RADIOACTIVITY

The phenomenon of spontaneously and continuously emitting active radiations is called as radioactivity and the substance emitting such radiations is called as radioactive.

All the heavy elements from bismuth and few lighter elements possess radioactive properties.

Radioactive Rays

In 1905, Rutherford analyzed that the radiations from radioactive substances are composed of three important rays

1. α rays
2. β rays
3. γ rays

1. α rays :- These rays consist of material particles of mass for each and carrying two positive charges. They are Helium nuclei, ${}^{4}_{2}He$. They have least penetrating power and they are therefore, easily absorbed by thin sheet of metal foil. They are emitted with a great velocity and have the greatest ionizing power. They have a limited range in air. They produce luminosity in ZnS due to high kinetic energy.
2. β rays:- These rays consist of negatively charged particles identical with electrons. This β particle has a unit negative charge and a negligible mass. These are more penetrating than α rays. They are emitted from radio-active substances with a very high velocity comparable to that of light. They have weak ionizing power.
3. γ rays:- These are non-material rays like X-rays, i.e. electromagnetic radiations, and are unaffected by electric field. These have high penetrating power and can penetrate even quite thick layers of lead. They have very feeble ionizing power. They have high energy and short wave-length.

DISINTEGRATION THEORY OF RADIOACTIVITY

The theory was given by Rutherford and Soddy in 1902. According to this theory, radioactive elements are unstable and undergo spontaneous breakdown from one chemical atom to another. This process continues till a stable non- radioactivative nuclear species is obtained. The emission of radioactive rays takes place during this process. This process is called as radioactive decay.

Rate of Radioactive Decay

The radioactive atoms in a sample of a radioelement disintegrate. But all the atoms do not disintegrate at the same time. The number of atoms which disintegrate in unit time is directly proportional to the total number of atoms of radioactive element.

If the number of atoms of radioelement is 'N' at any instant then the rate of decay disintegration will be,

$$\frac{-dN}{dt} \propto N$$

The equation can be written as,

$$\frac{-dN}{dt} = \lambda N$$

Where λ= decay constant

$$\frac{-d}{N} = \lambda dt$$.

Integrating the equation between the limits N_0 and N_t. we get,

$$\int_{N_0}^{N_t} \frac{dN}{N} = -\lambda \int_0^1 dt$$

$$\ln \frac{N_t}{N_0} = -\lambda t$$

$$N_t = N_0 e^{-\lambda t}$$

Conversion of above equation to $\log_{10}$, we get

$$\lambda = \frac{2.303}{t} \log_{10} \frac{N_0}{N_t}$$

<u>Half Life Period</u>

The half life period of a radioactive element is defined element is defined as the time in which half the amount of the substance has disintegrated.

The half life period is related to decay constant and is not related to the initial concentration of the radioactive element. Half life period is related to decay λ constant as follow

We know that,

$$t = \frac{2.303}{\lambda} \log \frac{N_0}{N_t}$$

At half life period, the N_t will be $N_0/2$

Therefore

$$t_{1/2} = \frac{2.303}{\lambda} \log \frac{N_0}{(\frac{N_0}{2})}$$

$$t_{1/2} = \frac{2.303}{\lambda} \log 2$$

$$t_{1/2} = \frac{0.6933}{\lambda}$$

Thus, it can be seen that half life period of the radioactive element is not related to the initial concentration.

UNITS OF RADIOACTIVITY

The first type of unit is Curie (Ci) which describes the intensity of radiation source.

One Curie is the amount of a radioactive substance which produces 3.7×10^{10} disintegrations per second. Thus, the weight of 1 Curie of U-238 is different from the weight of 1 Curie of K-40. The value of 3.7×10^{10} disintegrations per second is chosen as standard based on the fact that one gram of radium produces 3.7×10^{10} dps. Now, smaller units viz. millicurie (mci) & microcurie (uci) are often used.

$$1 \text{ mci} = 3.7 \times 10^{7} \text{ dps.}$$

$$1 \text{uci} = 3.7 \times 10^{4} \text{ dps.}$$

The S.I. unit of radioactivity is Becquerel (bq) It is defined as the amount of a radioactive isotope, which gives one disintegration per second.

