Greening Chemistry Labs+

Colloque AQPC 2024

Gatineau, June 6th, 2024

Kim Silkauskas

Agenda

WHO am I?

WHY is this important?

WHAT is this all about?

WHAT I've done

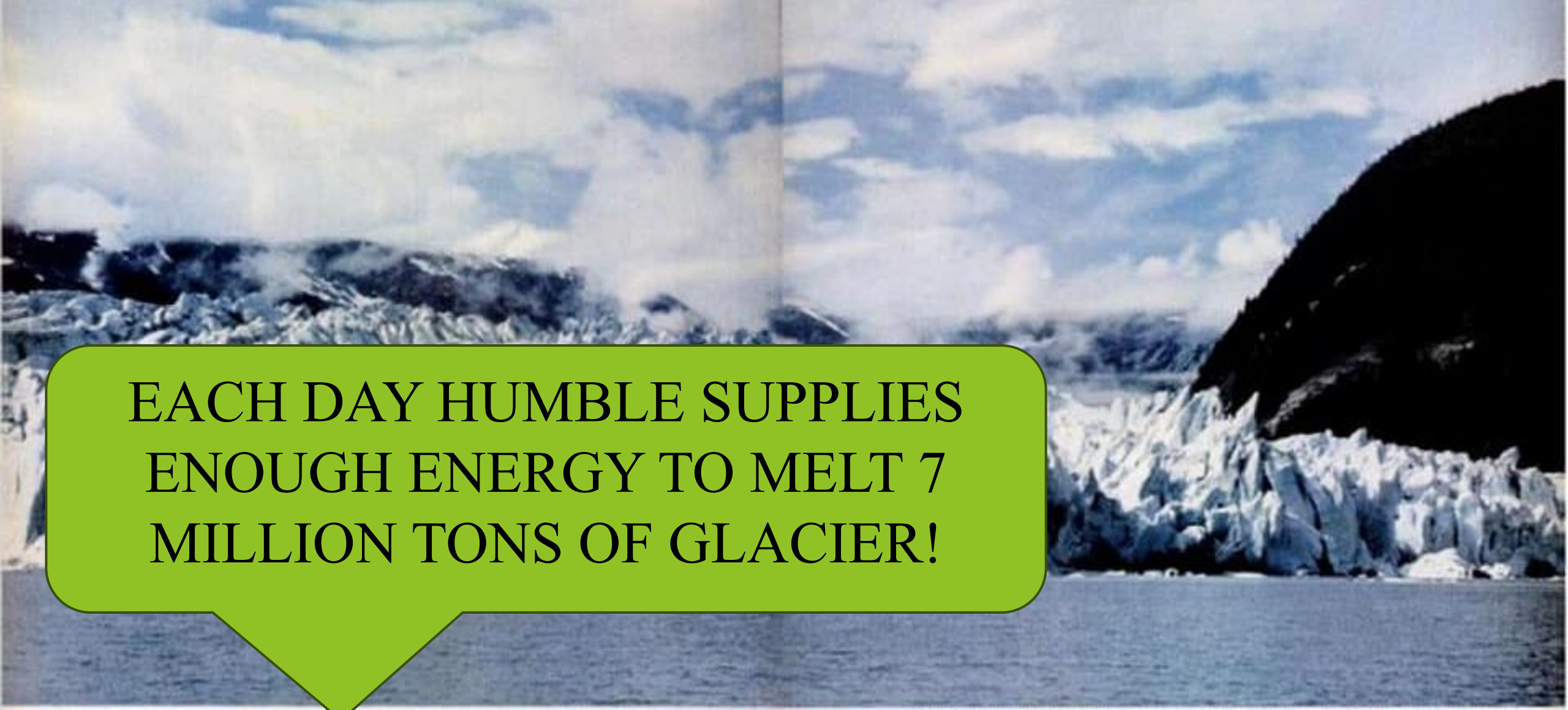
WHAT you can do

Who?

COLLÉGIAL INTERNATIONAL SAINTE-ANNE
COLLÉGIAL | LACHINE

- Science and Education
- Teaching STEM for 33 years
- Grades 7 - 13 and CEGEP
- Collégial international Sainte-Anne
  - First year CEGEP chemistry courses
    - 202-SN1-RE and 202-SN2-RE

Why?



EACH DAY HUMBLE SUPPLIES ENOUGH ENERGY TO MELT 7 MILLION TONS OF GLACIER!

EACH DAY HUMBLE SUPPLIES ENOUGH *ENERGY* TO MELT 7 MILLION TONS OF GLACIER!

This giant glacier has remained unmelted for centuries. Yet, the petroleum energy Humble supplies—if converted into heat—could melt it at the rate of 80 tons each second! To meet the nation's growing needs for energy, Humble has applied science to nature's resources to become America's Leading Energy Company. Working wonders with oil through research, Humble provides energy in many forms—to help heat our homes, power our transportation, and to furnish industry with a great variety of versatile chemicals. Stop at a Humble

HUMBLE
OIL & REFINING COMPANY

ENCO

McCarty Glacier, Alaska

July 30, 1909
Photo by Ulysses Sherman Grant

August 11, 2004
Photo by Bruce F. Molnia

Glacier Photograph Collection, National Snow and Ice Data Center/World Data Center for Glaciology


