



Nucleosynthesis

How were the first Elements in the Universe formed?

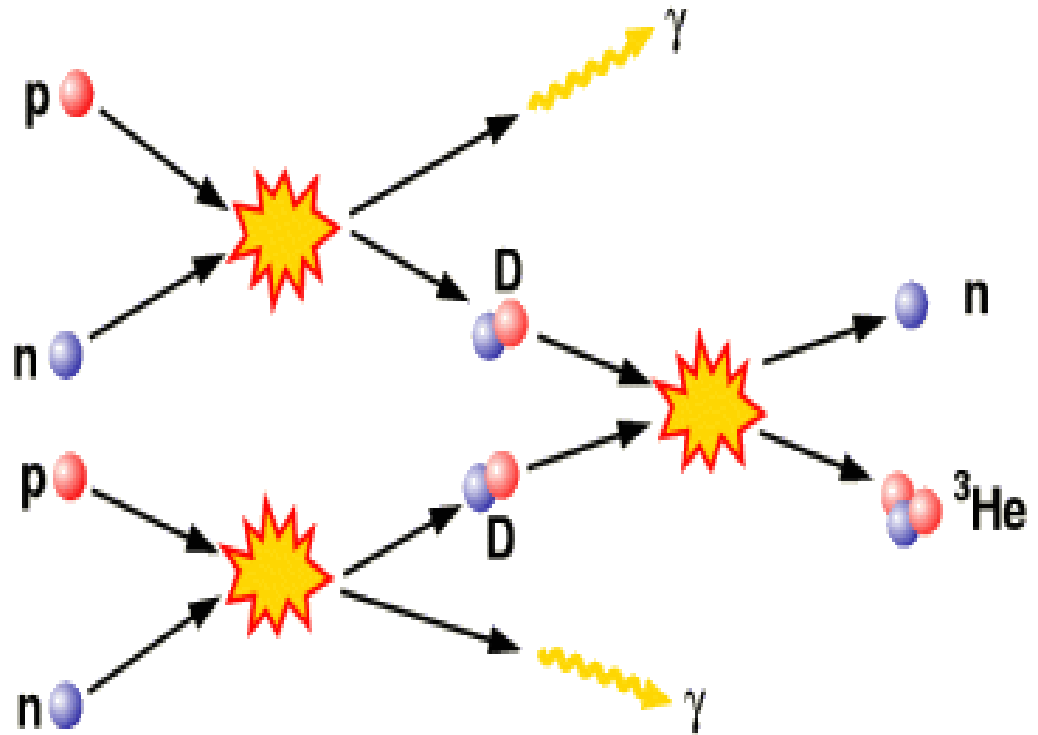
- A few seconds after the big bang, protons, neutrons, and electrons consisted the universe.
- At present, the universe consists of mostly hydrogen and helium.
- The elements of the present universe were formed in a process known as **nucleosynthesis**.

Definition of Terms:

- 1) Nucleus (plural: nuclei)** – the central part of the atoms which contains the nucleons.
- 2) Nucleons** – subatomic particles found in the nucleus. (proton and neutron)

Nucleosynthesis

Process that
creates new
atomic nuclei
from
nucleons.



Nucleosynthesis

1. Building up of complex atoms through the formation of deuterium nuclei or deuterons.
Deuterons are a combination of a proton and a neutron.



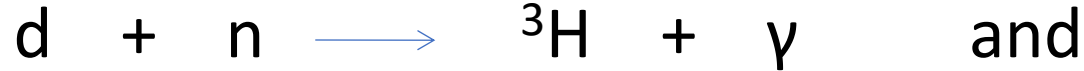
To break up a deuteron nuclei apart into its components - proton and neutron; the reverse reaction process must occur.





