Jacket steam: 150 psig (365.9°F saturation temperature)
Overall heat-transfer coefficient of jacket, $U$: 150 Btu/h · ft$^2$ · °F
Agitator shaft horsepower: 25 hp
Heat of reaction, $\Delta H^\circ_{\text{Rx}} = +20{,}000$ Btu/lb-mol of A (independent of temperature)

TABLE P12-6$_B$ FEED CONDITIONS AND PROPERTIES

| | *Component* | | |
|---|---|---|---|
| | *A* | *B* | *C* |
| Feed (lb-mol/hr) | 10.0 | 10.0 | 0 |
| Feed temperature (°F) | 80 | 80 | — |
| Specific heat (Btu/lb-mol · °F)* | 51.0 | 44.0 | 47.5 |
| Molecular weight | 128 | 94 | 111 |
| Density (lb$_m$/ft$^3$) | 63.0 | 67.2 | 65.0 |

* Independent of temperature. (***Ans.:*** $T$ = 199°F)
(Courtesy of the California Board of Registration for Professional & Land Surveyors.)

**P12-7$_B$** Use the data in Problem P11-4$_A$ for the following reaction.
Th elementary, irreversible, organic liquid-phase reaction

$$A + B \longrightarrow C$$

is carried out in a flow reactor. An equal molar feed in A and B enters at 27°C, and the volumetric flow rate is 2 dm$^3$/s and $C_{A0}$ = 0.1 kmol/m$^3$.

*Additional information:*

$H^\circ_A(273\text{ K}) = -20$ kcal/mol, $H^\circ_B(273\text{ K}) = -15$ kcal/mol,

$H^\circ_C(273\text{ K}) = -41$ kcal/mol

$$C_{P_A} = C_{P_B} = 15 \text{ cal/mol} \cdot \text{K} \quad C_{P_C} = 30 \text{ cal/mol} \cdot \text{K}$$

$$k = 0.01 \frac{\text{dm}^3}{\text{mol} \cdot \text{s}} \text{ at 300 K} \quad E = 10{,}000 \text{ cal/mol}$$

$$Ua = 20 \text{cal/m}^3\text{/s/K} \qquad \dot{m}_C = 50 \text{g/s}$$

$$T_{a0} = 450\text{K} \qquad C_{P_{\text{Cool}}} = 1 \text{cal/g/K}$$

**(a)** Calculate the conversion when the reaction is carried out adiabatically in one 500-dm$^3$ CSTR and then compare the results with the two adiabatic 250-dm$^3$ CSTRs in series.

The reversible reaction (part **(d)** of P11-4$_A$) is now carried out in a PFR with a heat exchanger. Plot and then analyze $X$, $X_e$, $T$, $T_a$, $Q_r$, $Q_g$, and the rate, $-r_A$, for the following cases:

**(b)** Constant heat-exchanger temperature $T_a$
**(c)** Co-current heat exchanger $T_a$ (***Ans.:*** At $V$ = 10 m$^3$ then $X$ = 0.36 and $T$ = 442 K)
**(d)** Countercurrent heat exchanger $T_a$ (***Ans.:*** At $V$ = 10 m$^3$ then $X$ = 0.364 and $T$ = 450 K)
**(e)** Adiabatic operation
**(f)** Make a table comparing all your results (e.g., $X$, $X_e$, $T$, $T_a$). Write a paragraph describing what you find.
**(g)** Plot $Q_r$ and $T_a$ as a function of $V$ necessary to maintain isothermal operation.

**(a)** What is the $\Delta H_{Rx}$ of the reaction?
**(b)** What are the inlet ignition and extinction temperatures?
**(c)** What are all the temperatures in the reactor corresponding to the inlet ignition and extinction temperatures?
**(d)** What are the conversions at the ignition and extinction temperatures?

**P12-15$_B$** The first-order, irreversible, exothermic liquid-phase reaction

$$A \rightarrow B$$

is to be carried out in a jacketed CSTR. Species A and an inert I are fed to the reactor in equimolar amounts. The molar feed rate of A is 80 mol/min.

*Additional information*

| | |
|---|---|
| Heat capacity of the inert: 30 cal/mol·°C | $\tau = 100$ min |
| Heat capacity of A and B: 20 cal/mol·°C | $\Delta H^{\circ}_{Rx} = -7500$ cal/mol |
| $UA$: 8000 cal/min·°C | $k = 6.6 \times 10^{-3}$ min$^{-1}$ at 350 K |
| Ambient temperature, $T_a$: 300 K | $E = 40{,}000$ cal/mol·K |

**(a)** What is the reactor temperature for a feed temperature of 450 K?
**(b)** Plot and then analyze the reactor temperature as a function of the feed temperature.
**(c)** To what inlet temperature must the fluid be preheated for the reactor to operate at a high conversion? What are the corresponding temperature and conversion of the fluid in the CSTR at this inlet temperature?
**(d)** Suppose that the fluid inlet temperature is now heated 5°C above the reactor temperature in part (c) and then cooled 20°C, where it remains. What will be the conversion?
**(e)** What is the inlet extinction temperature for this reaction system? (***Ans.:*** $T_0 = 87$°C.)

**P12-16$_B$** The elementary reversible liquid-phase reaction

$$A \rightleftarrows B$$

takes place in a CSTR with a heat exchanger. Pure A enters the reactor.
**(a)** Derive an expression (or set of expressions) to calculate $G(T)$ as a function of the heat of reaction, equilibrium constant, temperature, and so on. Show a sample calculation for $G(T)$ at $T = 400$ K.
**(b)** What are the steady-state temperatures? (***Ans.:*** 310, 377, 418 K.)
**(c)** Which steady states are locally stable?
**(d)** What is the conversion corresponding to the upper steady state?
**(e)** Vary the ambient temperature $T_a$ and make a plot of the reactor temperature as a function of $T_a$, identifying the ignition and extinction temperatures.
**(f)** If the heat exchanger in the reactor suddenly fails (i.e., $UA = 0$), what would be the conversion and the reactor temperature when the new upper steady state is reached? (***Ans.:*** 431 K.)
**(g)** What heat exchanger product, $UA$, will give the maximum conversion?
**(h)** Write a question that requires critical thinking and then explain why your question requires critical thinking. *Hint:* See Preface Section I.
**(i)** What is the adiabatic blowout flow rate, $v_0$?
**(j)** Suppose that you want to operate at the lower steady state. What parameter values would you suggest to prevent runaway, e.g., the upper SS?

*Additional information*

| | |
|---|---|
| $UA = 3600$ cal/min·K | $E/R = 20{,}000$ K |
| $C_{P_A} = C_{P_B} = 40$ cal/mol·K | $V = 10$ dm$^3$ |
| $\Delta H^{\circ}_{Rx} = -80{,}000$ cal/mol A | $v_0 = 1$ dm$^3$/min |
| $K_C = 100$ at 400 K | $F_{A0} = 10$ mol/min |
| $k = 1$ min$^{-1}$ at 400 K | |
| Ambient temperature, $T_a = 37$°C | Feed temperature, $T_0 = 37$°C |