Canada's record-breaking wildfires in 2023: A fiery wake-up call
60,000 People Died from Blistering
Waves, New Analysis
Ocean Cleanup crew removes 54 tonnes
of plastic from Pacific garbage patch
leat
Landmark study links
microplastics to serious health
problems
Indian capital swelters as temperatu
hits all-time high of 52.9 C
Marine animals are swallowing and
becoming entangled in pla
rates, report fi
Arctic Ocean acidifying up to four times
as fast as other oceans, study finds
eniable link to climate change' in
California's fire season, expert says
Heat and drought linked to climate change has worsened wildfires.
UN wea
climate c
melt incr
cord heat, ice-
on
s in 2023
Unhealthy coral fueled by climate change threatening fish and supply: experts
Deforestation of Amazon rainforest
highs at start of 2022, says Brazil
was Earth's hottest month on record
with 'dire consequences' for people and
planet

Eco-anxiety:

75% of young people say

‘*the future is frightening*.’

What?

slido

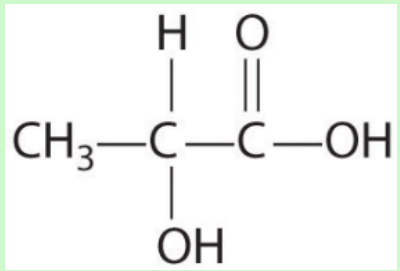
Please download and install the Slido app on all computers you use

What is Green Chemistry?

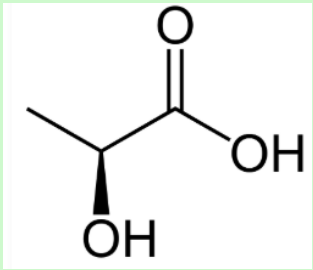
ⓘ Start presenting to display the poll results on this slide.

Comparative Analysis: Lactic Acid Production

- Lactic acid ($C_3H_6O_3$) or 2-hydroxypropanoic acid:



or

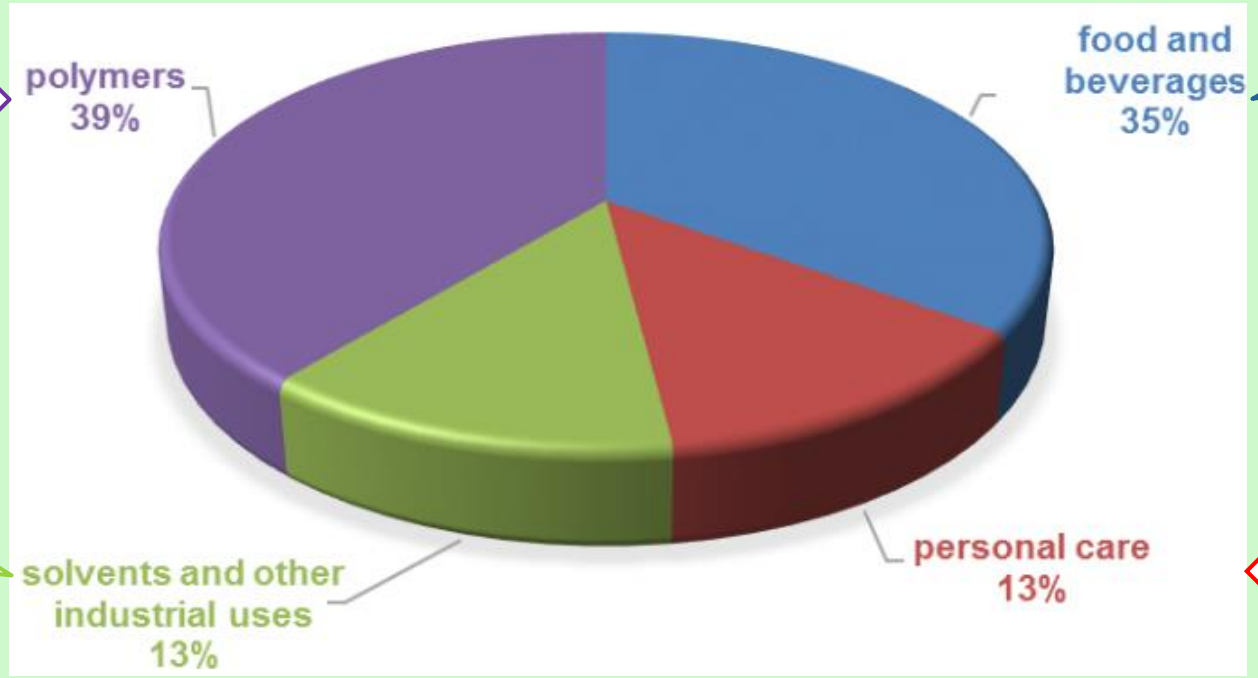


- ✓ Chemical names
- ✓ Chemical formulas
- ✓ Lewis structures
- ✓ Skeletal structures

- Commercially and industrially useful molecule.

Uses of Lactic Acid

Plastics (Polylactic Acid, PLA)



Preservatives
Flavoring agents

Cleaning agents
Green solvents

Moisturizers
Anti-acne agents

- ~1.81 million metric tons (= 1.81 x 10^9 OR 1 810 000 000 kg).
- Demand increasing 5 - 8% per year.
- 4.6 billion US$ by 2029.

Which production process is ‘greener’? Why?

CHEMICAL SYNTHESIS	MICROBIAL FERMENTATION

Which production process is ‘greener’? Why?

