Electron Impact Ionization of Ne, O, and N

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The Bethe approximation gives a functional relation between the cross sections for electron impact ionization (Q) and photoionization (a). Estimates of Q_{N} and Q_{O} are obtained using experimental values for Q_{Ne} and calculated values for a_{N}, a_{O}, and a_{Ne}.

LET $Q(E)$ be the total cross section for ionization of an atom by electrons of kinetic energy E and let $a(W)$ be the cross section for photoionization, W being the energy of the ejected electron. The approximation of Bethe[1] is

$$Q(E)=\frac{I_{\mathrm{H}}}{\pi\alpha E}\int_0^{E-I}\frac{a(W)}{(I+W)}\ln\left(\frac{4E\tau}{I+W}\right)dW, \quad (1)$$

where I is the threshold ionization energy, I_{H} is the threshold ionization energy of hydrogen, α is the fine structure constant, and τ is a constant of order unity.

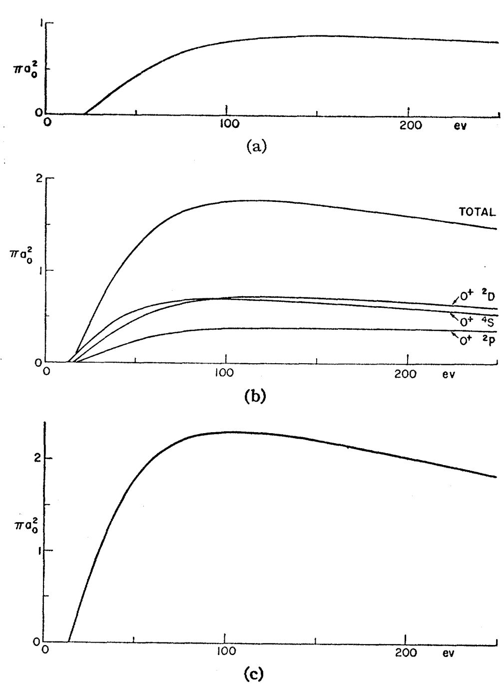

FIG. 1. (a) Experimental cross section for Ne ionization by electron impact ($\mathrm{Ne}+e\rightarrow\mathrm{Ne}^++2e$). (b) Calculated cross sections for O ionization by electron impact ($\mathrm{O}+e\rightarrow\mathrm{O}^++2e$). The curves show the total cross section and the cross sections for O $2p^4\ ^3P\rightarrow\mathrm{O}^+\ 2p^3\ ^4S$, ^2D, and ^2P. (c) Calculated cross section for N ionization by electron impact ($\mathrm{N}+e\rightarrow\mathrm{N}^++2e$). (N $2p^3\ ^4S\rightarrow\mathrm{N}^+\ 2p^2\ ^3P$ only; the transitions $2p^3\ ^4S\rightarrow 2p^2\ ^1D$ and ^1S do not occur in photoionization and may be expected to have small cross sections for collisional ionization.)

We consider two atoms, A and B, for which the photoionization cross sections a_A, a_B are such that

$$a_A(I_A\chi)/a_A(0)=a_B(I_B\chi)/a_B(0). \quad (2)$$

Then from (1) and (2)

$$I_AQ_A(I_A\epsilon)/a_A(0)=I_BQ_B(I_B\epsilon)/a_B(0). \quad (3)$$

The Bethe approximation (1) is valid for large values of $\epsilon=(E/I)$. For values of ϵ which are not large we may expect that (1) will give similar percentage errors for Q_A and Q_B and that the functional relation (3) will remain a useful approximation.

The cross sections Q_{Ne} and a_{Ne} have been determined experimentally by Bleakney[2] and by Po Lee and Weissler,[3] and the cross sections a_{Ne}, a_{O}, and a_{N} have been calculated by the Hartree-Fock method by Bates and Seaton[4] and Seaton.[5] Owing to the use of approximate wave functions, the dipole length and dipole velocity formulas give somewhat different results, denoted by $a^{(L)}$ and $a^{(V)}$. For Ne the geometric mean,

$$a=[a^{(L)}a^{(V)}]^{\frac{1}{2}}, \quad (4)$$

agrees closely with the experimental result. The calculated ratio $a_{\mathrm{Ne}}/a_{\mathrm{O}}$ is in good agreement with (2); the ratio $a_{\mathrm{Ne}}/a_{\mathrm{N}}$ is in slightly worse agreement.

Figure 1 shows the experimental cross section Q_{Ne} and the cross sections Q_{O} and Q_{N} calculated by using Q_{Ne} and Eqs. (3) and (4). Our results for Q_{O} are compared with experimental results in an accompanying paper by Fite and Brackmann.[6] The very satisfactory agreement at moderate and high energies provides a useful check on the accuracy of a_{O} calculated by using (4).

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[6] W. L. Fite and R. T. Brackmann, following paper [Phys. Rev. **113**, 815 (1959)].