CHEM 489 – Spring 2020
Advanced Environmental Chemistry
Introduction to Green Chemistry
Dr. Brush

January 28 (T):

- **Writing Prompt-1 was due 5:00 pm yesterday!**
- **Journal Club-1 article selection due today**
- **Introduction to Green Chemistry (continued):**
    - ➢ **Why do we need Green Chemistry?**
    - ➢ **12 Principles of Green Chemistry**
    - ➢ **Metrics**

GREEN CHEMISTRY

Journal Club #xxx
CHEM 489
Green Chemistry

Your name
The topic you selected

Topic:

Title of article:

Source: Journal name, year, volume # or etc., pages

Why this topic and/or article is significant and interesting to me:

- Xxxxx
- Xxxxxx
- Xxxxxx
- Etc.

Topic:

Highlights from my article:

- Xxxxx
- Xxxxxx
- Xxxxxx
- Etc.

Topic:

Green chemistry relevance of my topic and article:

- Xxxxx
- Xxxxxx
- Xxxxxx
- Etc.

Questions?

What is Green & Sustainable Chemistry?

…pollution prevention starting with the design phase…

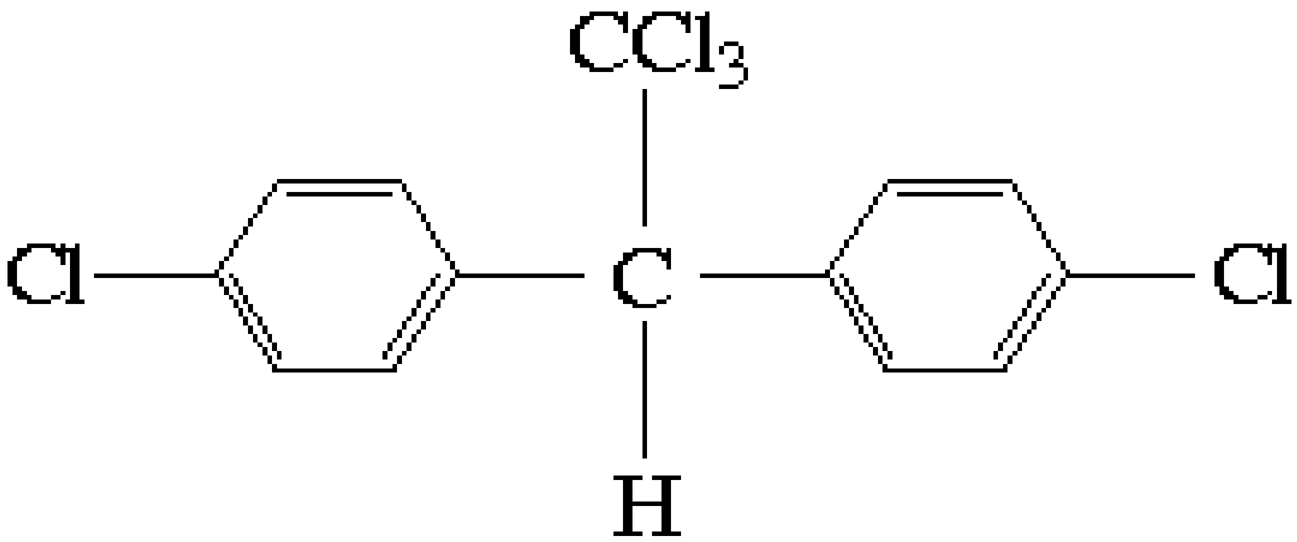
"Green Chemistry aims to reduce or eliminate the use and generation of hazardous substances associated with the design, manufacture, and use of chemicals"

Why do we need Green Chemistry……?
"Chemicals of Concern"

The EPA has identified Chemicals of Concern that "may present an unreasonable risk of injury to health and the environment".

