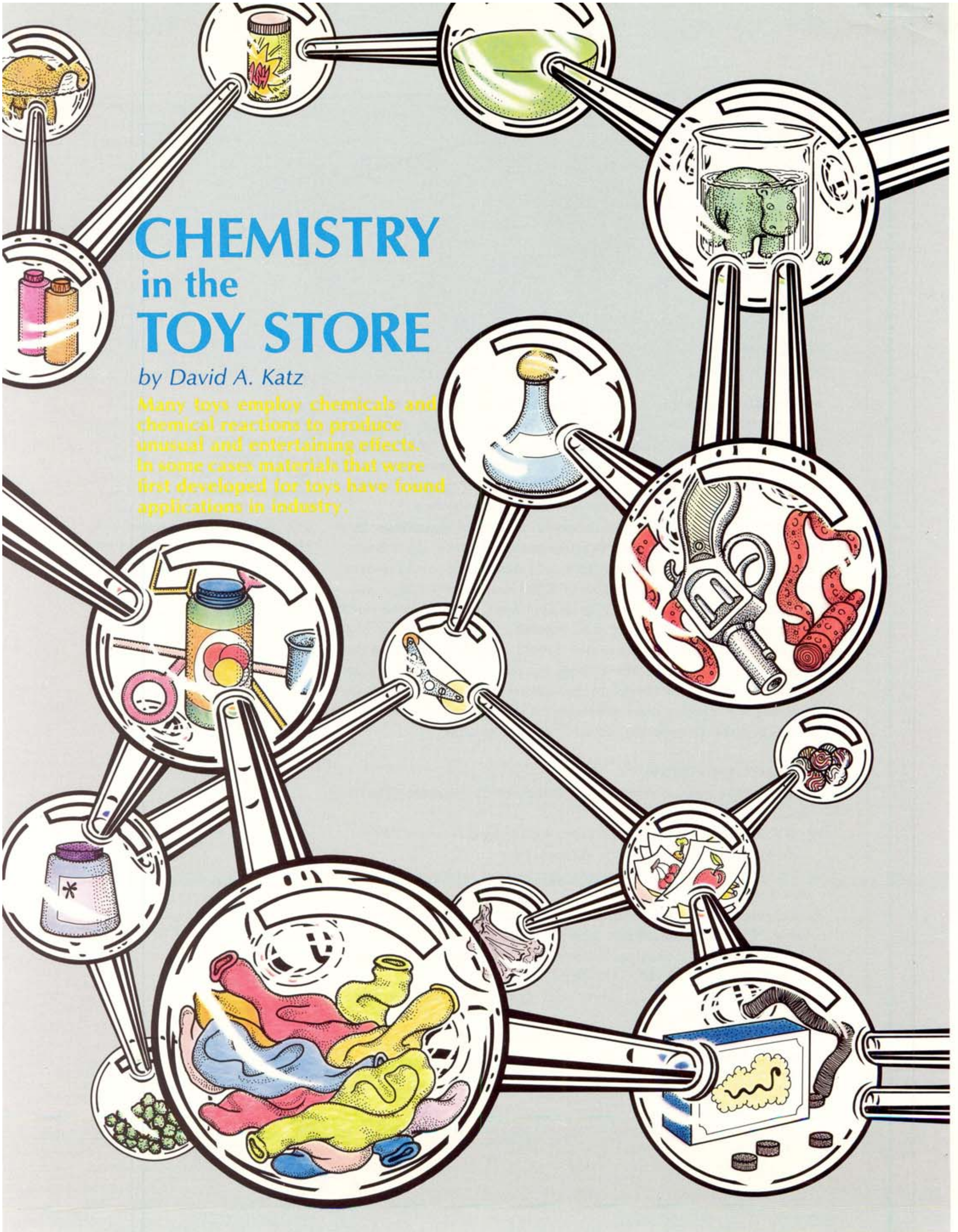

CHEMISTRY in the TOY STORE

by David A. Katz

Many toys employ chemicals and chemical reactions to produce unusual and entertaining effects. In some cases materials that were first developed for toys have found applications in industry.

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Illustrations by John Draves

The chemistry of everyday materials affects our lives in the form of consumer items that are used in the kitchen, laundry, bedroom, workshop, garden, and place of work. One place that is often overlooked is the toy store. Many toys involve chemicals, chemical reactions, and the unique properties of a particular material. Whether the item is a chemistry set, a silicone putty, a polymer with unusual properties, a material to make or mold another plaything, or the batteries used to power mechanical or electronic items, the toy store is a unique place for chemical products.

