FORT HAYS STATE UNIVERSITY
DEPARTMENT OF PHYSICS

Forward thinking. World ready.

Experimental Physics Research (TH203) *January 2016*

Main Research Focus:

Our research focus in the Department of Physics at Tomanek Hall (TH203) is in the field of experimental Atomic, Molecular, and Optical (AMO) physics. Experiments that we perform at this facility involve scattering low-energy electrons from target molecules in the gas phase. The motivation for conducting such scattering experiments is to better understand the fundamentals of electron-molecule interactions. Although such basic research has its own unique place in advancing our knowledge in all of sciences, appropriate choice of target molecules often results in important real-world applications in the field of radiation biology, environmental agriculture, and atmospheric science.

Briefly, a low energy electron beam in the range of 0 – 10 eV with relatively high energy resolution of about 70 meV is produced using a trochoidal electron monochromator *(18)* apparatus inside a vacuum chamber of about 10^{-7} Torr. At precise conditions, the electron beam interacts with selected target molecules. The interaction may include the attachment of an electron to a normally empty orbital of the molecule and forming a temporary negative ion or resonance. Subsequently, the negative ion may break apart, a process known as Dissociative Electron Attachment (DEA). Below, a simple line statement for a hypothetical diatomic molecule AB reveals this interaction:

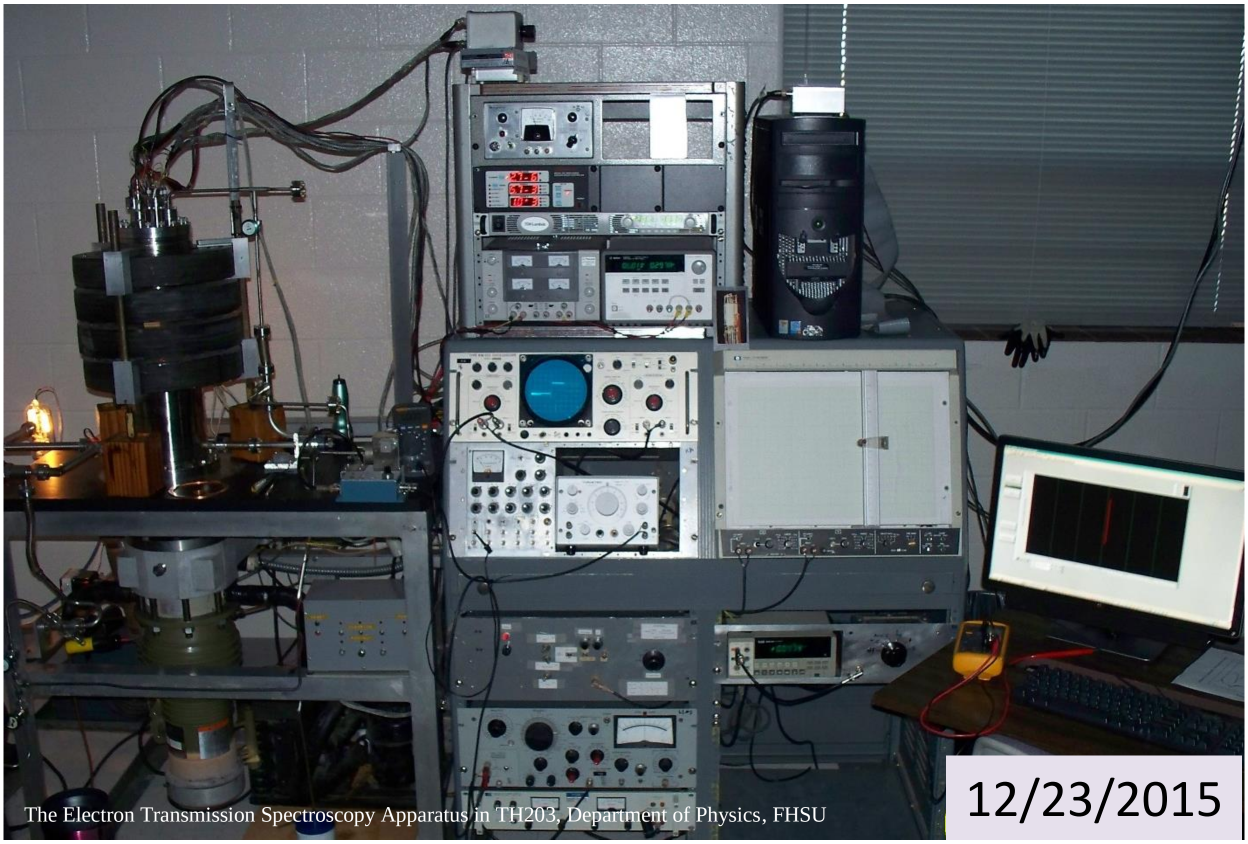
$$\textbf{(electron)}^{-} + \textbf{(AB)} \rightarrow \textbf{(AB)}^{-} \rightarrow \textbf{molecule may dissociates } \{(A)^{\cdot} + (B)^{-}\}$$

