States of Matter: Solids, Liquids, and Gases

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STATES OF MATTER

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Introduction and Background

We are surrounded by gases, liquids, and solids. Yet we rarely stop to think about the properties of these different states of matter, and how these properties are useful to us our daily lives. We will do some hands-on experiments to become more familiar with the different states of matter and their properties.

Let's talk about some of the properties of solids, liquids, and gases?

SOLIDS: Rigid, maintain their shapes.

LIQUIDS: Flow, conform to the shape of the container.

GASES: Expand and contract, fill available space, usually invisible.

What do all three states of matter have in common? All are made of MOLECULES. The molecules are always moving, but their arrangement and speed of motion determine whether the matter is a solid, liquid, or gas. For example, the water molecule (H_2O) is the basic building block of ice, liquid water, and steam; the temperature (and pressure) of the molecules determines which state of matter exists at a given time.

In a solid (ice), the molecules are packed together very tightly, in rigid arrangements, like soldiers in formation. In a liquid (water), the molecules can move freely, yet they remain close together and keep bumping into each other often–think of dancers on a crowded dance floor. In a gas (steam), the molecules are far apart and are moving very fast in all directions.

Molecules can go back and forth between different states of matter in processes known as PHASE TRANSITIONS. Evaporation is the phase transition that occurs when a liquid heats up and some of the molecules break away to form a gas. The reverse reaction is called condensation. This occurs when gas molecules slow down (due to cooling) and begin to coalesce into a liquid. Melting and freezing are also reverse reactions. When a solid melts to a liquid, the tight bonds between the molecules loosen. The molecules can now move about freely amongst themselves as long as they stay together as a group. When a liquid freezes, the molecules lose their random arrangement and begin to form an ordered, tightly packed assembly. Sublimation occurs when a solid is directly converted to a gas.

Solids and liquids typically expand when they heat up because the individual molecules in the solid or liquid are bigger when they are hot. Hot molecules, with their faster and more energetic vibrations, take up more space than cold ones, just as a person takes up more space doing jumping jacks than sitting quietly. The expansion of a liquid upon heating is the basis of many household thermometers. The thermometer is calibrated so that the liquid's volume can be precisely related to the temperature.

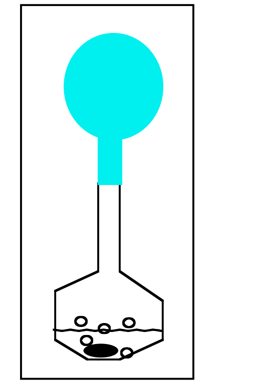
Unlike most other liquids, water does not always expand when it heats up and shrink when it cools. When water freezes and becomes ice, it expands. Ice, therefore, takes up more space than the water. This occurs because in the solid state (ice) the water molecules are further apart than in the liquid. If you fill a plastic bottle with water and put it in the freezer overnight, what do you think will happen? Why don't you try this?

Gases take up much more space than solids or liquids. If you melted an ice cube, the water produced would still fit into the ice cube tray. However, if you boiled that same amount of water, the steam would fill up the whole room. The gas expands to fill any available space.

References

1. Judith Hann, *How Science Works*, (Readers Digest, 1991).
2. Brenda Waypole, *175 Science Experiments to Amuse and Amaze Your Friends*, (Random House, 1988).

Experiment: Balloon Expansion with Vinegar and Baking Soda



Materials

1. Vinegar
2. Plastic or glass bottle
3. 1 balloon
4. Baking soda
5. Plastic or glass funnel

Procedure

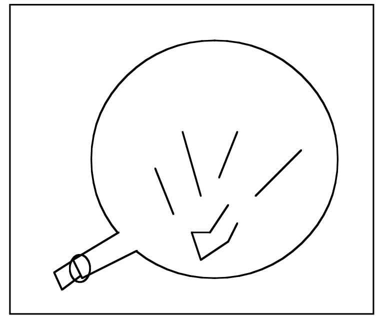
1. Place approximately ¼ cup vinegar in the bottle, using a funnel if necessary.
2. Place ½ teaspoon of baking soda inside the balloon, using a funnel if necessary.
3. Attach the balloon to the top of the bottle, taking care to keep the balloon hanging down over the side of the bottle
4. Quickly raise the balloon over the bottle and shake the baking soda down into the bottle
5. The balloon will expand due to the reaction of the vinegar and baking soda to make carbon dioxide gas (CO_2)
6. NOTE: If you use too much vinegar and baking soda, the reaction will be so vigorous that the balloon will pop off the bottle.

