Chip-Chat
Tuesday January 24th

Green Chemistry with Nanocatalysts

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Clean Techn Environ Policy
(2012) *14: 513-520*

What is green chemistry?

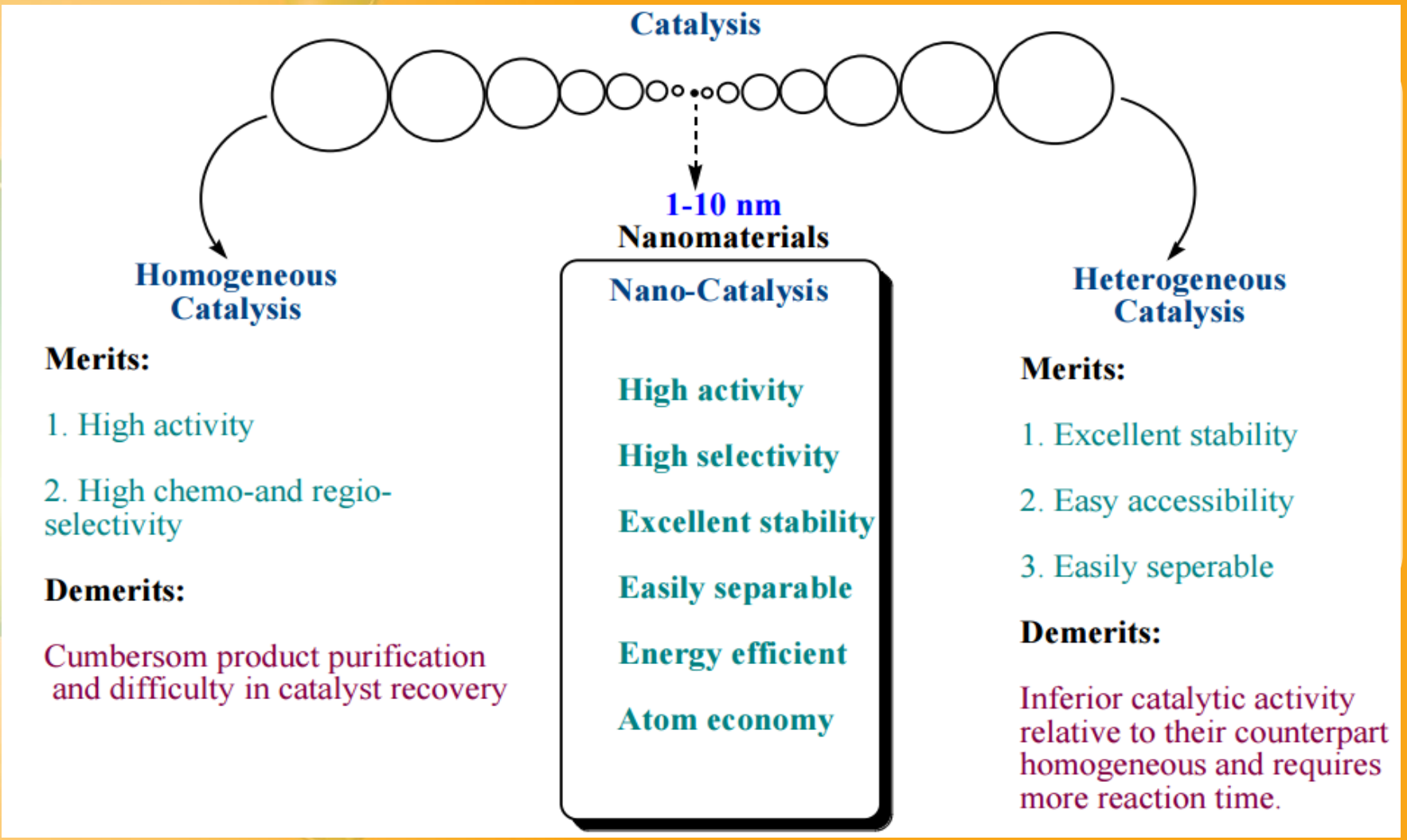
"Green chemistry is the **utilisation** of a set of principles that **reduces** or **eliminates** the **use** or generation of **hazardous substances** in the design, manufacture and application **of chemical products**."

