States of Matter
Studying the States of Matter

OBJECTIVE
Students will learn the four states of matter and will describe the characteristics of the primary three states. Students will then observe examples of matter moving from one state to another. Finally students will identify carbon, oxygen, and hydrogen on the periodic table.

LEVEL
Middle Grades: Chemistry

NATIONAL STANDARDS
UCP.1, UCP.2, UCP.3, A.1, A.2, B.2, B.5, B.6, G.1, G.2

TEKS
6.1(A), 6.2(A), 6.2(B), 6.2(C), 6.2(D), 6.2(E), 6.7(B), 6.8(A)
7.1(A), 7.2(A), 7.2(B), 7.2(C), 7.2(D), 7.2(E)
8.1(A), 8.2(A), 8.2(B), 8.2(C), 8.2(D), 8.2(E), 8.9
IPC: 1(A), 2(A), (B), (C), (D), 3(D), 8(A)

CONNECTIONS TO AP
AP Chemistry:

II. States of Matter A. Gases 2. Kinetic Molecular Theory c. Dependence of kinetic energy of molecules on temperature B. Liquids and Solids 1. Liquids and Solids from the kinetic-molecular view point

TIME FRAME
45-60 minutes

MATERIALS
(For a class of 28 working in three groups)

states of matter posters available at
http://download.micron.com/pdf/education/lessonplans/StatesOfMatter.pdf

periodic chart
experiment handouts for each station
newspaper
28 goggles or safety glasses
3 pairs of leather gloves
3-5 lbs dry ice
lighter or matches
food coloring
plastic tubes
isopropyl alcohol
thermometer
hammer or rubber mallet
dishcloth
Silly Putty®
oil
2 250 mL beakers
4 1 liter beakers
tea candle
container of water
liquid soap
stopper
large funnel
graph paper

TEACHER NOTES

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/Vaporization: Changing from a liquid to the gaseous state by the application of heat
Condensation: Changing from a gas or vapor to the liquid state
Sublimation: Changing from a solid to the gaseous state without passing through the liquid state
Deposition: Changing from a gas to the solid state without passing through the 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.

Safety Issues with Dry Ice

Handling

Dry ice is extremely cold. It freezes at –109.3°F (–78.5°C) and must always be handled with care. Wear leather gloves or oven mitts whenever you touch it. If touched briefly, it is harmless, but 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, like a sun burn or any other first-degree burn.

Storage

It's very 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 area and replace oxygenated air. This could cause suffocation if breathed excessively.
- Do not store dry ice in a refrigerator or freezer. Its extremely cold temperature will cause your thermostat to turn off the freezer causing possible damage to the freezer. It will keep everything frozen in the freezer, but it will be used up at a faster rate.

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 rapid breathing but otherwise are not harmful. 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're in an area that contains dry ice and start to pant or breathe rapidly, leave immediately. You have inhaled too much carbon dioxide and not enough oxygen. Carbon dioxide is more dense than air and will accumulate in low spaces.

Transporting
Dry ice is available at most grocery stores. Obtain it as close to the time you need it as possible. It sublimates at 10%, 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 unattended around children.
NOTE: Safety information adapted from http://www.dryiceinfo.com/safe.htm.

To break the dry ice into usable pieces:
Put on safety goggles to protect your eyes and leather gloves or oven mitts 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.

Set up each of the stations with the equipment needed. Organize the students into three groups at the conclusion of the introduction. Each station needs a facilitator.

Group #1	Dry ice in water
Group #2	Dry ice in soapy water
Group #3	Dry ice in plastic tube with a stopper

Suggested teaching procedures

1. Before breaking into smaller groups ask students the following questions aloud.
   Q: What is a chemist? What is chemistry?
   A: A chemist is someone who studies chemistry. 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 changes that can occur to matter: chemical and physical. Chemical changes occur when an object's original material changes into a different kind of material; *e.g.*, burning a match or baking a cake. Physical changes result in a new form of the same material; *e.g.*, 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? Who can name them?
   A. Matter is found in four different states: solid, liquid, gas and plasma. Each of these states is known as a phase. The plasma state will not be studied in this activity.

