

# Chemistry, Democracy, and a Response to the Environment

*The Priestley Medal Address is scheduled to be presented by Roald Hoffmann on April 24 at the awards ceremony during the American Chemical Society's 199th national meeting this week in Boston. Hoffmann is John A. Newman Professor of Physical Science at Cornell University. He shared the 1981 Nobel Prize in Chemistry, in part for jointly developing (with Robert B. Woodward) the well-known Woodward-Hoffmann rules, which use conservation of orbital symmetry to determine whether and how concerted thermal and photochemical reactions occur. More recently he has figured prominently in designing and appearing in a series of 26 half-hour television programs for a chemistry course called "The World of Chemistry," to air on public television and cable channels in 1991. The Priestley Medal, ACS's highest award, recognizes Hoffmann's wide-ranging chemical accomplishments.*

Joseph Priestley did not come to America 196 years ago because he was in search of professional advancement. He was hounded from England because of his political views, perceived as radical, specifically his public sympathy with the French Revolution and his spirited advocacy of democracy. I want to speak to you, friends, about chemistry and democracy. And because it is in the spirit of our times, about chemistry and democracy in the context of what I, as an individual, believe might be a response to environmental concerns.

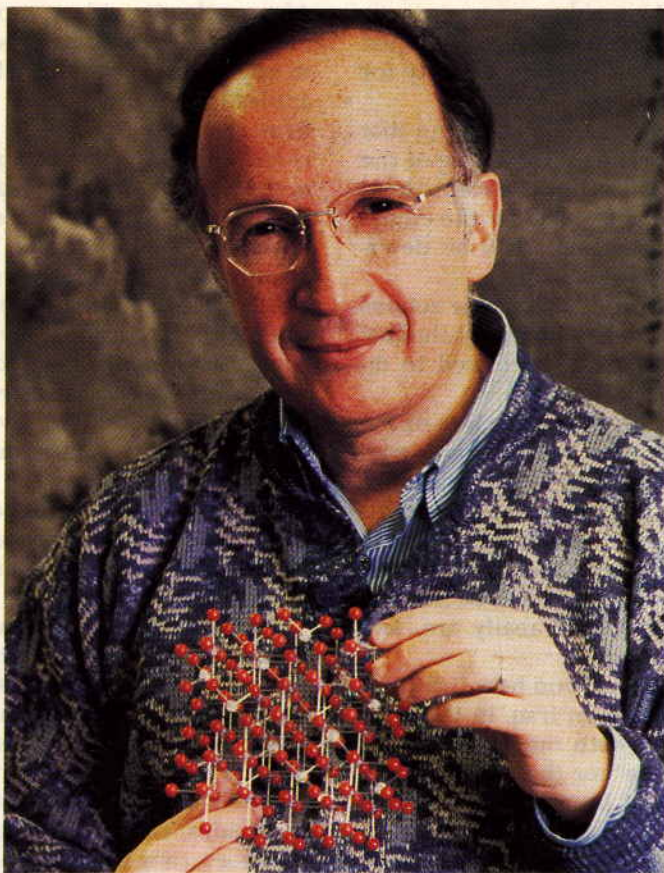
Chemistry is the study of substances and their transformations. Many practical streams flowed into it—metallurgy, cosmetics, fermentation and distillation, dyeing, apothecary formulations, the preparation of food, and that marvelous mixture of protochemistry and philosophy called alchemy. Joining the development of physics and astronomy, partaking of the power that comes through quan-

titation, chemistry began to become a science just around 200 years ago, at the time of the French Revolution.

There always was a chemical industry. I think, for instance, of the marvelous elite manufacture of the pigment called Tyrian purple. We now know that the active dye ingredient is indigo and a dibromo derivative thereof. The dye came from several species of muracid snails in the Mediterranean. The mollusks' mantles contain a clear fluid, which upon exposure to air and sunlight undergoes an irreversible series of chemical transformations, from clear to pus-yellow, to orange, red, and blue. The snails had to be correctly identified, their shells carefully broken, the precious mantle fluid collected and allowed to react, the dye separated, concentrated, the wool or silk prepared for dyeing. There may have been a simple reduction-oxidation sequence needed to make the dye soluble, then to fix it in the fiber. We have archaeological evidence of this simple

chemical activity along the eastern shore of the Mediterranean. It seems the Phoenician chemists had waste-disposal problems; there are vast shell dumps. The product had great economic value—in 301 AD a pound of wool dyed with Tyrian purple was worth 50,000 denari, about three years' wages of a baker.

