Comparing Kızılay Mineral Water and Different Antacid Tablets in terms of the Amount of Acid Neutralized

Research Question:

How many bottles of *Kızılay* natural mineral water neutralize the same amount of HCl (1M) as a common antacid tablet (Talcid, Kompensan, Acidpass), measured through a back titration?

Introduction

I have been dealing with stomach problems all my life. I constantly have to watch out what I eat because of my acid reflux disease. However, I love eating and sometimes I overeat chocolate or fast foods, then my symptoms get more severe. The time periods that my disease gets worse, I have to pay visits to the doctor's office and get on some medications called antacids. Each time this happens I am advised to change my dietary plans, because I cannot always be on antacids. My mother always advises me to drink a natural mineral water as an at-home remedy, to relieve my symptoms after a big meal. I have been wondering if a can of mineral water is as effective as the antacid tablets, if not how many glasses of natural mineral water would replace an antacid tablet So in this assessment, I decided to set up an experiment to determine their effectiveness.

Background Information

Our stomach digests the food we eat using the fluids that the stomach lining secretes. These are called "gastric juices". Stomach acids are also in these gastric juices. Even though the acids help the digestion of proteins, the overproduction of acid in the stomach can be deleterious.

One of the diseases that excess stomach acids may trigger is GERD (gastroesophageal reflux disease) which is also known as acid reflux disease. In this disease, the stomach acid moves up to the esophagus and damages that area. The symptoms of this disease include heartburn which is a burning pain and discomfort in your upper gastrointestinal tract and tasting acid in the back of your throat. The overacidity of the stomach may increase the heartburn the patient experiences. The treatment of this disease is done by lifestyle and dietary changes or with some medication. These medications can reduce the acid in your stomach by inhibiting the production of the acid or neutralizing the stomach acid; or some medication can produce a barrier between the stomach and the esophagus, capturing the acid[1].

The medications that neutralize the stomach acid is called "antacids". These medications consist of weak bases, which react with the HCl which is the main component of the stomach acid. Since this is a reaction between acids and bases, this is called "acid-base reaction" or "neutralization reaction". In this experiment, 3 different types of over-the-counter antacids will be used: Talcid, Acidpass and Kompensan. These tablets' active ingredients that can act as acid-neutralizing agents are shown in the table below.

Antacid tablet	**Active ingredients**
Talcid	hydrotalcite ($Mg_6Al_2CO_3(OH)_{16}{\cdot}4H_2O$)
Acidpass	calcium carbonate ($CaCO_3$) and magnesium hydroxide ($Mg(OH)_2$)
Kompensan	dihydroxyaluminum sodium carbonate and some calcium carbonate ($AlO(OH)_2CO_2Na$)

[1] Annie Stuart, "What Is Acid Reflux Disease?," WebMD, accessed June 22, 2022, https://www.webmd.com/heartburn-gerd/guide/what-is-acid-reflux-disease.

These active ingredients can react with HCl:
Hydrotalcite: $Mg_6Al_2CO_3(OH)_{16} \cdot 4H_2O + 18HCl \rightarrow 6MgCl_2 + 2AlCl_3 + CO_2 + 21H_2O$
Calcium carbonate: $CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$
Magnesium carbonate: $MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l) + CO_2(g)$
Magnesium hydroxide: $Mg(OH)_2(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + 2H_2O(l)$
Dihydroxyaluminum sodium carbonate: $AlO(OH)_2CO_2Na + 4HCl \rightarrow AlCl_3 + NaCl + 3H_2O + CO_2$

Apart from the medications, there are also natural remedies that are used to relieve the heartburn which is a symptom of acid reflux. One of them is natural mineral water. Natural mineral water is completely natural water that is extracted from the underground and it contains many minerals/ elements[2]. Natural mineral water has also bicarbonate in it. This carbonate can react with the HCl in the stomach to neutralize it, just like the antacids:

$$Na^+ + HCO_3^{-1} + HCl \rightarrow CO_2 + H_2O + NaCl$$

(Sodium ions are present in mineral water)
This experiment will be using *Kızılay* Natural Mineral Water to compare with antacid tablets, as it is the brand that my family buys the most. This brand also donates all of its profit to Turkish Red Crescent (Kızılay)[3]. However, it is clear that the same experiment can be done with other brands to find similar results.

In order to determine the amount of HCl antacids and mineral water will neutralize a method called back titration will be used.

In a titration, a solution of known concentration (titrant) is gradually added to a solution with unknown concentration (analyte) to find the concentration of it. When the titrant is fully reacted with the analyte, it reaches an "endpoint" and it is usually indicated by a color change.

In back titration, the titrant is added to the excess volume of a reactant from another chemical reaction[4]. In other words, in this experiment, first HCl with known concentration will be reacted with antacid tablets/ mineral water in an erlenmeyer. Then, the excess volume of HCl will be reacted with NaOH to find the volume of the excess HCl similar to titration.
The volume of HCl that reacts with antacids then can be found by subtracting the excess volume from the initial known volume of HCl. The back titration is used in this experiment instead of titration because;

i. The antacid tablets are in powder form and in a titration, it would be hard to dissolve in a titration.
ii. The antacid tablets/ mineral water may react slowly with HCl. Titration would take too long and the endpoint may have been hard to measure in a titration.

The endpoint of the titration, can be observed using a color change. Since NaOH is a basic and HCl is acidic, their reaction is a neutralization reaction:

$$NaOH(aq)+HCl(aq) \rightarrow NaCl(aq)+H_2O(l)$$[5]

In order to observe this, an acid-base indicator should be used. As the HCl is neutralized by NaOH, the solution in the erlenmeyer is acidic but when the endpoint is reached and all the HCl is neutralized; the solution will gradually be more and more basic.

For this aim, methyl red indicator is used. Methyl red is red under acidic conditions (below pH 4.4) and yellow in basic conditions (above pH 6.2)[6]. These values make methyl red suitable for this experiment.

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[2] "Kızılay Maden Suyu," accessed August 9, 2022, https://www.kizilaymadensuyu.com.tr/.
[3] "Bizim Hikayemiz," accessed August 9, 2022, https://www.kizilaymadensuyu.com.tr/bizim-hikayemiz/.
[4] "Stoichiometry - OpenStax CNX," accessed July 28, 2022, https://cnx.org/contents/951c03bf-d5f7-44f1-8c2c-c87beacc2256:af5866fb-86b6-4867-9465-a87d5c84a99b.
[5] David W. Ball and Jessie A. Key, "Neutralization Reactions," September 16, 2014, https://opentextbc.ca/introductorychemistry/chapter/neutralization-reactions/.
[6] Lucy Bell-Young, "What Is Methyl Red? | The Chemicals Blog," ReAgent Chemicals, July 26, 2021, https://www.chemicals.co.uk/blog/what-is-methyl-red.

Hypothesis:

Since common antacid tablets are the result of many chemical and medical procedures and particularly aim to deal with a disease, I believe that they will have more acid-neutralizing properties than mineral water which is a beverage.

Design

Variables:

Independent Variable: The acid (HCl) neutralizing agent (Mineral water, Talcid, Kompensan, Acidpass)
Dependent Variable: The volume of HCl (1M) that is neutralized

Controlled Variable	How do we control it?	Why do we control it?
The concentration of HCl which the antacid tablets/ mineral water is put in	1M HCl solution is prepared before the titration and aliquots of the same solution are used throughout the experiment.	Since the aim is to compare the volume of HCl that the antacid tablets/ mineral water neutralizes, it is crucial that they are all in the same concentration.
The volume of HCl which the antacid tablets/ mineral water is put in	30 cm^3 this solution is used for each trial, as measured through a measuring cylinder	For clearer and simpler calculation steps. (If they were of different volumes, the calculations would differ but the volume of HCl that were neutralized by antacid tablets/ mineral water could still be found.)
The number of drops of methyl red indicator	3 drops for each trial.	If larger amount of the indicator is put in the solution, it may disrupt the titration results because the indicators are a little acidic or alkaline.[7]
The concentration of NaOH	1M NaOH solution is prepared before the titration and aliquots of the same solution are used throughout the experiment.	For clearer and simpler calculation steps. Different concentrations of NaOH would mean different volumes of NaOH in the titrations and this would lead unnecessary calculations.
The number of antacid tablet/ bottles of mineral water put in the HCl	Always one portion is used. (1 antacid tablet or 1 bottle of mineral water.)	The aim of this experiment is to compare the antacid tablets and mineral water through the portion count.

[7] "Acid-Base Titrations," Chemistry LibreTexts, October 2, 2013, https://chem.libretexts.org/Ancillary_Materials/Demos_Techniques_and_Experiments/General_Lab_Techniques/Titration/Acid-Base_Titrations.

Materials:

- 1 x Clamp
- 1 x 50 mL Burette
- 1 x Funnel
- 1 x Mortar and Pest
- 2 x 1 L Volumetric flask (for HCl and NaOH solutions)
- 1 x Spatula
- 1 x 200 mL graduated cylinder
- 1 x 150 mL Erlenmeyer (for trials for antacid tablets)
- 1 x 500 mL beaker (for trials for mineral water)

Chemicals:

- 5 tablets of Kompensan (for a total of 5 trials)
- 5 tablets of Talcid (for a total of 5 trials)
- 5 tablets of Acidpass (for a total of 5 trials)
- 750cm^3 of 1M HCl (30cm^3 for each trial, a total of 25 titrations)
- Methyl red indicator (3 drops for each trial)
- 750cm^3 of 1M NaOH (30cm^3 for each titration, a total of 25 titrations)
- 5 bottles of *Kızılay* Mineral Water

<u>Procedure:</u>

A. Prepare 1 mol/dm^3 HCl solution (1 L)

I used the numbers on the package as well as the formula $M = \frac{w \times d \times 10}{m}$ where w is the amount of solute, d is density and m is molecular mass of HCl.

$$w = 31\%$$
$$d = 1.16\ kg\ dm^{-3}$$
$$m = 36.46\ g\ mol^{-1}$$
$$M = \frac{1.16 \times 31 \times 10}{36.46} \approx 9.86\ (3\ s.f.)$$

From the formula $M_1V_1 = M_2V_2$;

$$1M \times 1000\ mL = 9.86M \times V\ mL$$
$$V \approx 101\ mL$$

This means that $101\ mL$ of the solution should be added up to $1000\ mL$ using distilled water, in a $1L$ volumetric flask under a fume hood.

B. Prepare 1 mol/dm^3 NaOH solution (1 L)

I used a 99.5% pure NaOH. In order to make a $1M$ solution (from $M = \frac{n}{V}$ where M is molarity in $mol\ L^{-1}$, n is the number of moles and V is volume of the solute in liters) we need $n = 1 \times 1 = 1\ mol$ pure NaOH. Since the molecular mass of NaOH is $40\ mol/gr$, we need $40 \times \frac{100}{99.5} \approx 40.20\ g$ of the 99.5% pure NaOH.

C. Back titration (antacid tablets)

These are to be repeated for 5 times for each 3 types of antacid tablet.

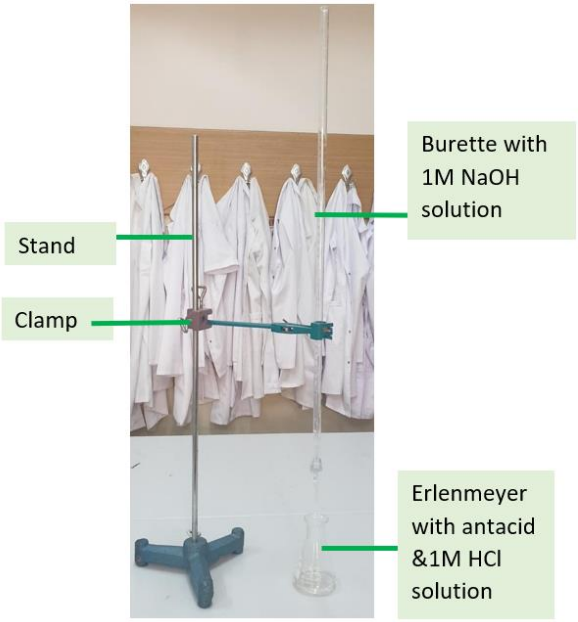
1. Set up the titration by attaching the burette to the stand with a clamp.
2. Add 30 cm^3 HCl solution to the erlenmeyer.
3. Crush 1 tablet of antacid in the mortar and pestle until it turns into powder.
4. Pour the antacid to the erlenmeyer which has HCl, scrape the most crushed tablet from the mortar as you can to the erlenmeyer using a spatula, and wait 1 minute.
5. Remove from the stand and add 3 drops of methyl red.
6. Pour NaOH to the burette using a funnel and note the initial reading down.

7. Slowly start to titrate the NaOH, shake the erlenmeyer continuously, noting down the final volume (which is when the solution turns pink, marking the end of titration) to determine volume of NaOH required.
8. Ensure that the erlenmeyer is all clean and dry after each trial.

D. Back titration (mineral water)
Replicate the steps from the previous part (skipping step 3), using mineral water instead of the powdered antacid tablet and a 500mL beaker instead of an erlenmeyer. Conduct this titration 5 times.

Risk Assessment:

Safety Precautions: Throughout the experiment, appropriate gloves and safety googles should be worn as well as a lab coat. While handling strong chemicals such as hydrochloric acid and sodium hydroxide, one should be careful since they are highly corrosive and may cause irritation to skin (as stated on the packaging of the chemicals). It was also kept in mind that HCl was handled under a fume hood.
The products of reactions between antacids and HCl are non-toxic or hazardous, since reactions are also happening in human stomach.
Environmental Precautions: The used chemicals are put in a chemical bin.
Ethical Considerations: There are none in this experiment.



Raw Data

Table 1: The burette readings of titration using **Talcid** as antacid

Trial	Initial reading (cm^3)	Final reading (cm^3)	Difference (cm^3)
	± 0.05	± 0.05	± 0.10
1	18.20	33.30	15.10
2	33.30	48.70	15.40
3	0.60	15.20	14.60
4	15.20	30.10	14.90
5	30.10	45.10	15.00

Table 2: The burette readings of titration using **Acidpass** as antacid

Trial	Initial reading (cm^3)	Final reading (cm^3)	Difference (cm^3)
	± 0.05	± 0.05	± 0.10
1	20.40	28.50	8.10
2	28.50	37.80	9.30
3	37.80	47.20	9.40
4	0.00	9.20	9.20
5	9.20	18.50	9.30

Table 3: The burette readings of titration using **Kompensan** as antacid

Trial	Initial reading (cm^3)	Final reading (cm^3)	Difference (cm^3)
	± 0.05	± 0.05	± 0.10
1	3.00	23.30	20.30
2	23.30	43.40	20.10
3	0.30	20.40	20.10
4	20.40	40.80	20.40
5	0.00	20.20	20.20

Qualitative Observations:
After each antacid was thrown in the acid, the solution produced bubbles and a cloudy texture on the surface. The progression of the reaction can be confirmed with a subtle fizz sound, which continued around 20 seconds after the antacid was added to the acid.
Talcid and Kompensan are white colored antacids and they formed a white solution combined with HCl. However, Acidpass tablet has a pink/red color so the solutions including Acidpass were pink colored.

Table 4: The burette readings of titration using **Kızılay Mineral Water**

Trial	Initial	Final	Difference
1	0.00	25.90	25.90*
2	4.20	25.20	21.00
3	0.30	21.50	21.20
4	1.60	23.00	21.40
5	3.70	24.50	20.80

*This data is identified as anomalous data and excluded from all possible calculations.

Qualitative Observations:
The mineral water itself produces hissing sounds in motion, and combined with the sound of the reaction; the solution made more noises than antacid tablet containing solutions.

Processed Data

Table 5: Volume of NaOH (in cm^3) that neutralizes the excess HCl that remains from the reaction of each antacid and HCl

Used acid-neutralizing agent before titration	Volume of NaOH used in the titration (cm^3) (± 0.1)					
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
Talcid	15.10	15.40	14.60	14.90	15.00	15.00
Acidpass	8.10	9.30	9.40	9.20	9.30	9.60
Kompensan	20.30	20.10	20.10	20.40	20.20	20.22
Mineral Water	25.90*	21.00	21.20	21.40	20.80	21.10

($Average = \frac{sum\ of\ the\ results\ of\ the\ trials}{number\ of\ trials}$)

Necessary calculations with explanations and sample calculations

The calculation step and its explanation	Sample calculation (for the first trial of Talcid)
A. <u>The moles of NaOH used:</u> Volume of NaOH in dm^3 are found by dividing the values in cm^3 by 1000.The number of moles is found by the formula $M = \frac{n}{V}$ where M is the molarity in $mol\ dm^{-3}$, n is the number of moles and V is the volume in dm^3.	$\frac{15.10\ cm^3}{1000} = 0.01510\ dm^3\ (4\ s.f.)$ $1\ mol\ dm^{-3} = \frac{n}{0.01510\ dm^3}$ $n = 0.01510\ mol = 1.5 \times 10^{-2}\ mol$
B. <u>The moles of HCl that reacted with NaOH:</u> Since NaOH and HCl reacts in a 1:1 ratio, the values should be the same as the previous line. NaOH(aq)+HCl(aq)→NaCl(aq)+H_2O(l)	1.5×10^{-2} mol NaOH should react with 1.5×10^{-2} mol HCl in this reaction.
C. <u>The volume of HCl that reacted with NaOH:</u> The volume (in dm^3) is found using $M = \frac{n}{V}$ where M is the molarity in $mol\ dm^{-3}$, n is the number of moles and V is the volume in dm^3; considering the given values of M and n. After that, the found value in dm^3 is converted to cm^3 by a multiplication with 1000.	$1\ mol\ dm^{-3} = \frac{0.01510\ \text{mol}}{V}$ $V = 0.01510\ dm^3$ $0.01510\ dm^3\ \times 1000 = 15.10\ cm^3$
D. <u>The volume of HCl that reacted with acid neutralizing agents:</u> Since this is a back titration, the rest of the HCl in the erlenmeyer that is not neutralized by the NaOH should be neutralized by the acid neutralizing agents. Since there initially was $30\ cm^3$ HCl in the erlenmeyer, the values from the previous table should be subtracted from $30\ cm^3$.	$30\ cm^3 - 15.10$ $= 14.90\ (2\ decimal\ places)$

Calculations for uncertainties

It should be noted that the uncertainty is found by the addition of the absolute uncertainties in an addition/ subtraction and by the addition of percentage uncertainties in a multiplication/division. The percentage uncertainty can be found by the ratio of the absolute certainty of a value and the value itself. The absolute uncertainty of a value is indicated by Δ symbol preceding it.

	The calculation step and formulas used	The calculation
The uncertainty in the concentration of the prepared $1M$ NaOH solution	The uncertainty of the moles of the solute (NaOH) The original formula: $n = \frac{m}{M_r}$ The formula for uncertainty: $\Delta n_{NaOH} = (\frac{\Delta m_{NaOH}}{m_{NaOH}}) \times n_{NaOH}$	Since the uncertainty of the electronic balance is ± 0.01, $\Delta n_{NaOH} = (\frac{0.01}{40.20}) \times 40 \approx 0.01$
	The original formula: $c = \frac{n}{V}$ The formula for uncertainty: $\Delta c_{NaOH} = (\frac{\Delta n_{NaOH}}{n_{NaOH}} + \frac{\Delta V_{NaOH}}{V_{NaOH}}) \times c_{NaOH}$	Since the uncertainty of the conical flask is ± 0.5, $\Delta c_{NaOH} = \left(\frac{0.01}{40} + \frac{0.5}{1000}\right) \times 1$ $= 0.0008\ M$
The uncertainty in the concentration of the prepared $1M$ HCl solution	The original formula: $M_1 = \frac{M_2 V_2}{V_1}$ The formula for uncertainty: $\Delta M_{1_{HCl}} = \left(\frac{\Delta V_{2_{HCl}}}{V_{2_{HCl}}} + \frac{\Delta V_{1_{HCl}}}{V_{1_{HCl}}}\right) \times M_{1_{HCl}}$	$\Delta M_{1_{HCl}} = \left(\frac{0.5}{101.5} + \frac{0.3}{1000}\right) \times 1$ $\Delta M_{1_{HCl}} \approx 0.005\ M$

The calculation step and its explanation	Sample Calculation (for the first trial of Talcid)
A. The uncertainty of the moles of NaOH in the titration $\Delta n_{NaOH} = (\frac{\Delta V_{NaOH}}{V_{NaOH}} + \frac{\Delta M_{NaOH}}{M_{NaOH}}) \times n_{NaOH}$	$\Delta n_{NaOH} = (\frac{0.10\ cm^3}{15.1\ cm^3} + \frac{0.0008\ M}{1\ M}) \times 0.01510\ mol$ $\Delta n_{NaOH} \approx 0.00011 (2\ s.f.)$
B. The uncertainty of the moles of HCl that reacted with NaOH Since they react in 1:1 ratio, $\Delta n_{HCl} = \Delta n_{NaOH}$	$\Delta n_{HCl} \approx 0.00011\ mol$
C. The uncertainty of the volume of HCl that reacted with NaOH $\Delta V_{HCl} = \left(\frac{\Delta n_{HCl}}{n_{HCl}} + \frac{\Delta M_{HCl}}{M_{HCl}}\right) \times V_{HCl}$	$\Delta V_{HCl} = \left(\frac{0.00011\ mol}{0.01510\ mol} + \frac{0.005\ M}{1\ M}\right) \times 15.10$ $\Delta V_{HCl} \approx 0.2$
D. The uncertainty of the volume of HCl that reacted with acid neutralizing agents The initial volume of HCl in the erlenmeyer was $30 \pm 0.5\ cm^3$ (because it was measured with a graduated cylinder). We should extract $V_{HCl} \pm \Delta V_{HCl}$ from this number. The uncertainty of the volume of HCl that reacted with acid neutralizing agents should be: $0.5 + \Delta V_{HCl}\ cm^3$	$0.5\ cm^3 + 0.2\ cm^3 = 0.7\ cm^3$

Table 6: The volume of HCl (in cm^3) that the acid neutralizing agents neutralize

Used antacid brand before titration	Volume of HCl (cm^3)					
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
Talcid	14.90± 0.7	14.60 ± 0.7	15.40± 0.7	15.10± 0.7	15.00± 0.7	15.00± 0.7
Acidpass	21.90± 0.7	20.70± 0.7	20.60± 0.7	20.80± 0.7	20.70± 0.7	20.94± 0.7
Kompensan	9.70± 0.7	9.90± 0.7	9.90± 0.7	10.60± 0.7	10.80± 0.7	8.06± 0.7
Mineral Water	-	9.00± 0.7	8.80± 0.7	8.60± 0.7	9.20± 0.7	8.90± 0.7

Calculating the amount of mineral water which is equivalent to an antacid tablet (considering the volume of HCl they neutralize)

a) Instead of taking a tablet of Talcid:

People can drink $\frac{15.00\pm 0.7}{8.90\pm 0.7} = 1.7 \pm 0.2$ bottles of Kızılay Mineral Water.

(The uncertainty is calculated by adding the percentage uncertainties of numerator and denominator: $\frac{0.7}{15.00} + \frac{0.7}{8.90} \approx \frac{0.2}{1.7}$)

b) Instead of taking a tablet of Acidpass:

People can drink $\frac{20.94\pm 0.7}{8.90\pm 0.7} = 2.4 \pm 0.3$ bottles of Kızılay Mineral Water.

(The uncertainty is calculated by adding the percentage uncertainties of numerator and denominator: $\frac{0.7}{20.94} + \frac{0.7}{8.90} \approx \frac{0.3}{2.4}$)

c) Instead of taking a tablet of Kompensan:

People can drink $\frac{8.06\pm 0.7}{8.90\pm 0.7} = 0.9 \pm 0.2$ bottles of Kızılay Mineral Water.

(The uncertainty is calculated by adding the percentage uncertainties of numerator and denominator: $\frac{0.7}{8.06} + \frac{0.7}{8.90} \approx \frac{0.2}{0.9}$)

Conclusion and Evaluation

Antacid tablets are medications that are designed to neutralize HCl in gastric juice. In this experiment, the amount of 1M HCl that antacid tablets (Talcid, Kompensan and Acidpass) neutralize is observed through a back titration. Kızılay mineral water is also used in this experiment as an at-home remedy for similar problems due to excess amount of gastric acid, to compare with the effects of the antacids.

This experiment also gave the chance for researchers to compare the effects of antacid tablets among themselves. It is seen that Acidpass neutralized the most volume HCl and Kompensan neutralized the least volume of HCl. However, because of systematic and random errors, the experimental results are different from the theoretical values. Both theoretical values and percentage errors are calculated below.

Table 7: Literature values of antacid tablets

	Mass of acid-neutralizing agents in one tablet	Number of moles of neutralizing agents in one tablet $n = \frac{m}{M_r}$	Moles of HCl neutralized	Volume of 1M HCl that should be neutralized (cm^3)
Talcid	$500\ mg = 0.500g$ hydrotalcite	$\frac{0.500\ g}{n(Mg_6Al_2CO_3(OH)_{16} \cdot 4H_2O)} = \frac{0.500\ g}{603.98\ g} \approx 0.000828\ mol = 8.28 \times 10^{-4}\ mol$	$0.01490 = 1.49 \times 10^{-2}$	14.90
Acidpass	$800mg = 0.800g$ calcium carbonate	$\frac{0.800\ g}{n(CaCO_3)} = \frac{0.800\ g}{100.09\ g} \approx 0.00799\ mol = 7.99 \times 10^{-3}\ mol$		21.64

	$165\ mg = 0.165\ g$ magnesium hydroxide	$\frac{0.500\ g}{n(\mathrm{Mg(OH)_2})} = \frac{0.165\ g}{58.32\ g} \approx 0.00283\ mol$ $= 2.83 \times 10^{-3}\ mol$	$0.01598 + 0.00566 = 0.02164 = 2.164 \times 10^{-2}$	
Kompensan	$340\ mg = 0.340\ g$ dihydroxyaluminum sodium carbonate	$\frac{0.340\ g}{n(\mathrm{AlO(OH)_2CO_2Na})} = \frac{0.340\ g}{143.99\ g} \approx 0.00236\ mol$ $= 2.36 \times 10^{-3}$	$0.00944 = 9.44 \times 10^{-3}$	9.44

Note: The ingredients of the antacid tablets and their masses were taken from the prospectuses of the tablets, that come with the tablets while purchase.

Sample Calculation for Talcid:

One tablet of Talcid contains $500\ mg = 0.500g$ hydrotalcite. If we find how many moles is this value, we can find the amount of HCl it will react with. The molar mass of hydrotalcite is:

$$n(\mathrm{Mg_6Al_2CO_3(OH)_{16} \cdot 4H_2O}) = 6(24.30) + 2(26.98) + 1(12.01) + 23(16.00) + 24(1.01) = 603.98$$

So $0.500g$ hydrotalcite is:

$$n = \frac{total\ mass}{molar\ mass} = \frac{0.500}{603.98} \approx 0.000828\ mol$$

From the equation we can see that $n(\mathrm{Mg_6Al_2CO_3(OH)_{16} \cdot 4H_2O}) : \mathrm{n(HCl)} = 1 : 18$

$Mg_6Al_2CO_3(OH)_{16}{\cdot}4H_2O + 18HCl \rightarrow 6MgCl_2 + 2AlCl_3 + CO_2 + 21H_2O$

So $0.500g$ hydrotalcite will react with $18 \times 0.000828\ mol = 0.0149\ mol$ HCl.

This means $1\ mol\ dm^{-3} = \frac{0.0149\ mol}{V\ dm^3} \rightarrow V = 0.0149\ dm^3 = 14.9\ cm^3$ from 1M HCl solution.

Literature value of the mineral water

On the package of the mineral water, it states that one bottle contains $454\ mg = 0.454\ g$ bicarbonate. The molecular mass of bicarbonate is:

$$n(HCO_3^-) = 1.01 + 12.01 + 3(16.00) = 61.02\ g$$

Since $n = \frac{m}{M_r}$, one bottle of mineral water contains:

$$n = \frac{0.454\ g}{61.02\ g} \approx 0.00744\ mol$$

Since bicarbonate and HCl reacts in a 1:1 ratio, one bottle of mineral water will react with $0.00744\ mol$ HCl.

This means $1\ mol\ dm^{-3} = \frac{0.00744\ mol}{V\ dm^3} \rightarrow V = 0.00744\ dm^3 = 7.44\ cm^3$ from 1M HCl solution.

Calculating percentage error for the volume of HCl that is neutralized (2 significant figures)

$$\%error = \frac{|theoretical\ value - experimental\ value|}{theoretical\ value} \times 100$$

a. For Talcid:

$$\%error = \frac{|14.90 - 15.00|}{14.90} \times 100 \approx 0.6711\% \approx 0.67\%$$

b. For Acidpass

$$\%error = \frac{|21.64 - 20.94|}{21.64} \times 100 \approx 3.234\% \approx 3.2\%$$

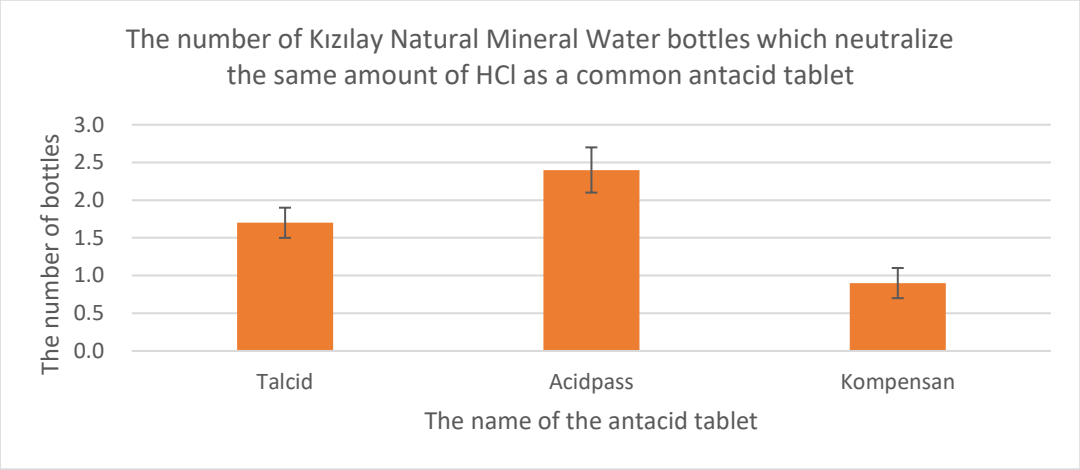
c. For Kompensan

$$\%error = \frac{|9.44 - 8.90|}{9.44} \times 100 \approx 5.720\% \approx 5.7\%$$

d. For Kızılay Mineral Water

$$\%error = \frac{|7.44 - 9.44|}{7.44} \times 100 \approx 26.88\% \approx 26\%$$

Comparing these results with the "at-home remedy" (natural mineral water), it is seen that a couple bottles of mineral water can also have the same neutralizing affect as an antacid tablet. For Talcid one would need 1.7 ± 0.2 bottles, for Acidpass 2.4 ± 0.3 bottles and for Kompensan 0.9 ± 0.2 bottles. However, it should be noted that drinking a lot of mineral water can have health risks. It can damage the tooth enamel because of its acidity or it can cause bloating. Also, mineral water is rich in a lot of minerals and ions so it may not be suitable for every diet plan.[8]



Even though this experiment assumed that the effects of antacid tablets can be measured though the amount of HCl they neutralize, in reality that is not the case. For example, compounds including aluminum has the "slowest" and weakest effect. This also correlates with this experiment's results, Kompensan being the least effective among the antacid tablets. Calcium carbonate is found to be quick and long lasting[9], this experiment also states that the tablet with calcium carbonate (Acidpass) neutralizes the most HCl. This may mean that, even considering the duration of action, Acidpass is the most "effective" antacid tablet among the three; however, there might be other factors to be considered.

Errors

Systematic Errors:	**Why this is important**	**How it can be improved**
Not being able to read at the top of the meniscus of the burette	For noting the correct amount of volume used in the burette, the readings should be done at the top of the meniscus, when looking at eye-level. Since the same person performed all the titrations in this experiment, the readings can have such error due to wrongly-performed reading constantly.	A digital burette could have been used for eliminating the human error.
Not being able to identify the end point	Even though the color change was abrupt for trials using the antacid tablets, the color change for mineral water was observed to be gradual. The endpoint was defined to be the slightest	The titration can be followed using a pH meter, this might give the exact point where the solution turns basic. As an alternative, an automatic titrator

[8] "Does Mineral Water Have Health Benefits?," accessed July 29, 2022, https://www.healthline.com/nutrition/mineral-water-benefits#drawbacks.

[9] "AAA-PIB2-GIS Ilaçları.Ppt," accessed July 29, 2022, https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Facikders.ankara.edu.tr%2Fpluginfile.php%2F163360%2Fmod_resource%2Fcontent%2F0%2FAAA-PIB2-GIS%2520ila%25C3%25A7lar%25C4%25B1.ppt&wdOrigin=BROWSELINK.

	shade of yellow, but it cannot be guaranteed to be the exact shade for every trial.	can signal the endpoint without the need for a color change.
Not waiting long enough for the reaction between the antacid/mineral water and HCl to fully take place	It was observed that hissing sounds end and the solution stays still after 60 seconds, so the titration was performed a minute after the antacid tablet/mineral water is added to HCl. However, it is possible that the reaction wasn't over yet and was continuing on a molecular level.	Waiting for longer time span for the reaction to fully end.
Other substances in the antacid tablets/ mineral water affecting the endpoint	Kompensan tablets included an unknown amount of $CaCO_3$, since it also could be reacting with HCl even in little amounts; this could be causing error.	Different techniques to extract a certain substance in the tablets and mineral water could have been used.

Random Errors:	**Why this is important**	**How it can be improved**
Not being able to close the burette at the exact endpoint	It is possible that the burette is closed after the endpoint is reached, so the volume of the titrant would be slightly in excess. We know this happened in this experiment because for Acidpass and Kompensan, the theoretical value is higher than the experimental value.	Performing the titration while adding the titrant in smaller portions and more slowly could give more accurate results.
The leftover substances that are in the volumetric flask while transporting liquids	The volumetric flash where the 30 cm^3 HCl is measured can have some of the acid left after it is transported to an erlenmeyer.	The titration could have been performed in the same erlenmeyer that is measured without any transportation.
The leftover grinded antacid in the mortar and on the pestle	After the grinding process, some of the substance is can be left on the mortar and pestle.	A brush could have been used to obtain more of the substance.

Possible extensions:

- Studying with more antacid tablets/ more brands of mineral water
- Studying with the liquid alternatives of antacids
- Studying the effectiveness of antacids based on their unit mass
- Studying the cost effectiveness of antacid tablets
- Studying with other home remedies for acid reflux (example: yogurt)
- Studying the rate of the reaction between the antacid tablets/ home remedies and gastric acid

Bibliography

"AAA-PIB2-GIS Ilaçları.Ppt." Accessed July 29, 2022. https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Facikders.ankara.edu.tr%2Fpluginfile.php%2F163360%2Fmod_resource%2Fcontent%2F0%2FAAA-PIB2-GIS%2520ila%25C3%25A7lar%25C4%25B1.ppt&wdOrigin=BROWSELINK.

Chemistry LibreTexts. "Acid-Base Titrations," October 2, 2013. https://chem.libretexts.org/Ancillary_Materials/Demos_Techniques_and_Experiments/General_Lab_Techniques/Titration/Acid-Base_Titrations.

Ball, David W., and Jessie A. Key. "Neutralization Reactions," September 16, 2014. https://opentextbc.ca/introductorychemistry/chapter/neutralization-reactions/.

Bell-Young, Lucy. "What Is Methyl Red? | The Chemicals Blog." ReAgent Chemicals, July 26, 2021. https://www.chemicals.co.uk/blog/what-is-methyl-red.

"Bizim Hikayemiz." Accessed August 9, 2022. https://www.kizilaymadensuyu.com.tr/bizim-hikayemiz/.

"Does Mineral Water Have Health Benefits?" Accessed July 29, 2022. https://www.healthline.com/nutrition/mineral-water-benefits#drawbacks.

"Kızılay Maden Suyu." Accessed August 9, 2022. https://www.kizilaymadensuyu.com.tr/.

"Stoichiometry - OpenStax CNX." Accessed July 28, 2022. https://cnx.org/contents/951c03bf-d5f7-44f1-8c2c-c87beacc2256:af5866fb-86b6-4867-9465-a87d5c84a99b.

Stuart, Annie. "What Is Acid Reflux Disease?" WebMD. Accessed June 22, 2022. https://www.webmd.com/heartburn-gerd/guide/what-is-acid-reflux-disease.