Physical Science
Unit 6

Chemical Reactions

Reaction Demonstrations

1. Written Word Equation:

Magnesium + Hydrochloric Acid → Magnesium chloride + Hydrogen

Observations:

Type of Reaction:

2. Written Word Equation:

Magnesium + Oxygen → Magnesium oxide

Observations:

Type of Reaction:

3. Written Word Equation:

Copper + Silver nitrate → Silver + Copper (II) nitrate

Observations:

Type of Reaction:

4. Written Word Equation:

Sodium chloride + Silver nitrate → Silver chloride + Sodium nitrate

Observations:

Type of Reaction:

5. Written Word Equation:

Aluminum + Copper (II) chloride → Aluminum chloride + Copper

Observations:

Type of Reaction:

6. Written Word Equation:

Hydrogen peroxide → Water + Oxygen

Observations:

Type of Reaction:

7. Written Word Equation:

Methane + Oxygen → Carbon dioxide + Water

Observations:

Type of Reaction:

8. Written Word Equation:

Hydrogen + Oxygen → Water

Observations:

Type of Reaction:

Conservation of Mass

We intuitively feel that matter shouldn't appear or disappear out of nowhere: that the amount of matter should be a conserved quantity. If that was to happen, then it seems as though atoms would have to be created or destroyed, which doesn't happen in any physical processes that are familiar from everyday life, such as chemical reactions. On the other hand, I've already cautioned you against believing that a law of physics must be true just because it seems appealing. The laws of physics have to be found by experiment, and there seem to be experiments that are exceptions to the conservation of matter. A log weighs more than its ashes. Did some matter simply disappear when the log was burned?

The French chemist Antoine-Laurent Lavoisier was the first scientist to realize that there were no such exceptions. Lavoisier hypothesized that when wood burns, for example, the supposed loss of weight is actually accounted for by the escaping hot gases that the flames are made of. Before Lavoisier, chemists had almost never weighed their chemicals to quantify the amount of each substance that was undergoing reactions. They also didn't completely understand that gases were just another state of matter, and hadn't tried performing reactions in sealed chambers to determine whether gases were being consumed from or released into the air. For this they had at least one practical excuse, which is that if you perform a gas-releasing reaction in a sealed chamber with no room for expansion, you get an explosion! Lavoisier invented a balance that was capable of measuring milligram masses, and figured out how to do reactions in an upside-down bowl in a basin of water, so that the gases could expand by pushing out some of the water. In one crucial experiment, Lavoisier heated a red mercury compound, which we would now describe as mercury oxide (HgO), in such a sealed chamber. A gas was produced (Lavoisier later named it “oxygen”), driving out some of the water, and the red compound was transformed into silvery liquid mercury metal. The crucial point was that the total mass of the entire apparatus was exactly the same before and after the reaction. Based on many observations of this type, Lavoisier proposed a general law of nature, that matter is always conserved.

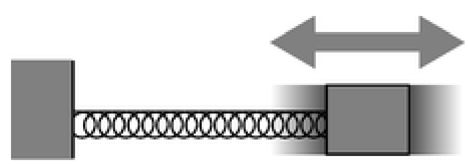
Although Lavoisier was an honest and energetic public official, he was caught up in the Terror and sentenced to death in 1794. He requested a fifteen-day delay of his execution so that he could complete some experiments that he thought might be of value to the Republic. The judge, Coffinhal, infamously replied that “the state has no need of scientists.” As a scientific experiment, Lavoisier decided to try to determine how long his consciousness would continue after he was guillotined, by blinking his eyes for as long as possible. He blinked twelve times after his head was chopped off. Ironically, Judge Coffinhal was himself executed only three months later, falling victim to the same chaos.

Example 1: A stream of water

The stream of water is fatter near the mouth of the faucet, and skinnier lower down. This can be understood using conservation of mass. Since water is being neither created nor destroyed, the mass of the water that leaves the faucet in one second must be the same as the amount that flows past a lower point in the same time interval. The water speeds up as it falls, so the two quantities of water can only be equal if the stream is narrower at the bottom.

