Chapter – 8

Magnetic Studies

8.1 Introduction

Magnetism and magnetic materials always fascinate man, ever since the discovery of lodestone (magnetite – Fe₃O₄) in Magnesia, Turkey in around 800 BC and later on by the invention of mariner’s compass – the maritime navigational aid enabling in the discovery of new continents. Magnetism is now a diversified field of study, encompassing paleomagnetism (magnetism of rocks), bio magnetism and new magnetic materials which are more ordered (single crystals) or more disordered (fine particles, amorphous ribbons, ferrofluids, spin glasses) and low dimensionality systems (thin films). The study of magnetic nanostructures is a recent emerging research area. The discovery of giant magneto resistance (GMR) in 1988 by P. Grunberg and A. Fert reckons the new era of spin electronics [1-3]. The vast proliferation of personal computers owes mainly due to the availability of hard disk devices with low grain size magnetic recording particles. Magnetics in partnership with semiconductors paved way to the present day information revolution. The range of applications in which magnetic materials are centrally involved includes audio, video and computer technology, transformer cores, telecommunication, automotive sensors, high speed trains, electric motors, medical imaging and so on [4-6].

8.2 Magnetism-Fundamentals

The rudimentary concepts in magnetism, helpful in the discussion of the ensuing sections, are briefly described.

8.2.1 Magnetic Moment

Magnetic moment is an important fundamental quantity. The concept of magnetic moment is helpful in visualizing many magnetic interactions and in the
solution of magnetic problems. The magnetic moment of a free atom has three main sources: the spin with which electrons are endowed; their orbital angular moment about the nucleus; and the change in orbital moment induced by an external magnetic field [7, 8].

The ground state \((1s^1)\) electron of hydrogen atom has a magnetic moment given by

\[
\mu_B = \frac{-e\hbar}{2m} \quad \text{(8.1)}
\]

The term \(\mu_B\) is called Bohr magneton with a value \(9.274 \times 10^{-24}\text{Am}^2\) and is used as a convenient unit for describing the size of magnetic moments.

The basic definition of magnetic moment \((m)\) is evolved from the torque on a dipole in the presence of a magnetic field \((B)\). The magnetic moment is expressed as the maximum torque on a dipole divided by \(B\),

\[
m = \frac{r_{max}}{B} \quad \text{(8.2)}
\]

In the case of a current loop,

\[
m = iA \quad \text{(8.3)}
\]

where \(i\) is the current flowing and \(A\) is the area of the loop

For a bar magnet, of length \(l\),

\[
m = pl \quad \text{(8.4)}
\]

where \(p\) is the pole strength (an archaic term arising from the more traditional treatment of magnetism).

The magnetic dipole moment due to orbital motion of electron is

\[
\mu_l = \frac{-eL}{2m} \quad \text{(8.5)}
\]
where e – charge, m – mass of electron and L – angular momentum of orbital motion. The quantity \( \frac{e}{2m} \) is called gyro-magnetic ratio.

The spin motion of electron is purely of quantum mechanical origin. The expression for spin magnetic moment in terms of spin angular momentum \( S \) is

\[
\mu_s = -g \frac{e}{2m} S
\]  

\[-------- (8.6)\]

where \( g \) is called Lande’s splitting factor, a measure of how much an energy level is shifted by the influence of a magnetic field [9, 10].

8.2.2 Magnetization (M)

When an external magnetizing field (H) is applied, the randomly oriented magnetic moments in a material get oriented more or less with H so that the net magnetic moment is non-zero. To describe the state of magnetic polarization of the material, a vector quantity magnetization (M) is introduced. It plays a role analogous to the polarization \( P \) in electrostatics. Magnetization is defined as the magnetic dipole moment per unit volume developed inside a material [11].

The sensitivity of a material to a magnetic field is expressed by the term susceptibility (\( \chi \)) defined as

\[
\chi = \frac{M}{H}
\]  

\[---------(8.7)\]

The expression is valid only for linear materials.

Magnetic induction \( B \) produced in a material due to the magnetizing field (H) is given by

\[
B = \mu_0 (H + M)
\]  

\[---------(8.8)\]

where \( \mu_0 \) is the permeability of free space. If \( \mu \) is the permeability of the medium, a dimension-less term \( \mu_r \) is also introduced as:

\[
\mu_r = \frac{\mu}{\mu_0}
\]  

\[---------(8.9)\]
8.3 **Magnetic behaviour of materials**

Depending upon the value of susceptibility and response towards an external magnetic field, materials are mainly classified into three – dia, para and ferromagnetic substances.

