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, 26th
  - New material is Newton through class on 19th
  - Mostly on new material not on first test.
  - Practice test. See link on the syllabus.
  - Missouri Club, Tues, 25th, 7:40-8:40pm, BPS 1420
  - Send me formulas for cheat sheet by Wed, 26th, 1:00am
- After dark at the Planetarium
  - Mike Velbel
  - Sample return from comets and asteroids
  - Thurs, 7:30pm

After a supernova, what is left?

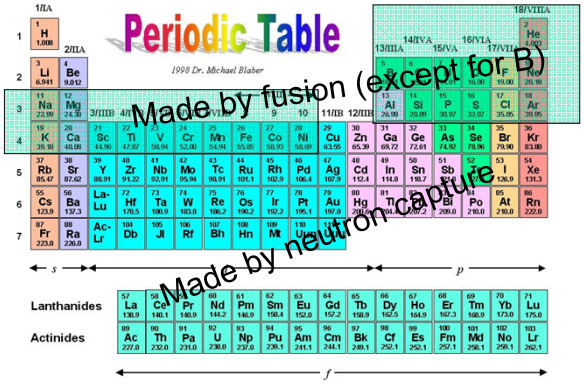
- Outer layers expelled into space. New stars & new planets may form from the material.
- Core becomes either
  - a neutron star (Neutron stars in Crab pulses every 1/30 s.)
  - or a black hole.
- Neutron star
  - Normally neutron decays into proton, electron, & neutrino

    $n \rightarrow p + e^- + \nu + \text{energy}$
  - 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
  - 4H → He + energy
  - 3He → C + energy
- Fe+He→ (heavier element) requires energy. No go.



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 → heavier nucleus
- Nucleus may decay into a more stable one.

  $n \rightarrow p + e^{-} + \upsilon$
- 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

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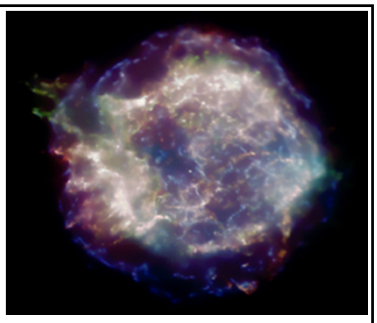
1. If ^{197}Au captures a neutron, it becomes ___. (Au has 79p. Hg has 80p. Pt has 78p.)
   A. ^{197}Hg
   B. ^{198}Au
   C. ^{198}Hg
   D. ^{198}Pt
2. If a neutron in ^{198}Au decays, it becomes ___.
   A. ^{198}Hg
   B. ^{198}Au
   C. ^{198}Pt

- The net effect is to turn gold ^{197}Au into mercury ^{198}Hg

Calculation of element production in a supernova



- Calculation of nuclear reactions in a supernova.
- "R-process move" 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 > 100μs
  - Yellow: lifetime > 10μs
  - Green: lifetime > 1μs
  - Blue: lifetime > 0.1μs

Questions on the Supernova Movie

"R-process move" 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
  - 4H $\rightarrow$ He + energy
  - 3He $\rightarrow$ C + energy
- Elements heavier than iron are made in supernovae and in giant st