Physical Science Study Guide
Unit 4
Bonding & Chemical Reactions (classifying, effects on reaction rate, catalysts)

Sources: (CP) Chapters 19 & 24; **(Honors)** Chapters 4 & 5

Indicators:

PS-4.1 **Explain** the role of bonding in achieving chemical stability

PS-4.2 **Explain** how the process of covalent bonding provides chemical stability through the sharing of electrons

PS-4.3 **Illustrate** the fact that ions attract ions of opposite charge from all directions and form crystal lattices

PS-4.4 **Classify** compounds as crystalline (containing ionic bonds) or molecular (containing covalent bonds) based on whether their outer electrons are transferred or shared

PS-4.5 **Predict** the ratio by which the representative elements combine to form binary ionic compounds, and represent that ratio in a chemical formula

PS-4.6 **Distinguish** between chemical changes (including the formation of gas or reactivity with acids) and physical changes (including changes in size, shape, color, and/or phase)

PS-4.7 **Summarize** characteristics of balanced chemical equations (including conservation of mass and changes in energy in the form of heat—that is, exothermic or endothermic reactions)

PS-4.8 **Summarize** evidence (including the evolution of gas; the formation of a precipitate; and/or changes in temperature, color, and/or odor) that a chemical reaction has occurred

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PS-4.9 **Apply** a procedure to balance equations for a simple synthesis or decomposition reaction

PS-4.10 **Recognize** simple chemical equations (including single replacement and double replacement) as being balanced or not balanced

PS-4.11 **Explain** the effects of temperature, concentration, surface area, and the presence of a catalyst on reaction rates

Key Terms and Concepts:

Single displacement reaction	Double displacement reaction
Decomposition reaction	Synthesis reaction
Chemical equation	Reactants
Products	Coefficients
Balanced chemical equation	Precipitate
Law of conservation of mass	Concentration
Endothermic	Exothermic
Exergonic reaction	Endergonic reaction
Catalyst	Inhibitors
Collision theory	Chemical formula
Chemical property	Physical property

Balancing, naming, and classifying reactions:

A balanced equation represents a chemical reaction that rearranges atoms but does not create or destroy them. For each element, the number of atoms on the reactant side must equal the number of atoms on the product side, e.g. $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$

Each substance on the ***left*** side of the arrow in a chemical equation is a ***reactant.***

Each substance to the ***right*** of the arrow in a chemical equation is a ***product.***

In the equation $Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$, there is 1 Ca atom, 4 hydrogen atoms, and 2 oxygen atoms on the reactant side.

When most chemical reactions take place, some chemical bonds in the reactants must be broken, a process that requires energy.

Each substance has a formula showing its composition. It is essential to have the correct formula of each substance involved in a reaction before attempting to write a balanced equation.

If the energy required to break the original bonds is ***less*** than the energy release when new bonds form in a reaction it is ***exergonic***. If the energy required to break the original bonds is ***greater*** then it is ***endogenic***.

Compound = element + element can represent a decomposition reaction.

In a chemical equation, the symbol (*aq*) means *dissolved in water or aqueous*.

Single-displacement (displacement) reaction - one element ***replaces*** another element in a compound, e.g. $2K + 2H_2O \rightarrow 2KOH + H_2$

Double-displacement (ionic exchange) reaction - an apparent ***exchange*** of atoms or ions between two compounds, e.g. $Pb(NO_3)_2 + 2KI \rightarrow PbI_2 + 2KNO_3$

Decomposition reaction - the ***breaking down*** of a substance (only one substance is needed) into two or more simpler substances, e.g. $2H_2O \rightarrow 2H_2 + O_2$

Synthesis reaction - a chemical reaction in which two or more substances ***combine*** to form another substance, e.g. $NH_3 + HCl \rightarrow NH_4Cl$

Law of conservation of mass - the mass of the products in a chemical reaction equals the mass of the reactants, e.g. mercury (II) oxide produces oxygen plus mercury. The combined mass of the released oxygen and mercury is 20 grams even when mercury (II) oxide is heated.

An ***exothermic*** reaction ***gives off heat*** to the area around the reaction, so this area will become warmer.

An ***endothermic*** reaction ***absorbs heat***. This type of reaction takes heat from the area surrounding it, so the area around the reaction will become cooler.

Chemical formula - indicates the ratio of atoms in a molecule or an ionic compound.

The formula tells what elements are in the substance using symbols, and indicates the ***number of atoms of each element*** in a unit of the substance using ***subscripts***.

