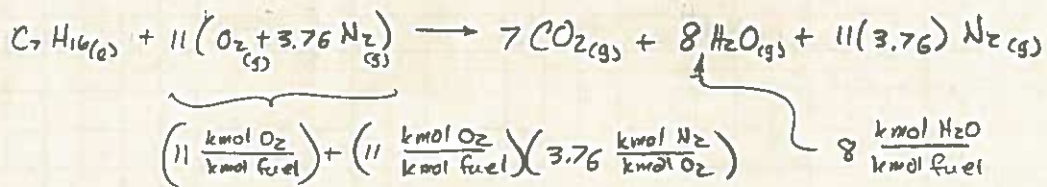


Example 1

Determine the stoichiometric air required for complete combustion of 1 kg n-heptane. What is the % analysis of the combustion products on a molar and mass basis?



$$\overline{A/F}^o = \frac{11(1+3.76)}{1} = 52.36 \frac{\text{kmol air}}{\text{kmol fuel}}$$

$$A/F^o = \overline{A/F}^o \cdot \frac{M_{air}}{M_{fuel}} = \left(52.36 \frac{\text{kmol air}}{\text{kmol fuel}} \right) \frac{(28.97 \text{ kg/kmol air})}{(100 \text{ kg/kmol fuel})} = 15.14 \frac{\text{kg air}}{\text{kg fuel}}$$

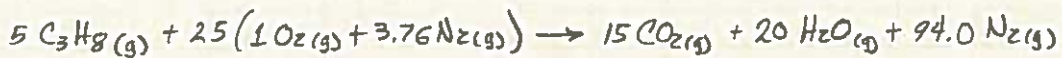
Products	molar basis				
CO ₂	7	12.4%	7 × 44 =	308.1	19.13% kg CO ₂ /kg product
H ₂ O	8	14.2%	8 × 18 =	144.1	8.95%
N ₂	41.36	73.4%	41.36 × 28 =	1158.6	71.92%
total	56.36	100%		1610.8	100%
	↑ kmol product / kmol fuel		↑ kg product / kmol fuel		

Alternative A/F calculation

$$A/F = \frac{(11 \text{ kmol } O_2/\text{kmol fuel})(32 \text{ kg/kmol } O_2) + (11 \cdot 3.76 \text{ kmol } N_2/\text{kmol fuel})(28 \text{ kg/kmol } N_2)}{(7 \text{ kmol } C/\text{kmol fuel})(12 \text{ kg/kmol } C) + (8 \text{ kmol } H_2/\text{kmol fuel})(2 \text{ kg/kmol } H_2)} = 15.1$$

Example 2

5 mols of propane, $C_3H_8(g)$, are completely burned at 1 atm with the theoretical amount of air. What is the volumetric analysis of the dry combustion products?



25 mols of O_2 , or 119 mols of air, are required for complete combustion

Treat the air as an ideal gas; ($25^\circ C$, 1 atm)

$$V_{air} = \frac{nRT}{P} = \frac{(119 \text{ mol})(8.3144 \text{ J/mol}\cdot\text{K})(25 + 273.15 \text{ K})}{(101.3 \text{ kPa})} = 2.92 \text{ m}^3$$

Dry Volumetric Analysis of Products

$$\frac{V_{CO_2}}{V_{CO_2} + V_{N_2}} = \frac{n_{CO_2}}{n_{CO_2} + n_{N_2}} = \frac{15}{15 + 94} = 13.76\%$$

$$\frac{V_{N_2}}{V_{CO_2} + V_{N_2}} = 86.24\%$$

Example 3

An analysis of coal gives the following % by mass:

carbon	80.7%
hydrogen	4.9%
oxygen	5.3%
nitrogen	1.1%
sulfur	1.8%
ash	balance

What is the air-to-fuel ratio if 20% excess air is used during combustion?

