

Example

Acetylene ( $C_2H_2$ ) at a fuel flow rate of 1 kg/min is burned with dry air with an air fuel ratio of 17:1. Assuming **complete combustion** and a total pressure of 110 kPa, find

- the percent excess air used,
- the **equivalence ratio**,
- the percentage of  $CO_2$  in the products by volume,
- the dew point temperature of the products in  $^{\circ}C$ ,
- the percentage of water vapor condensed if the products are cooled to  $20^{\circ}C$ , and
- the required volume flow rate of dry air if it is supplied at  $22^{\circ}C$  and 110 kPa.
- If the actual air supplied has a humidity ratio of 16 g  $H_2O$  per kg of dry air, find the dew point temperature of the products.

(2) COMPARE TO STOICH:

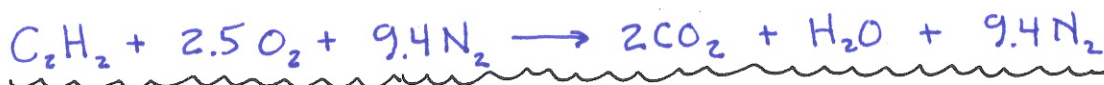


$$C: 2 = b \quad b = 2$$

$$H: 2 = 2c \quad c = 1$$

$$O: 2a = 2b + c \quad 2a = 2 \cdot 2 + 1 \quad a = 2.5$$

$$N: (3.76)a = d \quad d = 3.76(a) = 3.76(2.5) \\ d = 9.4$$



↑ THEORETICAL RXN

$$AF_{ACT} = 17 = \frac{m_{AIR}}{m_{fuel}} = \frac{n_{AIR} M_{AIR}}{n_f M_{fuel}} = \frac{n_a}{n_f} \frac{29 \text{ kg/kmol}}{26.04 \text{ kg/kmol}} \Rightarrow$$

$$(n_a/n_f) = 15.26$$

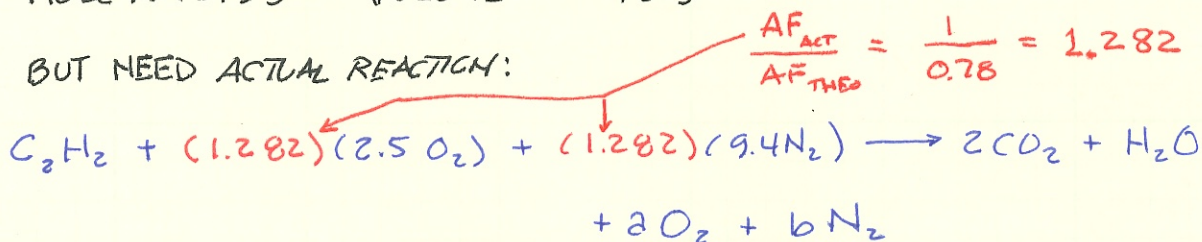
$$(n_a/n_{f,theo.}) = 2.5 \overbrace{(O_2 + 3.76 N_2)}^{4.76 \text{ mol air}} = 11.9$$

$$\therefore \% \text{ EXCESS} = \frac{15.26 - 11.9}{11.9} * 100 = \boxed{28.2\%}$$

$$(b) \phi = \frac{FA_{ACT}}{FA_{THEO}} = \frac{1/17}{\frac{n_f M_f}{n_a M_a}} = \frac{1/17}{\frac{1 \cdot 26.04}{11.9 \cdot 29}} = \boxed{0.78}$$

(c) MOLE ANALYSIS  $\rightarrow$  VOLUME ANALYSIS

BUT NEED ACTUAL REACTION:



$$O_2: (1.282)(2.5)(2) = (2)(2) + 1 + 2a$$

$$a = 0.705$$

$$N: (1.282)(9.4)(2) = 2b \quad b = 12.05$$

BALANCED ACTUAL RXN:



$$\% CO_{PRDT} = \frac{2}{2+1+12.05+0.705} \times 100 = \boxed{12.7\%}$$

$$(d) T_{DEW} = T_{SAT}(P_v)$$

$$P_v = y_v P \quad y_v = \frac{1}{2+1+12.05+0.705} = \underline{0.0635}$$

$$P_v = (0.0635)(110 \text{ kPa}) = 6.98 \text{ kPa}$$

$$T_{DEW} = T_{SAT}(6.98 \text{ kPa}) = \boxed{38.8^\circ C}$$

COULD YOU HAVE USED PSYCH. CHART? NO!  $P_{TOTAL} \neq 101.325 \text{ kPa}$ !

