HEAT CAPACITY AND SPECIFIC HEAT CAPACITY

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The *heat capacity* C of a sample of matter is the amount of heat that must be added to raise the temperature of the sample by 1 K. As a rule, the heat capacity depends on all the state quantities (pressure, volume and temperature) as well as on the method by which it is measured (whether pressure or volume held constant). The general definition is

$$C \equiv \frac{Q}{\Delta T} \tag{1}$$

where Q is the heat added and ΔT is the resulting temperature change. It's important to note that C is defined by considering only the *heat* which flows into the substance (recall that heat is defined to be energy flow due to temperature difference only), so we can't use the change in thermal energy ΔU on its own to calculate C; we must also know how much work W is done on the substance in order to isolate Q:

$$C = \frac{\Delta U - W}{\Delta T} \tag{2}$$

The total heat capacity of a sample therefore depends on how much matter is in the sample, so it's not a property of a particular substance in general (such as melting point). We can, however, define the *specific heat capacity*, which is the heat capacity per unit mass:

$$c \equiv \frac{C}{m} \tag{3}$$

[Note that c here is *not* the speed of light! As I've been posting a lot of relativity and electrodynamics recently, this post requires a bit of a phase change in your way of thinking.]

The *calorie* is the amount of heat required to raise the temperature of 1 gram of water by 1 K, and is equal to 4.184 Joules. This fact suggests a method of measuring the heat capacity of some substances, at least in the temperature range of liquid water. For example, if we take a chunk of metal with a mass of 100 grams, we can drop it in boiling water long enough for its temperature to become 100° C. We can then transfer it quickly (so as not to lose any heat in the transfer) to a styrofoam cup (styrofoam has a very low heat capacity itself so serves as a good thermal insulator) containing 250 g of water at 20° C, and seal the cup with a styrofoam lid. We can wait a few minutes to let the metal come into thermal equilibrium with the water, and then measure the temperature of the water. Suppose this is measured as 24° C.

The whole process involves heat transfer only, as the only transfer of energy that occurs is due to temperature differences between the metal and, first, the boiling water and, second, the water in the cup. Thus all temperature changes are due to Q on its own.

The water in the cup absorbs heat Q from the hot metal:

$$Q = C_w \Delta T \tag{4}$$

$$= 250 \text{ g} \times 1 \text{ cal g}^{-1}\text{K}^{-1} \times 4 \text{ K} \tag{5}$$

$$= 1000 \text{ cal} \tag{6}$$

Therefore the heat lost by the metal is -1000 cal. The heat capacity C_m of the metal is found by using $\Delta T = 24 - 100 = -76$ K:

$$C_m = \frac{Q}{\Delta T} = \frac{-1000}{-76} = 13.16 \text{ cal K}^{-1} \tag{7}$$

The specific heat capacity of the metal is

$$c_m = \frac{C_m}{m} = \frac{13.16}{100} = 0.1316 \text{ cal g}^{-1}\text{K}^{-1} = 0.55 \text{ J g}^{-1}\text{K}^{-1} \tag{8}$$

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