Lava Lite®
A Chemical Juggling Act

by Mike McClure

The tentacle of waxy goop stretched upward from the bottom of the glowing bottle. As the sinewy red mass ascended through clear fluid, a bizarre blob formed at the tip, broke loose, and floated upward. Then cooling and contracting, it spiraled downward in slow motion to be engulfed by the pulsating goo.

Some other-worldly life form emerging from the primordial ooze? Hardly! The glowing bottle, waxy material, and watery fluid are the basic components of every lava lamp.

In 1963, Craven Walker, an English engineer, invented a "display device", which consisted of a glass vessel containing water and mineral oil. When illuminated by a lightbulb in the lamp base, the oil would nearly jump off the bottom, rising and falling in weird patterns that were fascinating and relaxing to watch, especially if the liquids were brightly colored. Whether Walker's invention was a carefully planned experiment or a serendipitous discovery is not known. What we do know is that two American entrepreneurs bought the marketing rights for the lamp at a German trade fair soon after its invention. By 1965 Haggerty Enterprises of Chicago, a company specializing in novelty products, had begun production, and Walker's device had a new name—the Lava Lite Lamp.

Maybe you've seen lava lamps in novelty stores or specialty shops. But the original lamps from the

PHOTO BY MIKE CIESIELSKI

Big again. A fad in the 1960s, lava lamps are enjoying a resurgence of popularity in the 1990s. Three decades ago, the lamps were stylish enough to be used as a table centerpiece for a fancy dinner (opposite page).

late 1960s are nowadays commonly found only in flea markets and antique shops. Collectors who stumble upon a classic "Century" model, first introduced in 1965 and sold for $25, consider it a great find. The Century weighed 7 pounds and stood 17 inches high. A tapered glass bottle sat inverted on a golden metallic base punctured with tiny holes that sparkled like starlight in the dark. In one model, a saffron–yellow liquid filled the globe, and a blue blob of oil oozed up from the glass bottom like some alien life form.

PHOTO COURTESY OF LAVA WORLD INTERNATIONAL HAGGERTY ENTERPRISES, INC.

Haggerty Enterprises marketed the first lamps as home accessories, hoping to attract individuals who enjoyed watching late-night TV. Unlike the brightness of most lamps, Lava Lites glow feebly in the dark and give just enough light to read by. Company officials believed this TV night-light idea would appeal to traditional middle-age shoppers.

But the 1960s were anything but traditional. As expressed in a popular song, this was the "Dawning of the Age of Aquarius." And with this "Age" came new fads, attitudes, and looks. This was when the Beatles were hot, bell bottom pants stylish, and "Wow" was not only in, it was "Far out!" Maybe it was the lamp's unconventional shape. Maybe it was the wild combination of color, light, and motion. But whatever the reason, Lava Lites captured the freedom-loving mood of the times and became forever associated with the hippie counterculture of the 1960s.

Oil and Water Still Don't Mix

Craven Walker had created "a motion for every emotion" from simple laboratory chemicals. The exact recipe used in commercial lamps is a carefully guarded secret. Haggerty Enterprises will only admit that 13 mysterious chemicals are carefully blended to produce those goopy lava shapes. Although we may not know Haggerty's secret formula, we do know that the basic components are oil and water along with a slew of specially selected chemicals to improve safety, appearance, and performance. In fact, lava lamps would be boring if the only two ingredients were water and oil because both are clear and colorless. To brighten things up, engineers add light-absorbing dyes. Dyed lava gunk comes in almost every color of the spectrum. There is yellow gunk, red gunk, green gunk, and even neon pink gunk. The water, oil, dyes, and additives all work together to create the lamp's visual charm and special animated effects. The secret of how lava lamps work can be traced back to the molecular nature of oil and water.

