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Backscattering of Alpha Particles from Thick Metal Backings as a Function of Atomic Weight

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Alpha-particle backscattering from thick metal backings has been studied using two separate counters with geometries of 2π and approximately 1π steradians.

LA RÉTRO-DISPERSION DES PARTICULES ALPHA DES ADOSSEMENTS DE MÉTAL EPÀIS COMME FONCTION DU POIDS ATOMIQUE

On a étudié la rétro-dispersion des particules alpha des adossements de métal épais en employant deux compteurs séparés ayant des géométries de 2π et d'environ 1π stéradians.

ОБРАТНОЕ РАССЕЯНИЕ АЛЬФА-ЧАСТИЦ ИЗ ТОЛСТЫХ МЕТАЛЛИЧЕСКИХ ПОДКЛАДОК КАК ФУНКЦИЯ АТОМНОГО ВЕСА

Изучалось обратное рассеяние альфа-частиц из толстых металлических подкладок применяя два отдельных счетчика с геометрией 2π и приблизительно 1π стерадианы.

RUCKSTREUUNG VON ALPHATEILCHEN AUS DICKEN METALLBELAGE ALS FUNKTION DES ATOMGEWICHTES

Die Alphateilchenrückstreuung aus dicken Metallbelägen wurde unter Benutzung von zwei getrennten Zählern mit einer Geometrie von 2π und von etwa 1π Steradian untersucht.

1. INTRODUCTION

Very little theoretical or experimental work related to α-particle backscattering from thick metal backings, on which thin sources are deposited, has appeared in the literature. From the standpoint of radioactive source calibration, such studies are useful for relating α-particle emission rates including backscattering into a 2π geometry, to the total disintegration rate of the source. Jaffey[1] and Walker[2] have shown that backscattered α-particles come off predominantly at small angles with respect to the plane of the source. The tacit acceptance of this fact led to the development in 1960 of the "$1\pi\alpha$" counter by Robinson[3], which was designed for the purpose of making absolute calibrations of thin solid α-particle sources, on metal backings, which measurements would be free from error due to the backscattering of α-particles at small angles to the metal surface. (Although the counter is referred to as a "$1\pi\alpha$" counter, the solid angle subtended from the source position is $2\pi/2{\cdot}531$ steradians, based on the dimensions of the counter.)

The National Bureau of Standards has, for nearly 20 years, been issuing such solid α-particle standards which have been calibrated in a 2π proportional counter. It was realized that the calibrations of such sources, on monel, should be corrected by about 2 percent for backscattering, for the radionuclides used, to give the actual disintegration rates, although the effect might also have been slightly compensated for by some self-absorption in the solids of the source.

Some two years ago it was decided to develop a "$1\pi\alpha$" counter, following the design of Robinson[3], with some modifications, in order to improve the accuracy of the alpha-particle standards issued by the National Bureau of Standards. This brief paper is to report on the design of that counter, and also to describe some comparative measurements carried out with the NBS "$1\pi\alpha$" and $2\pi\alpha$ counters. These measurements give directly the magnitude of the backscattering correction which users of the older standards may wish to incorporate into their calibrations, and also a measured value for the geometrical efficiency of the counter.

The comparative measurements consisted of counting a group of sources on various source mount materials first in one counter and then in the other and determining the ratio of the rates for each source. The results can be analysed as follows.

The number of α-particles emitted into the $2\pi\alpha$ counter, $N_{2\pi}$, is composed of those directly emitted, $N_0/2$, where N_0 is the total α-emission rate of the source, and those backscattered from the source backing $(N_0/2)B$, where B is the probability that if a particle is emitted downward it will be backscattered. The number of α-particles detected in the "$1\pi\alpha$" counter is N_π. Thus the ratio of the counting rates into the $2\pi\alpha$ to the "$1\pi\alpha$" counter is:

$$\frac{N_{2\pi}}{N_\pi} = K(1 + B) \qquad (1)$$

where K is the ratio of the geometrical efficiency of the 2π to the "$1\pi\alpha$" counter. B depends upon the backing material and the initial energy of the emitted α-particle.

In the experiment described here, measurements were performed for ten different backing materials. Using equation (1), K and B were determined by means of a least squares fit. It was also found, however, that the effect of the backing material on α-particle backscattering was critically dependent on whether the α-particle source material, the chloride of polonium-210, was adsorbed on to a polished surface or whether the source was held in a collodion film deposited on the surface.

