CH495 Special Topics
Green Chemistry
UNIDO-Yale-Beyond Benign Curriculum*

Fall 2024

INSTRUCTOR: James Burrington

OFFICE HOURS : Tues/Thursday 10:15 am -11:00 pm

COURSE WEBSITE: CH495 Banner / Canvas Website

CLASS TIMES: Tues/Thursday 11:20 am-12:35 pm

COURSE DESCRIPTION

This course will explore the fundamentals of chemistry, how chemistry can help address global human health and environmental issues. It provides an introduction to the foundational principles of chemistry including atoms, molecules, chemical reactions, stoichiometry, chemical/physical properties, and periodic table trends. This knowledge is then related to various environmental and human health issues, and develop the appropriate solutions using green chemistry approaches covered in the course.

COURSE OBJECTIVES

1. Working knowledge of chemistry fundamentals including periodic table trends, electronegativity, stoichiometry, molecular structure, reactivity, and nomenclature.
2. To appreciate the history of chemical accidents and how Green Chemistry can be used to design safer products and industrial systems without harming the environment and subsequent human health.
3. To understand the historical and current role of chemicals in our society and economy.
4. To qualitatively and quantitatively examine the impacts on human health and the environment of chemical products and processes.
5. To recognize the tools available to scientists and engineers in the design and synthesis of new chemical products and processes including energy efficiency.
6. To have a basic knowledge of toxicity and the molecular basis of hazard.
7. To analyze the efficiency of various approaches to chemical design.
8. To understand the transformational role of Green Chemistry in the global economy and the associated material and energy benefits.

PREREQUISITES
Completion of undergraduate general and organic chemistry courses are recommended.

GRADING
Participation: 20% (Attendance and In-Class Participation: 15%, Peer Evaluation: 5%)
Exams: 30% (Exam 1: 10%, Exam 2: 10%, Exam 3, 10%)
Homework: 20% (6 Homework Assignments)
Final Exam: 30%

HOMEWORK
Students will be assigned homework which is due before the beginning of the class. And while students are encouraged to work together on the problem sets, everyone is required to turn in their individual work.

PARTICIPATION
Students are expected to watch assigned videos, read all assigned readings and participate in class discussions. Students should take an active role in the numerous in-class exercises during semester. Students' in-class performances will be evaluated.

COURSE MATERIALS
Required textbook:
"Green Chemistry: Theory and Practice", Anastas and Warner, Oxford University Press, 1998. (Designated as T&P in the table below).

Optional & Additional textbooks:

1. "Chemistry in Context", 8th Edition, McGraw Hill Education. Designated as CC in the table below.
2. "Chemistry for Changing Times", John W. Hill; Terry W. McCreary, Pearson, 14th Edition, 2015
3. "Introduction to Green Chemistry", Albert S. Matlack, CRC Press, 2nd Edition, 2010.
4. "Green Chemistry: An Introductory Text", Mike Lancaster, Royal Society of Chemistry, 2002
5. "Green Techniques for Organic Synthesis and Medicinal Chemistry", Wei Zhang; Berkeley W. Cue; Wiley Publishing, 2nd Edition, 2018
6. "Industrial Catalysis: Chemistry and Mechanism", James D. Burrington; Imperial College Press, 2016.

POWER POINT LECTURES: Will be available on the Course Website prior to each lecture.

REQUIRED READING: Materials can be accessed from the links in the LECTURE SCHEDULE below and from the Course Website.

VIDEOS: Can be accessed through the links in the LECTURE SCHEDULE below.

ACADEMIC INTEGRITY: Students will be expected to adhere to standards of academic honesty in compliance with John Carroll University. Academic dishonesty or cheating includes unacknowledged paraphrasing or quoting, use of another student's material, incomplete acknowledgement of sources including Internet sources, or submission of the same work to complete the requirements of more than one class. Details can be found in the John Carroll University student handbook.

