SCIENCE DETECTIVE'S NOTEBOOK

DIFFUSION

KMT

GAS LAWS

PHASE CHANGE

Produced by:

Molecules & Minds
Simulations for Chemistry Learning

Create
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NYU Steinhardt
Steinhardt School of Culture, Education, and Human Development

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SCIENCE DETECTIVE'S NOTEBOOK #1:

DIFFUSION

ENTRY 1: MAKE OBSERVATIONS AND PROPOSE A HYPOTHESIS

"The Case of the Punk and the Popcorn"

Entry 1A: Gaby could still smell the popcorn an hour after Tac made it. Suggest an explanation for this observation.

(An *explanation* can also be called a *hypothesis*)

ENTRY 2: EXPLORE A MODEL TO TEST YOUR HYPOTHESIS

- You will use a computer simulation to learn more about how Gaby could tell that Tac made the popcorn she had been saving.
- A simulation is a computer model that helps you understand how something works.
- Watch the *TUTORIAL* about how to use the *diffusion simulation*.
- After you have completed the tutorial, go ahead and make the following entries:

Entry 2A: According to the tutorial, the two *variables* that affect diffusion are:

______________________ and _________________________

Entry 2B: What can you learn about diffusion using this simulation?

____

____

Entry 2C: The temperature scale used in this model is called

____

Entry 2D: What units are used to measure the mass of atoms?

____

Entry 2E: The two gases that you can inject into the chamber are:

________________________ and _______________________

Entry 2F: Which gas is heavier? _________________

ENTRY 3: COLLECT YOUR DATA

Start exploring!

- Select a gas
- Choose a temperature
- Inject the gas into the diffusion chamber

Entry 3A: Observe what's happening

Describe how the particles move in the container.

Entry 3B: Collect your data: Gas #1

- Complete the table by running three separate tests before changing the temperature.
- Calculate the averages of your results for each temperature

Gas #1: ______________________________

Temperature: (K)	Trial 1: (seconds)	Trial 2: (seconds)	Trial 3: (seconds)	Average Time (seconds)
250				
500				

Entry 3C: Collect your data: Gas #2

- Repeat the process for the second gas

Gas #2: ______________________________

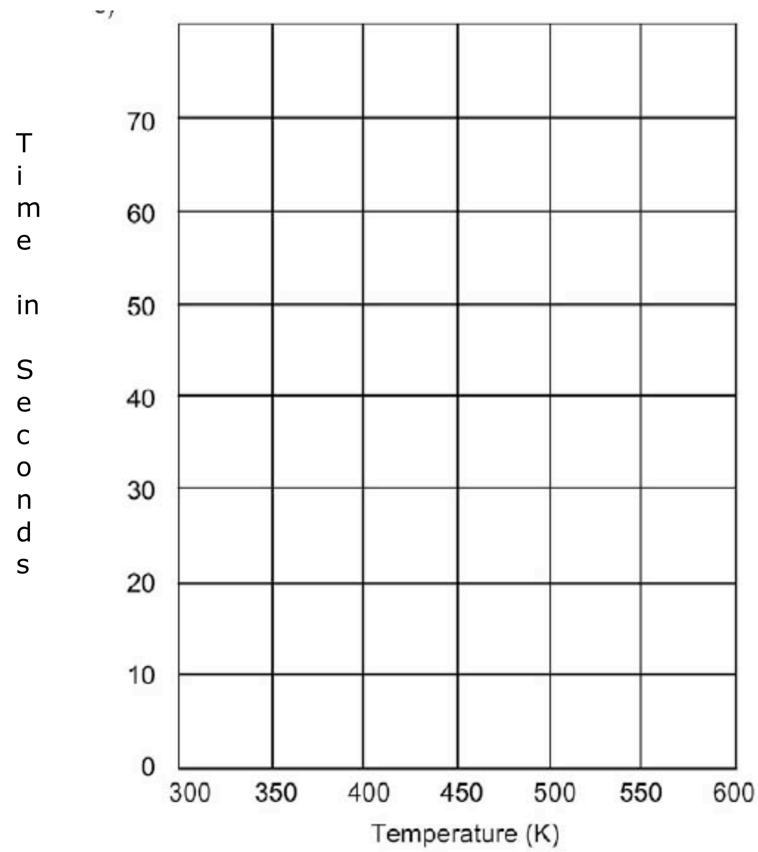
Temperature: (K)	Trial 1: (seconds)	Trial 2: (seconds)	Trial 3: (seconds)	Average Time (seconds)
250				
500				

Entry 3D: Complete the graph using the averages you calculated in the tables for Entries 3B and 3C.

Use the following symbols to plot your averages:

● Gas 1 ____________

▲ Gas 2 ____________



Entry 3E: Explain why it is useful to test a second gas.

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Entry 3F: Explain why it is useful to test several temperatures.

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Now we can use our data to answer two main questions:

Entry 3G:

Main Question #1: What role does temperature play in diffusion?

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Entry 3H:

Main Question #2: How does the mass of a gas affect the rate of diffusion?

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Entry 3I:

If you injected a gas made up of particles (molecules) with an amu of 20, where would you predict the average rate of detection would fall? Add your prediction to your graph in Entry 3D using a ■ for these plot points.

ENTRY 4: SYNTHESIZE WHAT YOU LEARNED

Apply your understanding to "The Case of the Punk and the Popcorn."

Entry 4A: How is Gaby and Tac's apartment like the gas container in the simulation?

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____

____

Entry 4B: How is the popcorn smell that Gaby detected like the atoms you injected into the gas container?

____

____

____

Entry 4C: How is the air in the apartment like the neon gas in the gas container?

____

____

____

ENTRY 5: GENERALIZE CONCLUSIONS

Entry 5A: A Claim

Circle one:

When molecules are injected into the container at a specific temperature, each molecule will take (**the same / a different**) amount of time to reach the detector.

Entry 5B: Evidence

What evidence did you find by using the simulation that allows you to make the claim in Entry 5A?

____

____

____

____

Entry 5C:

As the temperature increased, it took the molecules (**less / more**) time to reach the detector.

Entry 5D:

As the temperature increased, the gas molecules moved (**faster / slower**).

Entry 5E:

As the mass of the gas increased, it took the molecules (**less / more**) time to reach the detector.

Entry 5F:

As the mass of the gas increased, the gas particles moved (**faster / slower**).

Entry 5G:

Kinetic energy is energy due to motion. Why can we say that temperature is a measure of the average kinetic energy of the molecules?

____

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ENTRY 6: SOMETHING EXTRA – CONDUCT RESEARCH!

Entry 6A:

As you were exploring diffusion with the simulation, you may have thought that diffusion was the only concept involved in the motion of gas molecules. Actually, there is another concept called ***convection*** that is often more important for the movement of smells and other molecules. Find out how *diffusion* and *convection* are different at the molecular level.

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DIFFUSION LAB NOTEBOOK

ENTRY 1: DO IT NOW!

Use your experience with the diffusion simulation to answer the following questions.

Entry 1A:
What 3 gases were in the diffusion simulation?

Entry 1B:
Which gas was already in the container before you injected the other gas?

Entry 1C:
Which gas moved the fastest?

Entry 1D:

Why did that gas move faster than the others?

Entry 1E:

What is your definition of diffusion?

ENTRY 2: DISCUSSION QUESTIONS

Entry 2A:
How many of these concepts did your definition include?

1. Diffusion describes how particles of one gas or liquid spread through another gas or liquid
2. Diffusion depends on the mass (or size) of the particles and the temperature
3. Smaller particles travel more quickly than bigger particles
4. The colder the temperature, the more slowly the particles travel

Entry 2B: How is the diffusion we studied similar and different from the diffusion we learned about in living environment (biology)?

Entry 2C: How come each gas didn't always take the same amount of time to reach the detector?

Entry 2D: So what might we predict about the rate of Argon when compared with the rate of Helium?

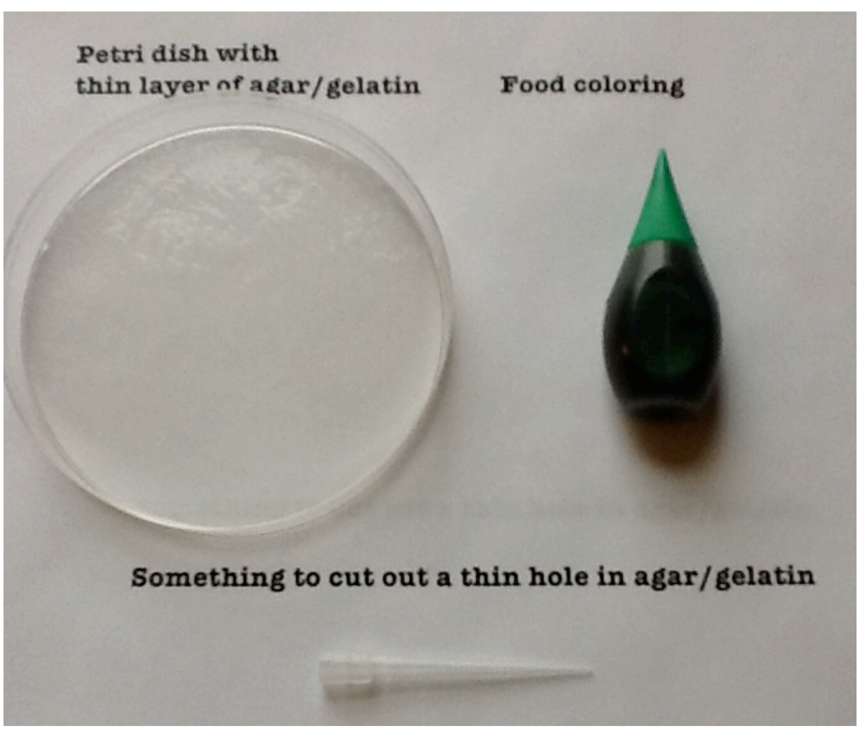
Entry 2E: How do the results you recorded from the simulation compare with your prediction?

ENTRY 3: LAB/DEMO

How do we know if the simulation is a good model?

You see diffusion every day but perhaps not in the same form as the gases you studied in the simulation. In this demonstration/lab you can observe diffusion in a different state of matter.

Demonstration/Lab: Agar and Food Coloring



Entry 3A: *Predict* what will happen if we cut a hole in the middle of the agar/gelatin and put a drop of food coloring in it.

____

____

____

Entry 3B: *Confidence*

What did you learn from the simulation that makes you confident about your prediction?

____

____

____

Entry 3C: *Collect* your equipment:

- A Petri dish with agar/gelatin
- A pipette tip or cork borer or something that can be used to make a small hole in the agar
- Food coloring.

Entry 3D: *Perform* your experiment:

- Remove a small circle of agar from the center of the plate using the cork borer
- Place a small drop of food coloring in the circle.

Entry 3E: *Observe* the rate of diffusion

Entry 3G: *Explain* your observations using the principles of diffusion.

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ENTRY 4: EXTENSION ACTIVITIES

Entry 4A:

- Write a story or a comic strip.
- Pretend that you are a gas particle that has been injected into a closed box. Describe your thoughts as a particle inside this box.
- Incorporate the following concepts/terms/facts into your narrative:
    1. Straight, random motion
    2. Elastic collisions
    3. Attraction toward other gas particles
    4. Your speed compared to other particles
    5. Your mass/size
    6. What happens when the temperature increases?

