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ABSTRACT

Recognizing basic elements as building blocks is essential to the study of science, and looking closer at one element in particular, chlorine, can help ignite students' interest in chemistry. This document contains a 2-day study of building block chemistry using basic concepts and easy-to-find materials. Teaching materials include objectives, safety notes, disposal of solutions, teaching strategies, sample student data table, chlorine background information, chlorine chemistry and product tree, and student worksheets. (MKR)

ED 393 650

CHLORINE CAN BRING CHEMISTRY TO LIFE

Introduce students to chemistry without tackling the whole periodic table at once.

MATERIALS ENCLOSED

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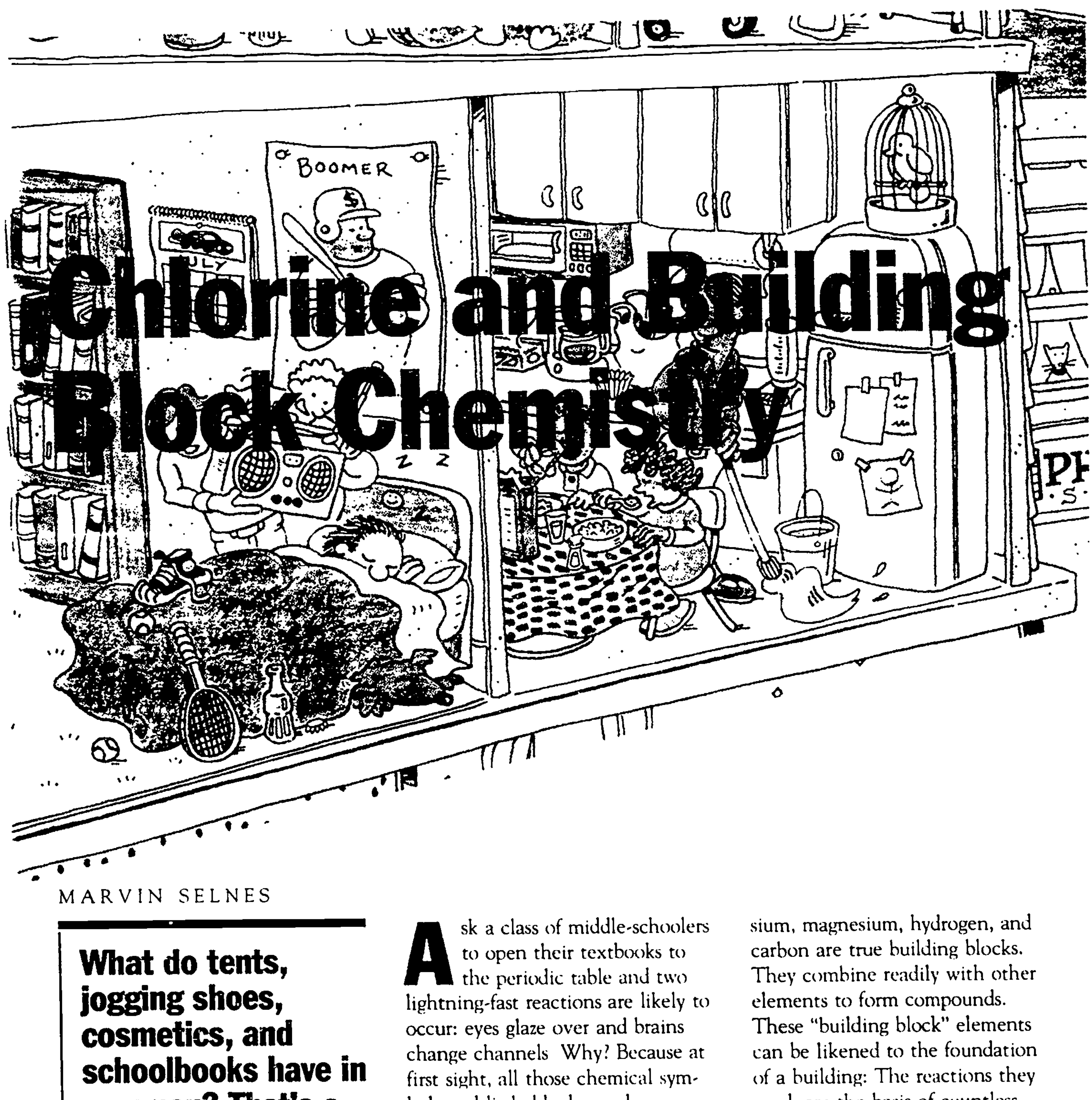


Chlorine and Building Block Chemistry

MARVIN SELNES

What do tents, jogging shoes, cosmetics, and schoolbooks have in common? That's a good question to ask your science students. Looking for the answer will lead to an eye-opening lesson in building block chemistry.

Ask a class of middle-schoolers to open their textbooks to the periodic table and two lightning-fast reactions are likely to occur: eyes glaze over and brains change channels Why? Because at first sight, all those chemical symbols and little blocks send one message, "Huhhh?"

In reality, those blocks represent more that 100 pure elements that combine to build just about everything in the world. That's a pretty awesome idea, even if your hero is Bart Simpson.

