Chapter 38

Quantitative Aside 38.1--Thinking Quantitatively—The Haber–Bosch Process

In 1856, the U.S. Congress passed the Guano Island Act that allowed citizens to take over islands not claimed by other governments to harvest guano (bird droppings that could be as deep as 150 feet). Guano is rich in nitrogen, and the demand for fertilizer to meet the needs of expanding agriculture was great. The shift to synthetic fertilizer began in the early 1900s with Haber's discovery that under high pressure (500 atm) and temperature (~450°C), atmospheric N_2 and H_2 could be combined to make ammonia (NH_3) if an iron catalyst was added. Although this discovery earned Haber the 1918 Nobel Prize in Chemistry, it was Carl Bosch's engineering work that scaled the process to an industrial level, earning him the 1931 Chemistry Nobel Prize. Annually, 131 million metric tons of ammonia is now produced synthetically and somewhere between 100 and 175 million metric tons of ammonia is produced by nitrogen-fixing bacteria.

The Haber–Bosch process is tremendously energy-intensive. Up to 5% of the world's annual natural gas production is consumed in making hydrogen and generating heat to run the reaction. If the United States produces 611,000,000,000 m^3 of natural gas each year and 5% of that is used to produce nitrogen fertilizer in the United States, what is the cost of production if the industrial price of natural gas is $5.00 for a cubic foot of gas? Applying your knowledge of plant biology, how might we reduce the amount spent in the United States on nitrogen fertilizer?