Chapter 2 - 2nd Law of Thermodynamics

↳ heat spontaneously flows from high temp to low temp

Einstein Solid → $\boxed{\text{Entropy}}$ ← Ideal Gas

Combinatorics

one coin

$$P(\text{heads}) = \frac{1}{2}$$

multiple coins

$$P(n) = \frac{n}{N}$$

5 coins

$$\text{microstates}\begin{cases} H\,H\,T\,T\,H & - \quad 3H \\ T\,H\,H\,H\,H & - \quad 4H \end{cases} \text{macrostates}$$

how many microstates are in a macrostate?

↳ multiplicity

$$\Omega(n) = \frac{5!}{n!(5-n)!}$$

number of heads

$\Omega(0) = 1$
$\Omega(1) = 5$
$\Omega(2) = 10$
$\Omega(3) = 10$
$\Omega(4) = 5$
$\Omega(5) = 1$

$$\Omega(1) = \frac{5!}{1!(5-1)!} = \frac{5!}{1!4!}$$

$$= \frac{5 \cdot \cancel{4} \cdot \cancel{3} \cdot \cancel{2} \cdot \cancel{1}}{1 \cdot \cancel{4} \cdot \cancel{3} \cdot \cancel{2} \cdot \cancel{1}}$$

$$= 5$$

$$\Omega(2) = \frac{5!}{2!3!} = 10$$

$$\Omega(N, n) = \frac{N!}{n!(N-n)!} \leftarrow \text{Notation: } \binom{N}{n}$$

$\uparrow$ # of coins

10 atoms each w/ 0 or 1 packets of energy (energy unit)

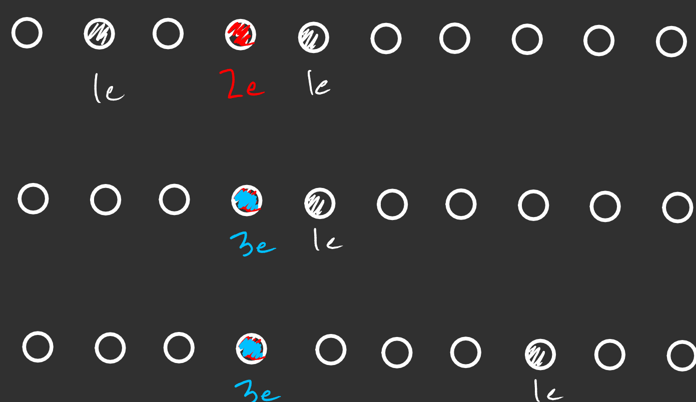
How many possible ways are there to distribute 4 energy units

$\leftarrow$ microstate

$$\Omega(10, 4) = \frac{10!}{4!\,6!} = 210$$

4 energy packets $\leftarrow$ macrostate

What if an atom can have more than one energy packet at a time?



microstates

$$\Omega(N, q) = \frac{(q + N - 1)!}{q!\,(N-1)!} \qquad \binom{q+N-1}{q}$$

# of atoms

# of energy packets

q = macrostate

4 energy packets $\leftarrow$ macrostate

This model of a collection of atoms w/ equal size energy quanta distributed among them is the Einstein Solid.

$\hookrightarrow$ Debye Model

Large Number $\rightarrow$ addition of small numbers is not important

$$10^{23} + 23 = 10^{23}$$

Very Large Number

$$10^{10^{23}} \times 10^{23} = 10^{10^{23} + 23} \simeq 10^{10^{23}}$$