

# Nuclear fusion and stars

## Physics HL Presentation

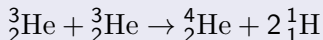
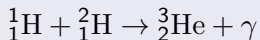
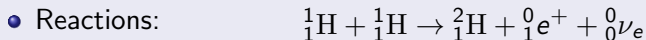
Eric, Jerrie, Louis and Tom

November 17, 2025

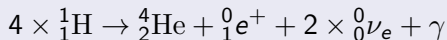
# Creation of Light Elements

## Proton-Proton (p-p) Chain

- Proton-Proton (p-p) chain is the most dominant reaction in the **low mass main sequence stars** like the sun.



- Net reaction (p-p chain):

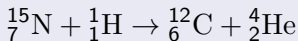
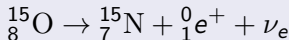
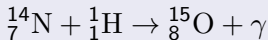
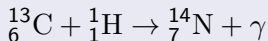
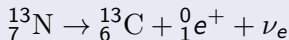
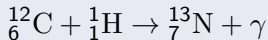


# Creation of Light Elements

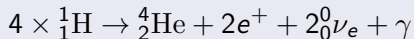
## CNO Cycle

- Dominates in **more massive stars** since greater Coulomb barrier is overcome.

- Reactions:



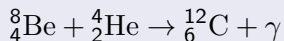
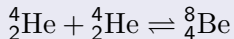
- Net reaction (CNO cycle):



# Creation of Light Elements

## Triple alpha process

- Occurs **after the main-sequence phase** ( $T \sim 10^8$  K,  $M > 0.5M_{\odot}$ ).
- $0.8M_{\odot} < M < 2.2M_{\odot}$ :helium flash;     $M > 2.2M_{\odot}$ :smooth start.
- Reactions:



## High mass stars

- After helium burning, temperatures become high enough for successive fusion stages:
- Carbon burning:  ${}^{12}\text{C} + {}^{12}\text{C} \rightarrow {}^{20}\text{Ne}, {}^{23}\text{Na}, {}^{24}\text{Mg}, \dots$
- Oxygen burning:  ${}^{16}\text{O} + {}^{16}\text{O} \rightarrow {}^{28}\text{Si}, {}^{31}\text{P}, \dots$

# “Life choices” of stars

## The Chandrasekhar Limit

- Electron-degenerate matter is present in white dwarfs.
- The Chandrasekhar limit:  $1.4 M_{\odot}$ .
- The largest mass a white dwarf star can have.

## The Oppenheimer-Volkoff Limit

- Neutron-degenerate matter is present in neutron stars.
- The Oppenheimer-Volkoff limit:  $3 M_{\odot}$ .
- The largest mass a neutron star can have.

## Black holes

- Happens when the mass of the star remnant reaches the OV limit.
- Mainly depends on the initial mass of the star ( $M > 20M_{\odot}$  makes it possible, usually  $M > 40M_{\odot}$ ).

# “Fate” of stars

Mass ( $M_{\odot}$ )	Main Sequence	Giant Phase	After Giant	Remnant
0.08–0.25	(pp chain)	—	—	He white dwarf
0.25–2.2	(pp chain)	Red giant (triple-alpha)	Planetary nebula	C white dwarf
2.2–8	( $\rightarrow$ CNO)	Red giant / AGB (He, C)	Planetary nebula	C white dwarf
8–12	(CNO)	Supergiant (He, C, Ne)	Supernova	O/Ne/Mg WD
12–40	(CNO)	Supergiant (He, C, Ne)	Supernova	Neutron star
40–150	(CNO)	Supergiant (full fusion chain to Fe)	Core-collapse supernova	Black hole

*“We are not figuratively, but literally stardust.”*

*— Neil deGrasse Tyson.*

Each atom in our body, everything we see around us, originated from a magnificent dying of a main sequence star. The star shined for millions of years before its final certain call, and the interstellar dust traveled light years before forming the world in which we live.