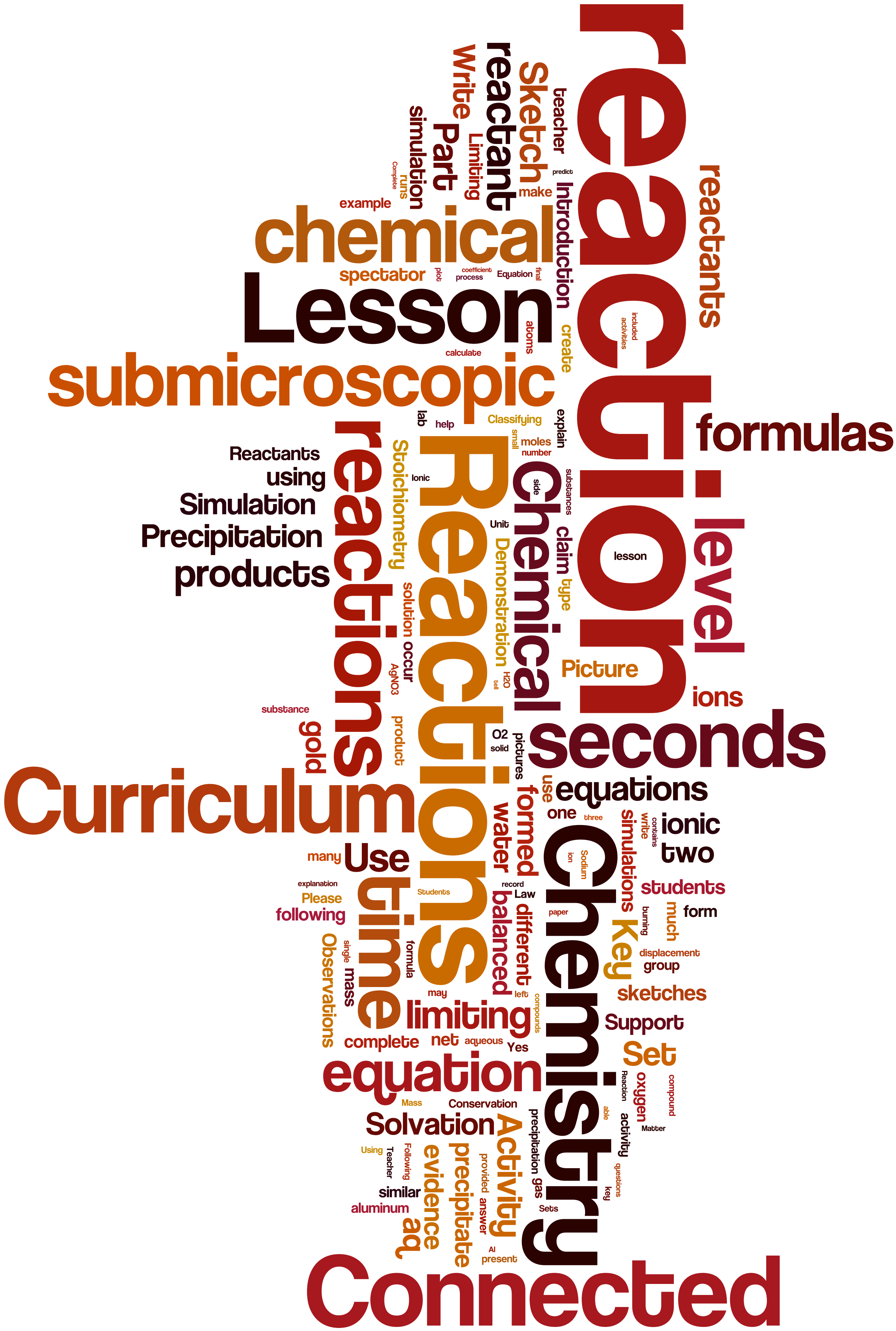
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The Connected Chemistry Curriculum

Acknowledgements

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Please direct all questions or concerns regarding The Connected Chemistry Curriculum to Dr. Mike Stieff at mstieff@uic.edu.

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U3S v4.0 1 January 2018

The Connected Chemistry Curriculum

Technology

System Requirements

The Connected Chemistry Curriculum has a software component (a set of *Simulations*) which is available at The Connected Chemistry Curriculum website, connchem.org. This software is necessary to use the curriculum, and is open-source and free of charge.

Besides the CCC software, you will need:

- **A personal computer of recent vintage, with an OpenGL-enabled graphics card.**
- **A 13" screen (or larger), with at least 1280 × 800 (WXGA) pixel resolution**
  For most computer monitors this is not a problem. Projectors, on the other hand, sometimes only manage VGA resolution (640 x 480), which will not allow sufficient room for our Simulations.
- **The latest Java runtime environment (JRE)**
  As of this writing, the latest JRE is Java 6, version 29. Java is free of charge: http://www.java.com/en/download/
- **Macintosh OS X 10.6 (Snow Leopard) or later, or Windows 7 or later**
  Earlier versions of the Macintosh OS or Windows may run, but may suffer performance issues. The software should also run on Linux. None of these options have been tested, however, so make sure you run all simulations before using them live in the classroom.

Troubleshooting

Please consult The Connected Chemistry Curriculum website (connchem.org) for up-to-date troubleshooting information, and to download software

Connected Chemistry

Reactions Unit

Contents

The Connected Chemistry Curriculum

Welcome

Welcome to *The Connected Chemistry Curriculum*! The Connected Chemistry Curriculum, or CCC, is designed to help students learn about chemistry by directly exploring the submicroscopic level of matter and phenomena that form the basis of study in chemistry. Educators designed CCC using direct feedback from teachers, students and researchers. CCC uses computer-based simulations to provide a unique submicroscopic perspective of the chemical world for students.

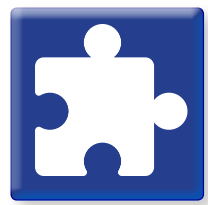
Activity Icons

These icons will be found throughout the teacher and student manuals.
The icons designate the purpose/theme of the activity or section.

Connecting

Hands-On Activity

Student Simulations

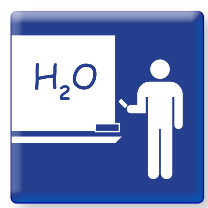


Putting It All Together

Questions

Lab Safety

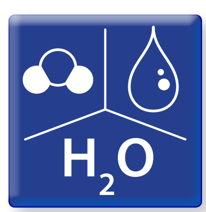
Sketching (without simulations)



Teacher Demonstration

Wet Lab

Teacher Facilitated Discussion



Chemistry Levels

Introductory Reading

Connected Chemistry

Reactions Unit

Lesson 1: Introduction to Chemical Reactions

Student's Lesson at a Glance

Lesson Summary

This lesson contains two activities that expose students to a brief introduction to chemical reactions. Using this knowledge, these activities help link chemical reactions to real-world scenarios. The lesson requires students to draw upon prior knowledge of chemical changes. Following the introduction of the lesson, students use a two-part activity to review how to name ions and decode models into chemical formulas.

SWBAT (Student will be able to)

- Know that chemists use models to reason about the sub-microscopic world and that models can only approximate that world
- Know that compounds are formed by combining two or more different elements and that compounds have properties that are different from their constituent elements
- Know that chemical changes cause atoms in the reactants to rearrange and form products with different properties and that physical changes do not result in new substances

Essential Vocabulary

Keep a list of all important words from this lesson. This list, in addition to the lists from other lessons, will make studying easier and improve scientific communication skills. The essential vocabulary from the unit is in bold. Additional words that will expand your scientific vocabulary are in italics.

CCC Reminder

- Students and teachers from many different schools helped designed CCC so that the lessons are more helpful and meaningful for all classroom participants.
- Use the vocabulary section and note section to take good notes so that studying for tests and quizzes will be easier.
- Supporting claims with evidence is not only a skill that scientists use, but a skill that will help you in other classes and everyday life.
- Draw a key when you are sketching. Symbolic keys can help you and others decode your sketches at a later time. Include ions separately from neutral atoms in your keys.
- Ions are charged particles that show up with a grey halo in the simulations. Ions make up ionic compounds. Use the periodic table to determine the charge of an ion.

Notes

Homework

Upcoming Quizzes / Tests

Activity 1: Connecting

The following are a set of common phenomena:

- exploding fireworks
- leaving a bike outside only to find later that the gears have rusted
- striking a match
- metabolizing food into energy in the human body
- leaves changing color in the fall
- burning a candle
- frying an egg

1. What do all these things or events have in common?

Chemical and physical changes constantly happen both inside and around us. In the exploration of this unit, you will focus on the relationship between chemical changes and reactions. Chemists communicate with each other about their observations of chemical reactions using the formal names of different substances, and they create word equations to represent different reactants and products in chemical reactions. For instance, the burning of substances is a specific type of chemical reaction called combustion. Chemists might describe the burning of ethane – a type of fuel – using the following word equation:

gaseous ethane + gaseous oxygen → gaseous carbon dioxide + gaseous water

In the word equation, the name of each substance is written out together with the state of matter. For example, you can see that all of the substances in the above reaction are gases. The reactants are listed to the left of the → and the products are listed to the right of the arrow, and each substance is separated by a +. The symbol → is pronounced "yields" and the symbol + is pronounced "and" when read aloud.

2. Explain one of the reasons why burning ethane is considered a chemical change?

Although word problems and submicroscopic drawings are useful, many chemists find they are too lengthy to write out and instead use symbolic representations to communicate. Chemists use **chemical equations** that use chemical formulas to replace the formal name of each substance. The state of matter is now represented by a new symbol following the chemical formula: solids are identified with the symbol (**s**), gases are identified with the symbol (**g**), and liquids are identified with the symbol (**l**). If the equation involves a solution with water as a solvent, dissociated ions in **aqueous** solution are identified with the symbol (**aq**).The chemical equation for burning ethane is:

$$2\,C_2H_6\,(g) + 7\,O_2\,(g) \rightarrow 4\,CO_2\,(g) + 6\,H_2O\,(g)$$

3. What must happen between ethane gas and oxygen for a chemical reaction to occur?

4. Write down three additional examples of chemical changes that you are familiar with. You do not need to write out chemical equations.

Lesson Reflection Question

5. Why is it important to include the states of matter in a chemical equation?

Activity 2: Decoding and Naming Submicroscopic Pictures

Part 1

1. When writing a chemical formula, which order do chemists follow? *Circle one.*

Cation before Anion (example: NaCl)

or

Anion before Cation (example: ClNa)

Use the information below to complete the table.

- The name of the element followed by a Roman numeral in parentheses is used to identify ions from elements that can form more than one cation. This is common with metals.
- The ***-ide*** ending is added to the name of a monoatomic anion of an element.

Element Name	Symbol	Ion Name
Lithium	Li^{+}	Lithium (I)
Fluorine	F^{-}	Fluoride
	Na^{+}	Sodium (I)
Magnesium		
Oxygen	O^{2-}	
Chlorine		
	S^{2-}	
	Al^{3+}	
	Fe^{2+}	Iron (II)
	Fe^{3+}	
	Cu^{+}	
		Copper (II)

Use the information to complete the missing information in table below.

- Some polyatomic anions contain oxygen. These anions are called *oxyanions*. When an element forms two oxyanions, the ion with less oxygen is given a name ending in ***-ite*** and the ion with more oxygen is given a name that ends in ***-ate***.

Symbol	Ion Name
NO_2^-	Nitrite
NO_3^-	Nitrate
SO_3^{2-}	
SO_4^{2-}	
ClO_3^-	
ClO_2^-	
PO_3^{3-}	
PO_4^{3-}	

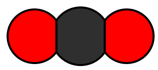
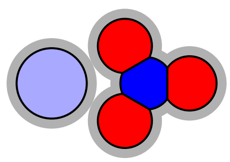
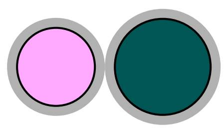
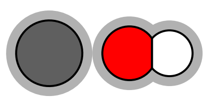
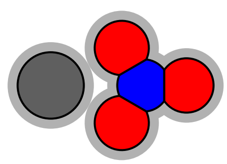
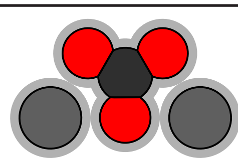
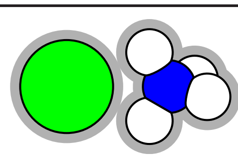
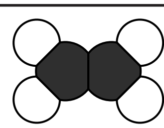
Use the information to complete the missing information in table below.

