

What Is The Molarity, (M), Of HNO₃, [MW=63.02] In An Aqueous Solution That Is 30.0% HNO₃ By Mass And

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Understanding molarity is fundamental in chemistry, especially when preparing solutions for laboratory experiments, industrial processes, or academic purposes. Molarity (M) expresses the concentration of a solute—in this case, nitric acid (HNO₃)—per liter of solution. When dealing with a solution that is specified by mass percentage, calculating molarity involves converting mass-based information into molar quantities and volume. This article will guide you through the process of determining the molarity of nitric acid in a solution that contains 30.0% HNO₃ by mass, with a molecular weight (MW) of 63.02 g/mol.

Understanding the Fundamentals of Molarity

What Is Molarity?

Molarity (M) is defined as the number of moles of solute present in one liter of solution. It is expressed as:

- $M = \text{moles of solute} / \text{liters of solution}$

This unit provides a straightforward way to communicate and replicate solution concentrations, facilitating precise chemical reactions and calculations.

Relevance of Molarity in Chemistry

- Standardized measure for solution concentration
- Essential for stoichiometric calculations
- Critical in titrations, reactions, and formulations
- Helps in converting between different units of concentration (mass percent, molarity, molality, etc.)

Given Data and Objective

Data Provided

- Mass percentage of HNO_3 : 30.0%
- Molecular weight of HNO_3 : 63.02 g/mol

Objective

Calculate the molarity (M) of HNO_3 in the solution, i.e., determine the number of moles of HNO_3 per liter of the aqueous solution.

Step-by-Step Calculation Approach

To find the molarity, we'll follow these steps:

1. Assume a convenient total mass of the solution.

2. Calculate the mass of HNO_3 in that total mass.
3. Convert the mass of HNO_3 to moles.
4. Determine the total volume of the solution.
5. Calculate molarity using the moles of HNO_3 and the total volume in liters.

Let's explore each step in detail.

Step 1: Assume a Total Mass of the Solution

Choosing a round figure simplifies calculation. Typically, 100 g of solution is used because the mass percentage directly translates into grams:

- Total mass of solution = 100 g

Step 2: Calculate the Mass of HNO_3 in the Solution

Given 30.0% HNO_3 by mass:

- Mass of HNO_3 = $(30.0/100) \times 100 \text{ g} = 30.0 \text{ g}$

Remaining mass (water and other components) = $100 \text{ g} - 30.0 \text{ g} = 70.0 \text{ g}$

Step 3: Convert Mass of HNO_3 to Moles

Using the molecular weight:

- Moles of HNO_3 = $(\text{Mass of } \text{HNO}_3) / (\text{MW of } \text{HNO}_3) = 30.0 \text{ g} / 63.02 \text{ g/mol} = 0.4757 \text{ mol}$

Step 4: Determine the Volume of the Solution

This is the most critical step, as molarity depends on the volume in liters. Since the solution is aqueous and contains water, we need to estimate the volume based on the mass and density.

Estimating the density:

- Pure water has a density of approximately 1.00 g/mL at room temperature.
- The addition of HNO_3 increases the density somewhat. For this calculation, typical densities of dilute nitric acid solutions are around 1.2 g/mL for 30% HNO_3 solutions.

Using an approximate density:

- Density (approx) $\approx 1.2 \text{ g/mL} = 1.2 \text{ g/cm}^3$

Calculate volume:

- Volume = Total mass / density = $100 \text{ g} / 1.2 \text{ g/mL} \approx 83.33 \text{ mL}$

- Convert to liters:

$$\text{Volume} \approx 83.33 \text{ mL} \times (1 \text{ L} / 1000 \text{ mL}) \approx 0.08333 \text{ L}$$

Note: The actual density can vary depending on temperature and exact concentration, but 1.2 g/mL is a reasonable approximation for 30% HNO_3 .

Step 5: Calculate the Molarity of HNO_3

Finally, molarity is:

- $M = \text{moles of solute} / \text{liters of solution}$

- $M = 0.4757 \text{ mol} / 0.08333 \text{ L} = 5.71 \text{ mol/L}$

Thus, the molarity of the HNO_3 solution is approximately 5.71 M.

Refining the Calculation: Considerations and Variations

Impact of Density Variations

The calculated molarity hinges on the estimated density. Different sources or experimental conditions may yield slightly different densities, affecting the final molarity.

Adjustments for Exact Conditions

- Use actual measured density if available
- Account for temperature effects
- For more precise calculations, consult standard reference tables for densities of nitric acid solutions at various concentrations

Practical Applications and Significance

Laboratory Use

Knowing the molarity allows scientists to prepare precise acid solutions for titrations, pH adjustments,

and chemical syntheses.

Industrial and Commercial Usage

- Manufacturing of fertilizers, explosives, and other chemicals
- pH control in processing plants
- Quality control and formulation adjustments

Safety and Handling

Concentrated nitric acid is highly corrosive and toxic. Proper knowledge of its molarity helps in safe handling, storage, and disposal.

