P.G.SEMESTER-II

CC- V (ADVANCES IN CHEMISTRY)

UNIT-I: NUCLEAR CHEMISTRY

TOPIC-NUCLEAR REACTIONS AND THEIR TYPES (PART-3)

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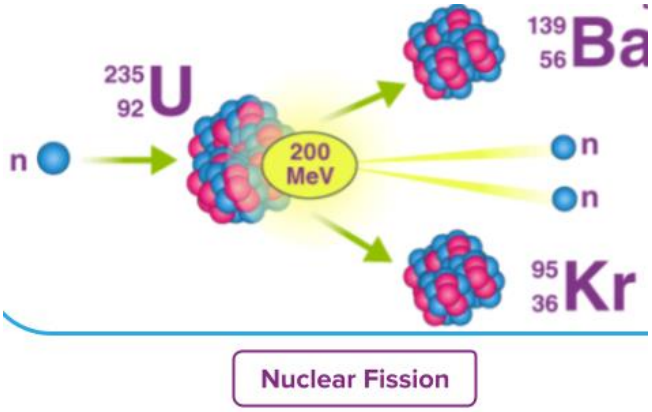
5. NUCLEAR FISSION REACTION

Nuclear fission reaction was discovered in 1938 by two German scientists, Fritz Strassmann and Otto Hahn. It refers to the splitting of heavier nuclei into two or more lighter nuclei in radioactive decay. It produces enormous amounts of energy and is accompanied by neutron and gamma-ray emissions.



One of the important examples of a nuclear fission reaction is the splitting of uranium-235 ($^{235}_{92}U$) when bombarded by the neutron, it forms different types of products.

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{137}_{52}Te + {}^{97}_{40}Zr + 2\,{}^{1}_{0}n + \text{Energy}$$

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{137}_{55}Cs + {}^{96}_{37}Rb + 3\,{}^{1}_{0}n$$

The energy released during the nuclear fission reaction is used to power nuclear power plants. The energy produced by the fission reaction converts water into steam, which is then used to turn the turbine and generate electricity.

NUCLEAR REACTOR:

It is an example of Nuclear Fission process.

Principle:

Nuclear reactor works on the principle of ***controlled chain reaction.*** Main parts of Nuclear reactor:

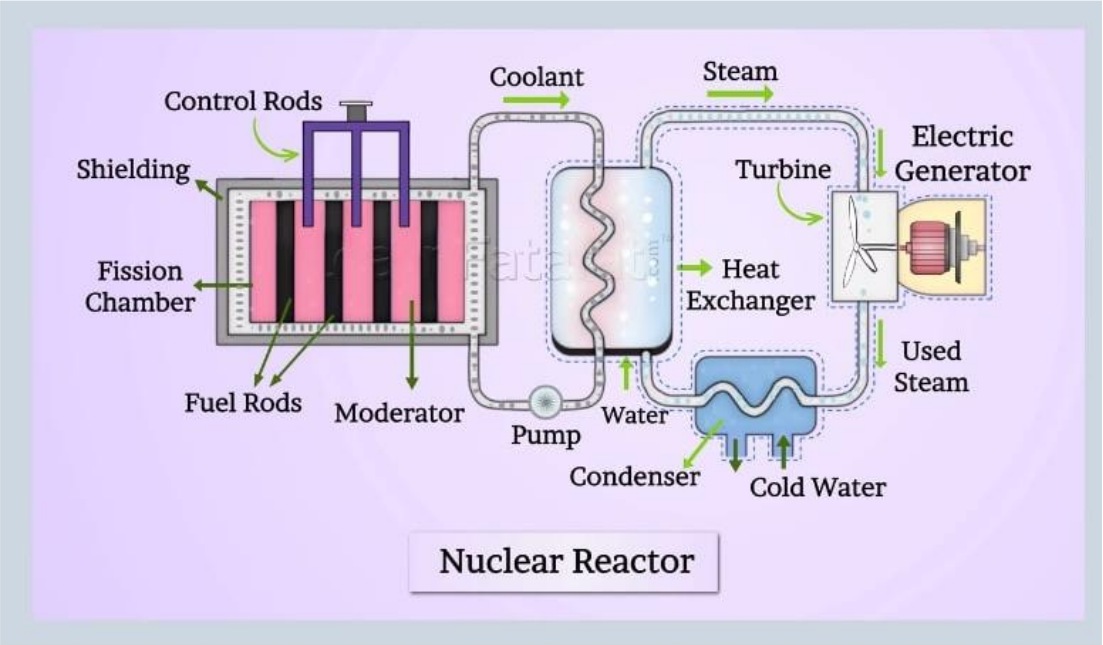
(i) Fuel

(ii) Moderator

(iii) Control rods

(iv) Protective Sheilding

(v) Coolant



The material which undergoes fission is called fuel. Ex: U-235. The material which slows down the fast Nuclear Reactor moving neutrons is called moderator. Ex: D_2O, Graphite . The rods which absorb neutrons to control the chain reaction are called control rods. Ex: Cd, B. The construction with cement and lead (Pb) around the reactor which protects from harmful radiations is called protective shielding. The liquid which removes the heat generated by the reactor is called circulating coolant. Ex: Water at high pressure, molten sodium.

