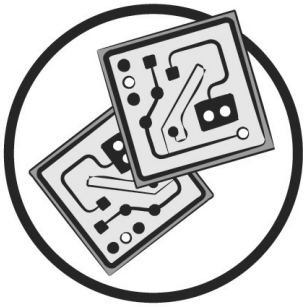


Penny for Your Thoughts

Learning Objectives: *Students learn how metals react with each other.*

GRADE LEVEL

3–8

SCIENCE TOPICS

Atoms and Molecules
Chemical Reactions
Industrial Chemistry

PROCESS SKILLS

Comparing/Contrasting
Predicting
Analyzing

GROUP SIZE

2–3

SNEAK PEAK inside …

ACTIVITY

Students copper plate metal objects by placing them in a jar with pennies, vinegar, and salt.

STUDENT SUPPLIES

see next page for more supplies

small jars with lids (e.g., baby food jars)
vinegar, salt
pennies (pre-1983 work best)
steel paperclips, etc….

ADVANCE PREPARATION

see next page for more details

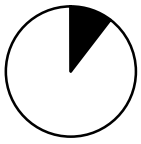
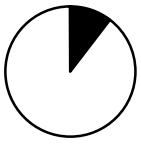
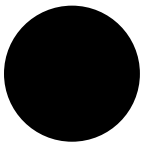
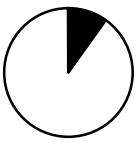
Fill pop-top bottles with vinegar
Set out cups of salt, etc….

OPTIONAL EXTRAS

DEMONSTRATION
Copper Corrosion (p. F - 26)

EXTENSIONS
Inquiry Opportunity—Substitute Ingredients (p. F - 31)
Electroplating (p. F - 31)

TIME REQUIRED

Advance Preparation	Set Up	Activity	Clean Up
			
5 minutes	**5 minutes**	**30–90 minutes waiting for reaction**	**5 minutes**

SUPPLIES

Item	Amount Needed
small jars with lids (baby food jars work well)	1 per group
vinegar	½ cup per group
pop-top squeeze bottles (e.g., water or sports drink)	1 per group
salt	2 spoonfuls per group
steel paperclips (or other small iron-containing objects)	3–4 per group
pennies (must be pre-1983)	15 per group
plastic spoons	1 per group
plastic cups, any size	1 per group

For Extension or Demonstration supplies, see the corresponding section.

ADVANCE PREPARATION

Supplies Preparation
Vinegar:

- Fill pop-top squeeze bottles with about ½ cup vinegar.
- Label the bottle "vinegar."

Salt:

- Fill plastic cups with 2 spoonfuls of salt.
- Label these cups "salt."

Notes and Hints

- Pennies made before 1983 have higher copper content and work better in this activity. Encourage students to collect pennies for a few weeks prior to starting this activity.
- Try to use paperclips that do not say "smooth finish." Smooth finish paperclips have a coating that turns gray instead of copper. To make sure paperclips work well, it is a good idea to test out the experiment the night before.
- Other small steel objects, such as nails, also work. If you use nails, caution students appropriately. Stainless steel objects (spoons, etc.) will not work, as they are specially formulated to resist this kind of reaction.

SETUP

For each group
- ❑ jar with lid
- ❑ 15 pennies (pre-1983)
- ❑ 3–4 paperclips
- ❑ vinegar in pop-top squeeze bottle
- ❑ salt in plastic cups
- ❑ spoon

At a central location (or with the teacher)
- ❑ towels and sponges for clean up

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided for the teacher.

Choose questions that are appropriate for your classroom.

In this activity, students will conduct a reaction between two metals—copper in pennies and iron in paperclips.

Are metals permanent? Can two metals react with each other?
Metals are not permanent; they can dissolve into solution or they can corrode. One example of a metal corroding is rust. If you leave a nail outside, the iron molecules will react with the oxygen and the water in the air to create iron oxide. Also some iron will dissolve in rainwater, causing the nail to weaken.

When a metal reacts or corrodes, where did those metal atoms go? Can you get them back?
When you leave a piece of metal in solution, bits of the metal break off and dissolve into the solution. These bits stay in solution unless you also have another, more reactive metal in the solution. When this happens, the molecules will travel from one metal and stick (or plate) onto the other.

Are all chemicals equally reactive? How are they different?
Some chemicals react more readily than others. Iron is very reactive, that is why you see it rust a lot. Gold is very unreactive, this is why you never see "rusted" gold.

Some metal things are made of layers of metals. Can you think of some examples? Why would you want to layer one metal on another?
Jewelry would be very expensive if it were pure gold, so many gold items are only covered with a thin layer of gold. Also, gold is very soft, so mixing gold with other metals can make it stronger.

