Today

I. Guest Lecturer for Next Week: Guillermo
II. Last Time
III. New Definition of Temperature: Examples
IV. Andrew's Guest Lecture: The Two-State Paramagnet
V. An Experimental Example

I. Defined reversible and irreversible processes. A process is, in principle, reversible if $\Delta S = 0$. And it is irreversible if $\Delta S > 0$.

Introduced a new definition of temperature:

$\frac{\partial S_A}{\partial U_A} = \frac{\partial S_B}{\partial U_B} \implies \frac{1}{T_A} = \frac{1}{T_B}$, in other words we introduced the definition

$$\frac{1}{T} \equiv \left(\frac{\partial S}{\partial U}\right)_{V,N}$$

I. Finally we unpacked the distinction between work and heat:

Roughly, work is a change in the value of an energy level, for example closing down the walls of an infinite square well.

Meanwhile, heat is a change in the way in which the energy levels are populated. This helps me to see why adding heat to a system also increases its entropy.

II. Going to the definition of Temperature, you might observe that it seems simpler to just compute

$$T = \left(\frac{\partial U}{\partial S}\right)_{V,N}.$$

If we could do this, it would be simpler. But, it is more common to have the entropy as a function of the energy $S(U, V, N)$.

III. Examples

Consider an Einstein solid in the $q \gg N$, high temperature limit.

$S = Nk[\ln(q/N) + 1]$. Let's define our energy unit to be ϵ, then

$U = q\epsilon$. Then,

$S = Nk[\ln(U/(N\epsilon)) + 1] = Nk \ln U - Nk \ln(\epsilon N) + Nk$

And the U derivative is

$$\frac{1}{T} = \frac{\partial S}{\partial U} = \frac{Nk}{U} \quad \Longrightarrow \quad U = NkT.$$

This is exactly equipartition in the case $f = 2$, which is perfect since the solid is made up of harmonic oscillators with two quadratic degrees of freedom per oscillator.

We're also in good shape for checking the ideal gas:

$S = Nk \ln V + Nk \ln U^{3/2} + f(N)$.

III. Examples

We're also in good shape for checking the ideal gas:

$S = Nk \ln V + Nk \ln U^{3/2} + f(N)$. Then

$$\frac{1}{T} = \frac{\partial S}{\partial U} = Nk \frac{1}{U^{3/2}} \frac{3}{2} U^{1/2} = \frac{3}{2} \frac{Nk}{U} \quad \Longrightarrow \quad U = \frac{3}{2} NkT.$$

The f is then three, which is the three quadratic pieces of the kinetic energy.

IV. For slides from Andrew's guest lecture see our course website.

V. We also checked out Dianna Cowern's (Physics Girl) video on the Curie Temperature: Oxygen is Magnetic?