MME 2009 Metallurgical Thermodynamics I

Problem Set II

1. Show that $C_P - C_V = \beta^2 VT/\kappa$ 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 liter

   Calculate 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

   $Pb(l) + CO_2(g) = PbO(s) + CO(g)$

   CO(g) ΔH_{298}=-110510 J/mol Cp= 28.42 + 0.0041T – 46000/T^2 J/molK

   CO2(g) ΔH_{298}=-394000 J/mole, Cp=44.3+0.0088T-860000/T^2 J/molK

   PbO(s) ΔH_{298}=-219350 J/mole, Cp=37.9+0.0268T J/molK, $H_T - H_{298}$= -3508 + 28.46T J/mol

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

   $Al_2O3(s)+3H_2(g) \rightarrow 2Al(s)+3H_2O(g)$

   ΔH_{298} (H_2O)= -285.8 J/mol

   ΔH_{298} (Al_2O_3)= -1669.8 J/mol

6. Liquid copper at 1150 °C is being poured into a water cooled continous casting mould. Mould has 0.02m^3 of volume. The casting rate is 10 cm^3/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

   $C_p(Cu(l))$ = 31.3 J/mole.K
   $\Delta H_m(Cu)$ = 13000 J/mole at T_m = 1083 °C
   $C_P(H_2O(l))$ = 75.47 J/mole.K

7. A mixture of 50% H_2, 25% CO, and 25% CO_2 by volume at 1 atm is passed into a reaction chamber at 727 C at a flow rate of 2 m^3/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-CO_2-H_2-H_2O 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
   $CaCO_3(s) = CaO(s) + CO_2(g)$
   180 kg of coke containing 100% C was used as fuel. If limestone, coke and air enter the furnace at room temperature, calculate
   a) The heat required for calcination
   b) 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
   c) Thermal efficiency (ratio of the required heat to available heat of the process
   $CaCO_3(s)$ ΔH_{298}=-1207 kJ/mole C_p=104.57+0.02193T -2595000/T^2 J/molK
   C(s) C_p=16.87+0.00477T -854000/T^2 J/molK
   CaO ΔH_{298}=-635.5 kJ/mole, C_p=49.95+0.00489T -352000/T^2 J/molK
   $O_2(g)$ C_p=29.97+0.00419T-167000/T^2 J/moleK
   $N_2(g)$ C_p=27.88+0.00427T J/molK (H_T-H_{298})= -8502+27.88T+0.00213T2
   $CO_2(g)$ C_p=22.24+0.0598T -349900/T^2 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
   Zn(s) Cp=22.4 + 0.01005 J/molK ΔHm= 7388 J/mole at 420 C
   Zn(l) Cp= 31.4 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
    Mg(s) Cp=25.7 + 0.00628T + 327000/T^2 J/molK, ΔHm= 9040 J/mol at 923K
    Mg(l) Cp=30.98 J/molK, ΔHv=131860 J/mol at 1363K
    Mg(g) Cp=20.80 J/molK