

## Element production in supernovae—24 Oct

- Outline
  - How and where was the gold in my ring made? What was it before it became gold?
  - What remains after a supernova
  - Elements are produced by neutron capture in a supernova
  - Movie of element production in a supernova
- Test 2 is on Wed, 26<sup>th</sup>
  - New material is Newton through class on 19<sup>th</sup>
  - Mostly on new material not on first test.
  - Practice test. See link on the syllabus.
  - Missouri Club, Tues, 25<sup>th</sup>, 7:40-8:40pm, BPS 1420
  - Send me formulas for cheat sheet by Wed, 26<sup>th</sup>, 1:00am
- After dark at the Planetarium
  - Mike Velbel
  - Sample return from comets and asteroids
  - Thurs, 7:30pm

## After a supernova, what is left?

- Outer layers expelled into space. New stars & new planets may form from the material.
- Core becomes either
  - a neutron star (Neutron stars in Crab pulses every 1/30 s.)
  - or a black hole.
- Neutron star
  - Normally neutron decays into proton, electron, & neutrino
 
$$n \rightarrow p + e^{-} + \nu + \text{energy}$$
  - Pressure is so high that it is better to have fewer particles
 
$$p + e^{-} + \text{energy} \rightarrow n + \nu$$
  - Whole star is like a big nucleus of neutrons.
  - Neutrons are degenerate
  - Star is size of Lansing
- Black hole: So compact that light cannot escape.



## Making elements heavier than iron

- Lighter elements (He, O, C, Ne, Mg, etc) are made by fusion with a release of energy
  - $4\text{H} \rightarrow \text{He} + \text{energy}$
  - $3\text{He} \rightarrow \text{C} + \text{energy}$
- $\text{Fe} + \text{He} \rightarrow (\text{heavier element})$  requires energy. No go.

**Periodic Table**  
1990 Dr. Michael Blaber

Made by fusion (except for B)

Made by neutron capture

## Neutron capture

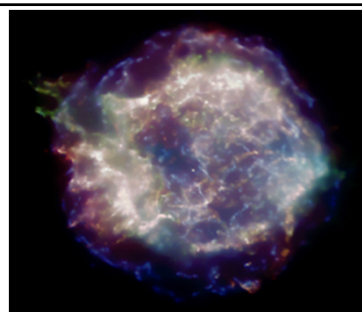
- In a supernova, there are free neutrons made by destroying nuclei.
  - Nucleus captures neutrons and turns into a heavier nucleus. Inside a nucleus,
    - nucleus + n  $\rightarrow$  heavier nucleus
  - Nucleus may decay into a more stable one.
    - $n \rightarrow p + e^- + \bar{\nu}$
  - Nucleus may capture more neutrons.
  - Eventually unstable nuclei decay into stable ones. Some heavy as uranium.
1. A supernova happened in seconds. Neutron capture can occur very quickly because the neutrons' \_\_\_\_ enables it to ...
    - A. mass
    - B. charge
    - C. number of nucleons

## Neutron capture

- In a supernova, there are free neutrons made by destroying nuclei.
  - Nucleus captures neutrons and turns into a heavier nucleus. Inside a nucleus,
 
$$\text{nucleus} + n \rightarrow \text{heavier nucleus}$$
  - Nucleus may decay into a more stable one.
 
$$n \rightarrow p + e^- + \nu$$
  - Nucleus may capture more neutrons.
  - Eventually unstable nuclei decay into stable ones. Some heavy as uranium.
1. If  $^{197}\text{Au}$  captures a neutron, it becomes \_\_\_\_\_. (Au has 79p. Hg has 80p. Pt has 78p.)
    - A.  $^{197}\text{Hg}$
    - B.  $^{198}\text{Au}$
    - C.  $^{198}\text{Hg}$
    - D.  $^{198}\text{Pt}$
  2. If a neutron in  $^{198}\text{Au}$  decays, it becomes \_\_\_\_\_.
    - A.  $^{198}\text{Hg}$
    - B.  $^{198}\text{Au}$
    - C.  $^{198}\text{Pt}$
- The net effect is to turn gold  $^{197}\text{Au}$  into mercury  $^{198}\text{Hg}$

## Calculation of element production in a supernova

- Calculation of nuclear reactions in a supernova.
- "R-process move"
  - [www.jinaweb.org/html/gallery3.html](http://www.jinaweb.org/html/gallery3.html)
- Start with iron and add neutrons
- Look at gold
  - 79 protons,  $197 - 79 = 118$  neutrons
- [Supernova](#)
- Color code
  - Black: stable
  - Red: lifetime >  $100\mu\text{s}$
  - Yellow: lifetime >  $10\mu\text{s}$
  - Green: lifetime >  $1\mu\text{s}$
  - Blue: lifetime >  $0.1\mu\text{s}$