Rutherford is a more recent unit. 1 Rutherford is equal to the amount of a radioactive isotope which gives 10^{6} disintegrations per second.

NUCLEAR REACTIONS

A nuclear reaction refers to a transformation of a target nucleus, usually at rest, by bombarding it with projectiles of light nuclei, or free nucleons, or photons of adequate energy.

The nuclear reaction is represent by an equation indicating the nuclear characteristics of the reactants and the products as

$$^{A_1}_{Z_1}X + ^{A_2}_{Z_2}a \rightarrow ^{A_3}_{Z_3}Y + ^{A_4}_{Z_4}b$$

Where, X = Target nucleus

a = Projectile effecting the reaction.

Y = Product of recoil nucleus

b = Ejectile

The first ever nuclear reaction in the laboratory was carried our in 1919 by Rutherford, when he bombarded nitrogen with $\propto$ particals.

$$^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}H$$

Bethe's Notation

A nuclear reaction may be written in shorter form by using Bethe's notation. While representing the nuclear reaction according to Bethe's notation, the target nuclide is written first and the product last, with the projectile and ejectile particles inside the parenthesis, in the same order but separated by a comma.

The reaction $^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}H$ is represented as $^{14}_{7}N(\propto P)^{17}_{8}O$

Q Value of Nuclear Reactions

Q value refers to the energy associated with the nuclear reactions.

As in chemical reactions, nuclear reactions also involve energy changes represented by the symbol Q. the value of Q may be positive or negative, the reaction is called endoergic i.e. energy is absorbed, and if Q is positive, the reaction is called exoergic i.e. energy is released.

The term Q is equivalent to enthalpy in a chemical reaction.

Calculation of Q value

The value of Q for a nuclear reaction is calculated as,

$$Q = \Delta m \times 931 \text{ MeV}$$

Where, Δm = sum of mass of reactants – sum of mass of products.

REACTION CROSS SECTION

An important quantity in nuclear reaction is the reaction cross section (σ) which expresses the probability of occurrence of a given type of a nuclear reaction.

If the nucleus of radius R represents a target of area πR^2 to an incident particle then the probability of an incident particle to strike the nucleus proportional to this target area. Although this simple equation does not always hold good nuclear reaction cross sections are generally of the magnitude of the target area. The unit in which the cross section is expressed is the barn (b) which corresponds to a value of 10^{-24} cm^2. By assuming that the reaction is possible only if the projectile passes through the area πR^2 of the target nucleus, we get

$$\sigma = \pi R^2 = \pi\,(A^{1/2} \times 1.4 \times 10^{-1})^2\ cm^2$$

Many different kinds of reactions may occur as consequence of the collision of the projectile with the nucleus. For example,

$$^{23}_{11}Na + ^{4}_{2}He \rightarrow \begin{array}{l} ^{27}_{13}Al + \gamma \\ ^{26}_{13}Al + ^{1}_{0}n \\ ^{26}_{12}Mg + ^{1}_{1}H \\ ^{25}_{12}Mg + ^{2}_{1}H \end{array}$$

We may imagine the total cross-section of the ($^{23}_{11}Na + ^{4}_{2}He$) reaction to be subdivided into areas corresponding to each of the different cross-sections; each reaction assigned an area proportional to the probability of the particular reaction taking place under given conditions. Further the product yield for each possible reaction will show energy dependence. For example, a particular reaction often predominates in an energy region.

When the energy of the incident particle is so low that its de-Broglie wavelength is larger than the radius of the target nucleus, the wavelength predominates in determining the probability of interaction. The maximum possible.

Classification of Nuclear Reactions

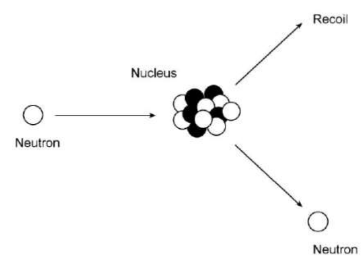
Nuclear reactions are classified into different categories on the basis of nature of projectile and ejectile.