Chemical toys come from several sources. Some items such as sparklers and flash powders originated in ancient technologies, and some, such as disappearing ink or Magic Rocks, are refinements of experiments that are part of any chemistry course. But most chemical toys are an application of a product used for other purposes or developed through research. Silly Putty is the result of an unsuccessful attempt by General Electric Co. to produce a synthetic rubber in 1941; Slime is an application of a common food ingredient used for thickening or for producing quick-forming gels; Magic Sand® was originally developed for cleaning up oil spills; and Magic Eggs were a result of superabsorbents developed for agricultural applications by the United States Department of Agriculture. In each case someone involved with the material decided that it would make an interesting toy and marketed it. Occasionally the process works in reverse, and a toy provides a way of bringing attention to a new material; this was the case of nitinol, a metal with a memory, used in a Thermobile.

Soap bubbles have long been a popular item in toy stores. Pipes are among the many devices used to produce the bubbles.

Charles Cegielski

Courtesy, Hedstrom Corporation; photo, Charles Cegielski

Large bubble loop with a smaller one inside (left) produces a small bubble within a large one. A simple loop can be constructed from string and soda straws (below).

Soap bubbles

Among the most common items found in toy stores are soap bubbles. The container is usually accompanied by a small plastic wand, consisting of a rod with a loop at one or both ends, or occasionally a bubble pipe or more complicated type of apparatus. Several companies have been producing large bubble loops approximately 19 centimeters (7.5 inches) in diameter; some of these have many smaller loops inside for producing multiple bubbles or concentric loops for making small bubbles in a large one. A large bubble loop can easily be made from plastic soda straws and string. The bubble solutions that accompany these special loops generally are dilute soap or detergent solutions that are not particularly effective for producing strong soap films or large bubbles.

There are many recipes for preparing soap solutions. A simple solution for making soap bubbles or films can easily be prepared by mixing a soap such as Ivory® flakes or a detergent such as Tide® in some distilled or deionized water. A better solution can be made with liquid detergent:

10% liquid dishwashing detergent such as Dawn® or Joy®, by volume
85% water (distilled or deionized)
5% glycerin

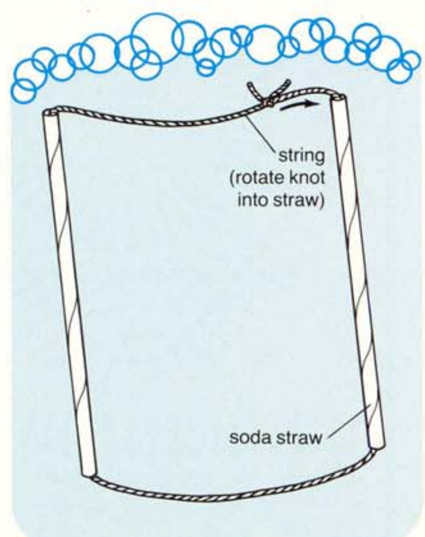
The soap mixture should always be stirred, not shaken; otherwise excessive amounts of suds may be produced. A low-suds or "controlled-suds" detergent should not be used.

The glycerin is used to strengthen the soap film. Sugar can also be added, but it is best to use it in the form of a sugar syrup because solid sugar does not dissolve readily. White Karo® syrup also works well. For producing large, long-lasting soap bubbles, one should use:

20% liquid dishwashing detergent
10% glycerin
70% water (distilled or deionized)

A recipe for "super bubbles" calls for:

4 parts glycerin
2 parts liquid Joy®
1 part white Karo® syrup

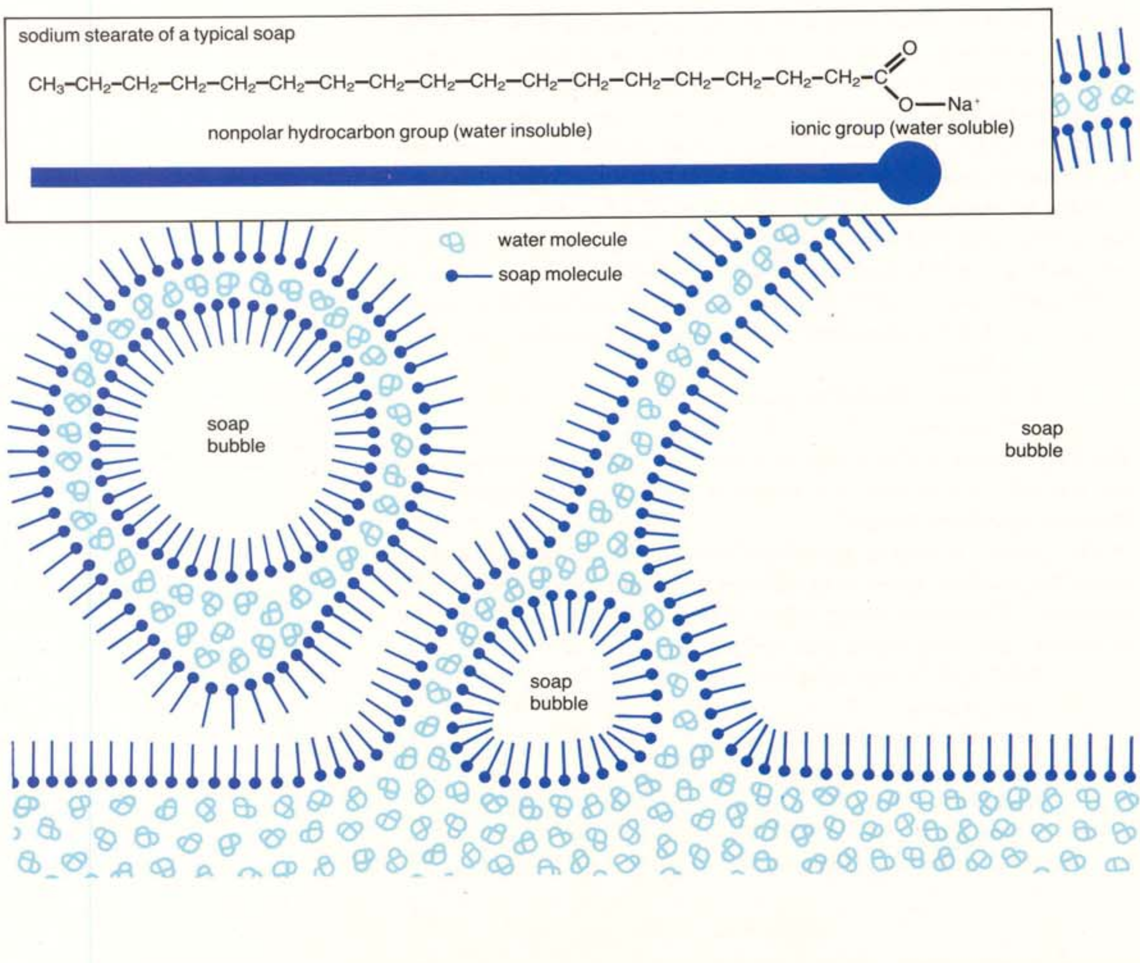


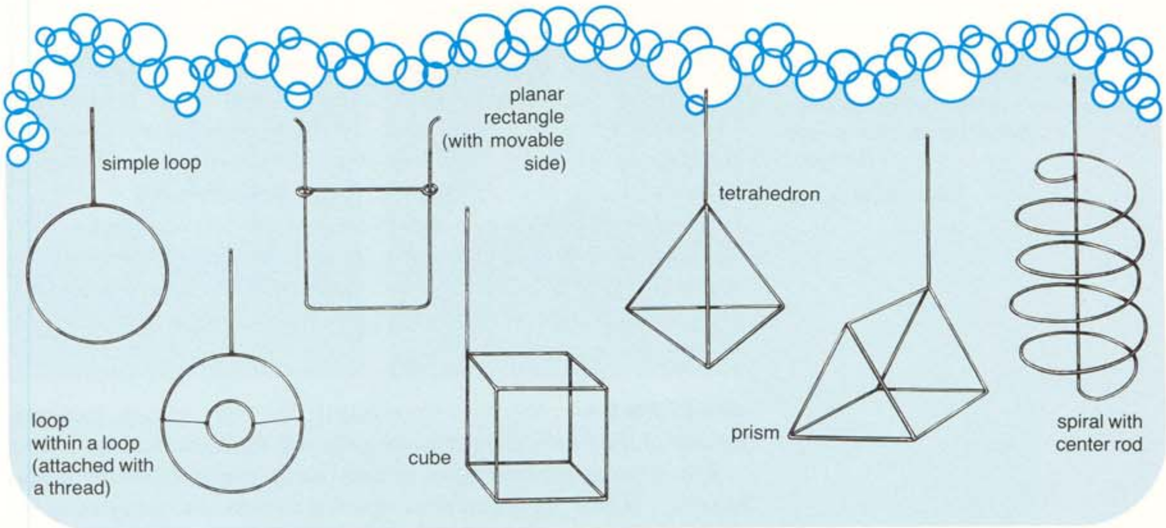
Distilled water is essential for the prevention of interference from dissolved metal ions, although detergents will not be affected as much as a soap such as Ivory®. (Metal ions in the water are responsible for producing the soap "scum" that forms a ring around the bathtub.). If the solution does not seem to work well, it should be allowed to sit for a few days to a week. Aging improves the characteristics of soap solutions. Super bubbles may even bounce on a clean, smooth floor. A note of caution: super bubbles break with a fair amount of force and so should be kept away from the face. Also, the solutions will make the floor slippery.