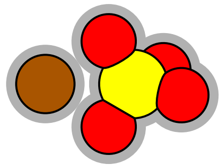
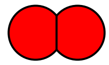
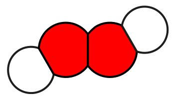
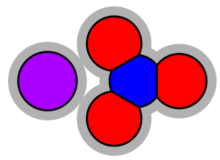
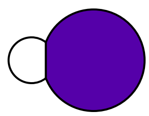
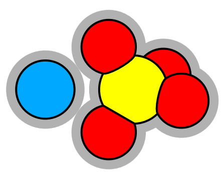
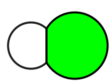
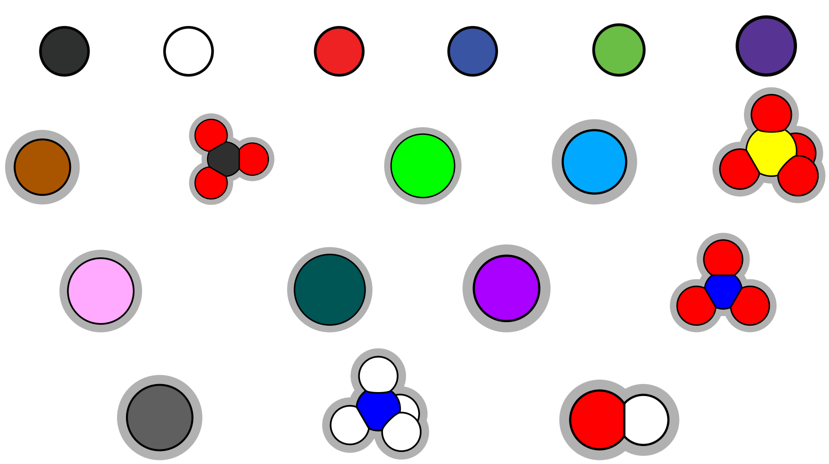
- A few polyatomic ions fall outside the pattern of naming.

Ion Name	Symbol
Carbonate	
	OH^-
Acetate	$C_2H_3O_2^-$
Ammonium	

Part 2

For this activity, students will create a key and translate the model of the compounds into a chemical formula. If an atom of an element and the ion of the same element appear (e.g., sodium and sodium ion), students should list them separately in the key.

Name	Model	Formula
Carbon dioxide		
Silver nitrate		
Potassium bromide		
Sodium hydroxide		
Sodium nitrate		
Sodium carbonate		
Ammonium chloride		
Ethene		

Name	Model	Formula
Copper (II) sulfate		
Oxygen		
Hydrogen peroxide		
Lithium nitrate		
Hydrogen iodide		
Iron (II) sulfate		
Hydrochloric acid		
Key		

Connected Chemistry

Reactions Unit

Lesson 2: Balanced Chemical Equations

Student's Lesson at a Glance

Lesson Summary

This lesson contains four activities that introduce students to five different kinds of chemical reactions (combination, decomposition, single displacement, double displacement, and combustion reactions). In the Connecting Activity, students apply the Law of Conservation of Mass to chemical equations by learning how to balance them. Following a teacher demonstration of the simulation and procedures, students will use the simulations to look at ten different reactions. In each of the reactions, students will create submicroscopic sketches and balance the chemical formulas for the reactants and products. In the final activity of the lesson, students can independently practice balancing equations.

SWBAT (Student will be able to)

- Know that compounds are formed by combining two or more different elements and that compounds have properties that are different from their constituent elements
- Know that chemical changes cause atoms in the reactants to rearrange and form products with different properties and that physical changes do not result in new substances
- Identify how the Law of Conservation of Mass applies to chemical reactions
- Create balanced chemical equations from simulations

Essential Vocabulary

Keep a list of all important words from this lesson. This list, in addition to the lists from other lessons, will make studying easier and improve scientific communication skills. The essential vocabulary from the unit is in bold. Additional words that will expand your scientific vocabulary are in italics.

CCC Reminder

- Students and teachers from many different schools helped designed CCC so that the lessons are more helpful and meaningful for all classroom participants.
- Many questions will ask you “what you think” or “to make predictions.” The only answer that is wrong is the answer that is left blank.
- Prefixes and suffixes on words can help you discover the meaning of a word.
- Use the vocabulary section and note section to take good notes so that studying for tests and quizzes will be easier.
- Supporting claims with evidence is not only a skill that scientists use, but a skill that will help you in other classes and everyday life.
- Draw a key when you are sketching. Symbolic keys can help you and others decode your sketches at a later time.
- Ions are charged particles that show up with a grey halo in the simulations. Ions make up ionic compounds. Use the periodic table to determine the charge of an ion.

Notes

Homework

Upcoming Quizzes / Tests

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Please turn to the next page.

Activity 1: Connecting

Magicians often claim that they can perform fantastic feats, such as making an elephant disappear. When the magician performs the trick, the audience is astounded by the feat. The elephant is composed of matter, which is anything that takes up space and has mass. Although the elephant has disappeared, did the magician destroy the matter of the elephant? Perhaps the magician tricked the audience into thinking that he made the elephant disappear. Unless the magician has figured out how to defy the **Law of Conservation of Mass**, the trick is just an illusion. The Law of Conservation of Mass states that mass (or matter) can neither be created nor destroyed. To begin to study the Law of Conservation of Mass, we will first examine an equation for burning aluminum: the reactants, solid aluminum and gaseous oxygen, combine to yield solid aluminum oxide as the product.

solid Aluminum + gaseous Oxygen → solid Aluminum Oxide

Using chemical formulas, the chemical equation would be:

$$Al\,(s) + O_2\,(g) \rightarrow Al_2O_3\,(s)$$

1. Using the table below, draw a submicroscopic view of the above equation.

Sketch reaction at submicroscopic level Before (at time 0 seconds)	Sketch reaction at submicroscopic level After (at time 30 seconds)
Key	

Another way to consider the Law of Conservation of Mass is that atoms that start as reactants in a reaction are the same atoms that are in the resultant products. Reactions generally involve the rearrangement of the original atoms of the reactants into a new arrangement, which produces the products.

2. How many aluminum atoms are present on the reactant side of the equation?

3. How many oxygen atoms are present on the reactant side of the equation?

4. How many aluminum atoms are present on the product side of the equation?

5. How many oxygen atoms are present on the product side of the equation?

6. Based on a comparison of reactants and products, does the equation as it is currently written follow the Law of Conservation of Mass? *Support your claim with evidence.*

The equation as it is written shows that there is a greater number of atoms of oxygen and aluminum on the product side than on the reactant side. However, this is impossible since the Law of Conservation of Mass states that atoms cannot simply be created from nothing.

To be consistent with the Law of Conservation of Mass, this equation must be balanced. A balanced equation shows the same number of atoms of each kind of element involved in a reaction on both sides of the chemical equation. Balanced chemical equations reflect the actual number of elements that are required for a reaction to occur. We can balance any equation by multiplying the different atoms and molecules on the reactant and product side using *coefficients*. Coefficients are numbers that are written immediately before the chemical formula in a chemical equation. For example:

$2Cu^{+}$ = two copper ions

$2CuS$ = two copper sulfide molecules = two copper atoms and two sulfur atoms

$2CuSO_4$ = two copper sulfate molecules = two copper atoms, two sulfur atoms, and eight oxygen atoms.

$2Cu(NO_3)_2$ = two copper nitrate molecules = two copper atoms, four nitrogen atoms, and twelve oxygen atoms.

CCC Simulation Note: Coefficients in chemical equations represent the ratio of atoms or compounds involved in a reaction and how many atoms or molecules are present at any given time. You can use the simulations in CCC to identify the products and reactants involved in the reaction, but ***you should not use the number of molecules in the simulation as the coefficients*** to balance the equation.

7. What coefficient can we add to aluminum to make the number of aluminum reactants equal to the number of aluminum products?

$$\_\_\_\_\_ \text{ Al (s)} + \text{O}_2\text{ (g)} \rightarrow \text{Al}_2\text{O}_3\text{ (s)}$$

To balance the oxygen atoms, you may suggest using a fraction as a coefficient on the oxygen on the product side as below.

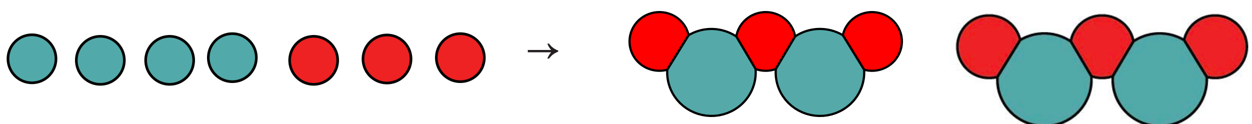
$$2\text{ Al (s)} + 3/2\text{ O}_2\text{ (g)} \rightarrow \text{Al}_2\text{O}_3\text{ (s)}$$

Although this is correct, chemists prefer to use whole numbers as coefficients whenever possible. We convert the 3/2 coefficient into a whole number if we multiple it by two. So that we are consistent with the Law of Conservation of Mass, we will need to multiply every coefficient in the equation by the same number to keep the number of atoms balanced. This will also give us the lowest whole number ratio.

$$2 \times 2\text{ Al (s)} + 2 \times 3/2\text{ O}_2\text{ (g)} \rightarrow 2 \times \text{Al}_2\text{O}_3\text{ (s)}$$

The new equation looks like this after we multiply through by 2.

$$4\text{ Al (s)} + 3\text{ O}_2\text{ (g)} \rightarrow 2\text{ Al}_2\text{O}_3\text{ (s)}$$



8. Is the equation balanced? *Support your claim with evidence.*

---

9. What is the state of matter for each reactant and the product?

---

10. Write out the balanced chemical equation as a word equation.

---

11. Based on the balanced equation, redraw the submicroscopic view of the equation.

Sketch reaction at submicroscopic level Before (at time 0 seconds)	**Sketch reaction at submicroscopic level After (at time 30 seconds)**
Key	

Activity 2: Translating Simulations Demonstration

In this modeling activity, you will learn to effectively translate diagrams of chemical reactions into chemical equations. In these reactions, you will initially see either one or two reactants that react together to form one or two products. As the reactions occur, there may be different phases of substances present (e.g., solids, liquids, gases). Some of the simulations will also contain *aqueous solutions*. For example, the compound silver nitrate, $AgNO_3$, will dissociate in water to form an Ag^+ cation and a NO_3^- anion. To indicate an aqueous compound use the symbol (aq) in place of the state of matter. Make sure you are familiar with common ionic compounds so you can easily create the chemical equations that involve aqueous solutions. Look back at your notes and sketches regarding solution chemistry as a reminder.

Your teacher will show you two different reactions and help you construct chemical equations from them as examples. Following these examples, you will explore several reactions on your own.

