An Educational Hands-On Demonstration Program
for Groups of 25 Students in Grades 2-6

Prepared by the

National Chemistry Week Planning Committee

of the

Cleveland Section

American Chemical Society

For

National Chemistry Week 2019

Called

Marvelous Metals

Overview: Join us this year to see how metals shape our living.

Note: **After Sept. 20, 2019, please see our Cleveland Section web site (p. 3) for an Errata sheet.**

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Acknowledgments

The National Chemistry Week (NCW) Program of the Cleveland Section of the American Chemical Society (ACS) began in 1994 with an idea to put together a scripted Program that could be performed at any local school or library. It is intended to be a fun and educational Program designed to interest students in grades 2-6 in chemistry and science. This idea has since expanded to become the centerpiece of the Cleveland Section's NCW activities. On numerous occasions it has received national recognition from the American Chemical Society including several *ChemLuminary* Awards. In 2019 the Cleveland Section's volunteers will perform at least 40 demonstrations at libraries, schools, and other public sites.

Our NCW efforts reach many students each year because of various sponsors who have donated money, materials and/or services to the Cleveland Section specifically for National Chemistry Week. This year we are very pleased to acknowledge support from the National Science Foundation (CHE-1753237 to SCW). We would also like to thank our Cleveland ACS Section for its financial support and our partners at the Cuyahoga County Public Library (CCPL) for hosting our Program and for creating and distributing flyers announcing it. We further extend our sincere thanks to John Carroll University for hosting both GAK Day (**G**rand **A**ssembly of **K**its Day) and our Dress Rehearsal.

Lastly and most importantly we thank all the volunteers who donate their time and expertise. This library/school Program and other NCW events are the result of the hard work of many dedicated and talented volunteers. It all starts with our local section NCW Planning Committee. The Committee recommends, tests, and reviews activities & experiments; writes this script; collects supplies and materials; prepares the kits; recruits sponsors and volunteers; contacts libraries and schools; and schedules demonstrations. Committee members include Katie Arendt, Lois Kuhns, Helen Mayer, Vince Opaskar, Shermila Singham, Susan Wang, Bob Williams and Bob Fowler. Additional credit and thanks are given to the many GAK Day volunteers including professors and students from Baldwin Wallace, Case Western Reserve, Cleveland State and John Carroll universities, Oberlin College & Conservatory and Notre Dame College who gave up a Saturday in September to help count, measure and assemble all of the necessary materials for our demonstration kits. A final thank you goes out to the dozens of dedicated chemistry professionals and scientists who lead the presentations and activities in schools, libraries, and other public locations. Without them there would be no Cleveland Section NCW Program.

List of Experiments

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How Experiment Write-ups are Organized

Each Experiment's write-up is presented as follows:

1. **Purpose & General Methodology**: Background on the Experiment.
2. **Introduce the Experiment:** Suggestions for introducing the Experiment to the students.
3. **Performance Details:** How to perform the Experiment in detail.
4. **Conclusions:** Suggested conclusions to draw from the Experiment.
5. **Technical Information (for the Demonstrator):** This information is background info to help you understand what we're trying to accomplish technically in the Experiment. It certainly isn't intended that you give these technical details to the students unless the students ask or request it.

VOLUNTEERS

This year the NCW Committee will be videotaping the annual "Dress Rehearsal" demonstrations as they are presented at JCU. We'll post this video on YouTube and the link to it on the *Volunteers* page at our web site at https://www.acscleveland.org/ as soon as possible. It can be found by searching YouTube for "Cleveland NCW 2019". It will demonstrate this year's NCW Program in detail and may be viewed by anyone interested in hosting our Program. Alternately, this script provides enough detail for a teacher or parent to perform the presentation. The Cleveland ACS and NCW Committee do not require background checks on its volunteers nor do we require formal educational/teaching experience from any of its volunteers.

Special Notes for 2019

1. Follow the instructions on p. 5 for "To Do the Night Before Demonstration".
2. Note the need for you to bring ice cubes and hot water on p. 7.
3. You might want to use the *Summary Sheet of Experiments* (on the back of the *Demonstrator Feedback* form) as your guide for your presentation.

MAKE SURE TO FOLLOW ALL DIRECTIONS IN EXPERIMENTS

If experiments have special safety concerns due to the materials being used, they will be listed in the section for that experiment. **Eye protection should be worn at all times by everyone**, and students should be specifically told to never touch their eyes or smell things directly. Some of the chemicals used this year are household chemicals, and some have been purchased from chemical distributors (see p. 45). If exposure to any chemical should occur, flush with water and report the incident to the librarian and parent. See also https://www.chemsafetypro.com/Topics/CRA/Skin_and_Eye_Irritation.html. For skin contact, washing with soap and water may suffice. Websites for where to obtain an SDS are listed in the Appendix A and also on our NCW website below.

For information about the American Chemical Society's NCW safety guidelines, visit https://www.acs.org/content/acs/en/chemical-safety.html.

Websites of Interest

Cleveland Section:
https://www.acscleveland.org/
National American Chemical Society's "National Chemistry Week" website:
www.**acs**.org/ncw

Check Lists

Activities To Do Well Before the Day of the Demonstration	Complete?
Contact the Children's Librarian and • Verify the date and time of your 1-hour Program • Also schedule AT LEAST 1.5 hours <u>before</u> and an hour <u>after</u> your Program for set-up and clean-up, respectively. Modify the setup time appropriately depending on how familiar you are with the materials in your kit and <u>if you will have an assistant</u>. Make sure the room *will* be available.	❑
Read through this script to familiarize yourself with the Experiments and verify that you have all the items as listed in the kit contents.	❑
<u>***If you're using a pre-printed hard copy of the script, obtain the*** **Script Errata/Addendum Sheet** ***which will be posted on our web page.***</u>	❑
Contact Bob Fowler at jrfowler@cox.net with any questions.	❑
Collect the materials you need to bring with you to the demonstration. A list is on page 7. The librarian may be able to provide some of the items, but you need to call to verify that—do **not** assume that the library has what you need. Do NOT assume you can easily obtain water in the library; at some sites faucets are close to the sink bottom and allow little room for easily filling bottles or cups.	❑
While not absolutely necessary, it's recommended that you ask a friend to assist, and/or contact the Head Children's Librarian well in advance to request a student assistant or librarian to be your assistant. Having someone available to help set up the room before the Program, collect trash and pass out materials as the Program progresses can be very helpful. That person can also assist if individual students need help with or have questions about the Experiments.	❑
If you wish to add other Experiments or demonstrations into your Program, you must contact the Head Children's Librarian through your local librarian ahead of time to get approval. Be careful and think "safety first". While we have insurance for the Program's performance, neither the NCW Committee nor the Cleveland ACS approves of any Experiments added to this Program, and you are responsible for your own actions.	❑
Activities To Do about ONE WEEK BEFORE your Program	**Complete?**
Contact the Head Children's Librarian who is helping you to coordinate our Program: ➢ VERIFY that they limited registration to 25 students. ➢ Ask the room to be arranged with 5 student Experiment tables with 5 chairs each, an additional table for the demonstrator and a small side table/area for literature, photo permission forms, and goggles. ➢ If their surfaces aren't waterproof, ask for all the Experiment tables to be covered with newspapers and for extra paper towels for each table. Otherwise take newspaper and do this during setup. ➢ Invite the librarian and/or student assistant to stay for the entire Program. (They might even offer to be an assistant if given the opportunity.)	❑

Activities To Do AT LEAST ONE DAY BEFORE the Demonstration	**Complete?**
Read over the Experiments a few times and become familiar with them. Our Program is designed for about one hour for someone who is comfortable with the script. Practicing your presentation is very helpful.	❑
Activity To Do *THE NIGHT BEFORE THE* Demonstration	**Complete?**
1. Uncap the 50ml vial labeled 0 containing vinegar (in the gallon bag also labeled 0) and put into it the 5 galvanized nails from the baggie labeled 0. Leave the vial sitting <u>uncapped</u> (some H_2 will be given off) overnight (8-10 hours).	❑
Activities To Do *AT HOME JUST BEFORE THE* Demonstration	**Complete?**
1. Fill a thermos with at least 25-30 ice cubes. 2. Fill a second thermos with boiling water (better: obtain hot tap water at the library—see Experiment 6). 3. Wearing the protective gloves provided, decant/discard the vinegar out of the 50 ml vial labeled 0 and lie the 5 nails down on a double paper towel without touching them. Remove as much of each nail's grey coating as possible with a third paper towel. Then sand each nail for about 30 seconds to a bright finish. When complete, wrap the 5 nails in a fourth paper towel and return them to your kit for use with Part 3 of Experiment 5. 4. See the footnote on the bottom of p. 33.	❑
Activities To Do When You Get To The Library	**Complete?**
Introduce yourself to the Head Children's Librarian.	❑
Confirm that the tables and chairs are set up properly and that that all tables are covered in newspaper or have chemical/liquid resistant surfaces.	❑
Optional: Ask the Head Children's Librarian or an assistant to take pictures **WHEN ABSOLUTELY EVERYONE IS WEARING GOGGLES** during the demonstration (subject to parents/guardians having given permission to take the pictures).	❑
Complete Set-Up; starting on p. 11.	❑
Set-up note! If you follow the script as originally written, there are many cups and other items on the tables. Depending on the size of your tables, and the activity level of your students, you may choose to distribute fewer items originally. If so, then perhaps keep the remaining Experiments' material at your demonstrator's table—on the plastic tray provided by an assistant—and distribute these items throughout the Program.	❑
Set up an 'Entrance' area table to allow space for goggle distribution and fitting by the parents, photo permission form signing, and (at the end of the Program) distribution of literature. Place copies of the *ACS Celebrating Chemistry*, the *ACS Photo Permission* forms and any other literature on this table.	❑
You may wish to set up an 'Exit' area table to allow space for end-of-Program activities such as goggle return and literature distribution.	❑

