B.Sc. (Honours) Part-I

Paper-IB

Topic: **Elementary Magnetochemistry: Ferromagnetism**

UG

Subject-Chemistry

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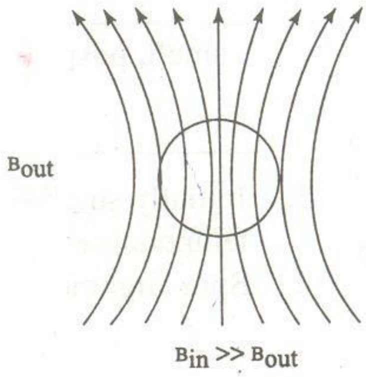
Elementary Magnetochemistry: Ferromagnetism

Ferromagnetic Materials

Certain metallic materials possess a permanent magnetic moment even in the absence of external magnetic field which results in very large and permanent magnetisation. Permanent magnetic moment in ferromagnetic materials is due to uncancelled spins of the electron, there is some amount of orbital magnetic moment but its value is small when compared with spin magnetic moment. In a ferromagnetic material the dipoles of the adjacent atoms interact with each other which results in parallel alignment of all the dipoles (Fig. 1). This interaction between the adjacent atoms is called exchange interaction or exchange coupling. Due to the parallel alignment if we apply a small value of magnetic field to a ferromagnetic material a large value of magnetisation is produced. Due to the parallel alignment of the atomic dipoles the material possesses a characteristic feature called spontaneous magnetisation. In presence of magnetic field the material allows more number of lines to pass through it as shown in fig.2. In presence of external magnetic field all the atomic dipoles are aligned in the direction of external magnetic field which results in a characteristic feature called saturation magnetisation (M_s) there is also corresponding saturation flux density (B_s). The saturation magnetisation is equal to the product of the net magnetic moment for each atom and the number of atoms present. For each of iron, cobalt and nickel, the net magnetic moments per atom are 2.22, 1.72 and 0.60 Bohr magnetons respectively. Ferromagnetic materials possess a characteristic feature called Hysteresis.

The susceptibility of a ferromagnetic material is temperature dependent. A ferromagnetic material exhibits two different properties. Below a particular temperature called Curie temperature it behaves as a ferromagnetic and above that Curie temperature it behaves as a paramagnetic material (Fig. 3). The relative permeability is very large. Magnetic susceptibility is as high as 10^6. Thus

H<<<M such that B can be written as



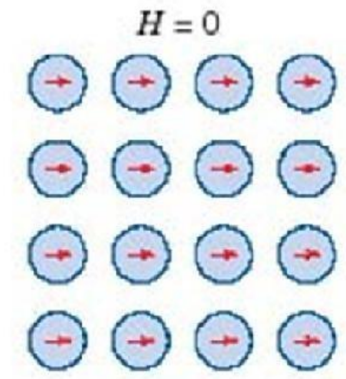


Fig. 1: Behaviour of ferromagnetic material of atomic in external magnetic field

Fig. 2: Shows the alignment dipoles in ferromagnetic materials

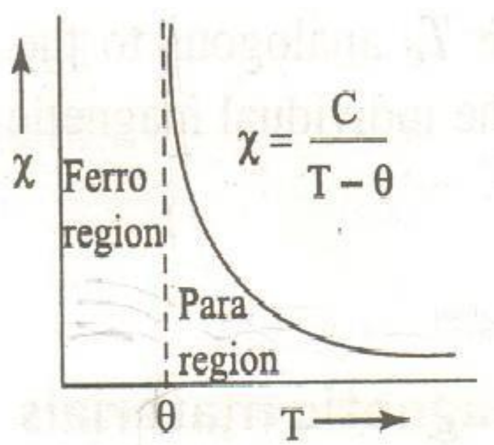


Fig. 3: Shows the variation of magnetic susceptibility with temperature for ferromagnetic material.

Curie Temperature

Even though electronic exchange forces in ferromagnets are very large, thermal energy eventually overcomes the exchange and produces a randomizing effect. This occurs at a particular temperature called the Curie temperature (T_C). Below the Curie temperature, the ferromagnet is ordered and above it, disordered. The saturation magnetization goes to zero at the Curie temperature. A typical plot of magnetization versus temperature for magnetite is shown Fig. 4.

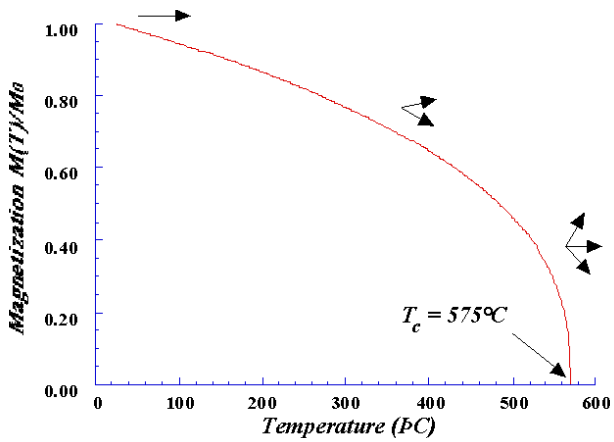


Fig. 4: Shows variation of magnetisation with temperature for ferromagnetic material.

Properties of ferromagnetic materials

1. The origin for magnetism in ferromagnetic materials is because of spin of electrons i.e. because of spin magnetic moment.
2. The materials possess permanent dipoles.
3. The dipoles or spins of the adjacent atoms interact with each other and due to this interaction all dipoles are aligned parallel to each other. This interaction between the adjacent atoms is called exchange interaction or exchange coupling. Since all dipoles are aligned along the same direction the material possess net dipole moment.
4. The one of the characteristic feature of the ferromagnetic materials is spontaneous magnetisation i.e. the material shows magnetic properties even in the absence of the external magnetic field.
5. When a ferromagnetic material is placed in external magnetic field the material get strongly magnetised resulting in saturation magnetisation i.e. the material gets strongly magnetised. Spontaneous magnetisation is another characteristic feature of ferromagnetic materials.

6. The susceptibility of ferromagnetic materials is positive and very large.

7. The susceptibility of ferromagnetic materials is dependent on temperature and independent of applied magnetic field. The equation for susceptibility is where C is Curie's constant and Θ is paramagnetic Curie temperature.

8. Inside the ferromagnetic material the material is divided into small regions or volumes called domains. Within each domain all the dipoles are aligned along the same direction resulting in spontaneous magnetisation. All these domains are randomly oriented thus resulting in zero net dipole moment.

9. In ferromagnetic materials the flux density (B) or magnetisation (M) is not directly proportional to applied magnetic field (H), i.e. the ferromagnetic material possess magnetisation for sometime even when magnetizing field is removed thus exhibiting the property of hysteresis. This is a characteristic feature of ferromagnetic materials.