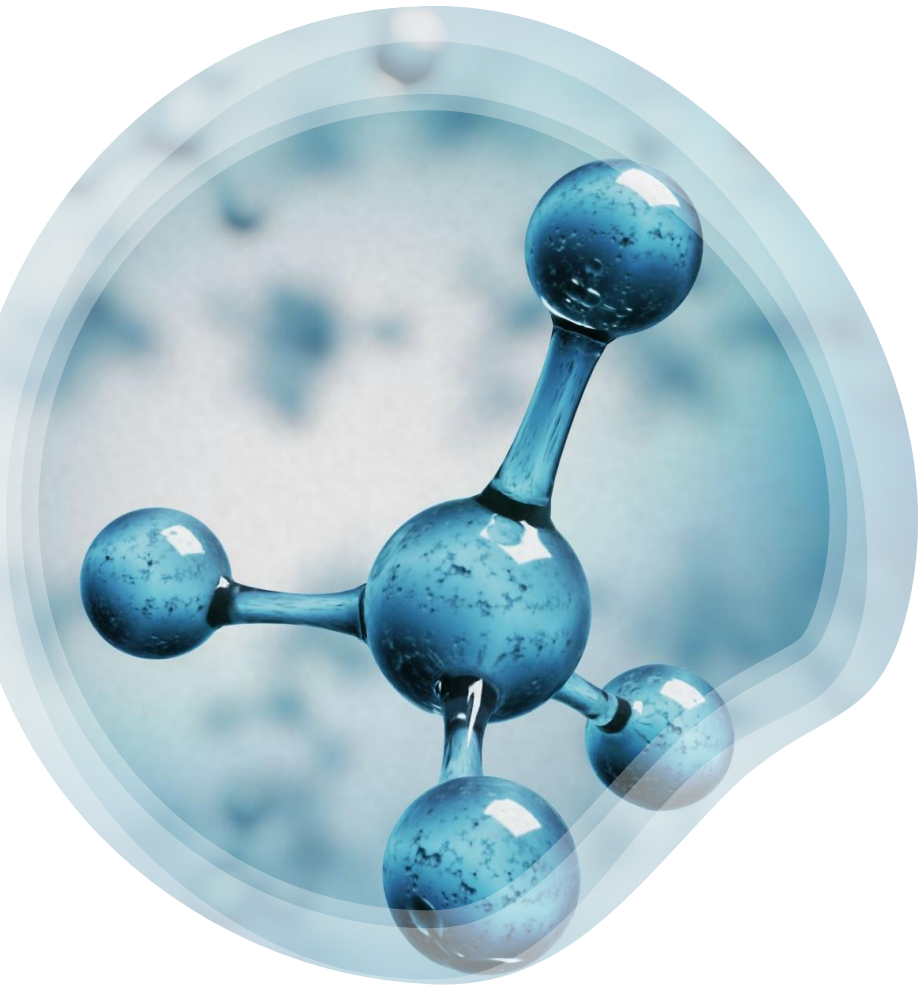
- The two reactions will take place at the same rate if the universe were filled with energetic photons, which means that the **deuterium will dissociate as quickly as it is formed**.
- But if the universe were adequately old enough, the energy of the photons would not be sufficient to accomplish the dissociation reaction and the deuterium would start to build up.

- Since deuterons are less abundant than protons and neutrons, **deuterons will readily react with them** according to the following reaction equations:



- ${}^3\text{H}$ and ${}^3\text{He}$ will also react with p and n :



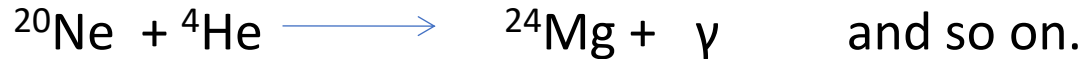


- The last step in the formation of matter in the big bang, was the **production of neutral atoms of H and He**. This happened when proton and ^4He nuclei combined with electrons.
- With the formation of neutral atoms, there were essentially no free charged particles left in the universe.

Simple Helium Fusion



- ${}^8\text{Be}$ is unstable and breaks apart as rapidly as it forms.
- A third ${}^4\text{He}$ is required to participate in the reaction.



When the fuel is exhausted, contraction sets in again increasing the temperature so that other reactions can occur, such as **Carbon burning**.



