Green Chemistry Replacements for General and AP

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Green Chemistry Kits

- Recycling Polylactic Acid to Make a Household Surface Cleaner
- Investigating the Toxicity of Road Deicers
- Design and Function: Blackberry Solar Cell
- Ash Water Titration

beyondbenign
green chemistry education

Non-profit organization founded in 2007 by Dr. John Warner and Dr. Amy Cannon, located north of Boston (Wilmington, MA).

Mission:

Beyond Benign's mission is to equip educators, scientists, and citizens with the tools to teach and practice green chemistry to achieve a sustainable society.

Vision:

Beyond Benign envisions a world where scientists and citizens enter the workforce with the skills to design and choose greener, sustainable technologies that spur the innovation economy.

www.beyondbenign.org

BB Programs

K-12 Curriculum & Training

- Green Chemistry curriculum
- Green math curriculum
- Biotechnology curriculum
- Teacher training institutes/workshops
- On-line course

Community Engagement

- College Student Outreach Fellows
- On-site field trips
- Outreach experiences and events

Green Chemistry Commitment

- Green Chemistry Education webinar series
- GC resources for higher education
- Toxicology in the chemistry curriculum

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K-12: Core Philosophies

- ✓ Teachers teaching teachers
- ✓ Classroom tested teaching materials
- ✓ Classroom support
- ✓ Hands-on, inquiry-based activities
- ✓ Science for all in an interdisciplinary format
- ✓ Open Access education materials
- ✓ Industry partnerships
- ✓ Neutrality

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Grouping Elements Game

- Metals
- Non-metals
- Noble gases
- Atomic mass
- _*Now let's think about a little more properties of materials*_
- Melting Point
- Conductivity
- Flammability
- Toxicity
- Environmental impact

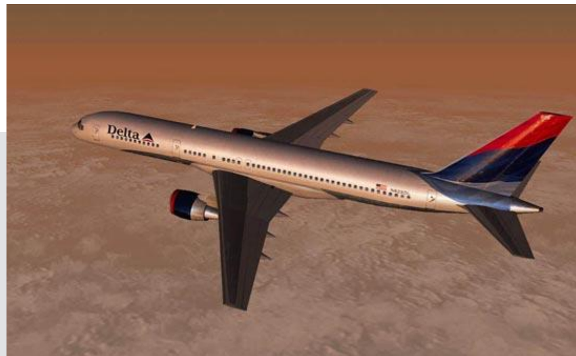
Risk = Exposure X Hazard

Lab Safety focuses on Exposure

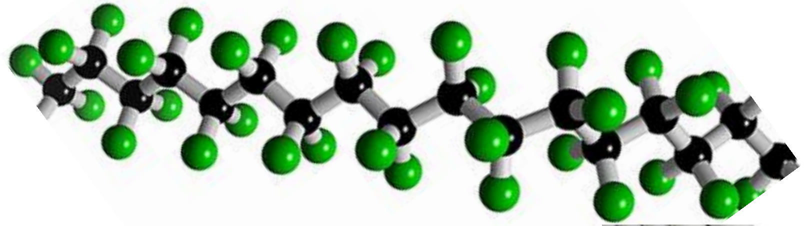
- Keeping students safe in lab (PPE, eye wash stations, showers, etc)
- Lab protocols
- Proper chemical storage
- Proper disposal of hazardous materials

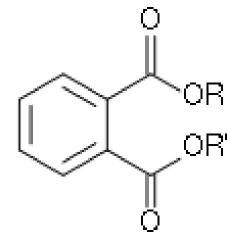
Traditional Risk Reduction Targets Exposure

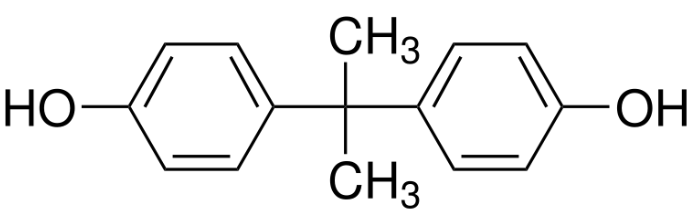
Accidents still happen!
Let’s think about everyday hazards

