A 0.15 M Solution Of NaOH Is Used To Titrate 200.0 ML Of 0.15 M HCN. What Is The PH At The Equivalence

A 0.15 M Solution Of NaOH Is Used To Titrate 200.0 ML Of 0.15 M HCN. What Is The pH At The Equivalence?

Understanding the pH at the equivalence point in titration processes is fundamental in analytical chemistry. In this article, we explore the titration of hydrocyanic acid (HCN) with sodium hydroxide (NaOH), focusing specifically on calculating the pH at the equivalence point. This involves understanding the chemistry of weak acids and strong bases, their titration behavior, and the relevant calculations to determine pH.

Introduction to Acid-Base Titration

Titration is a laboratory technique used to determine the concentration of an unknown solution by reacting it with a solution of known concentration. When titrating a weak acid like HCN with a strong base such as NaOH, the titration curve exhibits characteristic features, including the equivalence point where the acid has been neutralized completely.

The key concepts involved in this process include:

- Weak Acid and Strong Base Interaction: Hydrocyanic acid (HCN) is a weak acid, meaning it does not dissociate completely in solution.
- Equivalence Point: The point during titration where equivalent amounts of acid and base have reacted.
- pH at Equivalence: The pH value at this point depends on the nature of the acid and base involved.

Understanding the Chemistry of HCN and NaOH

Properties of Hydrocyanic Acid (HCN)

Hydrocyanic acid is a weak, volatile acid with the chemical formula HCN. Its dissociation in water can be represented as:

$$\text{HCN} \rightleftharpoons \text{H}^+ + \text{CN}^-$$

The acid dissociation constant (Ka) for HCN is approximately:

$$ K_a = 6.2 \times 10^{-10} $$

This small Ka value indicates that HCN is only slightly ionized in solution, maintaining most of its molecules intact.

Properties of Sodium Hydroxide (NaOH)

NaOH is a strong base that dissociates completely in water:

$$ \text{NaOH} \rightarrow \text{Na}^+ + \text{OH}^- $$

Because of its complete dissociation, NaOH readily neutralizes acids, making it ideal for titration purposes.

Details of the Titration Setup

Based on the problem, the titration involves:

- Volume of HCN solution: 200.0 mL (or 0.200 L)
- Concentration of HCN: 0.15 M
- Concentration of NaOH: 0.15 M

Since both solutions have the same molarity, the equivalence point will occur when equal moles of acid and base are mixed.

Calculating Moles of HCN

Number of moles of HCN initially present:

$$
\text{moles HCN} = \text{Molarity} \times \text{Volume} = 0.15\, \text{mol/L} \times 0.200\, \text{L} = 0.03\, \text{mol}
$$

Volume of NaOH Needed to Reach Equivalence

Since the molarity of NaOH is also 0.15 mol/L, the volume required to titrate all HCN:

$$
V_{\text{NaOH}} = \frac{\text{moles NaOH}}{\text{Molarity of NaOH}} = \frac{0.03\, \text{mol}}{0.15\, \text{mol/L}} = 0.200\, \text{L} = 200\, \text{mL}
$$

\]

Therefore, adding 200 mL of NaOH solution will reach the equivalence point.

Understanding the pH at the Equivalence Point

In titrations involving a weak acid and a strong base, the pH at the equivalence point is typically greater than 7. This is because the conjugate base formed from the weak acid can hydrolyze in water, producing hydroxide ions, thus increasing the pH.

Formation of the Conjugate Base (CN^-)

At the equivalence point, all HCN has been converted into its conjugate base, cyanide ion (CN-):

\[
\text{HCN} + \text{OH}^- \rightarrow \text{CN}^- + \text{H}_2\text{O}
\]

The solution contains only water, Na+, and CN-. The pH depends on the hydrolysis of CN-.

Hydrolysis of Cyanide Ion

The cyanide ion reacts with water:

\[
\text{CN}^- + \text{H}_2\text{O} \rightleftharpoons \text{HCN} + \text{OH}^-
\]

The equilibrium constant for this hydrolysis (Kb) can be derived from the acid dissociation constant (Ka) of HCN and the water ionization constant (Kw):

\[
K_b = \frac{K_w}{K_a}
\]

where,

\[
K_w = 1.0 \times 10^{-14} \quad \text{at 25°C}
\]

Calculating Kb:

$$
K_b = \frac{1.0 \times 10^{-14}}{6.2 \times 10^{-10}} \approx 1.61 \times 10^{-5}
$$

This indicates cyanide's basic nature in solution.

Calculating the pH at the Equivalence Point

To find the pH, we need to determine the hydrolysis of CN-. The steps involve:

- Calculating the concentration of CN- at the equivalence point.
- Setting up the hydrolysis equilibrium expression.
- Solving for the hydroxide ion concentration $[\text{OH}^-]$.
- Converting to pOH and then to pH.

Concentration of CN^- at Equivalence

Since 0.03 mol of HCN has been neutralized, the total volume after titration is:

$$
V_\text{total} = 200\, \text{mL} + 200\, \text{mL} = 400\, \text{mL} = 0.400\, \text{L}
$$

The concentration of CN-:

$$
[\text{CN}^-] = \frac{0.03\, \text{mol}}{0.400\, \text{L}} = 0.075\, \text{M}
$$

Equilibrium Expression for Hydrolysis

Let’s denote the amount of CN- hydrolyzed as x:

$$
\text{CN}^- + \text{H}_2\text{O} \rightleftharpoons \text{HCN} + \text{OH}^-
$$

The equilibrium expression:

$$
K_b = \frac{[\text{HCN}][\text{OH}^-]}{[\text{CN}^-]} \approx 1.61 \times 10^{-5}
$$

Assuming:

$$
[\text{OH}^-] = x
$$

and

$$
[\text{CN}^-]_{equilibrium} = 0.075 - x \approx 0.075
$$

because x is small compared to initial concentration.

Now, the concentration of $[\text{OH}^-]$:

$$
x = \sqrt{K_b \times [\text{CN}^-]} = \sqrt{1.61 \times 10^{-5} \times 0.075} \approx \sqrt{1.2075 \times 10^{-6}} \approx 1.10 \times 10^{-3} \text{ M}
$$

Calculating pOH and pH

$$
\text{pOH} = -\log [\text{OH}^-] = -\log (1.10 \times 10^{-3}) \approx 2.96
$$

Thus,

$$
\text{pH} = 14 - \text{pOH} = 14 - 2.96 = 11.04
$$

Therefore, the pH at the equivalence point is approximately 11.0.

Summary of Key Results

- The equivalence point occurs at 200 mL of NaOH added, neutralizing all HCN.
- The hydrolysis of cyanide ions produces a basic solution.
- The pH at the equivalence point is approximately 11.0.

Importance of This Calculation in Analytical Chemistry

Understanding the pH at the equivalence point in titrations such as this has practical applications:

- Determining Unknown Concentrations: By knowing the pH at the equivalence point, chemists can confirm the

Frequently Asked Questions

What is the pH at the equivalence point when titrating 0.15 M HCN with 0.15 M NaOH?

The pH at the equivalence point is approximately 7.0 because HCN is a weak acid neutralized by a strong base, resulting in a neutral salt solution.

Why is the pH at the equivalence point for titrating a weak acid with a strong base typically around 7?

Because the salt formed is neutral, and the strong base fully neutralizes the weak acid, leading to a solution with a pH close to 7.

Does the initial concentration of HCN affect the pH at the equivalence point in this titration?

No, the initial concentration of HCN does not affect the pH at the equivalence point when titrating with a strong base of equal concentration because the amount of acid and base are stoichiometrically equivalent.

How do you determine the amount of NaOH needed to reach the equivalence point in this titration?

Since both solutions are 0.15 M and the volume of HCN is 200.0 mL, the volume of NaOH required is 200.0 mL, as they have equal molarities and volumes.

What is the significance of the equivalence point in acid-base titrations like this one?

The equivalence point indicates the complete neutralization of the acid by the base, and the pH at this point provides insights into the nature of the acid and base involved.

Additional Resources

A 0.15 M Solution Of NaOH Is Used To Titrate 200.0 ML Of 0.15 M HCN. What Is The pH At The Equivalence Point? is a classic problem in acid-base chemistry that explores the principles of titration, acid-base neutralization, and pH calculation at the equivalence point. Understanding this scenario provides insight into how weak acids and strong bases interact, and how to determine the pH of the resulting solution after neutralization. In this comprehensive guide, we will walk through the entire process step-by-step, discussing the relevant concepts, calculations, and considerations involved in solving such titration problems.

Introduction to Titration and Acid-Base Chemistry

Titration is a laboratory technique used to determine the concentration of an unknown solution by gradually adding a reagent of known concentration until the reaction reaches the equivalence point. The equivalence point is where the amount of titrant added is just enough to completely neutralize the analyte.

In this specific problem, a 0.15 M solution of NaOH is used to titrate 200.0 mL of 0.15 M HCN, a weak acid. The goal is to find the pH at the equivalence point — the point at which all the HCN has been neutralized by NaOH.

Understanding the Components of the Problem

1. The Acid: Hydrocyanic Acid (HCN)
- Nature: Weak acid
- Chemical formula: HCN
- Acid dissociation constant (Ka): Approximately 6.2×10^{-10}

2. The Base: Sodium Hydroxide (NaOH)
- Nature: Strong base
- Concentration: 0.15 M

3. Volumes and Concentrations
- Volume of HCN: 200.0 mL (0.200 L)
- Concentration of HCN: 0.15 M
- Concentration of NaOH: 0.15 M

Step-by-Step Approach to Find the pH at the Equivalence Point

Step 1: Calculate the moles of HCN initially present

$$
\text{Moles of HCN} = M \times V = 0.15\, \text{mol/L} \times 0.200\,
$$

$$
\text{L} = 0.030\, \text{mol}
$$

Step 2: Determine the volume of NaOH needed to reach the equivalence point
Since NaOH and HCN have the same molarity, the molar ratio is 1:1. Therefore:

$$
\text{Moles of NaOH required} = 0.030\, \text{mol}
$$

$$
V_{\text{NaOH}} = \frac{\text{moles}}{\text{concentration}} = \frac{0.030\, \text{mol}}{0.15\, \text{mol/L}} = 0.200\, \text{L} = 200\, \text{mL}
$$

Thus, adding 200 mL of NaOH will reach the equivalence point.

Step 3: Understand what happens at the equivalence point

- All HCN has been neutralized:

$$
\mathrm{HCN} + \mathrm{OH}^- \rightarrow \mathrm{CN}^- + \mathrm{H_2O}
$$

- The resulting solution contains sodium cyanide (NaCN), which is a salt of a weak acid (HCN) and a strong base (NaOH).

Step 4: Determine the nature of the solution at the equivalence point
Since the salt formed, NaCN, results from a weak acid and a strong base, the solution will be basic due to the hydrolysis of the cyanide ion (CN^-):

$$
\mathrm{CN}^- + \mathrm{H_2O} \rightleftharpoons \mathrm{HCN} + \mathrm{OH}^-
$$

The pH at the equivalence point depends on the hydrolysis of CN^-, which acts as a weak base.

Calculating the pH at the Equivalence Point

Step 5: Determine the concentration of CN^- in the solution

Total volume after titration:

$$
V_{\text{total}} = 200\, \text{mL} + 200\, \text{mL} = 400\, \text{mL} = 0.400\, \text{L}
$$

Concentration of CN^-:

$$
[\mathrm{CN}^-] = \frac{\text{moles of } \mathrm{CN}^-}{V_{\text{total}}} = \frac{0.030\, \text{mol}}{0.400\, \text{L}} = 0.075\, \text{M}
$$

Step 6: Write the hydrolysis reaction and determine K_b

The hydrolysis of cyanide:

$$
\mathrm{CN}^- + \mathrm{H_2O} \rightleftharpoons \mathrm{HCN} + \mathrm{OH}^-
$$

The equilibrium constant K_b for CN^-:

$$
K_b = \frac{K_w}{K_a}
$$
where:
- $K_w = 1.0 \times 10^{-14}$
- K_a for HCN = 6.2×10^{-10}

Calculating K_b:

$$
K_b = \frac{1.0 \times 10^{-14}}{6.2 \times 10^{-10}} \approx 1.61 \times 10^{-5}
$$

Step 7: Set up the hydrolysis equilibrium expression

Let x be the concentration of OH^- produced at equilibrium:

$$
\mathrm{CN}^- + \mathrm{H_2O} \rightleftharpoons \mathrm{HCN} + \mathrm{OH}^-
$$

Initial concentration of CN^-:

$$
[\mathrm{CN}^-]_0 = 0.075\, \text{M}
$$

At equilibrium:

$$
[\mathrm{CN}^-] \approx 0.075 - x \approx 0.075
$$

(assuming x is small compared to initial concentration)

Using the expression for K_b:

$$
K_b = \frac{x^2}{[\mathrm{CN}^-]} \Rightarrow x^2 = K_b \times [\mathrm{CN}^-]
$$

$$
x^2 = (1.61 \times 10^{-5}) \times 0.075 \approx 1.21 \times 10^{-6}
$$

$$
x = \sqrt{1.21 \times 10^{-6}} \approx 1.10 \times 10^{-3}\, \text{M}
$$

This x is the concentration of OH^-:

$$
[\mathrm{OH}^-] \approx 1.10 \times 10^{-3}\, \text{M}
$$

Step 8: Calculate pOH and pH

$$
\text{pOH} = -\log [\mathrm{OH}^-] = -\log (1.10 \times 10^{-3}) \approx 2.96
$$

$$
\text{pH} = 14 - \text{pOH} = 14 - 2.96 = 11.04
$$

Final Result: pH at the Equivalence Point

The pH at the equivalence point during the titration of 0.15 M HCN with 0.15 M NaOH is approximately 11.04. This indicates a basic solution, consistent with the hydrolysis of the cyanide ion.

Additional Considerations and Tips

- Weak acid-strong base titrations typically result in a basic pH at the equivalence point due to the hydrolysis of the conjugate base.
- The calculation hinges on knowing the K_a of the weak acid; always verify the values from reliable sources.
- For more precise calculations, consider the activity coefficients, especially at higher ionic strengths, though these are often neglected in introductory problems.
- When performing titrations experimentally, pH meters should be calibrated

properly, and the titration should be performed slowly near the equivalence point for accuracy.

Summary

In this detailed analysis, we examined a titration involving a weak acid (HCN) and a strong base (NaOH). By calculating the initial moles, determining the volume needed to reach equivalence, and analyzing the hydrolysis of the resulting salt (NaCN), we deduced that the pH at the equivalence point is approximately 11.04. This process underscores the importance of understanding acid-base equilibria, salt hydrolysis, and titration principles in chemical analysis.

Understanding these calculations not only enhances your grasp of fundamental chemistry concepts but also equips you with the tools to approach similar tit

A 0 15 M Solution Of Naoh Is Used To Titrate 200 0 Ml Of 0 15 M Hcn What Is The Ph At The Equivalence

A 0 15 M Solution Of Naoh Is Used To Titrate 200 0 Ml Of 0 15 M Hcn What Is The Ph At The Equivalence

Related Articles

- ATM's Must Be Stocked With Enough Cash To Satisfy Customers Making Withdrawals Over An Entire Weekend.
- A Well-known Brokerage Firm Executive Claimed That 60% Of Investors Are Currently Confident Of Meeting
- A Cosine Signal Having Frequency Of500KHzand Amplitude100Vis Amplitude Modulated By A Cosine Signal Of

Back to Home