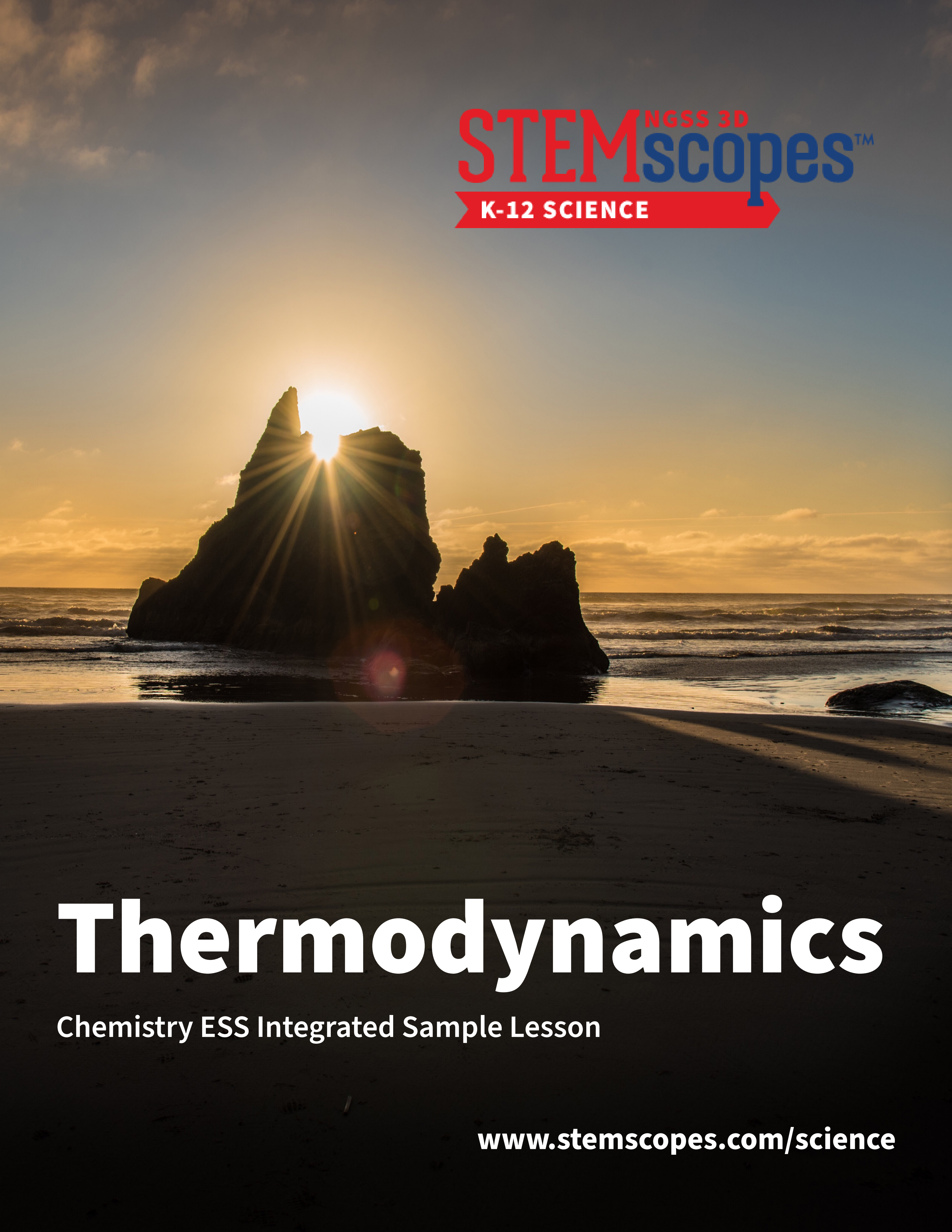

STEMscopes NGSS 3D
K-12 SCIENCE

Thermodynamics

Chemistry ESS Integrated Sample Lesson

www.stemscopes.com/science

Scope (Unit) Thermodynamics

Explore (Lesson) Scientific Investigation - System, Surroundings, and Calorimetry

The following pages introduce lesson resources that guide you through the STEMscopes NGSS Chemistry ESS Intergrated lesson. This sample lesson does not include all the elements and features of our digital and print science curriculum.

Resource List:

The following resources, as well as additional Scope resources not listed, can be found in the digital curriculum *Chemistry ESS Integrated Scope, Thermodynamics.*

Home

- Standards Alignment
- Sample Lesson Plan
- Teacher Scope Presentation
- Teacher Background
- CCC and SEP Scoring Rubric
- Answer Keys
- Materials List

Engage

- Investigative Phenomena – Introductory activity that facilitates a connection between the content and real-world phenomena and encourages students to ask why or how something happens.
- Graphic Organizer – Students fill this in as they work through the elements of this Scope.
- Accessing Prior Knowledge – A brief probing activity to gauge students' prior knowledge before engaging in the inquiry process.
- Hook – An engaging activity that includes instructor preparation, supplemental resources, and ready-made handouts for students.

Explore

- Explore 1: Scientific Investigation – This lesson sample.
- Explore 2: Scientific Investigation
- Explore 3: Inquiry Investigation

Explain

- Picture Vocabulary – Key terms explained through pictures and by definition.
- Linking Literacy – Strategies to help students comprehend difficult informational text.
- STEMscopedia – Reference materials that include parent connections, career connections, technology, and science news.
- Communicate Science – A class activity in which students use different forms of communication to discuss scientific topics connected to the content of this Scope.
- Concept Review Game – An interactive game that helps students review important concepts.
- Content Connections Video – A short video that supports student understanding of the content.

