

Problem Set 1

Issued: 02/07/06

Due: 02/16/06

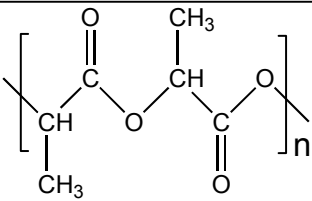
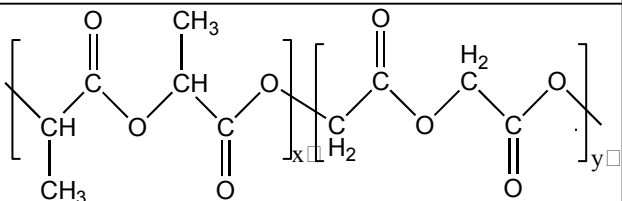
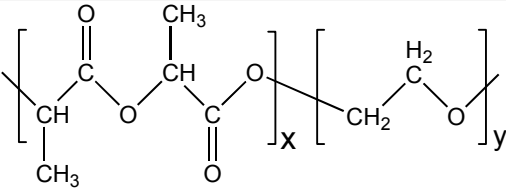
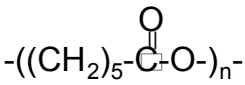
10 points/problem

20.462J/3.962J

Spring 2006

1. Listed in the table below are chemical and schematic structures of poly(L-lactide) and a number of derivatives of this polymer.

- Using physicochemical criteria, predict the hierarchy of degradation rates for these materials. Provide a concise but thorough explanation of your ranking. State any assumptions you make.
- State 2 physical properties/parameters you would measure for each polymer to make your ranking more accurate, and explain your choices.
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Polymer	Chemical structure	microstructure
Poly(L-lactide)	 $\left[\text{CH}(\text{CH}_3) - \text{C}(=\text{O}) - \text{O} - \text{CH}(\text{CH}_3) - \text{C}(=\text{O}) \right]_n$	Semicrystalline
Poly(lactide-co-glycolide)	 $\left[\text{CH}(\text{CH}_3) - \text{C}(=\text{O}) - \text{O} - \text{CH}(\text{CH}_3) - \text{C}(=\text{O}) \right]_x \left[\text{C}(\text{H}_2) - \text{C}(=\text{O}) - \text{O} - \text{C}(\text{H}_2) - \text{C}(=\text{O}) \right]_y$	amorphous
Poly(lactide-b-ethylene oxide)	 $\left[\text{CH}(\text{CH}_3) - \text{C}(=\text{O}) - \text{O} - \text{CH}(\text{CH}_3) - \text{C}(=\text{O}) \right]_x \left[\text{CH}_2 - \text{C}(\text{H}_2) - \text{O} \right]_y$	Semicrystalline
polycaprolactone	 $-\left((\text{CH}_2)_5 - \text{C}(=\text{O}) - \text{O} \right)_n -$	semicrystalline

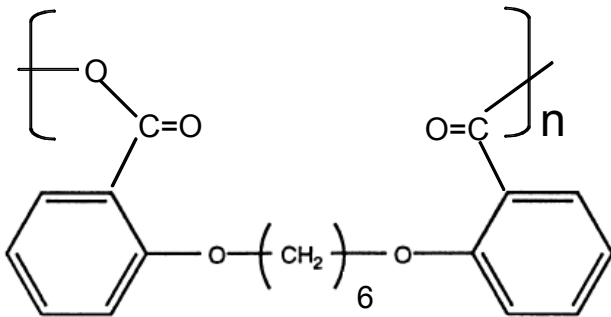
2. Given below are data from *in vitro* degradation experiments on poly(lactide-co-glycolide) and polycaprolactone (C. Pitt and Z.-W. Gu, *J. Contr. Rel.* **4**, 283-292 (1987)). Solid samples of each polymer (films 2 cm x 2 cm x 1.0 mm) were prepared; samples were incubated for the defined time periods in phosphate buffered saline pH 7.4. After incubation, each sample was washed with pure water, dried under vacuum, and then the average molecular weight of polymer chains in the samples was measured using gel permeation chromatography.
- Based on the data and experimental details, are these polymers exhibiting bulk or surface erosion?
 - Using the given data, calculate the effective rate constant for degradation of each polymer. For each polymer, explain whether the data allows you to distinguish whether the degradation is autocatalytic or non-autocatalyzed.
 - What is the maximum useful lifetime you would expect for an implanted device fabricated from each of these polymers given your calculations above, assuming that degradation kinetics of these materials are similar *in vivo*? (Explain your answer).

time (hr)	PLGA MW (g/mole)	PCL MW (g/mole)
0	24600	61800
500	9600	58700
1000	3400	56100
1500	1600	53500
2000	900	51000

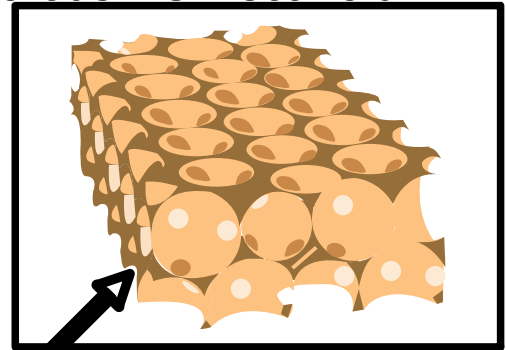
3. Göpferich erosion theory:

- a. Does Göpferich erosion theory account for autocatalysis during polymer degradation/erosion?
- b. Your research team at a startup company is working on using biodegradable polymers as scaffolds to promote bone regeneration. You have found that a polyanhydride, poly(carboxyphenoxyhexane) (PCH, structure shown below), has good mechanical properties for this application. However, porous bone scaffolds with mean strut dimensions of $250\ \mu\text{m}$ (as illustrated below) degrade by surface erosion and this causes the scaffold to loosen in its position when implanted at a bone defect. Show that the erosion number calculated for this situation agrees with the experimental observation.
- c. You'd like to engineer your PCH scaffolds to degrade by bulk erosion. Your colleagues suggest that the problem could be overcome by blending PCH with poly(ethylene glycol), which will phase separate and raise the average diffusion constant of water in the matrix to a value one tenth that of water's natural self-diffusion coefficient (water diffusion in water). Will this drive the scaffold to erode by a bulk mechanism? (Defend your answer with a calculation). An alternative proposal is to make the struts of the scaffold thinner. Which route would you pick and why?

PCH structure



Porous PCH scaffold



$250\ \mu\text{m}$ wide-struts

Data for PCH:

$$\rho = 1.05\ \text{g/cm}^3$$

$$\text{degradation rate constant } k = 1.9\ \text{s}^{-1}$$

$$D_{\text{H}_2\text{O}} (\text{diffusion coefficient of water in PCH}) = 1 \times 10^{-8}\ \text{cm}^2\ \text{s}^{-1}$$

Figure by MIT OCW.