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LESSON:

Using Chemistry to Treat Lead Poisoning

Summary: Students read the article "Challenging Assumptions about Lead and IQ: Effects Increase, Not Decrease, in Older Children" and conduct a chelation experiment to simulate how lead can be removed from the body. Includes lab activity.

EHP Article: "Challenging Assumptions about Lead and IQ: Effects Increase, Not Decrease, in Older Children"
EHP Student Edition, August 2005, p. A324
http://ehp.niehs.nih.gov/docs/2005/113-5/ss.html#chal

Objectives: By the end of this lesson students should be able to:

1. describe the chemistry of how a chelating agent such as succimer can remove lead from the body;
2. set up and conduct experiments involving weighing solids, measuring liquid volume, and making solutions;
3. explain the formation of a chemical precipitate; and
4. list sources of lead contamination in our environment and some of its health effects.

Class Time: 1.5–2 hours

Grade Level: 9–12

Subjects Addressed: Biology, Life Science, Environmental Science, Chemistry

Prepping the Lesson (15–20 minutes)

INSTRUCTIONS:

1. Obtain a class set of *EHP Student Edition*, August 2005, or download "Challenging Assumptions about Lead and IQ: Effects Increase, Not Decrease, in Older Children" at http://ehp.niehs.nih.gov/docs/2005/113-5/ss.html and make copies.
2. Review the article and lesson.
3. Review and make copies of the Student Instructions.
4. Review the manufacturers' material safety data sheets for ethylenediaminetetraacetic acid (EDTA), disodium salt, dihydrate crystal, calcium chloride, and sodium bicarbonate (baking soda).
5. Divide the class into groups of 3–4 students, or your preference.
6. Assemble the materials needed for the laboratory activity.

MATERIALS:

Per Student

- 1 copy of *EHP Student Edition*, August 2005, or 1 copy of the article "Challenging Assumptions about Lead and IQ: Effects Increase, Not Decrease, in Older Children"
- 1 copy of the Student Instructions
- 1 pair of safety glasses with side shields or goggles (the chemical compounds to be used for this activity are mild eye and skin irritants)

Per Group

- 1–2 eyedroppers
- Triple beam or other type of balance accurate to 0.1 g
- Water
- 100-mL graduated cylinder for measuring the water
- 3 approximately 50-mL containers or beakers (clear plastic drinking tumblers may be substituted)
- Masking tape and markers for labeling containers or beakers

- Sodium bicarbonate (0.6 g per experiment)
- White calcium chloride pellets (ice melter; 0.6 g per experiment)
- EDTA, disodium salt, dihydrate crystal (may be obtained from the chemical supply vendor for your school; 0.5 g per experiment)
- 3 chemical spatulas or plastic knives
- 3 stirring rods or plastic knives for stirring
- Sink or bucket to dispose of water and solutions
- Paper towels to clean up any spills

VOCABULARY:

- blood lead
- calcium chloride
- chelation agent
- chelation therapy
- chemical reaction
- disodium salt
- dihydrate
- ethylenediaminetetraacetic acid (EDTA)
- IQ
- lead
- placebo
- precipitation
- sodium bicarbonate

BACKGROUND INFORMATION:

Lead (Pb) is a heavy, highly toxic metal that has many sources in our environment. Lead was used in many materials and products before the harmful health effects, particularly in children, were recognized. While laws prohibit lead from being used in many products today, lead can still be found in our homes. Older homes may have lead-based paint as lead was not removed from paint until 1978. Lead-based paint is the most significant source of lead exposure in the United States today. People become exposed as the paint disintegrates into dust or flakes into the soil. Removing lead paint during remodeling is also a means of exposure.

Lead may also come from water when it flows through lead pipes, brass fixtures, or lead solder. Lead used as a glaze in ceramic dishes can contaminate food. This is common in ceramics from Mexico. Certain spices, foods, and cosmetics from other countries have also been found to contain lead. Certain jobs and hobbies may include use of lead products, as in working with stained glass. Lead can get into the air, water, food, soil, and even dust from these sources. Both adults and children can then breathe in or swallow these lead-contaminated sources, leading to a wide range of adverse health effects.

