

**2008
Winning Lesson Plan
from Colorado Springs,
Colorado**

*Linking Physical Properties
to Underlying Structure*

by Sandra J Smith
Palmer High School

Subject: Chemistry
(Chemical Bonding)

Grade Level: High School
(Physical Science,
Intro to Chemistry,
1st Year Chemistry)

Duration:
Five 55-Minute
Class Periods

Overview and Purpose

Can the properties of materials that appear similar be used to tell them apart?

Earlier in chemistry, students learned about physical and chemical properties of materials. Forensic chemists test properties of materials found at a crime scene. They also do similar tests on the materials found on a suspect's skin or clothing. These materials are often complex mixtures, such as soil, which contain many substances. In this lab, students compare the properties of five known materials with two samples of "evidence." These samples represent evidence from a crime scene and evidence from a suspect's shoe. Although the materials and equipment are less complex than those used by forensic chemists, the overall method is similar to the methods they use. Students work in small groups for this lab, but each student should maintain their own records.

Innovation

Although the "white powder" premise of the lab is a bit "tried and true", the approach is innovative in that the lesson is set in a forensic context, the materials and procedures are specifically selected and designed to be relatively "green", and the sequencing of the lesson is characterized as a guided inquiry experience. (Students are guided through a series of activities designed to lead them to certain conclusions.) In addition, the lesson focuses the use of a Venn diagram to help students process information, a great "research-based" strategy for emphasizing similarities and differences.

Context

This lesson is best placed at the beginning of a unit on chemical bonding. It serves as a great "Engage, Explore" activity at the beginning of a learning cycle approach. This lesson was originally designed for use in a unit with a forensic science approach. If the reader would like additional information about this lesson (i.e. teacher's hints, sample data, etc.) or the contextual unit, please contact the author at smithsj@d11.org.

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Educational Standards Addressed

Directly addresses *Colorado State Model Content Standard 2 for Physical Science*, focusing specifically on Benchmarks 2 and 3 which involve observing and measuring physical and chemical properties in order to compare and contrast substances and relating that information to the structure of the substances.

Objectives

At the end of this lesson, students should be able to:

- characterize the physical properties of ionic and covalent compounds,
- identify an unknown substance using its experimentally determined properties,
- predict whether a compound is likely ionic or covalent based on the position of the component elements on the periodic table and/or the compound's physical properties.

Materials

- 2 well plates with at least 5 wells each;
- 6 spatulas, one for each powder;
- small samples of six powders
(baking powder, baking soda, cornstarch, cream of tartar, salt, sugar);
- magnifying lens;
- distilled water, pipette;
- pH or litmus paper, stirring rod;
- conductivity tester;
- vinegar, pipette;
- iodine solution, pipette;
- coffee can lid, hot plate, aluminum foil, crucible tongs, stopwatch

Procedure Part A: Using Properties to Identify White Powders

1. Put on your safety goggles and obtain your materials.
2. Use the instructions on *Handout 13.1 : Methods for Testing Physical and Chemical Properties of White Powders* to determine some physical and chemical properties of the 6 white powders you have been given to study. You will need to keep careful observations as you move through each of the tests. Your data table might look like this:

Data Table 1 : Physical and Chemical Properties of Known White Powders

Material	Description	Solubility (in water)	pH	Electrical Conductivity	Vinegar	Iodine	Melting Time

3. After you have completed your testing of the known samples, show your instructor your data table. (S)he will provide you with two additional samples, one from the crime scene and one from a suspect. Your task is to decide if the two samples are identical. Make a second data table, similar to the one you used for your known samples. Study the physical and chemical properties of both materials. Record your observations.

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Procedure Part A: Using Properties to Identify White Powders (Cont'd)

Analysis

1. What patterns did you notice in the results for step 2? Were there any powders that behaved in similar ways? If so, indicate which ones and how their behavior was similar.
2. The chemical names and formulas for each of the powders are provided below. Look at the chemical formulas and note any patterns you see.

