In this chapter an introduction to the nanoscience & nanotechnology is given in detail. The definition of nanotechnology is mention. Nanometer length scale is given in brief. Why such scale length is so of import? is described in brief. Types of magnetic materials and origin of magnetic materials is written in detail. Classification of magnetic materials is also described in detail. Nanomagnetism is also written in detail.
1.1 Introduction:

On December 20, 1959, lecture *Plenty of Room at the Bottom*, R. P. Feynman the physicist talked of the hypotheses linked with the nascent field of nanotechnology, vision the revolution that was to come decades latter. Today, Feynman’s ambition is assuredly being recognized on a global scale and grand. In twenty first century we are poised to make use of it for atomic-level manipulation of matter or engineering at the atomic level for the well being of mankind. [1]

Nanotechnology means the “Engineering of functional systems at the molecular scale”. Easily define, “interlinked field is Nanotechnology combining principals of physics & chemistry with the principals of structural analysis, electrical engineering, mechanical design as well as system engineering. The product which is produced has improvement in toughness, strength, speed & efficiency & had low cost & high quality. Nanotechnology is field of preference to make everything light, cheap & small.

Nanotechnology is the study as well as system design at the manometer scale \([0.000000001(10^{-9}) \text{ meter}]\) which is the scale of molecules & atoms. The man has ability to manipulate materials at the nanoscale & made as nature does. The field of NSST is very broad
from nanocluster, nanoparticle & mesoscopic to individual molecules & atoms & thereaself assembly in the prescribed structure such as biomolecules & nanowires. Nanotechnology is a field in which there is broader between desciplines like chemistry, biology & physics no longer detectable & interesting synergies arise e.g. the equipments developed in the subject of physics gives the sensivity & precision to perform particular molecular expts.in biology.

To remove pollutents from environment and to deactivate chemical warefare agents for this purpose nanometer scale traps will be constructed. Computers with the capacities of current workstation shall be the size of small particles or grains of sand & able to work for decades with equivalent of battery of single wristwatch. To explore the solar system as well as very nearest star the Robotic spacecraft which is having weight few pounds will be sent. The nature of each & every man made subject will be changed by Nanotechnology. The total combined influences that the medical imaging, man made polymers, computer aided engineering & silicon integrated cktts. is less than the total socital influence of nanotechnology & it is expected to greater. The remarkable improvement in performance as well as changes of the production of paradigms will lead to thousand industrial revoluti ons in 21st century. [2]

**Nanometer length scale:**

One billionth of a meter is nanometer. 80000nm. is the width of a human hair. Approximately 70000nm. is the width of RBC & 0.3 nm. is the water drop.

**Why such scale of length is so of import?**

Five reasons are given below for why scale length is so important

1. Inside the matter the wavelike properties of electrons are influenced by changes on nm. scale. It is possible to vary basic fundamental properties of materials by patterning matter on nanoscale without any variation in chemical composition.

2. On the nanometer length scale the systematic organization of materials is main feature of biological system. Nanotechnology promises to permit all of us to put or place artcomponents as well as assemblies in to the cells and to produce the new materials by using self assembeled methods given by the nature. This gives us a new powerful combination of biotechnology and material science.
3. The nanoscale components are used in reacting systems, energy storage, composite materials and drug delivery because of its very richly surface field.

4. The material with the scale of molecule i.e. finite size determines the main importance of local electromagnetic effect and surface tension which makes the material nanosized and it is less brittle & hard.

5. The nanomaterial make suitable for various applications in the field of optoelectronics. [3]

1.2 Magnetism:

What is a Magnetic material?

For many countries the magnetic phenomena have been exploited and well known. With the old experience with the magnetism involved magnetite in the magnetic state the only material occurs naturally. This is Load stone, its properties is to align itself in proper direction if it is permitted to freely. So it indicates the position of South and North & also latitude. The two pieces of Loadstone can repel or attract with each other is another famous property of Loadstone.

