

Influence of Nuclear Architecture on Magnetism, Superconductivity, Nucleosynthesis and Binding Forces in Atoms and Molecules

Bijon Kumar Sen* and Subha Sen*

Department of Chemistry, University of Calcutta, INDIA

Abstract:

The unique nuclear structure of iron derived from the polyhedral cage architectural model contains four free neutrons which give stability to the atom. These are capable of aligning the magnetic moments in parallel direction producing ferromagnetism, a special property of iron. Hitherto unknown source of magnetism in atoms and molecules has now been resolved and it has been interpreted that the real source of magnetism lies in the meson cloud of neutron. However, argument against it is the mass of the meson and the idea of exchange as the generator force of attraction. This difficulty can be avoided by considering the exchange of d- and u- quarks by in-phase revolution making the proton and the neutron equivalent and offering magnetic force as an alternative to the exchange force. The compass behaviour of magnetite can be explained if the material Fe_3O_4 is placed in a ferrite lattice. The magnetic effects impart stability to atoms and molecules.

Superconductivity is another phenomenon which is found to depend on the nuclear architecture and the property is explained with the help of three-dimensional channel formation by the overlap of first and second Brillouin Zones in reciprocal space.

The well-known meson exchange theory for the nuclear force has been replaced by a single electron exchange between neutron and proton. The model is successful in predicting the formation of the virtual and the real alpha particles. Nucleosynthesis has been shown to occur only through the condensation of Paulion (p – n pairs), the unrecognized isomer of deuteron.

Key-words: Neutron as source of magnetism, Ferrite structure of magnetite, Ferromagnetism, Superconductivity, Paulion as a building block, Nucleosynthesis

*Retired, Address for correspondence DD - 114, Street no. 269, Action Area I, Newtown, Kolkata 700156, INDIA, E-mail: bk_sen@yahoo.com

Introduction:

The term 'magnet' was probably derived from the name of the province Magnesia in Greece from where the ore magnetite, Fe_3O_4 was found, but it was at about 2000 BC that China was able to constitute a compass with magnetite (leading stone or load stone). Some believe that the magnet stone was named after the name of its discoverer Shepherd Magnes. The adamant nature of a compass in orienting itself towards terrestrial north and south, bemused Sir Einstein when he was a child and the action – at a distance of attracting iron nails by magnet did not fit in the known course of things [1]. The origin and nature of magnetic force was not properly understood over the centuries and different theories put forward for these have been documented [2].

Different types of magnetism:

Although diamagnetism was first observed in bismuth and antimony by S.J. Brugmans (1778), Michael Faraday (1845) demonstrated magnetism as a property of matter and concluded that every material responds to an applied magnetic field (in either a diamagnetic or paramagnetic way) [3]. The term paramagnetic refers to the attraction of material to an external magnetic field while the term diamagnetic refers to the repulsion of material from an external magnetic field. Diamagnetism and Paramagnetism arise out of electron filling of elements.

Langevin [4] proposed diamagnetism as an application of Zeeman Effect where the imposed magnetic field produced an electric field accelerating the electron to produce an electrical loop affecting magnetism which was opposed to the applied field. He suggested that paramagnetism exists only in the atoms with unpaired electrons. The most important type of magnetism is ferromagnetism which is defined as a physical phenomenon by which a material, such as iron, in an external magnetic field becomes permanently magnetized. In anti-ferromagnetism, adjacent ions in a substance that behave as tiny magnets spontaneously align themselves at relatively low temperatures into opposite, or antiparallel arrangements

throughout the material. Ferrimagnetism can be thought of as a combination of ferromagnetism and anti-ferromagnetism. Similar to ferromagnets, ferrimagnets exhibit a spontaneous magnetic moment. Magnetic moments of ferrimagnets align antiparallel to one another but the net magnetic moment is non-zero.

Twentieth century saw the advancement of quantum mechanical ideas by stalwarts like Heisenberg, Planck and Dirac and attempts were made to explain the properties of the solid state in terms of the energies of the extranuclear electrons. Introducing fixed nucleus approximation to simplify the subject, the equation $H \psi = E \psi$ was derived by considering the kinetic energies of nucleons included in the Laplacian operator of the Hamiltonian and the role of nucleons was almost overlooked in the expression $H \psi = E \psi$ where E is the energy and ψ is the wave function of the extranuclear electrons. Thus, the onus of deriving the properties of atoms was vested on the properties of electrons in complete negligence of the nucleons.

In all these occasions, be it in classical theory or in quantum mechanical treatment, extranuclear electrons were considered as the driving force for origin of magnetism in atoms and molecules.

Temperature dependence of different types of magnetism and their interrelation:

The nucleons i.e., protons and neutrons are surrounded by extranuclear s-, p-, and d- electrons in an atom. These electron pairs have a profound impact on the magnetic properties of the atom. The pairing of these electrons is influenced by the neutrons present in the nucleus (*vide infra*). The extranuclear s- electron pairs are spherically symmetrical and uniformly impose a magnetic influence on all the atoms. However, in Chemistry, La-Chatelier Principle states that whenever any action is taken to change an existing physical system, the system reacts in such a way so as to oppose the action. This principle is similar to electrical circuits where Lenz' Law imposes an opposing electrical field to resist a change. In magnetism, the effect of the s-electron pairs is opposed by diamagnetism which has a negative value.

For some atoms, magnetic response comes from the interaction between the electron spins and the magnetic field which is known as Pauli paramagnetism. Van Vleck paramagnetism refers to a positive and temperature-independent contribution to the magnetic susceptibility. As the distance between nucleus and the extranuclear electrons is not subjected to much change with difference in temperature, all these magnetisms namely diamagnetism, Pauli and Van Vleck paramagnetisms which are produced by electronic motion are temperature independent.

For p- orbital electron pairs, spherical symmetry is lifted by the direction of neutrons and the effect becomes anisotropic. The p_z orbital which is affected by the direction of neutrons is different from the p_x and p_y orbitals. The splitting of the p- orbitals produce Pauli paramagnetism which has a lesser value than the Van-Vleck paramagnetism. The effect of s- and p- orbitals gives rise to temperature independent magnetism as shown in Fig, I. In case of d-and f- electron pairs, the situation is completely different and gives rise to ferromagnetism which can be explained by nuclear architectural model (*vide infra*).

Curie [5] studied the thermal properties of paramagnetic atoms and detected a temperature (T_c) where transition took place between ordinary paramagnetism and high value ferromagnetism. The reason of this change was, however, not explained.

It is observed that paramagnetism which is produced in a system containing unpaired electrons decreases in magnitude with rise of temperature. These unpaired electrons obey Fermi-Dirac statistics and their number is limited by Pauli Exclusion Principle. It is seen that ferromagnetism which is controlled by number of Bosons, also decreases with temperature. It is interesting that the Fermi-Dirac statistics applies to Bosons at about Fermi level and the ferromagnetism changes over to paramagnetism at the Curie-Weiss temperature (Fig. I).

