This quiz reviews the lectures and homework to date and Chapters 1-4. It is closed-book, but you may use one page of notes and a calculator. Show all work and use correct units and significant figures.

1. PFR DESIGN WITH PRESSURE DROP (20)

The gas-phase, packed bed reactor used at BAMACHEM to produce chlorocorro acid is suffering excessive pressure drop. You are a university consultant meeting with Ms. Rea Akton, the catalyst vendor, Mr. N. G. Near, the reactor designer and Mr. Otto Pilot, the operations supervisor. Using the Ergun equation, suggest 5 changes that could be made to the catalyst, reactor, or operating conditions that would reduce the pressure drop. Clearly and concisely explain what you would do, why it would work, and what compromises would be made.

\[
\frac{dP}{dZ} = -\frac{G}{\rho g c_D p} \left(\frac{1 - \Phi}{\Phi^3}\right) \left[\frac{150(1 - \Phi)\mu}{D_p} + 1.75G\right]
\]

a. Decrease total mass velocity which will decrease G. Results in higher conversion but lower throughput.

b. Increase the reactor diameter which will decrease G. Would need a new reactor and heat exchange may be more difficult.

c. Increase particle diameter, Dp. Requires an expensive change in catalyst and could cause diffusion resistances.

d. Use a different catalyst or filling technique that would increase the void fraction. This would result in less catalyst in the reactor.

e. Increase pressure which will increase gas density. This has advantages such as allowing more gas flow but compressing gases is expensive and high pressure could cause mechanical problems.

f. Decrease temperature which will increase gas density. This would decrease the reaction rate and could also affect selectivity.
2. ISOTHERMAL BATCH REACTOR (40)

The elementary, reversible, gas phase reaction, \( \text{N}_2 + \text{O}_2 \leftrightarrow 2\text{NO} \), takes place in a batch reactor. The initial charge of 20 atm is 77% \text{N}_2, 15\% \text{O}_2, and 8\% inert.

Write the equations needed to calculate the conversion as a function of time. Numerical values must be assigned to each variable (other than \( x \)) and the proper units must be used. The equations should be ready to type directly into an ODE solver like POLYMATH. Demonstrate that the units are consistent.

**Additional Data:**

- \( V = 0.4 \text{ L} \)
- \( k = 1.7 \text{ L/mol·min} \)
- \( K_{eq} = 0.2 \)
- \( P = 20 \text{ atm} \)
- \( T = 500 \text{ K} \)
- \( R = 0.0821 \text{ L·atm/mol·K} \)

**Equations:**

\[
\frac{dX}{dt} = -\frac{RAV}{NA_0}
\]

**Rate Equation:**

\[
RA = -k(C_A C_B - C_C^2 / K_{eq})
\]

**Concentration Equations:**

\[
C_A = CA_0 (1 - X)
\]

\[
C_B = CA_0 \left( \frac{77}{15} - X \right)
\]

\[
C_C = CA_0 2X
\]

**Calculation:**

\[
CA_0 = \frac{ YA_0 P}{RT} = \frac{0.15 \times 20}{0.0821 \times 500} = \frac{1}{72.31} \text{ atm·mol·K} / \text{L·atm·K}
\]

\[
= 0.0731
\]

**Initial Concentration:**

\[
NA_0 = CA_0 V
\]

**Unit Consistency:**

\[
\frac{1}{\text{min}} [\text{L}] = \frac{k}{\text{mol·min}} \left( \frac{\text{mol}^2}{\text{L}^2 \cdot \text{mol}} \right) \frac{1}{\text{mol}} = \checkmark
\]
3. ISOTHERMAL CSTR (40)

The elementary, liquid phase reaction $A + B \rightarrow C$ takes place in a 200 L CSTR operating at 350 K. The feed stream is 10 L/min with 1.0 mol/L of chemical A and 2.0 mol/L of chemical B. The rate constant is 0.10 L/mol·min at this temperature. Show that the conversion of the limiting reactant is about 72%.

$\nu = 10 \frac{L}{min}$

$C_{A0} = 1 \text{ M}$

$C_{B0} = 2 \text{ M}$

$200 \text{ L}$

$350 \text{ K}$

$\chi = 0.72$

$$F_{A0} \chi + r_A V = 0$$

$$-r_A = k C_A C_B$$

$$C_A = C_{A0} (1-\chi)$$

$$C_B = C_{A0} (2-\chi)$$

$$F_{A0} = \nu C_{A0}$$

$$\frac{10 \chi}{\min} \frac{1 \text{ mol}}{L} = \frac{0.1 \chi}{\text{ mol min}} \frac{1^2 \text{ mol}^2}{L^2} \frac{200 \text{ L}}{1-\chi} \frac{2-\chi}{2-\chi} = 0$$

$$10 \chi - 20 (1-\chi)(2-\chi) = 0$$

$$7.2 - 7.2 = 0 \checkmark$$