Reading 1.4 What Are The Parts Of An Atom and How Are They Arranged?

Section 1.4 What Are The Parts Of An Atom and How Are They Arranged?

Lesson Objectives

The student will:

1. explain the observations that led to Thomson's discovery of the electron.
2. describe Thomson's plum-pudding model of the atom.
3. draw a diagram of Thomson's plum-pudding model of the atom and explain why it has this name.
4. describe Rutherford's gold foil experiment and explain how this experiment disproved the plum-pudding model.
5. draw a diagram of the Rutherford model of the atom and label the nucleus and the electron cloud.
6. identify the three major subatomic particles and their charges, masses, and location in the atom.
7. briefly describe the discovery of the neutron.
8. define atomic number.
9. describe the size of the nucleus in relation to the size of the atom.
10. explain what is meant by the atomic mass of an element and describe how atomic masses are related to carbon-12.
11. define mass number.
12. determine the number of protons, neutrons, and electrons in an atom.

Vocabulary

- cathode ray tube
- electron
- nucleus
- proton
- subatomic particle
- atomic mass
- atomic mass unit (amu)
- atomic number
- dalton
- mass number
- neutron

Introduction

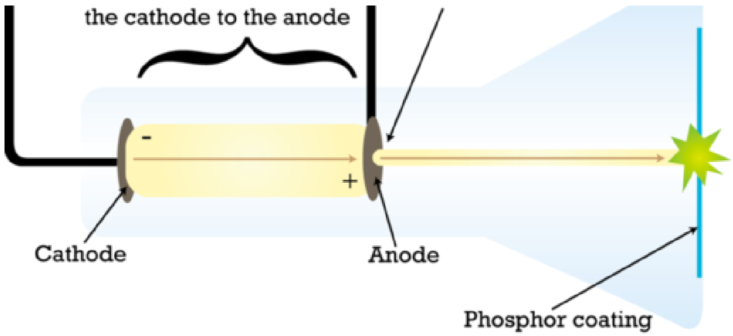
Dalton's atomic theory held up well in a lot of the different chemical experiments that scientists performed to test it. For almost 100 years, it seemed as if Dalton's atomic theory was the whole truth. It wasn't until 1897 when a scientist named J. J. Thomson conducted research that suggested Dalton's atomic theory wasn't the entire story. Dalton had gotten a lot right—he was right in saying matter is made up of atoms; he was right in saying there are different kinds of atoms with different mass and other properties; he was almost right in saying atoms of a given element are identical; he was right in saying that atoms are merely rearranged during a chemical reaction; and he was right in saying a given compound always has atoms present in the same relative numbers. But he was wrong in saying atoms were indivisible or indestructible. As it turns out, atoms are composed of even smaller, more fundamental particles. These particles, called subatomic particles, are smaller than the atom. The discoveries of these subatomic particles are the focus of this Module.

Thomson's Plum-Pudding Model

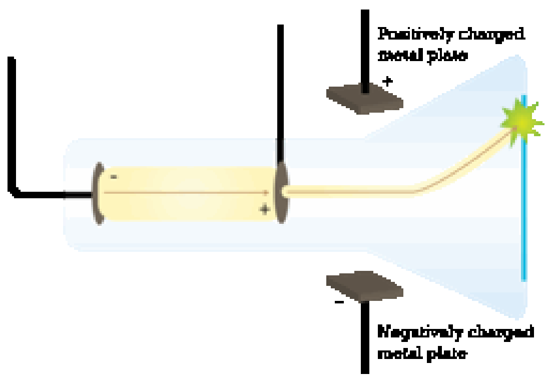
In the mid-1800s, scientists were beginning to realize that the study of chemistry and the study of electricity were actually related. First, a man named Michael Faraday showed how passing electricity through mixtures of different chemicals could cause chemical reactions. Shortly after that, scientists found that by forcing electricity through a tube filled with gas, the electricity made the gas glow. Scientists didn't, however, understand the relationship between chemicals and electricity until a British physicist named J. J. Thomson began experimenting with what is known as a cathode ray tube (Figure below).

A portrait of J. J. Thomson.

