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Physical Chemistry

... Is asking "Why?"

Most chemists are accustomed to asking the question "Why?" but physical chemists are notorious for their tenacity in pursuing the question. "Some disciplines of chemistry take the petals off the flower," says Geraldine Richmond, a professor of physical chemistry at the University of Oregon at Eugene. "The physical chemist wants to go to the stamen and dissect it."

This characteristic does not mean physical chemists see themselves as more rigorous than other chemists, but they are focused on understanding the physical properties of atoms and molecules, the way chemical reactions work, and finding out what these properties reveal. Their work involves analyzing materials, developing methods to test and characterize the properties of materials, developing theories about these properties, and discovering the potential use of the materials. Using sophisticated instrumentation and equipment has always been an important aspect of physical chemistry. "When you walk into a physical chemistry lab, it's full of big machines," says Richmond. These machines include lasers, mass spectrometers, nuclear magnetic resonance (NMR) spectrometers, and electron microscopes.

... Is applying physics and math

Physical chemists' discoveries are based on understanding chemical properties and describing the behavior of molecular and condensed matter using theoretical constructs and mathematical computations. Rick Bradley, a senior product development engineer at Flex Products, says, "Physical chemistry really clicked for me when I was taking a lot of math and chemistry at the same time. I became fascinated with how I could use a powerful tool like math to predict properties of chemicals." Luanne Rolly, a manufacturing development engineer for Hewlett Packard, also says that math is an important part of her work. "I use mathematical analyses and statistics on millions of data points every month," she says. "I work with the data in different ways to see what it reveals about the materials and processes I use."

A relatively new technology that similarly combines chemistry, math, and physics is the area of molecular simulation. "Molecular simulation tools are becoming key in research," says Lynn Davis, a principal staff engineer at Motorola. "And the ways in which these tools allow us to study manipulations on the molecular level are really just a basic application of the skills of physical chemistry. Physical chemists who understand the basis of these manipulations will be key to the development of this field," he adds.

... Is interdisciplinary

Physical chemistry has traditionally given students broad training and

positioned them to work in a variety of scientific careers. "Many physical chemists ultimately work as analytical chemists and develop responsibility for the advanced analytical work that moves the field forward," says George Flynn, professor of chemistry at Columbia University in New York City. Matt Lynch, senior scientist in the Beauty Care Division of Procter & Gamble, works in physical/analytical chemistry, conducting applied and basic surfactant research for product development applications. His work involves measuring and understanding the assembly of molecules. Lynch says, "We assemble molecules in crystals and solutions and look at how to measure that in terms of arrangements of atoms and molecules, how they grow to form bigger aggregates in solutions as well as in crystals, and how these aggregates of surfactants impart various properties to a product." Lynch notes that he uses diffraction, and infrared microscopy methods in his work.

Recently, more and more physical chemists have found work in the emerging fields of materials science and molecular modeling where their skills in analyzing and predicting the behavior of physical properties have exciting new applications.

The development of these areas makes it a good time to be studying physical chemistry. But, scientists already in the field caution students that job

opportunities in this discipline are increasingly relying on interdisciplinary knowledge. "Physical chemistry is truly becoming an interdisciplinary field," comments Bradley. "I think it is foolish to ignore other disciplines in your study of physical chemistry. People who stay in that school of thought may be left behind." Mary Mandich, technical manager for process and chemical engineering research in the Physical Science Division at Bell Labs Lucent Technologies, Inc., says, "It's vital to

combine your knowledge of physical chemistry with other disciplines. This doesn't just mean taking courses outside your major but actively working on projects with other scientists in other labs." She adds, "I encourage students to choose physical chemistry but to choose it in a nontraditional way."

Mary Mandich

Research Management

"Most days, I still can't believe they pay me to do what I'm doing," says Mary Mandich, a technical manager for process and chemical engineering research in the physical science division at Bell Labs Lucent Technologies, Inc., referring to her delight at getting paid to do what she enjoys most. Her work includes both basic research and managing a team of several other scientists who impact about half a billion dollars in business for Lucent every year. Mandich's own research is primarily focused on making and characterizing ultra-thin dielectric films for next-generation computer technology. "It's not traditional physical chemistry," she explains. "My work incorporates physics, materials science, and electrical engineering, but my background in physical chemistry is incredibly useful." Particularly applicable, she says, is her training in surface science that she uses to assess the films' voltage characteristics, capacitance characteristics, and interface properties.