Even more incredible is the fact that just a handful of those elements make up over 99 percent of the Earth's crust, atmosphere, and oceans by weight. Oxygen, chlorine, silicon, aluminum, iron, phosphorous, calcium, sodium, potassium, magnesium, hydrogen, and carbon are true building blocks. They combine readily with other elements to form compounds. These "building block" elements can be likened to the foundation of a building: The reactions they spark are the basis of countless chemical formations.

Recognizing these elements as building blocks is essential to the study of science. And looking closer at one element in particular—one of the liveliest on the periodic table—can help ignite students' interest in building block chemistry.

Marvin Selnes is a science supervisor for the Sioux Falls School District in South Dakota.

Chlorine, an element that's everywhere

Of all the elements, chlorine is among the most active. It is almost never found free, or uncombined, because chlorine teams up with nearly every element it meets—in nature, in the research lab, or at a manufacturing plant.

That's why chlorine is often found in some surprising places and products. Chlorine makes up two percent by weight of all sea water on Earth. Chlorine is in our bodies and in our blood; it forms the hydrochloric acid that helps our stomachs digest food. While most people are aware of chlorine's use in swimming pools, in laundry bleach, or as a drinking water disinfectant—they may never guess that chlorine is used to make tents, jogging shoes, telephones, cosmetics, or schoolbooks.

Chlorine compounds are used in the production of thousands of consumer goods, pharmaceuticals, and industrial products. The process can be very complex, such as the use of chlorine compounds in making polyester or polyvinyl chloride (PVC) products, such as vinyl rain gear and house siding. Or it can be extremely simple. Combining sodium with chlorine yields sodium chloride, a product that's part of many meals—table salt.

Without chlorine compounds, we wouldn't have many of the products and services that we often take for granted. Skeptics need only look around the classroom—notebook paper, electronic gadgets, pencil erasers, cassette tapes—to grasp the real-life impact of chlorine and other building block chemicals.

Chlorine and public health

Because water is so basic to our existence, ensuring safe drinking water also would be a natural topic for student exploration and class discussion. For example, the Latin American cholera epidemic in the news over the past year is a shocking reminder of what can happen when drinking water is not adequately disinfected. In fact, it is estimated that more than 25,000 children worldwide die every day from causes related to dirty water.

At the same time, questions have been raised about potential risks from drinking water that has been disinfected. While disinfection eradicates such life-threatening diseases as cholera, typhoid, and dysentery, some studies suggest it also may slightly increase the risk of certain types of cancer. The scientific and public health communities recognize that the benefits of disinfected drinking water outweigh the potential risk. But why not find out for yourself? Explore these issues with your students. As a class, weigh the risks and benefits of water disinfection.

Talk with your local public health officials to learn more about the threat of waterborne diseases and the use of chemicals (including chlorine) for water disinfection. Contact your local water-treatment authorities to arrange a visit to a local water plant for a close-up view of how water is made safe to drink. Conduct library research to learn more about waterborne diseases on a global scale. Perhaps most educational, facilitate class discussion on what students have learned, including how society uses science to weigh risks and benefits in areas such as public health.

From whiter whites to leukemia medications

Chlorine, the seventeenth atomic element, was discovered in 1774 by the Swedish chemist Carl Wilhelm Scheele. His find heralded the way for whiter whites. The bleaching properties of this new gas were an instant improvement over the only other method of lightening fabrics: bleaching them in the Sun for six weeks. However, there was one drawback. Chlorine gas rusted the metal machinery and equipment of the day, so it was not widely used. But in 1789, chlorine was combined with a potash solution that made it easier to use.

Interest in chlorine grew rapidly. Antoine Lavoisier, James Watt, Michael Faraday, and Humphry Davy (who first proved chlorine was an element) all experimented with chlorine. But it wasn't until early this century that chlorine's public health and commercial benefits became evident. Chlorine was found to be an effective drinking water disinfectant, virtually eliminating the threat of waterborne disease. About the same time, the discovery of an economical way to cool and pressurize chlorine gas paved the way for widespread commercial applications.

Today, chlorine is produced by electrolysis. An electrical current passed through salt water (from the sea or underground salt deposits) splits positive sodium and negative chloride ions. Since opposite charges attract, the negative chlorine ions collect at the positive poles to form molecular chlorine gas. The gas is dried, chilled, and pressurized or converted to liquid for storage and shipping. Chlorine is used as a building block in a range of products from laundry bleach to ski boots to leukemia medications.

Tune in students' imaginations to building block chemistry and hear some natural reactions—the "ahhs" and "ohhs" of discovery.

Introducing building block chemistry

Chlorine and chlorine compounds are a good way to introduce your students to building block chemistry without tackling the whole periodic table at once.

On its own, chlorine has a distinct odor, although smelling chlorine is not recommended. Liquid chlorine is amber in color. And in low concentrations, chlorine gas is nearly invisible. But when chlorine combines with other elements it *does* things that will keep students tuned in. Chlorine compounds can turn blue, brown, or sparkling white. They can change odor or have none at all. They can be hot or cold. They can bubble, liquefy, or harden. The ever-changing physical properties of chlorine compounds and the activities on the attached poster can help you deliver a two-day lesson on "What's in this stuff?"

