

Investigation Three: What happens when salt water freezes?

Getting Your Bearings

While their ship was imprisoned in the ice off Antarctica, the crew of the *Endurance* melted the sea ice and used it for their drinking water. How is that possible? Why wasn't it too salty?

The reason has to do with the behavior of ocean water when it freezes. When salt water freezes, much of the salt is expelled from the ice or gets trapped in pockets of salty liquid water within the ice. Eventually, most of the salt makes its way into the water just under the ice. This creates a layer of water under the ice that is saltier than the water below it. Because this layer of cold salty water is very dense, it sinks to the bottom levels of the ocean. As it sinks, it is replaced by water that is either warmer, less salty, or both. As ice continues to form, expelling more salt into the surface waters, this new layer of water in turn becomes saltier and it begins to sink, too. In this way, water circulates under the sea ice in a cycle that lasts the entire Antarctic winter.



Image Courtesy of Royal Geographic Society

In this investigation, you will get some firsthand experience with the behavior of salt water as it sinks, floats, and freezes. When you are done, you should be able to explain why Shackleton's crew could use melted sea ice for drinking water.

Goals

1. You will identify several properties of fresh water and salt water. In particular, you will see that when salt water freezes, the ice expels much of the salt.
2. You will see that saltier water sinks in less salty water and that the less salty water rises to replace it.

Exploring and Discovering

What Happens When Fresh Water and Salt Water Meet?

In this activity, you will see what happens when you add salt water to fresh water—and vice versa. You will use small amounts of colored water and small containers so you can observe the interactions closely. What you see will help you understand how ocean water circulates under sea ice throughout the Antarctic winter.

Materials

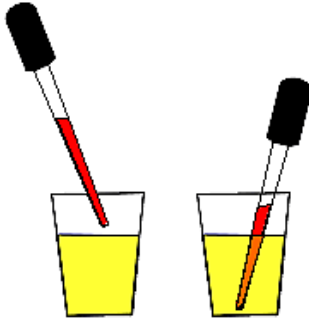
- Safety goggles
- Masking tape
- Fresh (tap) water
- Salt water
- 4 small, clear containers
- Dropper



Procedure and Record Sheet

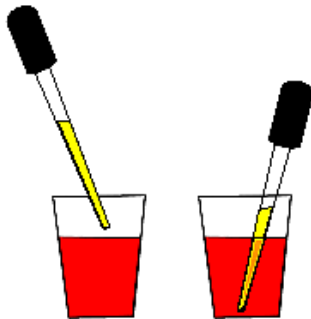
1. Use masking tape to label two containers "Fresh Water." Fill each half full of fresh water.
 2. Use masking tape to label two containers "Salt Water." Fill each half full of salt water.
 3. Find out what happens when you add salt water to fresh water.
- Use a dropper to add a few drops of salt water to the top of the fresh water in one of the containers. Work carefully.
 - Observe whether the salt water sinks to the bottom or floats to the top of the fresh water.
 - Fill the dropper with a little more salt water. Before you squeeze the bulb, lower the dropper to the bottom of the second container of fresh water, then release the salt water.
 - Observe whether the salt water stays at the bottom or floats to the top of the fresh water.

- Record your observations beside these diagrams.



What Happens When Fresh Water and Salt Water Meet?

4. Empty the fresh water from one of the cups. Replace it with more fresh water.
5. Repeat the procedure in Step 3, only this time find out what happens when you add fresh water to salt water. Record your observations beside these diagrams.



6. Make a statement about what happens when fresh and salt water meet. Describe the evidence that supports your statement.

Statement:

Evidence:

Exploring and discovering: Check for Understanding

Sink or Float?

Imagine making a salt solution that is even saltier than the one you have been using. If you add the "more salty water" to the original salty water, will it sink or float? Explain your prediction.

Looking Closer

What Happens When Salt Water Freezes?