Twelve principles were formulated:

1. Waste prevention
2. Atom economy
3. Less hazardous chemical synthesis
4. Designing safer chemicals
5. Safer solvents and auxiliaries
6. Minimization of environmental impact (room T, p)
7. Renewable raw material
8. Reduce derivatives
9. Use of catalysts
10. (Bio-) Degradable products
11. Real-time analysis for pollution prevention
12. Prevention of chem. accidents

Green Chemistry: Theory and Practice, P T Anastas and J C Warner, Oxford University Press, Oxford, 1998.

What are nanocatalysts?

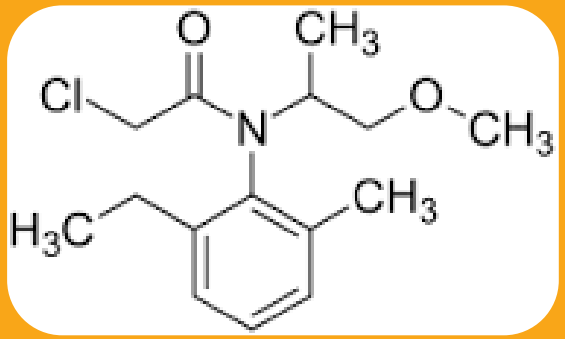


Sanchez, F., & Sobolev, K. (2010). Nanotechnology in concrete–a review. *Construction and building materials*, *24*(11), 2060-2071; Singh, S. B., & Tandon, P. K. (2014). Catalysis: a brief review on nano-catalyst. *J Energy Chem Eng*, *2*(3), 106-115.

Catalysis in the industry

- Catalysts used for production of 90% of chemicals
- Global catalyst demand: 6259 kt (2013)
  - expected to grow 25% to 2020
- Processes involving catalysts are becoming greener:
  - Example: herbicide „Metolachlor“
  - Used for maize crops
  - Amount used for crops decreased by 40%

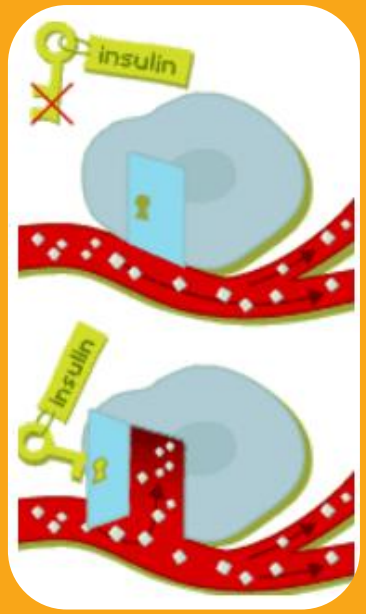
  → elimination of biol. inactive isomers

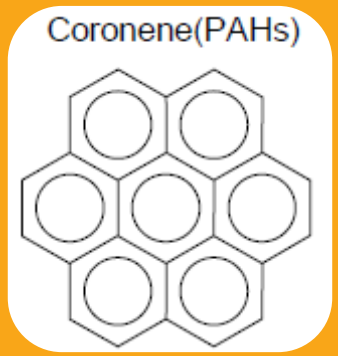


https://de.wikipedia.org/wiki/Metolachlor, https://marketexclusive.com/catalyst-pharmaceuticals-inc-nasdaqcprx-isnt-woods-firdapse-just-yet/35704/

Green synthetic power of enzymes

- Biocatalysts:
  - Alternative to synthetic chemistry
  - Biochemical cleaning of ‘dirty’ fossil fuels
  - Used for synthesis of biofuels
  - Used for bioremediation of contaminants (such as PAHs)
    - Biocatalysts should not disturb the ecosystem and remain in the ecosystem
- Associated problems:
  - High costs
  - Low yields



