States of Matter

Preparation

Grade Level: 3-6	Group Size: 25-30
Time: 50 minutes	Presenters: 3-5

Objectives:

The lesson will enable students to:

- Define three states of matter.
- Describe the characteristics of each state of matter.
- Provide examples of matter movement from one state to another.
- Describe the relationship of temperature and pressure to phase change.

Standards:

This lesson aligns with the following National Science Content Standards:

- Physical science, grades K-8

Note: While we strive to make our lessons as safe as possible, there are risks inherent in using certain equipment or materials. Safety guidelines have been published where necessary within each lesson. Please ensure that you have adequately reviewed the lesson and have the information and materials necessary to perform it safely. Micron is not liable for any injuries that result from use of these lessons. Some of the equipment and materials used in the States of Matter lesson can pose a safety hazard if used incorrectly. Follow all safety guidelines and instructions as noted within the text of the lesson and with the materials provided in the kit to avoid potential injury.

Materials:

- Dry ice (about 3-5 lbs)
- Bottle of vegetable oil
- Small rock (solid example)
- Clear plastic cup
- Six beakers: 4-250 ml, 2-1liter
- Tea candle
- Lighter/matches
- Food coloring
- Liquid dish soap (clear Dawn® is best)
- Small plastic bowl
- Kitchen thermometer
- 3´ x 1" I.D. plastic tube and stopper
- Isopropyl alcohol (rubbing alcohol)
- Two large balloons or lab gloves
- Safety glasses
- Three pairs of insulated gloves
- Tongs for picking up dry ice
- Hammer or rubber mallet
- Cloth for wrapping dry ice
- Styrofoam cups with lids (4)
- 250 ml filter flask with 6" surgical tubing on the vent
- Clear container with ping-pong or Styrofoam balls
- Science Journaling activity-Appendix A
- "Characteristics of Solids, Liquids & Gases" poster - Appendix B
- "Energy Level" poster - Appendix C
- Phase Diagrams - Appendix D

Preparation

Set up each of the stations with the equipment needed.

Station One: Dry ice and water

Station Two: Dry ice and soap

Station Three: Dry ice and Isopropyl Alcohol

Students, activity leaders and presenters must wear safety glasses when working with dry ice. It is suggested to pass them out at the beginning of the presentation so the students get used to wearing them.

Glossary:

Melting:	Changing from a solid to a liquid state by application of heat or pressure or both.
Freezing:	Changing from a liquid to a solid state by loss of heat.
Boiling:	Generating bubbles of vapor when heated.
Vaporization:	Changing from a liquid to a gaseous state by the application of heat.
Condensation:	Changing from a gas or vapor to a liquid state.
Sublimation:	Changing from a solid to a gaseous state without passing through a liquid state.
Deposition:	Changing from a gas to a solid state without passing through a liquid state.
CO_2:	Carbon dioxide: a gas made up of one carbon atom and two oxygen atoms.
H_2O:	Water: a liquid made up of two hydrogen atoms and one oxygen atom. It can be a solid, liquid, or gas.

Caution: This lesson calls for the use of dry ice and isopropyl alcohol. Read through and follow the safety precautions as given below to avoid possible injury.

Safety Issues with Dry Ice

Safety information adapted from http://www.dryiceinfo.com/safe.htm

Handling

Dry ice is extremely cold. It freezes at -109.3°F (-78.5°C) and must be handled with care. Wear insulated gloves or oven mitts whenever handling it. If touched briefly, it may be harmless. Prolonged contact will freeze cells and cause injury similar to a burn.

Burn Treatment

Treat dry ice burns in the same manner as heat burns. See a doctor if the skin blisters or comes off. If the skin only turns red, it will heal in time, similar to a sunburn or first degree burn. Apply antibiotic ointment to prevent infection and bandage only if the burned skin area needs to be protected.

