Designing and Testing a Device to Thaw a Watering Station

A Carolina Essentials™ Design Challenge

Student Worksheet

Overview

You are going to participate in a design challenge to make sure the water in recessed watering stations of a small mammal habitat in a zoo remains liquid. As night falls and the temperature drops below 28° F (-2.2° C), the water ices over. You will apply the concepts of heat transfer and heat released or absorbed by chemical reactions to solve this problem.

Phenomenon

Observe the teacher demonstration and record the following data.

Initial water temperature: _____

Final water temperature: _____

Change: _____

Why did the temperature change?

How did you explain the temperature of the water decreasing in the phenomenon activity? Many ionic compounds, salts, dissolve in water to form a crystal structure, but no new compound is formed. The gain or loss of energy involves a three-step process.

Consider the energy involved when sodium chloride (table salt) dissolves in water:

- **Step 1:** Energy is absorbed to break the *intramolecular forces* holding the sodium ions and chloride ions together (**endothermic**).
- **Step 2:** Energy is absorbed to break the *intermolecular forces* of the hydrogen bonds between water molecules (**endothermic**).
- **Step 3:** Energy is released when the solute-solvent bonds in solution form (**exothermic**).

If **Step 3 < Step 1 + Step 2**, then endothermic process and the solution temperature *decreases*.

If **Step 3 > Step 1 + Step 2**, then exothermic process and the solution temperature *increases*.

Use this information and what you know about heat transfer to complete the design project.

SAFETY REQUIREMENTS

MATERIALS

Product Design

Graduated cylinder, 100 mL

Plastic beaker, 250 mL

Electronic balance

Digital thermometer

Calcium chloride, 100–150 g

Deli container, 4 1/2 in

Foil tart pan, 4 7/8 in

Resealable plastic bags, various sizes

2 × 3 in
3 × 4 in
4 × 6 in
6 × 9 in

Weigh boats

Plastic spoons

Insulating materials (cotton balls, newsprint, pillow stuffing, foam cups, packing peanuts, and other materials you may suggest)

Tap water

Continued on the next page.

Scenario

You work at a zoo in the upper Midwest of the United States and manage a small mammal habitat. Many of the animals there are nocturnal. The animals' drinking water often freezes during the late fall through early spring, when the nighttime temperature falls below 28° F (-2.2° C), making it impossible for the animals to drink.

- The watering stations are concrete, with recessed holes, constructed in the ground, trees, and rocks.
- The holes are 4 3/4 inches in diameter and hold 7-ounce aluminum dishes that are 4 7/8 inches in diameter.
- The water is replenished twice a day, in the morning and late evening. The dishes are usually filled to the top.

You have been asked to design an inexpensive device that can quickly thaw the water or prevent it from freezing overnight. The device must fit the recessed holes and the watering tray must fit in the device. The materials supplied fit the specifications.

Chemicals may be used but **no chemicals may be added directly to the drinking water**. You must supply 2 sets of data:

- Set 1 should show how long the device takes to melt 150 mL of frozen water.
- Set 2 should show how long the device can prevent 150 mL of water from freezing.

The device will be judged on how quickly it can thaw frozen water, how long it can prevent freezing, and its cost. For the final presentation, you must supply design pictures, a materials list, test data, and cost.

Essential Question

How can chemical processes be used for heat transfer?

Objective

Design, test, and improve a device that can prevent the freezing of water in a watering station.

Activity Procedures

Guided Research: Dissociation of Calcium Chloride

1. In a weigh boat, measure 12.0 g of calcium chloride ($CaCl_2$).
2. In the graduated cylinder, measure 100 mL of water and pour it into the beaker.
3. Take the temperature of the water and record it in the data table.
4. Add the $CaCl_2$ to the beaker and stir gently with the spoon while taking the temperature.
5. Record the highest temperature reached.
6. Repeat the same procedure with 6.0 g of $CaCl_2$ and 100 mL of water.

Data Table

Exothermic Reaction

$CaCl_2$ (g)	Initial Temperature (°C)	Final Temperature (°C)	Change in Temperature (°C)
12.0			
6.0			

Engineering Design Project

1. Review the project specifications above.
2. Complete the design and testing phases using the Carolina™ Engineering and Design Process Worksheet.
3. Share your final design and data with the class.

Analysis and Discussion

Present your final design with supporting evidence to the class. Use the engineering worksheet and project specifications for the basis of the presentation.