14.1: Feeding the Anthrosphere

As the industrial revolution gained impetus since about 1800, and especially since about 1900 with the development of the chemical industry, the anthrosphere developed a voracious appetite for materials. This is especially true of the vast petrochemicals industry fed by materials from petroleum and producing huge quantities of polymers, plastics, synthetic detergents, agricultural chemicals and many other products. The era of petrochemicals must come to an end because sources of petroleum cannot sustain the enormous appetite of the anthrosphere for petrochemicals. The demand for the kinds of products now produced from petroleum will not go away, so alternate means of providing the materials desired by humans will have to be met. The only real alternative is biomaterials which in fact provided most of the stuff that humans used until very recently in the history of humankind. Although challenging, this shift in raw materials sources promises to be a very exciting one for chemistry. And it provides an opportunity for chemists and engineers to “get it right” by applying the principles of green chemistry, green engineering, and industrial ecology in ways that will ensure a sustainable future.

Feedstocks

Recall from Chapter 13, Section 13.15 that **feedstocks** are the main ingredients that go into the production of chemical products. Reagents act upon feedstocks and often the two are not readily distinguished. Feedstock selection largely dictates the reactions and conditions that will be employed in a chemical synthesis and is, therefore, of utmost importance in the practice of green chemistry. A feedstock should be as safe as possible. The source of a feedstock can largely determine its environmental impact, and the acquisition of the feedstock should not strain Earth’sresources. The process of isolating and concentrating a feedstock can add to the potential harm of otherwise safe materials. This is true of some metal ores in which corrosive and toxic reagents (in the case of gold, cyanide) are used to isolate the desired material.

As a general rule, it is best if feedstocks come from renewable sources rather than depletable resources A biomass feedstock, for example, can be obtained as a renewable resource grown by plants on land, whereas a petroleum-based feedstock is obtained from depletable crude oil resources. However, the environmental tradeoffs between these two sources may be more complex than first appears in that the petroleum feedstock may simply be pumped from a few wells in Saudi Arabia, whereas the biomass may require large areas of land, significant quantities of fertilizer, and large volumes of irrigation water for its production. Another important decision is whether or not the feedstock should be made entirely from virgin materials or at least in part from recycled material.

In the United States petroleum amounts to all but about two percent of the raw material used for the manufacture of organic chemicals and the many products made from them, such as textiles, plastics, and rubber. To a degree petroleum is an ideal feedstock for this purpose; during the last 100 years it has been readily available and relatively inexpensive except during times of temporary supply disruption. There are, of course, disadvantages to the use of petroleum as a feedstock, not the least of which is the fact that eventually available supplies will become exhausted. The transportation and refining of petroleum consume large amounts of energy, amounting to more than 15 percent of total energy use in United States. Chemically, a consideration with the use of petroleum as a raw material is that the hydrocarbon molecules that compose petroleum are in a highly reduced chemical state. In order to be utilized as feedstocks, petroleum hydrocarbons often must be oxidized. The oxidation process (see Section 13.15) entails a net consumption of energy and often requires the use of severe and hazardous reagents. Although commonly used oxidation processes are well contained and safe, there is always the consideration of possible combustion and explosion hazards in the partial oxidation of petroleum.

Much of the challenge and potential environmental harm in obtaining feedstocks is in separating the feedstock from other materials. This is certainly true with petroleum, which consists of many different hydrocarbons, only one of which may be needed as the raw material for a particular kind of product. Some metals occur at levels of less than 1% in their ores, requiring energy-intensive means of separating out the metals from huge quantities of rock. The smelting of copper and lead ores releases significant quantities of impurity arsenic with the flue dust, which must be collected from the smelting operation. Indeed, this byproduct arsenic provides more than enough of the arsenic needed in commerce. Biobased materials are also generally mixtures that require separation. Cellulose from wood, which can be converted to paper and a variety of chemicals, is mixed intimately with lignin, from which it is separated only with difficulty.

In evaluating the suitability of a feedstock, it is not sufficient to consider just the hazards attributable to the feedstock itself and its acquisition. That is because different feedstocks require different processing and synthetic operations downstream that may add to their hazards. If feedstock A requires use of a particularly hazardous material to convert it to product, whereas feedstock B can be processed by relatively benign processes, feedstock B should be chosen. This kind of consideration points to the importance of considering the whole life cycle of materials rather than just one aspect of them.

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