Experiment 39

MAGNETIC BEHAVIOR AND ELECTRON CONFIGURATIONS

MEB 07/22/2021

MATERIALS: Analytical balance, strong neodymium magnet, samples of sodium chloride, potassium chloride, magnesium oxide, calcium oxide, magnesium chloride, calcium chloride, aluminum chloride, aluminum oxide, iron (III) chloride, cobalt (II) chloride, copper (II) oxide, zinc (II) oxide, water, ethanol, sulfur, and iodine.

PURPOSE: The purpose of this experiment is to determine the electron configurations of ions in a group of ionic compounds by investigating the behavior of the compounds when placed into a magnetic field.

LEARNING OBJECTIVES: By the end of this experiment, the student should demonstrate the following proficiencies:

1. Determine the magnetic properties of several materials.
2. Relate the magnetic behavior of an ionic substance to the electron configurations of the component ions.

DISCUSSION:

Electron configurations are extremely important in determining many chemical and physical properties of elements and compounds. The electron configuration of an atom or ion helps to determine such properties as:

1. Valence – nature and number of chemical bonds that an atom can form
2. Conductivity – metallic or non-metallic behavior
3. Size – atomic and ionic radius
4. Phase behavior – melting and boiling point
5. Polarizability – interaction external electric fields
6. Magnetism – interaction with external magnetic fields
7. Color

Magnetism - The behavior of a substance when exposed to a magnetic field is related to the existence of paired and unpaired electrons in the material. We will consider two types of magnetism in this experiment.

> **Diamagnetism -** When an external magnetic field is brought close to a diamagnetic material, a very weak magnetic field is created which opposes the applied magnetic field. **The magnet and material *repel each other***. All electrons contribute to the property of diamagnetism but in order for a material to be diamagnetic, all of the electrons must be paired.
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> **Paramagnetism** - When an external magnetic field is brought close to a paramagnetic material, **the magnet and material *are attracted to each other***. In order to be paramagnetic, there must be at least one unpaired electron in the material.

While the forces associated with paramagnetism are fairly weak, they are generally quite a bit stronger than those associated with diamagnetism. So, **in a material that contains both paired and unpaired electrons, the paramagnetism is generally the stronger effect and the net result is an attraction of the material and the magnet**.

Magnetic properties of a material can be examined by noting the behavior of a magnet on an analytical balance when the material is brought close. **A diamagnetic material will repel the magnet when it is brought close. The magnet will appear to be heavier, noted by an increase in the mass value. A paramagnetic material will attract the magnet so that the magnet will appear to be lighter**, noted by a decrease in the mass value. The paramagnetic effect is considerably stronger. In this lab you will determine the magnetic behavior of certain classes of compounds or elements. You will then be asked to state how the magnetic behavior correlates with the electron configurations of the ions/atoms in the substance.

PROCEDURE:

1. Place a magnet on an analytical balance. Record the mass.

2. Position a container holding the sample near the top of the magnet. Record the new mass.

   If the magnet appears lighter in the presence of the sample, the sample is attracting the magnet. This indicates that the sample is paramagnetic (P), and at least one electron is unpaired

   If the magnet appears heavier in the presence of the sample, the sample is repelling the magnet. This indicates that the sample is diamagnetic (D), and all electrons are paired.

NOTES:

1. The balances are very sensitive to any movement. Ignore fluctuations of the balance reading that occur in the last decimal place. To minimize the turbulence, keep the side doors closed and insert the samples through the top door of the balance. Lower the samples slowly. Do not let the sample contact the magnet.

2. The containers and our hands also display these magnetic properties.

How diamagnetic are the containers? To get a baseline, do a run with the empty container.

Sample	mass (g) magnet alone	mass (g) magnet +container	apparent change in mass (g) (column 3 – column 2)	Magnetism (P or D)
Container				

How diamagnetic are you? To test your own diamagnetism, just place your hand close to the magnet.

Sample	mass (g) magnet alone	mass (g) magnet +hand	apparent change in mass (g) (column 3 – column 2)	Magnetism (P or D)
Your hand				

Name: _________________________ **Date:** ______________________

Section: _______________________

EXPT. 39 - DATA COLLECTION AND ANALYSIS

Part A: Simple 1:1 Ionic Compounds

Ionic compounds are formed by combining positively charged metal ions with negatively charged non-metal ions. We will examine some possible electron configurations for the ions in some simple ionic compounds. Assume the metal ions can have a charge as high as +3, and the non-metal ions can have a charge as large as −3.

