5.1: Structure of Atoms

Describe the structure of atoms.

All matter in the universe is made up of tiny little particles called atoms. For our purposes, we will use a simplified model of the atom in which electrons are orbiting the nucleus. More recent discoveries have altered the model of the atom; however, changes made to the atomic model are not critical to our understanding here.

The following slide show presents how the whole universe is made up of small atoms, which are made up of even smaller particles.

Fig. 5.1: The Universe broken down into atoms

As you may already know, atoms are made up of smaller, subatomic particles called protons, electrons, and neutrons. The protons and neutrons are found together in a region at the center of the atom called the nucleus. Particles in the nucleus are sometimes called nucleons. So protons and neutrons are nucleons but electrons are not.

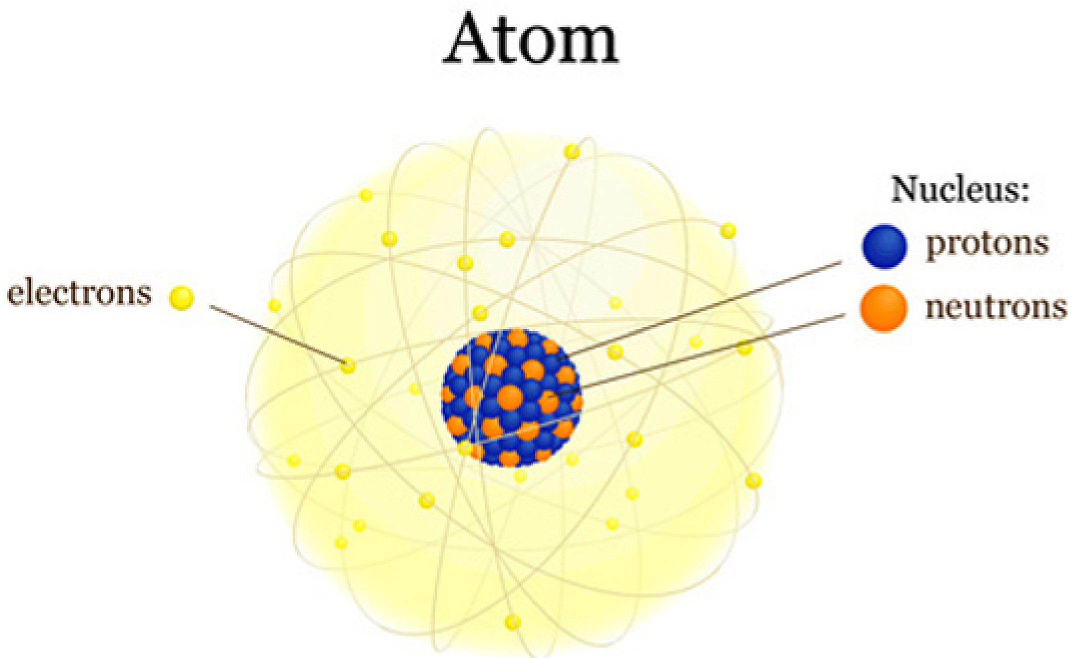

Fig. 5.2: The nucleus of an atom

Protons and neutrons are about the same size. Both are much larger and more massive than electrons. As stated earlier, all matter is made up of atoms. The protons from different atoms are all identical. Likewise, electrons and neutrons are always the same, no matter which kinds of atoms they come from. Although the size of the protons, neutrons, and electrons remains the same, there can be varying numbers of protons, neutrons and electrons within certain types of atoms. In fact, the number of protons within the nucleus of an atom distinguishes one atom from another. For example, a single carbon atom contains six protons in the nucleus, while a helium atom contains only two protons. The atomic mass of an element is generally the same as the number of protons plus the number of neutrons in the nucleus of that atom.

Here are some examples of the simplified structure of a few different types of atoms.

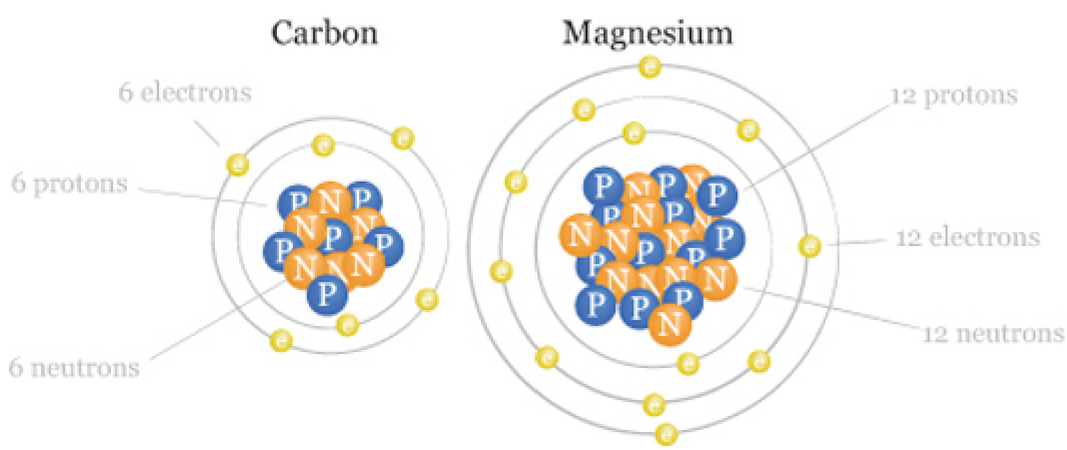

Fig. 5.3: The structure of various types of atoms

Elements

An element is a substance that is made up of entirely the same type of atom. By breaking elements down to their individual atoms, the same properties are observed. Elements are unique because the atoms of a particular element always have the same number of protons. For example, hydrogen atoms have exactly one proton. Oxygen atoms have exactly eight protons, and so forth. (So the atomic number of oxygen is 8.)