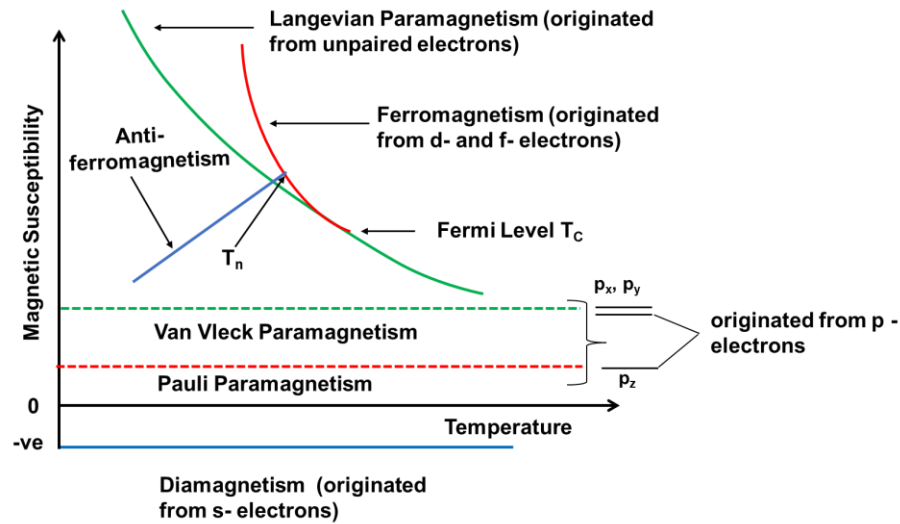


Fig. I: Temperature dependence of magnetic susceptibility of different types of magnetism

Ferromagnetism in the light of Nuclear Architectural Model:

In a previous communication [6], we presented an imaginary model for the nuclear architecture based on simple symmetry considerations. In this model, a “core” α - particle is sequentially encircled by all the platonic solid structures namely tetrahedral, cubical, octahedral, dodecahedral and icosahedral in order of their increasing capacities resulting in a polyhedral cage structure. Each side and face of each polyhedron is occupied by $p - n$ (Paulion) [7] and/or $n - n$ pairs successively in a symmetrical fashion to impart stability to the resulting nucleus. On gradual filling up of the polyhedrons, certain combinations of protons and neutrons that reach complete filling of each polyhedron usually correspond to the so called “magic numbers”. The model reflects qualitatively all the aspects of presently accepted nuclear models such as Shell, Liquid-drop, Composite, Fermi and Optical and is capable of explaining the fission and fusion processes. The model is also able to explain many of the properties of the nucleus like shape, stability, neutrino puzzle, existence of isotonic nuclei and emission of α -, β - and γ - rays.

According to this nuclear architectural model, structure of iron is unique which is totally symmetric having four free neutrons in its configuration disposed in a tetrahedral manner and is perfectly matched with the tetrahedrally oriented dxy, dxz and dyz orbitals (Fig. II).

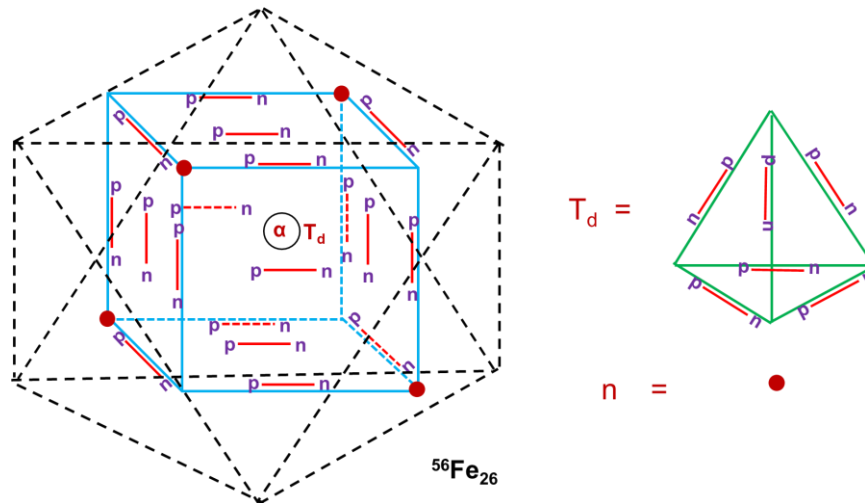


Fig. II: Nuclear structure of $^{56}\text{Fe}_{26}$

The resulting strong influence of the free neutrons in the alignment of angular momentum of electrons produces strong magnetic effect which compensates the negative diamagnetism (similar to Meissner Effect in superconductivity). This pairing effect produces spin-waves by augmentation of magnetic moments resulting in ferromagnetism.

Of the iron group of elements (Cr, Mn, Fe, Co, Ni), the structure of only $^{56}\text{Fe}_{26}$ is perfectly suitable for generation of ferromagnetism. In all the other accompanying metals the matching is not perfect due to either of the three reasons. 1). Unsymmetrical (tetrahedral) dispositions of free neutrons. 2). Unsymmetrical disposition of free electrons (dxy, dyz, dxz) and 3). Lack of symmetry of the overall nuclear architecture. The structures for $^{52}\text{Cr}_{24}$, $^{55}\text{Mn}_{25}$, $^{59}\text{Co}_{27}$ and $^{60}\text{Ni}_{28}$ are shown in Fig. III.

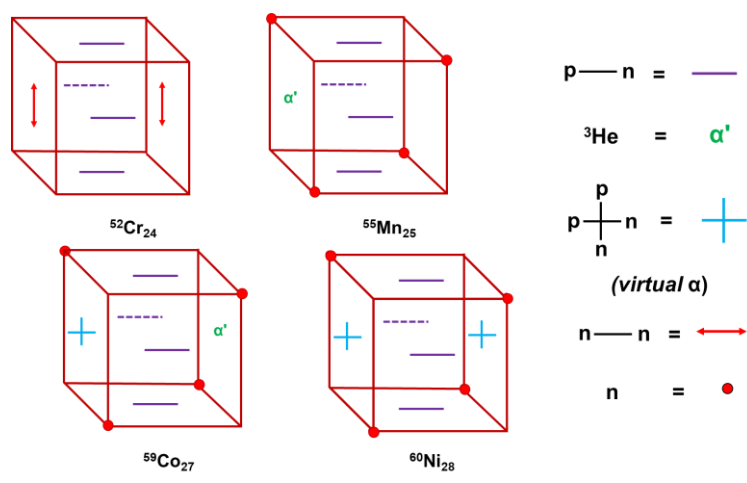


Fig. III: Structure of Iron group of elements

In case of both Cr and Mn, the overall d-electrons are less than those required for symmetrical tetrahedral disposition. Moreover, in Chromium the four neutrons are present as two di-neutrons symmetrically placed at the two opposite faces of the cube and there is no free neutron present at the corners. In Manganese, although there are four neutrons at the corners, the overall structure is unsymmetric. If, however, there is suitable ligand, the magnetic property of these metals may be quite different which is described later. ${}^{59}\text{Co}_{27}$ is a mononuclidic element with 100% abundance in nature. The structure contains four free neutrons tetrahedrally disposed at the corners to produce ferromagnetism. But the strength of magnetization is much less than that of ${}^{56}\text{Fe}_{26}$ as the presence of one α' (${}^3\text{He}_2$) at the face of the cube makes the structure unsymmetric. The Nickel structure is not apt to explain with 68% abundant ${}^{58}\text{Ni}_{28}$ for the deficit of necessary neutrons but with 26% abundant ${}^{60}\text{Ni}_{28}$, the ferromagnetism can easily be explained with four tetrahedrally disposed free neutrons.

When electron spins of many atoms are considered, properties such as ferromagnetism and anti-ferromagnetism arise due to co-operative behaviour of many unit cells in a crystal. This type of behaviour is special for iron group of elements particularly Fe, Co, Ni and also Gd, Tb and Dy (Table I) containing either d- or f- orbital electrons with the metals having free neutrons in the nuclear architecture of the atom [6].

