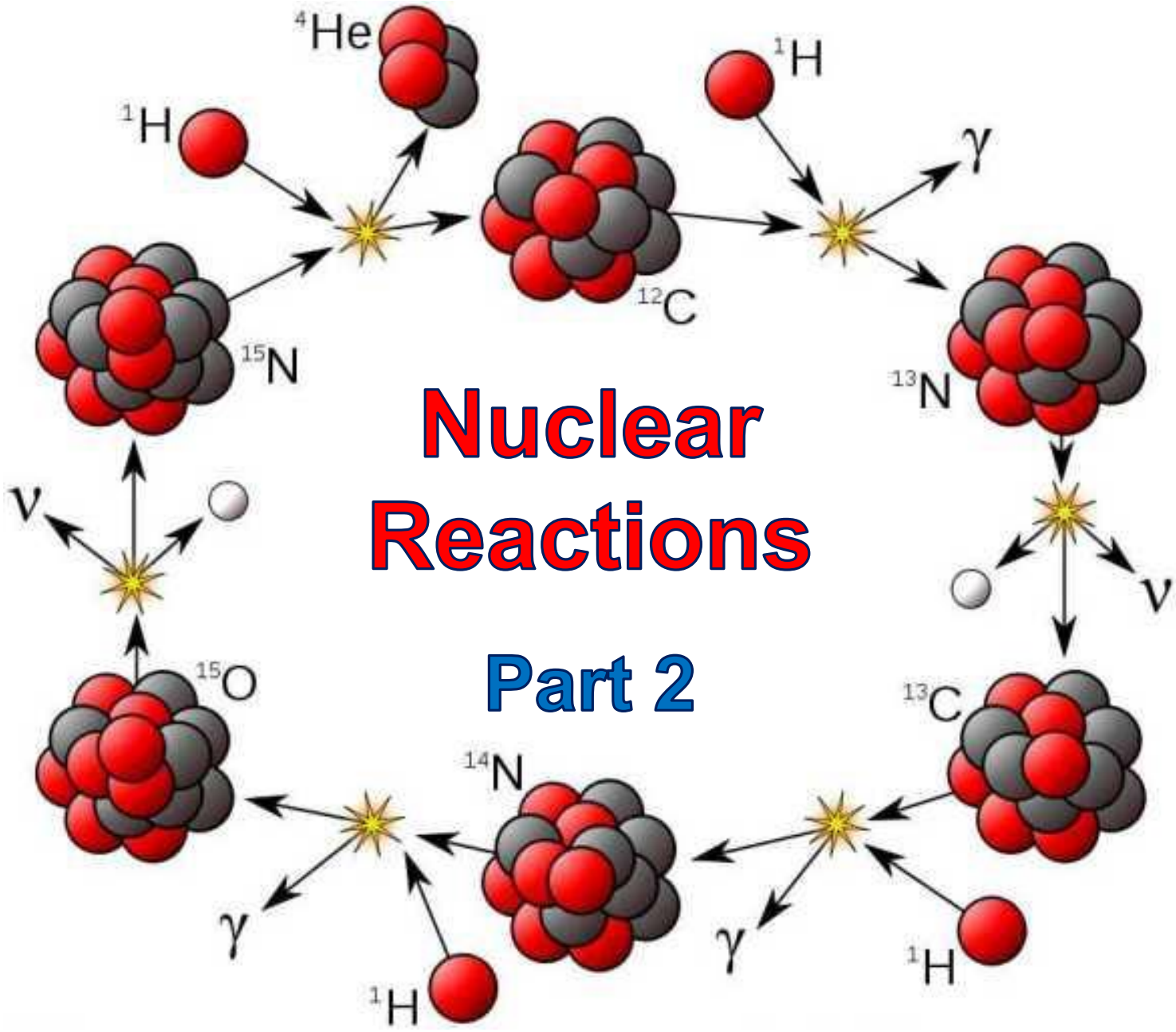


Nuclear Reactions

Part 2

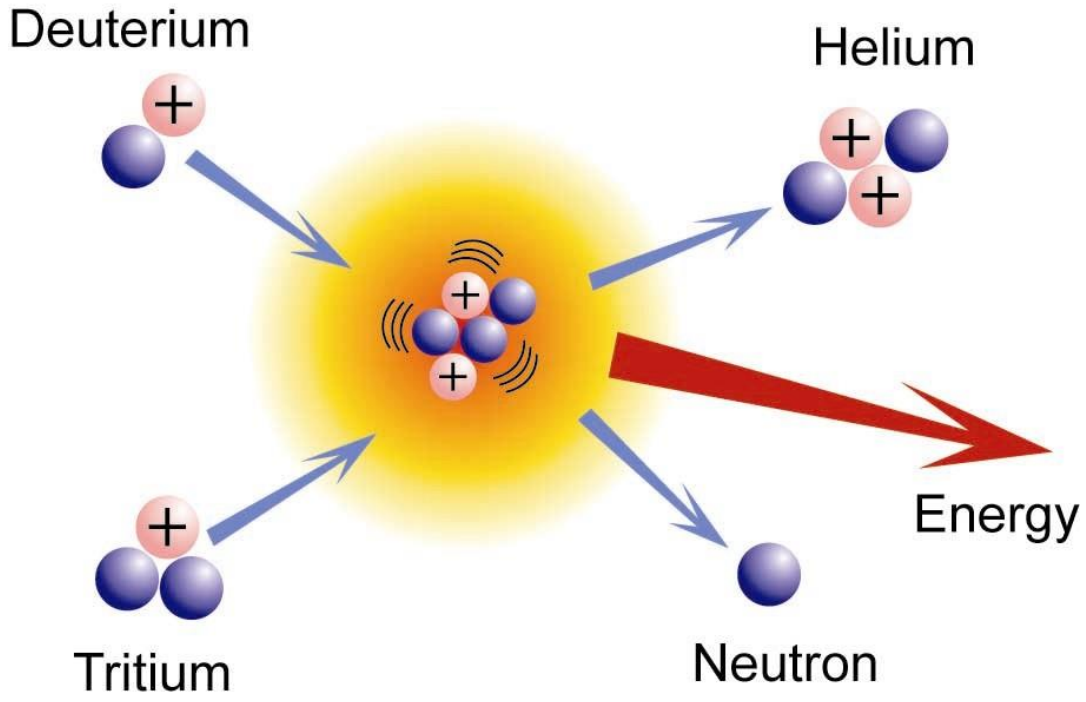
Nuclear Reactions
involve change of the atomic nucleus

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.**

What is Temperature?

REVIEW

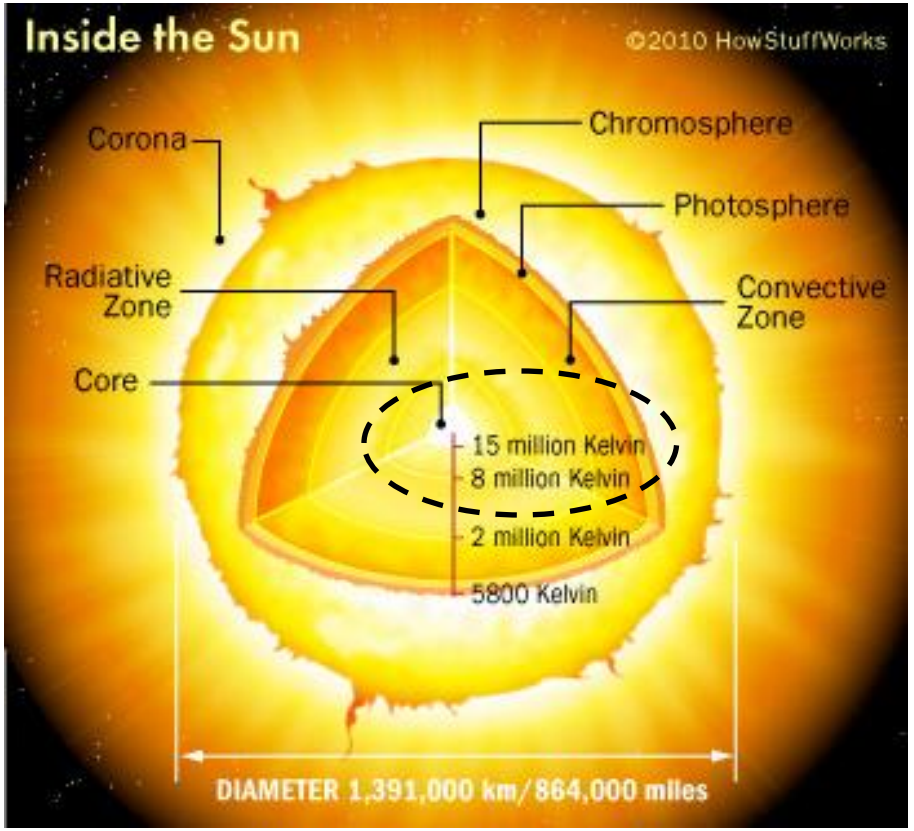
- **Particles of matter are in constant motion** (*vibrating* in place in solids, *sliding past each other* in liquids, *flying around freely* in gases)**, but they don't all move at the same speed and in the same direction all the time.**
- **<u>Temperature</u> is a measure of the *average* energy associated with *random motion* of the particles of a substance.**
- **The *higher* the temperature of an object, the *faster* on average its particles move.**