EXAMS AND FINAL

There will be **THREE** in-class exams during the semester. The exams will be closed-book and closed-note unless otherwise indicated. There will be a final exam at the end of the semester.

LECTURE SCHEDULE

Lecture 1: Course Introduction and Accidents and Their Unintentional Consequences

Required Readings: none

Optional/Supplemental Readings:

- Bhopal Plant Disaster – Situation Summary

Class Exercise: This week's exercise/ice breaker are incorporated into the beginning of the PowerPoint presentation.

Videos: Accidents Modern Disasters Accidents: Why we should care Green Chemistry Approach to Accidents

Lecture 2: Green Chemistry: Reimagining Chemistry

Required Readings: none

Optional/Supplemental Readings:

- Anastas, Paul T.; "Meeting the Challenges to Sustainability through Green Chemistry"; *Green Chem.* 2003, *5*, G29-G34. http://pubs.rsc.org/en/content/articlehtml/2003/GC/B211620K
- Collins, T.; "The Importance of Sustainability Ethics, Toxicity and Ecotoxicity in Chemical Education and Research"; *Green Chem.*; 2003, *5*, G51-G52. http://pubs.rsc.org/en/content/articlehtml/2003/gc/b307694f
- Our Common Journey - Executive Summary. Board on Sustainable Development, National Research Council, 1-14. http://www.nap.edu/catalog.php?record_id=9690
- Beach et al; "Green Chemistry: A design framework for sustainability"; *Energy Environ. Sci.*; 2009, *2*, 1038–1049. http://pubs.rsc.org/en/Content/ArticleLanding/2009/EE/b904997p

Class Exercise: none

Videos: none

Lecture 3: 12 Principles of Green Chemistry

Required Readings:

- Anastas, P.T., Eghbali, N. "Green Chemistry Principles and Practice"; *Chem. Soc. Rev.*; 2010, 39, 301-312. http://pubs.rsc.org/en/content/articlelanding/2010/cs/b918763b
- Presidential Green Chemistry Awards: 1996 – 2016
- Anastas, Paul T.; Warner, John C.; "Green Chemistry: Theory and Practice"; Oxford University Press: Oxford, 1998, Chapter 4.

Optional/Supplemental Readings:

- Mulvihill et al, "Green Chemistry and Green Engineering: A Framework for Sustainable Technology Development"; *Annual Review of Environment and Resources*; 2011, 36, 271-293. (optional) https://www.annualreviews.org/doi/abs/10.1146/annurev-environ-032009-095500

Class Exercise: E-factor (optional) and Writing the 12 Principles of Green Chemistry (optional)

Videos: The 12 Principles of Green Chemistry John Warner: Green Chemistry Introduction: Definition of Green Chemistry Introduction: Green Chemistry's Role in Sustainability Introduction: Life Cycle Historic and Ideal Community Relationships

Lecture 4: Real-World Cases in Green Chemistry

Required Readings: none

Optional/Supplemental Readings:

- "Presidential Green Chemistry Challenge: Award Recipients 1996-2016", US EPA. https://www.epa.gov/sites/production/files/2016-10/documents/award_recipients_1996_2016.pdf
- Newlight Technologies:
  - Popular Science, 2014: http://bestofwhatsnew.popsci.com/newlight-technologies-aircarbon
  - Plastics Today, 2016: https://www.plasticstoday.com/materials/newlight-licenses-aircarbon-ikea/57710583724253
  - Making Plastic from Pollution, January 11, 2017: https://powerpalletinc.com/making-plastic-from-pollution/
  - BCA Chemistry, 2013: https://bcachemistry.wordpress.com/tag/aircarbon/ (includes a good overview of the chemistry, including Thermodynamics and polymer chemistry)
- Buckman:
  - A 2012 article is included with some further information (Pulp & Paper International (PPI)) https://www.buckman.com/wp-content/uploads/2018/04/PPI-2012-Greener-Pckg.pdf
  - 2017 Paper Fact Sheet from Green America's Paper Project
  - 2018 Environmental Paper Network report titled "State of the Global Paper Industry", http://environmentalpaper.org/wp-content/uploads/2018/04/StateOfTheGlobalPaperIndustry2018_FullReport-Final-1.pdf
- Bruce Lipshutz:
  - Lipshutz, B., Current Opinion in Green and Sustainable Chemistry, 2018, 11: 1-8 https://www.sciencedirect.com/science/article/pii/S2452223617300780
  - Lipshutz, B., J. Org. Chem., 2017, 82, 2806-2816 https://pubs.acs.org/doi/ipdf/10.1021/acs.joc.7b00010
  - Lipshutz, B., ACS Sustainable Chem. Eng., 2016, 4, 5838 – 5849 https://pubs.acs.org/doi/abs/10.1021/acssuschemeng.6b01810
- Archer Daniels Midland and Novozymes, NovaLipid™:
  - Additional information about trans fats and health effects: Mayo Clinic, https://www.mayoclinic.org/diseases-conditions/high-blood-cholesterol/in-depth/trans-fat/art-20046114
- Pfizer:
  - Taber, G.P., Pfisterer, D.M., and Colberg, J., Organic Process Research & Development, 2004, 8, 385-388 https://pubs.acs.org/doi/10.1021/op0341465
- Dow Chemical Company (Rohm and Haas):
  - Additional educational modules by Michael Cann, University of Scranton, http://www.scranton.edu/faculty/cannm/green-chemistry/english/environmental.shtml
  - Additional information on Marine anti-foulants: International Marine Organization: http://www.imo.org/en/OurWork/Environment/Anti-foulingSystems/Documents/FOULING2003.pdf

Class Exercise: Real-World Cases in Green Chemistry Exercise
Videos: Newlight Technologies Buckman Maximyze® Technology SiGNa Technologies

Lecture 5: Green Chemistry: It All Starts at the Beginning
Required Readings:
- Compound Interest: History of the Atom http://www.compoundchem.com/2016/10/13/atomicmodels/
- The Periodic Table's Endangered Elements http://www.compoundchem.com/2015/08/19/endangered-elements/

Optional/Supplemental Readings: Additional readings from Instructors Chemistry textbook are encouraged.
Class Exercise: Periodic Table Battleship Game and Periodic Table "Guess Who" Game
Videos: Introduction to Periodic Table Groups in the Periodic Table Ionization Energy Electronegativity

Lecture 6: The Molecule
Required Readings: none
Optional/Supplemental Readings: Readings from Instructors Chemistry textbook are encouraged.
Class Exercise: This week's exercises are incorporated into the PowerPoint presentation. Animate slides according to your preference.
Videos: Introduction to Molecules Drawing and Naming Molecules Naming Simple Alkanes Functional Groups
Homework #1: Molecules and Nomenclature

Lecture 7: Stoichiometry and Reactions
Required Readings:
- Anastas, Paul T.; Warner, John C.; "Green Chemistry: Theory and Practice"; Oxford University Press: Oxford, 1998, Chapter 7.
- Readings from Instructors Chemistry textbook are encouraged.

Optional/Supplemental Readings: Readings from Instructors Chemistry textbook are encouraged.
Class Exercise: Beyond Benign Reactions Lab, Biomimicry Matching Game, Stoichiometry Challenge
Videos: Balancing Equations Part 1 Balancing Equations Part 2 Balancing Equations Part 3 Stoichiometry Example Types of Reactions

Lecture 8: Limiting Reagent, Yield, and the Atom Economy
Required Readings: Readings from Instructors Chemistry textbook are encouraged.
Optional/Supplemental Readings:
- Giraud, R., Williams, P., Sehgal, A., Ponnusamy, E., Phillips, A., Manley, J. "Implementing Green Chemistry in Chemical Manufacturing: A Survey Report"; *ACS Sustainable Chemistry & Engineering;* 2014, *2* (10), 2237-2242. https://pubs.acs.org/doi/abs/10.1021/sc500427d
- Mastronardi, M., Reyes, L. "Green Chemistry Principle #2: Atom Economy"; 2014, at GreenChemofT.wordpress.com. https://greenchemuoft.wordpress.com/2014/04/04/greenchemprinciple2/

