H.W 1

1. A system goes from specific volume V_1 to V_2 . If the gas in the system follows:

$$V = \frac{RT}{P} + b$$

where b is a positive constant. Please develop an equation for the work during this process if

(A) the pressure of the surrounding is maintained at P_{ext}.

(B) the process is a reversible process.

2. Liquid water at 200℃ and 1002.7 kPa has an internal energy of 762.0 kJ/kg and a specific volume of 1.128 cm^3/g.

(A) What is the enthalpy?

(B) The water is brought to the vapor state at 300℃ and 1700 kPa, where its internal energy is 2780.3 kJ/kg, and a specific volume of 148.91cm^3/g. Calculate $\Delta U, \Delta H$ for the process.

3. Four moles of diatomic ideal gas go from initial state $P_1 = 50kPa, V_1 = 160dm^3$ to final state of $P_2 = 200kPa$. The process is adiabatic and reversible. 1dm = 0.1m. Please calculate the temperature of the final state T_2, and W^t, $\Delta U^t, \Delta H^t$ during the process.

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1. A system goes from specific volume V_1 *to* V_2 . If the gas in the system follows:

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(A) the pressure of the surrounding is maintained at P_{ext}.

(B) the process is a reversible process.

Sol: (A) $W = -n\int_{V_1}^{V_2} P_{ext}\, dV = nP_{ext}(V_1 - V_2)$

(B) For the initial situation: $V_1 = \frac{RT_1}{P_{ext}} + b$, $V_1^t = nV_1$

For the final situation: $V_2 = \frac{RT_2}{P_{ext}} + b$, $V_2^t = nV_2$

Reversible Process:

$$W = -\int_{V_1^t}^{V_2^t} P\, dV = -\int_{V_1^t}^{V_2^t} \frac{RT}{V-b}\, dV = -RTn\ln\left(\frac{V_2 - b}{V_1 - b}\right)$$

2. Liquid water at 200°C and 1002.7 kPa has an internal energy of 762.0 kJ/kg and a specific volume of 1.128 cm^3/g.

(A) What is the enthalpy? H 焓

(B) The water is brought to the vapor state at 300°C and 1700 kPa, where its internal energy is 2780.3 kJ/kg, and a specific volume of 148.91cm^3/g. Calculate $\Delta U, \Delta H$ for the process.

Sol: (A) At 200°C and 1002.7 kPa:

$$Q = \Delta U - W = \Delta U + PV = 762.0\,kJ/kg + 1002.7\,kPa \cdot 1.128\,cm^3/g$$
$$= 762.0\,kJ/kg + 1002.7\,k\frac{N}{m^2} \cdot 1.128\times10^{-3}\frac{m^3}{kg}$$
$$= 763.13\,kJ/kg$$
$$H = Q = 763.13\,kJ/kg$$

(B) state variable: U, H

$$\Delta U = U_2 - U_1 = 2780.3\,kJ/kg - 762.0\,kJ/kg = 2018.3\,kJ/kg$$
$$H_2 = U + PV = 2780.3\,kJ/kg + 1700\,kPa \cdot 148.91\,cm^3/g$$
$$= 2780.3\,kJ/kg + 1700\cdot10^3\frac{N}{m^2} \cdot 148.91\cdot10^{-3}\frac{m^3}{kg}$$
$$= 3033.447\,kJ/kg$$

$\Delta H = H_2 - H$

$3033.447\,kJ/kg - 763.13\,kJ/kg$

$= 2270.317\,kJ/kg$

3. Four moles of diatomic ideal gas go from initial state $P_1 = 50kPa, V_1 = 160dm^3$ to final state of $P_2 = 200kPa$. The process is adiabatic (Q const.) and reversible. 1dm = 0.1m. Please calculate the temperature of the final state T_2, and $W^t, \Delta U^t, \Delta H^t$ during the process.

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Sol: $\Delta U^t = W + Q$, since it's a adiabatic process

Q is a constant,

$$T_1 = \frac{P_1 V_1}{nR} = \frac{50kPa \cdot 160dm^3}{8.314J/(mol \cdot K) \cdot 4mol}$$

$$= \frac{50\times10^3 \frac{N}{m^2} \cdot 160\times10^{-3} m^3}{8.314J/(mol \cdot k) \cdot 4mol}$$

$$= 240.56k$$

$\gamma = \frac{7}{5}$ since it's a diatomic gas

$TP^{\frac{1}{\gamma}-1} = \text{Constant} \Rightarrow T_1 P_1^{-\frac{2}{7}} = T_2 P_2^{-\frac{2}{7}}$

$$T_2 = T_1\left(\frac{P_2}{P_2}\right)^{-\frac{2}{7}} = 240.56k \cdot \left(\frac{50kPa}{200kPa}\right)^{-\frac{2}{7}} = 357.47k$$

$$W^t = \frac{nR(T_2 - T_1)}{\gamma - 1} = \frac{8.314J/(mol \cdot k) \cdot (357.47k - 240.56k) \cdot 4mol}{\frac{2}{5}} = 9719.8974J$$

$$\Delta U^t = W^t = 9719.8974J$$

$$\Delta H^t = n\int_{T_1}^{T_2} C_p^{'g}\, dT = n\int_{T_1}^{T_2} \frac{7}{2}R\, dT = n\frac{7}{2}R(T_2 - T_1) = 4mol \cdot \frac{7}{2} \cdot 8.314J/(mol \cdot k) \cdot (357.47k - 240.56k)$$

$C_i^{'g} = \frac{7}{2}R$

$$= 13607.85636J$$

HW 2

Problem 1. Use the compressibility factor chart to find the compressibility for oxygen gas at 298.15 Kelvin and 20270 kPa.

Problem 2. Find the specific volume $[cm^3/mol]$ for nitrogen gas at T=273.15K and P=40530× 10^3 Pa, using:

(A) Ideal gas law

(B) Van der Waals equation $\left(p+\frac{a}{V^2}\right)(V-b)=RT$. The correlations for nitrogen gas are $a=0.137\ Pam^6mol^{-2}, b=3.87\times10^{-5}\ m^3mol^{-1}$. Report the answer until the error $\frac{V_{i+1}-V_i}{V_i}$ is less than 1%.

Problem 3. Consider a reaction:

$$2H_2S\ (g)+3O_2(g)=2H_2O\ (g)+2SO_2\ (g)$$

(A) (5 points) Determine the standard heat of the reaction at 25°C.

(B) (8 points) Neglect part (A). If 3 mol of $H_2S\ (g)$ and 3 mol of $O_2(g)$ were put in a combustor for combustion and a 100% conversion occurs. After the combustion, the combustion product at 298K and 1 bar as its initial condition, then a simple isobaric heating process is performed to bring the product to a higher temperature. If the gases are ideal but they do depend on temperature, represent the received heat (Q) during the heating process as a function of the final temperature (T).