Physical Science Study Guide
Unit 3
Properties of Matter, Acids & Bases

Sources: (CP) Chapters 20 & 25; (Honors) Chapters 2 & 6

Indicators:

PS-3.1 **Distinguish** chemical properties of matter (including reactivity) from physical properties of matter (including boiling point, freezing/melting point, density [with density calculations], solubility, viscosity, and conductivity)

PS-3.2 **Infer** the practical applications of organic and inorganic substances on the basis of their chemical and physical properties.

PS-3.3 **Illustrate** the difference between a molecule and an atom

PS-3.4 **Classify** matter as a pure substance (either an element or a compound) or as a mixture (either homogeneous or heterogeneous) on the basis of its structure and/or composition

PS-3.5 **Explain** the effects of temperature, particle size, and agitation on the rate at which a solid dissolves in a liquid

PS-3.6 **Compare** the properties of the four states of matter—solid, liquid, gas, and plasma—in terms of the arrangement and movement of particles

PS-3.7 **Explain** the processes of phase change in terms of temperature, heat transfer, and particle arrangement

PS-3.8 **Classify** various solutions as acids or bases according to their physical properties, chemical properties (including neutralization and reaction with metals), generalized formulas, and pH (using pH meters, pH paper, and litmus paper)

Key Terms/Concepts:

covalent bond	ionic bond	chemical bond
oxidation number	valence electron	chemical formula
binary compound	crystal lattice	molecule
chemical stability	Lewis dot structure	ion
polyatomic ion	conductivity	polar molecule
non-polar molecule		

Be able to ***distinguish chemical*** from ***physical properties***.
Be able to ***categorize*** when given a list of the substance's chemical and physical properties.

Physical Properties:

A ***physical property*** of a substance is a characteristic of the substance that can be observed directly or measured with a tool ***without changing the composition*** of the substance.
Boiling, freezing, & melting point **-** do not refer to the phase change itself, but to a measurement, i.e. the temperature at which these changes occur.
The ***composition*** of a substance does ***not*** change during the phase change, therefore, boiling, melting, and freezing points are all physical properties.
Misconception**:** as the physical appearance of a substance changes during a phase change (e.g. water), that evaporation and freezing/melting are chemical changes.

Density - is the mass (in grams) of a substance per unit volume (in cubic centimeters - cm^3). The density of a particular substance (under constant conditions) is always the same, regardless of the sample size. The density of a substance ***changes*** with phase change due to the difference in the particle arrangement in solids, liquids and gases. The volume of a particular substance is dependent upon phase, therefore, the density of a particular substance is as well. Remember the procedures for measuring the mass and volume of solids (regularly and irregularly shaped) and liquids. Be able to calculate and re-arrange for unknowns using the formula: density = mass/volume. The composition of a substance does not change when measuring mass and volume in order to calculate density; therefore, ***density*** is a ***physical property***.

Solubility - a substance is soluble in a solvent if it will dissolve in that solvent. Solubility is the maximum amount of a solute (substance being dissolved) that can dissolve in a given volume of solvent (the dissolving medium) at a particular temperature and pressure. A ***saturated*** solution - the maximum mass of the solute is dissolved in the solvent at a particular temperature. The components of solutions and other mixtures do not chemically combine to form a new substance. Solutions are composed of two substances which each retain their own properties. ***Solubility*** is a ***physical property***.

As the physical appearance of a substance changes when it dissolves (the solute often disappears) students often mistakenly assume that dissolving is a chemical change. In a solution, the solute and solvent do not chemically combine, they form a homogenous mixture.

Viscosity - a property of fluids and is a measure of the material's ***resistance to flow***. High-viscosity fluids take longer to pour versus low-viscosity fluids. Viscosity may change with temperature although the ***composition*** of a fluid does ***not*** change when it is poured and, therefore, viscosity is a ***physical property***.

Electrical conductivity - the ability of a solid to act as an electrical conductor or an electrical insulator based on the solid's ability to complete an electric circuit, i.e. conduct electricity. Materials (such as ***metals***) with high conductivity are electrical ***conductors***. Materials with low conductivity are electrical insulators. Most ***non-metals*** are ***insulators***. Some solutions can conduct electric current, depending on the nature of the solute. Solutes that dissolve in water and that result in solutions ***allowing*** electric current to flow are called ***electrolytes***. Electrolyte solutions contain ***ions***.

Three examples of physical change are boiling of water, bursting of a balloon, and crumpling a piece of paper.

