Appendix 1.

Concept Analysis of Chemistry for Senior High School Eleventh Grade
Matter : Buffer Solution

No.	Concept Label	Definition of Concept	Kinds of Concept	Attribute of Concept		Position of Concept			Example	Non Example
				Attribute of Crisis	**Attribute of Variable**	**Sub Ordinate**	**Coordinate**	**Super Ordinate**		
1.	**Buffer Solution**	An aqueous solution that can maintain the pH of a system within a specified range when a small amount of acid or base is added, or when the system is diluted. (pH doesn't change significantly)	Concept have measurement attribute	• weak acid/ weak base • base conjugate/ acid conjugate	Bronsted Lowry of acid-base theory	Acidic buffer solution	Salt Hydrolysis	Acid-Base & Chemical Equilibrium	CH_3COOH solution + $NaCH_3COO$ solution	HCl solution + NaOH solution
2.	**Acidic buffer solution**	a weak acid solution comprising of its conjugate base is called acidic buffer solution.	Concept have measurement attribute	Weak acid / its base conjugate	Bronsted Lowry of acid-base theory	Basic buffer solution	Basic Buffer Solution	Acid-Base & Chemical Equilibrium	H_2CO_3 solution + $NaHCO_3$ solution	H_2SO_4 solution + NaOH solution
3.	**Basic buffer solution**	weak base solution comprising of its conjugate acid is called basic buffer solution.	Concept have measurement attribute	Weak base/ its acid conjugate	Bronsted Lowry of acid-base theory	-	Acidic buffer solution	Acid-Base & Chemical Equilibrium	NH_3 solution + NH_4Cl solution	NaOH solution + HNO_3 solution
4.	**K_a and K_b**	An equilibrium constant for the ionization of weak acid and weak base.	Abstract concept	Weak acid, weak base	Concentration of substance, temperature, mole, liter,	pH, pOH, Ionization degree	-	Kp and Kc	$CH_3COOH_{(aq)}$ + $H_2O_{(aq)} \leftrightarrow CH_3COO^-$	$2H_{2(g)} + O_{2(g)} \leftrightarrow 2H_2O_{(g)}$ Kc= 3×10^{81} at 25^oC

					pH, pOH				$_{(aq)}$ + $H_3O^+_{(aq)}$ Ka= 1.8 x 10^{-5}	
5.	**Ionization degree**	A tendention of a compound to ionize into its ions.	Abstract concept	Ionization of compound	Ionization degree (α), temperature, mole	Weak acid. Weak base, strong acid, strong base	Dissociation degree, pH and pOH	K_a and K_b	$NaCl_{(aq)} \leftrightarrow Na^+_{(aq)} + Cl^-_{(aq)}$	$2H_2O_{(l)} \leftrightarrow H_3O^+_{(aq)} + OH^-_{(aq)}$
6.	**Dissociation degree**	A tendention of a compound to dissociate into its ions.	Abstract concept	Dissociation of compound	Dissociation degree, mole, temperature	Weak acid. Weak base, strong acid, strong base	Ionization degree, pH and pOH	K_a and K_b	$HCl_{(aq)} + H_2O_{(aq)} \leftrightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$	$KCl_{(aq)} \leftrightarrow K^+_{(aq)} + Cl^-_{(aq)}$
7.	**pH and pOH buffer solution**	The negative logarithm of the concentration (mol/L) of the H_3O^+ or (H^+) and OH^- ion; that commonly used scale ranges from 0-14.	Abstract concept	Negative logarithm, H^+, OH^-	$[H^+]$, $[OH^-]$	-	Ionization degree	Ka and Kb	-	-
8.	**weak acid and weak base**	Acid or base that is ionized or dissociated partially, slightly, in dilute aqueous solution.	Based-principle concept	Ionization dissociation	Ionization degree, dissociation degree	-	Strong acid & strong base	Ionization degree, dissociation degree	$CH_3COOH_{(aq)} + H_2O_{(aq)} \leftrightarrow CH_3COO^-_{(aq)} + H_3O^+_{(aq)}$	$NaOH_{(aq)} \leftrightarrow Na^+_{(aq)} + OH^-_{(aq)}$
9.	**Base conjugate**	After releasing one proton, acid forms a species called as conjugate base. (it can attract back the proton and forms the acid again)	Abstract concept	Ionization dissociation	Ionization degree, dissociation degree	-	Weak acid / weak base	Ionization degree, dissociation degree	$HNO_2 \leftrightarrow H^+ + NO_2^-$	-

10.	**Acid conjugate**	After accepting one proton, base forms a species called as conjugate acid. (it can release one proton and forms base again)	Abstract concept	Ionization dissociation	Ionization degree, dissociation degree	-	Weak acid / weak base	Ionization degree, dissociation degree	$NH_3 + H^+ \leftrightarrow NH_4^+$	**-**

*Harizal, (2012), *Analyzing Of Students' Misconception On Acid-Base Chemistry At Senior High School In Medan*, Thesis, Mathematic and Natural Science Faculty, State University of Medan, Medan.

Appendix 2. Learning Material of Buffer Solution.

BUFFER SOLUTION

Attention:

Do not cite. Buffer Solution Material contained in this appendix are roughly compiled, without permission from the sources listed at the end of the material. For the citation of this material, it's strongly recommended to see the original and more detailed information by reading the books indicated in the references.

A. Conceptual Framework

Buffer solution is part of acid-base equilibria, because the fundamental concept to understanding of buffer solution, firstly must understanding acid-base chemistry concept and chemical equilibrium. In this learning material, we will address the different type of acid-base reactions and then move to study about buffer solution. So that, you can get a feeling for the importance of buffers in your world, we will also briefly discuss the chemistry of two important buffers in biological system. One of the more important types of acid-base solutions in terms of commercial and biological applications are buffers because they allow us to control the pH of a solution.

Buffers play an important role wherever you look:

- **Biology:** You are composed of molecules that depend on hydrogen bonding for their structure and function, and are therefore highly sensitive to pH. Most of the reactions in your body occur in aqueous solutions containing buffering agents. It is not surprising that human blood is highly buffered, for if blood is not maintained at a pH near 7.4, death can occur.
- **Industry:** Buffers are important in the syntheses of pharmaceutical chemicals, where the yield and purity of the desired product depends on solution pH.

Without buffers, an industrial process for the synthesis of a life-saving drug could yield a product contaminated with a poisonous impurity.

- **In your home:** Take a close look at your shampoo bottle, and you are likely to see the words ―pH balanced‖. Buffers are a central component in many consumer products, particularly personal hygiene products, where both effectiveness and safety depend on keeping the pH within a narrow range.

B. Overview of Acid-Base Reaction

You learned that acids and bases react to form water and a salt and that these reactions are called neutralization reactions because, on completion of the reaction, the solution is neutral. As shown in Table 2.1., however, acid-base reactions do not always result in the formation of a solution with a neutral pH. There are four classes of acid-base reactions: strong acid + strong base, strong acid + weak base, weak acid + strong base, and weak acid + weak base. For each, we will investigate the extent of reaction and the pH of the resulting solution when equimolar amounts of reactants are combined.

Table 2.1. Acid-Base Reaction

Reaction	Example	pH at Equilibrium
Strong acid + Strong base	$HCl_{(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(l)} + NaCl_{(aq)}$	= 7
Strong acid + Weak base	$H_3O^+_{(aq)} + NH_{3(aq)} \rightarrow H_2O_{(l)} + NH_4^+{}_{(aq)}$	< 7
Weak acid + Strong base	$HClO_{(aq)} + OH^-{}_{(aq)} \rightarrow H_2O_{(l)} + ClO^-{}_{(aq)}$	> 7
Weak acid + Weak base	$HClO_{(aq)} + NH_{3(aq)} <====> NH_4^+{}_{(aq)} + ClO^-{}_{(aq)}$	Depends on *K*a and *K*b

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C. Definition of Buffer Solution

A buffer solution is an aqueous solution that can maintain the pH of a system within a specified range when a small amount of acid or base is added, or when the system is diluted. A buffer solution contains a mixture of a weak acid and a weak base, typically the conjugate base of the weak acid. The principle property of a buffer solution is that it experiences a relatively small change in pH when a strong acid or a strong base is added. The ability of a buffer solution to resist pH change in a system is due to the fact that a buffer solution has acid-base components. The acid and base components generally take a form of a conjugate acid-base pair: weak acid and its conjugate base (HA/A^-) or weak base and its conjugate acid (B/BH^+).

Based on their components, buffer solution can be divided into two, i.e. acidic buffer solution and basic buffer solution. Acidic buffer solution maintain pH at acid areas (pH<7), meanwhile basic buffer solution maintain pH at basic areas (pH>7).

1. Acidic Buffer Solution (HA/A^-)

Acidic buffer solution is a weak acid solution comprising of its conjugate base. There are many ways to make acidic buffer solution:

(1) Mixture weak acid (HA) and its salt (MA salt produce A^- ion as conjugate base of weak acid (HA)

$$\underset{\text{weak acid}}{HA_{(aq)}} \rightleftharpoons H^+_{(aq)} + A^-_{(aq)}$$

$$\underset{\text{salt}}{MA_{(aq)}} \rightarrow M^+_{(aq)} + \underset{\text{Conjugate base}}{A^-_{(aq)}}$$

Example :

a. CH_3COOH solution + $NaCH_3COO$ solution (buffer's components: CH_3COOH and CH_3COO^-)

b. H_2CO_3 solution + $NaHCO_3$ solution (buffer's components: H_2CO_3 and HCO_3)

c. NaH_2PO_4 solution + Na_2HPO_4 solution (buffer's components: $H_2PO_4^-$ and HPO_4^{2-})

In water solvent, the weak acid HA undergoes partial dissociation and forms small amounts of H^+ and conjugate base A^-. The presence of the conjugate base A^- from salt MA will shift equilibrium of the weak acid HA though slightly as it is limited by very small concentration of H^+ ions. Thus, we obtain the acid component HA that comes from the weak acid HA and the base component A^- that is considered to come from the salt MA. The HA/A^- components will then act as "buffer" in attempts to change the pH of the system.

The equilibrium of the conjugate pair HA/A^- of buffer solution can be stated by its ionization constant, Ka

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

From the expression, the concentration of H^+ ions can be determined as follows:

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

The equation can be stated in the logarithmic form as follows:

$$-\log\left[H^+\right] = -\log K_a - \log\frac{\left[HA\right]}{\left[A^-\right]}$$

Thus we obtain the following equation known as the **Henderson-Hasselbalch equation**.

$$pH = pK_a - \log\frac{\left[HA\right]}{\left[A^-\right]}$$

(2) Acidic buffer solution also made by reacting weak acid with strong base in condition that weak acid residue is remaining while the strong base react completely.

$$CH_3COOH_{(aq)} + NaOH_{(aq)} \rightarrow CH_3COONa_{(aq)} + H_2O_{(l)}$$

Because NaOH reacts completely and there is CH_3COOH residue, in the end of reaction we have a mix of CH_3COOH and CH_3COONa which are the composing component of buffer solution. In the solution, the mix will form the following balance.

$$CH_3COOH_{(aq)} \rightleftharpoons CH_3COO^-_{(aq)} + H^+_{(aq)}$$

When a small amount of acid (H^+) or base (OH^-) is added into the solution, we will have the following reactions.

Acid added: $CH_3COO^-_{(aq)} + H^+_{(aq)} \rightleftharpoons CH_3COOH_{(aq)}$

Base added: $CH_3COOH_{(aq)} + OH^-_{(aq)} \rightleftharpoons CH_3COO^-_{(aq)} + H_2O_{(l)}$

The equilibrium equation above show that the equilibrium will shift to the left when acid added to the solution, acid (H^+) will react with CH_3COO^- ion to form acetic acid (CH_3COOH). In contrary, when base added to the solution, the OH- ion from its base will react with H^+ ion form water molecule. This is will shift the equilibrium to the right so the concentration can be maintained (doesn't change significantly). So, addition of base will decrease acid components (CH_3COOH), H^+ ion doesn't decrease. That base (OH^-) reacts with CH_3COOH to form CH_3COO^- ion and H_2O. Basically, the value of [CH_3COO^-/ CH_3COOH] has changed but the change is too small so that it is considered as constant.

2. Basic Buffer Solution

Basic buffer solution is weak base solution comprising of its conjugate acid. There are many ways to make basic buffer solution:

(1) Mixture weak base (B) and its salt (BHA)

$$\underbrace{B_{(aq)} + H2O_{(l)}}_{\text{weak base}} \rightleftharpoons BH^+_{(aq)} + OH^-_{(aq)}$$

$$\underbrace{BHA_{(aq)}}_{\text{salt}} \rightarrow \underbrace{BH^+_{(aq)}}_{\text{Conjugate acid}} + A^-_{(aq)}$$

Example :

a. NH_3 solution + NH_4Cl solution (Buffer's components: NH_3 and NH_4^+)

In water solvent, the weak base B undergoes partial dissociation and forms very little conjugate acid BH^+ and OH^- ions. Meanwhile the salt BHA will dissociate completely forming a large amount of conjugate acid BH^+. This causes the equilibrium of the weak base B to shift, though slightly, as it is limited by the very little concentration of OH^- ions. As a result, we obtain the base component B and also the acid component BH^+ that is considered to come from the salt B only. The B/BH^+ components will then act as "buffer" in attempts to change the pH of the system.

The equilibrium of the conjugate pair B/BH^+ of a buffer solution can be stated by its ionization constant, K_b.

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

In the expression, the concentration of OH^- ions can be determined as follows:

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

The equation can stated in the logarithmic form as follows:

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

Thus, we obtain the following Henderson-Hasselbalch Equation:

$$pOH = pK_b - \log\frac{[B]}{[BH^+]}$$

And we know that

$$pH = 14 - pOH$$

(2) Basic buffer solution is also made by reacting weak base and strong acid in condition that weak base residue is remaining while the strong acid react completely.

$$NH_4OH_{(aq)} + HCl_{(aq)} \rightarrow NH_4Cl_{(aq)} + H_2O_{(l)}$$

Because HCl reacts completely and NH_4OH residue remains, there is a mix of NH_4OH and NH_4^+ (conjugate acid from NH_4OH) in the end of reaction. In the solution, the mix will form the following equilibrium.

$$NH_4OH_{(aq)} \rightleftharpoons NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$$

The equilibrium equation above shows that addition of acid (H^+) will shift the equilibrium to the right. The H^+ ions react with OH- ions form water and ammonia will ionize to form more OH^- ions. On the contrary, the addition of base (OH^-) will shift the equilibrium to the left. The NH_4^+ ions with acidic property will react with additional OH^- ions to form ammonia molecules. Thus, the pH of solution can be maintained (does not change significantly).

Addition of a small amount of an acid or a base will not change the pH of buffer solution significantly.

D. How Buffer Solution Work

The way buffer solutions HA/A- and B/BH+ work are based on the equilibrium of acid nad base components in the buffer solutions. The attempts to change pH by adding a small amount of acid (H+) or bae (OH-), or by dilution (adding H2O) will change the concentrations of the acid and base components (HA/A- or B/BH+) of the buffer solutions. As a result, the equilibrium is attained. The pH change that occurs can be calculated by using the Henderson-Hasselbalch equation.

Table 2.2. How buffer solutions work

	Buffer solution HA/A^- $pH = pK_a - \log \frac{[HA]}{[A^-]}$	Buffer solution B/BH^+ $pOH = pK_b - \log \frac{[B]}{[BH^+]}$ $pH = 14 - pOH$
Adding a small amount of acid (H^+)	The acid H^+ added will be neutralized by the base component A^- H+ + A- $\rightarrow$ HA Acid base component	The acid H^+ added will be neutralized by the base component, B. H^+ + B $\rightarrow BH^+$ Acid base

	of being added buffer solution The neutralization that occurs causes a decrease in the A^- concentration and an increase in the HA concentration. The ratio [HA]/[A+] in the Henderson-Hasselbalch equation will increase, which means the pH of the system will decreases.	component of being added buffer solution The neutralization that occurs causes a decrease in the B concentration and an increase in the BH^+ concentration. The ratio $[B]/[BH^+]$ in the Henderson-Hasselbalch equation will decrease, which means the pOH of the system will increase or the pH will decreases.
Adding a small amount of base (OH-)	The base OH^- added will be neutralized by the acid component, HA. OH^- + HA $\rightarrow A^- + H_2O$ base acid component of being added buffer solution The neutralization that occurs causes a decrease in the HA concentration and an increase in the A. concentration in the buffer solutions. The ratio $[HA]/[A^-]$in the Handerson-	The base OH- added will be neutralized by the acid component, HA. OH^- + BH^+ $\rightarrow B + H_2O$ base acid component of being added buffer solution The neutralization that occurs causes a decrease in the BH+ concentration and an increase in the B concentration in the buffer solutions. The ratio

	Hasselbalch equation will decrease, which means the pH of the system will increase.	$[B]/[BH^+]$in the Handerson-Hasselbalch equation will decrease, which means the pH of the system will increase.
Dilution (Adding H_2O)	Dilution will affect the moles of H^+ (H_3O^+) and OH^- in the system, which will cause a shift in the buffer solution equilibrium. $H_2O + HA \leftrightarrow H_3O^+ + A^-$ $H_2O + A^- \leftrightarrow H_3O^+ + HA$ As a result, the moles of the acid component HA and the base component A^- will each change. the ratio $[HA]/[A^-]$ in the Henderson-Hasselbalch Equation will change and affect the pH of the system but doesn't significantly. (The effect of dilution can be observed if Ka is relatively large ($K_a > 10^{-3}$) and the concentrations of the acid and base components HA/A^- are very small).	Dilution will affect the moles of H+ (H3O+) and OH- in the system, which will cause a shift in the buffer solution equilibrium. $H_2O + B \leftrightarrow BH^+ + OH^-$ $H_2O + BH^+ \leftrightarrow B + H_2O$ As a result, the moles of the base component B and the acid component BH^+ will each change. the ratio $[B]/[BH^+]$ in the Henderson-Hasselbalch Equation will change and affect the pH of the system but doesn't significantly. (The effect of dilution can be observed if Kb is relatively large ($K_b > 10^{-3}$) and the concentrations of the acid and base components B/BH^+ are very small).

The weak acid and conjugate base components of a buffer make it possible for buffer solutions to absorb strong acid or strong base without a significant pH change.

- When a strong acid is added to a buffer it reacts with the conjugate base and is completely consumed. Despite the addition of a strong acid, the pH of the buffer solution decreases only slightly.

  Example: When H_3O^+ is added to a nitrous acid-sodium nitrite buffer it consumes some of the conjugate base, forming additional nitrous acid.

  $H_3O^+{}_{(aq)} + NO_2{}^-{}_{(aq)} \rightarrow H_2O_{(l)} + HNO_{2(aq)}$
- When a strong base is added to a buffer it reacts with the weak acid and is completely consumed. Despite the addition of a strong base, the pH of the buffer solution increases only slightly.

  Example: When OH^- is added to a nitrous acid-sodium nitrite buffer it consumes some of the weak acid, forming additional nitrite ion.

  $OH^-{}_{(aq)} + HNO_{2(aq)} \rightarrow H_2O_{(l)} + NO_2{}^-{}_{(aq)}$

It is a common misconception that buffer pH remains constant when some strong acid or base is added. This is not the case. As shown in the following example, a buffer minimizes the pH change upon addition of strong acid or base because only the weak acid/conjugate base ratio of the buffer is affected. The pH changes, but only by a small amount.

EXAMPLE PROBLEM:

Adding Reagents to Buffer Solutions

Determine the pH change when 0.020 mol HCl is added to 1.00 L of a buffer solution that is 0.10 M in CH_3CO_2H and 0.25 M in $CH_3CO_2{}^-$.

SOLUTION:

Step 1. Write the balanced equation for the acid hydrolysis reaction.

$$CH_3CO_2H_{(aq)} + H_2O_{(l)} \Longleftrightarrow H_3O^+{}_{(aq)} + CH_3CO_2{}^-{}_{(aq)}$$

Step 2. Use the Henderson-Hasselbalch equation to calculate the pH of the buffer solution before the addition of HCl.

$$pH = pKa + \log\frac{CH_3CO_2^-}{CH_3CO_2H} = -\log(1.8x10^5) + \log\left(\frac{0.25}{0.10}\right) = 5.14$$

Step 3. Assume that the strong acid reacts completely with the conjugate base. Set up a stoichiometry table that shows the amount (mol) of species initially in the solution, the change in amounts of reactants and products (based on the amount of limiting reactant), and the amounts of reactants and products present after the acid-base reaction is complete.

	$H_3O^+_{(aq)}$ +	$CH_3CO_2^-{}_{(aq)}$ →	$H_2O_{(l)}$ +	$CH_3CO_2H_{(aq)}$
Initial (mol)	0.020	0.25		0.10
Change (mol)	–0.020	–0.020		+0.020
After reaction (mol)	0 0.23	0.12		

Step 4. Use the new weak acid and conjugate base concentrations to calculate the buffer pH after adding strong acid.

$$\left[CH_3CO_2H\right] = \frac{0.12mol}{1.00L} = 0.12M \qquad [CH_3CO_2^-] = \frac{0.23mol}{1.00L} = 0.23M$$

$$pH = pKa + \log\frac{CH_3CO_2^-}{CH_3CO_2H} = -\log(1.8x10^5) + \log\left(\frac{0.23}{0.12}\right) = 5.03$$

Addition of 0.020 mol of HCl to the buffer decreases the pH only slightly, by 0.11 pH units. If the same amount of HCl is added to 1.00 L of water, the pH decreases by 5.30 pH units, from a pH of 7.00 to a pH of 1.70.

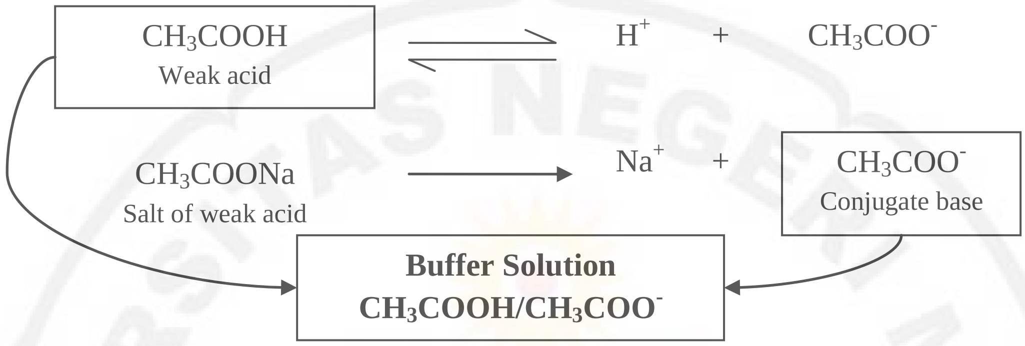
E. Preparing Buffer Solution

Buffer solution that contain acid and base components in the form of conjugate pairs, can be prepared as follows:

1. Buffer Solution HA/A-

- **Weak acid and Its salt**

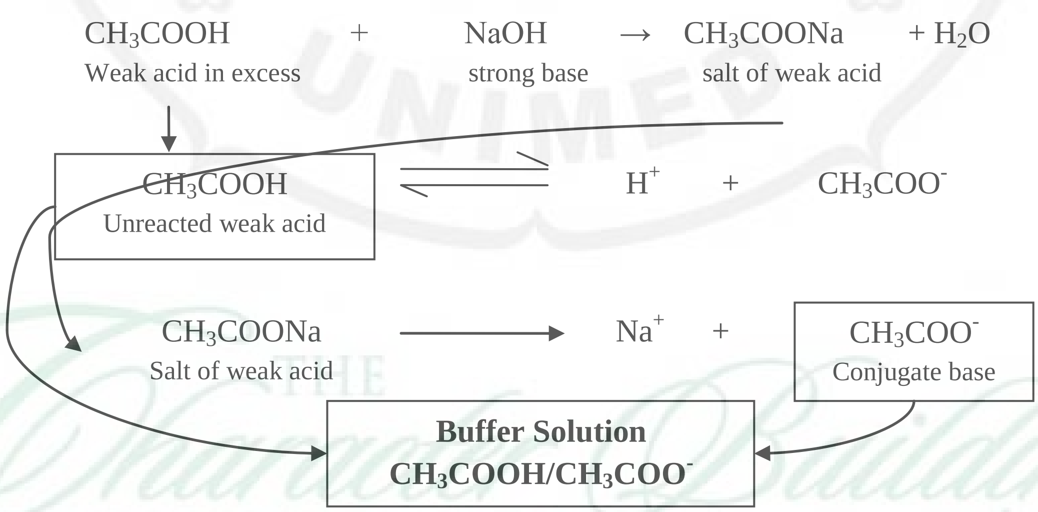
For example: buffer solution CH_3COOH/CH_3COO^- can be made from CH_3COOH and CH_3COONa.



- The acid component, CH_3COOH, in the buffer solution comes from the weak acid, CH_3COOH, which dissociate very slightly.
- The base component, CH_3COO^-, in the buffer solution is considered to only come from the salt of the weak acid, CH_3COONa, which dissociate completely.

- **Weak acid in excess + Strong base**

For example: buffer solution CH_3COOH/CH_3COO^- can be made from excess CH_3COOH and NaOH.

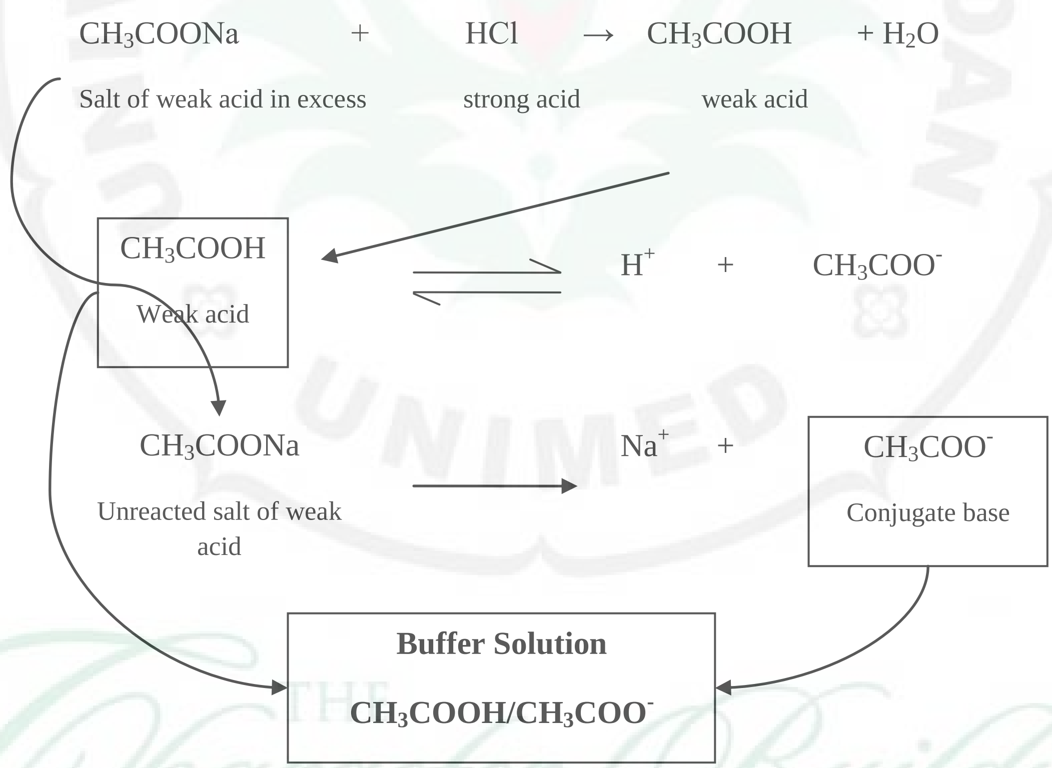


The excess weak acid, CH_3COOH, will react with the strong base, NaOH, to form the salt CH_3COONa.

- The acid component, CH_3COOH, in the buffer solution comes from the unreacted weak acid, CH_3COOH, which dissociates very slightly.
- The base component, CH_3COO^- , in the buffer solution is considered to only come from the salt of the weak acid, CH_3COONa, which dissociates completely.

  - **Salt of Weak Acid in excess + Strong acid**

  For example: buffer solution CH_3COOH/CH_3COO^- can be made from excess CH_3COONa and HCl.



The excess salt of the weak acid, CH_3COONa, will react with the strong acid, HCl, to form the weak acid, CH_3COOH.

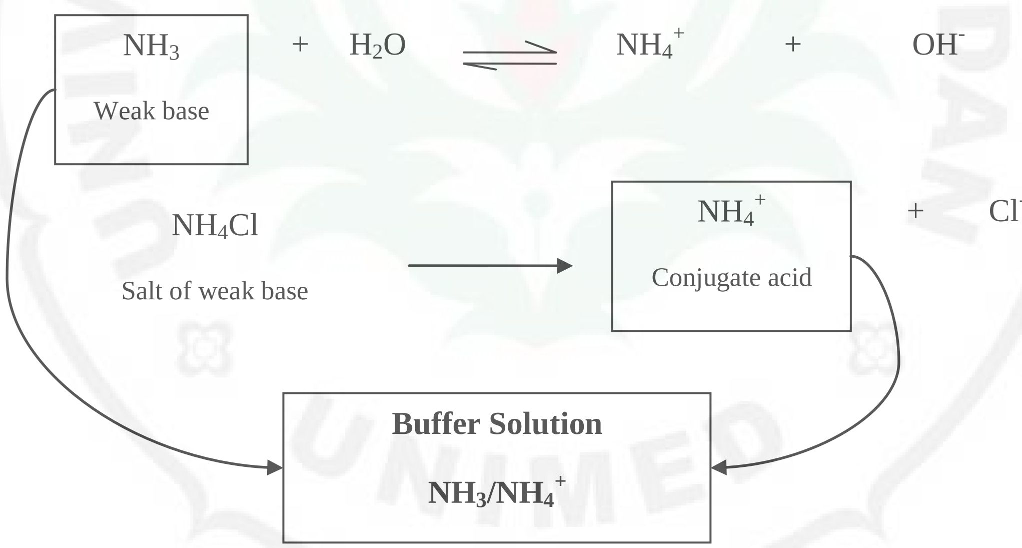
- The acid component, CH_3COOH, in the buffer solution comes from the weak acid, CH_3COOH, which dissociates very slightly.

- The base component, CH_3COO^-, in the buffer solution is considered to only come from the unreacted salt of the weak acid, CH_3COONa, which dissociates completely.

2. Buffer Solution B/BH^+

- **Weak base and Its salt**

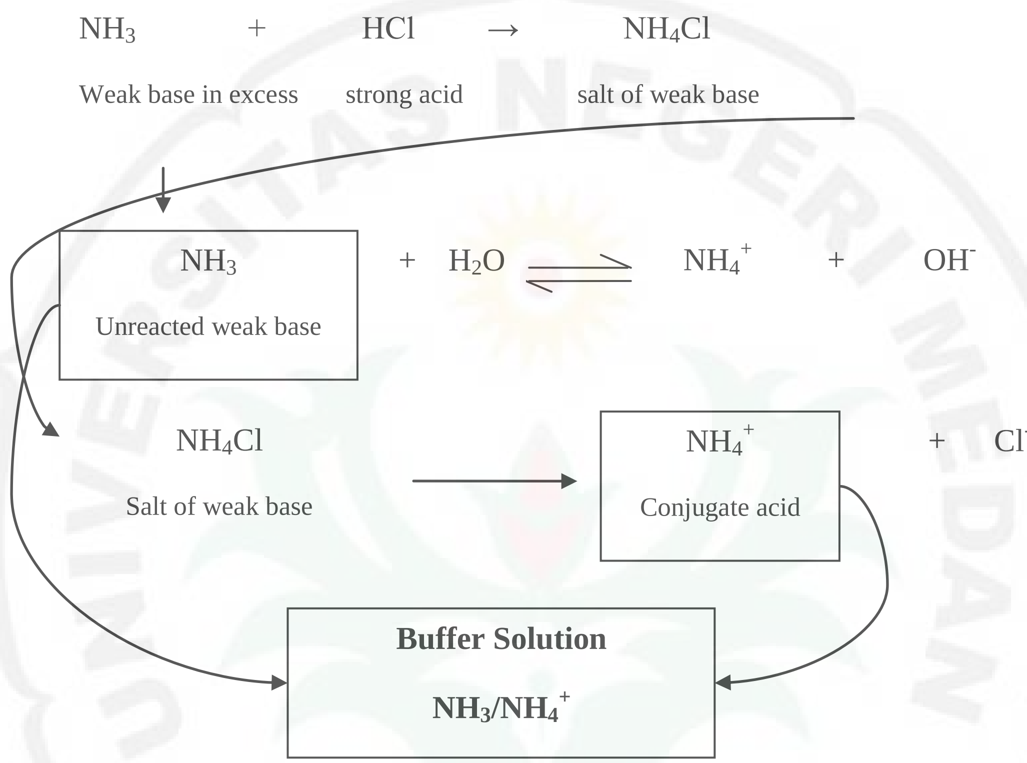
For example: Buffer solution NH_3/NH_4^+ can be made from NH_3 and NH_4Cl



- The base component, NH_3, in the buffer solution comes from the weak base, NH_3, which dissociates very slightly.
- The acid component, NH_4^+, in the buffer solution is considered to only come from the salt of the weak base, NH_4Cl, which dissociates completely.

- **Weak base in excess and Strong acid**

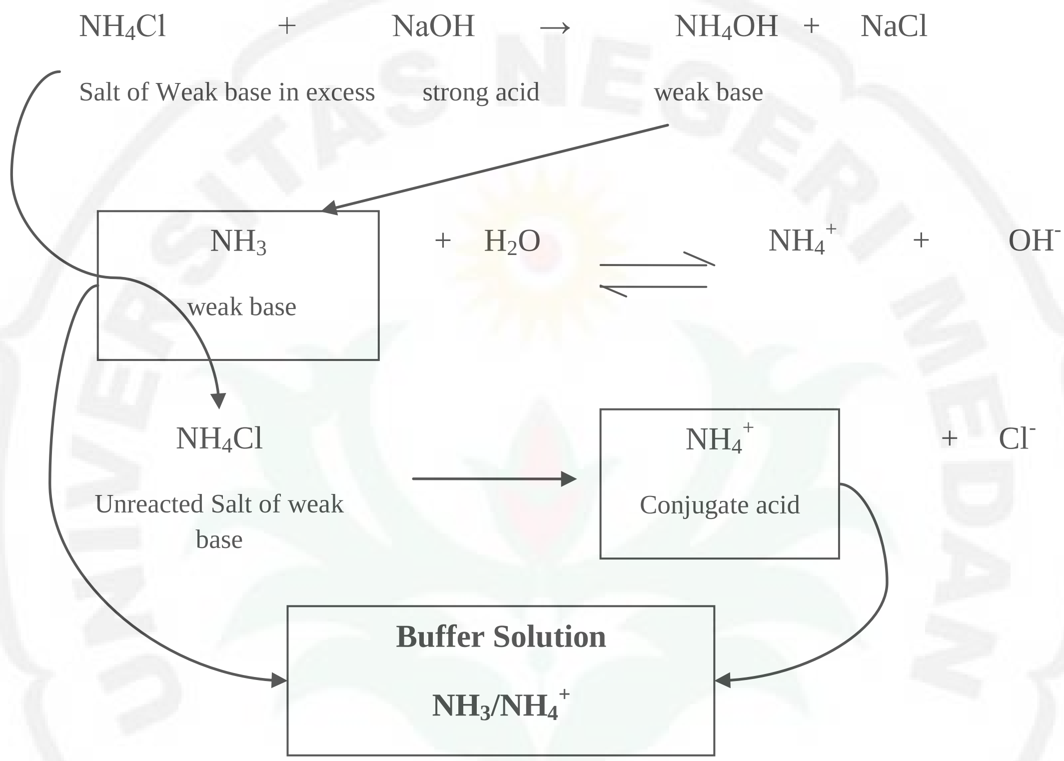
For example: Buffer solution NH_3/NH_4^+ can be made from NH_3 and HCl



The excess weak base, NH_3, will react with the strong acid HCl to form the salt of NH_4Cl.

- The base component, NH_3, will react with the strong acid, HCl, to form the salt of NH_4Cl.
- The acid component, NH_4^+, in the buffer solution is considered to only come from the salt of the weak base, NH_4Cl, which dissociates completely.
  - **Salt of Weak Base in excess + Strong Base**

    For example: Buffer solution NH_3/NH_4^+ can be made from NH_4Cl and NaOH.



The excess salt of the weak base, NH_4Cl, will react with the strong base, NaOH, to form the weak base, NH_4OH.

- The base component, NH_3, in the buffer solution comes from the weak base NH_3, which dissociates very slightly.
- The acid component, NH_4^+, in the buffer solution is considered to only come from the unreacted salt of the weak base, NH_4Cl, which dissociates completely.

The preparation of a buffer solution with a known pH is a two-step process.

- A weak acid/conjugate base pair is chosen for which the weak acid pKa is within about 1 pH unit of the desired pH. This guarantees that the [weak acid]:[conjugate base] ratio is between 10:1 and 1:10, ensuring that the solution will contain significant amounts of weak acid and conjugate base and will be able to buffer against the addition of strong acid or base.

- The desired pH and the weak acid pKa are used to determine the relative concentrations of weak acid and conjugate base needed to give the desired pH. Once the desired weak acid and conjugate base concentrations are known, the solution is prepared in one of two ways:

Method 1. Direct addition, where the correct amounts of the weak acid and conjugate base are added to water.

Method 2. Acid-base reaction, where, for example, a conjugate base is created by reacting a weak acid with enough strong base to produce a solution containing the correct weak acid and conjugate base concentrations.

F. Buffer Solution in Daily Life

Buffer solution are important in our daily life, be they within the body of human beings or in activities such as those in industries. Below are several of natural buffer solutions that are present in our blood and saliva, and prepared buffer solutions for hydroponic plants and industries.

a. Haemoglobin

Haemoglobin controls the pH of the blood between 7.35-7.45. haemoglobin binds O2 from respiration and forms equilibrium with oxyhaemoglobin.

$$HHb^{+} + O_2 \rightleftharpoons H^{+} + HbO_2^{-}$$

Haemoglobin acid — Oxyhaemoglobin

Attempts to change the blood pH take place in the metabolism process where the waste product, CO_2, forms H_2CO_3 that dissociate into H^+ and HCO_3^-. The increase of the H+ concentration will be neutralized by the oxyhaemoglobin.

b. Phosphate buffer $H_2PO_4^-/HPO_4^{2-}$ in blood, urine and saliva

- Phosphate buffer plays a dominant role in maintaining the pH of the blood in cells. This is because the value of its pK_a, 7.2 approach the pH of blood, 7.4.
- The concentration of phosphate buffer outside cells is relatively low. However, it plays an important role as buffer in urine with a wide pH range of 4.5-8.5. Drastic change in the blood pH is anticipated by the kidneys. If the pH decreases, i.e. the concentration of H^+ increases, the base component HPO_4^{2-} will bind to H^+ thus minimizing the decrease in pH. If the pH increases, the acid component $H_2PO_4^{2-}$ will release H^+. *(Kidneys will also form ammonia if the concentration of H^+ increases. Ammonia reacts with H+ to form ammonia salt that is excreted in urine).*
- Phosphate buffer solution in saliva neutralized the acid resulted from the fermentation of leftover food, and maintains the pH of the mouth at ~6.8. *(Acid condition can ruin the teeth and cause germs to penetrate the teeth).*

c. Carbonate buffer H_2CO_3/HCO_3^- in blood

Carbonate buffer is present in blood with ratio H_2CO_3/HCO_3^- = 1 : 20 to maintain the blood pH at ~7.4. the value of pKa for bicarbonate is around 6.1 and so it is not as dominant as the phosphate buffer above.

d. Buffer solutions for hydroponic plants

Every hydroponic plant has a certain pH range to grow well. To maintain the range of pH, buffer products, such as bio-enzyme, are now sold in the market. *(Hydroponic is a method of plantation with non-soil media, such as pebbles or clay).*

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Plants	pH range
Watermelon	4.5-5.5
Beans	5.5-6.5
Chili	5.5-7.0
Mangoes	5.5-7.5
Spinach	6.5-7.5

e. **Buffer solutions in industries**

Buffer solution are used in photography, waste treatment, and electroplating.

- In waste treatment, the pH of the process must be within the range 5-7.5 so that the organic matter can be separated. Waste can be disposed of in the sea when 90% of the solids have been separated and Cl_2 has been added.

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Appendix 3.

The Lattice of Buffer Solution Misconception Test (BSMT)

Concept Label	Indicators	Difficulties Level				Number of Items
		C1	C2	C3	C4	
• **How to prepare buffer solution**	✓ Explaining the component of buffer solution. ✓ Explaining how to prepare acidic buffer solution or basic buffer solution. ✓ Explaining how to prepare buffer solution in certain pH.	-	7, 11	1 12, 14	16	**6**
• **How Buffer Solution Work**	✓ Explaining how buffer solution work upon the addition of small amount of acid or base, and dilution.	-	2, 8, 18	17		**4**
• **Equilibrium System of buffer solution.**	✓ Explaining the equilibrium shift of buffer solution upon the addition of small amount of acid or base, and dilution.		4, 6	19		**3**
• **The change of pH of buffer solution.**	✓ Explaining the change of pH of buffer solution upon the addition of small amount of acid or base, and dilution.		5	15		**2**
• **Relation**	✓ Explaining the relationship of K_a and pH or			13	3, 10	**3**

between K_a and pH, pK_a and pH.	pH and pK_a.					
• **Buffer Solution in Daily Life**	✓ Explaining the function of buffer solution in body organism. ✓ Explaining the example of buffer solution in daily life.	9			20	**2**
Total						**20**

Appendix 4.

BUFFER SOLUTION MISCONCEPTION TEST (BSMT)

Instructions

Choose the most suitable option and the reason for your choice in each question by filling the appropriate circles in the answer sheet**. If you feel that all options given are inappropriate**, indicate the question number and write down what you think the correct answer should be at the back of the answer sheet.

1. When 100 mL acetic acid solution 0,2 M reacted by 100 mL NaOH solution 0,1 M will produce buffer solution.
   A. True
   B. False
   Reason:
   (1) Buffer solution composed of a mixture of strong acid and strong base.
   (2) Buffer solution composed of a mixture of weak acid and strong base with the same volume.
   (3) Buffer solution composed of a mixture of excess weak acid and strong base.
   (4) Buffer solution composed of a mixture of weak acid and weak base.
2. Buffer Solution can maintain the pH nearly constant.
   A. True
   B. False
   Reason:
   (1) Addition slightly acid/base or dilution will not change the pH of solution.
   (2) Addition slightly acid/base or dilution will shift the equilibrium of system and change the pH, but doesn't significantly.
   (3) Addition slightly acid/base or dilution will shift the equilibrium and increasing the pH significantly.

(4) Addition slightly acid/base or dilution will shift the equilibrium and decreasing the pH significantly.

3. Which is the following compound having the most acid characteristic…

   A. $CH_3COOH_{(aq)}$ + $CH_3COONa_{(aq)}$, where (K_a = 1.8 x 10^{-5})

   B. $NaH_2PO_{4(aq)}$ + $Na_2HPO_{4(aq)}$, where (K_a = 6.2 x 10^{-8})

   C. $HCOOH_{(aq)}$ + $Ca(HCOO)_{2(aq)}$, where (K_a = 1.8 x 10^{-4})

   Reason:

   (1) Higher K_a, higher the pH of buffers system.

   (2) Higher K_a, smaller the pH of buffers system.

   (3) Higher K_a, weaker the pH of buffers system.

   (4) Smaller K_a, stronger the acidity of buffers system.

4. Dilution will affect the mole of H^+ and OH^- in the system, which will cause equilibrium shift of buffers system.

   A. True

   B. False

   Reason:

   (1) The effects of dilution can be observed if K_a or K_b is relatively large and the concentrations of acid and base components are very small.

   (2) The effects of dilution can be observed if K_a or K_b is relatively small and the concentrations of acid and base components are very small.

   (3) The effects of dilution can be observed if K_a or K_b is relatively large and the concentrations of acid and base components are very large.

   (4) The effects of dilution can be observed in all circumstance.

5. Addition slightly acid in the buffer solutions will cause the change of pH and pK_a.

   A. True

   B. False

   Reason:

   (1) The change of pH is minimized a long addition slightly acid, so pK_a and pH remains constants.

(2) Addition slightly acid will cause the change of pK_a, but pH remains constants.
(3) Addition slightly acid will cause the change in pK_a and pH drastically.
(4) Addition slightly acid will affect the ratio of the concentrations of acid and base in buffer solutions.

6. Equilibrium system of base buffer solutions will not be disturbed although the addition of slightly acid/base or dilution.
   A. True
   B. False
   Reason:
   (1) Addition slightly acid will be neutralized by base component, so doesn't disturb the equilibrium system.
   (2) Addition slightly acid will shift the equilibrium to the right, because the acid reacted with the base component and increasing the acid conjugate.
   (3) Addition slightly base will shift the equilibrium to the right, because base reacted with the acid conjugate component and increasing weak base component.
   (4) Dilution will shift the equilibrium to the right, because of the change of the concentrations of acid and base.
7. Acid buffer solution can be prepared with reacted weak acid and weak base in the same mole.
   A. True
   B. False
   Reason:
   (1) Acid buffer solutions will be formed if base in excess and weak acid completely react.
   (2) Acid buffer solutions will be formed if weak acid in excess and base completely react.
   (3) Acid buffer solutions will be formed if both acid and base completely react.

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(4) Acid buffer solutions will be formed if the ratio of acid and base = 1:1.

8. When slightly base is added into the system that contains a buffer solution $HOCl/OCl^-$, so…

   a. [HOCl] decrease

   b. $[OCl^-]$ decrease

   c. $[HOCl]/[OCl^-]$ constant

   Reason:

   (1) Base added will be reacted with $[OCl^-]$ and completely react.
   (2) Base added will be reacted with [HOCl] and base component completely consume.
   (3) Base added will be reacted with acid component [HOCl] and acid component completely consume.
   (4) Acid component [HOCl] neutralized by base component, pH = constant.

9. pH of blood in human body remains constant.
   A. True
   B. False

   Reason:
   (1) The blood plasma contained of HCO_3^- and CO_2 dissolved acting captures H^+ or OH^- that enter into the blood.
   (2) In the human body there is a solution that can maintain a constant pH (pH does not change at all).
   (3) The blood contained hydroxide ion and CO_2 that is dissolved as buffer solution.
   (4) Acid substances that enter the body will be neutralized, so that the pH does not change at all.

10. Buffer solution with the smallest pH is…
   A. 10 mL CH_3COOH 0.20 M + 10 mL NaOH 0.05 M
   B. 10 mL CH_3COOH 0.25 M + 10 mL NaOH 0.15 M

C. 10 mL CH_3COOH 0.35 M + 10 mL NaOH 0.25 M

Reason:

(1) Smaller the change of ratio of acid and base component at Henderson Hasselbalch equation, smaller the change of pH will be occurred.

(2) Greater the change of ratio of acid and base component at Henderson Hasselbalch equation, smaller the change of pH will be occurred.

(3) Smaller the change of ratio of acid and base component at Henderson Hasselbalch equation, greater the change of pH will be occurred.

(4) Smaller the change of ratio of acid and base component at Henderson Hasselbalch equation, the change of pH will not be occurred.

11. Buffer solution $HCOOH/HCOO^-$ can be made from HCOOH and HCOONa.

A. True

B. False

Reason

(1) Acid component (HCOOH) in buffers system is come from weak acid (HCOOH), which dissociate completely.

(2) Base component ($HCOO^-$) in buffers system is considered come from salt of weak acid (HCOONa), which dissociate completely.

(3) Base component ($HCOO^-$) in buffers system is considered come from salt of weak acid (HCOONa), which dissociate partially.

(4) Acid component (HCOOH) in buffers system is come from its salt which dissociate completely.

12. For making buffer solution with pH 4, in 100 mL of CH_3COOH solution 0.5M ($Ka=10^{-5}$), must be added CH_3COONa 0.5 M as much as 20 mL.

A. True

B. False

Reason:

(1) Amount of mole of base component (CH_3COO^-) is determined from its salt (CH_3COONa), which dissociate partially and assumed in the x mole.

(2) Amount of mole of base component (CH_3COO^-) is determined from amount of mole of its salt (CH_3COONa), which dissociate completely and assumed in the x mole.
(3) Amount of mole of base component (CH_3COO^-) doesn't influenced by volume of its salt.
(4) Amount of mole of acid component come from its acid as much as 50 mol.

13. V mL NaOH 0.3 M is added by 2V mL CH_3COOH 0.3 M, if pKa = 5, so the pH of solution is 5.

A. True

B. False

Reason:

(1) pH = pKa, if the ratio [CH_3COO^-/CH_3COOH] >1.
(2) pH = pKa, if the ratio [CH_3COO^-/CH_3COOH] = 1.
(3) pH = pKa, if the ratio [CH_3COO^-/CH_3COOH] < 1.
(4) pH > pKa, if the ratio [CH_3COO^-/CH_3COOH] = 1.

14. For making solution with pH = 5, so into 100 mL of acetic acid solution 0.1M ($Ka=10^{-5}$) must be added by NaOH as much as 200g.

A. True

B. False

Reason:

(1) All of sodium hydroxide reacted in equilibrium reaction.
(2) All of acetic acid reacted in equilibrium reaction.
(3) Sodium hydroxide will excess in equilibrium reaction.
(4) Acetic acid will excess as much as 20 mmol in equilibrium reaction.

15. As much as 25 mL HNO_3 0.1 M added into 50 mL NH_4OH 0.1 M ($K_b = 2 \times 10^{-5}$), produced buffer solution with pH = 5-log2. If, that buffer solution added by 5 mL HCl 0.01 M , so the pH will change drastically.

A. True

B. False

Reason:

(1) Addition of HCl solution will decrease concentration of NH_4OH. So, the pH decrease drastically, pH < 5- log 2.
(2) Addition of HCl solution will increase concentration of its conjugate acid. So, the pH increase, pH > 5 – log 2.
(3) Addition of HCl solution will decrease the pH, but relatively small, pH < 5 – log 2.
(4) Addition of HCl solution will increase the pH drastically, pH > 5- log 2.

16. Which is buffer solution…
A. 100 mL Sodium hydroxide 0.1 M + 100 mL Chloride acid 0.1 M
B. 50 mL Nitrite acid 0.1 M + 100 mL Sodium nitrite 0.1 M
C. 100 mL Nitric acid 0.1 M + 50 mL Sodium nitrate 0.1 M
Reason:
(1) Come from acid and base mixture.
(2) Nitrite acid is weak base and Sodium nitrite is the source of its conjugate base, nitrite ion.
(3) Nitric acid is weak base and Sodium nitrate is the source of its conjugate base, nitrate ion.
(4) Come from the mixture of acid and its salt.

17. When one liter of a 0.50 M HOAc/0.50 M OAc^- buffer solution is diluted to a volume of two liters, the:
A. pH is doubled
B. pH is halved
C. $[H_3O^+]$ is nearly constant
Reason:
(1) Dilution will increase volume of solutions, so pH increase drastically.
(2) Addition of water will influence equilibrium system, but doesn't change the pH significantly.
(3) Addition of water doesn't influence equilibrium system, pH remain constant.

(4) Dilution will increase volume of solutions and decreasing the pH drastically.

18. When HCl solution added to buffers system, so the pH slightly _____, concentration of HF _____, and concentration of F^- _____.
    A. Increase, Increase, Increase
    B. Decrease, Increase, Decrease
    C. Decrease, Decrease, Increase

    Reason:
    (1) HCl ionized partially in the water to form H^+ ion which neutralized by base component $[F^-]$.
    (2) HCl ionized completely in the water to form H^+ ion which neutralized by base component $[F^-]$.
    (3) HCl shift the equilibrium to the right and increasing the pH.
    (4) H^+ ion in HCl have consumed base component $[F^-]$ and shift the equilibrium to the right.

19. If 10 mL nitric acid 0.01 M added to 15 ml HCN 0.1 M + 15 ml NaCN 0.1 M, so equilibrium will…
    A. Shift to the right
    B. Shift to the left
    C. constant

    Reason:
    (1) H^+ ion in the nitric acid reacted with CN^- from HCN and consumed HCN concentration.
    (2) H^+ ion in nitric acid reacted with CN- from NaCN and consumed NaCN concentration.
    (3) H^+ ion in the nitric acid reacted with its base conjugate cause increasing the pH.
    (4) Nitric acid component neutralize by base component without disturbing the equilibrium system.

20. Example of buffer solution in daily life, except…
    A. Bio-enzym

B. Shampoo

C. Vinegar

Reason:

(1) Contain acid and base components.

(2) pH = 7 have neutral characteristic.

(3) pH > 7 have base characteristic.

(4) pH < 7 have acid characteristic.

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Appendix 5.

Answer Key of BSMT

Test Item	SC	PC					SM					
Item 1	A(3)	A(1)	A(2)	A(4)	B(3)	-	B(1)	B(2)	B(4)	-	-	-
Item 2	A(2)	A(1)	A(3)	A(4)	B(2)	-	B(1)	B(3)	B(4)	-	-	-
Item 3	C(2)	C(1)	C(3)	C(4)	A(2)	B(2)	A(1)	A(3)	A(4)	B(1)	B(3)	B(4)
Item 4	A(1)	A(2)	A(3)	A(4)	B(1)	-	B(2)	B(3)	B(4)	-	-	-
Item 5	B(4)	B(1)	B(2)	B(3)	A(4)	-	A(1)	A(2)	A(3)	-	-	-
Item 6	B(2)	B(1)	B(3)	B(4)	A(2)	-	A(1)	A(3)	A(4)	-	-	-
Item 7	B(2)	B(1)	B(3)	B(4)	A(2)	-	A(1)	A(3)	A(4)	-	-	-
Item 8	A(3)	A(1)	A(2)	A(4)	B(3)	C(3)	B(1)	B(2)	B(4)	C(1)	C(2)	C(4)
Item 9	A(1)	A(2)	A(3)	A(4)	B(1)	-	B(2)	B(3)	B(4)	-	-	-
Item 10	C(1)	C(2)	C(3)	C(4)	A(1)	B(1)	A(2)	A(3)	A(4)	B(2)	B(3)	B(4)
Item 11	A(2)	A(1)	A(3)	A(4)	B(2)	-	B(1)	B(3)	B(4)	-	-	-
Item 12	B(2)	B(1)	B(3)	B(4)	A(2)	-	A(1)	A(3)	A(4)	-	-	-
Item 13	B(2)	B(1)	B(3)	B(4)	A(2)	-	A(1)	A(3)	A(4)	-	-	-
Item 14	B(1)	B(2)	B(3)	B(4)	A(1)	-	A(2)	A(3)	A(4)	-	-	-
Item 15	B(3)	B(1)	B(2)	B(4)	A(3)	-	A(1)	A(2)	A(3)	-	-	-
Item 16	B(2)	B(1)	B(3)	B(4)	A(2)	C(2)	A(1)	A(3)	A(4)	C(1)	C(3)	C(4)
Item 17	C(2)	C(1)	C(3)	C(4)	A(2)	B(2)	A(1)	A(3)	A(4)	B(1)	B(3)	B(4)
Item 18	B(2)	B(1)	B(3)	B(4)	A(2)	C(2)	A(1)	A(3)	A(4)	C(1)	C(3)	C(4)
Item 19	B(2)	B(1)	B(3)	B(4)	A(2)	C(2)	A(1)	A(3)	A(4)	C(1)	C(3)	C(4)
Item 20	C(4)	C(1)	C(2)	C(3)	A(4)	B(4)	A(1)	A(2)	A(3)	B(1)	B(2)	B(3)

Appendix 6.

Percentage of Students' Responses

Test Item	Categories	Sample						Total
		School A	School B	School C	School D	School E	School F	
1	SC	15	28	2	23	17	15	100
	PC	3	13	15	10	13	15	69
	SM	**0**	**0**	**1**	**1**	**8**	**1**	**11**
	NR	1	0	1	0	0	2	4
2	SC	12	17	12	9	14	5	69
	PC	6	24	7	24	22	26	109
	SM	**0**	**0**	**0**	**1**	**1**	**2**	**4**
	NR	1	0	0	0	1	0	2
3	SC	8	13	6	19	10	1	57
	PC	3	13	3	14	13	15	61
	SM	**0**	**14**	**10**	**1**	**14**	**17**	**56**
	NR	8	1	0	0	1	0	10
4	SC	6	0	3	2	4	17	32
	PC	3	1	8	29	25	15	81
	SM	**0**	**40**	**8**	**2**	**6**	**1**	**57**
	NR	10	0	0	1	3	0	14
5	SC	0	1	9	26	8	7	51
	PC	13	37	7	2	16	12	87
	SM	**6**	**0**	**3**	**6**	**14**	**13**	**42**
	NR	0	3	0	0	0	1	4
6	SC	0	16	1	2	6	1	26
	PC	12	0	3	8	14	22	59
	SM	**3**	**21**	**15**	**23**	**17**	**9**	**88**
	NR	4	4	0	1	1	1	11

7	SC	12	36	16	23	21	11	119
	PC	4	4	1	8	6	18	41
	SM	**3**	**0**	**2**	**0**	**11**	**4**	**20**
	NR	0	1	0	3	0	0	4
8	SC	0	0	0	4	1	2	7
	PC	8	9	14	30	21	23	103
	SM	**5**	**31**	**5**	**0**	**15**	**6**	**62**
	NR	6	1	0	0	1	2	10
9	SC	19	6	2	31	24	4	86
	PC	0	35	15	3	10	27	90
	SM	**0**	**0**	**2**	**0**	**1**	**2**	**5**
	NR	0	0	0	0	3	0	3
10	SC	1	0	0	0	0	0	1
	PC	0	24	13	13	20	6	76
	SM	**4**	**9**	**4**	**17**	**17**	**27**	**78**
	NR	14	8	2	4	1	0	30
11	SC	4	0	4	11	0	1	20
	PC	11	1	12	5	19	22	70
	SM	**0**	**35**	**2**	**16**	**18**	**10**	**81**
	NR	4	5	1	2	1	0	13
12	SC	0	0	2	2	5	12	21
	PC	6	28	2	9	23	11	79
	SM	**0**	**10**	**15**	**23**	**4**	**9**	**61**
	NR	13	3	0	0	6	1	23
13	SC	2	0	0	13	1	6	22
	PC	15	37	17	8	17	16	110
	SM	**0**	**2**	**2**	**13**	**19**	**11**	**47**
	NR	2	2	0	0	1	0	5
14	SC	0	0	0	0	16	3	19

	PC	13	2	14	16	16	20	81
	SM	**3**	**34**	**4**	**18**	**3**	**10**	**72**
	NR	3	5	1	0	3	0	12
15	SC	0	0	0	0	19	1	20
	PC	2	21	15	17	7	16	78
	SM	**8**	**17**	**3**	**15**	**12**	**15**	**70**
	NR	9	3	1	2	0	1	16
16	SC	13	20	0	1	2	0	36
	PC	0	15	4	14	5	1	39
	SM	**1**	**6**	**15**	**18**	**29**	**30**	**99**
	NR	5	0	0	1	2	2	10
17	SC	0	0	2	2	0	0	4
	PC	1	2	3	3	4	7	20
	SM	**2**	**38**	**13**	**28**	**31**	**24**	**136**
	NR	16	1	1	1	3	2	24
18	SC	12	0	1	1	1	0	15
	PC	0	37	5	14	28	23	107
	SM	**2**	**1**	**13**	**18**	**6**	**8**	**48**
	NR	5	3	0	1	3	2	14
19	SC	0	0	0	0	0	2	2
	PC	0	18	12	12	6	12	60
	SM	**0**	**20**	**7**	**22**	**28**	**18**	**95**
	NR	19	3	0	0	4	1	27
20	SC	1	0	2	17	2	0	22
	PC	12	41	3	13	20	17	106
	SM	**0**	**0**	**14**	**4**	**13**	**16**	**47**
	NR	6	0	0	0	3	0	9
Number of Students		**19**	**41**	**19**	**34**	**38**	**33**	184

Appendix 7

Data of diagnostic test for grouping students of school A

Students' code	Score	Mark	Categories
A.01	6	30	HG
A.02	6	30	HG
A.03	6	30	HG
A.04	6	30	HG
A.05	6	30	HG
A.06	6	30	HG
A.07	6	30	HG
A.08	5	25	MG
A.09	5	25	MG
A.10	5	25	MG
A.11	5	25	MG
A.12	5	25	MG
A.13	4	20	MG
A.14	4	20	MG
A.15	4	20	MG
A.16	4	20	MG
A.17	4	20	MG
A.18	3	15	LG
A.19	3	15	LG
Total		**465**	
Mean		**24.47**	
SD		**5.24**	

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Appendix 8

Data of diagnostic test for grouping students of school B

Students' code	Score	Mark	Categories
B.01	5	25	HG
B.02	5	25	HG
B.03	5	25	HG
B.04	5	25	HG
B.05	4	20	MG
B.06	4	20	MG
B.07	4	20	MG
B.08	4	20	MG
B.09	4	20	MG
B.10	4	20	MG
B.11	4	20	MG
B.12	4	20	MG
B.13	4	20	MG
B.14	4	20	MG
B.15	4	20	MG
B.16	4	20	MG
B.17	4	20	MG
B.18	4	20	MG
B.19	3	15	MG
B.20	3	15	MG
B.21	3	15	MG
B.22	3	15	MG
B.23	3	15	MG
B.24	3	15	MG
B.25	3	15	MG
B.26	3	15	MG
B.27	3	15	MG
B.28	3	15	MG
B.29	3	15	MG
B.30	3	15	MG
B.31	2	10	LG
B.32	2	10	LG
B.33	2	10	LG
B.34	2	10	LG
B.35	2	10	LG
B.36	2	10	LG
B.37	2	10	LG
B.38	2	10	LG
B.39	2	10	LG
B.40	2	10	LG
B.41	1	5	LG
Total		**665**	
Mean		**16.21**	
SD		**5.09**	

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Appendix 9

Data of diagnostic test for grouping students of school C

Students' code	Score	Mark	Categories
C.01	6	30	HG
C.02	3	15	MG
C.03	3	15	MG
C.04	3	15	MG
C.05	3	15	MG
C.06	3	15	MG
C.07	3	15	MG
C.08	3	15	MG
C.09	3	15	MG
C.10	2	10	MG
C.11	2	10	MG
C.12	2	10	MG
C.13	2	10	MG
C.14	2	10	MG
C.15	2	10	MG
C.16	2	10	MG
C.17	2	10	MG
C.18	1	5	LG
C.19	1	5	LG
Total		**240**	
Mean		**12.63**	
SD		**5.36**	

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Appendix 10

Data of diagnostic test for grouping students of school D

Students' code	Score	Mark	Categories
D.01	9	45	HG
D.02	9	45	HG
D.03	7	35	MG
D.04	7	35	MG
D.05	7	35	MG
D.06	7	35	MG
D.07	7	35	MG
D.08	7	35	MG
D.09	7	35	MG
D.10	6	30	MG
D.11	6	30	MG
D.12	6	30	MG
D.13	6	30	MG
D.14	6	30	MG
D.15	6	30	MG
D.16	6	30	MG
D.17	6	30	MG
D.18	6	30	MG
D.19	5	25	MG
D.20	5	25	MG
D.21	5	25	MG
D.22	4	20	MG
D.23	4	20	MG
D.24	4	20	MG
D.25	3	15	LG
D.26	3	15	LG
D.27	3	15	LG
D.28	3	15	LG
D.29	3	15	LG
D.30	3	15	LG
D.31	3	15	LG
D.32	3	15	LG
D.33	2	10	LG
D.34	2	10	LG
Total		**880**	
Mean		**25.88**	
SD		**9.57**	

Appendix 11

Data of diagnostic test for grouping students of school E

Students' code	Score	Mark	Categories
E.01	8	40	HG
E.02	5	25	HG
E.03	5	25	HG
E.04	5	25	HG
E.05	5	25	HG
E.06	5	25	HG
E.07	5	25	HG
E.08	5	25	HG
E.09	4	20	MG
E.10	4	20	MG
E.11	4	20	MG
E.12	4	20	MG
E.13	4	20	MG
E.14	4	20	MG
E.15	4	20	MG
E.16	4	20	MG
E.17	4	20	MG
E.18	4	20	MG
E.19	4	20	MG
E.20	3	15	MG
E.21	3	15	MG
E.22	3	15	MG
E.23	3	15	MG
E.24	3	15	MG
E.25	3	15	MG
E.26	3	15	MG
E.27	3	15	MG
E.28	3	15	MG
E.29	3	15	MG
E.30	3	15	MG
E.31	3	15	MG
E.32	3	15	MG
E.33	3	15	MG
E.34	2	10	LG
E.35	2	10	LG
E.36	2	10	LG
E.37	2	10	LG
E.38	1	5	LG
Total		690	
Mean		18.15	
SD		6.19	

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Appendix 12

Data of diagnostic test for grouping students of school F

Students' code	Score	Mark	Categories
F.01	5	25	HG
F.02	5	25	HG
F.03	4	20	HG
F.04	4	20	HG
F.05	4	20	HG
F.06	4	20	HG
F.07	4	20	HG
F.08	4	20	HG
F.09	4	20	HG
F.10	4	20	HG
F.11	3	15	MG
F.12	3	15	MG
F.13	3	15	MG
F.14	3	15	MG
F.15	3	15	MG
F.16	3	15	MG
F.17	2	10	MG
F.18	2	10	MG
F.19	2	10	MG
F.20	2	10	MG
F.21	2	10	MG
F.22	2	10	MG
F.23	2	10	MG
F.24	2	10	MG
F.25	2	10	MG
F.26	1	5	LG
F.27	1	5	LG
F.28	1	5	LG
F.29	1	5	LG
F.30	1	5	LG
F.31	1	5	LG
F.32	0	0	LG
F.33	0	0	LG
Total		**420**	
Mean		**12.72**	
SD		**6.85**	

Appendix 13

Table of Learning Source in each SHS

No.	Code of Schools	Code of Teacher	Teaching Experience	Sertification	Learning source/Books
1.	School A	Mr. R	19 Year	Yes	Erlangga
2.	School B	Mrs. E	10 Year	Yes	Masmedia
3.	School C	Mrs. P	19 year	Yes	Masmedia
4.	School D	Mrs. S	16 Year	Yes	Facil Grafindo
5.	School E	Mr. P	19 Year	Yes	Masmedia
6.	School F	Mrs. T	8 Year	No	Erlangga

Appendix 14

Documentations

Picture 1. The Students were answering BSMT in School A.

Picture 2. The Students were answering BSMT in School A.

Picture 3.The researcher was giving the test sheet to each student in School B

Picture 4. The Students were answering BSMT in School B.

Picture 5. The Students were answering BSMT in School C.

Picture 6. The researcher was monitoring the students in answering BSMT in School C.

Picture 7.The researcher was giving the test sheet to each student in School D

Picture 8. The Students were answering BSMT in School D.

Picture 9. The Students were answering BSMT in School E.

Picture 10.The researcher was giving the test sheet to each student in School E

Picture 11. The researcher was giving the test sheet to each student in School F

Picture 12. The researcher was giving students the instruction in answering BSMT in School F

Appendix 15

SURAT KETERANGAN
(VALIDASI ISI INSTRUMENT SOAL)

Yang bertandatangan di bawah ini menerangkan bahwa Instrumen penelitian yang akan digunakan oleh:

Nama : SITI RAHMAH
Nim : 409332030
Jurusan : Kimia
Program Studi : Pendidikan Kimia Bilingual

dengan Judul Penelitian **"Analyzing of Students' Misconceptions on Buffer Solution at Senior High Schools in Medan"**, benar telah dibaca butir per butir dan muatannya telah sesuai dengan instrument hasil belajar siswa. Hasil pemeriksaan menyimpulkan bahwa instrument tersebut telah dapat digunakan dalam penelitian.

Demikian Surat Keterangan ini diperbuat untuk dapat dipergunakan seperlunya.

Medan, Maret 2013
Validator Instrumen

Dr. Retno Dwi Suyanti, M.Si
NIP. 19660126 199103 2 003

UNIVERSITAS NEGERI MEDAN
UNIMED
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Appendix 16

UNIVERSITAS NEGERI MEDAN
(STATE UNIVERSITY OF MEDAN)
FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM
(FACULTY OF MATHEMATICS AND NATURAL SCIENCES)
KELAS BILINGUAL / KELAS BERSTANDAR INTERNASIONAL
Jln Willem Iskandar. Psr V Medan 20221. Telp. (061)6613319-6614002

Kepada Yth. Dr. Zainuddin Mukhtar, M.Si
Dosen Kelas Bilingual Berstandar Internasional

Nomor : 023/BIL/LK/VII/2012

FMIPA UNIMED
di
Medan

Dengan hormat, kami meminta kesediaan Saudara untuk menjadi dosen Pembimbing dalam penyusunan Skripsi atas nama mahasiswa:

Nama : Siti Rahmah
NIM : 409332030
Program Studi : Chemistry Education

Sebagai salah satu persyaratan untuk memperoleh gelar sesuai dengan Program Studinya. Demikian kami sampaikan, atas kerjasama yang baik kami ucapkan terima kasih.

Mengetahui,
A.n. Dekan
Pembantu Dekan I FMIPA UNIMED

Drs. P. Manalim Silitonga, M.S
NIP. 19590907 198503 1 003

Medan, 10 Juli 2012
Koordinator Kelas Bilingual

Prof. Dr. Herbert Sipahutar, M.Sc
NIP. 19610626 198710 1 001

SURAT PERSETUJUAN

Mahasiswa yang namanya tersebut di bawah ini:

Nama : Siti Rahmah
NIM : 409332030
Program Studi : Chemistry Education

Dapat saya setujui untuk dibimbing dalam penyusunan Skripsinya dalam rangka memenuhi salah satu persyaratan untuk memperoleh gelar sesuai dengan program studinya.

Medan, 10 Juli 2012
Dosen Pembimbing Skripsi

Dr. Zainuddin Mukhtar, M.Si
NIP.19670317 199203 1 004

Dibuat rangkap 4 (empat):
1. ***Kuning untuk Fakultas***
2. ***Merah untuk Bilingual***
3. ***Hijau untuk Dosen Pembimbing***
4. ***Putih untuk Yang Bersangkutan***

Appendix 17

KEMENTRIAN PENDIDIKAN DAN KEBUDAYAAN
UNIVERSITAS NEGERI MEDAN
FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM
JURUSAN KIMIA
Jln Willem Iskandar. Psr V Medan 20221. Telp. (061)6625970

No : 092 /UN33.4.1/DT/II/2013 Medan, 20 Maret 2013
Lamp : 1 Buah Proposal Penelitian
Hal : **Ijin Penelitian**

Kepada : Yth. Bapak/Ibu
1. Kepala SMA N 4 Medan
2. Kepala SMA N 5 Medan
3. Kepala SMA N 14 Medan
4. Kepala SMA N 15 Medan
5. Kepala SMA N 18 Medan
6. Kepala SMA N 21 Medan

Di
Tempat

Dengan hormat, kami memohon bantuan Saudara untuk memberikan ijin melaksanakan penelitian kepada mahasiswa tersebut dibawah ini:

Nama	: SITI RAHMAH
NIM	: 409332030
Jurusan	: Kimia
Program Studi	: Pendidikan Kimia Bilingual
Dosen Pembimbing	: Dr. Zainuddin Muchtar, M.Si
Judul Penelitian	: "Analyzing of Students' Misconceptions on Buffer Solution at Senior High School in Medan."
Tempat Penelitian	: SMAN 4 Medan SMAN 5 Medan SMAN 14 Medan SMAN 15 Medan SMAN 18 Medan SMAN 21 Medan

Perlu kami tambahkan bahwa penelitian ini dimaksudkan untuk Penyusunan Skripsi dalam rangka memenuhi salah satu syarat untuk memperoleh **Gelar Sarjana Pendidikan di FMIPA UNIMED** (proposal penelitian terlampir).
Demikian kami sampaikan kepada Saudara, atas kerja sama yang baik kami ucapkan terima kasih.

a.n. Dekan
Pembantu Dekan 1,

Drs. P. Maulim Silitonga, M.S.
NIP. 19590907 198503 1 003

Appendix 18

PEMERINTAH KOTA MEDAN
DINAS PENDIDIKAN
Jalan Pelita IV No.77 Telp.(061) 6629322 Fax.(061) 6629322
MEDAN -20236
http://www.disdik.pemkomedan.go.id

Medan, 28 Maret 2013

Nomor : 070/ 4362PPMP/2013
Lamp. : -
Hal : Izin Penelitian

Kepada Yth :
1. Kepala SMA Negeri 4 Medan
2. Kepala SMA Negeri 5 Medan
3. Kepala SMA Negeri 14 Medan
4. Kepala SMA Negeri 15 Medan
5. Kepala SMA Negeri 18 Medan
6. Kepala SMA Negeri 21 Medan

di -
Medan

1. Berdasarkan surat permohonan dari Dekan Fakultas Matematika dan Ilmu Pengetahuan Alam Universitas Negeri Medan Nomor 092/UN.33.4.1/DT/II/2013 tanggal 20 Maret 2013 perihal pada pokok surat ini, kami sampaikan kepada Saudara :

N a m a	:	Siti Rahmah
NIM	:	409332030
Jurusan	:	Kimia
Program Studi	:	Pendidikan Kimia Bilingual
Judul Penelitian	:	Analyzing of Students' Misconceptions on Buffer Solution at Senior High School in Medan.
Tempat Penelitian	:	SMA Negeri 4, SMA Negeri 5, SMA Negeri 14, SMA Negeri 15, SMA Negeri 18, dan SMA Negeri 21 Medan

2. Diharapkan Saudara dapat membantunya dengan ketentuan sebagai berikut :
   a. Tidak mengganggu proses belajar mengajar di sekolah.
   b. Yang bersangkutan berkoordinasi dengan Kepala Sekolah.
   c. Yang bersangkutan melaporkan hasilnya ke Dinas Pendidikan Kota Medan c/q Bidang PPMP selambat-lambatnya seminggu setelah selesai penelitian.
   d. Surat ini berlaku sejak tanggal dikeluarkan sampai kegiatan dianggap selesai.

3. Demikian disampaikan atas perhatian Saudara kami ucapkan terima kasih.

An. Kepala Dinas Pendidikan Kota Medan
Kabid Program dan Pengembangan
Mutu Pendidikan

PEMERINTAH KOTA MEDAN
DINAS PENDIDIKAN

Drs. H. JAKARIA HARAHAP
PEMBINA
NIP. 19610918 199512 1 001

Tembusan :
1. Dekan FMIPA UNIMED
2. Pertinggal

Appendix 19

PEMERINTAH KOTA MEDAN
DINAS PENDIDIKAN
SMA NEGERI 4 MEDAN
Jl. Gelas No. 12 Ayahanda Telp : 061 - 4158244 Fax : 061-4144110 Medan 20118

SURAT KETERANGAN
Nomor : 0449/0269/070/2013

Kepala Sekolah Menengah Atas (SMA) Negeri 4 Medan Kota Medan Propinsi Sumatera Utara dengan ini menerangkan :

N a m a	:	**Siti Rahmah**
N I M	:	409332030
Program Studi	:	Pendidikan Kimia Bilingual
Jurusan	:	Kimia

Adalah benar mahasiswi Fakultas Matematika dan Ilmu Pengetahuan Alam Universitas Negeri Medan (UNIMED) yang telah melaksanakan penelitian di SMA Negeri 4 Medan.

Demikian surat keterangan ini diperbuat dengan sebenarnya untuk dapat dipergunakan sebagaimana mestinya.

Medan, 17 Mei 2013
Kepala SMA Negeri 4 Medan

PEMERINTAH KOTA MEDAN SEKOLAH MENENGAH ATAS (SMA) NEGERI 4 DINAS PENDIDIKAN

Drs. RAMLY, M.Pd
NIP 19611012 199003 1 007

PEMERINTAH KOTA MEDAN
DINAS PENDIDIKAN
SMA NEGERI 5 MEDAN
Alamat : Jln. Pelajar No. 17 Telp. 061 – 7360664 Medan 20217 E-mail : smanlimedans@didikmedan.org

SURAT KETERANGAN PENELITIAN

Nomor : 800/ /TU/2013

Yang bertanda tangan dibawah ini :

Nama : Drs. SUTRISNO, M.Pd
Jabatan : KEPALA SMA NEGERI 5 MEDAN

dengan ini menerangkan bahwa :

Nama : SITI RAHMAH
NIM : 409332030
Program Studi : Pendidikan Kimia Bilingual
Fakultas : Universitas Negeri Medan (UNIMED)

Nama tersebut di atas telah melaksanakan penelitian di SMA Negeri 5 Medan Pada tanggal 01 Mei 2013 untuk mendapatkan informasi/keterangan data yang berhubungan dengan judul : " *Analyzing Of Student' Misconceptions on Buffer Solution at Senior High School in Medan.* "

Demikian surat keterangan ini diperbuat untuk dapat dipergunakan seperlunya.

Medan, 08 Mei 2013
KEPALA SMA NEGERI 5 MEDAN

Drs. SUTRISNO, M.Pd
NIP. 19660323 199601 1 001

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PEMERINTAH KOTA MEDAN
DINAS PENDIDIKAN
SMA NEGERI 14 MEDAN

Alamat : Jalan Pelajar Timur Ujung Telp. (061) – 7345465 Kec. Medan Denai Kota Medan KP. 20228

SURAT KETERANGAN
Nomor : 420/ 181 / 2013

Yang bertanda tangan dibawah ini :

N a m a	:	Drs. Guboan, M.Pd
J a b a t a n	:	Kepala SMA Negeri 14 Medan

Menerangkan bahwa	:	
N a m a	:	**SITI RAHMAH**
N I M	:	409332030
J u r u s a n	:	K i m i a
Program Studi	:	Pendidikan Kimia Bilingual
Judul Penelitian	:	Analysing of Students' Misconceptions on Buffer Solution at Senior High School in Medan.
Tempat Penelitian	:	SMA Negeri 14 Medan

Benar telah mengadakan penelitian di SMA Negeri 14 Medan Tanggal 24 April 2013 sesuai dengan Surat dari Dinas Pendidikan Kota Medan Nomor : 070/4362.PPMP/2013 Tanggal 28 Maret 2013.

Demikian Surat Keterangan ini diperbuat agar dapat dipergunakan seperlunya.

Medan, 23 April 2013
Kepala SMA Negeri 14 Medan

Drs. G U B O A N, M.Pd
NIP. 19541229 198403 1 003

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PEMERINTAH KOTA MEDAN
DINAS PENDIDIKAN
SMA NEGERI 15 MEDAN
Jln. Sekolah Pembangunan No. 7 Telp. (061) 8456806

SURAT KETERANGAN
No. 423.4/ 1085/ SMA.15/2013

Sesuai dengan surat nomor : 092/UN.33.4.1/DT/II/2013 tanggal 20 Maret 2013 Hal izin Penelitian, dengan ini Kepala SMA Negeri 15 Medan menerangkan bahwa :

Nama	:	SITI RAHMAH
NIM	:	409332030
Program Studi	:	Pendidikan Kimia Bilingual /S1
Judul Skripsi	:	"Analyzing of Students" Misconceptions on Buffer Solution at Senior High School in Medan."

Benar telah melakukan Penelitian di SMA Negeri 15 Medan pada tanggal 13 Mei 2013.

Demikian surat keterangan ini dibuat untuk digunakan seperlunya.

Medan, 18 Mei 2013
Kepala Sekolah,

PEMERINTAH KOTA MEDAN SEKOLAH MENENGAH ATAS (SMA) NEGERI 15 DINAS PENDIDIKAN

...rwin Siregar, M.Pd
Nip. 19590807 198803 1 004

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PEMERINTAH KOTA MEDAN
DINAS PENDIDIKAN
SEKOLAH MENENGAH ATAS (SMA) NEGERI 18
JLN. WAHIDIN NO. 15 A MEDAN

SURAT KETERANGAN
Nomor : 422 / 077 / SMAN 18 / 2013

Yang bertanda tangan dibawah ini, Kepala SMA Negeri 18 Medan dengan ini menerangkan bahwa :

Nama	: SITI RAHMAH
NIM	: 409332030
Jurusan	: Kimia
Program Studi	: Pendidikan Kimia Bilingual

Nama tersebut benar telah melakukan penelitian di SMA Negeri 18 Medan mulai tanggal 23-26 April 2013 dengan Judul Penelitian " **ANALYZING OF STUDENTS' MISCONCEPTIONS ON BUFFER SOLUTION AT SENIOR HIGH SCHOOL IN MEDAN "**

Demikian surat keterangan ini dibuat untuk dapat dipergunakan seperlunya.

Medan, 27 April 2013
Kepala SMA Negeri 18 Medan

Dra. Hj. Yurmaini Siregar, M.Si
Pembina Tk.I
NIP. 19581127 198203 2 004

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DINAS PENDIDIKAN KOTA MEDAN

SMA NEGERI 21 MEDAN

JL. Kramat Indah/Selambo Ujung Kel. Medan Tenggara
Kec. Medan Denai

SURAT KETERANGAN
NO. 420 /2063/ SMA 21/2013

Saya yang bertanda tangan dibawah ini :

N a m a	: **Drs. SALON SINAGA, M.Si**
N I P	: 19660215 199512 1 001
Jabatan	: Kepala Sekolah

Menerangkan bahwa :

Nama	: SITI RAHMAH
NIM	: 409332030
Jurusan	: Kimia
Program Studi	: Pendidikan Kimia Bilingual

Benar telah melaksanakan penelitian di SMA Negeri 21 Medan dengan judul **"Analyzing of Students' Misconceptions on Buffer Solution at Senior High School in Medan"**

Demikianlah Surat keterangan ini diperbuat untuk dapat dipergunakan seperlunya.

Medan, 4 Mei 2013
Kepala Sekolah,

PEMERINTAH KOTA MEDAN SEKOLAH MENENGAH ATAS (SMA) NEGERI 21 DINAS PENDIDIKAN

Drs. SALON SINAGA, M.Si
NIP. 19660215 199512 1 001

UNIVERSITAS NEGERI MEDAN UNIMED THE Character Building UNIVERSITY