Chapter one

Introduction

(1.1) Introduction:

The first reactors built by E.Fermi and Coworkers aroused wide interest in the construction of reactors, not only for academic and research purposes but also to meet our energy requirement. Nuclear reactor is just like a furnace where fuel like Uranium or Plutonium burns (controlled chain reaction) giving neutrons, radio-isotopes and enormous energy in the form of heat which can be utilized to produce steam to run turbines for production of electricity. Nuclear reactors are high complex installations and therefore physics of reactors is a vast. However, we shall describe some of the general types of nuclear reactors. The design, construction and operation of a nuclear reactor are today part of a huge and expanding field of nuclear engineering. The power level at which a reactor operates is proportional to the rate of fissions, which in turn, depends on the number of neutrons in the reactor [1]. Therefore, by controlling the number of neutrons, we can control the power level of reactor. As an energy source, fusion has several obvious advantages over fission: the light nuclei are plentiful and easy to obtain, and the end products of fusion are usually light, stable nuclei rather than heavy radioactive ones. There is one considerable disadvantage, however before light nuclei can be combined, their mutual coulomb repulsion must be overcome. Fission induced by neutrons has no coulomb barrier and thus very low energy incident particles can be used, indeed, the cross section for U^{235} increases as we reduce the neutron energy. On the other hand, cross sections for reactions induced by charged particles tend to decrease with decreasing energy. Of course, fusion also powers the sun and other stars and is therefore ultimately responsible for the evolution of life on earth. Understanding fusion is critical for understanding the end products of stellar reactions, when the thermonuclear fuel is mostly exhausted and a star may pass through anova or supernova stage ending as a chunk of cosmic ash or a neutron star or black hole . In this research, we cover the basic physics of fusion processes, controlled fusion reactors, and thermonuclear weapons[2].

(1.2) Research problem

The need of technology development, safe reactor, medical reactor, radiation therapy, generating electrical power and distributing energy.

(1.3)Aims:

To study the nuclear reactors and its types in term of physical concepts and their applications to explain nuclear reactor behavior, and in particular we study in details the nuclear fusion.

(1.4) Thesis layout:

Nuclear reactor physics play an important rule in area of peaceful application such as generating electrical power. There are other uses than electrical power production. The nuclear reactor are also used for basic neutron physics research, for material testing, for radiation therapy, and also national security applications.

(1.5) Research layout:

This work has come into four chapters. Chapter one, Introduction. Chapter two, atoms and nuclear. chapter three, nuclear fusion. and chapter four, results and conclusions.

Chapter two

Atom, nuclear reactors and isotope hydrology

(2.1) Introduction:

The first recorded speculations as whether matter is continuous, or is composed of discrete particles, were made by the Greek philosophers.
In particular following ideas of Anaxagoras (500-428 BC), and Empedocles (484-424 Bc), leucippus (ciraca 450 Bc) and his pupil democritus (460-370) argued that the universe consists of empty space and indivisible particles, the atoms, differing from each other in form, position and arrangement. The atomic hypothesis, however, was rejected by Aristotle (384-322 Bc) who strongly supported the concept of the continuity of matter[3]. In this chapter we discuss the Atom, nuclear reactors and isotope hydrology.

(2.2)Atom:

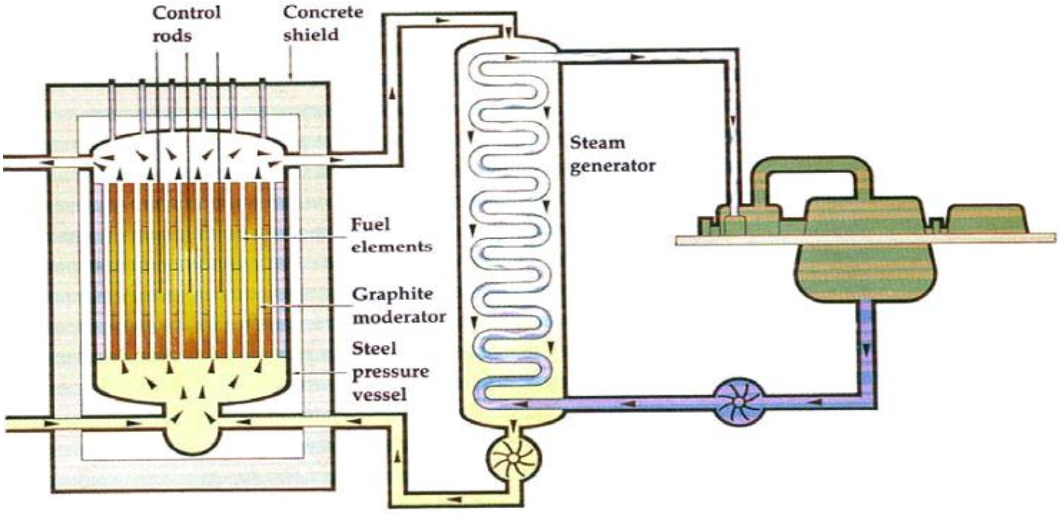
An atoms is smallest unit of matter that define the chemical elements. Every solid, liquid, gas and plasma is made up of neutral or ionized atoms. Atoms are very small: the size of atoms is measured in picometers-trillionths (10-12) of mete [3,4]. Every atom is composed of nucleus made of one or more photons and usually an equal or similar number of neutrons (except hydrogen-1, which has no neutrons). Protons and neutrons together are called nucleons. The nucleus is surrounded by one or more electrons over 99.94% of atom's mass is in the nucleus [4]. The protons have appositive electric charge, the electrons have a negative electric charge, and the neutrons have no electric charge. If the number protons and electrons are equal, that atom is electrically neutral. If an atom has surplus or deficit of electrons relative to protons, then it has an overall positive or negative charge, and is called an ion. Electrons of an atom are attracted to the protons in an atomic nucleus by this electromagnetic force. The protons and neutrons in the nucleus are attracted to each other by different force, the nuclear force which is usually stronger than the electromagnetic force repelling the positively charged protons from one another. Under certain circumstances the repelling electromagnetic force becomes stronger than nuclear force and nucleons can be ejected from the nucleus leaving behind a different element: nuclear decay resulting in nuclear transmutation. The number of protons in nucleus defines to that chemical element the atom belongs the electrons influences the magnetic properties of an atom. Atoms can attach to one or more other atoms by chemical bonds form chemical compounds such as molecules. The ability of atoms to associate and dissociate is responsible for most of physical changes observed in nature and is the subject of discipline of chemistry. Not all mass of the universe is composed of atoms. Dark matter comprises more of the universe than matter, and is composed not of atoms, but of particles of a currently unknown type. Also the classical physics of Newton dose not explain many of the properties and behavior of atoms and sup-atomic particles the field of quantum mechanics has been developed to better do so[4].