Discussion

- Carbon dioxide gas is produced by the chemical reaction that happens when baking soda is mixed with vinegar. The pressure of the CO_2 gas produced is enough to blow up the balloon.
- Can you think of another example in which gas is used to do work? How about a hot air balloon? A hot air balloon works on the principle of hot air being lighter than cold air. The hot air rises and expands to fill the balloon and eventually make it fly. Using this property of hot air/cold air, how would you adjust the vents in your car to efficiently heat it in winter? To cool it in the summer?
- The CO_2 gas can also extinguish a flame. This is the principle behind fire extinguishers. A flame requires the presence of oxygen (the colorless gas that we all breathe). Therefore, by pouring CO_2 (which is heavier than oxygen gas (O_2) in the air) over a candle, you remove the oxygen from the area of the candle, and it stops burning.

Experiment: Expanding a Balloon with Dry Ice

*****PARENTAL SUPERVISION **REQUIRED**.*****



Materials

1. Dry ice – CAUTION!!! You must use insulated gloves when handling dry ice, since it is extremely cold and will burn your skin.
2. Plastic balloon
3. Funnel
4. Insulating gloves

Procedure

1. Attach the balloon to the narrow end of the funnel.
2. Put small pieces of dry ice in the balloon, remove the funnel, and knot the balloon.
3. Shake the balloon and observe what happens.

Discussion

Dry ice is frozen carbon dioxide (CO_2). As the frozen CO_2 warms up due to contact with the room air, it changes directly from a solid to a gas (sublimation). The pressure of the CO_2 gas blows up the balloon.

* SAFETY NOTE: If you put too much dry ice in the balloon, the gas pressure can build up enough to inflate the balloon past its breaking point. This should be avoided, since you don't want the balloon to burst and send pieces of dry ice flying all over.

Experiment: Contracting a Balloon with Liquid Nitrogen

*****PARENTAL SUPERVISION **REQUIRED**.*****

Materials

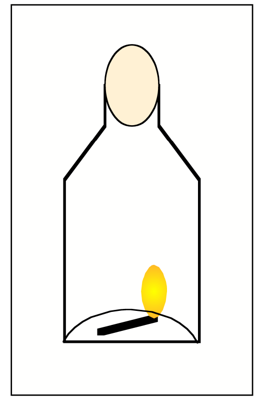
1. Liquid nitrogen – CAUTION!!! You must use insulated gloves when handling liquid nitrogen, since it is extremely cold and will burn your skin.
2. A balloon inflated with CO_2 (or air).
3. Tongs

Procedure

1. Using tongs, insert inflated balloon into liquid nitrogen. Observe what happens.
2. Remove the balloon from the liquid nitrogen and observe what happens.

Discussion

Why did the balloon collapse? Where did the gas go? When the balloon warms up a bit you can see that there is a solid in it: dry ice snow. You can turn this dry ice back into CO_2 gas by letting the balloon warm up to room temperature.



Experiment: Egg in a Bottle

*****PARENTAL SUPERVISION **REQUIRED**.*****

Materials
1. Hard boiled egg, peeled (large, not medium or extra large)
2. Empty juice bottle (glass, not plastic)
3. Matches

Procedure
1. Light a match and drop it into the empty juice bottle.
2. Quickly place the egg on the mouth of the bottle (narrow end down).
3. Watch as the egg is "pulled" into the bottle.

