DEMONSTRATION 1
Notes for the Instructor

PURPOSE

To illustrate and discuss some of the unique properties of ferrofluids prior to the student investigations that follow.

METHOD

A bottle cell will be used to demonstrate the behavior of a ferrofluid under the influence of a strong magnet. During the discussion that follows, students should be asked to explain the observations that were made.

Although a detailed discussion of the crystal structure of magnetite is not necessary, the fact that it is generally composed of particles of magnetite (Fe_3O_4) that are ferrimagnetic and nanoscale in size (approximately 100 angstroms or 10nm) should be mentioned. Further topics for discussion might include colloidal suspensions, surfactants, and magnetic domains.

MATERIALS

Bottle cell (Available commercially from Educational Innovations)

Strong magnet

Crystallizing dish large enough to hold the cell

Overhead projector

PROCEDURE

1. Drag the magnet up the side of the bottle cell. The ferrofluid will be attracted to the magnet, demonstrating the magnetic properties of the fluid.

2. Tape the cell to the bottom of a crystallizing dish, add water until the cell is entirely submerged, and place the assembly on an overhead projector.

3. With the overhead projector on, hold the magnet beneath the surface of the water in the dish and move it up to the side of the cell. The fluid will be attracted to the magnet and the “spiking phenomena” will be observed in profile.

FOLLOW-UP QUESTIONS

Either during or after the demonstration the following questions can be addressed.

1. The bottle cell consists of a dark brown fluid suspended in an aqueous medium. What are some of the properties of the darker fluid?

Answers will include: (1) it is a liquid (fluid);(2) it is denser than water; (3) it is not miscible with water; and (4) it is attracted to a magnet.

2. What are some other examples of substances that are affected by a magnet?

The most common response will surely include iron-containing substances, which will allow for the introduction of the terms *ferromagnetic* and, ultimately, *ferrofluid.*

3. The magnetic properties of the fluid are caused by a compound called magnetite, having the formula Fe_3O_4. At room temperature magnetite is a solid. How do we then explain the fluid nature of the dark brown substance?

Lead the students to understand that the magnetite must be dispersed as very small particles within a medium that is not miscible with water. In other words, it is a colloidal suspension of magnetic nanoparticles, whose sizes are in the neighborhood of 100 Angstroms, in a hydrocarbon or mineral oil medium.

4. If these particles are magnetic, why don't they agglomerate (stick together)?

There must be something that acts as a dispersing agent (surfactant). This agent must adhere to the particles, surround them completely, and create a net repulsion between them.

5. Once the magnet has been used to cause the spiking behavior of the fluid, why don't the spikes stay together? Why, in other words, does the fluid "relax" once the magnet has been removed?

Depending upon the students' knowledge of electron configurations, unpaired electrons and parallel spins, the discussion could involve those topics, or could be more simply addressed by noting that each of the particles of magnetite behaves as a tiny magnetic domain. In the presence of the magnet, the particles attempt to orient themselves in the magnetic field, but their mobility is limited by the fluid. This causes the spikes to form. In the absence of a magnetic field, and as a result of thermal agitation, the particles quickly return to a random orientation relative to one another and the spikes disappear.