ENERGY EFFICIENCY CHALLENGE

LEAD-FREE SOLDER - A GREEN SOLUTION FOR THE ELECTRONIC AGE

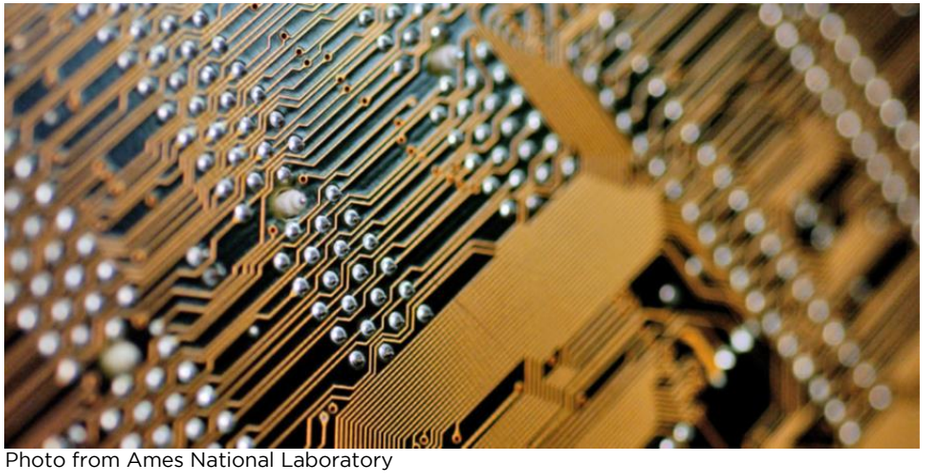


Photo from Ames National Laboratory

Summary: When you look at a circuit board like the one pictured above, what do you see? What makes the wires attach to the board and all of the electronic pieces attach to each other? This lesson will concentrate on circuits and the chemical content in solder. How is the Department of Energy leading the way for a greener future for all?

Background: Solder is a chemical mixture that binds the parts of a circuit board together. Proven to be long-lasting and sturdy, solder must meet certain criteria such as melting at a low temperature, so it does not damage delicate electronic parts. Historically, lead has been used as a solder because it was also cost-effective and met industry performance standards. Unfortunately, after using electronic devices such as electric toothbrushes or old cell phones, we throw them in the trash where they are taken to a landfill. People own more electronic devices now than ever, making the discard problem even worse. Over time, the lead can leak into the groundwater and poison the drinking water.

Do you remember when lead contaminated the Flint, Michigan drinking water in March 2016? The town's water contained too much lead, making the water unsafe to use.

Concerned about this growing problem of lead-filled discarded electronics and the risk it poses to the environment, some European countries have limited the amount of lead present in products sold there. Here at home, scientists at the U.S. Department of Energy's Ames Laboratory worked so hard to invent a lead-free solder, but it was not without its challenges. In order to encourage other vendors to use this green solder, it had to be comparable in price to its lead counterpart and retain the other properties of a good solder. After conducting many experiments, the Ames Laboratory scientists created a lead-free solder that contains not just one metal but three: tin, silver, and copper. This green substitute should help everyone in the US transition to lead-free solder and protect our environment.

Learning Objectives - After this activity, students should be able to:

- Use a periodic table to learn about the metals used in solder and the location of the heavy metals;
- Describe the difference in a homogeneous and heterogeneous mixture;
- Understand basic circuitry and what makes electrons flow;
- Disrupt a present technology and repurpose for redesign.

Introduction: We are living in the electronic age and much of our world is wired, so it makes sense that we should know how circuits are constructed. It is also interesting to think about new possibilities for electronics moving forward so the world we live in can become a greener and more energy efficient place to live.

Activities: The Power-Up activities for this lesson will help you understand circuits, parts of a circuit including solder, the chemical components involved in circuits as well as using what you learn to design a personalized motorized bot. While the explore part of the power-up activities is in the body of this lesson, the explanations are in the separate Power-up pages.

Materials: energy ball (http://www.teachersource.com/product/energy-ball/electricity-magnetism), 4 lemons, 4 pennies, 4 zinc nails, an LED, 5 alligator clip wires, two clear glasses, flashlight or laser pointer, cheap electric toothbrush, duct tape, electrical tape.