As well as blowing bubbles, one can examine the properties of soap films that form on the wire frames that have been dipped into the soap solutions. Simple frames can be made by bending pipe cleaners into various shapes. For more permanent frames heavy-gauge copper wire can be soldered together. Some shapes that can be used are a loop, cube, prism, tetrahedron, and spiral.

A soap or detergent molecule consists of a long, slender nonpolar hydrocarbon chain (a line of consecutively bonded carbon atoms that are bonded to surrounding hydrogen atoms) with a highly polar oxygen-rich group attached to one end. When such molecules are added to

Molecule of sodium stearate, a typical soap, comprises a long nonpolar chain of hydrocarbons with a highly polar oxygen-rich group attached at one end. Adding such molecules to water, a polar substance, causes them to migrate to the surface and orient themselves so that their nonpolar ends stick out. The diagram below shows the relationship between the soap and water molecules in a soap and water solution.



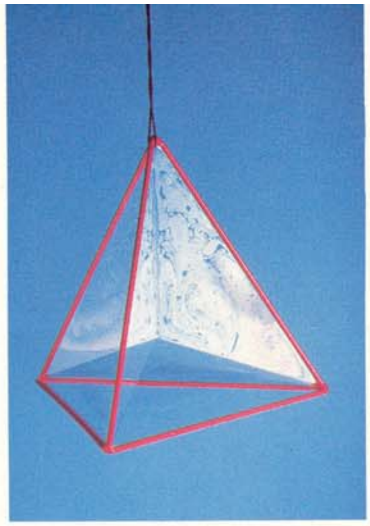


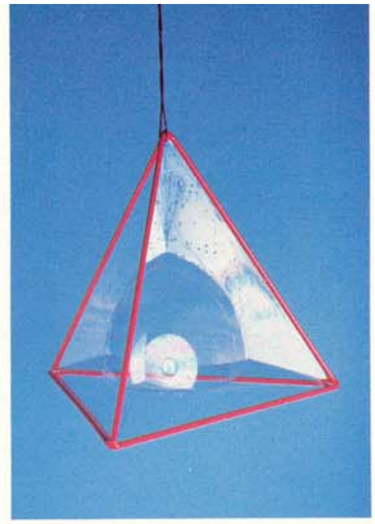
Wires are made into frames of different shapes for experimenting with soap films. Heavy-gauge copper wire is used to construct frames intended for long use. When the frames are dipped into a soap solution, films form between the wires.

water, a polar substance, they tend to migrate to the surface and orient themselves so that their nonpolar ends are sticking out. The surface of the water is, therefore, covered with a nonpolar layer that drastically reduces the surface tension (the beading-up effect of water on a smooth surface) and adds stabilizing elastic properties to the liquid along with an increase in surface area. When a wire (or plastic) frame is placed in the solution and then withdrawn, the water tends to drain from the inside of the raised surface, making the surface begin to collapse on itself and form a multilayered film. The soap limits the minimum thickness of the film to the length of two soap molecules stacked end to end. Films such as these are self-healing with respect to small punctures.

In the case of a bubble the water drains to the bottom of the bubble, producing a small bump there. One can observe water dripping from the bottom of a large bubble. When the top of the bubble becomes too thin to support the total mass of the bubble, it breaks. The addition of glycerin or other viscous material adds strength to a bubble because this material does not drain out of the soap film readily. The swirling colors observed in the bubble are a result of interference effects of light reflected at opposite sides of the soap film (thin film interference) and the changing thickness of the film due to the draining liquid.

