9.2: Change of State

According to my dictionary, the word "latent" means "present or existing and capable of development but not manifest".

In a liquid at its freezing point there is present or existing some heat, which is capable of development but is not manifest. That is, the liquid secretly holds some latent heat. When the liquid freezes, it gives up this latent heat to its surroundings. The heat is now manifest.

Definition: The *latent heat of freezing* of a quantity of liquid at its freezing point is the heat given up to its surroundings when it freezes. Its SI unit is the joule.

Likewise, we define the *specific latent heat* and the *molar latent heat* of a liquid at its freezing point as the heat given up when unit mass, or a molar amount, respectively, freezes. The SI units are J kg^{-1} and J kilomole^{-1} respectively.

> A distressingly large number of people use the words "latent heat" when they mean "specific latent heat". Thus, when you read or hear the words "latent heat" you have to be on guard to decide whether this is really what is meant, or whether "specific latent heat" is intended.

The latent heat of *fusion* of a solid body at its melting point is the heat required to melt it. This is just equal to the heat given up when the liquid freezes, so that, numerically, the latent heats of freezing and of fusion (melting) are the same – though somehow the word "latent" seems less appropriate for freezing, because you are supplying heat to the solid, rather than seeing latent heat being released by a liquid. If you prefer you could refer to the "latent heat" of fusion simply as the "heat of fusion" – or as the “enthalpy of fusion”.

Likewise we have a latent heat of condensation of a vapour at its condensation point, and the latent heat of vaporization of a liquid at its boiling point. These are equal in magnitude. We can also define the specific and molar latent heats of condensation and vaporization. The term latent heat of transformation will do to cover all four processes. The symbol L (with appropriate subscripts if need be) can be used for any of the latent heats of transformation.

The specific latent heat of fusion of ice at atmospheric pressure is about 3.36 × 105 J kg^{-1} or about 80 cal g^{-1}.

The specific latent heat of vaporization of water at atmospheric pressure is about 2.27 × 106 J kg^{-1} or about 540 cal g^{-1}.

Example $9.2.1$

70 g of ice at 0 ºC are mixed with 150 g of water at 100 ºC. What is the final temperature? (I make it 43º C.)

Solution

We'll reluctantly, for once, work in calories and grams, and of course the specific heat capacity of water is about 1 calorie per gram per Celsius degree. The heat required to melt the 70 g of ice, and then to raise its temperature from 0 $^{\circ}$C to t $^{\circ}$C is 70 × 80 + 70t calories. This heat is supplied by the hot water, which cools from 100 $^{\circ}$C to t $^{\circ}$C, is 150 % (100 − t) calories. Equating the two produces t = 43 $^{\circ}$C.

Example $9.2.1$

Suppose you apply 2.27 × 10^{6} J of energy to a kilogram of water, but, instead of using that energy to vaporize the water, you use it to raise the water from the ground. How high above the ground could you raise it with this energy? It may surprise you – it certainly surprised me! If you were to use the energy, not to vaporize the water, and not to raise it above the ground, but to throw it, how fast, in miles per hour, could you throw it?

For many liquids there is a very rough correlation between molar latent heat of vaporization and boiling point at atmospheric pressure, the ratio L/T usually being in the range 70,000 to 100,000 J kmole^{-1} K^{-1}.

One last point before proceeding. Generally it is only crystalline solids (including metals) that have a rather definite melting point. Amorphous substances such as plastics and glass generally change from solid to liquid over a rather large range of temperature. Indeed is not obvious when to cease calling such a substance a solid and to start calling it a liquid. Some writers would describe glass as a “liquid” even when it has all the obvious appearances of a solid. See also Section 6.4 for a further discussion of this. Mixtures, alloys and solutions, too, do not have such a definite melting point as a crystalline solid, and a salt solution does not have as definite a boiling point (at a given pressure) as a pure liquid does. Thus a salt solution in water at one atmosphere pressure boils at a little higher temperature than 100 °C. When some of the water boils off, the remaining solution is a little more concentrated, and so the boiling point becomes a little higher, and so on.