

Chemical Reactions

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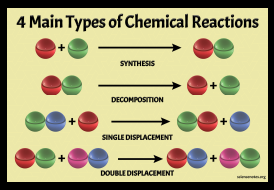
Types of Chemical Reactions

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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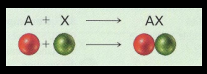
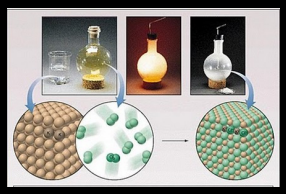
Combination (Synthesis) Reactions



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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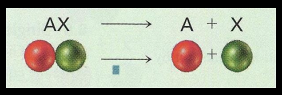
Decomposition Reactions



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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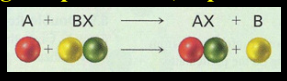
Single Replacement (Displacement)



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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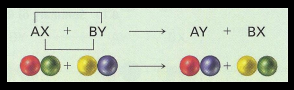
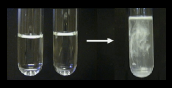
Double Replacement (Displacement) Reactions





Precipitation

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

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

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

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

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

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

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

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

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

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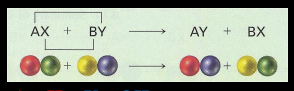
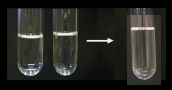
Double Replacement (Displacement) Reactions





Neutralization
Heat Evolved

A = H^+ Y = OH^-

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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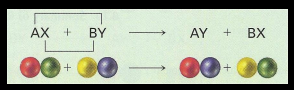
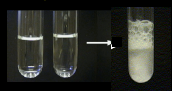
Double Replacement (Displacement) Reactions





Gas Forming

Gas Forming:

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

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

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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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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Chemical Reactions Lab

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Reactions Lab

Purpose:

observe a number of chemical reactions
note the signs that a chemical change has occurred,
classify chemical reactions, and
communicate chemical changes

Procedure:

The lab is a combination of instructor demos and student run reactions
The data is the observations
The data is already provided for you since this is a virtual class.

All you need to do to complete and balance the listed chemical reactions

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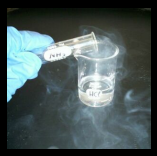
Combination Reactions

Metals + Oxygen reactions can be quite hot!

Lighting Mg

Thermite - Welder

Sparklers



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

$NH_3 + HCl \rightarrow NH_4Cl$

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Decomposition Reaction

Hydrogen Peroxide

$2\ H_2O_2 \rightarrow 2\ H_2O + O_2$

Oxygen kills anaerobic microbes
- Considered extremely potent for certain infections

Foaming result catalase enzyme decomposing peroxides
- Peroxides (ROS's) are very destructive to cellular components
- Catalase is one method of protecting cells
  - One of highest "turnovers" known
  - Catalase runs reaction on 40 million molecules / second

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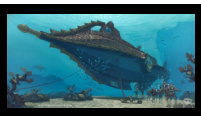
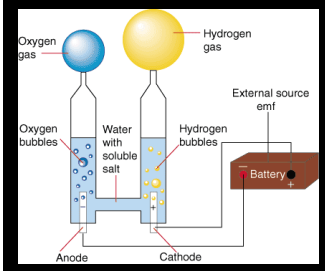
Decomposition Reaction





Electrical decomposition (Electrolysis) of water
Provides source of hydrogen and oxygen

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

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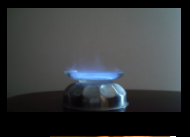
Burning or Complete Combustion

Note color of Bunsen Burner flame with complete & incomplete combustion

Place several drops of ethanol on a watch glass:
ignite it with a lighted match



Burning
Anything organic (contains C & H)
Puts Carbon Dioxide into the air

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Single Replacement (Displacement)

Put 20 drops of copper(II) sulfate solution into a small test tube
Add a small piece of zinc.
Observe the reaction for several minutes
Put the test tube aside and observe again after 30 minutes

Put 20 drops of hydrochloric acid into a test tube
Add a small piece of magnesium metal
Observe the reaction for several minutes

$Zn + CuSO_4 \rightarrow Cu + ZnSO_4$

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

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Single Replacement (Displacement)

Hydrogen was used in the civil war for observation balloons

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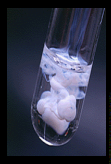
Double Replacement (Displacement) Reactions

Reactant A	Reactant B
Precipitation Reaction	
Copper(II) sulfate	Sodium hydroxide
Calcium chloride	Sodium sulfate
Potassium carbonate	Calcium chloride
Gas-Forming Reaction	
Potassium carbonate	Hydrochloric acid
Sulfuric acid	Sodium carbonate
Neutralization Reaction	
Nitric acid	Sodium hydroxide
Sulfuric acid	Sodium hydroxide



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Double Replacement: Precipitation

Ag_2CrO_4 PbI_2 CdS Bi_2S_3 $Ni(OH)_2$ $Al(OH)_3$

$Cu(OH)_2$ $Ni(DMG)_2$ AgBr SnS_2 Ag_3AsO_4 AgCl

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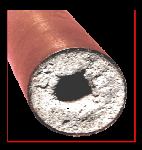
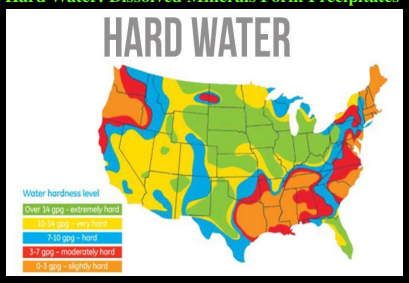
Double Replacement: Precipitation

Hard Water: Dissolved Minerals Form Precipitates





Test Strips

Test Meters

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Let's Boldly Go Explore Today's Lab

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