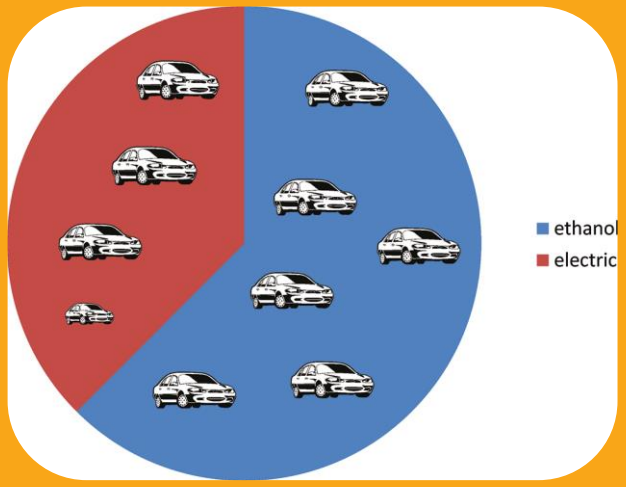


Alcalde, Miguel, et al. "Environmental biocatalysis: from remediation with enzymes to novel green processes." *TRENDS in Biotechnology* 24.6 (2006): 281-287.

Biofuels for transportation

- Enzymes can be used for biofuel production
  - problem: biofuel production not very efficient yet
- Calculated necessary land cover needed to fuel cars on a global scale:
  - 67 mio. hectares (using sugar cane)

  →use other plants than sugar cane
  - 11.3 billion hectares on Earth are usable landmass



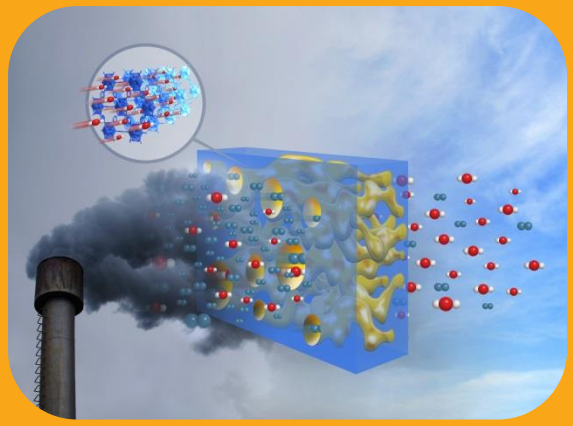
Number of cars fuelled per hectare of sugar cane.

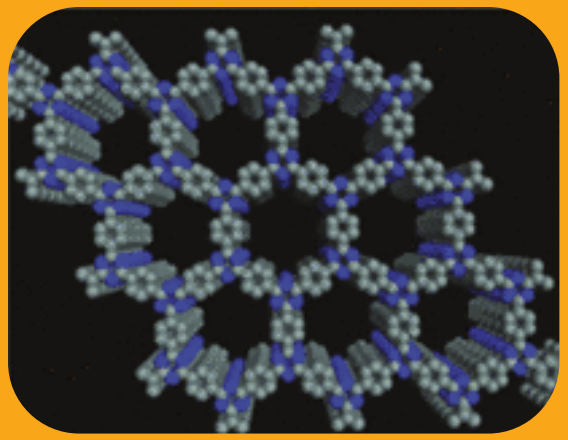
Pacca, S., & Moreira, J. R. (2011). A biorefinery for mobility?. *Environmental science & technology*, *45*(22), 9498-9505.

CO_2 trapping polymers

- To decrease emission of CO_2 in atmosphere, use CO_2 trapping polymers
- 30% of CO_2 emissions caused by coal fire plants (US)
  - Only 15% of the emitted gas is CO_2

  →highly diluted, selective polymers needed
- MOFs and MOPs have high up-take, some even high selectivity





Dawson, Robert, et al. "Microporous organic polymers for carbon dioxide capture." *Energy & Environmental Science* 4.10 (2011): 4239-4245; http://newscenter.lbl.gov/2016/03/17/carbon-capture-membrane/

Plastic recycling conversion technology

- 31 mio. Tons of plastic waste in US 2010:
  - Only 8% recycled
- New ideas for waste recycling:
  - *Gasification:* Decompose waste with little air
  - *Pyrolysis:* Decompose carbon based material in the absence of O_2 (“syngas”)
  - *Plasma Arc*: Production of elemental byproducts under high temp.
  - *Anaerobic digestion*

https://plastics.americanchemistry.com/Sustainability-Recycling/Energy-Recovery/Environmental-and-Economic-Analysis-of-Emerging-Plastics-Conversion-Technologies.pdf

