Digital Ion Trap Mass Analysis Utilizing β-2/3 Resonance Ejection and Pulsed Buffer Gas

Timothy Vazquez; Colette Taylor; Theresa Evans-Nguyen

Department of Chemistry, University of South Florida, Tampa, FL 33620

Overview

Purpose: Study resolution effects utilizing β-2/3 resonance ejection and pulsed buffer gas introduction in a digital ion trap mass spectrometer.

Methods: Interfaced a custom built ion trap mass spectrometer with a solenoid valve used for pulsed buffer gas introduction. The solenoid valve is operated using National Instruments Labview software, enabling gas introduction into the center of the trap. Electron impact ionization is performed external to the trap and ions are gated into the trap through an einzel lens. The trap is operated by frequency scanning the fundamental and supplemental utilizing a field programmable gate array (FPGA) in β-2/3 resonance ejection mode. Operational conditions were varied to compare resolution between pulsed and static buffer gas introduction.

Results: Design, fabrication, and interfacing of pulsed valve to the quadrupole ion trap. Study of resolution changes operating under static helium introduction and pulsed helium introduction.

Introduction

Conventionally, static buffer gas is introduced to dissipate residual kinetic energy from ions entering the trap enabling them to become trapped. Precise control and measurement of the buffer gas pressure can be utilized to optimize performance metrics such as dynamic range, resolution, etc… Even with optimization, ion losses occur during scan out under static conditions due to collisions with the buffer gas. Through the use of pulsed buffer gas introduction, ion trapping efficiency can be maximized while mitigating losses from scan out collisions.

The quadrupole ion trap mass spectrometer (MS) is operated in beta -2/3 resonance ejection mode using digital frequency scanning[1]. Interfacing a pulsed buffer gas introduction system to the custom built digital ion trap MS is described herein.

Methods – Instrument Setup

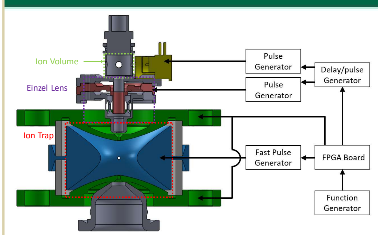


Figure 1: Electronics configuration for ion trap

Figure 2: β-2/3 waveform observed on ring electrode (yellow) and the endcaps (green)

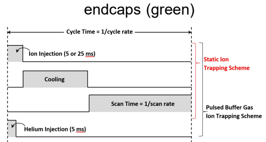


Figure 3: Timing scheme for static and pulsed ion trapping

- Ion trap electronics setup for β-2/3 resonance ejection mode shown in figure 1. Ion trap electrodes were repurposed from a finnigan GCQ Plus
- β-2/3 waveform applied at the endcaps and ring electrode can be seen in figure 2.
- Figure 3 displays the general timing scheme for operation in both static and pulsed He introduction.

Methods – Pulsed Buffer Gas Setup

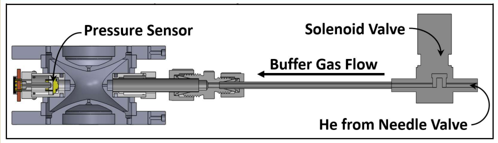


Figure 4: Cross sectional view of solenoid valve and pressure sensor incorporation into the ring electrode

Solenoid valve setup: Buffer gas flows through a variable leak valve and 1/8" stainless steel tubing prior to reaching the solenoid valve. Buffer gas then flows into 1/8" stainless steel tubing (ID: 0.075", length: 3.5") followed by 1/4" LDPE tubing (ID: 0.235", length: 1.5" before entering the trap as can be seen in figure 3. This increases the conductance of the tubing allowing for faster pulses of buffer gas to inject into the trap. Triggering the solenoid valve was performed utilizing a delay pulse generator coupled to a multifunction DAQ.

Results – Static He Introduction

LeCroy Wavepro 7200A Precision Digital Oscilloscope was used to obtain spectra for xenon under static helium introduction which can be seen in figures 5,6, & 7.

