# Simple Distillation

Separation of a Mixture

## Introduction

Distillation is a process for the purification or separation of the components in a liquid mixture. The mixture is heated to evaporate the volatile liquid components, and the vapor is then condensed to a liquid. How does the composition of the liquid that is collected (called the distillate) differ from the composition of the original liquid?

## Concepts

- Distillation
- Evaporation and condensation
- Boiling point
- Separation of a mixture

## Materials

Water
Boiling stones
Bunsen burner
Buret clamps, 2
Distillation apparatus* or Distilling flask, condenser, receiving flask, and adapters†
Food coloring
Fruit juice (optional)
Ring (support) stands, 2
Rubber tubing, 2 pieces
Stopcock grease (optional)
Thermometer

*See the *Tips* section.

†Follow the optional instructions in the *Procedure* section if using separate condensers and adapters.

## *Safety Precautions*

*Use care when working with a Bunsen burner and hot glassware. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron.*

## Procedure

1. Fill the distilling flask about one-half full with water and add several drops of food coloring to obtain a suitably dark-colored mixture. Add two boiling stones to the flask.
2. Attach rubber tubing to a faucet and connect the tubing to the bottom arm of the condenser. Attach a second piece of rubber tubing to the upper arm of the condenser and place the end of the tubing into the sink.
3. Set up the distillation apparatus as shown in Figure 1:

   *a.* Clamp the distilling flask to a support stand. Adjust the height of the distilling flask so that it will sit above the TOP of the Bunsen burner flame (see step 7).

   *b.* Place the one-piece, custom distillation head (or the three-way adapter) into the distilling flask (see Figure 1).

   *c,* Place the thermometer holder into the adapter and insert the thermometer so that the thermometer bulb is just below the side arm in the three-way adapter.

   *d,* Clamp the receiving flask into position as shown in Figure 1.
4. *(Optional)* Place the outlet adapter on the end of the condenser, insert the condenser into the three-way adapter, and clamp the outlet adapter to a support stand.

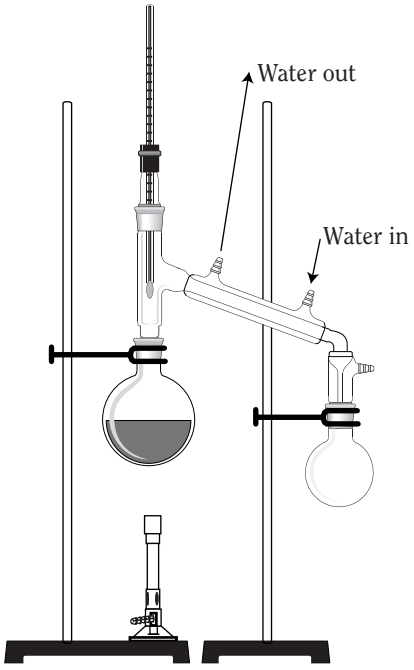


**Figure 1.** Custom Distillation Apparatus.



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5. *(Optional)* Place an Erlenmeyer flask beneath the outlet adapter. If a round-bottomed flask is used, it must be clamped into position.
6. Turn on the faucet and run water through the condenser. *(Remember, water goes in the bottom and out the top of the condenser. The condenser should feel cold to the touch.)*
7. Light the Bunsen burner and heat the distilling flask in the very top of the Bunsen burner flame. *(The water will begin to boil in about one minute.)*
8. Observe the temperature change as the vapor rises in the distillation apparatus and the temperature of the vapor increases. *(The temperature will begin to rise very rapidly. When liquid droplets condense on the thermometer bulb, the temperature increase will begin to level off and will eventually stabilize.)*
9. Observe the boiling point range and the color of the liquid that collects in the receiving flask. *(The vapor is converted to liquid in the condenser and the "distillate" is collected in the receiving flask. The temperature range over which the distillate is collected is the observed "boiling point" for the liquid. Water will usually distill in the boiling point range 99–101 °C. The water is clear and colorless—the food dye is a nonvolatile component and will not co-distill with the water.)*
10. Collect distillate as time permits while discussing the principles of distillation. *(In a typical setup, about 10–15 mL of water will distill in a five-minute period.)*
11. Turn off the Bunsen burner and allow the glassware to cool before dismantling the distillation apparatus.

## Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. The water may be washed down the drain according to Flinn Suggested Disposal Method #26b.

