The Case of The Exploding Chip Bag- Gas Laws in the Real World

<table>
<tr><td colspan="2">This 5E instructional activity will help students understand how particle movement in gases is affected by pressure.</td></tr>
<tr><td colspan="2" align="center">Student Science Performance</td></tr>
<tr><td>Grade level: 9- 12 Physical Science</td><td rowspan="2" align="center">Title: The Case of the Exploding Chip Bag</td></tr>
<tr><td>Topic: Behavior of Gases</td></tr>
<tr><td colspan="2">Performance expectations for GSE:
SPS5 Obtain, evaluate, and communicate information to compare and contrast the phases of matter as they relate to atomic and molecular motion.
a. Ask questions to compare and contrast models depicting the particle arrangement and motion in solids, liquids, gases, and plasmas.
b. Plan and carry out investigations to identify the relationships among temperature, pressure, volume, and density of gases in closed systems.
(Clarification statement: Using specific gas laws to perform calculations is beyond the scope of this standard; emphasis should focus on the conceptual understanding of the behavior of gases rather than calculations.)</td></tr>
<tr><td colspan="2">Performance Expectations for Instruction:
● Plan and carry out an investigation to demonstrate the effect of pressure on the volume of a gas.
● Analyze and interpret the reason for gas expansion at high altitudes.
● Ask questions and develop models for particle motion.</td></tr>
<tr><td colspan="2">Materials:
● 10cc Syringe without needle (1 for every 2-3 students)- these can be ordered cheaply online from science supply companies, sometimes local pharmacists will also be willing to donate them to schools
● Lab supplies for supplemental activities
● Marshmallows (3 for every 2-3 students)
● Map of the United States
● Access to internet for research or lists of the altitudes of the named locations

Additional notes on student supports</td></tr>
<tr><td>Engaging Learners</td><td>Phenomenon- The story of an exploding chip bag.

Tell or read the following account to students-
A Georgia family took a trip west to Yellowstone National Park. In preparation for their trip, they purchased a box of small bags of potato chips to eat as snacks. As they drove through Beartooth pass from Montana into the northeast gateway to Yellowstone they suddenly heard a large POP from the back of their car. When they pulled over to investigate the sound, the only thing they found was a bag of chips that had been blown open (as evidenced by the chip pieces scattered over their trunk). Ask questions about why this may have happened.

Here are a few additional clues you may provide to students:
The family noticed as they moved west and closer to the Rocky Mountains, when they would buy chips or other bagged products at stores, the bags were very tight and “full” of air (much more so than in Georgia).</td></tr>
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	Have students investigate the elevations (Students can use the sample data sheet or one like it.) of some of the locations along the way such as • the altitude of Atlanta, • the altitude of St. Louis, MO, • the altitude of Omaha, NE, • the altitude of Keystone, SD, • the altitude change over the Beartooth Pass; Beartooth Highway or National Park Service: Beartooth Highway Students also need to understand that pressure changes due to altitude. Teachers may ask why your ears pop when you drive up a mountain (or fly in a plane) to introduce this information. Teachers could also use this resource from CK12 to introduce this topic- Ask students to record the questions they have about this phenomenon. **Obtaining**-The focus of this activity will be on eliciting questions, not on explanations. Even if some students cite expanding gas, encourage them to consider other ideas. Additional teacher notes on topic, focus and phenomena
Exploring	Prepare a simple lab with medicine syringes (no needle) and marshmallows. Have students place a marshmallow (or mini-marshmallows or marshmallow pieces) in the syringe and then replace the stopper. Students should insert the plunger until it is just above the marshmallow, then place their finger over the tip of the syringe (creating a closed system). Students can then pull the stopper and observe the marshmallow. The marshmallow expands as the pressure is decreased in the syringe. Working in small groups, students can plan and carry out investigations of how gases change as pressure changes. Student groups should record, describe and share their observations of the model system. Encourage students to consider what data is being measured and recorded in the investigation. **Obtaining**- Students should describe their observations of the marshmallow in detail. Students should be allowed to explore as they desire (adding more marshmallows, pushing the plunger in and out, etc.) within reason and following safety protocols. An option to sequence the explore, explain, and elaborate parts of the lesson is to use a variety of investigations in the Gas Properties Station Lab. A student sheet is also provided.
Explaining	Students will explain how moving the plunger changes the pressure in the syringe. (Volume is changing as well, but you can use your discretion as a teacher as to whether you want to include this variable in the explanation). Students should also explain what they think is happening to the marshmallow. Student can design a model to explain their work by drawing or writing their explanations concerning the phenomenon. Allow students to use textbooks, online searches and other resources in this step in to develop accurate depictions

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<td>of the expansion of gas particles with a decrease in pressure.

