

# Development of a Forensic Science Laboratory Module

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## ABSTRACT

The primary objective of this research was to develop a forensic science laboratory module for an organic chemistry course. This module, based on a fictional case scenario, introduces new methodologies and reviews certain procedures that were learned by the class throughout the semester. Five evidence clusters were developed for students to examine using different methods of analysis for each cluster. The lab was constructed to encourage individuals to think on their own, but it also emphasizes the need for group cooperation. Small student groups would be asked to draw their own conclusions on a case and then be asked to view their evidence in conjunction with other cases to reach a final conclusion. Overall, the lab module serves to offer students the opportunity to experience elementary forensic science as well as to strengthen the skills that they have developed throughout their own organic chemistry experiences.

## INTRODUCTION

In the course of most science classes, students are required to complete a laboratory component. The purpose of a laboratory is to give students a hands-on learning experience in an attempt to solidify the concepts that have been taught in the classroom. Unfortunately, the laboratory modules that are used often have the opposite effect. Instead of focusing on the concepts and gaining useful knowledge from their experiments, students instead focus on completing their lab work in as little time as possible.

As students we feel that we have a strong understanding about what would best interest students and further motivate them to actively participate in their own education. Our objective was to create a forensics laboratory module that can be used as a comprehensive review of the analytical topics and methods covered in an organic chemistry laboratory. This “end-of-the-semester” module would ask students to pool their knowledge, work in teams and place themselves in the role of a forensic scientist. Students would be instructed that they must work together in order to charge the correct suspect.

The completed laboratory module requires four main evidence clusters as well as a case scenario that fully introduces all of the evidence necessary to “solve” the case. In addition, a suspect is identified and evidence is collected from that suspect’s home.

## METHODS

The first step in developing the laboratory module was to develop assays that were reasonable for an organic chemistry class to complete. The assays were divided in to four main evidence clusters that were examined for their feasibility in use for the laboratory module.

The first of the four evidence clusters was the use of the Gas Chromatography/Mass Spectrometry (GC/MS) machine. Analysis of either paint chips found at the scene from tool marks or accelerant usage in an arson case were discussed. Due to the potential volatilization and loss of the components necessary for GC/MS detection paint chips were not examined. Instead, wood fragments soaked in an accelerant were subjected to headspace analysis with the GC/MS. Headspace analysis works upon the principle that accelerant components that have soaked into the wood sample become volatilized when heated in a tightly sealed vessel. The accelerant particles will now be in the “headspace” of the vial. Some of the headspace is removed and injected into the GC/MS apparatus. The components of the accelerant are separated into peaks based upon the time that it takes for them to elute from the column. More volatile components will elute more quickly and will appear at the left side of the chromatogram. Using this specific elution profile, a chromatogram of a known liquid sample of accelerant can be compared to a chromatogram from the headspace of the charred wood sample to determine if any accelerant is present.

The protocol was begun by setting the GC/MS to the appropriate specifications. The method was set to “Forensic Science Lab” and then “Headspace Method.” Approximately 30 mLs of water was heated to 60<sup>o</sup> C in a

beaker. When the water had reached a steady temperature, the sealed vial with the wood sample in it was placed in to the beaker and heated for 60 seconds. After 60 seconds, the microsyringe was inserted in to the rubber septa, 5

μLs of headspace sample was withdrawn, and sample was injected in to the GC/MS. After the GC/MS had finished running, the chromatogram was printed (Figures 1 and 2). This chromatogram was compared to the liquid sample chromatogram and a positive confirmation was made showing that the headspace sample was the same as the liquid sample. This method was proven successful for identifying for tiki torch oil, charcoal lighter fluid, and lamp oil through headspace analysis.