Class Exercise: Greener Synthesis of Ibuprofen

Videos: Yield and Limiting Reagent Theoretical Yield Percent Yield Quick Snapshot of Atom Economy Atom Economy
Homework #2: Stoichiometry and Reactions

Lecture 9: Sustainability
Required Readings: none
Optional/Supplemental Readings:
- "Our common vision", *Nature Sustainability,* Volume 1, Page 1 (2018), https://www.nature.com/articles/s41893-017-0020-x
- U.N. Sustainable Development Goals, United Nations, https://www.un.org/sustainabledevelopment/sustainable-development-goals/
- Report of the World Commission on Environment and Development: Our Common Future (Brundtland Report), World Commission on Environment and Development, 1987, http://www.un-documents.net/our-common-future.pdf

Class Exercise: none
Videos: none

Lecture 10: Life Cycle Assessment
Required Readings: none
Optional/Supplemental Readings:
- Guidance on Life-Cycle Thinking and Its Role in Environmental Decision Making, Sustainable Materials Management Coalition, March 2014, https://www.michaeldbaker.com/wp-content/uploads/2014/03/Guidance-on-Life-Cycle-Thinking-031014.pdf

Class Exercise: Explore the materials flow of petrochemicals. See lesson plan for more details
Videos: Life Cycle Assessment Video

Lecture 11: Exam #1

Lecture 12: Designing for Recycling & Degradation
Required Readings:
- "Designing Small Molecules for Biodegradation" R. S Boethling, Chem. Rev. 2007, 107, 2207-2227. https://pubs.acs.org/doi/10.1021/cr050952t

Optional/Supplemental Readings: none
Class Exercise: Biodegradation Activity using BIOWIN, Estimating Biodegradation of Organic Molecules, and Design for Biodegradability
Videos: Introduction to Biodegradation
Homework #3: Estimating Biodegradation of Organic Molecules

Lecture 13: Solvents: Understanding Their Role
Required Readings:
- "Green Chemistry: Theory and Practice", Anastas and Warner, Oxford University Press, Ch. 4 Section 5

Optional/Supplemental Readings:

- "CHEM21 selection guide of classical and less classical solvents" Denis Prat and et. Al, Green Chem., 2016, 18, 288 https://pubs.rsc.org/en/content/articlelanding/2016/gc/c5gc01008j#!divAbstract
- "Chemistry in Context", 8th Edition, McGraw Hill Education. Ch. 5

Videos: Solvents: Introduction Why Use Solvents Solvents: Applications Solvents video (in PowerPoint)

Homework #4:

- Solvent Substitution: CHEM21 Solvent Selection Guide
    - More information available on the Guide here: (http://learning.chem21.eu/methods-of-facilitating-change/tools-and-guides/)

Lecture 14: Working without Solvents

Required Readings: "Green Chemistry: Theory and Practice", Anastas and Warner, Oxford University Press, Ch. 4 Section 5

Optional/Supplemental Readings:

- "Introduction to Green Chemistry", Albert S. Matlack, CRC Press, Ch. 8, 2nd Edition, 2010.
- Andrew P. Dicks (2009) Solvent-free reactivity in the undergraduate organic laboratory, Green Chemistry Letters and Reviews, 2:2, 87-100, DOI: 10.1080/17518250903164549 https://www.tandfonline.com/doi/full/10.1080/17518250903164549?scroll=top&needAccess=true
- Andrew P. Dicks (2009) A review of aqueous organic reactions for the undergraduate teaching laboratory, Green Chemistry Letters and Reviews, 2:1, 9-21, DOI: 10.1080/17518250902820182 https://www.tandfonline.com/doi/full/10.1080/17518250902820182

