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SYNTHETIC CHEMISTRY AND POLYMER PHYSICS

Problem-driven synthesis will be critical to probing the fundamental physics of polymers

MACROMOLECULES, INCLUDING synthetic polymers and biopolymers, have entered every aspect of our daily lives. Over the past half a century, increasing numbers of universities have established programs in macromolecular science and engineering. Macromolecules have become an important part of chemistry teaching and research. The development of macromolecules as a field has vitally involved chemistry, physics, engineering, and other disciplines. In turn, the development of various polymers has provided new materials with novel properties for the advancement of other sciences. I foresee that macromolecular science will play an even more crucial role as a bridge to other disciplines in the coming decades.

In this essay, I address the necessity of combining synthetic chemistry with polymer physics, but a similar discussion could be extended to other research areas related to chemistry. Long polymer chains continue to be complicated objects for most physicists to handle, even though chemists have made various wonderful macromolecules that are useful for studying such issues in physics as soft matter, condensed phases, complex fluids, and metastability.

It is often difficult or even frustrating for a physicist to collaborate with a synthetic chemist. However, to solve problems in physics, it is necessary to integrate synthetic chemistry into the physics laboratory. This requires training physicists who have sufficient knowledge in synthetic chemistry so that they can reasonably design, if not synthesize, macromolecules with specific compositions, architectures, and functions. To do this, we have to modify our current teaching curriculum and blur the existing boundary between traditional chemistry and physics departments.

In mainland China, only the University of Science and Technology of China in Hefei has a Department of Chemical Physics in which the teaching of physics and chemistry is well balanced. By contrast, the British-based education system in Hong Kong does not require physics students to learn any chemistry or chemistry students to learn any physics at the university level.

IN THE LAB **Wu discusses how to prepare a new "intelligent" hybrid gel with researcher Shufu Peng.**

Our own research illustrates how a polymer physicist can benefit from problem-driven synthesis. One of the basic problems in polymer science is the coil-to-globule transition of individual polymer chains in solution. A transition to a thermodynamically stable globule has long been predicted, but it was observed only a few years ago after the successful preparation of narrowly distributed, ultralong thermally sensitive poly(*N*-isopropylacrylamide) (PNIPAM) homopolymer chains. Recently, after introducing a few mole percent of hydrophilic or hydrophobic monomers uniformly into the PNIPAM backbone, we were able to observe individual copolymer chains undergoing the transition first fold to an ordered coil conformation before collapsing to a single-chain core-shell nanostructure.

Monomer-sequence-dependent chain folding and association is another interesting problem. To solve it, we need to prepare heteropolymer chains with similar length and composition but different distributions of the second monomer. As another example, the insertion of two different kinds of specifically interacting monomers into a long polymer chain with controllable distribution will enable us to imitate protein folding by investigating changes in chain conformation under different conditions.

Young polymer researchers mistakenly think that there are no problems left to solve concerning polymers in solution and that polymer solution properties are far away from real applications. Actually, we do not understand the behavior of polymer chains in solution, especially for heteropolymers in aqueous solution. If we design and synthesize macromolecules with a problem in mind, we can study the controllable formation of different mesophases and bulk structures. The self-assembly of block copolymers is one typical example.

Understanding the coil-to-globule transition of a single chain in solution led to the invention and preparation of a hybrid biodegradable "intelligent" polymer gel that has potential biomedical applications because it can shrink about 1,000 times faster than a normal polymer gel at body temperature. One application was illustrated when a hybrid gel tube successfully connected and repaired a broken nerve without any surgical stitches.

Polymer physicists need problem-driven synthesis, and synthetic chemists should move to research areas where they can use their expertise to solve scientific and practical problems. It is time to change our way of thinking, teaching, and doing research, because the future is multidisciplinary.

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