Bio Honors # General Chemistry Notes **Name** ___________________________

Directions: Carefully read the following information. Look for the ** *directions in italics* for prompts where you can do some work. Use the information you have reviewed here to help answer questions in your "Chemistry Take-Home Test."**

Chemistry is the study of **atoms** and the reactions they undergo to form compounds. Every biological system can be reduced to the chemical level. Therefore, the study of biology must start at the chemical level. **Metabolic processes** like photosynthesis and cellular respiration are composed of a series of chemical reactions which involve the combinations of atoms to form new compounds. An understanding of these atoms and their chemical and physical properties will help in the understanding of the chemical reactions that take place in living things.

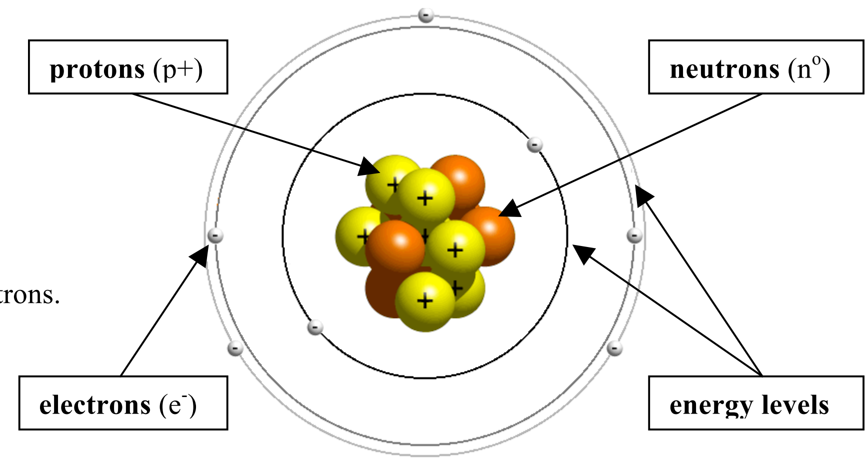
Everything on earth is made of matter. **Matter** is anything that occupies space (volume) and has mass (weight). The building blocks of matter are called atoms.

The Structure of an Atom:

An atom is made up of three basic particles.

1. Positively charged **protons** (p+)
2. Neutral **neutrons** (n^o)
3. Negatively charged **electrons** (e^-)

The **nucleus** is composed of protons and neutrons.



The particles of the atoms have charges, yet atoms have a net charge of 0 (they are neutral). This is because the number of positively charged protons is equal to the number of negatively charged electrons. The charges cancel each other out.

Electrons orbit the nucleus in different **energy levels.** All of these energy levels make up an **electron cloud.** Although the diagrams show electrons orbiting the nucleus in a circular fashion, this is not really accurate. The electrons in the different levels are different distances from the nucleus, but instead of orbiting in a circular track, they occupy a certain space at that distance. This will be explained in much more detail in honors Chemistry next year. Electrons in the different levels possess varying amounts of energy. Electrons that are further from the nucleus have more energy than those closer to the nucleus.

The different **energy levels** can hold different numbers of electrons:
Level 1 – Can hold up to 2 electrons.
Level 2 – Can hold up to 8 electrons.
Level 3 – Can hold up to 18 electrons but it is composed of sublevels. The first sublevel holds up to 8 electrons.
Most important biological elements have fewer than 18 electrons so the first sublevel of the 3rd energy level will be adequate for our studies.

The electron energy levels can be represented in a simple diagram. Hydrogen has 1 electron, oxygen has 8 electrons, and sodium has 11electrons. Each can be efficiently illustrated as follows:

Hydrogen	Oxygen	Sodium
1p) 1	**8p) 2) 6)**	**11p) 2) 8) 1)**

THE PERIODIC TABLE

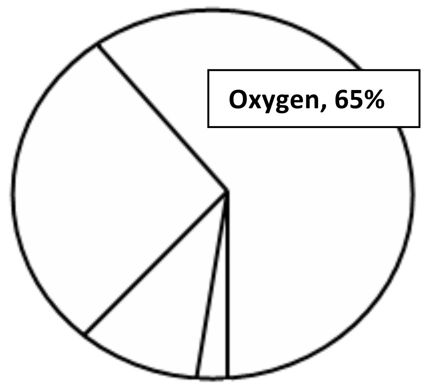
The Periodic Table is a chart of the elements found on Earth, both occurring naturally and man-made.

A chemical **element** is a single type of atom. For example, carbon, calcium, iron and silver are all elements. Any substance that is composed of only one type of atom is considered an element.

Note that the elements are represented by **symbols.** Some chemical symbols are only 1 letter (*ex.* C= carbon), while some symbols are represented by 2 letters (*ex*. Ca= calcium).

The 4 most abundant elementsin living things are:

1. Oxygen 65%
2. Carbon 19%
3. Hydrogen 10%
4. Nitrogen 3%
5. Trace elements like Na, Ca, K, S, P, Cl, Fe, Mg (Trace elements are essential for life but are needed Only in small amounts.)



*****Label the chart to the left with the elements that each section represents. Oxygen has been done for you. (Trace elements are not represented on the chart.)*****

How to Read the Periodic Chart:

Atomic Number –is equal to the number of protons in the atom's nucleus. Because the number of protons and electrons in the nucleus is equal in an atom, the atomic number is also equal to the number of electrons. It is usually the top number, above the symbol of the element.

Atomic Mass (Mass Number)-is equal to the number of protons PLUS the number of neutrons in the nucleus of the atom. The atomic mass is usually listed under the symbol for the element. The atomic mass may be represented by a whole number or, it may be a decimal number that is the weighted average of the masses of the existing **isotopes** of the element. *(See isotopes on the next page*) The **number of neutrons** can be calculated by subtracting the atomic number from the atomic mass. For example, the number of neutrons in an atom of sodium (Na) is, 23-11=12.

*****Use the periodic information below to fill in the components of the elements below:*****

6	17	7	11	1
C	Cl	N	Na	H
12.0	35.45	14.0	22.98	1.0
carbon	**chlorine**	**nitrogen**	**sodium**	**hydrogen**

atomic mass	______	______	______	______	______
atomic no.	______	______	______	______	______
protons	______	______	______	______	______
neutron	______	______	______	______	______
electrons	______	______	______	______	______

Isotopes –are atoms of the same element that have the **same number of protons but a different number of neutrons**. This will cause different isotopes of the same element to have different atomic masses. **The number of protons in an atom will define the element.** An atom of carbon always contains 6 protons. Different isotopes of carbon will contain 6 protons but may contain 6, 8 or 10 neutrons. Since the number of electrons remains the same, the reactivity (the way they combine with other atoms) is also the same for isotopes of the same element.
(Do not confuse isotopes with ions. ***Ions*** *of the same element will have different numbers of electrons.)*

Most elements have isotopes. Some examples are:

- Carbon- 14 contains 6 protons and 8 neutrons
- Carbon- 12 (most common isotope in nature) contains 6 protons and 6 neutrons
- Oxygen-18 contains 8 protons and 10 neutrons
- Oxygen-16 (common isotope in nature) contains 8 protons and 8 neutrons

Many isotopes are **radioactive**, which means they have an unstable nucleus which emits radiation, reducing the number of protons or neutrons over time.

MOLECULES AND COMPOUNDS

A **molecule** is composed of two or more atoms bonded covalently (they share electrons to be stable).

Ex. water $\mathbf{H_2O}$, oxygen $\mathbf{O_2}$, methane $\mathbf{CH_4}$, hydrogen $\mathbf{H_2}$, Ozone $\mathbf{O_3}$,

A **molecular compound** is a molecule composed of **more than one type** of atom. Some molecules are molecular compounds. Some molecules, like diatomic (N_2) are *not* considered a molecular compound because it only contains N.

