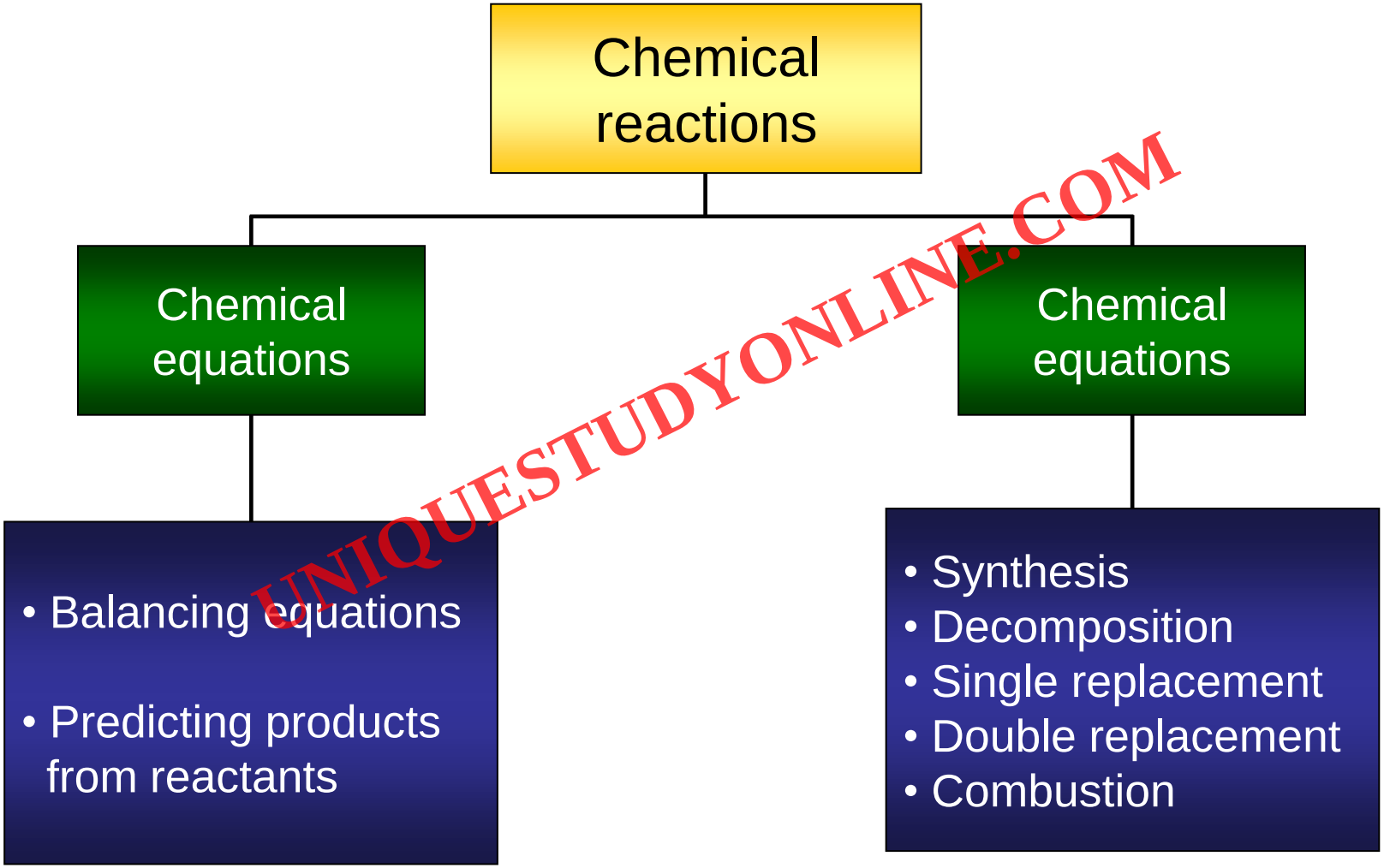
Chemical Equations & Reactions

Chemical Reactions

You should be able to

- Classify reactions by type.
- Write a balanced molecular equation, complete ionic equation, and a net ionic equation.
- Balance oxidation-reduction reactions.
- Predict if a precipitate will form using the solubility rules.
- Predict products of reactions given the chemical names of the reactants.

Organize Your Thoughts

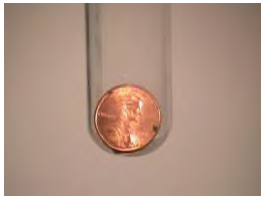


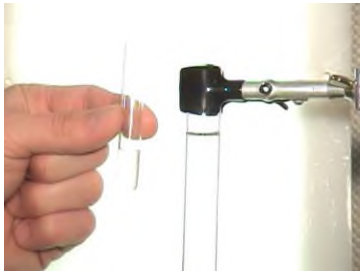
Packard, Jacobs, Marshall, Chemistry Pearson AGS Globe, page 175

Describing a Chemical Reaction

Indications of a Chemical Reaction

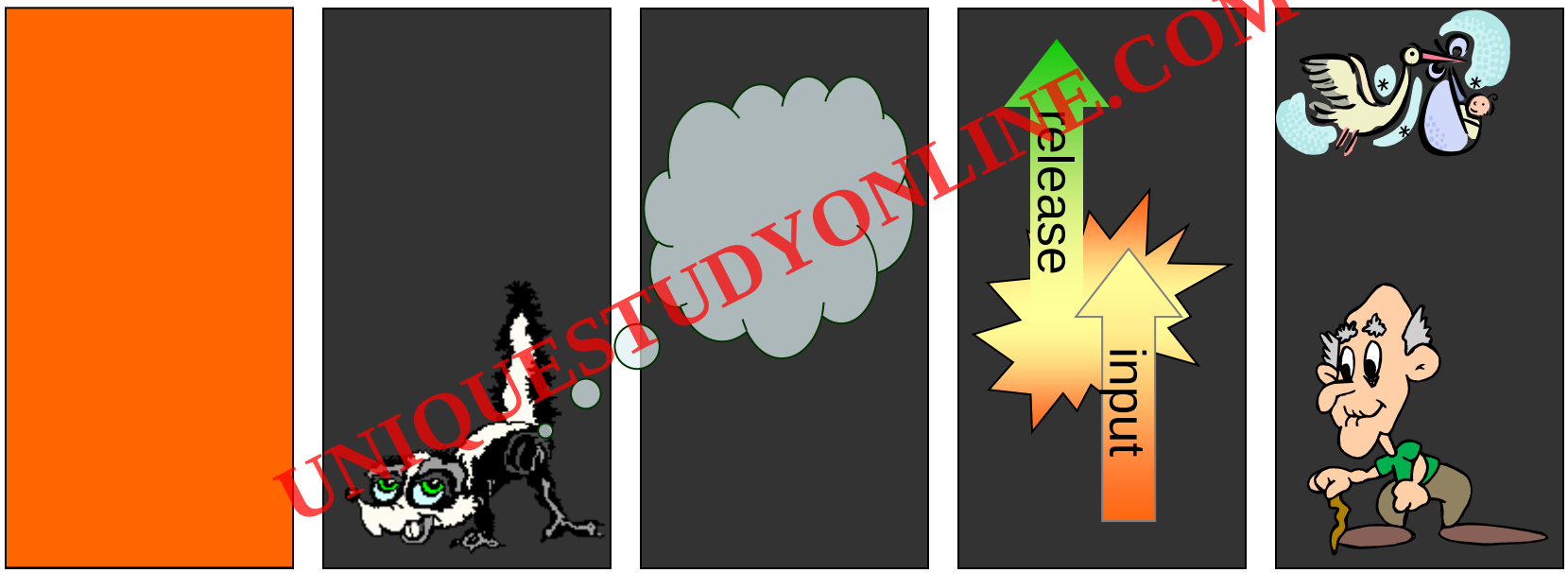
- Evolution of heat, light, and/or sound
- Production of a gas
- Formation of a precipitate
- Color change





Signs of Chemical Reactions

There are five main signs that indicate a chemical reaction has taken place:



change in color | change in odor | production of new gases or vapor | input or release of energy | difficult to reverse

Chemical Equations

aluminum oxide

Depict the kind of **reactants** and **products** and their relative amounts in a reaction.

$$4\ Al(s) + 3\ O_2(g) \longrightarrow 2\ Al_2O_3(s)$$

The letters (s), (g), and (l) are the physical states of compounds.

The numbers in the front are called **stoichiometric coefficients**.

Chemical Equations

aluminum oxide sandpaper

$4\ Al(s) + 3\ O_2(g) \longrightarrow 2\ Al_2O_3(s)$

$4\ g\ Al + 3\ g\ O_2$ yield $2\ g\ Al_2O_3$

This equation means:

4 Al atoms + 3 O_2 molecules yield 2 molecules of Al_2O_3

or

4 Al *moles* + 3 O_2 *moles* yield 2 *moles* of Al_2O_3

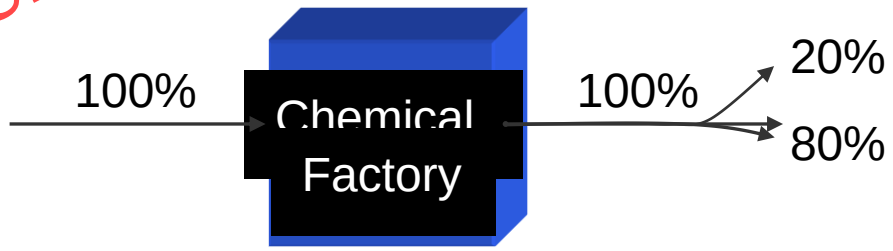
4 mol Al@27g/mol + 3 mol O_2@32g/mol = 2 mol Al_2O_3@102g/mol

108 g + 96 g = 204 g

Chemical Equations

Because the same atoms are present in a reaction at the beginning (*reactants*) and at the end (*products*), the amount of matter in a system does not change.

The Law of Conservation of Matter



Chemical Equations

Because of the principle of the **conservation of matter**,

An **equation must be balanced**.

It must have the same number of atoms of the same kind on both sides.

Lavoisier, 1788

Characteristics of Chemical Equations

- The equation must represent known facts.
- The equation must contain the correct formulas for the reactants and products.
- The law of conservation of mass must be satisfied.

Chemical Equations

- Reactants – the substances that exist **before** a chemical change (or reaction) takes place.

- Products – the **new** substance(s) that are formed during the chemical changes.

- CHEMICAL EQUATION indicates the reactants and products of a reaction.

REACTANTS → PRODUCTS

Word Equations

- A WORD EQUATION describes chemical change using the names of the reactants and products.

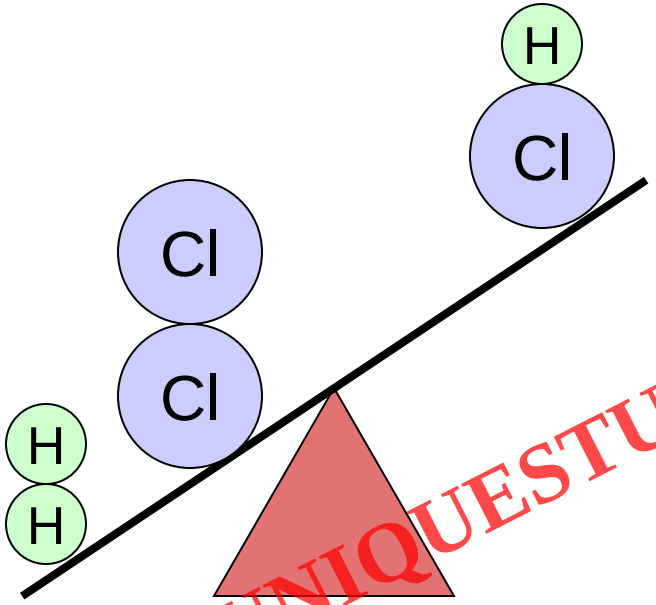
Write the word equation for the reaction of methane gas with oxygen gas to form carbon dioxide and water.

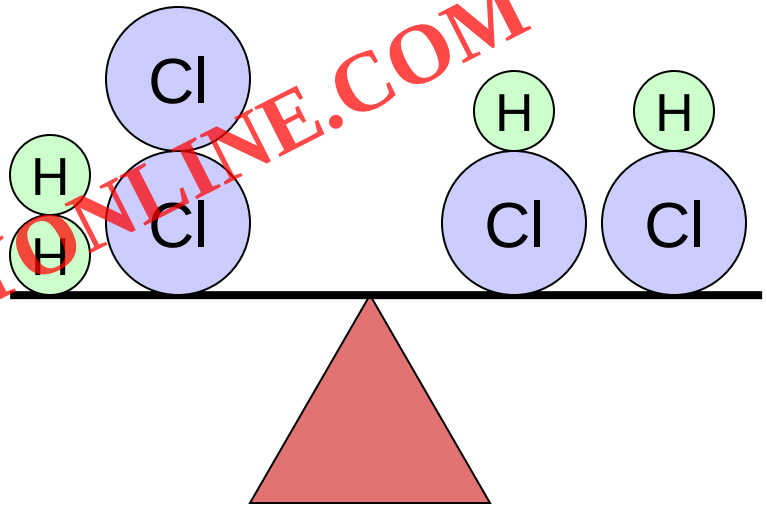
methane + oxygen ⟶ carbon dioxide + water

Reactant **Product**

$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$

Unbalanced and Balanced Equations





$H_2 + Cl_2 \rightarrow HCl$ (unbalanced)

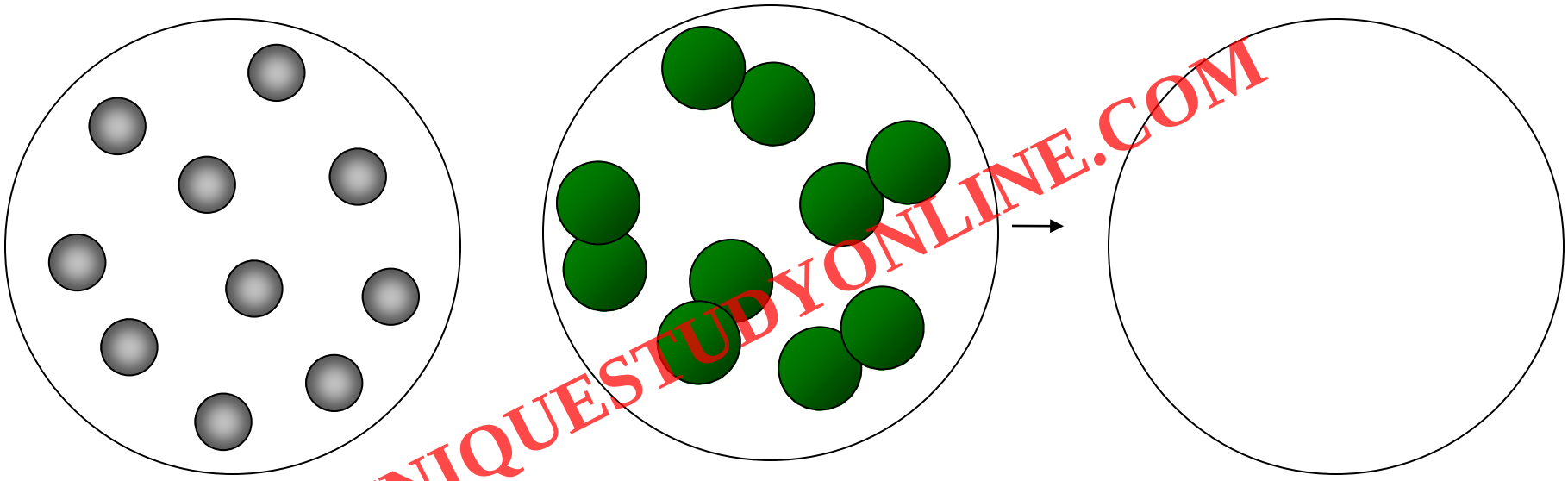
	reactants	products
H	2	1
Cl	2	1

$H_2 + Cl_2 \rightarrow 2\ HCl$ (balanced)

	reactants	products
H	2	2
Cl	2	2

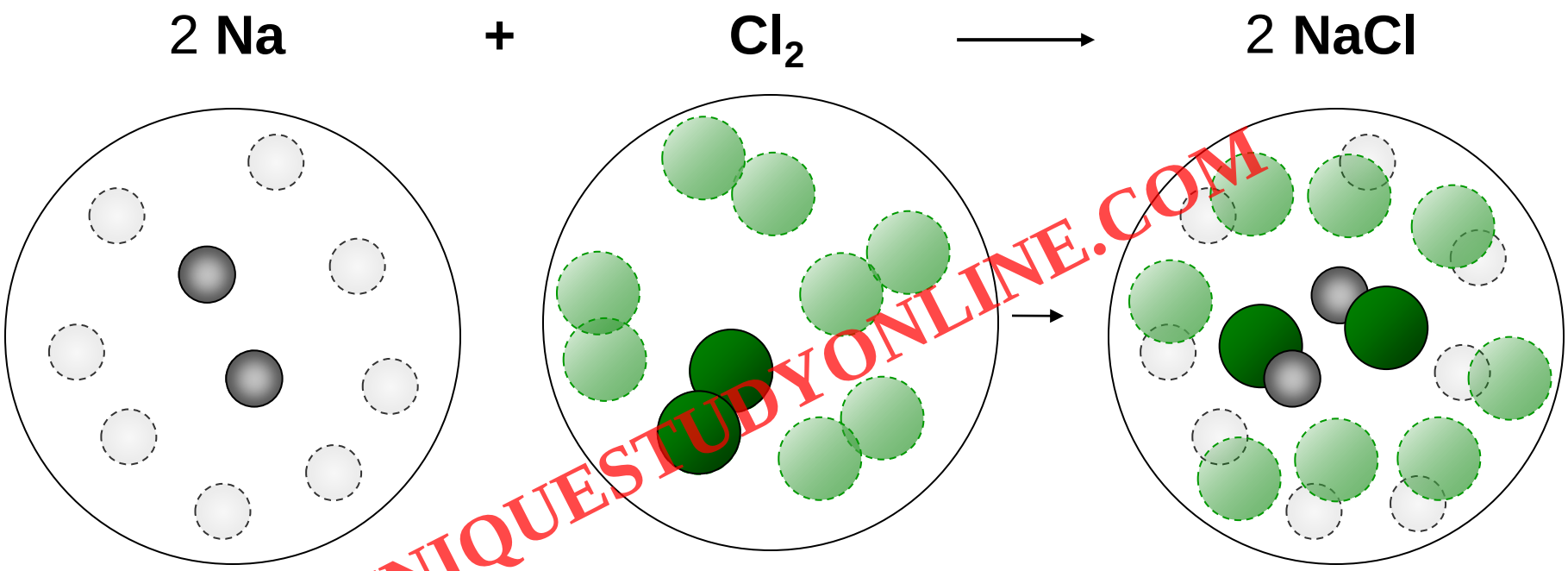
Visualizing a Chemical Reaction

2 **Na** + **Cl_2** ⟶ 2 **NaCl**

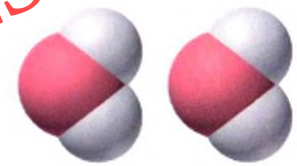


10 mole Na 5 mole Cl_2 10 mole NaCl

Visualizing a Chemical Reaction



Meaning of Chemical Formula

Chemical Symbol	Meaning		Composition
H_2O	One molecule of water:		Two H atoms and one O atom
2 H_2O	Two molecules of water:		Four H atoms and two O atoms
H_2O_2	One molecule of hydrogen peroxide:		Two H atoms and two O atoms

Balancing Chemical Equations

Balanced Equation – one in which the number of atoms of each element as a reactant is equal to the number of atoms of that element as a product

What is the relationship between conservation of mass and the fact that a balanced equation will always have the same number of atoms of each element on both sides of an equation?

Determine whether the following equation is balanced.

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

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

Balancing Chemical Equations

- Write a word equation for the reaction.
- Write the correct formulas for all reactants and products.
- Determine the coefficients that make the equation balance.

Balancing Chemical Equations

Other examples

$NO(g) + O_2(g) \rightarrow NO_2(g)$ is it balanced?

Is this balanced? $NO(g) + O(g) \rightarrow NO_2(g)$

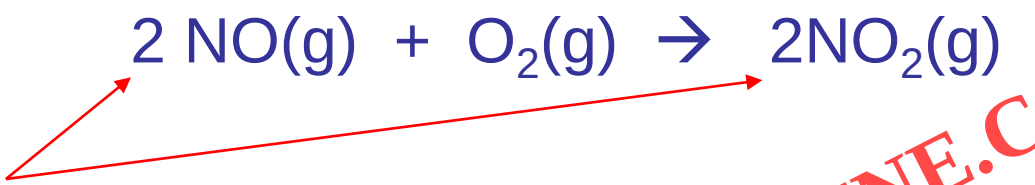
Is this OK?

Is this balanced? $NO(g) + \frac{1}{2} O_2(g) \rightarrow NO_2(g)$

Is this OK?

Balancing Chemical Equations

An important point to remember



The 2 to the left of NO(g) and NO_2(g) refers to the number of molecules present in the balanced equation.

It is a "multiplier" for every atom in the molecule.

The subscript 2 in O_2 (g) and NO_2(g) refers to the number of atoms of this type that are present in each molecules (or ionic compound).

Guidelines for Balancing Chemical Equations

1) polyatomic ions first
2) even / odd (make all even)
3) 2 H-OH vs. H_2O $Mg(OH)_2$
4) single elements last

Example: need 13 oxygen atoms

Multiply by "$\frac{13}{2}$" O_2 = 13

$$3X + \frac{13}{2} O_2 \longrightarrow 2Y + Z$$

$$2\left(3X + \frac{13}{2} O_2 \longrightarrow 2Y + Z\right)$$

$$6X + 13\ O_2 \longrightarrow 4Y + 2Z$$

$2\,(NH_4)_3PO_4 + 3\,Mg(OH)_2 \rightarrow Mg_3(PO_4)_2 + 6\,NH_4OH$?

ammonium phosphate | magnesium hydroxide | magnesium phosphate | ammonium hydroxide

NH_4^{1+} OH^{1-}

Now you try…

$2\,AlCl_3 + 3\,Li_2CO_3 \rightarrow Al_2(CO_3)_3 + 6\,LiCl$

Write a balanced equation for the reaction between chlorine and sodium bromide to produce bromine and sodium chloride.

1) Write a word equation for the reaction.

chlorine + sodium bromide → bromine + sodium chloride

2) Write the correct formulas for all reactants and products.

Cl_2 + NaBr → Br_2 + NaCl

3) Determine the coefficients that make the equation balance.

Cl_2 + 2 NaBr → Br_2 + 2 NaCl

Write the balanced equation for the reaction between aluminum sulfate and calcium chloride to form a white precipitate of calcium sulfate.

1) Write a word equation for the reaction.

? ?

aluminum sulfate + calcium chloride → calcium sulfate + aluminum chloride

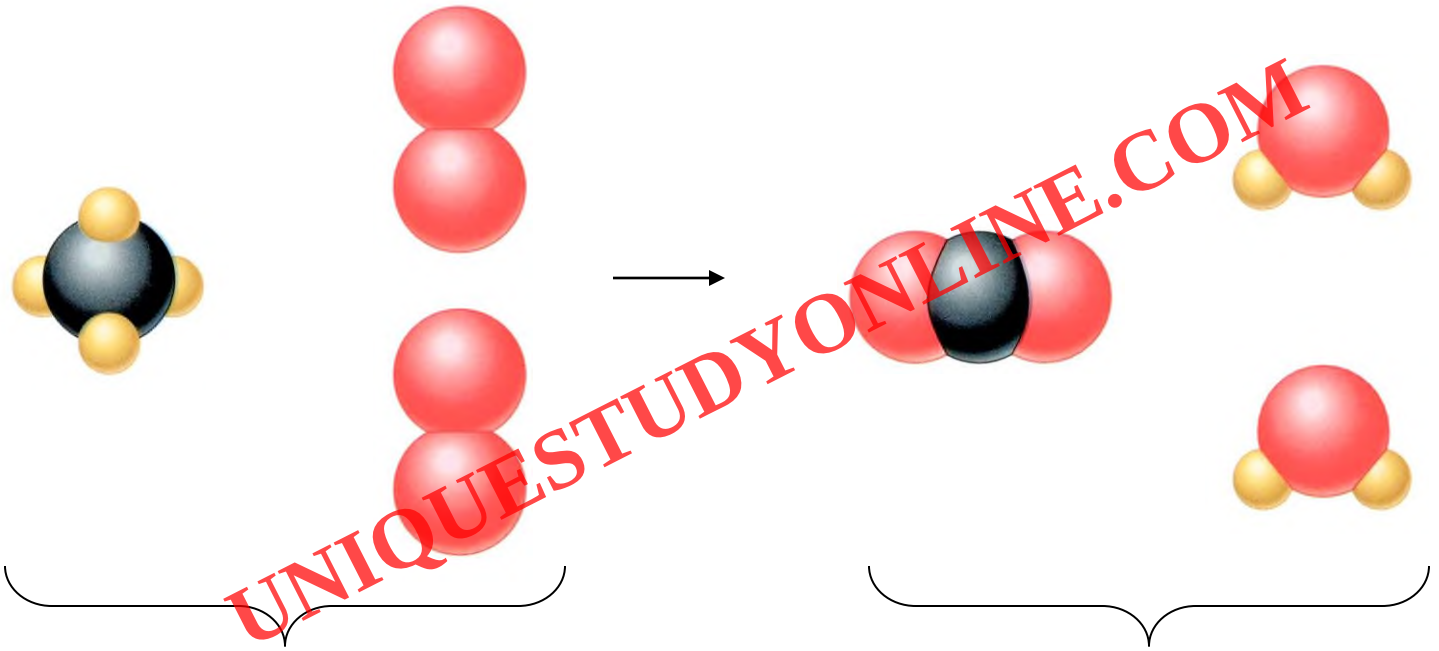
2) Write the correct formulas for all reactants and products.

$$Al_2(SO_4)_3 + CaCl_2 \rightarrow CaSO_4 + AlCl_3$$

3) Determine the coefficients that make the equation balance.

$$Al_2(SO_4)_3 + 3\,CaCl_2 \rightarrow 3\,CaSO_4 + 2\,AlCl_3$$

$$CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$$



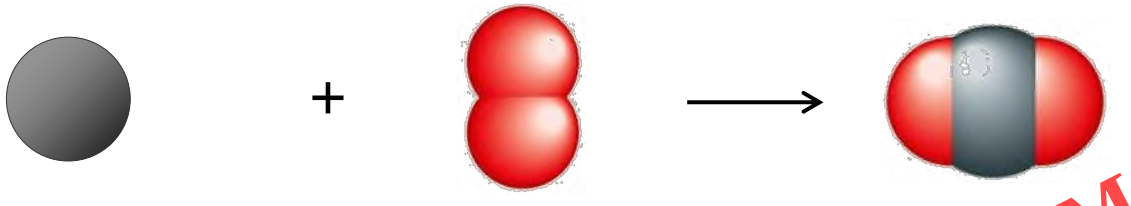
Reactants

1 C atom
4 H atoms
4 O atoms

Products

1 C atom
4 H atoms
4 O atoms

Reactants → Products

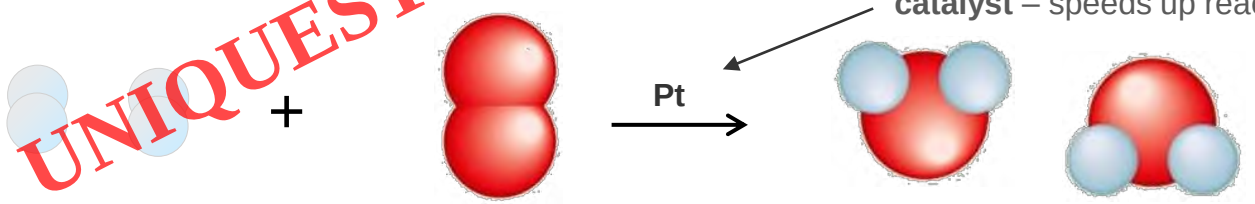


$C_{(s)}$ + $O_{2(g)}$ → $CO_{2(g)}$

carbon + oxygen → carbon dioxide

Reactants
1 carbon atom
2 oxygen atoms

Product
1 carbon atom
2 oxygen atoms



$2H_{2(g)}$ + $O_{2(g)}$ → $2H_2O$ (l)

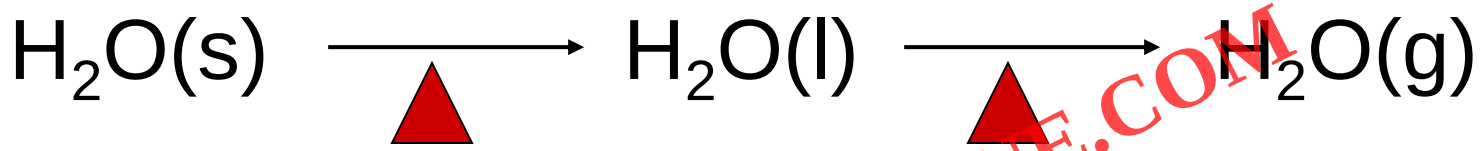
hydrogen + oxygen → water

Reactants
~~2~~ 4 hydrogen atoms
2 oxygen atoms

Product
~~2~~ 4 hydrogen atoms
~~1~~ 2 oxygen atoms

Unbalanced

Showing Phases in Chemical Equations

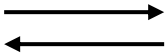


Solid Phase **– the substance is relatively rigid and has a definite volume and shape. NaCl(s)**

Liquid Phase **– the substance has a definite volume, but is able to change shape by flowing. $H_2O(l)$**

Gaseous Phase **– the substance has no definite volume or shape, and it shows little response to gravity. $Cl_2(g)$**

Additional Symbols Used in Chemical Equations

	"Yields"; indicates result of reaction
	Used to indicate a reversible reaction
(*s*)	A reactant or product in the solid state; also used to indicate a precipitate
	Alternative to (s), but used only to indicate a precipitate
(*l*)	A reactant or product in the liquid state
(*aq*)	A reactant or product in an aqueous solution (dissolved in water)
(*g*)	A reactant or product in the gaseous state

Additional Symbols Used in Chemical Equations

↑	Alternative to (g), but used only to indicate a gaseous product
$\xrightarrow{\Delta}$	Reactants are heated
$\xrightarrow{\text{2 atm}}$	Pressure at which reaction is carried out, in this case 2 atm
$\xrightarrow{\text{pressure}}$	Pressure at which reaction is carried out exceeds normal atmospheric pressure
$\xrightarrow{\text{0 }^{o}\text{C}}$	Temperature at which reaction is carried out, in this case 0 ^{o}C
$\xrightarrow{MnO_2}$	Formula of catalyst, in this case manganese (IV) oxide, used to alter the rate of the reaction

Solubility Ionic Equations

Cover the answers, work the problem, then check the answer.

1. Dissolve ammonium nitrate: $NH_4NO_3\ (s) \rightarrow NH_4^{+1}\ (aq) + NO_3^{-1}\ (aq)$

2. Precipitate cupric hydroxide: $Cu^{+2}\ (aq) + 2OH^{-1}\ (aq) \rightarrow Cu(OH)_2\ (s)$

3. Dissolve chromium thiocyanate: $Cr(SCN)_3\ (s) \rightarrow Cr^{+3}\ (aq) + 3SCN^{-1}\ (aq)$

4. Precipitate lead arsenate: $3Pb^{+2}\ (aq) + 2AsO_4^{-3}\ (aq) \rightarrow Pb_3(AsO_4)_2\ (s)$

5. Dissolve silicon permanganate: $Si(MnO_4)_4\ (s) \rightarrow Si^{+4}\ (aq) + 4MnO_4^{-1}\ (aq)$

6. Precipitate zinc phosphate: $3Zn^{+2}\ (aq) + 2PO_4^{-3}\ (aq) \rightarrow Zn_3(PO_4)_2\ (s)$

Types of Chemical Reactions

Synthesis (Combination) reaction $A + B \rightarrow AB$

Decomposition reaction $AB \rightarrow A + B$

[A]**Single-replacement** reaction $A + BC \rightarrow AC + B$ (element, compound, compound, element)

[B]**Double-replacement** reaction $AB + CD \rightarrow AD + CB$ (compound, compound, compound, compound)

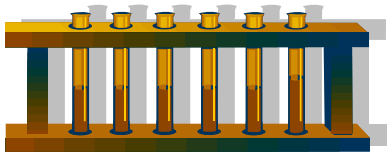
Neutralization reaction $HX + BOH \rightarrow BX + HOH$ (acid, base, salt, water)

Combustion reaction (of a hydrocarbon) $CH + O_2 \rightarrow CO_2 + H_2O$

Polymerization Polymer = monomer + monomer + …

[A]use activity series to predict

[B]driving force…*water*, *gas*, or *precipitate*

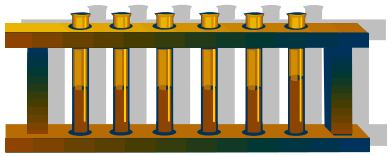


Types of Chemical Reactions

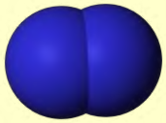
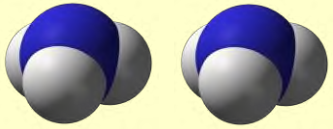
Synthesis (Combination) reaction	$A + B \rightarrow AB$
Decomposition reaction	$AB \rightarrow A + B$
[A]Single-replacement reaction	$A + BC \rightarrow AC + B$
[B]Double-replacement reaction	$AB + CD \rightarrow AD + CB$
Neutralization reaction	$HX + BOH \rightarrow BX + HOH$
Combustion reaction (of a hydrocarbon)	$CH + O_2 \rightarrow CO_2 + H_2O$
Polymerization	Polymer = monomer + monomer + …

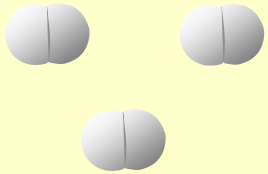
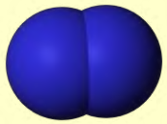
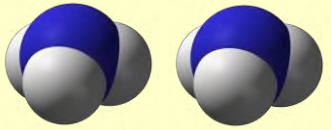
[A]use activity series to predict

[B]driving force…water, gas, or precipitate



Chemical Equations

	N_2 (*g*)	+	3 H_2 (*g*)	→	2 NH_3 (*g*)
		+		→	
"Microscopic recipe"	1 molecule N_2	+	3 molecules H_2	→	2 molecules NH_3
"Macroscopic recipe"	1 mol N_2	+	3 mol H_2	→	2 mol NH_3

Experimental Conditions	Reactants		Products
Before reaction	 2 molecules N_2	 3 molecules H_2	0 molecules NH_3
After reaction	 1 molecules N_2	0 molecules H_2	 2 molecules NH_3

Nitrogen is in excess – or hydrogen is limiting reagent.

Synthesis Reaction

Direct combination reaction (Synthesis)

$2\ Na + Cl_2 \rightarrow 2\ NaCl$

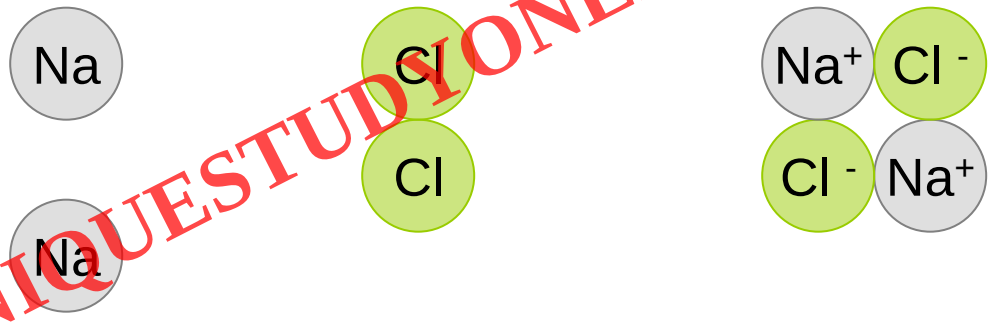
General form: **A** + **B** → **AB**

element or compound + element or compound → compound

Synthesis Reaction

Direct combination reaction (Synthesis)

$2\ Na + Cl_2 \rightarrow 2\ NaCl$

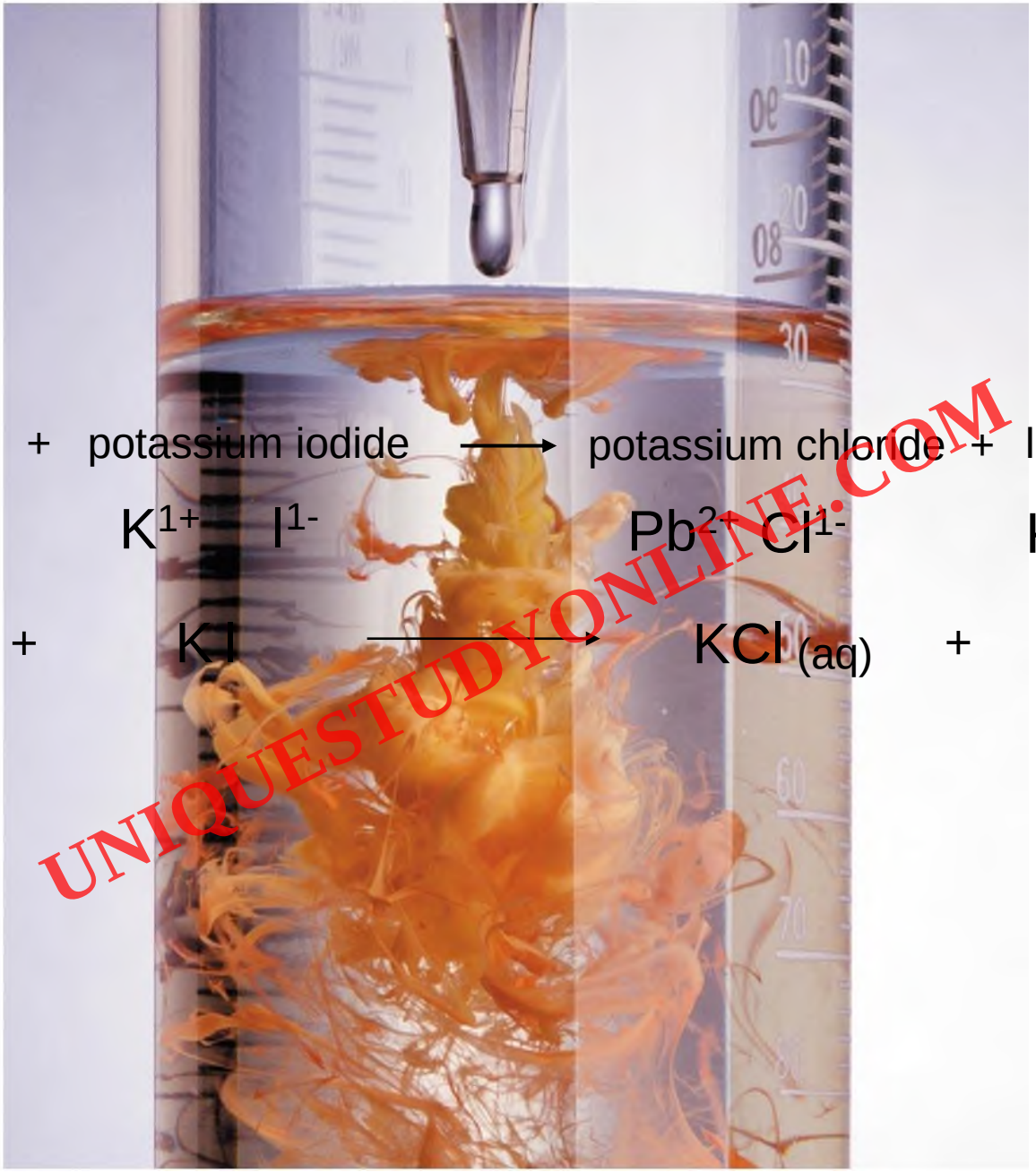


General form: **A** + **B** → **AB**

element or compound + element or compound → compound

Formation of a solid: AgCl

$AgNO_3(aq) + KCl(aq) \rightarrow KNO_3(aq) + AgCl(s)$



lead (II) chloride + potassium iodide → potassium chloride + lead (II) iodide

Pb^{2+} Cl^{1-} K^{1+} I^{1-} Pb^{2+} Cl^{1-} K^{1+} I^{1-}

$PbCl_2 + KI \longrightarrow KCl_{(aq)} + PbI_{2\,(ppt)}$

lead (II) chloride + potassium iodide ⟶ potassium chloride + lead (II) iodide

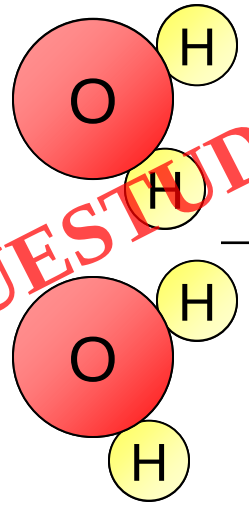
Pb^{2+} Cl^{1-} K^{1+} I^{1-} Pb^{2+} Cl^{1-} K^{1+} I^{1-}

$PbCl_2 + KI \longrightarrow KCl_{(aq)} + PbI_{2\,(ppt)}$

Decomposition Reaction

Decomposition reaction

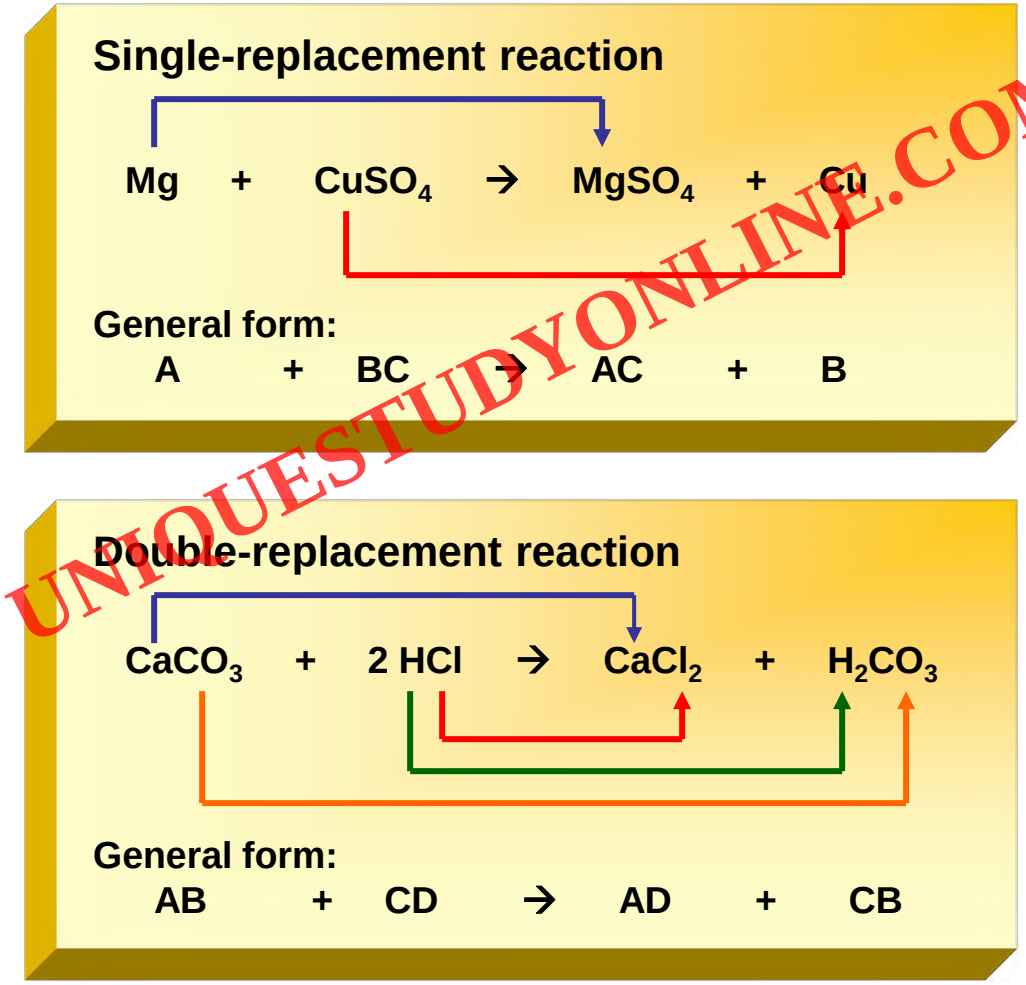
$2\ H_2O \longrightarrow 2\ H_2 + O_2$



General form: AB → A + B

compound → two or more elements or compounds

Single and Double Replacement Reactions



Activity Series

Printable Version of Activity Series

Foiled again –
Aluminum loses to Calcium

Element Reactivity

Li
Rb
K
Ba
Ca
Na
Mg
Al
Mn
Zn
Cr
Fe
Ni
Sn
Pb
H_2
Cu
Hg
Ag
Pt
Au

Halogen Reactivity

F_2
Cl_2
Br_2
I_2

TABLE OF SOLUBILITIES IN WATER

	acetate	bromide	carbonate	chloride	chromate	hydroxide	iodide	nitrate	phosphate	sulfate	sulfide
aluminum	ss	s	n	s	n	i	s	s	i	s	d
ammonium	s	s	s	s	s	s	s	s	s	s	s
barium	s	s	i	s	i	s	s	s	i	i	d
calcium	s	s	i	s	s	ss	s	s	i	ss	d
copper (II)	s	s	i	s	i	i	n	s	i	s	i
iron (II)	s	s	i	s	n	i	s	s	i	s	i
iron (III)	s	s	n	s	i	i	n	s	i	ss	d
lead	s	ss	i	ss	i	i	ss	s	i	i	i
magnesium	s	s	i	s	s	i	s	s	i	s	d
mercury (I)	ss	i	i	i	ss	n	i	s	i	ss	i
mercury (II)	s	ss	i	s	ss	i	i	s	i	d	i
potassium	s	s	s	s	s	s	s	s	s	s	s
silver	ss	i	i	i	ss	n	i	s	i	ss	i
sodium	s	s	s	s	s	s	s	s	s	s	s
zinc	s	s	i	s	s	i	s	s	i	s	i

Legend

i = **SOLID**
ss = **SOLID**
s = **AQUEOUS**
d = decomposes
n = not isolated

TABLE OF SOLUBILITIES IN WATER

	acetate	bromide	carbonate	chloride	chromate	hydroxide	iodide	nitrate	phosphate	sulfate	sulfide
aluminum	*s*	*aq*	n	*s*	n	*s*	*aq*	*aq*	*s*	*aq*	d
ammonium	*aq*	*aq*	*aq*	*aq*	*aq*	*aq*	*aq*	*aq*	*aq*	*aq*	*aq*
barium	*aq*	*aq*	*s*	*aq*	*s*	*aq*	*aq*	*aq*	*s*	*s*	d
calcium	*aq*	*aq*	*s*	*aq*	*aq*	*ss*	*aq*	*aq*	*s*	*s*	d
copper (II)	*aq*	*aq*	*s*	*aq*	*s*	*s*	n	*aq*	*s*	*aq*	*s*
iron (II)	*aq*	*aq*	*s*	*aq*	n	*s*	*s*	*aq*	*s*	*aq*	*s*
iron (III)	*aq*	*aq*	n	*aq*	*s*	*s*	n	*aq*	*s*	*s*	d
lead	*aq*	*s*	*s*	*ss*	*s*	*s*	*s*	*aq*	*s*	*s*	*s*
magnesium	*aq*	*aq*	*s*	*aq*	*aq*	*s*	*aq*	*aq*	*s*	*aq*	d
mercury (I)	*s*	*s*	*s*	*s*	*s*	n	*s*	*aq*	*s*	*s*	*si*
mercury (II)	*aq*	*s*	*s*	*aq*	*s*	*s*	*s*	*aq*	*s*	d	*si*
potassium	*aq*	*aq*	*aq*	*aq*	*aq*	*aq*	*aq*	*aq*	*aq*	*aq*	*aq*
silver	*s*	*s*	*s*	*s*	*s*	n	*s*	*s*	*s*	*s*	*s*
sodium	*aq*	*aq*	*aq*	*aq*	*aq*	*aq*	*aq*	*aq*	*aq*	*aq*	*aq*
zinc	*aq*	*aq*	*s*	*aq*	*aq*	*s*	*aq*	*aq*	*s*	*aq*	*s*

Legend

s = solid
aq = aqueous
d = decomposes
n = not isolated

TABLE OF SOLUBILITIES IN WATER

	acetate	bromide	carbonate	chloride	chromate	hydroxide	iodide	nitrate	phosphate	sulfate	sulfide
aluminum	ss	s	n	s	n	i	s	s	i	s	d
ammonium	s	s	s	s	s	s	s	s	s	s	s
barium	s	s	i	s	i	s	s	s	i	i	d
calcium	s	s	i	s	s	ss	s	s	i	ss	d
copper (II)	s	s	i	s	i	i	n	s	i	s	i
iron (II)	s	s	i	s	n	i	s	s	i	s	i
iron (III)	s	s	n	s	i	i	n	s	i	ss	d
lead	s	ss	i	ss	i	i	ss	s	i	i	i
magnesium	s	s	i	s	s	i	s	s	i	s	d
mercury (I)	ss	i	i	i	ss	n	i	s	i	ss	i
mercury (II)	s	ss	i	s	ss	i	i	s	i	d	i
potassium	s	s	s	s	s	s	s	s	s	s	s
silver	ss	i	i	i	ss	n	i	s	i	ss	i
sodium	s	s	s	s	s	s	s	s	s	s	s
zinc	s	s	i	s	s	i	s	s	i	s	i

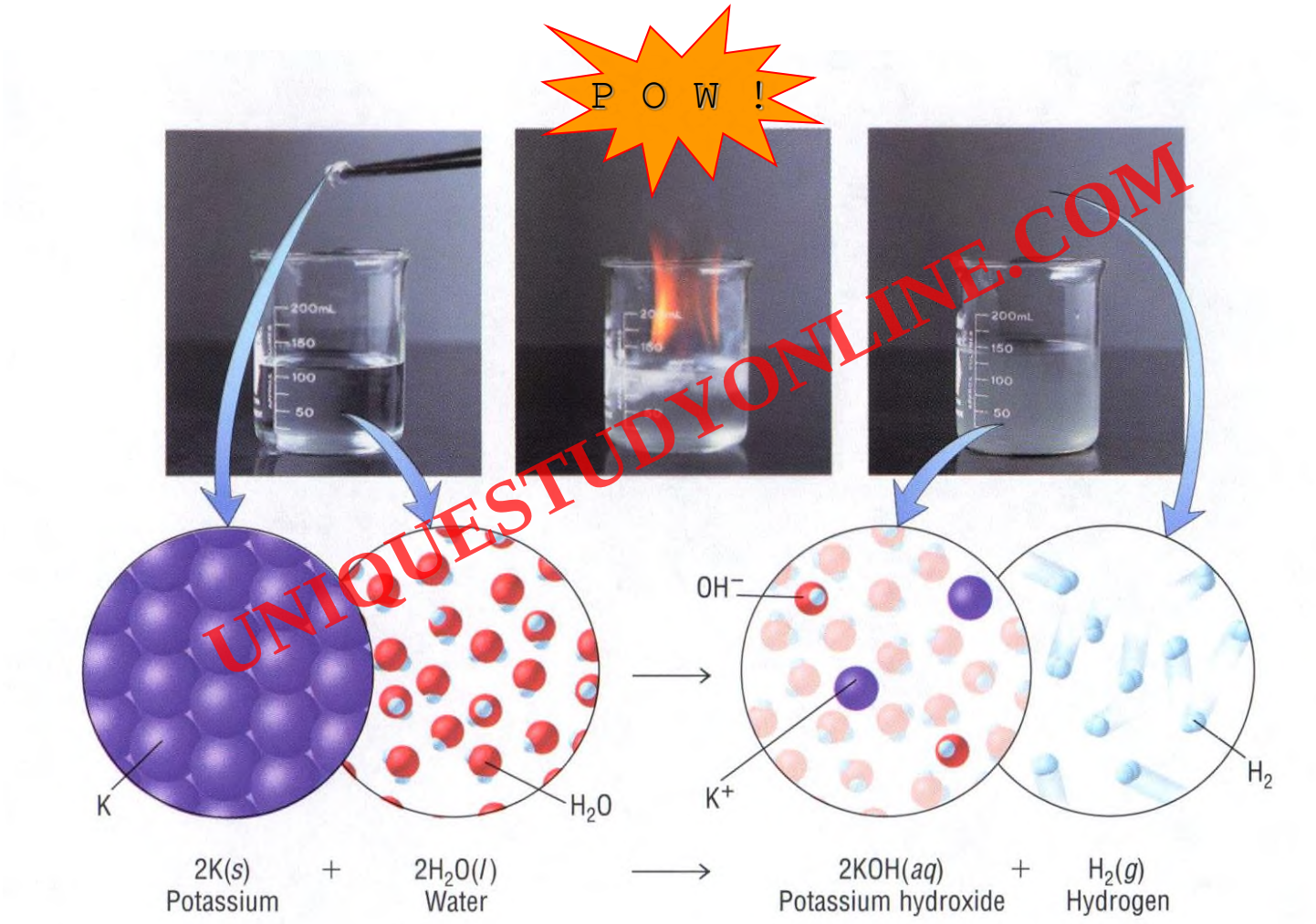
Legend

s = solid
aq = aqueous
d = decomposes
n = not isolated

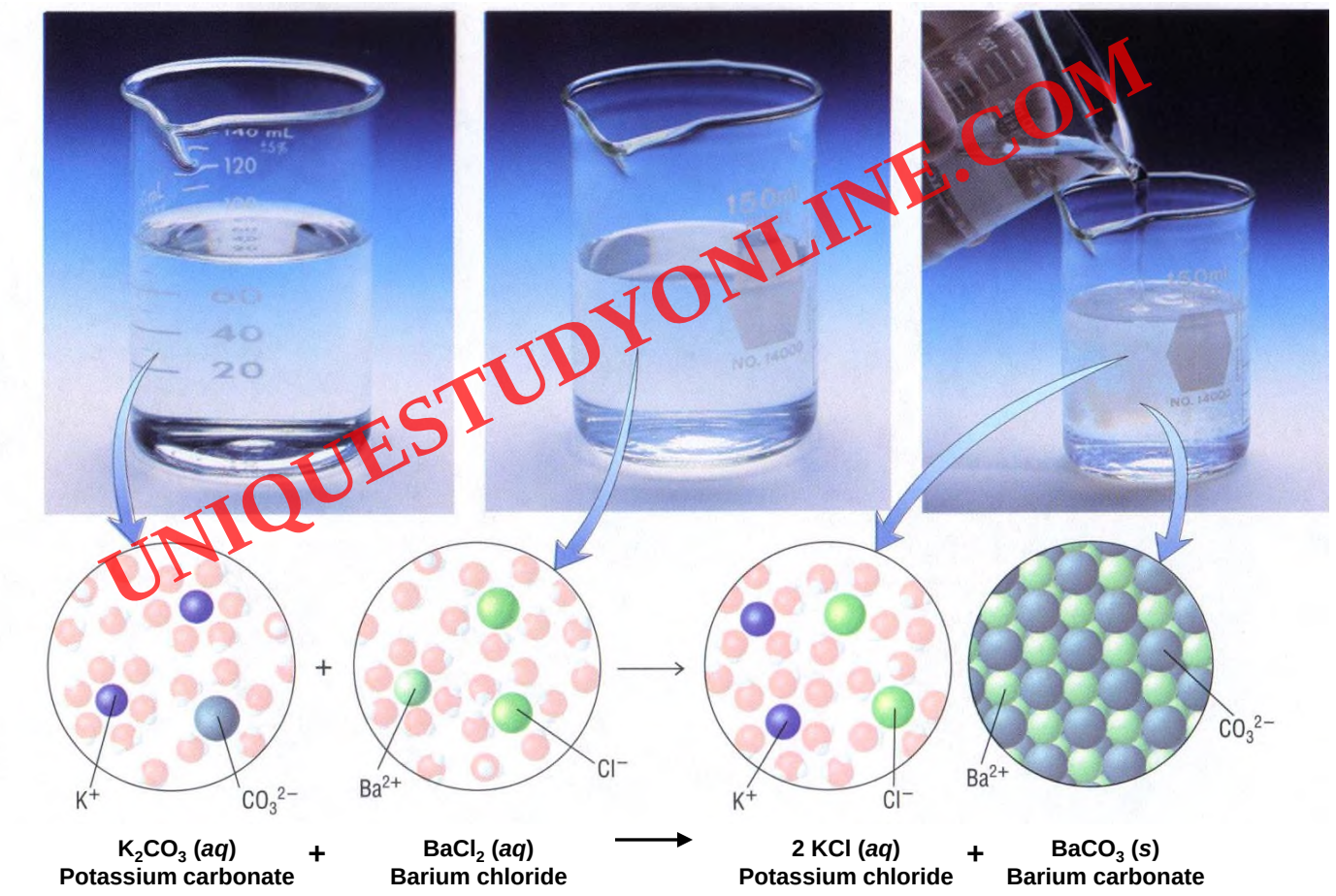
Solubility Rules

1. Most nitrates are soluble.
2. Most salts containing Group I ion and ammonium ion, NH_4^+, are soluble.
3. Most chloride, bromide, and iodide salts are soluble, except Ag^+, Pb^{2+} and Hg_2^{2+}.
4. Most sulfate salts are soluble, except $BaSO_4$, $PbSO_4$, Hg_2SO_4, and $CaSO_4$.
5. Most hydroxides except Group 1 and $Ba(OH)_2$, $Sr(OH)_2$, and $Ca(OH)_2$ are only slightly soluble.
6. Most sulfides, carbonates, chromates, and phosphates are only slightly soluble.

Potassium reacts with Water



Double Replacement Reaction



Synthesis Reactions

Photosynthesis

$$6\,CO_2 + 6\,H_2O \longrightarrow C_6H_{12}O_6 + 6\,O_2$$

Formation of water

$$2\,H_2 + O_2 \longrightarrow 2\,H_2O$$

Formation of salt

$$2\,Na + Cl_2 \longrightarrow 2\,NaCl$$

General Form

$$A + B \longrightarrow C$$

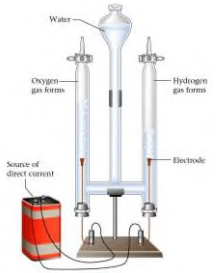
Decomposition Reactions

Hydrogen Peroxide

$$2\,H_2O_2 \longrightarrow 2\,H_2O + O_2$$

Electrolysis of water

$$2\,H_2O \xrightarrow{\textit{electricity}} 2\,H_2 + O_2$$



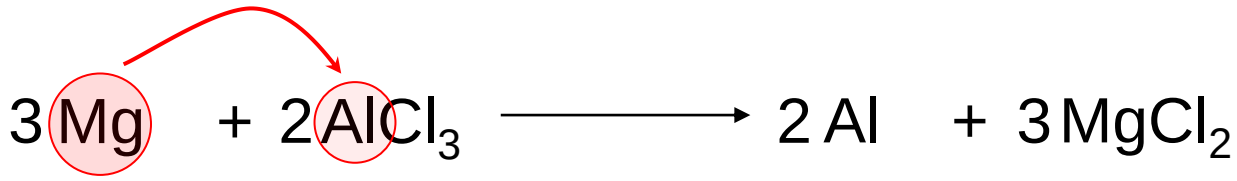
Nitrogen triiodide

$$2\,NI_3 \longrightarrow N_2 + 3\,I_2$$

General Form

$$AB \longrightarrow A + B$$

Predict if these reactions will occur



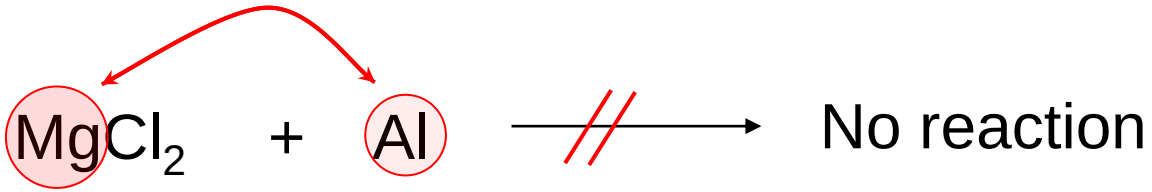
Can magnesium replace aluminum? **YES,** magnesium is more reactive than aluminum.

- Activity Series

Can aluminum replace magnesium? **NO,** aluminum is less reactive than magnesium.

- Activity Series

Therefore, *no reaction* will occur.



Order of reactants DOES NOT determine how they react.

The question we must ask is can the single element replace its counterpart?
metal replaces metal or nonmetal replaces nonmetal.

Single-Replacement Reactions

Activity Series

Li
Rb
K
Ba
Ca
Na
Mg
Al
Mn
Zn
Cr
Fe
Ni
Sn
Pb
H_2
Cu
Hg
Ag
Pt
Au

F_2
Cl_2
Br_2
I_2

"Magic blue-earth"

$$Fe + CuCl_2 \longrightarrow FeCl_2 + Cu$$

Can Fe *replace* Cu? Yes

Zinc in nitric acid

$$Zn + 2\,HNO_3 \longrightarrow Zn(NO_3)_2 + H_2$$

Can Zn *replace* H? Yes

NO REACTION

$$MgCl_2 + Br_2 \not\longrightarrow MgBr_2 + Cl_2$$

Can Br *replace* Cl? No

General Form

$$A + BC \longrightarrow AC + B$$

How would you prepare **potassium nitrate** (using a double replacement reaction)?

formation of water is a driving force.

$$KOH + HNO_3 \longrightarrow KNO_3 + H_2O$$

$$Ca(NO_3)_2$$

Both potassium nitrate and calcium chloride are soluble (no driving force – no reaction!)

$$2\,KOH + Ca(NO_3)_2 \longrightarrow 2\,KNO_3 + Ca(OH)_2$$

Combine a potassium hydroxide solution with nitric acid to yield soluble potassium nitrate.

$$KOH(aq) + HNO_3(aq) \longrightarrow KNO_3(aq) + H_2O$$

The water could then be removed by distillation to recover solid potassium nitrate.

Predict if a reaction will occur when you combine aqueous solutions of iron (II) chloride with aqueous sodium carbonate solution.

If the reaction does occur, write a **Balanced chemical equation** showing it. (be sure to include phase notation)

iron (II) chloride + sodium carbonate ⟶ sodium chloride + iron (II) carbonate

Fe^{2+} Cl^{1-} Na^{1+} CO_3^{2-} Fe^{2+} Cl^{1-} Na^{1+} CO_3^{2-}

$FeCl_2$ Na_2CO_3 $NaCl_{(aq)}$ $FeCO_{3\ (ppt)}$

Using a SOLUBILITY TABLE:
sodium chloride is **soluble**
iron (II) carbonate is **insoluble**

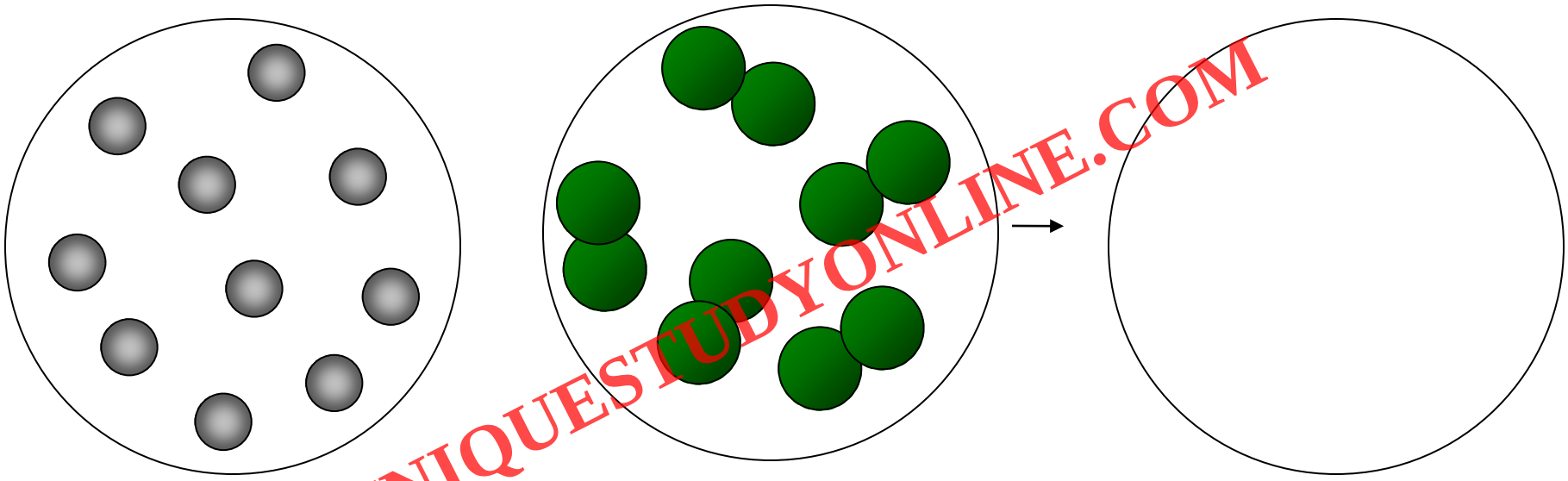
$$FeCl_{2\,(aq)} + Na_2CO_{3\,(aq)} \longrightarrow \mathbf{2}\,NaCl_{(aq)} + FeCO_{3\ (ppt)}$$

Complete Ionic Equation

$$Fe^{2+}(aq) + 2Cl^{1-}(aq) + 2Na^{1+}(aq) + CO_3^{2-}(aq) \longrightarrow 2Na^{1+}(aq) + 2Cl^{1-}(aq) + FeCO_3(s)$$

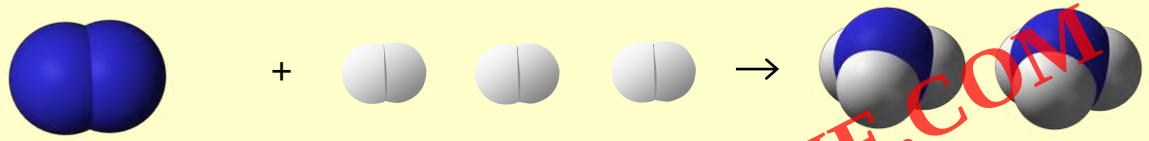
Visualizing a Chemical Reaction

2 **Na** + **Cl_2** ⟶ 2 **NaCl**



10 mole Na 5 mole Cl_2 10 mole NaCl

Formation of Ammonia

N_2 (*g*)	+	3 H_2 (*g*)	→	2 NH_3 (*g*)
				
2 atoms N	+	6 atoms H	→	2 atoms N and 6 atoms H
1 molecule N_2	+	3 molecules H_2	→	2 molecules NH_3
10 molecule N_2	+	30 molecules H_2	→	20 molecules NH_3
1 x (6.02×10^{23} molecules N_2)	+	3 x (6.02×10^{23} molecules H_2)	→	2 x (6.02×10^{23} molecules NH_3)
1 mol N_2	+	3 mol H_2	→	2 mol NH_3
28 g N_2	+	3 x 2 g H_2	→	2 x 17 g NH_3
		34 g reactants	→	34 g products
Assume STP 22.4 L	+	22.4 L, 22.4 L, 22.4 L	→	22.4 L, 22.4 L
22.4 L N_2		67.2 L H_2		44.8 L NH_3

Proportional Relationships

2 1/4 c. flour	3/4 c. brown sugar
1 tsp. baking soda	1 tsp vanilla extract
1 tsp. salt	2 eggs
1 c. butter	2 c. chocolate chips
3/4 c. sugar	Makes 5 dozen cookies.

Conversion Factor

I have 5 eggs. How many cookies can I make?

$$\frac{5 \text{ dozen}}{2 \text{ eggs}} \times \frac{5 \text{ eggs}}{} = 150 \text{ cookies}$$

Ratio of eggs to cookies

Courtesy Christy Johannesson www.nisd.net/communicationsarts/pages/chem

Proportional Relationships

- **Stoichiometry**
  - mass relationships between substances in a chemical reaction
  - based on the mole ratio

- **Mole Ratio**
  - indicated by coefficients in a balanced equation

$$2\ Mg + O_2 \rightarrow 2\ MgO$$

Courtesy Christy Johannesson www.nisd.net/communicationsarts/pages/chem

Stoichiometry Steps

1. Write a balanced equation.
2. Identify known & unknown.
3. Line up conversion factors.
   - Mole ratio - moles ↔ moles
   - Mole ratio - moles ↔ moles
   - Molarity - moles ↔ liters soln
   - Molar volume - moles ↔ liters gas

Core step in all stoichiometry problems!!

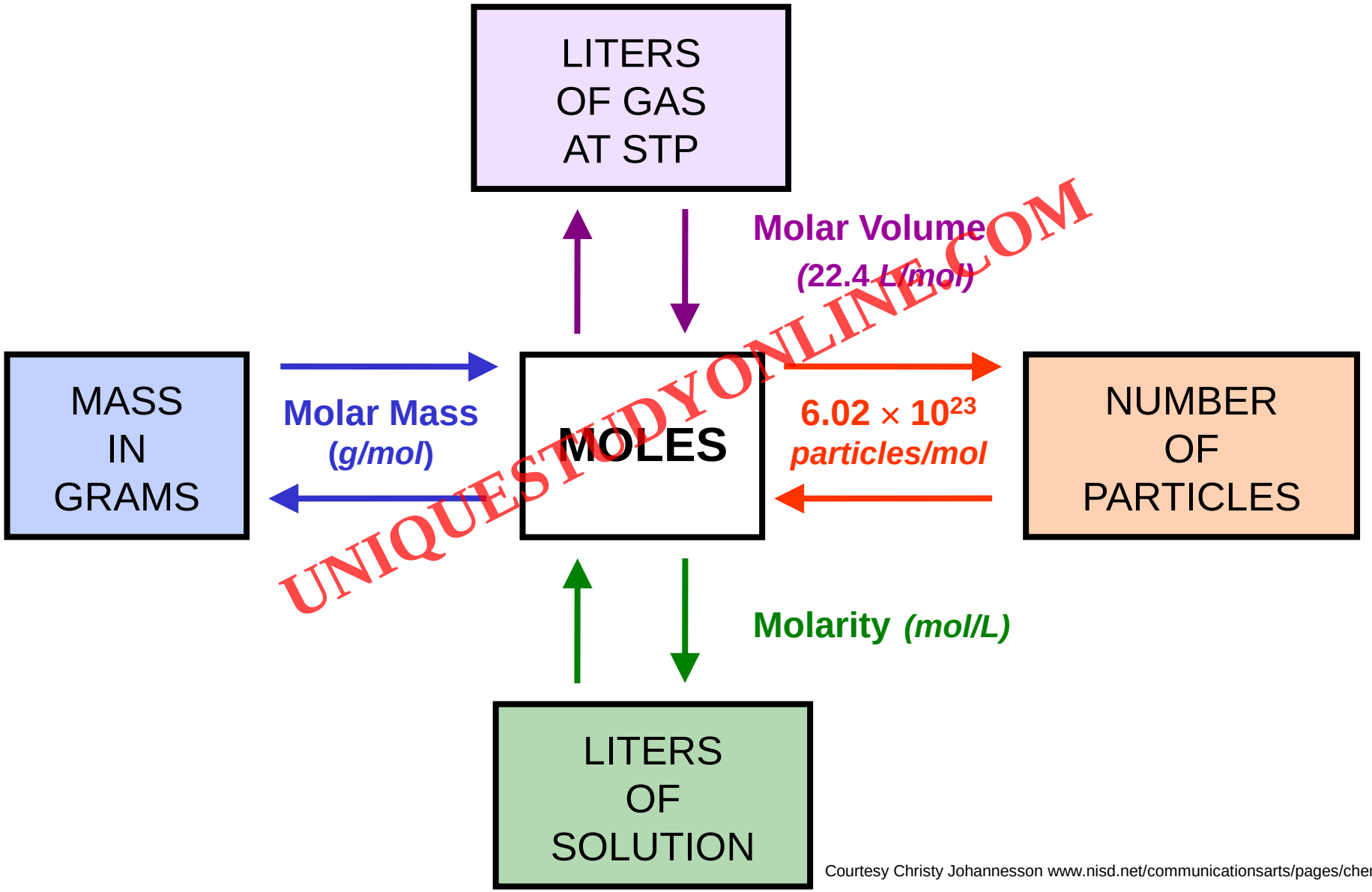
4. Check answer.

Molar Volume at STP

1 mol of a gas=22.4 L at STP

Standard **T**emperature & **P**ressure
0°C and 1 atm

Molar Volume at STP



Courtesy Christy Johannesson www.nisd.net/communicationsarts/pages/chem

Stoichiometry Problems

- How many moles of $KClO_3$ must decompose in order to produce 9 moles of oxygen gas?

$$2KClO_3 \rightarrow 2KCl + 3O_2$$

? mol 9 mol

$$\frac{9 \text{ mol } O_2}{3 \text{ mol } O_2} \times \frac{2 \text{ mol } KClO_3}{1} = 6 \text{ mol } KClO_3$$

Courtesy Christy Johannesson www.nisd.net/communicationsarts/pages/chem

1. $2\ Sb + 3\ Cl_2 \rightarrow 2\ SbCl_3$

2. $2\ Mg + O_2 \rightarrow 2\ MgO$

3. $CaCl_2 \rightarrow Ca + Cl_2$

4. $2\ NaClO_3 \rightarrow 2\ NaCl + 3\ O_2$

5. $Fe + 2\ HCl \rightarrow FeCl_2 + H_2$

6. $CuO + H_2 \rightarrow Cu + H_2O$

7. $2\ Al + 3\ H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3\ H_2$

1. $2\ Sb + 3\ Cl_2 \rightarrow 2\ SbCl_3$

5 mol excess | 7.5 mol excess | x mol

$$\frac{2}{5\ \text{mol}} = \frac{3}{x\ \text{mol}}$$

$2x = 15$

$x = 7.5\ \text{mol}$

How many moles of chlorine gas are required to react with 5 moles of antimony?

$$x\ \text{mol}\ Cl_2 = 5\ \text{mol Sb} \left(\frac{3\ \text{mol}\ Cl_2}{2\ \text{mol Sb}}\right) = 7.5\ \text{mol}\ Cl_2$$

How many moles of $SbCl_3$ are produced from 5 moles of antimony and excess Cl_2?

$$x\ \text{mol}\ SbCl_3 = 5\ \text{mol Sb} \left(\frac{2\ \text{mol}\ SbCl_3}{2\ \text{mol Sb}}\right) = 5\ \text{mol}\ SbCl_3$$

How many moles of $SbCl_3$ are produced from 7.5 moles of Cl_2 and excess Sb?

$$x\ \text{mol}\ SbCl_3 = 7.5\ \text{mol}\ Cl_2 \left(\frac{2\ \text{mol}\ SbCl_3}{3\ \text{mol}\ Cl_2}\right) = 5\ \text{mol}\ SbCl_3$$

2. $2\ Mg + O_2 \rightarrow 2\ MgO$

10 mol x L x mol

How many moles of magnesium oxide are produced from the burning of 10 mol of Mg?

$$x\ mol\ MgO = 10\ \cancel{mol\ Mg}\left(\frac{2\ mol\ MgO}{2\ \cancel{mol\ Mg}}\right) = 10\ mol\ MgO$$

How many liters of oxygen are needed to burn 10 mol of Mg? Assume 1 mol O_2 = 22.4 L

$$x\ L\ O_2 = 10\ \cancel{mol\ Mg}\left(\frac{1\ mol\ O_2}{2\ \cancel{mol\ Mg}}\right) = 5\ \cancel{mol\ O_2}\left(\frac{22.4\ L\ O_2}{1\ \cancel{mol\ O_2}}\right) = 112\ L\ O_2$$

$$x\ L\ O_2 = 10\ \cancel{mol\ Mg}\left(\frac{1\ \cancel{mol\ O_2}}{2\ \cancel{mol\ Mg}}\right)\left(\frac{22.4\ L\ O_2}{1\ \cancel{mol\ O_2}}\right) = 112\ L\ O_2$$

3. $CaCl_2 \rightarrow Ca + Cl_2$

8 mol x mol

calcium chloride  calcium  + chlorine 

How many moles of calcium metal and chlorine gas are produced from the decomposition of 8 mol of calcium chloride?

$$x \text{ mol Ca} = 8 \cancel{\text{mol } CaCl_2} \left(\frac{1 \text{ mol Ca}}{1 \cancel{\text{mol } CaCl_2}} \right) = 8 \text{ mol Ca}$$

How many moles of calcium metal and chlorine gas are produced from the decomposition of 8 mol of calcium chloride?

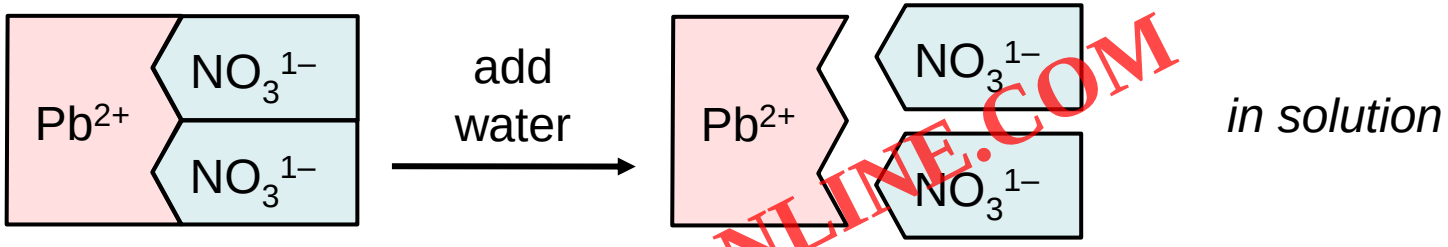
$$x \text{ mol } Cl_2 = 8 \cancel{\text{mol } CaCl_2} \left(\frac{1 \text{ mol } Cl_2}{1 \cancel{\text{mol } CaCl_2}} \right) = 8 \text{ mol } Cl_2$$

Print Copy of Lab

Ions in Aqueous Solution

$Pb(NO_3)_2(s) + H_2O(l) \longrightarrow Pb(NO_3)_2(aq)$

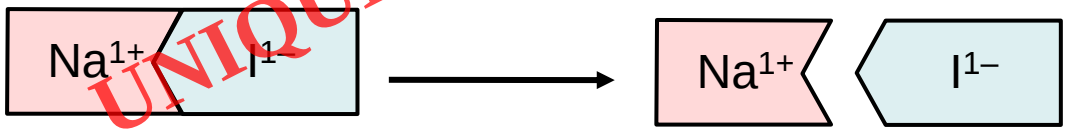
$Pb^{2+}(aq) + 2\ NO_3^{1-}(aq)$



dissociation:

$NaI(s) + H_2O(l) \longrightarrow NaI(aq)$

$Na^{1+}(aq) + I^{1-}(aq)$



Mix them and get…

Balance to get overall ionic equation…

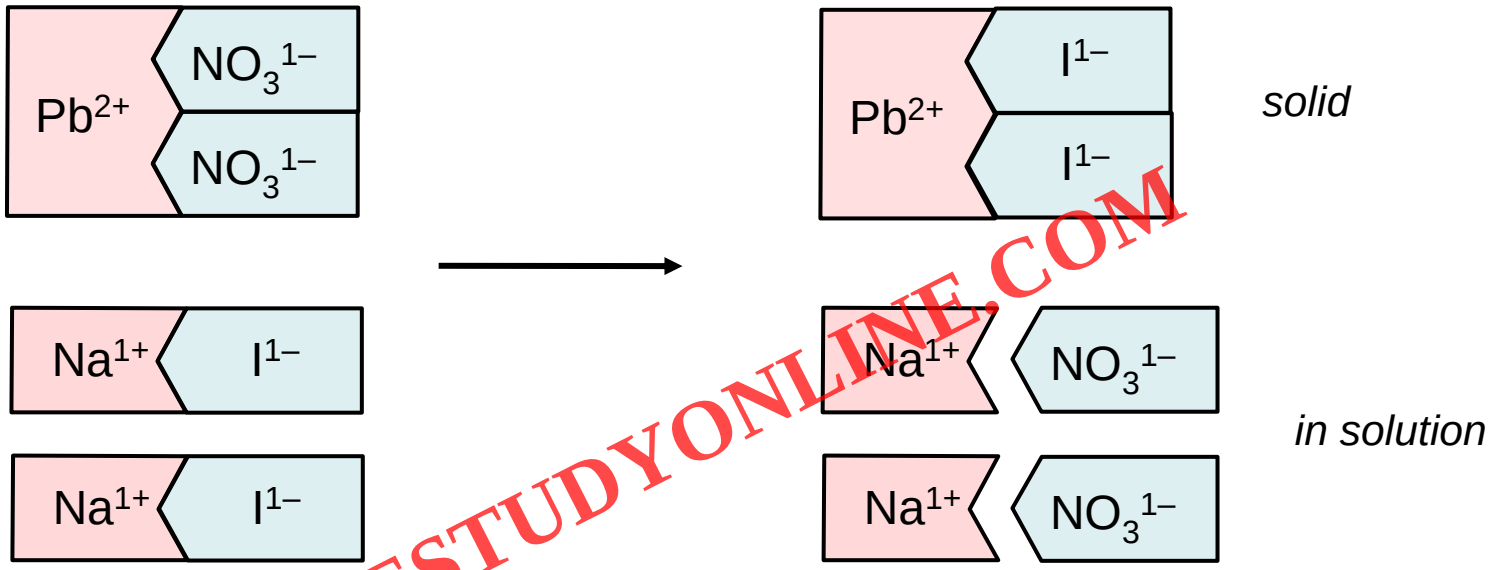
Cancel spectator ions to get net ionic equation…

Solubility Chart

Mix them and get…

$$Pb(NO_3)_2(aq) + 2\ NaI(aq) \longrightarrow PbI_2(s) + 2\ NaNO_3(aq)$$

$$Pb(NO_3)_2(aq) + 2\ NaI(aq) \longrightarrow PbI_2(s) + 2\ Na^{1+}(aq) + 2\ NO_3^{1-}(aq)$$



Balance to get <u>overall ionic equation</u>…

$$Pb^{2+}(aq) + 2\ NO_3^{1-}(aq) + 2\ Na^{1+}(aq) + 2\ I^{1-}(aq) \longrightarrow PbI_2(s) + 2\ NO_3^{1-}(aq) + 2\ Na^{1+}(aq)$$

Cancel <u>spectator ions</u> to get <u>net ionic equation</u>…

$$Pb^{2+}(aq) + 2\ I^{1-}(aq) \longrightarrow PbI_2(s)$$

Solubility Chart

Mix together $Zn(NO_3)_2(aq)$ and $Ba(OH)_2(aq)$:

Mix them and get… $Ba(NO_3)_2(aq)$ and $Zn(OH)_2(ppt)$

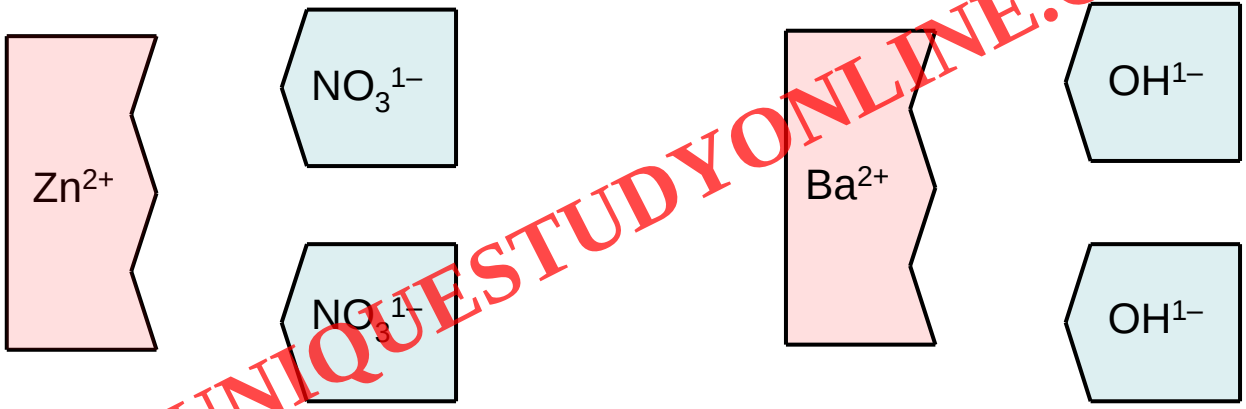
$$Zn(NO_3)_2(aq) + Ba(OH)_2(aq) \longrightarrow Zn(OH)_2(s) + 2\ NO_3^{1-}(aq) + Ba^{2+}(aq)$$

$Zn(NO_3)_2(aq)$

$Zn^{2+}(aq) + 2\ NO_3^{1-}(aq)$

$Ba(OH)_2(aq)$

$Ba^{2+}(aq) + 2\ OH^{1-}(aq)$



Balance to get overall ionic equation…

$$Zn^{2+}(aq) + 2\ NO_3^{1-}(aq) + Ba^{2+}(aq) + 2OH^{1-}(aq) \longrightarrow Zn(OH)_2(s) + 2\ NO_3^{1-}(aq) + Ba^{2+}(aq)$$

Cancel spectator ions to get net ionic equation…

$$Zn^{2+}(aq) + 2\ OH^{1-}(aq) \longrightarrow Zn(OH)_2(s)$$

$2\,(NH_4)_3PO_4 + 3\,Mg(OH)_2 \rightarrow Mg_3(PO_4)_2 + 6\,NH_4OH$?

ammonium phosphate | magnesium hydroxide | magnesium phosphate | ammonium hydroxide

NH_4^{1+} OH^{1-}

Now you try…

$2\,AlCl_3 + 3\,Li_2CO_3 \rightarrow Al_2(CO_3)_3 + 6\,LiCl$

Identify the spectator ions and write a net ionic equation when an aqueous solution of aluminum sulfate is mixed with aqueous ammonium hydroxide.

Al^{3+} SO_4^{2-} NH_4^{1+} OH^{1-} Al^{3+} OH^{1-} NH_4^{1+} SO_4^{2-}

aluminum sulfate + ammonium hydroxide → aluminum hydroxide + ammonium sulfate

$$Al_2(SO_4)_3(aq) + 6\ NH_4OH(aq) \rightarrow 2\ Al(OH)_3(ppt) + 3\ (NH_4)_2SO_4\ (aq)$$

$$2\ Al^{3+}(aq) + 3\ SO_4^{2-}(aq) + 6\ NH_4^{1+}(aq) + 6\ OH^{1-}(aq) \rightarrow 2\ Al(OH)_3(ppt) + 6\ NH_4^{1+}(aq) + 3\ SO_4^{2-}(aq)$$

"spectator ions"

$$2\ Al^{3+}(aq) + 6\ OH^{1-}(aq) \rightarrow 2\ Al(OH)_3(ppt)$$

Net Ionic Equation

Meaning of Coefficients

2 atoms Na 1 molecule Cl_2 2 molecules NaCl

$$2\ Na + Cl_2 \longrightarrow 2\ NaCl$$

2 g sodium + 1 g chlorine = 2 g sodium chloride

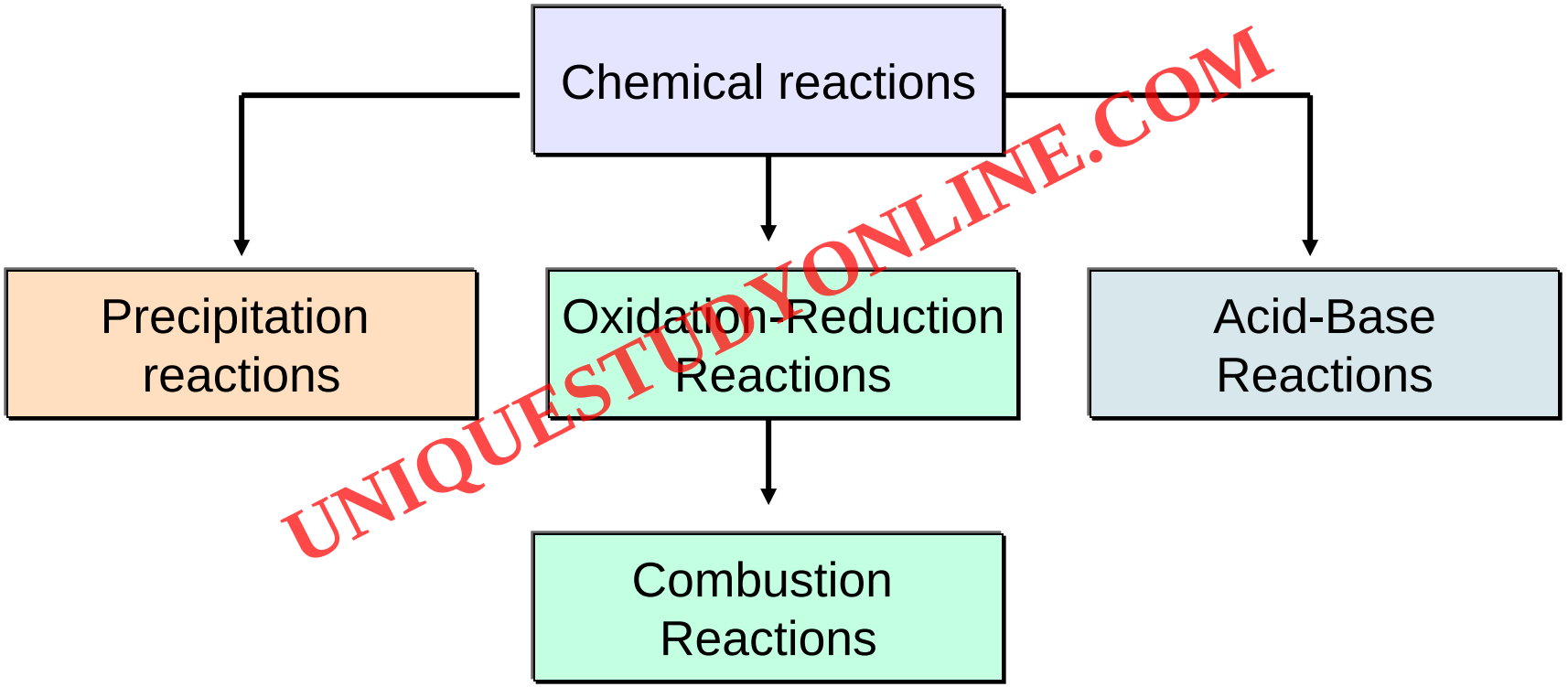
2 mol sodium 1 mol chlorine 2 mol sodium chloride

(2 mol Na) x (23 g/mol) **(1 mol Cl_2) x (71 g/mol)** **(2 mol NaCl) x (58.5 g/mol)**

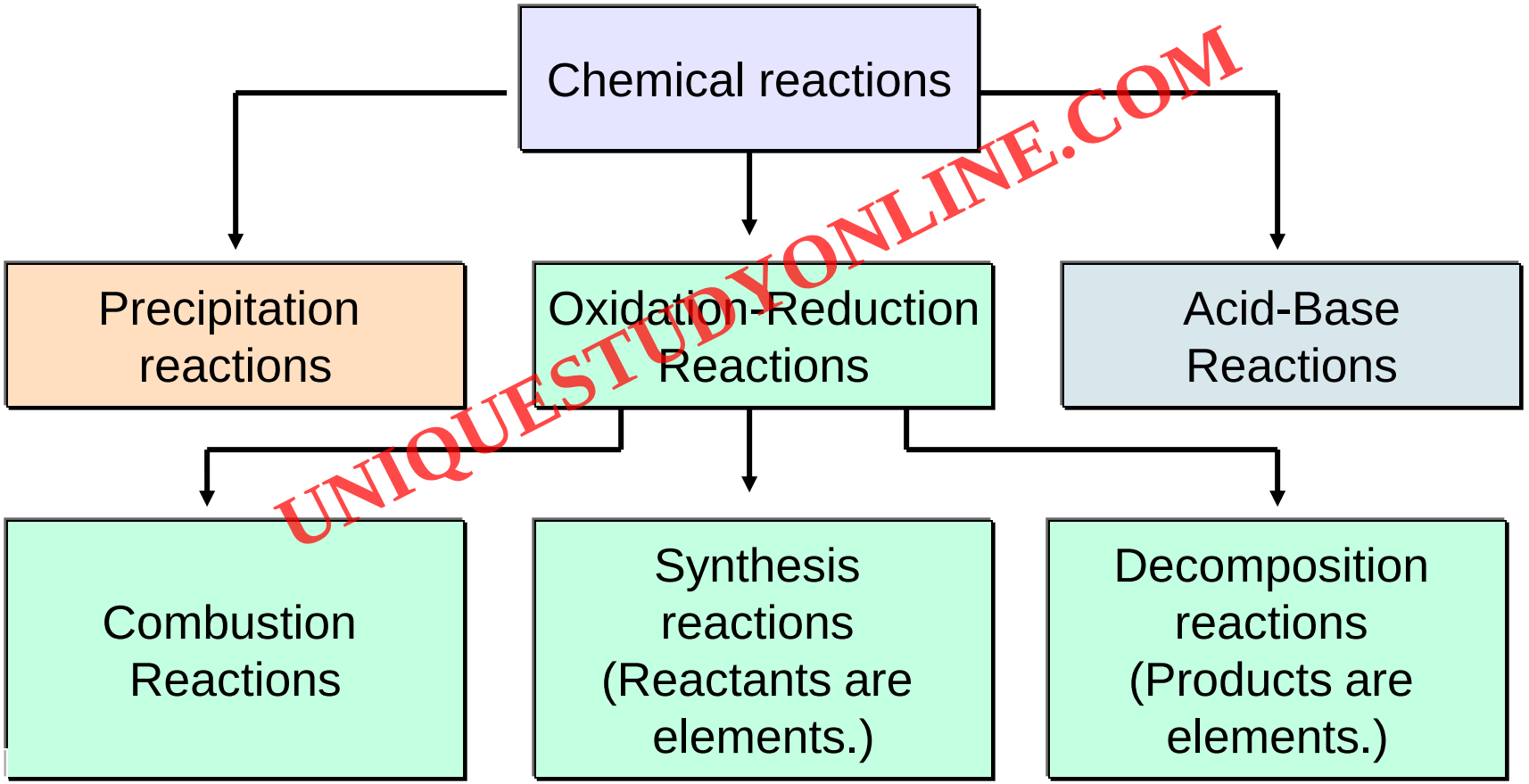
46 g 71 g 117 g

117 g

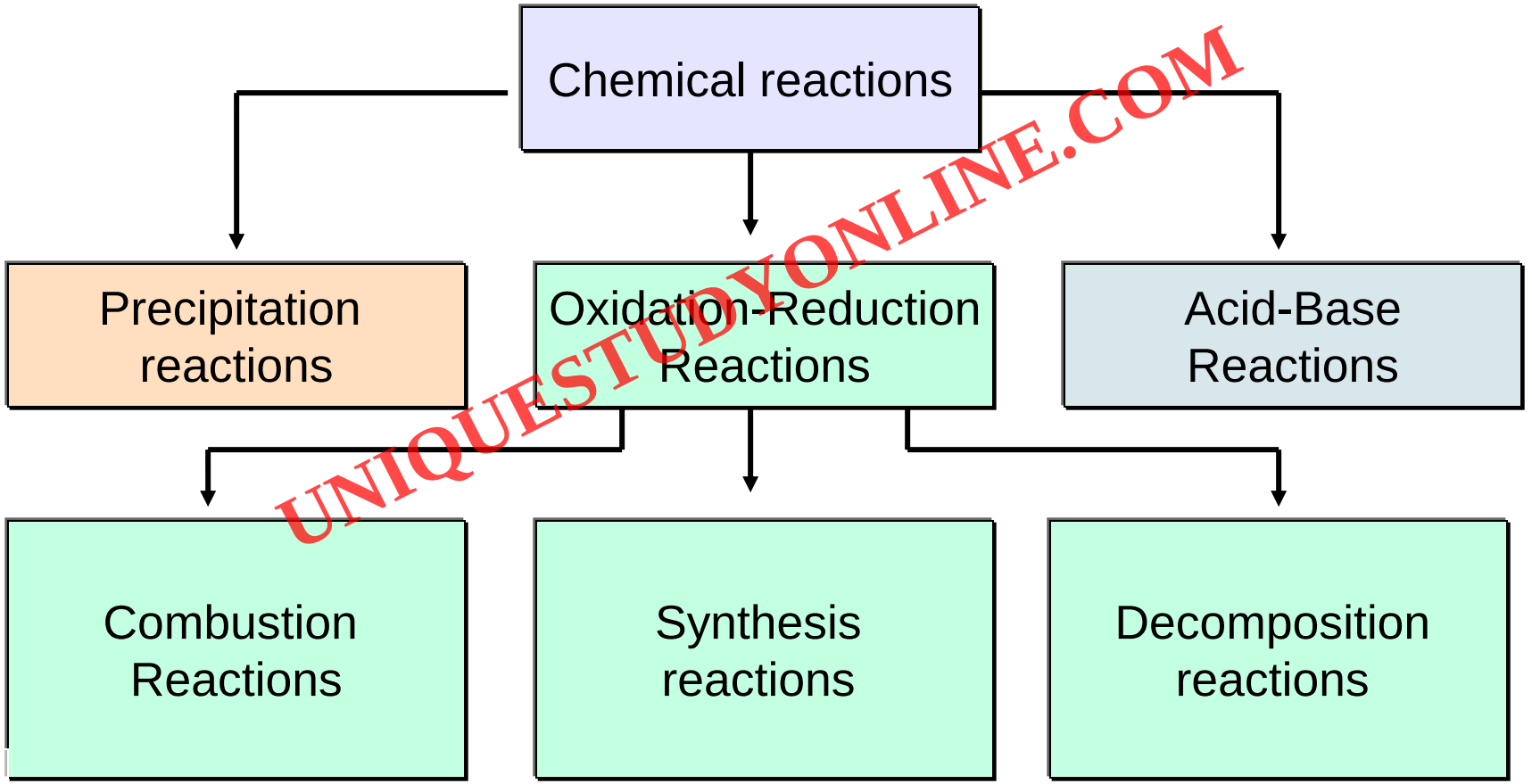
Classes of Reactions



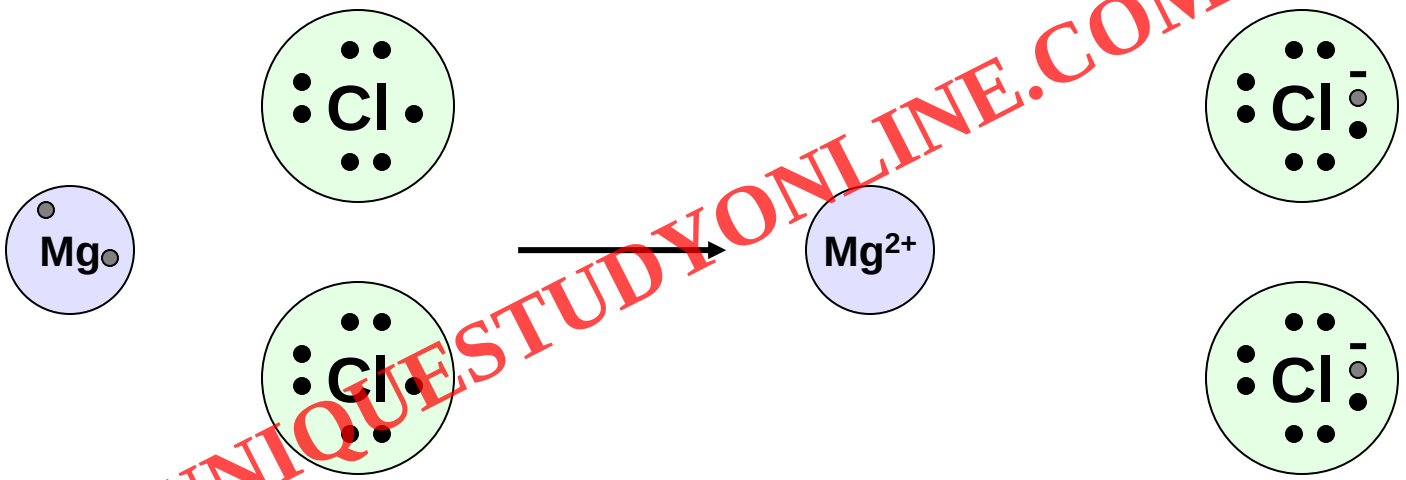
Summary of Classes of Reactions



Summary of Classes of Reactions



IONIC BONDING:
Formation of Magnesium Chloride



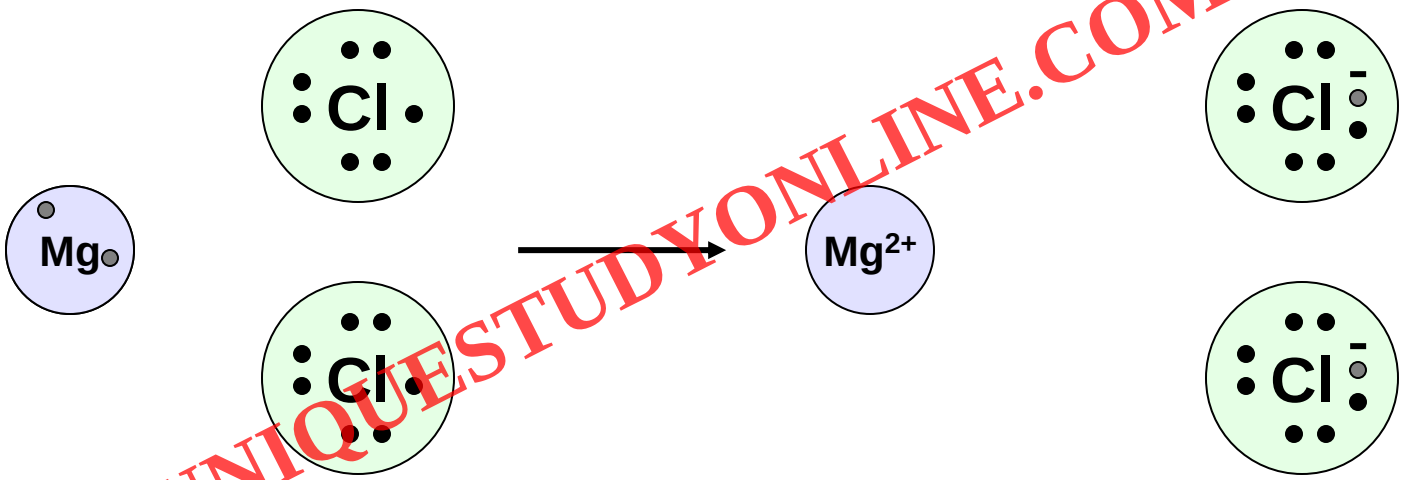
Loses 2*e*- **Each gains 1*e*-** **One magnesium ion** **Two chloride ions**

Mg^{2+} **Cl^{1-}**

[(2+) **2 (1-) = 0]**

$MgCl_2$ **magnesium chloride**

IONIC BONDING:
Formation of Magnesium Chloride



Loses 2*e*- **Each gains 1*e*-** **One magnesium ion** **Two chloride ions**

Mg^{2+} **Cl^{1-}**

[(2+) **2 (1-) = 0]**

$MgCl_2$ **magnesium chloride**