XVII. The Methane Mamba

Methane gas is bubbled up through a funnel of soapy water and a buoyant column of suds grows gracefully upward like a large bubbly snake swaying elegantly to the air currents in the room. Igniting this methane mamba provides for a rather charming effect!

Chemical Concepts:

1. Whether an object floats or sinks in a fluid depends on whether that object's density is less than or greater than the density of the fluid. This holds true for objects submerged in liquids as well as gases.
2. For gases under similar conditions, densities are essentially proportional to molecular weights.
3. Hydrocarbons are generally combustible — that is, they react exothermically with oxygen. The products are usually CO_2 and H_2O.

Materials:

source of natural gas

funnel (made from the top half of a 2-L plastic soda bottle)

#3 1-hole rubber stopper

glass tubing (6 mm diam) to fit stopper, 9 cm long

rubber hose to fit gas jet nozzle, approx. 1 m long

ring stand and large iron ring support (5 in. diam)

test tube clamp

candle taped securely to the end of a meter stick

Construction:

1. Carefully, and with adequate lubrication, slide the rubber stopper over the glass tube to about the midsection. Then insert the stopper securely into the mouth of the funnel.
2. Connect the protruding end of the glass tubing to the rubber hose. If the fit is too loose, wrap the end of the tube with some electrician's tape to make the hose fit more snugly.
3. Use the ring stand, clamp and large ring support to secure the funnel in a vertical position, stoppered end down. Run the hose up over the neck of the ring support (to avoid leakback) and then connect it to the gas jet.

Procedure:

1. Pour 300 mL of soap solution (3% Dawn® by volume) into the funnel. The top of the glass tubing should be submerged by about 1.5 cm. (See Figure 1 on the following page)

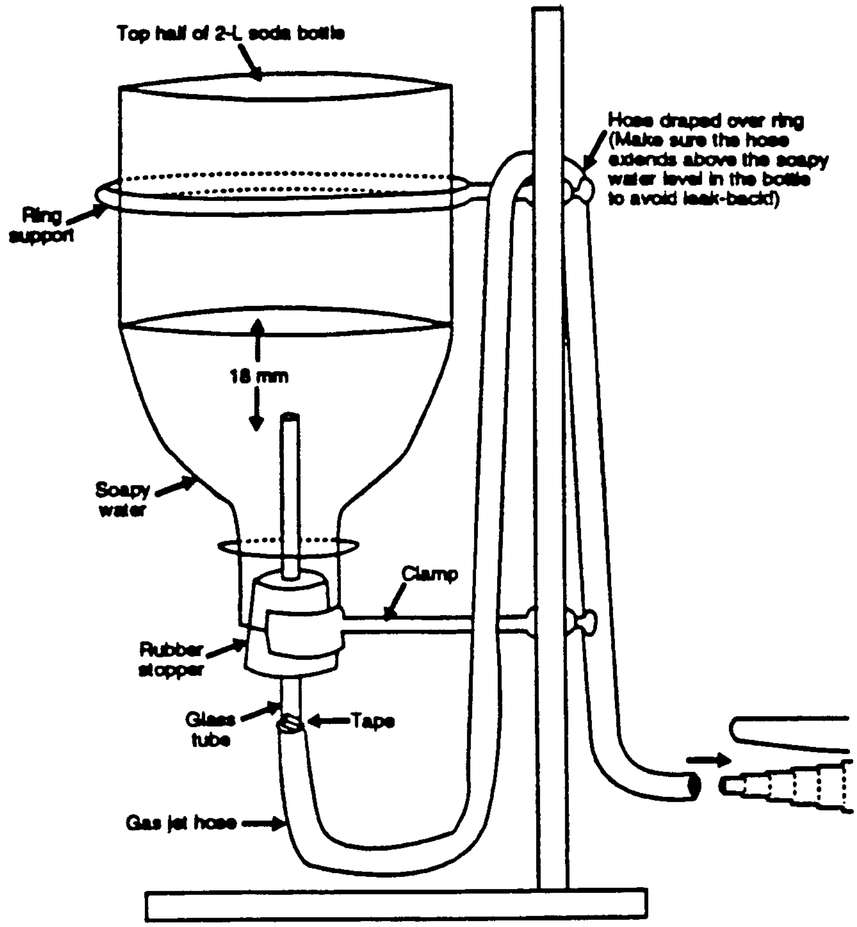

Figure 1—Set-up for creating a "Methane Mamba"

2. Begin the snake charming music (if available!). Then, with no open flames nearby, simply turn on the gas jet full throttle. A column of methane bubbles will begin to grow lazily upward, attaining a height of 2-3 meters in about 5 minutes.

Discussion:

Methane is about half as dense as air. You can approximate this by comparing their relative molecular weights: CH_4 (mw = 16) compared to air, a mixture of N_2 (mw = 28) and O_2 (mw = 32). Because of its lower density, pure methane rises rather rapidly in air. The soapy water adds significantly to the density, but with just the right proportions, as described below, you can achieve a soapy water/methane mixture that is just slightly less dense than the surrounding air, and that ascends very slowly. The adhesive nature of the soapy water, due mostly to the H-bonding that occurs between the water molecules, helps to hold adjacent bubbles (suds) together in a snake-like cluster.

