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Unfolding The Multiplex Marrow Matters Of Quantum Mechanics

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***Abstract:** This paper accounts to unfold the different dimensions of quantum mechanics as well as it tries to throw light on the different theories regarding nuclear physics. Special care has been taken to enlighten on the use of nuclear physics in the field of medical science and modern health care. To meet the energy need of today we need an alternative source which should be perfect from each and every angle and that could be done by the blessings of nuclear physics that is by virtue of the nucleosynthesis. It has efforts to clarify the concepts and possibilities regarding the nuclear fission and fusion phenomena. Here efforts have been taken to give a clear concept of the structure of the atom and the nucleus especially. Apart from all these things the paper has tried to focus on the different experiments at different levels with some graphical and pictorial evidences.*

***Keywords:** Quantum Mechanics, Nucleosynthesis, Isotopes, Mesons, Fission, Fusion, EURISOL, Super heavy Nuclei, Radioactive, Nucleons.*

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I. INTRODUCTION

Now this is a crucial need of the hour that we should have a strong option at hour hand for the future and the present time as well. For this we need to know the nature of the basic elements and atoms. Atoms are mysterious enough themselves. The scientists of different countries are working on its various aspects and possibilities with a great intensity. Ergo, unveiling the structure and functions of atom is obviously one of the greatest discoveries of nuclear physics. The uncovering of the structure of atom as composed of clouds of electrons surrounding a central nucleus, very obviously, is one of the landmarks of the 20th-century scientific discoveries. It has opened several new vistas in various aspects of daily life underpinning modern healthcare, advanced materials, information technology and meeting the need of energy. The significance of nuclear physics and technology has been felt in our core heart over the last decades. Intense and vivid studies of the nucleus have led to many major achievements that have really changed the colour of our lives and also have also been added a number of new dimensions to it. The chemical and physical properties and characteristics of atomic electrons have been studied with due intensity and seriousness in these days by several researchers. And to be very particular, these have been successfully exploited to make pharmaceuticals, modern treatments of a number of diseases, electronic devices and in different sectors. It is observed as well as experimentally proved that the forces, binding together the components of the nucleus, are extremely strong, and hence require the input of high energies, using large accelerator facilities, in order to probe and manipulate their structure and behaviour. Furthermore, the strong interactions involved here are extremely multiplex and difficult to unravel both theoretically and experimentally.

II. SEVERAL ‘HOWS’ IN NUCLEAR RESEARCH: A LOOK

Nuclear researchers are always ready and curious to know the pattern of nucleons arrangement in an atomic nucleus, i.e. “How are the nucleons arranged in nuclei?” Similarly, the researchers and scientists are busy to discover the different types of possible nuclei and different factors who may affect to their stability and the relating phenomena. Hence, it has always been a primary question in the mind of the nuclear researchers that how many kinds of nuclei are possible there and what affects their stability etc.. Another vital phenomenon is yet to know. That is how the building blocks of nucleons – quarks – bound together and what is the chances of their stability and their factors and some other related phenomena. How did quarks first form nucleons, and how did the nucleons then build up into the elements? This is one of the bigger question occurs ever in the mind of the nuclear researchers. Eventually, they want to know how and when or in what method we can exploit the properties and behaviour of nuclei and carry on several experiments on those.

III. BASIC NUCLEAR MODELS: A LOOK

There are a few number of models found as suggested by different scientists of different time. The commonest of them are the Cluster model, LD Model (Liquid Drop Model), Shell Model and the Solid Phase Nuclear Model (SPN Model).

A. CLUSTER MODEL

It is such a model which gives emphasis on the alpha particles. That is most probably it assumes anything with respect to the alpha particle, its structures and functions. "It proposes that nucleus is a cluster of alpha particles. The main property that cluster model accounts for is the alpha decay." [01]

B. LIQUID DROP MODEL

This model gives stress on the position of nucleons and their existence. It states that nucleons do exist in nucleus just like the molecules in liquid drop. The properties that liquid drop model could account for are the constancy of nuclear density consequently, the nuclear radius, also the nuclear binding energy and the fission process, but could not account for asymmetrical fission. [02] This may be stated as its one of the draw backs. Still, but the asymmetrical fission it states all other aspects very clear.

C. SHELL MODEL

According to this, the nucleons exist in gaseous state. The main property that shell model accounts for is the stability of nuclei which have certain numbers of protons or neutrons called magic numbers. [03] It says and more particularly gives emphasis on the number of neutrons and protons in an atom. Alternatively, it says that the ratio in which tare combined and by means of which the nucleus does exist is the most important thing. Hence, it well explains the existence of the atom as well as the existence of a nucleus. A comprehensive description of the nucleus; therefore, most likely should come from a model representing a different phase. The remaining phase left is solid. [04] It is the SPNM.

