Chemical Reactions

Sept. 20

Ex: $x_1\, CH_4 + x_2\, O_2 \longrightarrow x_3\, CO_2 + x_4\, H_2O$

Carbon: $x_1 = x_3$

Hydrogen: $4x_1 = 2x_4$

Oxygen: $2x_2 = 2x_3$

$$\begin{array}{cccc} x_1 & x_2 & x_3 & x_4 \end{array}$$
$$\begin{bmatrix} 1 & 0 & -1 & 0 \\ 4 & 0 & 0 & -2 \\ 0 & 2 & -2 & 0 \end{bmatrix} \to \begin{bmatrix} 1 & 0 & 0 & -1/2 \\ 0 & 1 & 0 & -1 \\ 0 & 0 & 1 & -1/2 \end{bmatrix}$$

$x_4 = t$

$x_3 = \frac{1}{2}t$

$x_2 = t$

$x_1 = \frac{1}{2}t$

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} = t \begin{bmatrix} 1/2 \\ 1 \\ 1/2 \\ 1 \end{bmatrix}$$

take 'simple' value of t
say $t = 2$

Ex: $x_1\, B_{10}H_{12}CNH_3 + x_2\, NiCl_2 + x_3\, NaOH \longrightarrow x_4\, Na_4(B_{10}H_{10}CNH_2)_2Ni + x_5\, NaCl + x_6\, H_2O$

$$\begin{array}{c|cccccc} & x_1 & x_2 & x_3 & x_4 & x_5 & x_6 \\ \hline B: & 10 & 0 & 0 & -20 & 0 & 0 \\ H: & 15 & 0 & 1 & -24 & 0 & -2 \\ C: & 1 & 0 & 0 & -2 & 0 & 0 \\ N: & 1 & 0 & 0 & -2 & 0 & 0 \\ Ni: & 0 & 1 & 0 & -1 & 0 & 0 \\ Cl: & 0 & 2 & 0 & 0 & -1 & 0 \\ Na: & 0 & 0 & 1 & -4 & -1 & 0 \\ O: & 0 & 0 & 1 & 0 & 0 & -1 \end{array}$$

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & -1/3 \\ 0 & 1 & 0 & 0 & 0 & -1/6 \\ 0 & 0 & 1 & 0 & 0 & -1 \\ 0 & 0 & 0 & 1 & 0 & -1/6 \\ 0 & 0 & 0 & 0 & 1 & -1/3 \end{bmatrix}$$

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \end{bmatrix} = \begin{bmatrix} t/3 \\ t/6 \\ t \\ t/6 \\ t/3 \\ t \end{bmatrix}$$

$\mathcal{E}x$: $MnS + As_2Cr_{10}O_{35} + H_2SO_4$

$\longrightarrow HMnO_4 + AsH_3 + CrS_3O_{12} + H_2O.$

FOR YOU!

Dimensional Analysis

mass, time, density

$$T_{turkey} = f(m, t, k, c, \rho)\,T_0$$

temperature of the turkey °C

Thermal Conductivity

specific heat capacity

oven temperature °C

must be 'dimensionless' no units.

Buckingham π Theorem: # variables − # units = # of ways to group variables for f.

$$[J] = \frac{kg \cdot m^2}{s^2}$$

$$[m] = kg$$

$$[t] = s$$

$$[k] = \frac{W}{m \cdot K} = \left(\frac{kg \cdot m^2}{s^3}\right) \Big/ m \cdot K = \frac{kg \cdot m}{s^3 \cdot K}$$

$$[c] = \frac{J}{kg \cdot K} = \left(\frac{kg \cdot m^2}{s^2}\right) \Big/ kg \cdot K = \frac{m^2}{s^2 \cdot K}$$

kg, s, m, K

$$[\rho] = \frac{kg}{m^3}$$

$$(5 - 4) = 1$$

$$f\left(m^{x_1} t^{x_2} k^{x_3} c^{x_4} \rho^{x_5}\right) = f\left(kg^{x_1} s^{x_2} \left(\frac{kg \cdot m}{s^3 \cdot K}\right)^{x_3} \left(\frac{m^2}{s^2 K}\right)^{x_4} \left(\frac{kg}{m^3}\right)^{x_5}\right)$$

kg: $x_1 + x_3 + x_5 = 0$

s: $x_2 - 3x_3 - 2x_4 = 0$

m: $x_3 + 2x_4 - 3x_5 = 0$

K: $-x_3 - x_4 = 0$

$$\begin{bmatrix} 1 & 0 & 1 & 0 & 1 \\ 0 & 1 & -3 & -2 & 0 \\ 0 & 0 & 1 & 2 & -3 \\ 0 & 0 & -1 & -1 & 0 \end{bmatrix} \qquad \begin{bmatrix} 1 & 0 & 0 & 0 & -2 \\ 0 & 1 & 0 & 0 & 3 \\ 0 & 0 & 1 & 0 & 3 \\ 0 & 0 & 0 & 1 & -3 \end{bmatrix}$$

$x_1 = 2a$
$x_2 = -3a$
$x_3 = -3a$
$x_4 = 3a$
$x_5 = a$

$a = \frac{-1}{3}$ so that $x_2 = 1$

$$\left\{ \begin{aligned} x_1 &= 2/3 \\ x_2 &= 1 \\ x_3 &= 1 \\ x_4 &= -1 \\ x_5 &= -1/3 \end{aligned} \right.$$

$$T_t = \frac{t \cdot K}{m^{2/3} c p^{1/3}} T_0$$

$R = \frac{T_0}{T_t}$ a constant

$$t = \underbrace{\frac{c p^{1/3}}{R K}}_{C_t} m^{2/3}$$

the 'turkey' constant.

SO.... $t = C_t \cdot m^{2/3}$

$C_t \approx 0.55$