CHAPTER NINE:

NUCLEAR ENERGY AND NUCLEAR REACTION

Introduction:

- Nuclear energy which is the most powerful kind of energy known, is also known as atomic energy.
- The tremendous heat and light produced by the sun is as a result of nuclear energy, as well as the energy produced by the atomic bomb and the hydrogen bomb.
- Nuclear energy results from changes which occur within the nucleus of the atom, which contains an enormous amount of energy.
- Nuclear energy is had when this enormous amount of energy bound in the nucleus is released.
- Nuclear energy is useful because it creates a great amount of energy in the form of heat.
- This heat can be used to generate steam and this can be used to generate electricity.
- A device called a nuclear reactor is used to produce and control nuclear energy.
- A nuclear reactor operates somehow like a furnace, but instead of using fuels such as coal or oil, almost all reactors use uranium.
- Electric energy production is the most important use of nuclear energy.
- But nuclear energy also produces high-energy particles and rays called nuclear radiation.
- Nuclear radiation has important uses in medicine, industry and science.
- Nuclear energy also powers some submarines and certain ships.
- Like nuclear power plants, these vessels have reactors to create heat for making steam.
- This steam is then used to turn the propellers of the ships, which results in their movement.
- Almost all the world`s electricity is produced by thermal and hydroelectric power plants.
- These thermal plants use the force of steam from boiling water to generate electricity.
- The great majority of thermal plants burn fossil fuels such as coal and oil, to produce the heat needed to boil the water.

- But for the rest of these thermal plants, this needed heat is produced by the use or the fission of uranium.

- Hydroelectric power plants which use the force of rushing water from dams , cost much less to operate than fossil-fuel plants.
- They do not produce much air pollution as do fossil fuel plants.
-Since only a few countries have enough natural power to generate large amounts of electricity, most countries therefore depend mainly on fossil fuel plants for their electric power.
- But since the world has a limited supply of fossil fuels, and the worldwide demand for them as well as electricity keeps on increasing every year, nuclear plant may thus become more and more important.
- For the amount of fossil fuels which remain on earth, keeps on decreasing.

The advantages of nuclear energy:

- Nuclear power plants have two main advantages over fossil fuel plants, and these are:(I) A nuclear power plant uses less fuel than a fossil-fuel plant.(II)Uranium, unlike fossil-fuel, does not cause air pollution.
- In spite of these advantages, nuclear power plants cost more to build than fossil fuel plants.
- Since the type of uranium used by most nuclear reactors i.e. u-235, is limited, then its supply is likely to become a problem in future.

Nuclear reaction;

This refers to the process by which a nucleus releases energy. A nuclear reaction involves changes in the structure of a nucleus. As a result of these changes, the nucleus may gain or lose one or more neutrons or protons. It therefore changes into the nucleus of a different isotope or element. If the nucleus changes into the nucleus of a different element, then such a change is called transmutation. There are three types of nuclear reactions which release useful mount of energy and these are:

(1) radioactivity (2)nuclear fusion

(3) nuclear fission

Einstein`s equation:

- According to this equation, energy can be converted into mass and mass can be converted into energy, and this equation is given by:

$E = \Delta MC^2$, where E = energy.
ΔM = change or loss in mass.
C = the velocity of light.