Types of nuclear reations

1. Elastic scattering
2. Inelastic scattering
3. Photonuclear reaction
4. Radioactive capture
5. Special nuclear reactions
   A) Evaporation
   B) Spallation
   C) Fragmentation
   D) Stripping reactions
   E) Fission

1. Elastic scattering

This is analogous to billiard ball type collision. In these reactions, the incoming projectile particle strikes the target nucleus thereby losing some of its kinetic energy in translating the target nucleus. The direction of the incoming particle gets deflected by angle ϴ after the striking as in the scattering of the billiard ball. The energy the projectile loses is gained by the target nucleus which moves away at an increased speed.



During elastic scattering, the target nucleus and the projectile retain their individual identities. An example of elastic scattering in $^{9}Be\ (n,n)^{9}Be$.

The amount of energy transferred to the target nucleus by the projectile is calculated as,

$$E_M = \frac{4mM(\cos\theta)^2}{(m+M)^2} E_m$$

Where, E_M= K.E. gained by the target nucleus of mass M.

E_m= Initial K.E. of the projectile of mass m.

θ= Angle between initial and final path of the projectile.

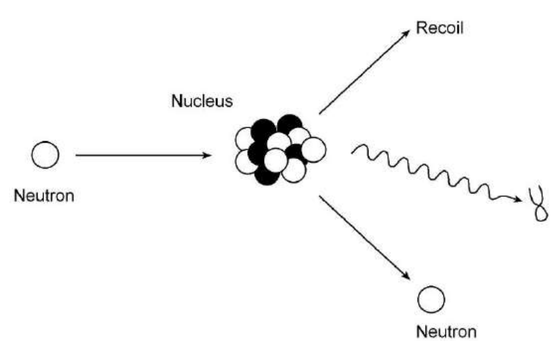
There is no change in the total potential energy and the kinetic energy is conserved during an elastic scattering.

The slowing down of fast neutrons by a moderator in a nuclear reactor is mainly by elastic scattering.

2. <u>Inelastic Scattering</u>

In these reactions, projectile strikes the target nucleus thereby loosing some of its kinetic energy in raising the potential energy of the target nucleus. The target nucleus gains the energy and is raised to an excited state and then decays releasing the energy as gamma radiation. During inelastic scattering the target nucleus and the projectile retain their individual identities. An example of inelastic scattering is $^{14}_{7}N\ (p,p)\ ^{14}_{7}N$

Here, the kinetic energy of the system is not conserved..



In the foregoing two processes, the reactants and the products are same.

3. **Photonuclear reations**

Nuclear reactions initiated by γ- photons of high energy are called as photonuclear reactions. Photonuclear reactions are endoergic in nature. An ejectile particle in photonuclear reactions is more often n or P but with some very high energy photons, d, l or α or even a mixture of particles is liberated as ejectile. An example of photonuclear reaction is,

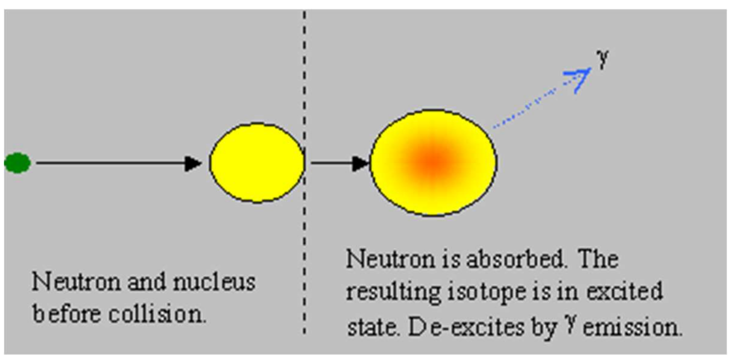
$$^{9}_{4}\mathrm{Be} + \gamma \rightarrow 2\,^{4}_{2}\mathrm{He} + ^{1}_{0}\mathrm{n}$$

(γ,γ'), (γ,P), (γ,n), (γ,2n), (γ,α) are some of the principle types of photonuclear reactions.

