Notice!

I've found that this book project has been showing up on more and more search engines lately and is also being directly linked to for the information it contains[1]. I therefore find it necessary to warn all persons viewing this document that it is a work in progress, and as such it contains errors of all kinds, be them in experimental procedures that may cause harm, or in faulty reasoning that would get you slapped by nearly any chemistry instructor. Please for now take the information here with a grain of salt.

Most Importantly!

By reading further you agree not to hold the authors of this document responsible for any injuries/fatalities that may occur from attempting to make any of the products or following any of the procedures that are outlined within. Chemistry inherently possesses a degree of danger and you must understand this, wear gloves and more if the situation calls for it, your safety is in your own hands, not mine!

Also note that this project is open for contribution by any party on the internet. Simply submit a section to bsarge1015@aol.com and it will be added into the text, pending editing. Any person contributing will have their name mentioned in the credits. Also, please feel free to contact the initial author and head of the project at Rob.Vincent@gmail.com.

Thank you for reading and enjoy!

1 Although this document may be directly linked to, it will not work in that manner as I have hotlink protection for PDF documents, however directly linking to the html document is possible, still though I would prefer links be to the main book project page.

1.0 Introduction/Statement of Purpose

There are lots of pages scattered across the internet that can serve the amateur chemist in their endeavors, however each one has its own focus. Improvising a distillation apparatus, production of a specific chemical, some go further and tell how to stock a lab at home. There are still other works that are similar in goal to this work and I don't mean to compete with these, just as there are innumerable books available to a 'professional' chemistry student covering the basics this work will just be a further reference in that series, though hopefully very comprehensive. There are other places to look for the information here and a student of chemistry should not be adverse to looking over the basics of chemistry from many different sources, after all some people learn better in one way over another.

It was originally my concept that this work should have as few web references as possible. The reasoning being that they will pass into non-existence in due time. But really, at home chemistry is a constantly evolving and changing hobby, an over the counter source for one chemical may be phased out without notice, during work on this project for example, sodium hydroxide which was widely available over the counter started to be phased out in some products (especially in a pure form). Hence despite my wishing that this work be somewhat timeless, that is impossible, links will be provided and they will pass into non-existence and sources for chemicals will be given that likely won't make it to the end of the decade. Still though, it is the goal of this work to explain many of the basic concepts/materials/apparatuses used in chemistry. It is further the goal of this work to depict this in a useful way directly relating to real life and real observations. In doing so this should most closely represent anything you would run across in real life giving you the best idea as to what to expect.

In reading this text you will notice that some things are in **bold face** these are either key points or are sections to which you can refer to for more information on the relevant topic. Words in *italics* are usually shown in this manner to indicate that the definition of that word can be found in section **12** the index under the subsection "Technical Terms". Additionally as you read through this you will see numbers in superscript with parenthesis around them such as (1) these indicate that at the end of the section you are in there is additional relevant information about the topic at hand, each piece of information matching up with the topic number, this can also include references to web works and book works.

Additionally since this is meant to be a highly readable work, some of the more in depth material including mathematical calculations and other material that might be considered supplemental is occasionally separated from the section where it would normally be contained, either following it immediately or referenced as being compiled into the index. For example, the calculation of the hydrogen ion concentration in an aqueous solution is a useful calculation to perform for some reactions, however it is on the whole dry boring material in most peoples' eyes, as such, these sections will be removed from the more literary part of the text so they do not disturb the flow of the section.

Back to the content, there are two sections of experiments for the amateur and, in the second half, experienced chemist to perform. Each experiment is intended to develop skills that are crucial to the chemist's repertoire. This text helps to explain strategies for projects that you devise yourself, as well as sections on real research and the gritty sections on out of control experiments and contingency plans. Upon reading though all the material presented here you should be able to go out and perform chemistry with a degree of confidence that the at home chemist is not normally afforded. As I said before, this will not be a timeless work, but hopefully it will be a good read, even in the future when performing these experiments in a home setting would be dubbed thoroughly insane (although, some might consider them insane right now). Never the less, I wish the readers the best of luck in all their chemical endeavors, even if you never make it past being an armchair chemist.(2)

--Bromic

(1) Example of a reference in the text, this is where relevant information to that passage would be found.
2 An armchair chemist is occasionally used as a derogatory term meaning that the person has no experience with how things work in the real world and draw all of their 'experience' from books where the information may conflict with actual observations or be entirely wrong, in other words a procedure they come up with may only work in theory, not practice, or may be difficult to carry out in real world conditions. Many people start out as armchair chemists.

1.1 Disclaimer

Each person is responsible for his or her own actions. It is not reasonable to hold the writers responsible for your mistake should you choose to pursue their strategies. As stated in the disclaimer at the start of this document: **by reading further you agree not to hold the authors of this document responsible for any injuries/fatalities that may occur from attempting the reactions and Chemistry that are outlined herein.**

Further, although many of these procedures have been attempted solely for the completion of this work, not every procedure was done or thoroughly researched. Chemistry always poses inherent dangers and there is always some chance that thing may go wrong. Please use common sense. If you are following a procedure and something occurs involving excessive heat generation or violent gas evolution and it is not mentioned in the procedure, do not just assume that it is normal. If it scares you, take steps to rectify the situation. Always have a contingency plan for any procedure you are doing for the first time. Also, always make sure you are aware of the dangers each chemical presents before running the reaction. Chemistry is 99% planning and researching and 1% actually performing the reaction.