Mandich did her undergraduate work in cellular biology and genetics. But it was her work-study job in the physical chemistry lab that led to her fascination with physical chemistry's route to understanding the world. "I was extremely fortunate to have two professors in that lab who provided wonderful guidance and mentorship," she says. "While I was working, they would pose questions to me such as, 'Did you ever think about how light reflects off of a surface?' Then we'd sit down and work out the math."

Today, Mandich provides mentorship to the team of scientists that work under her. In this role she has to balance the needs of basic research with delivering solutions on time. "One of the biggest challenges in being a manager is making decisions

about how to time research," she says. "Science doesn't happen on a schedule. But you have to look at when to stop working on one phase of a project so you can move forward to the next."

Phil Brode

Testing Techniques

"At this point, I describe myself as a biophysical chemist," says Phil Brode, a senior scientist in the corporate research division at Procter & Gamble (P&G). "Everyday, I deal with biology, physics, and chemistry, but I've moved more into the area of biochemistry than I ever dreamed," he says

When Brode first came to P&G, he was trained in the company's core business of detergents. Today, his job is to discover new enzymes with improved surface interactions. In the detergent business, the surface of interest is ultimately a soiled fabric, but the interaction mechanisms are first investigated on model surfaces. The information obtained from these measurements on new enzymes is then used by the molecular biologists at P&G to produce the next generation of basic detergent enzymes.

"I love to design new techniques to measure things," comments Brode. "But it never stops there. Those techniques are then used to discover new products. This is what is exciting and satisfying."

Brode explains that the nature of basic research at P&G has changed significantly during his career. "The early projects I was involved with were often seen as having commercial application 10 or 15 years down the road. Now there's more demand for each project to be connected to a product that can be commercialized soon," he says.

Rick Bradley

Product Development

"I love working in industry," says Rick Bradley, senior product development engineer at Flex Products. "I find it satisfying to be able to point to a product and say, 'I worked on that.' In basic research there's the idea that your work will be useful someday. I like the idea of making it useful now." One of Flex Products's core technologies is thin-film deposition. Bradley works on applications in which these films are applied to polyester that is imaged with lasers. "My job in product development is to develop new processes for applying the film to these surfaces and transferring that new process into a manufacturing environment," he says. "To do this, I draw on my knowledge of physical chemistry to understand how the deposition process affects the oxidation of films and how it will affect laser sensitivity. Another example of how I apply physical chemistry is in understanding the topcoats we use to create different properties. I need to understand the interactions between thin films and topcoats." Bradley says that measuring the process capability for thin-film design requires the same application of basic process measurements that he did in graduate school. "It's similar to measuring nonlinear optical response from a surface," he says. "It's the same set of skills; you just apply them in a different way."

Jeff Hinkley

Materials Testing

As a child, Jeff Hinkley had a chemistry set, a physics set, and an electronics set. "It was unclear to me which set I liked best, and in many ways a career in physical

chemistry has allowed me to have them all," he says. Hinkley has a Ph.D. in physical chemistry, with a concentration in math, but most of his work at the National Aeronautics and Space Administration (NASA) falls into the category of polymer science.

"NASA's primary mission in research is to improve aircraft and spacecraft. Part of this is developing newer and better materials from which to build them. I assist with the design of materials for a new generation of supersonic aircraft. This means making the new material in a test tube and then scaling up to the point where you actually fabricate an aircraft which uses it." Hinkley's job includes developing tests to determine how long the new materials will last in service. "Many of the planes flying today are over 20 years old," he explains. "This means the materials we develop must last at least 20 years. I work on calculations in chemical kinetics, trying to extrapolate the life of a material based on a short-term test. I also predict what will happen to the material on the molecular level through the use of computer modeling," he says.

Hinkley's job brings him into contact with many other chemists and chemical engineers. "Often, other scientists draw on my background in physical chemistry when the other scientists need to know how to test a material. For example, one team of polymer chemists at NASA was making a material they wanted to be able to stretch in four directions simultaneously. I advised them to do it by making a bubble out of the material so that as the bubble was inflated, the material would be pulled in all directions. This is just one example of how my background in math and physical chemistry enables me to work in a variety of areas and to explain mechanical and physical properties."

Luanne Rolly

Manufacturing Development

Luanne Rolly's job as a manufacturing development engineer at Hewlett Packard is a somewhat unusual career path for a physical chemist. "But it is a wonderful job for me," she says. "I consider myself a strong general chemist and what I like most about my work is that the problems I need to solve and the things I need to understand involve basic science that can be applied to a variety of situations.

Rolly adds, "The problems and questions I work on day to day can be anything from how permeable film may be to water or how a metal sheet changes its ductility on heating, to understanding how a salt component in an ink might corrode a metal component at a faster rate than another ink that doesn't have salt in it. These problems all require organic, inorganic, and physical chemistry to solve them, and I have such tremendous fun solving problems with the science."

