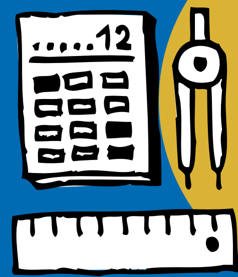
TGR EDU:
EXPLORE



MIDDLE SCHOOL

SENSITIVE DELIVERY

Mindset
Method
Mastery

TGR FOUNDATION
A TIGER WOODS CHARITY
Discovery EDUCATION

LESSON OVERVIEW:

Advances in packaging materials and self-heating and self-cooling technologies have a great impact on our food systems. In this lesson, students will use the Engineering Design Process to solve a real-world problem. A hospital cafeteria has been receiving feedback from patients that their soup is cold and their ice cream has melted by the time it reaches their room. Because of the large size of the hospital, and the fact that many patients are in therapy when their food arrives, the hospital catering team would like to design a "lunch box" that can keep the patients' hot foods hot and their cold foods cold for up to two hours.

Students will form teams and brainstorm the lunch box design process from the vantage of several careers (materials scientist, packaging specialist, designer, and food safety specialist). They will utilize the steps of the Engineering Design Process to create a successful product prototype.

THIS LESSON FOCUSES ON:

ENGINEERING DESIGN PROCESS	21ST CENTURY SKILLS
Defining the Problem	**Collaboration**
Designing Solutions	Communication
Creating or Prototyping	**Critical Thinking**
Refine or Improve	Creativity
Communicating Results	

OBJECTIVES

Students will be able to:

- **Understand** the importance and relevance of temperature-regulating and specially designed packaging materials.
- **Apply** their knowledge of materials science and chemistry to the design of a prototype.
- **Create** a prototype designed to address the complex real-world issue of food safety.
- **Develop** an equation to determine the total amount of surface area needed to design a package.

MATERIALS

- Scoring Tool
- Scissors
- Glue or tape
- Colored pencils
- Pre-constructed boxes of various sizes
- 2–3 cardboard boxes per group
- 6ft String
- 2 pint-sized resealable plastic bags per group with 50 mL of water in each
- One thermometer per group
- 25 mL of calcium chloride per group
- 25 mL of citric acid per group
- One ruler per group
- 2 pieces of cardstock per group

- 1–2 large sheets of foil per group
- 1–2 large sheets of bubble wrap per group
- One stopwatch per group
- Explore Energy Transfer student capture sheet
- Graphing and Analyzing student capture sheet

HAVE YOU EVER WONDERED...

How foods like fruits and vegetables travel across continents and arrive at the grocery store in perfect condition? Packaging materials are specifically engineered to fit certain fruits and vegetables that must travel over land and see to arrive in our grocery stores.

How a thermos retains the heat or cold of the liquid inside? The laws of thermodynamics dictate that heat is always looking to dissipate, or transfer. The materials used to create a thermos effectively block that energy transfer, trapping the heat energy either inside or outside of the bottle in order to keep the liquids either hot or cool.

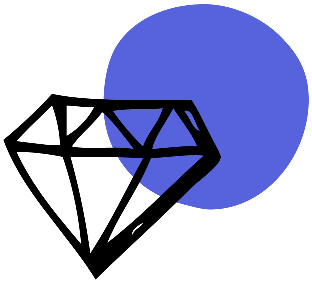
How ice packs can keep cold for days at a time? Commercial ice packs rely on endothermic reactions—chemical reactions that absorb heat—in order to stay cold. Commonly, ice packs will be made of water and a small tube of ammonium nitrate. When the tube is punctured and the ammonium nitrate interacts with the water, the endothermic reaction makes the pack cold.

MAKE CONNECTIONS!

This section captures how this activity connects to different parts of our lives and frames the reason for learning.

