Letters to the Editor

ON THE MASSEY PARAMETER IN THE THEORY OF ATOMIC COLLISIONS

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It has been shown by Hasted and Stedeford[1] and Fogel' and coworkers[2,3] that the extensive experimental material on the capture of electrons in collisions of atoms and ions can be well accounted for within the framework of the so-called adiabatic hypothesis of Massey.[4] Thus the magnitude of the cross section is determined by the parameter $|\Delta E|a/hv$, where $|\Delta E|$ is the change in the internal energy in the collision, v is the relative velocity of the atoms before the collision, and a is a quantity with the dimension of a length whose magnitude is of the order of atomic dimensions. For $a|\Delta E|/hv \gg 1$, when the process is adiabatic, the cross section is small. As the velocity increases the cross section becomes larger and reaches its maximal value for $|\Delta E|a/hv \sim 1$. For still higher velocities the cross section drops again.

With a defined as

$$a = hv_m / |\Delta E|, \qquad (1)$$

where v_m is the velocity for which the cross section is maximal, it appears that the numerical value of a is mainly determined by the type of process and is almost independent of the nature of the colliding particles. Thus, according to the data of Hasted, $a \sim 8\,A$ for the capture of an electron by singly charged ions, and $a \sim 1.5\,A$, from the data of Fogel', for the capture of two electrons.

It is of interest to clarify what physical characteristic of the process corresponds to the parameter a as defined by formula (1). For this purpose we consider the known formulas for the momentum $q(\theta)$ imparted in the scattering into the angle θ with a change ΔE in the internal energy (in the center of mass system). Let $\mathbf{p}_0$ and $\mathbf{p}$ be the momentum of the particle before and after the collision. Using the relation $(p_0^2 - p^2)/2m = \Delta E$ and observing that $|\mathbf{p}_0 - \mathbf{p}| \ll p_0$ (which is usually true in the case of atomic collisions), we obtain

$$q(\theta) = |\mathbf{p}_0 - \mathbf{p}| = [(\Delta E / v)^2 + 4p_0^2 \sin^2(\theta/2)]^{1/2}.$$

In the small angle forward scattering ($0 \le \theta \ll |\mathbf{p}_0 - \mathbf{p}|/p_0$) the momentum $q(0) = |\Delta E|/v$ is imparted. In particular, if $v = v_m$, we have $q_m = |\Delta E|/v_m$. Since the velocity v_m corresponds to the maximal cross section, q_m represents the most probable momentum imparted in the forward scattering.

We therefore have

$$a = h / q_m,$$

i.e., a is inversely proportional to the most probable momentum imparted in the forward scattering. The abovementioned characteristic peculiarities of the quantity a, therefore, express the fact that each process is characterized by a definite most probable momentum transfer q_m which is almost independent of the nature of the colliding particles. The circumstance that a is smaller for the double capture than for the single capture has, from this point of view, an obvious explanation: the momentum transfer in the double capture is, of course, larger than in the single capture.

The actual numerical values of a indicate that the magnitude of q_m is of the order of the atomic unit of momentum $\hbar/a_0$ (a_0 is the Bohr radius). Hence the adiabatic condition corresponds to $q \gg \hbar/a_0$.

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[1] J. B. Hasted and J. Stedeford, Proc. Roy. Soc. **A227**, 466 (1955).

[2] Fogel', Mitin, Kozlov, and Romashko, JETP **35**, 565 (1958); Soviet Phys. JETP **8**, 390 (1959).

[3] Fogel', Ankudinov, and Pilipenko, JETP **35**, 868 (1958); Soviet Phys. **8**, 601 (1959).

[4] H. S. Massey, Rep. Progr. Phys. **12**, 248 (1948).

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