Circle of Charges: Do you conduct electricity? What is electricity? Does water conduct electricity—why or why not?

Ideally, you can stand with at least one other person, but you can also do this activity alone or in a large group (preferred). Have everyone in the group stand up and hold hands. Can you feel any electricity moving through your body? Because adult bodies are 55-60% water, do you think water conducts electricity? Why or why not?

Now that everyone is connected, one person in the group will touch one of the electrodes (metal strip) on the energy ball, while the person standing directly next to them will not touch the person, just the opposite electrode on the energy ball.

What do you see? Ask two people to release hands—what happened? Ask a different pair to release hands but lightly tap the partner's arm with a finger—what happens?

Lemon Circuits: Lemons have citric acid inside of them and weak acids are weak conductors of electricity. You can use pennies, zinc nails, alligator clips, 4 lemons and an LED to make your own circuit.

Can a few lemons be used to light up an LED (light-emitting diode)? You can use pennies, zinc nails, alligator clips, 4 lemons and an LED to make your own circuit. When you connect 4 lemons together in a series you can light an LED. Do not cut lemons but gently squeeze them so the juice will flow inside. For each lemon, you will push a penny halfway in and it will be the positive (+) side.

On the other end of the lemon, gently push a zinc nail into the center and that will be your negative (-) side. You should now have 4 lemons each with a penny and a zinc nail. Arrange your lemons in a square, aligning the copper penny on one lemon next to the zinc nail on the other lemon. Use alligator clips to connect positive (penny) to negative (zinc nail). Always connect positive to negative to allow the flow of electrons. You should have a penny not connected so use an alligator clip and connect it to the negative side of the LED (flat-side of bulb and shorter leg). Connect the zinc nail with an alligator clip to the positive side of LED (longer leg). You may have to dim the lights, but you will see your LED light up!

Where are the Metals? Now that you have learned a little more about circuits, we will learn more about solder. Solder is a combination of a mixture of metals. There are two kinds of mixtures: homogeneous mixtures and heterogeneous mixtures. Homogeneous mixtures have the components evenly distributed throughout so it appears very uniform.

What metals are involved in traditional solder? How do those metals differ from the ones in the new green solder?

Follow this link to the interactive Los Alamos National Laboratory Periodic Table (http://periodic.lanl.gov/index.shtml). We will use this periodic table to examine the metals that make up a solder mixture.

Can you locate lead on the table—it has a symbol of Pb. Lead (Pb) is a heavy metal; you can see where it is located on the periodic table. Tin (Sn), Silver (Ag) and Copper(Cu) are the metals that are used in exact amounts to make up the green solder. Can you locate them o the periodic table?

The Tyndall Effect: The Tyndall Effect is used to distinguish liquids mixtures into categories of homogeneous mixtures or heterogeneous mixtures. If a liquid mixture is homogeneous, you can shine a light through it and all of the light will exit the other side. If it is a heterogeneous mixture, the light will stay in the mixture and not exit the other side. How can you tell if a mixture is homogeneous or heterogeneous?

Explore: Take two clear glasses and pour milk in one of the glasses and apple juice in the other glass. Using a flashlight or a laser pointer, point the light from one side of the glass. Did the light come out on the other side of the glass? Why or why not?

Make your own Brush Bot: You can disrupt a present technology and repurpose for a different use! Have you ever hacked a motor in a cheap electric toothbrush and made your own moving brush bot? You can do that in this fun exercise and examine solder from inside the toothbrush.

Procedure: You must always be supervised by an adult when working with electricity and tools. Take a cheap electric toothbrush (you can get them many places for $1) and break off the handle. Unscrew the bottom and carefully remove the inner components and the motor. Keep the battery and housing to use for your Bot.

Very carefully examine the solder points (remember these may have some lead on them). How can you use the motor and the battery housing to make a brushing bot? Use your imagination and try many things until you get one that works! There is no right or wrong way to do this activity—it is up to you to use your creativity and engineering skills.

Take a picture or video of your moving Bot!