Storage

It is important to follow these rules when storing dry ice:

- Store dry ice in an insulated container. The thicker the insulation, the slower the ice will sublimate.
- Do not store dry ice in a completely airtight container. The sublimation of dry ice to carbon dioxide gas will cause any airtight container to expand and possibly explode.
- Make sure the storage area is properly ventilated. Do not store dry ice in unventilated rooms, cellars, autos, or boat holds. The sublimated carbon dioxide gas will sink to low areas and replace oxygenated air. This could cause suffocation if breathed exclusively.
- Do not store dry ice in a refrigerator or freezer for a long period of time. The extreme cold temperature will cause your thermostat to turn off the freezer.

Ventilation

Normal air is composed of 78% nitrogen, 21% oxygen, and only 0.035% carbon dioxide. If the concentration of carbon dioxide in the air exceeds 5%, it can become toxic. Smaller concentrations can cause quicker breathing but otherwise are not harmful. However, people with respiratory conditions such as asthma may experience some discomfort at small concentrations. If dry ice has been in a closed vehicle, room, or walk-in for more than 15 minutes, open the doors and windows to allow adequate ventilation before you enter. If you are in an area that contains dry ice and start to pant and breathe quickly, leave immediately; you have inhaled too much CO_2 and not enough oxygen. Carbon dioxide is heavier than air and will accumulate in low spaces.

Transporting

Dry ice is available at most grocery stores. Obtain it as close to the time needed as possible. It sublimates at a rate of 10 percent or 5 to 10 pounds every 24 hours, whichever is greater. Carry it in a well-insulated container, such as an ice chest. If you transport it inside a car or van for more than 15 minutes, make sure the vehicle is well ventilated.

Disposal

Unwrap and leave the dry ice at room temperature in a well-ventilated area. It will sublimate from a solid to a gas. Do not leave it on a tiled countertop as the extreme cold could crack the tile. Do not leave dry ice that is to be disposed of in an area where it could be mishandled.

DO NOT leave dry ice unattended around children.

To break the dry ice into usable pieces:

- Put on safety goggles to protect your eyes and insulated gloves to protect your hands.
- Wrap the dry ice in a dishcloth and break it into approximately one-inch squares with a hammer or rubber mallet.

Safety Issues with Isopropyl Alcohol (IPA)

Isopropyl alcohol vapor is heavier than air and is highly flammable with a very wide combustible range. It should be kept away from heat and open flame. To avoid IPA poisoning, avoid ingestion, prolonged inhalation, or long term absorption. Use in well-ventilated areas and wear protective gloves.
Refer to http://www.cdc.gov/niosh/npg/npgd0359.html for further information on the proper use of Isopropyl Alcohol.

Introduction

Begin the presentation with all of the students in a large group. Ask the following questions and allow enough time for the students to answer.

Q: What is a chemist?
A: A chemist is someone who studies chemistry.

Q: What is chemistry?
A: Chemistry is the study of matter.

Q: How would you define or describe matter?
A: Matter is anything that has mass (weighs something) and occupies space.

There are two types of change that can occur to matter: chemical and physical. Chemical change occurs when an object's original material changes into a different kind of material, such as, burning a match or baking a cake. Physical change results in a new form of the same material. Examples include ice melting, water boiling or freezing, steam condensing, and carbon dioxide sublimating. We are going to look at physical changes today.

Q: How many states of matter are there and what are they?
A: Matter is found in four different states: solid, liquid, gas and plasma. Each of these states is known as a phase. Today we will study the phases of solid, liquid and gas.

Use the poster "Energy Levels" (Appendix C) to support the following discussion.

Elements and compounds can move from one phase to another phase when physical forces are applied. These physical forces either add or remove energy. Heat is one example of a physical force.

Q: How is heat measured?
A: Heat is measured by temperature.

Q: Is energy added or removed when temperature increases?
A: Energy is added when temperature increases.

Q: What is another example of a physical force?
A: Pressure

Refer to "Phase Diagrams" (Appendix D) to look at the relationships of temperature and pressure in determining the phase changes between the different states of matter.