You read that when ocean water freezes, much of the salt is expelled from the ice or gets trapped in pockets of liquid salty water within the ice. In this two-part activity, you will freeze salt water and fresh water to see these phenomena for yourself, then you will answer some questions. In the experiments, food coloring will show where the salt goes. This is possible because food coloring gets expelled from ice as it freezes in much the same way that salt does.



Part I: Freeze some Fresh Water and Some Salt Water

In this part of the activity, you will prepare two bottles of water—one fresh water, one salt water. You will predict what will happen to the salt water solution as it freezes. You will then put both bottles in the freezer.

Materials

- Safety goggles
- 2 1-liter plastic bottles with caps
- 450 ml fresh water
- 450 ml salt water
- blue food coloring
- thermometer
- masking tape

Procedure and Record Sheet

Use masking tape to label one of the bottles "Fresh Water." Fill it with 450 ml of fresh water. Add 3-4 drops of blue food coloring. Cap the bottle, then shake it to mix the food coloring.

Use masking tape to label one of the bottles "Salt Water." Fill it with 450 ml of salt water. Add 3-4 drops of blue food coloring. Cap the bottle, then shake it to mix the food coloring.

Think about the bottle of salt water you put in the freezer, then answer these three questions.

- *Where do you think the water will freeze first? At the top? Bottom? Middle? Sides?*
- *Where do you think the salt will move as the salt water freezes in the bottle?*
- *Why do you think so?*

1. Predict how salt will be distributed in the salt water bottle after 24 hours in the freezer. Record your predictions in words and by labeling the "Predictions Bottle" below, using the phrases provided with each prediction.



**Prediction Bottle
(Salt Water)**

Prediction 1: How the salt will be distributed in the bottle after freezing (label areas "least salty," "less salty," "more salty," "most salty," or "unchanged.")

Prediction 2: What region(s) of the bottle will freeze first and last ("freezes here first" and "last area to freeze.")

Prediction 3: What direction the salt will move (use arrows to show how the salt will as the water freezes.)

Part II: Design an Investigation

In this part of the investigation, you will take a close look at the two "ice cores" you have made in the freezer. You will work in a group with several other students. Together you will design an investigation to test your predictions about how the salt water would freeze.

To do this, you will need to find a way to determine the saltiness of several core samples. You may do this in any way you want, except that **you may not taste any of the samples at any time.**

Materials

- Safety goggles
- Frozen ice cores
- Tray or tub
- Blunt knife
- Spoon
- 4-6 small, clear containers for saving samples
- Masking tape
- Other materials as appropriate for your investigation



Procedure and Record Sheet

1. Decide on a plan for investigating the distribution of salt in your ice core.
 - Discuss different ways to tell whether ice from one part of the core is saltier than ice from another part of the core. Remember, **you may not taste the samples**.
 - Make a list of what you know about water, salt, freezing, evaporation, sinking, and floating of solutions (or anything else that could help you choose a plan).
 - Come to an agreement on a plan, then check it with your teacher.
2. Write out your plan step by step (use an extra sheet of paper if you need it.)
Explain how the results will let you compare the amount of salt in different parts of the salt water ice core.



3. Carry out your investigation. Remember to wear your safety goggles!
 - Look closely at your ice cores. Observe what you see. Use your knife to slice the ice cores so you can obtain samples. This process is messy, so work over a tray or tub.
 - Use small containers to save samples of ice from different parts of the ice cores. Use masking tape to label the containers with the necessary information.
 - Use your plan to find out what part of the salt water core is salty, very salty, not very salty, most salty, least salty, etc.
4. Record your results in both words and pictures. Be sure to label the "Results Bottle," below.



**Results Bottle
(Salt Water)**

Part II: Design an Investigation

Questions

1. *Is there more salt in the outer regions of the core or in the inner regions?*
2. *Is salt concentrated in any other region? How would you explain this?*
3. *Which part of the core contains the "oldest" ice, i.e. the ice that formed first?*
4. *What happens to salt when a bottle of salt water freezes?*
5.
Did the food coloring help demonstrate the movement of salt when salt water froze? Why?
6. *What part of a lake or ocean freezes first? How would you explain this?*