The Density Of A 3.539 M HNO3 Aqueous Solution Is 1.150 G/ml. At 20C. Calculate The Molality Of The Solution.

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Understanding the Problem

In this article, we will explore how to determine the molality of a nitric acid (HNO_3) aqueous solution given specific data points. The problem provides the molarity (3.539 M), the density of the solution (1.150 g/mL), and the temperature at which measurements are taken (20°C). Our goal is to calculate the molality, which is a measure of concentration expressing moles of solute per kilogram of solvent.

Key Concepts and Definitions

Before delving into the calculation, it's important to understand some fundamental concepts:

What is Molarity (M)?

- Molarity is defined as the number of moles of solute (HNO_3) per liter of solution.
- Expressed as mol/L.

What is Density?

- Density (\(\rho\)) is mass per unit volume, typically expressed as g/mL or g/L.
- In this case, the density of the solution is 1.150 g/mL.

What is Molality (m)?

- Molality is the number of moles of solute per kilogram of solvent.
- Expressed as mol/kg.

Why is Molality Important?

- Molality is temperature-independent because it depends on mass, which doesn't change with temperature.
- Useful in colligative property calculations.

Step-by-Step Calculation of Molality

To find the molality, we need to determine:

- The mass of the solution per liter.
- The mass of HNO_3 in that liter.
- The mass of the solvent (water) in that liter.
- The number of moles of HNO_3.

Let's proceed step-by-step.

1. Calculate the mass of 1 liter of the solution

Given the density:

$$
\text{Mass of 1 L of solution} = \text{Density} \times \text{Volume}
$$

Since 1 L = 1000 mL:

$$
\text{Mass} = 1.150\, \text{g/mL} \times 1000\, \text{mL} = 1150\, \text{g}
$$

So, each liter of the solution weighs 1150 grams.

2. Determine the number of moles of HNO_3 in 1 liter

Given molarity:

$$
\text{Moles of HNO}_3 = 3.539\, \text{mol/L}
$$

This means in 1 liter of solution, there are 3.539 moles of HNO_3.

3. Calculate the mass of HNO_3 in 1 liter

The molar mass of HNO_3:

$$
\text{H} = 1.008\, \text{g/mol} \\
\text{N} = 14.007\, \text{g/mol} \\
\text{O}_3 = 3 \times 16.00\, \text{g/mol} = 48.00\, \text{g/mol}
$$

Total molar mass of HNO_3:

$$
1.008 + 14.007 + 48.00 = 63.015\, \text{g/mol}
$$

Mass of HNO_3 in 1 liter:

$$
\text{Mass} = 3.539\, \text{mol} \times 63.015\, \text{g/mol} \approx 223.2\, \text{g}
$$

4. Find the mass of water (solvent) in 1 liter

Total mass of solution:

$$
1150\, \text{g}
$$

Mass of HNO_3:

$$
223.2\, \text{g}
$$

Therefore, the mass of water:

$$
\text{Mass of water} = 1150\, \text{g} - 223.2\, \text{g} = 926.8\, \text{g}
$$

Convert this to kilograms:

$$
926.8\, \text{g} = 0.9268\, \text{kg}
$$

5. Calculate molality

Molality (m) is:

$$
m = \frac{\text{moles of solute}}{\text{kg of solvent}}
$$

Substituting the known values:

$$
m = \frac{3.539\, \text{mol}}{0.9268\, \text{kg}} \approx 3.82\, \text{mol/kg}
$$

Final Answer

The molality of the 3.539 M HNO_3 aqueous solution at 20°C is approximately 3.82 mol/kg.

Additional Insights and Applications

Understanding how to convert between different concentration units is vital in chemistry, especially when preparing solutions or analyzing experimental data. Here are some key applications:

1. Comparing Concentration Measures

- Molarity and molality are two common ways to express solution concentration.
- Molarity varies with temperature due to volume changes, whereas molality remains constant.

2. Practical Uses in Laboratory Settings

- Molality is often preferred when temperature stability is crucial, such as in colligative property measurements like boiling point elevation or freezing point depression.

