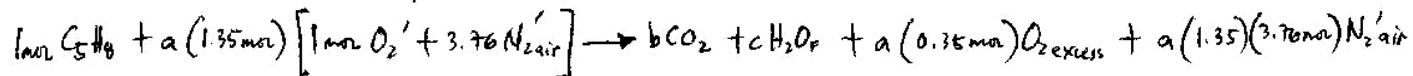


Answer Key

Ideal Gas Mixtures, Fuels and
Combustion, Chimney and Machine
Foundation

Fuel: C_5H_8 ; $e = 35\%$
 $M_F = 0.20 \text{ kg}$

Find: mass of air required:



for Carbon:

$$(1)(5) = b(1) \\ b = 5$$

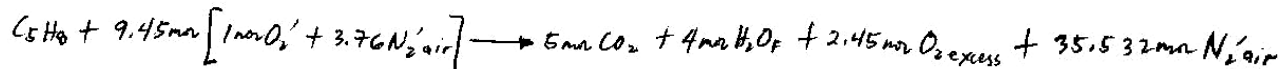
for Hydrogen:

$$(1)(8) = c(2) \\ c = 4$$

for Oxygen:

$$a(1.35)(1)(2) = b(2) + c(1) + a(0.35)(2) \\ a = 7$$

Balanced chemical equation:



the actual air-fuel ratio

$$A:F' = \frac{m_a'}{m_F} ; m_a' = [(9.45)(16)(2) + (9.45)(3.76)(14)(2)] \text{ mol} = 1297.296 \text{ kg}_a'$$

$$m_F = [(1)(12)(5) + (1)(1)(8)] \text{ mol} = 68 \text{ kg}_F$$

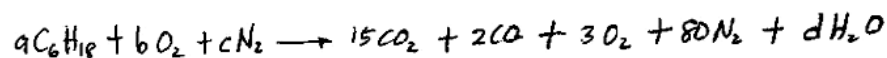
Subst:

$$A:F' = \frac{1297.296 \text{ kg}_a'}{68 \text{ kg}_F} = 19.0779 \frac{\text{kg}_a'}{\text{kg}_F}$$

the mass of air required:

$$m_a' = \left(19.0779 \frac{\text{kg}_a'}{\text{kg}_F} \right) (0.20 \text{ kg})$$

$$m_a' = 3.8156 \text{ kg}_a$$



for Carbon

$$a(6) = (15)(1) + 2(1)$$

$$a = 2.833$$

for Hydrogen;

$$a(18) = d(2)$$

$$d = 25.497$$

for Nitrogen;

$$c(2) = 80(2)$$

$$c = 80$$

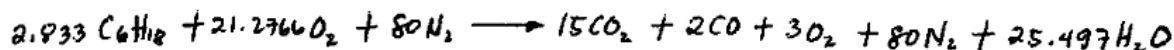
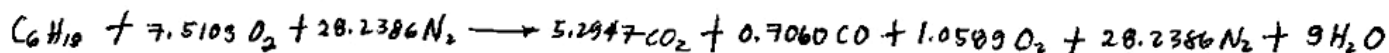
for Nitrogen - Oxygen ratio

$$\frac{c}{b} = 3.76$$

$$\frac{80}{b} = 3.76$$

$$b = 21.2766$$

BALANCED MOLECULAR EQUATION

OR

ACTUAL AIR-FUEL RATIO:

$$A:F' = \frac{m_a'}{m_F} ; m_a' = [(7.5103)(16)(2) + (28.2386)(14)(2)] kg = 1031.0104 kg_a'$$

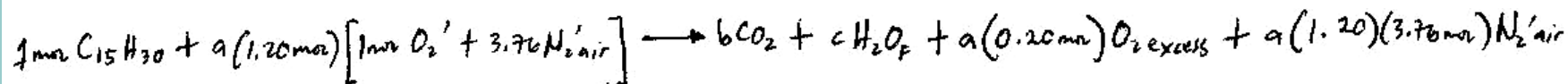
$$m_F = [(1)(12)(6) + (1)(1)(18)] kg_F = 90 kg_F$$

$$A:F' = \frac{1031.0104 kg_a'}{90 kg_F}$$

$$A:F' = 11.4557 kg_a'/kg_F$$

$C_{15}H_{30}$ with 20% excess air

Find: molar air-fuel ratio



For Carbon:

$$(1)(15) = b(2)$$

$$b = 7.5$$

For Hydrogen;

$$(1)(30) = c(2)$$

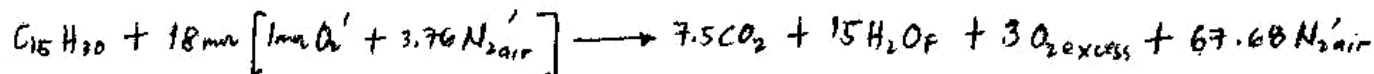
$$c = 15$$

For oxygen:

$$a(1.20)(2) = b(2) + c(1) + a(0.20)(2)$$

$$a = 15$$

Balanced molar equation:



Hence;

$$A:F = \frac{n_{a'}}{n_F} = \frac{[18 + (18)(3.76)] \text{ mol } a'}{1 \text{ mol } F'}$$

$$A:F = 85.68 \frac{\text{mola}'}{\text{mol}_F}$$

$$A:F = 11.5 \left(\% G_{Cp} \right) + 34.5 \left[\% G_{H_2F} - \frac{\% G_{O_2F}}{8} \right] + 4.3 \left(\% G_{SF} \right)$$

$$A:F = 11.5 (0.685) + 34.5 \left[0.03 - \frac{0.04}{8} \right] + 4.3 (0.08)$$

$$A:F = 9.084 \frac{kg_a}{kg_F}$$

for actual Air-fuel ratio w/ 30% excess air

$$A:F' = A:F (1 + e)$$

$$A:F' = \left(9.084 \frac{kg_a}{kg_F} \right) (1 + 0.30)$$

$$A:F = 11.8092 \frac{kg_a'}{kg_F}$$

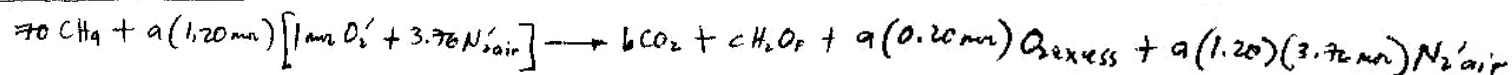
$$HHV = 14600(\%G_{cf}) + 62000 \left[\%G_{H,F} - \frac{\%G_{a,F}}{8} \right] + 4050(\%G_{s,F})$$

$$HHV = 14600(0.72) + 62000 \left[0.03 - \frac{0.035}{8} \right] + 4050(0.065)$$

$$HHV = 12364 \text{ Btu/lb}_F$$

PARTIAL pressure of water vapour

$$P_{H_2O} = \left(\frac{n_{H_2O}}{n_T} \right) P_T$$



for Carbon:

$$(70)(1) = b(1)$$

$$b = 70$$

For Hydrogen

$$(70)(4) = c(2)$$

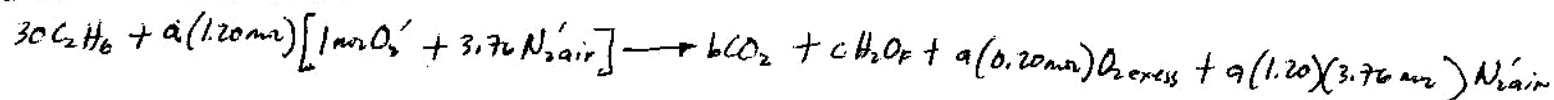
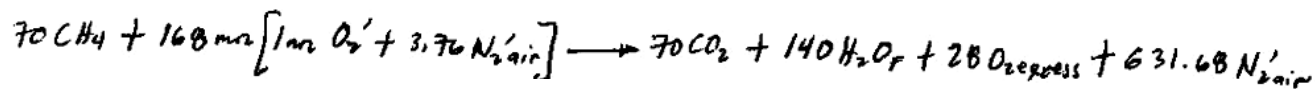
$$c = 140$$

for Oxygen;

$$a(1.20)(2) = b(2) + c(1) + a(0.20)(2)$$

$$a = 140$$

Balanced total equation



For Carbon:

$$(30)(2) = b(1)$$

$$b = 60$$

For Hydrogen

$$(30)(6) = c(2)$$

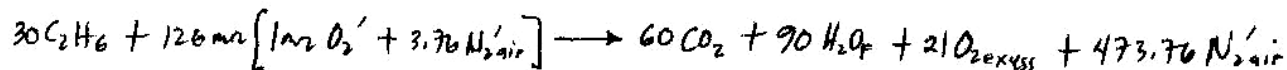
$$c = 90$$

For Oxygen:

$$a(1.20)(2) = b(2) + c(1) + a(0.20)(2)$$

$$a = 105$$

Balanced total equation:



6 (cont...)

