Chapter 2: Chemical Reactions

Learning Outcomes:

1) Students should be able to analyze, interpret and describe chemical equations.
2) Students should be able to balance, categorize and predict products of different chemical reactions
3) Interpret and analyze activity series metals, and solubility rules of ionic compounds

Essential Vocabulary

Chemical equations, reactants, products, phase labels, Arrhenius acid, Arrhenius base, strong acids and bases, weak acids and bases, pH, combination reaction, decomposition reaction, combustion reaction, single displacement reaction, double displacement reaction, Acid-base (neutralization reaction).

1.0 Chemical Equations

In chemistry, chemical equations are used to represent chemical reactions. Chemical equations describe a reaction in terms of ***reactants, products***, and ***reagents*** (often encountered in organic chemistry). Below is a generic example of a chemical reaction.

$$\text{reactant(s)} \longrightarrow \text{product(s)}$$

The reactants in a chemical reaction are always located on the left side of the arrow. The products are always located on the right (for irreversible reactions). The arrow means yields, produce or creates. The arrow also indicates the direction in which the reaction proceeds. If there are more than one reactant a plus sign is used to indicate the total number of reactants.

1.11 Phase labels

In chemical equations the phase of matter of each reactant and product is represented by phase labels. Solids are represented by an s in parenthesis (s). Liquids are represented by an l in closed parenthesis (l). Gases are represented by a g in closed parenthesis (g). Aqueous solutions (dissolved in water) are represented by an aq in closed parenthesis (aq). Phase labels are located to the right of a reactant or product. For example, hydrogen (H_2) gas reacts with oxygen gas (O_2) to produce liquid water (H_2O). The chemical equation, including phase labels, describing this reaction is written as follows. *Notice that this chemical equation is not chemically balanced:*

$$H_2(g) + O_2(g) \longrightarrow H_2O\,(l)$$

Example Problem: The element carbon, solid, reacts with oxygen, gas, to form carbon dioxide, gas. Write the chemical equation for this reaction including phase labels for all reactants and products.

Solution: In this reaction the reactants, carbon is a solid which has the phase label (s) and oxygen is a gas which has a phase label of (g).). The product carbon dioxide is a gas which has a phase label of (g). Below is the chemical equation of this reaction with phase labels for each reactant and product.

$$C\,(s) + O_2\,(g) \longrightarrow CO_2\,(g)$$

1.2 Balancing Chemical equations

Chemical equations are not completely accurate until the equation is balanced. A ***balanced chemical equation*** has the same number of atoms of each element involved in the reaction on both the reactant and product side. There is no loss or gain of atoms in the overall reaction (conservation of mass). Below is an example of the balanced chemical reaction of the formation of water from the reaction of H_2 (gas) and O_2 (gas).

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O\,(l)$$

In this balanced equation the number of atoms of each element are equivalent on the reaction and the product side. The number placed before each reactant and product is called the coefficient. Coefficients *can be changed* when balancing equations. If no coefficient is present before a reactant or product, we assume that the coefficient number is 1. For example, in the problem below, H_2 has the coefficient 2, O_2 has the coefficient 1 and H_2O has the coefficient 2. The coefficient number is always distributed throughout the entire reactant or product that it proceeds. Coefficient are represented by whole *numbers* when used in chemical equations. The number located in the lower right following a reactant or product is called the subscript. The subscript number indicates the number of atoms of the element it is associated with. When balancing a chemical equation subscripts *cannot be changed*. Let's calculate the number of atoms involved in the reaction of H_2(gas) plus O_2 (gas) to produce H_2O (water). The coefficients of each reactant are illustrated in red and the subscripts illustrated in black.

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O\,(l)$$

(2 x 2)	# of H atoms = 4	(2 x 2)	# of H atoms = 4
(1 x 2)	# of O atoms = 2	(2 x 1)	# of O atoms = 2

On the reactant side of the reaction we have a total of 4 hydrogen atoms and 2 oxygen atoms. On the product side of the reaction we also have a total of 4 hydrogen atoms and 2 oxygens atoms. This chemical equation is balanced.

