

CHAPTER ONE:

INTRODUCTION TO CHEMISTRY

<u>SUBTITLE</u>	<u>SECTION</u>	<u>PAGE</u>
The Central Science	1.1	2
Scientific Method	1.2	3
Experimentation	1.3	5
Analysis	1.4	6
Laboratory Safety	1.5	10
Laboratory Equipment	1.6	12

1.1 THE CENTRAL SCIENCE

How often have you thought about chemistry today? The answer is likely “very little” or “not at all,” but chemistry is all around you. From the processes that allow you to digest your breakfast to the many functions of the car you ride in - the engine, brakes, air conditioner, CD player - all of them can be explained with chemistry. Even the ability to read this page is dependent upon chemical signals and responses in your brain. Chemistry is often called “the central science” not because the course is between biology and physics, but because there is practically nothing that lies outside the realm of chemistry.



Chemistry is the study of matter and its interactions. Though there are many branches of chemistry, the differences lie only in the type of matter or the particular properties being studied. The Chemical Abstracts Service (CAS) Registry has catalogued the existence of over 27 million different substances, so it is impossible for one person to be an expert in every area of a field as broad as chemistry. Organic chemists, for example, only study substances that make up living matter. All living matter is made of compounds that contain the incredibly versatile element carbon in addition to other elements such as hydrogen, oxygen, nitrogen, and sulfur. Inorganic chemistry is the branch of science that studies all other substances. Although it may seem that inorganic chemistry is the larger field, approximately 85% of all compounds are classified as organic substances. The properties of carbon are such that it is capable of combining with other elements in nearly an infinite number of ways. Many of these compounds occur naturally, but a growing number are synthesized in a laboratory. Nearly 50,000 new substances are added to the CAS Registry every week.

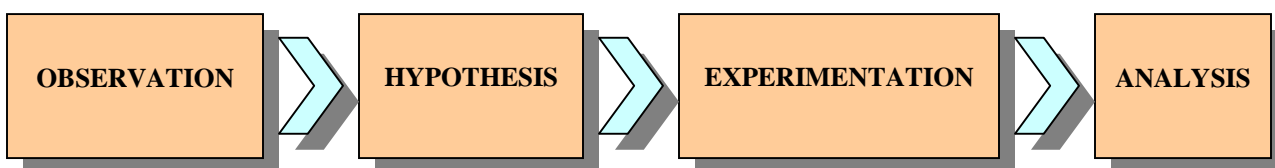
Other branches of chemistry include biochemistry (the study of the chemical processes of living organisms), physical chemistry (the study of the properties of matter and the energy associated with it), and analytical chemistry, which is concerned with the identification and measurement of substances.

1.2 SCIENTIFIC METHOD

Each of these branches of chemistry focuses on matter, but what exactly is matter? Simply put, matter is anything that has mass and takes up space. Practically everything in the universe is matter, and to understand it better, chemists - and you, now that you are in this course - need a methodical and practical way to study it. Chemistry is an experimental science. Everything we know is a result of careful observation and a lot of testing. The framework for gaining knowledge by experiment is called the scientific method, and here we will consider the following basic model:

Table 1-1

	Field of Study	Careers
ORGANIC CHEMISTRY	Compounds containing carbon	Pharmaceuticals, Plastics, Agro-chemicals
INORGANIC CHEMISTRY	Compounds without carbon	Environmentalist, Materials science, Metallurgy
ANALYTICAL CHEMISTRY	Identification and measurement of matter	Forensics, Food Quality, Manufacturing
PHYSICAL CHEMISTRY	Properties and Energy	Nanotechnology, Molecular modeling, Biosensors
BIOCHEMISTRY	Processes of living organisms	Medicine, Genetics, Pharmacy

