CHM 120 – UNIT 4 SUPPLEMENT

CHEMICAL STOICHIOMETRY

STOICHIOMETRY – THE MEANING OF THE WORD

The word stoichiometry derives from two Greek words: stoicheion (meaning "element") and metron (meaning "measure"). Stoichiometry deals with calculations about the masses (sometimes volumes) of reactants and products involved in a chemical reaction. It is a very mathematical part of chemistry, so be prepared for lots of calculator use.

Objectives for Unit 4:

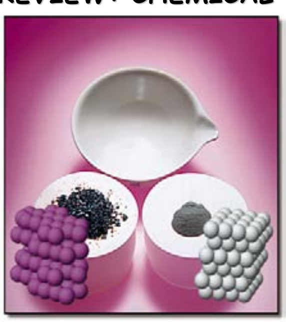
- ✓ To understand a chemical equation and the relationships between reactants and products.
- ✓ To convert mole and mass amounts in a chemical equation (Stoichiometry).
- ✓ To perform percent yield calculations.
- ✓ To perform limiting reactant problems.
- ✓ To perform concentration calculations of percentage by mass and molarity.
- ✓ To perform calculations based on diluting solutions.
- ✓ To understand a titration and the calculations involved.
- ✓ To understand the pH and pOH scale for identifying the concentration of hydrogen ions and hydroxide ions in solution.

CONVERSION FACTORS FROM A CHEMICAL EQUATION

STOICHIOMETRY – HISTORY

Jeremias Benjamin Richter, a chemist in 1974 became a mining official in Germany. He performed some of the earliest determinations of the quantities by weight in which acids saturate bases. He proposed the Law of Definite Proportions which he stated that the ratio by weight of the compounds consumed in a chemical reaction is always the same. In his published works he introduced the term **STOICHIOMETRY** which he defined as *the art of chemical measurements, which has to deal with the laws according to which substances unite to form chemical compounds.*

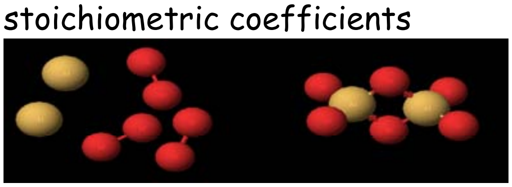
REVIEW: CHEMICAL REACTIONS/EQUATIONS



Reactants: Zn + I_2 → Product: Zn I_2

Chemical Equations

stoichiometric coefficients



2 Al(*s*) + 3 Br_2(*l*) ---> Al_2Br_6(*s*)

This equation means

2 Al atoms + 3 Br_2 molecules --->1 molecule of Al_2Br_6

2 moles of Al + 3 moles of Br_2 --->1 mole of Al_2Br_6

The letters (*s*), (*g*), and (*l*) are the physical states of compounds.

Why is this important?
As fascinating as it was to find out we could measure out 27.0 grams of aluminum and know it was exactly 6.02×10^{23} atoms of aluminum, chemical stoichiometry is just as amazing.
Before we let elements and compounds meet, we can predict how they are going to react, and even further, how much stuff they are going to produce. We could also be on the other end of things and find a waste product and determine exactly how much of a particular compound or element was needed to produce the waste. How WONDERFUL!! This is STOICHIOMETRY!!
REACTION STOICHIOMETRY involves the mass and mole relationships among reactants and products in a chemical reaction. A balanced chemical equation is used to determine these relationships.
Note: The stoichiometric coefficients in a balanced equation give the relative numbers of atoms, or molecules, or the number of moles of each substance reacting.
MOLE - MOLE RELATIONSHIPS involves mole conversions between substances in a chemical equation. To solve:

Write and Balance the chemical equation.

Convert from moles of the given material to moles of the unknown material (or moles of the given material to grams of the unknown material), using the balanced equation. *bridge step*

A reaction with iron oxide:

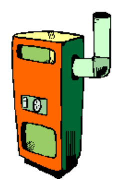
$Fe_2O_3(s) + 3\ H_2(g) \rightarrow 2\ Fe(s) + 3\ H_2O(l)$

The chemical equation indicates:

1 mole Fe_2O_3 and 3 moles H_2 react, 2 moles Fe and 3 moles H_2O are produced

How many moles of hydrogen are needed to react to produce 15.65 moles of iron?
Perform Step 2 (bridge step): mol Fe to mol H_2

$$15.65 \text{ mol Fe} \times \frac{3 \text{ mol } H_2}{2 \text{ mol Fe}} = 23.48 \text{ mol } H_2$$



Another Example:
Combustion of Propane (C_3H_8).
____$C_3H_8(g)$ + ___$O_2(g)$ $\rightarrow$ ___$CO_2(g)$ + ___$H_20(g)$
What does the Chemical Equation tell us?

$C_3H_8(g) + 5\ O_2(g) \rightarrow 3\ CO_2(g) + 4\ H_20(g)$

When the equation is balanced: 3 moles C_3H_8 react with 5 moles O_2, 3 moles CO_2 and 4 moles H_2O are produced.
Calculate the number of moles of oxygen reacting if 3.00 moles of CO_2 is produced.

$$3.00 \text{ mol } CO_2 \times \frac{5 \text{ mol } O_2}{3 \text{ mol } CO_2} = 5.00 \text{ mol } O_2$$

Calculate the number of moles of water produced if 2.00 moles of propane (C_3H_8) is burned.

$$2.00 \text{ mol } C_3H_8 \times \frac{4 \text{ mol } H_2O}{1 \text{ mol } C_3H_8} = 8.00 \text{ mol } H_2O$$

Calculate the number of moles of carbon dioxide produced if 4.60 moles of oxygen is needed to react with propane. $4.60 \text{ mol } O_2 \times \frac{3 \text{ mol } CO_2}{5 \text{ mol } O_2} = 2.76 \text{ mol } CO_2$

MASS - MASS RELATIONSHIPS involve gram conversions between substances in a chemical equation. The same steps provided above may be followed. Example:
If 454 g of NH_4NO_3 decomposes into N_2O and H_2O. What is the mass of H_2O produced? Balanced Chemical Equation: $NH_4NO_3 \rightarrow N_2O + 2\ H_2O$
1mol $NH_4NO_3 \rightarrow$ 1mol N_2O + 2 mol H_2O
80.0 g $NH_4NO_3 \rightarrow$ 44.0 g N_2O + 36.0 g H_2O
Convert g NH_4NO_3 to g H_2O (bridge step) (finding the theoretical yield)

$$454 \text{ g } NH_4NO_3 \times \frac{36.0 \text{ g } H_2O}{80.0 \text{ g } NH_4NO_3} = 205 \text{ g } H_2O$$

Other Examples:

$2HgO(s) \rightarrow 2Hg(s) + O_2(g)$

433.2 g HgO → 401.2 g Hg + 32.0 g O_2

Let's Put It In One Step

5.00 g mercury (II) oxide decomposes to mercury and oxygen. Determine the mass of mercury produced.

$$5.00\text{g HgO} \times \frac{401.2 \text{ Hg}}{433.2 \text{ g HgO}} = 4.63\text{g Hg}$$

PERCENT YIELD

PERCENT YIELD: Experimentally, quantities of products are determined that may not always match those quantities of products determined through stoichiometric calculations. The percentage of product obtained experimentally can be determined by percent yield.

Percent yield = $\frac{\text{Actual yield}}{\text{Theoretical yield}}$

PERCENT YIELD tells the efficiency of the reaction.

ACTUAL YIELD is the amount of product really obtained (by experimentation).

THEORETICAL YIELD is the amount of product that should be obtained (by calculation).

Example:

A little history, to illustrate a reaction of incandescent light bulbs.

It's a little known fact that if Lewis Latimer hadn't been on Thomas Edison's team (the only African American) that the light bulb might have been too impractical for most people to use. You see, Edison's light bulb used bamboo as the filament and the light bulb burned out after only 30 hours. Carbon lasted much longer and made the light bulb practical. Latimer, with Joseph V. Nichols, came up with both idea to use carbon filaments and the process for manufacturing the carbon filaments.

At present, tungsten metal, W is used to make incandescent bulb filaments. The metal is separated out of yellow tungsten (VI) oxide, WO_3 by reacting with hydrogen according to the following reaction:

$WO_3 + 3H_2 \rightarrow W + 3H_2O$

If 2.76 grams of W is experimentally obtained from the reaction between 15.8 grams of WO_3 and excess of H_2, calculate the percent yield obtained from the reaction.

First, Determine the Theoretical Yield of W using Stoichiometry

$$231.8 \text{ g } WO_3 + 6.0 \text{ g } H_2 \rightarrow 183.8 \text{ g W} + 54.0 \text{ g } H_2O$$

$$15.8\text{g } WO_3 \times \frac{183.8 \text{ g W}}{231.8\text{g } WO_3} = 12.5\text{g W}$$

Second, Determine the Percent Yield of W

$$\text{Percent Yield} = \frac{2.76 \text{ g W}}{12.5 \text{ g W}} \times 100 = 22.0\%$$

Thus, only 22.0% of the tungsten was recovered.

Another Example: Copper can be recovered from a mineral in our environment: Cu_2S (called chalcocite). When I performed this experiment, I started with 15.0 grams of Cu_2S and recovered 9.95 grams of copper. What was the percent yield of copper from my experiment?

Write the chemical equation: $Cu_2S \rightarrow 2\,Cu + S$

$1\text{mol } Cu_2S \rightarrow 2 \text{ mol } Cu + 1 \text{ mol } S$

$159.1 \text{ g } Cu_2S \rightarrow 127 \text{ g } Cu + 32.1 \text{ g } S$

First, Determine the Theoretical Yield of copper using stoichiometry.

$$15.0\text{ g Cu}_2\text{S} \times \frac{127\text{ g Cu}}{159.1\text{ g Cu}_2\text{S}} = 12.0\text{ g Cu}$$

Second, Determine the Percent Yield of W

$$\text{Percent Yield} = \frac{\text{Actual Yield}}{\text{Theoretical Yield}} \times 100$$

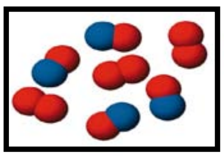
$$\text{Percent Yield} = \frac{9.95\text{ g}}{12.0\text{ g}} \times 100 = 82.9\%\text{ Cu}$$

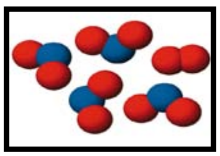
Thus, only 82.9% copper was recovered.

LIMITING REACTANT PROBLEMS

LIMITING REACTANT is the reactant that is completely used up in a chemical reaction. It limits the amount of other reactants that can combine and the amount of products formed in a reaction.

EXCESS REACTANT is the reactant in excess in a chemical reaction. It is not completely used up in a reaction.





Reactants **Products**

2 NO(g) + O_2 (g) → 2 NO2(g)

Limiting reactant = NO

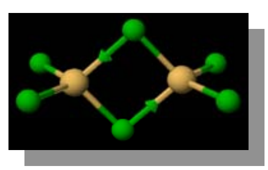
Excess reactant = O_2

Why is this important?

In our age of environmental awareness, we try to minimize our waste production. The same is true in chemical processes. We learned with stoichiometry that we can determine the exact amount of product that will be produced when using a known amount of reactant. Well, we've seen in many chemical reactions, that often more than one reactant is used. How can we minimize using too much of our reactants to produce a certain amount of product?

Remember the following things about Limiting Reactants:

- The reaction will stop when the reactants are used up.
- If one reactant is used up before the other, the reaction will stop.
- The first reactant used up is the LIMITING REACTANT, use it for the calculation.
- The other reactant is the EXCESS REACTANT.



Example:

Mix 5.40 g of Al with 8.10 g of Cl_2. What mass of Al_2Cl_6 can form?

$2\,Al + 3\,Cl_2 \rightarrow Al_2Cl_6$

$2 \text{ mol } Al + 3 \text{ mol } Cl_2 \rightarrow 1 \text{ mol } Al_2Cl_6$

$2\,Al + 3\,Cl_2 \rightarrow Al_2Cl_6$

Convert g Al to g Al_2Cl_6 and convert g Cl_2 to g Al_2Cl_6.

$$5.40\text{ g Al} \times \frac{1\text{ mol Al}}{27.0\text{ g Al}} = 0.200\text{ mol Al}$$

$$8.10\text{ g Cl}_2 \times \frac{1\text{ mol Cl}_2}{71.0\text{ g Cl}_2} = 0.114\text{ mol Cl}_2$$

Step 2 (bridge step) convert mol Al to mol Al_2Cl_6 and convert mol Cl_2 mol Al_2Cl_6.

Step 3 The reactant that produced the smaller mol Al_2Cl_6 is the L.R..

$$0.200\text{ mol Al} \times \frac{1\text{ mol Al}_2\text{Cl}_6}{2\text{ mol Al}} = 0.100\text{ mol Al}_2\text{Cl}_6$$

$$0.114 \text{ mol } Cl_2 \times \frac{1 \text{ mol } Al_2Cl_6}{3 \text{ mol } Cl_2} = 0.0380 \text{ mol } Al_2Cl_6$$

Cl_2 is the limiting reactant and Al is the excess reactant.

Step 4: Calculate mass of Al_2Cl_6 expected, using the limiting reactant.

$$0.0380 \text{ mol } Al_2Cl_6 \times \frac{267.0 \text{ g } Al_2Cl_6}{1 \text{ mol } Al_2Cl_6} = 10.1 \text{ g } Al_2Cl_6$$

How much of excess reactant will remain when reaction is complete?

Step 1: Determine the amount of excess reactant (Al) is actually needed in the reaction.

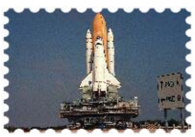
$$0.114 \text{ mol } Cl_2 \times \frac{2 \text{ mol Al}}{3 \text{ mol } Cl_2} = 0.0760 \text{ mol Al}$$

$$0.0760 \text{ mol Al} \times \frac{27.0 \text{ g Al}}{1 \text{ mol Al}} = 2.05 \text{ g Al}$$

Step 2: Subtract this amount from the amount of Al the reaction started with.

5.40 g Al – 2.05 g Al = 3.35 g Al is in excess when the reaction is complete.

Other Example:



To See a movie of the Shuttle Launch: Click Here

The fuel in the main cells of the Space Shuttle are liquid oxygen and liquid hydrogen. The explosive reaction results in the production of H_2O. Obviously, those working on the space shuttle had to have an understanding of limiting reactant problems.

The reaction: $2\ H_2 + O_2 \rightarrow 2\ H_2O$

If 45,450 grams of oxygen and 45,620 grams of hydrogen where put into the fuel cells of the space shuttle.

Which reactant is the limiting reactant?

$$45{,}450 \text{ g } O_2 \times \frac{1 \text{ mol } O_2}{32.0 \text{ g } O_2} \times \frac{2 \text{ mol } H_2O}{1 \text{ mol } O_2} = 2{,}841 \text{ mol } H_2O$$

$$45{,}620 \text{ g } H_2 \times \frac{1 \text{ mol } H_2}{2.0 \text{ g } H_2} \times \frac{2 \text{ mol } H_2O}{2 \text{ mol } H_2} = 22{,}810 \text{ mol } H_2O$$

Oxygen is the limiting reactant.

How much H_2O will be produced?

$$2{,}841 \text{ mol } H_2O \times \frac{18.0 \text{ g } H_2O}{1 \text{ mol } H_2O} = 51{,}140 \text{ g } H_2O$$

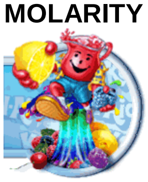
How much excess reactant was not needed to be put into the space shuttle?

$$45{,}450 \text{ g } O_2 \times \frac{1 \text{ mol } O_2}{32.0 \text{ g } O_2} \times \frac{2 \text{ mol } H_2}{1 \text{ mol } O_2} \times \frac{2.0 \text{ g } H_2}{1 \text{ mol } H_2} = 5{,}681 \text{ g } H_2$$

45,620 g H_2 – 5,681 g H_2 = 39,940 g H_2 in excess.

SOLUTION CONCENTRATION: MOLARITY

MOLARITY



Make a Kool-Aid® drink, and you have made a solution. If the Kool-aid is too sweet, add more water. If the Kool-Aid® is not sweet enough, add more sugar.

Thankfully, the Kool-Aid® package lets us know exactly how much sugar to add to a certain amount of water. This "recipe" on the package actually reports the **CONCENTRATION** of the Kool-Aid® solution.

MOLARITY is another type of **CONCENTRATION**, known as the **MOLAR CONCENTRATION**.

MOLARITY indicates the proportions of solute and solvent within a particular solution.

First: 1.00 cup $C_{12}H_{22}O_{11}$ = 192 grams $C_{12}H_{22}O_{11}$

2.00 quarts of solution = 1.89 liters solution

In Class

What does Molarity tell us in terms of **PREPARING A SOLUTION**?


Osmium tetroxide, OsO_4 is a very poisonous pale, yellow solid that is used as a fixing and staining agent for cell and tissue studies. It is one of the best methods for revealing lipids. It binds at double bonds of unsaturated lipids and imparts a dense brownish or black color. In the above picture you see the effects of this stain; the lipid-rich myelin sheath of nerve fibers is heavily colored.

How many grams of OsO_4 are needed to prepare 500. mL of a 0.00034 M OsO_4 solution?

In Class

Example: Barium bromate is a chemical used for coating wire.


$Ba(BrO_3)_2$ dissolved in water to make up one liter of solution, the ion concentration is as follows:

$Ba(BrO_3)_2 \rightarrow Ba^{2+}(aq) + 2\ BrO_3^{1-}(aq)$

DILUTION OF CONCENTRATION SOLUTIONS

SOLUTION BY DILUTION:

Equation:

Example: 20. mL of 5.6 *M* NaOH was diluted to 50. mL. What is the new concentration of NaOH?

In Class

TITRATION USING MOLARITY

ACID-BASE TITRATION

TITRATION is an analytical procedure that allows us to measure the amount of one solution (a base) needed to react exactly with the contents of another solution (an acid). Such analyses, which involve the measurements of volumes of solutions of reactants, are called **VOLUMETRIC ANALYSES**.

Some important terminology:

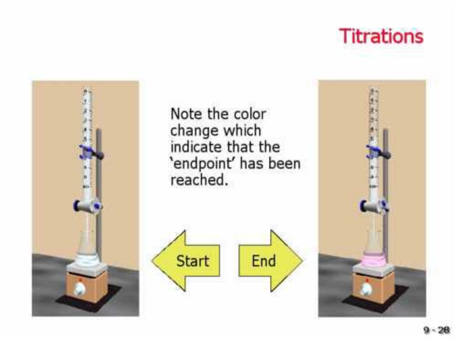
BURET: A long tube fitted at one end with a valve (stopcock). And precisely measures milliliter amounts.

TITRANT: The solution in the buret (usually the base).

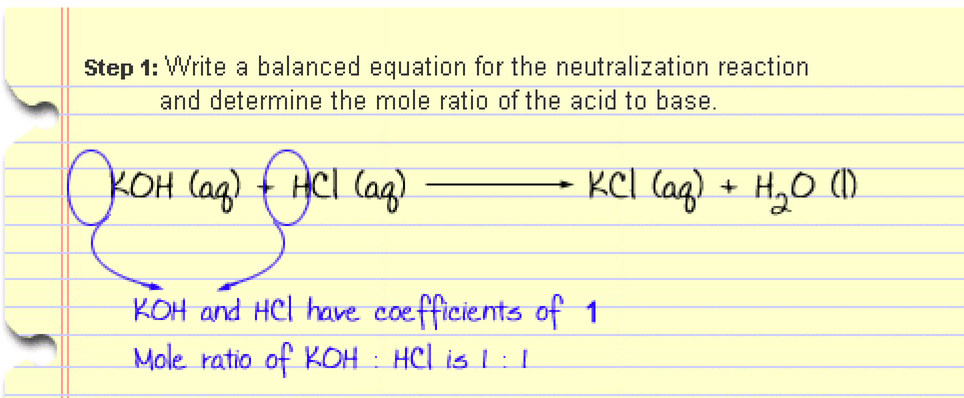
INDICATOR: A dye added to the solution in the receiving vessel, undergoes color change when reaction is over.

PHENOLPHTHALEIN: colorless in acid, pink in base.

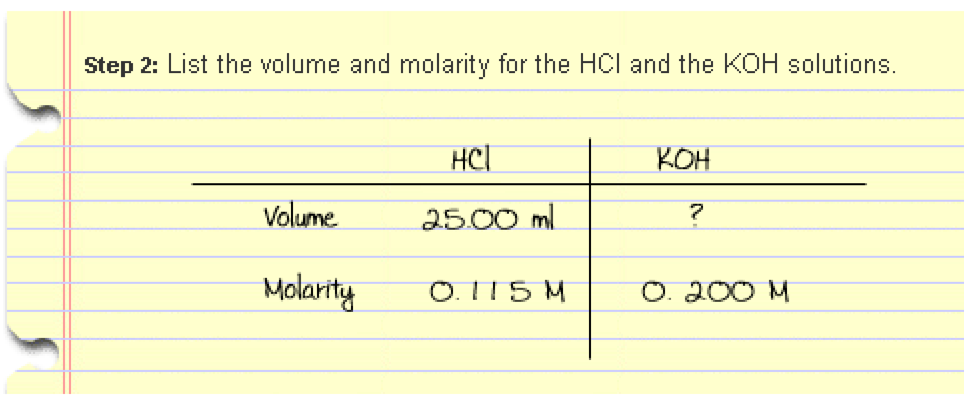
EQUIVALENCE POINT: When the indicator has suggested the reaction to be over.
STANDARDIZATION: The procedure by which the concentration of an analytical reagent is determined.



Calculations Involving Neutralization Reactions
Calculations involving neutralization reactions are usually carried out after performing the titrations.
Follow the steps outlined below to solve this type of problems.
Let's look at this example:
Calculate the volume of a 0.200 M KOH solution that is needed to neutralize 25.00 mL of a 0.115 M HCl solution.
Step 1: Write a balanced equation for the neutralization reaction and determine the mole ratio of the acid to base.



Step 2: List the volume and molarity for the HCl and the KOH solutions.



Step 3: Determine the availability of the number of moles of HCl that is available in the titration.

Step 3: Determine the availability of the number of moles of HCl that is available in the titration.

There is a specific number of moles in 25.00 ml of a 0.115 M HCl.

$$0.02500 \text{ liter} \times 0.115 \frac{\text{Moles}}{\text{liter}}$$

$= 0.002875$ moles (calculator answer)

Step 4: Apply the mole ratio determined in step 1 to determine the moles of base that is needed to neutralize the available acid.

Step 4: Apply the mole ratio determined in step 1 to determine the moles of base that is needed to neutralize the available acid.

From Step 2, we determined that the mole ratio of KOH: HCl is 1 : 1.

In Step 3 we determined that the number of moles of acid available for titration is 0.002875 moles.

Therefore, we need 0.002875 moles of KOH to completely neutralize the available acid.

Step 5: Divide the moles of base by the given concentration of KOH.

Step 5: Divide the moles of base by the given concentration of KOH.

The concentration of the KOH solution is 0. 200 M.

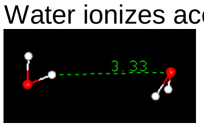
We need 0.002875 moles of KOH to neutralize the available HCl.

$$\frac{0.002875 \text{ moles}}{0.200 \frac{\text{moles}}{\text{liter}}} = 0.0144 \text{ liter or } 14.4 \text{ ml}$$

(3 significant figures)

THE WATER EQUILIBRIUM & pH AND pOH
pH is a measure of the [H_3O^+] in solution.
Developing the concept of pH:

Water ionizes according to the equation: $H_2O_{(l)} \rightleftharpoons H^+_{(aq)} + OH^-_{(aq)}$



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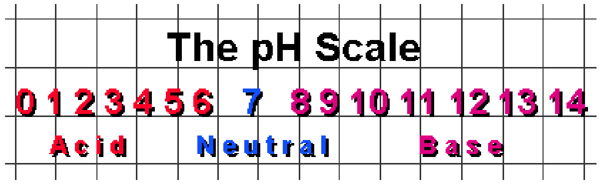
Experimental evidence indicates that pure water contains 1 X 10^{-7} mole of both H^+ and OH^-

This leads to the pH Scale:



←Acid strength increases 7 Base strength increases →

The "strength" of an acid or base increases with distance from pH=7

pH of some common substances:

Acid	Neutral	Base
stomach acid - 2 **cola drinks - 3** **tomatoes - 4** **coffee - 5** **milk - 6.5**	**pure water - 7**	**blood - 7.5** **sea water - 8** **detergent - 10** **household cleaners - 11** **oven cleaners - 14**

Calculating pH:

- **The equation is: pH = - log [H_3O^+]**
- [H^+] is expressed in powers of 10 from 10^{-14} to 10^{0}
- If [H^+] = 1 X 10^{-7}, the negative log of [H^+] = 7. The pH equals 7, indicating a neutral solution.
- The calculation of pH always gives a number between 0 and 14.

Sample pH Calculations:

Two ways are shown to work many of these problems:

- The left column shows the problem worked using logarithm
- The right column shows the problems worked using a calculator.

You are expected to understand logarithm tables, but you are allowed to work all problems in this class using a calculator.

Remember that you must show the equation to be used, then the numbers plugged into the equation, then the answer circled.

1. What is the pH of a solution with a [H^+] of 1.00 X 10^{-4} M?

Using Log Tables

pH = - log [H^+]
pH = - log (1 X 10^{-4})
pH = - (log 1.00 + log 10^{-4})
pH = - (0 + (-4))
pH = - (-4)
pH = 4

Using Calculator

pH = - log [H^+]
pH = - log (1 X 10^{-4})
Do the following on your calculator:
Enter 1 X 10^{-4}
Press " LOG "
Press " $^+$/- "
Hint: when the interger of the scientific notation is 1, the pH is the exponent of 10 as a positive number.
pH = 4

2. 0.01 moles of HCl is added to water to make 1dm^3 of solution. Assuming the HCl is completely ionized, what is the pH of the solution?

Using Log Tables

[H^+] = 1 X 10^{-2} M
pH = - log [H_3O^+]
pH = - log (1 X 10^{-2})
pH = - (log 1.00 + log 10^{-2})
pH = - (0 + (-2))
pH = - (-2)
pH = 2

Using Calculator

pH = - log [H^+]
pH = - log (1 X 10^{-2})
Do the following on your calculator:
Enter 1 X 10^{-2}
Press " LOG "
Press " $^+$/- "
Hint: when the interger of the

scientific notation is 1, the pH is the exponent of 10 as a positive number.

pH = 2

3. Calculate the $[H^+]$ of a solution with a pH of 3.70.

Using Calculator

- pH = - log $[H^+]$
- - pH = log $[H^+]$ . . . . (you may begin with this equation)
- -3.70 = log $[H^+]$
- antilog -3.70 = $[H^+]$
- Do the following on your calculator:
  - Enter -3.70
  - antilog is usually "INV", "shift", or "2nd" + "log" on a calculator. Now is the time to find out which of these it is on <u>your</u> calculator.
- $[H^+]$ = 2 X 10^{-4} M

pOH is a measure of the $[OH^-]$ in solution.

Calculating pOH:

- **The equation is: pOH = - log $[OH^-]$**
- $[OH^-]$ is expressed in powers of 10 from 10^{-14} to 10^0
- **$[H^+]$ $[OH^-]$ = 1 X 10^{-14}**
- **pH + pOH = 14**

Sample pOH Calculations:

1. What is the pOH of a solution with $[OH^-]$ = 3.98 X 10^{-5} M?

Using Log Tables

pOH = - log $[OH^-]$
pOH = - log (3.98 X 10^{-5})
pOH = - (log 3.98 + log 10^{-5})
pOH = - (.5999 + (-5))
pOH = - (-4.4)
pOH = 4.40

Using Calculator

pOH = - log $[OH^-]$
pOH = - log (3.98 X 10^{-5})
Do the following on your calculator:
Enter 3.98 X 10^{-5}
Press " LOG "
Press " $^+$/- "
pOH = 4.40

2. Find the pH of a solution that contains 0.0035 moles of H^+

Using Log Tables

pH = - log $[H^+]$
pH = - log (3.5 X 10^{-3})
pH = - (log 3.50 + log 10^{-3})
pH = - (.5441 + (-3))
pH = - (-2.46)
pH = 2.46

Using Calculator

pH = - log $[H_3O^+]$
pH = - log (3.5 X 10^{-3})
Do the following on your calculator:
Enter 3.5 X 10^{-3}
Press " LOG "
Press " $^+$/- "
pH = 2.46

3. What is the pOH of the solution above?

Using Calculator

- pH + pOH = 14
- pOH = 14 - 2.46
- pOH = 11.54

4. Calculate the pOH of a solution with a $[H_3O^+]$ of 4.09 X 10^{-2} M.

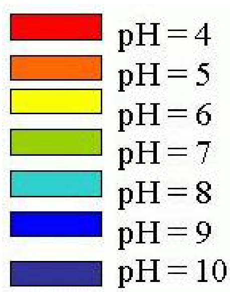
Using Calculator

- $[H_3O^+]$ $[OH^-]$ = 1.00 X 10^{-14}
- $[OH^-]$ = 1.00 X 10^{-14} / $[H_3O^+]$
- $[OH^-]$ = 1.00 X 10^{-14} / 4.09 X 10^{-2}

- $[OH^-] = 2.44 \times 10^{-13}$ M
- $pOH = -\log [OH^-]$
- $pOH = -\log (2.44 \times 10^{-13})$
- Do the following on your calculator:
    - Enter 2.44×10^{-13}
    - Press " LOG "
    - Press " $^+$/- "
- pOH = 12.6

SOME TERMS

- **pH meter:**
    - An electronic device that measures pH directly.
    - pH meters are used in most professional lab settings today.
- **Indicators:**
    - Weak organic acids and bases whose colors differ from the colors of their conjugate acids or bases.
    - The color is best viewed from above against a white background.
    - **Universal indicator solution** has a wide range of color changes:



    - **Hydrion paper:**
        - A paper that goes through changes similar to the universal indicator solution.
    - **Litmus paper:**
        - Red litmus paper turns blue in a base.
        - Blue litmus paper turns red in an acid.
        - There is a litmus liquid with similar color response.

SOURCES:

http://www.fda.gov/cder/drug/safety/sodiumphospate.htm
http://www.wkmerrimaninc.com/