D. SOLID PHASE NUCLEUS MODEL

In the last few decades scientists and researchers have started to ponder and ponder to account for a solid nucleus model. The Solid phase has not been considered as a viable option for many decades as the uncertainty principle and the lack of diffraction is there within.. In the 1960s the discovery of quarks and neutron star researches satisfactorily did answer to these objections and uncovered the mysteries and unfolded the door for solid nuclear structures. The proposed models assume that the protons and the neutrons have same size; the individual nucleon has a spherical shape; protons and neutrons are alternating; and the nucleons are arranged in a close packing crystal structure. These assumptions are reasonable. The radii of protons and the neutrons differ only slightly. [05] The main property that solid phase model accounts for is the asymmetrical fission. This was the lacuna of all other models propounded before. Another model of Nucleus is the FCC Lattice Model.

E. FACE-CENTERED-CUBIC (FCC) LATTICE MODEL

The FCC Lattice model of Nuclear Structure is well explained *by Norman D. Cook.* [06] This model completely considers the nucleons to have FCC lattice structure within an atom. This solid phase model accounts for nuclear properties that have been explained by different models like: a) Constancy of nuclear density, b) nuclear fission, depending of nuclear radius on A and saturation of nuclear force for liquid drop (LD) model. It has another advantage in it and that is it observes and gives the relationship between lattice positions of nucleons and quantum number in shell model. It also dealt with nucleus as alpha particles constructed body. Again, this model gives some explanation for asymmetric fission. Hence, it is comparatively a better model than other ones. Another prompt and more correct model has been discovered in this field by the researchers. That is the Body Centered Cubic (BCC) Lattice Model.

F. BODY-CENTERED-CUBIC (BCC) LATTICE MODEL

This model gives the smartest structural and functional ideas as well as it provides ample scopes with a number of analytical facilities to understand the nucleus better. It accounts for many nuclear properties like FCC model, but this model has an advantage that it gives more accurate explanation for asymmetric fission, its natures and products even about the nuclear binding energy and gives a new formula for calculating it. It provides several new properties of the nucleus which could not be explained or shown by any other model of nuclear structure. The crucial part or the main advantage of the shapes of nuclei in BCC model is that the distance between the identical nucleons will be much bigger than the distance between unlike nucleons and these distances will be kept constant in any nucleus. This advantage also exists in Simple Cubic lattice. It is clear that this shape (figure 1.1) gives the mentioned advantage, but it is a planner shape.

So how could we get the real shape of alpha particle?

The actual and factual shape of alpha particle (The BCC lattice) could be explained with respect to the Figure 1.2. given hereby below.

Two opposite sides of the square rotate on each other until we reach the real shape of alpha particle which will be two

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identical triangles shared in base and perpendicular on each other.

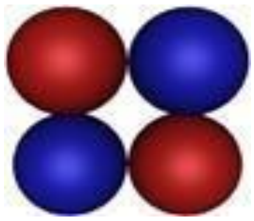
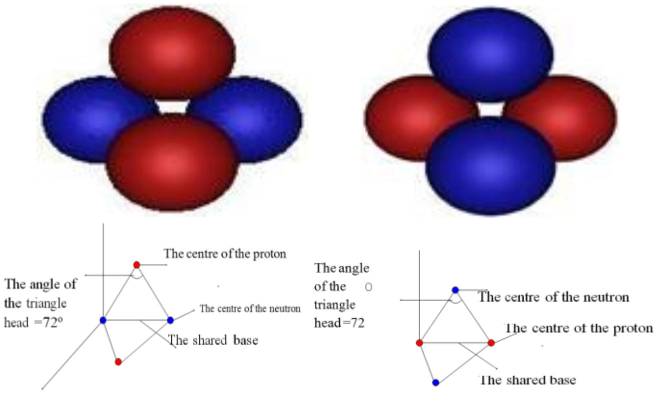


Figure 1.1



*Note: *The above two shapes are the same one but only rotated.*
***The distances are calculated from the centers of the nucleons*

Figure 1.2: The shape of ${}_2He^4$ Nucleus

IV. INTRODUCING ATOM: POSSIBILITIES AND SCOPES

A concentrated mass of positive charges surrounded by lightweight negative charges form an atom. Atoms, basically, consist of a positively charged nucleus, surrounded by lightweight negative electrons. The electrons are proved to be responsible for the chemical binding of atoms into molecules as well as for conducting electricity. Nuclei consist of positively charged protons and neutrally charged neutrons. Together, they are responsible for the mass of the element. The number of protons gives the element's atomic number. The lightest element, hydrogen, has one proton in its nucleus where as the heaviest naturally-occurring element, uranium, has 92 protons. Elements can have varying numbers of neutrons, which are essential for stability, giving rise to isotopes with different masses. Some isotopes are unstable, spitting out alpha particles (helium nuclei), electrons (beta-radiation) or positrons (the positive, antimatter version of electrons), together with high-energy electromagnetic radiation (gamma-rays). They are then transmuted into other elements. Many radioactive isotopes exist naturally on Earth and in stars, but they are also made in the laboratory. Protons and neutrons each consist of three fundamental particles called ***quarks***. They are combinations of the two lightest quarks; there are also four, heavier quarks that form unstable nuclear particles. Quarks can also bind in nuclear pairs to give rise a special nuclear particle called *mesons*, some of which played a significant role in the universe's evolution. Particles such as quarks and electrons also exist in antimatter forms with opposite charge.

