Polycyclic Aromatic Hydrocarbons and the Production of Infrared Radiation After Exposure to Ultraviolet Radiation in the Upper Atmosphere

Tessa Lowenstein
tdlowenstein@yahoo.com
Pikes Peak Community College
Liz Coelho
liz.coelho@ppcc.edu
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Abstract

In the upper atmosphere, there is more ultraviolet radiation than on ground level. Several studies in the field of Astrochemistry theorize that when UV radiation comes into contact with polycyclic aromatic hydrocarbons (PAH) in space, the UV radiation catalyzes a reaction within the PAH that causes it to vibrate and subsequently convert the vibrational energy into infrared radiation. A prominent theory is that this radiation is responsible for so called ‘unidentified infrared bands’ (UIE) detected in the interstellar medium. The purpose of this experiment is to determine whether there is an increased discharge of IR radiation from a highly conjugated PAH compound when exposed to the UV radiation of the Earth’s upper atmosphere. The importance of this information is significant in our search for hydrocarbons, and eventually life, in the outer reaches of space. PAH’s and their detection via increased expulsion of IR radiation can indicate the presence of hydrogen and carbon in the interstellar medium. My hypothesis is that a naphthalene compound will produce a small amount of IR radiation compared to the atmospheric amount and amount measured by the control sample on the ground, but levels will not be significant due to the protection from UV radiation by the sun. In order to test this hypothesis, a control sample of naphthalene will be placed near a UV radiation sensor and an IR radiation sensor, while a payload box will be sent up with the DemoSat weather balloon containing a sample of naphthalene placed near a UV/IR sensor, and an additional UV/IR radiation sensor placed further away from the sample. The results will determine if the atmosphere contains enough UV radiation to catalyze a vibrational expulsion of IR radiation in polycyclic aromatic hydrocarbons.

1. Introduction

Polycyclic aromatic hydrocarbons are uniquely structured compounds. The benzene ring structure is of interest to scientists in many fields, but can be difficult to study because of their chemical properties. According to the Environmental Protection Agency [1], PAH’s can be difficult in many ways such as stability in extreme temperatures, the ability to travel through the air, and tumor growth among subjects who inhaled certain PAH compounds [1]. Despite their detrimental qualities, research about PAH’s are being conducted in many fields, most notably in Astrochemistry: the study of chemicals in the interstellar medium. Astrochemists noted the stability of PAH compounds in extreme temperatures, and have formed several theories about their prevalence and importance in space. That brings the qualities of Unidentified Infrared Bands/Emissions (UIE) to the forefront of PAH importance. The presence of organic particles in the interstellar medium has been theorized for some time, but solid theory of detection of free-floating concentrated areas of organic material was not achieved until the classification of UIE’s. The commonly accepted theory is that these unidentified infrared bands have a source – polycyclic aromatic hydrocarbons [2]. The theory has been so widely accepted, that the bands are now being referred to as Aromatic Infrared Emissions. The regions of space where these emissions have been identified as the strongest are those regions with greater exposure to ultraviolet radiation, which is why the PAH theory is so prevalent. PAH’s, when exposed to high levels of UV radiation, have strong vibrations between the bonds of their benzene ring structures. The vibrations reach an extremely high level, creating excess energy that is released as infrared radiation [3]. The detection of these bands (and subsequently the molecules) is substantial in the search for organic particles in space, and gives researchers direction in the overall quest to find life-giving molecules. Eventually, the ability to discover new planets may result from the detection of PAH molecules in the planet’s surroundings or on the body itself. The experiment discussed in this paper will attempt to determine whether the UV radiation that penetrates the upper atmosphere at approximately 100,000ft (3km) catalyzes vibrational reactions between the PAH bonds of the naphthalene samples, and whether those reactions produce detectable amounts of IR radiation.

2. Experimentation

2.1 Hypothesis

I hypothesize that during the experiment, the payload box sensors will read higher levels of UV radiation than the control box sensors, and that due to this correlation I will see a higher amount of IR radiation in the payload box sensor closest to the sample of naphthalene. I also hypothesize that, while a higher IR amount will be present, the amount of IR radiation read will not be highly detectable from a large distance away, but that the number will be higher near the PAH.

2.2 PAH Selection

In order to test the theory that Earth’s upper atmosphere has enough UV radiation to catalyze detectable expulsions of IR radiation in PAH compounds, a sample of a polycyclic aromatic hydrocarbon had to be chosen. There were limited options because of the danger of using PAH’s, and I wanted to choose the PAH likely to expel the greatest amount of IR radiation. After consulting with Brett Mayer, Lab instructor at University of Colorado...
Colorado Springs and Juan Herraez, Professor of Chemistry at Pikes Peak Community College, it was determined that for engaging in this particular experiment, the specific bonding within a PAH did not matter. Naphthalene (Fig 1), an inexpensive and readily available compound used commonly for mothballs, would suffice for the experiment.