CHEMICAL SYNTHESIS

Petrochemical Resources

↓

Acetaldehyde (CH_3CHO)

Addition of HCN and catalyst ↓

Lactonitrile ($CH_3CH(OH)CN$)

Hydrolysis by H_2SO_4 ↓

Racemic mixture D- AND L-lactic acid

MICROBIAL FERMENTATION

Simultaneously

Renewable Resources

↓ *Acid hydrolysis of complex carbohydrates*

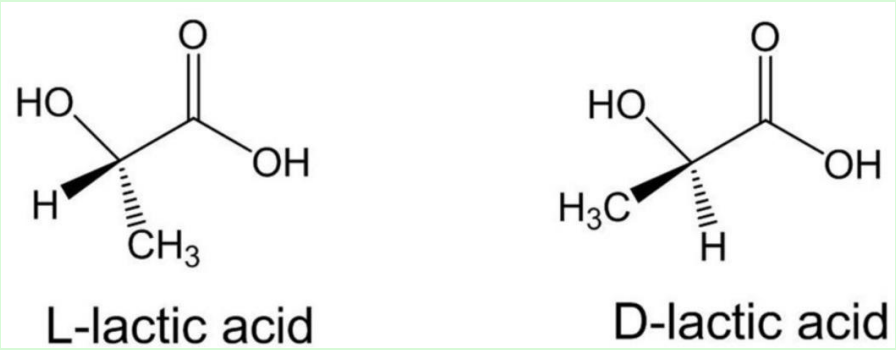
Fermentable carbohydrates

↓ *Microbial fermentation*

Fermented broth

↓ *Recovery & Purification*

Optically pure D- OR L-lactic acid



GREEN CHEMISTRY

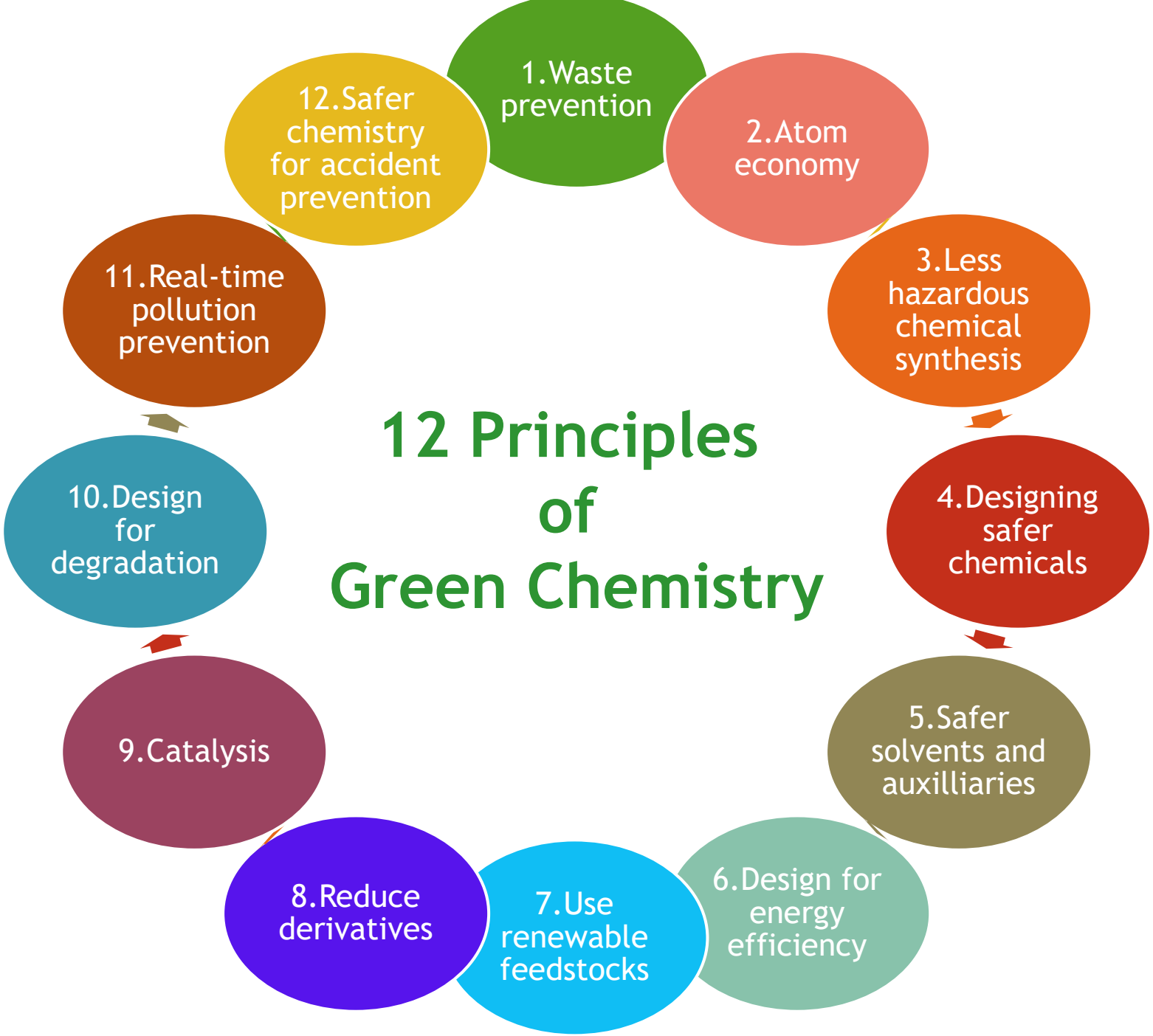
The utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the manufacture, and application of chemical product.

- Introduction to Green Chemistry (video: 1:57)

GREEN CHEMISTRY

reduces or eliminates hazardous substances in the application of chemical product.

Introduction to Green Chemistry (video: 1:57)


12 Principles of Green Chemistry
1.Waste prevention
2.Atom economy
3.Less hazardous chemical synthesis
4.Designing safer chemicals
5.Safer solvents and auxilliaries
6.Design for energy efficiency
7.Use renewable feedstocks
8.Reduce derivatives
9.Catalysis
10.Design for degradation
11.Real-time pollution prevention
12.Safer chemistry for accident prevention


How?

- Introduce Green Chemistry:
  - First year chemistry courses
  - Project
  - Labs

202-SN1-RE

Objective	*Standard*
Statement of the Competency	**Performance Criteria for the Competency as**
Analyze properties of matter and chemical changes.	• Appropriate use of terminology • Observance of mathematical and che • Use and conversion of appropri its of m • Consideration of environmental issues • Demonstration of rigour in the problem-solving approach

Elements of the Competency	Performance Criteria
1. Use chemical language and symbols.	• Relevant use of basic concepts and chemical symbols [1] • Accurate application of nomenclature rules of inorganic compounds
2. Carry out the quantitative analysis of chemical systems.	• Accurate application of the appropriate concepts for calculating quantities used in chemistry [2] • Accurate applic types of react
3. Explain the properties of the elements and how they relate to the periodic classification.	• Appropriate d probabilistic r • Appropriate d configuration • Summary de electron conf elements [4] • Accurate exp elements [5]
4. Explain the structure of matter according to the types of chemical bonds.	• Accurate distinction of compound bonds involved [6] • Exact calculations involving c • Appropriate determination o and molecular compounds • Accurate description of a
5. Explain the main macroscopic properties of matter.	• Accurate distinction of forces • Accurate determinati tive stren intermolecular force • Accurate demonst the relationship between the physical properti atter and the forces involved [9]
6. Verify, using an experimental method, some chemical and physical properties of matter.	• Appropriate us laboratory techniques, equipme measurement apparatus • Compliance with laboratory rules for health environmental protection • Appropriate data processing [10] • Relevance of the analysis and a y of the results • Communication of results ac ing to established requirements • Effective contribution to teamwork

202-SN2-RE

Code: 0C02

Standard
Performance Criteria for the Competency as a Whole
• Appropriate use of terminology • Observance of mathematical and chemical formalism • Use and conversion of appropriate units of measurement • Consideration of environmental issues • Demonstration of rigour in the problem-solving approach

Elements of the Competency	Performance Criteria
1. Solve problems related to different types of solutions.	• Appropriate distinction of the different types of solutions [1] • Appropriate use of units of concentration [2] • Precise calculations involving colligative properties [3]
of	• Appropriate determination of a reaction rate equation • Accurate application of the integrated rate laws [4] • Consideration of energetic aspects of catalysis
a	• Accurate application of the law of mass action [5] • Accurate prediction of a system's evolution according to Le Chatelier's principle • Correct resolution of problems involving acid-base systems [6] • Accurate application of the concept of reduction-oxidation concept
4. Verify, using an experimental method,	• Appropriate use of laboratory techniques, equipment and measurement apparatus • Compliance with laboratory rules for health, safety and environmental protection • Appropriate data processing [7] • Relevance of the analysis and accuracy of the results • Communication of results according to expected requirements • Effective contribution to teamwork

Consideration of environmental issues

Compliance with laboratory rules for health, safety and environmental protection

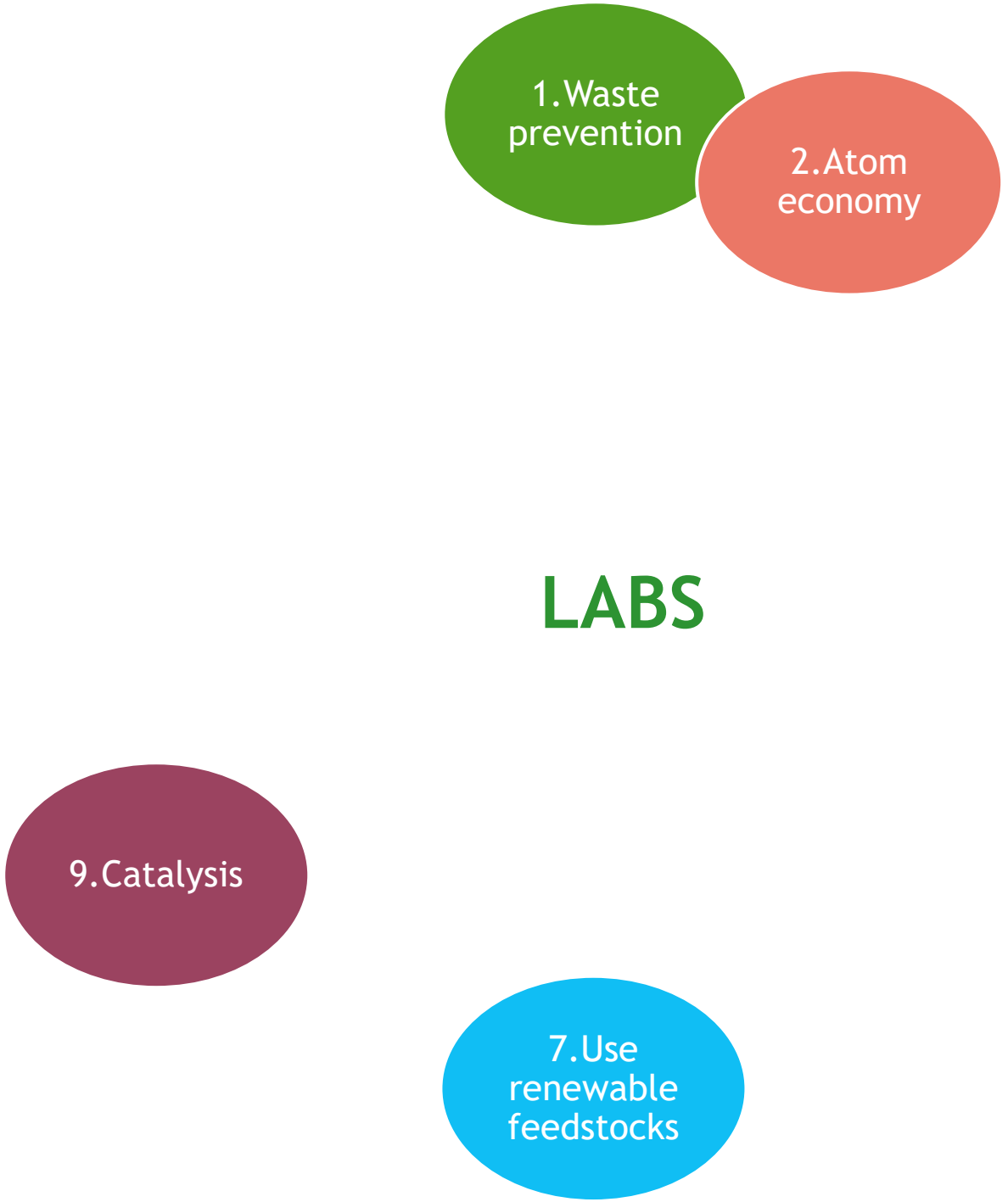
Effective contribution to teamwork

Project: Real-World Analysis of Green Chemistry

Overview	• Groups of 2 or 3 • Topics are released one week before. • 5-minute Powerpoint Presentation
Presentation	• Introduce topic • Chemistry - reactions, chemicals, conditions, etc. • Analyze – Advantages and Disadvantages (12 principles) • Conclusion: Is this option green? • References
Evaluation	• Student and Teacher (rubric)

Topics:

- **Computer chips:**
  - Affordable Composites from Renewable Sources (ACRES)
  - Los Alamos National Laboratory and supercritical CO_2
- **Pharmaceuticals:**
  - Simvastatin
  - Sitagliptin
- **Plastics:**
  - Polyester film
  - Polylactic acid
- **Paint:**
  - Sherman-Williams
  - Procter & Gamble and Cooks Composite and Polymers Co.
- **Textiles:**
  - Bamboo
  - Chitosan


1.Waste prevention
2.Atom economy
LABS
9.Catalysis
7.Use renewable feedstocks

Lab: Limiting and Excess Reagents

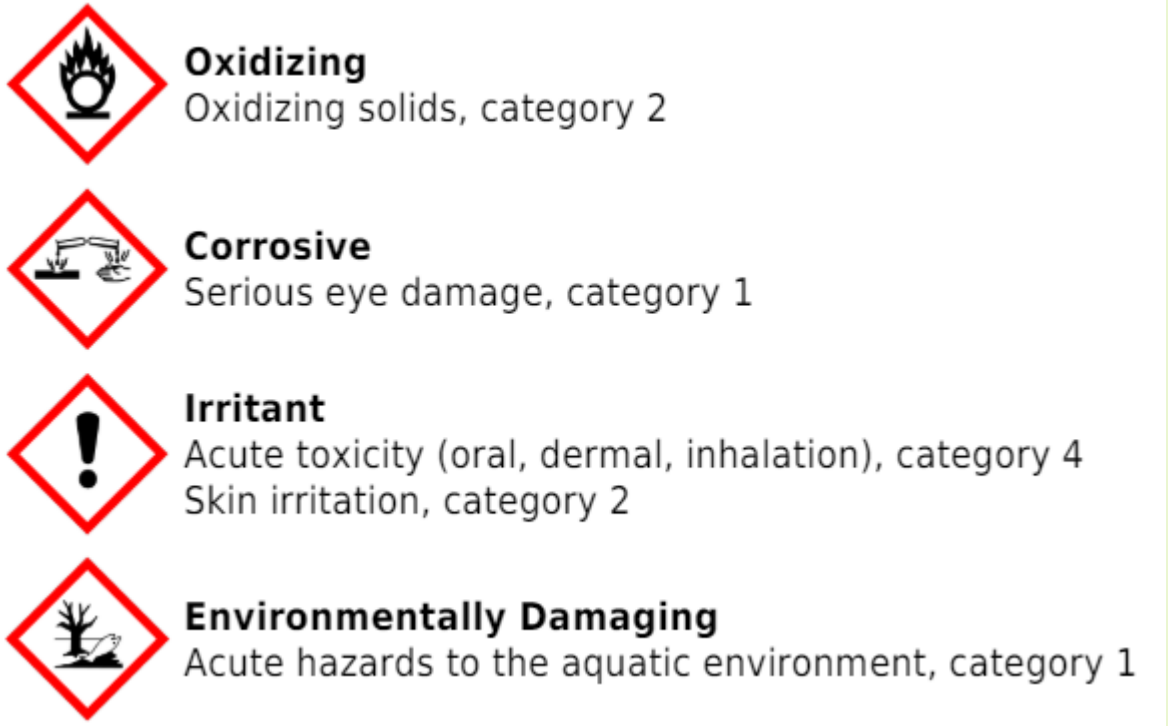
- **Course:** General Chemistry (202-SN1-RE)
- **Purpose:** Understand and apply concepts of limiting and excess reagents.
- **Competencies:**
  - Stoichiometry
  - Limiting and excess reagents
  - Precipitate and Supernatant
  - Percent Yield and ***Atom Economy***
  - Calculations, units, and significant figures

