Velocity Map Imaging and Time of Flight Mass Spectroscopy

Geet Ghanshyam

Tata Institute of Fundamental Research

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Disociative electron attachment (DEA) takes place due to electron-molecule collision at low energies resulting in the formation of negative ions.

Velocity map imaging (VMI) is used to study the dynamics of DEA processes by finding the K.E and angular distribution of the products.

Time of Flight Mass Spectrometry (ToFMS) can be used for absolute cross-section measurement of the products formed.
In this Project

- A VMI spectrometer was used in ToF mode to obtain the optimal resolution and for calibration of the mass spectrum.

- The spectrometer was then used in VMI mode to obtain the angular distribution of DEA to $O_2$.

- Simion simulations were carried out to obtain the optimal voltages to be used for VMI.
Basic steps: Time of Flight Mass Spectroscopy

- Ions are formed by electron-molecule collision.
- They are accelerated in a uniform field.
- They are then allowed to drift in a field free Flight tube and finally detected.
The Spectrometer

- Puller, lens and the opening end of FT had an aperture of 20mm dia.
- The other end of FT had a aperture of 40mm dia.
- Pusher-Puller distance 10mm.
- Puller-Lens distance 5mm.
- Lens-FT distance 5mm.
- Flight Tube length 50mm.

**Figure:** A Schematic of the spectrometer.
Interaction and formation of ions

- A pulsed extraction method was used for the formation and transport of ions.

**Figure:** A Schematic showing the various pulses and their delays.
Transport

Positive ions
- Pusher = +ve
- Lens = -ve
- Flight Tube = -ve

Negative ions
- Pusher = -ve
- Lens = +ve
- Flight Tube = +ve

Figure: A Schematic of the spectrometer.
Position Sensitive Detector

- The PSD consisted of 3 Micro Channel Plates (MCP) placed in the Z-stack configuration.

- This is followed by a Ge layer and a wedge and strip anode.

Figure: Structural representation of the Wedge-and-Strip anode. (a): the anode coated with Ge-Layer and facing the MCP, (b): the side view of the detector and (c): the main structural form of the Wedge-and-Strip anode.
Data Acquisition

Figure: A Schematic of the Data Acquisition system used for the ToFMS.
Optimization of the Spectrometer

- Molecular beam of Air was made to interact with the electron beam

- Voltages was varied systematically till the best resolution was achieved.

- Optimal voltages obtained were, Pusher: 100 V; Lens: -30 V; Flight tube: -60 V.
Figure: Resolution of the ToFMS as a function of FT voltage
Theoretically a linear fit was observed between $t^2$ and $m/q$.

Ions formed due to electron impact ionization of Air was used to calibrate.

Two peaks of the air spectrum whose $m/q$ was known were used to form a linear fit.

Electron impact ionization spectrum of Acetone was obtained and $m/q$ of various peaks identified.
Calibrated spectrum of Acetone

Figure: Mass spectrum of Acetone
Dissociative Electron Attachment

- Electron-molecule collision at energies less than 15eV result in the formation of a resonant negative ion (NIR).

- This negative ion can either decompose by auto-detachment or by DEA.

Figure: A potential energy diagram for a di-atomic molecule and its NIR.
**Figure**: Schematic of the experimental steps used in the photo-fragment imaging from photo-dissociation.
Optimization

- The only difference with the ToF setup is in the voltages applied at various stages of the ion optics and the data acquisition system.

- Simion simulations were done to find the optimal voltages. The real voltages in the spectrometer were also varied to find the optimal voltages for best resolution.

- Optimal voltages obtained were, Pusher: -40 V; Lens: 40 V; Flight tube: 130 V.
Simion optimization

Figure: Resolution vs FT voltage.

Figure: Resolution vs lens voltage.
Spectrometer Optimization

**Figure:** Resolution vs FT voltage.

**Figure:** Resolution vs lens voltage.
Position Sensitive Detection

- MCP front was at 170V. MCP back was at 2800 V.
- The wedge and strip anode was 50V higher than MCP back.
- The impact position of the ions onto the detector could be calculated from simple standard expressions:

\[ X = \frac{S}{S + W + M} \] (1)

\[ Y = \frac{W}{S + W + M} \] (2)

where S, W, and M refer the charge signals measured from strip, wedge, and meander respectively.
Data Acquisition System

Figure: DAS used for VMI
DEA to $O_2$

- DEA to $O_2$ produces $O^-$ which is a resonant process peaking at 6.5 eV.

- This was observed by sweeping the electron energy from 0 to 10 eV and plotting it w.r.t to the ion yield.

**Figure:** A plot of count of $O^-$ ions vs the electron energy.
Velocity Map Images

(a) Image at 5eV
(b) Image at 6.5eV
(c) Image at 8eV

Figure: Images obtained at different energies. The red arrow indicates the direction of the electron beam.
Angular Distribution

(a) Image at 5eV

(b) Image at 6.5eV

(c) Image at 8eV
The optimal voltage conditions for ToFMS and VMI were found.

The spectrum for electron impact ionization of acetone was obtained and calibrated and found to give a good match with the data on NIST website.

The angular distribution of DEA to $O_2$ was obtained. It was found to have two peaks as opposed to the four peaks which is expected.

This discrepancy maybe due to the limited resolution of the electron gun.
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