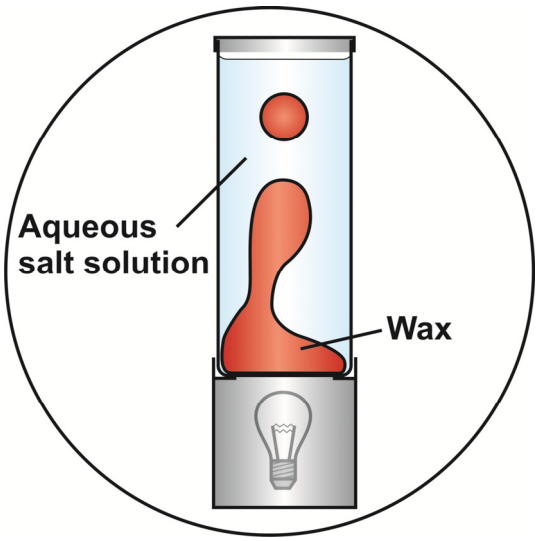
Lava Lamp



Equipment:

Lava lamp (lamp consisting of a glass vessel filled with a wax-water mixture and a base with an incandescent light bulb)

Safety:

During operation, the lamp becomes very hot. Therefore, it should not be touched during operation and for up to one hour after switching off. If the glass vessel is cracked or shows other damages, or if the power cord or plug is damaged, do not use the lamp.

Procedure:

The lamp is placed on a clean, flat surface and turned on 1 to 2 hours before the demonstration. The lamp warms up and the wax melts.

Observation:

Blobs of warm wax ascend slowly from the bottom to the top of the glass vessel where they cool and then descend to the bottom again. The result is a continuous movement of the two phases.

Explanation:

The lava lamp shows in an esthetic way that heterogeneous systems are composed of several phases—here two—at whose interfaces the physicochemical properties change abruptly. The basic principle of operation is quite simple to understand: Two immiscible phases with very similar densities are used. The slightly heavier waxy phase is heated by the incandescent light bulb. As a result, it becomes fluid and less dense than the aqueous phase, because the waxy phase expands more than the aqueous water when both are heated. Because the liquids have very similar densities, as mentioned, the previously heavier phase is now suddenly lighter than the other and blobs of the waxy phase begin to ascend. As the waxy phase ascends, it cools down which increases its density relative to that of the water and therefore it sinks back to the bottom.
In reality, there is a very complex equilibrium, which is determined by the temperature, the heating rate, the viscosity and the thermal expansion coefficients of the liquids, their surface tension and even their color. The waxy phase consists, for example, of a mixture of short-chained chlorinated paraffins (such as carbon tetrachloride), alkylated benzene and paraffin wax, but mineral oil, benzyl alcohol etc. can also be used as components. The density of the second, aqueous phase must be adjusted to that of the “lava liquid” in such a way that it is slightly lower. For this purpose, the distilled water is mixed with common salt (increasing the density of 1 kg m^{-3}) or isopropanol (decreasing the density).

Supplement:

The lava lamp can be easily simulated with the following experiment:

Equipment: empty clear plastic soda bottle, funnel, optional: light source (such as a flashlight)

"Chemicals": vegetable oil, water, food coloring, effervescent tablet (such as Alka Seltzer)

Procedure: The bottle is filled to about one fifth with water. A few drops of food coloring are added in order to color the water. The vegetable oil is slowly poured into the bottle with the help of the funnel until the bottle is nearly full. One may have to wait a few minutes for the two phases to separate. Subsequently, a tablet is broken into smaller pieces and one or two of the pieces are dropped at a time into the bottle.

Observation: The tablet pieces sink to the bottom and begin to dissolve as soon as it reaches the aqueous phase. Colored bubbles then erupt from this phase and ascend in the oil until they reach its surface. Then they descend again. When the bubbling slows down, one can add more tablet pieces … and the game starts again. In order to have a true lava lamp effect, one can shine for example a flashlight through the bottom of the bottle.

Explanation: Oil and water do not mix; because the oil is less dense than the aqueous phase, it floats on top of this phase.
An effervescent tablet contains a carbon dioxide releasing component such as sodium bicarbonate ($NaHCO_3$) and a solid acid such as citric acid ($C_6H_8O_7$). When the tablet is mixed with water, the two components react with each other and produce carbon dioxide bubbles:

$$3\ NaHCO_3|w + C_6H_8O_7|w \rightarrow Na_3C_6H_5O_7|w + 3\ H_2O|l + 3\ CO_2|g\ .$$

As these bubbles rise through the oil, they take droplets of colored water with them. At the surface, the bubbles pop and the gas escapes into the air while the water droplets sink back to the bottom again.