Name____

Dancing Magnets (Ferrofluids) Lab

Pre-Lab Assignment

- This pre-lab assignment is worth 5 points.
- This part of the pre-lab assignment is due *at the beginning* of the lab period, and must be done individually *before you come to lab!*

I. Background Preparation

- **Read this experiment thoughtfully**

Mentally note any procedural questions and plan how you and your partner will complete all experiments efficiently during the three-hour lab period.

II. Safety Hazards/Precautions

1. Complete the following table. Refer to the Safety Data Sheets (SDS) provided by your instructor. You can also search for a SDS by typing in the chemical name into the search box on the Sigma-Aldrich website: http://www.sigmaaldrich.com/united-states.html. After selecting the correct material, click on the SDS link to view.

Materials	GHS Pictograms (Circle all that apply)	Hazard Statements (Check and list all that apply)
ammonia		☐ Corrosive ☐ Toxic ___________________ ☐ Flammable ☐ Reactive _________________ ☐ Irritant ☐ Other? __________________
ammonium hydroxide		☐ Corrosive ☐ Toxic ___________________ ☐ Flammable ☐ Reactive _________________ ☐ Irritant ☐ Other? __________________

Iron(III) chloride hexahydrate		☐ Corrosive ☐ Toxic ___________________ ☐ Flammable ☐ Reactive _________________ ☐ Irritant ☐ Other? __________________
Iron(II) chloride tetrahydrate		☐ Corrosive ☐ Toxic ___________________ ☐ Flammable ☐ Reactive _________________ ☐ Irritant ☐ Other? __________________
Tetramethyl-ammonium hydroxide		☐ Corrosive ☐ Toxic ___________________ ☐ Flammable ☐ Reactive _________________ ☐ Irritant ☐ Other? __________________
Waste Disposal	Identify (briefly) how you will dispose of waste materials from this experiment.	

2. **Workplace/Personal Cleanup Notes** (indicate what you will do to clean up yourself and your lab space before you leave the lab):

Additional Safety Cautions

This procedure uses flammable substances and generates toxic fumes. Wear safety goggles, gloves and lab apron, because this fluid can stain skin and permanently stain clothing. Also work in a well ventilated area – some steps in this procedure must be conducted in a laboratory with a purge fan. See attached Safety Data Sheets.

III. Pre-Lab Questions

1. What is a colloid?

2. Describe how you might use a ferrofluid to measure a magnetic field

3. Why is it important to have nanoscale particles in a ferrofluid?

4. Describe one use of a ferrofluid in a consumer product.

Learning Objective

Investigate the properties of a material that acts differently when it is nanometer sized to create a model to explain the forces between objects.

Introduction

A liquid magnet or **ferrofluid** is a **colloid** mixture of **nanosized** magnetic particles suspended in a liquid, mixed with a **surfactant** to prevent the particles from sticking together. When no magnetic field is present, the fluid nature of the iron (magnetic) particles is random, but when an external magnetic field is applied, the particles align with the magnetic field lines, therefore one can actually measure the distance and strength of magnetic forces using a sample ferrofluid as an indicator.

A ferrofluid is a liquid consisting of nanoscale ferromagnetic particles dispersed evenly throughout a carrier fluid. Ferrofluids are strongly magnetized in the presence of a magnetic field. Here, Fe_3O_4 magnetite nanoparticles are produced by mixing Fe(II) and Fe(III) salts together in a basic solution. Ferrofluids are used in speakers, laser heads of CD & DVD players and in the inks used in paper currency.

Materials

- {1 mL} of 2.0M Ferrous Chloride Solution ($FeCl_2 \cdot 3H_2O$)
- {4 mL} of 1.0M Ferric Chloride Solution ($FeCl_3 \cdot 6H_2O$)
- {50 mL} 1.0M Ammonium Hydroxide (NH_4OH). *This is a caustic chemical so exercise caution!*
- {1-2 mL} 25% 1M FeCl3 in Tetramethylammonium Hydroxide Solution ($C_4H_{12}N \cdot OH$). *This a caustic chemical so exercise caution!*
- {2} 150 mL glass beakers
- {1} metal spatula
- Glass dropper
- {3} Plastic Pipettes
- {1} Glass Stir Rod
- Wash Bottle with Deionized H_2O
- Paper Towels
- Plastic Weighing Boat
- Rare Earth Magnets (a set consisting of one pair)

