Unit 8: Chemical Reactions

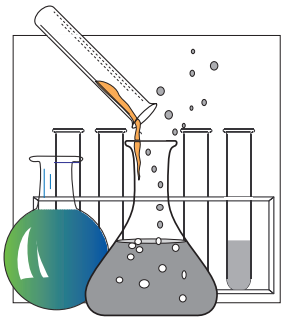
This unit emphasizes the factors that control and affect chemical reactions. Students will learn to represent the configurations of electrons for atoms and compounds and learn how these configurations determine what reactions are possible. Students are introduced to some concepts in biochemistry and are shown how biochemical reactions follow other chemical laws.

Student Goals

- Know that electron configuration in atoms determines how a substance reacts and how much energy is involved.
- Explain how physical factors affect the rates of reactions.
- Determine the electron dot structures for selected atoms and molecules and discuss how the electrons determine what type of bond is formed.
- Know that diversity in the bonds between atoms determines the properties of molecules.

Unit Focus

- Know that the number and configuration of electrons will equal the number of protons in an electrically neutral atom and when an atom gains or loses electrons, the charge is unbalanced. (SC.A.2.4.1)
- Know that the electron configuration in atoms determines how a substance reacts and how much energy is involved in its reactions. (SC.A.1.4.1)
- Know that the vast diversity of the properties of materials is primarily due to variations in the forces that hold molecules together. (SC.A.1.4.2)



Vocabulary

Use the vocabulary words and definitions below as a reference for this unit.

atom ..... the smallest unit of an element that is still that element; the basic building block of matter

biochemistry ..... the study of chemicals directly related to life processes

bond ..... the attraction that holds two or more atoms together

catalyst ..... a material or substance that increases the efficiency of a reaction without being consumed within the reaction

chemical equation ..... a shorthand, symbolic way of telling about a chemical reaction using symbols and formulas
Example: **NaOH + HCl → NaCl + H_2O**

compound ..... a substance formed when two or more elements combine chemically

covalent bond ..... a bond between atoms that is made when atoms share their outermost electrons

DNA (*d*eoxyribo*n*ucleic *a*cid) ..... a complex molecule that controls many functions of living organisms

electron ..... the negatively charged particle of an atom; the electron moves around the center of the atom (nucleus)

electron configuration ..... the number and location of electrons; it determines how substances react and how much energy is involved in these reactions

electron dot structure ..... a model that represents the electron configuration of atoms; it can be used to make predictions about the bonds between atoms

element ..... a substance that cannot be broken down into a simpler form by ordinary chemical means

energy level ..... most likely location where the electron can be found around the center of the atom; any of the possible energies an electron may have in an atom

gas ..... the form of matter that has no definite shape or volume

ion ..... an atom or group of atoms that has lost or gained one or more electrons and therefore has a net electric charge

ionic bond ..... a bond between atoms that is formed when atoms gain or lose electrons; by gaining or losing electrons, the atoms become ions

law of conservation of mass ..... the law that matter cannot be created or destroyed, only changed from one form to another during a physical or chemical change

molecule ..... two or more atoms that have a bond of shared electrons

nucleus ..... the center region of an atom around which the electron(s) move

organic ..... a chemical compound used by living organisms that contain carbon

pressure ..... the amount of force acting on a substance
Example: When divers reach the bottom of a pool, the water exerts force against them. This force is often felt as a push against the ears and other body parts.

proton ..... the positively charged particle in the nucleus of an atom

valence electrons ..... the electrons in an atom's outermost energy level that are involved in the forming of bonds

Introduction

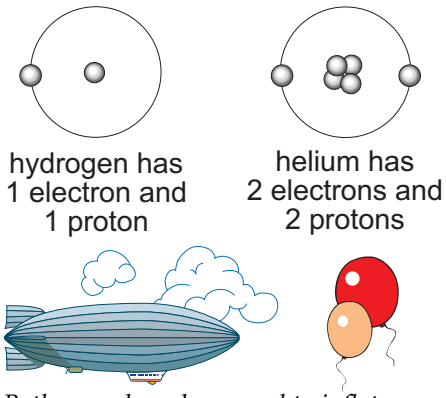
Chemical equations are a shorthand, symbolic way of telling about a chemical reaction. In other words, they describe chemical reactions. The simplest type of reaction takes place when two or more **elements** combine to form a **compound**. There are other kinds of reactions that occur between *elements* and *compounds*. Chemical reactions are the results of the properties and arrangement of **electrons**. All reactions follow the **law of conservation of mass** discussed in Unit 5: Chemical Formulas and Equations. This unit will discuss the factors that control and affect reactions.