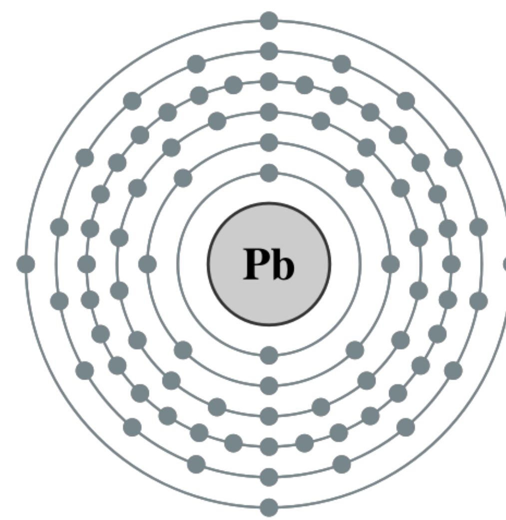


Unintended Consequences and Hazards









Green chemistry addresses the Hazard

- Keeping students safe in lab by limiting/eliminating the hazardous chemicals used in the lab.
- Challenging students to question lab protocols (are we using the safest materials we can?)
- Preventing the creation of hazardous waste in the first place
- Reducing costs associated with ordering, transporting and storing hazardous chemicals
- Many more considerations

Risk = Exposure x Hazard

Green Chemistry is the *design* of chemical products and processes that reduce or eliminate the *use and/or generation* of hazardous substances.

Chemists and materials scientists have the greatest potential to impact pollution prevention.

The Twelve Principles of Green Chemistry

1. **Prevention.** It is better to prevent waste than to treat or clean up waste after it is formed.

2. **Atom Economy.** Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.

3. **Less Hazardous Chemical Synthesis.** Whenever practicable, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment.

4. **Designing Safer Chemicals.** Chemical products should be designed to preserve efficacy of the function while reducing toxicity.

5. **Safer Solvents and Auxiliaries.** The use of auxiliary substances (solvents, separation agents, etc.) should be made unnecessary whenever possible and, when used, innocuous.

6. **Design for Energy Efficiency.** Energy requirements should be recognized for their environmental and economic impacts and should be minimized. Synthetic methods should be conducted at ambient temperature and pressure.

7. **Use of Renewable Feedstocks.** A raw material or feedstock should be renewable rather than depleting whenever technically and economically practical.

8. **Reduce Derivatives.** Unnecessary derivatization (blocking group, protection/deprotection, temporary modification of physical/chemical processes) should be avoided whenever possible .

9. **Catalysis.** Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.

10. **Design for Degradation.** Chemical products should be designed so that at the end of their function they do not persist in the environment and instead break down into innocuous degradation products.

11. **Real-time Analysis for Pollution Prevention.** Analytical methodologies need to be further developed to allow for real-time in-process monitoring and control prior to the formation of hazardous substances.

12. **Inherently Safer Chemistry for Accident Prevention.** Substance and the form of a substance used in a chemical process should be chosen so as to minimize the potential for chemical accidents, including releases, explosions, and fires.

Connections to NGSS

Cross-Cutting Concepts

- Interdependence of Science, Engineering and Technology
- Influence of Engineering, Technology and Science on Society & the Natural World
- Systems & System Models

Practices

- Asking Questions & Defining Problems
- Planning & Carrying Out Investigations
- Constructing Explanations & Designing Solutions

NEXT GENERATION SCIENCE STANDARDS

Green Chemistry Kits

- Recycling Polylactic Acid to Make a Household Surface Cleaner
- Investigating the Toxicity of Road Deicers
- Design and Function: Blackberry Solar Cell
- Ash Water Titration

Recycling PLA to Make a Household Surface Cleaner

- Compare and contrast 2 disposable cups
- Identical Function
- Both made from polymers
- Renewable vs Non-renewable resources
- Landfill vs. Compostable

2002 Presidential Green Chemistry Award Winner for developing Greener Reactions Conditions

- Cargill Dow, LLC (now NatureWorks, LLC)
- Polymers from Renewable Resources: Polylactic acid (PLA)
- Bio-polymer made from corn
- Designed to be bio-compostable
- Process continues to be improved

