Chapter-7
THE STORY OF CREATION

POWER INSIDE ATOM

It is not all true that the scientist goes after the truth, it goes after him. (Soren Kierkegaard)

7.01. INTRODUCTION

The ultimate constituents of matter on our planet, are dense and compact atoms of ninety two varieties (excluding laboratory elements). Even those atoms are found structured with fundamental particles – electrons, protons and another neutral particle. These particles are same for any atom of ninety two elements and so truly universal in character. Different elements differ in their properties only because of different number of particles arranged in different ways inside their atoms. If we can alter them, we would get atoms of different kind. Is it as simple as that? Yes, if we can master that magic, we would convert everything into gold, as our alchemists thought.

Radioactive elements change its number of atomic particles spontaneously. When they transform, they come up with some loss of mass that show up as energy. This energy, derived from atom, is called the atomic energy. As the transformation of mass results from the nucleus, consequent energy is also called *nuclear energy*.

By middle of 20^{th} century we learnt that there exist enormous amount of energy inside an atom. This powers our Sun and all other stars. How such a massive source inside a minute particle of matter could occur ? How scientists have learnt that? How they have used that source of energy?

That's a marvel of human skill and intelligence, quite unknown a century ago. This energy can be harnessed by the twin process of fission or fusion of atoms. Some amount of matter is encashed into energy. We shall briefly touch upon these issues to know how a minute matter can have it and how they release it. We need to know this because in stars or similar cosmic bodies, the energy is generated by the same process in a Nature's way.

7.02. BREAKING NEUCLEUS

Roentgen, Becquerel, Curie family, Rutherford, Soddy and a host of other scientists worked on radioactivity in late 19^{th} and early 20^{th} century. They studied emanation of radium and thorium. Their observations revealed that radioactivity is a decomposition of atom into charged particles and an atom of another element chemically different from the parent one. It is described as *hypothesis of radioactive decay*.

In 1903, **William Ramsay** (1852-1916) and **Frederick Soddy** (1877-1956) made one fine experiment. They passed electric charges through fifty milligram of radium bromide. It was found that the characteristic spectrum of radium gradually changed into another spectrum of helium. The experiment demonstrated how one element could undergo changes into another by decay before our eyes.

Emanation of radium was called *radon* by Rutherford. This was an alpha-decay reaction. The radio-active elements decay continuously at a characteristically definite rate. Scientists began to believe that there must be present a whole series of radio-active family in Nature. They jumped to explore all of them. By 1913, nearly all the sequences of radio-active decay were discovered. It was found that there occurred three radio-active families - uranium, thorium and actinium.

$$^{226}\mathbf{Ra}_{88} \text{ --- 1600 yrs} \longrightarrow {}^{222}\mathbf{Rn}_{86} + {}^{4}\mathbf{He}_{2} + \alpha$$

An atom is a system of nucleus and electrons. Protons are bound in compact nucleus that leaves a such a large void from electronic shell that the atom may be said to consist mostly of voids. It gradually appeared that the nucleus cannot be made up only protons. Nuclear mass does not conform to proton mass. Secondly, what makes the positively charged protons to remain packed inside a compact body when positively charged protons should repulse one another. The enormous electrostatic repulsive forces should blow up the nucleus. As it is not doing so, it must be prevented by some unknown strong force. The binding energy of nuclear particle has been calculated which amounts to about one million times more than that of an electron in an atom. Breaking nucleus became important to scientists for the study. The big question was – how can it be broken?

Rutherford suggested that charged particles on high voltage should behave like bullets and that may be used to break the hard core.

Just after the WWI, Rutherford carried out an experiment (1919) that resulted in *artificial transmutation of elements*. When alpha-particles (helium nucleus) passed through air, secondary particles (protons) came out on collision with nitrogen nuclei and nitrogen transformed into oxygen with release of one proton (hydrogen nucleus).

$$\alpha + {}^{14}N_7 \rightarrow {}^{17}O_8 + p^+$$

For next four years, Rutherford and Chadwick bombarded dozen of elements down to sodium, by alpha-particles and artificially transformed those elements. To bombard nucleus of heavier elements of higher order in the periodic table, high-energy protons were necessary. High-energy protons could be produced only in proton accelerators. Several proton accelerators were made that would work at different energy levels.