The Role of Electrons

Whenever a reaction takes place, *electrons* control and determine what will happen. Some **atoms** have only a few electrons, such as hydrogen (one electron) and lithium (three electrons). Other *atoms* have many electrons, such as gold (79 electrons) and lead (82 electrons). It is not just the number of electrons, however, that determine how an atom will react. Let's compare two elements, hydrogen and helium, and see how they behave.

Hydrogen has one electron and one **proton**. Helium has two electrons and two *protons*. These are the two lightest elements. You might expect for there to be many similarities between the two elements. Both are **gases** and both are colorless and odorless. Additionally, both have been used to inflate balloons and zeppelins (sometimes called blimps). In this regard, because both elements are similar, they have similar uses.

The Two Lightest Elements

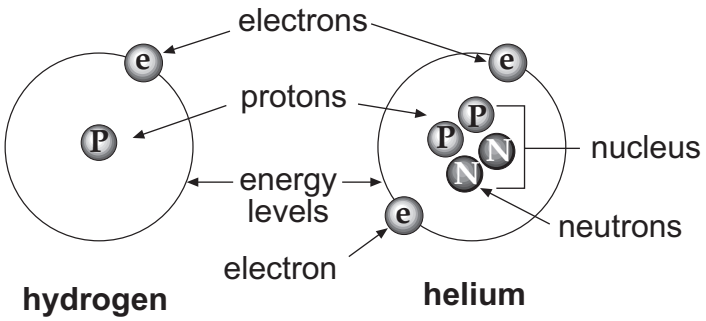


Both gases have been used to inflate balloons and zeppelins (sometimes called blimps).

If you take a moment to glance through previous chapters, though, you may notice something. Hydrogen is continually mentioned as being included in other compounds and **molecules**. The chemical symbol for helium is He. You won't find it in other compounds because of the way its electrons are configured. Hydrogen, on the other hand, is in literally thousands of compounds. Again, this is because of its **electron configuration**.

Electron Configuration

Remember that an atom's electrons are on the outside of the atom. Let's look at the *electron configurations* of hydrogen and helium:



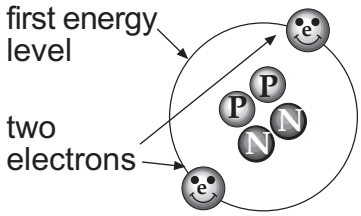
electron configurations of hydrogen and helium

The space or region that the electrons travel as they move around the **nucleus** of the atom is the **energy level**. In the cases of hydrogen and helium, there is only one *energy level*. An electron in the outermost energy level of an atom is called a **valence electron**. The *valence electrons* are the electrons that are involved in making **bonds** with other atoms. The properties of the different elements depend upon how many electrons are in the various energy levels of their atoms. The chemical bonding (combining) ability is determined by the arrangement of the electrons in the outermost energy level. Remember that it is the making and breaking of *bonds* that causes chemical reactions.

In the case of both hydrogen and helium, we can make some rules about electron configuration.

> One of the most important rules is a *tendency* to have two electrons in the first energy level.

In some ways, you can almost think of the atoms as *wanting* two electrons. When they have the two electrons, the tendency is fulfilled. In a sense, this might be compared to giving a person something that he wants. It might make him happy.



Two electrons in the first energy level compares to a happy person getting something they want.

Compare the configuration of hydrogen and helium. Helium already has two electrons. Because of this configuration, helium does not take part in chemical reactions. In fact, it is often used because it will not react. You may have heard of the *Hindenburg*. This was a large zeppelin used to transport people between Europe and the United States. While landing, the hydrogen *gas* used to inflate the zeppelin ignited. The fire spread quickly, and the zeppelin fell to the ground. Today, modern zeppelins and blimps are inflated with helium. Regardless of the amount of spark or heat, helium will not burn. This makes it safer for use in aviation.