Evaluating- Students should predict what is happening to the gas molecules in the marshmallow as the plunger is moved in the syringe. Prompt students to predict whether it expands, contracts, or has no change if additional help is needed.

Communicating- Students should explain based on the evidence they observed with the marshmallow as to what happens to gas particles when pressure is reduced.

In this phase, students can gain more experience with developing models and explaining particle motion and behavior through the Packing Particles Activity. Teachers notes are also provided.</td>
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<tr>
<td>Elaborating</td>
<td>Returning to the original phenomena, students should use what they learned about gas particles in their model system in response to changes in pressure to explain what happened with the chip bag.

Communicating- One method of communicating understanding of this phenomena for each group of students to complete a C-E-R poster. Students must make a “claim” about what was happening to the gas in the chip bag (ex. as the pressure decreased due to the increase in altitude, the gas inside the chip bag expanded in volume), using “evidence” (ex. the chip bags expanded as the family traveled along their route; the marshmallow expanded as the pressure decreased), resulting in a “reasoning” (ex. as pressure decreases, gas expands, or explanations from segment activities), for the phenomena. Students could share these with the class and allow peers to critique the strength of their argument. At this point, teachers should intervene if any misunderstanding persists among students.

Sample C-E-R poster:

<table>
<tr><td colspan="4">What caused the chip bag to explode?</td></tr>
<tr><td>Initial Claim:</td><td colspan="3">The chip bag exploded due to ____
____
____
__________________</td></tr>
<tr><td>Initial Reasoning</td><td colspan="3">1.____
2.____
3.____</td></tr>
<tr><td>Revised Claim after Investigation</td><td colspan="3"></td></tr>
<tr><td>Supporting</td><td>1.</td><td>Reasoning</td><td>1.</td></tr>
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</tr>
</table>

Evidence from Investigation	2.		2.
	3.		3.
	4.		4.

Evaluation	***Assessment of Student Learning*** Ask students to draw diagrams of what was occurring inside the chip bag as the family moved through different altitudes on their trip. While the focus of this activity is on what is happening in the closed system of the bag, note that it is the pressure of the air outside the bag that is driving the change. Students will show the understanding of the movement of gas particles. You can connect this to other activities on the movement of particles to compare why the chip bag explodes but other things in the car are not affected this way (solids and liquids). The student's' ability to explain that as pressure decreases, gas expands (volume increases) is the ultimate assessment of mastery. Challenge students to explain what happens to gas as pressure increases (volume decreases), which was also observed in the model system when the marshmallow contracted as the plunger was pushed back into the syringe.
SEP, CCC, DCI	**Science Essentials**
Science and Engineering Practices	● Planning and carrying out investigations ● Asking questions ● Analyzing and interpreting data ● Constructing explanations
Crosscutting Concepts	● Stability and Change ● Systems and System Models
Disciplinary Core Ideas	From A Framework for K-12 Science Education: PS1A. Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. In a liquid, the molecules are constantly in contact with each other; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and vibrate in position but do not change relative locations.

<u>Additional Supports for struggling learners:</u>

The following supports are suggestions for this lesson and are not the only options to support students in the classroom. These supports target students that struggle with science material, this lesson or a previous lesson. These are generalized supports and do not take the place of IEP accommodations as required by each student's Individualized Education Program.

General supports for the following categories:

<u>Reading:</u>

1. Provide reading support by reading aloud or doing partner reads
2. Have the teacher model what they are thinking when reading the text
3. Annotate the text with students so that they may refer to it as they work through the lab

<u>Writing:</u>

1. The teacher can provide a sentence starter for the students.
2. The teacher can give students an audience to write to (i.e. Write a letter to your sibling explaining this topic).
3. The teacher can provide constructive feedback during the writing process to help students understand the expectations.

<u>Math:</u>

1. Provide calculators as needed.
2. Provide graph paper as needed.

Supports for this specific lesson if needed:

Performance expectations for instruction:

1. The teacher should provide information to students in various formats to reach as many students as possible.
2. The students should be given adequate time to complete each part of the lesson.
3. The students should be allowed to express their knowledge in various formats.
4. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material.

Engage:

1. The story is a good illustration to some students. However, many students may not be able to visualize what is occurring in the story. The teacher should consider illustrating the story or showing a video that mirrors the story to engage students.
2. The teacher should provide the data sheet to the students. Then the teacher should explicitly teach students how to use the data sheet that they have been given.
3. Make sure to tell the students about the ear popping scenario because this will make it real to students. Almost everyone has experienced the ear popping sensation that occurs when driving or when a storm rolls in and changes the pressure.