(2.3) Nuclear Reactor Types:-

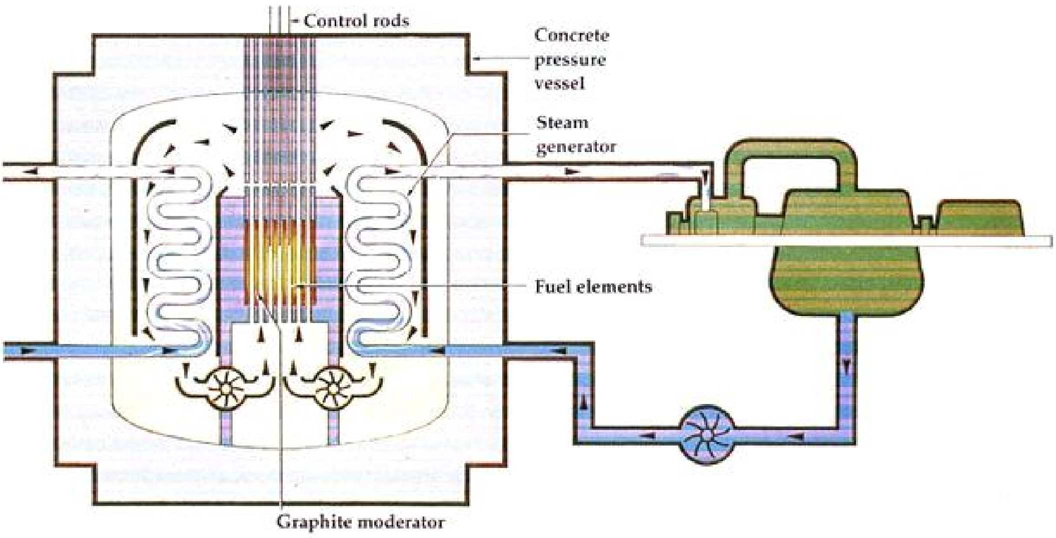
Many different reactor systems have been proposed and some of these have been developed to prototype and commercial scale. Six types of reactor (Magnox, AGR, PWR, BWR, CANDU and RBMK) have emerged as the designs used to produce commercial electricity around the world. A further reactor type, the so called fast reactor, has been developed to full-scale demonstration stage. These various reactor types will now be described, together with current developments and some prototype designs.

(2.4) Gas Cooled, Graphite Moderated:-

Of the six main commercial reactor types, two (Magnox and AGR) owe much to the very earliest reactor designs in that they are graphite moderated and gas cooled. Magnox reactors (see Fig 2.1) were built in the UK from 1956 to 1971 but have now been superseded. The Magnox reactor is named after the magnesium alloy used to encase the fuel, which is natural uranium metal. Fuel elements consisting of fuel rods encased in Magnox cans are loaded into vertical channels in a core constructed of graphite blocks. Further vertical channels contain control rods (strong neutron absorbers) which can be inserted or withdrawn from the core to adjust the rate of the fission process and, therefore, the heat output. The whole assembly is cooled by blowing carbon dioxide gas past the fuel cans, which are specially designed to enhance heat transfer[5]. The hot gas then converts water to steam in a steam generator. Early designs used a steel pressure vessel, which was surrounded by a thick concrete radiation shield. In later designs, a dual-purpose concrete pressure vessel and radiation shield was used. In order to improve the cost effectiveness of this type of reactor, it was necessary to go to higher temperatures to achieve higher thermal efficiencies and higher power densities to reduce capital costs. This entailed increases in cooling gas pressure and changing from Magnox to stainless steel cladding and from uranium metal to uranium dioxide fuel. This in turn led to the need for an increase in the proportion of in the fuel. The resulting design, known as the Advanced Gas-Cooled Reactor, or AGR (see Fig 2.2), still uses graphite as the moderator and, as in the later Magnox designs, the steam generators and gas circulators are placed within a combined concrete pressure-vessel/radiation shield[5,6].



figure(2.1):schematic: Basic Gas-Cooled Reactor(MAGNOX)



Figure(2.2):Schematic: Advanced Gas-Cooled Reactor (AGR).

(2.5) Heavy Water Cooled and Moderated:-

The only design of heavy water moderated reactor in commercial use is the CANDU, designed in Canada and subsequently exported to several countries. In the CANDU reactor, (see Fig 2.3) unenriched uranium dioxide is held in zirconium alloy cans loaded into horizontal zirconium alloy tubes. The fuel is cooled by pumping heavy water through the tubes (under high pressure to prevent boiling) and then to a steam generator to raise steam from ordinary water (also known as natural or light water) in the normal way. The necessary additional moderation is achieved by immersing the zirconium alloy tubes in an unpressurised container (called a callandria) containing more heavy water. Control is effected by inserting or withdrawing cadmium rods from the callandria. The whole assembly is contained inside the concrete shield and containment vessel.