Present to the class three different materials. Ask them to identify the state of matter for each material (rock, vegetable oil, inflated balloon). Use the poster, "Characteristics of Solids, Liquids, and Gases" (Appendix B) to support the discussion.

Q: What are the characteristics of a solid?

A: The characteristics of a solid are:

- Solids hold their own shapes (definite shape).
- Solids are hard to compress (definite volume).
- The atoms and molecules of solids are tightly packed.

Demonstrate a solid using a small rock; place it in a clear glass or cup, noting that it holds its shape.

Q: What are examples of solids?

A: Rocks, chairs, trees, books

Q: What are the characteristics of a liquid?

A: The characteristics of a liquid are:

- Liquids fill the shape of any container (indefinite shape).
- Liquids are hard to compress (definite volume).
- The atoms and molecules of a liquid tend to be a little more spread out than a solid, but much more compact than a gas.

Demonstrate a liquid using a half-filled bottle of water or vegetable oil. Show how the liquid fills the shape of the container by turning the bottle upside-down, etc.

Q: What are examples of liquids?

A: Oil, water, orange juice, syrup

Q: What are the characteristics of a gas?

A: The characteristics of gases are:

- Gases fill a container of any size or shape (indefinite shape).
- The volume of a gas is defined only by the size of its container (indefinite volume).
- The atoms and molecules of a gas are free to move around independently of one another.

Demonstrate a gas by blowing up a balloon and blowing bubbles. The balloon is an example of a gas surrounded by a solid; the bubbles are an example of a gas surrounded by a liquid.

Q: What are examples of gases?

A: Helium in balloons, air (nitrogen and oxygen).

Q: Think of a material, such as water. In what order does water move from one state to another?

A: Water can move from a solid, to a liquid, and then to a gas. It can also move from a gas to a liquid and then to a solid.

Q: Do you know of any materials that move from state to state in a different order?

A: Dry ice.

Dry Ice Sublimation Demonstration

Q: How does ice change state?

A: It goes from a solid to a liquid to a gas

Q: What do you think will happen when dry ice is placed on the counter?

A: It goes directly from a solid to a gas.

Remove a medium piece of dry ice from the ice container and place it on the countertop. You may have a student assist in this step with proper safety precautions.

Q: Describe what is happening.

A: The dry ice is sublimating and giving off a vapor (gas).

Q: Why isn't there a puddle, and how does that indicate what state was skipped?

A: There is no puddle because the liquid state was skipped.

Q: How is dry ice different than ice? What is dry ice?

A: Ice is frozen water (H_2O). Dry ice is frozen carbon dioxide ($C0_2$), the gas we exhale as we breathe. It is much denser and colder than ice. The temperature at which dry ice freezes is −109.3 °F (−78.5°C). Ice melts at 32°F (0°C). Dry ice doesn't melt; it sublimates. Sublimation is the process of going directly from a solid to a gas. Dry ice bypasses the liquid form. That's why we call it "dry" ice.

Have students observe the gas that comes from the dry ice.

Q: What direction does the gas move?

A: It moves downward.

Q: Why do you think the gas goes down instead of up, like steam?

A: This is due to two things:

1) The temperature difference between the dry ice and the air (cooler gas masses will sink)
2) The density of the CO_2 gas (CO_2 is heavier than air)

Candle/flame demonstration

Light a tea candle in the bottom of a small beaker.

Q: What do you think will happen when the dry ice is placed along side the candle in the bottom of the beaker?
A: Answers will vary.

Place a piece of dry ice in the beaker using the insulated gloves or tongs. You may have a student assist in this step with proper safety precautions.

Q: The flame is extinguished. Why? Why can CO_2 be used to extinguish a fire?
A: CO_2 gas is heavier than air. The gas stays in the bottom of the beaker and displaces the oxygen, so that there is not enough oxygen to support combustion. CO_2 is the gas that humans breathe out, and plants and trees breathe in. It is the bubbles in our soda pop. CO_2 fire extinguishers are quite common.

You can repeat the candle demonstration, only this time put the dry ice into an additional beaker and "pour" off the gas until the candle is extinguished.

