**Meanwhile, down in the nucleus…**

Protons have a positive electrical charge. Electrons have a negative electrical charge. Neutrons have no electrical charge.

Oppositely charged things pull on each other with an attractive force. That is why electrons want to stay in atoms instead of flying away—they are being pulled inwards towards the nucleus of the atom by the positively charged protons. ***But neutrons are neither positive nor negative—they have ZERO electrical charge. Why, then, do neutrons and protons stick together in the nucleus? And if like charges push each other apart, why doesn’t the nucleus fly apart due to the protons pushing each other away???***

It turns out that there is a different kind of force inside of atoms, a force that is unlike any of the forces that we are used to from our day-to-day lives. This force is called the STRONG FORCE, or sometimes the STRONG NUCLEAR FORCE, and it is kind of like the electric force, but one that only works over incredibly short distances—like the width of an atom’s nucleus!!!

Go to the Particle Adventure website and read about “Fundamental Particles” (http://www.particleadventure.org/fundamental.html). What does the word “fundamental” mean when talking about the building blocks of matter?

Are electrons, protons, and neutrons “fundamental”? Read the next few pages in the Particle Adventure and then fill in the table below.

|  |  |  |
| --- | --- | --- |
| Particle Type: | Is it fundamental? | If no, what is it made of? |
| The electron |  |  |
| The proton |  |  |
| The neutron |  |  |

Just like protons and electrons are pulled towards each other because of an electrical force, quarks stick to each other because of the Strong Force. And believe it or not, if the Strong Force didn’t exist—if quarks didn’t stick together—there wouldn’t be any life on earth. Because without a strong force, there wouldn’t be any atoms, nor would stars like the Sun produce the energy that heats our planet.

Have you ever wondered why we have different types of atoms (different elements) in our Universe? Are new atoms constantly being produced, or are the atoms that exist today the same exact atoms that have always existed since the creation of time? How are different types of atoms (like hydrogen, carbon, and oxygen) different from each other? Do we have an infinite number of different atoms, or is everything solid made from a finite number of atoms??? These are all EXCELLENT questions—it makes me so happy that you are asking them, because they are very important!

Let’s take a moment to familiarize ourselves with the notation used by scientists to keep track of the electrons, protons, and neutrons in an atom.

The **Atomic Number** of an atom is simply the number of protons found in the nucleus of an atom.

*The atomic number of hydrogen is 1. All hydrogen atoms have 1 proton.*

*The atomic number of oxygen is 8. All oxygen atoms have 8 protons.*

*The atomic number of gold is 79. All gold atoms have 79 protons.*

The **Mass Number** of an atom is the sum of all the protons and neutrons found in an atom.

*An oxygen atom with 8 neutrons (and 8 protons) would have a Mass Number of 16 (8 n + 8 p) and an atomic number of 8.*

*A carbon atom with 8 neutrons and 6 protons would have a Mass Number of 14 (8 n + 6p) and an Atomic Number of 6.*

The **number of electrons in an atom is always equal to the number of protons** (so that the positive and negative electrical charges cancel out).

**The Nuclear Symbol**

The nuclear symbol consists of three parts: the symbol of the element, the atomic number of the element, and the mass number of the specific isotope.

Here is an example of a nuclear symbol:



The element symbol, Li, is that for lithium.

The three, subscripted left, is the atomic number and the seven, superscripted left, is the mass number.

Here's another:



For this helium atom, the number of protons in the nucleus is \_\_\_\_\_, the mass number is

\_\_\_\_\_\_, and the number of neutrons is \_\_\_\_\_.

Neither the mass number, nor the atomic number of an atom, change during a chemical reaction. The only way to change the number of protons and/or neutrons in an atom is through a **nuclear reaction**. Let’s learn a little bit about nuclear reactions.

Check out the following video about nuclear fission and nuclear fusion.

[Fission and Fusion video](https://www.youtube.com/watch?v=xrk7Mt2fx6Y)

https://www.youtube.com/watch?v=xrk7Mt2fx6Y

Wear your ear buds. Answer the following questions as you work your way through the video.

What happens to an atom during nuclear fission?

What sizes of atoms experience nuclear fission?

What happens when a neutron runs into a Uranium atom?

When a Uranium atom breaks into smaller pieces, what gets created? Include everything!

Where does the energy produced by the Sun come from?

How is nuclear fusion different from nuclear fission?

How is Hydrogen-1 (1H) different from Hydrogen-2 (2H)?

What forms when Hydrogen-1 fuses with Hydrogen-2?

What is the most famous equation in science?

