

Forensic Science in High School Chemistry

Raymond Zanetti
Schenley High

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Overview

Forensic Science in High School Chemistry is a unit of study for students that are taking their first introductory level course in chemistry during the tenth grade. It is intended to help students become better observers by applying the use of careful inspection, and paying close attention to details by use of their senses of touch, sight, smell, and sound.

This curriculum unit is designed to help high school students understand concepts learned in chemistry class by having them examine the evidence left behind at a hypothetical crime scene. It presents the collection of evidence that is left behind at a crime scene, and then allows the student to analyze the clues by use of a variety of tests as a means to identifying a probable suspect. The student will inspect the clues to determine if the crime was most likely committed by one of several possible suspects. By examining the results of different forensic tests and comparing these observations with the evidence collected the student will rule out those suspects that most likely did not commit the crime. The tests will involve qualitative observations based on both physical and chemical properties of the body of evidence examined to establish the possible guilt or innocence of these suspects. The evidence can be altered to allow students to come to whatever conclusion is desired by the teacher.

Rationale

I have always started the school year by having students do a lab exercise where they make observations of a candle. The reason that I start them with this exercise is to improve their skill at making observations. Students are instructed that the purpose of their doing this lab is to make both qualitative and quantitative observations of an ordinary candle. They are given a candle, matches, a test tube and test tube rack, a small strip of magnesium ribbon, and two milliliters of hydrochloric acid. I control the distribution of the acid and watch them closely as they place the magnesium metal into the acid in the test tube to see what happens. I do this exercise after teaching a lesson and doing a demonstration, where they are shown how to distinguish between physical properties and the chemical properties of a substance, and also how physical change differs from chemical change. I tell them before the lab that they must make as many careful observations as possible about the physical characteristics of the candle before they set the wick on fire. I mention to them that color, volume, mass, smell, density, and texture, are all physical properties. Chemical properties depend on how a substance behaves chemically, and new substances are always produced when a chemical change has taken place. I discuss the active chemical nature of metals like magnesium, and how when magnesium is placed into a strong acid like hydrochloric acid that hydrogen gas is a product.

They are to make a list of all observations made while doing the lab in their lab report. I show them how to write up a lab report by going over a general format that they copy down at the front of their notebook. I supply them with a variety of measuring instruments to make their observations, such as: a metric ruler, an electronic balance, and a large graduated cylinder (for water displacement to determine the volume of the candle). I also carefully demonstrate how these devices are to be properly used. I recommend that they try to submerge the candle in water without getting the wick wet to determine the volume of the candle, and then I demonstrate how this is done. I also show them how to tare an electronic lab balance by pushing the tare button, and explain to them that this function is only used when they weigh out chemicals onto a small sheet of paper, and then set the weight back to zero.

The candle lab is the first part of a two-part lab with the candle part taking place first, followed by the reaction of the metal zinc reacting with hydrochloric acid. I tell students that they must watch closely what happens as the metal is put into the acid. They are usually shocked when I tell them to feel the test tube to sense the heat that is given off as the metal completely dissolves in the acid. Students get to use their sense of hearing during this chemical reaction because it makes a fizzing sound and creates bubbles of hydrogen gas as one of the products. By wafting

their hand across the top of the test tube the student experiences a faint smell that is also produced.

The lab doesn't take very long, and I explain to them that the reason for doing it is to broaden their ability to describe the physical characteristics of all materials before, during, and after they run the tests. I then ask them to summarize in a few sentences what they think has happened in both parts of the exercise by looking over their observations. It is a fairly sterile exercise that generates a small amount of thrill, but they tolerate the lack of excitement because it allows them to do a hands-on activity in the lab for the first time in the new school year. I've never really been very crazy about this exercise, but I use it because it's safe and fail-proof for a starter lab.

I would like to replace the candle and acid lab with this Forensic Science in High School Chemistry Unit because I feel that it will be a bit more exciting for the students than the lab that I presently use, and it can be completed in approximately the same amount of time as the candle lab, which is three thirty-nine minute periods. The students will use similar observation skills to examine the clues from the crime scene. They will observe and interpret what they see, smell, touch, and hear, while examining the evidence. They will attempt to make sense out of their observations, and then come to their own conclusions about who they think did not do the crime. They will then write a report that summarizes what they have learned from doing the investigation.

