

Will an Ice Cube Melt Faster in Freshwater or Saltwater?

Teacher Guide:

Learning Objectives

Years ago I gave my students four solutions with varying amounts of salt dissolved in water and asked them to figure out a way to rank them in order from least salty to greatest with only one rule, they weren't allowed to taste the solutions. There were a number of ideas ranging from measuring the salt left after evaporation to density and buoyancy.

One lab group came up with a unique way of solving this problem. They decided that they would float an ice cube in each solution and that the one that melted the ice fastest would be the saltiest solution, next fastest the third most salty and so on. To our surprise the exact opposite result happened. The ice melted fastest in the water that was least salty (which was actually freshwater) and slowest in the solution that was the most salty. After repeating the experiment we observed that as the ice cubes melted in solutions with less salt, there was circulation that did not happen in salt solutions. We learned something, and I thought that this would make a good laboratory activity, and it has.

I have had success in getting my students engaged because of the unexpected outcome to this experiment.

My students experience winters with snow and ice on roads and walkways where salt is used to prevent roadways and walkways from becoming icy, so they are absolutely certain that the ice cube will melt faster in saltwater. In fact they are so certain of this that they question why we're even bothering to do this experiment.

When they see that the ice cube melts faster in freshwater they're so surprised and they become truly engaged and really want to know how this can happen.

Thus the goal of this lesson is to engage students in the study of the ocean and saltwater and to see that saltwater has different physical properties than freshwater - namely its density. This lesson can serve as a springboard into other concepts such as convection, buoyancy.

Changing the density of fluids, whether through temperature or dissolved materials, leads to dynamic changes within a system. Thus, the principles behind the circulation or lack of circulation in this lesson can be applied to the circulation patterns in other systems such as freshwater lakes, the atmosphere, or even the currents in our mantle that drive tectonic plates.

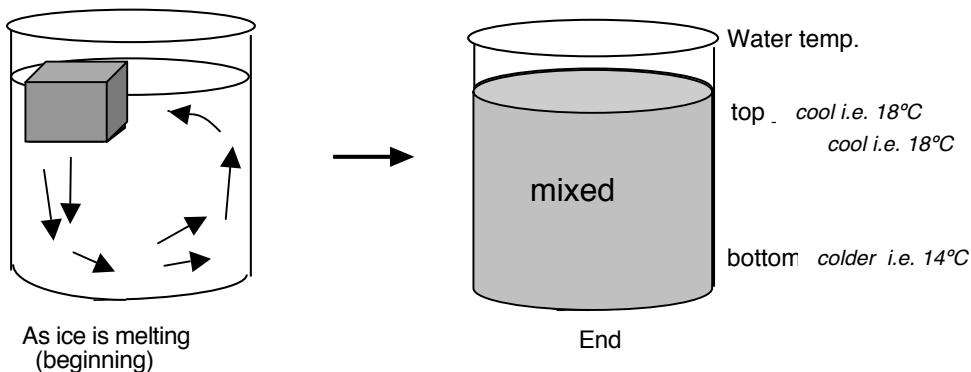
The lesson presented here introduces one aspect of ocean circulation and, with follow-up investigations, can reinforce its relevance to the Earth's climate, helping our students to realize that we all have an important connection to the ocean.

Explanation for why an ice cube melts faster in freshwater.

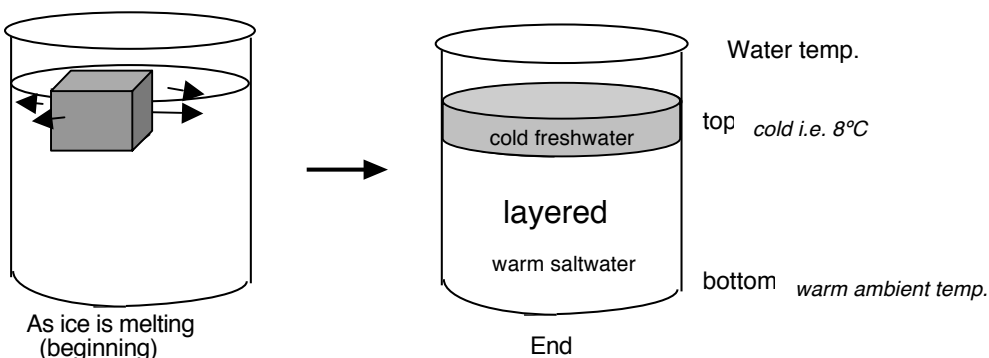
As the ice cube melts, the cold melt water from the ice cube sinks to the bottom of the cup forcing the water from the bottom of the cup (ambient temperature) to move toward the surface which transfers its heat to the ice cube, causing it to melt faster.

Meanwhile in the saltwater, the cold freshwater from the ice cube floats on top of the saltwater. Thus the ice cube sits in a pool of cold water, blocking the heat from the saltwater (ambient temperature) from getting to the ice cube. The evidence becomes more obvious with colored ice.

Colored Ice Cube placed in Freshwater



Colored Ice Cube placed in Saltwater



The evidence is in the observations throughout the experiment. Condensation of water vapor in the surrounding air forms different patterns on the outside of each cup. A ring of condensation forms around the top of the “saltwater cup” at the water’s surface. In the “freshwater cup”, the condensation initially forms as a vertical streak down the side of the cup eventually leading to the entire cup becoming covered in a fog or condensation. This reveals the layering of colder water on top of the warmer saltwater as well as the circulation of water in the freshwater cup.