1.3 Acids and Bases

An **Arrhenius acid** when dissolved in water (H_2O) gives a hydronium ion (H_3O^+). The hydronium ion can also be represented by the hydrogen ion (H^+). Acids are represented with a hydrogen first followed by elements.

Strong acids have the following physical and chemical characteristics:

1) Strong acids are slippery
2) React vigorously with water
3) Are strong electrolytes (conduct electricity when dissolved in H_2O0
4) Strong acids are corrosive
5) Have low pH

Strong acids dissociate 100% when dissolved in H_2O. This means that in water, referred to as an aqueous solution, a strong acid exists entirely as ions. For instance, when HCl is dissolved in water the following reaction occurs:

$$HCl + H_2O \longrightarrow H_3O^+ + Cl^-$$

The arrow used points in one direction (from reactants to products), this indicates that the reaction is irreversible. Below is a table of the most common strong acids

Table 1: Most common strong acids

HCl- Hydrochloric Acid	$HClO_4$- Perchloric Acid
HBr - Hydrobromic Acid	$HClO_3$ - Chloric Acid
HI - Hydroiodic Acid	HNO_3 - Nitric Acid
H_2SO_4 - Sulfuric Acid	

Weak acids do not dissociate appreciably in H_2O. This means that the weak acid does not exists entirely as its ions when dissolved in H_2O. Weak acids exist as mostly acid with a relatively small amount of dissociation. For instance, when hydrogen fluoride is dissolved in water the following reaction occurs:

$$HF + H_2O \rightleftharpoons H_3O^+ + F^-$$

The arrow used points in both directions (from reactants to products and from product to reactants). This indicates that the reaction is reversible. Notice that the bottom arrow is longer pointing from products to initial reactants. This indicates that the reverse reaction is favored. Generally, weak acids are those not listed in table 1.

Binary Acids

Binary acids are acids that contain Hydrogen and a nonmetallic element. For example, HCl, HBr, HF, H_2S and H_3P are examples of binary acids. When naming binary acids, the following rules apply:

1. Name the hydrogen part of the acid first by using hydro. This is the prefix
2. Use the elements anion name and replace the ***ide*** with ***ic***
3. End the name with acid.

Below is a table of several common nonmetallic elements that produce acids when combined with hydrogen and their anion names

Table 2: Element names, anions anion name and anion root names for common nonmetallic elements

Element Name	Anion symbol	Anion name	Anion Root
Fluorine	F^-	fluoride	fluor
Chlorine	Cl^-	chloride	chlor
Bromine	Br^-	bromide	brom
Iodine	I^-	iodide	iod
Sulfur	S^{2-}	sulfide	sulfur
Selenium	Se^{2-}	selenide	selen
Nitrogen	N^3-	nitride	nitr
Phosphorous	P^{3-}	phosphide	phosphor

Example Problem: Name the following Binary Acids

a) HBr b) HI c) H_2S d) H_3P

Solutions: a) Name the hydrogen of the acid as hydro. The anion of HBr is bromide. Replace the ide of the anion with the ending ic. End the name with acid. Therefore, the name is hydrobromic acid

b) Name the hydrogen of the acid as hydro. The anion of HI is iodide. Replace the ide of the anion with the ending ic. End the name with acid. Therefore, the name is hydroiodic acid.

c) Name the hydrogen of the acid as hydro. The anion of H_2S is sulfide. Replace the ide of the anion with the ending ic. End the name with acid. Therefore, the name is hydrosulfuric acid

d) Name the hydrogen of the acid as hydro. The anion of H_3P is phosphide. Replace the ide of the anion with the ending ic. End the name with acid. Therefore, the name is hydro phosphoric acid.