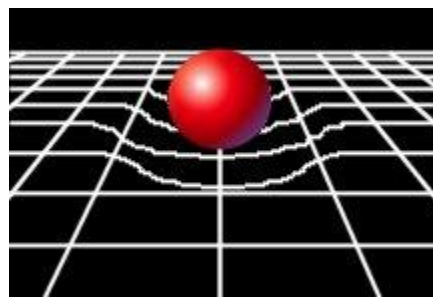


Observation is perhaps the most important tool we possess to help us understand the world around us. Observations can be either quantitative (measurements that involve a number and a unit) or qualitative. Sometimes an observation applies to many different systems and is formulated into a statement called a natural law. A common misconception is that a law is something that has been proven, but in fact a law is simply a summary of *what happens*. For example, when you drop a pencil, it falls to the floor. This is a qualitative observation. You might also say that a pencil dropped from a height of four feet takes exactly 0.5 seconds to reach the ground. This is a quantitative observation. In fact, you will find that a book, a nickel, a golf ball, or any object at all also takes 0.5 seconds to reach the floor from a height of four feet. This observation appears to apply to any system. The idea that all objects accelerate toward the earth is a natural law. There is nothing to prove, it is just an observation of a naturally occurring event.

Once an observation has been made, a hypothesis - a possible explanation for the observation - is formulated. Perhaps we may believe that objects fall to the ground because they are being pulled downward by tiny green men with ropes. It may sound absurd to you, but it is a hypothesis nonetheless. With our explanation in hand, it is time to perform an experiment in an attempt to verify or refute our hypothesis. Experimentation and the collecting of data form the basis for all scientific knowledge, and it is important for experimental data to be accurate and unbiased. So how will we test our hypothesis about little green men? Perhaps it will be as simple as looking for them: set up an array of high speed cameras, drop a pencil, and carefully examine every frame of recorded footage. But one trial is never enough to confirm or invalidate a hypothesis. The experiment must be repeated many times, sometimes by many different scientists, before the results can be claimed as truly valid. In our scenario, after recording the fall of a multitude of objects, there has been no evidence to support the existence of little green men with ropes. The gravitational attraction between objects must be caused by something else.



In 1920, a young patent clerk published an idea that appeared to experimentally account for the phenomenon of gravity, even the quite astounding observation that light can be “bent” by a strong gravitational attraction. This idea was firmly based upon years of observation, countless experiments, and a multitude of detailed calculations. The young man, Albert Einstein, suggested that space itself was distorted around very massive objects, and that what we see as “falling” is really just an object following the curves in space. This idea is called the General Theory of Relativity, and has been the accepted explanation for gravity for nearly a century. It is not a law, nor has it been “proven.” A theory is just an explanation of how or why something occurs and is backed up by experimentation. We assume this particular theory is true because there hasn’t been another explanation proposed that is supported by experimental evidence to the same degree. If observations are made which contradict the theory, General Relativity will have



to be modified, or even thrown out altogether. Science, along with the theories and models it produces, is constantly changing as new data is collected and analyzed.

1.3 EXPERIMENTATION

As you can see, experimentation is the focal point of science. It provides the evidence to support our conclusions about the both the visible and microscopic worlds. In an introductory chemistry class such as this one, experiments will be performed with one of three goals in mind:

- To test a hypothesis
- To confirm or demonstrate a natural law
- To gather and analyze data

It is important for you as a chemist to understand how an experiment is set up. As has been said before, experimental data must be accurate and unbiased. Any person who performs the experiment should be able to replicate the results of any other person. This can only be done when the focus of the experiment is explicitly defined - only one of the innumerable variables associated with the investigation can be changed by the researcher. This single variable is called the independent variable. To illustrate this concept, imagine that you are going to gather information about how plants grow when exposed to lights of different color. There can be only one independent variable - the color of the light - and everything else must remain the same for every trial. The type of plant used, the intensity of the light, the temperature, the amount of water, and the composition of the soil must be the same - constant - for every experiment. Although there can only be one independent variable, there can be numerous dependent variables which change as a result of the independent variable. For our experiment, several things might be affected by the color of light: the height of the plant, the number of leaves, the depth of the root system, etc. This type of experiment has one final component, the control. The control is a trial for which the independent variable is considered normal or unchanged. In this scenario, the control would be white light or sunlight. The control is used for comparison, serving as a baseline by which to evaluate the effectiveness of a change in the independent variable. In addition, multiple trials should be conducted for each change of the independent variable to prevent errors from skewing the results.

Collecting data from an experiment in an organized way allows a chemist to find information quickly and easily and often helps in evaluating its significance. There are many ways to organize gathered information, and the method used depends entirely on the type of experiment being performed. A data table is the most commonly used organizational tool, but every data table looks different. Two of the most common are shown below; the first for an experiment gathering qualitative data and the second for a quantitative investigation. Often a data table must be custom-made to fit the needs of a particular experiment, and when all else fails, a simple list can suffice.

