Chemical Reactions that Solve the Crime

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This curriculum unit is recommended for:
High School Forensic Science, extension topic in Honors or advanced chemistry

Keywords: science, forensic science, chemistry, chemical reactions

Teaching Standards: See Appendix 1 for teaching standards addressed in this unit. (Insert a hyperlink to Appendix 1 where you've stated your unit's main standards.)

Synopsis: This curriculum unit explores the chemical reactions involved in the collection and processing of evidence from a crime scene or other types of cases that the crime lab would investigate. The main focus emphasis is fingerprinting, blood spatter analysis and forensic toxicology. It provides opportunities for students to work individually and collectively in the roles of criminal laboratory technicians. The unit integrates many strategies to engage students in learning the content, making connections to other sciences as well as connections to the world beyond the classroom.

I plan to teach this unit during the coming year to 100 students in honors forensic science.

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Rationale:

Scientific curiosity begins at birth as the infant begins to observe the world around them by touching, feeling, observing, hearing and even to mom's dismay, tasting. Through this discovery, the infant learns about matter in the simplest of ways. This curiosity continues through childhood and into the school years as youngsters begin to study science formally through simple experiments and projects or visits to science museums. In high school, the curiosity still exists but sometimes is lost or buried under previous learning experiences that have tainted the taste of science for some. Forensic science provides a canvas to explore science and paint a picture of "what happened and why" while resurrecting the natural curiosity in students. It gives students an opportunity to use technology, case studies, and hands-on activities to explore and tie together concepts learned in other sciences.

From our earliest ancestors to today's medical researchers, man has sought to explain that which seems not to have an explanation. Toddlers learn at an early age to ask "why" because asking provides an avenue to information. For the criminologist, answering the questions "who", "how" and "why" are an essential part of case work and the answers to some of these questions many times can be found in the scientific realms of chemistry, biology, and physics. Crime scene analysis, commonly referred to as forensics, is an application of science to explain and understand physical evidence from the crime scene itself using logic and technology. There are many techniques and procedures involved to ensure proper collection, processing and testing of evidence. Forensic scientists use mathematical principles, microscopic analysis, instruments, problem-solving, and research in their work. For each procedure and process, the criminologist must not only be able to "do" the test but must also "understand" how the test produces the results and what the results mean.

Before the advent of live court television, Sir Author Conan Doyle's literary character Sherlock Holmes used fingerprinting, firearms detection, and serology to solve crimes in his fictional works.[1] In 1883 Mark Twain described the individuality of fingerprints in his book "Life on the Mississippi".[2] Today, the role of the forensic lab in solving a crime is depicted in television and movies as a high tech workplace where DNA analysis can be done in the time span of an hour long show. Many of the procedures used to process a crime scene takes hours, days and even weeks to complete. Through this unit, I hope to not only have students develop an understanding of specific methods of evidence processing and the chemical reactions that are involved, but also appreciate the important role of the forensic scientist as a member of a team of persons who work together for a common goal. Students will work as criminalists investigating a crime and will collect, process, test, and provide explanations and results of testing. They will investigate and analyze the chemical reactions that take place during the process of fingerprint development, DNA analysis, blood spatter testing, and other techniques that involve complex chemical reactions but provide definitive results. Activities will stress the importance of clean and careful evidence collection and processing as well as accurate and precise measurement. Careful attention to experimental technique and safety will be emphasized.

Through the use of this unit in my classroom I hope to resurrect the curiosity in the students that I teach at Myers Park High School. It is the largest school in our district with approximately 2750 students. The academic programs offered include occupational course of student and college preparatory pathways. International Baccalaureate and Advanced Placement programs provide additional academic rigor for students who desire to be enrolled in the programs and receive advanced placement college credits upon successful testing scores. Honors and standard level courses round out the curriculum. Our student body is very diverse ethnically, culturally, economically and academically. There are over 25 different nationalities represented at our school and the English language learner population is steadily increasing each school year. The population breakdown is as follows: approximately 60% white and 40% African-American, Hispanic, Asian and other. Thirty-two percent of our students are considered impoverished as determined by federal free and reduced lunch guidelines. My course load includes standard level chemistry and physical science as well as honors forensic science which is a new course offering this year. Science classes are large and often present challenges for doing lab experiments and keeping students engaged in learning science. With this obstacle in mind, I have sought to design this unit to be used in a forensics class with an emphasis in the chemistry involved in the tests performed by the crime lab. The unit can also be utilized in a chemistry class as an extension topic.

The implementation of the Common Core Standards in conjunction with the Essential Science Standards provides a framework for this unit as it seeks to integrate language literacy (reading, writing, speaking, listening, and language) and mathematics literacy into core curricular subjects like history, science and also in the technical subjects. As part of the common core standards, students will read and use scientific texts to support their analysis of science and to follow multistep procedures and analyze outcomes. Algebra I skills are used throughout chemistry and physics and support the core standards in math. Newly develop district standards in forensic science provide the science core of the unit.

