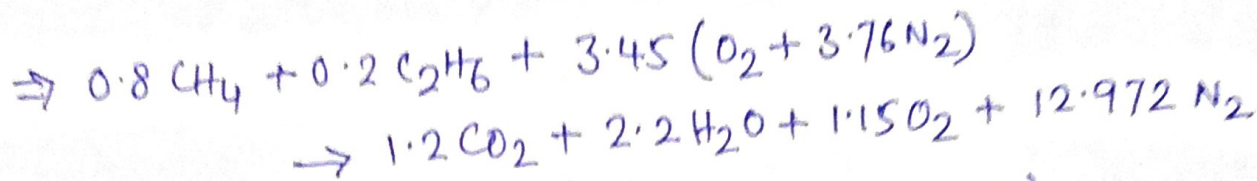
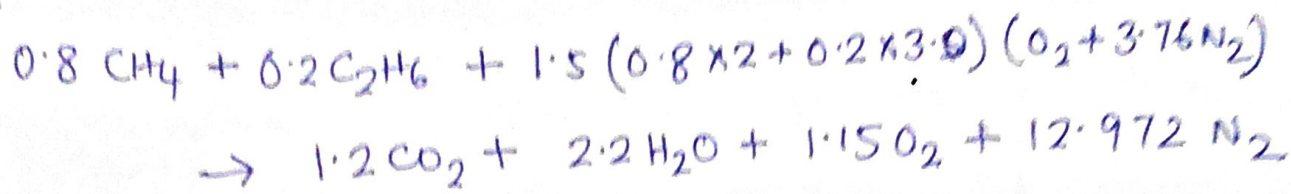


PL



$$H_{\text{reac}} = \sum_R n_i \bar{h}_i = 0.8 \times (-74850) + 0.2 \times (-84680) \\ + 3.45 \{0 + 3031\} + 12.972 \{0 + 2973\} \\ = -27793.3 \text{ kJ}$$

$$H_{\text{prod}} = \sum_P n_i \bar{h}_i = 1.2 \{-393520 + 22810\} + 2.2 \{-241820 + 18005\} \\ + 1.15 \{0 + 15838\} + 12.972 \{0 + 15046\} \\ = -723854.6 \text{ kJ}$$

$$H_{\text{reac}} + Q = H_{\text{prod}}$$

$$\Rightarrow Q = -723854.6 - (-27793.3) = -696061.3 \frac{\text{kJ}}{\text{kmol fuel}}$$

$$\Rightarrow Q = \frac{-696061.3}{\text{MW}_{\text{Fuel}}} \\ = -37624.5 \frac{\text{kJ}}{\text{kg fuel}}$$

$$\text{MW}_{\text{Fuel}} = 0.8 \times 16 + 0.2 \times 30 \\ = 18.8$$

b) Let n_v be the number of mole of water vapor.

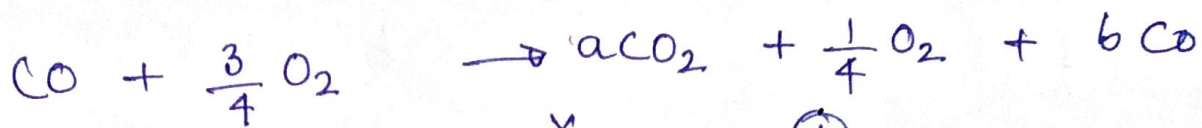
$$\frac{p_v}{p_{\text{tot}}} = \frac{n_v}{n_{\text{tot}}} = \frac{n_v}{1.2 + n_v + 1.15 + 12.972} = \frac{3.169 \times 10^3}{101325}$$

$$\Rightarrow n_v = 0.495 \text{ kmol}$$

$$\text{No. of mole of liquid water} = 2.2 - 0.495 = 1.705 \text{ kmol} \\ = \frac{1.705 \times 18}{18.8} \frac{\text{kg}}{\text{kg fuel}} = 1.632 \frac{\text{kg}}{\text{kg fuel}}$$

P.2

(a)



