P.G.SEMESTER-II

CC- V (ADVANCES IN CHEMISTRY)

UNIT-I: NUCLEAR CHEMISTRY

TOPIC-NUCLEAR REACTIONS AND THEIR TYPES (PART - 2)

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TYPES OF NUCLEAR REACTION

There are different types of nuclear reactions which include:

- Projectile Capture Reaction
- Particle-Particle Reaction
- Spallation Reaction
- Nuclear Fusion Reaction
- Nuclear Fission Reaction

1. PROJECTILE CAPTURE REACTION:

The projectile is captured by the target, resulting in the formation of an unstable nucleus that achieves stability through the emission of nuclear particles.

As an illustration:

$$^{238}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{239}_{92}\mathrm{U} + \gamma$$

In this case, "n" represents the neutron particle.

Uranium is represented by the letter "U" while 'γ'represents the gamma radiation emitted in the nuclear reaction

2. PARTICLE-PARTICLE REACTION:

This type of reaction is seen in most nuclear reactions. In this type of reaction, in addition to the stable nuclei present on the product side, elementary particles are also emitted.

For example: $^{23}_{11}Na + {}^{4}_{2}He \rightarrow {}^{26}_{12}\mathrm{Mg} + {}^{1}_{1}\mathrm{H}$

Here, “H” represents the symbol of the hydrogen element.

3. SPALLATION REACTION:

High-speed projectiles with the energy of approximately 40 MeV or more may chip fragments from a heavy nucleus leaving behind lighter and stable nuclei. This type of nuclear reaction is called a spallation reaction.

Example: $^{238}_{92}U + {}^{4}_{2}He \rightarrow {}^{187}_{74}W + 20\ {}^{1}_{1}H + 35\ {}^{1}_{0}n$

Here, “U” represents the symbol of uranium element

“n” represents the symbol of neutron

“H” represents the symbol of hydrogen element

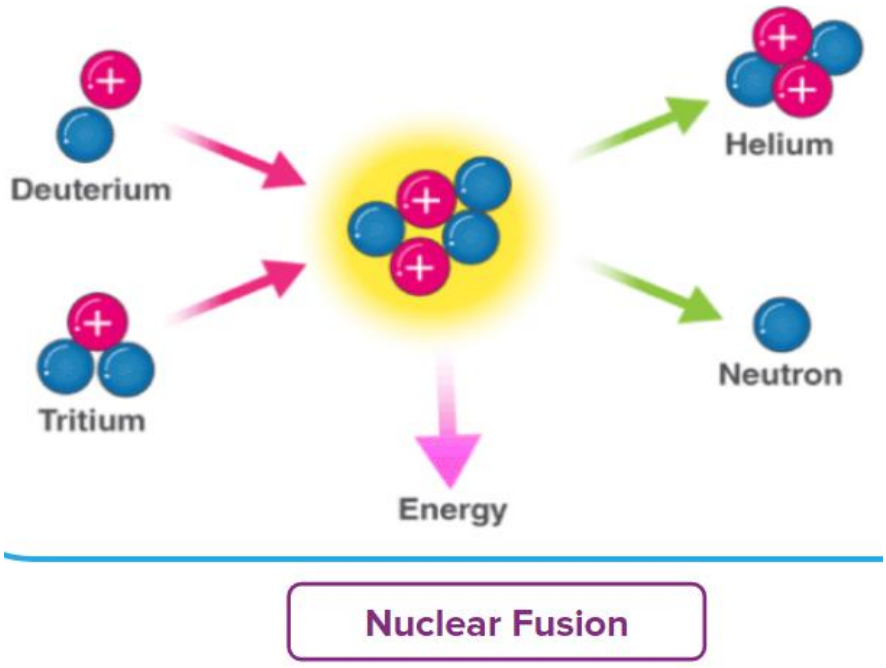
“W” represents the tungsten element

4. NUCLEAR FUSION REACTION

Nuclear fusion reaction is defined as the nuclear reaction in which two light nuclei fuse to form heavier nuclei. Subatomic particles such as protons and neutrons are also produced by the product. This type of reaction is also known as a thermonuclear reaction.

Consider the fusion of deuterium ($^{1}_{2}$H) and tritium ($^{1}_{3}$H) to produce helium and neutrons, which release enormous amounts of energy and are exothermic in nature due to the loss of mass that occurs when heavier nuclei are formed from two lighter nuclei. The massive amount of energy released during an atomic bomb explosion initiates the deuterium ($^{1}_{2}$H) and tritium ($^{1}_{3}$H) reactions.

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



Note: This reaction takes place in the core of the sun where hydrogen nuclei are fused to form helium nuclei. The temperature in the core of the sun is nearly 15 million degrees Celsius.

Natural Examples OF Nuclear Fusion:

- **The Sun:** The primary example of nuclear fusion is the continuous proton-proton chain reaction in the Sun's core, which converts hydrogen into helium at temperatures exceeding 15 million degrees Celsius, providing Earth with heat and light.
- **Stars:** All stars in the universe use fusion to combine lighter elements into heavier ones, producing energy throughout their life cycles.
- **Brown Dwarfs:** These "failed stars" are massive enough to sustain the fusion of deuterium.

Man-Made Examples

- **Thermonuclear Weapons (Hydrogen Bombs):** These weapons use a fission explosion to generate the extreme heat and pressure necessary to trigger a fusion reaction.
- **Experimental Fusion Reactors (Tokamaks):** Devices like the Joint European Torus (JET) (UK) and EAST (China) create high-temperature plasma confined by magnetic fields to produce controlled fusion energy.
- **Laser Inertial Confinement:** The National Ignition Facility (NIF) at Lawrence Livermore National Laboratory uses powerful lasers to compress fuel pellets, achieving "ignition" where more energy is produced than used to trigger the reaction.
- **Fusors:** Small-scale, DIY, or educational devices (sometimes built by students) that accelerate ions to create plasma and achieve low-level fusion, such as deuterium-deuterium fusion.

Energy Production: Fusion generates immense, clean energy (compared to fossil fuels) by releasing binding energy when light nuclei fuse.

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