Physics 467/667: Thermal Physics **Spring 2019**

Lecture 8: The Second Law and Entropy

Lecturer: Qiang Zhu *Scribes: scribe-name1,2,3*

8.1 Entropy

$$S = k\ln\Omega \tag{8.1}$$

8.2 Entropy of Einstein Solid

$$S = k\ln(eq/N)^N = Nk[\ln(q/N) + 1] \tag{8.2}$$

if N=10^{22}, q=10^{24}

$$S = Nk(\qquad\qquad) = \qquad\quad \text{J/K} \tag{8.3}$$

1. Discuss the relation between S and q, N?
2. Mixing A and B?
3. Entropy tends to increase?

Exercise
Based on Figure 2.5, compute the entropy of the total, most likely, least likely macrostate. Compare them with the number of typical values (0.77J/K).

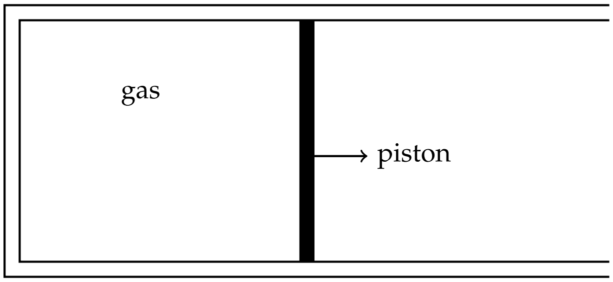
8.3 Entropy of an Ideal Gas

$$S = Nk[\ln(\frac{V}{N}(\frac{4\pi mU}{3Nh^2})^{3/2}) + \frac{5}{2}] \tag{8.4}$$

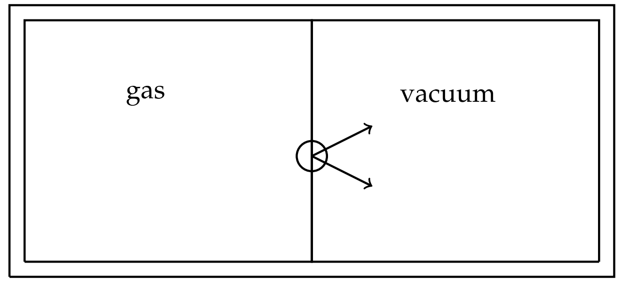
This is called the **Sackur-Tetrode equation**.

1. Discuss the relation between S and V, N, m, U, compare it with Einestein solid?
2. Compute S for He/Ar? (Same N, V, U, with a radius of the hypersurface of P is $\sqrt{2mU}$)
3. Free expansion? How to calculate ΔS, with an alternative way?

(a) isothermal expansion



(b) free expansion



8.4 Mixing Entropy of an Ideal Gas

If we mix two different gases, A and B, each with the same U, V and N, they occupy two halves of a divided chamber.

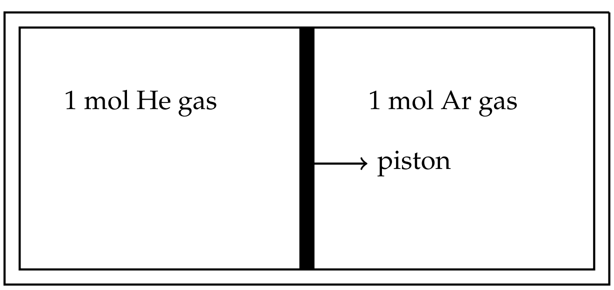
$$\Delta S_A = Nk\ln V_f/V_i = Nkln2 \tag{8.5}$$

$$\Delta S_B = Nk\ln V_f/V_i = Nkln2 \tag{8.6}$$

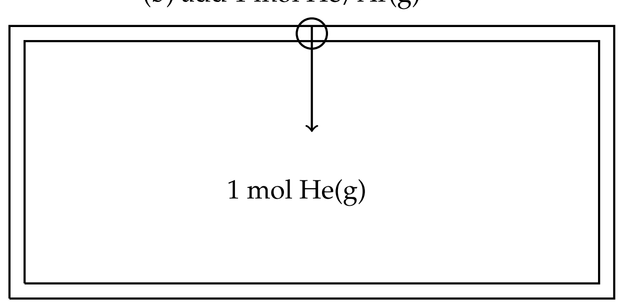
$$\Delta S_{\text{total}} = 2Nkln2 \tag{8.7}$$

What if A and B are indistinguishable? (double counting?) Mixing only applies when A and B are different?

(a) remove the piston



(b) add 1 mol He/Ar(g)



8.5 Irreversible process

1. Entropy increase → irreversible
2. Entropy unchanged → reversible
3. Slow compression, quasi static, reversible
4. Heat flow is always irreversible
5. Mixing (+V), stir salt in to soup, scrambling egg
6. +N, Burning gasoline, large molecule to small molecules, Cut down a tree

$CH_4(gas) + 2\,O_2(gas) \longrightarrow CO_2(gas) + 2\,H_2O(gas)$ S
$2\,H_2(gas) + O_2(gas) \longrightarrow 2\,H_2O(gas)$ S
If you consider it is not a isolated system. It also produces heat, so the total entropy is increasing due to heat.

8.6 Homework

Prove that 1 mol Ar gas has larger entropy than 1 mol He.
Problems 2.17, 2.18, 2.22, 2.29, 2.30, 2.31, 2.32, 2.34, 2.37