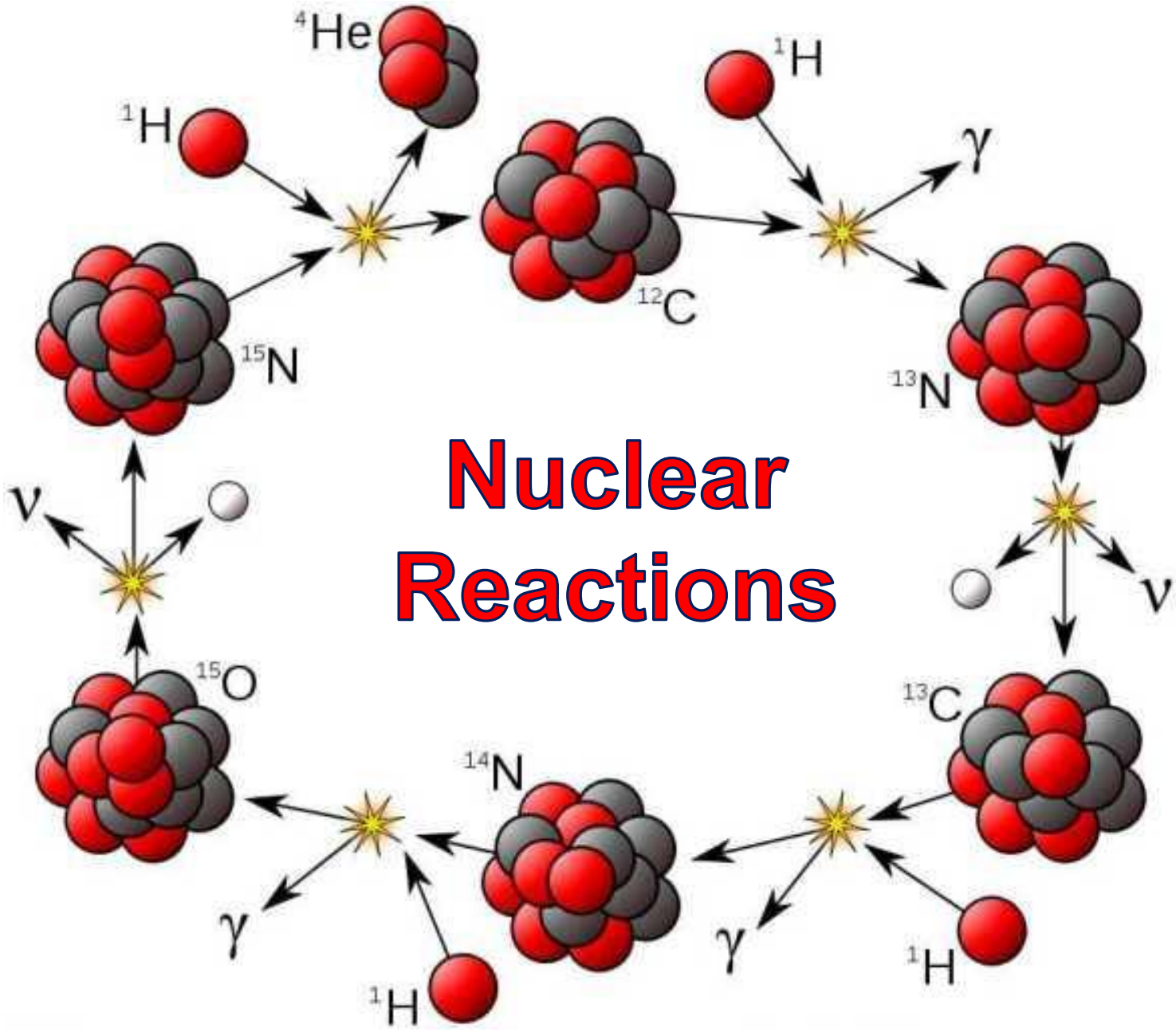
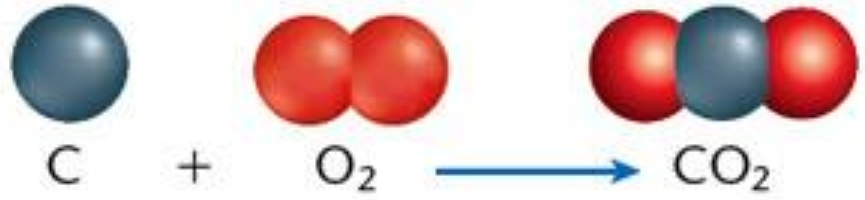