4. **Radioactive capture Reactions**

During radioactive capture, target nucleus emits radiations in the form of one or more photons after the projectile capture. The most common radioactive capture reactions are (n, γ) reactions in which the projectile neutron is captured by the target nucleus and emits only a gamma photons. (n,γ) reactions results in the product nucleus with one mass unit higher. Some examples of radioactive capture reactions are; ^{23}Na(n,γ)^{24}Na; ^{31}P(p,γ)^{32}P; ^{179}Au(n,γ)^{180}Au.

This reaction which occurs in most materials is the most important one for neutrons with low energy. (p,γ) reactions are the other common radioactive capture reactions.



5. **Special Nuclear Reactions**

Special nuclear reactions are the reactions involving high energy projectiles. The target nucleus is partly torn apart giving products lighter by several units, unlike in the above (1 to 4) reactions in which the product nucleus differs from the target nucleus only by a few units of mass. Some of the important types of these reactions are explained below;

a. *Evaporation reaction*

The nuclear reactions in which several nucleons or their combinations are ejected from the target nucleus are called as evaporation reactions. Some examples of nuclear reactions are ^{133}Ca(α,4n)^{133}La , ^{27}Al(d,pα)^{24}Na.

b. *Spallation*

Spallation involves expulsion of a large number of nucleons. In spallation, the excitation energy of the target nucleus is sufficient high and results in the emission of several particles such as α-particles and protons leaving behind a product nuclei of sufficiently smaller masses than the target. These reactions generally involve proton or neutron as a projectile.

Some examples of spallation are; $^{63}Cu(p, p3n9\alpha)^{24}Na$; $^{79}Br(p,p7n7\alpha)^{44}Sc$

c. Fragmentation

In fragmentation, a target on heavy excitation breaks into a light and a heavy fragment having about the same N/Z ratio as in the target nucleus. The light and heavy fragment thus produced decays by β^- and evaporation respectively.

d. Stripping reactions

Stripping is a direct interaction process in which the projectile leaves behind one of its nucleons without the formation of the compound nucleus. In many of the nuclear reactions, it is observed that projectile does not react as a whole with the target nucleus, but one or more constituents of the projectile alone are trapped by the target nucleus. Stripping, thus produces heaving products than the target nucleus.

Some of the stripping reactions of the $^{27}_{13}Al$ are listed below

$$^{27}_{13}Al \xrightarrow{+p} {}^{28}_{14}S$$

$$^{27}_{13}Al \xrightarrow{+\alpha} {}^{31}_{15}P$$

$$^{27}_{13}Al \xrightarrow{+3\alpha} {}^{39}_{19}K$$

NUCLEAR FISSION

Nuclear fission is a process in which a heavy nucleus excited by a neutron or by other means splits into two smaller fragments of approximately equal mass. Nuclear fission is generally accompanied by emission of one or more neutrons.

The nuclei with mass number over 200 when bombarded with subatomic particles like neutrons or other particles with sufficient energy show fission process.

Thermal neutrons are effective to carry out fission of $^{241}_{90}Th$, $^{233}_{92}U$, $^{235}_{92}U$, $^{242}_{93}Np$ while fast neutrons produce fission in $^{232}_{90}Th$, $^{231}_{91}Pa$ and $^{242}_{94}Pu$.

A typical nuclear fission is splitting of U-235.

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{143}_{54}Xe + {}^{90}_{38}Sr + 3{}^{1}_{0}n + 200\ \text{MeV}$$

This fission is achieved by bombarding U-235 nuclei with thermal neutrons.

NUCLEAR FISSION A CHAIN REACTION

When the U-235 splits, approximately 2 to 3 neutrons are released. If the neutrons from each nuclear fission are absorbed by other U-235 nuclei, these nuclei split and release even more neutrons. Thus, a chain reaction occurs. A nuclear chain reaction is a self sustaining series of nuclear fissions caused by the absorption of neutrons released from previous nuclear fissions. The chain reaction of nuclear fissions is the basis of nuclear power and nuclear reactors.