- The elements beyond $A = 56$ cannot be produced through fusion. These are produced through the process called the **neutron-capture process**.

Neutron-Capture Process

Neutrons are captured by the nucleus in the interior of a star until the amount of neutron excess is sufficient to convert extra neutron to a proton in a beta decay:



This increases the number of protons by one.



${}^{58}\text{Fe}$ and ${}^{57}\text{Fe}$ are stable, but ${}^{59}\text{Fe}$ is not – it is radioactive. It undergoes beta decay to ${}^{59}\text{Co}$.

${}^{59}\text{Co}$ can capture a neutron to become ${}^{60}\text{Co}$, which is radioactive, and beta decays to ${}^{60}\text{Ni}$.

3 types of Nucleosynthesis:

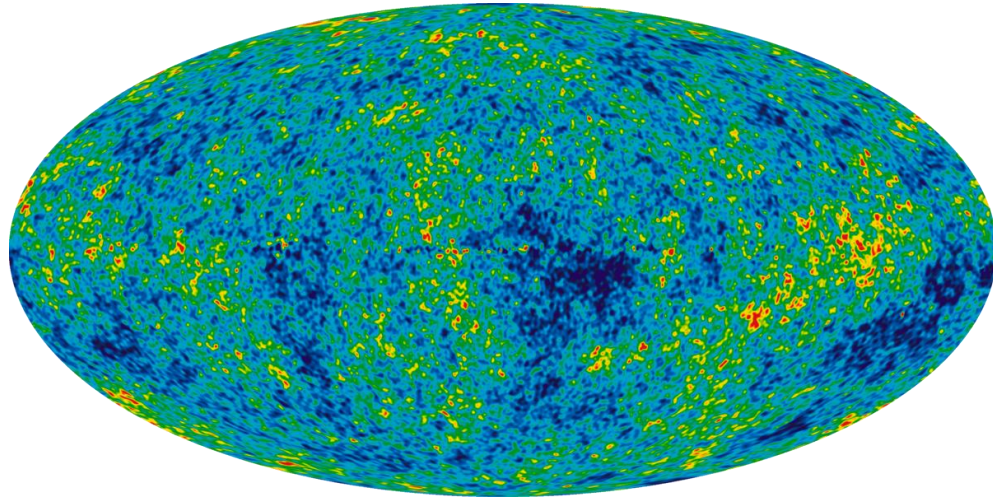
Big Bang Nucleosynthesis

Stellar Nucleosynthesis

Supernova Nucleosynthesis

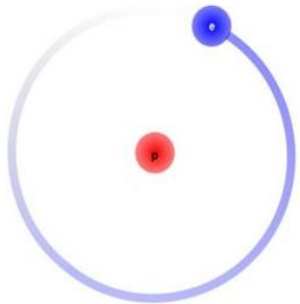
Big Bang Nucleosynthesis

After the expansion and cooling of the universe, nuclei started to form

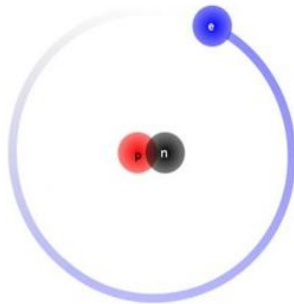


Big Bang Nucleosynthesis

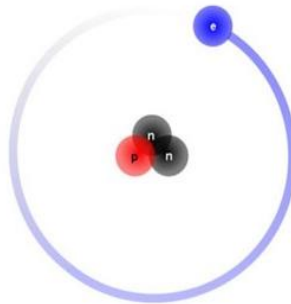
About 3 minutes after the Big Bang,
the nucleus of Hydrogen and Helium
formed