HOW DOES THIS CONNECT TO STUDENTS?	HOW DOES THIS CONNECT TO CAREERS?	HOW DOES THIS CONNECT TO OUR WORLD?
Students interact with material science and packaging design in a variety of different ways: • **At the grocery store:** much of the fresh food and produce that we purchase (milk, apples, etc.) are shipped in specifically-designed packaging materials meant to maintain maximum freshness. • **In the mail:** With the rise of online shopping and home meal delivery services, consumers need packaging that transports fragile goods cheaply, safely, and with minimal spoilage.	**Materials Scientists** use the properties of matter to improve the design of products in many realms, from the creation of non-stick cooking surfaces to the design of moisture-wicking clothing meant to maximize athletic performance. **Packaging Engineers** design packing materials that are lightweight, resilient, and keep the environment in mind. **Packaging Designers** optimize materials for use. They make sure that the material or packaging effectively serves its intended purpose and looks aesthetically pleasing. **Goods Specialists** help ensure the safe transfer of potentially dangerous goods.	In our digitized world, online shopping and delivery to your door is becoming the rule and not the exception. This booming industry requires scientists and engineers who can think critically and make informed designs to safely transport a wide variety of goods—from fruits and vegetables to hazardous materials. Well-designed packaging minimizes cost and waste, protects our environment and increases customer satisfaction.

BLUEPRINT FOR DISCOVERY



DAY 1

Whole Groups (20 minutes):

1. Place students into groups of 3–4 and assign each student a career role: Hospital Administrator, Materials Scientist, Packaging Engineer, and Designer.
2. Brief students on their challenge by distributing Sensitive Delivery student capture sheet and invite students to identify the problem and constraints, led by the student with the assigned role of Hospital Administrator.
3. Instruct students to discuss with their partners what are some self-heating/self-cooling devices.
4. As a class, come up with a list of objects that are self-cooling or self-heating.
5. Determine the characteristics that each have in common. Tell students that they will be exploring evidence of a chemical reaction by observing a temperature change. They will use this information to inform their lunch box design.
6. Using the **Fast Facts**, introduce the concepts of endothermic and exothermic reactions.

FAST FACTS

Chemical reaction: a change of a substance into a new one that has a different chemical identity

Endothermic: a reaction or process that absorbs heat in the form of thermal energy, environment decreases in temperature

Exothermic: a reaction or process that releases heat in the form of thermal energy, environment increases in temperature

Products: a new substance that has formed from chemical reaction

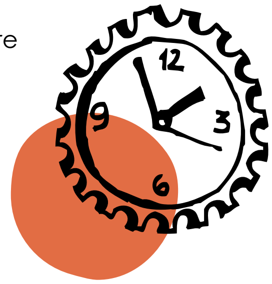
Reactants: a substance that takes part in and undergoes change during reaction

Signs of a chemical change: color change, temperature change, formation of a gas, or odor

7. Distribute Explore Energy Transfer student capture sheet and Graphing and Analyzing student capture sheet to each student. Explain the purpose of the lab and go over the lab directions for each chemical reaction using Explore Energy Transfer student capture Sheet.

Small Group (25 minutes):

1. Assign one student per pair or small group to be the Timekeeper and distribute a stopwatch to the designated student. Assign a different student per pair or small group to be the Thermometer Reader and distribute a thermometer to the designated student.
2. Instruct students to collect materials needed for Chemical Reaction 1 on Explore Energy Transfer student capture sheet. (one resealable plastic bag with 50 ml of water and one beaker with 25 ml of calcium chloride).
3. Instruct Thermometer Reader to place the thermometer inside the resealable plastic bag filled with 50 ml of water and record the temperature on Explore Energy Transfer student capture sheet under Chemical Reaction 1. Thermometer will stay in the resealable plastic bag throughout the experiment.
4. Instruct students to pour the 25 ml of calcium chloride from the beaker into the resealable plastic bag filled with 50 ml of water. The designated Timekeeper should begin the stopwatch immediately.
5. Instruct students to record the temperature at the immediate beginning (0 seconds) and every 10 seconds after until the stopwatch reaches 60 seconds.



