Interactive Chemistry Multimedia Courseware

The Properties of Acids, Bases and Salts
Program Supplement

The Properties of Acids, Bases and Salts

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Introduction

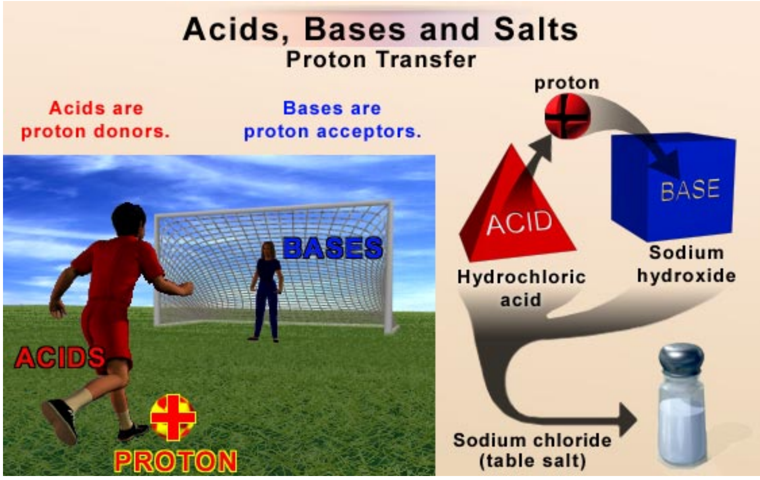
Scene Number

Scene 1

Acids, bases and salts are chemical compounds that affect your life on a daily basis. Familiar examples of acids, bases and salts are battery acid, laundry bleach, and table salt. Commercially, acids and bases are required in the manufacture of thousands of commonly used products. For example, sulfuric acid is required to produce, among other things, fertilizers, explosives, steel and plastics. Acid-base balance within living organisms is essential for life's processes. Although the acidity of our blood is constantly fluctuating, acid-base balance is maintained within a narrow margin. A significant shift in this balance quickly results in death.

Scene 2

Most acid-base chemistry involves the transfer of protons from one compound to another. Acids are compounds that donate protons, bases are proton acceptors. Acids and bases react with one another to form compounds known as salts. In this program you will review atomic structure, chemical compounds and chemical equations and apply these concepts towards an understanding of the properties of acids, bases and salts. This program will also explore the chemistry of water and explain the concept of pH.



Scene 3

You may already be familiar with some well-known characteristics of acids and bases. Certainly you wouldn't want to handle battery acid with your bare hands, nor would you want to use certain household cleaners without gloves and proper ventilation. Battery acid is a solution of sulfuric acid, and many products, such as drain openers, are strong bases. Acids and bases can burn your skin and must be handled with caution. Remember, if you ever spill an acid or base in the laboratory, immediately alert your instructor for advice on how to clean it up safely.

Scene 4

Certainly not all acids and bases need to be avoided. Many popular food items, such as soft drinks and pickles are acidic. Citric acid is responsible for the tart or sour taste of citrus fruits such as lemons, oranges and grapefruits. Acetic acid is responsible for the sour taste of vinegar. Bases, which are sometimes referred to as alkaline substances, or simply alkalis, are found in antacid tablets, baking soda and soaps.

Scene 5

Perhaps one of the first things you learned in chemistry is that an element is a chemical substance that cannot be separated into simpler substances. Elements, such as gold and carbon, are the building blocks of matter. When two or more elements combine, they form compounds. Water is a compound that is composed of the elements hydrogen and oxygen. Acids, bases, and salts are compounds that ionize in water. Ions are atoms or groups of atoms that carry an electrical charge. Cations are ions that have a positive charge and anions are ions that have a negative charge. When acids, bases and salts dissociate, they separate into cations and anions.

Scene 6

Chemists use the terms physical properties and chemical properties to describe matter. Physical properties may include the structure of a compound, its formula weight, boiling point or melting point. Chemical properties describe how a compound reacts with other substances. The physical and chemical properties of acids and bases can be used to identify them. A primitive method for identifying acids and bases is on the basis of taste. Acids, such as those found in lemon juice, taste sour and alkalis, or bases, such as soap, taste bitter. However, you are strongly cautioned not to attempt this method of identification. To illustrate this warning, examine the three solutions on your screen. Can you tell which one is hydrochloric acid, which is sodium hydroxide, and which one is water? Of course you can't, because they all look the same! If you value your life, the taste test is no way to determine the identity of anything.

Scene 7

The use of an indicator is a much more acceptable test to distinguish between acids and bases. An acid-base indicator is a substance that turns one color in an acidic solution and a different color in an alkaline solution. One of the most common and easy to use indicators is litmus paper. Litmus is a natural dye derived from lichens. Lichens are organisms found on exposed rocky areas and come in a variety of colors, depending on the acidity of their environment. A thin paper strip saturated with litmus is known as litmus paper. Litmus paper turns red in an acidic solution and blue in a basic solution. Water is a neutral substance, which means it is neither acidic nor basic. Litmus paper does not change color in neutral substances or solutions.

Scene 8

Acids and bases differ in properties related to reactivity; acidic solutions react vigorously with metals such as magnesium or zinc to form new compounds. For example, magnesium metal reacts with hydrochloric acid to form magnesium chloride and hydrogen gas. Bases, on the other hand, do not react with most metals. Acids also react with many non metal substances. You are probably familiar with the stinging, burning sensation that results when acids react with various compounds in your skin, or worse yet, on a cut or abrasion. Mild basic solutions such as soapy water are less reactive and tend not to burn like an acid.

Scene 9

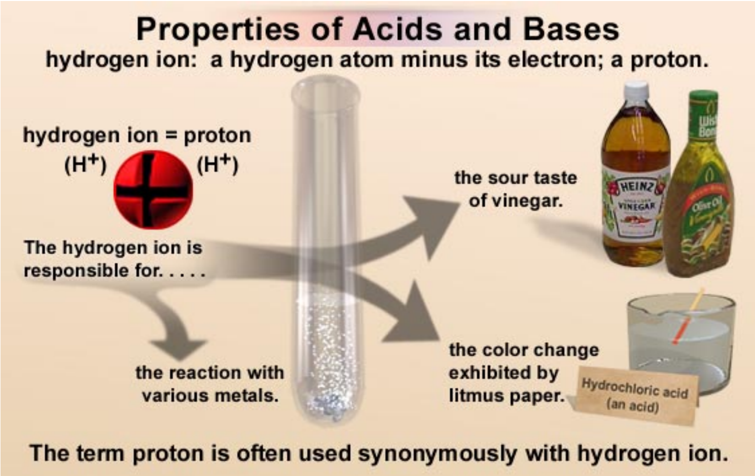
Acids, bases and salts are all examples of electrolytes. An electrolyte is a compound that dissolves in water forming a solution that conducts an electrical current. When an electrolyte, such as sodium chloride, dissolves, the positive and negative ions separate and are free to move about within the solution. In a solution of an electrolyte, ions are responsible for the transport of electrical charge through the liquid. The concentration of electrolytes is responsible for the degree of electrical conduction.