2. Use the Energy levels poster to support the discussion of energy levels.
   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 of these physical forces.

Q: How is heat measured?
A: Heat is measured when it flows from one system to another. Heat causes changes in temperature, changes of state, or changes in volume. Any of these may be used to measure heat. The unit for heat is joules (or calories.)

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

3. Present to the class three different materials. Ask them to identify the state of matter of each material (Silly Putty®, oil, and inflated balloon).

4. Ask students to define the different characteristics of the Silly Putty@, oil, and gas in the balloon.

5. Use the poster Characteristics of Solids, Liquids, and Gases to support the discussion.
Q: What are the characteristics of a solid?
A: Characteristics of a solid are:
Solids hold their own shapes (definite shape).
Solids are hard to compress (definite volume).
Their atoms and molecules are tightly packed.

Q: Who can give an example of a solid?
A: Examples are Silly Putty®, rocks, chairs, trees, books, etc.
* Silly Putty ® is known by its manufacturer as a "real solid liquid". In more technical terms it is known as a dilatant compound which means that it is a viscous suspension or gel but becomes solid under the influence of pressure.

Q: What are the characteristics of a liquid?
A: Characteristics of a liquid are:
Liquids fill the shape of any container (indefinite shape).
Liquids are hard to compress (definite volume).
Their atoms and molecules tend to be a little more spread out than a solid but much more compact than a gas.

Q: Who can give an example of a liquid?
A: Examples are oil, water, juice, syrup, etc.

Q: What are the characteristics of a gas?
A: Characteristics of a gas are:
Gases fill a container of any size or shape (indefinite shape).
The volume of a gas is defined only by the size of the container (indefinite volume).
The atoms and molecules are free to move around independently of one another.

Q: Who can give an example of a gas?
A: Examples are helium in balloons, air (nitrogen and oxygen), etc.

Q: Think of a material, such as water. In what order does it move from one state to another?
A: Water can move from a solid to a liquid to a gas. It can also move from a gas to a liquid to a solid.

Q: Can you think of any material that moves in a different order?
A: Dry ice

6. Dry Ice Sublimation Demonstration
Ask the students how ice changes states (solid-liquid-gas). Ask students to predict what they think will happen when dry ice is placed on the counter. Have a student put on a pair of leather gloves and remove one piece of dry ice from the ice container and place it on the countertop. Have students explain what is happening. Why isn't there a puddle? What 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 (CO_2), the gas we exhale when we breathe. Identify carbon and oxygen on the periodic table. It is much denser and colder than ice. The temperature at which CO_2 freezes and forms dry ice is –109°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 it is called "dry" ice.

Q: Observe the gas. What direction does it move? Why do you think it goes down instead of up, like steam does?
A: This is due to two things:
The temperature difference between the dry ice and the air, and the density of the CO_2 gas.

Place a lighted tea candle in the bottom of a 1-liter beaker.

7. Candle/Flame Demonstration
Q: Ask the students to predict what they think will happen when the dry ice is placed alongside the candle in the bottom of the beaker. Why?
Allow a student to put on leather gloves and then place a piece of dry ice in the beaker.

Q: The flame is extinguished. Why? Why can CO_2 be used to extinguish a fire?
A: CO_2 gas is more dense than air. When carbon dioxide floods the system there is not enough oxygen present to support combustion. CO_2 is the gas that humans breathe out and trees take in. It is the bubbles in carbonated drinks. CO_2 fire extinguishers are quite common.

8. The Fourth State of Matter
Scientists recognize a fourth state of matter called plasma.

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

T E A C H E R   P A G E S

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, like 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 fluorescent lights, neon signs and lightning.

Q: Where can more information on plasmas be found?
A: More information on plasmas can be found by contacting the Division of Plasma Physics of the American Physical Society.

Tell students: A chemist asks a lot 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. You will have scientific data sheets to record the results of each of the experiments.

9. Divide students into three groups and begin rotations. Ask the questions printed on the individual station guide pages.

10. When all three rotations are completed bring the students back into a large group and complete the concluding activity and questions.

