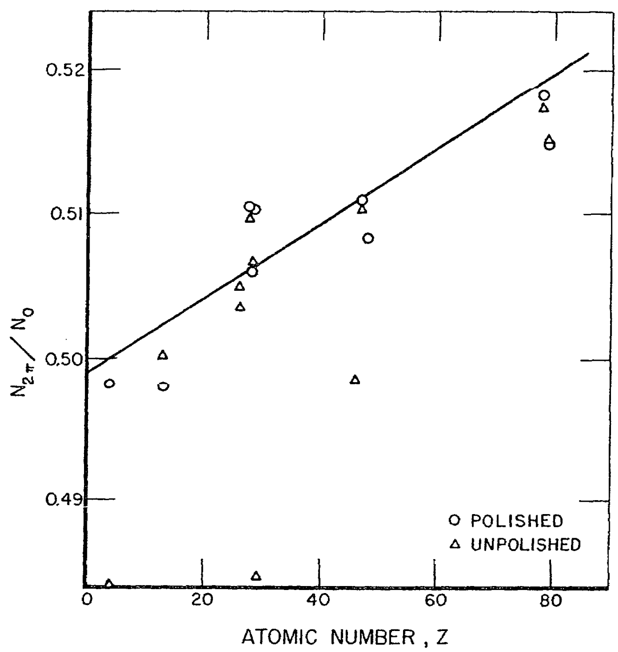

Fig. 33. Counting rate in the NBS 2π α-particle counter divided by N_0, for ^{210}Po sources adsorbed onto polished and unpolished mounts plotted against Z, the atomic number of the backing material.

$$f_b = \frac{N_{2\pi}}{N_0} - 0.5 \qquad (3.27)$$

where $N_{2\pi}$ is the alpha-particle count rate in 2π geometry, and N_0 is the total alpha-particle-emission rate. Figure 33 shows the experimental values of $N_{2\pi}/N_0$ plotted as a function of Z for sources adsorbed onto polished and unpolished mounts, and the large scatter of the points demonstrates the often great effect of even minor surface irregularities on the backscattering.

It has also been shown (Crawford, 1949; Hutchinson *et al.*, 1968) that backscattering varies approximately as $E^{-1/2}$, where E is the alpha-particle energy.

3.7.4 *Source Self-Absorption*

The absorption of alpha particles by the source is primarily a function of the thickness, d_s, of the source and the range, R_s, of the alpha particles in the source material. Thus, several authors [Robinson, H. (1960); Friedlander *et al.* (1964); Gold *et al.* (1968); White (1970)] have shown, both theoretically and experimentally, that for a uniformly thick source, the fraction of alpha particles absorbed by the source increases proportionately to $d_s/2R_s$ for $d_s < R_s$. Figure 34 demonstrates this dependence, which can be calculated from simple geometrical considerations and the assumptions that alpha particles have a well defined range and are not deflected from their initial direction in the source material.

3.7.5 *Calculation of Scattering and Source Self-Absorption*

These last assumptions (Section 3.7.4) represent only first order approximations, and scattering would not occur if they were strictly true.

An expression for $N_{2\pi}/N_0$, for the source configuration shown in Figure 35, is given in Eq. 3.28. A non-radioactive layer of absorber a, thickness d_a, covers an alpha-particle emitting source s, thickness d_s, deposited on a semi-infinite backing material b. Then

$$\frac{N_{2\pi}}{N_0} = \frac{1}{2}\left(1 - \frac{d_a}{R_a} - \frac{d_s}{2R_s}\right) + f_s, \qquad (3.28)$$

where R_a and R_s are the alpha-particle ranges in absorber and source, respectively, and f_s is the scattered fraction. For "weightless" sources and no absorbing material, f_s reduces to f_b, which is the backscattering due to the backing material. These results have been discussed in

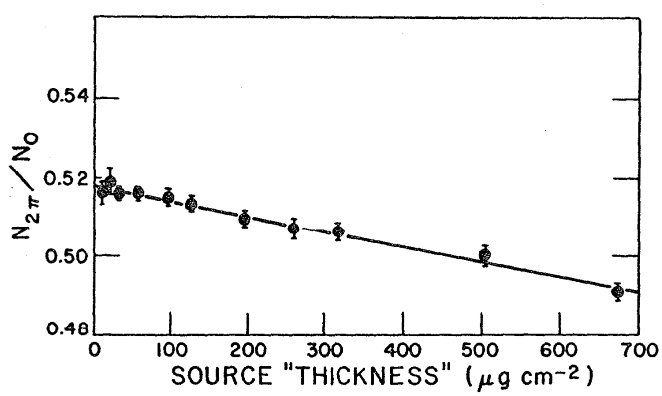

Fig. 34. $N_{2\pi}/N_0$ as a function of surface density in $\mu g\ cm^{-2}$ for UF_4 sources. Error bars are representative of one standard deviation. (From Gold *et al.*, 1968)

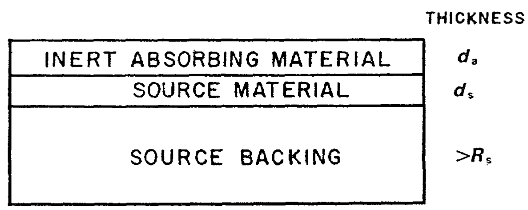

Fig. 35. Schematic illustration of a covered, deposited, alpha-particle source.

Lucas and Hutchinson (1976) and Hutchinson *et al.* (1976a). Figure 36 shows their experimental values and the theoretical curve for $N_{2\pi}/N_0$ *vs.* d_s/R_s for sources of $^{235}UO_2$ deposited on polished platinum.

3.7.6 *The Robinson Counter*

Robinson, H. (1960) has developed a counter, Figure 37, with an accurately defined geometrical efficiency close to 0.8π steradians, for alpha particles emitted in a direction normal to the plane of the source. Multiply scattered alpha particles, essentially all of which are emitted at grazing angles to the source, are not detected. The difficult problem of estimating the backscattering contribution, encountered in 2π counting, is thus avoided. The detector is usually of scintillating plastic, CaF(Eu), ZnS, or CsI(Tl) (Hutchinson *et al.*, 1968), and a baffle at its center is so designed that variations in source positioning of as much as 1 cm result in negligible changes in the overall detection efficiency. Consequently, the counter can be used to measure relatively large low-activity sources with accuracies of approximately 0.5 percent. In this geometry less than 0.2 percent of the counts are lost due to source self-absorption perpendicular to the source, if its thickness is less than 0.25 R_s. Such counters, during operation, are usually evacuated or filled with hydrogen at atmospheric pressure.

The detection efficiency, $\varepsilon_{0.8\pi}$, of the 0.8π counter was deduced from measurements on thin sources with the 2π and 0.8π counters for different values of atomic number, Z, of the backing material (Hutchinson *et al.*, 1968). The 2π count rate, $N_{2\pi}$, divided by the 0.8π count rate, $N_{0.8\pi}$, was plotted as a function of Z, and extrapolated to $Z=0$ where, theoretically, $\varepsilon_{0.8\pi} = N_{0.8\pi}/2N_{2\pi}$.

3.7.7 *Low-Solid-Angle Counters*

As mentioned in Section 1.5.2, the defined low-solid-angle counter, although often just used for relative measurements, has proved to be