

MM 202 – Thermodynamics of Materials – Assignment 3

1. An adiabatic system consists of a large thermal reservoir, containing an ice water mixture at 0°C and 1 atm., and a weight of 1 kg kept at a height of 2 m above the reservoir. Suddenly the weight is allowed to fall freely into the reservoir and the entire system to come to equilibrium. Calculate the entropy change for this process.
[Remember, entropy is a state property: the process is irrelevant as long as the end states are the same. Moreover, entropy can be measured only along a reversible path, either forward or backward].

2. I have one kg of super-cooled water at 263.15K (-10°C) and 1 atm. pressure. If it irreversibly solidifies to ice isothermally and isobarically, what is the entropy change in the system? What is the minimum entropy change in the surrounding (in the thermal reservoir) to which heat is withdrawn?

a. Data : $\Delta H_{273.15}^f = 333,600 \text{ J/kg}$ for fusion of ice.

b. $C_{p, \text{water}} = 4220$, $C_{p, \text{ice}} = 2030 \text{ J/kg}$

3. Two kmol of Zn(s) at 298K are added to 1Kmol of Zn(l) at 700K in an adiabatic container. Calculate the entropy change.

$$C_{p(\text{Zn,s})} = 22.38 + 10.04 \cdot 10^{-3} T \text{ J/mol.K}$$

$$C_{p(\text{Zn,l})} = 31.38 \text{ J/mol.K}$$

$$T_{\text{Zn,fusion}} = 692.7 \text{ K}; \Delta H_{\text{fusion}} = 7385 \text{ J/mol}$$

4. One kmol of water at 25°C is injected into an evacuated copper chamber immersed in a thermostat at 25°C and vaporized completely to steam at 15.84 torr pressure. Equilibrium vapor pressure of water is 23.76 torr at 25°C. Calculate the entropy change of the system.
5. One mole of O₂ and one mole of N₂, both at 1 atm pressure and 298K are mixed to give the mixture at 1 atm and 25°C. Calculate the entropy change. Assume gases to be ideal.
6. One mole of an ideal gas is subjected to the following sequence of steps :
starting at 298 K and 1 atm, the gas expands freely into a vacuum to double its volume
the gas is next heated to 398 K at constant volume
the gas is reversibly expanded at constant temperature until its volume is again doubled
the gas is then reversibly cooled to 298 K at constant pressure

Calculate ΔU , ΔH , q , w , ΔS , and ΔG in the gas.

7. Take 0.5 moles of liquid water and 0.5 moles of steam maintained at 1 atm. and 373.15 K. a) Compress this system isothermally and reversibly, withdrawing heat to an ideal reservoir, to decrease the volume by 10%. Calculate the change in U , H and S of the system. What is the change in S of the reservoir during the same process. b) Perform the above process of compression by the application of an external pressure of 1.2 atm. But reaching the same final state of the system. Calculate the change in S of the system and the surrounding. c) Perform the reversible compression of problem a), but with a thermal reservoir which is maintained at 273.16K. What is the additional entropy generation in the surrounding due to this change? d) Give a scheme as to how would you calculate the final state of a system if a compression was done reversibly but adiabatically. Just a clearly laid out scheme of calculation would suffice.

Data: $\Delta H_{\text{water}}^{\text{v}} = 40.8 \text{ kJ/mol}$. Assume steam to be ideal gas.

8. Consider the four steps of a Carnot engine with the operating material in the form of an ideal paramagnet. The equation of state is Curie's law, $M = DH/T$, where H is the magnetic field, T the absolute temperature, and D a constant. The internal energy is a monotonically increasing function, $U(T)$, of temperature. (a) Determine the heat transfer, ΔQ , the work performance, ΔW , and the change in internal energy, ΔU , for each of the four steps:
- 1 \rightarrow 2 isothermal demagnetization: $T = T_H = \text{const}$, $M_2 < M_1$.
 - 2 \rightarrow 3 adiabatic demagnetization: $S = \text{const}$, $M_3 < M_2$.
 - 3 \rightarrow 4 isothermal magnetization: $T = T_L = \text{const}$, $M_4 > M_3$.
 - 4 \rightarrow 1 adiabatic magnetization: $S = \text{const}$, $M_1 > M_4$.
- (b) Sketch the Carnot cycle in the (M, H) -plane and in the (U, S) -plane. (c) Show that the efficiency is $\eta_C = 1 - T_L/T_H$.