of screening, partial or complete, the *correction* should be the same as in (3), because for small q the differential cross section is unchanged. Therefore we may simply use the Bethe-Heitler formula, subtracting from the logarithm the amount $1.207a^2$.

The correction amounts to a decrease of the cross section, in accord with experiment. The decrease occurs in bremsstrahlung (which has not been well investigated experimentally) to the same extent as in pair production. The main factor in the energy distribution of the resulting electrons is unchanged; only a constant is added to the logarithmic term. That the correction to the Born approximation is small (experimentally about 10 percent for Pb) arises from the fact that the correction must be compared with the logarithm [first term in (3)] which is of the order of 5.

We have also calculated the integrals in (2) numerically for the case of lead for which $a=0.6$. In this case, the last term in (3) is placed by 0.67 whereas $2.4a^2=0.87$. Thus the correction for heavy elements is somewhat less than the Z^2 law would indicate.

Integration over the energy ϵ_1 gives for the total cross section for pair production for lead

$$\sigma=\frac{28}{9}\frac{Z^2r_0^2}{137}\left(\log 2k-\frac{109}{42}-0.33_5\right), \tag{4}$$

in which the last term is the correction calculated in this paper. In the case of complete screening we get (for smaller Z)

$$\sigma=\frac{28}{9}\frac{Z^2r_0^2}{137}\left[\log 183Z^{-\frac{1}{3}}-1.207\left(\frac{Z}{137}\right)^2\right]. \tag{5}$$

At 88 Mev, the calculated reduction of cross section for Pb is 11.8 percent, the observed[3] 11 percent; at 280 Mev, the numbers are 10.0 and[4] 10 percent. The agreement is excellent. Around 20 Mev where several experiments are available, our approximations based on $\epsilon\gg\mu$ are probably no longer good enough; our theory would give a reduction of 20 percent for Pb, whereas Walker's experimental value[2] is only 15.5 percent. This is not surprising; at still lower energies Hulme *et al.*[5] found a theoretical cross section larger than the Born approximation.

A fuller account of the calculations will be given later.

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Production of 40-Mev π^+ and π^- Mesons in Seven Elements by 240-Mev Protons*

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A MEASUREMENT has been made of the relative differential cross section for production of 40-Mev π^+ mesons in the angular range 130° to 150° by 240-Mev protons in Be, C, Al, Cu, Ag, W, and Pb. A similar measurement has been made for 40-Mev π^- mesons in the angular range 30° to 50°.

The targets in which the mesons were produced were exposed to the internal circulating proton beam of the Rochester synchrocyclotron. The π^+ mesons were detected with a scintillation counter telescope in the arrangement shown in Fig. 1, taking advantage of the focusing of the mesons in the fringing field of the cyclotron magnet. The detection scheme allowed the mesons to be distinguished from the background radiation on the basis of their rate of energy loss in the first counter, their range in matter, and by the requirement of coincident pulses from the three counters. The arrangement used for detecting π^- mesons can be visualized by reflecting the shield and telescope through the radius drawn through the target.

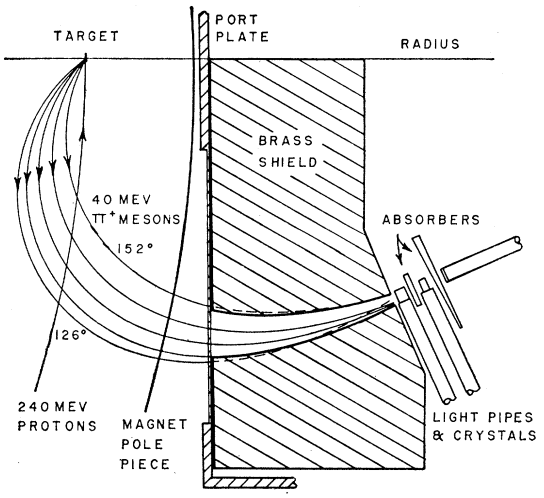

FIG. 1. Arrangement used for observing mesons.

The background correction was made by subtracting the counting rate observed with sufficient absorbing material, included in the telescope to stop the mesons, from that observed with the mesons traversing all three crystals. This correction amounted to about 10 percent.