- -Nuclear fission and nuclear fusion reactions are based on this type of equation.
- The heavy nucleus which disintegrates is called the parent nucleus.
- All nuclear reactors produce energy by this means.
- To produce fission, a reactor requires a bombarding particle such as a neutron, and a target material such as u-235.
- Fission occurs when the bombarding particle split a nucleus in the target material into two equal parts, each of which is referred to as a fission fragment.
- Fission only releases part of the energy of the nucleus which appears mostly as heat and radiation.
- One or both of the fission fragments is radioactive, and emits mainly gamma rays.
- For fission to occur, the bombarding particle must first be captured by the nucleus.
- Reactors use neutrons as bombarding particles, because they are the only atomic particles that are both easily captured and able to cause fission.
- Apart from that, neutrons can also pass through most kinds of matter, including uranium.
- Protons can also cause fission.
- But protons and nuclei both have positive charge and so they normally repel one another.
- Since neutrons have no charges, they can easily be captured by the nucleus.
- Power reactors use uranium as their target material or fuel.
- This is due to the fact that since it contains a large number of protons, it is the easiest of all the natural nuclei which can be splitted.
- Uranium also makes a good reactor fuel, since it can create a continuous series of fission reactions, and for this reason it can produce a steady supply of energy.
- If an atom or a nucleus undergoes fission, there is always a decrease in the resulting produce i.e. there is a loss in mass.
- In other words, the total mass of the reactants is greater than the total mass of the products.
- This loss in mass is called the mass deficit and is usually represented by ΔM.
- It is this mass deficit which is converted into energy, in the form of heat radiation.
- The equation can be illustrated as
  $^{8}X \longrightarrow {}^{3}Y + {}^{3}Y + {}^{1}_{0}n$ + energy.
- Fission can be spontaneous or caused by the impact of neutron, i.e. neutron induced.

- $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{141}_{56}Ba + ^{42}_{36}kr + 3^{1}_{0}n + Q$, is an example of a neutron induced fission reaction in which one atom of u-235 undergoes fission, with Q being the energy released.

Characteristics of neutron induced fission:

(i) The neutron is directed towards the nucleus so as to bombard it.
(ii) The neutron is absorbed by the nucleus, which results in the splitting of the nucleus.
(iii) Neutrons are then produced and a great amount of energy is released in the form of heat and radiation.

Nuclear fusion:

- This is the type of nuclear reaction, in which two light nuclei come together to form a heavy nucleus with the release of energy.
- An example is the fusion of the hydrogen isotopes (deuterium), i.e.

$^{2}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{2}He + ^{1}_{0}n + Q$, where Q = the energy released.

- Whenever two light nuclei are brought together, there is always a loss in mass and it is this loss in mass or mass deficit, which is converted into energy.
- In order to reduce the coulomb force of interaction between these nuclei, fusion reaction is normally brought about by using light nuclei and providing energy for the reacting particles.
- This can be done in two ways, i.e.(i) by accelerating the nuclei in a reactor.

(ii) by heating the nuclei in a reactor and in such a case, the fusion reaction is referred to as thermonuclear reaction.- Fusion reactions that produces large amount of energy can only be created by means of intense heat.
- Thermonuclear reaction can only occur in a special form of matter called plasma.- Plasma is a gas which is made up of free electrons and free nuclei.- Nuclei normally repel each other.- But if a plasma containing lightweight nuclei is heated to an extremely high temperature, the nuclei begin moving so fast that they break through one another`s electrical barrier and fuse.- A man-made radioactive isotope called trinium, and another isotope called deuterium or heavy hydrogen are both thermonuclear fuels.- But since deuterium can be obtained from ordinary water, it is considered as an ideal thermonuclear fuel.

- Also a given weight of deuterium can supply about four times as much energy as the same weight of uranium.
- It is fusion which produces the energy of the sum and the hydrogen bomb.

The differences between nuclear fission and nuclear fusion:

FISSION	FUSION
(1) A heavy nucleus splits into light nuclei. (2) Is a form of artificial radioactive disintegration or process. (3) Not normally agitated i.e. does not require high temperature. (4) Has been brought under control.	(1) Two light nuclei come together to form a heavy nucleus. (2) Is not a radioactive process. (3) Thermally agitated or initialed i.e. require high temperature. (4) Has not been brought under control.

Similarities between fusion and fission:

In both cases, the energy produced is due to mass deficit.

The advantages of fusion over fission:

(i) In terms of raw materials, fusion materials are much more abundant and cheaper.
(ii) In terms of radiation hazards, fusion produces less dangerous by-products than fission.

Uses of nuclear/atomic energy: These uses are classified into two and these are: (i) The peaceful uses. (ii)The destructive uses.

