Matter has mass and occupies space.

Periodic Table
Chemists organize matter on the periodic table of the elements (See Week 1 Handout). The periodic table is arranged by increasing atomic number (Z), which represents the number of protons in the nucleus. The periodic law states that properties of elements are periodic functions of their atomic numbers (Z). There are 7 periods (or rows) in the periodic table. The first period has 2 elements, H and He. There are 16 groups/families on the periodic table. Group IA has 7 elements, H, Li, Na, K, Rb, Cs, and Fr. The main group elements are labeled with an A designation after the group number. The transition elements have a B designation. Note that there are other conventions for designating the element groups.

Atomic Composition
Atoms are mostly empty space. Protons and neutrons are located in a dense nucleus. Electrons occupy the space around the nucleus. The number electrons is equal to number of protons for neutral elements. Protons have a +1 electrical charge. Neutrons have no electrical charge. Electrons have a -1 electrical charge. In chemistry, atoms can gain and lose electrons to become ions. Your periodic table gives some charges of ions that form from atoms. Ions can be indicated by a superscript in the upper right corner of the element box. For example Na^{+1} is a sodium ion that forms from a sodium atom losing one negatively charged electron. F^{-1} is a fluoride ion that forms when a fluorine atom gains one electron.

Periodic Trends
Group IA is the alkali metals. H, which appears in group IA, is a nonmetal. The metals (Li, Na, K, Rb, Cs, and Fr) are reactive, so they exist in nature as compounds. Alkali metals form +1 ions in compounds, so they also form similar compounds (HBr, NaBr, KBr, ...). A +1 ion has lost one electron. Alkali metals form alkaline (basic) solutions with water and also produce hydrogen gas, H_2.

Group IIA is the alkaline earth metals. The metals (Be, Mg, Ca, Sr, Ba, and Ra) are reactive, so they exist in nature as compounds. Alkaline earth metals form +2 ions in compounds, so they form similar compounds ($BeBr_2$, $MgBr_2$, $CaBr_2$, ...). A +2 ion has lost two electrons. All but beryllium form alkaline solutions when added to water.

Group VIIA are the halogens. The halogens F, Cl, Br, I, and At are nonmetals. These halogens are found as diatomic molecule in nature: F_2, Cl_2, Br_2, and I_2. At room temperature, F_2 and Cl_2 are gases. Br_2 is a liquid. I_2 is a solid. Halogens tend to form similar compounds (HF, HCl, ...) and tend to become −1 in compounds. Halogens react with metals and most nonmetals.

Group VIIIA are the noble, rare, or inert gases. Noble gases tend to be inert and not form compounds.

3 states of matter

- Solid : state symbol (s)
  - Matter tightly packed
  - Definite shape
  - Incompressible
  - Definite volume
  - Least energy
- Liquid : state symbol (l)
  - Matter loosely packed and moves past itself
  - Indefinite shape that assumes shape of container
  - Incompressible
  - Definite volume
  - Intermediate energy
- Gas : state symbol (g)
  - Matter is far apart and uniformly distributed in container
  - Indefinite shape that assumes shape of container
  - Compressible
  - Indefinite volume
  - Most energy

Substances change state with increasing temperature. For example, water is a solid <= 0°C (32°F), a gas >= 100°C (212°F), and a liquid in between those temperatures.

Descriptions of state changes (changes in physical state of matter)

- Melting (solid to liquid)
- Freezing (liquid to solid)
- Vaporization or boiling (liquid to gas)
- Condensing (gas to liquid)
- Subliming (solid to gas)
- Depositing (gas to solid)
- Increasing the temperature of a solid causes melting, then vaporization (or subliming).
- Decreasing the temperature of a gas causes condensing, then freezing (or depositing).

Two classifications of matter

- Mixtures – can be physically separated into pure substances. 2 types are:
  - Homogeneous mixtures – the same throughout, like salt dissolved in water
  - Heterogeneous mixtures – different throughout, like sand and water

Pure substances – made up of one substance that cannot be physically separated. 2 types are:

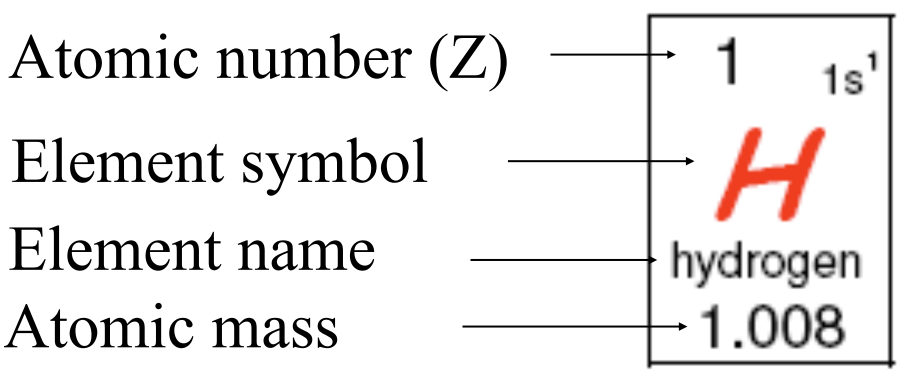
Compounds – can be chemically separated into elements

Elements – cannot be broken down by chemical reactions. Known elements appear on the periodic table of the elements.

Elements on the periodic table have an atomic number (Z), which corresponds to the number of protons in the nucleus (and the number of electrons in a neutral atom). Hydrogen has Z=1, helium has Z=2, and so on. The periodic table is arranged by atomic number.

Elements on the periodic table have a name and a symbol. The symbol is 1 or 2 (or sometimes 3 letters long temporarily) where the first letter is capitalized and the remaining letters are lowercase.

Elements on the periodic table have an atomic mass. The atomic mass it is a weighted-average value for all isotopes of the same element, where an isotope of an element differs only in the number of neutrons. The number of protons and electrons are the same among neutral isotopes of elements.



Metals, Nonmetals, and Metalloids/Semimetals

Metalloids or semimetals: appear with an edge of their box on the stepped line of the periodic table and include B, Si, Ge, As, Sb, Te. Note that Al also appears on the stepped line (See Week 1 handout), but Al is an exception. Al is a metal.

Metals appear to the left of the metalloids and include aluminum (Al)

1. Some physical properties of metals include high density, high luster, high melting point, good conductors of heat and electricity, malleable (can be hammered into sheets), and ductile (can be drawn into wires).
2. A chemical property of metals is that they tend to become positively charged in compounds.

Nonmetals appear to the right of the metalloids

1. Some physical properties of nonmetals include low density, dull, low melting point, poor conductors of heat and electricity, not malleable, not ductile, and 11 nonmetals occur in the gaseous state.
2. A chemical property of nonmetals is that they tend to become negatively charged in compounds.

Metalloids have physical and chemical properties in between metals and nonmetals.
On the Periodic Table of the Elements (See Week 1 handout), gaseous elements have symbols with an italic font, liquid elements have symbols with an outline font, and solids have symbols with a Times-Roman font.

Exercise: What are the main group metals?
Solution: The main group is group A. Main group metals includes the elements Li and below in group IA, the elements Be and below in group IIA, the elements of Al and below in group IIIA, the elements Sn and below in group IVA, the elements Bi and below in group VA, the elements Po and below in group VIA. The properties of elements Ts and Og must await more data.

A molecule is made up of two or more atoms held together by bonds. A chemical formula tells the number and type of atoms in a molecule. Seven elements are diatomic molecules in the standard state including H_2, O_2, N_2, Cl_2, Br_2, I_2, and F_2.

Some elements have allotropes. An allotrope is a pure element with a different bonding arrangement. Oxygen has 2 common allotropes, diatomic oxygen (O_2) and ozone (O_3). Carbon has many allotropes including graphite, diamond, amorphous, buckminsterfullerene, and graphene. Allotropes are still being discovered that have many potential scientific and technical applications.

The H_2SO_4 (sulfuric acid) molecule is made up of 2 hydrogen atoms, 1 sulfur atom, and 4 oxygen atoms (and 7 total atoms). Subscripts indicate the number of atoms in the formula (when only one atom of a given type is present, no '1' is written).

The chemical formula can be written from a description of the composition. For example, the molecule niacin consists of 6 carbon atoms, 6 hydrogen atoms, 2 nitrogen atoms, and 1 oxygen atom. The chemical formula is $C_6H_6N_2O$. As before, subscripts indicate the number of atoms in the formula (when only one atom of a given type is present, no '1' is written).

Some chemical formulas use parenthesis to indicate more than one of a particular unit. For instance, the formula for antifreeze is $C_2H_4(OH)_2$, which consists of 2 OH units. The atom count is 2 carbon atoms, 6 hydrogen atoms, and 2 oxygen atoms (a total of 10 atoms).

The Law of Definite Composition states that compounds always contain the same proportions of elements by mass. For example, sodium chloride is always 39.3% sodium and 60.7% chlorine by mass. Also, water is always 11.2% hydrogen and 88.8% oxygen by mass.

