1. Explain in your own words, Le Chatelier principle. Give an example. (Do not use equations only, explain using words. Your example should not be a chemical reaction of the form $A \rightarrow B + \textit{energy}$ or some simple modification of it as changing the coefficients.)

2. Write down the partition function for the electrons in an Hydrogen atom. Is it finite? Explain. Does it make sense to have an infinite partition function? What is a possible resolution of this problem.

3. Express the following derivative in terms of derivatives of the equation of state and C_p or C_v. Find processes for which each derivative is relevant.

$$\left(\frac{\partial E}{\partial P}\right)_T, \left(\frac{\partial W}{\partial V}\right)_T, \left(\frac{\partial E}{\partial T}\right)_P, \left(\frac{\partial W}{\partial P}\right)_T, \left(\frac{\partial W}{\partial T}\right)_V$$

4. Using the grand canonical distribution, derive the differential of Ω. (Do not use the thermodynamic differentials).

5. In quantum statistical mechanics, we have defined the entropy as the logarithm of the number of states available to the system. This number was finite since the states are always discrete for a system in finite volume. In classical statistical mechanics, the states form a continuum in phase space, hence it is not possible to count them. But still, a quantity analogous to the number if states is the phase space volume available to the system. Hence, for a classical system, define $\Gamma_{cl}(E)$ as the phase space volume occupied by states that have energies less than or equal to E, i.e.

$$\Gamma_{cl}(E) = \int dq dp \tag{1}$$

where the integration is restricted to the available region to the system (for the ideal gas, the region is restricted by the boundary of $K \leq E$ where K is the total kinetic energy of the gas) Then,

$$\Delta\Gamma_{cl}(E) = \frac{\partial}{\partial E}\Gamma_{cl}(E)\Delta E$$

will be the phase space volume occupied by states having energy close to E with an uncertainty ΔE. Define the entropy of a classical system as:

$$S(E) = k \ln \left(A \Delta \Gamma_{cl}(E) \right) \tag{2}$$

where A is some constant (Note that in thermodynamics entropy is defined up to an additive constant. This arbitrariness is reflected in the arbitrary value of A) Find the constant A such that entropy defined in this way overlaps with the entropy that we obtained in the class for the gas of N non-interacting identical particles. (Hint: Since the particles are identical, you have to modify $\Gamma_{cl}(E)$ by dividing it by $N!$)

Can you interpret the constant A in terms of the Heisenberg uncertainty relation?