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

Procedure
The activity should be carried out in teams of three or four students. Each team will design their own method of testing how each variable affects the amount of water collected in one day. The student teams should bring you their proposed methods for approval before carrying them out. A good method should involve building one control apparatus and three experimental apparatuses, in which only one of the variables has been changed from the control apparatus.

The saltwater solution should be prepared ahead of time. Preparing it yourself eliminates sodium-chloride concentration as a variable in the experiment. The exact concentration is not important, but a 3% to 4% sodium-chloride solution will roughly approximate the salinity of seawater.

This procedure calls for 1,000-mL and 500-mL beakers, but if you don't have enough large beakers (each team will need at least four large beakers), a soft-drink bottle will work well enough. By cutting the top off a 2-L plastic soft-drink bottle, you can make a "beaker" that is pretty close in size to a 1,000-mL one, and a 1-L bottle can give you something close to a 500-mL beaker. Soft-drink bottles have a nice advantage over proper beakers in that the "feet" of the bottle serve as collection reservoirs for the fresh water.

The apparatus should not take students very long to build. The major time consumer is letting the apparatuses sit outside for 24 hours. In addition, using solar power requires that you do the experiment on a sunny day and can find a place to put the apparatuses where they will be safe from people, animals, etc.

As an alternative, heat lamps work rather well. A 50-W floodlight bulb in a reading lamp also works well. However, you will need several lamps, as a lamp can only heat one apparatus at time. You may choose to have each group carry out only one experiment altering one variable, and then pool the class data. This method requires the experimental-design phase of the student procedure to be carried out as a whole-class activity. In addition, the bulb should be a safe distance above the plastic wrap, and you should not leave the apparatus under the lamps unattended. This should not be a hindrance: under a heat lamp several milliliters of water can be desalinized in just a few hours, and then you won't need to run the experiment for a whole 24 hours.

The water collected should be tested for electrical conductivity to determine whether it is fresh rather than salty. For safety reasons students should not test their collected water or the sodium-chloride solution by tasting.

The size of the smaller beaker affects the rate at which water is desalinized because the surface area of the sodium-chloride solution will be greater in the 50-mL beaker than in the 25-mL beaker. The greater the surface area of a liquid is, the faster the rate of evaporation. (Keep

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in mind that what we are really measuring here is the *rate* of evaporation, as the experiment is stopped after 24 hours.) Wrapping the apparatus in black construction paper can increase the amount of water collected, since it will lead to more solar heat being absorbed by the apparatus, increasing the rate of evaporation. Our tests showed a larger amount of water when using a smaller beaker for the outer collection beaker.

It should be stressed that while students are measuring the volume of water they collect, what they are really gauging is the *rate* at which water is desalinized when the various variables are manipulated. The experiment is not meant to investigate how the variables would affect the outcomes of the experiments were the systems allowed to reach equilibrium.

While the focus of this activity is learning how to manipulate variables in a scientific manner, the experiment also illustrates some scientific knowledge as well. Desalination is a separation, and like all separations it depends on a difference in the properties of the two substances being separated. This particular separation works because water evaporates, while sodium chloride does not. At the high-school level you may choose to point out that this difference is the result of water being made of covalently bonded molecules, while sodium chloride is an ionic compound.

Student Skills Required
Only general lab skills are required.

Answers to Pre-Lab Questions

1. What happens to a glass of water when it is left in the sun?

   Answer: The water evaporates.

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?

   Answer: Unlike water, salt will not evaporate.

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?

   Answer: Water evaporates from the ocean, but salt does not, so water is desalinized when it evaporates.

4. Which conducts electricity better: salt water or fresh water?

   Answer: Salt water conducts electricity better than fresh water.

5. What is a variable in a scientific experiment?

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Answer: A variable is an experimental condition that is altered during an experiment.

6. What are the independent variables in this experiment?

   Answer: The size of the smaller beaker, the size of the larger beaker, and whether black construction paper is used are independent variables in this experiment.

7. What is the dependent variable that you will measure in this experiment?

   Answer: The dependent variable is the amount of water collected in the apparatus.

8. What is a control in a scientific experiment?

   Answer: A control is an experiment in which none of the variables are altered. In subsequent experiments in which variables are altered, the results are compared with the results of the control experiment.

Answers to Post- Lab Questions

1. Did you collect the same amount of water in each experiment you carried out?

   Answer: Student answers may vary, but in general more water will be collected using the 50-mL beaker (small one).

2. If there was a difference, in which experiment did you collect the most water?

   Answer: Student answers will vary, but apparatuses using a 50-mL beaker, black construction paper, or a combination of the two will give the best results.

3. Did you use a control in your experiments? If so, which experiment was your control?

   Answer: Student answers will vary.

4. How did the amount of water you collected vary with the size of the smaller beaker that held the salt water?

   Answer: The 50-mL beaker should lead to more water being collected than the 25-mL beaker.

5. How did the amount of water you collected vary with the size of the larger beaker in which you collected the fresh water?

   Answer: The 500-mL beaker should lead to more water being collected than with the 1,000-mL beaker.

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6. How did the amount of water you collected vary depending on whether you wrapped your apparatus in black construction paper?

   Answer: Black construction paper should increase the amount of water collected.

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?

   Answer: Based on experimental results, the 100-mL beaker should lead to more water being collected than that in either a 25- or a 50-mL beaker.

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?

   Answer: Based on experimental results, the 250-mL beaker should lead to more water being collected than with either a 500-mL or a 1,000-mL beaker.

9. Which showed greater electrical conductivity: the saltwater solution 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?

   Answer: The collected water should have much lower conductivity than the original saltwater solution.

Assessment

1. As an authentic assessment you can ask students how they might experimentally test the effects of such changing variables as salt concentration, the length of time the apparatus is exposed to sunlight, etc.

2. You can use the post-lab questions as an assessment tool.

Answers to 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?

   Answer: Two variables were changed in this experiment, so it would not tell you how each variable affected the amount of water collected because you can't know how each variable contributed to the outcome independently of the other.

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

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Answer: Dark-colored objects tend to absorb heat better than light-colored objects, so the black construction paper allows the apparatus to absorb more heat from the sun, making water evaporate faster.

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.

   Answer: Other possible variables include the outside air temperature during the experiment, the original concentration of salt water, and the distance between the salt water and the heat lamp, if a heat lamp is used.

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

   Answer: Student answers will vary, but they may read something like this: "In a well-designed experiment a control is used, and only one variable is changed in each test."

Additional Teacher Resources

"Seawater Desalination in California**"**—extensive tutorial on desalination from the State of California Coastal Commission (http://www.coastal.ca.gov/desalrpt/dchap1.html).

"Thirsty? How 'Bout a Cool, Refreshing Cup of Seawater?**"**—part of "Water Science for Schools" from the U.S. Geological Survey (http://ga.water.usgs.gov/edu/drinkseawater.html).

References

1. Donald F. Othmer, oral history, conducted by James Bohning, 2 April 1986, 11 June 1986, and 15 January 1987, Chemical Heritage Foundation, Philadelphia.

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