Children aged 6 and under, as well as fetuses, are at the greatest risk for health effects associated with lead poisoning. They are particularly vulnerable as their nervous system is still forming. Even low levels of exposure to lead can result in IQ deficits, learning disabilities, behavioral problems, stunted or slowed growth, and impaired hearing. At increasingly high levels of exposure, a child may suffer kidney damage, become mentally retarded, fall into a coma, and even die from lead poisoning. Since lead acts a lot like calcium in the body, it can become deposited in the bones, increasing the risk for future re-exposure to lead as bones form, deteriorate, and rebuild. This mechanism can result in lead exposure to a fetus from a pregnant woman who was exposed to lead as a child.

According to the Centers for Disease Control and Prevention, approximately 310,000 U.S. children aged 1–5 years have blood lead levels greater than the recommended level of 10 micrograms of lead per deciliter of blood (µg/dL). The primary form of treatment for lead poisoning is to stop the exposure by moving to a lead-free location or having the lead professionally removed from the house and soil. If the blood lead levels exceed 45 µg/dL then chelation therapy may be used. Chelation is a medical treatment whereby a chemical agent is used to bind to heavy metals in the body and remove them via excretion.

Chelation therapy is somewhat controversial because of additional potential side effects of the treatment and uncertain benefits. Although chelation has been shown to remove lead from the body, it has not been shown to reduce the neurological impacts of lead exposure. In one rodent study (http://ehp.niehs.nih.gov/docs/2003/6517/abstract.html) scientists found that although succimer reduced blood lead levels, the reduction of lead levels in the brain were small and took much longer. Other potential benefits of chelation therapy, like reduction of storage of lead in the bone or reduction of kidney damage, have not yet been demonstrated.

RESOURCES:

Environmental Health Perspectives, Environews by Topic page, http://ehp.niehs.nih.gov/topic. Choose Children's Health, Lead, Neurology

American Academy of Family Physicians, "Lightening the Lead Load in Children," http://www.aafp.org/afp/20000801/545.html

Centers for Disease Control and Prevention, Childhood Lead Poisoning Prevention Program, http://www.cdc.gov/nceh/lead/lead.htm

Centers for Disease Control and Prevention. 2005. "Blood Lead Levels—United States, 1999-2002." *MMWR Morb Mortal Wkly Rep* 54(20):513–516; http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5420a5.htm

National Institute of Environmental Health Sciences, Environmental Health Resources, curricula and other lead materials, http://www-apps.niehs.nih.gov/outreach-education/Resources/BrowseResults.cfm?Subj=Lead

National Institute of Environmental Health Sciences, "Lead and Your Health," http://www.niehs.nih.gov/oc/factsheets/pdf/lead.pdf

National Safety Council, Lead Poisoning Factsheet, http://safety.webfirst.com/library/facts/lead.htm

National Safety Council, Lead Poisoning Program, http://www.nsc.org/issues/lead

U.S. Department of Housing and Urban Development, Lead Safe Homes, http://www.leadsafehomes.info, click on a location to get started

U.S. Department of Housing and Urban Development, Office of Healthy Homes and Lead Hazard Control, http://www.hud.gov/offices/lead/index.cfm

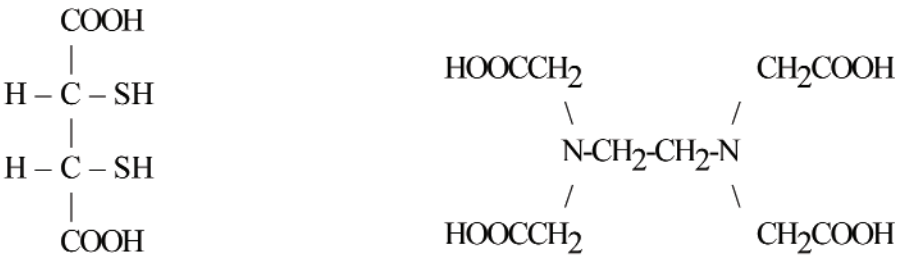
U.S. Environmental Protection Agency, Lead Awareness Program, http://www.epa.gov/opptintr/lead/index.html

Implementing the Lesson

INSTRUCTIONS:

1. Hand out copies of the *EHP Student Edition*, August 2005, and refer your students to the article "Challenging Assumptions about Lead and IQ: Effects Increase, Not Decrease, in Older Children," or hand out copies of the article.
2. Hand out the Student Instructions.
3. Lead a discussion about the research described in the article, focusing on what was studied, what the hypothesis was, and what the conclusions were. You may want to have a discussion about where lead is found in the environment and how people are exposed to it (see Background Information).
4. Explain to students that lead is not easy to get out of the body because it bonds tightly with blood and then becomes deposited in bone, which can be a source of re-exposure later in life. Physicians give people a medicine called a chelating agent to lower the dose of lead in their blood. The chelating agent used in the study was a drug called succimer (SUK-si-mer). The chelating agent bonds with the lead. This prevents the lead from bonding with a person's blood. The lead that has bonded with the chelating agent is then easily excreted into the urine. Using a chelating agent on a person with high blood lead levels is called chelation therapy.
5. Tell students that they will now conduct an experiment to understand how chelation therapy works.
6. There are different chelating agents that can be used to treat lead poisoning but they all follow the same chemistry. Succimer is one chelating agent used in the study, and another is EDTA (ethylenediaminetetraacetic acid). Both look like they have arms or fingers that could grab something. That is how a chelating chemical works. The "arms" or "fingers" grab the lead using a chemical bond (like a claw) and prevent it from bonding with anything else. The word *chelate* comes from the Greek word for "claw." Show your students the structural formulas for succimer and EDTA (Figure 1). (EDTA will be used in the experiment as this chemical can be purchased from the chemical supply vendor for your school.)

Figure 1. Structural formulas for succimer (left) and EDTA (right)



7. Depending on your students, you can expand the lesson by adding as much chemistry as you want (e.g., elements, compounds, chemical formulas, ions, ionic bonding, chemical reactions, precipitation reactions, equilibrium reactions, balancing equations).
8. Divide students into groups. Explain how the activity is to be done, including the following points:
   - Use eye protection. The chemical compounds used in this experiment are mild eye and skin irritants.
   - Review techniques you want students to use for weighing, reading the meniscus in the graduated cylinder, cleanup, etc.
   - Emphasize the steps to be taken to prevent cross-contamination of chemicals (i.e., do not put chemical spatulas into more than one chemical without washing first, do not put a wet chemical spatula into dry chemicals, do not stir different chemicals with the same stirring rod, etc.).
9. Have students conduct the activity.
10. After students have finished conducting the experiment, go over the answers to the questions on the Student Instructions.

Step 2: 8:
- Ask students what they saw when they mixed the calcium chloride solution with the sodium carbonate solution. (The solution turned cloudy, forming a white solid.)
- Ask students what they think is happening in the solution. (The calcium and carbonate in solution are reacting [forming a chemical bond] and coming out of the solution as a solid.)
- Explain to students that the calcium is bonding with the carbonate and that the cloudy white solution is the solid calcium carbonate coming out of the solution because of the reaction. Coming out of the solution in this manner is called precipitation. This is like lead bonding with parts of the body, making it take a long time for the body to eliminate the lead naturally. Lead behaves chemically somewhat like calcium, and that is why so much lead is stored in bones.

Step 2: 9:
- Ask students what they saw when they added the EDTA solution to the cloudy white solution containing the calcium chloride and the sodium bicarbonate. (The solution turned clear again and the white solid disappeared.)
- Ask students what they think is happening now. (The EDTA is forming a bond with the calcium, preventing it from bonding with the carbonate. Since the calcium is no longer available, the calcium carbonate does not form, and the white solid disappears.)
- Explain that this is exactly what happens in the body when a person receives chelation therapy for lead. The chelation drug (EDTA or succimer) bonds with the lead and prevents it from bonding with other parts of the body. The chelated lead is then much more easily eliminated from the blood through the kidneys into the urine.

11. After the chelation experiment, your students will have a better understanding of how a chelating agent can remove lead from the body. Step 3 asks the students to consider whether they would recommend using succimer to treat lead poisoning in children (considering the side effects and the data presented in the article) and what additional information they would need to be able to answer that question (such as whether or not chelation helps minimize damage to other areas of the body, such as kidneys—see the Assessing the Lesson section for more examples). Discuss as needed to help the students with such "if/then" scenarios (e.g., you could write "if/then" statements on the board to provide additional guidance. An example of an "if/then" statement would be "if succimer was shown to decrease kidney damage even though it does not help with IQ, would you use this therapy with a child? Why or why not?").