### 8.3.1 Diamagnetism

All materials show some degree of diamagnetism; a weak, negative magnetic susceptibility. The constituent atoms or molecules have their electrons paired up so as to cancel the dipole moments. Diamagnetism is characterized by materials having non magnetic atoms: their magnetization induced by the field is very weak and opposite to the field direction. The susceptibility ($\chi$) is virtually independent of the field and temperature. Diamagnetic materials find increasing potential applications in super conductivity [12]. Fig. 8.1 shows the atomic/magnetic behaviour of diamagnetic materials.

![Fig. 8.1 Atomic/magnetic behaviour of diamagnetic materials](image)

### 8.3.2 Paramagnetism

Atoms and ions with one or more unpaired electrons exhibit paramagnetism. For paramagnetic materials, $\chi$ has a small, positive value. The magnetization though weak, is aligned parallel with the magnetic field. Fig. 8.2 depicts the atomic/magnetic behaviour of paramagnetic materials. Paramagnetic susceptibility is independent of the applied field; but is temperature dependent, governed by Curie law, given by
\[ \chi = \frac{C}{T} \]  \hspace{1cm} (8.10)

T being the absolute temperature and C is the Curie constant.

![Diagram of atomic/magnetic behaviour of paramagnetic materials]

Fig 8.2 Atomic/magnetic behaviour of paramagnetic materials

8.3.3 Ferromagnetism

It is the phenomenon of spontaneous magnetism – a net magnetic moment even in the absence of an external magnetic field. The most widely recognized magnetic materials are the ferromagnetic materials for which the susceptibility is positive, much greater than one.

Ferromagnetism is evolved due to the magnetic dipoles associated with the spins of unpaired electrons. But the interaction between the many nearby dipoles produced in the material are appreciable, resulting in long-range interactions. Thus large-scale areas of magnetism called domains are developed. The dipoles within a domain are all aligned and the domains tend to align with a field. Domains are separated by domain boundaries or domain walls [13]. The atomic/magnetic behaviour of ferromagnetic substances is represented in Fig. 8.3. The variation of susceptibility with temperature follows a modified Curie law known as the Curie-Weiss law:

\[ \chi = \frac{C}{T-T_c} \]  \hspace{1cm} (8.11)

Above Curie temperature \((T_c)\), the moments are oriented randomly resulting in a zero net magnetization, the substance becoming paramagnetic [14].
The characteristic feature of ferromagnetism is **hysteresis**. The energy expended in reorienting the domains from the magnetized state back to the demagnetized state manifests into a lag in response to an applied field, giving rise to hysteresis. A wealth of information about the magnetic properties of ferromagnetic materials can be extracted by studying their hysteresis loops.

The suitability of ferromagnetic materials for applications is determined from the characteristics shown by their hysteresis loop. For transformer applications, high permeability and low energy hysteresis loss is needed. Materials for electromagnets require low remanence and coercivity; whereas permanent magnet materials should have high remanence and coercivity [9].

Apart from the above three main types of magnetic materials, there are other materials closely related to ferromagnets since they are magnetically ordered. They are ferrimagnets, antiferromagnets, helimagnets, superparamagnets and so on. In antiferromagnets, adjacent magnetic moments are aligned anti parallel. Ferrimagnetism represents an intermediate position between ferro – and antiferromagnetism. Helimagnetism is characterized by a parallel alignment of the spins within each layer, i.e., each plane shows ferromagnetic behaviour; but a rotation of the magnetization occurs from layer to layer. Nanomagnetic materials display unusual properties like superparamagnetism, single domain behaviour and spin glass phenomenon. The quantum mechanical approach provides an in-depth understanding of the solid state magnetism [15].
8.4 Magnetic measurements

There are several methods to measure the magnetic field, magnetic induction or magnetization. The common technique – induction method employs Faraday’s law of electromagnetic induction which states that the e.m.f induced in a circuit is equal to the rate of change of magnetic flux linked with the circuit,

\[ V = -N \frac{d\phi}{dt} \]

\[ \text{-------- (8.12)} \]

where \( N \) is the number of turns of the coil.