2. EXPERIMENTAL ARRANGEMENT AND PROCEDURE

The two counters used in the experiment were:

(a) 2π *counter*

TEMMER and WYCKOFF[4] and WALKER[2] have described the 2π counter. It is a gas-flow proportional counter with hemispherical inner wall with a 4-in. radius. The counting gas is 90 percent argon, 10 percent methane mixture. Sources were placed in the counter, and discrimination plateaus were taken.

(b) "$1\pi\alpha$" *counter*

The "$1\pi\alpha$" counter, shown schematically in Fig. 1, is essentially of the same design and dimensions as described by ROBINSON[3]. Instead of zinc sulphide, however, a 0·020 in.-thick disc of plastic scintillator was mounted on a 5 in.-dia. electronmultiplier phototube, which was positioned approximately 2 in. from the source. As in Robinson's counter, a baffle was located in the center of the disc scintillator and was of such a shape and size that small inaccuracies in source positioning cause negligible changes in the solid angle subtended by the detector. The two important modifications that have been made are (1) the use of the plastic scintillator in the place of zinc sulphide for α-particle detection; and (2) instead of evacuating the chamber, the air is displaced by hydrogen gas. The advantage of the plastic scintillator is that it is easy to mount, although it was necessary to use optical coupling glue (R313) because, when silicone grease was used, small bubbles were found after a period of several weeks, between the detector and phototube. The disadvantages, compared to the zinc sulphide screen, which were unimportant in our application, are increased gamma-ray and β-particle efficiency, and lower light output. The advantage of flowing hydrogen gas through the system is that it is at all times at atmospheric pressure. The expense and complications associated with a vacuum system are thus avoided. A drawback of the hydrogen system is that there is approximately a 1-MeV energy loss for some alpha-particles in traversing the hydrogen, which causes a reduction in pulse height and a shortening of the plateau. A thin but optically reflecting layer of aluminium was evaporated onto the surface of the detector to prevent detection of unwanted scintillations from the gas.

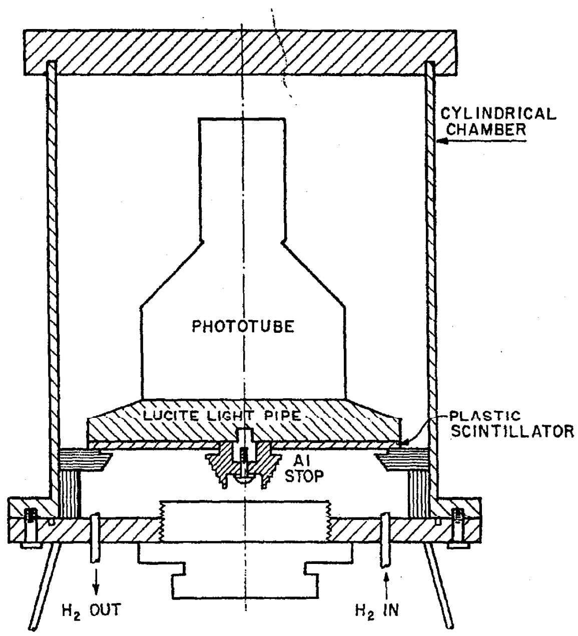

FIG. 1. Schematic diagram of "$1\pi\alpha$" counter.

When these modifications were made, discrimination plateaus with slopes less than 0·1 percent from 30–70 V in the amplifier output were obtained, which were considered satisfactory.

The count rates, as functions of vertical and horizontal displacements, respectively, of the source mount are shown in Figs. 2 and 3.

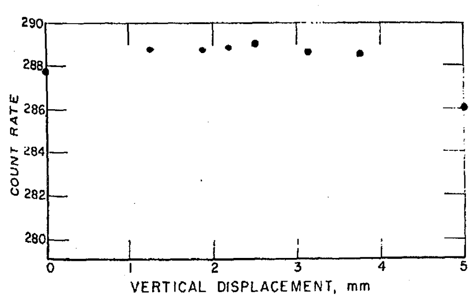

FIG. 2. Count rate versus vertical displacement.