Ternary Acids

Ternary acids also referred to as oxyacids, are acids that contain Hydrogen, Oxygen and a nonmetallic element. For example, H_2SO4, H_3PO4, HNO_3 and $HClO_4$ are examples of ternary acids. Ternary acids also result from the combining of a hydrogen and a polyatomic anion. For example, when $2H^+$ combine with $SO4^{2-}$ the oxyacid H_2SO4 is formed. Notice the charges sum is equal to zero. Below is a table of common polyatomic acids with their names and charges.

Table 3: Polyatomic names, formulas and charge of oxyacids

Polyatomic name	Polyatomic formula	Polyatomic charge
Nitrate	NO_3	-1
Nitrite	NO_2	-1
Chlorate	ClO_4	-1
Chlorite	ClO_3	-1
Bromate	BrO_3	-1
Bromite	BrO_2	-1
Iodate	IO_3	-1
Iodite	IO_2	-1
Carbonate	CO_3	-2
Carbonite	CO_2	-2
Sulfate	SO_4	-2
Sulfite	SO_3	-2
Phosphate	PO_4	-3
Phosphite	PO_3	-3

When naming ternary acids (oxoacids), the following rules apply:

1. If the polyatomic ion ends in ***ate*** the acid root will end in ***ic***
   For instance, nitrate become nitric
2. If the polyatomic ion ends in ***ite*** the acid root will end in ***ous***
   For instance, nitrite become nitrous
3. End the name with acid.
   Nitric acid or Nitrous acid

Example Problem: Name the following Ternary Acids

a) HNO_2 b) $HBrO_3$ c) HIO_2 d) $H3PO_3$

Solutions: a) The polyatomic ion NO_2^- is the nitrite anion. Replace the ite of the anion with the ending ous. End the name with acid. Therefore, the name is Nitrous Acid

b) The polyatomic ion BrO_3^- is the bromate anion. Replace the ate of the anion with the ending ic. End the name with acid. Therefore, the name is Bromic Acid

c) The polyatomic ion IO_2^- is the iodite anion. Replace the ite of the anion with the ending ous. End the name with acid. Therefore, the name is Iodous Acid

d) The polyatomic ion PO_4^{3-} is the phosphate anion. Replace the ate of the anion with the ending ic. End the name with acid. Therefore, the name is Phosphorous Acid

Example Problem: Give the formulas of the following Ternary Acids

a) Bromous Acid b) Chloric Acid c) Nitrous Acid d) Carbonic Acid

Solutions: a) The polyatomic acid name ends in ous. To determine the polyatomic ion it originated from replace the ous ending with ite. This gives the bromite anion (BrO_2^-) which has a -1 charge. Since the anion has a -1 charge the acid must have that same number of H (+1) charge. Therefore, the formula is $HBrO_2$.

b) The polyatomic acid name ends in ic. To determine the polyatomic ion it originated from replace the ic ending with ate. This gives the chlorate anion (ClO_4^-) which has a -1 charge. Since the anion has a -1 charge the acid must have that same number of H (+1) charge. Therefore, the formula is $HClO_4$

c) The polyatomic acid name ends in ous. To determine the polyatomic ion, it originated from replace the ous ending with ite. This gives the nitrite anion (NO_2^-) which has a -1 charge. Since the anion has a -1 charge the acid must have that same number of H (+1) charge. Therefore, the formula is HNO_2

d) The polyatomic acid name ends in ic. To determine the polyatomic ion, it originated from replace the ic ending with ate. This gives the carbonate anion (CO_3^{2-}) which has a -2 charge. Since the anion has a -2 charge the acid must have that same number of H (+1) charge. Therefore, the formula is H_2CO_3.

An **Arrhenius base** when dissolved in water (H_2O) gives a hydroxide ion (OH^-). Arrhenius bases have chemical formulas represented with the hydroxide ion located last in the molecular structure. Bases have the following physical and chemical characteristics:

1) Bitter taste
2) Slippery/oily
3) Are strong electrolytes (conduct electricity when dissolved in H_2O0
4) Strong bases are very corrosive
5) Have high pH (Show blue color on litmus paper)

Strong bases dissociate 100% when dissolved in H_2O. This means that in water, referred to as an aqueous solution, a strong base exists entirely as ions. For instance, when NaOH is dissolved in water the following reaction occurs:

$$NaOH + H_2O \longrightarrow Na^+_{(aq)} + OH^-_{(aq)}$$

Weak bases do not dissociate 100% when dissolved in H_2O. The solubility of the base serves as a strong indicator of the base's dissociation. Hydroxides derived from Alkali metals such as

Lithium, Sodium, Potassium, Rubidium, Cesium and Francium are strong bases. Hydroxides derived from alkaline earth metals such as Magnesium, Calcium, Strontium and Barium are strong bases. Note that the alkaline earth metals Beryllium and Radium do not form strong bases. Below is a table of the common strong Arrhenius bases.

Table 4: Most common strong bases

LiOH- lithium hydroxide	$Mg(OH)_2$-magnesium hydroxide
NaOH- sodium hydroxide	$Ca(OH)_2$- calcium hydroxide
KOH- potassium hydroxide	$Sr(OH)_2$- strontium hydroxide
RbOH- rubidium hydroxide	$Ba(OH)_2$- barium hydroxide
CsOH- cesium hydroxide	
FrOH- francium hydroxide	

When naming Arrhenius bases, the following rules apply:

1. The full name of the metal of the Arrhenius base is placed first
2. The polyatomic ion OH is named as hydroxide placed last

For instance, NaOH is named sodium hydroxide. Na is the symbol for sodium so it is placed first in the name. ^-OH, is the symbol of the polyatomic anion (hydroxide) and it is placed last.

1.4 pH

The pH of a substance measures the hydronium ion concentration present in a solution. On the pH scale the lower the pH the more acidic a solution is. Conversely, the higher the pH of a solution the less acidic (more basic) a solution is. The pH scale ranges from zero to 14 (with 0 being the most acidic and 14 being the most basic).

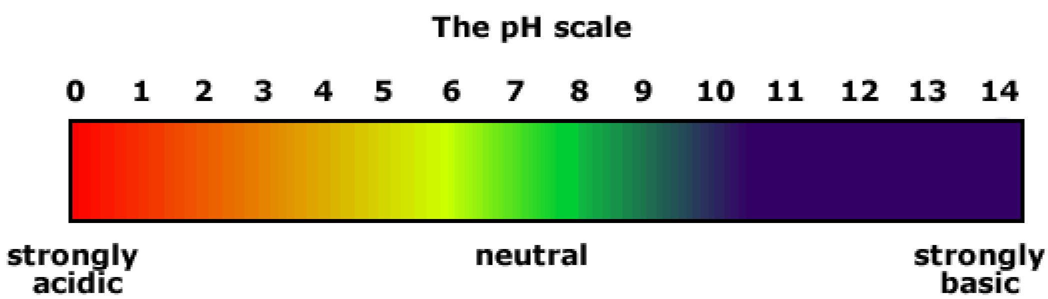


Figure 1: pH scale adapted from https://ibchem.com/IB16/08.31.htm

The use of *pH paper* to quantitatively determine the pH of a solution is the often used. Universal pH paper or strips indicate or measure the pH of a solution according to different colors that result from contact of the paper with the solution of interest. The indicator colors are as follows; red for acidic (pH range 0-7), green for neutral (pH = 7) and blue for basic (pH-7-14).

A *pH meter* is an instrument that determines the pH of a solution. The pH meter is a more accurate method than pH strips in the determination of pH of a solution. A pH meter consists of a pH probe. This pH probe passes electrical signals to the pH meter. The pH meter then displays the pH value of the solution that the probe is submerged in. The lower the value registered by the pH meter the higher the hydronium concentration and stronger the acid. The higher the pH value registered by the pH meter the lower the hydronium concentration and weaker the acid.

The pH of a solution can be mathematically calculated by determining the negative logarithm of the hydronium concentration. The mathematical formula for calculating the pH of a solution is as follows:

Eq. 1 $$pH = -\log[H_3O^+]$$

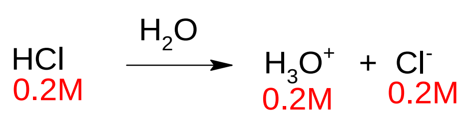
where $[H_3O^+]$ is the hydronium ion concentration.