Table I: Characteristics of d- and f- block elements showing Ferromagnetism

Metal	Iron	Cobalt	Nickel	Gadolinium	Terbium	Dysprosium
Crystal Structure	<i>bcc</i>	<i>hcp</i>	<i>fcc</i>	<i>hcp</i>	<i>hcp</i>	<i>hcp</i>
Spacings Å	2.87	2.51	3.52	3.60	3.80	3.50
Tc °K	1043	1388	627	292	220	88
M _s in Gauss	1707	1400	485	–	–	–

Included in the Table, the iron group of ferromagnets with their crystal structure, atomic spacings, Curie Temperature (T_c) and saturation magnetization (M_s). On examination, it appears that as the value of atomic spacing increases, the Curie Temperature with the exception of Co shows a uniform decrease in the values. This is due to the overlap of first Brillouin Zones in reciprocal space which is possible only with a lower value of Curie Temperature. However, the magnetization value uniformly decreases in the order of Fe, Co and Ni. The structures of Gd, Tb and Dy (almost alike in disposition of neutrons) contain extra neutrons which may combine with suitable symmetry adapted linear combination of f-orbitals but the resulting effect is not comparable with that of iron. Distribution of nucleons according to architectural model in different polyhedrons [8] for f-series elements that are likely to be ferromagnet are shown in Table II.

Table II: Ferromagnetism arising from free neutrons

Isotope	No. p – n	α	T_d	Cube			Octahedron			Dodecahedron		
	No. n			S	C	F	S	C	F	S	C	F
⁵⁶ Fe ₂₆	26	2	6	12	–	6						
	4			4								
¹⁵⁷ Gd ₆₄	64	2	6	12	–	12	12	–	12	8 p – n	2 n – n	
	29			4			6			15		
¹⁵⁹ Tb ₆₅	65	2	6	12	–	12	12	–	12	9 p – n	n – n	
	29			4			6			17		
¹⁶² Dy ₆₆	66	2	6	12	–	12	12	–	12	10 p – n		
	30			4			6			20		

S = Sides ; C = Corners ; F = Faces of Polyhedron

The Table reveals that the f-block elements (Gd, Tb, Dy) possess too many neutrons in the dodecahedral position and as a consequence, the isotope effect is somewhat inconsequential.

In this regard the term “Ferromagnetism” is to be reserved particularly for iron and all other metals mentioned above are to be considered as imperfect manifestation of this property.

A ferromagnet has a spontaneous magnetic moment which suggests that electron spins and magnetic moments are arranged in a regular way. An internal interaction tends to line up the moments in a parallel fashion [9]. This internal interaction is termed ‘exchange field’ or ‘molecular field’ or ‘Weiss field’. This orienting effect of the exchange field is opposed by thermal agitation above Curie temperature when the spin order is destroyed.

The common ferromagnetic materials other than metals are listed in Table III.

Table III: Ferromagnetic substances (other than metals) [10]

Substance	Representation as Ferrite type	Magnetization in Gauss at room temperature	Curie temperature in K
MnO-Fe ₂ O ₃	Fe ⁰ Mn(d ⁵)OFeO ₃	410	573
FeO-Fe ₂ O ₃	Fe ⁰ Fe(d ⁶)OFeO ₃	480	858
NiO-Fe ₂ O ₃	Fe ⁰ Ni(d ⁸)OFeO ₃	270	(858)
CuO-Fe ₂ O ₃	Fe ⁰ Cu(d ⁹)OFeO ₃	135	728
MgO-Fe ₂ O ₃	Fe ⁰ Mg(d ⁰)OFeO ₃	110	713
Mn-AS		670	318
Mn-Sb		710	587
Mn-Bi		620	630
CrO ₂		515	386

The ferromagnetic substances are divided into three types i) AB₂O₄ type, ii) MnAs type and iii) CrO₂ type. The former type is either considered as belonging to spinel or to BABO₄ i.e., inverse spinel or ferrite type. The properties of this group are more in conformity with the ferrite type where an *fcc* arrangement of oxide ions encloses ‘A’ species in tetrahedral position and ‘B’ species in octahedral position with one ‘B’ possessing metallic properties. Thus,

loadstone Fe_3O_4 may be considered as FeFeFeO_4 with Fe^0 as the magnetized iron species showing octahedral (Fe^{+3}) and tetrahedral (Fe^{+2}) sites with Fe^0 at the centre of the *fcc* array of the O_2^{2-} ions in the lattice (Fig. IV). The presence of metallic iron explains the properties of loadstone as a compass material which was identified by the Chinese at the very recognition of the compass.

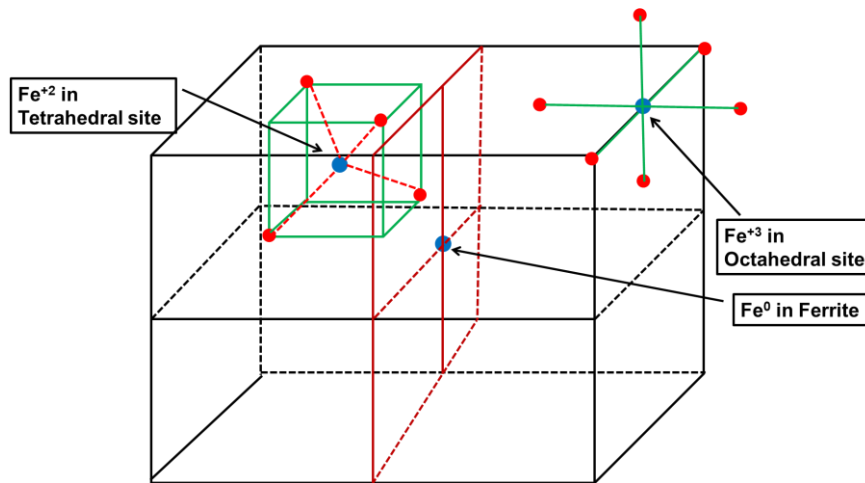


Fig. IV: A part of Ferrite structure

ii) MnAs , MnSb and MnBi are ferromagnetic in a completely different way. Mn (d^5) is ferromagnetic to some extent due to the presence of four free neutrons and gets an extra electron either from As , Sb or Bi to form 6 (d_{xy} , d_{yz} , d_{zx}) electrons but the overall symmetry of the architecture makes it ferromagnetic to a lesser extent than that of iron.

iii) The inclusion of CrO_2 in the ferromagnetic list is peculiar. Chromium dioxide is in fact anti-ferromagnetic in that Cr (d^4) may obtain two extra electrons from O_2^{2-} ligands but its effect on alignment of magnetic moments is much smaller and acts against the alignment of magnetic moment. In fact, CrO_2 acts as a hindrance or impedes the augmentation of magnetic moments and acts as a true anti-ferromagnetic substance.

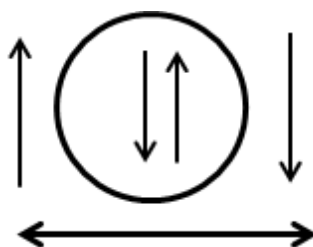
Anti-ferromagnetic substances

The anti-ferromagnetism of pure chromium metal is still a mystery since its discovery by Shull and Wilkinson [11]. Chromium with four electrons is able to fill the t_{2g} (d_{xy} , d_{xz} , d_{yx})

levels incompletely which under the influence of di-neutrons (cf. Fig. III) cannot augment the magnetic moments. On the other hand, this would impede the ferromagnetism and thereby acts as an anti-ferromagnetic. It is highly interesting observation that chromium metal (and a few rare earths) are anti-ferromagnetic as well as non-ferromagnetic. The reason of this unexpected phenomenon is not understood till today. The nuclear architectural model proposed by us [6] (albeit imaginary) can explain these in a satisfactory way. Chromium is a d^4 transition element with no free neutron but contains both $p - n$ and $n - n$ pairs. Those neutrons shared with protons are shown to be capable of pairing extranuclear electrons thus producing s -pairs, p -pairs etc. In a similar way these shared neutrons can produce pairing of d^4 electrons but no magnetic moment alignment is possible as in the case of the iron atom where free neutrons are present. This explains why chromium metal is non-ferromagnetic. On the other hand, partial replacement by chromium in iron produces a dilution in the concentration of iron which reduce the magnetic alignment to hinder ferromagnetism and may be considered as anti-ferromagnetic.