What transpired between then and the successful mass production of synthetic indigo around 1900 by Degussa and Hoechst? Quite a lot. The scale of transformation of the natural took a great leap. The Tyrian purple protochemistry took a natural product and without much understanding but with great care and skill (does that sound familiar?) transformed it into a product of utility and desire, therefore of commercial value. The German dye-stuffs industry also started





with natural raw materials—first coal tar, then petroleum, and ethanol, potash, acetic acid as well. But the 19th century industrial transformations involved many stages. A chemical process grew into what we know today, a sequence of hundreds of physical operations, carried out in gleaming glass or steel vessels.

You know the sequel: the growth of the German dye industry, its diversification to chemotherapy, fertilizers, explosives. There is nothing specifically German here; the knowledge, like all chemical knowledge, is universal. A larger and larger part of the gross national product of all industrialized countries became chemical in nature. Directly or indirectly, the wealth of nations depends on their collective capability to transform the natural, on chemistry.

But still something else happened between the Tyrian purple indigo protochemistry and our time, something in the world around. An old idea, democracy, grew into the souls of people. The notion was that men (and God knows it took 2400 years to see that women had that prerogative too) had the right to govern themselves. The idea was that the social contract implied a given equality at the beginning, so that if men and women lived together, that the legitimacy of their actions, delegated in some way if need be, stemmed ultimately from themselves and not from a master or king or czar or party secretary or ayatollah.

It is worthwhile to remind ourselves in this 201st anniversary year of the French Revolution what the soul of the revolution was about. It was democracy. Let me quote you some excerpts from the Declaration of the Rights of Man and the Citizen, issued in late August 1789 by the French National Assembly:

"Article 1. Men are born and remain free and equal in rights; social distinctions can be established only for the common benefit.

"4. Liberty consists in being able to do anything that does not harm another person. Thus the exercise of the natural rights of each man has no limits except those which assure to the other members of society the enjoyment of these same rights; these limits can be determined only by law.

"5. The law has the right to forbid only those actions harmful to society. All that is not forbidden by the law cannot be hindered, and no one can be forced to do what it does not order."

These words are not vitiated by the perversion of the revolution that killed the man who began, if any man did, modern chemistry, Antoine Laurent Lavoisier.

To Priestley, the American and French revolutions represented "a liberating of all the powers of man from that variety of fetters by which they have hitherto been held. So that, in comparison with what had been, now only can we expect to see what men really are, and what they can do."

The struggle began then. I remind you how it continues even this day, in South Africa, in Iraq, in those remarkable events we have seen with our own eyes in Eastern Europe. And neither we nor the Chinese people will forget the early days of June 1989 in Tiananmen Square.

Democracy is a social transformation as irreversible

as chemistry, the science of matter transforming. I need to mention this because I perceive in the attitudes of our profession today some strands of thought that seem to me to be forgetful or skeptical of the process of democratic governance.

In what follows I speak only for myself. I do not speak for the American Chemical Society or for Du Pont for which I am a consultant, or for the Office of Naval Research, which generously supports my work in surface chemistry. I'm an individual, admittedly privileged to have this forum even as I voice ideas that may disagree with yours.

Let me caricature some prevailing attitudes in the profession. We say that we're reasonably well off in the material reality of this world, in our remuneration (well, never rewarded sufficiently), in what we really contribute to society. But spiritually it's a different story. We ain't got no R-E-S-P-E-C-T, no respect. We're typed by society, so the complaint goes, as the producers of the unnatural, collectively labeled as polluters. We are surrounded by chemophobia, by unreasonable, irrational fear of what we do. The media seem to be engaged in a conspiracy against us, and what right does Meryl Streep have to testify to Congress about what's in our apples?

Actually I once had a chance to chat briefly with a radiant, pregnant Ms. Streep, and I can tell you she is a sensitive and intelligent human being. Her views on Alar are not that different from those of people you love. In fact, let me use that Alar story to make some points about chemistry and democracy.

The outlines of the story are well known to you. Alar, or daminozide, a growth regulator, is one of perhaps two dozen chemicals that may be legally applied to apples during their maturation process. It keeps the apples longer on the tree and helps the maturation of firmer, more perfect fruit. A very small fraction of Alar is absorbed into apples and metabolized to an unsymmetrical dimethyl hydrazine, UDMH for short. The levels of UDMH in apples are probably insufficient to have biological effects on humans. A public awareness group, the Natural Resources Defense Council, brought out the use of Alar, and in various alarmist ways publicized the carcinogenicity of the UDMH metabolite. Alar-treated apples, already of some concern (reasonable or not) to supermarkets selling them, were quickly pulled off the shelves. Eventually Uniroyal Chemical, the producer of Alar, halted sales of the hormone.

