Matter is the Stuff Around You

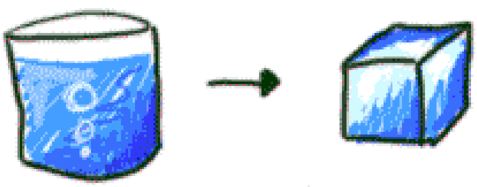
Matter is everything around you. Matter is everything made of atoms and molecules. Matter is anything that has a mass. Matter is also related to light and electromagnetic radiation. Even though matter can be found all over the universe, you usually find it in just a few forms. As of 1995, scientists have identified five **states of matter**. They may discover one more by the time you get old.

THE EARTH IS ONE LARGE MIXTURE OF MOLECULES IN GASES, LIQUIDS AND SOLIDS.

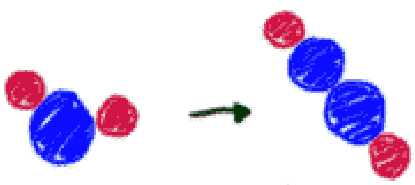
You should know about solids, liquids, gases, plasmas, and a new one called Bose-Einstein condensates. The first four have been around a long time. The scientists who worked with the Bose-Einstein condensates just received a Nobel Prize for their work in 1995. But what makes a state of matter? It's about the physical state of molecules and atoms.

Changing States of Matter

Elements and compounds can move from one physical state to another and not change. Oxygen as a gas still has the same properties as liquid oxygen. The liquid state is colder and denser but the molecules are still the same. Water is another example. The **compound** water is made up of two hydrogen atoms and one oxygen atom. It has the same molecular structure whether it is a gas, liquid, or solid. Although its physical state may change, its chemical state remains the same.



PHYSICAL CHANGE OF WATER INTO ICE

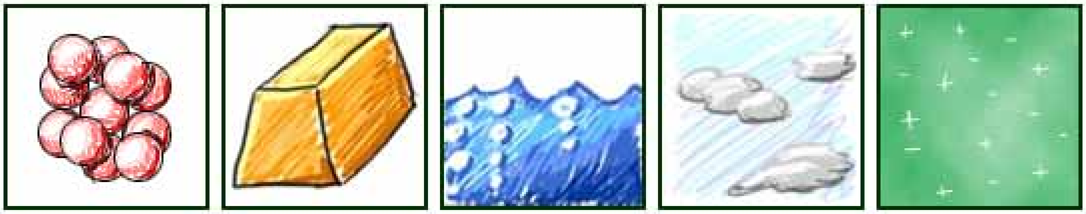


CHEMICAL CHANGE OF WATER INTO HYDROGEN PEROXIDE

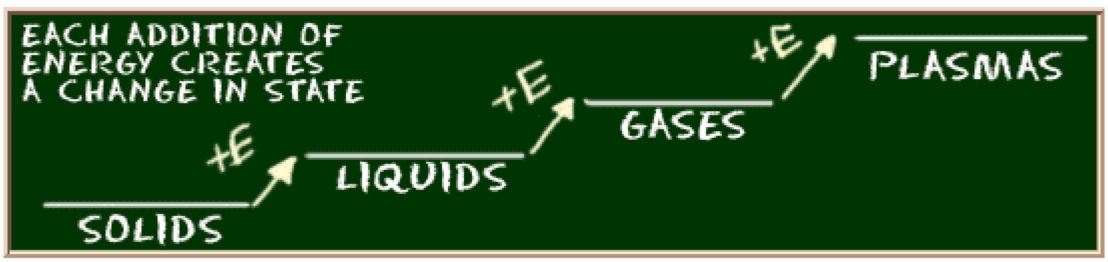
So you ask, "What is a chemical state?" If the formula of water were to change, that would be a **chemical** change. If you added another oxygen atom, you would make hydrogen peroxide. Its molecules would not be water anymore. Changing states of matter is about changing densities, pressures, and temperatures. The basic chemical structure does not change.

STATES OF MATTER

There are five main states of matter. Solids, liquids, gases, plasmas, and Bose-Einstein condensates are all different states of matter. Each of these states is also known as a phase. Elements and compounds can move from one phase to another phase when special **physical forces** are present. One example of those forces is temperature. The phase or state of matter can change when the temperature changes. Generally, as the temperature rises, matter moves to a more active state.



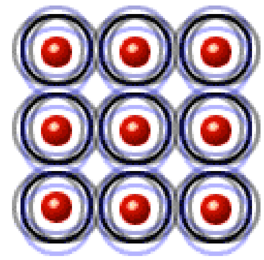
Phase describes a physical state of matter. The key word to notice is physical. Things only move from one phase to another by physical means. If energy is added (like increasing the temperature or increasing pressure) or if energy is taken away (like freezing something or decreasing pressure) you have created a physical change.



One compound or element can move from phase to phase, but still be the same substance. You can see water **vapor** over a boiling pot of water. That vapor (or gas) can **condense** and become a drop of water. If you put that drop in the freezer, it would become a solid. No matter what phase it was in, it was always water. It always had the same chemical properties. On the other hand, a chemical change would change the way the water acted, eventually making it not water, but something completely new.

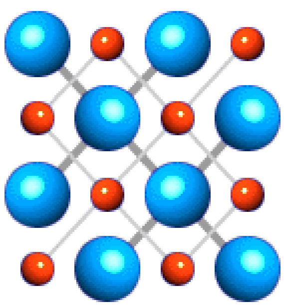
SOLID BASICS

So what is a solid? Solids are usually hard because their molecules have been packed together. The closer your molecules are, the harder you are. Solids also can hold their own shape. A rock will always look like a rock unless something happens to it. The same goes for a diamond. Even when you grind up a solid into a powder, you will see little tiny pieces of that solid under a microscope. Liquids will move and fill up any container. Solids like their shape.



In the same way that a solid holds its shape, the atoms inside of a solid are not allowed to move around too much. This is one of the **physical** characteristics of solids. Atoms and molecules in liquids and gases are bouncing and floating around, free to move where they want. The molecules in a solid are stuck. The atoms still spin and the electrons fly around, but the entire atom will not change position.

Solids can be made up of many things. They can have pure elements or a variety of compounds inside. When you get more than one type of compound in a solid it is called a **mixture**. Most rocks are mixtures of many different compounds. Concrete is a good example of a manmade mixture.



CRYSTALS

On the other end of the spectrum from a mixture is something called a crystal. When a solid is made up of a pure substance and forms slowly, it can become a crystal. Not all pure substances form crystals because it is a delicate process. The atoms are arranged in a regular repeating pattern called a cystal lattice. A crystal lattice is a very exact organization of atoms. A good example is carbon. A diamond is a perfect crystal lattice while the graphite arrangement is more random.

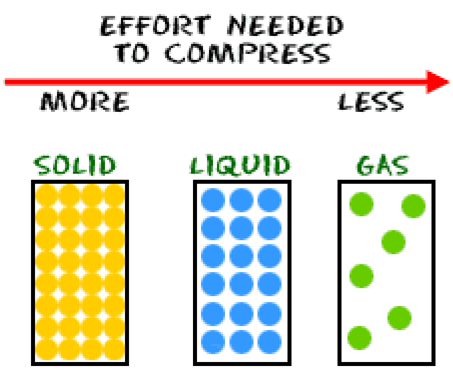
LIQUID BASICS

THE OCEANS OF THE WORLD ARE ALL SOLUTIONS.

The second state of matter we will discuss is a liquid. Solids are hard things you can hold. Gases are floating around you and in bubbles. What is a liquid? Water is a liquid. Your blood is a liquid. Liquids are an in-between state of matter. They can be found in between the solid and gas states. They don't have to be made up of the same compounds. If you have a variety of materials in a liquid, it is called a solution.

One characteristic of a liquid is that it will fill up the shape of a container. If you pour some water in a cup, it will fill up the bottom of the cup first and then fill the rest. The water will also take the shape of the cup. It fills the bottom first because of **gravity**. The top part of a liquid will usually have a flat surface. That flat surface is because of gravity too. Putting an ice cube (solid) into a cup will leave you with a cube in the middle of the cup; the shape won't change until the ice becomes a liquid.