Elaborate

- Math Connections
- Science Today
- Reading Science
- Career Connections
- Scientist Spotlight

Evaluate

- Claim-Evidence-Reasoning
- Open-Ended Response Assessment
- Multiple Choice Assessment

Intervention

- Guided Practice
- Independent Practice
- Concept Attainment Quiz

Acceleration

- Extensions
- Project-Based Learning
- Books on Topic

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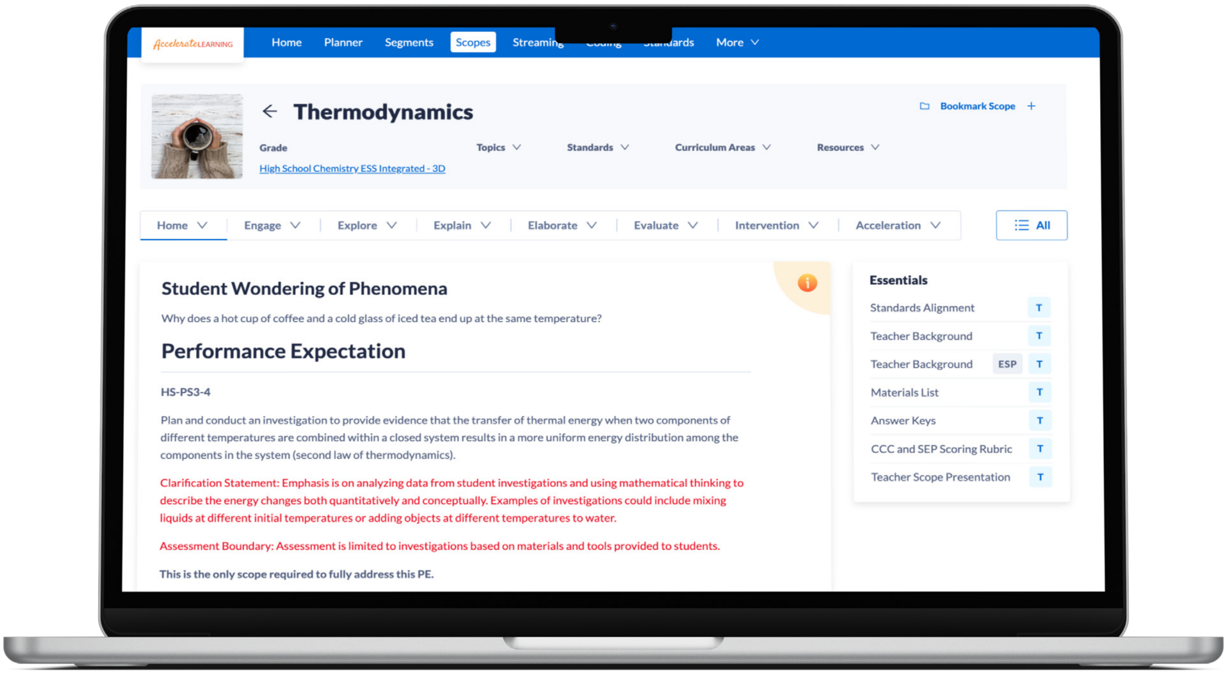
Scope (Unit) Overview

Scope (Unit) Thermodynamics



Student Wondering of Phenomena

Why does a hot cup of coffee and a cold glass of iced tea end up at the same temperature?

Performance Expectations

Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperatures are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.

Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.

Scope (Unit) Overview

Scope (Unit) Thermodynamics

Three-Dimensional Focus

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Planning and Carrying Out Investigations Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements, and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refind the design accordingly.	PS3.B Conservation of Energy and Energy Transfer PS.3.B.1 Uncontrolled systems always evolve toward more stable states – that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). PS3.B.3 Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. PS3.D Energy in Chemical Processes PS3.D.1 Although energy cannot be destroyed, it can be converted to less useful forms – for example, to thermal energy in the surrounding environment.	Systems and System Models When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Thermodynamics

Explore 1: Scientific Investigation - System, Surroundings, and Calorimetry

Description

Students will investigate how a calorimeter is used to measure the heat of reaction.

Materials

Printed Materials
1 System, Surroundings, and Calorimetry (per student)

Reusable
1 Graduated cylinder (per group)
1 Hot Plate (per group)
1 250 ml Beaker (per group)
3 Styrofoam cups (per group)
2 Lids to fit the cups (per group)
2 Thermometers (per group)
1 Hot mitt or beaker tongs (per group)
1 Stopwatch (per group)

Consumable
75 ml Room-temperature tap water (per group)
75 ml Hot tap water (per group)

Preparation

- System, Surroundings, and Calorimetry should be printed individually for student use.
- Students will work in groups.
- Materials should be gathered and readily available for the groups to access.

STEMcoach in Action

Cooperative learning involves more than students working together on a lab or field project. It requires teachers to structure cooperative interdependence among the students, holds students individually accountable, and enables students to experience face-to-face academic interaction with peers. It also fosters interpersonal and small-group social skills. For further information regarding Establishing Cooperative Learning, please click the provided link.
Site

Procedure and Facilitation Points

- Distribute copies of System, Surroundings, and Calorimetry and instruct students to read the introduction.

