We Mix 20 Ml Of 10 M Hcl(aq) With 17 Ml Of 10 M Koh(aq). If Both Solutions Are Initially At 85 C, How

We Mix 20 Ml Of 10 M Hcl(aq) With 17 Ml Of 10 M Koh(aq). If Both Solutions Are Initially At 85°C, How

When studying chemical reactions, especially acid-base neutralizations, understanding the interplay of molarity, volume, temperature, and resultant energy changes is essential. The scenario of mixing 20 mL of 10 M hydrochloric acid (HCl) with 17 mL of 10 M potassium hydroxide (KOH), both initially at a high temperature of 85°C, provides a compelling case study. This article aims to analyze the chemical and thermal implications of such a mixture, focusing on the reaction dynamics, heat transfer, and temperature change outcomes.

Understanding the Components: Concentration, Volume, and Moles

Before considering the reaction's thermodynamic aspects, it's crucial to understand the initial parameters of the solutions.

Molarity and Volume

- Hydrochloric Acid (HCl):
- Molarity: 10 mol/L (10 M)
- Volume: 20 mL (0.020 L)

- Potassium Hydroxide (KOH):
- Molarity: 10 mol/L (10 M)
- Volume: 17 mL (0.017 L)

Calculating Moles of Reactants

The number of moles for each solution is calculated using the formula:

$$ \text{Moles} = \text{Molarity} \times \text{Volume (in liters)} $$

- Moles of HCl:
$$ 10\, \text{mol/L} \times 0.020\, \text{L} = 0.20\, \text{mol} $$

- Moles of KOH:
$$ 10\, \text{mol/L} \times 0.017\, \text{L} = 0.17\, \text{mol} $$

This indicates that the mixture contains 0.20 mol of HCl and 0.17 mol of KOH.

Reaction Dynamics: Acid-Base Neutralization

The core chemical process involved is the neutralization reaction:

$$
\mathrm{HCl (aq) + KOH (aq) \rightarrow KCl (aq) + H_2O (l)}
$$

Since the molar ratio of HCl to KOH is 1:1, the limiting reagent determines the extent of the reaction.

Extent of Reaction

- KOH is the limiting reagent because it has fewer moles: 0.17 mol compared to 0.20 mol of HCl.

- Reaction outcome:
- All 0.17 mol of KOH reacts with 0.17 mol of HCl.
- Remaining HCl: 0.20 mol - 0.17 mol = 0.03 mol

- Products formed:
- 0.17 mol of KCl and 0.17 mol of H_2O.

Final Composition of the Mixture

- Excess HCl: 0.03 mol
- Neutralized KOH: 0.17 mol
- Products:
- 0.17 mol of KCl (aqueous)
- 0.17 mol of water

The final solution contains unreacted acid, water, and potassium chloride.

Thermal Considerations: Heat of Neutralization and Temperature Changes

One of the most interesting aspects is the heat released during the neutralization, especially given both solutions are initially at 85°C.

Heat of Neutralization

- Standard enthalpy change ($\Delta H_{neutralization}$) for strong acid-strong base reactions like HCl and KOH is approximately -57 kJ/mol.

- Total heat released:
- Only the reacted moles contribute: 0.17 mol

$$
Q = \text{moles} \times \Delta H_{neutralization} = 0.17\, \text{mol} \times (-57\, \text{kJ/mol}) = -9.69\, \text{kJ}
$$

This indicates approximately 9.69 kJ of heat is released into the solution during the reaction.

Temperature Change Calculation

Assuming all heat remains within the solution (no heat loss to surroundings), the temperature change can be estimated:

$$
Q = mc\Delta T
$$

Where:
- Q = heat absorbed or released (in joules)
- m = mass of the solution (in grams)
- c = specific heat capacity (approximately 4.18 J/g°C for water)
- ΔT = change in temperature (°C)

Estimating the Mass of the Mixture

- Density of dilute aqueous solutions is close to that of water (~1 g/mL).
- Total volume: 20 mL + 17 mL = 37 mL
- Mass: approximately 37 g

Calculating Temperature Change

- Convert heat to joules:
$$ 9.69\, \text{kJ} = 9690\, \text{J} $$

- Rearranged formula:
$$ \Delta T = \frac{Q}{m c} = \frac{9690\, \text{J}}{37\, \text{g} \times 4.18\, \text{J/g°C}} $$

- Calculation:
$$ \Delta T \approx \frac{9690}{154.66} \approx 62.6\, °C $$

Since the reaction releases heat, the temperature of the mixture would increase by approximately 62.6°C, potentially raising the final temperature well above the initial 85°C.

Final Temperature of the Mixture

- Initial temperature: 85°C
- Estimated temperature increase: ~62.6°C
- Final temperature:
$$ 85\,^\circ\mathrm{C} + 62.6\,^\circ\mathrm{C} \approx 147.6\,^\circ\mathrm{C} $$

This suggests that the mixture could reach temperatures exceeding 100°C, potentially causing boiling if the system is not sealed or cooled.

Implications of High Initial Temperatures

Starting both solutions at 85°C influences the reaction and thermal dynamics significantly.

Enhanced Reaction Rate

- Temperature dependence:
- Reaction rates increase with temperature due to higher kinetic energy among particles.
- The reaction proceeds faster at 85°C compared to room temperature.

Thermal Safety and Handling

- Potential hazards:
- Elevated temperatures increase risk of splattering or boiling.
- Proper safety protocols are essential to prevent burns or accidents.

Heat Loss Considerations

- In practical scenarios, heat loss to surroundings occurs, reducing the actual temperature rise.
- The calculated 62.6°C increase is theoretical under ideal, adiabatic conditions.

Real-World Applications and Practical Insights

Understanding the heat generated during neutralization reactions, especially at high initial temperatures, is critical in various industrial and laboratory settings.

Industrial Reactions

- Managing exothermic reactions to prevent equipment damage.
- Using cooling systems to control temperature during large-scale neutralizations.

Laboratory Procedures

- Ensuring safe handling of hot, reactive solutions.
- Monitoring temperature changes to understand reaction energetics.

Environmental and Safety Protocols

- Proper ventilation and protective gear are essential when working with hot, reactive solutions.
- Implementing safety measures to handle potential splattering or boiling.

Conclusion: Final Insights and Key Takeaways

Mixing 20 mL of 10 M HCl with 17 mL of 10 M KOH at an initial temperature of 85°C results in a highly exothermic neutralization reaction. The calculations show that approximately 9.69 kJ of heat are released, potentially raising the temperature of the mixture to over 147°C, highlighting the importance of controlled conditions during such reactions.

This scenario underscores critical concepts in chemistry:

- The relationship between molarity, volume, and moles in predicting reaction stoichiometry.
- The energy changes involved in acid-base neutralization.
- The influence of initial temperature on reaction kinetics and thermal behavior.
- The practical importance of safety measures when handling exothermic reactions at elevated temperatures.

By thoroughly understanding these principles, chemists and students can better predict, control, and utilize exothermic reactions in both academic and industrial environments.

Frequently Asked Questions

What is the reaction when 20 mL of 10 M HCl is mixed with 17 mL of 10 M KOH?

The reaction is a neutralization between hydrochloric acid and potassium hydroxide, producing potassium chloride and water.

How do you calculate the moles of HCl and KOH in the given solutions?

Multiply volume (in liters) by molarity: moles of HCl = 0.020 L × 10 M = 0.2 mol; moles of KOH = 0.017 L × 10 M = 0.17 mol.

Which reagent is the limiting reagent in this neutralization?

KOH is the limiting reagent because it has fewer moles (0.17 mol) compared to HCl (0.2 mol).

What is the resulting solution after mixing in terms of pH?

Since KOH is the limiting reagent, excess HCl remains, resulting in an acidic solution with a pH less than 7.

How does the initial temperature of 85°C affect the neutralization reaction?

The elevated temperature can increase reaction rate but may also cause some evaporation; the reaction remains exothermic and releases heat, possibly raising the temperature further.

What is the heat change during the neutralization at 85°C?

The heat released can be calculated using the enthalpy of neutralization (~-57 kJ/mol for strong acid-base), so Q = 0.17 mol × 57 kJ/mol ≈ 9.69 kJ.

How do you determine the final pH after the reaction is complete?

Since excess HCl remains, calculate the remaining moles of HCl and its concentration in the total volume to find the pH: pH = -log[H+].

What are the safety considerations when mixing hot acid and base solutions?

Always add acid to water or base slowly while stirring, wear protective gear, and conduct the reaction in a well-ventilated area to avoid splashes and fumes.

How does the temperature influence the equilibrium and extent of neutralization?

Higher temperatures can shift the equilibrium slightly, but since strong acid-base reactions are essentially complete, temperature mainly affects reaction rate and heat released rather than extent of neutralization.

Additional Resources

We Mix 20 Ml Of 10 M HCl(aq) With 17 Ml Of 10 M KOH(aq). If Both Solutions Are Initially At 85°C, How Does This Affect the Reaction Dynamics and Final Conditions?

Introduction

Mixing acids and bases is a fundamental process in chemistry, often used to understand reaction thermodynamics, heat transfer, and solution behavior. In this scenario, we are combining 20 mL of 10 molar hydrochloric acid (HCl) with 17 mL of 10 molar potassium hydroxide (KOH), both initially at an elevated temperature of 85°C. The question centers on understanding what happens during this mixture, specifically focusing on the reaction's heat exchange, temperature changes, and the resulting solution's properties. This analysis provides insight into the energetic and thermodynamic principles governing neutralization reactions, especially under conditions where initial solutions are hot.

Understanding the Components and Their Concentrations

Before delving into the reaction specifics, it's essential to understand the starting solutions:

- Hydrochloric Acid (HCl):
- Volume: 20 mL
- Concentration: 10 M
- Moles of HCl: $10\, \text{mol/L} \times 0.020\, \text{L} = 0.2\, \text{mol}$

- Potassium Hydroxide (KOH):
- Volume: 17 mL
- Concentration: 10 M
- Moles of KOH: $10\, \text{mol/L} \times 0.017\, \text{L} = 0.17\, \text{mol}$

The neutralization reaction proceeds as:

$$\mathrm{HCl (aq)} + \mathrm{KOH (aq)} \rightarrow \mathrm{KCl (aq)} + \mathrm{H_2O (l)}$$

Given the molar amounts, the reaction will be limited by KOH, which is present in slightly lesser molar quantity, making KOH the limiting reagent.

Thermodynamics of Neutralization

The neutralization of a strong acid with a strong base is highly exothermic. The standard enthalpy change ($\Delta H_\text{neutralization}$) for such reactions is approximately -57 kJ/mol of water formed. Since the reaction involves 0.17 mol of KOH, the total heat released (Q) can be estimated as:

\[

$$
Q = n \times \Delta H_\text{neutralization} = 0.17\, \text{mol} \times 57\, \text{kJ/mol} \approx 9.69\, \text{kJ}
$$

This significant release of heat influences the temperature of the resulting solution, especially considering the initial high temperature of 85°C.

Impact of Initial Temperature on Reaction Dynamics

The fact that both solutions are initially at 85°C introduces additional complexity. Typically, neutralization reactions are performed at room temperature (around 25°C), but here, the solutions' high initial temperature impacts:

1. Heat Transfer and Temperature Rise:
- The heat generated by neutralization is added to the combined solution, which is already hot.
- The initial temperature influences the final temperature, potentially leading to even higher temperatures than if the solutions were cold.

2. Reaction Rate:
- Elevated temperatures accelerate molecular movement, potentially increasing the reaction rate.
- This can lead to a rapid release of heat and possibly transient phenomena like boiling or splattering if the temperature surpasses boiling points.

3. Thermal Equilibrium:
- The final temperature depends on the total heat capacity of the solution, which depends on the total volume and specific heat capacity of water (~4.18 J/g°C).

Calculating the Final Temperature

To estimate the final temperature (T_f) after mixing, consider:

$$
Q_\text{reaction} = \text{Heat released} = \text{Change in thermal energy of the mixture}
$$

Assuming no heat loss to surroundings (an isolated system), the total heat released heats the entire solution:

- Total volume: $20\, \text{mL} + 17\, \text{mL} = 37\, \text{mL}$
- Total mass: approximately 37 g (assuming density of water ~1 g/mL)
- Specific heat capacity: 4.18 J/g°C

The initial combined temperature:

$$
T_\text{initial} = 85^\circ C
$$

The heat needed to raise the temperature of the entire solution from 85°C to T_f:

$$
Q = m \times c \times (T_f - T_\text{initial})
$$

Rearranged to find T_f:

$$
T_f = T_\text{initial} + \frac{Q}{m \times c}
$$

Substituting known values:

$$
Q = 9.69 \times 10^3\, \text{J}
$$
$$
m = 37\, \text{g}
$$
$$
c = 4.18\, \text{J/g°C}
$$

Thus,

$$
T_f = 85^\circ C + \frac{9690\, \text{J}}{37\, \text{g} \times 4.18\, \text{J/g°C}} \approx 85^\circ C + 59\,^\circ C \approx 144^\circ C
$$

Since water boils at 100°C under normal atmospheric pressure, the approximate final temperature suggests boiling would occur if heat is retained fully. In reality, some heat would be lost, and vaporization would occur, preventing the temperature from reaching such high levels.

Practical Considerations and Safety

The calculations above highlight that mixing hot, concentrated solutions can produce significant heat, potentially leading to:

- Boiling and Vaporization:
- Rapid temperature increase can cause vigorous boiling.
- Vapor formation could lead to splattering or pressure buildup if in a closed container.

- Safety Precautions:
- Conduct such reactions in a well-ventilated fume hood.
- Use appropriate protective gear.
- Employ heat-resistant and pressure-safe containers.

- Controlled Reaction Conditions:
- Gradually add solutions to control heat release.
- Use cooling systems or perform reactions at lower initial temperatures to mitigate risks.

Final Solution Composition

Post-reaction, the limiting reagent (KOH) is consumed, while excess HCl remains:

- Moles of HCl remaining: $0.2\, \text{mol} - 0.17\, \text{mol} = 0.03\, \text{mol}$

The resulting solution contains:

- Potassium chloride (KCl): 0.17 mol
- Excess hydrochloric acid: 0.03 mol
- Water: from both initial solutions and the neutralization reaction

The pH of the final mixture:

$$
\text{pH} = -\log [\mathrm{H^+}]
$$

Since excess HCl contributes to the hydrogen ion concentration:

$$
[\mathrm{H^+}] = \frac{0.03\, \text{mol}}{0.037\, \text{L}} \approx 0.81\, \text{M}
$$

$$
\text{pH} \approx -\log(0.81) \approx 0.09
$$

This indicates a strongly acidic solution, despite the neutralization, due to leftover acid.

Conclusion

Mixing 20 mL of 10 M HCl with 17 mL of 10 M KOH, both initially at 85°C, results in a highly exothermic neutralization process that releases substantial heat. The initial high temperature amplifies the thermal effects, potentially elevating the solution temperature to near boiling, which in practice would be mitigated by vaporization and heat loss. The reaction leaves excess acid, ensuring the final pH remains strongly acidic. Understanding these dynamics is crucial, not just for laboratory safety but also for industrial processes where heat management during acid-base neutralizations is vital. Proper precautions, controlled addition, and awareness of thermodynamic principles are key to safely managing such reactions.

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