Physical properties
Examples of physical properties include color, odor, boiling point, density, conductivity, and physical state. A physical property does not change the chemical composition of a substance.

Chemical properties describe the chemical reactions that a substance could undergo (or not undergo), meaning that the composition of elements changes.

Physical change means to change the physical state or shape of a substance without changing its chemical composition.

Chemical change means that a chemical reaction occurred. A chemical property means that the reaction could (or could not) occur, whereas a chemical change means it did occur. The difference between chemical property and chemical change is often the tense of the verb. See the previous paragraph about physical change and physical property for the explanation.

In the lab, formation of a precipitate, a color change, gas bubbles, or a release of heat are evidence of chemical change. Note that physical changes can give the same evidence as chemical change (for example, boiling makes gas bubbles), so it takes practice and experience to recognize the difference.

Isotopes
Isotopes of an element differ only by the number of neutrons in the nucleus. The mass number (A) for an isotope equals the number of protons plus the number of neutrons. A mass number for an isotope can be indicated with a superscript number before the element symbol or by a dash and a number following the element name. For example, ^{12}C and carbon-12 indicate carbon with 12 total protons and neutrons. The atomic number (Z) for carbon is 6, indicating the number of protons. Recall the the atomic number is available on the periodic table. The number of neutrons in ^{12}C is 12−6=6. The atomic number may be indicated in the lower left corner of an element symbol: $^{12}_{6}C$.

Exercise: How many neutrons are in carbon-14?
Solution: $^{14}_{6}C$ has A=14= protons + neutrons, and 6 protons (Z=6). The number of neutrons equals A-Z or 14-6=8.

Exercise: How many protons, neutrons, and electrons are in sodium-23?
Solution: $^{23}_{11}Na$ has A=23=protons + neutrons, and 11 protons (Z=11). The number of neutrons is A-Z or 23-11=12. The number of electrons is equal to the number of protons (11) for a neutral atom. No charge is indicated in the upper right corner.

Exercise: How many protons, neutrons, and electrons are in $^{79}_{35}Br^{+7}$?
Solution: $^{79}_{35}Br^{+7}$ has A=79, Z=35, and a charge of +7. The number of neutrons is A-Z=79-35=44. Each positive charge on ion reduces the number of electrons by one. The number of electrons is 35-7= 28.

Atomic mass on the periodic table can be calculated from the algebraic sum (or weighted average) of the isotope composition. Atomic mass and isotope composition can be measured with a mass spectrometer. Note that the atomic mass for an element (its isotope composition) may depend on where that element was found, so one convention is to report the atomic mass as a range rather than a single number. Use the periodic table provided for this class which gives the atomic mass as a single number. Recall that weighed-average atomic masses for elements are given on the periodic table.

Example: Estimate the atomic mass of lithium given that ^{6}Li is 7.5% abundant and ^{7}Li is 92.5% abundant.
Solution: Write the percentages as fractions, then form the algebraic sum from the isotope compositions and fractions: 6*0.075 + 7*0.925 = 0.45 + 6.475 = 6.925 = 6.93. (The products have 2SD and 3SD because 6 and 7 are counted (exact). The sum has 3SD because the answer is known to the hundredths place. Keep all the digits until the end, then round the final answer.) The answer can be compared to atomic mass for lithium on the periodic table (6.941). If precise mass data was available for these isotopes, those data should be used preferentially as shown another example.

Example: Estimate the atomic mass of silicon given that the percentage compositions of isotopes are ^{28}Si (92.23%), ^{29}Si (4.67%), and ^{30}Si (3.10%).
Solution: Write the percentages as fractions, then form the algebraic sum from the isotope compositions and fractions: 28*0.9223 + 29*0.0467 + 30*0.0310 = 25.8244 + 1.3543 + 0.930 = 28.1087 = 28.109. The estimated atomic mass is 28.109 from these data.

Example: Copper has 2 isotopes ^{63}Cu with mass 62.9298 and ^{65}Cu with mass 64.9278. What is the percent abundance of each?
Solution: The atomic mass of copper from the periodic table is 63.546. Percentages must add to 100%, or the fractions sum to 1. Form the algebraic sum from the isotope composition and fractions. If X represents the fraction of 1 isotope of copper, then 1−X is the fraction of the other. 62.9298 (X) + 64.9278 (1−X) = 63.546. Solve this algebraically. X = fraction of ^{63}Cu =0.6916. 1-X = fraction of 65Cu= 0.3084. Convert the fractions to percentages: %^{63}Cu= 69.16%. %^{65}Cu=30.84%.