Activities To Do At the Start of The Demonstration		**Complete?**
Ask the parent/guardian for permission to photograph the children for possible use on our website **and obtain their signatures to this effect**. If that permission is not obtained, make sure that that students are positioned in such a way in the room that they won't be included in the photographs, or do not take any photographs. It is advisable to seat students with photo permission at the same table.		❑
Hand out goggles and help adjust to the correct fit (if necessary). Tell the student to pull the air vents to the open position. ***Everyone must wear goggles at all times.***		❑
Activities To Do During The Demonstration		**Timing**
Activity/Experiment	***Type***	***Time (mins)***
Welcome & Introduction		2
1. Changing the Color of Metals	Demonstration	5
2. Metals Lead the Way	Individual/Group	10
3. Can Metals Conduct More Than Electricity?	Group	5
4. Where are Metals Found in Nature?	Demo/Ind/Group	15
5. Enhancing Metals with Metals	Demo/Ind/Group	10
6. Can Metals be Trained to Remember?	Individual	10
Closing Comments		2
Collect goggles, hand out literature & thank everyone for coming.		1
Ask students to complete their *Student Feedback* forms		1
	Total Time	~60
Activities To Do Immediately After The Demonstration		**Complete?**
Clean up as indicated in the **Clean Up & Return** section (p. 42).		❑
Give the two manila envelopes (containing the *Photo Permission*, *Student Feedback* and *Demonstrator Feedback* forms and return items) along with the box of student and adult goggles to the librarian for return to Julia Boxler via interlibrary mail. *(Those outside of the CCPL network can return items to your nearest CCPL branch for return to Julia Boxler-YTH. See www.cuyahogalibrary.org for branch listings.)* Please return all materials within two weeks of NCW.		❑
Give any leftover literature to the librarian *(CCPL library kits only).*		❑
Activities To Do Once You Get Home		**Complete?**
Email photos to Bob Fowler at jrfowler@cox.net along with some text describing each.		❑
Smile! You have just shared your joy of science and chemistry with children, possibly inspiring them to become great scientists, chemists, biologists, engineers...		☺

Supplies for Demonstrator to Bring from Home

Items for Presenter to Provide (do not expect the library to provide these materials):

1. 1 pair of scissors
2. 1 1-gallon plastic jug filled with tap water.
3. 1 smaller vessel for dispensing/pouring water into individual cups
4. 1 thermos filled with at least 25-30 ice cubes. Don't depend on the library to have ice cubes!
5. Another vessel capable of holding about 50-oz of hot tap water, preferably with a pouring spout. (See Experiment 6.) Alternately, if you have a second thermos, you could bring your own hot water (you should fill this thermo with boiling water as you're leaving home), but the library's hot tap water will do.
6. 1 pair of hot pads to handle the above hot water.
7. 1 large garbage bag for solid waste collection.
8. 1 bucket for liquid waste collection (optional if a sink is available within the demo room).
9. A small screwdriver for pushing goggle straps back through their slots and for removing the seals inside the bottles of H_2O_2.
10. Pens for parents to fill out photo permission forms.
11. 1 roll of paper towels.
12. Some extra newspapers to put on the tables if the library hasn't covered them for you. (Not necessary if the tables have chemical/water proof surfaces.)
13. A roll of masking tape to hold the newspapers (if any) flat on the tables.

Optional: IF you care to take pictures, please make sure students' parents have given their permission for the children to be photographed on the ACS form and that the students and any adults to be photographed are ALL wearing goggles. You might want to assign the photography chores to an assistant during the demonstration. It is better to have close-ups of one or a few students wearing goggles to show what they are doing and their excitement rather than pictures with lots of students and/or parents not wearing goggles. ACS refuses to accept pictures taken at Programs wherein all participants are not wearing goggles. Please send Bob Fowler copies of your pictures at jrfowler@cox.net along with some text describing each and the completed Permission form(s).

Note: If you will be performing multiple demonstrations on the same day with the same goggles, you'll need to sanitize them between demonstrations (refer to p. 42 for more information). For this you'll need:

1. small quantity of household bleach
2. wash bin or bucket
3. old towels or cotton paper towels for drying (soft so as not to scratch the goggles)…**OR**…individual sanitizer wipes (soft so as not to scratch the goggles).

Supplies Included in Your Kit

General

1. Materials for Experiments 1-6 in numbered plastic bags (sometime multiple bags).
2. 1 plastic tray for use in distributing materials.
3. 1 copy of this script.
4. 1 9x12 manila envelope addressed to *Julia Boxler – YTH* containing:
    a. 25 copies of the *ACS Photo Permission* form
    b. 25 copies of the *Student Feedback* form
5. 1 9x12 manila envelope addressed to *Julia Boxler – YTH* containing:
    a. 25 copies of the *Marvelous Metals* Word Puzzle with *Results of Experiment 4 (Part 2)* on the reverse side.
    b. 1 copy of the *Demonstrator Feedback* form (*Summary Sheet of Experiments* on the reverse side*)*
6. 1 extra 9x12 manila envelope addressed to *Julia Boxler–YTH* for returned hardware items.
7. 25 copies of *Celebrating Chemistry 2019* for distribution.
8. In a 1-gallon plastic bag labeled 0:
    a. 25 golf pencils in a sandwich-sized baggie.
    b. 1 2" piece of sandpaper[3].
    c. 1 small baggie containing 5 12d 3¼"[1] Zn-coated anodized nails[2].
    d. 4 paper towels[3].
    e. 1 pair of adult-sized plastic gloves[3].
    f. 1 50-ml vial containing vinegar[3].
    g. 25 sandwich baggies containing a cork, an NCW "business card" and a card magnet (like the kind that attach to refrigerators).
    h. 25 empty sandwich bags for the students to put their take-home items in.
9. 1 box of goggles (25 student & 2 adult sizes) addressed for return to *Julia Boxler – YTH*

Materials by Experiment:

Experiment 1*: *Changing the Color of Metals (*Demonstration*)

1. 1 50-ml vial marked 11 containing 10-ml 0.1M $CoSO_4$
2. 1 50-ml vial marked 12 containing 10-ml 1M $CuSO_4$
3. 1 50-ml vial marked W containing 10-ml water
4. 1 10-ml vial marked S containing 0.5 g sodium borohydride
5. 1 long stirrer
6. 1 beryl pipette
7. 3 2-oz clear polypropylene cups marked 11, 12 and 13.

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[1] The *12d* here denotes "12 penny"—the size of the nail. They're ~ 3¼" long.
[2] Other than the finishing nails that are part of the cork/nail assemblies, there are two kind of nails in your materials. One has an obvious gray Zn anodized coating. The second is relatively shiny and is called a "bright finish" nail.
[3] To be used the night before your demonstration.

Experiment 2*: *Metals Lead the Way (*Individual/Group*)

1. 5 corks each with an iron nail through it (cork/nail assembly)
2. 5 plastic bowls
3. 5 paper towels
4. 6 small pieces of Zr metal in a small baggie labeled Zr.
5. 6 small pieces of Mg ribbon in a small baggie labeled Mg.
6. 6 ¾" pieces of Cu wire in a small baggie labeled Cu.
7. 6 small paper clips in a small unlabeled baggie.
8. 6 small pieces of Al foil in a small baggie labeled Al.
9. 5 small round Ceramic Magnets.

Experiment 3*: *Can Metals Conduct More Than Electricity? (*Group*)

1. 5 5.5-oz cups
2. 5 6" square piece of Al foil
3. 5 wooden popsicle sticks
4. 5 3½" copper rods
5. 5 plastic knives
6. 5 Zn-coated anodized 12d (~3¼") steel nails

Experiment 4*: *Where are Metals Found in Nature? (*Demo/Individual/Group*)

1. 2 2-oz clear unlabeled polypropylene cups.
2. 5 4-oz plastic cups labeled 41.
3. 5 2-oz plastic cups labeled 42.
4. 1 small baggie labeled Ca containing several pieces of Ca.
5. 5 10-ml vials each labeled 4 containing 7 ml of 1M $CuSO_4$.
6. 5 small squares (about "1½") of aluminum foil (kitchen grade) in a small unlabeled baggie.
7. 5 long wooden stirring sticks.
8. 1 pair of adult-sized plastic gloves.
9. 25 pairs of student-sized plastic gloves.
10. 1 beryl pipette.
11. 5 small magnifying glasses.
12. 5 tweezers
13. 3 50-ml vials label 4 filled with 0.25M HCl.
14. 1 salt packet (see p. 11, **Preliminary Steps**).

Experiment 5*: *Enhancing Metals with Metals (*Demo/Individual/Group*)

1. 1 50-ml vial labeled 5 containing 40 ml of 0.05M $AgNO_3$ solution each.
2. 5 strips of copper foil, 1/2"x3"
3. 31 paper towels
4. 125 pennies
5. 25 50-ml vials labeled V containing ~ 20ml of vinegar

6. 35 packets of salt.
7. 1 water bottle containing 150 ml of blue 1M copper sulfate solution
8. 25 5-ml beryl pipettes
9. 5 4-oz. plastic cups labeled "C"
10. 25 12d "bright finish" nails and 5 Zn-coated nails. The outer coatings of 5 other Zn-coated anodized nails should have been treated beforehand to expose some of the steel underneath.
11. 1 brown bottle containing about 473 ml of 3% H_2O_2.
12. 5 4-oz cups labeled 53H
13. 5 4-oz cups labeled 53W
14. 1 long wooden stirrer

Experiment 6*: *Can Metals be Trained to Remember? (*Individual*)

1. 5 9-oz clear plastic cups labeled HW
2. 25 4" lengths of memory wire
3. 25 small paper clips
4. 1 small metal thermometer

Setup

Note: In our recommended setup there are 5 places each at 5 student tables.

Preliminary steps:

This year there are several demonstrations that need materials from your Demonstrator's table, but the students need to be able to see what you're doing. We recommend that you place your table near the center of the room and pick out a "strategic place" near your table from where you can easily access your materials and the students can see what's going on.

The $CuSO_4$ used in Experiment 4 this year requires an addition of salt for success. This salt was inadvertently left out of the solution on GAK Day, so we added a packet of salt to the materials for that experiment. Please add a pinch of salt 😋 (maybe ¼ of the salt packet) to the 10 ml vial with the $CuSO_4$, cap and shake to dissolve the salt before you proceed with the experiment.

- At **each station**[4] put the following:

1. 1 copy of the *Marvelous Metals* word puzzle with *Results of Experiment 4 (Part 2)* on the reverse side.
2. 1 copy of the *Student Feedback* form
3. 1 golf pencil.
4. In a sandwich bag:
    a. 1 National Chemistry Week "business card"
    b. 1 card magnet
    c. 1 cork

Experiment 1: Changing the Color of Metals *(Demonstration)*

- At the **demonstrator's table** place the following:

1. 1 50-ml vial marked 11 containing 10-ml 0.1M $CoSO_4$.
2. 1 50-ml vial marked 12 containing 10-ml 1M $CuSO_4$.
3. 1 50-ml vial marked W containing 10-ml water.
4. 1 10-ml vial marked S containing 0.5 g sodium borohydride.
5. 1 beryl pipette
6. 1 long stirrer
7. 3 2-oz clear polypropylene cups marked 11, 12 and 13.

