degree of non-isothermal nature of T_e/T_p and on the masses of the atoms of the gas in which the discharge takes place. For light gases the transverse field does not change its sign, while in a discharge in heavy gases there exists such a magnetic field, for which the sign of the transverse gradient reverses.* In the case of light elements relation (1) can be represented as

$$E_r^H / E_r = (Z^H / Z)(1 + b_p^2 H^2 / c^2), \quad (1a)$$

and for fields less than 1,000 gauss it reduces to

$$E_r^H / E_r = Z^H / Z. \quad (1b)$$

To compare (1b) with experimental results we employed measurements of the longitudinal gradient in neon with and without a magnetic field. The ratio of the transverse fields obtained from the longitudinal gradients with the aid of formula (1b) gave a result that was in satisfactory agreement with the measurements of Bicerton and Engel.[1]†

In the case of heavy elements Eq. (1) becomes

$$E_r^H / E_r = (Z^H / Z)\,[1 - (D_p b_e^2 - D_e b_p^2)\,H^2 / (D_e - D_p)\,c^2], \quad (1c)$$

and the magnetic field at which the transverse gradient vanishes is determined by

$$H_0^2 = c^2 (D_e - D_p) / (D_p b_e^2 - D_e b_p^2). \quad (2)$$

In the case of discharge in mercury vapor at a pressure 10^{-2} mm mercury and $T_e/T_p = 10^2$ the value of the magnetic field determined by (2) is approximately 2,000 gauss; at larger fields the transverse gradient should reverse its sign.‡ However, experiments in which such a phenomenon would be observed are unknown to this author, and it is therefore impossible to compare the calculated and experimental results.

In conclusion I feel it my duty to thank Professor Ia. P. Terletskii and A. A. Zaitsev for advice in various problems touched upon in this work.

*When $T_e/T_p = 10^2$ and the free paths are gas-kinetic, the sign of the space charge cannot change for a gas of atomic weight less than 15.

†If the magnetic fields are large, the ratio (1a) tends to a constant value, as can be verified by using the equations from the Schottky theory.

‡The phenomenon can be studied at fields less than H_0. In this case the ratio of the gradients in a discharge in light gases should approach asymptotically a constant value, something that does not happen for heavy gases.

[1] R. J. Bicerton and A. Engel, Proc. Phys. Soc. 69B, 468 (1956).
[2] G. Ecker, Proc. Phys. Soc. 67B, 485 (1954).

Translated by J. G. Adashko
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CONTRIBUTION TO THE THEORY OF STRIPPING AT HIGH ENERGIES

A. I. AKHIEZER and A. G. SITENKO

Khar'kov State University and Physico-Technical Institute, Academy of Sciences, Ukrainian S.S.R.

Submitted to JETP editor May 23, 1957

J. Exptl.' Theoret. Phys. (U.S.S.R.) 33, 1040-1042 (October, 1957)

SERBER[1] determined the cross section of the stripping reaction under the assumption that the nuclear radius R is considerably greater than the deuteron radius R_d. This, however, is a poor assumption even for the heaviest nuclei, where the ratio $p = R/R_d$ reaches approximately 5. It is therefore desirable to determine the cross section of the stripping reaction without assuming $R \gg R_d$. This communication is devoted to this problem.

Let us consider, to be specific, a reaction that causes a nucleus to liberate a neutron and absorb a proton. This process can be described by a wave function $\Psi = \Omega_n \psi_0(\rho_d)\varphi_0(r)$, where $\varphi_0(r) = \sqrt{\alpha/2\pi} \times e^{-\alpha}/r$ is the wave function of the deuteron ground state $(\alpha = 1/2R_v)$, $\psi_0(\rho_d) = 1$ is the portion of the wave function describing the motion of the center of gravity of the deuteron in a plane perpendicular to the momentum of the incident deuteron, and Ω_n is a factor allowing for the absorption of neutron by the nucleus; this factor, in the case of an absolutely black nucleus, is

$$\Omega_n \equiv \Omega(\rho_n) = \begin{cases} 0 & \rho_n \leqslant R \\ 1 & \rho_n > R \end{cases}$$

(ρ_n is the projection of the neutron radius vector on the plane perpendicular to the momentum p_0 of the deuteron).

