Chemical Reactions

Classifying chemical reactions *(in high school chemistry)*

synthesis $A + B \longrightarrow AB$

decomposition $AB \longrightarrow A + B$

single replacement $AB + C \longrightarrow AC + B$

double replacement $AB + CD \longrightarrow AD + CB$

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Metathesis (Exchange) Reactions

synthesis

two or more substances combine to produce a single (more complex) substance

(oxidation reduction reactions)

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$$

$$CaO(s) + H_2O(l) \longrightarrow Ca(OH)_2(s)$$

decomposition

a single substance is broken down into two or more simpler substances

(oxidation reduction reactions)

single replacement reactions

a free element becomes an ion, and an ion in solution becomes a neutral atom

(oxidation reduction reactions)

$$Zn(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2(g)$$

$$Cu(s) + 2AgNO_3(aq) \longrightarrow 2Ag(s) + Cu(NO_3)_2(aq)$$

double replacement reactions

Metathesis (Exchange) Reactions

the cation of one aqueous compound replaces the cation in another aqueous compound

(precipitation reactions)

$$AgNO_3(aq) + NaCl(aq) \longrightarrow$$

$$AgCl(s) + NaNO_3(aq)$$

Types of Chemical Reactions

Precipitation

Acid-Base

Oxidation-Reduction

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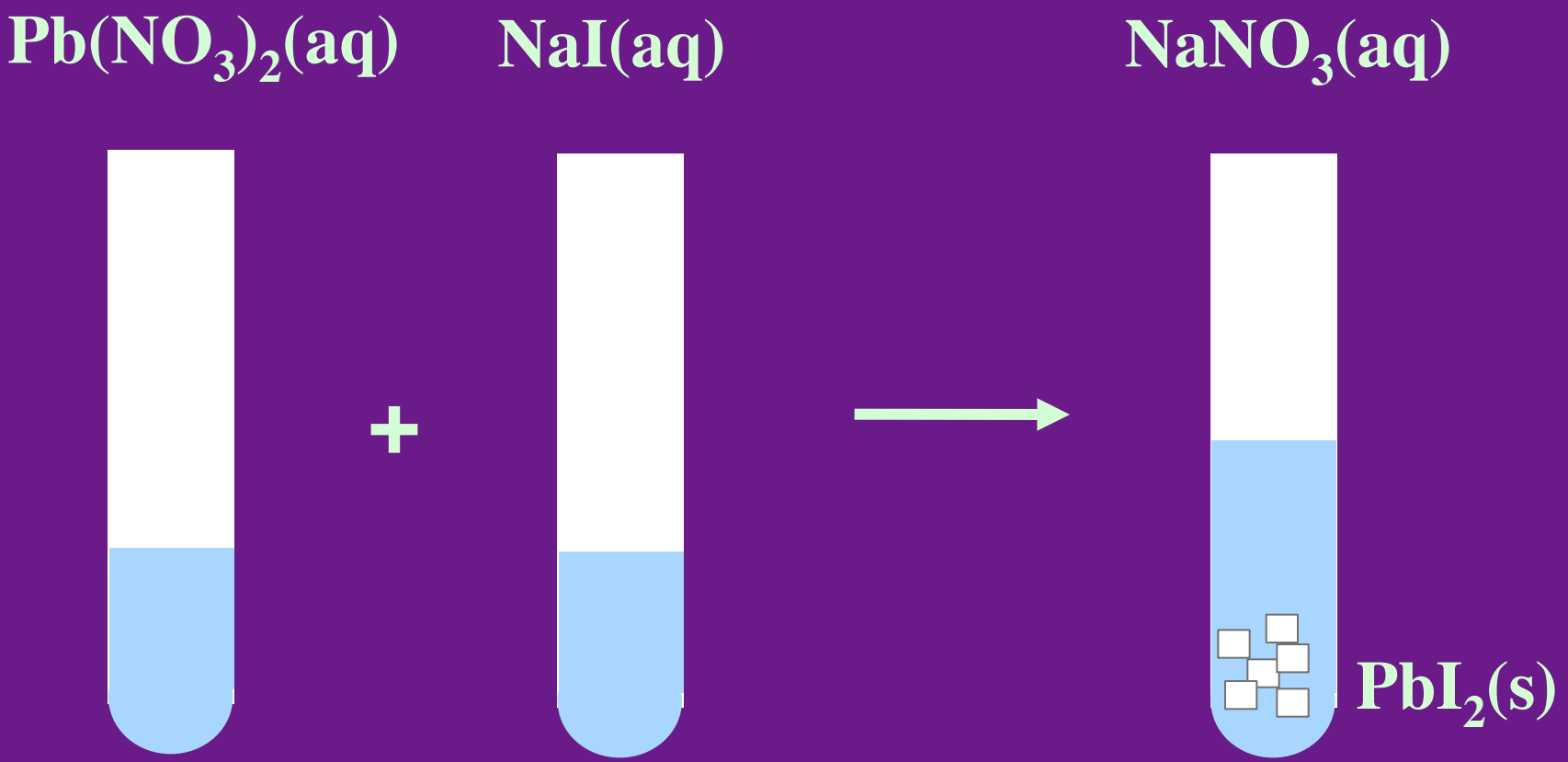
Precipitation Reactions

Precipitation Reactions

characterized by the formation of an insoluble solid that separates from the solution

usually involve ionic compounds

$$AX(aq) + BY(aq) \rightarrow AY(aq) + BX(s)$$


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

Precipitation Reactions

When one mixes ions that form compounds that are insoluble (as could be predicted by the solubility guidelines), a precipitate is formed.

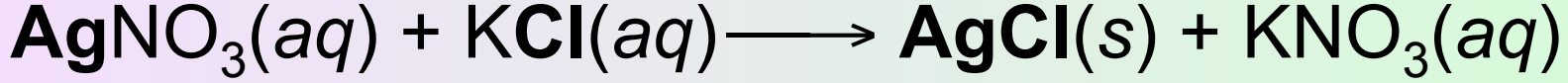
Metathesis (Exchange) Reactions

- Metathesis comes from a Greek word that means “to transpose.”

$AgNO_3(aq) + KCl(aq) \longrightarrow$

Metathesis (Exchange) Reactions

- Metathesis comes from a Greek word that means “to transpose.”
- It appears as though the ions in the reactant compounds exchange, or transpose, ions:



Solubility Rules

Soluble in water are most compounds containing:

- **a Group 1A metal ion (usually Na^+, K^+)**
- **an ammonium ion (NH_4^+)**
- **a nitrate (NO_3^-), chlorate (ClO_3^-), or perchlorate (ClO_4^-)**

(continued…)

Solubility Rules

Soluble in water are most compounds containing:

- **a sulfate ion (SO_4^{2-}) except when cation is Ag^+, Pb^{2+}, Ca^{2+}, Ba^{2+}, or Hg^{2+}**
- **a chloride (Cl^-), bromide (Br^-), or iodide (I^-) ion, except when cation is Ag^+, Pb^{2+}, or Hg_2^{2+}**

Solubility Rules

Insoluble (or slightly soluble) in water are most :

- **sulfides (S^{2-})**
- **carbonates (CO_3^{2-})**
- **phosphates (PO_4^{3-})**
- **metal hydroxides**

(NaOH , KOH and $Ba(OH)_2$ are soluble, $Ca(OH)_2$ is slightly soluble)

Example

Classify the following ionic compounds as soluble, insoluble or slightly soluble

(a) CuS **insoluble**

(b) $Ca(OH)_2$ **slightly soluble**

(c) $Zn(NO_3)_2$ **soluble**

Molecular Equations
And
Ionic Equations

Molecular equation expressed via chemical formulas:

$$AX(aq) + BY(aq) \longrightarrow AY(aq) + BX(s)$$

$$AX(aq) = A^{+}(aq) + X^{-}(aq)$$

$$BY(aq) = B^{+}(aq) + Y^{-}(aq)$$

$$AY(aq) = A^{+}(aq) + Y^{-}(aq)$$

Ionic equation showing all of the ions:

$$A^{+}(aq) + X^{-}(aq) + B^{+}(aq) + Y\text{-}(aq) \longrightarrow A^{+}(aq) + Y^{-}(aq) + BX(s)$$

Net ionic equation

an equation that shows all of the ions is not very useful

identify and discard "spectator ions"

$$A^+(aq) + X^-(aq) + B^+(aq) + Y^-(aq) \longrightarrow A^+(aq) + Y^-(aq) + BX(s)$$

$$X^-(aq) + B^+(aq) \longrightarrow BX(s)$$

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

$$2NaI(aq) \longrightarrow 2Na^+(aq) + 2I^-(aq)$$

$$Pb(NO_3)_2(aq) \longrightarrow Pb^{2+}(aq) + 2NO_3^-(aq)$$

$$2NaNO_3(aq) \longrightarrow 2Na^+(aq) + 2NO_3^-(aq)$$

Equation showing all of the ions

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

Net ionic equation

identify and discard "spectator" ions

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

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

Example

Predict the precipitate formed in the following reaction and write a net ionic equation for the reaction.

$$Al(NO_3)_3(aq) + 3NaOH(aq) \rightarrow 3NaNO_3(aq) + Al(OH)_3(s)$$

Example

$$Al(NO_3)_3(aq) + 3NaOH(aq) \longrightarrow 3NaNO_3(aq) + Al(OH)_3(s)$$

Rewrite as a complete ionic equation.

$$Al^{3+}(aq) + 3NO_3^-(aq) + 3Na^+(aq) + 3HO^-(aq)$$

$$3Na^+(aq) + 3NO_3^-(aq) + Al(OH)_3(s)$$

Example

Cancel spectator ions.

$$Al^{3+} + 3NO_3^-(aq) + 3Na^+(aq) + 3OH^-(aq)$$

$$3Na^+(aq) + 3NO_3^-(aq) + Al(OH)_3(s)$$

$$Al^{3+} + 3HO^-(aq) \longrightarrow Al(OH)_3(s)$$

Stoichiometry of Precipitation Reactions

derive the net ionic equation

obtain the moles of reactants from the volume of the particular solution and its molarity

Example

Calculate the mass of solid NaCl that must be added to 1.50L of a 0.100 M $AgNO_3$ solution to precipitate all the Ag^+ ions in the form of AgCl.

$$NaCl(aq) + AgNO_3(aq) \longrightarrow$$

$$Na^+(aq) + Cl^-(aq) + Ag^+(aq) + NO_3^-(aq) \longrightarrow$$

$$AgCl(s) + Na^+(aq) + NO_3^-(aq)$$

Example

$$Cl^-(aq) + Ag^+(aq) \longrightarrow AgCl(s)$$

$$1.50\,L \times \frac{0.100\ mol\ Ag^+}{L} \times \frac{1\ mol\ Cl^-}{1\ mol\ Ag^+} \times \frac{1\ mol\ NaCl}{1\ mol\ Cl^-}$$

$$\times \frac{58.4\ g\ NaCl}{1\ mol\ NaCl} = \mathbf{8.76\ g\ NaCl}$$