which the group structure occurs (about 1.9 Mev), is appreciably smaller than that reported by Cohen. Furthermore, Cohen and Rubin[9] show only a very weak effect in Ta and Gd at 45°. Our data at 30° indicate that the 3-Mev peak in Ta is about as pronounced as the one for Au. The Gd peak is certainly present, even though it is less pronounced than some of the others. It is to be noted that both Rh and Ag produce a very pronounced second peak at about 5 Mev excitation. Tomasini[10] has proposed an explanation for the occurrence of the anomalous peak. His formula can predict the second peak successfully also. However, Tomasini's treatment seems to give a shift in excitation energy of the residual nucleus as a function of angle, which is not observed experimentally. Also, Tomasini predicts that "anomalous" scattering should not occur for Gd.

[9] B. L. Cohen and A. G. Rubin, Phys. Rev. 111, 1568 (1958).
[10] A. Tomasini, Nuovo cimento 6, 927 (1957).

ACKNOWLEDGMENTS

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Elastic Scattering of 21.6-Mev Deuterons by Separated Isotopes of Nickel and Copper*

J. L. Yntema
Argonne National Laboratory, Lemont, Illinois
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The relative differential cross sections for the elastic scattering of 21.6-Mev deuterons by Ni^{58}, Ni^{60}, Cu^{63}, and Cu^{65} have been measured. The diffraction pattern shows a shift with atomic number. The shift from Ni^{58} to Ni^{60} is about the same as the one between Cu^{63} and Cu^{65}. The shift between Ni^{63} and Cu^{63} is about 1.5 times that of the others.

I. INTRODUCTION

THE elastic scattering of charged particles by nuclei in the neighborhood of nickel has indicated in some cases a rather abrupt change in the angular distribution. In the experiments by Waldorf and Wall[1] and Dayton and Schrank,[2] the cross section for Ni at backward angles is considerably larger than the one for Cu. The experiment by Waldorf and Wall indicates an odd-even effect in this respect for nuclei below Cu. An odd-even effect also has been found by Schiffer *et al.*[3] in the gross structure of the (d,p) reaction on elements in this region. Brussel and Williams[4] have scattered 40-Mev protons from Fe^{54}, Fe^{56}, Ni^{58}, Ni^{60}, and Cu^{65} and have found some indication of effects which they attribute to the closure of the $Z=28$ and $N=28$ shells. In the elastic scattering of deuterons at 21.6 Mev[5] there was no appreciable difference in the cross sections of Ni, Cu, and Zn at backward angles. The shift in the location of the maxima and minima in the diffraction patterns of Ni and Cu, however, appeared to be much larger than the one observed for Cu and Zn. Therefore, it seemed of interest to investigate the angular distribution of the differential cross section for the separated isotopes Ni^{58}, Ni^{60}, Cu^{63}, and Cu^{65} to determine whether there is a rather abrupt change in the pattern between Ni and Cu.

* Performed under the auspices of the U. S. Atomic Energy Commission.
[1] W. F. Waldorf and N. S. Wall, Phys. Rev. 107, 1602 (1957).
[2] I. Dayton and G. Schrank, Phys. Rev. 101, 1358 (1956).
[3] Schiffer, Lee, Yntema, and Zeidman, Phys. Rev. 110, 1216 (1958).
[4] M. K. Brussel and J. H. Williams, Bull. Am. Phys. Soc. Ser. II, 3, 50 (1958).
[5] J. L. Yntema, Phys. Rev. 113, 261 (1959).

II. EXPERIMENTAL PROCEDURE

The experiment was done in the 60-in. scattering chamber[5] with the 21.6-Mev deuteron beam from the Argonne 60-in. cyclotron.[6] The experimental procedure has been described in detail in the previous paper.[5] The targets consisted of foils approximately 1 cm in diameter obtained from Atomic Energy Research Establishment, Harwell. However, the Ni^{60} foil was considerably smaller and had to be held in the foil holder by clamping it between two Al foils 0.0005 in. thick. Since some of the beam was scattered by the Al foil, the data at angles below 41° would have required a correction and therefore have been disregarded in this work. No contamination with elements of either high or low Z was observed.

Since it was to be expected that any shift would be fairly small, the experimental points were obtained at each given angle for all four targets. The targets did not have the same thickness, but it is unlikely that this would change the average energy by more than 100 kev. Such a change should not affect the distribution measurably. In the forward direction the detector was at

[6] W. Ramler and G. Parker, Argonne National Laboratory Report ANL-5907 (unpublished).