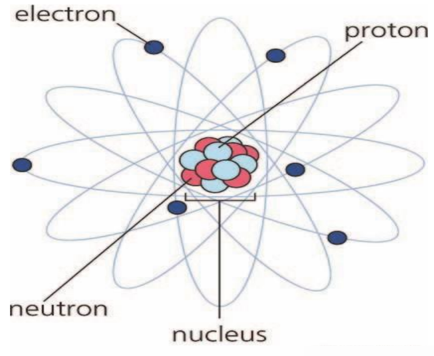


Figure 1.2.1: Illustrating the structure of atom

V. THE ARRANGEMENTS OF PROTONS AND NEUTRONS IN A NUCLEUS

As per the various models and theories and experiments done it is obvious that the nucleons sit in 'shells' with discrete quantum energies to create a diverse range of structures just as electrons are arranged in shells in atoms. So-called magic nuclei, with spherical shells of protons and neutrons, are very stable. However, some heavier nuclei can adopt more unusual shapes, with different shell arrangements. Three different shapes of the nucleus is given in the Fig. 1.2.2. Physicists at the University of Liverpool contributed to this seminal study to find the possible shapes of nucleus and they were successful too. Very light nuclei sometimes behave like clusters of nucleons. But heavy species are described as liquid drops of nuclear matter that can rotate and deform. Theorists and experimentalists work together to test these concepts. This discipline and this phenomenon is still not clear. We have yet to understand the nucleus and its particles and their arrangements.

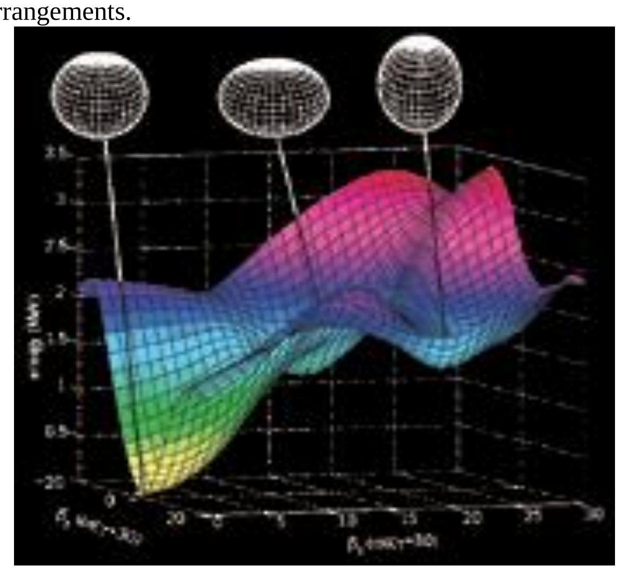


Figure 1.2.2: Experiments have shown that the lead-186 nucleus can adopt three different shapes at quite similar low energies. Physicists at the University of Liverpool contributed to this seminal study

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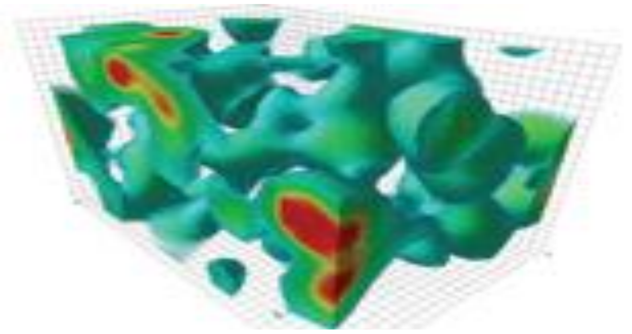

By Derek Leinweber/CSSM, University of Adelaide
Figure 1.8: A graphic visualising quark interactions in a nucleus

VI. POSSIBILITIES OF THE EXISTENCE OF NUCLEI

Possibilities are there to have about 7000 different combinations of protons and neutrons in nuclei. Experimentally, it has also been seen that most of them are short-lived. On the basis of the ratios of neutrons and protons the stability of the nuclei has been measured and assessed. Researchers are busy exploring the outer edges of stability where nuclei with extreme ratios of neutrons or protons can behave in exotic ways. Researchers say, "In very neutron-rich nuclei, for example, the neutrons may form extended 'halos' around a dense core." Again, the 'Super-heavy' nuclei are assumed to be more stable and will exist for a long period. These are totally artificial and are not found naturally.