Each element has a unique symbol and two unique numbers. The symbol is used to abbreviate the name. Many atomic symbols make sense—O for oxygen, H for hydrogen, Ca for calcium, and so forth. However, some of them may seem a bit strange to you, e.g., K for potassium, Au for gold, and Na for sodium. The symbols that seem a bit strange usually come from Latin names that early chemists gave to these substances. As these are accepted by scientists throughout the world today, you just have to get used to the symbols that are used for the different elements. Table 5.1 illustrates some of the elements with their symbols.

H - Hydrogen	**He** - Helium	**Li** - Lithium	**Be** - Beryllium
B - Boron	**C** - Carbon	**Na** - Sodium	**N** - Nitrogen
O - Oxygen	**F** - Fluorine	**Ne** - Neon	**Mg** - Magnesium
Al - Aluminum	**Si** - Silicon	**P** - Phosphorus	**Cl** - Chlorine
Cu - Copper	**Ag** - Silver	**K** - Potassium	**Ca** - Calcium
Pb - Lead	**Fe** - Iron	**Hg** - Mercury	**Au** - Gold

Table 5.1: Some of the elements with their symbols

The two numbers that are unique to each element are the atomic number and the atomic mass. Each element has its own atomic number and atomic mass. The number of protons in the nucleus of an element is called the atomic number. The atomic mass of an element is generally the same as the number of protons plus the number of neutrons in the nucleus of that atom.

There is another way to write the symbol for an element. A symbol with a set of two numbers in front of it indicates the atomic mass and the atomic number. For example, ${}^{14}_{6}C$ is the symbol for a carbon atom whose atomic number is 6 and atomic mass is 14. Remember, the atomic number is the number of protons, and the atomic mass is the sum of the number of protons and the number of neutrons. So this carbon atom (sometimes called carbon-14) has 6 protons and 8 neutrons (6 protons + 8 neutrons = 14). You should be able to identify the atomic number, atomic mass, and number of neutrons by looking at a symbol like this: ${}^{12}_{6}C$

Example 5.1:

How many neutrons does ${}^{35}_{17}Cl$ have?

- Remember the number on the bottom left is the atomic number, or the number of protons. The number on the top left is the atomic mass, which is the same as the sum of protons and neutrons.
- 17 protons + neutrons = 35
- Solve for neutrons.
- 35 – 17 = neutrons
- 18 neutrons

Isotopes and Molecules

It is possible for atoms of the same element to have different numbers of neutrons. Most carbon atoms have 6 protons and 6 neutrons, so the symbol for the carbon-12 atom is ${}^{12}_{6}C$. Atoms that have the same number of protons but different numbers of neutrons are called isotopes.

Hydrogen has three isotopes. ${}^{1}_{1}H$ has just 1 proton and 0 neutrons in the nucleus, and is called hydrogen. ${}^{2}_{1}H$ has one proton and one neutron, and is called deuterium. ${}^{3}_{1}H$ has one proton and two neutrons, and is called tritium. All three of these are isotopes of hydrogen because they all have the same atomic number (the number of protons) but different atomic masses (protons + neutrons).

Up to now we have discussed the characteristics of just a single atom, but most of the substances around us are made up of multiple atoms that are bonded together. When two or more atoms are bonded together, it is a molecule. Many substances are made of molecules. Oxygen in its natural state is actually made of two oxygen atoms that are bonded together; we call this an oxygen molecule. Molecules can also be made of different atoms. For example, the water molecule is made up of oxygen and hydrogen atoms. The symbol for a molecule has the symbol for the elements with a subscript (small number to the lower right) indicating the number of those elements present in the molecule. The oxygen molecule, for example, would look like this: O2 (because it contains two oxygen atoms).

Ions

An ion is an atom that has either a positive or negative electric charge. One of the unique characteristics of the subatomic particles is a property called *electric charge*. Scientists have observed that electrons are attracted to the protons of the nucleus but are repelled by (pushed away from) other electrons. The property that causes this attraction and repulsion is called electric charge. Since there are two distinct electric charges, scientists named the charges *positive* and *negative*. The electron has a negative charge, and the proton has a positive charge. Neutrons have no electric charge. They are electrically *neutral.*

Electric charge is considered a fundamental property of matter. *The positive electric charge of a proton is equal in amount to the negative electric charge of an electron.* Thus, if an atom consists of an equal number of positive and negative charges, it is said to be electrically neutral. In other words, it has zero net electric charge. Remember from our discussion of Newton's laws that *net* simply means what remains after positives and negatives cancel out as much as possible.

It is important to understand the process of losing and gaining electrons which makes neutral atoms turn into ions. figure 5.4 is helpful for learning about how ions are made.

If an atom has three electrons and three protons, what is its charge?

- Positive
- Neutral
- Negative

Check

H5P

Fig. 5.4: Ions are created by losing or gaining electrons.

The vast majority of all matter is made up of electrically neutral atoms. Sometimes, however, an atom may have a different amount of electrons and protons. If an atom has fewer electrons than protons, the atom has a positive net electric charge. If an atom has more electrons than protons, the atom has a negative net electric charge. Atoms such as these that carry a net electric charge are called ions. Ions are formed by either adding or removing electrons from an atom. These electrons are not "created" or "destroyed," but rather, simply come from other atoms or go to other atoms. In this way, we see that matter is conserved in much the same way as energy is conserved.

An ion can be written using the atomic symbol with a positive or negative superscript (little + or – symbol in the upper right) indicating the net electric charge of the ion. Sodium ions have lost one electron, so they have a net electric charge of +1 and are written as Na^+. Chloride ions have gained an extra electron, so they have a net electric charge of –1 and are written Cl^-.