MODULE 5- REACTIONS

CHAPTER 7 OF TEXTBOOK

SECTION 7.11 AND 7.6

REACTIONS

TOPIC COVERED :

- ✓THE LAW OF CONSERVATION OF MASS
- ✓WRITING CHEMICAL EQUATIONS
- ✓CHEMICAL EQUATION COEFFICIENTS
- ✓BALANCING PROCEDURES FOR CHEMICAL EQUATIONS
- ✓SPECIAL SYMBOLS USED IN CHEMICAL EQUATIONS
- ✓CLASSES OF CHEMICAL REACTIONS

WHAT IS CHEMICAL REACTION?

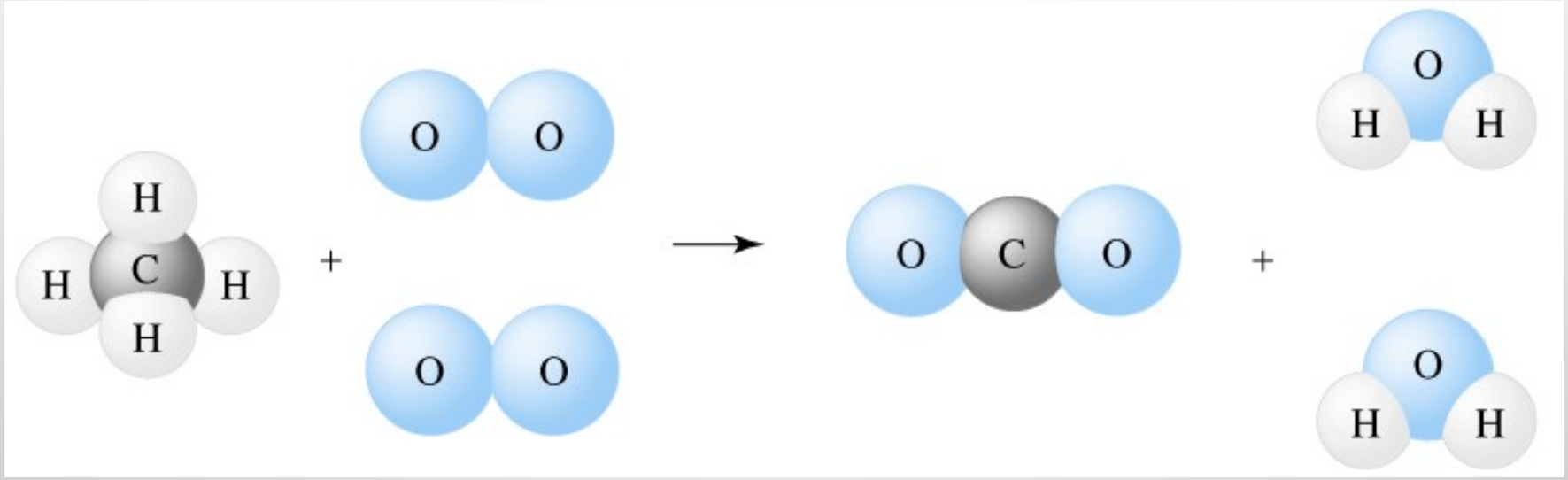
- CHEMICAL REACTION IS THE PROCESS IN WHICH AT LEAST ONE OR MORE NEW SUBSTANCES ARE PRODUCED AS A RESULT OF CHEMICAL CHANGE.
- EVIDENCES FOR CHEMICAL CHANGE.
  - COLOR CHANGE
  - EMISSION OF HEAT AND/OR LIGHT ENERGY
  - GAS EVOLUTION
  - FORMATION OF INSOLUBLE SOLID (PRECIPITATE)

STARTING MATERIALS FOR A CHEMICAL REACTION ARE :

- *REACTANTS* ARE THE STARTING SUBSTANCES THAT UNDERGO CHANGE IN A CHEMICAL REACTION.
- *PRODUCTS* ARE THE SUBSTANCES PRODUCED AS A RESULT OF A CHEMICAL REACTION.
- FROM A MOLECULAR VIEWPOINT, A CHEMICAL REACTION INVOLVES *THE UNION, SEPARATION OR REARRANGEMENT* OF ATOMS TO PRODUCE NEW SUBSTANCES.

THE LAW OF CONSERVATION OF MASS

MASS IS NEITHER CREATED NOR DESTROYED IN ANY ORDINARY CHEMICAL REACTION.



