4.4: Temperature Change

Explain how heat is transferred in changes of temperature.

You have just finished learning about how to calculate the amount of heat that is transferred during a change of state (this heat is called latent heat). Now we will focus on calculating the amount of heat transferred during a temperature change. Heat that is transferred and causes a temperature change is called sensible heat because you can sense the temperature change. Look at the formula for calculating sensible heat below. Q is used to denote the heat transferred during a temperature change.

$$Q = m \cdot c \cdot \Delta T$$
$$Q = m \cdot c \cdot (T_f - T_i)$$

Q = heat transferred measured in calories (cal)

m = mass measured in grams (g)

c = specific heat measured in calories per gram per degrees Celsius (cal/g/°C)

ΔT = change in temperature or difference between initial temperature (T_i) and final temperature (T_f) measured in degrees Celsius

T_f = final temperature after heat transfer

T_i = initial temperature before heat transfer

To solve for Q, take the mass *times* the specific heat *times* the change in temperature. The change in temperature is written as ΔT and can be found by taking the final temperature minus the starting temperature.

Every material has what is called specific heat. *The specific heat is a number that represents the amount of heat required to raise one gram of a substance by one degree Celsius.* The letter c is used as the symbol for specific heat.

Table 4.4 lists the specific heat for a few substances.

Substance		Specific Heat (c) (cal/g per °C)
Ice	(for temperature changes in ice	0.50
Water	(for temperature changes in liquid water)	1.00
Steam	(for temperature changes in water vapor)	0.48
Aluminum		0.21
Brass		0.09
Copper		0.09
Lead		0.03
Diamond		0.12
Air		0.24
Wood		0.42

Table 4.4: Specific heat for various materials

Notice that ice changes temperature by transferring 0.50 calories per gram per degree Celsius. For example, 1 gram of ice at –5°C would increase in temperature by 1°C by absorbing 0.50 calories. To increase 1 gram of ice from –5°C to 0°C would require 2.5 calories ([1 g] • [0.5 cal/(g •°C)] • [5°C] = 2.5 calories). The addition of this heat would change the temperature from –5°C to 0°C. In order to melt, however, this 1 gram of ice would then require the addition of 80 calories (the latent heat of fusion), which it would have to absorb (these additional calories would not result in an increase in temperature).

One application of this understanding about heat transfer is how we build houses. Insulation that has a high specific heat is often placed inside the walls of a house. As a result, heat will not flow easily through the walls. The insulation in the walls is used to control the amount of heat flowing in and out of the house. Controlling how heat flows into and out of our homes helps to make living more comfortable. During the winter months it is desirable to keep heat inside the home and prevent it from escaping. During the summer months we want to keep heat outside and prevent it from entering. What factors affect the heat flow into or out of our homes? The specific heat of the insulation is a major factor, as is the mass of the insulation. Another major factor is the difference in temperature between the inside and outside of our homes.

Example 4.9:

The temperature of 10 grams of water is 10°C. How much energy must be added to this in order to raise the temperature of the water to 50°C?

Hide Answer

- *Q = m c (Tf – Ti)*
- Insert given information. See table 4.4 to get the specific heat of water.
- Q = (10 g)(1 cal/[g ·°C])(50 – 10)
- Find the temperature difference first, then multiply through. Notice that like units on top cancel out with their corresponding units on bottom, leaving the final answer in calories.
- $Q = \frac{(10\ \text{g})(1\ \text{cal})(40°\text{C})}{\text{g}\cdot°\text{C}} = 400\ \text{calories}$

Example 4.10:

When 50 grams of aluminum at 20°C is heated until it reaches a temperature of 45°C, how much heat is transferred to the aluminum?

Hide Answer

- *Q = m c (Tf – Ti)*
- Insert given information. See table 4.4 to get the specific heat of aluminum.
- $Q = \frac{(50\text{g})\ (0.21\ \text{cal})\ (45 - 20)}{\text{g}\cdot°\text{C}}$
- Solve for temperature difference first, then cancel out like units, and then multiply through.
- $Q = \frac{(50\text{g})\ (0.21\ \text{cal})\ (25°\text{C})}{\text{g}\cdot°\text{C}} = 262.5\ \text{calories}$

Example 4.11:

If 500 calories are added to 100 grams of wood at 30°C, what will the final temperature of the wood be?

Hide Answer

- *Q = m c (Tf – Ti) or Q = m c ΔT*
- Insert given information. See table 4.4 to find the specific heat of wood.
- $500\ \text{cal} = (100\text{g})\ \frac{(0.42\ \text{cal})}{\text{g}\cdot°\text{C}}\ (\Delta\text{T})$
- Cancel like units then multiply.
- $500\ \text{cal} = \frac{42\ \text{cal}}{°\text{C}}\ (\Delta\text{T})$
- Divide by 42 to solve for ΔT. Remember to bring the units as well.
- $\frac{500\ \text{cal}}{42\ \frac{\text{cal}}{°\text{C}}} = \Delta\text{T}$

- Now, it may look a little confusing, but don't fret. Here is a little tip: Dividing by something is exactly the same as multiplying by the inverse. For example, 12 ÷ 3 is the exact same as 12 × ⅓. So, let's invert the 42 cal/°C and multiply it by 500 cal. Don't be scared by the word "invert" it basically means "flipping over."
- $\frac{(500\ \cancel{cal})(1\ ^\circ C)}{42\ \cancel{cal}} = \Delta T$
- Units cancel out, leaving you with a temperature, which is good because that is what the question is asking for! Now multiply through (500·1/42, or in other words 500 ÷ 42).
- 11.9°C = ΔT
- Now we have found the change in temperature, but the question asks for the final temperature. So, let's take the initial temperature (which is given in the question) and add the change to get the final temperature.
- 30°C + 11.9°C = **41.9°C**

There! We did it! Now can you do it by yourself? Be sure that you thoroughly understand the Self Check questions before moving on to the Speedback. If you need more practice, try the practice problems in the Appendices.