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NUCLEAR FISSION AND FUSION

CHEMICAL AND NUCLEAR REACTIONS

Chemical Reaction

The formation of a new compound molecule due to rearrangement of valence electrons in interacting atoms and molecules with the release or absorption of energy is called a chemical reaction.

In this process, the nucleus is not affected at all. Even the electrons in the inner orbits remain unaffected.

$$C + O_2 \rightarrow CO_2 + 4.8\ eV$$

In this chemical reaction, 4.08 eV energy is released for each reacting carbon atom. It is called the binding energy (B.E) of CO2 molecule. R

The important points to be noted in chemical reactions are Energies of the order of 10 eV are involved.

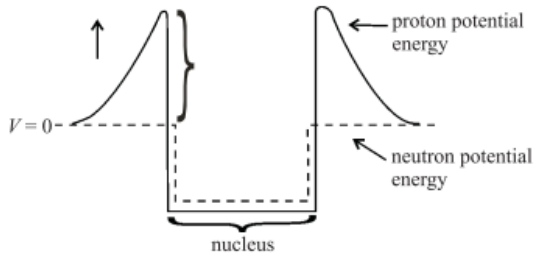
Change of mass is of the order of 10–35 kg, which is extremely small and we say that the mass is conserved.

The total number of atoms of each type on the right hand side of the chemical equation is always equal to the total number of atoms of each type on the left hand side.

Nuclear Reactions

In nuclear reactions, the nuclei, not electrons, of the reactants interact with each other. They result in the formation of new elements. This process is also called transmutation of nuclei.

The phenomenon of nuclear transmutation or nuclear reaction was discovered by Lord Rutherford in the year 1919. He bombarded nitrogen gas with high energy α-particles of energy 7.7 M eV obtained from a polonium source.



Conservation Laws for Nuclear Reactions

The sum of the mass numbers of the reactants is equal to the sum of mass numbers of the products. mass number 7 = 3 + 4 = 6 + 1 is conserved

The sum of atomic numbers of the reactants is equal to the sum of atomic numbers of the products. atomic number 4 = 3 + 1 = 2 + 2 is conserved.

Nuclear reactions follow the law of conservation of energy.

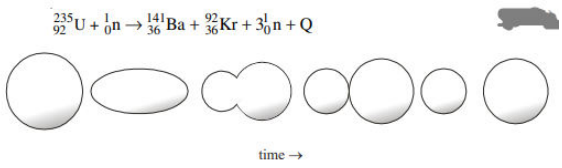
mass is concentrated form of energy. Therefore the sum of input kinetic energy plus the mass of the reactants is equal to the output kinetic energy plus the mass of the products.

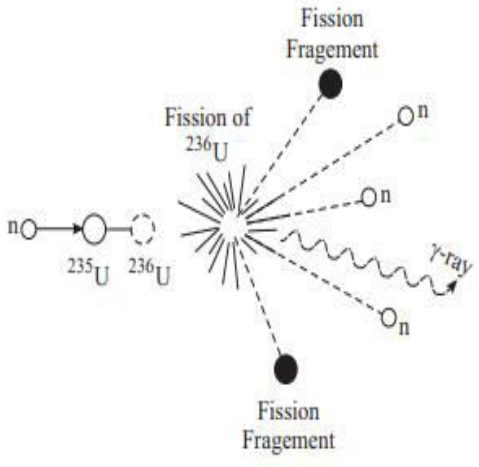
Nuclear reactions follow the law of conservation of momentum, which results in distribution of kinetic energy among various product nuclei.

NUCLEAR FISSION

When a heavy nucleus like uranium is bombarded by slow neutrons, it splits into two fragment with release of 2-3 neutrons and 200 MeV energy. This process is known as nuclear fission.

Mechanism of Nuclear Fission

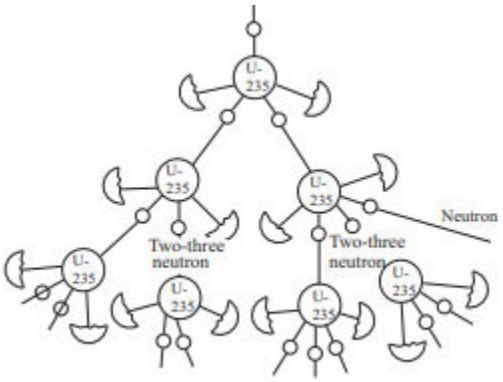




A substance like $^{235}_{92}U$ which undergoes fission by thermal neutrons is called a fissile material