Concluding Activity

Mystery Balloon
Q: From what you have learned, what do you think will happen when dry ice is funneled into the balloon?
Funnel a few pieces of dry ice into the balloon. Have one student hold the opening of the balloon under the funnel and another student scoop dry ice into the funnel. Make sure each wears leather gloves. After a few scoops of dry ice are funneled into the balloon, tie it off.

Q: What is the mystery? How did the balloon self-inflate?
A: Dry ice doesn't melt, it just gets smaller. When the dry ice sublimates, large amounts of gas are generated, causing the balloon to inflate. Eventually the pressure of the gas becomes so great that the balloon will burst. Hold the balloon away from your body and away from the students.

Station I: Dry Ice in Water

1. Fill a 250-mL beaker half full with warm or hot water.
2. Ask the group to predict what will happen when the dry ice is placed in the beaker of warm water. Record the predictions and discuss rationale.
3. Put on leather gloves or cooking mitts and carefully place a chunk of dry ice in the beaker of water. Point out that the dry ice is shrinking.
4. Remind each student to document what the water does, and what happens as the water cools.
5. Give each group of students a thermometer and a beaker of water at room temperature.
6. Instruct the students to measure and record the temperature of the water.
7. Assist the students in adding a chunk of dry ice to the water.
8. Instruct the students to measure the temperature of the water every minute for 5 minutes after the dry ice has been added.
9. Instruct the students to graph the change in temperature over time, with temperature on the y-axis and time on the x-axis.
10. Send the students to the next station.
11. Dump the contents of the 250-mL beaker into the 1-liter beaker and repeat 1-11 for the next group(s).

Q: What is causing the water to bubble?
A: The rate of bubbling slows as the water cools. Initially, the dry ice was heating 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 builds up inside the capsule of ice.

Station 2: Dry Ice in Soapy Water

1. Fill a 250-mL beaker half full with warm or hot water and add some liquid soap.
2. Ask the group to predict what will happen when the dry ice is placed in the beaker of soapy water and discuss their rationales. Record the predictions.
3. Place a chunk of dry ice in the beaker of soapy water. Establish with the group that the dry ice is shrinking.
4. Remind each student to document what the water does and how the soap bubbles look.
5. Each student should also record which way the bubble tube moves and why.
6. Ask the group to predict what color the soap bubbles will become when food coloring is added to the water. Record the predictions.
7. Add several drops of food coloring to the water.
8. Record what color the soap bubbles become and what color the CO_2 becomes and why.
9. Send the group on to the next station.
10. Dump the contents of the 250-mL beaker into the 1-l beaker and prepare the activity for the next rotation.
11. Repeat 1-11 until all groups have been through this station.

Q: What cause this physical reaction?
A: The dry ice is heated by the water, causing it to sublime 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 downward because CO_2 is more dense than air and because the bubbles are connected to each other.

Q: If we add food coloring to the water, would the CO_2 be trapped in the bubbles or would the bubbles become the color of the food coloring?
A: **Have the students predict what will happen.** Neither the CO_2 nor the bubbles took on the color of the food coloring. The food coloring dissolved in the water but not in the dry ice or the soap. And since the sublimation of the dry ice is a physical change and not a chemical change, the CO_2 remains unchanged. Likewise, the soap is not changed by the water, so it does not “react” with the food coloring dissolved in the water.

Station 3: Dry Ice in Tube with Stopper

1. Fill a plastic tube about 4-5 inches high with isopropyl alcohol.
2. Ask students to predict what will happen when the dry ice is placed in a sealed tube of alcohol and discuss their rationales. Record the predictions.
3. Put on the leather gloves or cooking mitts and place a chunk of dry ice in the plastic tube.
4. Place the stopper on the top opening of the tube. **Point away from yourself and others.**
5. Remind students to record what happens and why.
6. Ask students what changes are necessary to increase the reaction and why.
7. Ask the students to discuss why the time for the stopper to pop off should increase if water is used instead of alcohol.
8. Dump the contents of the plastic tube into the 1-l beaker and prepare the activity station for the next group.
9. Repeat 1-8 until all groups have been through the station.