This curriculum unit will use forensics to enhance the existing curriculum by allowing students to use techniques employed in an old-fashioned forensic lab. Forensic science is a subject that uses hands-on laboratory techniques and inquiry-based reasoning to arrive at who is responsible for a criminal offense. It blends scientific theory with technology to allow police and crime scene investigators to solve a crime. This curriculum will supplement the current curriculum by adding hands-on activities with laboratory equipment like the microscope, which is not normally used in the chemistry lab. It is unfortunate that I do not have the sort of modern equipment used in present forensic labs, but I think this lab will be more fun for the students than doing the candle lab.

Objective

The intended outcome of this curriculum unit is that students will attain competency in identifying and applying key concepts of content that are stated in the Pittsburgh Public Schools Student Syllabus for Chemistry. They will become skillful at making observations, and will take measurements of length, volume, and mass. They will carry out laboratory activities and submit a laboratory report. From making careful observations they will then make inferences and a prediction

based on the data collected. By doing this unit the student will see that there is a relationship between science, technology, and society. Concepts and theories learned in the chemistry classroom will be applied to a hypothetical real life situation where students can identify the importance of learning about scientific measurement and the application of scientific method to solve problems. They will come away from this experience with a new appreciation of how chemistry can be a useful tool to help society identify the evidence left behind by those who are agents of deviant behavior.

Strategies

This unit contains several forensic tests that will be conducted by the students. Before each test there is an explanation concerning the reason for doing the test, and a detailed description of the evidence collected at the crime scene. The student is presented with samples of what evidence was found when the company detective arrived at the start of the investigation. The crime takes place in the manager's office of a quality control testing lab at a chemical plant that manufactures the ester needed for a popular selling perfume. The chemical technique needed to make this perfume is extremely exotic, and the right mix of ingredients is considered to be statistically impossible for any competitor to duplicate. The secret recipe is stored in a wall safe behind a painting in the lab manager's office. It is the duty of the lab manager to check that the document containing the recipe is in the safe at the end of each workday. It has been determined that someone stole the secret recipe from this safe today. The office safe was opened by a small explosive device that has blown the safe door from its hinges, and a small piece of white fabric was found hanging from a hinge bracket on the wall safe. Only three people other than the manager were working in the lab today. One of these people is responsible for the missing recipe. As a sort of practical joke, the thief placed a post-it note in the safe, and on the note was written the word "Thanks." After close inspection of the evidence collected the student will decide which of the suspects has most likely stolen the document from the safe. All of the suspects are women, and all three are being held in the security office until the innocent parties are determined and released, and then the police will be called and charges filed.

The evidence given to each student will come in a zip-lock bag. Each piece of evidence will be tested and will have a full description of what it is and under what conditions it was discovered. There is a detailed listing of the laboratory equipment needed to do each test. Samples supplied for comparisons are from two sources; one taken from each suspect, and the evidence collected by the company detective at the crime site. A full explanation of each test will be supplied to the student before they go into the lab to run the various tests. After examining the evidence the students will screen out the suspects that are the innocent parties, and

then identify the most likely candidate as the one who committed the crime, based upon the evidence. They will do this by keeping a data table with four columns, each column having the name of the test at the top of the column. Intersecting these columns will be three rows, each row having the name of one of the possible suspects being investigated. After doing a specific test run, the students will then record the result at the intersecting row and column for each of the suspects. When all the tests are completed the suspect that best matches the findings will be the person considered most likely as being the criminal.

Classroom Activities

Test One (The Lip Print Examination)

Information provided to students concerning evidence exhibit number one:

The company detective has found a paper cup with a lipstick print imprinted on it in the trash can below the safe. The waste cans are emptied each night, and this paper cup was not put in the trash bin by Mr. Phelps, the lab manager. It is possible that the paper cup was left behind by the thief. Each of the suspects commonly buys beverages from a vending machine in the lab, which dispenses various liquids in the same type of paper cup that was found in the trash can. Lip prints have been taken from the suspects to use for comparisons with the evidence lip print found on the paper cup. Lip prints are not as reliable as finger prints to identify a criminal, but they can be used to a limited degree when identifying a potential criminal.

Experimental Procedure: A chart illustrating the five major categories of lip print patterns will be available for inspection by the student (see Appendix A). In addition to the chart will be lip prints taken of the three suspects being held in the security office. A ten power magnifying glass will be provided so that the lip lines in the evidence lip print can be compared to the examples provided on the lip print chart. This test will require students to have good observational skills as they look at the physical characteristics of the specimens being examined. They will inspect the evidence lip print for the types of line patterns that are present in the chart print, and then compare this with the three suspects' samples. The five major categories of lip prints are: short vertical lines; long vertical lines; lines that form diamond patterns; rectangular lines that crisscross; and branching lines like those in a plant root.