Chemical Properties:

A ***chemical property*** is a characteristic of a substance that indicates whether it can or cannot undergo a certain ***chemical change***. Chemical change produces ***new substances*** with ***new identifying properties***. For example;

Combustibility *or* ***flammability*** - carbon reacting with oxygen to form carbon dioxide (burning of charcoal).

Ability to oxidize **-** iron reacting with oxygen to form iron(III) oxide (i.e. iron rusting).

Ability to corrode **-** silver reacting with sulfur to form silver sulfide (i.e. silver tarnishing).

Ability to decompose - hydrogen peroxide decomposing into water and hydrogen gas when exposed to light.

Ability to react with acids - zinc reacting with hydrochloric acid to form zinc chloride and hydrogen gas.

Ability to not react - gold being used in jewelry because it does not readily react.

<u>Organic substances</u>:

Organic compounds contain ***carbon***. ***Hydrocarbons*** are a class of organic molecules composed of ***carbon*** and ***hydrogen*** that can combine to make thousands of different hydrocarbon compounds.

Be able to recall the names of selected types of organic biological molecules and summarize how their ***functions*** in organisms are dictated by their ***chemical properties***.

Protein molecules are ***long chains*** of small units (amino acid monomers) that are arranged in ***various configurations*** so they can form a ***wide variety*** of molecules. Proteins serve many functions in living organisms such as catalysts (enzymes) and tissue building.

Carbohydrate molecules (***sugars*** and ***starches***) provide organisms with energy when they break down into smaller molecules.

Lipid molecules (***fats*** and ***oils***) are good sources of stored energy because lipids produce more energy per gram than carbohydrates.

Many ***hydrocarbons*** are ***combustible*** and used for ***fuel*** (e.g. gasoline and diesel oil).

Many ***hydrocarbons*** form ***long chain*** molecules called ***polymers*** so they are used to make ***plastics*** and ***synthetic fibers*** and ***gels*** (remember Slime expt.).

<u>Inorganic substances</u>:

Inorganic substances are elements or compounds that do ***not*** necessarily contain ***carbon***. Potential uses of inorganic substances are dependent on the properties of the substance and include: copper - is ductile and conducts electricity and used in wiring; aluminum has a low density compared to substances with similar strength and is used in making airplanes; water is a good solvent for many compounds and is used to wash clothes; argon is an inert/stable gas that will not react with the filament and is used in light bulbs.

<u>Matter</u>:

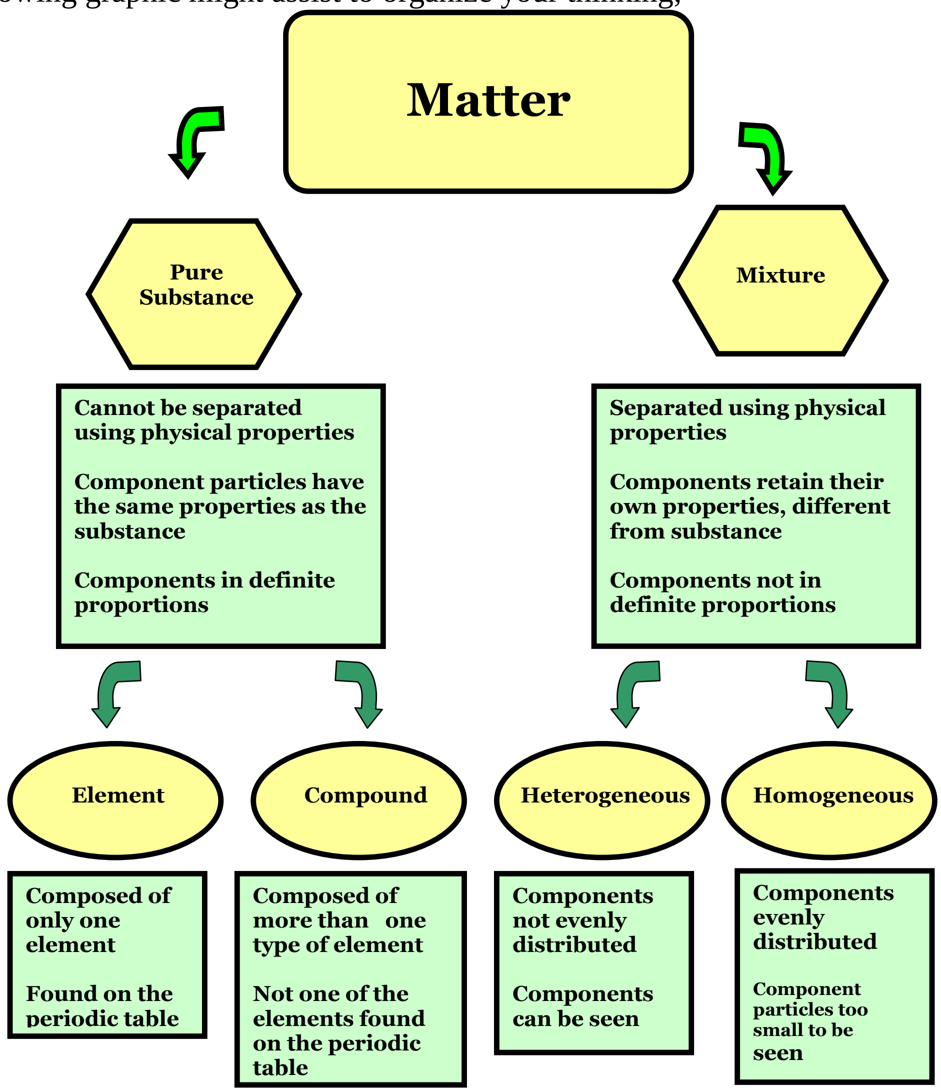
Element - a pure substance that is composed of only one type of atom. All of the elements are listed on the periodic table. An atom is the smallest unit of an element that can be involved in a chemical reaction.