Discussion

What is happening? The match heats up the air in the bottle. The air molecules in the bottle become more energetic and push harder on their surroundings. Some of these hot gas molecules will push out of the bottle even before the egg is in place. When the egg is in place, the pressure of the heating air can build up enough to make the egg bounce (each bounce lets out a little more air and releases a bit more of the excess pressure). After a while the egg settles down, and the gas inside the jar gradually cools back to room temperature.

Now what?

As the gas cools, the pressure inside the bottle becomes lower than the pressure outside the bottle, creating a partial vacuum inside the bottle. Why? Air molecules left the bottle when they were hot, but they can't get back in because the egg acts like a one-way valve. The density of the gas in the bottle is lower than the starting gas density because there are fewer molecules in the bottle volume. When the molecules remaining in the bottle were still hot, they had enough pressure to balance the pressure outside. But when they are cold their pressure is too low. The higher pressure outside the bottle pushes the egg in.

We use the principle of a vacuum often in our everyday lives. Food is often packed in vacuum-proof jars which is why they are hard to open. A thermos uses a vacuum liner to prevent conduction of heat from the inside to the outside of the thermos. We all use vacuum cleaners at home to clean our floors.

How can you get the egg OUT of the bottle? Here are some favorite methods, all of which temporarily make the air pressure inside the bottle higher than the air pressure outside the bottle.

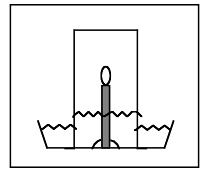
Generating gas in the bottle:
- Put dry ice in the bottle to make gaseous CO_2
- Mix vinegar and baking soda in the bottle to make gaseous CO_2

Temperature change:
- Heat the bottle (upside-down under running hot water, with the egg at the bottle's mouth)

Direct pressure change:
- Make a seal around the bottle with your mouth, blow into the bottle.
- Blow up a balloon and stretch the mouth of the balloon over the mouth of the bottle without letting the air out of the balloon. Get the egg in position, and then crack open the balloon.

Experiment: Candle/Water/Glass

*****PARENTAL SUPERVISION **REQUIRED**.*****



Materials

1. Candle
2. Small piece of modeling clay (about 1/2 inch diameter ball)
3. Tall glass or jar
4. Round glass pie plate
5. Food coloring
6. Water (enough to cover bottom of pie plate with 1/2 inch of water)
7. Matches

Procedure (PARENTAL SUPERVISION REQUIRED)

1. Use modeling clay to attach candle (in upright position) to center of pie plate.
2. Add a few drops of food coloring to the pie plate.
3. Fill pie plate with 1/2 inch of water.
4. Light the candle and wait til flame is steady (15-30 sec).
5. Place inverted glass over the candle and lower it onto the pie plate.
6. Observe what happens to the candle and to the water level INSIDE the inverted glass.

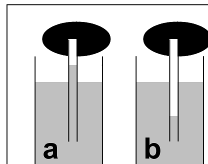
Discussion

Why does the candle stop burning?

In order for the candle to burn it must have oxygen (O_2). Air is composed of approximately 20% O_2 and 80% nitrogen (N_2). The flame goes out when the O_2 gets used up. Does this mean that there is less gas in the bottle after the flame goes out? Not necessarily: while there is less O_2, new gases have been produced as products of the burning process. These combustion products can include carbon dioxide (CO_2), carbon monoxide (CO), and water in the form of steam (H_2O).

Why does the water level rise inside the glass?

The burning candle heats the air inside the glass. The air inside the jar now has a higher pressure than the air outside the jar. Some of the hot air leaks out through the bottom of the glass. (Did you see the bubbles?) When the air left inside the glass cools, its pressure lower is than the pressure of the air outside the glass. You have created a partial VACUUM. This situation can't last for long! The higher pressure of the air outside pushes down on the water in the pie plate and forces it up into the glass. The same mechanism is at work when you control the liquid level in a straw by changing the pressure in your mouth.



BLOWING A STRAW: Pressure in mouth is low (a) or high (b).

