Atomic Tiles

Overview

This series of eight lessons are designed to enable students to use Atomic Tiles to explore foundational concepts about chemical bonding, building molecules and the periodic table. These lessons have been used with more than 3000 5-8th grade students in the Cal Poly Learn by Doing Lab, more than 100 K-12 teachers through professional development workshops run by the Central Coast Science Project and in several university and high school level introductory chemistry classrooms.

Lesson 1: Exploring Valence Electrons
Lesson 2: Making Bonds
Lesson 3: Periodic Pause: Elemental Families
Lesson 4: Making Molecules 1… Getting Started
Lesson 5: Making Molecules 2… The Octet Rule
Lesson 6: Making Molecules 3… Lewis Structures

Getting Started

Atoms are nature's building blocks. Everything around you, from the shoes on your feet to the air in this room, is made of atoms. In this series of activities we are going to explore how atoms come together to form molecules. To understand how atoms form bonds we have to understand a little bit about the structure of atoms. An atom has a dense inner core called the **Nucleus** that contains protons and neutrons. It has a squishy outer area that contains electrons called an **Electron Cloud**. Most chemical properties of atoms, including how atoms bond to one anther, are the result of the outermost electrons in the "electron cloud" known as the **Valence Electron**. Atomic tiles depict valence electrons as open or closed circles. **Open Circles** are electrons that are shared to form bonds. **Closed Circles** are electrons that are not shared.

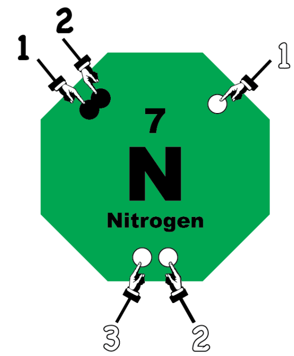
Valence Electrons:
- Outermost electrons of an atom.
- Play a role in forming bonds.
- Determine chemical properties.
- **Open** and **Closed** on Atomic Tiles.

Core Electrons:
- Do not play role in bonding.
- Not shown on Atomic Tiles.

In Lessons 1-6, we are going to explore Valence Electrons and Covalent Bonding. Covalent bonds are formed when atoms share valence electrons. Shared valence electrons count towards filling the valence shell for both atoms participating in the bond. It turns out that having a filled valence shell with 8 electrons is particularly stable. This is known as the octet rule and it helps Chemists predict how certain atoms and molecules will react.

Lesson 1: Exploring Valence Electrons Teacher Sheet

Background

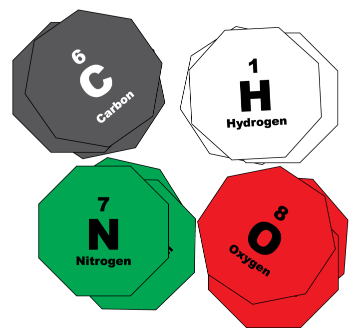


Most chemical properties of atoms, including how atoms bond to one another, are the result of the outermost electrons known as the Valence Electrons. Atomic Tiles depict Valence Electrons as open or closed circles. Open Circles are electrons that are shared to form bonds. Closed Circles are electrons that are not shared. Counting valence electrons with atomic tiles is as simple as counting open and closed circles on a tile. Consider the example depicted on the right. The nitrogen atom has three open circles and two closed circles, so this nitrogen atom has five valence electrons.

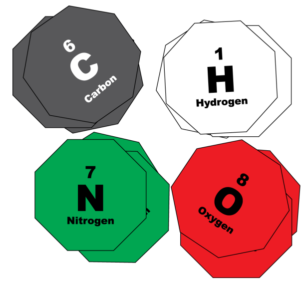
Objectives

The objective of this activity is to explore the elements Hydrogen, Carbon, Nitrogen, and Oxygen to look for similarities and differences.

- Students can recognize the open and closed circles on Atomic Tiles are Valence Electrons, and can count valence electrons on any card.
- Students can demonstrate and understanding that any card of given element has same number of valence electrons but may have different arrangements and different elements have different number of valence electrons.



Lesson 1: Exploring Valence Electrons



Objective

The objective activity is to explore the **Valence Electrons** of the elements Hydrogen, Carbon, Nitrogen, and Oxygen to look for similarities and differences.

Instructions

For each element, you will start by placing as many "different" types of that element on your virtual lab bench.

