Exercise 1. 100 g (1)

	m	M	N_i
C	35	12	
H	3.3	1	
O	35.7	16	
Na	19.7	23	
K	1.6	39	
S	4.0	32	
Cl	0.6	35.5	

$\rightarrow N_i = \frac{m_i}{M_i}$

We assume species that are present Na_2CO_3, K_2CO_3, Na_2SO_4, K_2SO_4, NaCl, KCl, Na_2S, K_2S and left over C_0, H_0, O_0 forms organic part.

We write balance for elements, molar amounts

$C = C_0 + Na_2CO_3 \cdot 1 + K_2CO_3 \cdot 1$

$H = H_0$

$O = O_0 + Na_2CO_3 \cdot 3 + Na_2SO_4 \cdot 4 + K_2CO_3 \cdot 3 + K_2SO_4 \cdot 4$

$Na = NaCl + Na_2CO_3 \cdot 2 + Na_2SO_4 \cdot 2 + Na_2S \cdot 2$

$K = KCl + K_2CO_3 \cdot 2 + K_2SO_4 \cdot 2 + K_2S \cdot 2$

$S = Na_2S + Na_2SO_4 + K_2S + K_2SO_4$

$Cl = NaCl + KCl$

11 unknowns > 7 equations

We need 4 equations more!

(2)

8) $\eta = \frac{Na_2S}{Na_2S + Na_2SO_4}$

9) $\eta = \frac{K_2S}{K_2S + K_2SO_4}$

10) $a = \frac{Na}{Na + K} = \frac{NaCl}{NaCl + KCl}$

also

11) $a = \frac{Na_2S}{Na_2S + K_2S}$

11 ⟷ 11

OK ☺

Let's solve

$NaCl(1-a) = a\,KCl$ $\qquad NaCl = \frac{a}{1-a} KCl$

$Cl = \frac{a}{1-a} KCl + KCl = KCl\left(\frac{a+1-a}{1-a}\right) = KCl \frac{1}{1-a}$

$KCl = Cl \cdot (1-a)$ $\qquad NaCl = a \cdot Cl$

$S = \frac{Na_2S}{\eta} + \frac{K_2S}{\eta} \Rightarrow \eta \cdot S = Na_2S + K_2S = \frac{Na_2S}{a}$

$Na_2S = a \cdot \overbrace{\eta \cdot S}^{*}$

$K_2S = (1-a) \cdot \eta \cdot S$

$Na_2SO_4 = a \cdot (1-\eta) \cdot S$

$K_2SO_4 = (1-a)\underbrace{(1-\eta) \cdot S}_{**}$

* reduced S

** oxidized S

from Na + K balances

$Na_2CO_3 = \frac{Na - NaCl - 2Na_2S - 2Na_2SO_4}{2}$

$K_2CO_3 = \frac{K - KCl - 2K_2S - 2K_2SO_4}{2}$

$C_0 = C - Na_2CO_3 - K_2CO_3$

$H_0 = H$; $O_0 = O - Na_2CO_3 \cdot 3 - K_2CO_3 \cdot 3 - Na_2SO_4 \cdot 4 - K_2SO_4 \cdot 4$

flue gas calculations

Exercise 2

Reactions

$C_o + O_2 \rightarrow CO_2$

$2H_o + \frac{1}{2}O_2 \rightarrow H_2O$

$\rightarrow H_o + \frac{1}{4}O_2 \rightarrow \frac{1}{2}H_2O$

O_2 - need for stoichiometric combustion

$O_2 = C_o + H_o \cdot \frac{1}{4} - O_o \frac{1}{2}$

$m_{O_2} = C_o \cdot 32 \frac{g}{mol} + H_o \cdot \frac{1}{4} 32 \frac{g}{mol} - O_o \cdot \frac{1}{2} 32 \frac{g}{mol}$

$m_{CO_2} = C_o \cdot 44 \frac{g}{mol} =$

$m_{H_2O} = H_o \cdot \frac{1}{4} \cdot 18 \frac{g}{mol} =$

$m_{N_2} = m_{O_2} \cdot 3.77$

Dry stoichiom. air input $= m_{O_2} + m_{N_2}$

On mass basis $m_i = N_i M_i$

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Actual flue gases contain excess O_2 + N_2 and H_2O from various sources.

Actual dry air input

$(m_{O_2} + m_{N_2}) \cdot \lambda$

Water from drying

$y_s = \frac{m_s}{m_s + m_w}$ $m_s = m_s y_s + y_s \cdot m_w$

$m_w = m_s(1-y_s)/y_s = 100 \cdot \frac{0.3}{0.7} = 42.9\ g$

Water from sootblowing 18 g / 100 g dry solids. → 18 g

Direct steam heating of BL 2.4 g / 100 g dry solids → 2.4 g

Air humidity

$\frac{m_w}{m_{air}} = \frac{N_w M_w}{N_a M_a} = \frac{N_w}{N - N_w} \cdot \frac{M_w}{M_a} = \frac{x_w}{1 - x_w} \cdot \frac{M_w}{M_a}$

$x_w = \frac{p_w}{p}$, relative humidity $\varphi = \frac{p_w}{p_w'(T)}$

$= \frac{\varphi \cdot p_w'(T)}{p}$

$\frac{m_w}{m_a} = \frac{\varphi \cdot p_w'(T)}{p - \varphi \cdot p_w'(T)} \cdot \frac{M_w}{M_a}$

25°C → $p_w' = 3200$ Pa $\frac{m_w}{m_a} = 0.014 \frac{g}{g}$

→ 6.1 g H_2O addition

Summed

→ 69.4 g + combustion of H

Excess O_2

$O_2 \cdot (\lambda - 1) \cdot 32 \frac{g}{mol} = 11.9\ g$

N_2:

$O_2 \cdot \lambda \cdot 3.77 \cdot 28 \frac{g}{mol} = 334\ g$

$H_2O = H_0 \frac{1}{2} 18 \frac{g}{mol} + 69.4\ g = 99.1\ g$

$CO_2 = C_0 \cdot 44 \frac{g}{mol} = \ldots = 114\ g$

$\sum m_i = \underline{559.8\ g}$ $y_i = \frac{m_i}{\sum m_i}$

Dry flue gases, remove H_2O

$\sum m_i = 460\ g$

Molar basis $m_i \rightarrow \sum m_i$

$\rightarrow N_i = m_i \cdot M_i$ $\sum N_i$

$x_i = \frac{N_i}{\sum N_i}$

See Excel Sheet !