A DIFFERENT CHEMICAL INDUSTRY

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An Altered Industry. The chemical industry today is completely different from the chemical industry of 25 years ago. The clearest evidence comes from the jobs taken by graduating chemical engineers. Twenty-five years ago, 80 percent of these graduating students went to the commodity chemical industry, exemplified by Dupont, Exxon, Shell, and Dow. Occasionally they went to international companies such as Bayer and ICI, though this was less common. The remaining 20 percent were roughly divided into equal groups. Some, perhaps 10 percent, went to product-oriented businesses such as PPG, Upjohn, or 3M. A similar number, perhaps another 10 percent, went to everything else, including consulting, government, and academia. This older chemical industry, dominated by large-commodity chemical companies, was very familiar and dependable.

Today, as Figure 1 shows, the situation is completely different. The percentage of graduates going to the commodity chemical companies has dropped dramatically, perhaps to a quarter of the total. Simultaneously, the percentage going to consulting has risen to around another quarter. This consulting includes functions such as process engineering, now contracted out rather than performed within the engineering laboratories of the commodity chemical companies.

The bulk of new graduates, however, now goes to industries where products are most important. Some of these products, such as pharmaceuticals, are familiar; others, such as foods, have existed previously but have not involved significant numbers of chemical engineers; still others such as electronics represent new efforts.

WHAT PRODUCTS ARE IMPORTANT

In this altered chemical industry, we must first ask what are the products that we are going to produce. I believe there are three types of these products, each with different characteristics. The first and most obvious are the familiar commodities—the same products which used to dominate the chemical engineering enterprise. The key for producing these new products is their cost. Styrene produced by Dow and styrene produced by BASF are chemically identical; the issue is who can produce large quantities at the lowest possible price.

The second and third types of products may be less familiar. The second type involves molecules with molecular weights of 500-700 and with specific social benefits. The most obvious examples are pharmaceuticals. The key to the production of pharmaceuticals is not their cost but rather their time to market, *i.e.*, the speed of their discovery and production. The first-to-market tends to get at least two-thirds of the eventual sales for the molecule, even after patents on the particular molecule expire. These products are normally not made in dedicated equipment but rather in whatever reactors are available at that specific time. Thus, process optimizations tend to be less important than questions of scheduling: If the equipment is being used for many different products, when can you get in to make yours?

The third product type includes those for which the value is added by processing to make a specific nanostructure. The key to these products is their function. For example, I don't

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care why my shoes shine after I have applied polish; I only care that they do shine. It is the shine, not the molecule that produces the shine, that is important. Customers are often willing to pay a premium for such a function, be it in a coating, in a food, or in a cleaner.

I find it helpful to think about these three types of products using the summary shown in Table 1. For commodity products, the key factor as stated previously is the cost of the product. The basis for producing the product will continue to be unit operations—unit ops—the familiar core of chemical engineering. Our action in this area should be to sustain the commodity industry. We are certainly not currently carrying out unit operations in the best way possible, but we are probably close to the limit of what is economically attractive.

With the key factor of the second type of molecular products being time to market, the major cost of products of this type, such as drugs, is not the process engineering but the cost of their discovery. At best, only one in a thousand drug candidates is commercially successful. This enormous drop-out rate is the reason drugs are expensive. The key to discovery normally comes from chemistry and microbiology, not from chemical engineering. As a result, it is not clear whether traditional process engineering has a major role to play in molecular products.

For nanostructured products, the third type, whose key factor comes from their superior function, the added value comes from the process rather than from the chemical synthesis. Their desired function is the shine of the polish or the cleaning of the detergent. Studies in this area seem to lack any unifying intellectual core. Flavor release in food science takes no advantage of what is known about controlled drug release in pharmaceutics. Micelle formation in latex paint is an independent topic from micelle formation in detergents. I believe there is a genuine need for a general theory of nanostructured products. Such a theory could be part of a required course common to departments including chemical engineering, food science, and pharmacy.

IMPLICATIONS FOR EDUCATION

Faced with this altered chemical industry, we must ask whether the skill set currently mastered by chemical engineers is appropriate for the future. This skill set consists of three roughly equal parts, based in physics and mechanics, in chemistry and biology, and in chemical engineering. I don't think this skill set is inappropriate for the future. The ideas of reaction engineering and separation processes will continue to be central to what chemical engineers do. Within these areas, some topics will recede and other topics will become more important, but the core will remain.

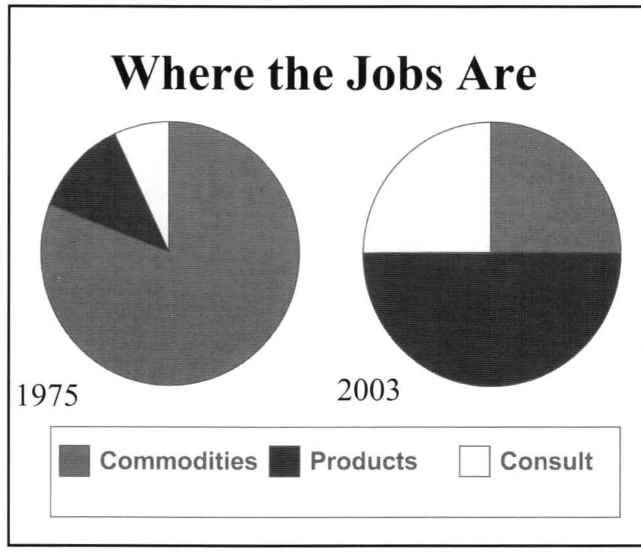

Figure 1. *Where the jobs are in chemical engineering.*

I do think that there may be a partial problem with the courses that present these topics. At the moment, these courses are biased heavily toward the commodity chemical industry. This bias includes such classical chemical engineering courses as transport phenomena and thermodynamics. In the future, new courses, including those based on biology, on polymer science, and on product design, must become more central to the chemical engineering curriculum. We require three such courses at the University of Minnesota precisely because we believe the content of those courses will better prepare our students for the new chemical industry.

Some may find this description of a changed chemical industry depressing. I don't. I think it is simply different. For example, it means that we may now work more on crystallization and less on fugacity, but I don't think that is a problem. In many ways, the reemergence of an emphasis on products and the corresponding de-emphasis of a few commodity chemicals suggests a broader intellectual challenge for chemical engineering. That challenge is interesting. I welcome it. I think it is exciting. And I think all of us will discover that excitement together. ❐

TABLE 1
Three Kinds of Products
Different strategies are appropriate for different kinds of products.

	Commodities	Molecules	Nanostructures
Key	Cost	Speed	Function
Basis	Unit Ops	Discovery	f (Properties)
Action	Sustain	Chemistry Key	Unified Theory