CHAPTER OVERVIEW

9: Surfaces, Interfaces and Electrochemistry

While burning oil is easy, there won't always be oil to burn. It took millions of years for carbon-based fuels to form on our planet. For example, a large portion of the world's coal stock was generated during the Carboniferous period (300M years ago), when the oxygen levels of the Earth were higher. This caused significant plant growth, and bacteria had not yet evolved to the point that they could decompose plant material effectively. All that locked-up energy is now being released over a fraction of the hundreds of million years that it collected, which will have devastating results.

Humanity has long recognized the problem of limited oil resources and has undertaken some lackadaisical effort to add longevity to existing reserves and find alternatives. Catalysts can extend the lifetime of Earth's hydrocarbon feedstock by making chemical transformation more efficient, resulting in less energy consumption. This is usually performed via heterogeneous catalysis using solid-state materials. Examples include the hydrogenation of carbon-carbon double bonds using rhodium nanoparticles, and the Haber-Bosch process that utilizes iron supported on alumina to generate ammonia from H_2 and N_2. Regardless of our ability to extend the lifetime of our oil reserves, they will run out eventually which is why we need to turn to renewables such as wind, water, and solar. Of these, solar is the only sensible choice. Solar energy comes in many forms; for example, the sun can be used to generate fuel. Essentially, the idea is to create carbon-carbon bonds that we subsequently burn like normal, for which we need new and effective solid-state catalysts to make such transformations efficient. Solar energy can also be harnessed using photovoltaics (solar cells). However, we must be able to store the energy generated during the day for use at night, especially at $\sim$6 pm when there is a strong spike in electrical consumption because people are coming home from work. The use of batteries is a good solution, and to understand batteries, we must explore electrochemistry.

All of these processes are inter-related because they involve interfacial phenomena. Heterogeneous catalysts work due to reactions occurring on their surfaces. Likewise, photovoltaics and batteries have metal electrodes where charge transport occurs. For example, in batteries electrons are transferred across a metal rod's surface into (or out of) an electrolyte, and often the electrode is part of the process. We will discuss these examples further on, but for now we will focus on the properties and synthesis of inorganic nanoparticles. These sub-microscopic solids are small to the point that an appreciable number of atoms reside on the surface.

9.1: Surfaces and Surface Energy

9.2: Surface Expansion Work

9.3: Electrochemistry and the Nernst Equation