EQW Report Template

# Determination of the Molar Mass of an Unknown Acid

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*Purpose:* Determine the precise concentration of NaOH by titrating the NaOH solution against a solution of $KHC_8H_4O_4$(KHP) then use this knowledge to determine the molar mass of an unknown acid by titrating the acid solution against the NaOH solution. Improve real life skills involving titration/observation and improve ability to use stoichiometric calculations to analyze data and interpret results.

*Procedure:* Please refer to "Determination of the Molar Mass of an Unknown Acid." *Chemistry 1210: General Chemistry Laboratory Manual*, Hayden-McNeil, Plymouth, 2016, pp. 59-60. for the correct procedure.

# Presentation of Data

## *A. Standardization of a dilute NaOH solution.*

**Dilution details** (show calculation):

| | Trial 1 | Trial 2 |
|---|---|---|
| Mass of potassium hydrogen phthalate(g) | 0.03555 | 0.3545 |
| Moles of potassium hydrogen phthalate(moles) | 0.001714 | 0.001736 |
| Volume of NaOH added(mL) | 17.46 | 17.20 |
| Molarity of NaOH solution(M) | 0.09971 | 0.1009 |
| Average molarity of NaOH solution(M) | 1.003 | |
| % difference between the 2 readings(%) | 1.2 | |

## *B. Molar mass determination.*

| | Trial 1 | Trial 2 |
|---|---|---|
| Mass of unknown acid sample(g) | 0.1038 | 0.1038 |
| Volume of NaOH used(mL) | 17.56 | 17.68 |
| Moles of NaOH used(moles) | 0.001761 | 0.001773 |
| Molar mass of acid **if monoprotic** (g) | 58.94 | 58.54 |
| Average molar mass(g) | 58.74 | |

## Sample Calculations

Show sample calculation for molar mass determination assuming the sample is **monoprotic**:

$$HX + NaOH = H_2O + NaX$$

$$0.001761\ mol\ NaOH \times \frac{1\ mol\ acid}{1\ mol\ base} = 0.001761\ moles\ acid$$

$$\frac{0.1038\ g\ acid}{0.001761\ mol\ acid} = 58.94\ g/mol$$

Show sample calculation for molar mass determination assuming the sample is **diprotic**:

$$H_2X + 2NaOH = 2H_2O + 2NaX$$

$$0.001761\ mol\ NaOH \times \frac{1\ mol\ acid}{2\ mol\ base} = 0.0008805\ moles\ acid$$

$$\frac{0.1038\ g\ acid}{0.0008805\ mol\ acid} = 117.9\ g/mol$$

Show sample calculation for molar mass determination assuming the sample is **triprotic**:

$$H_3X + 3NaOH = 3H_2O + 3NaX$$

$$0.001761\ mol\ NaOH \times \frac{1\ mol\ acid}{3\ mol\ base} = 0.0005870\ moles\ acid$$

$$\frac{0.1038\ g\ acid}{0.0005870\ mol\ acid} = 176.8\ g/mol$$

Additional sample calculations *(moles of KHP, molarity of NaOH, moles of NaOH, molar mass of acid)*

Moles of KHP:

$$0.03555\ g\ KHP \times \frac{1\ mol\ KHP}{204.22\ g\ KHP} = 0.001741\ moles\ of\ KHP$$

Molarity of NaOH:

$$M = \frac{moles}{L}$$

$$M = \frac{0.001741\ moles\ NaOH\ (same\ as\ moles\ KHP\ bc\ 1-1\ ratio)}{0.01746 L\ NaOH\ solution} = 0.09971 M$$

Moles of NaOH:

$$M = \frac{moles}{L}$$

$$0.1003 M = \frac{x}{0.01756\ L}$$

$$x = 0.001761\ moles\ NaOH$$

Molar mass of acid:

$$HX + NaOH = H_2O + NaX$$

$$0.001761\ mol\ NaOH \times \frac{1\ mol\ acid}{1\ mol\ base} = 0.001761\ moles\ acid$$

$$\frac{0.1038\ g\ acid}{0.001761\ mol\ acid} = 58.94\ g/mol$$

## *Discussion:*

Experimenters aimed to determine the molar mass of an unknown acid by titrating the acid solution against a solution of NaOH of known molarity calculated based on titration of the NaOH solution against a KHP solution. Data was collected through analysis of the titration process and calculations based on titration. The NaOH solution was added from a buret to a flask containing either KHP solution or unknown acid solution until the end point was reached. Experimenters measured mass of solids used and volume of NaOH solution used in the titration process to determine molarity of the NaOH solution and used the known molarity to calculate the moles and molar mass of an unknown acid that was in solution.

Analysis of the molar mass of the unknown acid reveals differences based on the possible natures of the acid itself, more specifically, how many protons it donates in solution. If the acid is monoprotic, the molar mass was calculated to be 58.94 g/mol, 117.9 g/mol if diprotic, and 176.8 g/mol if triprotic. The molarity of the NaOH solution was calculated to be 1.003M, the average molarity of the first two trials.

Adding an additional 10mL of water to the KHP solution to dissolve the solid would not affect the overall outcome of the data. While this would change the molarity of the solution, this value is not included in any calculations for the experiment. The experimenter is only concerned with the moles of KHP included in the solution, which is derived from the grams of KHP added. The change from 30mL of water to 40mL to create the KHP solution would not affect the results of the experiment, as the value of moles of KHP, which is actually important to later calculations, would remain unchanged.

The equivalence point describes when a stoichiometric amount of the titrant has been added to the analyte. The end point occurs when the reaction of the titration is observed to have occurred. The difference between these two points causes systematic error in the lab because of human imperfection in observation. The equivalence point is where the titration is ideally stopped; this would result in a technically perfect titration. However, because a reaction can only be observed at the end point, it is impossible to stop the titration exactly at the equivalence point regardless of what scientist is performing the lab, thus making this a systematic error. In addition, systematic error can be present in the observation process, as every experimenter will analyze the titration slightly differently and cannot perfectly stop the titration process at the point that will yield ideal results.

The experimenter impacts the identification of the end point because every scientist will analyze the color change in the flask differently and will react with different speed to stop the titration. No human can perfectly identify and isolate the titration at the end point. Interpretation of the color change will vary from scientist to scientist and cannot be perfect if a human is performing the experiment. This error is due to subjectivity in the experiment and would be present regardless of the experimenter, so this error is classified as systematic.

The indicator used in this lab, phenolphthalein, works as an indicator by changing color in response to the pH of the solution that it is in. Phenolphthalein turns pink in the presence of pH above 8.2. However, it is colorless in the presence of $H^+$ ions. During the titration process, the protons donated by the aqueous acid keep the phenolphthalein from turning pink. Once the acid is completely used up in the reaction, there are no longer any excess $H^+$ ions and the solution becomes increasingly basic, thus turning the indicator pink. As the solution becomes more basic, the color of the phenolphthalein turns a deeper shade of pink. If this indicator was not present during the titration process, there would be no visible change as the two solutions were combined. Both the reactants and the products would appear as clear, colorless liquids. When a drop of titrant is added, turns dark pink, and then disappears, this shows the reaction in process. The pink indicates a brief pH change when the titrant is added. When the NaOH solution comes in contact with the unknown acid solution, the basic product is formed, causing the brief presence of the pink color, but the ions quickly dissociate and the indicator is once again in the presence of $H^+$ ions and thus returns to its colorless state.

In this experiment, it is not possible to determine if the unknown acid is monoprotic, diprotic or triprotic. The titration setup allows for the determination of the molar mass of the acid, but only based on assumptions regarding how the acid donates its protons. The mass of the unknown acid used is known, but the moles of the unknown base is reliant on its proportional relationship to the moles of base, and this relationship depends on how many protons the acid donates when in solution. The equation for this reaction can be balanced based on all three options for the acid and all three equations produce a different molar mass when calculated. Therefore, the experimenter cannot determine if the acid is monoprotic, diprotic, or triprotic.

It is not possible to determine the chemical formula of the unknown acid based on the titrations alone. Because the unknown is an acid, the experimenter can be sure that it donates protons, but how many protons and even the composition of the rest of the acid cannot be determined by the titration alone. The experiment allows for the calculation of the molar mass of the unknown acid, which may be useful in determining the chemical formula, but the molar mass is based off of assumptions regarding proton donation. Therefore, there are three possible molar masses and when even the correct molar mass cannot be determined, there is no way to definitively identify the other elements that may be present in the unknown acid.

 

## *Conclusion:*

Experimenters prepared and standardized a solution of NaOH then used this data and solution to determine the molar mass of an unknown acid solution by titrating these two solutions together. Because the nature of the acid's proton donation is unknown, the experimental results the calculations for a monoprotic acid: 58.94 g/mol, a diprotic acid: 117.9 g/mol, and a triprotic acid: 176.8 g/mol. Random error was present in this lab due to the impossibility of making a perfect measurement; this was prevalent to the titration process, which includes measurement of the volume used out of the buret. Systematic error was also present in the titration process due to subjective analysis of the titration process, especially the identification of the end point as opposed to the equivalence point. The NaOH solution was calculated to be 1.003M and the possible molar masses based on if the acid was mono/di/triprotic were 58.94 g/mol, 117.9 g/mol, and 176.9 g/mol.