Class Exercise: none

Videos: none

Lecture 15: Green Analytical Chemistry

Required Readings: none

Optional/Supplemental Readings:

- Green Analytical Chemistry articles:
    - Vanhoenacker, G., Sandra, P., David, F., Sandra, K., Pereira, A., 2010, Green chromatography (Part 1): Introduction and liquid chromatography, LC-GC Europe, 23, 242-259 http://www.chromatographyonline.com/green-chromatography-part-1-introduction-and-liquid-chromatography
    - "Green Analytical Chemistry" by Paul Ferguson and Douglas Raynie, in Green Techniques for Organic Synthesis and Medicinal Chemistry, 2nd Edition, Zhang, W. and Cue, B. W., Eds., Wiley, 2018, pp. 43-66
    - M. Koel, M. Kaljurand, *Crit. Rev. Anal. Chem.*, **42**, 192-195 (2012). https://pubs.acs.org/doi/abs/10.1021/cr068359e
    - Galuszka, A., Migaszewski, Z., Namiesnik, J., 2013, The 12 principles of green analytical chemistry and the SIGNIFICANCE mnemonic of green analytical practices, Trends Anal. Chem., 50, 78-84
    - Galuszka, A., Konieczka, P., Migaszewski, Z. Namiesnik, J., 2012, Analytical eco-scale for assessing the greenness of analytical procedures, Trends Anal. Chem., 37, 61-72

- Tobiszewski, M., Namiesnik, J., 2015, Scoring of solvents used in analytical laboratories by their toxicological and exposure hazards, Ecotox. Environ. Safety, 120, 169-173
- Chem. Rev., 2007, 106, 6, 2695-2708
- National Environmental Methods Index (NEMI): https://www.nemi.gov/about/ (searchable database for analytical methods, includes a greenness metric)
- R. Helmy, R. Hartman, C. J. Welch, and M. Al-Sayah, *Green Chem.,* 2011, **13**, (934-939)

- Solvent Selection articles:
  - Dunn and Perry, et. al., Green Chem., 2008, 10, 31-36
  - Henderson, R.K., et. al., Green Chem., 2011, 13, 854
  - American Chemical Society's Green Chemistry Institute Pharmaceutical Roundtable, http://www.acs.org/content/acs/en/greenchemistry/industry-business/pharmaceutical.html
  - Solvent replacements for chromatography: Taygerly, J.P., Peterson, E.A., *et. al*., Green Chemistry, 2012, 14, 3020-3025
- Additional background information:
  - For more information on X-ray fluorescence: ThermoFisher, https://www.thermofisher.com/us/en/home/industrial/spectroscopy-elemental-isotope-analysis/spectroscopy-elemental-isotope-analysis-learning-center/elemental-analysis-information/xrf-technology.html
  - For more information on IR spectroscopy: Compound Interest, https://www.compoundchem.com/2015/02/05/irspectroscopy/
  - For more information on Raman Spectroscopy: NanoPhoton, https://www.nanophoton.net/raman/raman-spectroscopy.html

Class Exercise: none
Videos: Green Analytical Chemistry webinar

Lecture 16: Introduction to Toxicology

Required Readings: Anastas, Paul T.; Warner, John C.; "Green Chemistry: Theory and Practice"; Oxford University Press: Oxford, 1998, Chapter 5.
Optional/Supplemental Readings: none
Class Exercise:

- Relationship Between pKa and Skin Irritation Activity
- Module 1 Aqueous and Lipid Solubility (optional)

Videos: Toxicology Toxicology: Toxic Substances Toxicology: Dose and Exposure Toxicology: Toxicity Categories Toxicology: Factors Affecting Toxicity Toxicology: Chemical Interactions Concepts in Toxicology (optional)

Lecture 17: Chemical Exposure and Dosage

Required Readings: Toxicology - Dose Response (see folder)
Optional/Supplemental Readings: none
Class Exercise:

- In-Class Discussion - Which Solvent Would You Use?
- Lettuce Seed Assay (optional)
- Daphnia Bioassay LD%) (optional)

Videos: Toxicology - Dose Response

Homework #5: Chemistry for the Environment

Lecture 18: Molecular Toxicology

Required Readings:

- Zimmerman, J. B., & Anastas, P. T. "Toward designing safer chemicals"; *Science,* 2015a, *347*(6219), 215-215. doi: 10.1126/science.aaa6736 http://science.sciencemag.org/content/347/6219/215.full
- Zimmerman, J. B., & Anastas, P. T.; "Toward substitution with no regrets"; *Science*, 2015b, 347(6227), 1198-1199. doi: 10.1126/science.aaa0812 http://science.sciencemag.org/content/347/6227/1198.full

Optional/Supplemental Readings: none

Class Exercise:

- 5.B-D. Electrophilic Reactions in Toxicity (Optional)
- Module 8 ADME and Rational Chemical Design (Optional)

Videos: Toxicology - ADME

Lecture 19: Designing Future Products with Reduced Toxicity

Required Readings:

- Voutchkova, A. M., Osimitz, T. G., Anastas, P. T.; "Toward a Comprehensive Molecular Design Framework for Reduced Hazard*" Chem. Rev*, 2010, *110* (10), 5845-5882. doi: 10.1021/cr9003105 https://pubs.acs.org/doi/abs/10.1021/cr9003105
- National Academies Press "A Framework to Guide Selection of Chemical Alternatives", 2014, Chapter 13.

Optional/Supplemental Readings: none

Class Exercise:

- Module 5 Glutathione as a Tool for Testing Gene Function (optional)
- Module 6 Crossroads of Computational Chemistry and Toxicology (optional)
- Module 7 Using ProTox (optional)

Videos: none

Homework #6: Toxicology

Lecture 20: Exam #2

Lecture 21: Catalysis

Required Readings: none

Optional/Supplemental Readings:

- Lancaster, Mike; "Green Chemistry An Introductory Text"; 2002, Ch.4, 84-129 (Editions 1, 2, or 3).
- Clark, James; "Catalysis and Green Chemistry", Pure Appl. Chem., Vol. 73, No. 1, pp. 103–111, 2001.
- "Introduction to Green Chemistry", Albert S. Matlack, CRC Press, Ch. 5 & 6 2nd Edition, 2010.
- "Industrial Catalysis: Chemistry and Mechanism", James D. Burrington; Imperial College Press, 2016

Class Exercise: none

Videos: Catalysis Introduction and Life Cycle Catalysts (in Powerpoint)

Lecture 22: Catalysis and Enabler of Green Chemistry / Bio-based Catalysis

Required Readings:

- Olefin Metathesis - Chemistry LibreTexts
- Baixue Lin and Yong Tao, Whole cell biocatalysis by Design. Microbial Cell Factories 16, article no 106 (2017). https://microbialcellfactories.biomedcentral.com/articles/10.1186/s12934-017-0724-7#Fig2
- What Is Fermentation in Chemistry? (thoughtco.com)
- Difference Between Aerobic and Anaerobic Fermentation - Pediaa.Com
- SciELO - Brasil - Biotechnological production of citric acid Biotechnological production of citric acid

Optional/Supplemental Readings:

- Lasantha Rathnayake. THEORETICAL INVESTIGATIONS OF p-BENZOQUINONES AND THIOSEMICARBAZONES. 2 Catalytic hydrogen peroxide productions with the anthraquinone process | Download Scientific Diagram (researchgate.net)
- Weijie Zhao, Xuan Li. Haowei Li, Xinlai Zheng, Hongwei Ma, Jinxing Long and Xuehui Li*
  ACS Sustainable Chem. Eng. 2019, 7, 24, 19750–19760. Selective Hydrogenolysis of Lignin Catalyzed by the Cost-Effective Ni Metal Supported on Alkaline MgO | ACS Sustainable Chemistry & Engineering
- Synthetic biology used to engineer new route to biochemicals (phys.org) ; *Nature Communications* June 25th, Atsumi and colleagues Yohei Toshiro and Shuchi Desai.
- Presidential Green Chemistry Challenge: 2014 Small Business Award | US EPA