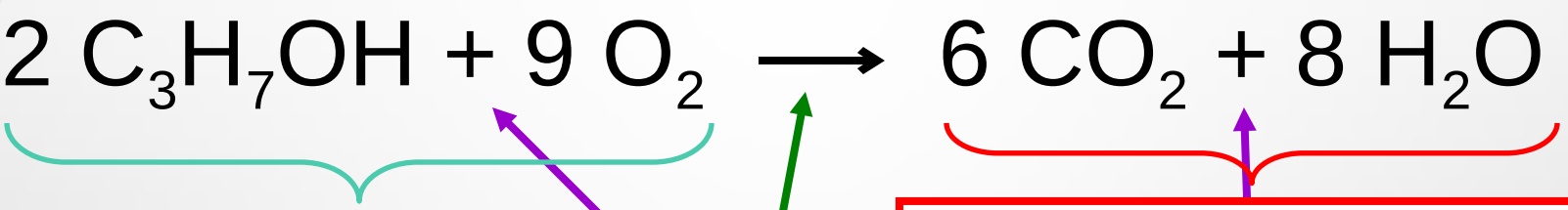
THEREFORE, THE TOTAL MASS OF REACTANTS IS ALWAYS EQUAL TO THE TOTAL MASS OF PRODUCTS.

WRITING AND BALANCING EQUATIONS

WRITING CHEMICAL EQUATIONS

- A *CHEMICAL EQUATION* IS A REPRESENTATION FOR A CHEMICAL REACTION THAT USES CHEMICAL SYMBOLS AND CHEMICAL FORMULAS TO DESCRIBE THE CHANGES THAT OCCUR IN A CHEMICAL REACTION.

IN WRITING CHEMICAL EQUATIONS, ONLY MOLECULAR FORMULAS ARE USED, NOT EMPIRICAL FORMULAS.



Reactants are written on the left side of the equation. These undergo chemical change.

Products are written on the right side of the equation. These are created by the chemical change.

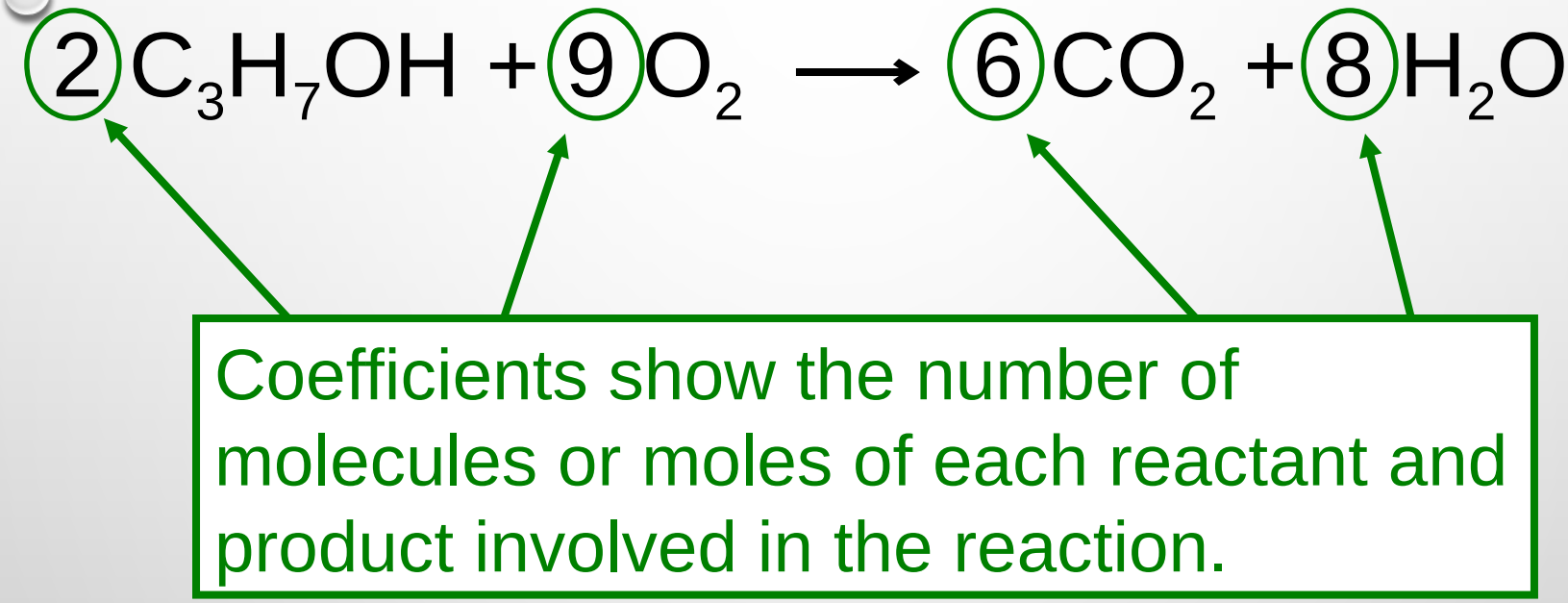
Reactants and products are separated by an arrow pointing to the products.