Scene 10

Now that you have learned several properties of acids and bases, let's review some differences between these compounds that can be used to identify them. First you learned that acids taste sour whereas bases are bitter tasting. Then we discussed how litmus paper turns red in an acidic solution, blue in a basic solution and undergoes no color change in neutral solutions such as pure water. Next you saw how acids react vigorously with metals such as magnesium but bases did not. Finally, you learned that acids, bases and salts are all electrolytes, which means they conduct electricity through a solution in which they are dissolved. Next you will learn how acids and bases are defined based on the ions that they donate to solution.

Scene 11

The properties of acidic solutions are due to the hydrogen ion. Often the term proton is used in lieu of hydrogen ion. The terms hydrogen ion and proton indicate slightly different concepts but are used interchangeably by most chemists. It is the hydrogen ion or proton that is responsible for the sour taste of vinegar and the color change to red exhibited by litmus paper. It is also the hydrogen ion in acidic solutions that reacts with various metals. To fully understand how the terms hydrogen ion and proton are derived and what they mean, you must first understand the atomic structure of the hydrogen atom.



Scene 12

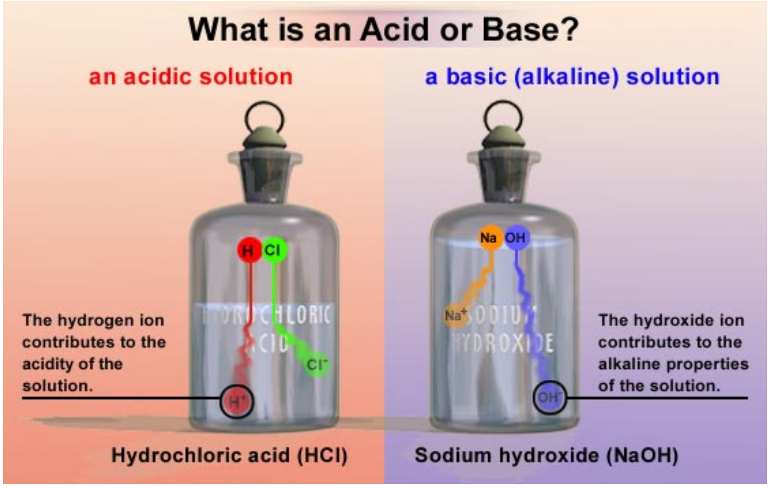
The hydrogen atom is different from all other atoms because the most abundant isotope of hydrogen does not have any neutrons. This means that, in general, a hydrogen atom is composed of one positively charged proton orbited by one negatively charged electron. Therefore, a hydrogen ion, which has lost its electron, is simply a proton.

Scene 13

Most acid-base chemistry involves liquid solutions. In chemical terms, a solution is a homogeneous mixture of more than one substance in the same physical state. Now let's interpret that statement. The components in a homogeneous mixture are so well blended that they can not readily be distinguished from each other. The air you breathe, a glass of powdered lemonade, and salt water are all examples of homogeneous mixtures. Obviously you cannot see the various types of molecules that make up these mixtures even though you might be aware of what they are. Acid-base solutions are most commonly liquids. In a solution, one substance is usually considered to be dissolved in the other. The substance that is dissolved is called the solute. The substance that does the dissolving is called the solvent.

Scene 14

This program will emphasize aqueous solutions of acids and bases. An aqueous solution describes a chemical species dissolved in water. Simply put, in an aqueous solution the solvent is water. An acid is a compound that donates a hydrogen ion, abbreviated H^+ to solution. The release of hydrogen ions as an acid dissolves in water contributes to the acidity of the solution. A base is a subtance that donates a hydroxide ion, written as OH^- to an aqueous solution. The properties of an alkaline or basic solution are due to the hydroxide ion. The hydroxide ion liberated by the base may also serve to accept a hydrogen ion, proton, in solution, neutralizing the acid and forming water in the process.



Scenes 15-28

Acids and Bases Defined

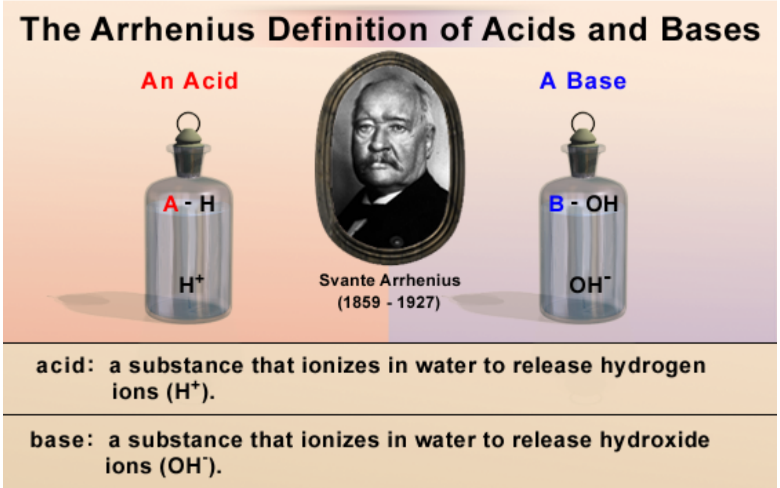
Scene Number

Scene 15

In 1884, a Swedish scientist by the name of Svante Arrhenius pioneered the study of acids and bases on the molecular level. While working towards his Ph.D. degree Arrhenius studied electrical conduction through solutions. Arrhenius was puzzled as to why some solutions conducted electricity and others did not. He believed that some compounds, such as sodium chloride, split into ions when dissolved in water while others, like sugar, did not. Arrhenius devised a theory stating these free ions were responsible for conducting the current. After concluding his work on electrical conduction, Arrhenius went on to apply his knowledge of ions and their properties to define and explain acid-base chemistry.

Scene 16

When acids, bases, and salts ionize, they form ions in solution. Arrhenius could not "see" compounds ionize, but he could infer the ionization by measuring the resulting increase in electrical conductivity. These, and other experiments led Arrhenius to propose the first accepted definition of acids and bases. Arrhenius defined an acid as a substance that ionizes in water to release positively charged hydrogen ions into solution. He defined a base as a substance that ionizes in water to release negatively charged hydroxide ions in solution.



Scene 17

Suppose a microscope was developed that could enlarge a drop of water to such a magnitude that the individual molecules were visible. Would you see that a sample of pure water contains only molecules of H_20? The answer is no, because pure water always contains small quantities of two other chemical species, positively charged hydronium ions, represented by the formula H_3O^+ and negatively charged hydroxide ions, represented by the formula OH^-. These ions exist because hydrogen ions spontaneously shift between water molecules. You may have thought that hydrogen ions simply exist in solution as independent charges. Actually, hydrogen ions almost never exist in a solution independently, hydrogen ions and their positive charge are simply transferred from one water molecule to the next.

