5e. Electrical Conductions in Gases

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Under normal circumstances (thermal equilibrium at temperatures less than 500°C) gases are very good insulators. If free charges are introduced into the gas, electrical conduction can take place. For weak constant fields the charges have superimposed on their thermal motions a drift in the direction of the field. The drift velocity **v** is proportional to the electric field, the proportionality constant being called the mobility μ. The current density **J** is related to the number density n of particle with charge q, by $\mathbf{J} = qn\mathbf{v}$; and the conductivity is given by $\sigma = qn\mu$. Charges of different sign move in opposite directions, and so the currents contributed are all in the same direction. The total conductivity is just the scalar sum $\sigma = \Sigma q_i n_i \mu_i$.

Unfortunately these simple expressions do not have wide applicability. At field strengths commonly of interest, the drift velocity is not proportional to the electric field because of the effect of the field on the distribution of velocities of the free charges. A more consequential breakdown of the simple description occurs in the very common circumstance where it is the conduction current which is responsible (by direct or indirect means) for the production of the free charges. These processes frequently involve interactions with solid surfaces at the container walls or the electrodes. A description of the conduction processes must be concerned not only with the rate of transport of the charges, i.e., **v**, but also with the density of charges and the processes which produce and remove the charges.

For a-c fields an inductive effect is important, and the complex conductivity at radian frequency ω is approximately

$$\sigma = \frac{q^2 n}{m(j\omega + \nu_m)}$$

where ν_m, the momentum transfer collision frequency, is related to the low-frequency mobility by $\mu = q/m\nu_m$. This formula is more generally useful at high than at low frequencies.

Many of the data needed for a description of gaseous conductors are available in the literature; however, much of this information is not, and in many instances the accuracy of the data is questionable. The volume of such data is much too large to reproduce here; however, several collections are available.

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