The above expression yields to

\[ V = -\mu_0 NA \frac{dH}{dt} \]

\[ \text{-------- (8.13)} \]

where \( \mu_0 \) is the permeability of free space, \( H \) – magnetizing field and \( A \) area of the coil.

Stationary coil method, moving coil method, rotating coil method, vibrating coil method, vibrating sample magnetometer and flux gate magnetometer also work on the induction principle, the measurement of magnetic field dependent on the change of flux linked with the circuit. But in Hall effect magnetometers, magnetostriction devices, magneto-optic devices, thin film magnetometers and magnetic resonance methods, the measurement depends on the changes in the properties of materials under the action of a magnetic field. Other methods like torque magnetometers and susceptibility balances are techniques depending on force on a magnetic dipole in a field. The advanced method which depends on the quantization of flux in a superconducting circuit containing a weak link (Josephson junction), is SQUID (Superconducting quantum interference device). The detection by means of a SQUID is extremely sensitive and is therefore best suited to measuring very small changes in magnetic field [9,16].
8.5 Vibrating Sample Magnetometer (VSM)

The instrument is based on the flux change in a coil when a magnetized sample is vibrated in the vicinity of it. A simplified block diagram of VSM is shown in Fig. 8.4.

![Block diagram of a Vibrating Sample Magnetometer.](image)

**Fig. 8.4** Block diagram of a Vibrating Sample Magnetometer.

The sample is subjected to a sinusoidal motion (of frequency \( v \)) and the corresponding voltage is induced in the near by pick-up coils. The position of the pick-up coils is adjusted so as to get maximum induction with minimum noise. The induced signal in the pick-up coil will be proportional to the magnetic moment produced in the sample and the vibrating frequency of the sample. A servo mechanism is used to maintain the vibration of sample holder. The signal developed in the pickup coil is buffered, amplified and applied to the demodulator. It is demodulated with respect to the reference signal. The resulting DC output is an analog signal, which depends only the magnitude of the magnetic moment. The VSM can be adapted for measurements at high and low temperatures because, only the sample and vibrating rod has to be cooled or heated [7,9].
8.6 Magnetic studies of malonates

Malonate ion (the dianion of 1,3 propanedioic acid) is a versatile ligand which can adopt chelating bidendate or unidendate and different bridging coordination modes. The ability of the bridging ligand to mediate magnetic coupling between the paramagnetic centers that it links, plays a fundamental role in the magnetic behaviour of metal malonates [17, 18]. S. Sain et.al reports on the magnetic properties of a novel 3-D open frame work of copper malonate complex [19]. C. Ruiz-Perez and co-workers have explored extensively on the structural aspects and in the design of malonate complexes with desired magnetic properties. Extended magnetic networks of dimensionalities one (1-D), two (2-D) and the three (3-D) chemically constructed from malonate-bridged metallic complexes behave as ferro-, ferri-, or antiferromagnets. The structural versatility of the malonate ligand can be used as a tool for crystal engineering and in the design of molecular magnets [20-24]. In this line, the gel- grown metal malonates were subjected to an elementary magnetic study using vibrating sample magnetometer. The magnetic properties of the crystals were explored and results are discussed in the ensuing sections.

8.7 Magnetic studies of the gel-grown metal malonate crystals

The magnetic behaviour of the six metal malonate crystals grown by gel technique was investigated using a vibrating-sample magnetometer, model Lakeshore 7300 VSM [25]. The magnetic moments of the samples were measured at room temperature with a maximum applied magnetic field of 10 kOe. The variation of magnetization (M) with the magnetizing field (H) was recorded. The M-H curve is analyzed and the magnetic behaviour of the material is discussed. From the hysteresis loop, the magnetic parameters namely saturation magnetization, remanent magnetization and coercivity are determined.
8.7.1 Magnetic studies of Strontium malonate

Magnetic properties of strontium malonate crystals were studied with the help of a vibration sample magnetometer with a maximum applied field of 10kOe. Fig. 8.5 shows the variation of magnetic moment with applied field.

