Determination of the pH of a Hydrochloric Acid Solution Using a Caustic Soda Titration

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Class: Chemistry 20
Instructor: Ms. Shute

Hypothesis:

If a solution of hydrochloric acid with an unknown concentration is titrated using 0.1M sodium hydroxide, then using phenolphthalein indicator will show when all the acid has been neutralized by changing colour.

Methods and Materials:

 This experiment will be carried out using the following laboratory instruments and supplies:

* a hydrochloric acid solution which has been prepared ahead of time at an unknown concentration
* sodium hydroxide pellets
* distilled water
* a burette for measuring the volume of sodium hydroxide used
* retort stand to hold the burette
* 4 beakers for performing the titration
* 100 mL volumetric flask to measure the amount of hydrochloric acid solution
* phenolphthalein
* pipette to put phenolphthalein into hydrochloric acid solution
* weigh scale

Experimental Procedure:

 To begin the experiment, 4 beakers are filled with the hydrochloric acid solution provided using the volumetric flask so that 50mL is in each beaker. The beakers are then labeled as run 1, 2, 3, and 4. In order to ensure the titrant is at 0.1mol/L, the mass of sodium hydroxide to add to the 250mL of distilled water is needed. To do this, the molar mass of sodium hydroxide, 40.00g/mol (Na – 22.99g/mol, O – 16.00g/mol, H – 1.01g/mol), is used such that 0.1 mole of sodium hydroxide, or 0.1 mole x 40.00g/mol = 4.00g is added to 1.0L of water. Since 250mL is needed, the mass of sodium hydroxide required is 4.00g x (250mL/1000mL) = 1.00g of sodium hydroxide. When this mass of sodium hydroxide is dissolved in the 250mL of distilled water, the titrant is then added to the burette on the retort stand in preparation for titration. Next, three drops of the phenolphthalein indicator are added to each of the 4 hydrochloric acid samples in preparation for titration. Finally, each sample is titrated drop by drop while swirling each beaker until the phenolphthalein indicator turns the hydrochloric acid solution pink without fading back to colourless. The volume of titrant used is then recorded for future calculations.

Results:

The results in Table 1 shows the number of drops of titrant required in column 2 and the corresponding volume of titrant in column 3 since 1 drop of water is equal to 0.05mL. The average volume of the NaOH(aq) titrant solution used can be seen from Table 1 as 1.56mL when the first run is excluded because it did not fit the trend well.

Table 1. Number of drops and volume of titrant needed to cause the indicator to change colour.

|  |  |  |
| --- | --- | --- |
| Test Number | Number of Drops of Titrant | Volume of Titrant (mL) |
| 1 | 38 | 1.90 |
| 2 | 31 | 1.55 |
| 3 | 33 | 1.65 |
| 4 | 30 | 1.50 |

Discussion:

This experiment went as predicted by the hypothesis of this report. As can be seen by Table 1, the average volume of 0.1M NaOH(aq) which was required to cause the phenolphthalein to change colour was 1.56mL which means that the number of hydroxide ions needed to neutralize the hydrogen ions in the original hydrochloric acid solution was 1.56mL x 0.1mol/L / 1000mL/L = 1.56 x 10-4mol. This means that there was 1.56 x 10-4mol of hydrogen ions in the original hydrochloric acid solution, which means that the concentration of hydrogen ions was 1.56 x 10-4mol / 50mL x 1000mL/L = 3.12 x 10-3mol/L. Using the equation:$pH=-log⁡(H^{+})$, the pH of the hydrochloric acid solution is pH = -log (3.12 x 10-3mol/L) = 2.51. When the instructor, Ms. Shute was asked what the concentration of the hydrochloric acid solution was after the results were complete, she said the pH of the solution she prepared was 2.55. This means that the concentration of the acidic solution under investigation was able to be calculated well by using sodium hydroxide titration with a phenolphthalein indicator. The first test was omitted from the values used to calculate the average volume of titrant used because the value for the first run was significantly larger than that of the other three, which were all fairly close together. This larger value for the first test could be caused by one of two factors. The first is that the glassware used in this experiment, particularly the volumetric flask or the first beaker were contaminated by an acidic substance from the last user because they were not cleaned out well enough. However, this event seems unlikely because only one of the beakers would have been contaminated or else all the rest of the samples would have been similar. Also, the acid that would have needed to be held in the beaker previously would have needed to be very strong to cause such a dramatic difference in the volume of titrant needed. The second factor that could cause the first run to have so much more titrant needed is that the concentration of the first hydrochloric acid solution sample was pulled from the bottom of the container. Since hydrochloric acid is denser than water (1198kg/m3 for HCl and 1000kg/m3 for water) and because Ms. Shute created the solution last week, the hydrochloric acid could have settled to the bottom of the container, making the concentration higher at the bottom of the container. The reason that the second through fourth samples were more consistent is because the container had been stirred by all the groups taking their first samples. In order to solve these two problems in the future and make sure that each sample taken is valid, the container of hydrochloric acid should be stirred well before the samples are taken and the glassware used should be washed well and dried before being used to ensure they are clean to prevent contamination.

Conclusion:

This experiment was done to find out the pH of a hydrochloric acid solution with an unknown concentration that was prepared by Ms. Shute through sodium hydroxide titration. To do this, a sodium hydroxide solution was prepared as a manipulated variable at 0.1M so the concentration and pH of the hydrochloric acid could be calculated using the volume of sodium hydroxide added, which is the responding variable. Finally, the controlled variable is the phenolphthalein indicator which was used to determine when all the hydrochloric acid was neutralized by the sodium hydroxide. In this experiment, it was determined that the pH of the hydrochloric acid solution was 2.51 when neutralized with an average volume of 1.56mL of 0.1M sodium hydroxide titrant. It was determined that one test out of four was contaminated by either dirty glassware or the solution settling in the container over the weekend, and as a result, two measures should be taken in future to prevent tests from failing. The first is to clean and dry all glassware thoroughly before using it, and the second is to stir the container well before taking any samples to make sure the solution is well mixed.