

Lab 12. Magnetism and Atomic Structure: What Relationships Exist Between the Electrons in a Substance and the Strength of Magnetic Attraction?

Introduction

The structure of atoms is both simple and complex at the same time. The bulk of the mass of an atom is located in the nucleus, where protons and neutrons are relatively evenly distributed. Outside an atom's nucleus are electrons, which are negatively charged particles that are attracted to the positively charged nucleus. Electrons inhabit regions of space known as orbitals. These regions represent the probable position of an electron at any given point in time. Each orbital has a unique shape and can hold only two electrons. Each orbital also has a defined energy level.

FIGURE L12.1

3-D representation of s and p electron orbitals

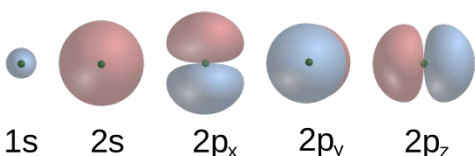
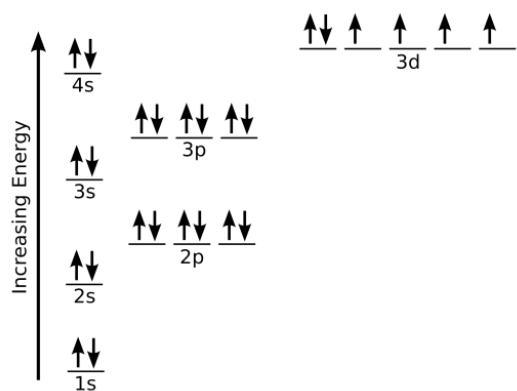


FIGURE L12.2

Electron configuration diagram for iron



At the first energy level is the 1s orbital. The “1” indicates that the orbital is in the energy level closest to the nucleus, and the “s” describes the shape of the orbital; s orbitals are spheres. At the second energy level, there is a second s orbital called the 2s orbital. This orbital is similar to the 1s orbital except that the region where there is the greatest chance of finding the electron is farther out from the nucleus. There are similar orbitals at higher energy levels (e.g., 3s, 4s, and 5s). At the second energy level there are also p orbitals; a p orbital looks like two balloons tied together. There are three different p orbitals that point at right angles to each other. These orbitals are called p_x, p_y, and p_z. The p orbitals at the second energy level are called 2p_x, 2p_y, and 2p_z (the 2 indicates that they are at the second energy level). There are also p orbitals at higher energy levels (e.g., 3p_x, 3p_y, 3p_z, 4p_x, 4p_y, and 4p_z). In addition to s and p orbitals, there are two other sets of orbitals at higher energy levels. At the third energy level, for example, there is a set of five d orbitals (with complicated shapes and names) as well as the 3s and 3p orbitals. At the third energy level there are a total of nine orbitals. At the fourth energy level, there are seven f orbitals as well as the 4s, 4p, and 4d orbitals. Figure L12.1 illustrates the 1s, 2s, and 2p orbitals.

The electron configuration of any atom can be determined using the *Aufbau principle*. According to this principle, electrons fill low-energy orbitals before they fill higher-energy ones. Electrons, however, are mutually repulsive, so individual electrons will occupy different orbitals at the same energy level before sharing the same orbital at a specific energy level. This tendency to occupy different orbitals at the same energy level, which is called Hund's rule, helps to minimize the repulsions between electrons and makes the atom more stable. As an example, consider the electron configuration of iron as illustrated in Figure L12.2. In this figure orbitals are represented as horizontal lines with the electrons in them depicted as arrows; up and down arrows are used to indicate that the electrons have different spins. The 26 electrons that are present in an iron atom are distributed across 15 orbitals according to the Aufbau principle and Hund's rule. The 1s, 2s, 2p, 3s, and 4s orbitals are completely filled. The five 3d orbitals are each occupied by at least one electron, and only one of these orbitals is completely filled.

The electron configuration of the atoms found within a substance will affect its magnetic properties. Many pure substances, besides iron metal, are attracted to a strong magnetic field. These substances are said to be paramagnetic. Substances that are not affected by strong magnetic fields are said to be diamagnetic. Past experiments with electricity and magnetism have demonstrated a connection between the magnetic properties of a substance and the movement of electrons. In the quantum mechanical model, one of the energy states of electrons is related to the electron's spin ($m_s = -1/2$ or $+1/2$). This electron spin produces a magnetic field with electrons spinning in opposite directions that have reverse magnetic poles. Paired electrons always have the opposite spin from their partner, which means their magnetic fields cancel out each other's effect. Unpaired electrons can spin in either direction and can change that direction when interacting with the magnetic fields of other unpaired electrons. In this investigation you will explore the relationship between electron configuration and magnetism in ionic compounds.

Your Task

Determine how electron configuration affects the magnetic properties of a substance.