4. The teacher should record the questions that the students have on the board.
Exploring: 1. The teacher should show students how the syringe works and how the plunger can be removed. 2. The teacher should discuss how to create a closed system. The teacher should also try to get students to explain what a closed system is and correct any misconceptions about closed vs open systems. 3. After giving students a few minutes to observe the marshmallow the teacher should ask students for observations and potential hypothesize for why the marshmallow is changing. 4. The teacher should provide students a template for planning and carrying out an investigation. 5. The teacher may want to consider doing a demo on how to write a procedure. The teacher can do a demo on making a sandwich (PB&J if no one is allergic to peanuts in the class) where the students are providing the instructions. The teacher should be prepared for this demo to be strange because students will forget directions like "open the jar" and the teacher will find themselves doing things like trying to get jelly out of a closed jar. The teacher should do nothing that the students do not instruct them to do. 6. The teacher should use flexible and intentional grouping.
Explaining: 1. Struggling students may need teachers to leave volume out of the lesson until later. 2. Students are constructing a model in this lesson. The teacher should provide multiple options for students to express their model. These formats could include writing, drawing or designing a play. 3. The teacher may need to provide students with resources such as page numbers and websites for students to use to ensure that students are constructing an accurate model. 4. The teacher should consider giving sentence starters to struggling students. This will help struggling students with the writing process.
Elaborating: 1. The teacher should remind students of the initial phenomena. The teacher should have students describe what happened with the chip bag. 2. The teacher should use flexible and intentional grouping. 3. The teacher should provide students with the CER poster example. 4. The students should complete a gallery walk of all the poster that have been created. The students should record new information on an organizer as they complete the gallery walk. 5. Then the teacher should allow students to return to their groups and revise their CER as needed.
Evaluating: 1. The teacher should provide multiple options for students to express their model. These formats could include writing, drawing or designing a play. 2. The teacher should move around as students are working. This will give the teacher an opportunity to see what misconceptions still exist and which students need re-teaching and reviewing. 3. The teacher should remind students that their ears popping is the same phenomena as the chip bag. 4. The teacher can provide other scenarios to help the students see how this phenomenon occurs in their life.

Return to Instructional Segment

Exploding Chip Bag Data Log

Student Names

____

____

____

Fill in the table below-

Location	Altitude	Pressure at Altitude	What did the family report?
Atlanta, GA			
St. Louis, MO			
Omaha, NE			
Keystone, SD			
Beartooth Pass at MT/WY border			
Beartooth Pass at Maximum Elevation			

Return to Instructional Segment

Gas Properties Station Lab

It is critical, prior to the experiments, that the students understand that:

1) gas particles are in constant motion

2) the temperature of a gas, in Kelvins, is directly proportional to the speed of the particles.

3) gas particles collide with objects creating a force (per unit area) which we call *pressure*.

4) the speed of the particles and frequency of the collisions determine the pressure that is exerted by the gas.

Initial Exploration:

This experiment should be performed in small groups, as a class.

Teacher note: If more quantitative data is desired, kits are made for exploring Boyle's Law. Typically, these kits consist of a large syringe and two wooden blocks which fit over the ends of the syringe. They are simply referred to as Boyle's Law Apparatus or Boyle's Law Kits.

Materials:

- 60mL syringe with Luer lock tip
- Luer lock syringe cap

Procedure:

1. Students work in groups of two- three, with each group using a 60 mL syringe with Luer lock cap and a large whiteboard or chart paper.
2. Students should wear safety goggles at all times.
3. Before beginning, they are instructed to draw an x- and y-axis graph with volume as the independent variable and pressure as the independent variable. The y-axis will be unitless, but the x-axis can be labeled in increments of 10 mL, from 0 to 40 mL.
4. Students are instructed to set the plunger in the syringe to 40 mL and then screw on the cap. Then, they should set the syringe, cap-side down against the desk/table with one student holding the syringe with both hands and the other student applying a downwards pressure to the stopper.
5. They should qualitatively take note of the amount of pressure needed to keep the plunger at 40 mL, 30 mL, 20 mL, and 10 mL and place a point on their graph above the corresponding volume increments on their whiteboard or paper.
6. Student groups should then develop an explanation, using a particle model for the gas, for their data. Groups can then share their results and compare graphs. If different models are presented, a discussion can take place to evaluate the strengths of the various models.