- **There are over 100,000 chemicals in commerce today**
- **thousands more discovered each year**
- **it takes decades for EPA safe exposure levels to come out!**

Why do we need Green Chemistry……?
"Silent Spring"



•**Rachel Carson's *Silent Spring* (1962) exposed the hazards of the pesticide DDT – start of the modern environmental movement.**

Disproportionate beauty product exposures among vulnerable populations

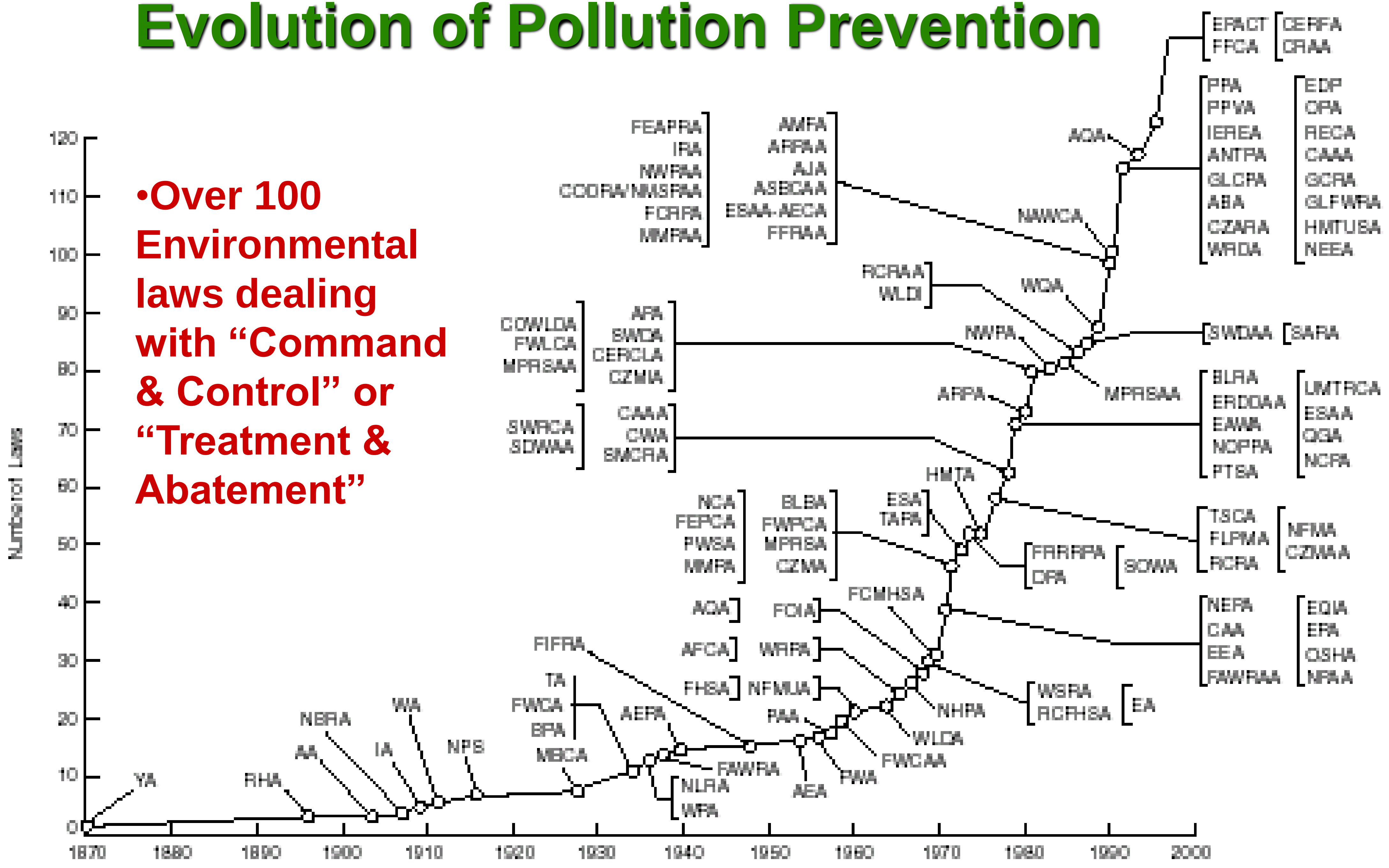
Examples of disproportionate beauty product exposures among vulnerable populations

External factors	Vulnerable populations	Product use	Chemical exposures	Potential adverse outcomes
Colorism	Dark skinned women (globally)	Skin-lightening creams	Mercury	Mercury poisoning, neurotoxicity, kidney damage
Hair texture preferences	African American women (United States)	Hair relaxers and other hair care products	Parabens and estrogenic chemicals from placenta	Uterine fibroid tumors, premature puberty, and endocrine disruption
Odor discrimination	African American women (United States)	Vaginal douches and other feminine care products	Phthalates and talc powder	Gynecologic cancers and endocrine disruption

Zota & Shamasunder. Beauty products, environmental chemicals, health disparities. Am J Obstet Gynecol 2017.