Molecules - composed of two or more of the same type of atom (e.g. H) covalently bonded together). A molecule is the smallest particle of a molecular substance that can exist and still have the composition and chemical properties of the substance. The chemical and physical properties of a molecular substance are ***different*** from the chemical and physical properties of the component elements.

Pure substances - substances with unique and identifying properties. There are two types of pure substances, elements and compounds.

Compound is a pure substance which is composed of ***more than one type*** of element (e.g. H_2O, water). Compounds all have identifying properties which are ***different*** from the properties of the elements which compose them. Compounds can be decomposed into elements only by chemical reactions and can not be separated into elements by physical means. Compounds have a definite chemical composition identified by a chemical formula, e.g. the ratio of the # of oxygen to hydrogen atoms in any sample of water is always 1 to 2. Molecular substances are one type of compound, and ionic substances are another type of compound.

Mixtures:
Mixtures can be classified into ***two*** groups, ***heterogeneous*** and ***homogeneous***.
Heterogeneous mixtures do ***not*** have the components ***distributed evenly*** throughout.
Homogeneous mixtures have components ***evenly distributed*** all the way down to the particles, whether atoms, molecules, or ions. A ***solution*** is a ***homogeneous mixture***.
A ***mixture*** *is* matter composed of ***two or more*** component substances which ***retain*** their own ***identifying properties***.
Mixtures do ***not*** have ***definite*** composition; the components of a mixture may be in any ratio.
A ***mixture*** can be ***separated physically*** because the components of the mixture have different physical properties. Examples of procedures for separating mixtures based on differing properties include: dissolving; filtering; evaporating; magnetic separation; chromatography; separating by particle size (screening).
Mixtures can occur between and among all phases of matter: gas/gas (air); gas/liquid (oxygen in water); liquid/liquid (alcohol in water); solid/liquid (sugar in water); solid/solid (alloy such as steel).
The following graphic might assist to organize your thinking;



The Kinetic Theory:

Three basic assumptions of ***kinetic theory***;
- All matter is composed of small particles (molecules, atoms, and ions).
- The particles are in constant, random motion.
- The particles are colliding with each other and the wall of their container.

