Properties of Compounds and Chemical Formulas

Strand Nomenclature, Chemical Formulas, and Reactions

Topic Investigating bonding, nomenclature, and formula writing

Primary SOL CH.2 The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of
g) electron configurations, valence electrons, and oxidation numbers;
h) chemical and physical properties.

Related SOL CH.1 The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated produce observations and verifiable data. Key concepts include
a) designated laboratory techniques;
b) safe use of chemicals and equipment;
c) proper response to emergency situations.

Background Information

A chemical reaction is a process that leads to the transformation of one set of chemical substances to another. Chemical reactions can be either spontaneous, requiring no input of energy, or nonspontaneous, typically following the input of some type of energy, such as heat, light, or electricity. Classically, chemical reactions encompass changes that strictly involve the motion of electrons in the forming and breaking of chemical bonds, although the general concept of a chemical reaction, in particular the notion of a chemical equation, is applicable to transformations of elementary particles, as well as nuclear reactions.

Before undertaking this experiment, be sure your school's chemical hygiene plan allows for the use of all the chemicals used. Be sure to have a container available to collect the waste since some of the compounds contain heavy metals and should not be poured down the sink drain.

In this experiment, students will group unknown compounds according to their chemical behaviors by

- mixing two solutions together to see whether a precipitate forms;
- observing which precipitates are dissolved by another solution; and
- recording any color changes that occur when two solutions are mixed together.

After analyzing the data, students will place each unknown substance into a group with other substances that show similar behavior and characteristics.

Unknown and test solutions can be placed in labeled flasks or beakers in a central location. Have students then fill labeled dropper pipettes with the unknown and test solutions and return to their lab stations to fill their well plates. If you have enough dropper bottles available, these could be filled with the test solutions, and a set could be provided to each lab table or group.

Although students may not have worked with chemical equations yet, you may wish to share the following reactions with them to reinforce similarities in chemical behaviors. They can then see that the compounds with similar formulas undergo very similar reactions.

$2\ NaBr + Pb(NO_3)_2 \rightarrow 2\ NaNO_3 + PbBr_2$
$2\ NaI + Pb(NO_3)_2 \rightarrow 2\ NaNO_3 + PbI_2$
$2\ NaCl + Pb(NO_3)_2 \rightarrow 2\ NaNO_3 + PbCl_2$

$Ca(NO_3)_2 + Na_2SO_4 \rightarrow 2\ NaNO_3 + CaSO_4$
$Ba(NO_3)_2 + Na_2SO_4 \rightarrow 2\ NaNO_3 + BaSO_4$
$Sr(NO_3)_2 + Na_2SO_4 \rightarrow 2\ NaNO_3 + SrSO_4$

$Li_2CO_3 + Pb(NO_3)_2 \rightarrow PbCO_3 + 2\ LiNO_3$
$K_2CO_3 + Pb(NO_3)_2 \rightarrow PbCO_3 + 2\ KNO_3$
$Na_2CO_3 + Pb(NO_3)_2 \rightarrow PbCO_3 + 2\ NaNO_3$

Materials

- 24-well plates
- Unknown solution 1: 5.0 grams of NaBr dissolved in 100 mL of distilled water
- Unknown solution 2: 5.0 grams of $Ca(NO_3)_2$ dissolved in 100 mL of distilled water
- Unknown solution 3: 1.25 grams of Li_2CO_3 dissolved in 100 mL of distilled water
- Unknown solution 4: 4.0 grams of $Ba(NO_3)_2$ dissolved in 100 mL of distilled water
- Unknown solution 5: 4.5 grams of NaI dissolved in 100 mL of distilled water
- Unknown solution 6: 7.5 grams of K_2CO_3 dissolved in 100 mL of distilled water
- Unknown solution 7: 5.8 grams of NaCl dissolved in 100 mL of distilled water
- Unknown solution 8: 3.8 grams of Na_2CO_3 dissolved in 100 mL of distilled water
- Unknown solution 9: 16.0 grams of $Sr(NO_3)_2$ dissolved in 100 mL of distilled water
- Test solution A: 7.5 grams of $Pb(NO_3)_2$ dissolved in 100 mL of distilled water
- Test solution B: 15.0 grams of Na_2SO_4 dissolved in 100 mL of distilled water
- Test solution C: 4 drops of 1.0 *M* HCl added to 1 mL of 1% phenolphthalein indicator and then diluted to 100 mL with distilled water
- Test solution D: 19 mL of concentrated HNO_3 added to 100 mL of distilled water *CAUTION! Concentrated HNO_3 is very corrosive.*
- Toothpicks
- Goggles
- Flasks or beakers
- Dropper pipettes

Vocabulary

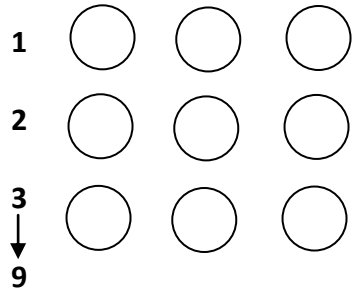
compound, corrosive, dissolve, formula, precipitate, similarity, solution

Student/Teacher Actions (what students and teachers should be doing to facilitate learning)

Introduction

1. Announce to the class that this laboratory experiment will enable them to group unknown compounds according to their chemical behaviors. Explain that they will mix two solutions together to see whether a precipitate forms. They will observe which precipitates are dissolved by another solution. Finally, they will record any color changes that occur when two solutions are mixed together. After analyzing their data, they will place each unknown substance into a group with other substances of similar behavior and characteristics.
2. Have students label the well plate vertically 1–9 for the nine unknown solutions, and horizontally A–C for test solutions A, B, and C, as shown below:

A B C



3. Place about 10 drops of unknown solution 1 into each of the three wells A, B, C in the first row. *CAUTION! Some of the solutions are corrosive. Avoid direct contact.*
4. To well A, add 5 drops of test solution A, and observe the results.
5. To well B, add 5 drops of test solution B, and observe the results.
6. To well C, add 5 drops of test solution C, and observe the results.
7. Use a clean toothpick to stir for 10 seconds any solution that does not show an immediate reaction, and then observe again. Record all results on a blank data chart similar to the filled-in one below.

Unknown solution	**A Precipitate? (yes/no)**	**B Precipitate? (yes/no)**	**C Color (describe color)**	**D Precipitate dissolved? (yes/no)**
1	*yes*	*no*	*none*	*no*
2	*no*	*yes*	*none*	*yes*
3	*yes*	*no*	*pink*	*yes*
4	*no*	*yes*	*none*	*yes*
5	*yes (yellow)*	*no*	*none*	*no*
6	*yes*	*no*	*pink*	*yes*
7	*yes*	*no*	*none*	*no*
8	*yes*	*no*	*pink*	*yes*
9	*no*	*yes*	*no*	*yes*

8. To any mixture that produces a precipitate, add 15 drops of test solution D, stir with a clean toothpick for 20 seconds, and then observe again. Solution D is to be added only to those mixtures that produce a precipitate.
9. Repeat steps 2–7 for each of the other unknown solutions 2–9. Record all results.
10. Pour waste material from the wells into the waste container. Rinse out the well plates thoroughly for use in the next laboratory. Clean up your work area, and wash your hands.
11. Analyze your observations by arranging the nine unknown solutions into groups according to similarities in their chemical behaviors. Justify your groups with data from the laboratory results.
12. After being provided with the chemical formula for each of the nine unknown substances, examine the similarities in the compounds, based on their formulas. Relate the similar chemical formulas to the similar chemical behaviors.

Observations and Conclusions

Possible Groups

1. Solutions 1, 5, and 7 had no reaction with B or C and formed a precipitate with A that did not dissolve with D. Solutions 1 (NaBr), 5 (NaI), and 7 (NaCl) are sodium salts of halogens (sodium halides). (Students may place #5 in a group by itself due to the yellow color of the precipitate.)
2. Solutions 2, 4, and 9 had no reaction with A or C and formed a precipitate with B that dissolved with D. Solutions 2 [$Ca(NO_3)_2$], 4 [$Ba(NO_3)_2$], and 9 [$Sr(NO_3)_2$] are alkaline earth nitrates.
3. Solutions 3, 6, and 8 had no reaction with B, turned pink with C, formed a precipitate with A that dissolved with D. Solutions 3 [Li_2CO_3], 6 [K_2CO_3], and 8 [Na_2CO_3] are alkali metal carbonates.

Assessment

- **Journal/Writing Prompts**
  - Explain the relationship of the reactants to the products.
- **Other**
  - Place the nine unknown solutions into groups according to similar chemical behaviors. Present the groupings to the class, and discuss any differences in groupings. Examine the similarities in the compounds based on their chemical formulas and relate similar chemical formulas to similar chemical behaviors.

Extensions and Connections (for all students)

- Have students research the compounds used in this lab to find additional similarities in both physical and chemical behaviors.

Strategies for Differentiation

- Videotape the precipitation reactions of each test, and project on screen to enlarge for easier viewing.
- Have students use a hand-held magnifying glass to view the reaction in wells.
- Have students use small sealed plastic dropper bottles instead of thin-stem dropper pipettes.
- For Procedure #1, provide students with three test solutions labeled with color-coded tape A, B, and C, respectively. Color coding will match three six-well columns of a 24-well plate. (The fourth column is not used.)
- Have students do Internet research to find commercial or industrial products (e.g., cleaners, paint) in which each of the ionic compounds are used. Have them create a poster displaying pictures of each product.
- Have students create questions, e-mail them to a chemist with a chemical company, and organize the responses into a report.
- Set up three stations for groups of two to three students to test solutions—three solutions per station. Label stations “Sodium Salts of Halogens,” “Alkaline Earth Nitrates,” and “Alkali Metal Carbonates.”