People who are pregnant should not attempt many of the experiments described herein. Additionally chemistry should not be practiced around small children who may interfere with the proceedings, consume chemicals, or become injured though mishaps. You should not perform a procedure mentioned here until you are familiar with the procedure, the chemicals involved, and the possible extraneous reactions that could take place. Please, for your own safety, consider all safety precautions, gas masks, gloves, aprons, gas scrubbing, etc. Damage done with many chemicals can be forgiving, but over time it can be disastrous, and some never give you a second chance. You only get one life, take precautions now so you do not ruin it.

1.2 Safety Precautions/Gear

The techniques used in modern chemistry in all fields of research often demand the handling of hazardous chemicals, equipment, and supplies which can cause fatal injury or death if misused. Thus, laboratory safety is a primary concern for any chemist, professional or amateur. In this section, we will discuss the types of safety equipment used in laboratories, their usage, why they are needed, as well as what must be done in the event of an accident. We will also include some general lab practices that supplement safety and significantly reduce hazards from arising.

If you read only one section in this book, make sure it's this one

Before beginning on any chemical adventure, there are certain steps that should be taken. First, research the properties of any reagents that are being used, and this also includes your intended products. This can be accomplished in many ways, looking up the compounds in a chemistry dictionary or on the internet. I should however point out that the internet is full of inaccuracies, so it is imperative to validate one source with another. The most thorough way to determine the properties of a compound is to look up its Material Safety Data Sheet (MSDS). They are full of exorbitant safety information and also disposal tips.

The next step is to prepare yourself with safety equipment known as Personal Protective Equipment, or PPE. There are five main types of PPE, namely protective eye/face-wear, protective gloves, protective clothing, respiratory protection and hearing protection. Perhaps the most important is eye protection, since the eyes are very sensitive to foreign materials and debris. Before any further discussions, it should be noted that contact lenses are usually forbidden in laboratories since vapors, mists, and corrosive liquids can often ‘weld’ them to the surface of the eye, potentially causing irreversible damage. They should therefore be removed before entering work areas. The most common type of protective eyewear is safety glasses, seen below. Many different models exist: standard versions, those that are designed to fit over prescription lenses, and brand-name glasses. The lenses are usually made from polycarbonate plastic, due to its high impact resistance and light weight, making them much more enjoyable over extended periods of time. Prescription safety glasses combine the adjustments required for vision correction and still function as a safety device. They are unfortunately quite expensive.

A Note from the Authors

Safety glasses are often disapproved by many chemists, mainly due to the incomplete seal to the face. This potentially exposes the eyes to harmful materials. Unfortunately, there are examples of accidents caused for this reason. One fateful accident involving deuterated chloroform rendered a student partially blind. She was incorrectly filling a chromatography setup with the solvent causing pressure to build up. An explosion of gas, solvent, and a pressurized glass tube, ended with the solvent seeping in through the gap where the safety glasses met her forehead. In this situation, safety *goggles*, which essentially provide a complete seal around the eyes, would have significantly reduced her injury.

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There are a couple different types of safety goggles. Many goggles sold in hardware stores contain rows of tiny holes poked in the sides for ventilation that make them unsuitable for laboratory use. These goggles are designed to protect against impact hazards, such as using a grinder or other power tools, not for resisting splashed liquids. Therefore, models featuring capped vents, as seen left, should be purchased. They still allow for adequate ventilation, but, due to their design, do not allow liquids to pass through. These goggles are sometimes carried locally, but often enough the best location for procurement is on the internet.

Another form of PPE that protects the eye and face area is the increasingly-popular face shield. The visors of these are made from polycarbonate and may sometimes feature a metal band around them for additional support. They can be invaluable when running reactions which are very hazardous, such as preparing bromine or handling compounds such as explosives, pyrophoric compounds, extreme corrosives, and water reactive reagents, or apparatuses under pressure or vacuum. Face shield provide protection of the entire face and often the neck. It should be noted, however, that face shields are designed to supplement safety glasses or goggles, **NOT** as a replacement. It should also be noted that they do not provide protection from some angles, so extreme care should still be taken with the above examples.

A Note from the Authors

It is imperative to wear safety glasses or goggles at all times, regardless of any other PPE being worn or what chemicals are actually being handled. Even if you are only making up a saturated NaCl solution, what if the person next to you is handling a hazardous compound and spilt it? Or if a bottle were to fall off the shelf in front of you, scattering chemicals everywhere? It is better have the basic safety measures in place and not need them, than to need them and not have them.

Even when PPE is worn and all of the safety precautions are followed, accidents can still happen. This section will discuss what to do if eye protection fails. If a chemical is splashed in one's eye, the first priority should be to immediately irrigate the affected eye. Sterilized saline eye washes are often availably inexpensively online or at specialist pharmacies and are the top choice in the event of an accident. If this is not available to you, the next best option is cold tap water. The tap should be turned on to a medium flow rate and the eye should be held open and placed under the stream. It should go without saying, but you should not be working in a lab alone. With that being said, the other person should dial the appropriate number for the emergency services to get immediate medical aid. Flushing of the eye should be continued for at least fifteen minutes or until help arrives, longer if possible in the presence of strong alkalis. In fact, strong acids in the eye often do less damage as the acid precipitates a protein barrier that helps resist further attack, whilst this effect is not obtained with strong, concentrated alkalis. It should also go without saying that under no circumstances should you attempt to neutralize or otherwise react away a chemical. This will only cause even further damage. If an ambulance is not necessary, the other person should take the victim to a hospital him or herself, just to be certain of no residual damage.

When it comes to clothing, it is somewhat debated what should be worn. The safest, however superfluous, gear you could wear would be a full environmental suit. Lacking that, disposable painting suits made of Tyvek® are widely available. Another choice for a full body suit would be a Nomex® flight suit, available on eBay. This is a top choice for persons working with high heat or interested in pyrotechnics due to the fantastic heat resistance of this fabric. Common cloth jump suits, like the one pictured, also work to a lesser degree, although still posing inherent flammability.

For the everyday home chemist, the outfit does not necessarily have to be something altogether different from normal wear. The only requirement is that it has to be is something that you will not care if it gets ruined. It should also be something not excessively flammable, like many synthetic fabrics. It should also not be too loose or skin tight. If the clothing is too loose it can knock over beakers or drag in reagents; if it is too tight and you get something on it, it might immediately soak though to the skin. You should always be able to remove any affected clothing quickly in case of spill or fire.

Another important piece of safety equipment in any lab is, of course, gloves. Many different types of gloves exist, but the two most common for general lab use are disposable and re-usable ones. The disposable types are most often made of latex, nitrile, or vinyl. They are widely available online or in local pharmacies. All three materials are acceptable in a lab, but nitrile generally has greater chemical resistance than the other two, although you should check any specific incompatibilities before working with any type.[(1)] An important example is for concentrated nitric acid, since this can actually set nitrile gloves on fire. Latex has the obvious disadvantage of causing allergy issues just by using it. It is recommended, if your budget permits, to invest in a box of vinyl gloves and a box of nitrile gloves for use in your lab. However efficient gloves are, no glove provides protection forever; they are only a temporary barrier between your skin and the chemicals being handled. Thus, they should be replaced any time a cut or fair chemical damage is observed. This is the one place in your lab that you should not be cheap. Bail the glove before it fails, your skin is much more important than your wallet. The reusable gloves, commonly being made of rubber, are usually wrist or elbow length and are good in situations where you are handling large quantities of reagent or there is a reaction that is causing extraneous conditions. For example, a solution splashing during boiling should be tended to with these gloves so you can easily handle the reaction without splatter hitting you. Plus, they can be rinsed and used again later. Once again, if this type of glove is starting to show signs of age and wear, dispose of them and buy a new pack.

Optional to some, mandatory to others, depending on the kind of experiments you plan to do, is a respirator. They are available as a full mask, which covers the eyes as well as the mouth and nose, eliminating the need for additional protective eyewear. The picture above shows a half-mask which only covers the lower part of the face. Masks are also available that utilize either one or two cartridges, two providing easier breathing and longer cartridge life. The protection afforded to you by your mask is directly related to the cartridge you use. Some masks which are for military use may be picked up as surplus and offer protection for a wide variety of chemical agents. However, they vary in their protection from mask to mask and therefore can only be compared on an individual basis. For a more detailed look at gas masks look at section **4.13** on gasses.

So far, all the considerations have been for working at what is known as standard temperature, defined as 25°C or about 75°F. Now though, we delve into the special gear that is necessary for working in other, more extreme conditions. For working at high temperature, a welding shop provides a wide range of products, such as welding aprons and gloves that can sustain prolonged exposure of upwards of 1000°C. On the other hand working at cryogenic temperatures might be a seasonal thing, since attempting to buy thick winter gloves in the middle of summer might prove to be difficult. Still, even a pair of gloves for welding can be used just as effectively to protect you from colder temperatures, but the reverse is not true, most of the fabrics used in winter gloves and such might combust if brought into contact with hot iron. Working at high temperatures is another aspect of chemistry that depends entirely on the type of projects you will undertake. Some people might never need a thermometer that goes over 150°C, while others may work in the realm where a thermometer would be unrealistic.

Aside from the personal gear that is worn, it is also a good idea to have some extinguishing media around in case of a fire. A fire extinguisher will work for most situations except some metal fires. In those cases, sand (another good thing to have on hand) is used to smother the fire.(2) If it is safe to do so, it is best to move any hazardous chemicals you can away from the flames and let the fire burn itself out. As such, putting water on a magnesium fire or other highly reactive metal can easily lead to explosion. Therefore, it is important to understand the hazards present before working with these types of reagents and always have a safety plan in case something were to go horribly wrong. It is always best to be prepared for the worst even during reactions you are comfortable with and have performed many times.

Another good thing to have handy are neutralization chemicals. In case of an acid spill you should have a large, wide-mouthed container of sodium bicarbonate (baking soda) nearby. Tossing this on an acid spill will neutralize its corrosive properties and render it somewhat safer, so you can at least more safely clean it up. Base spills are usually less of a problem but sodium bisulfate (used to adjust the pH of pools) can be conveniently located around your lab. Flushing most acids or bases with large quantities of water also helps the situation. However, in the case of large spills of concentrated phosphoric or sulfuric acid, extra care should be taken as these heat up greatly on combination with water, if you are applying water to these do so very quickly and in large quantity to help remove the heat and prevent *flash boiling*.

Always remember that safety should come first. It is not worth getting a severe burn because you are too cheap to buy long sleeve welding gloves or respiratory damage because you won't invest in a gas mask. Always consider the possibility of long-term damage and if you think there is something reasonably extra that you can do to prepare for an upcoming reaction, spare no expense. It is important to take the extra time to do it right the first time, get the right chemicals, set up the apparatus with all the extra safety precautions, and be patient. Following all of these steps will keep you, as well as those around you, safe and ensure a properly executed reaction every time.

(1) One exceptional substance that can easily penetrate gloves is methyl mercury, which can go through many commonly available glove materials, but considering the toxicity of it, it is better to just not use this compound.

(2) Note that fires of very reactive metals like magnesium will not appreciate being smothered in sand and will continue to react even with the sand, sometimes even more vigorously then with the air, there are special mixtures available commercially to smother these fires which contain among other things magnesium oxide.

1.2(a) Definitions of common medical terms

Let's assume that you are being responsible and looking out for your own health and the heath of those around you and you are looking up MSDS sheets of the chemicals you will be working with. Some of the information on the sheets may be easy to understand, but when it comes to side effects of chemicals you might often come upon words such as 'pulmonary edema' and 'renal failure' and you wonder to yourself, "What do these words mean?" This can be a stumbling block when deciding on choosing one compound over another, not knowing the potential side effects puts you at a large disadvantage, although you are still encouraged to look up specific definitions for each of these terms, here is a general overview of the major terminology(1) used:

Carcinogenic: Any substance that can lead to a mutation causing cancer.

Corneal Damage: A substance with this designation is dangerous to the eyes, specifically the cornea; however, wearing safety goggles (as you always should be) diminishes this hazard.

Fetotoxin: A chemical that can poison or cause degenerative effects in a developing fetus or embryo.

Fibrosis: It is the formation of connective, fibrous tissue in an organ.

Gangrene: It is the death and decay of body tissue caused by insufficient blood supply and usually following injury or disease.

Gastroenteritis: A substance that causes this leads to an acute inflammation of the lining of the stomach and intestines. Symptoms include anorexia, nausea, diarrhea, abdominal pain and weakness.

Lachrymator: Any compound that causes tearing or watering of the eyes.

Necrosis: A term used to describe the process of tissue dying and/or rotting while still on the body.

Nephrotoxin: Any substance that inhibits, damages or destroys the cells and/or tissues of the kidneys.

Pulmonary Edema: Corrosive gasses and other chemicals can cause this condition where fluids build up in the lungs, in serious cases this can be so bad that you can drown in your own fluids.

Renal Failure: Often used to designate that a chemical upon entering the body may cause massive damage to the kidneys causing them to shut down usually permanently.

Reproductive Damage: A substance that causes damage to the reproductive system.

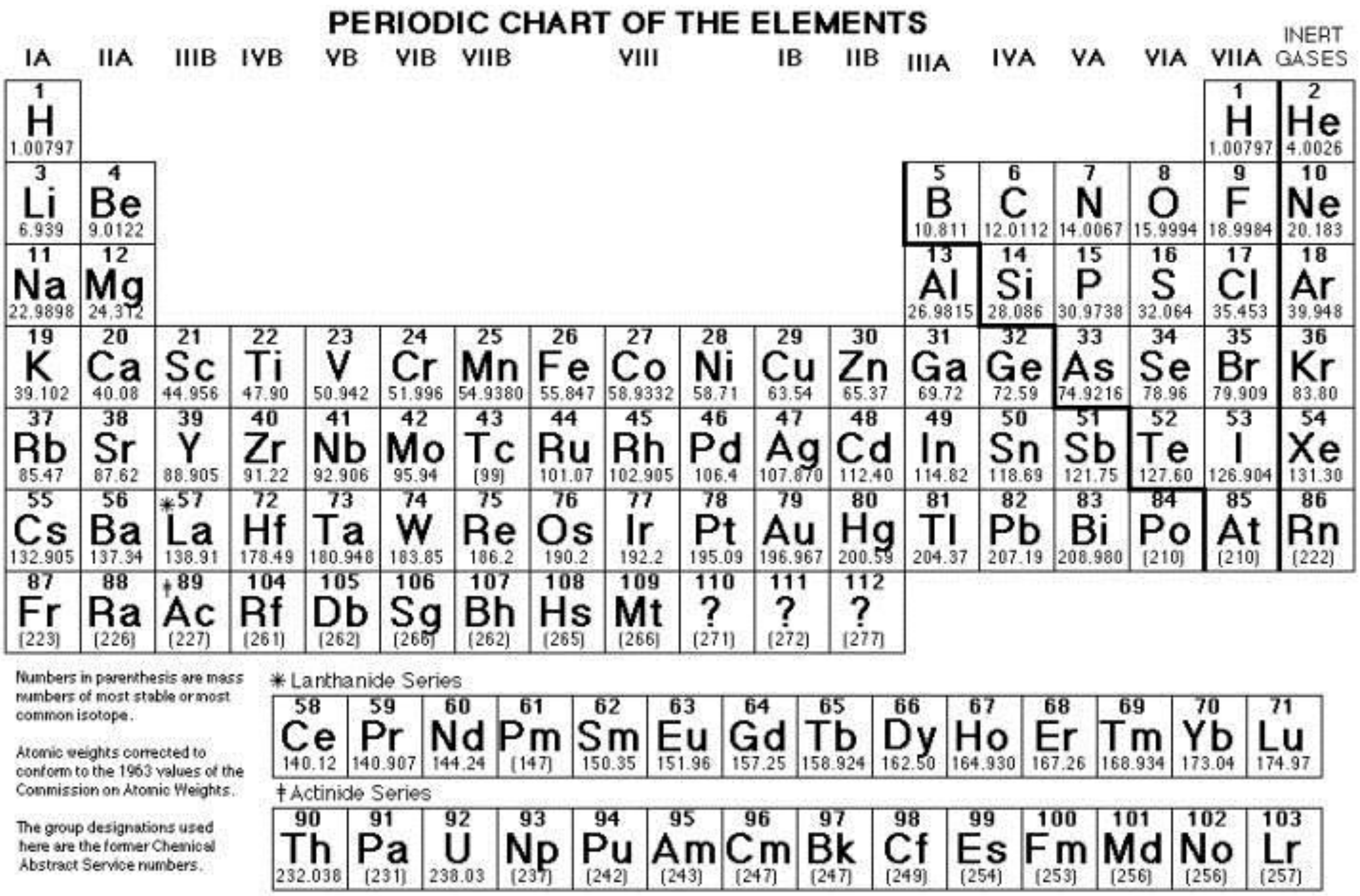
Sensitization: Any substance that, after prolonged exposure, leads to allergic reactions in normal tissue.

Teratogen: A chemical that can cause malformations of an embryo or fetus.

(1) Most of these were found at the MSDS home page: www.msds.com. Please refer to this site if you run into terms that are not listed here.

1.3 How to read/write a chemical reaction

If you're just beginning to start a chemistry hobby there are a few skills that you should have. The most useful of these is reading and writing chemical reactions. There are many places on the web and in books and classrooms what will be able to more thoroughly explain this procedure then I will be able to do. These skills are easy to explain but take practice to understand, therefore this section is mostly to just show the standard way in which a chemical reaction will be written in this text.



Pictured above is your basic periodic table (See section **12.1** for a complete legible listing off all the elements in alphabetical order). The periodic table lists elements by increasing atomic number (which usually means increasing atomic weight). The atomic number is a count of the number of protons in a molecule of an element. This is what gives each element its specific properties. The periodic table also has trends in it which can allow you to predict the properties of an element in its uncombined state. The most common grouping that people fall back on is the family, or the vertical groups of elements. For example, on the far right, second to last column, beginning with the letter F, that family is called the halogens. In descending order they are fluorine, chlorine, bromine, iodine and radioactive astatine. Fluorine is the most reactive of the group and the reactivity decreases as you go down.

Similar properties are present across the periodic table. These include, but are not limited to, electronegativity (increasing left to right and bottom to top), atomic radii (Increasing left to right, not including the far right *noble gases* family, and top to bottom), and reactivity trends, such as those listed above. Using a good Chemistry textbook will allow you to predict how a certain element will behave in many conditions. However, across the entire realm of Chemistry, there are always exceptions.

The atomic weight, as previously mentioned, is defined by the quantity called the mole (also referred to simply as mol). This is a powerful chemistry quantity and basically means 'one unit'. One mole refers to 6.022 X 10^{23} molecules or atoms. This is known as *Avogadro's number* and is a number every chemist should memorize. To compare, there are around 8 X 10^{9} people currently on the planet. A mole is fourteen powers of ten larger than the population. As such, when talking about Chemistry, using a number such as 3mol is easier than saying 1.8 X 10^{24} molecules. Take your time to read through this paragraph and wrap your head around what a mole is. At first glance it seems rather simple; however, the idea itself is quite abstract. The mole will follow you throughout your journey through the field of Chemistry and beyond. Make sure you know and understand the magnitude of this quantity before continuing.

This also brings up another point. Science fields use *scientific notation* to display large and small numbers. For example, one million can be represented as 1 X 10^{6}. One millionth on the other hand can be shown by .000001 or 1 X 10^{-6}. Scientific notation makes it easier to depict these quantities and can also be used to express *significant figures*. In the home lab setting, significant figures are not an important concept, but in the professional world, they help express uncertainty and error. We will not focus on significant figures in this text, since there are many good textbooks and sources that go into complete and intricate detail.

Moving onto examples, if you look at potassium on the periodic table (K is the symbol for potassium) you will see 39.102 underneath it, what that means is that 39.102 grams of potassium metal is one mole of potassium. Or, 39.102 grams of potassium is equivalent to 6.022 X 10^{23} potassium atoms. All the elements have units with respect to one another. For example, one unit of chlorine (Cl) weighs 35.453 grams and it will react with one unit, or mole, of potassium (K), which weighs 39.102 grams, completely to give one mole of potassium chloride, KCl which will have a weight equal to the sum of the two masses, 74.555 grams. This reaction would be expressed by the following system:

K + Cl ---> KCl

Reactions in this work will be in the same, generic form of:

A + B ---> AB

The previous example brings up the important point that mass cannot be lost in the reaction of the two chemicals. This is known as the conservation of mass law and is fundamentally important in chemistry. It states that mass can neither be created nor destroyed and is thus always conserved. The potassium and chlorine are still all present in the reaction above, however, they are now in an entirely different compound with new properties. This is a mechanism that most chemical reactions follow: two substances are reacted and form a new product(s) that contains entirely independent characteristics from its components. In the above reaction, potassium is a highly reactive metal, explosive when placed in water, and chlorine is an incredibly poisonous gas. After they react, the elements form potassium chloride which is actually found in grocery stores as a salt substitute (sodium-free table salt).

Another specific example would be:

$$2H_2 + O_2 \text{ ---> } 2H_2O$$

Translating this from the reaction above to everyday terminology is simple. Looking at a periodic table you find that the letter H represents hydrogen, a colorless odorless gas, and that O represents oxygen, and I would hope you are all familiar with the product H_2O. The prefix, that is, the number before the letter, signifies the molar equivalence in the reaction. The subscript numbers stand for the number of that element in a certain compound. Hydrogen and oxygen are gasses that exist not as individual atoms, but as two atoms bound together, hence the subscript two. The equation is saying this: four atoms of hydrogen combine with two atoms of oxygen, to produce two molecules of water. Note the distinction between atoms and molecules; O_2 is a molecule containing 2 atoms of oxygen, whereas H_2O is a molecule containing 2 atoms of hydrogen and one atom of oxygen. Chemical reactions of this type are balanced, with each molecule appearing in the same quantity on both sides. If that is not the case, the equation is dubbed 'unbalanced' and steps can be taken to rectify it (Note that, although a molecule of oxygen contains two oxygen atoms you can still treat it like it is just O in equations, just double the molecular weight to get the weight of the O_2 molecule).

Diatomic Molecules and More

When it comes to a chemical reaction the periodic table gives the symbols only for individual atoms of an element, which is not how many of them are found. For example, many gasses are diatomic molecules (di meaning two in this case, so the molecules are formed from two atoms). What this means is that two atoms of the substance have a bond between them and therefore come in a pair. Here is a quick list of elemental gasses that are diatomic:

H_2, N_2, O_2, F_2, Cl_2, Br_2, I_2

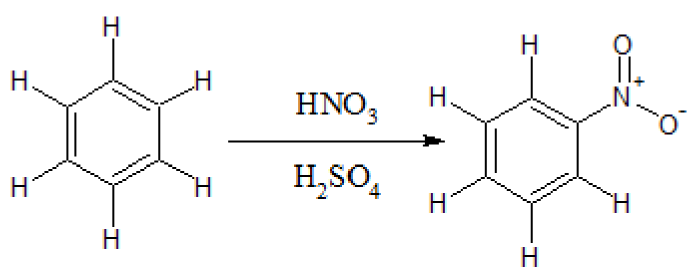
Although bromine and iodine are liquids and solids respectively, in the gas phase they consist of two atoms bonded together. These bonds between the atoms account for a degree of their reactivity. For example, the bond between fluorine atoms is very weak, readily breaking from incident light and as a consequence you end up with highly reactive free fluorine. The bond in chlorine will also break from exposure to daylight. When the bond breaks, free electrons can attack hydrocarbons and chlorinate them. On the other side of the spectrum, the nitrogen-nitrogen bond is actually a triple bond, meaning that there are three bonds connecting one nitrogen atom to another. This is actually one of the strongest bonds in chemistry and accounts to some extent for the lack of reactivity of nitrogen (note that it accounts for about 78% of the air we breathe).

The fact that these are diatomic is not of great importance in chemical reactions because the molecular weight of one atom is still the same in the gas phase. However, being diatomic is important in calculating the amount of a gas present in a reaction. One mole of gas usually takes up approximately 22.4L of space at standard temperature and pressure, due to the ideal gas law. But it’s not one mole of O that takes up that space, it is one mole of O_2. So actually there would be two moles of atomic oxygen for 22.4L of space.

Upon further exploration of compounds, there are other elements that associate so their formulas can be expressed as different combinations of atoms. Explanations are not given here and this list is not exhaustive, but notable examples include:

B_{12}, S_8, P_4

Exceptions to this rule are nonstoichiometric reactions, reactions that do not have a specific reaction that takes place and a number of products can be formed under different conditions; though a main product is usually known or is the desired product of the reaction. This includes a wide variety of organic reactions, a specific example being:



benzene - nitrobenzene (1:1)

This is another way to show a chemical reaction. Chemists use this shorthand in organic reactions to minimize drawing carbons out and show the individual bonds. Each line represents a bond between atoms, where two bonds represents a double bond. Each intersection point represents one of the six carbons of benzene. Normally, hydrogens are excluded from these drawings, but here they are depicted for clarity of the drawing. Notice how the by product, water, is not included in the reaction, and that the amount of HNO_3 (nitric acid) and H_2SO_4 (sulfuric acid) reacting with the C_6H_6 (benzene) to produce $C_6H_5NO_2$ (nitrobenzene) is not a part of the equation. This can be read as '*in the presence of*', therefore allowing the reaction to be read, "Benzene, in the presence of nitric acid and sulfuric acid, reacts to produce nitrobenzene". Another time that information can appear above or below the arrows could be to show a *catalyst* which speeds up the reaction and is not consumed. Additionally, temperature information can appear in this location, as well as pressure, solvents, *inert atmosphere* (Gases present), etc. Specific reaction conditions are not included in all condensed equations, so it is not safe to assume that every reaction you see will run at STP (standard temperature and pressure). In fact, there are many reactions that are not run at STP and, by not including information over and under the arrow, you hardly know anything of the reaction conditions. This can be a real pain and requires additional research before attempting a reaction.

Now let's say you want to write a chemical reaction. First you should know the chemicals/elements involved along with what you believe to be the products. You write them out in the format previously described, reactants (compounds or elements reacting to give your desired product) on the left and products on the right. Then you can attempt to balance the equation by adding to the products or reactants side. If an element only shows up on one side, something is wrong. Just remember that there is not always one correct chemical reaction and just because a reaction looks good on paper does not magically make it the real reaction. A reaction that is nearly impossible may look just as plausible on paper as a simple reaction tested over time for the past hundred years.

Anyone can make up a reaction, so be wary of reactions you see with no background information supporting it.

In addition to the common elements there are also components that the average chemist should know and be at least familiar with. They are most evident in aqueous solutions in the form of ionic species. Collectively they are known as *ions,* but more specifically, positively charged species are known as *cations* and negatively charged species are known as *anions*. Most aqueous chemistry (chemistry occurring in water) revolves extensively around cations and anions and it is quite useful to have a ready reference list of cations, anions, and their respective charges. The compounds listed below with more than one element in them are referred to as polyatomic ions. Of course, the list is not exhaustive and there are plenty of better ones on the web:

Anions:

Acetate	$C_2H_3O_2^-$		Hydrogen Carbonate	HCO_3^-		Hydride	H^-
Arsenate	AsO_4^{3-}		Carbonate	CO_3^{2-}		Hydroxide	OH^-
Arsenite	AsO_3^{3-}		Chloride	Cl^-		Nitrate	NO_3^-
Azide	N_3^-		Hypochlorite	ClO^-		Nitrite	NO_2^-
Bismuthate	BiO_3^-		Chlorite	ClO_2^-		Nitride	N^{3-}
Bisulfate	HSO_4^-		Chlorate	ClO_3^-		Oxide	O^{2-}
Sulfate	SO_4^{2-}		Perchlorate	ClO_4^-		Peroxide	O_2^{2-}
Hydrogen Sulfite	HSO_3^-		Chromite	CrO_3^{2-}		Phosphate	PO_4^{3-}
Sulfite	SO_3^{2-}		Chromate	CrO_4^{2-}		Phosphite	PO_3^{3-}
Thiosulfate	$S_2O_3^{2-}$		Dichromate	$Cr_2O_7^{2-}$		Metaphosphate	PO_3^-
Hydrosulfite	$S_2O_4^{2-}$		Cyanide	CN^-		Phosphide	P^{3-}
Peroxy-disulfate	$S_2O_8^{2-}$		Thiocyanate	SCN^-		Permanganate	MnO_4^-
Bisulfide	HS^-		Cyanate	OCN^-		Iodide	I^-
Sulfide	S^{2-}		Fluoride	F^-			
Borate	BO_3^{3-}		Formate	$HCOO^-$			
Bromide	Br^-		Oxalate	$C_2O_4^{2-}$			

Red = Compounds of these ions are usually insoluble in water **Blue** = Compounds of these ions are normally soluble in water **Black** = Follows no trend

Cations:

Hydronium Ion	H_3O^+		Ammonium	NH_4^+		Lithium	Li^+
Sodium	Na^+		Potassium	K^+		Magnesium	Mg^{2+}
Calcium	Ca^{2+}		Barium	Ba^{2+}		Chromous	Cr^{2+}
Chromic	Cr^{3+}		Manganous	Mn^{2+}		Manganic	Mn^{3+}

Ferrous	Fe^{2+}		Ferric	Fe^{3+}		Cobaltous	Co^{2+}
Cobaltic	Co^{3+}		Nickelous	Ni^{2+}		Nickelic	Ni^{3+}
Cuprous	Cu^{+}		Cupric	Cu^{2+}		Zinc	Zn^{2+}
Silver	Ag^{+}		Aluminum	Al^{3+}		Stannous	Sn^{2+}
Stannic	Sn^{4+}		Plumbous	Pb^{2+}		Plumbic	Pb^{4+}

Mind you, there are more cations and anions then just the ones listed here, these are just common examples. The charge of an unknown cation is usually more easily determined than that of an anion, especially if you are given a name. Charges of anions usually stay constant whereas metals can have differing charges. Knowing the anion a metal is coupled with can give you an indication of what the oxidation state of the metal is. In addition, some names are currently written out using the stock system. This greatly simplifies things, instead of a name like manganese dioxide you get manganese (IV) oxide, the Roman numeral four indicating that manganese is in the +4 state and therefore knowing that oxygen has a negative two charge you can determine the formula of this compound to be MnO_2. The use of –ous and –ic at the end of some names to differentiate between the higher and lower oxidation states is an older phenomenon and is somewhat being phased out, however tin (stannous +2 and stannic +4) and lead (plumbous +2 and plumbic +4) are somewhat stuck in this system of naming. Regardless, there are many anions and cations, existing in different situations, some not stable in water, some only found in water, and others only existing in the solid state. Just remember the overall charge of a molecule or species must remain neutral.

1.4 Units used throughout the text

The system used in this text will be the most accepted system in chemistry academia: the all-mighty metric system. Units of weight will often be expressed in grams (g), of volume, in liters (l) and milliliters (ml) and time in seconds (s), hours (h), and days. In addition temperatures will be measured in degrees Celsius (°C).