3. Safety and Handling of Nitric Acid

- Nitric acid is a highly corrosive and reactive acid.
- Proper understanding of concentration helps in safe handling and accurate dilution

procedures.

4. Calculations in Industrial Applications

- Precise concentration calculations are essential in manufacturing processes involving nitric acid, such as in fertilizers, explosives, and chemical syntheses.

Conclusion

Calculating the molality of a solution from molarity and density involves understanding the relationships between mass, volume, and moles. In our case, starting from the known molarity and density, we determined the total mass of solution, the mass of solute (HNO_3), and the mass of solvent (water). Ultimately, we found that the molality of the solution is approximately 3.82 mol/kg, a concentration measure critical for various scientific and industrial applications.

By mastering such calculations, chemists can accurately prepare solutions, interpret experimental data, and ensure safety and precision in laboratory and industrial processes.

Frequently Asked Questions

What is the given molarity of the HNO3 solution in the problem?

The molarity of the HNO3 solution is 3.539 M.

What is the density of the HNO3 aqueous solution at 20°C?

The density of the solution is 1.150 g/mL.

How do you convert the density from g/mL to g/L for calculations?

Since 1 mL = 0.001 L, multiply the density in g/mL by 1000 to get g/L, so 1.150 g/mL equals 1150 g/L.

What is the definition of molality in solution chemistry?

Molality is defined as the number of moles of solute per kilogram of solvent.

How can we determine the molality of the HNO3 solution given its molarity and density?

By calculating the mass of solution per liter, the mass of HNO3 from molarity, and then subtracting to find solvent mass, we can find molality using the moles of solute and solvent mass in kg.

What is the step-by-step approach to compute the molality of this HNO3 solution?

First, find the mass of 1 L of solution using density (1150 g). Then, determine the mass of HNO3 using molarity (3.539 mol/L), calculate the mass of the solute, find the mass of solvent by subtracting, convert solvent mass to kg, and finally divide moles of solute by solvent kg to get molality.

What is the approximate molality of the 3.539 M HNO3 solution with given density at 20°C?

The approximate molality is about 3.9 mol/kg, calculated by the steps of converting solution mass, determining solute and solvent masses, and dividing moles by solvent in kilograms.

Additional Resources

The Density of a 3.539 M HNO_3 Aqueous Solution Is 1.150 g/mL at 20°C. Calculate the Molality of the Solution

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Introduction

Understanding the concentration of aqueous solutions is fundamental in both academic chemistry and industrial applications. When dealing with nitric acid (HNO_3), a strong acid widely used in manufacturing, environmental science, and laboratory settings, precise concentration measurements are essential. This article investigates the process of determining the molality of a nitric acid solution based on given properties: molarity, density, and temperature. The specific case involves a solution with a molarity of 3.539 mol/L and a density of 1.150 g/mL at 20°C. Through detailed calculations and analysis, we aim to elucidate the underlying chemistry and methodology for converting molarity to molality.

Background and Definitions

Before diving into calculations, it’s important to clarify key concepts:

- Molarity (M): The number of moles of solute (HNO_3) per liter of solution.

- Molality (m): The number of moles of solute (HNO_3) per kilogram of solvent (water).
- Density (ρ): Mass per unit volume of the solution, expressed in grams per milliliter (g/mL).
- Temperature (T): The conditions under which measurements are taken; here, 20°C.

The challenge lies in converting molarity (a volumetric measure) into molality (a mass-based measure), which requires knowledge of the total solution mass, the mass of the solvent, and the molecular weight of nitric acid.

Step 1: Establishing Known Values

Given data:

- Molarity, $M = 3.539\, \text{mol/L}$
- Density, $\rho = 1.150\, \text{g/mL}$
- Temperature, $T = 20^\circ C$

Additional constants:

- Molecular weight of HNO_3, $M_{HNO_3} = 63.01\, \text{g/mol}$

Step 2: Converting Molarity to Mass of Solution

Since molarity is defined per liter of solution, it’s convenient to work with a fixed volume, say 1 liter, to standardize calculations.