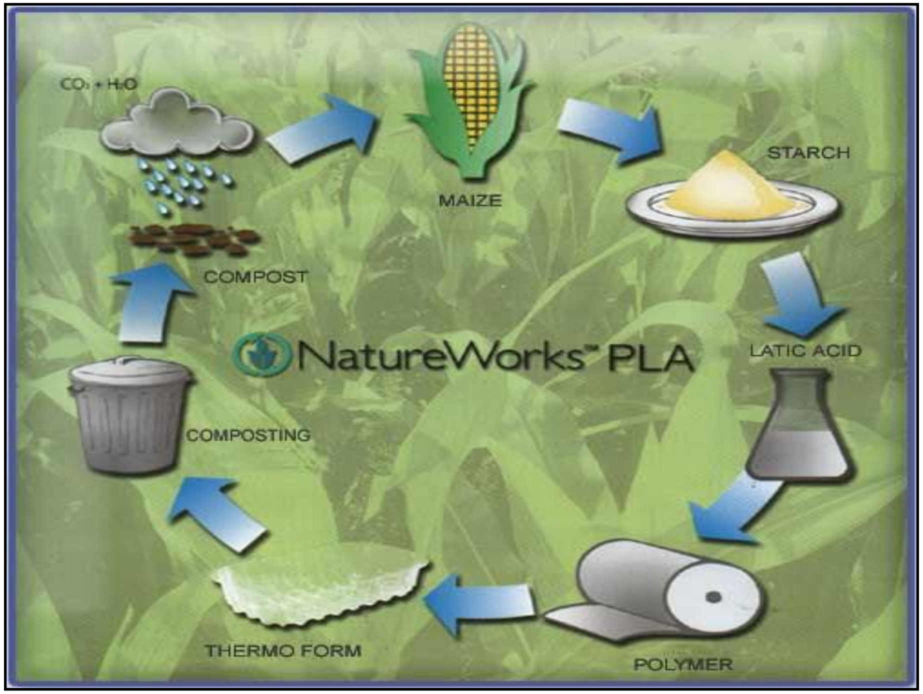
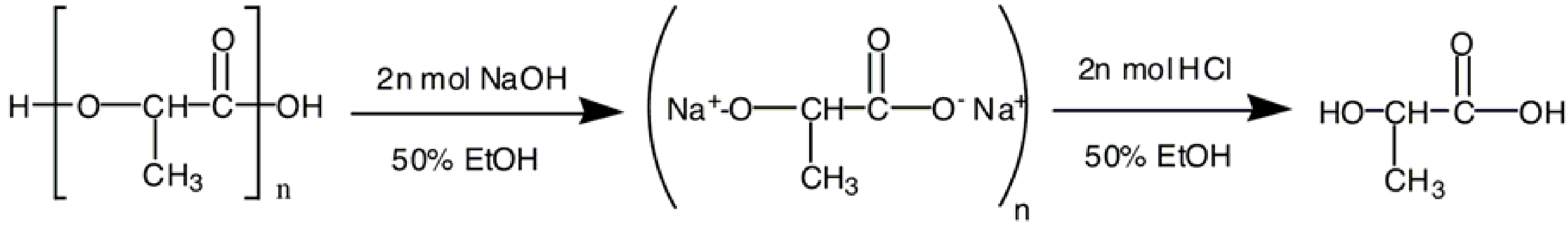


Image: http://www.ilip.co.za/main_compost.htm

Polylactic Acid Transformation

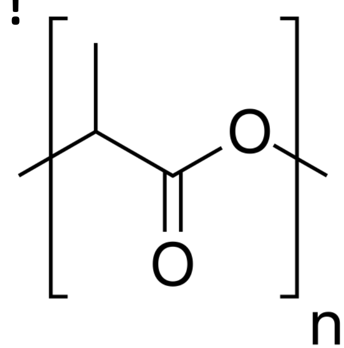
Depolymerization of PLA into sodium lactate

Protonation of sodium lactate to form lactic acid



Recycling PLA to Make a Household Surface Cleaner Lab Snapshot:

- Cut up 5g of PLA cup
- Place in Erlenmeyer flask with 100mL NaOH: 50% Ethanol mixture
- Heat to 90°C; stirring hot plate works best
- Cool in ice bath to 40°C
- Add 6M HCl until pH is 4-5, test with pH paper (titration option)
- Use the new solution to clean the classroom!



Special thank you!