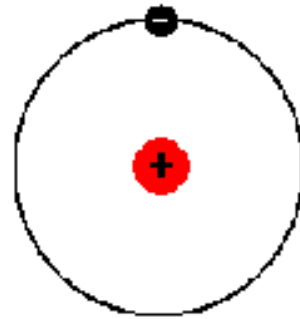
Hydrogen



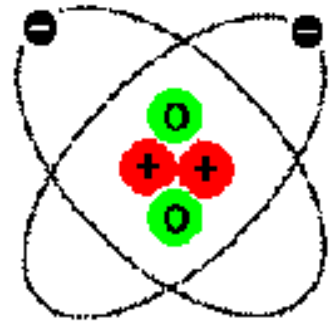
Deuterium



Tritium



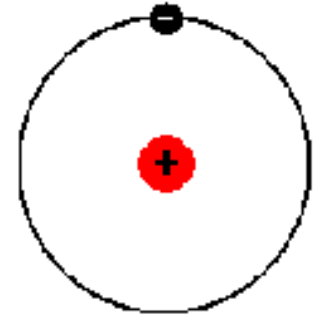
Hydrogen



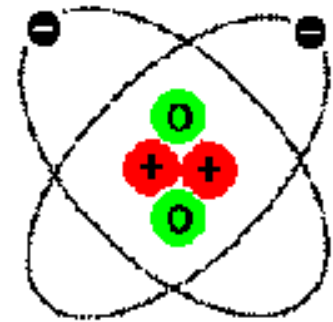
Helium

Big Bang Nucleosynthesis

After more cooling,
nuclei started to attract
electrons forming atoms.
This happened 300, 000
years after the big bang.



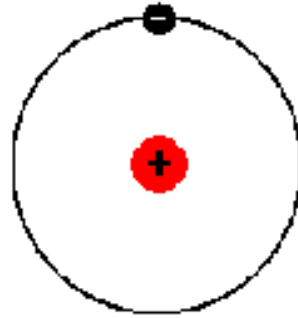
Hydrogen



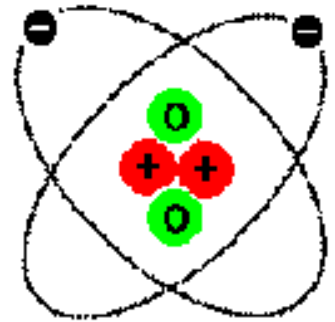
Helium

Evidence of the Big Bang:

All the Hydrogen
and Helium we
have in the
universe came
from the big bang.



