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Thank you for inviting me to speak at this very important conference. I could not resist an invitation from Nina McClelland! Dr. McClelland has an uncanny ability to be at the leading edge of "where the action is" on issues affecting the science, art, and industry of chemistry, and I have tremendous respect for her judgment. The theme of this year's conference is exceptionally important, and I am grateful for the opportunity to speak to it this afternoon.

We are meeting today during what I believe is still an early stage in a materials revolution that is every bit as powerful as the information revolution that has already transformed our global economy. This is not the first materials revolution in history, and certainly not the last. Recent predecessors include the birth of organic chemistry in the nineteenth century, the rise of petrochemicals in the first half of the twentieth century, and the flowering of plastics in the 1960's. The electronics industry and its close relatives in optics and magnetics – industries that made the information revolution possible – all depend on the development of chemical high technology in the post World War II explosion of materials science. And there is a forthcoming biochemistry revolution that will bring changes much greater than anything we have yet seen from this already substantial industry.

The chemical revolution attracting attention today results from a cluster of new technologies for analyzing, imaging, and manipulating matter at the atomic scale. These technologies not only make it possible for us to create substances with entirely new functional properties, but also to detect and analyze substances in trace amounts, molecule by molecule. The new tools of synthesis and analysis promise unprecedented control over material properties and open doors to vast new domains of applications. They have spawned a buzz-word – nanotechnology – whose meaning is vague but clearly overlaps much of chemistry. Many applications of atomic level control and understanding of chemical processes extend beyond even this broad territory.

It is an exciting time to be a chemist, and also a difficult and frustrating time. Just when we have the tools to make new materials with unprecedented functional properties, concerns about the environmental and health impacts of new as well as old materials are rising rapidly. And those concerns are leading to a rising tide of government actions around the world that encumber efforts to take advantage of the new materials in commercial processes and products. Fortunately, some of our new technical capabilities will help to meet these emerging challenges.

Science has matured in the post World War II era into a powerful force in society. It is important to keep in mind that society reacts to the superficial products of science, and not to the underlying investigations and technologies that lead to these products. Societies respond to

technology at the level at which technology affects society's interests, and the public discourse, the laws and regulations and fashions of the marketplace, are about those interests and not in the first instance about the science or the technology. This is natural, and even rational from the perspective of those whose interests are affected, but it can lead to a highly irrational and counterproductive pattern of behaviors. It leads, for example, to concepts like the "precautionary principle" that has been embraced officially by the European Commission as a guide to regulation and is appearing with increasing frequency in the policies of local governments and even corporations throughout the world. Let me dwell for a moment on this principle because it helps focus the issues that bring us here today.

The "precautionary principle" is explicitly invoked in the 1992 Maastricht Treaty, the framing document of the European Union. Article 174 states:

> *"Community policy on the environment shall aim at a high level of protection taking into account the diversity of situations in the various regions of the Community. It shall be based on the precautionary principle and on the principles that preventive action should be taken, that environmental damage should as a priority be rectified at source and that the polluter should pay …"*

What this means is that the precautionary principle is embedded in the very foundation of the EU, and is not likely to be diminished or significantly modified as a fundamental notion guiding laws, regulations, and judicial opinions within the European Community and elsewhere. In February 2002 the European Commission published a "Communication on the precautionary principle" that should be required reading for everyone attending this conference. It appears to be an effort, if not to put this genie back into the bottle, at least to circumscribe what had already become a proliferation of dubious applications of the principle in the business of the member countries. Strategic thinking in response to the EU policy ought to begin with this document and take it very seriously.

One statement in the 2000 EU Communication contains the crux of the difficulties that require a strategic response.

