聲明

本檔案之內容僅供下載人自學或推廣化學教育之非營利目的使用。並請於使用時註明出處。[如本頁取材自○○○教授演講內容]。

綠色/永續化學的內涵、歷史、現狀與面臨的挑戰

中央研究院化學所

趙奕姈

綠色/永續化學之內涵

The design of products and processes that reduce or eliminate the use and generation of hazardous substances

- 著重於避免毒害物質之使用與產生
- 著重於**“Reduction”**的概念 **(materials, waste, energy, cost, hazard and risk, non-renewables, environmental impact)**
- 不同於環境化學
- 不僅是找尋新能源材料
- 重點在**“Design”**

綠色化學與環境化學之涵蓋範圍

綠色化學

- 有機化學
- 無機化學
- 生物化學
- 分析化學
- 物理化學

環境化學

- 大氣化學
- 土壤化學
- 水化學
- 分析化學

綠色化學帶來的思考模式改變

風險 ＝ 毒害 × 暴露次數

Risk = f(hazard x exposure)

綠色化學之精神
從源頭減少毒害

向來以立法的方式控制

歷史與現狀

- **1987**年聯合國環境與發展委員會提出：

  “…meeting the needs of the present without compromising the ability of future generations to meet their own needs”

- **1990**年美國通過「污染防制法案」：建立由源頭預防或降低污染之國家政策。由環境保護署提出「**Green Chemistry**」一詞。在歐洲許多國家使用「**Sustainable Chemistry**」。

- 綠色/永續化學的蹤跡：美國 英國 日本 義大利 澳洲 加拿大 德國 中國 韓國 印度 其他

歷史與現狀

2020 Sustainability Goals

Zero Waste: eliminate the concept of waste in product, process, materials and energy

Zero Toxic Substances: eliminate substances known or suspected to be harmful to human health or the health of biological systems

100% Closed Loop Processes: take 100% responsibility for our products at all stages of our product and process lifecycle

Sustainable Growth and Profitability: create an economy the planet is capable of sustaining indefinitely

(***Zero Waste Alliance***, 2001)

歷史與現狀

- ***'Green chemistry' movement sprouts in colleges, companies*** *The New York Times* March 25, 2009
  - The **University of Oregon** began an outreach program nine years ago that **teaches professors nationwide** about integrating green chemistry into a curriculum.
  - …balancing **environmental, social and economic** decisions. Many universities are responding by creating a **green-chemistry curriculum**. Their efforts require addressing a **fundamental problem in chemistry education**: **a lack of toxicology training**.

http://www.nytimes.com/gwire/2009/03/25/25greenwire-green-chemistry-movement-sprouts-in-colleges-c-10287.html

歷史與現狀

- ***'Green chemistry' movement sprouts in colleges, companies*** *The New York Times* March 25, 2009
  - …**get the market working properly**, …demand for trained chemists who understand green chemistry and toxicology will ramp up. Universities will respond, as will research.
  - Green chemistry applications make up **1 percent** of the total chemical market share. …the field has tremendous potential for growth.
- 學校老師未開課，**UC Berkeley**的學生自行安排課程：**Green Chemistry and Sustainable Design**
  http://sites.google.com/site/berkeleygreenchemistry/Home

歷史與現狀

- 一般學校打先鋒 近來超級名校加入
  - University of Oregon, University of Massachusetts, University of Scranton, Hendrix College, St. Olaf College…
  - University of York (UK), Monash University (Australia), Carnegie Mellon, University of Illinois, Urbana-Champaign…
  - Center for Green Chemistry & Green Engineering at Yale (2007; First Director: Paul Anastas)
  - MIT Green Alternatives Wizard
  - The Berkeley Center for Green Chemistry (2009)

    A collaboration among the College of Chemistry, Haas School of Business, School of Law, College of Natural Resources, and School of Public Health.