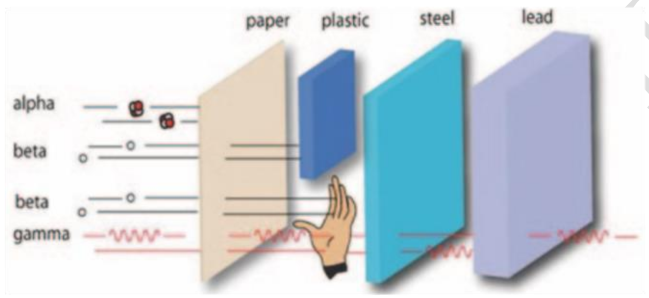

Figure 1.2.4: Penetrating Power of Radiation

The doubly positive alpha particles are heavy, positively charged particles which do not travel very far in air. They cannot penetrate the skin and can only be harmful if emitted inside the body, i.e. if ingested or inhaled. Similarly, the neutrons are the subatomic particles which can have a varying degree of energy. Low-energy or slow neutrons have the ability to transform elements, but are not very penetrating. However, fast neutrons can be destructive to human tissue. The beta particles are are fast moving, negatively charged particles and can travel much further through air than alpha particles. They are more penetrating (i.e. can penetrate the skin) but can easily be shielded, for example by a sheet of plastic. They are more harmful if ingested or inhaled. Gamma rays are waves of energy similar to light, but they have much higher energy and can travel great distance through air. They are very penetrating and require shielding of concrete or lead plating to stop them. Unshielded Gamma rays are harmful inside and outside the body. Similarly, X-rays are lower energy Gamma Rays similar in nature to light. X-rays can more easily penetrate the skin than the bones, and X-ray photographs work on this principle. The figure 1.2.4. shows what is the potency of different nuclear and radioactive rays and their penetrating capabilities.

VII. THE FORMATION OF LIFE AND NUCLEI

Extreme nuclei are really significant because they are thought to form the transient stepping stones in the nuclear reactions. This is by which the heavier elements are built up in stellar processes, particularly the supernova explosions. The elements then spread out into space, to form the construction materials for subsequent generations of new stars and planets – and eventually life. But it is true that this theory is not concrete, hence a number of researches are going on about this phenomenon. One of the fascinating aspect is making out how nuclei, and thus the elements, are cooked up in the fiery cauldrons of stars. Nuclear physicists design experiments to study particular nuclear reactions which may be a key to this process of nucleosynthesis. Many of them involve nuclei with unusual ratios of protons and neutrons, which can be made in the laboratory. This studies account for the origin and formation of element and thus life. This is being interesting day to day.

VII. A QUANTUM SYSTEM IN MINIATURE

Like all atomic and subatomic particles, the nucleus obeys the laws of quantum mechanics, the theory of how matter behaves at a very small scale (million-billionths of a metre for nuclei). A number of phenomena that are seen in nuclei mirror those in larger-scale quantum systems. So the nucleus offers an ideal microscopic laboratory for probing quantum behaviour. Nucleus itself is an autonomous system that obeys all the quantum mechanics with all its parts and particles and moulds the rules as per itself too.

VIII. QUARKS TO NUCLEONS: AN EVER FIXED QUESTION, A MYSTERY

How does nuclear matter behave across the wide range of conditions that exist – or have existed – in the universe- is still a mystery before us. As the researchers do say out of their experiments and out of their number of observations- about 14 billion years ago, much before the first stars formed, the temperature and pressure in the universe were high enough for the *quarks* to be free of their nuclear prisons. But how quarks became confined in protons and neutrons, as well as how they behave in the cooler but unbelievably high-pressure environment of a neutron star- is still a mystery and an unsolved question before the astrophysicist community.

IX. NUCLEAR FISSION: AN OVERVIEW

Nuclear physics is really one of the pertinent most discipline of science with reference to the society and age. This is being taken as an important most alternative source of

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energy for our need. Ergo, it can easily be concluded that nuclear physics and serious research in this field is one of the needs of the hour. We must know the actual strength or power of an atom and the possibilities concealed in it.

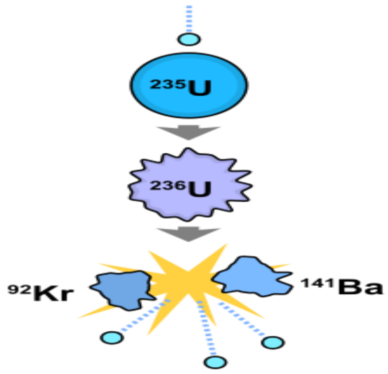

Figure 1.3: Nuclear Fission

Nuclear physics led to the creation of the atomic bomb. There are two types of nuclear reactions: fission and fusion, which are very important processes in the present world and in our life. Fission occurs when atoms usually larger than iron split so that mass is lost and huge amount of energy is emitted. Nuclear reactors produce energy by using the energy created from the fission of large nuclei to run a generator. In nuclear reactors, the elements most commonly split are $_{92}U^{235}$ and P^{238} as they are relatively unstable and capable of splitting. The basic reaction that occurs in a nuclear reactor is that a neutron is absorbed by the $_{92}U^{235}$, which soon after causes the atom to become unstable and split. In this process some unique products come out there. The products of the reaction are: Ba^{138} and Kr^{95} and a couple of neutrons in addition to the initially absorbed one. Therefore, the reaction that takes place here can be given below. i.e. U^{235} + 1 neutron Ba^{138} + Kr^{95} + 3 neutrons.

