Answer on Question #79764, Physics / Molecular Physics |Thermodynamics

A coal sample consists of 82.1 % carbon, 4.5 % hydrogen, 1.5 % sulphur, 3.0% oxygen and the remainder incombustible material. If 1 kg is burnt with 20 % excess air, determine (i) the mass of air required per kilogram of fuel and (ii) prepare an analysis by mass of the products of combustion per kilogram of fuel.

Solution

m(fuel)=1kg=1000g

w(C)=0.821

w(H)= 0.045

w(S)=0.015

w(O)=0.03

w(O_2) in air = 0.23

m_{air} -?

Combustible substances in fuel are : carbon, hydrogen and sulphur. Complete oxidation of these elements leads to oxide formation.

(i) Determine the mass of air required per kilogram of fuel.

For carbon: $C+O_2 \rightarrow CO_2$

$$n(C)=\frac{m}{M}=\frac{w(C)\times m_{air}}{M}=\frac{0.821\times 1000\ g}{12\frac{g}{mol}}=68.4\ mol$$

The equation gives mole ratio n(C):n(O_2)= 1:1, n(O_2)= 68.4 mol.

For sulphur: $S + O_2 \rightarrow SO_2$

$$n(S)=\frac{m}{M}=\frac{w(S)\times m_{air}}{M}=\frac{0.015\times 1000\ g}{32\frac{g}{mol}}=0.5\ mol$$

The equation gives mole ratio n(S):n(O_2)= 1:1, n(O_2)= 0.5mol.

For hydrogen: $4H + O_2 \rightarrow 2H_2O$

$$n(H)=\frac{m}{M}=\frac{w(H)\times m_{air}}{M}=\frac{0.045\times 1000\ g}{1\frac{g}{mol}}=45\ mol$$

The equation gives mole ratio n(H):n(O_2)= 4:1, n(O_2)= n(H)/4 = 45 mol/4 =11.3 mol.

Total amount of substance of oxygen used for combustion of carbon, sulphur and hydrogen is:

n_{total} = 68.4 mol + 0.5 mol+ 11.3 mol = 80.2 mol

$m(O_2)$= n×M = 80.2 mol × 32 g/mol = 2566.4 g

$$w(O_2) = \frac{m(O_2)}{m_{air}} \Rightarrow m_{air} = \frac{m(O_2)}{w(O_2)} = \frac{2566.4\ g}{0.23} = 11158.3\ g$$

Excess of air is 20%, $m_{excess\ iar}$ = 11158.3 g ×0.2 = 2231.7 g

Total mass of air with 20% excess is 11158.3 g + 2231.7 g = 13390 g = 13.4 kg

(ii) Prepare an analysis by mass of the products of combustion per kilogram of fuel.

Products of combustion are : CO_2, H_2O and SO_2

For CO_2 :

$C + O_2 \rightarrow CO_2$

The equation gives mole ratio n(C):n(CO_2)= 1:1, n(CO_2)= 68.4 mol.

m(CO_2) = n×M = 68.4 mol × 44 g/mol = 3009.6 g

For SO_2 :

$S + O_2 \rightarrow SO_2$

The equation gives mole ratio n(S):n(SO_2)= 1:1, n(SO_2)= 0.5mol.

m(SO_2) = n×M = 0.5 mol × 64 g/mol = 32 g

For H_2O :

$4H + O_2 \rightarrow 2H_2O$

The equation gives mole ratio n(H):n(H_2O)= 4:2, n(H_2O)= n(H)/2 = 45 mol/2 =22.5 mol

m(H_2O) = n×M = 22.5 mol × 18 g/mol = 405 g

Combustion of 1 kg of fuel gives 3009.6 g of carbon dioxide, 405 g of water and 32 g of sulphur dioxide. The main product of combustion is carbon dioxide, the minor product is sulphur dioxide.

$$w(CO_2) = \frac{3009.6}{3009.6+405+32} \times 100\% = 87.3\ \%.$$

$$w(SO_2) = \frac{32}{3009.6 + 405 + 32} \times 100\% = 0.9\ \%.$$

$$w(H_2O) = \frac{405}{3009.6 + 405 + 32} \times 100\% = 11.8\%.$$

Answer: (i) 13.4 kg

(ii) Combustion of 1 kg of fuel gives 3009.6 g of carbon dioxide, 405 g of water and 32 g of sulphur dioxide. The main product of combustion is carbon dioxide, the minor product is sulphur dioxide.

$w(CO_2) = 87.3\ \%$, $w(SO_2) = 0.9\ \%$, $w(H_2O) = 11.8\%$.