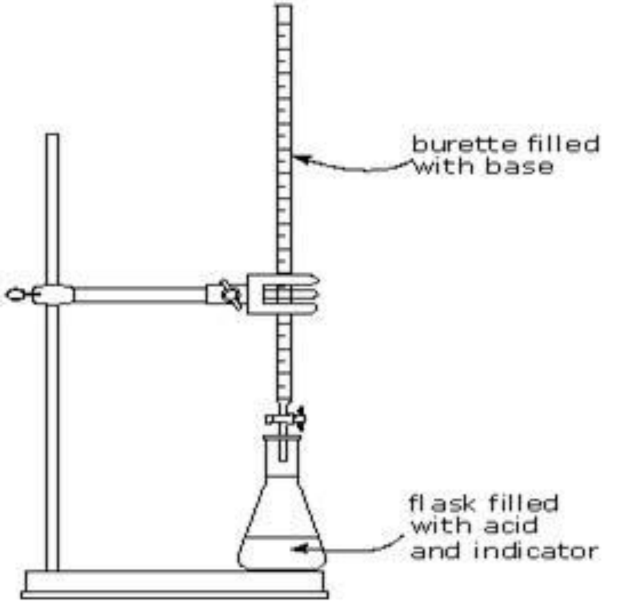
- Dr. Rich Gurney and the amazing students at Simmons College for developing this lab and sharing it with the world!

Ash Water Titration

- Traditional soap making process
- Readily available base (ovens)
- Alternative for creating base for biodiesel lab

Ash Water Titration

- Prep wood ash
  - Filter 50 g of wood ash with 150 mL water
  - Filter again with 100 mL of water
- Titrate ash water
  - Prepare 2 samples of KHP with 10 mL of water
  - Add 2 drops of phenolphthalein indicator
  - Titrate quickly first sample
  - Repeat titration slowly for exact reading



Special Thank you!

- Irv Levy and his amazing Green Chemistry Organic Literacy Forum (GOLUM) students

Design and Function: Blackberry Solar Cell

Traditional Photovoltaic Solar Cell Pros

- Renewable resource
- Emits no greenhouse gases once in operation
- Decreases US dependency on foreign fuel sources

Traditional Photovoltaic Solar Cell Cons

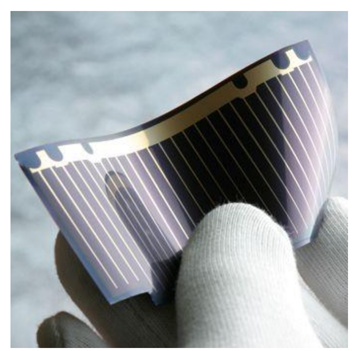
- Expensive product
- Not as efficient as fossil fuels
- High energy input
- Ends up in hazardous waste

- Expensive
- Toxic Materials
- Energy Intensive
- Long energy buy-back time

- Low Cost
- Non-toxic Materials
- Low Energy
- Short energy buy-back time

Design and Function: Blackberry Solar Cell

- Inspired by technology created by Michael Grätzel (1991)
- Continued research done by Dr. Amy Cannon, Dr. John Warner and team at WBI



warner babcock
institute for green chemistry

Preparing to Make a Solar Cell

- Begin by adding 2 g of TiO_2 in mortar
- Add 1 mL of 0.001 M nitric acid & grind to paste
- Dilute with total of 3 mL suspension should have no bubbles/clumps
- Determine conductive layer of ITO slide and place face up
- Tape 2 short edges to flat surface
- Using Beral-type pipette apply 2 thin lines of TiO_2 solution
- Use a clean microscope slide to “squeegee” across the glass