Scene 18

Water molecules are capable of self ionizing, meaning one water molecule can spontaneously transfer a hydrogen ion to an adjacent water molecule. This transfer of charge results in a positively charged hydronium ion and a negatively charged hydroxide ion. You can think of the self ionizing of water as a neutral water molecule splitting apart resulting in two ions. When compounds such as hydrochloric acid ionize in solution protons are released, these compounds are known as acids. Most bases ionize in solution to release hydroxide ions. Hydroxide ions strongly attract protons, therefore bases are considered proton acceptors.

Scene 19

In a sample of pure water, self-ionization produces an equal concentration of hydronium ions and hydroxide ions. The balanced chemical reaction of the self-ionization of water can be used to determine the equilibrium constant, K_{eq}. The equilibrium expression for the self-ionization of water shows the concentration of ions as a mathematical relationship. The brackets around each of the reactants and products indicate that the concentration is measured in molarity, which will be briefly reviewed in the next scene. The concentration of water molecules is so much larger than the concentrations of the ions that it is not significantly affected by the changes in ion concentration. This means that the concentration of water is essentially a constant. Therefore, it can be removed from the denominator of the equation by multiplying both sides of the equation by the square of the concentration of water. The product of two constants, in this case the equilibrium constant and the concentration of water, is also a constant. This constant is called the ion-product constant for water and is abbreviated as K_W. The significance of the ion-product constant will be explained in the next few scenes.

Scene 20

The amount of solute dissolved in one liter of water determines the concentration of an aqueous solution. This concept is familiar to anyone that has made lemonade from a concentrated powder. Unlike lemonade however, chemical substances do not usually come in pre-measured packets. In the laboratory, substances are measured in units of moles or grams. Remember a mole is equal to 6.02×10^{23} particles of any substance. Molarity, abbreviated as a capital M, describes the concentration of a solution as determined by the number of moles of solute in one liter of solution. The product of the molarities of hydronium and hydroxide ions in water and aqueous solutions has been determined to be a constant, expressed as K_W, the ion-product constant for water. K_W reflects the relative concentrations of hydronium and hydroxide ions as a steady state, even though water molecules are constantly interacting; forming ions and reforming water molecules.

Scene 21

The ion-product constant, Kw, relates the molar concentration of hydronium ions to the molar concentration of hydroxide ions. In pure water, the only source of these ions is the self-ionization of water, so these two concentrations are equal. Experiments have shown that the molar concentration of each ion at 25 degrees Celsius is 1×10^{-7} moles per liter. This means that one in ten million water molecules is ionized at any given time. To determine the ion-product constant for water, multiply the concentration of hydronium ions by the concentration of hydroxide ions. When multiplying numbers represented by scientific notation, multiply the coefficients, in this case one times one, and then add the exponents, in this case negative seven plus negative seven, which equals negative fourteen. Thus, the ion-product constant is 1×10^{-14}. The ion-product constant does not have units. K_W is important, as you will see when you learn how to determine pH later in the program.

Scene 22

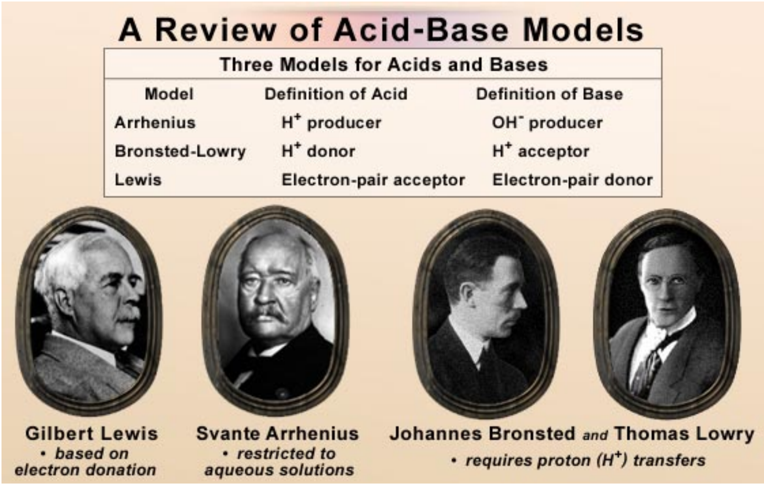
The previous several scenes have described the nature of the hydrogen atom, a brief definition of acids and bases and the chemistry of water. But how do these concepts interact to form the framework of acid-base chemistry? A water molecule, composed of 2 hydrogen atoms and one oxygen atom, can spontaneously dissociate, freeing a positively charged hydrogen ion, which is quickly accepted by a nearby water molecule and forms a hydronium ion, and a negatively charged hydroxide ion. Hydronium ions are responsible for the acidic properties of solutions and hydroxide ions are responsible for the basic properties of solutions.

Scene 23

Arrhenius defined an acid as a substance that dissociates in water to produce hydrogen ions and a base as a substance that dissociates in water to produce hydroxide ions. Although the Arrhenius model is still widely applied today, it has several limitations. The Arrhenius definition restricts acids and bases to aqueous solutions, even though similar reactions can occur between gases or in solvents other than water. Furthermore, the Arrhenius definition of a base excludes compounds, such as ammonia, which exhibit the properties of a base, but do not contain hydroxide ions. To overcome these limitations, chemists defined acids and bases in broader terms.

Scene 24

Most acid-base chemistry concerns the transfer of hydrogen ions. In 1923, Danish chemist Johannes Bronsted and English chemist Thomas Lowry separately proposed a definition of acids and bases based on the transfer of hydrogen ions. The Bronsted-Lowry definition defines an acid as a hydrogen ion donor and a base as a hydrogen ion acceptor. In the reaction on your screen, hydrogen chloride is a Bronsted-Lowry acid and water acts as a Bronsted-Lowry base. The Bronsted-Lowry model serves to include many acids and bases that were not considered within the narrower Arrhenius definition.



Scene 25

Another model for acids and bases was proposed by G.N. Lewis in the 1920's. Lewis described acids and bases in terms of electrons. According to the Lewis model, an acid-base reaction takes place when one chemical species shares a pair of electrons with another. The species that accepts the electron pair is an acid. The species that donates the electron pair is a base. Consider the reaction between the gases - boron trifluoride and ammonia. Here, boron trifluoride acts as a Lewis acid by accepting an electron pair and ammonia serves as the Lewis base because it donates an electron pair.

Scene 26

As you just learned, the Lewis model is the most general definition of acids and bases because it is based on electron transfer. One valuable aspect of the Lewis model is that it includes many reactions that are not included within the Arrhenius and Bronsted-Lowry models. The Lewis definition is not restricted to aqueous solutions like the Arrhenius definition and does not involve proton transfers as the Bronsted-Lowry definition requires. However, since this program will concentrate on the properties of acids and bases in solution, the Arrhenius and Bronsted-Lowry definitions will be referred to most frequently.