Evolution of Pollution Prevention

- Over 100 Environmental laws dealing with “Command & Control” or “Treatment & Abatement”



Green and Sustainable Chemistry Technologies: ACS Green Chemistry Challenge Awards

- Focuses on **pollution prevention** through **sustainable design** at the **molecular level**.
  - >800 million pounds of hazardous chemicals eliminated/year.
  - >20 billion gallons of water saved each year.
  - >8 billion pounds of carbon dioxide eliminated/year.
  - New catalysts using <u>earth-abundant</u> metals

Green & Sustainable Chemistry – Pollution Prevention through Sustainable Design at the Molecular Level

- Focuses on pollution prevention
- Safer chemistry by design (benign by design)
- Safer, cleaner, more efficient, more elegant
- Minimizes the risk of releases and exposure
- Greater efficiency = Lower production costs
- More dependable synthetic processes
- Improved worker safety
- Better…safer…cheaper…equitable
- Global impact

Green Chemistry and Risk Assessment

Risk = Hazard x Exposure x Vulnerability

Green Chemistry → Hazard

Command & Control → Exposure

Age, race, gender, socioeconomic status, health, genetics, etc. → Vulnerability

Green Chemistry and Risk Assessment

Risk = Hazard x Exposure x Vulnerability

Fundamental connection between Green Chemistry, Public Health, Technology

PREVENTION

3º Prevention: Treating disease, injury, exposure *after the fact* to prevent further damage. Technology impact….

2º Prevention: We minimize Risk by limiting Exposure or through training to handle the Hazard. The Hazard still exists!

1º Prevention: The inherent hazard is eliminated in a given situation, making the Risk moot! Technology impact….

12 Principles of Green Chemistry

Guidelines for sustainable molecular design to produce consumer products that are *better, safer and cheaper*.

1) Prevention
2) Atom Economy
3) Safe Processes
4) Safer Chemicals
5) Safer Solvents
6) Energy Efficiency
7) Renewable Feedstocks
8) Reduce Derivatives
9) Catalysis
10) Bio-degradation
11) Real-time analysis
12) Accident Prevention

Risk = ~~Hazard~~ x Exposure x Vulnerability

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12 Principles of Green Chemistry

1. Prevention. It is better to prevent waste than to treat or clean up waste after it has been created.

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 Syntheses. Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.

12 Principles of Green Chemistry (cont.)

4. Designing Safer Chemicals. Chemical products should be designed to effect their desired function while minimizing their toxicity.

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

6. Design for Energy Efficiency. Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.

12 Principles of Green Chemistry (cont.)

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

8. Reduce Derivatives. Unnecessary derivatization (use of blocking groups, protection/ deprotection, temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.

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

12 Principles of Green Chemistry (cont.)

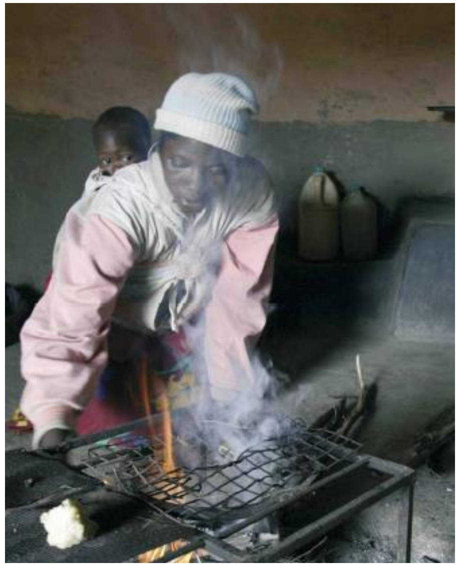
10. Design for Degradation. Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.

