CHAPTER 8

ACIDS AND BASES

CHEMICAL CONCEPTS USED IN THIS CHAPTER:

Acids and bases, strong and weak
Electrolytes and their behavior
Neutralization reactions
pH and acidity

CONTEMPORARY ISSUES IN THIS CHAPTER:

Antacid medicines: what are they, and how do they work?

Acidity values of everyday substances: water, soft drinks, toilet bowl cleaner, acid rain, shampoo, dishwasher detergent, oven cleaner. Which of these are hazardous, and why?

Why is the dissolving of tooth enamel one of the symptoms of bulimia?

CHAPTER 8. ACIDS AND BASES

What Is an Acid?

The chemistry of aqueous solutions is an important area of chemistry, and one of the most important properties of an aqueous solutions is its level of acidity. Nowadays even nonscientists know that "acid rain," for example, can have significant effects on chemical substances and living organisms. What do we mean when we talk about "acid" and "acidity"?

The simplest definition of an acid is that an acid is a substance which forms H^+ in water. The H^+ ion is unique among the common ions because it has no electrons at all, the hydrogen atom having lost its only electron to form the ion, leaving only a bare proton. In aqueous solution this tiny, positively charged proton does not exist on its own. It attaches to the nearest oxygen on a water molecule, being attracted to the partial negative charge of the oxygen's electron cloud. The resulting species, H_3O^+, which results from attaching H^+ to H_2O, is called the hydronium ion. Because the hydrogen ion does not actually exist on its own, some scientists prefer to refer to the hydronium ion as the species which defines the presence of an acid in aqueous solution. However, we know that hydrogen ions often are associated with more than one water molecule, so that the hydronium ion does not describe fully the nature of hydrogen ion in solution. For that reason, and because it is often simpler to refer to H^+, we will use H^+ when describing acid solutions in water.

There are two kinds of acids: strong acids and weak acids. A **strong acid** dissociates 100% in aqueous solution to form H^+ and an anion. For example, hydrochloric acid, HCl, breaks apart, or dissociates, completely in water to form H^+ and Cl^-. There are very few strong acids. All of them listed in Table 8-1. Of the six strong acids, only three are commonly used: hydrochloric acid, nitric acid, and sufuric acid. It is well worth remembering the names of these “big three,” because, unless they appear in highly diluted form, these highly reactive substances can cause serious harm as they react with human tissue. All three of these strong acids are important in chemical manufacture; sulfuric acid is the largest single product of the chemical industry. Strong acids also are encountered in everyday life: hydrochloric acid is used to clean mortar from bricks, and even appears in some toilet bowl cleaners, while sulfuric acid is the battery acid in auto batteries.

Table 8-1. *Names and Chemical Formulas of the Strong Acids.*

Name	Chemical Formula	Common Name
Hydrochloric acid	HCl	Muriatic acid
Nitric acid	HNO_3	
Sulfuric acid	H_2SO_4	Battery acid
Hydrobromic acid	HBr	
Hydroiodic acid	HI	
Perchloric acid	$HClO_4$	

Weak acids dissociate less than 100% in water to form H^+. Weak acids produce much lower H^+ concentrations than the same amount of strong acids. Typically 5% or less of the weak acid molecules break apart, or dissociate, to form H^+. There is a very large number of weak acids, many of them organic. A few of these weak acids are listed in Table 8-2.

Table 8-2. Decoding Product Labels: *Names and Chemical Formulas of Some Weak Acids.*

Name	Chemical Formula	Found In:
Acetic acid	$HC_2H_3O_2$	Vinegar
Carbonic acid	H_2CO_3	Rain water, carbonated drinks*
Boric acid	H_3BO_3	Eyewash
Benzoic acid	$HC_7H_5O_2$	Foods, as preservative

**Carbonic acid may not appear on the label of the soda can, but it is there! It results from the reaction of dissolved carbon dioxide (the bubbles in the soda) with water.*

Strongly acidic solutions, those with a high concentration of H^+, are **corrosive**, since the H^+ can react destructively with body tissues and other substances. Weakly acidic solutions, however, are a common part of our lives. Vinegar is a weak solution (approximately 5%) of the weak acid acetic acid. Lemons and other citrus fruit get their distinctive tangy flavor from citric acid, another weak acid. Pure rain water is weakly acidic because dissolved carbon dioxide from the air produces carbonic acid.