Scene 27

Acids may be classified by the number of ionizable hydrogen ions the compound contains. You can think of an ionizable hydrogen as one that is capable of being donated to solution. A compound such as hydrochloric acid, HCl, is called a monoprotic acid because upon dissociation, the compound donates one proton to solution. Similarly, sulfuric acid, H_2SO_4, or any acid that contains two ionizable protons is known as a diprotic acid. Phosphoric acid, H_3PO_4, contains three ionizable protons and therefore, is known as a triprotic acid.

Scene 28

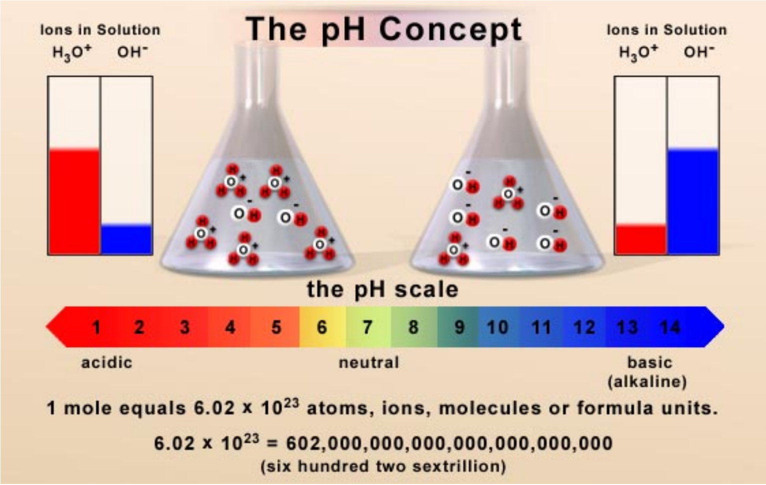
When an acid, such as hydrochloric acid, dissociates to contribute hydrogen ions to solution, the concentration of hydronium ions changes. Can you see how a rapid increase in the concentra tion of hydronium ions results as the protons are accepted by surrounding water molecules? Hydrogen ions are also accepted by hydroxide ions, forming water molecules and lowering the concentration of hydroxide ions. Acids increase the concentration of hydronium ions and decrease the concentration of hydroxide ions in a solution. What about the effect of the chloride ion? The chloride ion has little effect on the acidity of the solution, because acid-base solutions are defined entirely by their concentrations of hydronium ions.

Scenes 29 - 36

pH

Scene Number

Scene 29



As you just learned, the acid or base properties of a solution are described in terms of hydronium ion concentration. Since actual number of ions is measured in moles and the mole is an incredibly large number, the concentration of hydronium ions is typically written as a negative exponent, representing a fraction of a mole. For example the fraction one -one thousandth of a mole in a liter of solution would be expressed as 1 x 10^{-3} molar. Remember, the larger the negative exponent, the smaller the actual number. In a very acidic solution, such as battery acid, the concentration of hydronium ions may be as high as 1 x 10^{-2} molar. Compare the concentration of hydronium ions in battery acid to the concentration of hydronium ions in pure water, 1 x 10^{-7} molar. Because ten to the minus two divided by ten to the minus seventh is ten to the fifth, the concentration of hydronium ions is one hundred thousand times higher in battery acid than in pure water. In a very alkaline solution such as laundry bleach, the concentration of hydronium ions may be as low as 1 x 10^{-12} molar.

Scene 30

As you just learned, the acidity of a solution is determined by the molar concentration of hydronium ions. However, many people are unfamiliar with the meaning of exponential numbers or are uncomfortable with their use. Fortunately, Soren Sorensen, a Danish biochemist, came up with another way to describe the concentration of hydronium ions in solution. Sorensen's scale, known as the pH scale, ranges in numerical value from zero to 14. The abbreviation pH is derived from the German phrase potenz hydrogen. Potenz, the German word for power, describes the exponential power of ten in the hydrogen ion concentration that each unit of the scale represents.

Scene 31

All compounds and solutions can be classified as either acidic, basic or neutral. pH values below 7 indicate a solution is acidic. pH values above 7 indicate a basic solution. Any substance with a pH of exactly 7, such as pure water, is neutral - being neither an acid nor a base. Pure water is neutral, meaning it is neither acidic nor basic because the concentration of hydronium ions and hydroxide ions are in equal concentrations of 1 X 10^{-7} moles per liter. To understand the logic of the pH scale, it helps to realize that the molarity as indicated by pH reflects only the concentration of hydronium ions.

Scene 32

The base ten logarithm, also called the log, of a number represents the power to which ten must be raised in order for it to equal a given number. For instance, one hundred is equal to ten to the second, so the logarithm of one hundred is two. Logs allow one to represent very large or very small numbers, such as molar concentrations, in a more compact form. pH is defined as the nega tive log of the molar hydronium ion concentration. The log of a number written in scientific notation is equal to the log of the coefficient added to the power to which ten is raised. To determine the pH of water, start by noting that the concentration of hydronium ions in pure water is one times ten to the negative seven moles per liter. The log of the coefficient, which is one, equals zero, because one equals ten to the zero power. The log of the coefficient, in this case zero, is added to the log of ten to the negative seventh, which equals negative seven. Since pH is defined as the negative log of the hydronium ion concentration, the pH value is seven, because a negative times a negative is a posi tive. Can you see how solutions containing various molar concentrations of hydronium ions are expressed as pH values?

Scene 33

By now, you should recognize that a solution with a hydronium ion concentration of 1×10^{-3} molar has a pH of 3. But what if the coefficient is not one? For example, what would be the pH of a solution with a hydronium ion concentration of 1.4×10^{-3} M? This presents a slight problem, but one that you can handle. Simply add the log of the coefficient, which is one point four, to the log of ten to the negative third. The value of the log of one point four is .1461 and, of course, the log of ten to the negative third is negative three. This means the log of the concentration of hydronium ions is negative 2.854. pH is the negative log of the concentration of hydronium ions, so the pH is 2.854. The final answer, 2.85, is rounded to two digits beyond the decimal point because the number of digits reported beyond the decimal point must equal the number of significant digits in the given molar concentration.Now think about the answer (2.85). A hydrogen ion concentration of 1.0×10^{-3} molar would equal a pH of exactly 3. So, a slightly higher concentration of hydrogen ions (1.4×10^{-3} M) should decrease the pH slightly, resulting in a more acidic solution as indicated by the answer, 2.85.