FISSION PRODUCTS

Different types of fission of the same nucleus (U-235) producing different primary products are possible. The fission fragments of U-235 thus are not a unique but could be one of about 30 possible pairs such that the mass number of lighter fragment ranges in between 85-105 and that of heavier fragment ranges in between 130-160. Following are some of the possibilities.

$$
{}^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow
\begin{cases}
{}^{96}_{36}\mathrm{Kr} + {}^{140}_{56}\mathrm{Ba} + 2\mathrm{n} \\
{}^{95}_{38}\mathrm{Sr} + {}^{139}_{54}\mathrm{Xe} + 2\mathrm{n} \\
{}^{96}_{40}\mathrm{Zr} + {}^{137}_{52}\mathrm{Te} + 3\mathrm{n} \\
{}^{99}_{41}\mathrm{Nb} + {}^{138}_{91}\mathrm{Sb} + 4\mathrm{n} \\
{}^{95}_{39}\mathrm{Y} + {}^{144}_{53}\mathrm{I} + 3\mathrm{n} \\
{}^{92}_{37}\mathrm{Rb} + {}^{140}_{55}\mathrm{Cs} + 4\mathrm{n} \\
{}^{95}_{42}\mathrm{Mo} + {}^{139}_{57}\mathrm{La} + 2\mathrm{n}
\end{cases}
$$

How exactly the nucleus splits depends on the energy acquired by the fissile nucleus.

B-Decay of Primary Products

As most of primary fragments are neutron rich, they display β^- activity and continue to decay by successive β^- emissions till a stable nuclide isobaric with the primary fragment is obtained. This is illustrated for a typical fission fragment pair as,

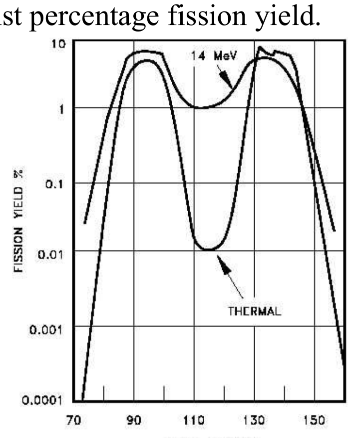
$$
{}^{236}_{92}\mathrm{U} \rightarrow
\begin{cases}
{}^{99}_{41}\mathrm{Nb} \xrightarrow{\beta^-} {}^{99}_{42}\mathrm{Mo} \xrightarrow{\beta^-} {}^{99}_{43}\mathrm{Tc} \xrightarrow{\beta^-} {}^{99}_{44}\mathrm{Ru}\ \text{(stable)} \\
{}^{133}_{51}\mathrm{Sb} \xrightarrow{\beta^-} {}^{133}_{52}\mathrm{Te} \xrightarrow{\beta^-} {}^{133}_{53}\mathrm{I} \xrightarrow{\beta^-} {}^{133}_{54}\mathrm{Xe} \xrightarrow{\beta^-} {}^{133}_{55}\mathrm{Cs}
\end{cases}
$$

FISSION YIELD

A term that is used in describing mass distribution between the fragments is called as cumulative chain fission yield and is described by the following equation.

$$Y(A) = \frac{No.\ of\ Product\ nuclei\ of\ mass\ A}{Total\ No.\ of\ Nuclei\ Fissioned} \times 100$$

Where, Y(A) is fission yield for the fragment with mass A. Experimentally, the yield of fragment with any mass number is given by the yield of the final stable isotope of that mass number. A typical fission mass yield curve is shown below where mass number of fission fragment is plotted against percentage fission yield.



Fission yield, frequency distribution of the fission products generated in the fission of U-235

From the curve it is evident that the isotopes obtained are with mass numbers 72-162. The yields are above 1% range from 85-105 for lighter fragments while 130-150 for heavier fragment. The maximum yields are from 90-100 for lighter fragments while 134-144 for heavier fragment.

It can also be seen from the graph that the yield for symmetrical fission where both the fragments have mass 177 is lowest being around 0.005%

FISSION ENERGY

The tremendous amount of energy is released during nuclear fission. The reason for this is a loss in mass. The energy released during a fission event can be calculated using the exact mass difference between the reactants and the products. Let's consider the following fission process;

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3^{1}_{0}n$$

Here, total mass of reactants = 235.044 + 1.0086 = 236.0526amu.

