

Math Review

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Metric System

The Metric System is the most commonly used measurement system in the world and in the scientific community. The metric system uses the units in the chart for measurement.

Unit	What it Measures
Meters	Distance
Liters	Volume
Grams	Mass
Second	Time
Kelvin	Temperature

Kelvin? What's that you say? Kelvin is the unit that is used in most calculations in Chemistry. Celcius is also often used because of its easy conversion to and from Kelvin. Fahrenheit is the most common scale in the U.S., so converting among all three is necessary.

Fahrenheit, Celcius, and Kelvin

- If you subtract 32 from the Fahrenheit temperature and multiply by $\frac{5}{9}$ (or divide by 1.8) then it will convert to Celcius temperature.
- If you multiply the Celcius temperature by $\frac{9}{5}$ (or 1.8) then add 32 it will give you the Fahrenheit temperature.
- Adding 273 to Celcius will give Kelvin, and subtracting 273 from Kelvin you will get Celcius.

The generic equations are as follows:

$$^{\circ}\text{F} = (1.8 * ^{\circ}\text{C}) + 32$$

$$^{\circ}\text{C} = \frac{^{\circ}\text{F} - 32}{1.8}$$

$$\text{K} = ^{\circ}\text{C} + 273$$

Example:

- $(451^{\circ}\text{F} - 32) / 1.8 = 233^{\circ}\text{C}$
- $(20^{\circ}\text{C} * 1.8) + 32 = 68^{\circ}\text{F}$
- $40^{\circ}\text{C} + 273 = 313 \text{ Kelvin}$

Note: Kelvin does not have a degree mark nor is it said with a degree.

Metric System Prefixes

One of the many reasons the metric system is used is for its easy ability to add prefixes that change the value of the unit. For example: the prefix kilo- on grams means that 1000 grams equals 1 kilogram. In the example the prefix multiplied the original unit's value by 1000 because that is what kilo- stands for. The chart shows the most used prefixes in italics and the least used in regular print. This chart can be used to find the prefix of whatever unit you are working with.

Metric System Prefixes		
Prefix	Multplied By	Symbol
exa	10^{18}	E
peta	10^{15}	P
tera	10^{12}	T
giga	10^9	G
<i>mega</i>	1000000	M
<i>kilo</i>	1000	k
hecto	100	h
deka	10	dk
<i>deci</i>	.1	d
<i>centi</i>	.01	c
<i>milli</i>	.001	m
<i>micro</i>	10^{-6}	μ
nano	10^{-9}	n
pico	10^{-12}	p
femto	10^{-15}	f

atto	10^{-18}	a
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** If you are not using Netscape, the numbers that are after the 10 in the chart are superscripts*

If you wanted to know how many meters are in 4 megameters the conversion chart could be consulted. You would discover that 1 megameter = 1000000 meters. So $4 * 1000000 = 4000000$. Therefore 4 megameters = 4000000 meters. (This can also be accomplished by moving the decimal six places)

Other Examples:

- 15cm = .15m
- 235kg = 235000g
- 12mm = 1.2cm

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Scientific Notation

Scientific Notation is a way to abbreviate very large or very small numbers. The format of Scientific Notation is this: a number that has a decimal after the first digit, multiplied by ten with an exponent. An example is: 1.23×10^4 . The exponent can be positive or negative. If the exponent is positive then you move the decimal to the right by the number of the exponent. If the exponent is negative then you move the decimal to the left by the number of the exponent. This form of numbers can express very large and small numbers depending on the exponent. More examples are as follows.

Scientific Notation Examples	
Scientific Notation	Regular Form
1.23×10^4	12300
4.91×10^3	4910
2.1×10^{-3}	.0021

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Significant Figures

Significant Figures or Digits are the amount of digits that are accurate in a calculation. This is determined by how many digits there are in the numbers of the calculation. The rules for determining how many significant digits are as follows:

- All non-zero numbers are significant.

- Zeroes at the end of a number that has no decimal point are not significant. Ex. 500 only has one significant digit because the zeroes after the five do not count.
- If a decimal point is placed after the last zero the zeroes do count as significant digits. Ex. 500. has three significant digits because the decimal point makes the zeroes significant.
- When the number has portions before and after the decimal then all the numbers are significant. Ex. 1700.023 has seven significant digits.
- In numbers that only have a decimal portion, zeroes at the beginning of the number do not count as significant. Ex. .00254 has three significant digits because the zeroes at the beginning of the number do not count.
- In Scientific Notation, significant digits are represented in the decimal number. Such as, 1.42×10^{12} has three significant digits because there are three numbers in the decimal number that is multiplied by 10 to some power.*

** If you are not using Netscape, the numbers that are after the 10 in scientific notation are superscripts*

The rules for determining the number of significant digits after a calculation are grouped by Addition and Subtraction, and Multiplication and Division.

Addition and Subtraction

When two or more numbers are added or subtracted the final answer is rounded off to the same decimal place as the number having its last significant digit the furthest to the left.

Example:

If you have the numbers 4.501 and 90.2 added together you will get 94.7 because the last column that both numbers use is the tenths place.

Multiplication and Division

Significant digits in Multiplication and Division are determined by the number of significant digits in each of the numbers in the calculation. The answer must have the same amount of significant digits as the number in the calculation with the least amount of significant digits.

Example:

If you multiply the numbers 500 and 256 together the answer would be 100000 because 500 only has one significant digit so the answer can have only one significant digit.

If you divide 1575 (four significant figures) by 17.6 (three significant figures), you round your answer to 89.5 (from 89.48863) so that it will have 3 significant digits.

Dimensional analysis is a process that allows changing of units. If you were going to change from centimeters to meters Dimensional analysis allows an easy way to change. To start you must decide what the conversion factor is, so we know that 100 centimeters = 1 meter. In Dimensional analysis you can setup the equation like this.

$$15 \text{ cm} \times \left(\frac{1 \text{ m}}{100 \text{ cm}} \right) = .15 \text{ m}$$

The centimeters are in the denominator of the conversion factor because the measurement is already in centimeters. The answer comes out in meters because the centimeters cancel in the division.

Other Examples:

$$13.1 \text{ g} (1000\text{mg} / 1\text{g}) = 13,100 \text{ mg}$$

$$5.0 \text{ hours} * \frac{60 \text{ min}}{1.0 \text{ hour}} * \frac{60 \text{ sec}}{1.0 \text{ min}} = 18000 \text{ sec}$$

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Matter and Its Changes

What exactly is matter? Matter is anything that has mass and takes up space. There are two main ways of classifying matter. Matter is classified first by its physical state as a solid, liquid, or gas. Secondly, we classify matter by its chemical constitution as an element, a compound, or a mixture. We are going to learn about the differences between atoms, ions, and molecules, the differences between compounds, elements, and mixtures, and the difference between physical and chemical changes.

- [Solids/Liquids/Gases](#)
- [Atoms/Molecules/Ions](#)

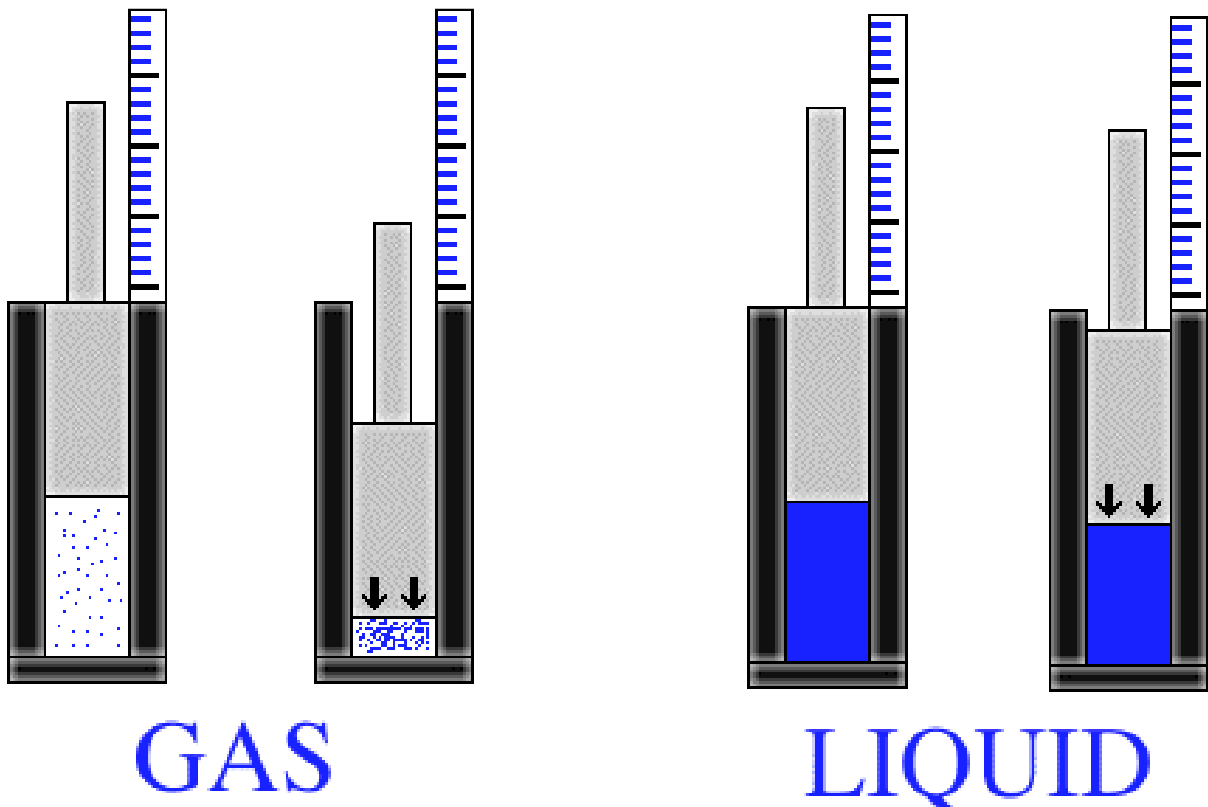
- [Compounds/Elements/Mixtures](#)
- [Physical & Chemical Changes](#)

Solids, Liquids, and Gases

To understand what matter is, we first must comprehend the three different states that it can exist in. Those three physical states are solids, liquids, and gases. A good example to illustrate this is water. Water, in its solid state is ice, in its liquid state is liquid water, and in its gaseous state is steam.

Solids usually have a definite shape and a definite volume. However, when a solid is broken into smaller pieces it is not changed chemically. For example if you crush an aspirin into a powder it is still a solid just in smaller pieces.

Now we have the problem of distinguishing between a liquid and a gas. What makes a liquid different from a gas is the characteristic of compressibility. A gas is easily compressible, where a liquid is not. Say for instance that you have a piston within an enclosed tube. If the tube is filled with steam, and then the piston is compressed, it is easy to compress the steam with the piston. As a result, the piston travels far into the tube. Now we put water into the enclosed tube. It is not nearly as easy to push the piston down into the tube now. Why? Well, a liquid is a lot harder to compress than a gas. This is because the molecules in the gas are farther apart than the molecules in the liquid.



These two characteristics that we have discussed, how rigid an object is, and an object's ability to be compressed, are used to determine the three basic states of matter

A solid is a form of matter which is made distinct by its rigidity. That is, a solid has a fairly fixed volume and shape, and is harder to compress than a gas or a liquid.

A liquid is a form of matter that is a fairly incompressible. This means that a liquid basically has a fixed volume, but not a fixed shape. It takes the shape of its container.

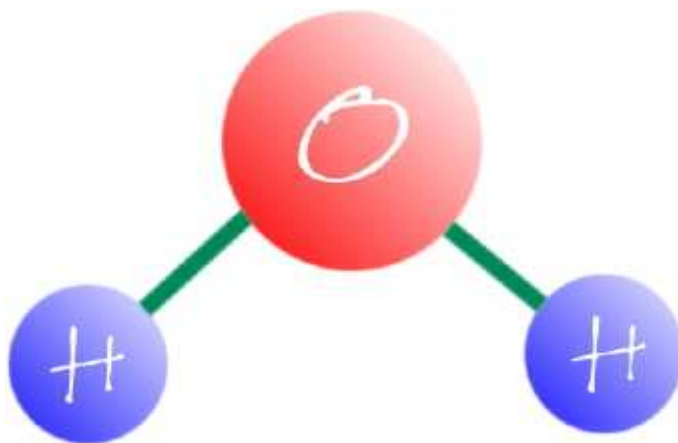
A gas is an easily compressible fluid. This means that a given quantity of gas will fit into a container of any size and shape. A gas has neither a definite volume nor a definite shape.

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Atoms, Ions, and Molecules

An atom is an extremely small particle of matter that retains its identity during chemical reactions. During the latter nineteenth century a series of experiments showed that atoms are comprised of smaller particles. An atom consists of a nucleus and one or more electrons surrounding the nucleus. The nucleus, the core of the atom, has the majority of the mass of the atom, and a positive charge. An electron is a very light particle which circles the nucleus. It has a negative charge. In an electrically neutral atom, the number of electrons equals the positive charge on the nucleus. The nucleus of the atom is composed of two smaller particles called neutrons and protons. A proton has a positive charge equal in magnitude to the negative charge of an electron. This means that in an electrically neutral atom (one with an equal number of protons and electrons), the positive charge of the protons, combined with the negative charge of the electrons, would result in no charge because they would cancel each other out. A proton's mass, however, is a whopping 1836 times that of the electron. A neutron has a mass almost identical to a proton's, but it has no electrical charge associated with it.

A molecule is a definite group of atoms that are chemically bonded together. They are tightly connected by attractive forces. A molecular formula is a chemical formula that gives the exact number of different types of atoms in a molecule. Some simple molecular substances are carbon dioxide, CO_2 ; ammonia, NH_3 ; and water, H_2O . The atoms that are in a molecule are not just stuffed together without any order. The atoms are chemically bonded to one another in order to form a definite arrangement. A structural formula is a chemical formula which shows how the atoms are bonded to one another to form a molecule. A good example is the structural formula for water, H-O-H. Those two horizontal lines connecting the H with the O (hydrogen and oxygen) represent the chemical bonds joining the atoms.