Hydrogen:

1.) Take some time to examine the Hydrogen tiles.

Are all the Hydrogen tiles the same? Yes No

2.) Add dots to the blank tiles. Use your observations to fill in the table.

Hydrogen 1 **H** **Hydrogen**	**Open Circles:**	
	Closed Circles:	
	Total Valence Electrons	

What conclusions can you make about hydrogen?

Oxygen:

1.) Take some time to examine the Oxygen tiles.

Are all the Oxygen tiles the same? Yes No (if No: sort Oxygens)

2.) Add dots to the blank tiles. Use your observations to fill in the table.

Oxygen 8 **O** **Oxygen**	**Open Circles:**		**Oxygen** 8 **O** **Oxygen**	**Open Circles:**	
	Closed Circles:			**Closed Circles:**	
	Total Valence Electrons			**Total Valence Electrons**	

What things are the same for each oxygen tile?

What things are different from one tile to another?

Nitrogen:

1.) Take some time to examine the Nitrogen tiles. Are all the Nitrogen tiles the same? Yes No

2.) Add dots to the blank tiles. Use your observations to fill in the table.

Nitrogen 7 **N** Nitrogen	**Open Circles:**		**Nitrogen** 7 **N** Nitrogen	**Open Circles:**	
	Closed Circles:			**Closed Circles:**	
	Total Valence Electrons			**Total Valence Electrons**	
Nitrogen 7 **N** Nitrogen	**Open Circles:**				
	Closed Circles:				
	Total Valence Electrons				

What things are the same for each Nitrogen tile?

What things are different from one tile to another?

Carbon:

1.) Take some time to examine the Carbon tiles. Are all the Carbon tiles the same? Yes No

2.) Add dots to the blank tiles. Use your observations to fill in the table.

Carbon 6 **C** Carbon	**Open Circles:**		**Carbon** 6 **C** Carbon	**Open Circles:**	
	Closed Circles:			**Closed Circles:**	
	Total Valence Electrons			**Total Valence Electrons**	
Carbon 6 **C** Carbon	**Open Circles:**		**Carbon** 6 **C** Carbon	**Open Circles:**	
	Closed Circles:			**Closed Circles:**	
	Total Valence Electrons			**Total Valence Electrons**	

What things are the same for each carbon tile?

What things are different from one tile to another?

Summary Questions

1.) What **differences** do you notice between Carbon, Nitrogen, Oxygen and Hydrogen?

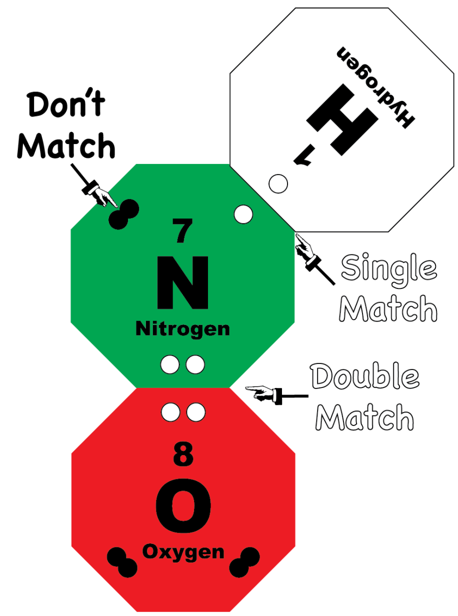
2.) Which element had the most configurations? Which had the least?

3.) Can you make a general rule about elements and valence electrons?

Lesson 2: Making Bonds Teacher Sheet

Background

In this activity we are going to explore how atoms share **Valence Electrons** to form **Bonds**. On Atomic Tiles, **Open Circles** depict **Bonding** valence electrons that form bonds and **Closed Circles** depict **Non-bonding** valence electrons that do not form bonds. When we match open circles using atomic tiles we are showing which valence electrons are shared to form bonds.



Match	Bonds	Name	Electrons Shared
single dots	1	Single Bond	2
double dots	2	Double Bond	4
triple dots	3	Triple Bond	6

In the example on the right, nitrogen has one single dot match (one single bond) and one double dot match (one double bond) and two closed circles that do not make matches. As a result, this nitrogen tile is making three bonds in total.