Class Exercise: none
Videos: none

Lecture 23: Renewable Feedstocks

Required Readings:

- "Green Chemistry: Theory and Practice", Anastas and Warner, Oxford University Press, 1998. Ch. 4 Section 7
- "Green Chemistry: Theory and Practice", Anastas and Warner, Oxford University Press, 1998. Ch. 6

Optional/Supplemental Readings:

- "Chemistry in Context", 8th Edition, McGraw Hill Education. Ch. 9.1-9.10, 12.6

Class Exercise: none
Videos: Feedstocks Feedstocks: Renewable Feedstocks Feedstocks (in PowerPoint)

Lecture 24: Renewable Feedstocks for Energy

Required Readings: none
Optional/Supplemental Readings:

- Clark, J.H., Luque, R., Matharu, A.S., Annu. Rev. Chem. Biomol. Eng., 2012, 3: 183-207, https://www.ncbi.nlm.nih.gov/pubmed/22468603
- "Agriculture: Beyond food versus fuel", Graham-Rowe, D., Nature, 474, S6-S8, 2011, https://www.nature.com/articles/474S06a
- "Introduction: Next generation biofuels", Fairley, P., Nature, 474, S2-S5, 2011, https://www.nature.com/articles/474S02a
- "Ethics of Biofuels", by Sharon Astyk, Resilience, originally published by Energy Bulletin, December 28, 2006, https://www.resilience.org/stories/2006-12-28/ethics-biofuels/
- "Grass Makes Better Ethanol than Corn Does", Scientific American, Biello, D., January 8, 2008, https://www.scientificamerican.com/article/grass-makes-better-ethanol-than-corn/
- "Switchgrass may unlock the future of biofuel", March 3, 2017, Silke Schmidt, University of Wisconsin – Milwaukee, https://phys.org/news/2017-03-switchgrass-future-biofuel.html

Class Exercise: none
Videos: none

Lecture 25: Green Chemistry and Energy

Required Readings: none

Optional/Supplemental Readings:

- Energy Independence, Transcript of the Testimony of Richard E. Smalley to the Senate Committee on Energy and Natural Resources —April 27, 2004: http://www.americanenergyindependence.com/energychallenge.aspx
- For more information about biodiesel and fact sheets see BDI Biodiesel: Biodiesel Fact Sheets: https://www.biodiesel.org/what-is-biodiesel/biodiesel-fact-sheets
- Open-access article on dye-sensitized solar cells: Efficient Dye-Sensitized Solar Cells for Direct Conversion of Sunlight to Electricity, Gratzel, M., Kalyanasundaram, K., Material Matters, 2009, 4.4, 88, https://www.sigmaaldrich.com/technical-documents/articles/material-matters/efficient-dye-sensitized.html
- For more information about microwave synthesis: Nuchter, M., Ondruschka, B., Bonrath, W., Gum, A., Green Chem., 2004, **6**, 128-141https://pubs.rsc.org/en/content/articlehtml/2004/gc/b310502d - DOI: 10.1039/B310502D
- For more information on Smart Grids and systems: Smarter planet: Energy and Utilities, Slideshare, IBM, 2011, https://www.slideshare.net/gmattathil/smarter-planet-energy-and-utilities

Class Exercise: Synthesis of Biodiesel, and Dye-sensitized Blackberry Solar Cell

Videos: none

Lecture 26: Hydrogen

Required Readings:

- ThoughtCo., Overview of the Haber-Bosch Process, March 6, 2017 by Amanda Briney, https://www.thoughtco.com/overview-of-the-haber-bosch-process-1434563
- "The true colors of hydrogen" https://whatswatt.com.au/true-colours-what-do-the-different-colours-of-hydrogen-mean/