The recirculation of the proton beam, i.e., the average number of traversals of protons through targets, the multiple scattering of which varied over a wide range, was measured by a method similar to that described by Knox.[1] The targets in which the mesons were produced were designed so that the effect of multiple traversals would not be large, and a correction was applied to the proton current from the multiple traversal measurement. This correction was largest for the Be target, for which it amounted to about a factor of 2, and was known within 10 percent.

The measured relative cross sections are given in Table I; the π^+ and π^- cross sections are separately normalized to unity for

TABLE I. Relative cross sections for meson production.

Element	σ^+	σ^-	$\sigma^+/A^{2/3}$	$\sigma^-/A^{2/3}$
Be	1.00±0.03	1.00±0.07	1.00±0.03	1.00±0.07
C	3.52±0.09	1.74±0.06	2.91±0.07	1.44±0.05
Al	7.95±0.11	6.0 ±0.2	3.83±0.05	2.9 ±0.1
Cu	13.7 ±0.3	14.6 ±0.4	3.74±0.08	4.0 ±0.1
Ag	16.6 ±0.3	19.1 ±0.7	3.18±0.06	3.66±0.13
W	19.4 ±0.4	23.8 ±0.9	2.60±0.05	3.20±0.12
Pb	19.0 ±0.5	23.5 ±1.0	2.35±0.06	2.91±0.12

Be. The actual π^+/π^- ratio for Be is 3 ± 1, but as pointed out above, the π^+ and π^- cross sections were not measured in the same angular range. The errors quoted in the table are probable errors and include contributions from counting statistics, proton current fluctuations, and time variation of the detector efficiency.

It is evident from Table I that the π^+ relative cross sections vary in about the same manner as the π^- relative cross sections, except for C and Al. The difference in these two elements may well be due to their considerably different energy thresholds for production of π^+ and π^- mesons.[2]

In contrast to a previous experiment on the production of mesons by γ-rays,[3] in which it was found that the sums of the relative cross sections varied as $A^{\frac{2}{3}}$ over a surprisingly wide range, there appears to be no such simple correlation of the cross sections of the present experiment with the mass number A. This is illustrated in Table I, where the relative cross sections have been divided by $A^{\frac{2}{3}}$. If, instead of $A^{\frac{2}{3}}$, one divides by the proton absorption cross section (which varies as A for small A and $A^{\frac{2}{3}}$ for large A) the variation is slightly less.

The author acknowledges with pleasure his indebtedness to Professor S. W. Barnes for suggesting this experiment, which was carried out under his guidance. He also wishes to thank the engineering and shop staff under the direction of Messrs. Richard Mortenson and Hugo Logemann, the cyclotron operating crew under the direction of Mr. Fred Palmer, and Messrs. Cecil Angell and John Perry for able assistance with the experiment.

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Nickel 56*,†

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IN the course of an investigation of the high energy spallation products of zinc,[1] evidence for the existence of a new isotope of nickel was obtained. In order to isolate and identify this new nickel activity, zinc target foils were bombarded with 340-Mev protons for approximately two hours. The nickel fractions were not isolated until approximately twenty days after bombardment, in order to allow most of the Ni^{57}, Ni^{65}, and Ni^{66} to decay prior to chemical separation. One of the final steps in chemical purification consisted of adding inactive cobalt to the isolated nickel fraction and separating the nickel and cobalt through the use of an anion exchange column. This method, originally developed by Diamond and Hollander,[2] consists of passing a concentrated hydrochloric acid solution of the activities through a column of Dowex-A-2 resin. Cobalt and other elements which form chloride complex ions adhere to the resin while nickel passes through with the elutriant. The chloride complex ions may be eluted with dilute hydrochloric acid. The cobalt was recovered and checked for activity, the absence of which indicated that no cobalt activity was in the nickel sample at the end of chemical purification. After the decay of the nickel sample had been followed with a Geiger counter for approximately eighteen days, cobalt was again separated chemically. The cobalt thus recovered from the nickel fraction contained an activity which was identified as Co^{56} by means of its characteristic 72-day half-life and its 1.5-Mev particulate radiation as identified from aluminum and beryllium absorption experiments. The fact that Co^{56} had grown into the sample definitely proved that Ni^{56} was present in the nickel fraction originally isolated.

