EXTENSIVE AND INTENSIVE QUANTITIES

Link to: physicspages home page.

To leave a comment or report an error, please use the auxiliary blog.

Reference: Daniel V. Schroeder, *An Introduction to Thermal Physics*, (Addison-Wesley, 2000) - Problem 5.21.

The various thermodynamic properties can be classified according to whether they are *intensive* or *extensive*. Basically, if we take a system and duplicate it exactly, an extensive quantity will also double, while an intensive quantity will remain unchanged. The intensive quantities include temperature, pressure and any form of density, such as mass density or energy density. Most other quantities are extensive. If we duplicate a system, clearly its volume doubles as does the number of particles. All forms of energy (U, H, F and G, for example) will double, as will the system's mass.

The ratio of two extensive quantities produces an intensive quantity, since the common factor that appears when a system is duplicated cancels out in the division. Multiplying two intensive quantities gives another intensive quantity, since the absolute size of the system doesn't appear in the product. Multiplying an intensive by an extensive quantity produces another extensive quantity, since the absolute size occurs once in the product (in the extensive quantity). You might think that multiplying two extensive quantities gives a quantity that increases according to the product of the sizes of the systems, but in fact such products don't appear in thermal physics.

For some examples, we'll look at the following.

The entropy is an extensive quantity. It is defined as

$$S = k \ln \Omega \tag{1}$$

where Ω is the number of microstates available to the system. If we duplicate a system then $\Omega \to \Omega^2$ since for each microstate in the original system, any of the microstates is available to the duplicate system. Therefore $S \to 2S$, so entropy is extensive.

The chemical potential is defined as

$$\mu \equiv -T \left(\frac{\partial S}{\partial N} \right)_{U,V} \tag{2}$$

The derivative is intensive, since it is the ratio of two extensive quantities S and N. T is also intensive, so μ is the product of two intensive quantities, making it intensive.

The total heat capacity C is extensive, since it is the amount of heat required to raise the entire system by one kelvin. If you double the system, you'll need twice as much heat. The *specific* heat capacity c, however, is intensive, since it gives the amount of heat required to raise a fixed amount of a substance by one kelvin, so it's independent of the size of the system.

PINGBACKS

Pingback: Gibbs free energy and chemical potential