Creating Hydrothermal Vent Chimneys

(adapted from the JASON Project by Ardi Kveven, Snohomish High School, Snohomish, WA and Veronique Robigou, University of Washington)

Key Concepts

1. As the temperature of water increases, the amount of material that can dissolve in the water increases as well.
2. Hydrothermal vent fluids are so hot that high concentrations of minerals and salts dissolve into them as they pass through the oceanic crust.
3. If a solution is supersaturated and then cooled, some of the solute (the dissolved material) will precipitate back to solid form.
4. Minerals and salts in the fluids pouring from vents precipitate out as the solution hits cold seawater, forming chimney structures at the sea floor.

Background

Hydrothermal vents form at spreading zones at mid-ocean ridges. Cracks in the oceanic crust at ridges allow magma to surface and harden into new crust. They also provide an opening for sea water to circulate through the rocks, descending toward the very hot magma chambers below. There, the water is superheated to as much as 700°C.

Such high temperatures make it possible for much higher concentrations of minerals and salts to dissolve in the sea water. The heat causes the molecules of sea water to spread out, allowing room between molecules for other materials. The salinity here can reach 250 parts per thousand. Each mineral dissolves most easily at different temperatures, so as the water circulates, it picks up different solutes each step along the way. By the time the sea water is back near the crust's surface, it may be saturated with copper, zinc, iron, sulfides, sulfates, silver, lead, gold and many other less common minerals and compounds.

When this superheated and supersaturated fluid finds its way back through passages in the oceanic crust and surfaces, it mixes with the very cold surrounding ocean water. Vent fluids typically are about 350° C when they leave the vent openings, but they rapidly lose heat to the 2°C ocean water and, at only 4 meters away from the vent, may have dropped to 10°C.

This extremely fast cooling causes the various solutes to form precipitates. Vents actually look like they are smoking, earning them the nickname "Black Smokers." The smoke is made up of particles coming out of solution into the seawater. As these particles settle, they form chimneys, some as high as 20 or 30 meters.

In the Vent Chimney Lab, students create their own supersaturated solution and then cool it to observe the solute precipitating. If they allow their material to sit overnight, they will see the growth of a chimney. The chimney is even more pronounced if the beaker is left out for as much as a week.

Materials

For each student or team of students:
Graduated cylinder (at least 50 mL)
50 mL water
100 mL Beaker containing 20 grams of ammonium chloride (NH_4Cl)
CAUTION! WASH HANDS THOROUGHLY BEFORE AND AFTER USING. WEAR GOGGLES.
Hot plate
Thermometer
Goggles
500 mL beaker or other clear, heat tolerant container large enough to create a water bath for the 100 mL beaker
Ice

Teaching Hints

Be sure to check the Material Safety Data Sheet (MSDS) that comes with your ammonium chloride. Care should be taken to avoid contact with mucus membranes. If you would like to use a more benign material, the lab Hydrothermal Vent Formation uses magnesium sulfate (Epsom Salts) to supersaturate a solution and then form a precipitate. It will not, however, form rigid chimneys.

The PBS television series NOVA produced an excellent episode, titled Volcanoes of the Deep, about scientists' efforts to bring selected hydrothermal vent chimneys to the surface for study. The chimneys are now on exhibit at the American Museum of Natural History in New York City. You can obtain a copy of the video, which aired in 1999, from PBS online at http://www.pbs.org, or by calling your local PBS affiliate. NOVA episodes often are available through educational video catalogs and through school district audio-visual loan programs.

Answer Key

7. A substantial amount of the ammonium chloride will not dissolve. The water molecules, at room temperature, are at a distance from one another large enough to allow only some of the material to dissolve. If your students are not familiar with these concepts, share this idea with them or allow for creative answers as students try to explain what they see.

8. The solution should boil at just under 100°C. All of the ammonium chloride should dissolve in the heated water. The water molecules are moving more rapidly and are far enough apart to allow room for all the ammonium chloride. Again, if students are not familiar with this concept, allow for creative answers as they attempt to explain what they see.

9. Accept the students' predictions about what will happen when they place the beaker with the supersaturated solution in the ice bath.

10. As the solution cools, it will become cloudy as materials precipitate out.

11. The precipitate that forms as the solution cools in the ice bath is not black, but it does look something like smoke. The process is the same. Materials that dissolved in the water under high heat now come out of solution and make the water look cloudy.

13. A rigid chimney will form overnight. This is the same process that forms the vent chimneys. The precipitates settle and accumulate to form a tower.

14. Precipitate forms when a solution cools and there becomes less room between the molecules in the solution. The materials dissolved in the solution get "squeezed out" and form solids that settle out of the solution.

15. A saturated solution is a liquid with as much material dissolved in it as possible. Solubility, or the amount of material that can be dissolved in a liquid, increases as temperature increases.

16. The fluid inside a black smoker is clear because it is still very hot. All the various minerals are still dissolved in the water. When the water suddenly cools at the vent opening, however, the minerals precipitate out and this solid material makes the water cloudy.

