College Guild
PO Box 6448, Brunswick ME 04011

SCIENCE SAMPLER
~ Chemistry ~
Unit 3 of 5

So far we have explored the birth of the universe and the fundamental laws of nature that played an important role during the early universe. In unit 1, we learned that at the beginning there was nothing, but then space burst into existence from a singularity. We saw how energy was converted into matter, which later combined to form stars. In this unit we will study matter. We will be examining the nature of particles: their composition, structure and properties. We are moving from the grand scale to the microscopic.

1. If you were a scientist, would you want to study the grand scale or the microscopic scale? Why?

2. What grand scale discovery could you make that would benefit our planet and its inhabitants?

3. What microscopic discovery?

4. Imagine you are writing up your discovery for a scientific journal. What title would you give the article? You want to sound like a serious scientist, but also get people to read it!

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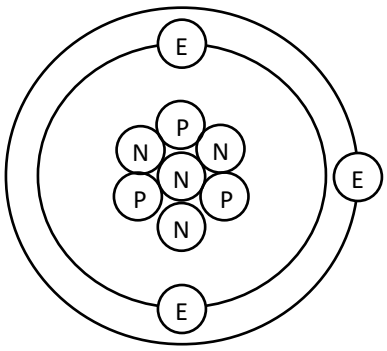
Part 1: Nuclear Reaction

During the Big Bang, the only elements that were formed were hydrogen, helium, and some lithium and beryllium. Here are some sketches of lithium and beryllium atoms:

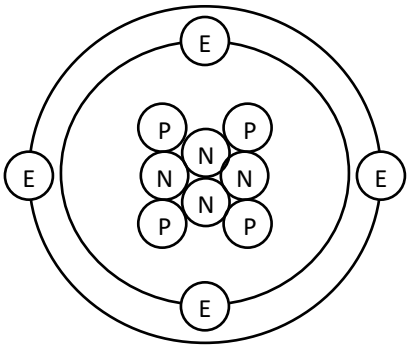


Lithium atom

E = electron (negative charge)

P = proton (positive charge)

N = neutron (no charge)



Beryllium atom

The difference between them is that the lithium atom has three protons, while the beryllium atom has four. Today, there are 118 different kinds of atoms, and many of them are much more complex than lithium and beryllium. For instance, the air that you are breathing is composed primarily of nitrogen (7 protons), oxygen (8 protons), argon (18 protons), carbon dioxide (one carbon atom with 6 protons plus two oxygen atoms), and other gases. Where did we get those elements?

5. Why were beryllium and lithium formed so early?

6. What else are we breathing today, and where does it come from?

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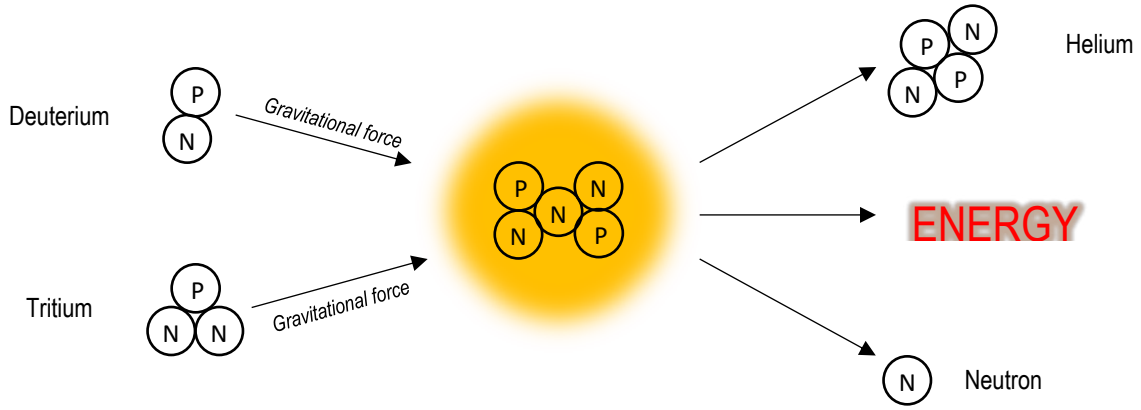
Stars are huge manufacturing centers of elements. They produce heavy solid materials from the light gases. The process in which stars covert light elements into heavy elements is called *nuclear fusion*. During nuclear fusion, the nuclei of two or more atoms come together. This process is not easy, and it requires a huge amount of energy, heat, and pressure to get two nuclei to come close enough to each other to combine. It is hard to get nuclei close to each other because a nucleus (the middle part, or core of an atom) is made of protons and neutrons. Protons have a positive charge, and neutrons have no charge, so the nucleus of any atom is always positively charged. Two positively charged nuclei want to repel, or push each other away. However, stars are so massive that the gravitational force of the star pulls the nuclei together, creating incredibly high pressure. Gravity is crushing everything down with so much force that the nuclei actually combine. That's nuclear fusion!

