

greatest number of cases, even a little below the solidification temperature cracks were formed in the disk, thus falsifying the measurements and causing an illusory increase of resistance. In the luckiest cases the resistance at the temperature of the liquid air was found to be almost equal to that of the solid just below the solidification point.

There was still the possibility that the solid resistance was much lower than the one measured with this method, because of the resistances in the contacts. Therefore measurements with a potentiometer method were carried out. The resistance of the solid also was always found with this method and so in all our experiments the phenomenon of superconductivity was absent. On the other hand, the fact which we demonstrated, that the sudden decrease of resistance occurs just at the solidification point, induces us to think rather of a phenomenon depending just on the change of state, than of a phenomenon of superconductivity.

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### Relative Abundance of the Copper Isotopes and the Suitability of the Photometric Method for Detecting Small Variations in Isotopic Abundance

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USING a Dempster double-focusing mass spectrograph,<sup>1</sup> the abundance ratio of the two copper isotopes was determined photometrically with a view to ascertaining the value of the method in detecting small variations in isotopic abundances. Following the general method of Mattauch and Ewald,<sup>2,3</sup> the blackening curve of Ilford Q11 plates was obtained by using as standards the isotopes of zinc, which have been accurately measured by Nier.<sup>4</sup> A brass rod served as one of the electrodes in a Dempster spark source<sup>5</sup> and provided both zinc and copper ions. The intensities of the mass spectrum lines were measured with a microphotometer, and a blackening curve was drawn for each photographic plate. On most plates there were more than one exposure and, in these cases, the blackening curve was drawn with considerable certainty.

The values of the ratio  $\text{Cu}^{63}/\text{Cu}^{65}$  obtained by measurement of twenty-one mass spectra are listed below:

2.258	2.335	2.242	2.284	2.135
2.292	2.433	2.160	2.342	2.400
2.296	2.215	2.010	2.425	2.392
2.145	2.370	2.342	2.362	2.230
		2.142		

These data lead to a mean value of the ratio  $\text{Cu}^{63}/\text{Cu}^{65} = 2.277 \pm 0.017$ , the probable error being based on the internal consistency of the experimental results. The manner in which the present blackening curves were obtained, namely, in most cases by use of two or more zinc spectra of varying intensity, tended to cancel out small errors in

the presumed abundance of the zinc standard. Consequently the isotopic constitution of copper is  $\text{Cu}^{63} = 69.48 \pm 0.16$  percent and  $\text{Cu}^{65} = 30.52 \pm 0.16$  percent. Flugge and Mattauch<sup>6</sup> give a value for the packing fraction of  $\text{Cu}^{63} = -8.13 \pm 0.10 \times 10^{-4}$ , while Duckworth<sup>7</sup> gives  $\langle f \rangle_{\text{AV}}$  for  $\text{Cu}^{63}$  and  $\text{Cu}^{65}$  to be  $-7.92 \pm 0.25 \times 10^{-4}$ . Assigning a value of  $f = -8.03 \pm 0.10 \times 10^{-4}$  to both copper isotopes, and using the ratio given above, namely,  $2.277 \pm 0.017$ , one obtains a chemical atomic weight of  $63.542 \pm 0.006$ . This is not in very good agreement with the accepted chemical atomic weight<sup>8</sup> of 63.57 but does agree splendidly with the recent value of 63.542 obtained by Hönigschmid and Johannsen.<sup>9</sup> Ewald's latest value<sup>3</sup> for the  $\text{Cu}^{63}/\text{Cu}^{65}$  ratio is  $2.330 \pm 0.032$ .

Some remarks should be made regarding the efficacy of the method for detecting small variations from the natural abundance. If enough of the sample material is available to make, say, ten determinations of the type described above, the probable error in the ratio would be of the order of 0.020. Since there is associated with the natural ratio a probable error of 0.017, variations would "probably" (used in the probable error sense) be real if they exceeded  $0.037/2.277 = 0.016$  of the natural ratio. As the measured ratios diverged still further from the natural value, the certainty of the variation being a real one would increase in the statistical manner. With the present accuracy the method would not be useful for variations from the natural abundance of less than about one-half percent.

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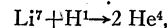
<sup>9</sup> O. Hönigschmid and T. Johannsen, *Naturwiss.* **31**, 548 (1943).