Different reactants and products are separated from each other using plus signs.

VALID CHEMICAL EQUATIONS

TO BE VALID A CHEMICAL EQUATION MUST SATISFY TWO CONDITIONS:

1. IT MUST BE CONSISTENT WITH EXPERIMENTAL FACTS
   - ✓ ONLY REACTANTS AND PRODUCTS INVOLVED IN THE REACTION ARE SHOWN
   - ✓ ACCURATE OR CORRECT FORMULAS MUST BE USED – NOT EMPIRICAL FORMULAS. DIATOMIC MOLECULES MUST BE PRESENT AS THE DIATOMIC, NOT SINGLE ATOMS (e.g. **H_2, O_2, N_2, F_2, Cl_2, Br_2, I_2, P_4, As_4, S_8**)
2. IT MUST BE CONSISTENT WITH THE LAW OF CONSERVATION OF MASS.
   - ✓ THE SAME NUMBER OF ATOMS OF EACH KIND ON EACH SIDE OF THE EQUATION.



This equation reads: "2 molecules of C_3H_7OH react with 9 molecules of O_2 to produce 6 molecules of CO_2 and 8 molecules of water."

$$2\ C_3H_7OH + 9\ O_2 \longrightarrow 6\ CO_2 + 8\ H_2O$$

For a chemical equation to be valid, it must:

1) Match the facts: for example, O_2, not O or O_3 is reacting with C_3H_7OH.

2) Obey the Law of Conservation of Mass - thus, equations must be balanced.

INFO ABOUT REACTION CONDITIONS MAY BE PLACED ABOVE OR BELOW THE ARROW.

heat is added

$$2\,Al + Fe_2O_3 \xrightarrow{\Delta} 2\,Fe + Al_2O_3$$

$$C_{11}H_{24} \xrightarrow[\text{catalyst}]{\text{heat}} C_9H_{20} + CH_2{=}CH_2$$

$$2\,H_2O \xrightarrow[\text{current}]{\text{electric}} 2\,H_2 + O_2$$

light

$$CH_4 + Cl_2 \xrightarrow{h\nu} CH_3Cl + HCl$$

The physical state of a substance may be indicated using symbols in parentheses after the substance. E.g.,

(s) for solid

(*l*) for liquid

(g) for gas

(aq) for aqueous solution

TO BALANCE AN EQUATION, ADJUST THE NUMBER OF ATOMS OF EACH ELEMENT SO THAT THEY ARE THE SAME ON EACH SIDE OF THE EQUATION.

Equations are balanced only by altering the equation coefficient for each item.

Never, never change a substance's formula to balance an equation.

STEPS FOR BALANCING EQUATIONS

Example: Write a balanced equation showing the decomposition of mercury (II) oxide to yield mercury and oxygen.

Step 1 Write the unbalanced (skeleton) equation.

$$HgO \rightarrow Hg + O_2$$

- The formulas of the reactants and products must be correct!
- The **reactants** are written to the left of the arrow and the **products** to the right of the arrow.

Step 2 Identify which elements need to be balanced.

- Count and compare the number of atoms of each element on both sides of the equation.

$$HgO \rightarrow Hg + O_2$$

Element	Reactant Side	Product Side
Hg	1	1

- There is one mercury atom on the reactant side and one mercury atom on the product side.
- Mercury is balanced.

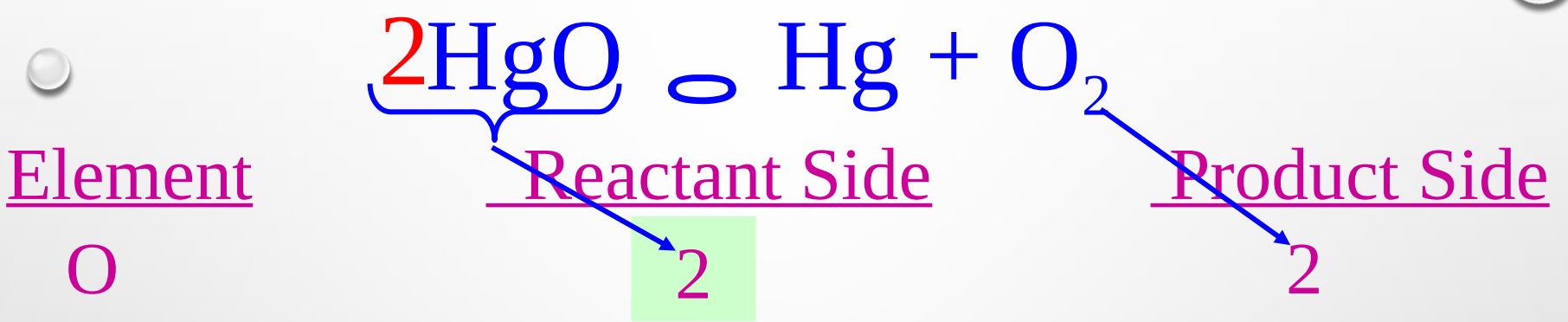
Element	Reactant Side	Product Side
O	1	2

