Magnetic Moment

- In this experiment you will determine the magnetic susceptibility of one of the compounds you previously synthesized; e.g., $[Cr(NH_3)_6](NO_3)_3$, $Mn(acac)_3$.

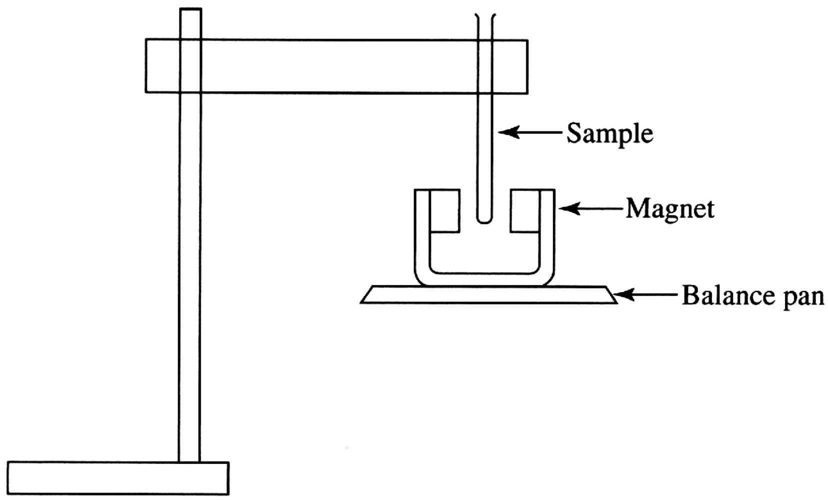
- From the corrected molar susceptibility you will calculate the magnetic moment of the compound, μ, which you will compare with the ideal spin-only moment for the compound.

- From $\mu_s = \sqrt{n(n+2)}$ B.M., the expected values of μ_s for transition-metal complexes with n = 1–5 unpaired electrons are as follows.

n	S	μ_s (B.M.)
1	1/2	1.73
2	1	2.83
3	3/2	3.87
4	2	4.90
5	5/2	5.92

Magnetic Susceptibility with an Evans Balance

- This experiment uses a modified form of the Guoy balance method, using a microscale apparatus devised by D. F. Evans and manufactured by Johnson-Matthey.



  - A moveable magnet attached to a torsion balance detects the force created by diamagnetic and paramagnetic moments in the sample.
    - ▼ Diamagnetic moment makes the magnet move down.
    - ▲ Paramagnetic moment makes the magnet move up.

Evans Balance Susceptibility Calculation

- The gram susceptibility of the sample is given by

$$\chi_g = \frac{L}{m}\left[C(R - R_o) + \chi_v' A\right]$$

where χ_g = mass magnetic susceptibility
L = sample length in centimeters
m = sample mass in grams
C = balance calibration constant
R = reading from the digital display when the sample (in the sample tube) is in place in the balance
R_o = reading from the digital display when the empty sample tube is in place in the balance
χ_v' = volume susceptibility of air (0.029×10^{-6} $erg \cdot G^{-2} cm^{-3}$)
A = cross-sectional area of the sample

- The volume susceptibility of air can be ignored with solid samples, so the equation becomes

$$\chi_g = \frac{CL(R - R_o)}{m \times 10^9}$$

☛ In this experiment you will determine the value of C by taking readings on a sample of $[Ni(en)_3]S_2O_3$, for which χ_g = 1.104×10^{-5} $erg \cdot G^{-2} \cdot cm^{-3}$.

Calculating Magnetic Moment, μ

- The *molar magnetic susceptibility*, χ_M, is obtained from the mass magnetic susceptibility by multiplying by the molecular weight of the sample in units of g/mol; i.e.,

$$\chi_M = M\chi_g$$

  - Units of χ_M are erg·G^{-2}.

- Diamagnetic corrections need to be applied to this measured molar magnetic susceptibility.
  - The diamagnetic contributions arise from core paired electrons, ligand electron pairs, and counter ion electron pairs.

$$\chi_A = \chi_M - \{\chi_M(\text{core}) + \chi_M(\text{ligand}) + \chi_M(\text{ion})\}$$

  - The diamagnetic correction factors are tabulated values, called Pascal's constants.

☛ Use the newly published values of G. A. Bain and J. F. Berry, *J. Chem. Educ.*, **2008**, 85, 532.

- We will assume that paramagnetic coupling is minimal (θ = 0), so the simpler Curie Law equation applies:

$$\mu = 2.828\sqrt{\chi_A T}$$

☛ Do not forget to take the temperature at the time of the measurements to use in this calculation.

Making the Measurements
Obtaining the Instrument Constant, *C*

① Determine R_o.
- Zero the balance.
- Weigh a clean, dry, empty sample tube on an analytical balance.
- Place the tube in the Evans balance and read R_o.
- The needle on the scale should drift no more than ±1.

② Fill the tube to at least 1.5 cm with $[Ni(en)_3]S_2O_3$.
- Gently tap the sample on a hard surface (away from the balance) to pack it well.
- Measure the length of the sample in the tube in centimeters to obtain the value of *L*.
- Obtain the mass of the tube and sample on the same analytical balance you previously used.
- Rezero the balance, insert the sample, and take a reading to obtain *R*.
- If a reading is off-scale, change to the X10 range and multiply the reading by 10.

③ Calculate the instrument constant, *C*, from your *L*, R_o, *R*, *m* data and the value of the mass susceptibility of $[Ni(en)_3]S_2O_3$, $\chi_g = 1.104 \times 10^{-5}$ erg·G^{-2}·cm^{-3}, using

$$\chi_g = \frac{CL(R - R_o)}{m \times 10^9}$$

Making the Measurements
Obtaining the Sample Data

① Empty the sample of $[Ni(\mathit{en})_3]S_2O_3$. (If absolutely sure it has not been contaminated, you may put it back in the original sample bottle.)

- Clean and dry the sample tube.

② Redetermine R_o.

- Zero the balance.
- Weigh the clean, dry, empty sample tube on an analytical balance.
- Place the tube in the balance and read R_o.
- The needle on the scale should drift no more than ±1.

③ Fill the tube to at least 1.5 cm with your sample; e.g., $[Cr(NH_3)_6](NO_3)_3$, $Mn(acac)_3$.

- Gently tap the sample on a hard surface (away from the balance) to pack it well.
- Measure the length of the sample in the tube in centimeters to obtain the value of *L*.
- Obtain the mass of the tube and sample on the same analytical balance.
- Rezero the balance, insert the sample, and take a reading to obtain *R*.
- If a reading is off-scale, change to the X10 range and multiply the reading by 10.

④ Be sure to take the temperature near the balance to obtain *T*, needed for calculating μ by the Curie Law equation.

Calculating χ_g and μ for the Sample

- Calculate the mass susceptibility of your sample from L, R_o, R, m and the previously determined instrument constant, C, using

$$\chi_g = \frac{CL(R - R_o)}{m \times 10^9}$$

- Calculate the molar susceptibility by $\chi_M = M\chi_g$.

- Calculate the corrected molar susceptibility by subtracting the Pascal's constants:

$$\chi_A = \chi_M - \{\chi_M(\text{core}) + \chi_M(\text{ligand}) + \chi_M(\text{ion})\}$$

- Calculate μ from χ_A and the temperature in kelvin (K), using the Curie Law:

$$\mu = 2.828\sqrt{\chi_A T}$$