[4] *Station* refers to a student's place at a table.

Experiment 2: Metals Lead the Way *(Individual/Group)*

- In the **<u>center of each student table</u>** put the following:
  1. 1 cork/nail assembly.
  2. 1 plastic bowl about ¾ filled with water.
  3. 1 small round Ceramic Magnet.
  4. 1 paper towel.
  5. 1 small piece of Zr metal from the small baggie labeled Zr.
  6. 1 small piece of Mg ribbon from the small baggie labeled Mg.
  7. 1 small piece of Cu wire from the small baggie labeled Cu.
  8. 1 small piece of Al foil from the small baggie labeled Al
  9. 1 paper clip from the small unlabeled baggie.

  (One of each metal sample in each bag is for your use with Exp. 4. You can put them on your table now or later when you set up Exp.4.)

Experiment 3: Can Metals Conduct More Than Electricity? *(Group)*

- In the **<u>center of each student table</u>** put the following:

  1. 1 5.5-oz cup.
  2. 1 6" square piece of Al foil.
  3. 1 wooden popsicle stick.
  4. 1 3½"copper rod.
  5. 1 plastic knife.
  6. 1 Zn-coated 12d anodized steel nail.

☛ You need to put at least 5 or 6 ice cubes and water into each 5.5-oz cup. This can be done now or at the beginning of the experiment—or, better yet, if you have an assistant, it's ideal to ask that assistant to begin to aliquot the ice cubes as you're completing Experiment 2.

Experiment 4: Where are Metals Found in Nature? *(Demo/Individual/Group)*

- At the **<u>demonstrator's table</u>** place the following:

  1. 2 2-oz unlabeled polypropylene cups, one empty and one about ½ filled with tap water.
  2. Several pieces of Ca from the small baggie labeled Ca.
  3. 1 pair adult-sized plastic gloves
  4. 1 pipette
  5. 1 piece of Zr metal from the small baggie labeled Zr from Exp. 2's materials.
  6. 1 piece of Mg ribbon from the small baggie labeled Mg from Exp. 2's materials.
  7. 1 piece of Cu wire from the small baggie labeled Cu from Exp. 2's materials.
  8. 1 paper clip from the small unlabeled baggie from Exp. 2's materials.
  9. 1 piece of Al foil from the small baggie labeled Al from Exp. 2's materials.
  10. 3 50 ml vials labeled 4 each filled with 0.25M HCl.

- At **at the center of each student table** place the following:

    1. 1 10 ml vial labeled 4 containing about 7 ml of the $CuSO_4$ solution.
    2. 1 piece of aluminum foil.
    3. 1 4-oz plastic cup labeled 41 about ¾ full of tap water.
    4. 1 empty 2-oz plastic cup labeled 42[5]
    5. 1 wooden stirring stick.
    6. 5 pairs of student-sized gloves.
    7. 1 small magnifying glass
    8. 1 disposable tweezer

Experiment 5: Enhancing Metals with Metals (*Demo/Individual/Group****)***

Preliminary steps:

- Open the water bottle containing 1M $CuSO_4$ solution and aliquot the contents into the 4-oz cups labeled C at the center of each table (each a little less than ¼ full).
- Open the brown bottle of H_2O_2 and aliquot the contents into the cups labeled 53H at the center of each table (each cup will be about ¾ full with H_2O_2).

At **the Demonstrator's table** place the following:

1. 1 50 mL vial labeled 5 containing 40 mL of 0.05M $AgNO_3$ solution
2. 1 strip of copper foil, ½"x3"
3. 1 paper towel
4. 1 long wooden stirrer

At **each station** place the following

1. 1 beryl pipette
2. 1 salt packet
3. 5 pennies
4. 1 50 mL vial labeled V containing about 20 ml of vinegar.
5. 1 paper towel
6. 1 12d "bright finish"[6] nail (do NOT use any of the sanded nails or Zn-coated anodizied nails here).

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[5] About 30 ml of 0.25M HCl from the vials labeled 4 will eventually go into each cup labeled 42 at the center of each table. In the text it tells you to aliquot the HCl when you get to that point in Exp. 4. But if you have an assistant, ask them to aliquot the HCl as you're finishing Exp. 3. The reason for this timing is to minimize the exposure of the students to the acid.

[6] There are two kind of nails in your materials. One has an obvious gray Zn coating and the other is relatively shiny. This latter nail is the "bright finish" nail.

At the **center of each table,** place the following

1. 1 4-oz cup labeled C containing about 20 ml of $CuSO_4$
2. 1 4-oz cup labeled 53H about ¾ full of hydrogen peroxide
3. 1 4-oz cup labeled 53W about ¾ full of tap water
4. 2 packets of salt
5. 2 12d nails—one a Zn-coated anodized nail and a second previously Zn-coated anodized nail that has been pretreated by you to remove most of its Zn coating and expose the steel underneath.
6. 1 paper towel.

Experiment 6: Can Metals be Trained to Remember? *(Individual)*

- At the **demonstrator's table** place the following:

    1. The demonstrator's thermos filled with very hot tap or previously boiling water and/or a measuring cup suitable for microwaving or pouring.
    2. 1 small thermometer.

- At the **center of each table** place the following:

    1. 1 clear plastic 9-oz cup labeled HW

- At **each station** place the following:

    1. 1 4" length of memory wire
    2. 1 small paper clip

Greet the Students (and Parents) Upon Their Arrival, Distribute Goggles, and Organize the Seating

1. Welcome the students and parents as they arrive and tell them that they're in for a lot of fun today. Maybe ask the librarian to do this as well.
2. Help the students or have the students' parents put on their goggles. Adjust the straps as necessary. (Note: These goggles are sanitized each year and prior to each demonstration.) Suggest that the students pull the air vents open for comfort while wearing the goggles.
3. Distribute the students 3-5 per table. 5 students per table would be best.

Opening Discussion

Introduce the Items on the Tables:

- Tell the students to **please** not touch anything until told to do so and not to shake the table or things could fall over and the fun ruined. We have liquids on the table which could stain clothing. Be careful!! Never taste or smell anything directly, as if they were in a laboratory!
- Tell the students that various items have been gathered for them on their table. Most items in today's Program are common household items.
- Put on a pair of the adult-sized goggles. If you have an assistant, ask them to do the same. Verify that all students have goggles on.

Introduce Yourself and the Program

- Introduce yourself as a chemist, science teacher or engineer (or state your interest in chemistry and science) and introduce the American Chemical Society as the largest organization in the world devoted to a single profession.
- Ask the students if they can think of any chemicals. After entertaining a few examples, tell them that the air they breathe is made up of several different chemical elements *[e.g., O_2, N_2, Ar, Ne, He]* and even some compounds *[e.g., CO_2 and H_2O]*. Since all of these students have heard of O_2, N_2 and CO_2 and H_2O, perhaps now would be a good time to use these to explain the difference between elements and compounds. We're going to encounter both in our journey during the next hour.
- Introduce National Chemistry Week—what it is and why we do it. *(Hint: it is a nationwide event put on by volunteers like you to let non-scientists know about chemistry, how much fun it can be and how it can improve our everyday lives[7].)*
- Please tell the students that we'd really like for them to vote for the Experiment they liked most in today's Program. At the end of the Program they're going to have a chance to vote for their favorite Experiment as well as the one that they think taught them the most. They'll do this via the hardcopy *Student Feedback* form at their places. So tell them to remember what they like about each Experiment.

[7] BTW, when you see an item in parentheses and in italics, it's an item intended for you only.

Introduction to This Year's Program

Please tell the students the following to introduce this year's Program.

Metals play such a central role in our modern society that sometimes we don't even think about what they do for us. Can you imagine

- coins made of wood instead of steel, bronze, copper, silver or gold?
- jewelry made of only wood or plastic?
- modern skyscrapers (like the one below) made only of stone without nails, metal pipes or steel girders?
- cars, cell phones, TV's and computers made completely of wood or plastic?
- or wooden magnets?

Figure 1. A building under construction in downtown Cleveland showing uses of steel.

No, living in our modern times without metals would be difficult indeed.

In our experiments this year we're going to investigate many facts about metals including

- How metals help us find our way
- Where we get them from
- How we can put thin metal coatings of expensive metals on cheaper metals to
    - Make them more attractive using very little of the expensive metal
    - Protect them from the elements
- The range of reactivities of metals (as an indicator of the form in which a metal is expected to be found in nature—elemental or compounded in ores).
- How metals can be combined with other elements and then change color.
- How metals can even be trained to remember things.

Today we're going to do several experiments that demonstrate all these unique qualities of metals.

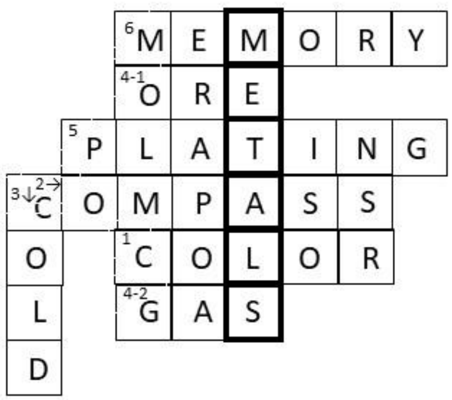
Please explain to the students that many of today's experiments involve the movement or transfer of something called *electrons*. These electrons are negatively charged particles which are one of the building blocks of atoms and are the same electrons which make up the electric current in our homes. We'll refer to electrons as we tell the students about *oxidation states* in Experiment 1.

We're also going to complete a word puzzle based on today's experiments. *(A completed puzzle is on the next page.)* Tell the students that at each of their places is a blank version of this word puzzle. You'll query the students after the completion of each experiment to see which of the 7 words in the list they heard during that experiment. Ask the students to write in each experiment's number as they figure them out. Note that 4-1 refers to Part 1 of Experiment 4; 4-2 refers to Part 2 of that experiment.

So let's go and let's have some fun with our *Marvelous Metals*.

Marvelous Metals

Word Puzzle



The Word list contains words that your demonstrator will use as he/she takes you through today's experiments. Listen as your demonstrator discusses each experiment and put the experiment's number next the key words as you hear them. At end of the hour you'll fill in the above crossword puzzle with the key words from each experiment. When finished, the magic word will be revealed.