Conversely the hydronium ion concentration can be mathematically calculated from the pH of a solution. The mathematical formula for calculating the hydronium ion concentration is as follows:

Eq. 2 $$[H+] = 10^{-pH}$$

Example Problem: Calculate the pH of a 0.2M solution of the strong acid HCl.

Solution: To solve this problem we must first determine the hydronium concentration of the 2M HCl solution: Remember that a strong acid disassociates 100% into its respective hydronium ion and anion.



Therefore, a 0.2M HCl solution contains 0.2M of hydronium ions. Next use equation 1 to solve for the answer:

$pH = -\log[H_3O^+]$

$PH= -\log[0.2]$

$pH= 0.70$

Example Problem: Calculate the hydronium ion concentration of a HBr solution that has a pH of 3.0.

Solution: Given that the pH of the solution is already known, we use equation 2 to solve for the answer:

$[H_3O+] = 10^{-pH}$

$[H_3O+] = 10^{-3.0}$

$[H_3O+] = 0.001$ M

1.5 Combination reactions

Combination or synthesis reactions occur when two smaller reactants combine to form a larger more complex compound.

$$\underset{\text{reactants}}{A + B} \longrightarrow \underset{\text{product}}{AB}$$

For example, hydrogen gas reacts with oxygen to produce water represented by the following chemical equation: *Note that the equation is chemically balanced.*

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O\ (l)$$

In this combination reaction two smaller reactants H_2 (gas) and O_2 (g) have combined to for a larger molecule water (l).

1.6 Decomposition reactions

Decomposition reactions occur when a larger more complex compound (reactant) splits to form two or more smaller products. Energy is supplied to the reactant to initiate this reaction.

$$\underset{\text{reactant}}{AB} \longrightarrow \underset{\text{products}}{A + B}$$

For example, NaCl decomposes into two elements Sodium (Na) and Chlorine (Cl) according to the following reaction: Note the equation is chemically balanced

$$2Na\ (s) + Cl_2\ (g) \longrightarrow 2NaCl\ (s)$$

1.7 Combustion reactions

In a combustion reaction, hydrocarbons (compounds containing only carbon and hydrogen) react with oxygen to produce carbon dioxide and water. This reaction releases energy in the form of heat.

$$C_xH_y + O_2 \longrightarrow CO_2 + H_2O + \text{ENERGY}$$

For example, when propane reacts with enough oxygen in heat the following reaction occurs. Notice that the equation is chemically balanced

$$CH_3CH_2CH_3 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$$

1.8 Single Displacement Reactions

In a single replacement reaction an element is replaced in a compound. The most common single displacement reactions consist of a metal being replaced by another metal to form a new product.

$$A + BC \longrightarrow B + AC$$

An activity series of metals arranges them in order of increasing reactivity. Figure 2 illustrates the activity series of common metals.

Figure 2: Metals ranked in increasing activity

Metal	Symbol
Potassium	K
Sodium	Na
Calcium	Ca
Magnesium	Mg
Carbon	C
Zinc	Zn
Iron	Fe
Tin	Sn
Lead	Pb
Hydrogen	H
Copper	Cu
Silver	Ag
Gold	Au

Metals that are higher in activity will replace a metal with a lower activity in a single displacement reaction. For example, the reaction of potassium with sodium nitrate results in a single displacement reaction.

