Emission and Absorption Spectrum Analysis of Rocket Fuel

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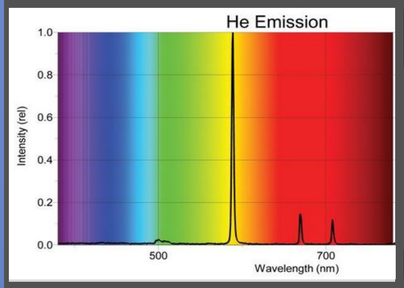
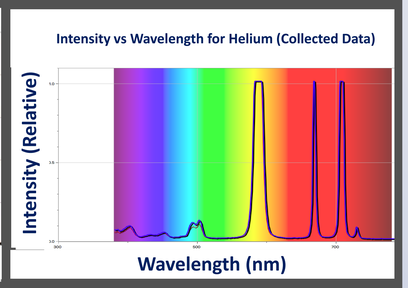
BACKGROUND

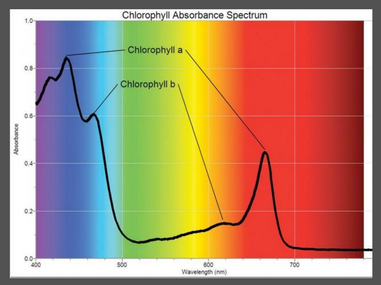
Model rockets are a fascinating sight. When ignited, the rocket emits a spark and shoots up into the air. This project was to determine what elements are in the black powder of model rocket engines, using spectroscopy. Spectroscopy is the study and measurement of light spectral lines, produced when matter interacts with or emits electromagnetic radiation. Two types of spectroscopy were used in this project, emission and absorption using a Vernier Spectrometer. Absorption spectroscopy is the process of passing light through a gas or element and analyzing the absorbed light from the source. Emission spectroscopy is the chemical analysis of a substance that uses the light emitted from a spark, plasma or flame at a wavelength to determine the elements in a sample.

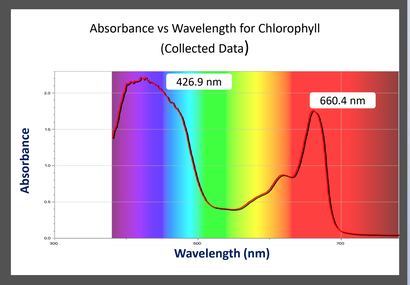
SPECTROMETER CALIBRATION

To ensure the spectrometer was working properly, two calibration experiments were conducted. To test the emission spectrum, a fiber optic cable was pointed at three gas tubes (neon, helium and mercury). After the information was gathered, sample data from the Vernier website [5] was compared to the collected data to conclude that the data corresponded to that element.



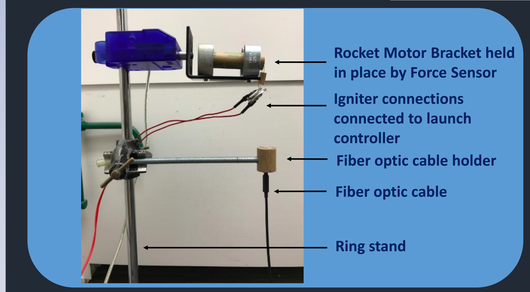






To check the equipment for the absorption experiment, the spectrum of chlorophyll was observed. Leaves were crushed and placed into 20mL of ethanol, then filtered to collect the mixture. The mixture was then poured into a cuvette for the chlorophyll to be analyzed. The collected data resulted with peaks in the visible blue light range at 426 nm and the red light range at 660 nm matching up with the accepted values of 430 $nm_{[1]}$ and $662nm_{[1]}$. Plot on the right is collected data and plot on left is known and accessed from source [5].

EXPERIMENT SETUP



To conduct the experiment, the rocket motors were ignited under a fume hood. A force sensor was attached to a stand, holding the rocket motor. Below the motor was a handmade apparatus that holds a fiber optic cable in place. To start testing, a small metal igniter was placed in the end of the motor and was secured with a plastic pin. Lastly, the launch controller was connected to the igniter, a button is pressed on the controller and the engine ignites.

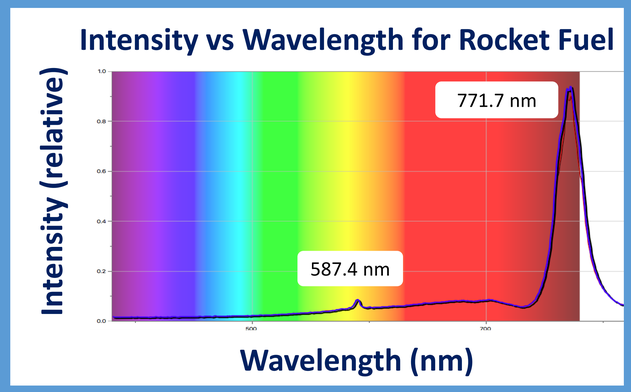
DATA AND OBSERVATIONS

It was observed during testing that there were two different types of flames, a conoidal (cone shaped) flame and an amorphic (shapeless) flame. The initial flame resulted from combusted sulfur which was the igniter for the self-oxidizing potassium nitrate, resulting in the second flame.

During testing, two peaks were collected using the fiber optic cable. One peak in the visible light range and the second peak in the infrared light range.

Initial flame color due to ignited sulfur

After all the sulfur burns off the KNO_3 ignites causing the whiter flame



EQUIPMENT, ANALYSIS, AND CONCLUSION

Black powder in B6-4 model rocket engines consists of 75% potassium nitrate (KNO_3), 15% charcoal and 10% sulfur [2]. Sulfur produces a wavelength of 647.1 nm which is seen as a small peak in the collected data at 587.4 nm in the graph. The peak is small due to the low percentage of it in the black powder. Potassium nitrate was identified through it's high reading of 771.7nm. The accepted value for KNO_3 is 724.2 nm [3]. Due to the lack of a vacuum and machine calibration the collected data is susceptible to error. The large peak of KNO_3 is due to the large portion of KNO_3 in the black powder. The visible light spectrum ranges from 390nm to 700nm. The Infrared light spectrum ranges from 700 nm to 1000 nm, leaving the collected data for potassium nitrate in this range. The absorption spectra for black powder is in process now.

Used for this project was the Vernier SpectroVis Spectrophotometer capable of both visual emission and absorption spectroscopy. Reasonably priced at $400, the resolution isn't as good as $4,000 spectrometers but for our purposes and its future use in sophomore physics labs, it does the job quite well.

FUTURE PLANS

For future testing, the rocket motors would be tested if ignition is possible in a near perfect vacuum. This would be done to determine which elements oxidize and do not oxidize during ignition. An additional experiment would be to carry out a flame test for sulfur and potassium nitrate to observe the flame color given off, capture the emission with the spectrometer. Then compare that emission spectrum to the ones we collected from the rocket ignition. We would also like to study burn times on solid rocket motors.

References

[1] Book: Pigments in Vegetables: Chlorophylls and Carotenoids ~ Jeana Gross

[2] http://www.skylighter.com/fireworks/how-to-make/Black-Powder-Quick-and-Cheap.asp

[3] http://webbook.nist.gov/cgi/inchi?ID=B6000529&Mask=80

[4] https://science-edu.larc.nasa.gov/EDDOCS/Wavelengths_for_Colors.html

[5] Known visible spectrum of Helium and known absorption spectrum of chlorophyll plots, accessed and used for education purposes from www.Vernier.com

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