Lab: Limiting and Excess Reagents, *continued*

- **Conventional lab:**

$$2\ Cu(NO_3)_2\ (aq) + 4\ KI\ (aq) \rightarrow 2\ CuI\ (s) + I_2\ (aq) + 4\ KNO_3\ (aq)$$

Copper (II) nitrate



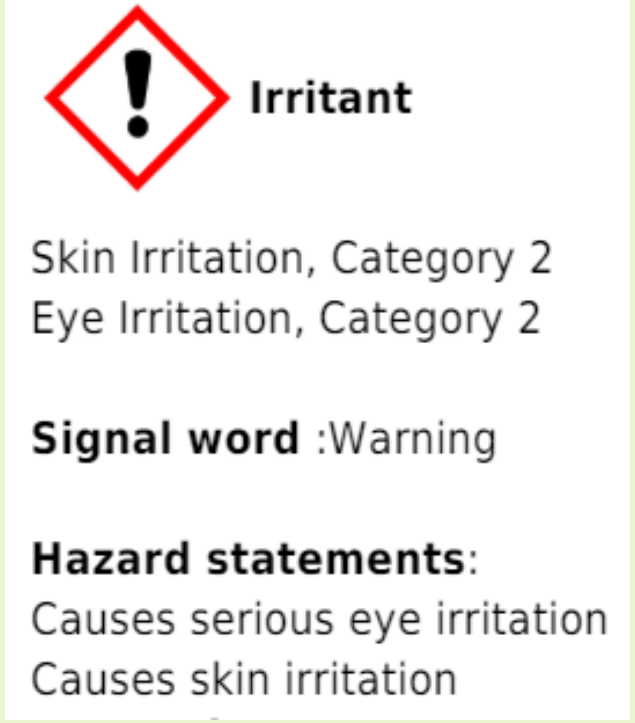
Oxidizing
Oxidizing solids, category 2

Corrosive
Serious eye damage, category 1

Irritant
Acute toxicity (oral, dermal, inhalation), category 4
Skin irritation, category 2

Environmentally Damaging
Acute hazards to the aquatic environment, category 1

Potassium iodide



Irritant

Skin Irritation, Category 2
Eye Irritation, Category 2

Signal word :Warning

Hazard statements:
Causes serious eye irritation
Causes skin irritation

Lab: Limiting and Excess Reagents, *continued*

- **Conventional lab:**

$$2\ Cu(NO_3)_2\ (aq) + 4\ KI\ (aq) \rightarrow 2\ CuI\ (s) + I_2\ (aq) + 4\ KNO_3\ (aq)$$

Copper (I) iodide

Causes skin irritation
May cause an allergic skin reaction
Causes serious eye damage
Causes damage to organs through prolonged or repeated exposure

Iodine

Potassium nitrate

Oxidizing
Oxidizing solids, category 2

Irritant
Skin irritation, category 2
Eye irritation, category 2A
Specific target organ toxicity following single exposure, category 3

Signal word: Danger

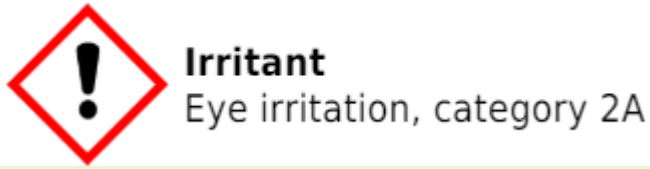
27

Lab: Limiting and Excess Reagents, *continued*

- **Greener lab:**

$$CaCl_2\,(aq) + Na_2CO_3\,(aq) \rightarrow CaCO_3\,(s) + 2\,NaCl\,(aq)$$

Calcium chloride



Not a dangerous substance according to the Global Harmonized System of Classification (GHS).

Sodium carbonate

SECTION 2: Hazards identification

2.1 Classification of the substance or mixture

GHS Classification in accordance with Hazardous Products Regulations (HPR) (SOR/2015-17)

Eye irritation (Category 2A), H319

For the full text of the H-Statements mentioned in this Section, see Section 16.

2.2 GHS Label elements, including precautionary statements

Pictogram

Lab: Limiting and Excess Reagents, *continued*

- **Green*er* lab:**

$$CaCl_2\,(aq) + Na_2CO_3\,(aq) \rightarrow CaCO_3\,(s) + 2\,NaCl\,(aq)$$

2.1 Classification of the substance or mixture

Not a hazardous substance or mixture according to Regulation (EC) No 1272/2008.

