

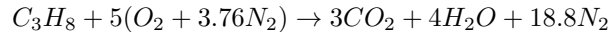
## JQ.3.6.Soln

October 6, 2014

(3.6)  $C_3H_8$  is burned with 10 times the stoichiometric air in a steady flow process. the reaction is complete, forming  $CO_2$  and  $H_2O$ . The fuel and air are mixed at  $400^\circ C$  before entering the combustor. The combustor is adiabatic. Specific heats are all constant,  $c_p = 1J/(gK)$ .

- (a) Calculate the stoichiometric air to fuel mass ratio.
- (b) Calculate the stoichiometric oxygen to fuel mass ratio.
- (c) If the flow rate of the  $C_3H_8$  is 10 g/s, calculate the exit flow rate.
- (d) Calculate the oxygen mass fraction at the exit.
- (e) Calculate the  $C_3H_8$  mass fraction at the inlet.
- (f) Calculate the exit temperature.
- (g) Calculate the enthalpy per unit mass for the  $H_2O(g)$  in the exit stream (with respect to the  $25^\circ C$  reference state).

Setup: With the exception of part (g), this problem is a continuation of previous problems and should not pose any particular conceptual challenges. Part (g) is not clear and I don't want you to do it.



a) The AF is  $\frac{5 \times 4.76 \times 28.8}{44}$ .

In [70]: AF\_STOICH=(5\*4.76\*28.8)/44; AF\_STOICH

Out[70]: 15.578181818181816

In [77]: 1/AF\_STOICH

Out[77]: 0.06419234360410832

The stoichiometric Air to Fuel ratio is 15.6.

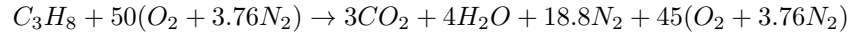
(b) The stoichiometric oxygen to fuel ratio is found from  $\frac{5 \times 1 \times 32}{44}$

In [71]: OF\_STOICH=(5\*1.\*32.)/44; OF\_STOICH

Out[71]: 3.6363636363636362

The stoichiometric oxygen to fuel ratio is 3.64.

(c) If the  $C_3H_8$  flow rate is 10 g/s, the exit flow rate is found by considering the reaction with  $10 \times$  stoichiometric air:



The air to fuel ratio for this case is 156. The flow rate of air would be  $156 \times 10g/s$ .

In [72]: `mdot_F= 10.; mdot_air=10.*AF_STOICH*mdot_F; mdot_total=mdot_air+mdot_F; mdot_total`

Out[72]: 1567.8181818181815

The total exhaust mass flow rate is  $1567g/s$

(d) The oxygen mass fraction at the exit is  $\frac{45 \times 32}{44 + 50 \times 4.76 \times 28.8}$

In [73]: `Y_O2= 45.*32./(44.+50.*4.76*28.8); Y_O2`

Out[73]: 0.2087440565928331

(e) The mass fraction of fuel in the inlet is found from  $\frac{m_F}{m_F + m_A} = \frac{1}{1 + A/F}$

In [74]: `Y_F = 1./(1.+157.); Y_F`

Out[74]: 0.006329113924050633

f) Assume that the reactants are at  $25^\circ C$ .

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

In [75]: `Dhc_mass_F= 46.; c_mix=29.1/28.`

In [76]: `T_P=400. + Y_F*Dhc_mass_F*1000./c_mix ; T_P`

Out[76]: 680.1339771194919

We find that the product temperature is  $53^\circ C$ . This is not the flame temperature. It is the temperature of the product gases (including excess air) after mixing the reaction generated hot gases with the cold excess air.