Chemical Engineering 310 Combustion Homework

1. Explain how a candle works to another person who has not had any engineering or combustion background, including:
    a. why the wick is necessary,
    b. what the different colors mean,
    c. the heat transfer mechanisms, and
    d. the chemistry.

   Have that person sign a paper telling how well you did. This person should not be in our class.

2. Assuming that the sun emits blackbody radiation at a temperature of 6000 K and the earth emits blackbody radiation at an average temperature of 290 K,
    a. Compute the wavelength at which the maximum emission occurs (in μm) for both the sun and the earth.
    b. Compute the amount of blackbody radiation emitted in the visible wavelength region (0.4 to 0.7 μm) for both the sun and the earth.
    c. Compute the amount of blackbody radiation emitted in the infrared wavelength region (2 to 25 μm) for both the sun and the earth.
    d. Compute the percentage of total radiation emitted in the visible and in the infrared regions for the sun and for the earth.

3. A Wyodak subbituminous coal analysis is

H_2O	28.09	wt.% as received
Ash	6.31	wt.% as received
High Heating value	8426	Btu/lb as received

Carbon	68.43 %	dry basis
Hydrogen	4.88	
Nitrogen	1.02	
Sulfur	0.63	

(a) Assuming that oxygen is the only element in the coal besides C, H, N, S, (and ash), calculate the amount of oxygen in the coal on a dry, ash-free basis.

(b) Calculate the high heating value on a dry, ash-free basis in kJ/g.

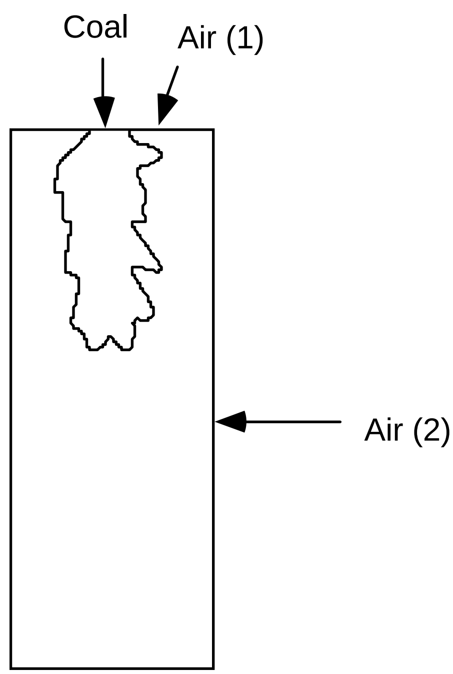
(c) Calculate the standard heat of formation of the coal in kJ/g of daf coal.

4. A laboratory coal reactor is being designed to burn 50 lbs/hr of the Wyodak subbituminous coal in problem #3.

(a) Please calculate the flow rate of air (lbs of air/hr) required to maintain 5 mol% 0_2 after complete combustion.

(b) What amount of heat must be removed from the reactor (Btu/hr) if the inlet temperature is 25°C and the outlet temperature is 1100°C? Assume that the heat capacity of ash is 2.1 cal/g/K.

(c) Your boss decides to operate the reactor in two stages, with the first stage to operate at a stoichiometric ratio of 0.6 and the final stage to operate at a stoichiometric ratio of 1.2. What air flow (lbs of air/hr) should be at each stage?



5. For a CH_4-air mixture at atmospheric pressure, please compute the adiabatic flame temperature using (a) the NASA - CEA program, and (b) using heats of formation and combustion.

Stoichiometric Ratio = 1.1

for part (b), use $CH_4 + 2O_2 \leftrightarrow 2H_2O + CO_2$

Please compare the results from (a) and (b) and explain any differences.

6. Using the NASA - CEA program, compare equilibrium temperatures and compositions of a mixture of coal, steam, and O_2 in the mass ratio 1.0:0.6:0.3 at (a) 1 atm and (b) 100 atm, where the coal mass is calculated on a dry-ash free basis. Use the Wyodak coal from problem #2. The inlet temperature is 25°C. Comment on any differences.

7. A 5-liter gas bottle is accidentally filled with a propane-air mixture at a stoichiometric ratio of 0.9 and a pressure of 5 psig at 298 K. The vessel has an ignition source, and the mixture combusts to reach chemical equilibrium. Assume that the ambient pressure is 1 atm, and assume ideal gas behavior.

   (a) Assuming the vessel expands to maintain 5 psig. What will be the final volume?

   (b) Assuming the container is well insulated and doesn't explode, what will be the final pressure and temperature in the vessel?

8. A premixed burner operates with CH_4 and air at the maximum flame speed.
   (a) Calculate the ratio of flow rates if acetylene is used as the fuel, designing for no flashbacks? Don't forget the density correction based on MW.

   (b) Assuming an equivalence ratio of 1.2 for both the fuels, calculate the ratio of flame temperatures.

   The flame speed of CH_4-air is 1.1 ft/s, and C_2H_2-air is 4.6 ft/s.