Nuclear reactors use this method to initiate a chain reaction (a continuous and increasing series of similar reactions) that is capable of producing a large amount of energy. They usually do control one of the chains, i.e. a particular hand and try to bring that to an end to stop the excessive nuclear energy emission process followed by absorption of neutron and atomic fission. If both the hands will run, it will be quite hard and no sooner will be impossible to control the reaction which may lead it to a hazardous explosion. In the nuclear reactors, nuclear chain reactions are created and continued by launching multiple neutrons into a large amount of U^{235} or P^{238}. The elements split and the neutrons released go on to cause another nuclei to split. As more nuclei are split, more power is produced, leading to more energy being created. The reactions are controlled with graphite control rods or it can be stopped by using Deuterium Oxide (D_2O).

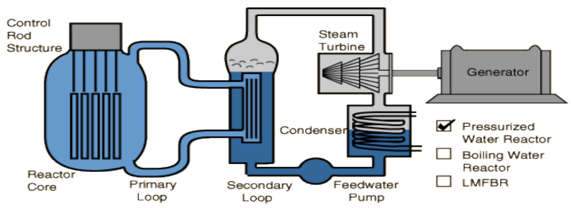

Figure 1.4: A Model of Nuclear Reactor

The graphite control rods or D_2O being retarders absorb extra neutrons that decrease the amount of nuclei being split, thereby slowing down the power emission. Now-a-days the nuclear plants have been prominent sources due to the increase of energy demand and discoveries of alternative energy sources. However, with the Fukushima Nuclear plants failing, along with the disasters in Chernobyl and Three Mile Island, have led many people to see the negative effects of nuclear reactors, despite its cheap energy.

X. FUSION REACTION AT A GLANCE

Nuclear fusion is the chemical reaction by which two light atomic nuclei combine to form a heavier atomic nucleus. As an example, a proton (the nucleus of a hydrogen atom) and a neutron will, under the proper circumstances, combine to form a deuteron (the nucleus of an atom of "heavy" hydrogen). Surprisingly, the net mass of the heavier product nucleus is lesser than the total mass of the two lighter nuclei. Nuclear fusion, in general, is the initial driving process of nucelosynthesis. There are numerous practical problems to set up a controlled fusion reactor. Hence, it has not been possible till date to set up the same. At out hand, the only fusion reactions that take place on earth are uncontrolled fusion reaction in nuclear weapons (e.g., H-bombs). A number of quality researches have been going on since years. Sandia scientists, in April, 2003, reported that a controlled thermonuclear fusion in a pulsed power source is achieved. Controlled fusion, in all respect, holds the promise to generate unlimited clean power. A good phenomenon is there with the fusion reaction, i.e. the fusion based energy technology doesn't produce long-lived radioactive waste.

"Instead of using magnetic containment to compress hydrogen and thereby achieve temperatures hot enough for fusion to occur, Sandia scientists used pulsed releases of current to achieve a rapid series of limited micro fusion reactions. Using an improved and more powerful Z accelerator, high current is induced in a tungsten wire cage surrounding a 2 mm plastic capsule containing deuterium (an heavier isotope of hydrogen). The tungsten cage is vaporized, but the short-lived current impulse generated in the wires creates a powerful magnetic pulse and shock-wave of superheated tungsten that creates an intense x-ray source that, along with the shockwave compresses and heats the hydrogen to more than 20 million degrees Fahrenheit (more than 11 million degrees Celsius) to induce fusion." [07]

Fusion reactions are less radioactive than fission reactions and at the same time it can be observed that in this process more energy is released. Fusion reactions generally occur only and only when light elements, usually Hydrogen or Helium, are fused together to form a heavy and larger molecule in order to lose some mass which is (the lost mass) further converted to energy we find. However, it is crystal clear that the nuclear fusion reaction is comparatively safer than that of the nuclear fission reactions. This process is only possible under extremely high temperature which is quite impossible in laboratory or under artificial reactor condition. This is because the energy needed to sustain fusion reactions can only be created in powerful magnetic fields, which field perturbations.

However, this perception is going to be proved wrong that no controlled fusion reactors will be there on Earth. The Sandia reaction process or the experiment done thereby is a challenge to the so called thought.

"The Sandia reaction process contrasts with another promising approach undertaken at the Lawrence Livermore National Laboratory (LLNL) that seeks to initiate fusion reactions by shining high energy lasers on hydrogen globules. The LLNL approach will be further explored at the National Ignition Facility." [08]

Another interesting phenomenon is there with the said couple of reaction processes, i.e. fission and fusion. It has come to knowledge that a fusion bomb also follows a fission reaction. Fusion principles are based on a fission reaction, that is why, because a fusion bomb uses a fission bomb as a trigger. The fusion principle uses the fission technique as an alternative source of immense heat and pressure to create a fusion chain reaction. Within a few microseconds, fusion begins to occur followed by the fission explosion within the casing surrounding the fission bomb. Here, protons, deuterons, and tritons begin fusing immediately with each other, with a release of high amount of energy, which also helps initiating other fusion reactions among other hydrogen isotopes. In this way the fusion and fission reactions are interlinked.

