General Physics B1 - Final Exam (01/10, 8:00AM~9:50AM)

There are 6 problme sets on two sides. Total:100 points

You may answer in English or Chinese. Please use SI units and take significant figure to the second decimal place for the answers.

Useful constant: Gas constant $R = 8.31 J/mol \cdot K$**, Boltzmann constant** $k = 1.38 \times 10^{-23} J/K$**,**

1.Thermal conductivity

Ice has formed on a shallow pond, and a steady state has been reached, with the air above the ice at -5.0°C and the bottom of the pond at 4.0°C. If the total depth of ice plus water is 1.4 m, how thick is the ice? (Assume that the thermal conductivities of ice and water are 0.40 and 0.12 cal/m·°C·s, respectively. The water's freezing point is 0°C)(15points)

Solution

Assume the thickness of ice is d meters. Then the thickness of water is $1.4 - d$ meters.

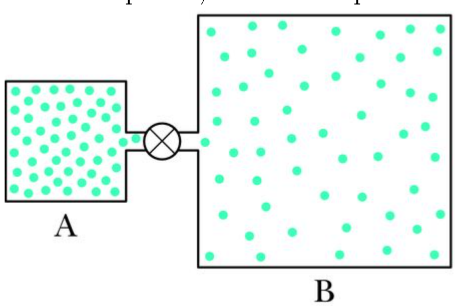
Since the system reach steady state, the heat flow through ice is equal to heat flow through water. Thus:

$0.40\frac{A[0-(-5)]}{d} = 0.12\frac{A(4-0)}{(1.4-d)}$

$\frac{2}{d} = \frac{0.48}{1.4-d}$Thus, we can get $d = 1.13m$ (Answer)

2. Ideal Gas

Container A in the following figure holds an ideal gas at a pressure of 4.0×10^5 Pa and a temperature of 300K. It is connected by a thin tube (and a closed valve) to container B, with five times the volume of A. Container B holds the same ideal gas at a pressure of 2.0×10^5 Pa and a temperature of 500K. The valve is opened to allow the pressures to equalize, but the temperature of each container is maintained. What then is the pressure?(15points)



Solution

Before the valve open, the ideal gases in the two containers follows:

$p_A V_A = n_A R T_A$ and $p_B V_B = n_B R T_B$

From the given condition, we have $p_A = 4.0 \times 10^5 Pa$, $p_B = 2.0 \times 10^5 Pa = \frac{1}{2}p_A$, $T_A = 300K$, $T_B = 500K = \frac{5}{3}T_A$, and $V_B = 5V_A$.

Thus, we have $n_A + n_B = \frac{p_A V_A}{RT_A} + \frac{p_B V_B}{RT_B} = \frac{p_A V_A}{RT_A} + \frac{3}{2}\frac{p_A V_A}{RT_A} = \frac{5}{2}\frac{p_A V_A}{RT_A}$.

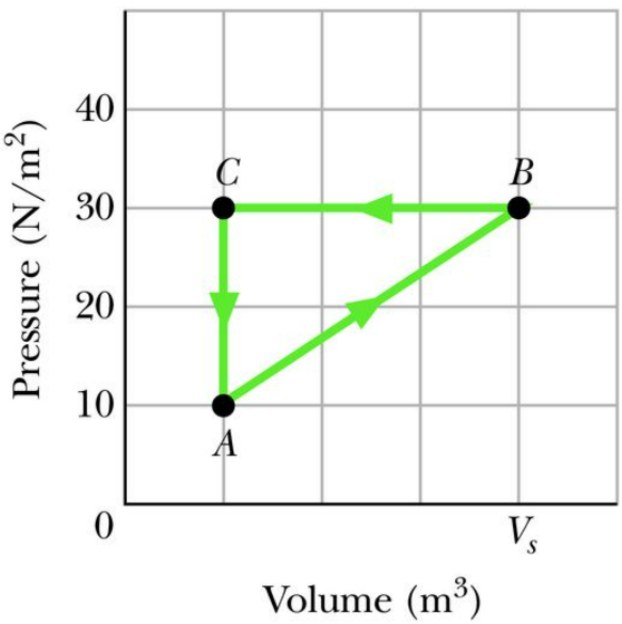
After the valve is opened, the container will reach new presure p' for both side while the volume, temperature, and the total number of molecules are the same.

Therefore, $\frac{p'V_A}{RT_A} + \frac{p'V_B}{RT_B} = p'(\frac{V_A}{RT_A} + \frac{5V_A}{R\frac{5}{3}T_A}) = p'(4\frac{V_A}{RT_A}) = n_A + n_B = \frac{5}{2}\frac{p_A V_A}{RT_A}$.

