

## Warm-Up

## Temperature and Heat



## Lesson Question

How are temperature and heat related?



## Lesson Goals

**Distinguish** between temperature, thermal energy, and

**heat**

**Explain** how temperature relates to kinetic energy.

**Describe** specific heat and explain why it differs from one substance to another.

**Solve** problems involving

**specific**

heat.



## Words to Know

Write the letter of the definition next to the matching word as you work through the lesson. You may use the glossary to help you.

C temperature

A. the amount of heat required to change the temperature of 1 gram of a substance by 1°C

A specific heat

B. the part of total internal energy that can be transferred from one substance to another substance

B thermal energy

C. a measure of the average kinetic energy of the particles in a substance

E internal energy

D. a relationship between two variables whereby both variables increase or decrease together

F heat

E. the total potential and kinetic energies of the particles in a substance

D direct relationship

F. the thermal energy that flows from one substance to another due to a temperature difference



### Kinetic and Potential Energy

- Potential energy is the energy an object has due to its position.
  - A person at the top of a water slide getting ready to slide down has **potential** energy.
- Kinetic energy is the energy an object has due to its motion.
  - A person sliding down a water slide has **kinetic** energy.

## Instruction

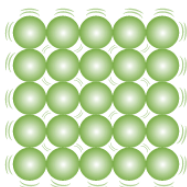
## Temperature and Heat

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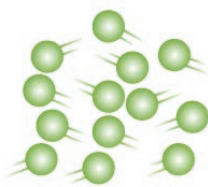
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**Kinetic Energy in Solids, Liquids, and Gases**

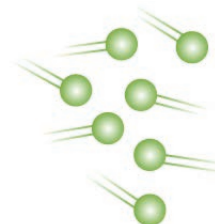
Particles of solids, liquids, and gases have kinetic energy because the particles are in constant motion.



The particles of solids have extremely **low** kinetic energy.



The particles of liquids have **moderate** kinetic energy.



The particles of gases have **high** kinetic energy.

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**Temperature**

- **Temperature** is a measure of the **average** kinetic energy of the particles in a substance.
- Three different scales can be used to measure temperature.

- Fahrenheit

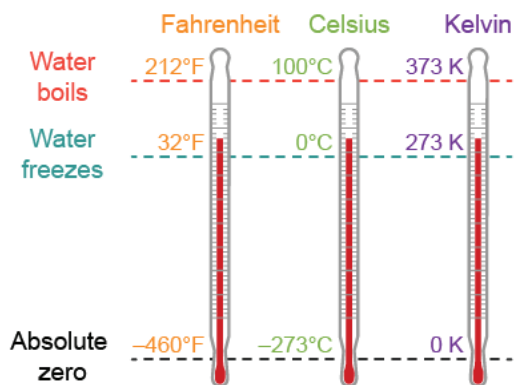
°F

- Celsius

°C

- **Kelvin**

K



## Instruction

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**The Relationship between Temperature and Kinetic Energy**

Temperature and kinetic energy have a **direct** relationship.

- The particles of water at 20°C have **less** kinetic energy.
- The particles of water at 100°C have **more** kinetic energy.

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**Internal and Thermal Energy**

- **Internal energy** is the total potential and kinetic energies of the particles in a substance.
- **Thermal energy** is the part of total internal energy that can be **transferred** from one substance to another substance.
- **Heat** is the thermal energy that flows from one substance to another due to a **temperature** difference.

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**Specific Heat**

**Specific heat** ( $c$ ) is the amount of heat required to change the temperature of 1 gram of a substance by **1°C**.

- Measured in  $\text{J/g}^\circ\text{C}$
- As an example, pure water has a specific heat of  $4.186\text{J/g}^\circ\text{C}$ . It takes **4.186 joules** of heat to raise **1** gram of water by 1 degree Celsius.

## Instruction

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**Specific Heats of Different Substances**

Different substances have different specific heat values.

- The difference is due to the different number of **atoms** in 1 gram of a substance.

Substance	Atomic mass (in amu)	Number of atoms in 1 gram sample	Heat needed to increase temperature	Specific heat (joules/gram °C)
Aluminum	26.98	$2.23 \times 10^{22}$	More per gram	<b>0.900</b>
Copper	63.55	$9.47 \times 10^{21}$	Less per gram	<b>0.386</b>

**Pizza Analogy**

The number of people sharing a pizza affects the amount of pizza each person gets.

- If there are 8 people sharing a pizza, each person will get **1/8** of the pizza.
- If there are **4** people sharing a pizza, each person will get 1/4 of the pizza.

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**Heat Equation**

Variables:

- $Q$ : heat required to raise the temperature
- $m$ : mass of the substance
- $c$ : **specific** heat of the substance
- $\Delta T$ : change in temperature (final temperature minus initial temperature)

$$Q = mc\Delta T$$

## Instruction

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**Heat Example Problem**

How much heat, in joules, is required to heat 15 grams of water  $\left(c = 4.186 \frac{\text{J}}{\text{g}^\circ\text{C}}\right)$  from  $20^\circ\text{C}$  to  $60^\circ\text{C}$ ?