Another trait of liquids is that they are difficult to compress. When you compress something, you take a certain amount and force it into a smaller space. Solids are very difficult to compress and gases are very easy. Liquids are in the middle but tend to be difficult. When you compress something, you force the atoms closer together. When pressure go up, substances are compressed. Liquids already have their atoms close together, so they are hard to compress. Many shock absorbers in cars compress liquids in tubes.



A special force keeps liquids together. Solids are stuck together and you have to force them apart. Gases bounce everywhere and they try to spread themselves out. Liquids actually want to stick together. There will always be the occasional evaporation where extra energy gets a molecule excited and the molecule leaves the system. Overall, liquids have **cohesive** (sticky) forces at work that hold the molecules together.

LOOKING FOR A GAS

Gas is everywhere. There is something called the atmosphere. That's a big layer of gas that surrounds the Earth. Gases are **random** groups of atoms. In solids, atoms and molecules are compact and close together. Liquids have atoms a little more spread out. However, gases are really spread out and the atoms and molecules are full of energy. They are bouncing around constantly.

CLOUDS ARE ACTUALLY LARGE AMOUNTS OF TINY WATER DROPLETS.

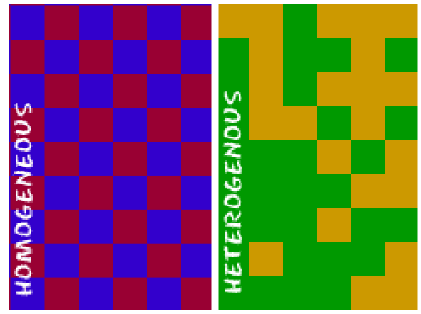
Gases can fill a container of any size or shape. That is one of their physical characteristics. Think about a balloon. No matter what shape you make the balloon it will be evenly filled with the gas atoms. The atoms and molecules are spread equally throughout the entire balloon. Liquids can only fill the bottom of the container while gases can fill it entirely.

You might hear the term **vapor**. Vapor and gas mean the same thing. The word vapor is used to describe gases that are usually found as liquids. Good examples are water or mercury (Hg). Compounds like carbon dioxide are usually gases at room temperature so scientists will rarely talk about carbon dioxide vapor. Water and mercury are liquids at room temperature so they get the vapor title.


PRESSURIZED GASES ARE ALL AROUND YOU.

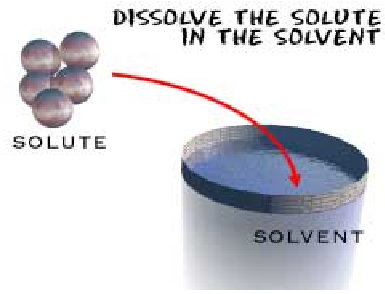
Gases hold huge amounts of energy, and their molecules are spread out as much as possible. With very little pressure, when compared to liquids and solids, those molecules can be **compressed**. It happens all of the time. Combinations of pressure and decreasing temperature force gases into tubes that we use every day. You might see compressed air in a spray bottle or feel the carbon dioxide rush out of a can of soda. Those are both examples of gas forced into a space smaller than it would want, and the gas escapes the first chance it gets.

SOLUTIONS AND MIXTURES



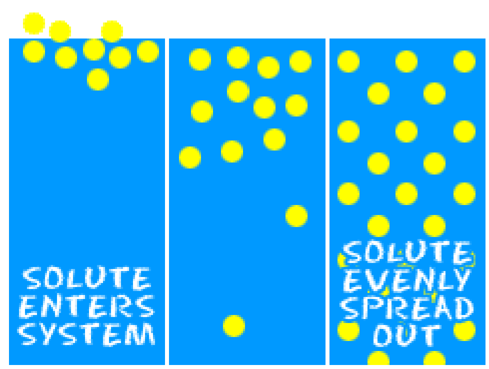
Before we dive into solutions, let's separate solutions from other types of mixtures. Solutions are groups of molecules that are mixed up in a completely even distribution. Hmmm. Not the easiest way to say it. Scientists say that solutions are **homogenous** systems. Other types of mixtures can have a little higher concentration on one side of the liquid when compared to the other side. Solutions have an even concentration throughout the system. An example: Sugar in water vs. Sand in water. Sugar dissolves and is spread throughout the glass of water. The sand sinks to the bottom. The sugar-water could be considered a solution. The sand-water is a mixture.

CAN ANYTHING BE IN SOLUTION?



Pretty much. Solutions can be solids dissolved in liquids. They could also be gases dissolved in liquids (such as carbonated water). There can also be gases in other gases and liquids in liquids. If you mix things up and they stay at an even distribution, it is a solution. You probably won't find people making solid-solid solutions in front of you. They start off as solid/gas/liquid-liquid solutions and then harden at room temperature. Alloys with all types of metals are good examples of a solid solution at room temperature. A simple solution is basically two substances that are going to be combined. One of them is called the **solute**. A solute is the substance to be dissolved (sugar). The other is a **solvent**. The solvent is the one doing the dissolving (water). As a rule of thumb, there is usually more solvent than solute.

MAKING SOLUTIONS



So what happens? How do you make that solution? Mix the two liquids and stir. It's that simple. Science breaks it into three steps. When you read the steps, remember... Solute=Sugar, Solvent=Water, System=Glass.

1. The solute is placed in the solvent and the concentrated solute slowly breaks into pieces.
2. The molecules of the solvent begin to move out of the way and they make room for the molecules of the solute. Example: The water has to make room for the sugar molecules.
3. The solute and solvent interact with each other until the concentration of the two substances is equal throughout the system. The concentration of sugar in the water would be the same from a sample at the top, bottom, or middle of the glass.

CAN ANYTHING CHANGE SOLUTIONS?

Sure. All sorts of things can change the concentrations of substances in solution. Scientists use the word solubility. Solubility is the ability of the solvent (water) to dissolve the solute (sugar). You may have already seen the effect of temperature in your classes. Usually when you heat up a solvent, it can dissolve more solid materials (sugar) and less gas (carbon dioxide). Next on the list of factors is pressure. When you increase the surrounding pressure, you can usually dissolve more gases in the liquid. Think about your soda can. They are able to keep the fizz inside because the contents of the can are under higher pressure. Last is the structure of the substances. Some things dissolve easier in one kind of substance than another. Sugar dissolves easily in water; oil does not. Water has a low **solubility** when it comes to oil.

ALLOYS

There are a few more words you might hear when people talk about **mixtures**. We can't cover all of them, but we'll give you a quick overview of the biggies. **Alloys** are basically a mixture of two or more metals. Don't forget that there are many elements on the periodic table. Elements like calcium (Ca) and potassium (K) are considered metals. Of course, there are also metals like silver (Ag) and gold (Au). You can also have alloys that include small amounts of non-metallic elements like carbon (C). **Metals** are the key thing to remember for alloys.

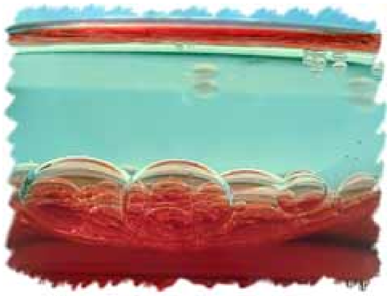
SOME FILLINGS IN YOUR TEETH ARE MADE OF AMALGAMS.

The main idea with alloys is that they are better at something than any of the metals would be alone. Metallurgists (people who work with metals) sometimes add chromium (Cr) and/or nickel (Ni) to steel. While steel is already an alloy that is a very strong metal, the addition of small amounts of the other metals help steel resist rusting. Depending on what element is added, you could create Stainless Steel or Galvanized Steel. It's always about improving specific qualities of the original. Another good example of an alloy happens when metallurgists add carbon (C) to steel. A tiny amount of carbon (a non-metallic element) make steel stronger. These special carbon-steel alloys are used in armor plating and weapons.

AMALGAMS

Amalgams are a special type of alloy. We like them because we think mercury (Hg) is a cool element. You might know **mercury** as "quicksilver" or the metal that is liquid at room temperature. Anyway, amalgams are alloys that combine mercury and other metals in the periodic table. The most obvious place you may have seen amalgams is in old dental work. The fillings in the mouths of your grandparents may have been amalgams. We already talked about mercury's being a liquid at room temperature. That physical trait was used when they made fillings. Let's say you have an amalgam of mercury (Hg) and silver (Ag). When it is created, it is very soft. As time passes, the mercury leaves the amalgam and the silver remains. The silver that is left is very hard. Voila! You have a filling!