Word List

Key Word	Experiment
Cold	3
Plating	5
Gas	4-2
Memory	6
Ore	4-1
Compass	2
Color	1

Experiment 1: Changing the Color of Metals *(Demonstration)*

Experiment Purpose & General Methodology

For the demonstrator:

In this experiment we're going to use sodium borohydride to reduce Co and Cu ions in aqueous solution resulting in precipitates and color changes. We're doing this to demonstrate to the students that metals can exist in elemental form or in compounds, and within compounds metals can exist in different oxidation states. Changes from one oxidation state to another are often accompanied by color changes as we shall see here.

We're not going to go into details about redox reactions since we believe this discussion is beyond second graders. Rather, please tell the students that we'll be using the term *oxidation state*, changes in which involve the gain or loss of electrons. Tell them that a change in one oxidation state to another in this experiment will be indicated by a change in color.

Note: Gas bubbles will result from the reaction of borohydride and the aqueous solutions. Therefore, once the experiment begins, ***NO*** containers containing liquid should be tightly capped.

Introduce the Experiment

Tell the students the following:

As we shall see later in Experiment 4, our *Marvelous Metals* are sometimes found in nature in their elemental state as rocks or veins in the earth or compounded with other elements as in salts. These salts are similar to table salt which is really a harmless combination of a metal and a deadly gas. In this experiment we're going to use two of our *Marvelous Metals*—cobalt and copper—to show that metals can exist in many oxidation states in these compounds as shown by changes in color.

Performance Details

The Demonstrator (only) will perform the following:

Perform this demonstration at your "strategic place" (cf., p.11) near your Demonstrator's table where all the students can observe your actions and the results.

1. Transfer the $CoSO_4$ into the 2-oz plastic cup marked 11
2. Transfer the $CuSO_4$ into the 2-oz plastic cup marked 12.
3. Pour the water from the 50-ml vial marked W into the 10-ml vial marked S containing sodium borohydride.
4. Use the stirrer to mix/dissolve the aqueous borohydride solution until it is approximately homogeneous and pour into the plastic cup marked 13, leaving the 10-ml vial UNCAPPED.
5. Using the beryl pipette, add a few (1 or 2) drops of the aqueous borohydride solution from the cup marked 13 into the cup marked 11.

6. A dark precipitate will form at the top of the cup marked 11. Swirl the cup gently to disperse the contents and watch the color change. The $CoSO_4$ solution in the cup marked 11 should turn gray (Co+2 reduction to Co +1).
7. Repeat this process with the cup marked 12 with the same procedure and same results. This time the $CuSO_4$ solution in the cup marked 12 should turn greenish (Cu+2 reduction to Cu+1).

Allow these solutions to sit/be observed on your Demonstrator's table throughout the remainder of the presentation. You should observe a gradual color change back to orange/pink (Co) or blue (Cu) as the ions are oxidized, though the amount of color change will depend on environmental conditions, how much borohydride was added, etc.

Conclusions

Tell the students:

In this experiment we demonstrated that our *Marvelous Metals* can exist in many oxidation states in metallic compounds with other elements and that these oxidation states can be changed by other chemicals. This was demonstrated by the color changes we observed that were caused by the transfer of electrons between the metals and other chemicals via chemical reactions called oxidation/reduction reactions.

Finally, ask the students to look at the Word List word in the *Marvelous Metals* Word Puzzle. Which of these did they hear in Experiment 1? *[Ans: color.]* Tell them to write 1 next to the word *color* in the Word List of their puzzles.

Technical Information (for the Demonstrator):

Sodium borohydride (NaBH4) is commonly used to reduce aldehydes and ketones to their related alcohols because it is a relatively mild reducing agent.

Experiment 2: Metals Lead the Way *(Individual/Group)*

Purpose & General Methodology

This Magnetism Demonstration involves a very interesting property of one of our most common *Marvelous Metals*—ferromagnetism of metallic iron. We'll perform this experiment in 3 parts:

1. check several materials for ferromagnetism
2. demonstrate how iron is attracted to magnets
3. rub an ordinary iron nail against a magnet to use its ferromagnetic property to magnetize it. The nail is then used as a compass pointer.

Introduce the Experiment

Tell the students:

One of our most useful and common *Marvelous Metals* is iron. Iron is the major component of steel, so without iron we wouldn't have nails, cars or modern skyscrapers—or compasses. Compasses have saved many lives over the centuries, so let's investigate what's required to make a pointer for one.

Performance Details

Tell the students:

***Part 1*: First, Let's See which Metals are Magnetic (Individual)**

In the center of the table there are 5 small metal samples. These are as follows:

1. a strip of Zr
2. a small piece of Mg ribbon
3. a small piece of Cu wire
4. a small strip of Al foil and
5. a small paper clip (Zn).

Some these small metal samples—in particular the Zr—have sharp edges. Tell the students to be careful to not cut themselves when they pick them up.

One of the small metal samples is Al foil—easily identifiable, as is the Cu wire. Tell the students that the paper clip is anodized so it actually represents a piece of Zn, so let's call it Zn. Of the two remaining samples, the Mg ribbon is the shinier, aluminum-colored strip while the Zr strip is a darker, duller gray. [*Help the students identify each metal sample.*] After the samples have all been identified, ask each of the five students at the table to pick up one of the metal samples.

The students should remember which sample is theirs and what their metal is. Each student should use his/her card magnet (from the sandwich bag) to check to see if his/her material is attracted to his/her magnet. [*only the paper clip will be and then only weakly because of the Zn coating.]* If their samples are not <u>strongly</u> attracted to their magnets, their samples are not ferromagnetic and useless as compass pointers. The students should now replace their metal samples back in the center of the table—we'll be using them again in a minute. <u>Remind them that they should remember which sample is theirs and what metal it is</u>.

Now ask one of the students to pick up the nail/cork combination and test the nail against the small round magnet next to it. The iron in the nail should be attracted to the magnet, so it should be a good candidate for a compass pointer.

<u>Part 2</u>*: *Test the Iron Nail's Properties (Group)

Do the following:

- Tell the student with the nail/cork combination to float it in the water in the plastic bowl.
- Tell the students to take turns positioning the round magnet next to the nail <u>outside</u> of the plastic bowl and pull the nail along the circumference of the bowl. *[The nail, of course, should follow the magnet and end up in a random position.]*
- Ask the students at the various tables which way the nail at their table points when the magnet is removed. *[Ans: all the nails should all be pointing in different directions, so the final direction is random.]*
- If the directions are random that means that the nail isn't functioning as a compass, so let's see if we can do something to change this.

<u>Part 3</u>*: *Making a Compass (Group)

Tell the students the following:

Several metals—iron, cobalt and nickel—are ferromagnetic which means they are potentially useful as compass pointers. Since we have plenty of iron nails available, we'll use one as our compass material. As we have seen, iron is attracted to a magnet, but it is not necessarily a magnet by itself or all the nails would have ended up pointing N/S. A compass points N/S because the pointer is magnetized. All magnets have two poles, a north pole and a south pole, and the north pole of one magnet is attracted to the south pole of another magnet.

- Ask the students to tell you which direction is north. *[Ans: toward the Lake.]* If possible, use the compass on your cell phone (or perhaps one of the students' phones) to find north and then point in that direction. Otherwise, just point north toward the Lake.
- Ask a second student remove the nail/cork combination from the bowl and dry it somewhat on the paper towel provided.
- When dry, a third student should hold the ends of the cork between two of his/her fingers of one hand. With the round magnet in the other, rub the magnet against one end of the nail, over the cork and down the other length of the nail 20 times <u>*in one direction only*</u>.

- Assist the fourth student to refloat the nail/cork assembly in the water.
- Give the assembly 30 seconds or so to settle down. Ask the fifth student if the nail now points in any one direction. *[Ans. It may take a bit for the nails' motions to settle down, but they should eventually point in that direction that the students identified as N/S]*.

Finally, ask the students which word in the *Marvelous Metals* Word Puzzle Word List that they heard in Experiment 2. *[Ans: Compass.]* Tell them to write 2 next to the word *compass* in the word list of their puzzles.

Conclusions

Tell the students the following:

- Iron is not necessarily magnetic by itself but can become magnetized by rubbing it against a permanent magnet because it's ferromagnetic.
- We used iron's ferromagnetic property to magnetize it and create a compass pointer.
- The iron nails all pointed to the north because of the magnetic field of the earth itself.
- This amazing property allowed sailors to tell which direction they were travelling when they could not see land. Without this property of the *Marvelous Metal* called iron, many travelers would have become helplessly lost and could have lost their lives.

Technical Information (for the Demonstrator):

- Ferromagnetism is a phenomenon that occurs in some metals, most notably iron, cobalt and nickel, that causes the metal to become magnetic when placed in a strong magnetic field. The atoms in these metals have an unpaired electron, and when the metal is exposed to a sufficiently strong magnetic field, these electrons' spins line up parallel to each other. The spinning of the charged electron creates a magnetic moment, which in turn can align with an external magnet, thus making iron magnetic.

Experiment 3: Can Metals Conduct More Than Electricity?*(Group)*

Purpose & General Methodology

This experiment is designed to show the students which of our *Marvelous Metals* is the most conductive and to compare the conductivity of our *Marvelous Metals* with other students' samples.

Introduce the Experiment

Tell the students:

Everyone probably knows that electricity is conducted around in our homes using copper wires. Electricity can be conducted through metals like copper because they have free electrons which actually flow through the wire as electric current. Now we're going to investigate if those same electrons can conduct heat (another form of energy) through metals just like electricity and if other materials conduct heat as well as those *Marvelous Metals* do.

Performance Details

Tell the students:

At the center of each table is a 5.5-oz cup, a 6" square piece of Al foil and samples of several materials: a wooden popsicle stick, a copper rod, a plastic knife and a 12d Zn-coated anodized steel nail. Go to each table and put about 5 or 6 ice cubes into the 5 5.5-oz cups and add sufficient water to fill each cup about half full. <u>You can do this now, during the setup or, ideally, if you have an assistant, ask him/her to set this up while you're completing Experiment 2.</u>

Ask one of the students to carefully cover the cup with the piece of 6" square Al foil and fold the foil over the sides. Then ask each of the other students to pick up one piece of the sample materials each and *carefully* stick them into the ice bath through the foil taking care not to tear the foil. The samples should be placed approximately on the perimeter of a small circle about 2" in diameter somewhere near the center of the foil—but not touching—and standing vertically. After about 30 seconds, ask the students to *carefully* grasp the samples one by one to see which is the coldest. The students should take turns doing this.