The figure below shows a basic diagram of a cathode ray tube like the one Thomson would have used. A cathode ray tube is a small glass tube with a cathode (a negatively charged metal plate) and an anode (a positively charged metal plate) at opposite ends. By separating the cathode and anode a short distance, the cathode ray tube can generate what are known as cathode rays – rays of electricity that flow from the cathode to the anode. Thomson wanted to know what cathode rays were, where cathode rays came from, and whether cathode rays had any mass or charge. The techniques that he used to answer these questions were very clever and earned him a Nobel Prize in physics. First, by cutting a small hole in the anode, Thomson found that he could get some of the cathode rays to flow through the hole in the anode and into the other end of the glass cathode ray tube. Next, he figured out that if he painted a substance known as phosphor onto the far end of the cathode ray tube, he could see exactly where the cathode rays hit because the cathode rays made the phosphor glow.



Thomson suspected that cathode rays were charged, and his next step was to place a positively charged metal plate on one side of the cathode ray tube and a negatively charged metal plate on the other side, as shown below. The metal plates didn't actually touch the cathode ray tube, but they were close enough that a remarkable thing happened. The flow of the cathode rays passing through the hole in the anode was bent upwards towards the positive metal plate and away from the negative metal plate. In other words, instead of glowing directly across from the hole in the anode, the phosphor now glowed at a spot quite a bit higher in the tube.



Thomson thought about his results for a long time. It was almost as if the cathode rays were attracted to the positively charged metal plate and repelled from the negatively charged metal plate. Thomson knew that charged objects are attracted to and repelled from other charged objects according to the rule: opposite charges attract, like charges repel. This means that a positive charge is attracted to a negative charge but repelled from another positive charge. Similarly, a negative charge is attracted to a positive charge but repelled from another negative charge. Using the "opposite charges attract, like charges repel" rule, Thomson argued that if the cathode rays were attracted to the positively charged metal plate and repelled from the negatively charged metal plate, the rays themselves must have a negative charge.

Thomson then did some rather complex experiments with magnets and used the results to prove that cathode rays not only were negatively charged, but they also had mass. Remember that anything with mass is what we call matter, along with the principle that space is filled by matter. . In other words, these cathode rays must be the result of negatively charged matter flowing from the cathode to the anode. It was here that Thomson encountered a problem. According to his measurements, these cathode rays either had a ridiculously high charge or very, very little mass – much less mass than the smallest known atom. How was this possible? How could the matter making up cathode rays be smaller than an atom if atoms were indivisible? Thomson made a radical proposal: maybe atoms are divisible. He suggested that the small, negatively charged particles making up the cathode ray were actually pieces of atoms. He called these pieces "corpuscles," although today we know them as electrons. Thanks to his clever experiments and careful reasoning, Thomson is credited with the discovery of the electron.

Now imagine what would happen if atoms were made entirely of electrons. First of all, electrons are very, very small; in fact, electrons are about 2,000 times smaller than the smallest known atom, so every atom would have to contain a lot of electrons. But there’s another, bigger problem: electrons are negatively charged. Therefore, if atoms were made entirely out of electrons, the atoms themselves would be negatively charged, which would mean all matter was negatively charged as well. Because like charges repel, if matter was completely composed of negatively charged particles, matter would be repelled by itself and atoms would be ripped apart.

For this reason, we can know that matter isn’t generally negatively charged. Most matter is what we call neutral – it has no charge at all. How can matter be neutral if it is composed of atoms and atoms are composed of negative electrons? The only possible explanation is that atoms must consist of more than just electrons but must also contain some type of positively charged material that balances the negative charge of the electrons. Negative and positive charges of equal size cancel each other out, just like negative and positive numbers of equal size. If an atom contains an electron with a –1 charge and some form of material with a +1 charge, overall the atom must have a (+1)+(–1) = 0 charge. In other words, the atom would be neutral, or have no overall charge.

Based on the fact that atoms are neutral and based on Thomson’s discovery that atoms contain negative subatomic particles called electrons, scientists assumed that atoms must also contain a positive substance. It turned out that this positive substance was another kind of subatomic particle known as the proton. Although scientists knew that atoms had to contain positive material, protons weren’t actually discovered, or understood, until quite a bit later.