Stations:

Teacher note: An alternative to having each group of students perform each activity if to jigsaw the stations and have groups prepare a brief presentation for the class about their particular activity.

A: Marshmallow Mash

Materials:

- 60mL syringe with Luer lock tip
- Luer lock syringe cap
- Mini marshmallows (2 per group)
- Safety goggles

Procedure:

1. Students should wear safety goggles at all times.
2. Without the cap on the syringe, students place a marshmallow in the syringe, then push the plunger until it just touches the marshmallow.
3. Place the cap on the syringe.
4. The students pull the plunger up, expanding the volume inside the syringe and hold. Observe any changes that occur in the marshmallow.
5. Release the plunger and observe what happens to the marshmallow.
6. Remove the cap from the syringe and replace the marshmallow with a new one.
7. Set the plunger at 60 ml and replace the cap on the syringe.
8. Push the plunger down to reduce the volume inside the syringe and hold. Be careful NOT to crush the marshmallow with the plunger. Observe any changes that occur in the marshmallow.
9. Release the plunger and observe what happens to the marshmallow.

B: Can Crush

Teacher Note: This should be performed as a whole-class demonstration rather than having students perform the activity.

Materials:

- Aluminum soda can (1 per group)
- Hot plate
- Beaker tongs or barbecue tongs
- Water
- Ice
- Large bowl or plastic bin (4 qt. or so)
- Safety goggles

Cautions:
1. Do not boil the can dry!
2. Do not touch the aluminum can with your hands while it is on the stove. It is very hot.
3. Be careful not to spill or splash any of the boiling water in the can as you invert it

Procedure:

1.Fill the bowl or bin approximately half-way with cold water. Add a cup of ice.

2. Place approximately 30mL of water in an empty aluminum soda can.

3. Heat the can of water on the hot plate on medium until visible steam escapes from the can for a period of about 5-10 seconds.

4. With the tongs, grab the can and invert it into the pan of ice water so the opening in the can is under water.

C. Condiment Cartesian Diver

Teacher Note: This station may be more effective if set up ahead of time by the teacher so that the students will have the time to explore and develop a model on how the diver works.

Materials:

- Cup
- Water
- Several squeeze-condiment packets such as soy sauce, ketchup, mustard, etc.
- Clear plastic bottle with screw-on cap, 1L or 2L will work (be sure to remove labels)
- Tweezers/forceps (used to remove the packet from the bottle).

Set up:

1. Fill a cup with water and drop in the unopened condiment packets, one by one. The ideal packets to use in this activity will just barely float in the water.
2. Fill an empty, clear plastic bottle to the very top with water. Put the unopened condiment packet that works the best into the plastic bottle and screw on the cap. (the packet should respond to gently squeezing and releasing the side of the plastic bottle.

Procedures:
Gently squeeze the plastic bottle. Observe how the packet responds.

- For model bear in mind that the condiment packet is a sealed system with an air bubble inside.

D. Confounding Candle
Materials:
- tall glass, cup, or beaker
- tea-light candle (a birthday candle will work also, just use a little clay to make it stand upright)
- Matches or lighter
- Baking soda
- Vinegar
- Safety goggles

**This experiment involves the use (briefly) of fire. Please exercise caution, wearing safety goggles at all times, avoiding loose clothing, and tying back long hair.

Procedures:

1. Place baking soda in the bottom of your cup/beaker – use just enough to cover the bottom of your cup.
2. Add approximately 30mL (2 tablespoons) of vinegar to your cup.
3. While the baking soda and vinegar are doing their thing, set the candle on the table.

4. Once the contents of the cup stop fizzing, *gently* swirl the remaining liquid a few times to make sure the reaction is complete.
5. Light the candle.
6. Imagining that the cup was full of liquid, slowly pour a small amount of the ‘imaginary liquid’ onto the candle. DO NOT pour our any of the real liquid in the bottom of the cup.
7. Observe what happens.