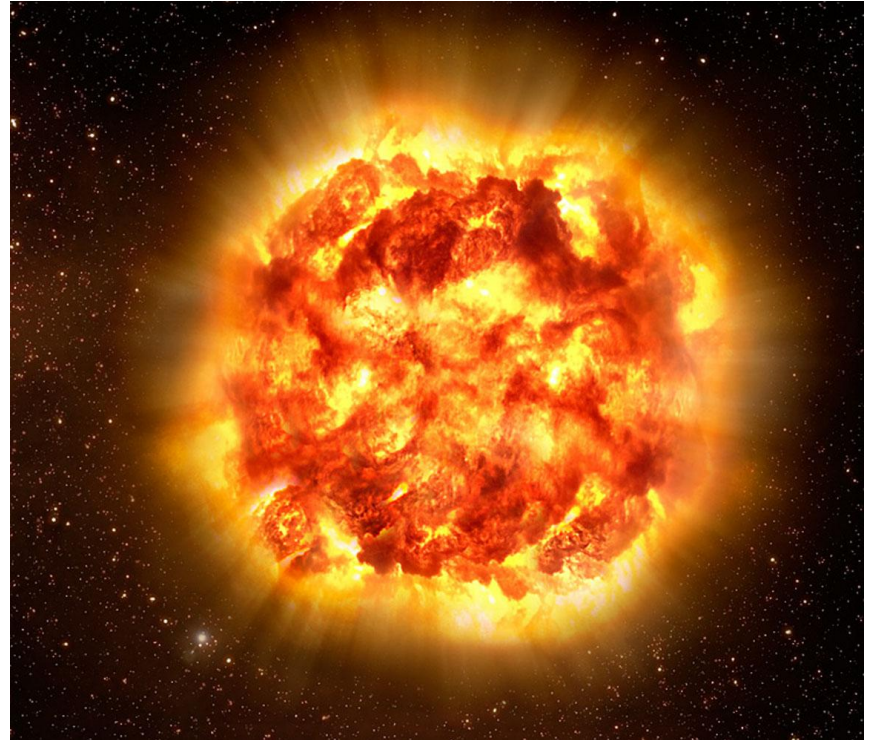
Hydrogen



Helium

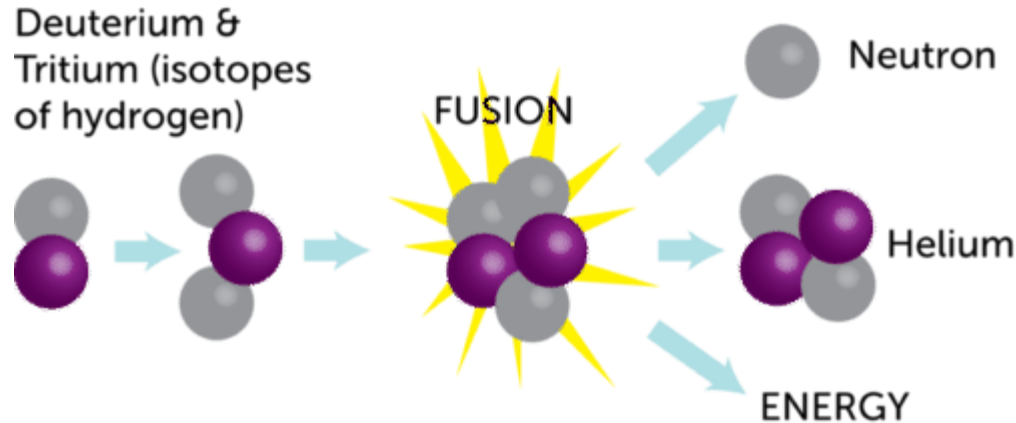
Stellar Nucleosynthesis

Process by
which nuclei are
formed in the
center of stars.