2.3. Methods
Available for use were several high altitude test tubes (HATT), specialized to ensure that changes in pressure were not noticeable for contents inside the tube, ensuring fewer variables in the experiment. Each tube holds approximately 1 gram of solid substance. After researching types of sensors, I determined that purchasing sensors that measured both infrared radiation and ultraviolet radiation would be most efficient. Three sensors were obtained, one to measure information coming from the tube, another to measure the ambient UV/IR readings, and a third for control measurements. 832mg of solid naphthalene was carefully placed in the payload HATT, while the amount inserted into the control HATT came to 560mg (Fig. 2). The difference in the amount of product should be negligible, as the expulsion of IR radiation will be read by the sensors at low volumes.

2.4. Balloon Payload Box Design and Launch
A sturdy Styrofoam box with tape securing it was chosen as the payload box. Sprayed with insulating foam inside for protection, it provides just enough room for the experiments, sensors, and batteries (Fig. 3). On April 11th at approximately 6am, the box with the polycyclic aromatic hydrocarbon experiment as well as two other separate experiments will be sent up into the upper atmosphere, approximately 100,000ft (3km). The entire process of launch, data collection, and descent should total to approximately 3 hours, not including payload box recovery efforts.

2.5. Electrical and Wiring
To accommodate this experiment and the two other experiments in the payload box, an extensive electrical system was installed. Two arduino’s were required for the sensor load, which included 2 UV/IR sensors, 1 temperature sensor, 1 Lumen sensor, and 2 OpenLog’s to house SD cards for information storage. An aluminum foil barrier was installed for two purposes: the first to ensure that a second experiment that is radiation dependent is not altered by the influx of IR radiation from the PAH tube, and second to maximize the separation between the two UV/IR sensors. Each sensor has specific programming to read required data (Fig 7), and will be stored on the SD cards to be recovered after launch. For my PAH experiment, only two sensors are necessary: both UV/IR sensors pictured above (Fig. 4 and 5).

2.6. Testing
To prepare for launch, various aspects of the experiment, box stability, and electrical consistency were tested.

2.6.1. Box Stability

Three box stability assessments were performed on both the payload box and ground control box. The first was the Drop Test. The boxes were thrown with force from a height of 25 feet. The payload box sustained minor damage externally by way of tape peeling from the surface, though the Styrofoam underneath was undamaged. Internally all was stable. The second test was the Whip Test, conducted to ensure that the central cord that would be attached to the balloon did not separate from the payload box. The box was spun around a central point with force. The box remained attached to the rope. Finally, a Stair Pitch Test was administered. The box was thrown down a flight of stairs at force, again with minor damage to the tape surrounding the box but no damage to either the Styrofoam exterior or the interior.

2.6.2. Bench Test

After completing the electrical setup, two tests of the electrical was run simultaneously with the Cooler Test (see 2.6.3). All sensors recorded data as expected, though during the first test the batteries failed. More batteries were added, and sensors were adjusted to the change, resulting in success during the second bench test.

2.6.3. Cooler Test

A cooler containing dry ice was obtained, and the payload box containing all electrical wiring, batteries, and high altitude test tubes containing naphthalene was put into the box. After 3 hours, the box was removed and sensor data was obtained. These sensor results serve as the base data for the PAH experiment, and the results are shown below (Fig 6, 7, and 8).

2.6.4. PAH Test

Testing on the naphthalene to obtain sample results was run with promising results. The sensor, hooked up to an arduino, was placed in front of a UV lamp. After reading initial sensor data, the test tube with PAH compound was placed in between the sensor and the lamp at periodic intervals. The dips are when the compound was initially entered, and the rises are both when the sensor was acclimated to the compound’s presence and when the compound was removed. The hypothesis for this test was that, after being exposed to the compound, UV levels would remain constant while IR levels would increase. Below (Fig. 9 and 10) are the results of this test.
These results show promise in that the IR radiation increases slightly out of sync with UV radiation. This indicates the probability that, when naphthalene is exposed to UV radiation, the IR levels go up due to the vibrational reaction. The ability to read that information on a graph will assist in the interpretation of results after launch.

### 2.7. Control Box

The control box is structured and wired similarly to the payload with several minor exceptions. The structure was deemed to be too heavy for the payload box; it is made of thick poster board and insulating foam. Fewer sensors are needed for the control box, so only one arduino is used. Instead of batteries, a computer connected to the arduino will directly power it. Below are the box and electrical diagrams (Fig. 11 and 12).

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**3. Discussion**

A full discussion will be presented at the Colorado Undergraduate Space Research Symposium.

**4. Conclusion**

After launch recovery, data from the SD card attached to the arduino’s with both UV/IR sensors will be gathered and examined. Results will be presented at the Colorado Undergraduate Space Research Symposium.

**5. References**