NOTES & HELPFUL HINTS:

1. Sodium bicarbonate dissolves in water to form sodium ions, hydrogen ions, and carbonate ions. The calcium chloride dissolves in water to form calcium ions and chloride ions. The calcium ions and carbonate ions in water react (ionic bond) and form insoluble white calcium carbonate, which precipitates. As you add the calcium chloride solution to the sodium bicarbonate solution, the mixture turns a cloudy white color as the solid calcium carbonate is created in solution. The equation for this reaction is:

$$NaHCO_3 + CaCl_2 : CaCO_3\ 9 + NaCl + HCl$$

2. The EDTA dissolves in the solution to form an $EDTA^{-4}$ ion. The $EDTA^{-4}$ attaches itself to the Ca^{+2} to form a stable soluble complex of $EDTA^{-4}$ and Ca^{+2}. Since the calcium is no longer available to react with the carbonate, the formation of calcium carbonate is reversed and the solid calcium carbonate disappears.
3. You could also have students check the pH of each of the solutions. Sodium bicarbonate is the salt of a weak acid and, when dissolved in water, is slightly basic. Calcium chloride is the salt of a weak base and, when dissolved in

water, is slightly acidic. The form of EDTA used in this experiment is its disodium salt. When EDTA is dissolved in water, it forms a weak acid solution. One of the reasons that part of the sodium bicarbonate solution is poured into the EDTA solution is to make the solution less acidic. EDTA is acidic enough to cause some of the carbonate to decompose and release carbon dioxide. The sodium bicarbonate is basic and helps neutralize the EDTA acidity.

Aligning with Standards

SKILLS USED OR DEVELOPED:
- communication (note taking, oral, written—including summarization)
- critical thinking and response
- experimentation
- observation

SPECIFIC CONTENT ADDRESSED:
- lead poisoning
- chelation therapy
- precipitate
- chemical reaction

NATIONAL SCIENCE EDUCATION CONTENT STANDARDS MET:

Unifying Concepts and Processes
- Evidence, models, and explanation
- Constancy, change, and measurement

Physical Science
- Chemical reactions

Science As Inquiry
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Science in Personal and Social Perspectives
- Personal and community health
- Environmental quality
- Natural and human-induced hazards

Assessing the Lesson

Students provide written responses to the questions on the Student Instructions. Examples of complete student responses are outlined below for each question. Please note your students' answers will vary.

Step 2: 8. Use the eyedropper to slowly add 25 drops of the "Lead (calcium chloride)" solution into the "Blood (sodium bicarbonate)" container or beaker. The calcium in the calcium chloride is behaving like lead in the body and the carbonate in the sodium bicarbonate is behaving like blood.

What do you see? Give an explanation of what you think is happening.

The solution turned cloudy, forming a white solid. The "Lead (calcium chloride)" bonded to the "Blood (sodium bicarbonate)." In technical terms, the calcium and carbonate in the solution are reacting (forming a chemical bond) and coming out of the solution as a solid (precipitate).

Step 2: 9. Pour all of the EDTA solution into the "Blood (sodium bicarbonate)" container or beaker. Remember, the EDTA is a chelating agent and will bond with lead (the calcium in the calcium chloride) to prevent it from bonding with the blood (the carbonate in the sodium bicarbonate).

What do you see? Give an explanation of what you think is happening.

The solution turned clear again and the white solid disappeared. The "Chelating Agent (EDTA)" bonded to the "Lead (calcium chloride)" removing it from the "Blood (sodium bicarbonate)." In technical terms, the EDTA formed a bond with the calcium, preventing it from bonding with the carbonate. Since the calcium is no longer available, the calcium carbonate does not form and the white solid disappears.

Step 3: The study researchers found that while blood lead levels went down in children who received succimer, their IQ levels were no different that the control group who received the placebo. The side effects of taking succimer include nausea, vomiting, loss of appetite, loose stools, metallic taste in the mouth, drowsiness, dizziness, watery eyes, and headache.

Based on the study results would you give succimer to treat a lead-poisoned child? Explain your reasoning and describe any additional information you would need in order to make this decision.

Answers will vary. Responses should be logical, thorough, and grammatically correct. Answers should consider at least one additional factor such as:

- If the succimer helped prevent or minimize kidney damage, would they use it?
- Does the succimer cause any potential long-term health effects, or are the vomiting, loose stools, and dizziness temporary?
- How do the age, size, and blood lead level of the child influence the effects of succimer?

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Student Instructions: Using Chemistry to Treat Lead Poisoning

Step 1: Read the article "Challenging Assumptions about Lead and IQ: Effects Increase, Not Decrease, in Older Children."

Step 2: Conduct the lab activity and answer the associated questions.