If bubble frames are used, the soap film does not coat the frame but collapses on itself to produce a minimum surface area. This results in the formation of several soap film planes that usually meet at the center of the geometric solid described by the frame. Soap films can meet only at two angles, 120° and 109° 28′. The angle depends on whether there are three or four soap film planes meeting on a line. Other angles are distortions due to physical constraints imposed by the surroundings. For example, if a tetrahedral bubble frame containing the collapsed soap films is dipped halfway into the soap solution, a tetrahedral bubble will form in the center of the soap-film planes. Similar results can be obtained





Soap film on a tetrahedral bubble frame (right) collapses on itself to produce a minimum surface area. When such a frame is dipped halfway into a soap solution, a tetrahedral bubble forms in the center of the soap-film planes (far right).

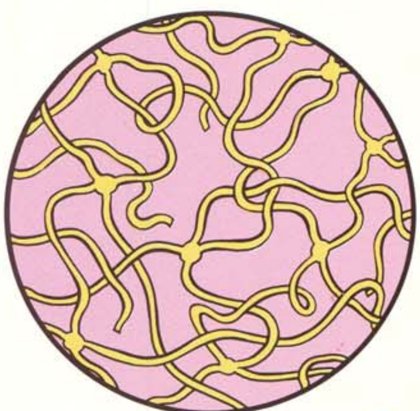
Photos, Charles Cegielski

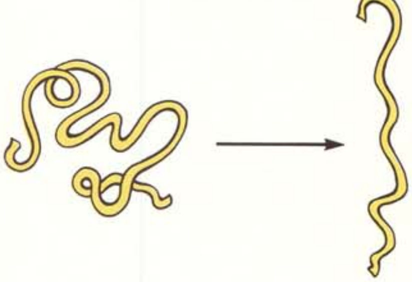
with a cubic frame, forming a cubic bubble. The shape of these bubbles is a result of the forces exerted by the collapsed films that surround them.

The elasticity of soap films is most easily demonstrated by simply blowing a bubble. To obtain more quantitative data one can measure the elasticity by using a bubble frame with a movable side. If the side is moved up and down, the soap film can be repeatedly stretched and compressed.

When using a large bubble loop, one can easily place a finger, a hand, or even an arm through the film without breaking it by first spreading the soap solution over the skin surface. With a big enough loop and enough soap solution, one could walk through a soap film and stand inside a large bubble.

Natural rubber consists of a network of flexible, cross-linked, polymeric chains (below). When stress is applied to rubber, such as when inflating a balloon, each chain undergoes chemical bond rotations that allow it to be extended or elongated (bottom).





Balloons

Among the most common items in toy stores are balloons. They are usually composed of rubber and come in a multitude of colors, shapes, and sizes. Natural rubber is a polymer of isoprene (2-methyl-1, 3-butadiene) in the form of polymeric chains that are joined in a network structure (cross-linked) and have a high degree of flexibility. Upon application of a stress to the balloon material, such as inflating it, the polymer chain, which is randomly oriented, undergoes bond rotations that allow it to be extended or elongated. The fact that the chains are joined in a network allows them to recover their original shapes since the cross-linked chains cannot irreversibly slide over one another. Also, the polymeric material that makes up the balloon is porous, as is evidenced by the deflation of the balloon over a period of time.

An interesting demonstration of some of the properties of the rubber material that composes the balloon is the needle-through-the-balloon trick. For this, one needs a large needle about 35–50 centimeters (14–20 inches) long and balloons of good quality. (Needles about 45 centimeters [18 inches] long are available from magicians' supply stores, as are good rubber latex balloons.) The balloon should be inflated to its maximum size and a small amount of air released from it to allow the molecules some recovery; the end should be tied in a knot. The needle then should be wiped with a cloth containing a small amount of oil, thereby allowing the needle to slide through the rubber more easily. At the end of the balloon, where the rubber is thicker and under less stress, the needle should be slowly pushed into the balloon with a twisting motion. If the needle does not slide easily, more lubrication is needed. If the needle is sufficiently sharp and smooth, it will not tear the rubber but will slide between the polymer chains; this allows the chains to stretch around the needle. The needle should then be pushed through the balloon until it comes through the other side near the knotted end. It can then be either withdrawn or pushed completely through the balloon, leaving two small holes where it passed through. (The rubber does not make a perfect seal in those spots.) After it has been shown that the balloon is intact, the balloon is tossed into the air and popped with the needle to hide the small holes from the audience. With latex balloons of good quality, the needle can also be passed through the balloon from side to side.