When it comes to liquids though, there are different units that come into play aside from milliliters. The most useful unit is molarity. This is defined as the number of moles of a substance (solute) dissolved in 1 liter of substance (solvent), commonly referred to as mol/L. From here, you can convert a solution of known molarity to another using the formula:

Molarity Initial (M_i) x Volume Initial (V_i) = Molarity Final (M_f) x Volume Final (V_f)

For Example:

Chemoleo wants to make a 1 M NaOH Solution in water. So he weighs out one mole of NaOH, looking at the periodic table he finds the atomic mass of sodium to be 22.9, that of oxygen to be 15.9 and that of hydrogen to be 1.0, adding these together he gets the weight of one mole of NaOH to be roughly 40 g. So after weighing out 40 g of sodium hydroxide he adds to them enough water to make the total volume 1 L thus making a 1 M solution. This sits on his shelf for quite some time until one day he finds that he needs 100ml of a .5 M NaOH solution. Having three components of the above equation he can solve for the initial volume of 1 M NaOH he needs to end up with a 100 ml amount of a .5 M solution.

$$1M \times (Vi) = .5 \times 100 \text{ ml}$$

$$Vi = 50 \text{ ml}$$

So Chemoleo must take 50 ml of his 1 M NaOH solution and add to it 50 ml H2O to bring the total volume to 100 ml of .5 M NaOH solution. Remember to label any reagents you keep laying around Chemoleo.

The molarity unit is exceptionally good for one specific reason; it greatly simplifies calculations involving precise reactions and the amount of reagents you are dispensing. Molarity is heavily used in *stoichiometry* and is the staple method of labeling many lab reagents. In physics academia a more popular unit is molality (m, not to be confused with meters), this is a measurement of moles per kilogram solvent, mol/Kg, in this way the molality of a solution will not change with temperature whereas molarity will due to the change in volume of the liquid as the temperature fluxuates.

Another method of measurement one will come across is the percent (%) solution. There are different variations on this, the weight/volume method, the volume/volume method, and the weight/weight method. One common example of a % solution would be 6% NaOCl available OTC as bleach.

The chemist known as BromicAcid just bought 3.8 L of a 6% NaOCl solution. In order to keep his lab space organized he must retain the labeling method he has already begun for his other reagents, therefore he must determine the molarity of the 6% NaOCl solution. So the solution is 6% NaOCl by weight, so 6.0 g / 100 g solution. Now, density would come in handy here, however Bromic was unable to find the information on the web and is too lazy to do physical measurements, therefore he is assuming that the density of the solution is close to water so 1.0 g/ml therefore 1000 ml or 1000 g would have approximately 60 g NaOCl. NaOCl has an atomic weight of around 74 g/mol therefore Bromic has 60/74 = .80mols of NaOCl per liter so the molarity equals 0.80M for the solution of NaOCl to store on his shelf.

Often times, as seen above, the density of the solution is necessary to determine a more precise molarity calculation from the percent solution. Tables are available online and in the CRC (Handbook of Chemistry and Physics) and elsewhere that give molarity to percent to density conversions that will aid in this task.

Common Percent Solutions to Molarity		
Substance Name	Percent Solution (in H2O)	Molarity
Sulfuric Acid H_2SO_4	100%	18.7 M

	91% 40%	17.1 M 5.4 M
Nitric Acid HNO_3	70% 90%	15.8 M 21 M
Hydrochloric Acid HCl	20% 28% 38%	6.0 M 8.7 M 12.4 M
Ammonia NH_4OH	4%	2.3 M
Acetic Acid CH_3COOH	5%	.8M
Sodium Hypochlorite NaOCl	6% 10% 12.5%	.85M 1.45 M 2 M
Hydrogen Peroxide H_2O_2	3%	1.25 M

1.5 Discussion of Legality/Words of Encouragement

Practicing chemistry as a hobby has fallen out of fashion in recent years and, as such, trying to delve into it may cause you to be greeted with skepticism at best and at worst a strange kind of desperation to wipe you off the earth. Trying to keep out of the public eye is usually a necessity for the continued practice of chemistry. Despite the fact that many reactions are totally legal, there always seems to be a way for you to get into trouble if someone decides to make trouble for you. For example, phosphorus, in all of its *allotropes*, is illegal to own anywhere in the United States. If you attempt and succeed to make phosphorus you are really breaking the law. This is because there are illicit (illegal) uses for this chemical and because of this, it has been outlawed. As such the chemistry of elemental phosphorus, the useful phosphorus halides and other chemicals, are taboo.

But the actual list of chemicals that are illegal is very short compared to the chemicals that can be made by a motivated individual. There are plenty of legal target chemicals that one can take aim at. Try not to break the law, but know that many energetic compounds are illegal, as of course are drug precursors, but do not let that discourage you from what you can legally do.

Chemistry is fun and if you keep up a beginning spirit you will have fun with it for a long time to come. Not only that, but Chemistry is immensely useful. Practicing Chemistry on your own will give you a background understanding that most individuals will never scrape in their lifetimes. Not only will this make your classes on the subject easier, but it can also take you into a rewarding and exciting career field. While most home chemists are not involved in a real lab setting, there are plenty that are. It may seem like you are the only one actually interested in the subject, but that is far from the truth. There are many communities out there, like the online Chemistry forum ScienceMadness.org, where thousands of people share the same passion as you. Your neighbor might even have a lab set up in his garage and you never cared enough to check out what he was doing. Ask around, because, as the authors of this book know, you are not alone in this great endeavor.

Chemistry just may be the best thing you do for yourself.

Be patient, practice it safely, and ultimately, enjoy the time you spend doing it.