Activity 3
Environmental Chemistry

Objectives
Students will be introduced to the science of environmental chemistry and scientists who use chemistry to monitor the health of the environment. After participation in this workshop students will have gained a basic understanding of the science of chemistry. They will be able to conduct simple physical and chemical analyses to identify an unknown substance by comparing the results of these tests with the results of analytical tests done on several known substances.

Terminology
Analyze, atoms, bond, chemical, chemical analysis, chemical reactions, classification, comparison, compound, concentration, contaminants, data, density, dependant variable, electron, element, gas, hypothesis, independent variable, inference, liquid, mass, matter, mixture, molecules, neutron, observation, particle, prediction, Periodic Table of Elements, proton, qualitative analysis, quantitative analysis, solid, states of matter, subatomic particles, toxin, texture, volume.

Grade Level: 3rd-6th grade

Ideal Class Size
24 students divided into six groups of four

Subject Areas
Earth Science, Physical Science, Inquiry Skills, Math: Alg-S2 & Alg-S4

Time
1 hour introduction and presentation.
1 hour activity/experiment.

Materials
- PowerPoint presentation or slide projector w/slides
- Flip chart or writing board and eraseable colored markers
- Demonstrations and Experiments
    - TV monitor and lens
    - solubility demo: wash bottle with water, 50 ml graduated cylinder, 100 ml beaker, plastic stirring sticks, 5 grams of salt, 5 grams of sand
    - melting point demo: candle, matches, clothes pin, aluminum foil
    - pH demo: lemon and 50 ml clear liquid laundry soap
    - iodine demo: few pieces of dried pasta, a carrot, counterfeit dollar bill pen

- "Known" and "unknown" substances and chemical reagents/indicators
    - 1 large box corn starch (distributed in labeled plastic vials)
    - 1 large box baking soda (distributed in labeled plastic vials)
    - 1 lb granulated white table sugar (distributed in labeled plastic vials)
    - 1 lb plaster of Paris (distributed in labeled plastic vials)
    - iodine solution – 500 ml (distributed in labeled dropper bottles)
    - pH indicator [boiled cabbage juice] – 500 ml (distributed in labeled dropper bottles)
    - white vinegar [acetic acid] – 500 ml (distributed in labeled dropper bottles)
- Lab materials

- small wooden spoons to scoop chemical from vials
- black construction paper cut in ~ 2" x 3" pieces (5 pieces/pair)
- magnifying glasses (1/student)
- safety goggles (1/student)
- spot plates with 12 wells (2/pair)
- "trash" cups (1/table)
- tooth picks (2 boxes/class)

- Posters
  - Methods of Science
  - SAFE Rules
  - SREL Student HazMat Response Team
  - Student Data Sheet--large laminated
  - pH Scale--large laminated
- Handouts
  - Student procedures and data sheet
  - Follow-up activities
  - "Spot Plate Illustrations" laminated handout (1/pair)
  - "Chemistry is Cool" word search puzzle

Advanced Preparation

1) Prepare the "known" substance materials:
   - Fill 12 plastic vials with a few grams of corn starch. Label vial and lid #1
   - Fill 12 plastic vials with a few grams of granulated white table sugar. Label vial and lid #2
   - Fill 12 plastic vials with a few grams of baking soda. Label vial and lid #3
   - Fill 12 plastic vials with a few grams of Plaster of Paris. Label vial and lid #4
   - Label 12 wooden spoons each with #1, #2, #3. #4
   - Cut black construction paper into ~ 2"x 3" squares
   - Label the spot plate wells 1 through 12

2) Assemble the above materials into small plastic trays creating one set for each pair of students:
   - 1 set of "known" substances in vials numbered 1 through 4
   - 1 set of wooden spoons numbered 1 through 4
   - 2 magnifying glasses
   - 5 pieces of black construction paper
   - 20 toothpicks

3) Prepare the following test reagents needed to analyze the "known" substances:
   - Fill 12 small dropper bottles with iodine solution; label
   - Fill 12 small dropper bottles with white vinegar (acetic acid); label
   - Fill 12 small dropper bottles with pH indicator; label

     To make a pH indicator simmer chopped red cabbage in water until the solution is very purple, then let cool. Strain the cabbage juice into screw-cap jars and refrigerate or freeze until needed

4) Assemble the prepared dropper bottles into small plastic trays creating 12 test reagent sets; one set per pair of students

5) Prepare the following "unknown" substance materials and test reagents

- Fill 6 plastic vials with a few grams of corn starch, OR granulated white table sugar, OR baking soda and label vial and lid according to the key below using colored markers if available, or an X, Y, Z code. *(Plaster of Paris is not used as an "unknown" as it does not produce definitive results with the tests being used)*
    - teal (X) = granulated white table sugar (sucrose)
    - red (Y) = corn starch (soluble starch)
    - purple (Z) = baking soda (sodium bicarbonate)
- Label 6 wooden spoons to match the "unknown" substance you chose

6) Clean and dry lab goggles prior to each class

7) Copy the "Task List Objectives" onto a classroom writing board or flip chart

Safety Notes
Safety goggles must be worn during chemical analysis experiment. The chemicals are safe to touch, but students should not put their fingers in their mouth our eyes and should wash their hands after class.

