

1. a. (12 points) n moles of an ideal gas originally confined to a volume V_A is allowed to expand spontaneously and freely into a volume $V_A + V_B$. Calculate the entropy change in this irreversible process by comparing the number of accessible states after and before.

b. (12 points) Now consider the same gas in the same initial volume undergoing an isothermal (temperature T) expansion into the same final volume. Calculate the entropy change in this reversible process.

c. (6 points) What are the entropy changes in the environment of the gas in these two cases?

2. (15 points) Calculate the fraction of Lithium atom in the first excited state (separated from the ground state by 1.2 eV) at the atmospheric temperature of the sun $T = 6000\text{K}$. (You can approximate the partition function using only the first two energy levels. The multiplicity of the ground state is 2, and that of the first excited state is 6).

3. (25 points) Calculate the entropy of an ideal gas of N particles each of mass m at temperature T confined to a one dimensional line of length L .
[Stirling's formula: $\ln N! \sim N \ln N - N$ when N is very large]

4. Calculate the efficiency of a heat engine made of an ideal monatomic gas running on a complete cycle made of two isothermal paths one at T_h ($1 \rightarrow 2$) and the other at T_c ($3 \rightarrow 4$) and two equal volume paths at V_2 ($2 \rightarrow 3$) and V_1 ($4 \rightarrow 1$) as shown in the diagram. Compare this with the efficiency of a Carnot engine operating at these two temperatures. [You may wish to give your answer in inverse efficiency which is simpler.] (30 points)

Note: You need to explain every step in your derivations. You won't get any credit if you just copy the results from your formula sheet. The following information may be useful:

Avagadro's number $N_A = 6.022 \times 10^{23}$ per mole

Boltzmann constant $k_B = 1.38 \times 10^{-23}$ J/K

Planck's constants $h = 6.63 \times 10^{-34}$ Joules-sec