decrease of this cross section is about 20% when the energy of the neutrons is raised from 270 to 590 mev. Since the total cross section of the elastic $(n - p)$ scattering represents the sum of interactions of nucleons in states with isotopic spins $T = 0$ and $T = 1$, and since, on the basis of available data [5,6], the cross section for elastic $(p - p)$ scattering (cross section of interaction in state with $T = 0$) remains constant in the indicated energy range, then the observed decrease of $\sigma_t^{elast}(n - p)$ is determined by the decrease with energy of the cross section of interaction of nucleons in a state of isotopic spin T equal to zero. This deduction, among others, indicating the difference in nucleon interaction in states with $T = 0$ and $T = 1$, was made by us previously[7], where the problem of $(n - p)$ interactions at high energies was studied in more detail.

2. The cross section of $(n - p)$ interaction when the energy was raised from 270 mev to 590 mev, increased by about 25%. The difference of total cross sections of $(n - d)$ and $(n - p)$ interactions for this energy interval increased by more than 60%. A comparison showed that within experimental errors the difference of cross sections $\sigma_t(n - d) - \sigma_t(n - p)$ found at $E_n = 590$ mev coincides in magnitude with the cross section for $(p - p)$ interaction determined in reference 8 for protons with the same energy. The latter fact, in the light of conditions of charge symmetry of nuclear forces, the existence of which is confirmed for high energy of nucleons[9], shows that interference effects at 590 mev introduce a small contribution to the cross section of $(n - d)$ interaction. In such case the observed increase of this cross section in the 270-590 mev energy interval is explained by the increase of the cross section of the interaction of neutrons with neutrons, depending as in the case of two protons interaction on the increase of the probability of inelastic $(n - n)$ resonances.

3. The total cross sections of complex nuclei when the energy is varied from the interval 200-400 mev, where they are practically constant, to 590 mev vary differently, depending on the atomic weight. Thus, the cross sections of light nuclei, such as Be, C, O increase by 10-15%. The cross sections of nuclei of heavy elements remain unchanged within experimental errors. The transparency of nuclei of elements of low A is $\sim$0.5 (see Table); for elements with high A it is equal to ~ 0.3.

The observed increase of the total cross sections of light nuclei when the neutron energy is raised from 400 to 590 mev is explainable by the growth of cross sections of elementary nucleon-nucleon interactions [particularly the cross section for $(n - n)$ interactions] in the energy range under consideration. The cause of the invariability, for these energies, of the total nuclear cross sections of elements with high A, is at present unclear. The quantitative analysis (for example on the basis of the optical model of the nucleus) of such behavior of these cross sections, could be considerably helped by data on the energy dependance of total cross sections for inelastic and diffraction scattering of neutrons by nuclei in the energy range under study.

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Neutron Spectrometry Based on the Measurement of the Decelerating Time of Neutrons

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THE process of the deceleration of neutrons in a medium possesses a property which permits us to develop a new method of neutron spectrometry. This property is the gradual monochromatization of neutrons resulting, essentially, from the fact that, of the neutrons introduced into the medium, the fastest neutrons collide relatively more frequently with the nuclei of the decelerator. If the mass of the nuclei of the decelerator M (the mass of the neutron is taken as unity) is large, $M \gg 1$, then the deceleration times are large enough to be measured easily. Such a change in the neutron spectrum $n(v,t)$ with respect to time t (v is the velocity) follows also from the so-called acceleration theory*. Since

$$\frac{\partial q}{\partial t} = -\frac{v}{\lambda_c} q + \frac{\xi v^2}{2\lambda_s} \frac{\partial q}{\partial v},$$

$$q = \frac{\xi v^2}{2\lambda_s} n, \quad \xi \approx \frac{2}{M+1}, \tag{1}$$

where λ_c and λ_s are the path lengths of capture and of scattering; then after substituting the variables

$$\omega = \int_{v_2}^{v} \frac{\lambda_s dv}{v^2 \xi}, \qquad q = e^{-\Omega(\omega)} \chi, \tag{2}$$

$$\Omega = -\int_{v}^{v_1} \frac{\lambda_s}{\lambda_c} \frac{2dv}{\xi v}$$

we arrive at an equation for χ (apparently, ω has the meaning of characteristic deceleration time):

$$\frac{\partial \chi}{\partial t} + \frac{\partial \chi}{\partial \omega} = 0. \tag{3}$$