Background (Content)

Allow me to engage your imagination for a few moments. It's 2:00 a.m. The phone is ringing and Sergeant Smith answers. With pen and pad in hand, he takes down the date, time, location and description of the incident from the dispatcher. Within minutes, he is on the scene where a female victim lies cold and still on a sofa clutching a Smith and Wesson revolver. A pool of blood surrounds her head and a bullet hole is visible above her left temple. A note on the table reads "I am so sorry. I just couldn't take it anymore." This one phone call has set in motion a whirlwind of events that will end only when all of the evidence is collected and the scene is cleared by the lead investigator. A crime scene team arrives and begins to snap photos, take measurements, bag and tag items while the investigator interviews witnesses in the area. Was it really a suicide or could it be a homicide? There are many questions to be answered and many of those answers will come from the analysis of the evidence that has been carefully and methodically collected and tested by the forensic technologist. Some of the testing will involve very sophisticated equipment while others will be based on comparisons of the evidence with computerized databases. Fingerprints, blood, and DNA are just a few samples of physical evidence that can be collected at the imaginary crime scene previously mentioned. While one test might not stand alone as a definitive test to match suspect to crime, a battery of tests when considered as a whole can paint a picture of what happened and make the critical link.

Fingerprints

As the crime scene team begins its work, several different "sub" teams will assume responsibility for collecting evidence. The physical evidence team will be charged with collecting fingerprints and other trace evidence with the hope that something will help them identify the victim and suspects. Guided by one of the oldest underlying principles of criminal investigation, the need to present factual, unbiased and undisputed evidence that links the perpetrator to the crime, the team conducts a thorough search of the scene. Identification of the suspect is critical and supporting the identification with strong evidence can mean the difference between a conviction and exoneration. Locard's Exchange Principle first penned by Edmond Locard states that every criminal can be connected to a crime by dust particles carried from the crime scene.[3] In 1883, Alphonse Bertillon introduced a method using anthropometry or precise body measurements coupled with detailed description and photographs as a means of personal identification. Several years prior, however, a Scottish physician, Henry Fauld, had published his ideas on fingerprinting and its use as an infallible proof of identification. It was rejected in favor of Bertillon's method. Bertillon's method was widely used for almost two decades but in the early 20th century, it became evident that the method had fallacies when two prisoners could not be distinguished by measurements or photographs because the men looked so much alike they could have been twins. Fingerprints of each revealed different individuals. New York City Civil Commission was the first to officially use fingerprints as personal identification in 1901.[4] Today the Federal Bureau of Investigation maintains the largest fingerprint database in the world. It is generally accepted that no two persons have exactly the same fingerprints. Statistically speaking, there is a 1 in 64 billion chance of having the same print as another person. Even identical twins have different fingerprints.

Fingerprints are a result of friction skin ridges found on the palm sides of the fingers and thumbs. Friction ridges are also found on the palms, soles of the feet and toes. These natural ridge formations allow for better grip by the hands and reduce slipping of the feet. Between the dermis (inner layer) and the epidermis (outer layer) lies a boundary of cells that separate the two layers. This boundary is responsible for the ridges and patterns on the skin. It forms during gestation at around 3-4 months and remains the same throughout life. It only enlarges as one grows. Sweat glands located in the ridges secrete sweat and oils which are deposited on the surface of the skin. When one's finger touches a surface, the sweat and oil is transferred to the surface leaving the ridge pattern of the finger behind resulting in a latent fingerprint. Latent prints are "invisible" prints. Fingerprints can also be left behind when the fingers are covered in blood, paint, or other substances. These fingerprints are referred to a patent prints. Plastic prints are prints that are 3 dimensional such as those left in clay, mud, paint or cement.

Fingerprints have 3 general ridge patterns: loops, whorls, and arches. Other patterns may be present such as double loops or pocketed loops. For general class content, loops, whorls and arches are the basis for grouping fingerprints. Within the human population, loops are the most common with 60-65% of persons having a loop pattern. Whorls are the next most common followed by arches[5]. For primary classification, the presence or absence of a whorl pattern on each of the fingers and thumbs is the basis of the Henry classification system. Henry classification became too limiting as fingerprint collections grew in size. Today automated systems such as AFIS (Automated Fingerprint Identification System) are used to scan and match fingerprints against a database of known prints. This system is linked statewide with the FBI database. AFIS is capable of making 500,000 comparisons per second usually completing a set of ten finger prints in about 0.8 seconds.[6] Once a possible match is has been obtained, a trained examiner must verify the results and make the final decision.

The composition of the fingerprint varies from one person to another depending upon the compounds present. The fingerprints of a teenager may contain more oils than those of an elderly person. Regardless of day, time, age, or additional chemicals such as lotions, there are some compounds that are common in all fingerprints: inorganic ions, organic acids lipids and water. Electrolytes lost during sweating include sodium, magnesium, calcium, potassium and chloride ions. These ions mix with perspiration and are deposited on the skin along with water and amino acids. Lipids such as oil, fats and waxes are insoluble in water (a polar substance) produced through sweating but are soluble in non-polar solvents. Water will evaporate (volatile) but the lipids will not (non volatile) leaving the fats, oils and waxes behind. Dusting powder applied to the surfaces will adhere to the lipids revealing the print. This method is good for non-absorbent surfaces and a variety of powder colors are available to provide contrast. Some powders are fluorescent and can reveal prints under a UV light.