XI. A LIGHT THROW ON THE FUSION SEQUENCE

The loss of mass in the combination of proton and neutron to form a deuteron is the ultimate source mechanism of the release energy. That is the lost mass is converted into energy. When a proton and neutron combine, the mass of the resulting deuteron is 0.00239 atomic mass units (amu) which is actually less than the total mass of the proton and neutron combined. This "loss" of mass is expressed in the form of 2.23 MeV (million electron volts) of kinetic energy of the deuteron and other particles and as other forms of energy produced during the reaction. In this Nuclear fusion reaction just like nuclear fission reactions, there is some quantity of mass is which transforms into energy. This is the reason the stars "shine" (i.e., radiate tremendous amounts of electromagnetic energy into space). We can only see light due to the electromagnetic wave of energy. The commonly involved particles in nuclear fusion reactions include the proton, neutron, deuteron, a triton (a proton combined with two neutrons), a helium-3 nucleus (two protons combined with a neutron), and a helium-4 nucleus (two protons combined with two neutrons).it is now obvious and crystal clear that except for the neutron, all of these particles involved here, carry at least one positive electrical charge which implies that fusion reactions always require a large amounts of energy in order to overcome the force of repulsion between two like-charged particles. Hence, practically such type of energy centric reactor is not available on this earth under the controlled situations.

Up to 1930s there were several fictitious concepts regarding the fusion reaction in the surface of stars. In 1939, the German-American physicist *Hans Bethe* worked out the mathematics of energy generation in which a proton first fuses with a carbon atom to form a nitrogen atom. The reaction then continues through a series of five more steps, the net result of which is that four protons are consumed in the generation of one helium atom. *Bethe* chose this sequence of reactions as it requires less amount of energy than does the direct fusion of four protons and, thus, is more likely to take place in a star. Bethe was able to show that the total amount of energy released by this sequence of reactions was comparable to that which is actually observed in stars. Obviously it could be told that the *Bethe carbon-cycle* is by no means the only nuclear fusion reaction. The only net difference between ${}_1H^1$ to ${}_2He^4$ reaction and Bethe's carbon cycle is the amount of energy involved in the overall set of reactions. Other fusion reactions include D-D and D-T reactions. i.e.

Deuterium + Deuterium = He^3 + 1 neutron +Energy … (i)

Deuterium + Tritium = He^4 + 1 neutron + Energy … (ii)

A few million degrees of energy is needed for fusion reactions, for which it is otherwise known as thermonuclear (thermo = heat) reactions. The heat to drive a thermonuclear reaction is created during the conversion of mass to energy during other thermonuclear reaction. Here, mass is the cause of energy and the law of conservation of mass and energy is well applied.

"In March of 1989, two University of Utah electro-chemists, Stanley Pons and Martin Fleischmann, reported that they had obtained evidence for the occurrence of nuclear fusion at room temperatures (i.e., cold fusion). During the electrolysis of heavy water (deuterium oxide), it appeared that the fusion of deuterons was made possible by the presence of palladium electrodes used in the reaction. If such an observation could have been confirmed by other scientists, it would have been truly revolutionary. It would have meant that energy could be obtained from fusion reactions at moderate temperatures. The Pons-Fleischmann discovery was the subject of immediate and intense scrutiny by scientists around the world. It soon became apparent, however, that evidence for cold fusion could not consistently be obtained by other researchers. A number of alternative explanations were developed by scientists for the apparent fusion results that Pons and Fleischmann believed they had obtained and most researchers now assert that Pons and Fleischmann's report of "cold fusion" was an error and that the results reported were due to other chemical reactions that take place during the electrolysis of the heavy water." [09]

On this fusion reaction a number of experiments are going on by different countries. For the defense purpose also many of the nations are trying to have this reactor and produce weapons with this nuclear fusion reaction. But at the same time it can be a better alternative of the energy need and meeting the same. These may make or mar the mankind, which depends upon the human intension. By the way in January 2003, the United States rejoined the International Fusion Program, which is of course an international effort to construct an experimental fusion reactor. Recent progress in controlling plasmas and developing technologies for burning plasma reactors may eventually provide a workable containment system.

XII. NUCLEAR PHYSICS AND TECHNOLOGY

The dimensions of our lives have come out with several radical changes over the past few decades. Scientific intensive studies of the nucleus have led to many major developments in different sects of our lives and the society itself. One of the most significant change or development that has come about is in the field of medicine: in developing nuclear methods to treat cancer safely, to analyse biological processes and diagnose diseases using medical isotopes, and to image the body non-invasively. The application of nuclear-based analytical techniques continues to revolutionize the chemical and life sciences, and plays a significant role in monitoring the environmental changes, as well as providing new portable devices used to aid national security. A prominent application of nuclear research is in developing the long-term means of securing our energy needs within a low-carbon economy. Nuclear transmutation is also being investigated as a means of destroying nuclear waste safely. This is one of the most important thing that we deal with this time. Nuclear science has immense possibilities in it to solve several problems occurred in history even. Previous nuclear tragedies may be solved by this discipline itself.