A process called *calorimetry* can be used to find the amount of heat, or energy that flows between systems and surroundings. It measures the quantity of heat transferred, such as specific heat. In a scientific laboratory, a complicated machine known as a *bomb calorimeter* is used. The substances to be measured are placed into the device, which is very well insulated so that there is no heat exchange between the system and surroundings. For this investigation, a simple device can be created that accomplishes close to the same goal. This device is called a *coffee-cup calorimeter* and consists of a Styrofoam™ coffee cup with a plastic lid placed on the cup to contain the heat. A thermometer is placed into the cup. As no heat is lost to the surroundings with this device, the following relationship is true:

$$q_{(gained)} = -q_{(lost)}$$

$$q = -q$$

When using a coffee cup calorimeter to determine the heat flow of a system, the water (or solution) in the system will absorb the heat of the reaction. During a chemical reaction, the change in the water (or solution) temperature can then be used to calculate the amount of heat lost or gained during the reaction. In this investigation, we will add hot water to room-temperature water and record the temperature changes.

The amount of heat that flows between substances and systems can be calculated using the equation:

$q = m \bullet c_p \bullet \Delta T$

q = Heat flow

m = Mass (g)

c_p = Specific heat of the substance (J/g°C). This is the amount of heat that is needed to change the temperature of a substance 1°C.

ΔT = Change in temperature ($T_{final} - T_{initial}$)

To measure the amount of heat transferred, we will set up our own calorimetry unit using coffee cups.

- Ask students the following questions:
  - What is the difference between temperature and heat?
    Temperature is a measure of the average kinetic energy (energy from motion) of the particles of a substance, which is related to heat but is not the same. Heat refers to the energy transferred between objects of different temperatures. Heat energy is measured in joules or kilojoules.
  - How would we determine the heat of reaction of a system?
    By measuring the temperature change in an isolated system, you can calculate the heat of reaction using the formula $Q = mC_p\Delta T$. In this case, the system will be the change in the temperature of the water, determined by using the following information: Q = heat in Joules, m = mass of water, C_p= specific heat of water, 4.18 J/g°C, ΔT = change in temperature of the system.
  - Interpret the meaning of the following formula, $q_{(system)} = q_{(gained)} + q_{(lost)}$. What does it mean? Be as specific as you can.
    The total heat gained by the system must equal the total heat lost by the system, so that the heat exchange (q) for the system is zero. If this holds true, then $q_{(gained)} = -q_{(lost)}$ for the system.
- Have students read over the question and procedure and answer any questions about the process. When all questions have been answered, have students begin the investigation.

Question:
How will the heat of a system change when hot water is added to cold water?

Materials:

Graduated cylinder
75 ml Room temperature tap water
75 ml Hot tap water
1 Hot plate
1 250 ml Beaker
3 Styrofoam cups
2 Lids to fit the cups
2 Thermometers
Hot mitt or beaker tongs
Stopwatch

Safety Precautions:

Use caution when handling hot glassware and water.

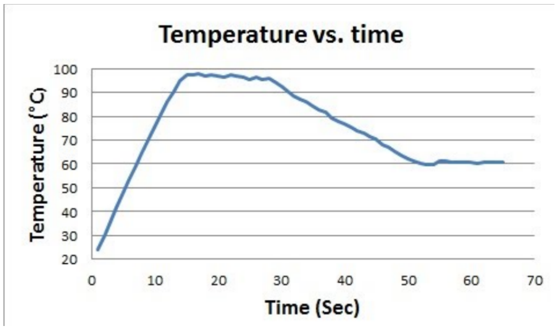
(SEP) Procedure:

1. Stack two cups together; this will be the calorimeter.
2. Label the third cup as the “hot” cup.
3. Place 75 ml of tap water in the calorimeter.
4. Place the lid on the calorimeter, and insert the thermometer into the water.
5. Wait for the water temperature to regulate in the cup.
6. While you are waiting, place 75 ml tap water into the beaker, and place it on hot plate to heat up for 10 minutes.
7. While the water is heating up, record the temperature of the water in the calorimeter in Table 1.
8. Pour the hot water into the “hot” cup, place the lid on it, and insert the thermometer.
9. Record the temperature of the hot water in Table 1.
10. You will now pour the hot water into the calorimeter.
11. Replace the lid, and record the temperature of the combined water in the calorimeter in Table 2.
12. Record the temperature every 30 seconds in Table 2.
13. Record the temperature for 5 minutes.
14. Pour the water into a graduated cylinder and record the final volume in Table 1.

- Monitor the students as they set up their apparatus to ensure that the thermometer is in contact with the water to get an accurate reading.
- Remind students of safety issues while transferring hot water.
- Students should record the temperature in the data table on their copy of System, Surroundings, and Calorimetry, then answer the analysis questions.

Analysis:

1. Draw a graph to represent the data collected (temperature and time).
   Answers will vary based on data but should resemble the curve in the graph shown below:



2. Calculate the heat gained or lost by each water temperature using the formula $Q = mC_p\Delta T$, and fill in the table with the correct values:

   Q = heat in Joules

   m = mass of water, 1 ml of water = 1 g of water

   C_p = specific heat of water, 4.18 J/g°C

   ΔT = change in temperature of the water

   Q = (150) (4.18) (25) = -1,463 J

   Answers will vary based on actual data.

Sample	m	ΔT (T_f - T_i)	C_p	Q	Did it Gain or Lose Heat?
Cold water	75g	25°C	4.18 J/g°C	7838 J	Gain
Hot water	75g	-25°C	4.18 J/g°C	-7838 J	Lose

3. **(CCC)** The question for this investigation was this: how will the heat of a system change when hot water is added to cold water? Use the formula $Q_{(system)} = Q_{(gained)} + Q_{(lost)}$, to answer the question.

   The Q of the system is zero since the amount of heat gained was the same as the amount of heat lost.