After the production of iron from its ores had become possible, it was realized that Magnetite could also attract iron. Several materials which are magnetic wellknown today, and it is therefore useful first of all to give a very important rule for what is called a magnetic material.

If two objects attract each other and also repel each other (depending on their relative operations), then those objects might be called magnets. There are also other objects that are attracted to, but not repelled by magnets, and are not attracted or repelled by each other. Such objects are said to consist of magnetic materials.

Origin of Magnetism:

The consequence of magnetic moment linked with the individual electron is macroscopic magnetic property of matter. From the two sources each electron in an atom has magnetic moment. One is linked on the orbital motion about the nucleus been a moving charge and is considered as a very small current loop. Due to which few magnetic field is produced and along its axis of rotation it has magnetic moment. Each electron shall be considered as
spinning around the axis. Due to spinning of electron the magnetic moment generates which is directed about the axis of spin. In antiparallel down direction or in up direction the spin magnetic moment is observed. Thus in an atom each electron is treated as a small magnet which is permanent. In each individual atom it has orbital spin magnetic moment. The orbital moments of some pairs of electrons cancelled with each other. This is also applicable for spin moment.

e.g. the moment of spin of one electron with spin up cancels the one with down spin. Then for an atom the resultant spin is addition of magnetic moments of to each one electron. This impart two, the orbital and spin. And taking in consideration of the calculations of moment for an atom which is having totally fulfilled electron shells & subshell. There is cancellation of considered, so the materials are made up of atoms having total filled electron shells are not permanently magnetized. This includes inert gases and materials which are ionic.

Magnetic Materials:

On the basis of characteristics of Hysterisis the ferromagnetic materials are classified in to either hard or soft.

Soft Magnetic Materials-

These materials are used in equipments or devices which are placed to magnetic field which is alternating and in which energy losses should not be high. The relative area under the Hysterisis loop must be small. The relative area should be characteristically narrow and thin. The magnetic material which is soft should have low coercivity and high initial permeability. A material which possesses these properties shall reach their saturation magnetization which have low hysteresis losses and with low applied magnetic field. A square hysteresis loop may be obtained by using some perfect heat treatment. This is preferable in pulse transformer applications and in some amplifiers which are magnetic. The magnetic materials which are soft having applications in motors, generators, switching circuits and dynamos.

- Easy to magnetize and demagnetize
- Remenance is minimal
- Low coercivity

Applications: Electromagnet, Motors, Transformers, Relays and switching circuits.
**Hard magnetic materials**-

These materials are used in magnets which are permanent. Those have high resistance to demagnetization. The magnetic materials which are hard has coercivity, high Remanance, low initial permeability and saturation flux density.

- Hard to magnetize and demagnetize
- Can be made into permanent magnet
- High coercivity

**Application:** Recording media, Micro-sized motors, Mini-pumps.

**1.3 Theory of Magnetism:**

Magnetism, the power of attracting iron by a material, is known to mankind for centuries before Christ. The oldest magnetic material or simply magnet, so called magnetite (Fe₃O₄) is a mineral was initially found in the district of Magnesia of the modern Turkey. The word magnet is a Greek word, and thought to come from the name of district. Very few people know how the magnet works and almost all of us we know what a magnetic material can do. The magnetic properties of materials are entirely due to the motion of electrons of the atoms. Any one first understands the connection which exists in between electricity and magnetism to know this phenomenon. By winding Cu wire to form a very simple electromagnet can be formed. Connect the two ends of the coil to the battery. Upto the electricity is flowing through wire the magnetic field remains as it is. The ordinary bar magnet do not have any connection with electricity so how is the working of it? The magnetic field created by the bar magnet is associated with the motions of electrons and collisions of its electrons. Electrons are the negatively charged particle revolves about the nucleus. The movement of electrons is electricity. Electricity is observed through wire or through atom, so atom represents a tiny magnet. The orbital magnetic moment is generated by rotating electron. It is measured in bohr magneton. Electron has spin motion similar the earth, its own axis given in
Fig 1.3 (a): Origin of magnetism-

