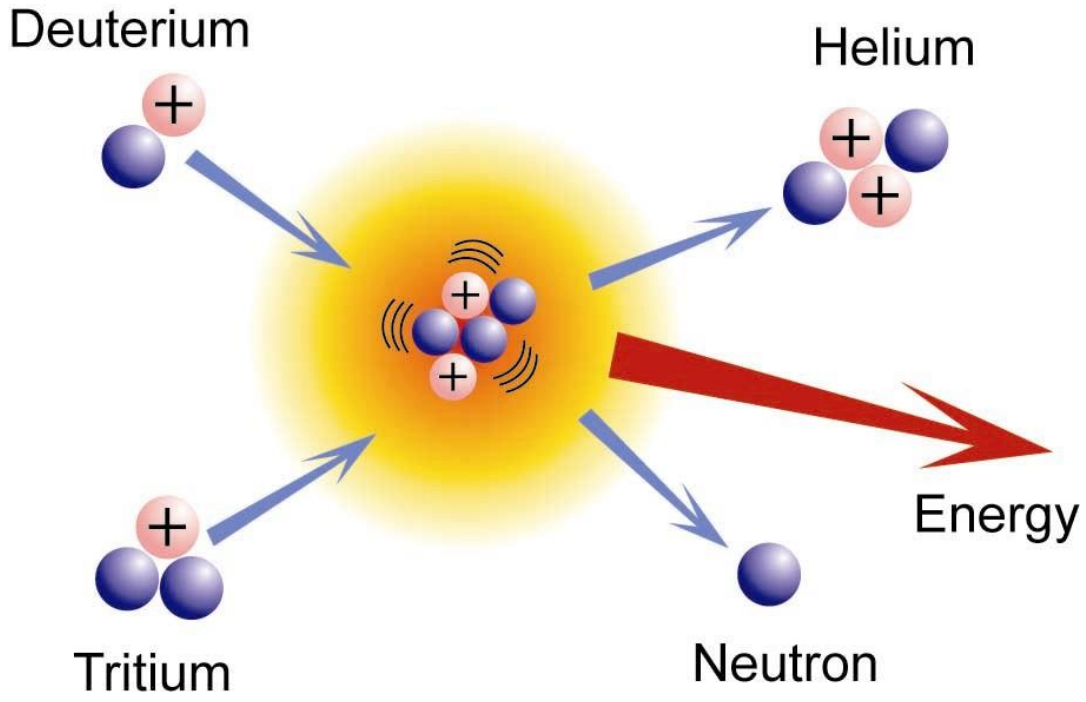
Nuclear Fusion



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

Fusion powers active stars!

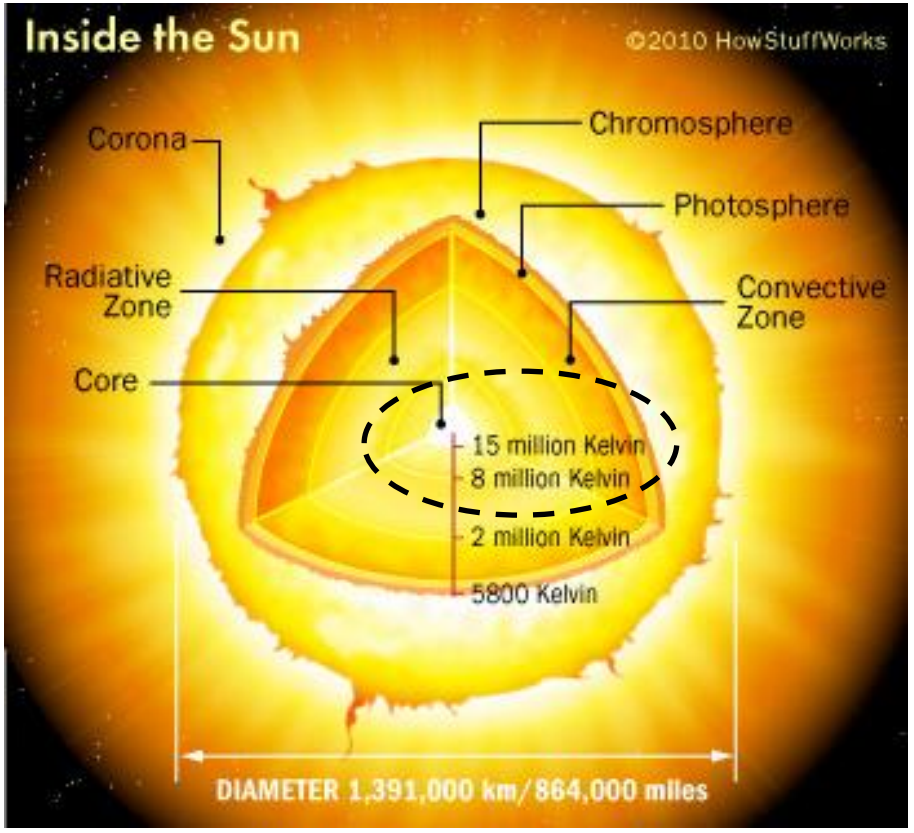
- **Fusion reactions have the greatest energy density, that is energy released per unit of mass, than any known process.**

