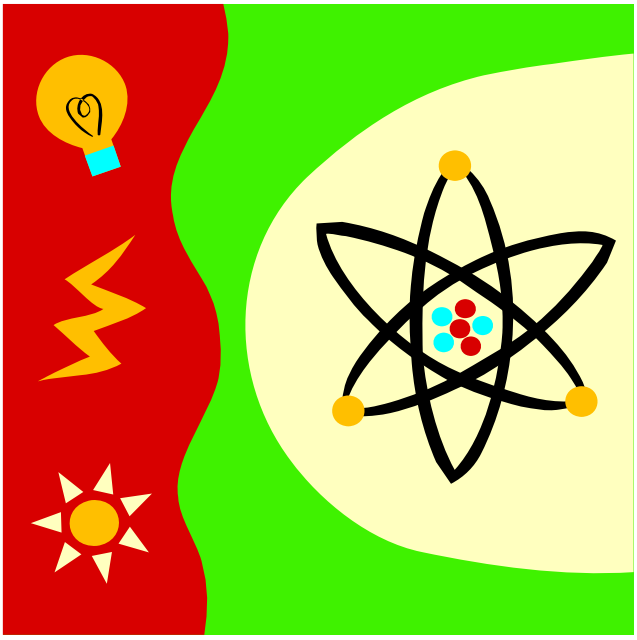
Properties of Matter



Concept Sheet
Properties of Matter

PS.2: The student will investigate and understand the basic nature of matter.

1. **Matter** is anything that takes up space and has mass. Matter is made up of small particles called **atoms**. Matter can exist in three different states: **solid**, **liquid**, and **gas.**

	State of Matter:	Has a Definite Shape?	Has a Definite Volume?
Lower temperature, less energy	**Solid**	YES	YES
	Liquid	NO (a liquid takes on the shape of its container)	YES
Higher temperature, more energy	**Gas**	NO (a gas takes on the shape of its container)	NO (temperature and pressure affect gas volume)

Particles of matter move faster at higher temperatures. When these particles are vibrating the least, the substance exists as a **solid**. As the particles gain more and more energy, the substance becomes a **liquid** and then may eventually become a **gas**.

2. **Elements** are pure substances whose atoms all have the same number of protons. Elements cannot be separated by physical or chemical means.
   - All the atoms in a particular element are basically the *same*.
   - Atoms of one element are different from atoms of other elements because they have different numbers of protons in their nuclei.
   - All elements are represented by a chemical symbol (*i.e., H stands for Hydrogen*)

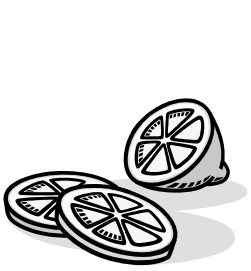
   Compounds are the chemical combinations of two or more *different* elements.
   - The elements combine chemically in a fixed ratio.
   - For example, the elements sodium (Na) and chlorine (Cl) combine to form sodium chloride (NaCl), commonly known as table salt.
   - A **chemical formula** shows the ratio of the atoms in each molecule of a compound. For example, each molecule of water, H_20, consists of 2 hydrogen atoms and 1 oxygen atom. Chemical formulas can be used to model chemical changes by showing how elements are rearranged in chemical reactions.
   - Compounds can only be separated back into elements by chemical processes.
   - Equal volumes of different substances usually have different masses.

   Mixtures exist when two or more kinds of matter are mixed together but are not chemically combined. *An example of a mixture would be table salt dissolved in water.* Table salt (NaCl) does not combine chemically (react) with the water. The sodium and chlorine elements stay combined to each other and just mix in with the water molecules. Therefore, if the water evaporates, the salt will remain. Mixtures can always be separated by some physical means.

3. **Acids and Bases**

Acids are a group of compounds that have hydrogen ions (H^+) joined to one or more kinds of atoms.

- All acids have a sour taste, are corrosive, have a pH of less than 7, and can conduct electricity (electrolyte).
- Examples are citrus fruits, vinegar, and battery acid.



