tribution. Since a chi-square probability of 0.01 is considered satisfactory,[14] the lines were assumed to be normal in shape, and line centers were determined from the computed "best-fit" curves.

The energy levels determined for Al^{27} are shown in Table I and Fig. 2. The probable errors in these have been estimated as being 0.020 Mev from the uncertainty in determination of the group centers and from the uncertainty in the calibration constant. In Table I the levels listed by Alburger and Hafner,[15] which were the result of a literature survey covering the work reported before 1950, are given, along with more recent data reported by Keller,[8] by Van Patter, Sperduto, and Enge,[10] and by Shoemaker, Faulkner, Bouricius, Kaufmann, and Mooring.[16] It will be noted that in this experiment no scattering was observed corresponding to excitation of the 1.85-Mev level. Ten levels which were not previously reported were found.

We wish to acknowledge the help received from Dr. D. Halliday, Dr. L. Page, Dr. P. Stehle, from Mr. E. Perkins, Mr. R. Weise, Mr. J. Kane, as well as from the many other members of the Laboratory who have taken an interest in this project.

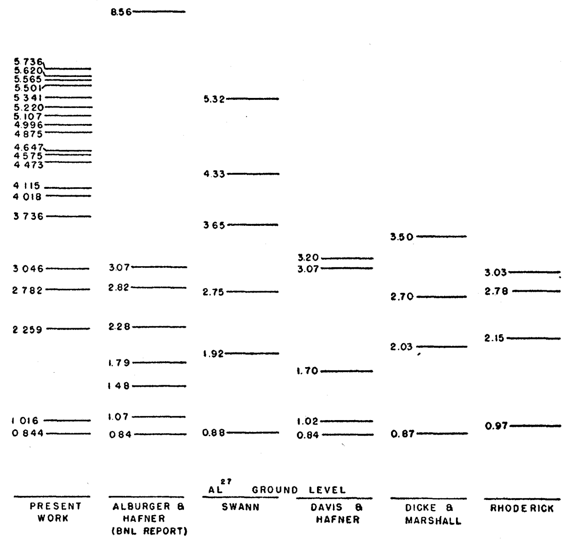

FIG. 2. Energy level scheme for Al^{27}.

[14] A. G. Worthing and J. Geffner, *Treatment of Experimental Data* (John Wiley & Sons, Inc., New York, 1946), pp. 183–184.

[15] D. E. Alburger and E. M. Hafner, Revs. Modern Phys. **22**, 373 (1950).

[16] Shoemaker, Faulkner, Bouricius, Kaufmann, and Mooring, Phys. Rev. **83**, 1011 (1951).

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Inelastic Scattering of Protons from Nickel*

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By use of the equipment developed for the precision scattering project at the University of Pittsburgh, inelastic scattering of 8-Mev protons from a thin nickel target has been observed at 90°. The energy levels obtained for natural nickel are 1.344, 1.479, 2.186, 2.326, 2.501, 2.660, 2.814, 2.946, 3.081, 3.161, 3.226, 3.308, 3.462, 3.575,3 .646, 3.773, 3.823, 3.944, 3.979, and 4.066 Mev. At present, only the three levels 1.344, 1.479, 2.501 Mev can be assigned to nickel 60 from comparison with beta-decay of cobalt 60.

INTRODUCTION

ENERGY levels in nickel have been observed by the inelastic scattering of protons from a nickel foil. The apparatus and method of analysis of the data are the same as that of the preceding paper.[1] Dicke and Marshall,[2] with incident protons of 6.9 Mev, were unable to observe any levels in nickel. Fulbright and Bush,[3] using 5–17 Mev protons from the Princeton cyclotron, reported one weak level in nickel at 3.8 Mev as well as a broad band of tracks in the photographic emulsion used for detection. This broad band suggests either that a three-particle disintegration is occurring or that the levels are too close to be resolved with their equipment. In the present study, twenty energy levels have been observed.

The target (obtained from the Chromium Corporation of America) was a nickel foil of areal density 0.592±2.5 percent mg/cm². Spectroscopic analysis showed less than 0.01 percent of copper in the target. The source and analyzer slits were $\frac{1}{8}$-inch wide. In all other respects the experimental details were essentially as reported in the preceding paper.

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[1] Reilley, Allen, Arthur, Bender, Ely, and Hausman, Phys. Rev. **86**, 857 (1952).

[2] R. H. Dicke and J. Marshall, Phys. Rev. **63**, 86 (1943).

[3] H. W. Fulbright and R. R. Bush, Phys. Rev. **74**, 1323 (1948).