The year 1932 was an eventful one. Several discoveries had been made in that year. The British physicist **John Douglas Cockroft** (1897-1967) and **Ernest Thomas Sinton Walton** (1903-1995) observed in Rutherford's laboratory splitting of nucleus which was so long appeared to be an impregnable fortress. They bombarded Lithium by accelerating high voltage (0.2 MeV) protons. The lithium converted into alpha particles and about 15 MeV energy was liberated.

$$p + {}^{7}Li_3 \rightarrow {}^{4}He_2 + {}^{4}He_2 + \text{energy}$$

1eV means the amount of energy an electron would gain when accelerated across a potential difference of 1 volt. The liberated energy could be calculated from the loss of mass or mass defect.

In this collision, mass defect amounts to (1.008 + 7.016 - 2 x 4.004 =) 0.016 atomic mass unit, where 1 amu = 1.66056×10^{-24} g. This mass has been converted into equivalent energy and amounts to 0.016 x 931 = 14.896 MeV. The story goes that after splitting the nucleus, the overjoyed English scientists came out on road. They informed the pedestrians that they had successfully broken the central fortress of an atom. Ha! the central fortress! Who cares for that except some mad scientists?

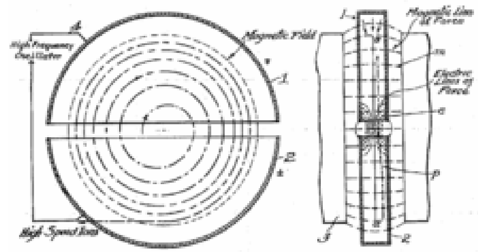


Fig:7.1. Diagram of cyclotron operation from Lawrence's 1934 patent

Particle Accelerators are devices for accelerating subatomic particles to sufficiently high energies for collision so as to break up atoms and nucleus of different types. John Douglas Cockroft and Ernest Thomas Sinton Walton of Rutherford's laboratory, developed a voltage multiplier which would accelerate particles at energy level 400,000 ev. It could produce high energy beam of proton. In 1931, the American physicist **Robert Jemison van de Graaff** (1901-1967) suggested electrostatic generator upto 8 million volts. At about the same time *linear accelerator* was conceived.

A better idea came in the mind of **Ernest Orlando Lawrence** (1901-1958) of University of California and he made the whirling device, the *cyclotron*. Next year he with **Stanley Livingstone** and **David Sloan**, built a 29 cm cyclotron that could accelerate proton to an energy of 1MeV. By 1939, the diameter of the largest cyclotron reached 1.5 m / 80". The University of California made a cyclotron which could raise particle energy to 20 Mev. In 1940, the American Physicist **Donald William Kerst** designed another device, called *Betatron***.**

In 1945, Soviet physicist **Vladimir Iosifovich Vekster** and California physicist **Edwin Mattison McMillan** made *synchrocyclotron*. In 1946, the University of California built one device to arrive at energy level of 200-400 Mev. The new 4.6m /184" synchrocyclotron machine began to produce its deuteron beam.

In 1952 Brookhavan National Laboratory on Long Island USA, made a proton *synchroton* which could attain energy level of 2000-3000 Mev. Within two years, University of California made a bevatron (proton synchroton) of 5000-6000 Mev and Soviet Union made a phasotron of 10,000 Mev.(10 Bev.)

In 1959, CERN in Geneva made a Synchotron which could reach 24,000 mev (24 Bev) energy level. In 1982 at Fermilab (Fermi National Accelerator Laboratory) near Chicago made a Tevatron which could reach 1000 Bev.

