



Activity 6

Paints

What Do You See?



GOALS

In this activity you will:

- Identify and predict properties of double-displacement reactions.
- Observe reactions that produce precipitates.
- Understand how insoluble compounds can be used as pigments.

What Do You Think?

Ancient cave dwellers used charcoal and minerals for their drawings because that is what they had available to them at the time. As time went by, an increased understanding of pigments (coloring agents) allowed people to develop different artwork with more brilliant colors.

- What are some desirable properties of a pigment?

Record your ideas about this question in your *Active Chemistry* log. Be prepared to discuss your responses with your group and the class.

Investigate

Part A: Precipitate Reactions

In this activity you will mix different pairs of solutions. After mixing, you will observe whether the product is a solution, a solid precipitate, or both.

1. You will use a piece of plastic wrap or a sheet of plastic on which to test your solutions. You will want to mix every possible pair of solutions.

Prepare a copy of the table shown to place beneath the plastic sheet. Make a second copy in your log to record your results.

	FeCl ₃	NaOH	Zn(NO ₃) ₂	KI	Na ₂ CO ₃	NaCl	K ₂ SO ₄	CuSO ₄
FeCl ₃ iron(III)chloride	X							
NaOH sodium hydroxide		X						
Zn(NO ₃) ₂ zinc nitrate			X					
KI potassium iodide				X				
Na ₂ CO ₃ sodium carbonate					X			
NaCl sodium chloride						X		
K ₂ SO ₄ potassium sulfate							X	
CuSO ₄ copper sulfate								X

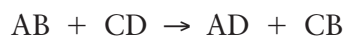
For the first set of reactions, you will mix FeCl₃ with NaOH and record whether a solid precipitate has formed. You will then continue along the first row and mix FeCl₃ with Zn(NO₃)₂ and record whether a solid precipitate is formed. You will then mix FeCl₃ with each of the other solutions and record the results in the first row of the table.

a) Why is an X noted in the first box?

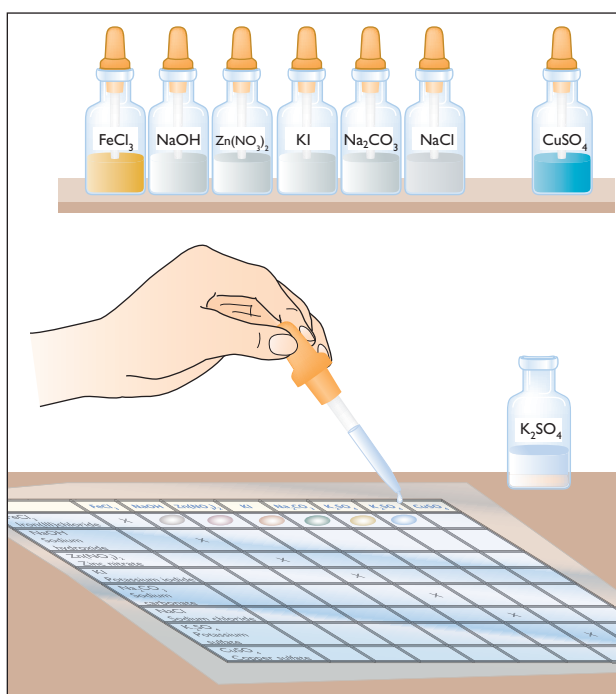
- The different solutions you will use are in dropper bottles. Using only one or two drops of each, react each solution with the others. Do not allow the tip of the dropper of one solution to come in contact with the other solution.

a) If a precipitate forms, record its color in the table in your log by using the notation “Ppt (color)”. If no precipitate forms, record “Sol” (for solution) in the table.

- To analyze the results, you must understand how the reactions proceed. All of these reactions are double-displacement reactions. The general equation for this type of reaction is:



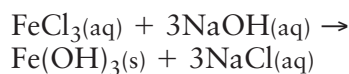
Safety goggles and a lab apron must be worn at all times in a chemistry lab.



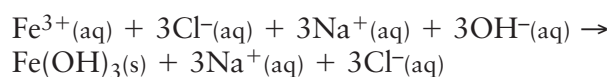


For example, the first reaction you investigated was:

Iron (III) chloride(aq) + sodium hydroxide(aq) → iron (III) hydroxide(s) and sodium chloride(aq)



The ionic equation would be:



Notice that the symbol (aq) has been added to the solutions to indicate that the chemical is dissolved in water (aqueous solution). The symbol (s) has been added to the solid precipitate.

The equation has also been balanced in order to conserve mass. For example, the three chlorine atoms in the reactant iron (III) chloride FeCl_3 must also be present as three chlorine atoms in the product sodium chloride NaCl .

