

Applying the Tools of Green Chemistry: A Progress Report

Presentation to Binational Toxics
Strategy Integration Workgroup

May 18, 2006

- What are the major tools of Green Chemistry?
- When does application of these tools make the most sense?
- How have these tools been applied?
- Where are there barriers to application?

Tools of Green Chemistry

GREEN

CHEMISTRY

THEORY AND PRACTICE

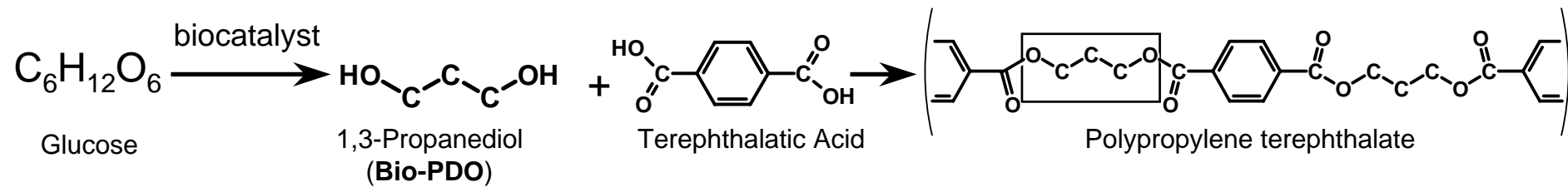
Paul T. Anastas
John C. Warner

- Alternative feedstocks/starting materials
- Alternative reagents
- Alternative solvents
- Alternative product/target molecule
- Process analytical chemistry
- Alternative catalysts

Opportunities

- Need
 - Development of new formulations or
 - Design of new chemical processes (early stage)
- Situation
 - Predictable regulatory environment that allows for flexibility in solutions and
 - Available capital and time
- Outcome
 - Inherently safe and
 - Less waste/pollution/energy use (balance) and
 - Lower costs

Alternative Feedstock



- Renewable resource (corn)
- Microbial production of PDO from glucose from cornstarch
- Balance of carbon, redox, and energy with respect to microbial growth & product formation
- Aerobic fermentation using 40% less energy than chemical route to PDO

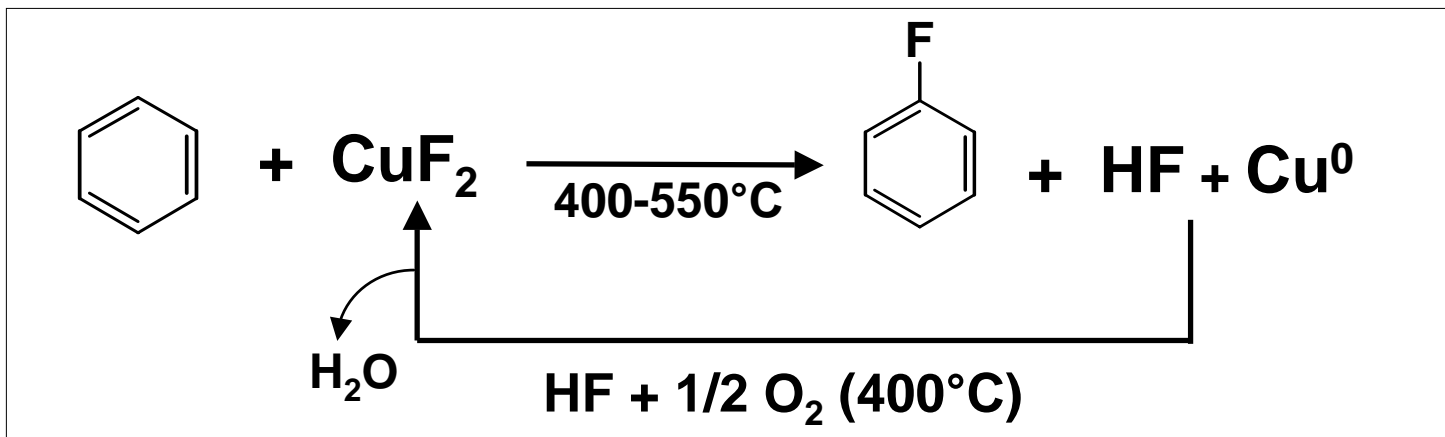


Courtesy of DuPont

Commercializing 2006

Alternative Reagent¹

Synthesis of fluorinated aromatics (FACs) using principles of inorganic chemistry²



- FACs: Starting materials for drugs & agrichemicals
- Efficient atom economy – CuF_2 capable of oxidizing C-H bond & regeneration with HF & O_2
- Eliminates production of wastes associated with traditional FAC synthesis

Patented 2000

¹ CuF_2 serves as a catalyst but also as a reagent F donor

² Subramanian & Manzer, "A 'Greener' Synthetic Route for Fluoroaromatics via Copper (II) Fluoride," *Science*, 9/6/2002.