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.

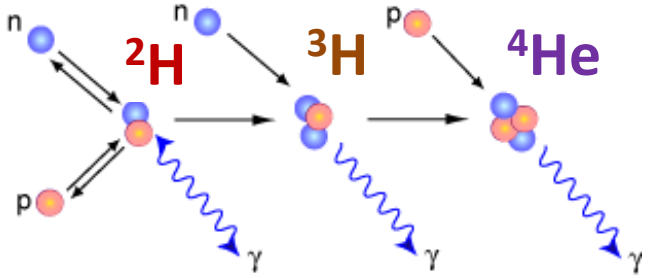
- If matter is sufficiently heated (*plasma state*), thermonuclear fusion reaction may occur due to collisions between the particles of extreme thermal kinetic energies.

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

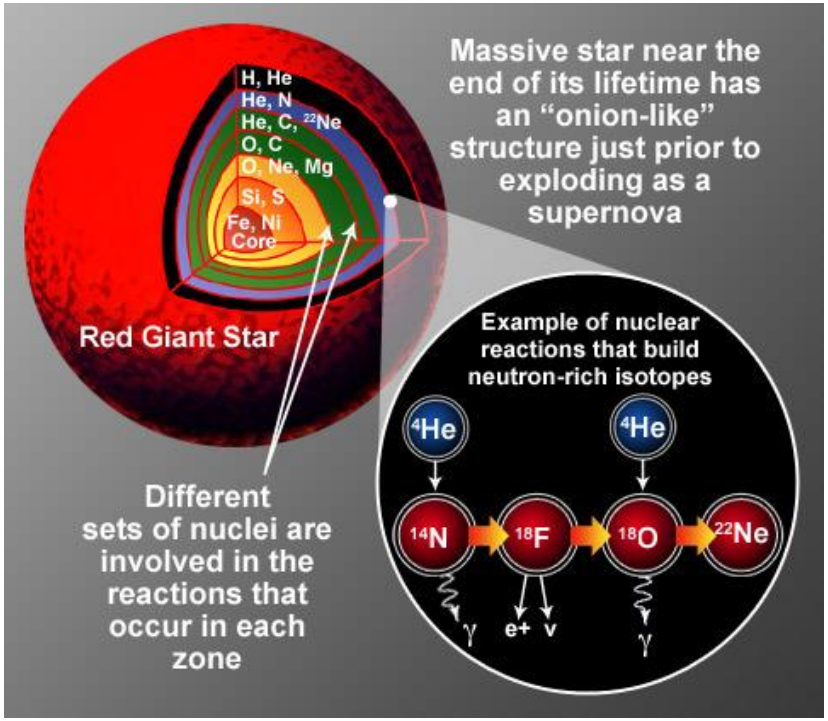


Nucleosynthesis

