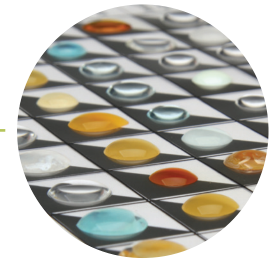
A Visual Introduction to Ionic and Net Ionic Equations

A Carolina Essentials™ Activity



Overview

This activity explores the phenomenon of chemical precipitation and asks students to construct an atomic level model of precipitation using ionic and net ionic equations. Initially, students run a series of reactions. Some reactions produce precipitates and some don't. Using only the reactions that produce precipitates, students then write ionic equations, cross out spectator ions, and conclude with the net ionic equation.

Use the activity as an extension to Carolina ChemKits®: Mystery Chemical Reactions or as a stand-alone visual introduction to precipitates, solubility, and ionic and net ionic equations.

Physical Science, Chemistry
Grades: 9–12

Essential Question

How is the phenomenon of precipitate formation explained on the atomic level?

Activity Objectives

1. Identify reactions that produce precipitates.
2. Model the formation of a precipitate using ionic and net ionic equations.

Next Generation Science Standards* (NGSS)

HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data • Use mathematical representations of phenomena to support claims.	**PS1.B: Chemical Reactions** • The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.	**Patterns** • The total amount of energy and matter in closed systems is conserved. • Macroscopic patterns are related to the nature of microscopic and atomic-level structure.

Safety Procedures and Precautions

Use safety goggles, gloves, and apron. Wash hands with soap and water when finished.

Use this kit only in accordance with established laboratory safety practices, including appropriate personal protective equipment (PPE) such as gloves, chemical splash goggles, and lab coats or aprons. Ensure that students understand and adhere to these practices. Students should not eat, drink, or chew gum in the lab and should wash their hands before or after entering and exiting the lab. Avoid contact with the dilute solutions in this lab— they might irritate or burn the skin. If contact occurs, flush the affected area with water.

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TIME REQUIREMENTS

PREP	ACTIVITY
.5 hr	45–60 min

Teacher Prep: 30 min if solutions are prepared; 120 min if solutions must be made

Student Activity: 45–60 minutes

SAFETY REQUIREMENTS

MATERIALS

8 dropper bottles

Sodium phosphate, Na_3PO_4, 0.1 M, 120 mL

Copper(II) sulfate, $CuSO_4$, 0.1 M, 120 mL

Potassium iodide, KI, 0.1 M, 120 mL

Lead(II) nitrate, $Pb(NO_3)_2$, 0.1 M, 120 mL

Sodium carbonate, Na_2CO_3, 0.1 M, 120 mL

Silver nitrate, $AgNO_3$, 0.1 M, 120 mL

Calcium chloride, $CaCl_2$, 0.1 M, 120 mL

Sodium hydroxide, NaOH, 0.1 M, 120 mL

1 reaction mat (template below) or spot plate/microplate

Absorbent paper towels

HELPFUL LINKS

Solution Preparation Guide

Carolina's Solution Preparation Manual

Solution Preparation Video

Frequently Asked Questions About Solution Preparation

REFERENCE KITS

Carolina ChemKits®: Mystery Chemical Reactions

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Teacher Preparation and Disposal

1. Prepare dropper bottles of 0.1 M test chemicals. (See the solution preparation resources below if making solutions from stock chemicals.) Label every bottle with the formula, concentration, and date prepared. Dropper bottles can be prepared the day before and stored for up to a year.
2. If using the reaction mat, make the needed number of copies of the template on copier transparency film.
3. Disposal: Solutions in dropper bottles may be stored for additional classes or additional activities. Know and follow all federal, state, and local regulations as well as school district guidelines for the disposal of laboratory wastes.