Optional/Supplemental Readings:

- An Overview of Hydrotreating. https://whatswatt.com.au/true-colours-what-do-the-different-colours-of-hydrogen-mean/
- M. Bampaou , K.D. Panopoulos , P. Seferlis , S. Voutetakis. Evaluation of novel hydrogen integration options in bio-oils introduction to petrochemical refineries, EnergyVolume 254, Part B, 1 September 2022, 124353
- Water Electrolysis - Principle of Water Electrolysis, Important Factors, Electrolytes, (byjus.com)

Class Exercise: none

Videos: none

Lecture 27: Alternate Energy Sources, Decarbonization and Net Zero Emissions

Required Readings:

- James D. Burrington. Renewable Energy Technical Potential Performance for Zero Carbon Emissions. ACS Omega 2024. https://doi.org/10.1021/acsomega.4c00273.

Optional/Supplemental Readings:

- Mark Z. Jacobson, No Miracles Needed, Cambridge University Press, 2023, New York, NY.

Class exercise: none
Videos: none

Lecture 28: Exam 3

Lecture 29: Safer Chemicals Design and ADME (Absorption, Distribution, Metabolism Excretion)

Required Readings:

- Karolina E. Mellor, Philip Coish, Bryan W. Brooks, Evan P. Gallagher, Margaret Mills, Terrance J. Kavanagh, Nancy Simcox, Grace A. Lasker, Dianne Botta, Adelina Voutchkova- Kostal, Jakub Kostal, Melissa L. Mullins, Suzanne M. Nesmith, Jone Corrales, Lauren Kristofco, Gavin Saari, W. Baylor Steele, Fjodor Melnikov, Julie B. Zimmerman & Paul T. Anastas (2018) The safer chemical design game. Gamification of green chemistry and safer chemical design concepts for high school and undergraduate students, Green Chemistry Letters and Reviews, 11:2, 103-110, DOI: 10.1080/17518253.2018.1434566 https://www.tandfonline.com/doi/abs/10.1080/17518253.2018.1434566

Optional/Supplemental Readings: none
Class Exercise: see above
Videos: none

John Carroll University is committed to fostering an equitable and accessible learning and working environment, based upon open communication, mutual respect, and ethical values consistent with our Jesuit and Catholic tradition. We express this commitment in the following policies and procedures:

In accordance with federal law, **if you have a documented disability** you may request accommodations from Student Accessibility Services (SAS). For more information go to the accessibility pageLinks to an external site. or you may contact the office directly at sas@jcu.edu or 216.397.4967. Please keep in mind that accommodations are not retroactive so it is best to register at the beginning of each semester. Only accommodations approved by SAS will be recognized in the classroom. Please contact SAS if you have further questions.

If you have **experienced sexual harassment, assault, or misconduct** based upon gender/sex/sexual orientation, and you share this with a faculty or staff member, that person must notify the Title IX Coordinator (TitleIX@jcu.edu or (216) 397-1559), who will discuss options with you. In most cases, communicating with the Title IX Coordinator does not automatically trigger a formal investigation. Members of the University community may communicate with the Title IX Coordinator in order to get more information and seek supportive measures without filing a formal complaint.

For more information about your options and resources in a Title IX matter, please go to the Title IX page,Links to an external site. where you can file an online report. An option to report anonymously is available. Members of the University community are encouraged to review the University's Sexual Harassment & Interpersonal Violence PolicyLinks to an external site., as well as the Resolution Process & Grievance Process for Title IX Sexual HarassmentLinks to an external site..

If you have **experienced bias or discrimination** based on race, age, color, sex, sexual orientation, gender identity or expression, religion, ethnic or national origin, disability, military or veteran status, genetic information, or any factor protected by law, you are encouraged to report this via the Bias Reporting SystemLinks to an external site..
For more information about the University's commitment to diversity, equity, inclusion, and accessibility, please visit the Diversity, Equity & Inclusion Division home pageLinks to an external site..

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