**Name:** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Exploring the Particle Model   
When does a liquid boil?**

Matter consists of atoms and molecules and all substances consist of matter. Changing a substance’s state requires energy. Adding or removing thermal energy from a substance causes a change of state. Energy affects the attraction between atoms or molecules and their rate of movement. A substance’s temperature determines whether it occurs in a solid, liquid or gas.

A substance changes from a solid to a liquid at its melting point, from a liquid to a gas at its boiling point, and from a liquid to a solid at its freezing point. A different amount of energy is needed to change the state of different substances. For example, it takes more energy to melt a solid metal into a liquid than to melt an ice cube into water.

In this virtual lab you will use the particle model to examine how changes in temperature and pressure affect the state, the atomic or molecular activity and the boiling point of a substance.

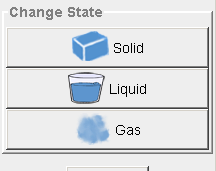
**Objectives: Students will be able to**

* Show the difference in the arrangement of atoms or molecules in the solid, liquid and gaseous states.
* Discuss how adding or removing heat from matter affects the motion of atoms and molecules.
* Determine some variables that bring about changes in *gas pressure* and the *boiling point* of a substance.

**Procedure:**

1. Open the internet browser and Google: PhET states of matter

 Click on the first link

 Click the button and select

2. Experiment with the buttons.



* Choose one of the materials from the ***Molecules*** box – **neon, oxygen, argon or water**
* Click on the solid, liquid and gas picture buttons until you can see the differences.
* Draw a diagram to represent the atoms or molecules during each state**.**

|  |  |  |
| --- | --- | --- |
| Solid | Liquid | gas |

3. Go to the **second tab** at the **top of your screen**.

* Click on the **‘Teacher’** tab, and select **‘Celsius’**.

4. **Click on Neon** as type of atom or molecule.Record all temperatures in Celsius (0C).

* **Heat** the neon to -220 0C.

At approximately what temperature does the neon become a liquid? (Melting point) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

At approximately what temperature does the neon become a gas? (Boiling point) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

* Add more atoms of neon using the pump. Try to double the number of atoms.

What happens to the pressure? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

* Now push down on the lid of the container. What happens to the pressure? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

What happens to the temperature? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
Does the volume of the container change as well? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

5. **Click on Reset All.** Click on **Oxygen** as the type of molecule.

* **Heat** the oxygen to -150 0C.

At approximately what temperature does the oxygen become a liquid? (Melting point) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

At approximately what temperature does the oxygen become a gas? (Boiling point) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

* Adjust the pressure when oxygen is a gas. **Push down on the lid then lift it**.  
  What happens to the molecules when you push down then lift up? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Does the pressure have anything to do with a change in phase? Explain using the particle model. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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6. **Compare** the Boiling points of **Oxygen and Neon**.

Which gas has the highest Boiling Point? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

* Look on the right at the **Potential Energy vs. Distance Between atoms scale**. The distance between atoms is shown as **δ**. The potential energy of atoms is shown by the size of the arrow **Ɛ**. This indicates the force of attraction between the atoms. The bigger the arrow, the stronger the force holding the atoms together.

In which gas are the **values of δ and Ɛ the greatest**? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Which gas has the strongest forces of attraction between atoms? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

* **Click on ‘Adjustable Attraction’.** Observe the particles when the slider is on **strong** and then on **weak**.

What happens to the particles? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

* How does the force of attraction between particles affect the boiling point of a substance?

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7. **Click on Reset All.** Click on **Water** as the type of molecule.

* Look on the right at the pressure vs. temperature scale.   
  Try to change the temperature or pressure to make the red dot move to the triple point.

What do you think the triple point is? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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* Are you able to keep the red dot on the triple point? Why or why not?

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8. The **Boiling Point** is the temperature at which the pressure of the gas above a liquid (vapour pressure) equals the  
 external pressure surrounding the liquid. Therefore, the **Boiling Point** **of a liquid depends on atmospheric pressure**.   
  
 Normal Melting Point of water = 00C  
 Normal Boiling Point of water = 1000C

Normal atmospheric pressure = 1 Atmosphere (1.00 ATM)

* **Click on Reset All.** Click on **Water** as the type of molecule.

**Heat** the water to **150 0C** and then slowly cool the water to 1000C (Normal Boiling Point).

Observe the pressure gauge on the left for about a minute and then record the maximum pressure reading.

Maximum Pressure at 100 0 C (ATM) = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

* Now **push down** on the lid of the container to about **half the volume**. Observe the pressure gauge on the left for about a minute and then record the maximum pressure reading and the temperature at this pressure.

Higher Temperature Reading (o C) = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Maximum Pressure Reading (ATM) = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

9. **Cool the water** until the pressure gauge reads **0.00 ATM**. Then slowly **heat the water to 100 0C**. The pressure should  
 be the same as before. **Observe the particles** and determine whether the water is boiling.

**Now heat the water to the higher temperature you recorded in Part 8**. Compare the pressure to the reading you  
 recorded at this temperature. **Observe the particles** and determine whether the water is boiling.

* What is the Boiling Point of water at this higher pressure? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

10. Refer to the particle model, to explain how increasing the pressure above a liquid affects the Boiling point.

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**Critical Thinking**

Q.1 The Boiling Points of the inert gases are shown in the diagram below.

**Increasing  
Atomic  
Radius   
(particle size)**

Use your knowledge of the particle model to explain the relationship between particle size and Boiling Points.

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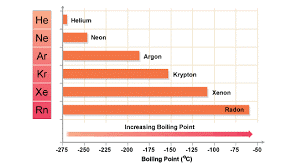
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Q.2 Imagine that you are trying to boil water for a cup of tea up a mountain. Why would the cup of tea taste  
 horrible?

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