Seminary exercise Nr. 11
Thermodynamics II – First and Second Law, Heat Engines

For all exercises, let assume the following values:

- gravity acceleration $g = 9.81\, m\, s^{-2}$
- gas constant $R = 8.31\, J\, mol^{-1} K^{-1}$

1. An air bubble of volume $20\, cm^3$ is at the bottom of a lake $40\, m$ deep, where the temperature is $4\,°C$. The bubble rises to the surface, which is at a temperature of $20\,°C$. Take the temperature of the bubble's air to be the same as that of the surrounding water. Just as the bubble reaches the surface, what is its volume? The density of water is $\rho = 1000\, kg\, m^{-3}$.
2. The temperature of $2\, mol$ of an ideal monoatomic gas is raised by $15\,°C$. What are the work done on the gas, the total energy transferred as heat, the change in the internal energy of the gas? Suppose the process is done under i) constant volume and ii) constant pressure.
3. The temperature of gaseous oxygen (suppose an ideal gas) is raised by ΔT. What is the total energy transferred as heat if the process is i) isobaric or ii) isochoric.
4. When $20\, J$ are added as heat to $2 \cdot 10^{-3}\, mol$ of an ideal gas, the volume changed from $50\, cm^3$ to $100\, cm^3$ while the pressure remained at normal atmospheric pressure. By how much did the internal energy of the gas change? What is the total energy transferred as work? Find the values of c_p and c_V.
5. Suppose that $12\, g$ of O_2 gas are heated at constant pressure from $25\,°C$ to $125\,°C$. How much energy is transferred to the oxygen as heat? What fraction of the heat is used to raise the internal energy of the oxygen? Consider oxygen as an ideal gas and its relative atomic mass is 16.
6. An ideal diatomic gas undergoes an adiabatic compression. Its initial pressure and volume are $1.2 \cdot 10^5\, Pa$ and $0.2\, m^3$ respectively. Its final pressure is $2.4 \cdot 10^5\, Pa$. How much work is done on the gas?
7. $50\, g$ of ice melted at a constant temperature of $0\,°C$. Determine the change of entropy. The specific latent heat of ice is $333.7\, kJ\, kg^{-1}$. Neglect the change of the volume of the substance.
8. Suppose a thermally insulated system consisting of two identical vessels connected by a pipe. $1\, mol$ of nitrogen gas is confined by the stopcock to the left half of the system. If we open the stopcock, the volume of the gas doubles. What is the entropy change of the gas for this irreversible process? Treat the gas as ideal.
9. Imagine a Carnot engine that operates between the temperatures $T_H = 850\, K$ and $T_L = 300\, K$. What is the efficiency of this engine? What is the condition that assures the efficiency to reach 100 %?
10. A Carnot engine whose low-temperature reservoir is at $17\,°C$ has an efficiency of 40%. By how much should the temperature of the high-temperature reservoir be increased to increase the efficiency to 50%?