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Department of Metallurgical and Materials Engineering

MME 2009 Metallurgical Thermodynamics I

Review Problems I

1- Calculate the partial pressure of carbon monoxide, P_{CO} from the following equation

$$18.2P_{CO}^2 + 96.2\ P_{CO} - 6.9 = 0$$

Hint: Use graphical and numerical methods and compare the solutions

2- Vapor pressure of Pb is related to temperature in the following form:

$$\log P_{Pb} = -10130/T - 0.985\ \log T + 8.279$$

where P_{Pb} is in atmosphere and T is in Kelvin. Calculate the normal boiling point of lead where P_{Pb} = 1 atm

3 – The composition of Pb-Zn alloy for a special application was given by the following equation

$$2.08\ X^2 - 1.81\ X^3 + \log X = -0.4157$$

where X represents the mole fraction of zinc in the alloy ($0<X<0.5$). Find the mole fraction of Zn in a Pb-rich alloy that is suitable for the present application

4 – What pressure increase is needed to make a cubic block of aluminum metal retain its initial volume while it is being heated from 0 to 50^{0}C? The average linear expansion coefficient α_L = $2.5\times10^{-7}\ K^{-1}$, the isothermal compressibility factor $\beta = 2.95\times10^{-10}\ (N/cm^2)^{-1}$.

Hint: $dV=(\delta V/\delta T)dT + (\delta V/\delta P)dP$, $\alpha=1/V(\delta V/\delta T)_P$, $=-1/V(\delta V/\delta P)_T$

5 - A 5-g lead oxide bullet moving at 200 m/s embeds itself into a wooden block. Half of its initial energy is absorbed by the bullet. What is the increase in temperature of the bullet?

6 - A solar collector has an area of 5 m^2 and the power of sunlight is delivered at 550 W/m^2. This power is used to increase the temperature of 200 g of water from 20^{0}C to 50^{0}C. How much time is required?

7 - How many grams of steam at 100^{0}C must be added to 30 g of ice at 0^{0}C in order to produce an equilibrium temperature of 40^{0}C?

8 - A large, insulated container holds 120 g of coffee at 85^{0}C. How much ice at 0^{0}C must be added to cool the coffee to 50^{0}C? Now, how much coffee at 100^{0}C must be added to return the contents to 85^{0}C? How many grams are finally in the container? Hint: Coffee and water have the same heat capacities.

9 - What equilibrium temperature is reached when 2 kg of ice at -10 C is dropped into a 3 kg aluminum cup containing 7.5 kg of water? The cup and water are initially at 80^{0}C.

10 - In an experiment to determine the latent heat of vaporization for water, a student measures the mass of an aluminum calorimeter cup to be 50 g. After a quantity of water is added, the combined mass of the water and cup is 120 g. The initial temperature of the cup and water is 18^{0}C. A quantity of steam at 100^{0}C is passed into the calorimeter, and the system is observed to

reach equilibrium at 47.4^{0}C. The total mass of the final mixture is 124 g. What value will the student obtain for the heat of vaporization?

11 - Four 200-g blocks are constructed out of copper, aluminum, zinc, and carbon so that they have the same mass and the same base area (although of different heights). The temperature of each block is raised from 20^{0}C to 100^{0}C by applying heat at the rate of 200 J/s. Find the time required for each block to reach 100^{0}C.

12 - Each of the blocks in the previous example are placed on a large block of ice. Find out how much ice is melted by each block when all reach equilibrium at 0^{0}C?

13- Show that C_P-C_V = $\beta^2 VT/\kappa$ for any material

14- 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

15- One mole of a gas initially at 100 °C and 10 atm, is subjected to the following sequence:

e. Adiabatic expansion until pressure is reduced to 5 atm
f. Isobaric volume change until temperature becomes 100 °C
g. Isothermal volume change until pressure becomes 10 atm

Schematically plot above processes on P-V diagram and compare the work produced in each path

16- 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

17- An aircraft turbofan adiabatically and reversibly compresses air from an initial state of 0.9 atm and 298 K to 9 atm just prior to admission to the combustion chamber. Determine the temperature of air at the entrance of the combustion chamber

(Assume air is a mixture of 21% O_2 and 79% N_2 by volume)
$C_V(N_2(g))$ = 31.8 J/mole.K
$C_V(O_2(g))$ = 33.5 J/mole.K