Iodine Fuming Development Method

Paper documents which are porous and absorb sweat require other methods of exposing or developing latent prints. Iodine fuming is a method which utilizes the property of iodine to sublimate at room temperature. Iodine is non polar as are the lipids found in sweat. The general rule of solubility is “like dissolves like” therefore the iodine will dissolve in the lipids. The result is a dark brown image from the dissolved iodine. This color will rapidly fade so it is necessary to photograph the image immediately. The image can be sprayed with a solution of starch to preserve it. The iodine and starch will form a complex that is blue in color.

Silver Nitrate Development Method

Silver nitrate development of fingerprints is based on the insolubility of silver chloride. Sweat contains dissolved sodium chloride. Aqueous silver nitrate reacts with aqueous sodium chloride to produce silver chloride (insoluble solid) and aqueous sodium nitrate. This is known as a double replacement/precipitation reaction. In a test tube, this reaction would net a white precipitate that will turn from white to black when exposed to sunlight. In fingerprint development, the silver nitrate reacts with the salt and the white silver chloride solid adheres to the ridge lines of the print making the print visible. The print can be photographed and saved.

Ninhydrin Development Method

Ninhydrin (1,2,3-Indantrione monohydrate) is used to develop latent prints on porous materials. Fingerprints contain amino acids. The ninhydrin degrades amino acids into aldehydes, ammonia and carbon dioxide in a series of reactions that net a partially reduced ninhydrin molecule referred to as hydrindantin.[7] Another reaction occurs in which the ninhydrin reacts with ammonia and ninhydrin to produce a pigment known as Ruhemann’s purple. Fingerprints will appear purple or deep blue as they develop. The development is slow sometimes taking up to 48 hours at room temperature. As with many chemical reactions, the reaction can be accelerated by increasing the temperature and providing additional humidity. This can be easily undertaken using a household iron and paper towels. Once visible, the prints can be photographed. If prints are not dark enough, several methods of enhancement can be done. One method is the application of nickel nitrate solution which allows the prints to be visualized under ultraviolet light or alternate light sources.

Super Glue Fuming Method of Development

Latent prints on non-porous surfaces such as soda cans, vinyl, leather, and some types of tape can be developed using cyanoacrylate ester found in superglue. It is a relatively inexpensive method. Superglue fumes can be created in two ways: heating superglue or putting superglue on absorbent cotton treated with sodium hydroxide.[8] The esters react with the amino acids in the fingerprint and humidity in the air to produce a white precipitate that adheres to the ridges of the print. Additional treatments can be performed to enhance the print. In some cases, colored dusting powder can be applied that will stick to the chemical precipitate and make it more visible. The super glue fuming method is useful in detecting prints in cars. Cyanoacrylate sticks are available that are easily transported and used at a crime scene.

Ballistics

The weapon found at our imaginary crime scene is a Smith and Wesson 9mm semi-automatic handgun. Upon examination at the scene, there were several fingerprints taken and a search for the serial number showed that an attempt had been made to etch or scrape the number off to render it unrecognizable. This would prevent the gun from being linked back to any registered owner or point of sale. Handguns and hunting rifles have a serial number etched in the barrel when they are manufactured. When a gun is sold by a reputable dealer, the serial number is recorded linking the owner to the purchase. In attempt to conceal stolen guns, perpetrators will often use files to try to remove or obscure serial numbers so that the gun cannot be traced. If this is the case, the ballistics technician can perform a simple oxidation-reduction reaction to restore the image of the serial number. The area is treated with acid. The acid reacts with the iron in the steel barrel of the gun. The products of this reaction are iron ions and hydrogen gas which appears as bubbles in the grooves of the compressed area.

Blood Evidence

The physical evidence team has noted numerous red and reddish brown stains throughout the crime scene. The big questions to answer: (1) Is it blood? (2) Is it human or animal origin? (3) If human, who's blood? In addition to the obvious and visible stains, investigators also want to know if there may be "hidden" evidence that would indicate that the perpetrator tried to clean up the scene.

Blood is a mixture of red blood cells, white blood cells, platelets, enzymes, proteins, and minerals suspended in water. Approximately 55 percent of blood is water and 45 percent is cells. In 1901, Karl Landsteiner made an astonishing discovery and announced that blood could be typed and that all human blood was not the same as the medical world previously thought. Blood can be classified into four distinct groups according the presence or absence of antigens on the red blood cells. This classification is known as the A-B-O systems and the groupings are A, B, O, and AB. In 1937, the presence or absence of Rh factor was demonstrated as well thus adding more specificity to the typing of blood. Blood factors are determined by inheritance (genes) and this provides forensic scientists with a test to link blood stains at a crime scene with a specific individual. This was the focus of investigations until the early 1990's when DNA technology emerged as the more definitive way to link suspect and or victim to the crime scene. Blood grouping has all but been abandoned but the importance of blood at a crime scene has not diminished.

