Name:

Regents Chemistry: Dr. Shanzer

Practice Packet

Chapter 13: Acids & Bases

Chapter 13: Acids, Bases and Salts

Monoprotic acid - acids that contain only 1 hydrogen ion (H^+) HNO_3

Diprotic acid - acids that contain 2 hydrogen ion (H^+) H_2SO_4

Conjugate acid – the particle formed when a base gains a hydrogen ion

Conjugate base – the particle that remains when an acid has donated a hydrogen ion

Hydronium ion ($H_3O^{+)}$ – a water molecule that gains a hydrogen ion and becomes positivity charged

Arrhenius Acid – hydrogen-containing compounds that ionize or yield hydrogen ions (H^+)

Arrhenius Base – compounds that ionize hydroxide ions (OH^-)

Neutral Solution – an aqueous solution in which $[H^+] = [OH^-]$

Acidic Solution – a solution in which $[H^+]$ is greater than $[OH^-]$

Basic Solution - a solution in which $[H^+]$ is less than $[OH^-]$

pH – negative logarithm of the hydrogen-ion concentration $pH = -\log [H^+]$

Strong Acid - completely ionizes (separate into ions) greater $[H^+]$

Strong Base - completely ionizes (separate into ions) greater $[OH^-]$

Neutralization Reaction – a reaction in which an acid reacts with a base to produce salt and water (neutral)

Equivalence Point – when the number of moles of hydrogen ions equals the number of moles of hydroxide ions

Titration – process of adding known concentration to determine the concentration of another solution

End point – the point in which the indicator changes color in a titration

Characteristics of Acids & Bases

Chemistry 200
Video Lesson 13.1

Objective:

How can we recognize characteristics of acids and bases?

How can we determine the difference between Arrhenius and Bronsted/Lowry acids and bases?

Acids & Bases

Acids & Bases can be recognized by their properties.

Acids

- Dilute solutions have a sour taste
  ex: lemons --> citric acid
  vinegar --> acetic acid
  carbonated drinks --> carbonic acid
  tomato --> ascorbic acid

Bases

- Have a bitter taste & slippery, soapy feel.
  ex: soap, milk of magnesia

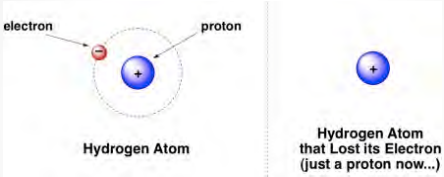
Acids

Two theories used to explain the behavior of acids:

Arrhenius Acid (Svante Arrhenius)

- a substance that releases hydrogen ions ***[H⁺]*** in an aqueous solution ex: HCl, H_2SO_4
- not all substances that contain hydrogen are acids. ***CH_4*** (methane) is ***not*** an acid because the hydrogen atoms do not ionize.

- A **Hydrogen Ion** is produced when a hydrogen atom loses an electron to become a positive ion



- A **Hydronium Ion $[H_3O]^+$** is formed when a hydrogen ion reacts w/ H_2O

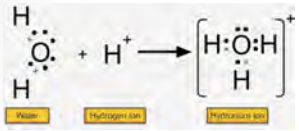
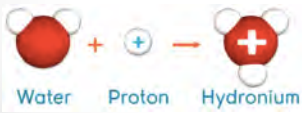


Table E



ex: $HCl_{(g)} \xrightarrow{H_2O} H_3O^+_{(aq)} + Cl^-_{(aq)}$

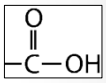
Arrhenius acids can be divided into 2 main categories

Inorganic Acid

- an acid that starts w/ hydrogen & does not have carbon
  ex: HCl, H_2SO_4

Organic Acid

- an acid that has carbon & ends w/ COOH
  (Carboxyl Group)



ex: CH_3COOH (ethanoic acid)
HCOOH (methanoic acid)

An Arrhenius acid can sometimes yield more than one hydrogen ion in aqueous solution

Monoprotic Acid

- acids that produce a single hydrogen ion (ionizes in 1 step)

ex: $HCl + H_2O \rightarrow H_3O^+ + Cl^-$

Diprotic Acid

- acids that produce 2 hydrogen ions (ionizes in 2 steps)

ex: $H_2SO_4 \rightarrow H^+ + HSO_4^-$ (step 1)
$HSO_4^- \rightarrow H^+ + SO_4^{-2}$ (step 2)

Triprotic acids: 3 hydrogen ions ex: H_3PO_4

The **Brønsted-Lowry theory** focuses solely on the hydrogen ion as a proton & can be used to further explain acid behavior:

Brønsted-Lowry Acid

- any species (any particle: atom, molecule or ion) that can donate a proton ***[H⁺]*** to another species ***(a proton donor)***
- all Arrhenius acids are also Brønsted-Lowry acids

  ex: $HCl_{(g)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$

- according to Brønsted-Lowry, HCl is an acid because it ***donates*** a proton (H^+)

Bases

Theories used to explain acid behavior can also be used to explain bases as well

Arrhenius Base

- a substance that releases hydroxide ions ***[OH⁻]*** in an aqueous solution

ex: **NaOH** $\xrightarrow{H_2O} Na^+_{(aq)} + OH^-_{(aq)}$

CH_3OH
C_2H_5OH

*An **Alcohol** should not be confused w/ an Arrhenius Base as it does not form a hydroxide ion [OH^-] in an (aq) solution, therefore it is **NOT** a base!!!*

Brønsted-Lowry Base

- any species that can accept a proton ***[H⁺]*** from another species --> ***a proton acceptor***
- according to Arrhenius, only metallic hydroxides are bases
- Brønsted-Lowry definitions explain why a substance that has no [OH^-], like NH_3, behaves like a base in H_2O

  ex: **NH_3** + $H_2O \rightarrow NH_4^+ + OH^-$

Amphiprotic (Amphoteric)

- a substance that can act as an acid or a base

ex: H_2O

$HCl + \boldsymbol{H_2O} \rightarrow H_3O^+ + Cl^-$

Base

$NH_3 + \boldsymbol{H_2O} \rightarrow NH_4^+ + OH^-$

Acid

Electrolytes

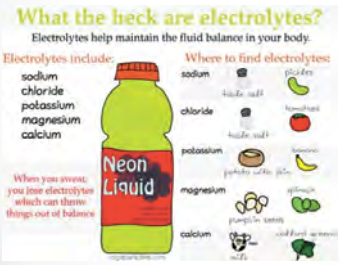
Chemistry 200
Video Lesson 13.2

Objective:

How do we determine which acids and bases are strong or weak electrolytes?

Electrolytes

- are substances that have mobile ions when put into solution (aq). This allows it to conduct electricity.



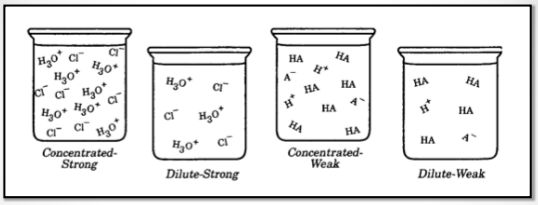
Ex: Acids
Bases
Salts

A ***Strong Acid*** is a strong electrolyte because it completely ionizes in water to produce a large number of H^+ ions in solution.

A ***Weak Acid*** is a weak electrolyte because it partially ionizes in water to produce a small number of H^+ ions in solution.

Table K
Common Acids

Formula	Name
HCl(aq)	hydrochloric acid
HNO_2(aq)	nitrous acid
HNO_3(aq)	nitric acid
H_2SO_3(aq)	sulfurous acid
H_2SO_4(aq)	sulfuric acid
H_3PO_4(aq)	phosphoric acid
H_2CO_3(aq) or CO_2(aq)	carbonic acid
CH_3COOH(aq) or $HC_2H_3O_2$(aq)	ethanoic acid (acetic acid)



A ***Strong Base*** is a strong electrolyte because it completely ionizes in water to produce a large number of OH^- ions in solution

A ***Weak Base*** is a weak electrolyte because it partially ionizes in water to produce a small number of OH^- ions in solution.