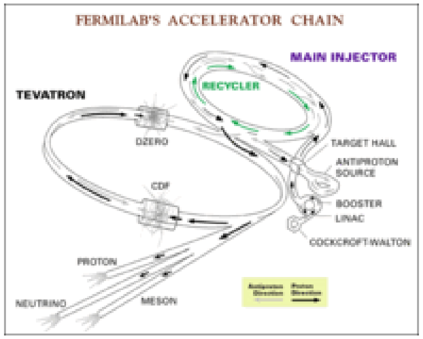


Fig:7.2. Fermilab's Accelerator Rings.

Alchemists tried for centuries to convert baser metals into gold. They were unsuccessful. For the first time, human learnt how to change elements. The change can be made if we can change the atomic structure of it. Cockroft and Walton converted lithium into helium. They could not convert lithium into gold! Even then, such simple nuclear transformation was a great achievement. Rutherford called it *The Newer Alchemy*. The pair won the Nobel Prize in 1951.

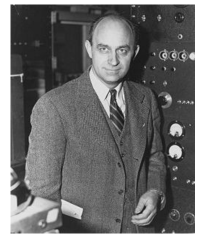
7.03. MANMADE ISOTOPE

Jean Frederic Joliot Curie (1900-1958) and **Irene Joliot Curie** (1897-1956) missed the chance of discovering the new particle neutron from a very close range.

When they irradiated aluminium nuclei with alpha-particles in 1934, they found a new beta-radioactive artificial isotope. It was called **radio-phosphorus** ($^{30}P_{15}$). That was the **first man-made radio-active isotope** (artificial isotope). For discovery of radio-phosphorus, Irene and Frederic Joliot-Curie were awarded Nobel Prize in chemistry (1935).

$$\alpha + {}^{27}Al_{13} \rightarrow {}^{30}P_{15} + n \rightarrow {}^{30}Si_{14} + e^{+} + \nu_e \text{ (neutrino)} + n$$

Marie Curie could not live to see her daughter and son-in-law honoured. She died the year before. Interestingly in the same experiment, Curie family found not only radiation of neutron but also another particle positron which again they could not identify. The particle was predicted by Dirac in 1928 and discovered by Carl David Anderson four years later in cosmic rays.



7.04. URANIUM FISSION

Enrico Fermi (1901-1954) of Italy received his doctorate from Pisa in 1922. Then he studied with Max Born in Gottingen and Paul Ehrenfest in Leiden and returned to Florence in 1924. He developed Fermi statistics within next two years. The Italian physicist with Bruno Pontecorvo, was quick to understand that the neutron was an ideal means of probing into the mechanism of nuclear reactions. They used neutron from a radon-beryllium source and irradiated various elements with this neutral particle. Their scheme of reaction was as follows:

$$n + {}^{27}Al_{13} \rightarrow {}^{28}Al_{14} \rightarrow {}^{28}Si_{14} + e + \text{electron antineutrino.}$$

In 1934, Fermi and his team observed that atoms are more efficient in capturing neutrons when reactions proceed under water. The **slow neutrons** are better in absorbing rate. Fermi transmuted uranium-238 by slow neutron. When he fissioned uranium, he thought that it produced two trans-uranic elements "ausonium" and "hesperium" in the process : $n + {}^{238}U_{92} \rightarrow {}^{239}U_{92} \rightarrow {}^{239}X_{93} + e + \text{(anti-neutrino)}$.

They published the paper "The *Influence of Hydrogen Containing Substance of Neutron-Induced Radio-activity*". In 1938, Fermi was awarded Nobel Prize in physics. He left Italy to settle in USA.

Why beta particles are ejected from the nucleus of radio-active atom? It is because radio-active nuclei are intrinsically unstable. A beta particle has fixed quantum of energy in a nucleus and so when it leaves the nucleus, it moves with pre-determined kinetic energy. The law of chance here appear to dictate the time and place of the decay event. A nucleus is a micro-reality and obeys quantum laws. Its description depends on probability. We can reliably predict the average lifetime of a nucleus and the average number of nuclei out of a large mass that will decay in second. But we cannot predict the time at which each individual nucleus would decay.