Today, modern zeppelins and blimps are inflated with helium.

The reactivity of hydrogen is based on the fact that it has only one electron in its outermost energy level. This means that it will readily react with other atoms. By doing this it can share an electron and fulfill its tendency to have two electrons. One more rule we can make about hydrogen's and helium's electron configuration is as follows:

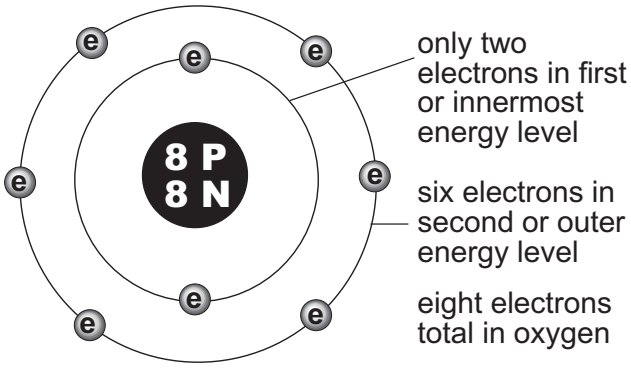
> They can have no more than two electrons.

Let's see how this rule works.

Making Water

Hydrogen and oxygen combine to make water. By now, you are familiar with this reaction. To fully understand the properties of water, we must look at the way the *molecules* of water are made. Let's look at the electron configuration of oxygen.

electron configuration of oxygen

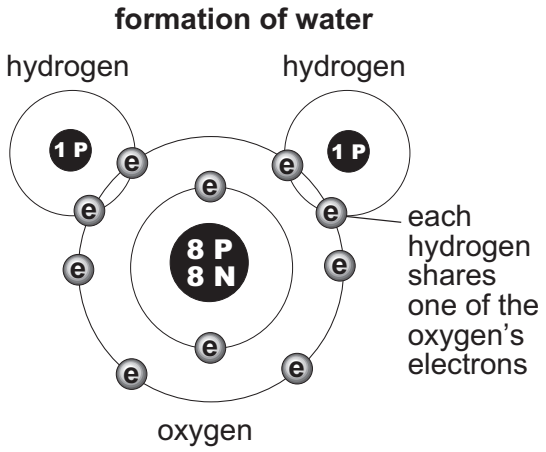


You will see that oxygen has two electrons in its innermost energy level. Regardless of the element, there can be no more than two electrons in this first energy level. Oxygen has

eight electrons, so there are six in its second energy level. There are a few other rules describing electron configuration. These apply to other atoms besides those of hydrogen and helium. These rules are as follows:

- Atoms can have up to eight electrons in their outermost energy level but no more. Atoms with eight valence electrons usually do not react.
- Atoms that have fewer than four electrons in their outermost energy level tend to give up electrons.
- Atoms that have four or more electrons in their outermost energy level tend to gain electrons.

Using these rules, what predictions can you make about oxygen? If you said that it will tend to gain electrons you did well. How many electrons could hydrogen have in the case of water? If you said two, you are right.



When water and hydrogen combine to form water, the oxygen shares electrons with hydrogen. The result is that each hydrogen shares one of the oxygen's electrons. This effectively gives each hydrogen two electrons in its outermost energy level. Because the electrons are being shared, oxygen shares the electrons of hydrogen. The result is that oxygen has eight electrons in its outermost energy level.

Practice

Match each definition with the correct term. Write the letter on the line provided.