Table L
Common Bases

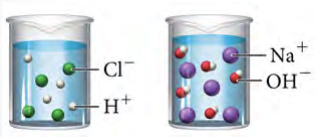
Formula	Name
NaOH(aq)	sodium hydroxide
KOH(aq)	potassium hydroxide
$Ca(OH)_2(aq)$	calcium hydroxide
$NH_3(aq)$	aqueous ammonia

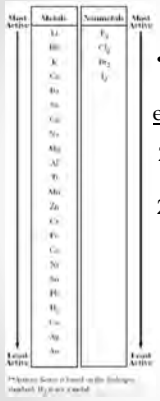
Acid/Base Reactions

- Acid react with a base to produce a salt and water

ex:

$HCl_{(aq)} + NaOH_{(aq)} \rightarrow \boxed{NaCl_{(aq)}} + HOH_{(l)}$





Acid/Metal Reactions

- Acids react with a metal to produce a salt and hydrogen gas ($\mathbf{H_{2(g)}}$)

ex:

$2HNO_{3(aq)} + Ca_{(s)} \rightarrow Ca(NO_3)_{2(aq)} + H_{2(g)}$

$2HCl_{(aq)} + Cu_{(s)} \rightarrow CuCl_{2(aq)} + H_{2(g)}$

NO REACTION!!

Conjugate Acid-Base pairs

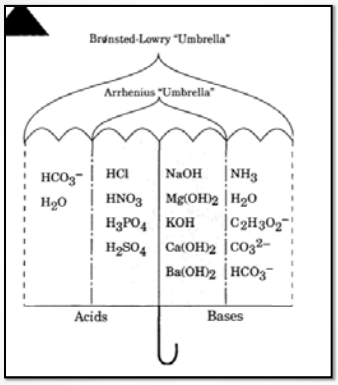
Video Lesson 13.3

Objectives

- Compare and contrast acids and bases as defined by the theories of Arrhenius and Bronsted-Lowry (alternate acid/base theory).

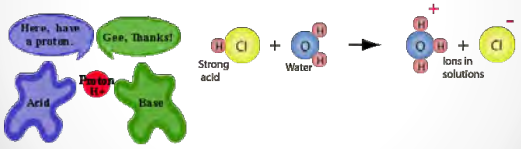
- QUESTION: Why is ammonia (NH_3) a base?

Acid Base Theories



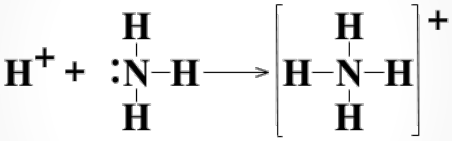
Alternate Acid-Base Theory
AKA Bronsted-Lowry Theory

- Explains the behavior of WEAK acids and BASES (Na_2CO_3 & NH_3)
- Bronsted-Lowry Acids are **PROTON DONORS**
  - The prefer to give away a proton (H^+)



Alternate Acid Base Theory

- Bronsted-Lowry Bases are PROTON ACCEPTORS

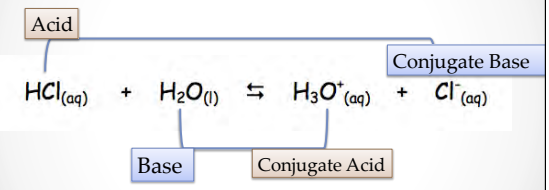


Conjugate Acid/Base Pairs

- An acid is a H^+ donor while a base is a H^+ acceptor.
- The substance produced when an acid has donated its proton is called the conjugate base.
- The substance produced when the base accepts a H^+ is called the conjugate acid

Practice

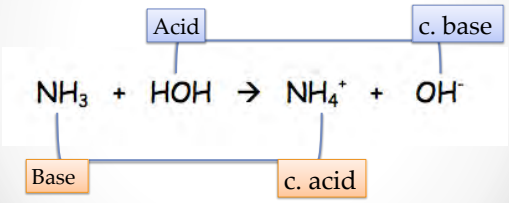
Label the acids and bases according to Bronsted-Lowry:



Conjugate Acid-Base Pairs

Practice

Label conjugate acid base pairs in the following equation



pH & Acid-Base Indicators

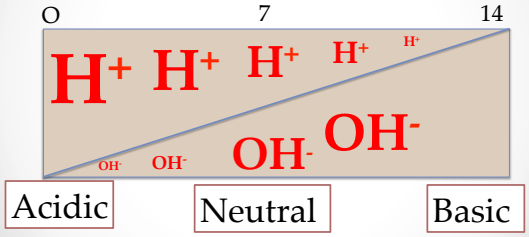
Video Lesson 13.4

Objectives

- Describe how [H^+] and [OH^-] are related in an aqueous solution.
- Classify a solution as neutral, acidic or basic.
- Describe the purpose of an acid-base indicator.

The pH Scale

- pH = direct measurement of H^+ ion concentration in a solution
- "power of hydrogen"



Logarithmic

- The pH scale is logarithmic
  - Based on exponents of the number 10
- The pH of a solution is the negative log of the [H^+] or [OH^-] ions

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

pH of .01 M HBr = $-\log(.01) = 2.00$

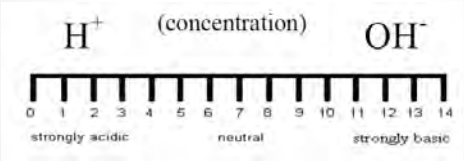
$pOH = -\log[OH^-]$

pH of .01 M LiOH = $14 - 2 = 12.00$

$pH = 14 - pOH$

A Tenfold Change

- Each change in a single pH unit signifies a tenfold change in [H^+] concentration



Ex: going from a ph of 4 to a pH of 5

Becoming [redacted] basic; [OH^-] [redacted] by [redacted]

Becoming [redacted] acidic; [H^+] [redacted] by [redacted]

Ex: going from a pH of 13 to a pH of 10

Becoming [redacted] acidic; [H^+] [redacted] by [redacted]

Becoming [redacted] basic; [OH^-] [redacted] by [redacted]

Acid-Base Indicators

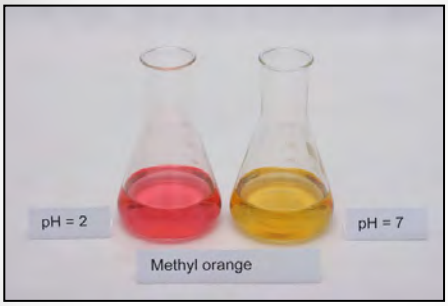
- Indicator
  - A substance that changes color as a result of a pH change
- Table M
- Example: Phenolphthalein → colorless up until a pH of 8, light pink from 8 to 9 and pink from pH of 9 up

pH = 5 pH = 11

Table M
Common Acid–Base Indicators

Indicator	Approximate pH Range for Color Change	Color Change
methyl orange	3.1–4.4	red to yellow
bromthymol blue	6.0–7.6	yellow to blue
phenolphthalein	8–9	colorless to pink
litmus	4.5–8.3	red to blue
bromcresol green	3.8–5.4	yellow to blue
thymol blue	8.0–9.6	yellow to blue

Source: *The Merck Index*, 14th ed., 2006, Merck Publishing Group



Indicator	pH of sample	Color indicator will turn
methyl orange	6.0	
bromothymol blue	2.0	
phenolphthalein	10	
Litmus	6.8	
bromocresol green	13	
thymol blue	1.2	

Acid-Base Titration

Video Lesson 13.5

Objectives

- Define products of an acid-base reaction.
- Explain how acid-base titration is used to calculate the concentration of an acid or base.
- Explain the concept of equivalence in neutralization reactions.

Neutralization Reactions

- Neutral
  - Neither acidic nor basic
  - Equal concentrations of H^+ **and** OH^-
  - Occurs when Arrhenius acid and an Arrhenius base react to form water and salt

Neutralization Reactions

Acid + Base → Salt + Water

Double Replacement!