Objectives

The objective of this activity is to explore how Carbon, Nitrogen, Oxygen, and Hydrogen share **Valence Electrons** to form **Bonds.**

- Students understand that matching dots means sharing electrons and that sharing electrons means forming bonds.
- Students identify four general trends: Carbon makes 4 bonds, Nitrogen 3 bonds, Oxygen 2 bonds, and Hydrogen 1 bond.
- Students can demonstrate an understanding that C, N and O have more than one way to bond.
- Students begin to think of the different configurations of each element as puzzle pieces.

Lesson 2: Making Bonds

Objective

In this activity we are going to explore how atoms share **Valence Electrons** to form **Bonds**. When we match open circles with atomic tiles, we are showing which valence electrons are shared to form bonds.

Match	Bonds	Name	Electrons Shared
single dots	1	Single Bond	2
double dots	2	Double Bond	4
triple dots	3	Triple Bond	6

Predictions

Given your observations of Hydrogen, Nitrogen, Carbon and Oxygen, make some predictions.

Which element likely forms the MOST bonds?

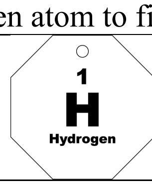
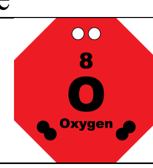
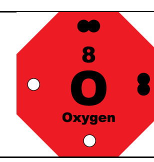
Which element likely forms the FEWEST bonds?

Instructions

We are going to systematically explore bonding for Hydrogen, Oxygen, Nitrogen, and Carbon. For each element, you will start by placing as many “different” types of that element on your virtual lab bench. You will then test each different tile to see how many bonds it can make.

Hydrogen and Oxygen:

Test Hydrogen and each Oxygen atom to fill in the following table

Hydrogen		**Oxygen**		
Single bonds		Single bonds		
Double bonds		Double bonds		
Triple bonds		Triple bonds		
Total bonds		Total Bonds		

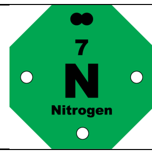
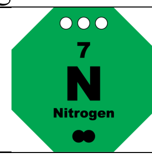
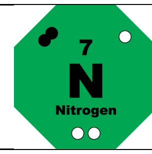
What can you conclude about Hydrogen?

What is the **SAME** about all the types of Oxygen?

What is **DIFFERENT** about the different types of Oxygen?

Nitrogen:

Test each Nitrogen atom to fill in the following table

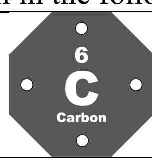
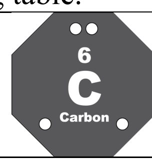
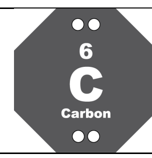
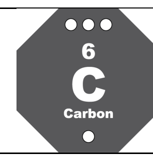
Nitrogen			
Single bonds			
Double bonds			
Triple bonds			
Total bonds			

What is the **SAME** about all the types of Nitrogen?

What is **DIFFERENT** about the different types of Nitrogen?

Carbon:

Test each Carbon atom to fill in the following table.

Carbon				
Single bonds				
Double bonds				
Triple bonds				
Total bonds				

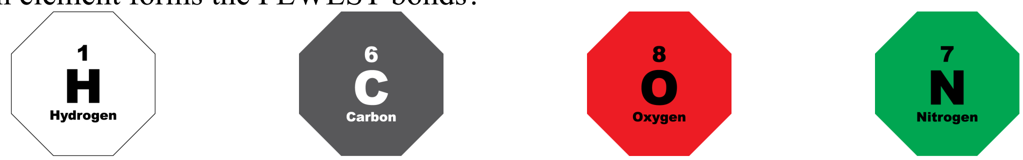
What is the **SAME** about all the types of Carbon?

What is **DIFFERENT** about the different types of Carbon?

Summary Questions

1.) Which element forms the MOST bonds?

2.)Which element forms the FEWEST bonds?



3.) Can you state a general bonding rule for:

i.) Carbon:

ii.) Nitrogen:

iii.) Oxygen:

iv.) Hydrogen:

4.) When playing with Atomic Tiles, Emily made the following statement: "C's are openers and H's are closers".

