Matter and Energy: Equations and Formulas

Strand Nomenclature, Chemical Formulas, and Reactions

Topic Investigating bonding, nomenclature, and formula writing

Primary SOL CH.3 The student will investigate and understand how conservation of energy and matter is expressed in chemical formulas and balanced equations. Key concepts include
a) nomenclature;
b) balancing chemical equations;
c) writing chemical formulas.

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
The concept of empirical formulas can be introduced on day four, but it is best taught after students have been introduced to the mole.

Note that the iron in the steel wool used in the demonstration rapidly oxidizes (rusts) to form iron(III) oxide. The result is a rusty piece of steel wool and a balloon that has been completely sucked into the flask. However, the mass is the same before and after the reaction. This should provide you with a nice hook to begin a discussion on the Law of Conservation of Matter.

Materials
Demonstration materials:
- Bare cooper wire
- Zinc chips
- Charcoal
- Empty covered jar
- Beaker of the compound water
- 250-mL beaker
- 250-mL flask
- White vinegar
- Steel wool
- Balloon
- Balance
- Periodic table of the elements

Lab materials per group:
- Solution of 4 g of NaOH dissolved in 1 L
- Solution of 22 g of $CuSO_4$ dissolved in 1 L
- Solution of NH_4OH

- Solution of 24 g of $Zn(NO_3)_2 \times 3\ H_2O$ dissolved in 1 L [or 30 g of $Zn(NO_3)_2 \times 6\ H_2O$ in 1 L]
- Four 3-oz. plastic cups
- Three 5-oz. plastic cups
- Balance
- Graduated cylinder
- Four pipe cleaners
- Large Styrofoam ball
- 4 small Styrofoam balls
- Metric ruler
- Protractor

Vocabulary

anion, atom, balance, binary, cation, chemical change, compound, electron, formula, formula unit, ion, ionic compound, mass, molecular compound, molecule, polyatomic ions, solution, ternary

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

Introduction

1. Display samples of common elements (e.g., bare copper wire, zinc chips, charcoal), an empty covered jar to represent diatomic molecules of oxygen gas and nitrogen gas (which comprise 99% of the air we breathe), and a beaker of the compound water.
2. Using the sample displayed elements, help students come up with working definitions of the following terms:
   - **element:** any substance that cannot be split into simpler substances by ordinary chemical means
   - **molecule:** a particle that has two or more atoms bonded together
   - **compound:** a substance with different kinds of atoms
3. Distribute copies of the periodic table of the elements, or have students use the one in their textbook. Point out the seven diatomic elements: H, N, C, O, F, Cl, and Br.
4. Explain the rules for writing a basic ionic compound formula, as follows:
   - Ionic compounds usually contain a metal and a nonmetal.
   - Use charges to write the formula.
   - If the ionic compound is a transition metal, a Roman numeral gives the charge.
   - The *-ide* ending indicates a binary compound without a polyatomic ion.
5. Explain the rules for using polyatomic ions in ionic compounds, as follows:
   - Each polyatomic ion is a complete unit; *never* break it up or change the numbers.
   - Use charges to write the formula, just as you would with regular ionic compounds.
   - Most names end in *-ate* and *-ite*; only a few (e.g., cyanide, hydroxide) have an *-ide* ending.
6. Explain the rules for writing a formula for a molecular compound, as follows:
   - Molecular compounds are nonmetals.
   - Do *not* use charges to write the formula.
   - The prefix gives the number of each element.

7. Explain the rules for writing the name of a compound, as follows:
   - Check whether it is ionic or molecular.
   - If it is molecular, the prefix gives the number of each element.
   - If it is ionic, name the first element, then name the second ion. If it is a single element, then just change the ending to *-ide*. If it is more than one element, it is a polyatomic ion (which you have memorized). Use the name you memorized.
   - Check whether the metal is a transition metal. If it is, use a Roman numeral.
   - Figure out the charge by working backwards. Examples:
     – $FeCl_2$ would be iron chloride, until you noticed that iron is a transition metal. To figure the charge, first find the charge of the negative ion (chloride). It is Cl^{-1}. Since there are two of these chlorides given in the formula $FeCl_2$, the total negative charge is −2. Therefore the iron must be a +2 to offset it. The name is "iron(II) chloride."
     – PtO_2: O has a −2 charge, and there are two of them, so the total negative charge is −4. Therefore, the platinum (Pt) must have a charge of +4. The name is "platinum(IV) oxide."
     – Fe_2O_3: O has a −2 charge, and there are three of them, so the total negative charge is −6. Therefore, the iron (Fe) must have a total positive charge of +6. Because there are 2 Fe, each of them must have a charge of +3. The name is "iron(III) oxide."
8. Assist students in writing the chemical symbols of elements and the chemical formulas for molecules and compounds.

Procedure

Part 1: Demonstration of the Law of Conservation of Matter

1. Tear off an egg-sized piece of steel wool. Be careful not to ball it up too tightly.
2. Place the steel wool into the 250-mL beaker, and add white vinegar until the entire piece of steel wool is immersed. Soak the steel wool for 4–7 minutes.
3. Remove the steel wool from the vinegar, and wring out all excess liquid.
4. Place the steel wool into the 250-mL flask, and cover the opening of the flask with a balloon.
5. Mass the entire steel wool-balloon-flask system, and record the results.
6. Allow the system to sit for 30–45 minutes.
7. Observe the results. Again, mass the steel wool-balloon-flask system, and record.
8. Provide students with an unbalanced version of the following chemical equation, and have them practice balancing it prior to proceeding to the main portion of the activity:
   $4\ Fe(s) + 3\ O_2(g) \rightarrow 2\ Fe_2O_3(s)$

Part 2: Lab for Balancing Equations

CAUTION! Sodium hydroxide is caustic and must be handled carefully. Students should wear gloves. If they do get it on their skin, it will feel slippery, just like liquid soap, and should be washed off immediately. Copper solutions can cause eye infections, so students should wash their hands after handling such solutions.

Have students do the experiment, as follows:

1. Measure 60 mL of NaOH solution in a graduated cylinder, and then pour into a small (3-oz.), clean plastic cup.
2. Rinse the graduated cylinder completely before making the next measurement.
3. Measure 60 mL of $CuSO_4$ solution in the graduated cylinder, and then pour it into a clean 5-oz. cup.
4. Carefully place the two solutions together on the balance, making sure the solutions do not mix. Mass the solutions and the cups together, and record the combined mass.
5. Pour the NaOH into the 5-oz. cup with the $CuSO_4$ solution. Allow the solutions to mix, and record your observations.
6. Mass both cups and the mixture again. Record the new mass. By how much did the mass change?
7. Repeat the process in steps 1–4 above for the combinations listed in the data section below. Do not allow the solutions to mix before measuring the initial mass.

Reaction	Mass (g) before	Mass (g) after	Observations
NaOH and $CuSO_4$			
NH_4OH and $CuSO_4$			
NH_4OH and $Zn(NO_3)_2$			

8. Have students complete the following equations and balance them:

___ NaOH + ___ $CuSO_4 \rightarrow$ ____

[$2\ NaOH + CuSO_4 \rightarrow Na_2SO_4 + Cu(OH)_2$]

___ NH_4OH + ___ $CuSO_4 \rightarrow$ ____

[$2\ NH_4OH + CuSO_4 \rightarrow (NH_4)_2SO_4 + Cu(OH)_2$]

___ NH_4OH + ___ $Zn(NO_3)_2 \rightarrow$ ____

[$NH_4OH + Zn(NO_3)_2 \rightarrow NH_4NO_3 + Zn(OH)_2$]

Part 3: Chemistry Geometrics Lab

In this lab, students will create models of molecules that have different molecular shapes. They will write molecular formulas and create structural formulas of several compounds. Have students do the experiment, as follows:

1. Stick one pipe cleaner into each of the four small Styrofoam balls.
2. Stick the other end of two of the pipe cleaners into the large Styrofoam ball so that the two small balls are as far apart from each other as possible.
3. Note the shape of this model of a molecule, and use the protractor to measure the angle between the two small balls. Record this measurement in the data table.
4. Detach the small balls from the model, and then attach three small balls to the large ball so that the three balls are as far apart from each other as possible.

5. Note the shape of this molecule model, and measure the angle between two of the small balls. Since the balls should be as far apart from each other as possible, the angles between all pairs of small balls should be the same. Record this measurement in the data table.
6. Repeat steps 4 and 5, using all four small balls.
7. Record the following data in another table: Independent Variable = Number of Balls; Dependent Variable = Angle between the Small Balls
8. Sketch the three molecule models you created, and name each. *(Linear, Trigonal Planar, Tetrahedral)*
9. Under each sketch, describe the relationship between the number of atoms in a molecule and the size of the angles between the bonds in the molecule. *(The greater the number of atoms, the smaller the angle between atoms.)*
10. Explain why atoms arrange themselves in their molecule so that they are as far apart from each other as possible. (Students should suggest that the electron clouds around atoms repel each other, thus forcing the atoms apart to the greatest possible degree. The fact that the valence electrons determine reactivity for forming compounds should be stressed.)

Part 4: Introduction to Empirical Formulas

1. Before the end of this lesson, introduce the concept of empirical formulas by giving the definition of the term, showing some examples of empirical formulas, and comparing the difference between empirical formulas and molecular formulas. Tell students that in the weeks to come, they will be working with “moles” calculating empirical formulas. This should pique their interest and keep them wondering.

Observations and Conclusions

Use the following questions to prompt conclusions:

1. Why is it necessary to balance the equation of a chemical reaction? (Balanced chemical equations obey the Law of Conservation of Matter and thus are true representations of what actually occurs in nature.)
2. Why do atoms arrange themselves in their molecule so that they are as far apart from each other as possible? (Electron clouds around atoms repel each other.)
3. What are four different “shorthand” systems chemists use to write chemical formulas? (Molecular, structural, empirical, and Lewis dot diagrams. Students may forget Lewis dot because it was introduced in a previous lesson, but use this as reinforcement.)

Assessment

- **Questions**
  - What are the rules for writing a basic ionic compound formula?
  - What are the rules for using polyatomic ions in ionic compounds?
  - What are the rules for writing a formula for a molecular compound?
- **Journal/Writing Prompts**
  - Explain why, in large-scale industrial product manufacturing, the mass of what is produced is always less than the mass of the starting materials. (Investigate this online

or interview a representative from a local industry that uses raw materials to manufacture a finished product.)

Extensions and Connections (for all students)

- Have students invent their own board game on the concepts of nomenclature, balancing equations, and/or writing chemical formulas.

Strategies for Differentiation

- Provide digital pictures of solutions labeled with colored labels for visual support on Part 2 Lab Step 7.
- Have students use a draw/paint program to complete Part 3, Step 8.
- Have students take digital pictures of models made in Part 3 Lab for student report.
- Have students use materials of their choice instead of Styrofoam balls and pipe cleaner (Part 3 Lab).
- Have students use colored tape to color code the labels of all solutions in Part 2 Lab.
- For Parts 1 and 2, model law of conservation of matter, using a molecular modeling kit to model a chemical reaction. Assemble the reactants for a chemical reaction and weigh them. Rearrange them to make models of the products and reweigh them.
- Provide students with sealable bags of set number of materials used in Part 3 Lab.
- Provide a data table labeled # of atoms, angle between atoms for use in Part 3 Lab.
- Have students use the digital pictures of the models created in the Part 3 lab and create a four-page word-processed document report, “Shapes of Molecules.” Page 1 should show two atoms (step 3), page 2 should show three or four atoms (step 5), and page 3 should show five atoms (step 6).