Type them into questions box!

“Why am I muted?”
Don’t worry. Everyone is muted except the presenter and host.
Thank you and enjoy the show.

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Keck Graduate Institute


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Thursday, April 25, 2018

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Experts

- Vincent Rotello
  University of Massachusetts at Amherst
- Christopher England
  ACS Publications

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Experts

- Nancy Jensen
  American Chemical Society
- Joerg Schuster
  American Chemical Society

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Free Resources from CCEW!

Articles and Activities

- Getters in a Metal-Organic Framework (Science News Letter)
- Developing Bandannas... for the officers
- How much carbon dioxide is in the air at various altitudes
- Healing for kids and mice
- Using the cell cycle
- The Future of Colloidal Nanomaterials
- Calcium carbonate is a chemical found in shells, teeth, and many other materials. It can be used to fight bacteria with common liquid.
- Water Cycle: Woodstock
- Use absorbent beads to help you remember the water cycle
- Studies in the Wetlab (School Chemistry)
- Carbon Dioxide: Cause and Solution
- Stop students from being duped by carbon dioxide effects.
- Natural Resources & Synthesis of Materials
- Students are making sense of the potential and the future of nanotechnology
- Students in AP Chemistry (Schools)
- Chemistry Connections on Climate Change
- Resources to teach global warming and climate change in your chemistry classrooms.
- ACS Student Chemists from ACS Green Chemistry Institute
- From Student Chemists for Plastic Pollution Initiative (SCPP)

Videos

- The ABCs of Ocean Acidification
- How Bacteria Make it Rain
- Should You Pee on a Jellyfish Sting?
- Do Mega Sharks Still Exist?

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Join us in celebrating Chemists Celebrate Earth Week 2018 by watching these webinars on sustainability and the environment! Want to share your passion for chemistry? Visit us at www.acs.org/ccew to learn how to get involved.

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“Riding the Wave of Green Chemistry: How to Enhance Awareness of Plastics in the Ocean”

Jane Wissinger
Professor of Chemistry, University of Minnesota, and Senior Principle Investigator, Center for Sustainable Polymers

Reuben Hudson
Research Professor, Colby College

Slides available now and an invitation to view the edited recording will be sent when posted.

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This ACS Webinar is co-produced with ACS Green Chemistry Institute, ACS Professional Education, and Chemists Celebrate Earth Week
Riding the Wave of Green Chemistry: How to Enhance Awareness of Plastics in the Ocean

Overview

- Experiments developed for the K-12 & college curriculum which introduce:
  - Plastics in society
  - Polymer basics
  - Green/sustainable chemistry solutions
  - (New) sustainable materials

- Feedback from students/teachers

- Resources
Today, how many kilograms of plastics does an average person in North America consume each year?

- 5 kg (11 lbs)
- 25 kg (55 lbs)
- 50 kg (110 lbs)
- 75 kg (165 lbs)
- 100 kg (220 lbs)

Plastics in Society – Attention Grabbers

World Economic Forum: “Rethinking the future of plastics” January 2016

- Today, **95% of plastic packaging** material value, or $80-120 billion annually, is **lost to the economy after a short first use**.

- More than 40 years after the launch of the first universal recycling symbol, only **14% of plastic packaging is collected for recycling**.

- In a business-as-usual scenario, the ocean is expected to contain 1 ton of plastic for every 3 tons of fish by 2025, and **by 2050, more plastics than fish (by weight)**.

http://www3.weforum.org/docs/WEF_The_New_Plastics_Economy.pdf

Plastics in the Ocean – Attention Grabbers

- Currently 250 million metric tons of plastic in the ocean; 5 trillion pieces

- Hazardous to marine life

- Studies show birds are ingesting (Midway-CNN video report)

- Studies show fish are ingesting

- We are ingesting marine life with microplastics

https://cen.acs.org/materials/polymers/Fighting-ocean-plastics-source/96/16
Plastics in the Ocean

Sperm Whale had 64 pounds of plastic & waste in its stomach

- Typical diet of giant squid
- This whale:
  - Plastic bags
  - Netting
  - Plastic water container
- Died of peritonitis and rupture of digestive system


POLYMER CHEMISTRY
GREEN/SUSTAINABLE CHEMISTRY
Polymer Basics and Unique Properties

High School
- Definitions
- Size, variety
- Representations
- Tensile testing
- UV/Smartphone apps

![Caprolactone Monomer](image1.png)

High Began
- Classification of polymers
- Representations
- Copolymers (block)
- Calculation of $M_n$
- $^1H$ NMR spectroscopy
- IR and $^{13}C$ NMR
- UV spectroscopy

Green Chemistry Solutions

- 12 Principles – Prevent pollution!
- Use of renewable feedstocks
- Safer solvents/reaction conditions
- **Design for degradation** (biodegradable; compostable)

![Corn Starch to PLA](image2.png)

http://makingsociety.com/2013/08/materialmatters-series-n1-pla-plastic/
Renewable Triblock Polymer Experiment