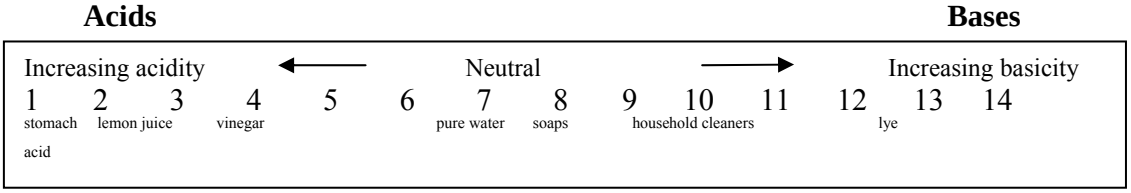
- When acids dissolve in water, they release hydrogen ions (H^+) into the resulting solution.

Bases are a group of compounds that have hydroxide ions (OH^-) joined to one or more other kinds of atoms.

- All bases have a bitter taste, are slippery to the touch, have a pH of greater than 7, and can conduct electricity (electrolyte).
- Examples are soaps and cleaning products.


- When bases dissolve in water, they release hydroxide ions (OH^-) into the resulting solution.

The **pH scale** measures the concentration of hydrogen ions in a solution. The pH scale ranges from 0-14 with 7 being neutral:



A **neutralization reaction** occurs when an **acid** reacts with a **base** and a **salt** and **water** are produced.

Example: When hydrochloric acid (an acid) is mixed with sodium hydroxide (a base), sodium chloride (a salt) and water are produced:

$$\underset{\text{reactants}}{HCl + NaOH} \longrightarrow \underset{\text{products}}{NaCl + H_2O}$$

4. **Organic compounds** contain the elements carbon (C) and hydrogen (H). Since carbon is found in living creatures, the word organic means "coming from life" (ex: $C_6H_{12}O_6$). Compounds that do not contain the element carbon, or which did not come from living things are known as **inorganic compounds** (ex. carbon dioxide, CO_2)**.**

5. Matter can be described using both **physical** and **chemical properties**.

A **physical property** is any characteristic of a material that can be observed without changing the material.

- Examples are shape, density, odor, solubility, melting point, boiling point, and color.
- Some physical properties are unique to a substance and can be used to identify unknown samples. These are called **characteristic properties.** Characteristic properties do not depend on the size of the sample.

Characteristic Properties

Density	Mass per unit volume of a substance. Formula for calculating density: mass divided by volume (g/cm^3).
Solubility	Maximum amount of solute that can be dissolved in a certain amount of solvent at a specific temperature (Solubility can be increased by increasing the temperature of the solvent. Stirring helps speed up the process but does not affect how much will dissolve at a given temperature.)
Melting Point	The temperature at which a substance changes from the solid phase (state) to the liquid phase (state). Note that this is also the freezing point of the substance.
Boiling Point	The temperature at which a substance changes from the liquid phase (state) to the gas phase (state). Note that this is also the condensation point of the substance.

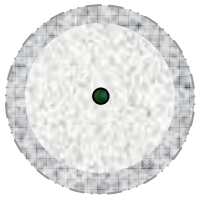
A **chemical property** is any characteristic of a substance that indicates whether it can change chemically. Examples are acidity, basicity, combustibility (ability to burn), and reactivity (how easily it combines with other substances).

PS.3: The student will investigate and understand the modern and historical models of atomic structure.

6. Atoms are made up of **electrons**, **protons**, and **neutrons**. The **nucleus**, in the center of the atom, contains protons and neutrons, which make up most of the mass of the atom.

Subatomic Particle	Location	Charge	Relative Mass
Proton	Nucleus	+ *(positive)*	1 atomic mass unit
Neutron	Nucleus	neutral	1 atomic mass unit
Electron	Around the Nucleus	- *(negative)*	$1/2000^{th}$ of an atomic mass unit

7. The model of the atom we use today is the result of the work of many scientists including Dalton, Thomson, Rutherford, Bohr, and Schrodinger. Scientists are constantly conducting research to better understand the structure and properties of atoms and their particles. Further advances will most likely cause our current model of the atom to undergo revision.



Currently, scientists use the **Electron Cloud Model** to explain how atoms look and act. In this model, the electrons constantly move in regions around the nucleus known as an electron cloud.

An older model that students often use to grasp basic atomic structure is the **Bohr Model**. Although outdated, it illustrates the charges, relative masses, and locations of the protons, neutrons, and electrons in an atom.