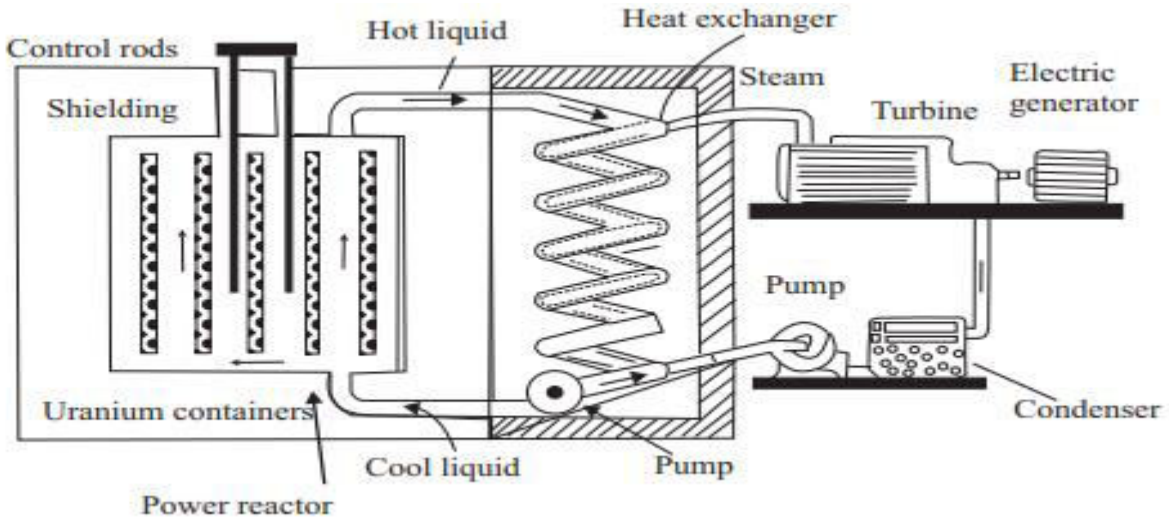
Nuclear Chain Reaction

Chain reaction occurs when more than one emitted neutron induce further fission for each primary fission.



NUCLEAR REACTOR

A reflector is put next to the core to stop neutron leakage from the core. z The whole assembly is placed inside a vessel, called pressure vessel. Usually, a few inches thick stainless steel is used for this purpose. z A thick shield is provided to protect the scientists and other personnel working around the reactor from radiations coming from the reactor core. It is usually in the form of a thick concrete wall. z The entire structure is placed inside a reactor building. It is air tight and is maintained at a pressure slightly less than the atomospheric pressure so that no air leaks out of the building



NUCLEAR FUSION

The process in which two light nuclei combine to form a heavier nucleus is called nuclear fusion

$$^{2}_{1}D + ^{2}_{1}D \rightarrow ^{4}_{2}He + Q$$

Energy in the Sun and Stars

The sun mainly consists of hydrogen and helium gases

four hydrogen nuclei fuse into a helium nucleus with the release of two positrons (electron-like microscope particles of the same mass but positive charge) and 26.8 MeV energy. The tremendous amount of energy released in a thermo-nuclear reaction is the source of energy in stars. The quantity of hydrogen in the sun is sufficient to keep it shining for nearly 8 billion years more.

$$4\,^{1}_{1}H \rightarrow ^{4}_{2}He + 2\,^{0}_{1}e + Q$$

NUCLEAR ENERGY

The nuclear energy is perhaps an important option for meeting our future energy needs through peaceful applications.

The most important peaceful application of nuclear energy is in the generation of electricity

One of the main advantages of nuclear power plant is that the fuel is not required to be fed into it continuously like the gas or coal in a thermal power plant. Further, it does not pollute the environment to the extent discharge of smoke or ash from fossil fuel/power plants do.

Check Yourself

1. Fission of a nucleus is achieved by bombarding it with
   A. Neutrons
   B. Protons
   C. X-ray
   D. Electrons
2. Nuclear energy is released in fission because binding energy per nucleon is

   A. Greater for fission fragment than for parent nucleus
   B. Smaller for fission fragment than for parent nucleus
   C. Same for fission fragment and nucleus
   D. None of the above
3. The Helium atom does not contain
   A. Two proton
   B. Two electron
   C. Six nucleon
   D. Two neutrons
4. Which of the following is a good moderator
   A. Helium
   B. Cadmium
   C. Graphite
   D. Ordinary water
5. Energy generation in star is mainly due to
   A. Chemical reaction
   B. Fission of heavy nuclei
   C. Fusion of light nuclei
   D. Fusion of heavy nuclei

Stretch Yourself

1. What is nuclear fusion and fission? Write an equation of nuclear fusion to support your answer.
2. What is the source of energy in the sun? How is it generated? Illustrate with an example.
3. Calculate the energy released in a fusion reaction $4{}_2^4He \rightarrow {}_6^{12}C$Given, the mass of on α-particle = 4.00263u
4. Calculate the mass of 235U consumed to generate 100 mega watts of power for 30 days.

Hint to Check Yourself

1A 2 A 3 D 4 C 5C