Thermonuclear Fusion

- In order to fuse, **two atomic nuclei must be brought close enough together** (***confinement requirement***) so the electrostatic repulsion can be overcome by the attractive nuclear force which is stronger at close distances.

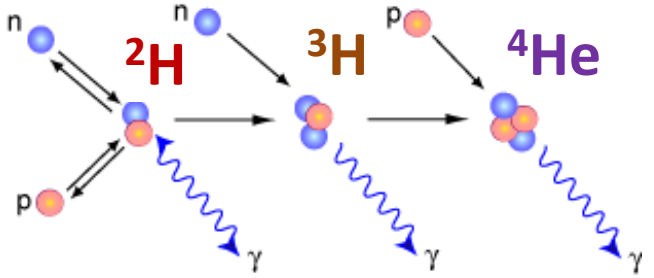
- If matter is sufficiently **heated** (***plasma state***), **thermonuclear fusion** reaction may occur due to **collisions between the particles of extreme thermal kinetic energies**.

- In nature, extremely high temperature conditions exist in the **cores of active stars**.

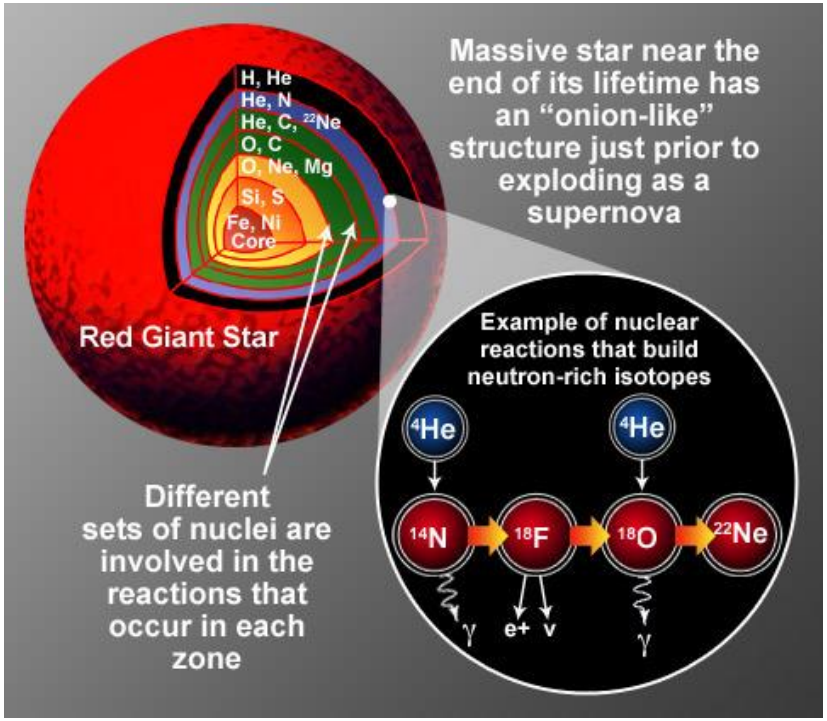


Nucleosynthesis

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

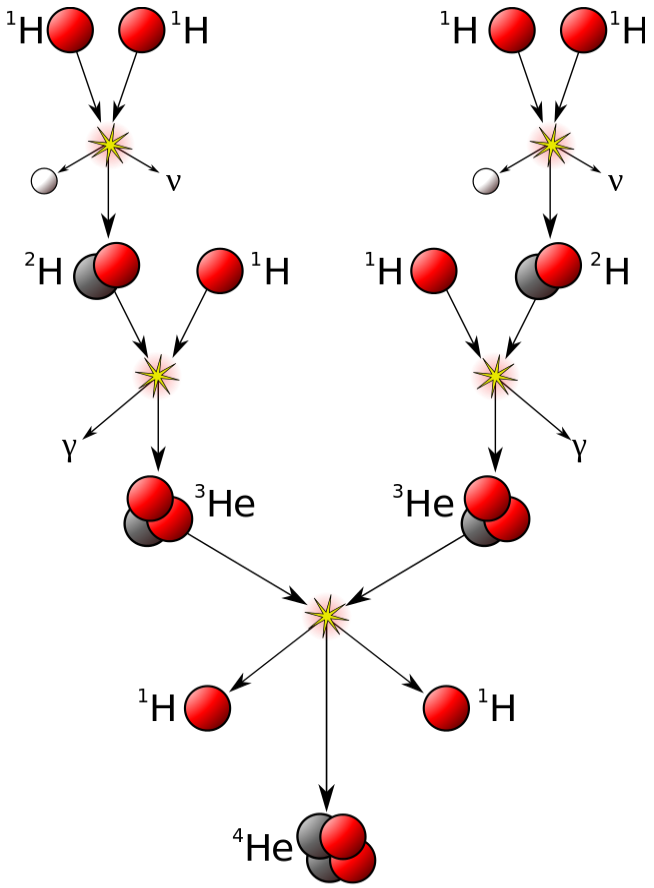


- **Big Bang nucleosynthesis**: the first nuclei, hydrogen and helium, were formed about *three minutes* after the Big Bang.
- **Stellar nucleosynthesis**: with the formation of stars, heavier nuclei were created from hydrogen and helium, a process that continues today; the heaviest element produced by fusion in a normal star is iron.
- **Supernova nucleosynthesis**: production of elements from iron to uranium occurs *within seconds* in a supernova explosion.

