CHAPTER OVERVIEW

2.6: Thermodynamics

$S = k \log W$ -- *Inscription on the tomb of Ludwig Boltzmann, 1844-1906. Boltzmann, who originated the microscopic theory of thermodynamics, was driven to suicide by the criticism of his peers, who thought that physical theories shouldn't discuss purely hypothetical objects like atoms.*

In a developing country like China, a refrigerator is the mark of a family that has arrived in the middle class, and a car is the ultimate symbol of wealth. Both of these are *heat engines*: devices for converting between heat and other forms of energy. Unfortunately for the Chinese, neither is a very efficient device. Burning fossil fuels has made China's big cities the most polluted on the planet, and the country's total energy supply isn't sufficient to support American levels of energy consumption by more than a small fraction of China's population. Could we somehow manipulate energy in a more efficient way?

Conservation of energy is a statement that the total amount of energy is constant at all times, which encourages us to believe that any energy transformation can be undone --- indeed, the laws of physics you've learned so far don't even distinguish the past from the future. If you get in a car and drive around the block, the net effect is to consume some of the energy you paid for at the gas station, using it to heat the neighborhood. There would not seem to be any fundamental physical principle to prevent you from recapturing all that heat and using it again the next time you want to go for a drive. More modestly, why don't engineers design a car engine so that it recaptures the heat energy that would otherwise be wasted via the radiator and the exhaust?

Hard experience, however, has shown that designers of more and more efficient engines run into a brick wall at a certain point. The generators that the electric company uses to produce energy at an oil-fueled plant are indeed much more efficient than a car engine, but even if one is willing to accept a device that is very large, expensive, and complex, it turns out to be impossible to make a perfectly efficient heat engine --- not just impossible with present-day technology, but impossible due to a set of fundamental physical principles known as the science of *thermodynamics*. And thermodynamics isn't just a pesky set of constraints on heat engines. Without thermodynamics, there is no way to explain the direction of time's arrow --- why we can remember the past but not the future, and why it's easier to break Humpty Dumpty than to put him back together again.

2.6.1: Pressure and Temperature
2.6.2: Microscopic Description of An Ideal Gas
2.6.3: Entropy As a Macroscopic Quantity
2.6.4: Entropy As a Microscopic Quantity
2.6.5: More About Heat Engines
2.6.6: Footnotes
2.6.E: Thermodynamics (Exercises)

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