The solution of this equation $\chi = \chi\ (t - \omega)$, that is,

$$n(v, t) = \frac{2\lambda_s}{\xi v^2} \tag{4}$$

$$\times \exp\left\{-\int_{v}^{v_1} \frac{2\lambda_s}{\lambda_c} \frac{dv}{\xi v}\right\} \chi\left(t - \int_{v_2}^{v} \frac{2\lambda_s dv}{\xi v^2}\right),$$

where v_1 and v_2 are constants. Here it is easy to satisfy the initial condition and to obtain a solution for the general case. Let the neutron spectrum at the initial instant of time be given by the function $n(v,0) = F\left(\frac{v - v_0}{\Delta_0}\right)$, where v_0 is some characteristic velocity, Δ_0 is the initial width of the spectrum. In practice, even when the source yields monochromatic neutrons with an energy of the order of 1 mev, however, even after the first inelastic collision we obtain $\Delta_0 \sim v_0$.

Let, further, λ_s be independent of v; then the "deceleration time" up to a velocity $v \ll v_2$ will be equal to $\omega = 2\lambda_s / \xi v$ and

$$n(v, t) = \left(1 - \frac{\xi v t}{2\lambda_s}\right)^{-2} \tag{5}$$

$$\times \exp\left\{\int_{v_t}^{v} \frac{\lambda_c}{\lambda_s} \frac{dv}{v}\right\} F\left(\frac{v_t - v_0}{\Delta_0}\right),$$

$$v_t = v \Big/ \left(1 - \frac{\xi v t}{2\lambda_s}\right).$$

The center of the distribution at the instant t is displaced to the point where the argument F is equal to zero, $v = v_c = v_0 \Big/ \left(1 + \frac{\xi v_0 t}{2\lambda_s}\right) \approx \frac{2\lambda_s}{\xi t}$. The distribution acquires a width determinable from the the value v, for which the argument F is equal to ~ 1, which is much smaller than the initial value:

$$\Delta_1 \sim \Delta_0 (v_c / v_0)^2. \tag{6}$$

This result follows at once also from the relationship of the deceleration time with the initial neutron velocity v_0 and the velocity v, which is expressed by the ratio:

$$\omega = \frac{2\lambda_s}{\xi}\left(\frac{1}{v} - \frac{1}{v_0}\right). \tag{7}$$

Differentiating, we have:

$$\frac{\delta v}{v^2} = \frac{\delta v_0}{v_0^2}, \quad \overline{\delta v} = \overline{\delta v_0}\ \frac{v^2}{v_0^2} \ll \overline{\delta v_0}. \tag{8}$$

Thus there occurs a narrowing of the neutron spectrum (monochromatization).

However, the substitution of the integral kinetic equation by a differential equation holds only when $\xi v\ (\partial q / \partial v) \ll q$, that is, the spectrum is quite diffused. One can easily become convinced that even for an initially diffused spectrum the inequality may finally be disturbed. This does occur, as can be easily verified (by considering $\xi v_c t / 2\lambda_s \sim 1$, $\Delta_0 \sim v_0$), when the deceleration approaches the stage $v_c \sim \xi v_0$. In lead at an initial energy of the order of 1 mev a similar deceleration corresponds to $\sim 10^3 - 10^4$ ev. At a further deceleration, when the condition λ_s = const is retained, no broadening can occur (since, if it would occur, the evaluations given above would enter into action, from which it becomes evident that a narrowing of the spectrum would occur again). However, there will also not occur any narrowing of the spectrum: in accordance with the determination of the moments of distribution[1], the dispersion, as it follows from exact theory, becomes equal to

$$\sqrt{\overline{\delta v^2} / v^2} = 3 / 2M = {}^3/_4 \xi, \tag{9}$$

that is, at $v_c < \xi v_0$ it will remain constant (until such time when the thermal movement of the atoms of the medium begins to produce an effect). A more complete theory of the deceleration of neutrons in heavy media was developed by Kazarnovskii[2].