Q: What caused the physical reaction?
A: The alcohol acts as a heat source because it is at room temperature (25°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 pushes on the sides and ends of the tube. Finally, the gas builds up enough pressure to pop the stopper off.

Q: What would you change to increase the reaction?
A: Warming the isopropyl alcohol so the dry ice would sublime faster would increase the reaction.

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

Note: The last and next question reinforce one another.

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, the water cools down much faster than the alcohol. In the water tube, the stopper takes longer to pop off for each consecutive "pop" as the water cools and then freezes. Isopropyl alcohol has a lower freezing point (–89.5°C) than carbon dioxide, and thus remains in the liquid state much longer and "pops" more frequently.

SAMPLE DATA AND ANSWERS TO THE CONCLUSION QUESTIONS

Data Table 1: Dry Ice in Water	
Test Performed	**Results**
Dry ice added to warm water	The water bubbled. Gas appears to rise off the top of the water. (CO_2 not steam)
Observed water as it cooled	Bubbling slowed down, finally ice formed on top of the chunk of dry ice. If the students wait long enough, the ice will pop off the chunk of dry ice as sublimation builds up inside the capsule of ice. In addition, the chunk of dry ice will be smaller than when it was first placed in the warm water.
Measured initial water temperature	Temperature will be higher than room temperature up to nearly boiling. (attach graph)
Measured temperature change	Temperature will approach the freezing point of water. (attach graph)
Data Table 2: Dry Ice in Soapy Water	
Test Performed	**Results**
Dry ice placed in soapy water	The rapid sublimation of the dry ice in the water will cause the dry ice to reduce in size and will cause a large quantity of soap bubbles. If the soap bubbles are popped, they will release the CO_2 gas into the air.
Observed direction of bubble formation	The bubble "tube" will move 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.
Added food coloring	The food coloring dissolves in the water but not in the dry ice or the soap. Since sublimation is a physical, not chemical, change, the CO_2 remains unchanged and the soap does not "react" with the food coloring.
Observed color of H_2O, CO_2, and bubbles	The water will be the color of the food coloring. The CO_2 and bubbles will not change in color.
Data Table 3: Dry Ice in Stoppered Tube	
Test Performed	**Results**
Dry ice added to tube partly filled with isopropyl alcohol; stopper put in.	The stopper popped off of the tube.

TEACHER PAGES

1. How many states of matter are there? List them.
   - Four—solid, liquid, gas and plasma

2. Describe how substances move from one state to the next.
   - Heated, cooled, pressure, can skip states

3. What are the characteristics of a solid, liquid, and gas.
   - Solids: Hold their own shapes (definite shape).
     Hard to compress (definite volume).
     Their atoms and molecules are tightly packed.
   - Liquids: Fill the shape of any container (indefinite shape).
     Hard to compress (definite volume).
     Their atoms and molecules are more spread out than a solid but much more compact than a gas.
   - Gases: Fill a container of any size or shape (indefinite shape).
     Volume of a gas is defined only by the size of the container (indefinite volume).
     Atoms and molecules are free to move around independently of one another.

4. Give an example of material moving from one state to the next.
   - Water to steam, steam to water, ice to water, water to ice, dry ice to gas, etc.
   - Students may answer with cooking examples. Give credit, but point out once more that cooking involves a chemical change—the substance is not the same as before beginning. In this lesson we focused on physical changes. Chemicals (ingredients) are mixed together according to a recipe. If heat is applied, **e.g**., baking a cake, the ingredients change from a liquid to a solid. If freezing is applied, *e.g*., making ice cream, liquid ingredients change from a liquid to a solid. In making candy, the ingredients are first liquefied by high heat and then cooled to become solid.

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. [Gases warm when compressed.] The CO_2 will liquefy at a pressure of approximately 870 pounds per square inch. Next, the pressure is reduced by sending the liquid CO_2 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.