Total mass of products = 140.908 + 91.905 + 3.0258 = 235.8388

Hence, mass defect, Δm = 236.0526 - 235.8388 = 0.2138amu.

The fission is thus accompanied by a loss of mass of 0.2138 amu, which is converted into energy.

Since, 1 amu = 931MeV

Therefore, energy released =0.2138x931 = 199.0478MeV.

Thus 199.0478 MeV of energy is released in above process.

Let us consider another case where ^{95}Mo and ^{139}La are two stable end products of fission. The reaction is

$$^{235}_{92}\mathrm{U} + ^{1}_{0}\mathrm{n} \rightarrow [^{236}_{92}\mathrm{U}] \rightarrow ^{95}_{42}\mathrm{Mo} + ^{139}_{57}\mathrm{La} + 2^{1}_{0}\mathrm{n}$$

For this reaction, the total mass of the reactants = 230.0526 amu and the total mass of the products = 235.8329 amu. thus, the mass difference = 0.2197amu. The energy released = 0.2197 x 931= 204.54 MeV.

Another method for calculating the fission energy is based on the binding energy per nucleon values. By taking a value of 7.6 MeV for uranium and 8.5 MeV for the fission products, we obtain the binding energy of ^{236}U compound nucleus = 236 x 7.6 MeV. the binding energy of the fission fragments = 236 x 8.5 MeV.

Therefore, the energy released per fission = 236(8.5-7.6) = 212 MeV.

If a mole of ^{235}U is made to undergo complete fission, the energy released is 200 x 6.02 x 10^{23} MeV or 4.3 x 10^{12} kcal or 2.2 MW of electric power / day. In comparison with this figure, the energy released when 1 mole of carbon undergoes combustion is only 94 kcal.

<u>Plutonium as Fissionable Material</u>

Ordinary uranium consists only of about 0.7 percent of ^{235}U. at the same time, it is extremely difficult to isolate ^{235}U from the other isotopes present in ordinary uranium. It was found that plutonium which does not occur in nature but which can be prepared from the more abundant (99.3%) isotope ^{239}U undergoes fission readily like ^{235}U.

The preparation of plutonium from involves the following three steps

$$^{238}_{92}U + ^{1}_{0}n \xrightarrow{\text{Bombarment by neutrons}} ^{239}_{92}U$$

$$^{239}_{92}U \xrightarrow{\text{emmision of } \beta \text{ Particle}} ^{239}_{93}Np + ^{0}_{-1}e$$

$$^{239}_{93}Np \xrightarrow{\text{emmision of } \beta \text{ Particle}} ^{239}_{94}Pu + ^{0}_{-1}e$$

Plutonium, being chemically different from uranium, can be separated relatively easily. The discovery of plutonium has solved the problem of release of nuclear energy through nuclear fission.

PROBLEMS WITH Uranium-238

U-238 is not suitable for chain reaction. This is because U-238 nuclei do not break until the energy of bombarding neutrons is above 1.2MeV. Such neutrons are called as fast neutrons. On the other hand U-235 which is commonly used for fission can be fission by slow neutrons. U-238 when bombarded by slow neutron forms excited unstable isotope U-239, which decays further to plutonium as mentioned in the above section.

NUCLEAR FUSION

A reaction in which two lighter nuclei combine to form a heavier nucleus accompanied by release of energy is called nuclear fusion. An example of fusion reaction is,

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

When the two nuclei to be fused are brought together, they experience a very large coulombic repulsion. Thus, the fusion can occur only by making one nucleus collide with another highly energetically, that is, the kinetic energy of each nucleus should be kept very high so as to overcome the repulsive coulombic potential energy barrier between them. This requires a very high temperature, of the order of millions of degrees.

Since, the kinetic energy needed to overcome the repulsion increases rapidly with the atomic number. The lighter the nuclei the greater the chance for them to approach closely. Thus, hydrogen isotopes are the best elements for bringing out the nuclear fusion.