In 1928, **Georgy Antonovich Gammow** (1904-1968), **Ronald Wilfred Gurney** (1899-1953) and **Edward Condon** (1902-1974), proposed that the motion of an alpha particle in the nucleus is like electron inside atom and is governed by the Schrodinger's Wave Function. Nuclear forces are attractive and extremely strong. Coulomb repulsive forces between alpha particle and nucleus is weak. Beyond the nucleus, an alpha particle is repelled by Coulumb field of the nucleus. At the boundary of the nucleus, repulsion changes into attraction and the alpha particles move about in a narrow deep potential well being separated from external world by a potential barrier. It is like quantum type volcano. Alpha particles obey quantum laws and their energy are quantized. If its energy quanta, $E_n<0$, no spontaneous emission of alpha particles occur. If $E_n>0$, alpha decay is possible. Further an alpha particle can break through the potential barrier and escape out of potential well even if its energy is low. This strange phenomena is known as **tunnel effect**. Beyond the potential barrier, the alpha particle is mightily pushed away by the Coulomb field of the nucleus. Then as it slides down the volcanic slope, it acquires at its foot exactly the same kinetic energy as it stored before its decay. The tunnel effect is a consequence of wave-particle duality of quantum objects.

In 1936, the German-American physicist **Walter Maurice Elasser** (1904-1991) predicted that neutron like electron must possess wave properties. **Peter Preiswerk** (1907-1972) and **Hans Halban** (1908-1964) confirmed the assumption experimentally at the Radium Institute in Paris.

The German radio-chemist **Otto Hahn** (1879-1968) a student of Ramsay and Rutherford, wanted to be an architect but became a radio-chemist. He with **Lise Meitner** (1878-1968) and **Fritz Strassman** (1902-1980), repeated Fermi's experiments with uranium in 1937. Next year, Hahn and Strassman resumed the same work and found that some beta-active substance resulted. Surprisingly one of its product was barium, an element in 56^{th} position in the periodic table. It meant that heavy uranium nucleus had split. In December (1938), a paper was written about irradiation of uranium by slow neutrons from which barium, lanthanum and cerium were

available. Their paper "*On Proof of the Existence and the Properties of Alkaline-Earth Metals produced by Irradiation of Uranium by Neutrons*" was published in *Naturewissenschafen* in 1939. Otto Hahn's Nobel came within five years. The 108^{th} element was named Hahnium (Ha) by International Union of Pure & Applied Chemistry in 1994.

Lise Meitner escaped to Sweden as she was a Jew and unsafe in Hitler's Germany. One day she was discussing with her nephew **Otto Robert Frisch** (1904-1979) about Hahn-Strassman experiment. Frisch realised that Hahn-Strassman observed disintegration of uranium nucleus by capturing neutron. The event was simply a **nuclear fission**. The mass defect in the reaction would liberate as energy. Therefore, power hidden inside the nucleus, might be used if some mass could be converted into energy by splitting the nucleus.

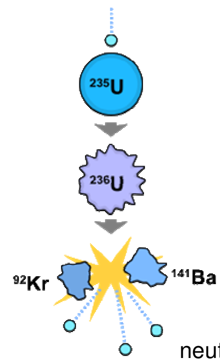


Fig:7.3. An induced fission reaction. A slow-moving neutron is absorbed by the nucleus of a uranium-235 atom, which in turn splits into fast-moving lighter elements (fission products) and releases 3 free neutrons.

From Aston's work, it was known that binding energy per nucleon in the uranium nucleus was 7.6 MeV. The fission of nuclei in 1 gm of uranium would give off an energy of 8×10^{10} joules. Back in Copenhagen, Neils Bohr Institute, on 13th January, 1939, Otto Frisch checked this **uranium-division hypothesis** and found it right. He sent for publication in *Nature* papers entitled "*Physical Evidence for the Division of Heavy Nuclei under Neutron Bombardment*" and "*Disintegration of Uranium by Neutrons: A New Type of Nuclear Reaction*".

In January 1939, Bohr and Fermi were in New York to attend a conference. They found nuclear fission a confirmed fact. According to

Fermi, in addition to two nuclear fragments, a fissioning uranium nucleus must yield several neutrons, which in turn might cause further fission events. Then it would be possible to obtain a chain reaction of fission.

