

For most probable distribution, we have

$$S_{FD} = k_B \ln W_{max}$$

$$= k_B \left( \frac{U}{k_B T} - \frac{\mu N}{k_B T} + \sum_{j=1}^n g_j \ln \left( 1 + \exp \left( \frac{\mu - E_j}{k_B T} \right) \right) \right)$$

$$S_{FD} T = \left( k_B T \sum_j g_j \ln \left( 1 + \exp \left( \frac{\mu - E_j}{k_B T} \right) \right) \right) - \mu N + U$$

$$T S_{FD} + \mu N - U = k_B T \sum_j g_j \ln \left( 1 + \exp \left( \frac{\mu - E_j}{k_B T} \right) \right)$$

$$dU = T ds + \mu dN - p dV$$

$$U = TS + \mu N - pV$$

$$pV = TS + \mu N - U$$

$$pV = k_B T \sum_j g_j \ln \left( 1 + \exp \left( \frac{\mu}{k_B T} - \frac{E_j}{k_B T} \right) \right)$$