A penny requires more than one cent's worth of copper, so pennies are only coated with copper and have a zinc core. Also, some metals corrode or rust very easily. By coating one metal that is less reactive on top, it protects the metal underneath.

In this activity, students will have the opportunity to plate metal objects with copper.

TEACHER DEMONSTRATION

Copper Corrosion
Teachers can demonstrate corrosion using copper coated steel BBs and bleach.

Since the activity takes some time, set up the experiment with students first. Then do this demonstration while you are waiting for the pennies and paperclips to react.

Supplies
- glass cup
- overhead projector
- about 50 (about 1 tablespoon) copper coated steel BBs (available at sporting goods stores)
- full strength bleach (enough to cover BBs in the cup)
- disposable gloves

CAUTION: Bleach is poisonous and hazardous to eyes, skin, and the respiratory tract. Handle with caution. Never mix bleach with other household cleaners, as it may release toxic gases. Wear gloves and use care when handling.

Demonstration

- Place about 50 copper BBs in a glass cup. While wearing gloves, immerse BBs in bleach solution and place on projector.
- Depending on how new/strong the bleach is, the BBs will start rusting anywhere from a few seconds to a few minutes after immersion. With very new bleach, the solution may heat up or bubble as well.
- Red-brown flakes will form on the BBs; some will come off and float in the solution.

Explanation

Bleach is very reactive and gives away oxygen very easily. This oxygen reacts with the copper almost instantly, creating copper oxide. This is similar to the reaction seen on iron when iron rusts. The substance we call "rust" is actually iron oxide.

In this reaction, the copper from the BBs dissolves in the bleach. Then it reacts with the oxygen to form copper oxide. The copper oxide is not able to dissolve in the bleach, so it forms a red-brown solid.

Have students follow the Scientific Procedure on page F-34, working in groups of 2–3 Below are suggestions to help the teacher facilitate the activity.

NOTES

Penny for Your Thoughts

SCIENTIFIC PROCEDURE

This handout is on p. F - 34.

1. Label a jar with your name(s).
2. Put fifteen pennies in the jar.
   - What do the pennies look like?

3. Add 2 spoonfuls of salt into the jar.
4. Fill the jar halfway with vinegar.
   - What does the salt and vinegar mixture look like?

Running Suggestions

- The reaction between the pennies and paperclips takes at least fifteen minutes before any change is obvious. Use this time to perform the teacher demonstration (corrosion of copper BBs in bleach, a fast and easily observed color changing reaction).
- Alternatively, use the time to explore vocabulary terms during this time, write down student hypotheses, or explore a cross-curricular connection.
- You may choose to do this activity at the beginning of the day and then revisit it periodically through the day. Or students can set up the experiment at the end of the day and look at them again at the beginning of the next day.
- Make sure pennies are all pre-1983, as they have more copper than more recent pennies and will react faster.

You may want to instruct students to write their answers and draw pictures on separate pieces of paper so they will have more space.

Ongoing Assessment

- Describe what the pennies look like before the experiment. Describe what the paperclips look like before the experiment.
- What purpose does each of the ingredients serve? What do you think the salt is for? What do you think the vinegar is for?
- What do you think is going to happen?
- Describe what the pennies and paperclips look like during the experiment.
- Describe what the pennies and paperclips look like at the end of the experiment.

Safety and Disposal

- The vinegar and salt mixture can go down the sink.
- Rinse pennies with water and reuse.

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

Allow students time to carefully inspect their pennies and paperclips after the reaction has finished.

What happened to the paperclip?
It became coated with copper and appears copper.

Have the students hypothesize how the nail or the paperclip became copper colored.
Students may have different theories about how this happens.

How could this process be used by industry?
Plating metals, jewelry, coating a reactive metal with one that is less reactive, etc.

Why would we want to cover one kind of metal with another?
Sometimes it is too expensive to make an entire object out of an expensive metal. In those cases, the expensive metal can be plated onto a cheaper metal. Jewelry and expensive metal objects are often made of inexpensive metals with a thin layer of expensive metal on the outside. We call this "plating." Objects can be silver-plated, gold-plated, copper-plated, etc. Even pennies are plated objects! The government makes them by plating copper over zinc.

EXPLANATION

This background information is for teachers. Modify and communicate to students as necessary.

In this activity, students make a mixture of salt, vinegar, pennies, and paperclips. The pennies become shiny, and the paper clips become copper colored.

BACKGROUND FOR ALL GRADES

Properties of Metals

Metals are a group of chemicals with similar physical properties. Metals are shiny and (except for mercury) solid at room temperature. They are **ductile**, which means they can be bent, stretched, and molded into different shapes. Aluminum is commonly flattened for use as a foil; tin and steel are folded and stretched to make food cans. Metals are also good **conductors,** which means they transfer heat and electricity well**.** Copper metal is a particularly good conductor. That is why copper is used in electrical wiring, and why it is sometimes used to coat the bottoms of pots and pans.