> *"Whether or not to invoke the Precautionary Principle is a decision exercised where scientific information is insufficient, inconclusive, or uncertain and where there are indications that the possible effects on the environment, or human, animal or plant health may be potentially dangerous and inconsistent with the chosen level of protection."*

Although the full document attempts to condition these lines, they show that the principle is to be invoked when the science is uncertain and where nevertheless attention has been drawn to a potential danger that current protections will not adequately mitigate. In practice this gives tremendous power to individuals or groups with a broad spectrum of motivations for pointing out potential dangers of various substances. Assertions about the quality or significance of the science, about the nature and impact of the danger, and about the adequacy of existing protection can all lead to controversy and litigation. When science cannot resolve the issues, all bets are

off. Invoking the precautionary principle basically says "do nothing unless you can prove no one will be harmed by your action."

Our own Toxic Substances Control Act (TSCA) of 1976, while also requiring testing and regulating potentially hazardous materials, is considerably less precautionary than the EU policy. It says (among many other things) that

> *It is the policy of the United States that … authority over chemical substances and mixtures should be exercised in such a manner as not to impede unduly or create unnecessary economic barriers to technological innovation while fulfilling the primary purpose of this chapter to assure that such innovation and commerce in such chemical substances and mixtures do not present an unreasonable risk of injury to health or the environment.*

And unlike Europe's recent monumental REACH act, TSCA largely applies to new substances and "grandfathers" old ones. REACH is the single most consequential result of Europe's precautionary policy to date, and exporters to the EU will simply have to comply. But it is by no means the only and possibly not even the most costly consequence of the proliferating applications of the precautionary principle.

When it comes to REACH, the European countries themselves have developed guidelines to help their own industries and trading partners to deal with the new regime. I have looked at some of the materials from the United Kingdom, and they appear to be very useful. They can help with the "reaction" part of the "action and reaction" theme of this conference. The deeper question is what actions can governments and industries take that will reduce the negative side effects of society's legitimate concern for health and environmental impacts of the materials used in commercial products? Many possible answers come to mind, and speakers in this conference will undoubtedly say much more about them than I can.

The first and most important strategy for all commercial enterprises is to *have* an explicit environmental, health and safety strategy that is integrated with the planning and budgeting of corporate operations. What we are talking about here is a form of risk management, and the first step in risk management is awareness not only of known risks but also of perceived risks that could lead to negative impacts on the organization. After awareness the next step is to act in good faith to communicate and to mitigate known risks to those who may conceivably feel threatened. Broadly construed, this step includes avoiding or limiting the use of materials, if possible, that are the objects of risk perception. A conscious strategy keeps the organization informed of alternatives and best practices for reducing the volume of potentially hazardous or risk-linked by-products that either are now or are likely to be regulated in the future. Awareness, communication, and mitigation cost money, and budgets need to be established for them and protected from cannibalization in the planning and budgeting cycle. These are best practices based on the experience of many companies, large and small. Many companies and suppliers of chemicals and materials do have explicit strategies like this, often linked to Green Chemistry campaigns and pollution prevention and control programs. Their experience has been generally positive, and in every case I know of, the programs have paid for themselves over shorter times than the organization had predicted.

I am emphasizing these things that individual companies can do because unless a company does them they will not be able to take advantage of broader initiatives by government or industry organizations like ANSI. These policies establish receptor-sites within each company for the information and communication networks that are essential for effective action and reaction to the rapidly changing environment of today's materials-intensive industries. This environment has good news and bad news. The bad news is that regulation is proliferating in scale and complexity. The good news is that new alternatives to materials and processes and new tools for developing more rational regulation are emerging even faster. How effective these new tools and alternatives will be depends on three things. I've already told you one – the ability of individual companies at risk to receive, understand, and use information about new ways to mitigate their risks. The other two are standards and what I call a "communications framework."

Part of the scientific uncertainty that triggers precautionary behavior and its adverse side effects is lack of agreement on what we're talking about. Concern about nano-things is a good example. Science fiction scenarios based on the proliferation of self-replicating nano-robots have intersected with legitimate concerns about the use of nano-materials in bulk products like paint, cosmetics, and building materials. Assuming we can sort out such obvious categories, we are still faced with a bewildering complexity in the response of health and environmental systems to specific substances, nano- or not. Part of that revolution in materials science I mentioned is a rapidly increasing appreciation for the variety of molecular level responses of complex systems to specific chemical or nano-particle stimuli. The federal government acknowledges its responsibility to fund research into these mechanisms, and to use the new knowledge to link causes with socially significant effects. We know that these links depend on specific conditions of the affected systems as well as the stimulating substances. Traditional ways of characterizing properties of chemical substances do not capture the details regulators and the public need to assess options in this new knowledge environment.

