STUDY OF THE REACTION $In^{115}(p, p\pi^+)$

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THE experiments were performed with spectroscopically pure indium contained in a quartz ampoule. The ampoule was 3 mm in inside diameter and 30 mm high, and had a wall thickness ~ 0.6 mm. For monitoring the proton beam the ampoule was wrapped in an aluminum foil. Irradiation of the targets was carried out in the internal proton beam of the synchrotron of the Laboratory of Nuclear Problems at the Joint Institute for Nuclear Research. After a twenty-four hour "cooling off," we separated the cadmium fraction from the irradiated target radiochemically, by use of chromatography. As a sample for the measurements we used a cadmium phosphate disc 10 mm in diameter. The activity measurement was carried out with an end window counter type MST-17 over a period of 10—12 months, with the statistical error of an individual measurement not exceeding 2%. We observed components with the following half-lives: 6—8 hours, 56 ± 2 hours, 44.6 ± 1.8 days, and more than one year. The maximum β-ray energy was determined by absorption in aluminum for the 56-hour and 44-day components and was found to be 1.6 ± 0.1 and 1.4 ± 0.2 MeV, respectively. Subsequently we detected in the cadmium fraction the isotopes Cd^{107}, Cd^{115}, Cd^{115m}, and, apparently, Cd^{113m}. The Na^{24} activity separated from the aluminum foil monitor was measured under similar conditions. The cross section for the reaction $Al^{27}(p, 3pn)Na^{24}$ was taken from the review by Bruninx[1].

We have determined the production cross section for only two isotopes: Cd^{115m} and Cd^{115}. The results are shown in the table. Assuming that at proton energies of 130 and 200 MeV the formation of these isotopes occurs by the (n, p) reaction

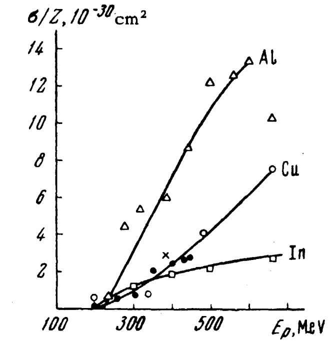

FIG. 1. Experimental data on the cross section for the reaction $(p, p\pi^+)$ in different nuclei according to various authors: △ from[2], ● from[3], ○ from[4], × from[5], □ present work.

from secondary neutrons and that this contribution is not a function of proton energy, we have determined the cross section for the $(p, p\pi^+)$ reaction at higher energies. Also given in the table is an estimate of the ratio $\sigma(Cd^{115m})/\sigma(Cd^{115})$ in the (n, p) and $(p, p\pi^+)$ reactions. The results are compared (see the figure) with the data for the same reaction in other nuclei in the same proton energy range. A systematic decrease in the rise of the cross section is observed as a function of atomic number. This can be due to the difference in absorption in the target nucleus of π^+ mesons from the observed reaction. The experimental data are in satisfactory agreement with the theoretical calculation carried out for this reaction by Ericson, Selleri, and Van De Walle[6]. The present work provides more accurate data on the behavior of the reaction near threshold.

[1] E. Bruninx, High Energy Nuclear Reaction Cross Sections, CERN 61-1, 1961.

E_p, MeV	Cross section, 10^{-27} cm²					$\sigma(Cd^{115m})/\sigma(Cd^{115})$
	Cd^{115m}	Cd^{115}	Cross section for $(p, p\pi^+)$			
			Cd^{115m}	Cd^{115}	Total	
130	0.065±0.012	0.031				2.1±0.4
200	0.068±0.004	0.029±0.002				2.3±0.3
300	0.113±0.018	0.046±0.009	0.045±0.022	0.017±0.011	0.062±0.033	2.7±2.7
400	0.139±0.037	0.055±0.009	0.071±0.041	0.026±0.011	0.097±0.052	2.7±2.7
500	0.142±0.027	0.065±0.013	0.074±0.031	0.036±0.015	0.110±0.046	2.1±1.7
660	0.161±0.016	0.078±0.012	0.093±0.020	0.049±0.014	0.142±0.034	2.0±1.0

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SPIN CORRELATIONS IN NEUTRINO AND ANTINEUTRINO SCATTERING BY ELECTRONS

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INTEREST has risen recently in the possibility of an experimental observation of weak neutrino-lepton interaction of the type $(e\nu)(\bar{\nu}e)$, predicted by Feynman and Gell-Mann[1]. They noted that the scattering of a neutrino and antineutrino by an electron can be observed by searching for recoil electrons in targets bombarded with neutrinos (antineutrinos). If the neutrino is capable of being scattered by an electron, then the recoil electrons may be polarized. The appearance of spin polarization of the recoil electrons is connected with the helicity properties of the neutrino.