The process started with hydrogen nuclei (each nucleus with one proton and one or more neutrons) getting together to form helium (each nucleus with two protons). Here is a picture of that fusion process:



This picture shows two types of hydrogen (Deuterium and Tritium) fusing to release a helium atom, a neutron, and some energy.

7. Draw a picture of one type of hydrogen atom combining with a helium atom and releasing a more complex atom.

8. What would you name this atom if you were a scientist who had just discovered it?

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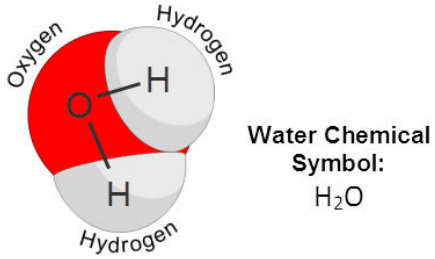
Part 2: Atomic Structure

What is an atom exactly, and what is its structure? Imagine you have a cup of water in your hand. What is water made of? Unfortunately, you cannot answer that question with your naked eye. For astronomy, we use telescopes to observe far away celestial objects, but for chemistry, we need to use a microscope.

If you magnify water down to the atomic level, you can see its molecular composition. Water is made of two hydrogen atoms and one oxygen atom. The chemical notation that represents water is H_2O. The "H" stands for a hydrogen atom, the number 2 tells you how many hydrogen atoms there are, and the "O" stands for an oxygen atom. Here is a picture of the structure of a water molecule[1]:



9. If the oxygen atom were combined with four hydrogen atoms instead of just two, what would its chemical notation be?

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To review the chemical language we have been discussing, here are some definitions:

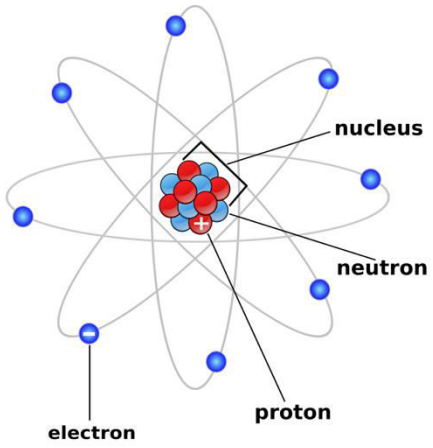
Atom: An atom is the smallest particle of an element that retains the chemical characteristics of the element. For example, hydrogen, oxygen, and helium are elements.

Molecule: A molecule is a collection of atoms chemically bonded together in characteristic proportions. For example, two hydrogen atoms can bond together, forming H_2.

Compound: A compound is a substance that consists of two or more elements that can be separated from one another. For example, water is a compound, because it is a molecule that contains two different elements – hydrogen and oxygen.

10. H_2 is a molecule. Can it be classified as a compound? Why or why not?

After magnifying the water molecule to see its structure, we saw that water is made of two hydrogen atoms and one oxygen atom. But what would happen if we magnified it even more so that we could see the structure of each atom? Unfortunately, no microscope that powerful exists yet. So, throughout history, scientists have been using what they knew about chemistry and physics to come up with models to accurately represent the structure of atoms. The model most widely accepted today was presented in 1913 by a great physicist named Niels Bohr. In the Bohr model, an atom is made up of protons, neutrons, and electrons. Protons and neutrons make the nucleus of the atom, and electrons orbit the nucleus.



The Bohr model[2]

As we have discussed, a proton is a subatomic particle with positive charge, a neutron is one with no charge, and an electron one with negative charge. Most of the mass of the atom is found at its nucleus. The mass of the electrons is almost insignificant in comparison to protons and neutrons.

11. How is an atom like our solar system?

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Part 3: The Periodic Table of the Elements

A Russian chemist named Dmitri Mendeleev was the forerunner of the modern periodic table. In chemistry, the periodic table of elements is a chart in which all the elements are arranged based on their atomic number. Below you will find a picture of the periodic table[3].

