CHALLENGES IN ORGANIC CHEMISTRY

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Abstract
Since "chemistry" has become the central core molecular science for energy, environment, sustainability, materials, biology, and medicine, great challenges in "organic chemistry" reflect more or less the same trend. In addition, advances in computing capacity and capabilities have opened avenues for big data treatment and analysis, systems chemistry, accurate simulations and predictions. Accordingly, it would be safe to say that *the great challenges and successes in organic chemistry would reside at the interface with energy, environment, sustainability, materials, biology, medicine, and computer science*. Now, let's move on to the examples of great challenges in branches of organic chemistry.

Key Words: branch, challenges, laboratory, matter, organic, study, substances, types.

Introduction

- Organic chemistry is the scientific study of the structure, properties, composition, reactions, and synthesis of organic compounds that by definition contain carbon.
- It is a specific discipline within the subject of chemistry.
- Organic compounds are molecules composed of carbon and hydrogen, and may contain any number of other elements.
- Many organic compounds contain nitrogen, oxygen, halogens, and more rarely phosphorus or sulphur.
- Current trends in organic chemistry are chiral synthesis, green chemistry, microwave chemistry and fullerene chemistry.

Chemistry is the study of matter, its properties, how and why substances combine or separate to form other substances, and how substances interact with energy. Many people think of chemists as being white-coated scientists mixing strange liquids in a laboratory, but the truth is we are all chemists. Understanding basic chemistry concepts is important for almost every profession. Chemistry is part of everything in our lives.

Every material in existence is made up of matter — even our own bodies. Chemistry is involved in everything we do, from growing and cooking food to cleaning our homes and bodies to launching a space shuttle. Chemistry is one of the physical sciences that help us to describe and explain our world.

Five branches
There are five main branches of chemistry, each of which has many areas of study.

Analytical chemistry uses qualitative and quantitative observation to identify and measure the physical and chemical properties of substances. In a sense, all chemistry is analytical.

Physical chemistry combines chemistry with physics. Physical chemists study how matter and energy interact. Thermodynamics and quantum mechanics are two of the important branches of physical chemistry.

Organic chemistry specifically studies compounds that contain the element carbon. Carbon has many unique properties that allow it to form complex chemical bonds and very large molecules. Organic chemistry is known as the "Chemistry of Life" because all of the molecules that make up living tissue have carbon as part of their makeup.

Inorganic chemistry studies materials such as metals and gases that do not have carbon as part of their makeup.

Biochemistry is the study of chemical processes that occur within living organisms.

Fields of study

Within these broad categories are countless fields of study, many of which have important effects on our daily life. Chemists improve many products, from the food we eat and the clothing we wear to the materials with which we build our homes. Chemistry helps to protect our environment and searches for new sources of energy.

Food chemistry

Food science deals with the three biological components of food — carbohydrates, lipids and proteins. Carbohydrates are sugars and starches, the chemical fuels needed for our cells to function. Lipids are fats and oils and are essential parts of cell membranes and to lubricate and cushion organs within the body. Because fats have 2.25 times the energy per gram than either carbohydrates or proteins, many people try to limit their intake to avoid becoming overweight. Proteins are complex molecules composed of from 100 to 500 or more amino acids that are chained together and folded into three-dimensional shapes necessary for the structure and function of every cell. Our bodies can synthesize some of the amino acids; however eight of them, the essential amino acids, must be taken in as part of our food. Food scientists are also concerned with the inorganic components of food such as its water content, minerals, vitamins and enzymes.

Food chemists improve the quality, safety, storage and taste of our food. Food chemists may work for private industry to develop new products or improve processing. They may also work for government agencies such as the Food and Drug Administration to inspect food products and handlers to protect us from contamination or harmful practices. Food chemists test products to supply information used for the nutrition labels or to determine how packaging and storage affects the safety and quality of the food. Flavorists work with chemicals to change the taste of food. Chemists may also work on other ways to improve sensory appeal, such as enhancing color, odor or texture.

Environmental chemistry

Environmental chemists study how chemicals interact with the natural environment. Environmental chemistry is an interdisciplinary study that involves both analytical chemistry and an understanding of environmental science. Environmental chemists must first understand the chemicals and chemical reactions present in natural processes in the soil water and air. Sampling and analysis can then determine if human activities have contaminated the environment or caused harmful reactions to affect it.

