Problem Set 3—Key

CENG 340–Introduction to Environmental Engineering
Instructor: Deborah Sills

September 17, 2013

Due Date

Wednesday 25 September, in class.

Learning Goals

1. Write and apply equilibrium equations to acid-base, precipitation-dissolution, and and sorption reactions.
2. Apply kinetic equations to determine reaction times.
3. Use the law of conservation of mass to write and apply a mass balance expression.

Questions

1. $C_0 = 400\ \frac{mg}{L}$ $C\,\text{after}\,19y = 400\ \frac{mg}{L}$

   (a) Try a zero order rate equation:

   $$\frac{dC}{dt} = -k$$

   After integration:

   $$C = C_0 - kt$$

   where $C_0 = 400\ \frac{mg}{g}$
   $C = 20\ \frac{mg}{g}$
   $t = 19$ year

   Solve for $k = 20\ t_{-1}$, and substitute k into the integrated zero rate equation above to obtain

$$\mathrm{C} = \mathrm{C_0} - 20\,\mathrm{year}^{-1} \times 20\,\mathrm{year} = 0$$

Answer: Yes the engineer is correct if the degradation rate is zero order.

(b) To find the "worst-case scenario," calculate the concentration of the pollutant after twenty years using a first order and second order rate equation.

First Order:

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

Solve for k:

$$\mathrm{k} = -\frac{\ln\frac{\mathrm{C}}{\mathrm{C_0}}}{\mathrm{t}} = -\frac{\ln\frac{20}{400}}{19\,\mathrm{y}} = 0.16\,\mathrm{y}^{-1}$$

Use k and solve for the time it will take to for $\mathrm{C} = 1\ \frac{\mathrm{mg}}{\mathrm{kg}}$, assuming first-order kinetics:

$$\mathrm{t} = -\frac{\ln\frac{\mathrm{C}}{\mathrm{C_0}}}{\mathrm{k}} = -\frac{\ln\frac{1}{400}}{0.16\,\mathrm{year}^{-1}} = 37\,\mathrm{y}$$

Second Order:

$$\mathrm{C} = \frac{\mathrm{C_0}}{1 + \mathrm{C_0 kt}}$$

Rearrange and solve for k:

$$\mathrm{k} = \frac{\frac{1}{\mathrm{C}} - \frac{1}{\mathrm{C_0}}}{\mathrm{t}} = \frac{\left(\frac{1}{20} - \frac{1}{400}\right)\frac{\mathrm{kg}}{\mathrm{mg}}}{19\,\mathrm{y}} = 0.003\,\frac{\mathrm{kg}}{\mathrm{mg} \times \mathrm{y}}$$

Use k and solve for the time it will take for $\mathrm{C} = 1\ \frac{\mathrm{mg}}{\mathrm{kg}}$, assuming second-order kinetics:

$$t = \frac{\frac{1}{C} - \frac{1}{C_0}}{k} = \frac{\left(\frac{1}{1} - \frac{1}{400}\right)\frac{kg}{mg}}{0.003\,\frac{kg}{mg \times y}} = 333\,y$$

In conclusion the "worst-case scenario" is second order, in which case, it would take 333 y for the pollutant to degrade. However, first order is more likely.

2. blah blah