E. Shifty Syringe

**Teacher Note:* An extension of this activity could involve attempting to extrapolate back to zero volume and “absolute zero”. For this activity, it may be more meaningful for the temperatures to be left in Celsius. Additional temperature/volume readings (4-5 total) are needed to generate a better line graph so a linear equation (y=mx + b) can be determined. A salt-ice bath could be used to produce an additional colder temperature. When volume is plotted on the y-axis and temperature on the x-axis, the x value at y=0 will approximate ‘absolute zero”

Materials:

- 60mL syringe with Luer lock tip
- Luer lock syringe cap
- Safety goggles
- 2 beakers
- Thermometer
- Water
- Hotplate
- Ice

Procedures:

1. Wear safety goggles at all times.
2. Fill a beaker about 2/3rds with cold water and add some ice.
3. Fill a beaker about 2/3rds with water. Set the beaker on the hot plate. Set the hot plate to medium.
4. Obtain a syringe, remove the cap at the end and set the volume to be about 30mL. Replace the cap for the duration of the lab in order to keep the number of air molecules constant.
5. Gently pull up on the plunger and release it to settle at equilibrium. Record the volume of the syringe.
6. Use the thermometer to record the temperature of the room.
7. Place the thermometer in the cold-water bath.
8. Put the syringe in the cold-water bath such that the trapped air remains submerged for about 2 minutes.
9. Gently pull up on the plunger and release it to settle at equilibrium. Record the volume of the syringe.
10. Measure the temperature of the ice water.
11. Place the thermometer in the cold-water bath. Ideally the hot water bath temperature should be in the 40-60^{o}C range. Adjust the temperature of the hot plate until the temperature of the water-bath stabilizes.
12. Immerse the syringe in the boiling water completely covering the gas for about 2 minutes.
13. Gently pull up on the plunger and release it to settle at equilibrium. Record the volume of the syringe.
14. Measure the temperature of the hot water.
15. Convert your temperatures to Kelvin.

Return to Instructional Segment

Gas Laws Student Sheet

Name_____________________________

INITIAL EXPLORATION

1) Read through the instructions for this activity. What two variables, related to gases, will you be examining?

2) Which of these two variables is the independent variable? Which is the dependent variable?

3) Predict what you think the graph of your data will look like. Recall that dependent variables go on the y-axis and independent variables are placed on the x-axis.

4) For the force that you apply to the syringe, rank these from 1-4, with 4 being the most force and 1 being the least. Place your final results in the data table below.

Data Table

Volume	Relative Force Applied
40mL	
30mL	
20mL	
10mL	

5) Examine your data. Would you describe the relationship between volume and force as *direct* or *inverse*? (use the CER model to answer this). *If you are not sure about these two terms, discuss with another group or investigate them in your text or online.*

6) Produce a graph of your data on the chart paper or white board. How does your actual graph compare to your predicted graph? Identify at least 3 similarities or differences between your graphs.

7) Re-examine your data and the graphs that the other groups produced. Would you describe the relationship between volume and the force you exerted as *direct* or *inverse*? (use the CER model to answer this).

STATIONS

Marshmallow Mash

1) Read through the instructions for this activity. What two variables, related to gases, will you be examining?

2) What did you observe happening to the marshmallow when you pulled out on the plunger?

3) In the boxes below draw a before and after picture of the marshmallow.

Before	**After**

4) If you could zoom in and see a marshmallow under a powerful microscope, it would look like a sponge: lots of tiny bubbles of air. Using the CER model, describe what happened to the particles inside the marshmallow that explains the changes you observed inside the syringe. Use the space below to make a new drawing showing the microscopic bubbles.

5) What did you observe happening to the marshmallow when you pushed in the plunger?

6) In the boxes below draw a before and after picture of the marshmallow.

Before	**After**

7) Re-examine your answer to questions 4. Does your explanation work for your new observations? Using the CER model, make revisions to your explanation OR re-enforce your previous explanation with the new data.

Can Crush

1) Read through the instructions for this activity. Predict what you think will happen with the can when you complete step 4.

2) What gas replaces the air while the water is boiling?

3) What is the chemical formula for the gas in question #2?

4) When you cool a gas, what happens to the particle of that gas? Using the CER model, explain what effect might this change have to the pressure exerted by the gas?

5) Construct an explanation for why the amount of water coming out of the can at the end of the experiment match the amount that you placed in the can initially (think about where the extra water might have come from).

Condiment Cartesian Diver

1) Read through the instructions for this activity. Predict what you think will happen with the condiment packet when you squeeze the bottle.

2) Based on prior experiments and experiences, are liquids like water compressible? Describe your experiment or experience that led you to your answer.

3) How do objects that are a different density than water behave when placed in water?

4) Based on the behavior of the condiment packet, what do you think is happening to the condiment packet when you squeeze and release the bottle (Use the CER model to answer this question).

5) Given that the formula for density is $\frac{mass}{volume}$, re-evaluate your previous explanation. Does this knowledge change your previous explanation?

6) If the system (bottle, water, and condiment packet) is sealed, is it possible for you to alter either the mass or the volume?