Ask the students: which material feels the coldest? [*Ans: the copper rod followed by the zinc-coated nail]*. Ask if they could discern any cooling in the plastic knife or the wooden stick. *[Ans: No.]* Their observations should follow the data in the table on the following page.

Finally, ask the students which word in the *Marvelous Metals* Word Puzzle Word List that they heard in Experiment 3. *[Ans: Cold.]* Tell them to write 3 next to the word *cold* in the Word List of their puzzles.

Conclusions

Tell the students:

Both of the metal samples conducted heat in the same way they might conduct electricity, but in this case, heat was conducted from the samples into the ice bath heating the bath slightly and thereby cooling the samples. The free electrons in these *Marvelous Metals* don't care which way electricity or heat flows—they flow from high potential to low and from hot to cold. The other materials we tested don't have those free electrons, so they don't conduct like the *Marvelous Metals* do.

Technical Information (for the Demonstrator)

Thermal conductivities for the metals tested are as follow:

Metal	Thermal Conductivity BTU/(hr·ft·°F)
Copper	223
Aluminum	118
Zinc	67
Steel	17
Wood	0.07
Polyurethane	0.01

One interesting device that makes use of the fact that metals can conduct heat is a heat pipe, used by NASA to cool satellites in communications, global positioning systems, and defense purposes.

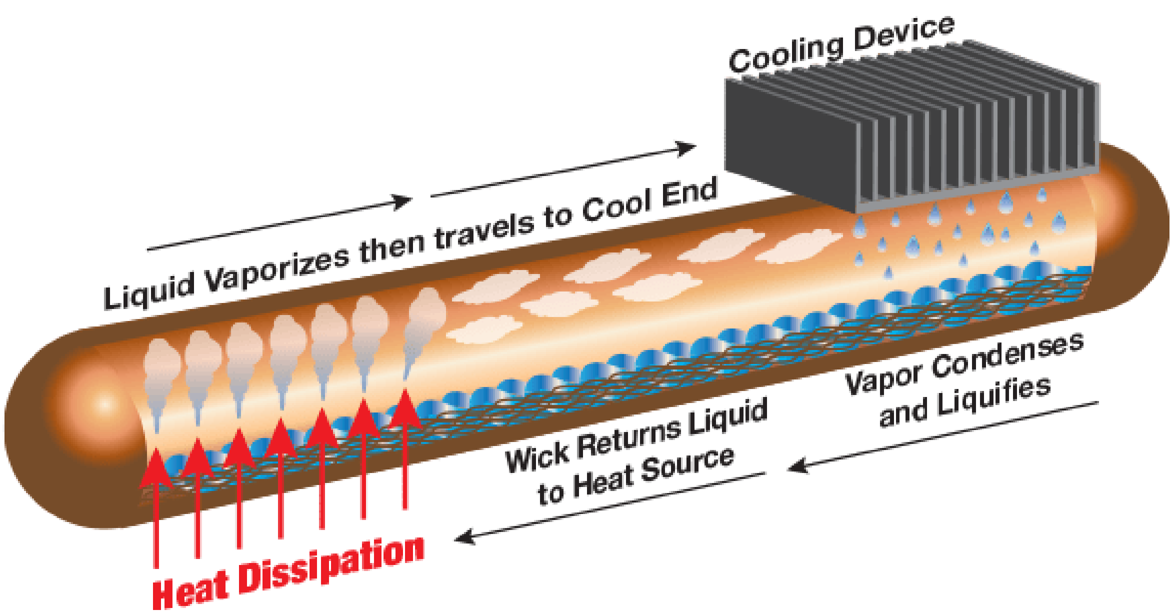


Figure 2. Heat Pipe from https://www.radianheatsinks.com/heatpipe/

A heat pipe is basically a hollow cylinder filled with a vaporizable liquid under vacuum. The heat pipe functions by absorbing heat in the Evaporator Section (lower, left in Figure 2), boiling the working fluid, then releasing heat in the Condenser Section (upper, right in Figure 2) where the working fluid condenses and returns by gravity (or by wicking as shown in Figure 2) to the Evaporator Section. Because the working fluid has a very high heat of vaporization, a large amount of heat can be transferred by a heat pipe from a hot spot to a cooler remote location without the use of a mechanical pump. This especially useful in NASA's space applications wherein the use of any rotating machinery is discouraged to minimize power requirements, to reduce weight and also to reduce the probability of a malfunction which obviously can be difficult to deal with in space.

NASA heat pipe technology used in spacecraft to keep hardware and critical electronics cool has found its way into everyday use. One such use is with notebook computers. Tiny heat pipes are in wide use to cool the main central processor chip. Keeping our computers cool is another way our *Marvelous Metals* are working for us today.

Experiment 4: Where are Metals Found in Nature? *(Demo/Group /Individual)*

Purpose & General Methodology

For the demonstrator:

Where metals are found in nature is often dictated by their reactivity. Metals which have a high reactivity are found as compounds in nature while less reactive metals are typically found in their metallic form. In this experiment we're going to examine the reactivity of metals (and hence where/how they're typically found in nature) in two ways:

1. by testing the reactivity of two metals by contacting one with another. We'll do this using a chemical reaction to precipitate a less active metal (Cu) out of a solution of one of its salts using a solid sample of a more active metal (Al) (Part 1).
2. by reacting several metals in water or acid to gauge their reactivity by observing the amount of H_2 bubbles produced[8] (Part 2).

In ***Part 1*** we'll simulate a copper ore with a $CuSO_4$ solution. When a piece of aluminum foil is placed into a vial containing the $CuSO_4$ solution, the more active aluminum is oxidized thereby reducing the copper ions in solution to a pile of copper metal particles on the bottom of the vial. This demonstrates that Al is more active than Cu, so Al is usually found compounded with other elements as in ores. In ***Part 2*** the demonstrator will drip tap water onto a piece of Ca to demonstrate its strong reactivity while the students will place various metal samples into 0.25M HCl and will observe the bubble formation as H_2 is produced.

At the end of the experiment the students will fill out a chart listing the metals in the order of their reactivity. From this listing they'll be able to predict which of the metals are most likely to be found in nature as bare metals and which are likely to be found in compounds such as ores.

Introduce the Experiment

Tell the students:

Something called *reactivity* of a metal measures its tendency to combine with other elements in a chemical reaction. Chemical reactions occur all around us. One of the most common reactions that we see (especially in northern Ohio!) is the rusting of iron—iron reacts with oxygen in a reaction known to chemists as oxidation. Metals that are very active tend to form compounds with other elements, so they are typically found as ores or other compounds in nature. Metals which are less active are often found as bare metals in nature. In this experiment we'll measure the reactivity of several metals, and, based on the results of our experiments with some metals, we

[8] https://www.thoughtco.com/activity-series-of-metals-603960

should be able to predict whether that metal should be found in nature as a bare metal or combined with other elements.

We'll measure the reactivity of metals two ways:

1. by putting two metals into contact with each other.
2. by putting samples into either water or weak acid where we'll measure each metal's reactivity by its tendency to create bubbles.

In the first way we start with the knowledge that aluminum is usually found in ores while copper is often found as bare metal. The suggests that copper is less active than aluminum. So we'll start with a compound of the less active Cu (the opposite of how it should be found in nature) with a sample of bare metal of the more reactive Al and see if the situation reverses itself—i.e., if Cu metal forms. Let's see what happens when we contact Al foil with $CuSO_4$ (a simulated ore) in an aqueous solution.

Performance Details

***Part 1:* Precipitation of Cu from aq. $CuSO_4$ in the presence of Al foil**

The students will perform the following:

- Ask each student to put on a pair of protective gloves and keep them on through Experiment 6. *You should do this as well*. Everyone should already be wearing protective eyewear.
- Ask a volunteer student at each table to locate the 10 ml vial of aqueous $CuSO_4$ labeled 4 at the center of the table. *(This solution has 0.5g NaCl added/12 g of $CuSO_4$—cf.,* Technical Information (for the Demonstrator) *below*). This student should pick up the vial, remove the cap and hold against the table in front of him/her to make sure it stays upright. This vial contains our simulated copper ore—a compound.
- Ask another student to pick up the small piece of aluminum foil on the table and the wooden stick. This student should put the piece of foil into the 10 ml vial labeled 4 and use the wooden stick to push it down into the blue liquid.
- The students should observe what's happening. *[Cu is precipitating out. The solution becomes warm and could actually boil if it weren't cooled as it produces hydrogen gas bubbles as well as the copper precipitate.]*
- Allow the students to carefully touch the side of the vial to feel the heat generated.
- **Ask the students which word in the *Marvelous Metals* Word Puzzle Word List that they heard in Part 1. *[Ans: Ore.]* Tell them to write 4-1 next to the word *ore* in the Word List of their puzzles.**
- Stand the 10-ml vial up into the water into the cup labeled 41 to cool it. Do NOT re-cap it. Put this cup in the center of the table and move to ***Part 2***.

***Part 2:* Reactivity of Metals in Water and HCl**

In this part we'll measure the relative reactivity of several metals by putting samples into either water or weak acid. We'll begin with dropping water onto a piece of Ca.

The Demonstrator will perform the following:

At the Demonstrator's table are several pieces of Ca, an empty 2-oz clear polypropylene cup, a 2-oz clear polypropylene cup of water and a pipette (*you should have your gloves and eye protection on*). Go to your table and place 1 or 2 Ca particles into the empty polypropylene cup. *[Use your discretion here and start with just 1 or 2 particles: the Ca is going to react* ***exothermically*** *with water while spewing off lots of H_2; even though it's polypropylene, melting the cup is NOT a good idea. You can always add more Ca later to demonstrate the high reactivity of Ca.]* Fill the pipette with water and take your cup with Ca and your pipette to your "strategic place" (cf., p.11). Holding the cup by the edge, drip one drop of water onto the Ca. It should react quickly expelling H_2 from the water. Drip a few more drops of water onto the Ca for effect. Tell the students that you're only using water, but you're still getting a rather violent reaction.

Return the Ca cup to your table and pick up the 5 metal samples there: a strip of Zr, a piece of Mg ribbon, the piece of Cu wire, a piece of Al foil and a paper clip. Take these and the small 2-oz cup with water to your "strategic place". Slide the 5 metal samples into the water one by one. Wait for a few seconds after each insertion and show the students that nothing's happening with those samples in the water.