Expanding Ψ into a Fourier integral in the functions $e^{-i\mathbf{k}\mathbf{r}_n}$ ($\mathbf{r}_n$ is the radius vector of the neutron), we determine the amplitude of the probability $a_{\mathbf{k}}(\mathbf{r}_p)$ that the neutron has a wave vector $\mathbf{k}$ and the proton is located at the point $\mathbf{r}_p$:

$$a_{\mathbf{k}}(\mathbf{r}_p) = \int e^{-i\mathbf{k}\mathbf{r}_n}\Omega_n\varphi_0(r)\,d\mathbf{r}_n.$$

Integrating $|a_{\mathbf{k}}(\mathbf{r}_p)|^2$ with respect to $d\rho_p$ from $\rho_p = 0$ to $\rho_p = R$ we obtain the differential stripping cross section $d\sigma_n$ for which the wave vector of the neutron lies in the interval $d\mathbf{k}$.

$$d\sigma_n = \frac{d\mathbf{k}}{(2\pi)^3}\int\limits_{\rho_p<R} d\rho_p\,|a_{\mathbf{k}}(\rho_p)|^2 = \frac{d\mathbf{k}}{(2\pi)^3}\int d\rho_p\{1-|\Omega_p|^2\}\,|a_{\mathbf{k}}(\rho_p)|^2, \tag{1}$$

where $\Omega_p = \Omega(\rho_p)$.

The total stripping cross section is obviously

$$\sigma_n = \iint d\rho_p d\mathbf{r}_n\{1-|\Omega_p|^2\}\,|\Omega_n|^2\,\varphi_0^2(r). \tag{2}$$

expanding $\{1 - |\Omega(\rho)|^2\}$ into a Fourier integral

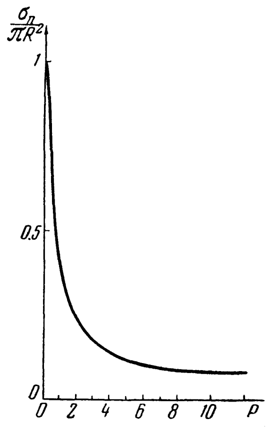
$$1 - |\Omega(\rho)|^2 = \int \chi(g)\,e^{i\mathbf{g}\rho}\,d\mathbf{g}, \quad \chi(g) = RJ_1(gR)/2\pi g,$$

where $J_1(x)$ is the Bessel function, we get

$$\sigma_n = \pi R^2\left\{1 - 2\int\limits_0^\infty \frac{p}{\xi}\tan^{-1}\frac{\xi}{p}\,\frac{J_1^2(\xi)}{\xi}\,d\xi\right\}. \tag{3}$$

In the limit for large p this formula becomes the Serber formula

$$\sigma_n^{(s)} = \pi R R_d/2. \tag{4}$$



The diagram shows the variation of σ_n with p. In the case of lead $p = 4.2$ and Eq. (3) yields $\sigma_n = 3.2 \times 10^{-25}$ cm^2, while Serber's formula gives $\sigma_n^{(s)} = 2.7 \times 10^{-25}$ cm^2. When $p = 1$, $\sigma_n = 5.8 \times 10^{-26}$ cm^2 and $\sigma_n^{(s)} = 6.9 \times 10^{-26}$ cm^2.

Formula (3) determines also the stripping cross section σ_p of the proton.

