

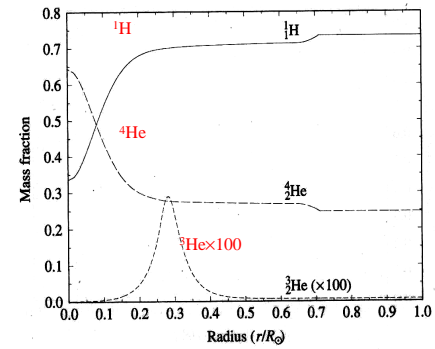
## When the Sun Dies—12 Oct

- Sun will use up the hydrogen in the center in 5Byr
- Center of sun must shrink to get hotter to balance gravity
  - Sun will become a red giant. Surface expands.
- Sun will become a planetary nebula
- Sun will become a white dwarf



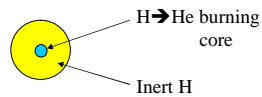
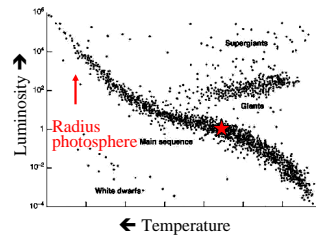
## Composition of the sun

- In center, hydrogen is half used up.



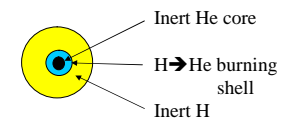
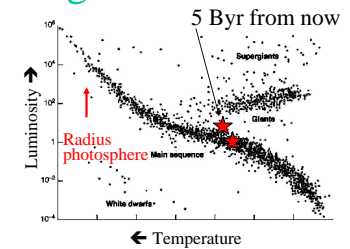
## Sun as a main-sequence star

- H? He in the core
- $T=15\text{MK}$
- Fuel will last another 5 Byr.



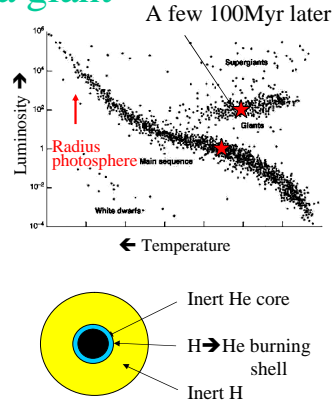
## Sun as a subgiant

- H is gone in the core
- The never-ending battle between gravity and pressure. How does the sun adjust?
  - Without burning fuel to keep temperature up, pressure ( $PV=nRT$ ) would fall and gravity would win.
  - Core shrinks, gets hotter
  - H? He in the a shell surrounding inert core
  - Balance restored.



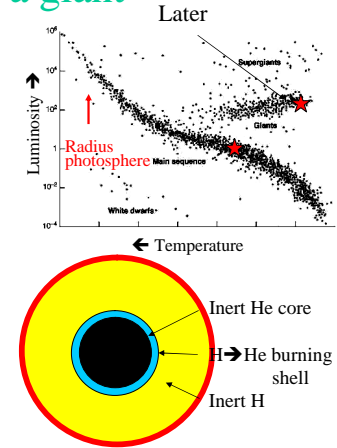
## Sun as a giant

- H is gone in the core
- The never-ending battle between gravity and pressure. How does the sun adjust?
  - Without burning fuel to keep temperature up, pressure ( $PV=nRT$ ) would fall and gravity would win.
  - Core shrinks, gets hotter
  - H? He in the a shell surrounding inert core
  - Balance restored.
- Inert He core expands



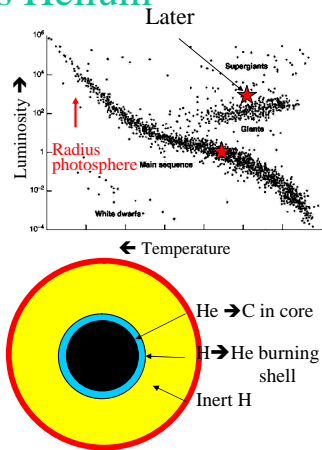
## Sun as a giant

- H is gone in the core
- The never-ending battle between gravity and pressure. How does the sun adjust?
  - Without burning fuel to keep temperature up, pressure ( $PV=nRT$ ) would fall and gravity would win.
  - Core shrinks, gets hotter
  - H? He in the a shell surrounding inert core
  - Balance restored.
- Inert He core expands



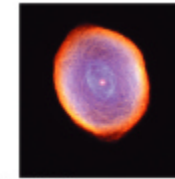
## Sun Burns Helium

- H is gone in the core & shell is exhausted
- The never-ending battle between gravity and pressure. How does the sun adjust?
  - Without burning fuel to keep temperature up, pressure ( $PV=nRT$ ) would fall and gravity would win.
  - Core shrinks, gets hotter  $T=200\text{MK}$
  - $3\text{He} \rightarrow \text{C}$  in the core (triple alpha process)
  - Balance restored.



## Other fusion reactions?

- Sun has one more trick after He is exhausted in core.
  - Burn He in a shell
- Sun is not massive enough to shrink further and get hotter
  - Core is supported by pressure of degenerate electrons.
  - Temperature does not rise to burn anything else.
- End of the road: planetary nebula & white dwarf core



triple-alpha process

Reaction	Min. Temp.
$4\ ^1\text{H} \rightarrow\ ^4\text{He}$	10 MK
$3\ ^4\text{He} \rightarrow\ ^{12}\text{C}$	200 MK
$^{12}\text{C} +\ ^4\text{He} \rightarrow\ ^{16}\text{O},\ \text{Ne},\ \text{Na},\ \text{Mg}$	800 MK
$\text{Ne} \rightarrow\ \text{O},\ \text{Mg}$	1500MK
$\text{O} \rightarrow\ \text{Mg},\ \text{S}$	2000MK
$\text{Si} \rightarrow\ \text{Fe peak}$	3000MK

## Summarizing question

- At what point will the earth die?