When Thomson discovered the negative electron, he also realized that atoms had to contain positive material as well. As a result, Thomson formulated what’s known as the plum-pudding model for the atom. According to the plum-pudding model, the negative electrons were like pieces of fruit and the positive material was like the batter or the pudding. In the figure below, an illustration of a plum pudding is on the left and an illustration of Thomson's plum-pudding model is on the right. (If you have never seen plum pudding, you can also think of a chocolate chip cookie. In that case, the positive material in the atom would be the batter in the chocolate chip cookie, while the negative electrons would be scattered through the batter like chocolate chips.)

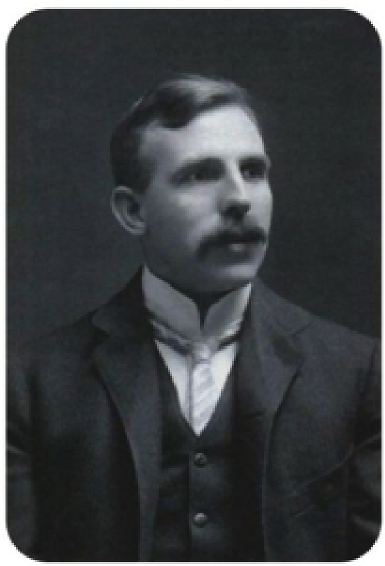
This made a lot of sense given Thomson’s experiments and observations. Thomson had been able to isolate electrons using a cathode ray tube; however, he had never managed to isolate positive particles. Notice in the image above how easy it would be to pick the pieces of fruit out of a plum pudding. On the other hand, it would be a lot harder to pick the batter out of the plum pudding because the batter is everywhere. If an atom were similar to a plum pudding in which the electrons are scattered throughout the “batter” of positive material, then you would expect it to be easy to pick out the electrons and a lot harder to pick out the positive material.

Everything about Thomson’s experiments suggested the plum-pudding model was correct. According to the scientific method, however, any new theory or model should be tested by further experimentation and observation. In the case of the plum-pudding model, it would take a man named Ernest Rutherford to conduct observation. In the case of the plum pudding model, it would take a man named Ernest Rutherford to conduct an experiment that would produce an observation to prove it wrong. Rutherford and his experiments will be the topic of the next section.

There was one thing that Thomson was unable to determine. He had measured the charge–mass ratio of the electron, but he had been unable to measure accurately the charge or mass of a single electron. Instead, a different scientist named Robert Millikan would determine the charge of the electron with his oil drop experiment. When combined with Thomson's charge-to-mass ratio, Millikan was able to calculate the mass of the electron. Millikan's experiment involved putting charges on tiny droplets of oil suspended between charged metal plates and measuring their rate of descent. By varying the charge on different drops, he noticed that the electric charges on the drops were all multiples of 1.6×10^{-19} C (coulomb), the charge of a single electron.

Rutherford’s Nuclear Model

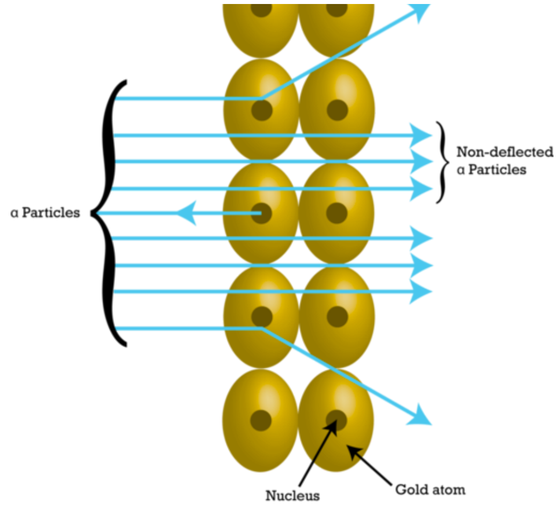
Disproving Thomson’s plum-pudding model began with the discovery that an element known as uranium emits positively charged particles called alpha particles as it undergoes radioactive decay. This radioactive decay occurs when one element decomposes into another element, and in the process loses a positively charged particle. . Alpha particles themselves didn’t prove anything about the structure of the atom, but they were used to conduct some very interesting experiments.



A portrait of Ernest Rutherford.

Ernest Rutherford (pictured in Figure above) was fascinated by all aspects of alpha particles and used them as tiny bullets that could be fired at all kinds of different materials. The results of one experiment in particular surprised Rutherford and everyone else.

