3a-3 $\bar{q} = P_1 q_1 + P_2 q_2 + P_3 q_3 + \ldots$

3a-4 (a) $2^3 = 8$. (b) HHH, HHT, HTH, HTT, THH, THT, TTH, TTT. (c) 1, 3, 3, 1. (d) 1/8, 3/8, 3/8, 1/8. (e) 1/8, 3/8, 3/8, 1/8.

3a-6 (a) Not equally lilkely. Probability = 1 of being diamond, = 0 for anything else. (b) Equally likely. 1/52, 1/52. (c) Same.

3a-7 (a) 36. (b) 0, 1, 2, 3.

3a-8 (a) Larger. (b) $(4\pi/3)\, v^3$. (c) $(4\pi/3)\,(v + dv)^3$. (d) $4\pi\, v^2\, dv$.
(e) 4 times larger.

3a-9 (a) Larger. (b) Twice as large.

3a-10 (a) 0.25. (b) 0.75. (c) 2.7 miles.

3a-11 (a) 1/6. (b) 5/6. (c) 5/36. (d) 25/36. (e) 11/36.

3a-12 (a) 8. (b) LLL, LLR, LRL, LRR, RLL, RLR, RRL, RRR. (c) 1, 3, 3, 1. (d) 1/8, 3/8, 3/8, 1/8. (e) 1.5.

3a-13 (a) 750,000. (b) 256.

3a-15 (a) 7. (b) Equal.

Chapter 4: Hints

4h-1 If X is in the *first* of its 3 possible states, Y can be in any one of its 5 possible basic states. If X is in the *second* of its 3 possible states, Y can also be in any one of its 5 possible basic states. If X is in the *third* of its 3 possible states, Y can also be in any one of its 5 possible basic states. What then is the total number of possible states available to the combined system consisting of X and Y?

4h-2 The number of ways that these places can be rearranged among themselves is $n\,(n\;1)\,(n-2)\ldots 1 = n!$.

4h-3 If you have difficulties listing the possibilities systematically, look again at the table in Fig. A-2. You may also find it useful to consider first the simpler case of a gas of 5 molecules and list the number of ways that 3 of these 5 molecules can be located in the left half of a box.

4h-4 When the molecules are at any of their Ω_{pos} possible positions, they can have any of their Ω_{vel} possible velocities.

4h-5 The atoms in the bob itself also move in random directions.

4h-6 What is the total number of possible ways that the three molecules can be distributed over the three parts of the box? When one molecule is in the left third of the box, what is the number of ways that the remaining two molecules can be distributed over the remaining two parts of the box?

4h-7 Remember that the absolute temperature specifies how rapidly a system's entropy changes with its internal energy. According to (F-7), an energy change of the same magnitude can thus produce different changes in the magnitude of the entropy if the absolute temperature is different.

4h-8 Remember that $d(\ln x)/dx = 1/x$. (See Appendix §.)

4h-10 In Problem E-3 you found the basic entropy of a typical system (a gas). Thus you have the information needed to determine the typical magnitude of such an entropy.

Chapter 4: Answers

4a-1 (a) Ink spreads out. (b) 10^{19}.

4a-2 (a) Yes, yes, no. (b) No, yes. (c) No, yes. (d) Very small. (e) Decreases.

4a-3 (a) $1.0 \times 10^{-15}\ m^3$. (b) 10^{15}. (c) 10^{15} N. (d) 3.5×10^{25}.

4a-4 See Fig. 4a-4.

4a-5 (a1) A pendulum, initially hanging at rest, starts swinging with swings of increasing magnitude. (a2) This is extremely unlikely to occur in actuality. The original process is irreversbile.

(b1) Ink, initially diffused throughout a whole glass of water, gradually becomes concentrated into a single drop. (b2) This is extremely unlikely to occur in actuality. The original process is irreversbile.

(c1) A cart rollsdown along a ramp with increasing speed. (c2) This process could readily occur in actuality. The original process is revesible.

(d1) A pile of debris suddenly assembles itself into a house. (d1) This is extremely unlikely to occur in actuality. The original process is irreversbile.