The compounds below have a 1:1 stoichiometry. Determine whether each compound is paramagnetic or diamagnetic.

Compound	mass (g) magnet alone	mass (g) magnet + compound	apparent change in mass (g) (column 3 – column 2)	Magnetism (P or D)
A1 sodium chloride				
A2 potassium chloride				
A3 calcium oxide				
A4 magnesium oxide				

Part B: Ionic Compounds without 1:1 Stoichiometry

Samples of magnesium chloride, calcium chloride, aluminum chloride and aluminum oxide are available for experimentation. Use the same procedure as above to determine the magnetic properties of these ionic compounds and their chemical formulas.

Compound	mass (g) magnet alone	mass (g) magnet + compound	apparent change in mass (g) (column 3 – column 2)	Magnetism (P or D)
B1 magnesium chloride				
B2 calcium chloride				
B3 aluminum chloride				
B4 aluminum oxide				

Part C: Ionic Compounds with Transition Metals

In this section, the charges of the metal ions are known.

Test the magnetic properties of each of the compounds listed above.

Compound	mass (g) magnet alone	mass (g) magnet + compound	apparent change in mass (g) (column 3 – column 2)	Magnetism (P or D)
C1 iron (III) chloride				
C2 cobalt (II) chloride				
C3 copper (II) oxide				
C4 zinc (II) oxide				

Part D: Molecular Substances:

Molecular compounds differ from ionic compounds in that they form discrete, independent units that we call molecules. The attraction of positive and negative ions goes a long way to explain why ionic compounds form. The bonding in molecular compounds is a bit harder to understand. Examine the magnetic properties of the following molecular substances: water, iodine, ethanol, and sulfur.

Compound/Element	mass (g) magnet alone	mass (g) magnet + compound	apparent change in mass (g) (column 3 – column 2)	Magnetism (P or D)
D1 H_2O (*l*)				
D2 I_2 (*s*)				
D3 C_2H_5OH (*l*)				
D4 S_8 (*s*)				

QUESTIONS:

1. Examine your experimental results for Part A. Use the possible electron configurations for each ion, as determined in your Pre-Lab, to determine the charges on the ions in each compound that are consistent with your experiment results. (e.g. CaS is found to be diamagnetic, so all electrons in both ions must be paired. The Ca^{+} - S^{-} combination has the correct stoichiometry, but is not consistent with diamagnetism, since both Ca^{+} and S^{-} have unpaired electrons. However, the Ca^{2+} - S^{2-} ion combination is consistent in both stoichiometry and magnetic behavior.)

A1 sodium chloride:
A2 potassium chloride:
A3 calcium oxide:
A4 magnesium oxide:

Are your metal charges consistent with what you have already learned about common ion charges? Explain.

2. In Part B, use possible electron configurations of the ions to give the chemical formulas that are consistent with your experimental results. Is there a single formula for each compound? (See the note in question 1 above. Also note that more than one combination may be consistent; e.g. both Li^{+} and Li^{3+} are diamagnetic, but would result in different stoichiometry with Cl^{-}.)

B1 magnesium chloride:
B2 calcium chloride:
B3 aluminum chloride:
B4 aluminum oxide:

3. In Part C, for each compound identify the electron shell and orbital responsible for the observed magnetic property of the metal ion. (An orbital box diagram of the valence shell for each might be helpful.)

C1 iron (III) chloride
C2 cobalt (II) chloride
C3 copper (II) oxide
C4 zinc (II) oxide

4. Based upon your results in Part D, does bonding in molecular compounds tend to lead to pairing or unpairing of electrons?

Name ______________________________________ **Date** _______________

Section ________________

EXPT. 39 PRE-LAB: For each of the atoms/ions, complete the following table.
P = paramagnetic D = diamagnetic

Atom/Ion	Electron Configuration (short-hand notation is OK)	# of unpaired electrons	Magnetism (P or D)
Na			
Na^{+}			
Na^{2+}			
Na^{3+}			
K			
K^{+}			
K^{2+}			
K^{3+}			
Mg			
Mg^{+}			
Mg^{2+}			
Mg^{3+}			
Ca			
Ca^{+}			
Ca^{2+}			
Ca^{3+}			
Al			
Al^{+}			
Al^{2+}			
Al^{3+}			
Fe			
Fe^{3+}			
Co			
Co^{2+}			
Cu			
Cu^{2+}			
Zn			
Zn^{2+}			
Cl			
Cl^{-}			
Cl^{2-}			
Cl^{3-}			
O			
O^{-}			
O^{2-}			
O^{3-}			