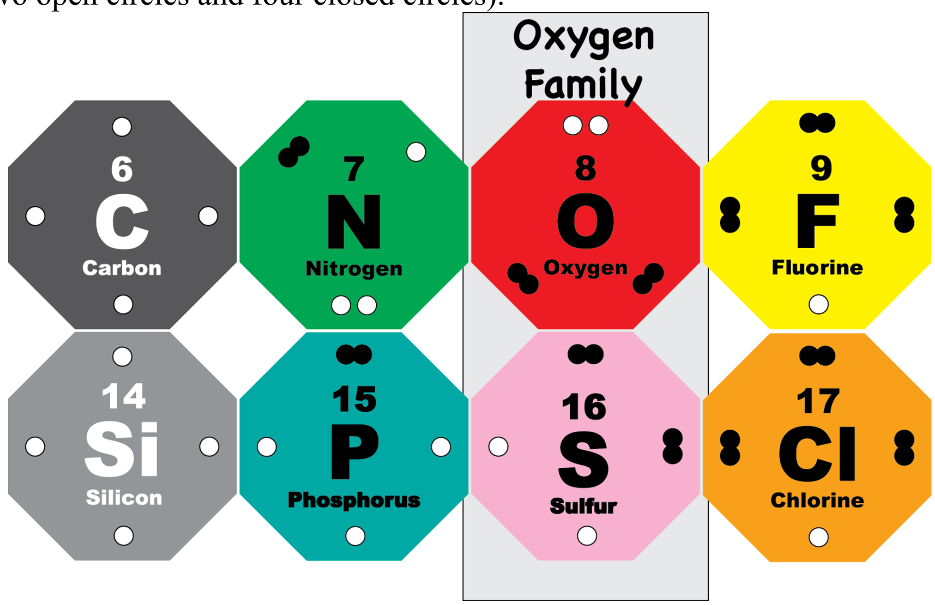
i.) What do you think she means?

ii. Does this statement match your observations?

Lesson 3: Periodic Pause Elemental Families Teacher Sheet

Background

The development of the periodic table is a triumph of critical thinking and careful observation. In the late 1800's chemists struggled to find coherence among the chemical and physical properties of elements. While many scientists worked on this problem, Dmitri Mendeleev, a Russian high school chemistry teacher in the late 1800's, is credited with envisioning the modern periodic table in his 1868 textbook, "Principles of Chemistry". His approach to organizing the known elements stood the test of time as much for what it ***did not*** include as for what it did include. Confident in his organizational structure, Mendeleev left several gaps in his periodic table that accurately predicted future elemental discoveries. Elements with the **Same Number of Valence Electrons** are said to be in the same "Family". As we have seen in Lesson 2, the number of valence electrons and element has leads to its bonding behavior. In the figure below the Oxygen Family is highlighted. You can see that both Oxygen and Sulfur have 6 total valence electrons (two open circles and four closed circles).



Objective

In this activity we are going to explore the idea of Elemental Families.

- Students will understand that families (up and down) have the same number of valence electrons, which means they have similar bonding characteristics.
- Students will be able to make predictions about bonding and number of valence electrons based on family patterns.

Lesson 3: Periodic Pause Elemental Families

Objective

In this activity we are going to explore the **Periodic Table** of the elements. We will look for valence electron and bonding patterns. We will try to make predictions based on patterns we see. And we will develop the idea of Elemental Families.

Instructions

You will need your virtual lab bench set to level 3. You will periodically need to consult with the built in periodic table.

Valence Electrons

Find elements that have the **Same Number of Valence Electrons** as each of the following. Sketch an example in the box below.

	Same Number of Valence Electrons
6 **C** Carbon	
7 **N** Nitrogen	
8 **O** Oxygen	

Elements with the **Same Number of Valence Electrons** are said to be in the same "Family". Why might that be?

Use the built-in periodic table to locate the elements you sketched in the table above. Do you notice anything interesting?

Where is the element with the same number of valence electrons as carbon found? How about nitrogen? Oxygen?

Can you make a general rule about Elemental Families?

Bonding:

Elements in a family tend to have very similar chemical properties. What bonding trends do you see amongst elements in the…

1. Carbon Family:

2. Nitrogen Family (pnicogens):

3. Oxygen Family (chalcogens):

4. Fluorine Family (halogens):

Summary Questions

1.) What does it mean for two elements to be in the same family?

