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Letters to the Editor

A NOTE ON THE MOBILITY OF SOME IONS IN A HIGH FIELD

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A uniform theory of the mobility of ions in parent gases, valid for the low, mean and high values of the ratio E/p has not been determined so far. There is a tendency to solve this problem by matching two distinct theories for the high and low electric fields.

In paper [1] Martišovitš has obtained an approximate formula for the mobility of positive ions in rare gases in the region of mean values of E/p. The author has combined the results of the Wannier theory for the limit of the high field with the Langevin theory derived for the low field, which yields the following formula

$$\frac{\mu_+}{\mu_{+0}} = \left(1 + a\,\frac{m_+ v^2}{kT_g}\right)^{-1/2}, \qquad (1)$$

where μ_+ and μ_{+0} are the ion mobilities in the mean and in the limit of the low („zero“) field, respectively; m_+ is the mass of the ion, v the drift velocity of ions, k the Boltzmann constant, T_g the temperature of the gas and a the constant with the same value of $a = 0.183$ for all inert gases.

But he has not dealt with the question of application of this formula to other gases. It should be noted that equation (1) is true only in the case, when the process of the charge transfer becomes dominant, which is the case of the ions moving in their respective parent gases.

The object of our work is to ascertain the validity of formula (1) for some other gases. For this purpose the data for the mobility of CO^+, Hg^+, O_2^+ and N_2^+ ions in parent gases referred to in [2, 3] were used; „zero“ — mobilities μ_{+0} were taken from [2—5]:

CO^+	$\mu_{+0} = 1.6\ \mathrm{cm^2V^{-1}sec^{-1}}$	[2]
Hg^+	$\mu_{+0} = 0.24\ \mathrm{cm^2V^{-1}sec^{-1}}$	[3]
O_2^+	$\mu_{+0} = 2.2\ \mathrm{cm^2V^{-1}sec^{-1}}$	[4]
N_2^+	$\mu_{+0} = 1.87\ \mathrm{cm^2V^{-1}sec^{-1}}$	[5]

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In Figure 1 the ratio μ_+/μ_{+0} is plotted against $\left\{v\left(\frac{m_+}{kT_g}\right)^{1/2}\right\}$ for CO, Hg, O_2 and N_2. In the same figure also the theoretical curve (the solid line) according to (1), is presented. A sharp increase in μ_+/μ_{+0} occurs at certain values of $\{v(m_+/kT_g)^{1/2}\}$ (4 for CO^+ and 3 for N_2^+), which is caused by the conversion of CO^+ and N_2^+ ions into $(CO)_2^+$ and N_4^+ according to Varney's reaction [2]. The data for CO^+ and N_2^+ ions agree quite well with the theoretical curve but for oxygen and mercury ions the situation is much less satisfactory. To explain the reason for this discrepancy, the slope of the curve together with the value of the parameter a were tested using a more general formula of the form

$$\left(\frac{\mu_{+0}}{\mu_+}\right)^2 = 1 + a\left(\frac{m_+ v^2}{kT_g}\right)^{\alpha}, \qquad (2)$$