Water quality is an important area of environmental chemistry. "Pure" water does not exist in nature; it always has some minerals or other substance dissolved in it. Water quality chemists test rivers, lakes and ocean water for characteristics such as dissolved oxygen, salinity, turbidity, suspended sediments, and pH. Water destined for human consumption must be free of harmful contaminants and may be treated with additives like fluoride and chlorine to increase its safety.

Agricultural chemistry

Agricultural chemistry is concerned with the substances and chemical reactions that are involved with the production, protection and use of crops and livestock. It is a highly interdisciplinary field that relies on ties to many other sciences. Agricultural chemists may work with the Department of Agriculture, the Environmental Protection Agency, the Food and Drug Administration or for private industry. Agricultural chemists develop fertilizers, insecticides and herbicides necessary for large-scale crop production. They must also monitor how these products are used and their impacts on the environment. Nutritional supplements are developed to increase the productivity of meat and dairy herds.

Agricultural biotechnology is a fast-growing focus for many agricultural chemists. Genetically manipulating crops to be resistant to the herbicides used to control weeds in the fields requires detailed understanding of both the plants and the chemicals at the molecular level. Biochemists must understand genetics, chemistry and business needs to develop crops that are easier to transport or that have a longer shelf life.

Chemical engineering

Chemical engineers research and develop new materials or processes that involve chemical reactions. Chemical engineering combines a background in chemistry with engineering and economics concepts to solve technological problems. Chemical engineering jobs fall into two main groups: industrial applications and development of new products.

Industries require chemical engineers to devise new ways to make the manufacturing of their products easier and more cost effective. Chemical engineers are involved in designing and operating processing plants, develop safety procedures for handling dangerous materials, and supervise the manufacture of nearly every product we use. Chemical engineers work to develop new products and processes in every field from pharmaceuticals to fuels and computer components.

Geochemistry

Geochemists combine chemistry and geology to study the makeup and interaction between substances found in the Earth. Geochemists may spend more time in field studies than other types of chemists. Many work for the U.S. Geological Survey or the Environmental Protection Agency in determining how mining operations and waste can affect water quality and the environment. They may travel to remote abandoned mines to collect samples and perform rough field evaluations, and then follow a stream through its watershed to evaluate how contaminants are moving through the system. Petroleum geochemists are employed by oil and gas companies to help find new energy reserves. They may also work on pipelines and oil rigs to prevent chemical reactions that could cause explosions or spills.

Forensic chemistry

Forensic chemists capture and analyze the physical evidence left behind at a crime scene to help determine the identities of the people involved as well as to answer other vital questions regarding how and why the crime was carried out. Forensic chemists use a wide variety of analyzation methods, such as chromatography, spectrometry and spectroscopy.

In new research appearing in the Journal of the American Society of Mass Spectrometry, scientists from the department of chemistry at Louisiana State University (LSU) set out to apply laser technology to the field of forensic science.

They developed a system that goes above and beyond the identification of a fingerprint. The technique can capture molecules contained within a fingermark, including lipids, proteins, genetic material, or even trace amounts of explosives, which can be further analyzed. The new tool essentially takes the mystery out of identifying the chemical composition of fingermarks at crime scenes.

The tool focuses a laser — using mirrors and optical fibers — onto a surface containing a fingermark. The laser then heats up any water or moisture on the surface, triggering chemical bonds in the water to stretch and vibrate, according to the LSU College of Science Blog. All of this focused energy causes the water to "explode," turning it into a gas and separating biomolecules such as DNA. This process is called laser ablation.

Next a small vacuum pump system pulls the water and molecules into a tiny filter that captures everything left behind by a person's finger. Forensic scientists can then put the contents into an analysis device such as a mass spectrometer or a gas chromatography-mass spectrometer.

Importantly, this laser ablation technique can easily capture fingermarks on porous surfaces, such as cardboard (on which traditional forensic methods have not been very successful).