Nuclear
Reactions
^{4}He
^{1}H
^{12}C
^{1}H
γ
^{15}N
^{13}N
ν
ν
^{15}O
^{13}C
^{14}N
γ
γ
^{1}H
^{1}H

Chemical Reactions

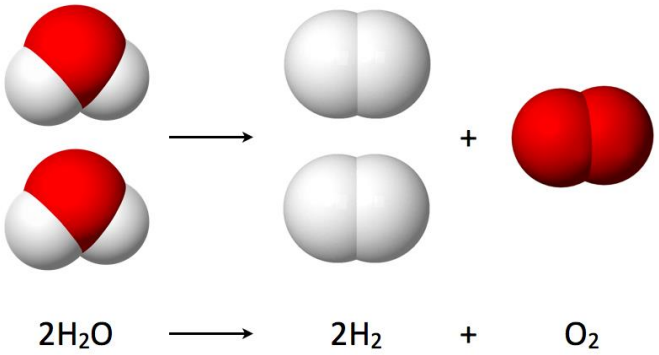
REVIEW

Change of matter that involves *bonding*, *separating* or *rearranging* of two or more atoms.

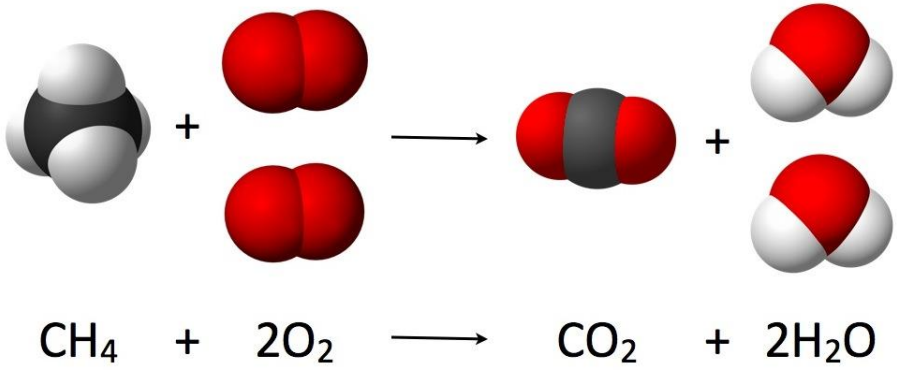
Formation of Carbon Dioxide



Electrolysis of Water



Combustion (burning) of Methane



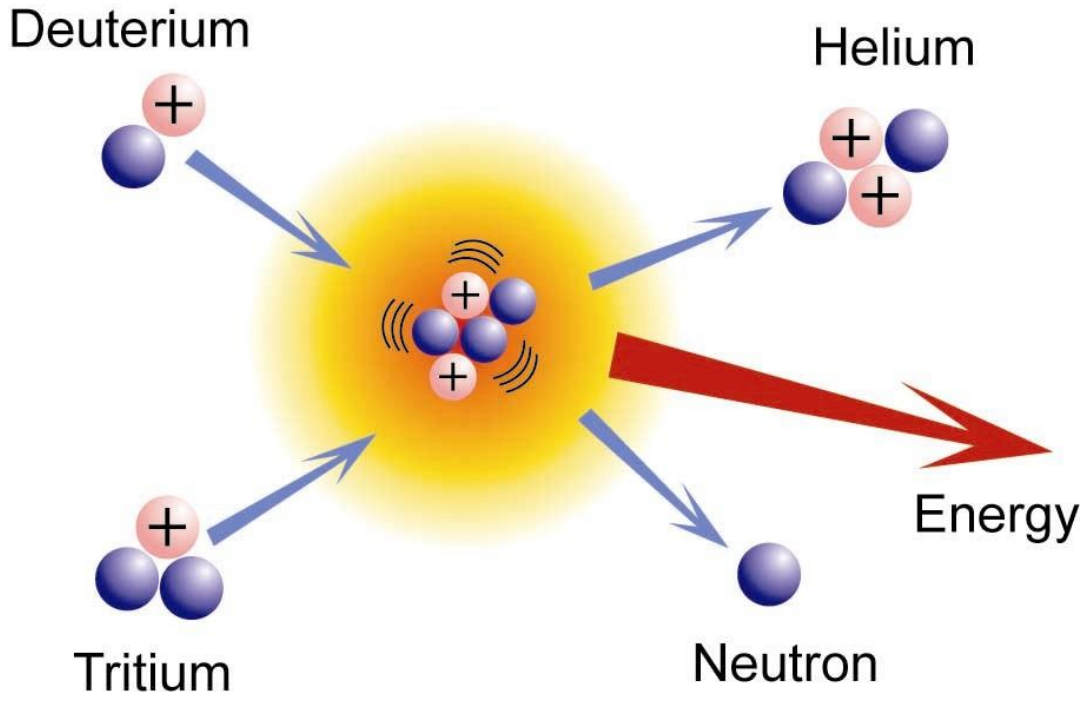
Nuclear Reactions
involve change of the atomic nucleus