- There are two oxygen atoms on the product side and there is one oxygen atom on the reactant side.
- Oxygen needs to be balanced.

Step 3 Balance the equation.

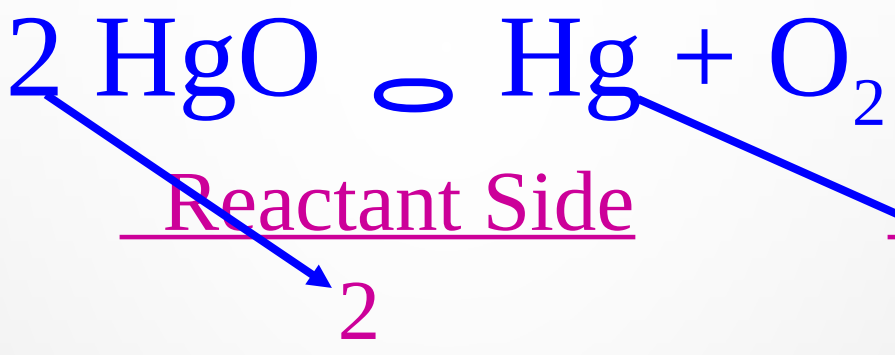
- Balance each element one at a time, by placing whole numbers (coefficients) in front of the formulas containing the unbalanced element.

- **A COEFFICIENT PLACED BEFORE A FORMULA MULTIPLIES EVERY ATOM IN THE FORMULA BY THAT NUMBER.**



- PLACE A 2 IN FRONT OF HgO TO BALANCE O.
- Now there are two oxygen atoms on the reactant side and there are two oxygen atoms on the product side.
- Oxygen (O) is balanced.

Step 4 Check all other elements after each individual element is balanced to see whether, in balancing one element, another element became unbalanced.



- THERE ARE TWO MERCURY ATOMS ON THE REACTANT SIDE AND THERE IS ONE MERCURY ATOM ON THE PRODUCT SIDE.
- THEREFORE, MERCURY (Hg) IS NO LONGER BALANCED.

$$2\,HgO \rightarrow 2\,Hg + O_2$$

Element	Reactant Side	Product Side
Hg	2	2

- Place a 2 in front of Hg to balance mercury.
- Now there are two mercury atoms on the reactant side and there are two mercury atoms on the product side.
- Mercury (Hg) is balanced.

¬¬ THE EQUATION IS BALANCED ¬¬

$$2\,HgO \rightarrow 2\,Hg + O_2$$

Element	Reactant Side	Product Side
Hg	2	2
O	2	2

GENERAL GUIDELINES:

THE COEFFICIENTS IN A BALANCED EQUATION ARE THE LOWEST WHOLE NUMBERS THAT WILL BALANCE THE EQUATION.

USEFUL TO CONSIDER POLYATOMIC IONS AS SINGLE ENTITIES, PROVIDED THEY MAINTAIN THEIR IDENTITIES IN THE REACTION.

SUBSCRIPTS ARE NEVER CHANGED!!!

GENERAL GUIDELINES:

IT IS USEFUL, WHEN BALANCING EQUATIONS THAT HAVE SEVERAL SUBSTANCES, TO USE THIS APPROACH…

BALANCE METALS.

BALANCE POLYATOMIC IONS IF STAY TOGETHER.

BALANCE NONMETALS.

BALANCE HYDROGEN.

BALANCE OXYGEN.

SUBSCRIPTS ARE NEVER CHANGED!!!

Write and Balance the Equation

EXAMPLE

When an aqueous solution of Sulfuric acid and an aqueous solution of Sodium hydroxide are mixed, the products are an aqueous solution of Sodium sulfate and Water.

$$H_2SO_4(aq) + NaOH(aq) \rightarrow Na_2SO_4(aq) + H_2O(l)$$

The Unbalanced (skeleton) Equation

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + H_2O(l)$$

	REACTANT SIDE	PRODUCT SIDE
SO_4	1	1
Na	1	2
O	1	1
H	3	2

Since the sulfate ion retains its identity in the products, we can treat it as a single entity in the balancing of the equation. The oxygen atoms not contained within the polyatomic ion will be considered separately.