If uranium is packed with such possibility, why nobody had not ever seen uranium to explode?

Bohr explained that slow neutrons would split uranium-235 and fast neutrons produced in the fission would be absorbed by uranium-238. Natural uranium consists of 99.98% U-238 and only 0.72% U-235. So the neutron flare-up would not occur in ore. That was one major point.

Works of Frederick Joliot Curie, von Halban and Kowarski of France, Flerov and Rusinov of Russia, Fermi, Anderson and Hanstein and Szilard and Zinn of USA confirmed around March, 1939, that each fissioning nucleus of U-235 emits two or three secondary neutrons with an average energy 2.42 MeV. It came out that slow neutrons would be best for U-235 fission (i.e. its cross-sections are large).

A **neutron moderator** had to be used to carry out chain reaction so that it could reduce the energy of neutrons from 1 MeV (with which they are released as a U-235 nucleus disintegrates) to energy of 0.1 eV. Further the moderator must be so efficient that the neutrons would be moderated before they would collide with a U-238 nucleus. Lastly the moderator itself must not absorb neutrons. The most efficient moderator was hydrogen as shown by Fermi (1934) :

$$(p + n \rightarrow d + \gamma).$$

In 1939, **Yakov Borisovich Zaldovich** (1914-1987) and **Yuli Borisovich Khariton** (1904-1996) showed that U-235 concentration in natural uranium had to be raised from 0.72% to 2.5%. Separation of uranium isotopes was of primary importance. By 1944, uranium isotope separation plant came up in operation.

Another moderator, graphite or heavy water (D_2O), also became necessary. Heavy water was preferred but it was not easily available. In 1939, heavy water was produced by a small plant of Norway. While Joliot-Curie and Heisenberg independently thought of heavy water, as moderator, Fermi, Szilard and Kurchatov tried with graphite.

The condition for chain reaction described by **four-factor formula,** is represented by : **$k\alpha = n.\varepsilon.\phi.\theta$,** where n = number of secondary thermal neutrons in natural uranium, ε = a factor to account for the fast fission neutrons capable of splitting U-238 nuclei, ϕ = a factor of probability for neutrons to escape resonance capture and θ = a factor of probability for an electron to escape being captured in the moderator and various impurities. Now $k\alpha > 1$ should be maintained for a divergent chain reaction. For natural uranium-graphite heterogeneous reactor, $k\alpha$ = 1.34x 1.03x 0.93x 0.84 = 1.07. This indicated that chain reaction would be possible in an infinite reactor. In an finite reactor, k= k α x P, where P depends on the size and shape of reactor. There must be some critical dimension for k=1. Fermi laboured to determine the critical dimensions of uranium-graphite reactor.

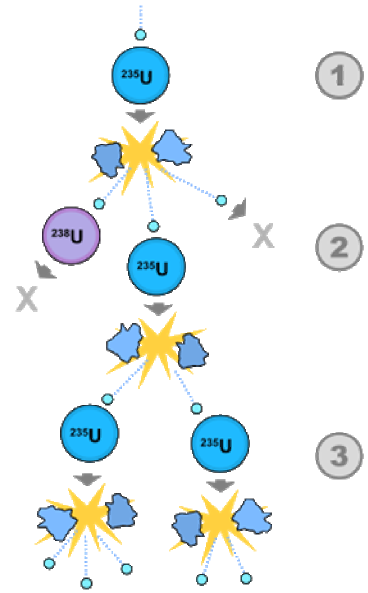


Fig:7.4. A schematic nuclear fission chain reaction. 1. One U-235 atom absorbs a neutron, fissions into two new atoms, releasing three neutrons and some binding energy. 2. One of those neutrons is absorbed by an atom of U-238 and does not continue the reaction. Another is simply lost, does not collide with anything and not continue the reaction. However one neutron does collide with an atom of U-235, which then fissions and releases two neutrons and some binding energy. 3. Both of those neutrons collide with U-235 atoms, each of which fissions and releases between one and three neutrons, which can then continue the reaction.

