

ARRHENIUS THEORY OF ACIDS & BASES NOTES

Acids increase concentration of \_\_\_\_\_ ions in aqueous solution.

- ~ Acids have more \_\_\_ ions than \_\_\_ ions.
- ~ Formulas for acids begin with \_\_\_.

Bases increase concentration of \_\_\_\_\_ ions in aqueous solution.

- ~ Bases have more \_\_\_ ions than \_\_\_ ions.
- ~ Formulas for bases end with \_\_\_.

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NAMING ACIDS NOTES

Binary acids (H + one element)

1. "hydro-"
2. root of name of second element
3. "-ic"

Practice:

- HF
- H<sub>2</sub>S

Oxyacids (H + more than 1 element)

1. root of polyatomic ion
2. a. If negative ion ends with "-ate", use "-ic" ending
- b. If negative ion ends with "-ite", use "-ous" ending

- HNO<sub>3</sub>

- HClO<sub>2</sub>

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MONOPROTIC & POLYPROTIC ACIDS NOTES

~ How many hydrogens does each type contain?

\* MONOPROTIC = \_\_\_ H's

\* DIPROTIC = \_\_\_ H's

\* TRIPROTIC = \_\_\_ H's

NEUTRALIZATION REACTIONS

~ ACID + BASE → \_\_\_\_\_ + \_\_\_\_\_  
H<sup>+</sup>neg + pos<sup>+</sup>OH<sup>-</sup>

~ salt:

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pH and pOH NOTES

Self-Ionization of Water:  $H_2O + H_2O \leftrightarrow H_3O^+ + OH^-$

- Water molecules have the ability to self-ionize.
- This is a naturally-occurring phenomenon.
- In one liter of pure water at 25 °C,  
the concentration of H<sub>3</sub>O<sup>+</sup> or simply H<sup>+</sup> = 0.0000001 moles/liter  
the concentration of OH<sup>-</sup> = 0.0000001 moles/liter

or

$$[H_3O^+] = [H^+] = 1.0 \times 10^{-7} \text{ moles/L}$$

$$[OH^-] = 1.0 \times 10^{-7} \text{ moles/L}$$

pH: the negative log of the hydrogen ion concentration [H<sup>+</sup>]

pOH: the negative log of the hydroxide ion concentration [OH<sup>-</sup>]

- Solve for the pH of pure water:

$$pH = -\log [H_3O^+] \qquad pOH = -\log [OH^-]$$

$$pH = -\log [1.0 \times 10^{-7}] \qquad pOH = -\log [1.0 \times 10^{-7}]$$

$$pH = 7 \qquad pOH = 7$$

- Equations that will be helpful when solving pH and pOH problems:

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

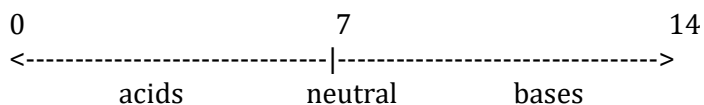
$$[H^+] = 10^{-pH}$$

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

$$[OH^-] = 10^{-pOH}$$

$$pH + pOH = 14$$

$$K_w = [H^+] \cdot [OH^-] = 1 \times 10^{-14}$$



**pH and pOH WORKSHEET**

Part 1 - Calculate the pH and identify as acidic, basic, or neutral.

- 1.)  $[H^+] = 1.0 \times 10^{-6} M$       pH = \_\_\_      A B N
- 2.)  $[H^+] = 2.61 \times 10^{-2} M$       pH = \_\_\_      A B N
- 3.)  $[H^+] = 4.0 \times 10^{-9} M$       pH = \_\_\_      A B N
- 4.)  $[H^+] = 5.9 \times 10^{-12} M$       pH = \_\_\_      A B N
- 5.)  $[H^+] = 1.0 \times 10^{-7} M$       pH = \_\_\_      A B N

Part 2 - Calculate the  $[H^+]$  and identify as acidic, basic, or neutral.

- 6.) pH = 4.00       $[H^+] =$  \_\_\_\_\_ M      A B N
- 7.) pH = 5.89       $[H^+] =$  \_\_\_\_\_ M      A B N
- 8.) pH = 7.00       $[H^+] =$  \_\_\_\_\_ M      A B N
- 9.) pH = 12.25       $[H^+] =$  \_\_\_\_\_ M      A B N
- 10.) pH = 9.11       $[H^+] =$  \_\_\_\_\_ M      A B N

Part 3 - Calculate the missing  $[H^+]$  or  $[OH^-]$  and identify as acidic, basic, or neutral.

- 11.)  $[H^+] = 4.2 \times 10^{-6} M$        $[OH^-] =$  \_\_\_\_\_ M      A B N
- 12.)  $[H^+] =$  \_\_\_\_\_ M       $[OH^-] = 8.7 \times 10^{-5} M$       A B N

Part 4 - Complete the following chart.

| Solution | pH    | pOH  | $[H^+]$                  | $[OH^-]$                | A, B, N |
|----------|-------|------|--------------------------|-------------------------|---------|
| A        | 3.68  |      |                          |                         |         |
| B        |       |      |                          | $8.60 \times 10^{-5} M$ |         |
| C        |       |      | $1.80 \times 10^{-13} M$ |                         |         |
| D        |       | 3.72 |                          |                         |         |
| E        | 10.84 |      |                          |                         |         |
| F        |       |      | $3.82 \times 10^{-10} M$ |                         |         |
| G        |       | 2.85 |                          |                         |         |

**ACID - BASE TITRATION NOTES**

**TITRATION:** process used in Chemistry lab to determine the concentration of an acid or a base; use a base or an acid with a known concentration to neutralize the acid or base with the unknown concentration  
 Titration problems are stoichiometry problems in disguise.

What is the molarity of a  $H_2SO_4$  solution if 190 mL of the acid is required to exactly neutralize 150 mL of a 2.5 M NaOH solution?      Eqn for neutralization:       $H_2SO_4 + 2 NaOH \rightarrow 2 H_2O + Na_2SO_4$

Reminder! Steps for stoichiometry:

- 1) Find moles of given substance. 2) Use mole ratio from balanced equation. 3) Find answer.

The problem says that there are 150 mL of a 2.5 M NaOH solution.

Molarity (M) =  $\frac{\text{moles of solute}}{\text{Liters of solution}}$       Use the molarity definition equation to calculate the number of moles of the given substance (in this case, NaOH).

Step 1 =       $2.5 = \frac{x}{0.15}$        $x = 0.375$  moles NaOH

Step 2 =       $\frac{0.375 \text{ moles NaOH}}{2} = \frac{x \text{ moles } H_2SO_4}{1}$        $x = 0.1875$  moles  $H_2SO_4$

Step 3 =  $M = \frac{0.1875 \text{ moles H}_2\text{SO}_4}{0.19 \text{ L}}$   $M = 0.99 \text{ M H}_2\text{SO}_4$

Because titrations always involve an acid and a base neutralizing each other, we don't have to go through all of these steps, the process can be shortened...

EQUATION TO USE FOR SOLVING TITRATION PROBLEMS:

$$n_A \cdot M_A \cdot V_A = n_B \cdot M_B \cdot V_B$$

$n_A$  = number of Hs at the beginning of the formula for the acid

$V_A$  = volume of the acid

$n_B$  = number of OHs in the formula for the base

$M_B$  = molarity of the base

$V_B$  = volume of the base

EXAMPLE PROBLEM:

What is the molarity of a  $\text{H}_2\text{SO}_4$  solution if 190 mL of the acid is required to exactly neutralize 150 mL of a 2.5 M NaOH solution? (Same problem as above. Just so you can see that we get the same answer...)

$$n_A \cdot M_A \cdot V_A = n_B \cdot M_B \cdot V_B$$

$$2 \cdot M \cdot 190 = 1 \cdot 2.5 \cdot 150$$

$$380 M = 375$$

$$M = 0.99 \text{ M}$$

What is the volume of a sample of 0.25 M HCl that requires 26.15 mL of 0.58 M NaOH to neutralize it?

ACID-BASE TITRATION WORKSHEET

1. A 25.0 mL sample of HCl was titrated to the endpoint with 15.0 mL of 2.0 M NaOH. What is the molarity of the HCl?
2. A 10.0 mL sample of  $\text{H}_2\text{SO}_4$  was exactly neutralized by 13.5 mL of 1.0 M KOH. What is the molarity of the  $\text{H}_2\text{SO}_4$ ?
3. How much 1.5 M NaOH is necessary to exactly neutralize 20.0 mL of 2.5 M  $\text{H}_3\text{PO}_4$ ?
4. How much of 0.50 M  $\text{HNO}_3$  is necessary to titrate 25.0 mL of 0.050 M  $\text{Ca(OH)}_2$  solution to the endpoint?
5. What is the molarity of NaOH solution if 15.0 mL is exactly neutralized by 7.5 mL of a 0.020 M  $\text{HClO}_3$  solution?

STRONG VS. WEAK ACIDS & BASES (ARRHENIUS THEORY) NOTES

Strong acid:

- The 6 strong acids are

Weak acid:

- any acid besides the 6 mentioned above

Strong base:

- Solution of strong base is called
- Strong bases contain any Group 1 or 2 metal (except Be) with OH-

Weak base:

- any base other than ones mentioned above

PROPERTIES OF ACIDS

- 1.
- 2.
- 3.
- 4.
- 5.

PROPERTIES OF BASES

- 1.
- 2.
- 3.
- 4.
- 5.

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BRONSTED-LOWRY ("B-L") THEORY OF ACIDS & BASES NOTES

~ Involve the transfer of a "proton". A proton is

Acid:

conjugate base (CB):

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Base:

conjugate acid (CA):

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How do you determine an acid's conjugate base and a base's conjugate acid?

~ An acid is a proton donor. So, conjugate base is the formula for the acid \_\_\_\_\_

\_\_\_\_\_  
 \*\* EXAMPLE: Acid = HCl; Conjugate Base (CB) = \_\_\_\_\_

~ A base is a proton acceptor/recipient. So, conjugate acid is the formula for the base \_\_\_\_\_

\_\_\_\_\_  
 \*\* EXAMPLE: Base = NO<sub>3</sub><sup>-1</sup>; Conjugate Acid (CA) = \_\_\_\_\_

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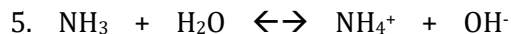
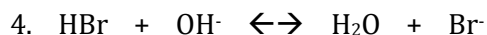
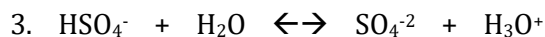
AMPHOTERISM NOTES

Example:



BRØNSTED - LOWRY ACIDS & BASES WORKSHEET

Label the Brønsted-Lowry acids (A), bases (B), conjugate acids (CA), and conjugate bases (CB) in the following reactions.



**CONJUGATE ACID-BASE PAIRS WORKSHEET**

| ACID  | BASE                          |
|---|-------------------------------|
|   | HSO <sub>4</sub> <sup>-</sup> |
| H <sub>3</sub> PO <sub>4</sub>              |                               |
|   | F <sup>-</sup>                |
|   | NO <sub>3</sub> <sup>-</sup>  |
| H <sub>2</sub> PO <sub>4</sub> <sup>-</sup> |                               |
| H <sub>2</sub> O                            |                               |

| ACID                           | BASE                          |
|--------------------------------|-------------------------------|
|                                | SO <sub>4</sub> <sup>-2</sup> |
| HPO <sub>4</sub> <sup>-2</sup> |                               |
| NH <sub>4</sub> <sup>+</sup>   |                               |
|                                | H <sub>2</sub> O              |
|                                | NO <sub>2</sub> <sup>-</sup>  |
| NH <sub>3</sub>                |                               |

STRENGTH RULE OF ACIDS & BASES (B-L theory):

\*\*The stronger a base is, the \_\_\_\_\_ its conjugate acid.

\*\*The weaker a base is, the \_\_\_\_\_ its conjugate acid.

\*\*The stronger an acid is, the \_\_\_\_\_ its conjugate base.

Which is a weaker base, Cl<sup>-</sup> or NO<sub>2</sub><sup>-</sup>?

Which is a stronger base, HSO<sub>4</sub><sup>-</sup> or H<sub>2</sub>PO<sub>4</sub><sup>-</sup>?

**Acid Dissociation Constant (K<sub>a</sub>) NOTES**

nA + mB  $\leftrightarrow$  eC + fD (general equilibrium rxn.)

Reminder #1  $K_{eq} = \frac{[C]^e [D]^f}{[A]^n [B]^m}$

Reminder #2 A weak acid does not completely dissociate (break into pos. & neg. ions); some remain together as molecules; "dissociation equation" for weak acids uses  $\leftrightarrow$

Example of a dissociation equation for a weak acid, HNO<sub>2</sub>:

How would we write the K<sub>eq</sub> expression for this?

The K<sub>eq</sub> gets renamed "K<sub>a</sub>" because it is dealing with the dissociation of an acid.

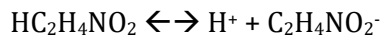
The value for K<sub>a</sub> for weak acids is very small because they do not dissociate very much.

**EXAMPLE PROBLEM:**

Nicotinic acid, HC<sub>2</sub>H<sub>4</sub>NO<sub>2</sub>, is a B vitamin. It is also a weak acid with K<sub>a</sub> = 1.4 x 10<sup>-5</sup>. What are the [H<sup>+</sup>] and pH of a 0.010 M solution of HC<sub>2</sub>H<sub>4</sub>NO<sub>2</sub>?

To solve...

1.) Write a dissociation equation for the weak acid.



2.) Write a K<sub>a</sub> expression for the reaction in step 1.

$$K_a = \frac{[H^+][C_2H_4NO_2^-]}{[HC_2H_4NO_2]}$$

3.) (All of the weak acids we will study are monoprotic. That means that the acid will only lose 1 H.

This means that the mole ratio between H<sup>+</sup> and the neg. ion in the equilibrium reaction will be 1:1.

Therefore, the [H<sup>+</sup>] = [neg. ion].) Substituting in the values from the problem...

$$1.4 \times 10^{-5} = \frac{[x][x]}{0.010}$$

$$1.4 \times 10^{-7} = x^2$$

$$x = 3.74 \times 10^{-4} \text{ M} = [H^+]$$

\* We assume that  $[\text{HC}_2\text{H}_4\text{NO}_2] = 0.010 \text{ M}$  because only a small amount dissociates. When the amount that actually dissociates is subtracted from the original concentration, the difference will be negligible.

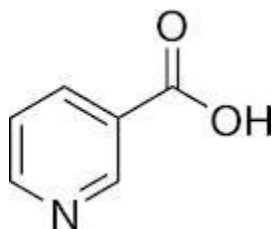
4.) To get the pH...  $\text{pH} = -\log[\text{H}^+]$   $\text{pH} = -\log[3.74 \times 10^{-4}] = 3.43$

Example on your own... Calculate the pH of a 1.00 M HF solution. The  $K_a$  for HF is  $7.2 \times 10^{-4}$ .

**Weak Acids &  $K_a$  WORKSHEET** (taken from *Chemistry – The Central Science*)

Before solving the problem, write out the dissociation equation for the weak acid. Then, write the  $K_{\text{eq}}$  expression for each. (This  $K_{\text{eq}}$  expression gets renamed  $K_a$  when used with acids.)

1. A student prepared a 0.10 M solution of formic acid,  $\text{HCHO}_2$  (monoprotic), and measured its pH at  $25^\circ\text{C}$  to be 2.38. Calculate the  $K_a$  for formic acid at this temperature.
2. Niacin, one of the B vitamins, has the following molecular structure: (When writing the dissociation equation for niacin, use "H-Nia" as the formula for niacin.)



A 0.020 M solution of niacin has a pH of 3.26. What is the acid dissociation constant,  $K_a$ , for the ionizable proton?

3. The  $K_a$  value for acetic acid at  $25^\circ\text{C}$  is  $1.8 \times 10^{-5}$ . What is the pH of a 0.30 M acetic acid solution at  $25^\circ\text{C}$ ?
4. Calculate the pH of a 0.20 M solution of HCN. (The  $K_a$  for HCN is  $4.9 \times 10^{-10}$ .)
5. The  $K_a$  for niacin is  $1.5 \times 10^{-5}$ . What is the pH of a 0.010 M solution of niacin?
6. Lactic acid,  $\text{HC}_3\text{H}_5\text{O}_3$ , has one acidic hydrogen. A 0.10 M solution of lactic acid has a pH of 2.44. Calculate the  $K_a$  for lactic acid.

Answers:

1.  $K_a = 1.8 \times 10^{-4}$ , 2.  $K_a = 1.5 \times 10^{-5}$ , 3.  $\text{pH} = 2.64$ , 4.  $\text{pH} = 5.00$ , 5.  $\text{pH} = 3.41$ , 6.  $K_a = 1.4 \times 10^{-4}$

**UNIT 14 REVIEW WORKSHEET**

Part 1 – Tell whether each of the following properties describes an acid (A), a base (B), or both (AB).

- |   |   |
|---|---|
| <input type="checkbox"/> 1. taste bitter                                  | <input type="checkbox"/> 6. 1 <sup>st</sup> element in formula is usually H |
| <input type="checkbox"/> 2. lose a proton (B-L Theory)                    | <input type="checkbox"/> 7. conduct electricity                             |
| <input type="checkbox"/> 3. feel slippery                                 | <input type="checkbox"/> 8. taste sour                                      |
| <input type="checkbox"/> 4. change color of indicators                    | <input type="checkbox"/> 9. gain a proton (B-L Theory)                      |
| <input type="checkbox"/> 5. 2 <sup>nd</sup> part of formula is usually OH | <input type="checkbox"/> 10. react with metals to form $\text{H}_2$ gas     |

Part 2 – Acid Nomenclature – Write the name or the formula for the following acids.

- |                                    |                      |
|------------------------------------|----------------------|
| 11. HI                             | 14. hydrobromic acid |
| 12. HNO <sub>2</sub>               | 15. carbonic acid    |
| 13. H <sub>3</sub> PO <sub>4</sub> | 16. sulfurous acid   |

Part 3 – Answer the following questions.

17. According to the Arrhenius theory, acids increase \_\_\_\_ ion concentration in aqueous solution.

Bases increase \_\_\_\_ ion concentration

18. List the six (6) strong acids.

19. How do you know if a base is strong or weak (in Arrhenius theory)?

20. The stronger a base is, the \_\_\_\_\_ its conjugate acid.

21. Which is a stronger base, ClO<sub>4</sub><sup>-1</sup> or S<sup>-2</sup>?

22. Which is a weaker base, I<sup>-1</sup> or SO<sub>4</sub><sup>-2</sup>?

23. What does it mean if a compound is said to be amphoteric?

24. Can SO<sub>4</sub><sup>-2</sup> be amphoteric? Why or why not?

25. What is the conjugate base of...

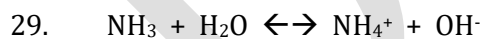
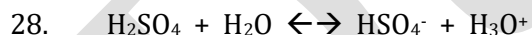
- (A) NH<sub>3</sub>                      (B) H<sub>2</sub>SO<sub>4</sub>                      (C) H<sub>2</sub>PO<sub>4</sub><sup>-</sup>

26. What is the conjugate acid of...

- (A) H<sub>2</sub>PO<sub>4</sub><sup>-</sup>                      (B) HSO<sub>4</sub><sup>-</sup>                      (C) HCO<sub>3</sub><sup>-</sup>

27. When an acid and a base react with each other, what are the two (2) products?

Part 4 – Draw lines between the conjugate acid-base pairs and label the acid (A), base (B), conjugate acid (CA), and conjugate base (CB).



Part 5 - Solve the following problems.

31. What is the pH of a solution whose [OH<sup>-</sup>] is 3.08 x 10<sup>-3</sup> M?

32. What is the [OH<sup>-</sup>] of a solution whose [H<sup>+</sup>] is 5.92 x 10<sup>-2</sup> M?

33. What is the concentration (molarity) of NaOH if 15.3 mL are needed to completely neutralize 20.4 mL of 2.50 M HCl?

34. What volume of 1.50 M  $\text{Ca}(\text{OH})_2$  is needed to reach the endpoint of a titration using 17.2 mL of 3.00 M  $\text{H}_3\text{PO}_4$ ?

Part 6 - Fill in the following chart.

| pOH  | pH    | $[\text{OH}^-]$                 | $[\text{H}^+]$                  | A, B, or N |
|------|-------|---------------------------------|---------------------------------|------------|
| 4.63 |       |                                 |                                 |            |
|      | 11.75 |                                 |                                 |            |
|      |       | $2.96 \times 10^{-8} \text{ M}$ |                                 |            |
|      |       |                                 | $5.27 \times 10^{-9} \text{ M}$ |            |

35. At 25°C, a 0.025 M solution of formic acid,  $\text{HCOOH}$ , is found to have a hydrogen ion concentration of  $2.03 \times 10^{-3} \text{ M}$ . Calculate the ionization constant of formic acid at 25°C.



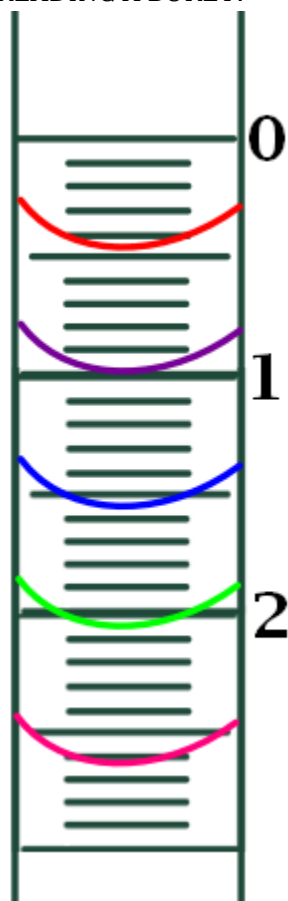
**ACID - BASE TITRATION LAB**

**PURPOSE:** - to determine the molarity of an aqueous solution of hydrochloric acid (HCl)  
- to learn and practice the technique for titration

**MATERIALS:**

| <u>EQUIPMENT</u>                 | <u>CHEMICALS</u>  |
|----------------------------------|-------------------|
| - 2 burets (labeled "A" and "B") | - _____ M NaOH    |
| - double buret clamp             | - phenolphthalein |
| - ring stand                     | - ? M HCl         |
| - Erlenmeyer flask               |                   |

**READING A BURET:**



**PROCEDURE:**

- 1.) Obtain approximately 10 mL of HCl from the buret labeled "A" for acid in the Erlenmeyer flask. (It is not necessary to have EXACTLY 10.00 mL. However, the volume of the HCl should be measured to the nearest hundredth.)
- 2.) Add 3 or 4 drops of phenolphthalein. (Only a few drops are needed. Adding more than 3 or 4 drops will not make the reaction any bigger or better.)
- 3.) Add NaOH from the buret labeled "B" for base SLOWLY until the solution changes color. (When the solution changes color, the acid is neutralized. Ideally, the solution in the flask should be a very faint shade of the color.)

DATA TABLE:

|   |                            | TRIAL 1 | TRIAL 2 | TRIAL 3 |
|---|----------------------------|---------|---------|---------|
| 1 | Reading of HCl (at start)  | mL      | mL      | mL      |
| 2 | Reading of HCl (at end)    | mL      | mL      | mL      |
| 3 | Volume of HCl used         | mL      | mL      | mL      |
|   |                            |         |         |         |
| 4 | Reading of NaOH (at start) | mL      | mL      | mL      |
| 5 | Reading of NaOH (at end)   | mL      | mL      | mL      |
| 6 | Volume of NaOH used        | mL      | mL      | mL      |

## QUESTIONS AND CALCULATIONS:

- 1.) Write a balanced equation for the neutralization reaction that occurs between hydrochloric acid (HCl) and sodium hydroxide (NaOH).
- 2.) What is the mole ratio between HCl and NaOH in the balanced equation?
- 3.) What volume of HCl was used in TRIAL 1? Show how you determined this volume.
- 4.) What volume of NaOH was used in TRIAL 1? Show how you determined this volume.
- 5.) The NaOH had a concentration of \_\_\_\_\_ M. Using your data, what is the concentration (molarity) of the hydrochloric acid? (CLEARLY and LEGIBLY show your calculations in detail!)
- 6.) If your group was able to do more than one successful trial, what was the average molarity?