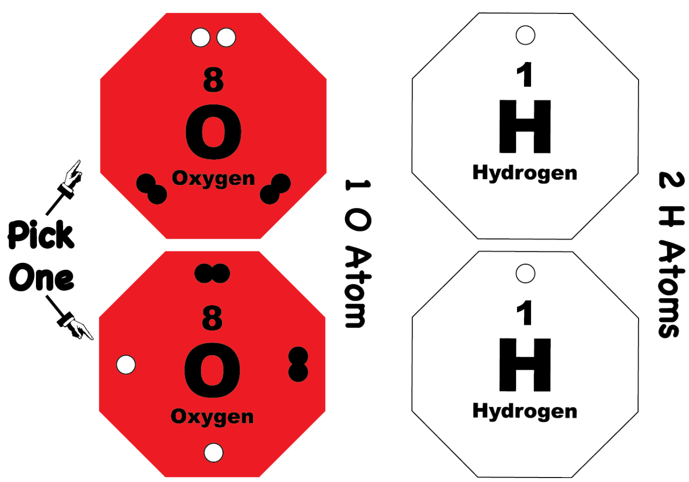
2.) Do elemental families run up and down the periodic table or right to left?

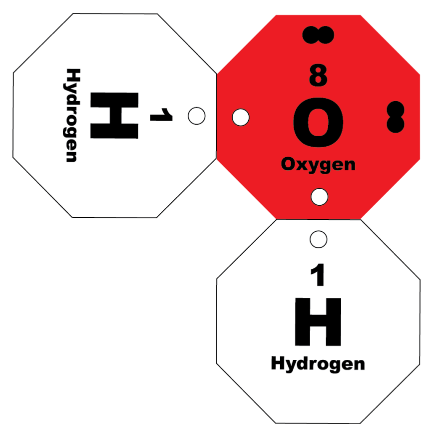
Lesson 4: Making Molecules 1… Getting Started Teacher Sheet

Background

Atoms are nature's building blocks, but we very seldom see atoms by themselves in nature. More often than not, atoms bond with other atoms to form **molecules and compounds**. **Covalent Molecules**, like water (H_2O) and ethanol (CH_3CH_2OH), form when valence electron from one atom are **shared** with valence electrons from a second atom to form a **Covalent Bond**. Forming covalent bonds lowers the potential energy of the atoms and thus creates a more stable state. As we saw, when we match open circles using Atomic Tiles we are showing which valence electrons are shared to form bonds.

Making molecules with Atomic Tiles is a natural extension of Lesson 2: Bonding, with two simple additions. In order to make a molecule we need to: A.) Pick the correct atoms & B.) Match all the open circles (this is a bit of a puzzle). We can figure out which atoms are in a molecule by looking at a Molecular Formula. For example, the Molecular Formula of water is H_2O. This means water is a molecule with two hydrogen atoms and one oxygen atoms. Now the puzzling begins… Which two hydrogen tiles and one oxygen tile can you pick, such that you can match all the open circles? Picking the hydrogen tiles is easy, because you only have one choice. But which oxygen tile should you pick? Well, since hydrogen can only make a single match, you should likely choose the oxygen that allows for single matches. Now puzzling out water is not too challenging because you only have to make one choice. As Molecular Formulae get more complicated, like CH_3CH_2OH you have more and more choices (4 choices for each carbon, 2 choices for each oxygen). Solving more complicated puzzles will require a bit of noodling and patience. You will know you have a good answer IFF… the atoms in your molecule matches the Molecular Formula AND all the open circles on every atom in the molecule are matched.





Objectives

In this activity we are going to build **Molecules** using Atomic Tiles.

- Student will understand that atoms come together to make molecules by matching all of their open circles.
- Students will understand that a chemical formula tells you about the elements in a molecule.
- Students understand that C, N and O have more than one way to bond and start to recognize patterns (C=4 bonds, N=3 bonds, O=2 bonds, H=1 bond) and continue to think of the different configurations of each element as puzzle pieces.

Lesson 4: Making Molecules 1… Getting Started

Objectives

In this activity we are going to build **Molecules** using Atomic Tiles. We will see that atoms come together to make molecules by matching all of their open circles. We will learn that a molecular formula tells us about the elements are in a molecule.

Instructions

You will need to put on your thinking cap and use your virtual lab bench. There are two rules you need to use to make good molecules:

1.) The atoms in the molecule must match the molecular formula.
2.) All the open circles for each in atom in your molecule must be matched.

