Chemical Bonds

NC Standards

PS.8.1.1 & PS.8.1.5

Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

Students use cards labeled with element names and the valence numbers to investigate chemical bonds, compounds, and the Law of Conservation of Matter. This lesson takes two 50-minute periods.

Correlations to NC Science Standards

PS.8.1.1 Construct an explanation to classify matter as elements, compounds, or mixtures based on how the atoms are arranged in various substances.

PS.8.1.5 Use models to illustrate how atoms are rearranged during a chemical reaction so that balanced chemical equations support the Law of Conservation of Mass (in both open and closed systems).

Learning Target

Students will demonstrate knowledge and understanding of the following ideas and content:

- Compounds are a chemical joining of two or more elements based on giving or sharing electrons between atoms.
- The location of an element in the periodic table gives a clue about how it will form compounds.
- In a chemical reaction, atoms cannot be created or destroyed. This is known as the Law of Conservation of Matter.

Students demonstrate this knowledge and understanding by creating compounds using a simple valence number model. They find the elements of the compound in the periodic table and use the atomic model to explain bonding tendencies. They count the number of atoms for each element in both the products and reactants of various chemical reaction.

Brief Science Background

Chemical reactions involve rearranging electrons among different atoms. Atoms can donate or share electrons. An element's reactivity is based on the available or active electrons in unfilled outer electron shells. The least reactive elements, the noble gases on the far right of the Periodic Table, have full outer electron shells. As a result, they are chemically inactive. The valence number of an element is generally regarded as the maximum number of bonds that element can form. However, elements are not always constant in this number. The elements and valence numbers used in this activity were selected as general models for simple ionic (giving and accepting electrons) and covalent bonds (sharing electrons). The nomenclature of these interactions can be confusing. A compound is formed by chemical bonds between two or more different atoms. An element is a substance composed of just one kind of atom. A molecule is the combination by chemical bonding of any two or more atoms. O_2 is a molecule but, by definition, not a compound. A mixture is just that, a mixture of matter without chemical bonds that can usually be separated by mechanical means.

Part 1 — Chemical Bonds

Materials

Materials for the whole class

- large version of the periodic table (supplied by teacher) or photocopied versions for pairs of students

Materials for groups of 2 students

- a set of valence cards
- student activity sheet (SD1)
- science notebook

Preparation

1. Check valence card sets to make sure they are complete. Shuffle them. Each set should contain the following 27 cards:

4 Hydrogen	1 Sodium	1 Calcium
1 Lithium	1 Magnesium	1 Zinc
1 Carbon	2 Aluminum	1 Bromine
1 Nitrogen	2 Silicon	2 Iodine
3 Oxygen	3 Chlorine	1 Mercury
1 Fluorine	1 Potassium	

Procedure

1. Pass out the card sets to pairs of students and ask them to look at them. Ask students for their observations of what is on the card. They should note that there are element names on the card and a mention of what that element does with its electrons. With regard to electrons, explain: “Chemists figured out that when elements are involved in a chemical reaction, electrons are the active part of the atoms.”
2. Ask the students to organize the cards by what the elements like to do with electrons. Ask them to find the elements in their groups on the periodic table. Challenge the students to make some general rules about their observations. Students will notice that elements that like to do the same thing with electrons are in the same group. They will also note that electron donators are on the left and electron acceptors are on the right side of the table.
3. Say, “Somebody tell me a chemical formula name for a compound that everybody knows.” Somebody will say, “H_20.” When they do, take a little time to talk about such a formula and what the 2 signifies (2 hydrogen atoms, not 2 oxygen atoms).
4. Have students find one oxygen card and ask "What do you notice about the electrons for oxygen?" Oxygen accepts two electrons, which makes a -2.

Procedure Cont.

