JQ.3.6.Soln

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(3.6) C_3H_8 is burned with 10 times the stocihiometric air in a steady flow process. the reaction is complete, forming CO_2 and H_2O. The fuel and air are mixed at 400^oC 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^oC 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.

$$C_3H_8 + 5(O_2 + 3.76N_2) \rightarrow 3CO_2 + 4H_2O + 18.8N_2$$

a) The AF is $\frac{5\times4.76\times28.8}{44}$.

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 $\frac{5\times1\times32}{44}$

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× stoichiometric air:

$$C_3H_8 + 50(O_2 + 3.76N_2) \rightarrow 3CO_2 + 4H_2O + 18.8N_2 + 45(O_2 + 3.76N_2)$$

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^oC.

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

```
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^oC. 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.