**How to Build an Atom**

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, 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!!! The Strong Force acts on teeny-tiny particles called quarks… quarks are smaller than protons and neutrons!

When talking about atoms, scientists say that something is “**fundamental**” if it is not made from smaller pieces.

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

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.

Find some orange Play-Doh and some yellow Play-Doh. Make three tiny (the size of the fingernail on your pinkie) spheres with the orange, and then do the same with the yellow.

Orange Play-Doh = an “up” quark

Yellow Play-Doh = a “down” quark

Take two of the “up” quarks and one of your “down” quarks and place them in front of you so that they are touching each other.

Congratulations… you have just made a PROTON!!!

Next, take the remaining Play-Doh spheres (the two “down” quarks, and the one “up” quark), and place them in a different place on the table, but touching each other. Those three quarks combine to produce a… NEUTRON!!!

**Building Chemical Elements using Play-Doh: how protons and neutrons determine the chemical elements in our Universe**

Have you ever wondered why we have different types of atoms (different elements) in our Universe? Hydrogen, helium, carbon, oxygen, iron, gold, silver… each of these chemical substances is a unique type of atom, a unique ***element***. How are different types of atoms (like hydrogen, carbon, and oxygen) different from each other? Do we have an endless number of different elements, or is the number of different elements clearly determined??? 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 number of protons in an atom’s nucleus is what determines the type of element the atom is.

*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 of an element**

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 on the left, is the atomic number and the seven, superscripted on the left, is the mass number.

The number of protons in this lithium atom is 3. The number of neutrons in this atom is 4. The number of electrons in this atom is 3.

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 \_\_\_\_\_.

**Building atoms with Play-Doh.**

Let’s put protons and neutrons together in a nucleus to create atoms of particular elements. We’ll use Play-Doh, like we did when we built protons and neutrons using quarks.

**Use orange or yellow Play-Doh** to make little spheres that represent **PROTONS**.

**Use Red, Pink, or Purple Play-Doh** to make little spheres that represent **NEUTRONS**.

1) Take a single proton and place it on the table in front of you. Congratulations… you have made the element Hydrogen! All hydrogen atoms have 1 proton… having only 1 proton is what makes hydrogen what it is!

$\begin{matrix}1\\1\end{matrix}H$ This hydrogen atom (which is called Hydrogen-1) has an **atomic number of 1**, meaning that it has 1 proton, and a **mass number of 1**, because it has 1 proton + 0 neutrons = 1 total proton plus neutron. Because it has 1 proton, this element also has 1 electron

$\begin{matrix}2\\1\end{matrix}H$ This hydrogen atom has an **atomic number of 1**, because it has 1 proton, and a **mass number of 2**, which tells us that it has 1 neutron in its nucleus: mass number = protons + neutrons; 2 = 1 proton + 1 neutron. Make this atom (which is called Hydrogen-2) by placing a single yellow sphere next two a single red sphere.

Now, let’s practice making some other chemical elements with Play-Doh. For each of the elements listed below, please write down both the Atomic Number and the Mass Number, and then make the atom with Play-Doh. We will not add electrons to these atoms. Check with a teacher after you build each atom to make sure that your work is accurate.

$$\begin{matrix}3\\2\end{matrix}He$$

The name of this atom is Helium-3.

Atomic Number = Mass Number =

Number of protons = Number of neutrons=

Make this atom with Play-Doh, and then check your work with a teacher.

$$\begin{matrix}4\\2\end{matrix}He$$

The name of this atom is Helium-4.

Atomic Number = Mass Number =

Number of protons = Number of neutrons=

Make this atom with Play-Doh, and then check your work with a teacher.

$$\begin{matrix}6\\3\end{matrix}Li$$

The name of this atom is Lithium-6.

Atomic Number = Mass Number =

Number of protons = Number of neutrons=

Make this atom with Play-Doh, and then check your work with a teacher.

$$\begin{matrix}7\\3\end{matrix}Li$$

The name of this atom is Lithium-7.

Atomic Number = Mass Number =

Number of protons = Number of neutrons=

Make this atom with Play-Doh, and then check your work with a teacher.

$$\begin{matrix}12\\6\end{matrix}C$$

The name of this atom is Carbon-12.

Atomic Number = Mass Number =

Number of protons = Number of neutrons=

Make this atom with Play-Doh, and then check your work with a teacher.

$$\begin{matrix}14\\6\end{matrix}C$$

The name of this atom is Carbon-14.

Atomic Number = Mass Number =

Number of protons = Number of neutrons=

Make this atom with Play-Doh, and then check your work with a teacher.

**How is a Chemical Reaction different from a Nuclear Reaction?**

A ***Chemical Reaction*** takes place whenever atoms of different chemical elements join together (or break apart) during the process of forming new chemical compounds and molecules. The nucleus of an atom NEVER CHANGES during a chemical reaction. Neither the mass number, nor the atomic number of an atom, change during a chemical reaction.

A ***Nuclear Reaction*** takes place whenever the number of protons and/or neutrons in an atom changes. 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 website about nuclear fission and nuclear fusion.

https://www.youtube.com/watch?v=oIe1EDExxyg&feature=youtu.be

Wear your ear buds (or turn the volume on). Answer the following questions as you work your way through the video.

What happens to an atom during the process of nuclear fusion?

What happens to an atom during the process of nuclear fission?

How is nuclear fusion different from nuclear fission?

Do atoms take in energy or release energy during fission and fusion?

What is a photon?

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???

**E = mC2**

Do you recognize this equation? E stands for “energy”, and m stands for “mass”. The equation says that mass and energy are equal to each other… the mass that is “lost” when two atoms fuse together is actually released from the atoms as ENERGY!!!! And this energy that is released in fusion is what powers stars like our Sun.

Isn’t that crazy?????

Let’s use Play-Doh to model the process by which hydrogen gets turned into helium in stars like our Sun…

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 very, very tightly together due to the intense gravity that they produce. Being squished so tightly together, while also moving very fast due to the high temperature in the star, allows nuclear fusion to begin.

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

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

4 spheres of Orange Play-doh, each about ½ inch in diameter

2 spheres of Red Play-doh, each about ½ inch in diameter

1 smaller (1/4 inch diameter) sphere of Blue Play-doh

1 smaller (1/4 inch diameter) sphere of Yellow Play-doh

a paper clip

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

Orange sphere = proton

Red sphere = neutron

Blue sphere = positron

Yellow sphere = neutrino

Paper clip = gamma ray photon

The fusion process in stars begins when a pair of 1H atoms smashes 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 (a 1H atom) to turn into a neutron, and this neutron sticks to the other proton to create a new nucleus, a 2H 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!!!

**Use the Play-Doh to “act out” this process, in which two protons smash together to create 2H and a positron and a neutrino. When you are ready, show these steps to your teacher.**

The newly formed 2H atom (a proton and a neutron in the nucleus) might smack into another 1H atom as the atoms 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.

**Use the Play-Doh to “act out” this second process, in which an 2H nucleus smashes into a proton to create 3He and a photon of gamma radiation. When you are ready, show these steps to your teacher.**

As this 3He nucleus moves around, it might collide with another identical 3He nucleus, 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 nuclear fusion process all over again!

**Use the Play-Doh to “act out” this third process, in which two 3He nucleii smash together to create 4He and two protons. When you are ready, show these steps to your teacher.**