# In class activity: Mole balances

### Lecture notes for chemical reaction engineering

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## **Problems**

1. Chloral is being consumed at a rate of 10 moles per second per m<sup>3</sup> when reacting with chlorobenzene to form DDT and water in the reaction described above. In symbol form, the reaction is written as

 $A + 2 B \longrightarrow C + D$ 

Write the rates of disappearance and formation (i.e., generation) for each species in this reaction.

### Solution

- + Rate of disappearance of A:  $-r_A =$  10  $mol/m^3 \ s$
- Rate of disappearance of B:  $-r_B = 2*10 = 20 \ mol/m^3 \ s$  Rate of formation of C:  $r_C = 10 \ mol/m^3 \ s$
- Rate of formation of D:  $r_D = 10 \ mol/m^3 \ s$
- 2. A rocket engine, burns a stoichiometric mixture of fuel (liquid hydrogen) in oxidant (liquid oxygen). The combustion chamber is cylindrical, 75 cm long and 60 cm in diameter, and the combustion process produces 108 kg/s of exhaust gases. If combustion is complete, find the rate of reaction of hydrogen and of oxygen.



Figure 1: Rocket engine

#### 🅊 Solution

V= 0.2121  $m^3$ Reactions occuring: H<sub>2</sub> +  $\frac{1}{2}$  O<sub>2</sub>  $\longrightarrow$  H<sub>2</sub>O Molecular weights: H<sub>2</sub> = 2gm; O<sub>2</sub> = 16gm; H<sub>2</sub>O = 18gm

- $H_2O$  produced: 108/18 = 6 kmol/s
- $H_2$  used: 6 kmol/s
- $O_2$  used: 3 kmol/s
- 3. A human being (75 kg) consumes about 6000 kJ of food per day. Assume that I the food is all glucose and that the overall reaction is

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O, -\Delta H_r = 2816kJ/mol$$

Find man's metabolic rate (the rate of living, loving, and laughing) in terms of moles of oxygen used per m<sup>3</sup> of person per second. Assume average density of a human being to be  $1000kg/m^3$ .

$$\begin{array}{l} \ref{eq:solution} \\ \ref{eq:solution} \\ \end{tabular} We want to find \\ \\ & \quad -r_{O_2}''' = -\frac{1}{V_{person}} \frac{dN_{O_2}}{dt} \left[ \frac{molO_2 used}{m^3 of \, person \, s} \right] \\ \\ \rho_{person} = 1000 kg/m^3 \\ V_{person} = 75/1000 = 0.075 m^3 \\ \end{tabular} \\ \end{tabular} Each mole of glucose consumed uses 6 moles of oxygen and releases 2816 kJ of energy \\ \\ \\ \frac{dN_{O_2}}{dt} = \left( \frac{6000 \, kJ/day}{2816 \, kJ/mol \, glucose} \frac{6mol \, O_2}{1mol \, glucose} \right) = 12.8 \frac{molO_2}{day} \\ \\ -r_{O_2}''' = \frac{1}{0.075} \frac{12.8}{24 \cdot 3600} = 0.002 \frac{mol \, O_2 \, used}{m^3 s} \\ \end{array}$$

4. Consider the liquid phase cis – trans isomerization of 2–butene which we will write symbolically as

$$cis - CH_3HC = CHCH_3 \rightarrow trans - CH_3HC = CHCH_3$$

The reaction is first order in A ( $-r_A = kC_A$ ) and is carried out in a tubular reactor in which the volumetric flow rate, v, is constant, i.e.,  $v = v_0$ .

- 1. Sketch the concentration profile.
- 2. Derive an equation relating the reactor volume to the entering and exiting concentrations of A, the rate constant k, and the volumetric flow rate.
- 3. Determine the reactor volume,  $V_1$ , necessary to reduce the exiting concentration to 10% of the entering concentration, i.e.,  $C_A = 0.1C_{A0}$ , when the volumetric flow rate is  $10dm^3/min$  (i.e., liters/min) and the specific reaction rate, k, is 0.231/min.

