# Solving Crimes with Chemistry:

***The case of the missing balances***

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**Field tested:** 11th grade chemistry, Watsonville High School, Watsonville, CA (Winter 2014)

**Module Type:** lab activity

**Duration:** 110 minute class session

**Key materials:**

* Evidence packets for each lab group
* Chromatography paper
* Ink pens (5 kinds)
* 70% isopropyl alcohol
* 400 ml and 100 ml beakers
* Wooden coffee stirrers
* Sugar
* Salt
* Chalk (powdered)
* KCl
* Boric acid
* Conductivity tester
* Hot plate
* Disposable glass slides
* Bunsen burner

**Concepts:** electronegativity; polarity; ionic and covalent bonding; conductivity

**Skills:** Using chemistry techniques (paper chromatography, flame testing, solubility testing, melting point testing, conductivity testing) to gather data, answer questions, solve problems, and argue from evidence.

**NGSS DCI:** HS-PSI.A Structure and Properties of Matter

**NGSS Practices:** HS-PS1-3: Planning and carrying out investigations, Analyzing and interpreting data; HS-PS1-2: Constructing explanations and designing solutions, Engaging in argument from evidence, and Obtaining, evaluating, and communicating information

**NGSS CCC:** 1. Patterns, Cause, and Effect: Mechanisms and explanation

Overview:

This module is an opportunity for students to synthesize the concepts they have learned on the structure and properties of matter throughout the semester. It can be modified easily to focus on one particular concept, such as polarity. During this lab activity students will learn:

* how chemical testing can be used to identify unknown substances,
* how to apply previously learned scientific techniques to novel questions/problems,
* how to collect data from a series of experiments with careful observations, and
* how to record and interpret data and make conclusions based on gathered evidence.

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# Background for Teachers

**Why this matters:** Basic concepts, like bonding and polarity, are often taught at the beginning of a chemistry course to build a foundation for understanding later, more difficult concepts. However, many students find it hard to remember these foundational lessons, hindering their later success. This module is intended to be a synthesis of several basic chemistry concepts regarding the properties and structure of matter. In addition to providing needed review and repetition of these concepts, this module is also intended to teach students necessary skills in the application of concepts to novel problems, collection of data, interpretation of evidence, and the communication of results.

**Assumed background:** Students should have prior knowledge of basic properties of matter, including electronegativity, polarity, solubility, and types of chemical bonding. Students should have completed previous labs using flame tests, solubility tests, conductivity tests, melting points, and chromatography. It will be helpful (though not necessary) for students to have notes on how to conduct each test for reference during this lab. This module can be used as a follow-up to the SCWIBLES module “Colors in Chemistry” for teaching the concept of molecular polarity.

**Special context:** Many specialty fields require practitioners to use a variety of scientific techniques to answer questions and/or solve problems. For example, forensic scientists often collect many different types of evidence from a crime scene. Each type of evidence might be tested in several different ways to determine what it is or how it is important to understanding the crime. This module allows students to become familiar with ways that techniques learned in chemistry class can be applied to new situations. The module encourages creative thinking as students choose which methods are appropriate to test the provided evidence. After conducting the appropriate chemical tests, the students can conclude, based on their tests, which suspect committed the crime. This reinforces students’ ability to make inferences and conclusions based on collected evidence. The lab capitalizes on many students’ interest in forensic sciences and crime scene investigation.

**Scaffolding supplements:** The SCWIBLES “Colors in Chemistry” module is a precursor to this module and can be used to teach electronegativity, polarity, and paper chromatography.

The following links are resources for teaching high school students to do flame tests:

Video showing how to identify substances using a flame test: <http://youtu.be/ZsvsptBQUVQ>

Examples of a typical high school flame test lab: <http://www.kentschools.net/ccarman/files/2009/08/1-4-Flame-Test-lab-fy11.pdf>

[http://www.rsc.org/learn-chemistry/wiki/Lab:Flame\_tests\_(wooden\_splint\_method)](http://www.rsc.org/learn-chemistry/wiki/Lab%3AFlame_tests_%28wooden_splint_method%29)

The following link has resources for teaching ionic and covalent bonding:

<https://www.oakland.k12.mi.us/portals/0/learning/bonding.pdf>

# Module Description

## Materials:

Each lab group should have an evidence packet with the following materials:

* Crime suspect bios (MBcrime\_bios.docx) – This document has pictures and brief biographies of the suspects introduced in the PowerPoint presentation (MissingBalances.pptx). The suspects in this lab are actually teachers from Watsonville High School (with the names altered, but still recognizable). Teachers from other schools should feel free to change the suspect photos and names to represent faculty at their own school. We found that using actual teachers as suspects increased students excitement and interest in the lab activity. Similarly, the crime (stolen equipment from Driscoll Berry Company in Watsonville) was written for Watsonville HS student. The crime story can be easily changed to make it more relevant to students elsewhere!
* Crime lab protocol (MBstudent\_guide.docx) – This can be provided to the students at discretion of the teacher. Teachers may wish to not provide the instructions and have students use their own notes from earlier in the semester to decide which tests to use for the provided evidence and for instructions on how to conduct those tests. Withholding the instruction sheet is only recommended for advanced classes, and can extend the amount of time needed to complete the module.
* Chemical reference sheet (MBchemical\_reference.docx) – During this lab, students test the unknown powder provided to them in their evidence packet. They do not test all of the possible known substances (salt, sugar, KCl, boric acid, chalk). The chemical reference sheet provides chemical properties of the known substances. Once students complete chemistry tests on their unknown white substance, they must compare their findings with the properties of the known substances on this sheet to identify their unknown (and determine the criminal).
* A pre-prepared strip of chromatography paper with the unknown dot of black ink evidence at the origin line – Students will be told that this has been pre-processed from the note found at the crime scene (see the PowerPoint presentation). Additional space should be left on the origin line to the right of the unknown ink sample since students are required to test all known pens as well. A diagram of the strip is included in the MBstudent\_guide.docx document and can be drawn on the board as well to show students how to prepare their chromatography test.
* A sample of unidentified white powder from the crime scene (sugar, salt, chalk, KCl, or boric acid).
* 5 different pens (confiscated from the crime suspects) for use in the chromatography test.

Additional materials needed for each group:

* 70% isopropyl alcohol
* 400 ml beaker for chromatography test
* Wooden coffee stirrers for flame test and chromatography test
* DI water
* 100 ml beaker for solubility, conductivity, and flame test (clean and rinsed with DI water)
* 50 ml graduated cylinder (clean and rinsed with DI water)
* Glass stir rod
* Metal spatula or scoopula
* Glass slide for melting point test
* Thermometer (Celsius) with a maximum temperature of at least 150 °C
* Bunsen burner
* Conductivity tester
* Hot plate

## Preparation: Teachers should prepare an evidence package for each lab group before the day of the lab. We have provided a cheat sheet for teachers (MBteachers\_guide.docx) for 9 different evidence packets. For classes with more than nine groups, evidence packets can be repeated. For less than nine groups, evidence packets can be eliminated. Each evidence packet is labeled with a letter and has a different guilty suspect. Teachers can tell the class this to encourage each group to work separately (a correct answer for one group will be incorrect for the group next to them!). Teachers should also prepare lab stations with materials to conduct paper chromatography, a flame test, a melting point test, a solubility test and a conductivity test. If time is an issue, we recommend setting up each station with the needed materials before class instead of having students collect the items themselves. If ink pens other than the types and brands noted in the teacher’s guide are used, teachers should run a paper chromatography test on the pens prior to conducting the lab to insure that student’s will be able to distinguish each pen from the others. Finally, teachers should soak wooden coffee stirrers (used for the flame test) in water for at least several hours before the lab begins.

## Timeline:

1. Introduction 20 min.
2. Lab preparation 20 min.
3. Lab activity 60 min.
4. Conclusion (clean-up and debrief) 15 min.

## Starting Point For Inquiry:

Most students are familiar with the field of forensic science from television shows like CSI: Crime Scene Investigation, NCIS, and Law and Order. Teachers can introduce this module by discussing the broad field of forensic science and its application to law enforcement, specifically mentioning techniques like fingerprinting, DNA testing, and trace analyses. They can then transition into the specifics of this module by talking about how forms of techniques that the students have already learned (e.g. chromatography, testing of chemical properties) can be applied to forensics.

## Detailed Procedure:

**1. Introduction (20 minutes)**

PowerPoint: Before students break into lab groups, teachers should introduce the activity with a PowerPoint presentation (MissingBalances.pptx). The PowerPoint allows students to review previously learned concepts that are necessary for this lab, and introduces the crime story, evidence and crime suspects. Notes for the presentation are included in the PowerPoint file.

Worksheet: While watching the PowerPoint, students should start to complete the Missing Balances worksheet (MBworksheet.docx). Once the Case Description section is complete, student’s can break into lab groups and receive their Evidence Packet.

**2. Lab preparation (20 minutes)**

Each lab group’s first task is to create a Crime Lab Work Plan (page 2 of worksheet). Teachers should sign the work plan for each group indicating that the group understands the lab and is ready to begin chemical tests.

**3. Lab activity (60 minutes)**

Students will now follow the lab plan that they recorded on their worksheet. Instructors should be checking in with groups regularly during the evidence-testing phase. Note that students should be filling out the worksheet with data as they go! All test results should be recorded in the appropriate sections of the lab report, and final questions should be answered after tests are complete. Each lab group will receive a different evidence packet, and thus not all groups will find the same suspect guilty. Lab groups will test only the unknown substance included in the lab packet, and compare the results to the Chemical Reference Sheet (included in supplemental materials) with melting point, solubility, flame test and conductivity values and results for materials corresponding to each suspect. Lab groups will test both the unknown pen and all five (5) pens given in the evidence pack with paper chromatography. A document of crime lab protocols (MBstudent\_guide.docx) is included in the supplemental material for students that need guidance to complete the chemical property tests.