In the present work, continuing earlier investigations[2,3], we calculated the cross sections for νe and $\bar{\nu}e$ scattering in the V-A variant of the weak four-fermion interaction with allowance for the polarization of the target electron and the recoil electron. The analysis was made within the framework of the theory of the four-component Dirac neutrino[2-9], with two different kinds of neutrinos (ν_R, ν_L) and two different antineutrinos $(\bar{\nu}_R, \bar{\nu}_L)$, having right-hand and left-hand polarizations.

The total cross sections of the scattering processes

$$\nu + e \to \nu' + e', \quad \bar{\nu} + e \to \bar{\nu}' + e'$$

with allowance for the longitudinal polarization of the recoil electron, are given by the following formulas (in the laboratory frame)

$$\sigma_{e\nu}(s_\nu, s_{\nu'}, s_{e'}, \omega) = \frac{1}{4}\sigma_0(1 + s_\nu s_{\nu'})\left(\frac{\omega^2}{2\omega+1} + \frac{1}{4}s_\nu s_{e'} f_1(\omega)\right),$$

$$\sigma_{e\bar{\nu}}(s_{\bar{\nu}}, s_{\bar{\nu}'}, s_{e'}, \omega) = \frac{1}{4}\sigma_0(1 + s_{\bar{\nu}} s_{\bar{\nu}'})\left(\frac{\omega}{6}\left(1 - \frac{1}{(2\omega+1)^3}\right) - \frac{1}{4}s_{\bar{\nu}} s_{e'} f_2(\omega)\right), \tag{1}$$

where

$$f_1(\omega) = 4(2\omega+1)^{-3}(4\omega^4 + 12\omega^3 + 13\omega^2 + 6\omega + 1) - 2\left(1 + \frac{1}{\omega}\right)\ln(2\omega+1),$$

$$f_2(\omega) = (2\omega+1)^{-3}\left(\frac{16}{3}\omega^4 + 40\omega^3 + 84\omega^2 + \frac{220}{3}\omega + 28 + \frac{4}{\omega}\right) - 2\left(1 + \frac{1+2\omega}{\omega^2}\right)\ln(2\omega+1),$$

$$\sigma_0 = \frac{2G^2 m_0^2}{\pi\hbar^4}, \qquad \omega = \frac{E_q}{m_0c^2}, \qquad q = \nu, \bar{\nu}. \tag{2}$$

E_q—energy of the initial neutrino (antineutrino); m_0—rest mass of the electron; $s_i = \pm 1$, ($i = e'$, ν, $\bar{\nu}$, ν', and $\bar{\nu}'$)—eigenvalue of the projection operator $\sigma_i \cdot p_i/p_i$[2,3,10], which determines the helicity of the recoil electron, neutrino, and antineutrino before and after scattering.

The degree of longitudinal polarization of the recoil electrons, defined as the ratio of the difference of the cross sections to their sum at $s_{e'} = 1$ and $s_{e'} = -1$, is

$$P_{e'}^{\nu e}(\omega) = s_\nu \frac{2\omega+1}{4\omega^2} f_1(\omega),$$

$$P_{e'}^{\bar{\nu}e}(\omega) = -s_{\bar{\nu}} \frac{3}{2\omega(E^{\bar{\nu}e}(1-(2\omega+1)^{-3})} f_2(\omega). \tag{3}$$

It follows from (3) that at the high limit of the neutrino energy $(\omega \gg 1)$ the recoil electrons produced in νe scattering will have the same helicity as the incident neutrino $(P_{e'}^{\nu e} \cong s_\nu)$, whereas the recoil electrons from $\bar{\nu}e$ scattering will have an helicity which is opposite that of the incident antineutrinos $(P_{e'}^{\bar{\nu}e} - s_{\bar{\nu}})$. Thus, for $\omega = 100$ $(E_\nu = 15\text{ MeV})$ we have $P_{e'}^{\nu e} \cong 0.97\, s_\nu$ and $P_{e'}^{\bar{\nu}e} \cong 0.90\, s_{\bar{\nu}}$. When left-polarized neutrinos (or right-polarized antineutrinos) of high energy