MME 4517 Materials and Energy Balance

Practice Question Sheet II

1. You are assigned to cool off heat of steel which is liquid but too hot. It weighs 90 tons and is at 1700 C. You want to add cold (25 C) steel to it to lower its temperature to 1500 C. Assuming no heat loss from the furnace, how many kilograms would you add? Assume all thermal properties are those of iron.
2. Producer gas of the following composition is burned with stoichiometric air. Both air and gas are preheated to 1000 C. Calculate the theoretical maximum temperature of the flame. What would the flame temperature be if pure oxygen at room temperature was blown instead of air?
   28% CO, 4% CO_2, 4% H_2, 2%CH_4, 1% H_2O, 61% N_2
3. A furnace calcining CaCO3 is burning coal (89% carbon, 3% hydrogen, 1% oxygen and 7% ash) with air and the airflow is controlled and metered so that air enters the furnace at 100 m3/min. The flue gas analysis is 55% N2. Calculate a) the theoretical coal requirement per minute, b) the amount of coal that would be consumed if the off-gas were recycled back to the furnace, c) the amount of coal that would be consumed if the off-gas were recycled and carbon in coal was burned partially to CO.
4. An anthracite coal contains 89% carbon, 3% hydrogen, 1% oxygen and 7% water. It is burned with 15% excess air. What is the flame temperature of the flue gases? What would the flame temperature be if a heat exchanger running at 50% efficiency was used to recycle the heat of the gases to heat the air?
5. 1000 kg of ore concentrate of 6% Cu and 35% S is roasted with oxygen in air. All copper in the ore concentrate is in the form of $CuFeS_2$ and sulphur also forms FeS_2. The rest of the ore is gangue minerals which do not contain Cu, Fe or S. Stoichiometric air is let in at 273 K for complete roasting. Assuming that the gangue minerals leave the furnace at 273 K, value minerals at 773, what is the flame temperature of the gases leaving the furnace?
   Reactions:
   $4FeS_2 + 11O_2 = 2Fe_2O_3 + 8SO_2$
   $4CuFeS_2 + 12O_2 = 2Cu_2O + 2Fe_2O_3 + 8SO_2$
6. A basic Bessemer steel converter is charged with 10 tons of pig iron of the following composition. All of the C, Si, Mn and P are oxidized prior to the initiation of iron reduction. Air compressor delivers air at 700 K at a rate of 100 m^3/min. 1 ton of flux containing only CaO is added to the furnace prior to the operation. Calculate the maximum temperature that the contents of the furnace will reach at the end of the process.

Ultimate Analysis wt%					
	Fe	C	Si	Mn	P
Pig iron	95	3.4	0.8	0.6	0.2

Reactions

$Si + O_2 = SiO_2$	$\Delta H = -205400$ kcal/kg-mole SiO_2
$2Mn + O_2 = 2MnO$	$\Delta H = -91991$ kcal/kg-mole MnO
$C + O_2 = CO_2$	$\Delta H = -94000$ kcal/kg-mole CO_2
$4P + 5O_2 = 2P_2O_5$	$\Delta H = -360000$ kcal/kg-mole P_2O_5

7. 1 ton pig iron of the following composition is produced hourly in a blast furnace. 2 tons of iron ore, 300 kg CaO as flux, coke of the following composition and 22535 m^3 of air are used to produce 1 ton of pig iron. Air is blown to the furnace at 1000 K and 26968 m^3 top gas of the following composition leaves the furnace at 1000 K. Pig iron and 886 kg slag leave the furnace at 1500 K. What is the amount of coke consumed per ton of pig iron?

Reactions

$C + 1/2O_2 = CO$	$\Delta H = -27000$ kcal/kg-atom C
$Fe_2O_3 + 3CO = 2Fe + 3CO_2$	$\Delta H = 117273$ kcal/kg-mole Fe_2O_3
$SiO_2 + 2C = \underline{Si} + 2CO$	$\Delta H = 146200$ kcal/kg-mole SiO_2
$MnO + C = \underline{Mn} + CO$	$\Delta H = 62400$ kcal/kg-mole MnO
$P_2O_5 + 5C = \underline{2P} + 5\ CO$	$\Delta H = 212000$ kcal/kg-mole P_2O_5
$C + O_2 = CO_2$	$\Delta H = -94000$ kcal/kg-mole CO_2
$H_2O + C = CO + H_2$	$\Delta H = 28200$ kcal/kg-mole H_2O
$H_2O(l) = H_2O(g)$	$\Delta H_v = 9756$ kcal/kg-mole H_2O

Ultimate Analysis wt%, v%														
	CO	CO_2	N_2	H_2	C	H_2O	Fe	Si	Mn	P	SiO_2	MnO	P_2O_5	CaO
Pig Iron					2		95	1	1	1				
Coke					85.7	14.3								
Slag											25	21.1	20	33.9
Top gas	15.5	15.5	66	3										

8. Vanadium is produced from its ore by reducing the oxide, V2O5 with Ca metal in a "bomb" reactor according to the following reaction

   5Ca + V2O5 = 5CaO + 2V

   In order to absorb some of the excess heat evolved in this reaction, SiO2 is added to the stoichiometric reactant mixture. This SiO2 combines with CaO to form a silicate:

   CaO + SiO2 = CaO.SiO2

   If 5 moles of SiO2 are added to the original stoichiometric mix of Ca and V2O5 per mole of V2O5, calculate the adiabatic flame temperature of the products. The initial temperature of all reactants is 298 K.

   Data

Materials	Cp Cal/mol.K	Tm C	Delt aH fusion Cal/mol	Delta H formation cal/mol
V2O5	46.5			-371800
V(s)	5.2			
V(l)	6.5	1860	3500	
CaO(s)	11.8			-151900
CaO(l)	12.0	2600	19000	
SiO2(s)	11.2			-203400
SiO2(l)	13.4	1713	3600	
CaO.SiO2(s)	26.4			-378600

CaO.SiO2(l)	27.0	1540	13400	
Ca(s)	5.3			

Substance	C_p	H_T-H_{298}
N_2	6.66+0.001T	
O_2	7.16+0.001T-40000/T^2	
CO_2	10.56+0.00216T-204000/T^2	
H_2O		0.0014T^2 + 6.9941T
Cu_2O		0.003T^2 + 14.719T
Fe_2O_3		0.0109T^2 + 20.344T
SO_2		0.0011T^2 + 10.69T
SiO_2	11.22+0.0082T-270000/T^2	
MnO	12.38+0.0016T-0.38/T^2	
P_2O_5	39.92+0.018T-10000000/T^2	
Fe	3.37+0.0071*T+43000/T^2	0.0005T^2 + 8.7811T
CH_4		0.005T^2 + 6.8039T
CO		0.0006T^2 + 6.7055T
H_2		0.0004T^2 + 6.48T