Chemistry: Step by Step
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Chapter 1: Fundamental Concepts and Tools of Chemistry

Section 1.1 From Chaos to Science.

Student Objectives

1. Distinguish between the natural world and the supernatural world.
2. Write down and define the four primary steps of the scientific method.
3. Know and use the primary tools of Observation and use them in making simple observations.
4. Explain in an essay why numerical observations are the best kind of observations.
5. Write down the statement known as "Ockham's Razor" and use it when making Hypothesis.
6. Describe the importance of asking the right questions when creating an Experiment to test a Hypothesis.
7. Distinguish between a Theory and a Law.
8. Use the scientific method to solve common everyday problems.

At the beginning of civilization, man's needs for science were simple. As a group of hunter-gatherers, man had to classify plants and animals into edible and non-edible or poisonous. As man became more sophisticated he had to classify that plants were suitable for fibers, dyes, and medicines. Biological taxonomy and the needs for biology became established early. As population grew and civilization became more complex, agriculture developed and towns and cities appeared along trade routes. Medicine also developed but its progress has less archaeological evidence and so we cannot figure out the exact discoveries. However, we do know it became a primary science in Egypt, resulting in drugs and procedures we use to this day.

In the physical sciences, developments were also confined to practical applications such as better brick making and the advancement of metallurgy skills. Metallurgy resulted in two practical arts, jewelry and weapons.

The Greeks were the first to develop theoretical science. They were the first to collect observations and try to find a principle cause for the observations. They also developed a scientific method, which Aristotle called the "inductive-deductive method," but it lacked formal experimentation to prove that the explanation worked. After the Alexander the Great of Macedonia conquered the Greeks, Hellenic culture evolved into Hellenistic culture and their science continued to thrive, especially in Egypt.

Roman rule brought the world good roads, bridges, and aqueducts but didn't continue the development of science. Under Roman rule, science existed only to serve the state. Theoretical science withered while applied science continued to make small advancements. Without continued discoveries in theoretical science, applied science lost the necessary tools to advance.

With the fall of the Roman Empire, much of the science of the western world was lost except for medicine. The church at Rome (which later evolved into the Roman Catholic Church), in adopting the care of the sick as a primary duty, preserved medical knowledge but did little to expand on it. In the eastern part of the empire, under the leadership of the Byzantines, science was preserved, but not improved upon, until Mohammed arose from the sands of the desert and formed the Islamic Empire. The Arabs, by virtue of their position were able to collect various writings, Greek, Syrian, Persian, Indian, and Chinese. Not content to sit on their knowledge, as had the Romans, the Arabs improved on former discoveries. They gave us algebra, trigonometry, reliable astronomical tables, the decimal system of numbers, chemistry as an experimental science, and refined optical instruments.

Alas, in Europe, science was almost unknown. Love potions, healing potions, spells, superstition and witchcraft dominated the thinking of the people of the Middle Ages. Explanations of natural occurrences relied on gods or demons, both of which have *supernatural* powers. Those who attempted to control or explain these events were tortured and made to confess their belief in a god or gods. Executions happened anyway because the prosecutors believed that those who confessed belief would go to a better place. Out of the mystical confusion of the middle ages, scientific inquiry arose to explain *natural* phenomena. William of Ockham (England) proposed, *"When several explanations of a phenomenon are offered, the simplest must be taken."* [1] This has become known as **Ockham's Razor** and serves to help choose a satisfactory explanation when the number of solutions becomes confusing.

Through the continued practice of the medical arts, European science was confined to practical techniques that would aid the medical efforts of the Roman Catholic Church. An early European biologist, Albertus Magnus, studied and classified plants all over Germany. A medical center opened in Montpelier, France and medical schools opened in Bologna, Padua, and Paris. In the physical sciences some progress was made with magnetism and Grossteste and Bacon experimented with optics. In chemistry, distillation (an Arab invention) developed. It met needs for purified acids as well as producing aqua vitae, a 96% alcohol for medicinal and industrial applications.

The wealth of Venice also had much influence on the reawakening of scientific thinking in Europe. The wealth supplied the financial resources for increased inquiry while trade with the Arab world stimulated the curiosity of those who were so inclined.

At the forefront of change were people such as da Vinci, Durer, and Michaelangelo, who robbed graves and dissected human corpses to depict, more accurately, humankind in their art. Da Vinci showed himself to be an able engineer as well as a gifted inventor. Durer contributed to the studies of geometry and astronomy, and Michaelangelo engineered the dome of St. Peter as well as being in charge of the fortification of Florence. In a more subtle way, the explorers of the Western Hemisphere classified hundreds of plants and transformed the diets of Europeans.

Figure 1.1.1 Leonardo Da Vinci, (1452-1519), The greatest scientific mind of his era.[i]

As the Renaissance picked up steam, Versalius's Anatomy and Copernicus's Heliocentric Theory of the Solar System were published. Galileo builds a telescope for astronomical observation and finds evidence to verify Copernican claims; he was excommunicated until he recanted.

The continued conflict between the Church and science hinged on the Church's claim of infallibility. Included in it's teachings throughout the dark ages were many of the writings of Plato and Aristotle. The idea that the earth was the center of the universe was from Plato. Aristotle was responsible for the idea that everything is made of only four elements, Air, Fire, Earth, and Water. Continued changes due to new discoveries in science were published by scientists outside of the Catholic Church's influence due to the reformation and the rise of Protestantism. Because discoveries of the natural world eroded the Catholic Church's position of infallibility, Pope Sixtus V decreed that "nature was not Aristotelian; it is a mechanical, non-ecclesiastical event." This declaration separated the natural world, as investigated by scientists, from the ecclesiastical, or religious, knowledge of the Church. It was a major idea of the Counter-Reformation.

By the end of the Renaissance, general inquiry began to divide itself into the fields of science we know today. The beginnings of the modern scientific method are found in Newton's "Philosophiae Naturalis Principia Mathematica" or "Principia" where he proposed his "method of analysis and synthesis."Simply stated Newton said that theories are based on sensory observations and these theories can be used to predict other events. The modern scientific method can be stated in four steps: **O**bservation, **H**ypothesis, **E**xperiment and **C**onclusion or OHEC.

Observation - The use of the ***5 senses***, or extensions of the 5 senses, to ***discover essential information about natural phenomena***.

A biologist uses a microscope to extend her sense of sight. A DJ, at a party, uses an amplifier to extend your ability to hear the music recorded on tape or disk. A sulfhydryl compound extends your ability to smell natural gas if your stove fails to light. Salt in food extends your sense of taste, and a x-ray crystallography apparatus extends your ability to feel and see the sharp outlines of crystalline compounds.

One of the common problems in urban areas across the country, SMOG, affects several of our senses. Those who live in smog prone areas can see, smell, taste and touch smog when it is concentrated enough. You can see the orange haze at sunset. You can smell the diesel exhaust of a bus and you can sometimes taste the unburned hydrocarbons (diesel oil) if you breathe in through your mouth. Those who are sensitive to smog, the elderly, asthmatics, and contact lens wearers can feel the effects of smog. Smog is such a terrible problem that all the cars in various parts of the country have to have a smog check every two years to have the license plates renewed.

When a mechanic checks a car for smog does he look to see if the car passes? Does he taste or sniff the car's exhaust? Does he get very close to the exhaust and breathe deeply so that he will experience a coughing fit if your car is putting out too much smog? Of course not! He places a sensor in your exhaust pipe and his computer prints out the condition of the car's exhaust and on his printout are numbers. All ***precise and reproducible observations have numbers*** in them!

The auto mechanic is not the only person who uses numbers in his line of work. A carpenter would not guess how big to make a tabletop for the table in your dining room. The carpenter would measure your table and measure the wood before making the cut. But how would he measure it? Most carpenters who specialize in furniture construction have their own shops. They would not come to your house to measure your table. You would have to measure the table for him.

You put the tabletop on the floor and you use your feet. You find that the tabletop is two of your feet wide and four of your feet long. You tell the carpenter that the tabletop is two feet wide and four feet long. So the carpenter puts a piece of wood on the floor and measures a piece of wood that is two of his feed wide and four of his feet long. He cuts it for you, stains it, and varnishes it and you proudly take it home. When you try to attach the legs, you find that the tabletop is too big! That stupid carpenter, he made the tabletop the wrong size!

What is wrong here? You carefully measured the tabletop; the carpenter carefully measured the tabletop. Yet the tabletop came out the wrong size. Something else must be wrong other than your abilities of measurement! The measurement itself is fundamentally flawed. Your feet and the carpenter's feet are two different feet with two different lengths. What you need is a standard foot. The need for a standard measurement was recognized by the Babylonians a long time ago. Standard measures have come and gone until the 1800's when several nations developed their own standards in response to the industrial revolution. Inches, feet, yards and miles are standard measures because they have the same value no matter where you use them. In science, and everywhere else except the United States of America, we use the metric system (system international, S.I.) where the standard measures are based on meters, grams, liters, or the worldwide standards of time.

Hypothesis - Try to interrelate all of the observations of the natural phenomena and try to explain what is occurring or why or how this occurs. In other words ***a hypothesis is an educated guess based on observations***.

Let's revisit our smog-test mechanic. He has found out that your car is putting out too much carbon monoxide and too much unburned hydrocarbons. At this point the mechanic must make a guess why your car is doing this. This guess is a hypothesis. He probably will tell you that you need a tune up to pass the smog test. How does he know this? He cannot be 100% certain but his experience and data tell him that a tune up is necessary. This hypothesis is an "educated guess."

When you go to the doctor with aches, pains, and coughing, she listens to your chest, takes your temperature, looks at your nose and ears and tells you that you have the flu. How does she know that you have the flu and not pneumonia? Like the mechanic she uses her observations and her experience to make an educated guess.

Experiment - Carefully select a group to perform the experiment with (the experimental group), and select another group who mimic the experiment in every way except for the tested characteristic (the control group). With the experimental group, make a change that specifically tests the hypothesis. The ***experiment tests the educated guess or hypothesis***.

The doctor has found that your flu did not go away. She has done additional tests and found that you have a rare disease that affects your lung surfactant and this prevents you from expectorating out (spitting up) your phlegm (mucous). She says she knows of a new, experimental treatment and gives you a pill. Is this pill a drug or is the pill made of sugar? What the pill is made of depends on whether you are a member of the experimental group or the control group. How you react to the pill will be documented. You were lucky, you were a member of the experimental group and the drug appears to have worked because most of the experimental group recovered. Regrettably the control group suffered and became worse, but they will now be given the therapeutic pill.

On the other hand, the mechanic does not usually get a control car. He relies on his collection of data and experience, with cars that run well, to serve as the control group. He performs the tune up on your car and tests to see if it made a difference with your smog emissions. This is different from what the doctor did. The auto mechanic is coming to a conclusion by applying something that has consistently worked in the past. He applied a scientific theory.

Conclusion – When given certain observations and under experimental conditions a certain action is known to work. This action was originally a hypothesis and is now a conclusion. A conclusion is an explanation that works under experimental conditions that uses observations made during an experiment to bolster the explanation.

Theory – Conclusions that have stood the test of time and still seem to explain natural phenomena become theories. A ***theory, like a conclusion, is a hypothesis that works under experimental and real life conditions. It is used to make reliable predictions.***

Some scientists insist that there are ***natural conditions in the universe that will never change. Statements about these conditions are called laws***. The idea that energy can never be created or destroyed is called the Law of Conservation of Energy. As we come across such situations they will be given the status of laws. But, we must remember that Newton's Law of Gravitation stood for several hundred years before Einstein found a flaw. Until every possibility has been investigated, including possibilities we have not dreamed of, a theory cannot really be considered a law.

Problem Set 1.1

1. From the following list of words, identify those that are related to the natural or the supernatural world.

Specters	Goblins	Colors
Heat	Fire	Dragons
Voodoo	Witchcraft	Taxonomy
Hurricanes	Earthquakes	Explosions
Fairy Fire	God/gods	Energy

2. Write down and define the four primary steps of the scientific method.
3. Describe the following items using the principle tools of observation.

Pizza	Your Music	Velvet
A friend	Fire Truck	

4. Explain in a paragraph why numbers make observations better.
5. Write down the statement known as "Ockham's Razor" and use it to choose the best course of action in the following situations.
    a. Your car is making a thumping noise as it travels down the road. Some possible explanations include: a flat tire, a slightly bent axle, a broken shock absorber, someone in the back seat thumping on the side of the car. In what order would you investigate the possibilities.
    b. Your hair dryer suddenly stopped working this morning while you were using it. Some possible explanations include: a car crashed into the power pole on your street shutting off the electricity throughout the neighborhood, it became unplugged, it blew the circuit breaker, it shorted out on the inside In what order would you investigate the possibilities.
6. Discuss the statement "All academic tests are fair." Now how does your position compare with the statement "All experiments are valid." Make sure you consider the definition of "experiment."
7. Distinguish between a Theory and a Law.
8. Read the stories below, put all of the facts given to you under the word observations on your paper. Come up with a logical guess (hypothesis), a logical test of your guess (experiment) and come up with a logical conclusion that works under experimental conditions (theory).
    a. You walk into your room and turn on the electrical switch. You hear a popping noise, and the light bulb flashes for an instant and it becomes dark.
    b. You are in the kitchen and you smell an odd sulfur-like odor coming from the stove. You see a frying pan with frozen sausages in it. You hear a hissing noise and you cannot see a flame.

Section 1.2 Fundamental Physical Terms and Concepts

Student Objectives

1. Relate Newton's statement regarding the interrelationship between mathematics and science and explain how science uses mathematics.
2. Describe mass, weight, distance, time, vectors, velocity, and acceleration and show how each are related to one another.
3. State Newton's three Laws of Motion.
4. In an essay answer the question, what is force and contrast it with net force?
5. Discuss the fundamental difference between mass and weight.
6. List the forms of energy.
7. State the idea of Conservation of Mass and the law of Conservation of Energy.and show how Einstein's mathematical relationship links the two.
8. Define and give examples of Physical Change.

Sir Isaac Newton of England was the Einstein of his age. His unique approach to science emphasized that every natural phenomenon can be explained by mathematical law. Newton emphasized the modeling of the natural world using mathematical formulas. His philosophy has most recently created the field of biomathematics that seeks to describe biological structures, function, and behavior with mathematical formulas. He provided an indivisible link between mathematics and science. His accomplishments include the invention of calculus, the laws of motion and the mathematical descriptions of the effects of gravity. His contributions founded the area of physics called mechanics.

In order to understand Newton's laws we need to understand some of his terms. Mass is the quantity of material involved. Mass is often misunderstood. We usually use the term weight when we want to use mass. Whether you use “Jenny Craig” or you use “Deal-a-Meal” to lose "weight" you really want to lose an amount of body fat. Body fat is a quantity of material and must be called mass. In contrast weight is the force that is caused by gravity acting on mass. If I wanted to lose weight, I could travel to the moon where the gravity is one-sixth the gravity on earth. My weight would therefore equal one-sixth my weight on earth. While I would have lost a lot of weight, I would still have the mass that was responsible for my weight. While mass is commonly measured on a balance and measured in grams it is not weight but the exact amount of material.

Distance is a measurement from one point to another. The distance from one goal line to another goal line in American Football is 100 yards. The distance jumped in the running long jump is from the take-off board to the landing in the sand pit. Distance will always have a beginning point and an ending point.

In science time also has a beginning point and an ending point; more specifically it is called elapsed time. Elapsed time is most commonly measured on a stop watch. When athletes participate in timed events (running, swimming, skiing, etc.) the time displayed is an elapsed time. The beginning time is zero and the ending time is what shows up on the stop watch.

Anything that affects mass must have a direction. Any effect or phenomenon with a direction is a vector. For example, gravity affects mass by pulling one mass toward the center of another mass. The gravity vector holds the smaller mass to the surface of the larger mass. The rates of velocity and acceleration are both vectors.

Velocity is the change of distance in a given period of time in a specific direction. If you were to head from downtown Los Angeles to downtown Santa Barbara on U.S. route 101 (West, Northwest) you might travel 137.5

miles. If you cover this distance in an elapsed time of 2.5 hours you have a change of distance in a given period of time. Dividing 137.5 miles by 2.5 hours you have a velocity of 55 miles per hour.

Acceleration is most simply defined as a change of velocity in a given period of time in a specific direction. Gravity is a phenomenon which causes acceleration. Its acceleration has been measured to be 9.8 meters per second per second. This means that if you dropped a ball from a tall building, the instant you released the ball would be time zero. At time zero the velocity equals zero. After one second, the velocity will equal 9.8 meters per second. After two seconds velocity will equal 19.6 meters per second. After three seconds velocity will increase to 29.4 meters per second. Notice that at time passes velocity increases. If velocity increases over time it fulfills the definition of acceleration.

In uniting these terms, Newton developed his famous laws of motion. His **First Law of Motion** can be considered his law of inertia. It says: "If there is no net force acting on a body, it will continue in its state of rest, or will continue moving along a straight line with constant speed."[2] In other words, if something is not moving it will not move without force and if it is moving, it will continue just as it has until force affects it. We rely on this law everyday. If you leave an item in your locker you have every right to expect that it will remain there. The only reason for something in your locker to move is the application of force. If you put your clothes in a dryer and start the dryer running, you expect that the dryer will continue to run until the time you set on the machine runs out. If it stops before it should have stopped then some force must have been applied to stop it. We usually call these forces, net forces. If you hold a ball at your side and you are standing still, the ball will not move. However, when you let go of the ball the ball will begin to move downward. According to Newton's first law, the ball begins to move because there is a net force present. While you held the ball, the force that was pulling down on the ball (usually called gravity) was defeated by the force of your hand and arm pulling up on the ball. The net force on the ball, while you were holding it was zero. When you let go of the ball there as a net force in the downward direction, therefore the ball moved in the downward directions. As children we spent many hours pushing spoons, cups, bowls, keys and anything we could get our hands on, off of tables and chairs and onto the floor. Net force pulled these objects to the floor each and every time.

Newton's **Second Law of Motion** says, "The effect of an applied force is to cause the body to accelerate in the direction of the force. The acceleration is in direct proportion to the force and in inverse proportion to the mass of the body."[3] This law can be illustrated by comparing the acceleration of a Cadillac with a 4.5 liter V8 and a Mustang with a 5.0 liter V8. The Cadillac has more mass and more inertia and the Mustang has much less mass. Assuming that the two V8 engines generate the same amount of force, the Mustang should accelerate at a higher rate than the Cadillac if Newton's second law of motion holds true. Since this happens in real life, we find that Newton's second law works. More importantly, Newton's second law gives us a means to calculate force. We can measure mass and we can find the amount of acceleration. Since mass and acceleration are inversely proportional we can multiply them to calculate force. In formula form, Force (f) equals Mass (m) times Acceleration (a), more conventionally $f = ma$.

Newton's **Third Law of Motion** states, "Whenever one body exerts a force on a second body, the second body exerts a force on the first body. These forces are equal and opposite in direction."[4] This law is often phrased as for every action there is an equal and opposite action. As children all of us have observed a balloon move all over the room when the air in the balloon comes out the mouthpiece end of the balloon. The air in the balloon rushes out of the back of the balloon because it is pushed that way by the force of the contracting rubber in the balloon. The balloon moves forward because of the reaction force pushing equally hard in the opposite direction. Less obviously, when you lean on a wall, you are placing force against the wall. Since you are not moving, the net force or total force must be zero (first law of motion). In order for the net force to equal zero, there must be a force that pushes against you as you lean against a wall. This force is accounted for in Newton's third law of motion.

Net force causes the acceleration of a given mass for a certain distance. The natural result of Newton's laws is the idea of work. In formula form Work (w), Force (f), Mass (m) and Distance (d) are related as follows:

$$w = fd \qquad \text{and} \qquad f = ma$$

Since f = ma we can substitute ma for f in the work equation, therefore:

$$w = mad$$

We have now proven that work and madness are equal. But in all seriousness, by definition work equals the product of force and the distance the object moved. By Newton's second law we know that force is the product of mass and acceleration. Because the two are equal we can substitute and derive that a given mass accelerated over a certain distance is work.

When work is done on any object energy results. The energy of motion is called **kinetic energy**. Its formula is $0.5\ mv^2$ (m represents mass, v represents velocity). If you throw a ball, that ball will possess a certain amount of energy. If you threw the same ball, with the same force up in the air and onto the roof of a building, the energy you put into that ball would have been stored in the ball. If the ball is knocked off the roof, it will release that energy. The energy that was stored in the ball is called **potential energy**. Later we will discuss how molecules, through bonds with atoms, store **chemical energy** which is a form of potential energy.

In an ideal, frictionless, environment work done on an object would stay 100% efficient. Because of friction this is not so. Because of friction, work is reduced. Because of friction, kinetic energy is reduced. In the case of the ball that landed on the roof, the kinetic energy was stored; but what happened to the kinetic energy that was lost due to friction. If you hold your hands together and move your hands back and forth, the friction caused by skin rubbing on skin slows the motion of your hands. This friction reduces the kinetic energy of your hands. Do you notice anything else that happens to your hands? Did your hands warm up? Of course they did! Did your hands start to warm up before you started to rub them together? Of course not! So the heat must have come from the reduction of kinetic energy. **Heat** is a form of energy! Other sources of heat include: burning gas (transformed from **chemical energy**), light bulbs (transformed from **electrical energy**).

While transfers of work and force are not 100% efficient, energy transfer (if we account for all transfers of energy including unproductive transfers) remains 100% efficient. This is a fundamental characteristic of nature. It is called the **Law of Conservation of Energy**. Simply stated, "Energy can never be created or destroyed" or “The energy of the Universe is constant.” According to this law, when you rubbed your hands, the kinetic energy that transformed into heat energy was not created but changed in form. As you rubbed your hands, did the heat continue to increase or did your hands heat up? Since the heat did not continue to increase, the heat either destroyed itself or it went somewhere else. Which event happens?

If you hold your hand near an incandescent light bulb, you can feel the heat moving through the air. If you bring your hand closer to the light bulb, you can feel an increase of heat. As heat moves away from the light it is transferred to more and more air. We could say that the heat is diluted by the air just as "Kool Aid" is diluted by the water that is added to it. Therefore the energy that is created by your hands did not destroy itself but was transferred to the surrounding air and it dissipates.

In chemistry another fundamental characteristic is the Law of Conservation of Mass. It says that mass can never be created or destroyed. Under stable, non-radioactive conditions, the law of conservation of mass still works. However, during this century, Einstein discovered that mass at a sufficient velocity transforms itself into energy. His famous statement is one of the most famous statements of physics.

$$E = mc^2$$

Einstein's equation of the relationship of mass and energy forever made the law of conservation of mass a mere extension of the law of conservation of energy.

Any changes in the level of energy of a given mass or a change in the position of the mass is a physical change. If you lower the energy level of liquid water you will produce ice. If you allow the ice to regain the energy, it will produce the original water. Changing the energy level does not change the fundamental composition of the object. Increasing the velocity of an object is a physical change because it changes the position and the energy level of an object. Moving a ball from the ground to the roof of a building is a physical change because it is a change of position. Taking a ball of clay and forming the shape of a bowl is a physical change. Physical changes can always revert to the original appearance. If we take the bowl of clay and fire it we will have another kind of change altogether.

Problem Set 1.2

1. Complete this sentence, Science uses mathematics to.....
2. Describe the difference between Set One (mass, distance, and time) and Set Two (velocity and acceleration).
3. State Newton's three Laws of Motion and give everyday examples of each that are not in the text.
4. In a two or three paragraph essay, answer the question, what is force and contrast it with net force. Make sure you use real life examples.
5. Discuss the fundamental difference between mass and weight.
6. List the forms of energy.
7. State the idea of Conservation of Mass and the law of Conservation of Energy.and show how Einstein's mathematical relationship links the two.

Problem Set 1.2 - continued

8. From the following list of changes, pick out the ones that are physical changes.

Fire	Digestion	Mold Plastic
Twist Wire	Breath Air	Dissolve Sugar in Water
Cook an Egg	Use Binoculars	Recycle Aluminum
Blow a Glass Mug	Straighten Up Your Room	Explosions
Chewing	Assaying Gold Ore	Panning for Gold

\Section 1.3 Fundamental Chemical Terms and Concepts

Student Objectives

1. Describe the science of chemistry.
2. Define the term matter and classify the terms: pure, mixture, element, atom, compound, molecule, heterogeneous and homogeneous in a hierarchical manner. Also define ions, cations, and anions.
3. From their position on the periodic table, identify which elements are cations and which elements are anions. Name simple compounds formed from a cation and an anion.
4. Describe density and tie density with the definition of matter.
5. Distinguish between homogeneous and heterogeneous matter.
6. Distinguish between solutions, compounds, elements, molecules and atoms.
7. Determine if a substance is pure.
8. Use the kinetic-molecular theory to explain the four states of matter.
9. Define Chemical Change and distinguish between Chemical and Physical Changes.

A middle aged man with white hair and a bad hairdo, holds a clear glass container of clear, bubbling, red liquid. On top of the liquid is a white fog. The man laughs an evil laugh as he raises the glass to his lips. Electrical bolts fly around the room as he starts to imbibe this foul brew. In walks Michael J. Fox who asks, "So what are we doing today Doc?"

Hollywood and authors such as Mary Shelley, Edgar Allen Poe and Robert Louis Stevenson have preyed on the fears of their viewers and readers for many years. Many "mad scientists" were depicted as participating in chemical research. While chemistry is exciting it has never taken on the aura given it from Hollywood and other fictional sources.

Chemistry is the science that is on the forefront of many of todays problems. From global warming, to nanotechnology, to characterization of the Human Immunodeficiency Virus, chemistry has the tools to deal with each of these problems. Chemistry is the <u>study of matter, its structure, and the structural and energy changes that are exhibited by matter</u>.

Matter is anything that has mass and takes up space. Let's look at two distinctly different types of matter, lead and chicken feathers. Which is heavier, a kilogram of lead or a kilogram of feathers? Now think about this carefully. If you pick up the kilogram of lead it certainly feels heavier than the kilogram of feathers. If you look at the space occupied by the lead you should notice that it takes up much less space than the feathers. While both have the same mass they have a great difference in the space occupied. Another way to say this is that lead has a higher density than the feathers. Density is mass divided by the volume and because of the definition of matter, it is a fundamental characteristic of matter. Like velocity and acceleration it is a calculated value of a natural condition of matter.

In addition to density, matter can be classified in ways similar to the way biology classifies living things (kingdom, order, class, etc.). Notice that biology starts to classify living things from the largest group of organisms (kingdom) and ends up with the smallest group of organisms (species). The kingdom is a mixture of all organisms which share certain specific characteristics. A species is a collection of organisms that are so closely related that they have essentially the same genetic code.

In a similar manner, matter is the largest group of chemicals. Like kingdoms, matter can be divided up into categories such as pure matter and mixtures of matter. Pure matter can either be an element or a compound. Elements in chemistry are most conveniently found on the Periodic Table of the Elements, that is why it is a table of elements. The smallest form of an element is an atom. Dividing an element beyond an atom results in a loss of identifiable characteristics such as density, color, reactivity, odor, and texture. Also when you divide an element into parts smaller than an atom, you end up with sub-atomic particles. You may have heard of some of these sub-atomic particles in science classes that you have already had. The most common ones are protons, neutrons, and electrons. If you combine two or more elements in a way that they form bonds (points where they are stuck together) you end up with compounds.

A typical compound found at home is table salt. This is made up of the elements sodium and chlorine. Sodium and chlorine stick together because each chlorine steals one electron from each sodium. Sodium has a positive charge because it is short an electron and chlorine has a negative charge because it has an extra electron. Opposite charges attract and the positive sodiums (a positive ion or cation) and the negative chlorine (a negative ion or anion) stick together like a bunch of magnets in a jar. Elements that are ions and stick together because of opposite charge are said to have an ionic bond. The smallest form of a compound that is made of ionic bonds is called a compound. In the periodic table below, you can clearly see a line that divides the metals and non-metals.

Table 1.1 The Periodic Table of the Elements

← Metals, Cations | Non-Metals, Usually Anions →

	IA 1	IIA 2	IIIB 3	IVB 4	VB 5	VIB 6	VIIB 7	8	VIIIB 9	10	IB 11	IIB 12	IIIA 13	IVA 14	VA 15	VIA 16	VIIA 17	VIIIA 18
1	1 H Hydrogen																	2 He Helium
2	3 Li Lithium [	4 Be Berylium [											5 B Boron [	6 C Carbon [	7 N Nitrogen [	8 O Oxygen	9 F Fluorine [	10 Ne Neon [
3	11 Na Sodium [	12 Mg Magnesiu m [											13 Al Aluminum [	14 Si Silicon [	15 P Phosphoru s [	16 S Sulfur [	17 Cl Chlorine [	18 Ar Argon [
4	19 K Potassium	20 Ca Calcium [	21 Sc Scandium [	22 Ti Titanium	23 V Vanadium [	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt [	28 Ni Nickel [	29 Cu Copper	30 Zn Zinc	31 Ga Gallium [	32 Ge Germaniu m	33 As Arsenic [	34 Se Selenium [	35 Br Bromine [	38 Kr Krypton [
5	37 Rb Rubidium [	38 Sr Strontium [	39 Y Yttrium [	40 Zr Zirconium [	41 Nb Niobium [	42 Mo Molybden um [	43 Tc Technetiu m [	44 Ru Ruthenium [	45 Rh Rhodium [	46 Pd Palladium	47 Ag Silver [	48 Cd Cadmium [	49 In Indium [	50 Sn Tin [	51 Sb Antimony [	52 Te Tellurium [	53 I Iodine [	54 Xe Xenon [
6	55 Cs Cesium [	56 Ba Barium [	57 La Lanthanum [	72 Hf Hafnium [	73 Ta Tantalum [	74 W Tungsten [	75 Re Rhenium [	76 Os Osmium [	77 Ir Iridium [	78 Pt Platinum [	79 Au Gold [	80 Hg Mercury [	81 Tl Thallium [	82 Pb Lead	83 Bi Bismuth [	84 Po Polonium [	85 At Astatine [	86 Rn Radon [
7	87 Fr Francium [	88 Ra Radium [	89 Ac Actinium [	104 Rf Rutherfordiu m [	105 Db Dubnium [	106 Sg Seaborgiu m	107 Bh Bohrium [	108 Hs Hassium	109 Mt Meitnerium [	110 Uun Ununniliu m [								

Lanthanide Series f subshell	58 Ce Cerium	59 Pr Praseodymiu m	60 Nd Neodymiu m	61 Pm Promethiu m	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium {	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Yttrium	71 Lu Lutetium
Actinide Series f subshell	90 Th Thorium	91 Pa Protactiniu m	92 U Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendeleviu m	102 No Nobelium	103 Lr Lawrenciu m

From their position on the periodic table, you can identify which elements will form cations and (most of the time) which elements will form anions. All metals form cations and all non-metals form anions (some non-metals can form cations, but we will study this phenomenon later). In simple ionic compounds the cation is always written first and the anion is written second. When we name simple compounds, the cation keeps its name and the anion ends in "ide". Following this pattern, our compound of table salt is named sodium chloride. In Table

1.2 is a list of the anions from the periodic table. Notice that boron is missing from the list. This is because boron is a non-metal by appearance, but chemically it typically behaves as a cation. Also notice that when a non-metallic element becomes an anion, the name changes slightly. This is different from the cations which do not change their name when they become positive ions. Table 1.2 shows the spelling of the non-metals when they become ions in the

groups they belong to on the periodic table:

Table 1.2 Anion Names in Compounds

Group IVA or Group 14	Group VA or Group 15	Group VIA or Group 16	Group VIIA or Group 17
Carbide	Nitride	Oxide	Fluoride
Silicide	Phosphide	Sulfide	Chloride
	Arsenide	Selenide	Bromide
		Telluride	Iodide
			Astatide
			Hydride (hydrogen behaves this way with Group 1 elements only)

So how do we use this information? If you left a piece of aluminum outside for a period of time, little white-silver spots would appear on its surface. These spots are made of aluminum that joined with oxygen and they have the chemical formula Al_2O_3. We call this compound aluminum oxide. The aluminum cation keeps its name and the oxygen anion (see table 1.2, column Group VIA or Group 16) becomes oxide. If we apply our original definition of chemistry (the study of matter, its structure, and structure and energy changes) aluminum oxide no longer resembles aluminum metal or oxygen gas. Aluminum oxide no longer has the characteristics of either of its combining elements. Aluminum is bendable, forgeable, and ductile. It is silver in color and considered a hard but slightly brittle metal. Oxygen is a colorless, odorless, gas. Aluminum oxide is a very hard silver-white crystal. When crushed into very small crystals, it can be used as an abrasive in self-cleaning sandpaper. When the elements of aluminum and oxygen are combined into aluminum oxide. there is a measurable energy change. This process involves both a change in structure and in energy, therefore, it is clearly within the scope of the science of chemistry.

There are compounds that are made with elements and ions that are made from more than one element. We call ions that are made from more than one element, polyatomic. The prefix “poly” means many, so polyatomic means many atoms. There are two common polyatomic cations (positively charged ions) and the other common polyatomic ions are anions (negatively charged ions). A list of these ions are shown in table 1.3.

Table 1.3 Common Polyatomic Ions

Cations		Anions			
Ammonium	NH_4^{+1}	Acetate	CH_3COO^{-1}	Hypochlorite	ClO^{-1}
Hydronium	H_3O^{+1}		$C_2H_3O_2^{-1}$	Nitrate	NO_3^{-1}
		Arsenate	AsO_4^{-3}	Nitrite	NO_2^{-1}
		Carbonate	CO_3^{-2}	Oxalate	$C_2O_4^{-2}$
		Chlorate	ClO_3^{-1}	Perchlorate	ClO_4^{-1}
		Chlorite	ClO_2^{-1}	Permanganate	MnO_4^{-1}
		Chromate	CrO_4^{-2}	Peroxide	O_2^{-2}
		Cyanide	CN^{-1}	Phosphate	PO_4^{-3}
		Dichromate	$Cr_2O_7^{-2}$	Sulfate	SO_4^{-2}
		Hydroxide	OH^{-1}	Sulfite	SO_3^{-2}

Just as a metal, such as the aluminum cation can combine with the anion of oxygen, the cation ammonium can combine with non-metals from the periodic table and any polyatomic anion. Any of the polyatomic anions can combine with ammonium and any of the metal cations to form a compound. Sodium combined with nitrite forms sodium nitrite which is found in smoked meats like smoked salmon or bacon. Notice that when a metal combines with a polyatomic anion, there are no changes to their name. Ammonium can combine with most non-metals, but it shows a preference with combining with the halogens or the group 17 elements. Ammonium chloride combines the polyatomic ion ammonium with the element chlorine. Since chlorine changes from an element to an anion, its name changes from chlorine to chloride as indicated in table 1.2.

A special class of ionic compounds are called acids and bases. Simple bases are composed of any metal cation and the polyatomic ion, hydroxide. Simple acids are made of the hydrogen ion (cation) and an anion. The only anions from the periodic table that form strong acids are the halogens, group 17. Acids made from a hydrogen ion and a halogen ion follow the naming pattern of hydro-first syllable of the halogen name-ic acid. When hydrogen and chlorine form an acid, it gets the name hydrochloric acid. Hydro is the prefix which says that you have an acid made of hydrogen and another element, chlor is the first syllable of the other element-chlorine, and ic is the suffix. All of the halogens when they form acids follow this pattern.

When hydrogen ions bond to a polyatomic ion, they have a different naming pattern. Acids using polyatomic ions with names that end in “ate” or “ide” will have acid names that end in “ic”. Hydrogen and acetate form acetic acid. Hydrogen with nitrate form nitric acid. Hydrogen with sulfate form sulfuric acid. Acids using polyatomic ions with names that end in "ite" have acid names that end with "ous". Hydrogen with nitrite form nitrous acid. Hydrogen with sulfite forms sulfurous acid.

There are many compounds that are not formed from ions. One of these compounds is found at home and we commonly call it sugar, more specifically table sugar. Table sugar is made up of carbon, hydrogen, and oxygen and it has a specific name, it's sucrose. Corn syrup, another sugar, is called fructose. This is why soda pop, which is sweetened primarily with corn syrup, lists as one of its main ingredients, high fructose corn syrup. The elements in sugars and similar compounds, stick together by sharing electrons (instead of non-metals stealing electrons from a metal as the ionic compounds do). Elements that stick together because of shared electrons are said to have a covalent bond. The smallest form of a compound that is made of covalent bonds is called a molecule. Molecules are a subset of compounds.

Within mixtures of matter you can have homogeneous and heterogeneous mixtures. Homogeneous mixtures are matter that has similar properties throughout. Apple juice is the same throughout. We cannot visually differentiate the parts that make up apple juice and these parts are uniformly distributed. Apple juice is an example of homogeneous matter. Homogeneous matter is also in the same phase of matter (solid, liquid, gas, and plasma). Homogeneous mixtures can also be called solutions.

Orange juice is different from apple juice and an example of heterogeneous matter. It has both juice and pulp. It is its heterogeneity that forces us to shake up orange juice before we drink it. Heterogeneous matter is made up of particles of distinctly different properties. All heterogeneous matter is a mixture of two or more types of matter with each type retaining its own properties.

If we strain orange juice through a filter, the resulting juice is homogeneous as is the pulp in the filter. We now have two homogeneous materials. The pulp is a homogeneous solid and the juice is a homogeneous liquid. Since the pulp and juice are both made of many substances and both are homogeneous, they are considered to be solutions. Solutions are mixtures that are homogeneous.

Not all matter is composed of multiple substances, some matter can consist of only one type of matter. Homogeneous matter that is composed of only one type of matter is considered a pure substance. Two types of matter are considered to be pure substances, compounds and elements. A collection of the same kind of molecules is a compound. Pure table salt is a collection of the same molecule, sodium chloride. The smallest form a compound can take is that of one molecule. Looking at the sodium chloride molecule we can see one atom of sodium stuck to one atom of chlorine. The sodium atom is bonded to the chlorine atom. If a molecule is broken up (the bond is broken) it results in atoms. A collection of the same kind of atoms is called an element. The smallest form an element can take is that of one atom.

All particles of matter have kinetic energy. Kinetic energy is the energy of motion. Particles of matter all have different levels of energy just as people do. Some people have lots of energy and you might find them dancing or playing a sport. Other people have less energy, these people are called couch potatoes. As a whole, people, world-wide, have an average level of energy and this could be called the pace of life on Earth.

Just as people have individual energies and an average energy, particles have individual energies and an average energy. Just as some people form connections with other people in the form of partnerships, corporate businesses, sports teams, friendships and lovers, atoms and compounds also have connections. Connections between atoms are called bonds while connections between molecules are called intermolecular forces (inter-between and molecular-molecules, so intermolecular means between molecules).

A collection of particles, with a low amount of energy, will not be moving very much at all. At the most, atoms or compounds may shake a little, rotate, or oscillate (move back and forth). Because their energy is low, these particles are remaining in about the same place in space (space is any volume). Imagine a bunch of marshmallows that have stuck together. If the marshmallows truly cannot move, this bunch is a solid. The same thing is true of a bunch of atoms or a bunch of compounds. When they are not moving much, and they remain in the same position, they form solids. Solids tend to be rigid and non-compressible, occupy a specific volume with a specific shape, diffuse from one solid to another at a very slow rate, and some solids tend to form crystals.

What happens when energy is added to solids? The inter-atomic and inter-molecular forces start to let go. If you have ever played “Crack-the-Whip,” you know that the more the line of people increase speed and rapidly change direction, one or even a group of people can break off of the whip. As particles (atoms or compounds) absorb more and more energy, their inter-atomic and inter-molecular forces let go in the same way that the people’s hands let go in “Crack-the-Whip.” Now you have lines of particles or clusters of particles. These lines and clusters can pack together in many different ways so they never have the same shape. In fact their shape tends to be limited to any boundaries that exist to hold them in. We have now reached the liquid state of matter.

Liquids tend to take on the shape of their containers but they still occupy a specific volume. Since liquids occupy the smallest volume possible and still stay a liquid, liquids are not compressible. Because liquids are lines or bunches of particles, they diffuse faster than a solid but not as fast as a gas

Gases represent the second most energetic state of matter. Particles of matter in the gaseous state have so much energy that they possess no effective inter-atomic or inter-molecular forces. The particles move freely in a volume. Gases readily diffuse, they occupy the maximum volume possible and so conform to the shape of their container. Because they fit their container, their volume is as large as they volume of their container. Since they are at maximum volume the particles are far apart and so gases can be compressed. With sufficient energy, gas particles are elevated to the next state of matter, the plasma state. With rare exception, the plasma state does not exist on Earth. Note that all of these states are achieved by simply increasing the energy of the particles. We have not broken or made new bonds between atoms. The relationship between particles and kinetic energy is called the kinetic-molecular theory. It explains the changes from ones state of matter to another.

The making and breaking of bonds (remember bonds are not the same as inter-atomic and inter-molecular forces) is called chemical change. Chemical change happens when chemical reactions take place. Chemical change has happened when a color change occurs or a temperature change takes place or gas is evolved or when there is a distinct change in structure. Unlike physical changes that are readily reversible (with physical changes, you can end up with the material you started with), chemical changes are not readily reversible. An example of a chemical change is a sunburn. When you stay out in the sun your skin reddens or it feels hot. A chemical change has taken place because your skin will not immediately return to its pre-sunburn condition. There is a color or a texture change and there is a temperature change.

All living organisms need chemical changes to produce usable energy. We call this process eating and digestion. A color change occurs, a temperature change occurs, gas is usually evolved and there is a distinct change in the structure of the food.

Problem Set 1.3

1. Discuss if the following statement is valid: Chemistry studies life. Make sure you use the definition of chemistry in your answer without directly quoting it.
2. a. What is matter?
   b. Organize the terms below into a hierarchical fashion. A hierarchy can look like an outline, a flow chart, or a scattergram.

atom	compound	element
heterogeneous	homogeneous	matter
mixture	molecule	pure

3. Part I: For the simple ionic compounds below, correctly give the name of the compound.

a. Al_2O_3	b. NaF	c. KCl	d. $CaBr_2$	e. MgS
f. $RaCl_2$	g. Ga_2Se_3	h. Rb_2O	i. BBr_3	j. CsH
k. NH_4Br	l. KNO_3	m. Ag_3PO_4	n. $Ca(OH)_2$	o. Na_2CO_3
p. $KMnO_4$	q. $MgSO_3$	r. $Al(CH_3COO)_3$	s. NH_4ClO_3	t. $K_2Cr_2O_7$

   Part II: For the acids below, correctly give the name of the compound.

a. $HClO_2$	b. HBr	c. HF	d. CH_3COOH	e. HI
f. $HClO_3$	g. H_2SO_4	h. H_2CrO_4	i. HNO_3	j. HCN

4. Oil and vinegar are the primary ingredients in Italian salad dressing. What natural characteristic of matter allows the layers to happen. Why is the oil on top of the vinegar?
5. Classify each of the following as a heterogeneous mixture or a homogeneous mixture.

Concrete	Pond Water	Sea Water
Pure Air	Smoggy Air	Salt in Water
Natural Gas	Chocolate Chip Cookies	Butter Cookies
Beef Broth	Cream of Mushroom Soup	Honey
Steel	Iron	Galvanized Steel

6. Classify each of the following homogeneous materials as a solution, element, or a compound (You may need to look up some of
   these in a good dictionary).

Tin	Rubbing Alcohol	Liquid Soap
Sugar	Carbon Monoxide	Kool Aid

7. In what ways does a pure substance differ from a homogeneous mixture? In what ways are they alike?
8. What are the four states of matter and give identifying characteristics to the three states that are common on Earth. What is the relationship of energy to the four states of matter?
9. From the following list of changes, pick out the ones that are chemical changes.

Move a Muscle	Polishing Gems	Painting Wood
Washing Clothes	Burning Coal	Smog Test
Bake a Cake	Weld Iron	Let Iron Rust
Freeze Dry Coffee	Bleach Stains	Use a Battery
Chewing	Blow Bubbles	Breath

Section 1.4 Numbers, Measurement, Significant Figures, and Rounding

Student Objectives

1. Given a measurement or a number, determine which digits are significant.
2. Why do measurements force us to use significant figures?
3. Identify exact numbers
4. Write down the four rules for rounding.
5. Use the four rules for rounding to correctly round off non-significant numbers.
6. Write down the rules for maintaining significant figures in addition and subtraction and multiplication and division.
7. Use your understanding of significant figures to determine where to round off a number after a calculation.
8. The student will be able to apply the rules of significant figures and rounding to calculations in order to preserve the correct number of significant figures in the answer.

Newton set the standard for scientific inquiry when he insisted on modeling natural phenomena mathematically. This implies that numbers, or variables that represent real numbers, will have an important role in scientific pursuits. In order to effectively attach numbers to natural phenomena, a straightforward and standardized system of measurement had to develop. The first system of measurement to find active use is called the English System of Measurement. As the empire of Great Britain developed throughout the world, their system of measurement spread with them. Common measures in this archaic system are the inch, foot, yard, mile, quart, gallon, pound, calorie and so on. In the United States of America we traditionally use this system of measurement. This system necessitates the use of fractions and odd conversion ratios (12 inches equals one foot, 5280 feet equals one mile, etc.)

Because the English system of measurement has proven cumbersome to use, science (and every other country in the world except the United States) has adopted the metric or system international (S.I.) measurement system as its standard. The S.I. uses increments of 10 to transition from one unit to another (10 millimeters in one centimeter, 100 centimeters in one meter, 1000 meters in one kilometer, 1000 milliliters in one liter). The S.I. allows the use of decimals which makes their use in calculations much easier. The S.I. also allows a more precise recording of individual measures.

The typical meter stick allows 5 digits of precision. So, what is meant by the phrase digits of precision? For the length of a meter stick you have whole meters that are recorded as whole numbers, starting in the ones place and increasing as necessary. For a meter stick, this number in the ones place is the **FIRST** digit of precision in the measurement. Notice that we start counting digits of precision or significant figures from the leftmost digit.

Decimeters occupy the tenths place (the Latin root for deci, for tenths is also the root for our coin the dime, a tenth of a dollar). This is the second digit of precision in a measurement using a meter stick, if there is a value in the ones place. Centimeters occupy the hundredths place (the Latin root for centi or a hundredth, is also the root for our coin the cent, or a hundredth of a dollar). This is the third digit of precision for a length measurement using a meter stick when there is at least one meter in length. Millimeters occupy the thousandths place (some old tokens were once called mils, meaning a tenth of a cent or a thousandth of a dollar). This is the fourth digit of precision. You might ask, "So where is the fifth digit of precision?" The fifth digit has to be estimated. You have to guess the nearest fraction of a millimeter (I recommend fifths of a millimeter that would result in 0, 2, 4, 6, and 8 occupying the ten thousandths place) that represents the length you are measuring. **IN THIS CLASS,**

YOU WILL ALWAYS ESTIMATE THE LAST DIGIT OF PRECISION IN MEASUREMENT OR YOUR LAB PAPERS WILL BE RETURNED AND YOU WILL HAVE TO REPEAT THE LAB. This last estimated digit of precision plays a significant role in every calculation and analysis that measure is used in. It determines the significance of our scientific results. Therefore the adage, "Close enough for government work," is not appropriate in science. The greater the number of significant figures in our measurements, the better our results. Because of its importance, we call this concept, significant figures. We will now learn the rules for using significant figures.

1. Always start counting significant figures from the leftmost place value with a non-zero number.
2. Numerical values from one through nine (non-zero integers) are always significant.
3. Because zero does not tell us how many are present it only says none are present, knowing that you have none of a value has special rules of significance.
   a. Zero is **not significant** to the **left** of a number. These numbers only hold place value and do not serve to tell us any other information. Also notice, the first rule. Zeros to the left of the first non-zero number are not supposed to be counted at all.
   b. Zero is **significant in between significant** numbers. In the numbers 402 and 60007, notice that in 402 the zero means you do not have any tens and in the number 60007 you do not have any tens, hundreds or thousands.
   c. Zero is significant when it is to the right of the first significant number **only if there is a decimal present**. In the number 7200, you have only two significant figures (the 7 and the 2, the zeros are not significant because there is not a decimal present). The number 7200 is a close estimate but not a precise value; the zeros are only holding place value. However in the number 3**.**10 and 450**.** you have three significant figures (the zero in this case is significant because it is on the right side of the number and a decimal is present.

Lets try to determine the number of significant figures and the number of significant decimals in the following numbers.

<u>Sample Problems 1.1, 1.2, and 1.3</u>

Underline the significant figures in each problem. Determine the number of significant figures and the number of significant decimals in each problem. Compare the three numbers and determine if that number has the most significant figures and if that number has the most significant decimals.

<u>Problem 1.1</u>

<u>189</u>	**Three** Significant **Figures** **Zero** Significant **Decimals**	<u>91.84</u>	**Four** Significant **Figures** **Two** Significant **Decimals**

<u>Problem 1.2</u>

<u>259</u>0	**Three** Significant **Figures** **Zero** Significant **Decimals**	<u>2590</u>**.**	**Four** Significant **Figures** **Zero** Significant **Decimals**

<u>Problem 1.3</u>

<u>1.20</u>	**Three** Significant **Figures** **Two** Significant **Decimals**	0.00<u>200</u>	**Three** Significant **Figures** **Three** Significant **Decimal**

Out of all of these numbers, 2590**.** and 91.84 have the most significant figures and 0.00200 has the most significant decimals.

In addition to numbers with varying numbers of significant figures and significant decimals, there are some numbers that have an infinite number of significant numbers. These numbers are called **Exact Numbers**. There are two categories of exact numbers, numbers determined by counting and numbers that are defined as exact numbers. If we were to count doors on cars, we would have some that are 2-door, some that are 3-door, and some that are four or even five-door. Because we arrived at these numbers by counting exactly how many doors are on a car, all of these numbers are considered to be exact. Later on in this chapter we will have ratios or equalities that by definition are exact. The ratio that 1 km = 0.6214 mile is considered exact. The 1 km would normally have only one significant figure but since it is defined as exact we consider that it has an infinite number of significant figures. Also, the 0.6214 mile would normally have only four significant figures, but because it is defined as exact, it has an infinite number of significant figures.

Now why is all of this important? The last thing you need to learn is something you will never use. Have you ever worked a problem on a calculator and ended up with a display full of numbers? How many of those numbers were important? Where should you round off those numbers? **Mathematical operations with significant figures will allow you to round off numbers that are not important.** Before we learn where to round we need to know **how to round because rounding numbers off in science is different than in math.**

The rules for rounding are as follows:

1. If the number you wish to round is **less than 5**, round off. For example, take the number 40.3 and round the number off to a whole number. You round off the 3 (it disappears) and the answer should be 40.
2. If the number you wish to round is and 91.84, drop that number and raise the preceding digit by 1. For example, take the number 41.6 and round the number off to a whole number. The six is dropped, the one is raised by one to a 2 and the answer is 42.
3. If the number you wish to round **is 5**, and the **preceding digit is even**, you round it off. For example, take the number 46.5 and you want to round the number to a whole number. You drop the 5 and since six is even you leave it alone and the answer is 46.
4. If the number you wish to round **is 5**, and the **preceding digit is odd**, you drop the 5 and raise the preceding digit by one. For example, take the number 47.5. You want to round the number off to a whole number. The 5 is dropped, the 7 is odd, so it is raised by one to an 8, and the answer is 48.

These rules can shown with a simple picture:

9	
8	round the preceeding number up ↑
7	
6	
	if the preceeding number is odd, round it up ↑
5	
	if the preceeding number is even, round the 5 off
4	
3	
2	round this number off
1	

Sample Problems 1.4, 1.5, 1.6 and 1.7

Lets combine the ideas behind significant figures and the rules for rounding. Round off the following numbers to three
significant figures (3 sig. fig.).

Problem 1.4 Rule 1	Problem 1.5 Rule 2	Problem 1.6 Rule 3	Problem 1.7 Rule 4	
1 2 3	123	1 2 3	123	(counting sig. fig.)
8.23|4	0.00601|9	92.2|5	0.307|5	
8.23	0.00602	92.2	0.308	

Mathematical operations are greatly affected by significant figures and addition and subtraction are affected differently than multiplication and division. When **adding or subtracting** with significant figures, the number with **the fewest number of significant decimal digits will determine the number of decimal digits in your answer**. This means you have to count the number of significant decimal digits in each number that is added or subtracted. Your answer must have the same number of significant decimal digits as the number with the fewest number of significant decimal digits.

Multiplication and division are also affected by significant figures but the result is more uniform than with addition and subtraction. When **multiplying or dividing, the number with the fewest number of total significant digits will determine the number of total digits in your answer**. Unlike addition and subtraction, when you multiply or divide, the number of significant figures in your answer will
equal the smallest number of significant figures among the numbers involved.

Sample Problems 1.8 and 1.9

Determine the number of significant **decimal digits** in each number in each problem. Perform the operation indicated. Round off your answer using the rules for determining the number of significant figures when adding and subtracting
as well as the rules for rounding.

Problem 1.8 Problem 1.9

Problem 1.8		Problem 1.9
802.304	<-----------3 significant **decimal digits**----------->	0.0369
+ 21.33	<-----------2 significant **decimal digits**----------->	- 0.00022
823.634		0.03672
823.63|4	<---must have only 2 significant **decimal digits**--->	0.036|72
823.63	<---------------------correct answer--------------------->	0.037

Even though we followed the rules for significant figures, notice that the total number of significant figures between problem 1.8 and 1.9 are very different while the number of significant decimal digits are identical. **This does not mean every addition and subtraction problem has two significant decimal places. The number of significant decimals in the answer always depends on the least number of significant decimals in all of the numbers added or subtracted.** 1.0023 – 0.1 = 0.9023. When we round this to the fewest number of significant decimal digits, our answer is 0.9.

Sample Problems 1.10 and 1.11

Determine the number of significant digits in each number in each problem. Perform the operation indicated. Round off your answer using the rules for determining the number of significant figures when multiplying and dividing as well
as the rules for rounding.

Problem 1.10

80.3	x	0.00348	x	12	=	3.353328	=	3.3|53328	=	3.4
3 digits		3 digits		2 digits				2 digits		2 digits

Because the number 12 has only 2 significant digits, your answer can have only 2 significant digits. You now need to apply rounding rules. The number you want to round off is a 5, the digit in front of it is odd, you drop the 5 and you change the 3 to a 4.

Problem 1.11

52,000**.**	÷	4,000**.**	=	13	=	13.00
5 digits		4 digits				4 digits

Because the number 4,000 has 4 significant figures, your answer must have 4 significant figures. Because the answer on the calculator has only two digits you need to add additional **zeros to hold the number of significant figures.**

Problem Set 1.4

1. For the following problems, underline the numbers that are significant and give the number of significant figures in each number. Also determine the number of significant decimal digits in each. Which number or numbers have the fewest number of significant digits.

   Example 0.0<u>304</u> 3 significant figures, 3 significant decimal digits May or may not have the fewest number of significant digits.

   a. 802 b. 0.0033 c. 93,000 d. 0.0500 e. 63.90 f. 0.0090400

2. Which of the following numbers are exact numbers

   a. 4 table legs b. 1 km c. 0.6214 mi d. 1 dozen eggs e. 867-5309 f. 1 in = 2.54 cm

3. Write down the four rules for rounding.
4. Round the following numbers to three significant figures.

a. 802.3	b. 0.003305	c. 931.05	d. 0.05075	e. 63.92	f. 121.1
g. 528.0	h. 12.086	i. 40.54	j. 0.0080500	k. 52.08	l. 40.45

5. Write down the rules for maintaining significant figures in addition and subtraction and multiplication and division.
6. For the following problems, do the indicated math, apply the ideas of significant figures and rounding to come up with the correct answer.

a. 245.795 + 80.22	b. 20.45 – 2.4	c. 12.52 + 13.50 + 9.66
d. 42.306 – 1.22	e. 3.40 + 0.022 + 0.5	f. 14.33 – 3.468
g. 102.45 + 2.44 + 1.9999	h. 234.1 – 62.04	i. 17.0 x 4.7
j. 292 / 4.2	k. 0.03 x 0.005	l. 194 / 4444
m. 4.50 x 9.2	n. 456.9 / 33	

Section 1.5 What Happens When the Number is Too Big For My Calculator or Why You Need to Know About Scientific Notation

Student Objectives

1. Express all numbers as factors (the numbers that you multiply to arrive at the number you desire) of their prime numbers.
2. Group those factors so that the factors can use power notation.
3. Use exponential notation in base 10 in order to change numbers of any size into scientific notation.
4. Write down the rules for adding, subtracting, multiplying and dividing using scientific notation.
5. Use the rules for mathematics in scientific notation to perform calculations with numbers in scientific notation.
6. Apply the rules for significant figures and rounding to calculations in order to preserve the correct number of significant figures in the answer.

All numbers can be expressed as the product of two or more numbers. The number 4 can be expressed as 1 multiplied by 4 or 2 multiplied by 2. There also exists a set of numbers that can be expressed as a product of the number one and itself. For instance the number 1 is the product of 1 multiplied by 1. The number 7 is the product of 1 multiplied by 7. Numbers which can only be expressed as a product of the number one and itself is called a prime number. The first 7 prime numbers are 1, 2, 3, 5, 7, 11, and 13.

All numbers can be factored until all of the factors are prime numbers. Take 75 for instance. Its prime factors are 1 x 75, 1 x 3 x 25, 1 x 5 x 15 and 1 x 3 x 5 x 5. The last set of factors is 75's set of prime factors. Since 5 appears more than once we can simplify 75's prime factors by using power notation. Using power notation, 75's prime factors are $1 \times 3 \times 5^2$. What this says is that 75 can be expressed as a product of its prime factors.

Sample Problems 1.12 and 1.13

Factor the following numbers into prime factors and simplify using power notation where applicable.

Problem 1.12	Problem 1.13
$32 = 2 \times 2 \times 2 \times 2 \times 2 = 2^5$	$49 = 7 \times 7 = 7^2$

Ten is a unique number because it is the basis for our entire numerical system; factors of ten establishes place values. When the one's place increases, it can only increase to 9. In order to continue to increase it must go to zero and the number in the ten's place must increase by 1, making the number 10. As the number in the ten's place increases it may increase to 90. The numbers in the one's place also may increase to 9 making the number 99. But to increase any more, the numbers in the ten's place and the one's place must go to zero and the number in the hundred's place must go to one making the number 100. Any place value can be expressed as a number multiplied by a power of 10. We will let that number be Z.

Table 1.3

Millionths	Z x 10^{-6}	1 x 10^{-6}	=	0.000001
Hundred Thousandths	Z x 10^{-5}	1 x 10^{-5}	=	0.00001
Ten Thousandths	Z x 10^{-4}	1 x 10^{-4}	=	0.0001
Thousandths	Z x 10^{-3}	1 x 10^{-3}	=	0.001
Hundredths	Z x 10^{-2}	1 x 10^{-2}	=	0.01
Tenths	Z x 10^{-1}	1 x 10^{-1}	=	0.1
Ones	Z x 10^{0}	1 x 10^{0}	=	1
Tens	Z x 10^{1}	1 x 10^{1}	=	10
Hundreds	Z x 10^{2}	1 x 10^{2}	=	100
Thousands	Z x 10^{3}	1 x 10^{3}	=	1000
Ten Thousands	Z x 10^{4}	1 x 10^{4}	=	10000
Hundred Thousands	Z x 10^{5}	1 x 10^{5}	=	100000
Millions	Z x 10^{6}	1 x 10^{6}	=	1000000

Scientific notation takes advantage of this and lets us handle very large numbers and very small numbers by multiplying numbers by a power of 10. This allows us to drop non-significant zeros and it allows us to use very large and very small numbers in a convenient and easy to use system. Let's look at a large number.

$$85{,}000 \text{ becomes } 8.5 \times 10^4$$

The first step in changing a number into scientific notation is to divide the number by another number and multiply by a power of 10 so the first significant figure is in the ones place. In the number 85,000 we need to divide 85,000 by a number so the decimal is between the 8 and the 5. We can't just move the decimal, we will be changing the value of the number if we move it without performing a mathematical operation. In order to change the appearance of a number but not change its value, we will need to multiply by a creative form of the number one which is usually a fraction. In other words the number we divide 85,000 by will be multiplied by a power of 10 that is equal to the number we divide by. We will show that fraction as x over y and z will be a power of 10.

$$85{,}000 \bullet \frac{x}{y} = 8.5 \times 10^z$$

Since we need to change 85,000 to 8.5 (which makes the number smaller), the denominator will be responsible for this change (because division makes numbers smaller). What number can we divide 85,000 by that will give us 8.5? That number is 10,000 and we will substitute it for y. The result from the division is 8.5.

$$85{,}000 \bullet \frac{x}{10{,}000} = 8.5 \times 10^z$$

Now the trick is to find a value of x which is equal to 10,000 but is an exponential value. If we look at Table 1.3, we can see that 10,000 is equal to 10^4. We can use this exponential value to substitute for x. Since the numerator and denominator are both equal, the fraction is equal to 1 and any number multiplied by 1 is not changed. Also, since z is equal to the exponent and the exponent on 10^4 is 4, we will substitute the number 4 for z.

$$85{,}000 \quad \bullet \quad \frac{10^4}{10{,}000} \quad = \quad 8.5 \text{ x } 10^4$$

Scientific notation also allows us to use very large numbers in chemistry, numbers which are so large that they won't fit our calculators. One of the major numbers in chemistry is called Avogadro's Number and it looks like this:

602213670000000000000000 particles/mole

Now, try to put this number in your calculator, including all of the zeros. Unless your calculator has 24 digits of precision, this is an impossible feat. You must change this number into scientific notation. Since the number 6 (at the front) is in the 24th place value to the left of the decimal, you need to divide by a number that has the number 1 in the 24th place value, all other places must have zeros in them (100000000000000000000000).

$$602213670000000000000000 \quad \bullet \quad \frac{x}{100000000000000000000000} \quad = \quad 6.0221367 \text{ x } 10^z$$

Our value for x must be equal to 100000000000000000000000. Before we could look on a chart and determine the correct exponent. However, this is beyond the range of our chart. Going back to our original example, notice the relationship between 10,000 and its exponential value 10^4. The exponent is equal to the number of zeros in 10,000 (this is because the fifth place value was taken care of by the number 10). If we count the number of zeros in 100000000000000000000000, we will come up with 23. The number which must be substituted for x is 10^{23}. This means our value for z is 23. The result is

$$602213670000000000000000 \quad \bullet \quad \frac{10^{23}}{100000000000000000000000} \quad = \quad 6.0221367 \text{ x } 10^{23} \text{ particles/mole}$$

While the number was much more difficult to handle the method remains identical.   Also notice that the units did not disappear. What happens when you have a very small number? Again scientific notation takes advantage of this and lets us multiply numbers by a power of 10. This allows us to drop non-significant zeros and it allows us to use very small numbers in a convenient and easy to use system. Let's look at a small number.

0.00003407 becomes $3.407 \text{ x } 10^{-5}$

The first step in changing a number into scientific notation is to move the decimal so the first significant figure is in the ones place. In the number 0.00003407 we need to divide by a number so the decimal is between the 3 and the 4. But we can't just move the decimal, we would change the value of the number. In order to change the appearance of a number but not change its value, we need to multiply by a creative form of the number one which is usually a fraction.

$$0.00003407 \quad \bullet \quad \frac{x}{y} \quad = \quad 3.407 \ \times 10^{z}$$

Since we need to change 0.00003407 to 3.407 (which makes the number larger), the numerator will be responsible for this change (because multiplication makes numbers larger). What number can we multiply 0.00003407 by that will give us 3.407? That number is 100,000 and we will substitute it for x. The multiplication gives us 3.407.

$$0.00003407 \quad \bullet \quad \frac{100{,}000}{y} \quad = \quad 3.407 \ \times 10^{z}$$

Now the trick is to find a value of y which is equal to 100,000 but is an exponential value. If we look at the table on the previous page, we can see that 100,000 is equal to 10^5. We can use this exponential value to substitute for y. Since the numerator and denominator are both equal, the fraction is equal to 1 and any number multiplied by 1 is not changed. Also, since z is equal to the exponent and the exponent is 5 we will substitute 5 for z.

$$0.00003407 \quad \bullet \quad \frac{100{,}000}{10^5} \quad = \quad \frac{3.407}{10^5}$$

Ooops! Our answer is not what we are looking for. Our exponent in in the denominator. In order to retain standard form we need to move the exponent from the denominator to the numerator. To accomplish this we will need to divide using exponential rules. We will need to make the numerator and the denominator have the form K x 10^z. The numerator lacks a power of ten. Which power of ten can we multiply 3.407 by which will leave it unchanged? The value which equals 1 (any number multiplied by 1 retains its value) is 10^0. We will put that in the numerator. Also we can multiply 10^5 by 1 (again this does not change its value).

$$\frac{3.407}{10^5} \quad \bullet \quad \frac{10^0}{1} \quad = \quad \frac{3.407 \times 10^0}{1 \times 10^5}$$

Standard division using exponents divides the numbers and subtracts the exponents. This gives us (3.407 ÷ 1) x (10^{0-5}). Our final answer is 3.407 x 10^{-5}

Scientific notation also allows us to use very very small numbers in chemistry, numbers which are so small that they won't fit our calculators. One of the major numbers in chemistry is called Plank's Constant and it looks like this:

0.000000000000000000000000000000000606260755 Joules/second

Now, try to put this number in your calculator, including all of the zeros. Unless your calculator has 42 digits of precision, this is an impossible feat. You must change this number into scientific notation. Since the number 6 (at the front) is in the 34th place value to the right of the decimal, you need to multiply by a the number 1 in the 34th place value, all other places must have zeros in them (10000000000000000000000000000000000).

This gives us:

$$0.000000000000000000000000000000000606260755 \bullet \frac{10000000000000000000000000000000000}{y}$$

Which equals

$$= \quad 6.06260755 \text{ x } 10^{z}$$

Our value for y must be equal to 10000000000000000000000000000000000. Before we could look on a chart and determine the correct exponent. However, this is beyond the range of our chart. Going back to our original example, notice the relationship between 100,000 and its exponential value 10^{5}. The exponent is equal to the number of zeros in 100,000 (this is because the sixth place value was taken care of by the number 10). If we count the number of zeros in 10000000000000000000000000000000000, we will come up with 34. The number which must be substituted for y is 10^{34}. The result is

$$0.000000000000000000000000000000000606260755 \bullet \frac{10000000000000000000000000000000000}{10^{34}}$$

Which equals

$$= \frac{6.06260755}{10^{34}}$$

Again we are left with a number in the numerator and an exponent in the denominator. We will again multiply the numerator by 100 and the denominator by 1 so we can divide using standard division of exponents.

$$\frac{6.06260755}{10^{34}} \bullet \frac{10^{0}}{1} = \frac{6.06260755 \text{ x } 10^{0}}{1 \text{ x } 10^{34}}$$

Standard division using exponents divides the numbers and subtracts the exponents. This gives us (6.06260755 ÷ 1) x (10^{0-34}). Our final answer is 6.06260755 x 10^{-34} J/s. While the number was much more difficult to handle the method remains identical. Also notice that the units did not disappear.

Now that we have a number that can fit into our calculators, how can we use numbers that are in scientific notation in calculations? When using scientific notation in addition and subtraction problems, we use a procedure that is analogous (similar) to adding and subtracting fractions. When we add or subtract fractions we need to set the denominators to be equal. When we **add or subtract using scientific notation, we need to adjust the powers of ten so they are the same**. I recommend that when you adjust the power of 10 that you adjust all powers so they match the largest power**.** We do this by multiplying by the proper form of the number one. Once the powers are the same, addition and subtraction can proceed normally. For **multiplication you multiply all numerical values and add the exponents** together. For **division you divide the numerical values and subtract the exponents**.

Sample Problems 1.14 and 1.15 Addition and Subtraction Using Scientific Notation

Solve the following using standard rules

Problem 1.14-When your numbers start as non-scientific notation numbers.

$$\begin{array}{l} 822.1 \\ \underline{+\ 0.0303} \end{array}$$

Start by changing the larger one into scientific notation.

$$822.1 \quad \bullet \quad \frac{x}{y} \quad = \quad 8.221 \times 10^{Z} \quad = \quad 822.1 \quad \bullet \quad \frac{10^2}{100} \quad = \quad 8.221 \times 10^2$$

$$\begin{array}{l} 8.221 \times 10^2 \\ \underline{+\quad 0.303} \end{array}$$

Now change the smaller number into scientific notation so that the exponents match. This procedure is slightly different than before. We need to solve for a specific exponent, in this case the exponent is 2 (8.221×10^2). We will put in the 2 where the variable z was before, this leaves the number portion unknown and we will leave that y.

$$0.0303 \quad \bullet \quad \frac{x}{y} \quad = \quad ? \times 10^{Z} \qquad\qquad 0.0303 \quad \bullet \quad \frac{10^2}{y} \quad = \quad \frac{0.0303 \times 10^2}{y}$$

We need to ask ourselves, "What number is equal to 10^2?" Based on the table on page 14, we can see that 10^2 equals 100. So we will substitute 100 for y. Now all we have to do is divide the numbers ($0.0303 \div 100$) and multiply by the power of 10.

$$\frac{0.0303 \times 10^2}{100} = 0.000303 \times 10^2$$

Now we can put this value in to replace 0.0303

$$\begin{array}{rl} 8.221 & \times 10^2 \\ +\ \ 0.000303 & \times 10^2 \\ \hline 8.221303 & \times 10^2 \end{array}$$

Notice that the exponents are equal and the decimal points must still line up.

Now we must apply significant figures. The number with the least number of significant decimals, 8.221×10^2, has three significant decimals of the greatest value, so we need to round off the answer to match this number.

$8.221|303 \times 10^2$ rounding, we end up with 8.221×10^2

Sample Problems 1.15-When Your Numbers are Already in Scientific Notation.

a.
$$\begin{array}{rl} 6.06 & \times 10^3 \\ \underline{+\ \ 4.8} & \underline{\times 10^4} \end{array}$$

b.
$$\begin{array}{rl} 8.79 & \times 10^{-6} \\ \underline{-\ \ 2.3} & \underline{\times 10^{-8}} \end{array}$$

The first step is to change the smallest powers of ten to match the largest. In sample problem 1.15a, we will change 6.06×10^3 into a number $\times 10^4$. In problem 1.15b, we will change 8.79×10^{-6} into a number $\times 10^{-3}$. Again, we will do this by **using a number that equals one**. This particular version of the number must include two parts, a numerical value and a power of 10 value. In previous problems we used the variables x and y to represent these values and we will do so again. For example the number 100 and the power of ten, 10^2 are equal. The solutions to parts a and b will take place side by side below. As you read through these examples, notice what is similar and what is different. The first step is to multiply the number we want to change by $Y \times 10^x$. Also we must remember that $Y \times 10^x$ has to equal 1.

$$6.06 \times 10^3 \ * \ Y \times 10^x = ? \qquad\qquad 8.79 \times 10^{-6} \ * \ Y \times 10^x = ?$$

We must now choose a value for "x" so that 3 + x = 4. It has to equal 4 because that is the power of 10 that matches 4.8×10^4. Let x = 1, this gives us $Y \times 10^1$. We need to find a value for Y so that $Y \times 10^1 = 1$. To make this equation true, we need to let **Y equal the reciprocal of our power of 10**. Since 10^1 is equal to 10, the reciprocal is 0.1. Substituting in for x and Y we get

$$6.06 \times 10^3 * 0.1 \times 10^1 = ?$$

Now we can multiply using the rules for multiplying numbers with scientific notation (multiply the
numbers and add the exponents).

$$6.06 \times 10^3 * 0.1 \times 10^1 = 6.06(0.1) \times 10^{3+1}$$

$$6.06(0.1) \times 10^{3+1} = 0.606 \times 10^4$$

Now we can substitute 0.606×10^4 for 6.06×10^3.

a.
$$\begin{array}{r} 0.606 \times 10^4 \\ +\ 4.8 \quad \times 10^4 \\ \hline 5.406 \times 10^4 \end{array}$$

Now we need to round this number off using significant figures. 0.606×10^4 has three significant decimals and 4.8×10^4 has one significant decimal so our answer must have only one significant decimal.

$$5.4|06 \times 10^4 = 5.4 \times 10^4$$

We must now choose a value for "x" so that –6 + x = –3. It has to equal –3 because that is the power of 10 that matches 2.3×10^{-3}. Let x = 3, this gives us $Y \times 10^3$. We need to find a value for Y so that $Y \times 10^3 = 1$. To make this equation true, we need to let **Y equal the reciprocal of our power of 10**. Since 10^3 is equal to 1000, the reciprocal is 0.001. Substituting in for x and Y we get

$$8.79 \times 10^{-6} * 0.001 \times 10^3 =$$

Now we can multiply using the rules for multiplying numbers with scientific notation (multiply the numbers
and add the exponents).

$$8.79 \times 10^{-6} * 0.001 \times 10^3 = 8.79(0.001) \times 10^{-6+3}$$

$$8.79(0.001) \times 10^{-6+3} = 0.0089 \times 10^{-3}$$

Now we can substitute 0.0089×10^{-3} for 8.79×10^{-6}.

b.
$$\begin{array}{r} 0.00879 \times 10^{-3} \\ -\ 2.3 \qquad \times 10^{-3} \\ \hline 2.29121 \times 10^{-3} \end{array}$$

Now we need to round this number off using significant figures. 0.00879×10^{-3} has three significant decimals 2.3×10^{-3} has one significant decimals so our answer must have only one significant decimals.

$$2.2|9121 \times 10^{-3} = 2.3 \times 10^{-3}$$

Sample Problem 1.16 Multiplication Using Scientific Notation

Solve the following using standard rules

$(6.02 \times 10^{23}) \times (3.0 \times 10^3) =$

Apply the rules for multiplication and observe the commutative property.

$(6.02 \times 10^{23}) \times (3.0 \times 10^3) = (6.02 \times 3.0) \times (10^{23} \times 10^3) = 18.06 \times 10^{23+3} = 18.06 \times 10^{26}$

Notice that 6.02 has 3 significant figures and 3.0 has two significant figures, therefore the answer must have two significant figures.

$18.|06 \times 10^{26} = 18 \times 10^{26}$

Sample Problem 1.17 Division Using Scientific Notation

Solve the following using standard rules

$$\frac{6.06 \times 10^{-34}}{1.2 \times 10^8} =$$

Apply the rules for division.

$$\frac{6.06 \times 10^{-34}}{1.2 \times 10^8} = \frac{6.06}{1.2} \times 10^{(-34)-8} = 5.05 \times 10^{-42}$$

Notice that 6.06 has 3 significant figures and 1.2 has two significant figures, therefore the answer must have two significant figures.