Organizations like ANSI are essential for surveying the needs of all the actors – government, industry, and researchers – identifying the priority issues, and brokering solutions that end up in widely accepted standards. No activity has higher leverage on the growth of the new materials industries – or the survival of the old ones – than the establishment of standards for materials and materials properties. This is the main reason the President has targeted NIST for rapid growth in his American Competitiveness Initiative. Your support of ANSI and of NIST is essential if Congress is to fund this activity commensurate with its importance. Consensus on standards is the most powerful tool for rationalizing regulation and bringing uniformity into the complex decentralized global regulatory environment. It also influences and improves the quality of environmental and health advocacy and the behavior of legislative bodies. Standards make it possible to resolve litigation, assure product performance, and specify new product functions.

As I prepared for this address I read the recent analysis in BNA's *"Daily Environment Report"* (April 30, 2007) subtitled "Stakeholders Mull Need for Strategy To Address Emerging Chemical Issues." It is an excellent summary that gives concrete examples of the themes I am highlighting today. One theme common to nearly all the issues brought forward by the stakeholders was *information*. Regulators, researchers, corporate managers and planners, policy makers, educators, legislators, and advocacy groups all need access to a wide variety of

information on chemical substances and processes and their behavior at different technical levels available in formats and with credentials that will ensure their use. A great deal of information already exists that would be helpful to many parties if only they knew about it. It is not enough to accumulate it in a single database and put it on the web. We are talking about an information universe in which rapidly accumulating data must be characterized and made available with informatics tools that allow stakeholders to access and use it who have widely different needs.

The information revolution I mentioned is providing new tools for addressing such a wide range of needs and functions. I know that chemists have contributed to some of these tools and that there is a long history of chemical informatics that can form the basis for a badly needed new information framework. What seems to be missing is a kind of meta-information structure that links various sources of information and permits users to navigate them and create applications tailored to their needs, much as users are able to create "mash-ups" of geographical data bases with Google Maps.

The information stakeholders talked about comes in several layers. At the bottom is the highly technical basic map of chemicals, substances, and processes, continually expanding and filling in with links and technical data. Then comes information about interactions with various environments – physical, biological, environmental, etc. Next comes information about customer requirements – military or government procurements, manufacturers, supply chain vendors and purchasers, etc. And finally information about regulations at the international, federal, state and local levels. It is not necessary that all this information be compiled, owned, and managed by a single entity. Models exist today where many independent actors contribute data and tools to an essentially open system that builds on a basic capability that allows users to surf along different dimensions of the information landscape.

I do not mean to advance a specific idea of what this information framework should look like or how it might be structured. My point is that information tools exist today that have the potential for addressing many of the problems I read about in the survey of stakeholder issues. The chemical industry, like other industries today, needs sophisticated information capabilities to function effectively in a complex, globalized environment. Even slightly increased attention to these capabilities could make life easier for many companies.

In summary, the regulatory environment is unlikely to get simpler than it is today, and we must learn to live with its complexity. Individual companies must invest in activities resembling risk management programs as a cost of doing business, and they are likely to discover the investments are profitable. Increased private and public sector investment in standards research and development for materials and processes will have enormous payoff for all stakeholders. And stakeholders need to brainstorm a strategy for assembling an information framework that will make the vast amount of information we already have – and will generate in the future – available to the diverse parties who need it to make rational decisions.

One important issue I did not talk about is the need for chemists with the broad training necessary to assist in these daunting tasks. And there are others. Fortunately you have ample opportunities to discuss these during this conference. Thanks again for inviting me.