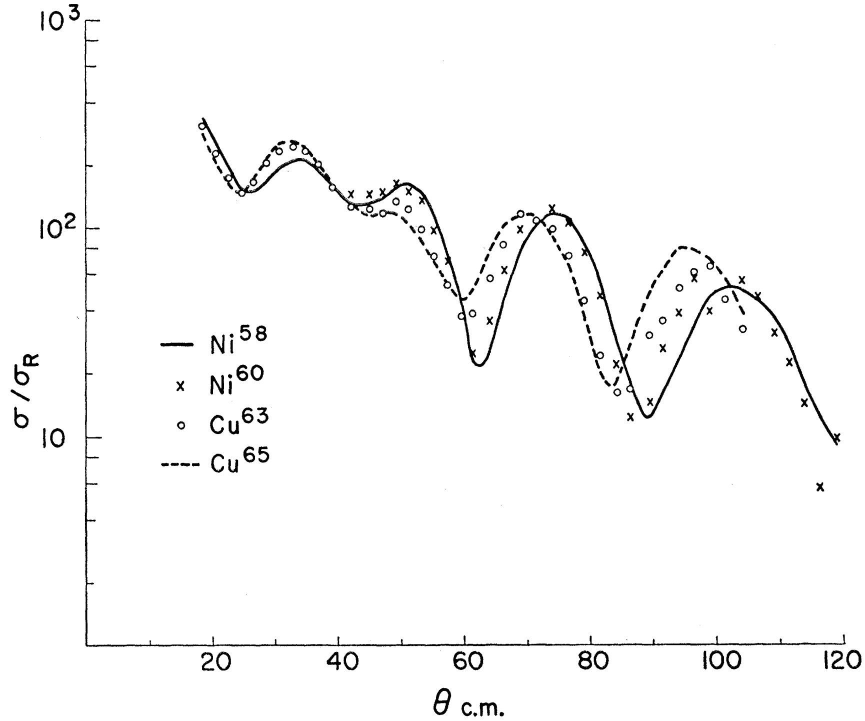

FIG. 1. Angular distributions for the elastic scattering of 21.6-Mev deuterons by Ni^{58}, Ni^{60}, Cu^{63}, and Cu^{65}. The data have been multiplied by $\sin^4(\theta/2)$ and normalized with respect to each other at forward angles. The statistical errors are less than 2% at angles smaller than 80 degrees and less than 4% in the others.

35.0 cm from the target, where it subtended about 0.5°; while at 58° and beyond the distance was 20.0 cm, the subtended angle about 0.9°. The standard deviation in the number of counts varied from 0.5% in the forward direction to about 4% at 100°. The data were recorded on the 100-channel analyzer.[7] The analyzer is erratic when the ambient temperature exceeds 75°F, so intermittent faulty operation of the controls on the air-

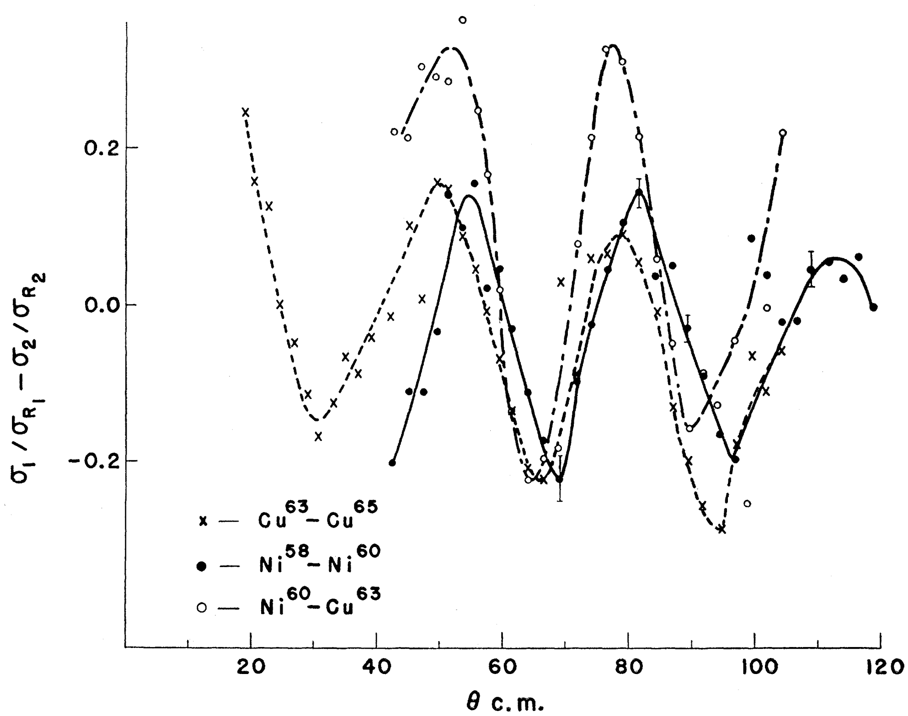

FIG. 2. Angular distributions of $\sigma_1/\sigma_{R1}-\sigma_2/\sigma_{R2}$ for Cu^{63}–Cu^{65}, Ni^{60}–Cu^{63}, and Ni^{58}–Ni^{60}. The errors shown are the standard deviations derived from the number of counts in the elastic peaks.