Understand ***dissolving*** in terms of the kinetic theory.
For example, the solvent water is composed of individual water molecules (H_2O), all close enough to touch, but in constant motion, moving over, under, and past one another. The solute such as table sugar is composed of crystals, each crystal composed of billions of individual sugar molecules. The individual molecules are attracted to each other (not chemically bonded) together. The sugar molecules in the crystal are also moving but because sugar is a solid the molecules do not move past each other, they vibrate in place. Because sugar is a molecular compound, the individual sugar molecules can not be decomposed by a physical process such as dissolving, so the dissolved sugar remains as sugar molecules and not separated carbon, hydrogen and oxygen atoms. The dissolving process involves the sugar molecules being pulled ***away from each other*** by the water molecules but each molecule of sugar remains intact. The sugar molecules on the surface of the crystal are the only ones to dissolve because they are the ones in contact with the water molecules. As surface sugar molecules dissolve, they expose the ones beneath to the water. Because the dissolved sugar molecules are surrounded by water molecules, they are not attracted to each other (the water molecules block the attractive force). In the resulting solution, the sugar molecules are distributed throughout the water. The water can be removed by boiling the water or allowing it to evaporate. When the water boils or evaporates away, the sugar molecules will once again be attracted to each other and sugar crystals will reform.
Temperature affects the rate at which substances ***dissolve***. The higher the temperature the faster the rate of dissolving for a solid in a liquid. At higher temperatures more of the solvent molecules are moving faster and collisions with the surface of the solute occur more often carrying off particles of the solute so dissolving occurs more rapidly.
Particle size affects the rate at which substances ***dissolve***. Are they large chunks of material or ground into many small pieces as in a powder? The smaller the size of the pieces of solute, the faster they dissolve. The smaller the size of the individual pieces, the more surface area the sample will have to be in contact with the water molecules. With more surface area in contact the water molecules, the water will have more opportunities to pull the solute molecules away from the solute's surface, thereby, dissolving it faster.
Agitation affects the rate at which substances ***dissolve***. The more the solution is agitated, the faster the rate of dissolving for a solid in a liquid. When a solution is agitated, the water particles collide with the surface of the solute more frequently and the dissolving process occurs faster. Understand that if a substance is soluble in water, it will eventually dissolve even if the size of the sample pieces of solute are large, the temperature is low and there is no agitation.
Misconception: confusing the rate of dissolving (how fast a substance dissolves) with solubility (what quantity of a substance can dissolve).
Understand the characteristics of solids, liquids, gases, and plasma in terms of the kinetic theory.

Solids	• The particles of solids are closely packed together because there is an attractive force holding them together. • The particles of solids are ***constantly*** vibrating, but they do not readily slip past one another. • Because the particles vibrate in place and do not readily slip past one another, a solid has a definite shape.
Liquids	• The particles of liquids are in contact with each other because there is an attractive force holding them together. • The particles of liquids have enough energy to partially overcome the attractive force of the surrounding particles. Liquid particles can slip past surrounding particles and slide over one another. Because the particles slip past one another, a liquid does not have a definite shape and so takes the shape of the container. A sample of a liquid can be poured.
Gases	• The particles of gases are not in contact with each other because they have enough energy to completely overcome the attractive force between or among the particles. • The particles of gases are moving randomly, in straight lines until they bump into other particles or into the wall of the container. When a particle hits another particle or the container, it bounces off and continues to move. • Because gas particles move independently, the particles move throughout the entire container. The forces between the particles are not strong enough to prevent the particles from spreading to fill the container in which the gas is located.
Plasma	• Plasma is matter consisting of positively and negatively charged particles. • A substance is converted to the plasma phase at very high temperatures, such as those in stars (e.g. the sun). High temperature means that the particles of a substance are moving at high speeds. At these speeds, collisions between particles result in electrons being stripped from atoms. • Plasma is the most common state of matter in the universe, found not only in stars, but also in lightning bolts, neon and fluorescent light tubes and auroras.

Temperature - describes the average kinetic energy of the particles in a substance. In a sample of material at any temperature there are particles moving at all speeds. Temperature is a measure of the average motion of the particles. At higher temperatures, more of the particles are moving fast and at lower temperatures, more of the particles are moving slowly.

Phase changes in terms of the kinetic theory.

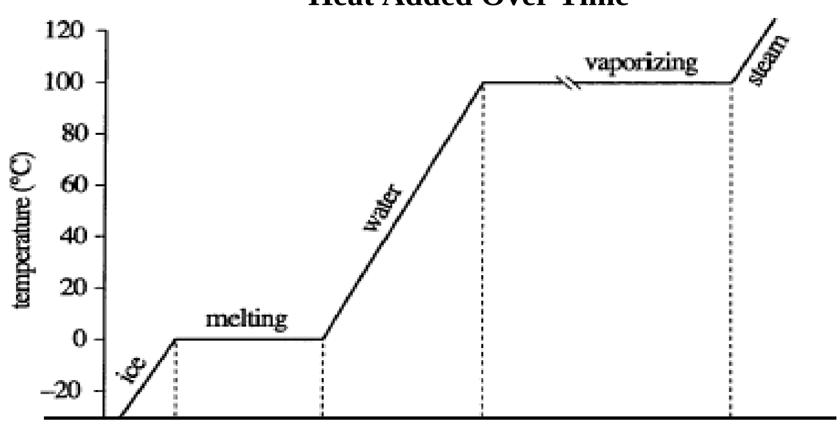
Phase change is due to ***changing*** the freedom of movement of the particles by the addition of energy.

