

# EXPERIMENTS WITH A 140-mL SYRINGE

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## Pressure-Volume Relationships I: Expanding a Marshmallow

### Materials Required

140-mL syringe with end cap  
mini-marshmallow

### Safety

Wear safety goggles in the laboratory at all times.

Do not try to compress the marshmallow with the syringe. Increasing pressure on the marshmallow will cause the syringe to break.

Do not eat any marshmallows in the laboratory. There is no assurance that the marshmallows are free from chemical contamination.

### Disposal

The marshmallow can be thrown in the trash at the conclusion of this experiment.

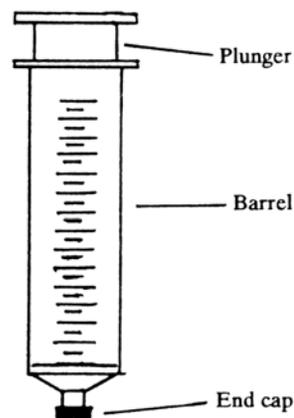


Figure 1. A 140-mL syringe.

### Experimental Procedure

Take the syringe apart. Place one mini-marshmallow in the syringe replace the plunger, pushing it down until it just reaches the marshmallow. Place the end cap on the syringe.

Pull the plunger and observe the marshmallow. If desired, you can repeat this several times.

Remove the end cap, pull the syringe apart, and remove the marshmallow. Observe the marshmallow.

### Explanation

A gas will expand to fill its container. Pulling the plunger of the syringe creates a low pressure inside the syringe (a vacuum). The marshmallow is filled with air. Under reduced pressure, the air expands to fill the container (the syringe) causing the marshmallow to increase in size.

After removing the marshmallow from the syringe, it is observed that the marshmallow is smaller in size than a normal mini-marshmallow. This is a result of air escaping from the marshmallow. (It is slightly deflated.)

## Pressure-Volume Relationships II: Boyle's Law

### Materials Required

- 140-mL syringe with end cap
- Ring stand with clamp or wood block with hole drilled in it or other device to hold syringe in an upright position.
- Weights or books (each should be the same size)

### Safety

Wear safety goggles in the laboratory at all times.

The syringe must be well supported to prevent it from falling over when weights or books are placed on it.

### Experimental Procedure

Withdraw the plunger of the syringe to some position, such as 100-mL. Place the end cap on the syringe and support the syringe in an upright position (plunger on top).

Place a weight or book on the top of the plunger. Read the volume of the air trapped in the syringe and record it. Repeat this procedure with a second I weight or book. Repeat with a third, fourth, fifth, etc... book.

Graph the results using the volume of the gas on the x-axis and the number of books, or weights, on the y-axis.

### Explanation

There is a great deal of open space between the molecules of a gas. When pressure is applied to a volume of a gas, the molecules are compressed (pushed closer together).

The relationship between the pressure of a gas and its volume is known as Boyle's law. It states that, at constant temperature, the pressure times the volume is equal to a constant:  $PV = k$  Thus, if the pressure on a gas is increased, its volume is decreased and if the pressure on the gas is decreased, its volume increases.

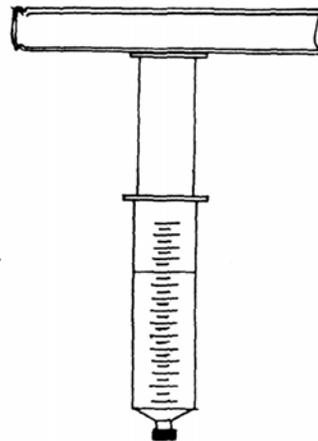


Figure 2. Measuring pressure-volume relationships by placing a book on an upright

# Pressure-Volume Relationships III: Boiling Water

## Materials Required

140-mL syringe with end cap  
water (room temperature or warm)

## Safety

There are no safety hazards with this procedure.

## Experimental Procedure

Draw 20-mL of room temperature or warm water into the syringe. Expel all the air from the syringe. Place the end cap on the syringe.

Pull the plunger and observe the water. What do you observe? Has the temperature of the syringe changed?

## Explanation

Boiling of a liquid occurs when the vapor pressure of the liquid (the tendency of the liquid molecules to change state to a gas) is equal to the atmospheric pressure. Vapor pressure, and the boiling point, are related to the size of the liquid molecules, the mass of the liquid molecules, and the forces of attraction between them. The vapor pressure of a liquid increases as the temperature of the liquid increases until the liquid reaches its boiling point.

Vaporization of a liquid can be demonstrated by pouring a small amount of liquid onto a cotton ball or a small piece of sponge and wiping it on a clean, dry chalkboard. To compare the rates of vaporization (differences in vapor pressure) of several liquids, have several students wipe small amounts of liquid on a chalkboard simultaneously. Some liquids that can be used are acetone (nail polish remover – non-oily type), ethyl rubbing alcohol, isopropyl rubbing alcohol, dry cleaning fluid (naphtha), and water. **Safety Note:** Provide adequate room ventilation for this demonstration.

If the atmospheric pressure above a liquid is reduced, then the liquid can boil at a lower temperature. Less heat, or in many cases, no additional heat will be required to boil the liquid.

# Measuring the Mass of a Gas

## Materials Required

140-mL syringe with end cap  
nail  
gases: natural gas, butane (from a cigarette lighter), carbon dioxide (from dry ice or vinegar and baking soda), oxygen or nitrogen from compressed gas cylinders, etc...  
plastic bag (with twist tie or Zip-Loc type)  
balance (centigram or milligram capacity)  
electric drill with drill bits (to prepare syringe)

## Safety

Wear safety goggles at all times in the laboratory

Some of the gases used may be flammable. Avoid all flames.

Work with adequate ventilation

## Experimental Procedure

### To prepare the syringe

Withdraw the plunger of the syringe to some preset volume such as 100 mL or 140-mL. Mark the plunger, even with the top of the syringe barrel, and drill a hole through the plunger handle large enough to accommodate a metal nail. With the nail inserted in the hole, the plunger cannot be pushed into the syringe barrel but it can still be withdrawn.

### Weighing an empty syringe

Assemble the syringe. Push the plunger all the way into the syringe. place the end cap on the syringe. Pull the plunger out to a preset volume and have someone place a nail through the hole in the plunger. Weigh the syringe. This is the mass of the empty syringe.

### Weighing a gas

Fill a plastic bag with a gas (or use air). Put the syringe tip through the plastic bag and fill it with the gas. Remove the syringe and exhaust the gas. (This flushes the syringe) Insert the syringe back into the plastic bag and fill the syringe to the preset volume. Insert the nail and push the syringe to the "closed" position. Weigh the syringe and gas. Subtract the mass of the empty syringe to get the mass of the gas.

The density of the gas can be calculated by dividing the mass of the gas by the preset volume used in the syringe. Correct the density for standard temperature and pressure.

Calculate the molar mass of the gas.

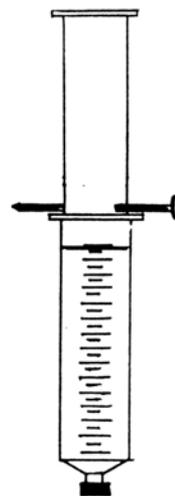


Figure 3. A 140-mL syringe with a nail through the plunger for measuring the mass of a gas.