• Known information:

- Mass of water: 15 g
- Specific heat:  $4.186 \frac{\text{J}}{\text{g}^\circ\text{C}}$
- Change in temperature:

$$60^\circ\text{C} - 20^\circ\text{C} = \boxed{40^\circ\text{C}}$$

- Unknown information: heat required
- Equation to be used:  $Q = mc\Delta T$

Solution:

$$\begin{aligned} Q &= mc\Delta T \\ &= (15 \text{ g}) \left(4.186 \frac{\text{J}}{\text{g}^\circ\text{C}}\right) (40^\circ\text{C}) \\ &= \boxed{2,511.6 \text{ joules}} \\ &= 2,512 \text{ joules} \end{aligned}$$

**Manipulation of the Heat Equation**

$$Q = mc\Delta T$$

$$c = \frac{Q}{m\Delta T}$$

$$m = \frac{Q}{c\Delta T}$$

$$\Delta T = \frac{Q}{mc}$$

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**The Mixing of Two Liquids**

When two liquids are added together:

- the warmer liquid cools down as it **loses** heat to the cooler liquid.
- the cooler liquid warms up as it **gains** heat from the warmer liquid.

Equilibrium Equation

$$Q_{\text{lost}} = Q_{\text{gained}}$$

Final Temperature

In this scenario we are assuming that heat is not lost to the surroundings.

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**How to Determine Final Temperature**

- Equilibrium equation:  $Q_{lost} = Q_{gained}$ 
  - $Q_1 = Q_2$
  - $m_1c_1\Delta T_1 = m_2c_2\Delta T_2$
  - $m_1c_1(T_i - T_f)_1 = m_2c_2(T_f - T_i)_2$
  - $T_f = \frac{m_1c_1\Delta T_{i1} + m_2c_2T_{i2}}{m_1c_1 + m_2c_2}$

**How to Determine Final Temperature**

Abel has 50.00 grams of water ( $c = 4.186 \frac{\text{J}}{\text{g}^\circ\text{C}}$ ) at  $85^\circ\text{C}$ . He adds 30.00 grams of water at  $20^\circ\text{C}$ . What is the final temperature of the liquids?

Known information:

- $m_1 = 50.00 \text{ g}$
  - $T_{i1} = 85^\circ\text{C}$
  - $m_2 = 30.00 \text{ g}$
  - $T_{i2} = 20^\circ\text{C}$
  - $c_1$  and  $c_2 = 4.186 \frac{\text{J}}{\text{g}^\circ\text{C}}$
- Unknown information:  $T_f$  of the liquids

Equation to be used:  $T_f = \frac{m_1c_1T_{i1} + m_2c_2T_{i2}}{m_1c_1 + m_2c_2}$

Solution:

$$T_f = \frac{50.00 \text{ g} \times 4.186 \frac{\text{J}}{\text{g}^\circ\text{C}} \times 85^\circ\text{C} + 30.00 \text{ g} \times 4.186 \frac{\text{J}}{\text{g}^\circ\text{C}} \times 20^\circ\text{C}}{50.00 \text{ g} \times 4.186 \frac{\text{J}}{\text{g}^\circ\text{C}} + 30.00 \text{ g} \times 4.186 \frac{\text{J}}{\text{g}^\circ\text{C}}}$$

$$= 60.62^\circ\text{C}$$

## Summary

## Temperature and Heat

**Lesson Question**

How are temperature and heat related?

**Answer**

(Sample answer) Heat is thermal energy that flows from a warmer object to a cooler object. When an object gains heat, the thermal energy of the object increases, which may result in an increase in an object's temperature. An object with a higher temperature loses more heat compared to an object with a lower temperature.

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**Review: Key Concepts**

Term	Definition
Internal energy	Total potential and kinetic energies of the particles in a substance
<b>Thermal</b> energy	Part of total internal energy that can be transferred from one substance to another substance
Heat	Thermal energy that flows from one substance to another due to a temperature difference
<b>Temperature</b>	Measure of the average kinetic energy of a substance

# Summary | Temperature and Heat

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## Review: Key Concepts

- Temperature and kinetic energy have a direct relationship.
  - As temperature increases, kinetic energy also increases.
  - As temperature decreases, kinetic energy also decreases.
- Different substances have different specific heat values.
  - Heavy atoms have **low** specific heat values.
  - Light atoms have **high** specific heat values.
- Specific heat values and the heat equation can be used in a variety of calculations.

Be sure you understand these equations so you can solve problems related to temperature and heat.

$$Q = mc\Delta T$$

$$T_f = \frac{m_1 c_1 T_{i1} + m_2 c_2 T_{i2}}{m_1 c_1 + m_2 c_2}$$

$$Q_{lost} = Q_{gained}$$



# Summary

## Temperature and Heat

*Use this space to write any questions or thoughts about this lesson.*

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