Water

+1 -1 +1 -1 +1 -1 +1 -1

$HCl + KOH \rightarrow KCl + HOH$

Acid

Base

Salt
Or
Ionic Substance

Magnesium hydroxide

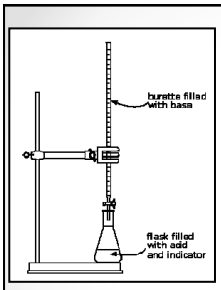
- Stomach acid
  - pH between 2-3
- Heart burn
  - Happens when pH level drops in the stomach
- Milk of Magnesia brings the pH up
- $Mg(OH)_2$

1. $HBr + KOH \rightarrow$
2. $NaOH + HC_2H_3O_2 \rightarrow$
3. $KOH + H_3PO_4 \rightarrow$
4. $2HNO_3 + Ca(OH)_2 \rightarrow$

Acid-Base Titration

- Titrations are used to calculate the concentration (Molarity) of an unknown solution.
- Lab process in which an unknown solution is systematically reacted with a solution of known concentration by adding measured volumes of an acid or a base to the unknown until neutralization occurs.

- In all neutralization reactions there must be a 1:1 ratio of moles of H^+ ions and moles of OH^- ions.
- Equivalence Point
  - $[H^+] = [OH^-]$



Titration formula (Table T): $M_A V_A = M_B V_B$

Where: M_A = molarity of acid (H^+)
V_A = volume of acid
M_B = molarity of base (OH^-)
V_B = volume of base

- Use this formula when you are dealing with a titration or neutralization word problem
- Make sure that all units are in agreement when plugging into formula (so they cancel out and you get the right answer!)

Example #1

- What is the concentration of a solution of HI if 0.3 L is neutralized by 0.6 L of 0.2 M solution of KOH?

Titration	$M_AV_A = M_BV_B$	M_A = molarity of H^+	M_B = molarity of OH^-
		V_A = volume of acid	V_B = volume of base

M_A = ?
V_A = 0.3 L
M_B = 0.2 M
V_B = 0.6 L

$M_A V_A = M_B V_B$
$M_A (0.3) = (0.2)(0.6)$
$M_A = \frac{(0.2)(0.6)}{(0.3)}$
$M_A =$ 0.4M or moles/L

Example #2

- You have 50 mL of 1.0 M $H_2SO_{4\,(aq)}$. What volume of 0.5 M NaOH would be required to neutralize the acid? (Diprotic Acids yield 2 H^+ ions in solution!)

$M_A = 2(1.0\ M)$
$V_A = 50\ mL$
$M_B = 0.5\ M$
V_B = ?

$2(M_A V_A) = M_B V_B$
$(2)(1.0)(50) = (0.5)V_B$
$V_B = \frac{(2)(1.0)(50)}{(0.5)}$
$V_B =$ 200 mL

Sketch Notes

Video 13.1: Characteristics of Acids and Bases

Acid/Base/Salt Characteristics:

On the line to the left, write A if the statement is a property of an acid, write B if the property is that of a base, and write X, if it is a property of both acidic and basic solutions.

_____ 1) Often feels smooth and slippery

_____ 2) Has a sour taste

_____ 3) Stings in open wounds

_____ 4) Typically reacts vigorously with metals

_____ 5) Has a bitter taste

_____ 6) Turns litmus paper from blue to red

_____ 7) Is an electrolyte

_____ 8) Often looks like pure water

_____ 9) Turns litmus paper from red to blue

_____ 10) Typically does not react with metals

Complete the chart.

Substance	Acid, Base or Salt?	How do you know?
1. $NaOH$		
2. HCl		
3. $NaCl$		
4. HF		
5. K_2SO_4		
6. $Fe(OH)_3$		
7. H_3PO_4		

Answer the following questions

1. _____ Which species can conduct an electric current?
   1. $H_2O_{(s)}$
   2. $CH_3OH_{(aq)}$
   3. $NaOH_{(s)}$
   4. $HCl_{(aq)}$

2. _____ According to Arrhenius theory, which species does an acid produce in aqueous solution?
   1. hydroxide ions
   2. sodium ions
   3. hydrogen ions
   4. chloride ions

3. _____ Which substance is an Arrhenius acid?
   1. $Mg(OH)_{2(aq)}$
   2. $LiF_{(aq)}$
   3. $CH_3CHO_{(aq)}$
   4. $HBr_{(aq)}$

4. _____ According to the Arrhenius theory, when a base is dissolved in water, it produces a solution containing only one kind of negative ion. What is the name of this negative ion?
   1. hydrogen sulfate ion
   2. hydrogen carbonate ion
   3. hydride ion
   4. hydroxide ion

5. In terms of H^+ ions, explain the difference between monoprotic, diprotic and triprotic acids.

Arrhenius Acids and Bases

1. Which compounds are classified as Arrhenius acids?

   A) HCl and $NaOH$
   B) HNO_3 and $NaCl$
   C) NH_3 and H_2CO_3
   D) HBr and H_2SO_4

2. What can be explained by the Arrhenius theory?

   A) the behavior of many acids and bases
   B) the effect of stress on a phase equilibrium
   C) the operation of an electrochemical cell
   D) the spontaneous decay of some nuclei

3. Potassium hydroxide is classified as an Arrhenius base because KOH contains

   A) OH^- ions B) O^{2-} ions
   C) K^+ ions D) H^+ ions

4. When one compound dissolves in water, the only positive ion produced in the solution is H_3O^+ (aq). This compound is classified as

   A) a salt B) a hydrocarbon
   C) an Arrhenius acid D) an Arrhenius base

5. Given the equation:

   $HCl(g) + H_2O(\ell) \rightarrow X(aq) + Cl^-(aq)$
   Which ion is represented by *X*?

   A) hydroxide B) hydronium
   C) hypochlorite D) perchlorate

6. The only positive ion found in $H_2SO_4(aq)$ is the

   A) ammonium ion B) hydronium ion
   C) hydroxide ion D) sulfate ion

7. Which substance is an Arrhenius acid?

   A) $Ba(OH)_2$ B) CH_3COOCH_3
   C) H_3PO_4 D) $NaCl$

8. Which two formulas represent Arrhenius acids?

   A) CH_3COOH and CH_3CH_2OH
   B) $HC_2H_3O_2$ and H_3PO_4
   C) $KHCO_3$ and $KHSO_4$
   D) $NaSCN$ and Na_2S_2O

9. Which chemical equation represents the reaction of an Arrhenius acid and an Arrhenius base?

   A) $HC_2H_3O_2(aq) + NaOH(aq) \rightarrow NaC_2H_3O_2(aq) + H_2O(\ell)$
   B) $C_3H_8(g) + 5\ O_2(g) \rightarrow 3\ CO_2(g) + 4\ H_2O(\ell)$
   C) $Zn(s) + 2\ HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$
   D) $BaCl_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2\ NaCl(aq)$

10. According to the Arrhenius theory, when a base dissolves in water it produces

    A) CO_3^{2-} as the only negative ion in solution
    B) OH^- as the only negative ion in solution
    C) NH_4^+ as the only positive ion in solution
    D) H^+ as the only positive ion in solution

11. Which substance yields hydroxide ion as the only negative ion in aqueous solution?

    A) $Mg(OH)_2$ B) $C_2H_4(OH)_2$
    C) $MgCl_2$ D) CH_3Cl

12. According to the Arrhenius theory, which list of compounds includes only bases?

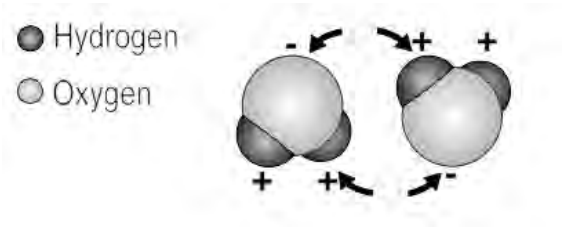
    A) KOH, $Ca(OH)_2$, and CH_3OH
    B) KOH, NaOH, and LiOH
    C) LiOH, $Ca(OH)_2$, and $C_2H_4(OH)_2$
    D) NaOH, $Ca(OH)_2$, and CH_3COOH

6. Identify each of the following acids as monoprotic, diprotic or triprotic and state how many H^+ ions are released in solution.
    1. H_2CO_3
    2. H_3PO_4
    3. HNO_3
    4. CH_3COOH
    5. H_2SO_4
    6. HCl
    7. C_2H_5COOH
    8. H_2S

Video 13.2: Electrolytes

Answer the questions below based on the information provided and your knowledge of chemistry.