Rutherford found that when he fired alpha particles at a very thin piece of gold foil, an interesting phenomenon happened. The diagram below helps illustrate Rutherford's findings. Almost all of the alpha particles went straight through the foil as if they had hit nothing at all. Every so often, though, one of the alpha particles would be deflected slightly as if it had bounced off something hard. Even less often, Rutherford observed alpha particles bouncing straight back at the “gun” from which they had been fired. It was as if these alpha particles had hit a wall head-on and had ricocheted right back in the direction that they had come from.



An Explanation for Rutherford's Results: Most alpha particles passed through the negatively charged outside, some were deflected by approaching the positive center, and some were completely bounced back by hitting the positive center right on

Rutherford thought that these experimental results were rather odd. He expected firing alpha particles at gold foil to be like shooting a high-powered rifle at tissue paper. The bullets would break through the tissue paper and keep on going, almost as if they had hit nothing at all. That was what Rutherford had expected to see when he fired alpha particles at the gold foil. The fact that most alpha particles passed through did not shock him, but how could he explain the alpha particles that were deflected? Furthermore, how could he explain the alpha particles that bounced right back as if they had hit a wall?

Rutherford decided that the only way to explain his results was to assume that the positive matter forming the gold atoms was not distributed like the batter in plum pudding. Instead, he proposed that the positive matter was concentrated in one spot, forming a small, positively charged particle somewhere in the center of the gold atom. We now call this clump of positively charged mass the nucleus. According to Rutherford, the presence of a nucleus explained his experiments because it implied that most of the positively charged alpha particles would pass through the gold foil without hitting anything at all. Occasionally, though, the alpha particles would actually collide with a gold nucleus, causing the alpha particles to be deflected or even bounced back in the direction they came from.

While Rutherford's discovery of the positively charged atomic nucleus offered insight into the structure of the atom, it also led to some questions. According to the plum-pudding model, electrons were like plums embedded in the positive batter of the atom. Rutherford's model, though, suggested that the positive charge was concentrated into a tiny particle at the center of the atom, while most of the rest of the atom was empty space. What did that mean for the electrons? If they weren't embedded in the positive material, exactly what were they doing? How were they held in the atom? Rutherford suggested that the electrons might be circling the positively charged nucleus as some type of negatively charged cloud, like in the image below. At the time, however, there wasn't much evidence to suggest exactly how the electrons were held in the atom.

Positive Nucleus

Negative Electrons

Despite the problems and questions associated with Rutherford's experiments, his work with alpha particles seemed to point to the existence of an atomic nucleus. Between Thomson, who discovered the electron, and Rutherford, who suggested that the positive charges were concentrated at the atom's center, the 1890s and early 1900s saw huge steps in understanding the atom at the subatomic (smaller than the size of an atom) level. Although there was still some uncertainty with respect to exactly how subatomic particles were level. Although there was still some uncertainty with respect to exactly how subatomic particles were organized in the atom, it was becoming more and more obvious that atoms were indeed divisible. Moreover, it was clear that an atom contained negatively charged electrons and a positively charged nucleus. In the next lesson, we'll look more carefully at the structure of the nucleus. We'll learn that while the atom is made up of positive and negative particles, it also contains neutral particles that neither Thomson nor Rutherford were able to detect with their experiments.

Electrons, Protons, and Neutrons

Electrons have a negative charge. As a result, they are attracted to positive objects and repelled from negative objects, including other electrons (illustrated below). To minimize repulsion, each electron is capable of staking out a "territory" and "defending" itself from other electrons.

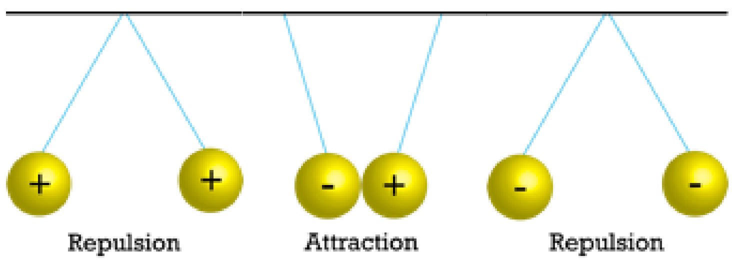
Protons are another type of subatomic particle found in atoms. They have a positive charge, so they are attracted to negative objects and repelled from positive objects. Again, this means that protons repel each other (illustrated below). However, unlike electrons, protons are forced to group together into one big clump in the nucleus of the atom, even though they repel each other. Protons are bound together by what are termed strong nuclear forces. These forces are responsible for binding the atomic nuclei together, allowing the protons to form a dense, positively charged center.