Student Procedure	Teacher Preparation and Tips
1. At the central materials station, get a dropper bottle of each of the 8 chemicals listed in the materials list.	*Chemicals may be made early and stored in capped dropper bottles.*
2. If using a reaction mat transparency, place it on top of the equations grid, so that the boxes line up. If using spot plates, position the spot plates to align with an ordered list of reactants.	*Place a lab set of dropper bottles in a small basket for easy pickup by students.*
3. Place one drop of sodium phosphate in the reaction square or well in the top left corner of the grid or spot plate. Add one drop of copper(II) sulfate to that reaction square or well. Do not let the dropper bottle tip touch the drop of the chemical you have already placed in the block or well.	*Make sure students are keeping the drops within the reaction area on the mat or in the well on the spot plate so no secondary reactions occur.*
4. Record observations.	*Remind students to look for cloudiness or particles. For this experiment, color change or bubbles are not indicative of a precipitate.*
5. Add the remaining chemicals as listed, one at a time, to the columns and rows of reaction squares.	
6. Record observations after each reaction.	*Even though students are using small amounts of chemicals they should still wear goggles, gloves, and aprons.*
7. If chemicals are placed in the wrong reaction square or well, use a rolled-up piece of absorbent paper towel to remove the chemical.	

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Ionic and Net Ionic Equations Grid

When finished, wipe clean with a damp paper towel.

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Ionic and Net Ionic Equations Grid

	$CuSO_4$	KI	$Pb(NO_3)_2$	Na_2CO_3	$AgNO_3$	$CaCl_2$	NaOH
Na_3PO_4							
NaOH							
$CaCl_2$							
$AgNO_3$							
Na_2CO_3							
$Pb(NO_3)_2$							
KI							

When finished, wipe clean with a damp paper towel.

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Data and Observations

	$CuSO_4$	KI	$Pb(NO_3)_2$	Na_2CO_3	$AgNO_3$	$CaCl_2$	NaOH
Na_3PO_4	Blue ppt	X	White ppt	X	Beige ppt	White ppt	X
NaOH	Blue ppt	X	White ppt	X	Brown ppt	White ppt	
$CaCl_2$	X	X	White ppt	White ppt	White ppt		
$AgNO_3$	X	Light green ppt	X	Beige ppt			
Na_2CO_3	Blue ppt	X	White ppt				
$Pb(NO_3)_2$	White ppt	Yellow ppt					
KI	Brown ppt						

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Analysis and Discussion

1. Identify all reactions that produced a precipitate and write a balanced chemical reaction to model the bonds being broken and reformed at the atomic level and the conservation of matter. *See below. Note the (ppt) designation may be written as (s).*

2. What evidence do you have that all the reactants are soluble? *All the reactant solutions were transparent, and none showed the reactant falling out of the solution as a solid.*

3. Using the chart of solubility rules above, identify the product that is the precipitate and place a (ppt) or (s) to the right of the product formula. Place an (aq) to the right of all chemicals that are soluble.

   a. $2Na_3PO_4(aq) + 3CuSO_4(aq) \longrightarrow 3Na_2SO_4(aq) + Cu_3(PO_4)_2(ppt)$

   b. $2Na_3PO_4(aq) + 3Pb(NO_3)_2(aq) \longrightarrow 6NaNO_3(aq) + Pb_3(PO_4)_2(ppt)$