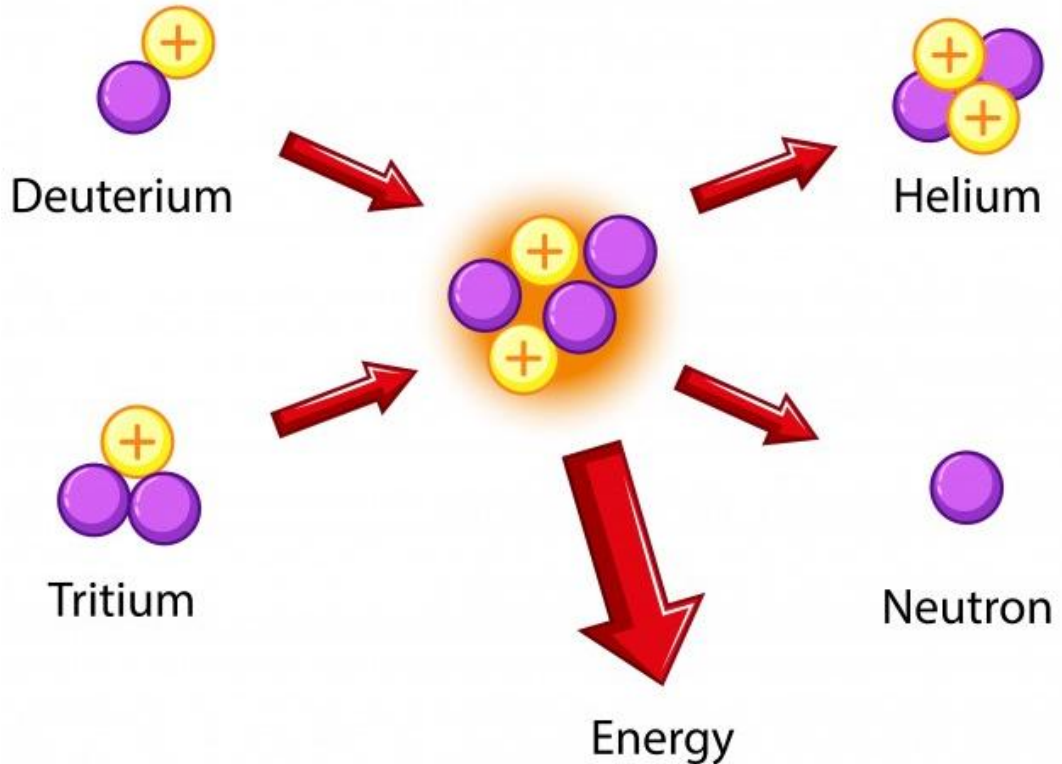
Stellar Nucleosynthesis

Elements from helium (He) to Iron (Fe) are made through the process called **Nuclear Fusion**.



