The formulas required for solution are as follows:

For stoichiometric and lean mixtures;

1) $C + O_2 \rightarrow CO_2 + Q$ (ısı)

$12kg (C) + 32 kg (O_2) = 44 kg (CO_2)$

$$1kgC + \frac{32}{12} kgO_2 = \frac{44}{12} kgCO_2$$

1 kmol C+1kmol O_2 =1kmol CO_2+Q(ısı)

$$1kgC + \frac{1}{12} kmolO_2 = \frac{1}{12} kmolCO_2$$

2) $2H_2 + O_2 \rightarrow 2H_2O + Q$ (ısı)

$4kg (H_2) + 32 kg (O_2) = 36 kg (H_2O)$

2 kmol H_2+ 1kmol O_2 =2 kmol H_2O

1 kmol H_2+ 1/2kmol O_2 =1 kmol H_2O

$$1kgH_2 + \frac{1}{4} kmolO_2 = \frac{1}{2} kmolH_2O$$

3) $S + O_2 \rightarrow SO_2 + Q$ (ısı)

$32kg (S) + 32 kg (O_2) = 64 (SO_2)$

1 kmol S+ 1kmol O_2 =1 kmol SO_2

$$1kgS + \frac{1}{32} kmolO_2 = \frac{1}{32} kmolSO_2$$

$$O_{min} = \frac{1}{12}c + \frac{1}{4}h + \frac{1}{32}s - \frac{1}{32}o_y \text{ [kmol } O_2\text{/kg yakıt]}$$

$$O_{min} = \frac{c}{12}\left[1 + \frac{\frac{h}{4} + \frac{s}{32} - \frac{o_y}{32}}{\frac{c}{12}}\right] \text{ [kmol } O_2\text{/kg yakıt]}$$

$$O_{min} = \frac{c}{12}\left[1 + \frac{\frac{12h}{4} + \frac{12s}{32} - \frac{12o_y}{32}}{c}\right] \text{ [kmol } O_2\text{/kg yakıt]}$$

$$O_{min} = \frac{c}{12}\left[1 + \frac{3\left(h + \frac{s - o_y}{8}\right)}{c}\right] \text{ [kmol } O_2\text{/kg yakıt]}$$

$$\left[1+\frac{3\left(h+\frac{s-o_y}{8}\right)}{c}\right]=\sigma \text{ dersek.}$$

σ → yakıtın karakteristik değeri.

$$O_{min}=\frac{c}{12}.\sigma \text{ [kmol } O_2\text{/kg yakıt]}$$

1 kmol O_2 = 32 kg

$$O_{min}=\frac{c}{12}.\sigma.32=\frac{8}{3}c.\sigma \text{ [kg } O_2\text{/kg yakıt]}$$

Avogadro kanununu hatırlarsak,

0° C ve 760 mm Hg S basınçta 1 komol 22,4 Nm^3 işgal eder.

15° C ve 760 mm Hg S basınçta 1 kmol 24 nm^3 işgal eder.

Buna göre;

$$O_{min}=\frac{c}{12}.\sigma.22{,}4=1{,}87.c.\sigma \text{ [} Nm^3\ O_2\text{/kg yakıt]}$$

veya

$$O_{min}=\frac{c}{12}.\sigma.24=2c.\sigma \text{ [} nm^3\ O_2\text{/kg yakıt] olur.}$$

O_{min} = 0,232. L_{min} (kg O_2/ kg yakıt)

$$L_{min}=\frac{O_{min}}{0{,}232} \text{ (kg hava / kg yakıt)}$$

L_{min} (Nm^3, nm^3 veya m^3) olarak hesaplanması.

1 m^3 havanın içinde oksijenin hacimsel yüzdesi 0,21 dir.