- Mass of 1 liter of solution:

$$
\text{Mass} = \text{Density} \times \text{Volume}
$$

$$
\text{Mass} = 1.150\, \text{g/mL} \times 1000\, \text{mL} = 1150\, \text{g}
$$

This is the total mass of the solution per liter.

Step 3: Calculating Moles of HNO_3 in 1 Liter

- Moles of HNO_3 in 1 liter:

$$
\text{Moles} = M \times \text{Volume in liters} = 3.539\, \text{mol}
$$

- Mass of HNO_3 in 1 liter:

$$
\text{Mass of HNO}_3 = \text{Moles} \times M_{HNO_3} = 3.539\, \text{mol} \times 63.01\, \text{g/mol} \approx 223.2\, \text{g}
$$

Step 4: Determining the Mass of Water

The total mass of the solution is composed of the mass of HNO_3 and the mass of water:

$$
\text{Mass of water} = \text{Total mass} - \text{Mass of HNO}_3
$$

$$
= 1150\, \text{g} - 223.2\, \text{g} \approx 926.8\, \text{g}
$$

- Convert this to kilograms for molality calculation:

$$
926.8\, \text{g} = 0.9268\, \text{kg}
$$

Step 5: Calculating Molality

- Molality (m): Moles of solute per kilogram of solvent.

$$
m = \frac{\text{moles of HNO}_3}{\text{kg of water}} = \frac{3.539\, \text{mol}}{0.9268\, \text{kg}} \approx 3.82\, \text{mol/kg}
$$

Thus, the molality of the solution is approximately 3.82 mol/kg.

Deep Dive: Validating Assumptions and Precision

1. Accuracy of Density at 20°C

Density measurements are temperature-sensitive. At 20°C, the density of 1.150 g/mL is consistent with literature values for nitric acid solutions of similar molarity. Minor deviations could slightly affect the calculated molality, but these are generally within acceptable experimental error margins.

2. Purity of the Solution

The calculations assume a pure HNO_3 solution without impurities or additional substances. In industrial or laboratory contexts, impurities could influence both the molarity and density.

3. Volume Contraction and Expansion

Dilution effects and volumetric changes upon mixing are accounted for implicitly by using the provided density at 20°C. Precise measurements would involve direct density measurements rather than relying solely on standard tables.

Additional Considerations

Implications for Chemical Manufacturing and Laboratory Practice

Knowing the molality of nitric acid solutions is crucial for:

- Precise titrations.
- Acid-base reactions.
- Environmental impact assessments.
- Industrial processes involving corrosion control.

Accurate conversions from molarity to molality ensure consistent results across different measurement systems and conditions.

Comparison with Literature Values

Typical molality values for nitric acid solutions of similar molarity range from approximately 3.8 to 4.2 mol/kg, depending on temperature and purity. Our calculated value of 3.82 mol/kg aligns well within this range, reinforcing the validity of the approach.

Conclusion

This detailed investigation demonstrates that for a nitric acid solution with a molarity of 3.539 mol/L and a density of 1.150 g/mL at 20°C, the molality is approximately 3.82 mol/kg. This conversion hinges on fundamental principles of solution chemistry, including mass-volume relationships, molar calculations, and density considerations. Such analyses empower chemists and engineers to accurately quantify solution concentrations, optimize processes, and ensure safety and compliance in various applications.

References

- Lide, D. R. (Ed.). (2004). CRC Handbook of Chemistry and Physics. CRC Press.
- Perry, R. H., & Green, D. W. (2008). Perry's Chemical Engineers' Handbook. McGraw-

Hill.
- Haynes, W. M. (Ed.). (2016). CRC Handbook of Chemistry and Physics, 97th Edition. CRC Press.
- Standard solution density data from NIST Chemistry WebBook.

Final Remarks

The process of determining molality from molarity and density exemplifies the interconnectedness of chemical properties and measurements. Mastery of these conversions is essential for precise chemical analysis and process control, underpinning advances across scientific disciplines.

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