4a-6 (a) Fluctuates. (b) The air molecules move in random directions. Sometimes more molecules may strike the bob from the right than from the left, at other times the reverse may be true. (c) The atoms in the bob oscillate randomly about their normal positions. Sometimes more of the atoms may move to the right than to the left, at other times the reverse may be true.

4a-7 (a) Same. (b) No. Decreases, increases, remains the same.

(c) Negative, positive, equal. (d) No. $E_f/N = E'_f/N'$.

(e) $E_f = N(E + E')/(N + N')$. $E'_f = N'(E + E')/(N + N')$.

4a-8 (a) $2^6 = 64$. (b) 1. (c) 20 ways. (See Fig. 4a-8 which lists which three of the molecules (labeled 1,2,3,4,5,6) can possibly be in the left half of the box). (d) 1/64 = 0.016, 20/64 = 0.31. (e) 0.05.

4a-9 (a1) Situation *B*. (a2) Situation *B*. (b1) Number of non-sensical words. (b2) Less random.

4a-10 (a) The randomly moving molecules in the liquid strike the particle from random directions. (b) Smaller. (If the particle has a larger mass, the random forces produced by the striking molecules of the liquid produce smaller accelerations of the particle.)

4a-11 (a) 1/243 = 0.0004. (b) 32/243 = 0.132. (c) 80/243 = 0.329.

4a-12 (a) $10^{-15}\ m^3$. (b) 10^{15}. (c) 10^{15} N. (d) 3.5×10^{25}.

4a-13 (a) $\beta = (3N/2)(1/E)$. (b) $E/N = (3/2)\ kT$. (c) 3 times larger.

		molecule #			
n	n'	1	2	3	4
4	0	L	L	L	L
3	1	L	L	L	R
		L	L	R	L
		L	R	L	L
		R	L	L	L
2	2	L	L	R	R
		L	R	L	R
		L	R	R	L
		R	L	L	R
		R	L	R	L
		R	R	L	L
1	3	L	R	R	R
		R	L	R	R
		R	R	L	R
		R	R	R	L
0	4	R	R	R	R

Fig. 4a-4.

1 2 3	2 3 4
1 2 4	2 3 5
1 2 5	2 3 6
1 2 6	2 4 5
1 3 4	2 4 6
1 3 5	2 5 6
1 3 6	3 4 5
1 4 5	3 4 6
1 4 6	3 5 6
1 5 6	4 5 6

Fig. 4a-8.

4a-14 (a1) This process is extremely unlikely to occur. Movie is being played backwards. (a2) Actual process is one where a box, lying on a table, topples and falls to the ground. This process is irreversible.

(b1) This process could readily occur in actuality. One cannot tell whether the movies is being played backward. (b2) Actual process is one where two billiard balls collide and move off in different directions. This process is reversible.

(c1) This process is extremely unlikely to occur. Movie is being played backwards. (c2) Actual process is one where a chicken crawls out of a newly hatched egg. This process is irreversible.

4a-15 (a) Negative. (b) Increase. (c) Decrease. (d) Remains same.
(e) Increase. (f) Decrease. (g) Increase.

4a-16 (a) $\Omega_{pos}\,\Omega_{vel}$. (b) $\ln\Omega = \ln\Omega_{pos} + \ln\Omega_{vel}$.
(c) $\ln\Omega = \text{constant} + N \ln V + (3N/2) \ln E$.

4a-17 (a) $8/27 = 0.30$. (b) $12/27 = 0.44$. (c) $6/27 = 0.22$. (d) $1/27 = 0.04$.

4a-18 (a) $\ln 3 \approx 1.10$. (b) $\ln 5 \approx 1.61$. (c) 15, $\ln 15 \approx 2.71$. (d) It is equal to the sum of these entropies.

4a-19 (a) Less. (b) Smaller. (c) Yes, no.

4a-20 (a) 2^N. (b) $N(N-1)$, $N(N-1)/2$. (c) $N(N-1)(N-2)\ldots(N-n+1) = N!/(N-n)!$ where $N! = N(N-1)(N-2)(N-3)\ \ldots(1)$.

