25.5: In Summary

1. *Temperature* is a statistical quantity that provides a (typically indirect) measure of the *concentration* of thermal energy in a system. For a system that is (approximately) well described by classical mechanics, the temperature, as measured by a conventional thermometer, is directly proportional to the average translational kinetic energy per molecule.
2. In a process in which a system does no work, a change in the system's temperature is related to a change in its total internal energy (which typically includes more than just translational kinetic energy contributions) by $\Delta E = C\Delta T$, where C is the system's *heat capacity* for the process.
3. The transfer of thermal energy between two systems without either one doing macroscopic work on each other is generally possible. Thermal energy transferred in this way is called *heat*, and denoted by the symbol Q.
4. The actual definition of a system's heat capacity is $C = Q/\Delta T$. For a homogeneous system (made of just one substance), $C = mc$, where m is the system's mass and c the substance's specific heat. Specific heats typically depend on temperature in nontrivial ways.
5. Two systems isolated from the rest of the world but allowed to exchange thermal energy with each other will eventually reach a state of *thermal equilibrium* in which their temperatures will be the same (zero-th law of thermodynamics).
6. The work done on (or by) a system by (or on) its environment, plus the heat given to (or taken from) the system by its environment, always equals the net change in the system's total energy (conservation of energy, or first law of thermodynamics; Equation (13.3.1)).
7. For any system in thermal equilibrium, there exists a state variable, called *entropy*, with the property that it can never decrease for a closed system. When a system at temperature T takes in a small amount of heat dQ, its change in entropy is given by $dS = dQ/T$.
8. This principle of never-decreasing entropy is equivalent to the statement that "No process is possible whose *sole result* is the transfer of heat from a cooler to a hotter body."
9. The principle 7. is also equivalent to Carnot's theorem, which states that "it is impossible for an engine that operates in a cycle, taking in heat from a hot reservoir at temperature T_h and exhausting heat to a cold reservoir at temperature T_c, to do work with an efficiency greater than $1 - T_c/T_h$."
10. Either one of 7., 8., or 9., above, may be regarded as an equivalent statement of the *second law of thermodynamics*.
11. Carnot's theorem shows the limitations inherent in the conversion of thermal energy into macroscopic work, which is the reason why one usually regards mechanical energy that is converted into thermal energy as "lost."
12. Microscopically, the entropy of a system is a measure of the range of distinct states available to its microscopic components (atoms or molecules) that are compatible with the set of macroscopic constraints that determine its thermal equilibrium state. More entropy means a greater range of possible "microstates."
13. Entropy always increases in irreversible processes.