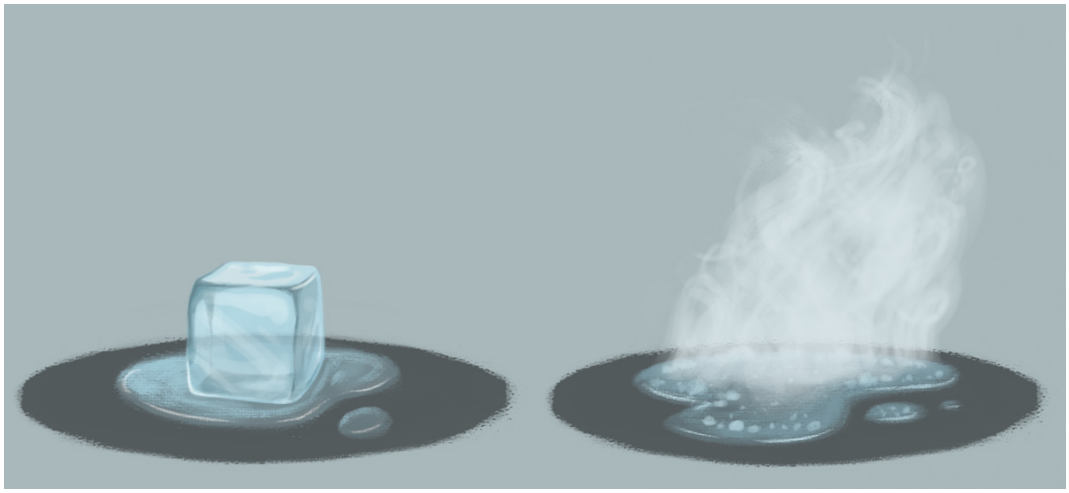
4.3: Heat Transfer

Explain how heat is transferred in changes of state.

So, what really happens with heat when matter changes state? In every case there must be some amount of heat transfer. Heat is either absorbed or released, depending on which change of state is involved. Heat that is involved in changes of state is called **latent heat**. It is important to remember that latent heat is the heat that is involved in changes in states of matter.

Let's again consider the example of water. Solid ice absorbs heat in the process of melting. The same amount of heat is released as liquid water freezes to become ice. Liquid water absorbs heat to become water vapor. The same amount of heat is released as water vapor condenses to become liquid water. It is also important to understand that during a change in state, the temperature of the substance is not changing although heat is still being applied to it. For example, when you put a pot of water on the stove, the temperature of the water begins to increase. The temperature will continue to increase until the water can no longer support the higher temperature in its current form and begins to change state, or in other words boil. While water is boiling it does not change temperature.

We learned in our last objective that heat is a form of energy. The unit of measurement we used for energy was the joule. There is another unit often used to measure amounts of energy—specifically to measure heat being transferred. This unit is the calorie. One calorie is the heat energy required to raise one gram of liquid water by one degree Celsius. This is equal to about 4.18 joules. It is important to note that the calorie is used to measure the amount of heat that is transferred. For this lesson we will be using calories to measure the amount of heat absorbed or released when matter goes through a change of state.



Ice-to-water and water-to-steam transformations

It turns out that it takes 80 calories of heat to melt 1 gram of ice at 0°C into liquid water at 0°C (notice that the 80 calories don't change the temperature of the water—they just cause it to change states). Heat that is absorbed or released in a solid–liquid or liquid–solid change of state is called the heat of fusion. So the heat of fusion for water is 80 calories per gram. In changing from liquid to gas, water at 100°C must absorb 540 calories per gram. This heat that is absorbed or released in a gas–liquid or liquid–gas change of state is called the heat of vaporization.

Water does not have to be at 100°C to vaporize. Try setting a pan of water out in the sun and watch it slowly disappear. The sun's heat is not boiling the water, but it is evaporating it. In a given amount of water at a given temperature, some molecules of water will have more energy than others, so some molecules will be able to evaporate, while others remain in the liquid state. The lower the temperature of the water, the more energy is required for evaporation. If the water is liquid at a temperature of 0°C, the latent heat of vaporization is about 600 calories per gram compared to 540 calories per gram at 100°C1. In others words, hot water evaporates easier (or requires less energy) than cooler water.

Table 4.2 illustrates how much heat must be absorbed or released for water as it undergoes changes of state[1].

Process	Latent Heat (L)
Heat of fusion (Liquid-solid or solid-liquid)	80 cal/g
Heat of vaporization (Liquid-gas or gas-liquid)	540 cal/g

Table 4.2: Latent heat of water

It is important to note when the heat is absorbed and when it is released. Heat is absorbed when a substance changes from liquid to gas (vaporization) or from solid to liquid (melting). Heat is released when a substance changes from gas to liquid (condensation) or from liquid to solid (freezing).

Process	Heat released or Absorbed
Melting (solid to liquid)	Absorbed
Vaporization (liquid to gas)	Absorbed
Freezing (liquid to solid)	Released
Condensation (gas to liquid)	Released

Table 4.3: Heat transfer as released or absorbed during various processes

You can determine how many calories it would take to change the state of a particular amount of water with the following formula:

$QL = m \cdot L$

m = Mass measured in grams (g)

L = Latent heat measured in calories or grams (cal/g)

QL = calories required for change

Notice how the formula does not include temperature. Remember, when a substance like water changes state the temperature remains the same—heat is absorbed or released, but the temperature does not change.

Example 4.7:

The temperature of 10 grams of ice is 0°C. How much energy must be added to this in order to melt the ice?

Hide Answer

Notice that the ice is changing from solid to liquid. We will therefore use heat of fusion (see table 4.2). Also notice that like units on top and on bottom cancel out, leaving the final answer in calories.

$$(10\ \text{g})\left(\frac{80\ \text{cal}}{\text{g}}\right) = 800\ \text{calories}$$

Example 4.8:

The temperature of 30 g of steam is 100°C. How much energy must be transferred to convert this to liquid water? Is the heat absorbed or released?

Hide Answer

1. Notice that the steam is changing from gas to liquid. We will therefore be using heat of vaporization (see table 4.2). Cancel like units then multiply through.

$$(30\ \text{g})\left(\frac{540\ \text{cal}}{\text{g}}\right) = 16{,}200\ \text{calories}$$

2. The heat is released.

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[1] Joseph F. Alward, PhD., University of the Pacific, http://sol.sci.uop.edu/~jfalward/spedificandlatentheats/specificandlatentheats.html.