Given, $\frac{b}{a} = \frac{3}{4} = \frac{X_{\text{CO}}}{X_{\text{CO}_2}} \quad \text{--- (1)}$

$$K_p = \frac{P_{\text{CO}_2} / P^0}{\left(\frac{P_{\text{CO}}}{P^0}\right) \left(\frac{P_{\text{O}_2}}{P^0}\right)^{1/2}} = \frac{X_{\text{CO}_2}}{X_{\text{CO}} X_{\text{O}_2}^{1/2}} \left(\frac{P}{P^0}\right)^{-1/2} = \frac{X_{\text{CO}_2}}{X_{\text{CO}} X_{\text{O}_2}^{1/2}}$$

$$\Rightarrow \frac{\#C}{\#O} = \frac{1}{\left(1 + \frac{3}{4} \cdot 2\right)} = \frac{2}{5} = \frac{X_{\text{CO}_2} + X_{\text{CO}}}{2X_{\text{CO}_2} + X_{\text{CO}} + 2X_{\text{O}_2}} \quad \text{--- (2)}$$

$$X_{\text{CO}} + X_{\text{CO}_2} + X_{\text{O}_2} = 1 \quad \text{--- (3)}$$

Using (1), (3) becomes $X_{\text{CO}_2} \left[1 + \frac{3}{4}\right] + X_{\text{O}_2} = 1$

$$\Rightarrow X_{\text{O}_2} = 1 - \frac{7}{4} X_{\text{CO}_2}$$

(2) become

$$5(X_{\text{CO}_2} + X_{\text{CO}}) = 4X_{\text{CO}_2} + 4X_{\text{O}_2} + 2X_{\text{CO}}$$

$$\Rightarrow X_{\text{CO}_2} + 3X_{\text{CO}} = 4 \left[1 - \frac{7}{4} X_{\text{CO}_2}\right]$$

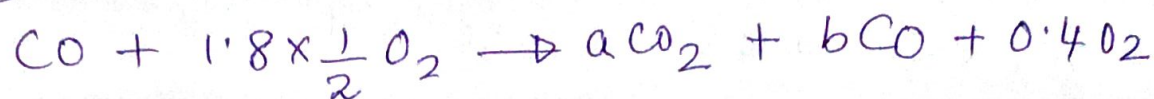
$$\Rightarrow X_{\text{CO}_2} + 3 \cdot \frac{3}{4} X_{\text{CO}_2} = 4 - 7X_{\text{CO}_2}$$

$$\Rightarrow X_{\text{CO}_2} \left[1 + \frac{9}{4} + 7\right] = 4 \Rightarrow X_{\text{CO}_2} = \frac{16}{41}$$

$$X_{\text{CO}} = \frac{12}{41}, \quad X_{\text{O}_2} = \frac{13}{41}$$

$$K_p = \frac{(16/41)}{\left(\frac{12}{41}\right) \left(\frac{13}{41}\right)^{1/2}} = 2.37$$

2(b)



$$\frac{\#C}{\#O} = \frac{1}{1+1.8} = \frac{5}{14} = \frac{X_{\text{CO}_2} + X_{\text{CO}}}{2X_{\text{CO}_2} + X_{\text{CO}} + 2X_{\text{O}_2}} \quad - (1)$$

$$X_{\text{CO}_2} + X_{\text{CO}} + X_{\text{O}_2} = 1 \quad - (2)$$

$$\frac{X_{\text{CO}_2}}{X_{\text{CO}} X_{\text{O}_2}^{1/2}} = K_p = 2.37 \quad - (3)$$

Solving, $X_{\text{CO}_2} = 0.369$, $X_{\text{CO}} = 0.254$, $X_{\text{O}_2} = 0.377$

$$\therefore \frac{X_{\text{CO}}}{X_{\text{CO}_2}} = \frac{0.254}{0.369} = 0.69 \quad (\text{Ans}).$$

P4

$$B.P. = \frac{2\pi NT}{60 \cdot 1000} = \frac{2\pi \cdot 1440 \cdot 100}{60 \cdot 1000} = 15.086 \text{ KW} \quad (2P)$$

$$(i) \eta_{bth} = \frac{15.086 \times BP}{\dot{m}_f \times CV} = \frac{15.086}{\frac{5}{3600} \times 42000} = 25.86\% \quad (2P)$$

$$\dot{m}_f = 5 \text{ kg/hr} = \frac{5}{3600} \frac{\text{kg}}{\text{s}}$$

$$CV = 42 \text{ MJ/kg}$$

$$(ii) BMEP = \frac{BP \times 60 \times 1000}{LA n K}$$

$$= \frac{15.086 \times 60000}{0.12 \times 7.857 \times 10^{-3} \cdot (720) \cdot 4}$$

$$= 3.33 \times 10^5 \text{ N/m}^2$$

$$= 3.33 \text{ bar} \quad (4P)$$

$$K = \text{No. of cyl} = 4$$

$$n = \frac{N}{2} \quad (\text{four-stroke})$$

$$\Rightarrow n = \frac{1440}{2} = 720$$

$$L = 0.12 \text{ m}$$

$$A = \frac{\pi}{4} D^2$$

$$= \frac{\pi}{4} (0.1)^2$$

$$= 7.857 \times 10^{-3} \text{ m}^2$$

$$(iii) \dot{V}_a = C_d A_{orifice} \sqrt{2g \Delta h_w \frac{\rho_w}{\rho_a}}$$

$$= 0.62 \times 1.9643 \times 10^{-3} \sqrt{2g \cdot 4.6 \times 10^{-2} \cdot \frac{1000}{1.16}}$$

$$= 0.0339 \frac{\text{m}^3}{\text{s}} = 2.036 \frac{\text{m}^3}{\text{min}}$$

$$V_s = \frac{\pi}{4} D^2 L n K$$

$$= \frac{\pi}{4} \cdot 7.857 \times 10^{-3} \cdot 0.12 \cdot 720 \cdot 4$$

$$= 2.715 \text{ m}^3/\text{min}$$

$$\eta_v = \frac{\dot{V}_a}{V_s} = \frac{2.036}{2.715} = 75\%$$

(4P)

$$\Delta h_w = 4.6 \text{ cm} = 4.6 \times 10^{-2} \text{ m}$$

$$A_{orifice} = \frac{\pi}{4} D^2$$

$$= \frac{\pi}{4} (0.05)^2$$

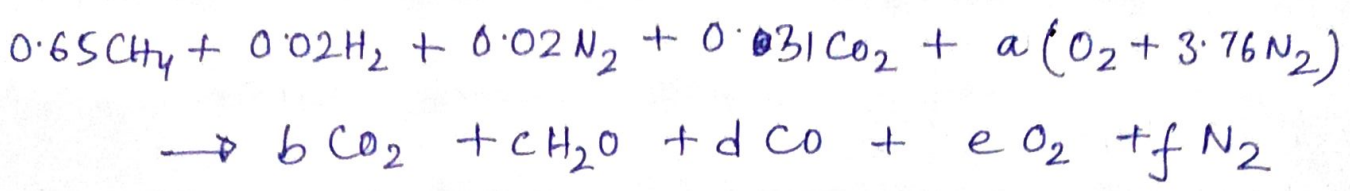
$$= 1.9643 \times 10^{-3} \text{ m}^2$$

$$C_d = 0.62$$

$$\rho_a = \frac{P}{R_{air} T} = \frac{10^5}{28.7 \times 300}$$

$$= 1.16 \frac{\text{kg}}{\text{m}^3}$$

P.5



Dry exhaust gas analysis

$$\begin{aligned} \# \text{C} : \quad 0.65 + 0.31 &= b + d & \text{--- (1)} \\ \# \text{H} : \quad 0.65 \times 4 + 0.04 &= 2c \Rightarrow c = 1.32 \\ \# \text{O} : \quad 0.31 \times 2 + 2a &= 2b + c + d + 2e & \text{--- (2)} \\ \# \text{N} : \quad 0.04 + 7.52a &= 2f & \text{--- (3)} \end{aligned}$$

From Dry gas analysis

$$\frac{11.4}{83} = \frac{b}{f}, \quad \frac{5.3}{83} = \frac{e}{f}$$

$$\frac{0.3}{83} = \frac{d}{f},$$

$$\Rightarrow b = 0.137 f, \quad e = 0.0639 f,$$

$$d = 3.615 \times 10^{-3} f$$

Using these expⁿ in Eq (2), we get

$$0.4054 f + 1.32 = 0.62 + 2a$$

$$\Rightarrow f = 4.93a - 1.727 \quad \text{--- (5)}$$

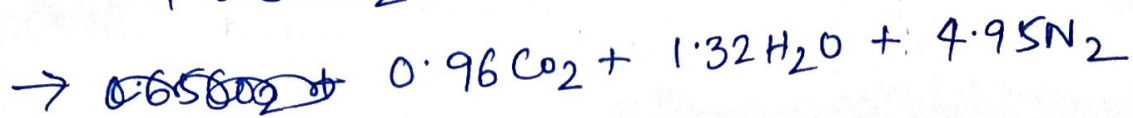
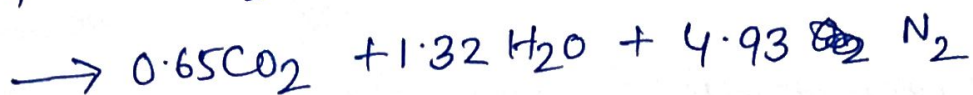
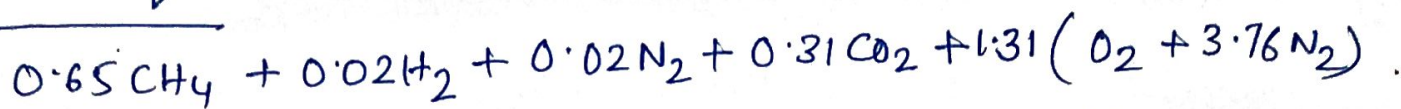
Solving (3) & (5), $a = 1.493, \quad f = 5.634$

$$b = 0.772, \quad e = 0.36, \quad d = 0.02, \quad c = 1.32$$

$$\left(\frac{A}{F}\right)_{\text{act}} = \frac{1.493(32 + 3.76 \times 28)}{0.65 \times 16 + 0.02 \times 2 + 0.02 \times 28 + 0.31 \times 44} = 8.32$$

~~% excess air~~

Stoic. eqⁿ



$$\left(\frac{A}{F}\right)_{\text{st}} = \frac{1.31(32 + 3.76 \times 28)}{0.65 \times 16 + 0.02 \times 2 + 0.02 \times 28 + 0.31 \times 44} = 7.3$$

$$\% \text{ excess air} = \frac{8.32 - 7.3}{7.3} \times 100 = 14\%$$

P3 a) $\frac{d[N]}{dt} = k_{1f}[O][N_2] - k_{2f}[N][O_2] = 0$ (at steady state)

$$\Rightarrow [N]_{ss} = \frac{k_{1f}[O][N_2]}{[O_2]}$$

$$\frac{d[NO]}{dt} = k_{1f}[O][N_2] + k_{2f}[N][O_2] = 2k_{1f}[O][N_2]$$

b) $X_0 = 8.036 \times 10^{-5} \Rightarrow [O] = \frac{X_0 P}{R_u T} = \frac{8.036 \times 10^{-5} \times 10^{1325}}{8314 \times 2400}$

$$= 4.08 \times 10^{-7} \frac{\text{kmol}}{\text{m}^3}$$

$$[O] = 4.08 \times 10^{-10} \frac{\text{gmol}}{\text{cm}^3}$$

$X_{N_2} = 0.735 \Rightarrow [N_2] = \frac{0.735 \times 10^{1325}}{8314 \times 2400} = 3.73 \times 10^{-3} \frac{\text{kmol}}{\text{m}^3}$

$$[N_2] = 3.73 \times 10^{-6} \frac{\text{gmol}}{\text{cm}^3}$$

$$k_{1f} = 1.82 \times 10^{14} \exp\left(\frac{-38370}{T}\right) = 2.0739 \times 10^7 \frac{\text{cm}^3}{\text{gmol} \cdot \text{s}}$$

$$\frac{d}{dt}[NO] = 2k_{1f}[O][N_2] = 63.12 \times 10^{-9}$$

$$\Rightarrow [NO]_f - 0 = 63.12 \times 10^{-9} t$$

$$\Rightarrow t = \frac{3.66 \times 10^{-7}}{63.12 \times 10^{-9}} = 5.8 \text{ sec}$$

$$[NO]_f = 3.66 \times 10^{-4} \frac{\text{kmol}}{\text{m}^3}$$

$$= 3.66 \times 10^{-7} \frac{\text{gmol}}{\text{cm}^3}$$