Tips:

1. If there are too many large bubbles, the column will be too buoyant and will tend to pinch off before reaching its full height. If there are too many small bubbles (suds), the column will be too dense and will simply spill over the rim of the funnel. The best results are obtained from a combination of large and small bubbles, producing a column that is just barely less dense than air—enough to support its own weight but not cause a substantial upward tug. This might require some "fine tuning"—adjusting the flow rate of the methane, the position of the glass tubing and the depth of the soapy water in the funnel. Humidity may also play a role, for the top of the column does tend to dry out.

2. An interesting effect can be achieved by placing a few drops of water on the top of the growing column. Since the water increases the density, it causes the top to arch over—accentuating

the snake-like appearance even more! But as the head of the snake drops down, water falls from its snout, the density decreases and the snake rears its head back up! Adding another drop or two repeats this cycle.

3. A similar arching effect occurs naturally if the column is allowed to grow for a long enough period of time, for as the methane diffuses out of the top bubbles and as air diffuses in, the upper section increases its density and eventually bends over on its own.

4. At any point, the column of bubbles may be gently scooped up off the funnel and carefully walked around the room. (Wetting the hands first avoids popping too many bubbles.) Large sweeping motions make for a very graceful display! And with a quick jerk of the hand, the bubble column can be turned loose, free to snake its way up to the ceiling. If the density is close enough to that of air, however, the column will ascend very slowly, allowing the opportunity to inject into it a drop or two of water. This causes the column to hover in mid-air, perhaps even descend downwards a little bit, but as the excess water then drips off, the column will start to float up again. With a little practice, it is possible to keep a column suspended this way for quite some time.

5. Perhaps most impressively, these bubble columns may be ignited. The safest manner for presenting this is to turn the gas jet off, scoop the column off the funnel, set it down on the lab bench at least two meters away, and ignite it with a lit candle attached to the end of a meter stick. The columns may be lit from the bottom (this produces the fastest burning and therefore the largest flame), from the top (this shows an interesting downward progression of the fire) or from somewhere in between.

   Safety Precaution: Safety goggles should be worn at all times, and a fire extinguisher should be on hand. Remove all combustible material from the vicinity of the demonstration. Note: A 10 cm high column may produce a flame well over a meter tall. Let the height of your ceiling and the flame retardant capability of the ceiling tiles dictate how large a cluster can be safely ignited.

6. The diffusion of the methane across the soap film can be demonstrated by holding the flame a few centimeters above the bubble column. After a few seconds the top of the column ignites, even though the flame never touches the column! Furthermore, a small cluster of bubbles may be flattened out on the lab bench and left there for about two minutes. When a flame is then held directly to the bubbles, nothing happens—they pop, of course, but they do not ignite—even though the cluster appears just as it did when the bubbles were blown. This indicates not only that the methane has diffused out of the bubbles, but also that air must have diffused in.

   Furthermore, if the column is allowed to grow for a long enough period of time to form a full arch, as described above, and then this arch is ignited at the near (most recently blown) end, the flame will race up the near side and then down the other but will invariably stop 10-20 cm before reaching the tip—leaving a small cluster of unignited suds dangling momentarily in the air. And if a flame is held to this slowly descending cluster, again, the bubbles will pop, but no combustion occurs.

7. Variation: Hydrogen gas may also be used, either from a tank or from a Zn/HCl reaction, and the effect, at least initially, is very much the same. Hydrogen, however, has a substantially lower density than methane. The hydrogen bubble columns therefore have a tendency to pinch off after reaching a height of only 70-80 cm. On the other hand, ignition of these hydrogen bubble columns is perhaps more impressive (certainly more noisy) than the methane bubble columns.

Acknowledgments:

The idea for this demonstration came to me while viewing a tape of the Flinn Scientific "Evening of Chemistry" (from the Boston NSTA Convention, 1992). In the performance, DeWayne Lieneman demonstrated the infamous "Elephant Toothpaste" in which a snake-like stream of suds leaps up out of a large test tube and covers the table below (50 mL 30% H_2O_2, some dish detergent and some KI solution to catalyze the peroxide decomposition). A few demos later, Penney Sconzo and Larry Flinn showed the tricky art of blowing hydrogen bubbles and lighting them as they ascended. The merging of these two ideas came to me the following day during study hall duty!!!

Related Reading:

Boys, C. V. "Soap Bubbles and the Forces Which Mould Them"; Educational Services Incorporated. A Doubleday Anchor Book: New York, 1959.

Alyea, H. "Tested Demonstrations in Chemistry, 6th ed." Journal of Chemical Education: Easton, Pennsylvania, 1965.

Shakhashiri, B. Z. "Chemical Demonstrations, Vol. 1"; p. 106-110; University of Wisconsin Press: Madison, Wisconsin, 1983.