Thus, we have two types of anti-ferromagnetism. 1). Presence of metallic chromium (and a few rare earth elements) will reduce the concentration of iron in the magnetic substance and thereby reduces ferromagnetism. 2). Presence of ligands with paired electrons which produce pairing of spins and reduces ferromagnetism. Anti-ferromagnetism is the hindrance or impedance of ferromagnetism. However, the spin-coupling responsible for anti-ferromagnetism generally occurs through intervening ligands. The spin of a metal atom induces the polarization for the spin in an occupied orbital of ligand. This polarization results in anti-parallel alignment of a spin in the adjacent metal atom. This mechanism is called 'Super Exchange'. The critical temperature for the onset of anti-ferromagnetism is called 'Néel temperature (T_n). T_n is uniformly less than T_c (Table IV) and never meets, crosses or overtakes critical temperature. As the temperature is reduced to 0K, the coupling is complete. Oxides and halides of metals, CrO_2 are anti-ferromagnetic due to the presence of paired orbital electronic

ligands. These are compounds in which the spin-waves are not free to align the moments of metals in same direction due to the involvement of ligands with paired electrons.



This explanation is an indirect support for the architectural model which cannot be “proved” by experimental methods.

In this connection, it should be proper to include CrO_2 in Table IV as this acts as a real anti-ferromagnetic substance by arranging the magnetic alignment in opposite direction and not augmenting the moments as is described in case of ferromagnetic substances. At best, the ligands with paired electrons which intervene in the augmentation of magnetic moment may be called as anti-ferromagnetic substances.

Table IV contains a group of substances which are usually represented as anti-ferromagnetic but they are truly non-ferromagnetic. They have nothing to do with hindering or impeding ferromagnetism.

Table IV: Anti-ferromagnetic Materials

Ligands	Molecule	Lattice Type	Néel Temperature in K	Curie temperature in K
Oxide	MnO	<i>fcc</i>	116	610
	FeO	<i>fcc</i>	198	870
	CoO	<i>fcc</i>	291	330
	NiO	<i>fcc</i>	525	--
Halide	MnF ₂	<i>bc tetra</i>	67	82
	FeF ₂	<i>bc tetra</i>	79	117
	FeCl ₂	<i>hexa layer</i>	24	48
	CoCl ₂	<i>hexa layer</i>	25	38.1
	NiCl ₂	<i>hexa layer</i>	50	68.2

Ferrimagnetism

In the ferrite arrangement of Fe_3O_4 , the ferric ions are in an octahedral site with d^5 electronic configuration with the spin value of $5/2$ at weak ligand field. The ferrous ion is in a tetrahedral site with d^4 electronic configuration with $4/2 = 2$ spin value at weak ligand field. If all the spins are arranged in the same direction, the moment will be $5 + 4 = 9$ Bohr magneton. The actual value is 4 BM which is explained by the pairing of 6 ferric orbital moments arranged alternately to cancel their values. This is described as ferrimagnetism which is the reduction of ferromagnetism by assumed parallel alignment of ferric orbital moments.

The structure of neutron and its effect on electrons:

After its discovery, it was soon learnt that neutrons are associated with mesons from theoretical calculations of H. Yukawa [12]. The neutron is surrounded by a magnetic field and is itself a magnet. But since the neutron is electrically neutral, it was originally thought to be positive to neutralize the negative meson. Internal structure of neutron is far from simple and contradictory results were obtained from different types of experiment. One type of experiment predicts absence of any positive charge at the axis of the neutron. There is a possibility that neutron is a central core of uncharged matter surrounded by at least two types of mesons circulating in opposite directions [13]. These two types of mesons are capable of pairing of electrons producing s- band, p- band, d- or f- bands of electrons particularly when the neutron is joined to a proton to form a p – n pair. However, a free neutron as is in the iron group of metals, is far stronger to produce alignment of magnetic moment of electrons. This produces spin-waves and consequently a very strong magnetic interaction results in ferromagnetism.

The coupling interaction of free neutrons aligns the magnetic moment but are not strong enough to align the spins to form a bond. The effect of the neutron in this orientation process can be understood from Fig. V which shows the similarity in the orienting effect of a

magnet, an electrical circuit and a neutron. The direction of the field due to neutron may be up or down depending on the direction of the meson cloud.

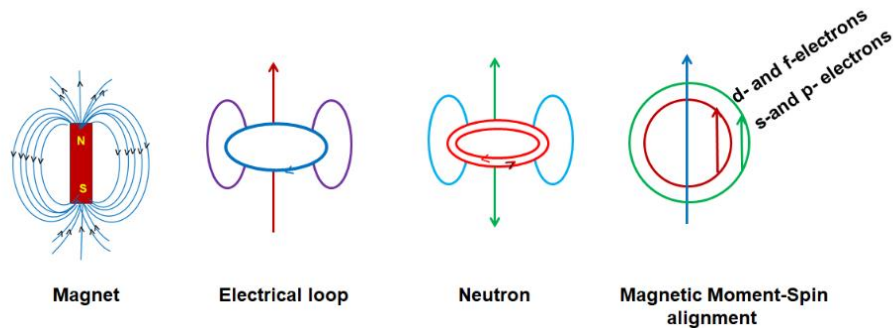


Fig. V: Orienting effect of a magnet, an electric field and a neutron

The effect of free neutron on the d-level electrons of iron is to orient them in the same direction so as to augment the magnetic moments leading to ferromagnetism. The result is that the net magnetic moment becomes very large due to augmentation with each other to form spin-waves which travel through the crystal lattice of the metal.

A perfect match between tetrahedral dispositions of neutrons in the nuclear architecture of iron (cf. Fig. II) with the tetrahedral disposition of six electrons in d_{xy} , d_{xz} , d_{yz} orbitals, it is expected that the combination will produce a perfect tetrahedral lattice in three-dimensions like a Diamond structure. But the spin-waves produced by the neutrons undergo interference as a result of which stationary waves of different dimensions are produced in the metallic structure which may be identified with the various domains predicted by Weiss at the start of the 20th century.

The spin-waves which pass out of the metal produce magnetic lines of force which form equipotential surface around the magnetic material like electrical forces. These forces depend on the distance from the metal surface and may be considered as longitudinal waves with transverse characteristics. The rest of these spin-waves produce magnetic force resulting in the alignment along the field of the earth's magnetic moment (Fig. VI).