Start by awing your students with magic: Turn "wine" (water tinted with red food coloring) into water right before their eyes. Household bleach, or sodium hypochlorite, is the secret ingredient that clears up the water. Once the secret is out, point to the poster to launch a hunt for all the unexpected things chlorine compounds help build. On day two, give students an opportunity to put chlorine to the test themselves—experimenting with a variety of chlorine salts—to see what happens when chlorine combines with other compounds. For instance, when light blue chunks of copper chloride react with ammonia, they turn dark blue. However, copper chloride's reaction with water and aluminum is surprisingly different; the new mixture bubbles, gets warm, and turns brown. A video that complements the lesson plan is also available free from the Chlorine Institute. (See box for information).

The accompanying poster and activities were developed and tested by science teachers, with support from the Chlorine Institute, to supplement regular classroom chemistry studies. The objective of the lesson plan is to help students understand that chlorine is just one of several important single elements or building blocks essential to the production of a variety of different compounds.

The lesson procedures and guidelines are complete, easy-to-use resources and tools for teachers. They can be implemented as they are or adapted to meet your needs. Lesson objectives, teaching strategies, and key discussion points are provided. Student hand-outs can easily be photocopied from the back of the poster. The materials used in the experiments can be obtained inexpensively through any school science supplies vendor. Always follow your schools' safety precautions regarding chemical use, including providing protective eyewear for students.

More building block chemistry

For your free copy of the *Building Blocks of Our World: Chlorine* video or additional activities that illustrate the use of chemicals in everyday life, please contact **Schools,**
Chlorine Chemistry Council
2501 M Street, N.W.
Washington, D.C. 20037
(202) 887-5418

Other activity resources

Chemical Education for Public Understanding Program (CEPUP)
Lawrence Hall of Science
University of California
Berkeley, CA 94720
(510) 642-8718

The American Chemical Society
Education Division
1155 Sixteenth Street, N.W.
Washington, DC 20036

In addition, the Chemical Manufacturers Association publishes an education resource guide that identifies classroom support material available from more than 50 chemical companies.

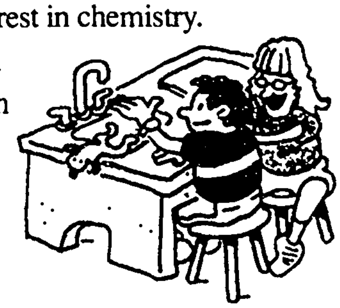
The Chemical Manufacturers Association
Education Services
2501 M Street, N.W.
Washington, DC 20037

CHLORINE CAN BRING CHEMISTRY TO LIFE

Introduce your students to chemistry without tackling the whole periodic table at once.

Recognizing basic elements as building blocks is essential to the study of science. And looking closer at one element in particular—**chlorine**—can help ignite students' interest in chemistry.

The following two-day study of building block chemistry uses basic concepts and easy-to-find materials. Additional free materials that can extend your lessons on chemicals in everyday life are available by writing to: **Schools,** Chlorine Chemistry Council, 2501 M Street, NW, Washington, DC 20037.



TEACHER MATERIAL

Chlorine: One very special building block

Objectives

The students will:

- Understand that chlorine is one of several important single elements or "building blocks" of matter which can be combined to produce a variety of different compounds.
- Observe and record different chemical and physical properties of selected chlorine compounds
- Understand that chlorine compounds are used to make products that play important roles in homes, schools, and industry.

Safety notes

Instruct students not to bring the chemicals into contact with their eyes, skin, nose or mouth. Remind students to wash their hands after the activity. Follow your school policy regarding the use of student safety eyewear. **Safety eyewear is strongly recommended.**

Disposal of solutions

These solutions can be disposed of in the sink or collected for later disposal, according to existing local regulations. Always check for local restrictions on disposal.

Teaching strategies

Day One—Building Awareness

(Before class, fill two clear plastic 8-ounce cups half full of warm water. Add one drop of red food coloring to one cup. Add 3 - 4 droppers full of full strength household bleach to the other. If larger containers are used, adjust the proportions accordingly.)

Ask students to observe very closely, because you are about to perform some chemical "magic." Display the two cups. Ask the students to describe what they see. Most will say that one is a solution of red food coloring and the other contains water. Pour the red solution into the "water" and set aside. In 30 - 60 seconds (exact time varies) the solution will mysteriously clear!

Continued on back.

Ask students to explain what they have observed. Explain, if needed, that the second cup contained bleach, or sodium hypochlorite. (You may wish to contrast observation and inference at this time.) Tell students that chlorine is present in many other compounds that are a common part of our daily lives. Distribute student sheet 1, "Chlorine in our lives," and ask students to mark off those items they use or see in school.

Discuss their responses. Explain that chlorine likes to combine with other elements and compounds, and scientists have found ways for chlorine to help build or improve things. Define "element" and "compound" as needed. Ask them to take the student sheet 1 home to check for household items containing chlorine or requiring chlorine during the manufacturing process. Tell them they may want to ask their parents for help.

Introduce chlorine as an important "building block," one of a handful of single elements that combine to form most of the matter on the earth. Write the names of the following elements on the chalkboard or overhead projector: oxygen (O), silicon (Si), aluminum (Al), iron (Fe), calcium (Ca), sodium (Na), potassium (K), magnesium (Mg), hydrogen (H), phosphorus (P), chlorine (Cl), and carbon (C). Use chemical abbreviations if desired. Tell students that these elements are sometimes called "building blocks" because they make up over 99% of the earth's crust, atmosphere, and oceans, by weight.