Molecules and compounds are represented by **chemical formulas**: (ex. $\mathbf{O_2}$ $\mathbf{C_6H_{12}O_6}$, $\mathbf{H_3CO_3}$, $\mathbf{N_2}$)
The **chemical formula** tells you 1) the **types** of elements present in the molecule or compound
2) the **number** of atoms of each element in the compound.

*****Look at the following chemical formulas, and determine if they represent a molecule, a compound, or both.*****

$\mathbf{H_2O}$	$\mathbf{O_2}$	$\mathbf{CH_4}$	$\mathbf{H_2}$	$\mathbf{O_3}$
______	________	________	_______	_______

Subscripts and Coefficients-used to represent the number of molecules in a reaction and the number of atoms in a molecule.
The number **before** the letters (the **coefficient**) in a chemical formula refers to the number of **molecules**. The number after the letter (the **subscript**) refers to the number of that particular **atom**. To calculate the total number of a particular atom in a compound, multiply the coefficient times the subscript. If there is no coefficient or subscript number it is considered to be 1. In the first example in the chart below, there is no number before the glucose molecule - $\mathbf{C_6H_{12}O_6}$. - this means that there is one molecule of glucose.

*****Using the examples filled in for you, complete the information below:*****

	$\mathbf{C_6H_{12}O_6}$	$\mathbf{2NH_3}$	$\mathbf{3H_2O}$	$\mathbf{3CO_2}$	$\mathbf{2PO_4}$
Number of Molecules					
Number of Atoms	**C- 6**			**C- 3**	
	H- 12			**O- 6**	
	O- 6				

MOLECULES AND BONDING

Atoms are **Reactive** *(react with other atoms*) if they don't have 8 electrons in their outermost energy level (valence level) In order to obtain 8 electrons, atoms can either combine with other atoms in **chemical bonds**, or form ions*. **In this section we will focus on how atoms share electrons in chemical bonds. Ions will be discussed later.***

The number of electrons in the valence level determines how atoms bond together to form molecules.

Once the valence level has 8 electrons the atom becomes **stable**. Most atoms obey the **octet rule** *(must have 8 electrons,)* but in the case of hydrogen (H), only 2 electrons are needed in order to fill the outer level. This is because H only has one energy level.

*****Determine if the following atoms are stable, or unstable. If they are unstable, explain how they can become stable.*****

1. **Carbon 2) 4) -** has 2 electrons in the inner most (1^{st}) energy level and 4 in the valence level. Because the outer level can hold 8 electrons, carbon must share 4 electrons with other atoms to become stable.
2. **Oxygen 2) 6) -** has 2 electrons in the 1^{st} energy level and 6 in the second level. Oxygen must share, gain or lose 2 electrons in order to become stable.
3. **Hydrogen 1) -** will lose an electron to become stable.
4. **Nitrogen 2) 5) -**____
5. **Neon 2) 8)-**____

BONDING - The two kinds of chemical bonds you will study are **covalent bonds** and **ionic bonds.** *(ionic bonds will be discussed later in the section on ions).*

COVALENT BONDS

Covalent bonds are bonds formed when atoms **"share"** electrons in order to satisfy the octet rule. Atoms may share one, 2 or 3 electrons in order to become stable. They may form **single** bonds, **double** bonds or **triple** bonds.

The number of electrons an atom needs to become stable will determine how many bonds it will form.

*****How many bonds will the following atoms form? Carbon has been done for you. *****

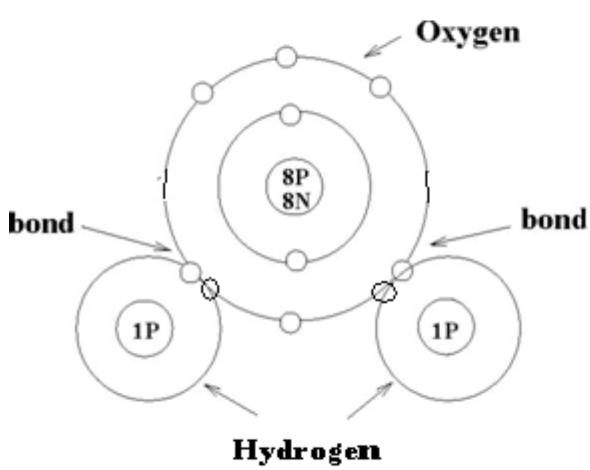
(The number of bonds will be equal to the number of electrons needed to fill the outer valence level.)

Carbon_____4__________ **Oxygen______________**

Hydrogen_____________ **Nitrogen_____________**

An easy way to remember the number of bonds these common atoms form – HONC - 1234!**

Example of how a water molecule is formed from covalent bonding of hydrogen and oxygen:



*One way to easily remember the number of bonds that the major organic elements can form is to remember **HONC, 1234**. Hydrogen forms one bond to become stable, oxygen forms two, nitrogen three and carbon four.*

CHEMICAL AND STRUCTURAL FORMULAS

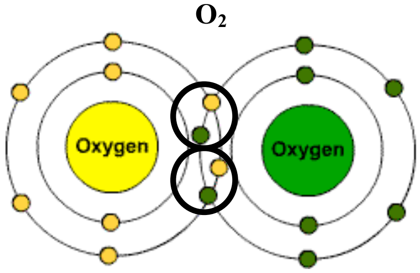
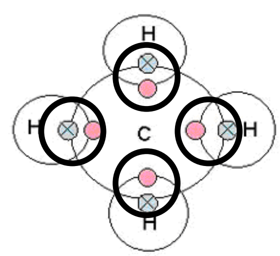
Remember, Molecules and compounds can be represented by **chemical formulas. (ex. O_2, $C_6H_{12}O_6$, N_2)**

Molecules can also be represented by **structural formulas**. The **structural formula** tells you the **types** and **numbers** as well as the **arrangement of atoms** and the **number of covalent bonds** between atoms in the molecule or compound. Each line between atoms represents one covalent bond or a shared pair of electrons. ***A **single** covalent bond is shown by a single line between the atoms. A **double** covalent bond, where 2 pairs of electrons are shared, is shown by 2 lines*

*****Diagram the structural formulas of the following molecules (water and oxygen have been done for you):*****

H_2O	NH_3	O_2	CH_4	CO_2
H—O—H		**O=O**		

*****Diagram how the following molecules are formed by covalent bonding. Show the <u>energy levels</u> in your drawing (Methane and Oxygen have been done for you.) Circle each covalent bond in your diagram:*** **Note**: Oxygen forms a double bond with other Oxygen atom. This means that they are sharing **two pairs** of electrons. There are also **triple bonds**, where **3 pairs** of electrons are shared. An example of this would be the molecule N_2.**

<table>
<tr><td>H_2</td><td>NH_3</td></tr>
<tr><td>O_2

</td><td>CH_4

</td></tr>
<tr><td>N_2</td><td>CO_2</td></tr>
</table>

In the box below draw the structural formulas for the following compounds. Make sure that the number of bonds between the atoms are correct. Note that sometimes there is more than one way to diagram a structural formula from a chemical formula. Remember HONC, 1234!

CH_2O	NHO	$CNOH_3$	C_2OH_3N

IONS AND IONIC BONDING

Ion- an atom that becomes charged due to the gain or loss of one, two or three electrons. In addition to sharing electrons in covalent bonds, atoms can satisfy the octet rule by becoming **ions**. Some atoms become ions by **gaining** electrons, and therefore become **negatively charged**. Other atoms become ions by **losing** electrons, and therefore become **positively charged.** The charge on the ion is based on how many electrons it gains or loses:

Na: 2)8)1 Loses one electron to become $\mathbf{Na^+}$

Mg: 2)8)2 Loses two electrons to become $\mathbf{Mg^{2+}}$

F: 2)7 Gains one electron to become $\mathbf{F^-}$

O: 2)6 Gains two electrons to become $\mathbf{O^{2-}}$

Ionic Bonds-are formed when two ions of opposite charge (one + and one -) are attracted to each other. There is no sharing of electrons in an ionic bond, just the attraction of two atoms that have gained or lost electrons to one another to become stable. In the process, they are of opposite charges and become attracted to each other.