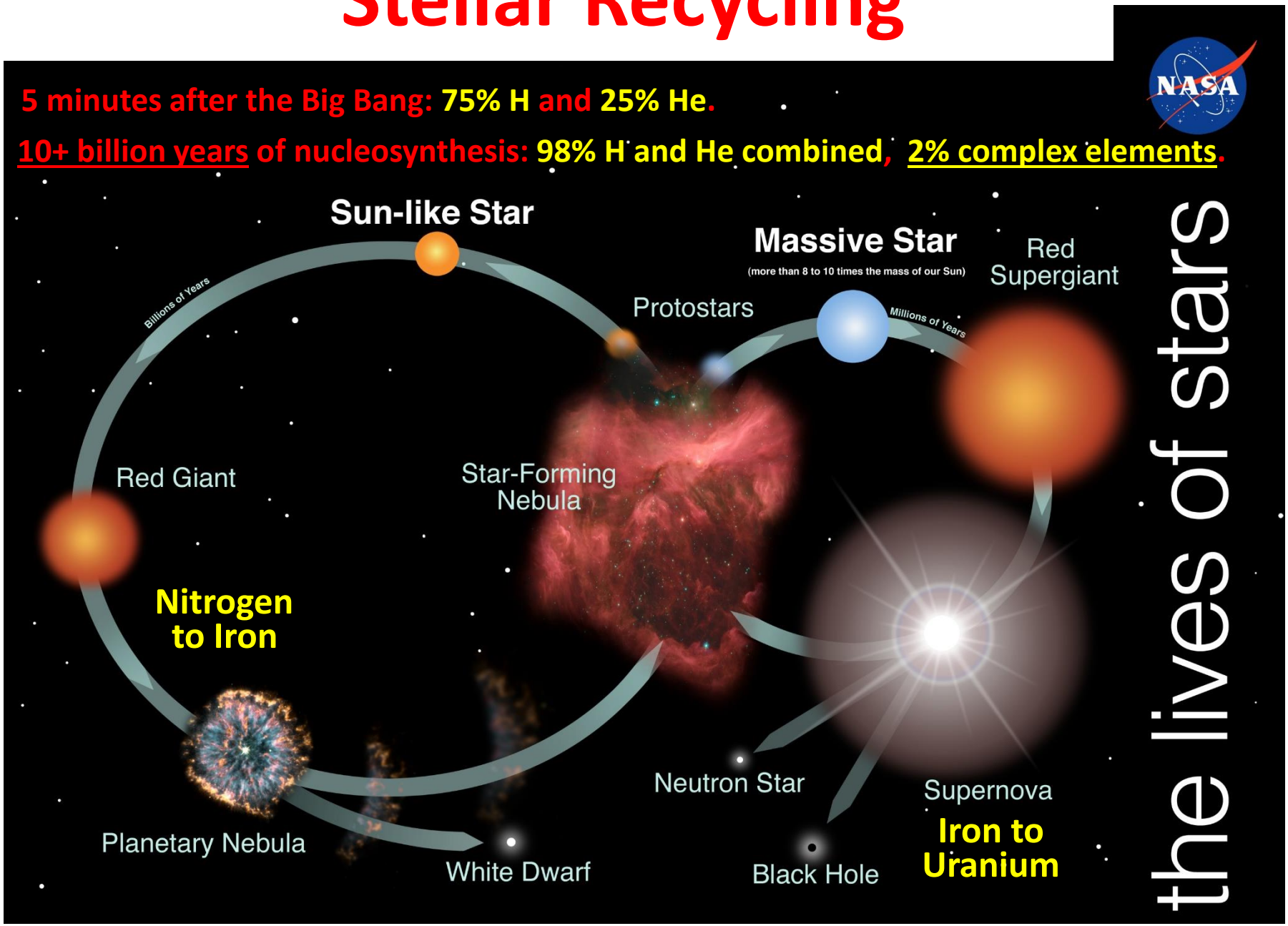
Nucleosynthesis is the natural process that creates new atomic nuclei from pre-existing nucleons, primarily protons and neutrons:



- **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



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:

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

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