Chapter 15

Temperature, Heat, and Expansion

The Concept of Temperature…

…originally arose with our senses. (We can "feel" whether something is "hot" or "cold."

A more reliable measure of temperature is to use a thermometer (a device that assigns a numeric value to a certain "degree of hotness" using a scale that is defined by two fixed points—such as the melting and boiling points of water at atmospheric pressure).

More fundamentally, temperature is a direct measure of the average (translational) kinetic energy per molecule in a substance.

Measuring Temperature

- Temperature in NOT energy (although is a directly related to the average kinetic energy of the atoms and molecules in a substance.
- Temperature is commonly measured in “degrees” using the Farhenheit scale (in the United States) or the Celsius scale (everywhere else).
- In the scientific community temperature id measure on the Kelvin scale. The Kevin scale has the sme intervals as the Celsius scale, but the “0” on the Kelvin scale is at the “absolute zero” of temperature (Classically, this is the point where the atoms and molecules have no more energy left to give up.

Heat…

…is a form of "energy in transit."

Specifically, heat is energy that transfers from ne substance to another because of a temperature difference between them.

Heat will spontaneously flow from a substance having a higher temperature to one at a lower temperature, but nor the other way around.

Heat is NOT the thermal energy that an object contains. It is the amount of energy <u>transferred</u>.

Internal Energy…

…refers to the sum total of the kinetic and potential energies among ALL of the atoms and molecules in a substance.

When a substance absorbs heat, its store of internal energy increases. When giving up heat, the internal energy of a substance decreases.

Internal Energy (cont’d)

Questions: While heat will not spontaneously flow from a lower temperature to a higher temperature, is it possible for heat to flow from a substance of lower internal energy to one of higher internal energy?

Answer: Yes! A tub of room temperature water has more internal energy than a red-hot paperclip because there are much more mass of water than the paperclip. So even though the average kinetic energy of the molecules in the water is less, the sum of all the energies from all the water molecules is greater. The heat flows from the hot paperclip to the cold water.

Measuring Heat

Since heat is a form of energy (energy in transit), heat can be measured in any energy unit (like Joules, for example).

A common unit of heat used is the *thermal calorie* (cal) which is the amount of heat required to change the temperature of 1 gram of water by 1 C^o.

Do not confuse the thermal calorie with the Food Calorie used in nutrition. One "Food Calorie" (designated, Cal) is actually 1000 thermal calories.

Specific Heat Capacity…

…conceptually describes the "thermal inertia" of a substance. (That is, the resistance to changes in temperature of a specific mass of material when heat is added or removed.)

More accurately the specific heat capacity describes the amount of energy required to change the temperature of a unit mass of substance by some specified amount. (It is a property of the substance.)

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The symbol for specific heat capacity is c.

Specific Heat Capacity (cont'd)

Using the definition of the (thermal) calorie, we can write the specific heat capacity of water as:

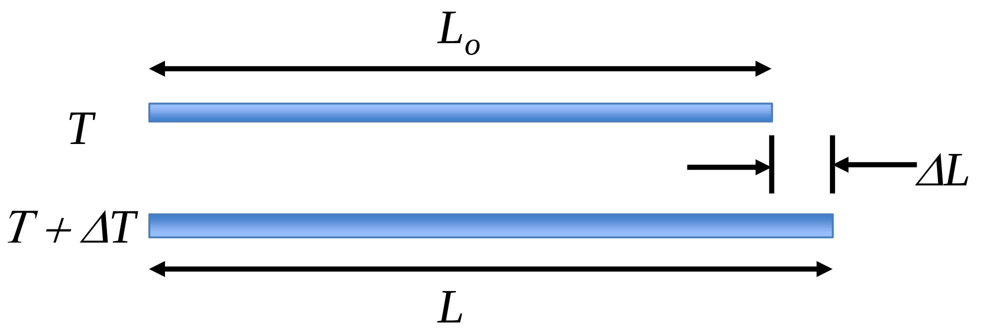
$$c = 1 \frac{\text{calorie}}{\text{gram} \cdot \text{C}^{\text{o}}}$$

The specific heat capacity of water is much higher than almost all other common material. For instance, the specific heat capacity of water is about ten times that of iron. As a result, it aks about ten times as much energy to change the temperature of some mass of water by some amount than it does to change the same mass of iron by the same amount.

Thermal Expansion

Nearly all substances expand when heated and contract when cooled*.

The fractional change in dimension is directly proportional for the change in temperature.



The *fractional change* in length: $\frac{\Delta L}{L_0} = \alpha \Delta T,$

where α is the expansion coefficient and is a property of the material.

*Notable exception: Water between 0 ^oC and 4 ^oC.