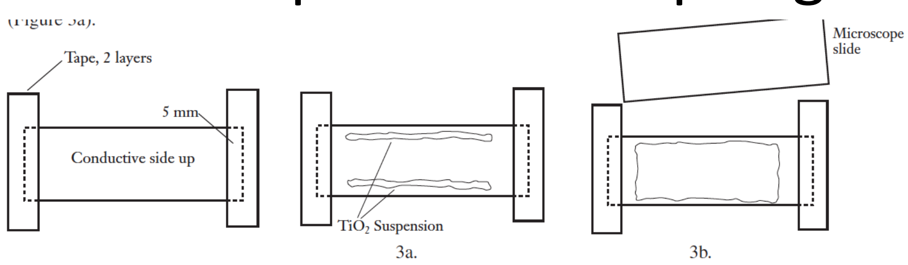


Figure 2. **Figure 3.** Coating the Anode with the Titanium Oxide

Let's Make a Solar Cell

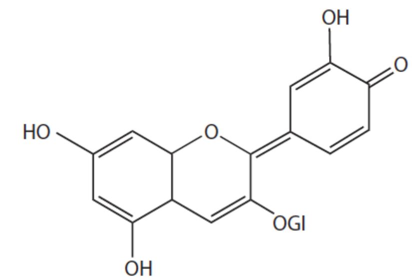
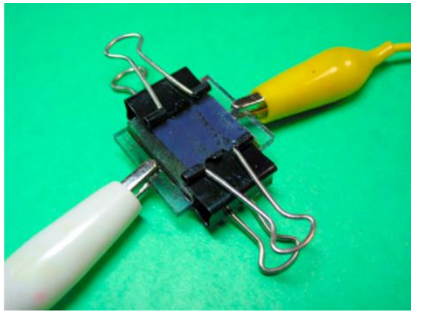


Figure 6. General Structure of Anthocyanin Dyes

- Work in groups of 2-4 students
- Mash the blackberry
- Place TiO_2 slide face down in juice
- *Opportunity to elaborate on materials*
- The dye is key!
- Multimeter testing to determine conductive layer of ITO slide (Ω)
- Apply carbon layer
- Remove TiO_2 slide from juice and dab dry

Solar Cell Assembly



- Assemble TiO_2 slide (cathode) and anode slides in an offset/staggered sandwich
- Clamp binder clips on long edges
- Add 2 drops of Iodine electrolyte solution
- Attach alligator clips to the transparent edges
- Use multimeter to:
  - Measure cell potential in volts (1–10 V)
  - Measure current in milliamps (1–20 mA)

TiO_2 Dye-Sensitized Solar Cells

How do they work?

1. Dye molecule absorbs visible light.

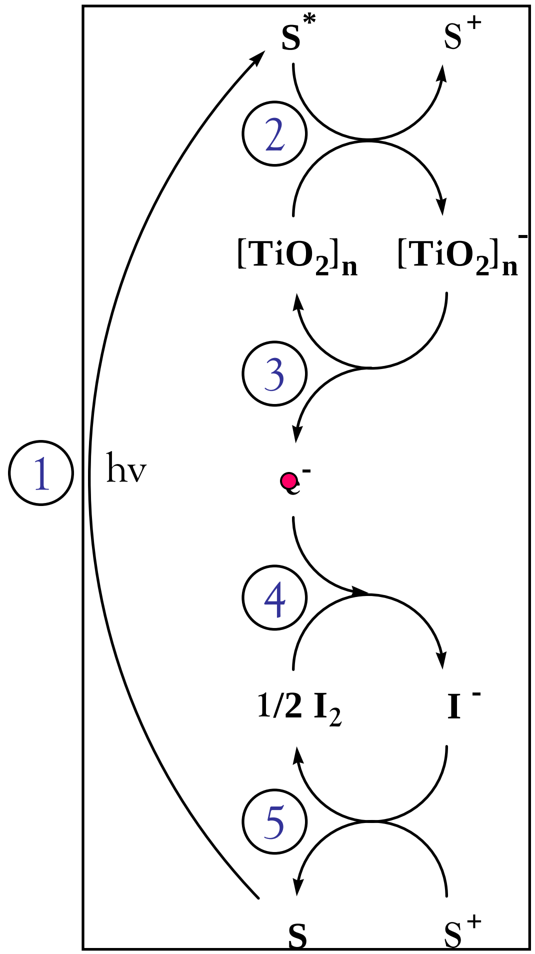
2. An electron in the dye (S) is promoted to a "photoexcited state" (S*).

