① There are two systems, namely A and B, that have the fixed numbers of particles (N_A and N_B, respectively) and are confined in the fixed volume (V_A and V_B, respectively). The energy states of the two systems are {E_{1A}, E_{2A}, ……, E_{iA},…… } and {E_{1B}, E_{2B}, ……, E_{iB},…… }, respectively. Now, the two systems are in direct contact and can exchange heat, and both systems are immersed in a large thermal bath at temperature T. Please derive the expression of chance (P_{ij}) to find A in state E_{iA} and B in state E_{jB} at the same time as a function of T and E_{1A}, E_{2A}, ……, E_{iA},……, E_{1B}, E_{2B}, ……, E_{iB},……, etc.

② For a grand canonical ensemble containing two types of particles whose chemical potentials are μ_A and μ_B, respectively. Please derive the expression of chance $P_j(N_1, N_2)$ to find the system in a state E_j (N_1, N_2) with N_1 A particles and N_2 B particles and being confined in a fixed volume V and at temperature T.

③ Show that in a two-component, open, isothermal system,

$$\overline{N_1 N_2} - \overline{N_1} \cdot \overline{N_2} = k_B T \left(\frac{\partial \overline{N_1}}{\partial \mu_2}\right)_{V,T,\mu_1} = k_B T \left(\frac{\partial \overline{N_2}}{\partial \mu_1}\right)_{V,T,\mu_2}$$