Many chemists reacted to this episode instinctively by (a) tut-tuting the concerns, (b) impugning the motives of the public awareness group and Ms. Streep, and (c) pointing to this story as a typical, irrational example of chemophobia.

That wasn't my reaction. I must admit, however, that I wasn't consistent, and tended to fall into the three stances I just enumerated some of the time. But my initial reaction as a chemist and a human being was "Gee, I didn't know there were synthetic chemicals in my apples." I didn't know Alar existed. To be sure, I knew apples were treated in various ways, with fertilizers, herbicides, insecticides, fungicides, ripening agents. I had been trained since childhood to wash off fruit for



getting dirt off it. Subtly over the years, the reason for washing it off changed to removing any chemical residue. (Am I the only one to have this feeling? I don't think so.) But I didn't know, or maybe I didn't want to know, what found its way inside, what had not been degraded. I didn't know what remained inside—such as UDMH—at what levels, and what were its biological effects. I didn't like that; what I mean is that I didn't like the feeling of ignorance. Here I was a Columbia B.A., a Harvard Ph.D., supposedly a good chemist. And I didn't know what there was in apples! And even when I heard what was there—Alar, daminozide—I didn't know what these were. I was not happy with myself for not knowing; I was not happy with the apple producers for putting those chemicals in and not letting me know about it. I was not happy with my education for withholding this information.

Maybe I'm an exception in not knowing the chemistry of pomology. But I doubt it; I somehow doubt, because I know very well what we teach, whether many of you knew what Alar was before the flare-up of interest in it. How many of us know what man-made products are in the bread we had for breakfast, in the milk, in our coffee, in our carrot cake?

To take the view that even if we do not know that someone else knows and that we should trust that someone else to ensure our health is naive, unscientific, and undemocratic.

Undemocratic, because it is not only our right to know, but more importantly as citizens, especially citizens to whom society has given a free graduate education in chemistry, it is our duty to know. If you and I do not know, who then will?

The judgment of naïveté is based on history and knowledge of human nature. The great majority of producers and merchants are scrupulous as far as safety of their products goes. But there are also ample examples to the contrary, from stories in the Bible to the Gerber baby food scandal and all those spills in the shipping channels around New York. The evaluation of safety often involves a cumulation of borderline decisions. There are many grey areas; a test that comes down between harm and safety, experimental points that must be disregarded. Under competitive pressure, faced with the difficult prospect of telling a superior what he or she doesn't want to hear, it is all too easy to close one's eyes and wish for what the facts may not support. Much of this is not done with ill intent, it's human, it's natural.

My statement that to believe that someone else knows is unscientific is based on what we as scientists learn early on—analyze, check, don't trust the label. If you prepare 1-deuterioethane according to a procedure

detailed by another scientist, or if you purchase it, do you use it in a critical labeling experiment without some test that it doesn't contain two deuteriums per ethane, or none? Actually science is a complex, working balance of trust (reliable knowledge) and mistrust (the synthetic procedure that isn't reproducible).

What is, or should be, the proper response of chemists to environmental concerns? I believe that response must involve: (1) the recognition that these concerns are based both on technical risk assessment and on risk perception. And that these ways of evaluating risk, which I will try to distinguish, may not coincide. (2) A realization that in devising the controls that a democratic society imposes on unavoidable risks to person and property, the perception of risks figures legitimately, whether we like it or not. (3) The fact that democracy demands a platform for countervailing opinions, and that environmentalist attitudes are clearly within the range of what is acceptable.

Finally, I will plead for us as chemists not to isolate ourselves in defense of a supposed super-rationality on environmental issues.

The assessment of risks is not easy. It involves centrally analytical chemistry and chemical instrumentation. It requires great ingenuity, which we have as a profession given in the design of schemes, scales, and chemistry, to detect reliably substances at unimaginably small levels. In this context I think of various species-specific electrodes, Bruce Ames' indexes of carcinogenicity, the promising silicon biosensors of J. Wallace Parse, Harden M. McConnell, and their coworkers. I want to make a special note of the courage that is required by scientists to push

their analytical techniques into new ranges when society demands it.

Risk perception, as I see it, is not just technological risk assessment, a matter of spelling out the hazards as best as we know. There is a strong psychological component to risk perception, and empowerment figures prominently. By empowerment I mean the reality and perception that the person undergoing the risk has some control over the risk.