Trading Places

In this reaction, copper atoms from the pennies replace iron atoms in the paperclips. First, the copper atoms **dissolve** in the vinegar salt solution. Then they travel through the solution to the paperclip. The iron atoms in the paperclip trade places with the copper in the solution. The copper becomes solid on the paperclip, and the iron dissolves into the vinegar and salt solution.

BACKGROUND FOR GRADES 6–8

Properties of Ions

If an atom loses or gains **electrons**, it becomes electrically charged. An electrically charged atom or group of atoms is called an **ion.**

Copper atoms are not able to dissolve in water, but copper ions are able to dissolve in water. In this activity the copper atoms on the pennies lose electrons to become ions. The acid and salt work together to help **dissolve** the copper ions into solution.

For more detail on how things dissolve in solution, read the Explanation section of the activity ***Salting Out***.

Copper Plating

The copper ions travel in solution, and, if those ions reach the paperclip, they trade places with an iron atom. That iron atom loses electrons to become an ion in solution; the copper ion gains those electrons and becomes a copper atom on the paperclip. As this continues, the copper plate on the paperclips grows one atom at a time until the entire paperclip is coated. Once the paperclip is completely coated with copper, no more iron will react, because the outer layer of copper atoms protects it.

The iron in the paperclip is more reactive than the copper from the pennies. For this reason, the iron allows the copper to take its electrons, causing the iron to dissolve in solution and the copper to become solid on the paperclip. This process of coating the paperclip with copper is called **plating**.

If the jars sit for 1 to 5 days, grayish clumps may be visible in the solution. This is the iron that came off the paperclip.

Batteries
The transfer of electrons between metals also happens in a **battery**. In a battery, two different metals are combined with acid and separated from each other. The exchange of electrons is not allowed to happen directly between the metals. Instead, the electrons are forced to travel through a wire. A traveling stream of electrons is called **current**. This current of electrons is what we call **electricity**.

EXTENSIONS

Extension A: Inquiry Opportunity—Substitute Ingredients
Have students design their own experiments. Let them hypothesize what will happen when they substitute different metal objects for the pennies or the paperclips. Students can also take out or substitute one ingredient, like salt or vinegar, to see the effect of each ingredient on the experiment. They will gradually build a greater knowledge base by methodically recording their experiments.

For more information about experimental design, see the section ***Science* Inquiry** in the beginning of the Guide.

Extension B: Electroplating (Grades 5–8)
Students will copper plate a metal object using a battery to transfer electrons.

Extra Supplies
For each group:
- ❑ steel wool
- ❑ two wire leads
- ❑ small jar
- ❑ salt
- ❑ ½ teaspoon measure
- ❑ battery (a 6-volt lantern battery works well)
- ❑ metal object to be plated
- ❑ copper object (coiled wire, pre-1983 penny, or strip)
- ❑ water

Extra Instructions

- Use steel wool or a paste of salt and water to gently polish or scour the surface of the metal object to be plated. This removes the surface layer of metal that has reacted with oxygen in the air, giving the copper a better place to stick.
- Connect lead #1 (an insulated wire with alligator clips at each end) to the negative terminal of a battery. Attach the other end of lead #1 to a metal object that you wish to plate, e.g., a key or a nickel.
- Connect lead #2 to the positive terminal of your battery. Attach the other end of lead #2 to a clean, bare coil of copper wire, a clean penny, or a clean strip of copper.
- Fill a small jar with water. Add ½ tsp of salt and stir the solution.
- Place the metal object to be plated and the copper object attached to lead #2 in the water. Do not let the two metal objects touch.
- Observe the solutions while the electroplating is taking place. The metal object attached to the negative terminal of the battery should become plated with metal from the object (copper) at the positive terminal of the battery. You should be able to see other evidence of chemical reactions, such as formation of tiny gas bubbles.
- Carefully rinse the solutions down the drain with ample water

Explanation

In the regular activity, copper spontaneously coats the iron paperclips because the iron is more reactive than the copper. When people want to plate copper on metals that are less reactive, or they want to plate copper on more quickly, they use batteries. The battery will remove electrons from the copper, creating positive copper ions that go into solution. The copper ions will be attracted to the electron-rich metal at the negative end of the circuit, and so will plate onto the metal object.

CROSS-CURRICULAR CONNECTIONS

MATHEMATICS — **Worth Your Weight in Gold**

Look in the newspaper or online for current market prices of gold, copper, and silver. Have students weigh silverware or coins and use multiplication to determine the value of the object if it were made exclusively of gold, copper, or silver.