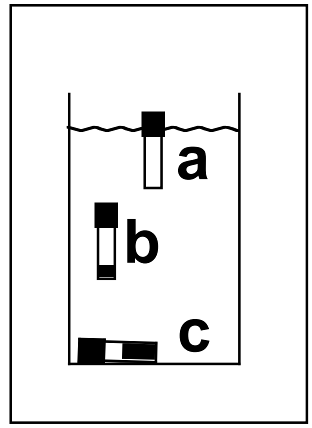
Can you get the water to completely fill the glass?

It's easy, but you have to cheat a little. Turn the glass right-side-up, and get the air out of the glass by filling it with water. Place the pie plate over the glass, invert the whole assembly, then add a little water to the pie plate. The water will stay in even when the glass is lifted slightly above the pie plate! How tall a column of liquid can atmospheric pressure support? It depends on the liquid: about 33 feet of water (or 30 inches of mercury).

Interesting Fact:

Many textbooks give the wrong explanation for the candle/water/glass experiment! They say the water level rises in the glass to replace the volume of O_2 consumed by the candle. The numbers agree (both are about 20%), but this is just a coincidence. Hmm... how could you prove this?

Experiment: Neutral Density Floats



Materials

1. Large tall jar with that you can fit your hand or tongs into
2. 3 little jars that will float in water with their caps on
3. Water
4. Salt
5. Optional: small waterproof weights (fine gravel, bee-bees, small beads, etc.)
6. Optional: tongs
7. Optional: eyedropper

Procedure

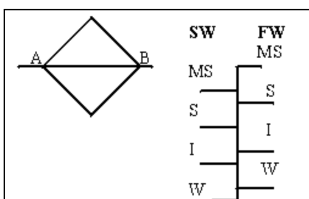
1. Fill the large jar with water.
2. Add weights (or water) to the little jars until one just floats (a), one just sinks (c), and one is exactly balanced (b).
3. Observe what happens to the little jars when you add salt to the water in the large jar.

Discussion

When will an object float or sink?
It is not weight alone that determines whether an object will sink or float. A metal fork will sink, yet an ocean liner floats very nicely. What matters is the object's average *density*, the ratio of its mass (weight) to its volume. An object will sink if its average density is greater than the density of the liquid it is in; it will float if its density is lower. In this experiment, you change the density of the little jar floats by changing how much water is in them. Adding water to the jar floats makes them heavier, but doesn't change their size or volume. When the jar float is exactly balanced, its average density matches the density of the water it is in.

Why do the objects seem lighter in saltwater than freshwater?
Adding salt to the water increases its density: a cubic centimeter of saltwater weighs more than a cubic centimeter of freshwater. The jar floats are very sensitive; sometimes you can raise a sunken one just by adding a little salt to the water.

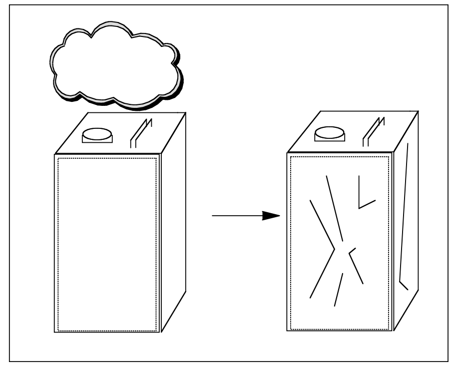
Interesting Fact:
Cargo ships can sink if they are overloaded. Special marks, named Plimsoll lines after the British merchant and shipping reformer Samuel Plimsoll (1824-1898), are painted on ships' hulls to make it easy to see how deep a ship is in the water. As you can see from the diagram, the marks for freshwater (FW) and saltwater (SW) are at different heights, as are the marks for summer (S) and winter (W). The ship is overloaded if the Plimsoll mark is underwater.



Plimsoll markings

Demonstration: Collapsing Can

*****PARENTAL SUPERVISION **REQUIRED**.*****



This is a wonderful demonstration of the power of air pressure. Even though you can't see the air, you see the force it exerts on an aluminum can.