Solid, liquid, gas atoms demonstration

Materials:

- Closed wire cage, basket, or clear container
- 1" Styrofoam balls or ping-pong balls (enough to fill the container, one a different color)

Start with the container full of the balls. Show the students that when the container is moved around, the balls don't move. When you shake the container, note that the colored ball doesn't move.

Q: What does this represent, a solid, liquid or gas?
A: A solid. The molecules or atoms are packed tightly together, and the object doesn't change shape when moved around.

Remove 1/3 of the balls and repeat the inquiry. Note that with fewer balls, the colored ball can move about, and that the balls move like a liquid.

This represents a liquid. The molecules are further apart, and move like a liquid in the container they are in.

Remove another 1/3 of the balls and repeat the inquiry.

This represents a gas as the molecules are free to move about. Gas molecules that are lighter than air would distribute themselves all about the space. Any gas molecules that are heavier than air would fall to the bottom of the container, and are actually pourable!

Mystery Balloon/Rubber Glove

Q: What do you think will happen when dry ice is placed in a balloon or rubber glove? Why?
A: Answers will vary.

We'll do this as an experiment, and look at the results during our conclusion of the activities.

Place a few pieces of dry ice into the balloon or glove, using tongs and a funnel, and wearing insulated gloves. You may have a student do this, if desired. Tie off the balloon or glove.

A chemist asks a lot of questions: What? How? Why? Today you have an opportunity to be a chemist as you participate in three different activities. Ask what, how, and why about each of the activities in which you participate. Use your science journal page to record your observations.

Divide the class into three groups and begin rotations. Ensure that students and leaders wear safety glasses.

Dry Ice and Water

Caution: Use proper handling techniques and provide adequate ventilation to avoid the risks involved with using dry ice. Make sure you have read the Dry Ice Safety Information on page 2 before doing this lesson station.

Fill a 250-ml beaker half full with warm or hot water.

Have students make predictions about what they think will happen when the dry ice is placed in the beaker of warm water and have them share their rationale for their predictions.

Use insulated gloves and/or tongs to place a chunk of dry ice in the beaker of hot water. Have students record their observations. You may instruct a student to do this.

Q: What is causing the water to bubble?

A: Guide the students to the fact that the water is not boiling, even though it is bubbling. The bubbles are created from the pressure of the CO_2 gas sublimating in the (H_2O) water. The gas coming off the top is not steam, like when a pot of water boils, but CO_2 gas.

Q: Why was the bubbling rapid at first and then slow?

A: The rate of bubbling slows as the water cools. Initially, the dry ice was sublimating at a rapid rate due to the extreme temperature difference between the dry ice and the water. As the water begins to cool and the temperature difference between the dry ice and water becomes smaller, the bubbling begins to slow.

Q: What happens as the water cools?

A: When the water cools enough, water ice will form a covering on the dry ice. The ice will even encapsulate the chunk of dry ice, then pop, as further sublimation takes place and CO_2 gas builds up inside the capsule of ice.

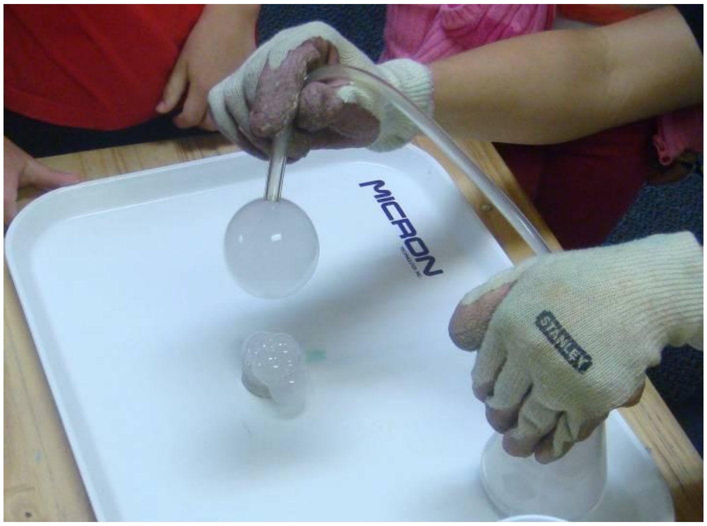
To prepare for the next student rotation, dump the contents of the 250-ml beaker into the 1 liter beaker and prepare for the next group.