4. **(CCC)** An uncontrolled system will always move toward a more stable state. Simply stated, the energy of the molecules will become more uniform within a system. Explain how this investigation supports this statement.

   The molecules of water had a certain amount of energy before the hot water was added. When the two different temperature waters were mixed, the energy of the molecules of the warmer water was transferred to the molecules of the colder water resulting in a uniform temperature.

5. What conclusion can you draw about heat transfer based on this investigation?

   Heat transfer will occur, from molecules with more energy to molecules with less energy.

6. Why is it important to use a calorimeter for this investigation?

   When investigating a system, you have to account for interactions with the surroundings. A calorimeter allows for an isolated system that is not impacted by the surrounding air, so you get more accurate results.

7. How might a temperature probe impact measurements?

   The measurements would be more precise and accurate than the traditional thermometer.

- Debrief the investigation with the following questions:

  - What is calorimetry and what does it measure?
    Calorimetry can be used to find the amount of heat that flows between systems and surroundings. It measures the quantity of heat transferred, such as specific heat.
  - **(CCC)** Coffee-cup calorimeters are often used in high school chemistry calorimetry labs. What are the benefits and drawbacks of using a coffee-cup calorimeter instead of a bomb calorimeter in the high school classroom?
    A bomb calorimeter is very well insulated, therefore, there is no heat exchange between the system and the surroundings. This allows the researcher to very accurately calculate q. Even though a bomb calorimeter is extremely accurate, it is an intricate piece of equipment that requires specific training. Due to these factors, a bomb calorimeter is extremely expensive. This expense inhibits the access of multiple calorimeters in the high school chemistry lab. On the other hand, a coffee cup calorimeter is an extremely inexpensive piece of equipment. This enables calorimeters to be widely available as a tool for use in a high school chemistry lab. Despite the fact that it has less accuracy than a bomb calorimeter, the coffee-cup calorimeter is a simple and inexpensive device which still allows students to calculate the value of q. The double layer of coffee cups insulates the system well from the surroundings; the thin, plastic lid, however, does allow for some heat to be transferred between the system and the surroundings.
- At this time, introduce or review the following vocabulary terms, using the Picture Vocabulary found in the Explain section:
  - Calorimeter
  - Kinetic energy
  - Specific heat
  - Temperature
  - Calorimetry
  - Heat
  - System
  - Energy
- When appropriate, close the activity by referring students to the Investigative Phenomena/Graphic Organizer and fill in the appropriate information.

Connection to the Investigative Phenomena

Once students have completed the activity, have them refer to the Investigative Phenomena question, anchor their learning, and revise their thinking.

ELL Strategies

Chain Note:

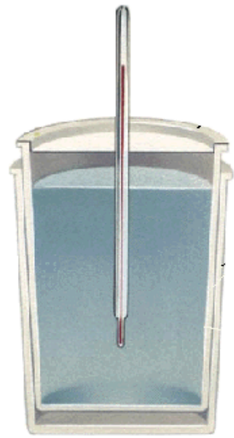
Students will write one or two sentences that begin to explain the benefits and drawbacks of using a coffee calorimeter instead of a bomb calorimeter. Then students must pass their paper to the right. Once each student has a new paper, they must read what is written and then add an additional sentence or two, working to completely explain the benefits and drawbacks. Have students pass papers one or two more times as needed to allow for complete thoughts. Share a few samples and discuss what information may be missing or may need to be clarified.

Explore

Explore Lesson

Name: ______________________________ Date: __________

System, Surroundings, and Calorimetry



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The amount of heat that flows between substances and systems can be calculated using the equation:

$q = m \cdot c_p \cdot \Delta T$

q = Heat flow

m = Mass (g)

c_p = Specific heat of the substance (J/g°C). This is the amount of heat required to change the temperature of a 1 gram sample of a substance 1°C.

ΔT = Change in temperature ($T_{final} - T_{initial}$)

To measure the amount of heat transferred we will set up our own calorimetry unit using coffee cups.

Explore

Question:

How will the heat of a system change when hot water is added to cold water?

Materials:

Graduated cylinder

75 ml Room-temperature tap water

75 ml Hot tap water

1 Hot plate

1 250 ml Beaker

3 Styrofoam cups

2 Lids to fit the cups

2 Thermometers

Hot mitt or beaker tongs

Stopwatch

Safety Precautions:

Procedure:

1. Stack two cups together; this will be the calorimeter.
2. Label the third cup as the "hot" cup.
3. Place 75 ml of tap water in the calorimeter.
4. Place the lid on the calorimeter and insert the thermometer into the water.
5. Wait for the water temperature to regulate in the cup.
6. While you are waiting, place 75 ml tap water into the beaker and place on hot plate to heat up for 10 minutes.
7. While the water is heating up, record the temperature of the water in the calorimeter in Table 1.
8. Pour the hot water into the "hot" cup, place the lid on it, and insert the thermometer.
9. Record the temperature of the hot water in Table 1.
10. You will now pour the hot water into the calorimeter.
11. Replace the lid, and record the temperature of the combined water in the calorimeter in Table 2.
12. Record the temperature every 30 seconds in Table 2.
13. Record the temperature for 5 minutes.
14. Pour the water into a graduated cylinder and record the final volume in Table 1.