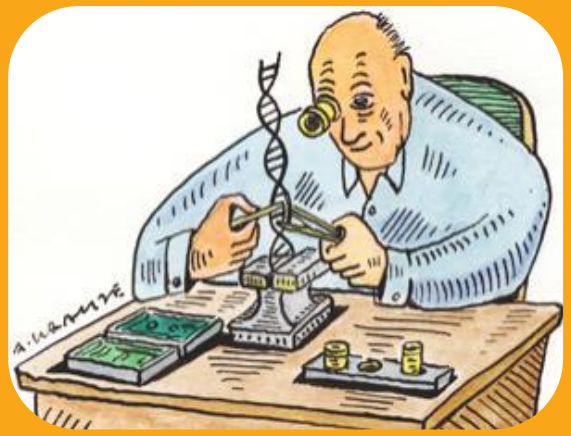
Future of green chemistry

- "Green chemistry is a good chemistry"
  - Increased efficiency, environ-mental sustainability, reduced costs
- Biocatalysis is said to be the future of green chemistry:
  - Examples are production of antidepressant sertraline and production of vitamin B12

http://pubs.rsc.org/en/content/articlelanding/2011/gc/c1gc15579b#!divAbstract

Synthetic biology disaster avoidance

- Synthetic microbes have received strong interest:
  - Chemical and energy applications
- Areas of risk:
  - Synthetic organisms will occupy new niches
  - Gene transfer between organisms
  - Survivability of synthetic organisms
  - Synth. Org. might push natural aside
- Detailed studies on influence of plants on environment needed



Transgenic plant labelled with fluorescent protein

http://peccoud.org/language-for-plant-synthetic-biology/; https://www.newscientist.com/article/mg21428684-800-lets-get-real-on-synthetic-biology/; Dana, Genya V., et al. "Synthetic biology: Four steps to avoid a synthetic-biology disaster." *Nature* 483.7387 (2012): 29-29.

Skyfarming

- Loss of 10% cultivated land per 1°C temperature increase (estimate):
  - Demand for cultivated land will increase
- Skyscraper farming:
  - Functionally constructed to provide necessary space and sun exposure
  - Independent of climate change, potential to lower greenhouse gas emissions

http://inhabitat.com/skyscraper-farming-farming-reaches-to-the-sky/; http://www.aprilli.com/urban-skyfarm/; Germer, Jörn, et al. "Skyfarming an ecological innovation to enhance global food security." *Journal für Verbraucherschutz und Lebensmittelsicherheit* 6.2 (2011): 237.

Subsidy independence for clean technology

- At the time of the paper:
  - Federal funding decrease by 75%
  - 50% reduction of testing programs and technology development

→be independent of govnmt. funding

- Recent numbers:
  - International Energy Agency predicts an increase in subsidies from 66 billion to 250 billion US-$ for renewables
  - In 2010 fossil fuels were subsidies with 409 billion $ and renewables with 66 billion (→ 6 times as much)

https://en.wikipedia.org/wiki/Energy_subsidies, http://www.mybulkleylakesnow.com/6092/30000-for-wetsuweten-fn-to-explore-clean-energy/; http://www.climate-change-guide.com/the-clean-energy-revolution-is-underway.html

Conclusion

- *Catalysts* are important and their use will most likely increase

→especially biocatalysts will play a more important role in the future

- Change to biofuels possible

- *CO_2 trapping* polymers could be used meanwhile to lower the CO_2 emissions

- Ideas for *plastic recycling* exists and are being implemented

- Need to be careful with designed *organisms*

- Many new ideas for *alternative farming*

Questions

- Paper related:
  - Does the title of the paper fit to the rest of it?
  - “Enzymatic catalysis missing in twelve principles”…true? Catalysis has been mentioned and it has not been specified what kind of catalysis (s.4)
  - “chemical biology […has] not established strong footing within the community of organic chemists due to a general phobia to the use of biological methods”…why would that be? (s.4)
  - Does biofuel have the potential to replace fossil fuels? (s.6)
  - Does it make sense to trap CO2? Would that be a short-term solution? (s.7)
  - Would skyfarming really be independent of climate change? (s.11)
  - Do you expect funding for renewables to go down? (s.12)