1. Using the diagram below, draw a diagram of the molecule formed when one hydrogen (proton) is pulled off one water molecule and attached to another.



2. What are the formulas of the ions formed?

3. Write an equation showing the formation of the ions from two molecules of water.

4. The hydronium ion (H_3O^+) and the hydroxide ion (OH^-) are formed by the reaction between water molecules. What would form from the reaction between hydronium and hydroxide ions? Write an equation showing the reaction.

5. How does the reaction between water molecules compare to the reaction between hydronium and hydroxide ions?

6. Pure water is actually a mixture of water molecules, hydronium ions, and hydroxide ions:

    a. How does the concentration of hydroxide ions compare to the concentration of hydronium ions in pure water? Explain

    b. How does the concentration of ions compare to the concentration of molecules in pure water?

Electrolytes

1. Which two compounds are electrolytes?

   A) CH_3OH and C_5H_{12}
   B) KOH and C_5H_{12}
   C) KOH and CH_3COOH
   D) CH_3OH and CH_3COOH

2. Which compounds can be classified as electrolytes?

   A) saturated hydrocarbons B) alcohols
   C) alkynes D) organic acids

3. Which laboratory test result can be used to determine if KCl(s) is an electrolyte?

   A) electrical conductivity of KCl(aq)
   B) pH of KCl(s)
   C) electrical conductivity of KCl(s)
   D) pH of KCl(aq)

4. Which sample of HCI(aq) contains the greatest number of moles of solute particles?

   A) 1.0 L of 2.0 M HCI(aq)
   B) 2.0 L of 2.0 M HCI(aq)
   C) 3.0 L of 0.50 M HCI(aq)
   D) 4.0 L of 0.50 M HCI(aq)

5. As water is added to a 0.10 M NaCl aqueous solution, the conductivity of the resulting solution

   A) increases because the concentration of ions decreases
   B) decreases, but the concentration of ions remains the same
   C) increases, but the concentration of ions remains the same
   D) decreases because the concentration of ions decreases

6. Which compound dissolves in water to form an aqueous solution that can conduct an electric current?

   A) C_2H_5OH B) $CC1_4$
   C) CH_3COOH D) CH_4

7. A student tested a 0.1 M aqueous solution and made the following observations:
   - conducts electricity
   - turns blue litmus to red
   - reacts with Zn(s) to produce gas bubbles

   Which compound could be the solute in this solution?

   A) LiOH B) LiBr C) CH_3OH D) HBr

8. Which of the following aqueous solutions is the best conductor of electricity?

   A) 1.0 M NaOH B) 0.10 M NaOH
   C) 0.10 M CH_3OH D) 1.0 M CH_3OH

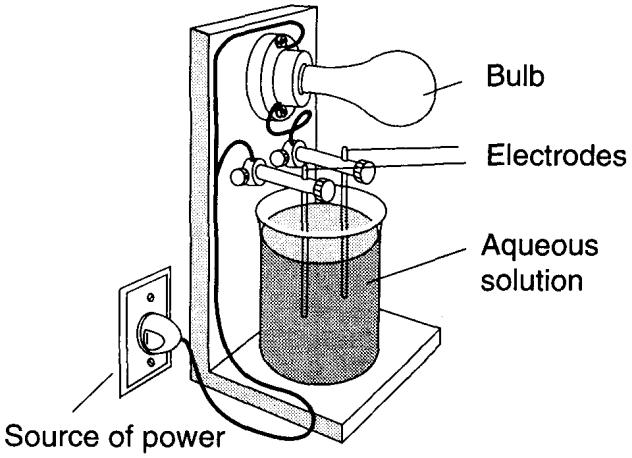
9. Based on Reference Table *F*, which of these salts is the best electrolyte?

   A) barium sulfate B) sodium nitrate
   C) silver chloride D) magnesium carbonate

10. An example of a nonelectrolyte is

    A) $K_2SO_4(aq)$ B) NaCl(aq)
    C) HCl(aq) D) $C_6H_{12}O_6(aq)$

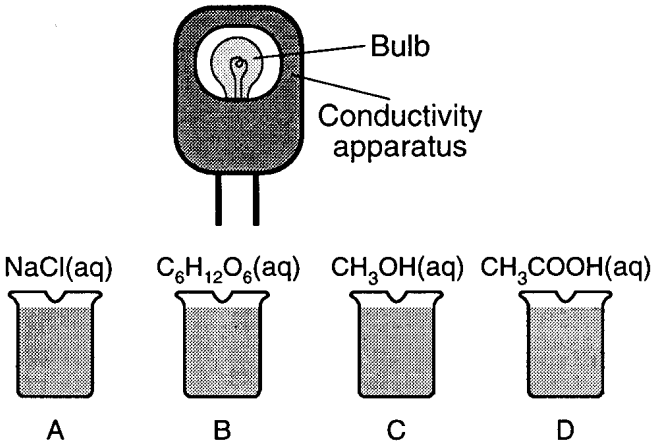
11. The diagram below shows an apparatus used to test the conductivity of various materials.



    Which aqueous solution will cause the bulb to light?

    A) $C_{12}H_{22}O_{11}(aq)$ B) LiOH(aq)
    C) $C_6HI_2O_6(aq)$ D) $CH_3OH(aq)$

12. Beakers *A, B, C,* and *D* shown below each contain a different solution.



    The bulb will glow when the conductivity apparatus is placed into which beakers?

    A) *A* and *D* B) *C* and *D*
    C) *B* and *C* D) *A* and *B*

Complete the following reactions, balance and indicate phase of the products

1. ____ $HNO_{3(aq)}$ + ____ $Mg_{(s)}$ →
2. ____ $H_2SO_{4(aq)}$ + ____ $Li_{(s)}$ →
3. ____ $HBr_{(aq)}$ + ____ $Zn_{(s)}$ →
4. Aluminum metal reacts w/ phosphoric acid.

5. Calcium metal reacts w/ hydrochloric acid

Using Table J answer the following questions.

1. Why does gold occur uncombined where as zinc does not?
   _____
2. Why was silver used to make coins in the past?
   _____
3. Why is copper used to make electrical wires and cables?
   _____
4. Why do we know little about the lifestyles of the people of the Iron Age?
   _____

Video 13.3: Conjugate Acid-Base Pairs

Operational Definition: Acids and bases are chemical species that exhibit distinctive sets of observable properties. Acids taste sour, bases are bitter.

Conceptual Definitions: Acids and bases are defined conceptually to help account for what is happening on the microscopic level.

Arrhenius Concept: An acid is a substance that when dissolved in water forms hydrogen ions (H^+). A base is a substance that when dissolved in water produces hydroxide ions (OH^-). This concept is limited because other chemicals have operational acid or base properties but do not form H^+ or OH^-. An example would be ammonia (NH_3) has basic properties but doesn't contain hydroxide ions.

Alternate Acid Base Concept (Bronsted-Lowry): An acid is a proton (H^+) donor and a base is a proton (H^+) acceptor.

$$HF + H_2O \Leftrightarrow H_3O^+ + F^-$$
Acid Base C. Acid C. Base

Fill in the following table. Identify the acid, base, conjugate acid and conjugate base in each of the equations.