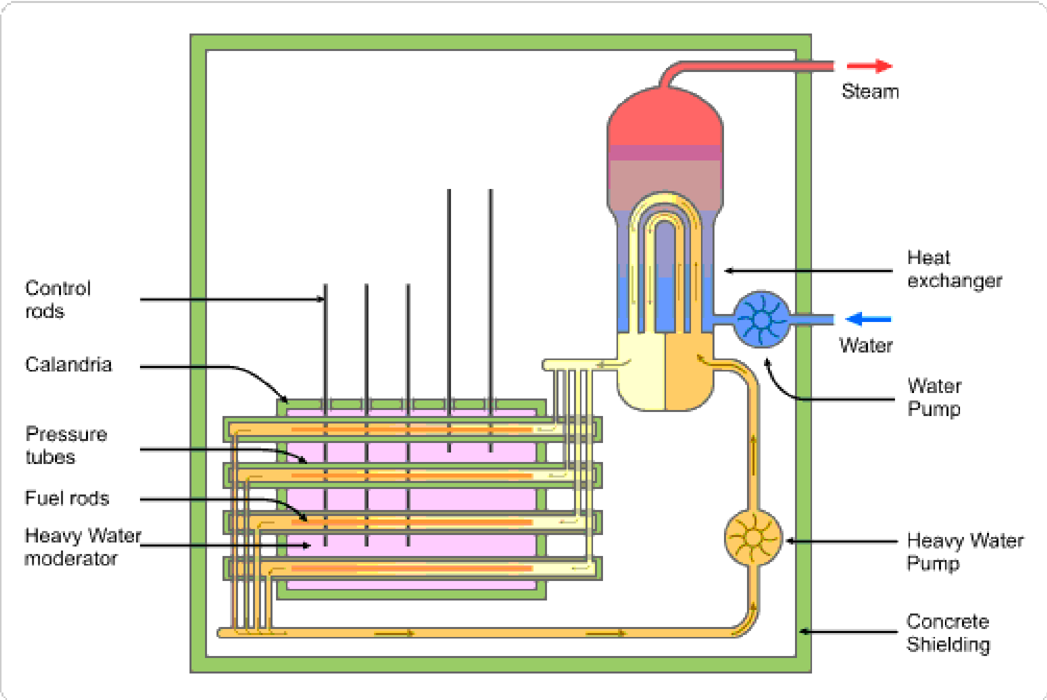
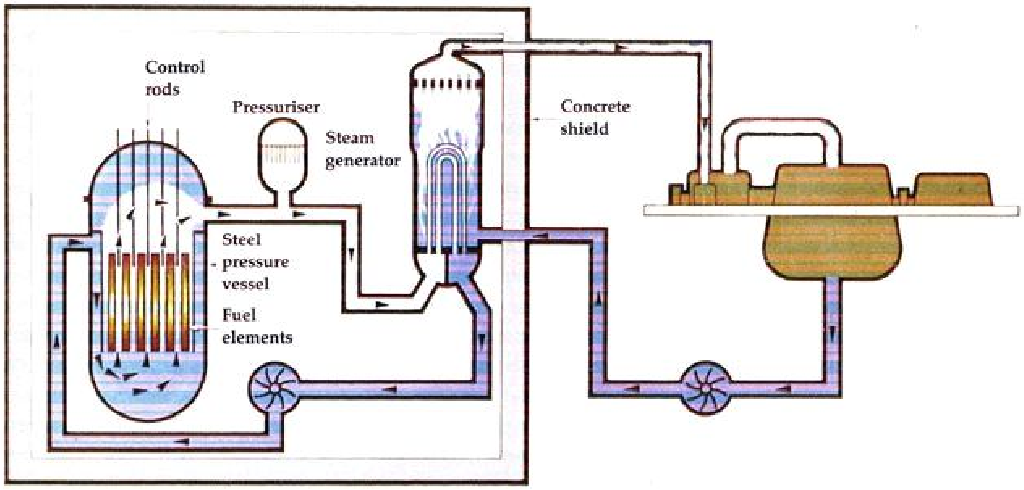


Figure (2.3) Schematic: Pressurised Heavy Water Reactor (CANDU).

(2.6) Water Cooled and Moderated:-

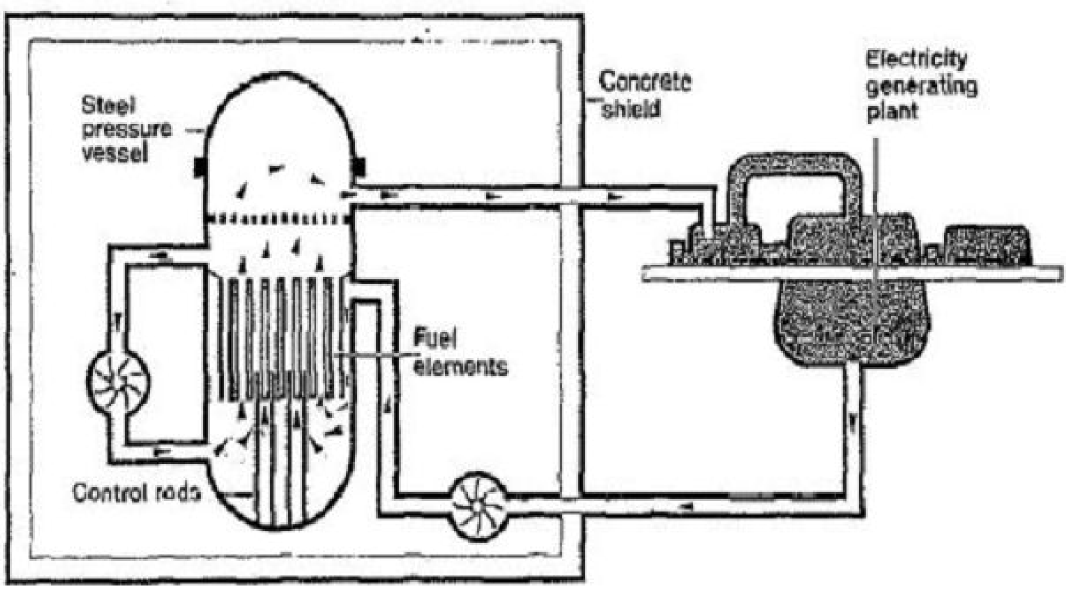
By moving to greater levels of enrichment of , it is possible to tolerate a greater level of neutron absorption in the core (that is, absorption by non-fissile, non-fertile materials) and thus use ordinary water as both a moderator and a coolant. The two commercial reactor types based on this principle are both American designs, but are widely used in over 20 countries. The most widely used reactor type in the world is the Pressurised Water Reactor (PWR) (see Fig 2.4) which uses enriched (about 3.2%) uranium dioxide as a fuel in zirconium alloy cans. The fuel, which is arranged in arrays of fuel "pins" and interspersed with the movable control rods, is held in a steel vessel through which water at high pressure (to suppress boiling) is pumped to act as both a coolant and a moderator. The high-pressure water is then passed through a steam generator, which raises steam in the usual way. As in the CANDU design, the whole assembly is contained inside the concrete shield and