(d) $\dfrac{N!}{n!\,(N-n)!}$. (e) $\dfrac{N!}{n!\,(N-n)!}\,\dfrac{1}{2^N}$. (e) $20/64 \approx 0.31$.

4a-22 (a) $(3N/2)(0.001) = 0.0015\,N$. (b) 1.5×10^{21}. (c) 1.5×10^{21}.
(d) $e^{1.5\times 10^{21}} = 10^{6.5\times 10^{20}}$. Gigantic increase.

4a-25 (a) Huge. (b) Huge. (c) Gigantic. (d) Gigantic.

Chapter 5: Hints

5h-1 It is easier to calculate $\log(P_1/P_2)$ before findin gthe ratio P_1/P_2 itself.

5h-2 Suppose that system X were in equilibrium with system Y and that one has just determined that the thermometer is in equilibrium with system X. According to this information, should the thermometer be in equilibrium with Y or not? Is this consistent with the known facts? Is the preceding supposition then true or false?

5h-4 Which of the two systems absorbed positive heat and which of them absorbed negative heat (i.e., gave off positive heat)? Which of the systems had then inittially the higher absolute temperature?

Chapter 5: Answers

5a-1 (a) -20 J, 20 J, 0. (b) X', X. (c) -4×10^{21} k, 6×10^{21} k, 2×10^{21} k.

5a-2 (a) No. (b) Heat flows from X to Y. (c) X has larger absolute temperature. (d) Yes.

5a-3 (a) See Fig. 5a-3. (b) 120 J. (c) 120 J, 180 J.
(d) 6×10^{-21} J, 120 J, 180 J. Yes.

E (joule)	S (10^{22}k)	E' (joule)	S' (10^{22}k)	S* (10^{22}k)
60	12.3	240	24.7	37.0
80	13.1	220	24.3	37.4
100	13.8	200	23.8	37.6
120	14.4	180	23.4	37.8
140	14.8	160	22.8	37.6
160	15.2	140	22.2	37.4
180	15.6	120	21.5	37.1
200	15.9	100	20.7	36.6
220	16.2	80	19.7	35.9
240	16.4	60	18.4	34.8

Fig. 5a-3.

5a-4 (b1) Positive for E_1 and $E_{2,}$, infinite for E_3, negative for E_4 and E_5.

(b2) Increases. Increases. (b3) Negative, positve, increases.

(b4) Warmer.

5a-5 (a) No. (b) Inadequate information. (c) Inadequate information. (d) No.

5a-6 (a) 0.4 J. (b) 0.4 J. (c) Yes.

(a2) Decreases. (a3) Increases. Smaller.

5a-8 Not in equilibrium, heat transfer occurs. (Suppose that system X were in equilibrium with system Y and that one has just determined that the thermometer is in equilibrium with system X.. Then the thermometer should also be in equilibrium with system Y. But this is contrary to fact. Hence the previous supposition must be false, i.e., X and Y cannot be in equilibrium with each other.)

5a-10 (a) $e^{(S_1^* - S_2^*)/k}$. (b) $10^{2 \times 10^{21}}$.(i.e., this is gigantically large).

6a-22 (a) $\frac{3}{2}$pV. (b) 1.52×10^5 J.

6a-23 (a) p (V1 + V2)/[V1 + (T/T2) V2]. (b) 1.15.

6a-24 1.004.

6a-25 (a) 7.3×10^{-26} kg. (b) 400 m/s.

6a-26 (a) $-p\,(V_B - V_A)$. (b) $(3/2)p\,(V_B - V_A)$. (c) $(5/2)p\,(V_B - V_A)$.

6a-27 6.89×10^3 N/m^2.

6a-29 (a) Larger. (b) Smaller. (c) Smaller. (d) T_A, T_C, T_B.

Chapter 7: Hints

7h-1 In a steady state, the same amount of heat flows through every square meter of the rock-wool insulation and of the brick wall. (See the preceding problem.)

7h-2 Remember that the internal energy of an ideal gas does not depend on its volume, but only on its temperature.

