Student Activity
Chemical Engineering: Desalination and Variables in Science
Companion Web page:
http://www.chemheritage.org/classroom/chemach/engineering/index.html

Introduction and Historical Context

Humans cannot drink salt water, but salt water can be turned into fresh water. This process is called *desalination*. Water desalination is important because most of the water on Earth is salty and unfit to drink. In many parts of the world, like the Middle East and the western United States, fresh water is in short supply, and desalination gives us a way to turn undrinkable salty ocean water into fresh water that people can drink.

A chemical engineer's job is to do chemistry on a really big scale. A desert city like Los Angeles uses an awful lot of fresh water each day, obviously more than could be produced in a small apparatus like the ones you will use in this experiment. An lot of seawater would have to be desalinized to meet the city's needs, and apparatus the size of factories would be needed.

Donald Othmer was an important chemical engineer, and he had a lifelong fascination with desalination. He hoped to build large desalination plants that could provide whole cities with fresh water. Othmer invented several clever ways to turn salt water into fresh water. However, other methods of desalination have become more common.

The most common way to turn salty seawater into fresh drinking water is called reverse osmosis. The process is really simple. Seawater is forced through a membrane (a kind of thin film) with tiny holes in it. The holes are very small and allow water molecules to pass through them, but the sodium ions and chloride ions that make up salt are not allowed to pass through. Reverse osmosis works well; Saudi Arabia, a country that is mostly desert, gets most of its drinking water through this process.

But reverse osmosis has one drawback. It takes a lot of energy to force salt water through the membrane. If that energy comes from fossil fuels, greenhouse gases like carbon dioxide will be produced. What is more, fossil fuels are becoming more expensive. It is no wonder that desalinization is widely used in Saudi Arabia—a wealthy country with lots of oil—but not so widely used in other places.

A method of desalinizing water that uses solar power would be a good solution to these drawbacks. In desert climates where desalination is most useful, there is usually plenty of sunshine to provide solar power. The apparatus you will use in this experiment is a simple device for using solar energy to drive desalination. Scaling up a small apparatus into a giant plant that can desalinate enough water for a city would be a huge challenge, the kind of challenge that requires skilled and clever chemical engineers.

Purpose

In this activity you will learn how to remove salt from salt water to produce fresh water. In the apparatus you will use, a small beaker of saltwater solution is placed inside a larger beaker sealed with plastic wrap. The whole apparatus is then placed in the sun. When the saltwater

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solution gets warm, the water in it will evaporate, but the salt will not. Some of the water vapor that is produced will condense on the inside of the larger beaker. Because the salt did not evaporate with the water, the water that condenses will be fresh.

You will also learn an important scientific skill in this experiment: how to work with variables. In many experiments that scientists do, they are trying to discover whether two events are related to each other. For example, a biologist might ask whether plants grow in the dark as well as they do in the light. We might ask, “Does the amount of light affect the growth of plants?” Another way of asking the question would be, “Is there a relationship between the amount of light and the growth of plants?” In this example there are two things that can be varied—the rate of growth of the plant and the amount of light it gets. The rate of growth and the amount of light are called variables. In this example, the amount of light is called the **independent variable,** and the rate of growth is called the **dependent variable**. We control the independent variable and try to find out whether the other variable depends on it.

In the example above we really want to know what happens to the growth of plants if we vary the amount of light they get. In most experiments there is one variable, the independent variable, that the scientist varies intentionally in order to find the effect of that variable on the other one (the dependent variable). But suppose in the experiment that one plant was watered and the other one was not watered, in addition to getting different amounts of light. When the experiment is over, we would not know whether any difference in the growth of the plant was due to the amount of light it received or the amount of water it received.

Scientists try to control all the variables in an experiment except one. That means they try to keep all conditions constant except one—the one they are studying. In the example above the amount of light was the variable that was being studied. Changing how the plants were watered would introduce a second variable into the experiment that would prevent the scientist from finding a clear answer to the question. In a good experiment only one variable is allowed to change. The other variables are held constant.

In this activity you will do an experiment that has three variables. In this experiment only one variable is allowed to change at a time.

Safety

- You should never taste any material you work with in the laboratory. Do not try to test whether the water you collect is fresh or salty by tasting it.
- The heat lamps used in this experiment get very hot. Do not touch the bulbs.

Materials and Apparatus

Consumables

NaCl
Water

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Non-consumables

1,000-mL beakers
500-mL beakers
Saltwater solution
Plastic wrap
Rubber bands
Heat lamps
50-mL beakers
25-mL beakers
10-mL graduated cylinders
Black construction paper
Scissors
Adhesive tape
Electrical conductivity apparatus

Pre-Lab Questions

1. What happens to a glass of water when it is left in the sun?
2. What happens to a pile of salt when it is left in the sun? Does the salt behave like the water in this situation?
3. Water evaporates from the ocean and becomes water vapor, which forms clouds and then falls back to the earth as rain. If the rainwater originally came from the ocean, why isn't rainwater salty like ocean water?
4. Which conducts electricity better: salt water or fresh water?
5. What is a variable in a scientific experiment?
6. What are the independent variables in this experiment?
7. What is the dependent variable that you will measure in this experiment?
8. What is a control in a scientific experiment?

Procedure

1. Make predictions about how you think the amount of fresh water you will collect in your apparatus will vary with each of the following variables:
    a. size of the smaller beaker holding the salt water,
    b. size of the larger collection beaker, and
    c. whether or not you wrap your apparatus in black construction paper.

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2. Devise a plan to test each of your team's predictions. Include in your plan several experiments, using several apparatuses. You will have all the materials you need to build the apparatus for carrying out your experiments.