NOTE: Never, ever, play with mercury (Hg)! It is very poisonous. You shouldn't even touch it because it will seep into your skin. Dentists don't usually use amalgams with mercury anymore because it may have slowly poisoned people and gotten them sick.



AS TIME PASSES, EMULSIONS BEGIN TO SETTLE AND SEPARATE.

EMULSIONS

Let's finish up with a little information on emulsions. These special **colloids** (another type of mixture) have a mixture of oils and waters. Think about a bottle of salad dressing. Before you mix it, there are two separate layers of liquids. When you shake the bottle, you create an emulsion. As time passes, the oil and water will separate to their original states.

Atoms Around Us

If you want to have a language, you will need an alphabet. If you want to build proteins, you will need amino acids. Examples in chemistry are not any different. If you want to build molecules, you will need elements. Each element is a little bit different from the rest. Those elements are the alphabet to the language of molecules.

Why are we talking about elements? This is the section on atoms.

Let's stretch the idea a bit. If you read a book, you will read a language. Letters make up that language. But what makes those letters possible? Ummm… Ink? Yes! You need ink to crate the letters. And for each letter, it is the same type of ink.

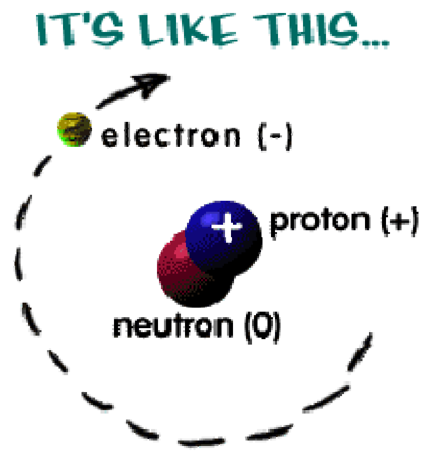
Confused? Don't be. Elements are like those letters. They have something in common. That's where atoms come in. All elements are made of atoms. While the atoms may have different weights and organization, they are all built in the same way. Electrons, protons, and neutrons make the universe go.

If you want to do a little more thinking, start with particles of matter. Matter, the stuff around us, is used to create atoms. Atoms are used to create the elements. Elements are used to create molecules. It just goes on. Everything you see is built using something else.

You could start really small...
- Particles of matter
- Atoms
- Elements
- Molecules
- Macromolecules
- Cell organelles
- Cells
- Tissues
- Organs
- Systems
- Organisms
- Populations
- Ecosystems
- Biospheres
- Planets
- Planetary Systems with Stars
- Galaxies
- The Universe

…And finish really big.

Wow. All of that is possible because of atoms.



ATOMS = BUILDING BLOCKS

Atoms are the basis of chemistry. They are the basis for everything in the Universe. You should start by remembering that matter is composed of atoms. Atoms and the study of atoms are a world unto themselves. We're going to cover basics like atomic structure and bonding between atoms. As you learn more, you can move to the biochemistry tutorials and see how atoms form compounds that help the biological world survive.

SMALLER THAN ATOMS?

Are there pieces of matter that are smaller than atoms? Sure there are. You'll soon be learning that atoms are composed of pieces like neutrons, electrons, and protons. But guess what? There are even smaller particles moving around in atoms. These super-small particles can be found inside the protons and neutrons. Scientists have many names for those pieces, but you may have heard of **nucleons** and **quarks**. Nuclear chemists and physicists work together with particle accelerators to discover the presence of these tiny, tiny, tiny pieces of matter.

Even though those super tiny atomic particles exist, there are three basic parts of an atom. The parts are the **electrons**, **protons**, and **neutrons**. What are electrons, protons, and neutrons? A picture works best. You have a basic atom. There are three pieces to an atom. There are electrons, protons, and neutrons. That's all you have to remember. Three things! As you know, there are over 100 elements in the **periodic table**. The thing that makes each of those elements different is the number of electrons, protons, and neutrons. The protons and neutrons are always in the center of the atom. Scientists call the center of the atom the **nucleus**. The electrons are always found whizzing around the center in areas called orbitals.

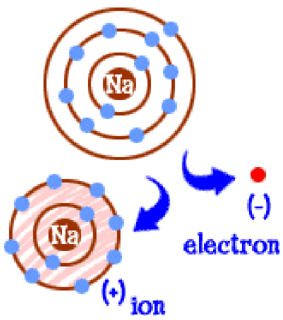
You can also see that each piece has either a "+", "-", or a "0." That symbol refers to the charge of the particle. You know when you get a shock from a socket, static electricity, or lightning? Those are all different types of electric charges. There are even charges in tiny particles of matter like atoms. The electron always has a "-" or negative charge. The proton always has a "+" or positive charge. If the charge of an entire atom is "0", that means there are equal numbers of positive and negative pieces, equal numbers of electrons and protons. The third particle is the neutron. It has a neutral charge (a charge of zero).

LOOKING AT IONS

We've talked about ions before. Now it's time to get down to basics. Ions are atoms with either extra electrons or missing electrons. A normal atom is called a neutral atom. That term describes an atom with a number of electrons equal to the **atomic number**.

What do you do if you are a sodium (Na) atom? You have eleven electrons, one too many to have your shell filled. You need to find another element who will take that electron away from you. Bring in chlorine (Cl). Chlorine (Cl) will take that electron away and leave you with 10 electrons inside of two filled shells. You are a happy atom. Now you are also an ion and missing one electron. You are a sodium ion (Na+). You have one less electron than your atomic number.

ION CHARACTERISTICS



So now you've become a sodium ion (Na+). Now you have ten electrons. That's the same number as neon (Ne). But you aren't neon (Ne). Since you're missing an electron you aren't really a complete sodium (Na) atom either. You are now something completely new. An ion. Your whole goal as an atom was to become a "happy atom" with completely filled **electron orbitals**. Now you have those filled shells. You are stable. What do you do that's so special now? Now that you have given up the electron, you are quite electrically attractive. Other electrically charged atoms (ions) are now looking at you and seeing a good partner to bond with. That's where chlorine comes in.

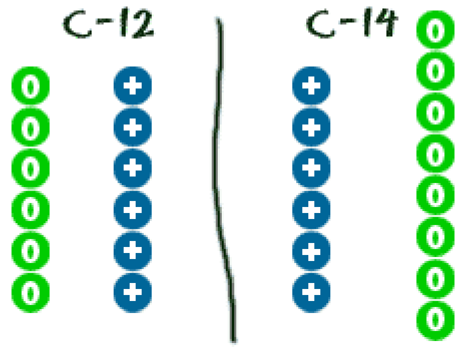
ELECTROVALENCE

Don't get worried about the big word. **Electrovalence** is just another word for something that has given up its electron and become an ion. If you look at the periodic table, you might notice that elements on the left side usually become positively charged ions and elements on the right side get a negative charge. That trend means the left side has a positive valence and the right side has a negative valence. Valence is a measure of how much an atom wants to bond with other atoms.

There are two main types of bonding, **covalent** and **electrovalent**. Scientists also call ionic bonds electrovalent bonds. **Ionic bonds** are just groups of charged ions held together by electric forces. Scientists call these groups ionic agglomerates. When in the presence of other ions, the electrovalent bonds are weaker because of outside electrical forces and attractions.

Look at sodium chloride (table salt) as an example. Salt is a very strong bond when it is sitting on your table. It would be nearly impossible to break those ionic bonds. However, if you put that salt into some water the bonds break very quickly. It happens easily because of the electrical attraction of the water. Now you have sodium (Na+) and chloride (Cl-) ions. Remember that ionic bonds are normally strong but very weak in water.

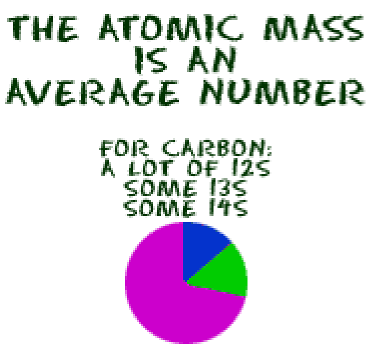
NEUTRON MADNESS



We have already learned that ions are atoms that are either missing or have extra electrons. Let's say an atom is missing a neutron or has an extra **neutron**. That type of atom is called an **isotope**. An atom is still the same element if it is missing an electron. The same goes for isotopes. They are still the same element. They are just a little different from every other atom of the same element.