7h-3 Suppose that an additional thickness dx of ice is formed at the bottom of the ice sheet during some short time dt. How much mass of ice is then created over an area A of the ice sheet? As a result, how much heat is liberated at the bottom of the ice sheet? How much heat per second must then flow through the ice andhow is this related to the thickness x of the ice sheet? These considerations lead to an equation relating dx, dt, and x itself.

7h-4 Exploit the ideal-gas law.

7h-5 How much heat is absorbed by one-third of the 3.00 kg lead block?

7h-6 Exploit the ideal-gas law and the relation between pressure and volume.

7h-7 What are the implications of the thermodynamic energy law (A-9)?

7h-8 When the total entropy change is minimum, it neither increases nor decreases when y changes by an infinitesimal amount. Hence the rate of change (or drivative) of this entropy change must then be zero [i.e., $d(\Delta S^*)/dy = 0$].

7h-9 Exploit the thermodynamic energy law.

7h-10 Would the heat required to melt all of the ice be larger or smaller than the heat that can be supplied if the soda and mug are cooled to 0°C (the temperature at which water freezes or ice melts)?

7h-11 Remember that the internal energy of an ideal gas does not depend on its volume, but only on its temperature. The change of internal energy of the gas is thus the same as if its volume remained unchanged.

7h-12 First relate the temperature T_C to the temperature T_B. Then use the result obtained in the preceding part of this problem.

7h-14 Exploit the answers to the preceding problem and the ideal-gas law.

Chapter 7: Answers

7a-1 0.042 W/m·K.

7a-2 (a) C_V dT, C_V dT. (b) Same. (Theinternal energy of an ideal gas depends on its temperature, but is unaffected by any change of its volume.) (c) Increase. (This is implied by the ideal-gas law if the temperature increases.) (d) Negative. (e) Larger (since d'Q = dE – d'W by the thermorynamic energy law and –d'W is positive. (f) Larger.

7a-3 (a) 6.3×10^4 J. (b) 2.1 minutes.

7a-4 (a) 81 W. (b) 1100 W, 72 W. (c) 15 times larger.

7a-5 (a) 195 J/K. (b) Increases by 47 J/K.

7a-6 (a) 170 J. (b) 0.49 K.

7a-7 (a) $x = \sqrt{(2\kappa\,\Delta T/\rho L)\,t}$. (b) 4 T. (c) 27 hours.

7a-8 (a) 0.50 K. (b) 390 J/K. (c) 130 J/K.

7a-9 $(\kappa_1/\kappa_2)\,(L_2/L_1)$.

7a-10 (a) 0.01 times larger. (b) 100 times larger.

7a-11 0.45 kg.

7a-12 (a) $(T_1 + T_2)/2$. (b) $C \ln[(T_1 + T_2)^2/4\,T_1T_2]$.

7a-13 (a) $\frac{5}{2}$RT. (b) $\frac{5}{2}$R. (c) 20.8 J/mol K.

7a-14 (a) $(\Delta T)\,(L_0/L)$. (b) $\hat{Q}\,(A_0/A)$. (c) $\hat{Q} = (BL_0/A_0)\,(A/L)\,\Delta T$. Inversely proportional to L. Proportional to A. (d) Yes. $\kappa = B\,(L_0/A_0)$.

7a-15 (a) $M_Lv^2/2$. (b) $M_Lv^2/[2\,(M_Lc_L + M_Ac_A)]$. (c) 44°C.

7a-16 (a) 240 W. (b) –5°C. (c) 60 W.

7a-17 Increases by 411 J/K.

7a-18 Q/T.

7a-19 (a) 7600 J. (b) 7600 J.

7a-20 (a) $\frac{5}{2}$R. (b) $\frac{7}{2}$R.

7a-21 26°C.

7a-22 (a) $-C \ln[1 - (\Delta T/2T_f)^2]$. (b) Larger. Same if $T_1 = T_2$.

7a-23 54.1°C.

7a-24 6.8 gram.

7a-25 (a) T_0, 2.52 T_0. (b) T_0, 1.74 T_0.