Then $p' = \frac{5}{8}p_A = 2.5 \times 10^5 Pa$ (Answer)

3. The First Law of Themodynamics

A gas within a closed chamber undergoes the cycle shown in the p-V diagram of the following diagram. The horizontal scale is set by $V_s = 4.0m^3$. Calculate the net energy added to the system as heat during one complete cycle? Notice that absorbing heat is postive and releasing heat is negative in our textbook's convention (20points)



Solution

Since one cycle, the system goes back to A. This means the internal energy doesn't chage, $\triangle E = 0$.

According to the first law of thermal dynamics$\triangle E = 0 = Q + W$.

Therefore, the heat added to energy equal to negative work done on system(or work done to the outside world): $Q = -W$.

The work done on the system is area of triangle ABC=$W = \frac{20\times 3}{2} = 30J$

Thus the net energy added to the system as heat during one cycle is $Q = -30J$ (Answer). The negative sign means the net heat in one cycle is release from the system.

4. Isothermal Expansion

A scuba diver is 25m down, where the pressure is 3.5atm. The air she exhales forms bubbles of 8.0mm in radius. How much work does each bubble do as it rises to the surface, assuming the bubbles remain at the uniform 300K of water. ? (15points) 1atm=101.325 kPa=101325N/m^2.

Solution:

The process is isothermal process(temperature is constant). For ideal gas in this isothermal process, $\frac{V_2}{V_1} = \frac{P_1}{P_2} = 3.5$

the work done in isothermal process is: $-W = nRTln(\frac{V_1}{V_2}) = p_1 V_1 ln(\frac{V_2}{V_1}) = p(\frac{4}{3}\pi r_1^3) ln(\frac{V_2}{V_1}) = 0.95J$ (Answer)

5. Cv of Gas Mixture

A gas mixture consists of 2.0 mole of oxygen (O2) and 1.0 mole of argon (Ar). Find the contant volume specific heat Cv of the mixture. (15points)

Solution:

For O2, the degree of freedom of the molecule is 5. Thus, the constant volume specific heat $C_{vO2} = \frac{5}{2}R$

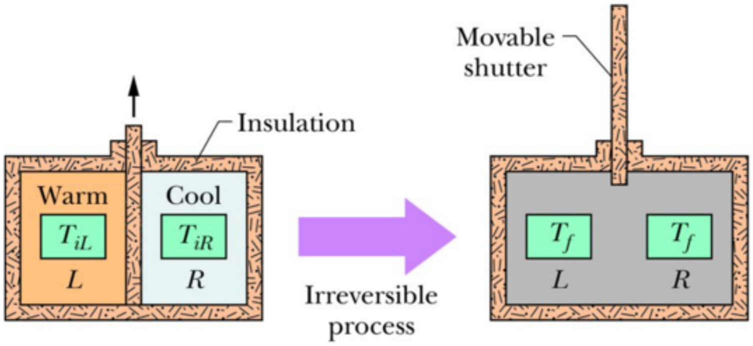
For Ar, the degree of freedom of the molecule is 3. Thus, the constant volume specific heat $C_{vAr} = \frac{3}{2}R$

Thus the mixture $C_{vmixture} = \frac{2\times\frac{5}{2}R + 1\times\frac{3}{2}R}{2+1} = 18.00 J/mol\cdot K$

6. Change of Entropy

Two identical copper blocks of mass m = 1.0 kg: block L at temperature T_{iL} =50°C and block R at temperature T_{iR} =30°C. The blocks are in a thermally insulated box and are separated by an insulating shutter. When we lift the shutter, the blocks eventually come to the equilibrium temperature T_f =40°C. What is the net entropy change of the two-block system during this irreversible process? The specific heat of copper is 386 J/kg·K and 0°C= 273K (20points)

Maybe useful:$ln(\frac{323}{313}) = 0.03145$, $ln(\frac{313}{303}) = 0.03247$, and $ln(\frac{a}{b}) = -ln(\frac{b}{a})$.



Solution:

We can assume two reversible process to have left hand block cooling down and right hand block warming up with two different heat reservior. Thus, the entropy change can be calculated with two different blocks as:

Left hand block $\triangle S_{left} = \int \frac{dQ}{T} = cm \int \frac{dT}{T} = 386 \cdot 1 \cdot ln(\frac{313}{323}) = -12.14J/K$

Right hand block $\triangle S_{Right} = \int \frac{dQ}{T} = cm \int \frac{dT}{T} = 386 \cdot 1 \cdot ln(\frac{313}{303}) = 12.53J/K$

Thus the total entropy change is: $\triangle S = \triangle S_{left} + \triangle S_{Right} = 0.39J/K$ (Answer)