(i) orbital magnetic moment

(ii) Spin magnetic moment

There are resultant magnetic moments in most of the materials due to grouping of paired electrons. This causes the cancellation of magnetic moment. The magnetic moment of maximum electrons align in a certain magnetic materials. It produces unfilled magnetic field. The magnetic field generated in the material have a proper direction of flow and any magnet is experienced by a force trying to align along applied field as like compass needle. Such force is used for production of sound, in CD player, to drive electric motor etc.so the electricity & magnetism is necessary aspect for many appliances which are used in day todays life. The atom as a unit has not resultant magnetic moment as the electron’s magnetic moments are cancelled to each other. The phenomenon of cancellation of magnetic moment is partial and dimagnetism occurs and the atom is with a final magnetic moment and the atom is called a magnetic atom. This results to Ferromagnetism Paramagnetism, Ferrimagnetism and Antiferromagnetism. [4]

1.4 Classification of Materials which are Magnetic:

The magnetic forces will be affected when the material is placed in the charm of magnetic field. This is Faraday’s law of magnetic induction. Under the action of magnetic field material can react quite different. This reaction depends upon the no. of factors like molecular & atomic structure of material also on resultant magnetic field linked with atom. The atomic magnetic moment have three origins. These are orbital motion of electron, the orbital motion changes due to field of magnet and electron’s spin motion. Electrons occurs in pairs in most of the atoms. These electrons have opposite spin. Due to opposite spin magnetic field canceled
with each other when electrons are paired together. So there is no resultant magnetic field. On the other hand some materials have unpaired electrons, they have resultant magnetic field and react to field. Most materials can be classified as ferromagnetic diamagnetic, paramagnetic and, antiferromagnetic & ferromagnetic.

In terms of the material’s magnetic behavior all materials are classified. Depending on bulk magnetic susceptibility their behavior falls one of the 5 categories. The two common types of magnetism are paramagnetic and diamagnetic. Fig 1.4(a).

![Fig 1.4 (a): A periodic table](image)

These elements are non-magnetic. But some are termed as magnetic are classed as ferromagnetic. Some former case of magnetism which is detected generally in pure elements are ferromagnetism. Ferromagnetism is also one class of magnetic material. Eventhough this isn’t detected in some pure elements but these are detected in the mingled oxides called ferrites. From this the name is ferromagnetism device. For each type of material the assess of magnetic susceptible lies in a prescribed array.

**Diamagnetism:**

When there is no applied field there is no resultant magnetic moment of atom in diamagnetic material. In the experience of employed field (H) , velocity of spinning electron changes. Finally the magnetization is produced in opposite direction to applied field.

**Table 1.4 (a)(i): magnetic behavior of material.**
Consequently under bearing of outside applied field dimagnetism is form of magnetism which exhibited by the substance. In the most materials it is generally quite weak effect although superconductor exhibit strong effect. All the electrons which have pairs including the core electrons in an atom makes always weak diamagnetic contribution to materials response. The value of susceptibility is not dependant on temperature. Those electrons contains closed shell in atom bear orbital and spin moment. This orientation is such that there is no resultant magnetic moment to the atom as a whole. So polyatomic gas like N₂,H₂ as well as monoatomic inert gases like Ne, He etc. are diamagnetic. In periodic table most of the elements including Ag, Cu, and gold are diamagnetic.