Water is a vital ingredient in lava lamps. The clear liquid that the blobs swim through is mostly water. The molecular structure of water is directly related to its chemical and physical properties. Each tiny V-shaped water molecule is made of two hydrogen atoms covalently bonded to oxygen. Because oxygen has a greater attraction for electrons than hydrogen, the electrons between these two atoms are not shared equally. Imagine the electrons as a rope with oxygen and hydrogen pulling at each end. In this atomic tug-of-war, oxygen is most powerful, and its prize is a slight negative charge. Both hydrogens relax their grip on the electron rope and finish positively charged. These permanent electrical charges are responsible for water's unique polarity.

Walker knew water is a polar substance. And he knew the solubility rule that "like dissolves like." Many substances dissolve in water because they also have polar molecules. Ethyl alcohol, for example, has a polarized oxygen–hydrogen bond and, consequently, mixes freely with water. But to create those weird lava shapes, Walker needed something water could not dissolve. That substance turned out to be paraffin.

The paraffin used in Walker's lamp had waxlike properties but was not a true wax like carnauba or beeswax. Carnauba wax, which is from a plant, and beeswax, which is secreted by bees, are esters; their molecules contain some oxygen. Paraffin is a hydrocarbon; it contains only hydrogen and carbon atoms. You don't have to look far to find hydrocarbons. Mineral oil, kerosene, and Vaseline are just a few common hydrocarbons.

In nature, paraffins exist as mixtures. A typical hydrocarbon in this molecular soup may contain 20 to 30 carbons and more than twice that number of hydrogens. And unlike electron-greedy oxygen, carbon shares electrons equally with its hydrogen partners, making paraffins nonpolar. This means that water and paraffin have completely different properties. Like oil and vinegar, they don't mix or dissolve. This difference in polarity is what Walker used to turn his idea into a wacky invention.

Let There Be Lava

When a lava lamp is turned on, an ordinary 40-watt bulb illuminates and warms the contents of the glass globe. The solid paraffin melts, changing into a thick molasses-like liquid. As the temperature increases, the blob of paraffin expands, like a soap bubble. When the paraffin's volume goes up, its density decreases; and when the density of the paraffin falls just below the density of water, an interesting phenomenon happens. Struggling to float in the surrounding water, an expanding pillar of brightly colored gunk squishes upward. Usually a glob of paraffin breaks loose, wobbles into a sphere and rises like a hot air balloon to the top of the globe. As it rises, the paraffin releases some of its heat to the surrounding water and cools. When this happens, the lava shrinks and its density increases. Soon the blob becomes denser than water and sinks slowly back to the bottom where the cycle begins again.

Successful operation of any lava lamp depends on this relationship between the density of water and wax. The water and paraffin must begin with nearly the same densities so that, with just a little heating and cooling, the paraffin becomes less dense than water, then more dense. The density of water is 1.00 g/mL. Ordinary paraffin has a room temperature density of about 0.90 g/mL. Because its density is less than water, the paraffin will float at room temperature, even before it's heated. At first this seems contradictory to what we observe in the lamp. Something must be in the paraffin to make it heavier than water.

Haggerty Enterprises keeps that information top secret, but we know from Walker's original patent that chlorinated hydrocarbons were added to the paraffin. Because they contain heavier chlorine atoms, these organic compounds are much denser than water. Because these chlorine-rich substances are nonpolar, they dissolve easily in the paraffin but will not dissolve in the water. By adding just the right amount of chlorinated hydrocarbons to the paraffin, the density of the paraffin mixture can be made just slightly greater than the density of water when the paraffin mixture is at room temperature. When warmed, the density changes, and the paraffin rises.

Walker also dissolved some polyethylene glycol, a polar compound, in water. Polyethylene glycol has two effects. First, it increases the viscosity of the water so the paraffin blobs rise and fall more slowly. Second, when heated, polyethylene glycol expands more rapidly than pure water, so the delicate balance of densities is not disrupted when the lamp heats up. At operating temperature, the density of paraffin changes just slightly more than the density of water; and the paraffin blobs rise and fall, rise and fall in what seems like perpetual motion.