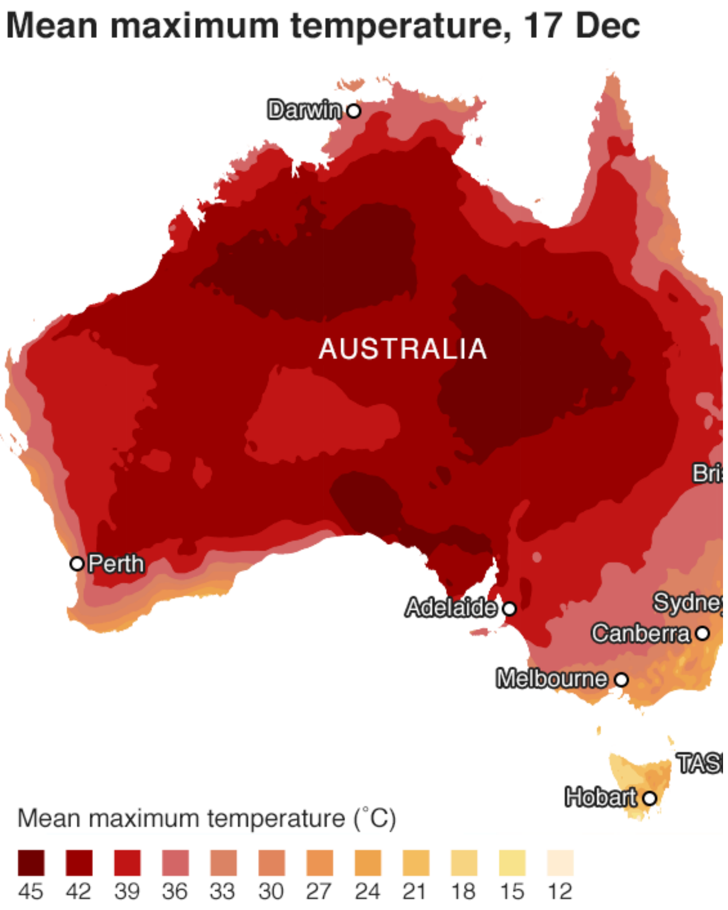
11. Real-time analysis for Pollution Prevention. Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.

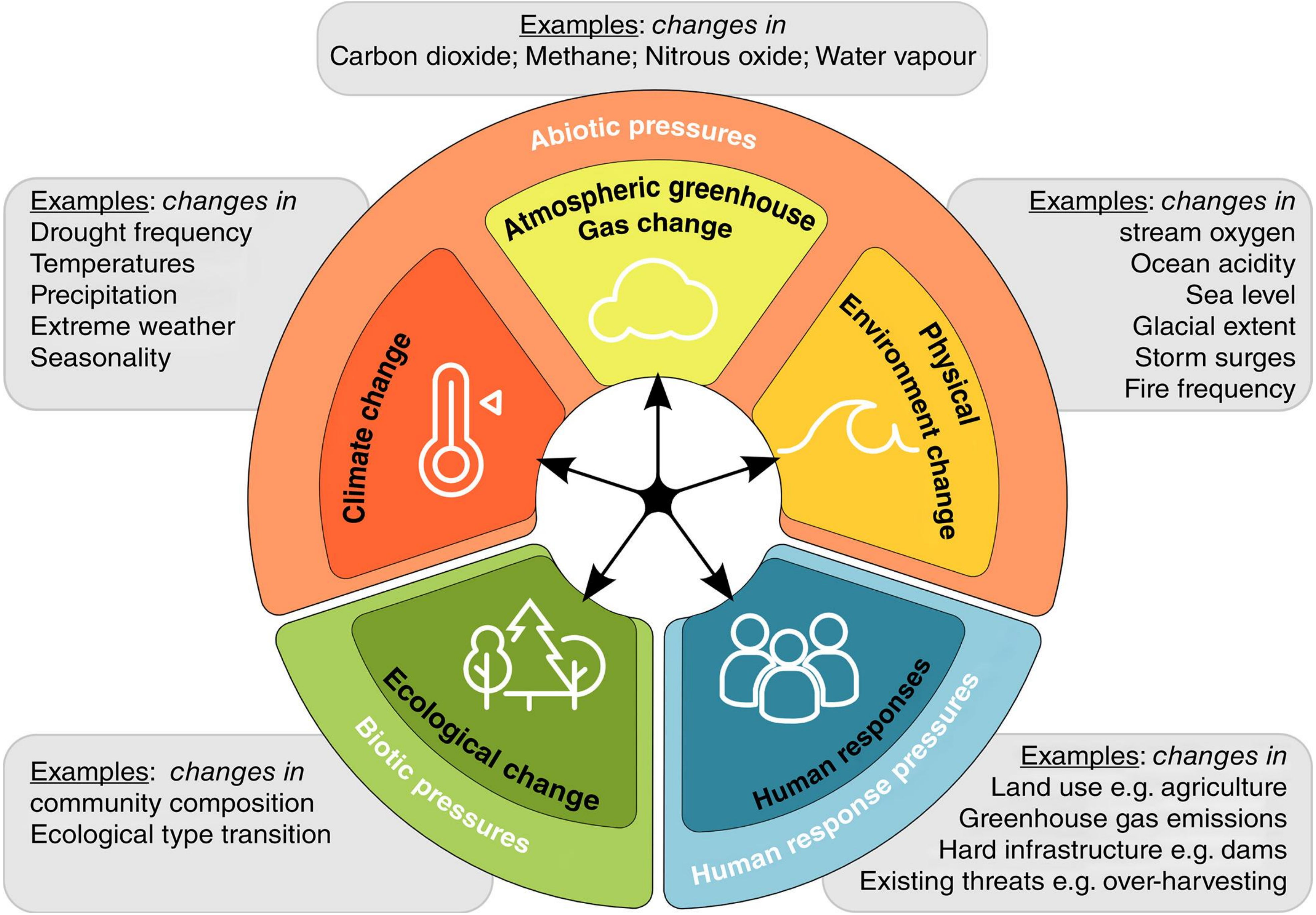
12. Inherently Safer Chemistry for Accident Prevention. Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.