Your story needs to be at least 1 page long; if you choose to do a comic strip, it needs to be 15-20 frames long! Use the next few pages for this activity.

Entry 4A:

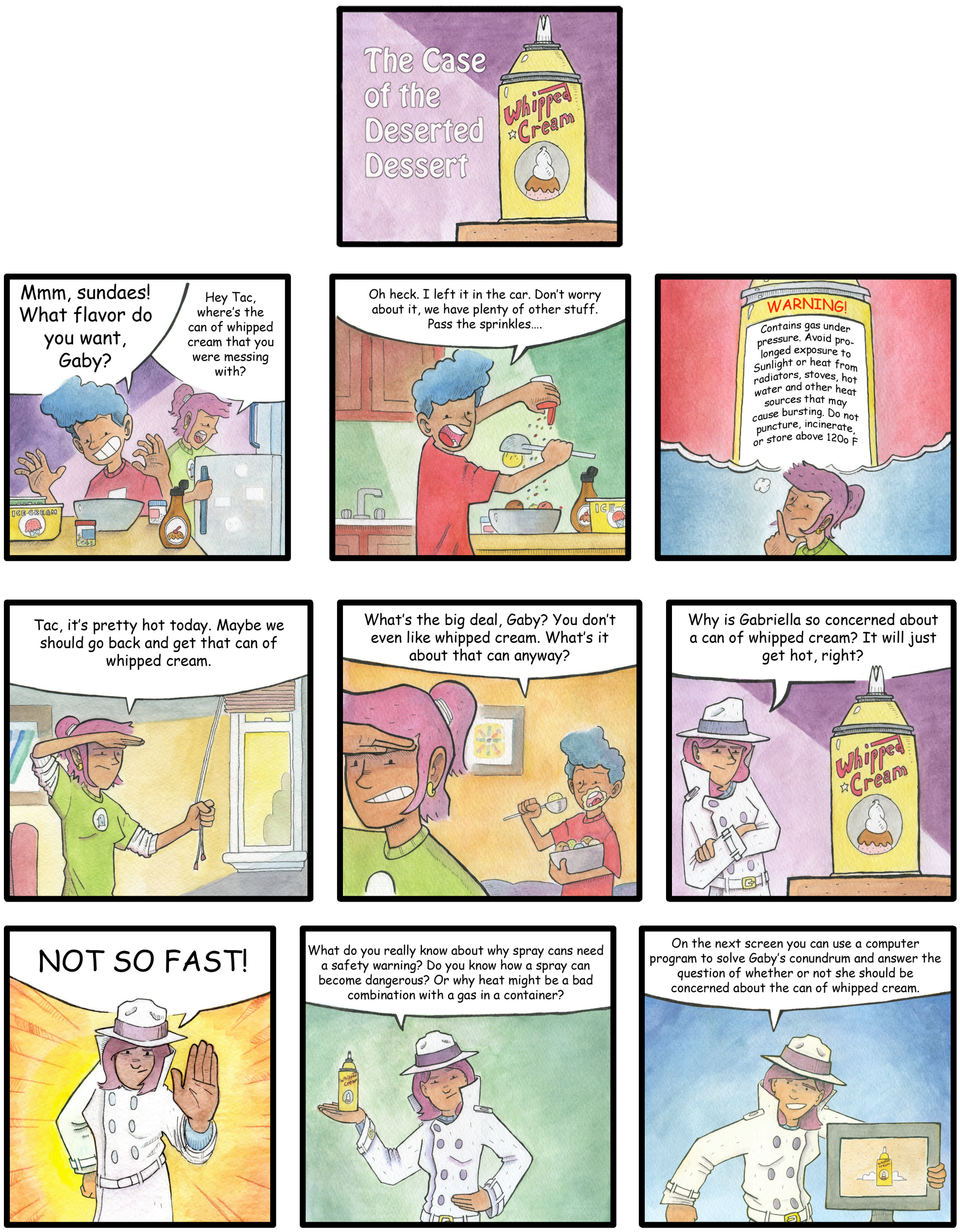
Entry 4A:

SCIENCE DETECTIVE'S NOTEBOOK #2:

KINETIC MOLECULAR THEORY

MAKE OBSERVATIONS AND PROPOSE A HYPOTHESIS

The Case of the Deserted Dessert



Entry 1A: Gaby was worried about the can of whipped cream Tac had left in the car. At what temperature could the can become dangerous?

Entry 1B: Use clues (observations) from the story to propose what conditions outside might allow the can to reach such a temperature.

Entry 1C: Using information from this case, hypothesize why Gaby was concerned about Tac leaving the can of whipped cream in the hot car.

ENTRY 2: EXPLORE LANGUAGE

Here is some information that can help you understand KMT:

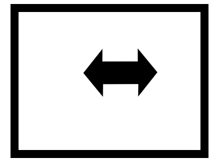
Theory: an accepted statement that explains why observations are the way they are. Theories can be used to make predictions and have been tested and reviewed many times.

Kinetic: KINETIC means *movement* in Greek. Kinetic energy has to do with things moving and is stored in objects.

Particles: All matter is made up of tiny particles we call atoms or *molecules*. KMT uses the movement of particles to explain things we observe in the world. For example, it can help us to understand *pressure*.

Pressure: The amount of force per area. If you are pushing against a wall, you are putting pressure on the wall.

Internal Pressure: The amount of pressure inside a container. Gas molecules inside a container collide with the walls of the container, exerting pressure.



External Pressure: The amount of pressure put on the outside of a container. If you sit on a box, you put pressure on the box. Atmospheric pressure is external pressure that presses down all over you.

Independent Variable: A variable you change (graphed on x-axis)

Dependent Variable: A variable that changes because of the independent variable (graphed on y-axis)

Atmosphere: This is a unit of pressure represented by 'atm'. In New York state, found on Table A in the reference tables.

Temperature: measure of the average kinetic energy of particles in a sample; measured in a scale such as Kelvin, Celsius, or Fahrenheit.

Kelvin: This is a unit of temperature that scientist use represented by 'K'. 298 K is about room temperature (= 25 degrees C). Found on reference tables [Table A and Table T].

ENTRY 3: EXPLORE A MODEL TO TEST YOUR HYPOTHESIS

Read the instructions for the Kinetic Molecular Theory simulation. What variables can you explore with this simulation? Complete the table:

Entry 3A:

	Variable	Unit of Measurement
1.		
2.		
3.		

Thinking about your hypothesis in Entry 1C, what are the two variables you need to test that hypothesis?

Entry 3B:
The two variables to explore are:

____________________ and ___________________ .

Entry 3C:
In order to test your hypothesis, which variable will be kept constant?

____

Entry 3D: Why can you only change one variable at a time?

____

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____

Before you use the simulation to test your hypothesis, carefully observe the behavior of the gas molecules in the container. Actual gas molecules are very small and cannot be observed directly but the simulation helps us to *visualize* the molecules.

Entry 3E: Click on the 'Trail' and 'Color' buttons and observe the one molecule closely. How would you describe its motion? Choose one:

a. circular

b. zig-zag

c. straight line

Entry 3F: What happens when paricles bump into each other?

____

____

Entry 3G: Watch one molecule until it collides with one of the walls of the container. Observe the movement of the molecule before and after the collision with the wall. Complete the table:

	Molecule motion before and after *colliding with the wall* of the container
Compare (How is molecule motion the same?)	
Contrast (How is molecule motion different?)	

Entry 3H: Describe how a molecule colliding with the wall of the container is different from a tennis ball hitting a wall.

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Entry 3I: Based on your observations of the simulations you've completed, write 3 rules about how gas molecules behave:

Rule 1:

____

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Rule 2:

____

____

Rule 3:

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____

Entry 3J: Explain why these rules are important.

ENTRY 4: COLLECT YOUR DATA

Look back at your hypothesis in Entry 1C. Now you will use the model to test your hypothesis by collecting data.

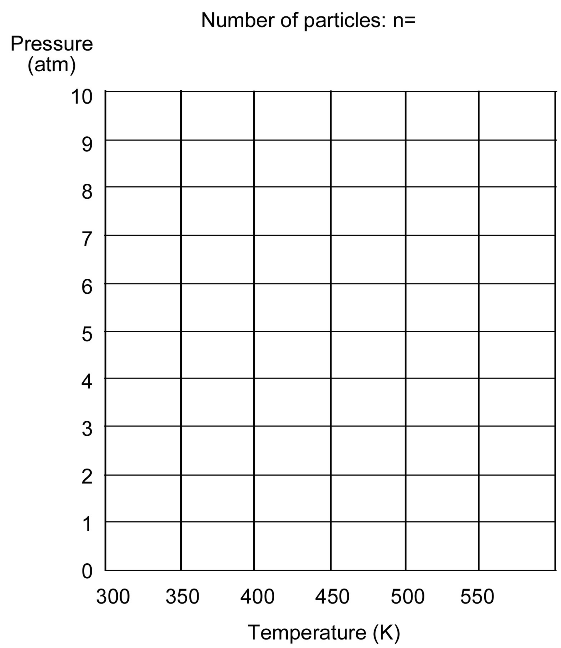
Entry 4A:

- Collect 10 data points
- This should only take a few minutes!
- Lock the number of particles at any number you want. Record that number here: ______.
- Record the temperature and the internal pressure on the table below

Temperature (Kelvin)	Internal Pressure (atmospheres)

Entry 4B:

Copy the graph you made onto this worksheet.



Entry 4C: Summarize the relationship between the two variables you explored. Was your hypothesis supported or not?

Entry 4D: Exploring another set of variables.

You just explored the effect of one variable on another. Write another question that you could investigate using the variables in this model.