	<u>mols per kg coal</u>	<u>stoichiometric kmols of O₂ per kg coal</u>	
C	$\frac{0.807}{12} = 0.0672$	0.0672	$0.0672 C_{(s)} + 0.0672 O_{2(g)} \rightarrow 0.0672 CO_{2(g)}$
H ₂	$\frac{0.049}{2} = 0.0245$	0.0123	$0.0245 H_{2(g)} + 0.0123 O_{2(g)} \rightarrow 0.0245 H_2O_{(g)}$
S	$\frac{0.018}{32} = 5.625 \cdot 10^{-4}$	$5.625 \cdot 10^{-4}$	$5.625 \cdot 10^{-4} S_{(s)} + 5.625 \cdot 10^{-4} O_{2(g)} \rightarrow 5.625 \cdot 10^{-4} SO_{2(g)}$ <u>0.0801 kmols O₂ required</u>
O ₂	$\frac{0.053}{32} = 1.656 \cdot 10^{-3}$	0	<u>-1.656 · 10⁻³ kmols O₂ in coal</u>
N ₂	$\frac{0.011}{28} = 3.929 \cdot 10^{-4}$	0	<u>0.0784 kmols of O₂ per kg coal</u>

Stoichiometric:

$$\frac{A}{F}^o = \left(\frac{0.0784 \text{ kmol } O_2}{\text{kg coal}} \right) \left(\frac{1 \text{ kmol air}}{0.2099 \text{ kmol } O_2} \right) \left(28.97 \frac{\text{kg air}}{\text{kmol air}} \right) = 10.82 \frac{\text{kg air}}{\text{kg coal}}$$

20% excess air:

$$\frac{A}{F} \Big|_{20\% \text{ excess}} = 1.2 \frac{A}{F}^o = 13 \frac{\text{kg air}}{\text{kg coal}}$$

Example 4

Volumetric analysis of dry combustion products of a hydrocarbon fuel combusted in air at 1 atm, 60°F, and 60% RH shows:

	% V
CO ₂	10.00
O ₂	2.37
CO	0.53
N ₂	87.10 (by difference)
	<u>100.00</u>

- (a) What is the mass ratio of hydrogen to carbon in the fuel?
 (b) What is the air-to-fuel ratio (by mass) of combustion?

	mols per dry product	C	O	N
CO ₂	0.10	0.10	0.20	
O ₂	0.0237		0.0474	
CO	0.0053	0.0053	0.0053	
N ₂	0.871			1.742
Total	<u>1</u>	<u>0.1053</u>	<u>0.2527</u>	<u>1.742</u>

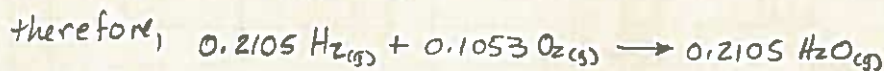
We can safely assume that all hydrogen is fully combusted into H₂O and that all product N₂ was originally from the air used for combustion.

The number of mols of O₂ associated with 0.871 mols of N₂ in air is:

$$\frac{0.871 \frac{\text{mol N}_2}{\text{mol product}}}{3.76 \frac{\text{mol N}_2}{\text{mol O}_2}} = 0.2316 \frac{\text{mol O}_2}{\text{mol product}} \leftarrow \text{from air used for combustion}$$

The number of mols ^{of O₂} used in combustion of carbon is $0.1264 \frac{\text{mol O}_2}{\text{mol product}}$.

The difference, $0.1053 \frac{\text{mol O}_2}{\text{mol prod.}}$, was used in combustion of hydrogen.



(a) Hydrogen-to-carbon ratio

$$\frac{n_H}{n_C} = \frac{2(0.2105)}{0.1053} = 4 \frac{\text{mols H}}{\text{mols C}} \quad \frac{m_H}{m_C} = \frac{2(0.2105)(1)}{(0.1053)(12)} = 0.333 \frac{\text{kg H}}{\text{kg C}}$$

(b) air-to-fuel ratio

$$A/F = \frac{(0.871 \frac{\text{kmol N}_2}{\text{kmol prod.}}) (\frac{1 \text{ kmol air}}{0.79 \text{ kmol N}_2}) (28.97 \frac{\text{kg}}{\text{kmol air}})}{(0.1053 \frac{\text{kmol C}}{\text{kmol prod.}}) (12 \frac{\text{kg C}}{\text{kmol C}}) + (0.2105 \frac{\text{kmol H}_2}{\text{kmol prod.}}) (2 \frac{\text{kg H}}{\text{kmol H}})} = 18.96 \frac{\text{kg air}}{\text{kg fuel}}$$