- *Draw sketches before and after the reaction. Follow the sketching and observation protocol to ensure you have accurate sketches. Make sure you include halos in your sketches.*
- *After sketching, use a key to represent the atoms that form the reactants and products.*
- *Once your key is developed, write out the chemical formulas for reactants and products before and after the reaction as a balanced chemical reaction. Reactants should be written under the section "chemical formulas before." Products should be written under the section "chemical formulas after." Do not forget subscripts, coefficients, states of matter, and aqueous when appropriate.*

Demonstration 1: *Use Simulation 1, **Set 1***

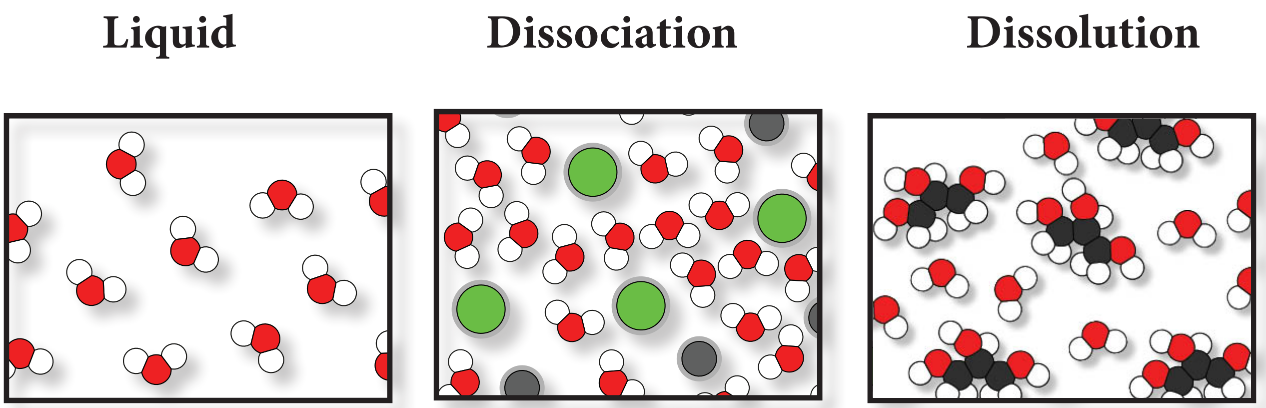
<table>
<tr><td colspan="2">Sketch reaction at submicroscopic level, Before (at time 0 seconds)</td><td>Sketch reaction at submicroscopic level, After (at time 30 seconds)</td></tr>
<tr><td colspan="3">Key</td></tr>
<tr><td>Chemical formulas before</td><td>→</td><td>Chemical formulas after</td></tr>
<tr><td colspan="3">Observations</td></tr>
</table>

Demonstration 2: *Use Simulation 1, Set 2*

Sketch reaction at submicroscopic level, Before (at time 0 seconds)		Sketch reaction at submicroscopic level, After (at time 30 seconds)
Key		
Chemical formulas before	→	**Chemical formulas after**
Observations		

Activity 3: Translating Simulations Into Chemical Reactions

Some reactions only occur in water. Recall that **dissociation** is the process by which an ionic solute separates into aqueous cations and anions. **Dissolution** is the process by which a molecular solute separates into individual compounds; molecular compounds *do not* separate into individual atoms when they dissolve. These processes are shown below with submicroscopic pictures along with a comparison liquid. Many students get confused and think that aqueous and liquid mean the same thing, but aqueous indicates a solution with water as the solvent. An aqueous solution is denoted by the abbreviation (aq) placed after the chemical formula of the solute. For example, sodium chloride dissociated in water is written as NaCl (aq). When a reaction occurs in water as a solvent, the reaction is said to be an aqueous reaction. ***The water acts as a medium for the reaction to occur, but it is not included in the chemical formula unless water itself acts as a reactant or is created as a product.***



You may want to turn water "on" or "off" for some of these simulations.

Complete the remaining eight simulations using the following steps.

1. In the initial menu, select a set number.

2. Before pressing start, draw submicroscopic pictures and write out the molecular chemical formula for the reactants. Remember that some of the next few reactions will contain water. When water is the solvent for a reaction, the reaction is said to occur in an aqueous solution. Water acts as the medium for the reaction to occur, but ***is not included*** in the chemical formula since it is not part of the reaction.

3. Click on the "Start" button and run the simulation for approximately 30 seconds.

4. Pause the model and draw submicroscopic pictures and write out the molecular chemical formula for the products. Again water acts as the medium for the reaction to occur, but ***is not included*** in the the chemical formula if it is not part of the reaction.

Part 1: *Use Simulation 1, **Set 3***

<table>
<tr><td colspan="3">Sketch reaction at submicroscopic level, Before (at time 0 seconds)</td><td colspan="2">Sketch reaction at submicroscopic level, After (at time 30 seconds)</td></tr>
<tr><td colspan="5">Key</td></tr>
<tr><td>Chemical formulas before</td><td colspan="2">→</td><td colspan="2">Chemical formulas after</td></tr>
<tr><td colspan="5">Observations</td></tr>
</table>

Part 2: *Use Simulation 1, **Set 4***

Sketch reaction at submicroscopic level, Before (at time 0 seconds)			Sketch reaction at submicroscopic level, After (at time 30 seconds)
Key			
Chemical formulas before		→	**Chemical formulas after**
Observations			

Part 3: *Use Simulation 1, **Set 5***

<table>
<tr><td colspan="3">Sketch reaction at submicroscopic level, Before (at time 0 seconds)</td><td colspan="2">Sketch reaction at submicroscopic level, After (at time 30 seconds)</td></tr>
<tr><td colspan="5">Key</td></tr>
<tr><td colspan="2">Chemical formulas before</td><td colspan="2">→</td><td>Chemical formulas after</td></tr>
<tr><td colspan="5">Observations</td></tr>
</table>

Part 4: *Use Simulation 1, **Set 6***

<table>
<tr><td colspan="3">Sketch reaction at submicroscopic level, Before (at time 0 seconds)</td><td colspan="2">Sketch reaction at submicroscopic level, After (at time 30 seconds)</td></tr>
<tr><td colspan="5">Key</td></tr>
<tr><td colspan="2">Chemical formulas before</td><td colspan="2">→</td><td>Chemical formulas after</td></tr>
<tr><td colspan="5">Observations</td></tr>
</table>

Part 5: *Use Simulation 1, **Set 7***

<table>
<tr><th colspan="3">Sketch reaction at submicroscopic level, Before (at time 0 seconds)</th><th>Sketch reaction at submicroscopic level, After (at time 30 seconds)</th></tr>
<tr><td colspan="3"></td><td></td></tr>
<tr><th colspan="4">Key</th></tr>
<tr><td colspan="4"></td></tr>
<tr><th>Chemical formulas before</th><td>→</td><th colspan="2">Chemical formulas after</th></tr>
<tr><th colspan="4">Observations</th></tr>
<tr><td colspan="4"></td></tr>
</table>

Part 6: *Use Simulation 1, **Set 8***

Sketch reaction at submicroscopic level, Before (at time 0 seconds)			Sketch reaction at submicroscopic level, After (at time 30 seconds)
Key			
Chemical formulas before	$\rightarrow$		**Chemical formulas after**
Observations			

Part 7: *Use Simulation 1, **Set 9***

<table>
<tr><th colspan="3">Sketch reaction at submicroscopic level,
Before (at time 0 seconds)</th><th colspan="2">Sketch reaction at submicroscopic level,
After (at time 30 seconds)</th></tr>
<tr><td colspan="5">Key</td></tr>
<tr><td colspan="2">Chemical formulas before</td><td colspan="2">→</td><td>Chemical formulas after</td></tr>
<tr><td colspan="5">Observations</td></tr>
</table>

Part 8: *Use Simulation 1, **Set 10***

Sketch reaction at submicroscopic level, Before (at time 0 seconds)		Sketch reaction at submicroscopic level, After (at time 30 seconds)
Key		
Chemical formulas before	→	**Chemical formulas after**
Observations		

Lesson Reflection Question

1. Did any of the reactions in the simulation have similarities? *Explain your answer with evidence from the simulation.*

Activity 4: Putting it All Together: Practice Balancing

1. Balance the following equations. Use a separate piece of paper if you need more room to do work. Your teacher may provide a few other examples.

1	___ Fe	+	___ H_2SO_4	→	___ $Fe_2(SO_4)_3$	+	___ H_2
2	___ C_2H_6	+	___ O_2	→	___ H_2O	+	___ CO_2
3	___ KOH	+	___ H_3PO_4	→	___ K_3PO_4	+	___ H_2O
4	___ SnO_2	+	___ H_2	→	___ Sn	+	___ H_2O
5	___ NH_3	+	___ O_2	→	___ NO	+	___ H_2O
6	___ $Pb(NO_3)2$	+	___ $AlCl_3$	→	___ $PbCl_2$	+	___ $Al(NO_3)_3$
7	___ Al	+	___ HCL	→	___ $AlCl_3$	+	___ H_2
8	___ BF_3	+	___ Li_2SO_3	→	___ $B_2(SO_3)_3$	+	___ LiF
9	___ $SeCl_6$	+	___ O_2	→	___ SeO_2	+	___ Cl_2
10	___ $(NH_4)_3PO_4$	+	___ $Pb(NO_3)_4$	→	___ $Pb_3(PO_4)_4$	+	___ NH_4NO_3

Student's Lesson at a Glance

Lesson Summary

This lesson contains two activities. These activities are designed to emphasize the Law of Conservation of Mass. Following a brief Connecting Activity with the teacher demonstration of burning paper, students use simulations to gather data so that they are able to calculate molar mass and moles of compounds.

SWBAT (Student will be able to)

- Know that chemical changes cause atoms in the reactants rearrange to form products with different properties and that physical changes do not result in new substances
- Identify how the Law of Conservation of Mass applies to chemical reactions

Essential Vocabulary

Keep a list of all important words from this lesson. This list, in addition to the lists from other lessons, will make studying easier and improve scientific communication skills. The essential vocabulary from the unit is in bold. Additional words that will expand your scientific vocabulary are in italics.

CCC Reminder

- Many questions will ask you "what you think" or "to make predictions." The only answer that is wrong is the answer that is left blank.
- Use the vocabulary section and note section to take good notes so that studying for tests and quizzes will be easier.
- Supporting claims with evidence is not only a skill that scientists use, but a skill that will help you in other classes and everyday life.
- Show all your calculations. Include labels on all numbers. These two steps will make checking your work easier.
- Ions are charged particles that show up with a grey halo in the simulations. Ions make up ionic compounds. Use the periodic table to determine the charge of an ion.
- The coefficients indicate how many moles of a substance are present in a reaction.

Notes

Homework

Upcoming Quizzes / Tests

Activity 1: Connecting

1. When atoms are rearranged in a chemical reaction, what do you think happens to the mass of the atoms?

2. When baking soda and vinegar react the mass of the reactants changes. Does this indicate that the Law of Conservation of Mass has been violated?

Recall that mass (or matter) can neither be created nor destroyed; this law is called the Law of Conservation of Mass. In a chemical reaction, the reactants are converted into new products when the atoms are rearranged. As you learned in the last lesson, chemical equations are balanced in accordance to the Law of Conservation of Matter; mass is conserved as reactants convert to products. During a chemical reaction, the atoms involved must retain the same mass. Thus, the Law of Conservation of Mass accounts for the fact that the total mass of the products formed in a reaction is always equal to the total mass of the reactants. To demonstrate the Law of Conservation of Mass, your teacher will measure the mass before and after burning a piece of paper in a combustion reaction. Paper is made up of cellulose, which has a chemical formula of $C_6H_{10}O_5$ organized in long chains.

3. What is the initial mass of the paper?

4. What do you think happens to the long chains of cellulose molecules on the submicroscopic level when paper burns?

5. What was needed for the paper to burn?

6. What is the final mass of the paper?

7. What do you think are the products of the combustion of paper?

8. Was mass conserved in the reaction?

Activity 2: Simulating the Law of Conservation of Mass

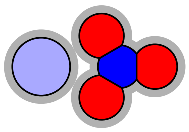
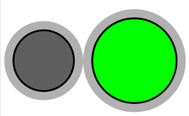
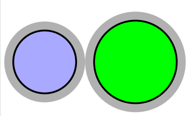
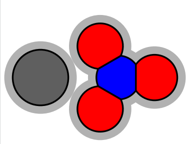
In this next activity, you will calculate the mass and moles of the reactants and products of the reaction.

Demonstration: *Use Simulation 1,* **Set 10**

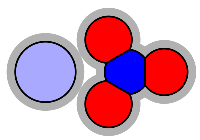
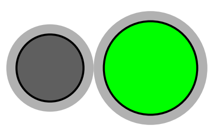
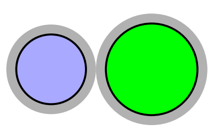
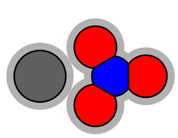
$$AgNO_3\,(aq) + NaCl\,(aq) \rightarrow AgCl\,(s) + NaNO_3\,(aq)$$

- *Set up the reaction, push the START/STOP button, and run the reaction until about the 30 second mark.*
- *Using the crosshairs on the plot, record the masses of each substance and calculate the molar mass and moles at time = 0 seconds* *(page 33)*.
- *After the reaction is complete, using the crosshairs on the plot, record the masses of each substance and calculate the molar mass and moles around time = 30 sec* *(page 34)*.