Tell the students that tomorrow they will explore a variety of chlorine compounds.

Day Two—The Science

Recall the list of chlorine compounds the students took home yesterday. Discuss their findings. Review the "building block" concept with the students, noting that chlorine combines with many other elements to form different compounds, each with different chemical and physical properties.

Tell them they will get a chance to work with several different chlorine compounds. Distribute student sheet 2, "Exploring chlorine compounds." Discuss the procedure with students. Highlight the difference between physical properties (appearance, color, odor, etc.) and chemical properties, which are determined by the interaction of the chlorine compound with other substances.

Make materials available and allow students to complete the activity, assisting as needed. Be sure that students follow recommended safety precautions when using these materials. The chloride salts can be obtained easily and inexpensively from almost any vendor of school science supplies, or contact local high school chemistry teachers. Litmus or other indicators can be used instead of pH paper. Sample student data tables and answers are listed below.

Discuss student results and summarize the main points of the activity. If students had trouble observing the temperature change with calcium chloride, tell them to try again with more solid. Hydrogen gas is given off when copper chloride reacts with aluminum foil. Iron chloride reacts with aluminum foil, but much more slowly, taking several minutes to produce observable results.

Sample student data table

compound	appearance	temperature change in water	acid, base or neutral	aluminum foil reaction	color change with ammonia
iron chloride	yellow-brown chunks	no change	acid	bubbles, gets warm, brown solid	red-brown solid forms
calcium chloride	large white irregular chunks	gets warmer	neutral	no reaction	no change
sodium chloride	white crystals	no change	neutral	no reaction	no change
cupric chloride	light blue chunks	no change	slightly acid	bubbles, gets warm, brown solid	dark blue solid forms

Answers to questions

1. Which of the chlorides seem to have the most similar physical properties and chemical properties? Sodium and calcium chloride seem to have the most similar properties. Although dissimilar in appearance and in their reaction with water, they are both white, form neutral solutions and do not react with aluminum foil or ammonia. Cupric and iron chloride both form acid solutions in water and react with ammonia and aluminum foil. The least similar physical properties and chemical properties? Answers vary. Cupric chloride has no common properties with either ammonium chloride or calcium chloride. Others may have some common properties.

2. How do you explain the differences in the chemical and physical properties of these chlorides? Student answers should indicate that all the compounds contain chlorine. Therefore any differences in properties must be due to the other chemicals present in the compounds.

3. How do the observations you made in this activity support the idea of chemicals as "building blocks?" (Note that chlorine is a gas at room temperature and has a strong odor.) Each chloride is a solid at room temperature and has no detectable odor. Each chloride has chemical and physical properties that differ from chlorine gas—and each other chloride. These changes result from the different elements or "building blocks" that combine with chlorine to form each compound.

BACKGROUND

Chlorine: A Common Building Block

Chlorine, oxygen, silicon, aluminum, iron, calcium, sodium, potassium, magnesium, hydrogen, phosphorous and carbon make up over 99 percent of the earth's crust, atmosphere and oceans (by weight). These elements are truly "building blocks"—they combine with other elements to form our world.

Chlorine chemistry

Chlorine is commonly found in nature, but almost always in combination with other building blocks. Chlorine's structure makes it very reactive (its outer shell is missing just one electron), which makes it attractive to other atoms and molecules. Because it is so reactive, it is very useful to chemists, engineers and other people involved in making things we use every day. When combined with other chemical building blocks, chlorine can change the nature of a substance, and build or improve a product.

To be used in manufacturing, chlorine must first be separated from the other elements with which it is combined. Manufacturers use a process known as "electrolysis," which breaks down salt water into basic components, including chlorine. An electrical current passes through the salt water and splits apart the positive sodium and negative chloride ions. Since opposite charges attract, the negative chloride ions collect at the positive poles and form molecular chorine gas. The gas is dried, chilled and pressurized, or converted to liquid for storage and shipping.

In other words:

$$\text{Salt+Water} \xrightarrow{\text{electricity}} \text{Chlorine+Caustic Soda+Hydrogen}$$

or:

$$2NaCL + 2H_2O \xrightarrow{\text{electricity}} Cl_2 + 2NaOH + H_2$$

Using chlorine

Where does chlorine go then? Into thousands of things you see and use every day. Every time you drink a glass of water, read a newspaper, put on a vinyl raincoat, brush your teeth or drive a car, you are using chlorine in some form.

Chlorine guards against diseases such as cholera, typhoid fever and dysentery in drinking water. Places like hospitals, households and swimming pools use chlorine-based compounds (such as bleach) for their disinfection needs. About 85 percent of the top-selling medicines are manufactured using chlorine chemistry. Chlorine also is used to manufacture versatile plastics such as vinyl (polyvinyl chloride). Crop-protection chemicals based on chlorine help feed the world and ward off insect-borne diseases. Chlorine helps ensure that products like disposable diapers and paper towels are strong and absorbent.

Chlorine also plays a role in the classroom. For example, it is used to make the vinyl and polyester in backpacks, is a critical component of computer chips, helps in the production of rubber for pencil erasers, and strengthens and brightens notebook paper.

Are all chlorinated compounds alike?

