



SOCIETY OF PHYSICS STUDENTS

An organization of the American Institute of Physics

SPS Chapter Research Award Proposal

Project Proposal Title	Alkaline Jet for Ion Collisions
Name of School	Southern Adventist University
SPS Chapter Number	6565
Total Amount Requested	\$1,999.86

Abstract

The "Alkaline Jet for Ion Collisions" project focuses on designing an alkaline oven to be integrated within our ion beam line. This apparatus aims to create stable, high-temperature alkaline environments suitable for ion interactions, with students building foundational infrastructure to enable precise collision studies and advancing experimental setups for ion-atom collision research.

Proposal Statement

Overview of Proposed Project

Research Question How can creating a controlled, alkaline oven within an ion beam line facilitate the dissociation of hydrogen gas into its constituent hydrogen atoms, and how can this alkaline oven be applied to other ion beams?

Motivation Ion-atom collision studies are crucial for understanding fundamental properties of matter, impacting quantum mechanics, nuclear physics, and material science. Achieving stable low energy conditions will enhance ion interactions, leading to the experimental measurements of rovibrational states of H_2^+ . This research will provide students with practical experience, preparing them for careers in research and industry. The project will focus on the construction of an alkaline jet for the neutralization of the H_2^+ beam.

Brief Description This research project will focus on the construction and testing of a beam line for studying rovibrational states of H_2^+ ions. The first phase of the project involves assembling the beam line using equipment sourced through a collaboration with Oak Ridge National Laboratory, including an ion source, chamber, turbo pumps, pressure gauges, and gaskets. Once these components are integrated, we will focus on building an alkaline oven using additional parts obtained through this proposal.

Research Goals of the Project

- Design and build an alkaline oven capable of providing a stable particle source.
- Make sure the alkaline jet is pointed straight upwards.
- Make a vacuum chamber for an H_2^+ beam.
- Hold trial and obtain measurements of the rovibrational states of H_2^+ .
- Equip students with technical skills in instrumentation, data analysis, and research methodologies.

SPS Connection This project supports the Society of Physics Students (SPS) by fostering collaborative research and learning, engaging students from various subfields, and promoting practical, hands-on experience. It strengthens our SPS chapter and inspires innovation by allowing students of different underrepresented groups in physics to participate in research.

Background for Proposed Project

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The study of rovibrational states in molecular ions, such as H_2^+ , is a critical area of research in both fundamental and applied physics. As the simplest molecular ion, H_2^+ plays a key role in understanding molecular behavior under low-energy conditions, and it is particularly important in astrophysics, where it is found in a variety of cosmic environments, such as hydrogen-rich nebulae and planetary atmospheres. By examining the rovibrational states of H_2^+ , researchers can gain deeper insights into the interactions between molecular ions and electromagnetic fields, as well as the physical processes that govern the behavior of these molecules in extreme environments.

While advances in experimental techniques, such as the use of position-sensitive detectors and ion beam spectroscopy, have significantly improved our ability to study these molecular ions.

This research project seeks to address these challenges by constructing a dedicated ion beam line system, integrating both pre-existing equipment and newly requested components, such as an alkaline oven, to enable precise measurements of the rovibrational states of H_2^+ . The work will contribute to the understanding of ion spectroscopy, particularly in relation to molecular ions in rovibrational states, and will advance experimental techniques in the study of atomic and molecular physics. By ensuring the system holds a vacuum and using cutting-edge detection methods, this research will provide valuable data for future studies and improve the accuracy and reliability of ion beam experiments in general.

Under the guidance of Dr. Vola Andrianarijaona and Dr. William Laing, students at Southern Adventist University have collaborated with Oakridge National Lab to successfully assemble and test a beam line and vacuum chamber. Reassembling the beam line using the apparatus sourced from Oak Ridge National Lab and integrating an alkaline jet will enable us to measure the rovibrational states of H_2^+ .

Expected Results

The primary objective of this research project is to obtain precise measurements of the rovibrational states of H_2^+ ions. Specifically, we expect to characterize these states by analyzing the spectral data

obtained by a time-of-flight technique that uses two position-sensitive detectors. This will provide valuable insights into the energy levels and transition dynamics of H_2^+ in a controlled ion beam environment.

Additionally, we expect to successfully construct and test the ion beam, ensuring that it maintains a stable vacuum throughout the experiment. This will allow us to verify the effectiveness of the setup and confirm that it meets the necessary conditions for accurate ion beam analysis. As part of this, we aim to demonstrate the viability of the alkaline oven system as a reliable source for introducing alkaline metals into the ion beam, further enhancing the precision of our measurements.

Ultimately, the project will contribute to a deeper understanding of the molecular behavior of H_2^+ ions, and the experimental methods developed can be applied to a broader range of ion spectroscopy studies. We also expect to refine the experimental setup, testing its capabilities for future use in similar high-energy molecular research.