When two atoms fuse together, the total mass of the newly formed atom is LESS than the total mass of each initial atom added together. In other words, when two atoms fuse, they LOSE mass and become less heavy!!!!! So where does that “missing” mass go???

The equation above tells us that mass and energy are equal to each other… the mass “lost” when two atoms fuse together is actually released as ENERGY!!!! And this energy that is released in fusion is what powers stars like our Sun.

Isn’t that crazy?????

**Nuclear Fusion: How Stars Create Elements!**

 If you look at the Periodic Table of the Elements, you will notice that there are 113 different elements listed. Remember that the number of protons in the nucleus of an atom determines which element that atom is-- in all of the Universe, there are only 113 different elements! Every chemical compound in the Universe is some combination of just those 113 elements!! (Actually, there are fewer than 113 elements in Nature, since a few of those elements listed in the Periodic Table have only been created in labs by scientists, and they exist for only fractions of seconds before experiencing nuclear fission and breaking down into smaller elements).

 You already know that an atom of one type of element can only change into a different type of element through the processes of nuclear fusion or fission. Nuclear fusion only happens in places with very high temperatures, where the particles involved are moving SUPER fast, so that they can smash into each other with enough force to cause the nucleus of an atom to gain extra particles. Do these places exist in the Universe, places with such high temperatures that new types of atoms can be produced?

 Surprisingly, the answer to that previous question is Yes! Stars, like our Sun, have so much mass that the atoms that they are made of get squeezed and squished tightly together due to the intense gravity that they produce. If a star has too much mass, the gravity that it produces can cause the star to DISAPPEAR FROM THE UNIVERSE COMPLETELY!!! A star so immense that it ceases to exist is called a Black Hole—a Black Hole is a place where a giant star used to be, and the only thing left behind when the star leaves our universe is the immense gravity created by its mass!!!! Our own Sun is too small to ever become a Black Hole, but it is still hot enough to create new types of elements out of other smaller elements that exist in the Sun. To learn how this happens, examine the diagram below, which outlines the process whereby hydrogen atoms fuse together to create helium atoms.



The fusion process begins on the left side, where pairs of 1H atoms smash together to make a 2H atom. A 1H hydrogen atom is really nothing more than a proton and an electron, but because stars are so hot, the atoms flying around in them have lost all of their electrons. When the two 1H atoms collide, the intense force of the collision causes one of the protons (1H atoms) to turn into a neutron, and this neutron sticks to the other proton to create a new nucleus, a nucleus made of both a proton and a neutron.

When a proton turns into a neutron, two weird nuclear particles are also produced: a positron (which is an electron with a + charge), and a neutrino. Neutrinos don’t have any charge, and they are sooooooooo tiny that they can pass through entire planets without running into anything!!!

The newly formed 2H atom (with a proton and a neutron in the nucleus) might smack into another 1H atom as they fly around in the star, and in this collision a new nucleus is produced, the nucleus of a Helium atom. This nucleus contains two protons and a neutron, making it 3He. A high energy photon of gamma radiation is also released when this nucleus forms.

As this 3He nucleus moves around, it might collide with another identical 3He, resulting in the formation of a single nucleus of 4He. Two protons are also expelled from the collision when this new helium atom forms, and these two protons might run into other protons, starting the whole process all over again.

**Activity: Using Playdoh to model nuclear fusion in the Sun.**

Work with your next-door neighbor to gather the following:

2 spheres of Color 1 Playdoh, each about ½ inch in diameter

2 spheres of Color 2 Playdoh, each about ½ inch in diameter

1 smaller (1/4 inch diameter) sphere of Color 3 Playdoh

1 smaller (1/4 inch diameter) sphere of Color 4 Playdoh

a short segment of a cut drinking straw

You will be using these pieces to demonstrate the nuclear fusion process in which protons join together to form Helium. Use the following key in your demonstration:

Color 1 sphere = proton

Color 2 sphere = neutron

Color 3 sphere = positron

Color 4 sphere = neutrino

Straw = gamma ray photon

“Act out” each step in the nuclear fusion process that is diagramed on the first page of the activity. For each step in the process, take a photograph of the arrangement of your model pieces. When you are done, arrange all of the photos in sequence (digitally), so that they show the steps by which two protons in a star can ultimately become the nucleus of a helium atom.

Each photograph must a have some form of written explanation that describes what is happening in the image, or what has just happened. This written explanation can be placed in the scene before you take the photos, or it can be added to the images with your computer after you have uploaded the photos.

Please submit your finished photo story digitally through Google docs.