Activity 3: Environmental Chemistry
Workshop Outline

LECTURE AND DEMONSTRATIONS (1 hour)

1. Introduction (10 minutes)
A. Today's topic – Environmental Chemistry
B. Today's task list / workshop outline
C. Review SAFE Rules
D. Review last month's workshop

II. Power Point Presentation (15 minutes)

III. Demonstrations (30 minutes)
A. Physical properties of substances
B. States of matter
C. Chemical properties of substances

EXPERIMENT (1 hour)
I. Conduct an experiment (40 minutes)
A. Student HazMat drill and classroom preparation
B. Analyzing known and unknown substances

II. Science Seminar (10 minutes)
A. Sharing test results
B. Interpreting the data

III. Close out (10 minutes)
A. Wrap-Up Questions
B. Follow-Up

Background Information:
"Chemistry – it's all about the nature of things!" What is chemistry anyway? Chemistry is the study of matter. Just look around. If you can see it, hear it, taste it, smell it, or feel it is made of matter.

Ancient Greeks, curious about matter and what it might be made of, wondered what they would find if they cut a piece of gold in half, over and over again, until they had the smallest possible piece of gold before it wasn't gold anymore. They were the first to hypothesize about pure elements and the possible existence of atoms and sub-atomic particles. Twentieth Century scientists confirmed the existence of elements and atoms, named them, and classified and categorized them using the Periodic Table of the Elements that lists over 100 individual atoms. Chemists have even invented a few atoms of their own!

On a microscopic level elements are made up of atoms, and atoms are made up of even smaller sub-atomic particles: protons, neutrons, and electrons. Each type of atom has a precise number of protons in its nucleus (center). A hydrogen atom has one proton, a helium atom has two protons, a lithium atom has three protons and so on all the way up to Lawrencium that has one-hundred and three protons. Protons and neutrons exist in the center of an atom and have a positive charge. Electrons have a negative charge. Sometimes the number of electrons equals the number of protons and the atom is considered balanced. Usually the number of electrons is less than or greater than the number of protons in an atom's nucleus. Electrons zoom around the outside of the nucleus just below the speed of light looking for other atoms with electrons to share and help balance out the atom's positive and negative charges. An atom's charge is what makes elements bond with one another and what makes chemicals react.

Matter, when broken down into its smallest components, usually exists in two forms: as pure elements made up of a single kind of atom bound together with other like atoms, and as molecular compounds made up of different kinds of elements bound together to make a new substance. An example of a pure element is gold. Whether it is a big chunk or a small flake, gold is gold. A molecular compound is a substance made up of more than one kind of element. Sodium chloride, or salt, is really just sodium and chlorine atoms existing together as a molecular compound. Their individual charges and atomic structures make them suitable molecular partners.

What happens when molecular compounds are mixed together? Substances that do not react when they are combined are called mixtures, while substances that combine to form new by-products are said to be chemically reactive. Pour salt and pepper into a beaker and stir. The result is a mixture of salt and pepper. Pour vinegar (an acid) and baking soda (a base) into a beaker and a chemical reaction occurs, producing carbon dioxide (a gas) and water: two new substances.

Matter is not static. Matter exists in four different physical states: solid, liquid, gas, and plasma. At certain temperatures elements and compounds change physical form. When water reaches its freezing point of $32^{o}F/0^{o}C$ it becomes a solid (ice). When it reaches its boiling point of $212^{o}F/100^{o}C$ it becomes a gas or vapor (steam) and it exists as a liquid between $0^{o}C$ and $100^{o}C$. Plasma is a very interesting state of matter that is created when an atom's electrons are torn away from the nucleus. The surface of the sun is mostly made up of

hydrogen and helium gases that have become so hot (roughly 9,981^{o}F/5,527^{o}C) that they exist as plasma.

Environmental chemists use their knowledge of chemistry to identify potentially toxic substances in the environment. Sometimes they know exactly what contaminant is causing problems in an ecosystem, and sometimes they don't. They can use what they know about the physical and chemical behavior of known substances to help identify unknown chemicals in the environment.