5. Have students find two hydrogen cards, and ask "What do you notice about the electrons for hydrogen?" Each hydrogen will give up an electron, that makes +2.
6. Have the students place them all together. Explain that they just created a compound. Ask "How many hydrogen cards are in our compound? How many oxygen cards are in compound?" Explain that each card represents one atom of that element. Therefore in H_20 there are two hydrogen atoms and one oxygen atom. We will use math here: In water one oxygen accepts two electrons (-2) and two hydrogens each give up an electron (+2). Therefore, the electrons in the water molecule add up to zero (-2 +2 = 0) and the molecule is balanced. When a compound is formed the electrons must balance in this way.
7. Ask students to try another compound that we all use, which is salt, or NaCl. Have them check the math and see if it comes out to 0. Have students write a general rule for the sum of electron donors and acceptors in a compound based on what they found in H_2O and NaCl.
8. Challenge students to use the element cards to create compounds with two or more different atoms. Ask them to record their compounds on their student activity sheet. Inform students that they have to be able to keep track of how many of each atom are in the compound and that they indicate this by writing the number as a subscript to the right of the element as in H_2O. Inform students if there is only one atom they do not place a subscript (H = 1 hydrogen atom). Most of the possible combinations are listed in SD 2: Sample Compounds.
9. Ask students to write their largest compound on the board and ask the class to check them for a zero balance.

Content Connection

Start with the simple compound H_2O and NaCl, and ask students to locate the elements they contain on the periodic table. Explain that early chemists realized that different elements could combine to make compounds, but they didn't know why some combinations were possible but other were not. After the development of the periodic table, the actual ways different elements combined (or didn't combine) started to make sense. This was because some elements, the ones in the same group, behaved chemically in one way, while other elements in a different group acted another way. The development of atomic theory and the understanding of how electrons behaved explained what people had noticed for a long time. For example, the ends of the rows (or periods) of the periodic table contained elements that had no active electrons because their outer shells were filled. With no electrons to either donate or accept, they could not form bonds with other elements.

Formative Assessment/ Guided Practice

Display the following formulas and ask the students to figure out if they can exist based on the idea of a zero molecule total: $NaHCO_3$ (sodium bicarbonate) and $H_2Al_3Si_2O_8$ (kaolin clay). They will not have enough of some of the cards so they will need to work mathematically.

Part 2 — Chemical Reactions

Materials

Materials for the whole class

- calcium chloride, $CaCl_2$
- sodium bicarbonate, $NaHCO_3$
- water
- phenol red
- candle in a 3.5 oz. plastic cup
- long match
- pint Mason jar with a new lid
- electronic balance

Materials for groups of 2 students

- a set of valence cards
- student activity sheet SD 3
- science notebook

Procedure

1. Have students find one sodium (Na) and one chlorine (Cl) card. Explain to students that when one sodium atom bonds with one chlorine atom it forms sodium chloride (NaCl). Sodium chloride is also known as salt. Ask students to explain how NaCl can exist based on what they have learned.
2. Write the equation Na + Cl --> NaCl on the board. Ask students a) what they notice about the number of Na atoms on the left side of the arrow and the number of Na atoms on the right side of the arrow and b) what do they notice about the number of Cl atoms on the left side of the arrow and the number of Cl atoms on the right side of the arrow?
3. Explain to students that in a chemical reaction atoms cannot be created or destroyed. They can only be rearranged. **The number of atoms for each element must be the same before and after the reaction.** This is called the Law of Conservation of Matter.
4. Have students find one sodium (Na) card, one chlorine (Cl) card, two hydrogen (H) cards, and one oxygen (O) card. Ask students to build the compounds HCl and NaOH and explain how those two compounds can exist based on what they know about electrons.
5. Write HCl + NaOH on the board and ask students to determine the total number of atoms for each element. Explain to the students that as a class they are going to look at when HCl and NaOH react together. Therefore HCl and NaOH are called reactants. When they combine they react and create the new compounds NaCl and H_2O. NaCl and H_2O are called products.
6. Write NaCl + H_2O on the board and ask the students to determine the total number of atoms for each element.
7. Write the complete equations HCl +NaOH --> NaCl +H_2O on the board. Tell students that the reactants are on the left side of the arrow and the products are on the right side of the arrow. Have students explain how the equation supports the Law of Conservation of Matter.

Content Connection

1. Explain that chemist often use different types of equipment to study a reaction. Remind students of the experiment from the activity chemical change. Inside the mason jar, carefully place the following:
    - 5 mL (1 teaspoon) of calcium chloride
    - 2.5 mL (1/2 teaspoon) of sodium bicarbonate
    - 5 mL of water and 10 drops of phenol red in a medicine cup.

