

RESONANT ION PAIR FORMATION AND DISSOCIATIVE RECOMBINATION IN ELECTRON COLLISIONS  
WITH GROUND STATE HF<sup>+</sup> IONS

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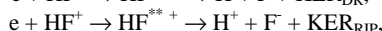
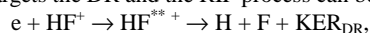
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In this paper, we present the experimental studies of two dissociative processes resulting from electron impact on vibrationally relaxed HF<sup>+</sup> ions. We consider processes wherein an electron is resonantly captured by the ion, losing its kinetic energy either to electronic or vibrational excitation of the resulting neutral molecule. Dissociation of the compound state can occur rapidly and competes favorably with autoionization, and depending on what dissociative channel is followed, one may end up with neutral fragments (dissociative recombination, DR) or resonant ion pair formation (RIP) and with excess energy appearing as kinetic energy of the fragments in each case. Studies of dissociative collisions of electrons with molecular ions have been dominated for decades by examination of DR especially in the last decade by studies of DR with ion storage ring.<sup>1</sup> On the other hand, much less attention has been paid to the RIP process.<sup>2</sup>

For HF<sup>+</sup> targets the DR and the RIP process can be viewed as:



where KER is the kinetic energy release. Together with the HF<sup>\*\*</sup> being repulsive state, (characteristics of the *direct* process recombination process) bound states lying in the same energy range may be formed, leading to resonance appearance in the cross sections (signature of the *indirect* process). Both DR and RIP involve stabilization of the same compound state HF<sup>\*\*</sup>, and one may expect some similarities between these two cross sections.

Our measurements were carried out in the heavy-ion storage ring, CRYRING, in Stockholm. Data for the DR and RIP are obtained simultaneously by changing the cathode voltage of the electron cooler to different values and covering a center-of-mass energy range of  $0 < E_{\text{c.m.}} < 1$  eV and by keeping the ion velocity constant. For the DR measurements we monitor neutral fragments (H and F) produced in the interaction region, while for the RIP process we detect F<sup>-</sup> fragments from the H<sup>+</sup> + F<sup>-</sup> channel.

Absolute rate coefficients for RIP and DR of HF<sup>+</sup> over the c.m. energy 10<sup>-4</sup> to 1 eV are presented in Fig. 1. Certain features stand out as one examines this figure:

1. The DR rate coefficients (and corresponding cross sections) are significantly smaller than those for diatomic molecular ions when there is a crossing of the repulsive portion of a neutral curve with the ground ionic state between the classical turning points of the  $v = 0$  vibrational level
2. The general trend of both cross sections with energy is roughly E<sup>-1</sup> up to 0.03 eV, but there are structural features associated with both. Beyond 0.03 eV, ignoring the features, the general trend of the DR cross section continues roughly as E<sup>-1</sup> up to 1 eV, while the RIP cross section assumes a much steeper decline with energy.
3. At low energy up to 0.1 eV, the RIP process competes strongly with DR, with the cross section ratio being about 0.3. As energy increases beyond this, the ratio gets much smaller.

4. There is no observed positive energy threshold for the rates/cross sections for either of the processes, which is consistent with the energy-level diagram of HF<sup>+</sup>.

5. Certain of the structural features are common to both DR and RIP, while fewer features show up in the DR curves. The most obvious commonalities are the broad "hump" in the cross section between about 0.002 eV and 0.02 eV and the very steep decline in the cross sections at about 0.04 eV leading to minima in the two cross sections at around 0.07 eV.

Strong complementarities have been found between RIP in HF<sup>+</sup> and the process of ion pair production by photodissociation<sup>3,4</sup> of HF. The results from photodissociation have been used to interpret many of the structures found in the RIP cross section.

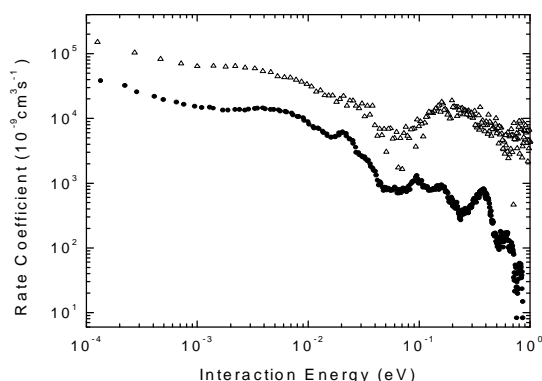


Figure 1. Absolute rate coefficients for HF<sup>+</sup> as a function of interaction energy. Open triangles show the data for DR, and solid circles represent the data for RIP.

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