Lets get started:

Use your Atomic Tiles to make…

A.) H_2O (Water) (Water has 2 H atoms and 1 O atom… hence H_2O)

B.) O_2 (Molecular Oxygen) (Molecular Oxygen has 2 O atoms… hence O_2)

Check your molecules. Do they follow the two rules for good molecules? If not, try again.

What decisions did you have to make about Oxygen Cards to make each molecule?

Lets get a little tricky:

Use your Atomic Tiles to make…

A.) NH_3 (Ammonia)

B.) HCN (Hydrogen Cyanide)

C.) N_2 (Molecular Nitrogen)

D.) HNO (Nitroxyl)

As you go, check your molecules. Do they follow the two rules for good molecules? As the molecules get more complicated, you may need to try a few times.

What decisions did you have to make about Nitrogen Cards to make each molecule?

Think you've got it?:

Use your Atomic Tiles to make…

A.) CO_2 (Carbon Dioxide)

B.) C_2H_6 (Ethane)

C.) C_2H_4 (Ethene)

D.) C_2H_2 (Ethyne)

As you go, check your molecules. Do they follow the two rules for good molecules?

What decisions did you have to make about Carbon Cards to make each molecule?

Summary Questions

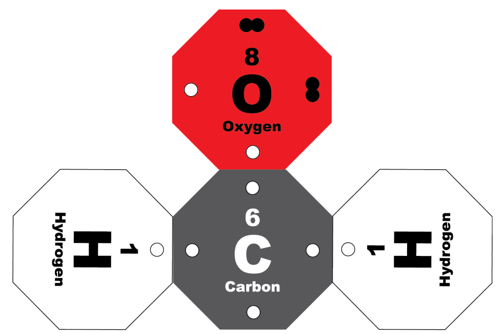
1.) When picking atoms to build a molecule, which atom, Hydrogen, Oxygen, Carbon, or Nitrogen, has the most choices? Which has the fewest?

2.) Did you see any patterns with Hydrogen, Oxygen, Carbon, or Nitrogen?

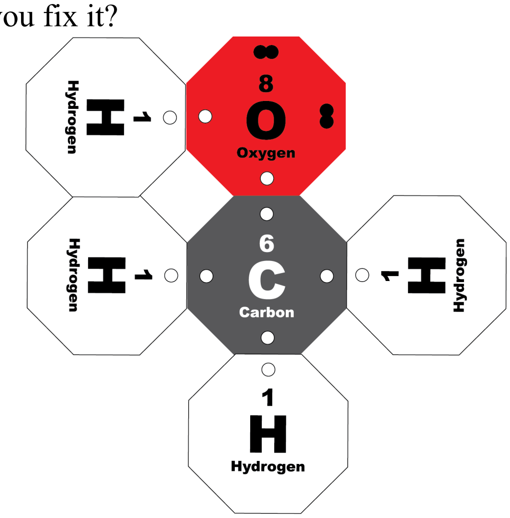
3.) When making molecules with Atomic Tiles, Daniel made the following statement: "C's are normally in the middle, H's are on the edges".
What do you think he means?

Does this statement match your observations?

4.) Consider this Atomic Tiles model of formaldehyde, CH_2O:
Is this a good model? If so why? If not why not AND how would you fix it?



5.) Consider this Atomic Tiles model of methanol, CH_3OH:
Is this a good model? If so why? If not why not AND how would you fix it?



Lesson 5: Making Molecules 2… The Octet Rule Teacher Sheet

Background

Shared valence electrons count towards filling the valence shell for both atoms participating in the bond. For many common elements, like Carbon, Nitrogen and Oxygen, having a filled valence shell, with eight electrons, is particularly stable. This is known as the octet rule and it helps Chemists predict how certain atoms and molecules will react.

