SMB The free energy of an ideal gas of atoms is

$$F(T,V) = nk_BT(\ln(N/n_QV) - 1),$$

where N is the number of atoms, V the volume of the container, T the temperature and k_B is Boltzmann's constant. The quantity n_Q is the *quantum density* that can be expressed as $3.03/\lambda^3$ where λ is the de Broglie wavelength of a particle with average thermal energy at temperature T.

a) Compute n_Q for a gas of Ar atoms (atomic weight = 40) at $T = 300\,\mathrm{K}$.

b) Compute the entropy of 1 liter of Ar gas at a pressure of 1 atm and temperature 300 K.

c) The walls of the container have a total of M sites at which the Ar atoms can bind with binding energy Δ. Show that the free energy of N_s atoms bound to the surface is

$$F_{\text{bound}} = -N_s\Delta + N_sk_BT(\ln(N_s/M) - 1),$$

assuming that $M \gg N_s \gg 1$.

d) Calclulate the binding energy Δ in terms of N, N_s, M, n_Q, T, V, assuming that $N \gg M \gg N_s \gg 1$.

e) Evaluate Δ (preferably in units of eV) assuming that $V = 1$ liter, $T = 300\,\mathrm{K}$ and that 1% of the surface sites are occupied.

Useful constants:

$$\begin{aligned}
m_{\mathrm{p}} &= 1.673 \times 10^{-27}\,\mathrm{kg}, \\
h &= 6.625 \times 10^{-34}\,\mathrm{J.s} = 4.140 \times 10^{-15}\,\mathrm{eV.s} \\
k_{\mathrm{B}} &= 1.381 \times 10^{-23}\,\mathrm{J/K} = 8.6175 \times 10^{-5}\,\mathrm{eV/K} \\
1\ \mathrm{atm} &= 10^5\,\mathrm{Pa}.
\end{aligned}$$