<table>
<thead>
<tr>
<th>Magnetism type</th>
<th>Susceptibility</th>
<th>Magnetic/ Atomic Behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diamagnetism</td>
<td>Negative and Small</td>
<td>No magnetic moment.</td>
</tr>
<tr>
<td>Paramagnetism</td>
<td>positive and Small</td>
<td>arbitrarily oriented magnetic moments</td>
</tr>
<tr>
<td>Ferromagnetism</td>
<td>positive and Large, function of used field, microstructure reliant</td>
<td>parallel arrayed magnetic moments.</td>
</tr>
<tr>
<td>Antiferromagnetism</td>
<td>+ ve and little</td>
<td>mingled parallel and anti- parallel arrayed magnetic moments.</td>
</tr>
<tr>
<td>Ferrimagnetism</td>
<td>positive &amp; big function of used field, microstructure subject.</td>
<td>anti- parallel arrayed magnetic moments.</td>
</tr>
</tbody>
</table>
In existence of external magnetic field paramagnetism occurs. In absent of field molecules or atoms of such materials had dipole. Due to spin of unpaired electrons in molecules/atoms this occurs. In absent of outside field because of thermal agitation the dipoles don’t colloide on one another & at random oriented giving 0 resultant magnetic moment. The dipole will align giving resultant magnetic moment in way of applied field. This happens while magnetic field is applied. For the specific type of material there are several valid theories of paramagnetism. For the materials with non interacting electrons the Langevin model is true. Langevin model states that each atom have magnetic moment. These randomly orients & give rise to thermal agitation. The slight alignment of moments is due to applied field of magnet & there is small magnetization in direction of field. The thermal agitation grows with growth in temperature & it is very hard to magnetic moment to align. Finally susceptibility decreases. This is recognized as Curie law, depicted below in Equ.1, where C, Curie constant.

\[ \chi = \frac{C}{T} \]

Eq.1

The materials in which moments are localized at ionic sites or atomic & there is no collision among neighbouring moments those moments obey this law. The transition metals
have hydrated salt e.g. CuSiO$_4$.5H$_2$O. The magnetic moment is surrounded by non magnetic ions/atoms. These forbid collision among nearer moments. In reality the Curie law is a especial case of the universal Curie-Weiss law (Equ.2), which contains a temperature constant (q) and deduces from Weiss theory, suggested for ferromagnetic substance that comprises the collision within magnetic moments.

$$\chi = \frac{C}{T - \theta}$$

Eq.2

$\theta$ may be +ve, -ve or 0. As $\theta = 0$, Curie-Weiss law is equate to the Curie law. If q is not equal to 0 and so is an collision within neighboring magnetic moments and the substance is simply paramagnetic over a confident transition temperature. If $\theta$ is +ve the substance is ferromagnetic under transition temperature and the value of $\theta$ matches transition temperature (Curie temperature, $T_C$). $\theta$ is -ve the substance is antiferromagnetic under the transition temperature (Néel temperature, $T_N$) still the value of $\theta$ does not associate to $T_N$. It is significant to notice to this equation is merely reasonable when the substance is in a paramagnetic phase. It is also not reasonable for lots good conductors since the electrons leading to the magnetic moment aren’t placed. Even so, the rule does employ to approximately metals. Paramagnetic materials include molybdenum, magnesium, tantalum, and lithium.

![Diagram](image)

(i) Magnetization versus external applied field

(ii) Susceptibility against temperature for paramagnetic substances.

**Ferromagnetism:**
In 1907 the scientist Weiss postulated first that this impression is explicated in classical theory by the bearing of field of molecule inside the substance which is ferromagnetic. To magnetize material to saturation this field is sufficient. The magnetic moments with parallel arrangement in terms of an substitute collision among adjacent moments is described by Heigenberg model of ferromagnetism in quantum mechanics. The occurrence of magnetic domains in the substance was postulated by Weiss. In those domain regions atomic magnetic moments are aligned. How the substance replies to the magnetic field is determined by the movement of these domains & susceptible is function of employed field. In terms of saturation magnetization ferromagnetic materials are generally compaired.(Magnetization while entirely domains are adjusted) instead than susceptibility.

When the magnetic field is removed ferromagnetic materials retain their property. The material which exhibit spontaneous magnetization the term ferromagnetism is used.