17. Geologists know that vent fields are transitory. They have found evidence of former vent fields, no longer active and now devoid of life. How vent fields develop and then shut down is still largely mysterious. One possibility is that conduits leading through the rocks to the vent opening can get clogged, blocking vent fluids.

Hydrothermal Vent Lab

Hydrothermal vents are amazing places where black smoke erupts from cracks in the sea floor and giant towers grow in just weeks or months and may topple back to the sea floor just as quickly.

Where would one find hydrothermal vents and what are they? They develop at spreading zones along ridges in the ocean floor. Remember that spreading zones are areas where magma from the mantle below the sea floor erupts through cracks in the crust and forms new crust material.

These same cracks allow sea water to sink down through the oceanic crust. As the sea water travels farther and farther through the crust, it is warmed by the magma below. Eventually, it returns back to the ocean, seeping out of cracks in the spreading zone and forming black smoke and chimneys.

How does this happen? What has changed this water to turn it black? Where do the towers come from? This lab gives you a chance to model a hydrothermal vent and see for yourself what makes the smoke and chimneys.

Materials

<u>For each student of team of students:</u>
Graduated cylinder (at least 50 mL)
50 mL water
Beaker, 100 mL

20 grams of ammonium chloride (NH4Cl)
CAUTION! WASH HANDS THOROUGHLY BEFORE AND AFTER USING. WEAR GOGGLES.
Hot plate
Thermometer
Goggles
500 mL beaker or other clear, heat tolerant container large enough to create a water bath for the 100 mL beaker
Ice

Procedure

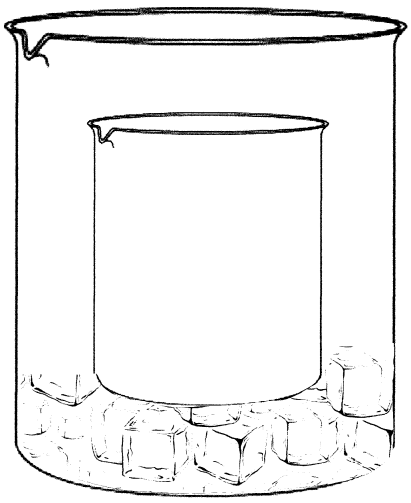
1. Read through all the steps so you will be familiar with what you need to do and will know all the safety precautions.

2. WASH YOUR HANDS BEFORE YOU START THIS LAB.

3. WEAR GOGGLES.

4. IT IS IMPORTANT THAT THE CHEMICAL YOU ARE USING, AMMONIUM CHLORIDE, NOT COME IN CONTACT WITH MUCUS MEMBRANES. THIS MEANS YOU DO NOT WANT IT IN CONTACT WITH ANY CUTS IN YOUR SKIN, NOR WITH YOUR EYES, MOUTH OR NOSE.

5. Add a layer of ice to the bottom of the 500 mL beaker. This represents the very cold water around hydrothermal vents.



6. Obtain your beaker containing ammonium chloride. The oceanic crust around the spreading zone is full of a wide variety of minerals. The ammonium chloride crystals represent one of these minerals in the sea floor.

7. Add 50 mL of water to your beaker of ammonium chloride. Stir. The water represents the ocean water that seeps through the cracks in the sea floor

How much of the ammonium chloride dissolved? What explanation can you give to explain why the crystals did or did not dissolve?

8. Place the beaker on the hot plate and bring it to a boil while you stir the solution. This represents the sea water moving down through the crust toward the mantle. The hot plate functions as the mantle in this model, heating the water.

Record the temperature at which the mixture boils: _____°C

How much of the ammonium chloride is dissolved now? What explanation can you give to explain why the crystals did or did not dissolve as the solution heated?

9. Next, you will place the beaker with the heated solution into the ice bath. This models the superheated, super-salty water coming back out through cracks in the crust and hitting the very cold ocean water. What do you think will happen inside the beaker?

12. Remove the beaker from the hot plate using tongs. Place it in the container of ice. Record the temperature now and every two minutes.

TIME	TEMPERATURE

13. What happens in the beaker as the solution cools? At what temperatures do you see these changes begin?

14. What did you see in your beaker that was like the black smoke or the chimneys that form around hydrothermal vents?

15. Let your beaker sit overnight. Clean-up all the rest of your lab materials. WASH YOUR HANDS.

What happened in your beaker overnight? What do you see in your beaker that is like the black smoke or the chimneys that form around hydrothermal vents?

CONCLUSION

16. Explain what causes a precipitate to form.

17. What is a saturated solution? How does the solubility of a solution change as the temperature changes?

18. The fluid **inside** a black smoker is clear and hot. Why, then, is the fluid coming out of the vent so cloudy?

19. Chimneys eventually become inactive. What can you think of that would cause a vent to stop releasing fluids and growing a chimney?