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 $2\pi$ and approximately $1\pi$ steradians

LA RÉTRO-DISPERSION DES PARTICULES ALPHA DES ADOSSEMENTS DE MÉTAL ÉPAIS 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 $2\pi$ et d'environ $1\pi$ stéradians.

ОБРАТНОЕ РАССЕЯНИЕ АЛФА-ЧАСТИЦ ИЗ ТОЛСТЫХ МЕТАЛЛИЧЕСКИХ ПОДСЛОДОК КАК ФУНКЦИЯ АТОМНОГО ВЕСА

Исследовано обратное рассеяние альфа-частиц из толстых металлических подкладок различными счетчиками с геометрией $2\pi$ и примерно $1\pi$ стерадиан.

RÜCKSTREUUNG VON ALPHATEILCHEN AUS DICKEN METALLBELÄGEN ALS FUNKTION DES ATOMGEWICHTE

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

1. INTRODUCTION

Very little theoretical or experimental work related to $\alpha$-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 $\alpha$-particle emission rates including backscattering into a $2\pi$ geometry, to the total disintegration rate of the source. JAFFE(1) and WALKER(2) have shown that backscattered $\alpha$-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 $\alpha$-particle sources, on metal backings, which measurements would be free from error due to the backscattering of $\alpha$-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 $2\pi/2-531$ steradians, based on the dimensions of the counter.)

The National Bureau of Standards has, for nearly 20 years, been issuing such solid $\alpha$-particle standards which have been calibrated in a $2\pi$ 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 "1πα" and 2πα 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 2πα counter, \( N_{2πα} \), 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 a particle is emitted downward it will be backscattered. The number of α-particles detected in the "1πα" counter is \( N_{1πα} \). Thus the ratio of the counting rates into the 2πα to the "1πα" counter is:

\[
\frac{N_{2πα}}{N_{1πα}} = \frac{1 + D}{2}
\]

where \( K \) is the ratio of the geometrical efficiency of the 2πα to the "1πα" 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) 2πα counter

Temmer and Wyckoff\(^{41}\) and Walker\(^{43}\) have described the 2πα 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) "1πα" counter

The "1πα" counter, shown schematically in Fig. 1, is essentially of the same design and dimensions as described by Robinson\(^{39}\). Instead of zinc sulphide, however, a 0.020-in. thick disc of plastic scintillator was mounted on a 5-in.-dia. electron multiplier 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 gammaray 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 α-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.
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.

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 "1π" counter for different mounting materials

<table>
<thead>
<tr>
<th>Source mount</th>
<th>Effective atomic mass number (A)</th>
<th>(^{210}\text{Po}) on unpolished mount</th>
<th>(^{210}\text{Po}) on polished mount</th>
<th>(^{210}\text{Po}) in collodion on polished mount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beryllium</td>
<td>9-02</td>
<td>2-453</td>
<td>2-521</td>
<td>2-522</td>
</tr>
<tr>
<td>Aluminum</td>
<td>26-98</td>
<td>2-532</td>
<td>2-520</td>
<td>2-545</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>55-27</td>
<td>2-546</td>
<td>—</td>
<td>2-555</td>
</tr>
<tr>
<td>Iron</td>
<td>55-84</td>
<td>2-555</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Nickel</td>
<td>58-71</td>
<td>2-563</td>
<td>2-560</td>
<td>—</td>
</tr>
<tr>
<td>Monel</td>
<td>60-11</td>
<td>2-579</td>
<td>2-583</td>
<td>2-570</td>
</tr>
<tr>
<td>Brass</td>
<td>63-84</td>
<td>—</td>
<td>—</td>
<td>2-562</td>
</tr>
<tr>
<td>Copper</td>
<td>63-57</td>
<td>2-454</td>
<td>2-502</td>
<td>2-557</td>
</tr>
<tr>
<td>Palladium</td>
<td>106-7</td>
<td>2-523</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Silver</td>
<td>107-80</td>
<td>2-582</td>
<td>2-585</td>
<td>2-587</td>
</tr>
<tr>
<td>Cadmium</td>
<td>112-41</td>
<td>—</td>
<td>2-572</td>
<td>2-582</td>
</tr>
<tr>
<td>Platinum</td>
<td>195-09</td>
<td>2-617</td>
<td>2-621</td>
<td>2-637</td>
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<tr>
<td>C-14</td>
<td>107-0</td>
<td>2-606</td>
<td>2-604</td>
<td>2-628</td>
</tr>
</tbody>
</table>

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

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 \(N_{2\pi}/N_{1\pi}\) 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:

\[
B = \beta Z
\]  

(2) \(\beta\) is a constant. Values of \(K\) and \(\beta\) were determined by means of the fit to be \(2.525 \pm 0.002\) and \((1.50 \pm 0.08) \times 10^{-4}\) respectively. The quoted errors correspond to the estimated
Backscattering of alpha particles from thick metal backings as a function of atomic weight

![Graph showing backscattering ratio as a function of atomic weight.](image)

FIG. 5. Counting rate in 2π counter divided by the counting rate in the "1πa" 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 \(Z_{\text{eff}} = \sum n_i Z_i\), 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\(^{(a)}\), who derived the following relationship:

\[
B = b_2 \left[ \frac{\sum n_i A_i^2}{\sum n_i A_i} \right]^{1/2}
\]

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

Values of \(N_{\text{pol}}/N_e\) 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 \(N_{\text{pol}}/N_e\) 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 \(a\)-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 "1πa" counter.
CONCLUSIONS

(i) A new "1-m" counter has been constructed using a plastic scintillator and a hydrogen gas atmosphere which gives reproducible results on thin sources to a precision of ±0.1 percent.

(ii) The accuracy of the geometrical factor for the new counter has been checked to ±0.3 percent using a procedure of extrapolating \( N_{2d}/N_s \) 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.

Acknowledgement—The authors wish to thank Dr. H. P. Robinson of the Lawrence Radiation Laboratory of the University of California for providing drawings of his "1-m" counter, and also for carrying out intercomparative measurements on a polonium-210 source without collodion on polished monel, which agreed with ours to within 0.3 percent.

REFERENCES

1. **Jaffey A. H.** Private communication.