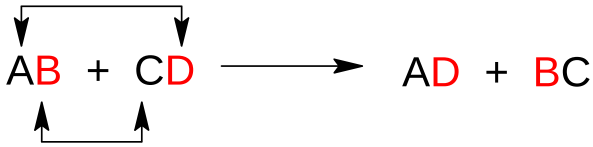
$$K + NaNO_3 \longrightarrow Na + KNO_3$$

Analyzing the activity series, we see that potassium has a higher activity than sodium therefore it will replace it in a single displacement reaction. Conversely, the reaction between sodium and potassium nitrate does not result in a single displacement reaction. Analyzing the activity series, we see that potassium has a higher activity than sodium therefore it would not be displaced.

$$Na + KNO_3 \longrightarrow \text{No reaction}$$

1.9 Double Displacement Reactions

In a double displacement reaction, the cations and ions of the reactants recombine to form new products. In the double displacement reaction, the cation, illustrated in black color (always written first) of one reactant combines with the anion, illustrated in red color (always written last) of the other reactant. This results in the formation of two new ionic compounds.



Double displacement reactions occur when two aqueous solutions are mixed together. The formation of a precipitate (solid) is an indication that a reaction has occurred.

1.9.1 Solubility rules of ionic compounds

Many ionic compounds dissolve in water creating aqueous solutions. There are general rules that can be used to predict if an ionic compound will be soluble in water

Rule 1: Alkali Metals cations (Li, Na and K) and the ammonium cation (NH4) form soluble compounds regardless of the anion it combines with.

Rule 2: Nitrate and acetate anions form soluble ionic compounds regardless of the cation it combines with.

Rule 3: The halogen anions (Cl, Br, I) form soluble ionic compounds except when combined with silver, lead of mercury cations

Rule 4: The sulfate anion forms soluble ionic compounds except when combined with silver, lead mercury, strontium and barium cations

Rule 5: Hydroxides (OH^-) are generally insoluble in water except when combined with the alkali metal cations (Li, Na and K), the ammonium cation (NH4) and the calcium, strontium and barium cations.

Rule 6: Sulfides (S^{2-}) are generally insoluble in water except when combined with the alkali metal cations (Li, Na and K), the ammonium cation (NH_4) and the calcium, strontium and barium cations.

Rule 7: Phosphates and carbonates are insoluble in water except when combined with alkali metal cations (Li, Na and K), the ammonium cation (NH_4)

Table 5: Solubility rules for ionic compounds

Ion	Soluble in water	Exceptions
Li^+, Na^+, K^+, NH_4^+, NO_3^-, CH_3COO^-	Yes	None
Cl^-, Br^-, I^-	Yes	When combined with the Ag^+, Pb^{2+} and Hg_2^{2+}
SO_4^{2-}	Yes	When combined with the Ag^+, Pb^{2+} and Hg_2^2 Sr^{2+}, Ba^{2+},
OH^-	No	Li^+, Na^+, K^+, NH_4^+, Ca^{2+}, Sr^{2+}, Ba^{2+},
S^{2-}	No	Li^+, Na^+, K^+, NH_4^+, Ca^{2+}, Sr^{2+}, Ba^{2+},
CO_3^{2-}	No	Li^+, Na^+, K^+, NH_4^+,
PO_4^{3-}	No	Li^+, Na^+, K^+, NH_4^+,

Example Problem: Determine if the following ionic compounds are soluble or insoluble in water according to the solubility rules given in Tale 5.

a) NaCl b) PbI_2 c) NH_4OH d) CaS

Solutions: a) The sodium cation of NaCl is soluble in water regardless of the ion it combines with therefore NaCl is soluble in water and forms an aqueous solution.

b) The iodine anion is generally soluble however it is combined with the lead cation therefore it forms an insoluble ionic compound (solid).

c) The ammonium cation when combined with any cation makes a soluble ionic compound therefore NH4OH is soluble in water and forms an aqueous solution.

d) The sulfide anion is generally insoluble however it is combined with the calcium cation making CaS soluble in water and forms an aqueous solution.

Example Problem: Aqueous silver nitrate, $AgNO_3$, reacts with aqueous sodium chloride, NaCl, to produce solid silver chloride, AgCl and aqueous sodium nitrate, $NaNO_3$. Write the balanced chemical equation for this reaction including phase labels for all reactants and products.

