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THE RELATION BETWEEN THE SCATTERING LENGTH AND THE RADIATIVE CAPTURE CROSS SECTION FOR NEUTRONS

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FOR low energy neutrons, when the main contribution to the interaction with nuclei comes from the partial wave for zero angular momentum, there is a simple relation between the cross sections for elastic scattering and for radiative capture of neutrons in the region between resonances:

$$\sigma_{\gamma J}(E) = -g_J \lambda \Gamma_\gamma da_J(E)/dE. \quad (1)$$

Here $\sigma_{\gamma J}$ is the total cross section for radiative capture of neutrons in the channel with spin J: $g_J = (2J+1)/2(2i+1)$ is the statistical weight for the J channel; i is the spin of the target nucleus; λ is the neutron wave length; Γ_γ is the radiative width; a_J is the amplitude for scattering in the J channel. For even-even nuclei $a_J \equiv a = (\sigma_s/4\pi)^{1/2}$, where σ_s is the scattering cross section. Formula (1) is valid to an accuracy of order $[\Gamma/(E-E_0)]^2:1$ and $(kR)^2:1$ ($|E-E_0|$ is the distance to the nearest resonance, Γ is the resonance width at energy E, $k = 2\pi/\lambda$ is the wave number of the neutron, and R is the nuclear radius), and is gotten on the following assumptions.

1. There is no interference between resonances in the total cross section for radiative capture. The absence of interference may be regarded as an experimental fact; the reason for the washing out of the interference is the very large number of channels for radiative capture in the case of neutrons of medium or high energy.

2. For resonances with the same spin and parity, the total radiation widths are the same. The experimental data[1] indicate a constant radiation width within the limits of error of the experiments (±10–15%). If the radiation widths are not constant, Γ_γ in (1) will be some average value which has a weak energy dependence.

To obtain (1) we use the expression for the S matrix element which follows from the R matrix theory of Wigner and Eisenbud:[2]

$$S_{st} = e^{-2i\varphi_{st}}\left\{\delta_{st} + i\sum_\lambda \frac{\Gamma_{\lambda s}^{1/2}\Gamma_{\lambda t}^{1/2}}{E_\lambda - E - i\Gamma_{\lambda\lambda}/2} - \frac{1}{2}\sum_\lambda\sum_{\mu(\neq\lambda)} \frac{\Gamma_{\lambda s}^{1/2}\Gamma_{\mu t}^{1/2}\Gamma_{\lambda\mu}}{(E_\lambda - E - i\Gamma_{\lambda\lambda}/2)(E_\mu - E - i\Gamma_{\mu\mu}/2)} + \ldots\right\}$$

$$\Gamma_{\lambda\mu} = \sum_c \Gamma_{\lambda c}^{1/2}\Gamma_{\mu c}^{1/2}. \quad (2)$$

Here $\Gamma_{\lambda s}$ is the neutron width, $\Gamma_{\lambda t}$ ($t \neq s$) is the partial radiation width, $\varphi_{st} = kR$ for the elastic scattering channel ($t = s$) and is of no importance for the radiative channels ($s \neq t$).

Because of the assumption that there is no interference between resonances in the radiative capture,

$$\sum_{c(\neq s)} \Gamma_{\lambda c}^{1/2}\Gamma_{\mu c}^{1/2} = \Gamma_\gamma \cdot \delta_{\lambda\mu},$$

i.e.,

$$\Gamma_{\lambda\mu} = \Gamma_\gamma \delta_{\lambda\mu} + \Gamma_{\lambda s}^{1/2}\Gamma_{\mu s}^{1/2}. \quad (3)$$

Using (3) and expanding (2) in powers of kR and $\Gamma_\lambda/(E_\lambda - E)$, we get

$$k^2\sigma_\gamma/\pi = \sum_{t(\neq s)} |S_{st}|^2 = \sum_\lambda \Gamma_{\lambda s}\Gamma_\gamma/(E_\lambda - E)^2 + O[(\Gamma/(E-E_0))^4], \quad (4)$$

$$|a| = |1 - S_{ss}|/2k = \left|R - \sum_\lambda \Gamma_{\lambda s}/2k(E_\lambda - E)\right| \times \{1 + O[(kR + \Gamma/|E-E_0|)^2]\}. \quad (5)$$

Differentiating (5) (with $\Gamma_{\lambda S}/k = \text{const}$) and comparing with (4), we get (1) and the estimates of accuracy given above. The latter are unchanged if we include the contribution of p neutrons to the scattering and capture.

