JQ.2.13.setup

September 15, 2014

2.13 (a)Write the balanced chemical equation for stocihiometric combustion of benzene (C_6H_6). Assume complete combustion. Calculate the mass of air required to burn a unit mass of combustible.

You know at this point how to use an element balance to solve this problem.

$$C_6H_6 + a(O_2 + 3.76N_2) \rightarrow bCO_2 + dH_2O + 3.76aN_2$$

b) For a benzene air equivalence ratio of 0.75, write the balanced chemical equaton and calculate the adiabatic flame temperature in air. The initial temperature is 298K and pressure is 1 atm. Assume complete combustion.

Use the definition of the equivalence ratio $\phi = (F/A)/(F/A)_{ST}$ where the (F/A) is the mass of fuel to mass of air at the $\phi = 0.75$ condition. You know the moles of each component species and can easily calculate the molecular weights of the components.

The adiabatic flame temperature is calculated using equation 2.26 with $Q = 0$:

$$-Q = \nu_F \Delta\tilde{h}_c + \sum_i n_i \tilde{c}_{p,i}(T_R - 25) - \sum_j n_j \tilde{c}_{p,j}(T_P - 25)$$

There is an equivalent statement that can be developed using the mass basis.

$$-Q = m_F \Delta h_c + \sum_i m_i c_{p,i}(T_R - 25) - \sum_j m_j c_{p,j}(T_P - 25)$$

This mass form is particularly useful for a case in which the reactants are already at 25^oC since the sum on the reactant enthalpies is then zero. Next we can define a mass averaged specific heat capacity as:

$$m_T\bar{c} = \sum m_i c_i$$

$$0 = m_F \Delta h_c - m_T\bar{c}(T_P - 25)$$

$$T_P = 25 + \frac{m_F}{m_T}\frac{\Delta h_c}{\bar{c}} = 25 + Y_F\frac{\Delta h_c}{\bar{c}}$$

(c) calculate the mole fraction for each product of combustion in part (b). W

We use the simple definition of mole fraction $X_i = \frac{n_i}{n_T}$.

(d) Benze often burns incompletely. If 20% of the carbon in the benzene is converted to solid carbon and 5% is being converted to CO during combustion, the remainder being converted to CO_2, calcuate the heat released per gram of oxygen consumed. How does this compare with the value in Table 2.3.

We need to revise our model for the consumption of C_6H_6.

$$C_6H_6 + a(O_2 + 3.76N_2) \rightarrow bCO_2 + dH_2O + eC + fCO + 3.76aN_2$$

Note that we must include the solid carbon and CO given by the problem statement. We are told that 20% of carbon in benzene is solid and 5% is converted to CO. Of the 6C in benzene, 0.2 is in C and 0.05 is in CO. Use these in the element balance.

$$C_6H_6 + a(O_2 + 3.76N_2) \rightarrow bCO_2 + dH_2O + eC + fCO + 3.76aN_2$$

We can calculate the heat released per gram of fuel and also per gram of oxygen using heat of formation data.