Color Tests for Blood

A preliminary color test can quickly ascertain if the stain is blood. The most common test used is the benzidine color test. Due to the cancer causing nature of benzidine, the Kastle-Meyer test is used and phenolphthalein is the indicator. The basis of the test is a chemical reaction between hemoglobin which has a peroxidase activity and hydrogen peroxide. When phenolphthalein is added to the mixture of hemoglobin and peroxide, the solution will turn a deep pink color. The hemoglobin accelerates the oxidation of the peroxide and the organic compounds in the blood. This is not a specific test for blood because some vegetables such as potatoes and horseradish turn give a pink color with Kastle-Meyer but investigators feel that at a crime scene the likelihood of errors with vegetable matter is low.

Another testing method for blood that is easily transported to the scene is the Hemastix test strip. The strip is moistened with sterile water and then placed on the stain. The pad contains diisopropylbenzene dihydroperoxide and 3,3,5-5-tetramethylbenzidine. Hemoglobin in blood removes oxygen from the peroxide and catalyzes the reaction. The color of 3,3,5-5 tetramethylbenzidine changes from no color to orange color and eventually to green. If a large amount of blood is present, the color may even progress to blue.[9]

In *A Study in Scarlet* by Arthur Conan Doyle (1887), detective Sherlock Holmes references the use of a resin from the guaiacum tree that precipitates hemoglobin. Holmes referred to it as an infallible test for blood. The resin reacts with hemoglobin and peroxide. The *heme* in the hemoglobin catalyzes the peroxide and the oxidation of alpha-guaiaconic acid to quinine. This results in the formation of a blue color indicative of blood.

Suppose our team of evidence collectors find themselves out of guaiacum tree resin or cannot find a nearby tree to extract some resin, what shall they do to determine the presence of blood in a more definitive manner? All the previous tests are presumptive but also have factors that can produce false positive results. Today's crime television shows reveal the spectacular test that can light up a room if blood is present. In reality it's cool but not as dramatic as television would like you to believe. Luminol (3-aminophtal-hydrazide) is one of the most sensitive and presumptive tests for blood. It is capable of detecting bloodstains diluted 100,000 times making it useful even if the crime scene has been cleaned or blood has been wiped away. Luminol emits light rather than producing a color change as in the previous tests discussed. The chemical is sprayed on objects or over large areas in darkness and observed for the emission of a faint blue light. The light is produced by chemiluminescence as electrons give off energy when transitioning from an excited state to a lower energy or ground state. This occurs through a series of multi-step reactions in which the ferric heme groups from hemoglobin catalyze the decomposition of peroxide and the oxidation of luminol.

A relatively new product called Bluestar is commercially available. It works similar to luminol but does not require complete darkness to see the light produced. It is to be noted that both tests are presumptive tests for blood and will not degrade stains or interfere with subsequent DNA testing.

Forensic Toxicology/Chemical Tests

Forensic toxicology units examine blood and tissues for chemical substances such as drugs or toxins. The services of a forensic toxicology lab include death investigations, human performance enhancement, doping control and forensic workplace testing. Testing for legal, medical and workplace reasons can provide information about the concentration of the drug and its identity. Conclusions can be made as to whether the level constitutes a therapeutic or harmful level or if a person is abusing a drug. This provides an aid in making inferences as to manner of death or impairment and if the substance was a contributor. Often the blood of the driver in a car crash is tested for alcohol to determine if intoxication was a factor in causing the crash. If suicide by drug overdose is suspected as a manner of death, toxicology results could reveal the identity of the drug used.

The roots of toxicology extend far back in history. In the 1800's, many murders were committed using arsenic and the murderers went unpunished. The lack of a forensic test to determine arsenic levels during autopsy was beneficial to anyone wanting to knock off a family member and collect the inheritance. In some homes for the elderly and terminally ill, it was used as a method of illegal euthanasia. Later it was discovered that arsenic would remain unchanged in tissues such as hair and nails. James Marsh, an English chemist developed the one of the first tests for arsenic in the early 1800's. The blood, urine or tissue sample was exposed to a zinc and acid solution in a ceramic bowl. If arsenic was present, the reaction would produce arsine gas and hydrogen gas. Hydrogen gas supports combustion so if ignited, the hydrogen gas burns and the arsine gas is oxidized to arsenic and water vapor. Heating of the ceramic bowl in a flame would cause the arsenic to deposit on the interior of the bowl and it would appear as a silver-black stain. The intensity of the stain could be compared to other samples to determine the approximate concentration. In the case of famed Black Widow murdered Blanche Taylor Moore of Burlington, North Carolina, the bodies of her victims were exhumed and tissues tested years later to reveal deadly levels of arsenic. This led to her conviction and subsequent life imprisonment for murder of her first husband and a boyfriend.

The precipitation of silver nitrate is not only useful for developing fingerprints as previously mentioned, but also in determining whether a victim died of thallium poisoning. Evidence suspected of containing thallium chloride mixed with silver nitrate will produce the same insoluble compound, silver chloride. If thallium sulfate is suspected as a potential poison, the evidence can be tested with barium nitrate which results in barium sulfate as the precipitate.