(e)  $20^\circ C < T_{DEW} \Rightarrow$  WATER WILL CONDENSE.

$$\rightarrow \text{PRDTS ARE SATURATED} \Rightarrow P_{v, PRDTS} = P_{SAT}(20^\circ C) = 2.339 \text{ kPa}$$

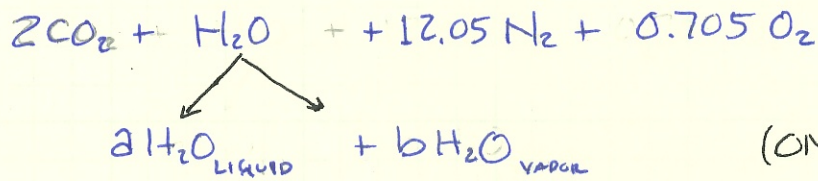
$$y_v P = P_v \Rightarrow y_v = \frac{P_v}{P}$$

$$= \frac{2.339 \text{ kPa}}{110 \text{ kPa}} = 0.02126$$



$$\% \text{ CONDENSE} = \frac{N_{\text{H}_2\text{O, LIQUID}}}{N_{\text{H}_2\text{O, TOTAL}}} = \frac{N_{\text{H}_2\text{O, LIQUID}}}{N_{\text{H}_2\text{O, VAP}} + N_{\text{H}_2\text{O, LIQUID}}} \times 100\%$$

LOOK @ PRDTS:

(ONLY VAPOR of H<sub>2</sub>OCONTRIBUTES TO y<sub>v</sub>.)

$$y_v = \frac{b}{2 + b + 12.05 + 0.705}$$

$$= 0.02126 \quad \Rightarrow \quad b = 0.321$$

$$\therefore a = 1 - b = 0.679 \quad \% \text{ COND} = \frac{0.679}{1} \times 100\% = \boxed{67.9\%}$$

(f)

$$\dot{V} = \dot{m}_{\text{air}} v_a$$

$$\dot{m}_{\text{air}} = (\text{AF}) \dot{m}_{\text{fuel}}$$

$$= (17)(1 \text{ kg/s}) = 17 \text{ kg/s min}$$

$$v_a = \frac{R_a T}{P_a}$$

$$= \frac{(0.287 \text{ kJ/kg}\cdot\text{K})(22+273)\text{K}}{110 \text{ kPa}} = \underline{0.770 \text{ m}^3/\text{kg}}$$

$$\dot{V} = \left( \frac{17 \text{ kg}}{\text{min}} \right) (0.770 \text{ m}^3/\text{kg}) = \boxed{13.1 \text{ m}^3/\text{min}}$$

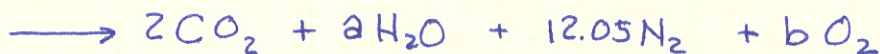
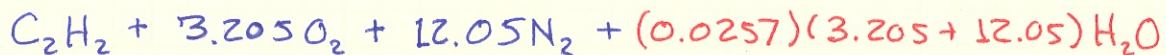
(g) NEED A NEW RXN! AGAIN!

$$\omega_{\text{RXT}} = 0.0016 \frac{\text{kg}_v}{\text{kg}_{\text{air}}} = \frac{m_{\text{H}_2\text{O}}}{m_{\text{AIR}}} = \frac{N_{\text{H}_2\text{O}} M_{\text{H}_2\text{O}}}{N_{\text{AIR}} M_{\text{AIR}}} = 0.622 \frac{N_{\text{H}_2\text{O}}}{N_{\text{AIR}}}$$

LOOK FAMILIAR?

$$\therefore N_{\text{H}_2\text{O, RXT}} = \frac{(0.0016)}{(0.622)} N_{\text{AIR}} = 0.0257 N_{\text{AIR}}$$

NEW RXN:



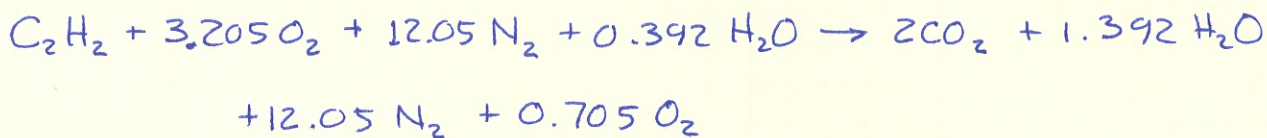
$$H: (0.0257)(3.205 + 12.05)(2) = (a)(2)$$

$$a = 1.392$$

$$O: 3.205(2) + (0.0257)(3.205 + 12.05) = (2)(2) + a + b(2)$$

$$\dots b = 0.705 \leftarrow \text{UNCHANGED. WHY?}$$

BALANCED RXN:



$$y_{Y, \text{PROT}} = \frac{1.392}{2 + 1.392 + 12.05 + 0.705} = 0.0862$$

$$P_{v, \text{PROT}} = y_{v, \text{PROT}} P = (0.0862)(110 \text{ kPa}) = 9.483 \text{ kPa}$$

$$T_{\text{DEW}} = T_{\text{SAT}}(9.483 \text{ kPa}) = \boxed{44.7^\circ \text{C}}$$