Study of Chars Produced by Fabrics and Accelerants

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ABSTRACT:

Constant volume bomb calorimetry was used to carry out complete and incomplete combustion reactions while the temperatures at different points of the reaction were recorded. Using this data, the heat of combustion (q_{comb}) and the change in energy (ΔU_{comb}) were calculated for the 9 char samples of fabrics. Fourier Transform Infrared Spectroscopy (FTIR) was used to analyze these char samples.

INTRODUCTION:

Arson is the "willful and malicious burning of property with criminal or fraudulent intent"[1]. In trying to determine the cause of the fire, forensic chemists determine what materials were involved. This also includes the use of accelerants. In analyzing samples, infrared (IR) spectrometry can be applied in order to determine the functional groups present in a sample. Spectra used to identify these functional groups are obtained by shining the light from a source on a sample. Based on the light that is absorbed, a computer to convert the signal into a spectrum.

MATERIALS:

Textiles, or any woven or knit fabric, are common items found in most places that are the victims of arson crimes. Three pure fabrics (wool, cotton, and nylon) were chosen as samples. Wool (**Figure 1**[2]) is a natural protein that is generally made up of nitrogen, hydrogen, carbon, oxygen, and sulfur (-R group). One of the major components of cotton is cellulose (**Figure 2**[3]). Nylon is a set of repeating amides, called polyamide, that are also composed of carbon, hydrogen, oxygen, and nitrogen (**Figure 3**[4]). The fabric samples were soaked in one of three accelerants (Kingsford Charcoal Lighter Fluid, Ace Turpentine, or diesel fuel from a local "Budget Gas" gas station obtained at the beginning of September 2011).

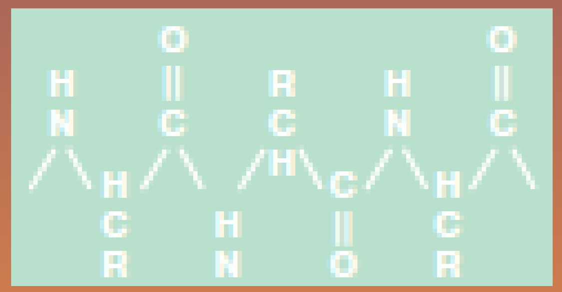


Figure 1: Wool

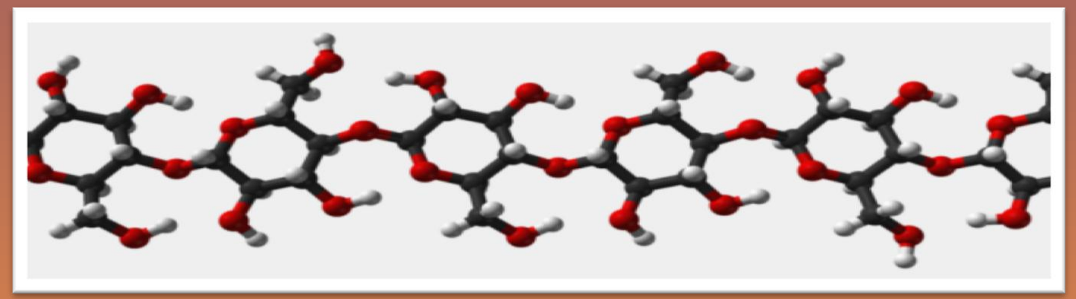


Figure 2: Cellulose

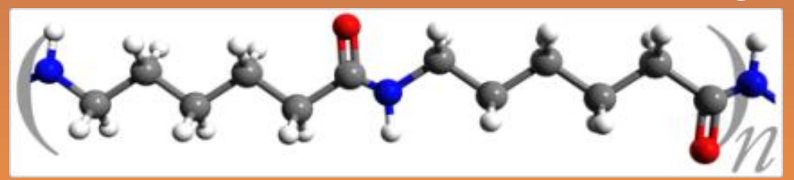


Figure 3: Amides

BOMB CALORIMETRY (Figure 4[5]):

Complete and incomplete combustion reactions were carried out under constant volume conditions. The samples combusted completely when the temperature was being recorded every 10 s. Using this data the heat of combustion and heat of capacities were calculated. Incomplete combustion occurred when ash was being collected for further analysis with the FTIR-PAS.

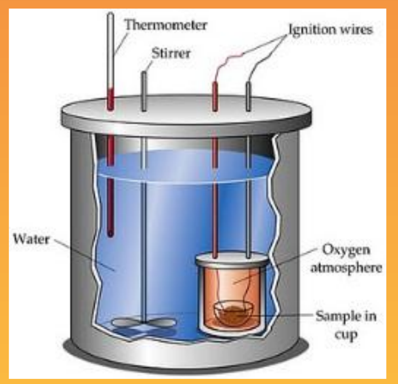


Figure 4: Bomb Calorimeter

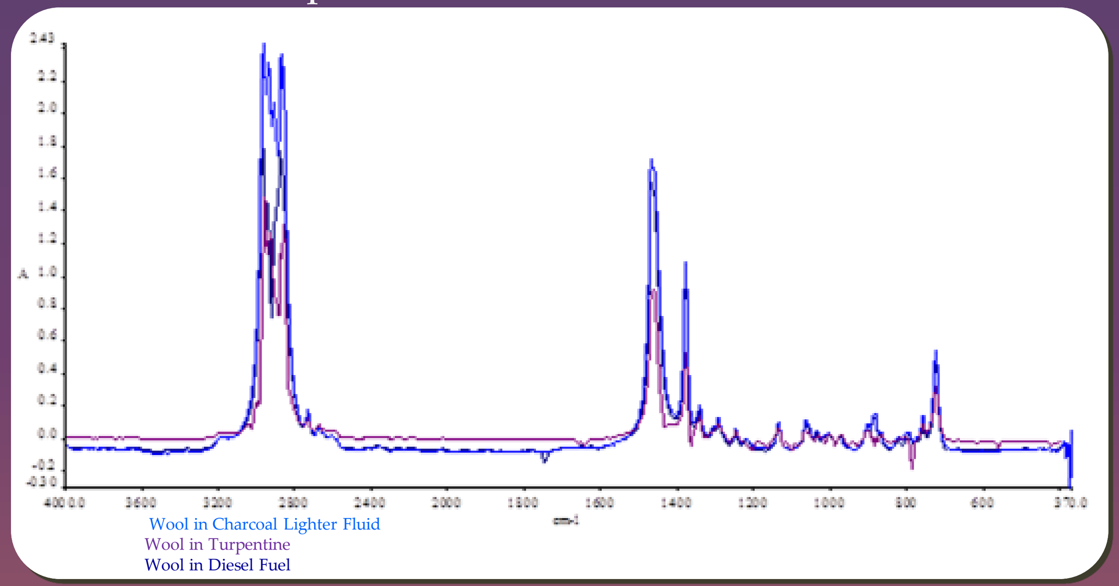
DATA:

Table #: Bomb Calorimetry Results

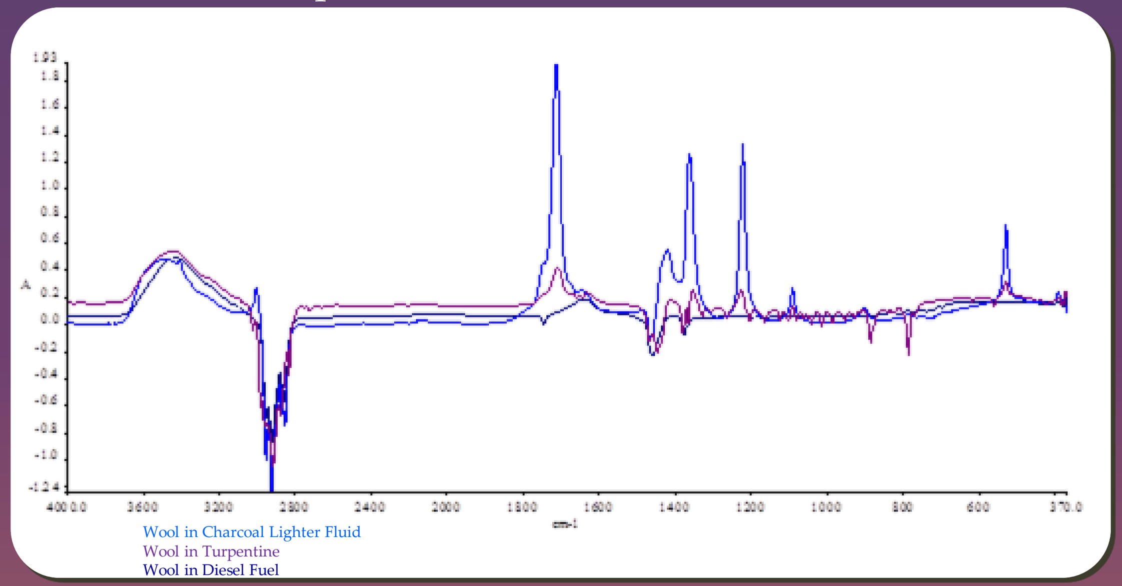
Sample Number	Fabric	Accelerant	% Weight Increase	ΔT	q_{comb} [kJ/g]
3W	Wool	Lighter Fluid	131.67	3.524	34.48
5W		Turpentine	194.37	3.343	31.94
7W		Diesel Fuel	145.52	4.123	34.23
10W, 11W, 12W		None	--------	1.035	19.52
3C	Cotton	Lighter Fluid	118.58	2.273	29.13
6C		Turpentine	184.54	1.131	31.77
7C		Diesel Fuel	278.60	3.827	31.77
10C, 11C		None	--------	0.623	15.78
2N	Nylon	Lighter Fluid	21.63	0.747	33.03
4N		Turpentine	44.22	0.531	27.36
7N		Diesel Fuel	75.74	1.057	33.74
10N		None	--------	0.486	27.84