Purpose: This lab activity simulates how a chelating agent works in the body to remove lead. You will be using three chemical compounds:

- Sodium bicarbonate (the carbonate will act like blood);
- Calcium chloride (the calcium will act like lead in the body that will bond with the carbonate); and
- Ethylenediaminetetraacetic acid (EDTA; the chelating agent that is used to prevent the "lead" from bonding with the "blood"). This is a chelating agent similar to succimer.

Tip: Always use a different chemical spatula or plastic knife for each chemical compound. For example, do not use the same chemical spatula that you used to add EDTA to the balance to also add the sodium bicarbonate. The same rule applies to the stirring rods or plastic knives used for stirring. If you do not keep the chemical spatulas and plastic knives separate for each chemical compound, you will cross-contaminate your solutions.

Materials:

- Safety glasses with side shields or goggles for each student
- Eyedroppers
- Triple beam or other type of balance accurate to 0.1 g
- Water and 1 100-mL graduated cylinder for measuring the water
- 3 approximately 50-mL containers or beakers
- Masking tape and markers for labeling the beakers
- Sodium bicarbonate (baking soda)
- Calcium chloride pellets (ice melter)
- EDTA
- 3 chemical spatulas or plastic knives
- 3 stirring rods or plastic knives for stirring
- Sink or bucket to dispose of water and solutions
- Paper towels to clean up any spills

Procedure:

1. Put on your safety glasses with side shields or goggles.
2. Using the masking tape and markers, make three labels. One should say "Blood (sodium bicarbonate)," one should say "Lead (calcium chloride)," and one should say "Chelating Agent (EDTA)." Put each of the labels on a 50-mL container or beaker.
3. Adjust the balance so that it reads zero when nothing is on the balance.
4. Put the 50-mL "Chelating Agent (EDTA)" container or beaker on the balance. Using a chemical spatula or plastic knife, weigh out 0.5 g of EDTA in this container. (Be sure to take the mass of the container into consideration by either "zeroing" the scale or adding 0.5 g to the beaker mass.) Remove the container from the balance and add 20 ml of water to the container. Stir the solution use a stirring rod. (Do this step first since EDTA takes a long time to dissolve in water. Swirl or stir the water occasionally to help the EDTA dissolve more quickly.)
5. Put the 50-mL "Blood (sodium bicarbonate)" container or beaker on the balance. Using a clean chemical spatula or plastic knife, weigh out 0.6 g of baking soda (sodium bicarbonate) in this container (again, account for the mass of the beaker.) Remove the container from the balance and add 20 mL of water to the container. Use a clean stirring rod to stir the solution.
6. Put the 50-mL "Lead (calcium chloride)" container or beaker on the balance. Using a clean chemical spatula or plastic knife, weigh out 0.6 g of calcium chloride into this container. Remove the container from the balance and add 20 mL of water to the container. Use a clean stirring rod to stir the solution.

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7. Swirl or stir each beaker until all of the chemicals have dissolved and each solution is clear. Note: It is difficult to dissolve the EDTA solution. It will not affect the experiment if some of the solid remains at the bottom of the beaker. To help the EDTA to dissolve more quickly, pour about half of the "Blood (sodium bicarbonate)" solution into the "Chelating Agent (EDTA)" container or beaker. Even though you are helping the "Chelating Agent (EDTA)" solution to dissolve more quickly, it still will retain the qualities of "Blood (sodium bicarbonate)."
8. Use the eye dropper to slowly add 25 drops of the "Lead (calcium chloride)" solution into the "Blood (sodium bicarbonate)" container or beaker. The calcium in the calcium chloride is behaving like lead in the body and the carbonate in the sodium bicarbonate is behaving like blood.
   What do you see? Give an explanation of what you think is happening.

9. Pour all of the EDTA solution into the "Blood (sodium bicarbonate)" container or beaker. Remember, the EDTA is a chelating agent and will bond with lead (the calcium in the calcium chloride) to prevent it from bonding with the blood (the carbonate in the sodium bicarbonate).
   What do you see? Give an explanation of what you think is happening.

Step 3: The study researchers found that while blood lead levels went down in children who received succimer, their IQ levels were no different than the control group who received the placebo. The side effects of taking succimer include nausea, vomiting, loss of appetite, loose stools, metallic taste in the mouth, drowsiness, dizziness, watery eyes, and headache.

Based on the study results would you give succimer to treat a lead-poisoned child? Explain your reasoning and describe any additional information you would need in order to make this decision.