2.2 Label elements

No hazard pictogram, no signal word, no hazard statement(s), no precautionary statement(s) required

Signal words: *none*

- Less dangerous
- Possibly cheaper
- Fulfills competencies
- Global citizen

Lab: Kinetics

- **Course:** Chemistry of Solutions
- **Purpose:** Determine the rate law, the rate constant, and activation energy of the oxidation of iodide ion by peroxydisulaphate ion.

$$2I^-_{(aq)} + {S_2O_8}^{2-}_{(aq)} \rightarrow I_{2(aq)} + 2{SO_4}^{2-}_{(aq)}$$

- **Competencies:**
  - Apply the method of initial rates
  - Temperature dependency of the rate constant, k
  - Determine the activation energy by plotting *Ln*k vs T^{-1}

Lab: Kinetics, *continued*

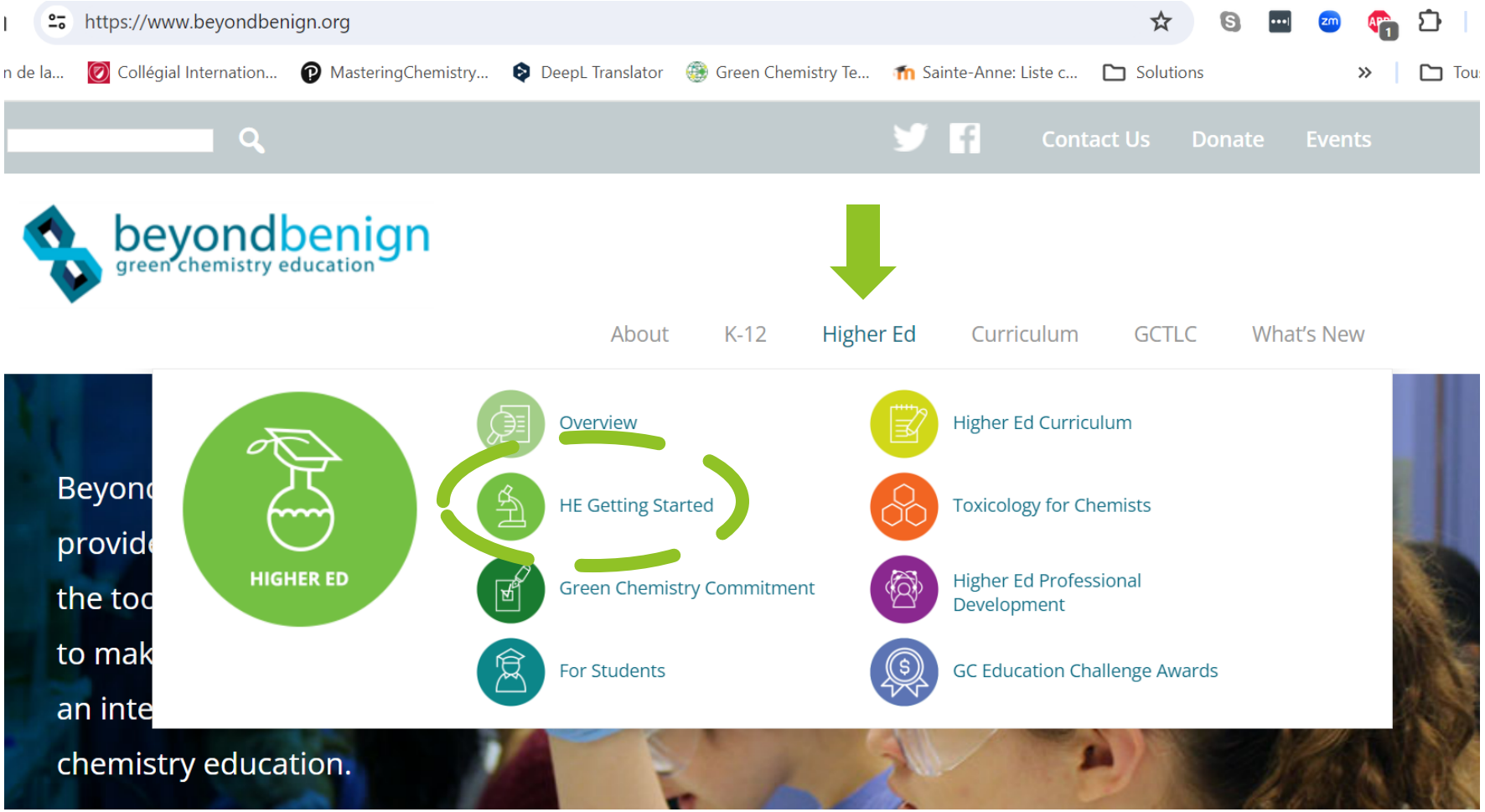
- *Teams of 4 vs 2:*
  - Reduced amount of chemicals used
  - Produced less waste
    - Lowered cost to dispose waste
    - 660$ vs 1328$ (~150 students)
  - Lowered carbon footprint
  - Reinforced sustainability
  - Teamwork

What can you do?


Reduce
Reuse
Recycle

Beyond Benign

- **www.beyondbenign.org**
  - Educational materials, webinars, and videos to help make green chemistry an integral part of chemistry education.



General Chemistry

Select another topic

General Chemistry

Green Chemistry University Curriculum

Organic Chemistry

Toxicology

Virtual Resources

Case Study: A Greener Approach for Measuring Colligative Properties

Organic solvents are typically used in the traditional experiments for measuring colligative properties, such as freezing point depression. This experiment uses fatty acids and oils to avoid the use of organic solvents.