Solution: In this reaction the reactants, silver nitrate both and sodium chloride exists as solutions in water (aqueous). Therefore, we represent each of the reactant phases (aq). The product sodium nitrate also exists as a solution in water its phase label is also (aq). Silver chloride exists as a precipitate or solid in water therefore its phase label is (s).

$$AgNO_3\,(aq) + NaCl\,(aq) \longrightarrow AgCl\,(s) + NaNO_3\,(aq)$$

Reactants	Products
(1 x 1) # of Ag atoms = 1	(1 x 1) # of Ag atoms = 1
(1 x1) # of N atoms = 1	(1 x1) # of N atoms = 1
(1 x 3) # of O atoms = 3	(1 x 3) # of O atoms = 3
(1 x 1) # of Na atoms = 1	(1 x 1) # of Na atoms = 1
(1 x 1) # of Cl atoms = 1	(1 x 1) # of Cl atoms = 1

The number of atoms of each element on the reactant side is equivalent to the number of atoms of each element on the product therefore this chemical equation is balanced

1.10

Acid Bases Reactions

Acid-base reaction are often referred to as neutralization reactions. In an acid-base reaction the products formed are a salt and water. A salt is defined as an ionic compound that does not consist of a H+ or OH-. The acids and bases are in aqueous solution and indicated by the (aq) phase label.

$$\text{Acid} + \text{Base} \longrightarrow \text{Salt} + H_2O$$

In an acid-base reaction, the cations and ions of the acids and bases recombine to form the salt and water products. In the acid-base reaction below, the cation, illustrated in black color (always written first) of the acid combines with the anion of the base, illustrated in red color (always written last) which forms water. Conversely, the cation of the base combines with the anion of the acid, illustrated in black color to form the salt.

$$\underset{\text{acid}}{HCl} + \underset{\text{base}}{NaOH} \longrightarrow \underset{\text{salt}}{NaCl} + \underset{\text{water}}{H_2O}$$

A strong acid and strong base reactions always produce a water-soluble salt which forms an aqueous solution and liquid water. For instance, HCl (hydrochloric acid) and NaOH (sodium hydroxide) react to form NaCl (water soluble salt) and H_2O (water). Notice this chemical equation is balanced.

$$\underset{\text{acid}}{HCl_{(aq)}} + \underset{\text{base}}{NaOH_{(aq)}} \longrightarrow \underset{\text{salt}}{NaCl_{(aq)}} + \underset{\text{water}}{H_2O_{(l)}}$$

Example Problem: Sulfuric Acid (H_2SO_4) reacts with aqueous potassium hydroxide (KOH)to produce the salt potassium bromide (KBr) and water according to the following chemical equation. Write the balance chemical equation for this reaction including phase labels for all reactants and products.

Solution: In this reaction the reactants, both sulfuric acid and potassium hydroxide are strong acids. Therefore, we represent each of the reactant phases (aq). The product potassium nitrate also exists as a solution in water its phase label is also (aq). Water (H_2O) is a liquid

$$H_2SO_4\,(aq) + 2KOH\,(aq) \longrightarrow K_2SO_4\,(aq) + 2H_2O\,(l)$$

(1 x 2) + (2 x 1) # of H atoms = 4	(2 x 2) # of H atoms = 4
(1 x1) # of S atoms = 1	(1 x1) # of S atoms = 1
(1 x 4) + (2 x 1) # of O atoms = 6	(1 x 4) + (2 X 1) # of O atoms = 6
(1 x 1) # of S atoms = 1	(1 x 1) # of S atoms = 1
(2 x 1) # of K atoms = 2	(1 x 2) # of K atoms = 2

The number of atoms of each element on the reactant side is equivalent to the number of atoms of each element on the product therefore this chemical equation is balanced

Review

Essential Vocabulary

Chemical equations, reactants, products, phase labels, Arrhenius acid, Arrhenius base, strong acids and bases, weak acids and bases, pH, combination reaction, decomposition reaction, combustion reaction, single displacement reaction, double displacement reaction, Acid-base (neutralization reaction).