INFRARED SPECTRA:

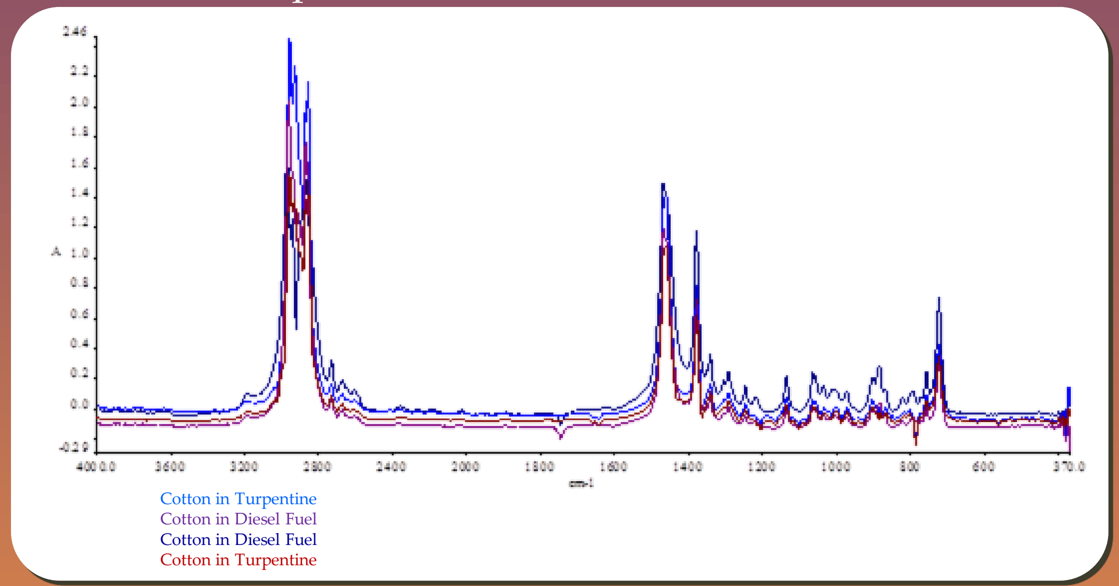
Spectrum 1: Wool in Hexanes



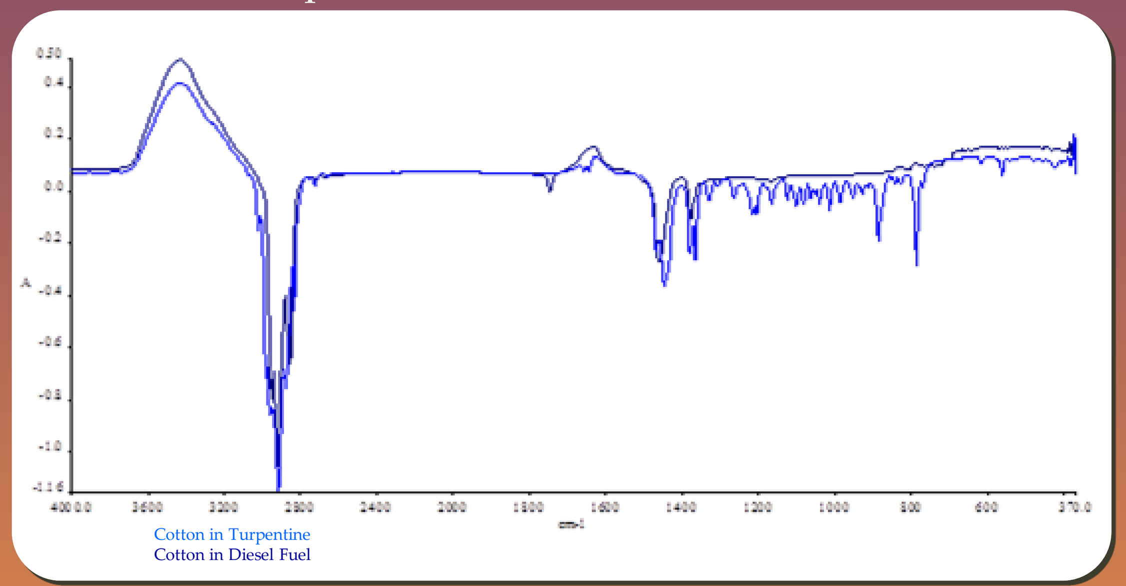
Spectrum 2: Wool in Acetone



Spectrum 3: Cotton in Hexanes



Spectrum 4: Cotton in Acetone



RESULTS:

In order to carry out combustion reactions, the bomb calorimeter was used in cooperation with a thermometer in order to calculate the change in temperature (ΔT) and the heat of combustion (q_{comb}) for each of the different samples. Of the three fabrics used (wool, cotton, and nylon), the samples involving cotton showed the greatest percent weight increase upon exposure to the accelerant (in some cases almost doubling in weight). Similarly, diesel fuel seemed the easier of the three accelerants to be absorbed in two out of three circumstances. When comparing the heat of combustions, the samples that involved either wool or cotton had the higher values (with wool having the highest values) when burned after being soaked in the accelerants. Respectively, nylon had relatively lower values. Diesel fuel repeatedly had the highest values (respectively) of the accelerants and different fabrics.

RESULTS (continued):

Using the FTIR, spectra were obtained for each of the samples using both hexanes and acetone as the solvents. Spectra for each of the accelerants were also obtained using the same solvents. Using a spectral calculator, the spectra for the accelerants and blank solvents were subtracted from each of the samples' spectra. Theses differences are overlaid with one another (with similar fabrics) and provided in Spectra 1-4. While there are these varying intensities, the general "shape" of