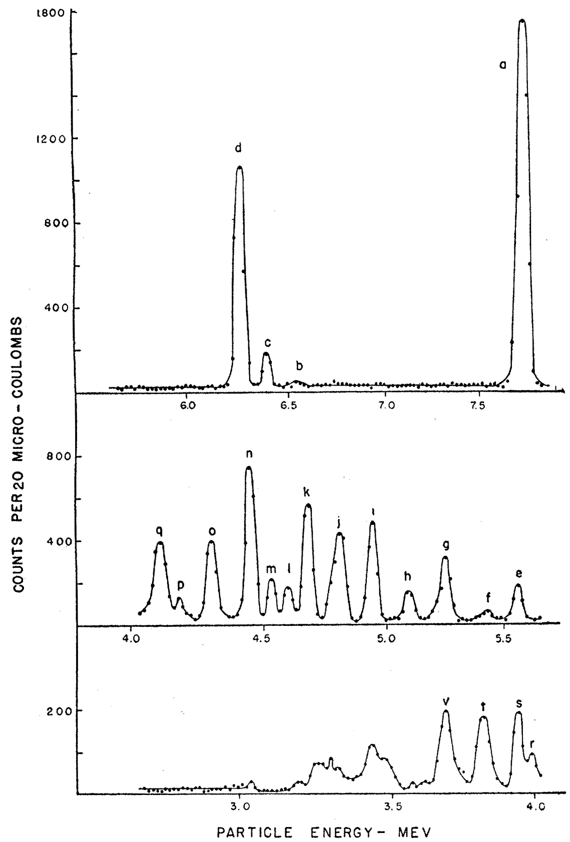

FIG. 1. Spectrum of protons scattered from nickel at 90°.

RESULTS

Figure 1 shows the energy spectrum obtained for 8-Mev protons scattered from nickel at 90°. Inserting absorption foils in front of the detector shows that all are proton peaks. Peak "*a*" is the nickel elastic peak, while "*b*" is the elastic peak caused by a thin carbon deposit which formed during bombardment. Table I shows the energies of the resultant levels; they are corrected for recoil nucleus, relativistic, and target energy loss effects. A probable error of the order of 20 kev seems reasonable. Below 3.6 Mev in Fig. 1 are several partially resolved peaks. Tentative but questionable assignment of these peaks are: 4.29, 4.33, 4.44, 4.47, and 4.50 Mev.

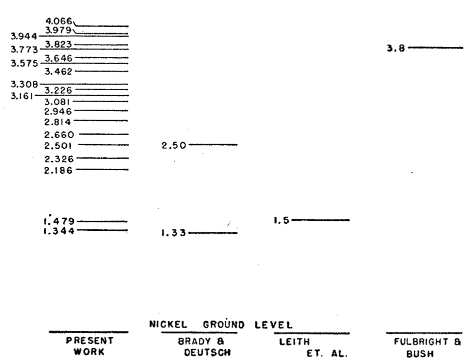

FIG. 2. Energy level scheme for nickel.

Figure 2 shows the energy level scheme for nickel. Brady and Deutsch,[4] from beta-decay of Co^{60}, report levels of 1.33 Mev and 2.50 Mev in Ni^{60}. The third level is at 1.5 Mev in Ni^{60} as reported by Leith, Bratenahl, and Moyer[5] from positron decay of Cu^{60}. The remaining levels are as yet unassigned to a particular isotope. The level obtained by Fulbright and Bush[3] is shown at 3.8 Mev.

TABLE I. Energy levels of nickel.

Level	Energy Mev	Brady and Deutsch Mev	Leith *et al.* Mev	Fulbright and Bush Mev
c	1.344	1.33		
d	1.479		1.5	
e	2.186			
f	2.326			
g	2.501	2.50		
h	2.660			
i	2.814			
j	2.946			
k	3.081			
l	3.161			
m	3.226			
n	3.308			
o	3.462			
p	3.575			
q	3.646			
r	3.773			
s	3.823			3.8
t	3.944			
u	3.979			
v	4.066			

We wish to acknowledge the help received from Dr. D. Halliday, Dr. L. Page, Dr. P. Stehle, Mr. E. Perkins, Mr. R. Weise, and Mr. J. Kane, as well as from the many other members of the Laboratory who have taken an interest in this project.

[4] E. L. Brady and M. Deutsch, Phys. Rev. **74**, 154 (1948).
[5] Leith, Bratenahl, and Moyer, Phys. Rev. **72**, 732 (1947).