

## 8.26: Cross-Linking

The formation of covalent bonds which hold portions of several polymer chains together is called **cross-linking**. Extensive cross-linking results in a random three-dimensional network of interconnected chains, as shown in the figure. As one might expect, extensive cross-linking produces a substance which has more rigidity, hardness, and a higher melting point than the equivalent polymer without cross-linking. Almost all the hard and rigid plastics we use are cross-linked. These include *Bakelite*, which is used in many electric plugs and sockets, *melamine*, which is used in plastic crockery, and epoxy resin glues.

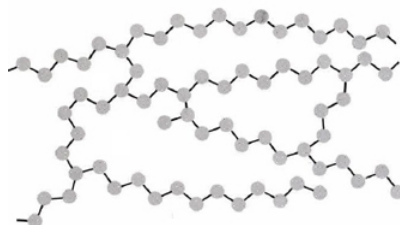
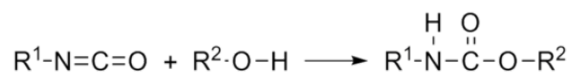


Figure 8.26.1: A cross-linked polymer. For purposes of clarity, hydrogen atoms and side chains have been omitted, and only the carbon atoms in the chains are shown. Note that the cross links between chains occur at random.

Below is a video of the formation of Polyurethane Foam.



Polyether polyol, a blowing agent, which adds a gas to the mixture to produce a foam, silicone surfactant, and a catalyst is mixed with a second liquid contains a polyfunctional isocyanate. The polyol and the polyfunctional isocyanate react to form polyurethane - a very hard substance when dried. The general reaction is shown below:



isocyanate group   **hydroxyl group**   **urethane linkage**

"R" 1 single bond "N" double bond "C" double bond "O" reacts with "R" 2 single bond "O" single bond "H" to give "R" 1 single bond "N" "H" single bond "C" double bond "O" single bond "O" single bond "R" 2.

In the reaction in the video, each  $\text{R}^1$  group has multiple isocyanate groups; the reactants are polyfunctional. Thus there is a high degree of cross-linking in the polyurethane. This causes the foam to become rigid after cooling.

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