

MME 2009 Metallurgical Thermodynamics I

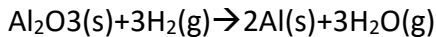
Problem Set II

1. Show that $C_p - C_v = \beta^2 VT/k$ for any material
2. A sample of gas initially occupies a volume of 1 liter under a pressure of 1 atm. The gas is reversibly taken through the following cycle:
 - a. Heated at constant volume until $P=2$ atm
 - b. Heated at constant pressure until $V=2$ liters
 - c. Cooled at constant volume until $P=1$ liter
 - d. Cooled at constant pressure until $V=1$ literCalculate the total change in internal energy, heat and work for the complete cycle

3. Two moles of an ideal gas at 3 atm and 300 K in a cylinder fitted with a piston is compressed isothermally to half of the initial volume by an external pressure of 7 atm. Find the change in internal energy, heat and work

4. Calculate the isothermal enthalpy change at 1000 K for the following process at 298 K
 $\text{Pb(l)} + \text{CO}_2(\text{g}) = \text{PbO(s)} + \text{CO(g)}$
 $\text{CO(g)} \quad \Delta H_{298} = -110510 \text{ J/mol} \quad C_p = 28.42 + 0.0041T - 46000/T^2 \text{ J/molK}$
 $\text{CO}_2(\text{g}) \quad \Delta H_{298} = -394000 \text{ J/mole}, \quad C_p = 44.3 + 0.0088T - 860000/T^2 \text{ J/molK}$
 $\text{PbO(s)} \quad \Delta H_{298} = -219350 \text{ J/mole}, \quad C_p = 37.9 + 0.0268T \text{ J/molK}, \quad H_T - H_{298} = -3508 + 28.46T \text{ J/mol}$

5. Calculate the standard enthalpy change for the following reaction at 298 K:



$$\Delta H_{298}(\text{H}_2\text{O}) = -285.8 \text{ J/mol}$$

$$\Delta H_{298}(\text{Al}_2\text{O}_3) = -1669.8 \text{ J/mol}$$

6. Liquid copper at 1150 °C is being poured into a water cooled continuous casting mould. Mould has 0.02 m³ of volume. The casting rate is 10 cm³/s. Calculate the minimum flow rate of water entering at 15 °C, required to yield a discharge temperature of 80 °C. The average temperature at the bottom of the mould is 1083 °C and copper is in solid state

$$C_p(\text{Cu(l)}) = 31.3 \text{ J/mole.K}$$

$$\Delta H_m(\text{Cu}) = 13000 \text{ J/mole at } T_m = 1083 \text{ °C}$$

$$C_p(\text{H}_2\text{O(l)}) = 75.47 \text{ J/mole.K}$$

7. A mixture of 50% H₂, 25% CO, and 25% CO₂ by volume at 1 atm is passed into a reaction chamber at 727 C at a flow rate of 2 m³/min. How much heat has to be given or taken through the walls of the reaction chamber in order to keep the temperature constant? Equilibrium between CO-CO₂-H₂-H₂O is established inside the reaction chamber.

Take C_p for monatomic gases as $5/2R$, C_p for diatomic gases as $7/2R$ and C_p for polyatomic gases as $4R$

8. 1 ton of limestone (CaCO_3) is calcined at 727 C according to reaction



180 kg of coke containing 100% C was used as fuel. If limestone, coke and air enter the furnace at room temperature, calculate

- The heat required for calcination
- The heat available when coke is burned with air (21% O_2 , 79% N_2) to yield an exhaust gas (CO_2 - N_2) at 727 C
- Thermal efficiency (ratio of the required heat to available heat of the process)

$$\text{CaCO}_3(\text{s}) \quad \Delta H_{298} = -1207 \text{ kJ/mole} \quad C_p = 104.57 + 0.02193T - 2595000/T^2 \text{ J/molK}$$

$$\text{C}(\text{s}) \quad C_p = 16.87 + 0.00477T - 854000/T^2 \text{ J/molK}$$

$$\text{CaO} \quad \Delta H_{298} = -635.5 \text{ kJ/mole}, \quad C_p = 49.95 + 0.00489T - 352000/T^2 \text{ J/molK}$$

$$\text{O}_2(\text{g}) \quad C_p = 29.97 + 0.00419T - 167000/T^2 \text{ J/molK}$$

$$\text{N}_2(\text{g}) \quad C_p = 27.88 + 0.00427T \text{ J/molK} \quad (H_T - H_{298}) = -8502 + 27.88T + 0.00213T^2$$

$$\text{CO}_2(\text{g}) \quad C_p = 22.24 + 0.0598T - 349900/T^2 \text{ J/molK}$$

9. One gram of supercooled liquid zinc at 400 C is in a container of large heat capacity. Find the enthalpy change of zinc during solidification

$$\text{Zn}(\text{s}) \quad C_p = 22.4 + 0.01005 \text{ J/molK} \quad \Delta H_m = 7388 \text{ J/mole at } 420 \text{ C}$$

$$\text{Zn}(\text{l}) \quad C_p = 31.4 \text{ J/molK}$$

10. Mg powder is condensed from a supercooled gaseous phase at 600 C in the production of magnesium by Pidgeon process. Calculate the enthalpy change for the system

$$\text{Mg}(\text{s}) \quad C_p = 25.7 + 0.00628T + 327000/T^2 \text{ J/molK}, \quad \Delta H_m = 9040 \text{ J/mol at } 923\text{K}$$

$$\text{Mg}(\text{l}) \quad C_p = 30.98 \text{ J/molK}, \quad \Delta H_v = 131860 \text{ J/mol at } 1363\text{K}$$

$$\text{Mg}(\text{g}) \quad C_p = 20.80 \text{ J/molK}$$