	Equation	Acid	Base	Conjugate Acid	Conjugate Base
1.	$HCl + NH_3 \rightarrow NH_4^+ Cl^-$				
2.	$PO_4^{3-} + HNO_3 \rightarrow NO_3^- + HPO_4^{2-}$				
3.	$HCO_3^- + OH^- \rightarrow H_2O + CO_3^{2-}$				
4.	$NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$				
5.	$HPO_4^{2-} + H_2O \rightarrow OH^- H_2PO_4^-$				

6. Write the equation that shows ammonia, NH_3 reacting with hydrobromic acid, HBr. Label the acid, the base, the conjugate acid and the conjugate base.

7. Write the equation that shows the reaction of hydrogen sulfide, HS^- with hydroxide ion, OH^-. Label the acid, the base, the conjugate acid and the conjugate base.

Video 13.4: pH & Acid-Base Indicators

Indicators: Given the pH of the following substances, use table M of your reference to determine what color the indicator will turn when placed in each substance.

Solution	pH Range	Methyl Orange	Bromothymol blue	Phenolphthalein	Litmus	Bromocresol green	Thymol blue	Acid/Base
Vinegar	1.3							
Soap	8.4							
Cola	3.2							
Ammonia	12							
Coffee	5.2							

Video 13.3 Alternate Acid-Base Theory

___ 1. According to one acid-base theory, NH_3 acts as a base when an NH_3 molecule

1) accepts an H^+ ion
2) donates an H^+ ion
3) accepts an OH^- ion
4) donates an OH^- ion

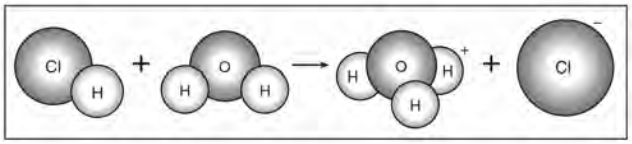
___ 2. According to one acid-base theory, a base is an

1) H^+ acceptor 2) H^+ donor
3) Na^+ acceptor 4) Na^+ donor

___ 3. A substance that dissolves in water and produces hydronium ions as the only positive ions in the solution is classified as

1) an alcohol 2) an acid
3) a base 4) a salt

___ 4. Given the diagram representing a reaction:



According to one acid-base theory, the water acts as

1) a base because it accepts an H^+
2) a base because it donates an H^+
3) an acid because it accepts an H^+
4) an acid because it donates an H^+

___ 5. Given the balanced equation representing a reaction:

$$HSO_4^{\ -}(aq) + H_2O(\ell) \rightarrow H_3O^+(aq) + SO_4^{\ 2-}(aq)$$

According to one acid-base theory, the $H_2O(\ell)$ molecules act as

1) a base because they accept H^+ ions 2) a base because they donate H^+ ions
3) an acid because they accept H^+ ions 4) an acid because they donate H^+ ions

___ 6. One acid-base theory defines a base as an

1) H^+ donor 2) H^+ acceptor
3) H donor 4) H acceptor

___ 7. One alternate acid-base theory states that an acid is an

1) H^+ donor 2) H^+ acceptor
3) OH^- donor 4) OH^- acceptor

8. Given the balanced equation representing a reaction:

$NH_3(g) + H_2O(\ell) \rightarrow NH_4^+(aq) + OH^-(aq)$

According to one acid-base theory, the $NH_3(g)$ molecules act as

1) an acid because they accept H^+ ions
2) an acid because they donate H^+ ions
3) a base because they accept H^+ ions
4) a base because they donate H^+ ions

9. Given the equation representing a reaction at equilibrium:

$NH_3(g) + H_2O(\ell) \leftrightarrow NH_4^+(aq) + OH^-(aq)$

The H^+ acceptor for the forward reaction is

1) $H_2O(\ell)$
2) $NH_3(g)$
3) $NH_4^+(aq)$
4) $OH^-(aq)$

10. Given the reaction:

$$NH_3 + H_2O \leftrightarrow NH_4^+ + OH^-$$

The water acts as the

1) base
2) acid
3) proton acceptor
4) electron donor

Video 13.4 pH & Acid-Base Indicators

1. When the pH of an aqueous solution is changed from 1 to 2, the concentration of hydronium ions in the solution is

   1) decreased by a factor of 2
   2) decreased by a factor of 10
   3) increased by a factor of 2
   4) increased by a factor of 10

2. When the pH of a solution is changed from 4 to 3, the hydronium ion concentration of the solution

   1) decreases by a factor of 10
   2) increases by a factor of 10
   3) decreases by a factor of 100
   4) increases by a factor of 100

3. When the hydronium ion concentration of a solution is increased by a factor of 10, the pH value of the solution

   1) decreases 1 pH unit
   2) decreases 10 pH units
   3) increases 1 pH unit
   4) increases 10 pH units

4. **OMIT**

5. When the pH value of a solution is changed from 2 to 1, the concentration of hydronium ions

   1) decreases by a factor of 2
   2) increases by a factor of 2
   3) decreases by a factor of 10
   4) increases by a factor of 10

6. Which change in pH represents a hundredfold increase in the concentration of hydronium ions in a solution?

   1) pH1 to pH 2 2) pH 1 to pH 3
   3) pH 2 to pH 1 4) pH 3 to pH 1

7. What is the pH of a solution that has a hydronium ion concentration 100 times greater than a solution with a pH of 4?

   1) 5 2) 2 3) 3 4) 6

8. As the pH of a solution is changed from 3 to 6, the concentration of hydronium ions

   1) increases by a factor of 3
   2) increases by a factor of 1000
   3) decreases by a factor of 3
   4) decreases by a factor of 1000

9. Which pH indicates a basic solution?

   1) 1 2) 5 3) 7 4) 12

10. Which of these pH numbers indicates the highest level of acidity?

    1) 5 2) 8 3) 10 4) 12

11. Phenolphthalein is pink in an aqueous solution having a pH of

    1) 5 2) 2 3) 7 4) 12

12. What is the color of the indicator thymol blue in a solution that has a pH of 11?

    1) red 2) blue
    3) pink 4) yellow

13. Three samples of the same solution are tested, each with a different indicator. All three indicators, bromthymol blue, bromcresol green and thymol blue, appear blue if the pH of the solution is

    1) 4.7 2) 6.0 3) 7.8 4) 9.9

14. Based on the results of testing colorless solutions with indicators, which solution is most acidic?

    1) a solution in which bromthymol blue is blue
    2) a solution in which bromcresol green is blue
    3) a solution in which phenolphthalein is pink
    4) a solution in which methyl orange is red

15. Which indicator would best distinguish between a solution with a pH of 3.5 and a solution with a pH of 5.5

    1) bromthymol blue 2) bromcresol green
    3) phenolphthalien 4) thymol blue

Modeling Neutralization Reactions

Engage:

- Predict what will happen to the pH when equal volumes of acid and base are combined?
- Test pH of solutions then mix together. Test pH of resulting solution after mixing. Make observations
- Test conductivity before and after

Activity:

1. Write the balanced neutralization reaction for the reaction of HCl and NaOH similar to the one you saw in the "Upset Tummy" phenomena.
2. Using the key, draw particle models to represent the reaction before and after mixing. Draw five dissociated acid particles in beaker 1 and five dissociated base particles in beaker 2.
3. Match each hydrogen ion in beaker one with one hydroxide ion in beaker two. Then draw the number of water molecules that form in beaker three.

