

Entrusted with Creation

Green and Sustainable Science at Marian University



IGSS'09

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“Creation is not just the starting point of life; it is the foundational and continuing relationship that links the creature to the Creator, for he is the cause of every being and all becoming.”

- Pope Benedict XVI



Overview

- The birth and development of **Green and Sustainable Science** at Marian University
 - The **Green Chemistry Program** at Marian
 - Institute for Green and Sustainable Science**
-
- Please ask questions as we are going along!



Me Green???

Green Chemistry

EARTH FIRST!

No Compromise in the Defense of Mother Earth!

Sustainability?



Atom Economy?



Convergence



Catholic
stewardship

responsible
stewardship

writing thesis
introspection

Franciscan values

**Green
Chemistry**

benign
chemistry

undergraduate
research

solvents in
organic chemistry

faculty position
at Marian

job search



Opportunity for Change



- Started in August 2003
- I wanted to bring our core Franciscan value of environmental stewardship into the curriculum.
- Opportunity to craft organic chemistry curriculum
- Started our green chemistry program
- Interests include:
 - modernizing and greening the organic lab
 - engaging students through research
 - engaging everyone through green chemistry

Green Chemistry Program at Marian University



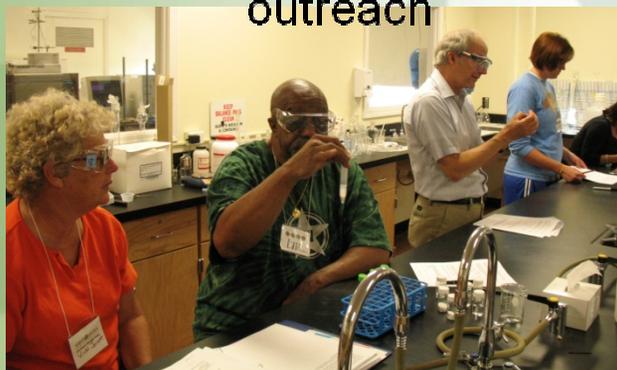
Undergraduate research

Green organic chemistry laboratory curriculum



Only comprehensive green organic program in the state

High school outreach



Green Organic Chemistry Laboratory Curriculum



- Marian University is the only college in the state of Indiana to offer a comprehensive green organic chemistry laboratory curriculum
- The practice of green chemistry also allows student to participate in the College's Franciscan value of responsible stewardship

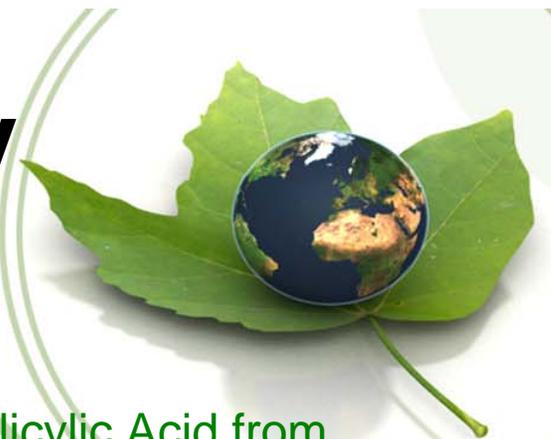
Green Organic Chemistry Laboratory Curriculum



Fall 2008

1. Simple Distillation: Purification of Acetone
2. Effect of pH on Sodium Benzoate
3. Extraction, Evaporation, and Recrystallization: Separating and Identifying the Components of "Pain Smack"
4. Liquid CO₂ Extraction of an Essential Oil from Orange Rind
5. Stereochemistry – Dry Lab
6. The S_N1 Synthesis of 2-Chloro-2-methylbutane: An Introduction to Reaction Efficiency
7. A Green Formulation: Where Chemistry and the Market Meet
8. Thin Layer Chromatography: Analysis of Drug Components
9. Bromination of trans-Stilbene with Pyridinium Tribromide
10. A Greener Bromination of Stilbene