    Tighten the lid down very hard. Take care when tightening the lid not to tip over any ingredients in the jar. You do not want a reaction yet.

2. Display the mason jar with lid on and explain that, in a few minutes, you will tip the jar to start the reaction. Before starting the reaction say, "Early chemists were interested in the amounts of reactants and products in reactions. If I weigh the jar before and after the reaction what might the results be?" Ask students for student answers and their reasoning. Weigh the jar and record the weight before the reaction. Inform students that the scale is accurate within 0.1 g.
3. Tip the jar and shake the reactants to start the reaction. Ask students to point out what is happening in the jar. Weigh the jar again. The weight should be unchanged. Say that other early chemists also observed this. If they caught all of the reaction products of any chemical reaction, the starting and ending weights were the same. Whenever all reactants and products are weighed and not allowed to escape, the setup always weights the same before and after. This is called conservation of matter. Remember in a chemical reactions, matter changes but is never lost. It is always "conserved."
4. Finish discussing all questions about conservation of matter and inform the class that we can investigate the gas that was produced.
5. Say, "We know some gas was produced because we saw bubbles. Early chemists often used a candle to test an unknown gas." Light a candle and place it in a 3.5 oz. plastic cup. Ask the class what could happen when you open the lid and pour the gas out of the jar and what each of the possibilities mentioned could indicated. Possibilities include:
    a. Nothing happens so the gas must be just like the air around us.
    b. The candle burns brighter so the gas contains more of what a candle needs to burn.
    c. The flame explodes, so the gas must contain some fuel.
    d. The candle burns dimmer, so it must not be like the air around us.
    e. The candle goes out so the gas must be something that inhibits burnings.

6. Open the lid slowly to release some pressure. Ask the class what the sound indicates. After the pressure is released, slowly tip the jar over the edge of the cup. You are pouring carbon dioxide, which is heavier than air. As the carbon dioxide fills the cup, the candle will go out. Be careful to not pour the liquid out of the jar. After the candle is extinguished light a long match and pace it in the jar and watch it extinguish.
7. Ask the class for detailed descriptions of what they have just observed. They should see that an invisible gas was poured out of the jar and it extin-guished the candle and then it extinguished a burning match.

Content Connection cont.

8. Ask for predictions on what the weight of the jar is now. The weight will be between several tenths of a gram and nearly a gram less. Once the jar was opened the gas dispersed into the larger area. This is an example of what happens in an open container when a gas is produced.

9. Ask what this tells us about the gas produced in the reaction. Students should notice that it has weight, it is invisible, it seems to be heavier than air (it pours down through the air) and it can extinguish a flame.

Formative Assessment/ Guided Practice

Guided Practices are similar to typical tests, but require students to reveal their thinking about content. They serve as a practice before a test and should not be graded. They are intended to expose misconceptions *before* an assessment and provide opportunities for discussions, re-teaching, and for students to justify answers. They are best given as individual assignments without the manipulative used in the activity. In the context, pose the following "test items" to the class.

1. A teacher was trying to convince students that conservation of matter always occurs in a chemical reaction. To do this, the teacher mixed vinegar and baking soda in a cup. Students had carefully weighed the ingredients and cup, and recorded the weights before the reaction. They combined the reactants in the cup and got a fizzing reaction. When the reaction was over, the class couldn't see any baking soda. However the sum of mixed compounds weighed less than it weighed before the reaction. The teacher still says that whenever a chemical reaction occurs, what you start with (reactants) and what you end with (products) have the same weight. Which explanation below would be best for students to use to help the teacher understand why the law of conservation of mass appeared not to work.
   a. Part of the cup dissolved into the vinegar so it all weighed less.
   b. The fizzing is a gas produced during the reaction, so she needs to catch the gas to weigh it.
   c. The baking soda disappeared so it all weighed less.
2. Students started proposing new experiments that would allow this reaction to prove the law of conservation of matter in a chemical equation. When experiment or combination of experiments might supply evidence supporting the law, and why?
   a. Do the reaction in a container made of glass.
   b. Do the reaction with more reactants so they are easier to weigh.
   c. Do the reaction in a container with a tightly closed lid.
   d. Weigh all reactants and products before and after the reaction.
3. Display the equation $NaHCO_3 + H_2O$ --> $NaOH + H_2CO_3$ and ask students to provide evidence that this equation supports the Law of Conservation of Matter.

