Statistical and Thermal Physics: Homework 8

Due: 18 February 2020

1 Changes in entropy for ideal gas processes.

A monoatomic ideal gas undergoes the process indicated on the PV diagram. The curved line is an isothermal compression. The initial process at volume V_i reduces the pressure to one quarter of P_i.

a) Determine the change in entropy, in terms of P_i and V_i, along the constant volume process.

b) Determine the change in entropy, in terms of P_i and V_i, along the constant pressure process.

c) Starting with the first law of thermodynamics and using the fundamental thermodynamic identity show that along an isothermal process

$$\mathrm{d}S = \frac{Nk}{V}\mathrm{d}V.$$

determine a general expression for the change in entropy for an isothermal process.

d) Determine the change in entropy, in terms of P_i and V_i, along the isothermal compression.

e) Determine the change in entropy for gas for the entire process.

f) Does the gas do work for the entire process? Is heat supplied to the gas for the entire process? Can this process occur so that the entropy of the system plus surroundings does not increase?
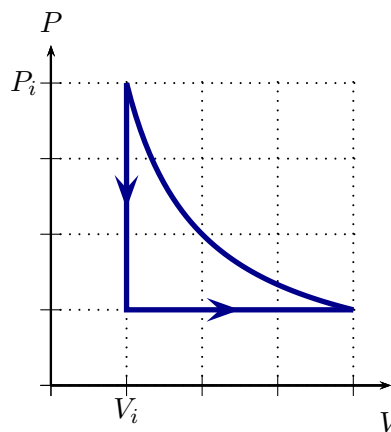
2 Gold immersed in water

A block of zinc with mass $0.750\,\mathrm{kg}$ is initially at temperature $120°\,\mathrm{C}$. The zinc is immersed in water with mass $1.25\,\mathrm{kg}$ and which is initially at temperature $20°$. The specific heat capacity of water is $4.186 \times 10^3\,\mathrm{J/kg\,K}$ and of zinc, $387\,\mathrm{J/kg\,K}$.

a) Determine the change in entropy of the zinc as it reaches equilibrium with the water.

b) Determine the change in entropy of the water as it reaches equilibrium with the zinc.

c) Determine the net change in entropy of the zinc and water.

3 Gould and Tobochnik, *Statistical and Thermal Physics*, 2.62, page 106.

4 System interacting with a heat bath

Consider a system with heat capacity C that interacts with a heat bath. Suppose that the system is initially at temperature T_{sys} and that the bath is a temperature T_B. The two are then placed in contact and during the process that follows the system remains at constant volume.

a) Show that the change in entropy of the system plus bath is

$$\Delta S = C \left[\ln \left(\frac{T_B}{T_{\text{sys}}} \right) + \frac{T_{\text{sys}}}{T_B} - 1 \right]$$

and note that this involves a function of the form

$$f(x) = \ln x + \frac{1}{x} - 1.$$

b) Determine when $f(x)$ attains a minimum and what this minimum is. Use this to describe the condition under which $\Delta S = 0$.

c) Use results from the previous part to describe whether the change in entropy is always positive when the bath is initially at a lower temperature than the system.

d) Use results from the previous part to describe whether the change in entropy is always positive when the bath is initially at a higher temperature than the system.