Rolly's job in manufacturing development is to sustain a manufacturing process and to look for ways to improve that process to make it more cost-effective. "The demands of the job can be pretty heavy," she says. "I am often on call seven days a week and 24 hours a day. When the line goes down, it can cost thousands of dollars in lost production. There's an immediacy to problem solving in manufacturing. You have to come up with an answer quickly, and you have to understand what caused the problems so they don't happen again."

Lynn Davis

Materials Chemistry

Lynn Davis is a principal staff engineer in the Land Mobile Products sector of Motorola, which manufactures communications products such as two-way radios, paging systems, and cellular telephones. "These products are used in harsh conditions—from the fireman working in a burning building to the vacationing skier on the slopes," says Davis. "The materials they are made out of need to withstand these extremes." Part of Davis' role as a physical chemist is to develop a

fundamental understanding of these materials.

"One of the biggest issues in the electronics industry is adhesion," he says. "It can be very complicated to just get two things to stick together. You may have to get metal to stick to plastic, or metal to stick to Teflon. To do this, it's necessary to understand what's happening at the interface between the two materials. I may introduce an oxide into a material to see if the adhesion improves. But, at the same time, I have to make sure that by introducing that oxide, I'm not changing the fundamental properties of the material."

Davis says his job can be seen as similar to that of a materials scientist. "But there are some important differences," he notes. "Materials scientists tend to understand the characteristics of a material and how these characteristics match performance requirements. As a physical chemist, I'm called upon to have knowledge about what's happening on the molecular or atomic level. This knowledge helps the design engineers manipulate and work with the material and develop the characteristics they want."

WORK DESCRIPTION

Physical chemists work in a variety of different industries, but their common goal is to discover, test, and understand the fundamental physical characteristics of a material—be it solid, liquid, or gas. Precision and attention to detail make their work similar to analytical chemistry, although physical chemists also stress the importance of applying knowledge of math and physics to develop an understanding of the material.

WORKING CONDITIONS

A physical chemistry lab is characterized by the large machines and sophisticated instrumentation these scientists use to test and analyze materials. Many who work in the lab say their time is divided between working at the bench and working at their desks doing calculations and reviewing data. Physical chemists who go into management also spend time supervising other scientists, reviewing department needs and goals, and meeting with business managers in their companies. The great strength of physical chemistry is that it permits the scientist to approach a complex problem whose solution might include many measurements and understandings.

PLACES OF EMPLOYMENT

Physical chemists find employment in almost any industry, government agency, research institute, or educational institution that is involved with the development of materials. This includes industries as diverse as plastics, ceramics, catalysis, electronics, pharmaceuticals, surfactants and colloids, and personal care products. Physical chemists also work in such areas as environmental and analytical chemistry. Materials science is a growing field for physical chemists, and the emerging field of molecular modeling uses all the basic skills of physical chemistry.

PERSONAL CHARACTERISTICS

Physical chemists generally describe themselves as having a strong curiosity about how things work at the atomic level. They enjoy working with their hands as well as working with machines. Many describe having been drawn toward engineering and say physical chemistry's processes are similar to those of engineering. As physical chemists, however, they are also able to

combine their knowledge and love of chemistry to make discoveries.

EDUCATION AND TRAINING

In addition to a foundation in chemistry, physical chemists say this career requires strong skills in math and physics. Hands-on courses, such as lab, electronics, and optics courses are particularly helpful. Also, because the field is becoming increasingly interdisciplinary, physical chemists encourage students to take courses outside of their major and to develop an understanding of the synergies among the different disciplines. A fundamental understanding of kinetics, thermodynamics, and structure are crucial.

JOB OUTLOOK

There are many high-tech and materials science careers for which a degree in physical chemistry provides ideal training. Because training in physical chemistry provides a strong understanding of the dominant structural and dynamical merits of real materials, many physical chemists are redirecting their skills into applications research and interdisciplinary fields such as materials science.

FOR MORE INFORMATION

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WHAT YOU CAN DO NOW

Today's physical chemists strongly urge students to work in an industrial lab (for example, through an internship) prior to choosing physical chemistry as a course of graduate study. Those interested in pursuing a career in physical chemistry should familiarize themselves with machine tools and sophisticated equipment and how matter and instrumentation work. Actual bench experience is very valuable. An understanding of how computers work and a rudimentary knowledge of software, graphics, and programming are very helpful. The most important aspect, however, is a real curiosity about molecules, how they work, and how they can be studied.

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