Some drawbacks of the Bohr model are:

1. It does not show the model of atom as it exists in space (i.e. in three dimensions).
2. It implies that the electrons are in predictable circular orbits around the nucleus that stay the same instead of constantly changing around the nucleus (i.e., electron clouds).

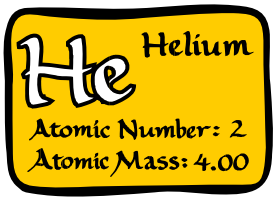
PS.4: The student will investigate and understand the organization and use of the periodic table of elements to obtain information.

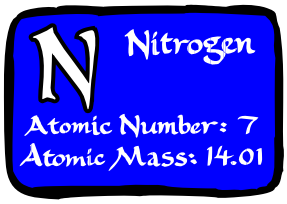
8. There are more than 110 known elements listed in the **Periodic Table of Elements**. Only elements 1-92 are found naturally on Earth. The rest are produced in laboratories. Elements combine in many ways to create all of the substances found on Earth.

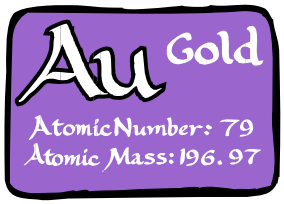
   Most of the Earth's crust, living matter, oceans, and atmosphere is made up of only a small number of elements. These include silicon, aluminum, iron, sodium, calcium, potassium, magnesium, hydrogen, oxygen, nitrogen, and carbon.

   The Periodic Table includes the following information about each element:

Chemical symbol:	An abbreviation of the element's name
Atomic number:	The number of protons in the nucleus (determines the atom's identity)
Atomic mass:	The average mass of all isotopes of an element
Valence number:	The number of electrons in the outermost energy level



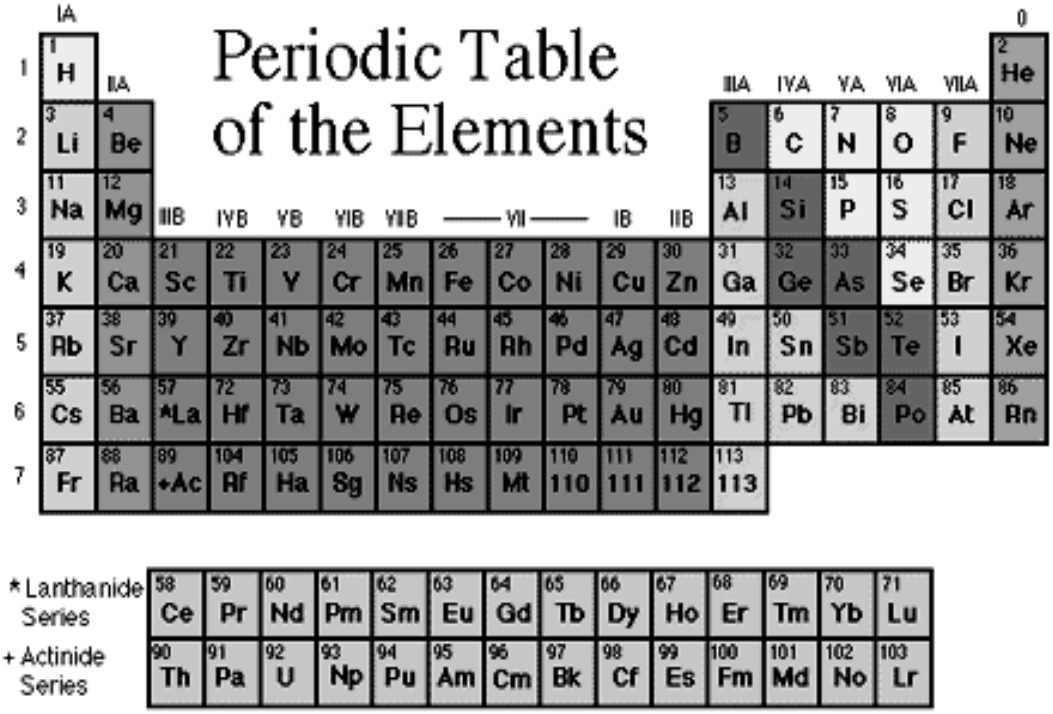




Note: The first letter of an element is capitalized and the second letter (if there is one) is always written in lowercase.

