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Inelastic Scattering Cross Sections of Nuclei for 2.5 MEV Neutrons

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IN this communication we present briefly the results of measurements of inelastic cross sections for 2.5 mev neutrons. These measurements were carried out in the Institute of Physics of the Academy of Sciences, Ukrainian SSR during 1951-1952.

Inelastic scattering cross sections for neutrons can be measured rather easily by attenuation methods, using radioactive threshold detectors. In such experiments, the shapes of the scatterer and detector must be chosen in such a way as to eliminate the effect of elastic scattering or else make possible the evaluation of this effect. The threshold of the detector should be high enough so that the inelastically scattered neutrons cannot activate it. These problems were solved in two ways. In one method, a spherical scatterer was surrounded by a thin wrapper of the detector such that all neutrons elastically scattered by the scatterer had a chance to pass through the detector and activate it. Since inelastically scattered neutrons lose a significant fraction of their energy and do not activate the detector the experiment gives the attenuation of the neutron beam as a result of inelastic scattering.

In the second method, the spherical threshold detector was surrounded by a wrapping of scatterer. Here the neutrons scattered elastically by the part of the scatterer between the source of neutrons and the detector and not impinging on the detector will be compensated (completely or partly) by neutrons elastically scattered into the detector by other parts of the scatterer. It follows that in this way also the decrease in activation of the detector due to inelastic scattering can be determined after establishing the amount of cancellation .

A detailed analysis showed that both methods of measurement are valid under the experimental conditions used.

The reaction $P^{31}(n, p)Si^{31}$ was used as a thresholddetector. The effective threshold here is equal to ~2 mev; the half-life is about 170 min. The neutrons were obtained from the D(*d*, *n*)He reaction. A thick, heavy ice target was bombarded with 190 kev deuterons obtained from a low voltage accelerator constructed for this purpose.

The measurements were carried out in the following fashion. A detector with scatterer and a detector without a scatterer were placed symmetrically with respect to the target at an angle of 90° relative to the deuteron beam. The irradiations of the two detectors were carried out simultaneously. After the end of the irradiation the activity of the detectors was measured using counters.

TABLE. Inelastic Scattering Cross Sections for 2.5 mev Neutrons.

Scatterer	Cross section for inelastic scattering, in barns	Scatterer	Cross section for inelastic scattering, in barns
Na	0,53±0.26	Zn	1.88±0,15
Mg	0,77±0,25	Se	1.88±0,17
Al	0,96±0,17	Mo	1,9±0.3
P	0,7±0,2	Ag	2.1±0,2
S	0,54±0.21	Cd	2.2±0.2
Cl	0,6±0,3	Sn	2,2±0.2
Ca	0.4±0.2	Sb	1.9±0.2
Cr	1.4±0.3	Te	2.0±0,35
Fe	1.16±0.12	J	1,96±0,25
Co	1.40±0.11	Ba	1.6±1.0
Ni	0.83±0.12	W	2,6±0.25
Cu	1,58±0.15	Hg	2,6±0.3
		Pb	1.7±0.3
		Bi	0.7±0.3

The cross sections for chlorine and barium were calculated from measurements of the inelastic cross sections of NaCl, BaS, Na and S and the assumption of the additivity of cross sections.

The results of the measurements are shown in the Table. They make possible the following conclusions: (1) the inelastic cross sections for 2.5 mev neutrons for most nuclei increase smoothly with a mass number; (2) nuclei having a magic number of nucleons have inelastic scattering cross sections that are significantly smaller than neighboring nuclei. It may be that this is the result of the presence of particularly stable nuclear clouds, whose influence is felt even at neutron energies of 2.5 mev.

In conclusion, I take the opportunity to acknowledge the direction of A. I. Leypounskii in this work and the valuable advice and interest of M.V. Pasechnik.

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Level Shifts in μ-Mesic Hydrogen and the Structure of the Proton

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THE work of Wheeler[1] showed that a study of μ-mesic atoms can serve to give information on the internal structure of the nucleus and to determine some of its properties. The purpose of this note is to call attention to the possibility of using data on the fine structure of the μ-mesic hydrogen system to give information concerning the internal structure of the proton and the limits of the applicability of quantum electrodynamics.

The energy of the stationary state of μ-mesic hydrogen to an accuracy including order $\alpha^3 \times$ ($\alpha = e^2/\hbar c$) can be written in the form

$$E = E_0 + \alpha E_1 + \alpha^2 E_2 + \alpha^3 E_3. \qquad (1)$$

In this equation the main term, E_0, is the energy of the μ^--meson in a Coulomb field of a point proton including the correction for retarded interaction. The correction proportional to α is due to the polarization of the electron vacuum in the neighborhood of the μ-mesic atom and was first pointed out in the work of Galanin and Pomeranchuk[2] (see also Ref. 3). The term proportional to α^2 contains the correction to the "ordinary" fine structure of the level determined by spin orbit interaction and the relativistic dependence of mass on energy, and also the second approximation to the polarization of the electron vacuum. There is also included in the approximation the so-called hyperfine structure of the level determined by the interaction of the magnetic moments of the proton and μ-meson. In the given situation this is comparable to the fine structure. Finally, the term involving α^3 includes the interaction of the μ^--meson with the zero point vibrations of the electromagnetic field, the effect of the polarization of the μ-mesic vacuum and third order corrections to the electron vacuum polarization. It should be emphasized that in all these terms, it is necessary to take into account electromagnetic corrections arising from the finite mass of the proton and retarded potentials.

It is not hard to see, however, that in addition to the electromagnetic terms included above, the terms of order α^2 and α^3 should also contain effects of nonelectromagnetic origin. The term of order α^2 should be strongly affected by the interaction of the proton with the zero point vibration of the π-mesic vacuum. The existence of this interaction should lead to a smearing of the proton charge over a distance of the order of the Compton wavelength of the π-meson. This will result in a deviation of the electric field from the Coulombic in the indicated regions. We will examine some of the effects arising from the existence of the proton in a dissociated state (neutron + π-meson) during a time interval τ. Corresponding to this effect, there exists a correction to the basic energy level of the μ-mesic hydrogen of the order of the quantity

$$\Delta E \sim \tau (\mu / m)^2 \alpha^2 n^{-3} \mathrm{Ry}' (1 + \mu / M)^{-3}, \qquad (2)$$

where m, μ and M correspond to the masses of the π, μ-meson and of the proton; $Ry' = \mu e^4 / 2k^2$. Since the quantity $(\mu/m)^2$ in Eq. (2) is of the order of unity, this effect introduces a significant contribution to the relativistic fine structure of the level of the μ-mesic hydrogen ($\sim \alpha^2$). For ordinary hydrogen, because of the smallness of the quantity $(m_e/m)^2 = (1/273)^2$, the dissociation of the proton has an effect only of the order of electromagnetic