8 The analysis by mass of a solid fuel is as follows:

Carbon 70%, Hydrogen 15%, Oxygen 5%, Ash 10 %.

The fuel is burnt with 20% excess air. Assuming complete combustion, calculate

(a) the composition by mass of the products of combustion,
(b) the dewpoint,
(c) for each kg of fuel burnt, the mass of water which will condense when the products of combustion are cooled at a constant pressure to 20 °C.

Assume that the barometric pressure is 1 atm.

| | | | | | |
|---|---|---|---|---|---|
| C + | $O_2$ ↔ | $CO_2$ | $2H_2$ + | $O_2$ ↔ | $2H_2O$ |
| 12 | 32 | 44 | 4 | 32 | 36 |
| 0.7 | 1.867 | 2.57 | 0.15 | 1.2 | 1.35 |

There are .7/12 = 0.05833 kmol of C and 0.15/2 = 0.075 kmol of $H_2$

Total $O_2$ needed = 1.867 + 1.2 – 0.05 = 3.0167 kg
Air needed = 3.0167/0.233 = 12.947 kg
Actual air 12.947 x 1.2 = 15.537 kg
Nitrogen in this air = 0.77 x 15.537= 11.963 kg
oxygen in this air = 3.620 Oxygen used = 3.0167 Oxygen left over = 0.603 kg

PRODUCTS

| | kmol | mass | % |
|---|---|---|---|
| $N_2$ | 0.427 | 11.963 | 72.6 |
| $CO_2$ | 0.0584 | 2.57 | 15.6 |
| $H_2O$ | 0.075 | 1.35 | 8.2 |
| $O_2$ | 0.01884 | 0.603 | 3.6 |
| Total | 0.5792 | 16.486 | 100 |

If everything ends up as gas then the partial pressure of $H_2O$ is
$p_{H2O}$ = (0.075/0.5792) x 1 atm = 0.1295 atm = 0.131 bar

The corresponding saturation temperature is 51.2$^o$C (The dew Point)

If cooled to 20$^o$C some condensation must occur and the vapour left will be dry saturated vapour.
ps at 20$^o$C is 0.02337 bar
Let the kmol of $H_2O$ vapour be x. The total kmol is the same = .5792 – 0.075 + x = 0.5042 + x

$$p_{H_2O} = \frac{x}{0.5042 + x} \text{ x } 1.013 = 0.02337 \text{ bar}$$

$$0.01163 + 0.02307x = x$$

$$0.01163 = 0.9769x \qquad x = 0.0119 \text{ kmol}$$

The mass of vapour is m = 0.0119 x 18 = 0.2142 kg
Condensate formed is 1.35 - 0.2142 = 1.1358 kg