Scene 34

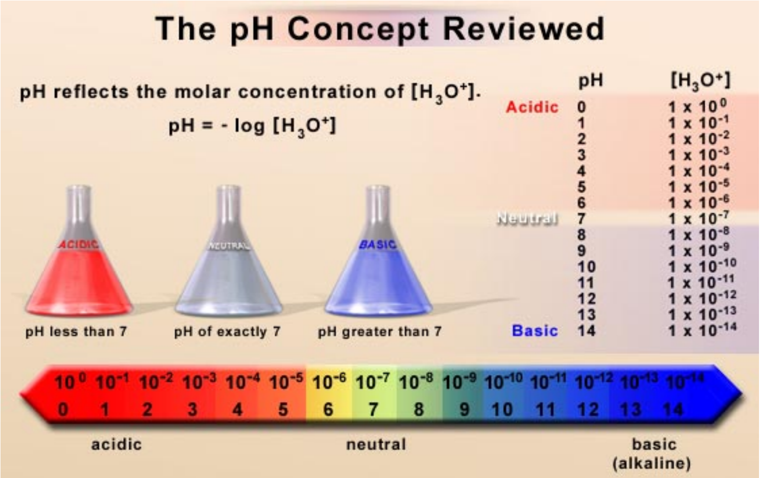
In a neutral solution, hydronium and hydroxide ions exist in equal concentrations as expressed by the ion constant for water K_W. However, most solutions are not perfectly neutral and hydronium and hydroxide ions exist in inverse concentrations. In the simplest of terms, you can think of these two ions as two children on a teeter totter. When one child goes up, the other must go down, and vice versa. If the concentration of hydronium ions decreases then the concentration of hydroxide ions increases and likewise, if the concentration of hydronium ions increases then the concentration of hydroxide ions must decrease.

Scene 35

You have already learned that the product of the concentration of hydroxide ions and the concentration of hydronium ions equals the ion-product constant, 1×10^{-14}. Therefore, dividing the ion-product constant by a known concentration of hydroxide ions gives you the concentration of hydronium ions. For example, if the concentration of hydroxide ions in a solution is 3.5×10^{-2} molar, what is the concentration of hydronium ions? Dividing the ion product constant of 1×10^{-14} by the concentration of hydroxide ions, 3.5×10^{-2} molar, gives you a hydronium ion concentration of 2.86×10^{-13} molar. Do you remember how to convert molar concentration to pH? Add the log of 2.86, which is .4563, to the log of 10^{-13}, which is negative thirteen. This gives you a log of -12.5437, and multiplying by negative one gives a pH of 12.5437. Now round the answer to two places past the decimal point, which gives a pH of 12.54.

Scene 36

In summary, the acid-base properties of a solution are determined by the concentrations of hydronium ions. These ions occur naturally in solution due to the self- ionization of water molecules. The product of the concentrations of hydronium and hydroxide ions in aqueous solution is known as the ion-product constant of water and is represented by the symbol Kw. Since numbers of ions are reported in units of moles, the actual number of ions is a fraction of a mole written in exponential notation. The pH concept converts these small values to positive numbers on the 14 unit pH scale. Neutral solutions with equal numbers of hydroxide and hydronium ions have a pH of exactly 7.0. A solution in which hydronium ions outnumber hydroxide ions is acidic and will have a pH below 7.0. A solution in which hydroxide ions outnumber hydronium ions is basic, or alkaline, and will have a pH above 7.0.



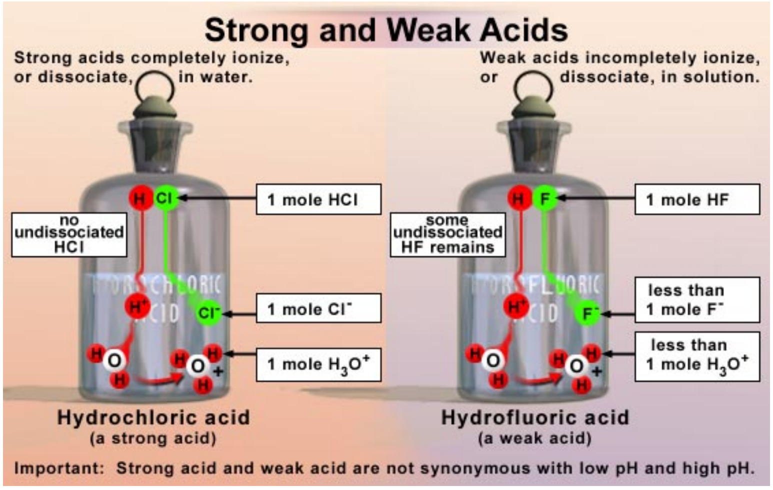
Scenes 37-47

Acid & Base Interactions and Strength

Scene Number

Scene 37

In chemistry, acids are broken up into two broad categories; strong acids and weak acids. It is important to note that these terms are not synonymous with low pH and high pH. Depending on concentration, a solution of a strong acid, such as hydrochloric acid, can have a pH close to neutral, and a solution of a weak acid, such as acetic acid, can have a low pH, meaning it is far from neutral. A strong acid is one that dissociates completely in water. For example, in an aqueous solution of hydrogen chloride, there are essentially no hydrogen chloride molecules in solution because they all dissociate to produce hydrogen ions and chloride ions. This means one mole of hydrogen chloride in solution produces one mole of hydronium ions. In contrast, in an aqueous solution of hydrofluoric acid, most of the acid does not dissociate. This means one mole of hydrofluoric acid, or any other weak acid, will produce less than one mole of hydronium ions. A measure of the strength of weak acids, the acid dissociation constant, will be discussed in the next few scenes.



Scene 38

The acid dissociation constant, K_a, quantifies the extent of dissociation among weak acids. This allows comparison of the relative strengths of weak acids and calculations of their pHs acids to be made. K_a is derived from the equilibrium equation of a weak acid that dissociates in aqueous solution. If the acid is represented as HA, the balanced chemical equation is

$HA(aq) + H_2O(l) \longleftrightarrow H_3O^+(aq) + A^-(aq)$. At equilibrium, this can be represented as

$K_{eq} = [H_3O^+][A^-]/[HA][H_2O]$, where K_{eq} is known as the equilibrium constant. As with the ion-product constant, the concentration of water in the dilute solutions made by weak acids is essentially a constant. Multiplying both sides of the equation by the concentration of water removes the term from the denominator on the right side of the equation and separates the variables from the constants. The product of the two constants on the left side, K_{eq} and the concentration of water, gives a new constant, K_a, called the acid dissociation constant. Since a strong acid completely dissociates in water, the denominator of the acid dissociation constant expression would be zero, and the value of the expression would be undefined. This is why K_a is typically used only for weak acids. Like the ion-product constant, the acid dissociation constant has no units.

Scene 39

As you just learned the acid dissociation constant K_a , is used to describe the behavior of acids in an aqueous solution. Keep in mind, an aqueous solution is a solution in which the solvent is water. The acid dissociation constant, K_a, represents the degree to which an acid dissociates or splits apart in water. Observing the K_a expression for acetic acid will help you visualize how the mathematical expression relates to actual acids and the ions they form in solution.