歷史與現狀

- **Presidential Green Chemistry Challenge Awards**
  (USA EPA 1996)
  - Greener **Synthetic Pathways** Award
  - Greener **Reaction Conditions** Award
  - Designing **Greener Chemicals** Award
  - **Small Business** Award
  - **Academic** Award

- **The European Sustainable Chemistry Award**
  (EuCheMS 2010)
  - Alternative **Synthetic Pathways**
  - Alternative **Feedstocks**
  - Alternative **Reactor Design and Reaction Condition**
  - Design and Use of **Less Hazardous Chemicals** and Chemical Products

歷史與現狀

- **Presidential Green Chemistry Challenge Awards**
  - *C&EN* **2008**, *86(33)*, 59-68: The 67 winners have collectively made **1.1 billion lb** of progress in eliminating hazardous chemicals and emissions over the 13 years of the program. It's the result of "cleaner, cheaper, and smarter chemistry," *C&EN* **2008**, *86(33)*, 59-68.
    http://pubs.acs.org/cen/coverstory/86/8633cover3.html

- **IUPAC Green Chemistry Directory**中整理了其他國家之相關獎項（如: 澳洲、英國、日本） http://www.incaweb.org/transit/iupacgcdir/awards.htm

歷史與現狀

- **Joseph Breen Memorial Fellowship**
  - Sponsors a young international green chemistry scholar to participate in an international green chemistry technical meeting, conference, or training program.
  - “Young” international scholar is defined as undergraduate students, graduate students, post-docs, and above, but below the level of Assistant Professor and within the first seven years of a professional career.
- **ACS Summer School on Green Chemistry and Sustainable Energy**
  - Graduate students and postdoctoral scholars

歷史與現狀

- **ACS course: Toxicology for Chemists**
- **Free video course: Carnegie Mellon Univ. The Institute for Green Science** (Under construction).
  - Introduction to Green Chemistry
  - Toxicology for Green Chemists
  - Endocrine Disruption for Green Chemists

歷史與現狀

- 值得觀察與瞭解的組織：
  - **ACS Green Chemistry Institute**（美）
    - **ACS GCI Industrial Roundtables**
      - ACS GCI Pharmaceutical Roundtable
      - ACS GCI Formulator's Roundtable
      - ACS GCI Suppliers Roundtable under development
  - **Green Chemistry Network**（英）
    - Very informative **Newsletter**
    - Great **education materials**
  - **SusChem**（歐）
    - **Strategic Research Agenda** 提出創新方向
    - **Brokerage Database** 提供媒合平台

Pharmaceutical Roundtable

加入**Roundtable**之企業討論出以下之項目

應優先找「綠色途徑」，並向外徵求研究計畫

- Amide formation
- OH activation
- Amide reduction
- Green Mitsunobu reactions
- Oxidation/Epoxidations
- C-H activation of aromatics
- Chiral amine synthesis
- Asymmetric hydrogenation
- Green fluorination methods
- *N*-centered chemistry

