Introduction to Reactor Design, 3K4

Assignment/Tutorial 1

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Assignment objectives: math refresher; chemistry refresher; review mol balances

- Always state assumptions in this assignment, midterms and exams.
- Never use an equation by just writing it down; state its origin and all simplifying assumptions. *For example*: using the general mol balance in a batch reactor, under the assumption of a well-mixed and constant volume system, we have: $\dfrac{dN_j}{dt} = r_j V$

Question 1 [10]

1. $\displaystyle\int \frac{1}{x}\, dx =$
2. $\displaystyle\int \frac{1}{x^2}\, dx =$
3. $\displaystyle\int \frac{1}{ax+b}\, dx =$
4. $\displaystyle\int \frac{1}{\sqrt{x}}\, dx =$
5. When do we require an integration constant; and when do we not require it?

Question 2 [10]

1. A vessel contains a gas of concentration $20\,\text{mol.m}^{-3}$. The gas is stored at 375°C. Assuming this is an ideal gas, what is the pressure in the vessel measured in kPa? What assumption are you making (apart from the ideal-gas law)?
2. A constant volume batch reactor operates at 14.7 psi and 1340°F. The reactor volume is $290\,\text{ft}^3$. How many mols are in the system, assuming an ideal gas?

Question 3 [10]

Milk is pasteurized if it is heated to 63°C for 30 min, but if it is heated to 74°C it only needs 15 seconds for the same result. Find the activation energy of this sterilization process.

Recall the activation energy for a chemical reaction is the E term, and the rate constant in is given by $k = k_0 e^{\frac{-E}{RT}}$.

Hint: assume pasteurization proceeds via first-order kinetics; what is the "reactant"?

Question 4 [13]

The fermentation of an active ingredient A is to be carried out in a reactor. The reaction kinetics are given by:

$$A \longrightarrow R$$
$$-r_A = \frac{0.1C_A}{1 + 0.5C_A} \left[\frac{\text{mol}}{\text{L.min}}\right]$$

1. Consider a batch reactor filled with 750 L of reactant at $C_{A,0} = 2\,\text{mol.L}^{-1}$. How long must the reactor be operated to achieve an exit concentration of A of $0.1\,\text{mol.L}^{-1}$?

If the feed rate is continuously fed at $25\,\text{L.min}^{-1}$, with $C_{A,0} = 2\,\text{mol.L}^{-1}$. Determine the volume required for a

2. CSTR
3. PFR

to achieve an exit concentration of A of $0.1\,\text{mol.L}^{-1}$.

4. Which of the CSTR or PFR require a smaller volume?

Question 5 [7]

The gas phase reaction:

$$A \longrightarrow B + C$$

is carried out at 100°C in a 20 L constant-volume, sealed batch reactor, at atmospheric pressure. The reaction is second order: $-r_A = kC_A^2$ where $k = 2\,\text{L.mol}^{-1}.\text{min}^{-1}$.

One mole of pure A is initially placed in the reactor, which is well mixed (is this a reasonable assumption?). Determine:

1. the partial pressure due to A in the reactor
2. the concentration of A in the reactor after 5 minutes have elapsed
3. the partial pressure due to A in the reactor after 5 minutes have elapsed.

Question 6 [10]

Consider a municipal water treatment plant for a smallish community. Waste water at $32,000\,\text{m}^3.\text{day}^{-1}$, flows through the treatment plant with a mean residence time of 8 hours. Air is bubbled through the tanks, and microbes in the tank attack and break down the organic material:

$$\text{Organic waste} + O_2 \xrightarrow{\text{microbes}} CO_2 + H_2O$$

A typical entering feed has a BOD (biological oxygen demand) of $200\,(\text{mg } O_2).\text{L}^{-1}$, the effluent has a negligible BOD. Find the average rate of reaction, or decrease in BOD, in the treatment tanks.

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