**Magnetic Behavior and Electron Configurations**

**Physical Chemistry II Lab**

**CHM4111L**

**Dr. Clark**

**1. Objective and Relation to Lecture**

Provide a brief description of the purpose of the experiment. What are you trying to achieve or learn?

**2. Introduction / Theory**

The magnetic behavior of a substance is intrinsically tied to its electron configuration. Electrons have magnetic moments that result from their spin and orbital angular momentum. The presence or absence of unpaired electrons determines whether a material is paramagnetic or diamagnetic.

Magnetic Properties:

Diamagnetism: A material is diamagnetic if all electrons are paired. In the presence of an external magnetic field, the electron clouds slightly shift, generating an induced magnetic field that opposes the applied field. This leads to a weak repulsion from the magnetic field. Every material exhibits diamagnetism to some degree, but the effect is weak compared to paramagnetism.

Paramagnetism: Paramagnetic materials have one or more unpaired electrons. The magnetic moments of these unpaired electrons align with the external magnetic field, resulting in attraction to the field. Paramagnetism is stronger than diamagnetism, but still weak compared to ferromagnetism (which is not observed in this experiment).

Magnetic Susceptibility (χ):

Magnetic susceptibility quantifies how much a material becomes magnetized when exposed to a magnetic field:

where:

* is the magnetization of the material,
* is the external magnetic field strength.
* **For diamagnetic materials**: χ is negative, indicating repulsion.
* **For paramagnetic materials**: χ is positive, indicating attraction.

**Electron Configuration and Magnetism:**

The magnetic properties of atoms and ions are related to the electron configuration and the number of unpaired electrons. To determine whether an atom or ion is paramagnetic or diamagnetic, we must first determine its electron configuration. The number of unpaired electrons corresponds to the degree of paramagnetism observed.

For an atom or ion with unpaired electrons, the magnetic moment (in Bohr magnetons, ​) is given by the equation:

where:

* ​ is the effective magnetic moment,
* is the number of unpaired electrons,
* is the Bohr magneton.

Paramagnetic materials have , and diamagnetic materials have .

**Magnetization and Weight Change:**

In this experiment, the paramagnetic or diamagnetic nature of a substance is determined by observing the change in mass readings of a magnet on an analytical balance when the sample is brought close. The effect is due to the force exerted by the sample on the magnet:

* **For diamagnetic substances**: The induced field opposes the applied field, causing the magnet to appear **heavier** due to the repulsion.
* **For paramagnetic substances**: The magnetic moments align with the field, causing the magnet to appear **lighter** due to the attraction.

The change in mass () is related to the magnetic force () acting on the magnet:

where:

* is the acceleration due to gravity.

By examining the direction and magnitude of the change in mass, the paramagnetic or diamagnetic nature of the sample can be determined.

This experiment seeks to connect the observed behavior to the electron configurations of the substances being tested. The electron configurations help explain the presence of unpaired electrons, which are responsible for paramagnetic behavior.

**3. Materials and Equipment**

* Analytical Balance
* Neodymium Magnet
* Samples

**4. Safety Precautions**

* **Magnetic Safety**: Handle neodymium magnets with care, as they are strong and can snap together unexpectedly, causing injury or damage.

**5. Experimental Procedure**

* **Baseline Measurement**: Place a neodymium magnet on the analytical balance and record its mass as a baseline.
* **Sample Measurement**: Place approximately 5 g of the sample in a labeled weigh boat. Make sure everything is properly cleaned and labeled because you will be putting the samples back into their containers when finished. Hold the weigh boat with the sample near the top of the magnet. Ensure that the sample does not touch the magnet or the balance. Record the new mass displayed on the balance.
* **Magnetic Behavior Determination**: If the magnet appears **heavier** in the presence of the sample, it indicates the sample is **diamagnetic** (repelled by the magnetic field). If the magnet appears **lighter**, the sample is **paramagnetic** (attracted to the magnetic field).
* **Disposal:** Return the weighed-out samples to their labeled containers.

**7. Calculations and Analysis**

**Question 1 (1 point)** Complete the table below

**Data Collection and Analysis**

| **Compound** | **Mass (g) Magnet Alone** | **Mass (g) Magnet + Compound** | **Δ Mass (g)** | **Magnetism (P or D)** |
| --- | --- | --- | --- | --- |
| Sodium Chloride |  |  |  |  |
| Potassium Chloride |  |  |  |  |
| Magnesium Chloride |  |  |  |  |
| Magnesium Oxide |  |  |  |  |
| Cupric Oxide |  |  |  |  |
| Cobalt Chloride |  |  |  |  |

**Question 2 (4 points)** How do the electron configurations of the metal ions in Part A compounds (e.g., Na⁺, K⁺, Ca²⁺) explain their paramagnetic or diamagnetic behavior?

**Question 3 (5 points)** For transition metal compounds, which d-electrons are responsible for paramagnetism, and how does this correlate with the experimental results?

**Question 4 (4 points)** In molecular substances, what role does bonding play in determining whether electrons are paired or unpaired? How does this affect their magnetic behavior?

**Question 5 (1 point)** The compound FeCl3 contains the Fe3+ ion. Considering the electron configuration of Fe3, calculate the effective magnetic moment. Show your calculations with the equation editor.