Physics 161: Thermodynamics

Solutions to Practice Questions

1) An ideal gas expands isothermally against a constant pressure, from 100 atm to 1 atm. Which of the following is true?

(a) $\Delta S_{\text{universe}} > 0$ (True. It is an irreversible process.)

(b) $\Delta S_{\text{surroundings}} < 0$ (True. Since W is positive, and since $\Delta U = 0$, Q is positive. That means that $Q_{\text{surroundings}}$ is negative, and $T\Delta S_{\text{surroundings}} = Q_{\text{surroundings}}$ is negative, so $\Delta S_{\text{surroundings}} < 0$.)

(c) $\Delta S > 0$ (This must be so because of the answers to a and b, and because $\Delta S_{\text{universe}} = \Delta S_{\text{surroundings}} + \Delta S$.)

(d) $\Delta U = 0$ (True. For an ideal gas at constant T, because for an ideal gas, U only depends on T.)

(e) $Q = W$ (True because $\Delta U = Q - W$, and $\Delta U = 0$.)

2) An ideal gas expands adiabatically against a constant pressure, from 100 atm to 1 atm. Which of the following is true?

(a) $\Delta S_{\text{universe}} > 0$. (True, because the process is irreversible.)

(b) $\Delta S_{\text{surroundings}} = 0$ (True, because $Q_{\text{surroundings}} = 0$ because the process is adiabatic.)

(c) $\Delta S > 0$ (True, because $\Delta S_{\text{universe}} = \Delta S_{\text{surroundings}} + \Delta S$.)

(d) $\Delta U < 0$ (True, because $Q = 0$ and W is positive, and so $\Delta U = -W$.)

(e) $Q = 0$ (True because process is adiabatic.)

3) An ideal gas expands adiabatically and reversibly from 100 atm to 1 atm. Which of the following is true?

(a) $\Delta S_{\text{universe}} = 0$ (True because process is reversible.)

(b) $\Delta S_{\text{surroundings}} = 0$ (True because $Q_{\text{surroundings}} = 0$ because the process is adiabatic.)

(c) $\Delta S = 0$ (True because $\Delta S_{\text{universe}} = \Delta S_{\text{surroundings}} + \Delta S$.)

(d) $\Delta U < 0$ (True, because $Q = 0$ and W is positive, and so $\Delta U = -W$.)

(e) $W > 0$ (True, because this is an expansion.)

4) An ideal gas expands isothermally and reversibly, from 100 atm to 1 atm. Which of the following is true?

(a) $\Delta S_{\text{universe}} = 0$. (True, because the process is reversible.)

(b) $\Delta S_{\text{surroundings}} < 0$ (True because $\Delta U = 0$ for ideal gas isothermal process, and because W is positive, and therefore Q must positive, which means that $Q_{\text{surroundings}}$ is negative.)

(c) $\Delta S > 0$ (True, because $\Delta S_{\text{universe}} = \Delta S_{\text{surroundings}} + \Delta S$.)

(d) $\Delta U = 0$ (True see above.)

(e) $W > 0$ (True because this is an expansion.)

5) A cup of water is in equilibrium with the surroundings at $T = 298$ K and $P = 1$ atm.The water spontaneously warms up to $T = 398$ K and $P = 1$ atm.

Take C_P and C_V to be independent of temperature. Which of the following is true?

(a) $\Delta S_{\text{universe}} < 0$ (True, because this is an *impossible* spontaneous process!)

(b) $\Delta S_{\text{surroundings}} < 0$ (True, because $\Delta S > 0$, $\Delta S_{\text{universe}} < 0$, and $\Delta S_{\text{universe}} = \Delta S_{\text{surroundings}} + \Delta S$.)

(c) $\Delta S > 0$ (True, because $\Delta S = C_P \ln\left(\frac{398}{298}\right)$.)

(d) $\Delta U = C_V \times (398\text{K} - 298\text{K})$ (False, because the volume may change, and $\left(\frac{\partial U}{\partial V}\right)_t$ may not be zero for water as it is for an ideal gas.)

(e) $\Delta H = C_P \times (398\text{K} - 298\text{K})$ (True, because the process takes place at constant pressure.)

6) Two glass bulbs each having a volume of 1 liter are connected by a stopcock. Initially there is a mole of He gas in one bulb, and a mole of N_2 gas in the other bulb. When the stopcock is opened, the gases mix. In equilibrium there is 1/2 a mole of each type of gas in each bulb.

(a) $\Delta S_{\text{universe}} > 0$ (True because this is a spontaneous process.)

