related many-body forces, even without repulsive cores, might account roughly for nuclear binding energies and radii.

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Charged Pion Production from Carbon by Protons*

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A STUDY has been made with nuclear emulsions of the cross sections for production of positive and negative pions from carbon at 0° and 90° to a 340-Mev proton beam. For the 0° experiment and the 90° π^+ spectrum a uniform magnetic field was used. The 90° π^- spectrum was obtained with the aid of a symmetric heterogeneous magnetic field of a 22-inch spiral orbit spectrometer. The proton source was the external electrically deflected beam of the 184-inch synchrocyclotron. From this study[1] the following conclusions are drawn.

(a) The peak of the cross section for π^- production at these laboratory angles occurs much earlier than the corresponding peak for π^+ production.

(b) The maximum pion energy cutoff for π^- production is smaller than the corresponding pion energy cutoff for π^+ production.

(c) The shapes of the π^- production spectrum disagree with the previously reported spectrum shapes,[2] particularly in the low-pion-energy region.

(d) In the low-energy region the $\pi^\pm$ spectrum shapes when plotted against pion energy qualitatively resemble the corresponding shapes in $\beta^\pm$ decay.

(e) These spectra when integrated over the pion energy give the following results per carbon nucleus:

Laboratory angle θ	$\frac{d\sigma^+}{d\Omega}\times 10^{28}$ cm² sterad⁻¹	$\frac{d\sigma^-}{d\Omega}\times 10^{28}$ cm² sterad⁻¹	$\frac{\pi^+}{\pi^-}$	$\frac{\pi^+(0°)}{\pi^+(90°)}$	$\frac{\pi^-(0°)}{\pi^-(90°)}$
0°	21.0 ±0.5	0.71±0.02	29.5±1.2	6.3±0.2	1.67±0.09
90°	3.35±0.07	0.43±0.02	7.8±0.04		

(f) An estimate can be made of the total production cross section per carbon nucleus from the following data:

(1) Leonard's 180° results[3] on charged-pion production from carbon, which are $d\sigma^+/d\Omega=(1.77\pm0.40)\times10^{-28}$ cm²/sterad; $d\sigma^-/d\Omega=(1.90\pm0.56)\times10^{-29}$ cm²/sterad;

(2) the preliminary results at 30° on π^+ production which show that the π^+ peak occurs at a pion energy $T_\pi>55$ Mev; and

(3) the assumption that the angular dependence of the π^+ production cross section at each angle when integrated over pion energies can be represented by

$$\frac{d\sigma^+}{d\Omega}(\theta)=A+B\cos\theta+C\cos^2\theta,$$

and the corresponding π^- production cross section by

$$\frac{d\sigma^-}{d\Omega}(\theta)=A'+B'\sin^2\theta+C'\cos\theta.$$

This estimate gives

$$\sigma_T{}^+=(7.6\pm0.7)\times10^{-27}\text{ cm}^2,$$
$$\sigma_T{}^-=(0.55\pm0.09)\times10^{-27}\text{ cm}^2,$$
$$\pi^+/\pi^-=14\pm4.$$

(g) The disagreements between previously published data[2] on π^+ production at 90° can be resolved so that all results on π^+ production at this angle are in good agreement for pion energies above 25 Mev.

(h) For the calculation of the π^- production cross section a more appropriate zero-prong correction that is based on 4883 negative pions in clean C-2 Ilford nuclear emulsions is 1.35.

(i) The spiral-orbit principle[4] is especially suited for the study of charged pion production at 90° to the proton beam.

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Natural Radioactivity of Rhenium*

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THE natural radioactivity of rhenium[1] was characterized by an aluminum absorption curve as having an energy of some 43 kilovolts. We have had occasion to attempt a better measurement of the energy and have been surprised to find that the energy is much lower than was originally deduced. In fact an aluminum foil of only 270 micrograms per cm² transmits less than 6 percent of the radiation, whereas the earlier result corresponded to a half-thickness of about 400 micrograms per cm². It seems likely that the earlier result was due either to a small amount of impurity or

to contamination of the foil. In any case it seems quite clear at this point that the radiation emitted by rhenium, which in total intensity is in agreement with the earlier result, 0.14 count per minute per cm^2 of area of the metal under 2π geometry counting conditions is much less energetic than a 43-kev beta spectrum.

When the screen wall counter was used,[2,3] with a distance of 1.26 cm between the sample cylinder on which the metallic rhenium was mounted and the screen gauze defining the wall of the counter, it was observed that with the wall of the counter negative by any voltage larger than 10 volts with respect to the sample cylinder the rhenium radiation was undetectable with the lowest pressures of gas obtainable. For example, 3 millimeters of Hg pressure of ethylene mixed with 1.1 cm Hg pressure of argon gave less than 3 percent transmission of the rhenium radiation. This would correspond, for an exponential absorption law, to a mean free path of 10 micrograms per cm^2, or using a ratio of 10 empirically deduced between the range and the mean free path of soft beta radiation,[4] we calculate that the range of the beta radiation from rhenium must be less than 100 micrograms per cm^2, which according to the relation of Katz and Penfold[5] gives an upper energy limit to the beta radiation from rhenium of 8 kev instead of the 43 kev given earlier.[1]

It is also clear that having reduced the energy of the radiation, the half-life must be recalculated. Whereas the earlier half-life was thought to be about 10^{12} yr, it now is clear that it must be reduced by at least the ratio of the range of 43-kev radiation—about 3 milligrams per cm^2—to the new upper limit to the range—0.1 milligram per cm^2—or to 10^{11} years or less. It cannot be clear how much less than 10^{11} years the half-life of rhenium 187 is until a successful attempt to measure the radioactivity in a gaseous state has been made. The systematics of the penetrating power of radiations as soft as rhenium is relatively unknown, since there is no other known beta spectrum as soft as this natural radioactivity seems to be.

Several attempts have been made in our laboratory to prepare gaseous compounds of rhenium which could be used in proportional counters to determine not only the half-life, but also the energy of the radiation. The compounds tried were: rhenium trimethyl, which we failed to prepare, and rhenium oxy-chloride and rhenium hexafluoride. The latter two were prepared successfully, but proved to be rather recalcitrant counter gases, and no important data have yet been obtained.

It would seem reasonable to attempt to test for the possibility that the natural radioactivity of rhenium may correspond to a half-life of as short as a few billion years, in which case the accumulation of osmium 187, the daughter isotope, in old rocks should be observable, and use of this observation might produce the first reliable value of the half-life of this most interesting naturally radioactive isotope. The shell model and beta decay systematics[6] say that rhenium 187 should have an ft value of about 10^{10} and be only first-forbidden with a spin change of two. This indicates that a one-kev transition should correspond to a half-life of about 10^{11} years, which is in permissive agreement with the facts as stated previously.

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Fine Structure in U^{233} Fission

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FINE structure in the light group of the mass distribution for slow-neutron-induced fission of U^{235} was reported in a previous publication.[1] An abnormally high yield was observed at mass 100 suggesting a preference for this mass in the fission act, perhaps as the complement of a preferred 82-neutron

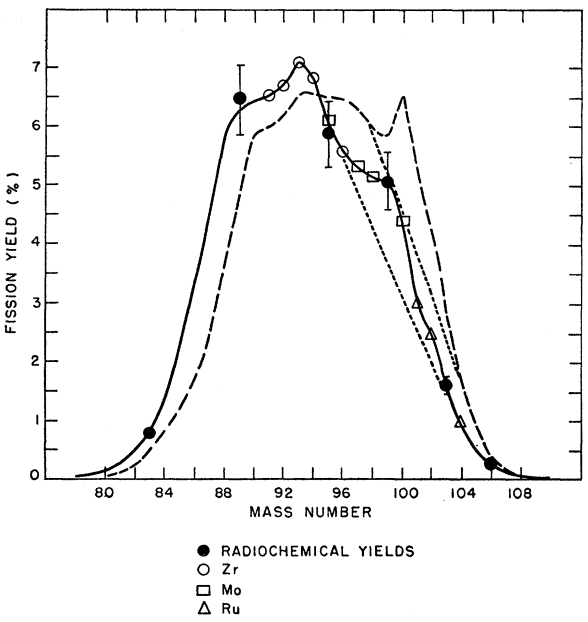

FIG. 1. Yield-mass curves for the light groups in slow neutron-induced fission of U^{233} (solid line) and U^{235} (dashed line).