Coefficients - numbers that precede symbols and formulas indicating the ***number of units*** of each material that is involved in a chemical reaction.

Coefficients can be changed in a chemical equation to balance it, but subscripts cannot be changed.

Subscripts are part of the formula for a substance indicating the number of atoms or ions in one chemical unit of that substance.

Subscripts are used to write the ***formula*** for a substance; the ***coefficient*** in front of the formula is then used to ***balance*** the equation after the formulas are written correctly.

Manipulate only coefficients to balance the atoms in the equation for a simple *synthesis reaction* or *decomposition reaction*.

Example: (The coefficients are underlined in this example.) $\underline{4}\,Al + \underline{3}\,O_2 \rightarrow \underline{2}\,Al_2O_3$

Precipitate - an insoluble compound that forms during a chemical reaction.
The burning of wood in a campfire that produces heat and light would be both an exergonic and an exothermic reaction.
Elements like oxygen exist ordinarily as diatomic molecules, are written in a chemical equation by writing the subscript 2.
In the equation $Ca(\boldsymbol{s}) + 2H_2O(\boldsymbol{l}) \rightarrow Ca(OH)_2(\boldsymbol{aq}) + H_2(\boldsymbol{g})$, Ca is a ***solid***, H_2O is a ***liquid***, H_2 is a ***gas*** and $Ca(OH)_2$ is ***aqueous***.
In the following reaction, $CaCl_2(aq) + Na_2CO_3(aq) \rightarrow CaCO_3(s) + 2NaCl(aq)$, $CaCO_3$ is the precipitate.
Atoms bond chemically to become more stable.
When forming compounds, atoms gain, lose, or share electrons to reach an electron situation equal or similar to one of the noble gases.
In all ***chemical reactions*** there is an ***energy change***, i.e. release or absorb energy. For example, when paper burns, heat and light are given off, an exothermic change. This would be evidence that a chemical reaction has occurred.
The breaking and forming of chemical bonds is the source of this energy.
Ionic bonds occur between a metal and a non-metal, while covalent bonds occur between a non-metal and a non-metal.
Atoms of the noble gases (neon, argon, krypton and radon) are stable atoms with ***eight*** electrons in the outside energy level.
Some atoms lose, gain or share electrons to have ***eight*** (i.e. Octet) electrons in the outside energy level like the closest noble gas and become chemically stable.
Metal atoms tend to ***lose*** electrons to become stable, for example, ***Group 1*** and ***Group 2*** metals ***lose electrons*** so that their outside energy level is "complete" or full, forming a stable electron structure like a noble gas. In the case of Group 1 metals, the atom becomes an ion with a 1+ charge (positive ions) because the number of electrons (-) is now one less than the number of positive protons.
Ionic bonds form (to achieve stability) when positively charged metal ions attract negatively charged nonmetal ions due to the attraction between oppositely charged particles.
Positively and negatively charged ions surround each other and pack together as closely as possible to form an ionic crystal. The ions cluster in a ratio that will cancel the net charge of the ions.
Nonmetal atoms tend to ***gain*** electrons. For example, Group 16 atoms have two electrons less that the closest noble gas on the periodic table and six electrons in the outside energy level. Group 16 atoms, such as oxygen, become stable by ***gaining*** two electrons so that its outer energy level becomes like the closest noble gas. The atom becomes an ion with a 2- (negatively charged) charge because it now has two more negative electrons (-) than positive protons.
Covalent bonding - sharing electrons, e.g. nonmetal atoms to obtain an electron situation like the stable noble gases.
Nonmetals may gain electrons through ionic bonding or share electrons through covalent bonding to become more stable.
It is possible for two nonmetal atoms to share electrons in order to become more stable.
For example: An atom from group 17 can bond with another group 17 atom~~s~~ by sharing one electron from each atom. Sharing electrons in this manner results in both atoms attaining eight electrons in their outer energy level and each would have a stable number of electrons equal to the nearest noble gas.
Molecule formed is more stable than the individual atoms. In water, oxygen shares two pairs of electrons, one pair with each of two hydrogen atoms, forming one covalent bond with

each. This gives the oxygen atom eight outer energy level electrons and each hydrogen atom, two outer energy level electrons. All of the atoms in the molecule are stable since they each have a number of electrons equal to the nearest noble gas. A hydrogen molecule, H_2, forms a covalent bond by sharing the electron from each hydrogen atom. This gives each hydrogen atom two electrons in the outside energy level which is stable.

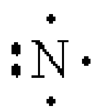
There are ***combinations*** of nonmetals that achieve electron stability by sharing different numbers of electrons to have a number of electrons like a noble gas (2 or 8 electrons in the outer energy level).

