Should I Stay or Should I Go???

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| **Chemistry Topic** | Solubility rules for ionic compounds, a discovery lesson |

**Concept Statement:**

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| * Solubility is the temperature-dependent quantity of a substance to dissolve in a given quantity of solvent. It is an intrinsic property of a substance, and the level of solubility is determined by the nature of the solute and the nature of the solvent. In general, ionic compounds can dissolve in a polar solvent such as water, but there are a large number of ionic compounds who has a solubility so small that it appears insoluble in water. However, there are broad, general rules for solubility of ionic compounds that apply in chemistry. The compounds that are always soluble in water are sodium compounds, potassium compounds, ammonium compounds, and nitrate compounds.
* Solubility of substances in aqueous systems is an important concept for students to learn so that they can see how bonding and intermolecular forces are applied in a concrete manner with an important solvent to life, water. Precipitation reactions, a form of a double replacement reactions, occur because certain substances are insoluble in aqueous systems.
* This concept is useful for understanding why bathtub rings and hard water stains form on plumbing, why water quality is determined by the presence of certain ions, molecules, and suspended particles, and how federal and state regulations on water quality are determined.
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**Source of Lesson:**

Flinn Scientific. (2013) Precipitation Reactions and Solubility Rules.

American Chemical Society. (2006). *Chemistry in the Community* (5th Edition ed.). (H. Heikkinen, Ed.) Washington, DC: American Chemical Society.

**List of appropriate TEKS: 19 TAC § 112.35 (Chemistry)**

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| **TEKS #** | **Student Expectation** |
| 10 (B) | Science concepts. The student understands and can apply the factors that influence the behavior of solutions. The student is expected to: develop and use general rules regarding solubility through investigations with aqueous solutions. |
| 2(E) | Scientific processes: The student uses scientific methods to solve investigative questions. The student is expected to: plan and implement investigative procedures, including asking questions, formulating testable hypotheses, and selecting equipment and technology, including graphing calculators, computers and probes, sufficient scientific glassware such as beakers, Erlenmeyer flasks, pipets, graduated cylinders, volumetric flasks, safety goggles, and burettes, electronic balances, and an adequate supply of consumable chemicals |
| 2(H) | Scientific processes: The student uses scientific methods to solve investigative questions. The student is expected to: organize, analyze, evaluate, make inferences, and predict trends from data. |
| 2 (I) | Scientific processes: The student uses scientific methods to solve investigative questions. The student is expected to: communicate valid conclusions supported by the data through methods such as lab reports, labeled drawings, graphs, journals, summaries, oral reports, and technology-based reports. |

|  | **Objectives**Students will be able to: | **Evaluation Questions**  |
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| 1 | Design a laboratory experiment to determine solubility of substances in water. | What would you do to see if two clear solutions form an insoluble compound? What would you expect to observe? |
| 2 | Implement and adjust designed lab experiment to determine solubility of various ionic compounds in water. | How did you adjust your experimental design to more effectively determine which combinations would form an insoluble compound? Why did you do this? |
| 3 | Develop general solubility rules for various ionic compounds based on experimental data. | Which ionic compound categories always completely dissolve in water?  |
| 4 | Predict products of precipitation reactions using solubility rules. | Will the following reactions occur in aqueous solution? If the reaction will occur, write the products of the precipitation reaction. If the reaction will not produce a precipitate, write NR.* 1. NaCl (aq) + Pb(NO3)2 (aq) 🡪
	2. Ca(NO3)2 (aq) + K2CO3 (aq) 🡪
	3. (NH4)2SO4 (aq) + NaNO3 (aq) 🡪
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**Resources, Materials, Handouts, and Equipment List:**

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| **ITEM****(Specify worksheets)** | **Quantity****(How many do you need?)** | **Source** **(Who is responsible?** | **List who this is for (teacher, student, group)** |
| Goggles and splash apron | 30 | Already in classroom | Students and teacher |
| 500 mL of 0.1 M solutions containing: AgNO3, BaCl2, Na2CO3, (NH4)2SO4, Pb(NO3)2, Ca(NO3)2, K3PO4, Na2SO4, Na2CrO4,FeCl3, NaOH, MgBr2, and K2CO3 | 1 bottle of each | Flinn Scientific or chemical storage | class |
| 48 well reaction plate | 1 | Flinn Scientific or lab equipment storage | Per group |
| Micropipettesc  | Two sets of 7 with labels | Lab equipment storage | Per group |
| Micropipette stand | 1 | Lab equipment storage | Per group |
| Data sheet | 1 | Flinn Scientific | Per student |
| Lab instructions sheet | 1 | Teacher/Flinn Scientific | Per student |
| Wash bottle with water | 1 | Lab equipment | Per group |
| Waste disposal container - labeled | 1-2 | Lab equipment | Per class |
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**Safety:**

* Barium chloride, lead(II) nitrate, and sodium chromate solutions are toxic by ingestion. Silver nitrate is toxic, corrosive, light-sensitive, and stains skin and clothing. Sodium hydroxide solution is corrosive and a body tissue irritant. Avoid all eye and body tissue contact with all solutions. Wear chemical splash googles, chemical resistant gloves and chemical splash aprons during this experiment. (Flinn Scientific, p 2)
* All waste reaction mixtures must be disposed of in the waste disposal container. Use a wash bottle with water to rinse the solutions/precipitates into the waste container. Refer to the MSDS for additional disposal information.
* Be sure to mention safety issues at the beginning of the Exploration portion of the lesson BEFORE students begin the activity.

**Advanced Preparations:**

* Complete the Pre-Lab Preparation directions as stated on page 2 of the directions in the Flinn lab. Wrap the silver nitrate pipet bulb with masking tape before labeling to minimize light exposure. All solutions are 0.1 M, and more can be easily prepared if the solutions run out. Set out sets of the solutions, stir rods, wash bottles with water, and labeled waste disposal containers for students to use.

**PowerPoint: **

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| **Objective Statement:** The goal of this lesson is for students to discover the solubility rules for ionic compounds in water through experimentation with various solutions.  |
| **ENGAGEMENT Time: 5 Minutes** |
| **What the Teacher Will Do**  | **Probing/Eliciting Questions and Students Responses** | **What the Students Will Do** |
| Teacher will state objectives of the lesson.Teacher will ask questions regarding the vocabulary words (soluble, insoluble, precipitate, solvent, solute, aqueous).Teacher will then pose the question: “How can I tell if a substance is soluble in water?” All answers will be accepted and acknowledged. Follow-up questions like “How do you know?” will be asked? This is a review of the process of dissolution and the characteristics of solutions.Teacher then poses a second question: “What if I have two solutions, and I mix them. How will I know that a reaction has occurred?”Teacher will then introduce the lab activity “Precipitation Reactions and Solubility Rules” to the class. Teacher will show them the tray with seven solutions in them so the students can see what they will mix together, and write down the names of the compounds on the board. Teacher will ask students to give the formulas for each of these compounds and write them down on the board. | What do the following terms mean?* Soluble – able to dissolve in a solvent
* Insoluble – unable to dissolve in a solvent
* Precipitate – an insoluble substance formed by a chemical reaction. The reaction mixture would look cloudy or you would see a solid on the bottom of the reaction container.
* Solvent – the substance doing the dissolving
* Solute – the substance being dissolved
* Aqueous – a system that has water as the solvent

How can I tell if a substance is soluble in water? (The substance dissolves/disappears when put into water and mixed.)What if I have two aqueous solutions and I mix them? How will I know that a reaction has occurred? (*A precipitate will form, and the reaction mixture will look cloudy. A gas will form, and bubbles will appear in the reaction mixture.*) | Students will sit quietly and attentively listen to the teacher. Students will raise their hand and give thoughtful answers to the questions that the teacher asks.  |

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| **EXPLORATION Time: 45 Minutes** |
| **What the Teacher Will Do**  | **Probing/Eliciting Questions and Student Responses** | **What the Students Will Do** |
| Teacher will instruct students to write a step-by-step procedure for determining the solubility of compounds formed when two solutions are mixed. Teacher will monitor student work and give permission for students to go into lab to work. Teacher will remind students to put on safety gear before getting materials or beginning lab.Teacher will monitor student work and following of safety rules during lab. Teacher will ask probing questions to individuals while monitoring lab activity.10 minutes before end of lab time, teacher will tell students to end lab work and clean up the lab area. Teacher will instruct students to sit down with their lab partner and look for the patterns in the solubilities of various compounds, then write generalizations about patterns for solubilities. | What safety gear will you need for this lab? (*goggles and apron*)What will you do first? What will you do next? Why will you do these things?How will you know if you have made an insoluble compound when you mix the solutions? (*A cloudy mixture has formed that can be a different color from the original solutions.*)Is a color change alone sufficient to determine if an insoluble compound is formed? (*No, a cloudy mixture that settles is evidence of a precipitate, an insoluble compound.*)Do you expect to see any bubbles form? (*No*, *because we are looking for precipitates not gases.*) NOTE: The solution combinations will not produce a gas. They are all precipitation reactions.What should you do with the reaction mixtures when you are finished? (*Pour them into the waste container and rinse the reaction plate into the waste container*.)Do you need to do the same reaction twice? Why/why not? (*No, each combination of solution is doubled in the table.*)What patterns are you noticing as you are mixing the solutions? (*Na+ compounds formed are soluble. K+ compounds formed are soluble. Some sulfate compounds formed are insoluble, while others are soluble. ETC…*)How can you write the pattern you see as a rule? (*All sodium compounds are soluble in water. ETC…)* | Students will write a step-by-step procedure for determining the solubility rules of the different ionic compounds. They will write the procedure using complete sentences and complete thoughts. Students will get approval to begin lab by teacher.Students will follow their procedure for determining solubility of the substances and make appropriate adjustments to their procedure so as to complete the lab in the time allotted.Students will clean up lab and dispose of materials according to teacher instructions. After cleaning up lab, students will sit down and work with their lab partner to classify all the substances as soluble, insoluble, or unknown in Table 3 according to the directions in Part 3.After classifying all the substances in Part 3, students will examine the categories to look for patterns and form generalizations about different compounds with specific anions and cations in terms of solubility. This is done according to the directions in Part 4. Results are recorded in Table 4. |

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| **EXPLANATION Time: 15 Minutes** |
| **What the Teacher Will Do**  | **Probing/Eliciting Questions and Student Responses** | **What the Students Will Do** |
| Teacher will have students report out their generalizations and will write down these rules on the board. Teacher will call on groups to give a rule, clarify a rule, or remove a rule so as to generate one list for the class.Teacher will provide a solubility table for specific compounds to the students so they can verify that their classification of the new compounds is correct. Teacher will then discuss precipitation reactions and how to use the solubility rules to predict products of reactions. | What was your first solubility rule? How did you know?Do you agree with what \_\_\_ said? Why/why not? If not, how can you clarify this rule?What solubility rule can you add to the list? What is your evidence for this rule?\*Questions 2 and 3 are repeated until a complete list is obtained from the class.\* | Students will share their generalizations with the class when called upon. They will update their set of rules as the discussion progresses.Student lab groups will use the solubility tables to revise/add to their list of solubility rules. Students will then participate in the continued discussion of a more complete set of solubility rules. |

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| **ELABORATION Time: 15 Minutes** |
| **What the Teacher Will Do**  | **Probing/Eliciting Questions and Student Responses** | **What the Students Will Do** |
| Teacher will provide a set of precipitation reactions.Teacher will lead discussion about products for these reactions (if they occur). | Why was this reaction classified as “NR?”What would the balanced equation for the reaction look like?What is the name of the precipitate in #3? #5? #10? | Students will predict the products for the 10 precipitation reactions by completing the equation if a precipitate forms, then balancing the equation. Students will write “NR” if no precipitate forms.Students will share their results discuss why. |
| **Closure Statement**  |
| In this lesson, you have designed and ran an experiment to determine the solubility rules for various ionic compounds in water. We spent time discussing the patterns we saw in the data and came up with a good set of rules that will apply to many different ionic compounds. |

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| **EVALUATION Time: 10 Minutes** |
| **What the Teacher Will Do** |  | **What the Students Will Do** |
| The teacher will allow 10 minutes for the post-test.  | See evaluation questions above. | Students will clear their desks for the final evaluation. The students will complete a post-test. |