2

2

4

There is one Na on the reactant side and there are two Na on the product side.

Place a 2 in front of NaOH to balance Na.

¬¬ THE EQUATION IS BALANCED ¬¬

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

	REACTANT SIDE	PRODUCT SIDE
SO_4	1	1
Na	2	2
O	2	1
H	4	2

2

4

Place a 2 in front of H_2O to balance H.

There are 4 H on the reactant side and two H on the product side.

Write and Balance the Equation

Example

When gaseous butane (C_4H_{10}) is completely burned in oxygen, the products are carbon dioxide and water.

$$C_4H_{10}(g) + O_2(g) \rightarrow CO_2(g) + H_2O(l)$$

Balance the Equation

$$C_4H_{10}(g) + O_2(g) \rightarrow 4CO_2(g) + H_2O(l)$$

ELEMENTS	REACTANT SIDE	PRODUCT SIDE
C	4	1
H	10	2
O	2	3

4

9

Place a 4 in front of CO_2 to balance C.

There are four C on the reactant side and there is one C on the product side.

$$C_4H_{10}(g) + O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$$

ELEMENTS	REACTANT SIDE	PRODUCT SIDE
C	4	4
H	10	2
O	2	9

10

13

Place a 5 in front of H_2O to balance H. There are 10 H on the reactant side and there are two H on the product side.

$$2\,C_4H_{10}(g) + O_2(g) \rightarrow 8\,CO_2(g) + 10\,H_2O(l)$$

	REACTANT SIDE	PRODUCT SIDE
C	4	4
H	10	10
O	2	13

8

20

8

20

26

To balance O double all of the other coefficients. There is no whole number coefficient that can be placed in front of O_2 to balance O.

¬¬ THE EQUATION IS BALANCED ¬¬

$$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$$

	REACTANT SIDE	PRODUCT SIDE
C	8	8
H	20	20
O	2	26

26

Place a 13 in front of O_2 to balance O.
There are now 26 O on the product side.

BALANCE THIS REACTION :

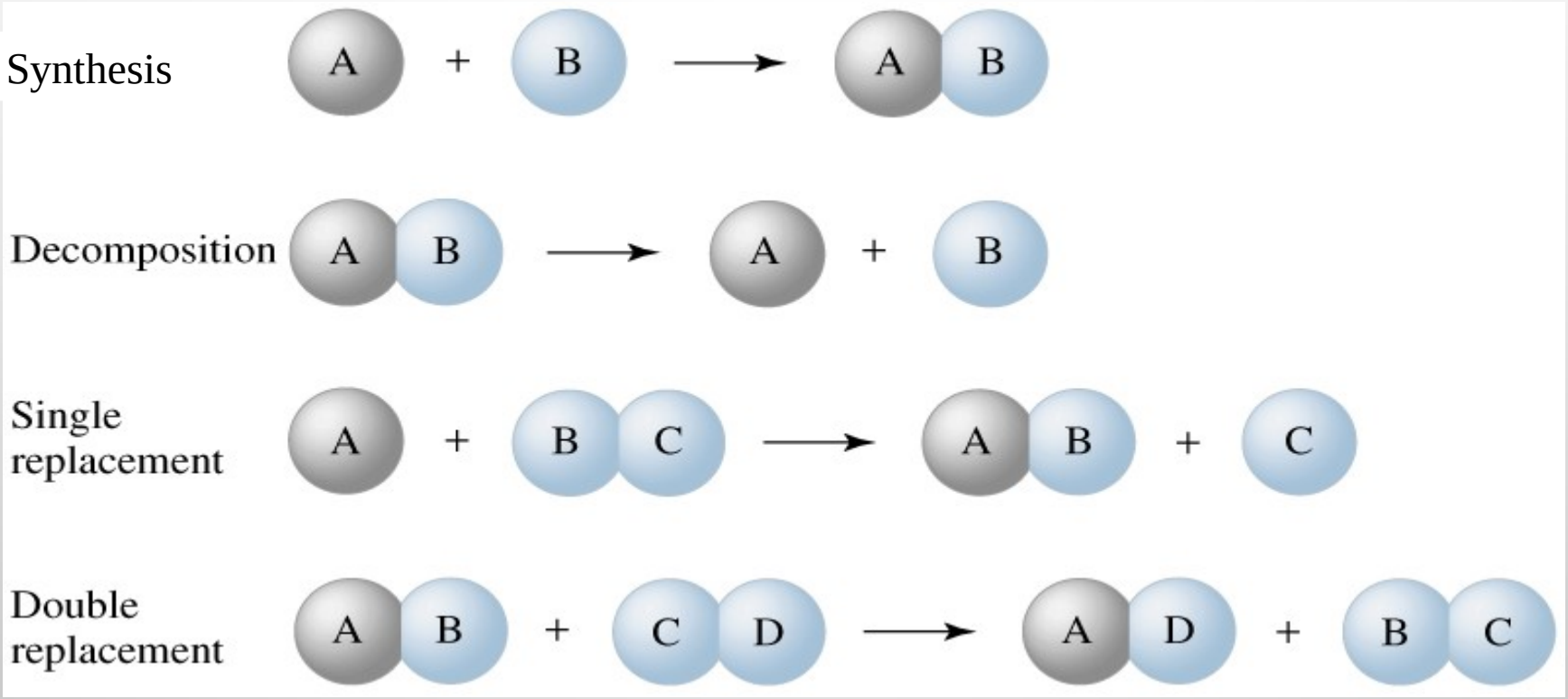
$$C_6H_{10}(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$$