Balancing Chemical Reactions:

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O\,(l)$$

(2 x 2) # of H atoms = 4 (2 x 2) # of H atoms = 4
(1 x 2) # of O atoms = 2 (2 x 1) # of O atoms = 2

Essential Equations:

Eq. 1 $pH = -\log[H^+]$

Eq. 2 $[H+] = 10^{-pH}$

Essential Reactions:

Combination or synthesis reactions occur when two smaller reactants combine to form a larger more complex compound.

$$\underset{\text{reactants}}{A + B} \longrightarrow \underset{\text{product}}{AB}$$

Decomposition reactions occur when a larger more complex compound (reactant) splits to form two or more smaller products. Energy is supplied to the reactant to initiate this reaction.

$$\underset{\text{reactant}}{AB} \longrightarrow \underset{\text{products}}{A + B}$$

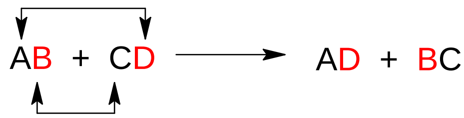
Combustion reaction occur when hydrocarbons (compounds containing only carbon and hydrogen) react with oxygen to produce carbon dioxide and water. This reaction releases energy in the form of heat.

$$C_xH_y + O_2 \longrightarrow CO_2 + H_2O + \text{ENERGY}$$

Single replacement reaction occur an element is replaced in a compound. The most common single displacement reactions consist of a metal being replaced by another metal to form a new product.

$$A + BC \longrightarrow B + AC$$

Double displacement reactions occur when two aqueous solutions are mixed together. The formation of a precipitate (solid) is an indication that a reaction has occurred.



Acid-base reaction (neutralization reactions) occur when an acid and base are mixed together. In an acid-base reaction the products formed are a salt and water.

$$\text{Acid} + \text{Base} \longrightarrow \text{Salt} + H_2O$$

<u>Essential Problems with answers:</u>

Example Problem: Name the following Binary Acids

a) HBr b) HI c) H_2S d) H_3P

Solutions: a) hydrobromic acid b) hydroiodic acid c) hydrosulfuric acid d) hydrophosphoric acid.

Example Problem: Give the formulas of the following Ternary Acids

a) Bromous Acid b) Chloric Acid c) Nitrous Acid d) Carbonic Acid

Solutions: a) $HBrO_2$. b) $HClO_4$ c) HNO_2 d) H_2CO_3

Example Problem: Calculate the pH of a 0.2M solution of the strong acid HCl.

Solution: To solve this problem use Equation 1

pH= 0.70

Example Problem: Calculate the hydronium ion concentration of a HBr solution that has a pH of 3.0.

Solution: To solve this problem use Equation 1

$[H_3O+] = 0.001$ M

Example Problem: Determine if the following ionic compounds are soluble or insoluble in water according to the solubility rules given in Tale 5.

a) NaCl b) PbI_2 c) NH_4OH d) CaS

Solutions: a) an aqueous solution b) insoluble ionic compound (solid) c) an aqueous solution d) an aqueous solution

Virtual Labs

pH scale: https://phet.colorado.edu/en/simulations/ph-scale

Topics

pH, dilution, concentration, acids and bases

Learning Goals

1) Determine if a liquid is acidic, basic, or neutral

2) Place acids or bases in relative strength order

3) Describe on a molecular scale, with illustrations, how the water equilibrium varies with pH

4) Determine concentration of hydroxide and hydronium ions in water at a given pH

5) Predict (qualitatively and quantitatively) how dilution and volume will affect the pH and concentration of hydroxide, hydronium and water

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Virtual Labs

pH scale: https://phet.colorado.edu/en/simulations/balancing-chemical-equations

Topics

Chemical Equations and Conservation of Mass

Learning Goals

1) Balance a chemical equation.

2) Recognize that the number of atoms of each element is conserved in a chemical reaction.

3) Describe the difference between coefficients and subscripts in a chemical equation.

4) Translate from symbolic to molecular representations of matter