Powder	Chemical	Chemical Formula
Baking powder	sodium bicarbonate (soda), cream of tartar, and some starch	NaHCO_3 and $\text{mC}_4\text{H}_4\text{O}_6$ and $(\text{C}_6\text{H}_{10}\text{O}_5)_n$
Baking soda	sodium hydrogen carbonate or sodium bicarbonate	NaHCO_3
Cornstarch	4 parts amylopectin (>1000 glucose units) to 1 part amylose (>200 glucose units) [amylopectin and amylose are polymers of glucose; each time two glucose units join, a water is produced]	$(\text{C}_6\text{H}_{10}\text{O}_5)$
Cream of tartar	potassium hydrogen tartrate or potassium bitartrate	$\text{KHC}_4\text{H}_4\text{O}_6$
Sugar	α -D-glucopyranosyl- β -D-fructo-furanoside a.k.a. sucrose - a dimer (or disaccharide) of glucose and fructose	$\text{C}_{12}\text{H}_{22}\text{O}_{11}$
Table salt	sodium chloride	NaCl

3. Which of the tests were most helpful in identifying the white powders? least helpful? Support your answers with specific examples.
4. Did the sample of the white powder from the suspect match powder found at the crime scene? Cite multiple pieces of evidence for your answer.
5. If an unknown white powder has the following properties, can you identify it based on this lab experience? Why or why not? *Unknown X is described as a white powder that will dissolve in water and conducts electricity when it is dissolved in water. This unknown has a high melting point. It does not react with vinegar or iodine.*
6. Compare your answers to questions 1–4 with one or more other groups. Do other groups agree or disagree with your findings? Feel free to revisit and revise your answers to these questions based on your discussions.

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Procedure Part B: Taking a Closer Look at Compounds

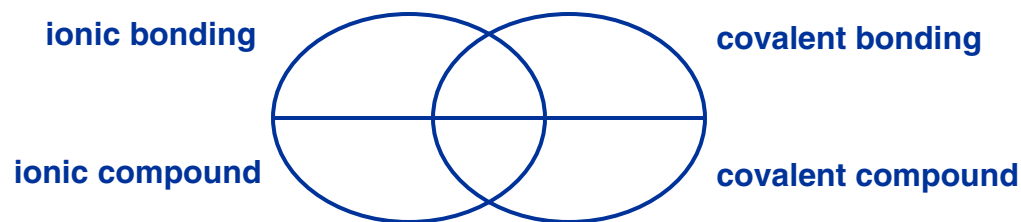
In Part A you began to notice patterns between the observed properties of the white powders and their chemical structure. In this part of the lesson you will learn more about the structure of the chemicals and relate that information to what you discovered in Part A. You'll likely noticed that most of the chemicals you worked with in Part A are compounds. [Which chemical is not a compound? How can you tell?] Remember that compounds are made up of two or more different elements that have chemically combined to form a new substance. The forces that hold these atoms together may be described as covalent bonds or ionic bonds. Perhaps you have heard of these two types of bonds before? If not, or if you need some reminders, take some time to do some background reading about ionic and covalent bonds and the compounds they form. You may use your textbook or other resources your teacher provides. Some possible web-sites include:

- Chemical Bonding lesson at the Vision Learning website:
http://www.visionlearning.com/library/module_viewer.php?mid=55
- Chemical Bonding – An Introduction at:
<http://www.newi.ac.uk/buckleyebonding.htm>

As you read, keep these questions in mind:

- What is a bond? What is an ionic bond? What is a covalent bond?
- What types of elements are joined together in an ionic compound? A covalent compound?
- How can you determine if two or more elements will join together to form an ionic compound? A covalent compound?
- What properties are associated with an ionic compound? A covalent compound?

When you have completed your background reading, make a Venn diagram to show what you have learned. Use a full sheet of paper and fill it with a diagram that looks like the example below. Add terms and phrases to fill the circles. Remember, only features that are common to both ionic and covalent should appear in the areas where the circles overlap.



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Procedure Part C: Relating Properties to Underlying; Structure

Now that you know a little more about compounds, you are going to put together what you observed in Part A with what you learned in Part B. You may work in small groups.

1. Consider the chemical formulas for each of the compounds you used in Part A. Use the formula and the relative location of the elements on the periodic table to determine whether each substance is likely to be considered ionic or covalent. Record your conclusions in a chart similar to the one below.