1.4 ANALYSIS

Collecting data is only part of experimentation. Equally important is the analysis of the data that is collected. There are many ways to analyze data, but here we will look at three:

- compare and contrast
- patterns
- graphs

It is as important to look at what is similar as to examine the differences between things. For example, in Table 1-3 we see that each plant sprouted on the third day, was 0.5 cm tall, and had two leaves. This should lead us to the conclusion that light does not play an important role in the initial growth of a plant. We also see that there is always an even number of leaves. The

Table 1-2

ACTION	OBSERVATION	INTERPRETATION
Put ice in water	Ice floats	Ice is less dense than water
Put ice in alcohol	Ice sinks	Ice is more dense than alcohol
Put alcohol in water	Liquids mix	Water and alcohol are miscible
Put oil in water	Liquids separate	Oil and water are immiscible

Table 1-3

Day	White Light		Red Light		Blue Light	
	Height	Leaves	Height	Leaves	Height	Leaves
1	0 cm	0	0 cm	0	0	0
2	0 cm	0	0 cm	0	0	0
3	0.5 cm	2	0.5 cm	2	0.5 cm	2
4	1.0 cm	2	0.5 cm	2	0.5 cm	2
5	1.5 cm	2	0.5 cm	2	0.5 cm	2
6	2.0 cm	4	1.0 cm	2	0.5 cm	2
7	2.5 cm	4	1.0 cm	2	0.5 cm	2
8	3.0 cm	4	1.2 cm	2	0.5 cm	2
9	3.5 cm	4	1.2 cm	2	0.5 cm	2
10	4.0 cm	6	1.5 cm	2	0.5 cm	0

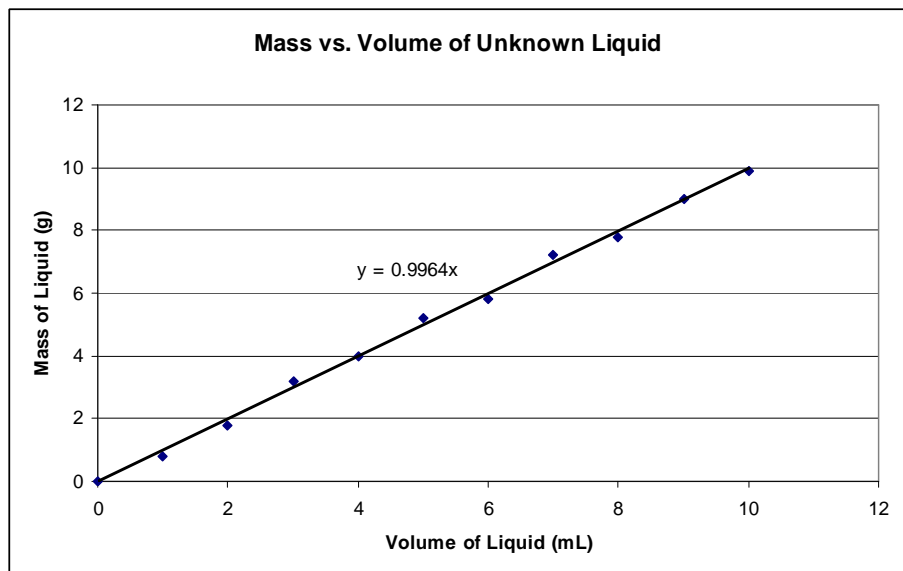
differences are obvious; plants grew larger under white light than red light, and larger under red light than blue light. Therefore our conclusion might be that colored light hinders the

growth of plants, but we might improve this experiment by testing more colors such as yellow, orange, or green.