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Group→ / ↓Period	1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																		2 He
2	3 Li	4 Be												5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg												13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca		21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr		39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	*	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	**	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	118 Uuo
			*	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb		
			**	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No		

In the periodic table, the horizontal rows are called **Periods** and the 18 columns are called **Groups** or **Families**.

The first element in the periodic table is hydrogen, which can be found in the upper left hand corner of the table. It has only one proton. The "H" is the symbol that stands for Hydrogen, and the number "1" indicates the number of protons. If you look at the second element, Helium (upper right hand corner) you would notice that its symbol is He, and the number 2 tells you that there are two protons in a helium atom. The number of protons in an atom is called its **atomic number**. The number of protons plus the number of neutrons is the atom's **atomic mass**.

12. Guess or make up names for elements with the abbreviations: Zr, Rf and Sb.

13. Pick your favorite abbreviation from the Table and make up five properties of that element.

The elements in the table are divided into three categories: **metals, nonmetals and semimetals.** The metals, which you would find mostly to the left of the table, tend to conduct heat and electricity well, and tend to be malleable (capable of being shaped by hammering).

The nonmetals, which you would find in the upper right corner, are poor conductors of heat and electricity; most are gases at room temperature. The semimetals, which you would find in between the metal and nonmetal elements, tend to have the physical properties of metals but the chemical properties of nonmetals. Elements with atomic numbers above 94 do not occur naturally in nature; they are created in the laboratory. The most abundant elements in the solar system and on Earth are elements from groups 1, 2 and 13 through 18.

14. The chemical symbol for Gold is Au. List all ways in which gold is useful.

15. Did you expect that there would be more or less elements that exist in nature? Why?

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16. **Maybe this table is incomplete. If there are other metals that we haven't discovered, where do you think we would find them? Where would we find new non-metal elements? How about semi-metals?**

17. **Create your own element! You can name it after you and give it whatever properties you like. You can even invent some properties!**

Here is a game you can play with the table of periodic elements – it was suggested by a College Guild student!

As mentioned above, each element has a unique one or two letter symbol, which can be used as an abbreviation (and keeps us sane when writing complex combinations of atoms). Some symbols make sense (O for oxygen, Ba for barium), and some are surprising (Au for gold, K for potassium). Usually, we can find the reason for the "odd" symbol by looking back to Latin or ancient Greek; for example, "aurum" is the Latin word for gold.

We can use the periodic table to play word games, for example making as many words as possible by combining the elements' symbols. We are assuming that we can use the same element more than once; for example, BOOK uses two oxygen atoms, B + O + O + K (boron + oxygen + oxygen + potassium). Other words are COAT, Co + At (cobalt + astatine), and BUREAUCRACY, B + U + Re + Au + C + Ra + C + Y (boron + uranium + rhenium + gold + carbon + radium + carbon + yttrium). Some words may have several combinations that work and others may have none. For example, there are four ways to come up with the word "coin".

18. **How many ways can you derive COIN? What are they?** (We provide the answer at the end of the unit. Try it on your own first and then see if you got them all.)

19. **Find five words that can be derived by combining the symbols in the periodic table. Challenge yourself: try to make words that are at least five letters long.**

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As with Unit 2 on Physics, Chemistry also has many assignments with one right answer. Here are the ones in Unit 3 and, again, no peeking until you try them!

#5- They were formed so early because they were created during the Big Bang, whereas heavier elements were created later.
#6- Some examples are smoke, pollen and dust.
#7- Hydrogen occurs as 3 different isotopes (protium, deuterium & tritium). Possible combinations of a hydrogen isotope and helium:

Protium (1 proton & 0 neutrons) & Helium (2 protons & 2 neutrons) = element with 3 protons & 2 neutrons
Tritium (1 proton & 2 neutrons) & Helium = element with 3 protons & 4 neutrons

#9- H_4O
#10- no, because it is composed of only one type of atom
#11- Atoms consist of a nucleus with electrons rotating around it, just like the sun has planets rotating around it.
#14- Jewelry, dentistry and electronics are just a few examples

COIN C + O + I + N (carbon + oxygen + Iodine + nitrogen)
C + O + In (carbon + oxygen + indium)
Co + I + N (cobalt + iodine + nitrogen)
Co + In (cobalt + indium)

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Remember: First names only & please let us know if your address changes

Photo Credits:

1. *Study.com, Facts About Water Molecules*
2. *Emaze.com*
3. *3.Wikipedia.org, Periodic Table*

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