Test Two (The fiber test)

Information provided to student concerning evidence exhibit number two:

When the blown safe was examined there was a tiny patch of torn cloth found on the shattered door latch of the safe. It is a white fiber strand. Each of the suspects in the security office is dressed in clothing that contains white fibers. The evidence team thinks that the fiber was accidentally torn from the sleeve of the thief's clothing as the document was being removed from the safe. Samples of white fibers have been collected by the company detective from each suspect being held. Fibers from clothing found at crime scenes are often studied by forensic investigators. These fibers often contain evidence in the form of body fluids like blood and sperm. Fibers are either natural or synthetic. Natural fibers include animal fibers like silk, cashmere, wool and hides, or plant fibers like cotton. Fibers are frequently examined microscopically to see specific physical characteristics like surface texture and color. Chemical behavior can also be tested. The rate of speed that a fiber burns is a chemical property. Both physical and chemical properties of the products of combustion of a fiber can be used to identify the type of material that it is made from.

Experimental Procedure:

Part 1

The students will use a microscope to examine a strand of the evidence fiber that was found snagged on the door latch of the safe. Using thumb forceps to handle the fiber they will put the strand onto a microscope slide and then add a drop of water to the fiber before covering it with a cover slip. The fiber will be examined under a 75x magnifying lens. The microscope will have a top lighted stage, but a bottom mirrored stage can also be used if desired. Students will then repeat this process to examine samples taken from the clothing of the suspects. This test will require students to use their observational skills to look at the physical properties of the sample strands of the suspects, and then compare these features with the evidence strand. The students will be told before doing the examination that there is a difference in the way that synthetic fibers look when compared to most natural fibers under a microscope. They will be told that the surface of a synthetic strand is smooth like the fibers produced by a silk worm, but that most natural fibers appear to have rough surfaces when under magnification. Students should also look for external features like tightly versus loosely braided fibers, and orderly versus disorganized strands.

Part 2

Because it is sometimes difficult to visually distinguish between the fibers of different synthetic materials, students will do an additional test where they burn sample fibers from the suspects to see which one burns in the most similar manner as a strand of fiber from the evidence material collected at the scene of the crime. The student will use thumb forceps to hold onto the fibers, and then ignite the different fibers using a match. The fiber should not be allowed to burn completely, and the remaining portion should be examined under magnification.

They will be informed that synthetics tend to melt upon heating and that when fibers burn they will often produce a different colored product. The product of the evidence burn test will be examined under a 10x and 20 x stereoscopic microscope, and then compared with the test burn products of the suspect samples to identify the closest match.

The following facts about burned fabrics should be shared with the students at the start of the test: polyester fiber when burned produces a black bead of melted plastic residue at the tip of the strand; natural fibers do not yield a beaded end upon burning, but produce an ash residue.

Test Three (The spot of blood test)

Information for the student concerning evidence exhibit number three:

The piece of cloth that was found on the jagged safe door latch was spotted with two small dots of reddish-brown liquid that appeared to be dried blood. Each of the suspects being held in the security office has volunteered to supply a small sample of their blood upon threat of job termination if they refused to cooperate with the investigation. Blood analysis is used at many crime scenes when blood is present on any surface. The human red blood cells carry antigens on their surface that will cause these cells to clump together when treated with matching antibody solutions. This form of blood typing is referred to as Rhesus factor (Rf), and can be used to identify ABO, and AB blood groups.

Experimental Procedure:

Part 1

Students will examine the spots on the evidence cloth to test for the presence of blood. They will apply a tiny drop of hydrogen peroxide to one of the spots to see if it reacts to give off gas bubbles, testing positive for blood. If the test indicates that the spot is blood, they will then go on to the part two follow-up test.

Part 2

Having identified the presence of blood on the evidence cloth the student will do a follow-up test for blood type by using a blood-type test kit for simulated human blood. Using various testing solutions, they will determine if the blood on the evidence collected is Type O, A, B, or AB. Students will then do the same test on the blood samples collected from the suspects to exclude those that do not have the same blood type as being the thief. Blood testing kits are to be prepared by the teacher prior to the day of the lab. There will be no human blood used while doing this lab. The kit will use substitute test solutions that simulate the results of using real blood, but without the associated hazards of real blood.

