# 14475 Modeling States Of Matter
## TEACHER GUIDE

**Time Allocation:**

**To prepare this product for an experimental trial should take less than twenty minutes. Actual experiments will vary with needs of students and the method of instruction, but are easily concluded within one class period.**

## Introduction

You are probably familiar with three states of matter that are commonly encountered in our environment, solids, liquids, and gases. These three phases all have certain characteristics. Solids have definite volumes and shapes; liquids have definite volumes, but no fixed shape; and gases have no definite volume or shape. If you start with a solid object and add heat, it will eventually melt, yielding a liquid. Continue adding heat and the liquid will evaporate into a gas. One substance that is commonly used to demonstrate these three states of matter is $H_2O$. It exists as a solid (ice), liquid (water), and gas (water vapor) within a relatively narrow range of temperatures. With this activity, you will observe a simulation of matter undergoing changes to demonstrate these three states of matter.

The additional exercise will let you further explore the behavior of a gas. Specifically, you will examine the relationship between the volume, temperature, and pressure of a simulated gas. The way we measure the average kinetic energy of atoms and molecules is by their temperature. You will use voltage as an analog to temperature. As the temperature of the particles representing an ideal gas within the tube increases, the volume they occupy also increases. This is seen by the rise in the height of the floating piston. This direct relationship between the temperature and the volume of the gas can be expressed mathematically as:

$$V \alpha T$$

Where:

V represents the volume of the gas

T represents the temperature (kinetic energy) of the gas

α means "is proportional to"

The relationship between the volume and the pressure of a gas can be expressed mathematically as:

$$V \alpha 1/P$$

Where:

V is the volume of the gas

P is the pressure of the gas

These two equations can be combined to yield:

$$V \alpha T/P$$

Adding a proportionality constant allows us to replace the proportionality symbol with an equal sign.

$$V = kT/P$$

The proportionality constant is represented by k. Multiplying both sides by P produces:

$$PV = kT$$

This is the mathematical expression, which is related to the ideal gas law:

$$PV = nRT$$

Where:

**n** = the number of particles

**R** = the universal gas constant

## Objective

Mechanically model three states of matter: solid, liquid, and gas. Measure and graph the behavior of a simulated gas under different temperature and pressure conditions.

## Materials Included in the Kit

1 Plastic tube (clear)
1 Floating piston assembly
1 Electric motor assembly
1 Vial of plastic beads
1 Bag of magnetic particles
1 Hardware package:
Wing nuts
Machine screw, 1/2"
Machine screw, 1 1/4"
Gripper clip
5 Metal washers
1 Base, pegboard stand
1 Back, pegboard stand
1 Teacher's Guide
1 Set Student Study and Analysis Copymasters.

## Materials Needed but Not Provided

Variable low voltage power supply (1 to 3 volt)

## Optional Accessories

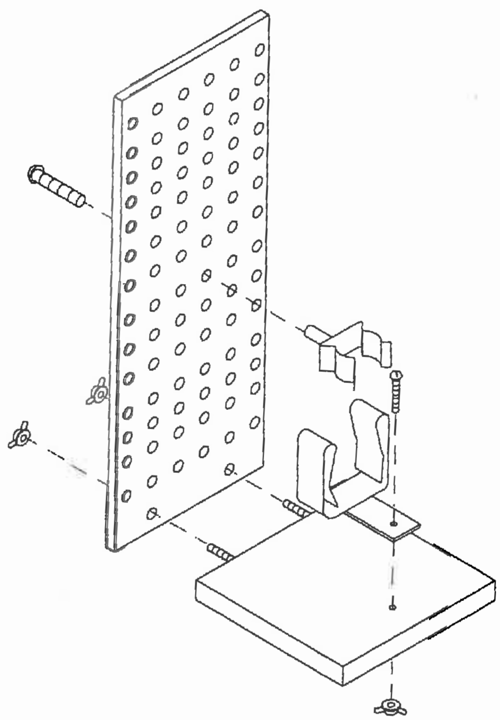
Voltmeter (0 – 3VDC)
Graph Paper
Short metric scale (ruler)
Grease pencil

# Procedure

## Assembling the Apparatus

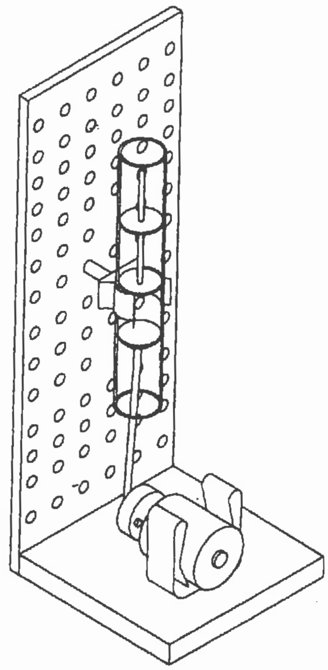
1. Assemble the stand by inserting the two screws from the base into holes on the second row of the peg board. Secure the pegboard to the base with two flanged wing nuts from the hardware package. See Fig. 1.
2. Clamp the motor bracket to the base using the long machine screw and a wing nut.

Figure 1



3. Insert the plastic disk on the motor's crankshaft into the clear plastic tube.
4. Attach the gripper clip to the pegboard with the short machine screw and flanged wing nut from the hardware package.
5. Fasten the clear plastic tube in the gripper clip so that the tube is vertical and directly over the motor shaft.
6. Turn the motor's flywheel through several revolutions by hand to make sure that the piston remains within the plastic tube and does not show any signs of jamming.
7. When you are satisfied that the piston will run smoothly within the tube, tighten the gripper clip on the pegboard back to hold the tube securely in place.

Figure 2



## Demonstrate the States of Matter

1. Pour all of the magnetic particles into the open top of the plastic tube.
2. Insert the floating piston (the straight rod attached to two plastic disks) into the top of the tube with the disk end facing downward. The floating piston should be free to move up and down.
3. Attach the motor leads to the power supply. **Do not start the motor yet!**
4. Begin with the motor at rest. Notice that the magnetic particles have assumed a rigid alignment suggesting the internal structure of a solid.
5. Turn the power supply on. Start with the voltage at its minimum setting. The low voltage results in low motor RPM.
6. Increase the voltage slightly to speed up the piston.
7. Lift the floating piston up, but don't remove it completely from the tube.
8. Let the floating piston drop back into position in the tube. Increase the voltage until the particles move independently.
9. Increase the voltage one more time.
10. Carefully place a washer on top of the floating piston's upper disk.

# Additional Investigation

## Behavior of a Gas

1. You will now conduct a more detailed study of the behavior of an ideal gas.
2. Remove the magnetic particles from the plastic tube and put them back into their container.
3. Add the small neutral particles to the plastic tube. Open the vial carefully to prevent loss of the particles.
4. Put the floating piston back into the tube.
5. Turn the motor by hand until the drive piston is at its lowest position. Mark the position on the plastic tube with a grease pencil.

6. Rotate the motor by hand until the drive piston is at its highest position. Mark that point also.
7. Using your ruler, find the halfway point between the upper and lower positions. Mark that spot. It will be the baseline for measuring the height of the "gas".

   **Note:** *By marking the highest and lowest positions of the driven piston on the clear plastic tube, an average of these can be used as a baseline to measure the height of the upper piston. The height gives a sense of the volume of the modeled gas since the cross sectional area of the column is a constant.*

8. Measure and record the distance from the baseline to the bottom disk on the floating piston.
9. Connect the voltmeter leads to the two motor terminals. The voltmeter will provide a measurable property that you will use to simulate the "temperature" of the modeled gas.
10. Turn on the power supply at the lowest voltage that will cause the particles to move independently.
11. Read the voltage on the voltmeter and measure the height of the gas. Record both values.
12. Increase the voltage by .5 volts and repeat your measurements.
13. Continue to increase the voltage in .5-volt increments and record your results. Repeat this step until you have from five to eight sets of measurements. Turn off the power supply.
14. Draw a graph of the "temperature" (voltage) vs. "volume" (height) using the data set you just recorded.
15. Add a metal washer to the top of the floating piston. The weight of the washer will be used to model pressure. Repeat steps 10-14.
16. Add another washer and repeat the measurements. Continue adding washers one at a time until all five are on the floating piston.
17. Add the data you collected with the washers to your graph. You should have six lines on the graph, one each for zero through five washers.