$5.0|5 \times 10^{-42} = 5.0 \times 10^{-42}$

In applying the rounding rules to 5, we have to look at the number in the place value immediately in front of 5, which is zero. Zero is an even number therefore 5.05 must round to 5.0.

Problem Set 1.5

1, 2. Factor the following numbers into their prime number factors, and simplify your answer using exponential notation. Remember the first 6 prime numbers are 2, 3, 5, 7, 11, and 13.

a. 36 b. 150 c. 256 d. 21 e. 12

3. Change the following into scientific notation. If the zeros are not significant, you may drop them from your answer. If the zeros are significant, you must keep them in your answer.

a. 6,500 b. 0.000347 c. 847633.66 d. 420 e. 666.0

f. 0.70581 g. 8,040 h. 569.930 i. 0.004452 j. 0.00002757

4. Write down the rules for adding, subtracting, multiplying and dividing using scientific notation.

5, 6. Solve the following problems by first changing the numbers into scientific notation. Then solve using the rules for mathematics in scientific notation. Then apply the rules for significant figures and rounding to your answers in order to preserve the correct number of significant figures in the answer. Note that you have to apply the rules of addition and subtraction separately from the rules for multiplication and division. The order of applying the rules must follow the order of operations.

a. 1,600 + 15,000

b. 41,700 - 7,027

c. 0.00625 - 0.0702

d. 11.24072 + 3,284

e. 33,882 - 8,276 + 48.1

f. 0.00074 + 0.00658 + 0.000003

g. 300 x 18,700 x 1,300

h. 0.004 x 0.009 x 0.02

i. 7,500 x 20

j. 25,000 x 0.00064 x 1.2

k. $\dfrac{1{,}984}{75}$

l. $\dfrac{0.00698}{160}$

m. $\dfrac{6400}{160}$

n. $\dfrac{0.005637}{0.0625}$

o. $\dfrac{(7{,}500 - 500)(0.598 - 0.098)}{(6{,}000{,}000 - 5{,}999{,}997)}$

p. $\dfrac{(0.598 + 0.002)(79{,}000 - 9{,}000)}{(19{,}999{,}995 + 20{,}000{,}005)}$

Section 1.6 Basic Conversions - Unit to Unit Conversions

Student Objectives

1. Use the technique called dimensional analysis to change a unit-value (6 feet) of one type of measurement (length) into another unit-value (? centimeters) of the same type of measurement (length).
2. Solve unit to unit conversion word problems by using the 5 rules given for solving word problems and the technique called
   dimensional analysis.

Let's revisit our carpenter who had trouble making a table to our specifications by using feet. He is planning to export his tables to Europe. In order to export tables to Europe, he must use metric measurements, preferably in centimeters. He thinks a long time and he feels that to change his tables over to metric measurements is too difficult, so he looks for an easy way out. He comes across an old handy-dandy chemistry textbook. He looks up conversions and finds a large table of conversion factors or equalities. Any equality will allow him to change any unit-value (2 feet) into another unit value (? centimeters) by using an appropriate equality. You will get a chance to help the carpenter out, by learning how to use the following table.

THE EQUALITIES/CONVERSION FACTORS

LENGTH

12 inches (in) = 1 foot (ft)
3 feet (ft) = 1 yard (yd)
5280 feet (ft) = 1 mile (mi)
1000 millimeters (mm) = 1 meter (m)
100 centimeters (cm) = 1 meter (m)
1000 meters (m) = 1 kilometer (km)
30.48 centimeters (cm) = 1 foot (ft)
1 kilometer (km) = 0.6214 mile (mi)
2.54 centimeter (cm) = 25.4 millimeters (mm) = 1 inch (in)

MASS/WEIGHT

16 ounces (oz) = 1 pound (lb)
2000 pounds (lb) = 1 ton
1000 grams (g) = 1 kilogram (kg)
1000 milligrams (mg) = 1 gram (g)
1000 grams (g) = 2.20 pounds (lb)
453.59 grams (g) = 1 pound (lb)
1000 kilograms (kg) = 1 metric ton

VOLUME

2 pints (pt) = 1 quart (qt)
4 quarts (qt) = 1 gallon (gal.)
1000 milliliters (ml) = 1 liter (l)
1 milliliter (ml) = 1 c.c. = 1 cubic centimeter (cm^3)
0.9463 liters (l) = 1 quart (qt)

TIME

60 seconds (s) = 1 minute (min.)
60 minutes (min.) = 1 hour (hr)
24 hours (hr) = 1 day
5 days = 1 work week
7 days = 1 week

These equalities will allow you to change any measured value into another equivalent measurement through the use of ratios which we call dimensional analysis or conversions. You will first try conversions with single measurements. You will then have the ability to use conversions to change rates.

Sample Problem 1.18 Single Conversions

Convert 12 inches into ? feet using the previous list of equalities

Step 1. Draw a cross.

Step 2. Place your starting information in the upper left slot.

12 inches	

Step 3. Transfer your units diagonally.

12 inches	
	inches

Step 4. Find a relationship among the EQUALITIES/CONVERSION FACTORS that will lead you toward your answer. In this case
12 inches = 1 foot. In the slot above inches add the word foot and only the word foot, no numbers.

12 inches	foot
	inches

Step 5. Now that you have established a relationship between the units inches and feet, put in the appropriate numbers, in this case 12
and 1.

12 inches	1 foot
	12 inches

Step 6. Next, you should notice that the words $\frac{\text{inches}}{\text{inches}}$ equals the number one and no longer

affects the solution of the problem. The words inches can now disappear.

12	1 foot
	12

Step 7. You may now multiply all numbers in the numerator and all numbers in the denominator.

$$12 \times \frac{1 \text{ foot}}{12} = \frac{12 \text{ feet}}{12}.$$

Step 8. You may now simplify and apply the rules for significant figures and rounding. Notice that the number of significant figures in your answer is dependent on the number of significant figures in your givens, not on the number of significant figures in
your conversion factors.

$$\frac{12 \times 1 \text{ foot}}{12} = \frac{12 \text{ feet}}{12} = 1.0 \text{ foot}$$

Notice that since the given unit-value (12 inches) had two significant figures, the answer must also have two significant figures. A
zero was added to the tenths place to bring the number of significant figures to the correct value.

What happens when you need more than one equality/conversion factor to get your desired answer in the desired units? Essentially you must repeat steps 3 through 6 until the units you want appear in the numerator.

Sample Problem 1.19 Multiple Step Single Conversions

Convert 2,000 inches to ? miles using the previous table of equalities.

Step 1. Draw a cross.

Step 2. Place your starting information in the upper left slot.

2,000 inches	

Step 3. Transfer your units diagonally.

2,000 inches	
	inches

Step 4. Find a relationship among the EQUALITIES/CONVERSION FACTORS that will lead you toward your answer. In this case 12 inches = 1 foot. In the slot above inches add the word foot and only the word foot, no numbers.

2,000 inches	foot
	inches

Step 5. Now that you have established a relationship between the units inches and feet, put in the appropriate numbers, in this case 12 and 1.

2,000 inches	1 foot
	12 inches

Step 6. Next, you should notice that the words $\frac{\text{inches}}{\text{inches}}$ equals the number one and no longer affects the solution of the problem. The words inches can now disappear.

12	1 foot
	12

Step 7. Compare the units in the numerator with the units you want in your answer (you have foot but the problem wants miles). Since feet are not miles, you must continue by **adding an additional cross** and by **repeating Step 3** which says to transfer your units diagonally

2,000 inches	1 foot	
	12	

Step 8. Now repeat step 4, find a relationship among the EQUALITIES/CONVERSION FACTORS table that will lead you toward your answer. In this case 5280 feet = 1 mile. You must now change foot to feet (to keep the vertical relationship equal). In the slot above feet, add the word mile and only the word mile (5280 feet = 1 mile).

2,000 inches	1 foot	mile
	12	feet

Step 9. You need to continue by repeating step 5. Now that you have established a relationship between the units feet and mile, put in the appropriate numbers, in this case 5280 and 1.

2,000 inches	1 foot	1 mile
	12	5280 feet

Step 10. Next, you should notice that the words $\frac{\text{foot}}{\text{feet}}$ equals the number one and no longer affects the solution of the problem. The words foot/feet can now disappear.

2,000 inches	1	1 mile
	12	5280

Step 11. You may now multiply all numbers in the numerator and all numbers in the denominator.

$$\frac{2{,}000 \times 1 \times 1 \text{ mile}}{12 \times 5280} = \frac{2{,}000 \text{ mile}}{63360}.$$

Step 12. You may now simplify and apply the rules for significant figures and rounding. Notice that the number of significant figures in your answer is dependent on the number of significant figures in your givens, not on the number of significant figures in your conversion factors.

$$\frac{2{,}000 \times 1 \times 1 \text{ mile}}{12 \times 5280} = \frac{2{,}000 \text{ mile}}{63360} = 0.03156|5 \text{ miles}$$

$$= 0.03156 \text{ miles}$$

Unfortunately real life is not as neat as changing one set of numbers into another set. Most of life's problems more closely resemble word problems (Oh no, word problems!). Word problems can be solved through a methodical approach (algorithm).

<u>Algorithm for Solving Word Problems</u>

1. Read the problem all the way through.
2. Ask yourself **what am I required to solve for?** The value that you are solving for is usually **given away by words such as what, how or when.**
3. You must **find your given values and their units.** In a math proof these would be called your givens. Organize your givens into numbers and measurements or rates, equalities and derived measurements.
4. **What do you know that will help you solve this problem?** This includes the technique of dimensional analysis, mathematical formulas, the table of equalities given earlier, any equalities that you have learned in science, all math postulates and theorems and all math techniques. **You know much more than you give yourself credit for!**
5. Are you missing any information? To solve any problem, you can only be missing the information you are looking for. **If you are missing any information (other than what you are solving for), go back to rule 3 and think for a while.**
6. **Is your information in the proper units?** This goes back to the problem the carpenter had. If any of your values are not in units that allow you to solve for the problem, you need to change them into the units that are required.

Sample Problem 1.20 Word Problems

Manuel Noriega had a mass of 112 kg when he was arrested in Panama for drug smuggling. When he was interned into prison in the United States of America, his mass was measured in pounds. How much mass was recorded on his prison file in pounds?

1. Read the problem.
2. What are you solving for? "How much mass ... in pounds?"
3. What values have you been given? "mass of 112 kg."
4. What do you know that will help you solve this problem? Dimensional Analysis.
5. Are you missing any information? Not this time.
6. Is your information in the proper units? Yes.

Now start to solve your problem by putting your starting information (112 kg) into the upper right hand block and find the appropriate equalities to change the units. Notice that the procedure for solving the word problem is the same as changing inches into feet. Also notice that the number of significant figures in your answer is dependent on the number of significant figures in your givens, not on the number of significant figures in your conversion factors. This is because your conversion factors are defined as exact numbers.

112 kilograms	1000 grams	2.20 pounds
	1 kilogram	1000 grams

$$\frac{112 \text{ x } 1000 \text{ x } 2.20 \text{ pounds}}{1 \text{ x } 1000} = \frac{112 \text{ x } 2.20}{1} = 246.|4 \text{ lb} = 246 \text{ lb}$$

Problem Set 1.6

1. Using dimensional analysis solve the following simple conversions.

   a. 0.50 miles to inches b. 60 seconds to hours c. 32,000 ounces to tons

   d. 60 millimeters to meters e. 12 inches to meters f. 2.0 pounds to kilograms

2. Solve the following using the algorithm for solving word problems and dimensional analysis.

a. In the modern Olympics, track and field events are measured in meters while competitions in this country were recently measured in yards. Carl Lewis ran the 100. meter dash. What event would he run if that distance were measured in yards?

b. You are using an old-fashioned cookbook that gives all of your measurements in English units rather than international units (metric). Your pancake recipe calls for a cup of milk but you only have a measuring cup that measures in milliliters and liters. You remember that 1 cup = 0.5 pints. How many milliliters of milk should you measure?

c. The Titanic had a mass of 52728.5 metric tons. How many pounds is that? How many tons is that?

d. 72 akunosh passed before Agli realized that the ship had entered normal space. If 14 akunosh = 1 kinosh, and 14 kinosh = 1 tyrnosh, and 196 tyrnosh =1akutyr, how many akutyrs have elapsed. What base time does Agli's empire use?

e. A bottle of Minute Maid 100% Apple Juice in the United Kingdom says it has 0.7919 pints. How many milliliters would this same sized bottle show in France?

