traversing the condenser the ions are discharged by the collector Q.

The sensitivity of the instrument is determined from the ratio of the number N of ions per cm^3 and the minimum density n required for detecting absorption, i.e., $N/n \approx N/10^4$. Thus the sensitivity will be the higher, the larger the ion current and the lower the ion energy. It is not difficult to see that in principle it is possible to raise this quantity to values of the order of 10^6 to 10^7; thus the possibility is disclosed of detecting isotopes having a natural abundance of a part in ten million.

The dispersion of the instrument is linear and according to formula (1) is obtained from the relation

$$D = (eH/2\pi mc)\,(1/100m) \qquad (2)$$

for a 1 percent change of mass. For elements of the center of the periodic table D will be about 10^4cps.

The resolving power is given by $R = m^* / \Delta m = \nu/\Delta\nu$, where $\Delta\nu$ is the error in the frequency measurement. Since $\Delta\nu = 10^{-5}\,\nu$ is easily attained, it is possible to hope for the creation of an instrument with a resolving power of about 10^5 and higher.

Thus experiments with cyclotron resonance on ion beams may prove to be useful in measuring nuclear masses. Such an experiment is easier to carry out for light elements.

[1] Ia. G. Dorfman, Dokl. Akad. Nauk SSR 81, 765 (1951).

[2] Dresselhaus, Kip and Kittel, Phys. Rev. 92, 827, (1953).

[3] Lax, Zeiger and Dexter, Physica 20, 818 (1954).

[4] A. F. Kip, Physica 20, 813 (1954).

[5] R. B. Dingle, Proc. Roy. Soc. (London), A212, 38 (1952).

[6] Dresselhaus, Kip and Kittel, Phys. Rev. 98, 368 (1955).

[7] B. Bleany and K. Stevens, Rep. Progr. Phys. 16, 108 (1953).

[8] Hipple, Sommer and Thomas, Phys. Rev. 76, 1877 (1949).

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Scattering Lengths of Slow Neutrons on Deuterons

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THE scattering of slow neutrons on free deuterons is completely specified by the two scattering lengths a_4 and a_2 that are associated with the two possible spin states of the system composed of two neutrons and one proton. From the experimental values of the total and coherent scattering cross sections for neutrons on deuterons it is possible to establish[1,2] that a_4 and a_2 are given by either α) $a_4 = 6.2 \times 10^{-13}$ cm and $a_2 = 0.8 \times 10^{-13}$ cm or β) $a_4 = 2.4 \times 10^{-13}$ cm and $a_2 = 8.3 \times 10^{-13}$ cm. Since the choice between these two possibilities cannot be made without experiments with polarized particles, it has to be based on theory. The theoretical solution of the problem of scattering in a three-body system has been carried out only under considerable simplifications. According to the theoretical work of some[3,4] one had to give a preference to the values β because according to theory $a_2 > a_4$. Others[5,6] obtained the opposite inequality $a_2 < a_4$, and one had to consider the values α as being the correct ones.

In the present note qualitative considerations in favor of the values α are pointed out.

The potential energy of the system composed of two neutrons and one proton depends only upon three "internal" coordinates, for which one may choose the distances ξ and η of the two neutrons from the proton and the cosine μ of the angle between them. The wave function of the S-states of such a system will depend only on the internal variables ξ, η, and μ and on the spin variables σ_1, σ_2 and σ_3 of all three particles. In particular, the wave function of the quartet state may be represented in the form

$$\Psi^{(s)}_{3/2\,M} = \varphi_{3/2}(\xi, \eta, \mu)\,\chi_{3/2\,M}(\sigma_1, \sigma_2, \sigma_3),$$
$$M = \pm 1/2, \pm 3/2,$$

where $\chi_{3/2\,M}$ is the spin wave function symmetric in an interchange of the spin coordinates of any pair of particles. Because of the identity of the two neutrons the complete wave function $\Psi_{3/2\, M}$ must be antisymmetric in a single interchange of the space and spin coordinates of the neutrons. Since $\chi_{3/2\, M}$ is symmetric, the space wave function must be antisymmetric in an interchange of the space coordinates of the neutrons. The transformation $\xi \to \eta$, $\eta \to \xi$, $\mu \to \mu$ corresponds to an interchange of the neutrons. Therefore the antisymmetry of the function $\varphi_{3/2}(\xi, \eta, \mu)$ is expressed by the simple equation