## Questions on the Supernova Movie

“R-process move” [www.jinaweb.org/html/gallery3.html](http://www.jinaweb.org/html/gallery3.html)

1. What is the only element at the start? Iron. How many neutrons does it have? 44
2. At what time did some gold form? Gold has 79 protons. Is this gold stable?
  - A. 0.1s
  - B. 1s
  - C. 10s
  - D. 100s
3. At the end of the calculation, how many protons does the nucleus with the most protons have? 90. Thorium
4. What is the time at the end of the calculation?
  - A. 1min
  - B. 1hr
  - C. 1day
5. Are the end products stable? No

## Where were the elements in the baby made?

- Lighter elements (He, O, C, Ne, Mg, etc) are made by fusion with a release of energy
  - $4\text{H} \rightarrow \text{He} + \text{energy}$
  - $3\text{He} \rightarrow \text{C} + \text{energy}$
- Elements heavier than iron are made in supernovae and in giant stars

Periodic Table  
1998 Dr. Michael Blaber

Made by fusion (except for Bi)

Made by neutron capture

1	1A	1	H	1.008	2	2A	2	He	4.0026
3	3A	3	Li	6.941	4	4A	4	Be	9.012
5	5A	5	B	10.81	6	6A	6	C	12.011
7	7A	7	N	14.007	8	8A	8	O	15.999
9	9A	9	F	18.998	10	10A	10	Ne	20.180
11	11A	11	Na	22.990	12	12A	12	Mg	24.305
13	13A	13	Al	26.982	14	14A	14	Si	28.086
15	15A	15	P	30.974	16	16A	16	S	32.06
17	17A	17	Cl	35.453	18	18A	18	Ar	39.948
19	19A	19	K	39.098	20	20A	20	Ca	40.078
21	3B	21	Sc	44.956	22	3B	22	Ti	47.88
23	3B	23	V	50.942	24	3B	24	Cr	51.996
25	3B	25	Mn	54.938	26	3B	26	Fe	55.845
27	3B	27	Co	58.933	28	3B	28	Ni	58.693
29	3B	29	Cu	63.546	30	3B	30	Zn	65.38
31	4B	31	Ga	69.723	32	4B	32	Ge	72.61
33	4B	33	As	74.922	34	4B	34	Se	78.96
35	4B	35	Br	79.904	36	4B	36	Kr	83.80
37	5B	37	Rb	85.468	38	5B	38	Sr	87.62
39	5B	39	Y	88.906	40	5B	40	Zr	91.224
41	5B	41	Nb	92.906	42	5B	42	Mo	95.94
43	5B	43	Tc	98.906	44	5B	44	Ru	101.07
45	5B	45	Rh	102.905	46	5B	46	Pd	106.42
47	5B	47	Ag	107.868	48	5B	48	Cd	112.41
49	5B	49	In	114.818	50	5B	50	Sn	118.710
51	5B	51	Sb	121.757	52	5B	52	Te	127.6
53	5B	53	I	126.905	54	5B	54	Xe	131.29
55	6B	55	Cs	132.905	56	6B	56	Ba	137.33
57	6B	57	La	138.905	58	6B	58	Ce	140.12
59	6B	59	Pr	140.908	60	6B	60	Nd	144.24
61	6B	61	Pm	144.913	62	6B	62	Sm	150.36
63	6B	63	Eu	151.964	64	6B	64	Gd	157.25
65	6B	65	Tb	158.925	66	6B	66	Dy	162.50
67	6B	67	Ho	164.930	68	6B	68	Er	167.26
69	6B	69	Tm	168.930	70	6B	70	Yb	173.05
71	6B	71	Lu	174.967	72	6B	72	Hf	178.49
73	6B	73	Ta	180.948	74	6B	74	W	183.84
75	6B	75	Re	186.207	76	6B	76	Os	190.23
77	6B	77	Ir	192.222	78	6B	78	Pt	195.084
79	6B	79	Au	196.967	80	6B	80	Hg	200.59
81	6B	81	Tl	204.387	82	6B	82	Pb	207.2
83	6B	83	Bi	208.980	84	6B	84	Po	209
85	6B	85	At	210	86	6B	86	Rn	222
87	7B	87	Ra	226	88	7B	88	Ac	227
89	7B	89	Th	232.0377	90	7B	90	Pa	231.03688
91	7B	91	U	238.02891	92	7B	92	Np	237.048173
93	7B	93	Pu	244.06422	94	7B	94	Am	243.061381
95	7B	95	Cm	247.07125	96	7B	96	Bk	247.07125
97	7B	97	Cf	251.0832	98	7B	98	Es	252.0832
99	7B	99	Fm	257.10375	100	7B	100	Mendelevium	258.10375
101	7B	101	Nobelium	261.10375	102	7B	102	Lr	262.10375