Drunk driving is a serious problem that law enforcement personnel battle on a daily basis. Each year thousands of people lose their lives in automobile accidents caused by drivers with blood alcohol concentrations that exceed the legal limit. Blood alcohol concentrations can be determined by the police officer at the scene using a device to measure the alcohol concentration of the breath. The first such device dubbed the "Drunkometer" was invented by Rolla Harger at Indiana University[10] The reaction of alcohol with potassium permanganate causes the reduction of the potassium permanganate and a color change. Since potassium permanganate is a deep purple color, the reaction causes the color to lighten. Higher alcohol concentrations would result in less color. Other devices have replaced this one with the most recent being the "Breathalyzer". The suspect breathes into the chamber which contains potassium dichromate, sulfuric acid and silver nitrate. The ethanol in the sample reacts with the potassium dichromate. The silver nitrate catalyzes the reaction and the acid provides hydrogen ions necessary for the reaction to proceed. The red-orange dichromate ions are converted to chromium (III) ions and a green color is produced. Photometric analysis of the chromium (III) solution determines the wavelengths present. These wavelengths are converted into an electrical signal that is displayed on the screen[11]. For legal purposes, a blood alcohol concentration that exceeds the legal limit is verified by a blood alcohol analysis performed by the toxicology lab. This is usually done by a spectroscopic method.

Fuel cells are also being adapted to test blood alcohol concentration. Fuel cells are devices that contain two platinum electrodes separated by an electrolyte solution of sulfuric acid. The casing of the cell is porous and allows air to flow in and out of the container. When a person breathes into the cell, the alcohol in the breath is oxidized to produce acetic acid, hydrogen ions and electrons. The free electrons travel to the cathode via an electrical meter back to the electrolyte. The blood alcohol concentration is measured by recording the amount of current produced. Higher alcohol concentrations result in more current. [12]

Teaching Strategies

Forensic science lends itself to many strategies for teaching the concepts and allowing students to interact with the content. The desire for this unit is to engage students in meaningful learning that fosters further interest and curiosity. Through collaboration and critical thinking, students will develop knowledge and skills that are transferable to a variety of tasks and situations. Literacy and writing will be incorporated into various activities giving students opportunities to share thoughts and opinions as well as information learned throughout the unit. Concept maps, labs, writing and independent reading will provide opportunities for students to link concepts to prior knowledge and experience, current experiences and future learning.

Anticipation Sets/Warm-Up Exercises

Each day, students will be given a five minute warm up activity to complete in their notebooks. For these, I use scrambled forensic vocabulary terms, forensic trivia questions, mini-case scenarios, and picture comparisons. These activities allow students to learn new terms, review, and practice their crime tech skills.

Mini-lectures

Powerpoint© presentations will be used to disseminate background information. These will be posted on the class website for students to pre-read before class. Essential questions will be provided as a guide for learning.

Mock Crime Scene (Performance Assessment)

A mock crime scene or crime scene scenario will frame the learning experiences for the students. Students will assume the role of crime scene investigators and emulate the processes of securing the scene, collecting, bagging and tagging evidence and finally testing it. Throughout this process, students will follow the correct procedures for maintaining integrity of evidence and the chain of custody. A number of vocabulary terms are associated with crime scene processing and students will be introduced to them prior to beginning work in the crime scene area. A vast library of resources for setting up a mock crime scene can be found by searching the Internet or talking with a local police officer. In my case, one of our school security associates is a retired law enforcement officer and has offered to help me with setting up the scene.

Storyboard

Students will construct a storyboard to outline the suspects, victims and links to the crime. This board will provide a visual map of the crime and the information that the students obtain from their investigation. Upon completion of all testing, students will use the storyboard to arrive at conclusions about the crime.

Notebook/Journal

Students will interview witnesses and record findings in a field notebook. This will include sketches of the scene, notes about the scene and measurements. A list of evidence and evidence numbers will be generated. Photographs of the scene will be included. This information will be used in a formal report detailing the crime scene and evidence collected.

Evidence testing

Lab exercises will involve the students in learning testing procedures, limitations and interpretation of results. Students will test the evidence collected at the mock crime scene and record results in their notebook. Each method of testing along with the background of the sample will be presented prior to lab. Pre-lab and post-lab analysis questions will be provided. The school system science curriculum department provided a first set of the lab series “The Mystery of Lyle and Louise” kits designed by Crosscutting Concepts which contain a class set of materials for each type of evidence tested.

Video Analysis

Television and movies provide more than ample opportunities to look at how crime scenes are secured, processed, and cleared. Because true crime stories and shows such as CSI often differ in how this process is portrayed, every attempt will be made to address misconceptions. I give students a template to use when watching a show or reviewing a case. Students record information pertinent to the case such as suspects, victim, modis operandi, evidence, and outcome. NOVA television’s “JFK: The Smoking Gun” is one way to tie in historical events with forensic science. The documentary looks at modern ballistics and bullet identification methods and offers a possible solution of the 50 year question: Did Oswald act alone?