For $E < 10$ keV and $|E - E_0| > 10\Gamma$, relation (1) is accurate to better than 1%, if interference of resonances is completely absent in the radiative capture. The interference terms can give a relative contribution of $\sim 1/\sqrt{N}$ to (4), where N is the number of channels for radiative capture. For $N = 100$, the error in (1) can therefore amount to $\sim 10\%$.

Relation (1) can be used to determine radiation widths and capture cross sections from measurements of total cross sections of even-even nuclei. In some cases using (1) may give valuable information for odd nuclei also. Thus, it has been applied to get the radiative widths of Cl^{35} and Sc^{45}.

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MAGNETIZATION OF A FERROMAGNETIC METAL BY THE MAGNETIC FIELD OF LIGHT WAVES

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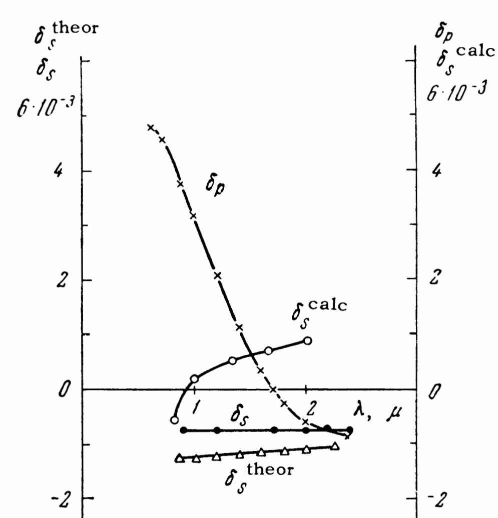
IT has been shown[1] that to measure the permeability of a ferromagnet at optical frequencies we can use the equatorial Kerr effect $\delta = \Delta J/J_0$, where ΔJ is the change in the intensity of the reflected light due to the magnetization of the ferromagnet. The magnitude of this effect, δ_s, for the s-wave of linearly polarized light (the magnetic vector of the light wave perpendicular to the magnetization vector of the sample) is determined by the nondiagonal component of the permeability tensor, and for the p-wave (δ_p) it is determined by the nondiagonal component of the permittivity tensor. From previous measurements, it follows that for pure ferromagnetic metals δ_s is at least two orders of magnitude smaller than δ_p, i.e., $\delta_s \lesssim 10^{-5}$.

The construction of the experimental apparatus to record the reflected-light intensity changes $\Delta J/J_0$ of the order of 10^{-5}–10^{-6},[2] made it possible to measure directly the gyromagnetic Kerr effect δ_s and to determine the permeability of iron in the wavelength region 0.9–2.4 μ. The iron sample was made in the form of a thin-walled toroid (60 mm in diameter and having a cross section of 0.5 × 24 mm) in order to reduce induction. The working part of the toroid surface, measuring 24 × 30 mm and free of the magnetizing winding, was first polished mechanically and then annealed in vacuum at 1100° C for 6 hours and then polished electrolytically.

The results of measurements for the s- and p-components of linearly polarized light are shown in the figure. The values of the gyromagnetic Kerr effect were approximately 100 times smaller than those of the gyroelectric Kerr effect. The negative sign of δ_s was determined as follows: with the polarizer oriented for the s-component in the region where $\delta_p > 0$, the total effect could be reduced to zero by rotating the polarizer to the left or right by some angle; the value of this angle decreased



Equatorial Kerr effect in iron for $\varphi = 45°$: δ_p is the gyroelectric effect, δ_s is the gyromagnetic effect, δ_s^{theor} is the gyromagnetic effect calculated using Eq. (1), δ_s^{calc} is the gyromagnetic effect according to [4].