Time = 0 Seconds

Name	Formula	Molecule	Mass from Plot	Calculate Molar Mass (show calculations)	Calculate Moles (show calculations)
Silver Nitrate	$AgNO_3$				
Sodium Chloride	NaCl				
Silver Chloride	AgCl				
Sodium Nitrate	$NaNO_3$				

Time = 30 seconds

Name	Formula	Molecule	Massfrom Plot	CalculateMolarMass (show calculations)	Calculate Moles (show calculations)
Silver Nitrate	$AgNO_3$				
Sodium Chloride	NaCl				
Silver Chloride	AgCl				
Sodium Nitrate	$NaNO_3$				

9. Is the Law of Conservation of Mass observed in this reaction? *Support your claim with evidence.*

Lesson Reflection Questions

10. A student balances an equation for a chemical reaction that was performed in lab. The student discovers the products have twice as much mass as the reactants. The student does not think this is correct and thinks that she balanced the equation improperly. If the wrong coefficients are added to a chemical equation while the equation is being balanced, how would this effect the Law of Conservation of Matter?

11. A student balances an equation for a chemical reaction that was performed in lab that explored the following chemical reaction:

$$Cu(NO_3)_2 + 2\ NaOH \rightarrow Cu(OH)_2 + 2\ NaNO_3$$

The student reacted 30g of copper nitrate with 12.8g of sodium hydroxide. How much copper hydroxide and sodium nitrate should have been produced in this reaction? Balance the chemical equation and determine the mass of each of the products that the student should have at the end of the reaction.

12. If the student predicted that there should have been 55.5g of sodium nitrate, would the Law of Conservation of Mass be upheld? Explain your answer.

Connected Chemistry
Reactions Unit
Lesson 4: Classifying Reactions

Student's Lesson at a Glance

Lesson Summary

This lesson contains five activities designed to help students define and understand five basic types of reactions: combination (synthesis), decomposition, single displacement, double displacement, and combustion reactions. Students begin with a Connecting Activity that provides a general introduction to the different types of reactions. Teachers can provide the formal definitions and examples of the reactions. Following the teacher demonstration of the simulation, students compare and contrast the ten reactions from Lesson 2 (**L2A2-3**). Students provide balanced equations and then classify the types of reactions. In the final activity, small groups will teach each other about their assigned reaction.

SWBAT (Student will be able to)

- Classify chemical reactions according to how the reactants rearrange to form products
- Know that chemical reactions occur from the collisions between elements or molecules
- Know that combustion reactions occur when an element or a compound reacts with oxygen
- Know that double displacement reactions occur from the exchange of anions and cations between two ionic compounds
- Know that combination reactions occur when two or more reactants combine to form a single product
- Know that decomposition reactions occur when a single reactant is broken down into two or more products
- Know that single replacement reaction when one element replaces a second element in a compound
- Classify a chemical reaction from an observation of submicroscopic interactions
- Represent different types of chemical reactions using submicroscopic chemical representations
- Represent different types of chemical reactions using chemical equations

Essential Vocabulary

Keep a list of all important words from this lesson. This list, in addition to the lists from other lessons, will make studying easier and improve scientific communication skills. The essential vocabulary from the unit is in bold. Additional words that will expand your scientific vocabulary are in italics.

CCC Reminder

- Prefixes and suffixes on words can help you discover the meaning of a word.
- Use the vocabulary section and note section to take good notes so that studying for tests and quizzes will be easier.
- Make sure equations are balanced on both sides.
- Phases will be used in the chemical equations. Make sure you are correctly sketching the location of the substances in the simulation so that you are able to identify the phase of each substance.
- Draw a key when you are sketching. Symbolic keys can help you and others decode your sketches at a later time. Make sure to include ions separately from regular atoms in the key.
- Ions are charged particles that show up with a grey halo in the simulations. Ions make up ionic compounds. Use the periodic table to determine the charge of an ion.

Notes

Homework

Upcoming Quizzes / Tests

Activity 1: Connecting

Millions of reactions occur in the universe. Although many reactions seem unique, chemists created a classification system by comparing similarities. There are five types of reactions.

The first type of reaction is a **combination** or **synthesis reaction**. An example of this is when hydrogen gas and oxygen gas combine to produce water.

$$2H_2\,(g) + O_2\,(g) \rightarrow 2\,H_2O\,(g)$$

1. Based on what "combination" means, predict the product of the following generic reaction. $A + B \rightarrow$ __________

The second type of reaction is a **decomposition reaction**. An example of this is when water undergoes electrolysis, a process that uses electrical current to drive a chemical reaction. During electrolysis, liquid water becomes hydrogen gas and oxygen gas.

$$2\,H_2O\,(l) \rightarrow 2\,H_2\,(g) + O_2\,(g)$$

2. Based on what "decomposition" means, predict the products of the following generic reaction.

$AB \rightarrow$ __________

The third type of reaction is called a **single displacement reaction**. An example of this is when magnesium reacts with hydrochloric acid to form magnesium chloride and hydrogen gas.

$$Mg\,(s) + HCl\,(aq) \rightarrow MgCl_2\,(aq) + H_2\,(g)$$

3. Based on the words "single" and "displacement," predict the products of the following generic reaction.

$AB + C \rightarrow$ __________

The fourth type of reaction is a **double displacement reaction**. An example of this is when two ionic compounds are mixed together such as silver nitrate and lithium chloride yields silver chloride and lithium nitrate.

$$AgNO_3\,(aq) + LiCl\,(aq) \rightarrow AgCl\,(s) + LiNO_3\,(aq)$$

4. Based on the words "double" and "displacement," predict the products of the following generic reaction.

$AB + CD \rightarrow$ __________

The final reaction is a **combustion reaction**. An example of this reaction is when magnesium reacts with oxygen to produce magnesium oxide.

$$2\,Mg\,(s) + O_2\,(g) \rightarrow 2\,MgO\,(s)$$

5. Based on the example of magnesium combusting, predict the products of the following generic reaction. $A + O_2 \rightarrow$ __________

Some combustion reactions, such as the combustion of a *hydrocarbon* like pentane, can produce H_2O.

Activity 2: Defining the Five Chemical Reactions

Complete the chart below as your teacher reviews the types of reactions.

Type of Reaction	Definition	General Equation	Example Reaction
Combination (Synthesis)	Two or more reactants combine to make a single product.		
Decomposition	A single reactant is broken down into two or more products.		
Single Displacement	A single element displaces a second element within a compound.		
Double Displacement	The cations and anions in two reactants are exchanged.		
Combustion	An element or a compound reacts with oxygen.		

Activity 3: Classifying Reactions Demonstration

Based on the submicroscopic interactions of the reactions in Lesson 2, all five basic types of reactions are represented by the simulations. Using the classification system defined in Activity 2, we can categorize the reactions seen in Lesson 2 (**L2A2-3**). Use the sketches and formulas completed starting on page 17 to complete comparisons. If clarification is needed on any of the simulations, watch each simulation again for ***30 seconds*** and then make comparisons. Your teacher will demonstrate how to categorize the first pair of reactions. Next, your small group will complete the remaining comparisons.

Demonstration: *Use Simulation 1,* ***Sets 3 and 5***

Compare sketches and formulas for these reactions.

6. What is similar between the two reactions ***before*** the simulation runs?

____

7. What is similar between the two reactions ***after*** the simulation runs?

____

8. Write balanced chemical equations for these reactions. Include phases in both equations.

Set 3: _________ + _________ → _________ + _________

Set 5: _________ + _________ → _________ + _________

9. What type of reaction are these two reactions? *Provide evidence for your response.*

____

____

Activity 4: Students Classifying Reactions

Complete the next set of exercises with your small group as you did with the teacher.

Part 1: *Use Simulation 1, **Sets 1 and 8***

Compare sketches and formulas for these reactions.

10. What is similar between the two reactions ***before*** the simulation runs?

____

11. What is similar between the two reactions ***after*** the simulation runs?

____

12. Write balanced chemical equations for these reactions. Include states of matter in both equations.

Set 1: __________ + __________ → __________

Set 8: __________ + __________ → __________

13. What type of reaction are these two reactions? *Provide evidence for your response.*

____

____

Part 2: *Use Simulation 1, **Sets 4 and 6***

Compare sketches and formulas for these reactions.

14. What is similar between the two reactions ***before*** the simulation runs?

____

15. What is similar between the two reactions ***after*** the simulation runs?

____

16. Write balanced chemical equations for these reactions. Include phases in both equations.

Set 4: __________ + __________ → __________ + __________

Set 6: __________ + __________ → __________ + __________

17. What type of reaction are these two reactions? *Provide evidence for your response.*

____

____

Part 3 *Use Simulation 1,* ***Sets 2 and 9***

Compare sketches and formulas for these reactions.

18. What is similar between the two reactions ***before*** the simulation runs?

____

19. What is similar between the two reactions ***after*** the simulation runs?

____

20. Write balanced chemical equations for these reactions. Include phases in both equations.

Set 2: __________ → __________ + __________

Set 9: __________ → __________ + __________

21. What type of reaction are these two reactions? *Provide evidence for your response.*

____

____

Part 4: *Use Simulation 1,* ***Sets 7 and 10***

Compare sketches and formulas for these reactions.

22. What is similar between the two reactions ***before*** the simulation runs?

____

23. What is similar between the two reactions ***after*** the simulation runs?

____

24. Write balanced chemical equations for these reactions. Include phases in both equations.

Set 7: _________ + _________ → _________ + _________

Set 10: _________ + _________ → _________ + _________

25. What type of reaction are these two reactions? *Provide evidence for your response.*

____

____

Lesson Reflection Question

26. How did you determine the states of matter of each substance from the simulation?

____

____

____

Connected Chemistry

Reactions Unit

Lesson 5: Limiting Reactants

Student's Lesson at a Glance

Lesson Summary

This lesson contains four activities designed to help students better understand limiting reactants. Following a teacher demonstration on the technology and procedures, students use simulations to create submicroscopic sketches, balance equations, and identify limiting reactants with supporting evidence. The final activity guides students through the process of balancing, conversions, and identifying the limiting reactants using written steps and graphs from the simulations. Students use static screen shots to complete limiting reactant problems as independent practice.

SWBAT (Student will be able to)

- Understand what limiting reactants are and how they influence a chemical reaction
- Understand how to calculate the limiting and excess reactants

Essential Vocabulary

Keep a list of all important words from this lesson. This list, in addition to the lists from other lessons, will make studying easier and improve scientific communication skills. The essential vocabulary from the unit is in bold. Additional words that will expand your scientific vocabulary are in italics.

CCC Reminder

- Show all your work on calculations. Label all numbers. These steps will make checking work easier.
- Use the vocabulary section and note section to take good notesso that studying for tests and quizzes will be easier.
- Supporting claims with evidence is not only a skill that scientists use, but a skill that will help you in other classes and everyday life.
- Sketches have been provided from simulations. Use the sketches as you would your own drawings.
- Make sure you understand how to convert mass to moles as well as calculate molar mass.
- Ions are charged particles that show up with a grey halo in the simulations. Ions make up ionic compounds. Use the periodic table to determine the charge of an ion.

Notes

Homework

Upcoming Quizzes / Tests

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Please turn to the next page.

Activity 1: Connecting

A teenager is babysitting for a child in the family. To keep the young child occupied, the teenager pulls out Legos® to help the child build cars. In the bucket of Legos there are 13 axles and 7 bodies.

1. Each car needs two axels and one body for the car to function. How many complete cars can the child build?

2. What part of the car has "limited" the child's ability to make more functional cars? How did you make your choice?

3. A group of friends come home after school and want a snack. They have 3 chocolate bars, 5 marshmallows, and 12 graham crackers. A complete snack contains: 1 marshmallow, half of a chocolate bar, and 2 graham crackers. How many complete snacks can this group of friends make?

4. What ingredient "limited" the friends' ability to make more complete snacks? How did you make your choice?

Chemical reactions are similar to the above situations. Reactions often contain reactants that limit how much products can be produced. These reactants are called **limiting reactants.** Recall the simulation that modeled the synthesis of sodium chlorine from Lesson 2. One chlorine molecule collided with two atoms of solid sodium to form one formula unit of sodium chloride. In the simulation, there were three molecules of chlorine gas left without any sodium atoms to have a collision. The sodium was the limiting reactant in this scenario.

