

Closed-System Distillation Apparatus

Phase Changes and Phase Diagrams

Introduction

A hand boiler is a completely closed glass container made of two bulbs connected by a looped piece of tubing. Within the hand boiler is an ethanol-dye solution. You can perform a simple distillation on this system with just a warm hand and a cup of ice water.

Concepts

- Distillation
- Vapor Pressure

Materials

Hand Boiler

Ice Water in a cup

Safety Precautions

Handle the hand boiler carefully—it is easily broken. Students should wear goggles at all times in the chemistry lab. Ethanol is flammable and poisonous by ingestion.

Procedure

1. Transfer all of the colored liquid into the large lower bulb. This may take some effort due to the bends and loops in the glass tube, but the demonstration works best when all of the colored liquid is in the lower bulb.
2. Turn the hand boiler over as in Figure 1. The liquid does not drain into the other bulb due to the tube extending so far into the bottom (now upper) bulb.
3. Cup the hand boiler in your hand as shown in Figure 2 and immerse the lower bulb into the cup of ice water. Observe that the upper bulb becomes very cold as the boiler is set into the ice water.
4. 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.
5. 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 (see Figure 3).

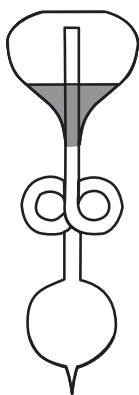


Figure 1.

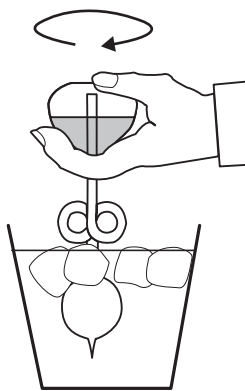


Figure 2.

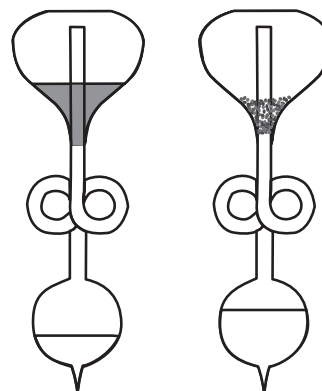


Figure 3.

Discussion

The pressure of a gas in equilibrium with its liquid phase is the vapor pressure of the liquid. Vapor pressure is a physical property that indicates the tendency of molecules in the liquid phase to escape.

In the case of the hand boiler, when the bottom bulb is cooled the vapor pressure of the ethanol inside the bottom bulb is lowered. In other words, the tendency of the ethanol to exist as a vapor is *decreased*. The opposite effect occurs in the upper bulb. The warmth from the hand increases the vapor pressure of the ethanol in the upper bulb. The tendency of the ethanol in the upper bulb to exist as a vapor is *increased*. The ethanol therefore quickly vaporizes in the upper bulb and condenses when it reaches the cool lower bulb. The dye molecules cannot evaporate so they remain in the upper bulb.

Distillation is a very common procedure in the organic chemistry lab. It is often used to separate mixtures of solids and liquids, and even two or more liquids. The separation of the solid dye from the ethanol in this lab is simple and quick and it serves as a great introduction to the many distillations students will perform as they go on in chemistry. In this distillation, the air is evacuated from the distillation apparatus, thereby speeding up the vaporization of the ethanol.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12

Evidence, models, and explanation
Constancy, change, and measurement

Content Standards: Grades 5–8

Content Standard B: Physical Science, properties and changes of properties in matter, transfer of energy

Content Standards: Grades 9–12

Content Standard B: Physical Science, structure of atoms, structure and properties of matter, chemical reactions, interactions of energy and matter

Acknowledgment

Special thanks to Jenna Becker and her father Bob Becker of Kirkwood, MO for providing the instructions for this activity. It was Jenna's discovery of the separation of the dye and the ethanol that made this demonstration possible.

References

Becker, B. *Twenty Demonstrations Guaranteed to Knock Your Socks Off—Volume II*; Flinn Scientific: Batavia, IL, 1997.
Ouellette, R. J. *Introduction to General, Organic, and Biological Chemistry*; Macmillan: New York, 1992.

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Closed-System Distillation Apparatus* activity, presented by Bob Becker, is available in *Phase Changes and Phase Diagrams* and in *Teaching with Toys*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Closed-System Distillation Apparatus* are available from Flinn Scientific, Inc.

| Catalog No. | Description |
|-------------|-------------|
| AP9293 | Hand Boiler |

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.