Thus, by carrying out measurements with neutrons at given instants of time after their introduction into the decelerator, it is possible, if we know their energy from Eq. (7), to use this process for the spectral investigation of neutron reactions; moreover, lead which is available in fairly pure form is a very adequate decelerator in this case.

With regard to the possibilities of this method, one may advance the following considerations (these were given in the report by F. L. Shapiro at the Seminar of the Academy of Sciences of the USSR in 1950). At an equal intensity of the source, the neutron current of a given energy inside of a fairly large mass of lead exceeds considerably the current attainable in neutron spectrometers on the principle of time of flight, in which the detector is located at a distance of several meters from the source. In fact, the neutron current in lead in the vicinity of the source is equal to

$$nv = \Phi_1 \approx \frac{Q}{(4\pi\tau_{Pb})^{3/2}} \frac{4\lambda_{s\,Pb}}{\xi v^2}. \qquad (10)$$

For the current at a distance R from the source of the fast neutrons surrounded by paraffin,(an arrangement generally used in the time-of-flight method), we have:

$$\Phi_2 < \frac{Q}{(4\pi\tau_{\Pi})^2} \frac{2\lambda_{s\Pi}}{v^2} \frac{S}{4\pi R^2}, \qquad (11)$$

where S is the area of the paraffin decelerator. Assuming that $\tau_{Pb} = 4 \times 10^3 \text{cm}^2$, $\tau_{paraf} = 60 \text{ cm}^2$, $\lambda_{sPb} = 3\text{cm}$, $\lambda_{s\,paraf} = 0.8\,\text{cm}$, $S = 200 \text{ cm}^2$ and $R = 3\text{m}$, we find:

$$\Phi_1 / \Phi_2 > 2 \cdot 10^3.$$

A more detailed evaluation, taking into account the leakage of neutrons during deceleration in a finite volume, shows that, by using a mass of lead of several ten-folds of tons, a gain in the neutron current can be attained of the order of 3 - 4 as compared with the time-of-flight method. This evaluation was also substantiated experimentally by measuring the densities of neutrons generated by an Ra-Be source inside a lead cube having dimensions of ~1 m^3, and in air at a distance of ~1 m from the same source surrounded by paraffin.

The high "luminosity" of the method of decelerating time makes it possible to carry out experiments on the spectrometry of slow neutrons, even if we possess only a comparatively simple and accessible source such as the reaction $D + T$ in an ionic accelerating tube of several hundred kilovolts.

The second advantage of this method of spectrometry by the decelerating time is the simple possibility of measuring the cross sections of the absorption, which is particularly important in the cases when the absorption is small as compared with the scattering. On the one hand, the passage of a thin sample, surrounding the neutron detector, placed in the mass of lead, is dependent only on the cross section of the neutron absorption in the sample. On the other hand, the small γ - background inside a large mass of lead permits us to measure simply the cross section of capture from the intensity of the captured γ - rays.

A disadvantage of the method proposed is the limited resolving capacity (~ 30% by energy) determinable by the dispersion (8). It may be assumed, however, that owing to the advantages mentioned above the method of the time deceleration, irrespective of its small resolving capacity, will prove to be a useful addition to the other known methods of neutron spectroscopy. The practical realization of this method[2] justified the above considerations.

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Diffusion Coefficient of Particles in a Magnetized Interstellar Medium

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THE diffusion of charged particles in a magnetized interstellar medium is very important for the explanation of the properties of the primary cosmic radiation[1]. The mechanism of passage of charged particles through a magnetized interstellar medium is similar to the process of diffusion of particles in gases. It follows from the mechanism