containment vessel[6].



Figure(2.4):Schematic: Pressurized Water Reactor(PWR).

The second type of water cooled and moderated reactor does away with the steam generator and, by allowing the water within the reactor circuit to boil, it raises steam directly for electrical power generation. This, however, leads to some radioactive contamination of the steam circuit and turbine, which then requires shielding of these components in addition to that surrounding the reactor. Such reactors, known as Boiling Water Reactors (BWRs), (see Fig. 2.5) are in use in some ten countries throughout the world.

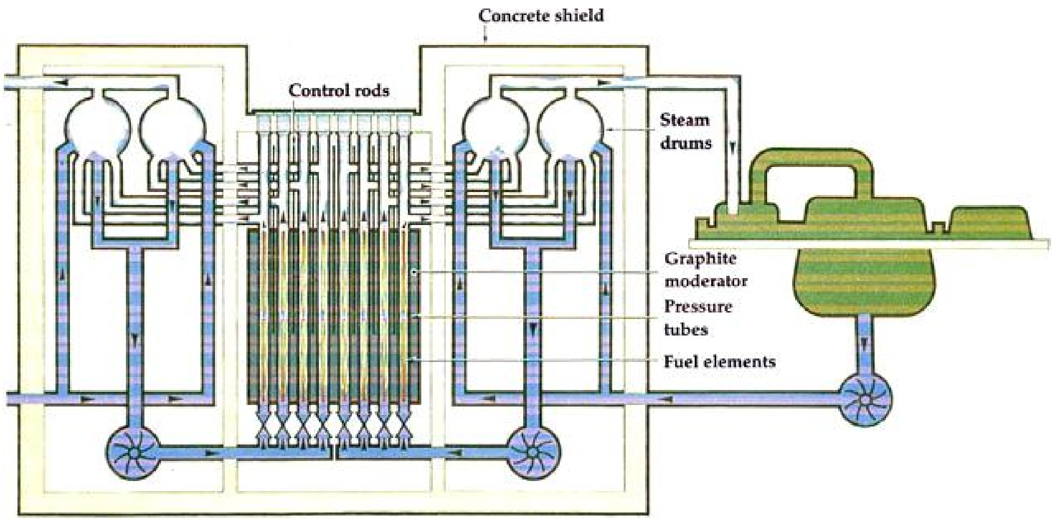


Figure(2.5):Schematic: Boiling Water Reactor(BWR).

(2.7) Water Cooled, Graphite Moderated:-

At about the same time as the British gas cooled, graphite moderated Magnox design was being commissioned at Calder Hall in 1956, the Russians were testing a water cooled, graphite moderated plant at Obninsk. The design, known as the RBMK Reactor (see Fig 2.6), has been developed and enlarged, and many reactors of this type have been constructed in the USSR, including the illfated Chernobyl plant. The layout consists of a large graphite core containing some 1700 vertical channels, each containing enriched uranium dioxide fuel (1.8%). Heat is

removed from the fuel by pumping water under pressure up through the channels where it is allowed to boil, to steam drums, thence driving electrical turbo-generators. Many of the major components, including pumps and steam drums, are located within a concrete shield to protect operators against the radioactivity of the steam[6].



Figure(2.6):schematic: RBMK Reactor Boiliong Light Water, Graphite Moderator Reactor.

(2.8) Fusion reactions:-

Fusion reactions are the combining of two nuclei to form a more massive nucleus. Many fusion reactions release large amounts of energy. An example is the combining of two isotopes of hydrogen (tritium and deuterium) to form helium and a neutron plus a large amount of kinetic energy in the reaction products:

$$H^3 + H^2 \rightarrow He^4 + n + 17.6\ MeV \qquad (2.1)$$

Another example of fusion is the reaction set that powers the Sun and other low-mass stars:

$$H^1 + H^1 \rightarrow H^2 + e^+ + v_e \qquad (2.2)$$

$$H^2 + H^1 \rightarrow He^3 + \gamma \qquad (2.3)$$

$$He^3 + He^3 \rightarrow He^4 + H^1 + H^1 \qquad (2.4)$$

The net energy output from this chain is 26.7 MeV for each helium-4 nucleus formed. Neutron-induced fission of massive nuclei into two lower-mass nuclei plus neutrons is also an energy source for power generation. Compound nucleus formation is a reaction in which two nuclei combine into a single excited nucleus; the excited nucleus lives for a relatively long time and “forgets” how it was formed. The decay from this state of excitation is by “evaporation” of nucleons from the heated liquid drop of the compound nucleus, by gamma decay, or by fission of the compound nucleus. The statistical nature of this process teaches us about the average properties of excited states of complex nuclei. Multi fragmentation reactions, in which high-energy nuclei collide with other nuclei, are a method of creating nuclear matter in unusual conditions of density and excitation energy. These states may be in a different phase from normal nuclei and be characteristic of the matter in the early universe. The fundamental force between nucleons in nuclei is dominated by the exchange of pmesons (pions). When these particles are created in high-energy proton reactions, they can be used to bombard nuclear targets. When the pion interacts with a nucleus, it forms a resonance with one of the bound nucleons. The resonance is shifted and broadened compared to the reaction on a free nucleon. These changes reflect the influence of the neighboring nucleons. When nucleons are flung at one another, they can mesh briefly. During the time they are one nucleus, the quarks in the nucleons can interact with one another as if they were free particles. As with Rutherford scattering, an investigation of the angle that a particle is scattered gives information about the conditions inside the nucleons. The sun is main sequence star, and thus generates its energy by nuclear fusion of hydrogen nuclei into helium . In its core, the sun fuses 620 million metric tons of hydrogen each second. In nuclear physics nuclear fusion is a nuclear reaction which two or more atomic nuclei collide at every high speed and join to form a new type of atomic nucleus. During this process matter is not conserved because some of the matter of the fusing nuclei is converted to photons (energy)[7]. Fusion is process that powers active "main sequences" stars. The fusion of two nuclei with lower masses than iron (which, along with nickel, has largest binding energy per nucleon).generally releases energy, while the fusion of nuclei heavier than iron absorbs energy. The opposite is true for the reverse process, nuclear fusions. This means that fusion generally occurs for lighter elements only and likewise, that fission normally astrophysical events that can lead to short periods of fusion with heavier nuclei. This is the process that gives rise to nucleosynthesis, the creation of the heavy elements during events such as super nova[8].

(2.9) Isotope Hydrology:-

"Isotope Hydrology" is a relatively young scientific discipline (or rather an interdisciplinary field), that evolved since around the 1950s, when it was first realised the methods of nuclear physics for the detection of isotopes could have useful applications in hydrology. The classical tools of isotope hydrology are the isotopes of the constituents of the water molecule (H_2O) itself, namely the rare stable isotopes of hydrogen and oxygenn (H^2, O^{18}) and the radioactive tritium (H^3) These were soon complemented by radiocarbon (C^{14}), which enabled water dating via the decay of (C^{14}) in the carbon dissolved in the water[9].

Chapter three

Nuclear Fusion

(3.1) Introduction:

Nuclear fusion may be considered as the reverse of nuclear fission that is at least one of the products of the nuclear reaction will be more massive than any of the initial reactants.

Nuclear fusion will lead to a release of energy in those cases in which the total mass of the product nuclei is less than the total mass of the reactants.

(3.2) Nuclear fusion:-

In fusion reaction-energy is also released . (it is an exothermic process) . this is evident from the fact the sum of the masses of the fusing lighter nuclei is greater than fused (product) nucleus and the missing mass is converted into energy However, in fusion reaction ,the two lighter nuclei, being positively charged ,while colliding experience a coulomb .This repulsive force acts as a potential barrier and in order to combine ,the nuclei must have sufficient kinetic energy so that they may come close enough ,where strong nuclear forces produce the necessary fusion effect. Even at low kinetic energies the nuclei may tunnel through the barrier (a quantum mechanical effect).This problem of coulomb repulsion does not arise in fission ,because the neutron which causes fission is electrically neutral . The coulomb repulsion increases with atomic number (Z) , the nuclear fusion is therefore ,expected to occur at reasonable kinetic energies for low atomic number (Z) nuclei. The temperature of the centre of sun is a bout 10^7 K It is now well established that nuclear fusion ,has been the source of the energy in the sun and stars .We ,thus, find that for nuclear fusion reaction to take place , colliding particles must have sufficient kinetic energy, such energies ($\approx$1MeV or so) can be imparted to charged particle by accelerators .But these energetic particles are found to be unable to sustain fusion reaction. The accelerated particles lose energy in scattering when they strike target and thus become unable to cause fusion. However, as seen above , in principle it is possible to have such kinetic energies by increasing the temperature and to have kinetic energies of the order of 1MeV temperature of around 10^9-10^{10}Kelvin would be required. Also at these temperatures the atoms and molecules of the substance lose their extra-nuclear electrons (due to collisions..) and there exists just a neutral mixture of positively charged ions and negative electrons .such a completely ionized system is termed as PLASMA. It is also referred, as fourth state of matter. One of the important fusion process occurring in sun known as A proton-proton cycle The cycle occurs in the following different steps[8,9].

(i) To begin with two protons combine to form deuterium nucleus, through a weak interaction and a positron and neutron are emitted

$$ {}^1_1H + {}^1_1H \rightarrow {}^2_1H + \beta^+ + \nu + 0.42\text{MeV} \quad (3.1)$$

(ii) The deuteron then captures a proton and form a 2He nucleus, emitting a γ-ray

$$ {}^2_1H + {}^1_1H \rightarrow {}^3_2He + \gamma + 5.5MeV \quad (3.2)$$

(iii) The ${}^3_2He$ nuclei, once formed in a bundanc , collide amongst themselves producing a helium nucleus (α −particles) and two protons are also emitted

$$ {}^3_2He + {}^3_2He \rightarrow {}^4_2He + {}^1_1H + {}^1_1H + 12.8\text{MeV} \quad (3.3)$$

Each $^{3}_{2}He$ nucleus will need, in turn, three protons for its production i.e reaction(i) and(ii) have to occur twice. But in the end (reaction) (ii) two protons are produced

$$4^{1}_{1}H \rightarrow {}^{4}_{2}He + 2\beta^{+} + 2\gamma + 24.64\text{MeV} \tag{3.4}$$