On 2nd December, 1942 on a tennis court under the stand of stadium at Stagg Field, Chicago, Fermi became successful to get a controlled nuclear chain reaction using pure graphite moderator and slow neutrons with enriched uranium. It consisted of (40,000) graphite blocks with some (22,000) holes to contain uranium. This was the world's first nuclear reactor, a flattened ellipsoid 8m dia and 6m high. It was followed by soviet reactor (25.12.1946) and French reactor (15.12.1948).

In Los Alamos, New Mexico, USA, under the name of Manhattan project under the leadership of J. Robert Oppenheimer, atomic bomb was manufactured . On 16th June, 1945, the 1st atomic Bomb was detonated for test in the Almogorado. The 1st nuclear bomb was dropped on Hiroshima of Japan on 6th August, 1945. The world was shocked by the devastating power of the bomb.

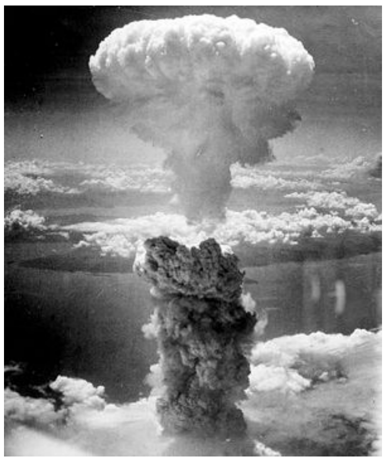


Fig:7.5. The mushroom cloud of the atomic bombing of Nagasaki, Japan on August 9, 1945 rose some 18 km above the bomb's hypocenter.

What happens inside the bomb ? The atomic nucleus is broken down into other nucleus and in its breaking down, some mass of matter was converted into energy. Only 20 kg uranium was required to wipe out a city with millions lost. What resides inside that 20 kg of radioactive matter? What makes it to flare up like a Sun? Nothing but pure matter, a special kind of matter, devised to bang with enormous energy.

7.05. OTHER FISSION PROCESS

Uranium is not the only raw material for an atomic explosion. Plutonium was also found to do the job. Pure plutonium is steel grey and heavy metal, of density 19.82 gcm^{-3} and melting point at 640°c. It has 15 isotopes of which plutonium-239 could undergo fission when exposed to slow neutron. In July, 1940, **Carl von Weizsacker** in Germany could figure out that U-235 can be replaced by plutonium and so was the Dutch-Austrian-German physicist **Freidrich George**

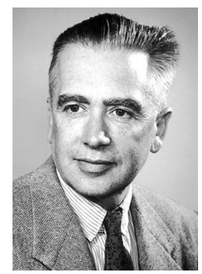
Fritz Houtermans. (1903-1966) USA understood its importance in 1940 through Louis Turner's report.

Edwin MacMillan

In 1939, **Edwin Mattison McMillan** (1907-1991), worked in California with a brand new cyclotron. He observed that U-238 captured neutron and decayed into U-239 which again decayed into another elements called Neptunium. To get the requisite neutron flux, he used standard radon-beryllium source.

Philip Hauge Abelson (1913-2004) studied in 1940 that neptunium-239 might transform into a new element Plutonium with atomic number 94. The total reaction scheme is shown below:

$$n + {}^{238}U_{92} \rightarrow {}^{239}U_{92} - \beta \rightarrow {}^{239}Np_{93} + e + ve.$$
$${}^{239}Np_{93} - \beta \rightarrow {}^{239}Pu_{94} + e + ve \rightarrow {}^{235}U_{92} + \alpha$$



Left: Glenn Seaborg
Right: Emilio Segre

Next year, **Joseph William Kennedy** (1916-1957), **Glenn Theodore Seaborg** (1912-1999), **Emilio Gino Segre** (1905-1989) and **Arthur C. Wahl** (1917-2006) proved that Np-239 decays into Pu-239. They also proved that Pu-239 is split by slow neutrons, like U-235, as predicted by Bohr-Wheeler-Frenkel. McMillan and Seaborg were awarded Nobel Prize in 1951. In 1942, **Burris Bell Cunningham** (1912-1971) and **Louis Werner** of Berkeley isolated 0.1 mg of plutonium.