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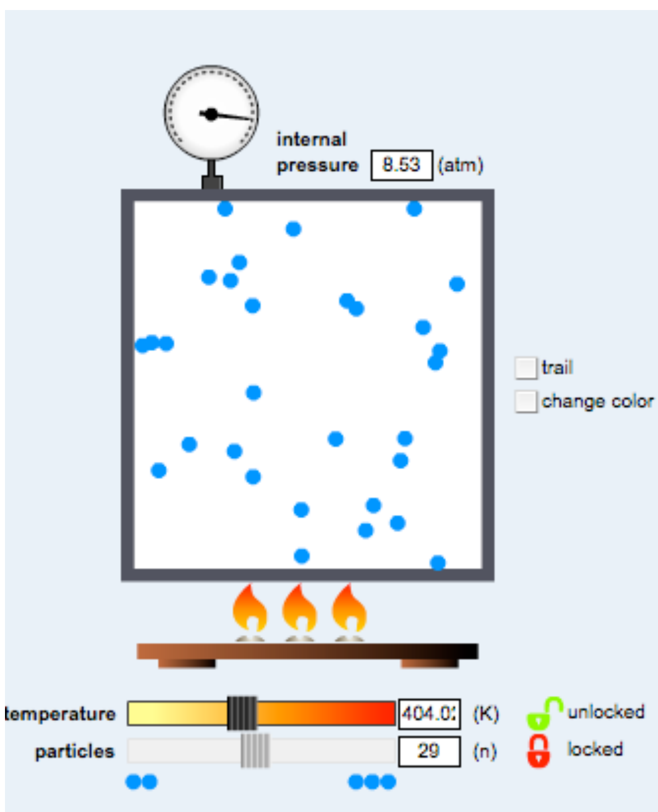


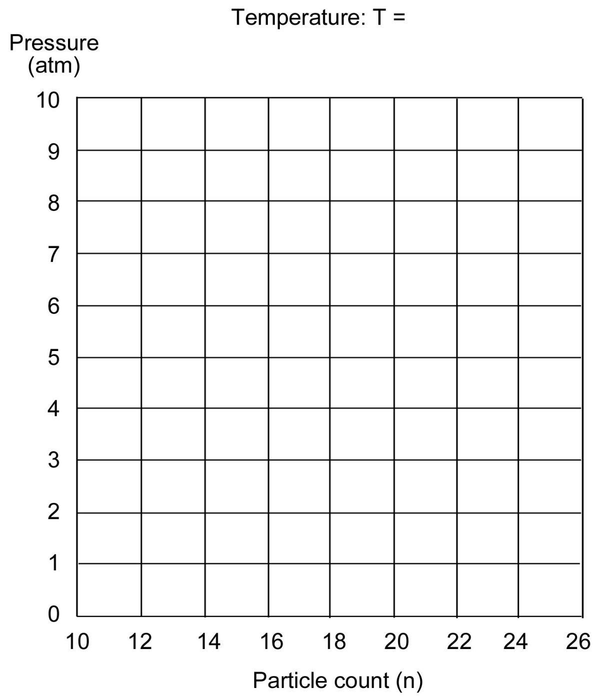
Entry 4E: Investigating a second hypothesis

- Collect 10 data points
- This should only take a few minutes!
- Lock the temperature at any value you want. Record that number here: ______ K.
- Record the number of particles and the internal pressure on the table below

Number of Particles (n)	Internal Pressure (atmospheres)

Entry 4F:

Copy the graph you made onto this worksheet.



Entry 4G: Summarize the relationship between the two variables you explored:

____

____

____

____

ENTRY 5: GENERALIZE CONCLUSIONS

Entry 5A:
When the temperature increases, the internal pressure

__________________________.
(increases/decreases)

Entry 5B:
This means the gas molecules pushed

_____________________ against the walls of the
(harder/softer)

container.

Entry 5C:
When the number of molecules in the container increases,

the internal pressure ___________________________.
(increases/decreases)

Entry 5D:

This is ________________________ relationship.
(a direct/an indirect)

ENTRY 6: SYNTHESIZE WHAT YOU LEARNED

Apply your understanding to "The Case of the Deserted Dessert."

Entry 6A: Compare and contrast the *spray can* in the story and the *container* in the model.

	The *spray can* in the story and the *container* in the model
Compare (How are they the same?)	
Contrast (How are they different?)	

Entry 6B: Compare and contrast the *particles* inside the spray can of whipped cream that Tac left in the car and the *moving particles* in the model?

	The *particles in the spray can* and the *moving particles in the model*
Compare (How are they the same?)	
Contrast (How are they different?)	

Entry 6C: Would Gaby have been as worried if the air temperature was lower? Why or why not?

____

____

____

ENTRY 7: SOMETHING EXTRA – CONDUCT RESEARCH!

Entry 7A: Think of another everyday example of particles inside a container that could be explained using Kinetic Molecular Theory.

KINETIC MOLECULAR THEORY LAB NOTEBOOK

ENTRY 1: DO IT NOW!

Kinetic Molecular Theory describes the behavior of gases. The variables involved are pressure, volume, temperature, number of molecules, and size of molecules.

Gases contain molecules that move randomly and in straight paths.

When gas molecules collide with each other or with the walls of a container they do not lose energy.

Gas particles spread out to fill whatever space is available.

Gas molecules are not attracted to each other.

Entry 1A: Compare and contrast the 3 rules you wrote about the behavior of gases [Science Detective Notebook Entry 3I] to the actual parts of Kinetic Molecular Theory presented above. What parts are different? What parts are the same?

____

____

____

____

Entry 1B: Do you think that all gases behave this way all of the time? Why or why not?

____

____

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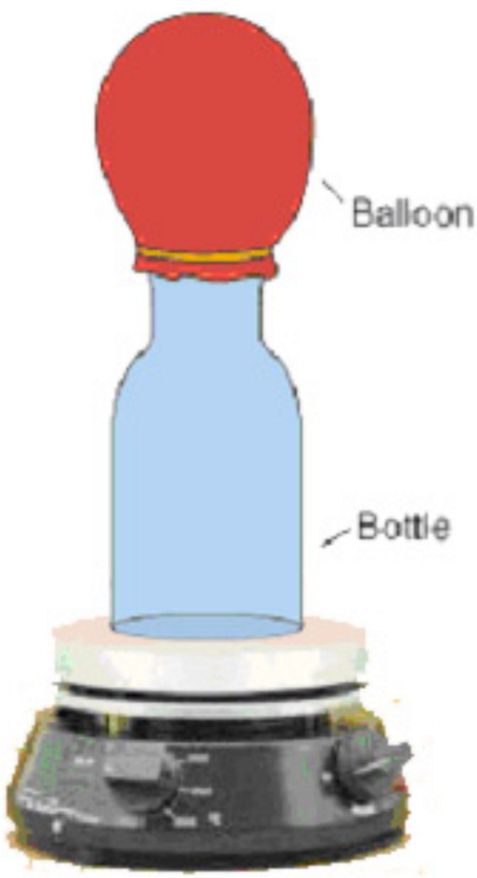
ENTRY 2: LAB/DEMO

How do we know if the simulation is a good model?

Demonstration/Lab*: Balloon and flask on hot plate*



Entry 2A: *Predict*
What do you predict will happen if we heat the air in a bottle with a balloon attached over the open top of the bottle?

____

____

____

Entry 2B: *Confidence*
What did you learn from the simulation that makes you confident about your prediction?

____

____

____

Entry 2C: *Collect* your equipment:

- Balloon
- Bottle
- Hotplate

Entry 2D: *Perform* your experiment

- Secure a balloon over the opening of a bottle
- Place the bottle on a hot plate
- Heat the bottle.

Entry 2E: *Observe* what happens

Entry 2F: *Explain* your observations using Kinetic Molecular Theory.

ENTRY 3: EXTENSION ACTIVITIES

Entry 3A:

A student investigated heat transfer using a bottle of water. The student placed the bottle in a room at 20.5 °C. The student measured the temperature of the water in the bottle at 7 a.m. and again at 3 p.m. The data from the investigation are shown in the table below.

Water Bottle Investigation Data

7 a.m.		3 p.m.	
Mass of Water (g)	Temperature (°C)	Mass of Water (g)	Temperature (°C)
800.	12.5	800.	20.5

Compare the average kinetic energy of the water molecules in the bottle at 7a.m. to the average kinetic energy of the water molecules in the bottle at 3 p.m.

___

___

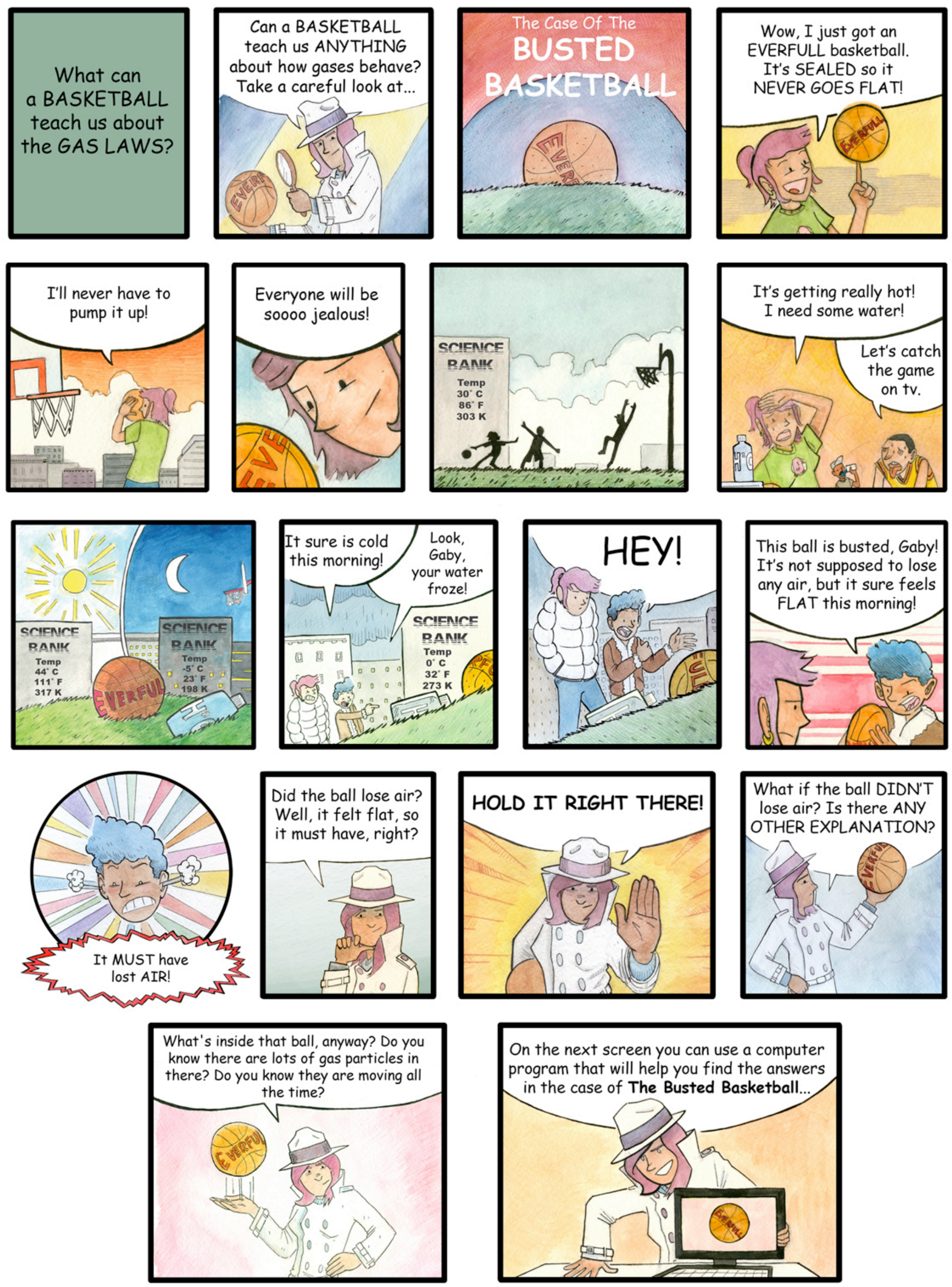
Entry 3B: Based on the simulations and the demonstrations from today, when is a gas most likely to behave ideally?

SCIENCE DETECTIVE'S NOTEBOOK #3:

GAS LAWS

ENTRY 1: MAKE OBSERVATIONS AND PROPOSE A HYPOTHESIS

The Case of the Busted Basketball



Entry 1A: One of the *variables* that is important in the story is the *pressure* of the basketball. Based on the story, what other variable is important?