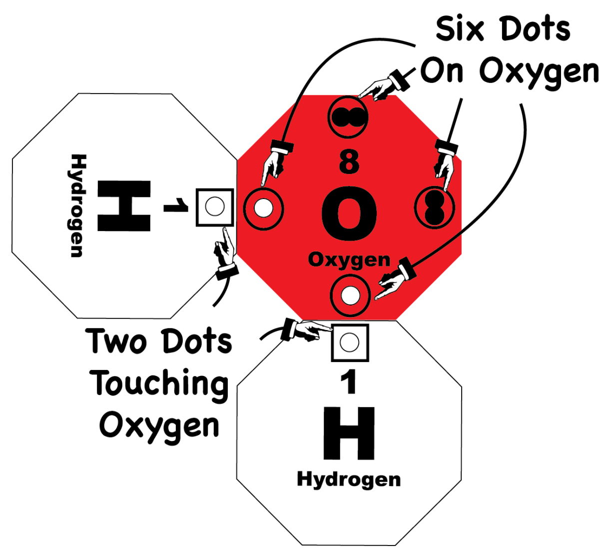
It is fairly easy to "discover" the octet rule using Atomic Tiles. The trick is being able to count the total number of valence electrons around an atom after bonding, i.e. the number of electrons in the valence shell after bonding.

Total Valence Electrons After Bonding = Shared Electrons + Non Bonding Electrons

Shared Electrons ↑ Open Circles

Non Bonding Electrons ↑ Closed Circles

Using the cards, the total number of valence electrons around an atom after bonding is: the number of dots on the card of interest plus the number of dots touching the card of interest. Lets look at the oxygen in water (H_2O). The oxygen tile has six dots on it and two dots touching it. So… the oxygen in water has eight total valence electrons associated with it.



Objectives

In this activity we are going to explore the octet rule by building **Molecules** using Atomic Tiles.

- Students will be able to count the total number of valence electrons around an atom after bonding.
- Students will see the octet pattern for the total number of valence electrons around an atom after bonding with C, N &O.

Lesson 5: Making Molecules 2… The Octet Rule

Objectives

In this activity we are going to unearth fundamental rules of bonding. Using Atomic Tiles we will build molecules and look for patterns in the total number of valence electrons around an atom after bonding for Carbon, Nitrogen and Oxygen.

Instructions

You will use your virtual lab bench to build a series of molecules. For each molecule you will count the total number of valence electrons around each Carbon, Oxygen and Nitrogen atom after bonding. This is the number of dots on the card of interest plus the number of dots touching the card of interest.

Oxygen:

Use your Atomic Tiles to make…

A.) H_2O_2 (Hydrogen Peroxide)   B.) CH_2O (Formaldehyde)

As you go, check your molecules. Do they follow the two rules for good molecules?

Count the total number of valence electrons after bonding for:

Each O in H_2O_2:__________   O in CH_2O:__________

Nitrogen

Use your Atomic Tiles to make…

A.) N_2O_2 (Dinitrogen Dioxide)   B.) HCN (Hydrogen Cyanide)   C.) N_2H_4 (Hydrazine)

As you go, check your molecules. Do they follow the two rules for good molecules?

Count the total number of valence electrons after bonding for:

Each N in N_2O_2:__________   N in HCN:__________   N in N_2H_4:__________

Carbon

Use your Atomic Tiles to make…

A.) CH_3OH (Methane)   B.) HCN (Hydrogen Cyanide)

C.) CH_2O (Formaldehyde)   D.) CO_2 (Carbon Dioxide)

As you go, check your molecules. Do they follow the two rules for good molecules?

Count the total number of valence electrons after bonding for:

C in CH_3OH:__________   C in HCN:__________

C in CH_2O:__________   C in CO_2:__________

Summary Questions

1.) Did you see any pattern in the **Total Valence Electrons after Bonding** for C, N and O?

2.) This pattern is often referred to as the “Octet Rule”. Why might that be?

