Development of a System for Doppler-Free Kinetic Energy Release Spectroscopy

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Kinetic energy release spectroscopy has been the subject of numerous investigations during the last ten years. In principle, coincidence measurements of the times of flight of ion pairs can be used to determine the kinetic energy released in a diatomic molecular dissociation with high energy resolution. Lundqvist et. al., [1] have developed a method which eliminates Doppler broadening caused by the thermal motion of the molecules and gives sufficient resolution to resolve vibrational structure.

For a randomly moving diatomic molecule at temperature T dissociating into two fragments of masses m_A and m_B yielding a total kinetic energy release E, the FWHM of the resulting Doppler broadened line in either fragment is given by :

$$\Gamma=\frac{4}{m_A+m_B}\sqrt{\ln 2\ m_A m_B E k T} \qquad (1)$$

For example, a stationary CO molecule dissociating with 10.0 eV total energy release produces two ions with 5.71 and 4.29 eV kinetic energy, respectively. The FWHM Doppler broadening at 293 K resulting from individual measurements of either of these fragment energies is 0.83 eV. However, if both fragment energies E_A and E_B are measured, the center of mass kinetic energy can be eliminated and the dissociation energy is given by:

$$E=E_A+E_B-\frac{[\sqrt{E_A m_A}-\sqrt{E_B m_B}]^2}{m_A+m_B} \qquad (2)$$

The purpose of the present work is to explore the possibility of applying this method to the study of molecular dissociation caused by fast-ion bombardment. Figure 1 shows a schematic of the system that is under development.

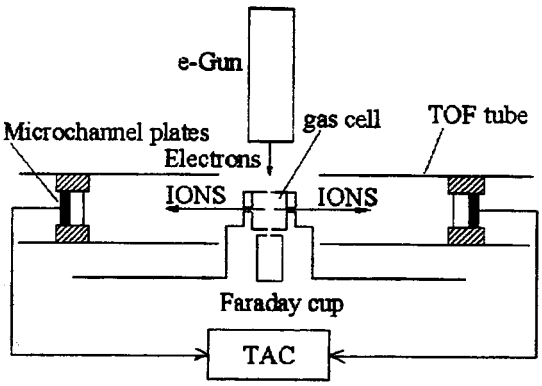

Figure 1. Schematic diagram of the time of flight system under development.

The target gas (in this case, CO) is ionized in a differentially pumped gas cell by an electron beam. The resulting detector pulses from each of the two microchannel plate detectors are routed through a timing filter amplifier (TFA) and a constant fraction discriminator (CFD) which outputs a logic signal when the amplitude of the analog signal pulse exceeds the discriminator level setting. The two logic signals from the CFD's provided the START and STOP signals for the time to amplitude converter (TAC). Since the target molecules may initially have any orientation, dissociation products may be ejected at any angle with respect to the beam axis. Thus the START and STOP signals can be provided by either MCP.

A typical time difference spectrum corresponding to O^+/C^+ coincidences for 0.6 mT gas cell pressure, 0.61 keV electron energy, 1.3 nA beam current, and 6.90 cm target-detector

distance, is shown in Figure 2. The recording time was 40 min.

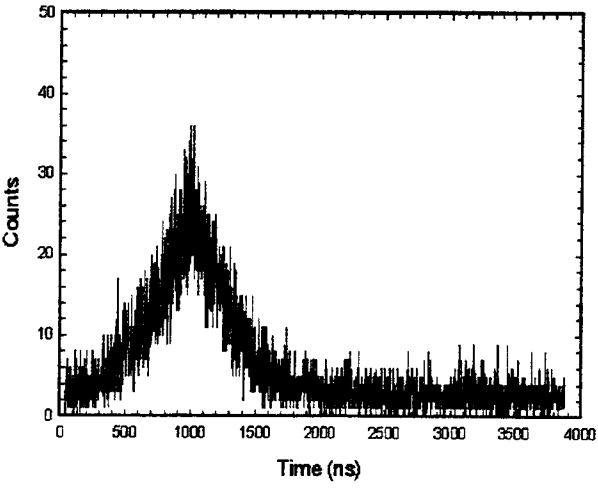

Figure 2. Typical O^+/C^+ coincidence spectrum for 0.6 mT gas cell pressure, 0.61 keV electron energy, 1.3 nA beam current, and 6.90 cm target-detector distance.

Since this test employed a DC type e-gun it was not possible to generate t=0 signals, a necessary condition if the individual ion times of flight are to be measured. Nevertheless, the operational characteristics of the system were found to be acceptable and it is being adapted for use on a cyclotron beamline.

References

[1] M. Lundqvist, P. Baltzer, L. Edvardsson, and B. Wannberg, Phys, Rev. Let. **75**, 1058 (1995).