O_{min} = 0,21. L_{min} (Nm^3, nm^3 oksijen / kg yakıt)

For rich mixtures;

$$\lambda(\frac{8}{3}c+8h-O_y)+O_y=\frac{8}{3}c(1-x)+\frac{4}{3}cx+8h$$

$$\lambda(\frac{8}{3}c+8h-O_y)=\frac{8}{3}c-\frac{4}{3}cx+8h-O_y$$

$$\frac{4}{3}cx=\frac{8}{3}c+8h+s-O_y-\lambda(\frac{8}{3}c+8h+s-O_y)$$

$$\frac{4}{3}cx=(1-\lambda).(\frac{8}{3}c+8h+s-O_y)$$

$$x=\frac{3}{4c}(1-\lambda).(\frac{8}{3}c+8h+s-O_y)$$

$$x=\frac{3}{4c}(1-\lambda).O_{min} \quad O_{min}=0{,}232\,L_{min}$$

$$x=\frac{3}{4c}(1-\lambda).0{,}232\,L_{min}$$

$CO_2=\frac{11}{3}c(1-x)$ (kg CO_2 / kg y) ; $CO_2=\frac{c}{12}(1-x)$ (kmol CO_2 / kg y)

$CO=\frac{7}{3}cx$ (kg CO / kg y) ; $CO=\frac{c}{12}x$ (kmol CO / kg y)

$H_2O=9h$ (kg H_2O / kg y) ; $H_2O=\frac{h}{2}$ (kmol H_2O / kg y)

$SO_2=2S$ (kg SO_2 / kg y) ; $SO_2=\frac{s}{32}$ (kmol SO_2 / kg y)

$N_2=\frac{11}{3}c(1-x)$ (kg N_2 / kg y) ; $N_2=0{,}79\lambda L_{min}$ (kmol N_2 / kg y)

$O_{min}^{kmole} = \left[\frac{c}{12} + \frac{h}{4} + \frac{s}{32} - \frac{o_{fuel}}{32} \right]$ kmole-O_2/kg-fuel

$O_{min}^{kg} = \left[\frac{32}{12} c + \frac{32}{4} h + \frac{32}{32} s - \frac{32}{32} o_{fuel} \right] = \left[\frac{8}{3} c + 8h + s - o_{fuel} \right]$ kg-O_2/kg-fuel

$L_{min}^{kmole} = O_{min}^{kmole} / 0,21$ kmole air/kg-fuel

$L_{min}^{kg} = O_{min}^{kg} / 0,232$ kg-air/kg-fuel

For lean and stoichiometric mixtures:

$N_{CO_2} = \frac{1}{12} c$ kmole-CO_2/kg-fuel , $M_{CO_2} = \frac{44}{12} c$ kg-CO_2/kg-fuel

$N_{H_2O} = \frac{1}{2} h$ kmole-H_2O/kg-fuel , $M_{H_2O} = 9h$ kg-H_2O/kg-fuel

$N_{N_2} = 0,79 \lambda L_{min}^{kmole}$ kmole-N_2/kg-fuel , $M_{N_2} = 0,768 \lambda L_{min}^{kg}$ kg-N_2/kg-fuel

$N_{SO_2} = \frac{1}{32} s$ kmole-SO_2/kg-fuel , $M_{SO_2} = 2s$ kg SO_2/kg-fuel

For rich mixtures:

$x = \frac{3}{4c} (1-\lambda) O_{min}^{kg}$; O_{min} term must be in form of kg term.

$N_{CO_2} = \frac{1}{12} c(1-x)$ kmoleCO_2/kg-fuel , $M_{CO_2} = \frac{44}{12} c(1-x)$ kg-CO_2/kg-fuel

$N_{CO} = \frac{1}{12} cx$ kmole-CO/kg-fuel , $M_{CO} = \frac{28}{12} cx$ kg-CO/kg-fuel

$N_{H_2O} = \frac{1}{2} h$ kmole-H_2O/kg-fuel , $M_{H_2O} = 9h$ kg-H_2O/kg-fuel

$N_{N_2} = 0,79 \lambda L_{min}^{kmole}$ kmoleN_2/kg-fuel , $M_{N_2} = 0,768 \lambda L_{min}^{kg}$ kg-N_2/kg-fuel

Critical air excess ratio is a special form of lean mixtures, which carbondioxide doesn't exist at product side. All carbon atoms are oxidized to carbon monoxide at $\lambda_{critical}$.