There is a third subatomic particle known as a neutron. Rutherford proposed the existence of a neutral particle along with the approximate mass of a proton, but it wasn't until years later that someone proved the existence of the neutron. In the 1930's, a physicist named James Chadwick observed that when beryllium was bombarded with alpha particles, it emitted an unknown radiation that had approximately the same mass as a proton, but the radiation had no electrical charge. Chadwick was able to prove that these beryllium emissions contained a neutral particle–Rutherford's neutron.

As you might have already guessed from its name, the neutron is neutral. In other words, it has no charge and is therefore neither attracted to nor repelled from other objects. Neutrons are in every atom (with one exception), and they're bound together with other neutrons and protons in the atomic nucleus. Again, the binding forces that help to keep neutrons fastened into the nucleus are known as strong nuclear forces.

Since neutrons are neither attracted to nor repelled from objects, they don't really interact with protons or electrons beyond being bound into the nucleus with the protons. Protons and electrons, however, do interact. Using what you know about protons and electrons, what do you think will happen when an electron approaches a proton? Will the two subatomic particles be attracted to each other or repelled from each other? As we have seen before "opposites attract, likes repel." Since electrons and protons have opposite charges (one negative, the other positive), you'd expect them to be attracted to each other, as illustrated below. The reason that the electrons do not fall into the nucleus is complex, but part of the reason is the electrons have too much energy as they move around the nucleus to fall into the nucleus.

Even though electrons, protons, and neutrons are all types of subatomic particles, they are not all the same size. When comparing the masses of electrons, protons, and neutrons, you will find that electrons have an extremely small mass compared to the masses of either protons or neutrons (see Figure below). On the other hand, the masses of protons and neutrons are fairly similar, with the mass of a neutron being slightly greater than the mass of a proton. Because protons and neutrons are so much more massive than electrons, almost all of the atomic mass in any atom comes from the nucleus, which is where all of the neutrons and protons are located.



Electrons are much smaller than protons or neutrons. How much smaller? If an electron was the size of a penny, a proton or a neutron would have the mass of a large bowling ball!

The Table below gives the properties and locations of electrons, protons, and neutrons. The third column shows the masses of the three subatomic particles in grams. The second column, however, shows the masses of the three subatomic particles in amu, or atomic mass units. An atomic mass unit (amu) is defined as one-twelfth the mass of a carbon-12 atom (a carbon that has 6 protons and 6 neutrons). Atomic mass units are useful because, as you can see, the mass of a proton and the mass of a neutron are almost exactly in this unit system. The dalton is equivalent to the atomic mass unit, with the two terms being different names for the same measure. The two terms are often used interchangeably, and both will be used throughout this text.

Subatomic Particles, Properties, and Location			
Particle	*Electron*	*Proton*	*Neutron*
Relative Mass (amu)	1/1840	1	1
Mass in Grams (g)	9.10938×10^{-28}	1.67262×10^{-24}	1.67493×10^{-24}
Electric Charge	–1	+1	0
Location	outside nucleus	nucleus	nucleus

In addition to mass, another important property of subatomic particles is the charge. The fourth column in Table above shows the charges of the three subatomic particles. You already know that neutrons are neutral and thus have no charge at all. Therefore, we say that neutrons have a charge of zero. What about electrons and protons? Electrons are negatively charged and protons are positively charged, but the positive charge on a proton is exactly equal in magnitude (magnitude means "absolute value") to the negative charge on an electron.

