

CHEM 115

Precipitation Reactions and Writing Net Ionic Equations

Lecture 8
Prof. Sevian



Important Announcement

- Exam #1 is next Thursday (February 26)
- Please read the information about exams on the website
- Important: You will sit every other row, and every other seat
- Don't forget to bring a pencil, eraser and calculator
- Be on time!

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Agenda

- Why to learn solubility rules
- Overview of types of reactions
- Focus on exchange reactions
 - Given two reactants, predicting whether a reaction takes place – is a product formed?
 - Requires using solubility rules to determine if one (or both) of the products is a precipitate (insoluble compound)
 - Learn how to write net ionic equations
 - These are easiest to learn for exchange reactions in which a precipitate is formed, but you will also need to know how to write net ionic equations for other kinds of reactions

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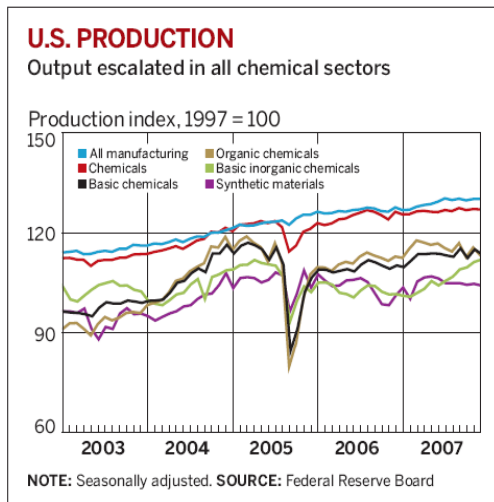
What we learned last lecture

- A solution is a mixture that is made of a solvent and solute(s)
- In an aqueous solution, the solvent is water
- We explain solubility with a particle level model for how ionic solute particles (individual + and - ions) are “solvated” by water molecules
- If the solute in an aqueous solution is ionic, then the solution will conduct electricity (charged particles must be mobile)
- All solutes dissolve to some extent
- The extent to which a solute dissolves can be arbitrarily categorized as
 - Minimally soluble – we call this “insoluble”
 - Somewhat soluble
 - Very solublewe call these “soluble”
- To remember whether an ionic compound is soluble in water, you have to memorize the solubility rules

Where we are going next

- If two different aqueous ionic solutions are mixed, a chemical reaction might occur
- If a reaction occurs, one (or both) of the products might be a precipitate
- To predict whether an ionic product dissolves or precipitates, you rely on your memorized solubility rules
 - If both ionic products are soluble, then there is really no product produced, so we say there is no reaction that occurred
- If a reaction occurs when two aqueous ionic solutions are mixed, then you can write a net ionic equation

Why learn about reactions? The Chemical Process Industries

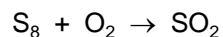


Top chemicals produced in the U.S. in 2007

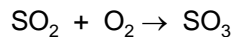
Sulfuric acid	36.6×10^6 metric tons
Phosphoric acid, as P_2O_5	11.0×10^6 metric tons
HDPE	8.3×10^6 metric tons
Nitric acid	7.4×10^6 metric tons
LDPE	6.1×10^6 metric tons
Ammonia gas	7.9×10^6 m ³
Sodium hydroxide	8.0×10^6 metric tons
Polypropylene	8.8×10^6 metric tons
Polyvinyl chloride	6.6×10^6 metric tons

Sulfuric Acid

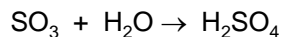
- Produced by burning iron pyrites or sulfur in air:



then reacting sulfur dioxide in the presence of a catalyst with more oxygen to produce sulfur trioxide:



and finally reacting sulfur trioxide with water to make sulfuric acid:



- Involved in the production of nearly all manufactured goods
- Used primarily in production of fertilizers (lime, ammonium sulfate)
- Also used in production of other acids, sulfate salts, detergents, dyes & pigments, explosives, drugs
- Other uses include washing gasoline, processing metals, making rayon
- Serves as electrolyte in lead-acid storage battery

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Macroscopic Level: How Can You Tell If There Is a Chemical Change?

- **We say a chemical reaction has occurred if a chemical is formed that was not present before**
- Evidence of chemical change can be:
 - Solid appears (precipitate)
 - Gas forms: bubbles, odor
 - Color change (usually when a solid reacts with chemical dissolved in a solution)
- (Confusing) Other evidence of change that could indicate either chemical or physical change:
 - Heat released (feels warm)
 - Heat absorbed (feels cold)
 - One of the chemicals changes phase (changes to solid, liquid or gas of itself) because the temperature changed

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Macroscopic Level: Classifying Chemical Reactions Based on Evidence Observed

Consider only reactions that occur in aqueous solutions

1. Precipitation reactions
 - Formation of a precipitate (solid) where there wasn't one before
2. Acid-base reactions
 - pH of product solution is different from the pH's of the reactant solution
3. Oxidation-reduction (redox) reactions
 - If the reactions are separated in a special way, electricity can be generated

*Categories are not unique, in part because 1 and 2 are based on evidence, but 3 is based on particle-level model

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History of Classes of Reactions

- Names of “classes” of chemical reactions reflects the history of understanding them
- Macroscopic = properties observed in laboratory
 - Precipitation and gas-forming
 - Acid-base
 - Combustion
- Particle level = model of underlying process
 - Redox

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Particle Level Chemical Reactions

- It is called a “chemical reaction” only if a chemical change occurs
- Chemical changes are ALWAYS about ELECTRONS
- Four kinds of processes involved
 - Transfer of a “proton” (a naked hydrogen atom) from one chemical species to another (this really has to do with electrons holding the pieces together)
 - Sharing of electron pairs between chemical species
 - Transfer of an electron from one chemical species to another
 - Sharing of single electrons between chemical species

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Some Types of Reactions (According to Your Textbook)

1. Precipitation and gas-forming reactions
2. Acid-base reactions
3. Oxidation-reduction reactions (short name: redox reactions)
4. (Combustion reactions)

Some other ways to categorize reactions

- Based on patterns in the chemical equations
 - Exchange, single replacement, S_N1 , S_N2 , condensation polymerization, etc.
- Based on functional groups that get replaced
 - Halide-alcohol exchange, others

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Focus for now on Precipitation Rxns

Macroscopic View

- An insoluble compound forms, usually from two soluble compounds (dissolved in water) that react in aqueous solution
- The insoluble compound precipitates (insoluble crystals form, which then fall to the bottom of the solution due to their higher density than the aqueous solution)
- The insoluble compound can be white or colored
- When the insoluble compound precipitates, it leaves the solution, thereby causing more reaction to occur between reactants
- Some examples

<http://www.jce.divched.org/JCESoft/CCA/samples/index.html>

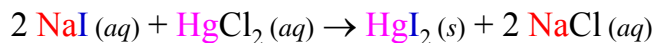
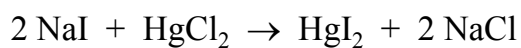
- Sodium iodide + mercury (II) chloride
- Cadmium nitrate + sodium sulfide

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Precipitation Rxns

Symbolic Representation

Sodium iodide + mercury (II) chloride



sodium iodide + mercury (II) chloride → mercury (II) iodide + sodium chloride

Many names for this pattern (synonyms):

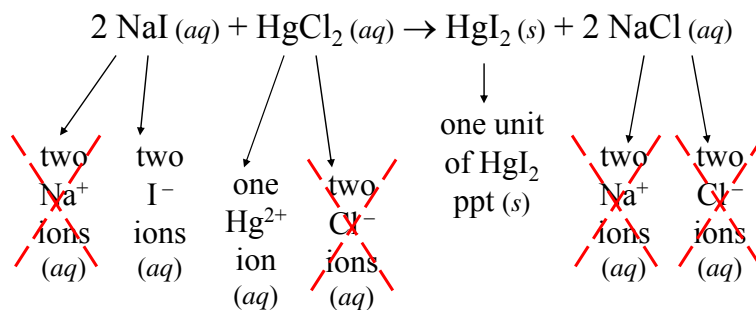
- Exchange reaction
- Metathetical reaction
- Double displacement reaction
- Double replacement reaction

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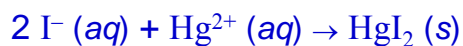
Precipitation Rxns

Symbolic Representation

Sodium iodide + mercury (II) chloride

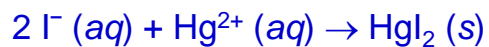
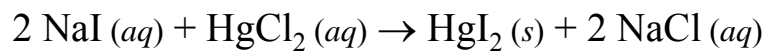


Net reaction: two I^- ions + one Hg^{2+} ion → one unit of HgI_2 ppt



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Complete equation vs. Net ionic eqn



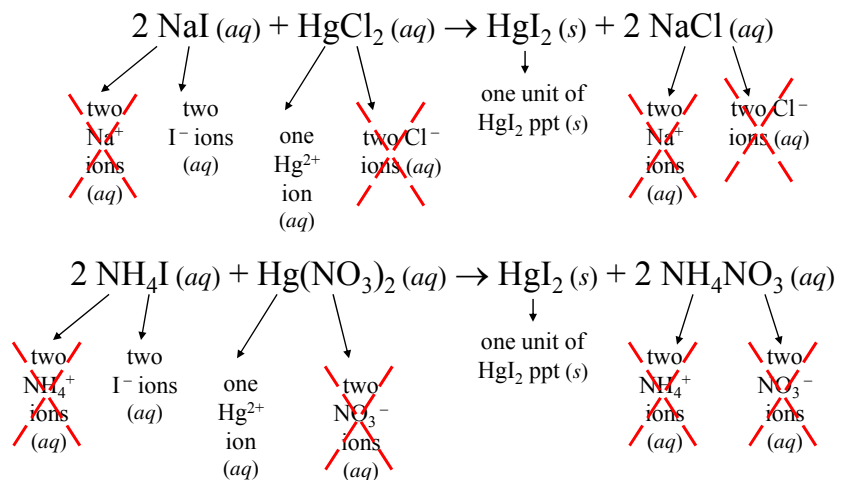
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Writing Net Ionic Equations

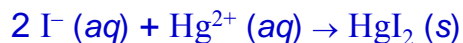
1. Start with the balanced reaction, written with phases
2. Identify ions in aqueous solution, ionic solids that precipitate, and any molecules on both sides of the arrow
3. Cross out any spectator ions
4. What's left is the net ionic equation

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Spectator Ions are Vehicles



Net reaction: two I⁻ ions + one Hg²⁺ ion → one unit of HgI₂ ppt

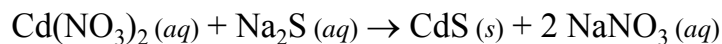


You Try It

Write the Net Ionic Equation

Cadmium nitrate + sodium sulfide

cadmium nitrate + sodium sulfide → cadmium sulfide + sodium nitrate



Net reaction:

What we have learned so far

- A solution is a mixture that is made of a solvent and solute(s)
- In an aqueous solution, the solvent is water
- Particle level model for how ionic solute particles (individual + and - ions) are “solvated” by water molecules
- If the solute in an aqueous solution is ionic, then the solution will conduct electricity (charged particles must be mobile)
- If two different aqueous ionic solutions are mixed, a chemical reaction might occur
- If a reaction occurs, one (or both) of the products might be a precipitate
- To know whether an ionic compound dissolves or precipitates, you have to memorize the solubility guidelines
- If a reaction occurs when two aqueous ionic solutions are mixed, then you can write a net ionic equation



Clicker question #1

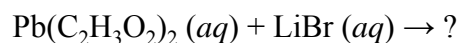
A solution of sodium sulfate and a solution of silver nitrate are poured together. What are the products of the reaction?

- A. NaAg (s) and $\text{SO}_4\text{NO}_3 \text{ (aq)}$
- B. $\text{Na}_2\text{SO}_4 \text{ (aq)}$ and $\text{AgNO}_3 \text{ (s)}$
- C. $\text{NaNO}_3 \text{ (aq)}$ and $\text{AgSO}_4 \text{ (s)}$
- D. $\text{NaNO}_3 \text{ (aq)}$ and $\text{Ag}_2\text{SO}_4 \text{ (s)}$
- E. No reaction occurs because there is no product that precipitates (i.e., the ions all remain dissolved)



Clicker question #2

The following two reactant solutions are poured together:



What are the spectator ions in the net ionic equation?

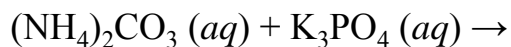
- A. Pb^{2+} and $\text{C}_2\text{H}_3\text{O}_2^-$
- B. Pb^{2+} and Br^-
- C. $\text{C}_2\text{H}_3\text{O}_2^-$ and Br^-
- D. Li^+ and Br^-
- E. Li^+ and $\text{C}_2\text{H}_3\text{O}_2^-$

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Clicker question #3

Two solutions are mixed:



What, if any, reaction occurs?

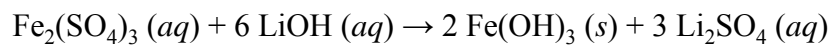
- A. A reaction occurs; the products are $(\text{NH}_4)_2\text{PO}_4 + \text{K}_3\text{CO}_3$
- B. A reaction occurs; the products are $(\text{NH}_4)_3\text{PO}_4 + \text{K}_2\text{CO}_3$
- C. A reaction occurs; the products are $(\text{NH}_4)_4\text{PO} + \text{K}_3\text{CO}$
- D. A reaction occurs; the products are $\text{NH}_4\text{PO}_4 + \text{KCO}_3$
- E. No reaction occurs

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Clicker question #4

For this reaction:



What is the balanced net ionic equation?

- A. $\text{Fe}_2^{3+} (aq) + \text{OH}^- (aq) \rightarrow \text{Fe}(\text{OH})_3 (s)$
- B. $\text{Fe}_2^{3+} (aq) + 6 \text{OH}^- (aq) \rightarrow 2 \text{Fe}(\text{OH})_3 (s)$
- C. $\text{Fe}^{3+} (aq) + 3 \text{OH}^- (aq) \rightarrow \text{Fe}(\text{OH})_3 (s)$
- D. $2 \text{Fe}^{3+} (aq) + 6 \text{LiOH} (aq) \rightarrow 2 \text{Fe}(\text{OH})_3 (s) + 6 \text{Li}^+ (aq)$
- E. $\text{Fe} (aq) + 3 \text{OH} (aq) \rightarrow \text{Fe}(\text{OH})_3 (s)$

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