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

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

3. **Nuclear Fission** – the **splitting** of an atomic nucleus into two smaller ones.

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!

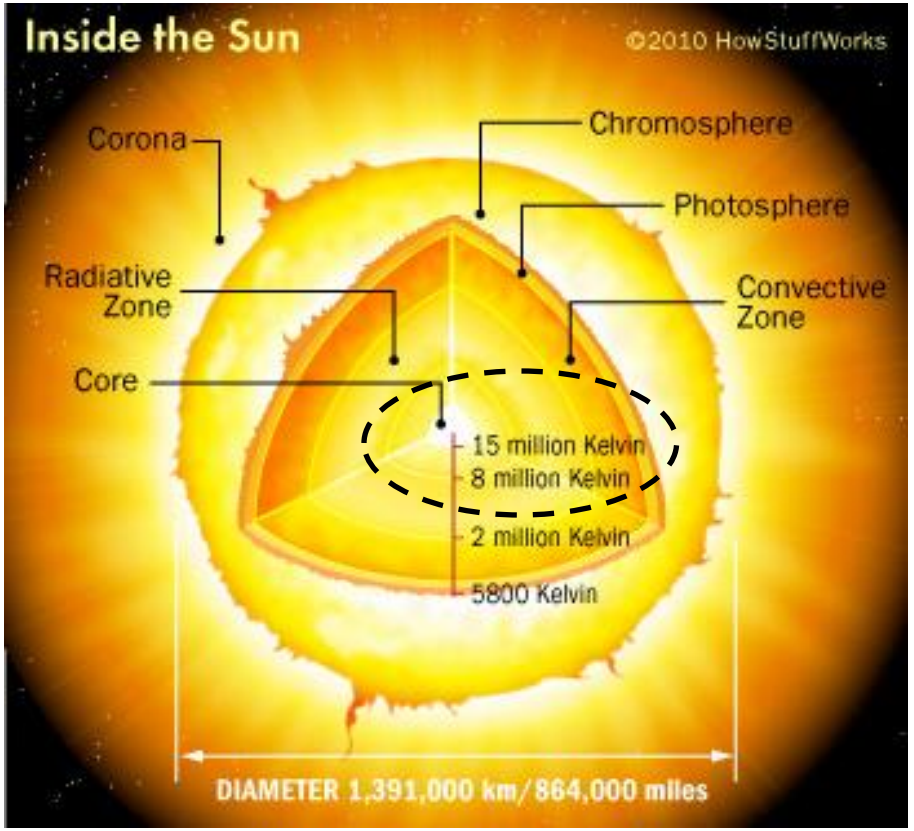
- **Fusion reactions have the greatest energy density, that is energy released per unit of mass, than any known process.**

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.