Example: Combustion of Fossil Fuels and Risk Assessment

Risk = Hazard x Exposure x Vulnerability





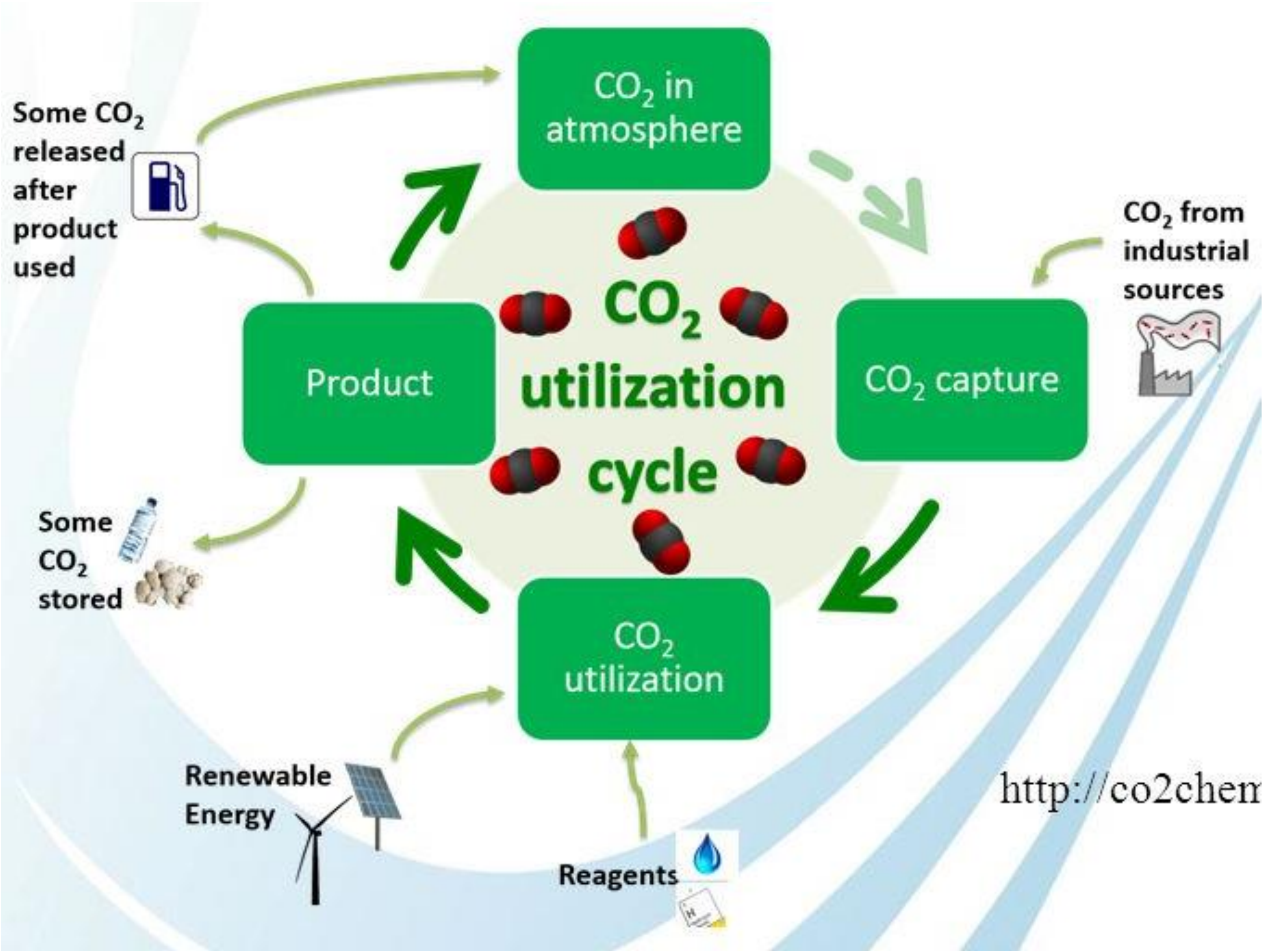


Examples: changes in
Carbon dioxide; Methane; Nitrous oxide; Water vapour
Abiotic pressures
Atmospheric greenhouse Gas change
Examples: changes in
Drought frequency
Temperatures
Precipitation
Extreme weather
Seasonality
Climate change
Examples: changes in
stream oxygen
Ocean acidity
Sea level
Glacial extent