7a-26 c_p = d'Q/dT. $c_p = c_V + R$.

7a-27 (a) $C\,(T_B - T_A)$. (b) $C \ln(T_B/T_A)$. (c) $-C\,(T_B - T_A)/T_B$. (d) $\Delta S^* = C\,(\ln y + 1/y - 1)$. (e) See Fig. 7a-27. (f) y = 1. $\Delta S^* = 0$. (e) If $T_A = T_B$. Always positive.

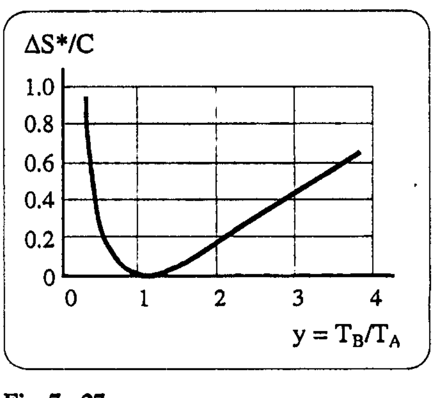

Fig. 7a-27.

7a-28 (a) 10.0°C. (b) 1.25×10^4 J.

7a-29 (a) 0°C. (b) 23 grams of ice.

7a-30 (a) 0.0635 kg. (b) 15.75 moles. (c) 391 J/kg K. (d) 70.1 J/K.

7a-32 (a) 0.038 C. (b) 0.011 C. (c) 0.009 C. (d) 0.020 C. Smaller.

7a-34 (a) 1950 /kg·K. (b) 17.6 J/mol·K.

7a-35 77.5°C.

7a-36 300 watt.

7a-37 (a) 2.05×10^5 N/m^2. (b) −38.2 J, 0, −38.2 J.
(c) 1.21×10^{-3} m^3, 1.57×10^5 N/m^2.

7a-38 (a) 4 p_o, 10.1 p_o. (b) 4 p_o, 6.96 p_o.

7a-39 (a) T_i (i.e., essentially unchanged).
(b) T_i (i.e., essentially the same as that of the heat reservoir).

7a-40 (a) 0, $\frac{5}{2}R(T' - T)$, $\frac{5}{2}R(T' - T)$.

(b) $-R(T' - T)$, $\frac{7}{2}R(T' - T)$, $\frac{5}{2}R(T' - T)$.

(c) $\frac{5}{2}R(T' - T)$, 0, $\frac{5}{2}R(T' - T)$.

7a-41 (a) 2.46×10^{-2} m^3. (b) 2.46×10^{-2} m^3, 2.20×10^5 N/m^2.
(c) 3.69×10^{-2} m^3, 1.013×10^5 N/m^2.

7a-42 $\gamma - 1$.

7a-43 (a) $-\frac{5}{2}RT_A$, $\frac{5}{2}RT_A$. (b) $2^{5/3}\,V_A \approx 3.17\,V_A$.

7a-44 (a) 6.9×10^{-22} J. (b) Remains the same. (Since pV in the ideal-gas law remains the same.) (c) Decreases.

7a-46 (a) Larger (because of the ideal-gas law and larger pressure). (b) Smaller (because the energy of the gas has decreased since negative work has been done on it). (c) Smaller (because of the ideal-gas law and smaller volume). (d) $T_A\,(V_C/V_A)$. (e) $T_A\,(V_C/V_A)^{5/3}$.

7a-48 (a) 0, $\frac{3}{2}R(T_B - T_A)$, $\frac{3}{2}R(T_B - T_A)$.

(b) $\frac{3}{2}R(T_C - T_B)$, 0, $\frac{3}{2}R(T_C - T_B)$.

(c) $-R(T_A - T_C)$, $\frac{5}{2}R(T_A - T_C)$, $\frac{3}{2}R(T_A - T_C)$.

(d) For process *AB*: 0, 4.36 kJ, 4.36 kJ.
For process *BC*: −2.49 kJ, 0, −2.49 kJ.
For process *CA*: 1.25 kJ, −3.12 kJ, −1.87 kJ.

(e) −1.24 kJ, 1.24 kJ.