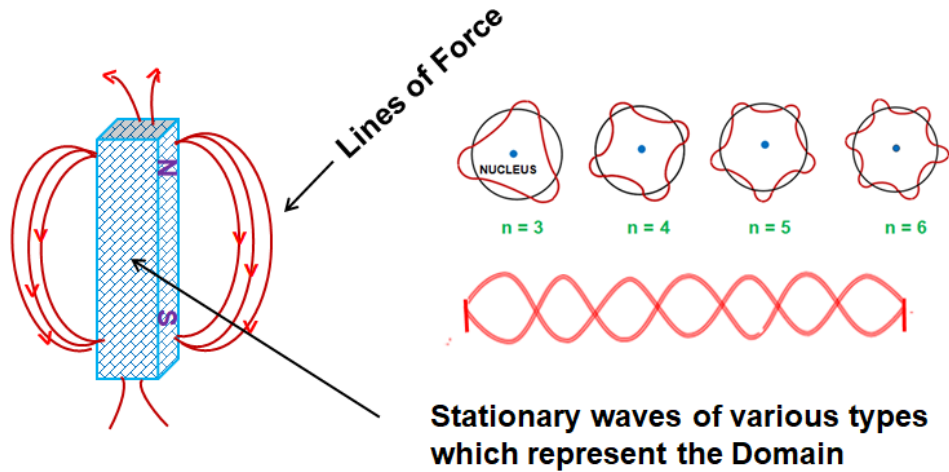


Fig. VI: Magnetic Iron core showing Stationary Waves

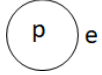
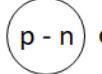
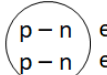
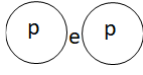
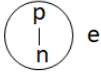
The magnetic energy of an iron block cannot be made zero in conformity with the observation of well-known ‘Hysteresis loop’ which shows the relationship between the external magnetizing force and the induced magnetic flux density. If the temperature is brought above Curie point, all the magnetic moments are lost and the system is totally disturbed.

Neutron as a source of magnetic moment and attractive forces:

Irrespective of whether the neutron is linked to a proton to form a p – n pair or it is in free state as in iron, the axis of the neutron is capable of aligning magnetic moment of an electron. If the electron is at a long distance, as in the case of extranuclear s- or p- electrons, this alignment is rather small but if the electrons are nearer (as d- or f- electrons), this interaction is comparatively stronger.

The type of interaction between nucleons in simple atoms and molecules is shown in Table V.

Table V: Forces operating in simplest atoms and molecules

Type	Equivalent Nuclear Composition	Prevalent Existing Form	Nuclear Arrangement	Forces Operating
Atoms	n	H		Coulombic Interaction
	(n - n)	¹ D		Coulombic Interaction, Magnetic Alignment
	2 (n - n)	He		Coulombic Interaction, Magnetic Alignment, Electron Pairing
Molecules	(p - n)	H ₂ ⁺		Coulombic Interaction
	(n - n)	H ₂		Coulombic Interaction, Neutron-Electron magnetic Alignment

The forces operating in the simplest H₂ molecule (Table V), shows that in addition to Coulombic interaction between proton and electron, neutron-electron spin alignments are also possible. In the quantum mechanical treatment of H₂ molecule (Heitler-London treatment), along with the Coulombic interaction, the electron-electron spin pairing has been taken into account by a term $-2jS_1.S_2$ where 'j' is the exchange energy operator. However, no consideration was made about neutron-electron spin alignment. Coulson [14] has made an in-depth analysis of exchange interaction and categorically inferred that exchange process is not a phenomenon. But even then, for want of a suitable alternative, the exchange process is adopted by scientists although the idea has not been supported by any example, analogy or suitable conceptual background. We propose that neutron-electron spin alignment might be a suitable alternative in explaining the stability of H₂ molecule.

As is presently accepted in the literature, a single proton that forms a nucleus of the H atom has a radius of $\sim 1.0 \times 10^{-13}$ cm. The H atom itself has a radius of ~ 53 pm. As the shared electrons are attracted by both the nuclei, the size of H₂ molecule is smaller than that of H atom. However, the actual radius of H₂ molecule is ~ 120 pm which is greater than that of H- atom i.e., ~ 53 pm as shown in Fig. VII.

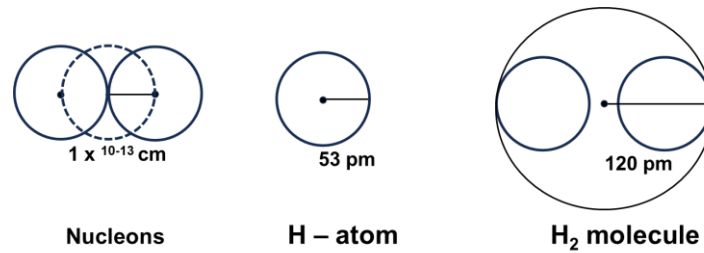


Fig. VII: Radial distances of nucleons, H- atom and H₂ molecule

The formula for the interaction force between two dipoles (μ_1 and μ_2) goes as the inverse fourth power of the distance (r) $F \approx -\mu_1\mu_2/r^4$. From this, ratio of the attractive forces becomes approximately $10^{52} : 10^{33} : 10^{31}$ for the above mentioned three figures respectively. The results for H-atom and H₂ molecule appear surprising, but actually, these include the forces of Coulombic interaction between proton and electron and if these are eliminated, the forces will become much less. This reduced magnetic interaction may be quite sufficient to become an alternative to the exchange force. However, in absence of any quantitative calculation, this is to be considered only as a suggestion.

Yukawa [12] attributed the enormous nucleonic attraction to the exchange of π -meson between protons and neutrons thus making them equivalent. This idea suffers from the fact that the π - meson which is about 300 times heavier than an electron involves large mass transfer which is unlikely in a nucleus (dimension $\sim 10^{-13}$ cm). Moreover, the phenomenon of exchange of similar particles are not allowed by theoretical consideration.

The objection to this theory may be overcome if we consider the interchange of proton and neutron by considering their composition in terms of quarks of quantum chromodynamics. The configuration of proton and neutron may be represented as 'ddu' and 'duu' respectively where 'u' is a quark of mass $\frac{2}{3}$ of an electron with positive charge and 'd' is a quark with $\frac{1}{3}$ mass of an electron with negative charge. Thus, the identity of proton and neutron may be interchanged by a description as follows (Fig. VIII):

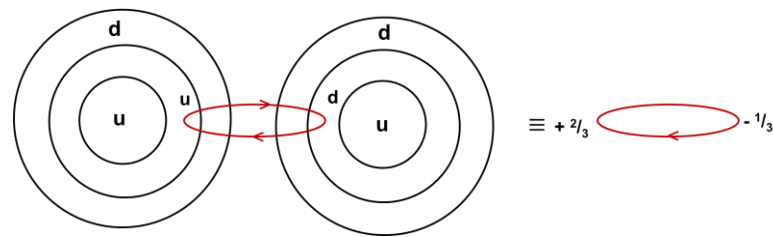


Fig. VIII: Proton-neutron interconversion by in-phase exchange of single u- and d-quarks

The in-phase revolution of the u- and d- quarks in the middle zone will cause interchange of proton and neutron. This involves a very small quantity of mass transfer and is allowable. The particles changing position are not the same, so the question of exchange of similar particles does not arise. The changing particles are electrically charged so that additional Coulombic interaction may contribute to the binding energy.

The trail of this magnetic interaction goes over to the molecular binding energy as well. Interchanging of the identity of neutron when it is joined to a proton to form a p-n pair makes its magnetic property quite interesting. It changes its magnetization alternately which causes spin-pairing of the extranuclear electrons (Fig. IX).

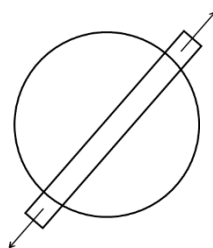


Fig. IX: Reversal of magnetization of neutron effecting spin-pairing of s- and p-electrons

Thus, in an atom, we recognize two types of neutrons, one which is joined to a proton that makes spin-pairing possible and the other as free neutron which are powerful enough to align the magnetic moments in the same direction (as in iron producing ferromagnetism) generating spin-waves which leads to Weiss's domain.

