STATE-DIAGNOSED ION-NEUTRAL COLLISIONS LEADING TO CHARGE TRANSFER

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Introduction

A significant reservoir of potential energy in hot astrophysical plasmas exists in multiply charged positive ions. Inelastic collisional processes involving such ions govern the ionization and energy balance in such plasmas. Although inelastic processes such as, charge transfer, have been widely investigated, there remains a paucity of knowledge about charge changing processes where both reactions and products are state-diagnosed. We have applied high-resolution translational energy gain/loss spectroscopy to investigate state-diagnosed collisions between Kr^{2+} and H_2 leading to single electron capture into specific electronic states of Kr^+ at collision energies in the range 1-6 keV.

When the speed at which the Kr^{2+} and H_2 nuclei approach each other is slow compared to the orbital speed of the bound electron in H_2 being captured, the electron cloud in the collision system adjusts to the changing internuclear field as the nuclei approach and separate, and a quasi-molecular description of the collision process becomes necessary for a detailed treatment of the problem. Electron capture can then be pictured as a transition between the stationary states of the (Kr^{2+} H_2) and (Kr^+ H_2^+) quasi-molecules, and the charge changing cross sections depend strongly on the Kr^{2+} - H_2 distance at which the potential energy surfaces have minimum separation, or "cross", and on the coupling between them. Thus, ion kinetic energy studies of the type reported here can provide sensitive tests of model calculations on the dependence of capture cross sections on the subtleties of electronic structure.

Results and Discussion

Kr^+ kinetic energy measurements show that the incident Kr^{2+} beam is purely in the ^3P ground state; the principal exoergic exit channel for Kr^+ products is into the $^2P_{3/2}$ state, with some slight contribution from the Kr^+ $^2P_{1/2}$ exit channel. An endoergic channel leading to Kr^+ ions in the $^2S_{1/2}$ state is also favoured; thus charge transfer in this

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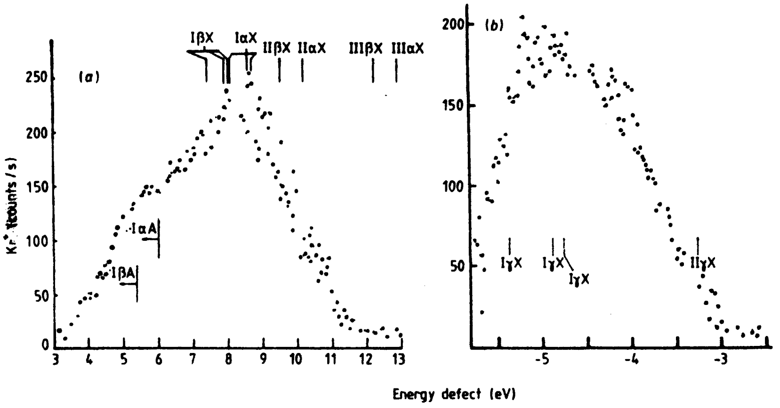
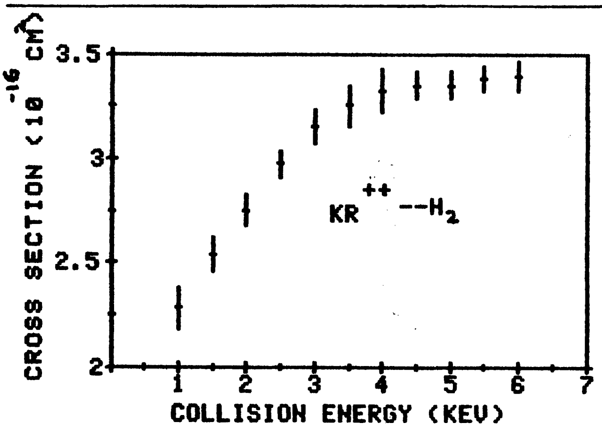
collision system occurs via avoided crossings of potential energy surfaces as well as by non-crossing mechanisms.

There is no evidence to suggest that transfer ionization leading to proton formation occurs on a significant scale.



Energy defect distributions for Kr^+ product ions in zero degree collisions of Kr^{2+} ions with H_2 at an impact energy of 2 keV for (*a*) exoergic reactions and (*b*) endoergic reactions. The labelling scheme is described in the text and referred to in table 1. Vertical lines marked IαA, IβA indicate the onset of dissociative ionisation of H_2

Reaction	ΔE	R_c	Label
$Kr^{2+}\,{}^3P_2 + H_2({}^1\Sigma_g^+, \nu=0) \rightarrow Kr^+\,{}^2P_{3/2} + H_2^+$	+8.13	3.35	I α X
${}^3P_1$	+8.63	3.15	
${}^3P_0$	+8.75	3.11	
${}^3P_2 \rightarrow Kr^+\,{}^2P_{1/2} + H_2^+$	+7.46	3.65	I β X
${}^3P_1$	+7.96	3.42	
${}^3P_0$	+8.08	3.37	
${}^3P_2 \rightarrow Kr^+\,{}^2S_{1/2} + H_2^+$	−5.38		I γ X
${}^3P_1$	−4.88		
${}^3P_0$	−4.76		
$Kr^{2+}\,{}^1D_2 + H_2({}^1\Sigma_g^+, \nu=0) \rightarrow Kr^+\,{}^2P_{3/2} + H_2^+$	+10.24	2.66	II α X
$\rightarrow Kr^+\,{}^2P_{1/2}$	+9.57	2.84	II β X
$\rightarrow Kr^+\,{}^2S_{1/2}$	−3.27		II γ X
$Kr^{2+}\,{}^1S_0 + H_2({}^1\Sigma_g^+, \nu=0) \rightarrow Kr^+\,{}^2P_{3/2} + H_2^+$	+12.96	2.10	III α X
$\rightarrow Kr^+\,{}^2P_{1/2}$	+12.29	2.21	III β X
$\rightarrow Kr^+\,{}^2S_{1/2}$	−0.55		III γ X



Single electron capture cross section pertaining to ${}^3P_2$ Kr^{2+} ions incident on H_2, leading to Kr^+ formation in ${}^2P$ and ${}^2S$ electronic states.

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