The freezing/melting point - the temperature where a phase change occurs as both the liquid and solid phases exist in equilibrium with each other. If heat energy is being added at this temperature, bonds between particles will break and a solid will melt. If heat energy is being taken away, bonds will form between particles and a liquid will freeze at this temperature.

Boiling point - the temperature where a liquid is changing to a gas throughout the liquid. Evaporation at the surface of a liquid can occur at any temperature. Bubbles of the vapor

are formed throughout the sample and rise to the top and escapes at which point the sample.
Heat of fusion - the amount of energy needed to change a material from a solid to a liquid.
Heat of vaporization - the amount of energy needed to change a material from a liquid to a gas.
When energy (such as heat) is added to a substance, the energy of the particles of the substance increases. Evidence of this would be that: (1) the temperature of the substance increases, or (2) a phase change occurs.
When heat is added to a solid the particles will move faster and the temperature will increase until the temperature of the solid reaches its melting point.
When the temperature of a solid is equal to the *melting point* and more heat is added to the substance, the temperature will not change. The extra heat will be used to break some of the bonds between the molecules of the solid and change the phase to a liquid.
When heat is added to a liquid the particles will move faster and the temperature will increase until the temperature of the liquid reaches its boiling point.
When the temperature of a liquid is equal to the *boiling point* and more heat is added to the substance, the temperature will not change. The extra heat will be used to break the bonds between the molecules of the liquid and change the phase to a gas. When a substance boils, it forms bubbles of the gas. (For example when water boils, the bubbles are filled with water vapor.)
The line of the graph has a positive slope until a phase change occurs. At the melting point or boiling point the temperature does not change as more heat is added over time. The slope of the line will be flat during the time that the phase is changing. After the phase change the slope of the line becomes positive again.

Heat Added Over Time



Time (s)

Liquids may evaporate at any temperature because some of the molecules at the surface are moving fast enough to escape the attraction of the other molecules.
Solids may undergo ***sublimation*** - particles changing directly from the solid to gaseous phase, e.g. dry ice (solid carbon dioxide).
Misconceptions: confusing heat with temperature. A huge pot of very hot water and a coffee cup of very hot water can both have the same temperature, but the pot of water contains much more heat energy than the water in the cup because the mass of the water in the pot is so much greater.

Heat is a form of ***energy*** and ***temperature*** is an indication of the ***average kinetic energy*** (i.e. speed) of the particles.

Acids & Bases:

Acid is a chemical that releases ***hydrogen ions (H^+)*** in solution and a ***base*** is a chemical which releases ***hydroxide ions (OH^-)*** in solution.
pH scale is a way to measure the ***concentration of hydrogen ions*** in solution, and, how acidic or how basic a solution is.
pH of a solution can be ***measured*** using ***pH paper, Litmus paper, or pH meters***.
pH range falls between ***0*** and ***14***.
pH of 7 (e.g. pure water) contains equal concentrations of H^+ and OH^- and is considered a ***neutral solution***, i.e. it is neither an acidic or basic solution.
pH <7 is an ***acidic solution***, i.e. it contains more H^+ than OH^- ions. The lower the number the more acidic the solution.
The Hydronium ion is H_3O^+
pH >7 is a ***basic solution***, i.e. it contains more OH^- than H^+ ions. The higher the number the more basic the solution.
The ***physical*** and ***chemical properties*** of ***acidic solutions*** are they; conduct electricity (are electrolytes); have a tart or sour taste; turn blue litmus paper red; have a pH less than 7; react with active metals such as zinc and magnesium. Examples of acids include; HCl - Hydrochloric acid (stomach acid); H_2SO_4 - Sulfuric Acid (common industrial acid).
The ***physical*** and ***chemical properties*** of ***basic solutions*** are they; have a slippery feel, conduct electricity (are electrolytes); pH > 7; turn red litmus paper blue. The formula of a base ends in OH for example NaOH - Sodium Hydroxide (drain cleaner) and $Ca(OH)_2$ Calcium Hydroxide (hydrated lime - fertilizer).
Neutralization reaction - ***acids*** and ***bases*** reacting to form ***water*** and a ***salt***.
An acid is used to neutralize a base; a base is used to neutralize an acid.

Websites:
http://school.discoveryeducation.com/quizzes/cc_karent/Quiz9acidsandbases.html