Next Generation Science Standards (NGSS, MS):

- Develop models to describe the atomic composition of simple molecules and extended structures. (MS-PS1-1)
- Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes. (MS-PS1-6)
- Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact. (MS-PS2-5)

Science and Engineering Practices:

- Develop a model to predict and/or describe phenomena (MS-PS1-1) (MS-PS1-4)
- Analyze and interpret data to determine similarities and differences in findings. (MS-PS1-2)
- Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system. (MS-PS3-3)

Disciplinary Core Ideas:

- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of the characteristics may be incorporated into the new design. (secondary to MS-PS1-6)

- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (secondary to MS-PS1-6)

- Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively). (MS-PS2-5)

- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. (MS-PS4-2)

Cross-Cutting Concepts:

- The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time. (MS-PS1-3)
- Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). (MS-PS3- 5) The transfer of energy can be tracked as energy flows through a designed or natural system. (MSPS3-3)
- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (MS-PS4-2)
- Structures can be designed to serve particular functions. (MS-PS4-3)

Sources:

1. Next Generation Science Standards www.nextgenscience.org
2. Los Alamos National Laboratory Periodic Table: http://periodic.lanl.gov/index.shtml

ENERGY EFFICIENCY CHALLENGE

POWER UP ACTIVITIES – LEAD-FREE SOLDER LESSON

ACTIVITY ONE:

CIRCLE OF CHARGES

Students will learn what it means to conduct electricity and complete a circuit.

Question:

Do you conduct electricity? What is electricity? Does water conduct electricity—why or why not?

Photo by Los Alamos National Laboratory

Explore:

Ideally, you can stand with at least one other person, but you can also do this activity alone or in a large group (preferred). Have everyone in the group stand up and hold hands.

Can you feel any electricity moving through your body? Because adult bodies are 55-60% water, do you think water conducts electricity? Why or why not?

Now that everyone is connected, one person in the group will touch one of the electrodes (metal strip) on the energy ball, while the person standing directly next to them will not touch the person, just the opposite electrode on the energy ball. What do you see? Ask two people to release hands—what happened? Rejoin hands and then ask a different pair to release hands but lightly tap the partner's arm with a finger—what happens?

Explain:

Surprisingly, people conduct electricity, which is the name given to moving electrons. When the circuit is closed and everyone is touching, the ions (charged particles) in our bodies that are dissolved in the water help us to conduct electricity. Pure water does not conduct electricity because there are no charged particles to force electrons to move. The metal strips on the energy ball are called electrodes. Their purpose is to make contact with a non-metallic part of the circuit, in this case your skin!

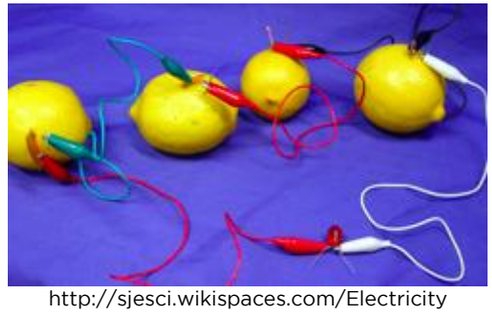
ACTIVITY TWO:

LEMON CIRCUITS

Lemons have citric acid (an example of a weak acid) inside of them and weak acids are weak conductors of electricity. You can use pennies, zinc nails, alligator clips, 4 lemons and an LED to make your own circuit.

Question:

Can a few lemons be used to light up an LED (light-emitting diode)?



http://sjesci.wikispaces.com/Electricity

Explore:

You can use pennies, zinc nails, alligator clips, 4 lemons, and an LED to make your own circuit. When you connect 4 lemons together in a series you can light an LED. Do not cut lemons but gently squeeze them so the juice will flow inside. For each lemon, you will push a penny halfway in, and it will be the positive (+) side. On the other end of the lemon, gently push a zinc nail into the center, and that will be your negative (-) side. You should now have 4 lemons each with a penny and a zinc nail. Arrange your lemons in a square, aligning the copper penny on one lemon next to the zinc nail on the other lemon.

Use alligator clips to connect positive (penny) to negative (zinc nail). Always connect positive to negative to allow the flow of electrons. You should have a penny not connected so use an alligator clip and connect it to the negative side of the LED (flat-side of bulb and shorter leg). Connect the zinc nail with an alligator clip to the positive side of LED (longer leg). You may have to dim the lights, but you will see your LED light up!

Explain:

Lemons contain an acid that helps electrons flow. When copper and zinc are together in a circuit, electrons flow from the zinc to the copper. If you have an inexpensive clock, you can try powering the clock with lemon juice also. You can also try other fruits and vegetables to see what produces enough electricity to power an LED or clock

ACTIVITY THREE:

WHERE ARE THE METALS?

Now that you have learned a little more about circuits, we will learn more about solder. Solder is a combination of a mixture of metals. There are two kinds of mixtures, homogeneous mixtures and heterogeneous mixtures. Homogeneous mixtures have the components evenly distributed throughout so it appears very uniform.

Question:

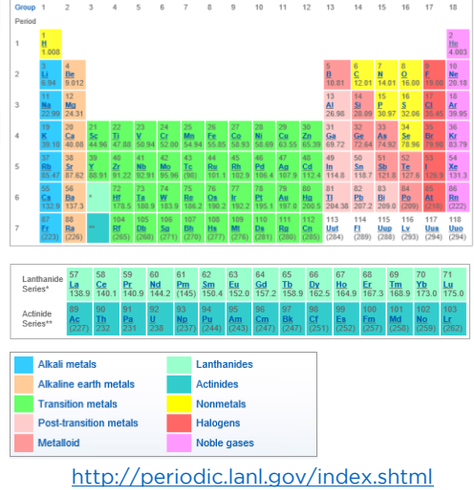
What metals are involved in traditional solder? How do those metals differ from the ones in the new green solder?

Explore:

Follow the link to the interactive Los Alamos National Laboratory Periodic Table. We will use this periodic table to examine the metals that make up a solder mixture. Can you locate lead on the table with the symbol Pb?

Pb is a heavy metal; you can see where it is located on the periodic table. Tin (Sn), Silver (Ag) and Copper (Cu) are the metals that are used in exact amounts to make up the green solder. Can you locate them on the periodic table?

Use the periodic table to learn more about the specific metals mentioned above. Do you see any patterns? Could you suggest a combination of metals with similar properties that could be used as a good solder?



http://periodic.lanl.gov/index.shtml

Explain:

After you find each of the metals in the green solder and learn more about them, you can see that they are non-toxic and much lighter metals. Scientists and engineers at DOE laboratories are working to make our world more energy efficient, greener, and safer. Over 60 companies have licensed to use this green solder, we hope many more will follow suit! Continue to research the viability of your proposed solder. Has anyone designed a solder with your particular combinations?

ACTIVITY FOUR:

THE TYNDALL EFFECT

The Tyndall Effect is used to distinguish liquids mixtures into categories of homogeneous mixtures or heterogeneous mixtures. If a liquid mixture is homogeneous, you can shine a light through it and all of the light will exit the other side. If it is a heterogeneous mixture, the light will stay in the mixture and not exit the other side.

Question:

How can you tell if a mixture is homogeneous or heterogeneous?

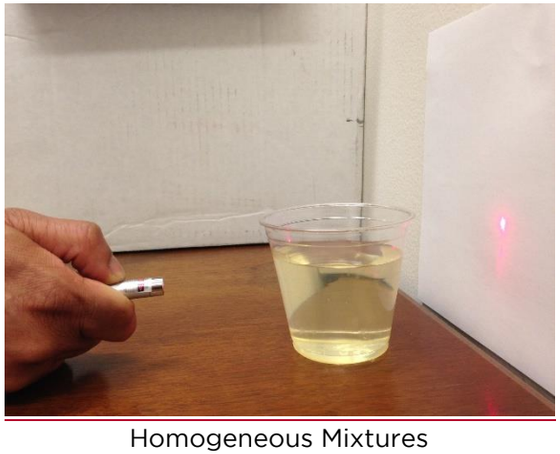
Explore:

Take two clear glasses and pour milk in one of the glasses and apple juice in the other glass. Using a flashlight or a laser pointer, point the light from one side of the glass. Did the light come out on the other side of the glass? Why or why not

Explain:

Homogeneous mixtures are evenly distributed and are called solutions. Because they are so well mixed, there are no particles for the light to run into or bounce off of, so the light travels straight through the liquid to the other side. Heterogeneous mixtures are not even throughout (even though it might look like they are with the naked eye!) so the light gets caught by the particles in the mixture and bounces around.

What other liquids can you test?



Homogeneous Mixtures

Heterogeneous Mixtures