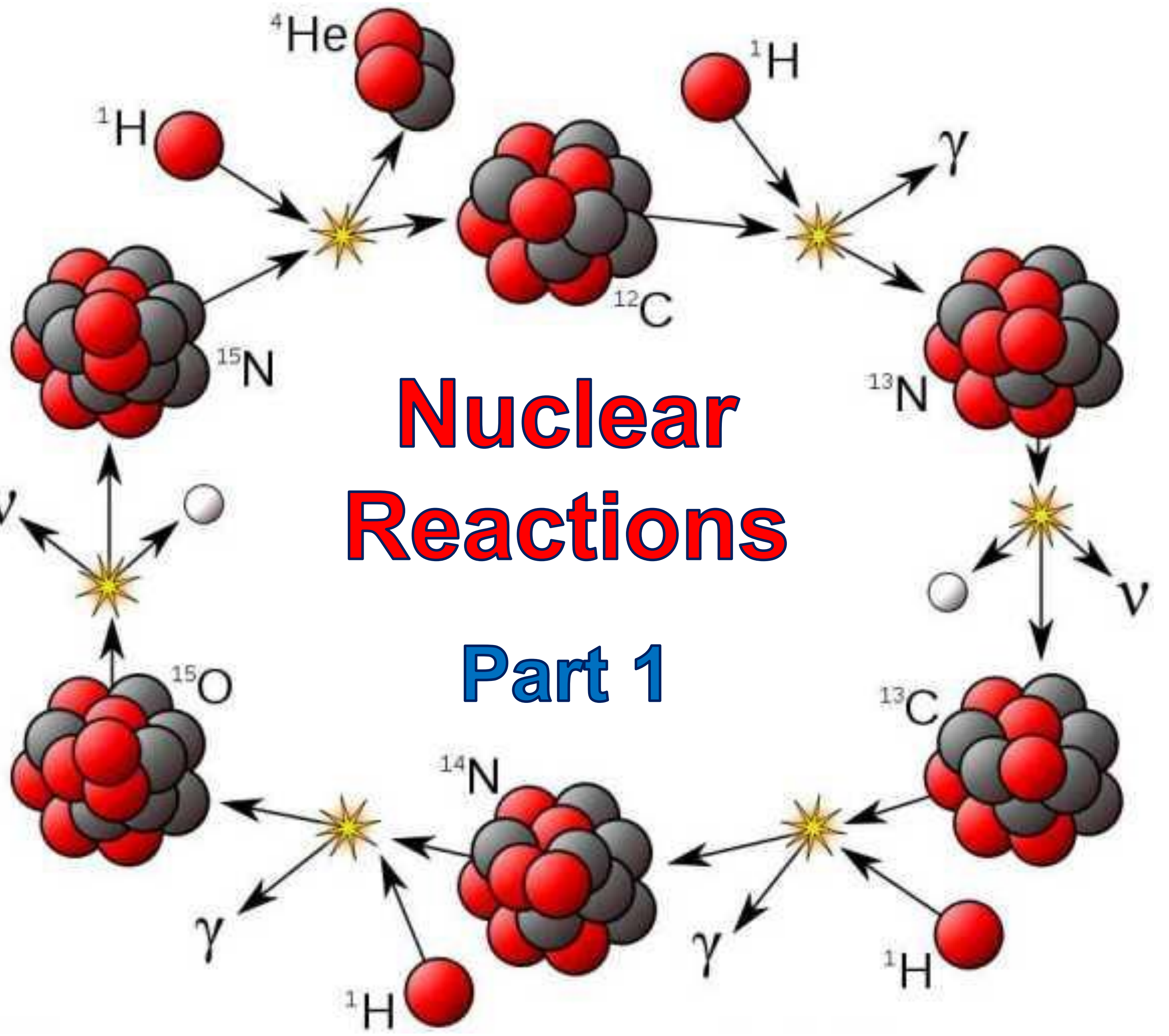
Nuclear Reactions

Part 1



Three Types of Nuclear Reactions

1. **Radioactive decay** – an unstable nucleus spontaneously emits a small particle of radiation to become a **different isotope** of the same element or a **different element** (such process is called ***transmutation***).

