MOBILITIES OF ATOMIC IONS IN COOLED HELIUM GAS

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Mobility of an ion in a gas is very sensitive to the shape of the interaction potential between the ion and the neutral gas. If a metastable ion is not de-excited by collisions with gases, we will be able to measure the mobility of the ion in the gas and to obtain the information about the interaction potential between the electronic excited ion and the gas molecule.

In our group, a low temperature drift tube mass spectrometer with a mass-selected-ion-injection system had been developed to measure mobilities of ions in helium gas cooled by liquid nitrogen and helium. In this work, we measured the motilities of C^+, N^+, O^+, Kr^+ and Xe^+ ions in He gas at 77 and 4.3 K by using the drift tube apparatus. Because all these ions are produced by electron impact in an ion source with electron energy of about 150 eV, the metastable states of C^+, N^+ and O^+ ions must be contained in the injected ions with fractions of several percents [1], and also the primary ions of Kr^+ and Xe^+ include two fine-structure states, namely the total angular momentum $J = 1/2$ and $J = 3/2$.

Fig. 1 shows the mobilities of the ground ($2s^22p\ ^2P^\circ$) and metastable ($2s2p^2\ ^4P$) states of C^+ in He, which are measured at 4.3 and 77 K, as a function of the effective temperature $T_{\rm eff}$. As can be seen in this figure, the separation of the electronic states has been observed in the higher $T_{\rm eff}$ region above 500 K. The electronic state was identified from the intensity ratio in an arrival time spectrum.

We have performed the calculation of the interaction potentials for the ground-state and metastable ions with He by using the multi-reference CI method, and have calculated the mobilities with the two-temperature theory using the classical momentum-transfer cross sections. At the small internuclear distance, the potential of CHe^+ has splits into more than two molecular state. Therefore we have averaged cross sections taking into account the multiplicities of the molecular states. The solid and broken lines in Fig. 1 are the calculated values of mobilities for $C^+(^2P^\circ)$ and $C^+(^4P)$, respectively. The similar measurements and calculations have been performed for the mobilities of N^+ , O^+ and Kr^+ ions in He gas. However, the metastable state has been observed in the mobility measurements for only N^+ in these ions. The reason why the metastable state has not be observed separately from the ground state in many cases should be discussed.

In the mobility of Xe^+, the separation of the electronic states has not been observed. Fig. 2 shows the mobility of Xe^+ in He, which is measured at 4.3 and 77 K, as a function of $T_{\rm eff}$. We can see a deep minimum around $T_{\rm eff} \sim 80$ K. Similar structure was observed for Kr^+. Such minimum has not been seen for the other ions, the mobility of which we have measured. According to the calculation by Viehland *et al.* using the model interaction potential, the large $-r^{-6}$ term in the potential $V(r)$ makes the minimum in the mobility. Therefore we consider the deep minimum in the mobility of Xe^+ in He indicates the large $-r^{-6}$ term in the Xe^+-He potential.

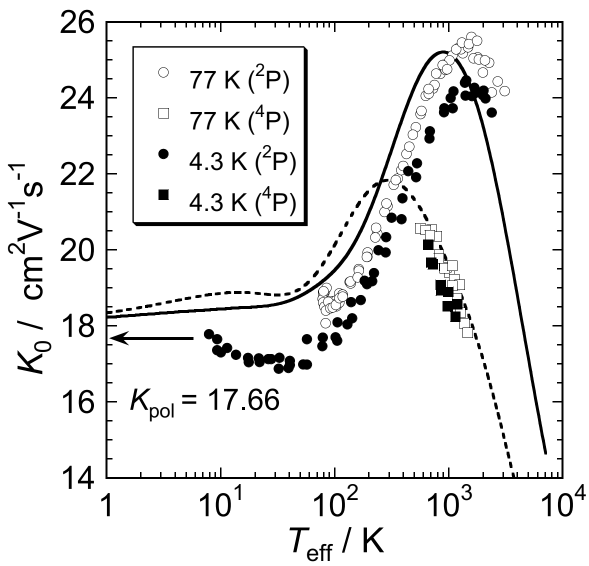

Fig. 1. Mobility of C^+ ion in He gas.

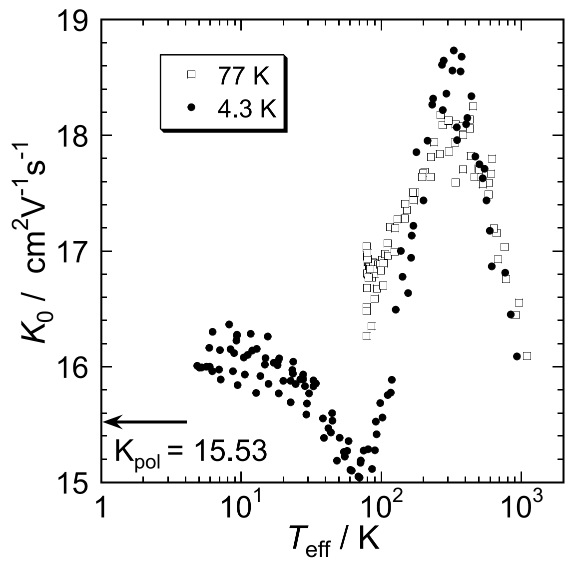

Fig. 2. Mobility of Xe^+ ion in He gas.

References

[1] C. S. Enos *et al.*, J. Phys. B, **25** (1992) 4021.