PHOTO BY MIKE CIESIELSKI

Lava Market Ups and Downs

Getting paraffin and water to perform this chemical juggling act was not the only challenge facing Haggerty Enterprises. Another problem was competition. Several copycat companies tried to recreate the secret formula and construct their own version of the lava lamp. One Japanese imitator marketed a lamp shaped like a flying saucer that is now a collectors' item. And a company

Analysis by Accident

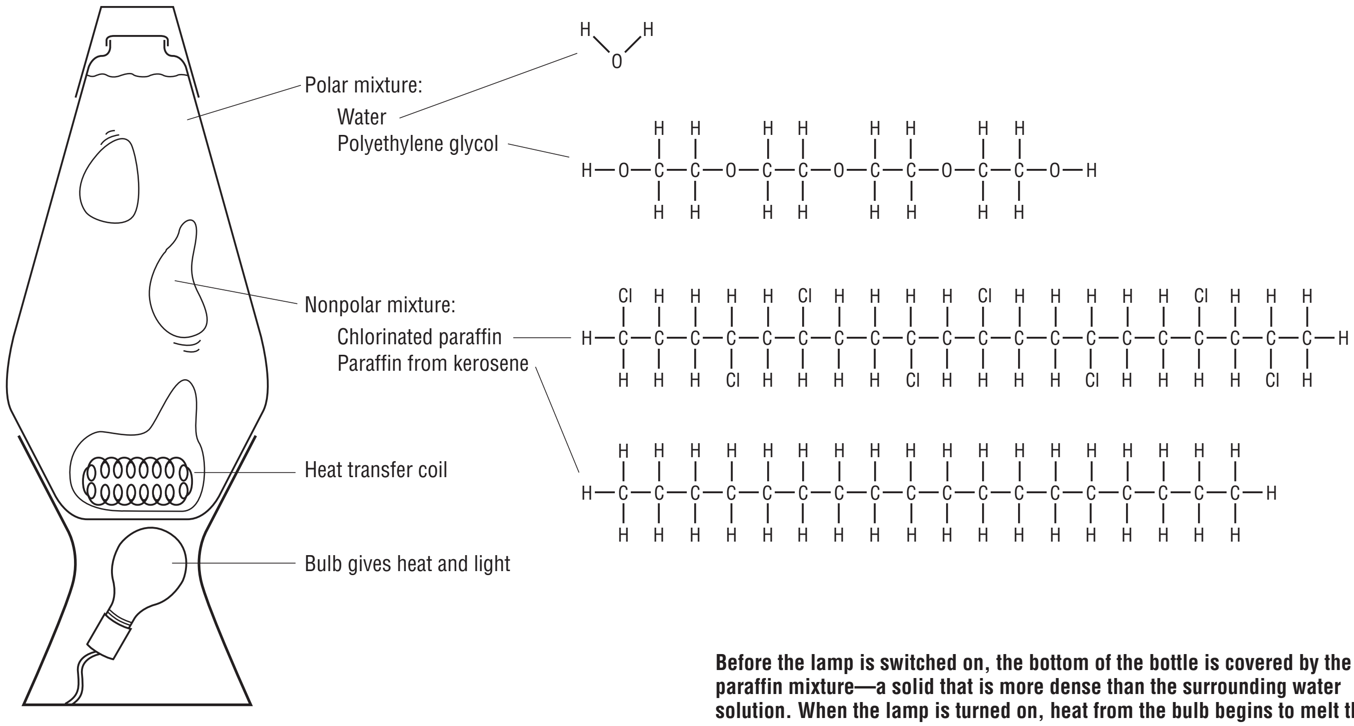
In 1993, the wall of secrecy surrounding the chemical ingredients of the lava lamp was accidentally breached by a Chicago alcoholic. The 65-year-old man was taken to the emergency room at University of Illinois Hospital because he was unresponsive and lethargic. He had rapid pulse and respiration. Blood tests showed starvation, dehydration, excess positive ions, malfunctioning kidneys, and a blood pH of 7.32 (normal is 7.40). Although he was given intravenous fluids, his condition declined and, three days later, doctors began dialysis to clear his blood of some of the chemicals that his kidneys could not handle.