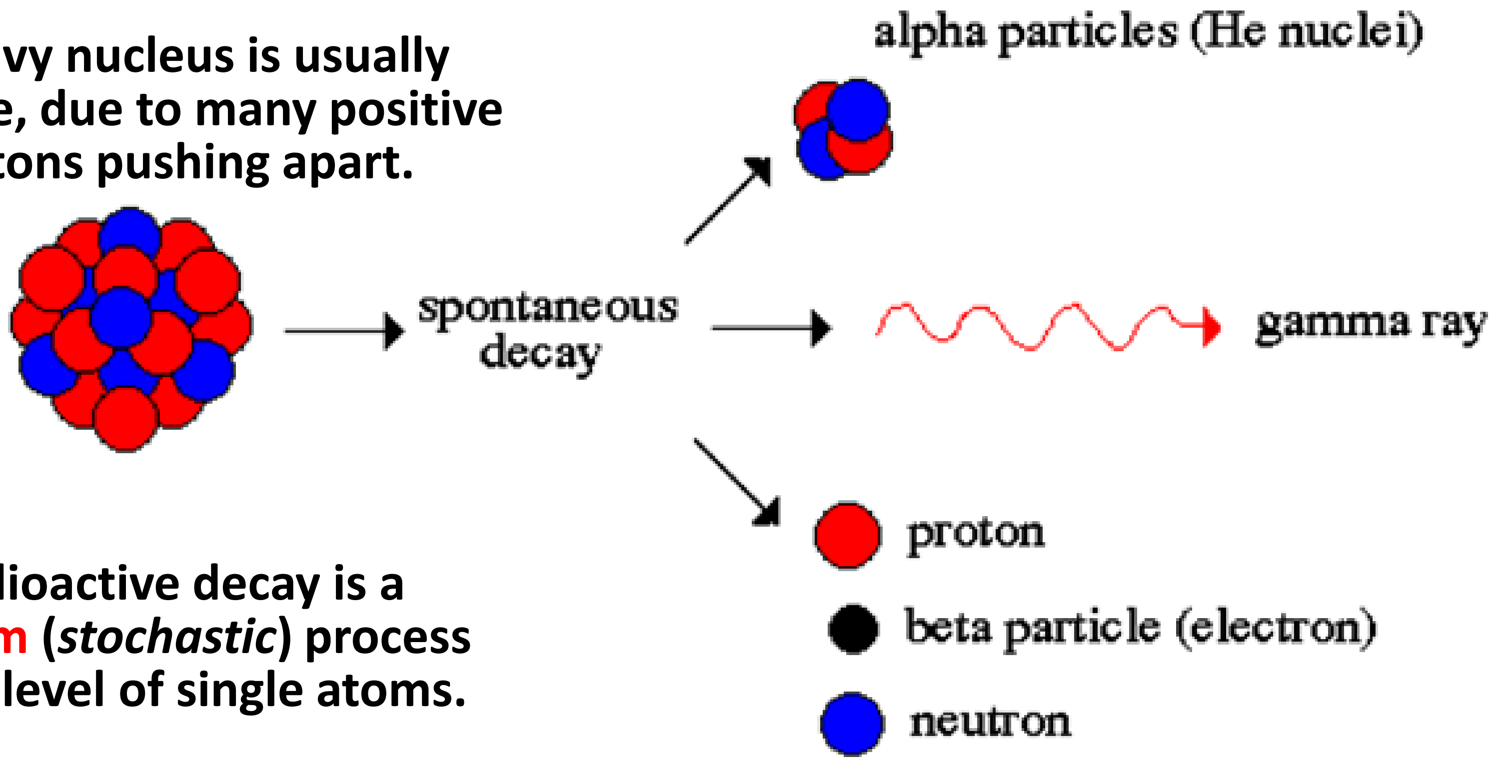
2. **Nuclear Fusion** – the **joining** of two atoms to form a larger one.