Storm surges
Fire frequency
Physical Environment change
Ecological change
Biotic pressures
Human responses
Human response pressures
Examples: changes in
community composition
Ecological type transition
Examples: changes in
Land use e.g. agriculture
Greenhouse gas emissions
Hard infrastructure e.g. dams
Existing threats e.g. over-harvesting

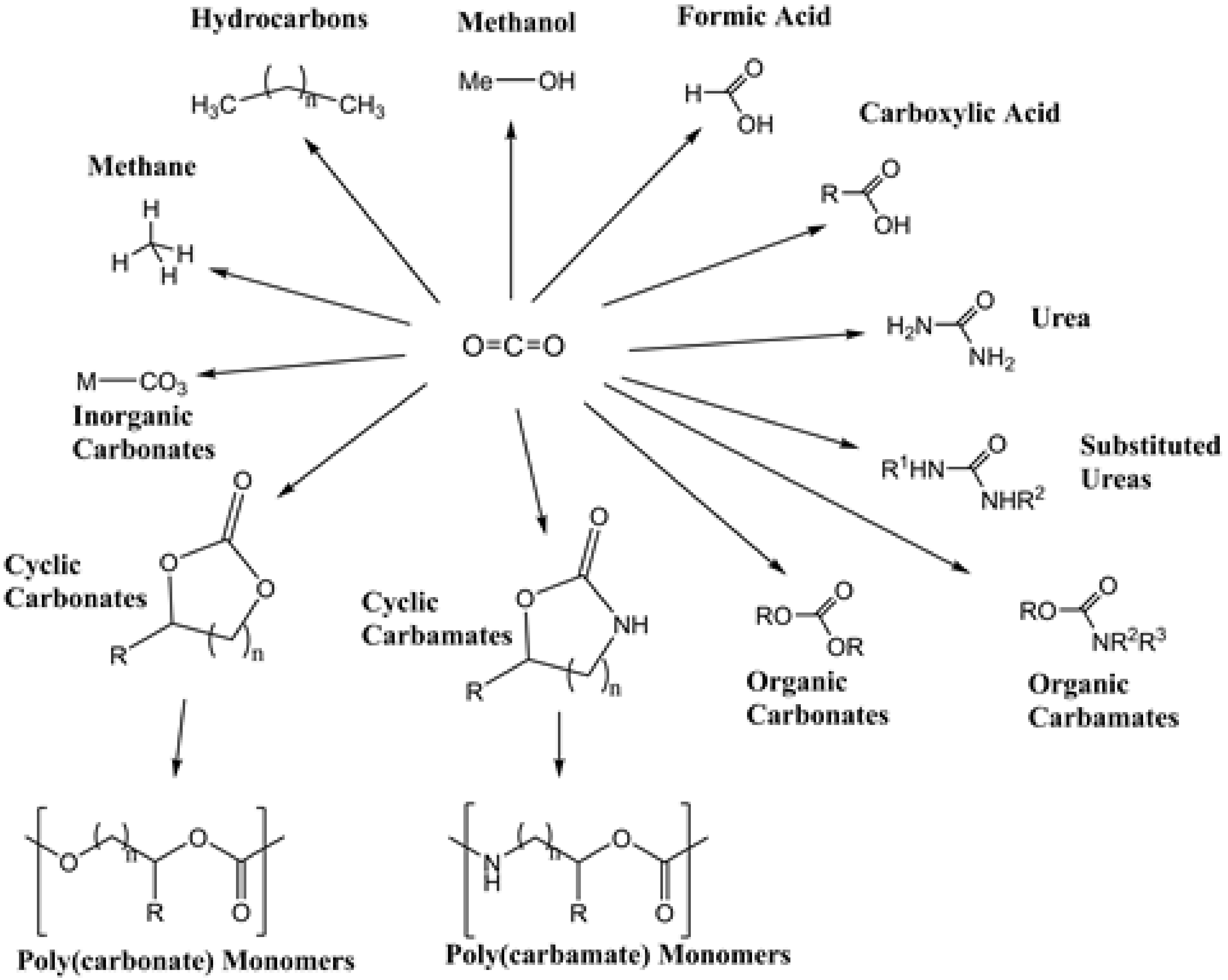
Carbon Capture, Green & Sustainable Chemistry, Risk Assessment