The carbon –cycle (the carbon-Nitrogen cycle):

This cycle take place in the following steps:

$$^{1}_{1}H + {}^{12}_{6}C \rightarrow {}^{13}_{7}N + 1.95MeV \tag{3.5}$$

$$^{13}_{7}N \rightarrow {}^{13}_{6}C + \beta^{+} + 2.22MeV \tag{3.6}$$

$$^{1}_{1}H \rightarrow {}^{13}_{6}C \rightarrow {}^{14}_{7}N + \gamma + 7.54MeV \tag{3.7}$$

$$^{1}_{1}H \rightarrow {}^{14}_{7}N \rightarrow {}^{15}_{8}O + \gamma + 7.35MeV \tag{3.8}$$

$$^{15}_{8}O \rightarrow {}^{15}_{7}N + \beta^{+} + V + 2.7MeV \tag{3.9}$$

$$^{1}_{1}H + {}^{15}_{7}N \rightarrow {}^{4}_{2}He + {}^{12}_{6}C + 4.96MeV \tag{3.10}$$

$$4^{1}_{1}H \rightarrow {}^{4}_{2}He + 2\beta^{+} + 2v + 26.7MeV \tag{3.11}$$

(3.3)ThermoNuclear Reaction on The Earth:-

The most promising fusion reaction on the earth therefore, involve deuterium ($^{2}_{1}H$) and tritium ($^{2}_{1}H$)) both isotopes of hydrogen .The fusion reactions are

$$^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{1}H + {}^{1}_{1}H + 4.2\text{MeV} \tag{3.12}$$

(D-D reaction)

$$^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}H + {}^{1}_{0}n + 3.3\text{MeV} \tag{3.13}$$

(D-D reaction)

Both these reaction have same probability.

The other possible fusion reaction is between deuterium and tritium.

$${}_{1}^{2}H + {}_{1}^{3}H \rightarrow {}_{2}^{4}He + {}_{0}^{1}n + 17.6\text{MeV} \quad (3.14)$$

(D-T reaction)

$${}_{1}^{2}H + {}_{2}^{3}He \rightarrow {}_{2}^{4}He + {}_{1}^{1}H + 18.3\text{MeV} \quad (3.15)$$

(3.3.1) Conditions for fusion reaction:

1-Is a high temperature.

2-Is high density of nuclei , so that in a given time interval, the number of collisions between nuclei may be large .

3-Is that fusion reaction should be self sustained so that the system of the reacting nuclei may be able to stand the time till the nuclear fusion take place[9].

(3.3.2) Critical Ignition Temperature:

The rate of loss of energy from the reacting system must be less than the rate of the generation of the energy .the loss of energy from the plasma take place mainly through radiation. Therefore, there must stricke abalance between the rate of energy generation in fusion reaction and rate of energy lost by radiations which escape the system. Therefore, a critical ignition temperature $t_c$which determines the fusion proceeds once it is produced .

(3.3.3) Lawson Criterion:

A criterion was proposed by J.D Lawson which is referred as Lawson criterion .It is product of the density of the reacting nuclei n and the time t in sec .

The calculated values for (n.t) are about $10^{20}\ {}^{s}/_{m^3}$ for D-T reaction and a bout 10^{22} for D-D reaction

$$^{6}_{3}Li + {}^{1}_{\circ}n \rightarrow {}^{3}_{1}H + {}^{4}_{2}He \qquad (3.16)$$

(3.4) Plasma confinement:

Pinch confinement or pinch effect, Magnetic Bottle, Toroidal confinement (the stellarator), inertial Confinement.

(3.5) Hydrogen Bomb As An Uncontrolled Thermo-Nuclear Device:

The release of fusion energy is possible only when high temperatures of the order of 10^{7}K-10^{8}K available such high temperature cannot be produced in laboratories through conventional methods .However, it was through that tremendous amount of heat at extremely high temperatures $(10^{6}-10^{7})$K produced in the explosion of fission bomb or atomic bomb, could be utilized to trigger a fusion reaction. Thus, if a chain of fusion reaction could be produced among the deuterium or deuterium-tritium mixture then a very powerful explosion can take place. The hydrogen bomb is a nuclear device where a chain of thermonuclear fusion reaction take place in an uncontrolled manner. It is effectively a fission-fusion bomb yielding explosive energy equivalent to megaton of TNT. (megaton bomb).Since neutrons are produced in fusion reactions , they can be utilized to cause fission in fissile materials if put a round the fusion device. This is the basis of what is refereed as fission-fusion-fission bomb. Thus maintaining hot plasma at ultra high temperatures for long enough time (~1mill-second) to produce fusion reaction in a sustained manner had been a problem. Effect are going on to solve such problems throughout the world in cluding india .Only partial success could be achieved in confining hot and dense plasma for micro-second[10].

(3.6) Types of Reactions And Conservation Laws:-

Atypical nuclear reaction is written

A+x→y+b (3.17)

where a is the accelerated projectile, X is the target (usually stationary in the laboratory), and Y and b are the reaction products. Usually, Y will be a heavy product that stops in the target and is not directly observed, while b is a light particle that can be detected and measured.Generally, a and b will be nucleons or light nuclei, but occasionally b will be a γ- ray, in which case the reaction is called radiative capture. (if a is γ −ray, the reaction is called the nuclear photoeffect.) An alternative and compact way of indicating the same reaction is X(a,b)y

Which is convenient because it gives us a natural way to refer to a general class of reactions with common properties for example (α,n) or (n,γ) reactions.

(3.7) Basic Fusion process:-

The basic fusion process are thus considerably simpler to understand and explain than fusion process. The most elementary fusion reaction[3].