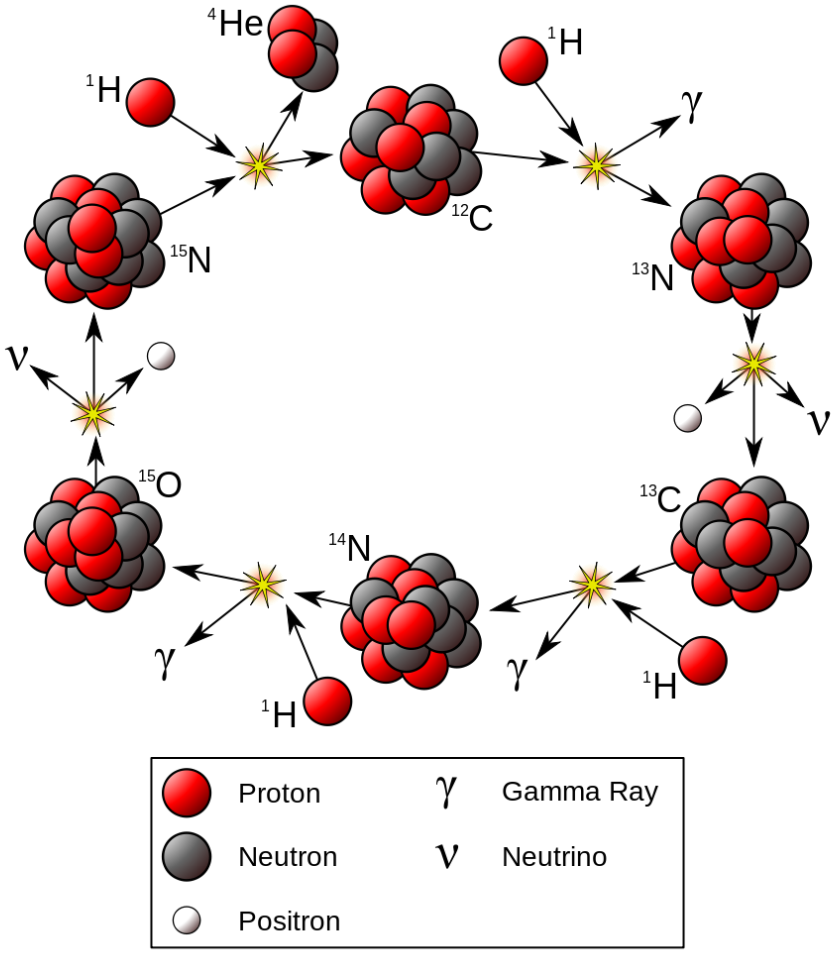


Stellar Nucleosynthesis

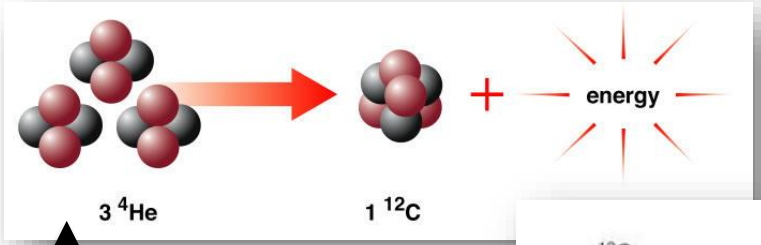
The proton-proton chain dominates in stars *the size of the Sun or smaller*.



The CNO cycle dominates in stars *heavier than the Sun*.

