1.1-1.7 The solutions for these problems are the solutions for problems 1.1-1.7 in the 2nd edition Solutions Manual.

1.8 The washing machine is a batch reactor in which a first order decay of grease on the clothes is occurring. The integrated form of the mass balance equation is:

$$C = C_0 \mathrm{e}^{-kt}$$

First, find k:

$$k = \frac{1}{t}\ln\frac{C}{C_0} = \frac{1}{1\,\text{min}}\ln\frac{C_0}{0.88C_0} = \frac{1}{1\,\text{min}}\ln\frac{1}{0.88} = 0.128\ \text{min}^{-1}$$

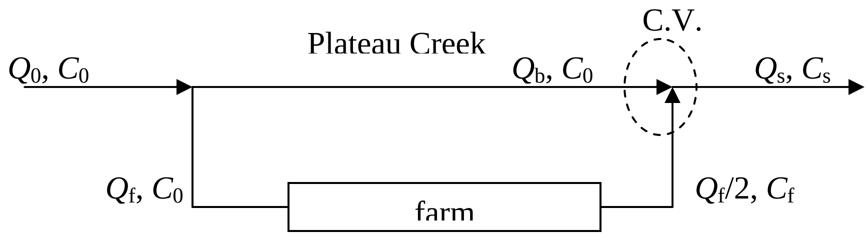
Next, calculate the grease remaining on the clothes after 5 minutes:

$$m = m_0 \mathrm{e}^{-kt} = (0.500\ \text{g})\mathrm{e}^{-(0.128\ \text{min}^{-1})(5.00\ \text{min}^{1})} = 0.264\ \text{g}$$

The grease that is not on the clothes must be in the water, so

$$C_\text{w} = \frac{0.500\ \text{g} - 0.264\ \text{g}}{50.0\ \text{L}} = 0.00472\ \text{g/L}$$

1.9



a. A mass balance around control volume (C.V.) at the downstream junction yields

$$C_s = \frac{(Q_f/2)C_f + Q_b C_0}{Q_s} = \frac{(0.5\,\mathrm{m^3/s})(1.00\,\mathrm{mg/L}) + (4.0\,\mathrm{m^3/s})(0.0015\,\mathrm{mg/L})}{(4.5\,\mathrm{m^3/s})} = 0.112\,\mathrm{mg/L}$$

b. Noting that $Q_b = Q_0 - Q_f$ and $Q_s = Q_0 - Q_f/2$ the mass balance becomes

$$(Q_f/2)C_f + (Q_0 - Q_f)C_0 = (Q_0 - Q_f/2)C_s$$

and solving for the maximum Q_f yields

$$Q_f = \frac{Q_0(C_s - C_0)}{\left(\frac{C_f}{2} - C_0 + \frac{C_s}{2}\right)} = \frac{(5.0\,\mathrm{m^3/s})(0.04 - 0.0015\,\mathrm{mg/L})}{\left(\frac{1.0}{2} - 0.0015 + \frac{0.04}{2}\,\mathrm{mg/L}\right)} = 0.371\,\mathrm{m^3/s}$$

1.10 Write a mass balance on a second order reaction in a batch reactor:

Accumulation = Reaction

$$V\frac{dm}{dt} = Vr(m) \qquad \text{where } r(m) = -km^2$$

$$\int_{m_0}^{m_t}\frac{dm}{m^2} = -k\int_0^t dt \qquad \text{so,} \quad \frac{1}{m_0} - \frac{1}{m_t} = -kt$$

$$\mathrm{k} = \frac{1}{t}\left(\frac{1}{m_\mathrm{t}} - \frac{1}{m_0}\right)$$

calculate $\mathrm{m}_{t=1}$ based on the equation's stoichiometry that 1 mole of methanol yields 1 mole of carbon monoxide

$$(100\ \mathrm{g\ CO})\left(\frac{\mathrm{mole\ CO}}{28\ \mathrm{g\ CO}}\right)\left(\frac{1\ \mathrm{mole\ CH_3OH}}{1\ \mathrm{mole\ CO}}\right)\left(\frac{32\ \mathrm{g\ CH_3OH}}{\mathrm{mole\ CH_3OH}}\right) = 114.3\ \mathrm{g\ CH_3OH}$$

so, $C_{\mathrm{CH_3OH,\ t=1}} = 200\ \mathrm{g} - 114.3\ \mathrm{g} = 85.7\ \mathrm{g}$

and $k = \dfrac{1}{1\,\mathrm{d}}\left(\dfrac{1}{85.7\ \mathrm{g}} - \dfrac{1}{200\ \mathrm{g}}\right) = 0.00667\ \mathrm{d^{-1}g^{-1}}$

1.11-1.13 The solutions for these problems are the solutions for problems 1.8-1.10 in the 2nd edition Solutions Manual.

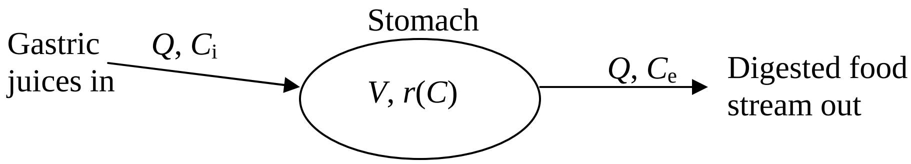
1.14 Calculate the pipe volume, V_r, and the first-order rate constant, k.

$$V_{\mathrm{p}} = \frac{\pi\,(3.0\ \mathrm{ft})^2\,(3400\ \mathrm{ft})}{4}\ 24{,}033\ \mathrm{ft}^3 \qquad \text{and} \qquad k = \frac{\ln 2}{\mathrm{t}_{1/2}} = \frac{\ln 2}{(12\ \mathrm{min})} = 0.0578\ \mathrm{min}^{-1}$$