Materials

1. Large thin-walled aluminum can (empty and preferably NEW). If it has been used before, wash with soap and water to be sure it is clean. Rinse well.
2. Hot plate
3. Approx. 1 cup water
4. Oven mitts or thick dishtowel

Procedure

1. Place water inside can and put can on hot plate UNCOVERED.
2. CAUTION: DO NOT HEAT THE CAN WITH THE TOP ON!
3. Heat up can until the water is boiling and steam is rising from the can.
4. Place the cover on the can TIGHTLY (using insulating mitt). As the can cools watch what happens! (You can place it in cold water to speed up the cooling process.)

Discussion

Boiling water produces steam. The steam replaces the air in the can. When the lid is replaced, air cannot get back into the can. As the steam cools and condenses back to water, a partial vacuum is created. The air pressure outside the can is now greater than the pressure in the can. This causes the can to collapse.

Demonstration: Making Ice Cream with Liquid Nitrogen

This is a demonstration of solidification of a liquid into a solid with which we are all familiar – ICE CREAM!

Materials

1. Large metal bowl
2. Ice cream recipe mixture (any flavor)
3. Large metal spoon
4. Liquid nitrogen

CAUTION – *Liquid Nitrogen is VERY cold; make sure it does not contact your skin or eyes, it WILL cause freezer burn.*

Procedure

Mix the ingredients for the ice cream recipe in the large metal bowl. ANY STANDARD RECIPE will work. Stir in the liquid nitrogen to chill the mixture until it solidifies.

Discussion

Using liquid nitrogen takes the work out of ice cream making because it is so much colder than the salt/ice mixture usually used in making ice cream. The temperature of the liquid is about -196^{o}C. Liquid nitrogen is often used by dermatologists for skin surgery.

Demonstration: Liquid Nitrogen Flower Crunch

Materials

1. Liquid nitrogen
2. Long-stemmed flowers

Procedure

1. 1.CAREFULLY dip flower head into liquid nitrogen. Take it out when it reaches liquid nitrogen temperature (or the liquid stops boiling)
2. 2.Smash the flower into a hard surface and observe what happens.

Discussion

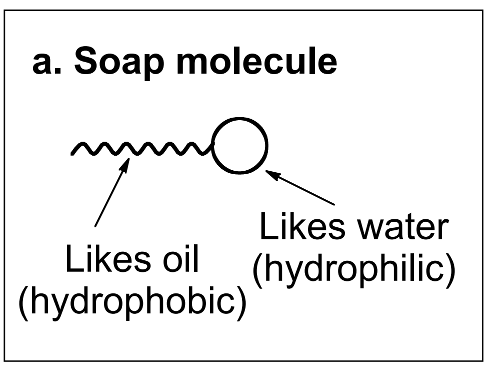
The moisture in the flower freezes and the flower becomes very brittle.

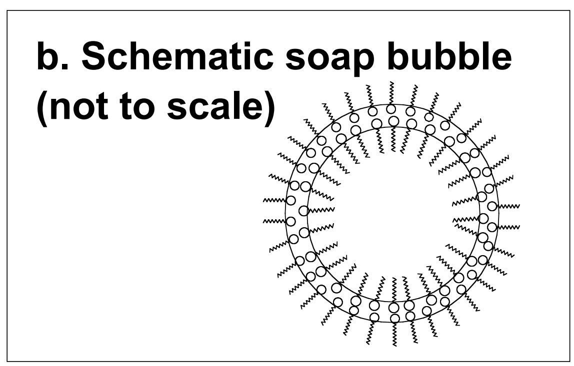
Appendix: SOAP BUBBLES

Most of you have played with bubble solutions before. But have you ever thought about why soap bubbles act the way they do? Soap solutions are made of a mixture of water and soap (and sometimes other liquids like glycerin). Soap molecules (see figure "a") are composed of very long chains of carbon and hydrogen. One end of the soap molecule only likes to stick to water while the other end only likes to touch other soap molecules.

Soap solutions have special properties because of a force called surface tension. Surface tension is what helps soap bubbles keep their shape. Surface tension is what causes liquids to move up small tubes (capillary action). This is how plants obtain water.

