Predicting Products and Writing Equations

Strand Nomenclature, Chemical Formulas, and Reactions

Topic Investigating chemical reactions and equations

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

e) reaction types.

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.

In a synthesis reaction, two or more simple substances combine to form a more complex substance. Two or more reactants yielding one product is another way to identify a synthesis reaction. These reactions are in the general form: $A + B \rightarrow AB$ For example, simple hydrogen gas combined with simple oxygen gas can produce a more complex substance, such as water.

A decomposition reaction is the opposite of a synthesis reaction, where a more complex substance breaks down into its more simple parts. These reactions are in the general form:

$AB \rightarrow A + B$

In a single replacement reaction, a single uncombined element replaces another in a compound.

In a double replacement reaction, parts of two compounds switch places to form two new compounds. This is when the anions and cations of two different molecules switch places, forming two entirely different compounds. These reactions are in the general form:

$AB + CD \rightarrow AD + CB$

Redox reactions can be understood in terms of transfer of electrons from one involved species (reducing agent) to another (oxidizing agent). In this process, the former species is oxidized and the latter is reduced, thus the term *redox*. Though sufficient for many purposes, these descriptions are not precisely correct. Oxidation is better defined as an increase in oxidation number, and reduction as a decrease in oxidation number. In practice, the transfer of electrons will always change the oxidation number, but there are many reactions that are classed as "redox" even though no electron transfer occurs (such as those involving covalent bonds).

Before undertaking these lab experiments, be sure your school's chemical hygiene plan allows for the use of the chemicals required.

If you do not feel confident that your students have sufficient lab skills to safely do some of the reactions involving flammable materials, do those as demonstrations. These experiments can be conducted over several days as you introduce the types of reactions, or you can do them on one day as a review of the different types of reactions. Partners can work in larger groups to do certain assigned experiments and then present their results to the rest of the class either as a demonstration or simply as a discussion.

Depending on the level of students' knowledge at this point, they may write a word equation first, then translate that to a formula equation, and finally balance the equation; or they may write the balanced equation directly.

Students will need to know the positive results of the splint tests for the gases hydrogen, oxygen, and carbon dioxide. If they are not familiar with the splint tests for these gases, you can demonstrate them prior to the lab. (Hydrogen gas will "pop" when tested with a burning splint. Oxygen gas will relight a glowing splint. Carbon dioxide will extinguish a burning splint.)

Solution concentrations are not typically crucial for most of the lab except the neutralization reaction. For that reaction, about equal drops of acid and base are needed to reach the neutralization point; hence, the molarity of the NaOH and HCl for this part are important.

Materials

- Wooden splints
- pH paper or strips
- Plastic pipettes
- Test tubes in a variety of sizes
- Beakers in a variety of sizes
- Test tube rack
- Tongs
- Candle
- Scoop
- Burner
- Watch glass
- Ethanol
- Magnesium metal (ribbon form)
- Manganese dioxide (catalyst)
- 3% hydrogen peroxide solution
- Iron filings
- Zinc metal (Mossy zinc is fine.)
- *M* HCl and 1.0 *M* HCl (Exact concentration is not crucial.)
- Solid $CuCO_3$
- Solid $(NH_4)CO_3$
- *M* KI (Exact concentration is not crucial.)

- *M* $Pb(NO_3)_2$ (Exact concentration is not crucial.)
- Solid $NaHCO_3$
- Copper metal pieces
- *M* $AgNO_3$ solution (Exact concentration is not crucial.)
- *M* NaOH and 0.1 *M* HCl (These concentrations need to be equal to be accurate.)
- *M* Na_2CO_3 solution (Exact concentration is not crucial.)
- *M* $CuSO_4$ (Exact concentration is not crucial.)
- Small pieces of Ca metal
- Phenolphthalein indicator

Vocabulary

acid, balance, base, chemical reaction, classify, combustion, decomposition, double replacement, endothermic, equation, exothermic, observation, oxidation, precipitate, prediction, redox reaction, single replacement, synthesis

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

Introduction

1. Tell students that chemists observe what is happening in a chemical reaction and try to describe what is happening in a clear and concise way. A chemical equation uses formulas and symbols to describe the substances that are involved in a reaction, the physical state of the substances, the use of a catalyst, and the changes in energy that occur. In this experiment, you will perform a series of reactions and make careful observations of the changes that occur. Using simple tests and your knowledge of chemistry, you will identify the products of the reactions. With this information, you will then write and balance chemical equations to describe the reactions. Finally, you will classify the reactions as to type: combustion, oxidation, synthesis, decomposition, single replacement, double replacement, or acid-base.

Procedure

Either demonstrate or have students conduct the following reactions. Have students write a balanced chemical equation for each reaction, showing the product(s), and classify the reaction as to type: combustion, oxidation, synthesis, decomposition, single replacement, double replacement, or acid-base. Some reactions may have more than one classification. Direct students to indicate in their balanced equations all phases of matter (*s, l, g*) for reactants and products. Also, have them indicate whether the reaction is exothermic or endothermic by adding energy as either a reactant or a product.

1. Place a very small amount—no more than 4 drops—of ethyl alcohol (ethanol, C_2H_5OH) on a watch glass on the lab table, and ignite it with a match. Use crucible tongs to hold the match. *CAUTION! Ethyl alcohol is very flammable. Remove all flammable materials from the lab area.*

   $2\ C_2H_5OH + 6\ O_2 \rightarrow 4\ CO_2 + 6\ H_2O$; combustion; exothermic. The alcohol burns with a nonluminous blue flame. If you turn off the lights, the flame will be more visible.

2. Ignite a very small piece (less than 0.5 in.) of Mg metal in the burner flame. *CAUTION! Magnesium metal burns with a very bright light. Do not stare directly at the flame. Remove all flammable materials from the lab area.*
   $2\ Mg + O_2 \rightarrow 2\ MgO$; oxidation; synthesis; exothermic.
3. Place a very small amount (fill only the very tip of your scoop) of solid catalyst, MnO_2, in a test tube that is half filled with 3% hydrogen peroxide. Test with a glowing splint the gas that is given off.
   $2\ H_2O_2 \rightarrow 2\ H_2O + CO_2$; decomposition; endothermic. The MnO_2 acts as catalyst for the reaction.
4. Sprinkle a very small amount of Fe filings directly into a candle flame. Do not use your burner flame for this. *CAUTION! Metal powders are very flammable and reactive. Use only a small amount of Fe, and remove all flammable materials from the lab area.*
   $4\ Fe + 3\ O_2 \rightarrow 2\ Fe_2O_3$; oxidation; synthesis; exothermic. The iron fillings spark in the flame: Fe is used in fireworks to make gold sparks.
5. Place a test tube in the test tube rack, and fill it half way with 3.0 M HCl. Place a small piece of zinc metal in the tube, and collect the gas that is released by using a test tube holder to hold another test tube upside directly above and touching the reaction tube. Test the gas in the collection test tube by inserting a burning splint. *CAUTION! 3.0 M HCl is corrosive. The gas that is released is very reactive and explosive. DO NOT ignite the gas that is produced.*
   $Zn + 2\ HCl \rightarrow ZnCl_2 + H_2$; single replacement; exothermic. The zinc and HCl make hydrogen gas that gives a sharp “pop” when ignited.
6. Heat a small amount (about 1/4 of a test tube) of solid $CuCO_3$ in a test tube, and test the gas that is produces with a burning splint.
   $CuCO_3 \rightarrow CuO + CO_2$; decomposition; endothermic. The CO_2 gas puts out the burning splint, and the blue-green $CuCO_3$ turns black as the CuO forms.
7. Heat a very small amount (just enough to fill the bowl of the test tube) of $(NH_4)_2CO_3$ in a test tube. Place a damp piece of pH paper in the vapors released during the reaction. *CAUTION! The vapors being released are irritating to the throat and eyes. Conduct this procedure in a fume hood or in a room with good ventilation.*
   $(NH_4)_2CO_3 \rightarrow 2\ NH_3 + H_2O + CO_2$; decomposition; endothermic. The ammonia gas that is produced reacts with the damp pH paper to form a base.
8. Add a few drops of 0.1 M KI solution to a few drops of 0.1 M $Pb(NO_3)_2$ solution in a small test tube. *CAUTION! Do not dispose of these chemicals in the sink. Place them in the labeled waste container.*
   $2\ KI + Pb(NO_3)_2 \rightarrow 2\ KNO_3 + PbI_2$; double replacement. A yellow precipitate of PbI_2 forms.
9. Add several drops of 1.0 M HCl solution to a small amount of solid $NaHCO_3$ in a test tube. Test with a burning splint the gas that is released. *CAUTION! HCl is corrosive.*
   $NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$ acid-base. The carbonated base produces carbon dioxide gas, which puts out the burning splint.

10. Place a small piece of Cu metal in a clean dry test tube, and add several drops of 0.1 M $AgNO_3$ solution. Add just enough $AgNO_3$ solution to cover the metal. *CAUTION! $AgNO_3$ causes skin discoloration.*
    $Cu + AgNO_3 \rightarrow Ag + Cu(NO_3)_2$; single replacement. The $AgNO_3$ solution reacts with the Cu metal to produce a silver coating on the copper surface.
11. Put 20 drops of 0.1 M NaOH solution in a test tube, and add 5 drops of universal indicator. Then, add 20 drops, one at a time, of 0.1 M HCl solution to the test tube, tapping the test tube gently as you add it to allow it to mix. *CAUTION! HCl and NaOH are corrosive.*
    $NaOH + HCl \rightarrow NaCl + H_2O$; acid-base; double replacement. The indicator color changes from purple to green as the base is neutralized.
12. Add about 1 mL of a solution of 1.0 M Na_2CO3 to about 1 mL of a solution of 1.0 M $CuSO_4$ in a test tube.
    $Na_2CO_3 + CuSO_4 \rightarrow CuCO_3 + Na_2SO_4$; double replacement. A cloudy, blue precipitate of $CuCO_3$ forms.
13. Add a very small piece of Ca metal to a 50-mL beaker that is about half filled with water. When the reaction is finished, add a few drops of phenolphthalein indicator. *CAUTION! Calcium metal is very reactive and produces a flammable gas. Do not pick the calcium metal up with your hands, but use forceps or tongs. DO NOT have open flames during this reaction.*
    $Ca + 2\ H_2O \rightarrow Ca(OH)_2 + H_2$; single replacement; exothermic. The $Ca(OH)_2$ forms a cloudy, white precipitate. This turns pink upon the addition of the indicator phenolphthalein, indicating a base. Hydrogen gas is released.
14. Heat a small piece of copper metal directly in a burner flame.
    $2\ Cu + O_2 \rightarrow 2\ CuO$; oxidation; synthesis; endothermic. A black coating of the oxide will form on the surface of the copper metal.

Assessment

- **Questions**
  - How were you able to predict the products and write the balanced chemical equation for each chemical reaction? What did you need to know about the reactants? What did you need to know about the reactants
- **Other**
  - If the lab is done as a demonstration, write the balanced equations and classify the reactions as each reaction is completed. Compare and discuss answers.
  - Conduct Internet research to find real-life applications for three out of the seven different categories of chemical reactions. Then, contact a chemist at one of the companies of a product. If possible, schedule a visit or an Internet video call with the chemist. Prepare questions in advance to ask him/her. Create a poster that identifies the specific chemical reaction, gives the balanced chemical equation, and explains its industrial and/or environmental application.

Extensions and Connections (for all students)

- Manganese dioxide acts as a catalyst for the decomposition of hydrogen peroxide. Have students research the mechanism by which catalysts act—i.e., find out how catalysts make chemical reactions go faster.

Strategies for Differentiation

- Videotape chemical reactions for student reference as needed.
- Have students take digital photos of the reactants and observations, which will help them make predictions about their products. Have students use photos in small-group electronic slide presentation reports.
- Have students use a draw/paint program to create simple molecular models for electronic slide presentations.
- Have students use a small sealed plastic dropper bottle instead of thin-stem dropper pipettes.
- Put students in groups of two to three, and assign each group one of the 14 chemical reactions. Have each group become experts on their chemical reaction and demonstrate/present to the whole class.
- Have each small group prepare an electronic slide presentation of their assigned chemical reaction, including digital pictures. Presentation reports will include picture(s) of reactants, picture(s) of their observations of the reaction, explanation of how their observations helped them identify their products, a balanced chemical equation with "state of matter symbols," and molecular models representing the balanced chemical equation. Give each student a booklet that includes all electronic slide presentations.