Above the room temperature & at the room temperature the elements Co,Fe,Ni are ferromagnetic. The degree of alliance of atomic magnetic moment falls as the ferromagnetic materials are heated. Also there is decrease in saturation magnetization. The thermal agitation gets so more that the substance turns paramagnetic. The temperature of conversion is the Curie temperature, Tc (Fe: Tc=770°C, Co: Tc=1131°C). Above Tc the susceptibility changes conceding to the Curie-Weiss law.

![Graphs](image)

**Fig 1.4 (d):** Plot of (i) magnetization versus external applied field.

(ii) Spontaneous magnetization against. temperature for ferromagnetic

### Antiferromagnetism:
These materials are like ferromagnetic materials. The magnetic moment of molecules or atoms is related to electron spin & aligns regular with neighbored spin directed in the direction which is opposite. The magnetic field cancel & behavior of material is paramagnetic material. The antiferromagnetic structure corresponds to end total magnetization when there is no external field. At all temperatures antiferromagnetic substances had small but +ve susceptibility but with the temperature their susceptibility changes. The element having only antiferromagnetism at room temperature is Chromium. similar to ferromagnetic substances these substances turn paramagnetic over a conversion temperature, recognized as the Neel temperature, $T_N$. (Cr: $T_N=370^\circ C$).

**Fig 1.4 (e):** Variation of susceptibility and inverse of susceptibility with temperature.

**Ferrimagnetism:**

The compounds that experience extra complex crystal structure than pure elements, in those compounds ferrimagnetism is observed. In these materials the exchange interaction is observed, so antiparallel alignment of atoms is observed of the other sides & parallel alliance of atoms of the crystal sides. On the basis of the ferrites which are the cubic in nature have molecular formula “MFe2O4” the principal of ferrimagnetism is explained..
Fig 1.4(f): plot of (i) magnetization versus external applied field

(ii) Spontaneous magnetization against temperature for ferromagnetic

Fig 1.4(g): cases of magnetism: (A) Paramagnetism (B) Ferromagnetism (C) Antiferromagnetism (D) Ferrimagnetism (E) Enforced ferromagnetism

1.5 Nanomagnetism:

It is wellknown that the at hand veers in technological & scientific research in magnetism are associated to improvements in nanotechnology & nanoscience. The modern phenomena have been presented with the optimization of exptal. techniques. So the new research field is stimulated. It should be underlined that improvement is to a prominent level, being constructed possible by the latest growth in the technics for the processing and fabrication of substances with assured features on the nanoscale. This gives us the preparation
of nanometric dimension material, Zero Dimensional (nanoparticles, nanodots), One
Dimensional (nanowires, nanotubes), or Two Dimensional (heterostructures, multilayer’s), and
features (i.e. bulk nanocomposites, as nanocrystalline admixtures, layer coats).

The technological & scientific importance of magnetic nanostructure is having three reasons:

1) There is variety of structures with some physical properties which are interesting from
natural nanomagnets & easy to produce nanocomposites for demanding unnatural
(artificial) nanostructures.

2) To improve the properties of magnetic materials & in the explanation there is
involvement of nanoscale effects, and

3) For completely new technology nanomagnetism had open the door.

Clusters as well as naturally occurring magnetic materials & artificially structured low
dimensional magnetic materials are composed by the nanomagnetism. Electron have quantum
mechanical property so magnetism occurs. Medical imaging, disparate as electricity &
information storage such applications are anchored by traditional magnets. The decreased
dimensionality which comes on nanoscale magnetic structures, however, inserts rich novel
developments concerning on both an applied level and fundamental. The reduction of
coordination this change occure when moving from bulk material to nanosized materials. The
outershell electrons are nonmagnetic as each bonding couple holds electrons with spin opposite
according to Pauli principle. Due to coordination is reduced maximum number of electrons are
present to head to magnetism. In band picture anyone may find the said. [5]

