International Symposium on
Electron- and Photon-Molecule Collisions and Swarms

22-25 July 1995 • Berkeley , California

Program and Abstracts

A Satellite of the XIX ICPEAC
hosted by
Lawrence Livermore National Laboratory
and
National Energy Research Supercomputer Center

Organizing Committee

Thomas. N. Rescigno, Chairman
Lawrence Livermore National Lab

Kurt Becker
City College of New York

Steve Buckman
Australian National University

Helmut Ehrhardt
Universität Kaiserslautern

Alan Garscaddan
Wright Patterson AFB

Franco Gianturco
University of Rome

C. William McCurdy
Lawrence Livermore National Lab

Richard Van Brunt
National Institute of Standards and Technology

Kinetic Energy Distributions of H^+, H_2^+, and H_3^+ from a Diffuse Townsend Discharge in H_2 at High E/N

M. V. V. S. Rao, R. J. Van Brunt, and J. K. Olthoff

National Institute of Standards and Technology
Gaithersburg, MD 20899 USA

The translational kinetic-energy distributions of the predominant ions, H^+, H_2^+, and H_3^+, formed in a diffuse Townsend discharge in H_2 were measured for electric field-to-gas density ratios (E/N) from 7×10^{-19} Vm^2 to 2×10^{-18} Vm^2 (700 to 2000 Td, 1 Td $\equiv 10^{-21}$ Vm^2). The discharge was generated in a parallel-plate electrode gap for conditions corresponding to the "left-hand" side of the Paschen minimum where the electric field in the gap is expected to be constant and uniform, i.e., the discharge is characterized by a well defined E/N. The discharge cell configuration and ion measurement system are similar to those described previously [1]. The ions were sampled through a 0.1 mm diameter orifice in the center of the stainless-steel cathode. Simultaneous analysis of ion energy and mass was performed using a cylindrical mirror analyzer coupled to a quadrupole mass spectrometer.

Examples of measured kinetic-energy distributions for H^+, H_2^+, and H_3^+ at three different values of E/N are shown by the data points in Fig. 1. The measured data are compared in this figure with results from calculations (indicated by the solid lines) of Bretagne and coworkers [2] based on a "convective scheme" model [3]. The solid and open data points correspond respectively to measurements made using electrode gap spacings of 1.17 cm and 2.36 cm, and the solid line applies to an assumed spacing of 1.17 cm. For H_2^+ and H_3^+, the instrument provides reliable energy-distribution data (relatively unaffected by energy discrimination) at ion energies in the range of 20 to 200 eV [1]. However, for H^+, there was evidence of low-energy discrimination up to about 50 eV. The distributions for H^+ and H_3^+ have been normalized to the calculated results and the distributions for H_2^+ are shown in arbitrary intensity units that have not been normalized.

Approximate indications of the relative fluxes for the three ions were obtained by integration of the measured energy distributions recorded on comparable intensity scales [1]. The results are shown in Table 1 in comparison with the model predictions [2]. The observed trends are consistent with the model, i.e., the relative contributions from H^+ and H_2^+ increase with increasing E/N, while the contribution from H_3^+ decreases with increasing E/N. At $E/N = 1 \times 10^{-18}$ Vm^2, the H^+ distribution agrees with the predicted distribution at energies above 40 eV where discrimination effects are not important; but for $E/N = 7 \times 10^{-19}$ Vm^2, the H^+ distribution is only consistent with predictions made assuming gaps greater than 1.7 cm. The H_3^+ distributions at 1×10^{-18} Vm^2 and 7×10^{-19} Vm^2 do not exhibit the predicted high-energy tail at ion energies greater than 70 eV. This discrepancy suggests that the cross sections for destruction of H_3^+ by high-energy (> 50 eV) collisions with H_2 may be greater than assumed in the model [2,4]. Consistent with equilibrium ion kinetics [2], the measured energy distributions for all ions were found to be independent of gap spacing from 1.0 to 4.0 cm at fixed values of E/N. There is no unequivocal evidence from the present experimental results for significant nonequilibrium ("runaway") contributions to the ion flux at E/N up to 2×10^{-18} Vm^2 (2 kTd) [4].