Risk = Hazard x Exposure x Vulnerability

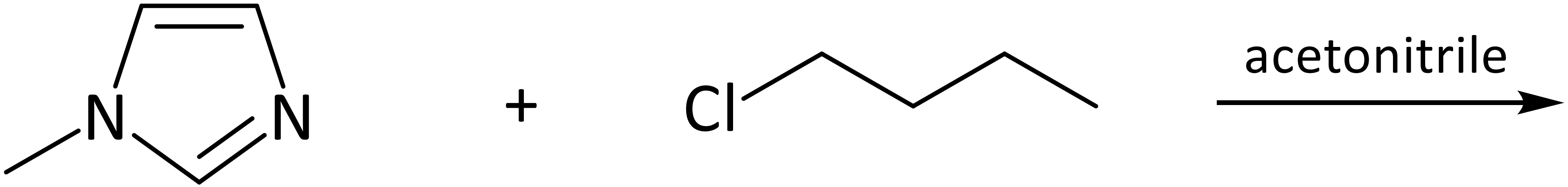
Carbon Capture, Green & Sustainable Chemistry, Risk Assessment



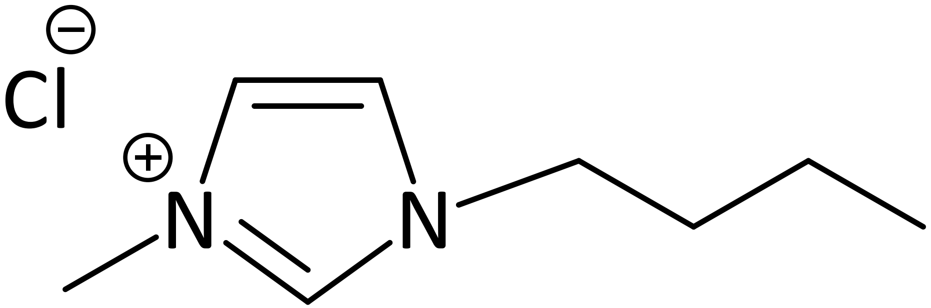
Carbon Capture, Green & Sustainable Chemistry, Risk Assessment



Ionic Liquids for Carbon Capture?



N-methyl imidazole **1-chlorobutane**



3-butyl-1-methylimidazolium chloride
(BMIM-Cl)