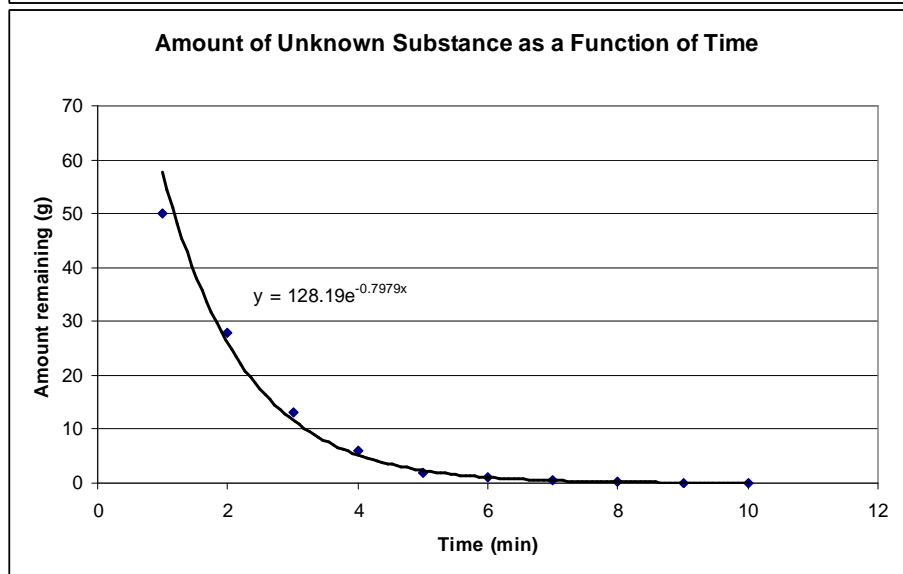
Patterns in data lead us to important conclusions. In Table 1-2, four substances are mixed together in various ways. We see that ice is less dense than water but more dense than alcohol. We can create a pattern out of this that lists the three substances in order of increasing density: alcohol, ice, water. The data for the fourth substance, oil, does not give us any indication as to its relative density. This experiment could be improved by examining the relationship of oil to ice and alcohol as well. In the experiment described in Table 1.3, the number of leaves is a pattern. There is always an even number of leaves, and each pair appears to develop after an additional 2.0 cm of growth. The last plant, however, lost leaves on the 10th day, leading us to conclude that the plant has died and its leaves have fallen off.

Perhaps the most useful way to analyze data is to create a graph - a model that shows the relationship between one variable and another in an experiment. For most graphs, the independent variable is plotted along the x-axis and the dependent variable along the y-axis. The data points are plotted and the mathematical relationship is determined to be linear, exponential, quadratic, etc. Since all experimentation involves a certain amount of error, it is important to create best-fit lines or best-fit curves. Examples are shown on the following pages. All graphs must be labeled appropriately - a title that describes the graph, labels on each axis that include the units of the measurements being utilized, and if necessary, the slope of the line or its equation.

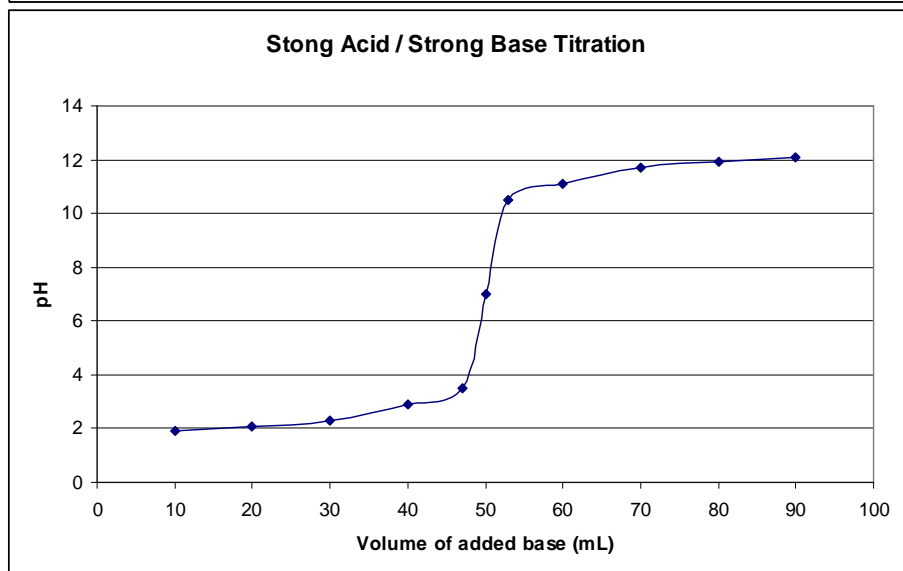
Graph #1: A scatter plot with a best-fit line. In this experiment, the mass (dependent variable) of a liquid was measured at varying volumes (independent variable). The data points indicate a linear relationship, so a best-fit line was drawn that most closely approximates each point. Notice that it is not essential for every point to be on the line. The equation for the line is in slope-intercept form, $y = mx + b$, and the slope indicates the density of the liquid ($d=m/V$).