Lesson 6: Making Molecules 3… Lewis Dot Structures Teacher Sheet

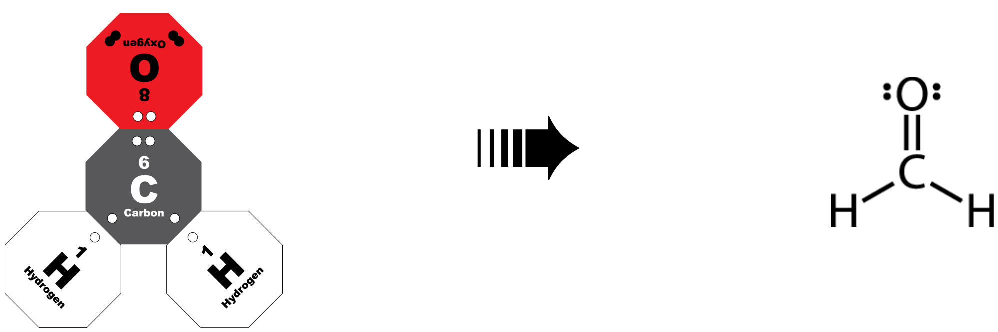
Background

So how can we depict the structure of a molecule? This question was addressed by Gilbert Lewis in 1916 with his electron dot symbols which have become standards for representing bonding. Lewis expanded on electron dot diagrams to include not only representing valence electrons and lone pairs as dots, but also using lines to represent shared pairs in a chemical bond. Using each atom’s chemical symbol Lewis structures show their position within the molecule, specifically, each element symbol represents the nucleus and inner electrons. The Lewis symbol provides valuable information about an element’s bonding behavior.

We are going to translate Atomic Tile molecular models onto paper to create Lewis structures.

Bonds:			
Single Dot Match	=>	Single bond…	**Single line between atoms**
Double Dot Match	=>	Double bond…	**Double line between atoms**
Triple Dot Match	=>	Triple bond…	**Triple line between atoms**
Lone Pairs:			
Non-bonding electrons	=>	lone pairs…	**two dots**

e.g. Formaldehyde CH_2O



Objectives

In this activity we are going to translate Atomic Tile molecular models into Lewis Dot Structures.

- Students will be able to translate Atomic Tile Molecular Models into Lewis Dot Structures.

Lesson 6: Making Molecules 3… Lewis Dot Structures

Objectives

In this activity we are going to learn how to make Lewis Dot Structures using atomic tiles.

Instructions

We are going to translate Atomic Tile molecular models onto paper to create Lewis Dot Structures. For each molecule, you will start by making an atomic tile model.

Bonds:

Single Dot Match	=>	Single bond…	**Single line between atoms**
Double Dot Match	=>	Double bond…	**Double line between atoms**
Triple Dot Match	=>	Triple bond…	**Triple line between atoms**

Lone Pairs:

Non-bonding electrons	=>	lone pairs…	**two dots**

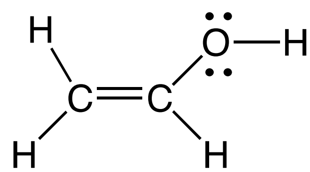
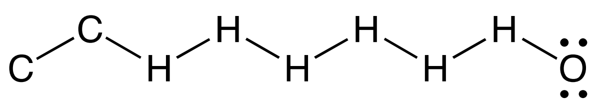
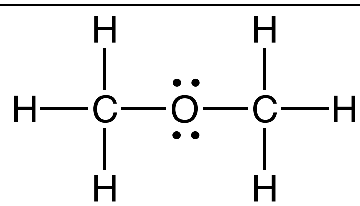
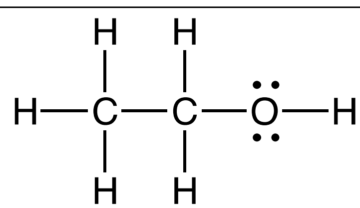
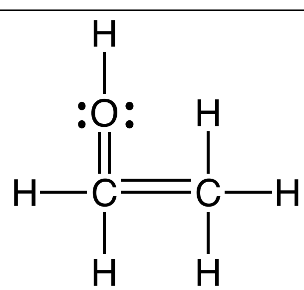
Use an Atomic Tile model to sketch a Lewis dot structures for each molecule in the space provided.

H_2O		CO_2	
CH_4		C_2H_4	
CH_2O		CH_3CH_2OH	
CH_3COOH		N_2O_2	

Summary Questions

Combustion of plant-derived ethanol (C_2H_6O) is one way people have thought about curbing CO_2 emissions. The hope is ethanol could be a “carbon neutral” fuel. Plants absorb CO_2 as they grow to form sugars. These sugars are fermented to form ethanol, which, when combusted releases, CO_2. As a result, the net change in CO_2 in the atmosphere is zero.

1.) Below are Lewis dot structures other students have proposed for C_2H_6O. Use your atomic tiles to predict which (if any) is likely a good structure for C_2H_6O. If a structure is not good explain what is wrong with it and think about what a student might be thinking to get this answer.

Proposed structure	Response
	
	
	
	
	

2.) Are there more than one “good” Lewis Dot structures?