Description of Proposed Research - Methods, Design, and Procedures

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The research will be conducted in several stages, each of which is critical to achieving the overall goal of measuring the rovibrational states of H_2^+ ions. The following outlines the experimental setup, execution, and analysis procedures:

1. Beam Line Construction and Setup:

- **Ion Source and Vacuum System Assembly:** We will begin by assembling the ion beam line using components from the collaboration with Oak Ridge National Laboratory. This includes integrating the ion source, vacuum chamber, turbo pumps, pressure gauges, and gaskets to establish a working vacuum system as stated before.
- **Pressure Testing:** After the vacuum system is assembled, we will conduct a series of pressure tests to ensure that the beam line holds a vacuum necessary for ion beam operation. This will involve monitoring the pressure over time and ensuring that the system maintains stable low-pressure conditions. We will also use an existing residual gas analyzer (RGA) to measure the different substances in the vacuum and adjust accordingly.

2. Alkaline Oven Construction:

- **Alkaline Oven Fabrication:** The alkaline oven, which will be used to introduce the alkaline metal into the ion beam, will be constructed using parts requested through this proposal. The oven will be designed to heat the alkaline metal to the necessary temperature, allowing it to be introduced into the ionization chamber in a controlled manner.

3. Ion Beam Generation and Adjustment:

- **Introduction of Alkaline Metal into Beam Line:** Once the alkaline oven is fully operational, we will introduce the alkaline oven into the ion beam path. When appropriately heated, the oven produces an alkali jet directed to the ion beam. One of the collision products is a short-lived H_2^* that will dissociate into two hydrogen atoms.

- **Ion Beam Source Activation:** The ion source will be activated, and we will monitor the production of H_2^+ ions. Parameters such as beam current, and ionization efficiency will be adjusted to optimize the production of these ions.

4. Measurement of Rovibrational States of H_2^+ :

- **Position-Sensitive Detectors:** The ion beam will be aligned so that the two H from the dissociation are directed towards position-sensitive detectors that will record the transitions in the rovibrational states of H_2^+ . These detectors will provide high-precision data on the ion's energy levels and allow us to analyze the specific rovibrational transitions.
- **Spectral Data Collection:** As the ionized H_2^+ passes through the detectors, we will collect data on the kinetic energy release of the molecular ion. This data will be used to construct a detailed spectroscopic profile of the rovibrational states of H_2^+ .

5. Data Analysis and Interpretation:

- **Data Processing:** The data collected from the position-sensitive detectors will be analyzed using standard computational tools for spectral analysis. This will involve writing codes that help identifying peaks in the spectroscopic data and correlating them with known rovibrational energy levels of H_2^+ .
- **Parameter Estimation:** We will use the spectral data to constrain the energy parameters of the H_2^+ molecule, such as its bond length and vibration frequency, through comparison with theoretical models and previously published data.

6. Dissemination of Results:

- **Reports and Publications:** Once the data has been analyzed and the results interpreted, the findings will be compiled into a detailed SPS research report.
- **SPS and Institutional Dissemination:** Additionally, the results will be shared with the Society of Physics Students (SPS) at national and local meetings, through presentations and posters, to engage the broader scientific community and inspire further research.

Plan for Carrying Out Proposed Project

Principal Investigator: Dr. Vola Andrianarijaona, responsible for leading the project, overseeing construction, and data analysis.

SPS Members: Oscar Coral, Colton Edelbach, Annie Castilo, Benjamin Chun, Sungrae Kim and Derek Renck

Faculty Advisors: SPS Chapter Advisor Dr. Blake Laing

Contributors: Oakridge National Lab

Project Timeline

Timeline for Carrying Out the Project

Month 1-2 (January - February):

Milestone 1: Assemble and set up the ion beam line components (ion source, vacuum chamber, turbo pumps, pressure gauges).

Milestone 2: Begin construction of the alkaline oven using parts from the proposal.

Milestone 3: Conduct initial pressure tests to ensure vacuum system functionality.

Month 3-4 (March - April):

Milestone 4: Finalize the alkaline oven construction and integrate it with the ion beam line.

Milestone 5: Begin ion source activation and fine-tune experimental setup for optimal ionization of H_2^+ .

Month 5-6 (May):

Milestone 6: Conduct preliminary measurements of rovibrational states of H_2^+ using position-sensitive detectors.

Milestone 7: Submit **Interim Report** by May 31, detailing progress, challenges, and any adjustments made to the setup.

Month 7-8 (June - July):

Milestone 8: Analyze preliminary data, adjust experimental parameters as needed, and perform additional tests to refine measurements.

Month 9-10 (August - September):

Milestone 9: Collect full data set on rovibrational states of H_2^+ , complete data analysis, and start writing the final report.

Month 11-12 (October - December):

Milestone 10: Finalize data analysis and interpretation, draft conclusions, and prepare the **Final Report**.

Milestone 11: Submit **Final Report** by December 31.

Budget Justification

- **Alkaline Oven Parts:** The requested funds will cover materials to build the alkaline oven, a critical piece of equipment that will be used to introduce alkaline metals into the ion beam.
- **Vacuum Components:** Additional funding will be used to purchase specific vacuum chamber parts, gaskets, and pressure gauges that are essential for maintaining the required low-pressure environment for ion beam experiments.

The project will leverage in-kind support from the collaboration with Oak Ridge National Laboratory, including the donation of the ion source, chamber, turbo pumps, and other vacuum equipment. These contributions will significantly reduce the need for additional purchases, making the requested funding more focused on critical components.

Additionally, the department will provide access to laboratory space, instrumentation, and computing resources, further maximizing the efficiency of the allocated funds.