Explore

Data:

Table 1

Sample	Volume (ml)	Temperature (°C)
Cold water		
Hot water		
Combined water		(Final temp from table 2)

Table 2 Combined Samples

Time	Temperature
Initial temp of water	
30 sec	
60 sec	
90 sec	
120 sec	
150 sec	
180 sec	
210 sec	
240 sec	
270 sec	
300 sec	

Explore

Analysis:

1. Draw a graph to represent the data collected (temperature and time).

2. Calculate the heat gained or lost by each water using the formula $Q = mC_p\Delta T$, and fill in the table with the correct values:

   Q = heat in Joules
   m = mass of water, 1 ml of water = 1 g of water
   C_p = specific heat of water, 4.18 J/g^{o}C
   ΔT = change in temperature of the water

Sample	m	ΔT (T_f - T_i)	C_p	Q	Did it Gain or Lose Heat?
Cold water					
Hot water					

Explore

3. The question for this investigation was: How will the heat of a system change when hot water is added to cold water? Use the formula $Q_{(system)} = Q_{(gained)} + Q_{(lost)}$, to answer the question.

4. An uncontrolled system will always move toward a more stable state. Simply stated, the energy of the molecules will become more uniform within a system. Explain how this investigation supports this statement.

5. What conclusion can you draw about heat transfer based on this investigation?

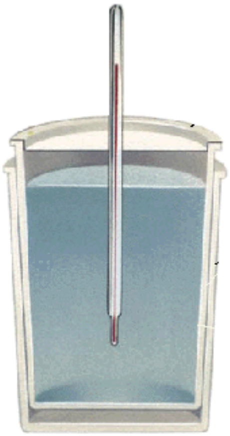
6. Why is it important to use a calorimeter for this investigation?

7. How might a temperature probe impact measurements?

Explore

Name: ______________________________ Date: __________

System, Surroundings, and Calorimetry



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2 Thermometers
Hot mitt or beaker tongs
Stopwatch

Safety Precautions:
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Procedure:
1. Stack two cups together; this will be the calorimeter.
2. Label the third cup as the “hot” cup.
3. Place 75 ml of tap water in the calorimeter.
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13. Record the temperature for 5 minutes.

Explore

14. Pour the water into a graduated cylinder and record the final volume in Table 1.

Data:

Table 1

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Hot water		
Combined water		(Final temp from table 2)

Table 2 Combined Samples

Time	Temperature
Initial temp of water	
30 sec	
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180 sec	
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Explore

Analysis:

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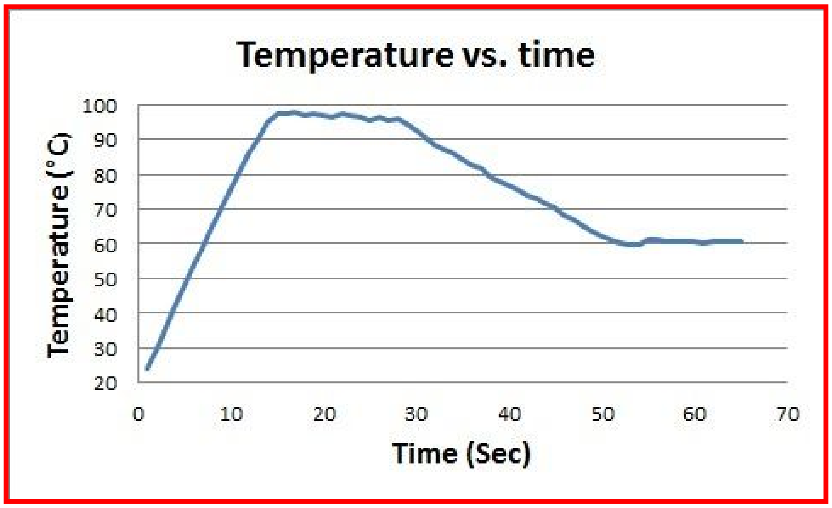
   Answers will vary based on data but should resemble the curve in the graph shown below:



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   Q = (150) (4.18) (25) = -1,463 J

   Answers will vary based on actual data.

Sample	m	ΔT (T_f - T_i)	C_p	Q	Did it Gain or Lose Heat?
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Hot water	75g	-25°C	4.18 J/g°C	-7838 J	Lose

Thermodynamics
Explore 1

Explore

3. The question for this investigation was: How will the heat of a system change when hot water is added to cold water? Use the formula $Q_{(system)} = Q_{(gained)} + Q_{(lost)}$, to answer the question.
   The Q of the system is zero since the amount of heat gained was the same as the amount of heat lost.

4. An uncontrolled system will always move toward a more stable state. Simply stated, the energy of the molecules will become more uniform within a system. Explain how this investigation supports this statement.

   The molecules of water had a certain amount of energy before the hot water was added. When the two waters were mixed, the energy of the molecules of the warmer water was transferred to the molecules of the colder water resulting in a uniform temperature.

5. What conclusion can you draw about heat transfer based on this investigation? Heat transfer will occur from molecules with more energy to molecules with less energy.

6. Why is it important to use a calorimeter for this investigation?

   When investigating a system, you have to account for interactions with the surroundings. A calorimeter allows for an isolated system that is not impacted by the surrounding air, so you get more accurate results.

7. How might a temperature probe impact measurements?

   The measurements would be more precise and accurate than the traditional thermometer.