LECTURE AND DEMONSTRATIONS (1 hour)

1. Introduction (10 minutes)

A. Today's topic

Today's topic is "Environmental Chemistry." We're going to meet a chemist, Dr. Brian Jackson, who studies the "components" that water, soil, plants and animals are made of. Then you'll get to perform some chemistry experiments to help us determine the identity of an "unknown" substance.

B. Today's task list / workshop outline

C. Review SAFE Rules

In today's class you will be conducting chemical analyses of known and unknown chemicals, so safety goggles MUST be worn.

D. Review the methods of science

II. Power Point Presentation (15 minutes)

III. Demonstrations (30 minutes)

A. Physical properties of substances (5 minutes)

[Take about 5 minutes and quickly discuss identification of substances using physical properties.]

1. Color

All materials have color and a substance's color can help you identify what the substance is. If I were to show you red, orange, and blue KoolAide powder and asked you to tell me which flavor was strawberry, what would you guess? (Red.) Now look at all these powders. What color are they? (They're all white.) *[Show the students the vials containing the known substances: soluble starch, sucrose, sodium bicarbonate, calcium sulphate hemihydrate.]*

2. Particle size

Since all of these substances are white we are going to have to use some other physical property to help us distinguish one substance from another. This is where magnifying glasses come in handy. Who knows what magnifying glasses do? In a few minutes all of you will be getting some substances to observe with magnifying glasses, but for right now let's take a close look at these substances with this camera lens. It magnifies things and shows them on the TV monitor. *[Put a tiny sample of each substance, side by side, onto a black piece of construction paper underneath the lens. Spread out the substances so that the individual particle sizes are easy to see. Explain to the students that this is exactly how you want them to conduct their particle size observations.]*

These substances are made up of smaller pieces. Which one of these samples has the largest particles? (Sucrose-table sugar.) What do the particles remind you of? (Sand... salt...) You could describe its particle size as "large as gains of sand." Which substance has the smallest particle size? (Soluble starch and calcium sulphate hemihydrate. They are "tiny, tiny, tiny.") These two substances are so similar that it would be hard to tell them

apart just by looking at their particle size. Let's look at one more physical property that might help us identify these two substances.

3. Texture

To analyze the texture of a substance you need to feel it using your fingers and hands. Take a small portion of the soluble starch and rub it between your fingers. Describe how it feels. *[It feels smooth and silky. It even squeaks when you rub some in the palm of your hand.]* Now let's try some of the calcium sulphate hemihydrate. How does its texture feel? *[It doesn't feel as smooth and silky like the soluble starch. It feels smooth and chalky and clumps up between your fingers and on your palm.]*

B. States of matter (10 minutes)

[Take about 10 minutes and discus states of matter and solubility using a couple of demos if time permits.]

1. Freezing points and melting points

At what temperature does water turn to ice? (0^oC.) At what temperature does water begin to boil and change from a liquid into steam? (100^oC.) If I give you a beaker full of an "unknown" clear liquid and ask you to identify it, using the information I just shared with you, how could you do it? (Heat the water and record its temperature with a thermometer when it started to boil. If it began to boil at 100^oC, the unknown liquid is probably water.) There are other liquids that boil at 100^oC, but not many, so finding boiling points can help identify substances. Chemists have books full of melting points and freezing points of almost every substance you can think of to help them identify "unknowns." When you do your experiments we'll help you heat your substances to find out what they look like when they melt – if they melt!

2. Solubility

Solubility is a term used to describe how well a liquid can dissolve a solid. If something dissolves in water we say it is soluble in water. If it does not dissolve in water we say it is insoluble in water. Let's conduct two solubility tests. *[Demonstrate how to measure 50 ml of water using a wash bottle and a graduated cylinder. Pour the measured water into the 100 ml beaker and add the pre-measured 5 grams of salt or sand into the water and stir. Make observations.]*

First we'll add 5 grams of sand to 50 ml of water and stir. What is happening? *[Sand sinks to the bottom]* Is sand soluble or insoluble in water? *[Insoluble]* Now let's add five grams of salt to 50 ml of water and stir. Do you have any predictions? *[Survey the class before adding the salt to the water]* What is happening to the salt? *[it's dissolving]* Where did it go? *[The salt is still in there. The water molecules react with the salt molecules and separate them into their tiniest particle sizes – so small that we can't see them. If I leave this beaker of water out in the sun for a couple of days the water molecules will evaporate, turn to gas, and the salt will be left behind in the bottom of the beaker.]*

C. Chemical Properties of Substances (15 minutes)

[Take about 15 minutes to describe the chemical properties of substances, and explain how they can be tested for using the following test reagents. Some quick demos.]