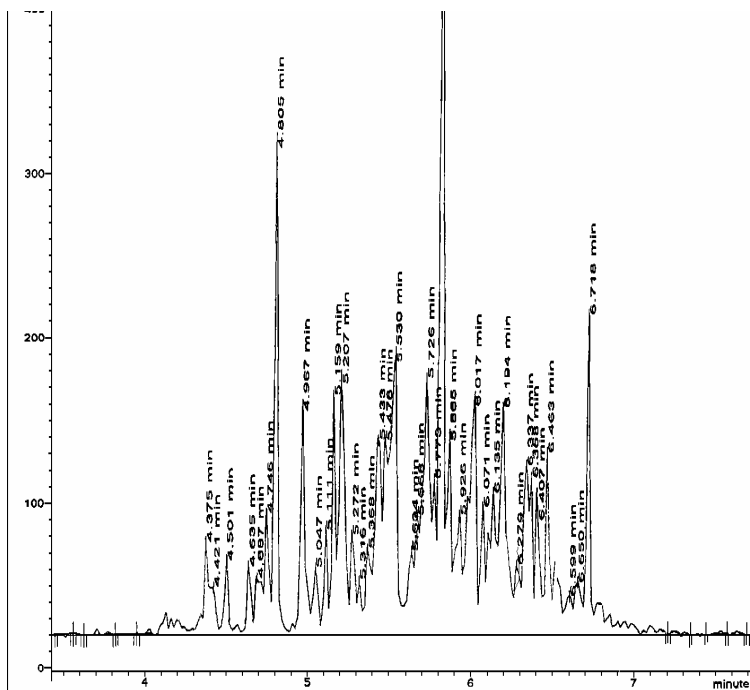
The second evidence cluster examined was soil found at the scene of the arson and soil found in the treads of the suspect's shoes. Soil is composed of millions of tiny particles of different sizes. When a small sample is shaken in a cuvette these particles begin to sink to the bottom at different rates. By using a spectrophotometer, it is possible to detect two soil samples with the same composition as they will show the same pattern of settling. The spectrophotometer measures the amount of light that the sample absorbs by passing a beam of light through the cuvette, a detector registers how much light is allowed to pass through the sample. The absorbance is measured every thirty seconds for ten minutes and the values are plotted. It is important to note that the actual values are not of importance in this assay, but rather it is the pattern of settling determines if two soil samples are consistent.

The procedure was begun by setting the Spec20 to 450 nm and blanking the instrument with a cuvette of distilled water. The soil sample was carefully sifted until it was very fine. The cuvette was filled approximately  $\frac{3}{4}$  full of distilled water, the soil sample was added and shaken vigorously for approximately one minute. The cuvette was placed in the Spec20 and absorbance readings were taken every thirty seconds for ten to twelve minutes, or until the absorbance stopped changing. A graph of time vs. absorbance was plotted on Excel and a best fit line was inserted (Figure 3). This procedure was repeated for other soil samples that were obtained.

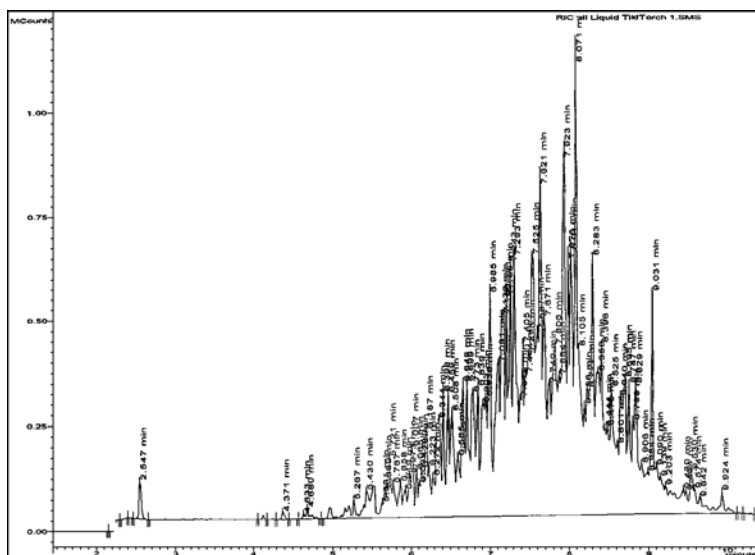
The third analysis explored were methods of comparing fabric found at the crime scene with fabric collected from the suspect. This evidence cluster aimed to use the Fourier Transform - Infrared Spectrophotometer (FT-IR) but testing of several methods was done before the best method was determined. The first method involved laying single fibers across the salt plates, but due to the nature of the IR beam this method produced unreliable results. The second attempt was to dissolve fibers in an anhydrous solvent so the mixture could be used on salt plates in order to obtain a spectrum. Unfortunately the solvents tried; ethyl ether, methylene chloride, acetone and hexanes were not strong enough to dissolve any of the fabric samples. Sparse results were seen with the methylene chloride, but upon IR examination it was seen that, at best, some of the dye from the polyesters and cottons were stripped and in fact the fabric was not dissolving. The final method attempted utilized Diffuse Reflectance Infrared Fourier Transform (DRIFT) technique. DRIFT spectroscopy works much the same as a regular IR, however the DRIFT apparatus allows a spectrum to be taken from a ground solid sample. Using the mortar and pestle enough dried KBr is ground to fill two sample cups. The first sample cup is packed with pure KBr and leveled off. This sample cup serves as a background. The second sample cup of equal size is packed with finely cut pieces of the evidence fabric mixed with ground KBr. A spectrum of the evidence sample is then taken and analyzed to identify the type of fabric. In DRIFT spectroscopy radiation from an infrared light source passes through the fabric particles and reflects off of the surface of the KBr. A spectrum results from transmitted light at frequencies that are characteristic of the functional groups that are found in the fabric sample (Figures 4 and 5). Although this analysis cannot determine if two fabric samples are the same because it only identifies the functional groups, it will help to determine if there is a possibility that the two fabrics are the same or if they are definitely different.

