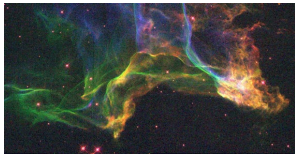


Supernovae—March 23



- Where were the elements in the baby made?
 - Carbon was made and expelled by giants
 - Iron was made in massive stars and expelled by supernovae
- Supernova
 - Neutron star
 - Black hole
- Study guide for test 3



Cygnus Loop
Supernova 20,000 yr ago

Large Magellanic Cloud

© Andriy Fedotkin Observatory/Brand Observatory, Malibu

Supernova 1987A

- Exploded in Large Magellanic Cloud
- LMC is small galaxy that orbits our own Milky Way Galaxy.

February 2, 2000 Difference

Pre-existing circumstellar ring lit up first by photons from SN, now by blast wave from SN.

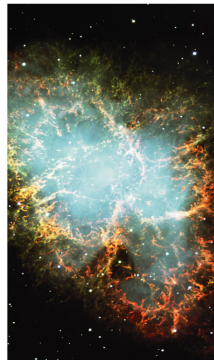
Feb. 04 Sept. 04 Mar. 05 Feb. 05

Supernova 1987A HST - WFPC2

PHOTONIC - ST. SUI DMC - January 14, 1997
© P. M. HARRIS/STFC, R. SCHMIDT/STFC and NASA

Guest star of 1054

- Records of Sung Dynasty
 - In the first year of the period Chih-ho, ..., a guest star appeared several degrees SE of Thien-kuan. After more than a year it gradually became invisible.—p564.
- Gas expelled in 1054AD, still glowing
- Other SN
 - 1572 Tycho
 - 1604 Kepler



Supernova remnants

Crab
1,000 yrs old

We expect one supernova in Milky Way every 25-100 yrs.

Cygnus Loop
20,000 yrs old.
2500 LY away.

IC 443
8000 yrs old

Supernovae

- Explosion releases enormous energy
- Luminosity in photons temporarily exceeds that of whole galaxy full (100 billion) of stars.



What is a supernova? Why sun becomes a white dwarf, not a supernova

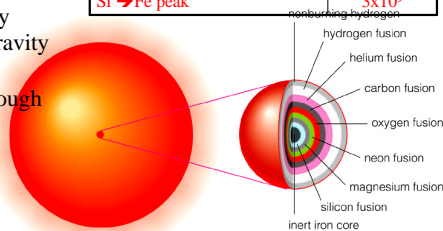
- In future double-shell burning sun, hot enough to burn $3^4\text{He} \rightarrow ^{12}\text{C}$
- When He exhausted, gravity wins, and core contracts.
- Temperature rises.
- Electrons are so tight that they become degenerate.
- New source of pressure to resist gravity.
- Temperature not hot enough to burn carbon.

Reaction	Min. Temp.
$4\ ^1\text{H} \rightarrow\ ^4\text{He}$	$10^7\text{ }^\circ\text{K}$
$3\ ^4\text{He} \rightarrow\ ^{12}\text{C}$	2×10^8
$^{12}\text{C} +\ ^4\text{He} \rightarrow\ ^{16}\text{O},\ \text{Ne},\ \text{Na},\ \text{Mg}$	8×10^8
$\text{Ne} \rightarrow\ \text{O},\ \text{Mg}$	1.5×10^9
$\text{O} \rightarrow\ \text{Mg},\ \text{S}$	2×10^9
$\text{Si} \rightarrow\ \text{Fe peak}$	3×10^9

What is a supernova? Why massive star becomes a supernova

- In future double-shell burning massive star, hot enough to burn $3^4\text{He} \rightarrow ^{12}\text{C}$
- When He exhausted, gravity wins, and core contracts.
- Temperature rises by larger amount b/c gravity is stronger.
- Temperature hot enough to burn carbon. $^4\text{He} + ^{12}\text{C} \rightarrow ^{16}\text{O}$, etc

