7.4 Thermosetting Plastics

When the long-chain molecules in a polymer are cross-linked in a three-dimensional arrangement, the structure in effect becomes one *giant molecule*, with strong covalent bonds. These polymers are called **thermosetting polymers** or **thermosets** because, during polymerization, the network is completed and the shape of the part is permanently set; this **curing** (**cross-linking**) reaction, unlike that of thermoplastics, is irreversible. The response of a thermosetting plastic to a sufficiently elevated temperature can be likened to what happens when baking a cake or boiling an egg: Once the cake is baked and cooled, or the egg boiled and cooled, reheating it will not change its shape.

Some thermosets (such as epoxy, polyester, and urethane) cure at room temperature, because the heat produced by the exothermic reaction is sufficient to cure the plastic. A typical thermoset is **phenolic**, which is a product of the reaction between phenol and formaldehyde. Common products made from this polymer are the handles and knobs on cooking pots and pans and components of light switches and outlets.

The polymerization process for thermosets generally takes place in two stages. The first occurs at the chemical plant, where the molecules are partially polymerized into linear chains. The second stage occurs during the final step of part production, where cross-linking is completed under *heat* and *pressure* during molding and shaping of the part (Chapter 19).

Thermosetting polymers do not have a sharply defined glass-transition temperature. Because of the nature of the bonds, the strength and hardness of a thermoset are not affected by temperature or by rate of deformation, unlike those for thermoplastics. If the temperature is increased sufficiently, a thermosetting polymer instead begins to burn, degrade, and char. Thermosets generally possess better mechanical, thermal, and chemical properties; electrical resistance; and dimensional stability than do thermoplastics.