Just because a chlorine molecule is attached to something does not make it the same as something else containing chlorine. For example, consider the following four salts. All contain chlorine, but they are not alike; each contains a different set of building blocks and offers unique characteristics.

Iron (ferric) chloride ($FeCl_3$): Used to make pigments, inks and dyes, in controlling odors and removing phosphates from municipal waste water, in photographic processes, and as medicine.

Calcium chloride ($CaCl_2$): Used (when in a water solution) as antifreezes and in refrigerating solutions, in preservation of wood and stone, in the manufacture of glues, cements and fireproof fabrics, and to speed the setting of concrete.

Sodium chloride ($NaCl$): Used in ceramic glazes, soap manufacturing, fire extinguishing solutions, and—of course—as table salt.

Cupric chloride ($CuCl_2$): Used in wood preservation, in the fabric dyeing process, and, when mixed with other copper salts, as an agricultural fungicide.

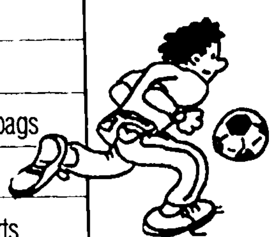
STUDENT SHEET #1

Chlorine in our lives

Many of you may know that chlorine is used in swimming pools, and to keep our water safe to drink. But chlorine has many other important uses as well. It is a "building block" in thousands of products: medicines, plastics, other chemicals, paper products, etc.

- Chlorine is used to manufacture each of the following products. Which have you used recently? Circle the products you have used or seen used **at school** in the past week.
- Take this sheet home. Check ✓ the products you have used **at home** in the past week. Ask your parents, or an adult at home, to look over your answers. Add items to the list if you can.

tents	awnings	luggage	seat covers
golf bags	bicycle seats	nylon	floor coverings
wallpaper	camera film	insulation	baby strollers
air conditioners	car bumpers	fabric dye	perfume
deodorants	drain cleaners	household bleach	toothpastes
paint removers	dry cleaning	adhesives	cosmetics
sleeping bags	electronic parts	shoes	toys
adhesive bandages	erasers	oil additives	fungicides
soft drink bottles	fire extinguishers	PVC pipe	detergents
fire resistant fabrics	fishing poles & line	handbags & purses	prescription drugs
gelatin	flash bulbs	fireworks	hair permanents
toothbrushes	furniture fabrics	pen tips	soft drinks
automobile tires	garden hose	newspaper	guitar strings
baby cribs	compact discs	boats	shower stalls
spot removers	leather processing	circuit boards	dental cements
coffee filters	notebook paper	paper towels	seat cushions
paint	plastic bottles	household glue	anesthetic
refrigerators	upholstery	exercise equipment	polyester fabric
umbrellas	seat covers	window screens	telephones
gasoline	semiconductors	mirrors	food additives
brushes	camera cases	photographs	vitamins
jogging shoes	tennis shoes	boat sails	antifreeze
tennis racket strings	caulks and sealants	card tables & chairs	paper & plastic bags
watch straps	wallets	raincoats	audiotape
sunscreens	weed killers	computer parts	power tool parts



STUDENT SHEET #2

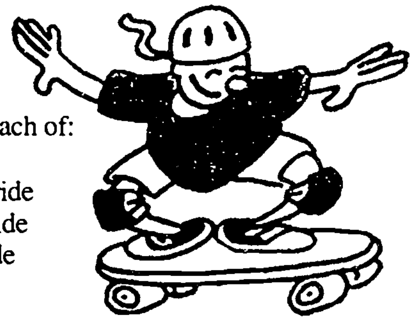
Exploring chlorine compounds

Purpose

You will observe and compare the physical and chemical properties of different chlorine compounds.

Materials

Magnifying glass
Aluminum foil, 1 x 4 cm strip
pH paper, 4 strips
Chemplate or 4 small jars or test tubes (with rack)
Small jar of tap water
Dropper bottle of household ammonia
Dropper
Small spoon
Paper towel
Small spoonful each of:
- iron chloride
- calcium chloride
- sodium chloride
- cupric chloride



Safety

Please be sure to use safety eyewear and to follow all other safety precautions. Do not taste or smell any of the chemicals.

Procedure

1. Examine each of the chlorides with the magnifying glass. Record your results on the data table.

2. Place half a small spoonful of iron chloride in a test tube or chem plate. Add 20 drops of water. Feel the outside of the tube. Record any up or down temperature change in the data table. Repeat for the other chlorides.

3. Dip a piece of pH paper in the iron chloride solution. Record the acid/base properties in the data table (red or pink = acid, no change = neutral, light green or blue = base). Repeat for the other chlorides.

4. Tear the aluminum foil into four equal pieces. Add one of the pieces to the iron chloride solution. Record your observations on the data table. Repeat for the other chlorides. Clean and dry the test tubes or chem plates.

5. Place half a small spoonful of iron chloride in a clean test tube. Add 20 drops of water. Add five drops of household ammonia. Record your observations in the data table. Repeat for the other chlorides.

Follow your teacher's instructions for clean-up and return of materials.