Physicists are no different than plumbers or ballerinas in that they have a technical vocabulary that allows them to make precise distinctions. A pipe isn't just a pipe, it's a PVC pipe. A jump isn't just a jump, it's a grand jeté. We need to be more precise now about what we really mean by “the amount of matter,” which is what we're saying is conserved. Since physics is a mathematical science, definitions in physics are usually definitions of numbers, and we define these numbers *operationally*. An operational definition is one that spells out the steps required in order to *measure* that quantity. For example, one way that an electrician knows that current and voltage are two different things is that she knows she has to do completely different things in order to measure them with a meter.

If you ask a room full of ordinary people to define what is meant by mass, they'll probably propose a bunch of different, fuzzy ideas, and speak as if they all pretty much meant the same thing: “how much space it takes up,” “how much it weighs,” “how much matter is in it.” Of these, the first two can be disposed of easily. If we were to define mass as a measure of how much space an object occupied, then mass wouldn't be conserved when we squished a piece of foam rubber. Although Lavoisier did use weight in his experiments, weight also won't quite work as the ultimate, rigorous definition, because weight is a measure of how hard gravity pulls on an object, and gravity varies in strength from place to place. Gravity is measurably weaker on the top of a mountain that at sea level, and much weaker on the moon. The reason this didn't matter to Lavoisier was that he was doing all his experiments in one location. The third proposal is better, but how exactly should we define “how much matter?” To make it into an operational definition, we could do something like the picture. A larger mass is harder to whip back and forth --- it's harder to set into motion, and harder to stop once it's started. For this reason, the vibration of the mass on the spring will take a longer time if the mass is greater. If we put two different masses on the spring, and they both take the same time to complete one oscillation, we can define them as having the same mass.



1. Who was the first scientist to discover the law of conservation of mass?

2. What happens to a log when you burn it? Is it gone?

3. What was Lavoisier's last scientific experiment?

4. Give an example of the conservation of mass found in the story.

5. Try to come up with your own example of the law of conservation of mass.

6. What does the word operationally mean in the story?

What is a definition of mass in your own words?

There's HOW Many Atoms??!

	Ca	O	H	N	C
$Ca(OH)_2$					
3 $Ca(CO_3)_2$					
2 $Ca(NO_2)_2$					
CO_3^{2-}					
4 OH^-					
$Ca(C_2H_3O_2)_2$					
2 $Ca(C_2O_4)$					
3 $Ca(CO_3)$					

	S	O	Fe	N	H
7 SO_2					
5 SO_4^{2-}					
3 S^{2-}					
$Fe_2(SO_4)_3$					
FeO					
3 NH_4NO_2					

Things to remember:

- Co-efficients (the numbers in front of the formula) multiply by every atom in the formula
- Subscripts tell you how many atom's you have (it's written right after the atomic symbol it describes)

Atom Inventory

Complete an atom inventory for the following reactions, and determine if they are balanced or not.

1. $Zn + O_2 \rightarrow ZnO$

Balanced? Yes No

Left		Right
	Zn	
	O	

2. $3\ N_2 + 2\ H_2 \rightarrow 6\ NH_3$

Balanced? Yes No

Left		Right
	N	
	H	

3. $3\ Fe + 4\ H_2O \rightarrow Fe_3O_4 + 4\ H_2$

Balanced? Yes No

Left		Right
	Fe	
	H	
	O	

4. $Cl_2 + 4\ NaBr \rightarrow 2\ NaCl + 2\ Br_2$

Balanced? Yes No

Left		Right
	Cl	
	Na	
	Br	

5. $Al_2(SO_4)_3 + Ca(OH)_2 \rightarrow Al(OH)_3 + CaSO_4$

Balanced?

Yes No

Left		Right
	Al	
	SO_4	
	Ca	
	OH	

6. $Al_2(SO_4)_3 + 3\ Ca(OH)_2 \rightarrow 2\ Al(OH)_3 + 3\ CaSO_4$

Balanced?

Yes No

Left		Right
	Al	
	SO_4	
	Ca	
	OH	

7. $4\ SiO_2 + 2\ HF \rightarrow SiF_4 + H_2O$

Balanced?

Yes No

Left		Right
	Si	
	O	
	H	
	F	

8. $Pb(NO_3)_2 + K_2CrO_4 \rightarrow PbCrO_4 + 2\ KNO_3$

Balanced?

Yes No

Left		Right
	Pb	
	NO_3	
	K	
	CrO_4	

Balancing Equations

Information: Subscripts and Coefficients

A subscript is a small number that tells you how many atoms are in a compound. For example, in $CaCl_2$ the two is the subscript and it tells us that there are two chloride ions bonded to one calcium.