_____ 1. the negatively charged particle of an atom

_____ 2. the form of matter that has no definite shape or volume

_____ 3. the electrons in an atom's outermost energy level that are involved in the forming of bonds

_____ 4. the positively charged particle in the nucleus of an atom

_____ 5. the smallest unit of an element that is still that element

_____ 6. the center region of an atom around which the electron(s) move

_____ 7. the attraction that holds two or more atoms together

_____ 8. the number and location of electrons

_____ 9. most likely location where the electron can be found around the center of the atom

_____ 10. a substance that cannot be broken down into a simpler form by ordinary chemical means

A. atom

B. bond

C. electron

D. electron configuration

E. element

F. energy level

G. gas

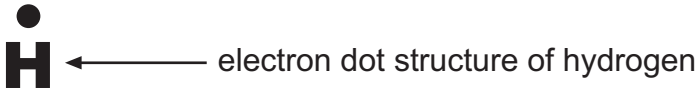
H. nucleus

I. proton

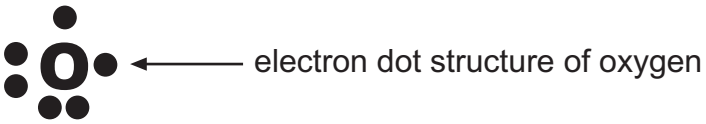
J. valence electrons

Electron Dot Structures

Picturing the way the rules on page 172 function can be difficult. Because of this, we have a model we can use called **electron dot structures**. *Electron dot structures* model atoms. The model represents the electron configuration of atoms. Electron dot structures are used to make predictions about the bonds between atoms. For instance, hydrogen has one electron. Below is the dot structure of hydrogen.

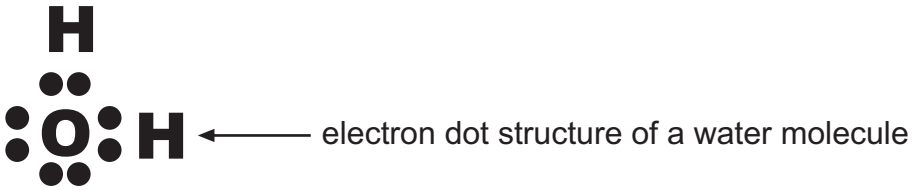


The *electron dot structure* of oxygen is below.



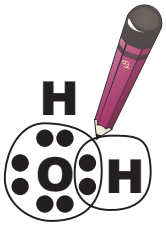
Notice that the structure only shows six electrons. This is because only six of oxygen's electrons are in its outermost energy levels. Only electrons in outermost energy levels are involved in chemical reactions. For this reason, the electron dot structure of oxygen does not show oxygen's two innermost electrons.

Now let's look at the electron dot structure of a water molecule:



- Take a pencil and draw a circle around the electrons that are on the edges of the oxygen molecule.
- Count the number of electrons. You should have counted eight electrons.

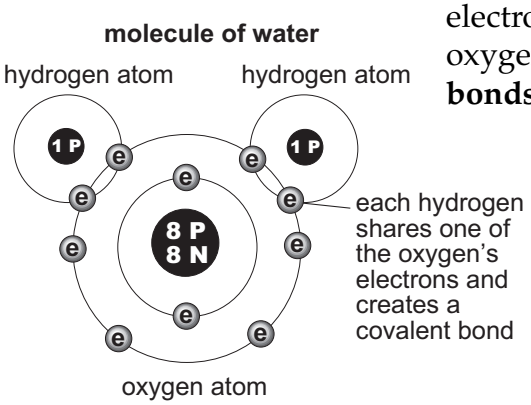
- Now, choose one of the hydrogen atoms.
- Circle the electrons that are around the hydrogen atom.
- Count them. You should have counted two electrons.



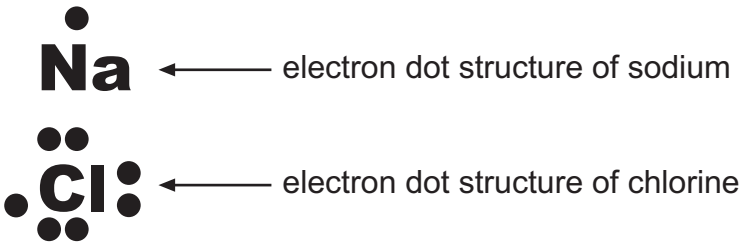
This is the way that the atoms share the electrons.

Other Bonds

The first example we have shown was a molecule of water. Remember that a molecule is two or more atoms that share electrons. With the electron dot structures, we showed that hydrogen and oxygen share electrons. The bonds created between oxygen and hydrogen were **covalent bonds**. The valence electrons were shared.