REFERENCES:

http://www.micron.com/K-12/lessonplans
http://www.dryiceinfo.com/safe.htm
http://www.plasmacoalition.org/edmaterials.htm

States of Matter
Studying the States of Matter

Matter is anything that has mass (weighs something) and occupies space. Matter is found in four different states: solid, liquid, gas and plasma. Each of these states is know as a phase. (The plasma state will not be studied in this experiment.) Solids have definite shape and definite volume with tightly packed atoms and molecules. Liquids have indefinite shape and definite volume with atoms and molecules more spread out than in solids but much more compact than in gases. Gases have indefinite shape and indefinite volume with atoms and molecules that are free to move around independently of each other.

Chemistry is the study of matter. Compounds (ingredients) are mixed together according to a recipe. If heat is applied, e.g., baking a cake, the ingredients change from a liquid to a solid. If freezing is applied, *e.g.*, making ice cream, liquids change to solids. In making candy, the ingredients are first liquefied by high heat and then cooled to become solid. Chemists and other scientists and engineers ask lots of questions: What? How? Why? These questions and along with the observations and measurements made to answer them are the basis of scientific exploration and knowledge.

There are two types of changes that can occur to matter: chemical and physical. Chemical changes occur when an object's original material changes into a different kind of material; *e.g.*, burning a match or baking a cake. 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 of these physical forces. Physical changes result in a new form of the same material; *e.g.*, ice melting, water boiling or freezing, steam condensing, and carbon dioxide sublimating. We are going to look at physical changes today.

The facts in this paragraph will assist you in determining why some of the observations you make today occur. Dry ice is extremely cold. It freezes at –78.5°C and must be handled with care. Dry ice is frozen carbon dioxide (CO_2), the gas we exhale when we breathe. It is much more dense and colder than frozen water. 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 rapid breathing but otherwise are not harmful. Frozen water melts at 0°C. Dry ice does not melt; it sublimates. Sublimation is the process of going directly from a solid to a gas. Since dry ice does not melt, it shrinks as it sublimates. CO_2 gas is heavier than air and does not have enough oxygen to support combustion, so it is a common gas in fire extinguishers. Isopropyl alcohol has a freezing point of –89.5°C.

PURPOSE

In this activity you will be able to define the four states of matter and the characteristics of the three primary states. You will observe several examples of matter moving from one state to another and will measure the temperature change associated with one of those changes. You will also locate carbon, oxygen, and hydrogen on the periodic table.

MATERIALS

- newspaper
- goggles or safety glasses
- leather gloves
- dry ice
- food coloring
- plastic tubes
- thermometer
- isopropyl alcohol
- graph paper
- oil
- hammer or rubber mallet
- dishcloth
- 2 250-mL beakers
- 4 1-liter beakers
- container of water
- liquid soap
- stopper
- large funnel

Safety Alert

1. Goggles should be worn at all times during the lab investigation.
2. Care must be taken to avoid direct contact with dry ice. Leather gloves or cooking mitts must be used to handle the dry ice.
3. Stoppered tubes must be pointed away from any person.

PROCEDURE

Follow your teacher's instructions as to how you will be rotated through the demonstration stations. Record your observations and measurements in the data table on your student answer page. Answer the conclusion questions after finishing all three stations.

Name ________________________________

Period ________________________________

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DATA AND OBSERVATIONS

Data Table 1: Dry Ice in Water	
Test Performed	Results
Dry ice added to warm water	
Observed water as it cooled	
Measured initial water temperature	(attach graph)
Measured temperature change	(attach graph)
Data Table 2: Dry Ice in Soapy Water	
Test Performed	Results
Dry ice placed in soapy water	
Observed direction of bubble formation	
Added food coloring	
Observed color of H_2O, CO_2, and bubbles	
Data Table 3: Dry Ice in Stoppered Tube	
Test Performed	Results
Dry ice added to tube partly filled with isopropyl alcohol; stopper put in.	

CONCLUSION QUESTIONS

1. How many states of matter are there? List them.

2. Describe how substances move from one state to the next.

3. What are the characteristics of a solid, a liquid, and a gas?

   a. Solid:

   b. Liquid:

   c. Gas:

4. Give at least one example of material moving from one state to another.

Write Your Notes and Ideas Here!