____

Entry 1B: Which of these variables is the *independent* variable?

____

Entry 1C: Which of these variables is the dependent variable?

____

Entry 1D: Identify clues (observations) in the story that might explain how the ball could feel flat even if it did not lose air. Place all your observations in the table below.

Table 1: Laying out the clues	
Clue #1	
Clue #2	
Clue #3	
Clue #4	

Entry 1E: Using the observations you just identified, propose a hypothesis involving temperature and pressure for why the ball felt flat.

ENTRY 2: EXPLORE A MODEL TO TEST YOUR HYPOTHESIS

Use the GAS LAWS SIMULATION to test your hypothesis.

Entry 2A: Which temperature scale is used in this simulation?

____

Entry 2B: What three variables does this simulation allow you to investigate?
List them in the table below:

Table 2:	
Variable	Unit of measurement
1.	
2.	
3.	

Entry 2C: Use the simulation to test your hypothesis from Entry 1E.

- Create 10 plot points in the simulation and draw the graph below.
- Don't forget to label the X and Y-axes!

Entry 2D: Does the evidence from your exploration support your hypothesis? Why or why not?

ENTRY 3: MAKE GENERALIZATIONS TO GENERATE A LAW

Entry 3A: The relationship you just explored between two variables is a famous gas law. Note that when you were exploring the relationship between these two variables, the third variable in the gas law simulation was held constant.

Complete the table:

Independent Variable	Dependent Variable	Constant (didn't change)

Now, summarize what you have learned:

Entry 3B:

As the ________________________ increases, the
(independent variable)

______________________ ____________________________.
(dependent variable) *(increases or decreases)*

Entry 3C:

As the ________________________ decreases, the
(*independent variable*)

______________________ ____________________________.
(dependent variable) *(increases or decreases)*

Entry 3D: Using the terms *directly proportional* or *inversely proportional*, describe the general relationship between the two variables:

____

____

____

ENTRY 4: SYNTHESIZE WHAT YOU LEARNED

Apply your understanding to "The Case of the Busted Basketball"

Entry 4A: Compare and contrast the basketball in the story and the closed container in the simulation.

______

______

______

Entry 4B: Compare and contrast the air in Gaby's basketball and the gas in the simulation.

______

______

______

Entry 4C: The law you have explored is called *Amontons' Law*. How does it help you explain what happened to Gaby's basketball?

______

______

______

Guillaume Amontons (1633-1705) was a French physicist and scientific instrument inventor. He became deaf at an early age, perhaps through an infection. Although he did not go to university, he studied mathematics and the physical sciences at home.

His law relates pressure and temperature. One of the instruments he made was a thermometer, which used air instead of mercury. He realized that for people to study the effect of hot and cold, accurate thermometers were needed. He was able to show that the pressure of a gas increased by one third when the temperature went from cold to the boiling point of water.

He also suggested that if temperature could be made low enough pressure would disappear, so he seems to be the first person to think about the possibility of absolute zero.

Entry 5: Explore Another Gas Law: Boyle's Law

Entry 5A: Working with the gas laws simulation, choose to lock the temperature between 300K and 550K. Record that temperature:

____

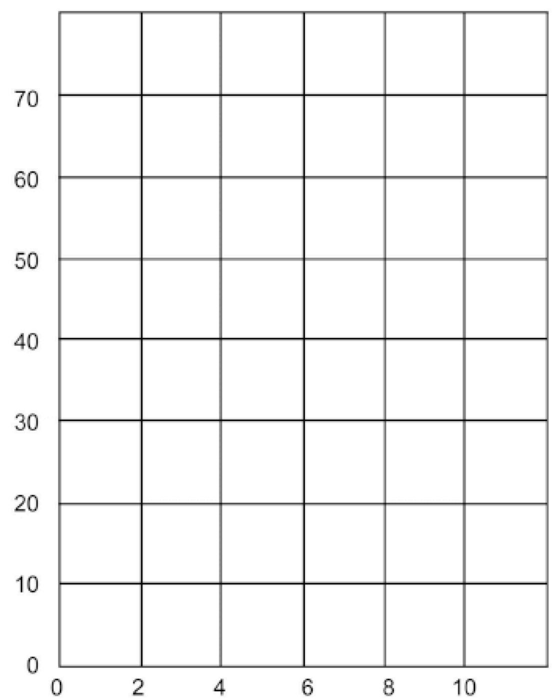
Entry 5A: Complete the table for this entry:

Independent Variable	Dependent Variable	Constant (doesn't change)

Entry 5B: Complete the following graph by varying the pressure.

- While you are collecting the data, record the data points on the graph
- You need to collect 10 data points

Label the axes and add a title!

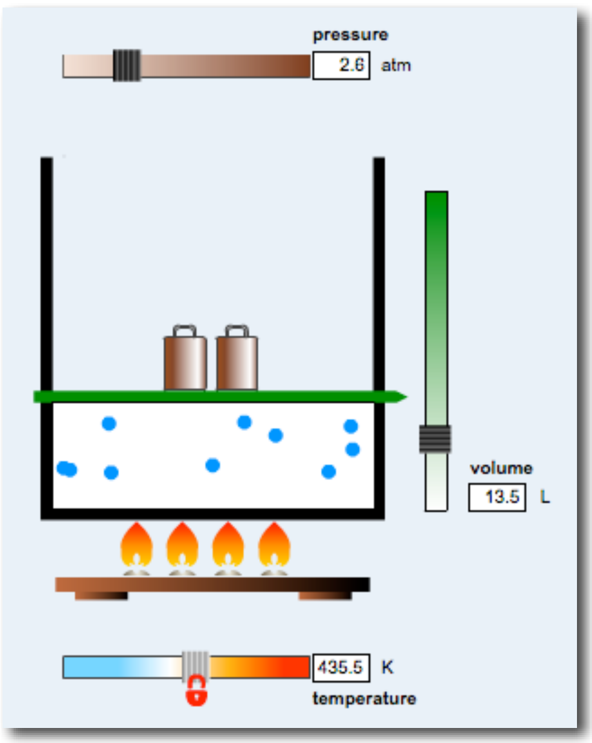


Entry 5C: How are *pressure* and *volume* related?

- As you increase the pressure, the volume

  ____

  (increases/decreases)



- As you decrease the pressure, the volume

  ____

  (increases/ decreases)

- This means that pressure and volume are

  ____

  (inversely proportional/ directly proportional)

Robert Boyle (1627-1691) published what would become known as "Boyle's Law" in 1662, describing the relationship between *pressure and volume* of a gas at a constant temperature remains within a closed system.

Many consider Boyle, who was born in Ireland, to be the first modern chemist. He is also considered a pioneer of scientific method and wrote about physics, philosophy, and theology.

ENTRY 6: EXPLORE ANOTHER GAS LAW: CHARLES' LAW

Entry 6A: Now that you have used the gas laws simulation several times, identify the variables that you have not explored yet:

Complete the table:

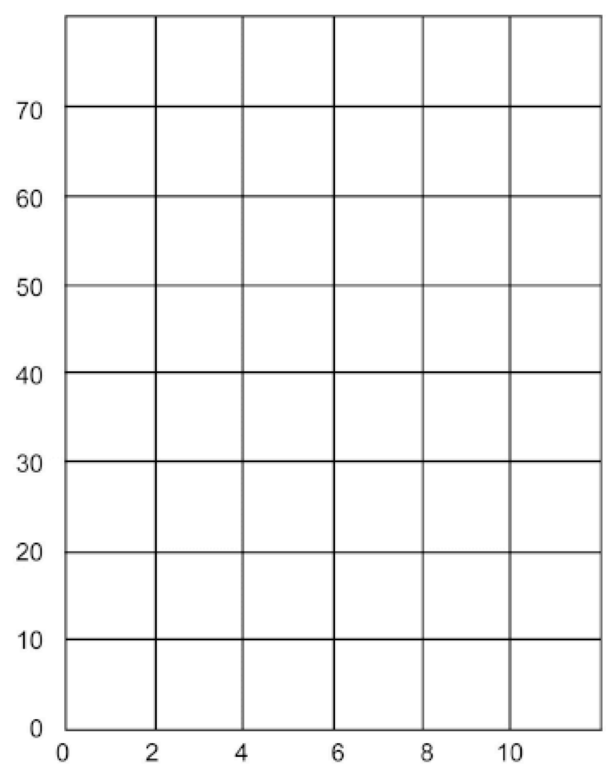
Independent Variable	Dependent Variable	Constant (doesn't change)

Entry 6B: Use the gas laws simulation to explore the relationship between these variables.

Complete the following graph by varying the temperature.

- While you are collecting the data, record the data points on the graph
- You need to collect 10 data points

Label the axes and add a title!



Entry 6C: Summarize how these two variables are related in Charles' Law:

Jacques Charles (1746-1823) came up with the law that bears his name in 1787, while studying the effect of *temperature on the volume* of a gas kept at constant pressure.

Charles was a French physicist, inventor, mathematician, and balloonist. He was the first balloonist to use hydrogen gas instead of hot air.

His law describes the way gasses expand when heated.

ENTRY 7: APPLY YOUR NEW UNDERSTANDING TO "THE CASE OF THE BUSTED BASKETBALL"

Entry 7A: Based on what you have learned about the gas laws, should Gaby complain to the basketball manufacturer? Why or why not?

ENTRY 8: PUT IT ALL TOGETHER: THE COMBINED GAS LAW

Every day the National Oceanic and Atmospheric Administration (NOAA) sends up 102 weather balloons from sites in the US, the Caribbean, and the Pacific to help weather forecasting. The balloons lift up instruments into the atmosphere. Those instruments collect data on air pressure, temperature, and relative humidity from the Earth's surface to over 20 miles (about 100,000 feet) up in the sky. When the balloon reaches 100,000 feet, it pops, sending the instruments back to Earth. Together, the three laws you have explored in this study guide make up **The Combined Gas Law**. This Law can help us to understand why weather balloons pop.


Courtesy: NOAA

The Combined Gas Law allows you to calculate an outcome when you have three variables (pressure, volume, and temperature). It is based on the formulas for all of the individual gas laws.

Here are the mathematical equations for the individual gas laws:

Boyle's Law

$$P_1V_1 = P_2V_2$$

Charles' Law

$$V_1/T_1 = V_2/T_2$$

Amontons' Law

$$P_1/T_1 = P_2/T_2$$

[NOTE 1: Amontons did not develop this formula for his Law. That came later]

[NOTE 2: All calculations require you to use Kelvin units for temperature.]

- If we multiply all three laws, we get *The Combined Gas Law*, which can be represented as:

$$P_1V_1/T_1 = P_2V_2/T_2$$

The Combined Gas Law can help you to calculate any one of the three variables if you know the other two variables, but it *cannot* tell you which variable caused another variable to change.

See if you can do a couple of calculations using the Combined Gas Law:

1. A helium-filled weather balloon has a volume of 10.0L at 300K and a pressure of 1.0 atm (~101 kPa) when it is released. What will be the volume of the balloon once it has reached an altitude where the pressure is 0.1 atm (~10 kPa) and the temperature is 240K?

