CHEMICAL REACTIONS

Types of changes in matter: Physical, chemical and nuclear

Each type of change involves changes in energy; amount increases from physical to chemical to nuclear.

1. **Physical Changes**:
   - fundamental particles remain unchanged, therefore no change in chemical formula

E.g. Phase (state) change: $H_2O_{(s)} \rightarrow H_2O_{(l)} \rightarrow H_2O_{(g)}$

1. **Chemical Changes**:
   - involve changes in chemical bonds between atoms and/or ions
     - old bonds are broken (reactants) and new bonds are formed (products)
     - a rearrangement of atoms and/or ions occurs, therefore chemical formulas do change

Ex $2Na_{(s)} + 2H_2O_{(l)} \rightarrow H_{2(g)} + 2NaOH_{(aq)}$

   - at least one new substance is formed, with different properties than the reactants
   - may be accompanied by changes in color, odor, state (solid precipitate or gas)
   - always accompanied by a change in energy: a net amount is absorbed or released

http://www.youtube.com/watch?v=FofPjj7v414&safe=active

Physical Change	~Chemical Change
~No new or different substance is formed. The composition of the substance that undergoes the change remains unchanged	~Results in the formation of at least one new substance. The particles of the new substance are different from the particles of the original substance
~It is temporary change and in most cases it can be reversed by the reversal of conditions	~It is permanent change and cannot be reversed by mere reversal of conditions
~No change occurs in the mass of the substances undergoing the change	~Mass of the individual substances that undergoes the change, always, either increases or decreases. However, the total mass of all the reactants is equal to the total mass of all the products

3. **Nuclear Change:** involves the changes within the nuclei of atoms

CHEMICAL TESTS:

These are distinctive chemical reactions that allow you to identify an unknown substance.

1. **Oxygen test:** If a glowing splint, held in a gas, bursts into flame, then $O_{2(g)}$ is present.

2. **Carbon Dioxide:** If limewater, a clear, colorless solution of calcium hydroxide, turns cloudy (white precipi forms), then carbon dioxide is present.

1. Hydrogen test: If a POP sound is heard when a burning splint is held in a gas, then $H_{2(g)}$ is present.

4. **Water:** If cobalt (II) chloride paper changes from blue to pink, then water is present.

5. **Acid:** If blue litmus paper turns red, an acid is present.

6. **Base:** If red litmus paper turns blue, a base is present.

http://www.youtube.com/watch?v=LiAvDpl5aJA&safe=active

Energy Changes in Chemical Reactions:

In a chemical reaction, energy is absorbed to break bonds of reactants and is released as new bonds form in the products.

1. **Exothermic reactions:**
   - release a net amount of energy
   - more energy is released by the products than is absorbed by the reactants

E.g. Combustion of coal: $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)} + \text{Energy}$

2. **Endothermic reactions:**
   - absorb a net amount of energy
   - more energy is absorbed by the reactants than is released by the products

E.g. Decomposition of $CaCO_3$: $CaCO_{3(s)} + \text{Energy} \rightarrow CaO_{(s)} + CO_{2(g)}$

Note: Physical changes are also exothermic or endothermic

E.g. melting of ice: $H_2O_{(s)} \rightarrow H_2O_{(l)}$ ***Endothermic***

E.g. freezing of water: $H_2O_{(l)} \rightarrow H_2O_{(s)}$ ***Exothermic***

http://www.youtube.com/watch?v=Rtcf6Pjahec&safe=active

Law of Conservation of Energy:

Energy is neither created nor destroyed (during any chemical or physical change), but can be converted fro one form of energy to another.

e.g. photosynthesis: $6\ CO_{2(g)} + 6\ H_2O_{(g)} + \text{Energy} \rightarrow C_6H_{12}O_{6(s)} + 6\ O_{2(g)}$

Plants use sunlight (solar energy) to convert carbon dioxide and water into carbohydrates such as glucose (stored chemical energy = potential energy).

Law of Conservation of Mass (Matter):

In any chemical or physical change, mass (matter) is neither created nor destroyed.

i.e. total mass of the reactants = total mass of the products.