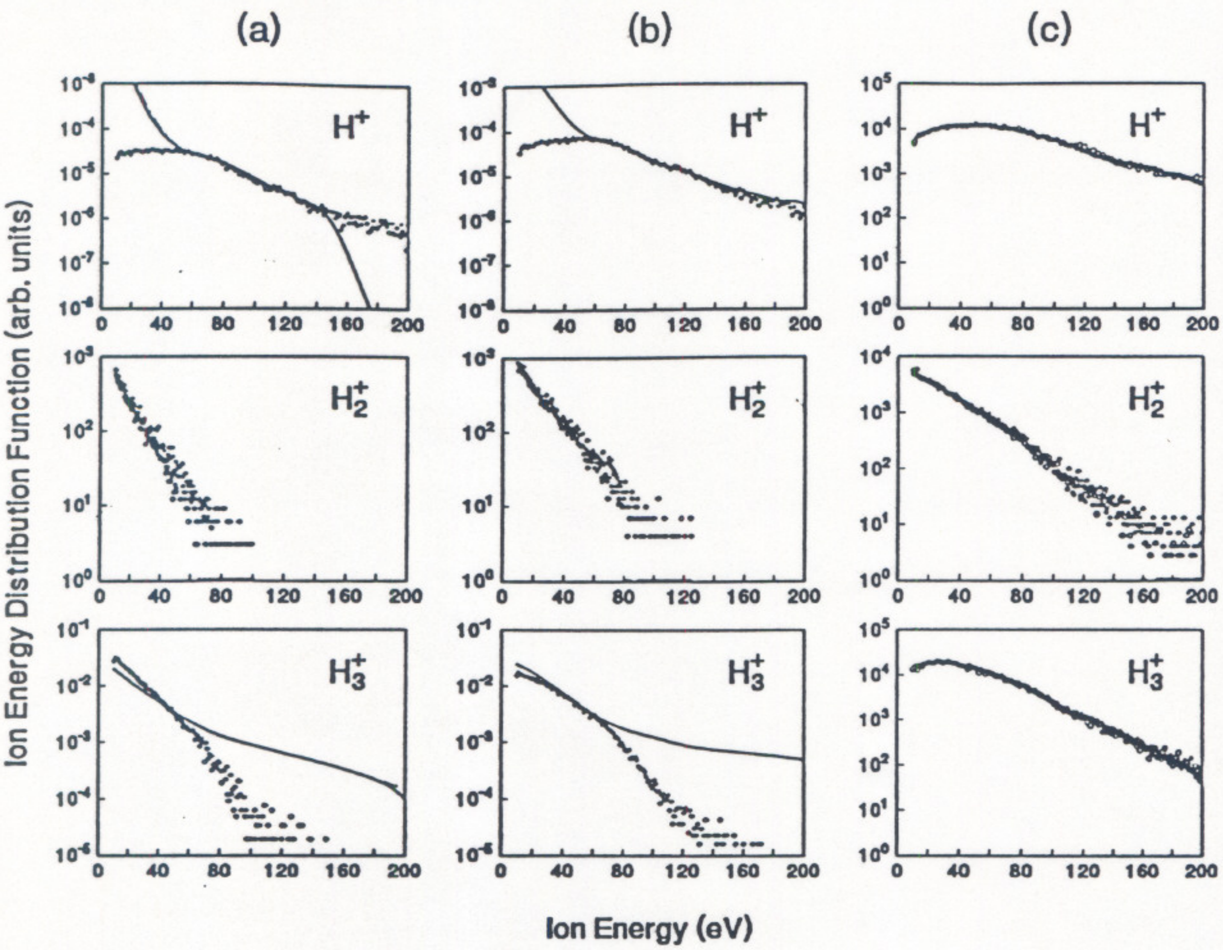

Figure 1. Measured kinetic energy distributions of H^+, H_2^+, and H_3^+ at: (a) $E/N = 7.0 \times 10^{-19}$ Vm^2, (b) $E/N = 1.0 \times 10^{-18}$ Vm^2, and (c) $E/N = 2.0 \times 10^{-18}$ Vm^2. The closed and open symbols correspond respectively to electrode gap spacings of 1.17 and 2.36 cm. The solid lines are model predictions [2] for a gap of 1.17 cm.

Table 1. Percent relative contributions of H^+, H_2^+, and H_3^+ to the total ion flux at different E/N from the model prediction [2] and from estimates using the present energy distribution data.

E/N	H^+		H_2^+		H_3^+	
10^{-21} Vm^2	model	present	model	present	model	present
700	9.8%	24.5%	-3.2%	2.5%	87.0%	73.0%
1000	13.6%	27.0%	-5.0%	7.0%	81.4%	66.0%
2000	35.4%	30.0%	16.4%	11.0%	48.2%	59.0%

References

1. S. B. Radovanov, R. J. Van Brunt, J. K. Olthoff, and B. M. Jelenkovic, Phys. Rev. E 51 (June 1995).
2. J. Bretagne, G. Gousset, and T. Simko, J. Phys. D 27, 1866 (1994).
3. W. N. G. Hitchon, D. J. Koch, and J. B. Adams, J. Comp. Phys. 83, 79 (1989).
4. A. V. Phelps, J. Phys. Chem. Ref. Data 19, 653 (1990).