3. S* transfers an electron into the conduction band (Ef) of TiO2.

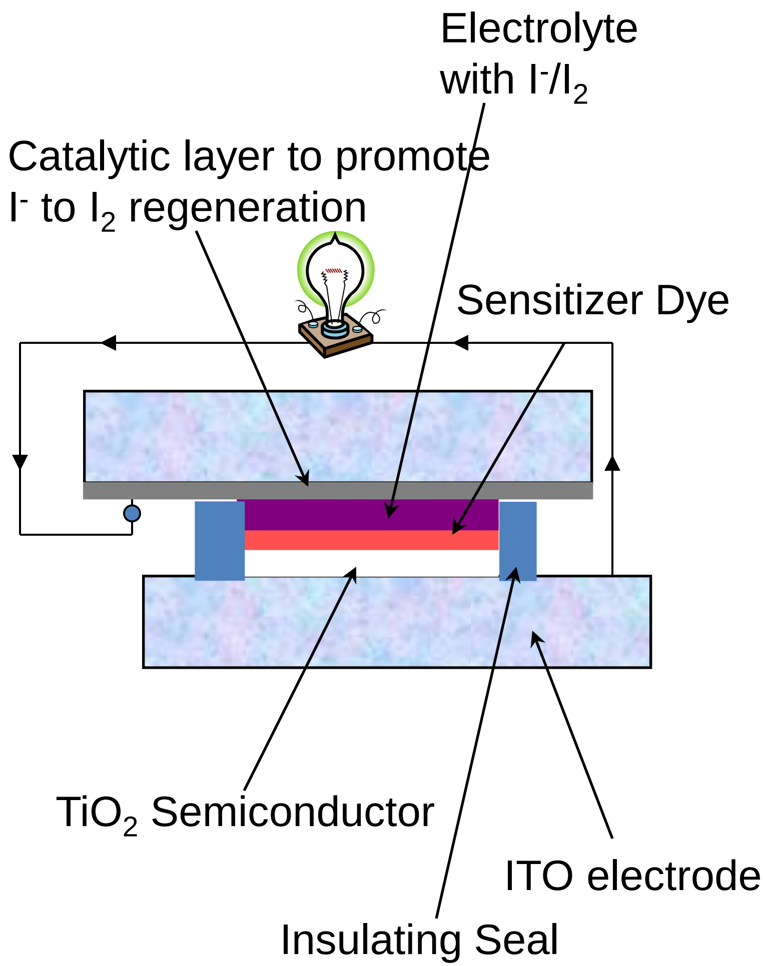
4. The oxidized dye accepts an electron from the redox catalyst (I–).

5. Electrons migrate through the external circuit to the cathode.

6. Iodine is reduced to iodide at the cathode, thus regenerating the redox catalyst.



What do they look like?



Investigating the Toxicity of Road Deicers

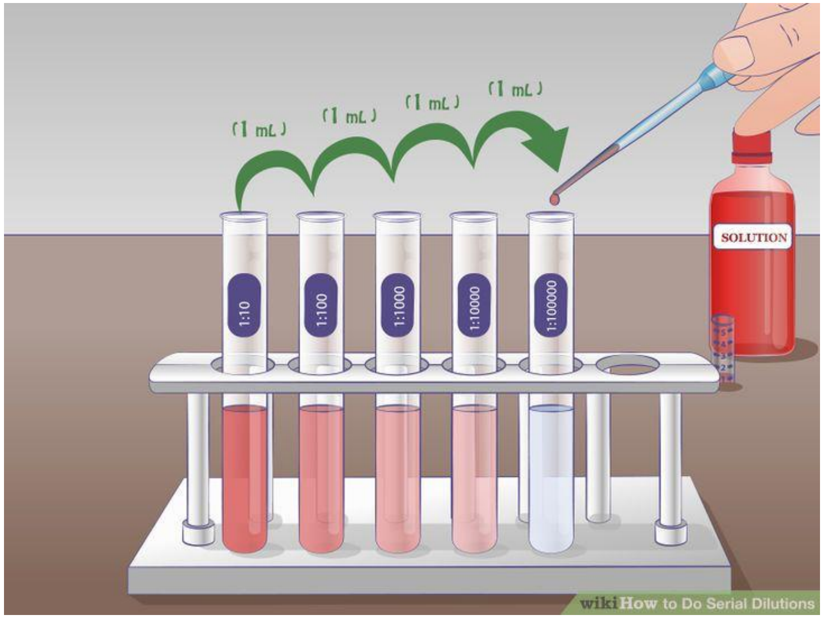
- How do road deicers work?
- Designed to keep roads drivable in winter conditions
- Many areas in the US use common salts as road deicers
- How does salt impact aquatic ecosystems?