9. The **Periodic Table of Elements** is a tool used to organize information about the elements. Each box in the table contains information about an element. Elements are arranged by increasing atomic number.

The table is organized into horizontal rows called **periods** and vertical columns called **groups** (or families). *Each group/family has elements with similar properties because they have the same number of electrons in their outermost energy level.*



Source: http://genesismission.jpl.nasa.gov/science/mod2_aei/fig15.gif

The elements on the Periodic Table are grouped as metals, nonmetals, or metalloids.

- A **metal** is an element that is a good conductor of heat and electricity, is shiny, malleable, ductile, and has a high melting point. Metals tend to lose electrons in a chemical reaction, forming positive ions. Metals are on the left side of the table.
- A **nonmetal** is an element that is a poor conductor of heat and electricity, is brittle, dull, and has a low melting point. They tend to gain electrons in chemical reactions, forming negative ions. Nonmetals are located on the right side of the periodic table.
- A **metalloid** can have properties of both metals and nonmetals. Metalloids are located between the metals and nonmetals on the periodic table

10. Atoms combine in chemical reactions to form chemically stable substances. *The number of electrons in the outermost energy level determines an element's chemical reactivity*. When atoms **bond** to other atoms, electrons are gained, lost, or shared.

- In **ionic bonds**, electrons *transfer* from one atom to another. Ionic bonds most often occur between metals and nonmetals. In a molecule of sodium chloride (table salt), the sodium atom *loses* an electron and the chlorine atom *gains* an electron.

  $Na + Cl \longrightarrow Na^+ + Cl^-$

  sodium chloride

  There is one atom of Sodium (Na) and one atom of Chlorine (Cl) in this chemical formula.

- In **covalent bonds**, electrons are *shared*. In a molecule of water, each hydrogen atom shares one electron with the oxygen atom. Covalent bonds often occur between non-metals.

  $H + H + O \longrightarrow H\ O\ H$

  hydrogen hydrogen oxygen — water

  There are two atoms of Hydrogen (H) and one atom of Oxygen (O) in this chemical formula.

11. Atoms of a particular element are all basically alike. They always have the same number of protons. Atoms that have gained or lost one or more neutrons are **isotopes** of that element. An **ion** is an atom that has gained or lost one or more electrons.
Note: An atom that has gained or lost a proton becomes a <u>different element</u>. This occurs in radioactive decay.

PS.5: The student will investigate and understand changes in matter and the relationship of these changes to the Law of Conservation of Matter and Energy.

12. Matter can undergo **physical** or **chemical changes**.

A **physical change** is a change in the size, shape, or state of the matter, but the nature of the matter is unchanged. For example, melted ice is still water. Likewise, water that has evaporated into the atmosphere is still water (H_2O) which can condense and fall again as liquid water or rain.

A **chemical change** involves the combining of one or more substances into new and different substances. Evidence of a chemical change can be a gas given off, a color change, precipitate formation, or a temperature change.

13. The **Law of Conservation of Matter (Mass)** states that matter cannot be created or destroyed in a chemical reaction, but it can only change form. The total mass of the reactants must equal the total mass of the products.

The **Law of Conservation of Energy** states that energy cannot be created or destroyed, but it can only change form.

14. A **chemical equation** uses **symbols** and **formulas** to represent a chemical reaction. The substances that enter into a chemical reaction are the **reactants**. The substances they become are the **products**. In a chemical formula, the reactants are on the left side of the formula, and the products are on the right side. The arrow represents the change into new substances.

Example:

$HCl + NaOH \rightarrow NaCl + H_2O$

(reactants) *(products)*

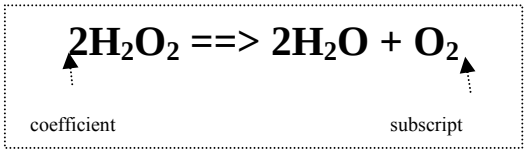
Chemical equations must always be balanced (remember, matter cannot be created or destroyed in a chemical reaction). Therefore, every atom from the reactants must become part of the products.