18- 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

Thermochemical Data

Substance	ΔH^o (kJ/mol)	S^o (J/mol.K)	C_P (J/mol.K)
PbO(s)	-219.35	73.60	37.9+0.0268T
Pb(l)		71.71	31.2
O_2(g)		205.11	33.44
Cu_2O(s)	-167.44	93.14	83.6
N_2(g)		191.5	31.8
H_2O(g)	-241.83	188.84	41.8+0.00564T
C_7H_{16}(l)	-224	186	28.42 + 0.0041T

$CaCO_3$(s) ΔH_{298}=-1207000 J/mole, C_p=104.57+0.02193T -2595000/T^2 J/molK

CaO(s) ΔH_{298}=-635500 J/mole, C_p=49.95+0.00489T -352000/T^2 J/molK

CO_2(g) ΔH_{298}=-393520 J/mole, C_p=22.24+0.0598T -349900/T^2 J/molK

CO(g) ΔH_{298}=-111000 J/mole C_p=28.4+0.0041T J/moleK

C(s) C_p=16.87+0.00477T -854000/T^2 J/moleK

Al_2O_3(s) ΔH_{298}=-1674400 J/mol, H_T-H_{298}=115.1T + 0.0059T^2 + 3500000/T J/mol

Al(s) H_T-H_{298}=-6719 + 20.68T + 0.0062T^2 J/mol

Al(l) H_T-H_{298}= 1381 + 29.30T J/mol

Cr_2O_3(s) ΔH_{298}=-1128400 J/mol, H_T-H_{298}= 103.2T + 0.03128T^2 + 2120000/T J/mol

Cr(s) H_T-H_{298}= -9774 + 15.82T + 0.045T^2 J/mol

Fe_2O_3(s) ΔH_{298}=-821710 J/mole, H_T-H_{298}= -37758 + 98.3T + 0.03893T^2 + 1490000/T J/mole

Fe(l) C_p=4.18 + 0.00592T J/molK

Zn(s) C_p=22.4 + 0.01005T J/molK, ΔH_m= 7388 J/mole at 693K,

Zn(l) C_p= 31.4 J/molK, ΔH_v= 115350 J/mole at 1181K

Zn(g) C_p=20.76 J/molK

Cu(s) C_p=22.65+0.00628T J/molK ΔH_m= 13000 J/mole at 1356 K

Cu(l) C_p= 31.40 J/molK

Universal Gas Constant

R = 8.3144621 J/mole.K = 8.3144621 L.kPa/mole.K = 8.3144621 m^3.Pa/mole.K = 83.144621 L.mbar/mole.K = 0.082057 L.atm/mole.K = 8.2057*10^{-5} m^3.atm/mole.K = 62.36368 L.mmHg/mole.K

Table of Units Conversions

Quantity	Conversion	Quantity	Conversion
Length	1 m = 100 cm = 3.28084(ft) = 39.3701(in)	Volume	1 m^3 = 10^6 cm^3 = 10^3 liters = 35.3147$(ft)^3$ = 264.172(gal)
Mass	1 kg = 10^3 g = 2.20462(lb_m)	Density	1 g cm^{-3} = 10^3 kg m^{-3} = 62.4278(lb_m)$(ft)^{-3}$
Force	1 N = 1 kg m s^{-2} = 10^5(dyne) = 0.224809(lb_f)	Energy	1 J = 1 kg m^2 s^{-2} = 1 N m = 1 m^3 Pa = 10^{-5} m^3 bar = 10 cm^3 bar = 9.86923 cm^3(atm) = 10^7(dyne) cm = 10^7(erg) = 0.239006(cal) = 5.12197 × $10^{-3}$$(ft)^3$(psia) = 0.737562(ft)($lb_f$) = 9.47831 × 10^{-4}(Btu) = 2.77778 × 10^{-7} kWhr
Pressure	1 bar = 10^5 kg m^{-1} s^{-2} = 10^5 N m^{-2} = 10^5 Pa = 10^2 kPa = 10^6(dyne) cm^{-2} = 0.986923(atm) = 14.5038(psia) = 750.061(torr)	Power	1 kW = 10^3 W = 10^3 kg m^2 s^{-3} = 10^3 J s^{-1} = 239.006(cal) s^{-1} = 737.562(ft)(lb_f) s^{-1} = 0.947831(Btu) s^{-1} = 1.34102(hp)