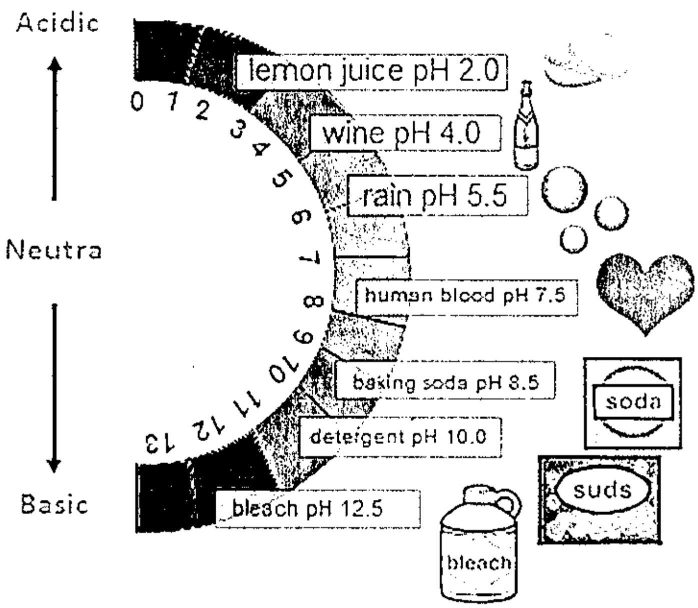
Acids, Bases, and Salts – Chap 15

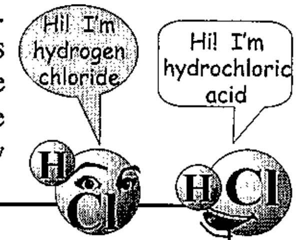
Acids, Bases, Salts – Arrhenius, Bronsted Lowrey, Lewis Definitions
Acidity, Basicity (Alkalinity), and pH
Neutralization and Titration
Equilibria of weak acids and bases (K_a and K_b)



Chemistry: Form WS9.6.1A Name ______________________

ACIDS, BASES, AND SALTS Date ______________ Period ____

Naming Acids or (An Acid by Any other Name Would still Smell just as Sour)



Acids have regular chemical names, just like other compounds. HCl(*g*) is hydrogen chloride. Mix it with water to form HCl(*aq*) and you have hydrochloric acid. The rules for naming acids are different from the rules for naming other compounds, All binary acids (hydrogen and one other element) have the prefix HYDRO and suffix IC. HF is hydrofluoric acid. Oxyacids are most easily named based on the names of their polyatomic ions from *Table E*. The chart below shows how the name of the ion relates to the name of the acid.

oxidation state	polyatomic ion			acid name	
	example	prefix	suffix	prefix	suffix
two less than most common	ClO^{-1}	hypo	ite	hypo	ous
one less than most common	ClO_2^{-1}	-	ite	-	ous
most common	ClO_3^{-1}	-	ate	-	ic
one more than most common	ClO_4^{-1}	hyper	ate	per	ic

The prefixes and suffixes are added to the root (*fluor* for fluorine, *sufur* for sulfur, *nitr* for nitrogen, etc.) HNO_2 is normally hydrogen nitrite. Mix it with water to form HNO_2(*aq*) and you get nitrous acid. Nitrous because the regular chemical name of the ion is nitrite.

Name the acids below, following the directions above:

1. H_2SO_4(*aq*) ______________
2. HBr(*aq*) ______________
3. HCH_3COO(*aq*) ______________
4. H_3PO_4(*aq*) ______________
5. H_2S(*aq*) ______________
6. HCl(*aq*) ______________
7. HClO(*aq*) ______________
8. $HClO_4$(*aq*) ______________
9. H_2SO_3(*aq*) ______________
10. HI(*aq*) ______________
11. H_2SO_4(*aq*) ______________
12. H_2CrO_4(*aq*) ______________
13. $HMnO_4$(*aq*) ______________
14. H_2CO_3(*aq*) ______________
15. HF(*aq*) ______________
16. $H_2C_2O_4$(*aq*) ______________
17. HNO_3(*aq*) ______________
18. $HClO_2$(*aq*) ______________

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Activity 7-3
Arrhenius Acids and Bases II

Names and formulas

Give the chemical name for each of the following acids in water solution.

1. HCl ______
2. $HClO$ ______
3. $HClO_2$ ______
4. $HClO_3$ ______
5. $HClO_4$ ______
6. HNO_2 ______
7. HNO_3 ______
8. H_2SO_3 ______
9. H_2SO_4 ______
10. H_2S ______

Give the chemical formulas for each of the following acids.

11. phosphorous acid ______
12. phosphoric acid ______
13. hydrobromic acid ______
14. bromous acid ______
15. iodic acid ______
16. hydrofluoric acid ______

Give the chemical formula for each of the following bases.

17. magnesium hydroxide ______
18. iron (III) hydroxide ______
19. aqueous ammonia (ammonium hydroxide) ______
20. lithium hydroxide ______
21. potassium hydroxide ______

Anhydrides

22. What is an acid anhydride? ______

23. What is a basic anhydride? ______

Write a balanced chemical equation for the reaction of each of the following anhydrides with water.

24. K_2O ______
25. SO_3 ______
26. N_2O_5 ______
27. MgO ______

Write the formula for the anhydride of each of the following.

28. $Al(OH)_3$ ______ 29. H_2SO_3 ______ 30. $NaOH$ ______ 31. H_3PO_4 ______

Displacement reactions between metals and acids

Write balanced equations for each of the following reactions.

32. zinc + hydrochloric acid

____

33. magnesium + phosphoric acid

____

34. aluminum + sulfuric acid

____

Neutralization

35. What is the definition of neutralization in the Arrhenius system of acids and bases? ______

____

____

Write balanced equations for the following neutralization reactions.

36. hydrochloric acid + sodium hydroxide

____

37. sulfuric acid + calcium hydroxide

____

38. oxalic acid + potassium hydroxide

____

Complete and balance each of the following equations for neutralization reactions. In the spaces below the formulas, write the names of the compounds.

39. ___ HNO_3 + ___ $Mg(OH)_2$ $\longrightarrow$ ___ ________ + ___ ________

________ ________ ________ ________

40. ___ KOH + ___ HBr $\longrightarrow$ ___ ________ + ___ ________

________ ________ ________ ________

41. ___ H_2SO_4 + ___ ________ $\longrightarrow$ ___ $(NH_4)_2SO_4$ + ___ ________

________ ________ ________ ________

Chemistry: Form Ls9.1A Name ____________________

ACIDS, BASES, AND SALTS Date ______________ Period _____

Nature of Acids and Bases

Aim

- classify compounds as acids or bases based on their characteristics

Notes

Properties of acids and bases are caused by ions

★ Hydronium ions (H_3O^+) cause acid properties

★ Hydroxide ions (OH^-) cause base properties

Water - the neutral substance

★ Water is polar

★ The positively charged hydrogens in one water molecule are attracted to the negatively charged oxygens of another

★ Due to this attraction, water ionizes to a very small extent as follows:

$$2H_2O \rightleftharpoons H_3O^+ + OH^-$$

- ☆ concentration of the ions in pure water - $[H_3O^+]=[OH^-]=10^{-7}M$
- ☆ importance of ionization of water
  - ✯ since the concentration of hydronium and hydroxide are equal in pure water, water is neutral
  - ✯ the concentration of ions in pure water is very low because the ions are more likely to combine to form water than water is to ionize
  - ✯ the limited ionization of water is responsible for the properties of acids and bases

Acids

★ **Arrhenius Theory** - an acid is a substance that yields hydrogen ions (H^+) as the only positive ions in aqueous solution; the properties of acids are caused by excess hydrogen ions

- ☆ Acids are polar molecules that contain hydrogen as a metal
- ☆ Acids ionize in water to produce hydrogen ions (H^+) or hydronium ions (H_3O^+) [H^+ can't exist alone. It combines with water to form H_3O^+]

$$HCl(g) \rightarrow H^+(aq) + Cl^-(aq) \quad \textit{or} \quad H_2O(\ell) + HCl(g) \rightarrow H_3O^+(aq) + Cl^-(aq)$$

★ Other theories explain how substances behave like acids outside of water solution

★ Examples

- ☆ HCl
- ☆ HNO_3
- ☆ H_2SO_4

Base

★ **Arrhenius' theory** - a base is a substance that yields hydroxide ions as the only negative ions in aqueous solution; the properties of bases are caused by hydroxide ions

- ☆ Bases are ionic compounds that contain hydroxide as a nonmetal
- ☆ Bases dissociate in water to release hydroxide ions

$$NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$$

★ Other theories explain how substances behave like bases outside of water solution

★ Examples

- ☆ NaOH
- ☆ NH_4OH
- ☆ $Ca(OH)_2$ [*NOTE:* Alcohols such as ethanol (C_2H_5OH) are bases because they are not ionic, and do not release OH^- in water]

Answer the questions below by circling the number of the correct response

1. In the reversible reaction, $2H_2O \rightleftharpoons H_3O^+ + OH^-$, showing the ionization of water, which of the following is true? (1) The forward reaction forming ions from water is favored. (2) The concentration of ions in pure water is high. (3) The concentration of hydronium in pure water is higher than the concentration of hydroxide. (4) The concentration of ions in pure water is low.

2. The ion represented by the formula H_3O^+ is (1) hydroxide, (2) hydroxyl, (3) hydronium, (4) hydrogen III oxide.

3. In pure water, 10^{-7} M represents the concentration of (1) hydroxide only, (2) hydronium only, (3) both hydroxide and hydronium, (4) neither hydroxide nor hydronium

4. The fact that the concentration of hydronium and hydroxide are equal in pure water accounts for the fact that water is (1) neutral, (2) acid, (3) base.

5. Water tends to ionize because the water molecule is (1) ionic, (2) polar, (3) nonpolar, (4) wet.

For each of the phrases below (questions 6 -7), write the correct number in the appropriate place on the answer sheet to indicate whether the compound described is (1) an acid only (2) a base only, (3) an acid or a base, or (4) neither an acid nor a base.

6. Increases the hydroxide ion concentration of water

7. Increases the hydronium ion concentration of water

8. Which of the following is *NOT* a characteristic of acids? (1) decrease the hydroxide ion concentration of water (2) ionize in water to produce hydronium ions (3) polar molecules that contain hydrogen as a metal (4) contain hydroxide as a nonmetal

9. The compound, NaOH (*aq*), is best described as (1) an acid, (2) a base, (3) neutral

10. The compound, HNO_3 (*aq*), is best described as (1) an acid, (2) a base, (3) neutral

11. As the concentration of hydronium ions increases in water, the hydroxide ion concentration (1) increases, (2) decreases, (3) remain the same.

12. When an acid is added to water the (1) hydronium ion concentration increases, (2) hydroxide ion concentration increases, (3) hydronium ion concentration decreases (4) hydroxide ion concentration first increases and then decreases.

13. When added to water, which of the following will cause the hydroxide ion concentration to increase? (1) NaCl (2) HCl (3) NaOH (4) HOH

14. Which of the following is *NOT* an acid? (1) HCl (2) HNO_3 (3) H_2SO_4 (4) H_2O

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Name ______________________ Class______ Date__________

Activity 7-5
Brønsted-Lowry Acids and Bases

Operational and conceptual definitions

1. What is an operational definition? ______________________

2. What is a conceptual definition? ______________________

3. Which kind of definition provides for the prediction of properties? Explain your answer

The Brønsted-Lowry theory

The Brønsted-Lowry definitions of an acid and a base are conceptual definitions.

4. What is the Brønsted-Lowry definition of an acid? ______________________

5. What is the Brønsted-Lowry definition of a base? ______________________

6. What is the meaning of the term *proton* as used in the definitions above? ______________________

7. The following rule is often used to describe Brønsted-Lowry acid-base reactions:

$$\text{Stronger acid} + \text{Stronger base} \rightleftharpoons \text{Weaker acid} + \text{Weaker base}$$

Explain this rule in terms of the tendencies of substances to donate and accept protons.

8. What is a conjugate acid-base pair? ______________________

Conjugate acid-base pairs

9. How does an acid differ from its conjugate base? ______________________________

____

____

10. How does a base differ from its conjugate acid? ______________________________

____

____

For each of the following reactions, complete the equation and then identify the stronger acid (SA), stronger base (SB), weaker acid (WA), and weaker base (WB), as shown in the example. Draw a proportionate double arrow to show the predominant direction of the reaction. (If the equilibrium point is toward the right, the longer arrow will point toward the right, and if the equilibrium point is toward the left, the longer arrow will point toward the left.) Refer to Table J in the Appendix as needed.

Example $HNO_3 + C_2H_3O_2^- \rightleftharpoons NO_3^- + HC_2H_3O_2$
SA SB WB WA

11. $PO_4^{3-} + HNO_2$ ________ + ________
______ ______ ______ ______

12. $HSO_4^- + NO_3^-$ ________ + ________
______ ______ ______ ______

13. $HSO_4^- + NO_2^-$ ________ + ________
______ ______ ______ ______

14. $OH^- + HC_2H_3O_2$ ________ + ________
______ ______ ______ ______

15. $H_2S + NH_3$ ________ + ________
______ ______ ______ ______

16. $H_2PO_4^- + F^-$ ________ + ________
______ ______ ______ ______

BRONSTED-LOWRY ACIDS AND BASES

Name ____________________

According to Bronsted-Lowry theory, an acid is a proton (H^+) donor, and a base is a proton acceptor.

> H^+
>
> **Example:** $HCl + OH^- \rightarrow Cl^- + H_2O$
>
> The HCl acts as an acid, the OH^- as a base. This reaction is reversible in that the H_2O can give back the proton to the Cl^-.

Label the Bronsted-Lowry acids and bases in the following reactions and show the direction of proton transfer.

H^+ H^+

Example: $H_2O + Cl^- \leftrightarrow OH^- + HCl$

Acid Base Base Acid

1. $H_2O + H_2O \leftrightarrow H_3O^+ + OH^-$
2. $H_2SO_4 + OH^- \leftrightarrow HSO_4^- + H_2O$
3. $HSO_4^- + H_2O \leftrightarrow SO_4^{-2} + H_3O^+$
4. $OH^- + H_3O^+ \leftrightarrow H_2O + H_2O$
5. $NH_3 + H_2O \leftrightarrow NH_4^+ + OH^-$

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Chemistry: Form WS9.2.2A Name ______________________

ACIDS AND BASES Date ______________ Period _____

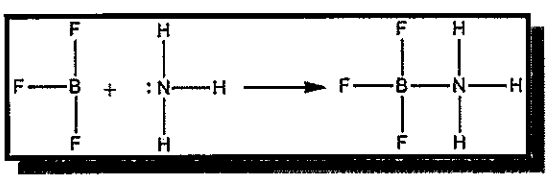
Acids and Bases: An Operational Definition

Ammonia's artistic debut

There are three models to explain the nature of acids and bases: [1] The Arrhenius Theory; [2] The Brönsted-Lowry Model; and [3] The Lewis Model. Each of these models is successively more general than the one that precedes it. The more general models include the earlier models.

According to Arrhenius an acid is a substance that yields hydrogen ions (H^+) as the only positive ions in aqueous solution. The properties of acids are caused by excess hydrogen ions. A base, on the other hand, is a substance that yields hydroxide (OH^-) ions as the only negative ions in aqueous solution. The properties of bases are caused by hydroxide ions.

Brönsted-Lowry broadens the definition of acids and bases. According to Brönsted-Lowry, an acid is any species that can donate a proton to another. For example, when ammonia dissolves in water, water donates a proton to form the ammonium ion, so water is a Brönsted-Lowry acid ($NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$). According to Brönsted-Lowry, a base is any species (molecule or ion) that can combine with or accept a proton. In the reaction between water and hydrochloric acid, water acts as a Brönsted-Lowry base by accepting a proton ($HCl + H_2O \rightleftharpoons H_3O^+ + Cl^-$). In the reaction $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$ between ammonia and water, NH_4^+ and NH_3 are conjugate acid base pairs. NH_4^+ behaves like a Brönsted-Lowry acid, donating a proton to become NH_3. NH_3 behaves like a Brönsted-Lowry base, accepting a proton to become NH_4^+. Conjugate acid-base pairs always differ by one hydrogen atom.



The Lewis model expands the definition of acid and base even further. A Lewis acid is an electron pair acceptor. It has an empty atomic orbital that it can use to accept an electron pair from a molecule with a lone pair. It may be deficient in a pair of electrons. Boron trifluoride (BF_3) is a typical Lewis acid. It is electron deficient. Ammonia (NH_3) is a typical Lewis base. It has a lone pair of electrons. Boron trifluoride and ammonia will combine by forming a coordinate covalent bond.

Answer the questions below based on your understanding of acids-base models.

1. According to Arrhenius, are both HCl(*aq*) and HCl(*g*) acids? Explain. ______________________

____

____

____

(CONTINUED ON THE NEXT PAGE)

2. For each of the reactions below, identify the Arrhenius acids, Brönsted-Lowry acids, and Lewis acids. (*NOTE*:A substance may fit more than one model.) If none are present, write *NONE*.

	Arrhenius	Brönsted-Lowry	Lewis
a. $HI(aq) + H_2O(\ell) \rightarrow H_3O^+(aq) + I^-(aq)$			
b. $NH_3(g) + BF_3(g) \rightarrow NH_3BF_3(g)$			
c. $2H_2O(\ell) \rightarrow H_3O^+(aq) + OH^-(aq)$			
d. $NH_3(g) + H_2O(\ell) \rightarrow NH_4^+(aq) + OH^-(aq)$			
e. $NH_4OH(aq) \rightarrow NH_4^+(aq) + OH^-(aq)$			
f. $NH_3(g) + H_2O(\ell) \rightarrow NH_4OH(aq)$			

3. For each of the same reactions below, identify the Arrhenius bases, Brönsted-Lowry basess, and Lewis bases. (*NOTE*:A substance may fit more than one model.) If none are present, write *NONE*.

	Arrhenius	Brönsted-Lowry	Lewis
a. $HI(aq) + H_2O(\ell) \rightarrow H_3O^+(aq) + I^-(aq)$			
b. $NH_3(g) + BF_3(g) \rightarrow NH_3BF_3(g)$			
c. $2H_2O(\ell) \rightarrow H_3O^+(aq) + OH^-(aq)$			
d. $NH_3(g) + H_2O(\ell) \rightarrow NH_4^+(aq) + OH^-(aq)$			
e. $NH_4OH(aq) \rightarrow NH_4^+(aq) + OH^-(aq)$			
f. $NH_3(g) + H_2O(\ell) \rightarrow NH_4OH(aq)$			

4. Describe how each of the three models of acid-base theory would account for the acid properties of $HNO_3(aq)$?

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NAME:________________________________ DATE:_______SECTION______LAB______

ACIDS AND BASES

By the 1884 definition of Svante Arrhenius (Sweden), an acid is a material that can release a proton or hydrogen ion (H^+). Hydrogen chloride in water solution ionizes and becomes hydrogen ions and chloride ions. If that is the case, a base, or alkali, is a material that can donate a hydroxide ion (OH^-). Sodium hydroxide in water solution becomes sodium ions and hydroxide ions. By the definition of both Thomas Lowry (England) and J.N. Brønsted (Denmark) working independently in 1923, an acid is a material that donates a proton and a base is a material that can accept a proton. Was Arrhenius erroneous? No. The Arrhenius definition serves well for a limited use. We are going to use the Arrhenius definitions most of the time. The Lowry- Brønsted definition is broader, including some ideas that might not initially seem to be acid and base types of interaction. Every ion dissociation that involves a hydrogen or hydroxide ion could be considered an acid- base reaction. Just as with the Arrhenius definition, all the familiar materials we call acids are also acids in the Lowry - Brønsted model.

In a way, there is no such thing as a hydrogen ion or proton without anything else. They just don't exist naked like that in water solution. Remember that water is a very polar material. There is a strong partial negative charge on the side of the oxygen atom and a strong partial positive charge on the hydrogen side. Any loose hydrogen ion, having a positive charge, would quickly find itself near the oxygen of a water molecule. At close range from the charge attraction, the hydrogen ion would find a pair (its choice of two pairs) of unshared electrons around the oxygen that would be capable of filling its outer shell. Each hydrogen ion unites with a water molecule to produce a ***hydronium ion***, $(H_3O)^+$, the real species that acts as acid. The hydroxide ion in solution does not combine with a water molecule in any similar fashion. As we write reactions of acids and bases, it is usually most convenient to ignore the hydronium ion in favor of writing just a hydrogen ion.

For the properties of acids and bases we will use the Arrhenius definitions.

Properties of Acids

Acids release a hydrogen ion into water (aqueous) solution.

Acids neutralize bases in a neutralization reaction. An acid and a base combine to make a salt and water.

Acids corrode active metals. When an acid reacts with a metal, it produces a salt and hydrogen gas.

Acids turn blue litmus to red. Litmus is one of a large number of organic compounds that change colors when a solution changes acidity at a particular point. Litmus is the oldest known pH indicator. It is red in acid and blue in base. The phrase, 'litmus test,' indicates that litmus has been around a long time in the English language. Litmus does not change color exactly at the neutral point between acid and base, but very close to it. Litmus is often impregnated onto paper to make 'litmus paper.'

Acids taste sour. TASTING LAB ACIDS IS NOT PERMITTED BY ANY SCHOOL Stomach acid is hydrochloric acid. Although tasting stomach acid is not pleasant, it has the sour taste of acid. Acetic acid is the acid ingredient in vinegar. Citrus fruits such as lemons, grapefruit, oranges, and limes have citric acid in the juice. Sour milk, sour cream, yogurt, and cottage cheese have lactic acid from the fermentation of the sugar lactose.

Properties of Bases

Bases release a hydroxide ion into water solution. (Or, in the Lowry - Brønsted model, cause a hydroxide ion to be released into water solution by accepting a hydrogen ion in water.)

Bases neutralize acids in a neutralization reaction.

Bases denature protein. This accounts for the "slippery" feeling on hands when exposed to base. Strong bases that dissolve in water well, such as sodium or potassium lye are very dangerous because a great amount of the structural material of human beings is made of protein. Serious damage to flesh can be avoided by careful use of strong bases.

Bases turn red litmus to blue. This is not to say that litmus is the only acid - base indicator, but that it is likely the oldest one.

Bases taste bitter. There are very few food materials that are alkaline, but those that are taste bitter. It is even more important that care be taken in tasting bases; NO SCHOOL PERMITS TASTING OF LAB CHEMICALS. Tasting of bases is more dangerous than tasting acids due to the property of stronger bases to denature protein.

For the following acids, show how the acid ionizes in water to release the hydrogen ion and then show how it reacts with water to produce the hydronium ion.

1) $HBr \rightarrow$

$HBr + H_2O \rightarrow$

2) $HNO_3 \rightarrow$

$HNO_3 + H_2O \rightarrow$

3) $H_2SO_4 \rightarrow$

$H_2SO_4 + H_2O \rightarrow$

4) $CH_3COOH \rightarrow$

For the following bases, show how the base ionizes in water to release the hydroxide ion.

5) $NaOH \rightarrow$

6) $KOH \rightarrow$

7) $Ca(OH)_2 \rightarrow$

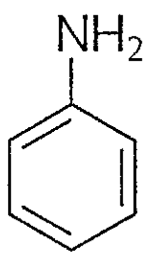
For the following bases, show how the base acts as a proton acceptor to produce the hydroxide ion when dissolved in water.

8) $NH_3 + H_2O \rightarrow$

9) $CH_3NH_2 + H_2O \rightarrow$

Use the following information to answer questions 10 through 13

Aniline, phenylamine or **aminobenzene** is an organic compound with the formula $C_6H_5NH_2$. Consisting of a phenyl group attached to an amino group, aniline is the prototypical aromatic amine. Being a precursor to many industrial chemicals, its main use is in the manufacture of precursors to polyurethane. Polyurethane is a low-density flexible foam used in upholstery, bedding, and automotive and truck seating

10) 

$+ H_2O \rightarrow$

11) Calculate aniline's gram formula mass. ____________g/mol

12) In terms of functional groups, describe why the passage classifies aniline as an amine.

13) In the space below give the structural formula for 3-choloroaniline.

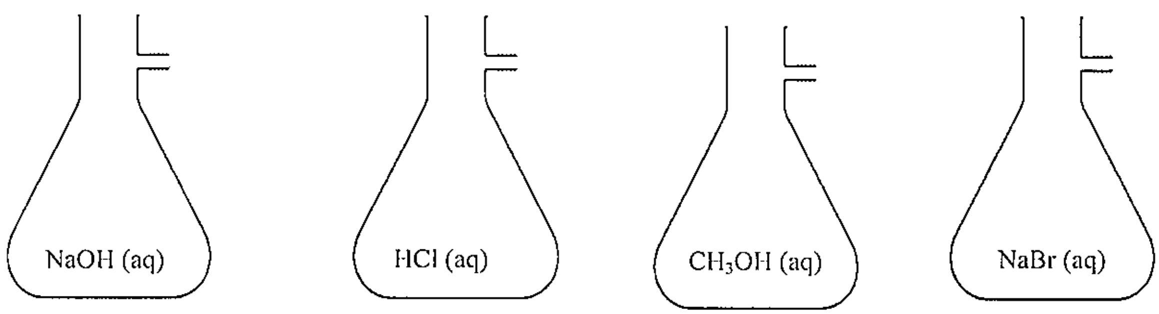
Questions:

1) Which of the following substances can turn litmus red? Explain your choice.
(1) NaCl
(2) HF
(3) CH_3OH
(4) KOH

2) Which of the following substances can turn litmus blue? Explain your choice.
(1) CH_3COOH
(2) C_2H_5OH
(3) LiOH
(4) HCl

3) Another property of both acids and bases is their ability to act as an electrolyte. Describe why acids and bases both can act as electrolytes.

Reflection: Answer the following questions based on the 4 flasks which each contain an aqueous solution.



A) Which flask(s) contains an H_3O^+ ions? ________

B) Which flask(s) contains a $OH^-(aq)$ ions? _________

C) Which flask(s) contain an electrolyte? _________

D) Which two flasks when mixed will neutralize? ____________

CONJUGATE ACID-BASE PAIRS

Name ____________

In the exercise, Bronsted-Lowry Acids and Bases, it was shown that after an acid has give up its proton, it is capable of getting back that proton and acting as a base. Conjugate base is what is left after an acid gives up a proton. The stronger the acid, the weaker the conjugate base. The weaker the acid, the stronger the conjugate base.

Fill in the blanks in the table below.

Conjugate Pairs

	ACID	BASE	EQUATION
1.	H_2SO_4	HSO_4^-	$H_2SO_4 \leftrightarrow H^+ + HSO_4^-$
2.	H_3PO_4		
3.		F^-	
4.		NO_3^-	
5.	$H_2PO_4^-$		
6.	H_2O		
7.		SO_4^{-2}	
8.	HPO_4^{-2}		
9.	NH_4^+		
10.		H_2O	

Which is a stronger base, HSO_4^- or $H_2PO_4^-$? ____________

Which is a weaker base, Cl^- or NO_2^-? ____________

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Predicting Salt Formation

Complete the following table by predicting the formula for the salt formed from each acid–base combination.

	NaOH	$Ca(OH)_2$	NH_4OH
HCl			
HNO_3			
H_2SO_4			
H_3PO_4			
$HC_2H_3O_2$			
H_2CO_3			

In the table below, list the correct name for each salt formed.

	NaOH	$Ca(OH)_2$	NH_4OH
HCl			
HNO_3			
H_2SO_4			
H_3PO_4			
$HC_2H_3O_2$			
H_2CO_3			

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Name ______________________________ Class______ Date__________

Activity 7-6
The pH Scale

The pH scale was developed to provide a convenient method of describing the concentration of hydrogen ions in aqueous solution, particularly dilute solutions.

1. What is the mathematically stated definition of pH? ______________________________

____

____

2. What values on the pH scale correspond to:

   a. The acid range? ______________________________

   b. Neutrality? ______________________________

   c. The basic range? ______________________________

3. Complete the following table showing the pH value for each $[H_3O^+]$ given.

$[H_3O^+]$	pH	$[H_3O^+]$	pH
0.0010		1.0×10^{-7}	
0.0100		1.0×10^{-9}	
1.0×10^{-4}		1.0×10^{-13}	

Experiments show that in pure water

$$[H^+] = [OH^-] = 1.0 \times 10^{-7}$$

Experiments also show that for any aqueous solution at 25°C, the ion-product, K_w, is equal to a constant value:

$$K_w = [H^+] \times [OH^-] = 1.0 \times 10^{-14}$$

A description of alkaline properties, pOH, can then be defined as $-\log\,[OH^-]$. From the equations above, it can be seen that

$$pH + pOH = 14$$

Complete the following table by finding the missing values.

	pH	$[H_3O^+]$	pOH	$[OH^-]$
4.			2.0	
5.		1.0×10^{-3}		
6.				1.0×10^{-4}
7.	8.0			
8.	9.0			
9.			10.0	
10.				1.0×10^{-5}

pH AND pOH

Name ______________________

The pH of a solution indicates how acidic or basic that solution is.

pH range of 0 - 7 acidic
7 neutral
7-14 basic

Since $[H^+][OH^-] = 10^{-14}$ at 25° C, if $[H^+]$ is known, the $[OH^-]$ can be calculated and vice versa.

$pH = -\log[H^+]$ So if $[H^+] = 10^{-6}$ M, pH = 6.

$pOH = -\log[OH^-]$ So if $[OH^-] = 10^{-8}$ M, pOH = 8.

Together, pH + pOH = 14.

Complete the following chart.

	$[H^+]$	pH	$[OH^-]$	pOH	Acidic or Basic
1.	10^{-5} M	5	10^{-9} M	9	Acidic
2.		7			
3.			10^{-4} M		
4.	10^{-2} M				
5.				11	
6.		12			
7.			10^{-5} M		
8.	10^{-11} M				
9.				13	
10.		6			

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Name ________________

pH AND pOH CONTINUED

Calculate the pH of the solutions below.

1. 0.01 M HCl

2. 0.0010 M $NaOH$

3. 0.050 M $Ca(OH)_2$

4. 0.030 M HBr

5. 0.150 M KOH

6. 2.0 M $HC_2H_3O_2$ (Assume 5.0% dissociation.)

7. 3.0 M HF (Assume 10.0% dissociation.)

8. 0.50 M HNO_3

9. 2.50 M NH_4OH (Assume 5.00% dissociation.)

10. 5.0 M HNO_2 (Assume 1.0% dissociation.)

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 Name ____________

 Date ____________ Period ______

Calculating pH

pH is defined as the negative logarithm of the hydronium ion concentration ($pH = -\log[H_3O^+]$). For neutral substances, such as water, the hydronium ion concentration is 10^{-7} *M*, and the pH is 7, because $-\log(10^{-7}) = 7$. In this case, the relationship between the exponent for the hydronium ion concentration and pH is straight forward. For less obvious examples, use a calculator. The pH of a solution with a hydronium ion concentration of 2.45×10^{-10} *M* is 9.61 because $-\log(2.45 \times 10^{-10}) = 9.61$. Check it! By the way, it is clear that since the hydronium ion concentration is between 10^{-9} *M* and 10^{-10} *M*, the pH is between 9 and 10.

pOH, on the other hand, is the negative logarithm of the hydroxide ion concentration ($pOH = -\log[OH^-]$). The equilibrium constant for water, K_w, is 10^{-14} ($K_w = [H_3O^+][OH^-] = 10^{-14}$), so pH + pOH = 14. As a result, it is possible to determine the pH if the hydroxide ion concentration is known (pH = 14 – pOH).

Sample Problem

What is the pH of a solution with a hydroxide ion concentration of 1.45×10^{-9} *M*?

- $pOH = -\log[OH^-] = -\log(1.45 \times 10^{-9}) = 8.84$
- pH = 14 – pOH = 5.16

Converting from pH to hydronium ion concentration or from pOH to hydroxide ion concentration is a matter of doing an antilog, again using a calculator. If the pH is 7.3, then $7.3 = -\log[H_3O^+]$. The hydronium ion concentration is 5×10^{-8} *M*. Again, you should be able to estimate that it is between 10^{-7} *M* and 10^{-8} *M*, because the pH is between 7 and 8.

pHs can also be calculated from the acid or base concentration. First consider strong acids and bases. Strong acids include HCl, HBr, HI, H_2SO_4, HNO_3, and $HClO_4$. Strong bases are hydroxides of group 1 and 2 metals. To calculate the pH of a strong acids or strong bases, assume the ions are 100 percent separated. This means, for example, that 0.15 *M* HCl has a hydronium ion concentration of 0.15 *M*, and a pH of 0.82. A solution of 0.010 *M* $Ca(OH)_2$ has a hydroxide ion concentration of 0.020 *M* because each mole of $Ca(OH)_2$ dissociates into 1 mol of calcium ions and 2 mol of hydroxide ions. As a result, the pOH is 1.7, and the pH is 12.3. Check these calculations!

The pH of weak acids and bases is a bit more complicated. It requires use of the equilibrium expression. For weak acids, write a balanced equation for the ionization of the acid, write the equilibrium expression, and write the algebraic expression substituting known values and variables for unknowns. Keep in mind that the balanced equation provides the mole ratios of the ions which are all integral multiples of the same unknown, *x*. Because the equilibrium constant is small, for weak acids, the change in the concentration of the acid when it ionizes is negligible and can be ignored. Weak bases work the same way. Find pOH instead of pH. Then subtract (pH = 14 – pOH).

Sample Problem

What is the pH of 0.100 M HNO_2? ($k_a = 7.2 \times 10^{-4}$)

- Write a balanced equation for the ionization of the acid.
  $HNO_2 = H^+ + NO_2^-$
- Write the equilibrium expression
  $$k_a = \frac{[H^+][NO_2^-]}{[HNO_2]}$$
- Write the algebraic expression substituting known values and variables for unknowns.
  $$7.2 \times 10^{-4} = \frac{(x)(x)}{(0.100)}$$
- Solve the expression for $[H^+]$ (or $[H_3O^+]$)
  $x^2 = 7.2 \times 10^{-5}$ $x = 8.5 \times 10^{-3}$
- Calculate pH
  $pH = -\log[H_3O^+] = -\log(8.5 \times 10^{-3}) = 2.1$

The pH of buffers is calculated using the *Henderson-Hasselbalch Equation* which says $pH = pK_a + \log([A^-]/[HA])$ where $pK_a = -\log K_a$

Sample Problem

What is the pH of a solution with 0.1 *M* hydrofluoric acid (HF) and 0.01 sodium fluoride? ($K_a = 6.6 \times 10^{-4}$)

- $pH = -\log(6.6 \times 10^{-4}) + \log((0.01)/(0.1\ M))$
- $pH = 3.2 + \log(10^{-1}) = 3.2 + (-1) = 2.2$

(CONTINUE ON THE NEXT PAGE)

Answer the following questions based on your reading and your knowledge of chemistry.

1. Find the pH for each of the following:

   a. $[H_3O^+] = 0.0315\ M$

   b. $[OH^-] = 0.0067\ M$

   c. $0.0025\ M\ HNO_3$

   d. $0.00012\ M\ Ba(OH)_2$

   e. $0.0325\ M\ HIO_3$ ($K_a = 1.6 \times 10^{-1}$)

   f. $3.0\ M\ NH_3$ ($K_b = 1.8 \times 10^{-5}$)

2. Find the hydronium ion concentration for each of the following:

   a. A base with a pH of 8.2

   b. A base with a pOH of 3.4

3. What is the pH of a buffered solution of $0.3\ M\ HCH_3COO$ and $0.02\ M\ NaCH_3COO$? ($K_a = 1.8 \times 10^{-5}$)

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NAME:_________________________ DATE:________SECTION_______LAB_______

pHAT

Acid rain is a problem in industrialized countries around the world. Oxides of sulfur and nitrogen are formed when various fuels are burned. These oxides dissolve in atmospheric water droplets that fall to earth as acid rain or acid snow.

While normal rain has a pH between 5.0 and 6.0 due to the presence of dissolved carbon dioxide, acid rain often has a pH of 4.0 or lower. This level of acidity can damage trees and plants, leach minerals from the soil, and cause the death of aquatic animals and plants.

If the pH of the soil is too low, then quicklime, CaO, can be added to the soil to increase the pH. Quicklime produces calcium hydroxide when it dissolves in water.

1) The reading passage says acid rain could have a pH of 4.0. How much more acidic is it than neutral water?

2) When carbon dioxide dissolves in water carbonic acid is formed. Give the formula for carbonic acid.

3) A sample of wet soil has a pH of 5.0. When the soil is treated with quicklime the H^+ ion concentration is 1/100th of the original H^+ concentration. What is the new pH of the soil? How much did the OH^- concentration go up by?

4) Give the formula for Calcium Hydroxide.

5) What color would bromthymol blue be in a sample of the 4.0 pH rain water?

A student was studying the pH differences in samples from two waste water streams. The student measured a pH of 2 in stream *A* and a pH of 5 in waste water stream *B*.

6) Compare the hydronium ion concentration in stream *A* to the hydronium ion concentration in stream *B*.

7) What color is methyl orange in a sample from stream *A*? What color is a sample from stream *B*?

ISA

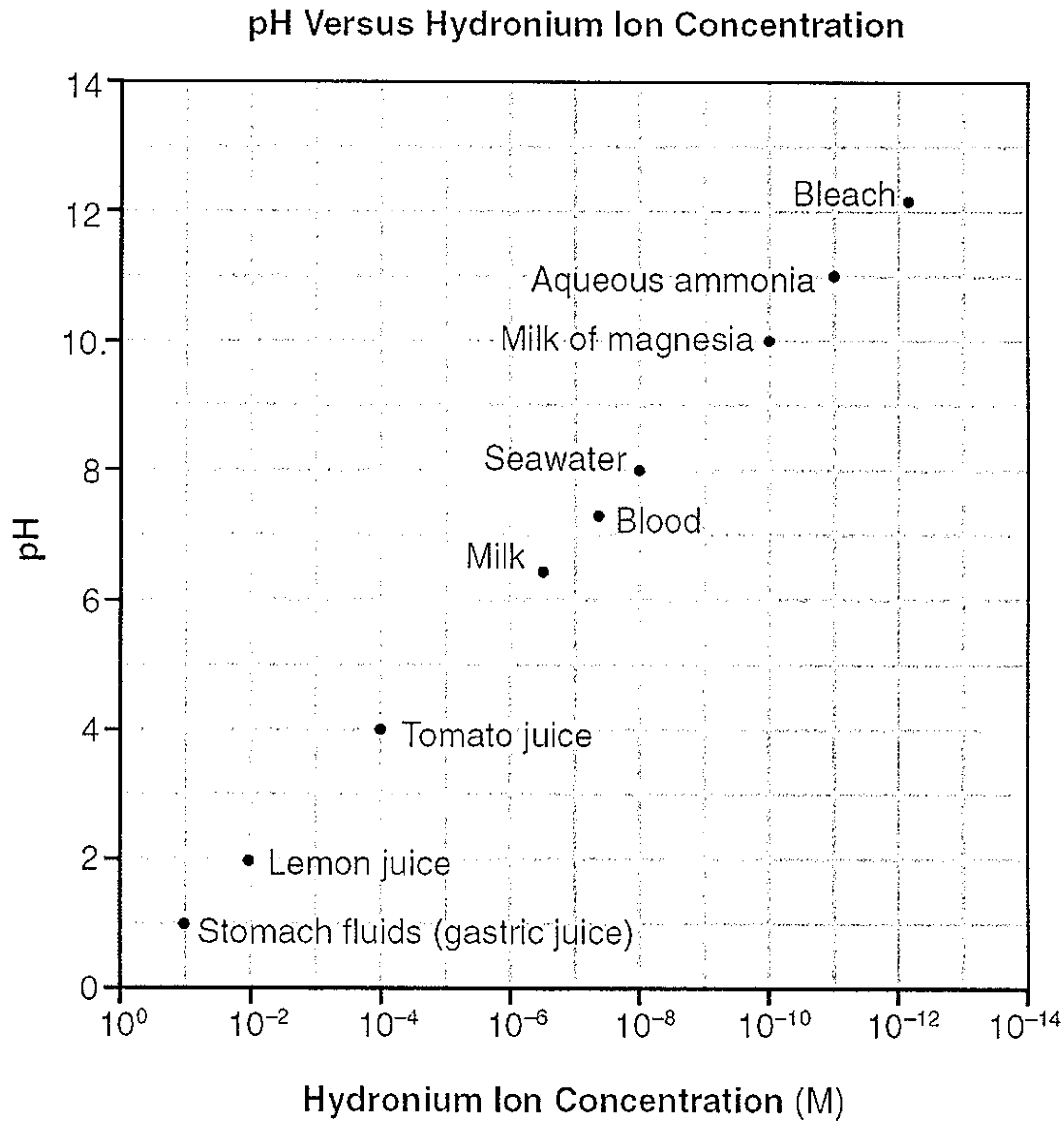
Most lakes are acidic in nature. Some lakes in New York State are basic due to being feed from mineral rich ground water. The pH range for the basic lakes in NYS is from 8.0 to 11.0.

8) How much more basic is a lake with pH of 11 than a neutral pool of water.

9) What color would phenolphthalein be in a sample of the pH 11 lake water?

10) What would the pH of the pH 11 lake would be if the H_3O^+ ion concentration increased by 10 fold? How much would the OH^- concentration change by?

Base your answers to the following questions on the graph below. The graph shows the relationship between pH value and hydronium ion concentration for common aqueous solutions and mixtures.



11) What is the hydronium concentration of lemon juice? ___________M

12) What is the pH of milk? __________

13) What color is methyl orange when it is added to stomach fluids? _________

14) What color is phenolphthalein when added to aqueous ammonia? __________

15) Which substance is 1000 times more acidic than tomato juice? ___________

16) How many more times acidic is lemon juice than tomato juice? ___________

17) How many more times basic is milk of magnesia than seawater? __________

18) Describe the blood's acidity in terms of the pH scale.

Reflection:

Describe the relationship between hydronium ion concentration and pH.

Going Further:

$pH = -\log[H_3O^{+1}]$

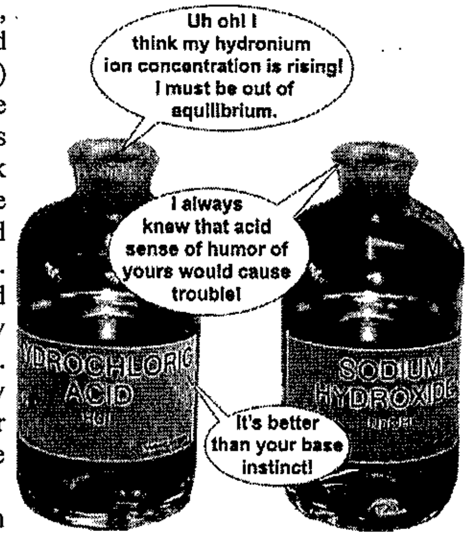
Determine the pH of a solution with a hydronium ion concentration of 3.7×10^{-3} M.
Determine the hydronium ion concentration of a solution with a pH of 10.8.

Name ______________________

Date ______________ Period ______

Acid-Base Equilibria

The ionization of acids and dissociation of bases are reversible reactions. As such, they can be described by equilibrium expressions. The general reaction for an acid dissolved in water is as follows: $HA(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + A^-(aq)$. $HA(aq)$ and $A^-(aq)$ are conjugate acid-base pairs, while $H_3O^+(aq)$ and $H_2O(\ell)$ are conjugate acid-base pairs. If A^-(aq) is a much stronger base than $H_2O(\ell)$, then equilibrium lies to the left and most of the acid will be in the form HA(aq), making HA(aq) a weak acid. If $H_2O(\ell)$ is a much stronger base than A^-(aq), then equilibrium lies to the right and the acid will be largely ionized, making HA(aq) a strong acid. The acid ionization constant (K_a) comes from the equilibrium expression for the reaction. For acids, the higher the ionization constant is, the stronger the acid is. If the acid is ionized completely, [HA] = 0 and K_a is infinite. Ionization constants for very strong acids cannot be calculated. In that case, K_a is listed as "very large." Ionization constants for acids that do NOT ionize completely can be calculated.



Acid-Base banter

Equilibrium Constants and Expressions

Acids

$$K_a = \frac{[H^+][A^-]}{[HA]} = \frac{[H_3O^+][A^-]}{[HA]}$$

Bases

$$K_b = \frac{[BH^+][OH^-]}{[B]}$$

Water

$$K_w = [H^+][OH^-] = [H_3O^+][OH^-]$$

The general reaction between a base and water is $B(aq) + H_2O(\ell) \rightleftharpoons BH^+(aq) + OH^-(aq)$. The equilibrium constant for the general reaction refers to the reaction of a base with water to form the conjugate acid and the hydroxide ion.

The ionization equation of water is the reversible reaction $H_2O(\ell) \rightleftharpoons H^+(aq) + OH^-(aq)$. At 25°C, $[H^+] = 1 \times 10^{-7}$ mol/L and $[H^+] = [OH^-]$ in pure water. $K_w = [H^+][OH^-] = (1 \times 10^{-7}\ \text{mol/L})(1 \times 10^{-7}\ \text{mol/L}) = 1 \times 10^{-14}\ \text{mol}^2/\text{L}^2$. The significance of this is, in any aqueous solution, no matter what else it contains, at 25°C, the product of $[OH^-]$ and $[H^+]$ is always 1.0×10^{-14}, resulting in three possible situations: [1] a neutral solution where $[H^+] = [OH^-]$; [2] an acidic solution where $[H^+] > [OH^-]$; and [3] a basic solution where $[H^+] < [OH^-]$. It is possible to calculate the concentration of hydronium or hydroxide when either one or the other ion's concentration is known.

$$[H^+] = \frac{1 \times 10^{-14}}{[OH^-]} \quad and \quad [OH^-] = \frac{1 \times 10^{-14}}{[H^+]}$$

Answer the following questions based on your understanding of the equilibria involved.

1. For the following strong acids and bases (100 percent ionized or dissociated), what are the hydronium and hydroxide ion concentrations?

   a. 3.00×10^{-4} *M* HNO_3 $[H_3O^+] =$ $[OH^-] =$

   b. 2.50×10^{-2} *M* $Ca(OH)_2$ $[H_3O^+] =$ $[OH^-] =$

   c. 4.00×10^{-3} *M* NaOH $[H_3O^+] =$ $[OH^-] =$

(CONTINUE ON THE NEXT PAGE)

2. The equilibrium constant for nitrous acid (HNO_2), $K_a = 4.6 \times 10^{-4}$.

   a. Write the equation for the ionization of the acid in water. Identify the conjugate acid base pairs.

   b. What is the hydronium ion concentration if $[HNO_2] = 3.00\ M$ and $[NO_2^-] = 0.037\ M$?

   c. What is the hydroxide ion concentration based on the above concentrations?

3. The equilibrium constant for acetic acid (HCH_3COO), $K_a = 1.8 \times 10^{-5}$.

   a. Write the equation for the ionization of the acid in water. Identify the conjugate acid base pairs.

   b. What is the hydronium ion concentration if $[HCH_3COO] = 2.50\ M$ and $[CH_3COO^-] = 0.027\ M$?

   c. What is the hydroxide ion concentration based on the above concentrations?

4. The equilibrium constant for hydrofluoric acid (HF), $K_a = 3.5 \times 10^{-4}$.

   a. Write the equation for the ionization of the acid in water. Identify the conjugate acid base pairs.

   b. What are the relative strengths of the conjugate acids and bases. Justify your response. ____________________

5. The equilibrium constants for hydrochloric acid and nitric acid are listed as "very large," instead of having a numerical value. Why is this so? ____________________

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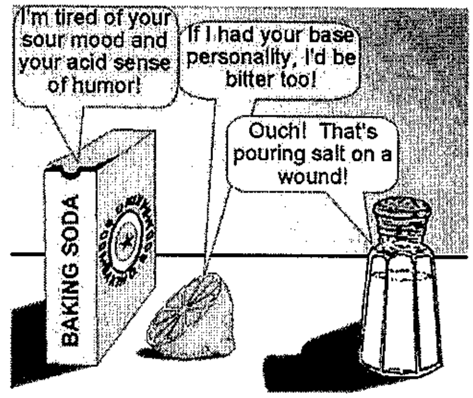
Chemistry: Form WS9.2.1A

ACIDS, BASES, AND SALTS

Name ______________________

Date ______________ Period ____

Acid, Base, or Salt?



Enmity between hydronium and hydroxide ions

The properties of acids and bases are caused by the ions they form in water. Due to the presence of ions, aqueous solutions of both acids and bases are electrolytes. Acids and bases react with each other to form a salt and water. The reaction is a double replacemnt reaction known as neutralization. (*Example:* $HCl + NaOH \rightarrow NaCl + H_2O$) Since acid characteristics are caused by hydronium ions and base characteristics are caused by hydroxide ions, there are some differences as well.

Acids increase the hydronium ion concentration of water. Hydronium ion concentration is measured on the pH (**P**ower of **H**ydronium) scale. Acids have a pH below 7. They also taste sour, the taste of hydronium. Since acids are polar molecules with metallic hydrogen, they react with active metals to release hydrogen. This single replacement reaction is responsible for the fact that acids corrode metals. Acids can be used to clean metals.

Bases, on the other hand, increase the hydroxide ion concentration of water and reduce the hydronium ion concentration in water. As a result, they have a pH above 7. Hydroxide ions taste bitter. Bases don't react with metals, but they are not so kind to skin. Bases feel slippery because they dissolve skin. (Dissolved skin makes a great lubricant.) Substances that dissolve skin are called caustic. Bases can be used to unclog drains or to make soap.

Aqueous solutions of acids and bases look identical. Indicators, substances that react with acids or bases to show a definite color change, are used to distinguish between them. See the table to the right.

Salts are ionic compounds formed during the neutralization reaction between acids and bases. Salts tend not to have the characteristics of either acids or bases, because they are generally neutral like water. Salts do dissolve in water, however, to form electrolyte solutions.

Indicator	Color in	
	Acid	Base
litmus	red	blue
phenolphthalein	colorless	pink
bromthymol blue	yellow	blue
methyl orange	red	yellow

Fill in the table below based on your reading above and on your knowledge of chemistry.

Characteristic	Acids	Bases
Conductivity		
pH		
Taste		
Indicators		
Corrosive / Caustic		
Neutralization		

Continue ☞

Write the appropriate number on the answer space next to each statement to indicate whether it describes (1) AN ACID, (2) A BASE, (3) A SALT, or (4) NONE OF THESE. If more than one choice is described by a statement, write more than one number on the answer space.

__________ **1.** Has a pH less than 7.

__________ **2.** Formed during a neutralization reaction.

__________ **3.** Ionic compound.

__________ **4.** Polar covalent compound.

__________ **5.** Feels slippery to the touch.

__________ **6.** Tastes bitter.

__________ **7.** Water.

__________ **8.** Increases the hydronium ion concentration of water.

__________ **9.** Contains hydroxide ions.

__________ **10.** Ionizes in water.

__________ **11.** Reacts with active metals to release hydrogen gas.

__________ **12.** C_2H_5OH [*HINT:* What kind of bonds are in this compound?]

__________ **13.** CH_3COOH [*HINT:* Which element is the most metallic in this compound?]

__________ **14.** Conducts electricity in water solution.

__________ **15.** Turns litmus red.

__________ **16.** Turns phenolphthalein red.

__________ **17.** Used in the production of soap.

__________ **18.** Found in vinegar.

__________ **19.** Water solution of carbon dioxide [$H_2O(\ell) + CO_2(g) \rightarrow H_2CO_3(aq)$].

__________ **20.** Can be neutralized to form a salt and water.

__________ **21.** Water solution of ammonia [$H_2O(\ell) + NH_3(g) \rightarrow NH_4OH(aq)$]

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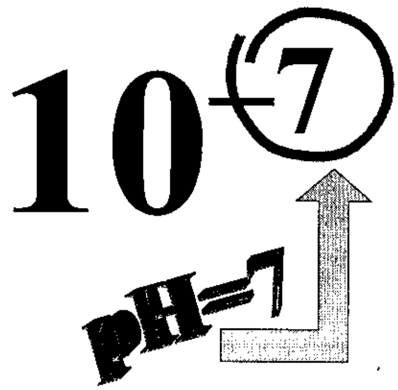
Name ______________________

Date ________________ Period _____

Interpreting pH

The term "pH" means *power of hydrogen*. It refers to hydrogen released by acids when they ionize to form hydronium ions.

Example: $HCl(g) + H_2O(\ell) \rightarrow Cl^-(aq) + H_3O^+(aq)$



The more hydrogen a substance releases, the more hydronium it forms, and the stronger an acid it is. Substances that form the most hydronium ions have the greatest power of hydrogen. Strangely enough, however, the stronger the acid is and the greater its power of hydrogen, the lower the pH is.

Pure water has a hydronium ion concentration $[H_3O]$ of 10^{-7} M. The negative exponent tells the pH. When $[H_3O] = 10^{-7}$ M, pH = 7. When $[H_3O] = 10^{-4}$, pH = 4. As $[H_3O^+]$ increases, the negative exponent decreases and pH goes down. In pure water, the hydroxide ion concentration $[OH^-]$ is also 10^{-7} M, because the concentration of hydroxide and hydronium are equal. $[OH^-] = [H_3O^+]$.

Remember, as $[H_3O^+]$ increases, $[OH^-]$ decreases. The product of the two is constant. $[H_3O^+][OH^-]=10^{-14}$. When the concentration of each is 10^{-7} M, this is so because $10^{-7} \times 10^{-7} = 10^{-14}$. If $[H_3O^+]$ increases from 10^{-7} M to 10^{-6} M, then $[OH^-]$ must decrease from 10^{-7} M to 10^{-8} M so, again, the product is 10^{-14}. ($10^{-6} \times 10^{-8} = 10^{-14}$) Notice the negative sum of the exponents is always 14. If $[OH^-] = 10^{-4}$ M, then $[H_3O^+] = 10^{-10}$ M, and the pH is 10.

Answer the questions below based on the reading above and on your knowledge of mathematics and chemistry.

1. Which is a higher concentration, 10^{-9} M or 10^{-8}M? Explain. ______________________________

____

2. What is the pH in each of the following cases:

a. $[H_3O^+] = 10^{-12}$ M? _______ d. $[H_3O^+] = 10^{-5}$ M? _______ g. $[H_3O^+] = 10^{-6}$ M? _______

b. $[H_3O^+] = 10^{-2}$ M? _______ e. $[H_3O^+] = 10^{-14}$ M? _______ h. $[H_3O^+] = 10^{-9}$ M? _______

c. $[H_3O^+] = 10^{-7}$ M? _______ f. $[H_3O^+] = 10^{-3}$ M? _______ i. $[H_3O^+] = 10^{-13}$ M? _______

3. What is the **concentration of hydronium** in each of the following cases:

a. $[OH^-] = 10^{-12}$ M? _______ d. $[OH^-] = 10^{-5}$ M? _______ g. $[OH^-] = 10^{-6}$ M? _______

b. $[OH^-] = 10^{-2}$ M? _______ e. $[OH^-] = 10^{-14}$ M? _______ h. $[OH^-] = 10^{-9}$ M? _______

c. $[OH^-] = 10^{-7}$ M? _______ f. $[OH^-] = 10^{-3}$ M? _______ i. $[OH^-] = 10^{-13}$ M? _______

4. What is the pH in each of the following cases:

a. $[OH^-] = 10^{-12}$ M? _______ d. $[OH^-] = 10^{-5}$ M? _______ g. $[OH^-] = 10^{-6}$ M? _______

b. $[OH^-] = 10^{-2}$ M? _______ e. $[OH^-] = 10^{-14}$ M? _______ h. $[OH^-] = 10^{-9}$ M? _______

c. $[OH^-] = 10^{-7}$ M? _______ f. $[OH^-] = 10^{-3}$ M? _______ i. $[OH^-] = 10^{-13}$ M? _______

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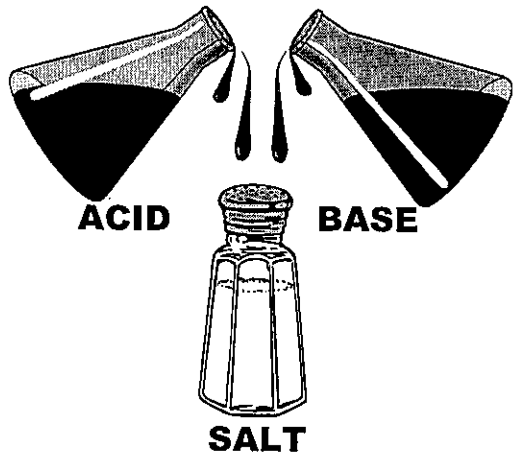
Chemistry: Form WS9.4.1A Name ____________

ACIDS, BASES, AND SALTS Date ____________ Period ______

Neutralization Reactions



Acids and bases are opposites, so it makes sense that when they react together, the result is neutral. What happens during the chemical reaction that makes everything neutral? Technically, every acid base reaction is a double replacement reaction [$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(\ell)$]. Actually, it is a little more involved. Recall that acids ionize in water to produce hydronium ions [$HCl(g) + H_2O(\ell) \rightarrow H_3O^+(aq) + Cl^-(aq)$]. Bases, on the other hand, dissociate in water to release hydroxide ions [$NaOH(s) + H_2O(\ell) \rightarrow Na^+(aq) + OH^-(aq) + H_2O(\ell)$]. This means the double replacement reaction between HCl(*aq*) and NaOH(*aq*) really looks as follows:

$$H_3O^+(aq) + Cl^-(aq) + Na^+(aq) + OH^-(aq) \rightarrow 2H_2O + NaCl(aq)$$

Salt (NaCl) is an ionic compound. When it is placed in water, it dissociates [$NaCl(s) + H_2O(\ell) \rightarrow Na^+(aq) + Cl^-(aq)$]. This means, the complete reaction is $H_3O^+(aq) + Cl^-(aq) + Na^+(aq) + OH^-(aq) \rightarrow 2H_2O(\ell) + Na^+(aq) + Cl^-(aq)$. The highlighted ions are exactly the same on both the product and reactant side of the equation. Because these ions did not actually participate in the reaction, they are called *spectator ions*. What is left, $H_3O^+(aq) + OH^-(aq) \rightarrow 2H_2O(\ell)$, is the net reaction. Since the final product is water, the result is neutral.

Answer the questions below based on the reading above, and on your knowledge of chemistry.

1. Complete and balance each of the acid base neutralizations below. Identify the spectator ions.
   a. ___ H_2SO_4 + ___ $Mg(OH)_2 \rightarrow$ ____________
   b. ___ HNO_3 + ___ $Al(OH)_3 \rightarrow$ ____________
   c. ___ H_3PO_4 + ___ $Ca(OH)_2 \rightarrow$ ____________
   d. ___ HI + ___ KOH $\rightarrow$ ____________
   e. ___ HBr + ___ $Ba(OH)_2 \rightarrow$ ____________
2. How are the net reactions for each of the examples above similar? ____________
3. The definition of neutralization is a reaction between an acid and a base to produce a salt and water. Where does the salt come from in the neutralization reaction? ____________
4. Where does the water come from in a neutralization reaction? ____________
5. What occurs during a neutralization reaction that causes the end product to be neutral? ____________

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Name ______________________

Date ______________ Period ______

Titration

Aim

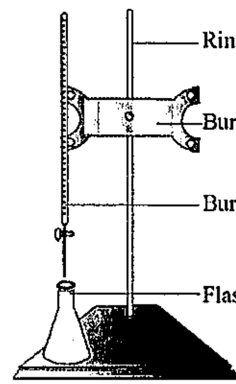
- describe neutralization and titration

Notes

★ Definition - method of determining the concentration of an acid or base by neutralizing it with a solution of known concentration

★ Procedure

- ☆ Place a measured amount of acid or base of unknown concentration in a flask and add two drops of phenolphthalein
- ☆ Use a ring stand with a buret clamp and a buret as shown in the diagram to the right. Fill the buret with a standard solution (an acid or base of known concentration)
  - ★ the buret is used to dispense the standard solution and measure the amount dispensed
- ☆ Hold the flask containing the acid or base of unknown concentration under the buret. Run the standard solution slowly into the flask, mixing occasionally by swirling. When the color begins to change on contact with the standard solution, add the standard solution one drop at a time until one final drop causes a complete and permanent color change.
- ☆ Determine the volume of standard solution used
- ☆ Calculate the concentration of the unknown solution using the data you gathered and the equation below



★ Calculation

$$M_a \times V_a = M_b \times V_b$$

★ Diprotic and triprotic acids/dihydroxy and trihydroxy bases

- ☆ During a neutralization reaction each hydrogen ion (hydronium ion) is neutralized by one hydroxide ion
- ☆ Therefore, during a titration, the concentration of hydrogen ions and hydroxide ions is more important than the concentration of the acid or base, so it is necessary to determine the effective concentration due to these ions
- ☆ Effective concentration
  - ★ Polyprotic acids
    - ★ Sulfuric acid (H_2SO_4) is diprotic: It forms 2 *mol* of hydrogen ions (protons) per *mol* of acid
      $H_2SO_4(aq) \rightarrow 2H^+(aq) + SO_4^{2-}(aq)$
    - ★ The effective concentration of 0.2M H_2SO_4 is 0.4M in titration problems

$$M_{AE} = M_A \times n_H$$

M_{AE} = effective concentration of acid
M_A = concentration of acid
n_H = number of hydrogens

NOTE:

$$M_A = \frac{M_{AE}}{n_H}$$

  - ★ Polyhydroxy bases
    - ★ Calcium hydroxide [$Ca(OH)_2$] is dihydroxy: It forms 2 *mol* of hydroxide ions per *mol* of base
      $Ca(OH)_2(aq) \rightarrow Ca^{2+}(aq) + 2OH^-(aq)$
    - ★ The effective concentration of 0.25M H_2SO_4 is 0.5M in titration problems

$$M_{BE} = M_B \times n_{OH}$$

M_{BE} = effective concentration of base
M_B = concentration of base
n_{OH} = number of hydroxides

NOTE:

$$M_B = \frac{M_{BE}}{n_{OH}}$$

★ Use the effective concentration for titration calculations and actual concentration for answers

Sample Problem 1

Determine the concentration of H_3PO_4 if a 90. mL sample is neutralized by 30. mL of 0.9 M $Ca(OH)_2$.

Step 1: Determine the effective concentration of the known substance

$0.9\ M \times 2 = 1.8\ M$

Step 2: Substitute values into the equation and solve for the unknown

$M_A \times V_A = M_B \times V_B$

$M_A(90.\ mL) = (1.8\ M)(30.\ mL)$

$M_A = 0.6\ M$

Step 3: Determine the actual concentration of the unknown from the effective concentration

$$M_A = \frac{M_{AE}}{n_H} = \frac{0.6M}{3} = 0.2M$$

Sample Problem 2

How much 3.0 M H_2SO_4 is needed to neutralize 50. mL of 1.2 M $Al(OH)_3$?

Step 1: Determine the effective concentrations of the substances

$M_A = 3.0\ M \times 2 = 6.0\ M$

$M_B = 1.2\ M \times 3 = 3.6\ M$

Step 2: Substitute values into the equation and solve for the unknown

$M_A \times V_A = M_B \times V_B$

$(6.0\ M)\ V_A = (3.6\ M)(50.\ mL)$

$V_A = 30.\ mL$

Answer the questions below by circling the number of the correct response

1. How much 6 M HCl is needed to neutralize 90 mL of 2 M KOH? (1) 30 mL (2) 7.5 mL (3) 270 mL (4) 78 mL

2. What concentration is H_2SO_4 if 10.0 mL of it can be neutralized by 15.0 mL of 2.0 M $Ca(OH)_2$? (1) 3.0 M (2) 12.5 M (3) 1.3 M (4) 10.0 M

3. A technique used to determine the concentration of a base using a standard solution of an acid is known as (1) ionization, (2) neutralization, (3) molarity, (4) titration.

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Name ____________________

Date ______________ Period _____

Titration

Titration is a process that uses a neutralization reaction to determine the concentration of an acid or a base. Concentration, remember, is the mass of the solute per unit volume of solution. Chemists measure concentration in moles per liter or molarity (*M*). For acids and bases that produce the same number of hydrogen and hydroxide ions per mole [HCl and NaOH, H_2SO_4 and $Ca(OH)_2$, or H_3PO_4 and $Al(OH)_3$], the molarity of the acid used in a neutralization times its volume is equal to the molarity of the base used in the neutralization times its volume.

$$M_a \times V_a = M_b \times V_b$$

For acids and bases that do not produce hydrogen ions and hydroxide ions in a 1 to 1 ratio, it is necessary to calculate the effective concentration before applying the formula. See below:

Effective Concentration

$$M_{AE} = M_A \times n_H$$

M_{AE} = effective concentration of acid
M_A = concentration of acid
n_H = number of hydrogens

NOTE: $M_A = \dfrac{M_{AE}}{n_H}$

$$M_{BE} = M_B \times n_{OH}$$

M_{BE} = effective concentration of base
M_B = concentration of base
n_{OH} = number of hydroxides

NOTE: $M_B = \dfrac{M_{BE}}{n_{OH}}$

Sample Problems

Sample Problem 1

What is the concentration of a 30. mL sample of HCl if it can be neutralized by 50. mL of 1.2 M NaOH?

Step 1: Note the ratio of H^+ to OH^- is 1 to 1

Step 2: Substitute values into the equation

$$M_A \times V_A = M_B \times V_B$$
$$M_A(30.\ mL) = (1.2\ M)(50.\ mL)$$

Step 3: Solve for the unknown

$$M_A = \frac{(1.2M)(50.mL)}{(30.mL)} = 2.0M$$

Sample Problem 2

Determine the concentration of H_3PO_4 if a 90. mL sample is neutralized by 30. mL of 0.9 M $Ca(OH)_2$.

Step 1: Determine the effective concentration of the known substance

$$0.9\ M \times 2 = 1.8\ M$$

Step 2: Substitute values into the equation and solve for the unknown

$$M_A \times V_A = M_B \times V_B$$
$$M_A(90.\ mL) = (1.8\ M)(30.\ mL)$$
$$M_A = 0.6\ M$$

Step 3: Determine the actual concentration of the unknown from the effective concentration

$$M_A = \frac{M_{AE}}{n_H} = \frac{0.6M}{3} = 0.2M$$

Sample Problem 3

How much 3.0 M H_2SO_4 is needed to neutralize 50. mL of 1.2 M $Al(OH)_3$?

Step 1: Determine the effective concentrations of the substances

$$M_A = 3.0\ M \times 2 = 6.0\ M$$
$$M_B = 1.2\ M \times 3 = 3.6\ M$$

Step 2: Substitute values into the equation and solve for the unknown

$$M_A \times V_A = M_B \times V_B$$
$$(6.0\ M)\ V_A = (3.6\ M)(50.\ mL)$$
$$V_A = 30.\ mL$$

Continue ☞

Answer the questions below by referring to the examples on the previous page. Write the answer in the answer space to the left of the question.

______ **1.** How much 6.0 M HNO_3 is needed to neutralize 39 mL of 2.0 M KOH?

______ **2.** How much 3.0 M NaOH is needed to neutralize 30. mL of 0.75 M H_2SO_4?

______ **3.** What is the concentration of 20 mL of LiOH if it is neutralized by 60 mL of 4 M HCl?

______ **4.** What is the concentration of 60 mL of H_3PO_4 if it is neutralized by 225 mL of 2 M $Ba(OH)_2$?

______ **5.** How much 2 M HBr is needed to neutralize 380 mL of 0.1 M NH_4OH?

The answers to the questions above are all integers. Each answer stands for a letter of the alphabet. Write the correct letters in the spaces below to find the solution to the riddle.

ANSWERS:	1	2	3	4	5	6	7	8	9	10	11	12	13
LETTERS:	A	B	C	D	E	F	G	H	I	J	K	L	M
ANSWERS:	14	15	16	17	18	19	20	21	22	23	24	25	26
LETTERS:	N	O	P	Q	R	S	T	U	V	W	X	Y	Z

RIDDLE: How many varmints does it take to ruin a chemist's lawn?

SOLUTION: ______ ______ ______ ______ ______
Question 1 | Question 2 | Question 3 | Question 4 | Question 5

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ACID-BASE TITRATION

Name ____________________

To determine the concentration of an acid (or base), we can react it with a base (or acid) of known concentration until it is completely neutralized. This point of exact neutralization, known as the endpoint, is noted by the change in color of the indicator.

We use the following equation:

$$N_A \times V_A = N_B \times V_B$$

where N = normality
V = volume

Solve the problems below.

1. A 25.0 mL sample of HCl was titrated to the endpoint with 15.0 mL of 2.0 N NaOH. What was the normality of the HCl? What was its molarity?

   ____

   ____

2. A 10.0 mL sample of H_2SO_4 was exactly neutralized by 13.5 mL of 1.0 M KOH. What is the molarity of the H_2SO_4? What is the normality?

   ____

   ____

3. How much 1.5 M NaOH is necessary to exactly neutralize 20.0 mL of 2.5 M H_3PO_4?

   ____

4. How much of 0.5 M HNO_3 is necessary to titrate 25.0 mL of 0.05 M $Ca(OH)_2$ solution to the endpoint?

   ____

5. What is the molarity of a NaOH solution if 15.0 mL is exactly neutralized by 7.5 mL of a 0.02 M $HC_2H_3O_2$ solution?

   ____

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Name ______________________________ Class______ Date__________

Activity 7-8
Hydrolysis of Salts

Hydrolysis occurs when certain salts dissolve in water to form solutions that have acidic or basic properties. A rule for predicting the properties of solutions of salts is based upon the concept of strong acids and strong bases in the Arrhenius sense (see Activity 7-1). This rule applies to salts from different combinations of strong and weak acids and bases *except* for those salts formed from a weak acid and a weak base. The table below summarizes the rule.

Salt formed from	Water solution exhibits	Example
strong acid + strong base	no hydrolysis—neutral solution	KCl
strong acid + weak base	hydrolysis to form acidic solution	$Al_2(SO_4)_3$
weak acid + strong base	hydrolysis to form basic solution	Na_2CO_3
weak acid + weak base	(no simple rule is applicable)	$Pb(C_2H_3O_2)_2$

The commonly used strong acids are HCl, HNO_3, and H_2SO_4.
The commonly used strong bases are NaOH, KOH, and (usually) $Ca(OH)_2$.

Examples

KCl	
from strong base KOH	from strong acid HCl

no hydrolysis; neutral solution produced

$Al_2(SO_4)_3$	
from weak base $Al(OH)_3$	from strong acid H_2SO_4

hydrolysis occurs; acidic solution produced

Na_2CO_3	
from strong base NaOH	from weak acid H_2CO_3

hydrolysis occurs; basic solution produced

Predict the hydrolysis effect in a solution of each of the following salts. For each answer, write: *acidic, basic,* or *neutral.*

1. Na_3PO_4 ______________
2. Na_2SO_4 ______________
3. $K_2C_2O_4$ ______________
4. NH_4Cl ______________
5. $FeCl_3$ ______________
6. NH_4NO_3 ______________
7. $Ca(NO_3)_2$ ______________
8. $KC_2H_3O_2$ ______________

What range of pH values is associated with an aqueous solution of each of the following salts? (See Activity 7-6.) For each answer write: >7 (greater than 7), 7, or <7 (less than 7).

9. $NaC_2H_3O_2$ ________
10. $Al(NO_3)_3$ ________
11. NaCl ________
12. $CuSO_4$ ________
13. K_2SO_4 ________
14. K_2CO_3 ________

HYDROLYSIS OF SALTS

Name ____________________

Salt solutions may be acidic, basic or neutral, depending on the original acid and base that formed the salt.

Strong Acid + Strong Base → Neutral Salt
Strong Acid + Weak Base → Acidic Salt
Weak Acid + Strong Base → Basic Salt

A weak acid and a weak base will produce any type of solution depending on the relative strengths of the acid and base involved.

Complete the table below for each of the following salts.

Salt	Parent Acid	Parent Base	Type of Solution
1. KCl			
2. NH_4NO_3			
3. Na_3PO_4			
4. $CaSO_4$			
5. $AlBr_3$			
6. CuI_2			
7. MgF_2			
8. $NaNO_3$			
9. $LiC_2H_3O_2$			
10. $ZnCl_2$			
11. $SrSO_4$			
12. $Ba_3(PO_4)_2$			

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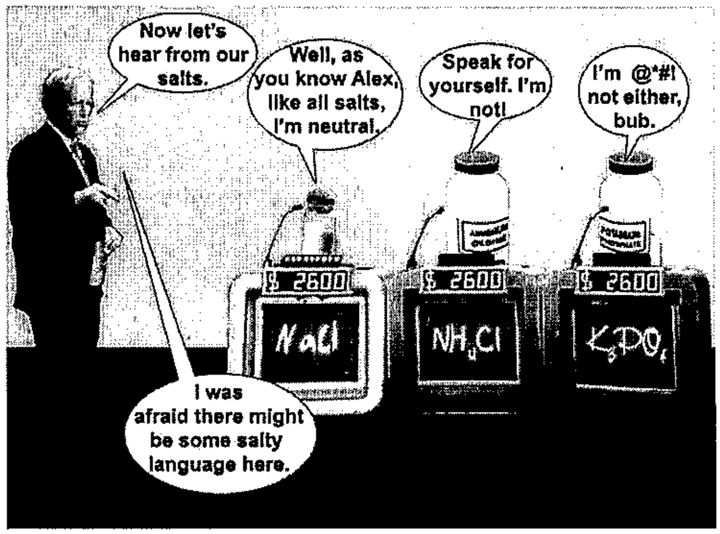
Chemistry: Form WS9.7.1A Name ____________________

ACIDS AND BASES Date ______________ Period _____

Hydrolysis

Hydrolysis is essentially the reverse of neutralization. A salt reacts with water to produce an acid and a base. It happens because there are a small number of hydronium and hydroxide ions in pure water. The metal ions from the salt can combine with hydroxide ions to form a base. Of course, if the base formed is strong, it dissociates back into ions, however, if the base formed is weak, it does not dissociate. The nonmetal ions from the salt can combine with hydronium ions in water to form an acid and water. If the acid formed is strong, it ionizes again, but if the acid formed is weak, it does not ionize. The significance of this reaction is, salts may not be neutral. A salt of a strong acid and a weak base is ACID. The salt dissolves in water to form a strong acid which reionizes releasing hydroniums, but it produces a weak base which does not dissociate so hydroxides are removed from solution. A salt of a weak acid and strong base is a BASE. The salt dissolves in water to form a weak acid which does not ionize so it removes hydroniums from solution, but it forms a strong base which dissociates releasing hydroxide.



Not all salts are created equal.

For each of the salt solutions listed below, state whether the solution would be *ACID*, *BASE*, or *NEUTRAL*.

1. $KF(aq)$ .... ____________
2. $NH_4CH_3COO(aq)$ .... ____________
3. $FeCl_3(aq)$ .... ____________
4. $Na_2CO_3(aq)$ .... ____________
5. $AgNO_3(aq)$ .... ____________
6. $NaBr(aq)$ .... ____________
7. $Li_3PO_4(aq)$ .... ____________
8. $CaCl_2(aq)$ .... ____________
9. $MgSO_4(aq)$ .... ____________
10. $NH_4SO_4(aq)$ .... ____________
11. $Cs_2CO_3(aq)$ .... ____________
12. $MnF_7(aq)$ .... ____________
13. $Na_2S(aq)$ .... ____________
14. $Al(NO_3)_3(aq)$ .... ____________
15. $CuSO_4(aq)$ .... ____________
16. $BaI_2(aq)$ .... ____________
17. $Ca(CH_3COO)_2(aq)$ .... ____________
18. $NH_4ClO_4(aq)$ .... ____________
19. $MgCr_2O_7(aq)$ .... ____________
20. $FeSO_4(aq)$ .... ____________

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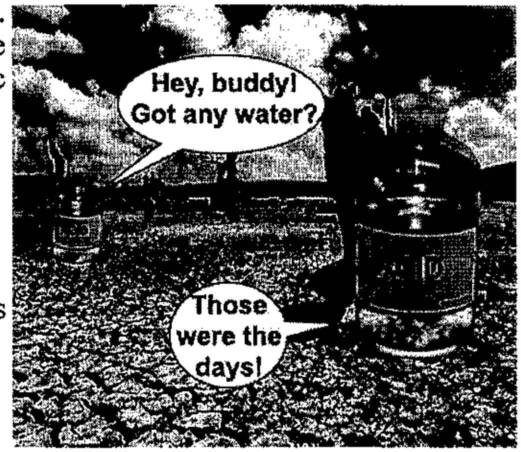
Acid and Base Anhydrides

Acid and base anhydrides are essentially acids or bases minus water. Acid anhydride form oxyacids when mixed with water. It is easy to see the relationship between oxyacids and their anhydrides by doing a basic mathematical subtraction.

H_2CO_3	H_2SO_3	$2HNO_3$
$-\underline{H_2O}$	$-\underline{H_2O}$	$-\underline{H_2O}$
CO_2	SO_2	N_2O_3



Anhydrides lament their condition

Notice that the acid anhydrides are nonmetallic oxides. Acid anhydrides are the source of acid rain.

Environmental Source	Nonmetallic Oxide	Acid Formed
Car exhaust	Carbon dioxide Nitrogen oxides	Carbonic acid Nitric acid
Coal	Sulfur dioxide Carbon dioxide	Sulfurous acid Carbonic acid
Smelters	Sulfur dioxide Sulfur trioxide	Sulfurous acid Sulfuric Acid
Volcanoes	Sulfur dioxide	Sulfurous acid
Lightning	Nitrogen oxides	Nitric acid

Base anhydrides are metallic oxides. They can be found by subtraction of water too.

$2NaOH$	$Ca(OH)_2$	$2Al(OH)_3$
$-\underline{H_2O}$	$-\underline{H_2O}$	$-\underline{3H_2O}$
Na_2O	CaO	Al_2O_3

Base anhydrides such as lime (CaO) are used to neutralize acid soil.

Answer the questions below based on the reading above and on your knowledge of chemistry.

1. State whether each of the following anhydrides is an acid or a base. Write the formula for the acid or base that forms.
   a. Li_2O ______________________ d. BaO ______________________
   b. P_2O_5 ______________________ e. Cl_2O_7 ______________________
   c. N_2O_3 ______________________ f. Fe_2O_3 ______________________

2. State whether each of the following is an acid or a base. Write the formula for the acid or base anhydrides that forms.
   a. H_2SO_3 ______________________ d. $HBrO_3$ ______________________
   b. $HClO$ ______________________ e. $Zn(OH)_2$ ______________________
   c. $Mg(OH)_2$ ______________________ f. KOH ______________________

3. What effect do carbon dioxide and nitrogen oxides in car exhaust have on the air? ______________________

____

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