

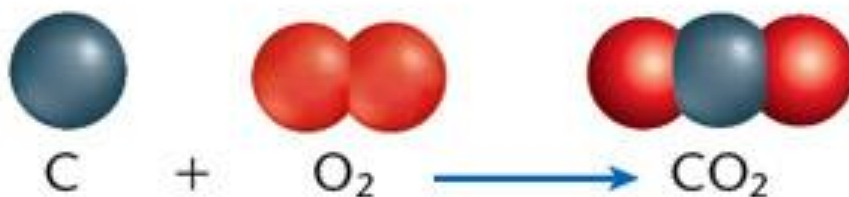
Nuclear Reactions

Part 1

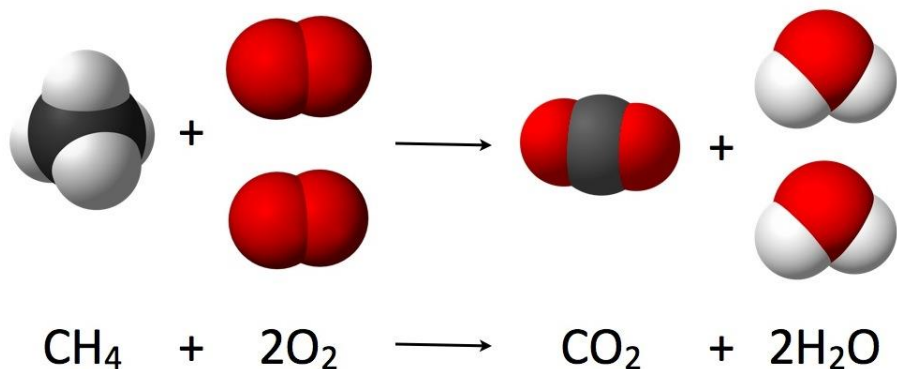
Review: Chemical Reactions

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

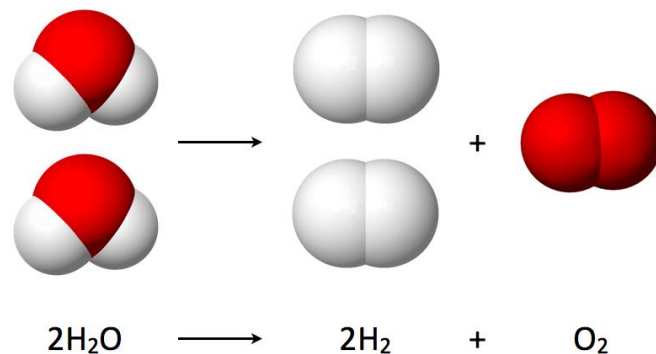
Formation of Carbon Dioxide



Combustion (burning) of Methane



Electrolysis of Water



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.

Ionizing Radiation can pose a serious health threat to humans: it is capable of changing the basic makeup of atoms and molecules in cells, and more specifically the DNA molecules inside of cells.

Alpha Particle

LARGE PARTICLE, TRAVELS A FEW INCHES
STOPPED BY A SHEET OF PAPER



- interacts strongly with matter
- unable to penetrate the outer layer of dead skin cells
- **capable of causing serious cell damage if an alpha emitting substance is ingested in food or air**

Beta Particle

VERY SMALL PARTICLE, TRAVELS A FEW FEET
STOPPED BY WOOD, PLASTIC OR ALUMINUM



- can penetrate skin a few centimeters
- **main threat is still primarily from internal emission from ingested material**

Neutron

SMALL PARTICLE, TRAVELS A FEW FEET
ENERGY ABSORBED BY WATER AND CONCRETE



- the only type of radiation that is **able to turn other materials radioactive**

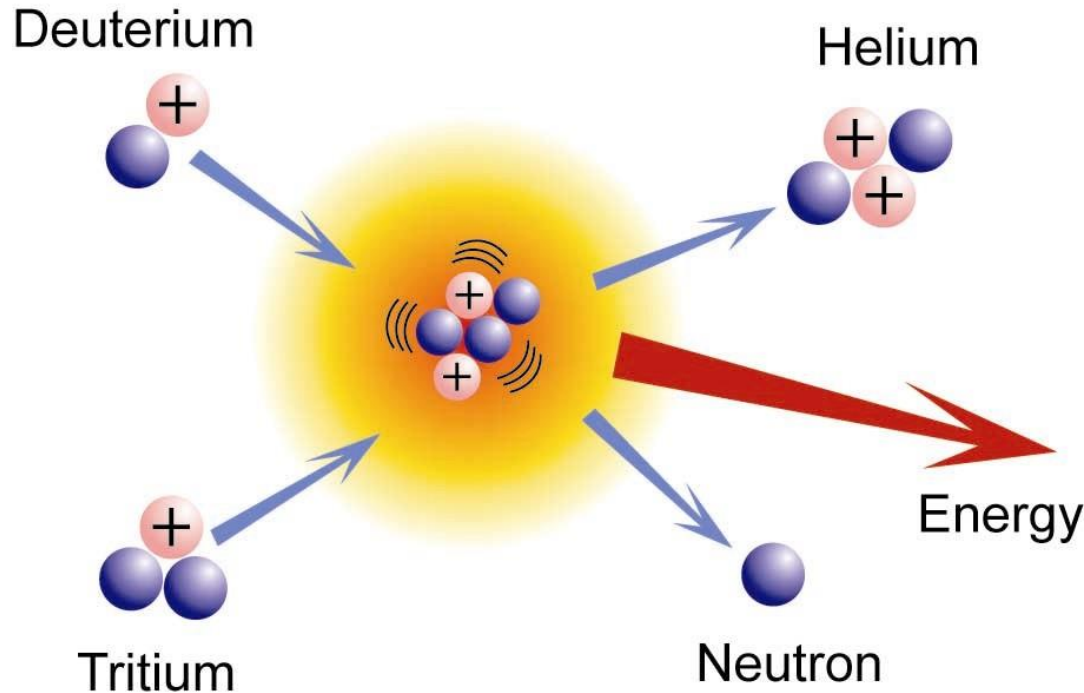
Gamma Ray

HIGH ENERGY, TRAVELS LONG DISTANCES
ENERGY ABSORBED BY HEAVY METALS AND CONCRETE



- very high energy electromagnetic radiation
- **cause diffuse damage throughout the body ("radiation sickness")**

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.

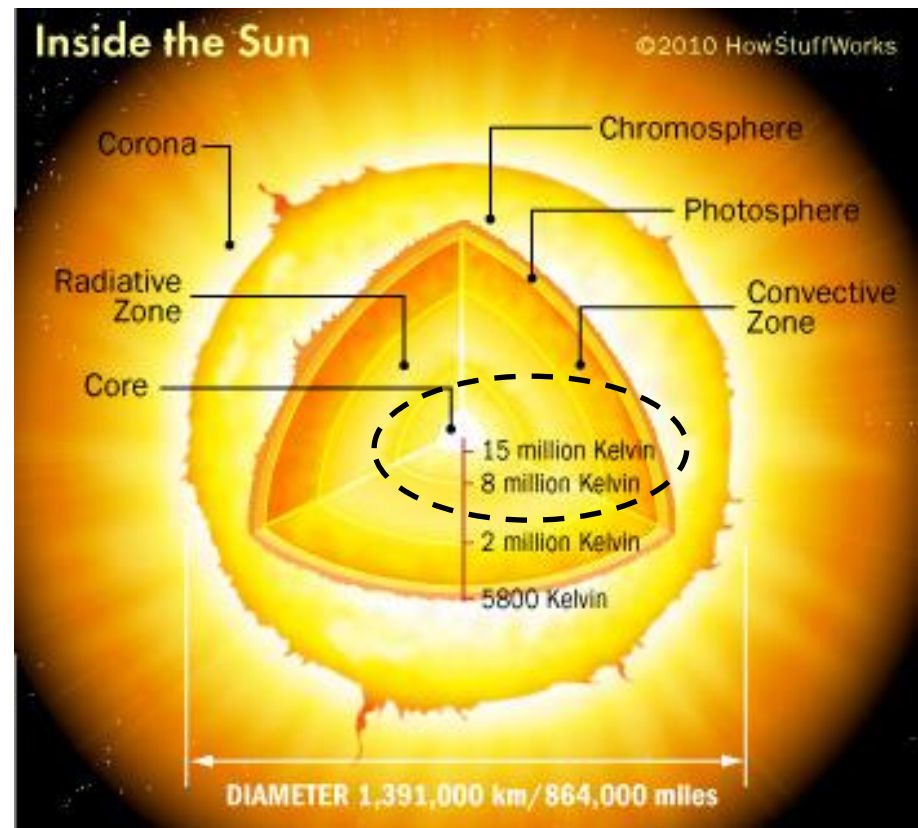
Fusion powers active stars!



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

Thermonuclear Fusion

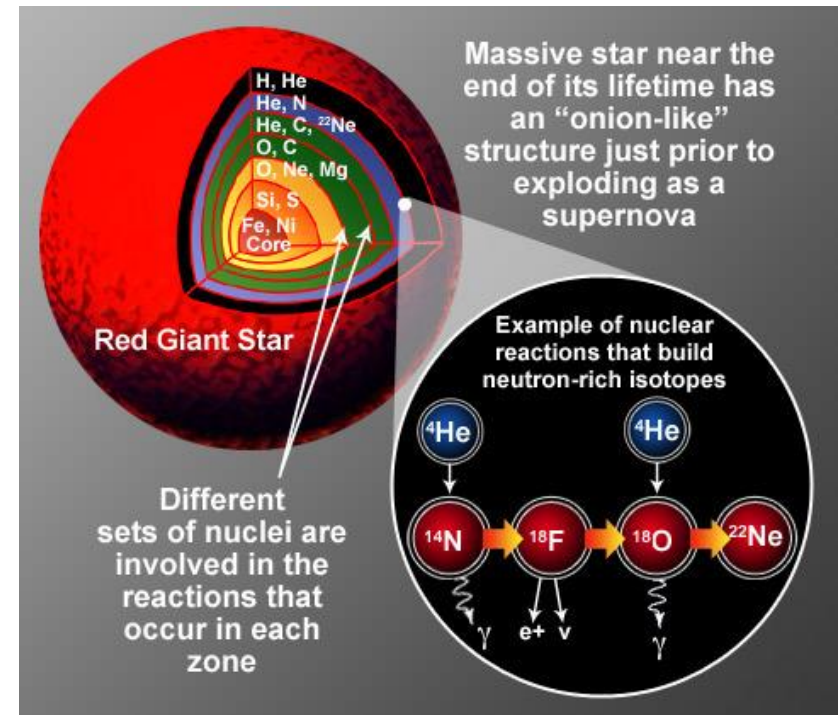
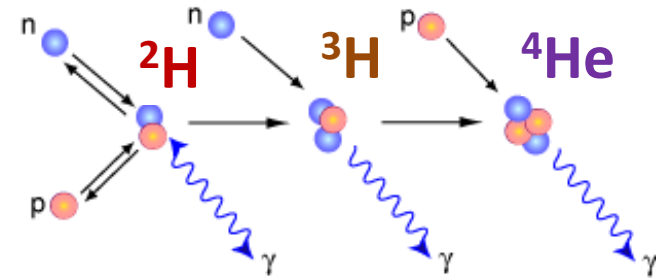
- In order to fuse, **two atomic nuclei must be brought close enough together** (*confinement requirement*) so the electrostatic repulsion can be overcome by the attractive nuclear force which is stronger at close distances.
- If matter is sufficiently **heated** (*plasma state*), **thermonuclear fusion**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