7) Examining the condiment packets, is the condiment (ketchup, soy sauce, mustard, etc) the only thing in each packet?

8) Using the answers to last few questions, apply the CER model to modify (if necessary) or re-enforce your previous explanation (from question 5) about the behavior of the condiment packet when you squeeze and release the bottle.

Confounding Candle

1) When the baking soda and vinegar interacted, what type of process took place – chemical or physical? Be sure to include your pieces of evidence to support your answer.

2) What were you pouring out of the cup? Use the CER model to support your answer.

3) Using the mass number from the periodic table, calculate the molar mass of N_2 (the primary gas in the atmosphere)

4) Using the mass numbers from the periodic table, calculate the molar mass of CO_2.

5) Using the information from questions 3 & 4, would it be possible to pour CO_2 from the glass onto the candle?

Shifty Syringe

1) Read through the instructions for this activity. What two variables, related to gases, will you be examining?

2) Which of these two variables is the independent variable? Which is the dependent variable?

3) Predict what you think the graph of your data will look like. Recall that dependent variables go on the y-axis and independent variables are placed on the x-axis.

4) Fill in the data table below. Be sure to convert your Celsius temperatures to Kelvin. You may not need to use all of the rows

Data Table

Temperature (°C)	Temperature (K)	Volume (mL)

5) Examine your data. Would you describe the relationship between volume and temperature as *direct* or *inverse*? (use the CER model to answer this). *If you are not sure about these two terms, discuss with another group or investigate them in your text or online*.

6) Produce a graph of your data on the chart paper or white board. How does your actual graph compare to your predicted graph? Identify at least 3 similarities or differences between your graphs.

7) Re-examine your data and the graphs that the other groups produced. Would you describe the relationship between volume and temperature as *direct* or *inverse*? (use the CER model to answer this).

Return to Instructional Segment

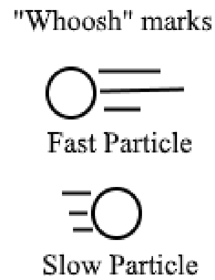
Packing Particles

Purpose:

To examine the way matter behaves, particularly as it is compressed, and develop particle models that attempt to explain this behavior.

Materials:

Goggles
60-mL syringe (preferably with Luer lock tip)
Luer lock cap for syringe
Air
Water
A small rock that will fit inside the syringe



Procedures:

Part I:

1. In previous courses you have learned that matter is composed of tiny particles that move.
2. In the spaces on the lab sheet, please draw a diagram of how you visualize the three states of matter (solid, liquid, gas), at the particle level. USE PENCIL FOR THIS DRAWING.
3. Your drawing should take into account the relative spacing between the particles (how close or far apart they generally are) and the type and speed of motion (use "whoosh" marks on the particles to show motion.
4. Your drawing must include at least 10 particles, but you do not have to fill the box.

Part II:

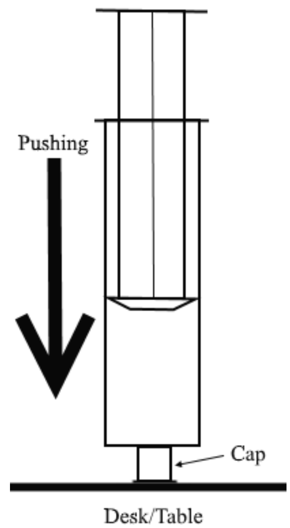
1. In the boxes to the right of your diagram, write a few bullet points explaining WHY you drew your model the way it is. Use the Claim, Evidence, Reasoning framework to help with your response.
2. Compare your models/drawings to those of a person sitting nearby. Discuss with this partner how your models are similar and/or different.
3. In the space provided, write a bullet point or two that summarizes your comparisons.

Part III:

A. Solids

1. Obtain a syringe, a cap, and the small rock you are using for a solid.
2. Remove the plunger from the syringe and place the rock inside the syringe cylinder
3. Put the plunger back in the syringe and GENTLY press down until the plunger is barely touching the rock.
4. Place the cap on the end of the syringe and set the syringe down.
5. In a moment you will attempt to compress the rock using the syringe. On the back of your lab sheet, in the space provided, make a prediction about what you think will happen when you attempt to compress the rock. Your prediction must reference your model/diagram on the front as a piece of evidence for your prediction/claim.