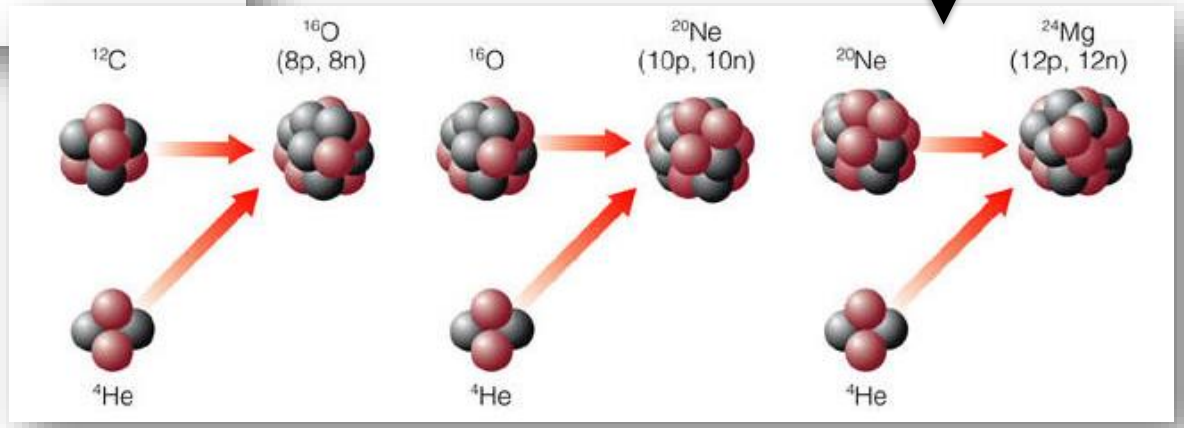


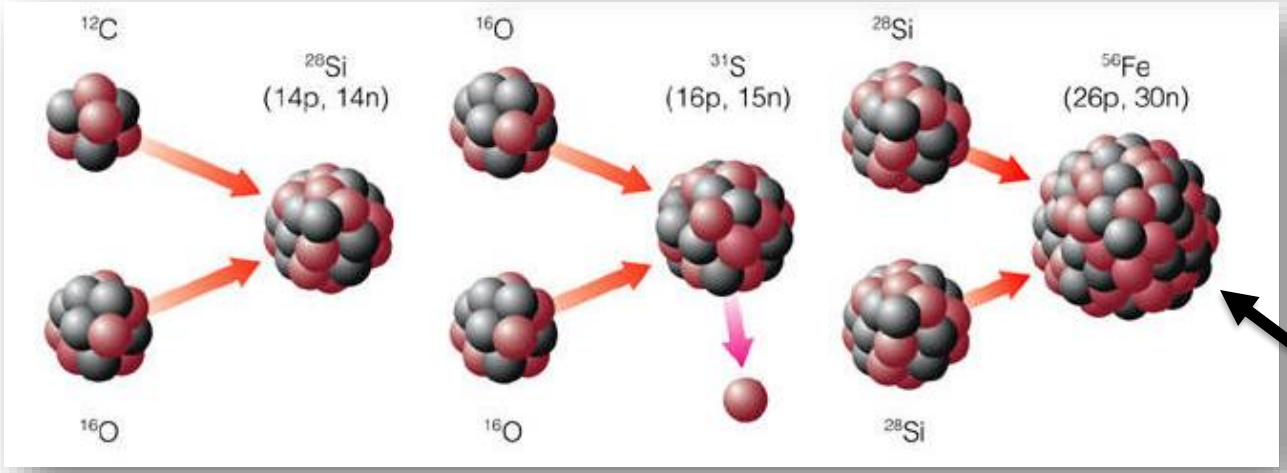
More Stellar Nucleosynthesis