This leads us to believe that atoms of reactants are not changed, but simply rearranged. For example;

Methane + oxygen → water + carbon dioxide

Or symbolically, $CH_4 + O_2 \rightarrow H_2O + CO_2$

1 carbon atom	1 carbon atom
4 hydrogen atoms	2 hydrogen atoms
2 oxygen atoms	3 oxygen atoms

Note that the numbers of carbon, hydrogen and oxygen atoms are different. Have we violated the law of conservation of mass?

No, we have simply not correctly written the balanced chemical equation describing the reaction.

- Demonstrated by Lavoisier (1700's), the father of modern chemistry.
- His experiments led to the emphasis on quantitative measurement, close observation and careful recording of data. All of his experiments were carried out in closed vessels.

Ex1. Lavoisier dehydrated gypsum by heating it.

$CaSO_4 \bullet 2H_2O_{(s)} \rightarrow CaSO_{4(s)} + 2\ H_2O_{(g)}$

172.2 g 136.2 g + _____

Ex2: Lavoisier burned mercury in air. Then he heated the product further, which decomposed back into its elements.

mercury + oxygen → mercuric oxide → mercury + oxygen

201 g + 32 g → _____ → _____ + _____

Ex3: He also burned phosphorus in air:

$P_{4(s)} + 5\ O_{2(g)} \rightarrow P_4O_{10(s)}$

124 g + _____ → 284 g

CHEMICAL EQUATIONS

- These show the rearrangement of atoms and/or ions that takes place as a result of a chemical change of reactants into products.
- Chemical equations are a shorthand method of representing what experimental evidence indicates happens in a chemical reaction.

BALANCING CHEMICAL EQUATIONS

Balancing chemical equations involves using experimental evidence form chemical reactions. The experimental evidence indicates that:

- **Atoms are conserved**
- **Mass is conserved**
- **Energy is conserved**

A chemical equation must:

- Represent the correct chemical formula and state for each reactant and product
- Show that atoms or ions are conserved:
- Total # of each kind of atom/ion in reactants = total # of each kind of atom/ion in products

General Steps:

1. Balance atoms by using *coefficients* (in front of chemical formulas) to indicate the number of formula units or molecules of each reactant and product required.
2. Generally, begin by balancing the atom of which there is the greatest number. Find the lowest common multiple of the number of reactant and product atoms.
3. Continue progressively to balance the rest of the atoms.

Example: **Copper metal reacts with silver nitrate solution to produce silver and aqueous copper (II) nitrate.**

Note: Subscripts (s), (l) and (g) are used to indicate solid, liquid or gas and (aq) indicates an aqueous solution (in water).

Step 1: Write the word equation

Copper metal + silver nitrate → silver + copper (II) nitrate

Step 2: Write the chemical formulas

$\mathbf{Cu_{(s)} + AgNO_{3(aq)} \rightarrow Ag_{(s)} + Cu(NO_3)_{2(aq)}}$

Step 3: Count atoms of each type for reactants and products.

1 Cu	**1 Cu**
1 Ag	**1 Ag**
1 NO_3	**2NO_3**

Note that NO_3 is treated as one complex ion.

Step 4: Balance the equation.

$\mathbf{Cu_{(s)} + 2AgNO_{3(aq)} \rightarrow 2Ag_{(s)} + Cu(NO_3)_{2(aq)}}$

Note that balancing the nitrate ion affects the silver, which must also be balanced.

Examples:

1. ___ $Mg_{(s)}$ + ___ $O_{2(g)}$ → ___ $MgO_{(s)}$

2. ___$Cu_{(s)}$ + ___ $AgNO_{3(aq)}$ → ___ $Ag_{(s)}$ + ___ $Cu(NO_3)_{2(aq)}$

3. ___ $Pb(NO_3)_{2(aq)}$ + ___$KI_{(aq)}$ → ___ $PbI_{2(s)}$ + ___ $KNO_{3(aq)}$

4. ___ $NH_{3(g)}$ → ___ $N_{2(g)}$ + ___ $H_{2(g)}$

5. ___$CH_{4(g)}$ + ___$O_{2(g)}$ → ___ $CO_{2(g)}$ + ___ $H_2O_{(g)}$

WRITING BALANCED CHEMICAL EQUATIONS

To write a balanced chemical equation from a statement or word equation:

- write the chemical formulas for all reactants and products involved (including sta
- Follow the steps outlined above for balancing equations

Examples:

Translate each of the following statements into word equations, then balanced chemical equations. Remember that ***The "HONorable Halogens" are all diatomic.***

1. Hydrogen and chlorine react to produce hydrogen chloride gas.

2. Word Equation:

3. Chemical Equation:

4. Solid potassium and aqueous magnesium chloride react to produce solid magnesium and aqueous potassium chloride.

5. Word Equation:

6. Chemical Equation:

7. Solid aluminum combines with oxygen gas to produce solid aluminum oxide.

8. Word Equation:

9. Chemical Equation:

10. Hydrogen peroxide decomposes (breaks down) into water and oxygen gas.

11. Word Equation:

12. Chemical Equation:

13. Zinc reacts with hydrochloric acid to produce zinc chloride solution and hydrogen gas.

14. Word. Equation:

15. Chemical Equation:

16. The combustion (burning) of ethyne gas, $C_2H_{2(g}$ in the presence of oxygen gas produces carbon dioxide gas and water vapor.

Word Equation:

Chemical Equation:

TYPES OF CHEMICAL REACTIONS

Reactions can be classified according to different types.

1. **Synthesis (*Formation, Composition)***
   - 2 elements (or 2 compounds) react to produce a single compound
   - states of reactants and products: usually all pure substances except acids (aq)

Element + element → compound

A + B → AB

Where A and B are atoms and /or molecules and AB is a larger molecule.

Examples: a) magnesium reacts with oxygen from the air

1. hydrogen and oxygen react to produce water

http://www.youtube.com/watch?v=-hQW5a5D5aE&safe=active

1. Decomposition

- A single compound is broken down (decomposed) into 2 or more products (elements &/or compounds)
- states of reactants and products: usually all pure substances except acids (aq)
- most require energy as heat, light or electricity

Compound → two or more elements or compounds

AB → A + B

Examples: a) mercury(II)oxide decomposes

b) water is broken down into its elements

1. Single Displacement (*Single Replacement)*

- An element and a compound react to produce a new element and new compound
- Metal elements replace the cation: metal ions in ionic compounds or H^+ ions in acids or water
- Nonmetal elements replace the anion: nonmetal ions in ionic compounds
- States of reactants and products
  - Metal elements: all pure substances (solid except for mercury, $Hg_{(l)}$).
  - Nonmetal elements: all pure substances (solid, liquid or gas).
  - Compound reactants: usually aqueous solution (aq) or water, $\mathbf{HOH_{(l)}}$
  - Compound products: if **ionic**, use solubility chart on back of periodic table

1. a) If compound is high solubility = aqueous (aq)
   b) If compound is low solubility = solid (s)

Generally single displacement reactions follow the pattern,

Element + compound → compound + element

Z + AB → ZB + A Where Z is a metal.

Or

Element + compound → compound + element

Y + AB → AY + B Where Y is a nonmetal

Ex1: potassium + calcium iodide → calcium + potassium iodide

Z + AB → A + ZB

Ex2: Bromine + calcium iodide → iodine + calcium bromide

Y + AB → B + AY

How do we decide which element is displaced? Generally, **metals replace metals** and **nonmetals replace nonmetals**. In the example above, iodine replaced bromine (both nonmetals).

Examples:

1. mercury and silver nitrate solution react

2. zinc reacts with sulfuric acid

3. calcium reacts with water

d) chlorine reacts with sodium bromide solution

4. **Double Displacement (*Double Replacement)***
   - Usually 2 ionic compounds in aqueous solution are reacting
   - Products may be one or more of:
     - Low solubility, therefore forms a precipitate (solid)- use solubility chart
     - A gas (that bubbles out of the mixture)
     - A molecular compound such as water ($HOH_{(l)}$)

compound + compound → compound + compound

AB + XY → AY + XB Where A and X are metals and B and Y are nonmetals

Example: Write the balanced chemical equation for the word equation given:

Potassium sulfate + copper (II) bromide → copper (II) sulfate + potassium bromide

Examples:

1. solutions of barium chloride and potassium carbonate react

2. solid iron(II)sulfide reacts with hydrochloric acid (one product is a gas)

5. Neutralization reaction

A neutralization reaction occurs between an acid and a base. The products of such a reaction are a salt and water.