P+P→ 2_{He} (3.18)

$$is\ not\ possible, owing\ to\ the\ instability\ of\ 2_{He}$$

but an alternative process analogous to $\beta\ decay$ and leading to 2_H is a primary first step in nuclear fusion.Another elementary reaction is:

$2_H + 2_H \rightarrow 4_{He+\gamma}$ (3.19) where the γ is essential for energy balance, since 4_{He} has no excited states. The energy release (Q value) is 23.8MeV which happen to be greater than both the neutron and proton separation energies of 4_{He}. More likely reactions are thus:

$2_H + 2_H \rightarrow 3_{He}$+n(Q=3.3MeV) (3.20)

$2_H + 2_H \rightarrow 3_{He}$+p(Q=4.0MeV) (3.21)

(3.8) Characteristics of fusion:

Energy release The energy released, and the final total energy of the product particles, will then be equal to the Q value:

$$\frac{1}{2} m_b v_b^2 + \frac{1}{2} m_y V_Y^2 = Q \quad (3.22)$$

For product particle b and y Again neglecting the initial motions, the final momenta are equal and opposite:

$$m_b v_b = m_y v_y \quad (3.23)$$

And thus

$$1/2\, m_b v_b^2 \approx \frac{Q}{1+ {m_b}/{m_y}} \quad (3.24)$$

$$1/2\, m_y v_y^2 \approx \frac{Q}{1+\frac{m_y}{m_b}} \quad (3.25)$$

The ratio of the kinetic energies is from equation (3.24)

$$\frac{\frac{1}{2} m_b v_b^2}{\frac{1}{2} m_y v_y^2} = \frac{m_y}{m_b} \quad (3.26)$$

Coulomb Barrier: If Ra $and\ R_{x\ are}$ the radii of the reacting particles, the coulomb barrier is

$$V_c = \frac{e^2}{4\pi\varepsilon_0} \frac{Z_a Z_X}{R_a + R_x} \quad (3.27)$$

Cross section

$$\sigma \alpha \frac{1}{v^2} e^{-2G} \qquad (3.28)$$

Where G is essentially given

$$G \approx \frac{e^2}{4\pi\varepsilon_0} \frac{\pi Z_a Z_X}{\hbar v} \qquad (3.29)$$

Where v *represents the relative* velocity of the reacting particles Reaction Rate .In thermonuclear fusion there will be a distribution of particle speeds described by usual Maxwell-Boltzmann velocity distribution

$$n(v) \alpha\, e^{-mv2/2KT} \qquad (3.30)$$

where $n(v)v^2\, dv$ gives the relative probability to find particle with speed between v and v+dv in a collection of particles in thermal eguilibrium at temperature T. In sush a collection of nuclei undergoing thermonuclear fusion , it appropriate to calculate σv average over all speeds or energies.

$$\langle \sigma v \rangle \alpha \int_0^\infty \frac{1}{v} e^{-2G}\; e^{-mv^2/2KT} v^2 dV \qquad (3.31)$$

Or

$$\langle \sigma v \rangle \alpha \int_0^\infty e^{-2G} e^{-E/KT} dE \qquad (3.32)$$

(3.9) Solar fusion:

The basic process in the sun is the fusion of hydrogen into helium. hydrogen is by far the most abundant material in the universe-more than 90%,helium~9% *and other* atoms less than 1% all reaction in any fusion cycle must be two-body reaction because the simultaneous collision of three particles is too improbable an even to be significant.

The first step in fusion process must be the combination of two protons to form the only stable two-nucleon system[9,10].:

$1_H + 1_H \rightarrow 2_H + e^+ + \upsilon$(Q=1.44MeV) (3.33)

The υ in final state signals a weak interaction process ,which must occur to turn a proton into a neutron. The centeral temperature of the sun is about 15 x10^6 K, corresponding to a mean proton energy of about 1KeV, but to calculate the reaction rate it is necessary to find $\langle\sigma\upsilon\rangle$ $averaged$ over all energies, and easy penetration of the coulomb barrier for MeV particles in the high energies. the reaction rate is nevertheless very small and even at high densities at the core of the sun the reaction rate is only a bout 15x$10^{-18}/^{\cdot}$s per proton. What keeps the sun radiating is enormous number of reacting protons, of the order of 10^{56}so that the total reaction rate is of the order of [3].

$10^{38}/S$. This step in the solar fusion cycle is often called the" $bottleneck$" because it is the lowest and least probable step. Following deuteron formation, it becomes very likely for the following reaction to occur:

$2_H + 1_H \rightarrow 3_{He}+\gamma$ (Q=5.49MeV) (3.34)

$3_{He} + 3_{He} \rightarrow 4_{He} + 1_H + \gamma$(Q=12.86MeV) (3.35)

$^1_4H \rightarrow 4_{He} + 2e^+ + 2\upsilon$ (3.36)

$3_{He} + 4_{He} \rightarrow 7_{Be} + \gamma$ (3.37)

$7_{Be} + e^- \rightarrow 7_{Li} + \upsilon$ (3.38)

$7_{Li} + P \rightarrow {}^4_2He$

(3.36)

Or perhaps by the sequence

$7_{Be} + P \rightarrow 8_{B} + \gamma$ (3.39)

$8_{B} \rightarrow 8_{Be} + e^{+} + \upsilon$ (3.40)

$8_{Be} \rightarrow {}_{2}^{4}He$ (3.41)

If in addition to hydrogen and helium there are heavier elements present in the interior of a star, a different series of fusion reactions can occur. one such series in the carbon or CNO cycle.

$12_{C} + 1_{H} \rightarrow 13_{N} + \gamma$ (3.42)

$13_{N} \rightarrow 13_{C+}e^{+} + \upsilon$ (3.43)

$13_{C+}1_{H} \rightarrow 14_{N} + \gamma$ (3.44)

$14_{N} + 1_{H} \rightarrow 15_{O} + \gamma$ (3.45)

$15_{O} + 1_{H} \rightarrow 12_{C} + 4_{He}$ (3.46)

In this case the 12_{C} *is* neither created or destroyed, but acts as catalyst to aid in the fusion process.