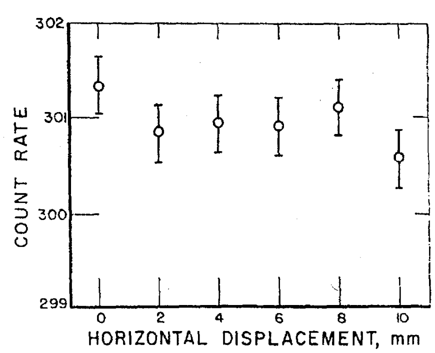

FIG. 3. Count rate versus horizontal displacement.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Data have been obtained from two groups of sources, namely, (1) those adsorbed on to unpolished and highly polished backings, and

TABLE 1. Ratio of counting rate in 2π counter to rate in "$1\pi\alpha$" counter for different mounting materials

Source mount	Effective atomic mass number A	Po^{210} on unpolished mount	Po^{210} on polished mount	Po^{210} in collodion on polished mount
Beryllium	9·02	2·453	2·521	2·522
Aluminum	26·98	2·532	2·520	2·545
Stainless steel	55·27	2·548	—	2·555
Iron	55·84	2·555	—	—
Nickel	58·71	2·563	2·560	—
Monel	60·11	2·579	2·583	2·570
Brass	63·84	—	—	2·562
Copper	63·57	2·454	2·582	2·557
Palladium	106·7	2·523	—	—
Silver	107·88	2·582	2·585	2·587
Cadmium	112·41	—	2·572	2·582
Platinum	195·09	2·617	2·621	2·637
Gold	197·0	2·606	2·604	2·623

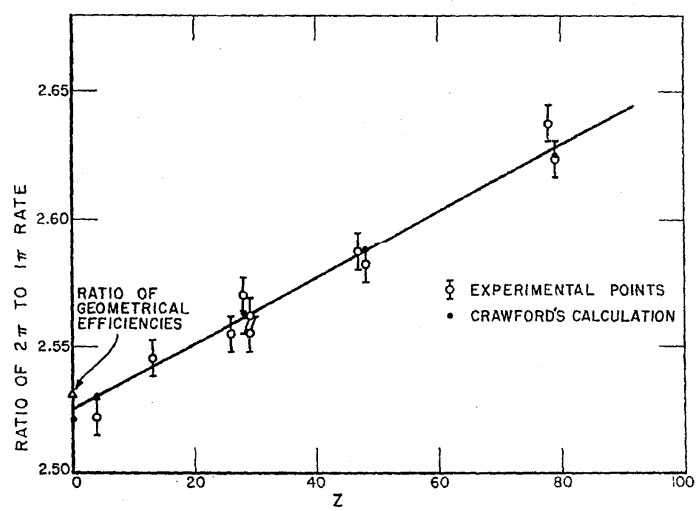

FIG. 4. Counting rate in 2π counter divided by counting rate in "$1\pi\alpha$" counter for Po^{210} sources impregnated in collodion on polished mounts plotted against Z. Points from Crawford's calculation, indicated by ●, are seen to agree with the experimental points.

(2) sources consisting of a collodion solution of polonium-210 deposited in a thin layer on to highly polished metal backings. The results for the two groups are given in Table 1.

In Fig. 4, values of $N_{2\pi}/N_{\pi}$ for group (2), are plotted as a function of Z. A least squares fit was made to the points using equation 1, where B is assumed to have the form:

$$B = b_1 Z \qquad (2)$$

b_1 is a constant. Values of K and b_1 were determined by means of the fit to be $2{\cdot}525 \pm 0{\cdot}002$ and $(1{\cdot}30 \pm 0{\cdot}08)10^{-3}$ respectively. The quoted errors correspond to the estimated

