Gaseous ion mobility of SO_2^+ ions in He and Ar

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Abstract: The parameters of (n,6,4) potential model and Pirani's potential for He−SO_2^+ and Ar-SO_2^+ systems were obtained from experimental gaseous ion-mobility data. These potentials were then used to calculate the mobility of SO_2^+ ions in helium and argon gases at 300 K. Results show good agreement between the ion mobility data calculated via the (n,6,4) potential and experimental data. The Pirani's potential yields ion mobilities of a lower accuracy especially for He−SO_2^+.

Introduction: Analysis of charged particle transport in dilute gases under the influence of electric fields has theoretical and practical applications in science and technology[1-3]. Investigation of ions mobility in gases is an important issue in plasma chemistry, atmospheric physics, and numerical simulations of industrial plasma [4]. There is now a large amount of data available for such analysis[5]. Here, we compare ion mobilities calculated from the (n,6,4) and the Pirani's potentials with the experimental values for the two systems He-SO_2^+ and Ar-SO_2^+. The motivation behind this study is the active current research toward elimination the SOx poisonous materials from industrial gaseous streams by non-thermal, atmospheric pressure plasma technology.

Method of Calculation: Under high electric field strength for producing charged particles in a neutral buffer gas, i.e. partially ionized plasma, where the ratio of the electric field strength, *E*, to the number density of the neutral gas, *N*, is high the ion energy is much greater than the thermal energy of the neutral molecules. In such circumstances the Enskog-Chapman's classical kinetic theory of dilute gases [6] is no longer valid and therefore the two-temperature theory of Viehland and Mason [7] is useful to calculate the mobility of ions in neutral gases.
According to two-temperature theory, the mobility *K* and drift velocity v_d of an ion through a single-component neutral gas can be represented by

$$K = \frac{v_d}{E} = \frac{3q}{8N}\left(\frac{\pi}{2\mu k_B T_{eff}}\right)^{1/2} \frac{1+\alpha}{\Omega^{(1,1)}(T_{eff})} \qquad (1)$$

where q is the ion charge, k_B is Boltzmann's constant, $\mu = mM/(m+M)$ is the reduced mass with m and M being the ion and neutral masses respectively, and $\Omega^{(1,1)}(T_{eff})$ is diffusion type collision integral, which is a function of effective temperature T_{eff} defined by

$$\tfrac{3}{2} k_B T_{eff} = \tfrac{3}{2} k_B T + \tfrac{1}{2} M v_d^2 (1+\beta) \qquad (2)$$

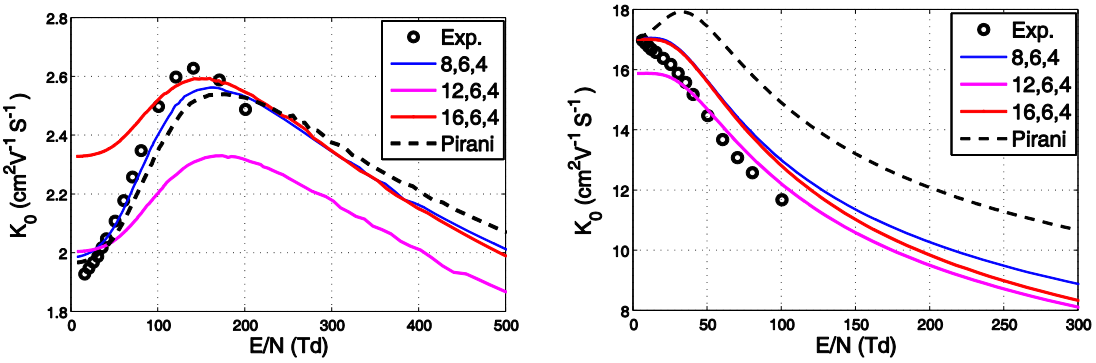
The terms α and β include all of the higher approximations that occur in the kinetic theory and almost are smaller than 0.1 for most practical purposes. The gaseous ion mobility is connected to ion-neutral interaction potential through collision integral $\Omega^{(1,1)}(T_{eff})$ [7].

Results

At the first step, the parameters of the (n,6,4) ion-neutral interaction potential [8] for the two systems He-SO_2^+ and Ar-$SO_2^+$was estimated from the experimental ion mobility data using the procedure described by Viehland and Mason [9]. The parameters of the Pirani's potential was evaluated by the method described by Laricchiuta et al. [10]. The average of percent absolute deviations (AAD%) of ion-mobilities calculated by these potentials from experimental data at 300 K are summarized in **Table 1. Fig. 1** compares the calculated mobilities of SO_2^+ ion in neutral buffers helium and argon. It can be seen that the (16,6,4) potential for He-SO_2^+ and (8,6,4) potential for Ar-SO_2^+ yield the best agreement with experimental results. Also the (n,6,4) and Pirani's potentials for the interaction of SO_2^+ ion with He and Ar neutrals, which are obtained in this work, are compared with each other in **Fig. 2**.

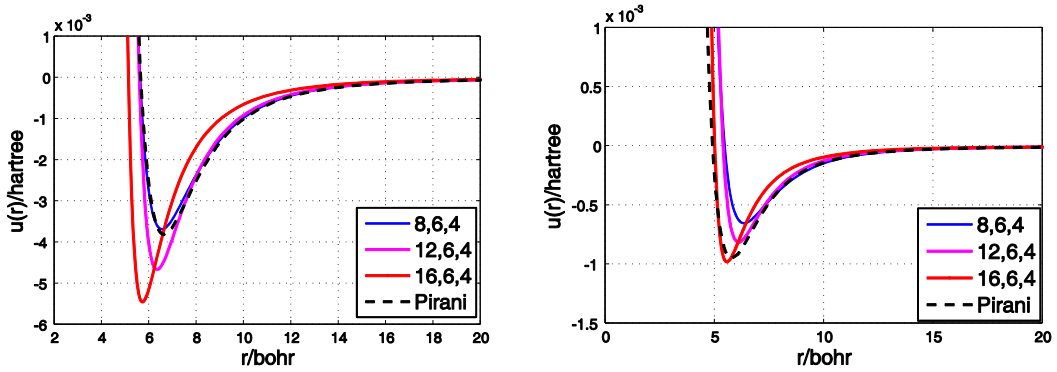
Table 1.Average and maximum (in parentheses) deviations of calculated ion mobilities from experimental data at 300 K.

System	(8,6,4) potential [3]	(12,6,4) potential	(16,6,4) potential	Pirani's potential
Ar−SO_2^+	2.02 (3.70)	5.96 (12.80)	9.86 (20.84)	2.71 (5.84)
He−SO_2^+	5.59 (11.17)	3.49 (6.45)	5.15 (9.63)	13.25 (27.43)



(a) (b)

Fig. 1: Experimental and calculated values of the standard ion-mobility, *K*, as a function of *E*/*N* for a− Ar-SO_2^+ and b− He-SO_2^+ at 300 K.



(a) (b)

Fig. 2: Comparison of interaction potentials ((n,6,4) potentials , Pirani potential) for (a) Ar−SO_2^+ and (b) He−SO_2^+

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