Reactants that do not limit the reaction and are still present when the reaction is complete are called **excess reactants**. In the example described above, the chlorine is an excess reactant. When one of the reactants has formed the compound before the others, no more products can be formed. If you were to add more sodium to the simulation, the remaining chlorines would be able to react to form sodium chloride.

For example, adding vinegar to baking soda will yield a chemical reaction. If a small amount of baking soda is added to a large amount of vinegar, the reaction happens until the small amount of baking soda is completely consumed, and some vinegar will be left over. Baking soda is the limiting reactant because if more baking soda is added the reaction continues. The limiting reactant in this reaction can be identified macroscopically. The reaction on a macroscopic level is similar to how you identified what limited the Legos® and the snacks. Scientists also use mathematical calculations using experimental data to more accurately predict not only what substance is the limiting reactant, but also the amount of product that will form based on the amount of limiting reactant available. These calculations are central to **stoichiometry**, which involves the analysis of the relative quantities of substances involved in a chemical reaction.

Activity 2: Limiting and Excess Reactants Demonstration

Part 1

The **limiting reactant** is the reactant in a chemical reaction that limits the amount of product that can be formed. The reaction will stop when all of the limiting reactant is consumed. The **excess reactant** is the reactant in a chemical reaction that remains when a reaction stops after the limiting reactant is completely consumed. The excess reactant remains because there is nothing with which it can react. If there is only a limited amount of one reactant available for a reaction, the reaction will stop when that reactant is consumed whether or not the other reactant has been used up.

5. Using pictures of the reactants and products from the submicroscopic simulation, how could the limiting reactant and the excess reactant be identified after the reaction has occurred?

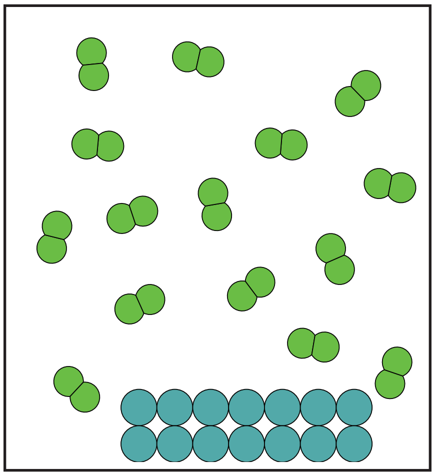
6. How do you represent excess reactants in a chemical equation?

7. Using the graphs for the reactions, how could the limiting reactant and excess reactant be identified after the reaction?

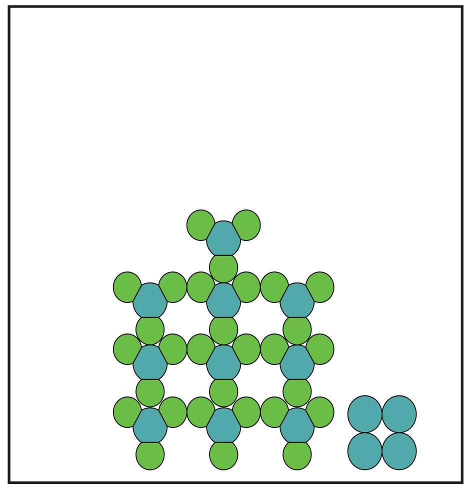
Part 2

Follow your teacher's demonstration to use the following pictures to label the limiting reactant and excess reactants in the submicroscopic picture, determine the reaction type, and indicate the reactants and products in the space provided. Also indicate the states of matter for each reactant and product.

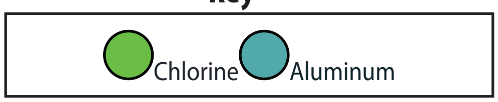
Picture of reaction at submicroscopic level; Before (at time 0 seconds)

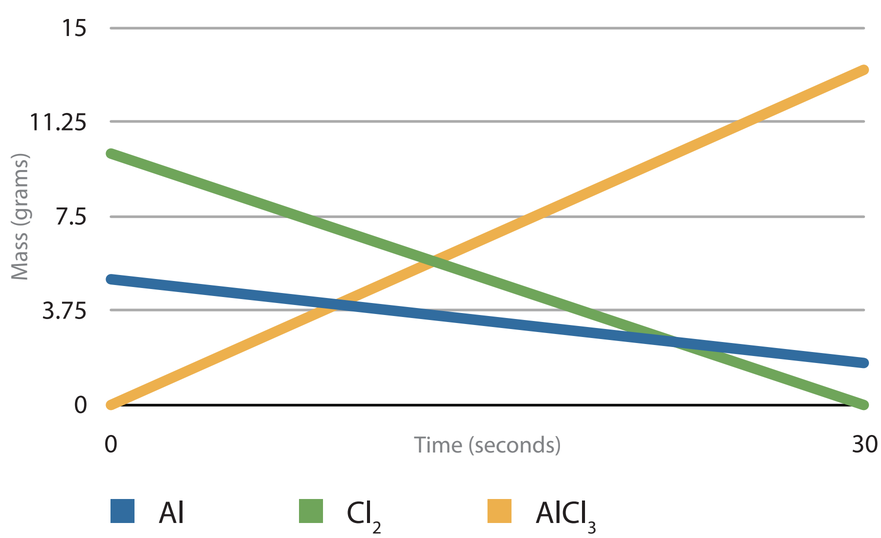


Picture of reaction at submicroscopic level; After (at time 30 seconds)



Key





Limiting Reactant	Excess Reactant	Products	Reaction Type

8. Write out the balanced chemical equation using the screen shots. Remember to include the phases of the reactants and products.

---

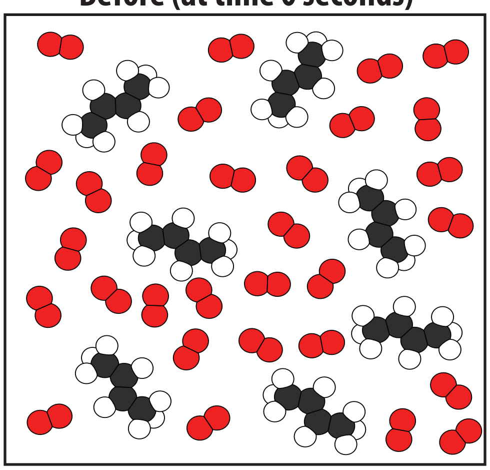
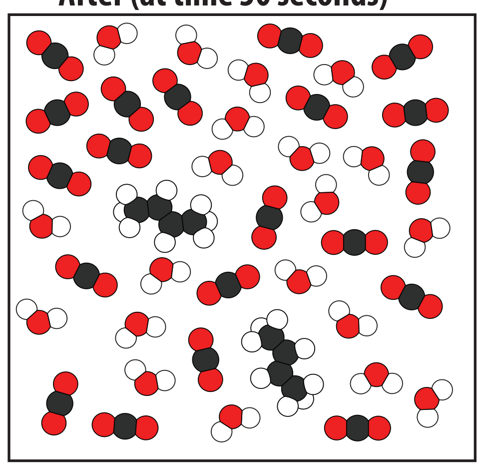
9. What is the limiting reactant for the reaction? *Support your claim with evidence using your sketches.*

---

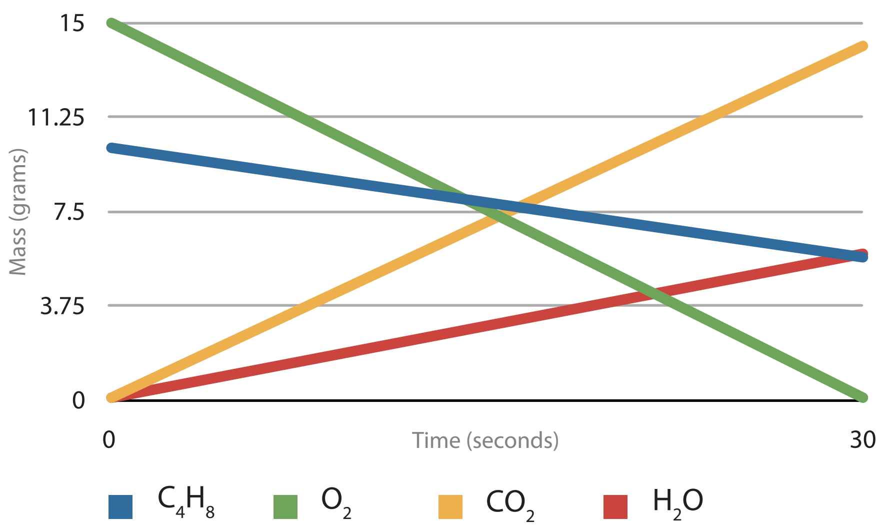
10. Identify one additional piece of evidence from the information provided that would support your answer for the limiting reactant.

Lesson Reflection Questions

Follow your teacher's demonstration to use the following pictures to label the limiting reactant and excess reactants in the submicroscopic picture, determine the reaction type, and indicate the reactants and products in the space provided. Also indicate the states of matter for each reactant and product.

Picture of reaction at submicroscopic level; Before (at time 0 seconds)	Picture of reaction at submicroscopic level; After (at time 30 seconds)
	

Key



Limiting Reactant	Excess Reactant	Products	Reaction Type

11. Write out the balanced chemical equation using the screen shots. Remember to include the phases of the reactants and products.

____

12. What is the limiting reactant for the reaction? Support your claim with evidence using your sketches.

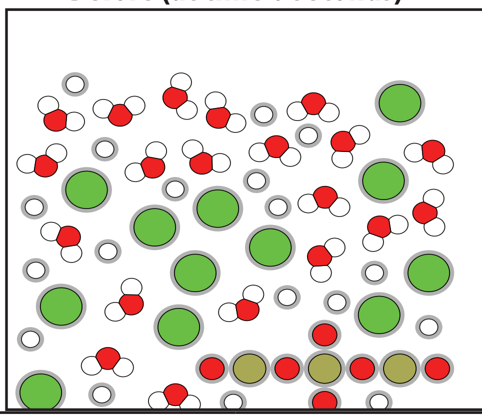
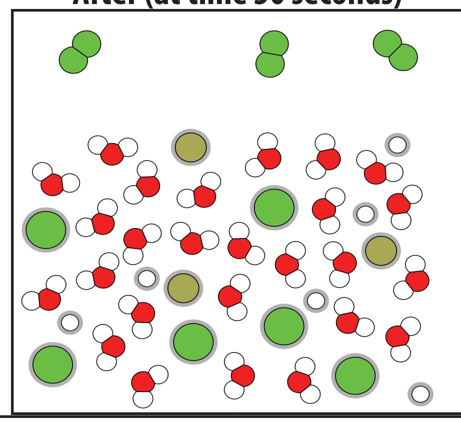
____

13. Identify one additional piece of evidence from the information provided that would support your answer for the limiting reactant.

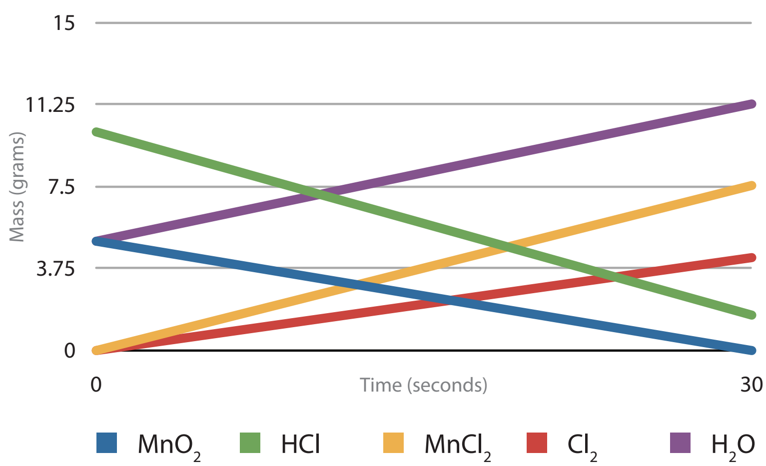
____

Part 3

Follow your teacher's demonstration to use the following pictures to label the limiting reactant and excess reactants in the submicroscopic picture, determine the reaction type, and indicate the reactants and products in the space provided. Also indicate the states of matter for each reactant and product.