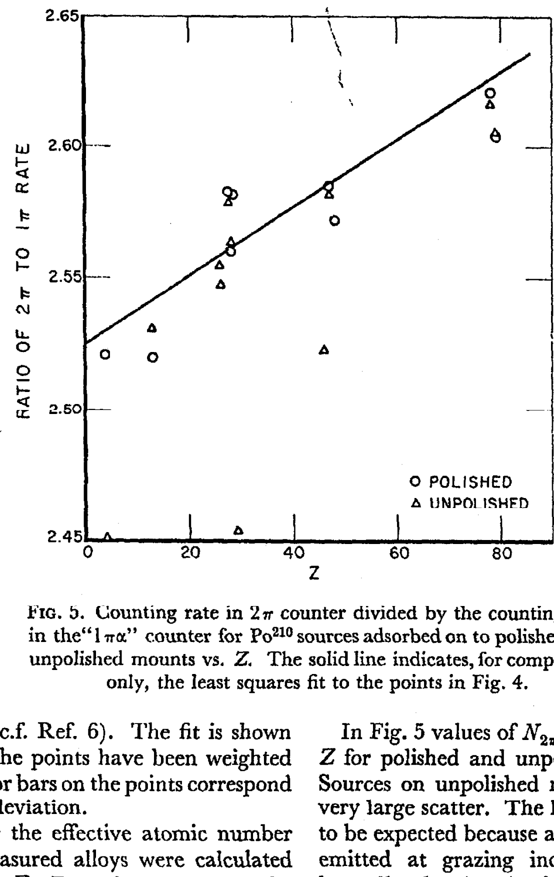

FIG. 5. Counting rate in 2π counter divided by the counting rate in the "$1\pi\alpha$" counter for Po^{210} sources adsorbed on to polished and unpolished mounts vs. Z. The solid line indicates, for comparison only, the least squares fit to the points in Fig. 4.

standard errors (c.f. Ref. 6). The fit is shown in Fig. 4 where the points have been weighted equally. The error bars on the points correspond to one standard deviation.

The values for the effective atomic number for the three measured alloys were calculated using $Z_{\text{effective}} = \Sigma n_i Z_i$, where n_i are the atomic fractions of the elements whose atomic numbers are Z_i.

The only theoretical calculation in the literature of B is by CRAWFORD[5], who derived the following relationship:

$$B = b_2 \left[\frac{\Sigma n_i A_i^2}{\Sigma n_i A_i^{1/2}}\right]^{1/2} \qquad (3)$$

where b_2 is a constant and A_i are the atomic weights of the constituents.

Values of $N_{2\pi}/N_\pi$ obtained using Crawford's theory, in which his calculated values of B have been multiplied by 1·05, are seen to agree with the data.

In Fig. 5 values of $N_{2\pi}/N_\pi$ are plotted against Z for polished and unpolished source mounts. Sources on unpolished metal backings show a very large scatter. The latter result is probably to be expected because absorption of α-particles emitted at grazing incidence may be haphazardly absorbed in the minute craters of an irregular surface.

The results from the polished surfaces without collodion show an unexpectedly large spread. It is possible that, even in polished surfaces, significant irregularities still exist so that by putting the polonium chloride in a collodion film which remains just above the surface, the result, seen in Fig. 4, could be to smooth out the effects of the irregularities.

It is clear that more research is needed to clarify the problem of surface effects, but a least squares extrapolation obtained from the results in Fig. 4 is sufficient to justify confidence in the calculated geometrical efficiency of the new National Bureau of Standards "$1\pi\alpha$" counter.

CONCLUSIONS

(i) A new "$1\pi\alpha$" counter has been constructed using a plastic scintillator and a hydrogen gas atmosphere which gives reproducible results on thin sources to a precision of $\pm 0 \cdot 1$ percent.

(ii) The accuracy of the geometrical factor for the new counter has been checked to $\pm 0 \cdot 3$ percent using a procedure of extrapolating $N_{2\pi}/N_{\pi}$ to $Z = 0$.

(iii) It is deduced that small angle backscattering from thick metal backings is predominantly a multiple scattering phenomenon. The results shown in Fig. 4 show that the data are consistent with Crawford's calculation both as to functional dependence of B on A and the magnitude of B.

(iv) Surface effects cannot be removed merely by electroplating on to polished surfaces as demonstrated by Fig. 5.

(v) Measurements using unpolished mounts show that, in some cases, surface effects are as large as backscattering effects.

(vi) Values of K and b_1 were determined.

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REFERENCES

1. Jaffey A. H. private communication.
2. Walker D. H. *Int. J. appl. Radiat. Isotopes* **16**, 183 (1965).
3. Robinson H. P. *The Metrology of Radionuclides*, p. 147, International Atomic Energy Agency, Vienna (1960).
4. Temmer G. M. and Wyckoff J. M. *Phys. Rev.* **92**, 913 (1953).
5. Crawford J. A. *Theoretical Calculations Concerning Back-scattering of Alpha Particles*, edited by Glenn T. Seaborg *et al.* in *The Transuranium Elements*, National Nuclear Energy Series, Manhattan Project Technical Section, Division IV-Plutonium Project Record, Vol. 14. Part II, p. 1307, McGraw-Hill, New York (1949).
6. Ku H. H. Statistical Concepts in Metrology, in American Society of Tool and Manufacturing Engineers, *Handbook of Industrial Metrology*, p. 53, Prentice-Hall, New York (1967).