To obtain the energy distribution of the freed neutrons it is necessary to integrate (1) over the perpendicular components of the vector $\mathbf{k}$:

$$d\sigma_n(k_z) = \frac{dk_z}{2\pi}\int\frac{\partial\varkappa}{(2\pi)^2}\int d\rho_p\{1-|\Omega_p|^2\}\left|\int d\rho_n e^{-i\varkappa\rho_n}\,\Omega_n\int dz e^{ik_z z}\varphi_0(r)\right|^2,$$

where κ is the projection of vector $\mathbf{k}$ on the plane perpendicular to $\mathbf{p}_0$. Using the completeness of the functions $e^{i\kappa\rho_n}$ and expanding $|\Omega_n|^2$ and $|\Omega_p|^2$ into Fourier integrals, we obtain finally

$$d\sigma_n(k_z) = F(k_z)\,dk_z, \quad k_z = (E - E_0/2)/\hbar\sqrt{E_0/M},$$

$$F(k_z) = \frac{8pR^3}{\pi} \int_0^1 K_0^2 (p \sqrt{1 + k_z^2/\alpha^2}\, \zeta) (\sin^{-1} \zeta + \zeta \sqrt{1-\zeta^2}) \zeta d\zeta, \quad (5)$$

where $K_0(x)$ is the modified Bessel function, E_0 is the energy of the incident deuteron, and M the neutron mass.

In the limiting case $p \gg 1$ this formula becomes the Serber formula

$$d\sigma_n^s(k_z) = (\pi/4) RR_d \alpha^2 dk_z / (\alpha^2 + k_z^2)^{3/2}. \quad (6)$$

Let us determine also the deuteron absorption cross section σ_a. Since[2]

$$\sigma_a + \sigma_n + \sigma_p = \sigma_t / 2,$$

where

$$\sigma_t = 4\pi R^2 \left\{ 1 - \int_0^\infty \frac{p}{\xi} \tan^{-1} \frac{\xi}{p} \frac{J_1^2(\xi)}{\xi} d\xi \right\},$$

is the integral cross section for all the interactions between fast deuterons and nuclei, then

$$\sigma_a = 2\pi R^2 \int_0^\infty \frac{p}{\xi} \tan^{-1} \frac{\xi}{p} \frac{J_1^2(\xi)}{\xi} d\xi. \quad (7)$$

When $p \gg 1$ we get

$$\sigma_a = \pi R^2 - \pi R R_d / 2. \quad (8)$$

It is possible to determine the influence of the Coulomb field and of the semi-transparency of the nucleus, as was done in Ref. 2. It is easy to see that the Coulomb field affects neither the total cross section nor the energy distribution of the particles. The semi-transparency of the nucleus decreases the stripping cross section. If the absorption is large, i.e., $|b|R \gg 1$ and if $p \gg 1$, then

$$\sigma_n = (\pi/2) RR_d \{1 - (1/2 |b|^2 R^2)\}. \quad (9)$$

[1] R. Serber, Phys. Rev. 72, 1008 (1947).
[2] A. I. Akhiezer and A. G. Sitenko, J. Exptl. Theoret. Phys. (U.S.S.R.) 32, 794 (1957); Soviet Phys. JETP 5, 652 (1957).

Translated by J. G. Adashko
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PARAMAGNETIC RESONANCE IN NEODYMIUM NITRATE

T. I. SANADZE

Tbilisi State University

Submitted to JETP editor June 2, 1957

J. Exptl. Theoret. Phys. (U.S.S.R.) 33, 1042-1043 (October, 1957)

THE paramagnetic resonance spectra of rare-earth ions have been intensely investigated in recent years by Bleany and his colleagues. The measurements were made primarily on ethyl-sulphates $M(C_2H_5SO_4)_3 \cdot 9H_2O$, where M is a rare-earth ion. A study of the paramagnetic resonance of rare-earth ions in other compounds is also of great interest. At the suggestion of S. A. Al'tshuler and B. M. Kozyrev, we began an investigation of the nitrates of rare-earth elements, $M(NO_3)_3 \cdot 6H_2O$.

The measurements were made at a wavelength of 3.2 cm at liquid-hydrogen temperatures using a bal-