

**Teacher’s Guide**

**The Mesmerizing Pull of Ferrofluids**

***December 2021***

**Table of Contents**

[Anticipation Guide](#_Anticipation_Guide) 2

Activate students’ prior knowledge and engage them before they read the article.

[Reading Comprehension Questions](#_Student_Reading_Comprehension_2) 3

These questions are designed to help students read the article (and graphics) carefully. They can help the teacher assess how well students understand the content and help direct the need for follow-up discussions and/or activities. You’ll find the questions ordered in increasing difficulty.

[Graphic Organizer](#_Graphic_Organizer) 5

Thishelps students locate and analyze information from the article. Students should use their own words and not copy entire sentences from the article. Encourage the use of bullet points.

[Answers 6](#_Answers_to_Reading)

Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.

[Additional Resources 8](#_Additional_Resources_1)

Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article.

[Chemistry Concepts, Standards, and Teaching Strategies 9](#_Chemistry_Concepts,_Standards,)

# Anticipation Guide

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Directions: *Before reading the article*,** in the first column, write “A” or “D,” indicating your **A**greement or **D**isagreement with each statement. Complete the activity in the box.

As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

|  |  |  |
| --- | --- | --- |
| **Me** | **Text** | **Statement** |
|  |  | 1. Ferrofluids come in many colors. |
|  |  | 1. Magnetite is a naturally occurring mineral containing iron. |
|  |  | 1. Iron’s electron configuration is the key to its magnetic properties. |
|  |  | 1. Iron (II) and iron (III) have the same number of electrons in the d-subshell. |
|  |  | 1. Iron (II) has a larger magnetic field than iron (III). |
|  |  | 1. The spins of neighboring iron atoms in magnetite are oriented randomly. |
|  |  | 1. Ferrofluids are colloidal suspensions containing magnetite and oil. |
|  |  | 1. Ferrofluids have been around for hundreds of years. |
|  |  | 1. Dollar bills have ferrofluids as an anti-counterfeiting feature. |
|  |  | 1. Researchers are developing ways to use ferrofluids to target the delivery of medicine to specific sites in the body. |

# Student Reading Comprehension Questions

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Directions**: Use the article to answer the questions below.

1. What is the chemical composition of ferrofluids?
2. Write the electron configuration for a neutral (ground state) iron atom.
3. Write the electron configuration for the Fe+2 and Fe+3 ions.
4. Compare and contrast paramagnetism and ferrimagnetism.
5. Define a colloid and give an everyday example (other than ferrofluids) of a common colloid.
6. List some common uses of ferrofluids
7. Write the orbital diagrams for the Fe+2 and Fe+3 ions and use the diagrams to explain why Fe+3 is more magnetic than Fe+2.
8. The article focuses on the magnetic properties of ferrofluids, list some common other magnetic metals. What is the strongest magnetic in the world composed of?

**Student Reading Comprehension Questions, cont.**

1. Ferrofluids were originally developed as a possible additive to rocket fuel. What is the composition of rocket fuel and how does it compare to the gasoline used in cars?
2. Research and explain how ferrofluids made rocket fuel less efficient and thus rejected as a possible additive to rocket fuel.

**Questions for Further Learning**

***Write your answers on another piece of paper if needed.***

1. Prolonged, commercial, space travel seems to be a primary goal of companies such as SpaceX and Blue Origin. Humans need three basic components of life to survive a long trip into space: Air (gas), water (liquid), and food (solid). What state of matter, based on its properties, is best suited for prolonged space travel? Explain your reasoning.
2. Create an infographic (Digital or hand drawn) about the chemistry of ferrofluids. The infographic must include information on the uses of ferrofluids, composition, colloids, magnetism, and have visuals.

# Graphic Organizer

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Directions**: As you read, complete the graphic organizer below to describe adhesives

|  |  |
| --- | --- |
| **Properties** | **What they are made of** |
| **How they work** | **Uses (now and in the future)** |

**Summary:** On the back of this sheet, write a one-sentence (18 words or less) summary to describe ferrofluids.

# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. **What is the chemical composition of ferrofluids?**

*Ferrofluids contain iron in the form of Fe3O4, commonly known as magnetite, oil, and a surfactant (oleic acid or soy lecithin).*

1. **Write the electron configuration for a neutral (ground state) iron atom.**

*1s2 2s2 2p6 3s2 3p6 4s2 3d6*

1. **Write the electron configuration for the Fe+2 and Fe+3 ions.**

*Fe +2  1s2 2s2 2p6 3s2 3p6 3d6*

*Fe +3 1s2 2s2 2p6 3s2 3p6 3d5*

1. **Compare and contrast paramagnetism and ferrimagnetism.**

*In paramagnetism the electron spins are randomly oriented and causes a weak attraction to a magnetic field. In ferromagnetism the electron spins are parallel which causes a strong attraction to a magnetic field.*

1. **Define a colloid and give an everyday example (other than ferrofluids) of a common colloid.**

*A colloid, in simple terms, is a mixture of one substance spread out evenly inside another substance. Examples: Mayonnaise, whipped cream, butter.*

1. **List some common uses of ferrofluids**

*Ferrofluids are used in speakers, currency as an anti-counterfeiting measure, and computer chips. Researchers are developing possible uses for ferrofluids in the medical field and to clean up oil spills.*