I suspect empowerment plays the dominant role in personal judgments of risk. We feel safer driving a car rather than flying in an airplane, despite accident statistics to the contrary. Why? Because it is we who are driving, but someone else is flying the plane. Much of the fear of nuclear power generation and of other technological dangers, real or unreal, derives not so much from ignorance of the processes as from the feeling that we are not near control.

Empowerment requires access to knowledge and a



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democratic system of government. The best of present systems of governance are just an approximation to the ideal of democracy. Still, no amount of knowledge, no matter how skillfully and widely taught, will assuage fear of the synthetic unless people feel that they have something to say, politically, in the use of the materials that frighten them.

What I say here is not radical but the common opinion of experts on risk. Here is what Peter M. Sandman, director of the Environmental Communication Research Program at Rutgers, says: "When you have a public that is both informed and empowered, it is more reasonable. . . . It's not that an informed public tolerates more risk; it chooses better which risks to tolerate. But an informed public without being empowered or explanations without a dialogue have next to no value."

Sandman points to "outrage factors," all the psychological components of risk perception. Let me choose some from among many he enumerates:

• *Voluntariness:* A voluntary risk is much more acceptable to people than a coerced risk, because it generates no outrage. Consider the difference between getting pushed down a mountain on slippery sticks and deciding to go skiing.

• *Morality:* American society has decided over the past two decades that pollution isn't just harmful—it's evil. But talking about cost-risk trade-offs sounds very callous when the risk is morally relevant. Imagine a police chief insisting that an occasional child-molester is an 'acceptable risk.'

• *Diffusion in time and space:* Hazard A kills 50 anonymous people a year across the country. Hazard B has one chance in 10 of wiping out its neighborhood of 5000 people sometime in the next decade. Risk assessment tells us the two have the same expected annual mortality: 50. 'Outrage assessment tells us A is probably acceptable and B is certainly not.'

The greater the perceived dread of a hazard, the more people will want to see regulation employed to reduce the risk in question. Is there anything wrong in the enactment of legal codes based not only on technical risk assessment but also on a moral perception of the risk? I don't think so—the laws of our country have always had a consensual moral as well as a material basis. If you don't like that, I ask you to conceive of arguing before a Congressional committee on that acceptable rate of child molestation or in favor of euthanasia of the physically impaired elderly.

The environmentalist movement—individuals and organizations—has a distinct right to speak on issues of chemical risks. To quote a Supreme Court decision, "We have recognized that the First Amendment reflects a 'profound national commitment' to the principle that 'debate on public issues should be uninhibited, robust, and wide open.'"

Their right to speak needed to be protected when

"they" were a minority. They're not that now. Edgar S. Woolard Jr., current chairman and chief executive officer at Du Pont, has said it well, in a remarkable speech advocating corporate environmentalism: "We sometimes position ourselves on an environmental issue on the basis of the available technical or scientific data alone. We have been too inclined to act as though public wishes and concerns matter less than technical opinions." He states quite clearly that the most powerful environmentalist group in every modern society is now not a fringe group, a bunch of kooks, but the general public. And that the challenge to industry does not lie in responding to the next regulatory proposal or combating environmentalist propaganda. It's instead the fostering of "an attitude and a performance commitment that places corporate environmental stewardship fully in line with public desires and expectations."

And on the question of empowerment, Richard Mahoney, the chairman and chief executive officer at Monsanto, has said that as part of a corporate commitment, "It is our pledge to keep our plants open to our communities and involve the community in plant operations."

This quotation was brought to my attention by Barbara Lynch, who also noted the positive aspects of Environmental Protection Agency release to the public of its extensive database on toxic chemical release. The importance of these data is that they inform the community, both in dealing with its representatives in Congress and EPA, but also in negotiating directly with the industries to resolve air pollution problems.

Knowledge empowers—isn't that what science is about?

A friend of mine has argued that Meryl Streep and her like have exceeded the limits of free speech, much as the man falsely shouting "fire" in a theater and causing panic. The reference is to a famous Supreme Court decision written by Oliver Wendell Holmes in 1919. The context restricted the right of a group to publish and disseminate propaganda against recruitment and enlistment in wartime. Holmes wrote: "The question in every case is whether the words used are used in such circumstances and are of such a nature as to create a clear and present danger that they will bring about the substantive evils that Congress has a right to prevent."

The evils that Congress must legislate against include the damage to environment and to persons that Streep is legitimately concerned about. There is a fire, though we may disagree on its magnitude. (Here I paraphrase Peter Sandman again.) That protection of the law must also be extended to individuals and corporations damaged by irresponsible alarms and responses. The "cyanide in Chilean grapes" episode of a year ago would come very close, I think, to being a prosecutable offense against the public, and it is this excess, undefensible, that my friend complained about.