![Moment vs field curve for gel-grown Strontium malonate crystal](image)

**Fig. 8.5** Moment vs field curve for gel-grown Strontium malonate crystal

The ability of the bridging ligand to mediate magnetic coupling between the paramagnetic centers that it links plays a fundamental role in these studies. The malonate group (the dianion of 1,3-propanedioic acid) is a suitable candidate in designing extended magnetic networks. The occurrence of two carboxylate groups in 1,3-positions allows this ligand to adopt several coordination modes. Large number of crystal structures ranging from mononuclear species to threedimensional networks can be built with the malonate ligand depending on the metal ions it bridges. Strontium malonate is 8 coordinated with four oxygen atoms of the malonate ligand and four strontium atoms, the bridging ligand mediates magnetic coupling between the paramagnetic centers that it links. In addition to the bidentate chelation, one of the oxygen acts as a \( \mu \)-oxo bridge between two metal centers. The magnetic coupling among the magnetic centres is given by J value, J being negative or positive depending on the antiferro- or ferromagnetic character of the coupling. The carboxylato bridge will be affected by the possible syn–syn, syn–anti and anti–anti bridging modes that it can adopt.
The nature of the coupling (ferro- or antiferro-) is dependent upon the nature of the magnetic orbitals of the spin carriers connected by the bridging ligand. The two crystallographically independent strontium (II) ions [Sr(1) and Sr(2)] have distorted square pyramidal surroundings. The four coplanar carboxylate oxygen atoms which are coordinated to Sr(1), define the basal plane, whereas the apical position is occupied by a weakly coordinated water molecule. Each malonate adopts bidentate and unidentate coordination modes. Two slightly different carboxylate bridges, exhibit the anti–syn conformation, regularly within each strontium (II) chain. Due to strict orthogonality of the magnetic orbitals of the spin carriers, the ferromagnetic contribution may dominate, leading to ferromagnetism [26-29].

8.7.2 Magnetic studies of Manganese malonate

Fig. 8.6 shows the magnetic moment vs applied field curve of the manganese malonate dihydrate crystals. The curve depicts paramagnetic nature.

![Graph showing magnetic moment vs field for manganese malonate dihydrate crystals](image)

**Fig. 8.6** Moment vs field curve for gel-grown Manganese malonate dihydrate crystals
The IR and Raman studies reveal a chelating polyhedra with axial ligands for these crystals. MnC₃H₂O₄. 2H₂O is structurally is made up of aqua malonato manganese (II) units. The two crystallographically independent manganese (II) ions (Mn₁ and Mn₂) exhibit elongated octahedral surroundings with four oxygen atoms from the two bidentate malonate groups in equatorial positions [30, 31]. This octahedral surrounding is due to Pseudo tetrahedral arrangements inter linked with malonate ligand. The [Mn(mal)₂(H₂O)₂]⁺ units are linked through hydrogen bonds involving the free malonate–oxygen atoms and the coordinated water molecules. It is in general found that ligands with weaker donor strengths favour a pseudo tetrahedral structure, whereas ligands with higher donor strengths tend to produce square planar structure. It is also noteworthy that ligands which contain bulky substituents on the donor atoms may prevent a planar structure due to steric hindrance, and a distorted tetrahedral structure may become preferred [32-34].

Pseudo tetrahedral complexes are paramagnetic and are relatively rare. The sub normality in magnetic moments is ascribed to paramagnetism which is due to the interaction between electronic spins on neighboring metal ions. Paramagnetic compounds with divalent metal ion, such as Mn(II), are of more interest because the 3d electron shell responsible for paramagnetism is just half filled with five electrons and the resultant angular momentum is zero. Moreover the ground state of Mn(II) is ⁶S₅/₂. It is generally accepted that mechanism of the exchange interaction involves the mutual pairing of electronic spins via some d orbital overlap. The complex exhibits a positive magnetic susceptibility i.e. the magnetization M is oriented parallel to an external magnetic field B. Without an external magnetic field no favoured orientation of magnetic moment occurs and the resulting magnetization tends to zero. Application of external field brings in a preferential orientation [35-37]. This is evidenced from the M-H curve. Due to the structural arrangement orientation of spins is set up resulting in a paramagnetic behaviour.
8.7.3 Magnetic studies of Nickel malonate

The variation of magnetic moment with external field for nickel malonate crystal is shown in Fig.8.7. The material exhibits ferromagnetism at the ambient temperature. The shape of the graph obtained for the sample is due to the fact that the applied field is at right angles to the easy axis. This applies to a material with a strongly developed uniaxial anisotropy together with preferred orientation. The change of $M$ with $H$ is nearly linear over most of its range and is obtained at the cost of decreased permeability. The retentivity and coercivity will approach zero value [38, 39].