1. **Write the orbital diagrams for the Fe+2 and Fe+3 ions and use the diagrams to explain why Fe+3 is more magnetic than Fe+2.**

*The orbital diagram for Fe+2 should end in 3d6 and the orbital diagram for Fe+3 should end in 3d5. Fe+3 contains 5 unpaired electrons, while Fe+2 has 4 unpaired electrons which makes it more magnetic.*

1. **The article focuses on the magnetic properties of ferrofluids, list some common other magnetic metals. What is the strongest magnetic in the world composed of?**

*The strongest magnets in the world are composed of neodymium (Nd). Nickel and cobalt are other examples of magnetic metals.*

1. **Ferrofluids were originally developed as a possible additive to rocket fuel. What is the composition of rocket fuel and how does it compare to the gasoline used in cars?**

*The solid component of rocket fuel is composed of aluminum and ammonium perchlorate. The liquid component is composed of liquid hydrogen and liquid oxygen. Both are used to produce a power reaction that propels a rocket into space. Regular gasoline is a mixture of many hydrocarbons derived from oil such as isoalkanes and butane.*

1. **Research and explain how ferrofluids made rocket fuel less efficient and thus rejected as a possible additive to rocket fuel.**

*NASA scientists realized that in the low gravity of space the the use for ferrofluids was not needed therefore the extra weight of ferrofluids to the fuel mixture was deemed inefficient and thus canceled due to the creation of simpler, lighter alternatives.*

**Questions for Further Learning**

1. **Prolonged, commercial, space travel seems to be a primary goal of companies such as SpaceX and Blue Origin. Humans need three basic components of life to survive a long trip into space: Air (gas), water (liquid), and food (solid). What state of matter, based on its properties, is best suited for prolonged space travel? Explain your reasoning.**

*Gases, due to the fact that they can be compressed, are best suited for prolonged space travel. Travelers can compress a large amount of oxygen into tanks. Water and food cannot be compressed and will add a great deal of weight and take up significant space inside a prolonged space flight.*

1. **Create an infographic (Digital or hand drawn) about the chemistry of ferrofluids. The infographic must include information on the uses of ferrofluids, composition, colloids, magnetism, and have visuals.**

*Answers will vary.*

**Graphic Organizer Rubric**

If you use the Graphic Organizer to evaluate student performance, you may want to develop a grading rubric such as the one below.

|  |  |  |
| --- | --- | --- |
| **Score** | **Description** | **Evidence** |
| 4 | Excellent | Complete; details provided; demonstrates deep understanding. |
| 3 | Good | Complete; few details provided; demonstrates some understanding. |
| 2 | Fair | Incomplete; few details provided; some misconceptions evident. |
| 1 | Poor | Very incomplete; no details provided; many misconceptions evident. |
| 0 | Not acceptable | So incomplete that no judgment can be made about student understanding |

# Additional Resources

**Lessons and lesson plans**

**Electron Configuration Activity**: In this activity students will learn how to apply the Aufbau principle, Pauli exclusion principle, and Hund’s rule to model electron configurations and orbital diagrams.

<https://teachchemistry.org/classroom-resources/electron-configuration-and-orbital-diagrams>

**Metallic Bonding & Magnetics Demonstration:** Students will observe how electrons flow through a metal in an example of metallic bonding.

<https://teachchemistry.org/classroom-resources/metallic-bonding-magnetics>

**Rocket Challenge:** Students will have the opportunity to construct a rocket, with the challenges of both designing it and preparing a chemical reaction for its “fuel” in order to propel the rocket the highest possible distance.

<https://teachchemistry.org/classroom-resources/rocket-challenge>

**Other Resources**

**Making Chemistry Visible with Magnets Webinar:**  See how Doug Ragan uses his colored magnetic circles and molecule magnets to enhance his students' understanding of the particulate level of chemistry. Doug has used them to describe everything from simple solid, liquid, gas representations to balancing equations, formula writing, molecule building, and even to help his students write redox half reactions correctly.

<https://teachchemistry.org/professional-development/webinars/making-chemistry-visible-with-magnets>

# Chemistry Concepts, Standards, and Teaching Strategies

**Connections to Chemistry Concepts**

The following chemistry concepts are highlighted in this article:

* Electron configuration
* Orbitals
* Periodic table
* Physical properties

**Correlations to Next Generation Science Standards**

This article can be used to achieve the following performance expectations and dimensions of NGSS:

**HS-PS1-1.**  Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

**HS-ETS1-2.** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

**Disciplinary Core Ideas:**

* PS1.A: Structure and properties of matter
* ETS1C: Optimizing the design solution

**Crosscutting Concepts:**

* Patterns
* Structure and function

**Science and Engineering Practices:**

* Developing and using models
* Constructing explanations and designing solutions

**Nature of Science:**

* Scientific knowledge assumes an order and consistency in natural systems.

**Correlations to Common Core State Standards**

See how *ChemMatters* correlates to the[**Common Core State Standards** online](https://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/teachers-guide.html).

**Teaching Strategies**

Consider the following tips and strategies for incorporating this article into your classroom:

* **Alternative to Anticipation Guide:** Before reading, ask students what they know about magnets, and if they have ever seen liquid magnets. Their initial ideas can be collected electronically via Jamboard, Padlet, or similar technology.
  + As they read, students can find information to confirm or refute their original ideas.
  + After they read, ask students what they learned about ferrofluids.