(3.10) Controlled fusion reactors:

The controlling fusion reactions and extracting usable energy is to heat a thermonuclear fuel to temperatures of the 10^{8}K. at these temperatures the atoms must be ionized . the electrostatic properties of the plasma determine a length scale called the Debye length[3].

$L_{D} = (\frac{4\pi\varepsilon_{0}}{e^{2}}\frac{KT}{4\pi n})^{\frac{1}{2}}$ (3.47)

Where n is the mean ion or electron density .The radiated by an electron experiencing an acceleration a is

$P=\frac{e^{2}a^{2}}{6\pi\varepsilon_{0c^{3}}}$ (3.48)

If the electron is at a distance r from an ion of charge Z, the acceleration is

$$a=\frac{F}{m_e}=\frac{Ze^2}{4\pi\varepsilon_{0m_{er^2}}} \qquad (3.49)$$

Thus

$$dp =\frac{e^2 n}{\mathbf{6\pi\varepsilon_{0c}3}}\frac{ze^4 ve\tau(2\pi r dr)}{(4\pi\varepsilon_0)^2 m_e^2 r^4} \qquad (3.50)$$

τ is the characteristic time during which the ion and electron interac

$$dp=\frac{4\pi e^6 z^2 n}{3{(4\pi\varepsilon_{0)}}^3 m_e^2 c^3}\frac{dr}{r^2} \qquad (3.51)$$

The power per unit volume radiated in bremsstrahlung becomes

$$P_{br} = \frac{4\pi n n_e Z^2 e^6 \upsilon_e}{3{(4\pi\varepsilon_{0)}}^3 m_e c^3 \hbar} \qquad (3.52)$$

$$\upsilon_{e\approx\sqrt{3KT/m_e}} \qquad (3.53)$$

Then the final estimate is

$$P_{bi=0.5\times10^{-36}Z^2 n n_e(}KT)^{\frac{1}{2}} W/m^3 \qquad (3.54)$$

Where KT is in KeV. The reaction rate for fusion reactions is $n_1 n_{2\,\langle\sigma v\rangle}$where$n_1 n_2$ $are\ densities\ of\ the\ two\ kinds\ of\ fusion\ ions$.The energy released per unit volume from fusion reactions in the plasma is

$$E_f = \frac{1}{4} n^2 \langle\sigma v\rangle Q\tau \qquad (3.55)$$

Where D and T are equal to $\frac{1}{2}n$.

Q is energy released $\tau\ length\ of\ time$.Then the thermal energy per unit volume needed to raise the ions and electrons is[3].

$$E_{th\,=\,3nKT} \qquad (3.56)$$

The reactor shows a net energy gain if $E_f > E_{th}$ E_f $is\ fusion\ energy$

$$\frac{1}{2}n^2\langle\sigma v\rangle Q\tau > 3nKT \qquad (3.57)$$

Or

$$\mathrm{n}\tau > \frac{12KT}{\langle\sigma v\rangle Q} \qquad (3.58)$$

(3.11) Thermonuclear weapons:

The first two nuclear weapons were dropped on the Japanese cities of Hiroshima and Nagasaki in August1945, killing over 200,000 people. These were fission weapons, also known as atomic, or A-bombs, which utilize the principle of the chain-reaction fission of the heavy elements uranium or plutonium.

The Hiroshima bomb used the fissile isotope uranium-235, which makes up only 7 of every 1,000 atoms of uranium found in the earth. In order to be effective in a bomb, the percentage of the uranium-235 isotope must be increased to about 800 to 900 parts per 1,000, and then converted into metallic form, a difficult and very dangerous process.

The other bomb dropped on Japan used plutonium as fissile material. Plutonium does not occur naturally, and can only be produced as a byproduct of nuclear fission in a specially designed reactor. The atomic bombs each produced an explosive energy (heat and blast) about egual to 20 kilotons of TNT chemical explosive. Only a small fraction of their actual nuclear fuel was "burned" by the fission reaction[11].

By the early 1950s, both united stated and the soviet union had also developed nuclear weapons based on the thermonuclear fusion of the isotopes of hydrogen, or H-bomb. The nuclear fusion is the same process that energizes the stars like our sun. in principle, it can be unlimited in scale, and generates potentially far greater energy densities than can be achieved through nuclear fusion.

In 1961,the soviet union exploded the Tsar Bomb with an output of 50 megatons (50 million tons) of TNT eguivalent. But such a large device is militarily inefficient, because most of its energy is simply blown out into space[11].

The total explosive energy is of the order of 10^{10} tons of TNT, the population of the earth is of order 5x10^{9}, and thus we are each allotted as a share of about 2 tons of TNT roughly a cubic mater. Every person on earth is thus living precariously with his or her personal cubic meter of high explosive. It is apparent to any reasonable thinker that this silly overkill capability compromises everyone’s security, and the only sensible course is a reduction in the number of weapons and control their proliferation. Achieving this reduction is a major challenge facing both physicist and politicians in the next decade[11].

Chapter four

Conclusion and Recommendation

(4.1) Conclusion

Power from nuclear fusion reactors would be a welcome achievement for the 12^{th} century and at the current rate of progress it seems likely that before the end of the new century energy will be available from nuclear fusion. It is estimated that it will take over a decate from the time a sustainable fusion reaction is achieved before fusion power will be available for use. But the attention being devoted to research is strong, and we are coming closer to having an almost limitless supply of energy[11].

(4.2) Recommendations

Peace uses for nuclear reactors in order to safety with high security, we must to clear generated energy to protect the environment from effects of industrial nuclear ,so reduce to lower level from generating residues nuclear, also for guarantee safety transport to radiated materials by international procedures opportunity[11].

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