The resolution of the total decay curve of the nickel fraction indicated values of 5.6 days and 6.0 days, respectively, for the Ni^{56} half-life in two separate experiments.

Comparison of the counts of Ni^{56} and its Co^{56} daughter on a Geiger counter indicated a counting efficiency of approximately 28 percent for the Ni^{56}. This counting efficiency would indicate that some particulate radiation is associated with the Ni^{56}. The charcter of this particulate radiation could not be determined due to the low level of activity in the sample.

In order to isolate Ni^{56} in larger quantities, elemental iron was bombarded with helium ions. Conditions were such that the $(\alpha, 2n)$ reaction predominated to give Ni^{56} as the principal nickel activity through the reaction $Fe^{54}(\alpha, 2n)Ni^{56}$. The radiation from the nickel fraction was measured through the use of a scintillation detector connected to a pulse analyzer. Four distinct peaks were observed corresponding to gamma-rays of approximately 0.16, 0.5, 0.8, and >1.4 Mev of energy. In addition there was less definite evidence for another peak corresponding to a gamma-ray of approximately 0.25 Mev; this was largely masked by the peak at 0.16 Mev and consequently the characterization was not very exact. The peak corresponding to a gamma-ray of 0.5 Mev includes annihilation radiation from the Co^{56} daughter and possibly from the Ni^{56}. Comparison of the counts due to Co^{56} with those due to Ni^{56}, however, indicates that there is also an independent gamma-ray of about this energy associated with the decay of Ni^{56}. The decay of the sample was followed on the scintillation pulse analyzer over a period of approximately twelve days and activity included in the 160-kev peak decayed with a half-life of six days. The activities of the other three peaks exhibited a half-life of approximately six days at the start and then a gradually increasing half-life as the decay proceeded. Analysis of the radiation on a crude beta-ray spectrometer indicated the presence of both positrons and negatrons, but the positrons could be accounted for in the main by the undecayed Ni^{57} which was present. The negatrons appeared to be mainly conversion electrons.

From this work it may be deduced that (1) the half-life of Ni^{56} is 6.0 ± 0.5 days; (2) there are at least four gamma-rays associated with the disintegration, with energies of approximately 0.16, 0.5, 0.8, and >1.4 Mev; (3) the decay is mainly by electron capture rather than positron emission.

The isotope Ni^{56} should be especially interesting to study due to the fact that its nucleus is composed of 28 neutrons and 28 protons and there are indications that 28 is a "magic number" for both protons and neutrons.[3-5]

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Radioactivity Produced in Platinum by Slow Neutron Capture

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BY slow neutron capture platinum can produce only the radioactive isotope of mass numbers 191, 193, 197, and 199. Previous workers[1-3] have assigned the half-lives 4.33 days, 18 hr, and 31 min to the mass numbers 193, 197, and 199, respectively. McMillan and his co-workers[2] observed by the bombardment of platinum with slow neutrons an activity of half-life 3.4 days which they assigned to the mass number 197. Later Sherr, Bainbridge, and Anderson[4] did not observe the 3.4-day activity but found an activity of long period and of small intensity. Recently Cork and others[5] have reported that by the slow neutron bombardment of supposedly pure platinum in Oak Ridge and Argonne piles they have observed three activities of half-lives 18 hr, 3.4 days, and 82 days. According to them the 3.4-day activity associated with platinum is due to 3.3-day Au^{199} produced from 31-min Pt^{199} and the 82-day activity is possibly due to Pt^{197}. It appears from the work of Cork and others[5] that the active platinum used in their experiments has not been purified from 3.3-day Au^{199} produced by the β^-decay of 31-min Pt^{199}. Since 31-min Pt^{199} is produced by slow neutron reaction with platinum along with other activities, it is expected that their experiments would give results characteristic of Au^{199}. If the 3.3-day activity is due to Au^{199}, it should be absent in the active platinum chemically purified from gold activity. In the present study pure platinum bombarded with slow neutrons in the Oak Ridge pile has been chemically purified