3. **Nuclear Fission** – the **splitting** of an atom into two smaller atoms.

Radioactive Decay

<u>**Radioactive decay**</u>**, also known as** <u>**radioactivity**</u> **or** <u>**nuclear decay**</u>**, is the process by which a nucleus of an unstable atom loses energy by emitting ionizing radiation: ^{4}He (alpha particles), β particles (electrons), γ rays (energetic photons), neutrons.**

A heavy nucleus is usually unstable, due to many positive protons pushing apart.



Radioactive decay is a random (*stochastic*) process at the level of single atoms.

Half-Life of Radioactive Isotope

The decay rate of a radioactive isotope is characterized by its half-life: the *time it takes for one-half of the atoms* of a radioactive material *to disintegrate*.

Radioisotope	Half-life
Polonium-215	0.0018 seconds
Bismuth-212	60.5 seconds
Sodium-24	15 hours
Iodine-131	8.07 days
Cobalt-60	5.26 years
Radium-226	1600 years
Uranium-238	4.5 billion years

Naturally Occurring Sources of Radiation

Food:

- Bananas, being naturally very high in potassium, consequently have a higher than usual amount of potassium-40, a radioactive isotope.
- The food with the highest concentration of radioactive elements, in this case radium, is the Brazil nut.

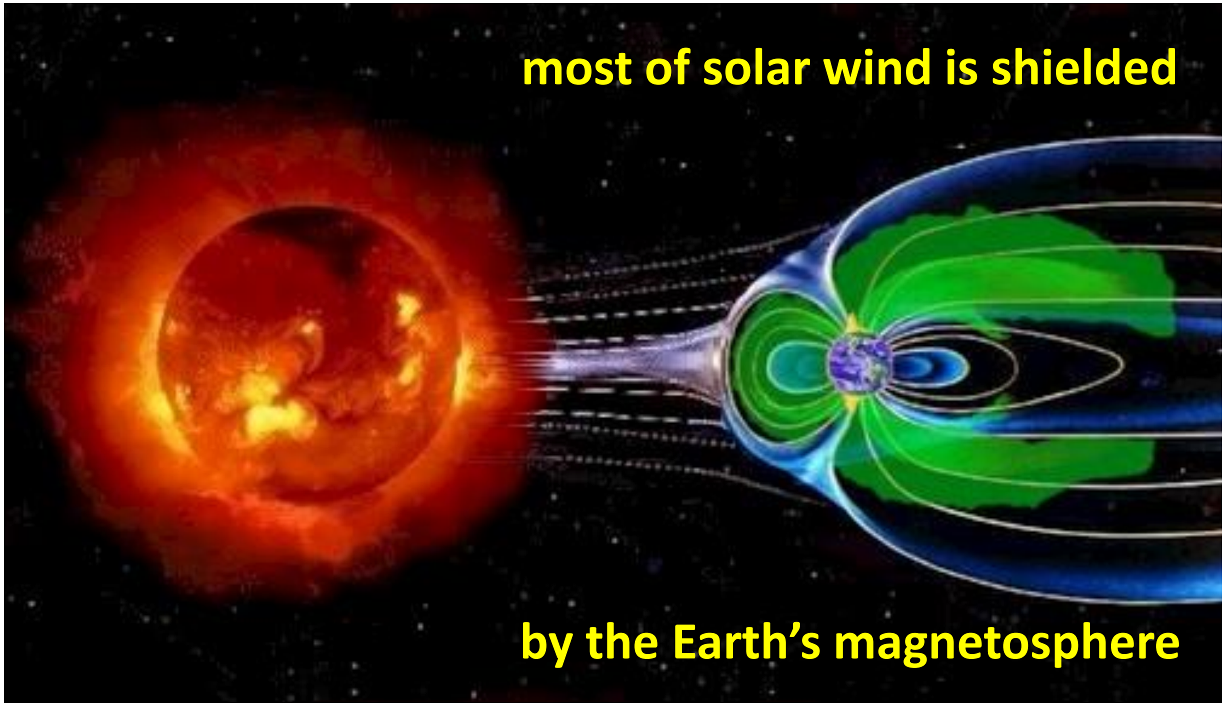
Minerals and materials buried in the earth:

- Most common are potassium-40, uranium-238, and thorium-232 (all with fairly long half-lives).
- Additionally, there are small quantities of shorter-lived materials (greater activity), such as radium-226 and radon-222 (both come as decay products of uranium deposits in the bedrock).
- Radon, being a gas, can become a problem in some houses and other buildings, seeping in usually through cracks in solid foundations, and accumulating in rooms with poor ventilation.

Naturally Occurring Sources of Radiation

The Sun:

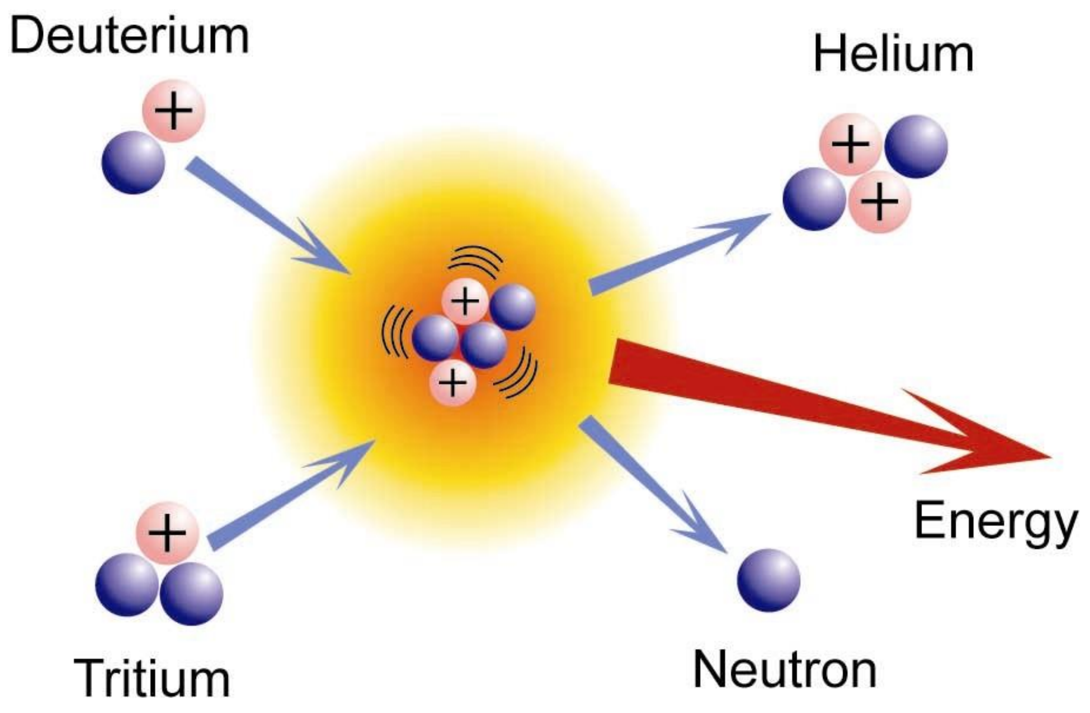
- Powered by a continuous nuclear reaction, main sequence stars give off quite a bit of radiation of every sort!



Cosmic radiation:

- Makes up about 14% of the total annual background radiation a person is exposed to over the course of a year.
- The exposure rate is slightly increased by living at higher altitudes, and even more so by air travel (flight crews on long-distance, high-altitude flights tend to accumulate about 30% more annual radiation exposure than the average person!).