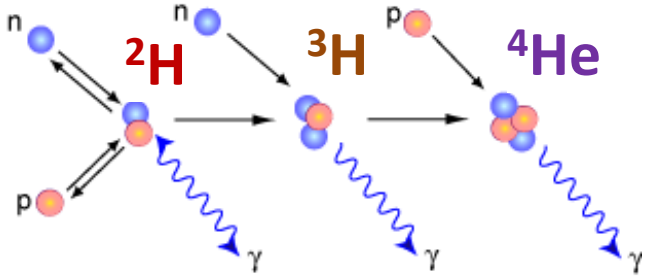
- If matter is sufficiently heated (*plasma state*), thermonuclear fusion reaction may occur due to collisions between the particles of extreme thermal kinetic energies.

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



Nucleosynthesis

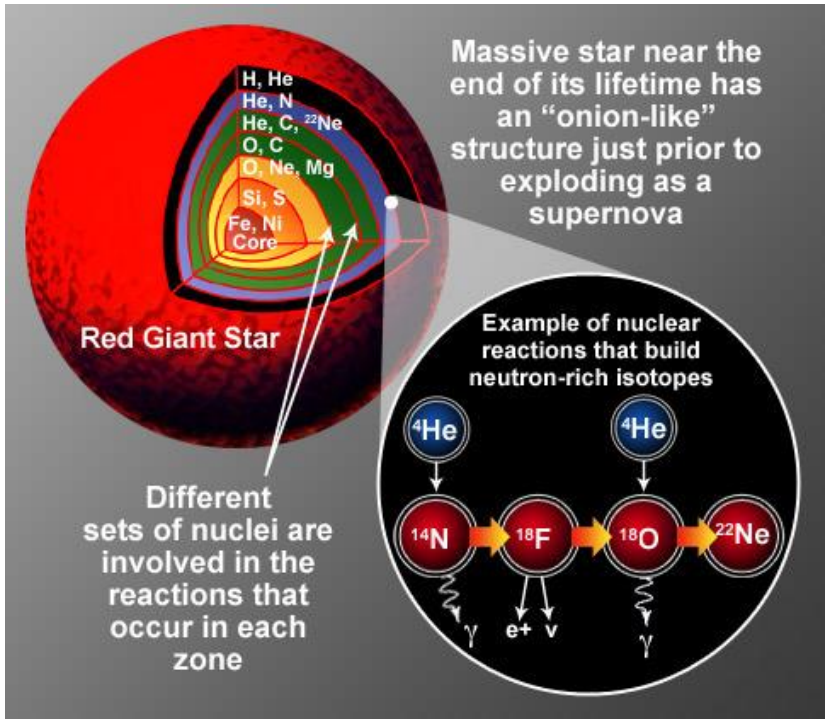
Nucleosynthesis is the natural process that creates new atomic nuclei from pre-existing nucleons, primarily protons and neutrons:



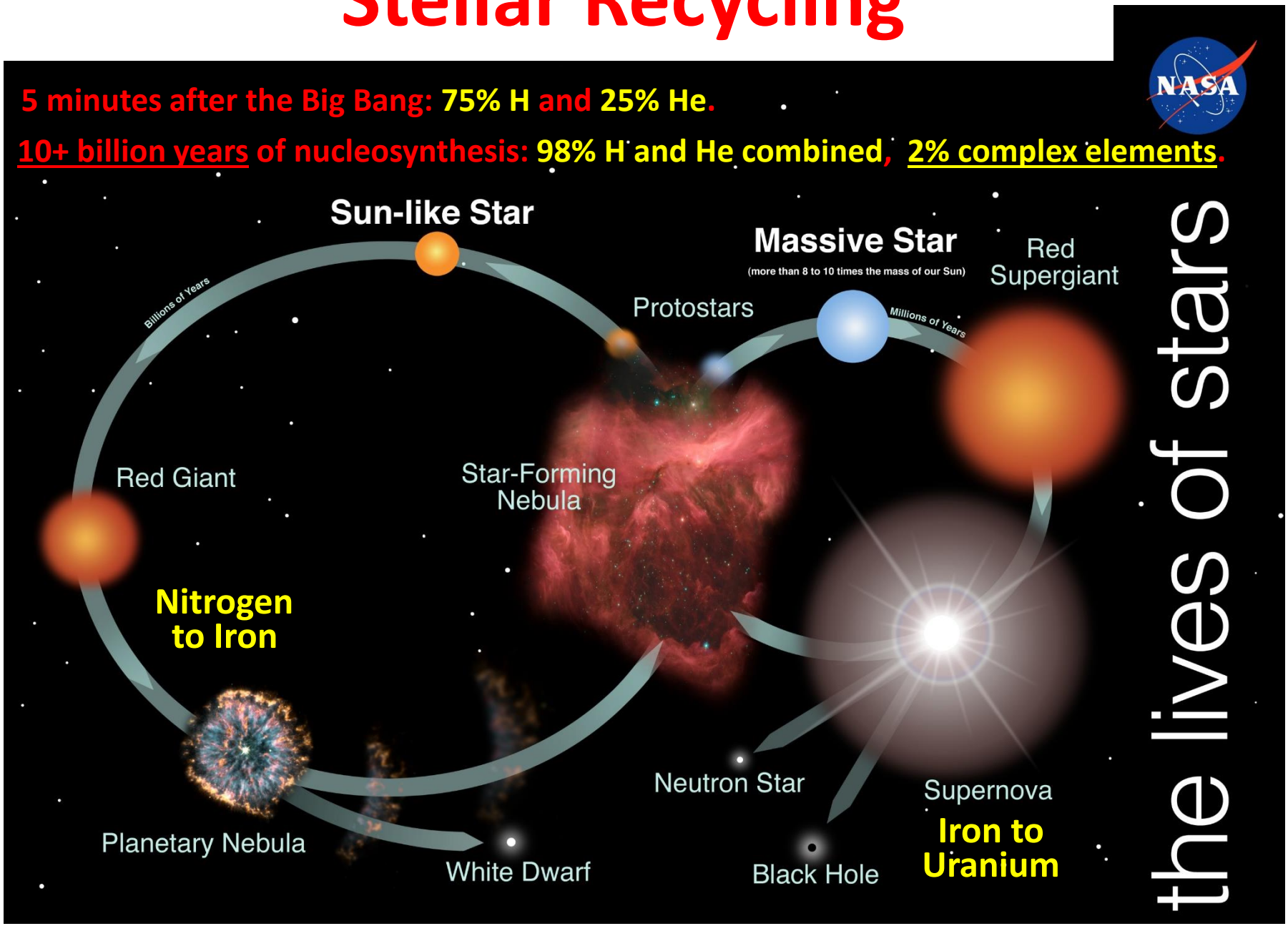
- **Big Bang nucleosynthesis**: the first nuclei, hydrogen and helium, were formed about *three minutes* after the Big Bang.

- **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.

