Science & Technology Class 06

19th July, 2023 at 9:00 AM

OVERVIEW OF THE PREVIOUS CLASS: (9:06 AM)

- U-235 is fissile but U-238 is not.
- **Question:**Provide an account of the growth of nuclear science and technology in India. What is the advantage of a fast breeder reactor? (250 words/15 marks)
- **Approach:** Introduction: How things have progressed i.e. with the first reactor APSARA, which became critical in 1956.
- Then, Pokhran I and Pokhran II established nuclear reactors with the help of Russia, and then a nuclear deal with the USA.
- Application in various areas (agriculture, medicine, etc.)
- 2nd part: Define fast breedor(3 stage), advantage of fast breedor reactor.
- Conclusion: Even if we don't have a domestic uranium supply, we can use our thorium reserve much more effectively.

NUCLEAR FUSION: (9:26 AM)

- Nuclear Fusion is opposite to fission.
- In fusion, 2 or more lighter nuclei fuse together to form a heavy nucleus and in the process, a huge amount of energy is released.
- This energy can be calculated using Einstein's mass-energy equivalence (e=mc^2)
- Fusion is responsible for energy production inside the core of stars.
- In the core of stars, hydrogen nuclei fuse to form helium.
- This process requires very high temperature, as when nuclei come closer there is a powerful electromagnetic repulsion, which needs to be overcome.
- However when nuclei are very close to each other in the range of a few femtometers.
- Strong nuclear force starts operating which helps in fusing nuclei together.
- Because of the high-temperature requirement, it is called thermonuclear fusion.
- **Fusion-based energy production on Earth:**
- There are mainly 2 approaches:
- **1. Magnetic Fusion:** A magnetic fusion device is called Tokamak. Inside a tokamak, a powerful magnetic field is used, to contain deuterium and tritium plasma (both are isotopes of hydrogen).
- At very high temperatures, deuterium and tritium are fused to form helium, and energy is produced.
- There are many Tokamak settlements all across the world such as International Thermonuclear experimental reactor.
- It is situated in France with collaboration among many countries including India.
- It aims to produce 500 megawatts of fusion power.
- Experimental Advanced Superconducting Tokamak in East also known as China's artificial Sun.
- Joint Europeon Torrus (JET).
- Aditya Tokamak, Steady State Superconducting Tokamak (SSST -1), operated by the Institute of Plasma Research, under the Department of Atomic Energy. As of now, SSST-2 is under construction facility.
- It is situated in Gujarat.

- **2. Static Fusion or Inertial Fusion:**
- With the help of powerful laser beams, deuterium, and Tritium is illuminated so that they implode and at very high temperature can fuse into helium.
- Recently, for the first time in the world, Lawrence Livermore Lab in the USA announced that they have produced surplus energy using nuclear fusion.

BENEFITS OF FUSION: (10:25 AM)

- Both Fission and Fusion are clean sources of energy that is they do not produce greenhouse gases.
- **However, Fusion has many additional benefits:**
- 1. For the same amount of material, it produces more energy than fission.
- 2. Raw material is deuterium which is available in every natural source of water and Tritium which can be produced in the lab.
- Thus, Fusion will not cause adverse environmental consequences, because of mining.
- Fusion produces helium as the end product, which is an inert gas, thus there is no fear of nuclear waste.
- At one point in time, a limited amount of deuterium and tritium are kept.
- Thus, it cannot cause a chain reaction and there is no fear of reactor meltdown.

Question: Discuss the concept of nuclear fusion as a potential source of clean energy. Evaluate the current progress and challenges in achieving controlled nuclear fusion.

RADIOACTIVITY (10:48 AM)

- Certain nuclei are not that stable, but they want to attain stability.
- For gaining stability, they undergo 3 types of reaction:
- 1. Alpha decay: It can emit an alpha particle (helium nuclei).
- In this process, they disintegrate and change into something else.
- 2. Beta decay: It occurs in 2-3 stages.
- The end product is all types of beta particles produce an isobar. Atomic number increases which changes its element, but atomic mass does not increases.
- 3. Gamma decay: It is actually a light particle photon, which we cannot see.
- They have the highest energy among all the waves.
- Nothing happens to atomic number or mass, but the energy reduces by releasing gamma particles.
- All these reactions take place naturally and together we call them radioactivity.
- There are many radioisotopes that exist in nature. But we can also make them in the lab using different elements, and that radioisotope is not stable, but can attain stability when it emits these alpha, gamma, and beta particles.
- Often gamma particle emits simultaneously with alpha and beta emission.
- All molecules inside our body are organic molecules which are carbon-based (carbon 14 and carbon 12)
- Plants cannot distinguish between Carbon 14 and Carbon 12, whatever molecules they are making that exactly have the same atmosphere in the plants and other organisms.
- But when we die, carbon 12 remains the same, but carbon 14 disintegrates.
- So, after every 5700 years, half of carbon 14 becomes nitrogen, and so on.
- Whenever archeologists find fossil samples, they try to find the ratio of carbon 14 and carbon 12.

APPLICATIONS (11:16 AM)

- **Applications in agriculture:**
- 1. Mutation Breeding: Plant birds and seeds are exposed to gamma radiation in the hope that it will lead to a mutated variety with desirable properties.
- For example resistance to drought, salinity, etc.
- 2. Fertiliser efficiency: With the help of radioisotopes of nitrogen and phosphorus, scientists can determine the optimum requirement of fertilizer for a particular crop to grow.
- 3. Food irradiation: Food items especially perishable items are exposed to gamma, X-ray, and electron beams to kill microbial organisms.
- 4. Sterile insect technique: It involves exposing insects to gamma to make them sterile.
- They cannot produce babies but remain sexually competitive, thus we can control their population for a limited duration.
- **Application in medicines:**
- 1. External beam therapy, Brachytherapy, and proton beam therapy: All three are used in cancer treatment.
- Brachytherapy is more advanced than external therapy.
- It is located very near to the tumor cells.
- Besides, it is more expensive and cannot work for all types of cancer (Blood cancer).
- Proton therapy only destroys the tumor cells, so the side effect is very less. It is also very expensive.
- Radio isotopes are injected inside the body which injects low doses of gamma.
- The interaction of this, material with healthy and diseased cells can be recorded. This can be used for the diagnosis of diseases such as cancer.
- 2. Radiation sterilization: Medical equipment (Syringes, gloves, surgical sutures, among others can be sterilized with the help of gamma radiation
- **In Defence: (11: 48 AM)**
- 1. Nuclear weapons.
- 2. Nuclear-powered ships and submarines.
- **In Industry:**
- 1. To find material defects inside a solid object,
- 2. To find leakages, radio tracer gases can be used.
- 3. Nuclear power has applications in **water desalination**.
- 4. Radio isotopes such as carbon14 have applications in **geology, archeology**, etc.

TOPIC OF THE NEXT CLASS: NANOTECHNOLOGY