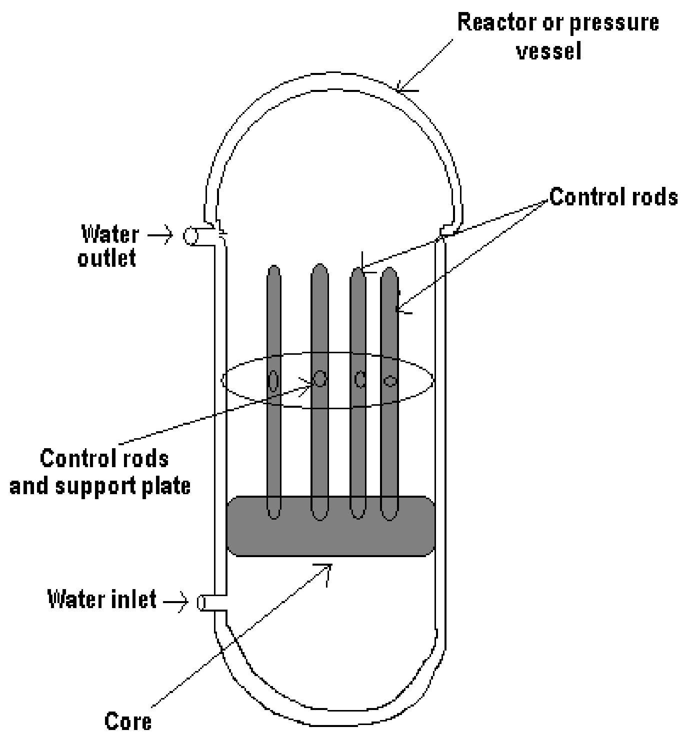
Peaceful uses:

(i) to power submarines, ships ad trains.
(ii) To produce electricity.
- The great amount of heat energy released in a nuclear reaction can be used to generate steam.
- This steam can then be used to rotate the turbine of a generator to produce electricity.

Destructive uses:

(i) In the manufacture of atomic bombs.
(ii) In the manufacture of nuclear weapons.

The nuclear reactor:



- This is a device that is used to produce a vast amount of energy from a small amount of fuel. - It is sometimes called an atomic reactor or an atomic pile.
- A nuclear reactor generates energy mainly in the form of heat by means of nuclear fission.
- Nuclear fission refers to the splitting of the atoms of uranium or plutonium.
- An atomic bomb gets its destructive power from uncontrolled fission.
- Since a nuclear reactor keeps fission under control, the energy it produces can be used for the generation of electricity and for other peaceful purposes.
- Reactors can also be used to make certain substances radioactive.
- These radioactive materials called radioisotopes have important uses in agriculture, industry and medicine.

Parts of nuclear reactor:

- Nuclear reactors vary in design and size but most of them have five basic parts, which are:

(1) The core.

(2) The moderator.

(3) The control rods.

(4) The coolant.

(5) The pressure vessel.

- They also have a biological shield and a safety system, to protect its operators and technicians.

The core:

- This is the central part of a reactor and consists of the nuclear fuel.
- Even though the nuclear fuel used by most reactors is a mixture of several isotopes or forms of uranium, it is only one of these isotopes, U – 235, which actually undergoes fission.

The moderator:

- This is a material used in many reactors to increase the probability of fission, and thus promote a chain reaction.
- Most moderators consist of graphite, water or heavy water which is a compound composed of oxygen and deuterium.
- The work of a moderator is to slow down the rate at which neutrons are released by the u-235 atoms during fission.
- By so doing, the moderator enables other u-235 atoms to capture the neutrons more readily and split in turn. - If the moderator did not reduce the speed of the rate of release of these neutrons, then many of them would be absorbed by u-238 atoms, which do not undergo fission.

The control rods:

- They regulate the rate of the chain reaction and are made of boron, cadmium or some other element which can absorb neutrons without any side effect.

- After loading the core with the fuel, the operator of the reactor partially withdraws the control rods so that they relatively absorb a small number of neutrons.

- This action allows a chain reaction which becomes self-sustaining.
- The rods are then inserted pathway into the core, to absorb enough neutrons to slow the reaction and prevent an explosion.

- If the operator wishes is to increase the power level of the reactor, the control rods can partly be withdrawn to increase the number of neutrons and speed up reaction.