Entry 8A:
What is V_1 in this question? ______________________

Entry 8B:
Want is P_1? ____

Entry 8C:
What is P_2? ____

Entry 8D:
What is T_1? ____

Entry 8E:
What is T_2? ____

Entry 8F:
What is the unknown? _____________________________

Entry 8G:
Use the Combined Gas Law to calculate this unknown in the space below.

$P_1V_1/T_1 = P_2V_2/T_2$

2. A 220.0 mL sample of helium gas is in a cylinder with a movable piston at 101 kPa (~1.0 atm) and 275 K. The piston is pushed in until the sample has a volume of 95.0 mL. The new temperature of the gas is 310.0 K. What is the new pressure of the sample?

Entry 8H:

Calculate P_2: ______________________________

(use the space below for your calculations)

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

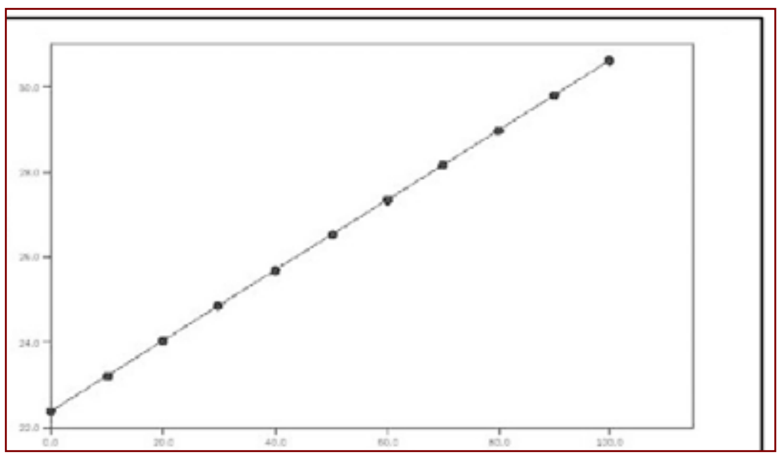
Entry 8I: Something Extra:

Think about Gaby's basketball: what might happen to a car tire in summer and in winter? Use the gas laws to explain that.

GAS LAWS LAB NOTEBOOK

ENTRY 1: DO IT NOW!

Entry 1A: Using what you know about the Gas Laws from the simulation, label the axes on this graph.

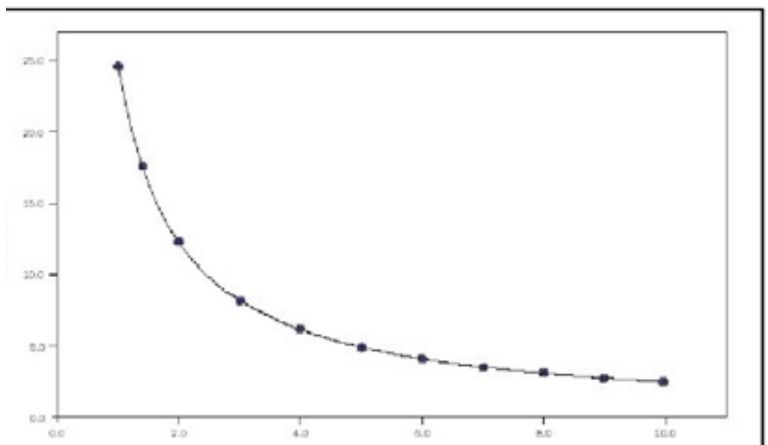


Entry 1B: What does the graph tell you about the relationship between the variables?

Entry 1C: Which quantity is held constant?

____

Entry 1D: Using what you know about the Gas Laws from the simulation, label the axes on this graph.

_____________ 

____

Entry 1E: What does the graph tell you about the relationship between the variables?

____

____

Entry 1F: Which quantity is held constant?

___

Entry 1G: Why was Gabriella's basketball flat in the COLD morning when it was full during the WARM afternoon?

___

___

___

___

Knowing what we know about pressure, volume and temperature, the Combined Gas Law relates all 3 of these variables.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Let's try some more practice problems using The Combined Gas Law:

Entry 1H: The gas in a 0.717 L cylinder of a diesel engine exerts a pressure of 0.9 atm at 300 K (27°C) The piston suddenly compresses the gas to 48.6 atm and the temperature rises to 820 K (547 °C). What is the final volume of the gas? What are the temperature and pressure at STP? (Check Table A). Show your work.

Entry 1I: What pressure (in atm) will be exerted by a tank of natural gas used for home heating if its volume is 19.6 L at STP and it is compressed to 6.85 L at 24C?

Entry 1J: How much higher is this than normal atmospheric pressure?

Entry 1K: The human lung has an average temperature of 310 K (37°C). If one inhales Alaskan air at 1 atm and 28.9 °C and then holds it, to what pressure will the air in the lungs rise?

Entry 1L: If a human lung can withstand 2 atm of pressure, do you think the lungs will burst?

Entry 1M: Explain how you are able to make this claim.

ENTRY 2: LAB/DEMO

Aim: Use simulations to discover how pressure, temperature and volume are related according to Amontons', Boyle's and Charles' Laws.

Important Concepts: There are three Gas Laws

Amontons' Law: Relates temperature and pressure at constant volume.

- **Temperature** – *independent*
- **Pressure** – *dependent*
- **Volume** – constant

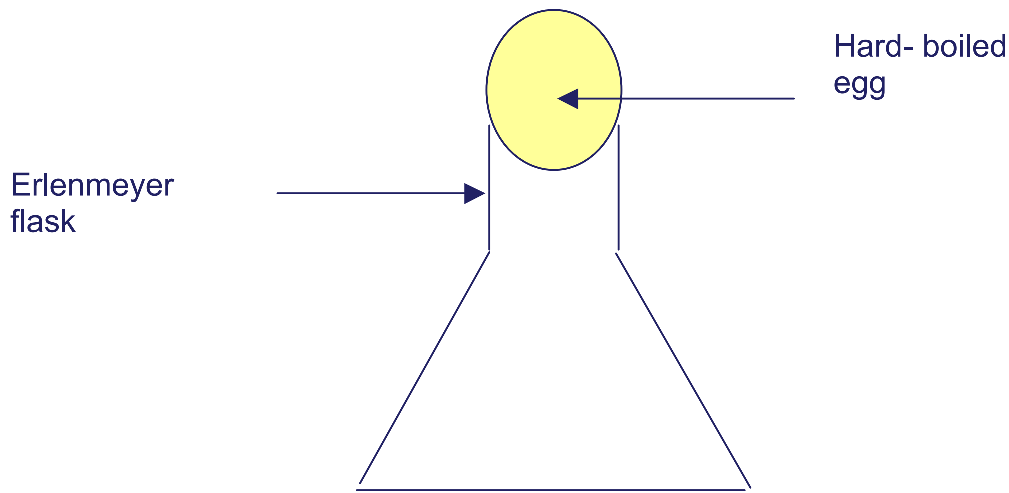
Boyle's Law: Relates pressure and volume at constant temperature.

- **Pressure** – *independent*
- **Volume** – *depend*ent
- **Temperature** – constant

Charles' Law: Relates temperature and volume at constant pressure

- **Temperature** – *independent*
- **Volume** – *dependent*
- **Pressure** – constant

Demonstration/Lab: ***Erlenmeyer flask & egg***



Entry 2A: *Predict*

What do you predict will happen if we heat the air in the flask and then put a peeled hard-boiled egg on the open top of the flask?

____

____

____

Entry 2B: *Confidence*

What did you learn from the simulation that makes you confident about your prediction?

____

____

____

Entry 2C: *Collect* your equipment:

- Narrow-mouthed Erlenmeyer flask (about 500 mL) or bottle that is similar
- Medium hard-boiled egg, peeled
- Hair dryer or something similar
- Tripod or clamp stand
- Thermometer

Entry 2D: *Perform* your experiment

1. Clamp the flask to the stand or place it on a tripod
2. Heat the flask with the hair dryer for about three minutes.
3. Measure and record the temperature of the air in the flask at this time (T_1). (Celsius degrees plus 273 = Kelvin)

- T_1 = _______________K

- What must P_1 be at this time? You can use your understanding of the relationship between internal and external pressure to work this out and suggest a likely value.

  P_1 = _______________atm

4. Then immediately place the egg on the mouth of the flask as shown in the previous illustration.

Entry 2E: *Observe* what happens to the egg

____

____

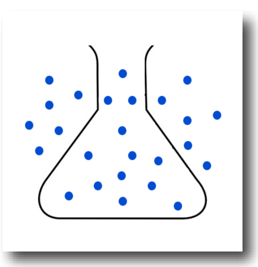
- Record the temperature of the flask.

  T_2 __________________

Use the mathematical formula for the relationship between Temperature and Pressure to calculate the final pressure. Show your work.

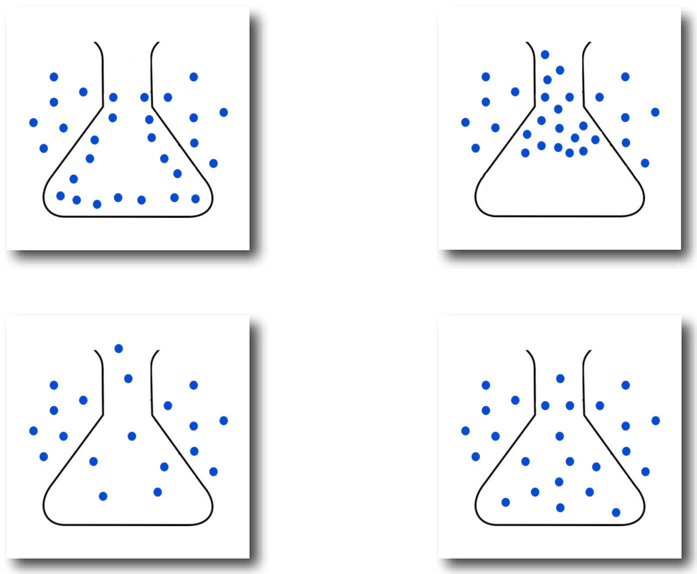
Entry 2F: *Explain* your original prediction was supported or not supported by the evidence you just collected.

Entry 2G: We can represent the gas molecules in a flask as dots (a bit like the dots in the model you just used).



Before you start heating the flask, the particles inside the flask are at the same temperature as particles outside. Use your knowledge from the previous simulations to describe how the particles will be moving.

Entry 2H: Predict how the molecules inside the flask will be organized after three minutes of heating. Circle the image that is most like your prediction.



Entry 2I: So long as the hair dryer is heating the air inside the flask, what can you say about the internal pressure of these heated gas molecules inside the flask and the air pressure outside?

Entry 2J: As the gas molecules inside the flask cool down, what does the external air pressure do to the egg?

____

____

____

Entry 2K: At this point, how does the internal air pressure of the flask compare with the external air pressure?

____

____

____

Entry 2L: What evidence (observation/fact) allows you to say this?

____

____

____

Entry 2M: Explain what happened at the molecular level to the gas particles in this flask. Use your calculated P_2 and your observations from the demonstration.