In the diagram below, the lithium atom has 1 electron in its outer energy level and so will lose that electron in order to become stable. This gives the Li ion a positive charge

Forming an ionic compound.
Ex. lithium and fluorine will combine to form lithium fluoride, and **ionic compound.**
Note: The opposite charges of the Li^+ and the F^+ cancel each other out so the compound formed, *lithium fluoride,* is not charged – it is neutral.

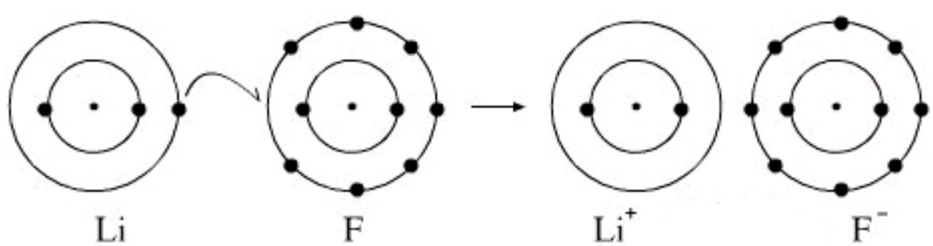
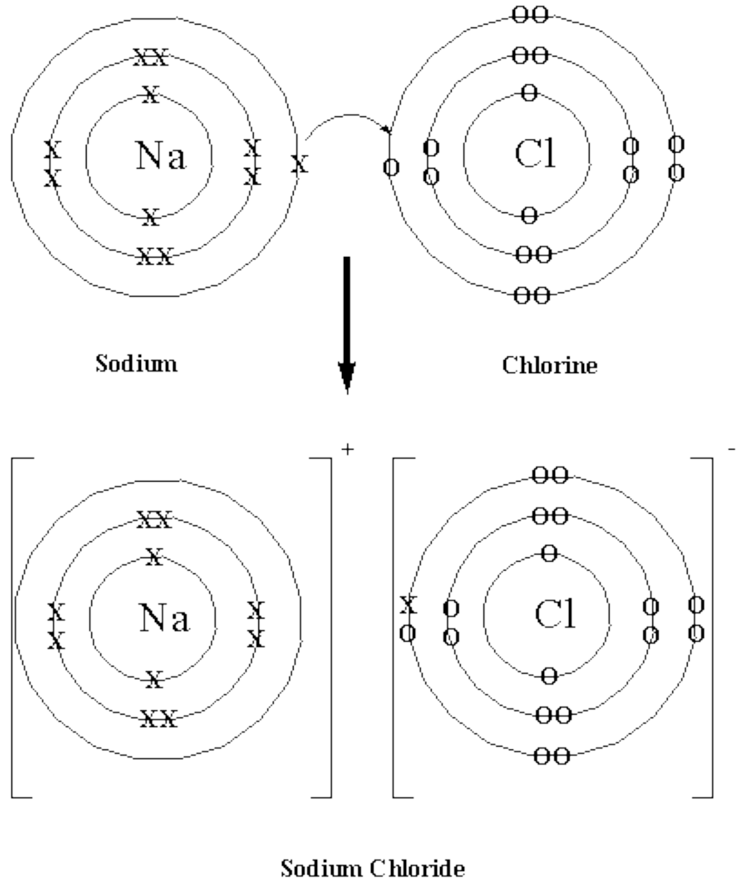


Diagram of a sodium ion and a chloride ion, forming the ionic compound, sodium chloride (NaCl):

(Recall that a sodium atom has 11 protons and 11 electrons. A chloride atom has 17 protons and 17 electrons.)



1) A sodium atom loses an electron 'X' and becomes **positive in charge** because it now has 11 protons and only 10 electrons. This forms a **Na^+ ion.**
When Na loses the electron it will have 8 electrons in its outer energy level.

2) A chlorine atom gains the electron lost by sodium and becomes **negative in charge** because it now has 18 electrons and only 17 protons. This forms a **Cl^- ion.**
When Cl gains the electron it will have 8 electrons in its outer energy level.

3) The opposite charges of the resulting ions causes the ions to be attracted to each other forming an **ionic bond**.

*****Diagram magnesium (Mg) ion and an oxygen ion, and show how they form the ionic compound Magnesium oxide.*****

*****Diagram a magnesium (Mg) ion and a chloride (Cl) ion, and show how they form the ionic compound Magnesium chloride.****

Note: You will need to use more than one chloride ion to form this ionic compound!

****Diagram a calcium (Ca) ion and an chloride (Cl) ion, and show how they form the ionic compound Calcium chloride.* You will have to decide how many of each ion is necessary to form this ionic compound!***

****Diagram a potassium (K) ion and an chlorine ion, and show how they form the ionic compound Potassium chloride.* You will have to decide how many of each ion is necessary to form this ionic compound!***

NOTE: The following material on "Polar" and "Nonpolar covalent bonds" will be discussed in greater depth in class. You should still make an effort to learn the material and answer the questions in the prompts. You will also have some questions on the multiple choice assessment on these concepts.**

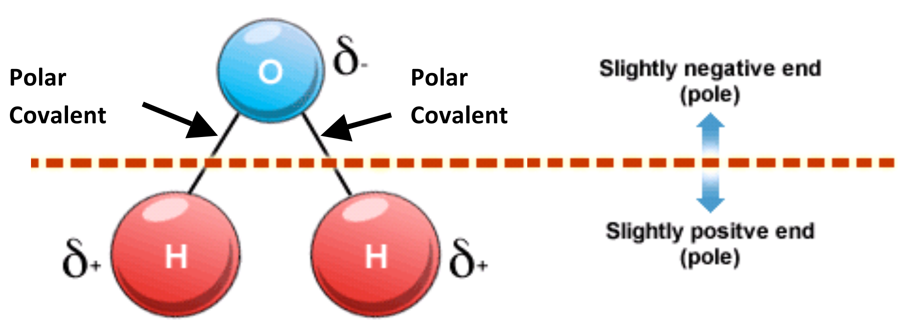
ANOTHER LOOK AT COVALENTLY BONDED MOLECULES

You will examine two kinds of covalent bonds: **Polar Covalent bonds** and **Nonpolar Covalent bonds.**

POLAR COVALENT BONDS

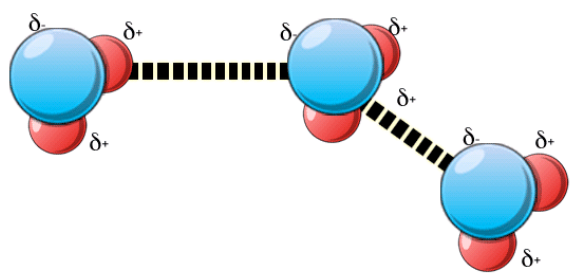
Polar means having two opposite ends, like the North and South Poles of the Earth. In the case of bonds it means 2 opposite charges.

