



Trading Places

1. Always wear safety goggles.
2. Rinse the small plastic dish in the sink.
3. Take a small nail out of the cup marked "Clean Nails."
It is steel, which is mostly iron.
 - What does the nail look like?
4. Place the nail in the small plastic dish.
5. Put 10 drops of the copper sulfate (CuSO_4) solution on top of the nail. Wait about two minutes.
 - What is happening?
 - What color was the copper sulfate solution?
6. Use some water to wash off the nail.
 - What color is the spot on the nail?
7. Rinse the nail and the dish in the sink.
Put the nail into the "Used Nails" container.
8. Wash your hands.



Did you see the copper trade places with the iron?



A Closer Look

In this experiment, when you add the copper sulfate to the nail, a layer of solid copper metal forms on the surface of the nail. At the same time, a little bit of the iron metal in the nail dissolves into the water. The copper and iron have "traded places."

In the iron nail, each iron atom had enough electrons to donate them to copper. In the blue solution of copper sulfate, each copper **ion** was missing two electrons. When the iron donated electrons to copper, the iron dissolved in the water. The copper became solid metal and appeared on the nail.

This kind of reaction is very important in industry. It can be used to coat objects with metal (like you did), to make pure metals (like pure copper), or to create protective finishes on metals (like anodized aluminum pots and pans).

Talking Points: Trading Places

Extensions

Ask the questions:

1) Is a chemical reaction occurring?

Yes. You can tell there is a chemical reaction because of the color change on the surface of the nail.

2) In general, how can you tell when a chemical reaction occurs?

Whenever substances change. There can be many ways to detect changes: heating (or cooling), color changes, a gas (or liquid) is given off, light is generated, the form of the material may change (a solid block may crumble to a powder, or a solid may change to a liquid).

Applications

This reaction involves the transfer of electrons, and is known as an **oxidation/reduction (redox) reaction**. In a **redox reaction**, one reactant donates electrons and is oxidized; the other accepts electrons and is reduced.

Redox reactions are used widely in the chemical industry. Ammonia is oxidized to produce nitric acid, used to produce fertilizers. Electroplating is a redox process. Compact disks and DVDs have a metal layer, deposited by a redox reaction.

In photosynthesis, green plants reduce carbon dioxide into sugars, while water is oxidized to form oxygen. In animals glucose (sugar) is oxidized to form carbon dioxide, while oxygen is reduced to form water. In a process that chemically is very similar, a fire causes fuel to be oxidized and oxygen to be reduced, the products being heat and carbon dioxide.

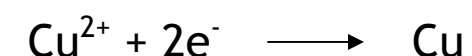
In-Depth Information

For the redox reaction in this experiment, iron atoms in the nail donate 2 electrons. As a result, the iron atoms are oxidized to become iron **ions** dissolved in the water:



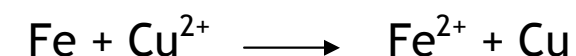
We say the iron is **oxidized** because its **oxidation state** changes from 0 to +2.

These electrons are made available to copper ions in the solution. The copper ions are reduced and deposit as copper metal on the surface of the nail:



We say the copper is **reduced** because its **oxidation state** changes from +2 to 0.

These two half-reactions can be combined to provide a single redox reaction:



This reaction occurs because copper atoms are slightly more **electronegative** than iron atoms. That means they attract electrons more strongly. Electrons are held more strongly to copper atoms than to iron atoms; this permits the copper ion to remove electrons from an iron atom when they come into contact at the interface of the nail and the copper sulfate solution.



Trading Places

Visitors add drops of copper sulfate solution onto a steel nail. They observe the nail change color from silver to brown as the copper plates onto the nail. They observe the growing crystals through a magnifying glass.



OBJECTIVES:

Visitors learn that liquids may be full of metal ions that are invisible. They learn that this particular solution contains copper ions that react with the solid iron.

SCIENCE TOPICS	PROCESS SKILLS	VOCABULARY
Properties of Matter	Observing	Atom
Chemical Reactions	Measuring	Chemical
Solubility	Inferring	Crystal
Properties of Solutions		Ion
Properties of Ions		Solution



MATERIALS

See *Materials Prep*
for more details

(with amounts to have on hand)

- wire nails size 1 x 16 (keep 100 on hand)
- One small dish or lid (about 2-in. diameter)
- One 30-ml dropper bottle
- One 250-ml squeeze bottle
- CuSO_4 (copper sulfate) (keep 500g on hand)
- Two 250 ml plastic beaker
- One 250 ml plastic bottle

Setup/Takedown Procedures**ORIGINAL SETUP**

- Label the 30-ml dropper bottle “Copper Sulfate Solution (CuSO_4).”
- Label the 250-ml squeeze bottle “Water (H_2O).”
- Label one 250 ml beaker “Clean Nails”.
- Label the other 250 ml beaker “Used Nails”.
- Label 250 ml bottle “copper sulfate solution”

WEEKLY SETUP

- Fill the 250-ml squeeze bottle with water
- Fill the 30-ml dropper bottle with CuSO_4 (copper sulfate) solution.

DAILY SETUP

- Set out the visitors’ instructions in a Plexiglas holder.
- On a tray lined with a white plastic mat, set out the following:



- One beaker of clean nails (about 20 nails)
 - Copper Sulfate Solution (CuSO_4) in the labeled dropper bottle
 - One small dish
 - One beaker labeled “Used Nails”
 - One 250-ml squeeze bottle labeled “Water (H_2O)”
- Fill the water bottle.
 - Refill the Copper Sulfate Solution (CuSO_4) bottle.

DAILY TAKEDOWN

- Rinse the dish and beakers.
- Tightly cap the Copper Sulfate Solution (CuSO_4) bottle.
- Return the equipment to the tub with all bottles in an upright position

WEEKLY TAKEDOWN

- Empty the water bottle.
- Tightly secure the Copper Sulfate Solution (CuSO_4) bottle cap and store it upright.
- Clean the tray and leave it at the station.



RUNNING SUGGESTIONS

- ◇ Only put a small amount of nails in the “Clean Nails” container. Nails can get wet during lab operations and become rusty. This makes the nails unusable, and confuses visitors.
- ◇ Nails are not reused. Put in metal recycling.
- ◇ Wipe up spills on counters, floor, etc., as soon as possible before they set.



EXTENSIONS

Applications: Metal plating is widely practiced.

Try Copper Sulfate Solution (CuSO_4) on other materials, such as iron filings (crystals will form slowly) or coins-pennies, nickels, dimes, quarters

— which ones work best?

Use a microscope for a closer view.

Try the Crystal Take-Home Activity.

SAFETY & DISPOSAL



Copper Sulfate (CuSO_4) is a hazardous substance; follow the handling and disposal instructions. Copper sulfate is poisonous, but the amount used in this experiment is not enough to be fatal. The 1.0M solution is strong enough that visitors should wash their hands before leaving the lab area.

Consult the Material Safety Data Sheets (MSDS) for additional information.

MATERIALS PREP

To prepare 1.0 M CuSO_4 (copper sulfate) solution:

- Weigh 125 g of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ (copper sulfate).
- Add water to total volume of 500 ml.
- Mix solution to dissolve.
- Store solution in a labeled/dated bottle.