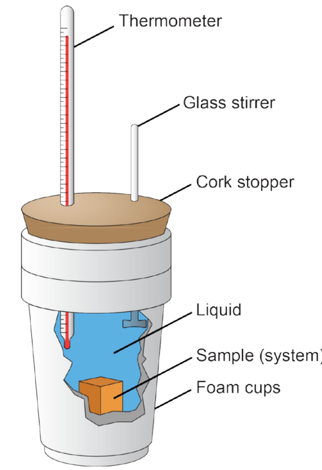
Picture Vocabulary

Thermodynamics

Picture Vocabulary

Calorimeter

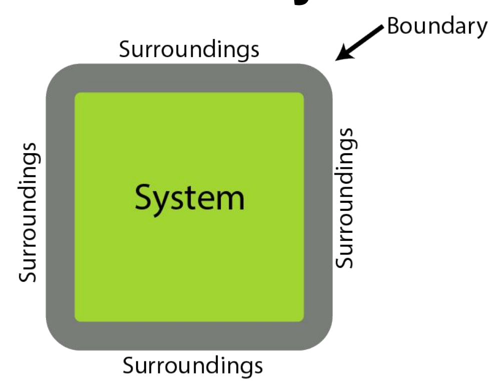
A device used to measure the heat generated or absorbed by a chemical reaction or physical change



Calorimetry

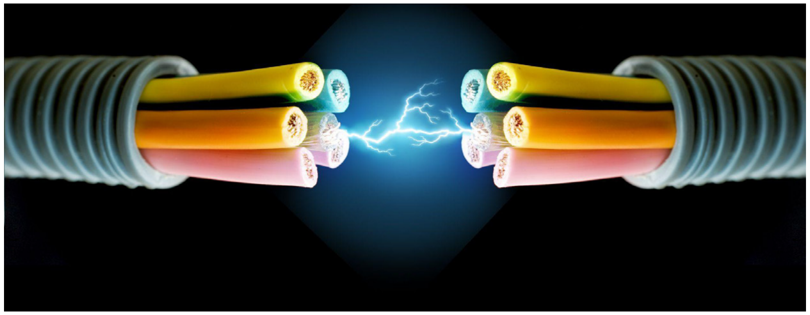
The complete set of equations used to measure the heat changes for physical and chemical processes

Closed System



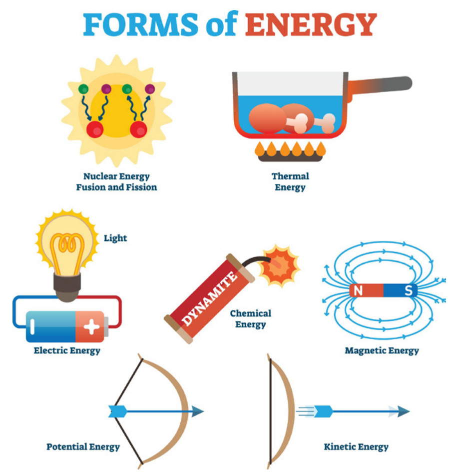
A system that does not exchange matter but does exchange energy with its surrounding environment

Conductor



A material that allows electrons to flow freely from particle to particle

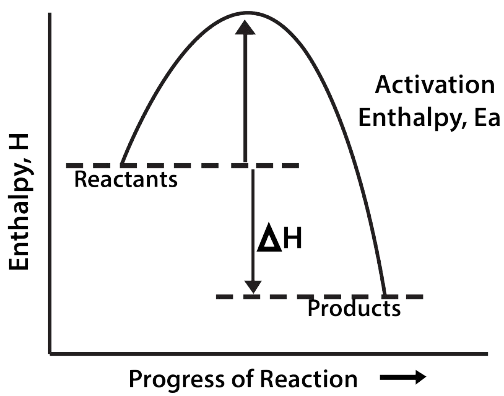
Energy



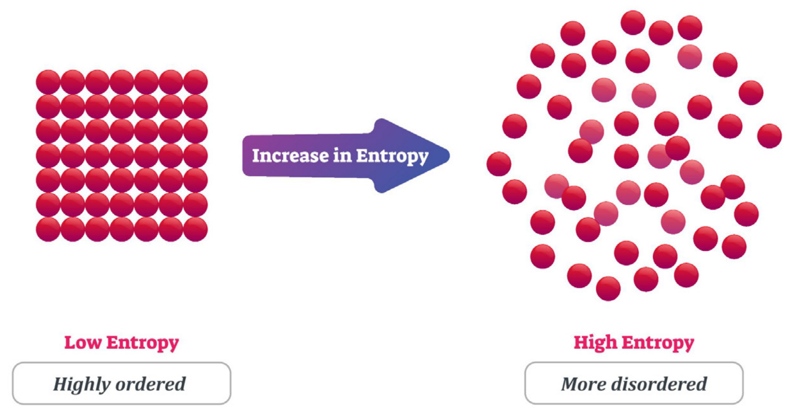
The ability of a system to do work or produce heat

Enthalpy

The total heat content of a system; equal to the internal energy plus the product of the pressure and volume



Entropy



A measure of disorder within a system

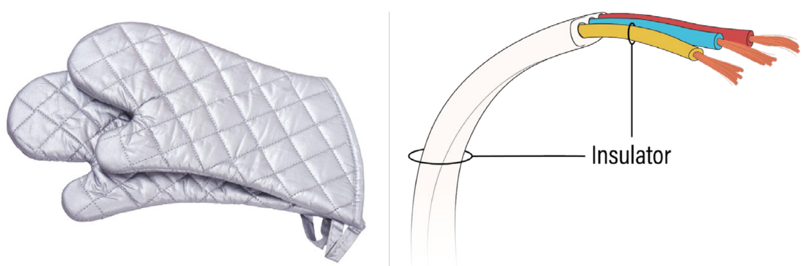
Heat

Energy transferred between two objects of different temperatures, moving continually in a predictable pattern from warmer site to cooler site until all sites have reached the same temperature