DOWNLOAD LESSON

Case Study: A Laboratory Sequence for Reducing Waste in the General Chemistry Laboratory

Dr. Matthew Fountain at SUNY Fredonia has revised their General Chemistry II labs to results in a drastic reduction in waste and the use of hazardous chemicals. By utilizing the waste from one experiment in the following experiment, there has been almost a 90% reduction in waste. The laboratory sequence is described in this case study.

Molar Mass Determination by Freezing Point Depression

A case study prepared by Beyond Benign as part of the Green Chemistry in Higher Education program: A workshop for EPA Region 2 Colleges and Universities

Molar Mass Determination by Freezing Point Depression

Table of Contents

beyondbenign
green chemistry education

Molar Mass Determination by Freezing Point Depression
Traditional Experiment

Volume of waste and purchasing and waste disposal costs per class of 100 students:
0.5 gallons of liquid waste
$52.98-$149.12 in purchasing and disposal costs

Freezing Point Depression
A Greener Approach

Volume of waste and purchasing and waste disposal costs per class of 100 students:
*0-1.2 lbs. of waste**
$38.14 - $272.34 in purchasing and disposal costs

- The Green Chemistry Initiative (GCI) University of Toronto
  - Fun videos on each of the 12 principles
  - Resources to promote green chemistry and sustainability.

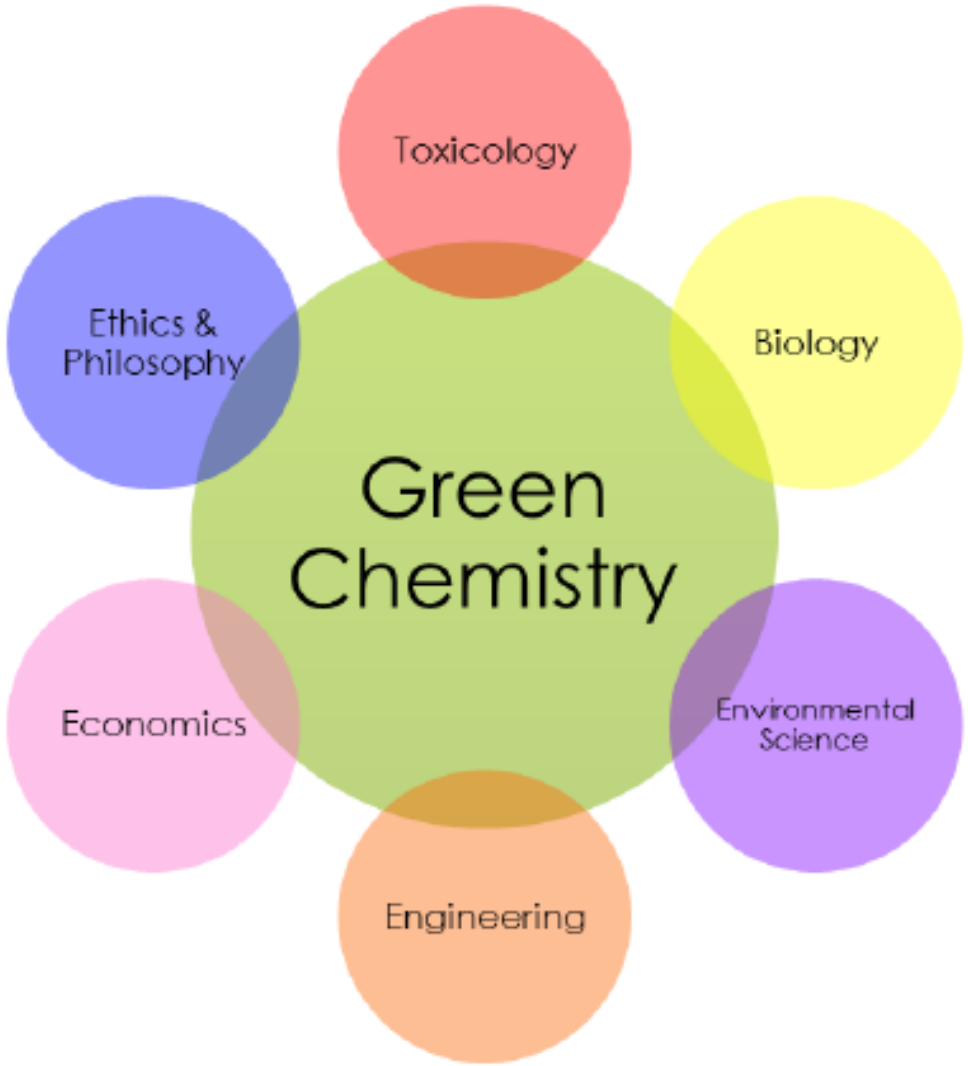
- Yale University YouTube Channel
  - Videos on various Green Chemistry topics:
    - What is Green Chemistry?
    - The 12 Principles.

- Green Chemistry Teaching and Learning Community (GCTLC)
  - Place to learn, share, connect, and grow.

- Green Chemistry Labs for Undergraduate Organic Chemistry
  - Comprehensive teaching guide by Beyond Benign, My Green Lab, and MilliporeSigma.

Green Chemistry is about…

- Increasing efficiency
- Reducing costs
- Enhancing performance
- Changing chemistry education
- Encouraging systems or life-cycle thinking about reagents and processes
- Encouraging innovation and exploration to discover new ways of working.



NETWORKING

Thank you

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