Case Studies

Several notable murders have occurred in North Carolina. One of these cases is the Jeffrey MacDonald case from the 1970’s which still makes the news occasionally as Dr. MacDonald is still trying to prove his innocence. A website is devoted to this case and scanned copies of evidence can be viewed and discussed. The story was also made into a movie titled “Fatal Vision”. After viewing the movie, students will review the actual evidence and write a comparison of the movie to the actual trial transcript. This case also provides an opportunity to look at the changes made in evidence collection and processing over the past 40 years. Students can write a short paper defending their views of whether MacDonald is guilty or not guilty and support with facts from the transcript review.

There are several other cases that can provide additional interest: Blanch Taylor Moore of Burlington, North Carolina (aka the black widow murderer), Lizzie Borden, The Rock Canyon murders and the O.J. Simpson case. The Simpson case provides a look at how the crime scene processing and evidence handling can make or break a case. There are several documentaries that discuss the case. The Madrid bomber case provides an interesting look at fingerprints and their use as a method of identification. It also challenges the use of fingerprints as positive identification.

Current events/News article review

Newspaper articles (online and print) as well as journals such as *Forensic Teacher* provide current information from around the world. Review and sharing of current events and methods will provide students will the experience of evaluating information for accuracy and fact versus opinion. Scholarly and peer reviewed papers will provide an insight into research methods that lead to the admission of certain tests and procedures in court as definitive evidence.

Mock Trial (role play, simulation)

A mock trial will bring all aspects of the crime scene investigation together. Students will use the evidence they have collected and results obtained to present their case before the court. A jury will be selected and the roles of prosecutor, defense attorney,a judge and expert witnesses for both sides will be assigned. Students will present arguments orally and in writing.

Story Telling/Writing

Common core standards require integration of reading, literacy skills, and writing into the areas of science. To address this, students will compose short stories in which they develop characters, plots, and themes based on solving a crime. Students will include information relating to type of crime, suspects, witnesses, motive, and outcome. This will serve as an assessment of content objectives as students will demonstrate their ability to link concepts together in a coherent written narrative.

Lessons and Activities

Lesson 1: Processing a crime scene

Essential vocabulary: forensic science,perimeter, physical evidence, chain of custody, circumstantial evidence, class evidence, crime-scene investigation, crime-scene reconstruction, direct evidence, first responder, individual evidence, primary crime scene, secondary crime scene and trace evidence.[13]

Objectives: (1) Students will explain how to approach the initial investigation of a crime scene. (2) Students will describe how to identify primary and secondary crime scenes and evidence. (3) Students will understand how to identify, preserve, and document evidence. (4) Students will construct a diagram and reconstruct a crime scene.[14]

Crime scene teams will be created and students will work with their team to brainstorm ideas and create a list of duties to be performed when processing a crime scene. After reading or viewing a presentation about securing and processing a crime scene, the students will revise their list and elect group members to perform the duties. For some duties such as gathering physical evidence, more than one person can be assigned. For others, only one person may be needed. The group will decide and each individual will be accountable to the whole group. Positions that should be considered are lead investigator who coordinates the activities, photographer or videographer to document the scene, interviewer to get witness statements, evidence collectors, and artists to sketch the scene and record measurements.

Activity1:

As preparation for processing the mock crime scene, students will practice their skills using a series of photos of a crime scene or a video tape segment of a crime scene. Students will document the scene and create numbered list of evidence with appropriate labels in their notebooks. There are a number of evidence photos from the Jeffery MacDonald murder case that are available online. A preliminary sketch will also be completed in the notebook. A computer generated final sketch will be done to scale showing placement of objects, evidence markers, body, and other references as well as measurements. Sketches will show views from all angles. Several students can divide the task of sketching with one assigned to complete the overhead view and others to complete the side views. This activity will address collaborative work, sharing of information in a systematic way and using technology to create the final sketch.

Lesson 2: Collecting the Evidence: Fingerprints and Fingerprinting Processes

Essential Vocabulary: loop, whorl, arch, minutiae, ten print card, Henry card, AFIS, IAFIS, epidermis, dermis, core, short ridge, ridge ending, delta, hook, crossover, bridge, bifurcation (fork), island (dot), enclosure, eye, latent prints, plastic prints, patent prints, Ulnar loop, Radial loop[15]

Objectives: (1) Students will understand how to identify, preserve, and document evidence. (2) Students will understand the mechanism each development method uses to develop a latent fingerprint: Iodine fuming, Cyanoacrylate (superglue)Fuming, Ninhydrin, Powders, and Silver Nitrate.[16]

Proper procures and protocols for evidence collection help to ensure integrity of the evidence and its admissibility in court. Students will view and take notes on a presentation about collection procedures including appropriate containers, chain of custody and documentation. Students will research evidence collections from the O.J. Simpson case and the Jeffrey MacDonald case and note the documentation done by actual crime scene technicians as well as the labeling of evidence.

There are different methods for collecting fingerprint evidence. Since latent prints are the most common ones found at a crime scene, these invisible prints must be revealed using powder dusting and tape lifting methods. Fingerprints can also be obtained from persons using ink and print cards. Prints are examined for characteristics such as pattern and minutiae. Prints of suspects or prints from the scene can be compared to determine common characteristics. Police investigators enter photographs of prints, prints on cards, or prints transferred from lifting tape into a national database known as AFIS (automated fingerprint identification system) where the computer runs comparisons to prints in the database and reveals any “hits”. Hits must be examined by a trained fingerprint analysis to make the final call.