Ask the students: which of the metals do they think had the highest relative reactivity? *[Ans: the Ca because it demonstrated a violent reaction with only water while the rest of the samples did nothing in water.]*

The students will now do the following:

Tell the students to keep a record of the results of this experiment by giving each metal a score of 0-10 (10 = maximum bubbling) in the *Reactivity Results* column on the back of the word puzzle (*Results of Experiment 4 (Part 2) form)* as we test them. *[Since none of the samples bubbled in water except the Ca, it must be the most active of all the metals present, so the students should give it a 10]. They should enter a 10 next to Ca in the* Reactivity Results *column.*

Now go around to each table and pour about 30 ml of the 0.25M HCl from the three 50 ml vials labeled 4 on your table into the 2-oz cup labeled 42 (about ½ full) in the center of each table.

N.B.: 0.25M HCl is a relatively weak acid, but still nothing to be played with. At this point the demonstrator must *insist* that all students are wearing their plastic gloves and their eye protection. Tell the students to not touch the cup with the acid or shake the table. Keep a close watch on the students during the following step.

Each of the students at the table should now retrieve that metal sample they used in Experiment 2. Tell the students that they're going to perform the next step in the following order:

1. first the student with the **Zr** sample
2. the one with the **Cu** sample
3. the one with the **Zn** sample
4. the one with the **Al** sample
5. finally the one with the **Mg** sample.

Each student—one by one in turn—should now pick up his/her metal sample with the tweezer, carefully slide it into the cup of acid and release it ***without touching the acid***. All of the students should observe that sample for about 30 seconds to see if any gas bubbles are being formed. If so, tell that student whose sample it is to assign a number—1 to 10 with 10 being the most bubbling—to describe the amount of bubbles that are forming. Each student should record this number next to that metal in the *Reactivity Results* column. As each student finishes, ask his/her to *carefully* spin the cup about 70º to expose a different point on the cup for each student to slide their sample in so that the samples aren't overlapping. Repeat this process for each of the other 4 students and their samples one by one. When complete tell the students to list the metals (using their chemical symbols) in the *Metals in Order of Reactivity* column based on the score each received.

Collect the cups with the acid from each table at this point and put them on your table.

Conclusions

Tell the students:

Their list of metals in the *Metals in Order of Reactivity* column (*Results of Experiment 4 (Part 2) form*) from ***Part 2*** starting with the most active should be the following:

Metal	Reactivity Result	Metals in order of Reactivity
Al (slight bubbling in the acid if any)	2	Ca
Ca (violent reaction with just water)	10	Mg
Cu (almost no bubbling in acid)	1	Al
Mg (vigorous bubbling in the acid)	8	Zn
Zn (almost no bubbling in the acid)	1	Cu
Zr (no bubbling in acid)	0	Zr

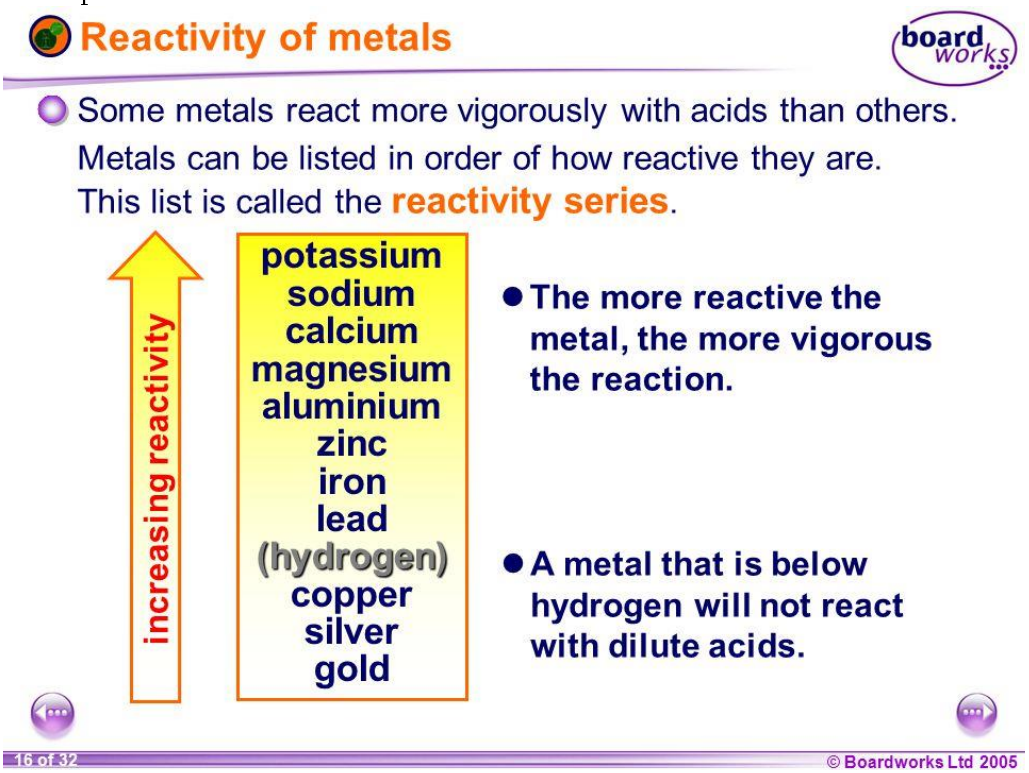
Ask the students to now look again at the vial from ***Part 1***. Let them remove the vial from the water and take turns using the magnifying glass to see the copper. We observe that by now lots of Cu has precipitated out of solution. This is exactly what is done with metals made in this fashion, i.e., made by metal extraction from ores, and it demonstrates again that Cu is less active than Al. So the result of Part 1 confirm those of Part 2.

Now ask the students which of the metals on our list is least active and therefore should be the most likely to be found in its metallic form in nature. *[Ans: Zr followed closely by Cu although both are sometimes found in ores and other compounds. When Zr is found in its metallic state, it typically has an outer oxide layer that renders it nearly inactive.]*

Finally, ask the students which word in the *Marvelous Metals* Word Puzzle Word List that they heard in Part 2. *[Ans: Gas.]* Tell them to write 4-2 next to the word *gas* in the Word List of their puzzles.

Technical Information (for the Demonstrator):

By using the reactivity series of metals as shown in the following diagram, one can predict the products of displacement reactions.



The salt added to the $CuSO_4$ in ***Part 1*** aids in the reaction producing hydrogen gas as it acidifies the solution which reacts independently with the aluminum:

$CuSO_4 + 2\ NaCl \rightarrow CuCl_2 + Na_2SO_4$
$CuCl_2 + H_2O \rightarrow Cu(OH)Cl + HCl$
$3\ CuCl_2 + 2\ Al \rightarrow 2\ AlCl_3 + 3\ Cu(s)\downarrow$
$2\ Al + 6HCl \rightarrow 2\ AlCl_3 + 3\ H_2(g)\uparrow$

Experiment 5: Enhancing Metals with Metals (Demo/Individual/ Group)

Experiment Purpose & General Methodology

An example of how our *Marvelous Metals* are used in daily life is in metal finishing. Metal finishing means coating an object with a thin layer of the metal, and it's used for some of the following purposes[9]:

- Greater corrosion resistance than the original object had
- Enhanced appearance of the original
- Increased electrical and thermal conductivity over the original
- Increased surface hardness over the original
- Greater wear resistance than the original.

This experiment will demonstrate metal finishing in 3 parts:

1. Ag deposition onto Cu foil (as might be done in costume jewelry)
2. Cu plating onto a galvanized ("bright finish") nail (as might be done by plating Cu onto the bottom of a steel pan to enhance conductivity and uniform cooking)
3. Demonstration of how Zn coating protects steel nails from corrosion

Part 1: Silver Deposition (Demonstrator Only)

Introduce Part 1

Tell the students the following:

- Metals such as gold, silver, chromium and copper are expensive.
- Many items in use around our homes are made of cheaper materials with a thin layer of the expensive metal applied on the surface. This is known as "plating" and it's an example of coating one metal with another to enhance its appearance or performance.
- Examples of this are gold plating on watches and chrome plating on automobile bumpers.
- Today we're going to watch this plating process take place as we "plate" a piece of copper foil with silver.

Performance Details:

Do the following:

- Still wearing your plastic gloves, go to your Demonstrator's table and open the 50 mL vial labeled 5 containing the $AgNO_3$ solution. Now go to your "strategic place" (cf., p.11) so all

9 https://www.sharrettsplating.com/blog/which-metal-finishing-option-is-for-you/

the students can see. Deposit the Cu foil into the vial using the wooden stirrer to push it down into the solution if necessary. Recap the vial and wipe it off with a paper towel. Tell the students the solution can stain, so you are **NOT GOING TO ALLOW THE STUDENTS TO HANDLE THE VIAL.**

- Tell the students that they'll begin to see something depositing on the copper foil soon.
- Place the vial in the center of your table for observation.

We'll come back to this a little later to see the progress of the silver plating, but for now let's move on to Part 2.

Part 2: Copper Plating (Individual)

Introduce Part 2

Tell the students the following:

- Have you ever seen one of your family's pots or pans that have copper coated on the bottom?
- Since copper conducts heat extremely well (remember Experiment 3?!), it's often coated onto the bottom of a steel or aluminum pot or pan to allow it to cook more easily and evenly.
- This plated cookware gives the benefits of even heating using copper without the expense of making the entire pot or pan completely out of expensive copper.
- In this part of the experiment we're going to see how copper can be coated onto another metal—in this case a steel nail to simulate a steel pot. But we have a twist to this part: we're going to get some of the copper that's going to be plated onto the nail from the surface of a penny.

Performance Details:

Tell each student to do the following:

1. On the table in front of each of them are 5 pennies, a 50 ml vial labeled V containing vinegar, a "bright finish" nail, a paper towel and a packet of salt. The pennies may look dirty[10], but much of the "dirt" on the pennies is actually black copper (II) oxide that has developed very, very slowly as the copper surface was exposed to the oxygen in the air for a long time (remember copper is a relatively inactive metal).
2. Carefully hold the vial at an angle and slide all of the pennies one by one into the vial labeled V. Be careful not to splash any vinegar during the loading. Close the vial tightly. Swirl the vial and take 30 seconds or so to see if the pennies are "cleaning" up, getting "brighter" or "dissolving". [*Very little if any change can be seen; the weak acid only slowly cleans the "dirt"*

[10] We get the pennies in rolls from the bank, so we have no control over what kinds of surfaces we might get on them. They might be new and shiny, old and oxidized or anywhere in between. Please adjust your comments about "dirty" pennies appropriately depending on which kind you get in your kit. If all you got was new, bright ones, unfortunately absolutely nothing will happen to the pennies in the absence of CuO so we recommend that you trade out the new pennies for some old ones of your own.