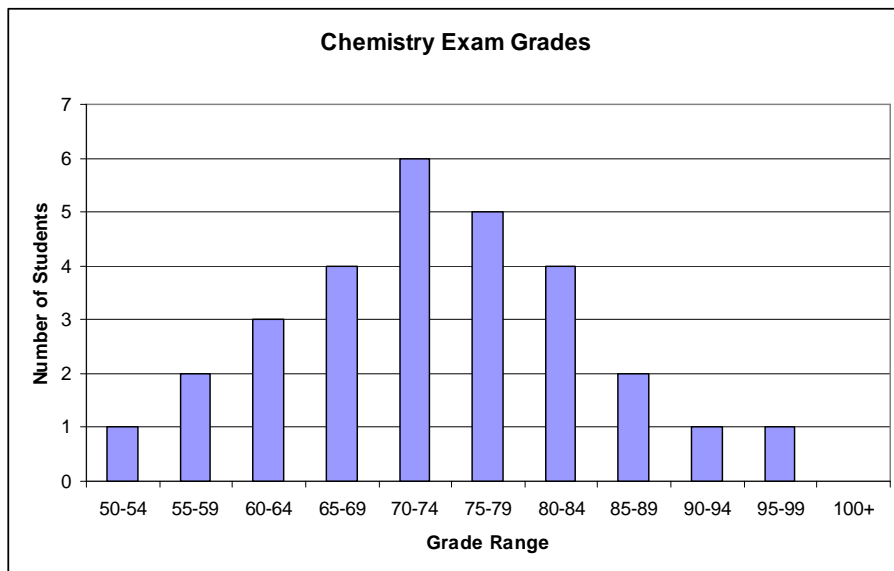
Graph #2: A scatter plot with a best-fit curve. In this experiment, the amount of substance remaining (dependent variable) was measured as time (independent variable) passes. The data indicates an exponential or logarithmic relationship, so a best-fit curve was drawn that most closely approximates each point. Notice that it is not essential for every point to be on the curve. The equation for the line is written in logarithmic form, $y = Ae^{-kx}$, where A is the original amount of sample and k is the rate of decay.



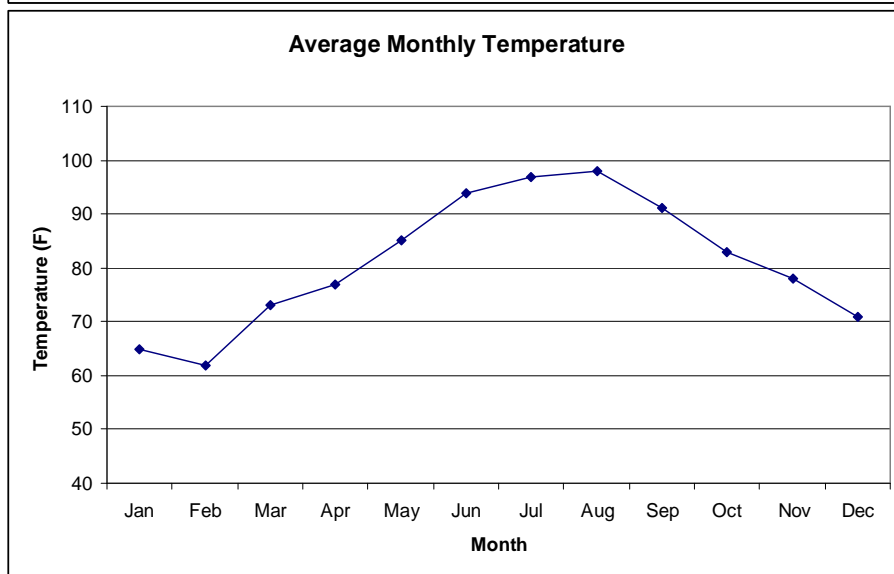
Graph #3: A scatter plot with a connecting smooth curve. In this experiment, the pH (dependent variable) of an acidic solution was measured as base is added (independent variable). The data indicates a complex polynomial relationship, so we connect all the data points with a smooth curve. No equation is given.