For n_T of CH_4 & C_2H_6

$$n_T = [70 + 140 + 28 + 631.68] + [60 + 90 + 21 + 473.76]$$

$$n_T = 1514.44 \text{ mol}$$

For n_{H_2O} ;

$$n_{H_2O} = (140 + 90)$$

$$n_{H_2O} = 230 \text{ mol } H_2O$$

Hence;

$$P_{H_2O} = \left(\frac{n_{H_2O}}{n_T} \right) P_T = \left(\frac{230 \text{ mol } H_2O}{1514.44 \text{ mol}} \right) (100 \text{ kPa})$$

$$P_{H_2O} = 15.1871 \text{ kPa}$$

$$m_g = 20 \text{ kg}$$

$$m_F = 1 \text{ kg F}$$

$$\text{Fuel: } C_{12}H_{26}$$

$$m_a' + m_F = m_g$$

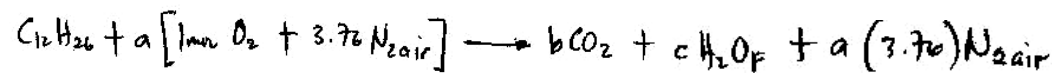
$$m_a' + 1 \text{ kg F} = 20 \text{ kg}$$

$$m_a' = 19 \text{ kg a'}$$

$$A:F' = \frac{26 \text{ kg a'}}{1 \text{ kg F}} = 19 \frac{\text{kg a'}}{\text{kg F}}$$

$$A:F' = A:F(1+e)$$

solving for the theoretical Air-fuel ratio



For Carbon;

$$(1)(12) = b(1)$$

$$b = 12$$

For Hydrogen;

$$(1)(26) = c(2)$$

$$c = 13$$

For oxygen;

$$a(2) = b(2) + c(1)$$

$$a = 18.5$$

For the mass of fuel

$$m_F = (1)(12)(12) + (1)(1)(26) = 170 \text{ kg F}$$

For the mass of air;

$$m_a = (18.5)(16)(2) + (18.5)(3.76)(14)(2) = 2539.68 \text{ kg a}$$

$$A:F = \frac{2539.68 \text{ kg a}}{170 \text{ kg F}} = 14.939 \frac{\text{kg a}}{\text{kg F}}$$

Hence;

$$A:F' = A:F(1+e)$$

$$19 \frac{\text{kg a'}}{\text{kg F}} = 14.939 \frac{\text{kg a}}{\text{kg F}} (1+e)$$

$$e = 27.18\%$$

By mass balance in the furnace

$$m_a + m_c = m_{\text{gas}} + m_{\text{ash}}$$

$$\left(\frac{18 \text{ kg}}{\text{kg coal}} \right) \left(2500 \frac{\text{kg coal}}{\text{hr}} \right) + \left(2500 \frac{\text{kg coal}}{\text{hr}} \right) = m_g + (0.12) \left(2500 \frac{\text{kg coal}}{\text{hr}} \right)$$

$$m_g = 47200 \frac{\text{kg}}{\text{hr}}$$

$$h_s = \frac{\gamma_w h_w}{\gamma_a - \gamma_g} = \frac{0.32 \text{ kPa}}{(1.18 - 0.80) \frac{\text{kg}}{\text{m}^3} \left(\frac{9.81 \text{ m/s}^2}{1000 \frac{\text{kg} \cdot \text{m}}{\text{N} \cdot \text{s}^2}} \right)}$$

$$h_s = 85.8415 \text{ m}$$

$$\dot{V}_g = \frac{m_g R_g T_g}{P} = \frac{\left(\frac{34000}{3600} \frac{\text{kg}}{\text{s}}\right) \left(0.208 \frac{\text{kJ}}{\text{kg-K}}\right) (28+273) \text{K}}{98 \text{ kPa}}$$