$$\varphi_{3/2}(\xi, \eta, \mu) = -\varphi_{3/2}(\eta, \xi, \mu). \qquad (1)$$

From (1) it follows immediately that $\varphi_{3/2} = 0$ for $\xi = \eta$. Thus, in the quartet state, events in which the neutron being scattered falls inside the deuteron are impossible. In other words, in the quartet state the n–d interaction is described by some effective potential of repulsion whose range of influence coincides with the dimensions of the deuteron. In this connection, the scattering length a_4 must be positive and exceed the "radius" of the deuteron, that is $a_4 \geq 4.3 \times 10^{-13}$ cm. Of the two possible pairs α and β of the experimental values for the scattering lengths only the values α satisfy the condition $a_4 \geq 4.3 \times 10^{-13}$ cm. Hence it is necessary to take $a_4 = 6.2 \times 10^{-13}$ cm and $a_2 = 0.8 \times 10^{-13}$ cm.

[1] D. Hurst and N. Alcock, Canad. J. Phys. **29**, 36 (1951).

[2] Wollan, Shull and Koehler, Phys. Rev. **83**, 700 (1951).

[3] M. Gordon, Phys. Rev. **80**, 1111 (1950).

[4] A. Troesch and M. Verde, Helv. Phys. Acta **24**, 39 (1951).

[5] L. Motz and J. Schwinger, Phys. Rev. **58**, 26 (1940).

[6] R. Christian and J. Gammel, Phys. Rev. **91**, 100 (1953).

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Contribution to the Theory of π-Meson Disintegration

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LET us consider the problem of the decay of the π-meson according to the scheme

$$\pi \to \mu + \gamma + \nu,$$

assuming that the μ-meson has an anomalous magnetic moment $\mu_a = \mu' + e/2M$, where M is the μ-meson mass. We consider the meson interaction as scalar (a pseudoscalar interaction yields the same results[1]):

$$H_{\pi,\, \mu\nu} = g(\bar{\varphi}_\nu \varphi_\mu)\Psi_\pi + \text{compl. conj.}$$

The interaction of a μ-meson with a γ-ray is given by the expression

$$H_{\mu,\gamma} = -ie\hat{A} - {}^1/_2\, i\mu'\gamma_i\gamma_k F_{ik},$$

$$F_{ik} = \partial A_k / \partial x_i - \partial A_i / \partial x_k.$$

The matrix element of the process is given by

$$M = \frac{2\pi eg}{\sqrt{E_\pi |k|}}\bar{u}_\mu \times \left[\hat{e} - \frac{i\mu'}{2e}(\hat{k}\hat{e} - \hat{e}\hat{k})\right](i\hat{p} + i\hat{k} - M)^{-1} u_\nu$$

where u_μ, u_ν are unitary bispinors of the wave functions of the μ-meson, and of the neutrino; $k = (\mathbf{k}, |k|)$ is the 4-momentum of the photon; $p = (\mathbf{p}, M)$ is the 4-momentum of the μ-meson and e is the unit polarization vector of the photon.

Averaging over polarizations and spins, we get the decay probability

$$dw = \frac{1}{16\pi^3}\frac{e^2g^2}{E_\pi E E_\nu k}\Big\{\Big[-2(\mathbf{pk} - Ek)$$

$$\times(-\mathbf{pk} - E_\pi k + Ek) - \frac{[\mathbf{pk}]}{k^2}(E_\pi^2 - [M-m]^2)$$

$$+ 8\Big[2\left(\frac{\mu'}{2e}\right)^2(\mathbf{pk} - Ek)^2\ (-\mathbf{pk} + Ek)$$

$$+ 2\left(\frac{\mu'}{2e}\right)(\mathbf{pk} - Ek)^2(M^2 - EE_\pi - mM)$$

$$+ \left(-\frac{\mu'}{2e}\right)(\mathbf{pk} - Ek)^2(m - M)$$

$$+ \left(-\frac{\mu'}{2e}\right)(\mathbf{pk} - Ek)(-ME_\pi k)\Big]\Big\}\frac{d\mathbf{p}\, d\mathbf{k}}{(Ek - \mathbf{pk})^2},$$

where m is the mass of the neutrino and E_π is the energy of the decaying meson.

Integrating over the directions of the photon, we get the probability of a decay with emission of a μ-meson with momentum p (we take $m = 0$):