3. After your plan is approved by your teacher, carry it out. For each experiment you carry out, use the following procedure for building and operating the desalination apparatus. You will need to make a separate apparatus for each experiment

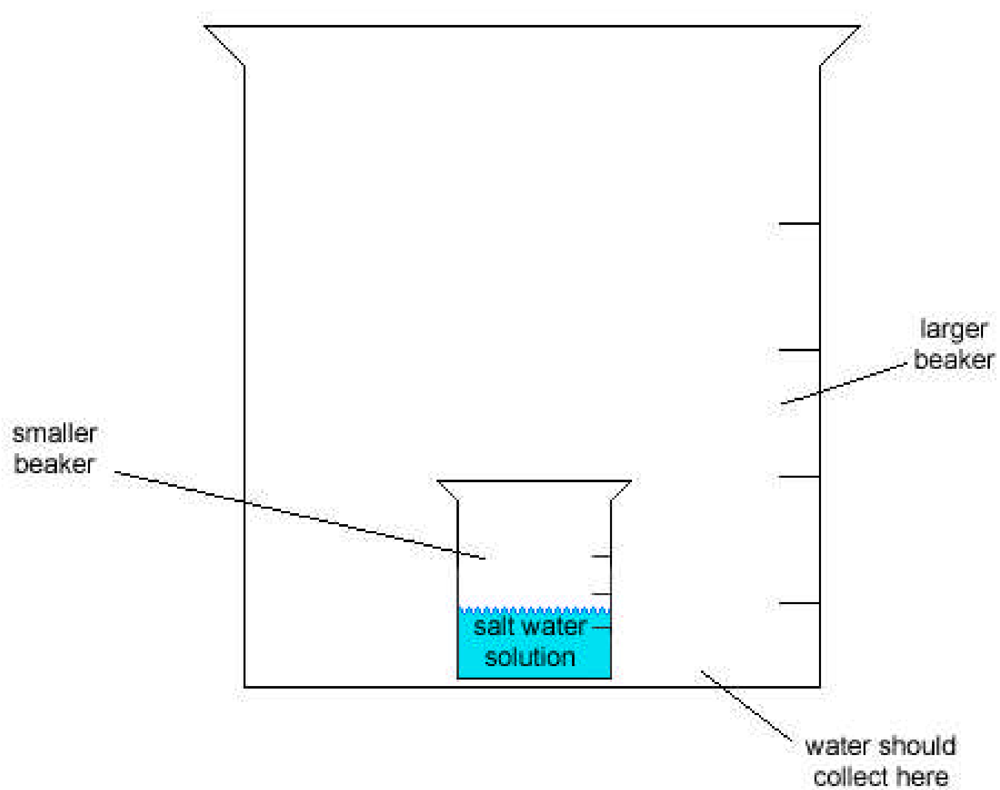
   a. Measure 10 mL of saltwater solution in a graduated cylinder.

   b. Pour the 10 mL of saltwater solution into the smaller beaker (25- or 50-mL).

   c. Test the electrical conductivity of the saltwater solution using a conductivity apparatus, as instructed by your teacher. Record the conductivity.

   d. If your plan calls for it, wrap the sides of the large beaker (500 or 1,000 mL) in black construction paper, and use adhesive tape to hold the paper in place. Cut the paper down to size to fit your beaker if necessary. The paper should not be higher than the lip of the larger beaker.

   e. Place the smaller beaker of saltwater solution into a larger beaker (500 or 1,000 mL) as shown in the image below.



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f. Completely cover the top of your beaker with plastic wrap. Secure the plastic wrap with a rubber band.

g. Place your apparatus outside in sunlight in a safe place as instructed by your teacher. Leave the apparatus overnight.

h. The next day observe your apparatuses, and record any changes you notice.

i. Bring your apparatuses inside. For each apparatus remove the plastic wrap, and carefully take the smaller beaker out of the larger beaker. Caution! It is important that you don't spill any of the saltwater solution in the smaller beaker into the water that has collected in the bottom of the larger beaker.

j. Pour the water in the bottom of the larger beaker into a graduated cylinder. Record the volume of water you collected from each experiment.

k. Test the electrical conductivity of the water you collected using the conductivity apparatus as instructed by your teacher. Record the conductivity and compare it with the electrical conductivity of the salt water you measured the day before.

Post-Lab Questions

1. Did you collect the same amount of water in each experiment you carried out?
2. If there was a difference, in which experiment did you collect the most water?
3. Did you use a control in your experiments? If so, which experiment was your control?
4. How did the amount of water you collected vary with the size of the smaller beaker that held the salt water?
5. How did the amount of water you collected vary with the size of the larger beaker in which you collected the fresh water?
6. How did the amount of water you collected vary depending on whether you wrapped your apparatus in black construction paper?
7. Based on your results, would you expect to collect more or less water in your apparatus if you used a 100-mL beaker as the smaller beaker for holding the saltwater solution?
8. Based on your results, would you expect to collect more or less water in your apparatus if you used a 250-mL beaker as the larger outer beaker for collecting the water?

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9. Which showed greater electrical conductivity, the salt water you put into the apparatus or the water you collected the next day? Do these results suggest that the water you collected was fresh or salty?

Extension Questions

1. Suppose you tested a desalination apparatus using a 500-mL outer beaker and a 25-mL inner beaker. Let's say you also test a desalination apparatus using a 1,000-mL outer beaker and a 50-mL smaller beaker. Could these two experiments tell you how the sizes of both beakers affect the amount of fresh water collected in a given time? Why or why not?

2. Why do you think the black construction paper had the effect that it did?

3. In this investigation you were trying to find out how three variables affect the experiment. Can you think of any additional variables that could have been tested in this experiment? List them.

4. Using the main idea about variables in an experiment, complete the following statement. "In a well-designed experiment . . . "

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