Unit 10
Chemical Reactions

Mrs. Valentine

Physical Science

Section 1
Evidence for Chemical Reactions

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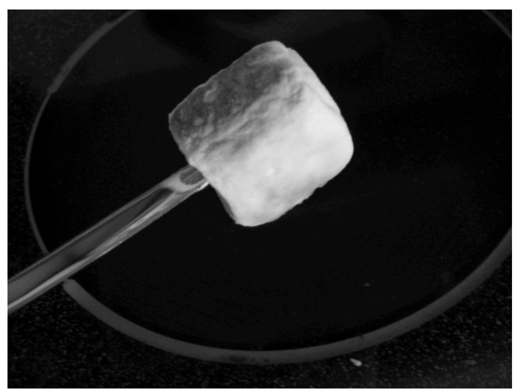
  doing some right now in our bodies.

- Picture yourself toasting marshmallows over a fire.
- How do you know when it's done?
- How do you know if it's over-done?


- Like roasting marshmallows, other chemical reactions involve two main kinds of observable change.

Changes in Properties

- One way to detect chemical reactions is to observe changes in the properties of the materials involved.
- These determine what new substances form.
- Some possible changes that you might see include:
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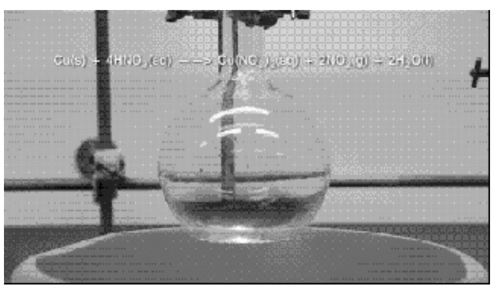
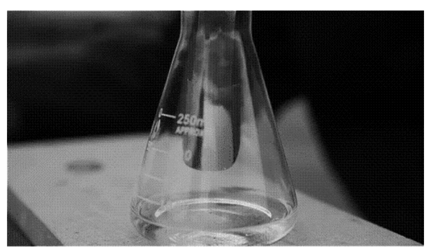
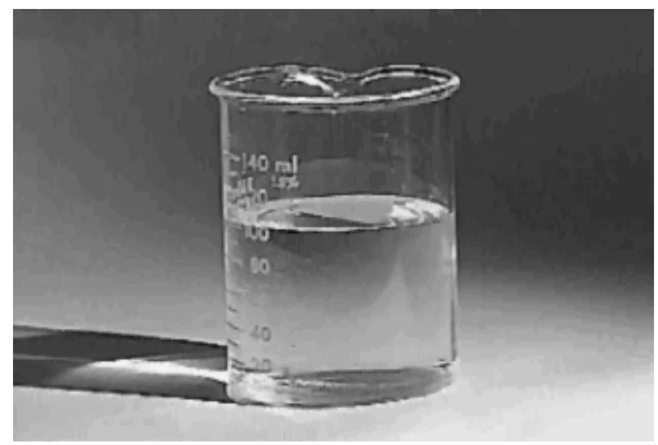
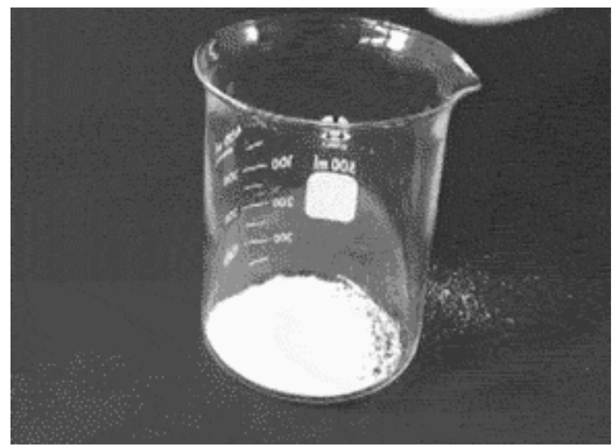




- <u>Precipitate</u> – A solid that forms from solution during a chemical reaction.

Changes in Properties

- Some of these changes may be an indicator of a chemical reaction, but it is not always a guarantee.
- Some physical changes can give similar results.

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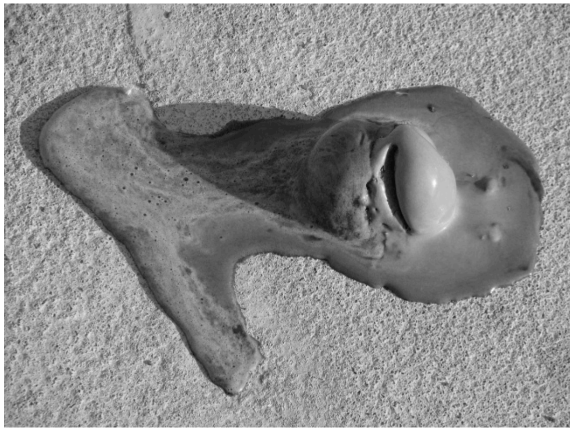
is the production of new materials with properties that are different from those of the starting materials.

Physical vs. Chemical Change Practice (on p.4 in packet)

- Identify whether each of the following is a chemical or physical change, and explain how you know.



Exploring: Evidence for Chemical Reactions

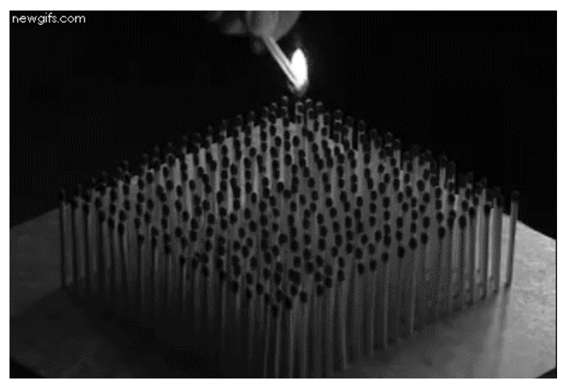
- Why is the formation of a precipitate an indication of a chemical change?

- When the water boils, a gas is produced, but it is still water. This makes this change a physical change.

- Is baking a chemical or a physical change?

Changes in Energy

- You are exposed to various types of energy every day.
- As matter changes, it either can absorb energy or release energy.
- **The second observable characteristic of a chemical reaction is a change of energy. Some reactions absorb energy, while others release energy.**



Changes in Energy

- **Definition:** Endothermic Reaction – A reaction (either chemical or physical) that absorbs heat.

- Examples of endothermic reactions –
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  -
  -

- **Definition:** Exothermic Reaction – A reaction (either chemical or physical) that gives off heat.

- Examples of exothermic reactions –
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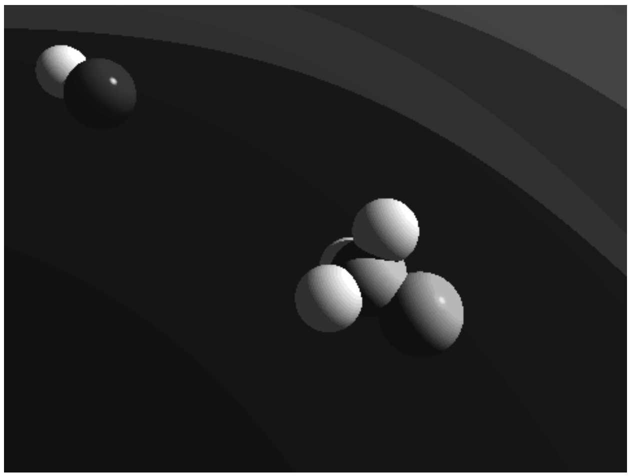
Chemical Reactions on a Small Scale

- Like the tides change a beach, chemical reactions occur one small step at a time.



- chemical change, we are detecting the combined effect of countless small, invisible changes involving the rearrangement of atoms.

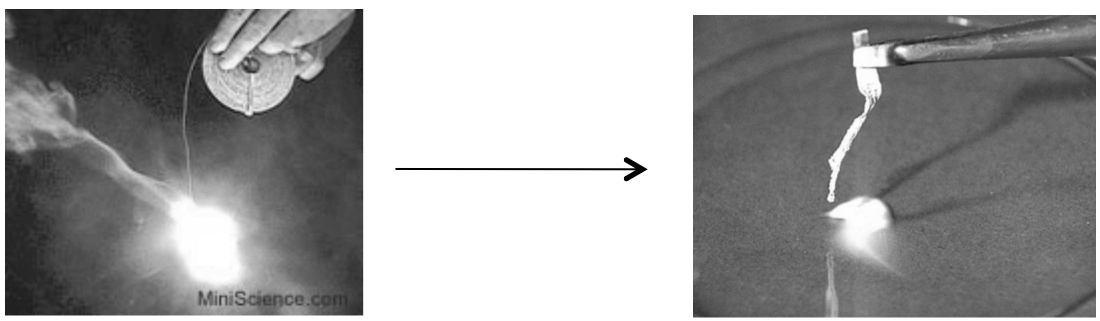
- **Chemical reactions occur when chemical bonds break or when new bonds form**.

- All reacting atoms must come into contact with one another.

Chemical Bonds and Chemical Reactions

- The types of atoms present and the types of chemical bonds formed in a substance determine its properties.

- For example, let's look at the reaction between magnesium and oxygen.



- The magnesium has two valence electrons, and the oxygen is "hungry" for two electrons, so they react rather rapidly together.

Chemical Bonds and Chemical Reactions

- The magnesium oxide (MgO) is an ionic compound with properties that are different from both magnesium and oxygen.
- For example, magnesium melts at about 650°C. Magnesium oxide needs a much higher temperature to melt (2800°C).
- The chemical bonds of a substance also determine whether or not a chemical reaction will occur under certain conditions.
- Example – How windows and wood fair under the weather.

Section 2
Writing Chemical Equations

- Symbols are typically universal. If you look at the signs below, you can easily tell what each one means.



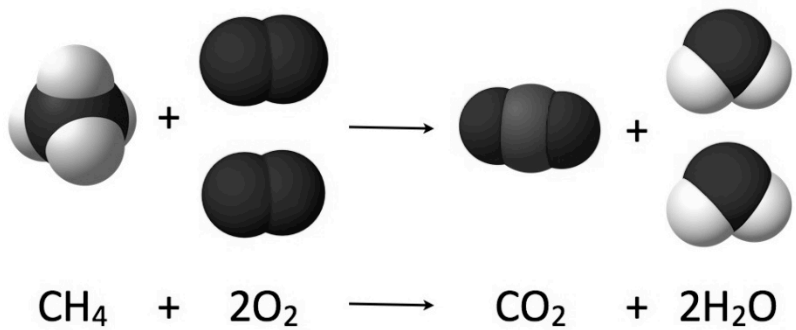

- Symbols represent a concept in shorter form.

- For example, “Hydrogen reacts with oxygen to produce water molecules” can be shortened to the following:

$$H \ \ +O \longrightarrow H \ O$$

Writing Chemical Equations

- **Definition:** Chemical Equation – A shorter, easier way to show chemical reactions, using symbols instead of words.



- While chemical equations are shorter than sentences, they typically contain more information.
- This is partly because they use chemical formulas and other symbols in place of the words.
- There is a common structure to chemical equations.

Writing Chemical Formulas

- You know that when writing the symbol for a compound, the letter symbols represent elements.

- Notice that the numbers in a formula are written smaller and lower than the letter symbols.

- **Definition:** <u>Subscripts</u> – the numbers that are smaller and lower than the letter symbols. They show the ratio of different elements in a formula.

$C_2H_4O_2$ Symbols

Subscripts

- If a letter symbol in a formula does not have a number, than it is understood that there is one atom of that element in the molecule.

Writing Chemical Formulas

- For example, CO has one carbon and two oxygen atoms. There are three atoms altogether.
- Besides identifying a compound, a formula also shows the ratio of the different atoms that make up that substance.
- For example –

Fe_2O_3 → 2:3 Fe:O

$C_6H_{12}O_6$ → 1:2:1 C:H:O

- Try to find the ratios of elements in the following compounds:

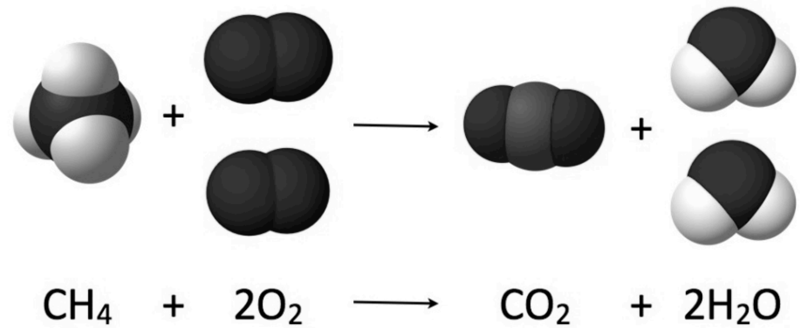
C H   H O   C H O

Structure of an Equation

- A chemical equation summarizes a reaction. It tells you what you are starting with, and what you are ending with.
- **Definition:** Reactants – the materials you have at the beginning of a reaction.
- **Definition:** Products – the materials you have at the end of a reaction.
- **A chemical equation uses symbols to show the reactants and the products of a reaction.**

Structure of an equation

Reactant + Reactant



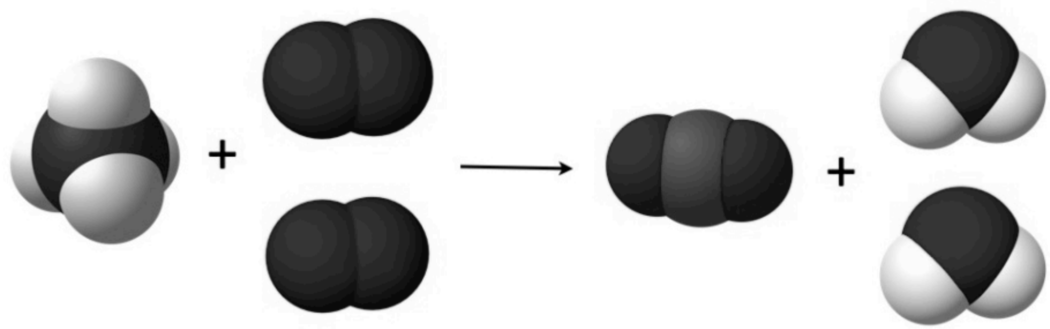
- number of each is determined by what the scientist adds to the reaction.