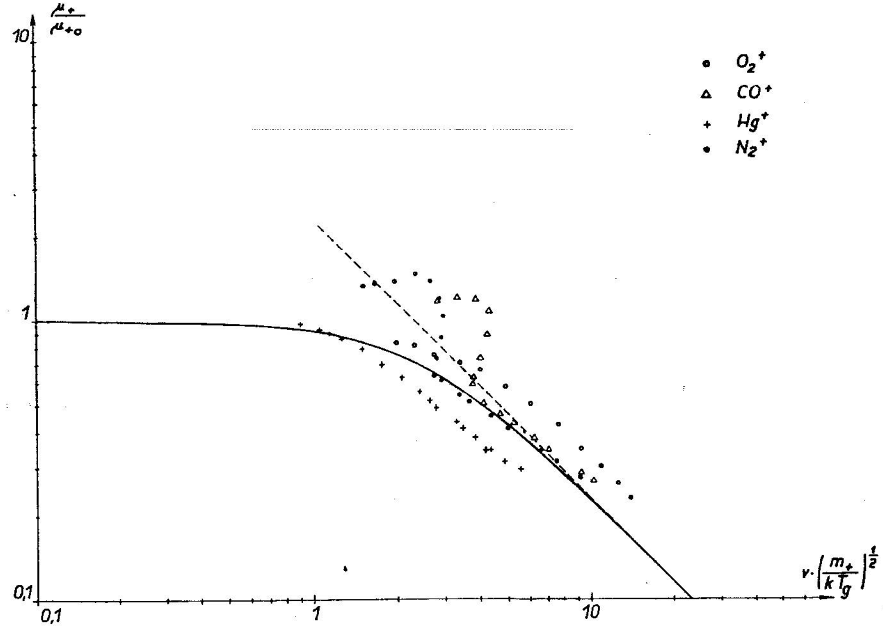

Fig. 1. Variation of normalized mobilities μ_+/μ_{+0} of CO^+, Hg^+, O_2^+ and N_2^+ ions in their parent gases with a drift velocity.

where α is a constant being equal approximately to 1 for inert gases. The last formula may be written as follows

$$\log \left[\left(\frac{\mu_{+0}}{\mu_+}\right)^2 - 1\right]^{1/2} = \frac{1}{2} \log \frac{a}{(kT_g)^\alpha} + \frac{\alpha}{2} \log (m_+ v^2). \qquad (3)$$

In Fig. 2 the quantity $[(\mu_{+0}/\mu_+)^2 - 1]^{1/2}$ is plotted against $\{m_+ v^2\}$ to give nearly straight lines on the log-log plot, with the slope $\alpha/2$. The ratio a/kT_g was also determined from Fig. 2 giving the value of the parameter a.

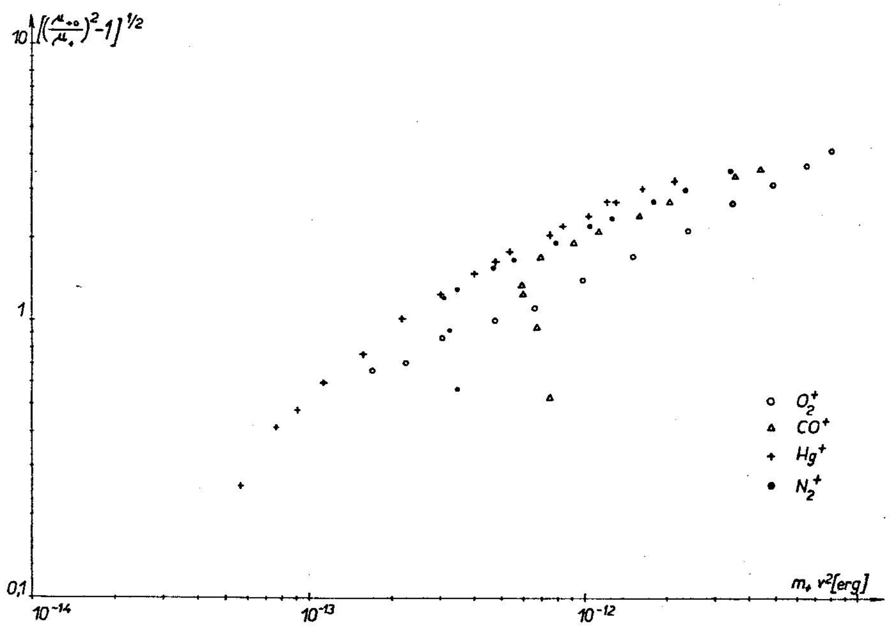

Fig. 2. Variation of the values $[(\mu_{+0}/\mu_+)^2 - 1]^{1/2}$ with the kinetic energy of the drift motion of ions.

Table 1

gas	CO	Hg	O_2	N_2
T_g [°K]	300	500	300	300
a	0.17	0.41	0.08	0.19

The following conclusions can be drawn: 1. The parameter a, appearing in the relations (1—3) is not a universal one for all gases but depends on the sort of gas. The values of a for different gases are presented in Tab. 1; they correspond to the temperature T_g that was maintained during the measurements. These computations were made according to (1) when $\alpha = 1$.

2. The slope of the curves for Hg and O_2 in Fig. 2 nearly equals 1/2 (α is 1.01 and 1.008 for Hg and O_2, respectively) while for CO $\alpha = 0.825$ and for N_2 $\alpha = 0.82$. If we have as the measure of the accuracy of formula (1) the relative difference between experimental and theoretical results (see Fig. 1), then the last discrepancy in the values of parameter α is not very significant excluding the region where the conversion of ions CO^+ and N_2^+ into $(CO)_2^+$ and N_4^+ occurs.

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