Picture of reaction at submicroscopic level; Before (at time 0 seconds)	Picture of reaction at submicroscopic level; After (at time 30 seconds)
	

Key



Limiting Reactant	Excess Reactant	Products	Reaction Type

14. Write out the balanced chemical equation using the screen shots. Remember to include the phases of the reactants and products.

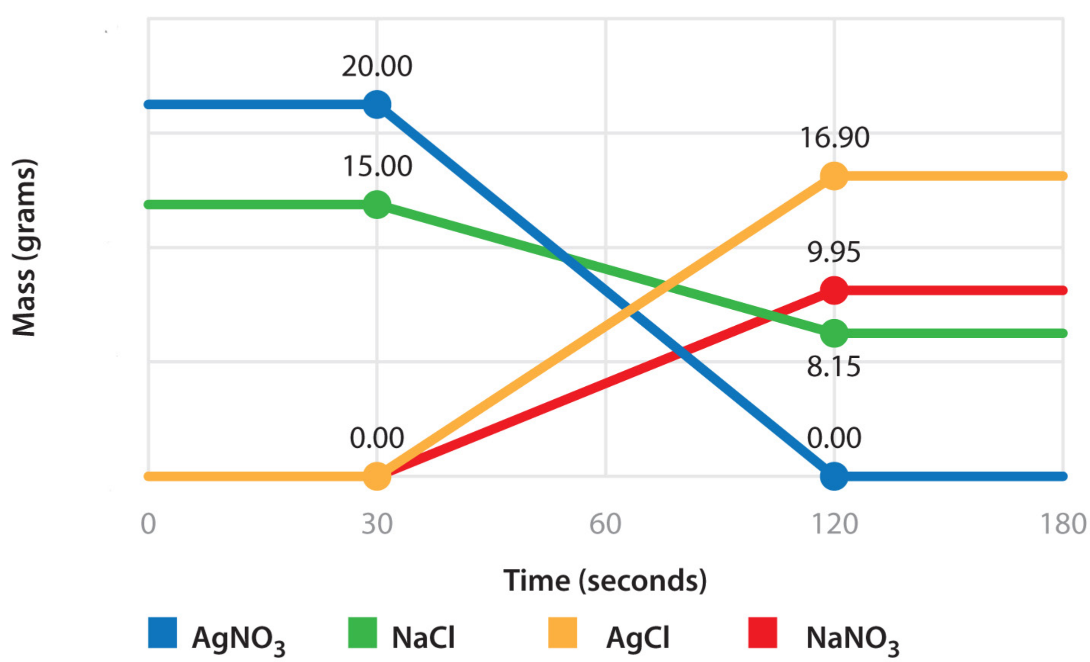
15. What is the limiting reactant for the reaction? Support your claim with evidence using your sketches.

16. Identify one additional piece of evidence from the information provided that would support your answer for the limiting reactant.

Activity 3: Calculating Limiting and Excess Reactants

Part 1

Use the graph below to answer the following questions.



17. What are the reactants in this reaction?

18. How much of each reactant did you start with?

19. How much of the limiting reactant is left?

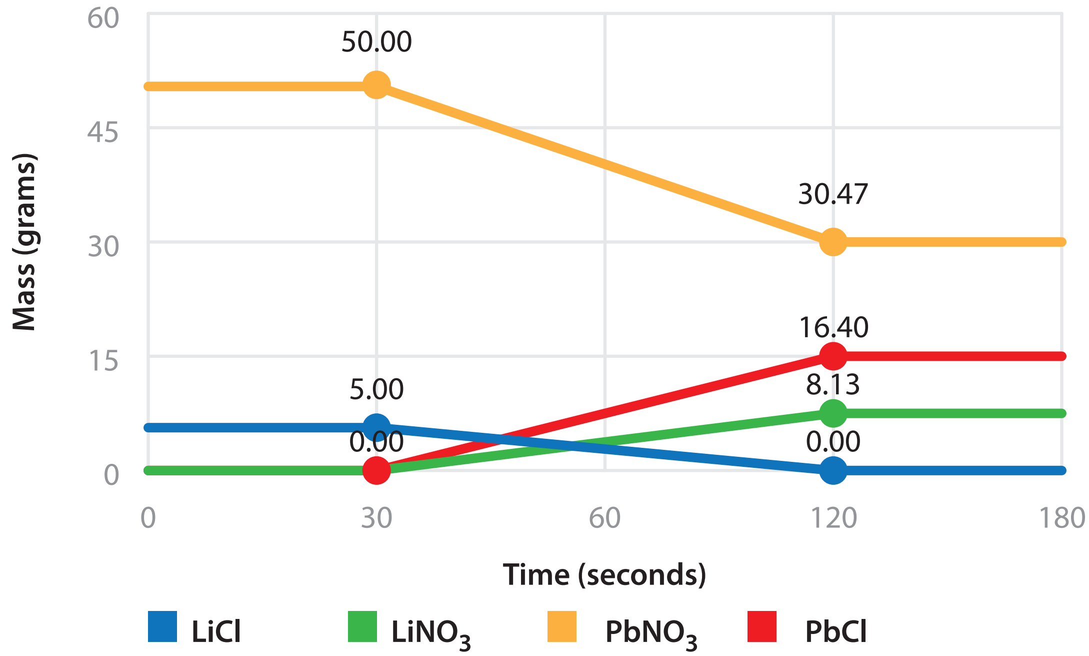
20. How much of the excess reactant is left?

21. What are the products?

22. How much of each of the products was formed?

23. Was mass conserved in the reaction? *Support your claim with evidence.*

Part 2: *Use the graph to answer the following questions.*



24. What are the reactants?

25. How much of each reactant did you start with?

26. How much of the limiting reactant is left?

27. How much of the excess reactant is left?

28. What are the products?

29. How much of each of the products was formed?

30. Was mass conserved in the reaction? *Support your claim with evidence.*

Part 3

Using the equations from the static pictures in Activity 2 -3 (starting on page 49), answer the following questions. For an example of how to calculate limiting and excess reactant look in Student Appendix A in the back of the book.

Note that the limiting reactant may be different than it was in the pictures.

31. If 6 grams of Al is reacted with 10 grams of Cl_2, what is the limiting reactant and how much $AlCl_3$ is produced?

$$2\ Al\ (s) + 3\ Cl_2\ (g) \rightarrow 2\ AlCl_3\ (s)$$

32. If 11g C_4H_8 is reacted with 25g O_2, what is the limiting reactant and how much CO_2 is formed?

$$C_4H_8\,(g) + 6\,O_2\,(g) \rightarrow 4\,CO_2\,(g) + 4\,H_2O\,(g)$$

33. If 2.7 g of MnO_2 is reacted with 2.7 g HCl, what is the limiting reactant and how much Cl_2 is formed?

Note: The unbalanced equation from Activity 2, Part 3, Question 14 (page 54) is:

$$MnO_2\,(s) + HCl\,(aq) \rightarrow MnCl_2\,(aq) + H_2O\,(l) + Cl_2\,(g)$$

Connected Chemistry
Reactions Unit
Lesson 6: Solvation and Precipitation

Student's Lesson at a Glance

Lesson Summary

This lesson contains seven activities, one of which is a wet lab to help students better understand precipitation reactions. Students connect the lesson to real-world examples through a reading that explains how gold is recovered through a series of precipitation reactions. Students are shown static screen shots of an undefined reaction and asked to determine if a chemical reaction occurred. Following the wet lab and a teacher demonstration of the technology and procedures, students will use the simulations to replicate the mixtures created in lab. From the simulations, students create submicroscopic sketches, determine if a chemical reaction occurred, and figure out if a precipitate was formed. The final activity introduces students to net ionic equations. Following a teacher demonstration, students will use static pictures of the simulations to create net ionic equations.

SWBAT (Student will be able to)

- Know that double displacement reactions can produce precipitates
- Know that a precipitate is a insoluble product that results from a chemical reaction
- Know that spectator ions are ionic compounds or ionic elements that remain in solution and do not participate in single displacement or double displacement reactions
- Use submicroscopic chemical representations and chemical symbols to represent chemical reactions observed macroscopically in the laboratory

Essential Vocabulary

Keep a list of all important words from this lesson. This list, in addition to the lists from other lessons, will make studying easier and improve scientific communication skills. The essential vocabulary from the unit is in bold. Additional words that will expand your scientific vocabulary are in italics.

CCC Reminder

- Recall some reactions occur in water; this includes precipitation reactions. An aqueous solution is denoted by the abbreviation *(aq)* following the name of a chemical species in a reaction. Water acts as the medium for the reaction to occur, but is not included in the chemical formula.
- Use the vocabulary section and note section to take good notes so that studying for tests and quizzes will be easier.
- Supporting claims with evidence is not only a skill that scientists use, but a skill that will help you in other classes and everyday life.
- Draw a key when you are sketching. Symbolic keys can help you and others decode your sketches at a later time. Include ions separately from non charges atoms when creating the key.
- Ions are charged particles that show up with a grey halo in the simulations. Ions make up ionic compounds. Ions are formed when the dissociate in a solution. Use the periodic table to determine the charge of an ion.

Notes

Homework

Upcoming Quizzes / Tests

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Activity 1: Connecting

When two solutions mix, sometimes a precipitate can form. A **precipitate** is a solid that forms in a solution during a single replacement or double displacement reaction. The solid that is formed is a new substance. However, not all solutions will generate precipitates.

Companies use many precipitation reactions to remove impurities. For example, gold is refined using precipitation reactions. Gold is among one of the most valuable metals on the planet. It has been valued by humans for thousands of years. This precious metal has been used in jewelry, coins, electronics, and in components for space shuttles. The process of retrieving the precious metal is much more complex and dangerous then just digging in the ground or panning streams to find gold nuggets. Some gold is trapped in quartz, a type of mineral, under the Earth's crust. Miners dig the quartz out, crush it, then separate the gold from contaminants using heavy machinery and water.

This process produces pure gold and gold sulfides. Further processing yields about 60% pure gold, but some gold is still left as the compound gold sulfide. The miners utilize solubility and precipitation to make sure they get the full monetary benefit. The gold sulfides are ground to a fine powder and dissolved in a solution of cyanide. The gold sulfide dissociates to form an *aqueous solution* with the cyanide. To recover the gold, zinc dust is sprinkled on the solution, causing a chemical reaction that makes the gold precipitate from the solution.

Part 1

1. Can the gold that is directly retrieved out of a mine be classified as a chemically "pure substance"? *Support your claim with evidence.*

2. Early during the processing, pure gold and gold sulfides sink to the bottom of a container full of water. Is this considered a precipitation reaction? *Support your claim with evidence.*

3. What do you think aqueous means?

The chemical equation that represents how gold is removed from the solution is:

$$2\ Au(CN)_2^-\ (aq) + Zn\ (s) \rightarrow 2\ Au\ (s) + Zn(CN)_4^{2-}\ (aq)$$

4. Classify the above reaction. *Circle one and explain your answer.*

Combination **Decomposition** **Single Displacement**

Double Displacement **Combustion**

Part 2

Gold jewelry is not pure gold; instead the jewelry is a mixture of different metals. The purity of gold in the jewelry is indicated by its *karat number.* For instance, 24K gold is is 99.7% gold and the most valuable. In comparison, 10K is only 41.7% gold.