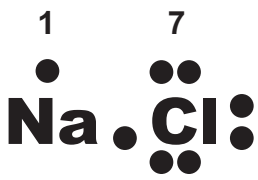


In the cases of salts, the bonds between the atoms are not covalent. In sodium chloride (table salt) chlorine does not share electrons with sodium. Instead, sodium is bonded to chlorine by an ionic attraction. An atom becomes ionized when it gains or loses electrons. If an atom gains or loses electrons, it no longer has the same number of electrons (-) as it does protons (+). Because the charges do not cancel as they did before, the **ion** that forms has a net electric charge. It is the opposite charges of the chlorine and sodium that bond them together. They have an **ionic bond**. To determine which atom has which charge, let's look at their electron dot structures:



Notice that sodium has only one valence electron. Chlorine has seven valence electrons. As our rules about electron configuration tell us, both

atoms could have up to eight electrons in their outermost energy level. The rules also tell us that sodium is more likely to lose one electron than gain seven.



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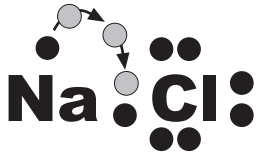


The rules tell us that sodium is more likely to lose one electron than gain seven.

Chlorine is more likely to gain one electron than lose seven.

Chlorine, on the other hand, is more likely to gain one electron than lose seven. The structure of sodium chloride is below:

In this structure, we see that chlorine now has eight electrons. The chlorine now has one more electron than protons. Because electrons have a negative charge, the chlorine now has a negative charge. The sodium has lost an electron. It now has one more proton than electrons. The sodium has a positive charge. It is the opposite charges of the atoms that bond them.

Properties of Substances

The properties of salts and water are very different. Largely these properties are based on the bonds between the atoms. For instance, water is a molecule because it has *covalent bonds*. These bonds are stable. Water does not spontaneously change into another substance. Table salt, on the other hand, has *ionic bonds*. When this salt is put in water, the bonds are broken.

Think back to your study of the periodic table. Remember that atoms of elements in the same group have the same number of valence electrons. So these elements have similar properties.

The properties of various materials is in large part based on electrons. Electrons determine when and how bonds will be formed. They determine when a bond will release or absorb energy. They determine what the properties of the materials will be. Chemical reactions are the results of the activity of electrons.

Other Factors Affecting Chemical Reactions

Other factors affect when electrons can or cannot be involved in reactions. Certain conditions make the reactions occur more quickly and completely. These include the following:

Pressure: When gases are reacting, increasing **pressure**, or the amount of force upon the gasses, increases the chance that atoms will come in contact. The increase in *pressure* improves the speed of the reaction.

Temperature: When temperature rises, atoms more frequently come into contact. Raising temperature will increase the speed of a reaction.

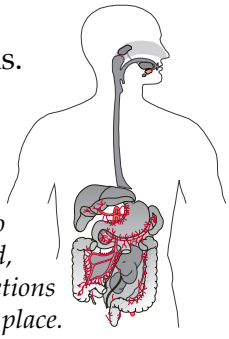
Catalyst: A **catalyst** will enable a reaction to occur at lower temperature and/or pressure. This saves effort and energy. *Catalysts* can also improve the speed and completeness of a reaction, but there are not catalysts for all reactions. The lack of a catalyst can slow other reactions that usually require a catalyst.

Concentration: By increasing the amount of substance in a solution, the speed of a reaction is increased.

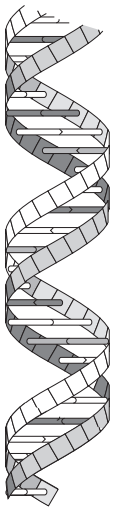
Chemistry in the Body

The factors affecting reactions are especially important in **biochemistry**. The study of the chemistry of living organisms is very complex. The human body, for instance, contains thousands of separate chemicals. In order to digest food, think, or move, many reactions must take place.

Thinking, moving, or digesting are all processes. Each is regulated by a complex series of specific chemical reactions. These reactions, however, must be controlled. Imagine what would happen if your digestive system did not function when you ate food. Your food would rot inside you. The effects would be both unpleasant and painful. Fortunately, healthy people have biochemical responses to food. They digest after they have eaten. When the food is digested, the process stops.



In order to digest food, many reactions must take place.



