# **Chemistry – Energy and Changes in Matter**

# **Information**: Specific Heat Constants Depend on the State of Matter

Recall that specific heat is the energy necessary to raise the temperature of one gram of a substance by one degree Celsius. The specific heat of liquid water is a constant equal to 4.18 J/(g-oC). This means that it takes 4.18 Joules (J) of heat energy to raise the temperature of each gram of water by one degree Celsius. For ice, the specific heat is 2.06 J/goC. Steam’s specific heat is 2.02 J/goC. You will want to remember the three different specific heat values for H2O.

**Critical Thinking Questions**

1. How much energy is required to heat 32.5g of water from 34oC to 75oC?
2. How many J of energy are needed to heat 45.0g of steam from 130oC to 245oC? Why don’t you use 4.18 J/goC in this calculation?
3. Why is it impossible for you to answer the following question right now: How much energy is required to heat 35g of H2O from 25oC to 150oC?

# **Information**: Energy Involved in Changing State

Obviously, it takes energy to heat a substance such as water. There is also an energy change when a substance changes state. For example, when water freezes, energy is taken away from the water and when water boils, energy is being added to the water.

When water is heated up to 100oC, it will NOT automatically boil unless more energy is added. Once water is at the correct temperature (100oC), it will boil IF you add energy to change it from a liquid to a gas. The extra energy is needed to separate the molecules from one another. Note: **at the boiling point of a liquid energy is added to the liquid, but the temperature of the liquid does NOT change.** The temperature of H2O will increase above 100oC only after all of the water has been changed to steam. After the phase change, if more energy is applied, the temperature will go up.

**Figure 1**: Graph of the temperature of H2O vs. energy added to the water.

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| Temperature of H2O (oC) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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0 25 50 75 100 125 150 175 200 225 250 275 300

Energy added to water in kilojoules (kJ)

# **Critical Thinking Questions**

1. What is the significance of the horizontal portions of the graph? What is going on during those times?
2. Label the temperature scale on the graph.
3. Does it require more energy to “vaporize” water at the boiling point or to melt water at the melting point? Explain.

# **Information**: Mathematics of Changes of State

Recall the equation: q = (m)(Cp)(T) where q is the heat energy, Cp is the specific heat of the substance, m is the mass of the substance, and T is the change in the temperature. This equation works ONLY when there is **no phase change**. You use it to find how much energy is required to change the temperature of a certain substance as long as you know the specific heat of the substance and as long as no change in state occurs.

Now for when there is a change in state: The energy required for a change of state is given a special name called enthalpy. So the “enthalpy of vaporization” (symbolized by Hvap) of water is the energy needed to vaporize (or boil) one gram of water when the water is already at its boiling point. The Hvap of water is 2260 J/g. So for each gram of hot (100oC) water, 2260 J are required to vaporize it. Similarly, the enthalpy of fusion (Hfus) of H2O is 334 J/g. So each gram of ice at 0oC there are 334 J of energy required to melt it. (Fusion is melting.)

# **Critical Thinking Questions**

1. Verify that it takes 4140.7 J of energy to heat 12.7 g of water from room temperature (22oC) to the boiling point (100oC). Recall that the specific heat (Cp) of water is 4.18 J/(g-oC).
2. Given the fact that the Hvap of water is 2260 J/g we know that 2260 J of energy is required to vaporize 1 gram of water. To vaporize 2 grams of water it requires 4520 J. For 3 grams, 6780 J are needed. Verify that it takes 28,702 J of energy to vaporize 12.7 g of water, when the water is already at its boiling point.
3. Verify that it takes 1513.6 J of energy to heat 12.7 g of steam from 100oC to 159oC. Note: the specific heat of steam (Cp) is 2.02 J/(g-oC).
4. Using only your answers to questions 7-9, calculate how many Joules of energy it takes to change 12.7 g of water at 22oC to steam at 159oC.
5. Calculate how many Joules of energy would be required to change 32.9 g of water at 35oC to steam at 120oC. You will need to break this problem into four steps.
6. Find the Joules needed to heat the water to the boiling point.
7. Find the Joules needed to vaporize the water.
8. Find the Joules needed to heat the vapor (steam) from the boiling point to 120oC.
9. Add your answers to steps a, b, and c.
10. How much heat energy would be required to change the temperature of 125g of ice from -32.9oC to liquid water at 75oC?