In our studies, we detect and analyze the electron attachment energies using the method of Electron Transmission Spectroscopy (ETS). We are also capable of collecting the negative molecular fragments, (such as **$(B)^{-}$** in above), toward understanding the DEA process.

Currently, the main focus of our research studies is to understand the fundamental resonance processes in low energy electron – biomolecule interactions. However with appropriate choice of molecules, our results has proven to be quite functional in real world. For example, in radiobiology the damaging effects of high energy ionizing radiation in living cells and organisms are explained due to *attachment* of secondary low energy (0 – 10 eV) electrons to the biomolecules. So, we are looking into the resonant attachment of low energy electrons and subsequent dissociation of the Amino Acid molecules. Furthermore, proteins in living organisms are made up of long chains of amino acids, known as polypeptide. We have also started to investigate the simplest of dipeptides, formed from the simplest of amino acids namely Glycine and Alanine.

A different example is the ETS studies of active molecules of pesticides and herbicides. Our experiments provided evidence that low energy electron resonances are responsible for dissociation of chlorine bearing compounds. The results of this study are published in *Environ. Sci. Technol. Journal (15)*. Collaborating with department of agriculture at University of Nebraska – Lincoln, a pesticide contaminated soil site was treated with iron filing, (as a source of free electrons), thoroughly mixed and kept wet. This process remediated pesticide concentrations by as much as 99 percent over 90 days for the cost of $70/cubic yard compared to customary method of remediation at a cost of $600/cubic yard for excavation, transport and incineration.

Shown below is a picture of the ETS apparatus that is currently in use for our research studies in TH203. Estimated at more than $100,000.00, the apparatus is loaned from my PhD advisor, Professor Emeritus Dr. Paul D. Burrow of University of Nebraska – Lincoln, Department of Physics and Astronomy. Fort Hays State University has contributed less than 20% of that value over the past 15 years. These first class research apparatus in TH203 has helped our department's student recruitment, retention, and students' senior research thesis/seminar for graduation

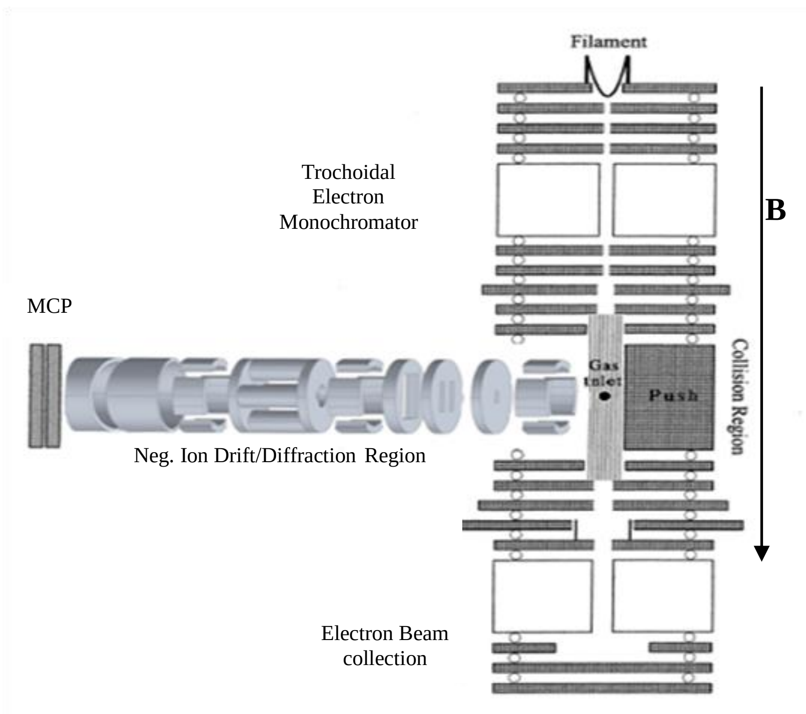


The Electron Transmission Spectroscopy Apparatus in TH203, Department of Physics, FHSU