A coefficient tells also tells us how many atoms or compounds there are, but in a different way. For example in the expression "3 H_2O" the three is the coefficient. The three tells us that there are three molecules of water present. In the expression "3 H_2O" there are a total of 6 hydrogen atoms and 3 oxygen atoms.

Critical Thinking Questions

1. Verify that in $4Ca_3(PO_4)_2$ there are 32 oxygen atoms present.

2. How many oxygen atoms are in each of the following:

_____ a) Al_2O_{30}

_____ b) 3 Na_2O

_____ c) 4 Na_2SO_4

_____ d) 5 $Mg(NO_3)_2$

Information: How To Balance Equations

Consider the reaction of sodium and chlorine to produce sodium chloride from question one:

$$Na + Cl_2 \rightarrow NaCl$$

Remember that when chlorine is by itself it is always written as Cl_2. On the reactant side of the reaction (left side) there are a total of two atoms of chlorine, but on the product side there is only one atom of chlorine. Atoms cannot simply disappear. In order for the equation to make sense, we need to balance the equation. This can be done, first, by adding a “2” to the product side:

$$Na + Cl_2 \rightarrow 2\ NaCl$$

Now the equation reads that one atom of Na reacts with one molecule of Cl_2 to produce two units of NaCl. However, now the Na atoms are not balanced because there is one atom of the reactant side, but two atoms of Na on the product side. This can be fixed by adding another two:

$$2\ Na + Cl_2 \rightarrow 2\ NaCl$$

Let us consider another example:

$$Ca_3N_2 + NaCl \rightarrow CaCl_2 + Na_3N$$

Notice that none of the atoms are “balanced”. There are three calcium atoms on one side and only one on the other. There are two nitrogen atoms on one side and one on the other. How can we fix this? Begin by “balancing” one atom at a time:

1. First, let’s balance the calcium atoms by placing a three in front of $CaCl_2$:

   $$Ca_3N_2 + NaCl \rightarrow 3\ CaCl_2 + Na_3N$$

2. Next, let’s balance the nitrogen atoms, by placing a 2 in front of Na_3N:

   $$Ca_3N_2 + NaCl \rightarrow 3\ CaCl_2 + 2\ Na_3N$$

3. Now we will balance the sodium atoms by placing a 6 in front of NaCl.

   $$Ca_3N_2 + 6\ NaCl \rightarrow 3\ CaCl_2 + 2\ Na_3N$$

4. Finally, examine the chlorine atoms and notice that they are already balanced.

5. Double check each atom to make sure there are equal numbers of each on both sides of the equation.

When balancing equations you NEVER change subscripts. Only change the coefficients.

Critical Thinking Questions

3. Which of the following equations are properly and completely balanced? (Circle as many as apply.)
   A) 2 NaCl + Cu → $CuCl_2$ + Na
   B) C_3H_8 + 3 O_2 → 3 CO_2 + H_2O
   C) $MgCl_2$ + F_2 → MgF_2 + Cl_2
   D) $FeCl_2$ + O_2 → 2 FeO + Cl_2

4. Balance each of the following equations by inserting the correct coefficient in each blank. Remember to balance one atom at a time. If the number "one" belongs in the blank you may either leave it blank or insert the number one.

   A) _____ $CaCl_2$ + _____ Li_2O → _____ CaO + _____ LiCl

   B) _____ Al_2S_3 + _____ Cu → _____ CuS + _____ Al

   C) _____ Na_3P + _____ $MgBr_2$ → _____ Mg_3P_2 + _____ NaBr

5. Here are the answers to question 4. Double check your answers to question 4:
   A) $CaCl_2$ + Li_2O → CaO + 2 LiCl
   B) Al_2S_3 + 3 Cu → 3 CuS + 2 Al
   C) 2 Na_3P + 3 $MgBr_2$ → Mg_3P_2 + 6 NaBr

Information: Balancing Equations Containing Polyatomic Ions

When an equation contains polyatomic ions, it may look a little more difficult to balance. But balancing an equation containing polyatomic ions is really not much different from the ones you just did. In the equations above, you kept in mind that you must balance only one atom at a time. With polyatomic ions, keep in mind that you balance *one polyatomic ion* at a time. For example, consider the following unbalanced equation.