For first-order decay in a steady-state PFR

$$C_0 = C\mathrm{e}^{-kt} = (1.0\ \mathrm{mg/L})\exp\left[(0.0578\,\mathrm{min}^{-1})(24{,}033\ \mathrm{ft}^3)\left(\frac{\mathrm{min}}{10^4\ \mathrm{gal}}\right)\left(\frac{\mathrm{gal}}{0.134\ \mathrm{ft}^3}\right)\right] = 2.82\ \ \mathrm{mg/L}$$

1.15 The stomach acts like a CSTR reactor in which a first order decay reaction is occurring.



$V = 1.15$ L, $k = 1.33$ hr^{-1}, $Q = 0.012$ L/min, $m_0 = 325$ g, $t = 1$ hr

Accumulation = In – Out + Reaction

$$V\frac{dC}{dt} = QC_i - QC_e + Vr(C)$$ where $r(C) = -kC$, $C_i = 0$, and $C = C_e$

so, $$\int_{C_0}^{C}\frac{dC}{C} = -\left(\frac{Q}{V}+k\right)\int_0^t dt$$

$$C = Ce^{-\left(\frac{Q}{V}+k\right)t} = \left(\frac{325\text{ g}}{1.15\text{ L}}\right)\exp\left(-\left(\frac{(0.012\text{ L/min})(60\text{ min/hr})}{1.15\text{ L}}+1.33\text{ hr}^{-1}\right)(1\text{ hr})\right)$$

$C = 40.0$ g/L and then $m_{t=1hr} = (40.0\text{ g/L})(1.15\text{L}) = 46.0$ g

1.16-1.20 The solutions for these problems are the solutions for problems 1.11-1.15 in the 2nd edition Solutions Manual.

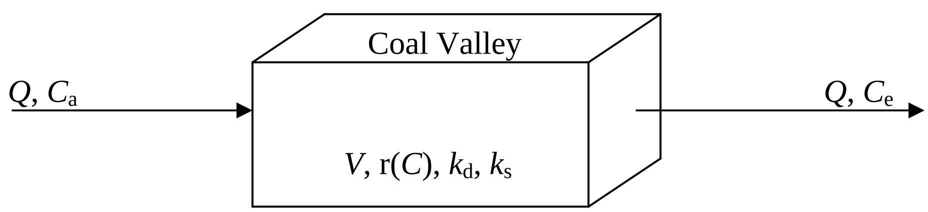
1.21 **a.** Calculate the volume that 1 mole of an ideal gas occupies at 1 atm and 20 °C.

$$V = \frac{nRT}{P} = \frac{(1\,\text{mole})(0.082056\,\text{L}\cdot\text{atm}\cdot\text{mol}^{-1}\cdot\text{K}^{-1})(293.15\,\text{K})}{1\,\text{atm}} = 24.04\,\text{L} \;\text{ then}$$

ppmv = (mg/m^3)(24.04 L/mol)(mol wt)$^{-1}$ = (60 mg/m^3)(24.04 L/mol)(131 mol/g)$^{-1}$

= 11.0 ppmv

b. Draw a sketch of the valley as the CSTR, non-steady state control volume.



k_d = radioactive decay rate constant = (ln2)/$t_{1/2}$ = (ln2)/(8.1 d) = 0.0856 d^{-1}
k_s = sedimentation rate constant = 0.02 d^{-1}

c. The mass balance for the CSTR control volume is

$$V\frac{\mathrm{d}C}{\mathrm{d}t} = QC_a - QC_e + V\mathrm{r}(C) = QC_a - QC_e - V(k_d C_e + k_s C_e)$$

Assuming C_a = 0 and integrating yields

$$t = \frac{1}{\left(Q/V + k_d + k_s\right)} \ln\frac{C_0}{C} = \frac{1}{\left(\dfrac{\left(6\times10^5\,\dfrac{\text{m}^3}{\text{min}}\right)\left(\dfrac{60\cdot 24\ \text{min}}{\text{d}}\right)}{\left(2.0\times10^6\ \text{m}^3\right)} + 0.0856\text{d}^{-1} + 0.02\text{d}^{-1}\right)} \ln\left(\frac{11.0}{1\times10^{-5}}\,\text{ppmv}\right)$$

t = 0.0322 d = 46.4 min

1.22 **a.**

$$m_{\text{NaOH}} = 2\left(\frac{8.00\,\text{mg}}{\text{L}}\right)\left(\frac{\text{mmole}}{98\,\text{mg}}\right)\left(\frac{40\text{mg}}{\text{mmole}}\right)(1.00\,\text{L}) = 6.53\,\text{mg NaOH}$$

b. The reaction (P1.3) is second-order (see the rate constant's units) so that

$$\frac{\text{d}C_{\text{H}^+}}{\text{d}t} = -kC_{\text{H}^+}C_{\text{OH}^-} = -\text{k}{\text{C}_{\text{H}^+}}^2$$

After integration and noting that at $t = t_{1/2}$, C = $C_0/2$, the equation can be written

$$t_{1/2} = \frac{1}{kC_0} = \frac{1}{\left(1.4\times 10^{11}\,\frac{\text{mol}}{\text{L}\cdot\text{s}}\right)\left(2\left(\frac{8.00\,\text{mg}}{\text{L}}\right)\left(\frac{\text{mmole}}{98\,\text{mg}}\right)\right)} = 4.38\times 10^{-8}\ \text{seconds}$$

Therefore, neutralization occurs almost instantly.

1.23 – 1.37 The solutions for these problems are the solutions for problems 1.16-1.30 in the 2nd edition Solutions Manual.