Sinking bubbles – This activity is a fun addition to the Dry Ice/Water station.

Materials:

- Clear liquid dish soap in a small plastic bowl
- 250 ml Erlenmeyer filter flask with 6” surgical tubing on vent
- Small plastic lid or stopper to cover flask

Fill the flask about 1/3 full with warm water. Place a small piece of dry ice in the flask, then cover the flask with a glove or small lid. Demonstrate how the gas comes out of the tube.



Uncover the top of the flask, dip the end of the tube in the soap, then cover the flask. Bubbles! Continue to make bubbles by dipping the end in the soap. Be sure to uncover the flask each time you dip the tube in the soap, or the soap may freeze. Allow each student to catch a bubble. As the first piece of dry ice sublimates, start the following discussion:

Q: Why do you think the bubble-making got slower?

A: Answers will vary. As the dry ice sublimates, the production of CO_2 gas slows down, therefore the production of bubbles slows down.

Q: How can we make the bubble production go faster?

A: The addition of more dry ice, warm water, or both will create a faster reaction rate.

Add more dry ice and/or more warm water and observe how much faster the bubbles are produced. The students will have a great time exploring how to catch the bubbles without breaking them, making them bounce, making them different sizes, etc.

Dry Ice and Water Extension – Measuring Temperature Change

Give each group of students a thermometer and a beaker of water at room temperature. Instruct the students to:

- Measure and record the temperature of the water before placing dry ice in the beaker.
- Add a cube of dry ice to the water.
- Measure the temperature of the water once every minute after the dry ice is added.
- Graph the change in temperature over time. The y-axis = temperature, x-axis = time.

Dry Ice and Soap

Caution: Use proper handling techniques and provide adequate ventilation to avoid the risks involved with using dry ice. Make sure you have read the Dry Ice Safety Information on page 2 before doing this lesson station.

Have students make predictions about what they think will happen when dry ice is placed in a beaker of soapy water. Have the students share their rationale for their predictions.

Fill a 250-ml beaker half full with warm or hot water and add some liquid soap. Use insulated gloves and/or tongs to place a chunk of dry ice in the beaker of water and soap. Have students record their observations. You may instruct a student to do this.

Q: What causes this physical reaction?

A: The dry ice is heated by the water causing it to sublimate rapidly. The carbon dioxide gas becomes “trapped” in the soap that is dissolved in the water. If you pop the soap bubbles, the CO_2 gas will be released into the air.

Q: Why does the bubble tube move in a downward direction?

A: The bubble tube moves in a downward direction because CO_2 is heavier than the O_2 in the air, and because the bubbles are connected to each other.

Fill another 250-ml beaker half full with warm or hot water. Add some liquid soap and a drop of food coloring. Have the students note the color of the bubbles in the original demonstration.

Q: If food coloring is added to the water, what color will the bubbles appear to be?

Have the students make predictions, then add the dry ice.

A: The bubbles still appear to be milky-white, because that is the “color” of the the gas. After some of the bubbles have spilled onto the table or tray, it can be observed that the bubble film does carry the color of the water, but since the film is very thin, the bubbles still appear to be the color of the gas – which is also the color of the solid.

To prepare for the next student rotation, dump the contents of the 250-ml beakers into the 1-liter beaker (or into a sink) and prepare for the next group.

Dry Ice and Isopropyl Alcohol

Caution: Use proper handling techniques and provide adequate ventilation to avoid the risks involved with using dry ice and isopropyl alcohol. Make sure you have read the Dry Ice Safety Information on page 2, and the Isopropyl Alcohol Safety Information on page 3 before doing this lesson station.