The structure of a soap bubble is shown in figure "b" below. It is composed of two layers of soap molecules. In between the layers are many many water molecules. The thickness of the soap bubble is constantly changing due to evaporation of water. Bubbles are approximately spherical so as to minimize the bubble surface area. Any distortion of the bubble from a perfect sphere is caused by the flow of water from the top to the bottom of the bubble. As the water drains away, the film thickness at the top of the bubble decreases. Eventually, the bubble pops when the top of the film is too thin to support the weight of the rest of the bubble. Soap films are even thinner than a human hair!





The thickness of the bubble is always changing and the film thickness is different everywhere along the bubble. When the light shines on a bubble, some of the light is reflected off of the outside surface of the bubble film, and some is reflected off the inside surface of the bubble film. This causes you to see a rainbow of colors. This is called interference.

Appendix: SOAP BUBBLES

Bubble solution recipe

- Simple solution consists of 1 part liquid dishwashing detergent to 5-6 parts distilled or deionized water.
- Addition of glycerin makes the soap solution work better for large bubbles:
  - 10% liquid dishwashing detergent
  - 84% water (distilled or deionized)
  - 6% glycerin (available at drug stores)

    (i.e. mix 1 cup liquid dishwashing soap, 10 cups cold water, 3-4 tablespoons glycerin; you may need to add more water on a very dry day)
- Add water to the container first to minimize formations of foam during mixing. The longer the solution sits, the better the bubbles.

References

1. David A. Katz, *Chemistry in the Toy Store*, 5th edition, 1990 (David Katz is a Professor at the Community college of Philadelphia, 1700 Spring Garden Street, Philadelphia, PA 19130. He has written extensively about the chemistry of toys).
2. Cyril Isenberg, *The Science of Soap Film and Soap Bubbles*, Dover (New York, 1992).
3. F.J. Almgren, Jr., and J.E. Taylor, "The geometry of soap films and soap bubbles," Scientific American **235**, 1, 82-93 (July 1976).
4. C.V. Boys, *Soap Bubbles: Their Colors and Forces Which Mold Them*, Dover (New York, 1959); reprint of 1911 edition.

Appendix: Working with Soap Films

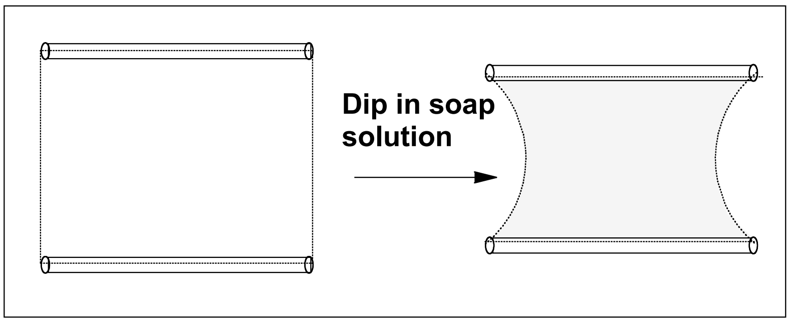
Making a Frame with Straws and String

Materials

1. Two straws
2. Thread
3. Rectangular pan filled with soap solution

Procedure

Connect the two straws together with thread as shown below:



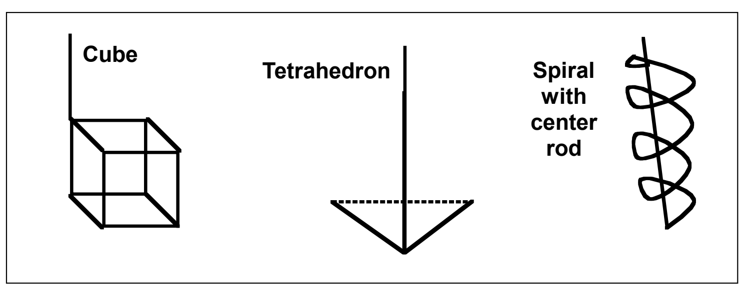
Place the straws in the soap solution and slowly pull out. What happens to the thread? Can you feel the force of the liquid soap pulling the two threads together? What happens if you do this with a water solution instead?

