Ion Beam Induced Fragmentation of Molecules

ABSTRACT

of the Ph.D. Thesis

Submitted to

Jamia Millia Islamia

for the award of the Degree of Doctor of Philosophy

Submitted by

Ajit Kumar

Dr. Lekha Nair

Department of Physics
Jamia Millia Islamia
New Delhi

Department of Physics
Faculty of Natural Sciences, Jamia Millia Islamia
New Delhi-110025

(January 2015)

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Key words: Ion molecule collision, Fragmentation, Reaction microscope, angular distribution

Abstract

The work reported in this thesis is on the fabrication of a new recoil ion momentum spectrometer at the Inter University Accelerator Center, New Delhi, India, equipped with a position sensitive micro-channel plate detector for detection of fragment ions, along with a data-acquisition system capable of acquiring data in multi-hit mode and initial results on the angular distribution of N_2 molecules are presented. The main purpose of building this spectrometer is to study the dynamics of formation, and dissociation of molecular ions and the anisotropies in the angular distribution of dissociation fragments in ion-molecule collision experiments. When multiply charged ions interact with atom/molecules, it leads to the multiple ionization and fragmentation of molecules. The study of these processes is important for both experimentalists and theoreticians due to their use in many areas of science. In the ion-molecules collision processes, interaction time is much shorter than the dissociation and rotation times of molecules. Thus, the alignment of molecules at the time of the interaction may be deduced from the alignment of the fragments, as the fragments fly apart along the internuclear axis.

The dependence of ionization and capture cross sections for molecules, on the orientation of the internuclear axis relative to the beam direction has been a topic of a long-standing experimental and theoretical interest. The influence of the orientation of the internuclear axis of the molecules with respect to the beam axis on the ionization cross sections and different dissociation channels can be studied using the multi-hit coincidence time-of-flight technique. A complete three dimensional image of the breakup process for each individual event can be obtained by using the time and position sensitive multi-hit particle detector.

The fabricated spectrometer has been characterized using both atomic and molecular targets to determine the time and momentum resolution. The projectile used for the testing was 450 keV Xe^{9+} ion. The typical time resolution of the setup was determined using data collected for an atomic (Argon) target, and was measured to be $2.9\times10^{-3}(\Delta t/t)$. The momentum resolution is of the order of 32 atomic units, and was obtained from our spectrometer for the two correlated fragments (N^{+} + N^{+}). The angular distribution of the correlated molecular fragments with respect to the incoming beam direction for the complete set of dissociation channels of multiply charged N_2 molecule was measured. We found that not only is the distribution anisotropic, there is a significant backward and forward asymmetry in the angles for two charge states. We note that the higher charged fragment is scattered more in the backward direction than the lower charged ion. It is possible that such a backward emission of the higher charged ion could be explained by post collision effects being dominant on the higher charged fragment.

The thesis is organised in the following manner

Chapter 1 introduces the formation and dissociation of molecular ions under the impact of various projectile such as photon, electron and ions. Kinematically complete analysis of molecular dissociation is an important step towards understanding the dynamic process and has been an active area of research for several decades. We have presented here an extensive review of the different experimental techniques previously used to study dissociation dynamic of atom/molecule. The limitations of experimental techniques and the need for advanced techniques is presented in detail.

In **Chapter 2** the experimental setup is described. The setup consists of a time-of-flight-mass spectrometer (TOFMS) equipped with a position sensitive multi hit detection system to measure the time (t) and position (x,y) of the recoil ions. The triplet (x,y,t) can be mapped one-to-one to the three momentum components (p_x,p_y,p_z) and in this way the momentum space spanned by the fragments can be sampled. Description of each part of the setup is given in detail such as mechanical drawing, principle of operation etc. We have also presented data acquisition methodology. At the end of this chapter, we have presented the calibration of time and position of the ions formed in HCI collisions with Ar.

In **Chapter 3** the offline analysis technique of the collected data to extract (x,y,t) information is describe. This chapter contains a brief introduction of the momentum imaging technique, calculation of the momentum components of the recoil ions and the momentum resolution of present system. This chapter also describes the measurement technique for the dynamical properties of a N_2 molecule such as the kinetic energy released in different dissociation channels and angular correlation between fragments. The consistency check of the present system is also presented.

In **Chapter 4** the Monte Carlo simulation results of angular distribution of fragments is describe. We also presented, how the collection efficiency due to finite size, a minimum time (dead time) and minimum radial separation that a multi-hit system needs to resolve two consecutive signals, affects the the angular distribution of fragments .

In **Chapter 5** the experimental results are presented and discussed. The angular distributions of the fragments with respect to the beam direction are analyzed. We have also present the comparison of the experimental results with the simulated data.

Chapter 6 contains the summary of the thesis and the outlook for future research.

Curriculum Vitae

Name: Ajit Kumar

Date of Birth: 3^{rd} December 1983

Place of Birth: Sonpur (Bihar)

Sex: Male

Nationality: Indian

Marital Status: Unmarried

Qualification: M.Sc. (Physics), Pursuing Ph.D. (Experimental Atomic Physics)

Mobile : +91-9891600529

E-mail Address : ajit.gupta529@gmail.com, gupta_ajit5286@yahoo.co.in

Academic Qualifications

- Pursuing Ph.D. (Experimental Atomic Physics), Thesis title "Ion Beam Induced Fragmentation of Molecules", Department of Physics, Jamia Millia Islamia, New Delhi, India
- M. Sc. (Physics), Jamia Millia Islamia, New Delhi, India, 2008.
- B.Sc. (Gen.), D. A. V. Centenary college, Faridabad, Haryana, M.D.U, 2006.
- Higher Secondary School, Govt. Boys Sen. Sec. School, R. K. Puram, Sector II, New Delhi, CBSE Board 2003.
- Secondary School, K.P.S.P. High School, Gangajal, Sonpur, Bihar, BSEB Board 1999.