The shape of the ice cube in the freshwater cup more or less maintains its rectangular shape and sometimes moves or flips, whereas the ice cube in the saltwater melts in the shape of a “v” .

By touching the cup, students may feel the difference in temperature between the surface and bottom in each cup. In the freshwater cup the temperature becomes colder on the bottom and then the entire cup feels cool. In the saltwater cup, the top of the cup feels cold whereas the bottom still retains a warm, ambient temperature.

Experiments: Activities 3 and 4.

The Salt Solution

- Make up a large batch of saturated salt solution.
(*2-3 tablespoons per cup of tap water.*)
- You may use ordinary table salt for the solution. However, using lab-grade sodium chloride or Kosher salt gives you a very clear solution and reinforces the concept that you can’t see dissolved salt in seawater.

Conducting the Experiments

- If possible conduct the experiment on a humid day as condensation patterns on the outside of the cup will provide valuable evidence for the explanation as to why an ice cube melts slowly in saltwater and faster in freshwater.
- During the experiment you’ll want to use solutions at room temp. If water is too cold, the experiment might not give you the desired outcome or the ice cubes might melt too slowly. If water is hot, the ice cubes will melt too quickly.

- If students don't come up with it on their own (they often do), it's important to suggest doing the follow-up experiment (Classroom Activity 4), which repeats the experiment using dyed ice cubes. When preparing colored ice cubes for this activity, it's important NOT to color the water to be frozen with too much food coloring/ or dye. If the cubes are too dark it will be difficult to trace the path of the water melting from the ice cube.

Extending the Activity: Science Concepts

Convection:

This activity can serve as a springboard to investigate additional concepts such as convection and heat transfer with the circulation of a fluid. This concept is important in:

- atmospheric circulation resulting in wind, the circulation of
- magma below the Earth's crust resulting in Plate Tectonics
- ocean circulation and circulation in lakes

Density and mathematical basis for what is observed.

An important question that may surface is why the cold water sinks in warmer freshwater and floats on saltwater? The answer lies in the density, that physical property of matter that reflects the amount of mass in a certain space and is calculated by dividing the mass by its volume. ($D = m \div v$)

Colder water is more dense than warmer water and freshwater is less dense than saltwater... but why?

As water is heated, molecules spread out increasing its volume without changing its mass. With an increase in dissolved salt, mass of the mixture will increase at a greater rate than the volume.

With temperature: $D = m \div v$, the denominator increases while the numerator remains constant.

With salinity: $D = m \div v$, the numerator increases at a greater value than the denominator.

Buoyancy:

Another question that might be addressed is why a less dense fluid will float or rise in a more dense fluid?

For this, the concept of buoyancy would need to be taught. In buoyancy, when an object or material is placed in a fluid, the fluid is pushed out of the way or displaced...but the fluid pushes back using its weight. And that is the buoyant force.

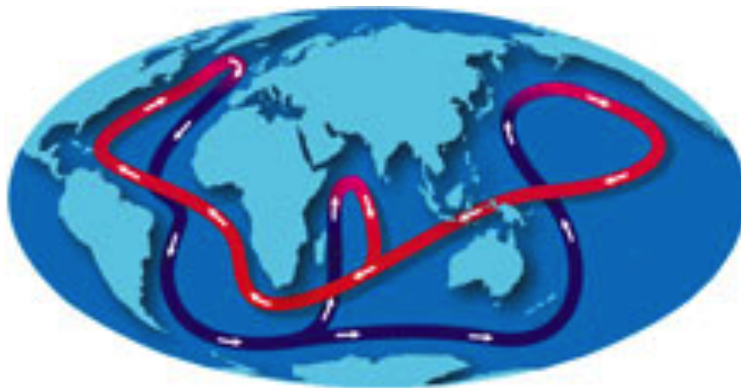
Archimedes Principle stated that buoyant force is the weight of fluid displaced by an object.

An object sinks if its weight is greater than the buoyant force of the fluid acting on it. An object floats if its weight is less than the buoyant force of the fluid acting on it.

So in the case of our experiment the weight of a certain volume of freshwater is less than the weight of the saltwater it displaces... so it floats. Colder water has more weight in a certain volume than the weight of the warmer water it displaces, so it sinks.

Extending the Activity: Relevant Topics. Video Segment 6.

Ocean Circulation and Climate Change.



The “Global Ocean Conveyor Belt.” image from National Oceanic and Atmospheric Administration : <http://oceanservice.noaa.gov/facts/conveyor.html>

The Global Ocean Conveyor Belt is a slow moving system of currents that circulate ocean water around the planet. This **thermohaline circulation** (*thermo..heat: haline..salt*) is driven by cold dense salty water sinking in polar seas and warmer less dense water rising to the surface in warmer regions. “Will an ice cube melt faster in saltwater or freshwater?” provides a basis for understanding this circulation.

This circulation is very important to Earth’s climate as well as the transport of nutrients or even pollutants throughout the seas. Physical oceanographers and climate scientists are interested in how global warming can impact this circulation, which may lead to further changes to our climate.