Experimental Procedure

(i) Synthesis of Ferrofluid

1. Transfer 4.0mL of 1.0 M Ferric Chloride solution ($FeCl_3$) to a 150 mL beaker.
2. Add 1 mL of 2.0 M Ferrous Chloride solution ($FeCl_2$) to the same beaker.
3. Stir solution with a glass stirring rod until the solution is homogenous and a red brick color.
4. Continue stirring throughout the drop-wise application of 50 mL of 1.0 M NH_3 solution over a period of about 5-10 minutes, adding approximately 1 mL every 10 seconds. Avoid addition that is faster than the solution can be mixed, but also avoiding addition that is so slow that the particles grow large. CAUTION Although 1 M NH_3 is fairly dilute, NH_3 is a strong base with corrosive properties.
5. Let the magnetite settle. You can speed the settling process by putting a magnet under the glass beaker.
6. Decant and discard the clear liquid without losing a substantial amount of the solid. Use both of your beakers and glass stir rod. This works best if you have your partner keep a magnet under the container while you decant.
7. Transfer the solid to a weighting boat with the aid of a few squirts from a wash bottle.
8. Use a strong magnet to attract the ferrofluid to the bottom of the weighing boat.
9. Pour off and discard as much clear liquid as possible, again keeping the magnet under the weight boat.
10. Rise with water from a wash bottle and decant the rinse as before at least two more times.
11. Remove the magnet. Add 1-2 mL of 25% Tetramethylammonium Hydroxide Solution. Again, use caution as this is a caustic and toxic chemical.
12. Gently stir with a glass stirring 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 weighting 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.

(ii) Investigation of Ferrofluid Properties

Using your dropper and a metal spatula, transfer 10 mL **ferrofluid** into a falcon tube. Fill it to the brim with kerosene and screw on the lid tightly. **You have now created a "display cell".**

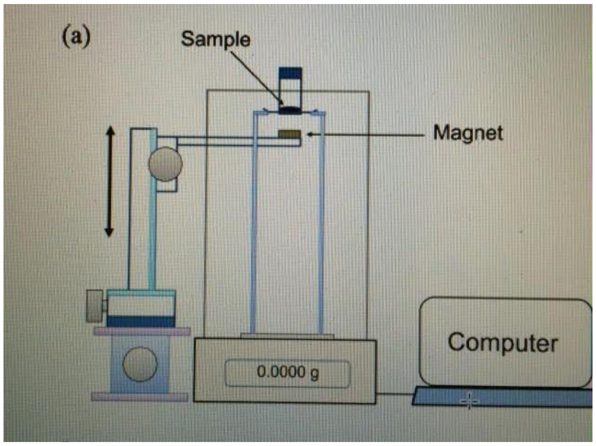
Use a magnet at various distances i.e. start farther away and move the magnet progressively closer to the fluid. Record your observations on the data table in the report sheet.

Optional Extension

The behavior of the ferrofluid in response to an applied magnetic field can be controlled by controlling the size of the magnetite nanoparticles in the ferrofluid (Dhumal et al.). This group also mentions that the size of the nanoparticles can be adjusted by changing the pH at which the magnetite synthesis takes place. The average size regime of individual ferrofluid nanoparticles dictates the manner in which the bulk ferrofluid responds to application of an external magnetic field.

Further studies can be performed to investigate how changes in; pH, OH^- concentration, ammonia delivered effects the magnetic susceptibility of prepared ferrofluid sample. Magnetic susceptibility can be "measured" by construction of a Gouy- balance-type apparatus illustrated in **Figure 1** and explained at length in the paper (Jin et al.). By normalizing the change in mass before and after with respect to sample mass, you can semi-quantitatively represent the relative magnitude of the change in magnetic susceptibility due to changes in the manipulated variable of choice.

Figure 1. (from Lin et al.)



References

Blaney, Lee. (2007) Magnetite (Fe_3O_4): Properties, Synthesis, and Applications. *Lehigh Preserve.* Vol.15. http://preserve.lehigh.edu/cas-lehighreview-vol-15

Dhumal, Jyoti; Bandgar,Sushilkumar,; Zipare , Kisan. Et, al (2015). Fe_3O_4 Ferriofluid Nanoparticles: Synthesis and Rheological Behavior. *International Journal of Materials Chemistry and Physics.* Vol. 1, No.2, 2015, pp.141-145. http://www.aiscience.org/journal.ijmcp

Jin, Daeseong and Kim, Hackjin (2013) Magnetization of Magnetitie Ferrofluid Studied by Using a Magnetic Balance. *Bull. Korean Chem. Soc.* Vol. 34, No. 6, pp. 1715-1721.

Massart, Rene'. (1981) Preparation of Aqueous Magnetic Liquids in Alkaline and Acidic Media. *IEEE Transactions on Magnetics*, Vol. Mag-17, No. 2, pp. 1247-1248.

Acknowledgements

Seattle's Hub for Industry-driven Nanotechnology Education: www.seattlenano.org
North Seattle College: www.northseattle.edu
Alicia Cohn, North Seattle College: alicia.cohn@seattlecolleges.edu
Chris Emmick, North Douglass High School: cemmick@northdouglas.k12.or.us
Terry Manning, Silverton High School: tmanning1006@frontier.com
David Whalley, Sheldon High School: whalley_d@4j.lane.edu

This material is based upon work supported by the National Science Foundation under Grant Number 1204279. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Name:____

Partner's Name:____

Dancing Magnets (Ferrofluids) Lab Report Sheet

Data and Results

Distance	# of spikes	Spike height	Shape	Orientation	Diagram

Data Analysis

1. Graph: Scientists create graphs to visually illustrate relationships. Derive a graph of distance vs. the number of spikes or spike height to show this relationship.

2. Create a model (drawings, diagrams or text) to illustrate and describe the forces between the magnet and the ferrofluid as an energy interaction.

3. Use the internet to gather information about ferrofluids **and** their application in the real world. Write at least three complete sentences to summarize your findings.