Remember during the slide presentation you learned how combining two chemical compounds can create a mixture like when we stirred together salt and pepper. Did a chemical reaction take place? (No – we got a mixture.) We're going to demonstrate what happens when we mix two compounds together and they chemically react.

1. pH indicators

   Let's talk about pH tests first. pH tests can show us if a substance is an acid or a base. pH is a measure of the activity of hydrogen ions in a substance. A substance that is an acid likes to share its hydrogen ions with other substances. A substance that is a base likes to get hydrogen ions from other substances. When a substance has just the right amount of hydrogen ions, it is balanced, so we say it is neutral. pH is measured on a scale from 0-14, 0 being the most acidic and 14 being the most basic or alkaline. *[Show the students the pH scale poster and point out the different categories of items on it.]*

   Let's check the pH of a few of these items using our purple cabbage pH indicator solution. The purple color will change depending on the chemical behavior of the substance we're testing. It will turn pink or red when dropped on an acidic substance and green or blue when dropped on a basic substance. *[Drop some pH indicator on half a lemon and discuss the pink/red acid results. Now drop some pH indicator into a few mls of clear laundry soap and discuss the green/blue basic results. Bases, like soaps, usually have a smooth, slippery quality.]* In just a few minutes we're going to lead you through some pH tests on several substances, so don't forget what we just talked about.

2. Acetic acid (acid-base reactions)

   The next chemical test we are going to demonstrate is how acetic acid reacts with other substances. Remember, acids like to give away hydrogen ions so they chemically react with most things. This is acetic acid, more commonly know as vinegar. Vinegar is an acid – it has that tangy taste sort of like a lemon. *[show them the vinegar and have a few students smell it]* Let's add some acetic acid to a few of our chemical substances and observe what happens. Remember we said that water has neutral pH. When we add acetic acid to water, nothing happens. There is no chemical reaction. What do you think will happen when we add two acids together? (Nothing.) *[add some acetic acid to the lemon – no reaction takes place]* What do you think will happen when we add an acid to a base? (An acid-base reaction occurs with lots of bubbling and fizzing.) *[combine some acetic acid and baking soda together and observe the reaction]* Chemists can use the fact that acetic acid will chemically react with bases to help them determine if a substance is an acid or base. We'll have you do some acid-base experiments in just a minute.

3. Iodine solution (starch test)

   Iodine is a chemical that can be used to determine whether starch is present in a substance. Starch is a complex molecule called a carbohydrate that plants store in their cells. When they need a little energy, the starch gets turned into sugar and they have instant energy.

   Let's add some of this iodine solution to a few things and see if there is a chemical reaction. Iodine will turn dark blue to black in the presence of starch. First we'll add some iodine to this piece of pasta. Color changed! Pasta must have starch in it. How about sucrose or table sugar – it turned orange – no starch. We'll use this information to help us identify some chemical substances! *[Interesting fact: agriculturalists use an iodine solution to test for ripeness in apples. They cut an apple in half and dip the cut side into a*

solution of iodine for a few minutes and then observe the percentage of stained surface. If over 50% of the apple is dark, then the majority of the starches haven't converted to sugars and the apple is considered immature or "un-ripe." If less than 10% of the surface is stained than the apple is considered over-ripe.]

EXPERIMENT (1 hour)

I. Introduction and Classroom Preparation (5 minutes)

[Setting the scene: Have someone hand the instructor a note that announces a chemical spill from an overturned chemical truck. The note asks students to form a Student HazMat Team to help identify the spilled substance. Follow the storyline and directions from the Student Data Sheet using the "SREL Student HazMat Response Team" poster to introduce the students to the task at hand.]

II. Conducting the Activity (30 minutes)

[Follow the directions outlined on the Student Data Sheet. Solubility and melting point tests are conducted as demonstrations to expedite the activity. Students will conduct the remaining physical and chemical tests of the four "known" substances and the "unknown" chemical selected for their class.]

III. Science Seminar (10 minutes)

A. Sharing the results

[After the students have determined, on their own, the identity of the Unknown Substance, have several teams stand and announce their results.]

B. Graphing and interpreting the data

[Ask the students how they determined the identity of the Unknown Substance. Based on the Unknown Substance's physical and chemical properties, ask the students to talk about how the chemical might have behaved if it had made its way into Upper Three Runs Creek.]

- How would the soluble starch, sucrose, sodium bicarbonate, or calcium sulphate hemihydrate have affected the water, the plants, the animals, the soil?
- Would it have been soluble or settled to the bottom of the creek?
- Would it change the color of the water or the pH?

IV. Close out (10 minutes)

A. Wrap-up questions

[Take a minute to answer questions the students may have come up with during the activity, and to assess their comprehension of the material covered.]