ChemTalk

## Laws of Thermodynamics

This worksheet will focus on the fundamental principles of thermodynamics known as the Laws of Thermodynamics. These laws govern the behavior of energy and matter in the universe. Each law has unique ideas and equations associated with it, and allows scientists to make assumptions and predictions about energy transfers in a system. This worksheet will approach the laws of thermodynamics conceptually as well as mathematically, and explain where they are found in calculations relating to other thermodynamic values.

1. Which law of thermodynamics applies to each of the following situations? Explain.
   a. Iced coffee and hot chocolate left on the counter for 3 hours have the same temperature.
   b. The potential energy of a ball on top of a building is equal to the kinetic energy the ball has on impact.
   c. Your room is messier a week after you have cleaned it than a day after you have cleaned it.

2. Consider a car engine as a system. Explain how the conversion of fuel into motion aligns with both the First and Second Laws of Thermodynamics.

3. A system undergoes a process where it absorbs 150 J of heat and performs 80 J of work. Calculate the change in internal energy using the First Law of Thermodynamics.

4. A piece of bread is burned in a bomb calorimeter, increasing the temperature of 690g of water by 45°C. How many kilojoules of energy does the piece of bread give off? (The specific heat of water is 4.18 J/g°C)

5. Consider astronauts exploring outer space. Due to the vast lack of matter, temperatures can get very low. Will the temperature ever go below 0°K? Explain using the 3rd law of thermodynamics.

6. A calorimeter contains 200 g of water at 25°C. A piece of metal with a mass of 50 g is heated to 100°C and then submerged in the water. If the final temperature of the water and metal is 30°C, calculate the specific heat capacity of the metal. (Specific heat of water, c = 4.18 J/g·°C)

**ANSWER KEY**

1. Which law of thermodynamics applies to each of the following situations? Explain.
    a. Iced coffee and hot chocolate left on the counter for 3 hours have the same temperature.

       Law Applied: Zeroth Law of Thermodynamics
       Explanation: The Zeroth Law states that if two systems are each in thermal equilibrium with a third system, they are in thermal equilibrium with each other. In this scenario, both the iced coffee and hot chocolate are in thermal equilibrium with the room, and therefore, they are in thermal equilibrium with each other.

    b. The potential energy of a ball on top of a building is equal to the kinetic energy the ball has on impact

       Law Applied: First Law of Thermodynamics
       Explanation: The First Law, or the Law of Energy Conservation, states that energy cannot be created or destroyed. The potential energy of the ball on the building is converted into kinetic energy on impact, and the total mechanical energy (kinetic + potential) remains constant.

    c. Your room is messier a week after you have cleaned it than a day after you have cleaned it

       Law Applied: Second Law of Thermodynamics
       Explanation: The Second Law states that natural processes tend to increase the overall entropy or disorder of a system and its surroundings. In the case of the messy room, over time, the room naturally tends toward a more disordered state.

2. Consider a car engine as a system. Explain how the conversion of fuel into motion aligns with both the First and Second Laws of Thermodynamics.

   Laws Applied: Both First and Second Laws of Thermodynamics
   Explanation: The First Law is evident in the conservation of energy during the conversion of fuel to motion. The chemical potential energy in the fuel is converted into kinetic energy. The Second Law is reflected in the fact that not all the energy in the fuel is converted into useful work; some is lost as heat, following the tendency of systems to increase entropy.

3. A system undergoes a process where it absorbs 150 J of heat and performs 80 J of work. Calculate the change in internal energy using the First Law of Thermodynamics.

Law Applied: First Law of Thermodynamics
Explanation: The First Law is expressed as:
$\Delta U = Q - W$
Where ΔU is the change in internal energy, Q is the heat added to the system, and W is the work done by the system.
Plugging in the values, $\Delta U = 150\,J - 80\,J =$ **70J**

4. A piece of bread is burned in a bomb calorimeter, increasing the temperature of 690g of water by 45°C. How many kilojoules does the piece of bread release? (The specific heat of water is 4.18 J/g°C)
   Due to the first law of thermodynamics, we know the amount of heat released by the bread is equal to the amount of heat it takes to heat the water. We can use the equation $Q = mC\Delta T$, where
   Q is the amount of heat absorbed/released
   m is the mass of the substance being heated
   ΔT is the change in temperature

   Plug the values given into the equation and solve.

   $Q = 0.690kg \times 4.18kJ/kg°C \times 45°C$ =**129.79kJ released**

5. Consider astronauts exploring outer space. Due to the vast lack of matter, temperatures can get very low. Will the temperature ever go below 0°K? Explain using the 3rd law of thermodynamics.

   Law Applied: Third Law of Thermodynamics
   Explanation: According to the Third Law, as the temperature of a system approaches absolute zero, the entropy of the system approaches a minimum. In outer space, temperatures can get very low, but reaching absolute zero is practically impossible due to the little bits of matter outer space contains. The Third Law implies that absolute zero is a theoretical limit that is never reached in reality.

6. A calorimeter contains 200 g of water at 25°C. A piece of metal with a mass of 50 g is heated to 100°C and then submerged in the water. If the final temperature of the water and metal is 30°C, calculate the specific heat capacity of the metal. (Specific heat of water, c = 4.18 J/g·°C)

   Due to the first law of thermodynamics, we know the amount of heat absorbed by the water is equal to the amount of heat energy released by the metal block. Therefore we know:

$Q_{metal} = \ -Q_{water} =- \ (mass\ of\ water\ \times 4.18\, J/g°C\ \times \Delta T)$

We also know $Q_{metal} = \ mass\ of\ block\ \times Specific\ Heat\ \times \ \Delta T$

Combining the equations together, we get

$mass\ of\ water\ \times (-\ 4.18\, J/g°C\,) \times \Delta T\ = mass\ of\ metal\ \times Specific\ Heat\ \times \ \Delta T$

Substitute the values given in the equation

$200g\ \times \ -\ 4.18\, J/g°C\ \times\ (30\ -\ 25)°C\ =\ 50g\ \times C \times\ (30\ -\ 100)$

Isolate and solve for C

$C\ = \frac{200 * -4.18 * 5}{50 * -70} = 1.194\, J/g°C$