Nonelastic Collision Cross Sections for Slow Neutrons

The production of artificial β-active isotopes by neutron impacts, which has been investigated by Fermi and others, shows a considerable increase by sending the neutrons through substances containing hydrogen. It is generally assumed that the effect of these substances is to reduce the velocity of the neutrons to a fairly small fraction of its initial value.

At first it seems very astonishing that the cross sections for these processes as reported by various authors become very much larger than the geometrical cross section of the nuclei in some cases. Chadwick and Goldhaber[1] use this as an argument in assuming that the collision processes are due to forces acting at distances which are large compared with nuclear dimensions. Such a phenomenon would be of very great interest. Indeed Beck and Sitte[2] have pointed out that the radioactive β-decay might possibly take place partially outside the transformed nucleus.

We wish to point out, however, that a very simple quantum-mechanical model sometimes leads to large cross sections and that therefore a definite conclusion cannot be drawn concerning the region in which these processes take place before more detailed evidence is available. We shall consider a small sphere absorbing an incident plane neutron wave. This model is evidently quite independent of detailed assumptions concerning the collision process and accounts for any nonelastic collisions. Let η_0 be the absorption coefficient of the sphere, $k_1=(2\pi/h)(2mE)^{\frac{1}{2}}=2\pi/\lambda_1$ the wave number of the neutrino outside the nucleus, and $k_2=(2\pi/h)[2m(E+U)]^{\frac{1}{2}}$ the same quantity inside the small sphere of radius R. Then the absorption cross section for particles with zero angular momentum becomes

$$Q_0=\frac{\pi}{k_1^2}\left\{1-\frac{\left|i\gamma\frac{1-e^{-2\beta}(\cos 2\alpha+i\sin 2\alpha)}{1+e^{-2\beta}(\cos 2\alpha+i\sin 2\alpha)}-i(\alpha+i\beta)\right|^2}{\left|i\gamma\frac{1-e^{-2\beta}(\cos 2\alpha+i\sin 2\alpha)}{1+e^{-2\beta}(\cos 2\alpha+i\sin 2\alpha)}+i(\alpha+i\beta)\right|^2}\right\} \quad (1)$$

$$\alpha=k_2R;\qquad \beta=\eta_0R;\qquad \gamma=k_1R.$$

Under favorable assumptions for $\eta_0(\eta_0R\to 1)$ and for sufficiently small values of k_1 (i.e., for slow neutrons) (1) reduces to the form

$$Q_0\sim R\lambda_1. \quad (2)$$

Thus, for sufficiently slow neutrons the cross section, Q_0, exceeds the geometrical cross section, $q=\pi R^2$, by a factor $\lambda_1/2\pi R$, which may take values as large as 10,000 provided the neutrons have ordinary temperature velocities.

Though no exactly corresponding phenomenon exists for light, we may regard this result as similar to the well-known fact that in the case of resonance the cross section between atoms and light quanta can become

$$Q\sim\lambda_1^2/4\pi, \quad (3)$$

which is even of one order higher with respect to λ_1 than (2).

If the velocity of the neutrons decreases, we shall thus generally expect an increase of the cross section (2) up to a lower threshold value of the effective neutron velocities, which of course will be different for various elements and in some cases may be at zero velocity.

Whether this explanation will be sufficient to account entirely for the observed facts cannot be said before more detailed experimental evidence is available.

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[1] Chadwick and Goldhaber, Nature **135**, 65 (1935).
[2] Beck and Sitte, Zeits. f. Physik **86**, 105 (1933).

The Far Ultraviolet Absorption Spectra and Ionization Potentials of Methyl Bromide and Chloride

The absorption spectra of methyl bromide and methyl chloride have been photographed under high dispersion in the region 1800–1000A. The bands in methyl bromide start around 1786A and go to two distinct limits. The strong bands can be arranged in two electronic series. The higher members conform very well to Rydberg formulas and there are only slight deviations in the case of the lower ones. As many as ten series members were observed in each case. The limits of the two series were found to be 85,020 cm^{-1} and 87,590 cm^{-1} corresponding to ionization potentials of 10.488 and 10.805 volts, respectively. The probable error is not greater than 0.002 volt.

In methyl chloride a similar absorption spectrum was found. The strong bands start at about 1400A and go to limits around 1100A. An analysis of the bands showed that they also consist mainly of two electronic series going to the limits 90,520 cm^{-1} and 91,180 cm^{-1} which correspond to the ionization potentials 11.17 and 11.25 volts. On account of the proximity of the two ionization potentials there is a little uncertainty as to the assignment of some of the higher members. However the values given are believed to be correct to 0.01 volt.

Professor R. S. Mulliken has privately informed the author that the difference between the two ionization potentials observed for each of the methyl halides is in each case in excellent agreement with the difference he has calculated on the assumption that the excitation is of a nonbonding $np\pi$ electron.[1] The absence of vibrational pattern accompanying the higher series members is further confirmation that the electrons are of a nonbonding type. However, the actual values of the ionization potentials observed are somewhat lower than those predicted and the author suggests that this may be partly accounted for by the presence of a dipole of about 0.3×10^{-18} e.s.u. in the methyl group.

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[1] R. S. Mulliken, Phys. Rev. **47**, 413 (1935).