# TEACHERS GUIDE

## HAND BOILER
ITEM # 2010-10

## ENERGY - HEAT

A classic example of thermodynamics in action! The heat of your hand on the bottom bubble causes the air in the hand boiler to expand, forcing the liquid into the top bubble, making it appear to boil! Glass construction with two bulbs connected by a spiral tube.

# Materials

- hand boilers
- ice
- water
- cups
- aluminum foil
- table salt
- sugar
- cereal bowls
- acetone
- stopwatches

# Goals & Objectives

***See page 7 for National Next Generation Science Standards***

# History

Hand boilers have been marketed as ‘Love Meters”

# Introduction

Demonstrate phase changes, distillation, intermolecular forces, and gas laws with one elegant and simple novelty called the hand boiler.

The volatile liquid appears to boil at the touch of your hand when instead vapor pressure is responsible.

Students can perform a simple distillation experiment by separating the dye from the ethanol. The hand boiler demonstrates evaporation, condensation, vapor pressure, separation of mixtures, and Charles Law (Increased temperature increases pressure). Older students can investigate how solutes affect the distillation rate, and explain how pure ethanol distillate exerts a greater vapor pressure than the dye-ethanol mixture using intermolecular forces of attraction.

# How it works

A closed system of liquid will eventually reach equilibrium with its vapor. That is, if the amount of liquid particles and the amount of vaporous particles will remain constant.

The pressure exerted down on the surface of the liquid is called vapor pressure. Thermal energy from your hand transfers to the liquid and its vapor in the hand boiler. Increased temperatures increase the vapor pressure because the vapor molecules are moving faster and hitting the surface of the liquid more.

The vapor in the hand boiler exerts more pressure on the liquid and the liquid rises up the tube. Once all the liquid is in the top bulb, vapor then rises in the tube and the liquid appears to boil.

# Vocabulary & Assessment

Vocabulary:

- boiling
- Charles Law
- condensation
- distillation
- endothermic
- evaporation
- exothermic
- intermolecular forces
- kinetic energy
- phase changes
- pressure
- temperature
- thermal energy
- vapor pressure

Assessment:

- participation
- vocabulary
- discussion

# Activities

**1** Force all the liquid into the large end and hold the large bulb in your hand. The liquid will rise into the smaller, cooler end and appear to boil.
Ask older students to draw particle diagrams with written explanations to describe this observation. They should include a way to show temperature and pressure differences.

- Is it the vapor or liquid causing the observed motion and "boiling?" (The drawings should show increased temperature results in increased vapor pressure on the surface of the liquid.)

**2** Force all the liquid into the larger bulb and place it in a beaker to hold it upright without touching it. Wrap a cold paper towel around the upper, empty bulb.

- What do you observe? (The liquid appears to defy gravity and rises into the upper bulb and appears to boil again despite the fact that it is cold).

Force all the liquid into the bottom large bulb again and place in the beaker. Drop a couple drops of acetone on the upper, smaller, empty bulb.

- What happens? Ask students to explain using how evaporation works and how it affects the hand boiler.
- How is this similar to the effects of sweating during exertion?

**3** Not everyone has the same core body temperature. Have races to see who is the hottest. After several races the hand boilers will slow and then stop working.

- Why? (The liquid and vapor are now the same temperature as your hands – it must be cooler again in order to create the temperature differential needed between the two bulbs for the vapor pressure in the two bulbs to charge).
- You can ask students to use stop watches to time it and wait until they observe something is "wrong" to continue the discussion.

**4** Distillation – separation of solid dye from liquid ethanol. Transfer all of the colored liquid into the large lower bulb. Turn the hand boiler over. The liquid does not drain into the other bulb due to the tube

***Note**

It is always best to DO an experiment ahead of time to be able to best present it to the class.

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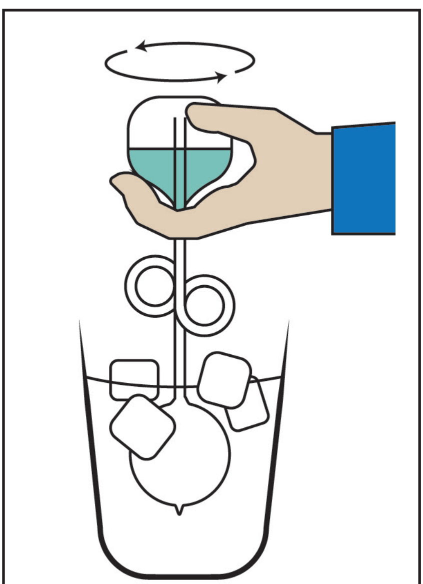
# ACTIVITIES

extending so far into the bottom (now upper) bulb. Cup the hand boiler in your hand and immerse the lower bulb into the cup of ice water as shown below.
Observe that the upper bulb becomes very cold as the boiler is set into the ice water. Gently swirl the bulb and continue to warm it with your cupped hand.
Better yet, pass the hand boiler and cup of ice water around to let other students with warm hands heat up and swirl the top bulb.

Observe that after only a few seconds, clear ethanol distillate condenses in the lower bulb. After 10–20 minutes all that is left in the top bulb is solid dye with clear distillate in the bottom bulb



**a** As a variation, add salt to the ice water in a student group (will make the distillation go faster).
Have the groups time how long the distillation takes with stopwatches.

Give a group sugar to add to the water and time that distillation. Compare the times it takes for all three distillations and discuss the results as a class.

Prior to collecting data discuss the following questions:

- Which experiment is the control?
- What are the dependent and independent variables?
- What variables need to be constant?

**5** Ask high school students to explain the results using intermolecular attractions between the solute and solvent particles, and colligative properties (freezing point depression).

Have a couple groups stop their distillation (by removing it from the ice bath) just before it is complete with varying amounts of ethanol still in the top with the dye.
Place each hand boiler in beakers with the clear ethanol distillate at the bottom.

Include one hand boiler that has gone to completion with the dye at the top.

*continued on page 6*

# Activities

### Student Activities *continued*

5. Ask students to predict what will happen now. (It will stop).
   - What will happen in the next 24 hours?
   - The next few weeks?
   - Which will reverse faster?

   Over the next few days and weeks – have students make observations of the liquid levels.

   Ask high school students to explain using intermolecular forces of attraction again. (The pure ethanol distillate evaporates faster because of lower intermolecular forces of attraction on the sure of the liquid as compared to the dye solution.)

# Discussion

### Additional Discussion and Real Life Applications

1. How do temperature, pressure, condensation, vaporization, vapor pressure influence our weather?
2. How do hot air balloons work?

# Next Generation Science Standards

**Students who demonstrate understanding can:**

**2-PS1-4.** Construct an argument with evidence that some changes caused by heating or cooling can be reversed and some cannot.

**4-PS3-2.** Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

**5-PS1-1.** Develop a model to describe that matter is made of particles too small to be seen.

## Standards Key

**K** = Kindergarten
**3** = 3rd Grade
(numbered by grade)
**MS** = Middle School
**HS** = High School
**PS** = Physical Science
**LS** = Life Science
**ES** = Earth Science

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**MS-PS3-4.** Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.

**MS-PS3-5.** Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

**MS-PS1-4.** Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

**HS-PS3-2.** Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).

**HS-PS1-3.** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.