The spin interaction by the neutron which is bound to a proton in H₂ molecule might lead to a reduced force by employing the formula $-\mu_1\mu_2/r^4$ for magnetic interaction. This formula suggests a strong binding energy. Although a quantitative estimate is not possible, it might be considered as an alternative to the explanation of the binding energy of H₂ molecule. Fig. X shows an approximate stabilization of the system by the dotted curve.

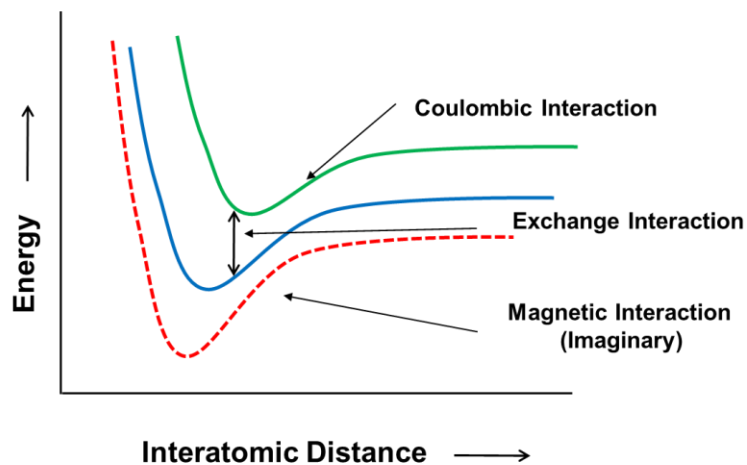


Fig. X: Magnetic interaction vs. Exchange force

Magnetic, conduction and thermal properties of atoms:

We now consider schematically, magnetic, conduction and thermal properties of atoms involving magnons, phonons and first and second Brillouin Zones in reciprocal space in one-dimension (Fig. XI).

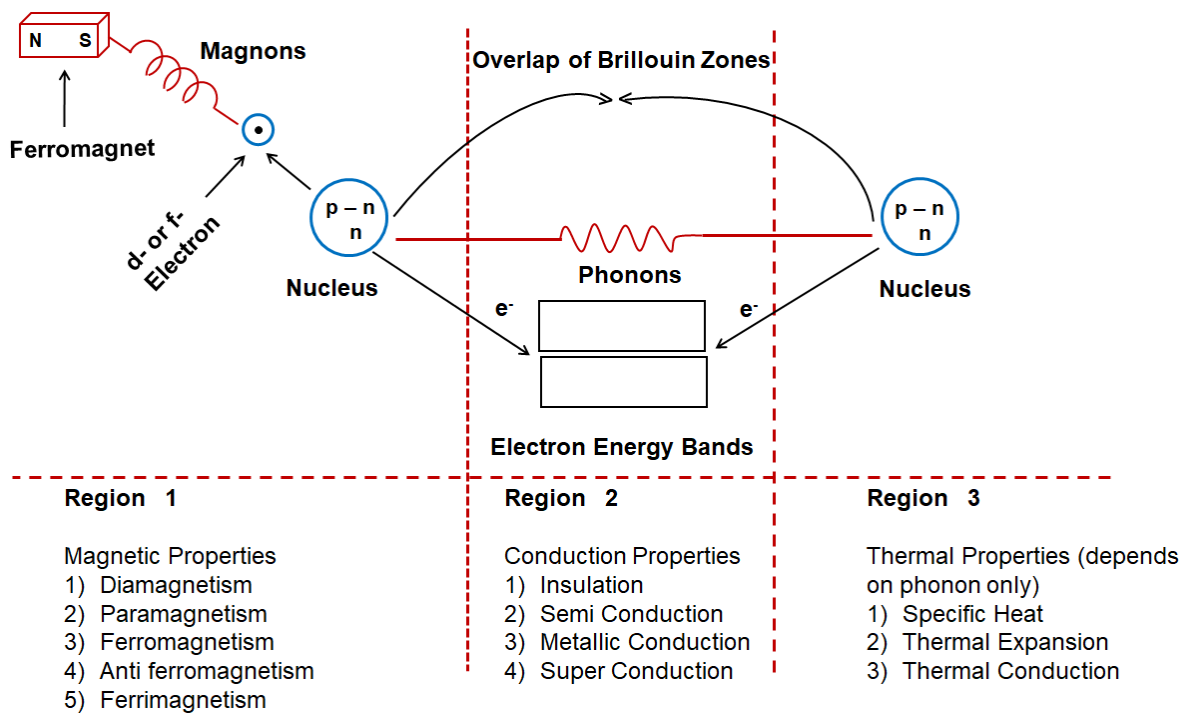


Fig. XI: Representation of magnetic, conduction and thermal properties involving magnons, phonons and overlap of Brillouin Zones in one-dimension

The figure is divided into three regions, the first represents the magnetic effect of electrons caused by nucleons. Second region involves valence electrons forming Fermi level energy bands and the third region describes the thermal properties which mainly depend on phonons with little influence from nuclear architecture.

Region 1. On examination, it transpires that magnetic energy is specific in that while all other forms of energy dissipate with time, magnetic energy resides inside a magnet for centuries with negligible loss provided of course that temperature is not raised above Curie point when thermal motion may produce loss of ferromagnetism. Thus, a magnet is a storehouse of energy which is exhibited by mechanical motion of attraction of iron nails towards magnetic lines of force. This attraction is independent of the dielectric of the medium i.e., it is the same in air, under water or in vacuum.

A tiny magnet (compass needle) adamantly orients it out in the direction of terrestrial magnetic field as exhibition of energy. Even if a magnet loses its power, it may be revived by rubbing it with another magnet which indicates that the source of energy lies in a nucleon and is not dependent on solar energy on which other forms of energy depend. If we consider the nucleus of an atom, it appears that the source of magnetism lies in neutron which involves the revolution of meson. It has been shown that a revolving meson in a neutron is either free or in combination with proton in a p – n pair may produce alignment of magnetic moments (*vide* Fig. V).

Region 2. In this region, the conduction property of atom is discussed. Although only two electrons are shown to contribute in Figure XI, actually there is a large number of electrons which supply a large number of electronic orbitals to form energy bands by overlap. The s-electrons by overlap produce s-band, p- electrons produce the p-band and these are usually separated by forbidden regions known as Band Gaps. It is known that if there is no overlapping band, the electrons will not be able to attain a higher level and the substance will be an insulator. In case of closely spaced bands, the substance will behave as a semiconductor while the overlapping bands will cause conduction. Most interestingly, in case of superconductivity, the nuclear architecture and the overlapping of Brillouin Zones in reciprocal spaces are involved which is described below.

Superconductivity

A superconducting state is characterized by the fact that its electrical resistivity is zero and the electric current can pass through the material for any length of time. Superconducting state was first discovered by Kamerlingh Onnes [15] with mercury at 4.2K, but the property is not restricted to temperature around absolute zero. Superconductivity of substances at relatively high temperatures are abundant. Not only metals and alloys but even ceramics have been found to show superconductivity at liquid nitrogen temperature. However, this

temperature is mostly guided by the overlap of Brillouin Zones with different crystal structure of the materials (*bcc, fcc, hcp*).

Bragg's Law, Temperature and Superconductivity

Bragg's Law, $n\lambda = 2d \sin \theta$ includes 'd' as the interplanar distance in a crystal lattice. But since the crystal is a quantum oscillator, 'd' could not be taken as constant but represents the distance at a particular instant of time and depends on temperature. The minimum value of 'd' must be the atomic spacing denoted by 'a'. But $|k| = 2\pi/\lambda$ which is the wavenumber and represented by the vector \vec{k} . $|k| = 2\pi/\lambda = 2\pi n/2d \sin \theta = \vec{k}$. The \vec{k} is defined in the reciprocal space and if its value is less than 'a' i.e., \vec{k} is $< 'a'$, \vec{k} cannot meet 'a' and there will be no overlap of the Brillouin Zones and this will affect superconductivity. It has been shown (*vide infra*) that the superconductivity depends on the number of free electrons (as vehicles) and the overlap of zones (as the Tower Bridge) which acts as the tunnelling path.