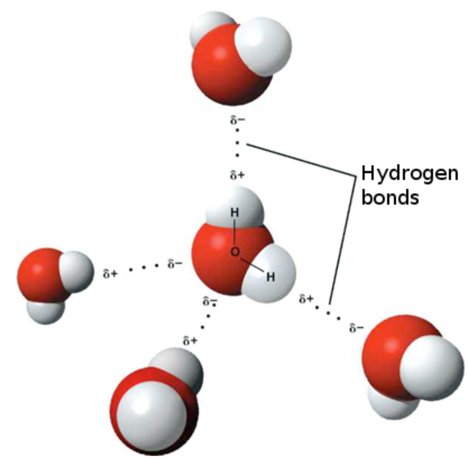
- A covalent bond between two atoms in which the electrons are **NOT SHARED EQUALLY**.
- The electrons involved in the bond spend more time hovering around the nucleus of one atom, giving it a **partial negative charge.**
- This results in the other atom having a **partial positive charge.**
- The partial positive and negative charges are not as strong as the charges in ions but can affect the attraction of the molecule or compound with other charged substances.



Water is an example of a polar molecule because electrons are more strongly attracted to the oxygen atom than to the two hydrogen atoms. This is because the oxygen atom has more protons in the nucleus which are attracting the shared electrons. This gives the **oxygen a partial negative charge**, and each of the **two hydrogens a partial positive charge**. You should note that the charges in a **polar molecule** are not complete charges, like an ion; they are only **partial charges** (indicated by the **delta sign**), because the atom that is more negative has not pulled an electron completely away from the atom that is positively charged. Electrons are still considered 'shared' in a polar covalent bond.

Because water molecules are polar, they tend to "stick" to each other. A positive side of one water molecule is attracted to the negative side of another water molecule.





Notice the dotted lines between the water molecules in the diagram on the left. These dotted lines represent a special type of bond called a **hydrogen bond.**

Hydrogen bond- is a bond between the hydrogen in a polar molecule and the oxygen or nitrogen in a polar molecule. Bonds can be found between atoms in different polar molecules (as in between 2 water molecules) or between atoms in the same polar molecule (DNA and proteins – will be discussed in another chapter).

Because hydrogen bonds are **much weaker** than covalent or ionic bonds, they are **constantly breaking and reforming**. For example, in a glass of water at any given time most of the water molecules are hydrogen-bound to each other. Even so, they are constantly breaking and reforming in liquid water. The weak nature of these bonds is extremely important in chemical reactions that occur within living things. They will be discussed throughout the year.

Other Polar Molecules

Some molecules have polar regions which make either part of or the entire molecule polar. An example of a **polar molecule** is the sugar **glucose.** The structural formulas of glucose can be shown in a **linear** or **ring** form. Note the locations of polar covalent bonds.
Notice all the **-O-H or hydroxyl groups** in the glucose molecule below. Because in each O-H bond the electrons are more strongly attracted to oxygen atom (as in water), the oxygen has a slightly negative charge, and the hydrogen has a slight positive charge. The bonds between the oxygen and hydrogen are **polar covalent bonds**. As in water, the oxygen atoms are **partially negative** in charge and the hydrogen atoms bonded to the oxygen are **partially positive** in charge. The presence of **hydroxyl groups** make glucose a **polar molecule**.

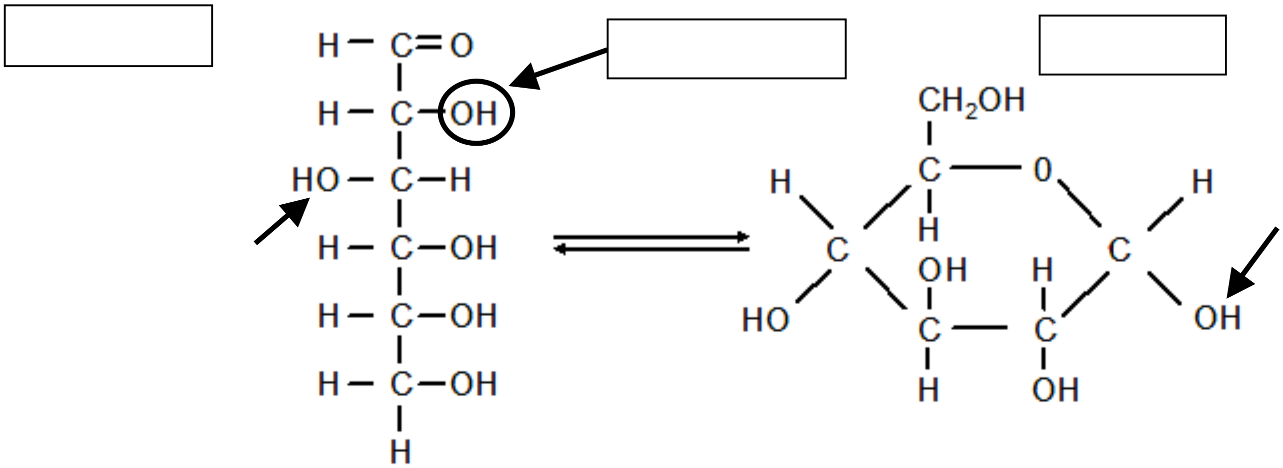
...ar Covalent Bond
...near Form
...etween the
...ydrogen and oxygen
... a hydroxyl group

Hydroxyl group

Ring Form

Polar Covalent Bond

Draw arrows to show the location of additional polar covalent bonds between the oxygen and hydrogen in the hydroxyl groups. One has been done for you:



NONPOLAR COVALENT BONDS

Nonpolar covalent bonds- a bond in which electrons are equally shared between 2 atoms. NO partial charge exists on either atom. Two common examples of nonpolar covalent bonds are:

1) When two identical atoms form a bond (ex. -C-C- or O=O). This example is easy to understand because both atoms have the same number of protons and should exert the same attractive force on the electrons shared in the bond.

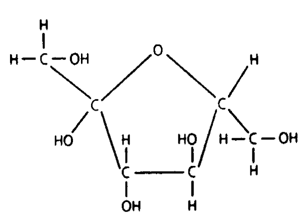
2) When carbon binds to hydrogen (-C-H). This is not as easy to understand because carbon has more protons than hydrogen. Even so, the electrons are **shared equally** between the two atoms. You will learn the other reasons that account for this in Chemistry next year. An example of a nonpolar molecule is methane (CH_4).

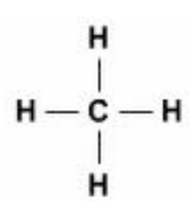
NOTE: although glucose also has C-H bonds, the presence of the OH groups makes it polar. We will discuss in more detail how to determine whether a compound is polar or nonpolar when you return to class in September.

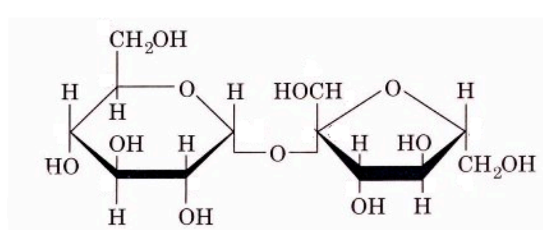
Comparing the degree of electron sharing and bond type:

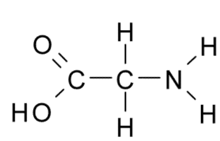
Nonpolar Covalent Bond	Polar Covalent Bond	Ionic Bond
Equal sharing of electrons	Partial sharing of electrons	No sharing

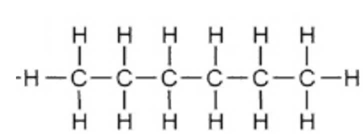
Label each of the following molecules as polar or nonpolar:











NOTE: The following material on "Solutions" will be discussed in greater depth in class. You should still make an effort to learn the material and answer the questions in the prompts.**

SOLUTIONS

Solution- a mixture where one substance is evenly dissolved into another. A **solution** is composed of a **solvent** and one or more **solutes**.