Ex 1. C_2H_6OS formulated **1 kg** fuel is combusted with **1.3** air excess ratio. Calculate the combustion products in terms of **kg** units.

$$c = \frac{m_c.2}{m_c.2 + m_h.6 + m_o.1 + m_s.1} = 24/78 = 0{,}307$$

$$h = \frac{m_h.6}{m_c.2 + m_h.6 + m_o.1 + m_s.1} = 6/78 = 0{,}076$$

$$o = \frac{m_o.1}{m_c.2 + m_h.6 + m_o.1 + m_s.1} = 16/78 = 0{,}205$$

$$s = \frac{m_s.1}{m_c.2 + m_h.6 + m_o.1 + m_s.1} = 32/78 = 0{,}410$$

$$O_{min} = \left[\frac{c}{12} + \frac{h}{4} + \frac{s - o_y}{32}\right] \frac{kmolO_2}{kgYakit}$$

$$O_{min} = \left[\frac{0{,}307}{12} + \frac{0{,}076}{4} - \frac{0{,}205}{32} + \frac{0{,}410}{32}\right] = 0{,}051 \; \frac{kmolO_2}{kgYakit}$$

$$O_{min} = 1{,}631 \frac{kgO_2}{kgYakit}$$

$$L_{min} = \frac{O_{min}}{0{,}232} = 7{,}030 \frac{kgHava}{kgYakit}$$

$$L_{min} = \frac{O_{min}}{0{,}21} = 0{,}242 \frac{kmolHava}{kgYakit}$$

$$M_{CO_2} = \frac{11}{3} c \;,\; \frac{11}{3} 0{,}307 = 3{,}377 \; \frac{kgCO_2}{kgYakit}$$

$$M_{H_2O} = 9.h \;,\; 9.0{,}076 = 0{,}684 \; \frac{kgH_2O}{kgYakit}$$

$$M_{SO2} = 2.s \;,\; 2.0{,}410 = 0{,}82 \; \frac{kgSO_2}{kgYakit}$$

$$M_{N_2} = 0{,}768.\lambda.L_{min} \;,\; 0{,}768.1{,}3.7{,}03 = 7{,}02 \; \frac{kgN_2}{kgYakit}$$

Ex 2. C_4H_{10} formulated **1 kg** fuel is combusted with **0.85** air excess ratio. Calculate the combustion products in terms of **kmole** units.

$$c = \frac{m_c.4}{m_c.4 + m_h.10} = \frac{12.4}{12.4 + 1.10} = 0,827$$

$$h = \frac{m_h.10}{m_c.4 + m_h.10} = 0,172$$

$$O_{min} = \left[\frac{c}{12} + \frac{h}{4}\right] = 0,112 \ \frac{kmolO_2}{kgYakit}$$

$$O_{min} = 0,112.32 = 3,581 \frac{kgO_2}{kgYakit}$$

$$L_{min} = \frac{O_{min}}{0,232} \ \frac{kgHava}{kgYakit}$$

$$L_{min} = \frac{3,581}{0,232} = 15,435 \ \frac{kgHava}{kgYakit}$$

$$L_{min} = \frac{O_{min}}{0,21} = 0,533 \frac{kmolHava}{kgYakit}$$

$$x = \frac{3}{4}(1-\lambda)\frac{O_{min}}{c}$$

$$x = \frac{3}{4}(1-0,85)\frac{3,581}{0,827} = 0,487$$

$$N_{CO_2} = \frac{1}{12}c(1-x) \ , \ \frac{1}{12}0,827(1-0,487) = 0,035 \ \frac{kmolCO_2}{kgYakit}$$

$$N_{CO} = \frac{1}{12}c(x) \ , \ \frac{1}{12}0,827(0,487) = 0,033 \ \frac{kmolCO}{kgYakit}$$

$$N_{H_2O} = \frac{1}{2}h \ , \ \frac{1}{2}0,172 = 0,086 \ \frac{kmolH_2O}{kgYakit}$$

$$N_{N_2} = 0,79.\lambda.L_{min} \ , \ N_{N_2} = 0,79.\lambda.\frac{O_{min}}{0,21} \ \ 0,79.0,85.0,533 = 0,357 \ \frac{kmolN_2}{kgYakit}$$

Ex 3. C_2H_5OH formulated **1 kg** fuel is combusted with **0.85** air excess ratio.Calculate the combustion products in terms of **kmole** units.