Nuclear Fusion



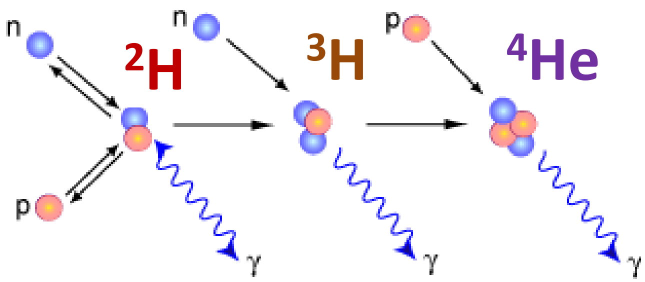
- **The fusion of two nuclei with <u>masses lower than iron</u> generally <u>releases energy</u>, while the fusion of nuclei <u>heavier than iron</u> <u>absorbs energy</u>.**

Fusion is the process that powers active stars.

- **Fusion reactions have the greatest energy density, that is energy per unit of mass, than any known process (nuclear fission or chemical reactions).**

Nucleosynthesis

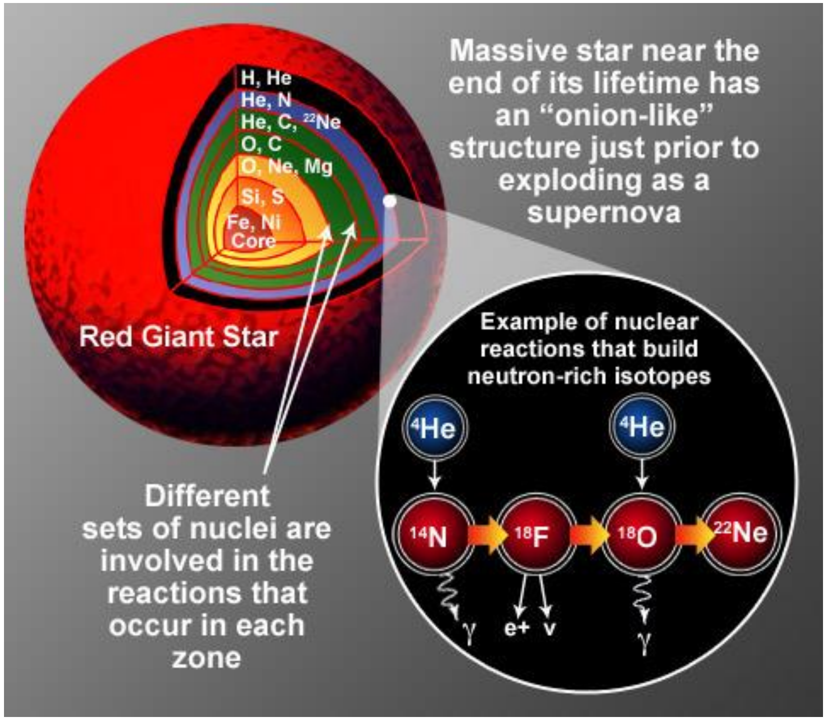
<u>Nucleosynthesis</u> is the natural process that creates new atomic nuclei from pre-existing nucleons, primarily protons and neutrons:



- **<u>Big Bang nucleosynthesis</u>: the first nuclei, hydrogen and helium, were formed about *three minutes* after the Big Bang.**

- **<u>Stellar nucleosynthesis</u>: with the formation of stars, heavier nuclei were created from hydrogen and helium, a process that continues today; the heaviest element produced by fusion in a normal star is iron.**

- **<u>Supernova nucleosynthesis</u>: production of elements from iron to uranium occurs *within seconds* in a supernova explosion.**



Stellar Recycling

5 minutes after the Big Bang: 75% H and 25% He.

10 billion years of nucleosynthesis: 98% H and He combined, 2% complex elements.