SD 1 Chemical Bonds Student Activity Sheet

Name:

1. Record what you notice about the information on the cards.

2. Organize your cards into groups based on what the element does with its electrons. What patterns do you notice?

   How do these patterns relate to the structure of the Periodic Table?

3. Let's look at H_2O.

   What do you notice about the electrons for oxygen?

   What do you notice about the electrons for hydrogen?

   How many hydrogen atoms are present?

   How many oxygen atoms are present?

   Add the electron donation number(s) to the electron acceptor number(s). Record your total.

4. Let's look at NaCl.

   How many sodium atoms are present?

   How many chlorine atoms are present?

   Add the electron donation number(s) to the electron acceptor number(s). Record your total.

5. Based on what you found in H_2O and NaCl, write a general rule for the sum of electron donors and acceptors in a compound.

6. Now your challenge is to create your own compounds using your cards and following the rules you noticed above. Record your compound and show that you've added the donors and acceptors and calculated the sum.

   ex: H_2O +1 +1 -2 = 0

SD 2 Sample Compounds

Two elements, one atom each

Hydrogen Chloride (Hydrochloric Acid) .... HCl
Hydrogen Fluoride (Hydrofluoric Acid) .... HF
Lithium Bromide .... $LiBr$
Lithium Chloride .... $LiCl$
Calcium Oxide (Quicklime) .... CaO
Magnesium Oxide (Magnesia) .... MgO
Mercury Oxide (Mercuric Oxide) .... HgO
Potassium Bromide .... KBr
Potassium Chloride .... KCl
Potassium Fluoride .... KF
Potassium Iodide .... KI
Sodium Bromide .... $NaBr$
Sodium Chloride (Table Salt, Halite) .... $NaCl$
Sodium Fluoride .... NaF
Sodium Iodide .... NaI
Zinc Oxide .... ZnO

Two elements, more than one atom each

Calcium Chloride .... $CaCl_2$
Magnesium Chloride .... $MgCl_2$
Mercury Chloride (Mercuric Chloride) .... $HgCl_2$
Mercury Iodide (Mercuric Iodide) .... HgI_2
Silicon Dioxide (Quartz, Sand) .... SiO_2
Zinc Chloride .... $ZnCl_2$
Aluminum Chloride .... $AlCl_3$
Aluminum Oxide .... Al_2O_3

Three elements

Ammonium Chloride .... NH_4Cl
Calcium Carbonate (Lime, Limestone) .... $CaCO_3$
Magnesium Carbonate .... $MgCO_3$
Potassium Hydroxide .... KOH
Sodium Hydroxide (Lye, Caustic Soda) .... $NaOH$
Sodium Nitrite .... $NaNO_2$
Ammonium Hydroxide (Ammonia) .... NH_4OH

Four elements

Potassium Bicarbonate .... $KHCO_3$
Sodium Bicarbonate (Baking Soda) .... $NaHCO_3$
Kaolin clay .... $H_2Al_2Si_2O_8$

SD 3 Chemical Reactions Student Activity Sheet

Name:

1. Based on what you learned in Part 1 about electrons, explain how NaCl can exist.

2. What do you notice about the numbers of Na atoms on the left side of the arrow and the number of Na atoms on the right side of the arrow?

   What do you notice about the numbers of Cl atoms on the left side of the arrow and the number of Cl atoms on the right side of the arrow?

3. Explain how the compounds HCl and NaOH can exist based on what you know about electrons.

4. Write down the total number of atoms for each element.

   HCl + NaOH **H =** **Cl =** **Na =** **O =**

5. Write down the total number of atoms for each element.

   NaCl + H_2O **H =** **Cl =** **Na =** **O =**

6. The chemical equation for the complete reaction is below. Explain how this equation supports the Law of Conservation of Matter.

$$HCl + NaOH \rightarrow NaCl + H_2O$$