Fill a plastic tube about 4-5 inches high with isopropyl alcohol.

Have students make predictions about what they think will happen when the dry ice is placed in the sealed test tube of isopropyl alcohol (rubbing alcohol). Have them share the rationale for their predictions.

Use insulated gloves and/or tongs to place a chunk of dry ice in the tube. Place a stopper on the top opening of the tube and point it away from people or objects. Have students record their observations.

Caution: Insure the tube is pointed away from people or breakable objects. The physical reaction will cause the stopper to be launched from the tube.

Q: What caused the physical reaction?
A: The isopropyl alcohol (rubbing alcohol) acts as a heat source because it is at room temperature (28° C) and dry ice is at -78° C. This heat speeds up the transition from solid to gas. In the tube, the gas builds up pressure and is pushing on all sides and ends of the tube. Finally, the gas builds up enough pressure to pop the stopper off.

Q: What could you do to increase the reaction time?
A: Warming the isopropyl alcohol would cause the dry ice to sublimate faster and would increase the reaction time.

Q: If you used water instead of isopropyl alcohol, why would it take longer for the stopper to pop off?
A: The increase in time is due to the water cooling down faster than Isopropyl alcohol, thus decreasing the heat provided to the dry ice, slowing the rate of sublimation. As sublimation slows, less gas is produced decreasing the force that pops the stopper.

Q: What is the effect of isopropyl alcohol compared to water in the plastic tube?

A: Due to differences in freezing points of isopropyl alcohol and water, water cools down much faster than isopropyl alcohol. This causes the stopper to take longer to pop off for each consecutive trial. Eventually, the water would freeze over. Since isopropyl alcohol has a lower freezing point –89.5° C, it does not freeze at the same temperature as water.

At the end of the presentation the Isopropyl alcohol can be returned to the container or emptied into the drain.

Conclusion

Mystery Balloon/Rubber Glove

Observe what happened to the balloon or glove with the dry ice in it.

Q: What is the mystery? How did the balloon/glove self inflate? Why isn't there water in the balloon?

A: As the dry ice sublimates, gas is generated causing the inflation. Depending on how much dry ice was used and the size of the balloon, the pressure of the gas can become so great the balloon will burst.

Concluding Questions

Q: What states of matter did we talk about today?

A: Three states were discussed today: solid, liquid, and gas. Plasma is the most familiar additional state of matter, although matter exists in many states (see "Additional Information" section).

Q: Describe how matter moves from one state to the next state.

A: When energy is added or removed matter moves from one state to another.

Q: What are the forms of energy that can cause a phase change from one state to another?

A: Heat and pressure.

Q: Give an example of material moving from one state to the next.

A: Water: ice to liquid to steam.

Q: What are the characteristics of solids, liquids, and gases?

A: Review introduction for answers.

Additional Information

Plasma

Plasma is the most familiar additional state of matter that scientists recognize. It is classified as a "high-energy" state of matter.

Q: What is plasma?

A: Plasma has properties similar to a gas except that it is composed of charged particles, called ions, which dramatically respond to electric and magnetic forces. Plasma has the highest energy of all the states of matter.

Q: Where can you find plasma?

A: Surprisingly, plasma is probably the most prevalent state of matter in the universe. Materials in the plasma state include flames, the outer portion of the earth's atmosphere, the atmosphere of stars including the sun, much of the material of nebular space, and part of a comet's tail. The aurora borealis is matter in the plasma state streaming through a magnetic field. Closer to home, plasmas are found in florescent lights, neon signs, and lightening.

Q: Where can I find more information on plasmas?

A: More information on plasma can be found by contacting The Division of Plasma Physics of the American Physical Society.

Dry Ice Trivia

Q: How is dry ice made?

A: The first step in making dry ice is to turn the carbon dioxide gas into a liquid. This is done by compressing the CO_2 and removing any excess heat. CO_2 will liquefy at a pressure of approximately 870 pounds per square inch. Next, the pressure is reduced further by sending the liquid carbon dioxide through an expansion valve. Part of the liquid sublimates, causing the remainder to freeze into snowflakes. The dry ice snow is then compacted together under a large press to form blocks. Dry ice is much heavier than traditional ice, weighing about the same as standard bricks.