LANGUAGE ARTS — **Spelling List: Metals**

Add some interesting metal names to your spelling list (e.g., lead, zinc, iron, magnesium, chromium, mercury).

SOCIAL STUDIES — **Coin Collecting**

Each coin is marked to show various facts including: where it was minted, the year it was made, the denomination of the coin. Also, in different years, pennies have different compositions. For instance, during World War II, the pennies were made of steel since copper was in short supply. After 1983, pennies were made from zinc with a copper plate because, again, copper became more expensive.

Start a coin collection with your class. Try to collect a penny from each year and from each minting location. Notice changes in the way pennies look from year to year.

RESOURCES

Web–http://www.jmckinley.com/us/metal-reactions.htm
Detailed discussion of silver jewelry and its reactions.

Web–http://electronics.howstuffworks.com/battery.htm
A detailed description of how batteries work. Good diagrams.

Web–http://www.energizer.com/learning/science/
Directions on making electrical circuits and batteries.

Web–http://www.unr.edu/sb204/geology/mas.html
This is a simplified table showing the comparative reactivity of different metals. Notice that iron is higher on the list than copper, so it is more reactive and allows copper to take its place on the paperclip.

Mathis, Sharon Bell, The Hundred Penny Box
Reading Level: 4th grade to 8th grade
Michael's great-great-aunt Dew has a box with a penny for every year of her life. She spends time with Michael telling stories about each of the hundred years of her life. Winner of a Newberry Honor.

VOCABULARY

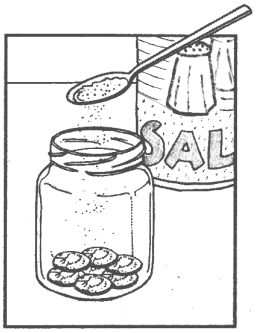
atom:	a very, very small particle that makes up all matter
battery:	a combination of metals and other chemicals that react together to produce current, i.e., moving electrons
conductor:	a material that transfers heat or electricity easily
current:	a flow of electrons
dissolve:	when the molecules of a substance separate and become completely surrounded by the molecules of another substance
ductile:	can be stretched or bent without breaking
electricity:	created by a continuous flow of electrons through a wire
electron:	a tiny, negatively charged particle found in atoms and molecules
ion:	an electrically charged atom or group of atoms
metal:	any material that is shiny, can be molded, stretched or shaped, and transfers heat or electricity; can be an element or mixture of elements
plating:	covering the surface of one metal with a layer of another metal

Penny for Your Thoughts

SCIENTIFIC PROCEDURE

1. Label a jar with your name(s).

2. Put fifteen pennies in the jar.
   - What do the pennies look like?



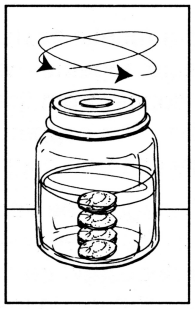
3. Add 2 spoonfuls of salt into the jar.

4. Fill the jar halfway with vinegar.
   - What does the salt and vinegar mixture look like?

5. Close the jar. Make sure the lid is tight.

6. Swirl the jar in circles until the contents have spun around 15 times.

7. Open the jar and add a paperclip.
   - What does the paperclip look like?



8. Close the jar. Make sure the lid is tight.

9. Look at the jar after 15–30 minutes

- What does the paperclip look like?

- What do the pennies look like?

- What does the solution around them look like?

10. Check back on your jar a day later.

- What does the paperclip look like?

- What do the pennies look like?

- What does the solution around them look like?

11. Clean up your area.

- Follow your teacher's instructions.

SUPPLY WORKSHEET

This worksheet is also available online at **www.omsi.edu/k8chemistry**.

Penny for Your Thoughts

Recommended group size: 2–4

Number of Students: ☐ Number of Groups: ☐

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
small jars with lids (baby food jars work well)	1 per group		
vinegar	½ cup per group		
pop-top squeeze bottles (e.g., water or sports drink)	1 per group		
salt	2 spoonfuls per group		
steel paperclips (or other small iron-containing objects)	3–4 per group		
pennies (must be pre-1983)	15 per group		
spoon	1 per group		
plastic cups, any size	1 per group		
Extension A			
needs will vary depending on experiment design			
Extension B			
steel wool	small amount		
wire leads	2 per group		
small jar	1 per group		
salt	½ spoon per group		
½ teaspoon measure	1 per group		
battery (a 6-volt lantern battery works well)	1 per group		
metal object to be plated	1 per group		
copper object (coiled wire, pre-1983 penny, or strip)	1 per group		
water			
Teacher Demonstration			
Copper Corrosion			
glass cup	1 for demonstration		
overhead projector	1 for demonstration		
copper coated steel BBs	about 50		
bleach	¼ cup (enough to cover BBs)		
disposable gloves	1 pair		