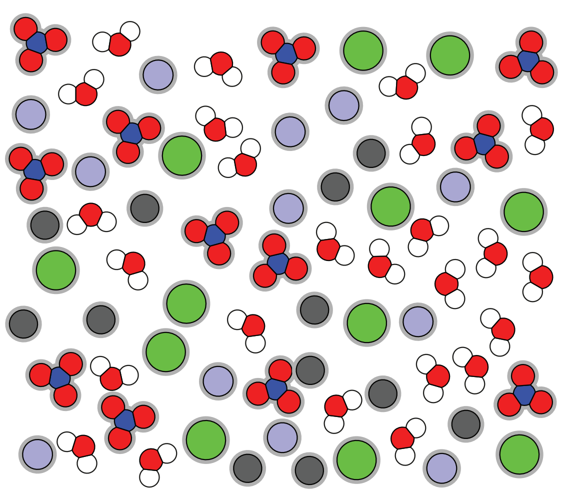
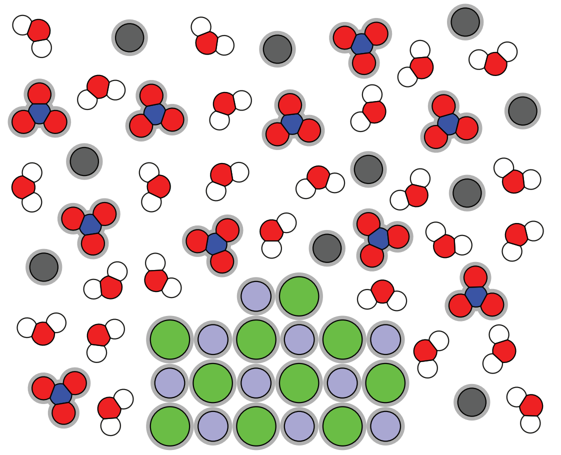
5. Why would mining companies need scientists who understand solubility and precipitation reactions to process the remaining 40% of material after the first stage of mining?

6. What would happen to price of gold if companies settled for retrieving only 60% of what was available in the mined material?

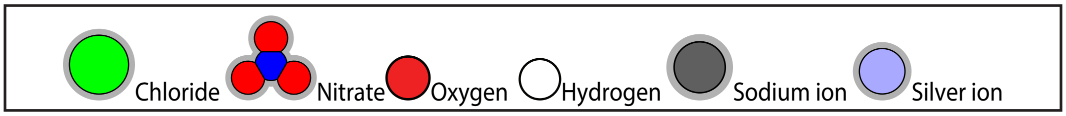
7. Gold mining requires the use of toxic substances which may be made into solutions to help purify gold. What is the potential environmental impact of mining companies who use the procedure described in the paragraph above?

Activity 2: Questions to Think About

Use the pictures below to answer the questions.

Picture of reaction at submicroscopic level; Before (at time 0 seconds)	Picture of reaction at submicroscopic level; After (at time 30 seconds)
	

Key



8. The reactants for the reaction are $AgNO_3$ (aq) and NaCl (aq). Why would it be difficult to identify the starting reactants from the pictures alone?

9. What are the products in the after picture?

10. Did a reaction occur between the before and after pictures? *Support your claim with evidence.*

11. Write out the chemical equation, including phases, that represents the reaction in the picture.

12. In the "after" simulation a precipitate was formed. Identify which product was a precipitate, the state of matter of the precipitate, and what type of reaction occurred.

Activity 3: Precipitation Wet Lab

This lab will help develop a better understanding of how ionic compounds in aqueous solutions can undergo chemical reactions and form precipitates when they are mixed together. Use the laboratory instructions provided by your teacher.

Key P = Precipitate formed

NP = No Precipitate formed

Use lab results to complete the data table below.

	KBr	$AgNO_3$	NH_4Cl	Na_2CO_3	NaOH
$LiNO_3$					
KBr					
$AgNO_3$					
NH_4Cl					
Na_2CO_3					

Activity 4: Generating Net Ionic Equations

Part 1: *Read the following introduction as a class.*

As you've seen in the simulations, ionic compounds are involved in some reactions. Remember that ionic compounds dissociate to form an aqueous solution when placed in water. If an ion is directly involved in the chemical reaction, the ions are always indicated on both sides of the chemical equation. However, if an ion is not directly involved in the reaction, it is called a **spectator ion**. That is, the ion stays in solution and is not part of the precipitate.

Scientists acknowledge all the ions present in a chemical reaction by creating a **complete ionic equation**. This involves writing down all of the aqueous substances as their dissociated ions and keeps all solids, liquids and gases unchanged. Sometimes scientists use a simplified version of the complete ionic equation to emphasize only the ions that participate directly in the chemical reaction. This is called a **net ionic equation**. All spectator ions are removed from the equation and all that remains are the ions that are involved directly in the reaction.

Net ionic equations help scientists understand what is happening during a chemical reaction. You can use a net ionic equation to determine whether a reaction has occurred or not. For example, if you add two aqueous ionic compounds together and a precipitate has not formed, then a reaction has not occurred because all of the ions were spectator ions. You can also use a net ionic equation to determine the identity of a precipitate in the simulations.

Generating Net Ionic Equations is a Three Step Process

Recall the chemical equation (double displacement reaction) for the formation of barium sulfate, a substance used in X-Rays.

$$BaCl_2\,(aq) + Na_2SO_4\,(aq) \rightarrow 2\,NaCl\,(aq) + BaSO_4\,(s)$$

1. Write the complete ionic equation.

To write a complete ionic equation, rewrite all aqueous substances as their dissociated ions and keep all solid, liquid, and gaseous substances unchanged. You may need to use your periodic table to determine the appropriate charge on the ions.

$$Ba^{2+}\,(aq) + 2\,Cl^-\,(aq) + 2\,Na^+\,(aq) + SO_4^{2-}\,(aq) \rightarrow 2\,Na^+\,(aq) + 2\,Cl^-\,(aq) + BaSO_4\,(s)$$

2. Identify and remove the spectator ions.

Spectator ions are all ions and ionic compounds in the reaction that are identical on both the reactant and product side of the reaction. When you have identified, the spectator ions, remove them from the equation. Remember, water molecules that are present are not included in the equation because water is the solvent.

$$Ba^{2+}\,(aq) + \cancel{2\,Cl\text{-}\,(aq)} + \cancel{2\,Na\text{+}\,(aq)} + SO_4^{2-}(aq) \rightarrow \cancel{2\,Na\text{+}\,(aq)} + \cancel{2\,Cl\text{-}\,(aq)} + BaSO_4\,(s)$$

3. Write out net ionic equation.

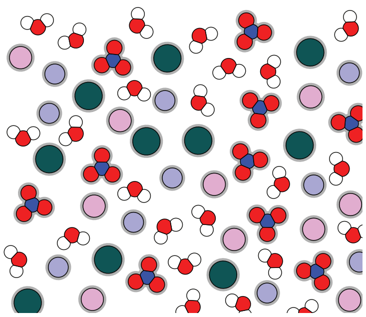
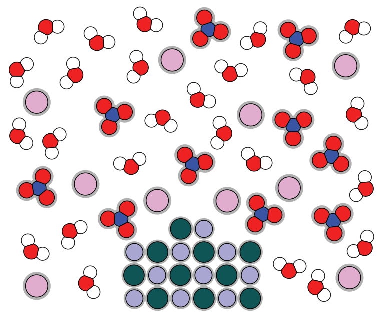
Write the net ionic equation by rewriting the reaction equation, including only those reactants and products directly involved in the reaction. Notice that a the final product is a solid; this solid is called the precipitate.

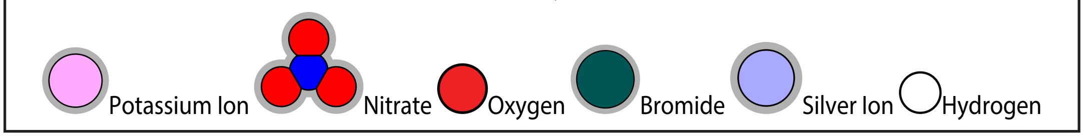
$$Ba^{+2}\,(aq) + SO_4^{-2}\,(aq) \rightarrow BaSO_4\,(s)$$

Always check to see that your net ionic equation is balanced.

Part 2 - Demonstration

With your teacher, you will look at static shots of the reaction provided and create a balanced net ionic equation for the reaction.

Picture of reaction at submicroscopic level; Before (at time 0 seconds)	Picture of reaction at submicroscopic level; After (at time 30 seconds)
	
Key	



1. Write the net ionic equation.

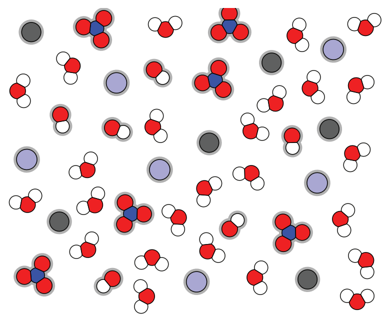
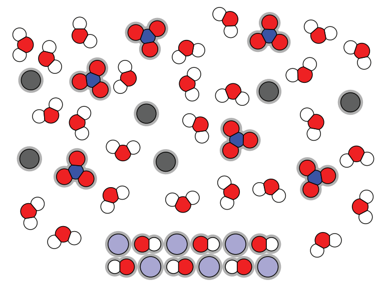
2. What are the spectator ions in this reaction? *Support your claim with evidence.*

3. Which ions precipitated out, if any? *Support your claim with evidence.*

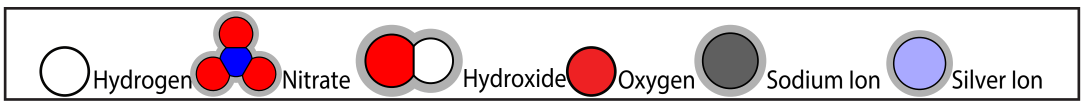
4. Is water a spectator ion? *Please explain.*

Activity 5: Generating Net Ionic Equations

Using the reaction provided in this activity, create a balanced net ionic equation for the reaction.

Picture of reaction at submicroscopic level; Before (at time 0 seconds)	Picture of reaction at submicroscopic level; After (at time 30 seconds)
	

Key



5. Write the net ionic equation.

6. What are the spectator ions in this reaction? *Support your claim with evidence.*

7. Which ions precipitated out, if any? *Support your claim with evidence.*

8. Is water a spectator ion? *Please explain.*

Activity 6: Lab Demonstration

In this simulation activity, your teacher will first demonstrate how to mix two different ionic compounds together in water. You will observe how these ionic compounds interact submicroscopically. You will complete the remaining simulations in small groups independently. If you completed the wet lab, these simulations will allow you to see the reactions submicroscopically. As you combine different compounds, select substances that have different cations and anions. For example, do not mix $AgNO_3$ with $LiNO_3$ because they both contain the NO_3^- anion.

Demonstration 1: *Use Simulation 2,* ***Set 1***

$$AgNO_3\ (aq) + KBr\ (aq) \rightarrow ?$$

9. Predict the products in the above reaction.

____

10. After you complete the simulation, did you observe a reaction occurring? *Support your claim with evidence.* **Yes** **No**

____

____

11. Did a precipitate form? **Yes** **No**

12. How are you able to tell whether a precipitate formed or not?

____

13. If a precipitate formed, what was it?

Sketch reaction at submicroscopic level, Before (at time 0 seconds)		Sketch of reaction at submicroscopic level; After (at time 30 seconds)
Key		
Complete Ionic Equation Before	→	Complete Ionic Equation After
Net Ionic Equation		
Observations		

Demonstration 2: *Use Simulation 2,* ***Set 1***

$$LiNO_3\,(aq) + KBr\,(aq) \rightarrow ?$$

14. Predict the products in the above reaction.

15. After you complete the simulation, did you observe a reaction occurring? *Support your claim with evidence.* **Yes** **No**

16. Did a precipitate form? **Yes** **No**

17. How are you able to tell whether a precipitate formed or not?

18. If a precipitate formed, what was it?

<table>
<tr><td colspan="2">Sketch reaction at submicroscopic level,
Before (at time 0 seconds)</td><td colspan="2">Sketch of reaction at submicroscopic level;
After (at time 30 seconds)</td></tr>
<tr><td colspan="4">Key</td></tr>
<tr><td>complete ionic equation before</td><td colspan="2">→</td><td>complete ionic equation after</td></tr>
<tr><td colspan="4">Net Ionic Equation</td></tr>
<tr><td colspan="4">Observations</td></tr>
</table>

Activity 7: Lab Simulation

Following your teacher's instruction, create three different mixtures using the simulation and record your observations about each below.

