What kind of organizations can innovate?

ACADEMIA

- YALE
- Massachusetts Institute of Technology
- The University of Nottingham
- VE RI TAS HARVARD

BUSINESS

- P2
- CATALYTIC Innovations
- sustainability
- inKemia green chemicals
- American GreenFuels LLC A KOLMAR AMERICAS COMPANY
- AIR CO

CAPITAL

- ELM STREET VENTURES
- OBVIOUS VENTURES
- PEGASUS CAPITAL ADVISORS
- SAIL CAPITAL PARTNERS

GOVERNMENT

- UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
- EXECUTIVE OFFICE OF THE PRESIDENT OF THE UNITED STATES OFFICE OF SCIENCE AND TECHNOLOGY POLICY

NOT-FOR-PROFIT

- cradletocradle
- ACS Green Chemistry Institute®
- BIOMIMICRY INSTITUTE
- GREEN ELECTRONICS COUNCIL
- U.S. GREEN BUILDING COUNCIL LEED USGBC
- The Arc/k Project

Here's to the crazy ones. The misfits. The rebels. The troublemakers. The round pegs in the square holes. The ones who see things differently. They're not fond of rules. And they have no respect for the status quo. You can quote them, disagree with them, glorify or vilify them. About the only thing you can't do is ignore them. Because they change things. They push the human race forward. And while some may see them as the crazy ones, we see genius. Because the people who are crazy enough to think they can change the world, are the ones who do.

- Steve Jobs, Apple CEO
1955-2011

Thinking differently.

Exquisite molecular portraits—at an affordable price p. 354

Suppression of movement during sleep pp. 366 & 440

Probing surfaces with ultrafast microscopy pp. 368 & 411

Science

$15
24 JANUARY 2020
SPECIAL ISSUE
sciencemag.org

AAAS

CHEMISTRY FOR TOMORROW'S EARTH

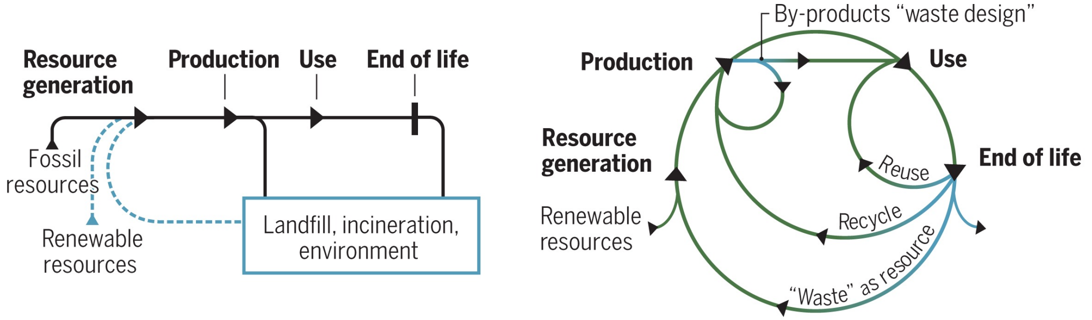
REVIEW

Designing for a green chemistry future

Julie B. Zimmerman[1,2,3*], Paul T. Anastas[2,3,4], Hanno C. Erythropel[1,3], Walter Leitner[5,6]

The material basis of a sustainable society will depend on chemical products and processes that ar designed following principles that make them conducive to life. Important inherent properties of molecules need to be considered from the earliest stage—the design stage—to address whether compounds and processes are depleting versus renewable, toxic versus benign, and persistent vers readily degradable. Products, feedstocks, and manufacturing processes will need to integrate the principles of green chemistry and green engineering under an expanded definition of performance t includes sustainability considerations. This transformation will require the best of the traditions of science and innovation coupled with new emerging systems thinking and systems design that begin the molecular level and results in a positive impact on the global scale.

Today's chemical sector | **Tomorrow's chemical sector**



Mostly linear processes →	Circular processes
Fossil feedstocks →	Renewable feedstocks
Reactive, persistent, or toxic chemical reagents and products →	Benign chemical reagents and products
Catalysis using rare metals →	Catalysis using abundant metals, enzymes, photons, or electrons
Covalent bonds →	Weak, noncovalent interactions
Conventional solvents →	Low toxicity, recyclable, inert, abundant, easily separable green solvents or solventless
Material- and energy-consuming isolation and purification →	Self-separating systems
Large "waste" volume →	Atom-, step-, and solvent-economical processes
"Waste" treatment →	"Waste" utilization
Design exclusively for use phase with reliance on circumstantial control →	Intentional molecule design for full life cycle
Performance = maximize function →	Performance = maximize function + minimize hazards
Maximum chemical production for increased profit →	Maximum performance with minimal benign material use for increased profit

4 August 1972, Volume 177, Number 4047

SCIENCE

More Is Different

Broken symmetry and the nature of the hierarchical structure of science.

P. W. Anderson

The reductionist hypothesis may still be a topic for controversy among philosophers, but among the great majority of active scientists I think it is accepted without question. The workings of our planation of phenomena in terms of known fundamental laws. As always, distinctions of this kind are not unambiguous, but they are clear in most cases. Solid state physics, plasma physics, and perhaps also biology are extensive. High energy less relevance they seem to have to the very real problems of the rest of science, much less to those of society.

The constructionist hypothesis breaks down when confronted with the twin difficulties of scale and complexity. The behavior of large and complex aggregates of elementary particles, it turns out, is not to be understood in terms of a simple extrapolation of the properties of a few particles. Instead, at each level of complexity entirely new properties appear, and the understanding of the new behaviors requires research which I think is as fundamental in its nature as any other. That is, it seems to me that one may array the sciences roughly linearly in a hierarchy, according to the idea: The elementary entities of science X obey the laws of science Y.

4 August 1972, Volume 177, Number 4047

SCIENCE

The main fallacy in this kind of thinking is that the reductionist hypothesis does not by any means imply a "constructionist" one: The ability to reduce everything to simple fundamental laws does not imply the ability to start from those laws and reconstruct the universe. In fact, the more the ele-

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according to the idea: The elementary
entities of science X obey the laws of
science Y.

X Y

1. Efficiency will help you do the thing you are doing, better. It will not help you do a better thing.

2. Efficiency is not the same as effective.

Sheet Music from www.mfiles.co.uk

Arranged for Piano Solo

Piano Concerto No.21 in C

(2nd movement - as used in Elvira Madigan)

Wolfgang Amadeus Mozart
arranged Jim Paterson

Why is innovation at the heart of green chemistry,

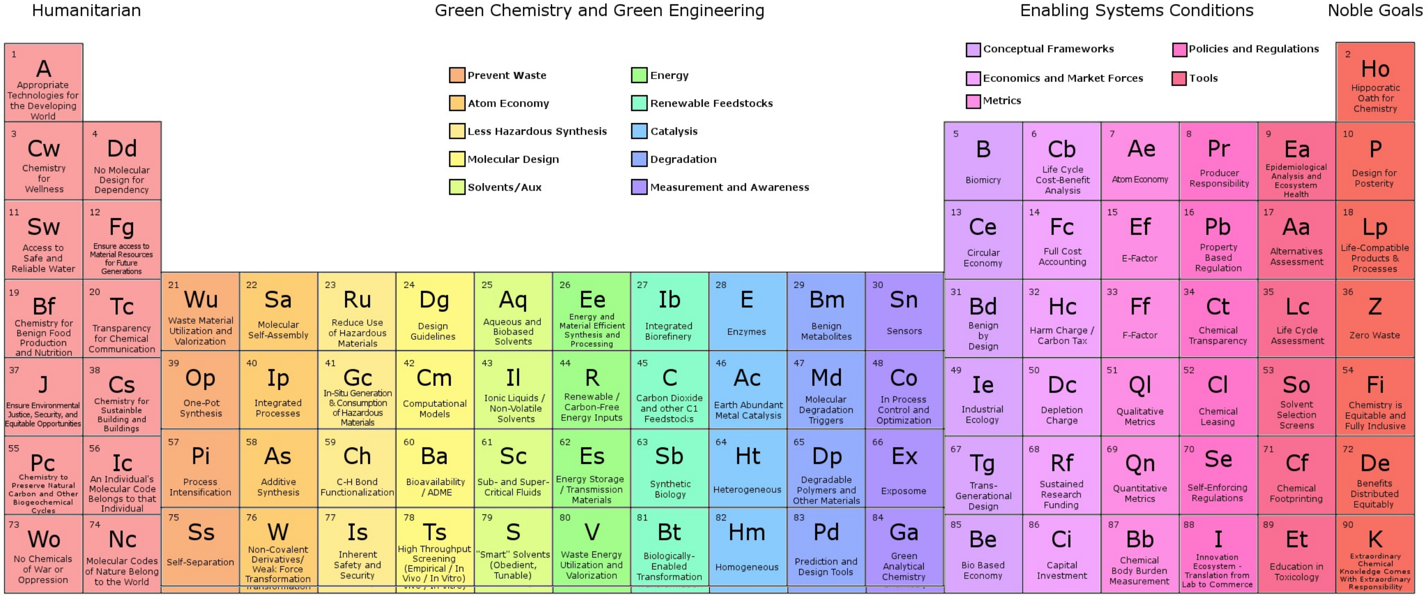
(and at the heart of P2 Science)?

The Green ChemisTREE: 20 years after taking root with the 12 principles.

Green Chemistry, *20*(9), 1929-1961.

Sustainable Development Goals

The Periodic Table of the Elements of Green and Sustainable Chemistry



This collection of science and technology is the manifestation of the Twelve Principles of Green Chemistry and the Twelve Principles of Green Engineering.

P2

Elegant Processes.

Sustainable Products.

To make the products

we use everyday

better.

Global human-made mass exceeds all living biomass

Elhacham, E. *et al*. Nature 2020

https://doi.org/10.1038/s41586-020-3010-5


SINAASAPPEL
MANGO
LIGHT
AFTER ACTIVITY DRINK
AA
DRINK

Biorenewable.

Biocompatible.

Biodegradable.

Some observations

The test of a first-rate intelligence is the ability to hold two opposing ideas in mind at the same time and still retain the ability to function. One should, for example, be able to see that things are hopeless yet be determined to make them otherwise.

– F Scott Fitzgerald

The customer is always right.

The customer doesn’t know what they want.

Innovation is all about big breakthroughs.

Innovation is all about execution.

It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness, it was the epoch of belief, it was the epoch of incredulity, it was the season of light, it was the season of darkness, it was the spring of hope, it was the winter of despair.

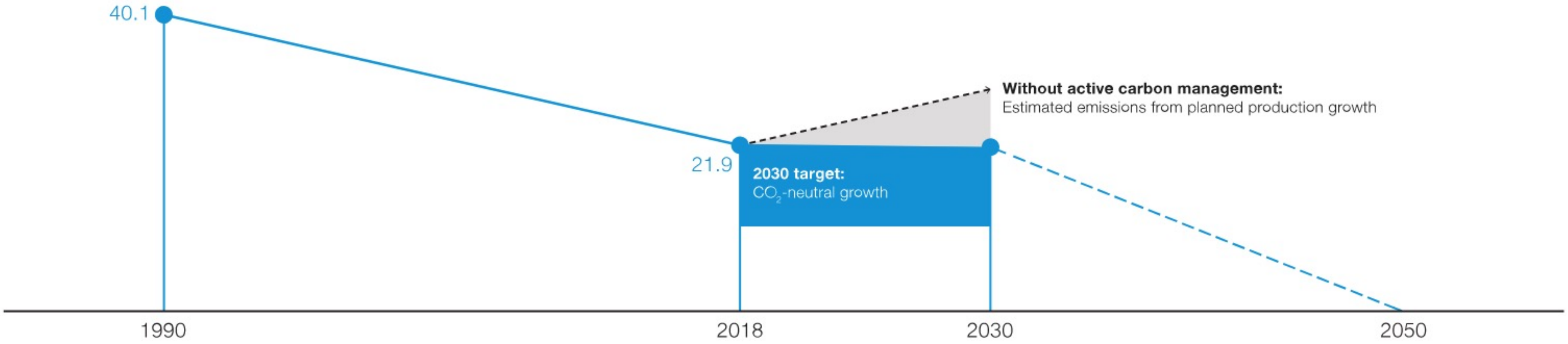
- *Charles Dickens*

L'Oréal 2030: 95% Of Ingredients To Be Sustainable, Renewables To Replace Petroleum-Derived Products

Unilever to eliminate fossil fuels in cleaning products by 2030

Green Deal: Commission adopts new Chemicals Strategy towards a toxic-free environment

Million metric tons of CO_2 equivalents



1990 to 2018

Sales product volumes doubled and emissions almost halved through:

– Decomposition of nitrous oxide
– Increased process and energy efficiency

2018 to 2030

Expand production while keeping emissions at the 2018 level, primarily through:

– Higher process and energy efficiency
– Purchasing electricity from renewable sources

From 2030

Reduce emissions through:

– Fundamentally new technologies developed in the Carbon Management R&D Program

BASF

P2