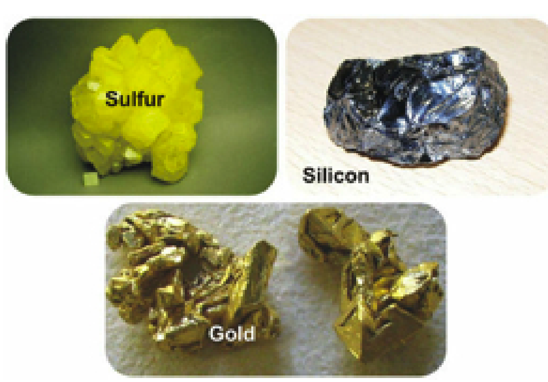
You may recall that Millikan discovered that the magnitude of the charge on a single electron is 1.6×10^{-19} C (coulomb), which means that the magnitude of the charge on a proton is also 1.6×10^{-19} C. In other words, a neutral atom must have exactly one electron for every proton. If a neutral atom has 1 proton, it must have 1 electron. If a neutral atom has 2 protons, it must have 2 electrons. If a neutral atom has 10 protons, it must have 10 electrons. Do you get the idea?

Atomic Number and Mass Number

Scientists can distinguish between different elements by counting the number of protons. If an atom has only one proton, we know it's an atom of the element hydrogen. If you take a look at the periodic table below, hydrogen is the first element, with the number one at the top of the box. The atomic symbol of hydrogen is "H." Hydrogen is the first box because it has only one proton. We say that "hydrogen has an atomic number of one" or "Z=1." An atom with two protons is always an atom of the element helium. The atomic symbol of helium is 'He' and has a two at the top of the box, representing an atomic number of two because there are two protons. When scientists count four protons in an atom, they know it's a beryllium atom, symbolized as 'Be' below. An atom with three protons is a lithium atom ('Li'), an atom with five protons is a boron atom ('B'), an atom with six protons is a carbon atom ('C') the list goes on (see Figure below for more examples). Notice that the atomic symbol is always capital first letter and lower case second letter if there is one in the symbol. A few pictures of these elements in their natural forms are also given below.

	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		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	87 Ra		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	71 Lu
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	103 Lr



Sulfur 16, Silicon 14, Gold 79

Sulfur 16, Silicon 24, Gold 79

How would you distinguish these three elements? You can't really distinguish between sulfur and gold based on color because both are yellowish. You could try to distinguish elements based on another parameter, such as shininess, but then how would you tell the difference between gold and silicon? Each element, however, has a unique characteristic: the number of protons. Every atom of sulfur has 16 protons, each silicon atom has 14 protons, and gold atoms have 79 protons.

Since an atom of one element can be distinguished from an atom of another element by the number of protons in the nucleus, the number of protons in the nucleus is the identification number. We call that ID number the atomic number and symbolize that number with the capital letter "Z." An element's **atomic number (*Z*)** is equal to the number of protons in the nuclei of any of its atoms. Again, all atoms with the same atomic number are the same element. The elements are arranged on the periodic table in order of increasing atomic number. The atomic number is a whole number usually written above the atomic symbol of each element in the table. The atomic number for hydrogen is $Z = 1$ because every hydrogen atom has 1 proton. The atomic symbol of hydrogen is 'H,' which we can see as the large letter in the first box of the periodic table. The atomic number for helium is $Z = 2$ because every helium atom has 2 protons, and the atomic symbol is 'He'. See if you can figure out what the atomic number 'and symbol' of carbon is. (Answer: Carbon has 6 protons, so the atomic number for carbon is $Z = 6$. The symbol in the box with a 6 is 'C,' so the atomic symbol is 'C.')

Since neutral atoms have to have one electron for every proton, an element's atomic number also tells you how many electrons are in a neutral atom of that element. For example, hydrogen has atomic number $Z = 1$. This means that an atom of hydrogen has one proton and, if it's neutral, one electron. Gold, on the other hand, has atomic number $Z = 79$, which means that a neutral atom of gold has 79 protons. To balance these 79 protons and make a neutral atom, gold must have 79 electrons.

The **mass number (*A*)** of an atom is the total number of protons and neutrons in its nucleus. Why do you think that the mass number includes protons and neutrons, but not electrons? You know that most of the mass of an atom is concentrated in its nucleus because the nucleus contains protons and neutrons: the most massive sub-atomic particles in the atom. Additionally, the mass of an electron is very, very small compared to the mass of either a proton or a neutron (like the mass of a penny compared to the mass of a bowling ball). By counting the number of protons and neutrons, scientists will have a very close approximation of the total mass of an atom.

mass number (A) = (number of protons)+(number of neutrons)

An atom's mass number is very easy to calculate once you know the number of protons and neutrons in the atom. Notice that the mass number is not the same as the mass of the atom. The mass number is a counted number. The atomic mass is a measured number. Again, the mass number will be close to the atomic mass because, if you recall, both protons and neutrons have a relative mass of approximately 1 amu.

