SI Chemistry - Full Discipline Demo

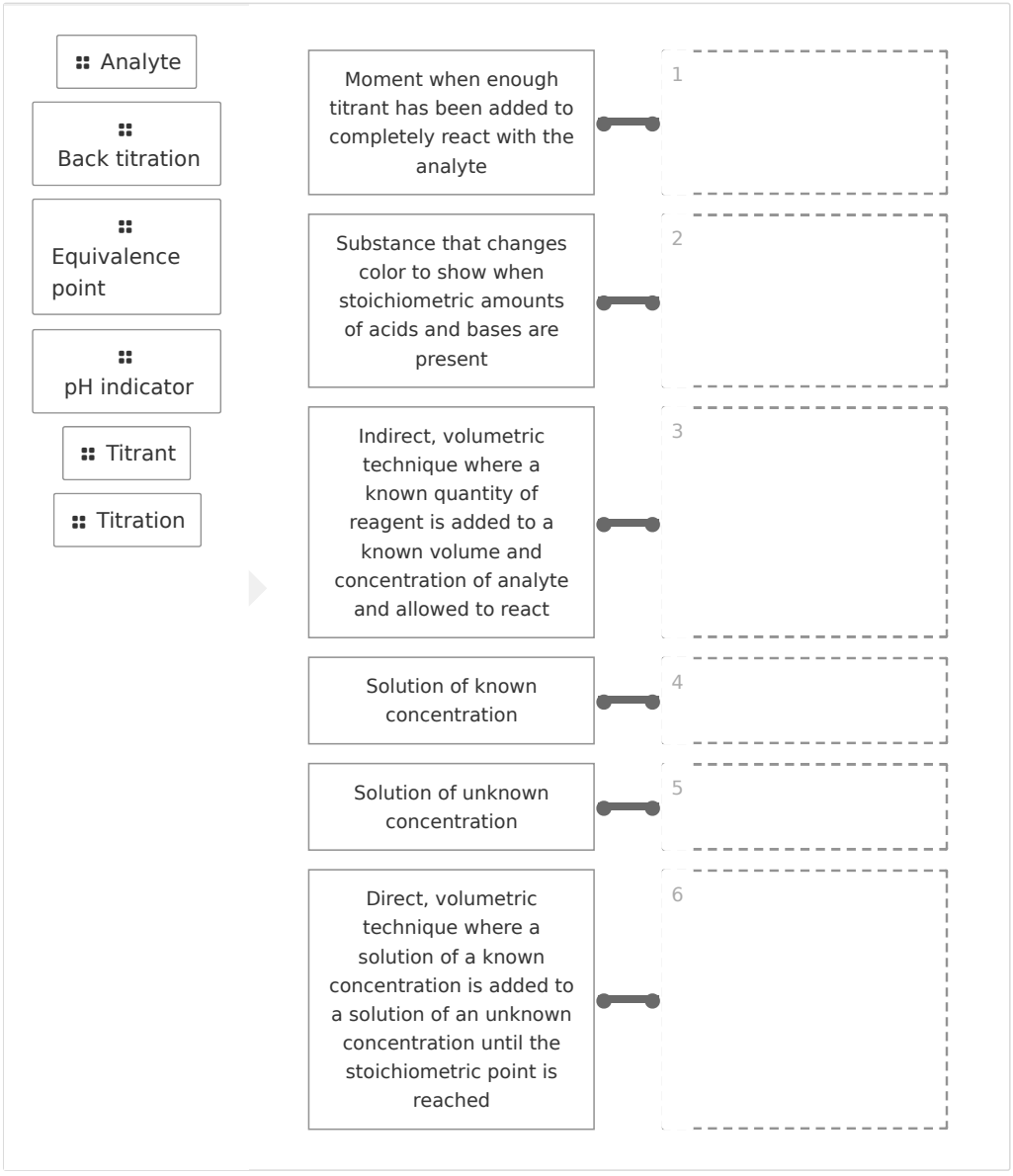
Antacid Analysis and Titration

Final Report - Answer Guide

Institution	Science Interactive University
Session	SI Chemistry - Full Discipline Demo
Course	SI Chemistry - Full Discipline Demo
Instructor	Sales SI Demo

Test Your Knowledge

Match each term with the best description.

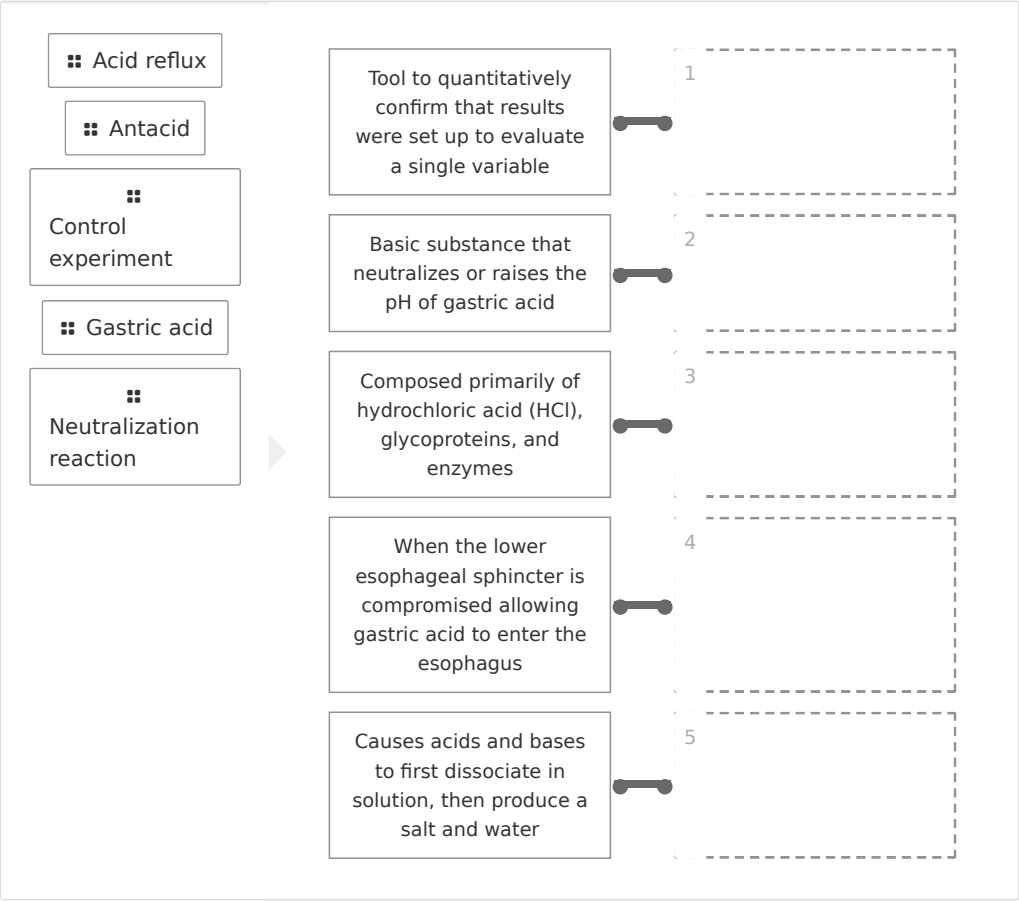


Correct answers:

1 Equivalence point 2 pH indicator 3 Back titration 4 Titrant

5 Analyte 6 Titration

Match each term with the best description.

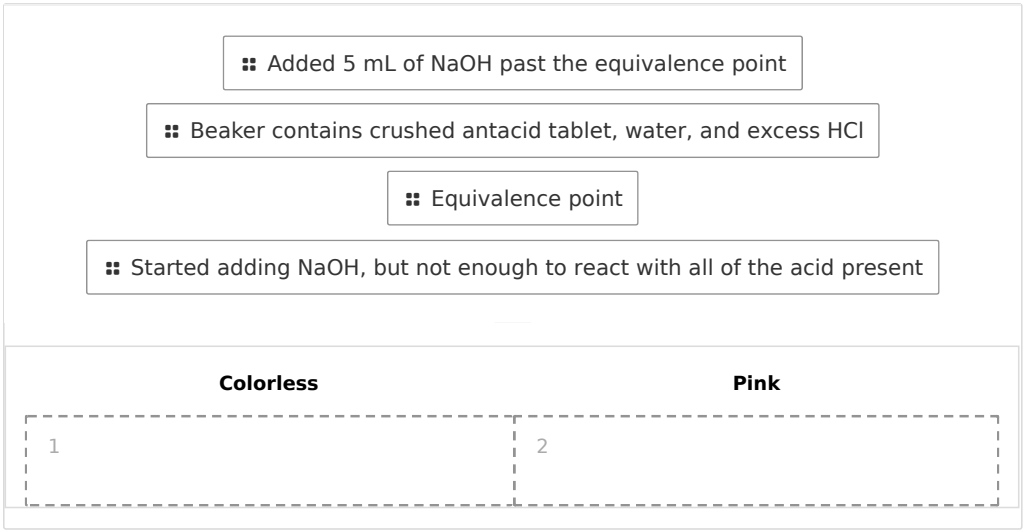


Correct answers:

1 Control experiment 2 Antacid 3 Gastric acid 4 Acid reflux

5 Neutralization reaction

Identify the color of the solution at the different points throughout a titration between an antacid tablet and NaOH if phenolpthalein is used as the indicator.



Correct answers:

1 Started adding NaOH, but not enough to react with all of the acid present

Beaker contains crushed antacid tablet, water, and excess HCl

2 Added 5 mL of NaOH past the equivalence point Equivalence point

Exploration

The duodenal sphincter is the internal mechanism to allow food to enter the stomach and to prevent gastric acid from entering into the esophagus.

- True
- False ✔

Gastric acid is produced and secreted by specialized glands in the stomach, where it functions to break down the food we consume into smaller nutrient particles so they can be absorbed by the small intestine.

- True ✔
- False

In a healthy digestive system, the gastric acid remains in the stomach.

- True ✔
- False

Phenolphthalein is a pH indicator that is _____ in the presence of strong acids.

- pink
- colorless ✔
- yellow
- white

A _____ is an indirect, quantitative volumetric technique where a known quantity of reagent is added to a known volume and concentration of analyte, and allowed to react.

- titration
- equivalence point
- back titration ✔
- analyte

If the initial and final amount of HCl involved in a reaction with antacid are known, then the _____ may be calculated.

- amount of HCl neutralized by the antacid ✔
- intermediate HCl (g/g)
- final number of moles of NaOH
- All of the above

Exercise 1

If an antacid tablet weighed 1.6 grams, how many moles of gastric acid (HCl) would it neutralize? Use the results obtained in Data Tables 1 and 2 to explain and quantify your answer.

Using the data in Data Tables 1 and 2, each gram of the antacid tablet neutralized 0.28 grams of HCl. If an antacid tablet weighed 1.60 grams, it would neutralize 0.45 grams of HCl. Converting this to moles, 1.60 grams of the antacid tablet would neutralize 0.012 moles of HCl.

If you performed this experiment with a titrant of 0.5 M NaOH, would you expect your results in Data Table 2 to change or stay the same? Explain your answer.

If the experiment were performed with 0.5M NaOH instead of 1.0M NaOH, the results in Data Table 2 would not change. As the results in Data Table 2 are based on mol of NaOH and HCl, a lower concentration of NaOH would result in a higher volume of NaOH needed to reach stoichiometric quantities, but the overall amount of moles required of NaOH would not change. For example: 20 mL of 1.0M NaOH contains the same quantity of moles as 40 mL of 0.5M NaOH.

The reaction that occurred when the antacid mixed with the HCl resulted in an additional product (besides a salt and water). Did you see evidence of this product? Describe the experimental evidence you witnessed that supports the formation of the additional product.

The reaction that occurred with the antacid mixed with the HCl produced CO_2(g) in addition to the salt and water. There was evidence of this product when performing the experiment as the addition of antacid to HCl resulting in a fizzing bubbling reaction, which was the CO_2 gas production and subsequent release into the atmosphere.

Data Table 1: Antacid Neutralization Data
(SAMPLE ANSWER BELOW)

	Trial 1	Trial 2	Average
Mass of Crushed Antacid (g)	0.5	0.5	0.5
Concentration of HCl (M)	1.0	1.0	1.0
Volume HCl (mL)	5.0	5.0	5.0

Concentration of NaOH (M)	1.0	1.0	1.0
Initial NaOH Volume (mL)	9.0	8.0	
Final NaOH Volume (mL)	8.0	6.8	
Total Volume of NaOH Used (mL)	1.0	1.2	1.1

Data Table 2: Experimental Results
(SAMPLE ANSWER BELOW)

HCl available for neutralization (g):	0.18
NaOH required to reach stoichiometric point (mol):	0.0011
HCl neutralized by antacid (g):	0.14
HCl neutralized per gram of antacid (g):	0.28

Exercise 2

Did the control experiment verify or refute the results from Exercise 1? Use your results from Exercises 1 and 2 to validate your answer.

The results from the control experiment verified the results from Exercise 1. While the results from the control experiment suggest that the antacid neutralized 0.15 grams of HCl and the back titration experiment suggest that the antacid neutralized 0.14 grams of HCl, there is only a 7% error between the two results. As the scale weighs to a precision of 0.1 grams, this amount of error is to be expected in such an experiment. If the control experiment were to suggest that there was not a difference in volume between the control and the back titration experiment, then it would suggest that the variable (antacid) of the back titration experiment was not set-up properly.

Why is it important to perform multiple trials of experiments?

It is important to perform multiple trials of experiments as there is always an opportunity for error. The more trials that are performed giving similarly accurate and precise results, the more likely it is that the experiment is resulting in reproducible data, which allows it to be verified as a successful experimental design and valid results/conclusions.

If a commercial was aired that claimed a new antacid was able to neutralize 25 times more acid than the antacid tablet investigated in this experiment, how would you test this claim?

If a commercial was aired suggesting a new antacid was able to neutralize 25 times more acid than the antacid tablet investigated in this experiment, the same experiment would be performed, using the new antacid in place of the antacid tablet already used in this experiment. However, more HCl would be needed than used in this experiment so that there was enough to back titrate due to the potency of this new antacid. The amount of acid neutralized, gram per gram, would then be compared to the original antacid tablet to see if the difference was, in fact, 25 times greater than for the original antacid.

Describe possible sources of error in both Exercise 1 and 2. Describe possible way to reduce this error in future experiments.

As with any experiment, there are a variety of possible sources of error, including: the accuracy of the scale weighing to only 0.1 grams, the accuracy of the titrator and graduated cylinder, a possible overshot of adding more NaOH than was needed to reach exact stoichiometric quantities, inconsistency in rounding numbers during calculations, having chemical concentrations that were not first standardized, etc. There are a variety of ways to reduce error in future experiments, including: using a scale, graduated cylinder, and titrator with higher degrees of precision, performing more than one experiment trial, standardizing chemical concentrations prior to use, etc.

Data Table 3: Control Experiment Data
(SAMPLE ANSWER BELOW)

	Trial 1	Trial 2	Average
Concentration of HCl (M)	1.0	1.0	1.0
Volume HCl (mL)	5.0	5.0	5.0
Concentration of NaOH (M)	1.0	1.0	1.0
Initial NaOH Volume (mL)	9.4	8.0	
Final NaOH Volume (mL)	4.0	2.8	
Total Volume of NaOH Used (mL)	5.4	5.2	5.3

Data Table 4: Control Experiment Results
(SAMPLE ANSWER BELOW)

NaOH needed to neutralize 5 mL of 1.0M of HCl (mol)	0.0053
HCl neutralized (g)	0.19

NaOH volume difference between back titratin and control (mL)	4.2
HCl neutralized by NaOH volume difference (g)	0.15

Competency Review

Acid reflux disease is caused by a compromised _____.

- stomach lining
- esophageal muscle
- lower esophageal sphincter ✔
- small intestine

Acid reflux disease results in _____.

- inflammation and irritation of the esophageal lining ✔
- inflammation and irritation of the stomach lining
- gastric acid overproduction
- gastric acid is contained in the stomach

Commercial antacids contain a wide variety of basic substances as their active ingredient, including _____.

- aluminum hydroxide ($Al(OH)_3$)
- magnesium hydroxide ($Mg(OH)_2$)
- sodium bicarbonate ($NaHCO_3$)
- calcium carbonate ($CaCO_3$)
- All of the above ✔

In a neutralization reaction, the acid and the base _____ .

- dissociate in solution, produce hydroxide (OH-) and hydrogen (H+) ions respectively, then react to produce a salt and water
- dissociate in solution, produce hydrogen (H+) and hydroxide (OH-) ions respectively, then react to produce a salt and water ✔
- react to produce a salt and water then dissociate in solution, producing hydrogen (H+) and hydroxide (OH-) ions respectively
- react to produce a salt and water then dissociate in solution, producing hydroxide (OH-) and hydrogen (H+) ions respectively

A pH indicator is used in a titration to determine _____.

- when the equivalence point has been reached ✔
- when a precipitate has formed
- when phenolphthalein is present

_____ is a direct, quantitative, volumetric technique, where a solution of a known concentration is added to a solution of an unknown concentration until the equivalence point is reached.

- A back titration
- A titration ✔
- A stoichiometric point
- A pH indicator test

If you were to run a control experiment to confirm the results of a back titration, what would be removed from the experiment?

- The product
- The titrant
- The variable tested ✔

When HCl is added to a carbonate-containing antacid a _____ occurs.

- color change
- major temperature change
- fizzing reaction (formation of gas) ✔
- change in the state of matter of the HCl

When performing a titration, it is important to add NaOH _____ to accurately identify the equivalence point.

- one mL at a time
- one drop at a time ✔
- before the addition of the antacid
- before the phenolphthalein

In a control experiment, to validate the amount of HCl neutralized by an antacid, identify the item that would not be present.

- Antacid ✔
- NaOH
- HCl
- Phenolphthalein

Extension Questions

The manufacturers of Brand A and Brand C antacids both claim that their product neutralizes 50% more HCl (stomach acid) per gram of tablet than Brand B. A pharmaceutical scientist completed a titration for each manufactured brand of antacid and recorded the findings in the table below.

Measurements	Brand A	Brand B	Brand C
Mass Crushed Antacid (g)	1.0	1.0	1.0
Concentration HCl (M)	1.0	1.0	1.0
Volume HCl (mL)	10.0	10.0	10.0
Concentration NaOH (M)	1.0	1.0	1.0
Total Volume NaOH Used in Titration (mL)	4.1	5.2	1.1

Using the experimental titration data collected by the pharmaceutical scientist, calculate the grams of HCl neutralized by each antacid and the grams HCl neutralized per gram of each antacid. Show your work. Based on your calculations, are the claims of Brand A and

Brand C true? Explain your answer and identify any sources of error. Based on your calculations, which antacid should a consumer suffering from excessive heartburn purchase for relief? Explain your answer.

(SAMPLE ANSWER BELOW)

Brand A's calculations:
4.1 mL NaOH x (1 L/1,000 mL) x (1 mol/L) = 0.0041 mol NaOH to reach stoichiometric point
0.0041 mol NaOH x (1 mol HCl/1 mol NaOH) = 0.0041 mol HCl
10.0 mL HCl x (1 L/1,000 mL) x (1 mol HCl/L) x (36.46 g HCl/mol) = 0.36 g HCl available for neutralization
0.0041 mol HCl x (36.46 g HCl/mol) = 0.15 g HCl neutralized by NaOH
HCl neutralized by antacid = 0.36 g – 0.15 g = 0.21 g HCl/g tablet

Brand B's calculations:
5.2 mL NaOH x (1 L/1,000 mL) x (1 mol/L) = 0.0052 mol NaOH to reach stoichiometric point
0.0052 mol NaOH x (1 mol HCl/1 mol NaOH) = 0.0052 mol HCl
10.0 mL HCl x (1 L/1,000 mL) x (1 mol HCl/L) x (36.46 g HCl/mol) = 0.36 g HCl available for neutralization
0.0052 mol HCl x (36.46 g HCl/mol) = 0.19 g HCl neutralized by NaOH
HCl neutralized by antacid = 0.36 g – 0.19 g = 0.17 g HCl/g tablet

Brand C's calculations:
1.1 mL NaOH x (1 L/1,000 mL) x (1 mol/L) = 0.0011 mol NaOH to reach stoichiometric point
0.0011 mol NaOH x (1 mol HCl/1 mol NaOH) = 0.0011 mol HCl
10.0 mL HCl x (1 L/1,000 mL) x (1 mol HCl/L) x (36.46 g HCl/mol) = 0.36 g HCl available for neutralization
0.0011 mol HCl x (36.46 g HCl/mol) = 0.04 g HCl neutralized by NaOH
HCl neutralized by antacid = 0.36 g – 0.04 g = 0.32 g HCl/g tablet

50% more g HCl/g tablet for Brand B = 0.17 g + 0.17 g = 0.34 g HCl/g tablet

Both Brand A and Brand C provide better heartburn relief than Brand B; however, Brand C is the closest to being 50% better at neutralizing HCl than Brand B. Possible sources of error include: data for only one experimental trial for each brand, calibration errors with the titration equipment, and rounding inconsistencies.

The consumer should purchase Brand C antacid, as 0.32 g HCl/g tablet is neutralized, and this result is closer to the stated claim of 50% more HCl neutralization per gram of tablet than Brand B.