Research Experiences for Teachers (RET) – 2015

MODULE TOPIC: Solubility and Buffering Property of Tums Vs. Alka-Seltzer

Lesson 1 – Investigating the effect of particle size on the solubility rate of Tums® vs. Alka-Seltzer® in aqueous solution.
Lesson 2 - Investigating the effect of temperature on the solubility rate of Tums® vs. Alka-Seltzer® in aqueous solution.
Lesson 3 - Investigating the buffering property of Tums® vs. Alka-Seltzer®.

Background Information:
Solubility is a chemical property of a substance that shows the ability of a solute to dissolve in a solvent. A compound is soluble in a solvent when it is capable of making stronger intermolecular forces with the solvent molecules than with its own molecules. These intermolecular forces are weak to strong electrostatic forces that can be calculated mathematically using coulombs law shown below.

$$F = \frac{k \bullet Q_1 \bullet Q_2}{d^2}$$

There are a few factors that can affect the rate of solubility of a solute in a solvent. Some of these factors are size, temperature, pressure, and common ion effect. The solubilized form of these compounds are ionic and therefore conductors of electricity. To determine the solubility of these compounds, electrical conductivity of their solution will be measured using a conductivity probe and logger pro software.

In lessons number one and two, the effect of size, and temperature on the solubility of Tums and Alka-Seltzer will be investigated. In lesson number three the buffering property of Tums Vs. Alka-Seltzer will be investigated.

Tums with calcium carbonate as the active ingredient and Alka-Seltzer with citric acid ($C_6H_8O_7$ -- anhydrous) and sodium bicarbonate (baking soda -- **$NaHCO_3$**) as its active ingredients have been used as over the counter medication for the treatment of heartburn also known as acid reflux.

<u>Properties of Calcium Carbonate ($CaCO_3$) (Tums Tablet)</u>

Calcium carbonate is poorly water soluble (47 mg/L at normal atmospheric CO_2 partial pressure) as shown below.

$CaCO_3 \rightleftharpoons Ca^{2+} + CO_3^{2-}$ $\qquad$ $K_{sp} = 3.7\times10^{-9}$ to 8.7×10^{-9} at 25 °C

It reacts with acids, releasing carbon dioxide:

$CaCO_3 (s) + 2 HCl (aq) \rightarrow CaCl_2 (aq) + CO_2 (g) + H_2O (l)$

It reacts with water that is saturated with carbon dioxide to form the soluble calcium bicarbonate.

$CaCO_3 + CO_2 + H_2O \rightarrow Ca(HCO_3)_2$

<u>Properties of Sodium Bicarbonate and Citric Acid (Akla-Setlzer Tablet)</u>

- Reaction of Sodium Bicarbonate in water is shown below:

$NaHCO_{3\,(s)} + H_2O_{\,(l)} \rightarrow Na^+_{\,(aq)} + HCO_3^-{}_{\,(aq)}$
$HCO_3^-{}_{\,(aq)} + H_2O_{\,(l)} \rightarrow H_2CO_{3\,(aq)} + OH^-{}_{\,(aq)}$
$H_2CO_{3\,(aq)} \rightarrow H_2O_{\,(l)} + CO_{2\,(g)}$

Reactions of Sodium Bicarbonate with two different acids, hydrochloric acid and acetic acid respectively are shown below,

$NaHCO_{3\,(s)} + HCl_{\,(aq)} \rightarrow NaCl + H_2O_{\,(l)} + CO_{2\,(g)}$
$NaHCO_{3\,(s)} + CH_3COOH_{\,(aq)} \rightarrow CH_3COO^-Na^+{}_{\,(aq)} + H_2O_{\,(l)} + CO_{2\,(g)}$

- Reaction of Citric acid in water is shown below:

Citric acid is a weak acid, which means that it does not completely dissociate in water.

$H_3C_6H_5O_{7\,(s)} + H_2O_{\,(l)} \Leftrightarrow H_2C_6H_5O_7^-{}_{(aq)} + H_3O^+{}_{(aq)}$ (first dissociation)

$H_2C_6H_5O_7^-{}_{(aq)} + H_2O_{\,(l)} \Leftrightarrow HC_6H_5O_7^{-2}{}_{(aq)} + H_3O^+{}_{(aq)}$ (second dissociation)

$HC_6H_5O_7^{-2}{}_{(aq)} + H_2O_{\,(l)} \Leftrightarrow C_6H_5O_7^{-3}{}_{(aq)} + H_3O^+{}_{(aq)}$ (third dissociation)

Solutions that are able to retain a constant pH regardless of small amounts of acids or bases added are called buffers. Classical buffer contains both a weak acid and its conjugate base. In a buffer solution addition of small amounts of acids or bases are absorbed by the buffer and the pH changes only slightly. The Henderson-Hasselbalch equation shown below is used to calculate pH of buffer solutions while adding known amounts of acids or bases.

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

When the concentration of HA is equal to A^-, pH = pKa and that is where the best buffering property is observed.

The role of these medications is to provide a better buffering solution to neutralize excess acid and maintain a stable pH. In lesson number three, solutions of Tums and Alka-Seltzer will be titrated with an acid to determine at what region of the titration curve (pH vs. the volume of the added acid), pH remains relatively stable. The longer the stable region within the graph, the better the buffering ability. In conclusion, the titration curve of both tablets will be compared to determine if there is any difference between their buffering properties.

Lesson 1
Investigating the effect of particle size on the solubility rate of Tums® vs. Alka-Seltzer® in aqueous solution.

Learning Objectives: Students will be able to:
Measure the conductivity (μS/cm) of solutions of a whole Tums tablet and of a whole Alka-Seltzer tablet as being dissolved at room temperature repeating it twice using a Vernier conductivity probe and logger pro software.

Measure the conductivity (µS/cm) of a solution of crushed Tums tablet and of a crushed Alka-Seltzer tablet is being dissolved at room temperature repeating it twice using a Vernier conductivity probe and logger pro software.

Identify the correct dependent and independent variables by **distinguishing** the measured variable from the varied variable.

Plot a scatter graph of the average conductivity (µS/cm) measurements of each solution of Tums and of Alka-Seltzer (tablet and powder) vs. time in minutes using Excel software following the instruction provided.

Compare and Contrast with clear description in one paragraph, how fast a Tums® tablet and an Alka-Seltzer tablet dissolves in water versus crushed one by comparing the graph of conductivity (µS/cm) vs. time (min).

Compare the dissolution profile of Alka-Seltzer with Tums using their conductivity (µS/cm) vs. time (min) graphs in one paragraph with clear description.

STANDARD (S) & INDICATOR (S):
CCSS.Math.Content.
HSF-IF.B.4.
For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. *Key features include: intercepts; intervals where the function is increasing, decreasing, positive, or negative; relative maximums and minimums; symmetries; end behavior; and periodicity*.
NGSS.Physcial Science Practices
Practice 3 Planning and Carrying Out Investigations - Grades 9-12
Planning and carrying out investigations progresses to include investigations that build, test, and revise conceptual, mathematical, physical, and empirical models.

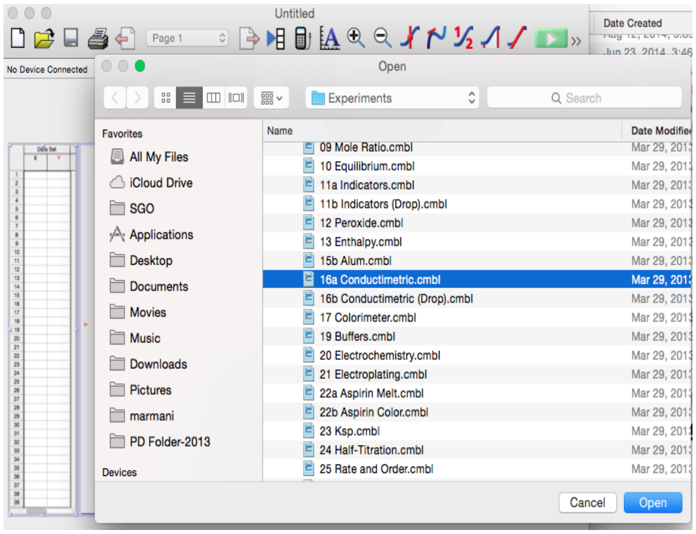
- Design an investigation individually and collaboratively and test designs as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.

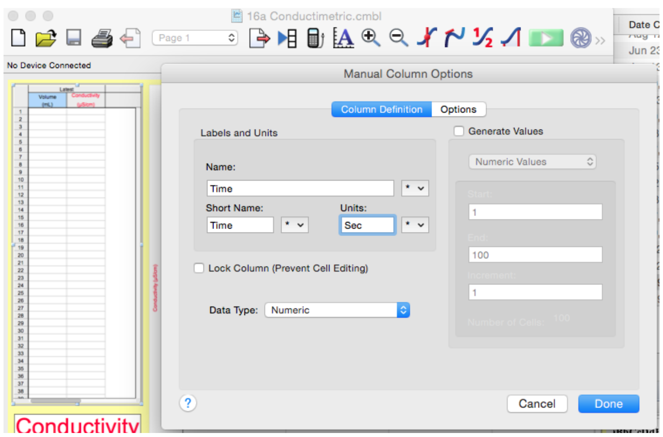
MATERIALS:
2 Tums Tablets
2 Alka-Seltzer Tablets
Deionized Water
1 (250) mL beaker
100 mL Graduated Cylinder
Mortar and Pestle
Weighing Paper
Spatula
1 Conductivity Electrode
Computer with logger pro software
Electronic Balance

Procedure:
1. Weigh out and record the mass of a Tums tablet in your notebook.
2. Measure out 100 mL of deionized water using 100 mL graduated cylinder and pour it into the 250 mL beaker.
3. Place the conductivity electrode into the beaker and secure it using a clip and a ring stand.

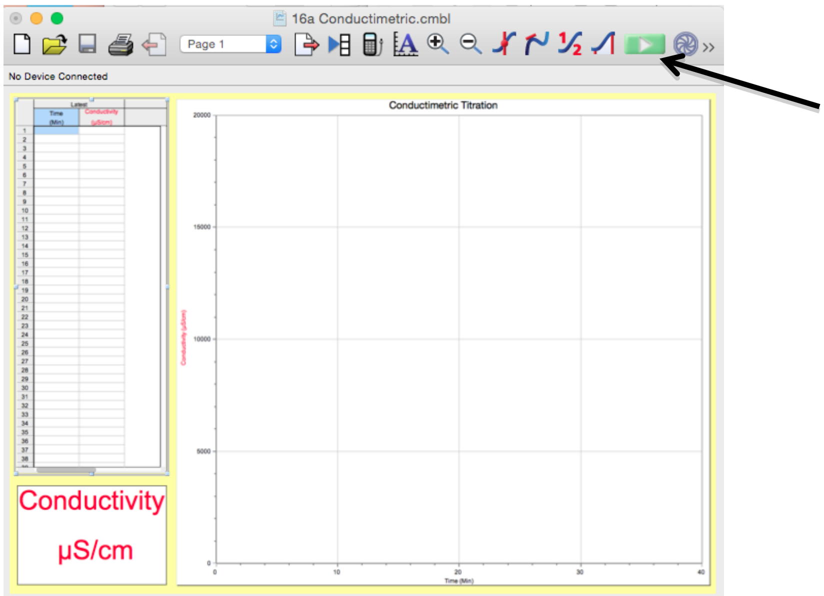
4. Connect the conductivity electrode to the computer and start the logger pro software.
5. Open the file, from the advanced chemistry choose “conductimetric.cmbl” experiment (refer to figure 1A and 1B).

Figure 1A and B – Logger Pro software, conductimetric experiment.





6. Double click on the column titled “volume” a window will open titled “Manual Column Options” and change “volume” to “time” and units to “minutes”. Click on “Done” Button.



Click here
to start

7. As another student drops the Tums tablet into the DI water click on the green arrow to start the analysis.
8. After 10 minutes stop the analysis.
9. Save the data and export it to an Excel spreadsheet to plot conductivity (µS/cm) vs. time (min).
10. Clean the electrode with DI water.
11. Clean the beaker and dispose all the solutions in the sink with running water.
12. Repeat the same with Alka-Seltzer tablet.
13. Take one or two Tums tablet and crush them into powder separately using mortar and pestle separately.
14. Measure and record the mass of the powder.
15. Repeat steps 7 through 11 for the powder separately.
16. Repeat the same for Alka-Seltzer tablets.
17. At the end you should have four plotted graphs:
    a. Tums Tablet
    b. Alka-Seltzer Tablet
    c. Crushed or powdered Tums Tablet
    d. Crushed or powdered Tums Tablet
18. To make a correct plot, divide the values for in the conductivity column by the mass of the sample to obtain conductivity per gram of each sample, which makes up the values that will be used for the Y-axis to make the plot.

Assessment:

1. Define dependent and independent variables and identify the dependent and independent variables in this investigation.
2. Plot conductivity (µS/cm) vs. time (min) for each tablet using Excel software.
3. Plot conductivity (µS/cm) vs. time (min) for each powdered tablet using Excel software (instruction is provided).
4. Compare the graphs of dissolution of each tablet vs. its powdered form to see if there is a difference and if so, explain why. (Be specific and provide detailed information)
5. Compare the graphs of dissolution of each tablet and determine if one dissolves faster than the other. If there is a difference explain that by looking at the molecular composition of each tablet. (Be specific and provide detailed information)
6. Write a formal report recording your data, data analysis, graphs, procedure and conclusion following the provided rubric.

ACKNOWLEDGEMENT

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Supporting Program: Center for Pre-College Programs, at the New Jersey Institute of Technology
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Lesson 2
Investigating the effect of temperature on the solubility rate of Tums® vs. Alka-Seltzer® in aqueous solution.

Learning Objectives: : Students will be able to:

Measure the conductivity (µS/cm) of solutions of a whole Tums tablet and of a whole Alka-Seltzer tablet as being dissolved at 0ºC (ice bath), 25ºC (room temperature), and 37ºC (water bath) repeating it twice using a Vernier conductivity probe and logger pro software.

Plot a scatter graph of the average conductivity (µS/cm) measurements of each solution of Tums and of Alka-Seltzer vs. temperature in degree Celsius using Excel software following the instruction provided.

Compare and Contrast in one paragraph with clear description the effect of temperature on the dissolution rate of Alka-Seltzer® in water vs. Tums using the best fit of the scattered plots of conductivity (µS/cm) vs. time at different temperature.

STANDARD (S) & INDICATOR (S):
CCSS.Math.Content.
HSF-IF.B.4.
For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. *Key features include: intercepts; intervals where the function is increasing, decreasing, positive, or negative; relative maximums and minimums; symmetries; end behavior; and periodicity*.

NGSS.Physcial Science Practices
HS-PS1-5.
Apply scientific principles and evidence to provide an explanation about the effects of changing the **temperature** or concentration of the reacting particles on the rate at which a reaction occurs.
Practice 3 Planning and Carrying Out Investigations - Grades 9-12
Planning and carrying out investigations progresses to include investigations that build, test, and revise conceptual, mathematical, physical, and empirical models.

- Design an investigation individually and collaboratively and test designs as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.

MATERIALS:
2 Tums Tablets
2 Alka-Seltzer Tablets
Deionized Water
Ice
1 (250 mL) beaker
100 mL Graduated Cylinder
Weighing Paper
Spatula
Electronic Balance
Hot Plate
1 Conductivity Electrode
Computer with logger pro software
Thermometer

Procedure:

1. Weigh out and record the mass of a Tums tablet in your notebook.
2. Measure out 100 mL of 0 ºC deionized water using 100 mL graduated cylinder and pour it into the 250 mL beaker.
3. Place the conductivity electrode into the beaker and secure it using a clip and a ring stand.
4. Connect the conductivity electrode to the computer and start the logger pro software.
5. Open the file, from the advanced chemistry choose "conductimetric.cmbl" experiment (refer to figure 1A and 1B of lesson 1).
6. Place the beaker in a 500 mL beaker containing crushed ice to maintain the temperature at 0 ºC.
7. As another student drops the Tums tablet into the DI water click on the green arrow to start the analysis.
8. After 10 minutes stop the analysis.
9. Save the data and export it to an Excel spreadsheet to plot conductivity (µS/cm) vs. time (min).
10. Clean the electrode with DI water.
11. Clean the beaker and dispose all the solutions in the sink with running water.
12. Repeat the same with 37 ºC DI water while the beaker is placed in a 37-ºC water bath.
13. Repeat steps 1 through 12 with Alka-Seltzer tablets.
14. Use the data from lesson 1 for Tums tablet and Alka-Seltzer tablet at room temperature for the 25-ºC temperatures.
15. Repeat steps 7 through 11 for the powder separately.
16. To make a correct plot, divide the values for in the conductivity column by the mass of each sample to obtain conductivity per gram of each sample, which makes up the values that will be used for the Y-axis to make the plot.

Assessments:

1. Identify the dependent and independent variables in this investigation.
2. Plot conductivity for each gram of the sample (µS/cm) vs. time (min) for each tablet at 0 ºC and 37 ºC
3. Compare the graphs of dissolution of each tablet at different temperature and if there is a difference explain why.
4. Compare the graphs of dissolution for both tablets to determine if temperature had more profound change on one more than the other. If so explain why.
5. Write a formal report recording your data, data analysis, graphs, procedure and conclusion following the provided rubric.

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Lesson 3
Investigating the buffering property of Tums® vs. Alka-Seltzer®.

Learning Objectives:
Measure pH of a solution of a Tums tablet and of an Alka-Seltzer tablet while titrating with an acid, collecting data for 5 minutes after sharp change in pH value, using a Vernier pH electrode and logger pro software.

Plot a scattered graph of the measured pH vs. volume (mL) of the added acid for each tablet using Excel software following the instruction provided.

Identify the buffering strength for each tablet by interpreting its titration graph and identifying the length of the buffering region where pH has remained relatively constant during titration.

Compare with clear description the buffering strength of Tums vs. Alka-Seltzer by comparing the buffering regions of the titration graph of each tablet.

STANDARD (S) & INDICATOR (S):
CCSS.Math.Content.
HSF-IF.B.4.
For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship.

NGSS.Physcial Science
Practice 3 Planning and Carrying Out Investigations - Grades 9-12
Planning and carrying out investigations progresses to include investigations that build, test, and revise conceptual, mathematical, physical, and empirical models.

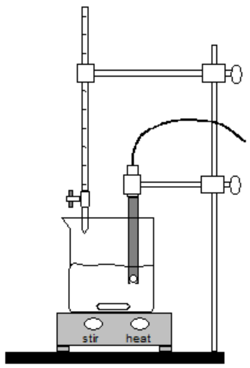
- Design an investigation individually and collaboratively and test designs as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.

Material:
1 Tums Tablets
1 Alka-Seltzer Tablets
Deionized Water
1.0 M acetic acid
2 (50 mL) beakers
50 mL Graduated Cylinder
Mortar and pestle
Weighing Paper
Electronic Balance
50 mL Burette
Spatula
1 Vernier pH electrode
Computer with logger pro software

Procedure:

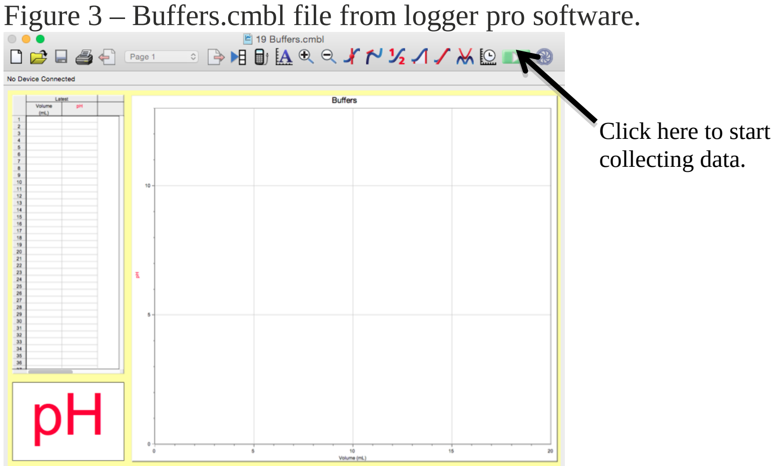
1. Crush a Tums tablet and an Alka-Seltzer tablet separately using a mortar and pestle.
2. Weigh out about 1 gram of each powder and record the exact mass.
3. Clean the burette and rinse it twice with 1.0 M Acetic Acid.
4. Fill up the burette with 1.0 M acetic acid and make sure the bottom of the meniscus is at the zero marking.
5. Attach the burette to the ring stand and place the beaker with the solution under the beaker on top of the magnetic stirrer. Place the mixing magnet into the beaker. Attach the Vernier pH electrode as depicted in the Figure 2.

Figure 2 – Titration Set-up.

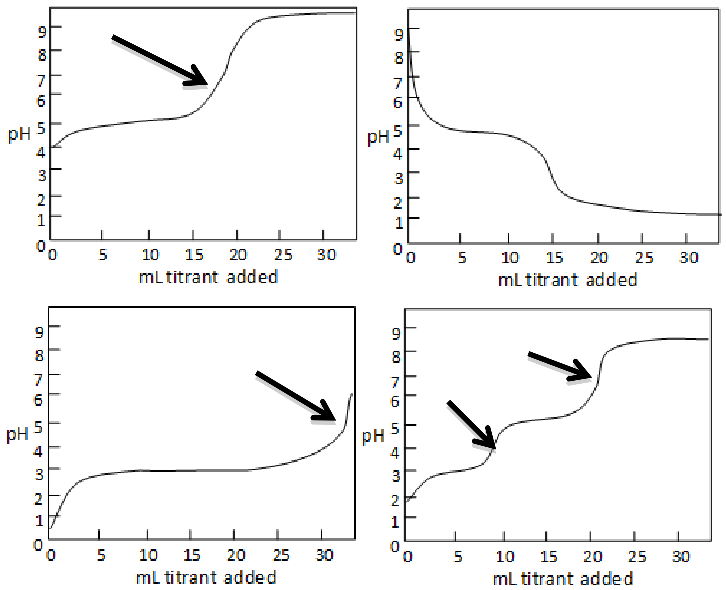


6. Start the mixing process. Attach the pH electrode to the computer and open up the logger pro software.
7. From the file menu chose and open the “Buffers.cmbl” file (Figure 3).

Figure 3 – Buffers.cmbl file from logger pro software.



8. Dissolve the measured Tums powder in 50.0 mL DI water.
9. Start collecting data by clicking on the green arrow.
10. Start adding the acetic acid drop by drop while mixing the solution and monitoring pH.
11. Stop the titration 2 mL after the sudden jump in the pH is observed. Refer to the Figure 4 where the black arrow is pointing.
12. Repeat the same procedure with the second solution.



Assessments:

1. Print the plotted pH vs. volume graph.
2. Define buffer and explain its property using the Henderson-Hassel Bach equation.
3. Use the plotted graph to indicate the buffering region for each tablet.
4. Comparing the titration curve of the two solutions, which one is a better buffer? Explain why.
5. Write a formal report recording data, graphs, procedure, data analysis and conclusion following the given rubrics.

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