	REACTANTS SIDE	PRODUCTS SIDE
C	6	1
H	10	2
O	2	3

THE BALANCED EQUATION WILL BE

$$2C_6H_{10}(g) + 17O_2(g) \rightarrow 12CO_2(g) + 10H_2O(g)$$

TYPES OF CHEMICAL REACTIONS



- **COMBUSTION REACTIONS - INVOLVE OXYGEN (TYPICALLY FROM THE AIR)**

Synthesis Reaction

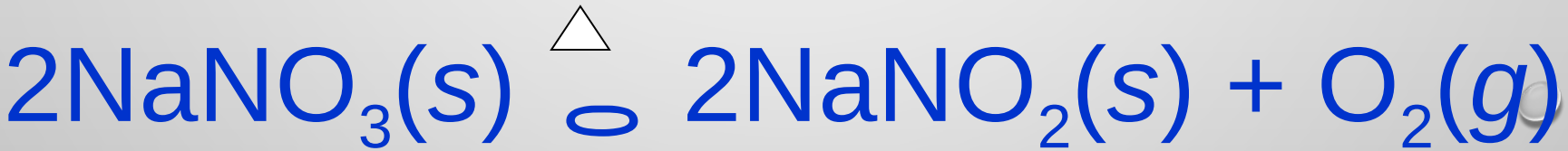
Two reactants combine to form one product.

In a synthesis reaction, there is only one product.

Decomposition Reaction

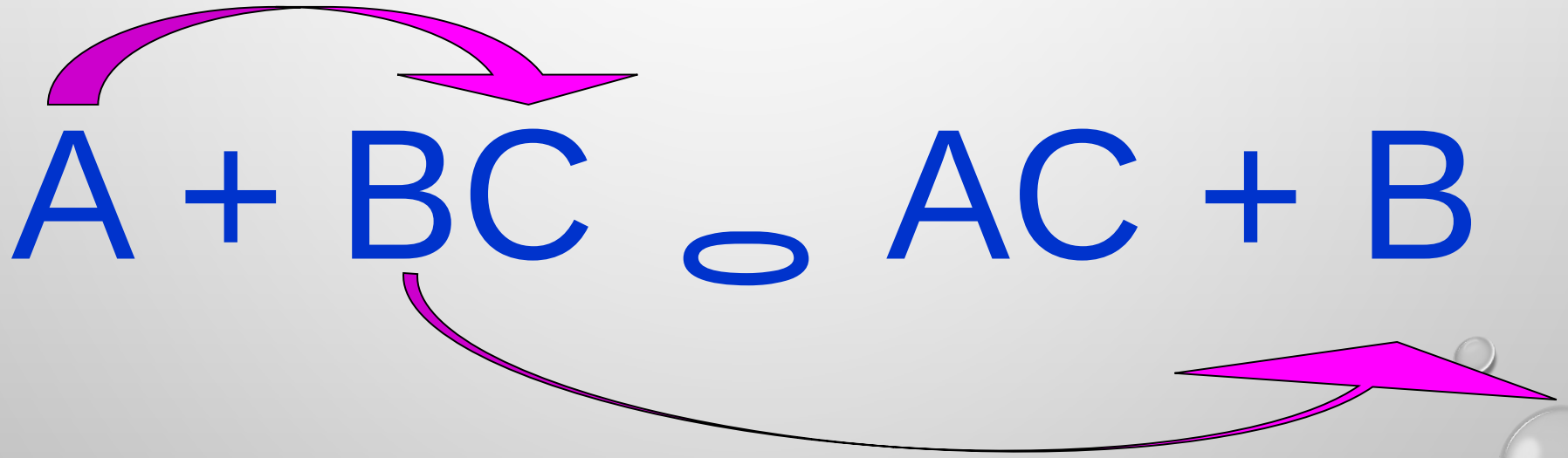
A single substance breaks down to give two or more different substances.