It is very clear that organic chemistry has been thriving by expanding its territories through exploration of the interfaces with other science disciplines. Thus, organic chemistry is undoubtedly serving as the core chemical science for the advancement of science and technology with clear goals to benefit human life and society. Accordingly, one of the grand challenges in organic chemistry is *how to explore new frontiers at the interface of organic chemistry and other science or technology fields*. In the past, the majority of interdisciplinary research was between two disciplines in two different laboratories. But now it is necessary to take multidisciplinary approaches, involving multiple disciplines and laboratories, for tackling significant scientific or technological problems. Under these circumstances, organic chemists must evolve into open-minded researchers who can effectively communicate and collaborate with other researchers from different disciplines. In order to achieve this goal, organic chemists should have good knowledge of other disciplines to understand the whole picture of the project. Thus, another grand challenge for organic chemists is *how to evolve into a key player in a multidisciplinary research project by cultivating the ability to effectively communicate and collaborate with other project team members from different disciplines*. Then another closely related grand challenge is *how to cultivate the next generation of organic chemists who can survive and thrive in the broad interfaces of organic chemistry and other science/technology disciplines*. Since traditional organic chemists enjoyed research only in their own comfortable playgrounds, these will be great challenges in research and education that organic chemists must face.

The Importance of Organic Chemistry

It is still a great challenge to understand the chemistry of life, which includes, among other things, the chemistry of nucleic acids, proteins, and carbohydrates.

Carbohydrates (saccharides), which among other things are important to the energy balance of the body.

How the first organic molecules were formed at the origin of life is still an unsettled question. It is assumed that methane (CH_4) was the most important carbon compound on earth several million years ago. At that time the atmosphere of the earth was made up of methane and the inorganic compounds water (H_2O), ammonia (NH_3) and hydrogen (H_2).

In 1952, Stanley Lloyd Miller imitated the origin of evolution of these few chemical compounds in a chemical experiment. He demonstrated that short-chain hydrocarbons, formaldehyde, urea, and prussic acid (hydrogen cyanide) are formed if a mixture of methane, water, ammonia, and hydrogen is irradiated with flashes of light. From these reaction products long-chain hydrocarbons, carboxylic acids, carbohydrates, and nucleic acids were formed. So the components of life could have been spontaneously formed in the atmosphere of the earth from the simple inorganic compounds water, ammonia, and hydrogen as well as methane.

Organic compounds

Organic chemistry deals not only with the chemistry of life and the natural carbon compounds but also with the huge, daily increasing number of synthetic carbon compounds. At the end of the last century the number of these carbon compounds amounted to 15 million with an annual increase of circ. 600,000 compounds. (Current values).

We are living in a world which is largely shaped by organic compounds, *e.g.*:

- the clothes we wear (wool, cotton, leather, synthetics)
- the commodities we use (wood, plastic)
- the sources of primary energy we still use every day (petroleum, natural gas, coal)
- the remedies with which illnesses can be cured

But organic compounds can also put our lives at risk

- the insecticide DDT (dichlorodiphenyltrichloroethane), which accumulates in nature and the food chain more and more
- the highly toxic polychlorinated biphenyls (PCBs) and dioxins
- the chlorofluorocarbons (CFCs), which among other things are used as propellants in spray cans and which damage the protective ozone layer of the atmosphere.

All the more reason the knowledge and control of organic chemistry must be improved, so it can be applied advantageously to men and nature.

At the interface with energy, solar energy and energy storage have been predominantly led by inorganic materials. Thus, there is a great challenge for organic chemists to create organic or hybrid materials to outperform existing inorganic materials.

At the interface with sustainability and environmental science, a challenge is the development of efficient chemical processes converting industrial and agricultural wastes, industrial bi-products, carbon dioxide, greenhouse gases such as fluoroform, recovered plastics, etc., to useful chemicals without producing another waste. If these processes include efficient photochemical processes utilizing solar energy, it will be ideal.

At the interface with materials, many great challenges can be envisioned, and already numerous research and development themes are ongoing in this field. The challenge here is how organic chemistry can play a key role in polymer and materials chemistry. The development of new, selective, and efficient polymerization methods and methodologies exploiting organometallic chemistry and organocatalysis make a huge impact on this endeavor. Supramolecular chemistry plays a significant role in the creation of novel organic, organometallic, coordination complex, and hybrid materials, wherein organic chemistry can make critical contributions. "Molecular machines" have already emerged as a new concept but how can organic chemists construct organic functional devices consisting of molecular machines with macroscopic motions?

