Acid-base titration chemistry formal lab writeup by a.mm essay sample

Science, Chemistry

Abstract

By using acid-base titration, we determined the suitability of phenolphthalein and methyl red as acid base indicators. We found that the equivalence point of the titration of hydrochloric acid with sodium hydroxide was not within the ph range of phenolphthalein’s color range. The titration of acetic acid with sodium hydroxide resulted in an equivalence point out of the range of methyl red. And the titration of ammonia with hydrochloric acid had an equivalence point that was also out of the range of phenolphthalein.. The methyl red indicator and the phenolphthalein indicator were unsuitable because their pH ranges for their color changes did not cover the equivalence points of the trials in which they were used. However, the methyl red indicator is more suitable, since it’s pH range is closer to the equivalence points of the titrations.

Introduction

Acid-base reactions are one of the most common and important chemical interactions. They are vital to both environmental and industrial systems. As an important variable, pH controls the toxicity, mobility, solubility, and fate of many aquatic ecosystems. Most aquatic life forms cannot survive outside a pH window from about 4. 5 to 9. From an industrial viewpoint, manipulation of pH is both a tool for and a prerequisite to all water treatment processes. 1 Along with pH indicators, titration is a vital tool in determining the factors of many commercial and environmental systems.

Therefore, knowledge of acid-base titration curves is critical to the environmental scientist. Titration, an analytical technique, allows the quantitative determination of a dissolved substance being titrated, known as an analyte. Titration requires knowledge of the equivalence point: a theoretical point where the chemical equivalents of titrant added are exactly equal to the chemical equivalents of the solute being titrated. It also requires the knowledge of the Endpoint: an operational point which approximates the position of the equivalence point by some physical change. 1

The purpose of this lab is to find the most suitable indicator. In the lab we used, Phenolphthalein or Methyl-Red, for differing titrations. Here are some other indicators: 1

In this lab we used the following reactions and equations in this lab:

Reaction 1: The neutralization reaction of Sodium Hydroxide and Hydrochloric Acid:

HCl (aq) + NaOH (aq) ? NaCl (aq) + H2O (l)

Reaction 2: The complete dissociation reaction of Hydrochloric Acid:

HCl (aq) + H2O (l) ? H3O+ (aq) + Cl- (aq)

Reaction 3: The incomplete dissociation reaction of Acetic Acid:

CH3COOH (aq) + H2O (l) ? H3O+ (aq) + CH3COO- (aq)

Reaction 4: The reaction of the Acetate Ion with Water:

CH_3COO^- (aq) + H_2O (l) ? CH_3COOH (aq) + H_3O^+ (aq)

Reaction 5: The reaction of Ammonia with Hydrochloric Acid:

NH_3 (aq) + HCL (aq) ? NH_4^+ (aq) + Cl^- (aq)

Reaction 6: The reaction of the left over Ammonia with Water:

NH_4^+ (aq) + H_2O (l) ? NH_3 (aq) + H_3O^+ (aq)

The three following mathematical equations were used :

Equation 1: To calculate the mass of a substance needed to prepare a solution:

Mass of substance (in grams) = (M)(V)(Formula Weight)

Equation 2: To calculate the pH:

pH = -log [H_3O^+]

Equation 3: To calculate the volume of titrant added to the analyte to produce a final solution with a specific Hydronium concentration:

[H_3O^+] = ($V_{analyte}$ x $M_{analyte}$) – ($V_{titrant}$)($M_{titrant}$) / ($V_{titrant}$ + $V_{analyte}$)

Equation 4: To calculate the number of moles:

Number of Moles = Molar Concentration Volume = Mass Molar Mass

Experimental

Materials Apparatus

-0. 1M NaOH (prepared from solid NaOH)

-0. 1M CH3COOH (aq)

-0. 1M Hcl (aq)

-0. 1M NH3 (aq)

-Phenolphthalein indicator

-Methyl-red indicator (1 (1

-electronic pH meter

-hot plate/stirrer

-50mL burette with stand

-250mL beaker

-100mL beaker

-25mL volumetric pipette

-pipette safety bulb

-scoopula

-magnetic stir bar

-plastic wash bottle

-500mL volumetric flask and stopper

-plastic or glass funnel

-safety goggles

Followed the procedures listed in the University of Winnipeg Laboratory Manual was followed. 2

Modifications: Instead of diluting the titrant with 75mL of water, we diluted it with 50mL of water.

Results

Part I: Data and Calculations

Table 2: Titration Data Table

Trial 1 – HCl and NaOH (Strong-Acid + Strong-Base)

Trial 2 – CH3COOH and NaOH (Weak-Acid + Strong-Base)

Trial 3 – NH3 and HCl (Weak-Base + Strong-Acid)

(*) marks equivalence range

Trial 1Trial 2Trial 3

Titrant Volume (mL)

pHTitrant Volume (mL)pHTitrant Volume (mL)pH

0. 001. 70. 003. 10. 0010. 4

5. 001. 75. 004. 05. 009. 7

10. 001. 710. 004. 410. 009. 3

15. 001. 815. 004. 815. 008. 9

20. 002. 020. 005. 120. 007. 9*

21. 002. 121. 005. 321. 006. 0

22. 002. 122. 005. 421. 503. 8

23. 002. 223. 005. 522. 003. 1

24. 002. 224. 005. 722. 502. 9

25. 002. 325. 006. 2*23. 002. 7

26. 002. 425. 506. 723. 502. 6*

27. 002. 726. 009. 824. 002. 5

28. 003. 026. 5010. 524. 502. 4

29. 003. 3*27. 0011. 2*25. 002. 4

30. 003. 827. 5011. 426. 002. 3

30. 509. 428. 0011. 627. 002. 2

31. 0010. 3*29. 0011. 728. 002. 2

31. 5010. 830. 0011. 830. 002. 1

32. 0011. 031. 0011. 835. 002. 0

33. 0011. 232. 0011. 840. 001. 9

35. 0011. 534. 0011. 9

40. 0011. 835. 0011. 9

40. 0012. 0

Table 3: Equivalence Point values.

Equivalence Point

Titration of HCl with NaOH7. 0

Titration of CH3COOH with NaOH8. 6

Titration of NH3 with HCl 5. 5

1)Initial pH

See Table 2.

2)Final pH

See Table 2.

3)Equivalence Range

Using Graph 1: The Volume of Titrant Added in order to reach the Endpoint and the Corresponding pH Values, observe the vertical line of each titration and see the points in which the horizontal lines intersect it. These points give the Equivalence Range. See Table 2 for values.

4)Equivalence Point

Using Graph 1: The Volume of Titrant Added in order to reach the Endpoint and the Corresponding pH Values a perpendicular line from the midpoint of the vertical equivalence range is drawn so that it will intersect the y-axis. The point at which it intersects the y-axis is the pH of the equivalence point. See Table 3 for values.

5)Calculation of the Mass Needed to Form 0. 1 M NaOH

Find Number of Moles of NaOH needed

0. 1M 0. 5 L = 0. 05 mol NaOH

Find Amount of NaOH needed in Grams

0. 05 mol NaOH mol mass NaOH = grams of NaOH needed

0. 05 mol (22. 989770 + 15. 9994 + 1. 00794) = 1. 999g NaOH

Part II: Observations

Table 4: Observations of colour changes of Acid-Base indicators during Titration.

Initial colour (before change)End point colourpH at End Point (colour change)

Titration of HCl with NaOHclearPinky-red10. 1

Titration of CH_3COOH with NaOHredyellow6. 0

Titration of NH_3 with HCl Pinkyclear8. 9

Discussion

The determination of the end points and equivalence points of various titrations allow for an evaluation of how suitable an indicator is for a particular reaction. The titration of hydrochloric acid with sodium hydroxide resulted in a neutral equivalence point at a pH of 7. 0. Phenolphthalein, the acid-base indicator that was used in this titration, has a color change range of pH range of 8. 2 to 9. 8 (see Table 1) and produced an endpoint colour change with Trial at a pH of 10. 1. This indicator is unsuitable since it does not cover the range of the equivalence point which is 7. 0.

The titration of acetic acid with sodium hydroxide resulted with a slightly basic equivalence point at a pH of 8. 6. The methyl red indicator used in this titration was not suitable in the titration of hydrochloric acid by sodium hydroxide because its equivalence point is out of methyl red's range (pH 4. 4 to 6. 2 from Table 1)

The use of phenolphthalein as the acid-base indicator in the titration of ammonia with hydrochloric acid was unsuitable since the range of phenolthailen (pH8. 2 to 9. 8) does not cover the equivalence point, which is pH of 5. 6.

Therefore, none of the indicators were suitable for the titrations they were involved with.

Report Questions:

1)Based on your results, which indicator of the two is more suitable for this type of titration experiment? Explain.

Methyl Red is the better indicator. The equivalence points for the titrations fell more closely with Methyl Red's range of color change (pH of 4. 4to 6. 2).

2)Calculate the volume of 0. 1 M NaOH which must be added to 50 mL of 0. 1 M HCl to give a final solution of pH 6.

To find [H+], Take the inverse log:

10-6 = [H+] = 1 10-6

Find the total number of initial moles of HCl

Total Initial moles = 0. 1 M HCl 0. 050 L = 0. 0050 mol HCl

Since our the goal pH is 6 (acidic) acid must be left over. Therefore the volume of NaOH added is unknown (z)

Mol NaOH = 0. 1 M(z)

The total number of final moles of HCl:

Mol HCl final = moles of HCl initial – moles of HCl reacted (aka mols NaOH)

Mol HCl final = 0. 0050 mol HCl – (0. 1M)(z)

The total volume:

Total Volume = initial volume of HCl + volume of NaOH added

Total Volume = 0. 050 L + z

The concentration of HCl:

[H+] = mol H+ / total volume

1. 6 10-6 = (0. 0050 – 0. 1z) /(0. 050 + z)

0. 0050 – 0. 1z = 5. 0 10-8 + 1. 0 10-6

so

z = 0. 049999L

Therefore 49. 99mL of NaOH must be added.

Sources of Error

There are numerous possible sources of error. The largest source of error in this experiment involves adding the titrant. Although the procedures indicate to add 5. 00 mL, 1. 00 mL, and 0. 50 mL amounts of titrant as the equivalence point is close to being reached, 0. 5 mL of titrant is too large to be added. Adding 0. 5mL may “ overshoot” the endpoint, making the results inaccurate. A possible solution is to use 0. 10 mL increments instead of 0. 50 mL. Yet, due to the limitations of human skill at adding the titrant, it may be hard to achieve smaller amounts and more accurate results.

Other sources of error include human errors. For example, contamination of samples may interfere with the titration's results. A solution to this problem is taking care when adding, mixing, or cleaning.

Conclusion

By using acid-base titration, we found that the equivalence point of the titration of hydrochloric acid with sodium hydroxide was determined to be at a pH of 7. 0. The titration of acetic acid with sodium hydroxide resulted in the equivalence point of found pH 8. 6. And the titration of ammonia with hydrochloric acid had an equivalence point at a pH of 5. 8. The methyl red indicator and the phenolphthalein indicator were unsuitable because their pH ranges for their color changes did not cover the equivalence points of the trials in which they were used. However, the methyl red indicator is more suitable, since it's pH range is closer to the equivalence points of the titrations.