Scene 40

What does the acid dissociation constant, K_a, really mean? The larger the given K_a value, the more the acid dissociates in water to form hydronium ions and therefore, the stronger the acid. Each weak acid has a characteristic K_a value. Weak acids have a dissociation constant, K_a, of much less than one, indicating that only a fraction of the acid molecules dissociate in water. By looking at the table provided for you on your screen, can you determine that acetic acid is a weaker acid than chlorous acid?

Scene 41

A base can contribute hydroxide ions to an aqueous solution in two ways. Bases may ionize, resulting in a direct increase in hydroxide ion concentration, or they may attract hydrogen ions from water molecules resulting in an indirect increase in hydroxide ions. Remember that when a base, symbolized as B, accepts a proton, it becomes the conjugate acid of that base, symbolized as HB^+. Derived in a fashion similar to the acid dissociation constant, the base dissociation constant, expressed as K_b, represents the contribution of hydroxide ion to solution by a weak base. The larger the K_b value the stronger the base and the greater the contribution of hydroxide ions to solution. Observe how the expression illustrates the contribution of hydroxide ions by aqueous ammonia.

Scene 42

Strong bases dissociate in water to release hydroxide ions or attract hydrogen ions from water to form hydroxide ions. Compounds such as sodium hydroxide that completely ionize in solution are strong bases. Like strong acids, strong bases completely ionize in water, so K_b values are not typically used for strong bases. Weak bases only partially dissociate in water. The smaller the K_b value, the smaller the extent of dissociation, and therefore, the weaker the base. There are several common weak bases, such as ammonia, NH_3. By looking at the table provided for you on your screen, can you determine that methylamine is a stronger base than ammonia?

Strong and Weak Bases

Strong Bases

Formula	Name
Na OH	Sodium hydroxide
K OH	Potassium hydroxide
Ca $(OH)_2$	Calcium hydroxide
Ca O	Calcium oxide

K_b Values for Some Weak Bases

Formula	Name	K_b
CH_3NH_2	Methylamine	4.4×10^{-4}
NH_3	Ammonia	1.8×10^{-5}
N_2H_2	Hydrazine	2.2×10^{-8}
HCO_3^-	Bicarbonate ion	1.5×10^{-11}

Scene 43

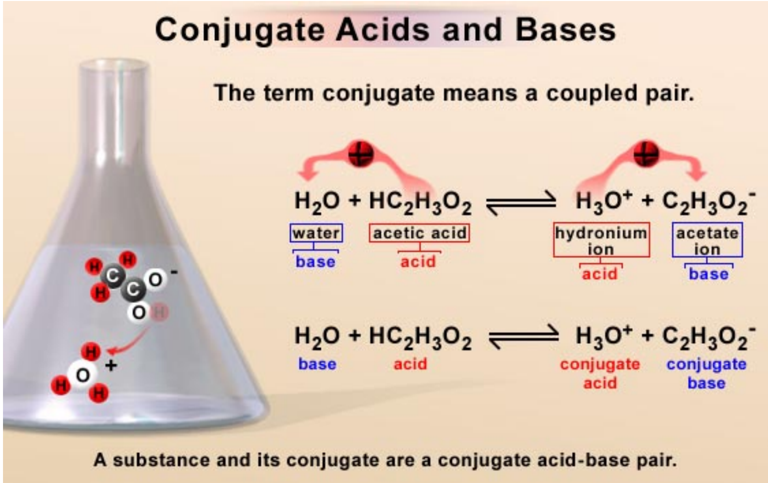
You have learned that the pH of a solution is based on the concentration of hydronium ions. You also know that bases increase the concentration of hydroxide ions by directly donating them or indirectly, by accepting hydrogen ions. Neutralization describes the process of bringing a solution closer to a neutral pH. A base can neutralize an acidic solution by attracting protons. In the same vein, acids neutralize basic solutions by donating protons. Hydroxide ions have a strong affinity for hydrogen ions and will attract them from nearby hydronium ions resulting in the formation of two water molecules. Some bases, such as ammonia, do not release hydroxide ions but instead steal protons from hydronium ions forming water and ammonium ion. Regardless of the mechanism, bases neutralize acidic and acids neutralize basic solutions, bringing a solution's pH closer to neutral. Neutralization reactions often result in the formation of water molecules and in ionic compounds called salts, which you will learn about in the next section of the program.

Scene 44

Some compounds function as either an acid or a base depending on the reaction conditions. These substances are defined as amphoteric. The term amphoteric is taken from the Greek language and means "partly one and partly the other". In acid-base chemistry, amphoteric compounds can act as both proton donors or proton acceptors. Though many substances may have amphoteric properties the best known amphoteric compound is water. In this reaction for example, water, acting as an acid, donates a hydrogen ion to ammonia forming ammonium ion. However, when water reacts with hydrochloric acid, it acts as a base accepting a hydrogen ion forming the hydronium ion.

Scene 45

The equation on your screen shows the reversible reaction of acetic acid and water. As the reaction proceeds from left to right, acetic acid ionizes and transfers a hydrogen ion to water, creating the products, a hydronium ion and an acetate ion. Because acetic acid donates a proton, by the Brosted-Lowry definition, it acts as an acid. By accepting a proton, water acts as a Bronsted-Lowry base. In the reverse direction, right to left, the hydronium ion donates a proton to the acetate ion. In this case, the hydronium ion is acting as an acid, by donating a proton, and the acetate ion is acting as a base, by accepting a proton. Notice that water acts as a base on the left side of the equation and forms the hydronium ion, which acts as an acid on the right side of the equation. The hydronium ion is therefore referred to as the conjugate acid of water. Acetic acid acts as an acid on the left side of the reaction and forms an ion that acts a base on the right side of the equation. The acetate ion is known as the conjugate base of acetic acid. The conjugate acid of a substance is formed when that substance gains a proton. In the same vein, a conjugate base of a substance is formed when that substance has donated a proton. A substance and its conjugate are known as a conjugate acid-base pair.

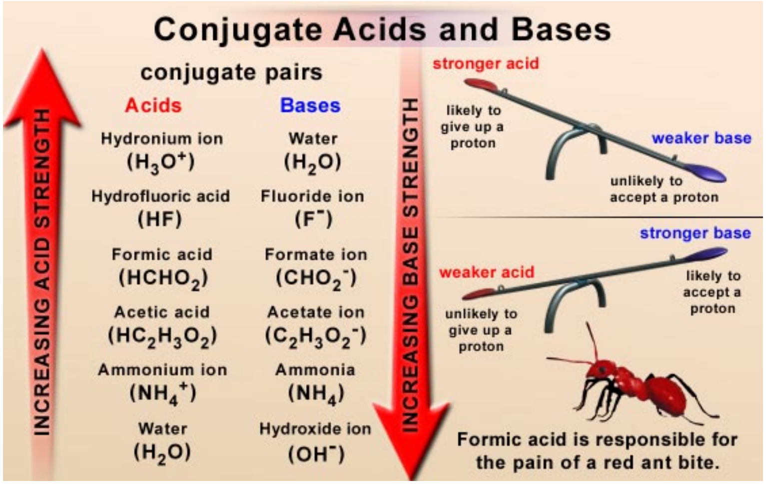


Scene 46

Now take a look at the reversible reaction of ammonia in an aqueous solution. As the reaction proceeds from left to right, aqueous ammonia acts as a base, accepting a proton from water. Since water is donating a proton, it is acting as an acid. In the reverse reaction, the ammonium ion is the conjugate acid of ammonia and acts as an acid, because it donates a proton to the hydroxide ion. The hydroxide ion is the conjugate base of water, because it accepts the proton. In this reaction, ammonia and the ammonium ion are a conjugate acid-base pair. A line is often used to connect a conjugate acid-base pair to one another. You may also have noticed that there is another conjugate acid-base pair. Do you see that the water molecule is an acid in this reaction, and that the hydroxide ion is its conjugate base?

Scene 47

As you can see from the chart provided, there is an inverse relationship between the strengths of the members of a conjugate acid-base pair. This means that the stronger an acid, the weaker its conjugate base, and the stronger a base, the weaker its conjugate acid. Compare formic acid, which is responsible for the painful bite of a red ant, to a weaker acid, acetic acid. The conjugate base of formic acid, the formate ion, is a weaker base than the conjugate base of acetic acid, the acetate ion. In simple terms, the more eager an acid is to give up its proton, that is, the stronger the acid is, the less eager its conjugate base will be to pick up a proton. Similarly, the more likely a base is to accept a proton, the less likely its conjugate acid will be to give up that proton.



Scenes 48-53

Salts

Scene Number

Scene 48

Now that you are familiar with some aspects of acid-base chemistry we can turn our attention to a related class of compounds, salts. Salts are ionic compounds composed of any positive ion other than hydrogen and any negative ion other than hydroxide or oxide. Acids and bases can react to form salts. Like couples in a chemical dance, the ions from acids and bases exchange partners, thus forming a salt.

Scene 49

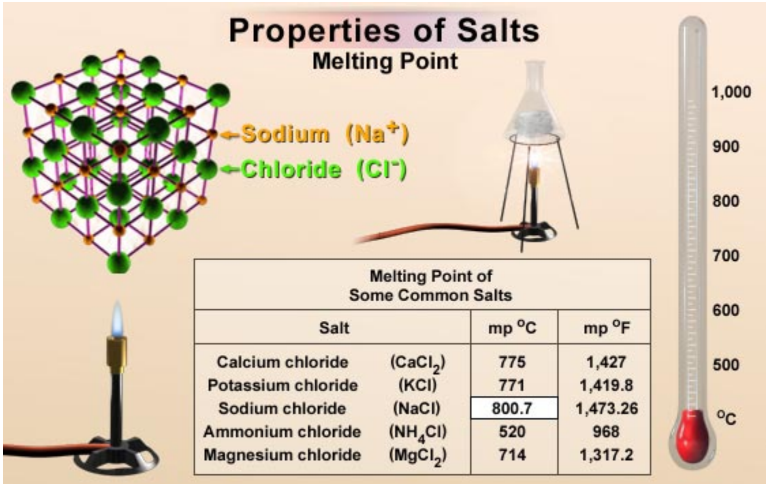
Although salts are formed from acids and bases, they exhibit almost none of the properties of their parent compounds. Whereas acids and bases react with other compounds, most salts are relatively non reactive. Acids and bases usually exist as a liquid or gas while salts form solids.

Scene 50

Salts form solid structures known as crystals. The properties of salts result from the arrangement of ions within these crystals. Attraction between oppositely charged ions and repulsion between ions of the same charge are strong. Consequently ions with opposite charges in a salt crystal align in an alternating pattern. The resulting crystal lattice gives salts their hard, yet brittle properties. The bonds between the positive and negative ions are very strong, therefore, ionic compounds such as salts are difficult to crush and are not very pliable. However, when struck sharply they easily break or shatter because ions in the crystal lattice shift, causing like charges to align and repel one another. The repulsion between ions with the same charge becomes so intense that the crystal shatters.

Scene 51

At a temperature specific to each salt, the energy from heat is great enough to overcome the strong attractions between the positive and negative ions within a crystal. This temperature is called the melting point. Salts exhibit high melting points because the bonds between positive and negative ions are very strong. At room temperature, ions within a crystal are tightly packed next to one another. Although they are constantly vibrating in place, they cannot move about within the lattice structure because the bonds are too strong. When heated, the ions gain energy and begin to move within the lattice, bouncing off one another.



Scene 52

One property that the crystal lattice does not confer upon salts is electrical conductivity. Normally, electricity cannot flow through the fixed ions in the lattice. Ionic compounds only conduct electricity when dissolved in solution or when a solid melts. When an electrolyte, such as sodium chloride, melts or dissolves, the positive and negative ions separate and are free to move about. In the liquid state, and in solutions, ions are responsible for the transport of electrical charge through the solution.

Scene 53

Although the best known salt by far is sodium chloride, there are many different salt compounds and some of them are commonly used by humans. Ammonium sulfate and ammonium nitrate are included in many commercial fertilizers. These salts ionize in the presence of water to add nitrogen and sulfur to soils depleted of these elements. Calcium sulfate, known commonly as plaster, is used to form casts. Potassium nitrate is used in the manufacture of explosives, including these fireworks.

Scenes 54-56

Acids & Bases & the Environment

Scene Number

Scene 54

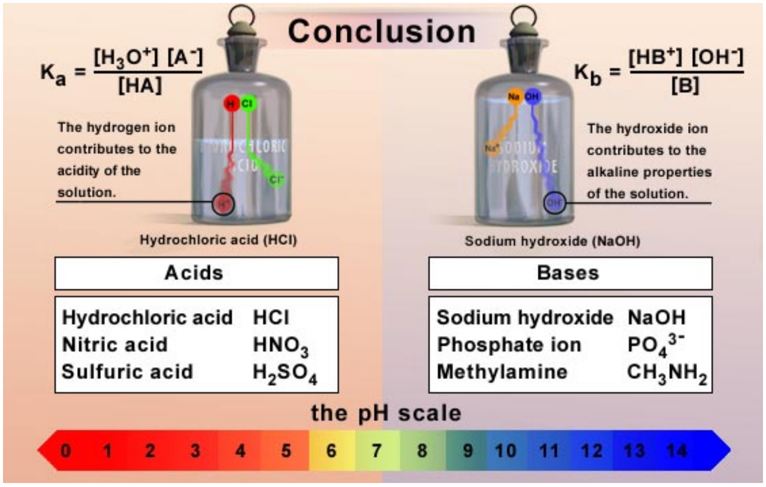
As you learned earlier, pure water has a pH of exactly 7. Normal rainwater has a pH of about 5.6, which is slightly acidic. The acidic pH of rain occurs because some of the carbon dioxide in the atmosphere reacts with water as rain falls to Earth, forming carbonic acid (H_2CO_3). You are probably familiar with the term acid rain. Acid rain has a pH below that of normal rainwater. Acid rain results primarily from air pollution produced by such sources as industrial emissions, car exhausts and volcanic eruptions. Most air pollution is a combination of sulfur dioxide and nitrogen oxides. These gases react with water vapor to form weak solutions of sulfuric and nitric acid which fall to Earth as acid rain.

Scene 55

Acid rain can have a variety of detrimental effects on ecosystems. When acid rain decreases the pH of lakes and rivers, it can affect the amphibians, fish, and other animals that live there. When it falls on land, it disrupts plant-life and can even disturb entire forests. Acid rain also causes damage to man-made structures, such as sculptures, and even historical buildings and bridges, which may be rendered unsafe.

Scene 56

In this program you learned that acids and bases can be potentially dangerous compounds and that safety should always be a consideration when handling these substances. Several definitions serve to describe the chemical behavior of acids and bases. This presentation has focused on the Arrhenius, Bronsted-Lowry and Lewis models. You have learned that the concept of pH serves to convert molar concentrations of hydronium ions into values arranged on a scale from zero to fourteen. The concept of strong and weak acids and bases was also discussed, based on the degree of ionization that takes place when an acid or base dissolves in water. Salts result from reactions between acids and bases. Salts, such as sodium chloride, display very different properties from either acids or bases and are usually found as crystalline solids. Finally, you learned about some of the impacts that acid rain has on the environment.



The Properties of Acids, Bases and Salts
Exam

1. Acids and bases react with one another to form _________.

A. strong bases
B. weak acids
C. salts
D. bleach

2. A base is a proton ___________.

A. donor
B. molecule
C. acceptor
D. separator

3. The acid responsible for the sour taste of grapefruit, lemons and oranges is _______.

A. acetic acid
B. hydrochloric acid
C. nitric acid
D. citric acid

4. The acid responsible for the sour taste of vinegar is ______________.

A. acetic acid
B. hydrochloric acid
C. nitric acid
D. citric acid

5. The term alkali or alkaline refers to the properties of a(n) ___________.

A. acid
B. salt
C. base
D. amphoteric

6. Compounds are electrically ___________.

A. neutral
B. negative
C. positive
D. charged

7. When a strip of litmus paper is dipped into an acidic solution the paper turns ______.

A. blue
B. green
C. red
D. yellow

8. When a strip of litmus paper is dipped into an alkaline solution the paper turns ______.

A. blue
B. green
C. red
D. yellow

9. Acids react vigorously with many metals.

A. True
B. False

10. Bases react vigorously with many metals.

A. True
B. False

11. A substance that dissolves in solution to conduct and electrical current is ____.

A. an electrolyte
B. an acid
C. a base
D. all the above

12. Hydrogen atoms do not contain a ___________.

A. proton
B. electron
C. nucleus
D. neutron

13. A hydrogen ion is often referred to as a __________.

A. proton
B. electron
C. nucleus
D. neutron

14. The term aqueous refers to _____.

A. water
B. salt
C. acid
D. base

15. The first person to define an acid and base in chemical terms was ________.

A. C.N. Lewis
B. Johannes Bronsted
C. Thomas Lowry
D. Svante Arrhenius

16. The abbreviation K_W represents the _________________.

A. acid dissociation constant
B. ion product constant of water
C. base dissociation constant
D. musical group “Killer Worms”

17. Most acid-base chemistry involves the transfer of _________.

A. electrons
B. calcium ions
C. neutrons
D. hydrogen ions

18. When acids dissociate they release ___________.

A. hydrogen ions
B. hydroxide ions
C. chloride ions
D. sodium ions

19. When bases dissociate they release ___________.

A. hydrogen ions
B. hydroxide ions
C. chloride ions
D. sodium ions

20. pH = -log $[H_3O^+]$

A. True
B. False

21. The abbreviation K_a represents the ___________.

A. acid dissociation constant
B. ion constant for water
C. base dissociation constant
D. salt dissociation constant

22. An amphoteric compound can act like _____.

A. an acid
B. a base
C. a salt
D. an acid or base

23. Pure water has a pH of _____________.

A. 1
B. 5
C. 7
D. 11

24. Normal rainwater is slightly acidic because water vapor combines with carbon dioxide in the atmosphere to form _____________.

A. acetic acid
B. citric acid
C. carbonic acid
D. hydrochloric acid

25. The first thing you should do when an accident occurs in the laboratory is _____.

A. try to clean it up
B. panic
C. tell your instructor
D. blame it on someone else

26. When a hydroxide ion (OH^-) accepts a proton (H^+) ___________.

A. hydrochloric acid is formed
B. sodium hydroxide is formed
C. hydronium ions are formed
D. water is formed

27. Protons float around in solution as tiny positive charges.

A. True
B. False

28. A solution with a pH of 8.5 is _______.

A. neutral
B. basic
C. acidic
D. salty

29. What is the pH of a solution with a hydronium ion concentration of 1×10^{-11} molar ?

A. pH 1
B. pH 8
C. pH 11
D. pH 14

30. What is the pH of a solution with a hydronium ion concentration of 1×10^{-2} molar?

A. pH 1
B. pH 2
C. pH 12
D. pH 1.2

31. A pH 5 solution would have a corresponding hydronium ion concentration of _________.

A. 1×10^{-4}
B. 1×10^{-15}
C. 1×10^{5}
D. 1×10^{-5}

32. The term “ionization” refers to ____________________.

A. the formation of a compound
B. the splitting of a compound into ions
C. the pH constant of water
D. a basic, or alkaline, solution

33. The term “conductivity” refers to __________________.

A. the conduction of electricity
B. litmus paper turning colors
C. the reaction of acids with metals
D. the sour taste of acids

34. Neutralizing reactions in a solution ___________.

A. make a solution more acidic
B. make a solution more alkaline
C. bring the solution closer to neutrality
D. None of the above.

35. Using a powerful microscope, it is possible to actually see hydronium and hydroxide ions in a sample of pure water.

A. True
B. False

36. Ammonia (NH_3) is a weak _____________.

A. acid
B. base
C. atom
D. compound

37. Salts have very low melting points.

A. True
B. False

The Properties of Acids, Bases and Salts

Exam Answer Key

1.	C	19.	B
2.	C	20.	A
3.	D	21.	A
4.	A	22.	D
5.	C.	23.	C
6.	A.	24.	C
7.	C.	25.	C
8.	A.	26.	D
9.	A.	27.	B
10.	B.	28.	B
11.	D.	29.	C
12.	D.	30.	B
13.	A.	31.	D
14.	A.	32.	B
15.	D.	33.	A
16.	B.	34.	C
17.	D.	35.	B
18.	A.	36.	B
		37.	B