![Graph of Moment vs Applied field](image)

**Fig. 8.7** Moment vs field curve for Nickel malonate dihydrate crystal

The value of saturation magnetization ($M_s$) for the title crystal is 0.3095emu/g and saturation remanant magnetization ($M_{rs}$) is 20.752 Oe and coercivity ($H_c$), which is a structure sensitive property that depends on crystal structure, grain size, preferred orientation, stress, defect density, thickness, etc is 0.00344mT.

The compound under study is isostructural consisting of corrugated layers of $[\text{Ni(II)(1)(mal)}_2(\text{H}_2\text{O})_2]^{2+}$ anions and $[\text{Ni(II)(2)(H}_2\text{O})_2]^{-2}$ cations which are linked by carboxylate-malonate groups in the anti-syn bridging mode. These layers exhibit an intra layer between malonate-oxygen atoms and an interlayer
between malonate oxygen and hydrogen bonds, the latter ones lead to a three dimensional structure.

The two crystallographically independent metal ions [M(1) and M(2)] which lie on a crystallographic site are six-coordinated in slightly distorted octahedral environments: they have in common two coordinated water molecules in the apical positions and four oxygen atoms from two [at M(1)] and four [at M(2)] malonate ligands in the equatorial plane respectively. Each M(1) atom is connected to four M(2) atoms through anti–syn carboxylate groups from two malonate ligands to afford corrugated layers. The two crystallographically independent metal atoms [M(1) and M(2)] are set in the same plane within each layer, whereas the malonate ligands are shifted from these metal planes leading to a two-dimensional and quasi quadratic structure in which the carboxylate–malonate groups act as bridges in the anti–syn conformation between the nickel(II) ions. Although magneto-structural studies on carboxylate-bridged nickel(II) with the carboxylate adopting the anti–syn bridging mode are rare, ferromagnetic interactions through this exchange pathway are known [40, 41]. This exchange pathway is most likely responsible for the ferromagnetic coupling observed in NiC₃H₂O₄. 2H₂O. Finally a point that the magnetic coupling between the nickel(II) ions through the carboxylate–malonate bridge is ferromagnetic. The different electronic configuration of the metal ions involved with two unpaired electrons for Ni(II), accounts for that. Thus the weak ferromagnetism exhibited by nickel malonate dihydrate is explained.

8.7.4 Magnetic studies of Copper malonate

The variation of magnetic moment with external field is depicted in Fig. 8.8. Saturation magnetization Mₛ, remanence magnetization Mᵣₛ, coercivity Hₑ are the parameters linked with the hysteresis loop. The saturation magnetization obtained by extrapolating the high field magnetization curve to the y axis and the value of Mₛ for CuC₃H₂O₄ 3H₂O is 0.16emu/g and saturation remanent magnetization (Mᵣₛ) is 242.2 Oe and coercivity which is structure sensitive
property that depends on crystal structure, grain size, preferred orientation, stress, defected density, thickness, etc is 0.00887mT.

![Graph](image)

**Fig. 8.8** Moment vs field curve for gel-grown Copper malonate trihydrate crystal.

The sample is expected to respond well to magnetic field without any permanent magnetization at the ambient temperature. This means that in the absence of the external field, thermal energy can overcome preferential orientation. The low value coercivity in bulk sample whose size exceeds domain wall width, magnetism reversal occurs due to domain wall motion. As domain wall moves through the sample, they become pinned at the grain boundaries and additional energy is needed to continue the motion. If domain size is less than the ferromagnetic exchange length \( d \), coercivity \( H_c \) will be close to zero, making hysteresis loss trivial.

The structure of \( \text{CuC}_3\text{H}_2\text{O}_4\cdot3\text{H}_2\text{O} \) is reported in literature which consists of two neutral diaqua malonato of copper units co-existing with diaqua dimalonate of copper; these three entities are connected by a three dimensional network of hydrogen bonds [42, 43]. The magnetic orbitals at each copper atom defined by the short equatorial bonds and the axial bonds of \( d \) orbitals, in indicating the out of plane exchange pathway. The carboxylato bridge connects the equatorial bonds to the Cu(1)-Cu(2) pair. The trinuclear cation is structurally independent in tetra acqua malonate of copper and is bridged by diaqua malonato.
of CuII and the basal CuO bonds reveal significant distortion from square pyramidal surroundings leading to out of plane exchange pathway. The malonato copper II unit acts as a bridging ligand in an anti-syn conformation mode. The mononuclear triaqua dimalonate of copper features octahedral co-ordination mode. The two different carboxylates bridge anti-syn configuration.

