Uranium, Nuclear Fuel

***Prelims:** Current events of national and international importance | Science and Technology*

Why in News?

Recently, global uranium production has rebounded post-pandemic, with Kazakhstan, Canada, and Namibia emerging as dominant suppliers.

- **Matter –** Uranium.
- **Symbol –** U.
- **Atomic Number –** 92.
- **Group –** Actinides (radioactive elements discovered relatively late).
- **Occurrence –** Found in rocks, soil, water, oceans and even in human bodies.

Radioactivity	
Unstable Nucleus	Some atoms have an uneven balance of protons and neutrons, so the nucleus cannot stay stable forever.
Decay Process	These atoms naturally break down into smaller, more stable ones in a random but natural way.
Energy Release	When the nucleus decays or splits (fission), it gives off energy as radiation (alpha, beta, gamma) or heat.
Nuclear Power	Controlled chain reactions of uranium-235 fission in reactors release heat, which is converted into electricity.
Nuclear weapons	Uncontrolled chain reactions release huge energy instantly, causing destructive explosions.

Isotopes and Enrichment

- **Natural Isotopes –** Exists in 3 main natural forms: U-234, U-235, and U-238.
- They share chemical properties but differ in mass and nuclear behaviour.
- **Fissionable Isotope –** U-235 is the key isotope that can undergo fission (splitting of the nucleus) to release energy, but it is rare in nature (only

0.72% of uranium).

- **Enrichment –** Since natural uranium has too little U-235, scientists artificially increase its concentration.
- For nuclear power plants, enrichment to **3–4% U-235** is enough to sustain a controlled chain reaction for electricity generation.
- For nuclear weapons, enrichment must reach **90% U-235**, enabling an uncontrolled chain reaction and massive energy release.
- **Chain Reaction –** When a U-235 nucleus splits, it releases 2–3 neutrons. These neutrons can split more U-235 atoms, creating an exponential reaction that produces huge amounts of energy.

U-238	U-234	Th-232
• Most abundant isotope (99.3% of natural uranium), not directly fissionable with slow neutrons, so cannot sustain a chain reaction on its own. • Absorbs neutrons and transforms into Plutonium-239 (Pu-239), which is fissionable and used in reactors and weapons. • Also used in *fast breeder reactors* non-fuel applications due to its density (armour, projectiles, radiation shielding).	• Present only in trace amounts (0.005%). • Formed as a decay product of U-238. • Radioactive but not fissionable, so it does not contribute to energy generation. • Important mainly because during enrichment of U-235, the proportion of U-234 also increases, raising the radiation hazard of enriched uranium fuel.	• Naturally occurring radioactive metal, more abundant in Earth's crust than uranium, • Fertile, not fissile, cannot directly sustain chain reaction. • Th-232 absorbs a neutron and converts into Uranium-233 (U-233) i.e. fissile. • India has large thorium reserves and central to India's 3-Stage Nuclear Programme

- **Reprocessed Uranium (RepU) –** Spent nuclear fuel can be recycled at special plants.
- The recovered uranium is reused as a new type of fuel, reducing waste and extending resources.

Global Uranium Supply

1. **Kazakhstan –** 39% of global supply
2. **Canada –** 24% of global supply
3. **Namibia –** 12% of global supply
4. **Australia –** 8% of global supply
5. **Uzbekistan –** 7% of global supply

Reference

Visual Capitalist | Uranium