- Based on publication\(^1\) and modified for organic chemistry laboratory
- Renewable monomers\(^2\)
- Triblock for tunability and discovery-based\(^3\)
- Interesting mechanical properties

Renewable Triblock Polymer Experiment

Day 1: Synthesis of 2 different homopolymers

\[ \text{initiator} + \text{monomer} \xrightarrow{\text{catalyst}} \text{homopolymer} \]

- \( \text{\( \delta \)-decalactone, } x = 4 \)
- \( \text{\( \delta \)-dodecalactone, } x = 6 \)

\[ \text{poly}(\text{\( \delta \)-decalactone}), \ x = 4 \]
\[ \text{poly}(\text{\( \delta \)-dodecalactone}), \ x = 6 \]

Day 2: Triblock formation adding L-Lactide

\[ \text{homopolymer} + \text{L-lactide} \xrightarrow{\text{Sn(Otig)_2}} \text{triblock polymer} \]

- Use initiator peaks to approximate \( M_n \) and integrations to determine size of each block polymer
- IR – distinct C=O
- \( ^{13}\text{C} \) NMR – distinct C=O
Renewable Triblock Polymer Experiment

Students design mechanical/physical property testing

- **Flexibility (% PLLA)**

- **Strength** - 1 inch x 0.5 inch strip (~0.5 g) could hold 290 g of clamps and others

- **Degradation** - place in aqueous NaOH solution for minutes, retest strength

- **Adhesion**

Dyeing to Degrade: A Bioplastics Experiment

- Renewable, non-toxic components
- Citric acid, glycerol, tapioca root starch
- Three combinations results in three different structural polymers
- FDA approved yellow dye 5 allows degradation studies

<table>
<thead>
<tr>
<th>Sample 1: Starch and Citric Acid</th>
<th>Sample 2: Starch and Glycerol</th>
<th>Sample 3: Glycerol and Citric Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Sample 1" /></td>
<td><img src="image2" alt="Sample 2" /></td>
<td><img src="image3" alt="Sample 3" /></td>
</tr>
</tbody>
</table>

FDA approved yellow dye 5 allows degradation studies

*manuscript in preparation*
Dyeing to Degrade: A Bioplastics Experiment

- Degradation in aqueous 1 M NaOH (dye stable)
- Release of dye followed by UV Spectrometer or Smartphone App
- Beer’s Law plots, graphing, Le Chatelier’s principles, polymer structures, plastics in society

Polymeric Medical Sutures: An Exploration of Polymers and Green Chemistry

**Part 1:** Drawing Sutures Using Polycaprolactone (PCL)

**Part 2:** Tie-Ability and Tensile Strength Testing

**Part 3:** Testing Degradability of Sutures

*Connection: Absorbable sutures → biodegradable polymers
Non-absorbable sutures → non-degradable polymers*


https://csp.umn.edu/labs/
**Student Feedback**

“I enjoyed learning about renewable and degradable polymers by performing this experiment.” (Fall 2017, 256 responses)

“The material associated with the sustainable polymer experiment enhanced my awareness of plastics in the ocean.” (Spring 2018, 230 responses)

“I think this was an interesting way to introduce the concept of sustainability as increased waste and plastic use is a current issue that is good for us to learn about.” – Ochem student 2014

---

**Green & Sustainable Chemistry Workshop for High School Teachers – Summer 2017**

Which green chemistry/sustainability lecture content are you likely to add to your curriculum?

- Pillars of Sustainability
- 12 Principles of Green Chemistry
- Biomimicry
- Plastics in the Environment
- Toxic Release Inventory (TRI) exercise
- Green Chemistry Challenge Awards
- Other
K-12 Outreach: Lobster Shells to Plastic Objects
Of the 320 million tons of plastic produced each year, what percent is sourced from biomass?

- 1 percent
- 2 percent
- 5 percent
- 10 percent
- 25 percent

https://www.european-bioplastics.org/market
Chitin and Chitosan

Durable Polymer
Earth Abundant

Inexpensive
Which of the following polymers is most expensive (kilogram scale, Alibaba):

- low density poly propylene
- polystyrene
- chitin
- poly lactic acid
Processing – in the lab


Processing – in the classroom

Green Chemistry Perspective

Renewable Resources

Molding Process

Benign Solvent:
dilute, aqueous acetic acid

Drying

Compostable

Design For Degradation

Durable Pieces

Small, single layer chitosan piece

Small, triple layer chitosan piece

Small, saw dust-filled chitosan piece

Large, single layer chitosan piece
Why we care

How does trash make it to the ocean?

How can the ocean stem tide of trash?
Conclusions: Polymer content for all levels

- Topic **relevant and engaging** to all levels
- **ACS major accreditation** includes macromolecules
- Tunable properties enable **inquiry based pedagogies**
- Exploring mechanical properties covers **engineering principles** (next generation science standards)
- Awareness → Science → Solutions

More to think about

- Reduction of single-use items
- More infrastructure for collecting/recycling waste
- ‘Mining’ oceans for discarded plastic to recycle or recover energy
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- **Triblock**
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  - Tomohiro Kubo

- **Dyeing to Degradе**
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  - Constance Anderson
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