

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

$$m(\text{fuel})=1\text{kg}=1000\text{g}$$

$$w(\text{C})=0.821$$

$$w(\text{H})= 0.045$$

$$w(\text{S})=0.015$$

$$w(\text{O})=0.03$$

$$w(\text{O}_2) \text{ in air} = 0.23$$

$$m_{\text{air}} \text{ -?}$$

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: $\text{C} + \text{O}_2 \rightarrow \text{CO}_2$

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

The equation gives mole ratio $n(\text{C}):n(\text{O}_2) = 1:1$, $n(\text{O}_2) = 68.4 \text{ mol}$.

For sulphur: $\text{S} + \text{O}_2 \rightarrow \text{SO}_2$

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

The equation gives mole ratio $n(\text{S}):n(\text{O}_2) = 1:1$, $n(\text{O}_2) = 0.5 \text{ mol}$.

For hydrogen: $4\text{H} + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$

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

The equation gives mole ratio $n(\text{H}):n(\text{O}_2) = 4:1$, $n(\text{O}_2) = n(\text{H})/4 = 45 \text{ mol}/4 = 11.3 \text{ mol}$.

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

$$n_{\text{total}} = 68.4 \text{ mol} + 0.5 \text{ mol} + 11.3 \text{ mol} = 80.2 \text{ mol}$$

$$m(\text{O}_2) = n \times M = 80.2 \text{ mol} \times 32 \text{ g/mol} = 2566.4 \text{ g}$$

$$w(\text{O}_2) = \frac{m(\text{O}_2)}{m_{\text{air}}} \Rightarrow m_{\text{air}} = \frac{m(\text{O}_2)}{w(\text{O}_2)} = \frac{2566.4 \text{ g}}{0.23} = 11158.3 \text{ g}$$

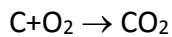
$$\text{Excess of air is 20\%, } m_{\text{excess air}} = 11158.3 \text{ g} \times 0.2 = 2231.7 \text{ g}$$

$$\text{Total mass of air with 20\% excess is } 11158.3 \text{ g} + 2231.7 \text{ g} = 13390 \text{ g} = 13.4 \text{ kg}$$

(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

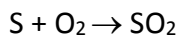
For CO_2 :



The equation gives mole ratio $n(\text{C}):n(\text{CO}_2) = 1:1$, $n(\text{CO}_2) = 68.4 \text{ mol}$.

$$m(\text{CO}_2) = n \times M = 68.4 \text{ mol} \times 44 \text{ g/mol} = 3009.6 \text{ g}$$

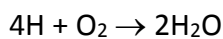
For SO_2 :



The equation gives mole ratio $n(\text{S}):n(\text{SO}_2) = 1:1$, $n(\text{SO}_2) = 0.5 \text{ mol}$.

$$m(\text{SO}_2) = n \times M = 0.5 \text{ mol} \times 64 \text{ g/mol} = 32 \text{ g}$$

For H_2O :



The equation gives mole ratio $n(\text{H}):n(\text{H}_2\text{O}) = 4:2$, $n(\text{H}_2\text{O}) = n(\text{H})/2 = 45 \text{ mol}/2 = 22.5 \text{ mol}$

$$m(\text{H}_2\text{O}) = n \times M = 22.5 \text{ mol} \times 18 \text{ g/mol} = 405 \text{ g}$$

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.

$$w(\text{CO}_2) = \frac{3009.6}{3009.6 + 405 + 32} \times 100\% = 87.3 \%$$

$$w(\text{SO}_2) = \frac{32}{3009.6 + 405 + 32} \times 100\% = 0.9 \%$$

$$w(\text{H}_2\text{O}) = \frac{405}{3009.6 + 405 + 32} \times 100\% = 11.8\%$$

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.

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

Answer provided by <https://www.AssignmentExpert.com>