Department of Chemical Engineering
Thapar Institute of Engineering & Technology, Patiala

Course: Material and Energy Balances UCH301

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Exercise (Combustion)

Ethane (C_2H_6) is burned with 50% excess air. The percentage conversion of ethane is 90%. 25% of the ethane burned forms CO and balance forms CO_2. Calculate (a) the molar composition of the stack gas on dry basis and (b) the mol ratio of water to dry stack gas.

Solution

- Theoretical air requirement is calculated on the basis of complete combustion.
- Basis: 100 mol C_2H_6

$$C_2H_6 + 7/2\ O_2 \rightarrow 2CO_2 + 3H_2O$$

$$C_2H_6 + 5/2\ O_2 \rightarrow 2CO + 3H_2O$$

- **Moles of O_2 required = 100*3.5 = 350 mol**
- O_2 supplied =350*1.5=525 mol
- Air supplied =525/0.21 =2500 mol
- N_2 in air = 2500*0.79=1975 mol
- Moles of C_2H_6 at outlet = 100-90 =10= n1
- Moles of CO formed = n4 = (90*0.25)* 2= 45 mol
- Moles of N_2 at outlet =n3=1975

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$$C_2H_6 + 5/2\ O_2 \rightarrow 2CO + 3H_2O$$

- H_2O formed = 90*3 = 270 mol
- Moles of O_2 exiting = In - consumed

  525-90*0.75*3.5-90*0.25*2.5 = 232 mol

  O_2 out =n2= 232 mol

  Moles of CO_2 exiting =n5

  = 90*0.75*2 = 135 mol

  Moles of H_2O exiting = n6= 90*3=270 mol

$$C_2H_6 + 7/2\ O_2 \rightarrow 2CO_2 + 3H_2O$$
$$C_2H_6 + 5/2\ O_2 \rightarrow 2CO + 3H_2O$$

- Composition on dry basis:

C_2H_6 = (10/2397)*100=0.4%;

O_2 = (232/2397)*100= 9.7%;

N_2 = (1975/2397)*100=82.4%

CO= (45/2397)*100=1.9%;

CO_2 = (135/2397)*100 =5.6%

- Water to dry gas ratio = 270/2397 =0.113

Solving this problem using elemental species balances

Elemental C balance: C input = C output

$$100 * 2 = 2n1 + n4 + n5$$

(since, mol CO_2 = 3 * mol CO, given)

$$200 = 2*10 + n4 + 3n4$$

$n4 = 45$ mol

$n5 = 3*45 = 135$ mol

$$C_2H_6 + 7/2\ O_2 \rightarrow 2CO_2 + 3H_2O$$

$$C_2H_6 + 5/2\ O_2 \rightarrow 2CO + 3H_2O$$

Elemental H balance: H input = H output

$$100*6 = 6n1 + 2n6$$

$n6 = 270$ mol

Elemental O balance: O input = O output

$$350*1.5*2 = 2n2 + n4 + 2n5 + n6$$

$n2 = 232$ mol

n3 = N_2 out = (350/0.21)*1.5*0.79 = 1975 mol

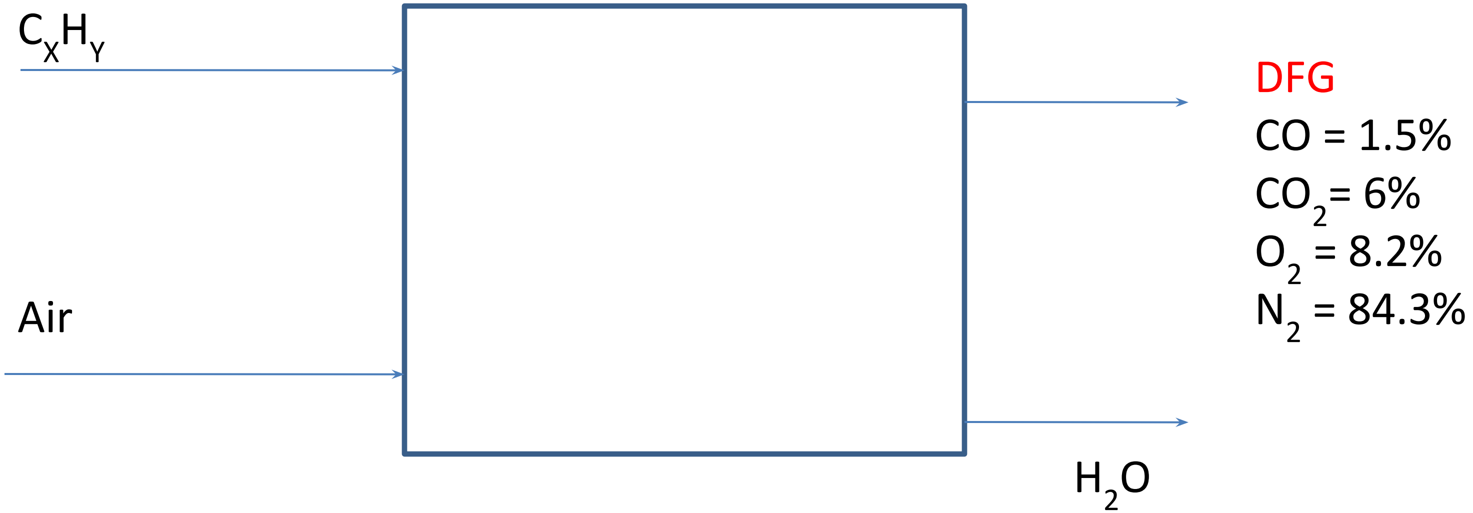
Problem

- A hydrocarbon gas is burned with air. The dry-basis composition of the product gas is :

1.5 % CO; 6% CO_2; 8.2% O_2; and 84.3%N_2

Calculate the ratio of hydrogen to carbon in the fuel.

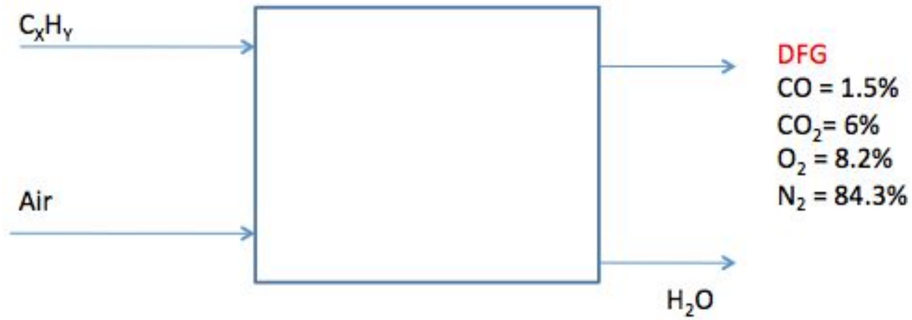
Solution



- Basis: 100 mol of dry flue gas

  Let X= mol of C entering with fuel

  Y= mol of H entering with fuel



N_2 balance:

0.79*mol of air = 100*(0.843)

mol of air = 106.7 mol

C balance:

$X = 100 * x_{CO,DFG} + 100 * x_{CO2,DFG}$

X = 7.5 mol

O balance:

$0.21*\text{Mol Air}*2 = \text{mol of water} + 100*x_{CO,DFG} + 100*x_{CO2,DFG}*2 + 100*x_{O2,DFG}*2$

$0.21*106.7*2 = \text{mol of water}+100*0.015+100*0.06*2+100*0.082*2$

mol of water = 14.9 mol

H balance:

y = mol of water*2 → y = 14.9*2 = 29.8

y/x = 29.8/7.5 = 3.97≈ 4 (H/C ratio)