Some chemists think that the environmentalists' fears are irrational. Simple psychology tells us that in

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addition to reason and empowerment, even before them, compassion figures prominently in responding to and allaying any fears. Friends, if someone comes before you verbalizing anxiety over a chemical in the environment, don't harden your hearts and assume a scientific, analytical stance. Open your hearts, think of one of your children waking at night from a nightmare of being run over by a locomotive. Would you tell him or her, "Don't worry, the risk of your being shot by a crack addict is greater"?

There is another reason why I want you to take a deep breath, slow the angering rush of blood, open up your hearts. No one is attacking you. The environmentalist, the one who doesn't want our nest fouled, is you, too. I hate to see human beings polarized by religion, race, or politics. It is not "us," whoever "us" is, versus "them," those irrational, Luddite critics of our lifestyle. There is much of "them" in "us"—allow for that life-enhancing and beautiful complexity of human beings, a complexity that does not forbid a chemist to be incensed at a rotting chemical dump at the same time as he or she knows that the production of those chemicals increased our life span.

To me the Alar controversy is humbling, educational, and instructive, an opportunity to learn rather than one to blow off some steam against environmentalists. I've learned some chemistry from it; I learned some from Bhopal and I intend to learn some from the next chemical disaster. People's minds open up when knowledge is accompanied by a relationship to something critical—a disaster, one's body, even the prurient and scandalous. One can use ill events in an educational sense.

I have come to education, and I should like to talk further about it. I view education as a crucial part of the democratic process; a privilege and a duty of the citizen. In fact, I'm not concerned about scientific illiteracy (and this is my opinion only, I remind you) so much from the point of view of it limiting our manpower base or affecting our economic competitiveness. What worries me about prevalent chemical illiteracy, a failure of the educational process, are two other matters.

First, if we do not know the basic workings of the world around us, especially that component that human beings themselves have added to the world, then we become alienated. We are distanced from our tools, and from the effects of our actions. We work on a piece of something, not the whole. To be efficient we work repetitiously, so that we may even lose interest in the whole. Mountains of paper insulate us from the human beings affected by our actions. Around us proliferate chemistries whose workings we don't understand. I doubt that there are many among my colleagues who could do what Mark Twain's Connecticut Yankee in King Arthur's Court could do, that is to reconstruct our technology from all those partial differential equations

we know. We press buttons and elevators come (or don't come). Worse, we press buttons and missiles are launched, and only the victims see the blood.

Alienation, due to lack of knowledge, is impoverishing. It makes us feel impotent, unable to act. Not understanding the world, we may invent mysteries, new gods, much as people did around lightning and eclipses, around St. Elmo's fire, and volcanic sulfur emissions a long time ago.

My second point of concern about chemical illiteracy returns me to democracy. Ignorance of chemistry poses a barrier to the democratic process. I believe deeply, as must be clear by now, that "ordinary people" must be empowered to make decisions—on genetic engineering, waste disposal sites, on dangerous and safe plants. They can call on experts to explain the advantages and disadvantages, the options, benefits and risks. But experts do not have the mandate; the people and their representatives do.

Here then is the importance of constructing high school and college general chemistry courses that reach out to a wide audience. And of training and rewarding teachers that can teach these. Our elected representatives, at least in the U.S., are unlikely to have learned much about chemistry. I hazard the guess that more than half of the U.S. Congress last saw a chemistry course in high school. Chemistry courses must be faithful to the intellectual core of the subject. But they also need to be attractive, stimulating, intriguing. They must aim, at least some of them, at the

informed citizen, not the professional.

At times the task of the chemist in society seems dishearteningly difficult. How can we educate people to our complex, well-developed science? How can we make them aware of their own molecular nature?

Here is where the late, wonderful George Pimentel (whom I remember every time I wear my western shirt) and I agree. His 1989 Priestley Award Address, which I urge you to reread, takes a very different road from mine. But he insisted, and I agree, that we cannot bring people to a better image of science unless we take a role individually. In small ways. Go into your children's classrooms; bring them a molecular model and an experiment. Encourage your newspaper to have a science page. If you are an academic, do the unthinkable and tell one of your better students to consider a high school teaching career. Impose on yourself the obligation to write a popular account of your work. Take a look at the chemistry books on the shelves of your local library. You will be shocked. Channel your envy of people who write about science by trying to do so yourself. Sublimate your anger at unreasonable environmental activists into an opportunity to teach chemistry.

For chemistry, and chemists, friends, there is no choice other than responsibility, personal and collective. No choice but education and democracy. □

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