19.1

Tuesday, February 26, 2019 12:58 PM

- NOTE: The number of basic states in a closed volume containing N distinguishable particles divide into M equal compartments

  $\Omega = M^N$

- Macrostate of a system is that state described by its large scale properties.

  Basic state is that state described in terms of the particles that make up the systems, such as the positions and velocities of the particles

- Brownian Motion : random motion of particles
- $\begin{cases} \text{distinguishable} \\ \text{indistinguishable (identical)} \end{cases}$

- recurrence time: the length of time it would take on average to cycle randomly through all basic states.

19.2 Equipartition of Energy

Thursday, February 28, 2019 2:39 PM

e.g.

many choice question

Suppose a container holds equal amounts of two types of gas; A and B. The mass of the gas A particles is m and the mass of the gas B particles is 9m. Compare the total kinetic energy of gas A, K_A, to the total kinetic energy of gas B, K_B, and the average speed of gas A particles, v_A, to the average speed of gas B particles, v_B.
Select all that apply.

$K_A = K_B$ $v_A > v_B$ $K = \frac{1}{2}mv^2$

- Equipartition of energy: the equal distribution of energy among the parts of a system.
  - Each part tend to have equal E (as long as the interactions between different parts of a system randomise the distribution of energy)

19.3 Equipartition of space

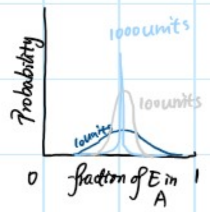
Thursday, February 28, 2019 2:43 PM

- The likelihood at any instant of finding a particle at any given position in the container is the same at any other position or instant.
    - Equipartition of space: the tendency to distribute particles uniformly over space.

19.4 Evolution toward the most probable macrostate

Sunday, March 3, 2019 5:38 PM

- Equilibrium state the most probable macrostate.
  - Only neighboring macrostates are accessible to the system after each collision.
- Ω: The number of basic states associated with each compartment.
  - $\Omega_{tot} = \prod_{i=1}^{n} \Omega_i$
  - probability of i'th macrostate: $\frac{\Omega_i}{\Omega_{tot}}$



- num of E units ↑
  width of probability distribution ↓
  still center at mean E.

- Second Law of Thermodynamics

A closed system always evolves to maximize Ω. When Ω reaches Ω_{max}, system at equilibrium.

e.g. ★★★

many choice question

A container holds three particles (A, B and C) and 30 indistinguishable units of energy distributed between the particles. A single collision transfers one unit of energy between the colliding particles. Which of the following statements is/are correct? Select all that apply.

A. If particle A initially has 29 units of energy, after a single collision it is just as likely that particle A has 30 units of energy as 28 units of energy.

B. If particle A initially has 29 units of energy, after a single collision it is more likely that particle A has 30 units of energy than 28 units of energy.

C. If particle A initially has 29 units of energy, after a single collision it is more likely that particle A has 28 units of energy than 30 units of energy.

D. After equilibrium is reached the energy distribution does not change.

E. After equilibrium is reached it is possible for the system to end up in a state where particle A has 29 units of energy.

CE

E is possible because it's possibility, it fluctuate around eq. state.

★★

multiple choice question

Warm water and an ice cube are placed in a thermos bottle. The ice melts and the warm water cools, and after equilibrium is reached the contents of the thermos bottle are removed and placed in a freezer. Which of the following do you agree with?

A.

After being placed in the freezer the water and ice system macro state does not change.

B.

After being placed in the freezer the water and ice system tends to a macro state with more basic states.

C.

After being placed in the freezer the water and ice system tends to a macro state with less basic states.

Freezing let the system lose entropy. C

but doesn't break 2th thermodynamics law, since frige is not closed.

19.5 Dependence of Entropy on Volume

Monday, March 4, 2019 9:44 AM

- Ideal gas:

  I. Elastic collision between particles & walls

  II. high T, low P

- $\Omega = M^N$ (closed system)
  - Ω: the number of basic states
  - M compartments, N distinguishable particles
  - $S \equiv \ln \underset{\Omega \text{ in a particular macro state.}}{\Omega} = \ln(M^N) = N\ln(M) = N\ln(\frac{V}{\delta V}) = N(\ln V - \ln \delta V)$ (closed sys at eq.)
    - Natural log will be less sensitive to a change in compartment size
    - S: entropy; unitless; Measure of num of basic states.
    - δV: (equal-sized compartment) a volume of δV

- Entropy Law

  $\Delta S > 0$ closed sys toward eq.

  $\Delta S = 0$ closed sys at eq.

  $\Delta S \geq 0$ for closed sys.