The surface tension of the soap solution makes the straws and string pull together to minimize the surface area of the soap film. The liquid is doing work here to keep the soap film area as small as possible.

Bubbles and Wire Frames

Materials

1. Frames in the shape of cubes, tetrahedrons, loops, spirals, etc. These frames can be made from copper wires crimped or soldered together.
2. Deep container with soap solution



Procedure

Dip the wire frames into the soap solution. What happens to the soap films? How many soap films are in contact at any one point?

Appendix: Surface Tension

Materials:

1. plastic cup or jar (4 to 6 ounce)
2. flat, plastic tray
3. water to fill the cup or jar
4. pennies (at least 15)

Procedure:

1. Place plastic cup or jar on top of flat plastic tray on a sturdy, level surface
2. Carefully pour water into the cup to fill it all the way to the top
3. Carefully place one penny on the edge of the cup and let go of the penny. Watch what happens to the water. Did anything happen when you added the penny?
4. Add another penny. Look at the jar from the side. What does the water look like?
5. How many pennies do you think you can add before the water spills?
6. Keep adding pennies *one at a time* and looking at what happens *each time*- until the water spills.

Discussion:

Water molecules stick together. Adding pennies to a full glass of water will force the water to bulge across the top of the cup showing how the water is sticking together. This is really a demonstration of surface tension. The surface of the water would rather bead, than spread over the side of the cup. Once you have added too many pennies (usually about 12), the surface tension will be overcome and the water will spill over the top.

Suggestion: You can sprinkle a little talc or baby power on the top of the water to see the surface better.

CAUTION: DO NOT SPRAY A LOT OF POWDER, SINCE THIS CAN CAUSE BREATHING PROBLEMS.

Appendix: Temperature and Thermometry

Have you ever wondered exactly what temperature is? Temperature is a measurement of how much energy the atoms and molecules of an object have. The more energy, the higher the temperature. It is not obvious, and first thought, how to go about measuring temperature, but it is very useful for scientists to be able to do this. Along with pressure, temperature is a very important quantity in understanding the states of matter.

The simplest way to define a temperature scale (but not necessarily the most useful) is to pick two different points and define the temperatures at those points. In 1714 Gabriel Fahrenheit did just that. He made a glass thermometer and filled it with mercury. He put his thermometer into an ice/salt/water (brine) solution and called it 0 degrees. Then (after wiping it off!) he put the thermometer in his mouth and called that 96 degrees. (No one seems to know why, and there are other stories about how he decided on his temperature scale.) Once he marked his thermometer, he could measure the temperatures of other things. He chose to measure the temperature of ice water, which came to be 32^o, and boiling water, which came to be 212^o. His temperature is called the Fahrenheit scale, and we use it in the United States, at least, to measure the temperature outside and the temperature in our refrigerators and ovens. The symbol for this temperature is ^oF.

Scientists and the people in a lot of countries other than the U.S. use a simpler temperature scale, one invented by Andre Celsius. Celsius proposed to call the temperature at which water freezes 0^o, and the temperature at which water boils 100^o. His temperature scale, with the symbol ^oC, is widely used today. Sometimes it is also called the Centigrade scale.

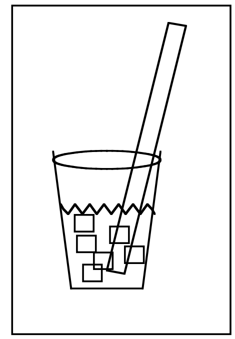
There is a more fundamental temperature scale that scientists sometimes use. It is called the “absolute” or Kelvin scale. It was proposed by William Thompson, a British scientist who was also known as Lord Kelvin. Its symbol is K. In this temperature scale, zero is defined as the absence of all energy (well almost!), so it is called "absolute zero." No one has ever been able to cool something to absolute zero, but scientists have come very, very close. Some temperatures of the things we talked about today in all three temperature scales are given below, along with the mathematical equation used to convert from one to the other. Knowing how to convert from ^oC to ^oF can be useful if you are planning to travel to other countries!