Studies of the nucleus are now extending our understanding of the basic laws and creation phenomena of nature that is how the universe evolved and does it exist etc. Nuclear physics research today involves exploring more exotic phenomena found in stars and the early universe. One of the most exciting areas of research is the investigation of stellar processes by which all the elements are created, which involve unusual, unstable nuclear species. Physics shows its mysterious identity by this discipline and most of the scholars get attracted to this discipline for this only.

XIII. THE UK ROLE IN NUCLEAR RESEARCH

The UK has played the significant role in the field of nuclear science from the beginning. The atomic nucleus was discovered at the University of Manchester for the first time and much of the early, numerous seminal research works into nuclear structure was carried out in the UK. Now other than UK this nuclear research is being carried out in Germany and France. The Engineering and Physical Sciences Research Council (EPSRC) and The Science and Technology Facilities Council (STFC) fund for the various nuclear research indifferent sectors. Now, UK is funding for different engineering and nuclear research programmes. All the matter we see around us are composed of different types of atoms. Deep in the heart of each atom there is the nucleus, which is composed of yet smaller particles, protons and neutrons (nucleons). Their behavior is controlled by three fundamental forces of nature – the strong force, together with the weak and electromagnetic forces. These forces combine to generate highly complex nuclear structures that are challenging to study and understand. This complex structure and energy based force is responsible for the large scale energy emission. The UK is having an experiment called NuSTAR. It is contributing to NuSTAR (Nuclear Structure, Astrophysics and Reactions) at a major new European facility based in Darmstadt, Germany – the Facility for Antiproton and Ion Research (FAIR). It will comprise a large accelerator complex for generating intense beams of a wide range of nuclei, of which many are unstable and very rare. The antiprotons beams (the antimatter version of protons) will also be generated to investigate quark interactions. Different nations are having their nuclear super specialized research centres to carry out the same and to ensure the new discoveries. At CERN in Geneva, Switzerland, the UK is already involved in ALICE, an experiment using the Large Hadron Collider (LHC) to study and know the whole phenomenon how quarks first interacted in the early universe. European physicists are also considering a future facility, EURISOL, to produce even more intense beams of exotic nuclei. The NuSTAR experiment can have a glance in the Fig. 1.8. Yes, how can we forget the contribution and the role of the university of Manchester in discovering the existence of the atomic nucleus. Today, the UK nuclear physicists continue their studies at facilities around the world: in Europe, the US, Canada, Japan, South Africa and even in Australia. The core community includes groups from the Universities of Birmingham, Brighton, Edinburgh, Glasgow, Liverpool, Manchester, Surrey, the West of Scotland and York, as well as the STFC Daresbury Laboratory in Cheshire. Increasingly, nuclear physics and its applications are becoming multidisciplinary, involving astrophysicists, and atomic, laser, medical and particle physicists, as well as materials scientists and engineers. This is a good sign for the lover of this discipline. And of course, it is becoming more and more wider and having more and more scopes within it.

XIV. QUARK-GLUON PLASMAS AND POSITRON IMAGING

As the world's most powerful particle different universities are studying the plasma, the positrons and quark particles. This Nuclear matters react at the extreme temperatures and pressures, just as in the conditions of the early universe. The researchers are busy enough in making and characterising quark-gluon plasmas; a perfect liquid of 'free' quarks and gluons using the ALICE detector. This new state of matter is also studied using the STAR detector at the RHIC accelerator facility at Brookhaven National Laboratory in the US. This advance research is of course a good news for the nuclear physics society and its lovers.

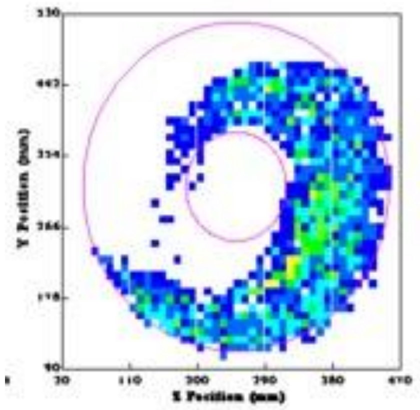

Figure 1.5: Positron imaging

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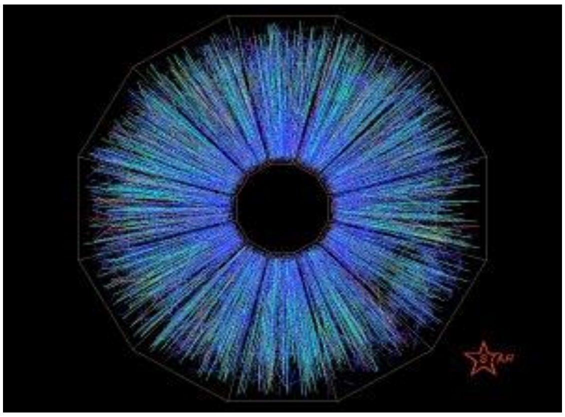

Figure 1.6: Quark-Gluon Plasmas

Researchers are producing the positron emitting isotopes. It is very useful in the fi of medicine, healthcare and automobile industries. The positron imaging in physics techniques is done to solve the real world problems. These positron-emitting isotopes are used to tag tracer particles both for studying real-time flow in industrial processes and for diagnosis in hospitals around the country. By detecting the back-to-back emission of gamma-rays that follow the annihilation of a positron and electron pair, imaging with millimeter precision in applications ranging from the lubricant distribution in engines and dynamic studies of fluid flow through geological samples is possible.