Effect of Ferromagnetism

Superconductivity behaves in a peculiar manner in a magnetic field. A bulk superconducting material becomes diamagnetic when placed in a magnetic field but on cooling through transition temperature, the diamagnetism is rejected by the material (Meissner effect [16]). More dramatic effect on superconductivity is the presence of ferromagnetic material (resulting from the presence of free neutrons containing mesons) which completely destroys superconductivity by shifting the transition temperature downwards. Thus, one part of iron in 10^4 will destroy the superconductivity of molybdenum with T_c 0.92 K when pure [9]. But it is known that the loss of superconductivity due to the presence of ferromagnetic material is not true for all cases particularly for high temperature superconducting materials. Non-magnetic substances are without any effect on the transition temperatures of superconducting materials.

Isotope effect

Another observation about superconductivity is that the critical temperature of metals varies with isotopic mass (isotope effect). The experimental results [17,18] with different series of isotopes may be expressed in the form $\sqrt{M} \times T_c = \text{constant}$ which is valid for Zn, Cd, Hg, Sn, Pb but does not apply for Ru and Zr. Thus, when the average atomic mass M varies from 199.5 to 203.4 atomic mass units in mercury, the T_c varies from 4.185 to 4.146K. The inverse relationship between mass supplied by isotopes and the critical temperature is expected since the isotopes have extra neutrons which increase the alignment of magnetic moments. Thus, ferromagnetism overrides the diamagnetism and makes the sample paramagnetic which increases the number of electrons and hence superconductivity. Dependence of T_c on isotopic mass was attributed to the lattice vibration and hence electron-lattice interaction [19], but actually superconducting transition temperature is dependent on the ferromagnetic effect of the neutron and thereby affecting T_c .

The equation $\sqrt{M} \times T_c = \text{constant}$ gives a hint to the possibility of existence of materials with superconductivity at higher temperatures. If M could be increased by supplying neutrons with higher mass, the T_c would be lower which means that ferromagnetism will be converted to paramagnetism at lower temperature thereby producing free electrons which will increase the superconductivity. An increase in temperature, will increase the distance between nucleons and overlap of first Brillouin Zones in reciprocal space will be hindered. But there will be no difficulty as the overlap of second and third Brillouin Zones at high temperatures will provide the pathways for electrons to pass and produce superconductivity.

Thus, LBCO i.e., $\text{La}_{1.85}\text{Ba}_{0.15}\text{CuO}_4$ ($T_c \sim 36\text{K}$) and BPBO i.e., $\text{BaPb}_{0.75}\text{Bi}_{0.25}\text{O}_3$ ($T_c \sim 12\text{K}$) are high temperature superconductors [20, 21], where some lower mass isotopes are replaced by heavier metal isotopes to increase the masses and hence reduce the T_c .

It has been observed that for simple metals, ferromagnetism and superconductivity does not coexist. But in some oxide superconductors, ferromagnetism and superconductivity appear to coexist on different sub-lattices of the same solids.

The oxocuprates are useful as superconductor at high temperatures, an example of which is YBCO i.e., $\text{YBa}_2\text{Cu}_3\text{O}_7$ ($T_c \sim 90\text{K}$) designated as “123” [22]. Y and Ba of “123” occupy particular sites while Cu atoms occupy different sites in a Perovskite structure. The square planar CuO_4 are arranged in chains. Sheets and chains of CuO_4 and CuO_5 are also detected in other oxocuprates as high temperature superconductors. However, the exact mechanism of high temperature superconductivity is not yet finally settled.

Entropy Effect

A superconducting state is an ordered state as the entropy of the system decreases. This ordering has been explained by the formation of pairs by electrons [23,24]. But be it in a material world or in science, pairing is connected with the impedance or loss of speed due to mutual attraction. An analogy may be drawn from three-legged race where the pairing or combination of two legs drastically reduces the speed of the athletes. Not only that, pairing by Pauli Exclusion Principle reduces the number of free electrons. The ordered state may well be the formation of pathways in three-dimensions by the overlap of suitable Brillouin Zones in reciprocal space.

Tunneling/Channeling Effect

Electron transport in superconducting substances is attributed to tunnelling effect [25-27]. Tunnelling suggests the escape of a particle through a barrier despite having insufficient energy to surmount it. The probability of finding the particle outside the potential barrier decreases exponentially with the width of the barrier and the distance between the metal centers. The quantum mechanical tunnelling effect is known to be free from temperature effect.

The tunnelling in case of superconductivity is supposed to take place through conduction of electrons from one metal to the other when the barrier is less than 10-20 Å. The insulating layer is a thin oxide layer on one of the two metal films [28]. It is doubtful whether this could be considered as a true quantum mechanical tunnel effect. It seems better to resort to “channeling effect” in place of tunneling effect which means the formation of three-dimensional channels (pathways) to allow for the passage of free electrons. Three-dimensional channels are formed by the overlap of first and second Brillouin Zones of different crystal structures (*bcc, fcc, hcp* as the case may be) to allow free electrons to pass through just like the Tower Bridge allows vehicles for transportation (Fig. XII). Number of free electrons (as vehicles) are reduced either by magnetic interaction or by the application of Pauli Exclusion Principle. As the temperature rises, the channels are cut off and superconductivity vanishes.

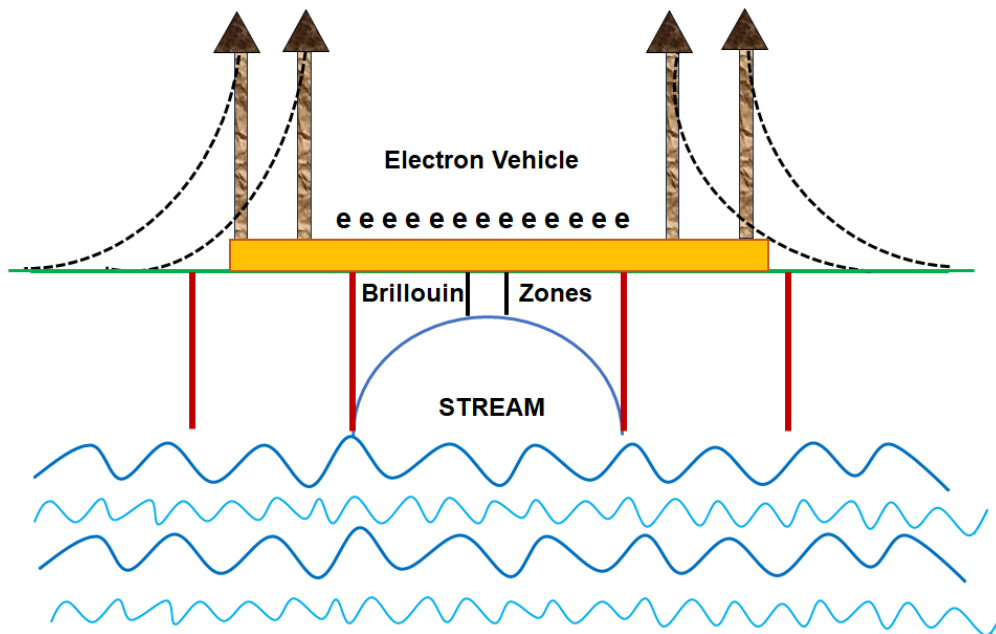


Fig. XII: Superconductivity represented as Tower Bridge and Vehicles

Region 3: This region describes thermal properties of solids namely, specific heat, thermal expansion and thermal conductivity which are mostly dependent on lattice vibrations of atoms (phonons) with marginal effect from nuclear architecture. This slightly affects the properties of electronic specific heat. A phonon is the quantum of elastic energy of lattice vibration.