There are a lot of carbon atoms in the universe. The normal ones are carbon-12. Those atoms have 6 neutrons. There are a few straggler atoms that don't have 6. Those odd ones may have 7 or even 8 neutrons. As you learn more chemistry, you will probably hear about carbon-14. Carbon-14 actually has 8 neutrons (2 extra). C-14 is considered an isotope of the element carbon.

MESSING WITH THE MASS



If you have looked at a periodic table you may have noticed that the atomic mass of an element is rarely an even number. That happens because of the isotopes. If you are an atom with an extra electron, it is no big deal. Electrons don't have much of a mass when compared to a neutron or proton.

Atomic masses are calculated by figuring out how many atoms of each type are out there in the universe. For carbon, there are a lot of C-12, a couple C-13, and a few C-14 atoms. When you average out all of the masses, you get a number that is a little bit higher than 12 (the weight of a C-12 atom). The mass for element is actually 12.011. Since you never really know which C atom you are using in calculations, you should use the mass of an average C atom.

RETURNING TO NORMAL

If we look at the C-14 atom one more time we can see that C-14 does not last forever. There is a point where it loses those extra neutrons and becomes C-12. That loss of the neutrons is called **radioactive decay**. That decay happens regularly like a clock. For carbon, the decay happens in a couple of thousand years. Some elements take longer and others have a decay that happens over a period of minutes.

COMPOUND BASICS

Compounds are groups of two or more elements that are bonded together. There are two main types of bonds that hold those atoms together, covalent and electrovalent/ionic bonds. **Covalent** compounds happen when the atoms share the electrons, and **ionic** compounds happen when electrons are donated from one atom to another.

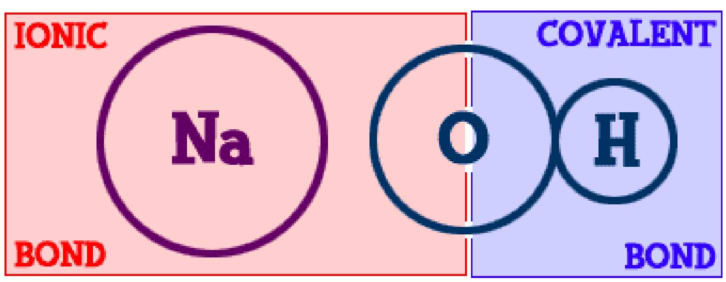
We talked about compounds and molecules in the matter tutorials. When we discuss **phase changes** to matter, physical forces create the changes. When we talk about compounds, bonds are built and broken down by chemical forces. **Physical forces** (unless you're inside of the Sun or something extreme) cannot break down compounds. **Chemical forces** are forces caused by other compounds or molecules that act on substances.

There are millions of different compounds around you. Chances are everything you can see is one type of compound or another. When elements join and become compounds, they lose their individual traits. Sodium alone is very reactive. But when sodium and chlorine combine, they form a non-reactive substance called sodium chloride (Salt, NaCl). The compound has none of the traits or the original elements. The new compound is not as reactive as the original elements. It has a new life of its own.

DIFFERENT BONDS ABOUND

Most compounds are made up of combinations of bonds. If you look at sodium chloride (NaCl), it is held together by one ionic bond. What about magnesium chloride (MgCl2)? One magnesium (Mg) and two chlorine (Cl) atoms. There are two ionic bonds. There's a compound called methane (CH<SUB< sub>4). It is made up of one carbon (C) and four hydrogens (H). There are four bonds and they are all covalent. Those examples are very simple compounds, but most compounds are combinations of ionic and covalent bonds.

Let's look at sodium hydroxide (Na-OH)…

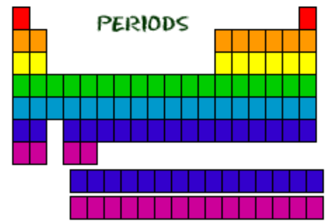


You can see that on the left is the sodium (Na) part and the right has the oxygen/hydrogen (-OH) part. The bond that binds the hydrogen (H) to the oxygen (O) is covalent. The sodium (Na) is bonded to the hydroxide part of the compound with an ionic bond. This is a very good example of how there can be different types of bonds within one compound.

Elements as Building Blocks

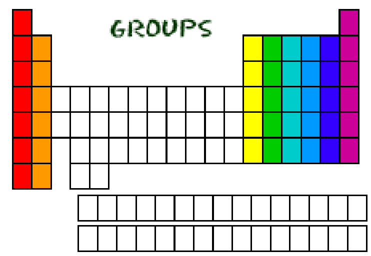
As you probably saw, the **periodic table** is organized like a big grid. The elements are placed in specific places because of the way they look and act. If you have ever looked at a grid, you know that there are rows (left to right) and columns (up and down). The periodic table has rows and columns, too, and they each mean something different.

You've got Your Periods...



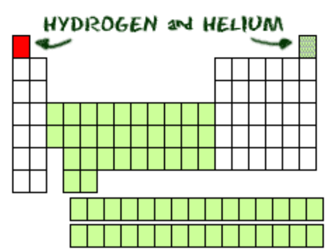
Even though they skip some squares in between, all of the rows go left to right. When you look at a periodic table, each of the rows is considered to be a different period (Get it? Like PERIODic table.). In the periodic table, elements have something in common if they are in the same row. All of the elements in a period have the same number of atomic orbitals. Every element in the top row (the first period) has one orbital for its electrons. All of the elements in the second row (the second period) have two orbitals for their electrons. It goes down the periodic table like that. At this time, the maximum number of electron orbitals or electron shells for any element is seven.

...and Your Groups



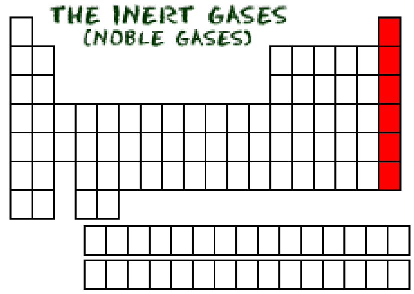
Now you know about periods. The periodic table has a special name for its columns, too. When a column goes from top to bottom, it's called a group. The elements in a group have the same number of electrons in their outer orbital. Every element in the first column (group one) has one electron in its outer shell. Every element on the second column (group two) has two electrons in the outer shell. As you keep counting the columns, you'll know how many electrons are in the outer shell. There are some exceptions to the order when you look at the transition elements, but you get the general idea.

Two at the Top



Hydrogen and helium are special elements. Hydrogen can have the talents and electrons of two groups, one and seven. To scientists, hydrogen is sometimes missing an electron, and sometimes it has an extra. Helium is different from all of the other elements. It can only have two electrons in its outer shell. Even though it only has two, it is still grouped with elements that have eight.

The elements in the center section are called transition elements. They have special electron rules.



THE NOBLE INERT GASES

We love the inert gases. Some scientists used to call them the **noble gases**. These gases are another family of elements, and all of them are located in the far right column of the periodic table. For all of you budding chemists, the far right is also known as Group Zero (Group 0) or Group Eighteen (Group XVIII). This family has the happiest elements of all.

WHY ARE THEY HAPPY?

Using the **Bohr** description of electron shells, happy atoms have full shells. All of the inert gases have full outer shells with eight electrons. Oh wait! That's not totally correct. At the top of the inert gases is little helium (He) with a shell that is full with two electrons. The fact that their outer shells are full means they are quite happy not reacting with other elements. In fact, they rarely combine with other elements. That nonreactivity is why they are called inert.

NEON IS USED
IN MANY STREET SIGNS.

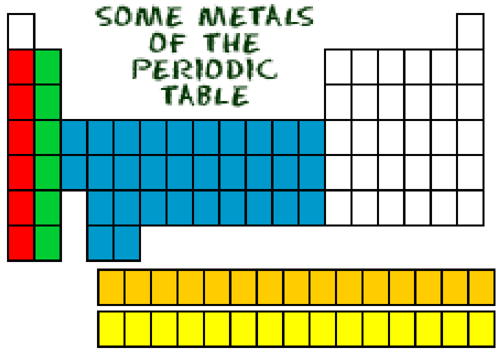
WHO'S IN THE FAMILY?