Constant parameters:

- Xenon Partial Pressure: 1.28 x 10^{-7} $torr_{Xe}$
- Fundamental Sweep Range: 600 – 525 kHz
- Supplemental Sweep Range: 200 – 175 kHz
- Fundamental Voltage: 500 $V_{p\text{-}p}$
- Detector: 2000 V
- Cycle Rate: 1 Hz

Scan Rate Study

- He Partial Pressure:1.93 x 10^{-4} $torr_{He}$
- Supplemental Voltage: 2 $V_{p\text{-}p}$

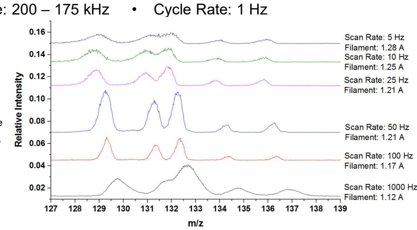


Figure 5: Xenon spectra obtained at varied scan rates

He Concentration Study

- Scan Rate: 100 Hz
- Supplemental Voltage: 2 $V_{p\text{-}p}$

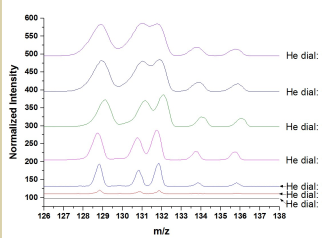


Figure 6: Xenon spectra obtained at varied He concentrations

Endcap Voltage Study

- Helium Partial Pressure:1.93 x 10^{-4} $torr_{He}$
- Scan Rate: 100 Hz

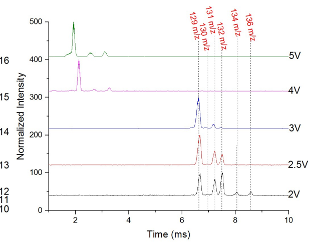


Figure 7: Xenon spectra obtained at varied endcap voltages

Results – Pulsed He Introduction

A MKS 905 micropirani sensor was used to measure the helium pressure inside the trap. A National Instruments PCI-6221 multifunction DAQ was used to record the helium pulse profiles as seen in figure 8.

LeCroy Wavepro 7200A Precision Digital Oscilloscope was used to obtain spectra for xenon under pulsed helium introduction which can be seen in figures 9 & 10.

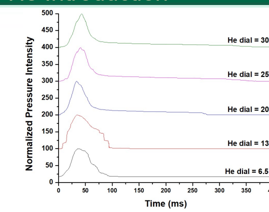


Figure 8: He pulse profiles at varied precision leak valve settings

Constant parameters:

- Xenon Partial Pressure: 1.28 x 10^{-7} $torr_{Xe}$
- Fundamental Sweep Range: 600 – 525 kHz
- Supplemental Sweep Range: 200 – 175 kHz
- Fundamental Voltage: 500 $V_{p\text{-}p}$
- Detector: 2000 V
- Cycle Rate: 1 Hz

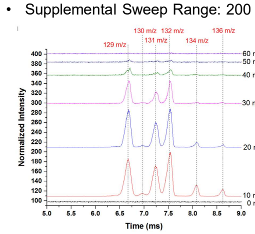


Figure 9: Delayed buffer gas introduction with respect to ion injection

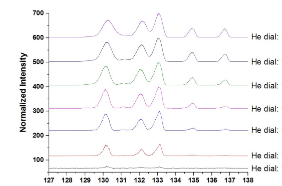
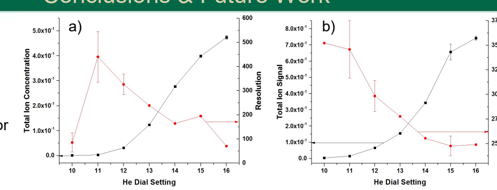


Figure 10: Pulsed buffer gas introduction at varied He dial settings

Conclusions & Future Work

Figure 11: Total ion signal (red) and resolution (black) under a) static introduction and b) pulsed introduction for m/z 132



Although the system was tuned to yield best performance it was found that incorporation of beta-2/3 resonance mode did not produce high resolution data as can be seen in figure 11. The cause of this is most likely due to the phase coupling between the fundamental and supplemental frequencies. It was also found that the amount of the ions detected is ~2x greater than of static mode and that resolution is slightly improved.

Future Work: Optimize electronics to obtain better resolution using static and pulsed buffer gas introduction.

Acknowledgements & References

Dr. Friso H. W. van Amerom for developing the program to run the FPGA board.

(1) Moxom, J.; Reilly, P. T. A.; Whitten, W. B.; Ramsey, J. M. Double Resonance Ejection in a Micro Ion Trap Mass Spectrometer. *Rapid Communications in Mass Spectrometry 16* (8), 755–760.