Study Questions ***25 pts*** Name Answer Key

Article: ***Star Born*** *(Chem Matters, Oct 1984)* Period _____ Date _____

1) [3 pts] Introduction:

a) What elements did the Big Bang create? H and He

b) What objects created all the other elements in our universe? Stars

c) What events created all the heavy elements such as iron? The deaths of stars.

2) [1 pt] Climbing the Ladder:

In the most basic sense, all elements were made by fusing smaller nuclei together. What difficulty arises on the way to making larger and larger nuclei (i.e. what is meant by a "weak rung")?

There are fragile, unstable nuclei as you fuse lighter nuclei in which proton-proton repulsion causes the next nuclei on the rung to tear themselves apart or disintegrate on colliding with another nucleus.

3) [5 pts] The first step and Stuck again:

a) Shortly after the big bang, protons and neutrons are abundant, thus they collide and stick together. Complete this nuclear reaction:

$$ {}^{1}_{1}\mathrm{H} + {}^{1}_{0}\mathrm{n} \rightarrow \underline{\ {}^{2}_{1}\mathrm{H}\ } \text{ (deuterium)} $$

b) But deuterium is relatively unstable, so it keeps blowing apart. What happens about 3 min 46 secs after the big bang to allow the deuterium nuclei to start sticking together?

The temperature drops to 1 billion degrees and collisions become less likely.

c) Complete the next two fusion reactions that can then occur:

$$ {}^{2}_{1}\mathrm{H} + {}^{1}_{0}\mathrm{n} \rightarrow \underline{\ {}^{3}_{1}\mathrm{H}\ } \text{ (tritium)} $$

$$ \underline{\ {}^{1}_{1}\mathrm{H}\ } + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} \text{ (helium)} $$

d) Why does the formation of new elements get stuck here at helium? Because masses of 5 are all unstable.

4) [8 pts] A star is born and Push vs. pull:

a) Originally the universe consisted of diffuse clouds of hydrogen and helium nuclei. Briefly explain how stars began to form. (Start with what force is responsible.)

Gravity pulled the clouds of helium and hydrogen together and they contracted until they reached about 10,000,000°.

b) What force pushes a star outwards? (What makes a star want to expand?)

The high temperature and energy released makes the star want to expand.

c) What is the force that pulls a star inwards?

The pull of gravity.

d) When the supply of hydrogen runs out, what happens to the star? Explain. (What happens to the balance of outward and inward forces? How does the star respond?)

The outward force decreases, the star collapses under gravity, the core contracts then heats up to 100,000,000°.

e) Now, since the star is hotter, helium nuclei begin to fuse with each other. Complete the reaction:

$$^{4}_{2}\text{He} + ^{4}_{2}\text{He} \rightarrow \underline{\ ^{8}_{4}\text{Be}\ }$$

f) When the supply of He runs out, the same process occurs over and over again (contracts, heats up, contracts, heats up). Heavier elements are formed. Complete these possible fusion reactions:

$$^{8}_{4}\text{Be} + ^{4}_{2}\text{He} \rightarrow \underline{\ ^{12}_{6}\text{C}\ } \quad (^{8}_{4}\text{Be} \text{ is very short-lived})$$

$$^{12}_{6}\text{C} + ^{4}_{2}\text{He} \rightarrow \underline{\ ^{16}_{8}\text{O}\ }$$

$$^{12}_{6}\text{C} + ^{12}_{6}\text{C} \rightarrow \underline{\ ^{24}_{12}\text{Mg}\ }$$

$$^{40}_{18}\text{Ar} + ^{16}_{8}\text{O} \rightarrow \underline{\ ^{56}_{26}\text{Fe}\ }$$

g) Why does fusion of larger nuclei like He require increasingly higher temperatures? *[Answer is NOT in article. Describe how He differs from H and how that affects the forces in the nucleus.]*
Larger nuclei have higher + charges, so it takes more energy to overcome the electrical repulsion and bring them close enough for the strong nuclear force to fuse them.

5) [5 pts] The Iron Barrier

a) The formation of new elements gets stuck at iron. Nothing gets formed beyond iron because fusing iron with other nuclei does not release any energy. Why isn't any energy released when iron fuses with other nuclei?
Because Fe is the most tightly bound nucleus, adding another nucleus requires energy to be *added*.

b) Once this iron barrier is reached, there are two possibilities for what will happen to the star next-- a planetary nebula (white dwarf) or a supernova might form. Describe the conditions and results of each possibility.

1) planetary nebula (white dwarf)
In a star 1.44 times the mass of our sun or less, the expanded outer layers simply drift off in a wispy ring called a "planetary nebula." The remnant, a brown dwarf, will burn more and more quietly, get dimmer, and slowly die out.

2) supernova
In a star greater than 1.44 times the mass of our sun, gravity causes the star to contract so violently that it explodes. In a few seconds the temperature reaches 10 billion degrees, and a shock wave tears through the star as it becomes a supernova. All of the bottom half of the periodic table is produced in this way.

6) [3 pts] Children of Stars:

a) What is a second-generation star? List their characteristics.
A star formed from the remnants of a first-generation star. It contains traces of heavy elements, which permits the star to combine nuclei in new ways, creating a different mix of isotopes.

b) Which elements on earth must have combined together to form life as we know it today?
Carbon, nitrogen, oxygen, and hydrogen.