Fig. 8-1. *Acids are part of our everyday lives.*

What Is a Base?

A base is defined as a substance which produces OH^- in solution. Basic solutions are often referred to as being **alkaline**. A **strong base** dissociates 100% in aqueous solution to form OH^- and a cation. A common example of a strong base is sodium hydroxide, NaOH. Sodium hydroxide is also called lye, or caustic soda. Used in drain cleaners and oven cleaners, sodium hydroxide is highly reactive in high concentrations. It acts as an oven cleaner by reacting with grease and changing it to soluble soap, and cleans drains by dissolving both grease and hair. Clearly a basic substance can be as hazardous to body tissues as an acid. The word caustic is used to describe substances containing hazardous concentrations of base. Potassium hydroxide, KOH, is another strong base sometimes encountered in the laboratory and in commercial products.

A weak base dissociates less than 100% in solution. A common example of a weak base is ammonium hydroxide, NH_4OH, which dissociates about 5% in aqueous solution. A solution found in the laboratory may be labeled "ammonium hydroxide" or "ammonia." In the home it may be labelled "household ammonia." These are all actually the same substance. Ammonia, NH_3, is a gas which dissolves readily in water to form ammonium hydroxide, NH_4OH.

$$NH_3 \quad + \quad H_2O \quad \rightleftharpoons \quad NH_4OH \qquad (8\text{-}1)$$

The ammonium hydroxide acts as a weak base by dissociating to form OH^- and NH_4^+. The double arrow means that this is an **equilibrium reaction**, which takes place both in the forward and the reverse direction at the same time. Both some products and some reactants are always present. In this equilibrium reaction, some ammonium hydroxide is always present and can dissociate to form a basic solution. Some gaseous NH_3 is always present, also, and can be easily detected by smell whenever a bottle of ammonia is opened. For this reason caution should be used when handling ammonium hydroxide solutions at home or in the laboratory, for, though ammonium hydroxide is a weak base, it can be extremely irritating to the respiratory system. Like other volatile (easily vaporized) substances, ammonia should be tightly capped when not in use, and used with adequate ventilation. When used properly, ammonium hydroxide can be an effective and inexpensive household cleaning agent.

A complete list of weak bases would be a long one. Any weakly soluble ionic compound that has hydroxide ion as an ion qualifies as a weak base, since it dissociates less than 100% to form OH^-. An example is magnesium hydroxide, $Mg(OH)_2$, or milk of magnesia. Some salts. like sodium carbonate, contain no hydroxide group, but react with water to form hydroxide ion. Finally, the amines are a nitrogen-containing class of organic compounds that may form basic solutions.

Fig. 8-2. Caption: *Basic substances, often in hazardous concentrations, are found in every household. Often labels do not indicate the caustic nature of the product; you should know, however, that products like oven cleaner, dishwashing detergent, and household ammonia are highly basic and are hazardous to handle or ingest.*

DECODING SKILLS: HOW DO WE IDENTIFY ACIDS AND BASES?

Now we know something about the chemistry of acids and bases, including the fact that both strong acids and strong bases can be hazardous. How can we identify acids and bases when we encounter them? First, let us consider **chemical formulas**: *if a formula begins with an H, that substance is expected to be an acid; if it contains an OH, it will be a base*. We know that this rule will not find all substances which can act like acids and bases; sodium bicarbonate, for example, with the formula $NaHCO_3$, can act to neutralize either acids or bases. Nevertheless, it is a useful guideline for identifying most acids or bases you will encounter. Most acids in the laboratory as named as such, and Table 1 shows there are only six strong acids; of these, only the first three, hydrochloric acid, nitric acid, and sulfuric acid are regularly used either in the laboratory or in the home. The strong bases in use are even fewer: sodium hydroxide is by far the most common, with potassium hydroxide running a distant second.