In a decomposition reaction, there is only one reactant.



Single Displacement Reaction

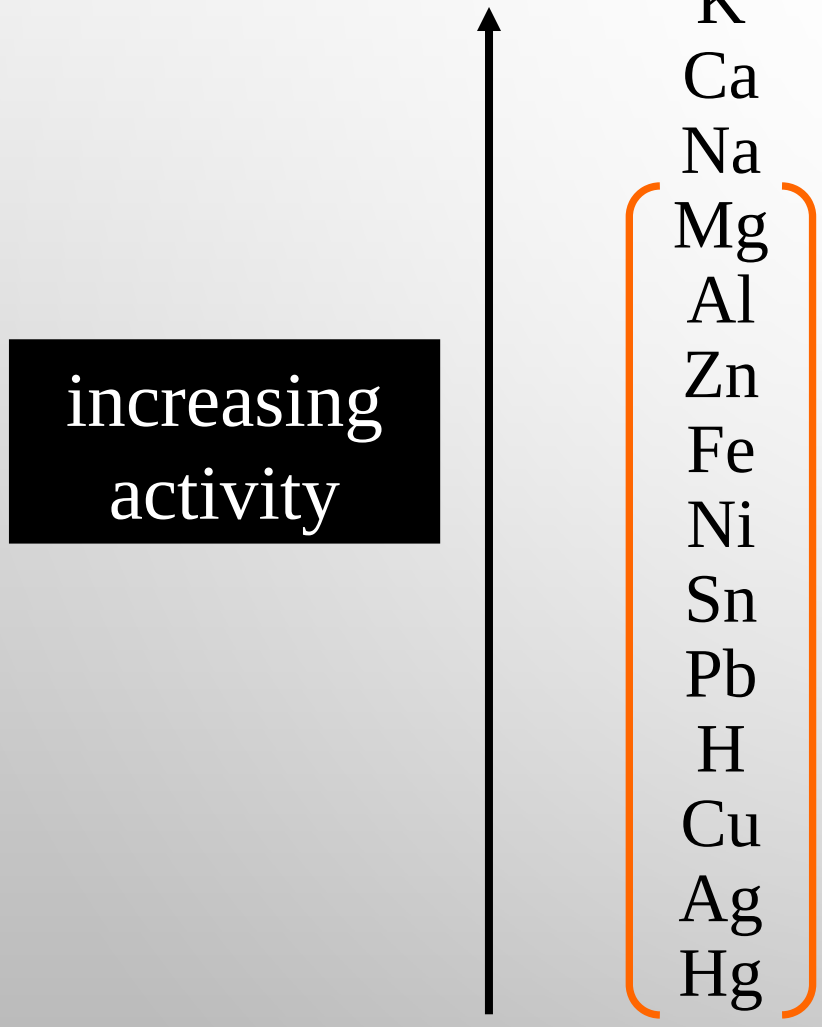
One element reacts with a compound to replace one of the elements of that compound.



$$Mg(s) + HCl(aq) \rightarrow H_2(g) + MgCl_2(aq)$$

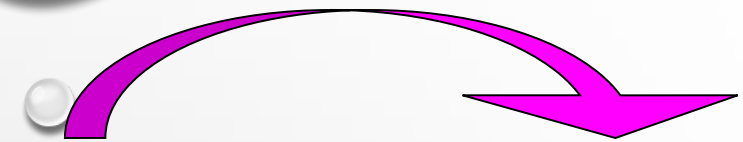
Notice that the formula for the magnesium-chloride compound is $MgCl_2$, not MgCl. You will have to be able to write correct formulas based on your understanding of the ions involved; (Mg $\rightarrow$ Mg^{2+}, therefore 2 Cl^- ions are required to balance the charges).

The Activity Series



An atom of an element in the activity series will displace an atom of any element below it from one of its compounds .

Sodium (Na) will displace any element below it from one of its compounds.



$$Mg(s) + PbS(s) \rightarrow MgS(s) + Pb(s)$$

Magnesium is above lead in the activity series.

$Ag(s) + CuCl_2(s) \rightarrow$?

<u>Metals</u>

Pb

H

Cu ← Silver is below copper in the activity series.

Ag

Hg

There is also a halogen activity series – it has the same order as the halogens are found in the Periodic Table

$Cl_2(g) + CaBr_2(s) \rightarrow$?

Halogens

F_2

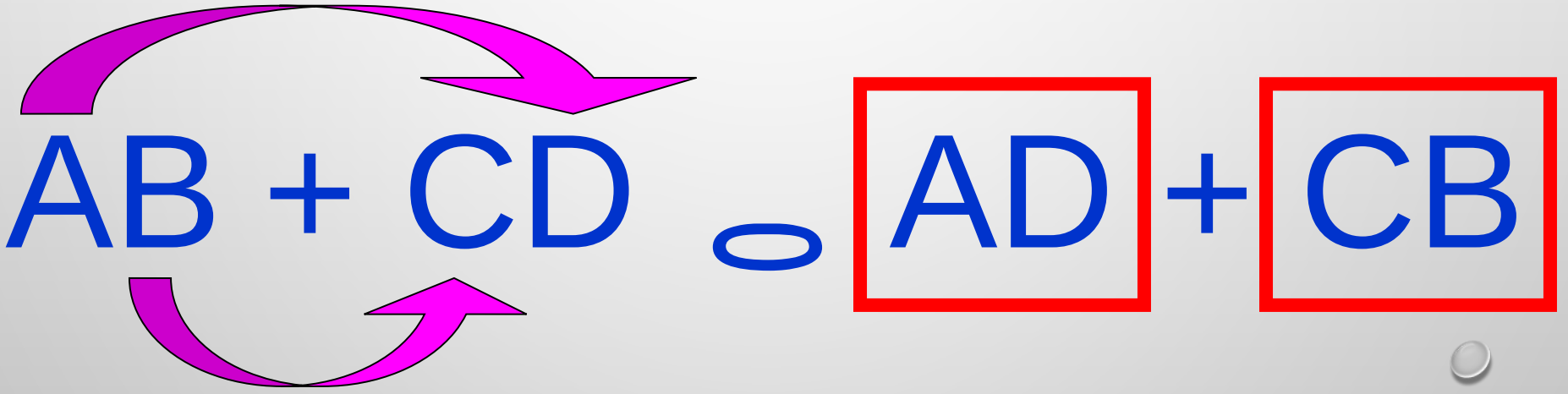
Cl_2 ← Chlorine is above bromine in the activity series.

Br_2

I_2

Double Displacement Reaction

And B combines with C



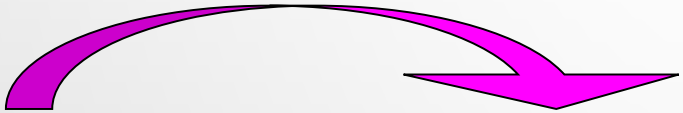
ONE OR MORE OF THE FOLLOWING WILL ACCOMPANY A DOUBLE DISPLACEMENT REACTION

- FORMATION OF A PRECIPITATE
- FORMATION OF A GAS (RELEASE OF BUBBLES)
- RELEASE OR ABSORPTION OF HEAT
- FORMATION OF A MOLECULAR COMPOUND (E.G., H_2O)

A precipitate is a reaction product that isn't soluble in the reaction medium; it falls out of solution as it forms.

Acid Base Neutralization

acid + base → salt + water

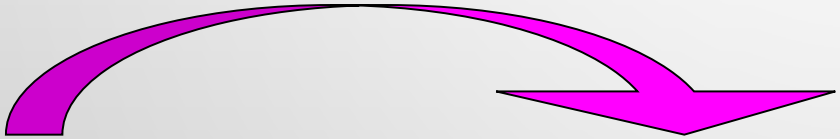


$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$

$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$

Formation of an Insoluble Precipitate

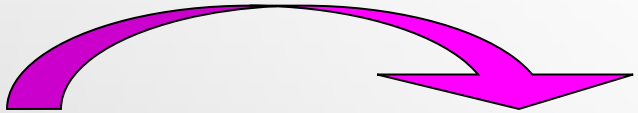
$AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$



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

Metal Oxide + Acid

metal oxide + acid → salt + water



$CuO(s) + 2HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + H_2O(l)$

$CaO(s) + 2HCl(aq) \rightarrow CaCl_2(s) + H_2O(l)$

Formation of a Gas

$H_2SO_4(aq) + 2NaCN(aq) \rightarrow Na_2SO_4(aq) + 2HCN(g)$

$NH_4Cl(aq) + NaOH(aq) \rightarrow NaCl(aq) + NH_4OH(aq)$

indirect gas formation

$NH_4OH(aq) \rightarrow NH_3(g) + H_2O(l)$

COMBUSTION REACTION

- A reaction in which a substance reacts with oxygen and which proceeds with the evolution of heat and usually also a flame.

$$2A + O_2 \longrightarrow 2AO$$

- **REACTANT CONTAIN OXYGEN GAS**
- **HYDROCARBONS (C_XH_Y) FORM CO_2 + H_2O**

$$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(g)$$