Secondary Research Interest- Negative Ion Matter Interferometer:

Over the last 200 years interferometers have become known for their ability to make accurate measurements. Light interferometers were the first on the market, and after it had been established that matter behaved like waves *(11)*, it did not take long before the first matter interferometer was realized. In 2013 the first usable positive ion interferometer was created, opening the door for more sensitive detection of electric and magnetic fields.

We attempt the first steps towards the construction of the first negative ion interferometer at FHSU, Dept. of Physics. A schematic of the apparatus which resides inside a vacuum chamber is shown below. Briefly, an electron beam with a current of about 1.0 µA and resolution of 200 meV is produced in the upper half of the trochoidal electron monochromator as shown to the right. The electrons collide with an effusive sample of Chloro-hydrocarbons at the gas inlet location. The interaction produces several tens of thousands of chlorine minus negative ions by the process of DEA *(14)*. Chlorine minus, Cl^-, has an electron affinity of about 3.7 eV, so it is a nice stable negative ion. The Cl^- s are pushed toward the Ion Drift/Diffraction Region by a pusher voltage. They are then collimated and accelerated by a series of steering plates, electrostatic lenses, and 5-10 micron wide slits. The Cl^- s are then passed through a diffraction grating and a set of quad rods for



formation of diffraction pattern and magnification of the patterns, respectively. The result is then observed on a phosphorous screen and ultimately digitized by a scanning multichannel plate or other charge particle detectors. To get started, a preliminary list of high quality DC power supplies are needed immediately, and future equipment and items will be needed for finalizing the results for publication. The negative ion interferometer can follow after that.

A List of stuff that are always Needed
Low Energy Electron Scattering Lab, TH203, FHSU

The vacuum chambers that are used in our experiments are pumped down using diffusion vacuum pumps that are water cooled. Currently, we use the city tap water which after cooling is drained and wasted. It is also subject to pressure and temperature variations which makes it unreliable. We suggest installing a recirculating chiller system that would provide the comfort of mind for continuous and reliable operation. Furthermore, we stop wasting thousands of gallons of precious water down the drain.

Item / Description	**Approx. $**	**Possible Vendors**
Recirculation Water Chiller (for cooling the vacuum pumps and other instruments in an efficient and reliable manner with least environmental harm. This may also require that the lab room walls or windows to be reconstructed to some extent).	$ (20k-30k)	-Applied Thermal Control (app-therm.com) -Thermo Scientific (thermoscientific.com) -National Lab (nationallab.eu) -VWR international (us.vwr.com) -Quorum Technologies (quorumtech.com)
Variety of DC power supplies; (high voltage-low current (4kV-mA), & mid-range voltage and current (400V-8A)).	$ 40k	-Kepco (kepcopower.com) -HiTek Power (hitekpower.com) -BK Precision (bkprecision.com) -TDK-Lambda (tdk-lambda.com)
Micro-channel Plates (MCP), or Dr. Suites' Channeltron (electrons or negative ions charge multipliers).	$ 10k	(hamamatsu.com) or (dmphotonics.com)
Quantum Chemical Computation Software / for Multiprocessor/core + cluster/LAN	$ 6k	Gaussian Inc. (gaussian.com)
Quadrupole Mass Spectrometer; (to mass analysis the fragments after molecular dissociation occurs due to electron attachment).	$ 50k	Extrel (extrel.com)
Turbo molecular pump package	$ 40k	Kurt J. Lesker Co. (lesker.com)
Vacuum components, & accessories	$ 10k	Kurt J. Lesker Co. (lesker.com)

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Refereed Publications:

1. A.M. Scheer, K. Aflatooni, G.A. Gallup, and P.D. Burrow, “Temporary Anion States of Three Herbicide Families”, **J. Phys. Chem. A**, 2014, **118** (35), 7242-7248 , *Special Issue: Kenneth D. Jordan Festschrift*
2. K. Aflatooni, G. A. Gallup, and P. D. Burrow, “Dissociative Electron Attachment in Non-Planar Chloro-Carbons with π^*/σ^* -Coupled Molecular Orbitals”, **Journal of Chemical Physics**, **132**, Issue 8 (2010)
3. K. Aflatooni, A. M. Scheer, and P. D. Burrow, “The Dissociative Electron Attachment Cross Sections for molecular constituents of DNA”, **Journal of Chemical Physics**, **125**, 054301 (2006)
4. D. Reingold, J. A. Kkowalski, G. C. Cummings, R. Gleiter, H. Lange, S. Lovell, B. Kahr, K. Aflatooni, P. D. Burrow and G. A. Gallup, “Electronic Structure of the 6+6 Dimer of Tropone”, **Journal of Physical Organic Chemistry**, **19**, 642-646 (2006)
5. M. Scheer, C. Silvernail, J. A. Belot, K. Aflatooni, G. A. Gallup, and P. D. Burrow, “Dissociative electron attachment to uracil deuterated at N_1 and N_3 positions” **Chemical Physics Letters, 411**, 46-50 (2005)
6. K. Aflatooni, A. M. Scheer, and P. D. Burrow, “Dissociative electron attachment in uracil: Total anion yield” **Chemical Physics Letters, 408**, 426-428 (2005)
7. M. Scheer, K. Aflatooni, G. A. Gallup, and P. D. Burrow, “Bond Breaking and Temporary Anion States in Uracil and Halouracils: Implications for the DNA Bases”, **Physical Review Letters**, **92**, No. 6, (2004)
8. G. A. Gallup, K. Aflatooni, and P. D. Burrow, “Dissociative electron attachment near threshold, thermal rates, and vertical attachment energies of chloroalkanes”, **Journal of Chemical Physics, 118**, 2562-2574 (2003)
9. K. Aflatooni, G. A. Gallup, and P. D. Burrow, “Temporary Anion States of *closo*-Carboranes and Diethyl Carborane”, **Journal of Physical Chemistry A**, **106**, 4703-4708 (2002)
10. P. D. Burrow and K. Aflatooni, “Dissociative electron attachment to molecules in the gas phase and in rare gas solids”, **Journal of Chemical Physics**, **116**, 5471-5475 (2002)
11. Daniel L. Friemund, Kayvan Aflatooni and Herman Batelaan, “Observation of the Kapitza-Dirac effect”, **Nature**, **413**, 142 - 143 (2001)
12. K. Aflatooni, B. Hitt, G. A. Gallup, and P. D. Burrow, “Temporary Anion States of Selected Amino Acids”, **Journal of Chemical Physics, 115**, 6489-6494 (2001)
13. K. Aflatooni and P. D. Burrow, “Dissociative Electron Attachment in Chlorofluoromethanes and the Correlation with Vertical Attachment Energies”, **International Journal of Mass Spectrometry, 205,** 149 (2001)
14. K. Aflatooni and P. D. Burrow, “Total Cross Sections for Dissociative Electron Attachment in Dichloroalkanes and Selected Polychloroalkanes: The Correlation with Vertical Attachment Energies” **Journal of Chemical Physics, 113**, 1455-1464 (2000)
15. P. D. Burrow, K. Aflatooni, and G. A. Gallup, “Dechlorination Rate Constants on Iron and the Correlation with Vertical Attachment Energies” **Environmental Science and Technology**, **34**, 3368-3371 (2000)
16. K. Aflatooni, G. A. Gallup, and P. D. Burrow, “Temporary Anion States of Dichloroalkanes and Selected Polychloroalkanes” **Journal of Physical Chemistry A**, **104**, 7359-7369 (2000)
17. K. Aflatooni, G. A. Gallup, and P. D. Burrow, “Electron Attachment Energies of the DNA Bases” **Journal of Physical Chemistry A**, **102**, 6205-6207 (1998)
18. K. Aflatooni, G. A. Gallup, and P. D. Burrow, “Dissociative Electron Attachment in Chloroalkanes and the Correlation with Vertical Attachment Energies” **Chemical Physics Letters**, **282**, 398-402 (1998)
19. K. W. McLaughlin, K. Aflatooni, and D. W. Duquette, “The near-Threshold Spectrum of Photoelectron Angular Distributions from Maximally Oriented Ca 4s5p ^1P” **Physical Review A**, **55**, 3615 (1997)