Instructions

1. Write your name at the top of each answer sheet and on the front page of the exam questions.
2. Start each problem at the top of a new page.
3. The exam consists of three equally weighted problems.
4. Useful integrals and equations are listed beginning on page 3.
5. Return the exam questions or you will receive a grade of zero.

R = 82.06 cm^3-atm/gmole-K; R = 1.987 cal/gmole-K

The van't Hoff relation is $\frac{\partial \ln K}{\partial T} = \frac{\Delta H^\circ}{RT^2}$

Problem 1

The reaction of isobutane and linear butenes to branched C_8 hydrocarbons is used to synthesize high octane fuel additives. One such reaction is listed below.

$$\text{isobutane} + \text{1–butene} \rightleftharpoons 2,2,3\text{–trimethylpentane} \quad (1)$$

Use the data below to determine the effect of decreasing the pressure from 2.5 to 1.5 atm on the equilibrium amount of 2,2,3–trimethylpentane that forms at 470°K. The reactor feed mixture consists of a 5:1 ratio of isobutane to 1–butene.

	ΔG_f° (kcal/mol)	ΔH_f° (kcal/mol)
isobutane		
400 °K	4.58	−33.99
500 °K	14.39	−35.48
1–butene		
400 °K	23.1	−1.49
500 °K	29.39	−2.70
2,2,3–trimethylpentane		
400 °K	23.96	−55.75
500 °K	44.19	−58.29

Problem 2

Consider the series, first-order, liquid-phase reactions.

$$\mathrm{A} \xrightarrow{k_1} \mathrm{B} \xrightarrow{k_2} \mathrm{C} \xrightarrow{k_3} \mathrm{D}$$

$$\begin{aligned} r_1 &= k_1 c_A \quad k_1 = 0.95 \text{ min}^{-1} \\ r_2 &= k_2 c_B \quad k_2 = 0.10 \text{ min}^{-1} \\ r_3 &= k_3 c_C \quad k_3 = 0.30 \text{ min}^{-1} \end{aligned}$$

(a) Determine the effluent composition if the reactions are conducted in an isothermal CSTR with a residence time of $\theta = 10$ min and the feed consists of pure A with a feed concentration of $c_{Af} = 5$ gmole/liter.

(b) How would you determine the residence time in the CSTR that maximizes the production of B if the same feed concentration and temperature are used as in Part (a)?

Problem 3

Consider the gas-phase reaction

$$2\mathrm{A} \longrightarrow \mathrm{B} \qquad r = kc_A \qquad k = 3.4 \text{ sec}^{-1}$$

The feed to an isothermal PFR is pure A at 8,120 g/sec. The molecular weight of A is 58 g/gmole. The temperature is 650 K and the pressure 1.5 atm.

(a) Determine the reactor volume required for 85% conversion of A.

(b) Pure A is still fed at 8,120 g/sec at the same temperature and pressure, only now the reactor diameter is doubled. Provided the flow remains turbulent, by what factor will the inlet velocity change and by what factor will the reactor volume change for a conversion of 85%? Does the answer you give for the volume make sense?