the overlaying spectra are very similar. In Spectra 1 and 2, there is a significantly large peak around 2900cm^{-1}. In Spectrum 3, there are significant peaks that occur 2800-3000 cm^{-1} and in Spectrum 4, there are significant peaks between 2800-3600 cm^{-1}. In all of the spectra, there are also significantly large peaks that occur 1800-700 cm^{-1}.

CONCLUSIONS:

Based on the overlaid spectra provided above, each of the differ spectra (same fabric and same solvents) have extremely similar spectra. However, when each of the different spectra above are compared to the corresponding spectra (wool with wool, cotton with cotton), the spectra are dramatically different. However, there are similar functional groups present. The major peaks that are displayed in Spectra 1 and 2 at 2900 cm^{-1} could be a result of a weak –SH group or –CH stretching, both of which could appear in a wool sample. In Spectra 3 and 4, the wide peaks that occur between 2800-3000 cm-1 could be attributed to simple –CH stretching. In Spectra 1 and 4, the broad peaks that occur between 3100-3600 cm-1 are –OH peaks that could be attributed to the accelerants (even though the designated accelerants were subtracted from each of the spectra). The remaining peaks that occur between 1800-700 cm-1 are attributed to C – C bending within the sample.

For future research, fourier transform infrared photoacoustic spectroscopy (FTIR-PAS) can be used to try to develop a method that is non-destructive method. This would be beneficial, especially for forensic purposes, in the identification of different samples.

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