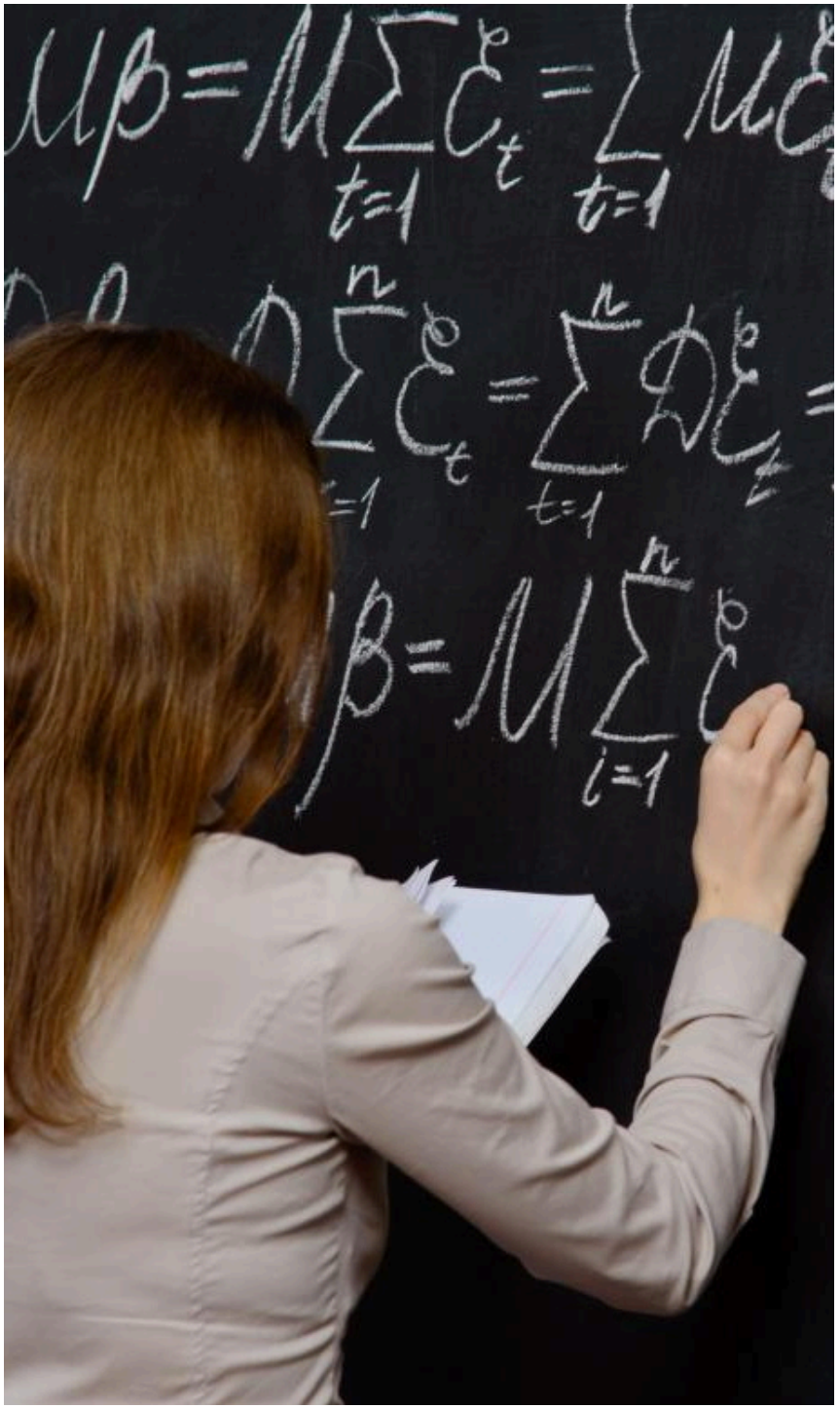
- **Theme Music:**
  Bruce Fowler
  Entropy

- **Cartoon:**
  S. Harris



The Equation of the Day

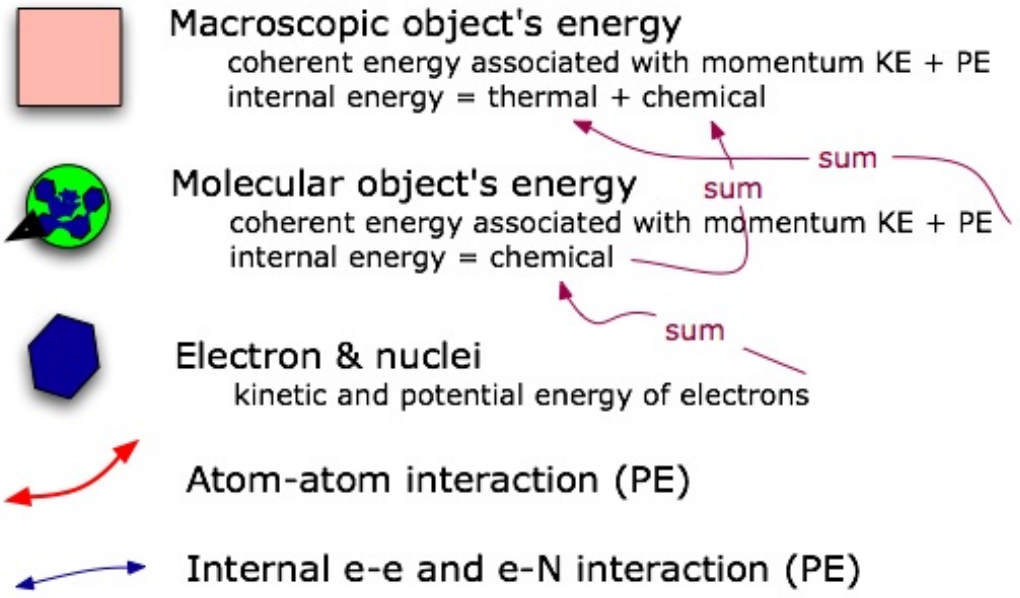
Entropy
(Thermal definition)