1.6 Ferrites:

Electrically nonconducting materials are ferrites. The different mixtures of iron oxides
like Magnetite or Hematite & the oxides of other metals are containing in ferromagnetic
ceramic compound materials. Ferrites are most important ferrimagnetic substances, which
contain certain double oxides of iron and another metal. The general form of ferrite is MFe₂O₄,
where M represents a divalent metal ion; generally transition metal ions like Fe, Mn, Co, Ni,
and Zn. Ferrites are predominantly ionic and have very stable crystal structure. Some ferrites
are based on Mn,Cr & other elements but the ferrites which are majority ferrites constitutes iron
oxides as a major constituents. In electronic transformers, inductors & electromagnets, the
cores of ferrites are used. There is very low eddy current losses due to ferrites have high electrical resistance. In computer cable, known ferrite bead these are normally found as a lump. This helps to resist electrical noise which have high frequency.

**Classifications of Ferrites:**

**On the basis of magnetization-**
- Soft ferrites
- Hard Ferrites

**On the basis of structure-**
- Spinel ferrites
- Garnets
- Orthoferrites
- Hexagonal ferrites

**On the basis of application-**
- Microwave ferrites
- Square loop ferrites
- Low loss ferrites
- Ferrites for ability practical application

**1.6 (a) Soft ferrites-**

These can be easily magnetized by exposing them to external applied magnetic field. They revert to nonmagnetic state when the field is taken off. A typical soft ferrite has a rounded s-shaped hysteresis loop and more significantly, the loop is very slim indicating that soft ferrites have a low coercive force. Good examples of soft ferrites are Mn-ferrite, Mn-Zn ferrite and Ni-Zn ferrite.

**1.6(b) Hard ferrites-**

They retain their magnetization as long as no counter-magnetizing force of sufficient strength annihilation or reverses the state of alignment. A hard ferrite is readily distinguished
by its broad hysteresis loop indicating high coercive force. Barium ferrite and Strontium ferrite are most widely used hard ferrites at present.

1.6 (c) Microwave ferrites-

These ferrites are finding increasing use in telecommunication in recent years. Typically microwave frequencies lie in the range of 1-300 GHz (wavelengths in the range of 30 cm to 1 mm). Microwaves can pass considerable distance through ferrites, because of its maximum electrical resistivity matched with minimum magnetic losses. During transmission, microwaves are modified by collision within the electrical and magnetic field constituents of the wave and the dielectric and magnetic characteristics of the substance. In such case, depending on the employed magnetic field and the frequency of the microwave, ferrites can exhibit gyro-magnetic resonance effects.

1.6 (d) Square loop ferrites-

Square loop ferrites in the form small torroids are used as memory elements in computers. The requirements of ferrites for such applications are high BR/ Bs, Fast switching time, a small but well controlled coercive force, high Bs, low temperature coefficients of magnetic properties. Generally, Mn ferrites with additives like Mg/Li/Cu/Zn are used as square loop ferrites.

1.6 (e) Low loss ferrites-

These ferrites are mainly used as cores for inductors in the telecommunication field to provide precise values of inductance in L.C. filters for frequency division multiflexing. The importance parameters are moderate initial permeability and its stability with respect to temperature and time, low loss. Up to 2MHz, Mn ferrite is preferred and in the range of 2MHz to 1GHz Ni-Zn ferrite is generally used.

The material exerts repulsive force as well as attractive force on the other materials which is important magnetism phenomena that have been introduced in Physics. Iron, cobalt, Nickel, gadolium & their alloys shows detectable magnetic characteristics. Because of the bearing of magnetic field all the materials are experienced to lesser or greater degree. Fe is mainly ferromagnetic material which gets spontaneously magnetise. In all countries magnetic phenomena were discovered, these countries are Greek, Mesoamerican, India, China & Persian.
The involvement of magnetic steels which are soft magnetic cores in different transformers around 1 hundred year before. To improve & to modify the life of mankind recently the contribution of magnetic recording is significant. For the discovery of Giant magneto resistance the scientist Albert fert & Peter Grunberg was awarded by Nobel in 2007. Now days the applications of hard magnet are widely employed in day to days life. These are used in controlling artificial satellites, Sophisticated magnetic sensors.