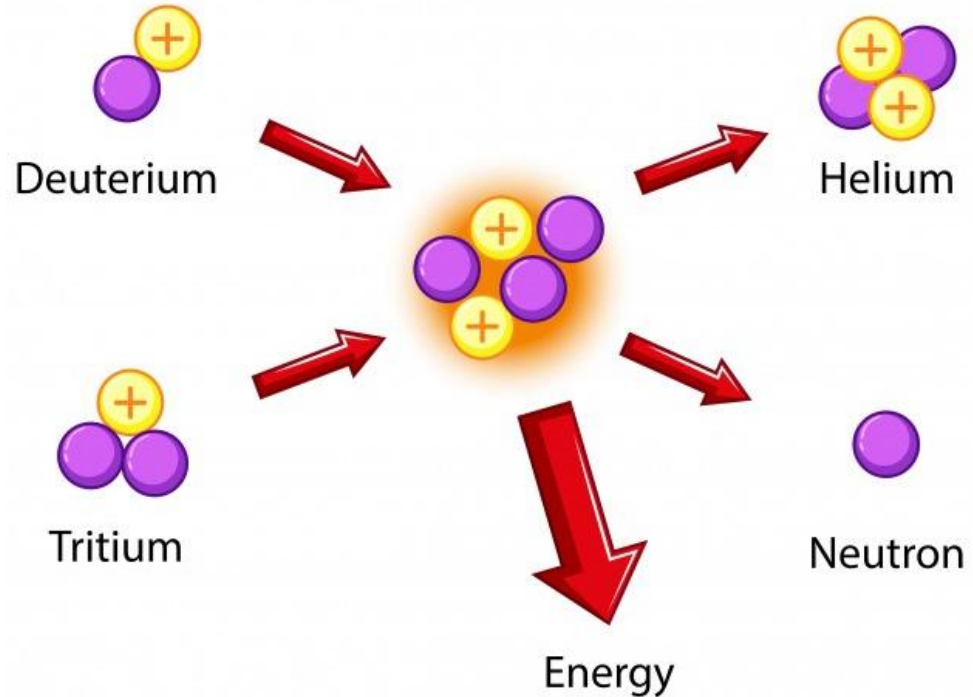
Nuclear Fusion

The process
of colliding
light elements
to form
heavier
elements



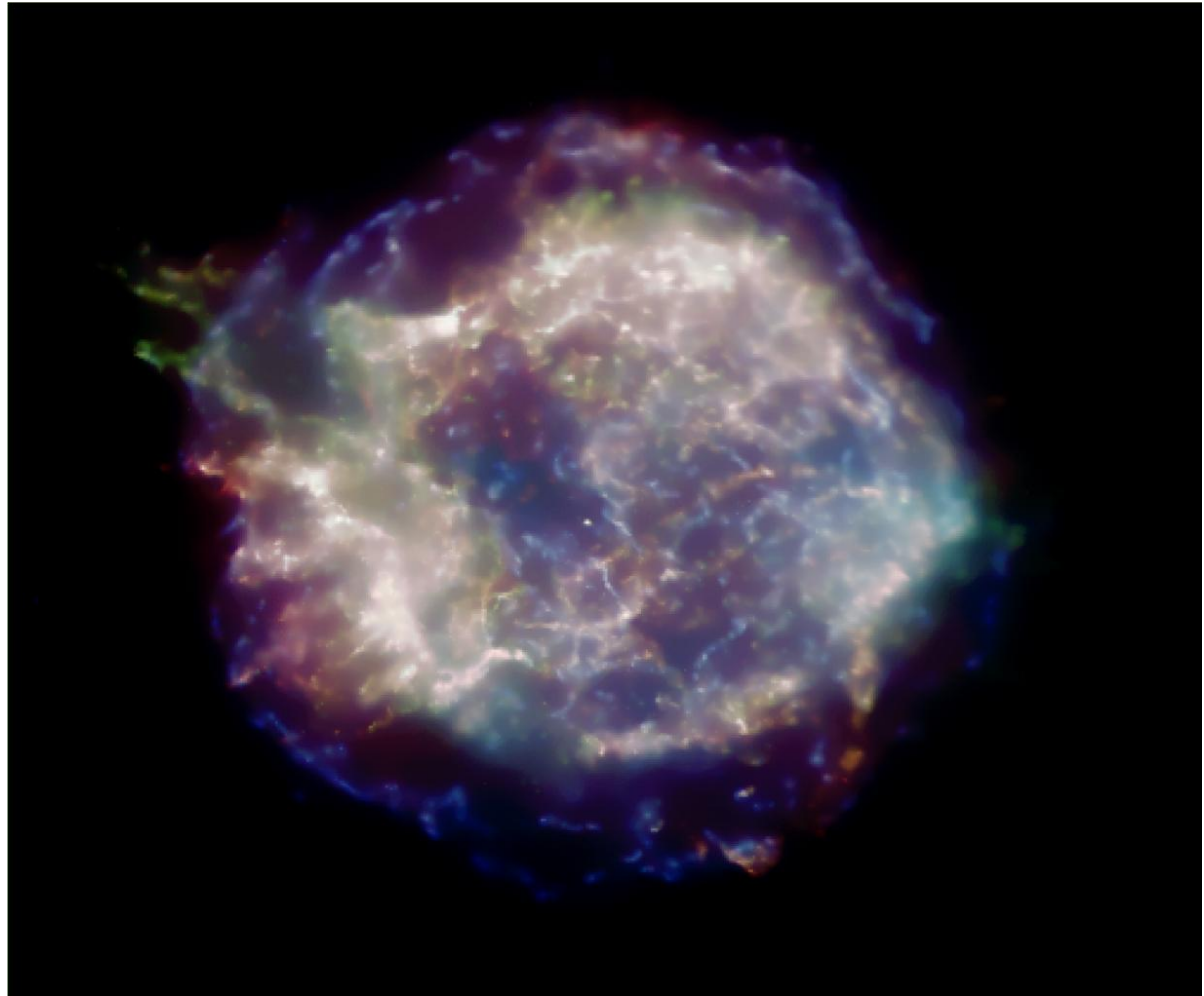
Nuclear Fusion

Energy that
stars produce
come from
the collision of
light elements



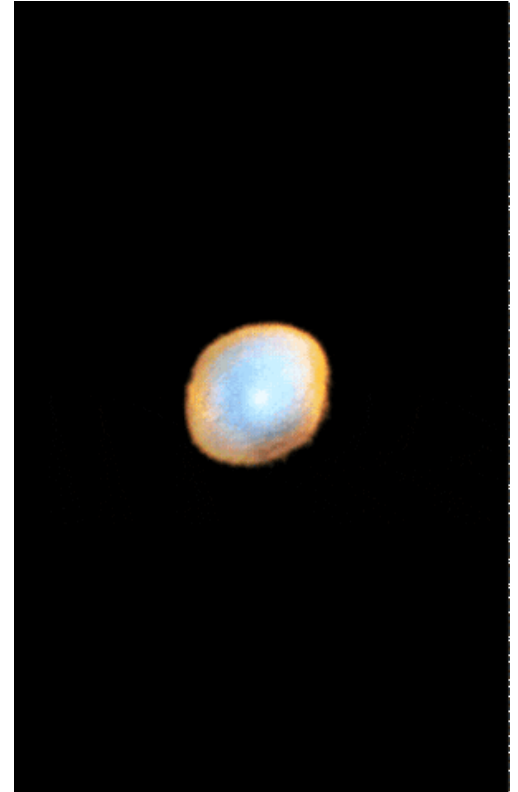
What happens when all of the hydrogen and helium in a star are made into heavier elements?