All of the elements in Group Zero are inert gases. The list includes Helium (He), Neon (Ne), Argon (Ar), Krypton (Kr), Xenon (Xe), and Radon (Rn). Don't think that because these elements don't like to react, we don't use them. You will find inert gases all over our world. Neon is used in advertising signs. Argon is used in light bulbs. Helium is used to cool things and in balloons. Xenon is used in headlights for new cars. When you move down the periodic table, as the atomic numbers increase, the elements become rarer. They are not just rare in nature but rare as useful elements, too.

BUT WAIT, THEY DO BOND!

Some do. As of about 40 years ago, scientists have been able to make some compounds with inert gases. Some have been used in compounds to make explosives and other just form compounds in a lab. The thing to remember is that they were forced. When going about their natural lives, you will never (never say never because there may be an exception) find the inert gases bonded with other elements.

METAL BASICS



We wanted to give you a big overview of **metals** before we talk about details in other tutorials. Almost 75% of all elements are classified as metals. They are not all like silver (Ag), gold (Au), or platinum (Pt). Those are the very cool and shiny ones. There are other metals like potassium (K) and iridium (Ir) that you might not think about right away.

MANY KINDS OF METALS

How many kinds of metals are there? So many. Don't even try to memorize them all. Just remember the ones you might need in class. Here's a quick list: Actinide Metals, Lanthanide Metals, Alkali Metals, Alkaline-Earth Metals, Noble Metals, Rare Metals, Rare-Earth Metals, and Transition Metals. Lucky for you the periodic table is excellent at organizing elements, and you will find each of these groups in specific areas of the periodic table.

HOW DO YOU IDENTIFY A METAL?

What are the characteristics of metals? We've got four traits that will help you identify whether an element is a metal or not.

BRONZE WAS ONE OF THE FIRST ALLOYS CRATED BY HUMANS.

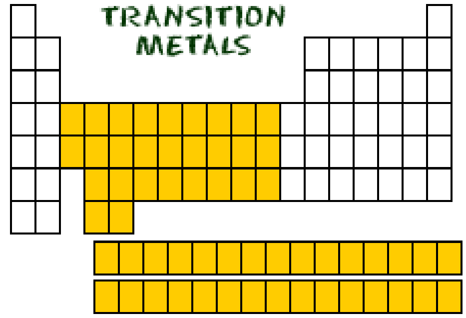
Conduction: Metals are good at conducting electricity. Silver (Ag) and copper (Cu) are some of the most efficient metals and are often used in electronics.

Reactivity: Metals are very reactive, some more than others, but most form compounds with other elements quite easily. Sodium (Na) and potassium (K) are some of the most reactive metals.

Chemical: A little complex here. Metals usually make positive ions when the compounds are dissolved in solution. Also, their metallic oxides make hydroxides (bases) (OH-) and not acids when in solution. Think about this example. Sodium chloride (NaCl), when dissolved in water, breaks apart into sodium (Na+) and chlorine (Cl-). See that sodium is the positive ion? Sodium is the metal. It works that way for other metals. Potassium chlorine (KCl) works the same way.

Alloys: Metals are easily combined. Mixtures of many elements are called alloys. Examples of alloys are steel and bronze.

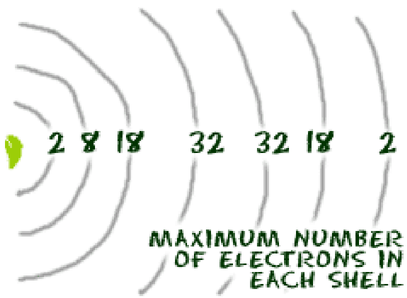
TRANSITIONING



Lets start off by telling you that there are a lot of elements that are considered **transition metals**. Which metals are the transition metals?
21 (Scandium) through 29 (Copper)
39 (Yttrium) through 47 (Silver)
57 (Lanthanum) through 79 (Gold)
89 (Actinium) and all higher numbers.

WHAT MAKES THEM SO SPECIAL?

It all has to do with their shells/**orbitals**. In **CHEM4KIDS** we try to stick to the first 18 elements because they are easy to explain. Transition metals are good examples of advanced shell ideas. They have a lot of electrons and distribute them in different ways.



Transition metals are able to put more than eight **electrons** in the shell that is one in from the outermost shell. Think about argon (Ar). It has 18 electrons set up in a 2-8-8 order. Scandium is only 3 spots away with 21 electrons, but it has a configuration of 2-8-9-2. Wow! This is where it starts. This is the point in the periodic table where you can place more than 8 electrons in a shell.

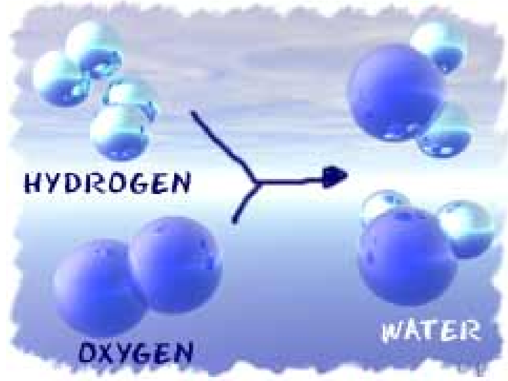
The transition metals are able to put up to 32 electrons in their second to last shell. Something like gold (Au) has an organization of 2-8-18-32-18-1. Of course, there are still some rules. No shell can have more than 32 electrons. It's usually 18 or 32 for the maximum number of electrons.

ONE MORE THING

Most elements can only use electrons from their outer orbital to bond with other elements. Transition metals can use the two outermost shells/orbitals to bond with other elements. It's a chemical trait that allows them to bond with many elements in a variety of shapes. Why can they do that?

As you learn more, you will discover that most transition elements actually have two shells that are not happy. Whenever you have a shell that is not happy, its electrons can bond with other elements. Example: Molybdenum (Mo) with 42 electrons. The configuration is 2-8-18-13-1. The shells with 13 and 1 are not happy. Those two orbitals can use the electrons to bond with other atoms.

Chemical Reactions



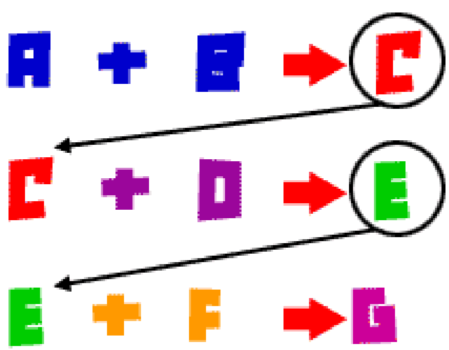
HYDROGEN AND OXYGEN MOLECULES COMBINE TO FORM WATER.

Let's start with the idea of a reaction. In chemistry, a reaction happens when two or more molecules **interact** and something happens. That's it. What molecules are they? How do they interact? What happens? Those are all the possibilities in reactions. The possibilities are infinite. There are a few key points you should know about chemical reactions.

Key Points

1. A chemical change must occur. You start with one compound and turn it into another. That's an example of a chemical change. A steel garbage can rusting is a chemical reaction. That rusting happens because the iron in the metal combines with oxygen in the atmosphere. A refrigerator or air conditioner cooling air is not a reaction. That is a physical change. Nevertheless, a chemical reaction can happen inside of the air conditioner.

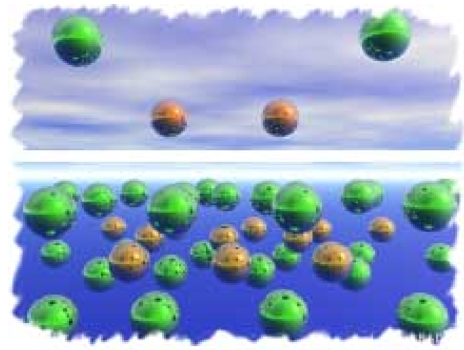
2. A reaction could include ions, molecules, or pure atoms. We said molecules in the previous paragraph, but a reaction can happen with anything, just as long as a chemical change occurs (not a physical one). If you put pure hydrogen gas and pure oxygen gas in a room, they can be involved in a reaction. The slow reaction will have the atoms bonding to form water very slowly. If you were to add a spark, those gases would create a reaction that would result in a huge explosion.