In this reaction, one of the products, iron hydroxide $\text{Fe}(\text{OH})_3$, was not soluble. You observed it as a solid precipitate.

- a) Write word equations [e.g., iron (III) chloride(aq) + sodium hydroxide(aq) → iron (III) hydroxide(s) and sodium chloride(aq)] for each of the double-displacement reactions that you investigated. Use the general format $\text{AB} + \text{CD} \rightarrow \text{AD} + \text{CB}$.

There were 64 boxes in the grid. Eight of the reactions (along the diagonal) were not carried out.

Of the remaining 56 boxes, there are only 28 reactions. Why are the reactions above the diagonal identical to the reactions below the diagonal? You are therefore required to write 28 double-displacement reactions.

- b) Make a list of all soluble compounds that you observed in these reactions. The first eight soluble compounds in your list will be the ones that you began with (e.g., iron (III) chloride, sodium hydroxide, zinc nitrate, etc.).

The next set of soluble compounds is the products of the reactions that did not produce a solid precipitate (from the chart of reactions).

- c) For each reaction that produced a precipitate, indicate which product is the precipitate by placing an (s) after the name of the compound. Remember that for the reactions that produced a precipitate, one of the products should be on your soluble list. The other is the precipitate.
4. Dispose of the materials as directed by your teacher.
5. In your *Active Chemistry* log, answer the following:
- a) Identify types of compounds that were found on the soluble list (for example: sodium compounds).
- b) Identify types of compounds that were generally insoluble.

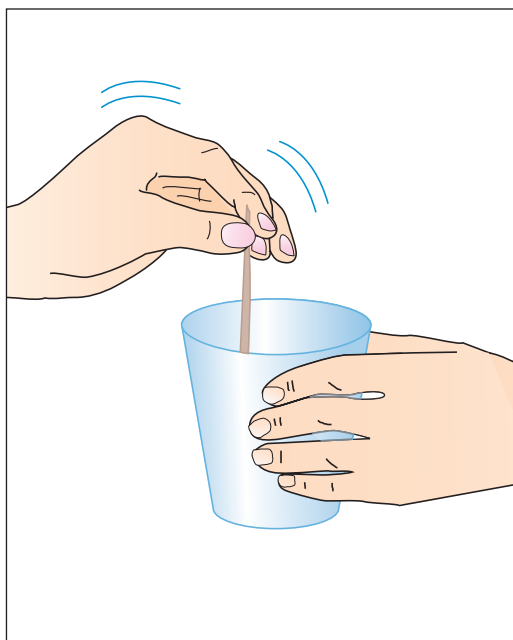
Part B: Paints

In this part of this activity, you will attempt to determine which compounds make good pigments and which liquids make good binders to carry the pigments.

Your teacher will supply you with some compounds or have you prepare larger amounts of compounds from *Part A*.

The compounds may include some of the following:

Oxides	Carbonates	Sulfates
copper	copper	copper
iron	iron	iron
zinc	zinc	zinc
nickel	nickel	nickel



1. Make a table in your *Active Chemistry* log similar to the one shown below.
2. Using each medium (water, egg white and linseed oil) and a small mixing container, add a small quantity of the compound to be tested and mix thoroughly with a toothpick. Record the color of the paint on the table.
 - a) Record your answers to these questions in your *Active Chemistry* log.
3. After you finish with single compounds, try mixing some of the compounds to make new colors. Try to make at least four or five different colors.
 - a) Record your observations in your *Active Chemistry* log.
 - b) Which medium seems to keep the color of the solid the best? Which medium is poorest? Which change the color?
 - c) Which colors were difficult to produce?

	Medium		
	Water	Egg white	Linseed oil
Compound A			
Compound B			
Compound C			



Chem Talk

Chem Words

cation: an ion that has a positive charge.

anion: an ion that has a negative charge.

precipitate: an insoluble salt that is formed when two solutions are mixed together.

ionic compound: a compound that is composed of positive ions (cations) and negative ions (anions).

salt: an ionic compound that is a product of neutralization reaction.

double-replacement reaction: a reaction in which two elements or groups of elements in two different compounds exchange places to form new compounds.

THE CHEMISTRY OF COLOR PIGMENTS

Using Solid Precipitates as Pigments

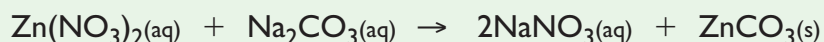
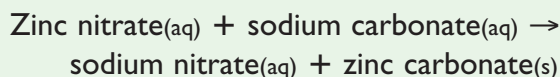
The solid precipitates you observed in this activity are insoluble compounds. They did not remain dissolved in solution. They can be used as pigments for paints. In making paint, the pigment is crushed into a powder and mixed with a liquid (called the binder). The liquid could be water or some other liquid such as linseed oil, turpentine, or guar gum. If the pigment is insoluble in the liquid, it will become a suspension of particles in the liquid. When the paint dries, the pigment particles are left behind.

Double-Replacement Reactions

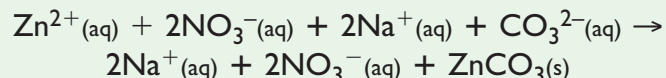
There are thousands upon thousands of reactions that occur in the world, and most of them take place in water (aqueous) solutions. When certain **cations** and **anions** are combined, water-insoluble ionic compounds may form. (Cations are positively charged ions and anions are negatively charged ions.) When these ions are in separate aqueous solutions and then brought together, an insoluble solid, or precipitate forms. The precipitate is an **ionic compound** (often called a **salt**) that forms because certain ions attract each other so strongly that they are removed from the water solution as the product of a chemical reaction. A **double-replacement reaction** is one type of precipitation reaction where a precipitate forms when one (or occasionally both) of the products is insoluble.

Look at the example of the reaction between solutions of zinc nitrate and sodium carbonate that you observed in the activity:

Note that (aq) means a compound is in aqueous solution, and (s) means that a solid has formed (the precipitate).



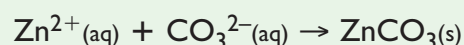
In solution, you have ions, according to the ionic equation: $\text{ZnCO}_3(s)$



The zinc ions and carbonate ions are strongly attracted to each other and form a solid that no longer stays in solution. Zinc carbonate is the precipitate in this reaction.



The Na^+ and NO_3^- ions do not undergo any change; they remain in solution before and after the reaction. Ions that do not participate in the reaction are called spectator ions. If you removed them from the total ionic equation, the net result would be:



which is called the Net Ionic Equation.

It is possible, based on experience, to predict whether or not a precipitate will form in a double-displacement reaction. The following solubility rules will help you to predict the products of precipitation reactions. Chemists do not memorize these rules but refer to them when needed. Some of these simple rules may have come from the analysis of the double-displacement reactions that you conducted in this activity.

Simple Rules for Solubility of Ionic Compounds in Water

1. Most nitrate (NO_3^-), acetate (CH_3COO^-), and perchlorate (ClO_4^-) compounds are soluble.
2. Group IA metal (Li^+ , Na^+ , and K^+) and ammonium (NH_4^+) compounds are soluble.
3. Most chloride (Cl^-), bromide (Br^-), and iodide (I^-) compounds are soluble. The most notable exceptions are when these anions are combined with Cu^+ , Ag^+ , Pb^{2+} , Hg_2^{2+} , and Hg_2^{2+} .
4. Most sulfate (SO_4^{2-}) compounds are soluble, except when they are combined with Ba^{2+} , Hg_2^{2+} , Sr^{2+} , and Pb^{2+} . Ca^{2+} compounds are slightly soluble.
5. Carbonate (CO_3^{2-}) and phosphate (PO_4^{3-}) compounds are only slightly soluble.
6. Most hydroxide (OH^-) compounds are insoluble except when combined with group IA cations. $\text{Ca}(\text{OH})_2$ is slightly soluble.

An ionic compound is said to be **soluble** if a large amount of it dissolves in water. How much is a “large amount”? Typically, this means a solution with a concentration of at least 0.1 mol/L (mole per liter) at room temperature. An **insoluble** ionic compound is defined as one that will not dissolve in water, typically producing an aqueous solution of less than 0.001 mol/L at room temperature. A slightly soluble compound falls somewhere between these two boundaries, usually forming a precipitate in water.

Chem Words

soluble: a substance that dissolves in a liquid.

insoluble: a substance that will not dissolve in a liquid.

Checking Up

1. Predict the products when the following aqueous solutions are combined; write the entire reaction as a word equation and then again using symbols.
 - a) copper sulfate plus sodium hydroxide
 - b) potassium iodide plus iron (III) bromide
2. Use the solubility rules to determine which of the following are insoluble in water:
 - a) lithium acetate
 - b) ammonium chloride
 - c) silver bromide



What Do You Think Now?

At the beginning of the activity, you were asked:

- What are some desirable properties of a pigment?

What makes a compound a good paint pigment? Will different binders give different results?

Chem Essential Questions

What does it mean?

Chemistry explains a macroscopic phenomenon (what you observe) with a description of what happens at the nanoscopic level (atoms and molecules) using symbolic structures as a way to communicate. Complete the chart below in your *Active Chemistry* log.

MACRO	NANO	SYMBOLIC
<i>What visual evidence do you have to prove that a double-displacement reaction has occurred?</i>	<i>How can mixing two clear solutions produce a solid material? What is happening at the molecular level? Provide a specific example in your discussion.</i>	<i>Use symbols in a chemical equation to explain what happens during a double-displacement reaction.</i>

How do you know?

What experimental data do you have that shows how a pigment can form from a precipitation reaction?

Why do you believe?

Silver bromide (AgBr) is used in photography. Finely divided silver bromide is suspended in a solution of gelatin, which is used to coat a plastic film. When light strikes the film, silver atoms are formed, creating what is known as the latent image. This is then subjected to the development process. Afterwards, excess AgBr must be washed off the negative. This is done by washing the negative with sodium thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3$) solution. From the knowledge you gained from this activity, explain why sodium thiosulphate dissolves the AgBr . Use a balanced equation in your discussion.

Why should you care?

Preparing your own pigments to be used as paints in your *Chapter Challenge* would be very interesting to many people. Creating a work of art about yourself with paints that you created yourself would be a significant addition to your *Chapter Challenge*. What color do you want your pigment to possess?

Reflecting on the Activity and the Challenge

You have seen on the macro level how some precipitates are formed. You have looked at the solubility of certain chemicals. On the micro level, you have read about the ions in solution and the fact that some combinations of ions will form precipitates. You can now predict the formation of precipitates from double-displacement reactions. The reactions can be represented symbolically in word equations and formula equations. There is chemistry behind the development of various colored pigments. For example, the solubility of pigments and the use of different pigments in watercolors, oil paints and acrylics will vary.

Precipitation reactions are also responsible for the formation of the patina on copper and its alloys. The opposite of a precipitation reaction occurs when an acid reacts with calcium carbonate. In this case, an insoluble substance (calcium carbonate) is made soluble by the reaction with the acid. This can cause the deterioration of statues and other artwork (refer back to *Activity 2*). Consider how you might incorporate this information in your artwork and museum display.

Chem to Go

Using the Simple Rules for Solubility in *Chem Talk*, answer the following questions.

1. Describe the difference between salts that are water soluble, slightly soluble, and insoluble.
2. Which of the following compounds are soluble in water?
 - a) NaOH
 - b) CuCl_2
 - c) PbSO_4
 - d) KCl
 - e) $\text{Mg}(\text{OH})_2$
3. Predict whether precipitation will occur when the following compounds in aqueous solution are combined. If so, what is the formula of the precipitate?
 - a) barium chloride + aluminum sulfate
 - b) silver nitrate + potassium chloride
4. Predict whether precipitation will occur when the following solutions are combined. If so, what is the formula of the precipitate?
 - a) $\text{AgNO}_3(\text{aq}) + \text{KBr}(\text{aq})$
 - b) $\text{Na}_2\text{SO}_4(\text{aq}) + \text{MgCl}_2(\text{aq})$
 - c) $\text{KOH}(\text{aq}) + \text{Fe}(\text{NO}_3)_3(\text{aq})$





5. Which set of compounds contains a salt that is insoluble in water?
- BaCl_2 , ZnCO_3 , LiOH
 - Cs_2SO_4 , KOH , MgBr_2
 - $(\text{NH}_4)_2\text{SO}_4$, Li_3PO_4 , $\text{KC}_2\text{H}_3\text{O}_2$
 - NaNO_3 , MgCl_2 , Li_2CO_3
6. Which of the following would most likely be a precipitate formed in a double-displacement reaction?
- AgCl
 - AgNO_3
 - NaCl
 - LiNO_3
7. Which of the following shows the general equation of a double-displacement reaction?
- $\text{AB} + \text{CD} \rightarrow \text{ABDC}$
 - $\text{AB} + \text{CD} \rightarrow \text{AD} + \text{CB}$
 - $\text{AB} + \text{CD} \rightarrow \text{BA} + \text{DC}$
 - $\text{AB} + \text{CD} \rightarrow \text{AD} + \text{CD}$
8. If a solid forms from a double-displacement reaction, it is called:
- precipitate
 - reactant
 - product
 - pigment
9. For the following reaction, write the products in a balanced equation, the total ionic equation, and the net ionic equation.
- $$\text{LiOH}(\text{aq}) + \text{AgHCO}_3 \rightarrow ?$$
10. In photography, silver halide (silver bromide or chloride) salts are used as described in the *Why do you believe* section. One way to produce AgCl is by reacting aqueous silver nitrate with aqueous potassium chloride. What is the other product of this reaction, and what are the “spectator” ions?

Inquiring Further

Paint pigments over time

Research the formulas for various paint pigments. How have their origins and ingredients changed over

