Welcome to 3.091

Lecture 29
November 22, 2004
\[
\begin{align*}
(1) & \quad \text{OH}^\cdot + \text{C=CH}_2 \\
\text{Initiation} & \\
(1') & \quad \text{HO-C-C}^\cdot \\
(2) & \quad \text{HO-C-C-C-C}^\cdot \\
\text{Growth} & \\
(3) & \quad \text{HO-C-C-C-C-C}^\cdot \\
(n) & \quad \text{HO-C-C-C-C-C-\ldots-C-C-C}^\cdot + \text{OH}^\cdot \\
\text{Termination} & \\
(n') & \quad \text{HO-C-C-C-C-C-\ldots-C-C-C-OH} \\
\end{align*}
\]
View as acid/base reaction

Terephthalic acid

HOCH₂CH₂OH
Ethylene glycol
(1,2-Ethanediol)

\[
\text{A polyester (Dacron, Mylar)} \quad + \quad n \text{ H}_2\text{O}
\]

poly(ethylene terephthalate) PET
<table>
<thead>
<tr>
<th>Structure</th>
<th>Trade Name or Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>(-\text{NH}-(\text{CH}_2)_6\text{-NH-CH}_2\text{-NH-}(\text{CH}_2)_4\text{-C-})_n)</td>
<td>Nylon 6, 6</td>
</tr>
<tr>
<td>(-\text{NH}-(\text{CH}_2)_6\text{-NH-CH}_2\text{-NH-}(\text{CH}_2)_5\text{-C-})_n)</td>
<td>Nylon 6, 10</td>
</tr>
<tr>
<td>(-\text{NH}-(\text{CH}_2)_5\text{-C-})_n)</td>
<td>Nylon 6</td>
</tr>
<tr>
<td>(-\text{NH-CH}_2\text{-CH}_2\text{-NH-}(\text{CH}_2)_10\text{-C-})_n)</td>
<td>Qiana</td>
</tr>
<tr>
<td>(-\text{NH-CH}_2\text{-CH}_2\text{-NH-}(\text{CH}_2)_10\text{-C-})_n)</td>
<td>Kevlar</td>
</tr>
<tr>
<td>(-\text{O-CH}_2\text{CH}_2\text{-O-C-})_n)</td>
<td>Dacron, Mylar</td>
</tr>
<tr>
<td>(-\text{O-CH}_2\text{-CH}_2\text{-O-C-})_n)</td>
<td>Kodel</td>
</tr>
<tr>
<td>(-\text{O-CH}_2\text{-CH}_2\text{-O-C-})_n)</td>
<td>Lexan</td>
</tr>
<tr>
<td>(-\text{O-Si-})_n)</td>
<td>silicone rubber</td>
</tr>
</tbody>
</table>
amino group

Carbonyl group
polyvinyl acetate
1. PETE

poly(ethylene terephthalate) (PET)

Invented by J.R. Whinfield and J.T. Dickson, 1940.
Uses: clothing, plastic films, plastic bottles

2. HDPE

high-density polyethylene (HDPE)

Uses: plastics of all kinds, high-strength fibers

3. PVC

poly(vinyl chloride)

Invented by Waldo Semon, 1926.
Uses: water pipes, LP records, vinyl car tops

4. LDPE

low-density polyethylene (LDPE)

Invented by Eric Fawcett and Reginald Gibson, 1935.
Uses: plastic films, bags
Hermann Staudinger 1922 (Nobel 1953)

[CH₂=CH]ₙ
CH₃

polypropylene (PP)

Invented by Robert L. Banks and J. Paul Hogan, 1951.
Uses: fibers for rope, indoor-outdoor carpeting, plastics

[CH₂=CH]ₙ

polystyrene (PS)

Invented by Eduard Simon, 1839.
Uses: rigid plastics of all kinds, polystyrene foams
Hermann Staudinger 1922 (Nobel 1953)

Anything else, including items made from more than one kind of polymer
nylon rope pull:

* beaker synthesis of nylon 6,6 by condensation polymerization:
  
  hexamethylene diamine + adipic acid
  \[ \Rightarrow \text{nylon 6,6} + \text{water} \]

* industrially this reaction is conducted at 280°C in the absence of solvents

* lab demo uses two immiscible solvents (water and hexane) and dissolves a reactant in each: reaction occurs only at the interface

\[
\begin{align*}
H_2N-(CH_2)_6-NH_2(aq) + HO_2C-(CH_2)_4-CO_2H_{(hexane)} & \Rightarrow -NH(CH_2)_6NH-C(CH_2)_4C- + H_2O \\
\text{O} & \quad \text{O}
\end{align*}
\]
Interfacial Polymerization of Nylon 6,10

- Reaction occurs only at the interface
- Very fast reaction
- nylon films are not made this way for 3 reasons: low molecular weight distribution, and molecular orientation in fiber
pattern of adoption

wonder

substitution

innovation

concern
At breakfast, your wife pours you a cup of coffee; the handle she takes hold of on the percolator is made Bakelite, as well as the button under the table she presses for service, and the twinline plug from which are carried the wires to the toaster.
plastic

- the Greek πλασσεῖν = to shape
  ☎ cognates include “potter”
  ☎ πλαστικός = can be shaped (malleable?)

- Samuel Johnson wrote:

  “Benign Creator, let Thy plastick hand
  Dispose its own effect.”
American Plastic
A Cultural History

Jeffrey I. Meikle
US annual production of polymers:
100 billion lb = 50 million tons
3 - 4 million tons recycled

cf. steel - US annual production:
140 million tons
- 80 million tons virgin metal
- 60 million tons recycled scrap
US annual production of polymers:
100 billion lb = 50 million tons
3 - 4 million tons recycled

cf. aluminum - US annual production:
4 million tons
1 million tons recycled
62% return rate on UBCs (DFE)
Wallace Carothers

* b. April 27, 1896, Burlington, Iowa
* B.S., Tarkio College (gen. sci. & Eng.)
* Ph.D., U. of Illinois
* lecturer Harvard
* head of fundamental research in organic chemistry at DuPont; synthesis of long-chain molecules similar to cellulose and silk
* invented neoprene 1931: synthetic rubber
* invented nylon 1937: synthetic fiber
* m. February 1936
* d. April 29, 1937, Philadelphia

62 technical publications 69 patents