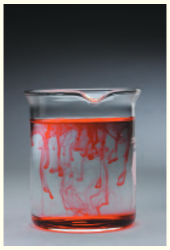
Entropy: Entropy is a quantitative measure of the randomness of a system. The entropy change in any reversible process depends on the amount of heat flow and the absolute temperature T. Entropy depends only on the state of the system, and the change in entropy between given initial and final states is the same for all processes leading from one state to the other. This fact can be used to find the entropy change in an irreversible process. (See Examples 20.5–20.10.)

An important statement of the second law of thermodynamics is that the entropy of an isolated system may increase but can never decrease. When a system interacts with its surroundings, the total entropy change of system and surroundings can never decrease. When the interaction involves only reversible processes, the total entropy is constant and $\Delta S = 0$; when there is any irreversible process, the total entropy increases and $\Delta S > 0$.

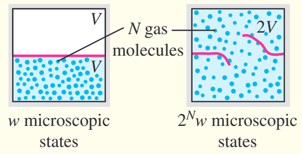
$$\Delta S = \int_1^2 \frac{dQ}{T} \qquad (20.19)$$

(reversible process)



Entropy and microscopic states: When a system is in a particular macroscopic state, the particles that make up the system may be in any of w possible microscopic states. The greater the number w, the greater the entropy. (See Example 20.11.)

$$S = k \ln w \qquad (20.22)$$



Chapter 20 Media Assets

GUIDED PRACTICE

For assigned homework and other learning materials, go to Mastering Physics.

KEY EXAMPLE √ARIATION PROBLEMS

Be sure to review EXAMPLE 20.1 (Section 20.2) before attempting these problems.

VP20.1.1 A diesel engine has efficiency 0.180. (a) In order for this engine to do 1.24×10^4 J of work, how many joules of heat must it take in? (b) How many joules of this heat is discarded?

VP20.1.2 In one cycle a heat engine absorbs 3.82×10^4 J of heat from the hot reservoir and rejects 3.16×10^4 J of heat to the cold reservoir. What is the efficiency of this engine?

VP20.1.3 Measurements of a gasoline engine show that it has an efficiency of 0.196 and that it exhausts 4.96×10^8 J of heat during 20 minutes of operation. During that time, (a) how much heat does the engine take in and (b) how much work does the engine do?

VP20.1.4 An aircraft piston engine that burns gasoline (heat of combustion 5.0×10^7 J/kg) has a power output of 1.10×10^5 W. (a) How much work does this engine do in 1.00 h? (b) This engine burns 34 kg of gasoline per hour. How much heat does the engine take in per hour? (c) What is the efficiency of the engine?

Be sure to review EXAMPLES 20.2, 20.3 and 20.4 (Section 20.6) before attempting these problems.

VP20.4.1 In one cycle a Carnot engine takes in 8.00×10^4 J of heat and does 1.68×10^4 J of work. The temperature of the engine's cold reservoir is 25.0°C. (a) What is the efficiency of this engine? (b) How much heat does this engine exhaust per cycle? (c) What is the temperature (in °C) of the hot reservoir?

VP20.4.2 For the Carnot cycle described in Example 20.3, you change the temperature of the cold reservoir from 27°C to −73°C. The initial pressure and volume at point a are unchanged, the volume still doubles during the isothermal expansion $a \rightarrow b$, and the volume still decreases by one-half during the isothermal compression $c \rightarrow d$. For this modified cycle, calculate (a) the new efficiency of the cycle and (b) the amount of work done in each of the four steps of the cycle.

VP20.4.3 A Carnot refrigerator has a cold reservoir at −10.0°C and a hot reservoir at 25.0°C. (a) What is its coefficient of performance? (b) How much work input does this refrigerator require to remove 4.00×10^6 J of heat from the cold reservoir?

VP20.4.4 A Carnot engine uses the expansion and compression of n moles of argon gas, for which $C_V = \frac{3}{2}R$. This engine operates between temperatures T_C and T_H. During the isothermal expansion $a \rightarrow b$, the volume of the gas increases from V_a to $V_b = 2V_a$. (a) Calculate the work W_{ab} done during the isothermal expansion $a \rightarrow b$. Give your answer in terms of n, R, and T_H. (b) Calculate the work W_{bc} done during the adiabatic expansion $b \rightarrow c$. Give your answer in terms of n, R, T_C and T_H. (c) For this engine, $W_{ab} = W_{bc}$. Find the ratio T_C/T_H and the efficiency of the engine.

Be sure to review EXAMPLES 20.6, 20.7, 20.8, 20.9, and 20.10 (Section 20.7) before attempting these problems.

VP20.10.1 Ethanol melts at 159 K (heat of fusion 1.042×10^5 J/kg) and boils at 351 K (heat of vaporization 8.54×10^5 J/kg). Liquid ethanol has a specific heat of 2428 J/kg · K (which we assume does not depend on temperature). If you have 1.00 kg of ethanol originally in the solid state at 159 K, calculate the change in entropy of the ethanol when it (a) melts at 159 K, (b) increases in temperature as a liquid from 159 K to 351 K, and (c) boils at 351 K.

VP20.10.2 Initially 5.00 mol of helium (which we can treat as an ideal gas) occupies volume 0.120 m^3 and is at temperature 20.0°C. You allow