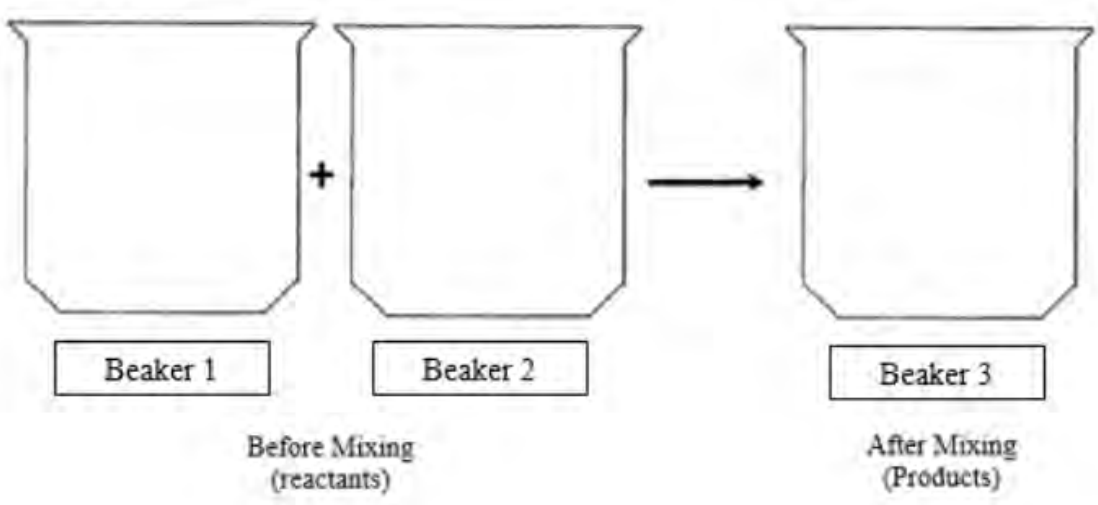
Key:

H^+ =

Cl^{-1} =

Na^+ =

OH^{-1} =



4. What was the pH of the resulting solution?

5. In a second neutralization reaction **H_2SO_4** and **NaOH** are mixed. Using the key below, draw three dissociated acid particles in beaker one and three dissociated base particles in beaker two.

6. Match each hydrogen ion in beaker one with one hydroxide ion in beaker two. Then draw the number of water molecules that form in beaker three. Draw the remaining ions in breaker three.

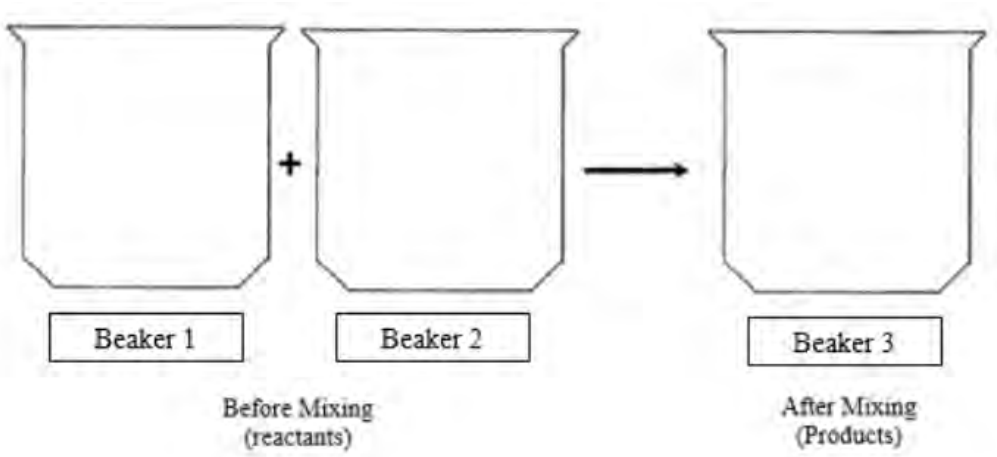
Key:

H^+ =

SO_4^{-2} =

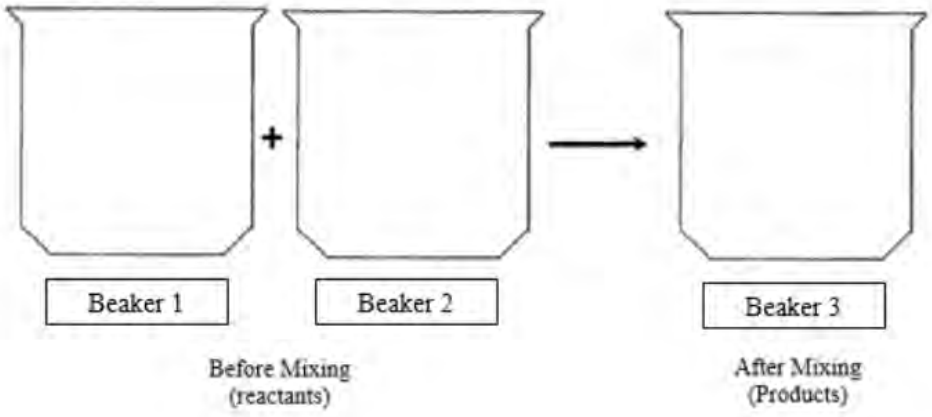
Na^+ =

OH^{-1} =



7. What additional ion(s) would be needed to neutralize the solution? How many more would you need?

8.Draw a model below to justify that neutralization has occurred.



8. Write the **balanced** equation for the complete neutralization of H_2SO_4 and NaOH .

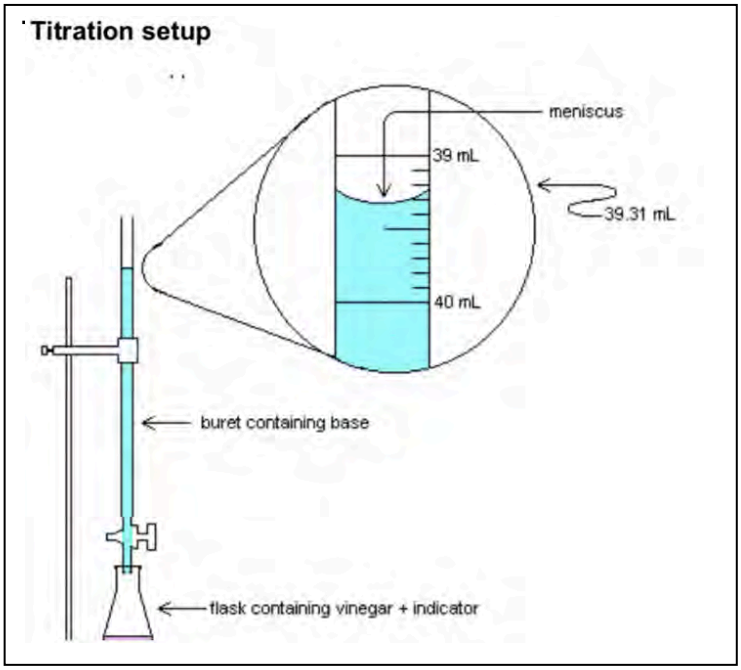
Titration and Neutralization Calculations

Do Now: Using your knowledge of chemistry, fill in each blank to complete the statements.

1. The chemicals HCl, HBr, HNO_3, H_2SO_4 are all categorized as acids because when dissolved in water they produce a _____ ion.
2. The chemicals NaOH, LiOH, and $Ca(OH)_2$ are all categorized as bases because when dissolved in water they produce a _____ ion.
3. When acids react with bases the reaction is known as a _____ reaction because the properties of the original acid and base are lost to form a _____ and water.
4. Calculate the Molarity of an acid created by dissolving 73.0g of HCl in 200.0mL if solution.

5. Calculate the moles of NaOH dissolved in a 2.0M basic solution with a total volume of 500.0mL.

READ ME! Titrations are procedures used to determine the concentration or Molarity (M) of an unknown acid or a base. The acid and base solutions are combined together in a ratio of 1 mole of Acid for every 1 mole of Base, thus neutralizing the reaction. Observe the titration set up below. A student placed 20.00mL of an unknown acid and two drops of phenolphthalein indicator in the flask. Then the student added the known base dropwise until the solution was neutralized (indicated by the color change of the phenolphthalein). Answer questions 1 through 4.



Read the volume of the base that was released from the burette

If the base concentration was known to be 2.00M, calculate the number of moles of basic ion are dissolved in the solution.

If the solution in the flask is now neutral, how many moles of acid ion are in the flask?

Calculate the molarity of the unknown

Using the equation on Reference Table T, you can solve for either the molarity/concentration (M) or a volume added (V) using the titration formula:

$$M_A V_A = M_B$$

M_A= molarity of H^+ V_A = volume of acid

M_B = molarity of OH^- V_B = volume of base

5. What unit of measurement is obtained when the Molarity of a solution is multiplied by the volume (in liters) of the solution?

6. Explain why the Titration formula is mathematically accurate for finding the concentration of solution when the solution is neutralized.

Notice that the Molarity formula requires the volume to be calculated in Liters. However, the titration formula has no such requirement, as long as the volume unit of measurement is the same for both V_A and V_B. Since the titration formula has two volumes, the volume unit of measurement will cancel out. Therefore, converting the units will also cancel out. Perform the calculations in question 7 to prove this rule.

7. A 100.00mL solution of 2.00M HCl is neutralized by 50.00mL of NaOH. Calculate the Molarity of the unknown base.
   a. Use the titration formula and calculate the Molarity with the volume values in mL.

   b. Use the titration formula and calculate the Molarity with the volume values in Liters.

   c. Compare your answers to questions 7a and 7b.

8. A 25.0-milliliter sample of HNO_3 (aq) is neutralized by 32.1 milliliters of 0.150 M KOH (aq). Calculate the concentration of the acid.

9. The titration formula can also be used to determine the volume needed to neutralize two known solutions. Calculate the volume of 0.200 M NaOH needed to neutralize 100. mL of 0.100 M HCl.

For each question, the two pH values are being compared. In terms of hydronium, how many times stronger or weaker is the pH of the solution?

1. pH 5 → pH 3 _____
2. pH 8 → pH 4 _____
3. pH 10 → pH 7 _____
4. pH 14 → pH 7 _____
5. pH 3 → pH 6 _____

Video 13.5: Neutralization & Titrations

Complete and balance each of the acid base neutralization reactions below.

1. _____ H_2SO_4 + _____ $Mg(OH)_2$ →
2. _____ HNO_3 + _____ $Al(OH)_3$ →
3. _____ H_3PO_4 + _____ $Ca(OH)_2$ →
4. _____ HI + _____ KOH →
5. _____ HBr + _____ $Ba(OH)_2$ →
6. _____ HCl + _____ KOH →
7. _____ H_3PO_4 + _____ LiOH →
8. _____ HF + _____ $Ca(OH)_2$ →
9. In a titration of $HClO_4$ with NaOH, 100.0 mL of the base was required to neutralize 20.0 mL of 5.0 M $HClO_4$. What is the molarity of the NaOH? (Be sure to write the neutralization reaction.)

10. In a titration of HNO_3 with NaOH, 60.0 mL of 0.020 M NaOH was needed to neutralize 15.0 mL of HNO_3. What is the molarity of the acid? (Write the neutralization reaction.)

11. In a titration, 20.0 milliliters of 0.15 M HCl(aq) is exactly neutralized by 18.0 milliliters of KOH(aq).
    (a) Complete the equation below for the neutralization reaction by writing the formula of *each* product.
    KOH(aq) + HCl(aq) → _____ + _____

    (b) Compare the number of moles of H^+(aq) ions to the number of moles of OH^- (aq) ions in the titration mixture when the HCl(aq) is exactly neutralized by the KOH(aq).

    (c) Determine the concentration of the KOH(aq).

    (d) What is the new pH of the solution?

12. In a laboratory activity, 0.500 mole of NaOH(s) is completely dissolved in distilled water to form 400. milliliters of NaOH(aq). This solution is then used to titrate a solution of HNO_3(aq).
    (a) Identify the negative ion produced when the NaOH(s) is dissolved in distilled water.

    (b) Calculate the molarity of the NaOH(aq). Your response must include *both* a correct numerical setup and the calculated result.

    (c) If 26.4 milliliters of the NaOH solution is needed to exactly neutralize 44.0 milliliters of the HNO_3 solution, what is the molarity of the HNO_3 solution?

    (d) Complete the equation below representing this titration reaction by writing the formulas of the products.
    NaOH(aq) + HNO_3(aq) → _____ + _____

13. If 10.0 mL of 0.300 M KOH are required to neutralize 30.0 mL of stomach acid (HCl), what is the molarity of the stomach acid? (Write the neutralization reaction.)

14. If it takes 50 mL of 0.5 M KOH solution to completely neutralize 125 mL of hydrobromic acid solution (HBr), what is the concentration of the HBr solution?

Titration Practice:

A titration was set up and used to determine the unknown molar concentration of a solution of NaOH. A 1.2 M HCl solution was used as the titration standard. The following data were collected.

	Trial 1	Trial 2	Trial 3	Trial 4
Volume of 1.2 M HCl	10.0 mL	10.0 mL	10.0 mL	10.0 mL
Intial buret reading of NaOH	0.0 mL	12.2 mL	23.2 mL	35.2 mL
Final buret reading of NaOH	12.2 mL	23.2 mL	35.2 mL	47.7 mL
Volume of NaOH used (mL)				
Molarity of NaOH (M)				

1. Calculate the volume of NaOH used to neutralize the acid for each trial. Record in the data table above. Show one sample calculation below.

2. Using the $M_AV_A = M_BV_B$ formula, calculate the molarity of the base for each trial. Record in the data table above. Show one sample calculation below.

3. Calculate the average molarity of the NaOH using your results from question 2. Your answer must include the correct number of significant figures and the correct units of measure.

Name: **Acid/Base/Salt Review**

1. Which laboratory test result can be used to determine if KCl(s) is an electrolyte?

   A) pH of KCl(aq)
   B) pH of KCl(s)
   C) electrical conductivity of KCl(aq)
   D) electrical conductivity of KCl(s)

2. Which substance is an electrolyte?

   A) CCl_4 B) C_2H_6
   C) HCl D) H_2O

3. Which two compounds are electrolytes?

   A) $C_6H_{12}O_6$ and CH_3CH_2OH
   B) $C_6H_{12}O_6$ and HCl
   C) NaOH and HCl
   D) NaOH and CH_3CH_2OH

4. A substance is classified as an electrolyte because

   A) it has a high melting point
   B) it contains covalent bonds
   C) its aqueous solution conducts an electric current
   D) its aqueous solution has a pH value of 7

5. Which of the following aqueous solutions is the best conductor of electricity?

   A) 0.10 M CH_3OH B) 1.0 M CH_3OH
   C) 0.10 M NaOH D) 1.0 M NaOH

6. A student was given four unknown solutions. Each solution was checked for conductivity and tested with phenolphthalein. The results are shown in the data table below.

Solution	Conductivity	Color with Phenolphthalein
A	Good	Colorless
B	Poor	Colorless
C	Good	Pink
D	Poor	Pink

   Based on the data table, which unknown solution could be 0.1 M NaOH?

   A) *A* B) *B* C) *C* D) *D*

7. Which compound is an Arrhenius acid?

   A) CaO B) HCI C) K_2O D) NH_3

8. When one compound dissolves in water, the only positive ion produced in the solution is H_3O^+ (aq). This compound is classified as

   A) a salt B) a hydrocarbon
   C) an Arrhenius acid D) an Arrhenius base

9. Which substance is always a product when an Arrhenius acid in an aqueous solution reacts with an Arrhenius base in an aqueous solution?

   A) HBr B) H_2O
   C) KBr D) KOH

10. Given the equation:

    $$HCl(g) + H_2O(\ell) \rightarrow X(aq) + Cl^-(aq)$$

    Which ion is represented by *X*?

    A) hydroxide B) hydronium
    C) hypochlorite D) perchlorate

11. An aqueous solution of lithium hydroxide contains hydroxide ions as the only negative ion in the solution. Lithium hydroxide is classified as an

    A) aldehyde B) alcohol
    C) Arrhenius acid D) Arrhenius base

12. According to the Arrhenius theory, an acid is a substance that

    A) changes litmus from red to blue
    B) changes phenolphthalein from colorless to pink
    C) produces hydronium ions as the only positive ions in an aqueous solution
    D) produces hydroxide ions as the only negative ions in an aqueous solution

13. Which compound releases hydroxide ions in an aqueous solution?

    A) CH_3COOH B) CH_3OH
    C) HCl D) KOH

14. Which formula represents a hydronium ion?

    A) H_3O^+ B) NH_4+
    C) OH^- D) HCO_3^-

15. A solution with a pH of 2.0 has a hydronium ion concentration ten times greater than a solution with a pH of

    A) 1.0 B) 0.20 C) 3.0 D) 20

16. Which change in pH represents a hundredfold increase in the concentration of hydronium ions in a solution?

A) pH1 to pH 2 B) pH 1 to pH 3
C) pH 2 to pH 1 D) pH 3 to pH 1

17. What is the pH of a solution that has a hydronium ion concentration 100 times greater than a solution with a pH of 4?

A) 5 B) 2 C) 3 D) 6

18. Which pH indicates a basic solution?

A) 1 B) 5 C) 7 D) 12

19. Which of these pH numbers indicates the highest level of acidity?

A) 5 B) 8 C) 10 D) 12

20. Based on the results of testing colorless solutions with indicators, which solution is most acidic?

A) a solution in which bromthymol blue is blue
B) a solution in which bromcresol green is blue
C) a solution in which phenolphthalein is pink
D) a solution in which methyl orange is red

21. Which indicator would best distinguish between a solution with a pH of 3.5 and a solution with a pH of 5.5

A) bromthyrnol blue B) bromcresol green
C) litmus D) thymol blue

22. Which indicator, when added to a solution, changes color from yellow to blue as the pH of the solution is changed from 5.5 to 8.0?

A) bromcresol green B) bromthymol blue
C) litmus D) methyl orange

23. The data below shows the color of the indicators methyl orange and litmus in two samples of the same solution.

Indicator	Color Result form the Indicator Test
methyl orange	yellow
bromthymol green	green

Which pH value is consistent with the indicator results?

A) 1 B) 5 C) 3 D) 10

24. Which indicator is yellow in a solution with a pH of 9.8?

A) methyl orange B) bromthymol blue
C) bromcresol green D) thymol blue

25. One acid-base theory defines a base as an

A) H^+ donor B) H^+ acceptor
C) H donor D) H acceptor

26. One alternate acid-base theory states that an acid is an

A) H^+ donor B) H^+ acceptor
C) OH^- donor D) OH^- acceptor

27. Which statement describes an alternate theory of acids and bases?

A) Acids and bases are both H^+ acceptors.
B) Acids and bases are both H^+ donors.
C) Acids are H^+ acceptors, and bases are H^+ donors.
D) Acids are H^+ donors, and bases are H^+ acceptors.

28. Given the reaction at equilibrium:

$$HSO_4^- + NH_3 \leftrightarrow SO_4^{2-} + NH_4^+$$

What are the two species that are acids?

A) NH_3 and NH_4^+
B) NH_3 and SO_4^{2-}
C) HSO_4^- and SO_4^{2-}
D) HSO_4^- and NH_4^+

29. According to one acid-base theory, water acts as an acid when an H_2O molecule

A) accepts an H^+ B) donates an H^+
C) accepts an H^- D) donates an H^-

30. Which compound is produced when HCl(aq) is neutralized by $Ca(OH)_2(aq)$?

A) $CaCl_2$ B) CaH_2
C) HClO D) $HClO_2$

31. Which word equation represents a neutralization reaction?

A) base + acid $\rightarrow$ salt + water
B) base + salt $\rightarrow$ water + acid
C) salt + acid $\rightarrow$ base + water
D) salt + water $\rightarrow$ acid + base

32. Which equation represents a neutralization reaction?

A) $4Fe(s) + 3O_2(g) \rightarrow Fe_2O_3(s)$
B) $2H_2(g) + O_2(g) \rightarrow 2H_2O(\ell)$
C) $HNO_3(aq) + KOH(aq) \rightarrow KNO_3(aq) + H_2O(\ell)$
D) $AgNO_3(aq) + KCl(aq) \rightarrow KNO_3(aq) + AgCl(s)$

33. During which process can 10.0 milliliters of a 0.05 M HCl(aq) solution be used to determine the unknown concentration of a given volume of NaOH(aq) solution?

A) evaporation B) distillation
C) filtration D) titration

34. A student completes a titration by adding 12.0 milliliters of NaOH(aq) of unknown concentration to 16.0 milliliters of 0.15 M HCl(aq). What is the molar concentration of the NaOH(aq)?

A) 0.11 M B) 0.20 M
C) 1.1 M D) 5.0 M

35. A 25.0-milliliter sample of $HNO_3(aq)$ is neutralized by 32.1 milliliters of 0.150 M KOH(aq). What is the molarity of the $HNO_3(aq)$?

A) 0.117 M B) 0.150 M
C) 0.193 M D) 0.300 M

36. Which volume of 0.10 M NaOH(aq) exactly neutralizes 15.0 milliliters of 0.20 M $HNO_3(aq)$?

A) 1.5 mL B) 7.5 mL
C) 3.0 mL D) 30. mL

37. What volume of 0.120 M $HNO_3(aq)$ is needed to completely neutralize 150.0 milliliters of 0.100 M NaOH(aq)?

A) 62.5 mL B) 125 mL
C) 180. mL D) 360. mL

Base your answers to questions **38** and **39** on the information below.

In one trial of an investigation, 50.0 milliliters of HCI(aq) of an unknown concentration is titrated with 0.10 M NaOH(aq). During the titration, the total volume of NaOH(aq) added and the corresponding pH value of the reaction mixture are measured and recorded in the table below.

Titration Data

Total Volume of NaOH(aq) Added (mL)	**pH Value of Reaction Mixture**
10.0	1.6
20.0	2.2
24.0	2.9
24.9	3.9
25.1	10.1
26.0	11.1
30.0	11.8

38. Write a balanced equation that represents this neutralization reaction.

39. In another trial, 40.0 milliliters of HCI(aq) is completely neutralized by 20.0 milliliters of this 0.10 M NaOH(aq). Calculate the molarity of the titrated acid in this trial. Your response must include *both* a numerical setup and the calculated result.

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40. Base your answer to the following question on the information below.

In liquid water, an equilibrium exists between $H_2O(\ell)$ molecules, $H^+(aq)$ ions, and $OH^-(aq)$ ions. A person experiencing acid indigestion after drinking tomato juice can ingest milk of magnesia to reduce the acidity of the stomach contents. Tomato juice has a pH value of 4. Milk of magnesia, a mixture of magnesium hydroxide and water, has a pH value of 10.

Compare the hydrogen ion concentration in tomato juice to the hydrogen ion concentration in milk of magnesia.

Base your answers to questions **41** through **43** on the information below.

A student used blue litmus paper and phenolphthalein paper as indicators to test the pH of distilled water and five aqueous household solutions. Then the student used a pH meter to measure the pH of the distilled water and each solution. The results of the student's work are recorded in the table below.

Testing Results

Liquid Tested	Color of Blue Litmus Paper	Color of Phenolphthalein Paper	Measured pH Value Using a pH Meter
2% milk	blue	colorless	6.4
distilled water	blue	colorless	7.0
household ammonia	blue	pink	11.5
lemon juice	red	colorless	2.3
tomato juice	red	colorless	4.3
vinegar	red	colorless	3.3

41. Explain, using the reference table, in terms of the pH range for color change why litmus is *not* appropriate to differentiate the acidity levels of tomato juice and vinegar.

42. Identify the liquid tested that has the *lowest* hydronium ion concentration.

43. Based on the measured pH values, identify the liquid tested that is 10 times more acidic than vinegar.