6. ***Put on your goggles.***
7. Pick up the syringe and point the capped end toward the desktop/table
8. Put the cap against the table so that when you attempt to compress, the cap cannot shoot off the syringe.
9. Press down on the plunger, holding the syringe upright against the table/desk, and attempt to compress the rock. DO NOT PRESS SO HARD THAT YOU BEND OR BREAK THE PLASTIC.
10. After a few seconds, put the syringe down on the table.
11. Record the outcome of your experiment on the lab sheet. If your prediction and the observed outcome do NOT match, you must offer an explanation for why the differences might have occurred – you may need to reference your model/diagram for this.



B. Gases - In a moment you will attempt the same experiment using a gas: your will attempt to compress air.

1. On the back of your lab sheet, in the space provided, make a prediction about what you think will happen when you attempt to compress air. Your prediction must reference your model/diagram on the front as a piece of evidence for your prediction/claim.
2. **Make sure you are wearing your goggles.**
3. Pick up the syringe and take the cap off the end.
4. Pull the plunger out and remove the rock from the syringe. Set the rock aside.
5. Put the plunger back in the syringe.
6. Set the plunger at 30mL.
7. Put the cap back on the syringe.
8. Put the cap against the table so that when you attempt to compress, the cap cannot shoot off the syringe.
9. Press down on the plunger, holding the syringe upright against the table/desk, and attempt to compress the air. DO NOT PRESS SO HARD THAT YOU BEND OR BREAK THE PLASTIC.
10. After a few seconds, put the syringe down on the table.
11. Record the outcome of your experiment on the lab sheet. If your prediction and the observed outcome do NOT match, you must offer an explanation for why the differences might have occurred – you may need to reference your model/diagram for this.

C. Liquids - In a moment you will attempt the same experiment using a liquid: your will attempt to compress water.

1. On the back of your lab sheet, in the space provided, make a prediction about what you think will happen when you attempt to compress water. Your prediction must reference your model/diagram on the front as a piece of evidence for your prediction/claim.
2. Pick up the syringe and take the cap off the end.
3. Pull the plunger out.
4. Place the cap back on the syringe and add approximately 30mL of water.
5. Put the plunger back in the syringe – be sure the rubber tip has formed a seal so that the water will not leak out.
6. Turn the syringe so that the cap is pointing upward.

7. Remove the cap and gently push the plunger upward to remove the air from the syringe. You will know that air is out when there are no more bubbles in the syringe AND you get a small bit of water squirting out the tip.
8. Place the cap back on the syringe.
9. Put the cap against the table so that when you attempt to compress, the cap cannot shoot off the syringe.
10. Press down on the plunger, holding the syringe upright against the table/desk, and attempt to compress the water. DO NOT PRESS SO HARD THAT YOU BEND OR BREAK THE PLASTIC.
11. After a few seconds, put pull the plunger out of the syringe and dump the water into a sink or back into the cup.
12. Return the plunger, cap, and syringe cylinder to your teacher, leaving the parts separate so they can dry.
13. Record the outcome of your experiment on the lab sheet. If your prediction and the observed outcome do NOT match, you must offer an explanation for why the differences might have occurred – you may need to reference your model/diagram for this.

D. Conclusions

On a separate sheet of paper, summarize your conclusions for the activity. Your conclusion should be written in complete sentences. Your conclusion should include:

- Any differences between your predictions and the outcomes of the experiments.
- Any modifications or improvements that you believe you should make to your models to better match the experimental data (this may include a new drawing).
- An assessment of whether your three models (include a newer version if you designed one) can explain other observed physical behaviors of the three states of matter:

	Solids	Liquids	Gases
Shape	Fixed	Varies according to container	Varies according to container
Volume	Fixed	Fixed	Varies according to container

Student Sheet: Packing Particles

Solid	Why I Drew This Model: Comparison:

Liquid	Why I Drew This Model: Comparison:

Gas	Why I Drew This Model: Comparison:

Solid

Prediction:

Outcome:

Liquid

Prediction:

Outcome:

Gas

Prediction:

Outcome:

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Packing Particles Teacher Notes

Standard: SPS5. Obtain, evaluate, and communicate information to compare and contrast the phases of matter as they relate to atomic and molecular motion.
a. Ask questions to compare and contrast models depicting the particle arrangement and motion in solids, liquids, gases, and plasmas.

It is essential that safety protocols be followed. Students MUST wear eye protection and the syringes MUST be compressed against the desk/table top. The caps can fly off at high velocity if the syringes caps are not placed against the table.

60mL syringes are sold by most science supply companies or other major online retailers, often for around a dollar each. The recommended Luer lock tips and caps are best because the cap has a flat bottom to it and is easier to hold against the desktop.