Finding acids and bases outside the laboratory is much more difficult: toilet bowl cleaner with hydrochloric acid reveals this fact on the label, but in extremely small type, unlike the clear labels in the laboratory. Oven cleaner or drain decloggers are very likely to contain sodium hydroxide, or sometimes potassium hydroxide, but this may be difficult to discern from the label... and the lemon scent that acompanies the product may give a message quite different from the cautionary label that the product displays. Watch for labels which warn of chemical hazards, and be aware that these warnings may not be prominently displayed. The word ***caustic*** is a sure indicator of a strong base; ***corrosive*** may indicate an acid or a base.

Since they dissociate to form ions in solution, both acids and bases are **electrolytes**. An electrolyte is any substance which forms ions in solution. Not only acids and bases, but all ionic substances, or salts, are electrolytes. An interesting experiment can be formed with electrolyte solutions using an ordinary electric light bulb wired so that an electric current must pass between two wires a few inches apart in order to complete the circuit and make the bulb light up.

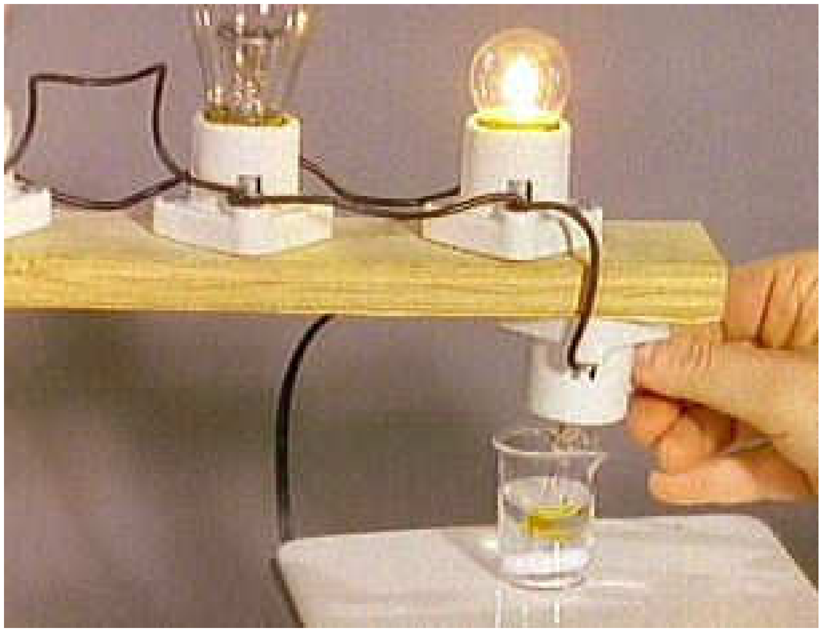

Fig. 8-3. *In this apparatus the moving ions create an electrical current. The greater the concentration of ions, the more strongly the current flows and the more brightly the light burns. Both 0.1 M NaCl and 0.1 M HCl dissociate completely in water to form ions, causing the bulb to burn brightly. The weak acid acetic acid dissociates only slightly to form ions; a 0.1 M solution causes the bulb to burn dimly.*

Moving electrical charges constitute an electrical current, so ions moving in aqueous solution between the two wires will make the bulb light up. The greater the concentration of ions, the more strongly the current flows, and the more brightly the bulb burns. When the bulb is immersed in pure water, it does not light up. Dissolving a molecular substance like sucrose, or table sugar, produces no light from the bulb, because no ions are produced in solution. When a soluble ionic substance is dissolved in the water, however, the ions produced are capable of producing a current. When a solution 0.1 M NaCl, for example, makes contact with the light bulb apparatus, a bright light results. A solution of 0.1 M HCl results in an equally bright light, because the strong acid is completely dissociated in solution to form ions. A 0.1 M solution of acetic acid, however, produces only a dim glow in the bulb, because it dissociates only slightly, forming far fewer ions in solution than the strong acid. We say that the strong acid HCl is a **strong electrolyte**, because it dissociates 100% in solution to form ions. The weak acid acetic acid is a **weak electrolyte**, since it dissociates less than 100% in solution to form ions. Not all substances are electrolytes. Many molecular substances do not dissociate at all in solution. If the apparatus is placed in a sugar solution, for example, the bulb does not light at all, meaning that sugar is a **nonelectrolyte** which does not form ions in solution.

Neutralization Reactions

The reactions of acids and bases with one another form a special class of reactions called **neutralization reactions**. These reactions, often dramatic in their consequences, take place around us constantly, in our bodies and in our environment. As an example, let us examine the reaction between the common strong acid HCl and the common strong base NaOH in aqueous solution. Both these substances are completely dissociated to form the ions in aqueous solution, so that is how we represent them in the chemical equation:

(8-2)

$$H^+ \quad + \quad Cl^- \quad + \quad Na^+ \quad + \quad OH- \quad \text{--->} \quad H_2O \quad + \quad Na^+ \quad + \quad Cl^-$$

The most important part of this reaction is the reaction of the H^+ ion and the OH^- ion to form water. The implications of this change are phenomenal. Unless they are very dilute, the strong acid solution of HCl and the strong base solution of NaOH are both very reactive, hazardous solutions. They would have to be handled with great care in the laboratory. Yet after the reaction, the H^+ and OH^- ions which give acid and base properties to solution are totally gone, and in their place is pure water! Notice that the Na^+ and Cl^- ions appear unchanged on either side of the equation. Sometimes they are called **spectator ions** because they do not take part in the action. The solution that exists after the reaction, then, is nothing but sodium and chloride ions in water, or saltwater, perfectly harmless.

The same pattern is followed whenever an acid and base react together. <u>The reaction between an acid and a base, called **neutralization**, gives as products water and a salt</u>. To label the reaction between aqueous HCl and NaOH in these terms,

(8-2)

$$\underbrace{\mathbf{H^+} \quad + \quad \mathbf{Cl^-}}_{\text{aqueous acid}} \quad + \quad \underbrace{\mathbf{Na^+} \quad + \quad \mathbf{OH-}}_{\text{aqueous base}} \quad \textbf{--->} \quad \underbrace{\mathbf{H_2O}}_{\text{water}} \quad + \quad \underbrace{\mathbf{Na^+} \quad + \quad \mathbf{Cl^-}}_{\text{aqueous salt}}$$

The salt, or ionic compound, formed as a product will be made of the positive ion and the negative ion left over from the reacting acid and base.

The neutralization reaction takes place in the same way whether strong or weak acids and bases are used. For example, the weak acid acetic acid can react with sodium hydroxide just as hydrochloric acid does:

(8-3)

$\mathbf{HC_2H_3O_2}$	**+**	$\mathbf{Na^+}$	**+**	$\mathbf{OH^-}$	**--->**	$\mathbf{H_2O}$	**+**	$\mathbf{Na^+}$	**+**	$\mathbf{C_2H_3O_2^-}$
aqueous acid		aqueous base				water		aqueous salt		

Notice that this time the aqueous acid is not written as ions, since the weak acid in solution remains mainly in undissociated form.

It is important to understand that neutralization reactions, which in some cases cause highly corrosive or caustic substances to change into harmless ones, are specific to acids and bases. There is no magic "neutralizing chemical," for instance, for the explosive substance TNT, or trinitrotoluene. The usual way to render explosives harmless is to take them out into a deserted field and detonate them from a safe distance. Radioactive substances, as we have learned, cannot be rendered harmless by chemical reactions, because the radiation originates in the nucleus. In order to know how to treat a chemical substance and dispose of it, we must first have a knowledge of the chemical reactions of that substance.

What is an Antacid?

Antacids are one of the most common types of over-the-counter medicines. More than a hundred different antacid medicines are regularly sold in the U.S., though the most popular ones are made from a few chemical compounds or combinations of these compounds (Table 8-3).

Table 8-3. **Decoding the Antacid Label:** ***Some Common Ingredients in Antacid Products.***

Antacid ingredient	Commercial Product	Other product ingredients
$NaHCO_3$	Alka-Seltzer	Aspirin
$Mg(OH)_2$	Milk of Magnesia	
	Maalox	$Al(OH)_3$
	Mylanta	$Al(OH)_3$
$CaCO_3$	Tums	

Pain-relievers or other added ingredients may sometimes be present, but the major active ingredient in an antacid product is a basic substance which is used to neutralize acid. Where does the unwanted acid come from? The stomach is essentially a bag containing 0.1 M HCl. Hydrochloric acid in this concentration breaks apart the bonds which hold together the large protein molecules in foods like meat in an important step in the digestive process. The mucosal stomach lining is uniquely able to contain this highly acidic solution; otherwise the proteins in the stomach and surrounding tissues would rapidly be broken down like the food proteins. A stomach ulcer, or hole in the stomach lining, produces just this effect. Without the hydrochloric acid in the stomach, we would not be able to digest food properly. Therefore, we don't want to neutralize all the stomach acid. Even if we did, the body would manufacture more. What, then, is the function of antacids?

Most likely, many of the antacids that are purchased are unnecessary. If the discomfort in the chest area is caused by a serious condition like an ulcer or a heart malfunction, self-treatment with over-the-counter antacids may be a dangerous substitute for appropriate medical attention. In some cases, however, temporary excess acidity can be relieved by antacids. Indigestion can cause a reflux, or backing up, of acid into the esophagus, causing a burning sensation, and swallowing a weakly basic substance can probably be useful in neutralizing acid in this area. The chemistry of antacids is simple, involving in each case a neutralization reaction. Understanding how they work helps us make appropriate choices as to which of the many commercial products to buy, and whether any purchase is necessary at all.

Fig. 8-4. *Antacid preparations can contain any of a variety of chemical compounds which neutralize stomach acid.*

One of the oldest and least expensive antacids is baking soda, or sodium bicarbonate, $NaHCO_3$. When used as an antacid the baking soda is first dissolved in water, forming the dissolved ions Na^+ and HCO_3^-. The bicarbonate ion reacts with H^+ to form carbonic acid, H2CO$_3$. Carbonic acid rapidly breaks apart into carbon dioxide and water.

$$H^+ + Cl- + Na^+ + HCO_3- \text{--->} H_2CO_3 + Na+ + Cl^- \quad (8\text{-}4)$$

$$H_2CO_3 \quad \text{-->} \quad H_2O + CO_2 \quad (8\text{-}5)$$

As the chemical equation shows, the sodium bicarbonate neutralizes an H^+ ion, removing it from the scene. The carbon dioxide gas produced ends up as a burp, which may be among the positive effects of this medication. Another positive aspect of sodium bicarbonate as an antacid is its price, which is much lower than that of competing products. A negative feature of sodium bicarbonate is the presence of the sodium ion. As we learned in Chapter 2, excess consumption of sodium ion is considered unhealthy. Like any sources of sodium ion, sodium bicarbonate consumption must be counted as part of the total daily sodium intake and compared against the desirable level for a given individual. Sodium bicarbonate is the major active ingredient in Alka-Seltzer, though in this form it is considerably more expensive. Two Alka-Seltzer tablets contain 1,042 mg of sodium, compared with a total sodium intake of 1.000 to 2,000 mg per day recommended for an average heart patient. Alka-Seltzer has also been criticized for containing aspirin in its formulation, since aspirin can be dangerous if a stomach ulcer is present.

Another common antacid ingredient is magnesium hydroxide, found in Milk of Magnesia, Maalox, and Mylanta. Magnesium hydroxide is not very soluble in pure water, but in acid solution the hydroxide ion reacts readily to neutralize H^+:

$$Mg(OH)_2 + 2\,H^+ \text{--->} 2H_2O + Mg^{2+} \quad 8\text{-}6)$$

When magnesium hydroxide is taken in large enough doses, it acts as a laxative, which can be an unwanted side effect when it is used as an antacid. Aluminum hydroxide, which has a similar antacid action, tends to constipate; it is often paired with magnesium hydroxide in antacid formulations like Maalox and Mylanta to minimize any laxative effect.

Calcium carbonate, the substance which forms marble and chalk, is also used as an antacid; Tums is a widely advertised brand of calcium carbonate antacid. Although calcium carbonate is not soluble in water, it reacts rapidly with hydrochloric acid. It has a high neutralizing capacity. The chemical equations for the neutralization of HCl with $CaCO_3$ show why this is so. First. the $CaCO_3$ reacts with H^+ to form bicarbonate ion:

$$CaCO_3 + H^+ \text{--->} Ca^{2+} + HCO_3^- \quad (8\text{-}7)$$

The bicarbonate ion that has been formed can then go on to react with another H^+ ion as we have seen previously in the case of sodium bicarbonate:

$$\mathbf{H^+ \quad + \quad HCO_3^- \quad \text{--->} \quad H_2CO_3} \qquad (8\text{-}8)$$

$$\mathbf{H_2CO_3 \quad \text{-->} \quad H_2O \quad + \quad CO_2} \qquad (8\text{-}9)$$

Calcium-containing products have gained popularity since the role of calcium deficiency in osteoporosis, or lowered bone mass in older people, has become widely recognized. Calcium carbonate, however, is not without side effects. It can cause constipation. More seriously, prolonged use can affect kidney function, an effect that is particularly likely for those who consume large quantities of milk or who have existing kidney problems. Calcium carbonate antacids have also been associated with a "acid rebound," the production of increased levels of hydrochloric acid in the stomach after the antacid has been ingested.

Measuring Acidity: pH

As we have seen, the hydrogen ion content has a profound effect on the properties of an aqueous solution. The calcium carbonate in Tums, insoluble in pure water, dissolves readily in acidic solution as it takes part in a neutralization reaction. The calcium carbonate of marble is similarly vulnerable to acid, as shown by the destruction of marble statuary by acid rain.

Fig. 8-5: *The chemical reactions of H^+ in aqueous solution can have important consequences, as evidenced by the damage caused to this statue by acid rain.*

Living cells are even more vulnerable to changes in acidity. A small difference in hydrogen ion concentration can determine which species can live in a lake or stream, or whether the system can support life at all. Soil acidity is a major factor in determining which plants can thrive in a garden or farm. Complex chemical systems in our bodies regulate hydrogen ion levels, and even a small malfunction of these systems is a serious sign of ill health.

Ecologists, farmers, and health professionals are among the many nonchemists who need to monitor the acidity level of aqueous solutions. A measurement scale called the pH scale enables them to do so without having to deal with the negative exponential numbers that describe the very low hydrogen ion concentrations in most aqueous solutions. On the pH scale the pH of a "neutral water solution is 7. Numbers lower than 7 indicate an acid solution, with decreasing numbers indicating greater acidity. Numbers higher than 7 indicate a basic, or alkaline, solution, with increasing numbers indicating greater alkalinity.

Fig. 8-6. ***The pH scale represents solution acidity on a simple numeric scale, with a value of 7 for neutral solutions. Numbers lower than 7 indicate acidic solutions, while numbers greater than 7 indicate basic solutions.***

etc. <--- 4 5 6 7 8 9 10 ---> etc.
more acidic neutral more basic
<----------------- ---------------->

Table 8-4 illustrates the relationship between H^+ concentration and pH. For a solution which has an H^+ concentration of 10^{-1} *M*, for example, the pH is 1. When the H^+ concentration is 10^{-2} *M*, the pH is 2. The pH is simply the power of ten of the hydrogen ion concentration in molarity units, with the sign reversed. To express this relationship with a mathematical formula,

$$\mathbf{pH = -log[H^+]} \qquad (8\text{-}10)$$

By using only the exponent (taking the logarithm) and making the result a positive number by changing the sign, a simple scale of positive numbers is formed from the hydrogen ion concentrations.

Table 8-4. ***pH Value and H^+ Concentration***

H^+ conc. (*M*)	pH	Example solution
1×10^{-1}	1	Stomach acid
1×10^{-2}	2	
1×10^{-3}	3	Vinegar, soft drinks
1×10^{-4}	4	Acid rain
1×10^{-5}	5	
1×10^{-6}	6	
1×10^{-7}	7	Pure water
1×10^{-8}	8	Shampoo
1×10^{-9}	9	
1×10^{-10}	10	
$1 \times 10\text{-}^{11}$	11	Household ammonia
$1 \times 10\text{-}^{12}$	12	Dishwasher detergent
1×10^{-13}	13	
1×10^{-14}	14	Oven cleaner

Problem example 8-1: A rain sample has a hydrogen ion concentration of 1×10^{-5}. What is the pH of this solution?

The exponent of ten for this number is -5. Changing the sign gives 5, the pH of the solution.

Problem example 8-2: A shampoo has a pH of 8. What is the hydrogen ion concentration?

First we reverse the sign of the number of the pH value, giving -8. This number is the exponent of 10 in the H^+ concentration, so the hydrogen ion concentration value is 1×10^{-8}.

Because the pH comes from the power of ten of the hydrogen ion concentration, decreasing the pH value by one unit increases the acidity of the solution by a factor of ten. A solution of pH 5 is ten times more acidic than a solution of pH 6, and a hundred times more acidic than a solution of pH 7. This exponential relationship helps to explain why a pH change of one unit or less can have devastating effects on an ecological system.

The relationship between pH and acidity in acid solutions is straightforward. Table 8-5 shows, however, that the pH of a neutral solution with no acid added is 7, corresponding to a hydrogen ion concentration of 1 x 10^{-7}. Why is hydrogen ion present in a neutral solution, and where does it come from? Pure water contains a very small amount of H^+ because the water molecule dissociates to a very slight extent, breaking apart into H^+ and OH^-.

$$\mathbf{H_2O \leftrightarrow H^+ + OH^-} \qquad (8\text{-}11)$$

The double arrows show that this is an equilibrium reaction, with both the forward and reverse reactions taking place at all times. The forward reaction, however, proceeds only to a very slight extent, accounting for the H^+ concentration of 1 x $10^{-7\,M}$, or 0.0000007 moles per liter. Even solutions containing hydroxide ion contain some H^+, though, as Table 8-5 shows, the greater the hydroxide concentration, the lower the hydrogen ion concentration.

Tools for Measuring pH

Though there are numerous ways of measuring pH, most methods rely on either indicating dyes or electrical potentiometers.

Indicating dyes have been known for hundreds of years and can be observed with everyday substances. For example, if a basic substance like ammonia or dishwasher detergent is added to purple grape juice, the color changes to deep green. Many other natural substances change color with changing pH, and for each substance the color change occurs at a characteristic pH. Litmus, for example, is a substance derived from lichens which is colored pink at pH below 7 and blue at pH above 7. (Its name probably comes from an old Norse name meaning "dye moss.") Litmus dye is often added to small pieces of white paper, forming an indicator paper that indicates by its color the pH of a solution dropped onto it. Other types of pH paper changing at characteristic pH values can be made from other indicator dyes. Alternatively, the dye can be added to a solution, so that the entire solution takes on a color characteristic of the dye at given pH values. The indicating dye phenolphthalein, for example, is often used to indicate solution pH. It changes from clear to deep pink at pH 9.

In the laboratory pH is often measured with an electrical potentiometer, more commonly called a pH meter. A sensing electrode inserted into the solution develops an electrical potential which is dependent on the pH of the solution, and the instrument reads the pH value directly on a meter.

Though more expensive than indicator dyes, the pH meter has advantages of both convenience and accuracy for most pH measurements.

Fig. 8-7.

The pH meter is a common feature of most chemistry laboratories.

CONCEPTS TO UNDERSTAND FROM CHAPTER 8

An acid is a substance which forms H^+ in water.

The hydronium ion H_3O^+ results from attaching H^+ to a molecule of H_2O.

Strong acids dissociate 100% in water to form H^+.

Weak acids dissociate less than 100% in water to form H^+.

A base is a substance which produces OH^- in water.

A strong base dissociates 100% in water to form OH^-.

A weak base disscoiates less than 100% in water to form OH^-.

An equilibrium reaction takes place both in the forward and the reverse direction at the same time.

An electrolyte is a substance which forms ions in solution.

A strong electrolyte dissociates 100% to form ions in solution.

A weak electrolyte dissociates less than 100% to form ions in solution.

A nonelectrolyte does not dissociate to form ions in solution.

An acid and a base react to form water and a salt in the chemical reaction known as neutralization.

pH is found by taking the negative logarithm (power of ten) of the hydrogen ion concentration.

FACTS TO LEARN FROM CHAPTER 8

Hydrochloric acid, sulfuric acid, and nitric acid are common strong acids.

Sodium hydroxide and potassium hydroxide are common strong bases.

The stomach contains hydrochloric acid in about 0.1 *M* concentration.

Sodium bicarbonate, magnesium hydroxide, aluminum hydroxide, and calcium carbonate are common antacid ingredients.

The pH of pure water is 7.

SKILLS TO LEARN FROM CHAPTER 8

After finishing this chapter, you should be able to:

Identify strong and weak acids, strong and weak bases that appear in consumer products.

Write a neutralization equation for the reaction of an acid and a base.

Explain how an antacid works.

Find the pH of a solution for which the hydrogen ion concentration is known.

Find the hydrogen ion concentration for a solution for which the pH is known.

Name __________________________ **Date ________________**

CHAPTER 8 PROBLEMS

8-1. For each of the substances below, tell whether the substance is a strong acid, a weak acid, a strong base, a weak base, or none of these.

a. NaCl
b. NaOH
c. Na_2SO_4
d. HCl
e. $HC_2H_3O_2$
f. H_2CO_3
g. H_2SO_4

8-2. For each of the substances below, tell whether the substance is a strong electrolyte, a weak electrolyte, or a nonelectrolyte.

a. NaCl
b. NaOH
c. CO_2
d. HCl
e. $HC_2H_3O_2$
f. H_2CO_3
g. H_2SO_4

8-3. Match the following substances with the correct chemical ingredient by placing the correct letter in the blank..

______	The active ingredient in vinegar	a. HC_2H_3O
_____	The active ingredient in Alka-Seltzer	b. Mg(OH
______	The active ingredient in Tums	c. $CaCO_3$
______	The active ingredient in oven cleaner	d. NaOH
______	The active ingredient in milk of magnesia.	e. $NaHCO_3$

8-4. Fill in the blanks in the table below.

H^+ Concentration	pH	Example
________	3	Soft drink
________	__	Pure water
1×10^{-8}	__	Egg white

8-5. Discuss the advantages and disadvantages of using baking soda (sodium bicarbonate) as an antacid.

8-6. Discuss the advantages and disadvantages of using Tums as an antacid.

8-7. In bulimia, a behavioral disorder, a person induces vomiting on a regular basis in order to lose weight. One side effect if this behavior is continued over time is that the person's teeth become dissolved. What chemical present in the stomach might be causing this chemical reaction?

8-8. A cleaning product dissolves in water to give a solution with a hydrogen ion concentration of 1 x 10^{-10}.

a. What is the pH of this solution?

b. What color does a strip of paper impregnated with litmus dye turn when a drop of this solution is applied?

c. What color will this solution be if a few drops of phenolphthalein indicator are added?

8-9. The sting of a bee injects formic acid. Tell whether you would recommend each of the following as a home remedy for beesting, and give your reasoning.

a. Sodium hydroxide solution

b. Ammonium hydroxide solution

c. Acetic acid solution

d. Hydrochloric acid solution

e. Sodium bicarbonate solution.

8-10. Write a chemical equation for the neutralization reaction of hydrochloric acid with sodium hydroxide.

8-11. Write a chemical equation for the neutralization reaction of hydrochloric acid and ammonium hydroxide.

8-12. Write a chemical equation for the neutralization reaction of nitric acid and sodium hydroxide.

8-13. Write chemical equations to show how calcium carbonate works as an antacid.

8-14. Write chemical equations to show how acid rain dissolves marble.

8-15. Acid rain is formed when sulfur impurities in coal are burned to form sulfur oxides which react with the water in rain. Which of the strong acids do you think is formed?

8-16. In the high temperatures of an automobile engine nitrogen and oxygen from the air react to form nitrogen oxides. When these react with the water vapor in the air, which of the strong acids do you think is formed?

8-17. Find in a grocery store or other retail outlet a product that contains a strong acid. Is the acid identified on the label? What information is given with regard to the acid and its reactivity? What is your own evaluation of any hazard associated with this product? Give your reasoning.

8-18. Find in a grocery store or other retail outlet a product that contains a strong base. Is the base identified on the label? What information is given with regard to the base and its reactivity? What is your own evaluation of any hazard associated with this product? Give your reasoning.

8-19. Find in a grocery store or other retail outlet a product that contains a weak acid. Is the base identified on the label? What information is given with regard to the acid and its reactivity? What is your own evaluation of any hazard associated with this product? Give your reasoning.

8-20. Find in a grocery store or other retail outlet a product that contains a weak base. Is the base identified on the label? What information is given with regard to the base and its reactivity? What is your own evaluation of any hazard associated with this product? Give your reasoning.

8-21. Find in a grocery store or other retail outlet a product that contains an antacid. What is the active ingredient? How is it listed on the product label? Give your own evaluation of the health issues associated with the use of this product.