XV. EXPERIMENTS IN NUCLEAR PHYSICS AND TECHNOLOGY – INSIDE THE ATOM

In the nations like USA, UK, Germany, France and in many countries the large scale and super specialized experiments are being performed in the field of nuclear physics. To know the internal structure, function and behaviours of the subatomic particles various experiments have been performed. To perform experiments to understand the nuclei require large-scale equipments that can accelerate to high energies beams of subatomic particles and charged ions. (atoms stripped of most of their electrons). These projectile nuclei are then directed onto a target. The principle is to make new nuclear species, either by fusion or fragmentation. That is by the fusion of the projectile nuclei with those in the target, or by fragmenting the nuclei. Three things are kept in sight as important aspects of the research. They are- the masses, lifetimes and the energies of the particles and the radiation (gamma-rays) emitted. These three things are measured carefully. Another aim is there to make new magic nuclei and study their structure. Often, the nuclei are generated in high-energy states with unusual shapes, and may be set spinning fast. The gamma-rays emitted, as the nuclei lose energy, give information about the respective nuclear structure and behaviour. Forming mirror nuclei is also a part of this experiment. Researchers are keeping interest in this too. They are testing their binding energy and other behaviours therein. To understand the binding forces better, nuclei may also be prepared where the proportions of protons and neutrons have been interchanged – to formulate ‘mirror’ nuclei. Additional experimental approaches include smashing together beams of heavy nuclei at high energies, with the aim of breaking them up into the constituent quarks; high-energy lasers and electron beams are used to probe the structure of target nuclei; and very high-energy lasers can induce nuclear reactions such as fission and fusion. medical and particle physicists, as well as materials scientists and engineers.

Figure 1.7: A photo of the NuSTAR experiment at FAIR in Germany

The forces holding nuclei together operate in an extremely complex way that is still not well understood. For example, the constituent quarks of a proton account for only one-fiftieth of its mass, with the rest arising from strong force interactions. Understanding the huge variety of nuclei, and the forces holding them together, not only helps scientists to understand the evolution of the universe and the conditions leading to life, but also provides the underpinning knowledge needed to exploit nuclear properties in new technologies. The nuclear science has its different and significant uses in the field of Energy Sources, Nuclear Forensics, Home land Security, Radiation treatments, Material science and Imaging and Diagnostics and in Art & Archaeology. It has its uses in the field of energy storage, nuclear trafficking proliferation, Radiobiology, various medical diagnosis and medical therapies, material analysis, Nanotechnology Ion Implantation, Material Structure, Geology & Climate Environment, ADS and transmutation, nuclear forensics, quantum computing, software development, Monte Carlo simulation, Network Simulation in the field of computing, Weapon Analysis, functionality etcetera are done with help of this branch and its techniques.

XVI. CONCLUSION

The forces holding nuclei together operate in an extremely complex way that is still not well understood. For example, the constituent quarks of a proton account for only one-fiftieth of its mass, with the rest arising from strong force interactions. Understanding the huge variety of nuclei, and the forces holding them together, not only helps scientists to understand the evolution of the universe and the conditions leading to life, but also provides the underpinning knowledge needed to exploit nuclear properties in new technologies. The nuclear science has its different and significant uses in the field of Energy Sources, Nuclear Forensics, Home land Security, Radiation treatments, Material science and Imaging and Diagnostics and in Art & Archaeology. It has its uses in the field of energy storage, nuclear trafficking proliferation,

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Radiobiology, various medical diagnosis and medical therapies, material analysis, Nanotechnology Ion Implantation, Material Structure, Geology & Climate Environment, ADS and transmutation, nuclear forensics, quantum computing, software development, Monte Carlo simulation, Network Simulation in the field of computing, Weapon Analysis, Functionality etcetera are done with help of this branch and its techniques. Medical Diagnosis (PET, MRI) cancer treatment with proton or heavy-ion beams, Radioactive dating (geology, paleontology, archeology, art) carbon-14 and uranium / thorium "clocks", Interplanetary spacecraft powered by nuclear energy (e.g. Pu-238 α-decay used by Mars rover "Curiosity") Household (smoke detectors, americium-241 α-decay). Similarly, the Positron Emission Tomography (PET) study metabolism, brain and heart functions uses radioisotopes (positron emitters such as fluorine-18). In this way this branch is as interesting as mysterious. Hence, it is told that a number of chapters are still to be opened, still to be unfolded.

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