A nuclear fusion reaction is highly exoergic. Nuclear fusion reactions are called as thermonuclear reactions.

FUSION ENERGY

A nuclear fusion reaction releases a tremendous amount of energy consequent to the conversion of mass into energy. Fusion reactions are more energetic that fission reactions. The fusion of 1 gm of deuterium would result in the energy equivalent to that of 65 tons of TNT.

NUCLEAR FUSION AND STELLAR ENERGY

Stars produce tremendous amount of light and energy. Nuclear fusion are the source of such energies. The surface of the stars is extremely hot. For example, the temperature on the cooler star like sun is 15 million degrees Kelvin. E. Salpeter suggested the following proton-proton chain reaction to account for the sun's energy.

$$ {}_{1}^{1}\mathrm{H} + {}_{1}^{1}\mathrm{H} \rightarrow {}_{1}^{2}\mathrm{H} + \beta^{+} + \gamma $$

$$ {}_{1}^{1}\mathrm{H} + {}_{1}^{2}\mathrm{H} \rightarrow {}_{2}^{3}\mathrm{He} + \gamma $$

$$ {}_{2}^{3}\mathrm{He} + {}_{2}^{3}\mathrm{He} \rightarrow {}_{2}^{4}\mathrm{He} + 2{}_{1}^{1}\mathrm{H} $$

$$ 4{}_{1}^{1}\mathrm{H} \rightarrow {}_{2}^{4}\mathrm{He} + 2\beta^{+} + 2\mathrm{v} + 2\gamma $$

It is believed that 3.685x 10^{10}tonnes of hydrogen is consumed per minute on the sun for this fusion process. Even at this loss of rate the sun will be able to offer its life giving energy to our beautiful earth for may be another 100 billion years.

FUSION POWER

Fusion reactions can serve as power source and produce electricity if these can be conducted in a controlled manner in a reactor. The naturally occurring deuterium can be used in such a reactor.

$$ {}_{1}^{2}\mathrm{H} + {}_{1}^{2}\mathrm{H} \rightarrow {}_{2}^{3}\mathrm{He} + {}_{0}^{1}\mathrm{n} + \text{ energy} $$

$$ {}_{1}^{2}\mathrm{H} + {}_{1}^{2}\mathrm{H} \rightarrow {}_{1}^{3}\mathrm{He} + {}_{1}^{1}\mathrm{H} + \text{ energy} $$

The fusion of Li with a proton is promising fusion reaction for the energy production,

$$ {}_{3}^{6}\mathrm{Li} + {}_{1}^{1}\mathrm{H} \rightarrow {}_{2}^{3}\mathrm{He} + {}_{2}^{4}\mathrm{He} + \gamma $$

In a fusion power reactor being experimented, the deuterium-tritium fusion produces high energetic neutrons. This neutron energy can be absorbed by a lithium shield. The heated lithium can then be made to exchange its heat with water to generate steam.

COLD FUSION

Two chemists, B. Stanley Pons of the University of U.S.A. and Martin Fleischmann of the University of Southampton (England) announced in 1989 their success if effecting cold nuclear fusion. They claimed that the passage of current between a platinium anode and a palladium cathode in a 0.1 M LiOD solution in D_2O produced nuclear fusion at room temperature along with a large amount of heat. They proposed deuterium-deuterium fusion through two paths.

$$ {}_{1}^{2}\mathrm{H} + {}_{1}^{2}\mathrm{H} \rightarrow {}_{2}^{3}\mathrm{He} + {}_{0}^{1}\mathrm{n} $$

$$ {}_{1}^{2}\mathrm{H} + {}_{1}^{2}\mathrm{H} \rightarrow {}_{1}^{3}\mathrm{He} + {}_{1}^{1}\mathrm{H} $$

If the cold fusion is real, it would solve the global problem as there is a vast amount of deuterium in nature.

PROBLEMS IN PERFORMING NUCLEAR FUSION

The production of extremely high temperature required for fusion in the laboratory is difficult and expensive. Even if such a temperature is produced no reaction vessel can withstand with such a high temperature.