The fourth evidence cluster, fingerprinting, posed several challenges. The first method attempted utilized a crystal violet solution which interacts with the protein in fingerprint residues. This method was reported to work well with fingerprints on tape, but did not work well with attempting to lift prints of glass or other smooth surfaces with tape. Problems were encountered in attempting to lift the fingerprint as well as with developing a dark enough fingerprint but not dyeing the background of the tape. The second method of developing fingerprints explored utilized a silver nitrate solution. The solution was made by dissolving one gram of silver nitrate crystals in 100ml of water and was then stored in a brown bottle. Silver nitrate works on porous surfaces such as paper or wood by reacting with the chlorides in the sweat contained in a fingerprint. Samples of paper and wood were analyzed by brushing the solution over planted fingerprints. The paper or wood is then allowed to dry in the dark and, once dry, exposed to sunlight or high intensity light. Drying in the dark allows the silver nitrate to form a silver chloride precipitate and the light exposure photochemically reduces this to a dark brown color revealing the fingerprint. After testing different types of paper and wood, light cardboard and untreated wood were found to work the best. In addition to the piece of wood to process, students would also be provided with 10-print cards to use for comparison with the developed fingerprint (Figure 6). These cards would contain fingerprints of all family members as well as any suspects that had been identified.

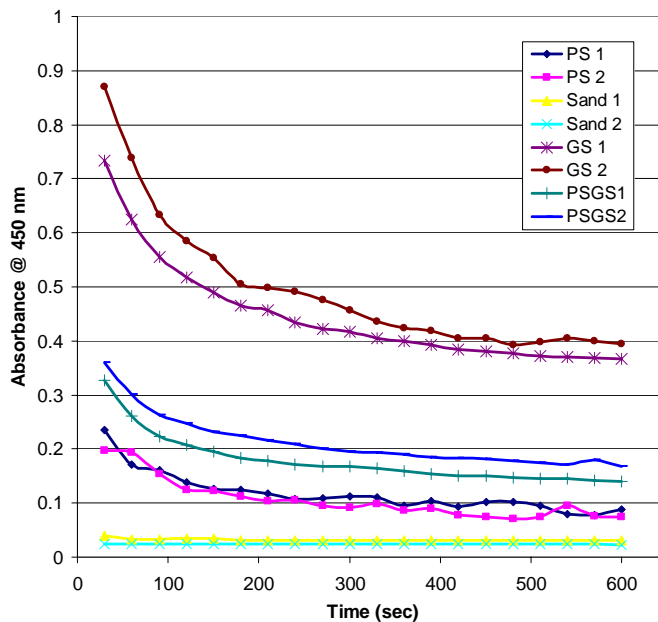
## RESULTS



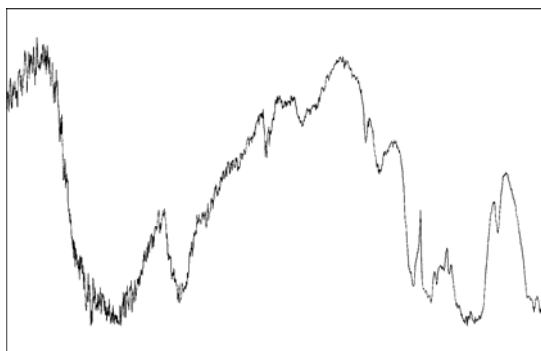
**Figure 1:** Liquid charcoal lighter fluid chromatogram. This chromatogram helps to identify the characteristic elution profile of the charcoal lighter fluid itself. Headspace analysis samples will closely resemble this specific profile. The headspace sample will usually be slightly less complex, but it will have the same major peaks at the same elution times.



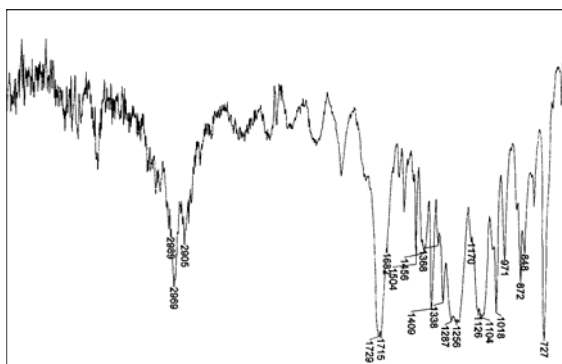
**Figure 2:** GC/MS chromatogram of liquid tiki torch oil. Note the distinct difference in elution profile between this sample and the previous charcoal lighter fluid sample. These differences are what will help students to identify if an accelerant is present and if so what that accelerant may be.



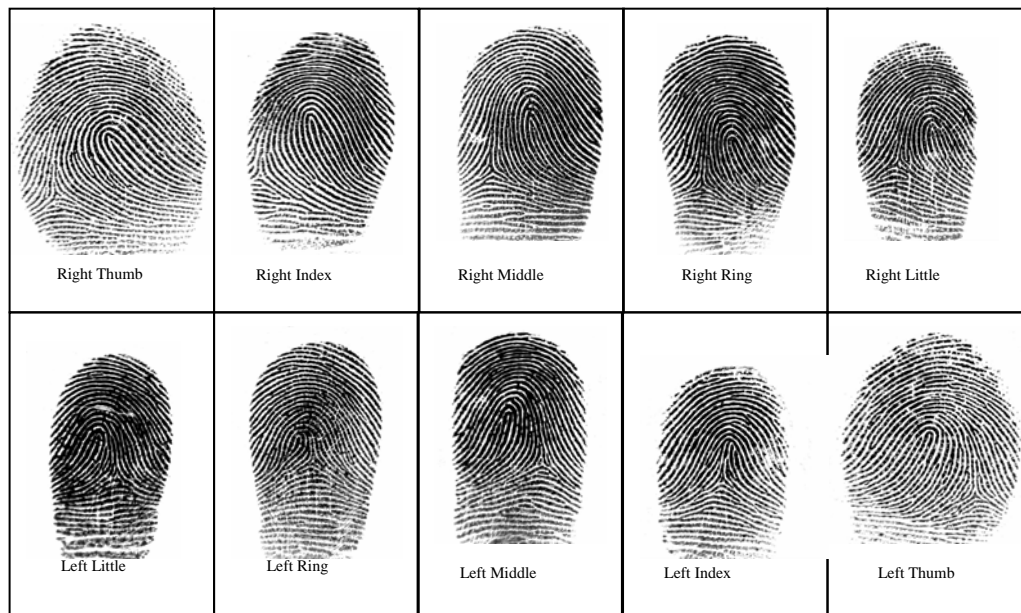
**Figure 3:** Soil Settling rate diagram used to show the different settling rates of various types of soil. Note that the lines that are “paired-up” are two different trials using the same soil sample. This shows that the settling rate of the different types of soil maintain the same rate.