Activity 2a: Fingerprint collection

As preparation and practice for processing the mock crime scene, students will complete a lab in which they collect their prints using ten-print cards and then classify them according to the Henry classification scheme. The prints will also be examined to determine pattern and prominent minutiae. Students will compile the data from the class and determine the prevalence of a particular classification ratio.

Activity 2b: Fingerprint lifting

Using carbon powder and lifting tape, students will collect fingerprints from glass slides previously prepared by students as unknown prints. Students will compare the lifted prints to known student prints and match prints of the unknown and the student who left the prints.

Lesson 3: The Mock Crime Scene

Students will be given the background information about the mock crime scene. Using their class kits, students will process the scene as crime technicians and engage in documenting the scene. Students will assume the roles that they determined in the first lesson of the unit. Once the scene is documented through photographs, sketches, and interviews with witnesses, students will collect evidence using collection methods learned in lessons 1 and 2.

Activity 3: Storyboard

Using large sheets of paper or a white board, students will begin constructing a storyboard to show information gathered about the crime and the scene from the evidence and interviews. As their work progresses, the story board will be updated with information. Students will use their information to determine the identity of the perpetrator.

Activity 4: Fingerprint collection from the crime scene/ processing and analysis of prints recovered

After reviewing the lecture on fingerprint characteristics and fingerprint development, students will analyze the fingerprints collected from the scene. Students will employ development methods appropriate for the type of material (porous or non-porous) that contains the print. When development is complete, students will analyze and document patterns and minutiae for each print. They will compare the unknown prints to a set of known prints as well as their own prints to determine common characteristics and matching criteria. Methods of development will be compared and students will draw conclusions as to the advantages and disadvantages of each development method.

Activity 5: Madrid Bomber case

This case presents an interesting argument regarding the individuality of fingerprints and the how fingerprints are matched. Students will research the case and prepare a ½ to 1 page written argumentative essay supporting their view on the use of fingerprints as primary evidence in a criminal case.

Activity 6: Blood or not??

In this activity, students will test evidence collected at the mock scene to determine if it is blood. Phenolphthalein and Hemastix tests will be performed. Luminol will be prepared and used to visualize trace or dilute stains. Results will be tested and compared with a set of known samples to determine if matches are possible. Students will write a comparison of the 3 methods of testing including the advantages and disadvantages of each.

Lesson 4: Forensic Toxicology

Activity 7: Independent reading/online discussion board

Students will read "*The Poisoner's Handbook*" by Deborah Blum. This is a non-fiction text describing the development of forensic toxicology in the early 1930's in New York. For each chapter, students will participate in an online discussion using the website www.edmodo.com. Classroom discussion will be facilitated. As a final product, students will choose one of the following to develop: film trailer video, theme song video, movie poster, movie prop or artifact. The products allow for students to use their creativity, interests, talents and skills in the areas of photography, video production and editing, arts and crafts to promote the book.

Activity 8: Simulated blood alcohol testing

For this activity, students will perform a simulated blood alcohol test using prepared concentrations of alcohol solution and potassium permanganate. Students will observe the degree of color change and rank the samples from least to greatest. After completion, students will write a short argument for the admissibility of this test in court using their results as support for their stance.

Summary

This unit represents a cameo look at some of the historical and modern tests performed by forensic technicians from a chemistry perspective. It concentrates mainly on lessons and activities that can be done in a high school classroom. Many of the activities and labs utilize materials that are using in chemistry and biology curricula and may be already available at a school.

Notes

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[1] Saferstein, R. Introduction to Criminalistics: An Introduction to Forensic Science. 5
[2] Filippo B., S.Lewis, A.Berti,G. Miskelly,& G. Laga. "Forensic application of the luminol reaction as a presumptive test for latent blood detection." *Science Direct.*1
[3] Saferstein, R. Introduction to Criminalistics: An Introduction to Forensic Science. 5
[4] ibid.
[5]Croscutting Concepts. Web
[6] Saferstein, R. Introduction to Criminalistics: An Introduction to Forensic Science.
[7] Senese, Fred. *Simple Test for the Presence of Amino Acids.*
[8] Saferstein, R. Introduction to Criminalistics: An Introduction to Forensic Science. 405
[9] Center, National Forensic Science Technology. *Hemastix Presumptive Test for Blood*.1
[10] Newton, David. *Forensic Chemistry*. 71
[11] ibid.
[12] ibid. 77
[13] Schools, Charlotte Mecklenburg. "Secondary Science Wiki." *Forensics Curriculum Document*
[14]ibid.
[15] ibid.
[16]ibid.

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Center, National Forensic Science Technology. *Hemastix Presumptive Test for Blood.* http://www.nfstc.org/pdi/lab_manual/Linked%20Documents/Protocols/pdi_lab_pro_2.17.pdf (accessed October 21, 2013).The website provides information about the hemastix test for blood as well as the chemical composition of the hemastix reagent.

