6 August 1982, Volume 217, Number 4559

SCIENCE

Long-Term Changes in the Chemical Industry

A combination of factors has caused the chemical industry to examine its future feedstock and energy sources. At present, petroleum and natural gas are by far the predominant sources of organic carbon and energy. However, increases in the price of oil and natural gas have had impacts on conservation, process design, and choice of future feedstocks. The price of these hydrocarbons will likely tend to rise faster than inflation, creating additional pressure for changes in the industry and in its needs for trained people.

One alternative is coal. As a source of heat, its cost is about one-fifth that of oil or natural gas, and increasingly it is replacing other fuels. Coal can also serve as a source of such compounds as benzene, toluene, phenol, and naphthalene. In future, coal is likely to be consumed in large quantities to make synthesis gas, that is, carbon monoxide plus hydrogen, which can be converted to methanol, ethanol, and a host of hydrocarbons.

But for the long-term future and to meet worldwide needs, the most interesting feedstock is derived from photosynthesis. In contrast to fossil fuels, biomass is renewable, and supplies will likely increase substantially in the coming years. As feedstocks, wood and plant materials are more versatile than coal, and advances in biotechnology are likely to lead to innovative processes for manufacturing chemicals from them.

In terms of ash or sulfur content, plant material is cleaner than coal, and it is converted to synthesis gas more readily. But the really interesting chemicals produced by plants and trees are the diverse natural products, such as rubber, resins, terpenes, carbohydrates (including starch, hemicellulose, and cellulose), proteins, fats, waxes, and lignin. Up to the present, research to improve plants has largely focused on food crops. This effort has been quite successful and indicates that similar efforts would improve the yields of other desired products. Already better management of silviculture in some instances has led to yields five times those of natural stands.

Of all the products of photosynthesis, glucose and its polymers are probably the most important as chemical feedstocks. Glucose is a favorite source of energy and carbon for many microorganisms, both aerobes and anaerobes. They can convert the sugar into hundreds of different chemicals, including ethanol, citric acid, and pharmaceuticals. By use of selected mutants and of recombinant DNA techniques, it should be possible to target specific products and improve their yields.

In spite of the increasing costs of oil and natural gas, the transition to other feedstocks will occur only gradually. The petrochemical complexes are in place. Biotechnology is likely to have its initial expansion in the production of substances that cannot be derived from fossil fuels. But fermentation is beginning to have a small but significant impact on the petroleum industry. Until recently, nearly all industrial alcohol was derived from ethylene. Now an increasing fraction is coming from grain, and some of it is being used in gasoline in an application other than gasohol. Some oxygenated organic compounds, including ethanol, increase the octane number of gasoline and thus serve as a substitute for tetraethyl lead.

For decades, biotechnology was overshadowed by the petrochemical industry. Fermenters producing ethanol, acetone, and butanol were dismantled. The pharmaceutical and food industries kept industrial microbiology alive, but academic training in biotechnology was almost nonexistent. Thus there are few academic experts in the field at a time of expanding opportunity. Some of the nation's most creative people are scientists versed in molecular biology, including recombinant DNA techniques. However, if their work is to lead to the production of useful products for society, biotechnology and biochemical engineers must be involved.

Many of the major chemical companies recognize that important future opportunities involve biotechnology and they are building their staffs accordingly. Students who have inclinations and aptitudes for the natural sciences can confidently seek training in biotechnology with the conviction that the field will expand in significance and usefulness for many decades.

—PHILIP H. ABELSON