  - $\Delta S = S_f - S_i = N\ln V_f - N\ln \delta V - (N\ln V_i - N\ln \delta V) = N\ln(\frac{V_f}{V_i})$

    Notice that ~~if~~ mole is given use mol $\times 6.023\times10^{23}$
  - $S = \sum_{i=1}^{n} S_i$

    $\because \Omega = \Omega_A \cdot \Omega_B$, A, B are two individual sys

    $S = \ln \Omega = \ln \Omega_A + \ln \Omega_B = S_A + S_B$

- $\frac{N_A}{V_A} = \frac{N_B}{V_B}$

Session 97624228

many choice question

A thermally insulated box contains gas in thermal equilibrium. The box is split into two compartments with 2/3rd of the gas particles in compartment A (system A) and the rest of the gas in compartment B (system B). The partition between the compartments is free to move, and initially the volume of compartment B is 3 times the volume of compartment A. Which of the following is/are correct? Select all that apply.

A. The entropy of system A increases.

B. The entropy of system A decreases.

C. The entropy of system A does not change.

D. The entropy of system B increases.

E. The entropy of system B decreases.

F. The entropy of system B does not change.

G. The entropy of the combined (A+B) system increases.

H. The entropy of the combined (A+B) system decreases.

I. The entropy of the combined (A+B) system does not change.

AE G

I. The entropy of the combined (A+B) system does not change.

AE~~I~~ G

A has high ΔS

careful!!

$V_A \uparrow \Rightarrow \Delta S_A \downarrow$

$V_B \downarrow \Rightarrow \Delta S_B \uparrow$

$$\Delta S = \Delta S_A + \Delta S_B = \frac{2}{3} N \cdot \ln\left(\frac{2}{3} \cdot \frac{4}{1}\right) + \frac{N}{3} \ln\left(\frac{1}{3} \cdot \frac{4}{3}\right)$$

$$\underline{\underline{> 0}} \qquad = 0.384 N$$

19.6 Dependence of Entropy on Energy

Monday, March 4, 2019 10:09 AM

- Monoatomic Ideal Gas (non of the atom's kinetic energy can be converted to thermal energy.
- Root-mean-square speed (rms speed)

  $V_{rms} = \sqrt{(V^2)_{av}}$ → speed! (this will not be affected by sign)

  - $V_{rms} = \left(\frac{2E_{th}}{mN}\right)^{\frac{1}{2}}$

    $K_{av} = \frac{1}{2}m(v^2)_{av} = \frac{1}{2}mV_{rms}^2 = \frac{E_{th}}{N}$

  - assume $V \in [-aV_{rms}, aV_{rms}]$

    $V = (2aV_{rms})^3$

    $M_v = \frac{aV}{\delta V} = \frac{b}{\delta V}(E_{th})^{\frac{3}{2}}$

  - $\Delta S = S_f - S_i = \frac{3}{2}N\ln E_{th,f} - \frac{3}{2}N\ln E_{th,i} = \frac{3}{2}N\ln\left(\frac{E_{th,f}}{E_{th,i}}\right)$
  - Thermal equilibrium: $S = S_{max}$, exchange of thermal energy stops.
  - Absolute temperature T $\frac{1}{k_BT} \equiv \frac{dS}{dE_{th}}$, kelvin(k)
    - Boltzman constant $k_B = 1.381 \times 10^{-23}$ J/K
    - $T_A = T_B \iff \frac{E_{th,A}}{N_A} = \frac{E_{th,B}}{N_B}$ (thermal equilibrium)

Session 97624228

multiple choice question

If m is the mass of single atom in a monoatomic gas, and v_{av} is the average velocity of the atoms, then what is the average kinetic energy for equal to?

A.
$\frac{1}{2}m(v_{rms})^2$

B.
$\frac{1}{2}m(v_{av})^2$

C.
A and B

D.
None of the above

$\vec{V}_{av}$ will be affected by sign. A

$K = \frac{1}{2}m(v^2)_{avg} = \frac{1}{2}m(V_{rms})^2$

- E_{th} & K_E: $K_{av} = \frac{E_{th}}{N}$, N atoms. (Equilibrium)

$\Rightarrow K_{tot} = E_{th}$

$W = K_{tot} - K_i$

19.7, 8 Monoatomic ideal gas

Monday, March 4, 2019 10:37 AM

- $\frac{1}{k_B T} = \frac{3}{2}\frac{N}{E_{th}} \Leftrightarrow E_{th} = \frac{3}{2} N k_B T$ (monoatomic ideal gas)
  - P : Pa (Convert atm to Pa)
  - Ideal gas law $P = \frac{N}{V} k_B T$, $k_B = 1.381 \times 10^{-23}$ J/K
    - Kelvin
  - $V_{rms} = \sqrt{\frac{3k_B T}{m}}$ → mass/atom
    - $K = \frac{1}{2} m v_{rms}^2 = \frac{3}{2} k_B T$
  - $\frac{dS_A}{dE_{thA}} = \frac{dS_B}{dE_{thB}}$