An ion is an electrically charged particle obtained from an atom or chemically bonded group of atoms by adding or removing electrons. Now what this means is that an ion is the result of taking away, or adding, electrons to an atom or a chemically bonded group of atoms. By taking away, or adding, these electrons, the particle takes on an electrical charge. Atoms are electrically neutral as they contain an equal number of positive and negative charges. An atom that adds an extra electron to it becomes a negatively charged ion. This type of ion is called an anion. An atom which loses one or more of its electrons now has a positive charge, and is called a cation. For example, a sodium atom can lose one of its electrons and form a sodium cation. Now, instead of being Na, it would be Na⁺¹. This means that the sodium atom has an overall positive charge of +1. Another example would be a neutral atom of Sulfur, S. If this atom of S were to gain two electrons it would become S⁻². The sulfur atom would now have a total negative charge of -2.

It has 16 protons and 18 electrons.

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Compounds/Elements/Mixtures

John Dalton (1766-1844) provided us with the Atomic Theory. His theory says that all matter is composed of small particles called atoms.

- All matter is composed of indivisible atoms. An atom is an extremely small particle of matter that retains its identity during chemical reactions.
- An element is a type of matter composed of only one kind of atom, each atom of a given kind having the same properties.
- A compound is a type of matter composed of atoms of two or more elements chemically combined in fixed proportions.

We now know that atoms are not indivisible, since they contain protons, neutrons, electrons and other subatomic particles. However, other than this mistake Dalton's ideas are essentially correct.

An element is a substance that is composed of only one kind of atom like aluminum, iron, or neon. Today, 109 elements are known and listed on the periodic table.

A compound is a substance of more than one element, chemically combined. A more scientific definition is that a compound is a type of matter composed of atoms of two or more elements chemically combined in fixed proportions. An example of a compound would be water. It is a compound that contains the elements hydrogen and oxygen fixed in the ratio 2 to 1. A compound has new properties unlike the elements which make it up. A compound has a chemical formula such as H₂O.

A mixture is a material that can be separated by physical means into two or more substances. A classic example of a mixture lab would be one in which you were presented a mixture of sand, iron filings, and salt. You are told to separate these materials. How do you do that? Well, think about the various physical properties of each material. You use a magnet to separate out the iron filings. You then mix water with the sand and salt mixture. You swish the water, salt and sand around for a while and then filter it. The salt dissolved into the water, so the salt water solution passes through the filter while the sand gets left in the filter. Now we slowly heat up the salt water solution, and evaporate the water, and we are left with salt. In a mixture, the compounds are not in a definite proportion. For example, a teaspoon of salt in a liter of water is salt water, but so is a cup of salt in a liter of water.

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Physical & Chemical Changes

A physical change is a change in the form of matter but not in its identity. An example of a physical change would be the dissolving of one thing into another thing. For instance, dissolving sugar into water. The water and the sugar retain their chemical identities and can be separated by physical means. Another example is ice melting to water. Ice and water are both H₂O. The identity of the matter is not changed, just the state that it is in.

A chemical change is a change in which one kind of matter is changed into a different type of matter. Some examples of chemical changes: the rusting of your car, setting your shoe on fire, digesting food, and the burning of magnesium metal in oxygen to form magnesium oxide. All of these materials combine chemically with another material, and cannot be separated by any physical means.

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Atomic Structure

In chemistry and physics the idea of the atom is a key concept. To understand many of the other concepts in chemistry some knowledge of the atom is necessary. In this section the following topics will be discussed:



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- [Basic Structure of an Atom](#)
- [Atomic Number, Mass Number, and Isotopes](#)
- [Avogadro's Number and The Mole](#)

Subatomic Particles

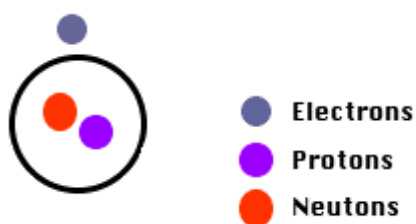
The basic conception of a subject now known as subatomic particle physics dates back to 500 BC when the Greek philosopher Leucippus and his pupil Democritus suggested that matter consists of small, indivisible particles, which they called atoms. For more than 2000 years after this, the notion of atoms lay in obscurity. For quite a long time, people believed that all matter consisted of four elements: earth, fire, air, and water. We now know that atoms do exist, and that some particles smaller than atoms also exist. These subatomic particles are divided into two main groups, the leptons and the hadrons. The best known lepton ("light" particle) is the electron. In order to account for the emission of electrons from the nucleus, the neutrino, an essentially massless neutral particle was postulated. The muon and the tau, both much more massive than the electron, comprise the rest of the lepton family. The hadrons are divided into two groups, the mesons and the baryons. Protons and neutrons are baryons. Mesons and baryons are made of smaller particles called quarks. There are six different quarks: up, down, charmed, strange, top, and bottom. While these are cool names, they convey nothing about the distinct properties of the quark. Each quark comes in three different colors: red blue and green. Again, the color label has nothing to do with the quark's appearance. Baryons are composed of three quarks, mesons are composed of a quark and an antiquark. Now that you have probably been thoroughly confused, move on, and hopefully that confusion will go away.

Basic structure of an atom

The picture below is an example of the arrangement of the particles in an atom. Most of the atom is just empty space. The rest of the atom consists of a positively charged nucleus of protons and neutrons that are surrounded by a cloud of negatively charged electrons. The nucleus is the center of the atom. An atom is an extremely small particle of matter that retains its identity during chemical reactions.

During the latter nineteenth century a series of experiments showed that atoms are comprised of smaller particles. An atom consists of a nucleus and one or more electrons surrounding the nucleus. The nucleus, the core of the atom, has the majority of the mass of the atom and a positive charge. An electron is a very light particle which circles the nucleus. It has a negative charge.

In an electrically neutral atom, the number of electrons equals the positive charge on the nucleus. The nucleus of the atom is composed of smaller particles called neutrons and protons. A proton has a positive charge equal in magnitude to the negative charge of an electron. This means that in an electrically neutral atom, the positive of charge the protons, combined with the negative charge of the electrons, would result in no charge because they would cancel each other out. A proton's mass, however, is a whopping 1836 times that of the electron. A neutron, however, has a mass almost identical to a proton's, but it has no electrical charge associated with it.



Particle	Location	Weight	Charge
Proton	Nucleus	1.0073 amu	Positive
Neutron	Nucleus	1.0087 amu	Neutral
Electrons	Electron Cloud	0.000549 amu	Negative

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Atomic Number and Mass Number

The atomic number of an element is what distinguishes it from all other elements. An atom's atomic number is the number of protons there are in the nucleus. Hydrogen's atomic number is 1. Helium's atomic number is 2. Any atom that has an atomic number of 1 is a hydrogen atom no matter how many electrons or neutrons the atom has.

The mass number is the number of neutrons added to the number of protons. The mass number of the most common isotope can be obtained from the periodic table. If you take the decimal number on the periodic table and round it to the nearest whole number, you have the mass

number. For example the atomic weight of Iron(Fe) is 55.847. When rounded it gives a mass number of 56.

The atomic number of Fe is 26. so most Fe atoms have 30 (56-26) neutrons. In addition, all neutral Fe atoms have 26 protons and 26 electrons. Atoms of the same element with a different number of neutrons are called isotopes. The most common isotope of an element is the one that is on the periodic table.



The above graphic shows two isotopes of Hydrogen. The picture on the left is the most common isotope of hydrogen with one electron and one proton. The picture on the right is another isotope of hydrogen with one proton, one electron, and a neutron. The most common isotope of uranium is uranium-238 which has 92 protons, 92 electrons, and 146 neutrons. Another isotope is uranium-235 with 92 protons, 92 electrons, and 143 neutrons.

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Avagadro's number

Avogadro's number and the mole are very important to the understanding of atomic structure. The Mole is like a dozen. You can have a dozen guitars, a dozen roosters, or a dozen rocks. If you have 12 of anything then you would have what we call a dozen. The concept of the mole is just like the concept of a dozen. You can have a mole of anything. The number associated with a mole is Avogadro's number. Avogadro's number is 602,000,000,000,000,000,000,000 (6.02×10^{23}). A mole of marbles would spread over the surface of the earth, and produce a layer about 50 miles thick. A mole of sand, spread over the United States, would produce a layer 3 inches deep. A mole of dollars could not be spent at the rate of a billion dollars a day over a trillion years. This shows you just how big a mole is. This number is so large that it is usually only represented in scientific notation.

Probably the only thing you will ever have a mole of is atoms or molecules. One mole of magnesium atoms (6.02×10^{23} magnesium atoms) weigh 24.3 grams. 6.02×10^{23} carbon atoms weigh a total of 12.0 grams. 6.02×10^{23} molecules of CO_2 gas only weigh a total of 44.0 grams. The decimal number on the periodic table is the atomic mass, the mass of one atom measured in atomic mass units(amu). Amu's are defined to be 1/12 the weight of the most common isotope of Carbon. This number in grams is the mass of 1 mole of that element. For example, 6.02×10^{23} iron atoms weigh only 55.847 grams.(This is equivalent to saying one mole of iron atoms weighs 55.847 grams.) One mole of sulfur weighs 32.066 grams. (This is the same as saying 6.02×10^{23} Sulfur atoms weigh 32.066 grams)

When not measured in grams, the decimal number on the periodic table is called the atomic mass and is in atomic mass units(amu). As mentioned earlier, one proton weighs 1.0073 amu and 1 neutron weighs 1.0087 amu. So the atomic mass is the mass in amus of one atom of an element, but you rarely use the mass of one atom. Even if you have a tiny speck of a metal or a microgram

of an element, you have billions and billions of atoms. Thus, the mass in grams of one mole of an element (the gram atomic weight) is more useful.

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Inorganic Nomenclature

Before a systematic method of naming different chemical substances was established, various compounds were named after people, places, or things. Some examples would be washing soda (sodium carbonate, which is used for softening wash water), and Glauber's salt (sodium sulfate, discovered by J.R. Glauber). Because of the vast number of compounds known to man, numbering into the millions, a system of naming was devised to prevent total confusion from occurring.

Chemical nomenclature is the systematic naming of chemical compounds.

Compounds can be divided into two basic categories, those which are true binary compounds (they contain only two types of elements), and those which contain more than two different types of elements. There is also a system of naming for organic (carbon-based) compounds.

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- [Naming of Acids](#)
- [Naming of Acids with Oxygen](#)

Naming of Binary Compounds

A binary compound is a compound that consists of a combination of two elements. Compounds that end in **IDE** indicate that they contain only two elements. The first element is usually a positively charged metal, and the second element is usually a negatively charged nonmetal. The positively charged ion is the name of the metal, while the negatively charged ion consists of the stem plus the suffix **IDE**.

Stems of the most commonly used elements:

Element	Stem
oxygen	ox
chlorine	chlor
carbon	carb
iodine	iod
bromine	brom
selenium	selen
nitrogen	nitr
phosphorus	phosph
fluorine	fluor
sulfur	sulf or sulfur

These stems are placed in the second part of the binary compound's chemical name, before the **ide**. Here are some examples using the element stems and the suffix **ide**.

CaO is calcium oxide

CaO is calcium oxide because you have a calcium atom bonded to an oxygen atom. Since this is a binary compound (meaning that it is a compound comprised of only two elements) there is a positive and a negative ion. The positive ion is calcium, because it is a metal, so the oxygen is the negative ion. Now we write **calcium** as the name of the metal, and **ox** as the prefix of the second word (because oxygen's stem is ox). Lastly, we attach the suffix **ide** behind the **ox** to get the name calcium oxide.

AlN is aluminum nitride

AlN is aluminum nitride because you have an aluminum atom bonded to a nitrogen atom. Since this is a binary compound there is a positive and a negative ion. The positive ion is aluminum, because it is a metal, so the nitrogen is the negative ion. Now we write **aluminum** as the name of the metal, and **nitr** as the prefix of the second word (because nitrogen's stem is **nitr**). Lastly, we attach the suffix **ide** behind the **nitr** to get the name aluminum nitride.

K₂S is potassium sulfide

K_2S is potassium sulfide because you have a potassium atom bonded to a sulfur atom. Since this is a binary compound there is a positive and a negative ion. The positive ion is potassium, because it is a metal, so the sulfur is the negative ion. Now we write **potassium** as the name of the metal, and **sulf** as the prefix of the second word (because sulfur's stem is **sulf**). Lastly, we attach the suffix **ide** behind the **sulf** to get the name potassium sulfide.

$NaCl$ is sodium chloride

$NaCl$ is sodium chloride because you have a sodium atom bonded to a chlorine atom. Since this is a binary compound there is a positive and a negative ion. The positive ion is sodium, because it is a metal, so the chlorine is the negative ion. Now we write **sodium** as the name of the metal, and **chlor** as the prefix of the second word (because chlorine's stem is **chlor**). Lastly, we attach the suffix **ide** behind the **chlor** to get the name sodium chloride.

Remember that the positively charged ion is the name of the metal, while the negatively charged ion consists of its stem plus a suffix (so far we have only used **IDE**). So far we have seen that in the name of a chemical compound, the first element usually is positive, and is the first part of the name. The second element in the compound's name is usually negative.

NaCl

Na is the metal, and has a positive charge of 1

Cl is the second part of the compound, a nonmetal, and has a charge of -1

We now find that the ammonium radical, NH_4^+ , is considered as a simple positive ion, and even though it is not a metal, it would go at the front of a compound name. Here are some examples:

NH_4Cl is ammonium chloride

NH_4Cl is ammonium chloride because you have an ammonium radical bonded to a chlorine atom. Since this is considered a binary compound there is a positive and a negative ion. The positive ion is ammonium even though it is not a metal. That makes the the chlorine the negative ion. Now we write **ammonium** as the name of the metal, and **chlor** as the prefix of the second word (because chlorine's stem is **chlor**). Lastly, we attach the suffix **ide** behind the **chlor** to get the compound's name, ammonium chloride.

$(NH_4)_2S$ is ammonium sulfide

$(NH_4)_2S$ is ammonium sulfide because you have an ammonium radical bonded to a sulfur atom. Since this is a binary compound there is a positive and a negative ion. The positive ion is ammonium even though it is not a metal. That makes the sulfur the negative ion. Now we write **ammonium** as the name of the metal, and **sulf** as the prefix of the second word (because

sulfur's stem is **sulf**). Lastly, we attach the suffix **ide** behind the **sulf** to get the compound's name, ammonium sulfide.

There are also two negative groups which are considered as special cases: the hydroxide radical, OH^- , and the cyanide radical, CN^- , are considered as simple negative ions. This means that they are added at the end of the compound name.

KCN is potassium cyanide

KCN is potassium cyanide because you have a potassium atom bonded to a cyanide atom. Since this is a binary compound, there is a positive and a negative ion. The positive ion is potassium because it has a positive charge. CN^- , the cyanide ion, is considered the negative ion. Now we write **potassium** as the name of the metal, and cyanide is the negative ion.

$\text{Mg}(\text{OH})_2$ is magnesium hydroxide

NH_4CN is ammonium cyanide

Some metallic ions can have two valence states, the one with the lower valence has the ending **OUS** while the one with the higher valence has the ending **IC**. Under the new international system, the valence is designated by a Roman numeral.

Fe^{+2} is the ferrous ion or iron (II) ion

Fe^{+3} is the ferric ion or iron (III) ion

Cu^{+1} is the cuprous ion or copper (I) ion

Cu^{+2} is the cupric ion or copper (II) ion

Pb^{+2} is the plumbous ion or lead (II) ion

Pb^{+4} is the plumbic ion or lead (IV) ion

Sn^{+2} is the stannous ion or tin (II) ion

Sn^{+4} is the stannic ion or tin (IV) ion

The rules given above apply to compounds of these elements in the same manner.

CuS is cupric sulfide or copper (II) sulfide

FeCl_2 is ferrous chloride or iron (II) chloride

When naming binary covalent compounds formed between two nonmetals, another system of nomenclature is preferred in which the numbers of each atom in a molecule are specified by a Greek prefix.

Number	Prefix
2	di
3	tri
4	tetra
5	penta
6	hexa
7	hepta
8	octa
9	nona
10	deca

NO_2 is nitrogen dioxide

NO_2 is nitrogen dioxide because you have a nitrogen atom bonded to two oxygen atoms. Since this is a binary compound of two nonmetals, we use the new way of naming we just learned. We keep nitrogen as the first name, and attach the prefix **di** before the oxygen because there are two atoms of oxygen. We then add the **ox** stem from oxygen after the di prefix. We attach the **ide** suffix after ox, and we have the finished product, nitrogen dioxide.

N_2O_4 is dinitrogen tetroxide

PCl_3 is phosphorus trichloride

In some cases the prefix mono is used to avoid ambiguity.

Examples :

CO is carbon monoxide

CO_2 is carbon dioxide

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Naming of Acids

For binary compounds with hydrogen as the positive ion, place the term **HYDRO** at the front of the stem of the negative ion, the letters **IC** at the end of the stem, and add the word acid.

Examples :

HBr is hydrobromic acid

H_2S is hydrosulfuric acid

HF is hydrofluoric acid

H_2Te is hydrotelluric acid

HCN is hydrocyanic acid

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Naming of Acids with Oxygen

These acids have hydrogen as the positive ion and a radical containing oxygen as the negative ion. If the radical ends in **ATE**, take off the ate, put on **IC** and add the word acid.

Examples :

HNO_3 is nitric acid

HClO_3 is chloric acid

H_2CrO_4 is chromic acid

H_2SO_4

is sulfuric acid

H_3PO_4 is phosphoric acid

If the radical ends in **ITE**, take off the ite, put on **OUS** and add the word acid.

Examples :

HNO_2 is nitrous acid

H_2SO_3 is sulfurous acid

HClO is hypochlorous acid

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Chemical Composition

- [Molecular Weight, Percent Composition, Empirical Formula](#)
 - [Molecular formula from Empirical Formula](#)
-

Molecular Weight, Percent Composition, Empirical Formula

The molecular weight of a substance is the sum of the atomic weight of the atoms in a molecule. The atomic weight is the average atomic mass for a naturally occurring element. This means that molecular weight is the average mass of a molecule of a substance. Molecular weight is expressed in atomic mass units. For example, we might want to find the molecular weight of a molecule of water. We have 2 atoms of H, with each hydrogen atom weighing 1 amu. We multiply 2 H atoms by 1 amu a piece to get 2 amu. We add the 16 amu from one O atom to the 2 amu from the oxygen to get a total of 18 amu for one molecule of water.

$\text{H}_2\text{O} = 2 \text{ atoms of hydrogen and 1 molecule of oxygen}$

$$\begin{aligned}2 \text{ H} * 1 \text{ amu} &= 2 \text{ amu} \\1 \text{ O} * 16 \text{ amu} &= 16 \text{ amu}\end{aligned}$$

$$2 \text{ amu} + 16 \text{ amu} = 18 \text{ amu} = \text{molecular weight of water}$$

The formula weight of a substance is the sum of the atomic weights of all atoms in a formula unit of the compound. Formula weight doesn't depend on whether or not the substance is a molecule. For example, sodium chloride, which is NaCl, has a formula weight of 58.44 amu. This results from having 22.99 amu from Na and 35.45 amu from Cl. You would use the formula weight for substances which are not molecules, such as ionic compounds.

Gram Formula Weight Examples:

Find the gram formula weight of H_2SO_4

1.

$$\begin{aligned}2\text{H} &= 2 \times 1 = 2 \\1\text{S} &= 1 \times 32 = 32 \\4\text{O} &= 4 \times 16 = 64 \\&98\text{g/mole}\end{aligned}$$

2. Find the gram formula weight of $\text{Na}_2\text{CO}_3 \cdot 10 \text{ H}_2\text{O}$

3.

$$\begin{aligned}2\text{Na} &= 2 \times 23 = 46 \\1\text{C} &= 1 \times 12 = 12 \\3\text{O} &= 3 \times 16 = 48 \\10\text{H}_2 &= 10 \times 18 = 180 \\&286\text{g/mole}\end{aligned}$$

Sometimes we want to find out what the formula of a compound would be. To figure this out, we analyze the compound into amounts of the elements for a given amount of the compound. This is expressed as the percent composition which is the mass percentages of each different element in

a compound. We must know the molecular weight of the compound in order to determine the molecular formula.

Say we have an element X in a compound. This element X is just part of the whole compound. We define the mass percentage of X as the parts of X per hundred parts of the total, by mass. That is:

$$\text{Mass \% X} = (\text{mass of X in the whole})/(\text{mass of the whole}) * 100\%$$

Percent Composition Example:

Calculate the percent composition of $\text{Mg}(\text{NO}_3)_2$

$$1\text{Mg} = 1 \times 24 = 24$$

$$2\text{N} = 2 \times 14 = 28$$

$$6\text{O} = 6 \times 16 = 96$$

$$148\text{g/mole}$$

$$\% \text{Mg} = 24/148 \times 100 = 16.2\%$$

$$\% \text{N} = 28/148 \times 100 = 18.9\%$$

$$\% \text{O} = 96/148 \times 100 = 64.0\%$$

The percentage composition of a compound leads directly to its empirical formula. An empirical formula for a compound is the formula of a substance written with the lowest integer subscripts. For example, hydrogen peroxide has the molecular formula H_2O_2 . The molecular formula tells us the precise number of atoms of different elements in the substance. The empirical number tells us ratio of numbers of atoms in the compound. The empirical formula of hydrogen peroxide is HO, while the molecular formula is H_2O_2 . Compounds with different molecular formulas can have the same empirical formulas and such substances will have the same percentage composition. An example is acetylene, C_2H_2 and benzene, C_6H_6 . In order to obtain the molecular formula of a substance, you need to know the percent composition and the molecular weight. The molecular weight allows us to choose the correct multiple of the empirical formula for the molecular formula.

Empirical Formula Example:

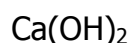
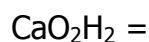
Determine the empirical formula for a compound which is 54.09% Ca, 43.18% O, and 2.73% H

Divide each percent by that element's atomic weight. To get the answers to whole numbers, divide through by the smallest one.

$$\text{Ca} = 54.09/40 = 1.352 \quad 1.352/1.352 = 1$$

$$\text{O} = 43.18/16 = 2.699 \quad 2.699/1.352 = 2$$

$$\text{H} = 2.73/1 = 2.73 \quad 2.73/1.352 = 2$$



Calcium Hydroxide

Molecular formula from Empirical Formula

The molecular formula of a compound is a multiple of its empirical formula. The empirical formula is the simplest formula of a substance, written with the smallest integers. For example, the molecular formula of benzene C_6H_6 is equivalent to the empirical formula, $(CH)_6$. This means that the molecular weight is some multiple of the empirical formula weight. The empirical formula weight is obtained by summing the atomic weights from the empirical formula. For any kind of molecular compound, we can write:

$$\text{Molecular weight} = n * \text{empirical formula weight}$$

where n is the number of empirical formula units in a compound. We can get the molecular formula by multiplying the subscripts of the empirical formula by whatever n is. We can calculate this from the equation:

$$n = (\text{molecular weight})/(\text{empirical formula weight})$$

Once we determine the empirical formula of a compound, we can calculate its empirical formula weight. If we have an experimental determination of its molecular weight, we can calculate n and then its molecular formula.

Molecular Formula Example:

A hydrocarbon is 84.25% carbon and 15.75% hydrogen and has a molecular weight of 114. What is its molecular formula?

$$C \ 84.25/12 = 7.021 \quad 7.021/7.021 = 1 \times 4 = 4$$

$$H \ 15.75/1 = 15.75 \quad 15.75/7.021 = 2.25 \times 4 = 9$$

$$4 \ C = 48$$

$$9 \ H = 9$$

$$57$$

$$114 / 57 = 2$$

$$2(C_4H_9) = C_8H_{18}$$

Octane

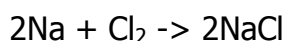


Balancing Equations

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- [Balancing Equations](#)
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What are chemical equations?

A chemical equation is a symbolic representation of a chemical reaction in terms of chemical formulas. An example of a chemical equation would be:

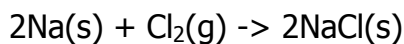


This chemical equation would stand for the burning of sodium in chlorine to produce sodium chloride. The formulas on the left side of the equation would stand for the reactant. A reactant is the starting substance in a compound. The arrow, \rightarrow , means either "yields" or "reacts to form." The formulas to the right of the arrow stand for the product formed in the chemical reaction. A product is the substance that results from a chemical reaction. The coefficient in front of the Na, 2, give the number of molecules or formula units involved in the reaction. Coefficients of one are usually understood, so they are not written.

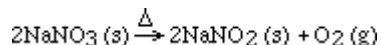
Sometimes it helps to indicate the states or phases of the substances in a chemical reaction. We can do this by placing certain labels, which stand for the various phases, following the formula of a substance in a chemical equation. Here are the labels:

(g)=gases (l)=liquid (s)=solid (aq)=aqueous solution

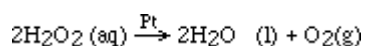
When we use the labels which we have just learned our former equation becomes:



In a chemical equation we can also indicate the conditions under which the reaction takes place. If the reactants in the chemical reaction are heated, we indicate this with the Greek symbol delta, Δ , over the arrow. Below is the equation that indicates that solid sodium nitrate, NaNO_3 decomposes when heated to give us solid sodium nitrate, which is NaNO_2 , and good ole oxygen, which is O_2 .



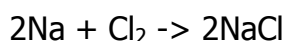
Oftentimes in chemical reactions there will be the addition of a catalyst. A catalyst speeds up a chemical reaction without being consumed in the overall reaction. Guess what, as you probably expected, there is a way to represent the addition of a catalyst to a chemical reaction. We do this by writing the catalyst involved in the reaction over the arrow. Here is an example, say that we have an aqueous solution of hydrogen peroxide, which is H_2O_2 . When this solution of hydrogen peroxide is exposed to platinum metal (Pt), the hydrogen peroxide decomposes into water and oxygen gas. The platinum speeds up the reaction of the decomposition of H_2O_2 into H_2O and O_2 and acts as a catalyst in this reaction (you see, hydrogen peroxide gradually decomposes on its own over time). We would represent the equation below:



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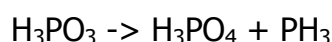
Balancing Equations

When the coefficients in a chemical equation are balanced, there are equal numbers of atoms of each element on both sides of the equation. We say that the chemical equation is balanced. You might ask, well, why does the chemical equation have to be balanced? Well, the answer to this stems from the atomic theory. In a chemical reaction, there is only a recombination of the atoms, no atoms are destroyed or created. Take our first equation:



In this reaction you have 2 atoms of sodium + 1 molecule of chlorine reacting to form 2 molecules of sodium chloride, which is salt.

In our next example we have:



Since the coefficients that give us the number of molecules have not yet been determined, this chemical equation is not balanced. To balance this equation, we select coefficients that will make the numbers of atoms of each element equal on both sides of the equations. It is best to write the

coefficients so that they are the smallest whole numbers possible. To balance the previous equation we first want to look at the pieces which comprise the overall chemical equation. We find that oxygen occurs in only one of the products, so it would probably be the easiest to balance first. We get:



Doing this also balanced the number of P and H atoms. So this means that in just one step we arrived at the balanced equation. You see, we now have 12 atoms of oxygen, 12 atoms of hydrogen, and 4 atoms of phosphorus on both sides of the equation. Before we balanced the equation, we had 3 atoms of oxygen, 3 atoms of hydrogen, and 1 atom of phosphorus on the reactants side, and 4 atoms of oxygen, 6 atoms of hydrogen, and 2 atom of phosphorus on the products side.

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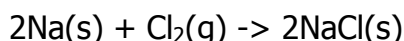
Types of Reactions

When we delve deeper into the study of chemistry, we find that there are several different types of reactions. There are several different ways to classify these reactions, mainly based on the patterns of similarity among them. There are 5 basic types of reactions we will be studying, and the way they are classified is based on how atoms or groups of atoms are rearranged during a particular reaction. These reactions are:

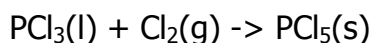
1. Combination reactions
2. Decomposition reactions
3. Displacement reactions
4. Metathesis reactions
5. Combustion reactions

Combination Reactions

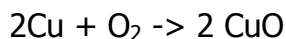
A combination reaction is a reaction in which two substances combine to form a third substance. A simple example would be where two elements react to form a compound of the elements. A good example of this would be:



Combination reactions can also have compounds as the reactants. An example of this would be where phosphorus trichloride reacts with chlorine to form phosphorus pentachloride:

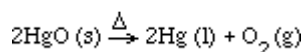


Here is another combination reaction, the burning of copper and oxygen to produce copper(II) oxide:



Decomposition Reactions

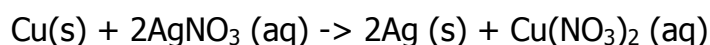
A decomposition reaction is a reaction in which a single compound reacts to give two or more substances. In order to decompose a compound, it is often necessary to raise the temperature. An example of a decomposition reaction would be the decomposition of mercury (II) oxide into mercury and oxygen when the compound is heated.



A compound can also decompose into a compound and an element, or two compounds.

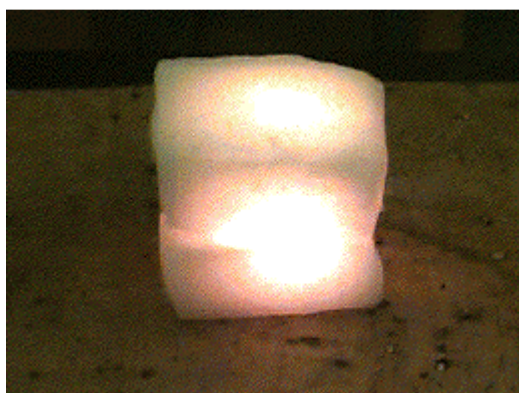
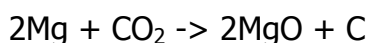
Displacement Reactions

Displacement reactions (sometimes referred to as single replacement reactions) are reactions in which an element reacts with a compound displacing an element from it. An example of this would be when a copper metal strip is dipped into a solution of silver nitrate. When this happens, crystals of silver metal are produced.



In this reaction, copper replaces the silver in silver nitrate. In the process it produces copper(II) nitrate solution and silver metal.

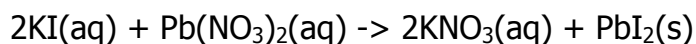
A fun fun fun single replacement reaction is one that we call "burning magnesium".



Metathesis Reactions

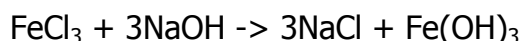
A metathesis reaction is a reaction that appears to involve the exchange of parts of the reactants. Metathesis reactions are also referred to as double-replacement reactions. When the reactants in the reaction are ionic compounds in solution, cations and anions of the compounds are the parts exchanged. An example of a metathesis reaction would be the reaction of potassium iodide solution and lead (II) nitrate solution. The reactants are colorless liquids, yet one of the products

of this reaction is lead (II) iodide, which forms a yellow precipitate. A precipitate is a solid compound formed during a reaction in solution.



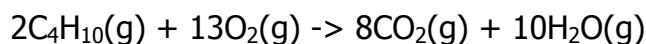
What happens in this metathesis reaction is that iodide ions in potassium iodide switch with the nitrate ions in lead (II) nitrate. What happens is that we get potassium nitrate (2KNO_3) and lead (II) iodide (PbI_2) as the products.

Here is another example of a double replacement reaction in which iron(III) chloride and sodium hydroxide are combined to produce a precipitate:

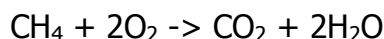


Combustion Reactions

So far, all the reactions which we have studied have been classified by the type of atom rearrangement that happens in the reaction. Combustion reactions are different in that they are characterized by the fact that one of the reactants is always oxygen. A combustion reaction is a reaction of a substance with oxygen, usually with the rapid release of heat to produce a flame. Organic compounds burn in oxygen to produce carbon dioxide and water vapor. Here is the formula for the chemical reaction involving butane burning in air to produce carbon dioxide and water vapor.



Here is an example of a combustion reaction. It involves burning methane. This results in carbon dioxide and water being formed from the reaction:



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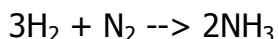
Stoichiometry

-
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Standard

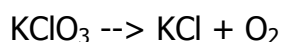
Stoichiometry consists of the calculations in chemistry that involve how much of each reactant is required to make the products of the reaction. The coefficients in the balanced equation are used to determine the number of moles of each element that are required in the reaction. Therefore, from the equation,



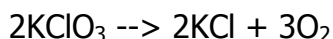
you can surmise that to make 2 moles of ammonia you need three moles of hydrogen gas and one mole of nitrogen gas. Yes, I know that almost everyone reading this page is saying that hey that sounds really cool, but what good is it to know how many moles you need to make something. I have the answer, if you know how many moles you need you can convert that to grams. On the periodic table there is an atomic weight. The atomic weight is equal to the number of grams in one mole of the element. If you have more than one element in a compound add the number of grams together according to the subscripts.

Examples:

1. How many moles of O_2 are produced when 7.5 moles of KClO_3 decompose according to the following equation?

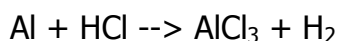


Balance the Equation

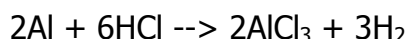


$$\begin{aligned} ? \text{ moles } \text{O}_2 &= 7.5 \text{ moles } \cancel{\text{KClO}_3} \frac{3 \text{ moles } \text{O}_2}{2 \text{ moles } \cancel{\text{KClO}_3}} \\ &= 11 \text{ moles} \end{aligned}$$

2. How many grams of Al will react with 2.3 moles of HCl according to this equation?

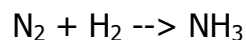


Balance the Equation

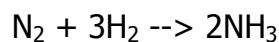


$$\begin{aligned} ? \text{ g Al} &= 2.3 \text{ moles HCl} * \frac{2 \text{ moles Al}}{6 \text{ moles HCl}} * \frac{27 \text{ grams}}{1 \text{ mole Al}} \\ &= 21 \text{ grams} \end{aligned}$$

3. How many grams of ammonia are produced when 32g of nitrogen react with excess hydrogen?



Balance the Equation



$$\begin{aligned} ? \text{ g NH}_3 &= 32 \text{ g N}_2 * \frac{1 \text{ mole N}_2}{28 \text{ g}} * \frac{2 \text{ moles NH}_3}{1 \text{ mole N}_2} * \frac{17 \text{ g NH}_3}{1 \text{ mole NH}_3} \\ &= 39 \text{ g NH}_3 \end{aligned}$$

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Limiting Reactant

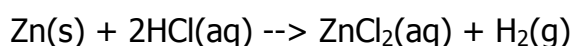
Now you say that stoichiometry is great, but what if you don't have such pretty numbers that work out evenly? That is where limiting reactant comes into play. In most situations one reactant will run out before the other. The reactant that is totally consumed is called the limiting reactant because it stops the reaction. Any other reactant that does not run out is called the excess reactant. Therefore the amount of product that can be produced is directly related to the limiting reactant.

The first step in a limiting reactant question is to determine the limiting reactant. To do this, for all reactants calculate the amount of product that would be produced if all of the reactant was used and there was excess of all the other reactants. The reactant that has the least product is the limiting reactant.

The amount of products is due to the amount of the limiting reactant.

An example:

Using the following reaction



Which is the limiting reactant and how much H_2 is produced if there is 0.30 mol of Zn and 0.52 moles of HCl?

Step one:

$$0.30 \text{ mol Zn} * \frac{1 \text{ mol H}_2}{1 \text{ mol Zn}}$$
$$= 0.30 \text{ mol H}_2$$

$$0.52 \text{ mol HCl} * \frac{1 \text{ mol H}_2}{2 \text{ mol HCl}}$$
$$= 0.26 \text{ mol H}_2$$

Since HCl is the limiting reactant, the number of moles of H₂ produced is .26 moles.

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Gas Laws

The main distinguishing property of gases is their uncanny ability to be compressed into smaller and smaller spaces. Gases are also the least complex state of matter. Don't get it wrong, just because they are the simplest doesn't mean that they are not one of the most interesting and useful states of matter.

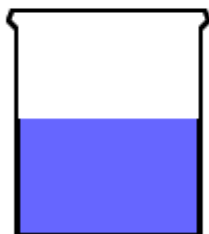
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 - [Boyle's Law](#)
 - [Charles's Law](#)
 - [STP and Gas Collected over Water](#)
 - [Combined Law](#)
 - [Ideal Gas Law](#)
-

Properties of Gases

Gases are easily expandable and compressible unlike solids and liquids. Gases have a measurement of pressure. Pressure is defined as force exerted per unit area of surface. It can be measured in several units such as kilopascals (kPa), atmospheres (atm), and millimeters of Mercury (mmHg). Gas has a low density because its molecules are spread apart over a large volume. A gas will fill whatever container that it is in. An example of this is a bottle of ammonia being opened in a room and the smell traveling throughout the room.

The Kinetic Molecular Theory is the basis of the many properties of gases. The five postulates to the Kinetic Theory are as follows:

- Gases are composed of molecules whose size is negligible compared to the average distance between them.
- Molecules move randomly in straight lines in all directions and at various speeds.
- The forces of attraction or repulsion between two molecules in a gas are very weak or negligible, except when they collide.
- When molecules collide with one another, the collisions are elastic; no kinetic energy is lost.
- The average kinetic energy of a molecule is proportional to the absolute temperature.



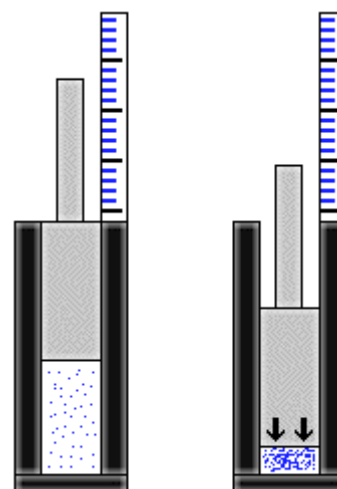
Effusion and Diffusion are the two ways that gases mix with other gases. Diffusion is a process in which a gas enters a container with another gas and the two mix to form a uniform mixture. Effusion occurs when a gas moves through a small hole in its current container into another container. An example of diffusion is the ammonia mentioned earlier where the ammonia moves into the room with the air. An example of effusion is if a coke bottle had a small hole in it just small enough for the gas inside to escape.

Since one of the properties of a gas is compressibility, a gas at a certain volume can be compressed by adding pressure. The mass of the gas will remain unchanged. Since the mass remains the same and the volume decreases, the density of the gas is greater.

This can be observed by using the density equation $D=m/V$.

If the mass of the gas is .50 grams and the volume of the gas is one liter then the density of the gas is .50 grams/liter. However, if the gas is compressed to only take up one half a liter then the density will change to 1 gram/liter.

The picture illustrates the compressing of a gas.



Many of the properties of gases can be measured in different ways. Conversion from one unit of pressure to another is very important. To achieve this there has to be a conversion factor to move from one unit to another. Here is a list of equivalent amounts of pressure:

- 1 atm
- 760 mmHg
- 76 cmHg
- 101.3 kPa
- 760 torr
- 29.92 inches Hg

If you are in atms and want to convert to mmHg then # of atms * (760 mmHg / 1 atm) = # of mmHg because the atms cancel. This dimensional analysis method of canceling the units will work for changing from any unit to another.

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Boyle's Law

Boyle's Law states the volume of a definite quantity of dry gas is inversely proportional to the pressure, provided the temperature remains constant.

Mathematically Boyle's law can be expressed as $P_1V_1 = P_2V_2$

- V_1 is the original volume
- V_2 is the new volume
- P_1 is original pressure
- P_2 is the new pressure

Suppose you have a gas with 45.0 ml of volume and has a pressure of 760.mm. If the pressure is increased to 800mm and the temperature remains constant then according to Boyle's Law the new volume is 42.8 ml.

$$(760\text{mm})(45.0\text{ml}) = (800\text{mm})(V_2)$$
$$V_2=42.8\text{ml}$$

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Charles's Law

Charles's Law can be stated as the volume occupied by any sample of gas at a constant pressure is directly proportional to the absolute temperature.

$$V / T = \text{constant}$$

- V is the volume
- T is the absolute temperature (measured in Kelvin)

Charles's Law can be rearranged into two other useful equations.

$$V_1 / T_1 = V_2 / T_2$$

- V_1 is the initial volume
- T_1 is the initial temperature
- V_2 is the final volume
- T_2 is the final temperature

$$V_2 = V_1 (T_2 / T_1)$$

- V_2 is the final volume
- T_2 is the final temperature
- V_1 is the initial volume
- T_1 is the initial temperature

Important: Charles's Law only works when the pressure is constant.

Note: Charles's Law is fairly accurate but gases tend to deviate from it at very high and low pressures.

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STP

STP is Standard Temperature and Pressure. STP is 0° Celcius and 1 atmosphere of pressure. Gases properties can be compared using STP as a reference.

To obtain the pressure of gas collected over water the partial pressure of the water must be taken into consideration. The reason for this is as the gas bubbles through the water the gas picks up water vapor. The amount of water vapor the gas picks up only depends on the temperature. To calculate the pressure of the gas the partial pressure of the water must be subtracted from the pressure in the container. The partial pressure of the water can be obtained from the table below.

Temperature (°C)	Pressure (mmHg)
0	4.6
5	6.5
10	9.2
11	9.8
12	10.5
13	11.2
14	12.0
15	12.8
16	13.6
17	14.5
18	15.5
19	16.5
20	17.5
21	18.7

22	19.8
23	21.1
24	18.7
25	23.8
26	25.2
27	26.7
28	28.3
29	30.0
30	31.8
35	42.2
40	55.3
45	71.9
50	92.5
55	118.0
60	149.4
65	187.5
70	233.7
75	289.1
80	355.1
85	433.6
90	525.8
95	633.9
100	760.0
105	906.1

For example if a gas is collected over water at 22°C and 1 atm of total pressure, the pressure of the gas would be calculated as follows:

1 atm = 760 mmHg therefore 760 mm - 19.8 mm = 740.2 mmHg would be the pressure of the gas.

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Combined Law

The combined gas law is a combination of Boyle's Law and Charles's Law; hence its name the combined gas law. In the combined gas law, the volume of gas is directly proportional to the absolute temperature and inversely proportional to the pressure.

This can be written as $PV / T = \text{constant}$. Since for a given amount of gas there is a constant then we can write $P_1V_1 / T_1 = P_2V_2 / T_2$.

- P_1 is the initial pressure

- V_1 is the initial volume
- T_1 is the initial temperature (in Kelvin)
- P_2 is the final pressure
- V_2 is the final volume
- T_2 is the final temperature (in Kelvin)

This equation is useful if you have the current volume, temperature, and pressure of a gas, and if you have two of the three final values of the gas.

For example if you have 4.0 liters of gas at STP, and you want to know the volume of the gas at 2.0 atm of pressure and 30° C, the equation can be setup as follows:

$$(1.0)(4.0) / 273 = (2.0)(V_2) / 303$$

$$(V_2)(2)(273) = (1)(4)(303)$$

$$V_2 = 2.2$$

Therefore the new volume is 2.2 liters.

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Ideal Gas Law

The ideal gas law is a combination of all the gas laws. The ideal gas law can be expressed as $PV = nRT$.

- P is the pressure in atm
- V is the volume in liters
- n is the number of moles
- R is a constant
- T is the temperature in Kelvin

The constant R is calculated from a theoretical gas called the ideal gas. The most commonly used form of R is .0821 L * atm / (K * mol). This R will allow the units to cancel so the equation will work out.

To find the volume of 2.00 moles gas that is at 1.00 atm of pressure and 235 Kelvin, use the ideal gas law equation.

$$(1.00 \text{ atm})(V) = (2.00 \text{ mol})(.0821 \text{ L} * \text{atm} / (\text{K} * \text{mol}))(235 \text{ kelvin})$$

$$V = (38.587 \text{ L} * \text{atm}) / (1.00 \text{ atm})$$

$$V = 38.6 \text{ L}$$

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Electron Configuration

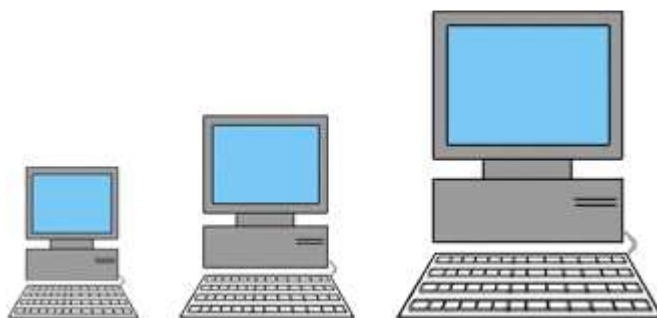
- [Electronic Structure of Atoms](#)
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-

Electronic Structure of Atoms

Each electron in an atom is described by four different quantum numbers. Three of these quantum numbers (n , l , and m) represent the three dimensions to space in which an electron could be found. A wave function for an electron gives the probability of finding the electron at various points in space. A wave function for an electron in an atom is called an atomic orbital. The fourth quantum number (m_s) refers to a certain magnetic quality called spin.

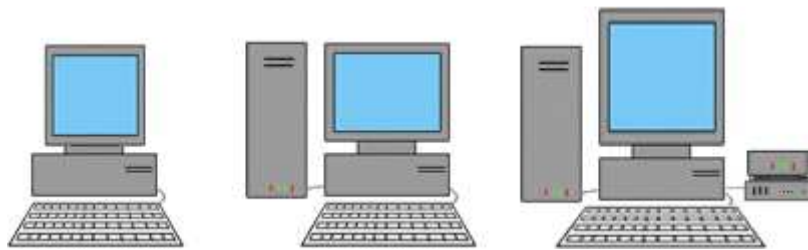
n-The Principal Quantum Number

The n quantum number relates to the size of the atomic orbital. n can have any positive integer value from 1 to 7. The smaller the n , the lower the energy, the higher the value of n , the higher the energy. In the case of any single-electron atom, or hydrogen atom, n is the only quantum number which determines the energy. The size of an orbital depends on n . The larger the orbital, the larger the value of n . Orbitals of the same quantum state belong to the same shell. To use an analogy for n , why not relate it to the size of a computer, where larger values would represent larger houses.



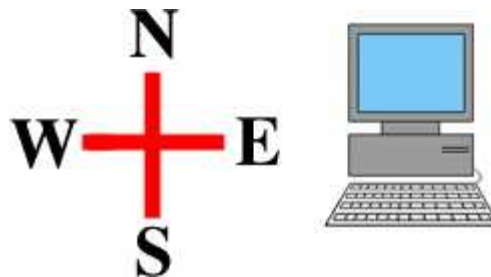
l-The angular momentum quantum number

l can have any integer value from 0 to 3. This quantum number distinguishes orbitals of a given n value which have different states. Or, the secondary quantum number gives the shape of the orbital so the analogy can be made to the shape of the computer with larger values associated with computers with more components.



M-magnetic quantum number

The third quantum number has to do with the orientation of an orbital in a magnetic field. Because of this, we can relate its values to different directions the computer might be facing.



The final quantum number is the spin quantum number, it describes the spin orientation of an electron.

The electron configuration of an atom is the particular distribution of electrons among available shells. It is described by a notation that lists the subshell symbols, one after another. Each symbol has a subscript on the right giving the number of electrons in that subshell. For example, a configuration of the lithium atom (atomic number 3) with two electrons in the 1s subshell and one electron in the 2s subshell is written $1s^2 2s^1$.

sublevel	orbital	maximum # of electrons
s	1	2
p	3	6
d	5	10
f	7	14

The notation for electron configuration gives the number of electrons in each subshell. The number of electrons in an atom of an element is given by the atomic number of that element.

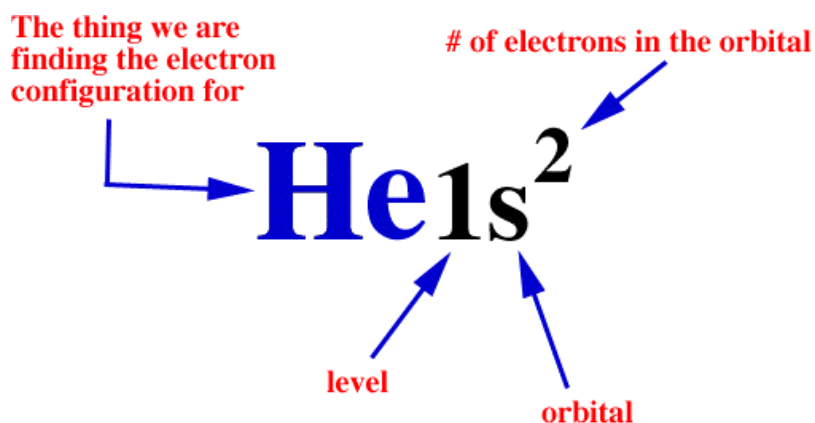
On the left we have a diagram to show how the orbitals of a subshell are occupied by electrons. On the right there is a diagram for the filling order of electrons in a subshell.

7s 7p
 6s 6p 6d
 5s 5p 5d 5f
 4s 4p 4d 4f
 3s 3p 3d
 2s 2p
 1s



Here are some examples that show how to use the filling order diagram to complete the electron configuration for a certain substance.

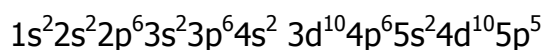
Element	# of Electrons in Element	Electron Configuration
He	2	$1s^2$
Li	3	$1s^2 2s^1$
Be	4	$1s^2 2s^2$
O	8	$1s^2 2s^2 2p^4$
Cl	17	$1s^2 2s^2 2p^6 3s^2 3p^5$
K	19	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$



Often times you will be asked to find the electron configuration for something that looks like this:



The 53 denotes the number of electrons in an atom of iodine. You would now proceed to do the electron configuration by looking at the filling order chart.



Periodicity

With increasing atomic number, the electron configuration of the atoms display a periodic variation. Because of this the elements show periodic variations of both physical and chemical behavior. The periodic law is a law stating that when the elements are arranged by atomic number, their physical and chemical properties vary periodically. We are going to be looking at three physical properties of an atom: atomic radius, ionization energy, and electron affinity.

Atomic Radius

The size of the electron cloud increases as the principal quantum number increases. Therefore, as you look down the periodic table, the size of atoms in each group is going to increase. When you look across the periodic table, you see that all the atoms in each group have the same principal quantum number. However, for each element, the positive charge on the nucleus increases by one proton. This means that the outer electron cloud is pulled in a little tighter. One periodic property of atoms is that they tend to decrease in size from left to right across a period of the table. So finally we have a good definition for how the atomic radii increases: the atomic radii increases top to bottom and right to left in the periodic table.

Ionization Energy

The energy needed to remove the most loosely held electron from an atom is known as ionization energy. Ionization energies are periodic. The ionization energy tends to increase as atomic number increases in any horizontal row or period. In any column or group, there is a gradual decrease in ionization energy as the atomic number increases. Metals typically have a low ionization energy. Nonmetals typically have a high ionization energy.

Electron Affinity

The attraction of an atom for an electron is called electron affinity. Metals have low electron affinities while nonmetals have high electron affinities. The general trend as you go down a column is a decreasing tendency to gain electrons. As you go across a row there is also a trend for a greater attraction for electrons.

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Bonding

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- [Resonance](#)

Lewis Dot Notation

Lewis Dot notation is a way of describing the outer shell (also called the valence shell) of an atom's electrons. Dots are drawn around the elements symbol to represent the electrons in the valence shell of the atom. For example Helium, which has two electrons in its valence shell, would be written as:



He has two electrons in an s orbital.

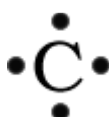


Al has 2 electrons in an s orbital and 1 in a p orbital

The three dots around the symbol stand for the three electrons.

Al has 3 valence electrons ($1s^22s^22p^63s^23p^1$). You can determine this by writing out the electron configuration or simply by the Roman numeral III at the top of the family on the periodic table containing Al. The dots are placed on all four sides of the symbol before repeating dots on a side. An example of this is the carbon atom which only has four electrons in its valence shell.

Note: C always makes four bonds; so one electron is promoted from the s orbital to the p orbital and C is represented as this:



Atoms will always promote electrons so they can make more bonds, thus increasing stability.

When the number of electrons in the valence shell is more than four electrons the dots are written as pairs on the side until all the electrons are accounted for. Examples are Fluorine and Sulfur.



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Ionic Bonds

An ionic bond is a chemical bond formed by the electron attraction between positive and negative ions. Ionic bonds are made when an electron from the valence shell of one atom is transferred to the valence shell of another atom. The atom that lost an electron becomes a positive ion and the atom that gains the electron becomes a negative ion.

In NaCl the sodium ion has one less electron than protons so it has a positive charge. The chlorine ion has one more electron than protons so it has a negative charge. Since positives are attracted to negatives the two ions are attracted to each other. The atom that loses an electron becomes a cation which is positive, and the atom that gains an electron becomes an anion which is negative. The nature of the ionic bonds facilitates the formation of ionic solids by attracting other charged atoms to form a solid. The ions are arranged in a crystalline structure with each Na^+ ion attracted to several Cl^- ions and each Cl^- ion attracted to several Na^+ ions. There are no NaCl molecules.

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Covalent Bonds

Covalent Bonds are chemical bonds formed by the sharing of a pair of electrons between atoms. The nuclei of two different atoms are attracting the same electrons. Therefore, unlike ionic bonds where an electron is moved from one atom to another the electrons are shared.

The Octet Rule is a tendency of atoms in molecules to have eight electrons in their valence shells. (Two for hydrogen atoms.) The octet rule is a general rule, but is not followed by all molecules.

Multiple Bonds are sometimes found in molecules so that the molecules satisfy the octet rule. A single bond (which was discussed earlier) is when a single pair of electrons is shared between the two atoms. A double bond is when two pairs of electrons are shared between two atoms. A triple bond is when three pairs of electrons are shared between two atoms. (Notice a trend?) Double and triple bonds mostly occur when the elements Carbon(C), Nitrogen(N), Oxygen(O) and Sulfur(S) are involved. An example of a molecule with double bonds is Carbon Dioxide (CO_2). Notice that each element ends up with eight electrons around it.



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Polar Covalent Bonds

In bonds between atoms of the same element the sharing of the electrons is equal between the two atoms. When two atoms of different elements make a bond, the electrons will not usually be shared equally. The electrons are pulled more toward the more electronegative element. Electronegativity is the measure of the ability of an atom in a molecule to draw bonding electrons to itself. In general, electronegativity increases from bottom to top and left to right on the periodic table. Fluorine is the most electronegative element since it has a tendency to pick up electrons easily and hold on to them strongly. An element like cesium has a low electronegativity. The unequal sharing of electrons is called a polar covalent bond. The definition of a polar covalent bond is a covalent bond in which the bonding electrons spend more time near one atom than the other.

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Lewis Dot Notation Revisited

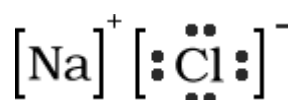
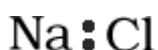
Now that you understand several types of bonds, a discussion of how to draw the different bonds using Lewis dot notation is in order. There is a generic procedure that can be used to draw almost all molecules. This procedure is as follows:

1. Calculate the total number of valence electrons that are in the molecule. The number of valence shell electrons can be determined by using the periodic table.
2. Write the skeleton structure of the molecule or ion. (Connect the bonds with two electrons or a line)
3. Distribute electrons to the atoms surrounding the central atom to satisfy the octet rule.
4. Distribute the remaining electrons as pairs to the central atom. If there are less than eight electrons around the central atom then a double or triple bond may exist. If the central atom is two short then it suggests a triple bond (or two double bonds). *Note:* double and triple bonds usually involve C, O, N and S atoms.

Examples:

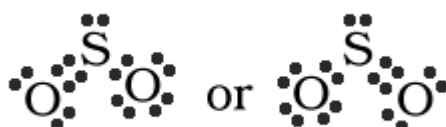
Ionic Bond: NaCl

Total Number of Electrons: 8



Resonance

Resonance is another kind of bond that exists between atoms. In resonance the bond that holds the compound together is not between two atoms, it is shared between more than two atoms. Looking at an example is the easiest way to understand resonance. If we try to draw sulfur dioxide (SO_2), there can be two plausible formulas written. These are:



One might conclude that the molecule would be one or the other but this hypothesis does not fit the experimental data. During experimentation the bonds were determined to be the same between sulfur and both of the oxygen atoms. There were two S-O bonds that were just alike. So neither of the above formulas are correct. So the proper way to write SO_2 is as follows:



The above notation symbolizes how the two bonds are the same **not** how the molecule can be one or the other. The actual structure is a composite of these two.

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Molecular Geometry

Molecular Geometry is the general shape of molecules. The shape is governed by how many bonding pairs there are around the central atom, and by how many of those pairs are participating in a bond. Molecular Geometry is an important topic for understanding the properties and reactions of chemicals.

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- [Polarity](#)
- [Hybridization](#)
- [Multiple Bonds](#)

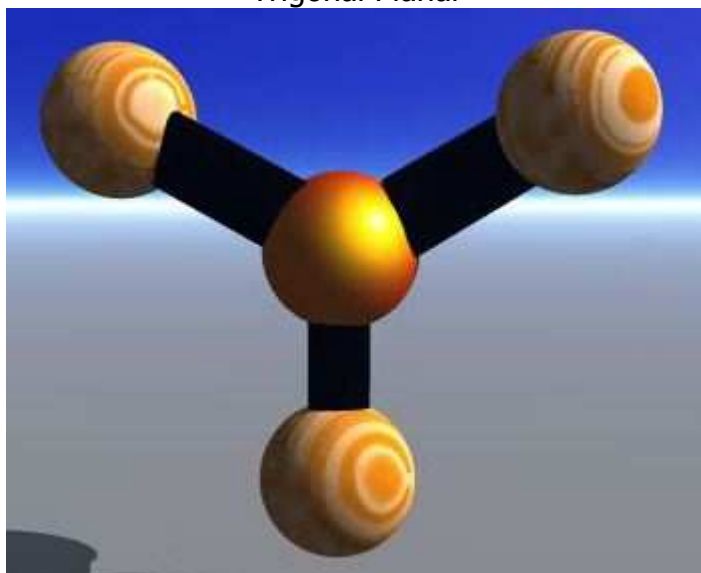
VSEPR Model

The Valence-shell electron-pair repulsion (VSEPR) Model is a model that states electron pairs in a molecule will be as far apart from one another as they can be because they repel each other. In a molecule that has two valence shell electron pairs the electrons tend to be on opposite sides of the central atom. If there are three electron pairs around the central atom they are in a trigonal planar shape. With four electron pairs the arrangement is called a tetrahedral arrangement. With five electron pairs the arrangement is called trigonal bipyramid. With six electron pairs the arrangement is called an octahedron.

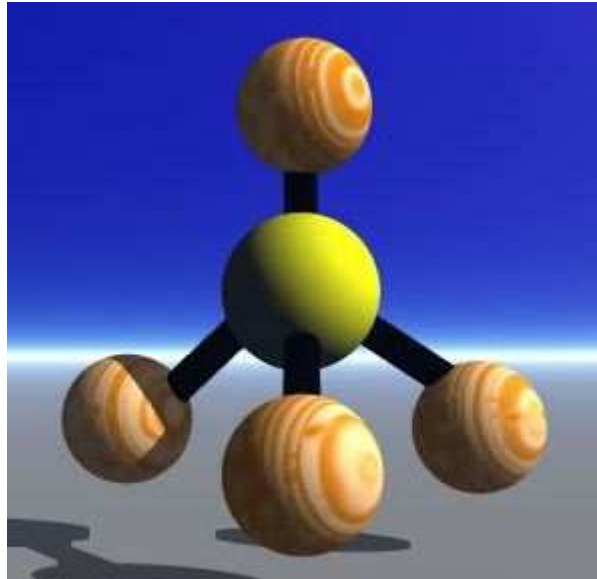
Linear



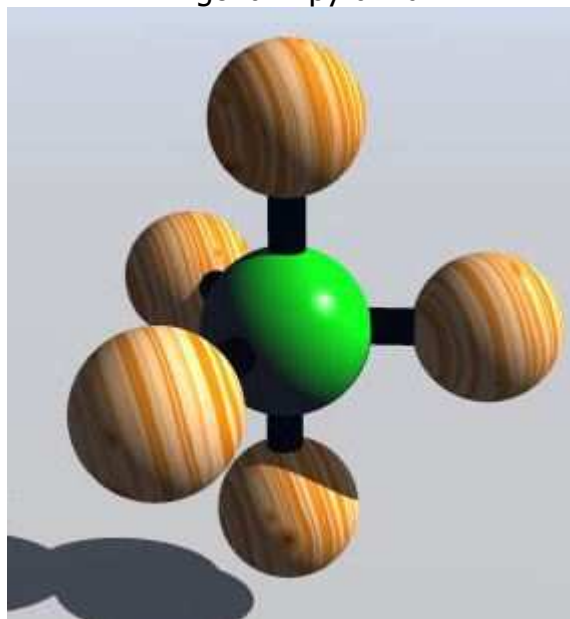
Trigonal Planar



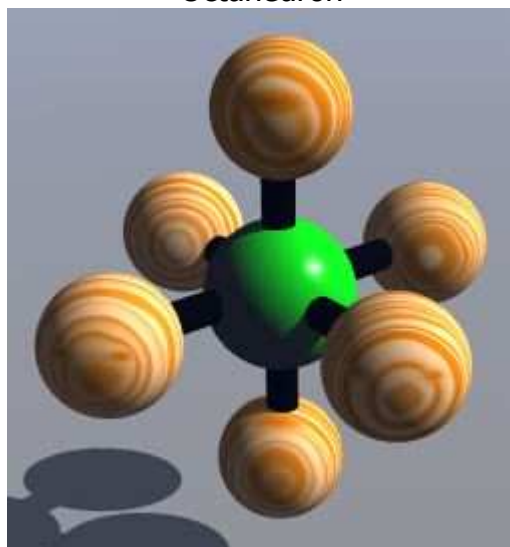
Tetrahedron



Trigonal Bipyramid



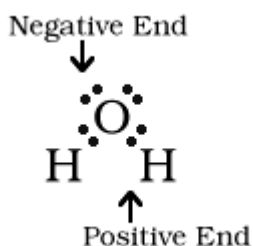
Octahedron



If the electrons are not distributed equally, the molecule is said to be polar. That is, the molecule has a negative end and a positive end. It has two poles and is polar; it has a measurable dipole moment.



The electrons are not distributed evenly so the water molecule is polar. The negative end of the molecule is the oxygen end. O is more electronegative than H and pulls the negative electrons toward itself. Also, there are two lone pairs around oxygen.

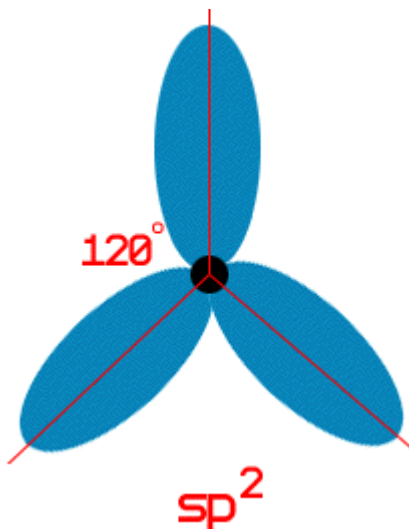


You can write a formula denoting the negative and positive end of the molecule. The sigma (with a plus or minus) above the symbol for the atom is the indicator for which end of the molecule is positive or negative.

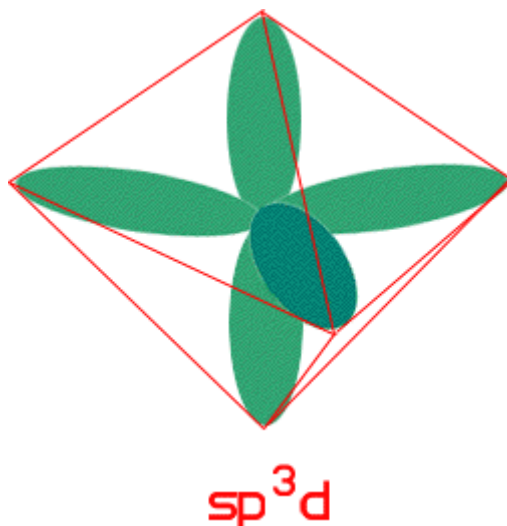
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Hybridization

As discussed in the electron configuration section when electrons bond they fill orbitals. One might think that the s, p, and d orbitals are different in the bonds. This would make sense but experimental data shows that all the bonding orbitals in many molecules are the same. The way that this occurs is through Hybridization. The hybrid orbitals are formed by combining s, p and d orbitals. If a molecule has three bonds it needs three orbitals. So the first three orbitals that are used are an s and two p orbitals. The hybrid orbital that is formed is called a sp^2 orbital. All three of the orbitals are the same.



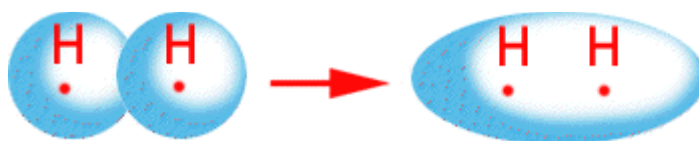
If the molecule has the trigonal bipyramidal shape then the molecule has sp^3d . (This is because it has five bonds so it needs five orbitals.)



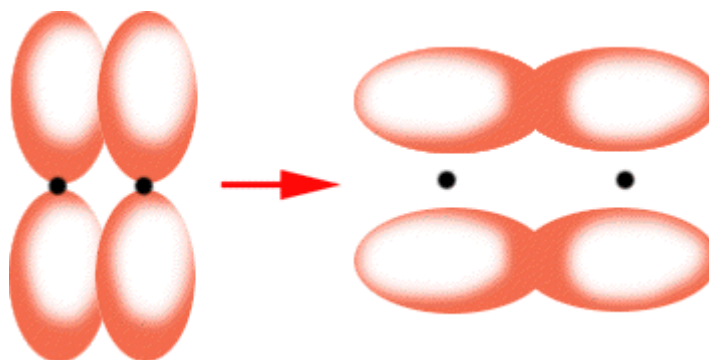
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Multiple Bonds

Single bonds which are the most prevalent of all bonds are called sigma bonds. These bond orbitals overlap end to end.



Double bonds which were discussed earlier have one sigma bond and one pi bond. The sigma bond acts the same in a double bond as it does in a single bond. (Overlapping end to end) The pi bond (which is the second bond) is different. The pi bond consists of a sideways overlap of two orbitals.



Triple bonds are just like double bonds except that there are two pi bonds not just one.

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Solutions

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 - [Molarity](#)
 - [Molality](#)
 - [Mole Fraction](#)
 - [K_f and K_b](#)
-

Types of Solutions

You may be asking yourself why solutions are necessary. Well, they serve a lot of practical purposes. For instance, most chemical reactions are run in solution. Solutions also usually have a lower melting and freezing point than just a substance by itself.

Let's say that we have a handful of salt crystals, NaCl. When this salt dissolves in water, there is a uniform dispersion of ions in this water. What we have just formed is called a solution. A solution is defined as a homogeneous mixture of two or more substances, consisting of ions or molecules. A solution can be a solid, liquid, or gas. A solution results from the combination of a solute and a solvent. A solute is, in the case of a gas or solid dissolved in liquid, the gas or solid, but in other cases it is the part that has the smaller amount. A solvent is, in the case of a gas or solid dissolved in liquid, the liquid, but in other cases it is the part that has the larger amount. In the example concerning the salt, the solvent would be water and the salt would be the solute.

So that we can understand the concept of solubility, let's consider the process of dissolving sodium chloride in water. We know that NaCl is an ionic compound, and that it dissolves in water as Na⁺ and Cl⁻ ions. When we mix 50 grams of salt in 100 mL of water we find something cool going on. The sodium and chlorine ions leave the surface of the crystal and enter into the solution. These ions then move about at random in the solution and occasionally bump into another crystal and stick, returning to their crystalline state. As time passes, more sodium chloride continues to dissolve into the solution, which means that the ion concentration increases. This means that eventually more ions are going to bump into each other and return to their crystalline state. Over time, a dynamic equilibrium will be reached in which the rate at which ions leave the crystals is equivalent to the rate at which ions collide to form a crystal.

At this equilibrium, no more salt appears to dissolve. We have reached what we call a saturated solution. A saturated solution is a solution that is in equilibrium with respect to a given dissolved substance. An unsaturated solution is a solution that is not in equilibrium with respect to given dissolved substance, leaving room for more substance to dissolve. The solubility of a substance is the amount that dissolves in a given quantity of water at a given temperature to give a saturated solution. Sometimes, through special circumstances we can obtain a supersaturated solution. A supersaturated solution is a solution that contains more dissolved solute than is normally possible at that temperature.

Molarity

Molar Concentration or Molarity is defined as the moles of solute dissolved in one liter of solution.

$$\text{Molarity} = \frac{\text{moles of solute}}{\text{liter of solution}}$$

Example:

.0678 g of NaCl is placed in a 25.0 ml flask full of water. When the NaCl dissolves, what is the molarity of the solution?

.0464 M NaCl

Molality

The molality of a solution is the moles of solute per kilogram of solvent.

$$\text{molality} = \frac{\text{moles of solute}}{\text{kilogram of solvent}}$$

Example:

.20 mol of ethylene glycol / 2.0 Kg of solvent = .10 m ethylene glycol

Mole Fraction

Mole fraction is the number of moles of a substance divided by the total number of moles in the solution.

$$\text{Mole Fraction} = \frac{\text{moles of substance A}}{\text{Total Moles of solution}}$$

Example:

If there is 4.0 moles of HCl in 12 moles of solution then the mole fraction of HCl would be 1/3. When all mole fractions are added together the total is always 1.

K_f and K_b

K_f and K_b are the freezing point depression constant and boiling point elevation constant. When a solute is added to a solvent, the boiling point of the solution is always greater than the boiling point of the pure solvent. Adding a solute also lowers the freezing point.

Solvent	Formula	Melting Point (°C)	Boiling Point(°C)	K _f (°C/m)	K _b (°C/m)
Benzene	C ₆ H ₆	5.455	80.2	5.065	2.61
Ethanol	C ₂ H ₅ OH	--	78.3	--	1.07
Water	H ₂ O	0.000	100.000	1.858	0.521

To determine the amount of change in boiling point you will need this equation:

$$\Delta T_b = K_b * m$$

- ΔT_b change in boiling point
- K_b boiling point elevation constant
- m molality of solution

Then ΔT_b is added to the normal boiling point of the pure solvent. Note that the identity of the solute is not important, just its concentration (expressed in molality). Therefore, boiling point elevation is a colligative property.

To determine the freezing point of a solution, you need to calculate the decrease in freezing point caused by the addition of a solute to the solvent. Use the equation:

$$\Delta T_f = K_f * m$$

- ΔT_f change in freezing point
- K_f freezing point depression constant
- m molality of solution

Then the ΔT_f is subtracted from the normal freezing point of the pure solvent. Freezing point depression is also a colligative property.

Example:

Calculate the boiling point and freezing point of a solution of .30 g of glycerol (C₃H₈O₃) in 20.0 g of water.

moles glycerol = (.30 g) (1 mole / 92 g) = .0033 moles
molality of solution = .0033 moles / .020 kg = .16 m

$$\Delta T_b = (.521 \text{ } ^\circ\text{C/m})(.16 \text{ m}) = .083 \text{ } ^\circ\text{C}$$

$$\text{Boiling point} = 100.00 + .083 = 100.083 \text{ } ^\circ\text{C}$$

$$\Delta T_f = (1.858 \text{ } ^\circ\text{C/m})(.16\text{m}) = .30 \text{ } ^\circ\text{C}$$

Freezing point = $0.00\text{ }^{\circ}\text{C} - .30\text{ }^{\circ}\text{C} = -.30\text{ }^{\circ}\text{C}$

In an ionic solution, the total concentration of ions is important. Therefore, another factor (i) is included in the equations.

$$\Delta T_b = K_b * m * i$$

$$\Delta T_f = K_f * m * i$$

"i" is the number of ions from each formula unit. In the previous example, if NaCl had been the solute your change in boiling point and freezing point would have needed to be multiplied by 2. (i=2 because NaCl consists of a Na^+ ion and a Cl^- ion)

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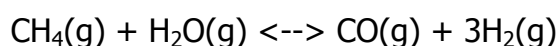


Chemical Equilibrium

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- [Equilibrium Constant \(a.k.a. K_c\)](#)
- [Le Chatelier's Principle](#)

Definition of Chemical Equilibrium

Chemical equilibrium applies to reactions that can occur in both directions. In a reaction such as:



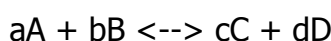
The reaction can happen both ways. So after some of the products are created the products begin to react to form the reactants. At the beginning of the reaction, the rate that the reactants are changing into the products is higher than the rate that the products are changing into the reactants. Therefore, the net change is a higher number of products.

Even though the reactants are constantly forming products and vice-versa the amount of reactants and products does become steady. When the net change of the products and reactants is zero the reaction has reached equilibrium. The equilibrium is a dynamic equilibrium. The definition for a dynamic equilibrium is when the amount of products and reactants are constant. (They are not equal but constant. Also, both reactions are still occurring.)

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Equilibrium Constant

To determine the amount of each compound that will be present at equilibrium you must know the equilibrium constant. To determine the equilibrium constant you must consider the generic equation:

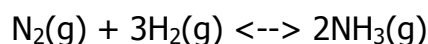


The upper case letters are the molar concentrations of the reactants and products. The lower case letters are the coefficients that balance the equation. Use the following equation to determine the equilibrium constant (K_c).

$$K_c = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

For example, determining the equilibrium constant of the following equation can be accomplished by using the K_c equation.

Using the following equation, calculate the equilibrium constant.



A one-liter vessel contains 1.60 moles NH_3 , .800 moles N_2 , and 1.20 moles of H_2 . What is the equilibrium constant?

$$K_c = \frac{[1.60]^2}{[.800][1.20]^3} = 29.6$$

Answer: 1.85

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Le Chatelier's Principle

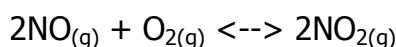
Le Chatelier's principle states that when a system in chemical equilibrium is disturbed by a change of temperature, pressure, or a concentration, the system shifts in equilibrium composition in a way that tends to counteract this change of variable. The three ways that Le Chatelier's principle says you can affect the outcome of the equilibrium are as follows:

- Changing concentrations by adding or removing products or reactants to the reaction vessel.
- Changing partial pressure of gaseous reactants and products.
- Changing the temperature.

These actions change each equilibrium differently, therefore you must determine what needs to happen for the reaction to get back in equilibrium.

Example involving change of concentration:

In the equation



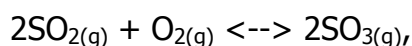
If you add more $\text{NO}_{(g)}$ the equilibrium shifts to the right producing more $\text{NO}_{2(g)}$

If you add more $\text{O}_{2(g)}$ the equilibrium shifts to the right producing more $\text{NO}_{2(g)}$

If you add more $\text{NO}_{2(g)}$ the equilibrium shifts to the left producing more $\text{NO}_{(g)}$ and $\text{O}_{2(g)}$

Example involving pressure change:

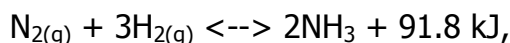
In the equation



an increase in pressure will cause the reaction to shift in the direction that reduces pressure, that is the side with the fewer number of gas molecules. Therefore an increase in pressure will cause a shift to the right, producing more product. (A decrease in volume is one way of increasing pressure.)

Example involving temperature change:

In the equation



an increase in temperature will cause a shift to the left because the reverse reaction uses the excess heat. An increase in forward reaction would produce even more heat since the forward reaction is exothermic. Therefore the shift caused by a change in temperature depends upon whether the reaction is exothermic or endothermic.

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Acids & Bases

Typically, we recognize acids and bases by their simple properties, such as taste. We know that a lemon is sour, so it is acidic. Bases tend to taste bitter. Acids and bases also change the color of certain dyes, such as phenolphthalein and litmus. Acids change litmus treated paper from blue to red. Acids change basic phenolphthalein from red to colorless. Bases change litmus treated paper from red to blue and phenolphthalein from colorless to pink. Acids and bases neutralize the action of each other. This is why we take antacids for stomachaches, because the antacid is a base, and neutralizes the acid in the stomach.

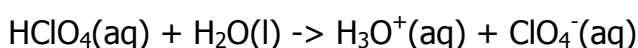
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Arrhenius Concept of Acids and Bases

This guy named Arrhenius concocted the first successful concept of acids and bases. He did this by defining acids and bases according to the effect these substances have on water. The Arrhenius concept of acids and bases is as follows: an acid is a substance that when dissolved in water increases the concentration of the hydrogen ion, H^+ . A base is a substance that when dissolved in water increases the concentration of the hydroxide ion, OH^- .

The hydrogen ion, is not just a bare proton, it is a proton bonded to a water molecule, H_2O . This results in a hydronium ion, H_3O^+ .

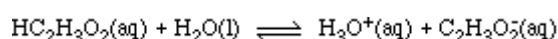
In Arrhenius's theory, something that is a strong acid is a substance that completely ionizes in aqueous solution to give a hydronium ion, H_3O^+ , and an anion. An anion is a negatively charged ion. An example of a strong acid is perchloric acid:



What is going on above is that we have perchloric acid in an aqueous solution. This perchloric acid ionizes entirely and results in an hydronium ion and a perchlorate anion. Some other examples of strong acids would be: HI, HBr, HCl, HNO₃, and H₂SO₄.

Now on to bases...A strong base is something that completely ionizes in aqueous solution to give a hydroxide ion and a cation. A cation is a positively charged ion. Strong bases are most of the hydroxides of Group IA elements and Group IIA elements including LiOH, NaOH, KOH, Ca(OH)₂, Sr(OH)₂ and Ba(OH)₂.

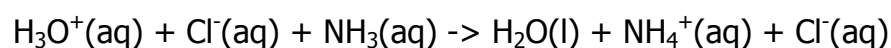
Many of the acids and bases that we encounter in our everyday lives are not strong acids, they are considered weak. Weak acids do not completely ionize in solution, but exist in equilibrium. Let's look at the reaction for acetic acid:



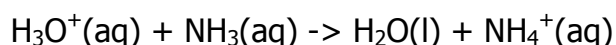
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Bronsted-Lowery Concept of Acids and Bases

The Bronsted-Lowery concept of acids and bases is that acid-base reactions can be seen as proton-transfer reactions. This results in acids and bases being able to be defined in terms of this proton (H⁺) transfer. According to the Bronsted-Lowery concept, acids donate a proton in a proton-transfer reactions. Bases accept the proton in a proton-transfer equation. As an example, lets look at the reaction of hydrochloric acid with ammonia. When we write it as an ionic equation we get:



which reduces to:



because there is two Cl⁻(aq) one each side. We now have the net ionic equation after we cancel out the "spectator ions"(Cl⁻).

What happens in this reaction in aqueous solution is a proton transfer. According to the Bronsted-Lowery concept, acids donate a proton in a proton-transfer reactions. Bases accept the proton in a proton-transfer equation. As an example, lets look at the reaction of hydrochloric acid with ammonia shown above. What happens in this reaction in aqueous solution is that a proton is

transferred from H_3O^+ to NH_3 . This results in H_3O^+ losing a (H^+), resulting in H_2O . The NH_3 gains the transferred proton, resulting in NH_4^+ . We call H_3O^+ the proton donor, or acid. We call NH_3 the proton acceptor, or base.

The Bronsted-Lowery concept defines something as either an acid or base depending on its function in the acid-base (proton transfer) reaction. Some things can act as either an acid or a base. These are called amphiprotic species, they can either lose or gain a proton, depending on the other reactant. An example of an amphiprotic species would be HCO_3^- . In the presence of OH^- , it acts as an acid. In the presence of HF it acts as a base. Water is also amphiprotic, as are most anions with ionizable hydrogens and certain solvents. Water as an amphiprotic species is very important to the acid-base reactions.

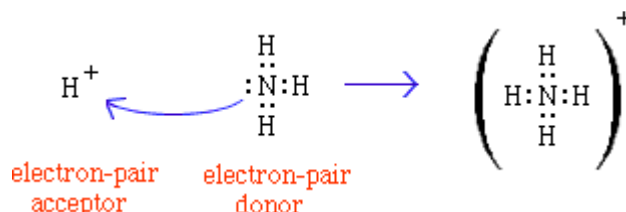
In the Bronsted-Lowery concept we have found that:

1. A base is a species that accepts protons, while an acid is a species that donates protons.
2. Acids and bases can be ions as well as molecular substances.
3. Some species can act as either acids or bases, depending on what the other reactant is.

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Lewis Concept of Acids and Bases

The Lewis concept of acids is generalized to include reactions of acidic and basic oxides and many other reactions. A Lewis acid is something that can form a covalent bond by accepting an electron pair from another species. A Lewis base is something that can form a covalent bond by donating an electron pair to something else. The Lewis and Bronsted-Lowery concepts are different ways of looking at the same chemical reactions. Here is a reaction in which an electron pair is transferred. The proton (H^+) is electron pair acceptor, a Lewis acid. NH_3 has a lone pair of electrons and is a Lewis Base.



The pH of a solution

Whether or not an aqueous solution is neutral, acidic or basic depends on the hydrogen-ion concentration. We give the acidity of an aqueous solution in terms of the pH. pH is defined as the negative logarithm of the molar hydrogen-ion concentration. A pH of 7 means that a solution is

neutral. A pH of below 7 means that a solution is acidic; a pH of above 7 means that a solution is basic.

$$\text{pH} = -\log[\text{H}^+]$$

For example, let's say that we have a glass of frosty orange juice. This orange juice has a hydrogen-ion concentration of 2.9×10^{-4} M. What is the orange juice's pH?

$$\text{pH} = -\log[\text{H}^+] = -\log[2.9 \times 10^{-4}] = 3.54$$

The pH of this solution is less than 7 so this orange juice is acidic.

We can also find pH by solving for the hydroxide-ion concentration of a solution. The measure of the hydroxide-ion concentration is called pOH.

$$\text{pOH} = -\log[\text{OH}^-]$$

Since we know that the pH scale goes from 0 to 14, we find that:

$$\text{pH} + \text{pOH} = 14$$

Let's say that we want to find the pH of an ammonia solution that has a hydroxide-ion concentration of 1.9×10^{-3} M. We start by finding the pOH.

$$\text{pOH} = -\log[1.9 \times 10^{-3}] = 2.72$$

Now we want to find the pH by subtracting:

$$\text{pH} = 14.00 - \text{pOH} = 14.00 - 2.72 = 11.28$$

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Equilibrium with Acids and Bases

Have you read the section about equilibrium yet? If you haven't this most likely won't make any sense to you. If you have, let's join in on the fun of acid-base equilibrium.

Remember K_c from the equilibrium section? It's back, and more useful than ever. Now to distinguish between the K_c of acids and bases we use K_a and K_b . (a for acids and b for bases) The equilibrium that is calculated in acids is usually the dissociation of the H^+ ions and the rest of the molecule. The weak acids and bases are the only ones that have K_a 's and K_b 's because in the strong acids dissociation is very close to 100%.

Table of K_a 's		
Substance	Formula	K_a
Acetic Acid	$\text{HC}_2\text{H}_3\text{O}_2$	1.7×10^{-5}

Benzoic Acid	HC ₇ H ₅ O ₂	6.3 x 10 ⁻⁵
Boric Acid	H ₃ BO ₃	5.9 x 10 ⁻¹⁰
Carbonic Acid	H ₂ CO ₃	4.3 x 10 ⁻⁷
	HCO ₃ ⁻	4.8 x 10 ⁻¹¹
Cyanic Acid	HCNO	3.5 x 10 ⁻⁴
Formic Acid	HCNO ₂	1.7 x 10 ⁻⁴
Hydrocyanic Acid	HCN	4.9 x 10 ⁻¹⁰
Hydrofluoric Acid	HF	6.8 x 10 ⁻⁴
Hydrogen Sulfate ion	HSO ₄ ⁻	1.1 x 10 ⁻²
Hydrogen Sulfide	H ₂ S	8.9 x 10 ⁻⁸
	HS ⁻	1.2 x 10 ⁻¹³
Hypochlorous acid	HClO	3.5 x 10 ⁻⁸
Nitrous Acid	HNO ₂	4.5 x 10 ⁻⁴
Oxalic Acid	H ₂ C ₂ O ₄	5.6 x 10 ⁻²
	HC ₂ O ₄ ⁻	5.1 x 10 ⁻⁵
Phosphoric Acid	H ₃ PO ₄	6.9 x 10 ⁻³
	H ₂ PO ₄ ⁻	6.2 x 10 ⁻⁸
	HPO ₄ ⁻²	4.8 x 10 ⁻¹³
Phosphorous Acid	H ₂ PHO ₃	1.6 x 10 ⁻²
	HPO ₃ ⁻	7 x 10 ⁻⁷
Propionic Acid	HC ₃ H ₅ O ₂	1.3 x 10 ⁻⁵
Pyruvic Acid	HC ₃ H ₃ O ₃	1.4 x 10 ⁻⁴
Sulfurous Acid	H ₂ SO ₃	1.3 x 10 ⁻²
	HSO ₃ ⁻	6.3 x 10 ⁻⁸

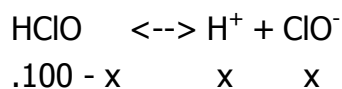
The base K_b's are as follows:

Substance	Formula	K _b
Ammonia	NH ₃	1.8 x 10 ⁻⁵
Aniline	C ₆ H ₅ NH ₂	4.2 x 10 ⁻¹⁰
Dimethylamine	(CH ₃) ₃ NH	5.1 x 10 ⁻⁴
Ethylamine	C ₂ H ₅ NH ₂	4.7 x 10 ⁻⁴
Hydrazine	N ₂ H ₄	1.7 x 10 ⁻⁶
Hydroxylamine	NH ₂ OH	1.1 x 10 ⁻⁸
Methylamine	CH ₃ NH ₂	4.4 x 10 ⁻⁴
Pyridine	C ₅ H ₅ N	1.4 x 10 ⁻⁹
Urea	NH ₂ CONH ₂	1.5 x 10 ⁻¹⁴

Examples

Weak Acid Example:

Calculate the pH of a 0.100 M solution of HClO



$$K_a = \frac{x^2}{.100 - x}$$

The x in the denominator can be dropped because K_a/M is less than 10^{-3} . If K_a/M is greater than 10^{-3} you have to use the quadratic formula to solve the equation.

Therefore:

$$3.5 \times 10^{-8} = \frac{x^2}{.100}$$

$$3.5 \times 10^{-9} = x^2$$

$$x = 5.9 \times 10^{-5}$$

$$[\text{H}^+] = 5.9 \times 10^{-5} \text{ M}$$

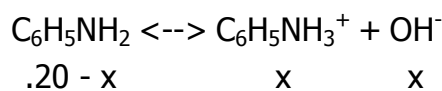
$$[\text{ClO}^-] = 5.9 \times 10^{-5} \text{ M}$$

$$[\text{HClO}] = .100 \text{ M} - 5.9 \times 10^{-5} \approx .100 \text{ M}$$

$$\text{pH} = -\log(5.9 \times 10^{-5}) = 4.2$$

Weak Base Example:

What is the concentration of OH^- of a .20 molar solution of aniline?



$$K_b = \frac{x^2}{.20 - x}$$

The x in the denominator can be dropped because K_b/M is less than 10^{-3} . If K_b/M is greater than 10^{-3} you have to use the quadratic formula to solve the equation.

Therefore:

$$K_b = \frac{x^2}{.20}$$

$$x^2 = 8.4 \times 10^{-11}$$

$$x = 9.2 \times 10^{-6}$$

$$[\text{OH}^-] = 9.2 \times 10^{-6}$$

Redox

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 - [Redox Reactions](#)
-

Oxidation Numbers

We are now going to look at some reactions that involve a transfer of electrons.

The oxidation number is the charge an atom in a substance would have if the pairs of electrons in each bond belonged to the more electronegative atom. Now this means that in a compound made up of monatomic ions, like NaCl, in which the bonding pairs do belong to the more electronegative atom, the oxidation number equals the ionic charge. The sodium ion has an oxidation number of +1 while the chlorine ion has an oxidation number of -1.

Here are some rules that are helpful in finding the oxidation number of a specific atom.

- The oxidation number of an atom in an elementary substance is 0. This means that the oxidation number of an O atom in O₂ is 0.
- The oxidation number of a Group IA atom in any compound is +1; The oxidation number of a Group IIA atom in any compound is +2.
- The oxidation number of fluorine is -1 in all of its compounds.
- The oxidation number of chlorine, bromine, and iodine is -1 in any compound containing only two elements.
- The usual oxidation number of oxygen in a compound is -2. The major exceptions of this rule are peroxides, like H₂O₂, which have an oxidation number of -1.
- The oxidation number of hydrogen in most compounds is +1.
- The sum of the oxidation numbers in a compound is always zero. For something that is an ion consisting of two atoms (a polyatomic ion), the oxidation numbers add up to the charge on the ion.

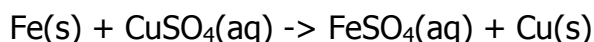
You might be heartily confused at this point as to what oxidation numbers are and how to find them. Don't worry, you can usually find the oxidation numbers of elements in ionic compounds by looking at the individual ions in the compound.

Example:

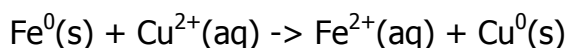
In H₂SO₄, H = +1 and O = -2. Since there are 4 oxygen atoms, the total charge from oxygen is -8. Therefore the charge of S must be +6, since the net charge of the molecule is zero.

Oxidation-Reduction Reactions

When we take an iron metal nail and dip it into a blue solution of copper (II) sulfate, the nail becomes covered with a reddish substance. This reddish substance is metallic copper. The equation for this is:



The net ionic equation, that is, the equation in which we have cancelled out the spectator ions (in this case the spectator ion is SO_4).



What we have done here is to show you the oxidation numbers above the elements in the equation. This shows that the iron metal loses electrons to form iron(II) ions while copper(II) ions gain electrons to create copper metal. The Cu^{2+} on the reactants side of the equation has a 2+ because SO_4 has a charge of 2-. Any reaction like this that involves a transfer of electrons is an oxidation-reduction reaction.

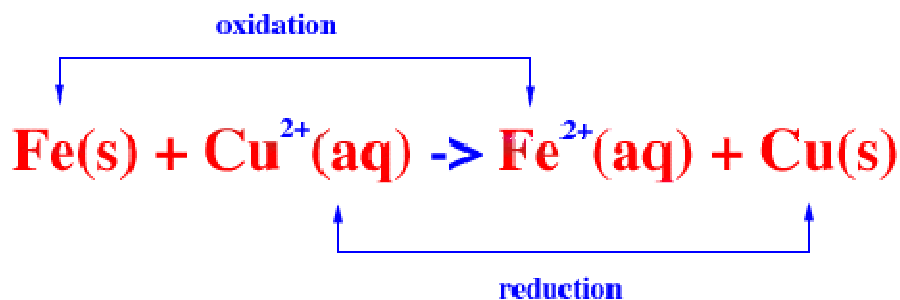
We can write the equation above in the form of two half-reactions. A half-reaction is one of two parts of an oxidation-reduction reaction, one of which involves a loss of electrons, and the other a gain of electrons. The half reactions for the iron nail reaction would be:

1. $\text{Fe(s)} \rightarrow \text{Fe}^{2+}(\text{aq}) + 2\text{e}^-$
2. $\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu(s)}$

The first equation shows us that electrons are lost by Fe, (2e^-). The second equation shows electrons being gained by Cu^{2+} . You know, we can also express this reaction in terms of what happened to the oxidation number. The oxidation number of iron increases after the reaction, while the oxidation number of copper decreases.

Basically, an oxidation-reduction reaction (redox reaction) is a reaction in which electrons are transferred between species or in which atoms change oxidation numbers. Oxidation is the portion of the redox reaction in which there is a loss of electrons by a species or an increase in the oxidation number of an atom. Reduction is the part of a reaction in which there is a gain of electrons by a species or a decrease in the oxidation number of an atom. Something that is oxidized loses electrons or contains an atom that increases in oxidation number. Something that is reduced gains electrons or has an atom that decreases in oxidation number. An oxidizing agent is a something that oxidizes something, meaning that the oxidation agent is itself reduced. A

reducing agent is a something that reduces something else, and is itself oxidized. Notice the example below.



Fe is oxidized and Fe is the reducing agent.

Cu²⁺ is reduced and Cu²⁺ is the oxidizing agent.

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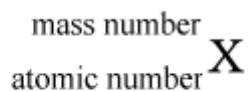
Nuclear
Chemistry

Radioactive elements are elements that do not have a stable nucleus. These elements give off particles and/or rays to change their nucleus and become a stable element. Some lightweight isotopes are radioactive but, all elements that have an atomic number greater than 82 are radioactive. The process of changing the nucleus to a stable one is called radioactive decay.

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 - [Radioactive Decay](#)
 - [Nuclear Bombardment Reactions](#)
 - [Half-Life](#)
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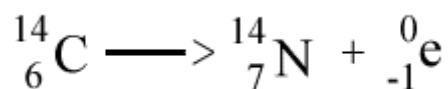
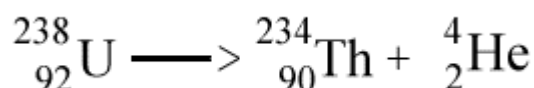
Nuclear Equations

Nuclear notations are used to represent the decay of one element into another. The generic formula for a radioactive element is as follows:



(X is the symbol for the element)

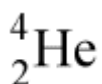
Some examples of nuclear decay equations are:



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Radioactive Decay

There are three types of natural radioactive decay. They are alpha emission, beta emission, and gamma emission. Alpha emission results in releasing an alpha particle. An alpha particle has two protons and two neutrons, so it has a positive charge. (Since it has two protons it is a helium nucleus.) It is written in equations like this:



Beta emission is when a high speed electron (negative charge) leaves the nucleus. Beta emission occurs in elements with more neutrons than protons, so a neutron splits into a proton and an electron. The proton stays in the nucleus and the electron is emitted. Negative electrons are represented as follows:



Gamma Emission is when an excited nucleus gives off a ray in the gamma part of the spectrum. A gamma ray has no mass and no charge. This often occurs in radioactive elements because the other types of emission can result in an excited nucleus. Gamma rays are represented with the following symbol.

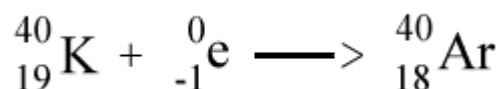


The two types of artificial radiation are positron emission and electron capture.

Positron emission involves a particle that has the same mass as an electron but a positive charge. The particle is released from the nucleus.



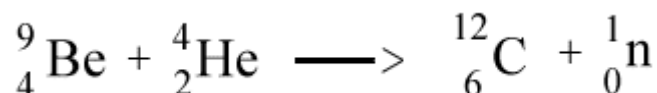
Electron capture is when an unstable nucleus grabs an electron from its inner shell to help stabilize the nucleus. The electrons combine with a proton to form a neutron which stays in the nucleus.



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Nuclear Bombardment Reactions

Bombardment reactions involve the nucleus of the atom being bombarded (hence the name) with particles from the nucleus or an entire nucleus. Examples of the particles are neutrons and alpha particles. These reactions usually give off a different particle than the one that they were bombarded with. Here is an example equation for a bombardment reaction.



Particle accelerators are where most of the bombarding takes place. The accelerators move the particles toward each other at great speeds, to overcome the repulsive forces.

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Half-Life

No one can say for sure when a particular nucleus will decay but one can predict how many in a given sample will decay over time. Radioactive elements have a half-life. The half life of any given element is the time that is required for one half of the sample to decay. So if you have 10 grams of a radioactive element, after one half-life there will be 5 grams of the radioactive element left. After another half-life, there will be 2.5 g of the original element left, after another half-life, 1.25 g will be left. The equation for half-life calculations is as follows:

$$A_E = A_O * .5^{\frac{t}{t_{\frac{1}{2}}}}$$

- A_E is the amount of substance left

- A_0 is the original amount of substance
- t is the elapsed time
- $t_{1/2}$ is the half-life of the substance

Other variations on the half-life equation are as follows:

$$t = \frac{\log \frac{A_E}{A_O}}{\log .5} * t_{\frac{1}{2}}$$

$$t_{\frac{1}{2}} = \frac{\log .5}{\log \frac{A_E}{A_O}} * t$$

An example problem is if you originally had 157 grams of carbon-14 and the half-life of carbon-14 is 5730 years, how much would there be after 2000 years?

$$A_E = 157 * .5^{\frac{2000}{5730}}$$

There would be 123 grams left.

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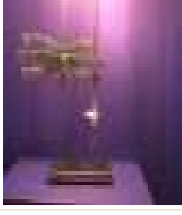



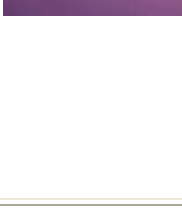

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Lab Equipment

Lab equipment is an important part of chemistry and science in general. In this page you will learn about lab equipment and its uses.

Name	Description	Picture
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Beaker	Used to hold and heat liquids. Multipurpose and essential in the lab.	
Bottle	Bottles can be used for storage, for mixing and for displaying.	
Bunsen Burner	Bunsen burners are used for heating and exposing items to flame. They have many more uses than a hot plate, but do not replace a hot plate.	
Buret	The buret is used in titrations to measure precisely how much liquid is used.	
Crucible	Crucibles are used to heat small quantities to very high temperatures.	
Erlenmeyer Flask	The Erlenmeyer Flask is used to heat and store liquids. The advantage to the Erlenmeyer Flask is that the bottom is wider than the top so it will heat quicker because of the greater surface area exposed to the heat.	
Evaporating Dish	The Evaporating Dish is used to heat and evaporate liquids.	
Florence Flask	The Florence Flask is used for heating substances that need to be heated evenly. The bulbed bottom allows the heat to distribute through the liquid more evenly. The Florence Flask is mostly used in distillation experiments.	
Food Coloring	Food Coloring is used in many experiments to show color change and to make the experiment more exciting.	

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