Stellar Fusion and Nucleosynthesis Name:________________________________
Note Taking Guide

Learning Targets:

1. I can use a model based on evidence to illustrate the life span of the Sun and the role of nuclear fusion in the Sun's core to release energy in the form of radiation. (NGSS HS-ESS1-1)
2. I can communicate scientific ideas about the way stars, over their life cycle, produce elements. (NGSS HS-ESS1-3)

Nuclear ____________ is the process by which atomic nuclei are _______________. This is the process stars use to covert ______________ into _______________.

Because fusion involves ______________ nuclei getting close enough combine, it's a difficult process to get going because the nuclei ________________ _____________.

Fusion therefore requires high ___________________ and _____________________. Stars have these in abundance!

Since _____% of the universe is _________________, most stars spend their lives fusing hydrogen into _______________. The mass of the helium produced is slightly __________ than the mass of the hydrogen that fuses to make it...the missing mass is converted into _______________ via __________.

The SI unit of measurement for energy is the ____________.

A smaller unit of energy called the ____________________ (____) is often used in nuclear science.

_____eV = ___________________J

Sometimes you'll see energies written in MeV or _______________________.

Nuclear Scientists also use mass units called ______________________ (_________ or ____ for short).

1 u is 1/12 the mass of a __________________atom. 1 u = 1.660 539 x 10—— kg.

Example 1:

Using $E=mc^2$, convert the mass of an electron ($9.109\ 383 \times 10^{-31}$ kg) into its energy equivalent in Joules, electron-Volts, and MeV.

As you already know, most hydrogen nuclei consists of a single proton and most helium consists of two protons and two neutrons. If it's hard to get two hydrogen nuclei to fuse because of electric repulsion, you can imagine how difficult it is to get _________ of them to fuse.

Low mass stars like our Sun, end up using a series of reactions called the

________________________(______________) to fuse ________________ into ______________.

Symbols in Nuclear Reactions

Draw the corrected symbol on the right after filling out the blanks:

We call the _____number on the _______ the "_______________number."

We use the __________number on the _______ for "___________________."

The symbol X can now be used for other particles that aren't elements such as

______________, __________________, etc.

Atomic Number (z)	Element	Symbol	Mass (u)
0	(electron)	$^{0}_{-1}e$	0.000 549
0	(positron)	$^{0}_{+1}e$	0.000 549
0	(neutron)	$^{1}_{0}n$	1.008 665
1	Hydrogen-1	$^{1}_{1}H$	1.007 825
1	Hydrogen-2, Deuterium	$^{2}_{1}H$	2.014 102
1	Hydrogen-3, Tritium	$^{3}_{1}H$	3.016 049
2	Helium-3	$^{3}_{2}He$	3.016 029
2	Helium-4	$^{4}_{2}He$	4.002 603

The p-p Chain

Write the reaction equations to the right of their descriptions:

1. Two hydrogen fuse to make deuterium and a positron.
2. Deuterium fuses with hydrogen to make helium-3 and a gamma photon.
3. Two helium-3 fuse to make helium-4 and two protons.

1 u = ______________MeV

Example 2:

Using the information in the mass table and the first reaction equation, determine the amount of mass lost in the reaction (in atomic mass units) and then convert to MeV.

Nucleosynthesis of heavier elements...

Equilibrium-Stars spend most of their lives fusing _____________ into __________________

--with _______________from _______________ reactions keeping _______________ from collapsing the star into a smaller object.

As stars run out of hydrogen to fuse in their cores, the core _______________ and _________

_____.

If the star's __________ is large enough, this extra heat (________ ________ ____________) allows nuclei with more ________________ _________ to begin fusing.

The Sun for example will begin fusing _____________ into beryllium and ________________.

For stars around the mass of the Sun and smaller, even when they ________________of helium and the core ________________ again, there _________ be enough heat to start fusing carbon into other elements--the electric _________________ is too ______________. The Sun will grow into a ______ __________ (like Aldebaran in Taurus and Betelgeuse in Orion) during the helium fusion. This will almost certainly end life on Earth.

_______________ ___________________ form as medium mass stars throw off their ____________ _______________ and the core contracts to become a slowly cooling _____________ ____________ star. This is the likely fate of the Sun and the nebulae can be "out of this world" beautiful!

Massive stars (________solar masses or so), can continue to fuse even heavier elements since the extra __________allows the core to continue to _______________ and increase temperature. After they run out of helium in the core, there's enough _________ to begin ____________ fusion.

Even massive stars though have _____________. Fusing some elements is impossible without adding additional energy. What do you notice about the last carbon fusion reaction?

$${}^{12}_{6}C + {}^{12}_{6}C \rightarrow {}^{20}_{10}Ne + {}^{4}_{2}He \quad \mathbf{4.617MeV}$$

$${}^{12}_{6}C + {}^{12}_{6}C \rightarrow {}^{23}_{11}Na + {}^{1}_{1}H \quad \mathbf{2.241MeV}$$

$${}^{12}_{6}C + {}^{12}_{6}C \rightarrow {}^{23}_{12}Mg + {}^{1}_{0}n \quad \mathbf{-2.599MeV}$$

Binding Energy

To discover that elemental limit, we need to know some more nuclear science. The mass of an atomic nucleus is ____________ than the mass of its constituent protons and neutrons. This mass difference is called ______________________________. It's as if the nucleon have to ________________ to join various clubs--they do so in ___________. It's the cost of keeping those nucleons bound together.

Binding Energy Background Practice...(separate paper)

Once a massive star reaches that final element ___________, nuclear fusion reactions ______longer __________ _________ and the star dies within a matter of seconds. The core collapses and the outer layers fall in and ___________off the collapsed core forming the most powerful explosion in the universe--a _____________. They can briefly ______________an entire galaxy of stars (100 billion) and release as much energy as the Sun does over its entire lifetime! The enormous energy released in these explosions allow for elements ______________ than _____ to be formed. Precious metals used in jewelry (gold, silver, platinum, etc.) were forged in the explosions of dying stars!

After the supernova has spread much of the star's former mass out into space, the collapsed core remains as one of a few interesting objects:

____________________--all the core's mass compacted into neutrons about 10 miles across.

____________________--all the core's mass is mathematically predicted to be located a single point!