1996 Presidential Green Chemistry Challenge Award Winner for Designing a Greener Chemical

- Rohm & Haas Co. (now Dow)
- SEA-Nine 211 is an anti-foulant
- Previous anti-foulants had negative impacts on aquatic ecosystems
- This formulation exhibits rapid biodegradation

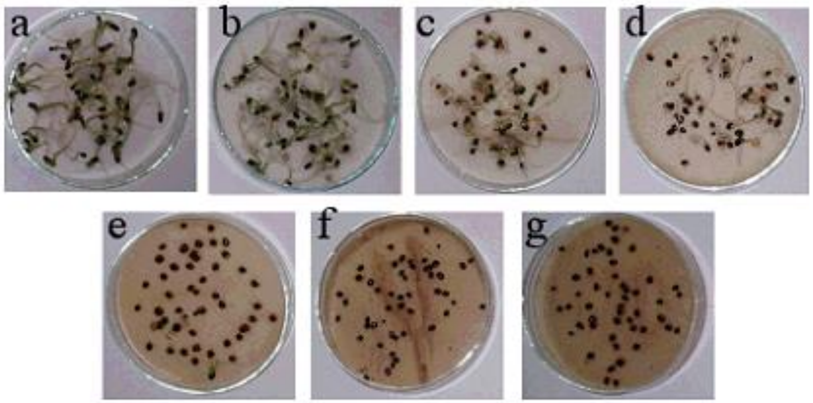
Toxicity Bioassay

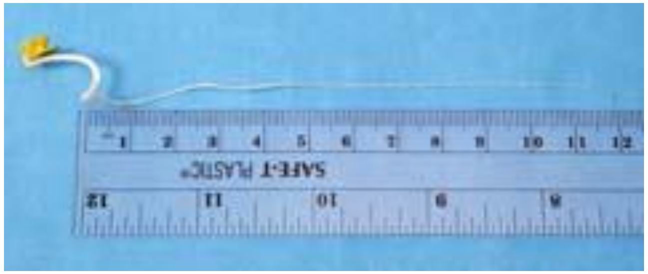
- Bioassay of road deicers
- Calculating and making % solutions or Molar solutions of $MgCl_2$, $CaCl_2$ and NaCl
- Performing serial dilutions
- Prepare and set up lab for large amount of data collection
- Can use seeds(radish/lettuce) to determine toxicity on plants



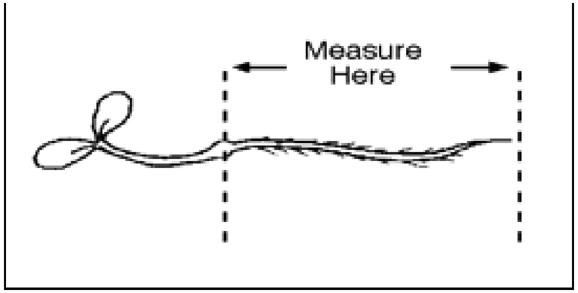
http://www.wikihow.com/Do-Serial-Dilutions

Investigating the Toxicity of Road Deicers





- Calculate and approximate the Lethal Dose(LD_{50}) of salts on seeds
- Plant germination and growth data collection allows for group and whole class graphing, analysis, and discussion



https://www.researchgate.net/figure/259248943_fig2_Figure-4-Survival-percentage-of-Daphnia-magna-population-during-24-d-bioassay

http://www.hometrainingtools.com/a/bioassay-test-toxicity-project

Beyond Benign
Lead Teacher Program

- 3-year program
- 10 teachers/year
- Teachers work with BB to become leaders in green chemistry education in their regions.
- Creating regional hubs for teacher expertise.
- Increasing Beyond Benign's capacity and providing regional expertise to leverage growth in green chemistry implementation at the K-12 level.
- New website: ABC's
  - -Monthly Blog

Sarah McCarron-Stewart
Tilton, NH

Teri Natoli
New Haven, CT

Maureen Clayton
Cornwall, NY

Richard Cooper
London, ON Canada

Annette Sebuyira
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Veronica O'Donnell
Cornwall, NY

Raksmey Derival
Lowell, MA

Kathe Blue-Hetter
Ann Arbor, MI

Ann Lambert
Wrentham, MA

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Green Chemistry Opportunities in K-12 Education

- The transformative power of green chemistry principles and practice
- Changing perception of chemistry/chemists
- Better prepares students for workforce
- Interdisciplinary approaches and problem solving through chemistry (chemistry as the solution)
- Providing context for teaching an abstract subject
- Removes hazards from labs and classrooms
- Valued by industry

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Companies are demanding chemists have 21st century skills: this includes green chemistry, toxicology & understanding of environmental mechanisms

Thank you!
Want more green chemistry?

Summer 2017 – Online courses for HS teachers (Intro to GC & Advanced GC)

Connect with Beyond Benign:

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www.beyondbenign.org

Please sign the e-mail list for updates on training opportunities & curriculum resources

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