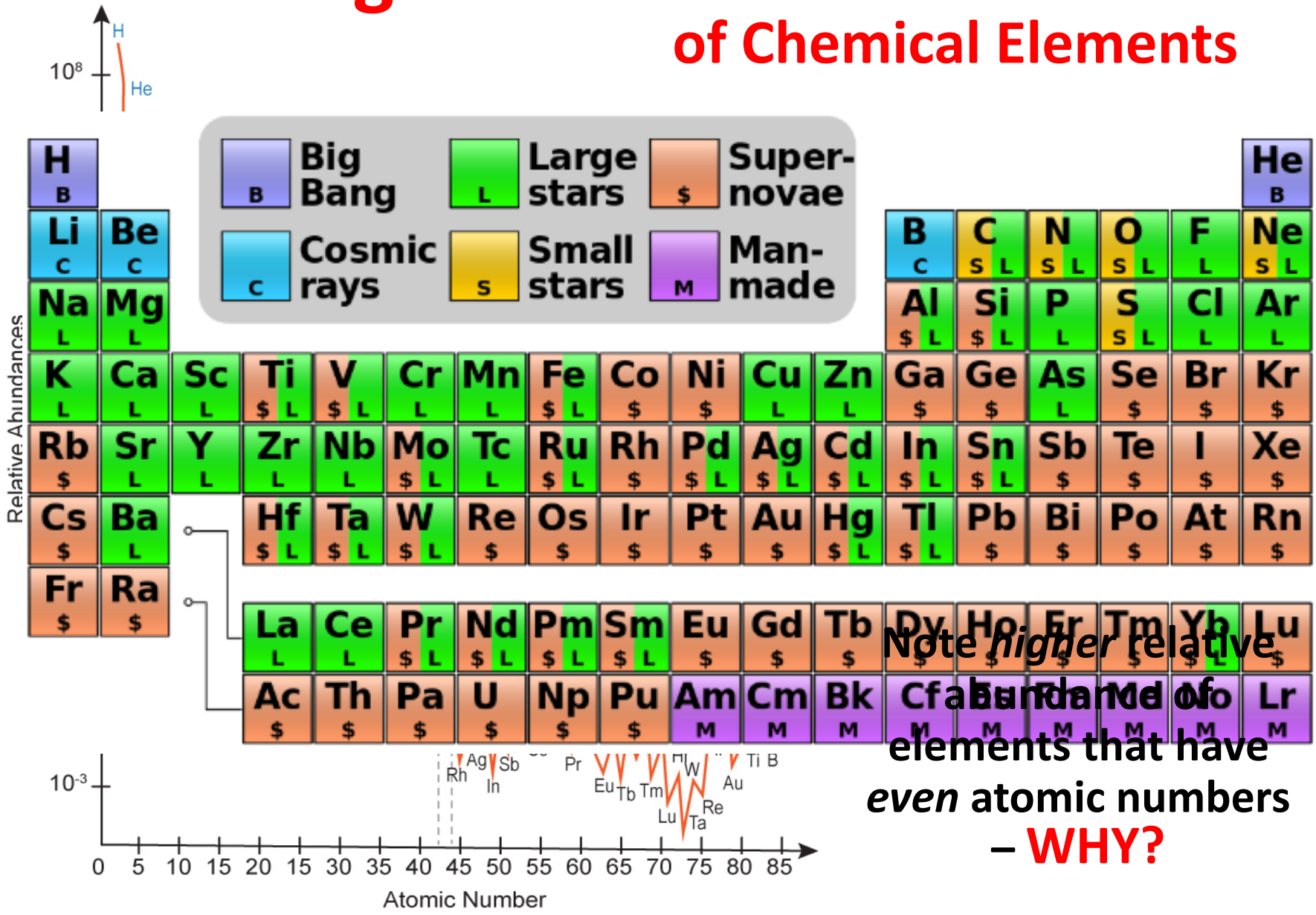
- **Supernova nucleosynthesis**: production of elements from iron to uranium occurs *within seconds* in a supernova explosion.



Stellar 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.**

Nuclear fusion can fulfill…

…the ancient dream of alchemists ☺

Gold can be made by slamming isotopes of hydrogen nuclei called deuterium into platinum:

$$H^2 + Pt^{196} \rightarrow Au^{197} + \text{neutron}$$

The catch is that gold produced in this manner would be much more expensive than gold mined from the Earth…