**4. Conclusion (15 minutes)**

Cleanup: each group should put all items back in the Crime Evidence Packet and leave the packet for the next class. All materials used during evidence testing should be brought back to the classroom materials table. Lab benches should be clean before students return to their seats to complete their lab report. Teachers who are interested in using this module as an opportunity for their students to gain writing practice can use the attached Missing Balances Lab Report Worksheet (*MBpolice\_report.docx).* This is a writing assignment for students to summarize their methods, results and lab conclusions that can be given as homework.

## Assessment Methods:

Instructors should check crime reports for the following:

Did students determine the thief correctly?

Did students correctly identify the unknown white powder?

Did students carry out the chromatography test correctly? Did they identify the correct pen?

Instructors should also discuss the concepts of electronegativity, polarity, solubility, and bonding with students throughout the lab. If students are able to answer questions about the underlying concepts, then they demonstrate understanding of the material. Example questions:

1. Why can you determine which pen the ink came from? Why does the ink separate into distinct color bands?

2. Why can you determine the identity of a substance using melting point? Flame testing?

## Possible pitfalls:

Students may have trouble remembering how to conduct the tests, even having their notebooks handy. It may be useful for teachers to write the page numbers on the board where students can find the procedures in their lab notebooks.

It is helpful to have additional chromatography strips for each evidence packet prepared ahead of time, so if a group messes up, they can repeat the test. In addition, each new class will need new sets of chromatography paper (with an unknown ink dot on it). Teachers can make these prior to the day of the lab. It is important for teachers to label the chromatography paper so that they know the identity of the unknown ink dot (we used a pencil letter in the upper corner of the paper).

If students use non-DI water or have contaminated glassware, then they may get incorrect results for the conductivity test. It is important to emphasize during set-up that they need to rinse and use DI water only during the lab.

The flame test color is only visible for a brief period of time when the powder begins to burn. If students see an immediate color change, they should record it record it. After the chemical has burned away, the flame will revert to a typical orange color.

Teachers: is helpful to always have the cheat sheet on you to identify when a group is making a mistake and guide them toward the right answer! For example, you may need to suggest that a group repeat a certain test. We also found it helpful to remind the students that they can be working on more than one test at once (especially that they can be working on other tests while the chromatography paper is developing).

This may be one of the first times that students are doing a lab without an explicit set of ordered instructions. It will be difficult for students to come up with their own instructions and directions. It is important to encourage all groups to think creatively and use the materials provided to them. Teachers can assist students by checking in regularly during the lab and pointing students back to the evidence that can be tested.

## Glossary:

Forensic Science Vocabulary

**Forensic Science (Forensics)** - the application of a broad spectrum of sciences and technologies to investigate and establish facts of interest in relation to criminal or civil law.

**Crime Scene** - Any physical location in which a crime has occurred or is suspected of having occurred.

**Suspect** - Person thought to be capable of committing a crime.

The following terms are words students should have been introduced to previously. This lab can be used as a review.

**Polarity** - Separation of electric charge (positive and negative) in a molecule. This leads to a dipole.

**Electronegativity** - The amount of pull that one atom exerts on the electrons that it is sharing with other atoms.

**Chromatography** – a laboratory technique for the separation of mixtures.

**Ionic Bond** – a chemical bond that involves one atom losing an electron to form a positive ion and the other atom gaining an electron to form a negative ion

**Covalent Bond** - a chemical bond that involves sharing a pair of electrons between atoms in a molecule

**Conductivity** - The ability of a material to conduct electrical energy

**NGSS Standards Addressed**

**Disciplinary Core Ideas**

HS-PSI.A Structure and Properties of Matter

**Science & Engineering Practices**

HS-PS1-3: Planning and carrying out investigations, Analyzing and interpreting data

HS-PS1-2: Constructing explanations and designing solutions, Engaging in argument from evidence, Obtaining, evaluating, and communicating information

**Cross Cutting Concepts**

1. Patterns, Cause and Effect: Mechanisms and explanation

Guide to supplemental materials

*Missing Balances* PowerPoint: MissingBalances.pptx

*Missing Balances* Worksheet: MBworksheet.docx

*Missing Balances* Lab Report Worksheet: MBpolice\_report.docx

Crime suspect bios: MBcrime\_bios.docx

Missing Balances Teacher Reference Sheet: MBteachers\_guide.docx

*Missing Balances* Chemical Reference Sheet: MBchem\_reference.docx

*Missing Balances* Student Instructions: MBstudent\_guide.docx