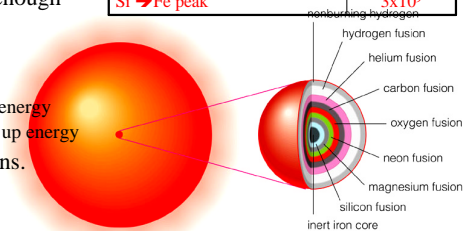
Reaction	Min. Temp.
$4\ ^1\text{H} \rightarrow\ ^4\text{He}$	$10^7\text{ }^\circ\text{K}$
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$\text{Si} \rightarrow\ \text{Fe peak}$	3×10^9



What is a supernova? Why massive star becomes a supernova

- Hot enough to burn $^4\text{He} + ^{12}\text{C} \rightarrow ^{16}\text{O}$, etc
- When C exhausted, gravity wins, and core contracts.
- Temperature rises.
- Temperature hot enough to burn neon. $^{20}\text{Ne} + ^4\text{He} \rightarrow ^{24}\text{Mg}$
- Disaster with iron
 - Burning releases energy
 - Fusing iron takes up energy
- Gravity finally wins.

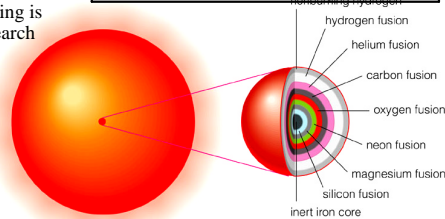
Reaction	Min. Temp.
$4\ ^1\text{H} \rightarrow\ ^4\text{He}$	$10^7\text{ }^\circ\text{K}$
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$^{12}\text{C} +\ ^4\text{He} \rightarrow\ ^{16}\text{O},\ \text{Ne},\ \text{Na},\ \text{Mg}$	8×10^8
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What is a supernova? Why massive star becomes a supernova

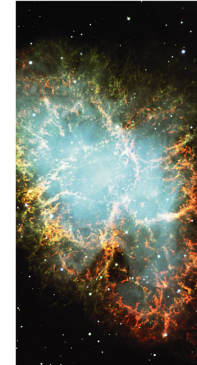
- Disaster with iron
 - Burning releases energy
 - Fusing iron takes up energy
- Gravity finally wins.
- Star collapses in few seconds
- Rebounds as supernova
 - Reason for rebounding is topic of current research
- Expel outer layers

Reaction	Min. Temp.
$4\ ^1\text{H} \rightarrow\ ^4\text{He}$	$10^7\ ^\circ\text{K}$
$3\ ^4\text{He} \rightarrow\ ^{12}\text{C}$	2×10^8
$^{12}\text{C} +\ ^4\text{He} \rightarrow\ ^{16}\text{O},\ \text{Ne},\ \text{Na},\ \text{Mg}$	8×10^8
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$\text{Si} \rightarrow\ \text{Fe peak}$	3×10^9



What is left?

- Outer layers expelled into space. New stars may form.
- Core becomes
 - Neutron star. One in Crab. Pulses every 1/30 s.
 - Black hole
- Neutron star
 - Normally $\text{neutron} \rightarrow \text{proton} + \text{electron} + \text{neutrino} + \text{energy}$
 - Pressure is so high that $\text{proton} + \text{electron} + \text{energy} \rightarrow \text{neutron} + \text{neutrino}$
 - Whole star is like a big nucleus of neutrons.
 - Neutrons are degenerate
 - Star is size of Lansing



- What prevents the sun from becoming a supernova?
 - Iron core is stable.
 - Degeneracy pressure prevents temperature from rising.
 - Carbon burning.
 - That is wrong; the sun will become a supernova.
- If neon was the most stable element, massive stars live
 - longer
 - shorter

- Missouri Club
 - Friday, 9:00am
 - Room 1410?
- Study guide
 - Will put on web by end of day.
 - Big ideas
 - Medium-sized ideas
 - Questions