§8. Verification of Janev's Predictions on the Cross-Sections of Charge Transfer by Slow Protons in Collisions with Hydrocarbon Molecules

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In current and next day large fusion devices with carbon-based plasma-facing materials, many kinds of hydrocarbon molecules as well as other impurities exist in their edge and divertor plasmas. In order to understand impurity behavior, cross section data for charge-transfer processes of H^+ ions with hydrocarbons are important. Therefore, we already measured the charge transfer cross sections of H^+ ions in collisions with CH_4, C_2H_2, C_2H_6, and C_3H_8 in the energy range from 0.2 to 4 keV.[1)]

Janev *et al*. compiled and assessed our and other existing experimental cross section data for the charge transfer process in H^+ + C_xH_y collision systems.[2)] They also presented the recommended values with the analytic fits, and predicted the cross section values for the collision systems, such as H^+ + C_3H_4, for which no data were available yet. To get a complete data set, therefore, we have measured the charge transfer cross sections of H^+ ions in collisions with C_2H_4, C_3H_4 [Allene and Propyne], C_3H_6, $(CH_2)_3$, n-C_4H_{10} and i-C_4H_{10} in the energy range of 0.2 to 4 keV as a continuation of our study. The present experimental results are compared with the predicted values by Janev *et al.*[2)]

In the present experiment, H^+ ions were extracted from an electron impact ion source and introduced into a 4 cm long collision cell filled with high purity hydrocarbon molecules. The cross sections of charge transfer were determined by an initial growth rate method combined with a position sensitive micro-channel detector.

The present cross sections for charge transfer in H^+ + C_3H_4 collisions are shown in Fig. 1. The present cross sections for allene are slightly larger than those for propyne. They gradually increase as the collision energy increases and reach maximum at about 1.5 keV. This means that these collisions are not fully resonant. The solid curve, which is the prediction by Janev *et al.*,[2)] is close to the present cross sections, but slightly smaller and almost flat in our investigated energy region.

The present cross sections for charge transfer in H^+ + C_3H_6 and $(CH_2)_3$ collisions are shown in Fig. 2. The present cross sections are practically the same for both C_3H_6 and $(CH_2)_3$ molecules. Both cross sections decrease as the collision energy increases. This means that these collisions are fully resonant. The prediction by Janev *et al.*,[2)] is in good accordance with the present measurements. The present cross sections for charge transfer in H^+ + C_2H_4, n-C_4H_{10} and i-C_4H_{10} collisions also decrease as the collision energy increases. This means that these

collisions are fully resonant. The prediction by Janev *et al.*,[2)] is in good accordance with the present measurements.

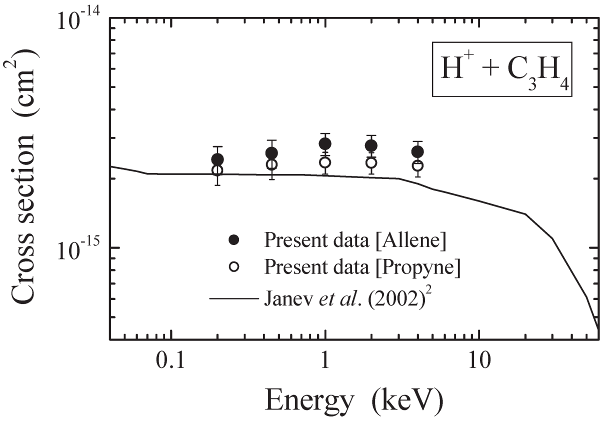

Fig. 1. Charge-transfer cross sections for H^+ ions in collisions with C_3H_4 (allene and propyne) molecules.

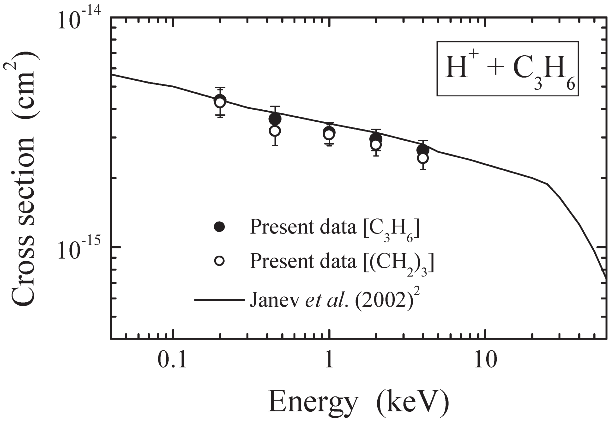

Fig. 2. Charge-transfer cross sections for H^+ ions in collisions with C_3H_6 and $(CH_2)_3$ molecules.

The dependence of these cross sections on the number of active electrons in the target hydrocarbons are found for the fully resonant cases and a simple relation is determined. On the basis of this relation, we propose a new empirical relation for the near-resonant single-charge transfer cross sections of H^+ ions in collisions with a number of hydrocarbons in the energies below about 20 keV (see Ref.3) in more detail).

The joint theoretical studies are now in progress for H^+ ions colliding with C_2H_4 to obtain clear conclusion of vibrational effect.

Reference

1) Kusakabe, T. *et al*.:Phys. Rev. A **62** (2000) 062715.
2) Janev, R. K. *et al*.:At. Plasma-Mater. Interact. Data Fus. **10** (2002) 129.
3) Kusakabe, T. *et al*.:Trans. Fusion Sci. Technol. **51** (2007) 132.