In some cases (e.g.; due to time constraints) the compression of the solid phase can be done as a “thought experiment” or the teacher can perform this portion as a demonstration. The students are typically comfortable with the incompressibility of solids.

Many students come to high school science class with preconceptions about the particle nature of matter. In most cases, the student models indicate the following:

- Gas particles have the highest kinetic energy (speeds) and are free to move the most of the three states. The particles are relatively far apart.
- Solid particles are packed close together and have the lowest kinetic energy of the three states. The have very little motion and are typically drawn touching each other.
- Liquids are thought of by many students as the “in between” state: they have more kinetic energy than solids, but less than gas particles. The students often draw these particles as being closer than gas particles, but not touching like solid particles.

The students’ experimental evidence generally supports their models for solids and gases: the gases are compressible because of the spacing between the particles, solids are not compressible for the same reason.

The experimental evidence for liquids will not match the aforementioned properties: the liquid will not compress. Based on the most common student model, liquids should compress more than solids but less than a gas. Students will sometimes try to create evidence (our water did compress a little!) to match their expectations.

At the end of the last writing prompt is the time to engage in a class discussion.

Prompt:

In science, if the evidence does not support the model, what must happen next?

It is important, both for the standard and to help students understand the nature of science, that the students correct (if necessary) their model of the particles in matter to better accommodate the experimental evidence.

A better model of liquid particles might be a bag of marbles. The particles are touching each other (no spacing) but are have freedom to move relative to each other. This model also better explains why liquids take the shape of their container but have a constant volume.

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Sample C-E-R Sheet

<table>
<tr><td colspan="4">What caused the chip bag to explode?</td></tr>
<tr><td>Initial Claim:</td><td colspan="3">The chip bag exploded due to ____</td></tr>
<tr><td>Initial Reasoning</td><td colspan="3">1.____
2.____
3.____</td></tr>
<tr><td>Revised Claim after Investigation</td><td colspan="3"></td></tr>
<tr><td rowspan="4">Supporting Evidence from Investigation</td><td>1.</td><td rowspan="4">Reasoning</td><td>1.</td></tr>
<tr><td>2.</td><td>2.</td></tr>
<tr><td>3.</td><td>3.</td></tr>
<tr><td>4.</td><td>4.</td></tr>
</table>

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Stability and Change in Reactions GSE: **SPS5a,b; SPS7a**			
Anchoring Phenomenon: Cars and rockets are powered by chemical reactions.			
Topic	**Focus**	**Lesson Phenomenon**	**GSE/Notes/Language**
Atomic and Molecular Motion	• Review of the states of matter • Identify student misconceptions of states of matter based upon previous definitions not involving molecular motion. • Students design and make models showing the molecular movement in the different states of matter. • Students use understanding from previous unit of subatomic particles to help explain plasma particle movement. • Phases of matter are states that have similar properties. • Changes in energy of a system may result in a change of phase. • Temperature and pressure have an effect on the phase of a substance and this can be shown in a phase diagram for pure substances.	*The Northern Lights* The Northern Lights (aka Aurora) are created when charged particles interact with the Earth's magnetic field. *Plasma* Introduces plasma and discuss an everyday use: plasma TVs CK-12: Plasma	SPS5a. Ask questions to compare and contrast models depicting the particle arrangement and motion in solids, liquids, gases, and plasmas.
Behavior of Gases	• Using knowledge of particle movement defining gases help students elicit an	*Exploding Chip Bag* A family on a trip west travels through areas of	SPS5b. Plan and carry out investigations to identify the relationships among temperature, pressure, volume, and density of gases

	understanding of the effect of temperature on gases. (Ask students to predict what would happen to gas in a closed container if heated.) • Understanding basics of gas laws without formulas. (will state what happens to volume in response to temperature and pressure changes) • Understanding of density of gas should be related to mass remaining steady and volume changing in relation to temperature and pressure. • Using a simple demonstration with an Erlenmeyer flask and balloon on a hot plate can help demonstrate temperature and volume.	high altitude (lower atmospheric pressures) and notices that the potato chip bags they brought with them expand until finally, while crossing the Bear Tooth Pass (10,000ft.), one of the chip bags explodes. The decreasing atmospheric pressure causes the volume of air in the bag (closed system) to increase leading to the explosion.	in closed systems. (Clarification statement: Using specific Gas laws to perform calculations is beyond the scope of this standard; emphasis should focus on the conceptual understanding of the behavior of gases rather than calculations.) Equations Density *Teacher note-This topic should tie strongly to SPS5a. as the underlying understanding of particle arrangement in gases is essential to understanding the behavior of gases in a closed system.*

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