Multiple bonds - form when more than one pair of electrons are shared, e.g. nitrogen has five electrons and needs to gain three electrons to be stable. Three electrons from each nitrogen atom are shared forming a "triple bond" (three covalent bonds). An oxygen molecule, O_2, forms a double bond when two electrons from each atom are shared. A carbon dioxide molecule, CO_2, forms when carbon, which needs four electrons to be stable, shares two electrons from each oxygen atom, which needs two electrons to be stable, forming "double bonds" (two covalent bonds) between each oxygen atom and the carbon atom.

Recognize examples of ***covalent bonding***. Examples may be in the form of "dot" diagrams, pictorial diagrams, or verbal descriptions. Atomic illustrations typically indicate the number of electrons (i.e. valence) in the outer-most energy level of the atom.

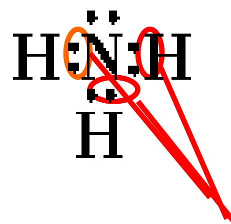
Molecular illustrations- the shared pairs of electrons in the molecular illustration should be labeled as "covalent bonds"

Example of Electron Dot Diagrams



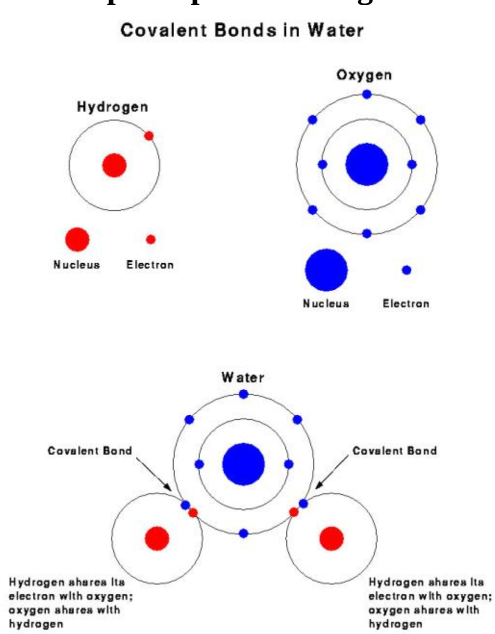
Nitrogen atom

Hydrogen atom

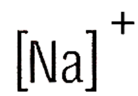


Ammonia molecule
Covalent bonds

Example of pictorial diagrams



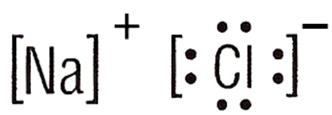
Ionic Crystals:
Ionic crystals consist of metals bonded to nonmetals with the transfer of electrons. The metals form positive ions and the nonmetals form negative ions and are attracted to one another. These positive and negatively charged ions pack together as closely as possible in a crystal lattice to form an ionic crystal, e.g. sodium chloride (NaCl) table salt as below. Examples may be in the form of pictorial diagrams, or verbal descriptions or electron dot formulas;

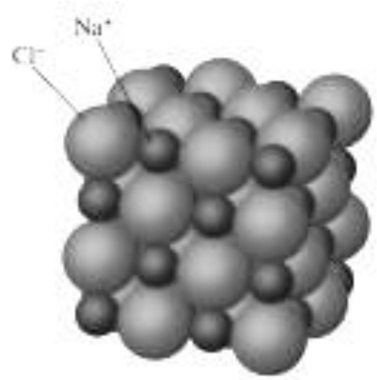
Sodium atoms lose one electron each to form sodium ions;


Chlorine atoms gain one electron each to form chloride ions.

These oppositely charged ions then attract each other in a one to one ratio to form a crystalline arrangement of many ions, e.g. sodium chloride.



or as a Pictorial diagram:



Molecular Substances - often consist of nonmetals bonded with other non-metals by forming covalent bonds (sharing electrons) to become stable.
Molecules are compounds that have covalent bonds, e.g. hydrogen gas (H_2), carbon dioxide (CO_2), water (H_2O), and sugar ($C_6H_{12}O_6$).

Charges and oxidation states:
Be able to predict the charge of the ions that the atoms in Groups 1, 2, 16, and 17 will attain, e.g. Group 1 metals form 1+ ions; Group 2 metals form 2+ ion; Group 16 nonmetals form 2- ions; Group 17 nonmetals form 1- ions.
Understand the meaning of the symbols and subscripts when given a chemical formula.
Compounds do not have a net charge, meaning that the negative charges balance the positive charges so that the compound as a whole is neutral.

