At-Home Chemistry Experiment

Volumetric Analysis of Household acid Using a Cabbage Juice Indicator

Experimental Objective

The concentration of an acid found in a household product will be determined by titration using cabbage juice as the acid-base indicator.

Learning Objective

- Prepare an acid-base indicator and evaluate its colour based on *p*H.
- Prepare a titrating solution and calculate its concentration.
- Perform a titration and calculate the acid concentration based on the observed endpoint.

Introduction

In chemistry, an indicator is used to detect the presence of a specific type of chemical. In this lab, red cabbage juice is used to indicate whether a solution is acidic or basic. Red cabbage contains water-soluble substances called anthocyanins, and is an example of a natural acid-base indicator. The anthocyanin pigment causes very strong acidic solutions to appear red, weak acidic solutions to appear violet, weak basic solutions to appear blue, and strong basic solutions appear yellow. The red leaves of poinsettia plants, common around Christmas time, or blueberries could also be used in this manner. Figure 1 shows the correlation between the color of a solution that contains a red cabbage indicator and its pH.

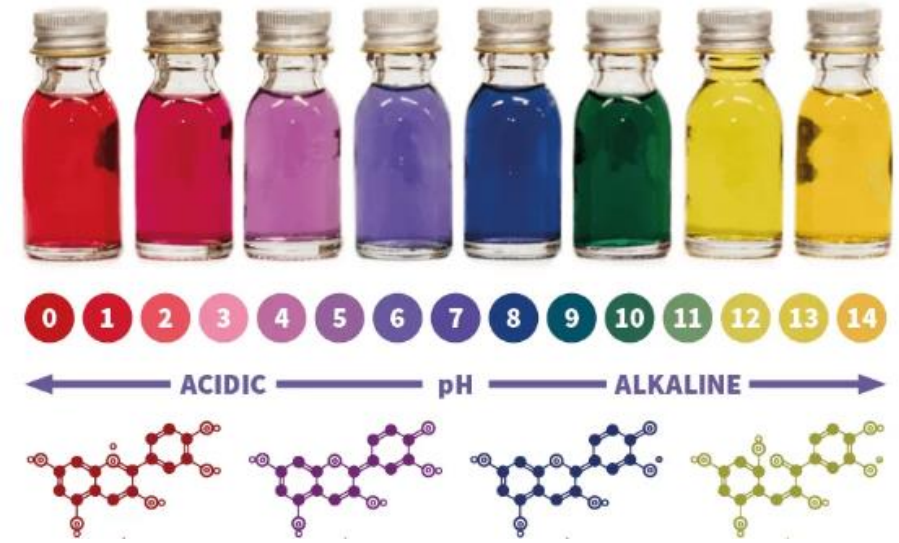

Figure 1[1] *: Color variations of solutions containing anthocyanins according to the pH.*

[1] Figure 1 is an excerpt from Making a Red Cabbage pH Indicator: The Method and the Chemistry, *Compound Interest*, Andy Brunning, https://www.compoundchem.com/2017/05/18/red-cabbage/ (Last accessed May 25th 2020)

***Figure 2**: Color variation of solutions containing red cabbage indicator according to the pH.*

An acid-base titration is used to determine the concentration of an acid or a base by neutralisation. In this experiment, the concentration of an acid (HA) of your choice will be titrated with a sodium bicarbonate ($NaHCO_3$) solution. The acid and $NaHCO_3$ solutions are referred to as the analyte and titrant respectively.

$$HA\,(aq) + NaHCO_3\,(aq) \rightarrow H_2CO_3\,(aq) + Na^+\,(aq) + A^-\,(aq) \qquad (1)$$

The conjugate acid of $NaHCO_3$ is carbonic acid (H_2CO_3), which is in equilibrium with water and carbon dioxide. Since the titration is carried out in an open system, the formation of bubbles will be observed during the neutralisation.

$$H_2CO_3\,(aq) \rightleftharpoons CO_2\,(g) + H_2O\,(l) \qquad (2)$$

The overall reaction is therefore:

$$HA\,(aq) + NaHCO_3\,(aq) \rightarrow CO_2\,(g) + H_2O\,(l) + Na^+\,(aq) + A^-\,(aq) \qquad (3)$$

During a titration, the titrant stops being added at the precise moment when the analyte has completely reacted and there is a change in color of the acid-base indicator. This is referred to as the endpoint, which should coincide with the equivalence point if the correct indicator is chosen. In this experiment, the equivalence point represents the moment when the number of moles of base (n_B) added is equal to the number of moles of acid (n_A) originally present.

$$n_A = n_B \qquad (4)$$

The number of moles of acid originally present can be determined with the known concentration (C_B) and volume (V_B) of the base used.

$$n_A = C_B V_B \qquad (5)$$

Using the moles and volume of the acid that was titrated, the concentration of the acid solution can be determined and compared with the expected value.

$$C_A = n_A / V_A \qquad (6)$$

If the acid solution was prepared from a solid sample, the mass of the acid (m_A) can be determined directly from the number of moles of acid (n_A) and its molar mass M_A.

$$m_A = n_A \cdot M_A \qquad (7)$$

The ingredients on the label of a household product will indicate the concentration of the active ingredient. However, the unit associated with the concentration of each substance varies so careful attention is required during the calculations.

Materials

- Red cabbage leaves (or alternatively blueberries)
- Vinegar (or aspirin or lemon juice)
- Baking soda
- Strainer
- 1 cup Measuring cup (250 mL)
- Measuring spoons (teaspoon and tablespoon)
- 10 mL Syringe with 1 mL graduation
- Clear jars or glasses

Conversion between kitchen instruments vary according to the manufacturer. Consult the table below. If you cannot identify the manufacturer, assume your kitchen instrument is American.

Table 1: Volume conversion from kitchen instruments to metric system.

Measuring instrument	1 Canadian teaspoon (CA tsp)	1 American teaspoon (US tsp)	1 Canadian tablespoon (CA tbsp)	1 American tablespoon (US tbsp)	1 Fluid Ounces (fl oz)	1 US Fluid Ounces (fl oz US)	1 cup
Volume[2] (mL)	4.735	4.929	14.207	14.787	28.413 mL	29.574	250 mL

Procedure

Part A - Preparing the indicator

Choose one of the three indicators below. Red cabbage has a wider color range than blueberries, but blueberries can be used if red cabbage cannot be obtained.

Red cabbage: Cut into small pieces about 1 cup (250 mL) of red cabbage leaves. Pour the cabbage into a saucepan containing 1 ½ cups (375 mL) of water and bring to a boil over high heat. Heat the mixture for 10 minutes with the lid on. Remove the lid and heat for an extra 5 minutes to evaporate a little water. Filter the cabbage pieces using a colander or sieve in a bowl to collect the dark purple-colored filtrate. Let the liquid cool down and transfer it to a resealable jar. See figure 3.

Blueberries (fresh or frozen): Pour 1 cup (250 mL) of blueberries into a saucepan with 1 cup (250 mL) of water. Heat the mixture for 10 minutes with the lid on. Remove the lid and heat for an extra 5 minutes to evaporate a bit of water. Filter the blueberry pieces using a sieve in a bowl to collect the dark purple-colored filtrate. If there are a lot of seeds in the filtrate, do a second filtration using a coffee filter or paper towels. Let the liquid cool down and transfer it to resealable jar.

[2] Conversions obtained from *Le convertisseur*, http://www.the-converter.net/fr/volumes/tbsp%20CA/ml (accessed May 25th 2020)

Blueberry jam: Measure 2 tablespoons (tbsp) of blueberry jam in a soup bowl and add ¼ cup of water. Put in the microwave for 90 seconds or heat on the stove for 3 to 5 minutes. Filter the blueberry pieces using a sieve in a bowl to collect the dark purple-colored filtrate. If there are a lot of seeds in the filtrate, do a second filtration using a coffee filter or paper towels. Let the liquid cool down and transfer it to a resealable jar.

Figure 3*: Cutting, boiling and filtering the red cabbage leaves to recuperate the homemade acid-base indicator.*

<u>Part B - Preparing the titrant solution of sodium bicarbonate (baking soda)</u>

1) To a 1 cup (250 mL) measuring cup, add precisely 1 tablespoon of baking soda (level the powder with a knife), then add water so that the cup is two-thirds full.

2) Stir the solution with a spoon to dissolve the solid. A slight release of gas may occur.

3) Add more water to the measuring cup until the total volume of the solution is precisely 250 mL and stir. You may find it useful to transfer the titrating solution to an identified resealable container.

Part C - Preparing the household acid

1) Prepare the sample containing the acid according to the guidelines in table 2 below, in a colorless and transparent container large enough to allow mixing.

Table 2: Measurements for the preparation of a household acid

Substance	Quantity to measure	Information on the preparation
Vinegar (cooking or cleaning grade)	10 mL of vinegar	Add about 15 mL of water to the vinegar.
Aspirin	Enough tablets to obtain approximately 1000 mg of acid. Record the exact amount.	Add approximately 30 mL of water and 30 mL of rubbing alcohol to the tablets. Wait 5 minutes for the tablets to break down into a fine powder. It is normal for the solution to be cloudy and for residue to remain on the bottom of the container.
Vitamin C	Enough tablets to obtain approximately 1000 mg of acid. Record the exact amount.	Add approximately 60 mL of water to the tablets. Wait 5 minutes for the tablets to break down into a fine powder. If the tablets do not come apart after this time, put the mixture in the microwave for 30 seconds and let it cool. It is normal for the solution to be cloudy and for residue to remain on the bottom of the container. If your tablets are colored, this may affect the color of the indicator.
Lemon juice	10 mL of lemon juice	Add about 15 mL of water to the lemon juice.

2) Add enough indicator (approximately 5 mL of cabbage juice or 2-3 mL of blueberry juice) to the acid solution to be analyzed such that the color is not too light nor too dark.

Part D - Titration of a household acid

1) Prepare the controls to help you visualize the color changes according to table 3 below. For each control, add the same amount of indicator that was added to the acid solution to be analyzed.

Table 3: Preparing the controls.

Acid control	Solvent control	Basic control
Same as your household acid solution to be analysed.	Volume of water equal to the total volume of household acid solution to be analysed.	Volume of sodium bicarbonate solution equal to the total volume of household acid solution to be analysed.

a)  b) 

Figure 4*: Color of acid, solvent (water) and basic controls using a) red cabbage juice b) blueberry juice*.

2) Place the 3 controls and the solution to be titrated on a clear surface to optimise the visibility of the color changes. A bright source of light is desirable. The colorful solutions are better visualized in narrower glasses. White sheets can be used to cover the countertop or table if it is too dark.
3) Make sure you are looking through the glasses at eye level, not from above.
4) Fill the 10 mL plastic syringe with the baking soda solution, remove any air bubbles inside.
5) Start the titration by gradually adding (1 mL or less of) the baking soda solution, into the household acid solution. Stir vigorously to evacuate the gas formed with each addition of titrating solution. Observe the color change and continue adding the titrant (refill the syringe if needed), stirring until you reach the endpoint (appearance of a color which is located between the water control and the basic control). The endpoint is mostly indigo blue with the red cabbage indicator and grey-blue with the blueberry indicator. In general, the endpoint is reached the moment you observe the ***disappearance of the purple color***. The color and cloudiness of the solutions will also vary depending on the household acid chosen.
6) **Record the volume of the baking soda solution used to reach the endpoint in the data section**.
7) **Take a picture of the set-up** (3 controls with your titrated sample at the endpoint).
8) Repeat step 4), 5) and 6) with new samples of your household acid until 3 consistent results are obtained (i.e. the volume at the endpoint for each trial should not differ by more than a few mL). Therefore, a minimum of three trials must be carried out for this experiment.

Calculations / Data Analysis

1. Baking soda has a volumetric mass of 1.00 g/mL. Calculate the mass of $NaHCO_3$ used to make the 250 mL titrant solution.
2. Calculate the number of moles of $NaHCO_3$ in the titrant solution.
3. Calculate the concentration of the $NaHCO_3$ solution.
4. Determine the number of moles of $NaHCO_3$ used in each titration.
5. Based on your titration results, calculate the original concentration of your acid if the acid was a solution. If the acid was a solid, then calculate the original mass of your sample. Show and identify each step of your calculations.
6. Calculate the average concentration of your acid solution. If the acid was a solid, then calculate the average mass of your acid.
7. Compare your experimental result with the commercial concentration of the acid if it was a solution, or the commercial mass if the acid was a solid. Take note of the units provided in the commercial label. For example, vinegar concentration is expressed in %, which represents mass of acid (g) / volume of vinegar (in mL) x 100%.

Name _____ Section _____

Date _____

Volumetric Analysis of Household Acid Using a Cabbage Juice Indicator

DATA

1. Net Ionic Equation (N.I.E.) of the reaction

2. Results and Observations

Initial Material:

Base

Brand name of baking soda used: _____

Indicator

Food item used: _____

Acid analyzed

Name and brand name of acid substance to be analyzed	
Name of the acid contained in the substance	
Chemical formula of the acid	
Molar mass of the acid	
Commercial quantity reported of the acid in the substance to be analyzed and its unit. *If the acid is a solution report the concentration. If the acid is a solid, report the mass. Add calculations when necessary. Your instructor might ask for a picture of the label.*	

Titrant:

Volume of $NaHCO_3$ powder, mL _____

Mass of $NaHCO_3$ powder, g _____

Amount of $NaHCO_3$, mol _____

Volume of $NaHCO_3$ solution, mL _____

Concentration $NaHCO_3$ solution, M _____

Titration

	Trial 1	Trial 2	Trial 3
Volume of indicator, mL			
Volume of $NaHCO_3(aq)$ to reach endpoint, mL			
Amount of $NaHCO_3$ used, mol			
Amount of acid titrated, mol			
If starting acid was a solution			
Volume of acid before dilution, mL			
Concentration of acid before dilution			
Average Concentration of acid			
If starting acid was a solid:			
Mass found of acid, g			
Average mass of acid, g			
For all acids			
% Error from commercial indication			

Picture:

Final set up (3 controls + titrated acid at endpoint):

Troubleshooting Suggestions

1. If the color change is too faint, you might need to adjust the amount of indicator added to your solution. If the solution is too clear, add some indicator. If the solution is too opaque, redo with a smaller amount of indicator.

2. Make sure to swirl your solution vigorously between each addition of titrant to make sure the acid and base reacted together, and let the gas formed escape, if ever.

References

Département de Chimie. (2020, Hiver). 'Titrage d'un acide à la maison', *Manuel de laboratoire mise à niveau pour chimie de la 5^{e} secondaire*, Cégep André-Laurendeau.

"Cabbage Juice Titration Lab" *Connections Education LLC*, 2010, http://assets.openstudy.com/updates/attachments/56e9a191e4b093c374921a07-welder55-1458151897656-cabbage5.pdf.

Acknowledgements

Dawson College CLAW (*Chemistry Laboratory Alternative Workforce*)

Department of Chemistry, Dawson College

Julie C. Boivin from CÉGEP André-Laurendeau for the lab procedure and helpful insights.

Last updated June 17, 2020

Red Cabbage Soup Recipe (Optional)

With your leftover cabbage, here is a recipe to impress your guest with a violet dish.

Red cabbage soup

4.8 from 19 reviews

Prep time	Cook time	Total time
5 mins	20 mins	25 mins

Author: Margarita @ Tasty Mediterraneo
Cuisine: Mediterranean Diet
Serves: 4 people

Print

Ingredients

- 2 Tablespoons Extra Virgin Olive Oil (EVOO)
- ½ Red cabbage, cut into slices (Aprox. 600g or 6 cups of sliced red cabbage)
- 1 Leek, sliced
- 1 Onion, peeled and chopped
- 1 Small potato, peeled and diced
- 1l (2 pints) Vegetable stock (or water)
- 100ml (3.4 fl oz) Almond milk
- 1 Teaspoon sea salt (or salt to taste)

Instructions

1. Have all the vegetables well washed and prepared as indicated in the ingredients description.
2. Heat the EVOO in a large saucepan over moderate heat. Add the leeks and onion and a pinch of salt and sauté for about 3 minutes until soft. Add then the diced potato and 2 tablespoons of the vegetable stock (or water if not available) and sauté for about 10 minutes until the potatoes are cooked. Add then the sliced red cabbage and sauté for 5 minutes. Cover with the rest of the vegetable stock, bring to a boil over medium heat and when it has reached a boil remove the saucepan from the heat.
3. Add the almond milk, one teaspoon sea salt (or salt to taste) and with the help of a hand mixer (ideally a powerful one of at least 450 watt) mix it all well until perfectly combined.
4. Serve hot.

Notes

You can add some freshly grounded black pepper right before serving.