- What is the number of reactants and products in the following reactions?

1 reactant	CaCO	CaO + CO	2 products
2 reactants	NaOH + HCl	H O + NaCl	2 products
2 reactants	2H + O	2H O	1 product

Conservation of Mass

- No matter how many reactants and products are involved in a reaction, all atoms present at the start of a reaction are present at the end of the reaction.



$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

- There are the same number of carbon atoms, hydrogen atoms, and oxygen atoms on both sides of the above reaction.

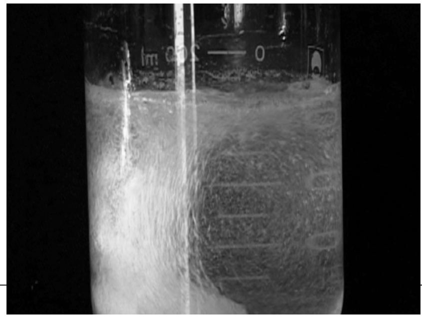
Conservation of Mass

- **Definition:** Principle of Conservation of Mass – The amount of matter involved in a chemical reaction does not change. The total mass of the reactants must equal the total mass of the products.

- In other words, mass is neither created nor destroyed.

- So what happened if you don't have the same amount of mass left in your beaker?

- Some of the mass probably escaped as a gas.



Balancing Chemical Equations

- Since the same number of atoms must exist in the products as in the reactants, a chemical equation must show the same number of atoms on both sides.

$$H \;\; + O \qquad H \; O$$

	Reactants	Products
H	2	2
O	2	1

- This reaction is obviously not balanced. Therefore, we must use coefficients to balance the equation.

Balancing Chemical Equations

- **Definition:** <u>Coefficient</u> – the number placed   of a chemical formula in an equation.

- We have already counted the number of atoms of each element on both sides of the equation. Now, we must start by trying to balance them out.

- In this case, we should put a 2 in front of the water molecule to balance out the oxygen atoms.

H + O   2H O

	Reactants	Products
H	2	~~2~~ 4
O	2	~~1~~ 2

Balancing Chemical Equations

- Now we have the same number of oxygen atoms on both sides, but an uneven number of hydrogen atoms.

- Since we have two more hydrogen atoms on the product side, we should increase the coefficient of H by 1. This will give us a coefficient of 2.

$$2H \;\; + O \qquad 2H \; O$$

	Reactants	**Products**
H	~~2~~ 4	~~2~~ 4
O	2	~~1~~ 2

- Now we have the same number of atoms on both sides of the reaction for all element types. We can say this equation is balanced.

Practice Problems (on p.4 in packet)

- C + Cl   CCl

Therefore, we should put a 2 in front of the Cl on the reactant side.

C + 2Cl

	Reactants	Products
C	1	1
Cl	~~2~~ 4	4

- Al O   Al + O

The least number that both 2 and 3 divide into is 6, so we should aim for 6 O on both sides.

2Al O   Al + 3O

	Reactants	Products
Al	~~2~~ 4	~~1~~ 4
O	~~3~~ 6	~~2~~ 6

Now we have an even number of O, but not Al. Therefore, we should put a 4 in front of Al on the product side.

2Al O   4Al + 3O

Classifying Chemical Reactions

- Chemical reactions can be classified by what happens to the reactants and products.

- Substances may combine to form new ones, decompose, or simply rearrange.

- **Many chemical reactions can be classified in one of four categories: synthesis, decomposition, replacement, or combustion.**

- As we explore these kinds of reactions, try to note how each changes from reactants to products.

Synthesis

- Let's listen to a synthesizer for a moment.

- Note how the different sounds are coming together to form a new, more complicated piece of music.

- **Definition:** Synthesis – when two or more substances (elements or compounds) come together to make a more complex substance.

$$A+X \rightarrow AX$$

- Let's look at the reaction with hydrogen and oxygen.

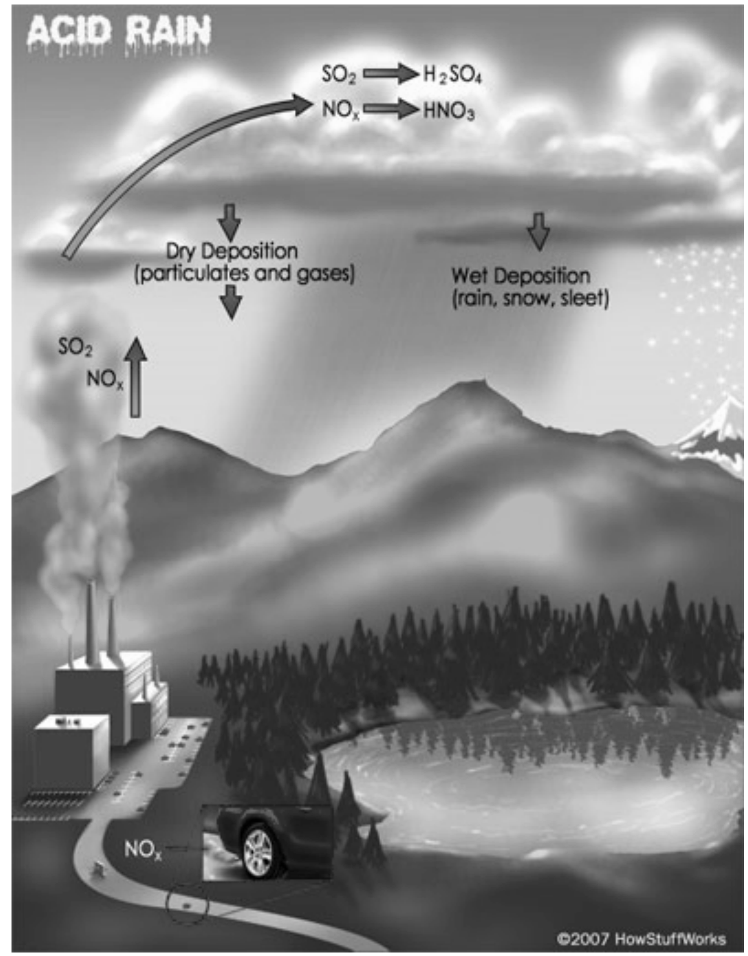
$$2H \;\; + O \qquad 2H \; O$$

- We are combining two different elements to make a compound.

Synthesis

- Acid rain is the product of a synthesis reaction.

$2SO \;\; + O \;\; + 2H \; O \qquad 2H \; SO$



- The sulfur dioxide comes from factories and car exhaust.
- The oxygen comes from the atmosphere.
- The water in the clouds combines with these two chemicals to produce sulfuric acid.

Decomposition

- **Definition:** <u>Decomposition</u> – a reaction that breaks down compounds into simpler products.

$$AX \rightarrow A+X$$

- Hydrogen peroxide breaks down into water and oxygen gas, for example.

2H O   2H O + O

- This is why there is an expiration date on the hydrogen peroxide bottles. After a time, you will no longer have hydrogen peroxide, you will have water.

Replacement

- **Definition:** Replacement – when one element or ion replaces another in a compound, or when two elements or ions replace each other.

- Single replacement: When one element replaces another.

$2CuO + C \qquad 2Cu + CO$

$2NaCl + F \qquad 2NaF + Cl$

$$AX + B \rightarrow BX + A$$

$$AX + Y \rightarrow AY + X$$

- Double replacement: When two elements replace each other.

$$AX + BY \rightarrow AY + BX$$

$CaCO \;+\; 2HCl \qquad CaCl \;+ H\ CO$

Combustion

- **Definition:** Combustion – a rapid reaction between oxygen and fuel that produces thermal energy.

$$C_xH_yO_z + O_2 \rightarrow CO_2 + H_2O$$

CH + 2O CO + 2H O

CH O + O CO + H O

- **Definition:** Fuel – a material that releases energy when it burns.

- The products of organic combustion are always carbon dioxide, water, and heat.

Reaction Type Practice Problems

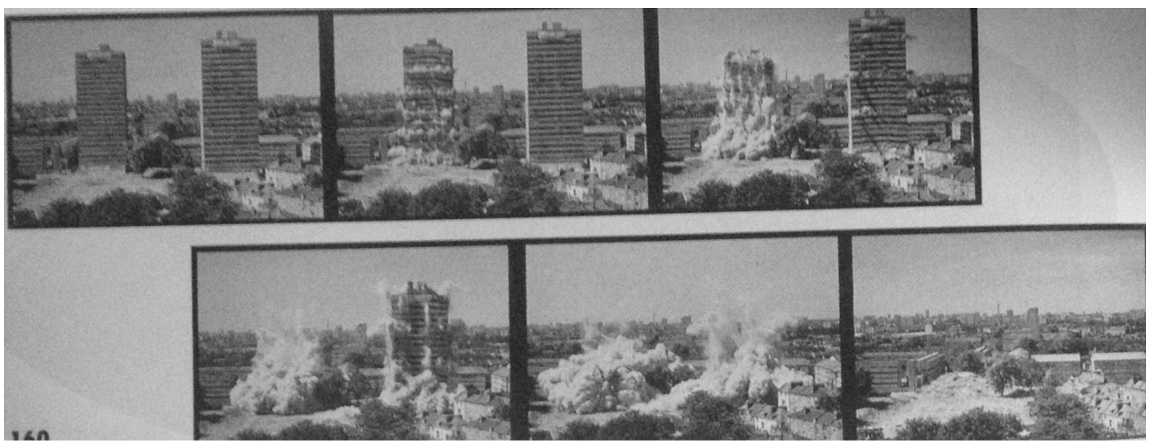
- Identify each of the following reactions as synthesis, decomposition, single replacement ,double replacement, or combustion. Balance them if they are not balanced.

1. $2NaCl + Ca(OH)_2 \rightarrow$ 2
2. $CaCO_3 \rightarrow CaO + CO_2$
3. $_8 \rightarrow FeS$
4. $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$
5. $AgNO_3 + KBr \rightarrow AgBr + KNO_3$
6. $Zn + HCl \rightarrow ZnCl_2 + H_2$

- Be aware that not all reactions can be classified as synthesis, decomposition, or replacement reactions.

Section 3
Controlling Chemical Reactions

- Think about the demolition of a condemned building.
- A series of controlled explosions can take one down in 15 seconds.



- These explosions are from chemical reactions.
- We are able to control reactions to get a desired effect.

Getting Reactions Started

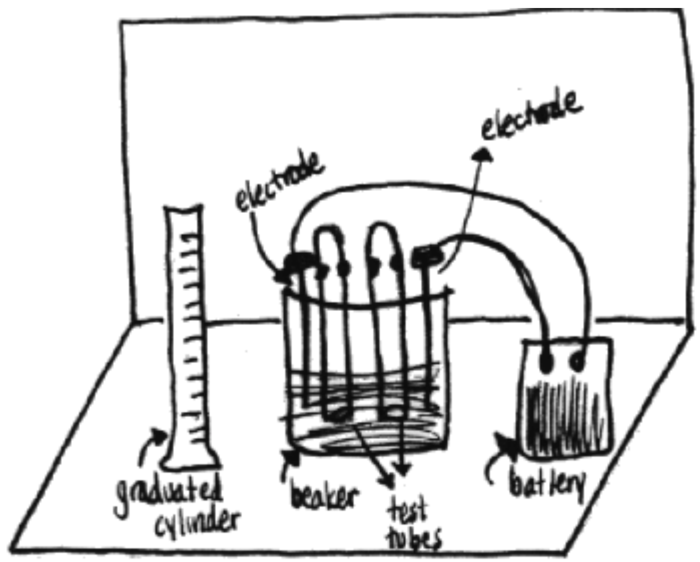
- Let's look at the following figure:

- **Chemical reactions need a certain amount of energy to get started.**

- **Definition:** <u>Activation Energy</u> – the minimum amount of energy needed to start a chemical reaction.

Activation Energy

- Consider the synthesis of water.
- This reaction gives off lots of energy, but it does not just happen. There's both hydrogen and oxygen in the atmosphere, but it is not all reacting right now.
- For this reaction to proceed, a spark of energy must be added.
- This starts a few molecules of hydrogen and oxygen reacting, which allows for a chain reaction.