6. Instruct students to respond to the two questions related to Chemical Reaction 1 on Explore Energy Transfer student capture sheet.
7. After completing the questions, students need to collect materials needed for Chemical Reaction 2 (one resealable plastic bag with 50 ml of water and one beaker with 25 ml of citric acid).
8. Instruct Thermometer Reader to place the thermometer inside the resealable plastic bag filled with 50 ml of water and record the temperature on Explore Energy Transfer student capture sheet under Chemical Reaction 2. Thermometer will stay in the resealable plastic bag throughout the experiment.
9. Instruct students to pour the 25 ml of citric acid from the beaker into the resealable plastic bag filled with 50 ml of water. The designated Timekeeper should begin the stopwatch immediately.
10. Instruct students to record the temperature at the immediate beginning (0 seconds) and every 10 seconds after until the stopwatch reaches 60 seconds.
11. Instruct students to respond to the two questions related to Chemical Reaction 2 on Explore Energy Transfer student capture sheet.
12. After completing the questions, instruct students to use the data collected from both Chemical Reaction 1 and Chemical Reaction 2 to create a graph comparing the temperature (y-axis) and time in seconds (x-axis) on the respective graphs provided on Graphing and Analyzing student capture sheet.
13. Instruct students to respond to the two questions for each Chemical Reaction (1 and 2) related to their graphs.

DAY 2

Whole Group (15 minutes):

1. Prior to students arriving, place pre-constructed boxes of various sizes and designs throughout the classroom.
2. Provide guided questions to the students to review exothermic and endothermic reactions
3. Have student reflect on the previous day's data gathered and draw a model of what occurred to determine whether it was an exothermic or endothermic reaction.

   Optional: the facilitator can show this video: Endothermic and Exothermic Reactions, Bozeman Science: https://www.youtube.com/watch?v=L-G7pLufXAo

Whole Group (30 minutes):

1. Instruct each group to locate and bring at least two boxes to their table.
2. Have the Materials Scientist lead this section of the lesson. Students should first discuss and examine the design of each box and whether they feel the box is an appropriate size for the product it holds.
3. Instruct students to measure each closed box using a ruler and to record the dimensions (length, width, and height) of each box on Packaging Design student capture sheet.
4. Instruct students to create an equation that represents the surface area of each box using the following variables:

      l = length of box

      w = width of box

      h = height of box

      Total Surface Area (answers may vary):

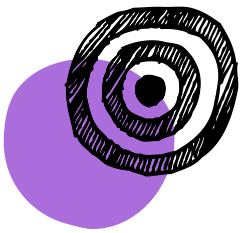
Rectangular prism: $2(lw) + 2(lh) + 2(wh)$ or $2(wl+wh+lh)$

Cube shaped: $6a^2$, where a=length of a side

Telescoping: $(2h + w)(2h + l)$

5. After completing the measurements of the closed boxes, instruct students to deconstruct and take apart the boxes so that they appear flat and 2-dimensional. Allow students to discuss in their groups about some similarities and differences they notice between the box layouts. With most boxes, students will likely notice there are sides or pieces that are hidden or secured behind others.

6. Have students record the Total Length, Total Width, and Total Surface Area of each box in Packaging Design student capture sheet table using the provided box templates as a guide.



DAY 3

Whole Group (25 minutes):

1. Ask small groups to share their equations with the whole class. Discuss any similarities and differences in the equations.
2. Inform students that they will be applying these new equations and creating their own lunch box. Invite the Packaging Engineer to facilitate steps 3–7.
3. Using Packaging Design student capture sheet have students create a 2-dimensional sketch of their packaging box design, with measurements. Students should include the compartment separations they plan to incorporate into their lunchbox to keep the food at the recommended serving temperature.
4. After they have completed their packaging design, display materials for students to use. Invite the Designer to facilitate steps 5–7. Students will select what they need to create their design.
5. Instruct students to cut out their layout with their calculated dimensions from the card stock.
6. If a scoring tool is available, instruct students to score the folds of their cutout before folding the boxes. Students can also add designs to the cardstock with colored pencils, markers, or printed material.
7. After constructing their boxes, instruct students to verify that the dimensions of their 3-dimensional lunch box are correct based on the equations they created.