States of Matter Science Journal

Date:

Name:

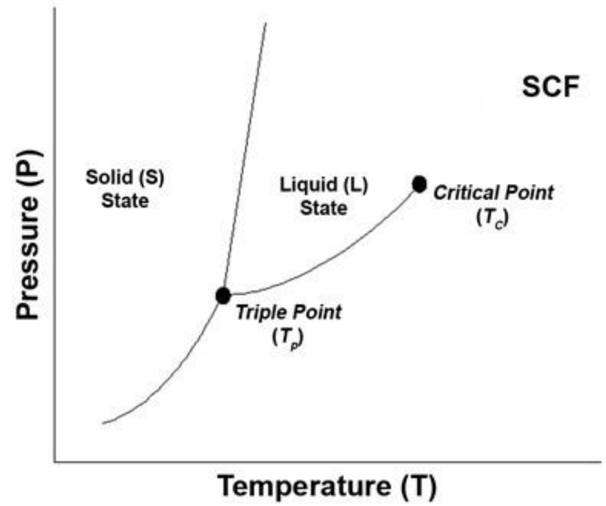
Vocabulary: What is sublimation?

Dry Ice and Water	Dry Ice with Water and Soap	Dry Ice and Isopropyl Alcohol
Predictions:	Predictions:	Predictions:
Observations:	Observations:	Observations:
Conclusions:	Conclusions:	Conclusions:


States of Matter
Gas
• Indefinite shape – Gases fill a container of any size or shape
• Indefinite volume – The volume is defined only by the size of its container
• Molecules have a lot of free space between them, and move freely at high speeds
250ml APPROX.
Liquid
• Indefinite shape – Liquids fill the shape of a container
• Definite volume – Liquids are hard to compress
• Molecules are somewhat close together, with room to move and slide past each other
Solid
• Definite shape – Solids hold their own shape
• Definite volume – Solids are hard to compress
• Molecules are tightly packed, with very little room for movement
Micron Foundation

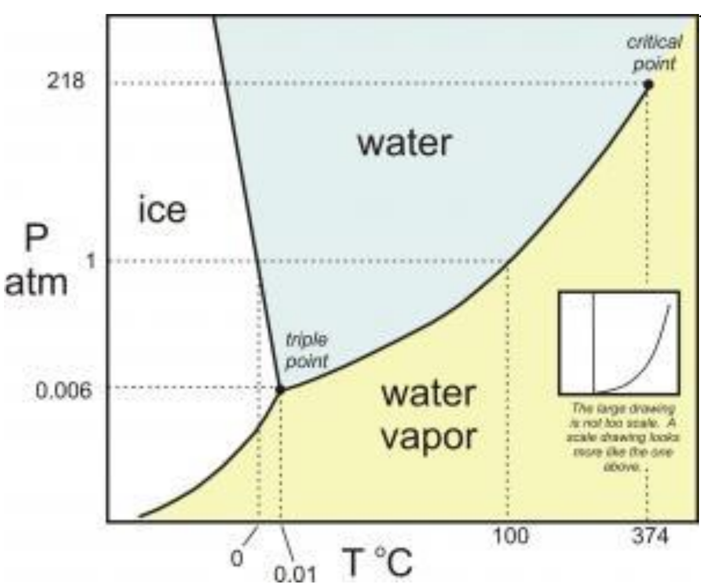

States
of
Matter
Gas
+ Energy
– Energy
Liquid
+ Energy
– Energy
Solid
Foundation
Micron

States of Matter Phase Diagrams



Generic Phase Diagram

The phase of a material depends on the temperature and pressure.



Water Phase Diagram

Water can sublimate over ~110,000 feet above sea level (middle stratosphere)

CO_2 Phase Diagram

Liquid CO_2 possible at ~170 ft. below sea level.