The student will prepare the evidence blood stain by adding 3 ml of distilled water into a 50 ml beaker, and then soaking the stained cloth in the water for two minutes to extract the dried material and make a solution for testing. Using a transfer pipette they will then add four small drops of the simulated extracted blood solution onto a glass slide. The droplets should be spaced apart by a distance of 1.5 cm. To each of the test droplets the student will add a similar sized droplet of simulated blood typing antiserum solution. Tiny dropper bottles are used for storing and distributing the simulated antiserums. Each of the resulting test droplet mixtures will then be stirred by the student by means of a toothpick. The students will use four different toothpicks for stirring, or they can thoroughly wash a single toothpick with distilled water between stirrings to prevent false positive readings from occurring. A full description of the chemical make up of the antiserum solutions can be found in Appendix B of this unit.

Test Four (The paper chromatography test)

Information for the student concerning evidence exhibit number four:

The post-it note left behind by the thief had the word “Thanks” written in black ink. The detective has gone through the purses of the suspects being held in the security office and has found that each woman is carrying a black ink pen. The pens that were collected are in the zip lock bag supplied to the student. Most inks are mixtures of different molecules that have a different color as a physical characteristic of their chemical structure. Mixtures of molecules can be separated by the use of a technique called paper chromatography, where fibers in a porous material like filter paper slow down the movement of different sized molecules that have different colors. This process will be used to compare the ink from each of the suspects’ pens to the evidence collected.

Experimental Procedure:

The student will take the pens supplied by the suspects and use them to place a 1mm dot of ink onto a separate strip of porous filter paper. The black spot mark will be placed exactly 2 cm of distance from the cut end of each strip. Each strip will be 3 cm in width and 8 cm in length. At the side of each strip of filter paper opposite from the ink spot, the students will insert a toothpick through the strip exactly 1 cm from the cut papers end. The same procedure will apply to the post-it note, with the exception that the post-it note will be covered with a strip of porous filter paper that is touching up against the spot to allow migration from the post-it note into and upon the filter paper. Paper clips can be used to hold the filter paper in close contact with the post-it paper. All four strips will then be suspended over a Styrofoam cup that contains 1cm of water. The students will position the

four strips by using the toothpicks as a bridge across the top of the Styrofoam cup edge so that 0.5 cm of the filter paper is submerged in the water. The end of the filter paper strips upon which the ink spots are marked will allow water to move upward through the filter papers, and then past the ink spots as it continues up towards the toothpicks. This method of separating a mixture of colors from an ink spot is called paper chromatography, and the students will see the different colors appear as a spectrum on the filter paper spreading upward above the ink spots. By comparing the patterns of the three suspects ink pen spectrums with the pattern of the post-it note spectrum, the process of identifying the pen that wrote the thank you note will then be possible.

Test 5 (The pH Test)

Information for the student concerning evidence exhibit number five:

When the company detective discovered the paper cup in the trash can he noticed that the cup still contained some liquid that was left behind and not consumed. The vending machine that this liquid came from has three different beverage selections. Being very smart, the company detective requested the personal files of each of the employees being held, and he has checked the responses made on their job application forms that questioned their favorite beverage. Each of the suspects responded to the question by picking a different favorite beverage. Each of the beverages dispensed by the vending machine has a different pH value range. The pH of the beverage in the paper cup can be tested using a specially treated paper called “pH litmus paper”. This paper will change color when placed into the evidence liquid. The color of the pH paper is compared with a color test scale found on the pH paper container box that indicates the pH value of that liquid. By measuring the pH value of the evidence in the paper cup the student is testing how acidic or basic the beverage is in the cup, with acids having a pH of less than seven, and bases having a pH of more than seven on the scale.

Experimental Procedure:

Liquid from the paper cup found by the company detective has been placed into a tiny vial that is in the zip lock bag of each student. Samples of the vending machine beverages are also in the zip lock bag. The students will test each of the liquids using a new piece of pH paper, and then compare the pH values to determine which beverage has the closest pH value to the liquid found in the paper cup. The beverages that are being tested are: coffee/tea, with a pH range of between 5.0-5.8; dark apple cider, with a range of between 2.9-3.3; and dark chocolate milk, with a range of 6.3-8.5. There is a qualitative difference in the color of these three beverages, but the pH value will help to quantitatively verify that the evidence collected is definitely one of the three possible beverages.