**THE STAR
WILL
COLLAPSE!!!**



Supernova Nucleosynthesis

When a star collapses, heavier elements can now be fused together.



Supernova Nucleosynthesis

Elements
heavier than
iron (Fe) are
made
through this
process.

Periodic Table of the Elements																		18 VIII 8A														
1 IA 1A								13 IIIA 3A		14 IVA 4A		15 VA 5A		16 VIA 6A		17 VIIA 7A		2														
1 H Hydrogen 1.0079	2 He Helium 4.0026																															
3 Li Lithium 6.941	4 Be Beryllium 9.01218							5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.00674	8 O Oxygen 15.9994	9 F Fluorine 18.998403	10 Ne Neon 20.1797																			
11 Na Sodium 22.989768	12 Mg Magnesium 24.305	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8 VIII 8	9 VIII 9	10 VIII 10	11 IB 1B	12 IIB 2B	13 Al Aluminum 26.981539	14 Si Silicon 28.0855	15 P Phosphorus 30.973762	16 S Sulfur 32.066	17 Cl Chlorine 35.4527	18 Ar Argon 39.948															
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955912	22 Ti Titanium 47.88	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938	26 Fe Iron 55.847	27 Co Cobalt 58.9332	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.921595	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80															
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium 96.9072	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.9055	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.90447	54 Xe Xenon 131.29															
55 Cs Cesium 132.90543	56 Ba Barium 137.327	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.9665	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98037	84 Po Polonium [209]	85 At Astatine [209]	86 Rn Radon [222]															
87 Fr Francium 223.0187	88 Ra Radium 226.0254	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [289]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Fl Flerovium [289]	115 Uup Ununpentium unknown	116 Lv Livermorium [293]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown															
Lanthanide Series																		57 La Lanthanum 138.9055	58 Ce Cerium 140.116	59 Pr Praseodymium 140.90768	60 Nd Neodymium 144.24	61 Pm Promethium 144.9127	62 Sm Samarium 150.36	63 Eu Europium 151.9655	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92534	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93032	68 Er Erbium 167.26	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
Actinide Series																		89 Ac Actinium 227.02781	90 Th Thorium 232.0377	91 Pa Protactinium 231.03688	92 U Uranium 238.02891	93 Np Neptunium 237.04817	94 Pu Plutonium 244.0642	95 Am Americium 243.06114	96 Cm Curium 247.0754	97 Bk Berkelium 247.0703	98 Cf Californium 251.07888	99 Es Einsteinium [254]	100 Fm Fermium [257]	101 Md Mendelevium 258.10	102 No Nobelium 259.1089	103 Lr Lawrencium [262]
Alkali Metals		Alkaline Earths		Transition Metals		Basic Metals		Semi-Metals		Nonmetals		Halogens		Noble Gases		Lanthanides		Actinides														

Supernova Nucleosynthesis

When supernovas occur,
temperatures increase to 100
billion degrees Celsius and there
are extreme numbers of
neutrons.

Generalization:

1. During Big Bang Nucleosynthesis, elements Hydrogen and Helium were formed.
2. During Stellar Nucleosynthesis, elements from helium to Iron were formed.
3. During Supernova Nucleosynthesis, elements from Iron to Uranium were formed.

Identification

- 1-2. These are subatomic particles found in the nucleus of an atom
3. Process that creates new atomic nuclei from nucleons.
4. During this type of nucleosynthesis, the elements hydrogen and helium were formed.

Identification

5. Process by which nuclei are formed in the center of stars.
6. The process of colliding light elements to form heavier elements.
7. This type of nucleosynthesis is where all the elements heavier than iron were made.

Identification

Describe how the elements form from the following equations:



