Acids and Bases

Arrhenius is the name of a scientist who studied acids and bases. His name appears a lot in this topic. Don't be frightened.
Acids: According to the **Arrhenius** definition, an acid is any compound that produces hydrogen ions ($\mathbf{H^+}$) as the only positive ions in an aqueous solution (water solution).

What is the Arrhenius definition of acid? _____

_____

Hydrogen ions (H^+) are very unique. They are ions with no electrons at all. A hydrogen ion is simply a proton. Protons have a + 1 charge.

Describe: hydrogen ion _____

In water, a hydrogen ion (H^+) attaches itself to a water molecule.
$\mathbf{H^+ + H_2O \rightarrow H_3O^+}$ The result is a **hydronium ion, "$\mathbf{H_3O^+}$".**

How is a hydronium ion formed? _____
The terms **hydronium ion** and $\mathbf{H^+}$ are used interchangeably to indicate the presence of an acidic solution.
How to identify an acid from its chemical formula.
Rule: Compounds that begin with **H** are **acids**.
Examples: HF; HCl; H_2SO_4; HNO_3; and H_3PO_4.
Additionally; organic acids begin with **C** and end in **COOH**.
Examples of organic acids: HCOOH (methanoic acid), CH_3COOH (ethanoic acid), CH_3CH_2COOH (propanoic acid), and $CH_3CH_2CH_2COOH$ (butanoic acid).

How can you identify an acid from its chemical formula? _____

How can you identify an organic acid? _____

Table K provides names and examples of some common acids.

Acids react with "active" metals to produce hydrogen gas "$H_{2(g)}$" by means of a **single replacement reaction**. (note packet # 18 pg. 4 will refresh your memory of single replacement reactions)

A metal is considered active if it is above hydrogen "H_2" in **Table J.**

Which metals are considered active on Table J? _____
Ex: $Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$
Zn is above H_2 in Table J therefore it reacts with HCl and replaces H.

Ex: $Ag_{(s)} + HCl_{(aq)} \rightarrow Ag_{(s)} + HCl_{(aq)}$
Ag is below H_2 in Table J therefore no reaction.

Complete and balance the following reactions. If no reaction occurs, write "no reaction". **Check Table J.**

1) $Mg_{(s)} + HCl_{(aq)} \rightarrow$

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

3) $Ca_{(s)} + HCl_{(aq)} \rightarrow$

4) $Fe_{(s)} + HCl_{(aq)} \rightarrow$

Bases: The **Arrhenius** definition of a base is any compound that produces **hydroxide** ions $(OH)^-$ as the only negative ions in aqueous solution.

What is the Arrhenius definition of base? _____

_____

The term **alkaline** is often used to describe how much of a base (basic) something is.

How to identify a base from its chemical formula.
Ionic compounds that end in **OH** are bases. When identifying bases, care must be taken to ensure that the **OH** is ionically bonded to the rest of the compound.
Examples: NaOH; KOH; $Ca(OH)_2$; and NH_4OH.

Table L gives names and examples of common bases.

How can you identify a base from its chemical formula? _____

_____

Warning! Do not confuse alcohols with bases. Remember that the functional group of an alcohol is -OH. The **OH** in a base must be part of an ionic compound. Alcohols are organic compounds, they are not ionic and therefore not bases. Multiple choice regents questions try to tempt you to choose an alcohol instead of a base.
Example alcohols: CH_3OH (methanol) and CH_3CH_2OH (ethanol) are not bases.

CH_3OH IS NOT A BASE!!!

It is an alcohol! You will be tested on this.

Is CH_3OH a base? _____

What is it? _____

Note; Table L refers to $NH_{3(aq)}$ "ammonia" as a base even though it is not ionic and does not end in **OH**. This is because $NH_{3(aq)}$ reacts with a water molecule to produce NH_4OH (ammonium hydroxide), which we can recognize as a base.

$$NH_3 + H_2O \rightarrow NH_4OH$$

Why is $NH_{3(aq)}$ a base even though it is not ionic and does not end in OH? _____

Group 1 metals (alkali metals) and **Group 2 metals** (alkaline earth metals) react with water to produce **strong bases** and **hydrogen gas**.

What 2 things are produced when a group 1 or group 2 metal is placed in water?

When water "H_2O" is part of an equation it is useful to show it as H(OH).
It makes the single replacement reaction more obvious.

Examples:

$2Na_{(s)} + 2H_2O_{(l)} \rightarrow 2NaOH_{(aq)} + H_{2(g)}$
Gp 1 water base hydrogen

$2Na_{(s)} + 2\mathbf{H(OH)}_{(l)} \rightarrow 2NaOH_{(aq)} + H_{2(g)}$
Gp 1 water base hydrogen

$Ca_{(s)} + 2H_2O_{(l)} \rightarrow Ca(OH)_{2(aq)} + H_{2(g)}$
Gp 2 water base hydrogen

$Ca_{(s)} + H(OH)_{(l)} \rightarrow Ca(OH)_{2(aq)} + H_{2(g)}$
Gp 2 water base hydrogen

$2Na_{(s)} + 2H_2O_{(l)} \rightarrow 2NaOH_{(aq)} + H_{2(g)}$
Gp 1 water base hydrogen

$2Na_{(s)} + 2H(OH)_{(l)} \rightarrow 2NaOH_{(aq)} + H_{2(g)}$
Gp 1 water base hydrogen

Complete the following reactions:

a) $2\ Li_{(s)} + 2\ H_2O_{(l)} \rightarrow$

b) $Mg_{(s)} + 2\ H_2O_{(l)} \rightarrow$

c) $Mg_{(s)} + 2\ H_2O_{(l)} \rightarrow$

Salts: Even though the most common and well-known salt is NaCl (sodium chloride), there are thousands of different types of salts. **Salts are ionic substances that are not acids or bases.** *Remember* An ionic compound consists of a metal and a nonmetal or a compound that contains a polyatomic ion.

Describe: salt _____

Electrolytes: Electrolytes are substances that conduct electricity when dissolved in water. For a solution to be an electrolyte, it must contain ions. Acids, bases and salts separate into + and - ions when dissolved in water.

Describe: Electrolyte _____

_____

Acids, bases and salts are electrolytes.

What 3 things are electrolytes? _____

Alternate Acid/Base Theory: Hydrogen Ion (H^+) donor/acceptor concept.
In addition to the Arrhenius definition of acids and bases there is the **Bronstead-Lowry** definition. The Bronstead-Lowry definition states that acids are proton ($\mathbf{H^+}$) donors and bases are proton ($\mathbf{H^+}$) acceptors.
Example: $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$
During the course of this reaction, NH_3 accepted a proton ($\mathbf{H^+}$) resulting in the formation of NH_4^+. H_2O donated a proton ($\mathbf{H^+}$) resulting in OH^-. Therefore according to the Bronstead-Lowry definition, NH_3 is a base (proton acceptor) and H_2O is an acid (proton donor).

Try one.
$NH_3 + HCl \rightarrow NH_4^+ + Cl^-$
According to the Bronstead/Lowry definition, which item is the acid and which item is the base? Why?

Neutralization: Acids and bases react together in a **double replacement reaction** to produce a **salt** and **water**. You will be required to recognize neutralization reactions. Remember! There are many different salts. Don't just look for NaCl.

Describe: neutralization _____

_____

Examples: $HBr_{(aq)} + NaOH_{(aq)} \rightarrow NaBr_{(aq)} + H_2O_{(l)}$
acid base salt water

$2\ HNO_{3(aq)} + Ca(OH)_{2(aq)} \rightarrow Ca(NO_3)_{2(aq)} + 2\ H_2O_{(l)}$
acid base salt water

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

$H_3PO_{4(aq)} + 3\ NH_4OH_{(aq)} \rightarrow (NH_4)_3PO_{4(aq)} + 3\ H_2O_{(l)}$
acid base salt water

Measuring Acids and Bases: pH

The term **pH** is used to measure how **acidic** or **basic** a solution is.
pH: Notice! The "p" is small and the "H" is capital. The term **alkaline** is sometimes used in place of the term basic because alkaline metals produce bases in water. Remember, the term "hydronium ion (H_3O^+)" can be used interchangeably with H^+ concentration when describing the pH of solutions.
All aqueous solutions whether acid, base, or neutral contain both H^+ (which become hydronium ions) and hydroxide ions. Even very acidic solutions contain some hydroxide ions. You have to realize that an acidic solution has more hydrogen ions (H^+) than hydroxide ions (OH^-). Concentration can be expressed with brackets. [ ].
Ex: $[H^+]$ means hydrogen ion concentration. $[OH^-]$ means hydroxide ion concentration.
If $[H^+]$ is greater than $[OH^-]$ the solution is considered **acidic**. $[H^+] > [OH^-]$
If $[OH^-]$ is greater than $[H^+]$ the solution is considered to be **basic**. $[OH^-] > [H^+]$
If $[H^+]$ is equal to $[OH^-]$ the solution is considered **neutral**. $[H^+] = [OH^-]$

The pH scale ranges from **0 – 14**. The lower the pH, the greater the **$[H^+]$** and the lower the **$[OH^-]$** .
The higher the pH, the lower the **$[H^+]$** and the greater the **$[OH^-]$**

pH Scale

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Acidic						Neutral						Basic	
	$[H_3O^+] > [OH^-]$						$[H_3O^+] = [OH^-]$						$[H_3O^+] < [OH^-]$	
	$[H^+] > [OH^-]$						$[H^+] = [OH^-]$						$[H^+] < [OH^-]$	

How to remember if high or low numbers are acidic or basic.
Look at the pH scale.
The #1 comes before the #14 when you count.
A for **Acid** comes before **B** for **Base** just like in the alphabet song. ☺

Important pH fact: every pH # is a factor of 10. This means that a solution with a pH of 5 is 10 times as acidic as a solution with a pH of 6. That means it has 10 times as much H^+ as a solution with a pH of 6.
A solution with a pH of 4 is 100 times as acidic and has 100 times as much H^+ as a solution with a pH of 6. That means it has 100 times as much H^+ as a solution with a pH of 6.

Ex: My orange juice has a pH of **4** and my grape juice has a pH of **6**. How many times more acidic is my orange juice than my grape juice?

Ex: A swimming pool has a pH of **10** and the swimming pool store states a pool should have a pH of **7**. How many times more basic is the pool than it is supposed to be?

Describe the following solutions as acidic, basic, or neutral.

a) $[H_3O^+] > [OH^-]$

b) $[H^+] < [OH^-]$

c) $[H_3O^+] = [OH^-]$

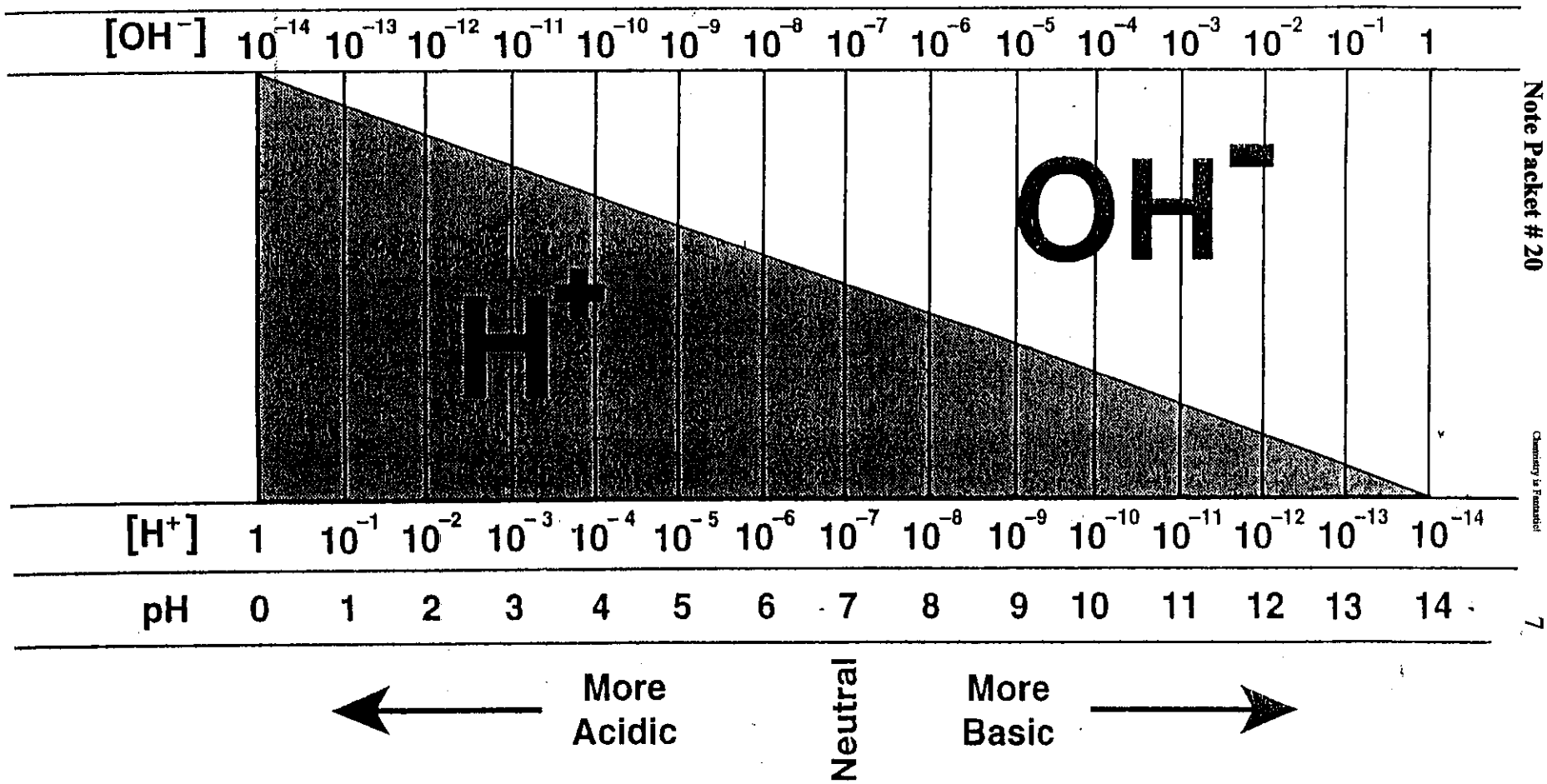
d) $[H_3O^+] < [OH^-]$

e) $[H^+] = [OH^-]$

f) $[H^+] > [OH^-]$

The diagram on page 7 illustrates how all solutions contain both H^+ and OH^-

All solutions contain both H^+ and OH^-. If the concentration of both are the equal the solution is neutral **pH 7**.
If the concentration of H^+ is greater the solution is acidic. If the concentration of OH^- is greater the solution is basic.



Acid-base Indicators: Scientists often need to know how acidic or basic something is. An electronic pH meter provides a very accurate measurement of pH. If a pH meter is unavailable an acid-base indicator can be used to determine pH. Acid-base indicators are colored dyes that change color according to pH. You may be familiar with acid-base indicators from swimming pool or aquarium maintenance. Some indicators are liquids and some indicators are strips of paper.

What is an acid/base indicator? _____

Table M

Common Acid-Base Indicators

Reference Table M is used to determine the pH of a solution by matching an indicator's color with known values.
Acid-base indicators are colorful. **Table M** is black and white.
The best way to learn how to use **Table M** is to compare it to a full color chart. Look at your attached **Table M** and compare it to your colorful chart on page 9.
Pay special attention to the change range zone.
Bromthymol blue, litmus, and phenolphthalein have color change ranges close to neutral (pH 7). They are good indicators to select for an acid/base **titration**. They can indicate the presence of a near neutral solution.

List 3 indicators from Table M that may indicate a near neutral solution.

_____ _____ _____

Table M
Common Acid–Base Indicators

Indicator	Approximate pH Range for Color Change	Color Change
methyl orange	3.2–4.4	red to yellow
bromthymol blue	6.0–7.6	yellow to blue
phenolphthalein	8.2–10	colorless to pink
litmus	5.5–8.2	red to blue
bromcresol green	3.8–5.4	yellow to blue
thymol blue	8.0–9.6	yellow to blue

Name _____

Table M
Common Acid–Base Indicators

Indicator	Approximate pH Range for Color Change	Color Change
methyl orange	3.2–4.4	red to yellow
bromthymol blue	6.0–7.6	yellow to blue
phenolphthalein	8.2–10	colorless to pink
litmus	5.5–8.2	red to blue
bromcresol green	3.8–5.4	yellow to blue
thymol blue	8.0–9.6	yellow to blue

1. Which indicator is blue in a neutral solution? _____
2. Name an indicator that is yellow at pH 4. _____
3. Name an indicator that is yellow at pH 9. _____
4. What is the pH of a solution that changes methyl orange indicator yellow and litmus red? _____
5. Which indicator appears colorless in HNO_3 (aq)? _____
6. Bromcresol green indicator is added to a beaker containing NaOH(aq). What color change will be observed as HCl is added to the solution in the beaker?

_____

For each acid-base indicator on Reference Table M, color the chart below to indicate appropriate color of the indicator from pH 1 to 14.

pH →	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Methyl orange														
Bromthymol blue														
Phenolphthalein														
Litmus														
Bromcresol green														
Thymol blue														

Acid-Base Titration: An acid-base titration is a laboratory method used to determine the unknown molarity (concentration) of an acid or base by using an acid or base of known molarity. The **endpoint** of a titration occurs when **neutralization (pH = 7)** has been reached. The term neutralization comes from the term **neutral** which refers to a pH of 7. This endpoint can be determined visually by using an appropriate **acid/base indicator** or an electronic pH meter. Acid/base indicators are chemicals that change color according to pH. When performing a neutralization titration it is important to use an indicator that changes color close to pH 7 (neutral). For regents chemistry, there are 3 main acid/base indicators that change color close to a
pH of 7. They are **phenolphthalein, bromthymol blue, and litmus.**

What are 3 acid base indicators that could be used to indicate neutralization? _____

Table **M** lists some common acid/base indicators and their pH change ranges. Look at your colorful acid/base indicator sheet to get a better idea. The specialized, calibrated glassware used for a titration is called a **buret.**
The titration formula $M_A V_A = M_B V_B$ can be found on page 12 of the reference table.
M_A = molarity of the acid
V_A = volume of the acid
M_B = molarity of the base
V_B = volume of the base

Example Neutralization Titration question.
What volume of 3 M hydrochloric acid would be required to neutralize 50 mL of 6 M sodium hydroxide.
To solve:
Step 1: First you must recognize that hydrochloric acid is an acid and that sodium hydroxide is a base.
Step 2: Next; you must determine what information is known and what information is unknown.
Step 3: Finally, insert the information into the formula and solve for the unknown.

$M_A = 3$
$V_A = ?$
$M_B = 6$
$V_B = 50$

$3\ V_A = 6 \times 50$ $\quad 3\ V_A = 300$ $\quad 3\ V_A = 300$ $\quad V_A = \frac{300}{3}$

$V_A = 100\text{mL}$

Now you try one!
If 100mL of 4 M $HCl_{(aq)}$ was required to neutralize 50 mL of $KOH_{(aq)}$, What was the molarity of the $KOH_{(aq)}$?

That was easy! Try another one.
What volume of 1.5 M hydrochloric acid would be required to neutralize 800 mL of 6 M potassium hydroxide.

When to use the **titration formula.**
There are several chemistry formulas that involve moles or molarity.
It can be confusing! ☹
Key terms that should lead you to $M_A V_A = M_B V_B$ are:
neutralize, neutralization, acid/base, titration & buret

Caution! Warning! Danger! Imminent peril!
To safely prepare an acid solution, always add the acid to the water. Remember! **AA,** Add Acid. The dilution of strong acids is very exothermic (releases lots of heat). If you are not careful, the acids could boil or spatter causing injury or damage.

How to Prepare a Solution of a Specific Molarity from a Standard Solution:
Yes; I know we saw this exact formula when we learned about solutions but it appears in this topic also.
A **standard solution** is a concentrated solution with a known molarity. A *standard solution* can be used to prepare a solution of desired molarity.
The formula used is $M_1 V_1 = M_2 V_2$ This formula is not available in the reference table but it looks similar to the titration formula which is on page 12 of the reference table.

M_1 = initial molarity	(concentrated standard solution)
V_1 = initial volume	(the amount of concentrated standard solution required)
M_2 = final molarity	(desired molarity)
V_2 = final volume	(the total volume of your final solution)

Ex: Describe how to prepare 600 mL of 4 M $HCl_{(aq)}$ (hydrochloric acid solution) from a 12 M $HCl_{(aq)}$ (hydrochloric acid solution).

To solve: insert the given information into the formula and solve for the amount of 12 M $HCl_{(aq)}$ required.

$12\ V_1 = 4 \times 600$ $\qquad 12\ V_1 = 2400$ $\qquad V_1 = \frac{2400}{12}$

$V_1 = 200$ mL 200 mL is the amount of 12 M $HCl_{(aq)}$ required.

The problem is not finished!

To prepare 600 mL of 4 M $HCl_{(aq)}$ you will have to add the 200 mL of 12 M $HCl_{(aq)}$ to 400 mL of distilled water.

Try one on your own.
Describe how to prepare 500 mL of 4M $H_2SO_{4(aq)}$ (sulfuric acid solution) from a standard18 M $H_2SO_{4(aq)}$ (sulfuric acid solution).

Remember! Once you know the amount of concentrated standard solution to use, you then add the acid to the distilled water.

Practice Questions
Define: Arrhenius acid

Electrolyte

Arrhenius base

Salt

Indicate whether the following compounds are acids, bases, salts, or none.

1. $HNO_{3(aq)}$
2. $NaOH_{(aq)}$
3. $NH_{3(aq)}$
4. $NH_4OH_{(aq)}$
5. $NH_4NO_{3(aq)}$
6. $HBr_{(aq)}$
7. $HCl_{(aq)}$
8. $NaCl_{(aq)}$
9. $CH_3COOH_{(aq)}$
10. $H_3PO_{4(aq)}$
11. $CH_3OH_{(aq)}$

Indicate whether the following compounds are electrolytes (yes or no) and state **why**.

12. $CH_3OH_{(aq)}$

13. $KCl_{(aq)}$

14. $CO_{2(aq)}$

15. $CH_3COOH_{(aq)}$

16. $NH_4OH_{(aq)}$

17. $C_6H_{12}O_{6(aq)}$

Answer questions **18 & 19** based on the following information.
Given a sample of $HCl_{(aq)}$ of unknown molarity. Your task is to determine its molarity.

18. List the materials and equipment you would use to make this determination.

19. Describe the steps you would perform to make this determination.

20. What color is phenolphthalein in an acidic solution?

21. Describe the color changes expected in a beaker of **pure water**.

a) If 2 drops of phenolphthalein are added to the beaker.

b) If lithium metal is added to the beaker with 2 drops of phenolphthalein.

22. Describe the color of a solution with a pH of 6.5 when tested with the following indicators.

a) methyl orange

b) bromthymol blue

c) phenolphthalein

d) litmus

e) bromcresol green

f) thymol blue

23. Explain why $NH_{3(aq)}$ is considered a base even though it is not ionic and it does not end in "OH".

Answer questions **24 – 26** based on the given reaction.

$NH_{3(aq)} + H_2O_{(l)} \rightarrow NH_{4(aq)} + OH^-_{(aq)}$

24. Indicate which compound is a proton donor and which compound is a proton acceptor.

25. Which compound is an acid and which compound is a base.

26. Explain your answer to question # 25

Answer questions **27-30** based on the following reaction.

$2HNO_{3(aq)} + Mg(OH)_{2(aq)} \rightarrow Mg(NO_3)_{2(aq)} + 2H_2O_{(aq)}$

27. What type of reaction is this?

28. Which compound is the acid?

29. Which compound is the base?

30. Which compound is the salt?

31. What are the products of any neutralization reaction?

32. Why is a H^+ ion considered a proton?

33. What is the name of this polyatomic ion $\mathbf{H_3O^+}$? How is it formed?

34. What is the name of this polyatomic ion $\mathbf{OH^-}$?

35. If 12.5 mL of 4.00 molar HCl is needed to neutralize 30.0 mL of KOH, What is the molarity of the KOH? **SHOW ALL WORK**

36. How much 6 M HCl would be needed to neutralize 300 mL of 3 M NaOH? **SHOW ALL WORK**

37. Compare the hydroniun ion concentration to hydroxide ion concentration in a solution with a pH of 4. **Be specific!**

38. Describe how to prepare 300mL of 3M $HCl_{(aq)}$ using a 12M solution of $HCl_{(aq)}$. **Remember AA!**

39. Will lithium react with hydrochloric acid to produce hydrogen gas? Write the balanced chemical equation if it does. (Hint : Table J)

40. Will gold react with sulfuric acid to produce hydrogen gas? Write the balanced chemical equation if it does. (Hint : Table J)