The magnetic moment of hydrated copper (II) malonate is 1.77BM at room temperature and is close to the "spin-only" value 1.73BM which is in agreement with earlier work of Ploquin [44].

8.7.5 Magnetic studies of Cadmium malonate

The variation of magnetic moment with external field is shown in Fig.8.9. The curve depicts ferromagnetic nature. Saturation magnetization ($M_s$), remanence magnetization ($M_{r}$) and coercivity ($H_c$) are the parameters linked with the hysteresis loop. The saturation magnetization obtained by extrapolating the high field magnetization curve to the y axis and the value of $M_s$ for CdC$_3$H$_2$O$_4$ 3H$_2$O is 0.0859emu/g and saturation remanant magnetization ($M_r$) is 62.28 Oe and coercivity is 0.00126mT. The low value of coercivity is ascribed to domain wall motion through the sample. As this occurs they get pinned at the grain boundaries and additional energy required to continue the motion. If the domain size is less than the ferromagnetic exchange length, coercivity will be low [45,46].

![Diagram](image)

Fig. 8.9 Moment vs field curve for gel-grown Cadmium malonate dihydrate crystals
FTIR and FTRaman studies on cadmium malonate dihydrate reveal a seven co-ordinate of cadmium (II) co-ordinated to five oxygen atoms and two terminal aqua oxygen atoms resulting in co-ordination polyhedra. The coordination geometry is defined by two bidentate malonate ligands and two water molecules, with the latter in a trans configuration. The molecules are linked through O-H-O hydrogen bonding interactions, forming a three-dimensional supramolecular network. The magnetic orbitals of each Cadmium atom are defined by the equatorial bonds and the axial bonds of d orbitals indicating an out of plane exchange pathway [47]. The carboxylate bridge connects the equatorial bonds to the M(1)-M(2) pair. The binuclear cation is structurally independent and is bridged by diaqua malonato of Cd(II) and the basal CdO bonds revealing significant distortion leading to out of plane exchange pathway in an anti-syn conformation mode leading to ferromagnetic coupling, explaining ferromagnetism [48, 49].

8.7.6 Magnetic studies of Lead malonate

Fig. 8.10 depicts the variation of magnetization with applied field. The parameters linked with the hysteresis loop such as Saturation magnetization \( M_s \), remanence magnetization \( M_{rs} \), coercivity \( H_c \) have values 0.08042 emu/gm, 149.49 Oe and 0.004031 m Trespectively. Thus the malonato - bridged complex of Lead exhibits weak ferromagnetism.

![Fig. 8.10 Moment vs field curve for gel-grown Lead malonate crystal](imageURL)
The magneto-structural data on malonato metal(II) complexes where the carboxylate exhibits the anti–syn coordination mode revealing the occurrence of moderate to weak ferromagnetic interactions, are well established [50, 51]. In Lead (II) complex under study the malonate group mediates ferromagnetic interactions between metal (II) ions when acting as a bridge through the anti–syn coordination mode. The orthogonality between the two lead centered magnetic orbitals through this carboxylate bridge accounts for the weak ferromagnetic coupling observed. This exchange pathway is most likely responsible for the ferromagnetic coupling observed in Lead malonate crystals [52, 53].

8.8 Conclusion

The possibility of controlling the shape of the networks depends on the coordination bond between the metal ion and the ligands and on supramolecular interactions such as stacking interactions or hydrogen bonding. The nature of the interactions between the transition metal ions (or transition metal ions and radicals) is not so easy to understand since it may be either electrostatic (orbital) or magnetic (mainly dipolar). In this work we show how the design of one-, two- and three-dimensional materials can strongly benefit from the use of crystal engineering techniques, which can give rise to structures of different shapes, and how these differences can give rise to different properties. Since the malonate dianion as a bridging ligand can mediate significant magnetic interactions, the magnetic interaction linked with strontium, manganese, copper, nickel, cadmium and lead are analyzed with the help of a Vibrating sample magnetometer at room temperature. The Carboxylato bridge will be affected by the possible syn–syn, syn–anti and anti–anti bridging modes that it can adopt. The nature of the coupling (ferro- or antiferro/para) is dependent upon the nature of the magnetic orbitals of the spin carriers connected by the bridging ligand. An explanation for the magnetism exhibited by each material on the basis of the structure has been discussed.
References


