Name: ____________________

Date: ____________

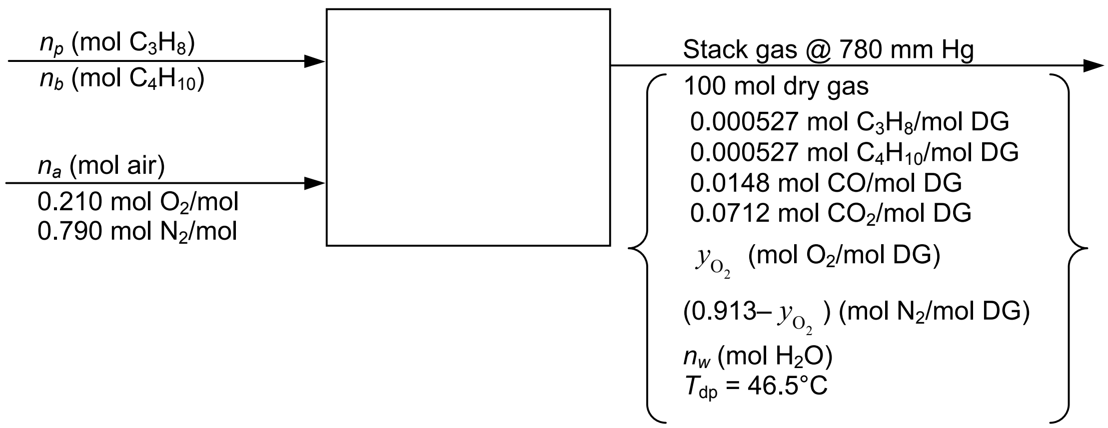
PROBLEM 6.39

A mixture of propane and butane is burned with air. Partial analysis of the stack gas produces the following dry-basis volume percentages: 0.0527% C_3H_8, 0.0527% C_4H_{10}, 1.48% CO, and 7.12% CO_2. The stack gas is at an absolute pressure of 780 mm Hg and the dew point of the gas is 46.5°C. Calculate the molar composition of the fuel.

Solution

Basis 100 mol dry stack gas

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O \qquad C_4H_{10} + \frac{13}{2}O_2 \rightarrow 4CO_2 + 5H_2O$$



Notice that oxygen and nitrogen must be present in the stack gas even though the problem statement does not mention them, and so they are shown on the flowchart. We will base the degree-of-freedom analysis on atomic species balances.

(6.39-1)

DEGREE-OF-FREEDOM ANALYSIS		
UNKNOWNS AND INFORMATION		**JUSTIFICATION/CONCLUSION**
+ __ unknowns	________________	
– __ atomic species balances	________________	Reactive substances
– __ molecular species balance	________________	Nonreactive substances
– 1 ______________________		
0 DOF		Problem is solvable

Strategy

- Pure butane at 1 atm condenses at –0.6°C (from Table B.1) and pure propane condenses at an even lower temperature. Clearly, the only substance in the stack gas that would condense at 46.5°C and 1 atm (or close to it) is water. We will therefore treat water as the only condensable substance in the stack gas and apply Raoult's law for the definition of the dew point (Eq. 6.3-3) to obtain a value for the mole fraction of water in the stack gas. Since the mole fraction is (by definition) $n_w/(100+n_w)$, we will then be able to calculate n_w.
- Mole balances on carbon and hydrogen will yield the values of n_p and n_b, and once we know them we can calculate the molar composition of the fuel. Since that's all the problem asks for, we can stop right there rather than proceeding to the remaining balances.