Balance the charges in chemical formulas of compounds that contain ions of the elements in Groups 1,2,16, and, 17 without being given the charges on the ions.
Be able to balance the charges on *binary ionic compounds* (two different elements bonded together) for any elements that form ionic compounds when the charges on the ions are given, thereby predicting the ratio of the ions in the formula of the resulting ionic compound.
The oxidation number of an atom is shown with a superscript.
The sum of the oxidation numbers in a neutral compound is always zero.
Be able to count the number of atoms in a given compound, e.g. 7 hydrogen atoms in ammonium acetate, $NH_4C_2H_3O_2$.
Be able to count the total number of atoms in the compound $Ca(ClO_3)_2$, i.e. 9
Be able to calculate charges, e.g. -3 is the charge of phosphate in K_3PO_4.
Be able to write the names of the following types of formulas, e.g. KBr
Be able to write the formulas for the following types of compounds, e.g. Aluminum sulfide
Fog is an example of a colloid. The scattering of light by colloids is called The Tyndall effect.

Chemical change:
A chemical change occurs when there is a ***change in the arrangement of the atoms*** involved so a different (i.e. new) substance with different properties is produced.
When a chemical reaction takes place, some type of ***evidence*** can be observed, e.g. baking soda with vinegar results in carbon dioxide gas (bubbles) being formed as evidence (remember Lab expt.); the reaction of a substance (e.g. metals) with an acid (e.g. HCl) is another chemical change (e.g. hydrogen gas released).
Color change – is evidence that chemical change has occurred, e.g. metal tarnishing and changing color because the atoms are rearranged and a new substance is formed (tan copper to green copper oxide; or silver and blackish tarnishing).
Odor – given off is often evidence that a chemical reaction has occurred, e.g. Ammonium carbonate is heated the odor of ammonia gas can be detected.

Physical change:
Physical change is a ***change in matter*** from one form or appearance to another but does not involve a change in the identity of a substance. When physical changes occur a new substance is ***not*** produced. For example, a substance may change size, such as being broken into smaller pieces, a substance may change in shape, such as being bent or stretched, a substance may expand or contract due to a temperature change.
Color change may indicate a ***physical change***, e.g. colors of paint, crayon, or food coloring are mixed together a mixture is formed and the color changes (no rearrangement of the atoms occurs).
Phase changes (freezing, melting, evaporation, sublimation, etc.) are ***physical changes***.
A *chemical equation* uses chemical formulas and symbols to show the reactants and the products in a chemical reaction.
A ***precipitate*** forms, it could be evidence that an insoluble solid has formed and fallen out of solution. This is a chemical reaction. An example of this is adding a solution of silver nitrate to a solution of sodium chloride, a white precipitate of silver chloride is formed.
It could also be true that some of a substance that was dissolved has fallen out of solution because of a change in conditions. This is a physical change.
Many physical changes also involve an energy change. For instance, melting is an endothermic change.

Odor can also occur because molecules are evaporating from the surface of a substance, which is a physical change.
Evidence is not proof. It is the combination of evidences that give validation for a chemical or physical change.

Reaction rate:
Chemical reactions occur when the particles of the ***reactants collide*** with sufficient energy to react**.**
Factors affecting reaction rate include;
- the average kinetic energy of the molecules of reactants increasing with increased temperature, a greater number of the molecules will be moving faster.
- more collisions can mean a faster reaction rate. More particles moving faster, there will be more ***total collisions*** between particles and more collisions can a mean faster reaction rate. More of the reactant particles will be moving faster and will, therefore, have enough energy to produce ***successful collisions*** and the reaction will proceed faster.
- more concentrated the reactants, the rate of a chemical reaction can increase. When reactants are more concentrated, it means there are more particles per unit volume. More particles in a given volume, means there is a greater chance that reactant particles will collide.
- if the ***surface area*** of reactants ***increases***, the reaction ***rate increases***. Only the particles at the ***surface*** of a sample of ***reactant*** can collide with particles of other reactants. If the same mass of reactants is broken into smaller pieces, there is ***greater*** surface area. With many more particles on the surface, there is a greater chance for collisions to occur, and the chemical reaction will proceed faster.

Catalyst - a substance that ***speeds up*** a chemical reaction ***without*** being permanently changed itself. Catalysts can lower the amount of energy needed to start a reaction (activation energy). Since the energy needed for successful collisions is less, there will be more successful collisions, and the chemical reaction will proceed faster.
Inhibitors - a substance that prevents or slows down a chemical reaction.