Small Group (15 minutes):

1. Invite students to revisit their initial lunch box design and now incorporate the heating and cooling elements.

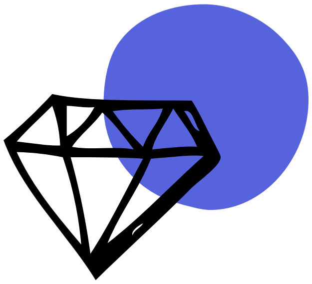
   Note to Teacher: Students can use the same volume as the previous Hot & Cold Packs investigation to test out different designs that incorporate the packs. They do not need to use the chemicals again. If time allows, students can make their hot and cold packs again and test the temperature over longer durations of time using their prototype.

2. Ask each student group to present their prototype to the class. Ask them to highlight each of the following aspects of their prototype:

   a. How did their designs work well? How do they need to be improved?
   b. What materials do they see in the grocery store or in the packages they receive at home? Why do they think these materials are used?
   c. Why is good packaging design important? Can it reduce food waste?

   Note to Teacher: It is anticipated that students will identify the energy transfer did not reach temperatures high or low enough to meet the U.S. Department of Agriculture's Food Safety recommendation for serving. This information can be recorded as not meeting the criteria.

TAKE ACTION!



The following links provide opportunities for exploration into materials science and packaging:

Thermodynamics: The Heat is On!

The Zero Waste Challenge

Materials experts challenged to protect athletes (article in ASM International)

NATIONAL STANDARDS

Next Generation Science Standards

MIDDLE SCHOOL

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Constructing Explanations and Designing Solutions Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.	**PS1.B: Chemical Reactions** Some chemical reactions release energy, others store energy.	**Energy and Matter** The transfer of energy can be tracked as energy flows through a designed or natural system.
Engaging in Argument from Evidence Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.	**ETS1.B: Developing Possible Solutions** A solution needs to be tested, and then modified on the basis of the test results, in order to improve it.	**Influence of Science, Engineering, and Technology on Society and the Natural World** The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.
Constructing Explanations and Designing Solutions Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	**PS1.B: Chemical Reactions** The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.	**Patterns** Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

COMMON CORE STATE STANDARDS

Math

Geometry
Solve real-world and mathematical problems involving area, surface area, and volume.
CCSS.MATH.CONTENT.6.G.A.2
Find the volume of a right rectangular prism with fractional edge lengths by packing it with unit cubes of the appropriate unit fraction edge lengths, and show that the volume is the same as would be found by multiplying the edge lengths of the prism. Apply the formulas V = l w h and V = b h to find volumes of right rectangular prisms with fractional edge lengths in the context of solving real-world and mathematical problems.
CCSS.MATH.CONTENT.7.G.B.6
Solve real-world and mathematical problems involving area, volume and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, and right prisms.
CCSS.MATH.CONTENT.8.G.C.9
Know the formulas for the volumes of cones, cylinders, and spheres and use them to solve real-world and mathematical problems.

Modeling with Geometry
Apply geometric concepts in modeling situations
CCSS.MATH.CONTENT.HSG.MG.A.3
Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).

Expressions & Equations
Apply and extend previous understandings of arithmetic to algebraic expressions.
CCSS.MATH.CONTENT.6.EE.A.2
Write, read, and evaluate expressions in which letters stand for numbers.

Solve real-life and mathematical problems using numerical and algebraic expressions and equations.
CCSS.MATH.CONTENT.7.EE.B.3
Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies.

SENSITIVE DELIVERY STUDENT CAPTURE SHEET

A local hospital cafeteria is receiving feedback that by the time a patient starts to eat their food, their hot foods like soups and pastas have gone cold, and the cold foods like ice cream have melted. The hospital has limited staff and is very large. In addition, patients are typically out of their rooms during meal delivery times and might return as much as one hour after the food has been delivered. It is not feasible for the hospital to stagger food delivery times because of their limited staffing, so they must devise a better way to transport the food.

The hospital has called in a team of professionals to address the problem. Each student team must design a lunch box prototype that includes one heating compartment, one cooling compartment, keeps food safe for the U.S. Department of Agriculture's Food Safety recommendation, and is small enough to transport easily (under 1 foot wide, 6 inches high and one foot long). The food must remain hot (140 degrees or above) or cold (40 degrees or below) for up to two hours.

