

LAST TIME:



1ST LAW (energy conservation): could have $T_1 \uparrow, T_2 \downarrow$ or $T_1 \downarrow, T_2 \uparrow$

But: always observe temperatures to equalize.

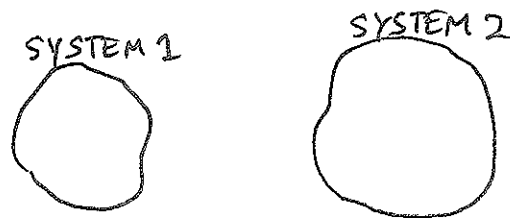
reason: vastly more microscopic configurations with $T_1 \approx T_2$.

interactions: allow system to move around randomly between possible configurations with same energy.

overwhelmingly likely to end up on configuration with $T_1 \approx T_2$

DEMO

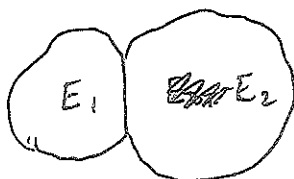
2ND LAW OF THERMODYNAMICS: macroscopic variables evolve toward values for which # of ~~microscopic states~~ possible microscopic configurations is greatest.



define $N_1(E)$: # of configurations of system 1 with energy E

$N_2(E)$: # of configurations of system 2 with energy E .

suppose total energy $E_{TOT} = E_1 + E_2$



will move toward config. where

$$N_1(E_1) \times N_2(E_2)$$

is maximum, for $E_1 + E_2 = E_{TOT}$.

define ENTROPY

$$S = k_B \ln(N(E))$$

(examples)

$$\text{Then } S_1 + S_2 = k_B \ln(N_1(E_1)) + k_B \ln(N_2(E_2))$$

$$= k_B \ln(N_1(E_1) \times N_2(E_2))$$

$$= S_{\text{TOTAL}}$$

want to maximize this.

2ND LAW: ^{isolated} systems move toward configurations with larger total entropy.

EQUILIBRIUM: maximum entropy state

$$\frac{d}{dE_1} (S_1(E_1) + S_2(E_{\text{TOT}} - E_1))$$

$$\frac{dS_1}{dE}(E_1) - \frac{dS_2}{dE}(E_{\text{TOT}} - E_1) = 0$$

$$\frac{dS_1}{dE}(E_1) = \frac{dS_2}{dE}(E_2)$$

condition for equilibrium

But wasn't $T_1 = T_2$ the condition for equilibrium?

YES!

$\frac{dS}{dE}$ is the DEFINITION OF TEMPERATURE

2ND LAW of THERMODYNAMICS: only distinction between past & future

microscopic laws: unchanged under time-reversal