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Synthesize a Nanoscale Ferrofluid

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The Interdisciplinary Education Group at the University of Wisconsin Madison has provided the following website with a description of the ferrofluid that you can synthesize in a laboratory.

http://mrsec.wisc.edu/Edetc/nanolab/ffexp/index.html

The website also includes a series of movies that illustrate each step of the chemical synthesis. The website also includes many background resources and the following description of a ferrofluid. "Ferrofluids are colloidal suspensions of magnetic nanoparticles. Ferrofluids respond to an external magnetic field enabling the solution's location to be controlled through the application of a magnetic field. Fe_3O_4 magnetite nanoparticles can be produced by mixing Fe (II) and Fe (III) salts together in a basic solution. The particles must remain small and separated from one another in order to remain suspended in the liquid medium. Surfactants are used to prevent the nanoparticles from approaching one another too closely. Once prepared, ferrofluids have the captivating property of exhibiting "spikes" when placed in the proximity of a strong magnet."

Additional Background Information:

The chemical synthesis of a ferrofluid is a nanoscale science activity that originally appears in the Journal of Chemical Education. Access to the following website requires a subscription to the journal. *J. Chem. Educ.*, **76**, 943-948 (1999). The article was authored by Jonathan Breitzer and George Lisensky.

Important Safety Messages: There are a number of precautions that you should take as you take as you prepare to synthesize a ferrofluid.

- Ferrofluids can be messy. The particular ferrofluid you will prepare will permanently stain almost any fabric.
- Wear lab aprons and goggles during the synthesis process.
- Wear chemical gloves when working with chemicals.
- Work in an adequately ventilated laboratory,

The Ferrofluid Synthesis Procedure:

The following procedure is describes at the Interdisciplinary Education Group's website.

- Add 4.0 mL of 1M $FeCl_3$ and 1.0 mL of 2M $FeCl_2$ solution to a 100 mL beaker. Add a magnetic stirring bar and begin stirring.
- Continue stirring throughout the **slow** addition of 50 mL of 1.0 M aqueous NH_3 solution over a period of 5 minutes. After an initial brown precipitate forms, a black precipitate will form (magnetite). One way to accomplish a slow addition is to drip the ammonia solution from a buret or separatory funnel or by using a dropper to transfer the solution. CAUTION: Although 1 M NH_3 is fairly dilute, NH_3 is a strong base.
- Turn off the stirrer and immediately use a strong magnet to work the stir bar up the walls of the beaker. Remove the stir bar with tongs or a gloved hand before it touches the magnet.
- Let the magnetite settle, then decant (pour off) and discard the clear liquid without losing a substantial amount of solid. You can speed the settling process by putting a magnet under the container.
- Transfer the solid to a weighing boat with the aid of a few squirts from a wash bottle.
- Use a strong magnet to attract the ferrofluid to the bottom of the weighing boat. Pour off and discard as much clear liquid from the weighing boat as possible. Rinse again with water from a wash bottle and discard the rinse as before. Repeat the rinsing a third time.
- Add 1-2 mL of 25% tetramethylammonium hydroxide. Gently stir with a glass rod for at least a minute to suspend the solid in the liquid. Use a strong magnet to attract the ferrofluid to the bottom of the weighing boat. Pour off and discard the dark liquid. Move the strong magnet around and again pour off any liquid. If the ferrofluid does not spike, continue to move the strong magnet around, pouring off any liquid.
- What happens when you move a magnet under the ferrofluid?