Part 1: *Use Simulation 2,* ***Set 1***

<table>
<tr><th colspan="3">Sketch reaction at submicroscopic level, Before (at time 0 seconds)</th><th colspan="2">Sketch of reaction at submicroscopic level; After (at time 30 seconds)</th></tr>
<tr><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td colspan="5">Key</td></tr>
<tr><td colspan="2">Total ionic equation before</td><td>→</td><td colspan="2">Total ionic equation after</td></tr>
<tr><td colspan="5">Net Ionic Equation</td></tr>
<tr><td colspan="5">Observations</td></tr>
</table>

19. Did a reaction occur? *Support your claim with evidence.*

Yes **No**

20. Did a precipitate form? **Yes** **No**

21. How are you able to tell whether a precipitate formed or not?

22. If a precipitate formed, what was it?

Part 2: *Use Simulation 2,* ***Set 1***

Sketch reaction at submicroscopic level, Before (at time 0 seconds)		Sketch of reaction at submicroscopic level; After (at time 30 seconds)
Key		
complete ionic equation before	→	**complete ionic equation after**
Net Ionic Equation		
Observations		

23. Did a reaction occur? *Support your claim with evidence.*

Yes **No**

24. Did a precipitate form? **Yes** **No**

25. How are you able to tell whether a precipitate formed or not?

26. If a precipitate formed, what was it?

Part 3: *Use Simulation 2, **Set 1***

<table>
<tr><td colspan="2">Sketch reaction at submicroscopic level,
Before (at time 0 seconds)</td><td colspan="2">Sketch of reaction at submicroscopic level;
After (at time 30 seconds)</td></tr>
<tr><td colspan="4">Key</td></tr>
<tr><td>complete ionic equation before</td><td colspan="2">→</td><td>complete ionic equation after</td></tr>
<tr><td colspan="4">Net Ionic Equation</td></tr>
<tr><td colspan="4">Observations</td></tr>
</table>

27. Did a reaction occur? *Support your claim with evidence.*

Yes **No**

28. Did a precipitate form? **Yes** **No**

29. How are you able to tell whether a precipitate formed or not?

30. If a precipitate formed, what was it?

Lesson Reflection Questions

31. Given the following complete ionic equation, explain what you think would remain in the beaker if the water were evaporated. *Explain your reasoning.*

Li+(aq) + NO3- (aq) + K+(aq) +Br-(aq) → Li+(aq) + NO3- (aq) + K+(aq) +Br-(aq)

32. Which reaction type do you think is represented in the precipitation simulations? *Support your claim with evidence.*

Activity 8: Capstone

Use what you have learned to interpret the information, draw a submicroscopic picture of the reaction at time at 0 seconds and 30 seconds that communicates the Law of Conservation of Mass, balance the equation, write a complete ionic equation if appropriate, write a net ionic equation, determine the reaction type, determine the states of matter for the products, and answer the question provided.

$$AgNO_3\,(aq) + K_2CrO_4\,(aq) \rightarrow Ag_2CrO_4\,(?) + KNO_3\,(?)$$

Ion	Solubility in water	Exceptions
Nitrates	Soluble	None
Ammonium compounds	Soluble	None
Group I compounds	Soluble	None
Halides	Soluble	Ag+, Cu+, Pb2+ , Hg22+
Sulfates	Soluble	Ag+, Pb2+, Ba2+, Sr2+, Ca2+
Carbonates	Insoluble	Group I and ammonium compounds
Phosphates	Insoluble	Group I and ammonium compounds
Sulfites	Insoluble	Group I and ammonium compounds
Sulfides	Insoluble	Group I, Group II, and ammonium compounds
Hydroxides	Insoluble	Group I and ammonium compounds, Ba2+, Sr2+, Ti+
Chromates	Insoluble	Group I and ammonium compounds

<table>
<tr><td colspan="2">Sketch reaction at submicroscopic level time = 0 seconds</td><td colspan="2">Sketch of reaction at submicroscopic level time = 30 seconds)</td></tr>
<tr><td colspan="4">Key</td></tr>
<tr><td>complete ionic equation before</td><td colspan="2">→</td><td>complete ionic equation after</td></tr>
<tr><td colspan="2">Net Ionic Equation</td><td colspan="2">Reaction Type</td></tr>
</table>

33. Is this a homogenous or a heterogenous mixture? *Explain your answer.*

Example

1. 10 grams of aluminum burns with 10 grams of oxygen. How much aluminum oxide is formed?

   Calculating the limiting reactant and the amount of product that is formed based on the limiting reactant.

   $$Al\ (s) + O_2\ (g) \rightarrow Al_2O_3\ (s)$$

2. Balance the equation.

   If the equation is not balanced, the math will be wrong later.

   $$4\ Al\ (s) + 3\ O_2\ (g) \rightarrow 2\ Al_2O_3\ (s)$$

3. Convert grams of reactants from the problem into moles.

   $$\text{Molar mass of Al} = 26.98\ \text{g/mol of Al}$$

   $$\text{Molar mass of } O_2 = 15.99\ \text{g/mol} \times 2\ \text{atoms of oxygen} = 31.99\ \text{g/mol of } O_2$$

   $$10\ \text{g Al} \times (1\ \text{mol Al}/\ 26.98\ \text{g Al}) = 0.37\ \text{mol Al}$$

   $$10\ \text{g } O_2 \times (1\ \text{mol } O_2/\ 31.99\ \text{g } O_2) = 0.31\ \text{mol } O_2$$

4. Remember that the coefficient on the substance indicates how many moles are present of that substance in the reaction. Determine how many moles of product each of the reactants can produce. To do this, multiply moles of each of the reactants by the ratio of product to reactant. This allows for the cancellation of units, which is moles of reactant, leaving moles of product. This is where a correctly balanced equation is important.

   $$0.37\ \text{mol Al} \times (2\ \text{mol of } Al_2O_3\ /\ 4\ \text{mol of Al}) = 0.185\ \text{mol } Al_2O_3$$

   $$0.31\ \text{mol } O_2 \times (2\ \text{mol of } Al_2O_3\ /\ 3\ \text{mol of } O_2) = 0.207\ \text{mol of } Al_2O_3$$

5. Identify the limiting reactant by comparing the values of product from the previous step. The reactant that yields less product limits the reaction.

0.185 moles of Al_2O_3 is less than 0.207 moles of Al_2O_3. Aluminum is the limiting reactant because 10 grams of Al produces less Al_2O_3 than 10 grams of O_2.

6. Convert moles to grams to determine how much product is produced based on the amount of limiting reactant available.

$$\text{Molar mass of } Al_2O_3 = (2 \text{ atoms of Al} \times 26.98 \text{ g/mol}) + (3 \text{ atoms of } O_2 \times 15.99 \text{ g/mol})$$
$$= 101.96 \text{ g/mol}$$

$$0.185 \text{ mol } Al_2O_3 \times 101.96 \text{ g/mol} = 31.61 \text{ g } Al_2O_3$$

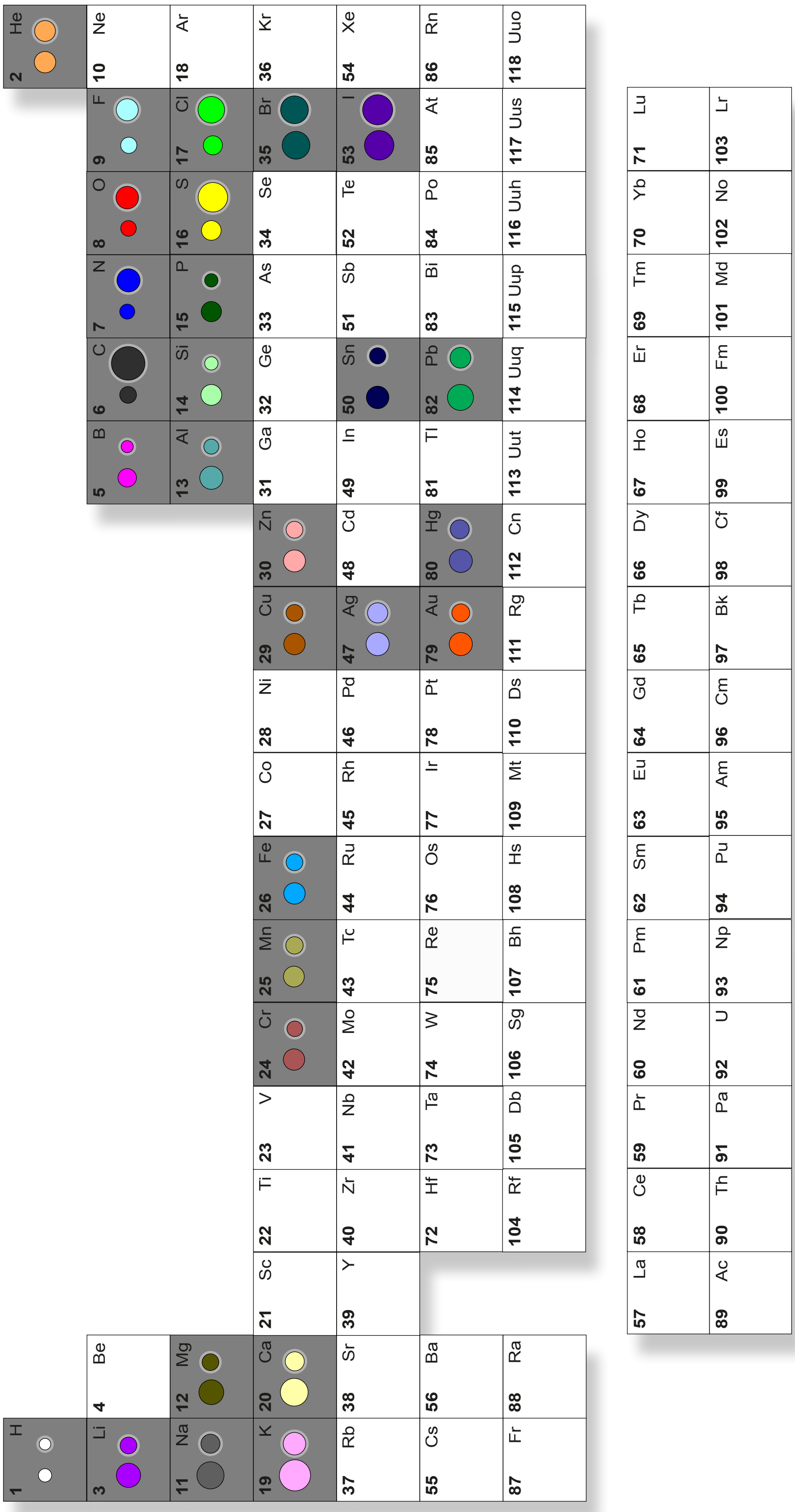
7. Since one of the reactants was available in a limited amount (aluminum in our example), there may be some of the other reactant left over. To find the amount of excess reactant, determine how much of the non-limiting reactant (oxygen) actually did react with the limiting reactant (aluminum).

$$10 \text{ g Al} \times (1 \text{ mol Al}/ 26.98 \text{ g Al}) \times (3 \text{ mol } O_2/ 4 \text{ mol Al}) \times (31.99 \text{ g } O_2/ 1 \text{ mol } O_2) =$$

$$8.89 \text{ g } O_2 \text{ reacted}$$

$$10 \text{ g } O_2 \text{ (initial)} - 8.89 \text{ g } O_2 \text{ (reacted)} = 1.11 \text{ g excess } O_2$$

Elements Used in the Connected Chemistry Curriculum



Name	Symbol	Atomic Number	Atomic Weight
Hydrogen	H	1	1.00794
Helium	He	2	4.00260
Lithium	Li	3	6.941
Boron	B	5	10.811
Carbon	C	6	12.0107
Nitrogen	N	7	14.0067
Oxygen	O	8	15.9994
Fluorine	F	9	18.9984
Sodium	Na	11	22.9898
Magnesium	Mg	12	24.3050
Aluminum	Al	13	26.9815
Silicon	Si	14	28.0855
Phosphorus	P	15	30.9738
Sulfur	S	16	32.065
Chlorine	Cl	17	35.453
Potassium	K	19	39.0983
Calcium	Ca	20	40.078
Chromium	Cr	24	51.9961
Manganese	Mn	25	54.9380
Iron	Fe	26	55.845
Copper	Cu	29	63.54
Zinc	Zn	30	65.38
Bromine	Br	35	79.904
Silver	Ag	47	107.8682
Tin	Sn	50	118.710
Iodine	I	53	126.904
Gold	Au	79	196.967
Mercury	Hg	80	200.59
Lead	Pb	82	207.2