§ 19.8

- $\Delta S = \frac{3}{2} N \ln\left(\frac{T_f}{T_i}\right)$
  - $\Omega = \Omega_{space}\Omega_{vel}$
  - $S = S_{space} + S_{vel}$

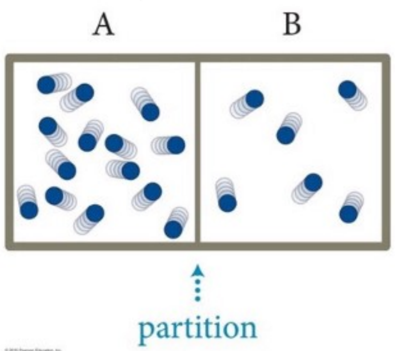
- $\Delta S = \frac{3}{2} N \ln\left(\frac{T_f}{T_i}\right) + N \ln\left(\frac{V_f}{V_i}\right)$
  - $S = N \ln\left(T^{\frac{3}{2}} V\right) + \text{constant}$ (equilibrium)
  - $\Delta S = N \ln\left(\frac{V_f}{V_i}\right) + \frac{d}{2} N \ln\left(\frac{T_f}{T_i}\right)$

Session 17383631

numerical question

Consider a closed system of two monatomic gases that can exchange energy with each other as shown. There are 14 gas molecules in compartment A and 6 in compartment B. Each molecules has a mass of 5.0×10^{-26} kg. The gas molecules in compartment A have a thermal energy of 8.4×10^{-20} J and those on compartment B have a thermal energy 7.0×10^{-20} J. At thermal equilibrium what is the energy in A?

Enter answer in J, but only include the number. Use notation 1E-30 for 1×10^{-30}

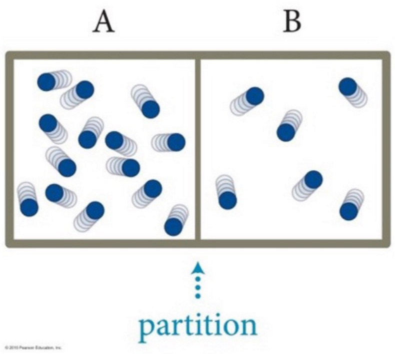


$(7\times10^{-20} + 8.4\times10^{-20}) \times \frac{14}{14+6} = 10.78\times10^{-20}$

Session 17383631

multiple choice question

Consider a closed system of two monatomic gases that can exchange energy with each other as shown. There are 14 gas molecules in compartment A and 6 in compartment B. Each molecule has a mass of 5.0×10^{-26} kg. The gas molecules in compartment A have a thermal energy of 8.4×10^{-20} J and those on compartment B have a thermal energy 7.0×10^{-20} J. How do the final temperatures in the two compartments compare?



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$T_A = T_B$, because they're at thermal temperature

$E_{th} = \frac{3}{2}Nk_BT = E_{thA} + E_{thB}$

$T_A = T_B = T$

numerical question

Gas is held in a constant volume container. The initial temperature is 20°C and initial pressure is 1.0 atm (1.013×10^5 Pa). What is the pressure after the temperature of the gas is increased to 40°C? Enter answer in Pa, but only enter number. Use notation 1.0E5 for 1.0×10^5.

$P_f = 1.013\times10^5 \times \frac{(40+273.15)}{(20+273.15)} = 1.08\times10^5\,Pa$

$\frac{P_f}{P_i} = \frac{T_f}{T_i}$

Session 17383631

numerical question

The temperature in this room is about 20°C. The total mass of air in this room is about 1000 kg, and it contains about 1.28% Ar and 0.0012% Ne by mass. Ar is a monatomic gas with a mass per atom of 6.6×10^{-26} kg and Ne is a monatomic gas with a mass per atom of 3.4×10^{-26} kg. Calculate the rms speed for which ever is moving faster between Ar and Ne atoms. Enter answer in m/s, but only include a number.

$v\uparrow \quad m\downarrow \quad (\because K \text{ equals})$

$V_{rms} = \sqrt{\frac{3\cdot k_B \times 293K}{3.4\times10^{-26}}} = 597\,m/s$ ← kelvin

Probs

Tuesday, March 5, 2019 1:30 PM