
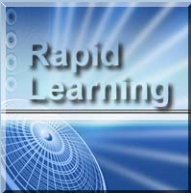
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 **Chemical Reactions**

College Chemistry Rapid Learning Series

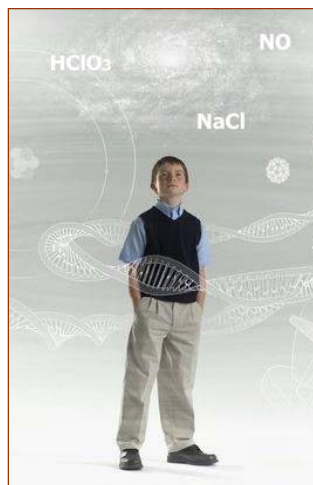
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Russell Dahl, PhD
Elizabeth James, PhD

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Learning Objectives

By studying this tutorial you will learn...



- How chemical reactions are written.
- What types of chemical reactions are common.
- How to determine redox reactions.
- How to determine if a product will be a precipitate.
- How to predict products of simple chemical reactions.

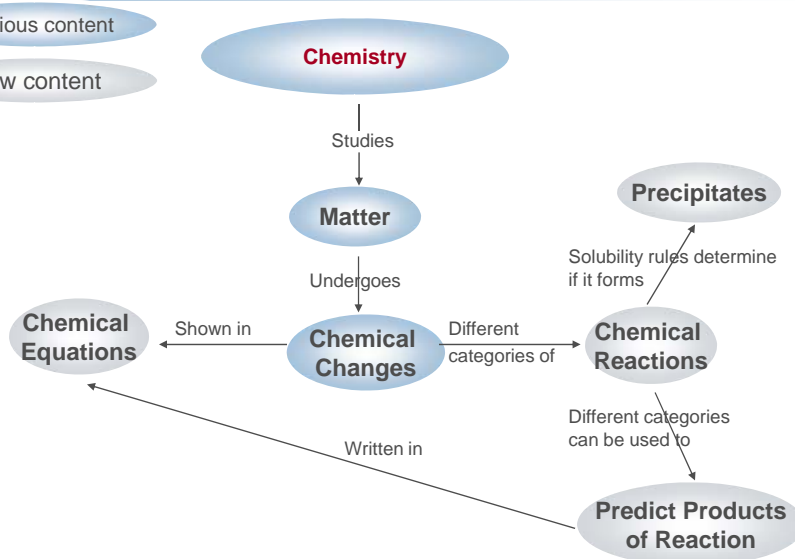
3/48



Concept Map


Previous content

New content





4/48






**What is a
Chemical
Reaction?**





5/48 



Definition: Chemical Reaction


Chemical Reaction – bonds and atoms are rearranged to form new compounds.




$$2 \text{H}_2 + \text{O}_2 \rightarrow 2 \text{H}_2\text{O}$$



The compounds in the end are different from those in the beginning

Watch as 2 H₂ and 1 O₂ undergo a chemical reaction



6/48 



Chemical Equations




7/48




Definition: Chemical Equation

Chemical Equation – the “sentence” of chemistry that shows the starting materials and the final products of a chemical reaction.



8/48





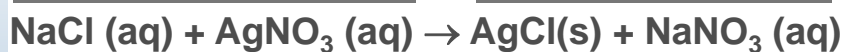
Parts of a Chemical Equation

The starting materials for the reaction—each compound is separated by a “+”

Reactants

Formed in the reaction

Products



States of matter

s = solid
l = liquid
g = gas
aq = aqueous
(dissolved in water)

Arrow

Read as:
Yields
Produces
Forms
Makes
etc.

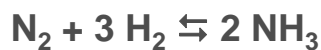


9/48



Equilibrium Reactions

Equilibrium Reaction – Some reactions can proceed in both directions. When the rate of the forward reaction (\rightarrow) equals the rate of the reverse reaction (\leftarrow) then it is at equilibrium.



Double Arrow

Indicates a reaction can proceed in both directions.

10/48





Mole Ratios in Chemical Equations

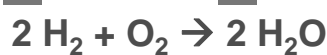
One of the most important pieces of information in a chemical reaction is the mole ratio (shown by the coefficients).

For every 2 moles
of H₂...