Based on the crystal structure ferrites are classified as Spinel ferrite, Hexagonal ferrite, Garnet ferrite, miscellaneous ferrite. Spinel ferrite is derived from mineral spinel MgAl₂O₄. Additional to mineral spinel, magnetoplumbites with general formula MFe₁₂O₁₉ M may be Sr, Pb or Ba. Garnet nanoferrite can have general formula M₃Fe₅O₁₂ where M is any rare earth ion. In miscellaneous structures there are Orthoferrites and chalcogenides. Due to nonparallel alignment of antiferromagnetically coupled ions MFe₃O₉, Orthoferrite shows weak ferromagnetism. In chalcogenides oxygen of ferrites are substituted by sulphur or selenium. Chalcogenides can not be used as a complete semiconductor or as a strictly the material which is magnetic. In addition to ferromagnetic nature chalcogenides are semiconducting.

On the basis of hysteresis characteristics of ferrites these are classified as hard or soft materials.

**Hard Ferrites:**

They have a large value of coercivity and can be demagnetized with a large magnetic field, and thus used as permanent magnets. E.g. Barium ferrite [BaO.6Fe₂O₃], Strontium Ferrite [SrO.6Fe₂O₃]. Hard ferrites are used in telecommunications, power uses.

**Soft Ferrites:**

They have a small value of coercivity and can be easily demagnetized with a small magnetic field. E.g. Ni-Zn, Mn-Zn.
Fig 1.6(a): Hysteresis of Ferrites

Crystal Structure of Soft Ferrites:

Soft ferrites are ferrites with the spinel structure of universal rule $\text{AB}_2\text{O}_4$, $A$, the divalent metal ion & $B$, the ferric ion. Soft ferrite is a cubic crystal type. In a spinel structure out of these 64 tetrahedral sites 8 are fulfilled by cations and of the 32 octahedral sites 16 are fulfilled by 8 cations.

The sites which are tetrahedral are generally fulfilled by ions which are divalent & the sites which are octahedral by ions which are trivalent. However, the site tastes of the ions for the two types of lattice depend upon:

1) The specific ions radii.

2) Interstices Size.

3) Orbital preference.

4) Temperature.

Generally the trivalent ions are smaller than the divalent ions. The octahedral places are bigger than the tetrahedral places. Therefore trivalent ions such as $\text{Fe}^{3+}$ would go to octahedral sites. According to site preference the soft ferrites can be classified as:

1) Normal Spinel Ferrite.

2) Inverse Spinel Ferrite.

3) Mixed Spinel Ferrite.

Normal Spinel Ferrite:
The normal spinel ferrite is the ferrite when the trivalent ions are in octahedral sites and when the divalent metal ions are in tetrahedral sites. E.g. Zink Ferrite (ZnFe$_2$O$_4$), Cadmium Ferrite (Cd Fe$_2$O$_4$).

**Inverse Spinel Ferrite:**

When the trivalent ions preferentially fill the sites of tetrahedral first and the remaining 8 ions fill the sites of octahedral. This spinel type is termed as inverse spinel ferrite. E.g. Cobalt Ferrite (Co Fe$_2$O$_4$), Nickel Ferrite (Ni Fe$_2$O$_4$).

**Mixed Spinel Ferrite:**

Many spinels show an intermediate behavior between normal and inverse spinels, and these are called mixed spinel ferrite. E.g. Ni Fe$_2$O$_4$ is 80% inverse spinel and 20% normal spinel, Mn Fe$_2$O$_4$ is 20% inverse spinel and 80% normal spinel.[6,7]
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7. Chan WCW (2007).” Toxicity Studies of Fullerenes and Derivatives”