Compound (formula)	Covalent or Ionic (based on formula)	Evidence	Covalent or ionic (based on properties)	Evidence
	<i>Fill in this part now.</i>		<i>Fill in this part for #2.</i>	

2. Consider the properties that you tested in Part A. Based on your lab results and what you now realize about the properties of ionic and covalent compounds, determine whether each substance is likely to be considered ionic or covalent. Record your conclusions in a chart similar to the one above. Be sure to include reasons for your conclusions.
3. Share your results for #1 and #2 with the rest of the class by posting them on the board. (Your teacher will have two labeled columns on the board: **IONIC** and **COVALENT**. Write the formulas for each of the compounds you tested under the appropriate column. If the formula already appears under the column place a check mark next to it to indicate that you agree with its placement.) Discuss the class results with your classmates and teacher.

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Handout

Methods for Testing Physical and Chemical Properties of White Powders

These methods make use of simple equipment and chemicals. It is important that you do Step 1 first, followed by Step 2 and/or Step 3.

Recording Initial Descriptions

When you initially look at your white powders, you might think “These all look the same.” But they aren’t. Take a closer look. What might initially look “white”, might actually be “slightly yellow” or “light tan”. What appears to be a “powder” might actually be small cubic crystals. Make note of the color of your powder, the size and shape of its particles, and any other physical properties you can think of. If possible, use a magnifying lens to help with your observations.

Testing for Solubility

Some materials dissolve in water, others do not. If a material does dissolve totally in water, it is said to be “soluble” in water. The resulting mixture is called a solution. If none of the material dissolves in water, then the material is said to be “insoluble” in water. If some of the material dissolves, but not all of it, then the material is said to be “partially soluble” in water. The actual amount of solid that will dissolve in water at a given temperature is called its “solubility”. For the purpose of this lab, you will only determine if something is soluble (**S**), insoluble (**I**), or partially soluble (**P**) in water. It is possible for some solids to dissolve in other liquids, like alcohol or oil. A material can be soluble in one liquid, but insoluble in another liquid.

- To test for solubility, place a small amount (size of a match head) of your solid in a well on your plate and add 10 drops of water. Stir thoroughly and observe. Add 10 more drops of water. Stir thoroughly and observe. Record your observations, using the symbols for soluble (**S**), insoluble (**I**), or partially soluble (**P**).

Do not discard this sample, you will use it to test for pH and conductivity.

Testing for pH

You have probably heard of acids and bases. For instance, hydrochloric acid (HCl) is the acid found in our stomachs and is also the acid used to clean stains off of concrete. Sodium hydroxide (NaOH) is a base that is used in drain cleaners and ammonia (NH₃) is a base that is often found in cleaners. Chemists use a number scale that ranges from 0 to 14 to describe acids and bases.

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Handout (Cont'd)

The scale ranges from stronger acids (pH=0-1) to weaker acids (pH=5-6) to a neutral solution (pH=7) and on to weaker bases (pH=8-9) to stronger bases (pH=13-14). Here are some pH values for some common materials:

pH	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
material	battery acid		lemons vinegar		oranges tomatoes		milk	distilled water	baking soda	soap		ammonia		drain cleaner	

There are many ways to test for pH. Sometimes chemists use instruments called pH probes, other times they use special chemicals, called indicators, to determine the pH. In this lab you will use pH paper to determine the pH of the dissolved solid. This paper has been soaked with one or more indicators that change color depending on the pH.

- To test for pH, simply place a small strip of pH paper flat on a paper towel. Dip a clean stirring rod into the mixture from step 1 and touch the tip of the stirring rod to the piece of pH paper. Match the color of the resulting spot to the color scale provided with the pH paper. Record your observations.

Testing for Electrical Conductivity

Earlier in this unit you tested various metals for electrical conductivity. You may recall that in order for any material to conduct electricity, it must have charged particles and those particles must be free to move about. Metals are able to conduct electricity because they have loosely held electrons in their valence shell that are able to move about freely. The electrons are negatively charged.

- To test for electrical conductivity you will use the same conductivity tester that you used to test metals, but this time you will be testing other materials. The white powders you will be testing may or may not contain charged particles, but even if they do, those particles are not free to move around. However, if the material dissolved in water, the dissolving process allows any charged particles to move around. Knowing this, you will be testing the electrical conductivity of the water mixture of your powder. Simply place the two copper wires from the conductivity tester into the well containing the water mixture of your powder. Observe the LEDs carefully and use the scale on the conductivity tester to record the conductivity of the mixture.