### Angular Distribution of the $\text{Li}^7(p, \alpha)\alpha$ Reaction

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MEASUREMENTS of the angular distribution of the 8-cm alpha-particles produced in the reaction



have been made for the range of proton energy from 400 to 1400 kev. Approximate agreement with previous work<sup>1,2</sup> up to 900 kev is observed, but there is only a gradual decrease in the asymmetry from 800 to 1400 kev.

The apparatus used was a scattering camera,<sup>3</sup> similar in principle to that described by Chadwick, *et al.*,<sup>4</sup> using photographic detection of the emitted alpha-particles. Figure 1 shows the apparatus schematically. The  $2'' \times 4''$

Eastman fine-grain alpha-particle plates were located close to the target, the center of which was 15.1 mm from the plane of the surface of the emulsion. The paths of the alpha-particles which struck the emulsion along a circular arc at 50 mm from the target extended over a continuous angular range of  $25^\circ$  to  $155^\circ$  to the direction of the incident beam. The target surface was at  $22^\circ$  to the proton beam, which was  $3/32'' \times 1/16''$  in cross section, making a target area of  $3/32'' \times 5/32''$ . An aluminum foil separated the target from the photographic plate to stop protons scattered from the target.

All the data were taken with a single thin target, consisting of a 20-kev thick coating of LiOH (measured parallel to proton beam), on beryllium metal. Beryllium was used in order to minimize x-ray emission from the target backing.<sup>5</sup> Preliminary data on a clean beryllium target showed only a very weak production of long range particles, probably caused by low energy deuteron contamination of the proton beam. The yield of these was too low to interfere with the measurements on the 8-cm Li alphas, and the occasional proton tracks could usually be recognized by their longer range and lower grain density, and ignored in counting the alpha-tracks.

The alpha-particle yield as a function of angle was obtained by counting individual tracks in the emulsion, using a microscope with a mechanical stage with micrometer screw. A total of 3000–10,000 tracks were counted on each plate, at 12–24 different angular positions, in equal plate areas (usually  $0.8 \text{ mm}^2$ ), along a circular arc at 50 mm from the target. The counts were corrected to equal solid angles from the target in center-of-mass coordinates, and the observed angles corrected to center-of-mass coordinates.

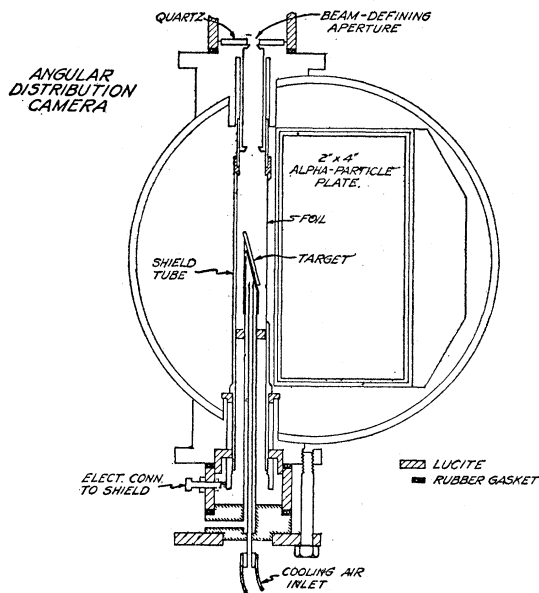


FIG. 1. Semi-schematic drawing of scattering camera. Most of the exposures were made after changing to a curved foil holder, to make the thickness more nearly the same at all angles.