___

___

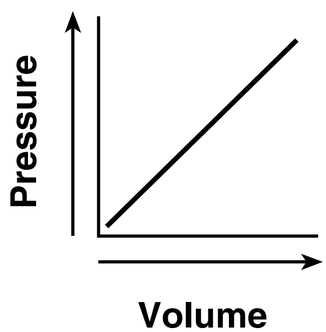
___

Summary Table of Concepts/Theories and Simulations:

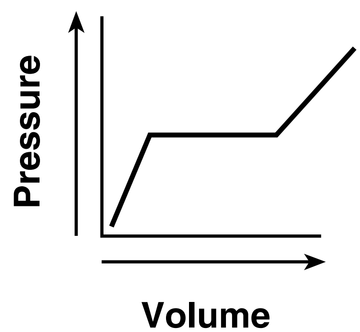
	Diffusion	*KMT*	*Gas Laws*
Variables	Temperature, atomic mass & time for diffusion	Pressure & temperature	Pressure, temperature, & volume
Examples	Tea in hot water; oxygen in bloodstream; gases used in WWI trenches	Boiling water & the lid popping off	Balloon rising with temperature; forcing gases into a smaller container
Simulation Narrative	Punk & Popcorn	Deserted Dessert	Busted Basketball
Lab/Demo	Food coloring & agar plate	Heating & cooling balloon on flask	Erlenmeyer flask & egg

ENTRY 3: EXTENSION ACTIVITIES

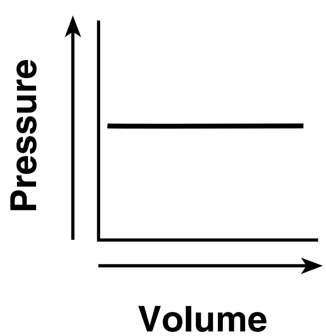
Entry 3A: Circle the graph that represents the relationship between pressure and volume for a sample of an ideal gas at constant temperature.



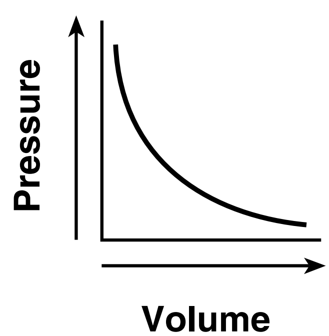
(1)



(3)



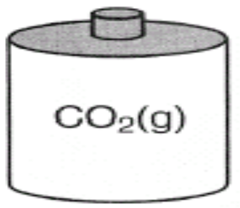
(2)



(4)

Entry 3B: Cylinder *A* contains 22.0 grams of CO_2(g). The volume, pressure, and temperature is indicated underneath the diagram of the cylinder.

Cylinder A



V = 12.3 L
P = 1.0 atm
T = 300. K

The temperature of the CO_2(g) is increased to 450. K and the volume of cylinder *A* remains constant.

Show a correct numerical setup for calculating the new pressure of the CO_2(g) in cylinder *A*.

Entry 3C: Air bags are an important safety feature in modern automobiles. An air bag is inflated in milliseconds by the explosive decomposition of $NaN_3(s)$. The decomposition reaction produces $N_2(g)$, as well as Na(s), according to the unbalanced equation below.

$NaN_3(s) \rightarrow Na(s) + N_2(g)$

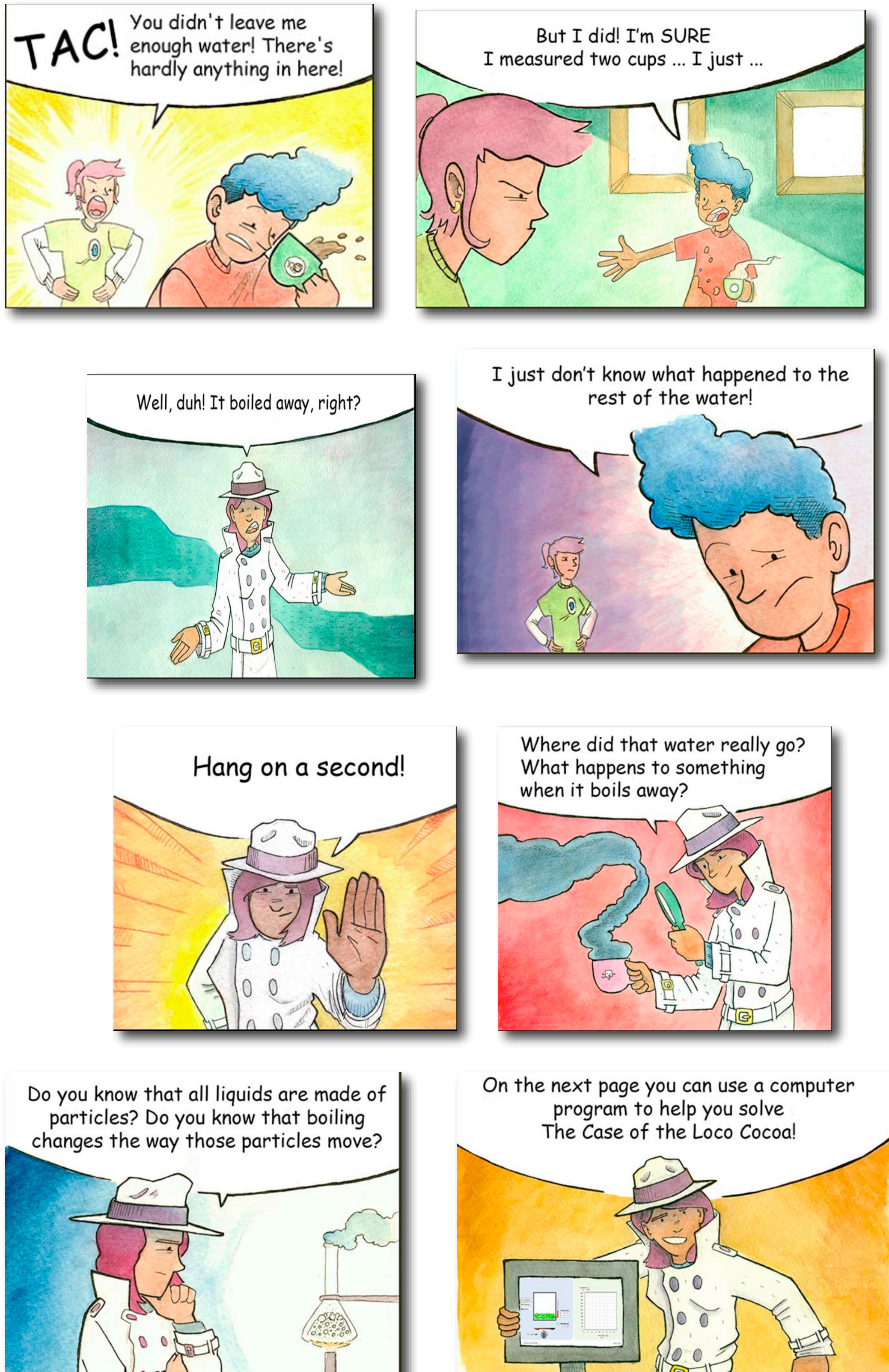
When the air bag inflates, the nitrogen gas is at a pressure of 1.30 atmospheres, a temperature of 301 K, and has a volume of 40.0 liters. In the space below calculate the volume of the nitrogen gas at STP. Your response must include *both* a correct numerical setup and the calculated volume.

SCIENCE DETECTIVE'S NOTEBOOK #4:

PHASE CHANGE

ENTRY 1: MAKE OBSERVATIONS AND PROPOSE A HYPOTHESIS

"The Case of the Loco Cocoa"
Phase Change in Action


TAC!
You didn't leave me enough water! There's hardly anything in here!
But I did! I'm SURE I measured two cups ... I just ...
Well, duh! It boiled away, right?
I just don't know what happened to the rest of the water!
Hang on a second!
Where did that water really go? What happens to something when it boils away?
Do you know that all liquids are made of particles? Do you know that boiling changes the way those particles move?
On the next page you can use a computer program to help you solve The Case of the Loco Cocoa!

Entry 1A: Describe how Tac put heat into the system of water, saucepan, and stove.

____

____

Using what you learned from previous studies of heat, complete the following sentences:

Entry 1B: Heat is a process for transferring

____

Entry 1C: Circle one:

Heat always transfers from

(*hot to cold / cold to hot*).

Entry 1D: How many cups of water did Tac begin

with? _________________

Entry 1E: How many cups did he end with?

____

Entry 1F: Write a hypothesis about what happened to the water using the words *heat* and *molecules.*

____

____

____

____

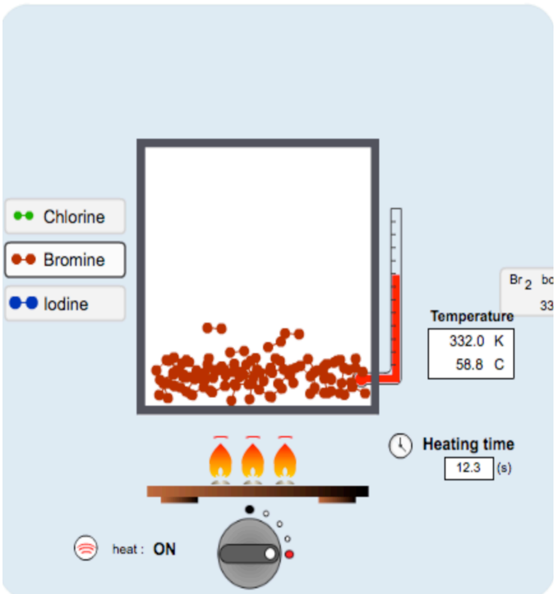
____

ENTRY 2: EXPLORE A MODEL TO TEST YOUR HYPOTHESIS

You can test the hypothesis you proposed in Entry 1F by exploring the Phase Change Simulation.

You will see how heat can be used to overcome forces between molecules in a liquid.

First, read the instructions.



The **internal pressure** of the gas is measured in **atmospheres (atm).**

Heat is measured in **kilojoules (kJ)** and can be turned on by using the dial. Adding heat increases the **temperature.** Temperature is measured in **Kelvins (K)** or **degrees Celsius (°C).**

The particles in this program are **molecules** that made up of two atoms chemically bonded together. You can choose to examine the effect of heat on molecules of different mass by exploring chlorine, bromine, and iodine.

Entry 2A: Name the three chemical elements in the model.

1. ______________________________

2. ______________________________

3. ______________________________

Entry 2B: These elements belong to a Periodic Group called the Halogens (Group 17) and all elements in the halogens are *diatomic*. What does that mean?

____

____

Entry 2C: The two variables that you can explore

in this simulation are ____________________ and

______________________ .

Entry 2D: Which variable do you need to use to test your hypothesis?

____

Entry 2E: What unit is used for measuring heat? Provide the full word and the symbol.

____

____

ENTRY 3:
EXAMINE CHLORINE, THE “GREEN” MOLECULE

Select chlorine and observe carefully.

Entry 3A: What is the temperature of chlorine before you turn on the flame?

______________ K = ____________ °C

(In New York state, found on Tables A and T of the Regent’s Chemistry Reference Tables)

Entry 3B:
What phase is the chlorine in before you turn on the flame?