$$Na_2SO_4 + Ca_3(PO_4)_2 \rightarrow Na_3PO_4 + CaSO_4$$

The first thing you should do is take note of which atoms/ions are not balanced. Keep the polyatomic ions together. In other words, do not balance the phosphorus and oxygen atoms separately; instead, balance the phosphate ions on each side of the reaction. Follow these steps:

1. Balance the sodium so that there are 6 sodium atoms on each side of the reaction:

$$3\ Na_2SO_4 + Ca_3(PO_4)_2 \rightarrow 2\ Na_3PO_4 + CaSO_4$$

2. Now there are three sulfate ions on the left and one on the right. Add a three to the right.

$$3\ Na_2SO_4 + Ca_3(PO_4)_2 \rightarrow 2\ Na_3PO_4 + 3\ CaSO_4$$

3. Take inventory of all the atoms and ions to make sure they are balanced. The equation is now balanced.

Critical Thinking Questions

6. Which of the following equations are properly balanced?

   A) $Ba(NO_3)_2 + Fe_2SO_4 \rightarrow 2\ FeNO_3 + BaSO_4$

   B) $3\ SrCl_2 + Al(NO_3)_3 \rightarrow 3\ Sr(NO_3)_2 + AlCl_3$

   C) $Ca_3(PO_4)_2 + 3\ Na_2CO_3 \rightarrow 2\ Na_3PO_4 + 3\ CaCO_3$

   D) $Fe(NO_3)_2 + Mg \rightarrow Mg(NO_3)_2 + Fe$

7. Balance each of the following equations by inserting the correct coefficient in each blank. Remember to balance one atom/ion at a time. If the number "one" belongs in the blank you may either leave it blank or insert the number one.

   A) _____ $Ca(NO_3)_2$ + _____ Na → _____ $NaNO_3$ + _____ Ca

   B) _____ $Al_2(CO_3)_3$ + _____ $MgCl_2$ → _____ $AlCl_3$ + _____ $MgCO_3$

   C) _____ $Ba_3(PO_4)_2$ + _____ Na_2CO_3 → _____ $Na_3\ PO_4$ + _____ $BaCO_3$

8. Make sure you got the following answers for question 6
   A) $Ca(NO_3)_2 + 2\ Na \rightarrow 2\ NaNO_3 + Ca$
   B) $Al_2(CO_3)_3 + 3\ MgCl_2 \rightarrow 2\ AlCl_3 + 3\ MgCO_3$

$Ba_3(PO_4)_2 + 3\ Na_2CO_3 \rightarrow 2\ Na_3\ PO_4 + 3\ BaCO_3$

Balancing Equations Rally Coach

Teammate A: ____________________ Teammate B: __________________

Directions:

- Teammate A balances the first problem. Teammate B watches, praises, and coaches until the problem is correct and both understand.
- Teammate A passes the pencil and paper to Teammate B.
- Teammate B balances the second problem. Teammate A watches, praises, and coaches until the problem is correct and both understand.
- Repeat the process until the entire worksheet is completed.

1. *Equation:* $Fe + O_2 \rightarrow Fe_2O_3$

Balanced Equation:

____

2. *Equation:* $NaOH + H_3PO_4 \rightarrow Na_3PO_4 + H_2O$

Balanced Equation:

____

3. *Equation:* $C_3H_8 + O_2 \rightarrow CO_2 + H_2O$

Balanced Equation:

____

4. *Equation:* $C_{10}H_{16} + Cl_2 \rightarrow C + HCl$

Balanced Equation:

____

5. *Equation:* $C_2H_6O + O_2 \rightarrow CO_2 + H_2O$

Balanced Equation:

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6. *Equation:* $Al + H_2SO_4 \rightarrow Al_2(SO_4)_3 + H_2$

Balanced Equation:

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7. *Equation:* $Pb_3O_4 \rightarrow PbO + O_2$

Balanced Equation:

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8. *Equation:* $Fe + H_2O \rightarrow Fe_3O_4 + H_2$

Balanced Equation:

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9. *Equation:* $FeCl_2 + Cl_2 \rightarrow FeCl_3$

Balanced Equation:

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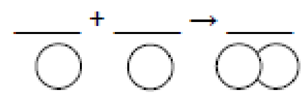
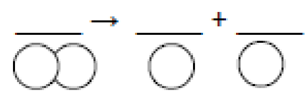
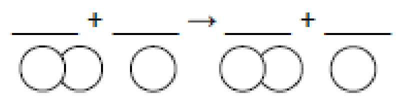
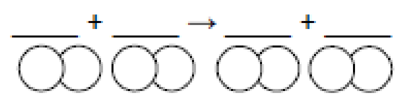
10. *Equation:* $CuSO_4 + KI \rightarrow CuI + K_2SO_4 + I_2$

Balanced Equation:

Chemical Reactions

Name ____________________________

1. Watch the video and then complete the chart.

Type of Reaction	Definition	★ Equation
Synthesis		
Decomposition		
Single Replacement		
Double Replacement		

Colors: A = Red, B = Blue, C = Green, D = Yellow

2. Use colored pencils to circle the common atoms or compounds in each equation to help you determine the type of reaction it illustrates. Use the code below to classify each reaction.

S = Synthesis D = Decomposition SR = Single Replacement DR = Double Replacement

____ $P + O_2 \rightarrow P_4O_{10}$

____ $Mg + O_2 \rightarrow MgO$

____ $HgO \rightarrow Hg + O_2$

____ $Al_2O_3 \rightarrow Al + O_2$

____ $Cl_2 + NaBr \rightarrow NaCl + Br_2$

____ $H_2 + N_2 \rightarrow NH_3$

____ $Na + Br_2 \rightarrow NaBr$

____ $CuCl_2 + H_2S \rightarrow CuS + HCl$

____ $HgO + Cl_2 \rightarrow HgCl + O_2$

____ $C + H_2 \rightarrow CH_4$

____ $KClO_3 \rightarrow KCl + O_2$

____ $S_8 + F_2 \rightarrow SF_6$

____ $BaCl_2 + Na_2SO_4 \rightarrow NaCl + BaSO_4$

Identifying and Balancing Chemical Equations

Balance each of the following equations. Then identify each of the equations below as synthesis (S), decomposition (D), single replacement (SR), or double replacement (DR),combustion (C), or Acid/Base Neutralization (AB).

_____ 1. $HgO \rightarrow Hg + O_2$

_____ 2. $NaCl + AgNO_3 \rightarrow NaNO_3 + AgCl$

_____ 3. $Mg + HCl \rightarrow MgCl_2 + H_2$

_____ 4. $C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O$

_____ 5. $NaOH + H_2SO_4 \rightarrow Na_2SO_4 + HOH$

_____ 6. $Al_2(SO_4)_3 + Ca(OH)_2 \rightarrow Al(OH)_3 + CaSO_4$

_____ 7. $H_2 + O_2 \rightarrow H_2O$

_____ 8. $C_7H_{16} + O_2 \rightarrow H_2O + CO_2$

_____ 9. $Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$

_____ 10. $KClO_3 \rightarrow KCl + O_2$

_____ 11. $H_2O + Fe \rightarrow Fe_2O_3 + H_2$

_____ 12. $Ca(OH)_2 + HNO_3 \rightarrow Ca(NO_3)_2 + HOH$

_____ 13. $Na_2O + CO_2 \rightarrow Na_2CO_3$

______ 14. H_2 + N_2 → NH_3

______ 15. $CuCl_2$ + Al → $AlCl_3$ + Cu

______ 16. $CuCl_2$ + H_2S → CuS + HCl

______ 17. C_2H_6 + O_2 → CO_2 + H_2O

______ 18. Cl_2 + NaBr → NaCl + Br_2

______ 19. Zn + H_2SO_4 → $ZnSO_4$ + H_2

______ 20. Al + O_2 → Al_2O_3

______ 21. HgO → Hg + O_2

______ 22. NaOH + H_2SO_4 → Na_2SO_4 + HOH

______ 23. Fe + O_2 → Fe_2O_3

______ 24. $Pb(NO_3)_2$ + K_2CrO_4 → $PbCrO_4$ + KNO_3

______ 25. $C_3H_6(NO_3)_3$ → CO_2 + N_2 + H_2O

______ 26. Fe + $CuSO_4$ → $Fe_2(SO_4)_3$ + Cu

______ 27. S + O_2 → SO_3

______ 28. HgO → Hg + O_2

______ 29. KI + Cl_2 → KCl + I_2