Energy and Types of Reactions

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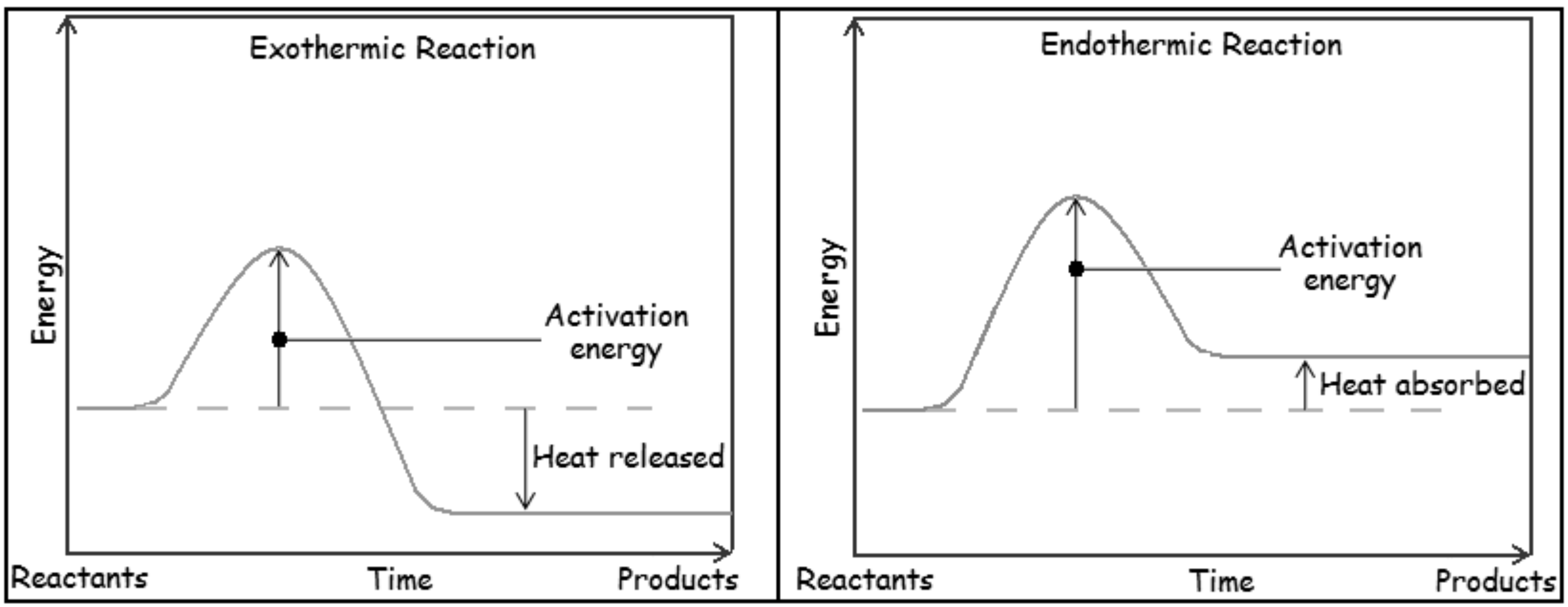
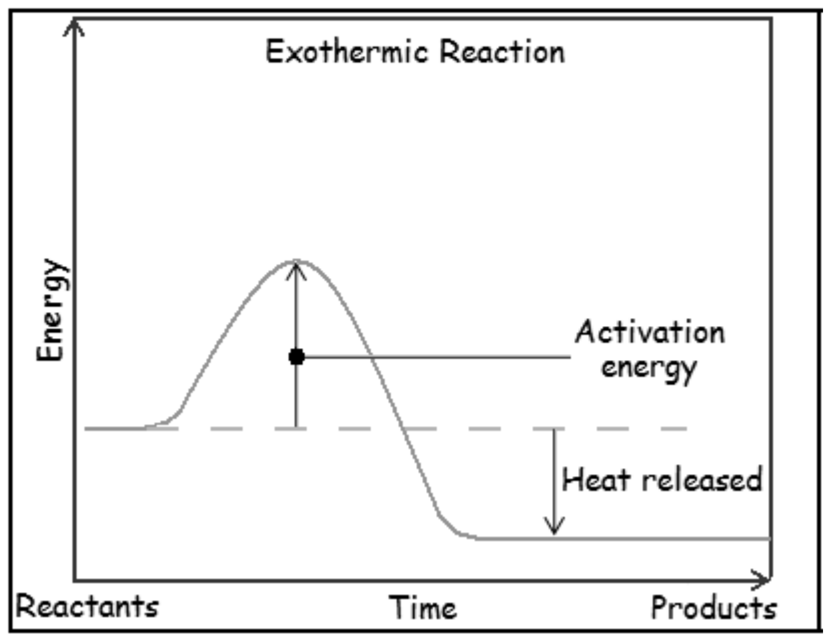
  depends on whether the reaction is endothermic or exothermic.



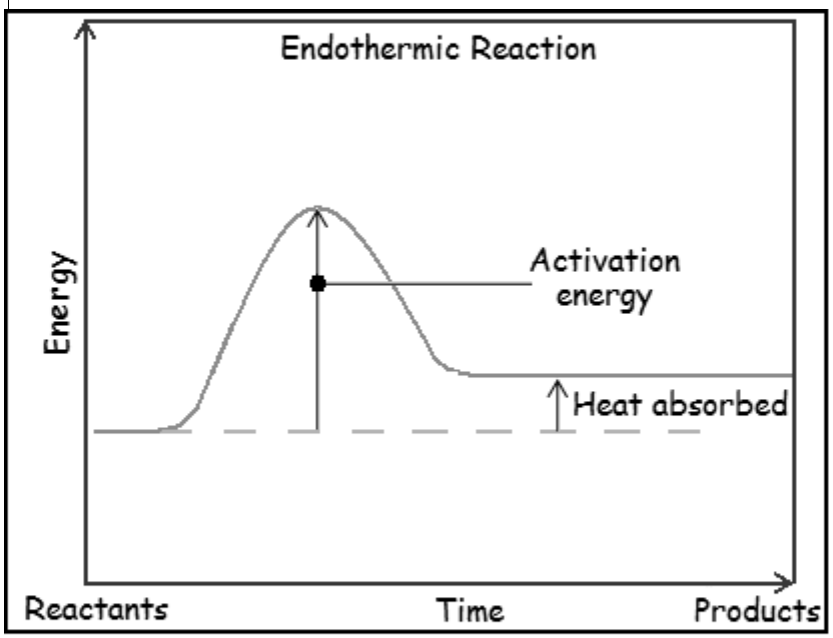
Energy and Types of Reactions

- Most chemical reactions are exothermic.
- Like all reactions, exothermic reactions require an activation energy.
- However, since energy is given off, the products are lower in energy than the reactants.



Energy and Types of Reactions

- In an endothermic reaction, energy is needed to get started.

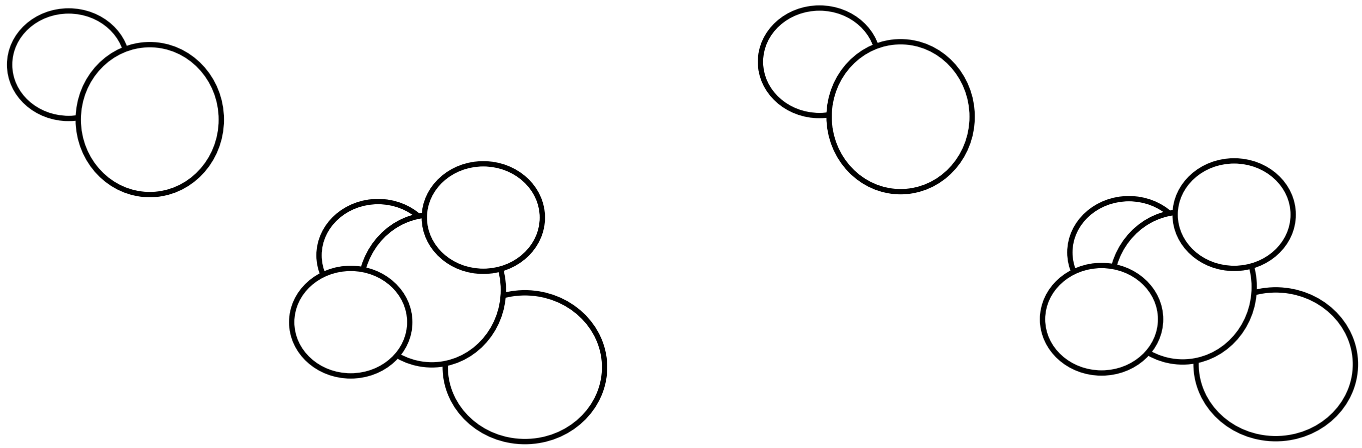


- These reactions also need a supply of energy to keep going, since the absorbed heat must come from somewhere.

- The energy of the products is higher than the energy of the reactants.

Rates of Chemical Reactions

- Not all chemical reactions occur at the same rate.



- As you've seen in your day-to-day lives, baking brownies and rusting iron do not happen in the same length of time.
- **Chemists can control the rates of reactions by changing factors such as concentration, temperature, and surface area, and by using substances called catalysts and inhibitors.**

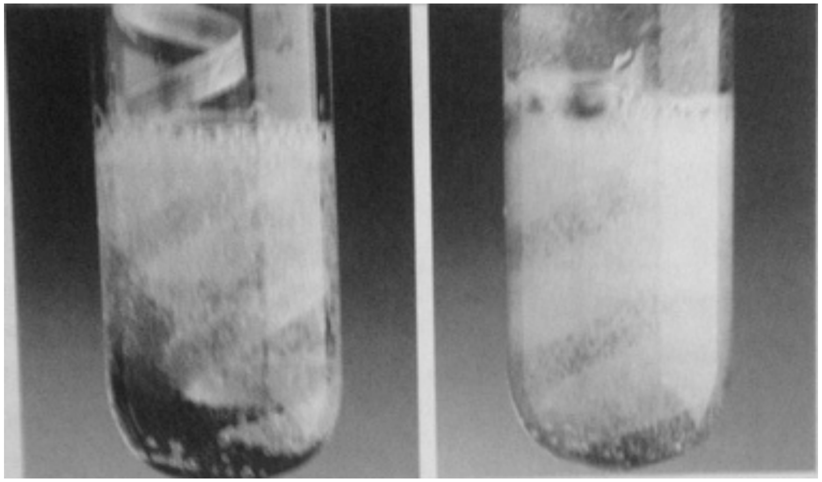
Concentration

- **Definition:** Concentration – the amount of one material in a given amount of another material.

- Think about the amount of sugar in a cup of lemonade. Which is sweeter, more or less sugar?

- Increasing the concentrations will increase the availability of the particles to react.

- Look at the figure to the right.



Temperature

- Controlling the temperature of a reaction can control the rate of the reaction.

- For example, does brownie batter bake at room temperature? How about at 350°F?

- When you heat a substance, its particles move faster. This increases the rate in two ways:
    1. The particles come into contact more often.
    2. The faster moving particles have more energy, allowing for them to get over the activation energy "hump" faster.

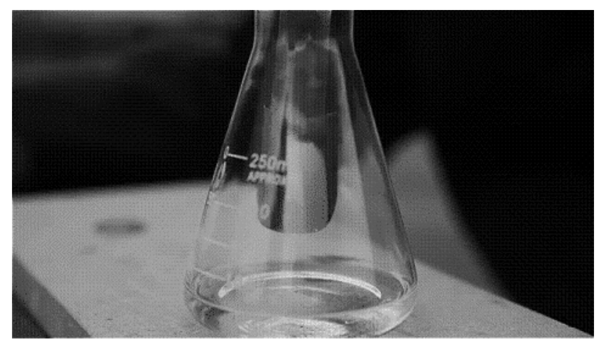
Surface Area

- The reaction will happen faster if more of the materials are exposed to each other.
- Therefore, if there are two samples with the same mass but different surface areas, the one with the larger surface area will react faster.

- We exercise this idea when we chew our food.
- Chewing breaks the food into smaller pieces, increasing the surface area exposed to the enzymes in our saliva.

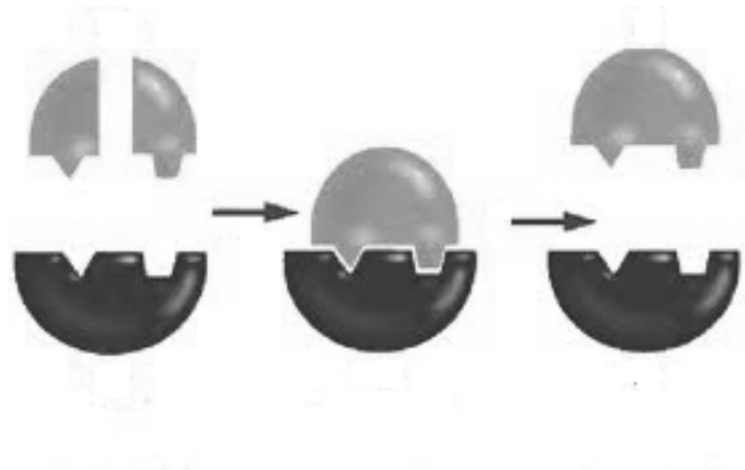
Catalysts

- If you decrease the activation energy of a reaction, the reaction will happen faster.
- **Definition:** Catalyst – a material that increases the rate of a reaction by lowering the activation energy.
- Catalysts participate in the reaction, but they do not change their chemical compositions.
- Therefore, catalysts are not considered reactants.



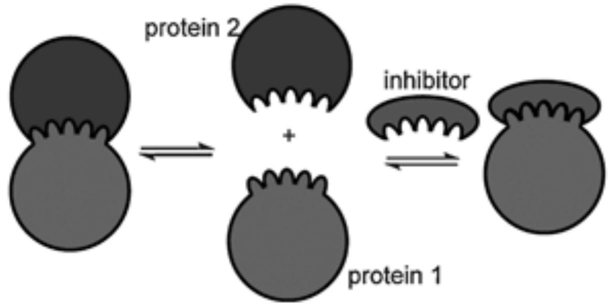
Catalysts

- **Definition:** Enzyme – a biological catalyst that lowers the activation energy of reactions in cells.