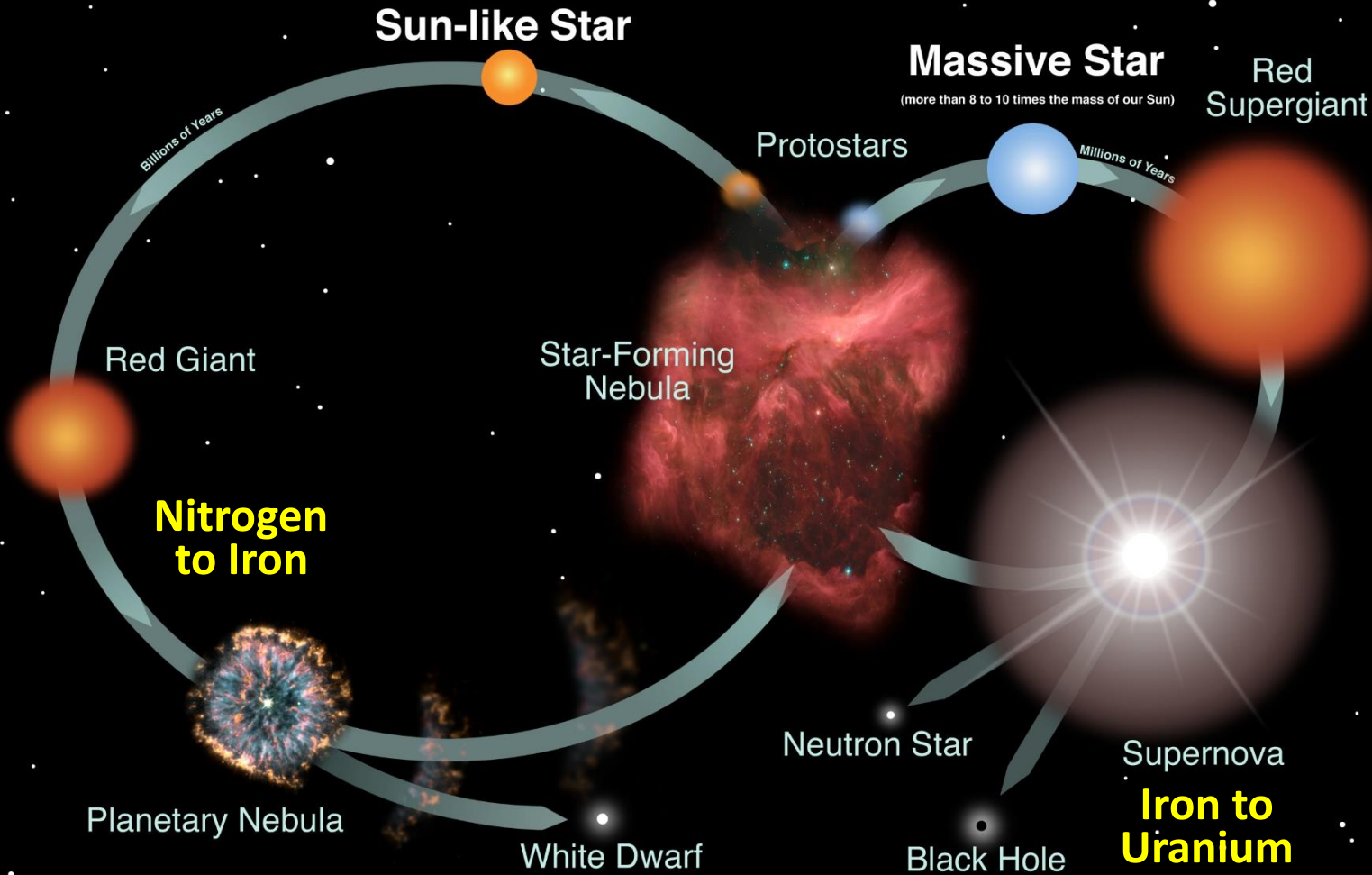


Stellar Recycling



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

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



the lives of stars

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.