(oxide) layer off the "dirty" pennies.]

3. After observing the pennies for about 30 seconds, open your vial and then your salt packet. Carefully add the salt from the packet into the vial with the pennies and then slowly swirl the vial to dissolve the salt. The salt will speed up the action of the acid to dissolve the copper oxide on the surface of the pennies.
4. Observe the "cleaning" for another 30 seconds or so. The copper oxides on the surface of the old pennies are gradually coming off and copper(II) ions are entering the solution. Given enough time and acidity, the solution would turn blue from the copper(II) ions. But in order to speed up the experiment (remember, this experiment is about electroplating) a lot more "predissolved" copper ions are going to be added to the tube.
5. Tell the students to locate the cup labeled "C" on their table (1 cup per table). As this cup is passed from student to student, tell them to fill their pipettes from this cup and gently squirt the contents (about 4-5 ml total of the blue 1M copper sulfate solution) into each of their 50 mL tubes. Note the nice light blue color. This is what it would look like if we were to add more acid and let the pennies sit for an extended period of time. Replace the cap, tighten and shake the tube gently.
6. Remove the cap once again. Now pick up the "bright finish" nail at their place, carefully slide it into the blue vinegar/salt/copper sulfate, replace the cap once again and observe what happens for a few seconds.
7. We will return to this experiment later to see the progress of the Cu coating, but for now let's proceed to Part 3.

Part 3: Corrosion Protection (Group)

Introduce Part 3

- Iron, which is the major component of steel, is one of the most useful of all metals to us. It can oxidize in air over time to form iron oxide which we call rust.
- Suppose we want to store steel nails for some future use around the house. If something's not done to protect the iron in the nails from corrosion, we might just have a pile of rust when we go to use the nails sometime later.
- So, another example of metal finishing is the coating of steel with a light skin of zinc. This process is called anodizing and without it here in northern Ohio the steel in our cars would rust quickly away.
- In this final part of this experiment we're not going to apply the zinc coating; instead, we're going to see how well an anodized nail resists corrosion compared to a nail that has had much of its zinc layer removed.

Performance Details:

Tell the students the following:

- In the center of the table is a 4-oz cup labeled 53H with hydrogen peroxide in it, another 4-oz cup labeled 53W with water in it, 2 more packets of salt, a paper towel and 2 nails, one of which has had its zinc layer partially removed (the shinier one) and the other of which has a complete Zn coating on it.
- One student should place the two nails into the cup of water labeled 53W.
- A second student should open the 2 packets of salt and carefully sprinkle the salt onto the paper towel in the shape of a square about 2" on a side.
- A third student should remove the wet nails from the water and place them side by side on the paper towel in the salt.
- A fourth student should roll the nails in the salt on the paper towel so that they're covered with salt.
- The last student should ***carefully*** place both nails into the hydrogen peroxide in the cup labeled 53H.
- While things are happening with the nails, let's return to Parts 1 and 2 to see what's happening with them.

Return to Part 1: Silver Deposition

- Go to your Demonstrator's table, pick up the vial with the $AgNO_3$ and Cu foil and show it to the students. What's happened to the vial with the copper foil in it? By now the students should have been able to see that silver has deposited on the copper foil as time proceeded. While you hold the vial, allow the students to take turns using their magnifying glass to examine the silver layer on the foil.

- Metals are coated with other metals for lots of reason. Pennies these days are actually zinc coated with a thin layer of copper to make them look like they're made completely of copper. Costume jewelry is often made of a relatively cheap metal coated with expensive silver or gold to lower the price of the item.
- In this experiment we have shown one way in which costume jewelry might be made or some coins are made—coating a relatively inexpensive metal with an expensive one to make it look more attractive.

Return to Part 2: Copper Plating

- In this part we started by using salt and vinegar to remove the copper oxide from the pennies and begin to put copper(II) ions into solution.
- Chloride from table salt speeds up dissolving metal. Acid will dissolve the metal oxide (copper) from pennies forming ions in solution—a blue material.
- We "spiked" the copper solution to help speed up the plating process. The copper in solution is free to move around by itself. When the copper met the steel nail, some of the iron (or zinc) in the nail dissolves (goes into the acid solution) and some of the copper goes out of solution and turns back into a solid on the surface of the nail.
- This is one more example of how one metal can be used to plate another—in this case we used a nail to simulate a steel pot or pan, and the experiment is an example of the use of metal finishing to make the item more useful. Again, the students can take turns using the magnifying glass to examine the copper layer.

Return to Part 3:

- In this final part iron nails had already been coated with zinc to protect them from rusting. We removed some of the zinc from one of them to expose the iron underneath.
- Have a close look at the cup labeled 53H. What's happened? By now the nail that had been sanded should be showing signs of rusting since we put both nails in a very corrosive environment. There should be no rust on the anodized nail at all.
- So here's a final example of how one metal had been used to coat another—this time to protect the iron from rusting.

Finally, ask the students which word in the *Marvelous Metals* Word Puzzle Word List that they heard in Experiment 5. *[Ans: Plating.]* Tell them to write 5 next to the word *plating* in the Word List of their puzzles.

Conclusions

Tell the students the following:

In this experiment we've demonstrated several ways in which a one of our *Marvelous Metals* was used to make another even more marvelous! We showed the principles of how costume jewelry and some coins might be made, how steel pot and pans can be made to cook better by coating them with copper and how zinc prevents iron from rusting in cars, nails and other items. *Marvelous Metals indeed!*

Technical Information (for the Demonstrator):

Part 1:

The deposition of silver onto the nail in Part 1 is an example of electroless or autocatalytic plating which is a redox displacement reaction. The metal plated in this way tends to be very hard and less porous, thereby more resistant to corrosion.

Part 2:

After the copper(II) ions are in solution, another displacement reaction occurs to plate the copper(II) ions from solution onto the nail.

Part 3:

Part 3 demonstrated the results of the process of anodization, a common method for protecting iron with zinc even though zinc is more active.

Experiment 6: Can Metals be Trained to Remember? *(Individual)*

Experiment Purpose & General Methodology

This experiment will demonstrate that scientists can make interesting materials because of changes at the atomic level. At the atomic and molecular level we are talking about nano-sized structures. Solid phase changes in metal alloys at this atomic level can result in interesting properties exhibited by the entire material. We will compare a "normal" metal wire (a paper clip) with a "memory wire". We will impose a straight shape on the paper clip, and we'll bend the memory wires into coils. When these two wires are immersed into hot water, the memory wire will assume its original shape (straight), while the paperclip won't: it will stay straight.

Introduce the Experiment

Tell the students the following:

This experiment with our *Marvelous Metals* begins with a special wire. When you bend wire what happens? Does it bend pretty well? *Yes*. Does it sometimes break, if you bend it a lot, back and forth? *Yes*. Does it bounce back like a rubber band? *No*.

Scientists have made some nanomaterials that act very differently from what you expect! Scientists have blended some metals together into what's called *alloys*…at the atomic level the atoms in these alloys are arranged in slightly different ways depending on their temperature. We are going to compare 2 metals: one is a "nanomaterial" called a "memory wire" and the other is a regular wire—a paperclip!

Note to the Demonstrator:

At this point where the kids are ready to immerse their wires, the water should be at 95ºF to 100ºF or slightly higher for a successful experiment. As you begin to discuss this experiment, have an assistant go to each table and fill the single 9-oz. plastic cup on each table labeled HW with the hot water from library's tap or your thermos. (Note: the hottest tap water should be around 95-105 ºF which is satisfactory for this experiment. We choose to use a plastic cup over a Styrofoam cup so that the wires could be viewed more easily. The water isn't hot enough to melt the cup. Use the small thermometer provided to get the temperature.)

Performance Details

Tell the students to do the following:

1. Locate the 4" piece of memory wire, the paperclip, and the pencil on the table in front of them.
2. Straighten out the paperclip and set it down.
3. Starting at blunt end of their pencil, hold one end of the "memory wire" against the pencil with one finger while wrapping it completely around the pencil to form a coil.

4. Now remove the coil from the pencil and sit it down for a second. Don't worry if it unravels just a bit.
5. Tell the students that this special "memory wire" exists in two different phases, just like two phases of water—ice and liquid water, except in the wire we're dealing with has two *solid* phases. We won't be able to tell the difference between these two phases, but the results will speak for themselves.
6. Ask them how they can change ice (one phase of water) into liquid (a second phase of water). *Ans: heat it*.
7. Maybe we can do the same thing with the wires. Let's see what happens when we put these wires into hot water.
8. Tell the students to take turns to **CAREFULLY** drop both their wires into the cup of hot water labeled HW, taking care not to put their fingers into the water.
9. Take a moment to look at your wires but leave them in the cup for now. We'll remove them shortly (the water will be cooled down some) and you can take them home (one memory wire and one paperclip per student).

Conclusions

Tell the students the following:

1. What happened to the wires? *Ans*: the "memory wire" returned to its original straight shape because it has a "memory", but the paperclips remained straight—they didn't return to their "normal" paper clip shape because they aren't made of a wire with a memory.
2. The "memory" metal is special. It is a blend, or alloy of nickel and titanium called Nitinol that was first made in the 1960's. It can be used in eyeglasses, in art, and in stents in blood vessels. It returns to its original shape when heated above a certain temperature. It can also be stretched a bit and then return to its original shape just like a rubber band.
3. Picture yourselves as atoms in a row holding hands. First stiffly hold hands, then stretch out, and pull back together. Now pretend to all lean in one direction, then another. This is a picture of what the atoms in the metal are doing.
4. The students make take their memory wires home with them (at the end of the program) and repeat the experiment there as often as they like with a parent's help. There are instructions for doing this at the bottom of the reverse side of the Word Puzzle.
5. Try to remember if this is your favorite experiment!