Data table

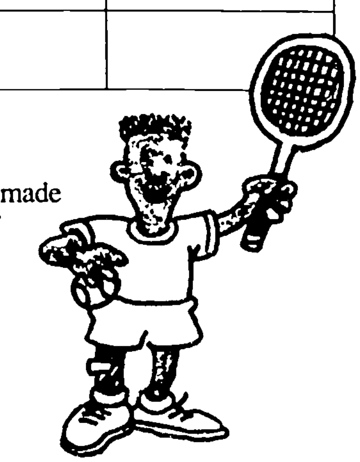
compound	appearance	temperature change in water	acid, base or neutral	aluminum foil reaction	color change with ammonia
iron chloride					
calcium chloride					
sodium chloride					
cupric chloride					

Questions (answer on back)

1. Which of the chlorides seem to have the most similar physical properties and chemical properties? The least similar physical and chemical properties?

2. How do you explain the differences in the chemical and physical properties of these chlorides?

3. How do the observations you made in this activity support the idea of chemicals as "building blocks?"



ADDITIONAL ACTIVITY

Eliminating Microorganisms from Water

Adding chlorine to drinking water has virtually eliminated waterborne diseases such as cholera in North America by destroying disease-causing microorganisms. You can safely and easily demonstrate how chlorine protects public health by removing microscopic life from a water culture that you create.

Materials

Tap or fresh water (untreated water will yield more microorganisms)

Wide-mouth glass vessel that holds about a quart of water (e.g., Mason jar) and several smaller glass vessels

Container and heat source to boil water

Handful of dry hay or straw (dry, untreated grass will do)

Microscope (minimum 100 power) with glass slides

Liquid laundry bleach (5.25% sodium hypochlorite)

Measuring cup

Eyedropper

Plastic stirrer

Thin rubber gloves

Safety goggles or glasses

Paper towels

Safety

- Wear rubber gloves during the experiment. Do not allow culture to contact your body (people with cuts should not touch the culture).
- Follow all label directions on bleach (it will bleach clothing).
- Keep hands away from face during the experiment. Wear safety goggles/glasses when handling the bleach.
- Thoroughly clean all equipment, gloves and hands when finished.
- Dispose of the culture in the toilet. Dispose of bleach solution in sink followed by a five-minute flush with cold water, and dispose of other materials in a clean trash bag.

Procedure

1. Boil about one quart of water (tap or freshwater) for two minutes, let cool to room temperature, and pour into a thoroughly clean, wide-mouth glass vessel. Put a handful of dry hay, straw or grass into the vessel and set it aside in a darkened place at room temperature for seven to nine days. You are creating a water culture that will teem with microscopic life.

2. After the wait, place a glass slide on the microscope and use the eyedropper to put a drop of the water culture on the slide. (Place a cover slip on the water culture drop). You and your students will be able to view many microscopic life forms, including protozoa (amoebas, parameciums) and nematodes (microscopic worms) moving around. These are the same types of organisms which live in surface waters and are removed during the water-chlorination process. In fact, certain protozoa are responsible for amoebic dysentery and giardia, which are common illnesses associated with water that is not properly chlorinated. Use several slides to sample water and view life forms from different parts of the culture.

3. Now pour about one cup (eight ounces) of the water culture (being careful not to spill) into another clean container. Make up a solution of one part bleach to nine parts water in another container. After stirring the solution and rinsing the eyedropper, place about 20 drops of bleach solution into the cup of water culture; stir the water culture/bleach solution and let sit for about one minute. Thoroughly rinse the eyedropper in tap water and examine several drops of the bleach-treated culture. You should see no animals still alive in the water.

Suggestion

Arrange a field trip for your class to the local water treatment facility to learn where tap water comes from and why water disinfection and source water protection are important. Discuss tradeoffs involved (e.g., disinfection by-products vs. microbial contamination).

Instructor's notes

If microscopes are not available, use pond water and add chemical fertilizer and set in direct sunlight, allowing eutrophication to take place.

Chlorine Chemistry Council, 2501 M Street, N.W., Washington, D.C. 20037

ADDITIONAL TEACHER BACKGROUND

Balanced Equations for the Chloride Salt Activity

ammonium chloride + ammonia

NH_4Cl (aq) +NH_3 (aq) --> no reaction

ammonium chloride + aluminum foil

NH_4Cl (aq) + Al (s) --> no reaction

cupric chloride + ammonia

$CuCl_2$ (aq) + NH_3 (aq) --> $Cu(NH_3)Cl_2$ (aq)
[note: some $Cu(OH)_2$ may be produced]

cupric chloride + aluminum foil

$3CuCl_2$ (aq) + 2Al (s) --> 3 Cu (s) + 2 $AlCl_3$

ferric chloride + ammonia

$FeCl_3$ (aq) + 3 NH_3 (aq) + 3 H_2O --> $Fe(OH)_3$ (s) + 3 NH_4Cl (aq)

ferric chloride + aluminum foil

$FeCl_3$ (aq) + Al(s) --> $AlCl_3$ + Fe (s)

calcium chloride + ammonia

$CaCl_2$ (aq) + 2 NH_3 (aq) + $2H_2O$ --> Ca $(OH)_2$ + 2 NH_4Cl (aq)

BACKGROUND

Natural Chlorine? You Bet!