The first plutonium bomb was manufactured by USA and tested on 16th July 1945. The second atomic bomb, a plutonium bomb, was dropped on Nagasaki, Japan on 8th August, 1945. Plutonium can be separated chemically. It is also easier than separation of uranium isotopes. Hence its discovery changed the approach to uranium purification problem.

7.06. ATOMIC FUSION

This is how fission of nucleus had been achieved in order to release atomic energy. The other way of harnessing energy from atom is through the process of fusion. Thermo-nuclear or hydrogen bomb involve such fusion energy. Here synthesis of deuterium (heavy hydrogen) nuclei and tritium nuclei, is done that resulted into release some energy :

$$d + t \rightarrow {}^{4}He + n^{0} + 17.6\ MeV.$$

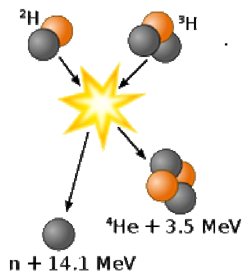


Fig:7.6. Fusion of deuterium with tritium creatinghelium-4, freeing a neutron, and releasing 17.59 MeV of energy, as an appropriate amount of mass converting to the kinetic energy of the products, in agreement with $E = \Delta mc^2$.[1]

Fermi and **Edward Teller** (1998-2003) thought over the process in 1942. Within ten years (1 Nov 1952), hydrogen bomb was exploded in the Marshall Island. It used a plutonium bomb as a primer. When the primer fires, a very high temperature to the tune of 100 million degrees occurs and at such temperatures two hydrogen atoms overcoming Coulumb's repulsion barrier merge into helium nucleus with liberation of tremendous energy. Real hydrogen bomb uses Lithium deuteride (^{6}Li D) instead of mixture of deuterium and tritium to produce tritium by neutron flux caused by explosion of nuclear primer This bomb has no critical mass.

The same principle of fission and fusion is now utilised to generate atomic power for industrial use. Since then Nuclear power harnessed is not insignificant in comparison to the total energy consumption. However the process is not full proof to safety.

In 1936, Hans Albrecht Bethe tried to establish that energy is generated in the Sun and other stars by nuclear fusion process. Matter like hydrogen and helium, are used as fuel. The burning of the star is nothing but the same thermonuclear fusion. The atom may be one of the smallest things but are devastatingly powerful.

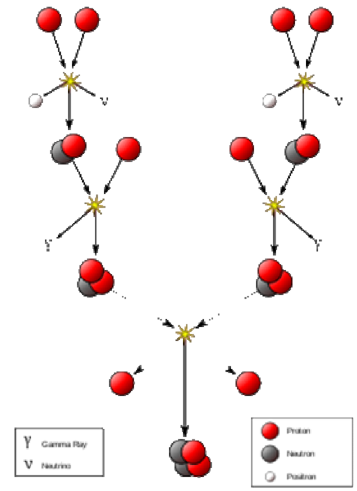


Fig:7.7. .The proton-proton chain dominates in stars the size of the Sun or smaller.

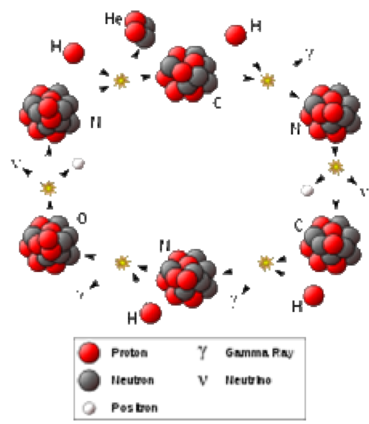


Fig:7.8. The CNO cycle dominates in stars heavier than the Sun.

7.07. RADIO CARBON DATING

Two important applications of radio-activity are in **radio carbon dating** and **labelled atoms**. We shall briefly describe them.

