PROBLEM 13.17

KNOWN: C_8H_{18} burns completely with 120% of theoretical air.

FIND: Determine (a) the air-fuel ratio on a molar and mass basis. (b) the dew point temperature at 1atm.

ENGINEERING MODEL: 3.76 kmol of N_2 accompany each kmol of O_2 in the combustion air. N_2 is inert.

ANALYSIS: (a) For complete combustion with the theoretical amount of air

$$C_8H_{18} + \alpha(O_2 + 3.76N_2) \rightarrow \beta CO_2 + \gamma H_2O + 3.76\alpha N_2$$

C: $8 = \beta$ O: $2\alpha = 2(8) + 9$, $\alpha = 12.5$

H: $18 = 2\gamma$, $\gamma = 9$

Then, complete combustion with 120 % of the theoretical amount of air

$$C_8H_{18} + (1.2)(12.5)[O_2 + 3.76N_2] \rightarrow 8CO_2 + 9H_2O + \delta O_2 + \underbrace{(1.2)(12.5)(3.76)}_{56.4}N_2$$

O: $2(1.2)(12.5) = 16 + 9 + 2\delta$, $\delta = 2.5$

Accordingly,

$$\overline{AF} = \frac{(1.2)(12.5)(4.76)}{1} = 71.4 \ \frac{\text{kmol(air)}}{\text{kmol(fuel)}}$$ (a)

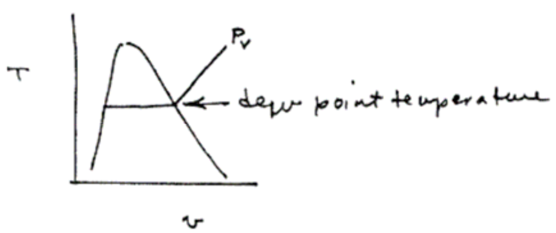
$$AF = \overline{AF}\left(\frac{M_{air}}{M_{fuel}}\right) = \frac{(71.4)(28.97)}{\underbrace{(8)(12.01) + 18(1.009)}_{114.152}} = 18.12 \ \frac{\text{kg(air)}}{\text{kg(fuel)}}$$

(b) The partial pressure of the water in the combustion products is $p_v = y_v p$, where

$$y_v = \frac{9}{8 + 9 + 2.5 + 56.4} = \frac{9}{75.9} = 0.1186$$

So

$$p_v = (0.1186)(1.01325 \text{ bar}) = 0.12015 \text{ bar}$$



Then, from Table A-2

$$T_{dew\,pt} \approx 49.4\ °C$$ (b)

PROBLEM 13.28

KNOWN: Carbon burns with 80% theoretical air yielding CO_2, CO, and N_2 only.

FIND: Determine (a) the balanced reaction equation, (b) AF, (c) the analysis of the products on a molar basis.

ENGINEERING MODEL: 3.76 moles of N_2 accompany each mole of O_2 in the air, and N_2 is inert.

ANALYSIS: (a) Complete combustion of C with the theoretical amount of air is described by

$$C + (O_2 + 3.76 N_2) \rightarrow CO_2 + 3.76 N_2$$

Thus, combustion with 80% theoretical air to produce CO_2, CO, and N_2 is

$$C + 0.80(O_2 + 3.76 N_2) \rightarrow a\, CO_2 + b\, CO + (0.80)(3.76) N_2$$

C: $\quad 1 = a + b \Rightarrow b = 1 - a$

O $\quad (.80)(2) = 2a + b \Rightarrow 1.6 = 2a + (1-a) \Rightarrow a = 0.6,\ b = 0.4$

Accordingly, the balanced reaction equation is

$$C + 0.80(O_2 + 3.76 N_2) \rightarrow 0.6 CO_2 + 0.4 CO + 3.008\ N_2 \longleftarrow (a)$$

(b) The air fuel ratio is

$$\overline{AF} = 0.80(4.76)/1 = 3.808 \text{ kmol (air)/kmol (fuel)}$$

Then with Eq. 13-2

$$AF = \overline{AF}\left(\frac{M_{air}}{M_{fuel}}\right) = (3.808)\left(\frac{28.97}{12.01}\right) = 9.19 \frac{\text{kg (air)}}{\text{kg (fuel)}} \longleftarrow (b)$$

(c) The molar analysis of the products is

$$\% CO_2 = \left(\frac{0.6}{4.008}\right)(100) = 15\%,\ \% CO = \frac{0.4}{4.008} = 10\%,\ \% N_2 = 75\% \longleftarrow (c)$$

PROBLEM 13.30

KNOWN: C_6H_{14} burns with dry air. The dry molar analysis of the products is given.

FIND: Determine (a) the balanced reaction equation, (2) the percent theoretical air, (c) the dew point temperature of the products at 1 atm.

ENGINEERING MODEL: (1) 3.76 moles of N_2 accompany each mole of O_2 in the air. (2) The N_2 is inert. (3) The combustion products are modeled as an ideal gas mixture.

ANALYSIS: (a) Balancing the reaction equation for 1 kmol of hexane

$$C_6H_{14} + \alpha(O_2 + 3.76\,N_2) \rightarrow \beta(0.085\,CO_2 + 0.052\,CO + 0.03\,O_2 + 0.833\,N_2) + \gamma H_2O$$

C: $6 = \beta(0.085 + 0.052) \Rightarrow \beta = 43.796$

H_2: $\frac{14}{2} = \gamma \Rightarrow \gamma = 7$

① N_2: $\alpha(3.76) = \beta(0.833) \Rightarrow \alpha = 9.703$

Thus

$$C_6H_{14} + 9.703(O_2 + 3.76N_2) \rightarrow 3.723\,CO_2 + 2.277\,CO + 1.314\,O_2 + 36.482\,N_2 + 7H_2O$$ ← balanced equation

(b) Theoretical combustion: $C_6H_{14} + \alpha_{th} O_2 \rightarrow 6CO_2 + 7H_2O \Rightarrow \alpha_{th} = 9.5$

$$\%\ \text{theoretical air} = \left(\frac{\alpha}{\alpha_{th}}\right) \times 100 = (9.703/9.5) \times 100 = 102.1\,\%$$ ← % theo. air

(c) Considering the combustion products, the total number of moles is 50.796 kmol. The fraction of water vapor is

$$y_v = \frac{7}{50.796} = 0.1378 \Rightarrow p_v = (0.1378)(1.01325\ \text{bar}) = 0.1396\ \text{bar}$$

From data in Table A-3; $T_{\text{dew point}} \approx 52.4°C$ ← T_{DP}

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1. Alternatively, for O_2: $\alpha = \beta(0.085 + 0.052/2 + 0.03) + \gamma/2$

$$\Rightarrow \alpha = 9.675$$

The difference between this number and the value calculated above is experimental error and round-off.