Example:

What is the mass number of an atom that contains 3 protons and 4 neutrons?

First, recall that the atomic number of helium is 2, so every atom of helium has 2 protons.

(number of protons) = ***3***

(number of neutrons) = ***4***

mass number *A* = (number of protons) + (number of neutrons) mass number A = ***3*** + ***4*** = 7

Example:

What is the mass number of an atom of helium that contains 2 neutrons?

(number of protons) = ***2*** (Remember that an atom of helium always has 2 protons.)

(number of neutrons) = ***2***

mass number A = (number of protons) + (number of neutrons)

mass number A = ***2*** + ***2*** = ***4***

Isotopes

Unlike the number of protons, which must always be same for all atoms of the same element, the number of neutrons can be different. Atoms of the same element with different numbers of neutrons are known as isotopes. Since the isotopes of any given element all contain the same number of protons, they all have the same atomic number (for example, the atomic number of helium is always 2). However, since the isotopes of a given element contain different numbers of neutrons, different isotopes have different mass numbers. The following two examples should help clarify this point.

Example

What is the atomic number and the mass number of a lithium isotope containing 3 neutrons? Note: the atomic number of lithium is 3, so all lithium atoms contain 3 protons in its nucleus.

Solution

atomic number = number of protons = 3

number of neutrons = 3

mass number = (number of protons) + (number of neutrons)

mass number = 3+3 = 6

Example

What is the atomic number and the mass number of a lithium isotope containing 4 neutrons? A lithium atom contains 3 protons in its nucleus.

Solution

atomic number = number of protons = 3

number of neutrons = 4

mass number = (number of protons) + (number of neutrons)

mass number = 3+4 = 7

Notice that because the lithium atom always has 3 protons, the atomic number for lithium is always 3. The mass number, however, is 6 for the isotope with 3 neutrons and 7 for the isotope with 4 neutrons. Similarly to how an element only has a particular number of protons, in nature, only certain isotopes exist. For instance, lithium exists as an isotope with 3 neutrons and as an isotope with 4 neutrons, but it doesn't exists as an isotope with 2 or 5 neutrons. In this case, having too few or too many neutrons can make the atom less stable, so only certain isotopes have the right number of neutrons to be stable enough to exist in nature.

So how do we distinguish between isotopes of the same element? We can use the nuclear symbol or hyphen notation. To write the nuclear symbol, write the atomic symbol of the element and put the mass number of the isotope in the upper left-hand corner and (optionally) the atomic number in the lower left-hand corner. For example, the nuclear symbols for the two isotopes of lithium discussed above are:
$^6_3Li\ or\ ^6Li\ and\ ^7_3Li\ or\ ^7Li.$

General format:
$^A_ZX\ ,\ \ A = mass\ number,\ Z = atomic\ number,\ X = atomic\ symbol.$

To write hyphen notation, write the name of the element (or sometimes the symbol) followed by a hyphen which is followed by the mass number. For example, the lithium isotopes discussed above could be expressed as "lithium-6 and lithium-7."

Lesson Summary

- Dalton's atomic theory wasn't entirely correct, as it was found that atoms can be divided into smaller subatomic particles.
- According to Thomson's plum-pudding model, the negatively charged electrons in an atom are like the pieces of fruit in a plum pudding, while the positively charged material is like the batter.
- When Ernest Rutherford fired alpha particles at a thin gold foil, most alpha particles went straight through; however, a few were scattered at different angles, and some even bounced straight back.
- In order to explain the results of his gold foil experiment, Rutherford suggested that the positive matter in the gold atoms was concentrated at the center of the gold atom in what we now call the nucleus of the atom.
- Electrons are a type of subatomic particle with a negative charge, so electrons repel each other but are attracted to protons.
- Protons are a type of subatomic particle with a positive charge, so protons repel each other but are attracted to electrons. Protons are bound together in an atom's nucleus as a result of strong nuclear forces.
- Neutrons are a type of subatomic particle with no charge (they're neutral). Like protons, neutrons are bound into the atom's nucleus as a result of strong nuclear forces.
- Protons and neutrons have approximately the same mass and are both much more massive than electrons (approximately 2,000 times as massive as an electron).
- The positive charge on a proton is equal in magnitude to the negative charge on an electron. As a result, a neutral atom must have an equal number of protons and electrons.
- Each element has a unique number of protons. An element's atomic number (*Z*) is equal to the number of protons in the nuclei of any of its atoms.
- The mass number (*A*) of an atom is the sum of the protons and neutrons in the atom
- Isotopes are atoms of the same element (same number of protons) that have different numbers of neutrons in their atomic nuclei.
- The periodic table is a convenient way to summarize information about the different elements. In addition