Section 1.7 Rate and Derived Measurement Conversions - Unit to Unit Conversions in the Numerator and Denominator

Student Objectives

1. Define a Rate.
2. Use the technique called dimensional analysis to change a unit-value (6 feet) of one type of measurement (length) into another
   unit-value (? centimeters) of the same type of measurement (length) and apply this technique to rates.
3. Solve rate to rate conversion word problems by using the 5 rules given for solving word problems and the technique called dimensional analysis.

When science attempts to create mathematical models of natural phenomena, often times scientists will record changes in the phenomena over a period of time. For instance, a car moving down a street will travel a certain distance in a given amount of time. We would then plot time on the x axis (because time is the independent variable, the variable of choice) and we would plot distance on the y axis. Calculating the slope of the graph we would know the distance traveled (rise) per unit of time (run). A change in distance per unit of time is called velocity or more commonly speed. When we drive our speedometer gives us an instantaneous readout of our change of distance per unit of time (miles per hour).

Information that is presented as a change in one unit of measure per change in another unit of measure is called a rate. All slopes are rates. Because rates are dependent on units of measures we will need to learn how to convert units of measure when they are in the form of rates. For example we may want miles per hour as meters per second.

Sample Problem 1.20 Rate Conversions

Convert 55 miles per hour to ? meters per second using the previous table of equalities.

Step 1. Draw a cross.

Step 2. Place your starting information in the left slots. Notice that you are now dealing with rates and rates have information in the numerator and the denominator. Therefore you must put all of the information into the corresponding slot. Information for the numerator must go into the numerator and information for the denominator must go into the denominator. When there is not a number specified use the number 1 (in 55 miles per hour, it is understood that there is only one hour).

55 miles	
1 hour	

Step 3. Begin the conversion process just as you would with a single unit conversion. Transfer your units diagonally.

55 miles	
1 hour	miles

Step 4. Find a relationship among the EQUALITIES/CONVERSION FACTORS that will lead you toward your answer. In this case 1 kilometer = 0.6214 mile. In the slot above miles add the word kilometer and only the word kilometer, no numbers.

55 miles	kilometer
1 hour	miles

Step 5. Now that you have established a relationship between the units miles and kilometers, put in the appropriate numbers, in this case 0.6214 and 1.

55 miles	1 kilometers
1 hour	0.6214 miles

Step 6. Next, you should notice that the words $\frac{\text{miles}}{\text{miles}}$ equals the number one and no longer affects the solution of the problem. The words miles can now disappear.

55	1 kilometer
1 hour	0.6214

Step 7. Compare the units in the numerator with the units you want in your answer (you have kilometers but the problem wants meters). Since kilometers are not meters, you must continue by **adding an additional cross** and by **repeating Step 3** which says to transfer your units diagonally

55	1 kilometer	
1 hour	0.6214	kilometer

Step 8. Find a relationship among the EQUALITIES/CONVERSION FACTORS that will lead you toward your answer. In this case 1 kilometer = 1,000 meters. In the slot above kilometers add the word meters and only the word meters, <u>no numbers</u>.

55	1 kilometer	meters
1 hour	0.6214	kilometer

Step 9. Now that you have established a relationship between the units kilometers and meters, put in the appropriate numbers, in this case 1 and 1,000.

55	1 kilometer	1,000 meters
1 hour	0.6214	1 kilometer

Step 10. Next, you should notice that the words $\frac{\text{kilometer}}{\text{kilometer}}$ equals the number one and no longer affects the solution of the problem. The word kilometer can now disappear.

55	1	1,000 meters
1 hour	0.6214	1

Step 11. Now you have meters in the numerator. That is only half of what you want because you still have hours in the denominator and you want seconds in the denominator. In order to do this you have to **<u>transfer the units diagonally UP.</u>**

55	1	1,000 meters	hour
1 hour	0.6214	1	

Step 12. Find a relationship among the EQUALITIES/CONVERSION FACTORS that will lead you toward your answer. In this case 1 hour = 60 minutes. In the slot below hour, add the word minutes and only the word minutes, <u>no numbers</u>.

55	1	1,000 meters	hour
1 hour	0.6214	1	minutes

Step 13. Now that you have established a relationship between the units hours and minutes, put in the appropriate numbers, in this case 1 and 60.

55	1	1,000 meters	1 hour
1 hour	0.6214	1	60 minutes

Step 14. Next, you should notice that the words $\frac{\text{hour}}{\text{hour}}$ equals the number one and no longer affects the solution of the problem. The word hour can now disappear.

55	1	1,000 meters	1
1	0.6214	1	60 minutes

Step 15. Compare the units in the denominator with the units you want in your answer (you have minutes but the problem wants seconds). Since minutes are not seconds, you must continue by **adding an additional cross** and by **repeating Step 11** which says to **<u>transfer the units diagonally UP.</u>**

55	1	1,000 meters	1	minutes
1	0.6214	1	60 minutes	

Step 16. Find a relationship among the EQUALITIES/CONVERSION FACTORS that will lead you toward your answer. In this case 1 minute = 60 seconds. In the slot below minutes, add the word seconds and only the word seconds, <u>no numbers</u>.

55	1	1,000 meters	1	minutes
1	0.6214	1	60 minutes	seconds

Step 17. Now that you have established a relationship between the units minutes and seconds, put in the appropriate numbers, in this
case 1 and 60.

55	1	1,000 meters	1	1 minutes
1	0.6214	1	60 minutes	60 seconds

Step 18. Next, you should notice that the words $\frac{\text{minutes}}{\text{minutes}}$ equals the number one and no longer affects the solution of the problem. The word minutes can now disappear.

55	1	1,000 meters	1	1
1	0.6214	1	60	60 seconds

Step 19. You may now multiply all numbers in the numerator and all numbers in the denominator and divide the numerator by the denominator. Remember to express your answer using the correct number of significant figures. Notice that the number of significant figures in your answer is dependent on the number of significant figures in your givens, not on the number of significant figures in your conversion factors.

$$\frac{55 \times 1 \times 1{,}000 \text{ meters} \times 1 \times 1}{1 \times 0.6214 \times 1 \times 60 \times 60 \text{ seconds}} = \frac{55{,}000}{2{,}237.04} = 24|.58606015 \frac{\text{meters}}{\text{second}} = 24 \frac{\text{meters}}{\text{second}}.$$

<u>Problem Set 1.7</u>

1. Using dimensional analysis solve the following simple conversions.

a. 40 $\frac{\text{km}}{\text{hr}}$ to ?? $\frac{\text{feet}}{\text{hr}}$. b. 1.2 $\frac{\text{gal.}}{\text{minute}}$ to ?? $\frac{\text{L}}{\text{sec}}$ c. 4.25 $\frac{\text{dollars}}{\text{hr}}$ to ?? $\frac{\text{cents}}{\text{year}}$.

d. 12 $\frac{\text{lb}}{\text{sec}}$ to ?? $\frac{\text{tons}}{\text{day}}$ e. $\frac{100\text{ m}}{10\text{ sec}}$ to ?? $\frac{\text{mi}}{\text{hr}}$ f. 5.5 $\frac{\text{kg}}{\text{L}}$ to ?? $\frac{\text{lb}}{\text{gal}}$.

Read and solve the following problems. Use the 5 rule algorithm for solving word problems. If necessary use the following

EQUALITIES/CONVERSION FACTORS:

Densities of some common materials:

Water	1.00 grams = 1.00 milliliter	Copper	8.9 grams = 1.00 milliliter
Balsa Wood	0.20 grams = 1.00 milliliter	Lead	11.3 grams = 1.00 milliliter
Bismuth	0.98 grams = 1.00 milliliter	Mercury	13.6 grams = 1.00 milliliter

2. A mini-ingot of lead measures 10.0 cm by 50.0 cm by 0.50 cm. How many grams does it weigh? If you know that 207 grams of lead equals one mole of lead, how many moles of lead is in this mini ingot?
3. A bicyclist was going 17.5 meters per second on a road with a speed limit of 25 miles per hour. A South Gate motorcycle police officer, using a radar gun, ticketed the bicyclist. How fast was the bicyclist going and did he deserve the ticket?
4. A Geo Metro, which gets 51 miles per gallon of gas, has a tank of only 48 liters. If this tank was 5/8 full, how many miles could the car go? How many kilometers could the car go?
5. An oil storage tank in Long Beach holds 450 gallons of light crude oil. It develops a leak of 2.2 liters per minute. After 3.5 hours the oil company manages to stop the leak. How many liters of oil leaked out? How many gallons of oil remain in the tank?
6. The United States of America produces 450,000 metric tons of copper per month. How many liters of copper is produced per year?
7. Isaac the Incredible can drink a can of soda in 0.343 seconds. A can of soda is measured as 12 fluid ounces. How many milliliters per hour can Isaac drink? (8 fluid ounces = 1 fluid cup. 1 fluid cup = 0.5 pints).
8. A used car salesman purchased 25 cars and then began to wheel and deal. He traded all of his cars for trucks at a rate of 6 cars for 5 trucks. Next he traded all of his trucks for motor homes at a rate of 3 trucks for 1 motor home. Next he sold all of his motor homes to an English company with each motor home selling for 62,000 pounds (English Currency). The current rate of exchange is approximately 1.9 pounds for 1 U.S. dollar.
   a. How much money did he make?
   b. If each car sold for $12,500 dollars (wholesale), how much money would he have made if he sold the cars directly?
9. A mother of four thirsty children needs 8 cartons of milk (0.50 gallons per carton) each week. If milk sells for $0.44 per pint, how many dollars does she spend on milk each month?
10. How much do you weigh in pounds? If you were exposed to mercury and the lethal dose was 0.0030 mg of mercury per kilogram of body mass, how many pounds of mercury could you be exposed to before you will certainly die?

Scientific Method, Scientific Notation, Conversions, Significant Figures and Rounding

Explain Using the Scientific Method

1. Your front door lock does not open. You notice that the lock has honey all over it. List your observations, then list the remaining three steps of the scientific method. Come up with logical guesses, tests, and conclusions to solve this problem.

Matching: Match each definition or object with the appropriate terms. Terms may be used more than once.

2.	Asphalt	a.	Atom
3.	Polystyrene (foam cups)	b.	Compound
4.	Gold	c.	Element
5.	Iron Ore (the stuff dug up out of the ground to make iron)	d.	Heterogeneous
6.	Coffee (the liquid in a cup)	e.	Homogeneous
7.	Sugar	f.	Matter
8.	A Plain Steel Nail	g.	Mixture
9.	Sand	h.	Molecule
10.	Isopropyl Alcohol (rubbing alcohol without any water added)	i.	Pure
11.	Salt	j.	Solution
12.	Kool Aid		
13.	Snickers Candy Bar		
14.	A Milk Chocolate Candy Bar		
15.	Aluminum Foil		
16.	Copper Wire		
17.	A quarter, newer than 1965		

2. For the following simple compounds, name them.
   a. Na_2S b. Al_2Se_3 c. BeI_2 d. LiCl

For 2 and 3, first, change the numbers into scientific notation, perform the operations indicated, using the rules you have learned, and apply significant figures and rounding to your answers when appropriate. Table 1.1 has been provided for your convenience.
Show Your Work!

3. 400 x 0.0002 x 8900

4. $\dfrac{(0.0045 - 0.0500)(6{,}000 - 450)}{(890 - 90.0)}$

For 5 - 8, CONVERT AS INDICATED, SHOW ALL THE IN CONVERSION FORMAT, DON'T CALCULATE AN ANSWER.

5. 55 miles into ?? kilometers
6. 603 weeks into ?? seconds
7. 5 pounds per day to ?? grams per second
8. 3000 ml to ?? gallons

For Problems 9 and 10, Solve Until You Have a Calculated Answer. Apply Significant Figures and Rounding to your final answer.

8. If you earn 200 federation credits per hour and work 60 hours per week and there are 2 weeks in a a pay period (the time on which the amount deposited into your account is determined), how many credits should appear on your bank statement as a payroll deposit?

9. The trash cans in an apartment complex that you own hold 2.0 kilograms. 400 apartment trash cans fill by the end of the day. In the back of the apartment complex you have 10 dumpsters. Each dumpster holds 2.0 standard tons (not metric tons). How often must the dump truck stop to empty the dumpsters? (USE COMMON SENSE WHEN YOU FIGURE THE FINAL ANSWER.)

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[i] "Da Vinci." The World Book Encyclopedia. Field Enterprises Educational Corporation, Chicago, Illinois. Page 39. 1973.