Specific heat

The heat capacity of solid is zero at 0K and rapidly rises with temperature to a value of 6 cal/mole (Dulong and Petit) [29]. This was theoretically deduced by Boltzmann. The discrepancy of the value of specific heat near 0K and above 40K was explained [30, 31] by Einstein and Debye. The electronic specific heat is contributed by free electrons near the Fermi level and their concentration is only about 1%. Other contribution comes from second order transformation like randomization of spins in ferromagnetic materials and change of distribution of electrons in superconductivity. All in all, the contribution of nuclear architecture on specific heat is marginally small.

Thermal expansion in solids arises from the asymmetry of bonding forces between atoms. Since a lesser force is required to separate atoms in a lattice than to press them closer together, increased thermal vibration tends to increase the range of atomic spacing.

Thermal conductivity arises from the transfer of heat through a solid by the phonons and electrons. Metals which are best conductor of heat, use the free electrons for the purpose.

About real and virtual alpha particles, Radioactive emissions and Nucleosynthesis:

It is now possible to correlate the nucleosynthesis, formation of virtual α - particle, the formation of real α - particle along with radioactive α - emission in a single framework. We consider the interconversion of proton and neutron by the exchange of an electron as represented in Fig. XIII.

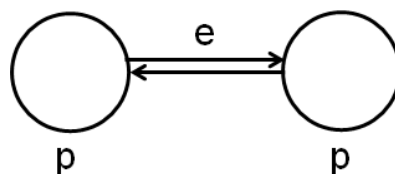


Fig. XIII: Interconversion of Neutron and Proton

An electron is made up of three d-quarks, each with a binding energy of 4.7 MeV. The p – n pair is termed Paulion [7] which is an isomer of deuteron ${}^2\text{H}_1$. The deuteron is a Boson with an accepted value of Binding Energy 2.2 MeV which cannot form ${}^4\text{He}_2$ by condensation either energetically, stereo-chemically or kinetically. For that matter, Paulion containing three d-quarks from an electron with a maximum Binding Energy of $4.7 \times 3 = 14.1$ MeV is also not able to condense to form an α - particle (with B.E. 28.2 MeV). Due to the rigidity of the nuclear structure and lack of mean free path [8], the inner zone of the nucleus is not free for the motion of the p – n pair. But the Paulions at the peripheral dodecahedral or icosahedral shells are freer to move in energy-rich condition in a more flexible environment. Thus, the inner Paulions do not condense and may be regarded as virtual α -particles. The peripheral Paulions use the availability of flexible, energetic free space to arrange themselves to stereo-chemically adjustable configuration. Available six d-quarks from two Paulions will adjust themselves to form 6 shared d-quarks along the six sides of a tetrahedron to form a real α - particle with B.E. of $6 \times 4.7 = 28.2$ MeV as discussed in an earlier communication [32].

The presence of virtual α - particle and correspondingly the absence of any real α -particle indicates that the often-considered alpha cluster model for nucleosynthesis is to be totally discounted. There is only one real α - particle at the core of a nucleus around which all other p – n and n – n pairs are arranged as the building blocks in the nucleosynthetic process.

The emission of an α - particle from a radioactive nucleon depends on three factors: 1) the preformation process, 2) the frequency factor and 3) the probability factor. The formation of a real α - particle in dodecahedral or icosahedral shells constitutes the preformation factor like hatching of an egg to form a nestling. The frequency factor indicates the number of times the α - particle hits the cage like the fledgling gains energy and tries to fly away. The probability factor is usually considered as a quantum mechanical tunnel effect which is rather questionable considering the mass of an α - particle. More acceptable is to consider the dynamics of the cage

of the p – n pairs through which the α - particles escape when the cage permits like the flying off the bird through the open window.

A question may arise as to how the six d-quarks in the preformation process of the α -particle arrange to form a tetrahedron? This may be explained as the catalytic effect of a third p – n present in the dodecahedral or the icosahedral shell of the nuclear architecture. The three p – n pairs are arranged in the manner shown in Fig. XIV to form a pseudo hexagon (which may not be as flat as is shown). Along with three usual p – n pairs, there are three more long range p – n forces forming a total of six attractive forces. These attractive forces distort the hexagon to change the stereochemical conformation of the structure. These bring the p – n pairs in chair conformation in which a tetrahedral structure is attained by overlap of six quarks as shown in the figure by dotted lines. The extra p – n escapes after its role as a catalyst is performed successfully.

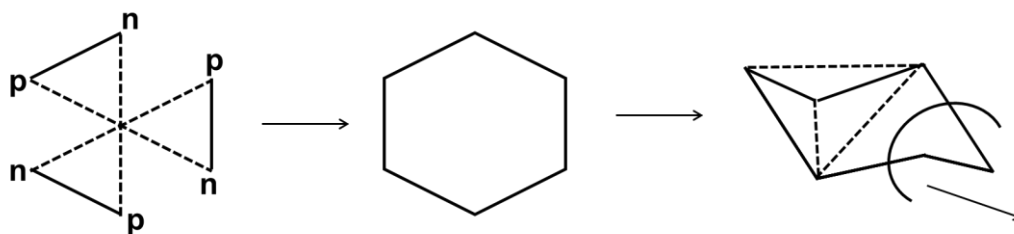


Fig. XIV: Catalytic Effect of p – n in the formation of real alpha particle

Conclusion:

Different types of magnetism namely, diamagnetism, paramagnetism, ferromagnetism, ferrimagnetism have been traced to neutrons in the nucleus of an atom. The neutron is a composite particle which owes its power of magnetic influence to the presence of π - mesons. Through the interchange of mesons which changes direction, the neutron imparts tremendous power of attraction which is known as nuclear force. In some atoms and simple molecules, the

dimensions are much greater than the nucleons. This attraction is much smaller but is still quite considerable to hold the constituents together. This provides a completely different explanation for the attractive force which is usually described as exchange force of the electrons. As this magnetic force is not proved quantitatively, this suggestion may be tested as an alternative to the exchange force. The idea of Yukawa's suggestion may be overcome by considering in-phase revolution of u- and d- quarks between a proton and a neutron to make them equivalent in the p – n pair thus making their directive influence on neutron to alternate the magnetic moments. This causes the pairing of s- and p- electrons possible. A free neutron is seemed to generate spin-waves to lead to ferromagnetism in iron group of atoms.

Involvement of quantum mechanical tunnel effect in the explanation of superconductivity seems to be questionable. Tunnel effect may occur at any temperature from very high to very low but superconductivity is restricted to relatively lower temperatures. Opening up of the three-dimensional channels through overlap of Brillouin Zones in reciprocal space may be considered as an alternative.

It appears conclusive that Paulion (p – n pair) which is an isomer of deuteron is the real building block of nucleosynthetic process.

Erratum:

We are sorry for an inadvertent error in an earlier communication in this series as stated below:

Sen, B.K., Sen, S., Architectural Pattern, Characteristics and Binding Energies of Nuclides in Terms of Quarks of Quantum Chromo Dynamics, viXra e-print archive, 2212.0166v1(2022), <http://viXra.org/abs/2212.0166>. **Page 27, Line 3 from bottom, Read “neutron” in place of “electron”**

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