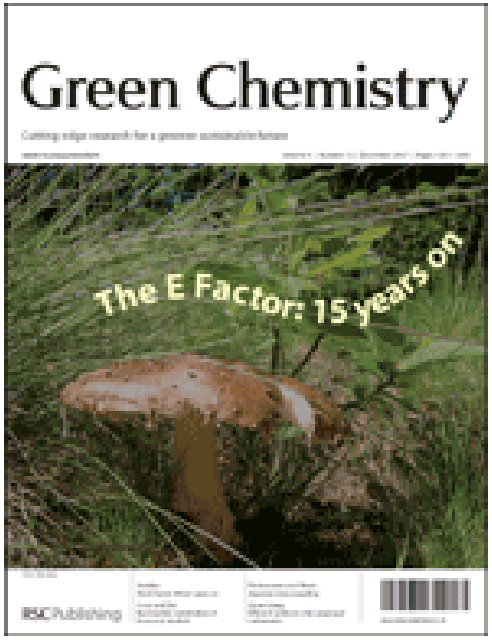
Outside the reaction theme

- Solvent-less reactor cleaning
- Green alternatives to dipolar aprotic solvents

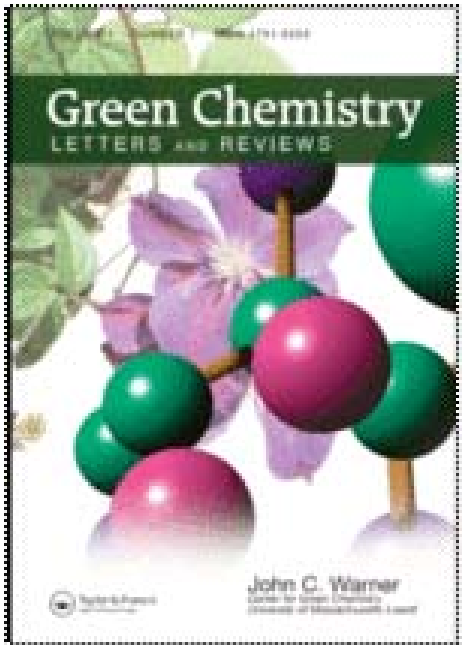
AstraZeneca, Boehringer-Ingelheim, Codexis, Dr. Reddy's, DSM Pharmaceutical Products, Eli Lilly & Company, GlaxoSmithKline, Johnson & Johnson, Merck & Co., Inc., Novartis, Pfizer, Inc., and Roche

歷史與現狀

- **Journals**
  - Green Chemistry (RSC)
    - 2008 impact factor: 4.542; 40% increase in 4 years
  - Green Chemistry Letters and Reviews (Taylor & Francis)
  - ChemSusChem (Wiley)



Since 1999



Since 2007

Since 2008

面臨的挑戰

- **Alternative feedstocks**
  - Move from petroleum to renewable or biologically derived sources
    - Petroleum chemistry => need oxidation chemistry
    - Sugar => need reduction chemistry
  - CO_2 => need new catalysts
- **Alternative solvents**
  - No solvent (neat solution; grinding)
  - Supercritical CO_2, ionic liquid
- **Alternative synthetic pathways**
  - New catalysts
  - Move to biocatalysts (no toxic metals; intrinsically safer)
  - Research into reuse and recycling catalysts still in infancy

http://www.sciencemag.org/cgi/content/full/297/5582/807

面臨的挑戰

- **Education**: 聯合國教科文組織(UNESCO)已定2005-2014為[永續發展教育的10年](Decade of Education in Sustainable Development)，與永續發展汲汲相關的化學界，應速起領導作用
  - 1991年即有綠色化學一詞，綠色/永續化學的重要性無庸置疑，為什麼2006年IUPAC才第一次召開綠色化學大會？ ACS National Meeting 2010年才有主題為 “Chemistry for a Sustainable World”之年會?
  - 為什麼世界上有綠色化學課程的學校仍不多？
  - 國外的綠色化學在教些什麼？
  - 如何自學？

面臨的挑戰

- **Lack of toxicology training**
- **Address the problems of waste, toxicity, energy consumption altogether**, rather than individually.
- **When to use what metrics**

Key References

- Beach, E. S.; Cui, Z.; Anastas, P. T. “Green Chemistry: A Design Framework for Sustainability” *Energy Environ. Sci.* **2009**, *2*, 1038-1049.
- Tundo, P.; Aricò F. “Green Chemistry on the Rise: Thoughts on the Short History of the Field” *Chemistry International* **2007**, *29(5)*
- Anastas, P. T.; Kirchhoff, M. M. “Origins, Current Status, and Future Challenges of Green Chemistry” *Acc. Chem. Res.* **2002**, *35*, 686-694.
- Poliakoff, M.; Fitzpatrick, J. M.; Farren, T. R.; Anastas, P. T. “Green Chemistry: Science and Politics of Change” *Science* **2002**, *297*, 807-810.
- Constable. D. J. C.; Dunn, P. J. ; Hayler, J. D.; Humphrey, G. R.; Leazer, J. L. Jr. ; Linderman, R. J. ; Lorenz, K. ; Manley, J.; Pearlman, B. A. ; Wells, A. ; Zaks, A. ; Zhang, T. Y. “Key Green Chemistry Research Areas—A Perspective from Pharmaceutical Manufacturers” *Green Chem.* **2007**, *9*, 411-420.

Good Starting Points

Internet

- Green Chemistry Network
- ACS Green Chemistry Institute
- SusChem
- 綠色/永續化學網路資源共享網

Book

- Green Chemistry : An Introductory Text
  by Mike Lancaster

Course materials

- 永續化學概論、永續性有機製備

  請向台大化學系劉廣定教授索取 ktliu@ntu.edu.tw

座談會可能之討論事項

- 工作坊改進的方向
- 資訊的流通與分享對臺灣綠色/永續化學的影響（如Pharmaceutical Roundtable, Strategic Research Agenda, Brokerage Database）
- 未來的運作方式
- 中文用詞