3. Single reactions often happen as part of a larger series of reactions. Take something as simple as moving your arm. The contraction of that muscle requires sugars for energy. Those sugars need to be **metabolized**. You'll find that **proteins** need to move in a certain way to make the muscle contract. A whole series (hundreds actually) of different reactions are needed to make the movement happen.

RATES OF REACTIONS

The rate of a reaction is the speed at which a reaction happens. If a reaction has a low rate, that means the molecules combine at a slower speed than a reaction with a high rate. Some reactions take hundreds, maybe even thousands of years while other can happen in less than one second. The rate of reaction depends on the type of molecules that are combining.



MOLECULES ON UPPER LAYER HAVE A LOWER CHANCE OF COMBINING.

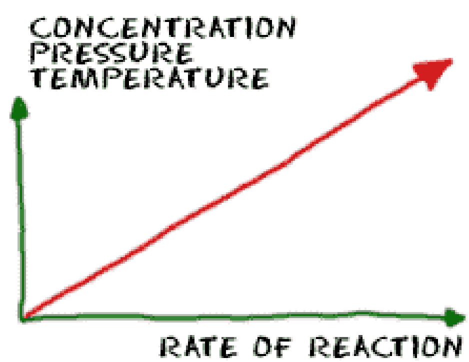
There is another big idea for rates of reaction called **collision theory**. The collision theory says that the more collisions in a system, the more likely combinations of molecules will happen. If there are a higher number of collisions in a system, more combinations of molecules will occur. The reaction will go faster, and the rate of that reaction will be higher.

Reactions happen, no matter what. Chemicals are always combining or breaking down. The reactions happen over and over but not always at the same speed. A few things affect the overall speed of the reaction and the number of collisions that can occur.

Concentration: If there is more of a substance in a system, there is a greater chance that molecules will collide and speed up the rate of the reaction. If there is less of something, there will be fewer collisions and the reaction will probably happen at a slower speed.

Temperature: When you raise the temperature of a system, the molecules bounce around a lot more (because they have more energy). When they bounce around more, they are more likely to collide. That fact means they are also more likely to combine. When you lower the temperature, the molecules are slower and collide less. That temperature drop lowers the rate of the reaction.

Pressure: Pressure affects the rate of reaction, especially when you look at gases. When you increase the pressure, the molecules have less space in which they can move. That greater concentration of molecules increases the number of collisions. When you decrease the pressure, molecules don't hit each other as often. The lower pressure decreases the rate of reaction.



EQUILIBRIUM BASICS

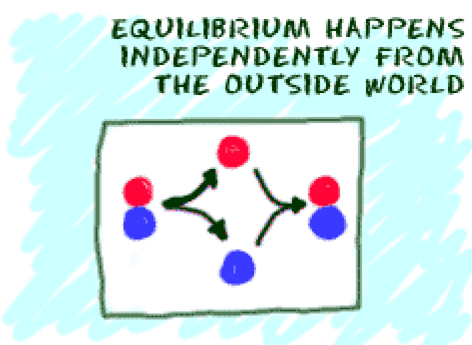
REACTANTS AND PRODUCTS COMBINE AND BREAK APART IN ALL REACTIONS.

Equilibrium is a pretty easy topic. Big name, but easy idea. First, when you have a system made up of a bunch of molecules, those molecules sometimes combine. That's the idea of a chemical reaction. Second, a **chemical reaction** sometimes starts at one point and moves to another. Now imagine the reaction finished and you have a pile of new chemicals. Guess what? Those chemicals want to go through a reverse chemical reaction and become the original molecules. We don't know why. Sometimes they just do.

Put those two ideas together and you have equilibrium.
1. Two **reactants** combine to make a **product**.
2. Products like to break apart and turn back into the reactants.
3. There is a point where those two reactions happen and you can't tell that any reactions are occurring. That point is when the overall reaction is happy. There is no pressure to do more of one thing or another.

There are some other traits of equilibrium. Equilibrium always happens at the same point in the reaction no matter where you start. So if you start with all of substance A, it will break up and become B and C. Eventually, B and C will start combining to become A. Those reactions happen until they reach equilibrium. They reach equilibrium at the same point if you start with all B and C or half A and half B/C. It doesn't matter. There is one special point where the two reactions cancel each other out.

IT HAPPENS ON ITS OWN

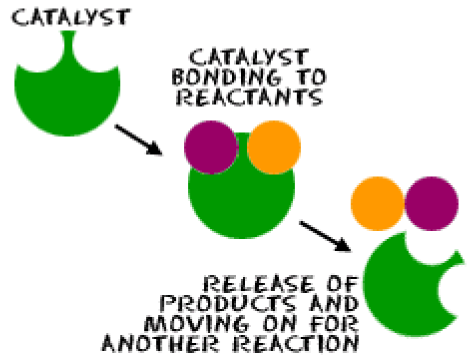


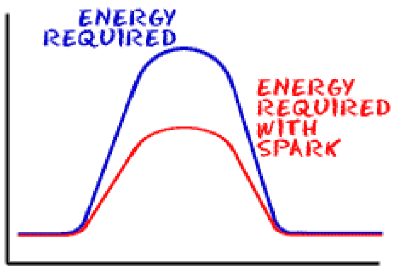
Another idea is that equilibrium is reached by itself with no outside forces acting on the system. If you put two substances in a mixture, they will combine and react by themselves. Eventually, they will reach equilibrium. Scientists say equilibrium happens through **spontaneous** processes. They happen on their own.

There is one last idea. Do you remember that some atoms and molecules have charges? A system "at equilibrium" appears to have no charge (**neutral**). All the pluses and minuses cancel each other out and give a total charge of "0". Scientists use the letter "K" to add up all of the actions and conditions in a reaction. That "K" is the equilibrium constant.

CATALYSTS SPEED IT UP

A catalyst is like adding a bit of magic to a reaction. Reactions need a certain amount of energy to happen. If they don't have it, oh well, the reaction probably can't happen. A catalyst lowers the amount of energy needed so that a reaction can happen easier. A catalyst is about energy; it doesn't have to be another molecule. If you fill a room with hydrogen gas and oxygen gas, very little will happen. If you light a match in that room (or just a spark), all of the hydrogen and oxygen will combine to create water molecules. It is an explosive reaction.



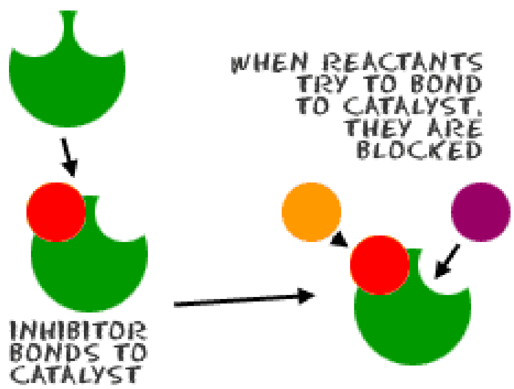


The energy needed to make a reaction happen is called the **activation energy**. As everything moves around, energy is needed. The energy a reaction needs is usually in the form of heat. When a catalyst is added, something special happens. Maybe a molecule shifts it's structure. Maybe that catalyst makes two molecules combine and they release a ton of energy. That extra energy might help another reaction to occur. In our earlier example, the spark added the **activation energy**.

Catalysts are also used in the human body, not to cause explosions but to make very difficult reactions happen. They help very large molecules combine. There is another interesting fact about catalysts. Catalysts lower the activation energy required for a reaction to occur. With the activation energy lower, the products can also combine more easily. Therefore, the forward and reverse reactions are both accelerated. It helps both reactions.

INHIBITORS SLOW IT DOWN

There is also something called an inhibitor that works exactly the opposite of catalysts. Inhibitors slow the rate of reaction. Sometimes they even stop the reaction completely. You might be asking, "Why would anyone need those?" You could use an inhibitor to make the reaction slower and more controllable. Without them, some reactions could keep going and going and going. If they did, all of the molecules would be used up. That would be bad, especially in your body.