The guiding question of this investigation is, **What relationships exist between the electrons in a substance and the strength of magnetic attraction?**

Materials

You may use any of the following materials during your investigation:

Consumables	Equipment
Vials containing copper(II) chloride (Cu^{2+}), iron(II) chloride (Fe^{2+}), manganese(II) chloride (Mn^{2+}), and zinc chloride (Zn^{2+})	<ul style="list-style-type: none"> • Empty vial • Neodymium-iron-boron magnet • Electronic balance • Plastic collar for electronic balance plate • Splints or rods

Safety Precautions

Follow all normal lab safety rules. Your teacher will explain relevant and important information about working with the chemicals associated with this investigation. *Caution: The neodymium-iron-boron magnet that you will use in this investigation is very powerful but extremely brittle. DO NOT test the magnet on the exposed metal at your laboratory station or bring anything metallic near your magnet.* In addition, take the following safety precautions:

- Wear indirectly vented chemical-splash goggles and chemical-resistant gloves and apron while in the laboratory.
- Wash your hands with soap and water before leaving the laboratory.

Investigation Proposal Required? Yes No

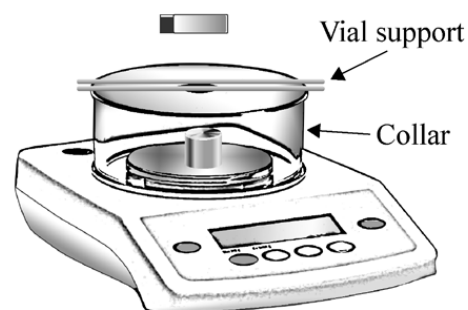
Getting Started

The first step in your investigation will be to create a device that you can use to measure the magnetic properties of different substances. Figure L12.3 shows how you can use an electronic balance to measure magnetic attraction. Once you have created your magnetic attraction measuring device, you will need to develop a procedure to determine how electron configuration affects the magnetic properties of the different chlorides that are available. Before you can design your procedure, however, your group will need to determine what type of data you need to collect, how you will collect the data, and how you will analyze the data. To determine *what type of data you need to collect*, think about the following questions:

FIGURE L12.3

Magnetic attraction measuring device

Place the vial on the support directly over the magnet



- What type of measurements will you need to record during your investigation?
- When will you need to make these measurements?

To determine *how you will collect the data*, think about the following questions:

- What comparisons will you need to make?
- How will you hold other variables constant?
- How will you use reduce measurement error?
- How will you keep track of the data you collect and how you will organize it?

To determine *how you will analyze the data*, think about the following questions:

- What are the similarities and differences in the electron configurations for each of the metal ions you used?
- What type of graph or table could you create to help make sense of your data?

Connections to Crosscutting Concepts, the Nature of Science, and the Nature of Scientific Inquiry

As you work through your investigation, be sure to think about

- the relationship between structure and function,
- how system models contribute to understanding science,
- the difference between laws and theories in science, and
- how scientific knowledge can change over time in light of new evidence.

Initial Argument

Once your group has finished collecting and analyzing your data, you will need to develop an initial argument. Your argument must include a *claim*, which is your answer to the guiding question. Your argument must also include *evidence* in support of your claim. The evidence is your analysis of the data and your interpretation of what the analysis means. Finally, you must include a *justification* of the evidence in your argument. You will therefore need to use a scientific concept or principle to explain why the evidence that you decided to use is relevant and important. You will create your initial argument on a whiteboard. Your whiteboard must include all the information shown in Figure L12.4.

FIGURE L12.4

Argument presentation on a whiteboard

The Guiding Question:	
Our Claim:	
Our Evidence:	Our Justification of the Evidence:

Argumentation Session

The argumentation session allows all of the groups to share their arguments. One member of each group stays at the lab station to share that group's argument, while the other members of the group go to the other lab stations one at a time to listen to and critique the arguments developed by their classmates. The goal of the argumentation session is not to convince others that your argument is the best one; rather, the goal is to identify errors or instances of faulty reasoning in the initial arguments so these mistakes can be fixed. You will therefore need to evaluate the content of the claim, the quality of the evidence used to support the claim, and the strength of the justification of the evidence included in each argument that you see. To critique an argument, you might need more information than what is included on the whiteboard. You might therefore need to ask the presenter one or more follow-up questions, such as:

- How did your group collect the data? Why did you use that method?

- What did your group do to make sure the data you collected are reliable? What did you do to decrease measurement error?
- What did your group do to analyze the data, and why did you decide to do it that way? Did you check your calculations?
- Is that the only way to interpret the results of your group's analysis? How do you know that your interpretation of the analysis is appropriate?
- Why did your group decide to present your evidence in that manner?
- What other claims did your group discuss before deciding on that one? Why did you abandon those alternative ideas?
- How confident are you that your group's claim is valid? What could you do to increase your confidence?

Once the argumentation session is complete, you will have a chance to meet with your group and revise your original argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the most valid or acceptable answer to the research question!

Report

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections that provide answers to the following questions:

1. What question were you trying to answer and why?
2. What did you do during your investigation and why did you conduct your investigation in this way?
3. What is your argument?

Your report should answer these questions in two pages or less. The report must be typed and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid!