
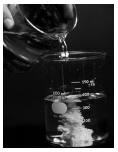


Types of Chemical Reactions



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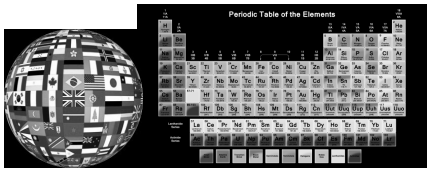
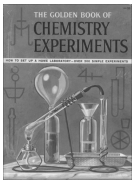
Chemistry Is A Foreign Language

Elemental Symbols = Characters





Formula = Words

H_2 O_2 H_2O

Reactions = Sentences

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

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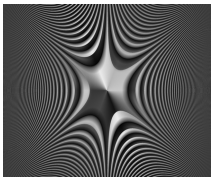
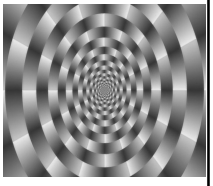
Types of Chemical Reactions

Knowledge of types useful for:

- **Predicting products from starting materials**
- **Estimating starting materials from analyzed products**
- **Evaluating potential health/safety issues**

Focus on type recognition (pattern recognition), NOT individual reactions





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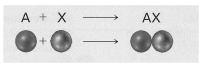
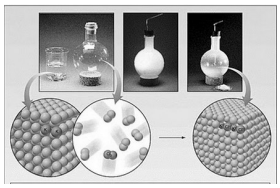
Combination (Synthesis) Reactions



2 or more substances combine to form 1 single product

$2\,Na + Cl_2 \rightarrow 2\,NaCl$
$2\,H_2 + O_2 \rightarrow 2\,H_2O$
$Br_2 + PBr_3 \rightarrow PBr_5$
$MgO + CO_2 \rightarrow MgCO_3$
$6\,Li + N_2 \rightarrow 2\,Li_3N$
$N_2 + 3\,H_2 \rightarrow 2\,NH_3$
$CaO + H_2O \rightarrow Ca(OH)_2$
$2\,Al + 3\,Br_2 \rightarrow 2\,AlBr_3$
$4\,Fe + 3\,O_2 \rightarrow 2\,Fe_2O_3$



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

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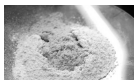
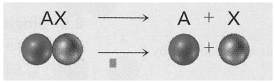
Decomposition Reactions





Opposite of combination reaction
1 compound breaks down into simpler substances

$2\,H_2O \rightarrow 2\,H_2 + O_2$
$2\,H_2O_2 \rightarrow 2\,H_2O + O_2$
$CaCO_3 \rightarrow CaO + CO_2$
$PCl_5 \rightarrow PCl_3 + Cl_2$
$2\,HgO \rightarrow 2\,Hg + O_2$
$2\,KClO_3 \rightarrow 2\,KCl + 3\,O_2$
$2\,Cl_2O_5 \rightarrow 2\,Cl_2 + 5\,O_2$
$2\,N_2O_5 \rightarrow O_2 + 4\,NO_2$
$2\,NaCl \rightarrow 2\,Na + Cl_2$

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Burning or Complete Combustion

$C_xH_yO_z + O_2 \rightarrow CO_2 + H_2O$

One reactant is organic (contains C & H; sometimes N & O)
Other reactant is always O_2

Products are always CO_2 + H_2O

$CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$ (methane)
$C_3H_8 + 5\,O_2 \rightarrow 3\,CO_2 + 4\,H_2O$ (propane)
$2\,C_2H_2 + 5\,O_2 \rightarrow 4\,CO_2 + 2\,H_2O$ (acetylene)
$C_2H_5OH + 3\,O_2 \rightarrow 2\,CO_2 + 3\,H_2O$ (ethanol)
$C_6H_{12}O_6 + 6\,O_2 \rightarrow 6\,CO_2 + 6\,H_2O$ (glucose)

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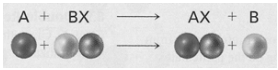
Single Replacement (Displacement)



One free element replaces another element
Reactant & Product side have different free element

Metal replaces another Metal

$Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$

$Fe + Cu(NO_3)_2 \rightarrow Cu + Fe(NO_3)_2$

$Zn_{(s)} + 2\,Au(CN)_2 \rightarrow 2\,Au_{(s)} + Zn(CN)_{4\,(aq)}$

Metal replaces Hydrogen

$Mg + 2\,HCl \rightarrow MgCl_2 + H_2$

$Zn + 2\,HCl \rightarrow ZnCl_2 + H_2$

Non-Metal replaces another Non-Metal

$Cl_2 + 2\,NaBr \rightarrow 2\,NaCl + Br_2$

$Br_2 + 2\,KI \rightarrow 2\,KBr + I_2$

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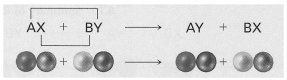
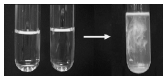
Double Replacement (Displacement) Reactions





Precipitation

Precipitation: (+) and (–) ions switch partners ; AY insoluble

$AgNO_{3(aq)} + NaCl_{(aq)} \rightarrow AgCl_{(s)} + NaNO_{3(aq)}$

$CuSO_{4(aq)} + 2\,NaOH_{(aq)} \rightarrow Cu(OH)_{2(s)} + Na_2SO_{4(aq)}$

$AgNO_{3(aq)} + KCl_{(aq)} \rightarrow AgCl_{(s)} + KNO_{3(aq)}$

$2\,AgNO_{3(aq)} + CaCl_{2(aq)} \rightarrow 2\,AgCl_{(s)} + Ca(NO_3)_{2(aq)}$

$CaCl_{2(aq)} + Na_2SO_{4(aq)} \rightarrow CaSO_{4(s)} + 2\,NaCl_{(aq)}$

$BaCl_{2(aq)} + Na_2SO_{4(aq)} \rightarrow BaSO_{4(s)} + 2\,KCl_{(aq)}$

$K_2CO_3 + CaCl_2 \rightarrow CaCO_{3(ppt)} + 2\,KCl$

$Pb(NO_3)_2 + 2\,KI \rightarrow PbI_2\downarrow + 2\,KNO$

LPT

What Precipitates?

Solubility Guidelines for Common Ionic Compounds in Water

Soluble Ionic Compounds		Important Exceptions
Compounds containing	NO_3^-	None
	CH_3COO^-	None
	Cl^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	Br^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	I^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	SO_4^{2-}	Compounds of Sr^{2+}, Ba^{2+}, Hg_2^{2+}, and Pb^{2+}
Insoluble Ionic Compounds		**Important Exceptions**
Compounds containing	S^{2-}	Compounds of NH_4^+, the alkali metal cations, and Ca^{2+}, Sr^{2+}, and Ba^{2+}
	CO_3^{2-}	Compounds of NH_4^+ and the alkali metal cations
	PO_4^{3-}	Compounds of NH_4^+ and the alkali metal cations
	OH^-	Compounds of the alkali metal cations, and NH_4^+, Ca^{2+}, Sr^{2+}, and Ba^{2+}

LPT

What Precipitates?

KNO_3 mixed with $BaCl_2$

Write ions formed:

$KNO_3 \longrightarrow K^+ + NO_3^-$

$BaCl_2 \longrightarrow Ba^{2+} + Cl^-$

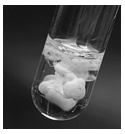
Examine possible Cation-Anion Combinations:

	NO_3^-	Cl^-
K^+	KNO_3	KCl
Ba^{2+}	$Ba(NO_3)_2$	$BaCl_2$

Solubility Rules: no insoluble compound
So, no reaction occurs!

LPT

What Precipitates?



$AgNO_3$ mixed with $BaCl_2$

Write ions formed:

$AgNO_3 \longrightarrow Ag^+ + NO_3^-$

$BaCl_2 \longrightarrow Ba^{2+} + Cl^-$

Examine possible Cation-Anion Combinations:

	NO_3^-	Cl^-
Ag^+	$AgNO_3$	AgCl
Ba^{2+}	$Ba(NO_3)_2$	$BaCl_2$

Solubility Rules: AgCl = insoluble compound
So, precipitation reaction occurs!

$2\,AgNO_{3\,(aq)} + BaCl_{2\,(aq)} \rightarrow 2\,AgCl_{\,(s)} + Ba(NO_3)_{2\,(aq)}$

LPT

Representing Reactions:

Molecular Equation: Complete Formulas of Reactants & Products

$Pb(NO_3)_{2\,(aq)} + Na_2SO_{4\,(aq)} \rightarrow PbSO_{4\,(s)} + 2\,NaNO_{3\,(aq)}$

Complete Ionic Equation: Represents Strong Ionic Species Present

$Pb^{2}_{+\,(aq)} + 2\,NO_3^-{}_{(aq)} + 2\,Na^+{}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow PbSO_{4\,(s)} + 2\,Na^+{}_{(aq)} + 2\,NO_3^-{}_{(aq)}$

Net Ionic Changes: Shows only directly involved species

$Pb^{2+}{}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow PbSO_{4\,(s)}$

Ions not directly involved called *Spectator Ions*
(Appear as ions on both sides of reaction arrow)
Spectator Ions: NO_3^- Na^+

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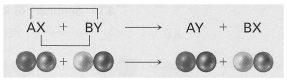
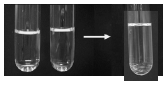
Double Replacement (Displacement) Reactions



A = H^+ Y = OH^-



Neutralization
Heat Evolved

Neutralization Reactions:

H^+ (Acid) combines with OH^- (Base) to form HOH (H_2O)

$HCl + NaOH \rightarrow NaCl + HOH$

$HNO_3 + NaOH \rightarrow NaNO_3 + H_2O$

$H_2SO_4 + 2\ NaOH \rightarrow Na_2SO_4 + 2\ H_2O$

$Ca(OH)_2 + 2\ HNO_3 \rightarrow Ca(NO_3)_2 + 2\ H_2O$

$Ca(OH)_2 + H_3PO_4 \rightarrow Ca_3(PO_4)_2 + H_2O$

$Co(OH)_3 + HNO_3 \rightarrow Co(NO_3)_3 + H_2O$

$Al(OH)_3 + H(C_2H_3O_2) \rightarrow Al(C_2H_3O_2)_3 + H_2O$

Salt = product of acid & base

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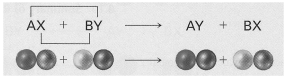
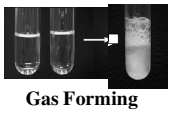
Double Replacement (Displacement) Reactions





Gas Forming

Gas Forming:

(+) and (–) ions switch partners; BX Breaks down to a gas

$K_2CO_3 + 2\ HCl \rightarrow 2\ KCl + H_2CO_3$ → $H_2O + CO_{2\ (g)}$

Written as: $K_2CO_3 + 2\ HCl \rightarrow 2\ KCl + H_2O + CO_{2\ (g)}$

$Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + H_2O + CO_{2\ (g)}$

Other Common Gasses Evolved

$H_2SO_3 \rightarrow H_2O + SO_{2\ (g)}$

$NH_4OH \rightarrow NH_{3\ (g)} + H_2O$

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Exercise:

Give the type of reaction for each:

$C_2H_5OH_{(l)} + 3\ O_{2\ (g)} \rightarrow 2\ CO_{2\ (g)} + 3\ H_2O_{(g)}$

$2\ Mg_{(s)} + O_{2\ (g)} \rightarrow 2\ MgO_{(s)}$

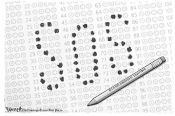
$HNO_{3\ (aq)} + KOH_{(aq)} \rightarrow H_2O_{(l)} + KNO_{3\ (aq)}$

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

$BaCl_{2\ (aq)} + K_2CrO_{4\ (aq)} \rightarrow BaCrO_{4\ (s)} + 2\ KCl_{(aq)}$

$NH_4Cl_{(s)} \rightarrow NH_{3\ (g)} + HCl_{(g)}$

$Na_2CO_{3\ (s)} + 2\ HCl_{(aq)} \rightarrow 2\ NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$



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Give the type of reaction for:

$C_2H_5OH_{(l)} + 3\ O_{2\,(g)} \rightarrow 2\ CO_{2\,(g)} + 3\ H_2O_{(g)}$

Characteristics:
Organic + Oxygen Reactants
CO_2 & Water Products
Combustion

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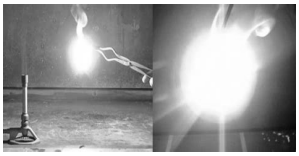
Give the type of reaction for:

$2\ Mg_{(s)} + O_{2\,(g)} \rightarrow 2\ MgO_{(s)}$

Characteristics:
2 Reactants
1 Product
Combination



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Give the type of reaction for:

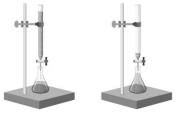
$HNO_{3\,(aq)} + KOH_{(aq)} \rightarrow H_2O_{(l)} + KNO_{3\,(aq)}$

Characteristics:
Acid & Base Reactants
Water & Salt Product
Ions "switch" Places

Double Displacement
Neutralization

K – OH
H – NO_3

Reaction forms water
And
" What's left" (KNO_3)



Neutralization: Basis for Many Titrations

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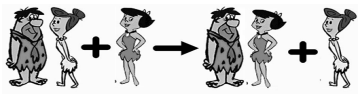
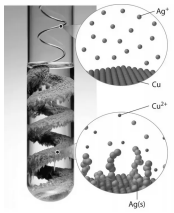
Give the type of reaction for:

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

Characteristics:
Reactant & Product Side Have Different Free Element
Cu, Free element, Replaces Ag
Single Replacement: Metal for Metal





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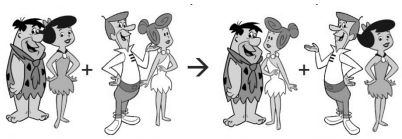
Give the type of reaction for:

$BaCl_{2\,(aq)} + K_2CrO_{4\,(aq)} \rightarrow BaCrO_{4\,(s)} + 2\,KCl_{(aq)}$

Characteristics:
Ions switch Places
Precipitate Formed
Double Replacement
Precipitation



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Give the type of reaction for:

$NH_4Cl_{(s)} \rightarrow NH_{3\,(g)} + HCl_{(g)}$

Characteristics:
1 Reactant
2 Products
Decomposition

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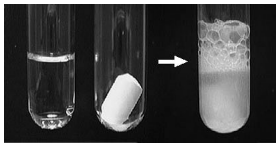
Give the type of reaction for:

$Na_2CO_{3\,(s)} + 2\,HCl_{(aq)} \rightarrow 2\,NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$

Characteristics:
Double Displacement
One Product decomposes to form a gas
Double Replacement
Gas Forming



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Exercise Summary:

$C_2H_5OH_{(l)} + 3\,O_{2\,(g)} \rightarrow 2\,CO_{2\,(g)} + 3\,H_2O_{(g)}$ **(Combustion)**

$2\,Mg_{(s)} + O_{2\,(l)} \rightarrow 2\,MgO_{(l)}$ **(Combination)**

$HNO_{3\,(aq)} + KOH \rightarrow H_2O_{(l)} + KNO_{3\,(aq)}$ **(Neutralization)**

$Cu_{(s)} + 2\,AgNO_{3\,(aq)} \rightarrow Cu(NO_3)_{2\,(aq)} + 2\,Ag_{(s)}$ **(Single Displacement)**

$BaCl_{2\,(aq)} + K_2CrO_{4\,(aq)} \rightarrow BaCrO_{4\,(s)} + 2\,KCl_{(aq)}$ **(Precipitation)**

$NH_4Cl_{(s)} \rightarrow NH_{3\,(g)} + HCl_{(g)}$ **(Decomposition)**

$Na_2CO_{3\,(s)} + 2\,HCl_{(aq)} \rightarrow 2\,NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$ **(Gas Forming)**

LPT

Summary of Types of Reactions and Equations

Reactants	Reaction Type	Equation Type	Products
Any combination of elements and compounds that form one product	Combination	A + X ⟶ AX	One compound
One compound	Decomposition	AX ⟶ A + X	Any combination of elements and compounds
Element + ionic compound or acid	Single-replacement	A + BX ⟶ AX + B	Element + ionic compound
Solutions of two compounds, each with positive and negative ions	Double-replacement	AX + BY ⟶ AY + BX	Two new compounds, which may be a solid, water, an acid, or an aqueous ionic compound

Fuel + Oxygen $C_xH_yO_z + O_2 \rightarrow CO_2 + H_2O$ $CO_2 + H_2O$

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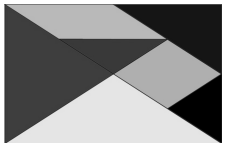
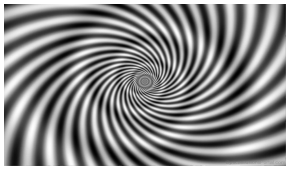
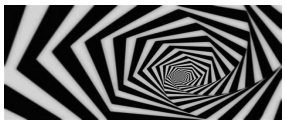
Think Patterns
Too many reactions to memorize







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