Answer on Question #79808, 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

Find masses of carbon, hydrogen, sulphur and oxygen in 1 kg of a coal.

$m(C)=0.821\times1000\ g = 821\ g$

$m(H)=0.045\times1000\ g = 45\ g$

$m(S) = 0.015\times1000g = 15\ g$

$m(O) = 0.030\times1000\ g = 30\ g$

The reactions that take place in the process of burning:

$C + O_2 \rightarrow CO_2$ (1)

$4H + O_2 \rightarrow 2H_2O$ (2)

$S + O_2 \rightarrow SO_2$ (3)

From the equation (1) we can see that mole ratio is $n(C):n(O_2):n(CO_2)=1:1:1$

Find amount of substance of carbon:

$n=m/M$

$$n(C) = \frac{821\ g}{12 g/mol} = 68.4\ mol$$

Then $n(O_2) = 68.4$ mol

$m(O_2)= M\ (O_2)\times n(O_2) = 32\ g/mol \times 68.4\ mol =2188.8\ g$

$n(CO_2) = 68.4$ mol

$m(CO_2)= M(CO_2)\times n(CO_2)= 44 g/mol \times 68.4\ mol = 3009.6\ g$

From the equation (2) we can see that mole ratio is $n(H):n(O_2):n(H_2O)=4:1:2$,

then $n(O_2)= n(H)/4$, $n(H_2O)= n(H)/2$

Find n(H): $n(H)= m(H)/M(H)= 45\ g / 1\ g/mol =45$ mol

$n(O_2) = 45\ mol/4 =11.3$ mol

$m(O_2)= M(O_2)\times n(O_2) = 32$ g/mol $\times 11.3$ mol = 361.6 g

$n(H_2O) = 45$ mol/2 = 22.5 mol

$m(H_2O)= M(H_2O)\times n(H_2O)= 18$ g/mol $\times 22.5$ mol = 405 g

From the equation (3) we can see that mole ratio is $n(S):n(O_2):n(SO_2)=1:1:1$

Find n(S):

$n(S)= m(S)/M(S) = 15$g / 32 g/mol= 0.469 mol

$n(O_2) = 0.469$ mol

$m(O_2)= 32$g/mol$\times 0.469$ mol = 15.0 g

$n(SO_2)= 0.469$ mol

$m(SO_2) = M(SO_2)\times n(SO_2)= 64$ g/mol $\times 0.469$mol = 30.0 g

So, determine (i) the mass of air required per kilogram of fuel:

Find the mass of oxygen required for burning 1 kg of coal

$m(O_2) = 2188.8$ g + 361.6 g + 15.0 g= 2565.4 g

The oxygen content of air by mass is 23 %.

Then m_{air} =2565.4 g/0.23 = 11153.9 g

As air was with 20 % excess then m_{air} = 11153.9 +11153.9$\times$0.2 =13384.7 g = 13.4 kg

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

Mass of fuel	Mass of CO_2	Mass of H_2O	Mass of SO_2
1 kg	3009.6 g ≅3 kg	405 g =0.405 kg	30.0 g = 0.03 kg

From the table data we can see that mass of CO_2 formed is the bigger, the mass of H_2O formed is 3009.6/405 = 7.4 times less than the mass of CO_2, and the mass of SO_2 is the minor (3009.6/30= 100 times less than the mass of CO_2)

Answer: (i) 13.4 kg

(ii)

Mass of fuel	Mass of CO_2	Mass of H_2O	Mass of SO_2
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