By Dr. Gordon W. Gribble

Chlorine's Natural Abundance

Most people know that table salt — a natural mineral essential for the proper functioning of our nervous and muscular systems — is sodium chloride. But many would be surprised to know that hundreds, probably thousands, of organic chlorine chemicals are produced by an array of biological and natural chemical processes in our environment. Many of these chemicals are identical to highly publicized man-made organochlorines: chlorophenols, chlorinated hydrocarbons, PCBs, CFCs and dioxins. But many others are entirely new molecular entities, many of which possess extraordinary and important biological properties similar to those of penicillin, morphine and the new anti-cancer drug taxol.

As a fundamental chemical element, chlorine is not only abundant in the Earth's crust (ranking 18th in the list of elements) but it is also ubiquitous in our soil, rivers, lakes, trees, plants and, of course, oceans. Like other common elements — carbon, hydrogen, oxygen, nitrogen, sulfur, phosphorous — that are present in all living things, it would appear that chlorine and the other halogens (bromine, iodine and, to a lesser extent, fluorine) are present as well. Although only 30 natural organochlorines had been discovered by 1968, as of April 1994, this number has grown to over 1000. And more are being discovered every month.

Organochlorine and the related organobromine compounds are produced naturally by marine creatures (sponges, corals, sea slugs, tunicates, sea fans and jelly fish) and seaweed, plants, seeds, trees, fungi, lichen, algae, bacteria, microbes and insects. The ocean is the single greatest source of different organochlorines. Nearly 100 different organochlorine, organobromine and organoiodine compounds are present in "limu kohu," the favorite edible seaweed of most Hawaiians. Other seaweeds produce bromoform, chloroform, carbon tetrachloride, methyl bromide and numerous polyhalomethanes. It had been reported that ozone destruction in the lower Arctic atmosphere is linked to the bromoform that is produced in large quantities by sea ice algae. As a matter of fact, the "smell of the oceans" is probably due to these volatile organochlorines and other organohalogens. A species of marine worm from the Gulf of Mexico secretes 20 different halogenated compounds, mainly phenols.

Chlorine Compounds Are Crucial for Survival

Extensive research has shown that these organochlorine compounds are **not** derived from pollutants but, rather, are produced by individual organisms for very specific purposes. They play an essential role in the organisms' survival, and their ability to synthesize these compounds has evolved over time under the stress of natural selection.

Many of these natural organochlorine compounds are used in chemical defense — as feeding deterrents, irritants, or pesticides — or to facilitate food gathering. One marine algae compound, called telfairine, which is chemically similar to many chlorinated pesticides, is 100 percent lethal to mosquito larvae at ten parts per million (ppm), and a related natural chlorinated chemical is three times more effective than the commercial chlorinated pesticide Lindane against mosquito larvae.

Other organochlorines serve as hormones. Plants such as lentil and sweet pea use 4-chloroindoleacetic acid as a growth hormone, and a Chinese folk medicine plant contains five natural chlorinated compounds. The German cockroach manufactures two chlorinated steroids as trail pheremones used in food gathering; the Lone Star tick produces 2,6-dichlorophenol as a sex pheremone; and locusts employ chlorinated proteins to strengthen the cuticle. A *Penicillium* species produces 2,4-dichlorophenol, the same chemical that man uses to synthesize the herbicide 2,4-D. Recently, a tiny Ecuadoran frog was found to secrete a chlorinated alkaloid, which is 500 times more powerful than morphine as a pain-killer and which is believed to thwart predators such as birds.

It is only a matter of time before many natural organochlorine compounds are found in humans. Indeed, organoiodines (thyroid hormones) and one organobromine compound are well known to be present in humans.

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Chlorine Chemistry Council, 2501 M Street, N.W., Washington, D.C. 20037

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An astonishing research development is the discovery that our immune system actually uses chlorine, bromine and iodine to halogenate and kill invading microorganisms. For example, cellular enzymes in mammalian white blood cells oxidize natural blood chloride (bromide and iodide) into active chlorine. This causes the death of pathogens (bacteria, yeast, fungi and even tumor cells) by chlorination. Chlorination is apparently as natural a biological process as blood clotting or salivation.

Part of Nature's Recycling Process

Nature is an incredible recycling center. Insects, microorganisms and fungi all break down dead matter to simpler chemicals for reuse. One such organism, the white-rot fungus, decomposes dead trees and other forest plant material. A major natural byproduct of this biological decay is methyl chloride (chloromethane) — the simplest organochlorine. Five million tons of this chemical are produced naturally every year. This amount dwarfs the 26 thousand tons produced annually by man. Some scientists believe that this natural methyl chloride is an innate regulator of stratospheric ozone.

Another breakdown process involves the biodegradation of humic and fulvic acids into phenols and chlorophenols. Several studies have shown that this natural production of chlorinated phenols outweighs man-made sources. For example, the total pool of chlorinated compounds in peat bogs in Sweden is several hundred thousand tons in areas where these chemicals can only be of natural origin. By comparison, the largest industrial source of these chemicals in Sweden is from the paper pulp industry, which produces 10,000 tons per year. Although "environmentalists" try to link the presence of organochlorine compounds in water samples to man-made causes, naturally produced chemicals have been found in groundwater samples dating back 5200 years.

Because organic matter contains natural chloride (up to 10,000 ppm) and this reacts to form organochlorines at high temperatures, methyl chloride, methyl bromide and many other haloalkanes are produced when organic matter burns.