Profiles of the Suspects

Suspect Number One (Aneedta Break)

Aneedta is a lab technician who has been with the company for twenty years. She is the mother of two teenage boys, and has always been a good employee that rarely misses work. The older of her boys is an explosives expert in the US Army. Lately she applied for a transfer to another section of the plant for reasons that she will not divulge. She tries to dress casually, but uses far too much make-up on her face. Today she wore a plain white cotton blouse to work. While working in the lab she often wears a white cotton lab coat over her clothing. Her blood type is O positive. The pen that she had in her purse was a Skilcraft ink pen that writes in black ink. The beverage choice that she selected on her job application form was tea. She claims that she never went into Mr. Phelp's office today.

Suspect Number Two (Sarah Sentless)

Sarah is a quality control engineer who just recently won a million dollars by being the final survivor on the popular television reality show called "Survivor". She is very competitive and is responsible for insuring that the perfume is meeting product specifications before shipping. She is fairly new to the company and has only been on the job for two months. She is a vegetarian and is very conscientious about her diet. She prefers to drink water and fruit juices, and tends to use only natural make-ups in a sparing manner. The white cashmere sweater that she wore today appears to have a light black stain on the left elbow. Her blood type is also O positive. Her pen is a black felt tipped Sharpie permanent marker. She was in and out of Mr. Phelp's office all day and she admits that it is normal for her to do this because of the requirements of the job. She is the one who found the safe door opened, and then reported it to the security office. She claims that she wants to continue working even though she won all the money on the show, and that she likes her new job.

Suspect Number Three (Gertrude Guiltridden)

Gertrude is a secretary that has worked for the company for thirty-four years. She is close to retirement and claims that she is looking forward to taking a trip onboard the new Queen Mary II after she retires. Everybody around the plant calls her "mom" because she is well liked and tries to be friendly to the point of appearing motherly. She is unmarried and likes to take gambling junkets to Las Vegas. Her blood type is A. Today she dressed in a white polyester skirt and blouse set that noticeably shines when she stands in direct sunlight. Her desk is on the other side of the lab away from Mr. Phelp's office. Coffee is her favorite drink and she drinks it constantly throughout the day. She has had several face lifts and

tends to wear lots of lip stick. Her pen is a black Pilot Precise V extra fine rolling ball.

Work Cited

Dead Men Do Tell Tales: Adventures in Science and Technology.

<<http://collections.ic.gc.ca/science/english/bio/projects/forensic2.html>

This website contains a description of how blood typing works. It explains the nature of antigens and antibodies, and has helpful tables and illustrations that will help the student understand blood analysis.

Forensic Science. The Shodor Education Foundation Inc. 2003.

<<http://shodor.org/succeed/forensic.html>

This site will provide students with a full explanation of how paper chromatography is useful when separating components making up a mixture.

Owen, David. "Police Lab: How Forensic Science Tracks Down and Convicts Criminals." Toronto, Ontario. Firefly Books. 2002.

This book focuses on the techniques and technology of forensic science and makes for fascinating reading.

Rainis, Kenneth G. "Crime-Solving Science Projects Forensic Science Experiments." Berkley Heights, New Jersey. Enslow Publishers, Inc. 2000.

This book is geared to younger readers, but it can be useful in explaining the simple lab projects that can be added to those mentioned in this curriculum unit.

Reading List for Students

Owen, David. "Police Lab: How Forensic Science Tracks Down and Convicts Criminals." Toronto, Ontario. Firefly Books. 2002.

This book focuses on the techniques and technology of forensic science and makes for fascinating reading by the students as a follow-up to the lab.

Rainis, Kenneth G. "Crime-Solving Science Projects Forensic Science Experiments." Berkley Heights, New Jersey. Enslow Publishers, Inc. 2000.

This book is geared to younger readers, but it can be useful in explaining the simple lab projects that can be added to those mentioned in this curriculum unit. Follow-up exercises described in this book will further student understanding of forensic science.

Appendix-content Standards

The Pittsburgh Public School standards that will be addressed for secondary science students include:

- (1) Students explain the relationships among science, technology, and society.
- (2) Students demonstrate knowledge of basic concepts and principles of chemistry.
- (3) All students demonstrate that they can work effectively with others.

Appendix A (Lip Print Patterns)

1. Short vertical lines
2. Long vertical lines
3. Branching lines
4. Crisscross lines
5. Diamond pattern lines

Appendix B (Synthetic blood solutions)

Type A Blood: 0.1 M potassium chromate solution with added red food coloring to get deep red coloration.

Type O Blood: Red food color in water.

Antibody A Solution: 0.1 M silver nitrate solution (only several drops are needed to see reaction with type A Blood)