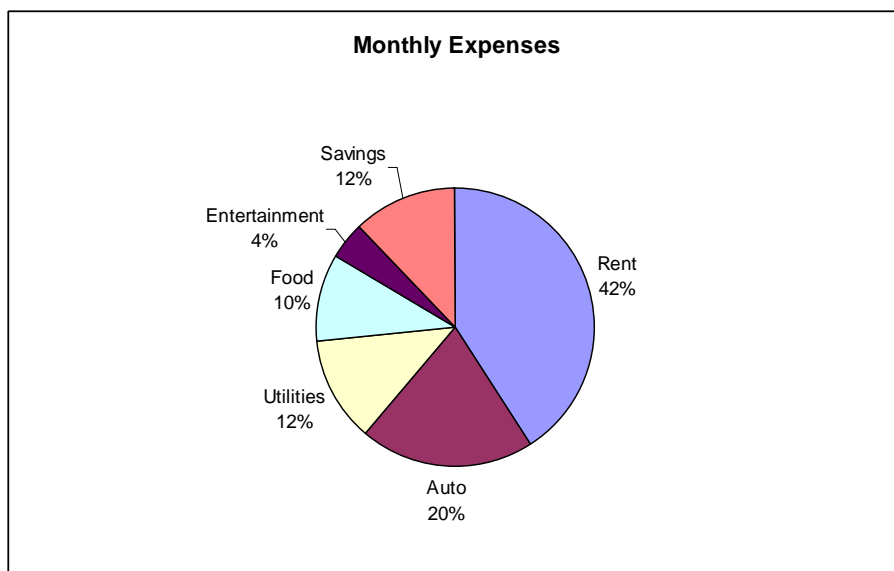
Scatter plots are used when we are certain that a mathematical relationship exists between the independent and dependent variables in an experiment.



Graph #4: A Histogram. This graph indicates the grade distribution on a typical chemistry exam. *Histograms are useful for graphing the number of items in a category.*



Graph #5: A line graph. This graph plots the average temperature (dependent variable) for twelve months (independent variable). *Line graphs are almost exclusively used for graphing the change in a property over time.*



Graph #6: A pie graph. This graph shows the relative amounts of an average person's income that are spent in certain categories. *Pie graphs are almost exclusively used for showing percentages, though data in a histogram can also be shown in pie graphs.*

1.5 LABORATORY SAFETY

Since much of your work in this class will be done in the laboratory, it is important that you learn to follow certain safety guidelines to protect yourself and your classmates from serious injury.

General Safety Rules:

1. Eye protection is required at all times in the laboratory. Your eyes are very sensitive and can easily become irritated or damaged if you are not wearing safety goggles at all times. Goggles protect your eyes from chemical splashes, harmful vapors, and sharp equipment.
2. No food or drinks are allowed in the classroom. Because of the nature of chemistry, you will be working with many substances that are harmful if they are ingested. It is not worth the risk to assume that what you are eating has not been contaminated in some way.
3. Horseplay and pranks are prohibited. Chemistry lab can be fun and exciting, but it can also be dangerous if care is not taken to ensure the safety of everyone working nearby.
4. Unauthorized experiments are prohibited. Even though science is based upon curiosity and seeking answers to questions, it is important to have a general idea of what to expect from an experiment so you will not accidentally cause injury to yourself or others.
5. Locate and know how to use all safety equipment. The fire extinguisher, fire blanket, safety shower, and eye-wash station can save your life if used properly and responsibly.

Emergency Procedures:

1. Chemical spills. If any chemical gets on your skin or clothing, flush the area with lots of cold water and notify the teacher immediately. Use the safety shower if the spill is extensive. If the chemical gets into your eyes, immediately irrigate the eye for 15 minutes at the eye-wash station.
2. Burns. Immerse the burned area in cold water and notify the teacher.
3. Cuts and abrasions. Immediately clean the wound with water and notify your teacher. Hold a sterile pad firmly over the wound until the bleeding stops, then apply a bandage.
4. Fires. A small fire at your desk can usually be put out by smothering it with a nonflammable material such as a damp rag or an inverted beaker. If your clothing catches fire, try to use your lab apron to put it out or wrap in a fire blanket. If necessary, roll on the floor. If a fire cannot be put out by the above procedures and there is little personal risk, use the fire extinguisher. Do not put yourself in danger to extinguish a fire.