Heat Capacity

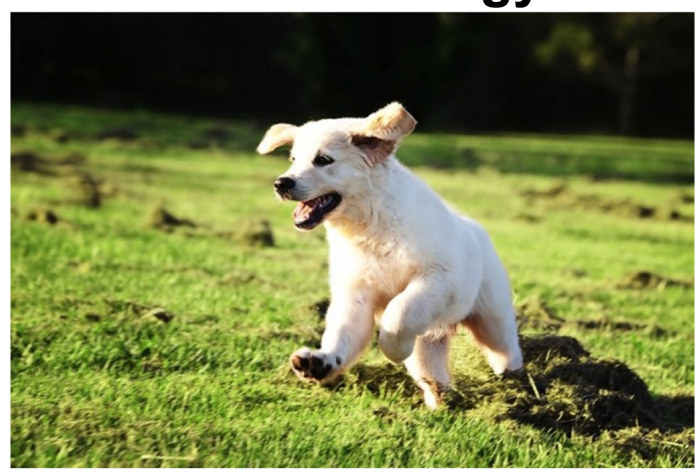
The number of heat units needed to raise the temperature of a substance by one degree

Insulator



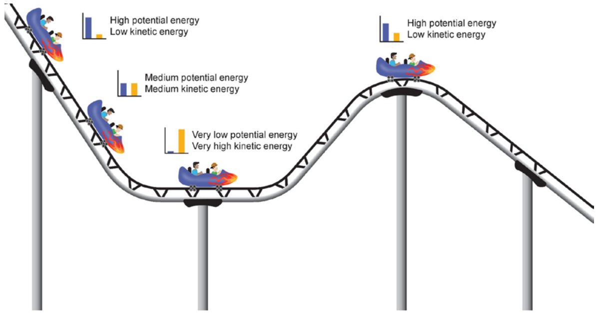
A substance that does not allow electrical or thermal energy to pass through it

Kinetic Energy



The energy of motion

Law of Conservation of Energy



Energy Transformations in a Roller Coaster

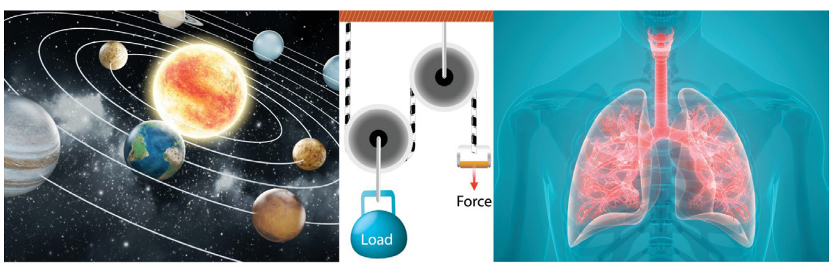
Potential energy | Kinetic energy

A law stating that energy cannot be created or destroyed—it can only change forms

Specific Heat

The amount of energy required to raise the temperature of one gram of a substance by one degree Celsius

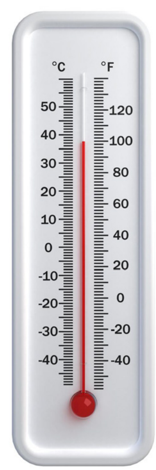
System



Solar System | Pulley System | Respiratory System

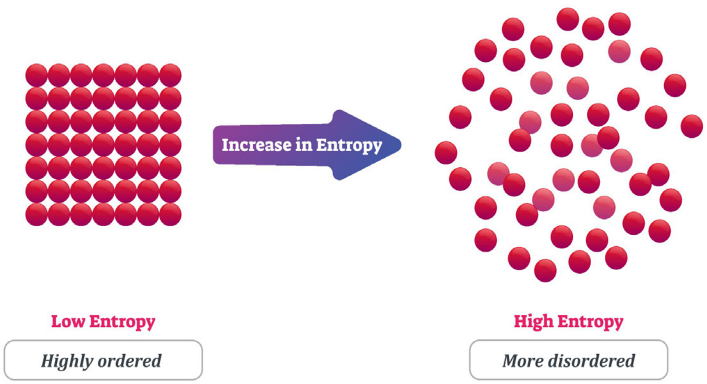
A group of interacting, interrelated, or interdependent elements forming a complex whole

Temperature



The hotness or coldness of matter as related to the average kinetic energy of the molecules of that substance

The Second Law of Thermodynamics



The law stating that, when left to itself, a system's entropy always increases, never decreases; also known as the law of entropy

Thermal Energy

The internal energy of a system, including the kinetic and potential energy of its particles

The

Math Connections

Math Connections

Name: ______________________________ Date: ______

The **law of conservation of energy** states that the total amount of energy in a closed system remains constant, although energy within the system can change from one form to another or be transferred from one object to another.

Heat is a measure of the amount of thermal energy transferred during a reaction. A **calorimeter** is the instrument used for measuring the **heat transfer** (ΔH). When it absorbs heat, the temperature increase in the instrument depends on the **heat capacity** (C), which is the amount of heat required to raise the temperature by a given amount.

You can calculate the amount of heat transferred during a chemical reaction with this formula:

$$\mathbf{Q(heat) = mC_p\Delta T}$$

in which m is mass (g), C_p is the specific heat of the substance (J/g°C), and ΔT is the change in temperature in °C ($T_{final} - T_{initial}$).

The **specific heat capacity** (C_p) is the amount of energy needed to raise an object's temperature by 1 degree.

1. Calculate the amount of heat released when one bottle (250 g) of ethanol is cooled from 45°C to 40°C. The specific heat of ethanol is 2.45 J/g°C.