Temperature	K	^oC	^oF
Boiling point of water	373	100	212
Freezing point of water	273	0	32
Really cold outside	255	-18	0
Freezing/sublimation point of dry ice	194	-79	-110
Boiling point of liquid nitrogen	77	-196	-321
Absolute Zero	0	-273	-459

$$^oC= (^oF-32)*(5/9)$$
$$^oF=(^oC*(9/5))+32$$
$$K= {^oC}+273$$

Appendix: Measuring Temperature and Melting Ice

Note: This experiment requires a scientific thermometer, preferably one filled with alcohol rather than mercury (in case of an accident). The thermometer must be able to read to –20°C. You may be able to borrow one from your school science department.



Materials:

1. 1 scientific Celsius thermometer
2. 3 Styrofoam cups
3. Ice cubes or crushed ice
4. Water
5. Table or Kosher salt
6. Calcium chloride ("ice-melting" pellets)

Procedure:

1. Label the cups 1, 2, and 3 with a marker.
2. Put 2-3 ice cubes or about 1 inch of crushed ice into each Styrofoam cup. Add ½ inch of water to the cup. Use the thermometer to determine the temperature of the ice water in each cup for about 5 minutes. What temperature did you get?
3. When all the cups are at the same temperature, add 2 tablespoons of table salt to cup 2. Stir and measure the temperature until it stops changing.
4. Add 2 tablespoons of calcium chloride to cup 3. Stir and measure the temperature.
   *Note: It is important that there be some solid ice in each cup at all times for the experiment to work. If it all melts, add some more.

From your observations, try to answer the following questions:

1. What is the temperature of an ice-water mixture? Why does it stay there?
2. What happened when you added salt to cup 2? Can you think of a practical use for this phenomenon?
3. What happened when you added "ice melting pellets" to cup 3?

Answers and Explanations

1. Since ice melts at 0°C and water freezes at 0°C, 0°C is a very special temperature for water. It is the temperature of a "phase transition." The temperature of the mixture will stay at 0°C as long as both ice and water are present.
2. Adding salt to the mixture causes the temperature to drop well below zero. This is the brine solution that Fahrenheit used to define 0°F or -18°C. Your mixture probably only went down to -5°C or -10°C, but if you really try hard enough and add enough salt you can go lower. Adding salt to the mixture causes the ice to melt faster than it otherwise would. When ice melts, it takes heat away, so the whole solution gets colder. Put another way, the salt depresses (or lowers) the freezing point of the water. So, salt can be used to melt ice on roads in winter or to cool old-fashioned ice cream freezers to below 0°C.
3. If you wait long enough and watch carefully, you will see the temperature first go up to +10 to +20°C then down below 0°C. The temperature rise comes because, unlike table salt (sodium chloride or NaCl), when calcium chloride ($CaCl_2$) dissolves in water heat is given off. Once all the calcium chloride has dissolved and the heat is consumed by the melting ice, the solution acts

the same as the salt solution in cup 2. The salty water causes the ice to melt faster than it otherwise would, and so the temperature goes down. Both calcium and sodium chloride melt ice, but calcium chloride does it faster. That is one reason people are willing to pay more for $CaCl_2$ when you buy it at the store. If you don't believe this, compare the price of calcium chloride ice melter with rock salt (yet another name for sodium chloride)!

SOME "FUN SCIENCE" INTERNET SITES

- http://www.llnl.gov/llnl/03education/science-list.html
- http://www.angelfire.com/ct/christaylor/funscience.html
- http://www.sciencegems.com
- http://www.funsci.com
- http://cse.ssl.berkeley.edu
- http://science-education.nih.gov
- http://www.amasci.com/edu.html

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Suppliers of laboratory equipment

- http://www.arborsci.com (they sell the Cartesian divers)
- http://www.sciencekit.com
- http://www.fisheredu.com