This natural chemical process occurs in forest fires and volcanos. In fact, it has been estimated that the largest [natural] source of dioxins in the environment is from forest fires, of which 200,000 occur annually (most of which are caused by lightening; *e.g.*, the Yellowstone fires in 1988). Indeed, dioxins have been identified in 100-year-old preserved soil samples.

Both Mount St. Helens and Hawaii's Kilauea, the latter of which has been erupting since 1983, produce methyl chloride. The Kamchatka volcanos in Siberia and Guatemala's Santiaguito volcano emit CFCs in quantities well above background levels. Many organochlorines now known to be produced by volcanos including tetrachloroethylene, chloroform, carbon tetrachloride, methylene chloride and several of the CFCs, were formerly thought only to result from the actions of man! From one Kamchatka volcanic vent, CF_2Cl_2 was detected in levels of 160 ppb, 400 times that of the background atmosphere. Such natural chlorine and fluorine compounds are produced by the combustion of organic material, such as vegetation, sediments or fossil soils in the presence of chloride and fluoride minerals. The extent to which these natural organochlorines and CFCs contribute to the global picture vis-à-vis ozone depletion remains to be seen. A study of Mount St. Helens ash revealed the presence of three previously unknown isomers of polychlorobiphenyls (PCBs) presumably formed from the combustion of carbon- and chloride-rich plant material during the 1980 eruption.

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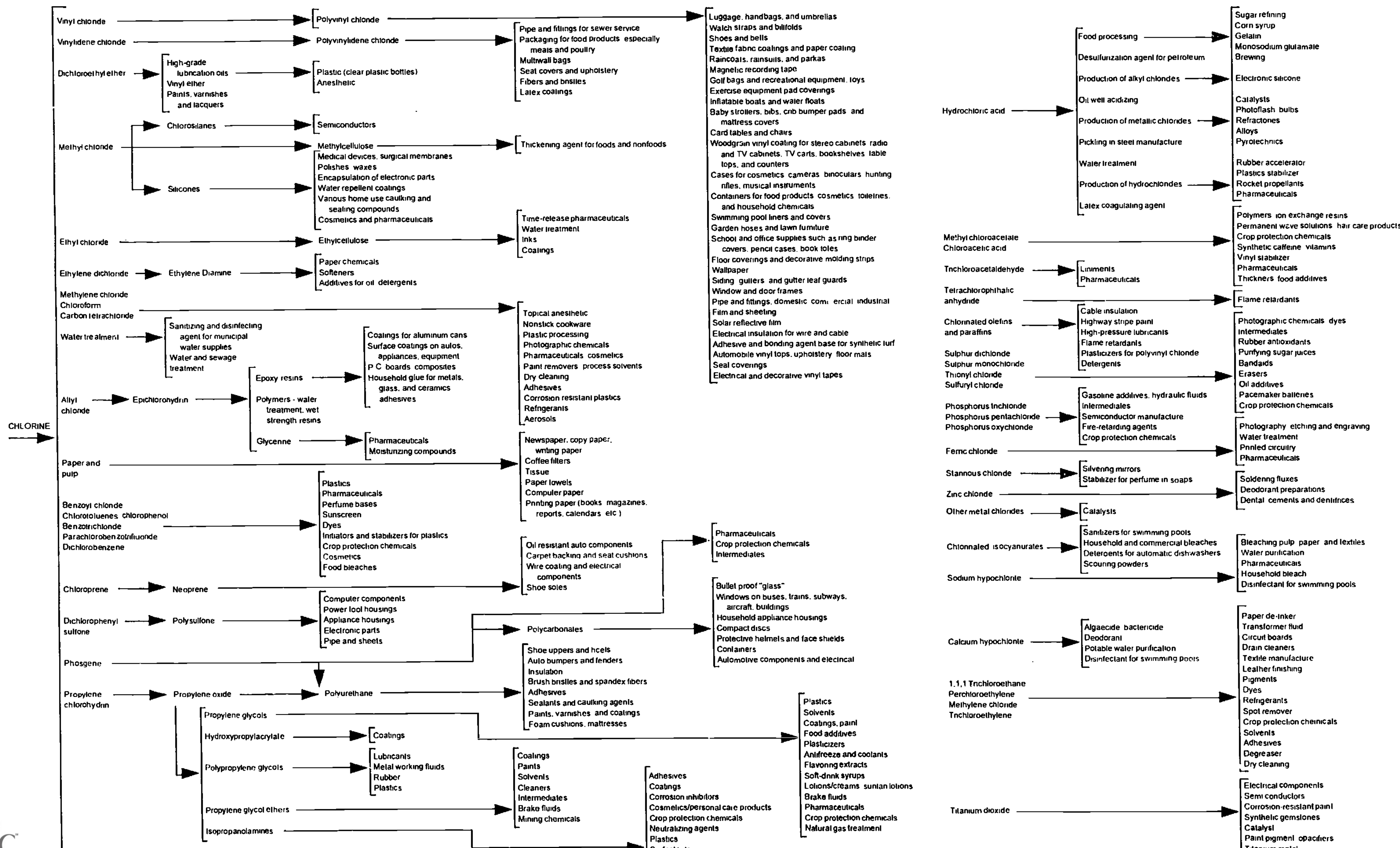
CHLORINE CHEMISTRY AND PRODUCT TREE



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