DNA model

You may wonder how this is all coordinated. Within your body is a chemical code that controls such processes. This code is in a complex molecule known as **DNA (*d*eoxyribo*n*ucleic *a*cid)**. Your *DNA* came from your parents. Like most other molecules in your body, it is **organic**. *Organic* molecules are produced or used by living organisms and contain the element carbon. DNA is the code that controls many of your body's functions.

As we noted, DNA is complex. You might imagine it as a thick book of instructions on how to operate a computer. The person who wrote the book didn't know how you would try to use the computer. Instead, the author tried to include instructions for every process. The result is a thick, complicated book. Now, consider the book again. It is made of only 26 letters. Although there are only 26 letters, they can make hundreds of thousands of words.

The substances that comprise DNA are like the letters in the book. They are combined in one way and then recombined in other ways. The result is that your DNA is very long and complex. This complexity allows your body to cope with all of life. Incredibly, though, there are only four basic units in DNA. That is like trying to write your book with only four letters!

These four substances, though, are like many other organic substances. They can serve many purposes. The important thing is how they are combined with other chemicals. Just like other reactions, each new combination has unique properties.

Summary

Chemical reactions occur when atoms share or transfer electrons. The sharing or transferring of electrons is based on the configuration of electrons. Electron dot structures model these configurations. The properties of substances are based on the configurations of their electrons. Factors such as temperature, concentration, pressure, and catalysts affect the speed of reactions. Reactions within a human body also follow biochemical principles. These organic chemicals can be combined and recombined in many ways.

Practice

Circle the letter of the correct answer.

1. The _____ is a model that represents the electron configuration of atoms. (Hydrogen is $\dot{H}$)

   a. organic dot structure
   b. electron dot structure
   c. gas dot structure

2. The bonds created between oxygen and hydrogen were _____ because the valence electrons were shared.

   a. covalent bonds
   b. atomic bonds
   c. electronic bonds

3. If an atom gains or loses electrons, it no longer has the same number of electrons (-) as it does protons (+). Because the charges do not cancel as they did before, the _____ that forms has a net electric charge.

   a. proton
   b. catalyst
   c. ion

4. An _____ is a bond between atoms that is formed when atoms gain or lose electrons.

   a. ionic bond
   b. organic bond
   c. electron bond

5. When gases are reacting, increasing _____ increases the chance that atoms will come in contact.

   a. gases
   b. pressure
   c. bonds

6. A _____ is a material or substance that increases the efficiency of a reaction without being consumed within the reaction.

   a. catalyst
   b. nucleus
   c. proton

7. The factors affecting reactions are especially important in _____ , which is the study of chemicals directly related to life processes.

   a. algebra
   b. reactionary
   c. biochemistry

8. Within your body is a chemical code that controls many functions of living organisms. It is known as _____ .

   a. DNA
   b. CC
   c. LAF

9. _____ molecules are produced or used by living organisms and contain the element carbon.

   a. Ion
   b. Organic
   c. Catalyst

Practice

Answer the following using short answers. Give examples where indicated.

1. What part do electrons play in chemical reactions?

   _____

   _____

   _____

2. What is electron configuration? _____

   Example: _____

   _____

3. What does an electron dot structure model? _____

   Example: _____

   _____

4. Which elements have only one energy level of electrons? _____

   _____

5. What is the greatest number of electrons the element chlorine can have in its outermost energy level?

   _____

   Why? _____

   _____

6. What type of bond is formed when atoms share electrons?

   _____

7. What type of bond is formed when atoms transfer electrons and create atoms with charges?

_____

8. What causes many of the differences between substances?

_____

_____

9. How would increasing the pressure of two gases affect the way they react?

_____

_____

10. What effects might you expect if you added a catalyst to a reaction?

_____

_____

_____

11. What would happen if your digestive system did not function when you ate food?

_____

12. DNA, like other organic compounds, contains what element?

_____

13. The code of DNA controls what? _____

14. The four substances that make up DNA are a good example of how organic compounds can do what?

_____ and _____

Practice

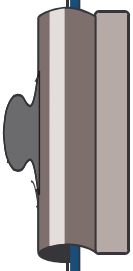
Use the **electron dot structures** *below to determine if the elements can react with other elements. (Remember, you must know how many* **valence electrons** *an element can possess. Refer to pages 170-172 and 174-176.) Make a check mark in the appropriate box.*

		structure	react	not react
1.	helium			
2.	sodium			
3.	calcium			
4.	argon			
5.	krypton			
6.	carbon			