Each student will take the role of a project professional in their small teams:

a. Hospital Administrator (Ask: What is the problem? What are the constraints?)

b. Materials Scientist (Imagine: Brainstorm ideas)

c. Packaging Engineer (Plan: Draw a diagram, gather needed materials)

d. Designer (Create: Follow the plan and test it out)

The hospital administrator should lead the group and record the following information about their challenge:

What is the problem?

What are the constraints?

PACKAGING DESIGN STUDENT CAPTURE SHEET

1. Record the measurements of boxes of different sizes in the table below.

   Total Length and Total Width represents the entire length and width of the box when broken apart and 2-dimensional.

BOX NAME	LENGTH (L)	WIDTH (W)	HEIGHT (H)	SURFACE AREA OF CLOSED BOX	TOTAL LENGTH (L)	TOTAL WIDTH (W)	TOTAL SURFACE AREA

Using your observations and the data in the table above, calculate the total length and total width of each of the 2-dimensional box layouts using the following variables:

l = length of folded box
w = width of folded box
h = height of folded box

Total Width =

Total Length =

Total Surface Area =

2. Create the sketch of your 2-dimensional package design below. Make sure to include the measurements in your drawing.

Box Purpose: ____

Box length: _______ Box Total Length: ______

Box width: _______ Box Total Width: ______

Box height: _______ Total Surface Area: ______

Surface Area of Closed Box: ___________

EXPLORE ENERGY TRANSFER STUDENT CAPTURE SHEET

Timekeeper: ________________ **Thermometer Reader:** ________________

CHEMICAL REACTION 1: CALCIUM CHLORIDE AND WATER

Put thermometer in water and take initial temperature: ______________

Pour calcium chloride into water and begin stopwatch immediately

Track the temperature at each time designated below, be quick and as accurate as possible

Time	Temperature in Celsius
0 seconds	
10 seconds	
20 seconds	
30 seconds	
40 seconds	
50 seconds	
60 seconds	

Stop and Jot

1. What do you notice about the temperature?

2. Based on your answer to number 1, do you think the temperature change is being caused by a release or absorption of heat?

CHEMICAL REACTION 2: CITRIC ACID AND WATER

Put thermometer in water and take initial temperature: _____________

Pour citric acid into water and begin stopwatch immediately

Track the temperature at each time designated below, be quick and as accurate as possible

Time	Temperature in Celsius
0 seconds	
10 seconds	
20 seconds	
30 seconds	
40 seconds	
50 seconds	
60 seconds	

Stop and Jot

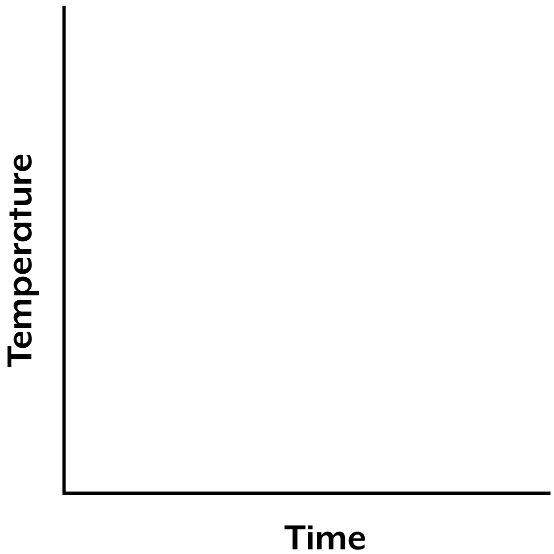
1. What do you notice about the temperature?