Triple-alpha process

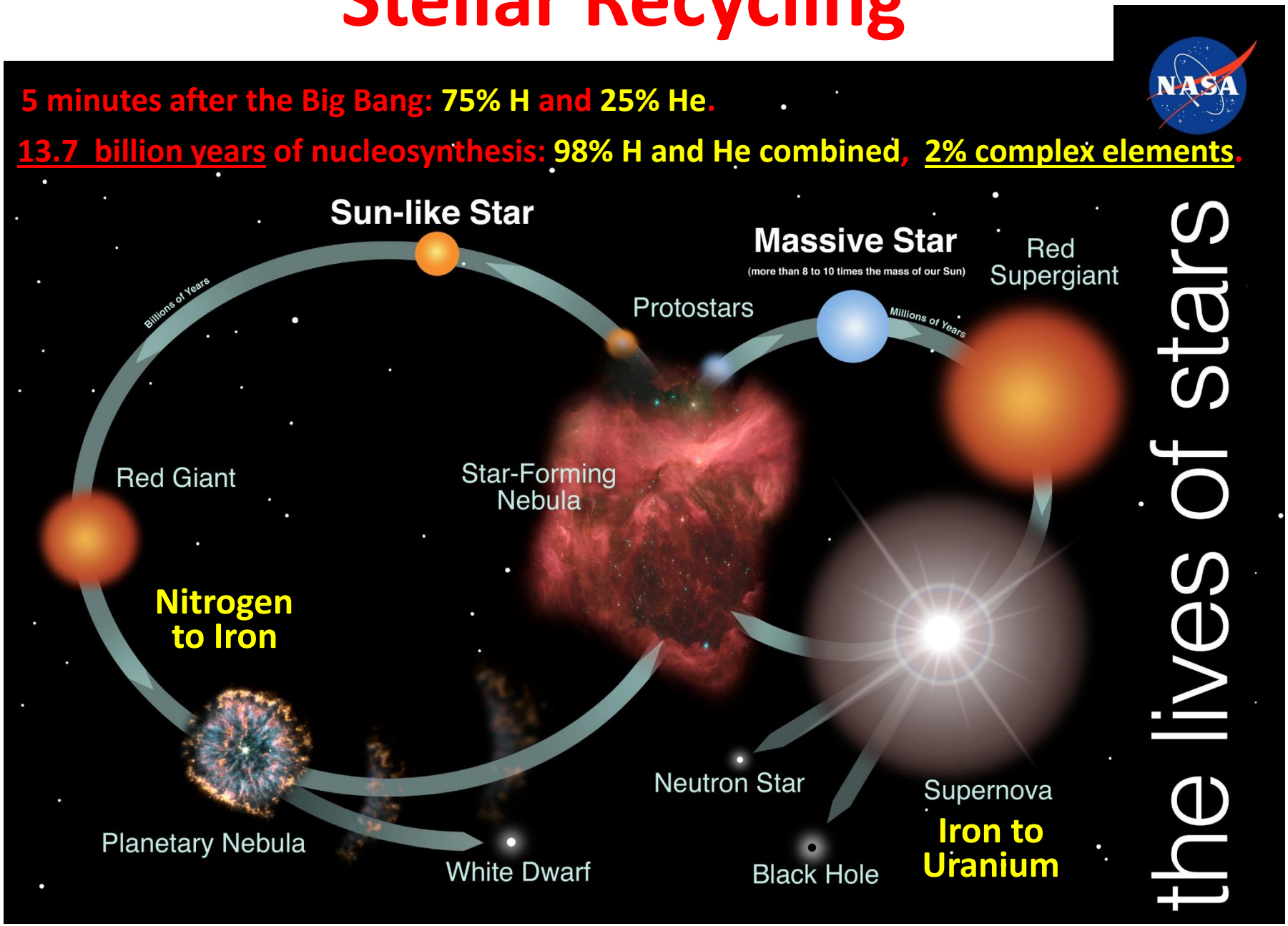
Alpha process (Helium capture)