Alternative Solvent

“Super Solids” ultra-low emissions coatings technology

- Reduced solids MW & particle size in paint to behave like liquid during application
- Increased solids content => less solvent needed + use of existing equipment
- Lower VOC emissions
- Improved scratch & mar resistance



Courtesy of DuPont

Commercialized 2002

Alternative Product

Development of O₃-compatible CFC alternatives



Courtesy of DuPont

- Technical Challenge:
 - Maintain health/physical properties
 - Minimize C-Cl bonds
 - Include C-H bonds

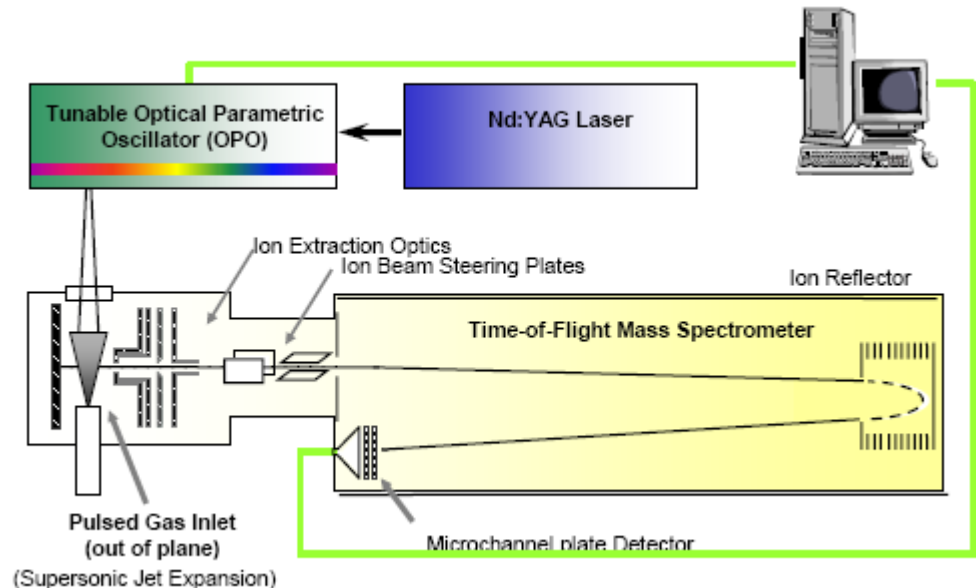
} Reduce ODP
- Developed & scaled-up manufacture of HFC-134a to replace CFC-12

Commercialized 1992

Process Analytical Chemistry

Jet Cooling & REMPI (Resonance Enhanced Multi Photon Ionization) coupled with TOFMS

- Can measure array of aromatics in incinerator exhaust
- Being developed as on-line monitor



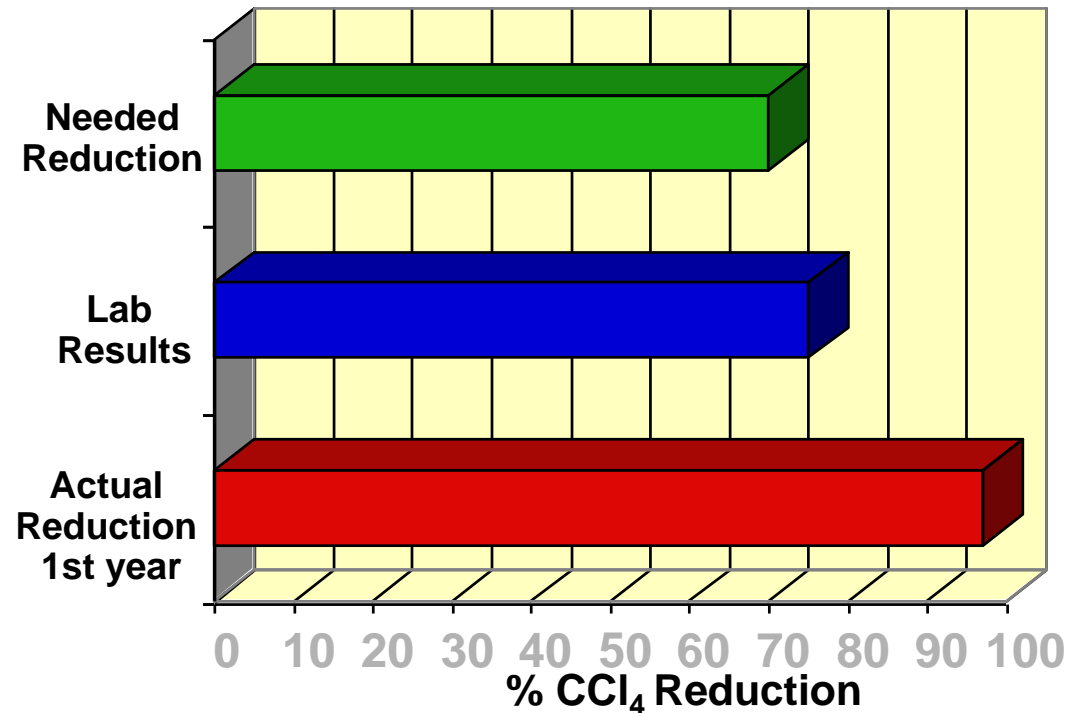
Courtesy of Brian Gullett, US EPA
(from Sept. 7, 2005 Presentation at ETV Field Day, RTP, NC)

Field Testing 2005

Alternative catalyst



- COCl_2 is ingredient for specialty fibers & intermediates
- Negotiations gave time for catalyst work in lieu of end-of-pipe control
- New carbon catalyst:
 - Efficient/selective chlorination of CO
 - Inert to chlorination of carbon surface



Commercialized 1996

Barriers

- Investment
- Infrastructure and integration
- U.S. tax code treatment of investment and depreciation
- Short compliance time lines
- Environmental regulations often geared toward control equipment rather than emissions
- Technology gaps

Summary

- Green Chemistry is being and will be used where technically & economically practicable.
- Promising developments are on the horizon.
- Business incentives & greater regulatory flexibility could encourage wider implementation of Green Chemistry.