In the name of God

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ADVANCED STATISTICAL MECHANICS I

Exercise Set 2: Review on Thermodynamics

(Due Date: 2025/05/07)

1. We have a box isolated from the environment with volume V. We divided it into two parts with xV and $(1-x)V$. Pressures and temperatures in both partition are equal. There are xn and $(1-x)n$ particle in left and right parts, respectively. Now we remove the partition, how much changes will be occurred in Entropy?

2. Gibss-Duhem relation: Prove that $SdT - VdP + Nd\mu = 0$. What is the physical meaning of this relation?

3. According to the first law of thermodynamics, show that:

$$dQ = \left(\frac{\partial U}{\partial T}\right)_V dT + \left[P + \left(\frac{\partial U}{\partial V}\right)_T\right] dV$$

and then show that the heat capacity at constant V is $C_V \equiv \frac{dQ}{dT}|_V = \left(\frac{\partial U}{\partial T}\right)_V$. Also show that only for Ideal gas we have the heat capacity at constant pressure is $C_P \equiv \frac{dQ}{dT}|_P = C_V + Nk_B$.

4. Show that for Ideal Gas in Adiabatic process, we have

$$PV^{5/3} = constant$$

and

$$VT^{3/2} = constant$$

and

$$PT^{-5/2} = constant$$

5. Prove that the Enthalpy for Ideal gas is:

$$H(S,P,N) = \frac{5}{3}U_0 \left(\frac{N}{N_0}\right)\left(\frac{P}{P_0}\right)^{2/5} \exp\left\{\frac{2}{5}\left(\frac{S}{Nk_B} - \frac{S_0}{Nk_B}\right)\right\}$$

6. Show that $dG = -SdT + VdP + \mu dN$.

7. According to the Maxwell relations in thermodynamics, show that:

$$-\frac{\partial S}{\partial P}|_{T,N} = \frac{\partial V}{\partial T}|_{T,N}$$

$$-\frac{\partial V}{\partial N}|_{T,P} = \frac{\partial \mu}{\partial P}|_{T,N}$$

Good luck, Movahed
