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Precipitation and Solubility

Purpose

The purpose of this experiment is to determine the role ionic charges play in reactions that form precipitates.

Introduction

Many important reactions take place in water, such as precipitation reactions. An example of a precipitation reaction is the formation of stalagmites and stalactites in caverns. When two aqueous solutions are mixed sometimes a solid forms, called a precipitate. The precipitate is a salt (ionic compound) with low solubility. A precipitate forms when a cation (positive ion) of a dissolved salt reacts with an anion (negative ion) of another dissolved salt. You can tell if a precipitate forms by observing the reaction mixture. Aqueous solutions are clear; you can see through them. After two aqueous solutions are mixed, you can observe the resulting mixture to determine if it looks clear or cloudy. A cloudy mixture indicates that a precipitate has been formed. A clear mixture indicates that no reaction has occurred. Whether or not a precipitate forms depends on the solubility of the new salt that is formed. If the salt has low solubility a precipitate will form, if the salt has high solubility, no precipitate will form (there will be no reaction).

In this experiment you will use aqueous solutions of six sodium salts and six chloride salts to create 36 different mixtures. You will look for a pattern for which ions react to produce precipitates. This pattern relates to Coulomb's law, which describes the electrostatic force between two charged particles. Two oppositely charged particles, such as a cation and an anion, will attract each other. The strength of the attraction depends on the magnitude of the charges and the distance between the particles. The formula for Coulomb's law is $F = k \frac{q_1 q_2}{r^2}$ where F = force, k = proportionality constant, q_1 = charge of particle 1, q_2 = charge of particle 2, r = radius of separation. The formula shows that the higher the magnitude of each particle's charge and the smaller the distance between the particles, the stronger the attraction.

Materials

Be certain that you can identify the equipment and reagents listed below, *before* starting the experiment.

- reaction wellplate
- dropper bottles containing the following reagents:

Cation Sources	Anion Sources
0.1 M KCl	0.1 M NaNO ₃
0.1 M LiCl	0.1 M NaBr
0.1 M CaCl ₂	0.1 M Na ₂ SO ₄
0.1 M MgCl ₂	0.1 M Na ₂ CO ₃
0.1 M CoCl ₂	0.1 M Na ₂ C ₂ O ₄
0.1 M FeCl ₃	0.1 M Na ₃ PO ₄

Safety and Waste Management

Ionic compounds contain metal ions. Many metal ions are toxic to varying degrees. However, the metal ions used in this experiment can safely be disposed of in the sink.

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Procedure

1. Obtain a reaction well plate. The reaction plate is set up as a grid.
2. To each well of horizontal row A (A1 through A6), add 2 drops of potassium chloride solution, KCl.
3. Add 2 drops of the solution listed to each of the wells in the horizontal row indicated:

Row B: add lithium chloride, LiCl

Row C: add calcium chloride, CaCl₂

Row D: add magnesium chloride, MgCl₂

Row E: add cobalt(II) chloride, CoCl₂

Row F: add iron(III) chloride, FeCl₃

4. To the vertical column 1 (A1 through F1) add two drops of sodium nitrate, NaNO₃.
5. Add 2 drops of the solution listed to each of the wells in the vertical columns indicated:

Column 2: add sodium bromide, NaBr

Column 3: add sodium sulfate, Na₂SO₄

Column 4: add sodium carbonate, Na₂CO₃

Column 5: add sodium oxalate, Na₂C₂O₄

Column 6: add sodium phosphate, Na₃PO₄

6. Observe each well to determine which combination of solutions produced precipitates. Record your observations in your data table.
7. Another way you can observe the mixtures in the reaction plate is by changing the background color. Use the laboratory bench top for a black background, and a sheet of white paper for a light background. Some precipitates will be easier to see because the solid particles will settle to the bottom of the plate and it will look opaque.
8. Clean your reaction plate with soap and water. Use a brush and/or Q-tip to remove any residue out of the wells. Rinse several times with tap water. The final rinse should be with distilled water.
9. Return the reaction plate to its storage location, and clean your workspace.

Pre-activity Assignment

Answer the following pre-activity questions. Record your answers in your laboratory notebook, or on the available report form according to the instructions from your teacher.

1. What is a precipitate?
2. What is solubility?
3. What would you observe if a precipitation reaction has occurred? Tell what would the mixture look like.
4. Describe Coulomb's law.
5. Table salt is made of sodium chloride, NaCl. Is sodium chloride soluble? What does an aqueous solution of NaCl look like?

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Data Record your observations for each of the wells in a data table. Include the color or if it is colorless.
 Clear = no reaction (N.R.) Cloudy = precipitate (ppt)

Column		1	2	3	4	5	6
		NaNO ₃	NaBr	Na ₂ SO ₄	Na ₂ CO ₃	Na ₂ C ₂ O ₄	Na ₃ PO ₄
Row							
A	KCl						
B	LiCl						
C	CaCl ₂						
D	MgCl ₂						
E	CoCl ₂						
F	FeCl ₃						

Results – What precipitates formed? Write the name and formula for the precipitate that formed in each well. If there was no precipitate, write N.R. (no reaction).

Anions		1	2	3	4	5	6
		(NO ₃) ⁻ nitrate	Br ⁻ bromide	(SO ₄) ²⁻ sulfate	(CO ₃) ²⁻ carbonate	(C ₂ O ₄) ²⁻ oxalate	(PO ₄) ³⁻ phosphate
Cations							
A	K ⁺ potassium ion						
B	Li ⁺ lithium ion						
C	Ca ²⁺ calcium ion						
D	Mg ²⁺ magnesium ion						
E	Co ²⁺ cobalt(II) ion						
F	Fe ³⁺ iron(III) ion						

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Post-activity Questions

- Analyze your data regarding the solubility of the following anions. Write a sentence that describes the solubility characteristics of each anion, following the example given in a.
 - nitrate: All nitrate compounds are soluble.
 - carbonate _____
 - sulfate _____
 - oxalate _____
- Analyze your data regarding the solubility of the following cations. Write a sentence that describes the solubility characteristics of each cation.
 - potassium ion _____
 - calcium ion _____
 - cobalt(II) ion _____
 - iron(III) ion _____
- Write a *complete chemical equation* for the reaction that occurred in each well in row C. If no reaction occurred, write "NR" instead of products.
 - C1 _____
 - C2 _____
 - C3 _____
 - C4 _____
 - C5 _____
 - C6 _____
- Write a *net ionic* equation for the reactions that occurred in each the well of row C. If no reaction occurred, write "NR" instead of products.
 - C1 _____
 - C2 _____
 - C3 _____
 - C4 _____
 - C5 _____
 - C6 _____
- According to Coulomb's Law, the higher the charge, the stronger the force of attraction. This would mean that ions with higher charge are more likely to form precipitates.
 - Which cations reacted to produce the most precipitates? _____
 - Which anions reacted to produce the most precipitates? _____
 - How does the magnitude of the ionic charge relate to the formation of precipitates?

- List two sources of error that could impact your results? Briefly explain how each error source would impact your results.
 - _____
 - _____

Conclusion

Write one sentence to describe the role ionic charges play in reactions that form precipitates.