Browsing Biochemistry

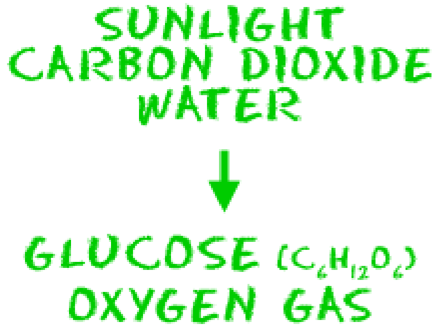
MANY BIOCHEMICAL PROCESSES ARE THE SAME IN ALL ORGANISMS.

If you had visited Biology4Kids you may recognize this section. We felt it was more appropriate to have the biochemistry section here on Chem4Kids. It is one of the crossover fields of chemistry. Biochemists have to understand both the living world and the chemical world to be the best at their jobs.

The key thing to remember is that biochemistry is the chemistry of the living world. Plants, animals, single-celled organisms... They all use the same basic chemical **compounds** to live their lives. Biochemistry is not about the cells or the organisms. It's about the smallest parts of those organisms, the molecules. It's also about the **cycles** that happen to make those compounds.

Those cycles that repeat over and over are the things that allow living creatures to survive on this planet. It could be the constant process of **photosynthesis** in plants or the building of complex proteins in the cells of your body. Every cycle has a place and they are just one building block to help organisms live. In each of those cycles, molecules are needed and changed. It's one big network of activity where each piece relies on all of the others.

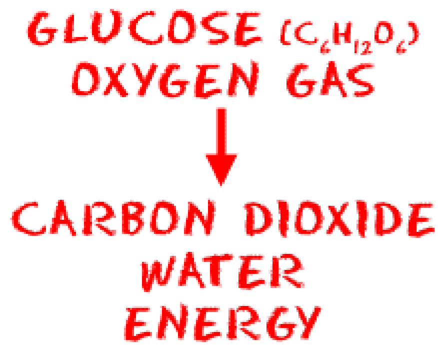
METABOLISM



Metabolism is such a big word to explain a simple idea. We all need energy to survive. Plants, animals, or bacteria, we all need energy. Energy doesn't just float around in a form we can use to survive. We need to eat (mainly sugars) and **digest** food. That process of chemical digestion and its related reactions is called metabolism. Metabolism is the total of all of the chemical reactions an organism needs to survive.

Sounds a lot like biology. Why's it here in biochemistry? Two main chemical processes make our world go round. There are two simple chemical **reactions**. The first is called glycolysis. That's the breakdown of sugars. The second process is called **photosynthesis**. That is the reaction that builds sugars. You need to remember that the overall metabolism of an organism includes thousands of chemical reactions. **Glycolysis** and photosynthesis are the cornerstones to life.

BUILDING UP



First, you need to build up the molecules that store energy. We'll start with photosynthesis. It's no use explaining the breakdown of sugars without telling you how they were made.

LIGHT (Energy) + CO_2 + H_2O --> $C_6H_{12}O_6$ + O_2

This is the reaction that only plants can do (and some algae/bacteria). They take sunlight and combine carbon dioxide (CO_2) and water (H_2O). They create **Glucose** ($C_6H_{12}O_6$) and oxygen gas (O_2). Remember, plants put the energy in glucose.

BREAKING DOWN

It's metabolism and the process of glycolysis that takes that energy out of the sugar related molecules.

$C_6H_{12}O_6$ + O_2--> Usable Energy (ATP) + CO_2 + H_2O

Cells then use that extra energy to power the functions of the cell. The energy isn't still floating around; it's stored in an excitable compound called adenosine triphosphate (ATP). **ATP** is the power molecule used all over organisms and their cells to power the secondary reactions that keep us alive.

SWEET SWEET CARBS

PURE CANE SUGAR IS ONLY ONE EXAMPLE OF THE SUGARS AROUND YOU

Carbohydrate is a fancy way of saying "sugar." Scientists came up with the name because the compounds have many carbon atoms bonded to **hydroxide** groups. Carbohydrates can be very small or very large molecules, but they are still sugars. What are they used for?

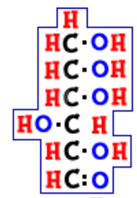
WHAT'S IT USED FOR?

A carbohydrate is called an organic compound because it contains carbon. Sugars provide living things with energy and act as substances used for structure. Some examples of structures might be the shell of a crab or the stem of a plant.

SACCHARIDES

Scientists also use the word saccharide to describe sugars. If there is only one sugar molecule, it is called a **monosaccharide**. If there are two, it is a **disaccharide**. If there are three, it is a trisaccharide. You get the idea.

SIMPLE SUGARS



Glucose

What about the simplest of sugars? A sugar called **glucose** is the most important monosaccharide on Earth. Glucose is used in cellular respiration and created by photosynthesis. When you think of table sugar, like the kind in candy, it is actually a disaccharide. The sugar on your dinner table is made of glucose and another monosaccharide called fructose.

POLYSACCHARIDES

When several carbohydrates combine, it is called a POLYsaccharide ("poly" means many). Hundreds of sugars can be combined in a chain. These chains are also known as starches. You can find starches in foods such as pasta and potatoes. They are very good sources of energy for your body.

SUGARS IN STRUCTURES

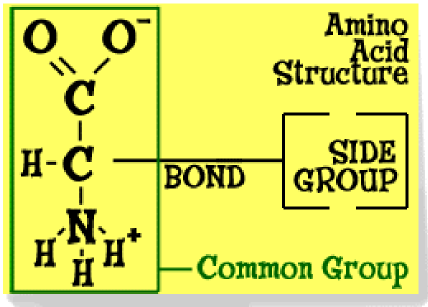
THE CHITIN IN THE SHELLS OF CRUSTACEANS IS A CARBOHYDRATE.

An important structural polysaccharide is cellulose. **Cellulose** is found in plants. It is one of those carbohydrates used to support or protect an organism. Cellulose is in wood and the cell walls of plants. You know that shirt you're wearing? If it is cotton, that's cellulose, too!

Polysaccharides are also used in the shells of such crustaceans as crabs and lobsters (**chitin**). It is similar in some ways to the structure of cellulose but has a far different use. The shells are solid, protective structures that need to be molted (left behind) when the crustacean needs to grow. It is very inflexible. On the other hand, it is very resistant to damage. While a plant may burn, it takes very high temperatures to hurt the shell of a crab.

ACIDS IN PROTEINS?

The first thing you might be asking is, "What is an amino acid?" There are over twenty, and each one of them is a little different. Amino acids are used in every cell of your body and are used to build the proteins you need to survive. All organisms need some proteins, whether they are used in muscles or as simple structures in the cell membrane. Even though all organisms have differences, they still have one thing in common, the need for basic chemical building blocks.



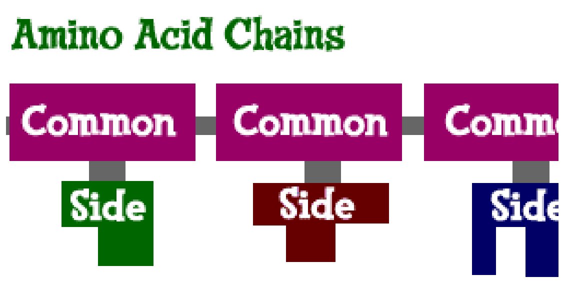
Amino acids have a two-carbon bond. One of the carbons is part of a group called the **carboxyl group**. A carboxyl group is made up of one carbon (C), two oxygens (O), and one hydrogen atom (H). The carboxyl group is acidic. The second carbon is a part of the amino group. Amino means there is an NH_2 group bonded to the carbon atom. In the image you see a "+" and a "-." Those positive and negative signs are there because, in amino acids, one hydrogen atom moves to the other end of the molecule. An extra "H" gives you a positive charge.

MAKING CHAINS

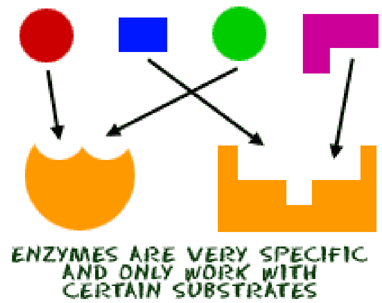
Even though scientists have discovered over 50 amino acids, only 20 are used to make something called proteins in your body. Of those twenty, eight are defined as essential. The other twelve can be synthesized by an adult body. Thousands of combinations of those twenty are used to make all of the proteins in your body. Amino acids bond together to make long chains and those long chains of amino acids are also called proteins.