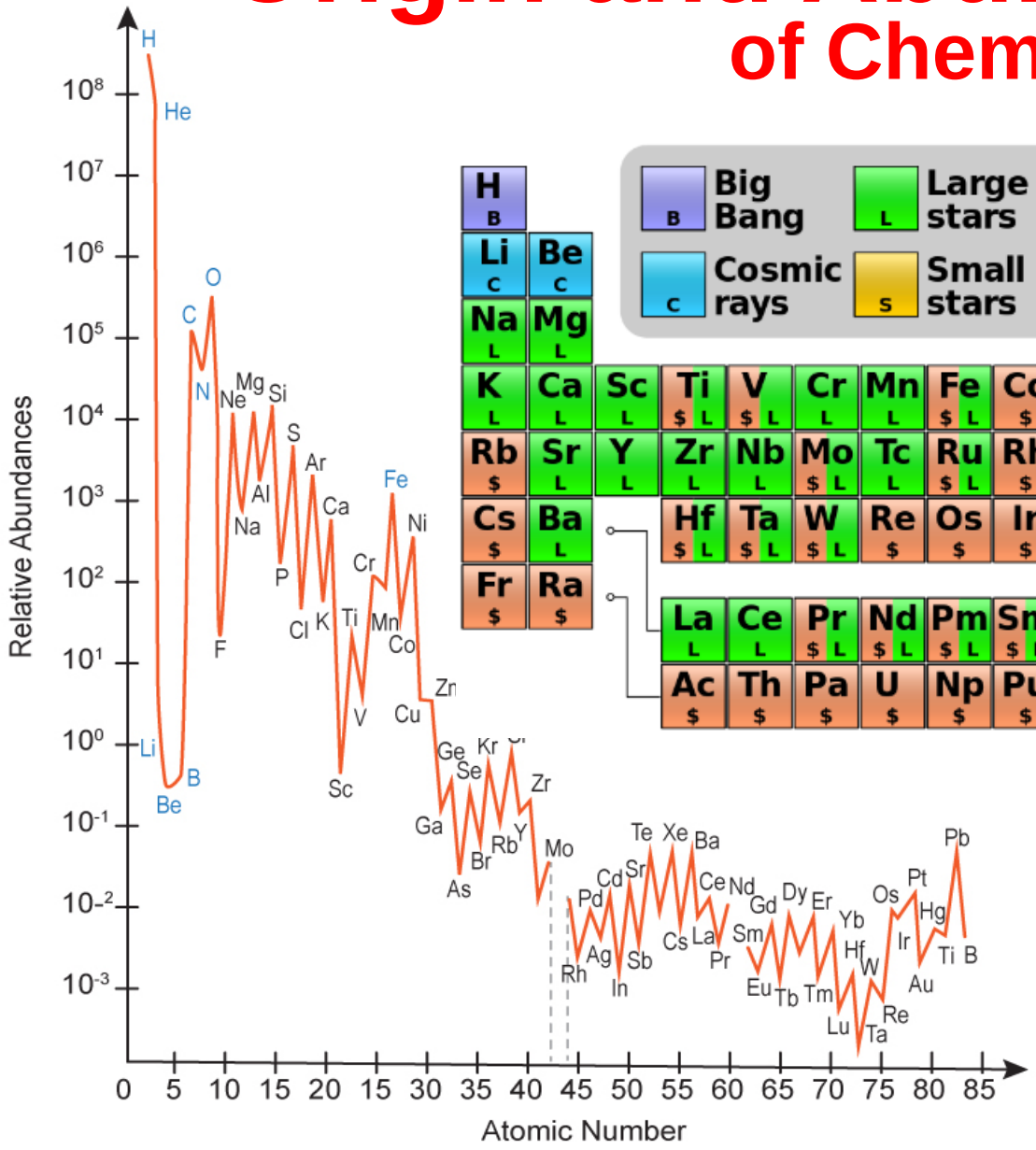


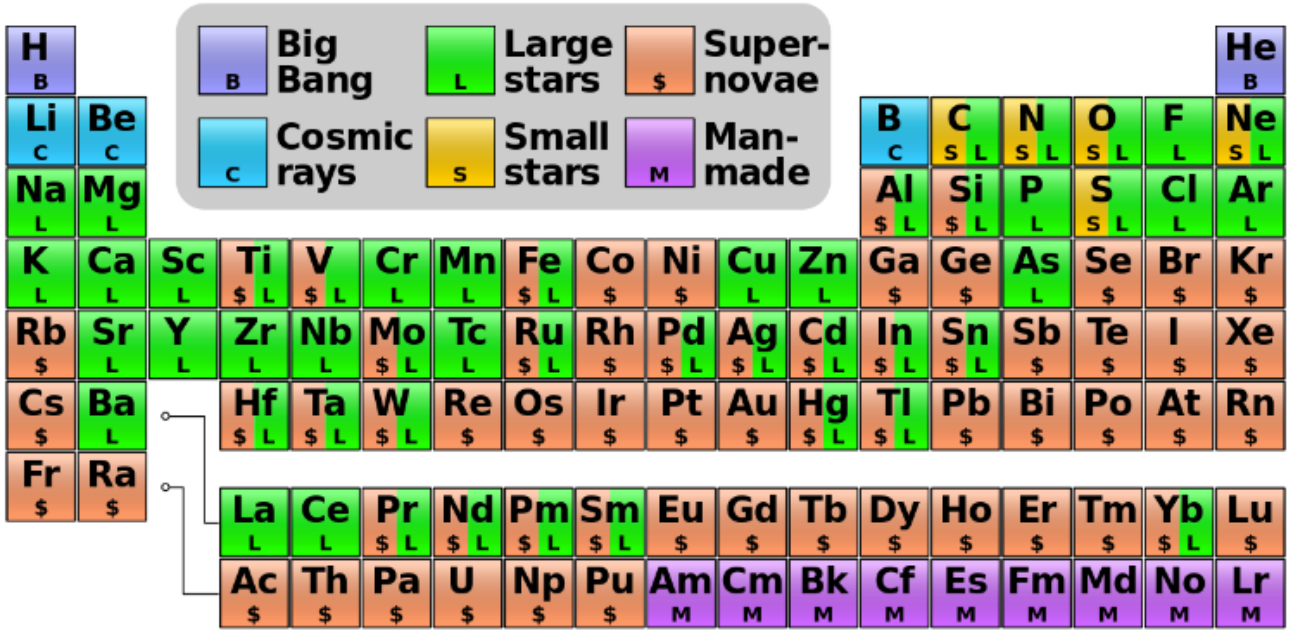
Stellar fusion in massive stars stops at IRON

Stellar Recycling



Origin and Abundance
of Chemical Elements





Note *higher* relative abundance of elements that have *even* atomic numbers – WHY?

Artificial Fusion

Laboratory fusion of hydrogen isotopes was first accomplished by Mark Oliphant in 1932 based on transmutation experiments.

- **Nuclear fusion on a large scale in an explosion was first carried out on November 1, 1952, in the *Ivy Mike* hydrogen bomb test on an island in the Pacific Ocean.**

- **International research into developing controlled self-sustained thermonuclear fusion (seen as a means of producing large scale cleaner energy) has been ongoing for more than 60 years and recently resulted in several breakthroughs.**