Solvent- the dissolving agent. The solvent is in higher concentration compared to the solute. The solvent in most biological systems is **water** but it can also be oils, gasses and other substances.

Solute- The substance that is dissolved in the solvent.

If salt is mixed with water, salt is the solute and the water is the solvent.

Water- the Universal Solvent

In biological systems, water is the main solvent. It is found in the **blood**, the **cytoplasm of a cell** and in the **tissue fluid** between cells. Materials dissolved in water can be transported to and from cells. The characteristics of water make it the universal solvent in biological systems:

Water is polar. It has partial positive and negative charges. It is attracted to molecules with opposite Charges. By sheer numbers, **water molecules can surround charged particles** like ions or polar molecules and cause them to separate. This separation is called **dissolving**.

How an ionic compound and a covalent compound dissolve in water

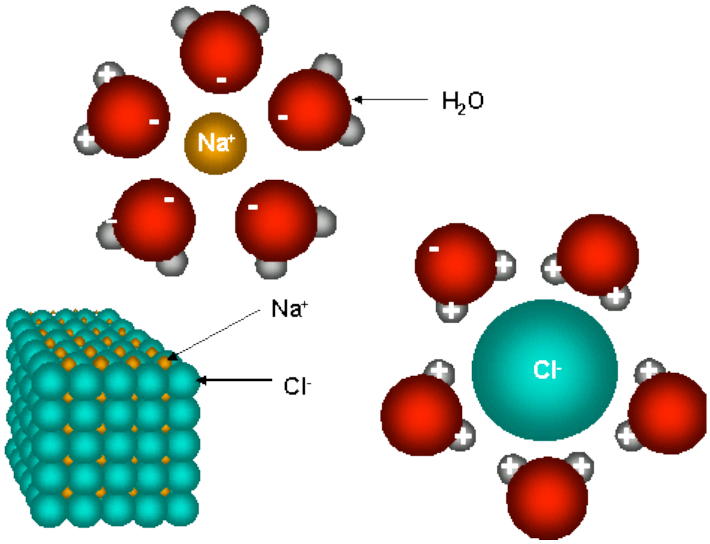
1) When sodium chloride (salt) dissolves in water the sodium ions (Na^+) **separate or dissociate** from the chloride ions (Cl^-). The ionic bonds in the salt crystal break as water surrounds the individual ions **Dissociation** only takes place when an ionic compound dissolves in water.

2) When glucose dissolves in water the glucose molecule do not separate or dissociate. This is because the atoms in glucose are joined by covalent bonds which usually do not separate in water. When glucose dissolves in water, the **molecules of glucose are separated from each other but the individual molecules remain intact – no covalent bonds are broken.**

Look at the diagrams on the next page, which show in more detail how salt and sugar dissolve in water.

Note: When sugar or salt dissolves in water, the crystals that you could easily see on your spoon seem to disappear. This is because the water molecules surround the ions or sugar molecules as they are dissolving and separate them into single units (ions or molecules) that are too small to be seen. A crystal of salt or sugar is composed of billions of molecules or ions that are compressed together. Crystals can be seen but molecules or ions are too small to see.

Water Dissolving an Ionic Compound:



Explanation of the diagram above:

1) Water is polar. The oxygen has a partial negative charge and the hydrogen has a partial positive charge.

2) The partial negative charge of the oxygen atom in the water molecule is attracted to the Na^+ ion because it has a positive charge.

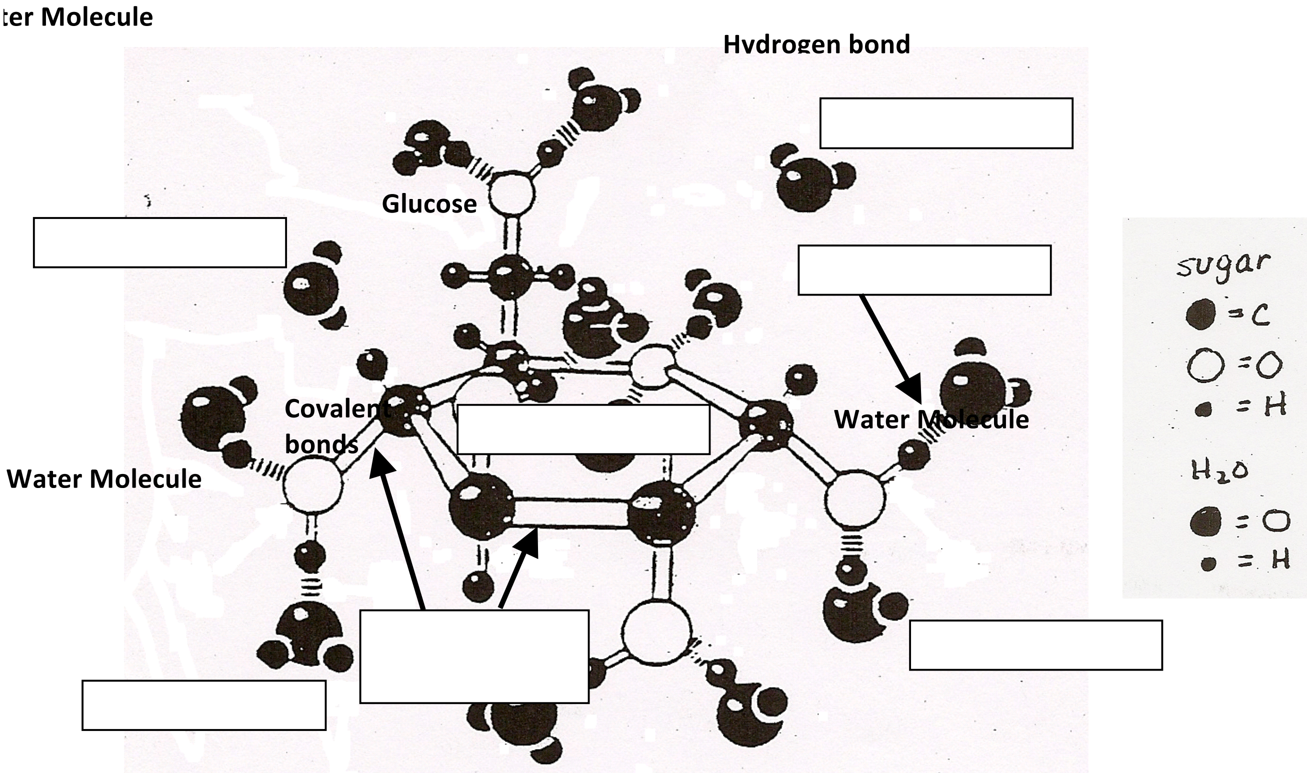
3) The partial positive charge of the hydrogen atoms in the water molecule is attracted to the Cl^- ion because it has a negative charge.

4) Water molecules surround the positive sodium ions and negative chloride ions in the sodium chloride crystal and cause them to separate from each other.

5) Dissociation of the Na^+ and Cl^- ions takes place and the salt crystal dissolves. Ionic bonds in the salt crystal break but the ions remain stable

Water Molecule

Water Dissolving a Covalent Compound:



Try this—it won't be graded for points, just for effort!--Use the points in the explanation of ionic dissociation to describe the diagram above. The first statement has been done for you. It is the same as for the ionic compound! Make sure to include the statements that are similar but change or exclude statements that are not the same. For example, you will not include 'dissociation' as a term to describe the formation of a covalent solution but you will use the term 'dissolves.'*

1) Water is polar. The oxygen has a partial negative charge and the hydrogen has a partial positive charge.