Crosscutting Concepts. January 1, 2012. www.crosscuttingconcepts.com (accessed September 16, 2013).Website provides teacher resource materials to accompany the company's forensic science kits for "The Mystery of Lyle and Louise."

Filippo Barni, Simon W. Lewis, Andera Berti, Gordon M. Miskelly, Giampietro Laga. "Forensic application of the luminol reaction as a presumptive test for latent blood detection." *Science Direct.* January 9, 2007. www.sciencedirect.com (accessed October 21, 2013).The article explaines the chemical reactions involved in using luminol as a test for blood.

Johll, Matthew E. *Investigating Chemisty: A Forensic Science Perspective, 2nd edition.* New York: W.H.Freeman, 2009.Textbook offering a wide range of criminal science topics, end of chapter questions and case studies.

Medicine, National Library of. "Visible Proofs: Forensic Views of the Body." https://www.nlm.nih.gov/visibleproofs/galleries/technologies/marsh_image_2.html (accessed November 12, 2013).

National Institute of Justice. (accessed November http://www.nij.gov/topics/forensics/evidence/toxicology/welcome.htm, 2013).

Newton, David. *Forensic Chemistry.* New York: Facts On File (Infobase), 2007.

Saferstein, Richard. *Criminalistics: An Introduction to Forensic Science.* Boston: Prentice Hall, 2011. This is a textbook used by colleges and universities in the criminal justice program. It introduces the student to basic evidence collection, processing of the crime scene and in-depth explanations of how various types of evidence is used in a case.

Schools, Charlotte Mecklenburg. "Secondary Science Wiki." *Forensics Curriculum Document.* August 2013. www.secondaryscience.cmswiki.wikispaces.net (accessed November 14, 2013). This is district curriculum website that contains core essential standards documents as well as resources for teaching science.

Senese, Fred. *Simple Test for the Presence of Amino Acids.* February 15, 2010. http://antoine.frostburg.edu/chem/senese/101/organic/faq/amino-acid-test.shtml (accessed October 21, 2013).The website provides an explanation of fingerprinting techniques and tests to detect amino acids in sweat left in a fingerpring.

Webster, Stewart. "Journal of Chemical Education." October 1947. http://pubs.acs.org/doi/pdf/10.1021/ed024p487 (accessed November 12, 2013).

Appendix I

District Standards

- HS-FS-F-1 Understand the characteristics of fingerprints that allow them be systematically classified.
- HS-FS-F-1a Students will be able to describe the physiology of fingerprints.
- HS-FS-F-1b Students will be able to describe, compare, and identify the different types of fingerprints.
- HS-FS-F-1c Students will be able to describe, compare, and perform fingerprint detection techniques.

This unit addresses each of the above standards through activities where students create ten print cards, analyze the prints for patterns and minutae. In the labs, students will compare their fingerprint characteristics (both class and individual) to those of their classmates. Using sets of known and unknown fingerprints students will match the prints based on the classification system of Henry as well as patterns.

- HS-FS-BS-1 Students will describe how to identify blood and blood types.
- Describe how to screen for the presence of human blood.

The above standards are addressed through an exploration of human blood types and genetics of blood type inheritance. Students will use commercially available simulated blood for typing as well as testing for blood as evidence.

- HS-FS-T-1a Students will understand that drugs, toxins and poisons may not be apparent at a crime scene and will learn the types of indicators present.
- HS-FS-T-2a Students will be able to describe the difference between drugs, toxins and poisons.
- HS-FS-T-3a Students will understand the process of isolating and identifying drugs, toxins and poisons in human tissue.
- HS-FS-T-3b Students will understand and appreciate the difficulties in isolating drugs, toxins and poisons in human tissue.
- HS-FS-T-3c Students will be able to compare and contrast chromatography, UV/VIS/IR spectrophotometry and mass spectrophotometry.

The previous standards are addressed in the unit through a presentation on toxicology and methods of toxicology testing. Students will explore the history of toxicology through individual reading articles and performance testing.

Appendix II
Additional Teacher and Student Resources

Reading List for Students
The Poisoner's Handbook by Deborah Blum

Websites for teachers and students
www.theforensicteacher.com (free online journal)
www.forensicmag.com
www.sciencespot.com
www.fbi.gov
www.trutv.com
www.wilburworldofscience.com
www.nclark.com

Videos and Video clips for teachers and students
www.youtube.com (Videos for fingerprint development techniques)
- http://www.youtube.com/watch?v=EZ4dIvspLqw
- http://www.youtube.com/watch?v=XgqwMeWlzgI
- http://www.youtube.com/watch?v=BZNXFbG-ux4
- http://www.youtube.com/watch?v=XLvZkx7HEEA
- http://www.youtube.com/watch?v=fF_v-MymoOk

http://video.pbs.org/video/2223977258/ (fingerprint analysis)

Commercially Available Forensic Kits

Crosscutting concepts *Lyle and Louise* forensic lab curriculum available from Fisher Scientific and Sergeant-Welch
There are 13 modules available as individual kits with resources for 30 students. Kits that can be used for this unit include fingerprinting, blood detection and drug toxicology.