   c. $Na_3PO_4(aq) + 3AgNO_3(aq) \longrightarrow 3NaNO_3(aq) + Ag_3PO_4(ppt)$

   d. $2Na_3PO_4(aq) + 3CaCl_2(aq) \longrightarrow 6NaCl(aq) + Ca_3(PO_4)_2(ppt)$

   e. $2NaOH(aq) + CuSO_4(aq) \longrightarrow Na_2SO_4(aq) + Cu(OH)_2(ppt)$

   f. $2NaOH(aq) + Pb(NO_3)_2(aq) \longrightarrow 2NaNO_3(aq) + Pb(OH)_2(ppt)$

   g. $NaOH(aq) + AgNO_3(aq) \longrightarrow NaNO_3(aq) + AgOH(ppt)$

   h. $2NaOH(aq) + CaCl_2(aq) \longrightarrow 2NaCl(aq) + Ca(OH)_2(ppt)$

   i. $CaCl_2(aq) + Pb(NO_3)_2(aq) \longrightarrow Ca(NO_3)_2(aq) + PbCl_2(ppt)$

   j. $CaCl_2(aq) + Na_2CO_3(aq) \longrightarrow CaCO_3(ppt) + 2NaCl(aq)$

   k. $CaCl_2(aq) + 2AgNO_3(aq) \longrightarrow Ca(NO_3)_2(aq) + 2AgCl(ppt)$

   l. $AgNO_3(aq) + KI(aq) \longrightarrow AgI(ppt) +$ KNO3(aq)

   m. $2AgNO_3(aq) + Na_2CO_3(aq) \longrightarrow Ag_2CO_3(ppt) + 2NaNO_3(aq)$

   n. $Na_2CO_3(aq) + CuSO_4(aq) \longrightarrow Na_2SO_4(aq) + CuCO_3(ppt)$

   o. $Na_2CO_3(aq) + Pb(NO_3)_2(aq) \longrightarrow 2NaNO_3(aq) + PbCO_3(ppt)$

   p. $Pb(NO_3)_2(aq) + CuSO_4(aq) \longrightarrow Cu(NO_3)_2(aq) + PbSO_4(ppt)$

   q. $Pb(NO_3)_2(aq) + 2KI(aq) \longrightarrow PbI_2(ppt) + 2KNO_3(aq)$

   r. $2KI(aq) + CuSO_4(aq) \longrightarrow K_2SO_4(aq) + CuI_2(ppt)$

4. Convert the balanced chemical equation to an ionic equation to model the process of dissociation. Split all soluble chemicals into a cation and anion. Show the charge on the ion. If needed, change the coefficient to reflect the total number of ions in solution.

   Example: 2 Ca(NO3)2 (aq) → 2Ca2+ (aq) + 4NO3-(aq)

   a. ~~$6Na^{1+}(aq)$~~ $+ 2PO_4^{3-}(aq) + 3Cu^{2+}(aq) +$ ~~$3SO_4^{2-}(aq)$~~ $\longrightarrow$ ~~$6Na^{1+}(aq)$~~ $+$ ~~$3SO_4^{2-}(aq)$~~ $+ Cu_3(PO_4)_2(ppt)$

   b. ~~$6Na^{1+}(aq)$~~ $+ 2PO_4^{3-}(aq) + 3Pb^{2+}(aq) +$ ~~$6NO_3^{1-}(aq)$~~ $\longrightarrow$ ~~$6Na^{1+}(aq)$~~ $+$ ~~$6NO_3^{1-}(aq)$~~ $+ Pb_3(PO_4)_2(ppt)$

   c. ~~$3Na^{1+}(aq)$~~ $+ PO_4^{3-}$ (aq) $+ 3Ag^{1+}(aq) +$ ~~3NO31-~~(aq) $\longrightarrow$ ~~3Na~~$^{1+}$(aq) + ~~$3NO_3^{1-}$~~ (aq) + Ag3PO4(ppt)

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d. ~~$6Na^{1+}(aq)$~~ + $2PO_4^{3-}(aq)$ + $3Ca^{2+}(aq)$ + ~~$6Cl^{1-}$~~ (aq) $\rightarrow$ ~~$6Na^{1+}(aq)$~~ + ~~$6Cl^{1-}$~~(aq) + $Ca_3(PO_4)_2(ppt)$

e. ~~$2Na^{1+}(aq)$~~ + $2OH^{1-}(aq)$ + $Cu^{2+}(aq)$ + ~~SO_4^{2-}~~(aq) $\rightarrow$ ~~$2Na^{1+}(aq)$~~ + ~~SO_4^{2-}~~(aq) + $Cu(OH)_2(ppt)$

f. ~~$2Na^{1+}(aq)$~~ + $2OH^{1-}(aq)$ + $Pb^{2+}(aq)$ + ~~$2NO_3^{1-}$~~(aq) $\rightarrow$ ~~$2Na^{1+}(aq)$~~ + ~~$2NO_3^{1-}$~~(aq) + $Pb(OH)_2(ppt)$

g. ~~$Na^{1+}(aq)$~~ + $OH^{1-}(aq)$ + $Ag^{1+}(aq)$ ~~$+ NO_3^{1-}(aq)$~~ $\rightarrow$ ~~$Na^{1+}(aq)$~~ + ~~$NO_3^{1-}(aq)$~~ + $AgOH(ppt)$

h. ~~$2Na^{1+}(aq)$~~ + $2OH^{1-}(aq)$ + $Ca^{2+}(aq)$ + ~~$2Cl^{1-}(aq)$~~ $\rightarrow$ ~~$2Na^{1+}(aq)$~~ + ~~$2Cl1-(aq)$~~ + $Ca(OH)_2(ppt)$

i. ~~$Ca^{2+}(aq)$~~ + $2Cl^{1-}(aq)$ + $Pb^{2+}(aq)$ + ~~$2NO_3^{1-}(aq)$~~ $\rightarrow$ ~~$Ca^{2+}(aq)$~~+ ~~$2NO_3^{1-}(aq)$~~ + $PbCl_2(ppt)$

j. $Ca^{2+}(aq)$ + ~~$2Cl^{1-}(aq)$~~ + ~~$2Na^{1+}$~~ + $CO_3^{2-}(aq)$ $\rightarrow$ $CaCO_3(ppt)$ + ~~$2Na^{1+}(aq)$~~ + ~~$2Cl^{1-}(aq)$~~

k. ~~$Ca^{2+}(aq)$~~ + $2Cl^{1-}(aq)$ + $2Ag^{1+}(aq)$ + ~~$2NO_3^{1-}(aq)$~~ $\rightarrow$ ~~$Ca^{2+}(aq)$~~ + ~~$2NO_3^{1-}(aq)$~~ + $2AgCl(ppt)$

l. $Ag^{1+}(aq)$ + ~~$NO_3^{1-}(aq)$~~ + ~~$K^{1+}(aq)$~~ + $I^{1-}(aq)$ $\rightarrow$ $AgI(ppt)$ + ~~$K^{1+}(aq)$~~ + ~~$NO3^{1-}(aq)$~~

m. $2Ag^{1+}(aq)$ + ~~$2NO_3^{1-}(aq)$~~ + ~~$2Na^{1+}(aq)$~~ + $CO_3^{2-}(aq)$ $\rightarrow$ $Ag_2CO_3(ppt)$ + ~~$2Na^{1+}(aq)$~~ + ~~$2NO_3^{1-}(aq)$~~

n. ~~$2Na^{1+}(aq)$~~ + $CO_3^{2-}(aq)$ + $Cu^{2+}(aq)$ + ~~$SO4^{2-}(aq)$~~ $\rightarrow$ ~~$2Na^{1+}(aq)$~~ + ~~$SO4^{2-}(aq)$~~ + $CuCO_3(ppt)$

o. ~~$2Na^{1+}(aq)$~~ + $CO_3^{2-}(aq)$ + $Pb^{2+}(aq)$ + ~~$2NO_3^{1-}(aq)$~~ $\rightarrow$ ~~$2Na^{1+}(aq)$~~ + ~~$2NO_3^{1-}(aq)$~~ + $PbCO_3(ppt)$

p. $Pb^{2+}(aq)$ + ~~$2NO_3^{1-}(aq)$~~ + ~~$Cu^{2+}(aq)$~~ + $SO4^{2-}(aq)$ $\rightarrow$ ~~$Cu^{2+}(aq)$~~ + ~~$2NO_3^{1-}(aq)$~~ + $PbSO_4(ppt)$

q. $Pb^{2+}(aq)$ + ~~$2NO_3^{1-}(aq)$~~ + ~~$2K^{1+}(aq)$~~ + $2I^{1-}(aq)$ $\rightarrow$ $PbI_2(ppt)$ + ~~$2K^{1+}(aq)$~~ + ~~$2NO_3^{1-}(aq)$~~

r. ~~$2K^{1+}(aq)$~~ + $2I^{1-}(aq)$ + $Cu^{2+}(aq)$ + ~~$SO_4^{2-}(aq)$~~ $\rightarrow$ $2K^{1+}(aq)$ + $SO4^{2-}(aq)$ + $CuI_2(ppt)$

5. With a single line, mark out the spectator ions with the coefficients. Write the net ionic equation modeling the formation of the precipitate on the atomic level. Make certain it is balanced to illustrate conservation of matter. ***See above for the strikethroughs.***

   a. $2PO_4^{3-}(aq) + 3Cu^{2+}(aq) \rightarrow Cu_3(PO_4)_2(ppt)$

   b. $2PO_4^{3-}(aq) + 3Pb^{2+}(aq) \rightarrow Pb_3(PO_4)_2(ppt)$

   c. $PO_4^{3-}(aq) + 3Ag^{1+}(aq) \rightarrow Ag_3PO_4(ppt)$

   d. $2PO_4^{3-}(aq) + 3Ca^{2+}(aq) \rightarrow Ca_3(PO_4)_2(ppt)$

   e. $2OH^{1-}(aq) + Cu^{2+}(aq) \rightarrow Cu(OH)_2(ppt)$

   f. $2OH^{1-}(aq) + Pb^{2+}(aq) \rightarrow Pb(OH)_2(ppt)$

   g. $OH^{1-}(aq) + Ag^{1+}(aq) \rightarrow AgOH(ppt)$

   h. $2OH^{1-}(aq) + Ca^{2+}(aq) \rightarrow Ca(OH)_2(ppt)$

   i. $2Cl^{1-}(aq) + Pb^{2+}(aq) \rightarrow PbCl_2(ppt)$

   j. $Ca^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CaCO_3(ppt)$

   k. $2Cl^{1-}(aq) + 2Ag^{1+}(aq) \rightarrow 2AgCl(ppt)$

   l. $Ag^{1+}(aq) + I^{1-}(aq) \rightarrow AgI(ppt)$

   m. $2Ag^{1+}(aq) + CO_3^{2-}(aq) \rightarrow Ag_2CO_3(ppt)$

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n. $CO_3^{2-}(aq) + Cu^{2+}(aq) \rightarrow CuCO_3(ppt)$

o. $CO_3^{2-}(aq) + Pb^{2+}(aq) \rightarrow PbCO_3(ppt)$

p. $Pb^{2+}(aq) + SO_4^{2-}(aq) \rightarrow PbSO_4(ppt)$

q. $Pb^{2+}(aq) + 2I^{1-}(aq) \rightarrow PbI_2(ppt)$

r. $2I^{1-}(aq) + Cu^{2+}(aq) \rightarrow CuI_2(ppt)$

6 Use an ionic and net ionic equation to explain why equations are not written for reactions in this activity that do not produce precipitates.

For reactions in this activity that do not produce a precipitate, all ions remain in the aqueous state. No molecular compounds are formed either. Consequently, all ions get canceled, and a net ionic equation cannot be written.

An example equation:

$NaOH(aq) + KI(aq) \rightarrow NaI(aq) + KOH(aq)$
$Na^{1+}(aq) + OH^{1-}(aq) + K^{1+}(aq) + I^{1-}(aq) \rightarrow Na^{1+}(aq) + I^{1-}(aq) + K^{1+}(aq) + OH^{1-}(aq)$

No net ionic equation possible. All ions are spectator ions and are crossed out.

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