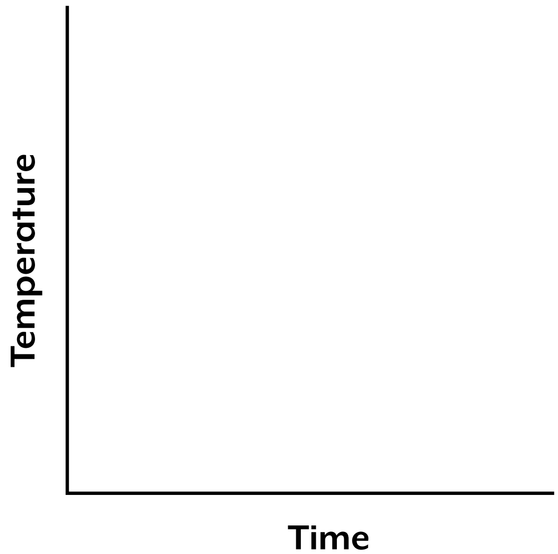
2. Based on your answer to number 1, do you think the temperature change is being caused by a release or absorption of heat?

GRAPHING AND ANALYZING STUDENT CAPTURE SHEET

Timekeeper: ________________ **Thermometer Reader:** ________________

Chemical Reaction 1	Chemical Reaction 2





Chemical Reaction 1

Stop and Jot

1. What changes occurred when you mixed calcium chloride and water in chemical reaction 1?

2. Examine the following two statements. Which do you think accurately represents the relationship between calcium chloride and water in chemical reaction 1? Circle the best answer and EXPLAIN.
   c. Energy was added to our starting material. (using energy)
   d. Energy was produced after the reaction. (releasing energy)

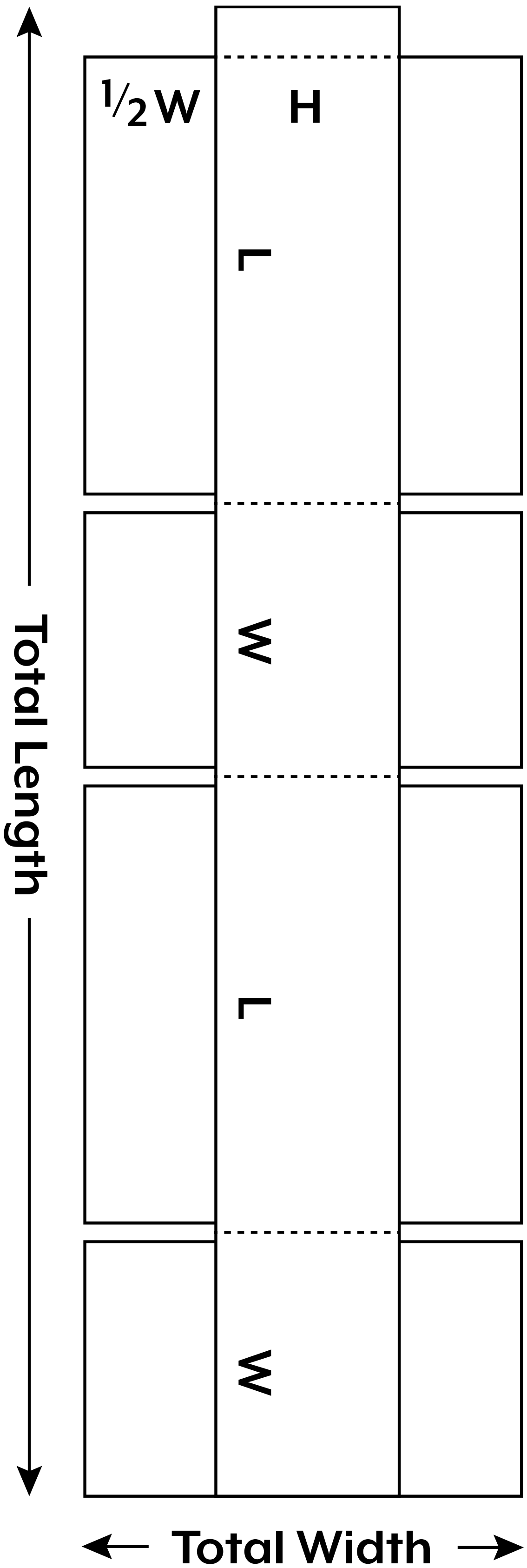
Chemical Reaction 2

Stop and Jot

1. What changes occurred when you mixed the citric acid and water in chemical reaction 2?

2. Examine the following two statements. Which do you think accurately represents the relationship between citric acid and water in chemical reaction 2? Circle the best answer and EXPLAIN.
   c. Energy was added to our starting material. (using energy)
   d. Energy was produced after the reaction. (releasing energy)