At this time his family reported that, in an apparent search for alcohol, he had opened a cool lava lamp and drunk most of the liquid in the lamp and some of the solid. His doctors needed to know—immediately—the chemical composition of the lava lamp. The lamp was sent to Hinez Veteran's Administration Hospital where chemist Ralston Reid promptly analyzed the remaining material by gas chromatography–mass spectrophotometry. The lava lamp was found to contain water, 38% by mass; chlorinated paraffin, 36%; low molecular weight polyethylene glycol, 13%; kerosene 7%; and microcrystalline wax, 6%. A similar analysis of the man's blood, saved from the day he was admitted to the hospital, showed some of the same materials.

Finally, the doctors knew how to treat the man, and he made a gradual recovery, which was complicated by alcohol withdrawal. After three months of hospitalization, the man was sent home, although his kidneys did not fully recover. Toxicologist Timothy Erickson and the other physicians who treated this man believe that the most prominent toxic effect was the kidney damage caused by the *low* molecular weight (200 daltons) polyethylene glycol. This chemical can damage the kidneys even though *high* molecular weight polyethylene glycol (3,500 daltons) is safe and is used therapeutically to flush certain toxins from the intestines.

After this incident, the manufacturer changed the design of the lamp so it contains less-toxic ingredients, and the bottle is harder to open.

—D. Robson



Before the lamp is switched on, the bottom of the bottle is covered by the paraffin mixture—a solid that is more dense than the surrounding water solution. When the lamp is turned on, heat from the bulb begins to melt the paraffin. The melting process is slow because paraffin is a poor conductor of heat. The process is speeded up somewhat by the heat transfer coil, a coil of wire that transfers heat from the lightbulb into the paraffin. When paraffin melts, its volume increases about 3%. When this expansion changes the density of the specially formulated paraffin mixture from slightly greater than water to slightly less than water, the paraffin begins to float. A pillar of warm paraffin detaches from the main blob and floats upward. The blob rises slowly because the paraffin mixture is thick and because polyethylene glycol has been added to the water to increase its viscosity. At the top of the bottle the surrounding water is not as hot, so the blob cools, increases density, and sinks. When the blob reaches the bottom, the wire coil helps break its surface tension, so it merges with the paraffin at the bottom. The tapered shape of the bottle guarantees that the water at the narrow top has greater surface area and thus cools faster than the water in the wide bottom.

started by Walker, called Crestworth Trading of London, continued marketing lamps in Europe under the brand name Astro Lamp. Fortunately for Haggerty Enterprises, most of these companies were unsuccessful in creating lava lamps that equaled theirs in quality or performance.

A more serious threat to the business of selling lava lamps came at the end of the 1970s. Hippies and flower children were reluctantly approaching middle age, and the whole hippie culture was fading into history. Attitudes and styles changed. Lamps once proudly displayed in college dorms and hippie communes were relegated to attics, garages, and trash bins. When lava lamp sales dipped to an all time low in 1983, company officials decided to take action.

The classic Century was given a facelift, and new models sporting sleeker, high-tech shapes were brought to market. In addition to the redesigned Century, there are now the Aristocrat, Enchantress, Midnight, Silver Streak, Princess, and Elek-Trick with eight shades of lava. In the early 1990s, these changes met a wave of 1960s nostalgia that brought renewed popularity to the globes of glowing goo.

In 1995 Haggerty Enterprises hosted a party celebrating the 30th anniversary of its star product. Aging hippies mingled in the mellow glow of hundreds of lava lamps. Some danced. Some traded lava lamp stories. Others gathered to admire a specially constructed 3-foot-tall lamp that oozed ruby red blobs the size of footballs. One guest gazing mesmerized into this giant lava lamp, expressed her feelings in one word...Wow!

Note: The current issue of *the Chem Matters Classroom Guide* contains a simplified recipe for making a demonstration lava lamp from laboratory chemicals.

Mike McClure worked for several years as a chemist at a veterinary diagnostic laboratory, investigating unusual animal deaths. He now teaches chemistry at Hopkinsville Community College in Kentucky and is a regular contributor to Chem Matters *magazine. The editors appreciate the author's careful and painstaking laboratory work to uncover the secrets of lava lamps!*

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