Salt: Ionic compound that is produced by the reaction of an acid with a base.

Acid + Base → Salt + Water

An acid is added to a basic solution, the base is gradually consumed. When the entire base has reacted, the result is a solution of a salt and water. The solution is neither acidic nor basic. Any additional acid will make the solution acidic.

Examples: Write the chemical equation for the following:

a) the reaction between hydrochloric acid and sodium hydroxide.

b) the reaction between sulfuric acid and sodium hydroxide.

c) the reaction between sodium hydroxide and sulfuric acid

Examples of neutralization reactions:

- Oven cleaner
- Baking (baking soda + acids → CO_2 bubbles which get trapped in batter causing it to rise)
- Antacids (neutralize stomach acid)
- Swimming pools
- Soda-acid fire extinguishers ($H_2SO_{4(aq)} + 2NaHCO_{3(s)} \rightarrow Na_2SO_{4(aq)} + 2CO_{2(g)} + 2H_2O_{(l)}$

6. **Combustion**

What is complete combustion?

It is the rapid reaction of a substance with oxygen to produce compounds called oxides. More commonly referred to as burning.

Generally, **Hydrocarbon + oxygen → carbon dioxide + water vapour + energy (exothermic reaction)**

$C_xH_y + O_{2(g)}$ Ý → $CO_{2(g)} + H_2O_{(g)} + E$

-Energy produced is in the form of heat or light.

-Fuels used in our society are mainly hydrocarbons (gas, kerosene, candles, etc.) .

-Because of the high heat involved water is produced as a gas. Also, CO_2 is produced in such large amounts it is a contributor to the greenhouse effect.

Note: In balancing hydrocarbon combustion reactions, it is easiest to balance the C and H atoms first and the oxygen last.

Examples:

a) Combustion of propane $C_3H_{8(g}$.

a) Butane, $C_4H_{10(g)}$ is burned as fuel in a lighter

c) A candle, assume $C_{25}H_{52(s)}$, combusts in the presence of oxygen

Incomplete combustion: This occurs when not enough oxygen is available. In this case the products are carbon monoxide (CO – an extremely poisonous gas), carbon (C), carbon dioxide (CO_2), and water (H_2O). Incomplete combustion does not generate as much heat energy as complete combustion.

Example: Incomplete combustion of $C_3H_{8(}g)$

REACTION TYPES – GENERALIZATIONS

REACTION TYPE	GENERALIZATION	STATES
Formation (Synthesis)	2 elements (or 2 cpds) → single cpd	all pure substances
Decomposition	single cpd → Ý 2 or more products (elements &/or cpds)	all pure substances
Single Displacement	element + cpd → element + cpd	pure elements, $HOH_{(l)}$ or aqueous reactants, *s or aq products
Double Displacement	2 cpds→ 2 new cpds	aq reactants, $HOH_{(l)}$ *s or aq products
Complete Hydrocarbon Combustion	$C_xH_y + O_{2(g)} \rightarrow$Ý $CO_{2(g)} + H_2O_{(g)}$	

***Use the solubility chart to predict the state (aqueous or solid) of ionic** products of displacement reactions.

NOTE:

1. Write water as HOH in displacement reactions and as H_2O in other types.

2. All metallic elements are monatomic. Eg. $Na_{(s)}$ $Pb_{(s)}$ & all are solid, except $Hg_{(l)}$.

3. Some nonmetallic elements are diatomic ie. The "HONorable Halogens"

   $H_{2(g)}$ $O_{2(g)}$ $N_{2(g)}$ $F_{2(g)}$ $Cl_{2(g)}$ $Br_{2(l)}$ $I_{2(s)}$

4. All pure ionic compounds are solids.

5. Some pure molecular compounds are gases. Eg. NH_3 H_2S HCl and
   Nonmetal oxides of C, N, and S ie. CO_2 CO SO_2 SO_3 NO NO_2 N_2O

6. In Single Displacement Reactions:

   - metal elements replace metal ions in ionic compounds or H in acids or water
   - nonmetal elements replace nonmetal ions in ionic compounds