$$\dot{V}_g = 13.2686 \text{ m}^3/\text{s}$$

then;

$$\dot{V}_g = A v$$

$$13.2686 \text{ m}^3/\text{s} = \frac{\pi D^2}{4} (6 \text{ m/s})$$

$$D = 1.6780 \text{ m}$$

$$m_a + m_c = m_g + m_{ash}$$

$$(16.2 \text{ kg/kg coal})(3200 \text{ kg coal/hr}) + (3200 \text{ kg coal/hr}) = m_g + (0.10)(3200 \text{ kg coal/hr})$$

$$m_g = 54720 \text{ kg/hr}$$

$$\dot{V}_g = \frac{m_g R_g T_g}{P} \quad ; \quad P_g = \frac{\bar{P}}{MW} = \frac{8.314 \text{ kJ/kg-k}}{31 \text{ kg/kg}}$$

$$R_g = 0.2682 \text{ kJ/kg-k}$$

$$\dot{V}_g = \frac{\left(\frac{54720}{3600} \frac{\text{kg}}{\text{s}}\right) (0.2682 \text{ kJ/kg-k}) (290 + 273) \text{ K}}{98 \text{ kPa}}$$

$$\dot{V}_g = 23.4199 \text{ m}^3/\text{s}$$

then; $\dot{V}_g = A v$

$$23.4199 \text{ m}^3/\text{s} = \frac{\pi D^2}{4} (8.8 \text{ m/s})$$

$$D = 1.8408 \text{ m}$$

$$h_s = \frac{\rho_w h_w}{\rho_a - \rho_g} = \frac{\rho_w h_w}{\rho_a - \rho_g}$$

$$\rho_a = \frac{P}{RT} = \frac{100 \text{ kPa}}{(0.287 \text{ kJ/kg} \cdot \text{K})(28+273) \text{ K}} = 1.1576 \text{ kg/m}^3$$

$$\rho_g = \frac{P}{RT} = \frac{100 \text{ kPa}}{(0.280 \text{ kJ/kg} \cdot \text{K})(18+273) \text{ K}} = 0.7747 \text{ kg/m}^3$$

subst;

$$h_s = \frac{(1000 \text{ kg/m}^3)(0.232 \text{ m})}{(1.1576 - 0.7747) \text{ kg/m}^3}$$

$$h_s = 605.9023 \text{ m}$$

Gravimetric Analysis of Gas

CO ₂	20%	$0.20/44 = 0.004545$
O ₂	8%	$0.08/32 = 0.002188$
N ₂	72%	$0.72/28 = 0.02571$
		0.03244 mol/g

$$MW = \frac{m}{n} = \frac{1 \text{ kg}}{0.03244} = 30.8233 \text{ kg/kmol}$$

$$R = \frac{\bar{R}}{MW} = \frac{8.314 \text{ kJ/kg-K}}{30.8233 \text{ kg/kmol}} = 0.2697 \text{ kJ/kg-K}$$

and;

$$h_s = \frac{\gamma_w h_w}{\gamma_a - \gamma_o}$$

$$j \quad p_a = \frac{P}{RT} = \frac{95 \text{ kPa}}{(0.2697 \text{ kJ/kg-K})(23+273) \text{ K}}$$

$$p_a = 1.118 \text{ kg/m}^3$$

$$p_g = \frac{P}{RT}$$

$$t = \frac{t_1 + t_2}{2} = \frac{(198 + 162)^\circ\text{C}}{2} = 180^\circ\text{C}$$

$$p_g = \frac{95 \text{ kPa}}{(0.2697 \text{ kJ/kg-K})(180+273) \text{ K}}$$

$$p_g = 0.7776 \text{ kg/m}^3$$

Hence;

$$h_s = \frac{0.18 \text{ kPa}}{(1.118 - 0.7776) \frac{\text{kg}}{\text{m}^3} \left(\frac{9.81 \text{ m/s}^2}{1000 \frac{\text{kg}}{\text{m}^3 \cdot \text{s}^2}} \right)}$$

$$h_s = 53.9031 \text{ m}$$