$$c = \frac{m_c.2}{m_c.2+m_h.6+m_o.1} = \frac{12.2}{12.2+1.6+16.1} = 0{,}521$$

$$h = \frac{m_h.6}{m_c.2+m_h.6+m_o.1} = \frac{1.6}{12.2+1.6+16.1} = 0{,}130$$

$$o = \frac{m_o.1}{m_c.2+m_h.6+m_o.1} = \frac{16.1}{12.2+1.6+16.1} = 0{,}347$$

$$O_{min} = \left[\frac{c}{12}+\frac{h}{4}+\frac{o}{32}\right] \frac{kmolO_2}{kgYakit}$$

$$O_{min} = \left[\frac{0{,}521}{12}+\frac{0{,}130}{4}-\frac{0{,}347}{32}\right] = 0{,}065 \ \frac{kmolO_2}{kgYakit}$$

$$O_{min} = 0{,}065.32 = 2{,}08 \frac{kgO_2}{kgYakit}$$

$$L_{min} = \frac{O_{min}}{0{,}232} \ \frac{kgHava}{kgYakit}$$

$$L_{min} = \frac{2{,}08}{0{,}232} = 8{,}965 \ \frac{kgHava}{kgYakit}$$

$$L_{min} = \frac{O_{min}}{0{,}21} = 0{,}309 \frac{kmolHava}{kgYakit}$$

$$x = \frac{3}{4}(1-\lambda)\frac{O_{min}}{c}$$

$$x = \frac{3}{4}(1-0.85)\frac{2{,}08}{0{,}521} = 0{,}449$$

$$N_{CO_2} = \frac{1}{12}c(1-x) \ , \ \frac{1}{12}0{,}521(1-0{,}449) = 0{,}024 \frac{kmolCO_2}{kgYakit}$$

$$N_{CO} = \frac{1}{12}c(x) \ , \ \frac{1}{12}0{,}521(0{,}449) = 0{,}019 \ \frac{kmolCO}{kgYakit}$$

$$N_{H_2O} = \frac{1}{2}h \ , \ \frac{1}{2}0{,}130 = 0{,}065 \ \frac{kmolH_2O}{kgYakit}$$

$$N_{N_2} = 0{,}79.\lambda.L_{min} \ , \ N_{N_2} = 0{,}79.\lambda\frac{O_{min}}{0{,}21} \quad 0{,}79.0{,}85.0{,}309 = 0{,}207 \ \frac{kmolN_2}{kgYakit}$$

Ex 4. 85% C_3H_8 and **15% CH_4** mass fractionally blended fuel is combusted with **critical air excess ratio**.Calculate the combustion products in terms of **kg** units.

$$c_{propan} = \frac{m_c.3}{m_c.3+m_h.8} = 0{,}82$$

$$h_{propan} = \frac{m_h.8}{m_c.3+m_h.8} = 0{,}18$$

$$c_{metan} = \frac{m_c.1}{m_c.1+m_h.4} = 0{,}75$$

$$h_{metan} = \frac{m_h.4}{m_c.1+m_h.4} = 0{,}25$$

$propan x 0{,}85$
$metan x 0{,}15$
$\Sigma C = 0{,}8095$
$\Sigma H = 0{,}1905$

$$O_{min} = \left[\frac{c}{12}+\frac{h}{4}\right] \frac{kmol O_2}{kg Yakit}$$

$$O_{min} = 0{,}1150 \frac{kmol O_2}{kg Yakit}$$

$$O_{min} = 3{,}682 \frac{kg O_2}{kg Yakit}$$

$$L_{min} = \frac{O_{min}}{0{,}232} = 15{,}8706 \frac{kg Hava}{kg Yakit}$$

$$L_{min} = \frac{O_{min}}{0{,}21} = 0{,}5476 \frac{kmol Hava}{kg Yakit}$$

$$x = 1 \rightarrow \lambda_{kr}$$

$$\lambda_{kr} = 1 - \frac{4x0{,}8095}{3x3{,}682} = 0{,}70$$

$$M_{CO_2} = 0$$

$$M_{CO} = \frac{7}{3}c(x) \ , \ \frac{7}{3}0{,}8095.1 = 1{,}888 \frac{kg CO}{kg Yakit}$$

$$M_{H_2O} = 9.h \ , \ 9.0{,}1905 = 1{,}714 \frac{kg H_2O}{kg Yakit}$$

$$M_{N_2} = 0{,}768.\lambda.L_{min} \ , \ 0{,}768.0{,}7.15{,}8706 = 8{,}532 \frac{kg N_2}{kg Yakit}$$