APS 104S, Mock Midterm Exam, January 2009
Solutions

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1. When 2 gr of gas A is introduced into an initially evacuated flask which is maintained at constant temperature T, the pressure will be 1 bar. After adding 3 gr of gas B to the flask containing 2 gr of gas A at the same temperature T, the pressure will be 1.5 bar. Assume both gases behave as an ideal gas; calculate the ratio of the molar mass of gas B to that of gas A, i.e., (M_B/M_A).

Solution:

For gas A alone: $P=P_A=n_ART/V=(2/M_A)(RT/V)=10^5$ Pa → $M_A=2RT/(10^5V)$

For mixture of A and B: $P_{mix}=P_A+P_B$ → $1.5*10^5=10^5+P_B$ → $P_B=0.5*10^5$ Pa

$P_B=(3/M_B)(RT/V)=0.5*10^5$ → $M_B=3RT/(0.5*10^5V)$

$$\frac{M_B}{M_A}=\frac{\dfrac{3RT}{0.5\times10^5V}}{\dfrac{2RT}{10^5V}}=\frac{3}{2\times0.5}=3$$

2. A piston/cylinder arrangement is filled with helium gas at 300 K and 1 bar. The initial volume is 1 m^3. Heat is transferred to the system reversibly until its final volume is 4 m^3. In this process, pressure varies with volume according to the following formula:

$PV^2 = const.$ where P is in Pa and V is in m^3

If helium behaves as an ideal gas with C_v=3/2R, calculate:

a) the work produced by the system during this process
b) the amount of heat added to the system during this process
c) the change in the enthalpy of helium during this process
d) Sketch this process in a P-V diagram and use that diagram to explain if an isothermal expansion to final volume of 4 m3 produces more or less work that the work obtained in part (a)

Solution:

$$n=\frac{PV}{RT}=\frac{10^5\times1}{8.314\times300}=40.1\ \ mol$$

$$PV^2=const.\ \ \rightarrow const.=(10^5\,Pa)(1m^3)^2=10^5\qquad Pa.m^6$$

$$W_{rev} = -\int_{V1}^{V2} PdV = -\int_{V1}^{V2} (\frac{10^5}{V^2})dV = +10^5(\frac{1}{V_2} - \frac{1}{V_1}) = 10^5(\frac{1}{4} - 1) = -0.75\times10^5 J$$

$$P_2V_2^2 = 10^5 \rightarrow P_2 = \frac{10^5}{4^2} = 6250 Pa$$

$$\frac{P_2V_2}{T_2} = \frac{P_1V_1}{T_1} \rightarrow T_2 = \frac{P_2V_2}{P_1V_1}T_1 = 75K$$

$$\Delta U = nC_v\Delta T = 40.1*3/2R*(75-300) = -112520J$$

$$\Delta U = Q + W \rightarrow Q = \Delta U - W = -37519.6J$$

$$\Delta H = nC_p\Delta T = 40.1*5/2R*(75-300) = -187533J$$

W	ΔU	Q	ΔH
-0.75 10^5 J	-112520 J	-37519.6 J	-187533 J

d. If you prepare a sketch in a P-V diagram, you will see that the isothermal expansion work is bigger than the work done in this process:

$$W_{rev} = -nRT\ln\frac{V_2}{V_1} = -40.1*8.314*300*\ln(4/1) = -1.386\times10^5 J$$

$$P_2 = \frac{P_1V_1}{V_2} = 25000 Pa$$ ◄ If the process is isothermal