____

(solid/liquid/gas)

Now turn on the heat and observe what happens.

Entry 3C: How many seconds does it take for the molecule to reach its boiling point?

______ seconds. *(You may need to reset the simulation and monitor the time to answer this question)*

Entry 3D: What is the temperature when the molecule reaches its boiling point?

____________ K = __________ °C

(In New York state, found on Tables A and T of the Regent's Chemistry Reference Tables)

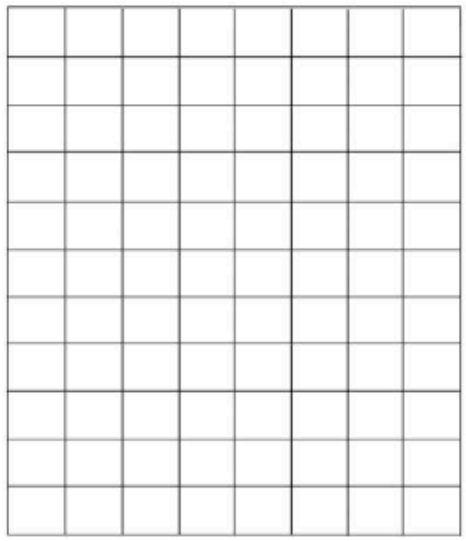
Entry 3E: According to the graph, how much heat was put into the container to make the liquid boil?

___________ kJ

Entry 3F: How much heat was added to the container after the phase change was completed?

___________ kJ

Entry 3G: Copy the graph, including the scale and labels, for both the X and Y-axis. Add a title!



ENTRY 4:
EXAMINE BROMINE
THE "RED" MOLECULE

Entry 4A: What is the temperature of bromine before you turn on the flame?

_____________ K = ___________ °C

(In New York state, found on Tables A and T of the Regent's Chemistry Reference Tables)

Entry 4B:
What phase is the bromine in before you turn on the flame?

____
(solid/ liquid/ gas)

Now turn on the heat and observe what happens.

Entry 4C: How many seconds does it take for the molecule to reach its boiling point?

______ seconds. *(You may need to reset the simulation and monitor the time to answer this question)*

Entry 4D: What is the temperature when the molecule reaches its boiling point?

____________ K = __________ °C

(In New York state, found on Tables A and T of the Regent's Chemistry Reference Tables)

Entry 4E: According to the graph, how much heat was put into the container to make the liquid boil?

___________ kJ

Entry 4F: How much heat was added to the container after the phase change was completed?

___________ kJ

Entry 4G: Copy the graph, including the scale and labels, for both the X and Y-axis. Add a title!

ENTRY 5: EXAMINE IODINE THE "BLUE" MOLECULE

Entry 5A: What is the temperature of iodine before you turn on the flame?

_____________ K = ___________ °C

(In New York state, found on Tables A and T of the Regent's Chemistry Reference Tables)

Entry 5B:

What phase is the iodine in before you turn on the flame?

____

(solid/ liquid/ gas)

Entry 5C: How many seconds does it take for the molecule to reach its boiling point?

______ seconds. *(You may need to reset the simulation and monitor the time to answer this question)*

Entry 5D: What is the temperature when the molecule reaches its boiling point?

____________ K = __________ °C

(In New York state, found on Tables A and T of the Regent's Chemistry Reference Tables)

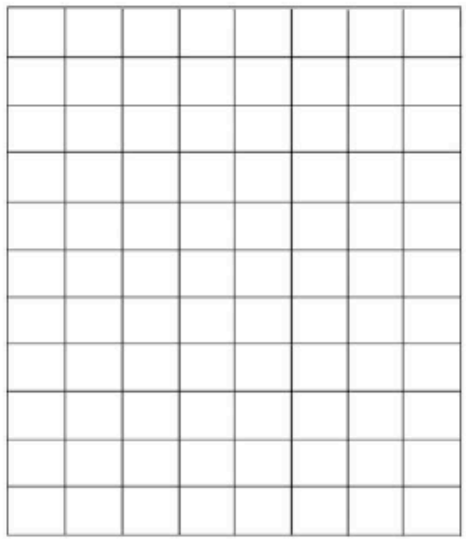
Entry 5E: According to the graph, how much heat was put into the container to make the liquid boil?

___________ kJ

Entry 5F: How much heat was added to the container after the phase change was completed?

___________ kJ

Entry 5G: Copy the graph, including the scale and labels, for both the X and Y-axis. Add a title!



ENTRY 6: EXAMINE YOUR DATA

Look at the the three graphs.

Entry 6A: Describe what is happening to the three liquids when their boiling points are reached.

Entry 6B: When the three liquids reach their boiling points, what happens to the temperature?

Entry 6C: What evidence from the graphs support your answer to Entry 6B?

Entry 6D: At boiling point, heat is still being transferred into the container, but the temperature stays the same. Where is the energy going?

Entry 6E:

Which element has the highest boiling point? Explain why.

ENTRY 7: SYNTHESIZE WHAT YOU LEARNED

Apply your understanding to
"The Case of the Loco Cocoa"

Entry 7A: Explain why there wasn't enough water in the saucepan for Gabriella to make hot cocoa.

____

____

____

Entry 7B: How is the water Tac was heating like the liquids you used in the simulation?

____

____

____

Entry 7C: How is the water Tac was heating different from the liquids you used in the simulation?

____

____

____

Entry 7D: What phase change were you observing in this simulation?

____

____

____

Entry 7E: In the simulation, bromine molecules were shown as red, chlorine molecules as green, and iodine molecules as blue. Are the molecules really those colors? Explain.

____

____

____

Entry 7F: What is the connection between heat and temperature? (Use your graph for support)

Entry 7G:

You should have observed that as you heated the molecules of chlorine, bromine, and iodine, they moved faster. As heat was added, the molecules gained kinetic energy (energy of motion) because temperature was increased. BUT, as the phase change took place the temperature of the element did not change, even though we continued to heat the element. *What was happening?*

(H*int: think about the different types of energy!*)

PHASE CHANGE LAB NOTEBOOK

ENTRY 1:
DO IT NOW!

Today you will be looking at phase change a little differently using lauric acid, which is a solid at room temperature.

Entry 1A: Go online or look up a table in your textbook to find out the published melting point for lauric acid. Write what you find.

________________°C and _________________K

Entry 1B: Today you will be investigating the melting point of lauric acid. What can you learn by comparing your experimental result to the published value?

____

____

____

ENTRY 2: LAB/DEMO

Introduction to the Lab:

You know that matter can exist in one of three physical states or phases—solid, liquid, or gas. For a pure substance, changes in state occur at a definite temperature. Water, for example, changes from a solid to a liquid at 0°C and at standard pressure from a liquid to a gas at 100°C.

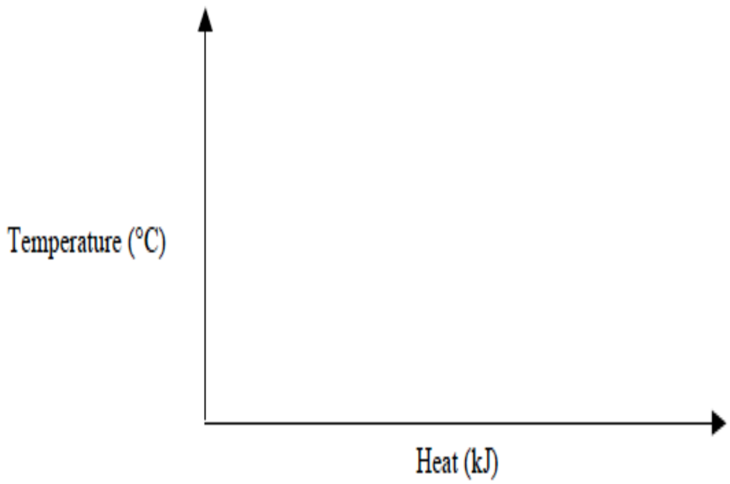
In a solid, the particles are arranged in an orderly, repeating, three-dimensional pattern. As the solid is heated, the energy of the particles increases. Eventually at some temperature, which is called the melting point, the molecules overcome the forces of attraction holding the particles together and the substance changes to a liquid. At another temperature, called the boiling point, molecules in the liquid state overcome the forces of attraction between them and the substance changes from a liquid to a gas.

When a liquid is cooled, the reverse process occurs. The temperature of the gas decreases until the condensation point is reached and the gas becomes a liquid. Only after the gas has completely changed to a liquid will the temperature decrease again. The temperature of the liquid decreases further until the freezing point is reached. Only after the liquid is completely changed to a solid will the temperature begin to decrease further. Any changes of a substance from liquid to gas or solid to liquid are called phase changes.

Purpose: In the phase change simulation, you observed a change between liquid and gas. In this activity, you will observe what happens when heat is applied to lauric acid ($C_{12}H_{24}O_2$). You will measure the temperature at timed intervals and determine its melting point experimentally.

Entry 2A: *Predict*

Based on the phase change simulations you have completed, predict the shape of its heating curve:



Entry 2B: *Confidence*

What did you learn from the simulation that makes you confident about your predictions?

____

____

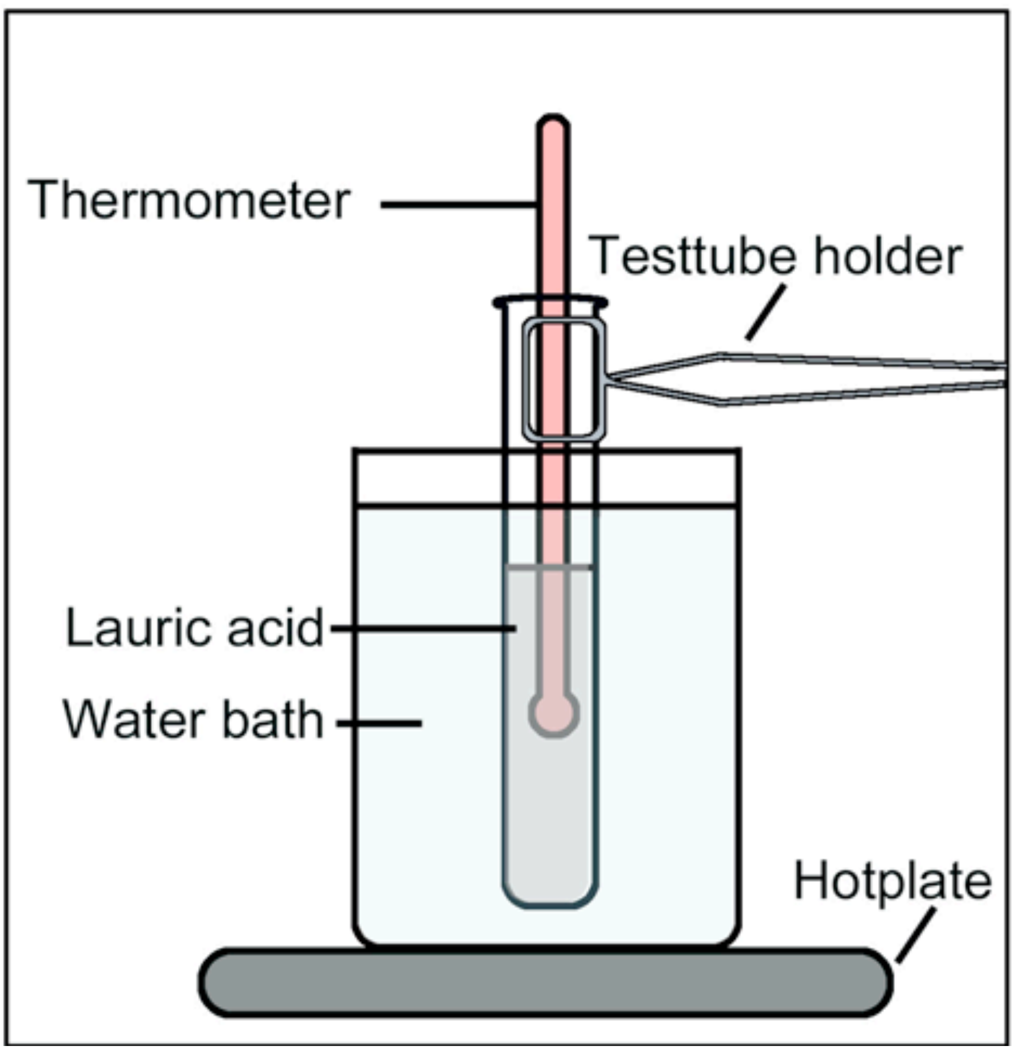
____

____

Entry 2C: *Collect* your equipment:

- Goggles
- Lauric acid test tube
- Two beakers, 400 mL
- Thermometers
- Hot plate
- Tap water
- Ice for ice bath

Demonstration: Lauric acid & phase change



Entry 2D: *Perform* your experiment

1. Put on goggles and other safety attire.

2. Fill one 400 mL beaker full of tap water and heat it on the hot plate. Turn the hot plate all the way to 10. Once you see tiny bubbles, turn it down to 6. CAUTION: Do not touch the hot plate or beaker.

3. At the same time make an ice bath using a 400 mL beaker and ice from the front desk.

4. Get a large test tube of lauric acid and hold it with a test tube holder. Place it in the hot water bath. (You need to melt the lauric acid so you can insert the thermometer into the acid)

5. As the solid begins to melt, place a thermometer into the test tube, once you are able to insert the thermometer (see diagram on previous page), use the test tube holder to place the test tube in an ice water bath. Stop once the temperature reaches about 30°C.

6. Carefully place the test tube containing the lauric acid back into the hot water bath (it should NOT be boiling).

7. Immediately begin to take temperature readings every 30 seconds. Record your temperatures and time in the data table provided (Entry 2H).

8. Begin stirring gently as soon as you are able to move the thermometer easily. Continue to

measure and record the temperature until the lauric acid is at approximately 55°C.

9. Turn off the hot plate. Remove the thermometer from the lauric acid and return test tube to your teacher.

10. Clean up your workstation and wash your hands.

Entry 2E: Record your *observations*
Approximate melting point of lauric acid:

________________°C and ________________K

Entry 2F: Describe the changes you witnessed.

____

____

____

Entry 2G: Could you see the actual molecules? Why or why not?

____

____

Entry 2H: Your data table

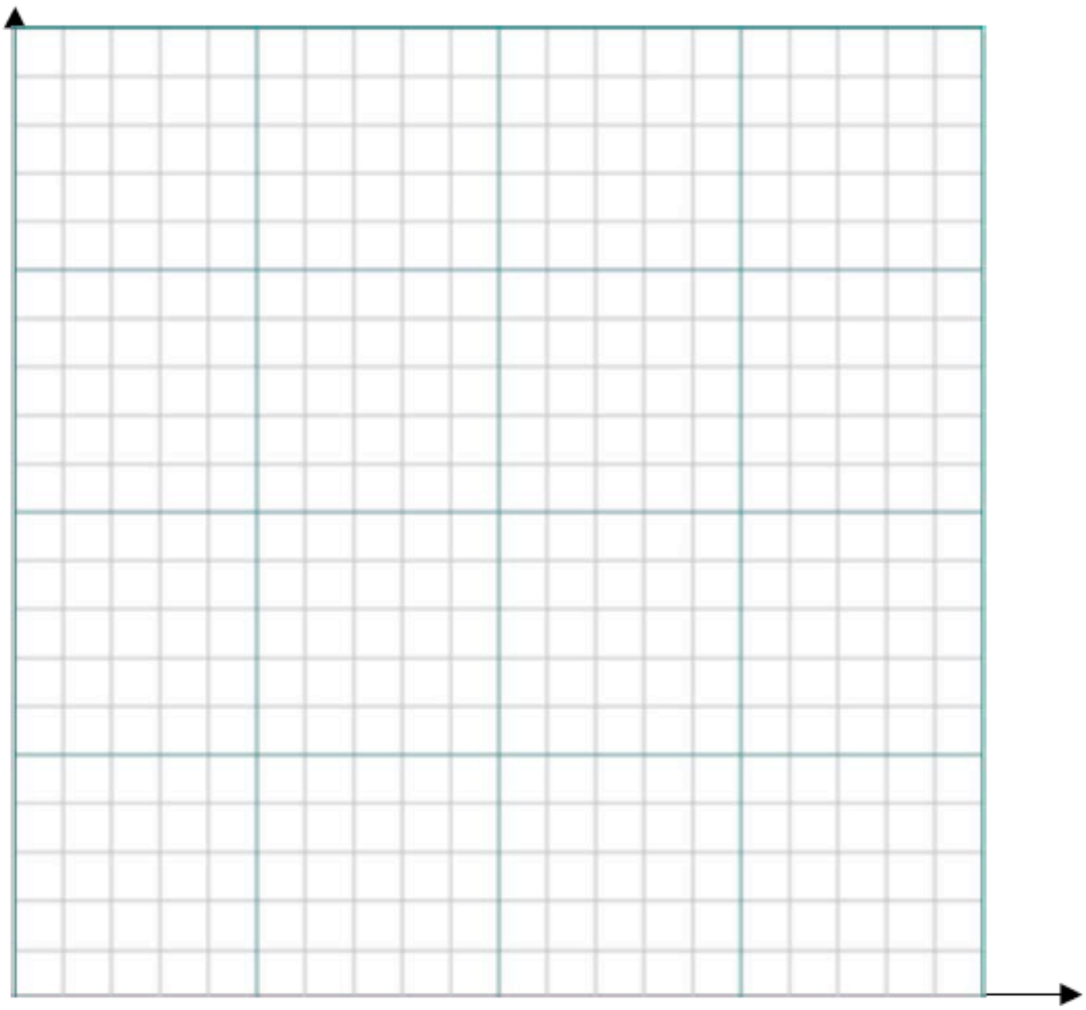
Data Table:

Title: ______________________________

Time (min)	Temperature (°C)
0 (right when you put the test tube in hot water)	
0.5 (30 seconds)	
1.0	
1.5	
2.0	
2.5	
3.0	
3.5	
4.0	
4.5	
5.0	
5.5	
6.0	
6.5	
7.0	
7.5	
8.0	
8.5	
9.0	
9.5	
10.0	
10.5	
11.0	
11.5	
12.0	

Entry 2I: Draw a graph representing the table on the previous page. You MUST label all axes, put in the scale, and write a title.

Title: ____



Entry 2J: *Explain your observations*
Did your prediction (from Entry 2A) match your actual data?

____

Why do you think it was the same or different?

____

____

____

Entry 2K: Explain why you need to record so many points.

____

____

____

Entry 2L: Think back to the simulation and explain why the temperature of lauric acid's melting point did not change even though you were still adding heat.

____

____

____

Entry 2M: What is happening to the forces of attraction between the lauric acid molecules when it is changing from a solid to a liquid?

____

____

____

____

Entry 2N: Draw particle diagrams of what you think the molecules will look like as a solid, while changing phase, and as a liquid.

Solid	During Melting	Liquid

Entry 2O: *Discussion Question*

You are attending a summer science fair, and one of the instructors gives you a sample of what he claims is pure lauric acid. When you measure the melting point of the sample he gave you, you get a value of 50°C. Using the results of your experiment, what can you deduce about the purity of this sample?

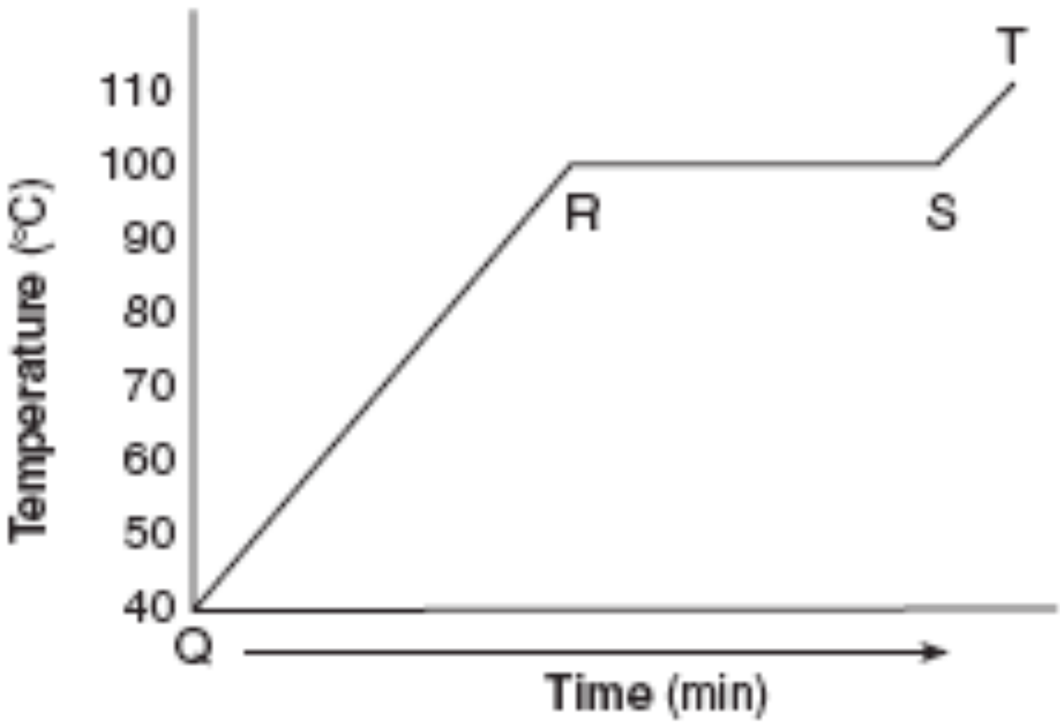
____

____

____

ENTRY 3: EXTENSION ACTIVITIES

Entry 3A: The sample of water that Tac heated from a liquid at 40°C to a gas at 110°C is shown in the heating curve below. Label the regions on the graph below with the correct state of matter.



Your choices are:

- Phase change
- Liquid only
- Gas only
- Solid only

Entry 3B:

Here is some information about ethanoic (acetic) acid.

Substance	*Melting Point/°C*	*Boiling Point/°C*
Ethanoic Acid	17	118

Describe what you would expect to observe as ethanoic acid was heated steadily from room temperature (25°C) to 120°C.