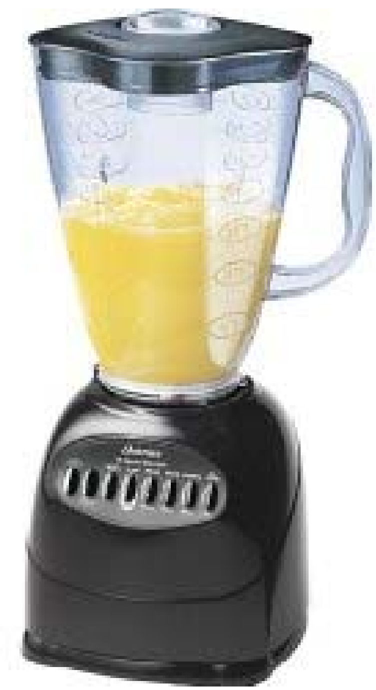
Experiment: Water in a Blender

- Fill blender with water
- Measure initial temperature
- Blend on high for 5 min.
- Measure temperature again
- Temperature increases: why?

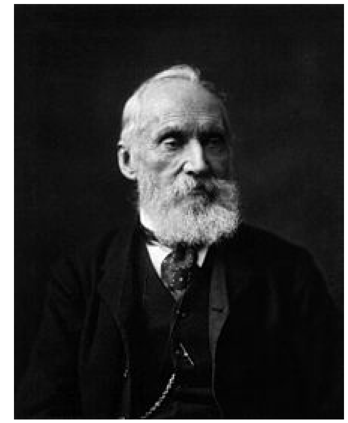


Energy Conversion Examples

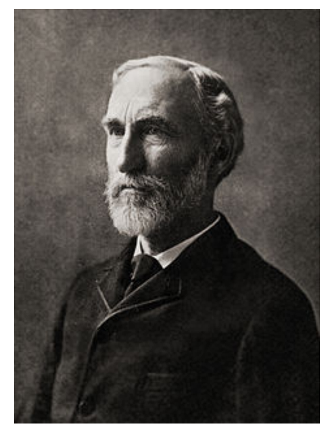
- Potential energy storage in a spring
- Electrical current generating heat in your computer
- Breaking and re-forming chemical bonds

Why Talk About Molecules?

- "If it's good enough for Lord Kelvin, it's good enough for me."
- Kinetic theory in its infancy (Brownian motion, c. 1830)
- Classical thermodynamics doesn't rely on a molecular framework



William Thomson, 1824-1907



J. Willard Gibbs, 1839-1903

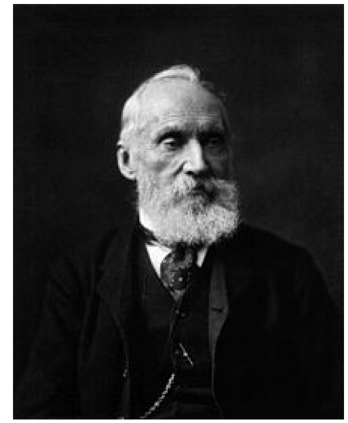
Images from Wikipedia.

Why Talk About Molecules?

- Molecular reasoning makes thermodynamics more intuitive

- Understanding protein and DNA structure is very useful

- Thermodynamics guides our understanding of molecular interactions



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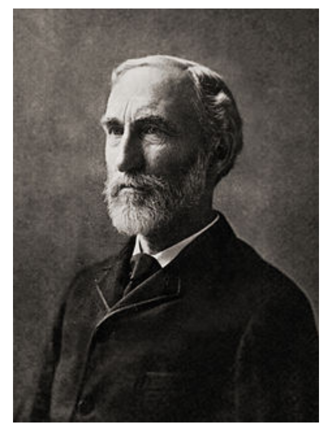


J. Willard Gibbs, 1839-1903

Images from Wikipedia.

Systems and Surroundings

- **System:** The part of the universe we're interested in

- **Surroundings:** Everything else (generally "local" surroundings, e.g. the lab vs. Jupiter)

- **Boundary:** Geometric surface between system and surroundings

Systems and Surroundings

- **Isolated System:** A system with no mass or energy exchange with surroundings

- **Closed System:** No exchange of mass, but heat exchange possible

- **Open System:** Both heat and mass can exchange

Work Example #1

A piston lifts a 10.0 kg mass from the ground to a height of 10.0 m off the ground. How much work does it do?

Work Example #2

A gas with a pressure P is stored in a cylinder. The top of the cylinder is airtight but can expand against an external pressure P_{ex}. Derive an expression for the work if the gas expands from a volume of V_1 to V_2.