2

and 2 moles of H₂O are
produced

2



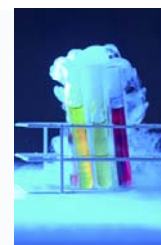
No coefficient = 1

1 mole of O₂ is
needed to
react...

11/48



Types of Reactions



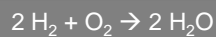
12/48





Composition Reactions

Composition Reactions – more than one compound combine to form one compound. (also called a **synthesis reaction**).



Even though there are  molecules in the end, there is still only one type of compound. This is a composition reaction.

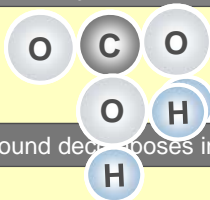
Watch as two types of compounds combine to form one compound

13/48



Decomposition Reactions

Decomposition Reactions – A compound decomposes to form more than one compound.



Watch as one compound decomposes into more than one compound

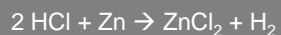
As H_2CO_3 is heated, it decomposes

14/48

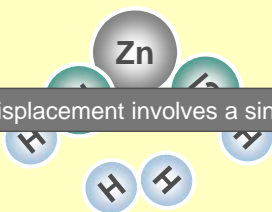


➤ Single Displacement Reactions

Single Displacement Reactions – A single element replaces an ion in a compound.



Single displacement involves a single element replacing an ion.



15/48

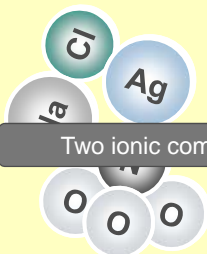


➤ Double Displacement Reactions

Double Displacement Reactions – The cations from two compounds replace each other.



Two ionic compounds switch ions



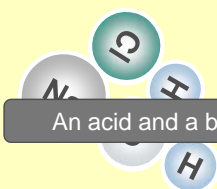
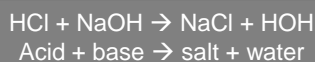
16/48





Neutralization Reactions

Neutralization Reactions – A double displacement reaction between an acid and a base. Also called **Acid-Base Reactions**.



An acid and a base undergo double displacement

17/48



Other Reactions

Not all reactions fit one of these types, some are “**uncategorized**” or they may be a combination of other reactions.

Example:



Is a combination of:



and



18/48

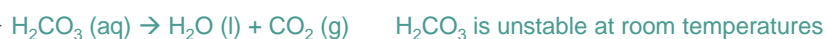
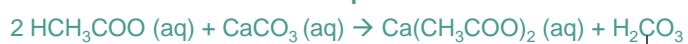




Gas Forming Reactions

Many reactions form **gases**. This becomes important when discussing equilibrium (in future tutorials) as the production of gases can “drive” a reaction to one side or another.

Examples:

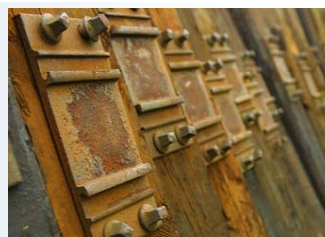


The gas escapes into the environment and drives the reaction to create more

19/48



Redox Reactions



20/48





Definition: Redox

Redox – Abbreviation for Reduction-Oxidation Reaction.



21/48



Reduction Versus Oxidation

Reduction – Gain of electrons, e^- . (charge is “reduced” by adding negative electrons).

Examples:



Oxidation – Loss of electrons, e^- .

Examples:



22/48



➤ Reduction and Oxidation


Reduction and oxidation must always occur together:

Electrons that are lost are gained elsewhere.

Oxidation
Loss of electrons

Reduction
Gain of electrons

The electrons that are gained must have come from somewhere.


23/48 

💬 Definition: Oxidation Number

Determined by the ratio of protons to electrons

Oxidation Number – Charge that would occur on an atom if shared electrons were assigned to the most electronegative atom.

The atom that has the greatest pull for electrons being shared in a covalent bond

24/48 



Assigning Oxidation Numbers

A set of rules for assigning oxidation numbers:

- 1 The sum of the oxidation numbers equals 0 for a compound or element, or the charge of the polyatomic ion.
- 2 Hydrogen is +1 when bonded to non-metals and -1 when bonded to metals
- 3 Oxygen is usually -2
- 4 All halogens (Group 7 or VII) are usually -1
- 5 The oxidation number of an ion in an ionic compound is equal to the charge of the ion

Example:



Rule 2: H = +1

Rule 3: O = -2

Rule 1: $2 \times \text{H} + 1 \times \text{S} + 4 \times \text{O} = 0$

$2 \times 1 + 1 \times \text{S} + 4 \times -2 = 0$

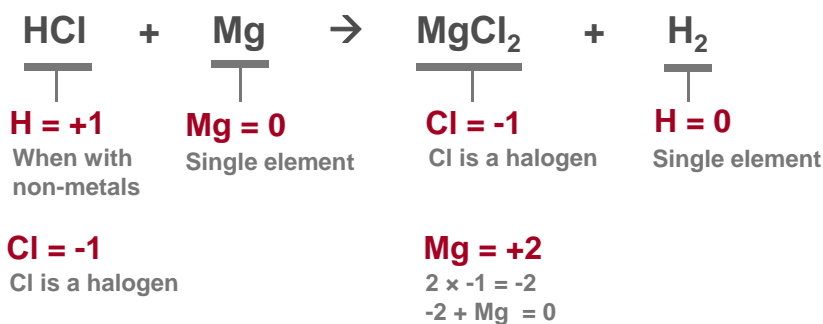
Therefore S = +6

25/48



Identifying Redox Reactions

All single displacement reactions are redox.



H: +1 → 0 → Oxidation number is reduced → H is reduced

Mg: 0 → +2 → Oxidation number is increased → Mg is oxidized

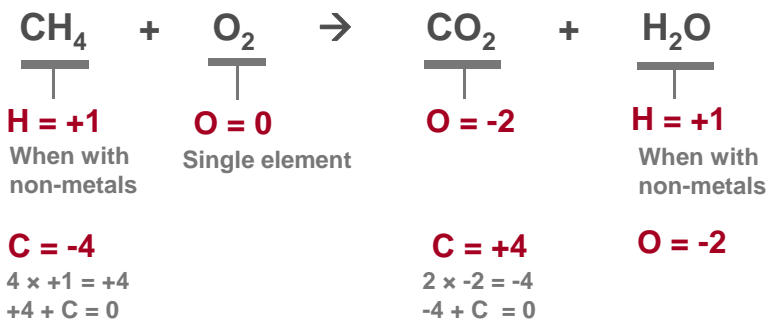
26/48





Identifying Redox Reactions - 2

But not all redox reactions are single displacement.



C: -4 → +4 → Oxidation number is increased → C is oxidized

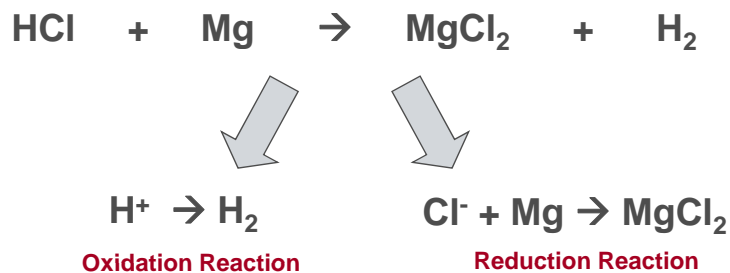
O: 0 → -2 → Oxidation number is reduced → O is reduced

27/48



Half-Reactions


Redox reactions can be split in half—into a reduction reaction and an oxidation reaction.




Although this method isn't always necessary to balance redox reactions, it is needed in more complex problems.

28/48







Precipitation Reactions & Solubility Rules




29/48




Definition: Precipitation Reaction

Precipitation reaction – One type of double displacement reaction: Two soluble compounds react to form an insoluble compound (the **precipitate**) in an aqueous solution.



30/48





Solubility Rules

Look up the anion in the left column to see which cations it forms insoluble compounds with.

| | Forms insoluble compounds with |
|--|---|
| NO_3^- | No common cations |
| CH_3COO^- | Ag^+ |
| Cl^- , Br^- , I^- | Ag^+ , Pb^{2+} , Hg_2^{2+} , Tl^+ |
| SO_4^{2-} | Ag^+ , Pb^{2+} , Ba^{2+} , Sr^{2+} , Ca^{2+} |
| CrO_4^{2-} | Ag^+ , Pb^{2+} , Ba^{2+} , Sr^{2+} |
| S^{2-} | All cations except NH_4^+ , column 1 & 2 |
| OH^- | All cations except NH_4^+ , Column 1, Ba^{2+} and Sr^{2+} |
| CO_3^{2-} , PO_4^{3-} | All cations except NH_4^+ , Column 1 (except Li^+) |

31/48

NH_4^+ , Na^+ and K^+ are soluble with all common anions.



Using Solubility Rules

Will each of the following compounds be soluble?



NO_3^- is insoluble with no common cations



Soluble



Cl^- is insoluble with Ag^+ , Pb^{2+} , Hg_2^{2+} , Tl^+



Insoluble



OH^- is insoluble except with NH_4^+ , cations of column 1, Ba^{2+} , Sr^{2+}



Insoluble



There is no rule for $\text{Cr}_2\text{O}_7^{2-}$, but Na^+ is soluble with all anions



Soluble

32/48

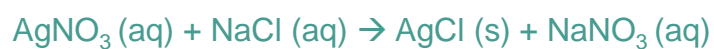




Designating a Precipitate

If an insoluble compound is formed from aqueous solutions of two soluble compounds, it is a **precipitate** and should be designated with a “(s)”.

Example:



—
|
Precipitate

33/48



Net Ionic Equations



34/48





Definition: Net Ionic Equations

When an ionic compound dissolves in water, the ions dissociate (separate) and move freely throughout the solution.

Ionic Equation – Any soluble ionic compound is dissociated into ions.

Net Ionic Equation – Only ions necessary for the chemical reaction are shown.

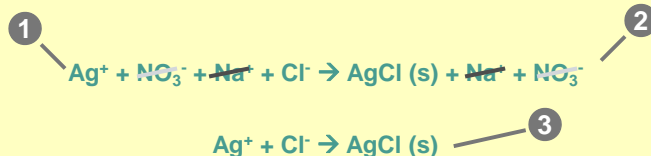
35/48



Writing Net Ionic Equations

- 1 Dissociate all soluble ionic compounds.**
Only dissociate soluble, ionic compounds in water ("aq").
Only subscripts within a polyatomic ion remain as subscripts.
All other subscripts are moved to coefficients.
- 2 Cross out any ion that is dissociated on both sides.**
These are called **spectator ions**.
- 3 Re-write the final net ionic equation.**

Example: Write the net ionic equation for:
 $\text{AgNO}_3 (\text{aq}) + \text{NaCl} (\text{aq}) \rightarrow \text{AgCl} (\text{s}) + \text{NaNO}_3 (\text{aq})$



36/48

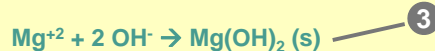
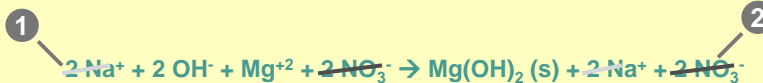
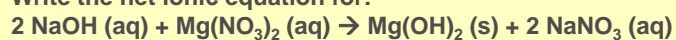




Writing Net Ionic Equations - 2

- 1 Dissociate all soluble ionic compounds.**
Only dissociate soluble, ionic compounds in water ("aq").
Only subscripts within a polyatomic ion remain as subscripts.
All other subscripts are moved to coefficients.
- 2 Cross out any ion that is dissociated on both sides.**
These are called **spectator ions**.
- 3 Re-write the final net ionic equation.**

Examples: Write the net ionic equation for:



37/48



Predicting Products of Chemical Reactions



38/48





A Difficult Task

Predicting the products of a chemical reaction can be difficult.

As you gain experience (see more reactions, take more courses and learn more about properties of elements & compounds), it will become easier.

But in the meantime, there are some guidelines you can follow for simple reactions...



39/48



Double Displacement

- 1 Determine it's a double displacement reaction (two compounds, each with a cation and anion).



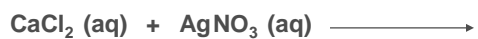
40/48





Double Displacement - 2

- 2 Combine the cation of the first reactant with the anion of the second reactant.

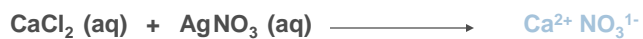


41/48



Double Displacement - 3

- 3 Combine the cation of the second reactant with the anion of the first reactant.



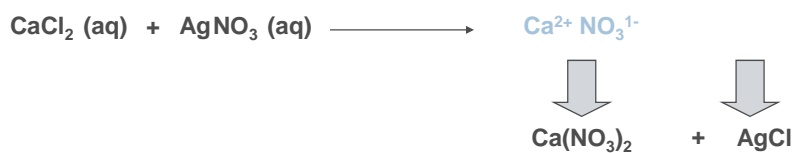
42/48





Double Displacement - 4

- 4 Remember to write cations first ...
& balance charges with subscripts when writing formulas.

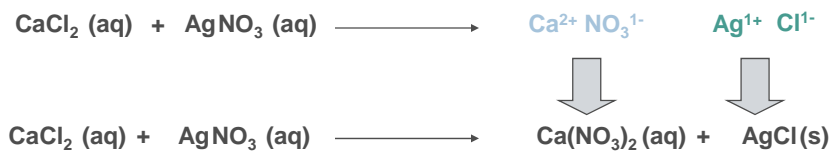


43/48



Double Displacement - 5

- 5 Determine if there are any precipitates using solubility rules.



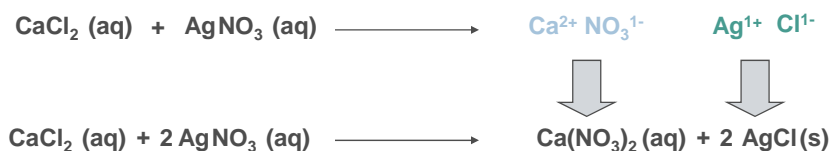
44/48





Double Displacement - 6

- 6 Balance the equation with coefficients (covered in a future tutorial).



45/48



Learning Summary

Solubility rules can be used to predict if a precipitate (insoluble compound) will form

Chemical reactions rearrange the bonds and atoms to form new compounds

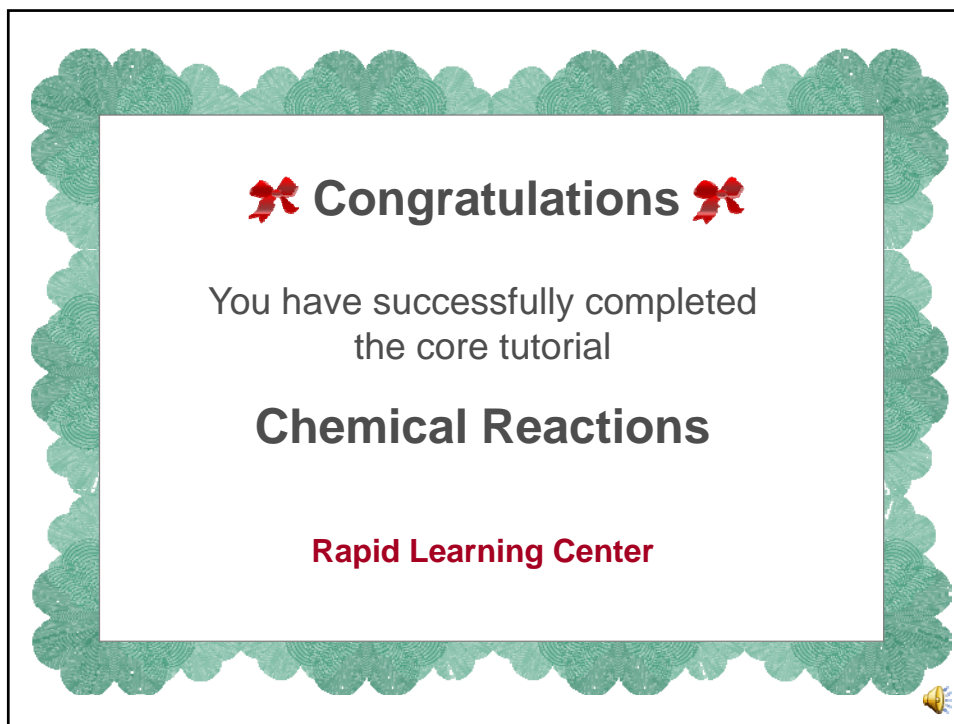
The **products** of a reaction can sometimes be predicted based upon the type of reaction

Chemical equations show the starting materials and the final products in a chemical reaction

There are several **categories** of reaction types

46/48







🎀 Congratulations 🎀


You have successfully completed
the core tutorial

Chemical Reactions

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What's Next ...

Step 1: Concepts – Core Tutorial (Just Completed)
→ Step 2: Practice – Interactive Problem Drill
Step 3: Recap – Super Review Cheat Sheet

Go for it!



48/48

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