Working with Chemicals:

All chemicals are potentially harmful to some degree. Avoid direct contact with any chemical. It is especially important to keep chemicals away from your hands, face, and clothing. Many substances are easily absorbed through the skin or through inhalation. Chemicals can also enter the body through the mouth or transferred to your eyes if your hands are contaminated.

1. Never taste any chemical.
2. Carefully read the label twice on any bottle prior to using it. Use chemicals only from containers that are clearly labeled.
3. Do not carry supply bottles to your desk as other students will need them. Bring your appropriate container to the supply table and take only what you need.
4. Do not return unused portions of chemicals to their containers as you could contaminate the entire bottle. See if other students in your area need the chemical or dispose of the excess as directed by your teacher.
5. Weigh chemicals in a previously-weighed container or on weighing paper rather than directly on the balance pan.
6. Never smell an unknown substance directly to determine its odor. Carefully waft the fumes toward your nose to protect yourself from harmful vapors.
7. Pour substances from the reagent bottles holding the label side of the bottle in your hand. This prevents dripping on the label and provides a clean side for holding the bottle.
8. If a solution spills onto the table, dilute the spill with lots of water and use paper towels to soak it up or to push it into the sink. Dispose of the towels. If an acid is spilled, neutralize it with sodium bicarbonate (baking soda), then clean up as before. Strong bases can be neutralized with acetic acid (vinegar).
9. Disposal of waste chemicals:
 - (a) Do not put any solids, paper or broken glass into the sink. They are to be disposed of in the trash or in the waste jars provided.
 - (b) Acids, bases and water solutions may be washed down the sink with large amounts of water, unless your instructor gives you other disposal instructions.
 - (c) Volatile or flammable liquids should not be poured down the drain, but should be placed in specially marked containers and kept sealed.
10. When diluting acid always add acid into the water. The water will absorb the heat produced and also prevent the acid from splashing onto your skin.

Working with Heat:

1. Never reach across an open flame. It is advisable to roll up long sleeves and to tie back hair that is longer than shoulder-length.
2. Before heating glass containers, examine them to see that they contain no cracks. The expansion caused by heating could cause the damaged glass to break.
3. When heating any solid or liquid in a test tube, keep the tube in constant motion and do not point the mouth of the tube at another person. Hold the test tube with test tube clamps to avoid burning yourself.
4. Always hold the test tube that is being heated at an angle, and heat the sides of the tube as well as the bottom.
5. Never look down into a tube containing a reagent or hot water, especially if it is being heated.
6. Never apply a direct flame to a container of volatile or flammable materials, and never place an open flame near such containers.
7. Hot glass looks just like cold glass, so always place hot objects on wire gauze to cool. Hot glass can inflict severe burns.
8. Never immerse hot glassware in cold water, which could cause it to shatter.

Conclusion of the Lab:

1. Clean and dry all of your glassware and your lab desk. Return all of your equipment to its proper place.
2. Check to see that the gas and water are turned off before you leave your working area.
3. Wash your hands thoroughly.
4. Place your goggles in the sterilizer and your apron in its proper place.

1.6 LABORATORY EQUIPMENT

Choosing the right equipment is just as important as designing an experiment.

Without the proper tools, it is difficult to achieve quality results that can be repeated by future researchers. It is important for you to be able to identify all of the equipment below and be able to use it effectively.

Measurement:

Graduated Cylinder
Buret
Volumetric Pipet
Dropper Bottle

Reaction Vessels:

Test Tube
Beaker
Erlenmeyer Flask
Florence Flask
Evaporating Dish
Crucible
Well Plate

Heating:

Bunsen Burner
Hot Plate
Wood Splint

Tools:

Scoopula
Dropper
Disposable Pipet
Beaker Tongs
Crucible Tongs
Test Tube Tongs

Miscellaneous:

Watch Glass
Stirring Rod
Funnel
Ring Stand
Ring Clamp
Utility Clamp
Clay Triangle
Wire Gauze