to the element’s symbol, most periodic tables will also contain the element’s atomic number and the element’s atomic mass.

Vocabulary

- **cathode ray tube:** a small glass tube with a cathode (a negatively charged metal plate) and an anode (a positively charged metal plate) at opposite ends
- **electron:** a negatively charged subatomic particle
- **nucleus:** the center of the atom
- **proton:** a positively charged subatomic particle
- **subatomic particles:** particles that are smaller than the atom
- **atomic mass:** the weighted average of the masses of the naturally occurring isotopes of an element
- **atomic mass unit (amu):** used to express atomic and molecular masses, it is the approximate mass of a hydrogen atom, a proton, or a neutron and is one-twelfth of the mass of an unbound carbon-12 atom at rest; it is equivalent to the dalton
- **atomic number:** the number of protons in the nucleus of an atom symbolized by Z.
- **dalton:** used to express atomic and molecular masses, it is the approximate mass of a hydrogen atom, a proton, or a neutron and is one-twelfth of the mass of an unbound carbon-12 atom at rest; it is equivalent to the atomic mass unit
- **isotopes:** atoms of the same element that have the same number of protons but different numbers of neutrons
- **mass number:** the total number of protons and neutrons in the nucleus of an atom symbolized by A.
- **neutron:** a subatomic particle with no charge

Further Reading / Supplemental Links

A short history of the changes in our model of the atom, an image of the plum-pudding model, and an animation of Rutherford's experiment can be viewed at this website.

http://www.newcastle-schools.org.uk/nsn/chemistry/Radioactivity/Plub%20Pudding%20and%20Rutherford%20Page.htm **(http://www.newcastle-schools.org.uk/nsn/chemistry/Radioactivity/Plub%20Pudding%20and%20Rutherford%20Page.htm)**

For a demonstration of cathode ray tubes (1h), see:

http://www.youtube.com/watch?v=XU8nMKkzbT8 **(http://www.youtube.com/watch?v=XU8nMKkzbT8)**

(http://www.youtube.com/watch?v=XU8nMKkzbT8)
(1:09).

A short animation of Rutherford’s experiment (1h) can be found at:

A short animation of Rutherford's experiment (1h) can be found at:

http://www.youtube.com/watch?v=5pZj0u_XMbc (http://www.youtube.com/watch?v=5pZj0u_XMbc)

(http://www.youtube.com/watch?v=5pZj0u_XMbc)
(0:47).

For another video discussing J.J. Thomson's use of a cathode ray tube in his discovery of the electron (1h), see:

http://www.youtube.com/watch?v=IdTxGJjA4Jw (http://www.youtube.com/watch?v=IdTxGJjA4Jw)

(http://www.youtube.com/watch?v=IdTxGJjA4Jw)
(2:54).

For a short animation demonstrating the properties of the electron using a cathode ray tube (1h), see:

http://www.youtube.com/watch?v=4QAzu6fe8rE (http://www.youtube.com/watch?v=4QAzu6fe8rE)

(http://www.youtube.com/watch?v=4QAzu6fe8rE)
video (3:46).

This video summarizes the concept of the atom and to the organization of the periodic table (1a, 1e):

http://www.youtube.com/watch?v=1xSQlwWGT8M (http://www.youtube.com/watch?v=1xSQlwWGT8M)

(http://www.youtube.com/watch?v=1xSQlwWGT8M)
(21:05).

Section Homework --> (https://uvu.instructure.com/courses/362094/assignments/2195015)