Name:______________________________ Class:__________________ Date:__________________

Heat

Problem C

CALORIMETRY

PROBLEM

In 1990, the average rate for use of fresh water in the United States was approximately 1.50×10^7 kg each second. Suppose a group of teenagers build a *really* big calorimeter and that they place in it a mass of water equal to the mass of fresh water consumed in 1.00 s. They then use a test sample of gold with a mass equal to that of the United States gold reserve for 1992. Initially, the gold has a temperature of 80.0°C and the water has a temperature of 1.00°C. If the final equilibrium temperature of the gold and water is 2.30°C, what is the mass of the gold?

SOLUTION

1. **DEFINE**

Given: $T_f = 2.30°C$ $\quad m_{water} = m_w = 1.50 \times 10^7$ kg

$T_{gold} = T_g = 80.0°C$ $\quad T_{water} = T_w = 1.00°C$

$c_{p,gold} = c_{p,g} = 129$ J/kg•°C $\quad c_{p,water} = c_{p,w} = 4186$ J/kg•°C

Unknown: $m_{gold} = m_g = ?$

2. **PLAN** **Choose the equation(s) or situation:** Equate the energy removed from the gold to the energy absorbed by the water.

energy removed from metal = energy absorbed by water

$$-c_{p,g}m_g(T_f - T_g) = c_{p,w}m_w(T_f - T_w)$$

Rearrange the equation(s) to isolate the unknown(s):

$$m_g = \frac{c_{p,w}m_w(T_f - T_w)}{c_{p,g}(T_g - T_f)}$$

3. **CALCULATE** **Substitute the values into the equation(s) and solve:**

$$m_g = \frac{4186 \text{ J/kg} \bullet °\text{C})(1.50 \times 10^7 \text{ kg})(2.30°\text{C} - 1.00°\text{C})}{(129 \text{ J/kg} \bullet °C)(80.0°\text{C} - 2.30°\text{C})}$$

$$m_g = \frac{4186 \text{ J/kg} \bullet °\text{C})(1.50 \times 10^7 \text{ kg})(1.30°\text{C})}{(129 \text{ J/kg} \bullet °\text{C})(77.7°\text{C})} = 8.14 \times 10^6 \text{ kg}$$

4. **EVALUATE** Although the masses of the gold sample and water are unrealistic, the temperatures are entirely reasonable, indicating that temperature is an intrinsic variable of matter that is independent of the quantity of a substance. The small increase in the water's temperature and the large decrease in the gold's temperature is the result of the water having both a larger mass and a larger specific heat capacity.

ADDITIONAL PRACTICE

1. In 1992, the average rate of energy consumption in the United States was about 2.8×10^9 W. Suppose all of the copper produced in the United States in 1992 is placed in the giant calorimeter used in the sample problem. The

quantity of energy transferred by heat from the copper to the water is equal to the energy used in the United States during 1.2 s of 1992. If the initial temperature of the copper is 26.0°C, and the final temperature is 21.0°C, what is the mass of the copper?

2. In 1992, a team of firefighters pumped 143×10^3 kg of water in less than four days. What mass of wood can be cooled from a temperature of 280.0°C to one of 100.0°C using this amount of water? Assume that the initial temperature of the water is 20.0°C and that all of the water has a final equilibrium temperature of 100.0°C, but that none of the water is vaporized. Use 1.700×10^3 J/kg•°C for the specific heat capacity of wood.
3. One of the nuclear generators at a power plant in Lithuania has a nominal power of 1.450 GW, making it the most powerful generator in the world. Nippon Steel Corporation in Japan is the world’s largest steel producer. Between April 1, 1993, and March 31,1994, Nippon Steel’s mills produced 25.1×10^9 kg of steel. Suppose this entire quantity of steel is heated and then placed in the giant calorimeter used in the sample problem. If the quantity of energy transferred by heat from the steel to the water equals 1.00 percent of all the energy produced by the Lithuanian generator in a year, what is the temperature change of the steel? Assume that the specific heat capacities of steel and iron are the same.
4. In 1994, to commemorate the 200th anniversary of a beverage company, a giant bottle was constructed and filled with 2.25×10^3 kg of the company’s lemonade. Suppose the lemonade has an initial temperature of 28.0°C when 9.00×10^2 kg of ice with a temperature of −18.0°C is added to it. What is the lemonade’s temperature at the moment the temperature of the ice reaches 0.0°C? Assume that the lemonade has the same specific heat capacity as water.
5. The water in the Arctic Ocean has a total mass of 1.33×10^{19} kg. The average temperature of the water is estimated to be 4.000°C. What would the temperature of the water in the Arctic Ocean be if the energy produced in 1.000×10^3 y by the world’s largest power plant (1.33×10^{10} W) were transferred by heat to it?
6. There is a little island off the shore of Brazil where the weather is extremely consistent. From 1911 to 1990, the lowest temperature on the island was 18°C (64°F) and the highest temperature was 32°C (90°F). It is known that the liquid in a standard can of soft drink absorbs 20.8 kJ of energy when its temperature increases from 18.0°C to 32.0°C. If the soft drink has a mass of 0.355 kg, what is its specific heat capacity?
7. The lowest temperature ever recorded in Alaska is –62°C. The highest temperature ever recorded in Alaska is 38°C. Suppose a piece of metal with a mass of 180 g and a temperature of –62.0°C is placed in a calorimeter containing 0.500 kg of water with a temperature of 38.0°C. If the final equilibrium temperature of the metal and water is 36.9°C, what is the specific heat capacity of the metal? Use the calculated value of the specific heat capacity and **Table 4** in your textbook to identify the metal.