Swinging Electrons

Introduction

This colorful demonstration will expand your students' understanding of magnetism while teaching electron orbital theory.

Concepts

- Paramagnetism
- Hund's rule
- Diamagnetism

Materials

Mega-Magnet or other very strong magnet
Horizontal bar
Ring stand with clamps, 2
Test tubes and stoppers, 13 × 100 mm, 10
Thread or light string, 5 to 10 ft

This chemical demonstration can be performed using any number of transition metal salts. The following materials are our recommendations but corresponding chlorides will also work. Enough material (~5 g) to fill a test tube about two inches is required.

Calcium sulfate, $CaSO_4 \cdot 2H_2O$
Copper(II) sulfate, $CuSO_4 \cdot 5H_2O$
Iron(III) sulfate, $Fe_2(SO_4)_3 \cdot nH_2O$
Iron(II) sulfate, $FeSO_4 \cdot 7H_2O$
Manganese sulfate, $MnSO_4 \cdot H_2O$
Nickel sulfate, $NiSO_4 \cdot 6H_2O$
Potassium ferricyanide, $K_3Fe(CN)_6$
Potassium ferrocyanide, $K_4Fe(CN)_6 \cdot 3H_2O$
Zinc sulfate, $ZnSO_4 \cdot 7H_2O$

Safety Precautions

Copper(II) sulfate is a skin and respiratory irritant; toxic by ingestion and inhalation. Zinc sulfate is a skin and mucous membrane irritant. Manganese sulfate may be a tissue irritant. Potassium ferricyanide and potassium ferrocyanide have low to moderate toxicity and are dangerous if heated or if in contact with concentrated acids since hydrogen cyanide gas will evolve. Iron(II) sulfate is toxic by ingestion. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Procedure

1. Fill labeled test tubes up about two inches with corresponding metal salts. Attach thread to test tube with tape or place under stopper.
2. Set up a horizontal bar between two ring stands and suspend the test tubes from the bar using the thread. A large ring clamp will also work.
3. Bring the Mega-Magnet close to each of the test tubes. The materials that exhibit paramagnetic properties will be attracted to the magnet.
4. Saturated solutions of the metal salts will also work, but to a lesser extent.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. Save test tubes with materials for future demonstrations.

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Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Systems, order, and organization
Evidence, models, and explanation
Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, properties and changes of properties in matter, motions and forces
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure of atoms, structure and properties of matter, motions and forces

Discussion

Magnetic properties are frequently associated only with iron, but many other compounds, including liquids and gases exhibit magnetic properties. The magnetic properties of a material depend on the pairing of electrons in an atom. If there are unpaired electrons present, the atom will be attracted to a magnetic field. Such behavior is called *paramagnetism*. If the atoms in the material contain only paired electrons, then it will be slightly repelled by a magnet. This phenomenon is called *diamagnetism*. Some metals, particularly iron, cobalt and nickel have unpaired electrons but also align themselves to form small magnets within themselves. These metals remain magnetic even after the magnetic field is removed. This property is called *ferromagnetism*.

Paramagnetism and diamagnetism are important concepts that can help teach the basics of atomic theory (orbital diagrams and Hund's rule) and bonding theory (valence bonds and Lewis structures).

Certain molecules, having an even number of electrons, may have some unpaired electrons due to Hund's rule. Hund's rule states that within a given sublevel, the order of filling orbitals is such that the maximum number of half-filled orbitals will exist. Single electrons in half-filled orbitals have parallel spins. The more unpaired electrons, the greater the paramagnetic behavior and attraction to a magnetic field.

Electron configurations of select ions:

Ion	Electron Configuration	Property
Ca^{2+}	$1s^2 2s^2 2p^6 3s^2 3p^6$	(diamagnetic)
Zn^{2+}	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^0 3d^{10}$	(diamagnetic)
Cu^{2+}	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^0 3d^9$	(paramagnetic)
Mn^{2+}	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^0 3d^5$	(most paramagnetic)
Fe^{2+}	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^0 3d^6$	(paramagnetic)
Fe^{3+}	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^0 3d^5$	(most paramagnetic)

Iron coordination complexes (e.g., $Fe(CN)_6^{3-}$) are different than iron salts. Bonding electrons from the CN^- ligand enter the $4sp^3 3d^2$ hybrid orbitals to form paired electrons within the iron complex and reduce paramagnetic behavior.

Reference

Bilash, B. B., Gross, G. R., Koob, J. K. *A Demo A Day;* Flinn Scientific: Batavia, IL, 1995; p 124.

Walker, N. *J. Chem. Ed.*, **1977,** *54*, 431.

Materials for *Swinging Electrons* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP1738	Mega-Magnet, Each
C0198	Calcium Sulfate, 100 g
C0102	Copper(II) Sulfate, 100 g
F0031	Iron(III) Sulfate, 100 g
F0016	Iron(II) Sulfate, 500 g
M0030	Manganese Sulfate, 50 g
N0013	Nickel Sulfate, 500 g
P0050	Potassium Ferricyanide, 100 g
P0053	Potassium Ferrocyanide, 100 g
Z0023	Zinc Sulfate, 100 g

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.