At the interface with biology and medicine, there are plethora of great challenges for organic chemists, e.g., epigenerics, DNA damage and repair, gene editing, nanomedicine, nano-formulations, molecular imaging, drug discovery and development, antibody-drug conjugates, next-generation fluorescence dyes for super-resolution imaging of living cells, just to mention a few. Chemical biology has evolved from bioorganic chemistry and biochemistry which provides powerful tools to investigate biological problems at the molecular level. For drug discovery and pharmaceutical sciences, synthetic organic and medicinal chemistry are indeed essential. However, the challenge here is how next-generation organic/medicinal chemists can play a key role in the whole drug discovery process, i.e., not simply serve as a contract research organization (CRO) for preparing library of compounds in a classical medicinal chemistry manner. Next-generation organic/medicinal chemists should be able to fully engage in drug design based on structural and computational biology. Physical organic chemists should be able to apply kinetics and thermodynamics analysis, especially in combination with molecular imaging, for the accurate evaluation of drug efficacy and mode of action, and better drug design.

At the interface with computer science, there are numerous great challenges for organic chemistry. How can computational organic chemistry expand quantum mechanics analysis and prediction for organic reaction mechanism and catalytic cycles with increasing molecular sizes without X-ray crystal structures? How can computational organic chemists connect big data science with organic chemistry to explore "systems organic chemistry"? How can organic chemists and computational chemists work together to do rational design for new, selective, and efficient organic reactions, as well as metal catalysts using non-noble metals? How can organic chemists work with computational scientists to accurately predict chemical, physical, and biological properties of organic molecules through reliable structure–property, structure–activity, and structure–function relationship studies? How can computational organic chemists construct a reliable program for indicating most efficient synthetic routes to organic compounds with certain structural complexity?

Of course, there are numerous challenges within the realm of organic chemistry and its branches. Creation of new chemical entities (NCEs) can only be achieved by chemists- no other science discipline can compete with chemistry in this respect. Then synthetic organic chemistry is responsible for all organic NCEs. Accordingly, both innovative and incremental advances in synthetic methods and methodologies are significant in this respect. In addition to the exploration of more selective, efficient and "greener" chemical processes, especially using metal or organic catalysts, development of highly efficient catalyst recovery and product separation technologies is critical, which has relevance to sustainability and environmental issues. Innovative synthetic methods and methodologies that enable late-stage modifications will significantly accelerate the analog design and synthesis in medicinal chemistry and drug discovery. Chemical informatics will play increasingly important role in synthetic organic and medicinal chemistry as well as organic materials chemistry. Computational analysis and design will also play critical role in medicinal chemistry, drug discovery, catalysis, supramolecular chemistry, and organic materials.

References

Brabec, Christoph; Vladimir Dyakonov; Jürgen Parisi; Niyazi Serdar Sarıçiftçi (March 2006). *Organic Photovoltaics: Concepts and Realization. Springer. p. 300. "So much more to know". Science. 309 (5731): 78–102.* July 2005.

Dill KA; et al. (June 2008). *"The Protein Folding Problem". Annu Rev Biophys. 37: 289–316.*

Duffie, John A. (August 2006). *Solar Engineering of Thermal Processes. Wiley-Interscience. p. 928.*

Hsieh M, Brenowitz M (August 1997). *"Comparison of the DNA association kinetics of the Lac repressor tetramer, its dimeric mutant LacIadi, and the native dimeric Gal repressor".* J. Biol. Chem. 272 (35): 22092–6.

King, Jonathan (2007). "MIT OpenCourseWare - 7.88J / 5.48J / 7.24J / 10.543J Protein Folding Problem, Fall 2007 Lecture Notes - 1". MIT Open Course Ware. Archived from the original on September 28, 2013. Retrieved June 22, 2013.

Narayan, Sridhar; Muldoon, John; Finn, M. G.; Fokin, Valery V.; Kolb, Hartmuth C.; Sharpless, K. Barry (2005). *"On Water": Unique Reactivity of Organic Compounds in Aqueous Suspension". Angewandte Chemie International Edition. 44 (21): 3275–3279.*

Peralta-Yahya, Pamela P.; Zhang, Fuzhong; Del Cardayre, Stephen B.; Keasling, Jay D. *(2012). "Microbial engineering for the production of advanced biofuels". Nature. 488 (7411): 320–328.*