Interstellar matter consists of hydrogen, helium and other elements. The galactic magnetic field accelerate these nuclei at very high energy. These are all atoms which enter as ray into Earth's atmosphere and break nuclei of atmospheric atoms. As a result they knock out secondary protons and neutrons. American physicist **Willard Frank Libby** (1908-1980) observed in 1946 that in this process the nitrogen turns into radioactive carbon nucei. These carbon isotopes again decay with half life 5730 years.

$$\mathbf{n + {}^{14}N \rightarrow {}^{14}C + p^{+} \rightarrow {}^{14}N + e^{-} + ve + p^{+}}$$

Each seconds about 4000 cosmic protons pass through an area of 1 sqm and yield about 2 nuclei of ^{14}C in each cc of the upper atmosphere. The ^{14}C combines with oxygen and is taken up by plants and then by animals as carbon dioxide. As a result of carbon turnover, an equilibrium concentration of carbon isotope is gained by all plants and animals. These radio isotopes can be detected easily. One gram of organic carbon whether in woods, grass, bacteria or animal bodies, contains about 70 billion radio carbon and each minutes 15 of them decay. When plant or animal die, metabolism is stopped. So in the remains, equilibrium of radio carbon (^{14}C) concentration is disturbed. Carbon isotopes begin to decay in numbers. In 5730 years, the number get halved and in the next 5730 years, it would be halved again. It means that 1 gm of carbon in dead organic body, will emit in 5730 years 8 impulses per minutes and in another 5730 years 4 impulses and so on. With this knowledge, radio-carbon dating technique has been developed. Many geological and archaeological things can now be dated back, by counting number of decays per minute of carbon isotope in a gram of sample. The discovery earned Libby 1960 Nobel prize for chemistry.

George Charles de Hevesy (1885-1966) of Hungary tried to separate out radium D from lead but the task is found to be chemically insolvable. Radium D is radioactive lead isotope (^{220}Pb). Hevesy and his associate Austrian radio chemist **Frisch Adolf Penet** (1887-1958) turned the problem upside down. They used radium D to study chemical reactions of lead. The technique gradually came to be known method of radioactive indicators,

tracers or labelled atoms. The method is now employed to probe into chemical reaction and structure of matter. It is in use in physics, biology, medicine, metallurgy, archaeology and criminalistics. There now occur dozens of radio-active isotopes that can be used as tracers. If one takes saline water added with radio-active sodium, ^{24}Na, the isotope would appear in a minute in finger tips and shortly within the whole body. This function is used to probe deep inside a system otherwise inaccessible. Hevesy earned 1943 Nobel Prize for the discovery.

7.08. REMARKS

Atoms are made of two charged particles, electron and proton and one neutral particle, neutron. These three are fundamental matter-particle at atomic level and constitute all atoms of all material bodies. A small variation in number of them make one atom different in nature. We call alternative forms of elements isotopes. In fact some matter exist in Nature in mixture of different isotopic forms. Larger variation result into qualitatively different element. These variations can be made by splitting the nucleus by fission process or by joining atom by fusion. We would find later that the Nature adopted these fission-fusion of atoms to create varieties of atoms during primordial creation of the Universe and later into stars.

We can make artificial isotopes by fission of the nucleus of some matter or by fusion of some others. We have checked the fact that mass of matter is convertible into energy and the amount of energy available expending some mass of the matter, is enormous. It can destroy a city. It can supply power to a city. We would see later that it can supply power not only to a city or country, but to several planets.

At basic level, all atoms of elements are numerical arrangement of these three simple matter-particles – electrons, protons and neutrons. Hundreds of elementary matter differ from one another in quantities and consequent structural arrangements only. Nature appeared now quite simpler. Instead of millions of compounds and a hundred of elements, we have now only three atomic particles to compose everything of our Nature.

Is our Nature so simple enough? No, it is not.

The mystery of nucleus structure is much more complicated. We are to go deeper into the heart of atom and ultimately find a puzzling quantum zoo. Mystery of Nature is inexhaustible.