2) ____

____

____

____

____

____

____

Note: Sometimes a covalently bound compound will dissociate in water, if it is extremely polar. An example of this is when covalently bonded ***hydrochloric acid (HCl) dissociates in water****, to generate H^+ ions and Cl^- ions. However, most of the organic compounds we will be discussing this year, such as sugars, do not dissociate. They are instead "surrounded" by water molecules and separated into single molecules.*

A C B D

Hydrophilic vs. Hydrophobic Substances

Substances that are dissolved by or interact with water are said to be **hydrophilic**. Both salt and sugar are hydrophilic substances. There are many other hydrophilic solutes in addition to salt and sugar that are dissolved in the fluids of your body. These will be discussed throughout the year.

Polar- hydrophilic (water-loving) Substances that are ionic compounds or contain many polar covalent bonds. Glucose, Sodium chloride, amino acids, sugars, proteins.

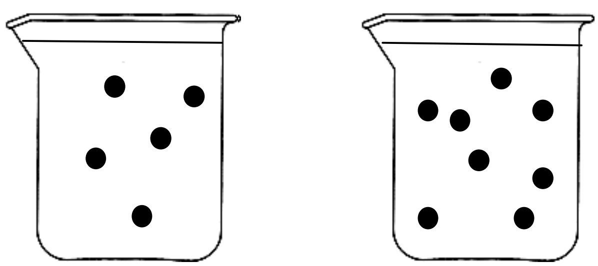
Substances that do not interact with water, such as oil, are said to be **hydrophobic.** Molecules that are nonpolar are hydrophobic.

Nonpolar- hydrophobic (water-fearing) Substances that contain many nonpolar, carbon to hydrogen bonds (-C-H). Fats, oils, waxes, mineral oils, seed oils.

THE CONCEPT OF CONCENTRATION

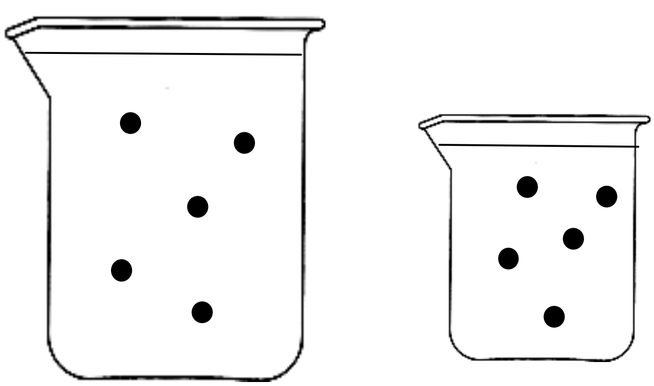
Concentration – is the quantity of a substance in a given volume.

The **identical beakers** below contain **different numbers of solute particles** dissolved in water.



Beaker **B** has a higher concentration of solute than beaker **A**. This is because beaker B has **more solute particles** per volume water than beaker A.

The **different sized beakers** below contain the **same number of solute particles** dissolved in water.



Beaker **D** has a higher concentration of solute than beaker **C**. This is because beaker D has more solute particles **per volume of water** than beaker C. Even Though the number of solute particles in beaker C and D are the same, there is **more solvent** (H_2O) in beaker C than in beaker D.

NOTE: The following material on Dissociation of Water will be discussed in greater depth in class. You should still make an effort to learn the material and answer the questions in the prompts.**

DISSOCIATION OF WATER

Water molecules themselves can break apart and form ions. However, this is a **very rare occurrence**. The majority of molecules in any sample of water will be covalently bound together. It is only approximately **2 in a billion of water molecules** in any sample that will **dissociate**.
Water molecules are constantly in motion. Water molecules may **dissociate** as shown below. This process is also **reversible**, and the H+ and OH- can recombine to form H_2O. This is constantly changing, but at any given moment, you would expect to find approximately 2 in a billion water molecules that have dissociated:

$$H_2O \leftrightarrow H^+ + OH^- \quad \textbf{(Dissociated)}$$

1. The water molecule contains one oxygen bonded to two hydrogen molecules. When it dissociates, the **proton** breaks away, but the electron is left behind with the remaining OH. This single **proton** is also called a **hydrogen ion (H^+).**

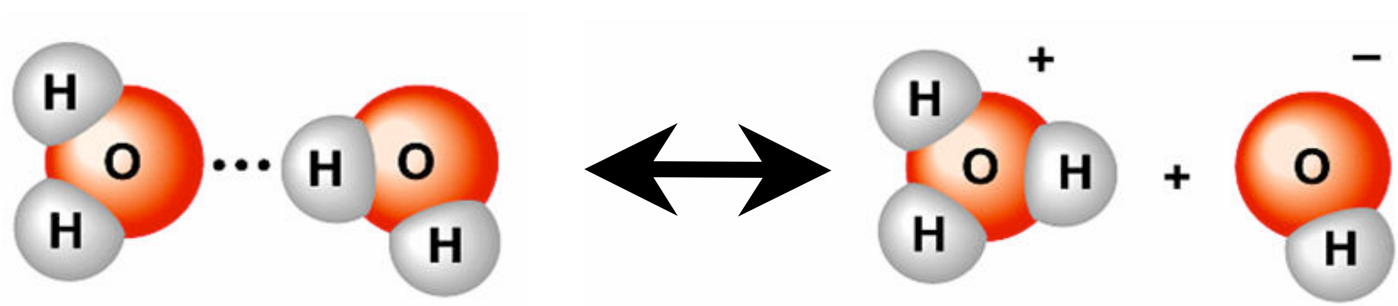
2. The molecule that remains after the hydrogen ion breaks away has an extra electron, and has a negative charge. This ion is called the **hydroxide ion (OH^-).** *(Do not confuse the **hydroxide ion** with a **hydroxyl group (-OH).** The hydroxyl group is an –OH bonded to another molecule. It was defined previously on page 9.)*
   In **pure** water, **the number of hydrogen ions would equal the number of hydroxide ions**, resulting in a **neutral** solution. For example, if a beaker of pure water has 50 H^+ ions, it will have 50 OH^- ions.

A more accurate way to explain what happens when water dissociates is that the free **hydrogen ion (H^+)** is attracted to another water molecule to form a **hydronium ion.** The oxygen in one molecule of water attracts the proton in another molecule of water so strongly that it literally steals the proton away and becomes a **hydronium ion**. The electron remains with the OH and produces a **hydroxide ion.**

Overall reaction:

$$H_2O + H_2O \leftrightarrow H_3O^+ + OH^-$$

Water + Water ↔ **Hydronium ion + Hydroxide ion**



The dissociation of water always results in a **neutral solution** because the number of **positively charged hydronium ions equals** the number of **negatively charged hydroxide ions**. **Pure water is a neutral solution.**

Simplified Equation: $H_2O \rightarrow H^+ (H_3O^+) + OH^-$

If 8 molecules of H_2O dissociate $\rightarrow$ $8\ H^+\ (8\ H_3O^+) + 8\ OH^-$

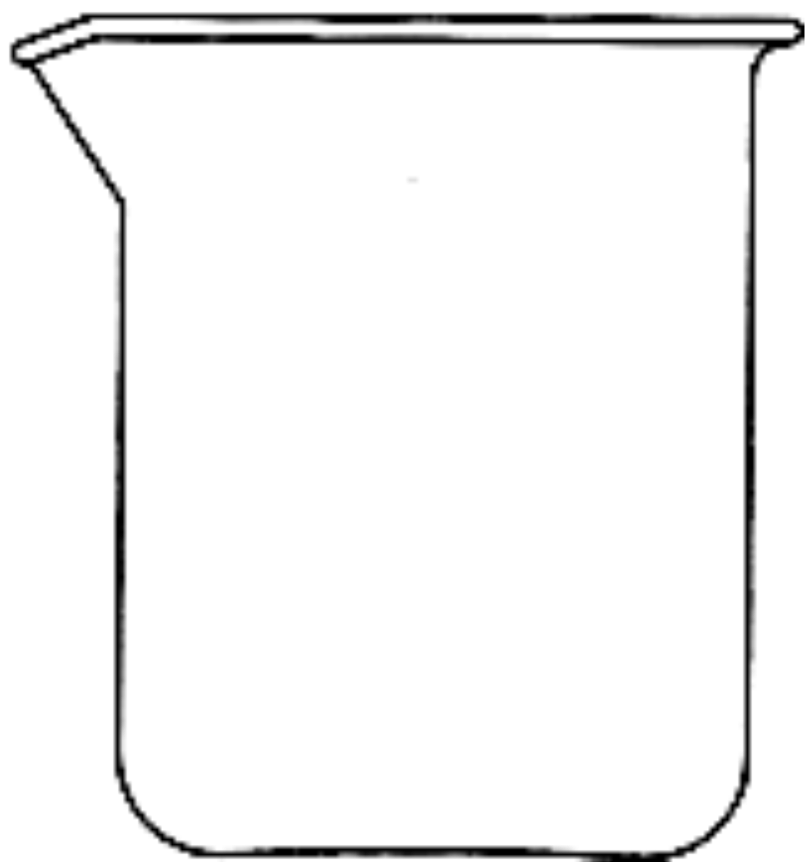
*****Use what you know about water to draw a picture of at least <u>four</u> water molecules in a beaker of water.***

Refer to the picture of water on page 8 of this packet.

You will need to orient the negative and positive sides of the molecules to each other.

Make sure to add hydrogen bonds between the molecules.

Then, add one hydronium and one hydroxide ion to represent dissociation.**



NOTE: The following material on acids and bases will be discussed in greater depth in class. You should still make an effort to learn the material and answer the questions in the prompts.**

ACIDS

If you were to dissolve some HCl (hydrochloric **acid**) into water, it would **dissociate**:

$$\mathbf{HCl \rightarrow H^+ + Cl^-}$$

This would **increase** the number of H^+ (hydrogen ions or protons) in the solution. The H^+ ion concentration would then be greater than the OH^- ion concentration.
The resulting solution is said to be an **acidic** solution.

Acid-a substance that **increases the H^+ ion concentration** of a solution. Since an acid is a substance that adds H^+ ions to a solution when it dissociates it is called a **hydrogen ion donor**. When acids add H^+ ions to a solution, the H^+ are attracted to water molecules and form hydronium ions ($H^+ + H_2O \rightarrow H_3O^+$).
Therefore, acids increase the number of hydronium ions (H_3O^+) in a solution. The H^+ also binds to OH^- forming H_2O. This decreases the OH^- concentration.

Note: Acids lower the pH of a solution because an increase hydrogen ions lowers pH. For example, if the pH of a solution goes from 7 to 4 the hydrogen ion concentration has increased.

BASES

If you were to dissolve some NaOH (sodium hydroxide) into water, it would dissociate as follows:

$$\mathbf{NaOH \rightarrow Na^+ + OH^-}$$

This would **increase** the number of OH^- (hydroxide ions) in the solution. The OH^- ion concentration would be greater than the H^+ ion concentration. The resulting solution is said to be a **basic** or **alkaline** solution.

Base-a substance that **decreases the H^+ concentration** (or the hydronium ion concentration-H_3O^+) of a solution. A base can attract the extra proton on the hydronium ion which results in the production of a water molecule. Because the **hydronium ion (H_3O^+) concentration decreases** we tend to say that **the hydrogen ion concentration has decreased**. Bases are therefore called **hydrogen ion acceptors**.

Note: **Many bases donate hydroxide ions which bind to (accept) hydrogen ions:**
Example-Sodium Hydroxide (NaOH):

$\mathbf{NaOH \rightarrow Na^+ + OH^-}$ — NaOH dissociates in water.

$\mathbf{OH^- + H_3O^+ (H^+) \rightarrow 2\,H_2O}$ — The hydroxide ion (OH^-) **accepts** a H^+ ion and water is formed. This **reduces** the concentration of H^+ (H_3O^+) in the solution.

Note: **Not all bases release hydroxide ions but they can accept and bind to hydrogen ions:**
Example-ammonia (NH_3) is a base.

$\mathbf{NH_3 + + H_3O^+ (H^+) \rightarrow NH_4^+ + H_2O}$ — NH_3 **accepts** a H^+ ion and water is formed. This reduces the concentration of H^+ (H_3O^+) in the solution.

Note: Bases raise the pH of a solution because a decrease in hydrogen ions raises pH. For example, if the pH of a solution goes from 7 to 10 the hydrogen ion concentration has decreased

***Draw the ions you would find in each of the following solutions. You should draw 2 intact water molecules to represent the majority of water in each beaker, and draw one hydronium ion and one hydroxide ion to represent the water molecules that are dissociated. In addition, in beaker 1, draw what happens when one molecule of HCL is added to form an acidic solution. In beaker 3, draw what happens when one molecule of NaOH is added to form a basic solution.*

Acid-HCL **Neutral Water** **Base-NaOH**

MORE ON ACIDS AND BASES

Some acids and bases are considered to be strong, and some are considered to be weak. Strong acids or bases tend to **dissociate completely** into separate ions, while weaker acids or bases tend to only **partially dissociate**. In other words, some of the acidic or basic compound will remain intact (not dissociate) in water. This would put fewer hydrogen ions or hydroxide ions into solution, which would make it a weaker acid or basic solution. **Hydrochloric acid (HCl) is a strong acid**, which dissociates completely, and **sodium hydroxide is a strong base**, which also dissociates completely.

MEASURING THE HYDROGEN ION CONCENTRATION

pH Scale – a scale from 1 to 14 used to measure how acidic or basic a solution is.

Usually the pH of a solution is considered to measure the concentration of hydrogen ions (hydrodium ions) of the solution. In other words, pH focuses on the hydrogen concentration instead of the hydroxide concentration, even though as one increases the other decreases.

pH Scale:

1 **7** **14**

← **neutral** →

more acidic (more H^+) **more basic (less H^+)**

less OH^- **more OH^-**

Try these questions:

1. pH of 7 = ___________________________solution.
2. pH **greater** than 7 =________________________solution
3. pH **less** than 7 =_________________________solution
4. A solution with equal H^+ and OH^- concentrations = ___________________________ solution
5. A solution of NaCl in water = ____________________________ solution
6. Which solution is more **acidic**, pH=6 or pH=2?_____________
7. Which solution is more **basic**, pH =9 or pH =12?_____________
8. Which solution has more **H^+ions**, pH =4 or pH =8?_____________
9. Which solution has more **OH^+ions**, pH =10 or pH =11?_____________
10. Which solution has fewer **H^+ions**, pH =3 or pH =5?_____________

NOTE: You may skip the additional discussion of pH and buffers. This material will be covered in class. Go to page 21 and complete the last section on "Changes in Matter and Chemical Reactions" as well as "Balancing Equations" on page 22.

Hydrogen Ion Concentration and pH:

The small number of water molecules that dissociate in a sample of water, measured at 1 x10^{-7} moles/liter, it is too difficult to talk about, because it is such a small number. Instead scientists chose to take the negative of the exponent (-7), and say that in pure water (neutral) the pH is 7. This "7" represents that there is 10^{-7} moles/liter of hydrogen ions, and 10^{-7} moles/liter of hydroxide ions. This would explain why a pH of 6 has more hydrogen ions, because the "6" is representing 10^{-6}, which is a greater number than 10^{-7}.

