CHEMICAL REACTIONS

1. Physical and Chemical Changes

Physical changes are changes in which the identity of a substance does not change. Chemical composition of substances remain unchanged. Breaking of a glass, cutting of a sheet of paper, dissolving of salt in water, freezing of water…etc are physical changes.

- No new substance is formed.
- Some physical changes are reversible.

Changes that cause to produce new substances are called *chemical changes*. The rusting of iron, boiling of an egg, spoiling fruits, burning of coal…etc. are chemical changes. Chemical changes usually irreversible.

2. Understanding Chemical Changes

Evidence of a Chemical Reaction

Solid Formation (precipitation)

$3NaOH + AlCl_3 \rightarrow Al(OH)_3 + 3NaCl$

white ppt

2. Color Change

$Pb(NO_3)_2 + 2KI \rightarrow PbI_2 + 2KNO_3$

yellow ppt

3. Gas Release

$CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$

4. Heat Exchange

$2Al + Fe_2O_3 \rightarrow 2Fe + Al_2O_3 + Energy$

3. Chemical Equations

- A chemical equation shows the chemical formulas and relative amounts of all reactants and products.
- A substance that undergoes a reaction is called a ***reactant.***
- When reactants undergo a chemical change, each new substance formed is called ***a product.***

methane + oxygen → carbon dioxide + water

$CH_4 + O_2 \rightarrow CO_2 + H_2O$

Symbol	Meaning
$(s), (l), (g)$	substance in the solid, liquid, or gaseous state
(aq)	substance in aqueous solution (dissolved in water)
$\rightarrow$	"produces" or "yields," indicating result of reaction
$\rightleftarrows$	reversible reaction in which products can reform into reactants; final result is a mixture of products and reactants
$\xrightarrow{\Delta}$ or $\xrightarrow{heat}$	reactants are heated; temperature is not specified
$\xrightarrow{Pd}$	name or chemical formula of a catalyst, added to speed a reaction

In chemical reactions following properties remain constant.

- Types and number of reacting atoms,
- Total mass of substances.
- Total number of protons, neutrons, and electrons.

In chemical reactions following properties may change.

- Number of electrons and electronic configurations of atoms.
- Total number of moles, molecules and volumes.
- Physical properties like color, odor, taste and states.

4. Balancing Chemical Equations

Conservation of Mass

- The law of conservation of mass states that mass is neither created nor destroyed during chemical reactions. Total mass is constant in a chemical reaction. This is known as Lavoisier's Law.
- The number of atoms for each element must be the same on the reactants' side and on the products' side.
- A coefficient multiplies the number of atoms of each element in the formula that follows.
  - H_2O: 2 hydrogen atoms, 1 oxygen atom
  - $2H_2O$: 4 hydrogen atoms, 2 oxygen atoms

Below are some tips for balancing equations:

- Take the coefficients of the most complex compound as one.
- Balance the elements found in this most complex compound first.
- Balance the elements last that is free in reactants or products.
- Balance oxygen and hydrogen atoms at the end.

Never change the subscripts

Sample Problem A

Balance the equation for the reaction of iron(III) oxide with hydrogen to form iron and water.

Sample Problem A Solution

$1\ Fe_2O_3 + 3H_2 \rightarrow 2Fe + 3H_2O$

Sample Problem B

Balance the equation below with integer numbers.

$Na + H_2O \rightarrow NaOH + H_2$

Sample Problem B Solution

$1Na + 1H_2O \rightarrow 1NaOH + 1/2H_2$

Then,

$2Na + 2H_2O \rightarrow 2NaOH + 1H_2$

Sample Problem C

Aluminum reacts with arsenic acid, $HAsO_3$, to form H_2 and aluminum arsenate. Write a balanced equation for this reaction.

Sample Problem C

$1Al + 3HAsO_3 \rightarrow 3/2H_2 + 1Al(AsO_3)_3$

Then,

$2Al + 6HAsO_3 \rightarrow 3H_2 + 2Al(AsO_3)_3$

Sample Problem D

Find the unknown substance represented by X in the following balanced equation.

$4FeS_2 + 11O_2 \rightarrow 2Fe_2O_3 + 8X$

5. Types of Chemical Reactions

A. Combination (Synthesis) Reactions

- Whenever two or more substances combine to form a single product, the reaction is called a synthesis reaction.
- Combination reactions can be illustrated;

$A + B \rightarrow AB$

- Here are some examples;

$C + O_2 \rightarrow CO_2$, $4Fe + 3O_2 \rightarrow 2Fe_2O_3$

$CaO + H_2O \rightarrow Ca(OH)_2$, $N_2 + 3H_2 \rightarrow 2NH_3$

B. Decomposition (Analysis) Reactions

- In a decomposition reaction a single compound breaks down, often with the input of energy, into two or more elements or simpler compounds.
- Decomposition reactions can be illustrated;

$AB \rightarrow A + B$

- Here are some examples;

$NH_4NO_3 \rightarrow N_2O + 2H_2O$

$2H_2O_2 \rightarrow 2H_2O + O_2$

$2NaCl \rightarrow 2Na + Cl_2$

$PCl_5 \rightarrow PCl_3 + Cl_2$

C. Single Displacement Reactions

- In a displacement reaction a single element reacts with a compound and displaces another element from the compound.
- Displacement reactions can be illustrated;

$A + BC \rightarrow B + AC$

- Single displacement reactions mostly take place due to activity differences of elements. A more active element displaces a less active one.

$Zn(s) + CuSO_4(aq) \rightarrow Cu(s) + ZnSO_4(aq)$

$Fe(s) + NaCl(aq) \rightarrow$ No reaction

Activity of Some Metals

Li Rb K Ba Sr Ca Na Mg Al Mn Zn Cr Cd Fe Co Ni Sn Pb **H** Cu Hg Ag Pt Au (Activity Decreases $\rightarrow$)

Activity of Some Nonmetals

F Cl Br I (Activity Decreases $\rightarrow$)

Some examples;

$NaBr(aq) + Cl_2(g) \rightarrow 2NaCl(aq) + Br_2(g)$

$Ca(s) + 2H_2O \rightarrow Ca(OH)_2(aq) + H_2(g)$

$Mg(s) + 2CuCl(aq) \rightarrow MgCl_2(aq) + 2Cu(s)$

D. Double Displacement (Metathesis) Reactions

- In a double-displacement reaction two compounds in aqueous solution appear to exchange ions and form two new compounds.
- One of the products must be a solid precipitate, a gas, or a molecular compound, such as water.
- Double displacement reactions can be illustrated;

$AB + CD \rightarrow AD + CB$

- Some examples;

$HCl(aq) + NaOH(aq) \rightarrow HOH(l) + NaCl(aq)$

$Pb(NO_3)_2(aq) + K_2CrO_4(aq) \rightarrow PbCrO_4(ppt) + 2KNO_3(aq)$

E. Endothermic and Exothermic Reactions

A reaction which absorbs energy is endothermic reaction and which release energy is exothermic reaction

- Some examples;

$Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g) + Energy$ Exothermic Reaction

$H_2O(l) + Energy \rightarrow H_2(g) + O_2(g)$ Endothermic Reaction

F. Combustion Reactions

A combustion reaction is a reaction of a carbon-based compound with oxygen.

- Some examples;

$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O + heat$

$CH_3CH_2OH + 3O_2 \rightarrow 2CO_2 + 3H_2O + heat$

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + heat$