APPENDIX A
Magnetic Properties of Magnetite

The magnetic properties of magnetite can be explained in terms of its crystalline structure. As was seen in Investigation 2, magnetite crystallizes in an inverse spinel structure within which the oxide ions are arranged in a cubic close-packed structure. Within this arrangement iron (II) ions occupy 1/4 of the octahedral holes (holes that are formed by six oxide ions in the shape of an octahedron). There are twice as many iron (III) ions as iron(II) ions, and the trivalent ions are equally divided between 1/8 of the tetrahedral holes (holes formed by four oxide ions in the geometry of a tetrahedron) and 1/4 of the octahedral holes.

Iron (III) has a d^5 electronic configuration and five unpaired electrons. The spins of the iron (III) ions in octahedral and tetrahedral holes are antiparallel and no net magnetization results from these ions. The iron (II) ions have a d^6 electronic configuration with four unpaired electrons and are responsible for the net magnetization. These divalent ions tend to align their spins parallel to those of the iron (III) ions in adjacent octahedral holes.

The magnetite nanoparticles represent a single magnetic domain and as such are described as superparamagnetic. In a sample of magnetite, there are many magnetic domains as represented below. Within a given domain the electron spins are pointed in a common direction, but the directions can change from one domain to another.

a) No external field. b) External field (H) applied as indicated.

Introduction of a magnetic field ***H*** can align the spins in all domains in the direction of the field as indicated above. This results in a substantial magnetization of the suspended solid, which, in turn, gives the entire fluid a net magnetization. Under the influence of the field, what are normally small waves on the surface of the fluid caused by the thermodynamic and hydrodynamic properties of the colloidal suspension, become amplified until the waves become peaks or spikes. When the field is removed, the magnetic domains of the particles become randomly orientated relative to one another due to thermal agitation.