

Overview

Students are familiar with seeing water transition from one state of matter to another, as its phase transitions are within the normal day-to-day experiences here on Earth. Metal, however, is a different story... Or so we thought. Imagine your students' surprise when they see metal change phase from a solid to a liquid and back again before their eyes!

Theory

Water changes phase from solid to liquid (and back again) at its melting (and freezing) point of 0°C (32°F). Metals such as aluminum, iron, and gold melt at much higher temperatures. Iron, for instance, has a melting point of 1530°C (2786°F). It's understandable, then, that most people would be surprised to find that there is a metal that has a melting point of 29.9°C (85.8°F) — less than typical human body temperature. That metal is *gallium*. Gallium is a silvery gray metal, somewhat similar in appearance to mercury. Its molecules interact with the molecules in glass and other materials, creating a silvery mirror finish on surfaces. Gallium is solid at room temperature, but if you warm it up just a little, it will transition into liquid. If you cool it down just a bit, it reaches its freezing point, 29.9°C (85.8°F), and becomes a solid again.



A close-up image of a small gallium disk (about the same diameter as a quarter, but about 5× thicker) held between a person's thumb and forefinger. Near the person's thumb, the surface of the disk appears rumpled; this is because the person's skin is warm enough to melt the gallium.

The behavior of gallium molecules in the solid and liquid phases are similar to molecular behavior of other materials in these same phases, such as the more-familiar ice and liquid water. As energy is added into the system, the molecules in the solid vibrate more, and the molecules start breaking away from their solid crystal structure. When energy is released to the environment during cooling, the molecules vibrate less and start connecting into a tight crystal structure again.

Important advisories for using gallium in the classroom

The gallium sample from the *States of Matter* kit is stored in a glass bottle which has been coated with mineral oil to prevent the gallium from wetting the glass and making a beautiful — and completely opaque — silvery mirror surface. If the glass wasn't coated with mineral oil, you wouldn't be able to see into your container to observe what your gallium was doing in its liquid and solid states. The gallium bottle is also taped shut so students don't open it and spill the mineral oil in the classroom. We inserted the glass bottle into a plastic tube to protect it from being dropped. If you pass the gallium around in its solid state for students to observe, please leave it in the plastic tube.

We don't recommend having students handle the gallium out of the tube. Although gallium metal isn't dangerous, it's still a good idea to avoid ingesting any of the residue, as is the case with any non-food chemical. When we prepared the samples, we used gloves and also washed our hands when we were done.

Don't shake the gallium when it is in its liquid state. We did this with our first sample; little particles of gallium separated from each other, and never went back to the smooth liquid state again. Some

kids may naturally want to shake the tube, so when the gallium is in its liquid state, we recommend having students gather around a teaching area to observe and watching you tip the container slowly back and forth. Alternatively, if you have a document camera, you could use it to project an image of the container; you could also experiment with using the USB microscope from the kit.

A 50-gram sample of gallium is rather expensive (around \$50), so caution is advisable. Follow these guidelines and you should be able to dazzle students with this sample for years to come!

Doing the activity

Preparation before class: Get familiar with your gallium. Take the glass bottle out of the plastic tube and check the time it takes to melt the gallium on your mug warmer. Experiment with it in its liquid state, then put the bottle back in its plastic tube. Cool the tube by placing it on its side in ice water, or in a refrigerator or freezer, to return the gallium to its solid state.

During class: Ask your students if they think metal would melt on a mug warmer. If some of them say yes, let them do an experiment with a few common metal objects (e.g., paperclips, coins, staples).

SAFETY NOTE: Be careful when taking these off the mug warmer; they may get rather toasty!

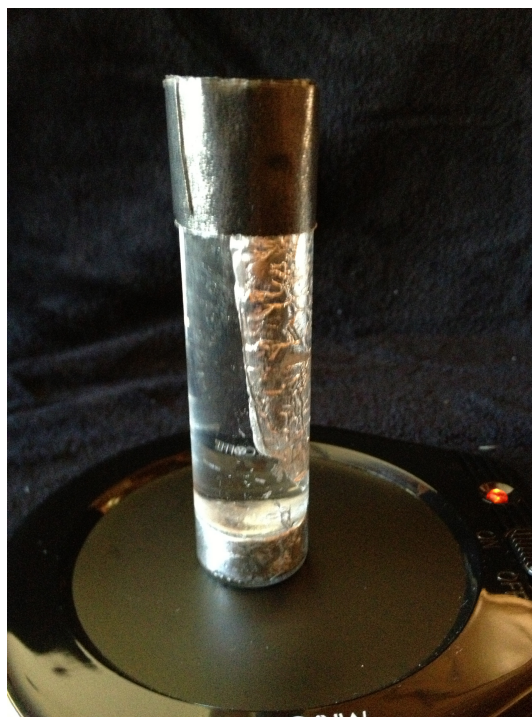
Encourage students to hypothesize why the metal isn't melting. Note that different solids have different melting points. Metals usually have very high melting points: For example, aluminum melts at 659°C (1218°F), and gold melts at 1063°C (1946°F). If you'd like, you can show students a video of someone pouring molten metal — the workers who do this need to wear a lot of safety gear to be protected from the extreme heat!

Now, tell your students that you have a sample of metal that you want to try. Pass the sample of gallium in its plastic tube around, and ask students to make some observations. (When gallium is in its solid form, it won't matter if it gets jostled a bit, but students should still be gentle with the tube.) When students are done observing, remove the glass container from the plastic tube. Put the glass container on the mug warmer and observe. Students should notice that part of the metal becomes liquid quite quickly. Invite students up to look at the liquid in the tube, or use a document camera or USB microscope to project an image of the liquid. (Again, we wouldn't recommend passing the liquid sample around, as someone may shake it). You can carefully tip the sample side-to-side as a demo.

Discuss what is happening to the molecules when the mug warmer added energy to the solid gallium. What are the gallium atoms doing? (Moving about more, breaking away from the tight crystal structure and sliding past other molecules as the solid transitions to liquid.) Ask students what you could do to remove heat from the system so that the

Necessary materials:

- gallium in storage capsule
- mug warmer
- small (non-gallium) metal objects to try on the mug warmer
- optional: ice water in wide container
- optional: hot water in wide container



Solid gallium: An image of a glass tube sitting on a mug warmer. The top of the tube is sealed shut using silver tape, and there is a solid disk of gallium sitting on the bottom of the tube.



Liquid gallium: The gallium disk in the glass tube has now melted; the tube is tipped toward the top right corner of the image, and the liquid gallium is flowing in that same direction. Small bubbles are visible in the mineral oil that prevents the liquid gallium from wetting the glass tube. The tube has been photographed against a bright green background for enhanced contrast.

For more information

Little Shop of Physics: <https://www.lsop.colostate.edu>

Colorado State University College of Natural Sciences: <https://www.natsci.colostate.edu>

molecules would have less energy and would start sticking together in their tight crystal structures. They may have many creative ideas. Put the bottle in the plastic tube and try one of the suggestions. Would the gallium change phase back into a solid in the refrigerator, or the freezer, or a bowl of cold ice water? Try it and see.

The next time you bring out the solid gallium, ask students to think of another way they could melt the gallium. Experiment and find out what happens!

Summing up

This is an excellent activity to engage students and stretch their thinking! It's also a great activity to reinforce what is happening when sufficient energy is added or removed from a system to initiate a phase change, and how this energy affects the behavior of the particles.