Green Organic Chemistry Laboratory Curriculum



Spring 2009

11. Natural Synthesis of Aspirin, Part I: Synthesis of Salicylic Acid from Wintergreen Oil

12. Natural Synthesis of Aspirin, Part II: Acylation of Salicylic Acid

13. Greening the Unknown Lab

14. An Environmentally Benign Synthesis of Adipic Acid

15. Sodium Borohydride Reduction of Vanillin: A Low Solvent Synthesis of Vanillyl Alcohol

16. A Green Electrophilic Iodination of Vanillin

17. A Heck Reaction in Water

18. Determination of the Best Method for Biodiesel Synthesis

19. A Greener Synthesis of Creatine

Esterification by Azeotropic Distillation: Generation of Fruity Fragrances

An Atom Efficient Reaction: The Crossed-Aldol Condensation

Scenarios at Marian



- Green chemistry affords us a unique opportunity to incorporate environment-focused or safety-focused scenarios as a theme
- Scenarios give purpose / importance to experiments
- Addressing environmental issues through green chemical techniques is rewarding to students, promoting their interest in green chemical research

Undergraduate Research



- While the backbone of the program is our organic lab curriculum, the life blood of the program is student research
 - the development of new green synthetic methodologies
 - the planning, development, and implementation of green procedures and techniques
 - it is this student research that feeds new the creation on new green chemistry educational materials

Student Research Projects

- Student research projects have included:
 - green formulations lab
 - azeotropic distillation of esters
 - a green low-solvent synthesis of vanillyl alcohol
 - a green S_N1 synthesis of 2-chloro-2-methylbutane
 - synthesis of salicylic acid
 - a greener synthesis of aspirin
 - a greener synthesis of creatine
 - a novel green electrophilic chlorination of vanillin



Process used to Develop and Teach Greener Laboratory Procedures



Assess existing procedure

Identify hazards or inefficiencies

Find/develop alternative methods

Test efficacy of new procedure

Greener alternative



Experiment Development as Research

- Modify existing labs or design new labs
- Use of literature
- Evaluation of lab procedures and techniques
- Problem solving
- Development of analytical techniques
- Analyzing and presenting data
- Writing of future laboratory experiments
- Evaluation and appreciation of previous lab work



What are the Important Aspects of a Research Experience?

- Ownership of new ideas
- Discovery of knowledge
- Design of experiments
- Collection and analysis of data for meaning
- Development of written and oral communication of ideas
- Membership in a community of scientists
- Wet appetite for additional research
- Development of green chemistry skill set



Green Chemistry Outreach



- The third aspect of the green chemistry program grew out of student inquires
 - Why didn't I learn anything about green chemistry in high school?
- Several reasons:
 - Lack of knowledge / awareness amongst teachers
 - Limited supply of green educational materials available for high school science educators
- Fundamental need exists for the creation of additional high school green chemistry experiments
- Excellent topic to be addressed by undergraduate research students

Criteria for High School Green Chemistry Experiments



- Maximize safety
- Minimize glassware requirements
- Minimize time requirements
- Must be able to be performed on the open bench
- Use inexpensive, safer reagents
- Use either benign solvents or be solvent free
- Reduce laboratory waste and hazards
- Illustrate green chemical concepts (recycling, hazard reduction, solvent reduction)

Criteria for High School Green Chemistry Experiments – cont.



- Generate both benign products and benign byproducts
- Complement the lecture materials
- Utility for introducing a variety of scientific concepts
- Convey important chemical concepts and laboratory techniques
- Be successfully completed within the constraints of the class period
- Illustrate green principles and strategies

Green High School Experiments Developed at Marian



- Green Fuels 1: Synthesis of Biodiesel from Cooking Oil
- Green Solvents 1: Introduction to Liquid CO₂
- Green Solvents 2: Liquid CO₂ Extraction of Limonene from Orange Rind
- Green Synthesis 1: Natural Synthesis of Aspirin, Part I: Synthesis of Salicylic Acid from Wintergreen Oil
- Green Synthesis 2: Natural Synthesis of Aspirin, Part II: Acylation of Salicylic Acid
- Green Synthesis 3: A Solventless Atom Efficient Reaction: The Crossed-Aldol Condensation
- Green Synthesis 4: A Greener Synthesis of Creatine
- Chemistry in the Body 1: The Effect of pH on Sodium Benzoate

Is Green Chemistry Expensive?



- Green chemistry at Marian is economically sound
- By minimizing the amount of chemical waste generated in the lab, we have lowered our yearly chemical disposal costs
- Our green organic labs also focus on using inexpensive and renewable solvents such as water and ethanol
- By dramatically reducing our dependence on expensive fume hoods

Future Projects

- We are a 'practicing' green chemistry lab
- We look for ways to expand systematic green chemistry practices through our teaching and research laboratories.
- Lifecycle assessment for products from green experiments
- More green organic labs
- More green high school labs
- The fun is only just beginning...



Institute for Green and Sustainable Science

- The future starts today!



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