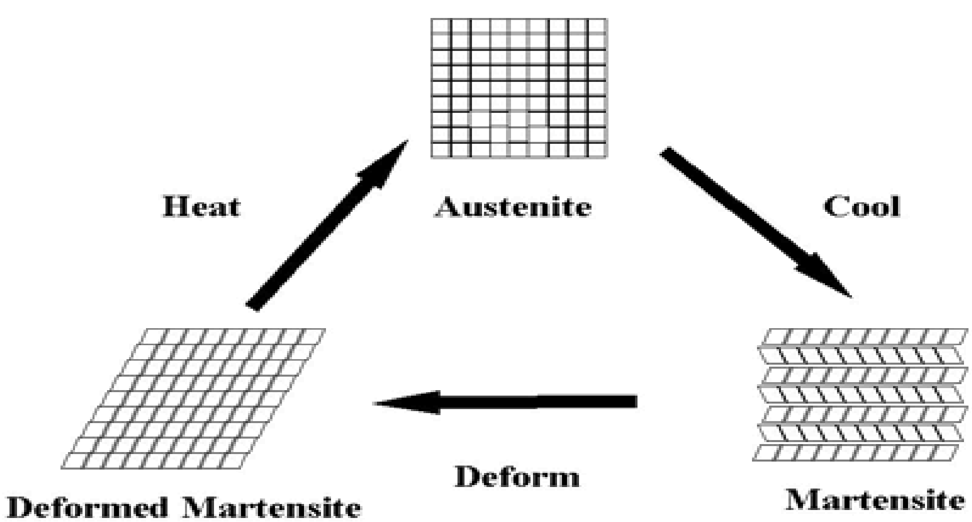
Finally, ask the students which word in the *Marvelous Metals* Word Puzzle Word List that they heard in Experiment 6. *[Ans: memory.]* Tell them to write 6 next to the word *memory* in the Word List of their puzzles.

Technical Information (for the Demonstrator):

In 1965, the first of a series of metal alloys of nickel and titanium was produced by the Naval Ordnance Laboratory. These alloys are called Nitinol, for Nickel Titanium Naval Ordnance Laboratory. Many of the alloys have a rather remarkable property: they remember their shape. This "smart" property is the result of the substance's ability to undergo a phase change – a kind of atomic ballet in which atoms in the solid subtly shift their positions in response to a stimulus like a change in temperature or application of mechanical stress. These "memory wires" have been included in this series of experiments about nanotechnology because the phase change involves transitions at the atomic level.

NiTi alloys change from austenite to martensite upon cooling. The alloy can exist in either of two structures (solid phases) at room temperature, depending on the exact ratio of nickel to titanium atoms. The structure found above the temperature of the phase change possesses the high symmetry of a cube and is called austenite; the structure found below the temperature of the phase change is much less symmetric and is called martensite. In the martensite phase the material is very elastic, while in the austenite phase the material is comparatively rigid.

Nitinol can be "trained" to have a new shape by heating it into the austenite phase and then deforming it into the desired shape. As it cools to below the phase transition temperature, the material enters the martensite phase. In the martensite phase the shape can then be changed by mechanical stress: groups of atoms that were "leaning" in one direction will accommodate the mechanical stress by "leaning" in another direction, as allowed by the less symmetric structure. The sample will revert to the shape enforced upon it while it was in the martensite phase by returning it to the austenite phase through an increase in its temperature.



(In our case, the wires were originally "set" into a straight shape by the manufacturer while heated into the austenite phase and then cooled below the phase transition temperature; they return to this straight shape after coiling them while in the martensitic phase and reheating back into the austenite phase.) The thermal energy acquired by the shape through heating it provides the energy the atoms need to return to their original positions and the sample to its original shape.

The transition from the martensite phase to the austenite phase is only dependent on temperature and stress, not time, as most phase changes are, as there is no diffusion involved. Similarly, the austenite structure receives its name from carbon steel alloys of a similar structure. It is the reversible, diffusionless transition between these two phases that results in special properties. While martensite can be formed from austenite by rapidly cooling carbon steel, this process is not reversible, so steel does not have shape-memory properties.

Many diverse applications have been developed for "memory metal" and other "smart" materials. These uses include eyeglass frames, coffee pot thermostats, electrical connectors, deicing system, heat pipes, clamps, and sculptures.

Research is underway on using shape memory alloys to deploy solar arrays and antennae on satellites and to control the balance on helicopter rotor blades. The biocompatibility of NiTi allows its use in many medical applications such as vascular stents, anchors for attaching tendons to bone, medical guidewires, medical guidepins, root canal files, bendable surgical tools, and devices for closing holes in the heart.

For more to do with Nitinol see:
https://nano-cemms.illinois.edu/media/content/teaching_mats/kits/nitinol/docs/nitinol--activity_guide--updated-pdf.pdf

Closing Session

- Remind the students that we need their help to determine which experiment they liked the most. So vote for your favorite experiment AND the experiment that helped you learn some fun facts about our *Marvelous Metals*. Use your golf pencil to complete your *Student Feedback* form <u>now</u>.

- Pass out a sandwich bag (there's an extra stack of them on your table) to each student for putting their "take-homes" in. The students can take the following home with them:

    1. Experiment 1: Nothing.
    2. Experiment 2: their ACS/National Chemistry Week "business" cards, their card magnets, their cork, their nail and a copy of the *Instructions for Magnets and Compasses* but NOT the cork/nail assemblies and NOT the metal samples—we don't want them taking the metal samples home and then swallowing them. They can put all their take-home items into the plastic sandwich bag provided.
    3. Experiment 3: nothing.
    4. Experiment 4: nothing—do <u>***NOT***</u> let the students take the nail/cork assemblies or any of the small metal samples home.
    5. Experiment 5: their pennies—once washed off.
    6. Experiment 6: memory wire and paper clips—go around to each table, decant off the now-warm water and give the kids their memory wire and paper clips. There are instructions for repeating this experiment at the bottom of the reverse side of the Word Puzzle.

    - Their copy of the *Marvelous Metals* word puzzle.
    - A copy of *Celebrating Chemistry 2019*. Leave any extra copies with the librarian.

- Tell the students that you hope they enjoyed our *Marvelous Metals* program and you hope that they've learned a lot.
- Deposit all other liquids into your bucket and then place all other items (with the exception of the items listed below in <u>**Returns**</u>) in the trash bag.
- <u>Thank</u> the students and parents for coming to this year's demonstration and learning about our *Marvelous Metals*.
- Have the students come to the closing area to turn in their goggles and *Student Feedback* forms. Have them put their goggles back into the box and then give it to the librarian for return to Julia Boxler at the main library.

Cleanup & Return Procedures

A. <u>General clean up procedures for Experiments</u>

- All solid waste *other than the chemicals* can be placed into a regular trash bag.
- Any liquid wastes should be collected in your bucket and disposed of into sinks or toilets as appropriate.

- Check with the librarian if they are willing to take the solid trash; otherwise, please dispose of it with your own trash.

B. Returns

- Please give the following items to the Children's Librarian at the end of your Program for return to us via the County Library's interoffice mail system:
  1. The goggles in the box provided.
  2. In the first manila envelope addressed to the Library's Julia Boxler:
     a. the golf pencils
     b. the nail/cork assemblies
     c. the magnifying glasses
     d. the tweezers
     e. the thermometers
  3. In the second manila envelope addressed to the Library's Julia Boxler:
     a. completed hardcopy *Student Feedback* forms
     b. completed hardcopy *ACS Photo Permission* forms.
     c. completed *Demonstrator Feedback* form.

C. Goggles:

- If you are performing another demonstration for this year's National Chemistry Week, sanitize the goggles between demonstrations with a dilute bleach solution as instructed in the written directions found on the underside of the cover of the goggle container. Be sure to dry them with soft cloth or soft paper towels to prevent scratching. Please stack them into their box without twisting or crushing!
- If you are finished performing your demonstration(s) for this year, place the used goggles into their box and give the box to the librarian for return to us through the Library system. Please stack them without twisting or crushing! There is no need to clean them when you are through; our Planning Committee will clean and sanitize them for the next year and/or for other Programs.

D. Before you leave the library

- Return any items borrowed from the library.
- Give any leftover literature to the librarian. (You may save a copy for yourself though!)
- Give the manila envelopes (containing completed forms and all **Returns**) as well as the box of goggles to the Children's librarian with instructions to put it them in the interlibrary mail. (Or take to your nearest CCPL library branch.)

At Home (Feedback)

- If you took any photos to share (and have submitted signed permission forms to us), please email them to Bob Fowler at jrfowler@cox.net. Please note that any photos that you care to share with us could end up on our web site and/or possibly with ACS if we choose to use your photo in one of award self-nominations.

- **Smile!** You may have expanded or even sparked scientific interest in a student today! ☺ ☺ ☺ ☺ ☺ ☺

THANK YOU! …for your participation in our Program this year.

We hope you will join us next year too. Planning of Experiments starts in April. You don't have to be a teacher or scientist to join our Planning Committee; all you need is a desire to share science with students. Development of ideas and refinement of experiments goes on throughout the summer (a couple of hours every other week), donation gathering and shopping is in late summer, and kit assembly (about 50 of them needing a lot of volunteer hands) is on a Saturday in September. It takes many, many volunteers to develop and put on all our programs. Even a little bit of help goes a long way. Please contact us this year or next at jrfowler@cox.net if you (or a friend of yours) want to join in on the activities!

Appendices

A. Material Safety Data Sheets

SDS's (safety data sheets—previously called MSDS's) can be found at http://www.flinnsci.com/msds-search.aspx.

B. Supply list for recreating these Experiments

Items used in this Program were purchased at:

	Item	Supplier
1.	Corrugated Boxes 20 x 14 x 12"	Uline[11], Item S-4206
	Kraft Clasp Envelopes, 9 x 12"	", Item S-5625
2.	Beryl pipettes (small, 5 mL)	Flinn Scientific[12], Item AP1444
3.	Reagents	Flinn Scientific[12]
4.	10 mL vials (Transport Tubes, 10 mL, with Separate White Screw caps, polypropylene, Conical Bottom, Self-Standing, Molded Graduations)	Globe Scientific[13], Item 6102
	50-ml vials	same source
6.	Golf Pencils	Office Depot[14], Item 212634
7.	Celebrating Chemistry 2019	ACS Store

8. Memory Wire: http://www.kelloggsresearchlabs.com/node/86. We worked through a very helpful individual named Joe at Kellogg's Research Labs (info@kelloggsresearchlabs.com). Joe worked with us "to tune the transition temperature to 95-100°F so that it doesn't respond to skin temperature". He also volunteered to cut the wire into 1125 4" long pieces for our immediate use.

Most of the other items are available for purchase at restaurant supply companies including http://www.webstaurantstore.com or at retail outlets.

[11] http://www.uline.com/Index
[12] https://www.flinnsci.com/
[13] http://www.globescientific.com/index.php
[14] Google for citation