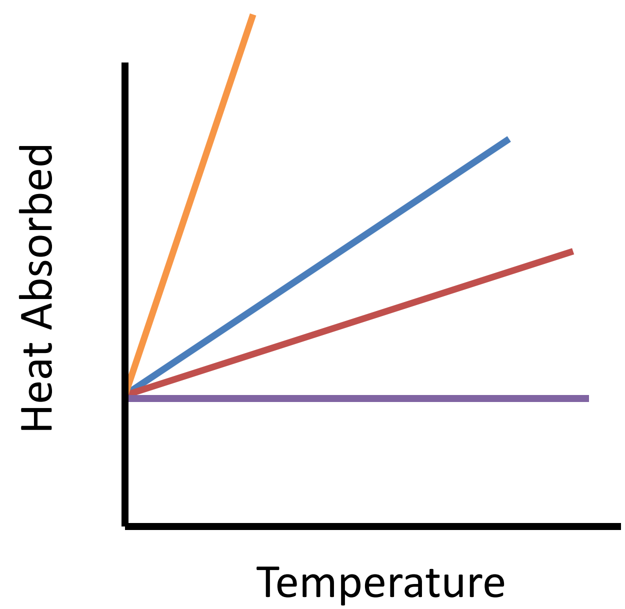
What is the work if P_{ex} is zero?

Properties of the Heat Capacity

- How easy is it to change an object's temperature?

- Orange curve has highest heat capacity: large change in heat → small change in T

- High C is like a buffer, resisting changes in T as q is added



Heat Capacity and Calculus

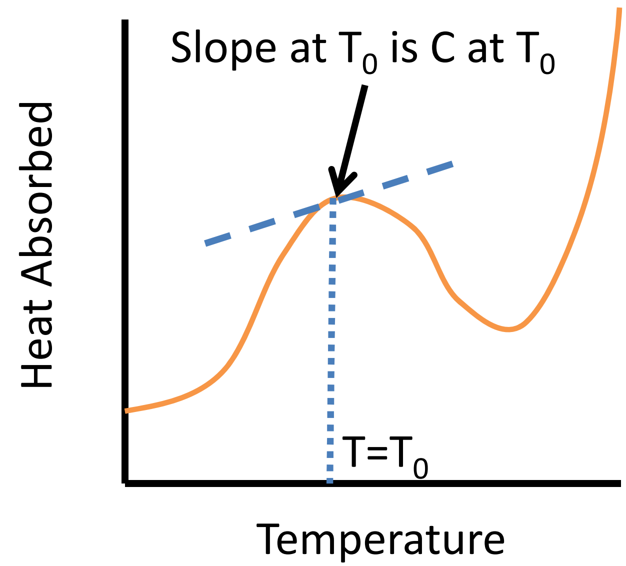
- If we know q(T):

$$C(T) = \lim_{h \to 0} \frac{q(T+h) - q(T)}{h}$$

- C is usually roughly constant for most materials over most temperature ranges

- Integration is possible to determine dq from dT.

$$C = \frac{dq}{dT} \rightarrow \Delta q = \int_{T_1}^{T_2} C \, dT$$



Heat Capacity and Materials

- C depends on conditions: i.e. whether volume of system is constant (C_V) or pressure is constant (C_P)

- Volume and pressure changes are small for liquids and solids, so $C_P \approx C_V$. For a gas, $C_P \neq C_V$

- Values given for 1 mol of water

C_P = 38.09 J/K C_V= 38.08 J/K

C_P = 75.33 J/K C_V= 74.53 J/K

C_P = 37.47 J/K C_V = 28.03 J/K

Question

(discuss at your table)

At 25 ^{o}C, which has a higher heat capacity, 100.0 g of water or 500.0 g of water?

Intensive vs. Extensive Properties

- **Extensive:** Properties that depend on the system size (they *extend* as the system gets bigger). E.g. Volume, Heat Capacity.

- **Intensive:** Properties that do not scale with the size of the system (they are *independent* of system size). E.g. Pressure, Molar Heat Capacity.

Internal Energy

- It is a property of the system:

$$E = E(V, T, N_1, N_2, \ldots)$$

- From first law:
  ONLY THE AMOUNT OF HEAT AND WORK MATTERS, NOT HOW IT IS GENERATED!!!! Thus, the change in E depends only on the initial and final conditions, not the process, reversibility, etc. (This is really important!)

- If no heat and no work, then no change occurs in the internal energy.