Working:

a. Uranium fuel rods are arranged in the cylinders.

b. The graphite moderator is placed in between the fuel cylinders.

c. When U235 undergo fission, fast neutrons are released.

d. These neutrons pass through the surrounding graphite moderator and loose their energy.

e. The heat generated here is used to produce steam.

f. This steam is used to rotate steam turbine then electric power is produced.

……..to be continued

PRACTICE PROBLEMS

Q. Select the correct option to classify the given nuclear reaction.

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{137}_{52}Te + {}^{97}_{40}Zr + 2\ {}^{1}_{0}n + \text{Energy}$$

1. Nuclear fusion reaction
2. Spallation reaction
3. Nuclear fission reaction
4. Both A and C

Answer: (A)

The reaction mentioned above is an example of a nuclear fission reaction in which the splitting of heavier nuclei takes place into two or more lighter nuclei in radioactive decay. It produces enormous amounts of energy and is accompanied by neutron and gamma-ray emissions. In the above reaction, the uranium-235 ($^{235}_{92}U$) when bombarded by the neutron produces tellurium and zirconium respectively.

Q. Select the correct option with respect to a nuclear fusion reaction.

1. An enormous amount of energy is released and is exothermic in nature
2. Nuclear fusion reaction takes place in the core of the sun

3. It generally results in the formation of heavier nuclei from two lighter nuclei
4. All of the above

Answer: (D)

Solution: Nuclear fusion reactions occur in the core of the sun in which lighter nuclei combine to form heavier nuclei which are exothermic in nature and release an enormous amount of energy.

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

Q. Select the correct option with respect to the nuclear reaction.

1. Product in the nuclear reaction is identified by conserving the number of neutrons and protons.
2. Nuclear reaction generally takes place when unstable nuclei interact with elementary particles like an alpha particle, proton, neutron etc.
3. Energy produced during the nuclear fission reaction is used in the generation of electricity in nuclear power plant
4. All of the above

Answer: (D)

Solution: Nuclear reaction generally takes place when unstable nuclei interact with the elementary particles like an alpha particle, proton, neutron etc. In this type of reaction, the number of neutrons and number of protons is conserved on both sides of the nuclear reaction and helps to identify the product of the reaction.

A large amount of energy is released during the nuclear fission reaction. The energy released during the nuclear fission reaction can be used to power nuclear power plants. The energy produced by the fission reaction converts water into steam, which is then used to turn the turbine and generate electricity.

Q. Select the correct option for the atomic number and symbol of the element formed when Cobalt-60 disintegrated by the emission of beta particles?

1. 30, Zn
2. 28, Ni
3. 29, Cu
4. 27, Co

Answer: (B)

Solution: Let the symbol of the element be M with atomic number Z and mass number A.

According to the question, beta particle emission takes place i.e., ($_{-1}^{0}e$)

Therefore nuclear reaction may be written as,

$$_{27}^{60}Co \rightarrow {}_{Z}^{A}M + {}_{-1}^{0}e$$

Since the sum of mass number and atomic number should be equal on both the sides of the reaction,

Therefore,

Z=27+1=28

A=60

Using the periodic table to find the element with atomic number 28 is Nickel (Ni).

Q. Explain the working of the atom bombs?

Answer: The working of the atom bomb is based on an uncontrolled nuclear reaction. The shape and size of fissionable material are adjusted such that it

reaches the over-critical stage and due to high surface area loss of neutrons takes place. Generally $^{235}_{92}U$ *and* $^{239}_{84}Po$ are taken as fissionable material.

Q. What are the different types of nuclear fuel used in nuclear reactors?

Answer: Nuclear fuel used in the nuclear reactor is of two types:

- Fissile material: It is defined as the material on bombardment with slow-moving neutrons that starts the chain reaction and produces a tremendous amount of energy. For example radioactive material like $^{235}_{92}U$
- Fertile material: Is a type of radioactive material which is itself not fissile in nature but can be made fissile by reaction with neutron like $^{238}_{92}U$

Q. What is the scope of nuclear energy in India?

Answer: In India, nuclear power is the fifth-largest source of electricity and 13th in the world after thermal, gas, hydropower and wind energy. India has 22 nuclear power plants which have tremendous potential to solve the energy crisis in the future.

Q. What is artificial radioactivity?

Answer: In 1934, it was observed that when boron and aluminium are bombarded with particles neutron, proton and positron were emitted. When the bombardment was stopped neutron and proton emissions ceased but the emission of positrons decreased exponentially. Artificial radioactivity is defined as the process in which a stable isotope is converted into radioactive elements and is known as artificial radioactivity.

Q. What is the difference between a nuclear reaction and the chemical reaction?

Answer: The difference between nuclear reaction and chemical reaction includes that in the case of nuclear reaction rate of reaction is independent of external factors such as temperature, pressure and catalyst whereas in the case of chemical reaction rate of reaction is influenced by the external factors. In a nuclear reaction, it is accompanied by the release or absorption of a tremendous

amount of energy. In contrast, in the case of a chemical reaction generally, it is accompanied by a comparatively less amount of energy released in some type of chemical reaction