This is the condition for thermal equilibrium for two systems in thermal contact. Here N_1 and N_2 may symbolize not only the numbers of particles, but all constraints on the systems.

TEMPERATURE

The last equality (22) leads us immediately to the concept of temperature. We know the everyday rule: in thermal equilibrium the temperatures of the two systems are equal:

$$T_1 = T_2. \tag{23}$$

This rule must be equivalent to (22), so that T must be a function of $(\partial\sigma/\partial U)_N$. If T denotes the absolute temperature in kelvin, this function is simply the inverse relationship

$$\frac{1}{T} = k_B\left(\frac{\partial\sigma}{\partial U}\right)_N. \tag{24}$$

The proportionality constant k_B is a universal constant called the **Boltzmann constant**. As determined experimentally,

$$\begin{aligned} k_B &= 1.381 \times 10^{-23}\ \text{joules/kelvin} \\ &= 1.381 \times 10^{-16}\ \text{ergs/kelvin}. \end{aligned} \tag{25}$$

We defer the discussion to Appendix B because we prefer to use a more natural temperature scale: we define the **fundamental temperature** τ by

$$\boxed{\frac{1}{\tau} = \left(\frac{\partial\sigma}{\partial U}\right)_N.} \tag{26}$$

This temperature differs from the Kelvin temperature by the scale factor, k_B:

$$\boxed{\tau = k_B T.} \tag{27}$$

Because σ is a pure number, the fundamental temperature τ has the dimensions of energy. We can use as a temperature scale the energy scale, in whatever unit