**Figure 4:** Infrared spectra of cotton fabric analyzed using the DRIFT method. This shows a broad OH peak as would be characteristic of the cellulose found in cotton plants. The scale is in (transmittance / cm<sup>-1</sup>)



**Figure 5:** Infrared spectra of polyester fabric analyzed using the DRIFT method. This shows the characteristic carbonyl peak of an ester. The scale is in (transmittance / cm<sup>-1</sup>). Note that these spectra are not sensitive enough to be used as a fingerprint to positively identify two fabrics as being the same, but they can identify them as being the same type of fabric or two different fabrics.



**Figure 6:** A sample fingerprint card that would be provided to the students for comparison with the developed prints. The students should be provided with fingerprints from the people who live in the home as well as the suspect(s) of the crime. This will allow comparison between the developed fingerprint and the fingerprints that do and do not belong at the crime scene.

## CONCLUSION

After developing the most adequate methods with which to test each evidence cluster and performing each experiment several times to assure continuity a case scenario was developed. This case scenario identified a victim, a possible suspect, and the location and reason for each piece of evidence to be collected. The scenario played forth as follows:

On the night of March 30<sup>th</sup>, 2005 La Crosse police, fire, and emergency personnel were dispatched to the Miller household at 4517 Main Street after an anonymous 911 call was received. The caller claimed to be passing by the residence and noticed flames coming from a lower level window. When fire personnel arrived they ascertained that the house was empty and quickly went to work to extinguish the fire. The house sustained major structural damage that rendered the home a complete loss. Authorities were unable to immediately determine the cause of the fire, and as such, are treating it as a possible arson, due to an unusual burn pattern.

It is your role as the forensic investigation team to examine the evidence that has been collected, determine the cause of the fire, and who, if anyone, is responsible. In addition, it is imperative that you carefully document your research, as it will need to be admissible in court, should a suspect be charged.

Crime Scene Personnel examined the scene for evidence and the following 4 items were collected:

Charred wood: Wood that was recovered from the fire's point of origin (as determined by the area with most damage) in the Miller's living room was collected. A sample of the wood is enclosed in a glass vial in evidence bag #1. This wood should be examined for evidence of the use of an accelerant.

Fabric: No signs of forced entry were present at the Miller household; however, upon inspection of the yard, a torn piece of fabric was found caught on the wooden fencing surrounding the yard. This fabric should be tested to determine its composition. In addition, it appears as though the fabric is stained. This stain should be extracted and the sample tested to determine the identity of the stain. The fabric is enclosed in evidence bag #2.

Fingerprints: As a result of the discovery of the fabric sample, crime scene investigators have removed a portion of the wooden fencing in order to determine if there are any fingerprints present that would indicate that a perpetrator entered the Miller yard through this route. The wood is enclosed in evidence bag #3 and should not be handled

without wearing gloves to avoid contamination. In addition, all members of the Miller family have been fingerprinted, and their prints are included in evidence bag #4 for comparison and exclusion.

Soil: Further investigation of the Miller yard found a partial footprint in the vegetable garden, where none of the family had tread since the rainstorm of the previous night. Because the print was not complete enough to take an impression, a soil sample was preserved for comparison to possible suspects. The soil sample is enclosed in evidence bag #5.

Upon interviewing Mr. Samuel Miller, it was determined that a possible suspect exists. The Miller's child-care provider has recently been fired as a result of the discovery that she had been stealing Ritalin<sup>®</sup> from the Miller children instead of administering it as directed. Because of the potential revenge motive and the fact that she had intimate knowledge of the crime scene, a warrant to search the Perkins home was provided to investigators.

The Crime Scene Personnel visited the suspect, Miss Emily Perkins' home, and collected the following additional samples.

Fingerprints: Miss Perkins was fingerprinted and these prints are enclosed in evidence bag #6.

Soil: Soil was recovered from the grooves of two different pairs of Miss Perkins' tennis shoes. These soil samples were collected and are enclosed in separate vials and labeled accordingly in evidence bags #7 and 8.

Fabric: A white rag, which appears to be stained, was found in the garbage can in Miss Perkins' garage. The rag, in evidence bag #9, was collected for analysis of the stain and for comparison with the fabric found on the fence in the Miller yard.

Each student group would receive a similar case scenario with the evidence clusters slightly changed so that they would have to perform the actual experiments themselves and not just confer with each other to find the solution. This case scenario was developed to allow for the framework to be left in place and for only minor details to be changed to create an entirely new case.

## ACKNOWLEDGMENTS

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