SOMETHING CALLED SIDE GROUPS

The **side groups** are what make each amino acid different from the others. Of the 20 used to make proteins, there are three groups. The three groups are ionic, polar and non-polar. These names refer to the way the side groups (sometimes called "R" groups) interact with the environment. **Polar** amino acids like to adjust themselves in a certain direction. **Non-polar** amino acids don't really care what's going on around them. You already know about ions and things that are ionic. The **ionic** amino acids should be easy to understand.



ENZYMES MAKE THE WORLD GO 'ROUND

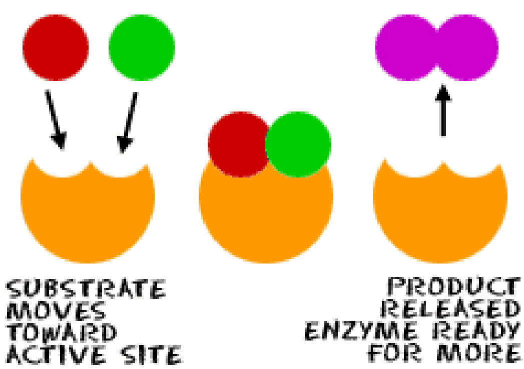


On Chem4Kids, we often talk about **reactions** and the molecules that change in those reactions. Those changes don't happen on their own. If you leave a blob of protein in a Petri dish, will it just break down to the amino acids? No. What will do it? Enzymes! Enzymes are the biological substance (proteins) that act as **catalysts** and help complex reactions occur everywhere in life.

LOCKS AND KEYS

When you go home at night and the door is locked, can it open itself? Nope. You need a key that is just the right shape to fit in that lock. Otherwise, you're stuck in the cold. Enzymes work in a similar way (locks and keys). Enzymes complete very specific jobs and do nothing else. They are very specific locks and the compounds they work with are the special keys. In the same way there are door keys, car keys, and bike-lock keys, there are enzymes for neural cells, intestinal cells, and your saliva.

Here's the deal: there are four steps in the process of an enzyme working.



1. An enzyme and a substrate are in the same area. The substrate is the biological molecule that the enzyme will attack.
2. The enzyme grabs onto the substrate with a special area called the active site The active site is a specially shaped area of the enzyme that fits around the substrate. The active site is the keyhole of the lock.
3. A process called catalysis happens. Catalysis is when the substrate is changed. It could be broken down or combined with another molecule to make something new.
4. The enzyme lets go. Big idea. When the enzyme lets go, it returns to normal, ready to do another reaction. The substrate is no longer the same. The substrate is now called the product.

CAN YOU STOP THEM?

Good question! We know what you're thinking. What if enzymes just kept going and converted every molecule in the world? They would never stop... like a monster! There are many factors that can regulate enzyme activity, including temperature, **activators**, pH levels, and **inhibitors**.

Science loves units. But then again, they are a necessity. If you are going to measure something you will need a way to tell people how much you have. Here are only a few we use in chemistry...

PERCENTAGES

When you need to know how much of something you have compared to the whole amount. It is figured out by taking a decimal number and multiplying by 100.
"I have 20% of what I started with." That means you lost 80%. L-L-Loser!

GRAMS, KILOGRAMS, MILLIGRAMS

These are measures of mass.
"This candy bar has a mass of only a few grams."

LITERS, MILLILITERS

These are measures of volume.
"I just bought a 2 liter bottle of soda."

CELSIUS, FAHRENHEIT AND KELVIN

These are different measurements scientists use for temperatures.
"It's freezing outside." That could mean it is 0oC, 32oF, or 273K (just Kelvins, no degrees).

ATOMIC MASS UNITS

The way to measure the mass of different atoms.
"Carbon-12 weighs 12 AMU."

CALORIES

A unit of energy.
"A calorie is the amount of energy needed to raise the temperature of 1 gram of water 1 degree Celsius."

JOULES

It is a unit of energy.
"4.18 Joules is the same as 1 Calorie."

SECONDS, MINUTES AND HOURS

Measures of time.
"There are 60 seconds in a minute and 60 minutes in an hour."

CONSTANTS IN CHEMISTRY

First we have to tell you what a constant is. Simply put... A constant is a number or measurement that is always the same. No matter where, when, or what condition. When you have a formula which asks for a constant it is always the same number. Here are some examples...

N_A **6.02×10^{23}**

NAME: Avogadro's Number

WHAT: It tells you the number of atoms in a mole or the number of molecules in a mole of a substance.

m_e **9.1×10^{-31}kg**

NAME: Mass of an Electron

WHAT: We talk about electrons spinning around the nucleus of an atom. Well the m_e is the mass of one of those electrons.

m_n **1.675×10^{-24}g**

NAME: Mass of a Neutron

WHAT: In the nucleus of an atom there are neutrons and protons. A neutron has this much mass.

m_p **1.673×10^{-24}g**

NAME: Mass of a Proton

WHAT: In the nucleus of an atom there are neutrons and protons. A proton a mass of this amount.

h **6.63×10^{-34}Js**

NAME: Planck's Constant

WHAT: Max Planck figured out that energy can be gained and lost by an atom. He used this constant to figure out how much energy. The "J" stands for Joules.

c **3×10^{8}m/s**

NAME: Speed of Light (in a vacuum)

WHAT: Scientists figured out that light always travels at the same speed in a vacuum. The number is really 299,792,458 meters per second, but we abbreviate it.

g **$9.8\ m/s^2$**

NAME: Acceleration of Gravity of Earth

WHAT: What if you drop a ball from a height? It speeds up as it falls. The amount it speeds up (acceleration) is because of gravity.

amu **$1.66 \times 10^{-27} kg$**

NAME: Atomic Mass Unit (also called a Dalton)

WHAT: It is 1/12 the mass of a Carbon-12 atom. It is the basis for figuring out the mass all other atoms.

e **$1.6 \times 10^{-19} C$**

NAME: Charge of an Electron

WHAT: This is the charge of one electron flying around the nucleus.

R **.082 Latm/molK**

8.3 J/molK

1.987 cal/Kmol

NAME: Universal Gas Constant

WHAT: This constant is used in the Universal Gas Law "PV=nRT". It has the same value for all gases. You use a different value depending on what measurements your formula uses.

CAREERS THAT USE CHEMISTRY

Not only are there all of these specialties to the large field of chemistry, there are loads of career paths you could choose. Some are 100% chemistry while others use chemistry every day but focus on other work. Some examples...

DOCTOR

You all know what a doctor is. Doctors have to know loads about biochemistry and the chemical reactions going on in your body. Not only how they work normally but what happens when they go wrong. They also have to understand how drugs affect your body's systems.

PHARMACIST, PHARMACOLOGIST

There are the people at the drug store who fill your prescriptions. There are also the people who study pharmacology in school and learn how to create new drugs to cure diseases. Someone with a Pharmacology major might work in a lab all day studying and creating new compounds. There are then several years of testing to see how the compounds interact with the human body.

UNIVERSITY RESEARCHER

These are the folks who spend their whole careers working at a university focusing on one or two specific ideas in chemistry. They may also be teachers of chemistry classes. They can work in any part of chemistry, not just the world of chemistry in living things (like the above examples). They often spend many years in school getting their Ph.D. before they begin their own research.

FORENSICS EXPERT

These scientists work with law enforcement officials. They go to scenes of the crime, gather clues, bring them back to their labs and analyze them. An example might be a murder scene where someone tracked mud all over the carpet. The forensics expert could come and take a sample of the mud, analyze the elements and then compare it to a database of mud around the city. That might help the police figure out where the mud came from and lead them to the killer.

HAZARDOUS MATERIALS EXPERT

Here's another time where you might work with law enforcement. These folks have information on thousands of types of chemicals and how they react with people, fire and the air. When there is a spill or exposure somewhere they come and work with fire fighters to evacuate people, tell them it's okay or maybe help tell them how to contain the unidentified chemicals. They work with huge databases of chemical information.