Once you have completed the first three tests (solubility, pH, electrical conductivity) with all six powders, dispose of the materials in the sink and rinse the wells out. It is not necessary to dry the wells unless you really want to.

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Testing for Reaction with Vinegar

Vinegar (CH_3COOH) is a weak acid that reacts with some materials, particularly with bases. There is a general pattern that acids will react with bases to form a neutral salt and water. Another general pattern is that acids will react with carbonates (materials containing CO_3^{2-}) to produce water, carbon dioxide, and a neutral salt. In this lab you may see evidence of these general patterns.

- To test for reaction with vinegar, place a small amount (size of a match head) of your solid in a well on your plate and add 5 drops of vinegar. Stir thoroughly and observe. Add 5 more drops of vinegar. Stir thoroughly and observe. Record your observations.

Once you have completed the vinegar test with all six powders, dispose of the materials in the sink and rinse the wells out. It is not necessary to dry the wells unless you really want to.

Testing for Reaction with Iodine

The iodine solution you are using for this test is a mixture of 5% iodine (I_2) and 10% potassium iodide (KI) in distilled water. Iodine alone is not very water soluble but potassium iodide is. The potassium iodide enables the iodine to dissolve in the water. This solution is used to test for the presence of starches, which are made up of long chains of simple sugars. The iodine reacts with the starch to form a large molecule that absorbs light in a particular way that results in a characteristic blue color. The iodine solution will not react with simple sugars, such as glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) or fructose ($\text{C}_6\text{H}_{12}\text{O}_6$).

Did you know? In years past, iodine solution was often used to treat gout and hypothyroidism in adults. Doctors had their patients "paint" the soles of their feet with the iodine solution before going to bed. While the patient slept the body absorbed what it needed from the soles. Patients repeated this nightly until they noted that the iodine solution was no longer being absorbed, meaning their body had what it needed.

To test for reaction with iodine solution, place a small amount (size of a match head) of your solid in a clean well on your plate and add 1 drop of iodine solution. Record your observations. Once you have completed the vinegar test with all six powders, dispose of the materials in the sink and rinse the wells out. It is not necessary to dry the wells unless you really want to.

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Testing for Relative Melting Point

You have noticed that some materials melt at low temperatures while others melt at high temperatures. It turns out that melting point can also be used to identify materials, particularly pure substances, but also some mixtures. The melting point of a material is related to its structure. If the material is made up of a simple structure that involves particles that are held together with weak forces, the material will melt at a low temperature. If the material has a more complex structure with stronger forces holding the particles together, the material will melt at a higher temperature.

Chemists most often use instruments to determine melting points. They are able to obtain very accurate and precise number values for the melting point. Because you do not have access to those instruments in a high school lab, you will simply determine the relative melting point of each substance.

1. Obtain a coffee can lid that has been separated into 6 numbered regions. Place the coffee can lid on top of a hot plate.
2. Make a container out of aluminum foil to hold a small amount of one of the substances. You may do this by simply pressing a 5–6cm square of aluminum foil around the bottom of a small test tube, forming a small boat. Remove the container and press it against a flat surface so that it can stand independently. Add a small amount (size of a match head) of one of the solids to the container. Repeat this process for the other 4 substances, being careful to keep track of which solid is where. (**Suggestion:** Record the number of the region where you place each solid in its container.)
3. Turn on the hotplate. As the heat is transferred from the hotplate to the coffee can lid, to the aluminum foil, and then to the solid, the solid may begin to melt. Once it has started to melt, immediately use crucible tongs to remove the container from the lid and note how much time has passed. Record your observations. Continue this process until all of the samples have melted or until 3 minutes have passed. (**Remember:** Materials that melt in the smallest amount of time have low melting points. Materials that took a long time to melt or did not melt at all in the time allowed have high melting points.)
4. After the 3 minutes have passed, shut off the hot plate and carefully remove the can lid from the hotplate. After the materials have cooled, pinch the containers shut and throw them away.