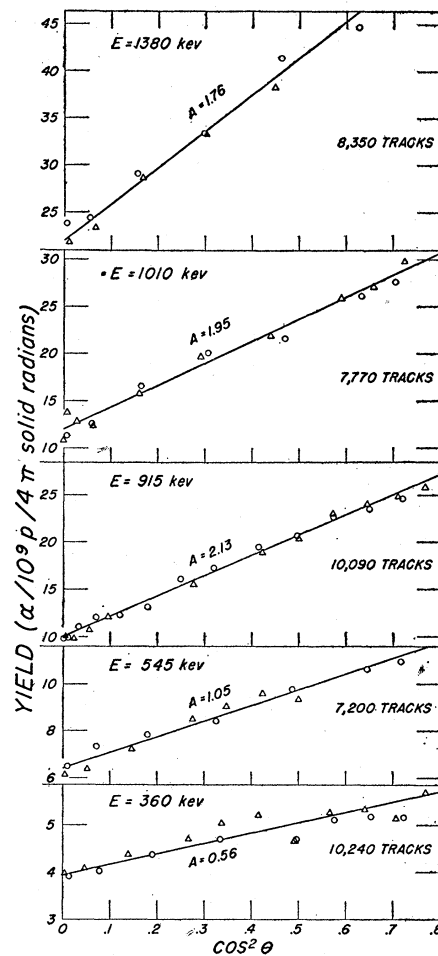


FIG. 2. Some of the observed angular distribution functions, in center-of-mass coordinates. Total number of tracks counted for each curve are given. Fractional P.E. of each point is roughly  $0.7(n/N)^{1/2}$  where  $n$  is No. of points;  $N$  is No. of tracks.

The proton charge to the target on each run was measured, so that the yield per proton could be calculated from the track density and the geometry of the arrangement.

Angular distribution functions at several different energies are shown in Fig. 2. The distribution is of the form:

$$Y(\theta, E) = Y_0(E) [1 + A(E) \cos^2 \theta],$$

where  $Y(\theta, E)$  is the yield per unit solid angle, at an angle  $\theta$  in the center-of-mass system with respect to the direction of the incident protons, and at a proton energy,  $E$ , measured in the laboratory system.  $Y_0(E)$  is the  $90^\circ$  yield function. The unit solid angle used for the yield data is a sphere, so that the total yield over the sphere is given by  $Y_0(1+A/3)$ .

Figure 3 shows the function  $A(E)$ , obtained from 13 such curves, at various proton energies. Although Swartz, *et al.*,<sup>2</sup> indicated a fairly sharp maximum in  $A$  at about 700 keV, we have found only a gradual decrease above 900 keV. The value of  $A$  reaches the same maximum

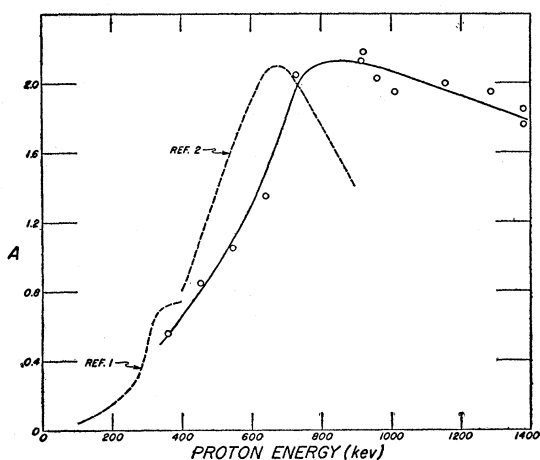


FIG. 3. Coefficient of  $\cos^2\theta$  term in the angular distribution as a function of proton energy. Solid curve is fitted to our data. Dashed curves are previously published results (references 1 and 2).

observed by Swartz, *et al.*, but does not appear to change rapidly between 800–1400 keV.

The data which we obtained on yield per proton as a function of energy are not particularly accurate, but show

no indication of any resonance, at  $90^\circ$ ,  $180^\circ$ , or in total yield over the sphere, in the region up to 1400 keV. The  $90^\circ$  yield is a linearly increasing function up to 1400 keV in essential agreement with previous results<sup>6,7</sup> up to 1000 keV.

Dr. R. F. Christy has made some calculations to relate these data on the angular distribution with the magnitude and energy dependence of the total cross section, in terms of the dispersion theory. Although the cross section is not accurately known above 0.2 Mev, it seems to show no pronounced indication of resonance from 0 to 1.4 Mev. A reasonable fit of the data is obtained with two resonances having  $\Gamma=1$  Mev at 0 and 1.8 Mev roughly. The latter is taken to have  $J=2$ , but the former may be  $J=0$  or  $J=2$ . If  $\sigma$  is normalized by the measurement of Haworth and King,<sup>8</sup> the proton width agrees well with that derived from the  $\gamma$ -ray resonance at 0.44 Mev only if the 0 energy resonance has also  $J=2$ .

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