- Your body contains thousands of different enzymes.
- Each enzyme is used for one specific purpose. They do not multitask.
- These molecules provide a place where a chemical reaction can take place.
- Without enzymes to lower activation energies, life would not be possible.

Inhibitors



- Sometimes a reaction is more useful when slowed down.
- **Definition:** Inhibitor – a material used to decrease the rate of a reaction.
- Example of a use for an inhibitor: nitroglycerine.
- Nitroglycerine is so reactive that just shaking the bottle can cause an explosion.
- Certain solid materials, such as wood pulp, can absorb the liquid to keep it from reacting until detonated.

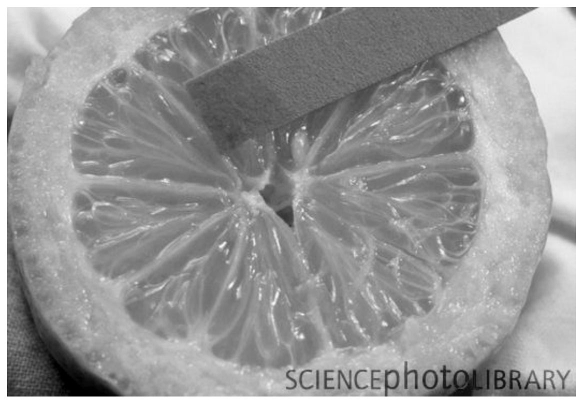
Section 4
Acids, Bases, and pH

- If you’ve ever eaten fruit, you’ve consumed an acid.

- Did you know that your shampoo is a base?
- There are many products today that contain acids and bases.
- Acid-base reactions even help to keep you alive!
- But what are acids and bases?

Properties of Acids

- All acids share similar properties.
- **Definition:** Acids – substances that taste sour, react with metals and carbonates, and turn blue litmus paper red.



- Lemons are a classic example of the sour taste of acids.
- Citrus fruits, including lemons, are acidic.

Sour Taste

- Can you think of any other foods that taste sour?

- Cherries, tomatoes, apples, tea, vinegar, and spoiled milk are all also acidic.




- Sour taste is not a property of acids that should be used in the lab to identify them.

- While some acids are okay to consume, many are not!

Reactions with Metals

- The bubbles on the metal plate are hydrogen gas being produced from the reaction between the metal and hydrochloric acid.

- In order to produce beautiful works of art this way, like the one to the left, the metal plate must first be coated in beeswax, or another acid-resistant material.

- Then the design is cut into the beeswax with a sharp tool, exposing the metal.

Reactions with Metals

- The metal is then treated with acid.
- The acid dissolves some of the metal where it is exposed
- Ink can be applied to the etched metal to make a stamp, of sorts.
- The ink will collect in the grooves of the etched design.
- It can then later be transferred to paper when the etching is printed.

Reactions with Carbonates

- Carbonate ions contain carbon and oxygen atoms bonded together (CO).
- When acids react with carbonate compounds, carbon dioxide is produced.
- Calcium carbonate, or limestone, will react with acid.

$$2HCl + CaCO \qquad CaCl + CO + H\ O$$

- When dilute acid is poured on the limestone, carbon dioxide bubbles form.
- This test can prove that a rock is made from limestone.

Reactions with Carbonates

- Many organisms live in limestone in the ocean.
- Coral rock, from coral reefs, is made of limestone.

- These are structures made from the skeletons of millions of tiny sea creatures that produce an outer layer of calcium carbonate.

- Chalk is another form of limestone.
- It forms from the hard parts of microscopic sea animals deposited on layers of the sea floor.

Reactions with Indicators

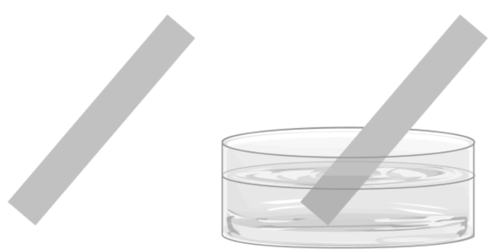
- Litmus is an example of an indicator.
- **Definition:** Indicator – a compound that changes color when in contact with an acid or base.
- Vinegar and lemon juice turn blue litmus red.
- Acids will always turn blue litmus red.
- Sometimes chemists use other indicators to test for acids, but litmus is one of the easiest to use.
- The color hydrangeas will be depends upon the acidity of the soil in which the bush grows.

Properties of Bases

- **Definition:** Bases – substances that taste bitter, feel slippery, and turn red litmus blue.
- Bases are also described as the opposites of acids.
- Tonic water, soaps, shampoos, and detergents all taste bitter, though you wouldn't want to taste most of these.
- Ever notice how soap makes your hands feel slippery before it is washed away?
- This is because soap is a base.

Slippery Feel and Reactions with Indicators

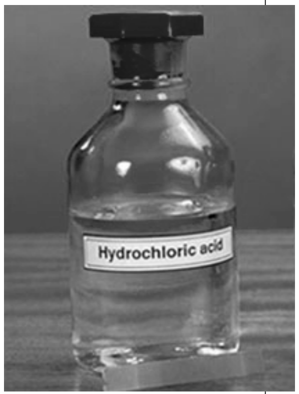
- The slipperiness of bases is another characteristic property.
- However, you wouldn't want to touch most bases to determine this property.
- Strong bases can irritate or burn your skin.
- Red litmus paper will be turned blue by bases.



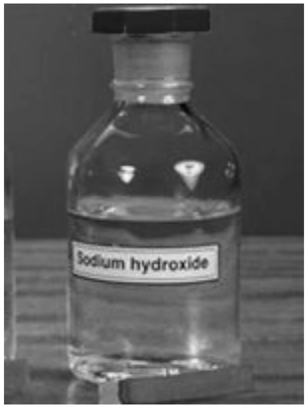
Reactions of Bases

- Bases do not react with carbonates to produce carbon dioxide.
- While this may seem counterproductive, it is a good indication that a substance is not an acid if it does react with the things that an acid reacts with.
- Another important property of bases is how they react with acids.

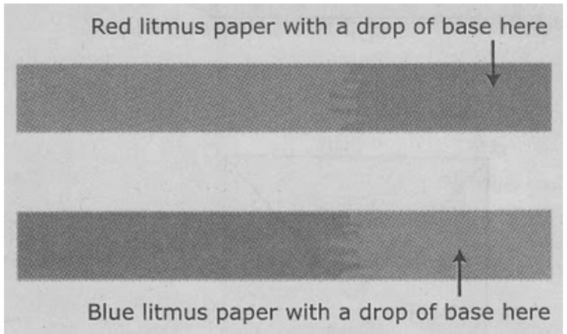
Acids and Bases in Solution



- If I have a beaker of hydrochloric acid, what will its properties be?



