

## JQ.3.2.Soln

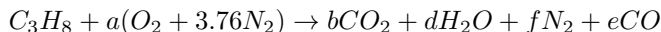
October 6, 2014

(3.2) Propane and air are supplied to a combustion chamber so that 20 g/s of propane reacts. the reaction forms  $H_2O$ ,  $CO_2$ ,  $H_2$  and  $CO$  where the molar ratio of  $H_2$  to  $CO_2$  is 0.1. The exhaust gases flow at a rate of 360 g/s. Assuming the process is steady and conditions are uniform at the exit, compute the exit mass fraction of the  $CO$ .

Setup:

First sketch a three port reactor with fuel and air inlets and a product outlet. Recognize that the three port system also represents a chemical reaction. The fuel flow rate is greater than or equal to 20 g/s.

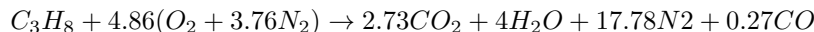
Balance the stoichiometric case using the constraint relationship between  $CO_2$  and  $CO$ .



$$C : 3 = b + e; H : 8 = 2d; O : 2a = 2b + d + e; e = 0.1 \times b; f = 3.76 \times a$$

In [46]: `b=3./1.1; d=8./2.; e=0.1*b; a=(2.*b+d+e)/2.; f=3.76*a; a`

Out[46]: 4.863636363636363



For the stoichiometric case, we calculate how much air will be required to consume 20 g/s of propane. The mass of air per mass of fuel is  $4.73 \times 4.76 \times 28.8$  grams of air per 44 grams of fuel.

In [47]: `AF=a*4.76*28.8/44.; AF`

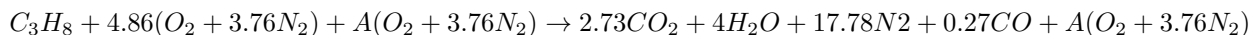
Out[47]: 15.153322314049586

The Air to Fuel ratio is 15.15. The mass of air required for 20 g/s of fuel is  $15.15 \times 20$ .

In [48]: `AF*20.`

Out[48]: 303.0664462809917

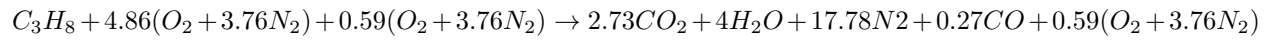
The mass flow rate of stoichiometric air is 295 g/s. The total flow rate of fuel and stoichiometric air is  $303 + 20 = 323$  g/s. An additional 37 g/s of either fuel or air must have been available to the reactor. Because one of the products is  $CO$ , we might assume that reaction was actually fuel rich. The answer would not change if we assumed that the additional 37 g/s had been air.



We find A by assuming that the air flow rate must be 340 g/s. The additional 37 g/s will come from the excess air.  $340 = AF_{LN} \times 20$ .

In [49]: `AF_LN=340./20.; M_AIR=AF_LN*44.; M_AIR_EXCESS= M_AIR-a*4.76*28.8; M_coeff_AIR_EXCESS=M_AIR_EXCESS/44.`

Out[49]: 0.5927128427128432



For every mole of fuel we produce 0.27 mole of CO. The mass ratio of product CO to fuel burned is  $\frac{0.27 \times 28}{44}$ . The mass flow rate of CO is  $\frac{20 \times 0.27 \times 28}{44}$

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In [52]: mdot_CO=20.*0.27*28./44.; Y_CO=mdot_CO/360.; Y_CO
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Out[52]: 0.009545454545454548
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We find that the CO mass fraction in the product gases is 0.01.