EXAMPLES OF BOX TEMPLATES



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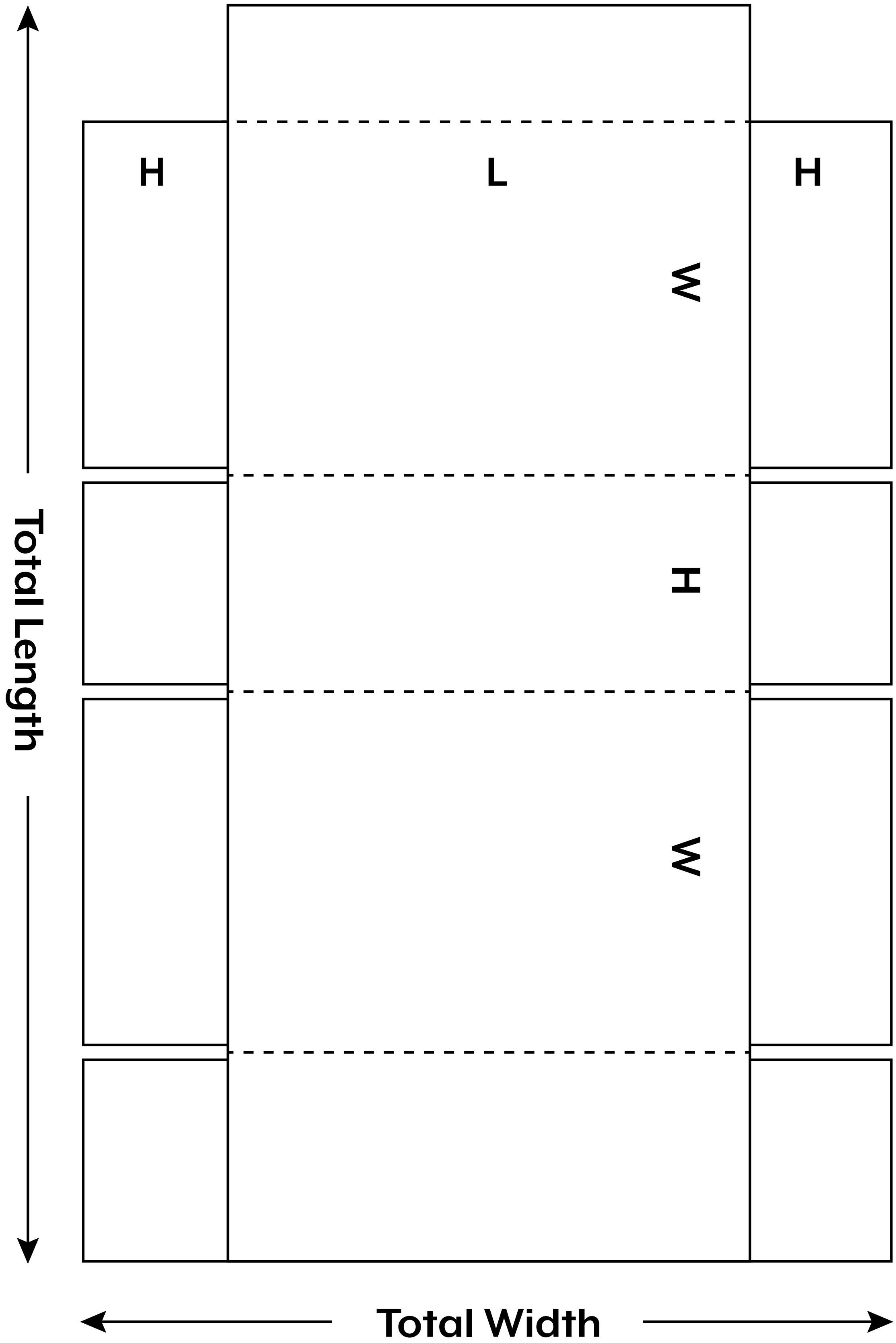

EXAMPLES OF BOX TEMPLATES