	H^+ ion concentration (H_3O^+ ion concentration)	**OH^- ion concentration**	**pH**
Neutral			

Difference in pH:

There is a *significant* difference in hydrogen ion concentration in a change of a single pH unit, such as between pH 3 and pH 4. There is really a **10 fold difference** between each unit. For example, the concentration of H^+ ions is 10 times greater in a pH of 3 versus a pH of 4; there would be 100 times more H^+ ions in a pH of 2 versus a pH of 4.

To better understand why there is a 10X difference in H^+ concentration between each pH unit, study the chart below:

pH 1	pH 2	pH 3	pH 4	pH 5	pH 6	pH 7

Note that as the pH goes up, the number of hydrogen ions (H^+) gets smaller. For example, 0.1 is greater than 0.01, and 0.01 is greater than 0.001, etc.

These numbers are expressed in units called moles/liter. You will learn more about this concept in chemistry.

BUFFERS AND pH

The body uses substances called **buffers** to insure that the pH of body fluids does not fluctuate very much. Buffers prevent large sudden changes in pH. Buffers work by accepting H^+ ions from solution when they are in excess, and donating H^+ ions to the solution when they have been depleted. Even small pH changes can drastically alter body function. Remember, each pH unit represents a tenfold difference, so a slight change in pH represents a large change in the actual pH. If the blood becomes too acidic or too basic it could cause serious problems.

An example of a buffer system in the human body is the **carbonic acid/ bicarbonate ion buffer system,** which exists in the blood, and helps keep the blood at a relatively neutral pH. The equation that follows explains how this system works to either remove excess hydrogen ions if the body fluid becomes too acidic, or release hydrogen ions if the body fluid becomes too basic. Note that this chemical reaction is reversible, which is to say it can go in both directions, depending on the needs of the body. $H2CO_3$ can be either a reactant or a product, depending upon which way the reaction is going.

Note: Not all bases release hydroxide ions, but all bases remove hydrogen ions from the solution by combining with them in some fashion, thereby raising the pH.

The equation below shows how the blood buffer system works.

Response to a
rise in pH →
H_2CO_3 ←→ HCO_3^- + H^+
H^+ donor Response to a H^+ acceptor
Hydrogen
(acid) drop in pH (base) ion
Carbonic acid ← Bicarbonate ion

How does this buffer system respond to a rise in pH (fluid becomes basic)?

____

____

____

How does this buffer system respond to a drop in pH (fluid becomes acidic)?

____

____

____

Questions:

________1) If the pH in a system changes from 8 to 7, how will the buffer system react?

a. act as an acid and release H^+ from carbonic acid forming more bicarbonate ions
b. act as a base and accept more H^+ to bind with HCO_3^- forming more carbonic acid
c. it will not shift at all

_________2) If the pH in your blood rises from 7.4 to 7.9, which of the following will result? (Choose **three** answers)

a. more carbonic acid will be formed
b. the reaction will shift from left to right above
c. more bicarbonate ion will be formed
d. more hydronium ions will form
e. the reaction will shift from right to left above
e. more OH^- ions will form .

CHANGES IN MATTER

Properties of Matter

Examples of the **physical properties** of a substance-density, volume, mass, color, shape, viscosity, texture.

Physical change-a change in the physical properties of a substance. The molecular structure is not changed, no bonds are broken but dissociation of ions may take place.

Examples of physical changes: evaporation, condensation, sublimation, freezing, dissociation of ions like that of NaCl in water, dissolving of sugar, ripping paper, breaking glass, chocolate melting, sawing wood, crushing chalk, rock weathering, dissolving of sugar in water.

Chemical change-a change where the chemical bonds break apart and the atoms rearrange to form new substances that have new chemical and physical properties. Old bonds in the reactants are broken and new bonds in the products form.

Examples of chemical changes: burning of wood, rusting, use of an antacid, production of glucose in photosynthesis and the breakdown of glucose in cellular respiration, any reaction producing heat, cooking food, digesting food, if there is a color change.

CHEMICAL REACTIONS

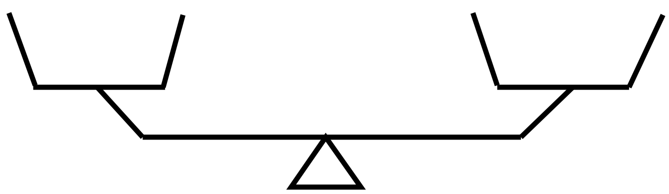
In chemical reactions, **reactants** (shown on the left side of the chemical equation) *react,* or undergo chemical changes, to *produce* **products**, shown on the right side of the chemical equation.

Chemical reactions are shown by using **chemical equations.** A chemical reaction may involve more than one reactant and may produce more than one product. The following equation is not balanced because there are two atoms of oxygen on the reactant side of the equation and only one on the product side.
Balance the equation by changing coefficients.

	(Reactants)			***(Product(s))***
Hydrogen	+	**Oxygen**	→	**Water**
H_2		**O_2**		**H_2O**

Equations must be **balanced** because of the L**aw of Conservation of Matter:**
Matter is neither created nor destroyed but it can and does change form in a chemical reaction.

*****Your teacher will go over the following diagram with you in class:*****



Balancing Equations:

In a chemical reaction, bonds in the reactants break and the atoms are rearranged. New bonds form to make new molecule (product). At no time during the reaction are both reactants and products present at the same time! The reactants are used to make the products.
Chemical reactions are said to be **balanced**. A balanced reaction can be identified by counting the numbers and types of atoms in the reactants and products. If an equation is balanced, they will be equal. When balancing reactions, remember that **<u>the numbers and types of atoms in the reactants must be equal to the numbers and types of atoms in the product. You cannot change a subscript when balancing a reaction but you may change a coefficient.</u>**

*****Review what you learned during 8th grade chemistry and balance the following reactions by changing the coefficients of the molecules involved in the reaction.*****

H_2S + ____O_2 → H_2SO_4

____Al + _____ O_2 → ____Al_2O_3

____H_2O_2 → ____ H_2O + O_2

C_3H_8 + _____ O_2 → ____ CO_2 + ____H_2O

$C_6H_{12}O_6$ + _____ O_2 → ____ CO_2 + ____H_2O

P_2O_5 + ____ H_2O → ____ H_3PO_4

Energy:

Energy is an important concept in chemical reactions. **In order to break apart the bonds of the existing reactants to form products, energy must be added to the reaction, and absorbed by the reactants.** For example, to break the covalent bonds of a sugar molecule, heat would have to be added to help destabilize the bonds, and cause more molecular collisions between individual sugar molecules. Both of these events would allow bonds to more easily break. Conversely, when the new bonds form in the products, energy is released. This concept of energy released when new bonds form is sometimes difficult to grasp, and will be discussed more in the next chapter on biochemistry.

When bonds break, energy is absorbed.

When bonds form, energy is released.

In some chemical reactions, there is so much energy released when the new bonds of the products form that you can visible measure the energy as light or heat. Although heat is released any time bonds, form, there is not always a significant amount released that can be observable.

Examples of reactions where energy being released can be observed: candles, dynamite and **wood burning** described below:

NOTE: You may skip the following discussion on the "Rate of Chemical Reactions." This material will be covered in class. You are finished with the Chemistry notes packet. Use the material in this packet to answer the questions on the Chemistry Take-Home Test.

RATES OF CHEMICAL REACTIONS

The rate or speed of chemical reactions depends upon how long it takes for the reactants to break apart, and the products to form.

One factor that influences the rate of a chemical reaction is heat (temperature) of the environment:

Heat **increase -** ____

____

____

Heat **decrease -** ____

____

____

Another factor that influences the rate of chemical reactions is a **catalyst:**

Catalyst - ____

____

____

____

____

____

Enzyme-____

____

____

Demonstration of an inorganic catalyst increasing reaction rate: **(** Breakdown of H_2O_2)