(b) $\Delta S_{\text{surroundings}} = 0$ (True because $\Delta U = 0$ for ideal gas at constant T, and then Q=W, but W=0 because the bulbs do not change size.)

(c) $\Delta S > 0$ (True, because $\Delta S_{\text{universe}} = \Delta S_{\text{surroundings}} + \Delta S$..)

7) Two glass bulbs are connected by a stopcock. Initially bulb A is filled with n moles of Helium, and bulb B is empty. When the stopcock is opened, the He distributes uniformly throughout the system. If bulb B is 3 times larger than bulb A, what is the change in entropy? Assume ideal gas behavior.

(a) $\Delta S = 0$

(b) $\Delta S = nR \ln 2$

(c) $\Delta S = nR \ln 3$

(d) $\Delta S = nR \ln (4/3)$

(e) $\Delta S = nR \ln (3/4)$

(f) $\Delta S = nR \ln 4$ (This is the answer, because the available space per particle increases 4-fold, and the multiplicity W should go as the available volume raised to the power N; $\Delta S = k \ln\left(\frac{V_{\text{final}}^N}{V_{\text{initial}}^N}\right) = Nk \ln\left(\frac{V_{\text{final}}}{V_{\text{initial}}}\right) = Nk \ln 4$. Alternatively, we could imagine the gas doing reversible work on a piston, use the fact that $\Delta U = 0$ for ideal gas at constant T, so $Q = W$, and then calculate $W = \int P dV = nRT \ln\left(\frac{V_{\text{final}}}{V_{\text{initial}}}\right) = nRT \ln 4$. Now $Q/T = \Delta S = nR \ln 4$.)

8) If C_V for an ideal gas is $(5/2)\, nR$, what is C_P?

(a) 7/2 nR (This is the answer, because $C_P = C_V + nR$ for ideal gas.)

(b) 3/2 nR

(c) 5/2 nR

9) For a process which takes place spontaneously at constant pressure, the following must be true:

(a) $\Delta H = Q$ (True, because $\Delta H = Q$ at constant pressure.)

(b) $\Delta U = Q$ (False, because $\Delta U = Q$ only at constant volume.)

(c) $Q = W$ (False, because ΔU need not be zero.)
(d) $\Delta U = 0$ (False.)
(e) $\Delta G < 0$ (False. We can only guarantee this when the process takes place at constant P and T.)
(f) $\Delta\left(PV\right) > 0$ (False. There is no reason to expect this.)
(g) $\Delta G = -T\Delta S_{\text{universe}}$ (False. This is only the case when the process takes place at constant P and T.)

10) For a process which takes place spontaneously at constant pressure and constant temperature, which of the following must be true?
(a) $\Delta G < 0$ (True, because $\Delta G = -T\Delta S_{\text{universe}}$ at constant T and P, and $\Delta S_{\text{universe}}$ is always >0.)
(b) $\Delta G = -T\Delta S$ (False.)
(c) $\Delta G = -T\Delta S_{\text{universe}}$ (True.)
(d) $\Delta G > 0$ (At constant T and P this must be False.)

11) For a spontaneous process taking place at constant pressure and constant temperature, the Gibbs free energy must always decrease.
(a) True (True.)
(b) False

12) For a spontaneous process, the entropy must always
(a) Increase
(b) Decrease
(c) Increase or Decrease or remain the same. (The entropy of the universe will increase, but the entropy of the system may increase or decrease.)

13) For a spontaneous process, the entropy of the system plus the entropy of the surroundings must always
(a) Increase (Must increase.)
(b) Decrease
(c) Increase or Decrease or remain the same.

14) A spontaneous process takes place in a system which is in contact with the surroundings at $T = 300$K. If $Q = 6$ kJ, what is $\Delta S_{\text{surroundings}}$?
(a) Can not be determined unless the process is reversible.
(b) $20\frac{J}{K}$
(c) $-20\frac{J}{K}$ (This is the choice to make. After all, $\text{Q}_{\text{surroundings}}$ is - 6 kJ, and $\Delta S_{\text{surroundings}} = \frac{-6\text{kJ}}{300\text{K}}$)

15) A spontaneous process takes place in a system which is in contact with the surroundings at $T = 300K$. If $Q = 6$ kJ, what can be said about ΔS?
(a) $\Delta S > 0$. (This is correct. We know that $\Delta S_{\text{universe}} > 0$, and we know that $Q_{\text{surroundings}} = -6$ kJ, so this means taht $\Delta S_{\text{surroundings}} < 0$. This means that $\Delta S > 0$ to make up the difference since $\Delta S_{\text{universe}} = \Delta S_{\text{surroundings}} + \Delta S$.)
(b) $\Delta S < 0$.