# Analysis

## Demonstrate the States of Matter

1. What effect does the moving piston have on the magnetic particles?

   **As the motor begins to turn and the piston moves up and down, the "solid" slowly melts. The particles are still connected to one another, but the collection can assume a variety of shapes.**

2. What effect does increasing the voltage to speed up the piston have on the particles within the tube?

   **As the motor turns faster, the "liquid" being modeled is seen to take up slightly more space.**

3. Describe what happens without the floating piston resting on top of the magnetic particles.

   **During this initial use of the apparatus, the disk above the piston can be raised, as the particles naturally tend to stay close to the piston. Some "evaporation" is noticed as an occasional particle is sent away some distance, only to return to the group as it "condenses."**

4. What phase of matter is represented by increasing the voltage until the particles move independently?

   **At some critical speed of the motor, all of the particles move independently, the upper disk is supported by the bombardment of particles and the "gas" being modeled has a different volume than before.**

5. What effect does increasing the voltage have on the volume of space between the two pistons?

   **A further increase in the motor speed is met with an increase in the volume occupied by the simulated gas.**

6. Describe any changes you observe after placing a washer on top of the floating piston.

   **An increase in the pressure exerted by the disk, by carefully weighting the floating piston with metal washers, will make the volume decrease.**

BEHAVIOR OF A GAS:
Distance from the baseline to the bottom disk:____________________

| No Washers | | |
|---|---|---|
| **Trial** | **Voltage** | **Height of Gas** |
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |

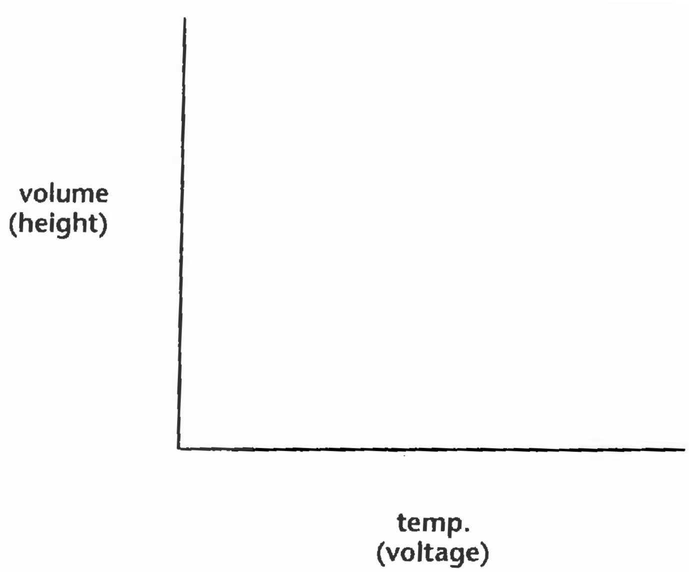
| One Washer | | |
|---|---|---|
| **Trial** | **Voltage** | **Height of Gas** |
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |

| Two Washers | | |
|---|---|---|
| **Trial** | **Voltage** | **Height of Gas** |
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |

| Three Washers | | |
|---|---|---|
| **Trial** | **Voltage** | **Height of Gas** |
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |

| Four Washers | | |
|---|---|---|
| Trial | Voltage | Height of Gas |
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |

| Five Washers | | |
|---|---|---|
| Trial | Voltage | Height of Gas |
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |




7. What effect did adding the washers have on the volume of the gas?

**As more weight is addded to the top of the floating piston, the smaller the gas's volume becomes, even though the kinetic energy (motion) of the particles has not changed.**

# Notes: