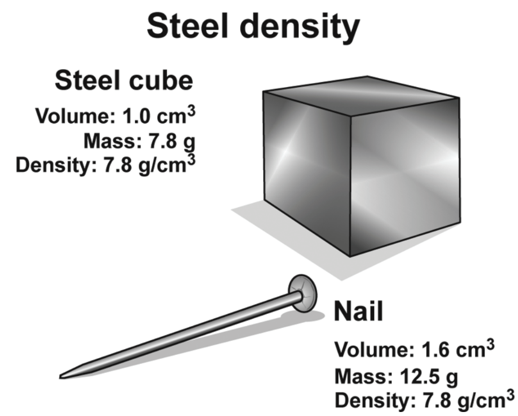
Name: ______________________ Date: ______________

Density

SKILL and PRACTICE 16.1

READ

- The density of a substance does not depend on its size or shape. As long as a substance is homogeneous, the density will be the same. This means that a steel nail has the same density as a cube of steel or a steel girder used to build a bridge.



- The formula for density is: $\text{density} = \frac{\text{mass}}{\text{volume}}$
- One milliliter takes up the same amount of space as one cubic centimeter. Therefore, density can be expressed in units of g/mL or g/cm^3. Liquid volumes are most commonly expressed in milliliters, while volumes of solids are usually expressed in cubic centimeters.
- Density can also be expressed in units of kilograms per cubic meter (kg/m^3).
- If you know the density of a substance and the volume of a sample, you can calculate the mass of the sample. To do this, rearrange the equation above to find mass: $\text{volume} \times \text{density} = \text{mass}$
- If you know the density of a substance and the mass of a sample, you can find the volume of the sample. This time, you will rearrange the density equation to find volume: $\text{volume} = \frac{\text{mass}}{\text{density}}$

EXAMPLES

Example 1: What is the density of a block of aluminum with a volume of 30.0 cm^3 and a mass of 81.0 grams?

$$\text{density} = \frac{81.0\ \text{g}}{30.0\ \text{cm}^3} = \frac{2.70\ \text{g}}{\text{cm}^3}$$

Answer: The density of aluminum is 2.70 g/cm^3.

Example 2: What is the mass of an iron horseshoe with a volume of 89 cm^3? The density of iron is 7.9 g/cm^3.

$$\text{mass} = 89\text{cm}^3 \times 7.9\frac{\text{g}}{\text{cm}^3} = 703\ \text{grams}$$

Answer: The mass of the horseshoe is 703 grams.

Example 3: What is the volume of a 525-gram block of lead? The density of lead is 11.3 g/cm^3.

$$\text{volume} = \frac{525\ \text{g}}{11.3\frac{\text{g}}{\text{cm}^3}} = 46.5\ \text{cm}^3$$

Answer: The volume of the block is 46.5 cm^3.

PRACTICE

1. A solid rubber stopper has a mass of 33.0 grams and a volume of 30.0 cm^3. What is the density of rubber?

2. A chunk of paraffin (wax) has a mass of 50.4 grams and a volume of 57.9 cm^3. What is the density of paraffin?

3. A marble statue has a mass of 6,200 grams and a volume of 2,296 cm^3. What is the density of marble?

4. The density of ice is 0.92 g/cm^3. An ice sculptor orders a one cubic meter block of ice. What is the mass of the block? Hint: 1 m^3 = 1,000,000 cm^3. Give your answer in grams and kilograms.

5. What is the mass of a pure platinum disk with a volume of 113 cm^3? The density of platinum is 21.4 g/cm^3. Give your answer in grams and kilograms.

6. The density of seawater is 1.025 g/mL. What is the mass of 1.000 liter of seawater in grams and in kilograms? (Hint: 1 liter = 1,000 mL)

7. The density of cork is 0.24 g/cm^3. What is the volume of a 240-gram piece of cork?

8. The density of gold is 19.3 g/cm^3. What is the volume of a 575-gram bar of pure gold?

9. The density of mercury is 13.6 g/mL. What is the volume of a 155-gram sample of mercury?

10. Recycling centers, for example, use density to help sort and identify different types of plastics so that they can be properly recycled. The table below shows common types of plastics, their recycling code, and density. Use the table to solve problems 10a -d.

Plastic name	Common uses	Recycling code	Density (g/cm^3)	Density (kg/m^3)
PETE	plastic soda bottles	1	1.38-1.39	1,380 - 1,390
HDPE	milk cartons	2	0.95-0.97	950 - 970
PVC	plumbing pipe	3	1.15-1.35	1,150 - 1,350
LDPE	trash can liners	4	0.92-0.94	920 - 940
PP	yogurt containers	5	0.90-0.91	900 - 910
PS	cd “jewel cases”	6	1.05-1.07	1,050 - 1,070

a. A recycling center has a 0.125 m^3 box filled with one type of plastic. When empty, the box had a mass of 0.755 kilograms. The full box has a mass of 120.8 kilograms. What is the density of the plastic? What type of plastic is in the box?

b. A truckload of plastic soda bottles was finely shredded at a recycling center. The plastic shreds were placed into 55-liter drums. What is the mass of the plastic shreds inside one of the drums?
Hint: 55 liters = 55,000 milliliters = 55,000 cm^3.

c. A recycling center has 100 kilograms of shredded plastic yogurt containers. What volume is needed to hold this amount of shredded plastic? How many 10-liter (10,000 mL) containers do they need to hold all of this plastic? Hint: 1 m^3 = 1,000,000 mL.

d. A solid will float in a liquid if it is less dense than the liquid, and sink if it is more dense than the liquid. If the density of seawater is 1.025 g/mL, which types of plastics would definitely float in seawater?

Name: ______________________________ Date: ______________

Calculating Concentration of Solutions

SKILL and PRACTICE 16.1

READ

What's the difference between regular and extra-strength cough syrup? Is the rubbing alcohol in your parents' medicine cabinet 70% isopropyl alcohol, or is it 90% isopropyl alcohol? The difference in these and many other pharmaceuticals is dependent upon the concentration of the solution. Chemists, pharmacists, and often consumers find it useful to distinguish between different concentrations of solutions. Remember that to calculate the percent concentration of a solution, use the formula:

$$\text{percent concentration} = \frac{\text{mass of solute}}{\text{total mass of solution}} \times 100$$

EXAMPLES

- What is the concentration of a solution made up of 12 grams of sugar and 300 grams of water?

  Solution:

  In this case, the solute is sugar (12 g), and the total mass of the solution is the mass of the sugar plus the mass of the water, (12 g + 300 g).
  Substituting into the formula, where *c* = the percent concentration, we have:

  $$c = \frac{12\text{ g}}{12\text{ g} + 300\text{ g}} \times 100 = \frac{12\text{ g}}{312\text{ g}} \times 100 = 3.8\%$$

  The concentration of a solution of 12 grams of sugar and 300 grams of water is 3.8%.

- How many grams of salt and water are needed to make 150 grams of a solution with a concentration of 15% salt?

  Solution:

  Here, we are given the concentration (15%) and the total mass of the solution (150 g). We are trying to find the mass of the solute (salt). Substituting into the same formula, where m is the mass of the salt, we have:

  $$15\% = \frac{m}{150\text{ g}} \times 100\text{, so } 0.15 = \frac{m}{150\text{ g}}\text{, and } 0.15 \times (150\text{ g}) = m = 22.5\text{ g}$$

  Since the total mass of the solution is 150 grams, and we now know that 22.5 grams are salt, that leaves:

  150 grams solution - 22.5 grams salt = 127.5 grams of water

  To make 150 grams of a solution with a concentration of 15% salt, you would need 22.5 grams of salt and 127.5 grams of water.

PRACTICE

Find the concentration of each solution.

1. 5 grams of salt in 75 grams of water
2. 40 grams of cinnamon in 2,000 grams of flour
3. 1.5 grams of chocolate milk mix in 250 grams of 1% milk

Find the mass of the solute in each situation.

4. 1,000 grams of a 40% salt water solution
5. 30 grams of a 12.5% sugar water solution
6. 555 grams of a 25% sand and soil solution

Carefully read and answer each of the following questions.

7. Dawn is mixing 450 grams of dishwashing liquid with 600 grams of water to make a solution for her little brother to blow bubbles. What is the concentration of the dishwashing liquid?
8. How many grams of glucose are needed to prepare 250 grams of a 5% glucose solution?
9. Jill mixes 4 grams of vanilla extract into the 800 grams of cake batter she has prepared. What is the concentration of vanilla in her "solution" of cake batter?
10. **Challenge**: Find the amount of red food coloring (in grams) necessary to add to 50 grams of water to prepare a 15% solution of red food coloring in water.

Name: ____________________ Date: ____________

SKILL and PRACTICE 16.1

Salinity and Concentration Problems

READ

Bodies of water like ponds, lakes, and oceans contain solutions of dissolved substances. Often these substances are in small quantities, measured in parts per thousand (ppt), parts per million (ppm), and parts per billion (ppb). This skill sheet will provide you with practice in using these quantities and in doing calculations with them.

Unit conversions

Table 1 below provides unit conversions that will be helpful to you as you complete this skill sheet.

Table 1: Unit Conversions

Milligrams	= Grams	= Kilograms	= Liters of water
1	0.001	0.000 001	0.000 001
10	0.01	0.000 01	0.000 01
1,000	1	0.001	0.001
1,000,000	1,000	1	1
1,000,000,000	1,000,000	1,000	1,000

Review: working with small concentrations

When working with small concentrations, remember that the units of the numerator and denominator must match, as shown in the examples below.

A. Parts per thousand (ppt)

Example: 0.009 grams of phosphate in about 1000 grams of oxygenated water makes a solution that has an phosphate concentration of 0.009 ppt.

$$\frac{0.009 \text{ grams}}{1{,}000 \text{ grams}} = 0.009 \text{ ppt}$$

B. Parts per million (ppm)

Example: A good level of oxygen in a pond is 9 ppm. This means that there are 9 milligrams of oxygen for every one liter (1000 grams) of oxygenated water.

$$\frac{9 \text{ milligrams}}{1 \text{ liter}} = \frac{9 \text{ milligrams}}{1{,}000 \text{ grams}} = \frac{9 \text{ milligrams}}{1{,}000{,}000 \text{ milligrams}} = 9 \text{ ppm}$$

C. Parts per billion (ppb)

Example: The concentration of trace elements in seawater is very low. For example, the concentration of iron in seawater is 0.06 ppb. This means that there are 0.06 mg of iron in 1,000 liters of water. One thousand liters is equal to 1,000 times 1,000 grams of seawater.

$$\frac{0.06 \text{ milligrams}}{1{,}000 \text{ liters}} = \frac{0.06 \text{ milligrams}}{1{,}000 \times 1{,}000 \text{ grams}} = \frac{0.06 \text{ milligrams}}{1{,}000{,}000 \text{ grams}} = \frac{0.06 \text{ milligrams}}{1{,}000{,}000{,}000 \text{ milligrams}} = 0.06 \text{ ppb}$$

EXAMPLES

Work through these example problems and check your answers. Then you will be ready to try the practice problems on your own.

- There are 16 grams of salt in 984 grams of water. What is the salinity of this solution?

  Solution:

$$\text{salinity} = \frac{16 \text{ grams salt}}{984 \text{ grams water} + 16 \text{ grams salt}} = \frac{16 \text{ grams salt}}{1{,}000 \text{ grams solution}} = 16 \text{ ppt}$$

- A liter of solution has a salinity of 40 ppt. How many grams of salt are in the solution? How many grams of pure water are in the solution?

  Solution:

$$40 \text{ ppt} = \frac{40 \text{ grams salt}}{1{,}000 \text{ grams solution}} = \frac{40 \text{ grams salt}}{40 \text{ grams salt} + x \text{ grams water}}$$

$$1{,}000 \text{ grams solution} = 40 \text{ grams salt} + x \text{ grams water}$$

$$1{,}000 \text{ grams solution} - 40 \text{ grams salt} = 960 \text{ grams water}$$

- You measure the salinity of a seawater sample to be 34 ppt. How many grams of salt are in this sample if the mass is 2 kilograms?

  Solution: First, remember that there are 1,000 grams per kilogram. If a solution is given in parts per thousand, you can think of it as “grams per 1,000 grams” or “grams per kilogram.” Therefore, you can set up a proportion like this:

$$\frac{34 \text{ grams salt}}{1 \text{ kilogram solution}} = \frac{x \text{ grams salt}}{2 \text{ kilograms solution}}$$

  Next, solve for *x*.

$$x = \frac{34 \text{ grams salt} \times 2 \text{ kilograms solution}}{1 \text{ kilogram solution}}$$

$$x = 68 \text{ grams salt}$$

PRACTICE

For each problem, show your work.

1. Complete Table 2 below:

Table 2: Salinity of Famous Places

Place	Salinity (ppt)	Amount of salt in 1 liter (grams)	Amount of pure water in 1 liter (grams)
Salton Sea California	44		
Great Salt Lake Utah	280		
Mono Lake California	210		
Pacific Ocean	87		

2. How many grams of salt are in 2 liters of seawater that has a salinity of 36 ppt?

3. A one-liter sample of seawater contains 10 grams of salt. What is the salinity of this sample?

4. You want to make a salty solution that has the same salinity as the Dead Sea. The salinity of the Dead Sea is 210 ppt. Write a recipe for how you would make 2 liters of this solution.

5. Five kilograms of seawater contains 30 grams of salt. What is the salinity of the volume of seawater?

6. You measure the salinity of a seawater sample to be 30 ppt. How many grams of salt are in this sample if the mass is 1.5 kilograms?

7. A solution has 2 grams of a substance in 1,000,000 grams of solution. Would you describe the concentration of the substance in solution as 2 parts per million or parts per billion?

8. A solution has 5 grams of a substance in 1,000,000,000 grams of solution. Would you describe the concentration of the substance as 5 ppb or 5 ppm?

9. Menthol is a substance that tastes sweet and minty and causes a cooling effect on your tongue. The taste threshold for menthol is 400 ppb. Could you taste menthol if there were 400 milligrams in 1,000,000 grams of menthol solution? Could you taste menthol if there were 400 milligrams in 1000 liters of menthol solution?

10. Above ground pipelines are used to transport natural gas, an important energy source. Gas leaks are potential problems with the pipelines. German Shepherd dogs can be trained to detect the gas leaks. The dogs sniff along the pipeline and then indicate a leak by perking up their ears or pawing the ground. The most sensitive electronic devices can detect gas leaks as low as 50 ppm. A German Shepherd can detect a gas leak as low as 1 ppb. How many times more sensitive is the dog as compared to the electronic device?

Name: ______________________________ Date: ______________

SKILL and PRACTICE 17.1

Internet Research Skills

READ

The Internet is a valuable tool for finding answers to your questions about the world. A search engine is like an on-line index to information on the World Wide Web. There are many different search engines to choose from. Search engines differ in how often they are updated, how many documents they contain in their index, and how they search for information. Your teacher may suggest several search engines for you to try.

EXAMPLE

Search engines ask you to type a word or phrase into a box known as a *field*. Knowing how search engines work can help you pinpoint the information you need. However, if your phrase is too vague, you may end up with a lot of unhelpful information.

How could you find out who was the first woman to participate in a space shuttle flight?

First, put **key phrases** in quotation marks. You want to know about the “first woman” on a “space shuttle.” Quotation marks tell the engine to search for those words together.

Second, if you only want websites that contain both phrases, **use a + sign** between them. Typing **“first woman” + “space shuttle”** into a search engine will limit your search to websites that contain both phrases.

If you want to broaden your search, use the word **or** between two terms. For example, if you type **“first female” or “first woman” + “space shuttle”** the search engine will list any website that contains either of the first two phrases, as long as it also contains the phrase “space shuttle.”

You can narrow a search by using the word **not.** For example, if you wanted to know about marine mammals other than whales, you could type **“marine mammals” not “whales”** into the field. Please note that some search engines use the minus sign (-) rather than the word **not**.

PRACTICE

1. If you wanted to find out about science museums in your state that are not in your own city or town, what would you type into the search engine?
2. If you wanted to find out which dog breeds are not expensive, what would you type into the search engine?
3. How could you research alternatives to producing electricity through the combustion of coal or natural gas?

READ

The quality of information found on the Internet varies widely. This section will give you some things to think about as you decide which sources to use in your research.

1. **Authority:** How well does the author know the subject matter? If you search for “Newton’s laws” on the Internet, you may find a science report written by a fifth grade student, and a study guide written by a college professor. Which website is the most authoritative source?
   Museums, national libraries, government sites, and major, well-known “encyclopedia sources” are good places to look for authoritative information.
2. **Bias:** Think about the author’s purpose. Is it to inform, or to persuade? Is it to get you to buy something? Comparing several authoritative sources will help you get a more complete understanding of your subject.
3. **Target audience:** For whom was this website written? Avoid using sites designed for students well below your grade level. You need to have an understanding of your subject matter at or above your own grade level. Even authoritative sites for younger students (children’s encyclopedias, for example) may leave out details and simplify concepts in ways that would leave gaps in your understanding of your subject.
4. **Is the site up-to-date, clear, and easy to use?** Try to find out when the website was created, and when it was last updated. If the site contains links to other sites, but those links don’t work, you may have found a site that is infrequently or no longer maintained. It may not contain the most current information about your subject. Is the site cluttered with distracting advertisements? You may wish to look elsewhere for the information you need.

PRACTICE

1. What is your favorite sport or activity? Search for information about this sport or activity. List two sites that are authoritative and two sites that are not authoritative. Explain your reasoning. Finally, write down the best site for finding out information about your favorite sport.
2. Search for information about a physical science topic of your choice on the Internet (*i.e.*, “simple machines,” “Newton’s Laws,” “Galileo”). Find one source that you would NOT consider authoritative. Write the key words you used in your search, the web address of the source, and a sentence explaining why this source is not authoritative.
3. Find a different source that is authoritative, but intended for a much younger audience. Write the web address and a sentence describing who you think the intended audience is.
4. Find three sources that you would consider to be good choices for your research here. Write two to three sentence description of each. Describe the author, the intended audience, the purpose of the site, and any special features not found in other sites.

Name: ______________________________ Date: ______________

SKILL and PRACTICE 17.1

Chemical Equations

READ

Chemical symbols provide us with a shorthand method of writing the name of an element. Chemical formulas do the same for compounds. But what about chemical reactions? To write out, in words, the process of a chemical change would be long and tedious. Is there a shorthand method of writing a chemical reaction so that all the information is presented correctly and is understood by all scientists? Yes! This is the function of chemical equations. You will practice writing and balancing chemical equations in this skill sheet.

What are chemical equations?

Chemical equations show what is happening in a chemical reaction. They provide you with the identities of the reactants (substances entering the reaction) and the products (substances formed by the reaction). They also tell you how much of each substance is involved in the reaction. Chemical equations use symbols for elements and formulas for compounds. The reactants are written to the left of the arrow. Products go on the right side of the arrow.

$$H_2 + O_2 \rightarrow H_2O$$

The arrow should be read as "yields" or "produces." This equation, therefore, says that hydrogen gas (H_2) plus oxygen gas (O_2) yields or produces the compound water (H_2O).

PRACTICE

Write chemical equations for the following reactions:

Reactants	Products	Unbalanced Chemical Equation
Hydrochloric acid **HCl** and Sodium hydroxide **NaOH**	Water **H_2O** and Sodium chloride **NaCl**	
Calcium carbonate **$CaCO_3$** and Potassium iodide **KI**	Potassium carbonate **K_2CO_3** and Calcium iodide **CaI_2**	
Aluminum fluoride **AlF_3** and Magnesium nitrate **$Mg(NO_3)_2$**	Aluminum nitrate **$Al(NO_3)_3$** and Magnesium fluoride **MgF_2**	

READ

Conservation of atoms

Take another look at the chemical equation for making water:

$$2H_2 + O_2 \rightarrow 2H_2O$$

Did you notice that something has been added?

The large number in front of H_2 tells how many molecules of H_2 are required for the reaction to proceed. The large number in front of H_2O tells how many molecules of water are formed by the reaction. These numbers are called *coefficients*. Using coefficients, we can balance chemical equations so that the equation demonstrates conservation of atoms. The law of conservation of atoms says that no atoms are lost or gained in a chemical reaction. The same types and numbers of atoms must be found in the reactants and the products of a chemical reaction.

Coefficients are placed before the chemical symbol for single elements and before the chemical formula of compounds to show how many atoms or molecules of each substance are participating in the chemical reaction. When counting atoms to balance an equation, remember that the coefficient applies to all atoms within the chemical formula for a compound. For example, $5CH_4$ means that 5 atoms of carbon and 20 atoms (5×4) of hydrogen are contributed to the chemical reaction by the compound methane.

Balancing chemical equations

To write a chemical equation correctly, first write the equation using the correct chemical symbols or formulas for the reactants and products.

The displacement reaction between sodium chloride and iodine to form sodium iodide and chlorine gas is written as:

$$NaCl + I_2 \rightarrow NaI + Cl_2$$

- Next, count the number of atoms of each element present on the reactant and product side of the chemical equation:

Reactant Side of Equation	Element	Product Side of Equation
1	Na	1
1	Cl	2
2	I	1

- For the chemical equation to be balanced, the numbers of atoms of each element must be the same on either side of the reaction. This is clearly not the case with the equation above. We need coefficients to balance the equation.

- First, choose one element to balance. Let's start by balancing chlorine. Since there are two atoms of chlorine on the product side and only one on the reactant side, we need to place a "2" in front of the substance containing the chlorine, the NaCl.

$$2NaCl + I_2 \rightarrow NaI + Cl_2$$

This now gives us two atoms of chlorine on both the reactant and product sides of the equation. However, it also give us two atoms of sodium on the reactant side! This is fine—often balancing one element will temporarily unbalance another. By the end of the process, however, all elements will be balanced.

We now have the choice of balancing either the iodine or the sodium. Let's balance the iodine. (It doesn't matter which element we choose.)

- There are two atoms of iodine on the reactant side of the equation and only one on the product side. Placing a coefficient of "2" in front of the substance containing iodine on the product side:

$$2NaCl + I_2 \rightarrow 2NaI + Cl_2$$

There are now two atoms of iodine on either side of the equation, and at the same time we balanced the number of sodium atoms!

In this chemical reaction, two molecules of sodium chloride react with one molecule of iodine to produce two molecules of sodium iodide and one molecule of chlorine. Our equation is balanced!

PRACTICE

Balance the following equations using the appropriate coefficients. Remember that balancing one element may temporarily unbalance another. You will have to correct the imbalance in the final equation. Check your work by counting the total number of atoms of each element—the numbers should be equal on the reactant and product sides of the equation. Remember, the equations **cannot** be balanced by changing subscript numbers!

1. $Al + O_2 \rightarrow Al_2O_3$
2. $CO + H_2 \rightarrow H_2O + CH_4$
3. $HgO \rightarrow Hg + O_2$
4. $CaCO_3 \rightarrow CaO + CO_2$
5. $C + Fe_2O_3 \rightarrow Fe + CO_2$
6. $N_2 + H_2 \rightarrow NH_3$
7. $K + H_2O \rightarrow KOH + H_2$
8. $P + O_2 \rightarrow P_2O_5$
9. $Ba(OH)_2 + H_2SO_4 \rightarrow H_2O + BaSO_4$
10. $CaF_2 + H_2SO_4 \rightarrow CaSO_4 + HF$
11. $KClO_3 \rightarrow KClO_4 + KCl$

Name: ______________________ Date: ______________

SKILL and PRACTICE 17.2

Classifying Reactions

READ

Chemical reactions may be classified into different groups according to the reactants and products. The five major groups of chemical reactions are summarized below.

Addition reactions - when two or more substances combine to make a new compound.

- *General equation*: $A + B \rightarrow AB$
- *Example*: When rust forms, iron reacts with oxygen to form iron oxide (rust).
  $4Fe\ (s) + 3O_2\ (g) \rightarrow 2\ Fe_2O_3\ (s)$

Decomposition reactions - when a single compound is broken down to produce two or more smaller compounds.

- *General equation*: $AB \rightarrow A + B$
- *Example*: Water can be broken down into hydrogen and oxygen gases.
  $2H_2O\ (l) \rightarrow 2H_2\ (g) + O_2\ (g)$

Displacement reactions - when one element replaces another element in a compound.

- *General equation*: $A + BX \rightarrow AX + B$
- *Example*: When iron is added to a solution of copper chloride, iron replaces copper in the solution and copper falls out of the solution.
  $Fe\ (s) + CuCl_2\ (aq) \rightarrow Cu\ (s) + FeCl_2\ (aq)$

Precipitation reactions - when two dissolved compounds react to form two new compounds, one of which is not soluble and forms a precipitate.

- *General equation*: $AX + BY \rightarrow AY + BX$
- *Example*: When carbon dioxide gas is bubbled into lime water, a precipitate of calcium carbonate is formed along with water.
  $CO_2\ (g) + CaO_2H_2\ (aq) \rightarrow CaCO_3\ (s) + H_2O\ (l)$

Combustion reactions - when a carbon compound reacts with oxygen gas to produce carbon dioxide and water vapor. Energy is released from the reaction.

- *General equation*: Carbon Compound + $O_2 \rightarrow CO_2 + H_2O$ + energy
- *Example*: The combustion of methane gas.
  $CH_4\ (g) + 2O_2 \rightarrow CO_2\ (g) + 2H_2O\ (g)$

EXAMPLE

Classify the following reaction as addition, decomposition, displacement, precipitation, or combustion. Explain your answer.

$Mg\ (s) + CuSO_4\ (s) \rightarrow MgSO_4\ (aq) + Cu\ _{(s)}$

Answer: Displacement. Magnesium replaces copper in the compound.

PRACTICE

Classify the reactions below as either: addition, decomposition, displacement, precipitation, or combustion. Explain your answers.

1. CO_2 (g) + H_2O (l) → H_2CO_3 (aq)
2. Cl_2 (g) + 2KI (aq) → 2KCl (aq) + I_2 (g)
3. H_2O_2 (l) → H_2O (l) + O_2 (g)
4. $MnSO_4$ (s) → MnO (s) + SO_3 (g)
5. $C_6H_{12}O_6$ (s) + $6O_2$ (g) → $6CO_2$ (g) + $6H_2O$ (g)
6. $CaCl_2$ (aq) + $2AgNO_3$ (aq) → $Ca(NO_3)_2$ (aq) + 2AgCl (s)
7. 2NaCl (aq) + $CuSO_4$ (aq) → Na_2SO_4 (aq) + $CuCl_2$ (s)
8. $CaCl_2$ (aq) + 2Na (s) → Ca (s) + 2NaCl (aq)
9. $CaCO_3$ (s) → CaO (s) + CO_2 (g)
10. C_3H_8 (g) + $5O_2$ (g) → $3CO_2$ (g) + $4H_2O$ (g)

Answer the following questions.

11. You mix two clear solutions. Instantly, you see a bright yellow precipitate form. What type of reaction did you just observe? Explain your answer.
12. What type of reaction occurs when you strike a match?
13. Solid sodium reacts violently with chlorine gas. The product formed in the reaction is sodium chloride, also known as table salt. What type of reaction is this? Explain your answer.
14. Hydrogen-powered cars burn hydrogen gas to produce water and energy. The reaction is:
    $2H_2$ (g) + O_2 (g) → $2H_2O$ (g) + Energy
    While this reaction can be classified as an addition reaction, it is sometimes referred to as combustion. What characteristics does this reaction share with other combustion reactions? How is it different?

Name:______________________________ Date: ______________

SKILL and PRACTICE 17.2

Lise Meitner

Lise Meitner identified and explained nuclear fission, proving it was possible to split an atom.

Prepared to learn

Lise Meitner was born in Vienna on November 7, 1878, one of eight children; her father was among the first Jews to practice law in Austria. At 13, she completed the schooling provided to girls. Her father hired a tutor to help her prepare for a university education, although women were not yet allowed to attend.

The preparation was worthwhile. When the University of Vienna opened its doors to women in 1901, Meitner was ready. She found a mentor there in physics professor Ludwig Boltzmann, who encouraged her to pursue a doctoral degree. Physicist Otto Robert Frisch, Meitner's nephew, wrote that "Boltzmann gave her the vision of physics as a battle for ultimate truth, a vision she never lost."

Pioneer in radioactivity

In 1906 Meitner went to Berlin after earning her doctorate, only the second in physics awarded to a woman by the university. There was great interest in theoretical physics in Berlin. There she began a 30-year collaboration with chemist Otto Hahn. Together, they studied radioactive substances. One of their first successes was the development of a new technique for purifying radioactive material.

During World War I, Meitner volunteered as an X-ray nurse-technician with the Austrian army. She pioneered cautious handling techniques for radioactive substances, and when she was off duty, continued her work with Hahn.

Elemental discoveries

In 1917, they discovered the element protactinium. Afterward, Meitner was appointed head of the physics department at the Kaiser Wilhelm Institute for Chemistry in Berlin, where Hahn was head of the chemistry department. The two continued their study of radioactivity, and Meitner became the first to explain how conversion electrons were produced when gamma rays were used to remove orbital electrons.

Atomic-age puzzles

In 1934, when Enrico Fermi produced radioactive isotopes of uranium by neutron bombardment, he was puzzled by the products. Meitner, Hahn, and German chemist Fritz Strassmann began looking for answers.

Their research was interrupted when Nazi Germany annexed Austria in 1938 and restrictions on "non-Aryan" academics tightened. Meitner, though she had been baptized and raised a Protestant, went into exile in Sweden. She continued to correspond with her collaborators and suggested that they perform further tests on a product of the uranium bombardment.

When tests showed it was barium, the group was puzzled. Barium was so much smaller than uranium. Hahn wrote to Meitner that uranium "can't really break into barium … try to think of some other possible explanation."

Meitner and Frisch (who was also in Sweden) worked on the problem and proved that splitting the uranium atom was energetically possible. Using Neils Bohr's model of the nucleus, they explained how the neutron bombardment could cause the nucleus to elongate into a dumbbell shape. Occasionally, they explained, the narrow center of the dumbbell could separate, leaving two nuclei. Meitner and Frisch called this process *nuclear fission*.

Meitnerium honors achievement

In 1944, Hahn received the Nobel Prize in chemistry for the discovery of nuclear fission. Meitner's role was overlooked or obscured.

In 1966, she, Hahn, and Strassman shared the Enrico Fermi Award, given by President Lyndon B. Johnson and the Department of Energy. Meitner died two years later, just days before her 90th birthday. In 1992, element 109 was named *meitnerium* to honor her work.

Reading reflection

1. **Research:** Ludwig Boltzmann was an important mentor to Lise Meitner. Who was Boltzmann? Research and list one of his contributions to science.
2. What element did Meitner and Otto Hahn discover? Using the periodic table, list the atomic number and mass number of this element. Does this element have stable isotopes?
3. What is nuclear fission? Explain this event in your own words and draw a diagram showing how fission occurs in a uranium nucleus.
4. **Research** and describe at least two ways nuclear fission was used in the twentieth century.
5. Meitner did not receive the Nobel Prize for her work on nuclear fission, though she was honored in other ways. List how she was honored for her work in physics.
6. On a separate sheet of paper, compose a letter to the Nobel Prize Committee explaining why Meitner deserved this prize for her work. Be sure to explain your reasoning clearly and be sure to use formal language and good grammar in your letter.

Name: ______________________________ Date: ______________

PRACTICE 17.2

Predicting Chemical Equations

READ

Chemical reactions cause chemical changes. Elements and compounds enter into a reaction, and new substances are formed as a result. Often, we know the types of substances that entered the reaction and can tell what types of substance(s) were formed. Sometimes, though, it might be helpful if we could predict the products of the chemical reaction—know in advance what would be formed and how much of it would be produced.

For certain chemical reactions, this is possible, using our knowledge of oxidation numbers, types of chemical reactions, and how equations are balanced. In this skill sheet, you will practice writing a complete balanced equation for chemical reactions when only the identities of the reactants are known.

Review: Chemical equations

Recall that chemical equations show the process of a chemical reaction. The equation reads from left to right with the reactants separated from the products by an arrow that indicates "yields" or "produces."

In the chemical equation:

$$2Li + BaCl_2 \rightarrow 2LiCl + Ba$$

Two atoms of lithium combine with one molecule of barium chloride to yield two molecules of lithium chloride and one atom of barium. The equation fully describes the chemical change for this reaction.

For reactions such as the one above, a displacement reaction, we are often able to predict the products in advance and write a completely balanced equation for the chemical change. Here are the steps involved:

1. Predict the replacements for the reaction.

In displacement reactions, one element is replaced by a similar element in a compound. The pattern for this replacement is easily predictable: if the element doing the replacing forms a positive ion, it replaces the element in the compound that forms a positive ion. If the substance doing the replacing forms a negative ion, it replaces the element in the compound that forms a negative ion.

For the reaction described above, we could predict that the lithium would replace the barium in the compound barium chloride since both lithium and barium have positive oxidation numbers. The resulting product would pair lithium (1+) and chlorine (1-): the positive/negative combination required for ionic compounds.

2. Determine the chemical formula for the products.

Once you have determined which elements will be swapped to form the products, you can use oxidation numbers and the fact that the sum of the oxidation numbers for an ionic compound must equal zero in order to determine the chemical formula for the reaction products.

3. Balance the chemical equation

Once you have determined the nature and formulas of the products for a chemical reaction, the final step is to write a balanced equation for the reaction.

EXAMPLE

- If beryllium (Be) combines with potassium iodide (KI) in a chemical reaction, what are the products?

  Solution:

  First, we decide which element of KI will be replaced by the beryllium. Since beryllium has an oxidation number of 2+, it replaces the element in KI that also has a positive oxidation number—the potassium (K^{1+}). It will therefore combine with the iodine to form a new compound.

  Because beryllium has an oxidation number of 2+ and iodine's oxidation number is 1-, it is necessary for two atoms of iodine to combine with one atom of beryllium to form an electrically neutral compound. The resulting chemical formula for beryllium iodide is BeI_2.

  In single-displacement reactions, the component of the compound that has been replaced by the uncombined reactant now stands alone and uncombined. The resulting products of this chemical reaction, therefore, are BeI_2 and K. Balancing the equation give us:

$$Be + 2KI \rightarrow BeI_2 + 2K$$

PRACTICE

Predict replacements

1. If Na^{1+} were to combine with $CaCl_2$, what component of $CaCl_2$ would be replaced by the Na^{1+}?
2. If Fe^{2+} were to combine with K_2Br, what component of K_2Br would be replaced by the Fe^{2+}?
3. If Mg^{2+} were to combine with $AlCl_3$, what component of $AlCl_3$ would be replaced by the Mg^{2+}?

Predict product formulas

For the following combinations of reactants, predict the formulas of the products:

4. $Li + AlCl_3$
5. $K + CaO$
6. $F_2 + KI$

Predicting chemical equations for displacement reactions

Write complete balanced equations for the following combinations of reactants.

7. Ca and K_2S
8. Mg and Fe_2O_3
9. Li and NaCl