[7] J. P. McMahon (to be published).

conditioning unit led to rejection of a number of runs while the experiment was in progress. Since there is a possibility that in some cases the erratic behavior was not immediately recognized, no significance should be attached to the behavior of the Ni^{60} curve near 100°.

The energy resolution of the detection system was about 2%. All deuterons scattered from levels more than 1 Mev above the ground state were clearly distinguished as not belonging to the elastic peak. The particle separation was similar to that previously obtained.[5,8]

III. EXPERIMENTAL RESULTS

The results are shown in Fig. 1.[9] The angle is given in the center-of-mass system and the numbers given are the relative differential cross sections in the center-of-mass system multiplied by $\sin^4(\theta/2)$, where θ is the center-of-mass angle. The data were normalized to facilitate comparison, since the targets did not have the same thickness and it was not possible to measure the foils without destroying them. The data were normalized by assuming that the sum of the values of σ/σ_R from 18° to 34° should be about equal. In the case of Ni^{60} the normalization was carried out by equalizing the sum of σ/σ_R from 41° to 60° to that of Ni^{58}. Since the differences in the angular distribution, as plotted in Fig. 1, are small, it was desirable to obtain some measure of the internal consistency of the data. The standard deviation in the number of counts in the elastic peak between 80° and 18° was less than 2%; and between 80° and 117.5° it was generally less than 4%. It would appear, therefore, that a plot of $\sigma/\sigma_R - \sigma'/\sigma_R'$ should give a reliable measure of the internal consistency and of the magnitude of the shift between neighboring masses. Figure 2 shows the results of these plots for Ni^{58} and Ni^{60}, Ni^{60} and Cu^{63}, and for Cu^{63} and Cu^{65} together with the standard deviations at some of the points. From this one may conclude that the shift between Ni^{58} and Ni^{60} is the same as that between Cu^{63} and Cu^{65} and about $\frac{2}{3}$ of that between Ni^{60} and Cu^{63}. It may be noted that the difference plot between Cu^{63} and Cu^{65} shows a consistent average slope. This cannot be due to the normalization procedure. It is also to be noted that even as far forward as 18° there is a noticeable difference between the cross sections for Cu^{63} and Cu^{65}.

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We are indebted to W. Ramler and the Cyclotron group for their cooperation. The assistance of W. J. O'Neill and E. Sundahl is gratefully acknowledged.

[8] J. L. Yntema and B. Zeidman, this issue [Phys. Rev. **114**, 815 (1959)].

[9] The tabulated angles and cross sections are contained in J. L. Yntema, Argonne National Laboratory Report ANL-5936 (unpublished); available upon request.

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Search for the Isotope Ir^{196}†

DONALD G. GARDNER* AND W. WAYNE MEINKE
Department of Chemistry, University of Michigan, Ann Arbor, Michigan

(Received December 8, 1958)

The isotope Ir^{196} has been reported to have a half-life of ~9 days and to emit β^- particles with a maximum energy of about 0.08 Mev. Using deuteron-bombarded enriched isotopes of platinum, it is shown that the previous mass assignment was incorrect. It is suggested that the ~9-day activity found in deuteron bombardments of natural platinum is due to Ir^{189} and Ir^{190} produced by the (d,n) reaction on osmium impurities. An experimental upper limit of 5 hours for the Ir^{196} half-life can be set by these experiments. Rough cross sections for the (d,α) reaction on Pt^{194} and Pt^{196} are given for several deuteron energies from 9.6 to 20.4 Mev.

I. INTRODUCTION

By 1953 an isotope of iridium, Ir^{196}, was listed in isotope tables as having a half-life of ~9 days and decaying by the emission of an ~0.08-Mev β ray. A half-life of that order was surprising since Ir^{194} has a half-life of only 19 hours. Furthermore, the half-life and β-ray energy indicated that the transition was allowed, an unlikely occurence for this section of the isotopic table. In 1954 Butement and Poe,[1] who had contributed the original information on this isotope, published further information substantiating their previous findings and listed γ rays at energies of 0.58, 0.76, and ~1.0 Mev. A search of the literature and isotope compilations[2,3] through September, 1958 has revealed no further work on this isotope.

II. EXPERIMENTAL PROCEDURE

The radioactive iridium was produced by the (d,α) reaction from deuteron bombardment of metallic

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* Present address: Westinghouse Electric Corporation, Pittsburgh, Pennsylvania.

[1] F. D. S. Butement and A. J. Poe, Phil. Mag. **45**, 31 (1954).

[2] Strominger, Hollander, and Seaborg, Revs. Modern Phys. **30**, 585 (1958).

[3] K. Way *et al.*, *Nuclear Data Cards* (National Research Council, Washington, D. C., 1958).