Unit 5. Nuclear Chemistry Basics Explained

Another article under our guest contributor program; this time covering the basics of nuclear chemistry. Those who have missed the last article covering basics of chemistry, you may read it here. Now let's us focus on Nuclear Chemistry which is an area given stress in most of the UPSC Preliminary question papers. Let's start from a few basic concepts first.

Atomic number (Z)

Atomic number is the number of protons or electrons present in an atom (for every atom, the number of proton and electron are same).

Eg: Nitrogen (N) = 7, Calcium (Ca) = 20, Oxygen (O) = 8.

Mass number (A)

Mass number is the sum of protons and neutrons present in an atom (or it is the sum of electron and neutron present in an atom.)

Eg: Nitrogen (N) = 14, Calcium (Ca) = 40, Oxygen (O) = 16

Isotopes

Elements having same atomic number but different mass number are called isotopes.

Eg: Protium, Deuterium, Tritium.

Isobars

Elements having same mass number but different atomic numbers are called isobars.

Eg: ^{40}S, ^{40}Cl, ^{40}Ar, ^{40}K, and ^{40}Ca.

Allotropes

Different forms of a single element are called allotropes.

Eg: Diamond and graphite are two allotropes of carbon; ie. pure forms of the same element that differ in crystalline structure.

Radioactivity

Unstable atomic nuclei will spontaneously decompose to form nuclei with a higher stability. The decomposition process is called radioactivity. Energy and particles released during the decomposition process are called radiation.

There are three major types of natural radioactivity : alpha, beta and gamma radiation.

Alpha Radiation

$^{238}_{92}U \longrightarrow {}^{4}_{2}He + {}^{234}_{90}Th.$
The helium nucleus is the alpha particle.

Beta Radiation

$^{234}_{90} \longrightarrow {}^{0}_{-1}e + {}^{234}_{91}Pa.$
The electron is the Beta particle.

Gamma Radiation

Gamma rays are high-energy photons with a very short wavelength. Gamma emission changes neither the atomic number nor the atomic mass.

Nuclear reactions

Nuclear reactions are mainly two types :

1. Nuclear fission.
2. Nuclear fusion.

Nuclear Fission

Nuclear fission takes place when an atom's nucleus splits into two or more smaller nuclei. These smaller nuclei are called fission products. Particles (e.g., neutrons, photons, alpha particles) may also be released along fission.

Example:

$^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{90}_{38}Sr + {}^{143}_{54}Xe + 3{}^{1}_{0}n.$

Nuclear Fusion

Nuclear fusion is a process in which atomic nuclei are fused together to form heavier nuclei. Large amounts of energy are released when fusion occurs.The reactions which take place inside the sun is an example of nuclear fusion.

Examples:

$^{1}_{1}H + {}^{2}_{1}H \longrightarrow {}^{3}_{2}He.$
$^{3}_{2}He + {}^{3}_{2}He \longrightarrow {}^{4}_{2}He + 2{}^{1}_{1}H.$
$^{1}_{1}H + {}^{1}_{1}H \longrightarrow {}^{2}_{1}H + {}^{0}_{+1}\beta.$