Predict whether an atom will gain or lose **electrons** *in a* **reaction** *by checking the appropriate box. Again, refer to page 170-172 and 174-176 for assistance.*

		number of electrons	gain	lose
7.	carbon	4		
8.	magnesium	2		
9.	fluorine	7		
10.	potassium	1		

Lab Activity: Concentration of Substances and Speed of Reaction



Facts:

- The concentration of substances affects the speed and completeness of reactions.

Investigate:

- You will determine how the concentration of vinegar (an acid) affects its reaction with baking soda (a base).

Materials:

- 120 grams of baking soda
- 2 uninflated balloons
- 150 mL of vinegar
- 50 mL of water
- 2 two 150 mL flasks

1. Place 60 grams of baking soda in 1 balloon.
2. Place 50 mL of vinegar and 50 mL of water in 1 flask.
3. Label the flask as Flask A.
4. Without spilling baking soda into the solution, place the balloon over the mouth of the flask. Set the flask aside.
5. Place 60 grams of baking soda in the second balloon.
6. Place 100 mL of vinegar in the second flask.
7. Label the flask as Flask B.
8. Without spilling baking soda into the solution, place the balloon over the mouth of the flask.
9. Which flask has the greater concentration of vinegar? _____

10. Set both flasks in front of you. Watching carefully, lift both balloons so that the baking soda falls into the vinegar and water solution. Let go of the balloon.

11. Which balloon inflated more quickly? _____

12. Using check marks, record your data in the chart below:

	Flask A	Flask B
greater concentration		
lesser concentration		
faster reaction		
slower reaction		

13. What relationship exists between reaction speed and concentration?

_____

_____

_____

Practice

Use the list above each section to complete the statements in that section.

covalent	**electrons**	**two**
eight	**ionic bonds**	**valence**
electron dot structure		

1. Chemical reactions depend on the configurations of _____ .

2. Hydrogen and helium can have no more than _____ electrons in their outermost energy level.

3. The electrons in an atom's outermost energy level are known as _____ electrons.

4. The atoms of carbon or oxygen may have as many as _____ electrons in their outermost energy level.

5. _____ can be used to model how the electrons of an atom are arranged.

6. In water, the bonds between hydrogen and oxygen are _____ because the electrons are shared.

7. _____ can be found in substances such as salts, where electrons are transferred and not shared.

biochemical	**concentration**	**increase**
carbon	**force**	**recombine**
catalyst		

8. Pressure is the amount of _____ acting on or pushing against a substance.

9. If the pressure of two gases is raised, the speed of a reaction between them will _____ .

10. A _____ can increase the speed of a reaction or enable a reaction to occur at a lower temperature or pressure.

11. If the speed of a reaction is increased by raising the amount of substances in solution, then the _____ has been increased.

12. Body processes involve specific reactions that are controlled by _____ principles.

13. Organic molecules are vital to living organisms. All of them include the element _____ .

14. The ability of the compounds in DNA to combine and _____ makes it possible for DNA to be highly complex.

Answer the following using short answers.

15. By lowering temperature, pressure, or concentration, the speed and completeness of reactions can be lowered. When food spoils, a chemical reaction has taken place. What common method of food storage helps prevent spoilage and why?

_____

_____

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16. Welding aluminum can be difficult because aluminum reacts with oxygen. To prevent this, the area being welded is flooded with helium gas. The helium displaces oxygen and prevents it from reacting with the aluminum. Why doesn't helium react with aluminum?

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17. Internal combustion engines pressurize a mixture of air and gasoline that react by burning. This burning provides the engine with power. Why does the engine provide more power if the gasoline and air are pressurized?

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18. Many industrial chemical reactions involve solutions of acids or bases. In many cases, the speed and completeness of the reaction must be high for the industry to make money. What relationship does this need have with the fact that many industrial chemicals are highly concentrated?

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