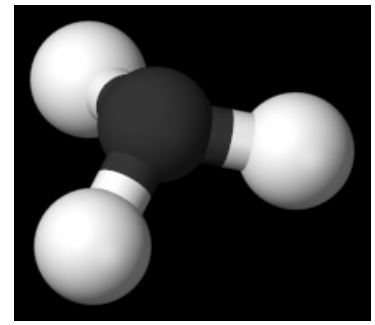
- If I have a beaker of sodium hydroxide base, what will its properties be?



- Each of these solutions independently will change the color of litmus.
- However, when added together in the correct proportions, they will not change the color of litmus because all that will be left is saltwater.

Acids in Solution

- Other than the properties we have already discussed, many acids have another trait in common.



- They all react to produce hydrogen ions, H .
- **Definition:** Hydrogen Ion – an atom of hydrogen that has lost its electron.
- For example, when hydrochloric acid reacts with water, hydrogen ions are produced.

$$HCl(aq) \qquad H\ (aq) + Cl^{-}(aq)$$

Acids in Solution

- If another acid were to be used, the anion would be different.
- However, hydrogen ions would be produced in each case.
- What are the products of the reaction below?

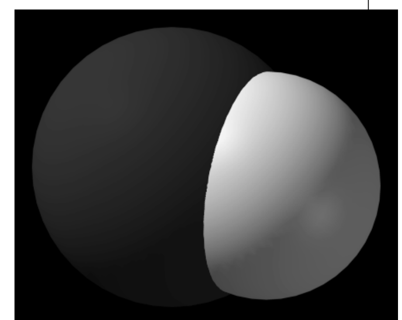
  HNO (aq)

- **An acid is any substance that produces hydrogen ions in water.**
- It is the hydrogen ions that react with blue litmus to turn it red, which is why every acid gives the same result.

Bases in Solution

- Many bases are positive ions combined with hydroxide ion, OH .

- **Definition:** Hydroxide Ion – a polyatomic anion made of oxygen and hydrogen.



- When these bases dissolve in water, the positive ion and hydroxide ion separate.

  NaOH(aq)   Na (aq) + OH (aq)

- Not all bases contain hydroxide ion.

Bases in Solution

- Ammonia, NH , for example, is a base.

- When reacted with water, ammonia produces hydroxide ion.

$$NH \quad + H \; O \qquad NH^{+} + OH^{-}$$

- **A base is any substance that produces hydroxide ions in water.**

- Hydroxide ions are responsible for turning red litmus blue, which is why all bases give the same results when tested.

Strengths of Acids and Bases

- Strength refers to how well an acid or a base produces ions in water.
- Acids and bases may be strong or weak.
- Strong acids easily produce hydrogen ions in water.
- Weak acids still produce hydrogen ions in water, but not as easily as strong acids.
- There are seven strong acids: hydrochloric acid, sulfuric acid, nitric acid, hydrobromic acid, chloric acid, hydroiodic acid, and perchloric acid.

Strengths of Acids and Bases

- All other acids are considered to be weak acids, including acetic acid and citric acid.
- Strong bases react in water in a similar way to strong acids.
- Strong bases produce more hydroxide ions than weak bases.
- Sodium hydroxide, potassium hydroxide, and lithium hydroxide are examples of strong bases.
- Ammonia is a weak base.

Strengths of Acids and Bases

- Strength determines, in part, how safe the acid or base is to use.
- All of the acids that are safe to eat are weak acids.
- A weak base may only irritate your skin while a strong base will burn your skin.
- **DO NOT MISTAKE STRENGTH OF THE ACID/BASE FOR HOW CONCENTRATED A SOLUTION OF THAT ACID/BASE IS.**

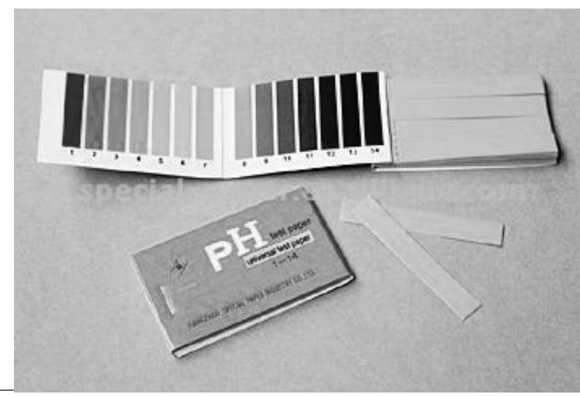
Measuring pH

- Knowing the concentration of hydrogen ions is the key to knowing how acidic or basic a solution is.

- **Definition:** pH scale – a range of values from 0 to 14 that expresses the concentration of hydrogen ions in a solution.

Measuring pH

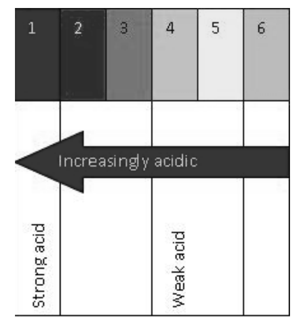
- You have already seen two examples of a universal indicator, meaning that it will detect both acids and bases.
- These indicators turn a specific color based upon the pH of the solution.
- One could use a universal indicator and a key to determine the pH of a solution.



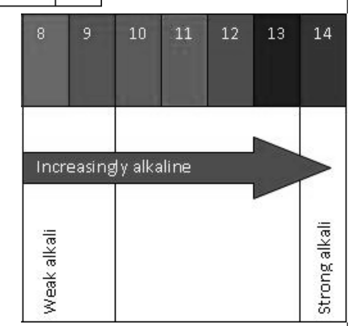
Measuring pH

- A pH of 7 means that the solution is neither acidic nor basic.

- Pure water is neutral with a pH of 7.



- If the pH is below 7, the solution is acidic.



- If the pH is above 7, the solution is basic.

- In order to handle acids and bases safely, both the pH and the concentration of the solution must be known.

Acid-Base Reactions

- When hydrochloric acid and sodium hydroxide are combined, they react to produce table salt and water.

$$HCl + NaOH \qquad NaCl + H\ O$$

- If you were to test the pH of this mixture, it would be near 7.0, or neutral.

- **Definition:** <u>Neutralization</u> – a reaction between an acid and a base.

- A neutralization reaction will not always result in a neutral pH.

Acid-Base Reactions

- The final pH depends upon the volumes, concentrations, and identities of the reactants.
- If only a small amount of base is added to a large amount of acid, will the solution be basic, neutral, or acidic?
- Also, some acids and bases may react to produce a compound that is not neutral.

Products of Acid-Base Reactions

- Salt does not only refer to table salt.
- **Definition:** <u>Salt</u> – any ionic compound that can be made from the neutralization of an acid with a base.
- A salt is made from the positive ion from the base and the negative ion from the acid.
- What salt will be produced from the reaction between KOH and HNO ?
- **A neutralization reaction produces water and a salt.**