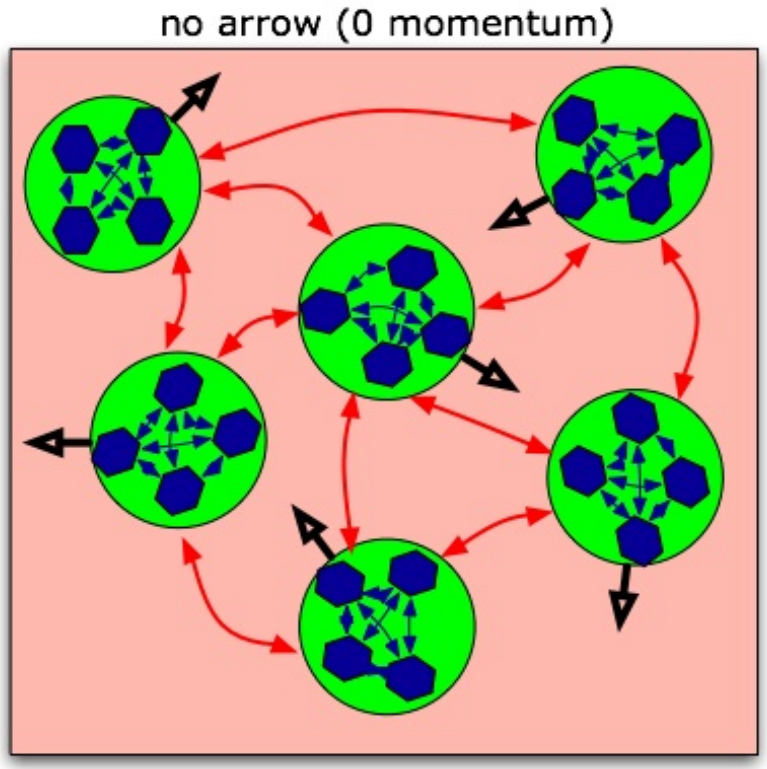
$$\Delta S = \frac{Q}{T}$$

Zooming in on internal energy

(a generalization of the system schema)

As the system moves, energy is moving randomly among these locations ("bins").

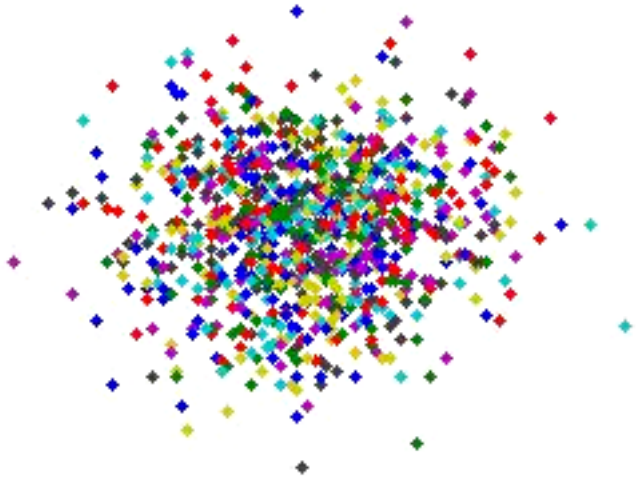




In a thermal dynamic system energy is always on the move

- The motion of energy in a system of degrees of freedom is like the random walk of particles in diffusion.
- Each particle (bit of energy) moves at random, not knowing about the motion of any other bit.
- How far a diffusing atom is likely to be from its starting point is proportional to how many ways there was for it to get there.
- Where energy tends to go depends on how many ways it can be in that situation.

Think of each pixel on the screen as a place to put energy. As the system develops in time, energy is continually being rearranged at random from one DoF to another.



Foothold ideas: Entropy

- ***Entropy*** – an extensive measure of how well energy is spread in a system.
- Entropy measures
  - The number of microstates in a given macrostate

$$S = k_B \ln(W)$$

  - The amount that the energy of a system is spread among the various degrees of freedom
- Change in entropy upon heat flow

$$\Delta S = \frac{Q}{T}$$

Foothold ideas: Thermal Equilibrium & Equipartition

- ***Degrees of freedom*** – where energy can reside in a system.
- ***Thermodynamic equilibrium is dynamic*** – Changes keep happening, but equal amounts in both directions.
- ***Equipartition*** – At equilibrium, there is the same energy density in all space and in all DoFs – on the average.

Foothold ideas:
The Second Law of Thermodynamics

- Systems composed of a large number of particles spontaneously move toward the thermodynamic (macro)state that correspond to the largest possible number of particle arrangements (microstates).
  - The 2nd law is probabilistic. Systems show fluctuations – violations that get proportionately smaller as N gets large.
- Systems that are not in thermodynamic equilibrium will spontaneously transform so as to increase the entropy.
  - The entropy of any particular system can decrease as long as the entropy of the rest of the universe increases more.
- The universe tends towards states of increasing chaos and uniformity. (Is this contradictory?)