## Connecting to the National Standards

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

***Unifying Concepts and Processes: Grades K–12***
Constancy, change, and measurement
Evolution and equilibrium

***Content Standards: Grades 5–8***
Content Standard B: Physical Science, properties and changes of properties in matter
Content Standard F: Science in Personal and Social Perspectives, populations, resources, and environments; science and technology in society

***Content Standards: Grades 9–12***
Content Standard B: Physical Science, structure and properties of matter, interactions of energy and matter
Content Standard F: Science in Personal and Social Perspectives, natural resources, science and technology in local, national, and global challenges

## Tips

- The "Organic Distillation Set" available from Flinn Scientific (Catalog No. AP6351) is a low-cost, easy-to-assemble distillation apparatus. The set contains two round-bottomed flasks (the distilling and receiving flasks), a one-piece, custom distillation head (three-way adapter, condenser, and outlet adapter), and a rubber thermometer holder. Please consult your current *Flinn Scientific Catalog/Reference Manual* for other types of distillation glassware.
- Never heat a closed system! The vacuum arm on the outlet adapter must be open to the air (except during a vacuum distillation). If the outlet adapter does not have a vacuum arm, then the adapter should be positioned inside the opening of the flask—do NOT insert the adapter into a closed flask.
- A Bunsen burner or heating mantle may be used for the distillation of water. Most organic liquids are flammable—never use a Bunsen burner as the heat source when distilling organic liquids.
- Other nonvolatile components may be added to the mixture to demonstrate that the observed temperature range at which

water distills is the boiling point of the pure liquid, not the boiling point of the mixture. (For a concentrated salt solution, although a higher temperature will required to boil the liquid in the flask, the thermometer records the temperature at which the vapor and the *condensing* liquid are in equilibrium.)

- For an interesting variation, distill fruit juice or soda.
- Ethyl acetate (boiling point 77 °C) may be used to show the distillation of an organic liquid. Ethyl acetate is a flammable liquid and a dangerous fire risk—use a boiling water bath on a hot plate as the heat source. The indicator thymol blue may be added to color the solvent yellow. The distillate will be colorless.
- Demonstrating the principles and practice of distillation offers a great opportunity for discussing the role of science and technology in managing our natural resources. (Content standard F in the National Science Education Standards). See the Discussion section.

## Discussion

The process of vaporizing a liquid in one vessel, condensing the vapor, and then collecting the condensate in a separate vessel is called distillation. Distillation is used in organic chemistry labs and in the chemical process industry (e.g., petroleum refining) to purify compoundsand to separate the components in a mixture. It is also the oldest and still most widely used technology for desalination (removing salt from saltwater). Simple distillation provides a perfect opportunity to develop student understanding of the role of science and technology in utilizing and managing our natural resources. Distillation is an essential technique for obtaining drinking water from seawater.

The use of distillation to separate the components in a mixture is based on the principle that the liquid in the boiling flask and the vapor have a different composition. When a mixture of several liquids (or of a liquid containing dissolved solids) is heated to its boiling point, the vapor will have a higher concentration of the more volatile component(s) of the liquid. When this vapor is condensed and collected in a separate flask, the distillate will also be enriched in the more volatile component(s) of the mixture. Simple distillation involves a single vaporization–condensation cycle. Simple distillation is used to purify liquids that contain either nonvolatile impurities, such as salts, or very small amounts of higher- or lower-boiling liquids. Fractional distillation is used to separate liquid mixtures where the components have similar boiling points and/or are present in comparable amounts. In fractional distillation, insulated fractionating columns permit multiple vaporization–condensation cycles in a single operation. The column consists of closely spaced "plates" or packing material. The vapor condenses on multiple surfaces in the fractionating column, and the resulting liquid revaporizes. At each stage in the series of vapor–liquid equilibrium, the vapor becomes more enriched in the more volatile (lower-boiling) component. Given a sufficient number of "plates," the mixture will distill in fractions, each fraction consisting of only a single pure substance.

## Reference

This activity was adapted from *Elements*, *Compounds*, *and Mixtures*, Volume 2 in the *Flinn ChemTopic™ Labs* series; Cesa, I., Editor; Flinn Scientific: Batavia, IL (2005).

## Materials for *Simple Distillation* are available from Flinn Scientific, Inc.

| Catalog No. | Description |
|---|---|
| AP6351 | Organic Distillation Set |
| GP7033 | Boiling Stones/Beads, Solid |
| V0003 | Food Coloring, Set of 4 |

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