For the lattice parameter determination, filings were prepared from the original specimens and annealed under the same conditions as the rods. The more general method of annealing the bulk metal, filing, and then stress-relieving the filings with a lower temperature anneal, proved unsatisfactory. It is difficult in this latter procedure to insure that no precipitation of the iron occurs during filing.

Lattice parameters were obtained from measurements of Debye-Scherrer x-ray photographs taken in an 11.46-cm diameter circular camera, using both cobalt and copper unfiltered radiations. Extrapolated values of lattice parameter were deduced in the usual way by computing the spacings and plotting against the Nelson-Riley extrapolation function,[4] the value of a thus obtained is estimated to be correct to within $\pm 1\times 10^{-4}$A. It is found that a decreases from a value of 3.6081A for pure copper to 3.6071A when the copper contains about 0.25 percent iron. For higher iron content the parameter remains constant. This, taken in conjunction with the fact that the atomic radius of iron is close to that of copper, excludes the possibility of an interstitial solution.

In the case of an alloy in the form of a substitutional solid solution it can be shown that the density is given by

$$d=n\bar{A}m_H/a^3.$$

In this expression n is the number of atoms in the unit cell of volume a^3, $\bar{A}$ is the average atomic weight of the alloy (relative to hydrogen and calculated from the weight percentages of the constituents), and m_H is the mass in grams of the hydrogen atom. For simple substitution, in the case of a face-centered cubic structure, $n=4$. Thus in the case of a solution of iron in copper we should find that a^3 is a continuous linear function of $\bar{A}/d$ up to the limit of solubility.

Taking our observed values of d and a, we have plotted $\bar{A}/d$ against a^3, obtaining the result shown in Fig. 1. The approximate linearity of the graph shows that substitution takes place up to an $\bar{A}/d$ value of 7.075, which corresponds to a room temperature solubility limit of about 0.26 percent by weight of iron. For higher percentages the fact that the lattice parameter is found to remain practically constant indicates that precipitation of the iron occurs beyond this limit.

We are greatly indebted to Mr. F. E. Hetherington for carrying out the density measurements, and to Mr. F. T. Hedgcock for assistance with the x-ray calculations. The Metals Division of Imperial Chemical Industries, Ltd., very generously supplied the alloys used.

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On the Angular Distribution of the π^+ Mesons from 341-Mev Protons on Protons*

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STUDIES of the production of π^+ mesons by 341-Mev protons on protons[1,2] have shown a continuous spectrum of mesons with a pronounced peak at the high energy end. It was suggested[3] that besides the reaction $p+p\rightarrow n+p+\pi^+$, a second reaction takes place, namely, $p+p\rightarrow d+\pi^+$, which could be expected to give a considerable yield of mesons in a line spectrum separated from the continuous spectrum produced by the first reaction by 2.2 Mev as measured in the center-of-mass system. Recently it was shown by Crawford *et al.*[4] that deuterons do come off in coincidence with the π^+ mesons around the peak energy. They did not measure the absolute yield. The reaction $p+p\rightarrow d+\pi^+$ is of great interest, since, as has been pointed out by Marshak and Cheston[5] and independently by M. H. Johnson, a measurement of the inverse process will by means of detailed balancing determine the spin of the π^+ meson.

It is very important for the sake of the complete detailed balancing arguments as well as for the theory of this process[6] to find the angular distribution of the mesons. The measurements of the meson yield at 0°,[1] and at 18° and 30°[2] show a non-isotropic distribution when transformed to the center-of-mass system and suggest that the total meson yield goes something like $\cos^2\theta$, where θ is the angle in the center of mass of the mesons with respect to the line of the protons. To determine the angular distribution more precisely we have measured the yield in the laboratory at 60°. The method we used is the same as was used to measure the yield at 0°, that is, to take a polyethylene-carbon difference. As before, the mesons are detected by means of nuclear emulsions. The spectrum obtained is shown in Fig. 1. The errors shown are the statistical

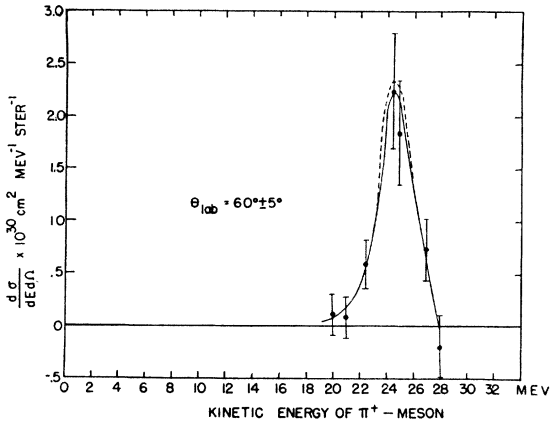

FIG. 1. Spectrum of π^+-mesons at $\theta_{lab}=60°\pm 5°$ to the proton beam.

probable errors. Because of the low yield from hydrogen the subtraction method becomes more difficult here, and no data were obtained at the low energy end of the spectrum. The spectrum shows the characteristic peak to be around 25 Mev. The energy of the beam was 341±3 Mev. The angle at which the mesons were observed was determined to be 58°±5°. From energy and momentum conservation, the energy of the meson peak if it is produced by the formation of a deuteron would be 25±2 Mev at 60°, using a meson mass equal to $(276.2\pm 2.3)m_e$. We believe that the energy of the peak is the best measure of the angle at which the mesons emerge with respect to the beam. The dotted curve is the spectrum corrected for nuclear interaction of the mesons in the absorber, assuming nuclear area for this interaction. The total cross section for the production of mesons in the peak at this angle is $(8.0\pm 2)\times 10^{-30}$ cm^2 sterad^{-1}.

The measurements of the yield of mesons at the various angles which have so far been made do not tell us whether a deuteron comes off in coincidence with every meson observed at the peak. However, the phenomenological calculations of Watson and Brueckner,[6] when compared to the meson spectrum at 0°, lead one to believe that most of the mesons in the peak come from the reaction in which a deuteron is formed. Because of the experimental uncertainties in our spectrum at 60°, it is more difficult to make comparisons with the theory at this angle. We will assume that here too the peak is primarily due to the reaction $p+p\rightarrow d+\pi^+$ and calculate the angular distribution in the center of mass on this basis. The integrated cross section due to the peak at 0° is $(1.3\pm 0.26)\times 10^{-28}$ cm^2 sterad^{-1} in the laboratory frame. Comparing this cross section with the cross section at 60°, we obtain the following formula for the differential cross section in the center of

mass as a function of θ, the angle in the center of mass:

$$(d\sigma/d\Omega)_{cm}=(3.20\pm0.78)(0.071\pm0.068+\cos^2\theta)$$
$$\times10^{-29}\ \text{cm}^2\ \text{sterad}^{-1}.$$

The total cross section for the mesons in the peak is therefore $(1.62\pm0.49)\times10^{-28}$ cm^2. This suggests that the meson comes off almost entirely in a P-wave, and since the majority of the mesons of the entire spectrum are in the peak, it would follow that the total spectrum is approximately in a P-wave.

It is a pleasure to acknowledge the continued encouragement we have received from Professors E. O. Lawrence and R. L. Thornton. Mr. Dan Hamlin was of great help with the scanning of the plates. We are indebted to Dr. K. M. Watson and Mr. E. M. Henley for discussions of the theoretical aspects of the problem. We would like to thank Mr. J. Vale and the cyclotron crew for making the bombardments.

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The Radioactivity of Barium 140

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RADIOACTIVE barium of half-life about 13 days was first noted[1] as a product of the bombardment of uranium by neutrons, even before the phenomenon of nuclear fission was recognized. Subsequent studies[2] have shown the activity to be in Ba^{140}, in which the beta-decay to La^{140} is complex and accompanied by gamma-emission. Three gamma-rays had been reported[3] with energies of 0.16, 0.30, and 0.54 Mev.

TABLE I. Summary of electron lines.

Electron energy (kev)	Relative intensity	Interpretation	Gamma-energy (kev)
23.3	20	$L_1^1(Z=57)$	29.6
23.7	2	L_2^1	29.6
24.1	1	L_3^1	29.6
28.2	10	M^1	29.6
29.3	5	N^1	29.6
79.8	1	K^2	118.5
93.1	4	K^3	131.8
123.3	10	K^4	162.0
156.0	5	L^4	162.3
160.8	2	M^4	162.2
265.5	4	K^5	304.2
382.8	1	K^6	421.5
397.1	1	K^7	435.8
498.0	4	K^8	536.7
530.0	1	L^8	536.3

A continued study of the fission product as supplied by the Oak Ridge National Laboratory, using photographic magnetic spectrometers, leads to a more accurate evaluation of energies and shows the existence of certain previously unreported gamma-rays. The barium radioactivity will usually be in equilibrium with the daughter, radioactive lanthanum. It appears, however, that in the original chemical separation of Ba^{140}, the La^{140} is carried down in excess of the equilibrium amount. This leads to a change in the relative intensity with time of the electron lines due to La^{140} as compared with the electron lines due to Ba^{140} and thus aids in their identification. The half-life curve of the specimen is complex, showing an initial 41-hour decay before settling into the longer barium half-life, now found to be 13.4 days. The K-L-M differences of the electron energies also make it possible, in most cases, to distinguish those electron lines associated with each activity.

A summary of the electron energies (believed to be accurate to ±0.2 percent) together with an arbitrary estimate of their relative intensities, and proposed gamma-origin is presented in Table I. A

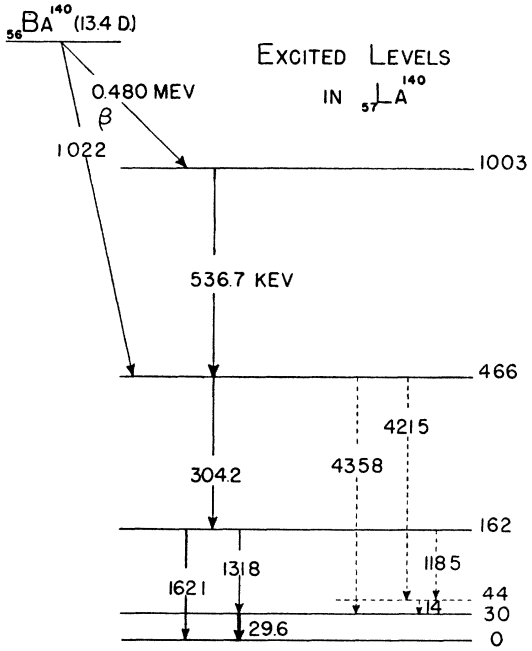

FIG. 1. Energy levels in La^{140} following beta-emission from Ba^{140}.

decay scheme had been proposed by Beach *et al.*, using their three observed gamma-energies, in which an unobserved gamma of 76 kev would have been required. It is now quite certain this gamma-ray does not exist. The observed gamma-energies do, however, fit very satisfactorily a modification and enlargement of the level scheme as shown in Fig. 1. The gamma-rays of greater intensity are represented as transitions with darker lines. The transitions shown as dotted lines are less certain, since only the "K" electron line was observed for each of these gamma-rays and there is some possibility that any or all of this activity is in the daughter product. In order to complete the scheme a gamma-ray of energy 14 kev would be required. This energy is slightly below the limit of the spectrometers.

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Gamma-Radiation from Lanthanum 140

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A PREVIOUS study of the radioactivity from La^{140} (41.4 hr) showed[1] the presence of twelve low energy gamma-rays, with an indication of others at higher energy. A contemporary report noted[2] the beta-decay of La^{140} to be complex with energies of 1.32, 1.67, and 2.26 Mev; but only five gamma-rays, mainly at higher energy, were found. The present spectrometric investigation,