2. If the same bottle of ethanol starts at 10°C and absorbs 2,500 J of heat, what is its final temperature?

3. An iron can weighing 50 grams absorbs 256.0 J of heat and warms by 11.4°C. What is the specific heat of the iron can?

Math Connections

4. How much heat is needed to raise 35 grams of gold from 25.0°C to 35.0°C? (The specific heat of gold is 0.13 J/g°C.)

Enthalpy is the total amount of heat in a system, or the energy change of a chemical reaction. The heat of reaction, or enthalpy change (ΔH), is equal to sum of the change in enthalpy of the products minus the sum of the change in enthalpy of the reactants.

$$\Delta H = \Sigma\Delta H^{\theta}_{(products)} - \Sigma\Delta H^{\theta}_{(reactants)}$$

In an **exothermic reaction**, heat flows from the system to the surroundings. Therefore, the change in enthalpy (ΔH) is negative.

In an **endothermic reaction**, heat flows into the system from the surroundings. Therefore, ΔH is positive.

Use the following table to help calculate the change in enthalpy for the reactions in questions 5-6.

Compound	$\Delta H^{\ominus}$ kJ/mol	Compound	$\Delta H^{\ominus}$ kJ/mol
$CO_{2(g)}$	-394	$PbO_{(s)}$	-218
$H_2O_{(l)}$	-286	$NO_{2(g)}$	+34
$CH_{4(g)}$	-74	$NaHCO_{3(s)}$	-948
$ZnCl_{2(s)}$	-416	$Na_2CO_{3(s)}$	-1131
$Pb(NO_3)_{2(s)}$	-449	$NH_4Cl_{(s)}$	-315
$NH_4^+{}_{(aq)}$	-133	Cl^-	-167

Note that the heat of formation for all elements including the seven diatomic elements (H_2, N_2, O_2, F_2, Cl_2, Br_2, I_2) is zero.

Math Connections

5. The combustion of methane produces carbon dioxide and water. Calculate the ΔH for the equation and classify the reaction as either endothermic or exothermic.

$$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(l)}$$

6. When heated above 200ºC, sodium bicarbonate decomposes quickly to form sodium carbonate, water, and carbon dioxide. Calculate the ΔH for the reaction and classify the reaction as either endothermic or exothermic.

$$2NaHCO_{3(s)} \rightarrow Na_2CO_{3(s)} + H_2O_{(l)} + CO_{2(g)}$$

Claim-Evidence-Reasoning

CER Assessment

Name: ______________________ Date: ________

Scenario

A manufacturer of helicopter blades heat-treats a part as one of the steps of the processing procedure. Heat-treating involves heating the metal up to a highly specific temperature and then quenching, or cooling, it down quickly. The blades are made from an aluminum alloy and have a mass of 273 kg. Water is normally used for the quenching phase. If the water is at a temperature of 22ºC, how much water (in kg) would be needed to cool the blade from 300ºC to at least 50ºC?

External Data

The C_p of water is 4,180 J/kg ºC, and the C_p of aluminum alloy is 900 J/kg ºC. The equation for calculating heat gained or lost by a material is $q = mC_p\Delta T$.

Prompt

Write a scientific explanation that identifies mathematical relationships that can be used to answer the question.

Claim-Evidence-Reasoning

Name: ____________________________ Date: ___________

Thermodynamics

Rubric for Writing a Scientific Explanation

Points Awarded	2	1	0
Claim	Not applicable.	Makes an accurate claim or answers the question.	No claim, or does not answer the question.
Evidence	Cites comparative data, uses labels, and addresses variables.	Cites some, but not all, appropriate data, or does not use labels or statistical analysis.	No evidence, or cites changes but does not use data from the data table.
Reasoning	Cites the scientifically accurate reason, using correct vocabulary, and connects this to the claim. Is able to accurately show understanding of the concept.	Cites a reason, but it is inaccurate or does not support the claim. Reasoning does not use scientific terminology or uses it inaccurately.	No reasoning, or restates the claim but offers no reasoning.

Thermodynamics

Claim-Evidence-Reasoning

Name: ______________________ Date: __________

Claim:

Evidence:

Reasoning:

Thermodynamics

Claim-Evidence-Reasoning

Name: ___________________________ Date: __________

Claim:

Based on the calculation using the heat equation, the minimum mass of water needed is 525 kg.

Evidence:

The heat lost by the rotor blade must be absorbed by the water. This means that $q_{metal} = q_{water}$
Since q = mcΔT, this means:
$m_{metal}C_p\Delta T_{metal} = m_{water}C_p\Delta T_{water}$
$\Delta T_{metal} = 300°C – 50°C = 250°C$
$\Delta T_{water} = 50°C – 22°C = 28°C$
$m_{metal} = 273$ kg
$m_{water} = ??$
C_p aluminum = 900 J/kg °C
C_p water = 4,180 J/kg °C

(273 kg)(900 J/kg °C)(250°C) = (??)(4180 J/kg °C)(28°C)
Multiply both sides and cancel out any units.
61425000 J = (??) 117,152 J/kg

$$\frac{61425000\ J}{1175142\ \frac{J}{kg}} = ?? = \mathbf{524.3\ kg}$$

Reasoning:

The law of conservation of energy states that energy cannot be created or destroyed. It can, however, be transferred between systems. In this case, heat energy is transferred from the aluminum blade to the water, flowing from a higher to a lower temperature. So, heat is transferred from the hot metal to the water until the temperature of the water and the blades are the same, reaching equilibrium. The heat lost by the blade is gained by the water. The factors that affect the amount of heat are based on the mass, change in temperature, and specific heat of the materials in the system. Based on the given variables and calculations, the minimum amount of water needed to demonstrate the conservation of energy of this system is 525 kg.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