$$\frac{S}{k} \approx \ln W\{n_i^*\} = \left[\sum_i n_i^* \ln\left(\frac{g_i}{n_i} - a\right) - \frac{g_i}{a}\ln\left(1 - a\frac{n_i^*}{g_i}\right)\right]$$
$$= \sum_i \left[n_i^*(\alpha + \beta\epsilon_i) + \frac{g_i}{a}\ln\left\{1 + ae^{-\alpha-\beta\epsilon_i}\right\}\right]$$

$$\frac{1}{a}\sum_i g_i \ln\left\{1 + ae^{-\alpha-\beta\epsilon_i}\right\} = \frac{S}{k} - \alpha N - \beta E$$

$$\alpha = -\frac{\mu}{T} \qquad \beta = \frac{1}{kT} \quad ,$$

$$\frac{S}{k} + \frac{\mu N}{kT} - \frac{E}{kT} = \frac{G - (E - TS)}{kT} = \frac{PV}{kT}$$

$$PV = \frac{kT}{a}\sum_i \left[g_i \ln\left\{1 + ae^{-\alpha-\beta\epsilon_i}\right\}\right]$$

$$PV = \sum_i g_i e^{-\alpha-\beta\epsilon_i} = kT\sum_i n_i^* = NkT$$