The number preceding a chemical formula is the **coefficient** and indicates how many of each type of molecule are taking part in a chemical reaction.

The small numbers, called **subscripts**, just after an element name in a compound indicates how many atoms of that particular element are in the compound.

For example, one molecule of water (H_2O) contains two atoms of Hydrogen and one atom of oxygen. Two molecules of water ($2H_2O$) contain four atoms of hydrogen and two atoms of oxygen.

Look at the chemical equation below When balancing a chemical equation, one can change the number of the coefficients but not the subscripts.



15. Chemical reactions are classified by whether they *absorb* (take in) or *give off* (release) heat energy.

Exothermic Reactions release heat energy. For example, nuclear reactions are exothermic. They occur when the nucleus of the atoms are involved, rather than the electrons. Combustion is also an example of an exothermic reaction.

Nuclear energy is the energy stored in the nucleus of every atom. In a nuclear reaction, a tremendous amount of energy is released by either joining the nuclei of atoms together (fusion) or by splitting the nuclei of atoms apart (fission). Only a small amount of matter is needed to produce a very large amount of energy. Nuclear reactions are exothermic reactions.

NUCLEAR REACTIONS

What type of nuclear reaction?	What Happens?	Where Does it Occur?	What are the Pros and Cons?
Fusion	The nuclei of atoms are joined together.	Stars *(example: the Sun)*	Scientists have not yet been able to find a way to create fusion in an affordable manner.
Fission	The nuclei of atoms are split apart.	Nuclear Power Plants	Nuclear energy is renewable and inexpensive. However, nuclear waste is extremely hazardous to the environment and living organisms. It remains dangerous for long periods and can be difficult to store safely.

Endothermic Reactions require the input of energy in order to take place. Photosynthesis is an example of an endothermic reaction. Without the constant input of light energy from the Sun, the process of photosynthesis stops.

Properties of Matter

Name _____ Class _____ Date _____

Read each question and choose the best answer or complete the required task.

1. List the 3 states of matter starting with the least active molecules.

   Least active: _____

   More active: _____

   Most active: _____

___2. When gasoline (a combustible liquid) is burned in a car engine, ___

   A. new substances are formed.
   B. mass is gained.
   C. mass is lost.
   D. gasoline evaporates.

___3. How many hydrogen atoms are present in one molecule of ammonium acetate: $NH_4C_2H_3O_2$?

   A. 3
   B. 4
   C. 7
   D. 11

___4. Which of the following will help a solid solute dissolve faster in water?

   A. Cool the solution
   B. Freeze the solute
   C. Grind up the solvent
   D. Stir the solution

___5. Two or more different elements that are chemically combined form a(n)___

   A. element.
   B. compound.
   C. mixture.
   D. acid.

___6. Coffee has a pH of about 5. Therefore, coffee is ___

   A. extremely acidic.
   B. extremely basic.
   C. slightly acidic.
   D. slightly basic.

7. Which of the states of matter has a definite shape ***and*** a definite volume?

   _____

___8. The ratio of the atoms of elements in a compound are shown in a ___

   A. chemical formula.
   B. chemical symbol.
   C. subscript.
   D. superscript.

___9. The color and density of ink are both examples of ___

   A. chemical changes.
   B. chemical properties.
   C. physical changes.
   D. physical properties.

___10. A solution with a slippery feel ***and*** a bitter taste is most likely a(n) ___

   A. acid.
   B. base.
   C. hydrate.
   D. salt.

___11. According to the Law of Conservation of Matter, if two atoms of hydrogen are in the reactant, how many atoms of hydrogen must be in the product?

A. 1
B. 2
C. 3
D. 4

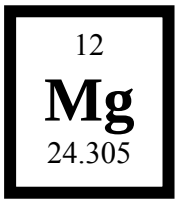
___12. The most current scientific thought on atomic structure is a model in which the electrons ___

A. may stream through a quantum hole.
B. orbit the nucleus at different orbital levels.
C. are easily seen using an electron microscope.
D. move about in a region known as an electron cloud.

___13. Which is ***not*** a property of a metal?

A. Poor conductor of electricity
B. Shiny
C. Good conductor of heat
D. High melting point

___14. What is the atomic number of this element?



A. 24
B. 12
C. 24.305
D. 12.305

15. Which particle of an atom has a positive charge?

_____

___16. Silver (Ag) and Gold (Au) are in the same column on the Periodic Table of the Elements. This means they have similar properties ***and*** ___

A. belong to the same period.
B. belong to the same group.
C. are the same element.
D. have the same atomic mass.

___17. Which three are ***all*** examples of physical changes?

A. Boiling water, bursting a balloon, and melting a candle.
B. Burning of gasoline, rotting of an egg, and exploding fireworks.
C. Freezing of water, evaporation of gasoline, and rusting of a nail.
D. Sawing of wood, crushing a can, and toasting a marshmallow.

___18. To neutralize an acid, you should add ___

A. a weak acid.
B. a salt.
C. a base.
D. water.

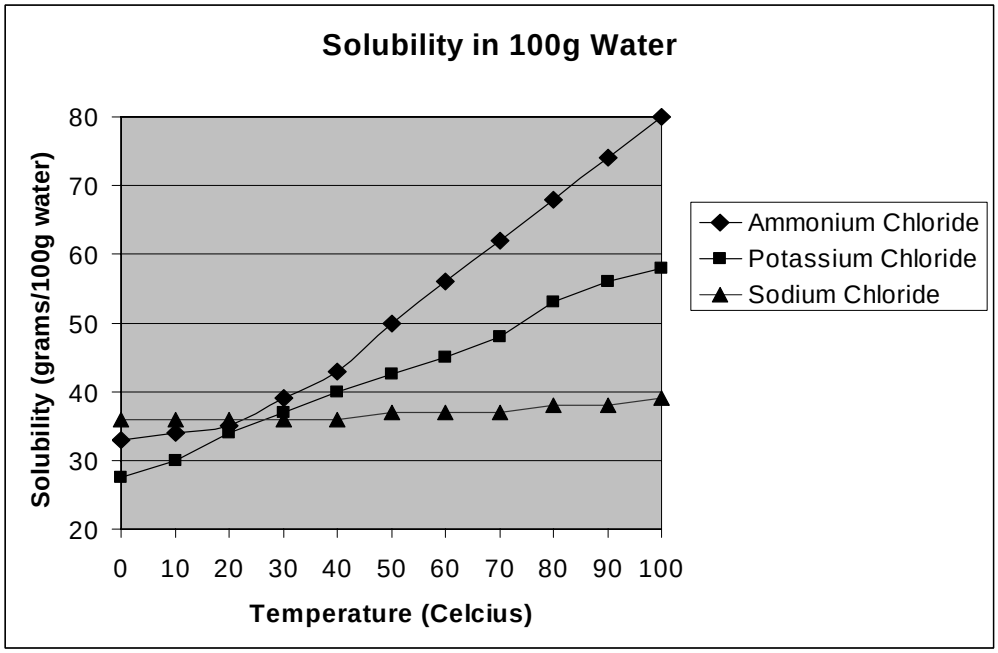
___19. The atomic number of an element corresponds to ___

A. the element's average mass.
B. the number of protons in the Nucleus.
C. the number of neutrons in the Nucleus.
D. the number of electrons in the outermost energy level.

20. Which particle of an atom has a negative charge?

_____

Refer to the solubility graph below to answer questions 21-24.



___21. Which chemical's solubility in 100 grams of water is ***most*** affected by increasing the temperature of the water?

A. Potassium chloride
B. Water
C. Sodium chloride
D. Ammonium chloride

___22. Which chemical has the best solubility in 100 grams of water at 0 degrees Celsius?

A. Potassium chloride
B. Water
C. Sodium chloride
D. Ammonium chloride

___23. How many grams of potassium chloride can be dissolved in 100 grams of water at 40 degrees Celsius?

A. 40
B. 35
C. 45
D. 30

___24. When each of the above chemicals are completely dissolved in the water, the resulting solution is a(n) ___

A. acid
B. mixture
C. compound
D. element

25. Balance the following equation:

$C_3H_8 + 5O_2 \rightarrow$ ___ CO_2 + ___H_2O

26. Balance the following equation:

___ $KClO_3 \rightarrow 2\ KCl + 3O_2$