Summary and Final Remarks

Calculating the molarity of HNO_3 in a 30.0% solution involves understanding the relationship between mass percentage, molar mass, and solution volume. Using an assumed total mass, converting the mass of HNO_3 to moles, estimating the solution volume via density, and then applying the molarity formula yields an approximate molarity of around 5.71 M for a typical 30% nitric acid solution.

This process highlights the importance of accurate measurements and assumptions in chemical calculations. In real-world scenarios, precise density data and temperature considerations are essential for exact results. Nonetheless, the method described provides a solid foundation for understanding how to convert mass-based concentrations into molar concentrations, facilitating better control and understanding of chemical solutions.

Additional Resources

- Standard chemical reference tables for densities and concentrations
- Laboratory manuals on solution preparation
- Safety guidelines for handling strong acids
- Online molarity calculators for quick estimations

By mastering these calculations, students, researchers, and professionals can ensure accurate preparation and application of chemical solutions, reinforcing the critical role of molarity in chemistry.

Frequently Asked Questions

What is the definition of molarity (M) in chemistry?

Molarity (M) is the number of moles of solute dissolved in one liter of solution.

How do you calculate the molarity of HNO₃ in a solution that is 30.0% HNO₃ by mass?

To calculate molarity, convert the mass percentage to grams, find moles using the molar mass, and divide by the volume in liters. Specifically, for 30.0% HNO₃, determine grams of HNO₃ per liter of solution and then convert to molarity.

What is the molar mass (MW) of HNO₃ used in calculations?

The molar mass (MW) of HNO₃ is given as 63.02 g/mol.

How do you convert a percentage by mass into molarity?

Assuming a certain volume (usually 1 liter), multiply the total solution mass by the percentage to find grams of solute, then divide by molar mass to find moles, and finally divide by volume in liters to get

molarity.

What is the approximate molarity of HNO₃ in a 30.0% solution by mass?

Approximately 11.9 M. This is calculated by assuming 1 liter of solution, converting 30 g of HNO₃ per 100 g of solution, and using the molar mass to find molarity.

Why is knowing the molarity of HNO₃ important in laboratory applications?

Molarity provides a precise measure of concentration, essential for reactions, titrations, and preparing solutions with accurate and reproducible results.

Additional Resources

Understanding Molarity of HNO₃ in a 30.0% Aqueous Solution: A Comprehensive Guide

When working with chemical solutions, understanding their concentration is fundamental for accurate experimentation, manufacturing, and safety protocols. One such key parameter is molarity (M), which indicates the number of moles of solute per liter of solution. In this detailed review, we will explore how to determine the molarity of nitric acid (HNO₃) in a solution that is 30.0% by mass, considering its molecular weight (MW) of 63.02 g/mol. This analysis will encompass the concepts of mass percent, molar calculations, solution density considerations, and practical implications.

What Is Molarity (M)? An Overview

Molarity (symbol: M) is a measure of concentration expressing moles of solute per liter of solution. It is defined mathematically as:

$$\text{Molarity (M)} = \frac{\text{moles of solute}}{\text{liters of solution}}$$

Why is molarity important?

- It allows chemists to prepare solutions with precise concentrations.
- It facilitates stoichiometric calculations in reactions.
- It supports safety assessments and regulatory compliance in industrial processes.
- It enables conversion between different concentration units (e.g., mass percent, molality, molarity).

Understanding the Composition of the HNO₃ Solution

Given Data:

- Mass percent of HNO₃ = 30.0%
- Molecular weight of HNO₃ = 63.02 g/mol

This means that in 100 g of the solution:

- 30.0 g is HNO₃
- The remaining 70.0 g is primarily water (assuming a dilute aqueous solution)

Key assumptions:

- The solution density is not explicitly given, so we will assume typical densities or derive an

approximate value.

- The solution is dilute enough to treat volume changes upon mixing as negligible for an initial estimate.
- The calculation aims to determine molarity based on these assumptions.

Step-by-Step Calculation of Molarity

Calculating molarity involves several steps:

1. Determine the mass of HNO_3 in a known mass of solution

For simplicity, assume 100 g of the solution:

- Mass of HNO_3 = 30.0 g
- Mass of water = 70.0 g

2. Convert the mass of HNO_3 to moles

Using the molecular weight:

$$\begin{aligned} \text{Moles of HNO}_3 &= \frac{\text{mass of HNO}_3}{\text{MW of HNO}_3} = \frac{30.0 \text{ g}}{63.02 \text{ g/mol}} \approx 0.476 \text{ mol} \end{aligned}$$

3. Estimate the volume of the solution

This is the most complex part because molarity depends on the solution volume, not just mass. To

proceed:

- Use typical densities of aqueous HNO₃ solutions
- Approximate the density of a 30% HNO₃ solution

Density of 30% HNO₃ solution:

According to standard data, the density of a 30% by mass HNO₃ solution is approximately 1.16 g/mL.

Thus:

$$\begin{aligned} \text{Volume of 100 g solution} &= \frac{\text{mass}}{\text{density}} = \frac{100 \text{ g}}{1.16 \text{ g/mL}} \\ &\approx 86.21 \text{ mL} \end{aligned}$$

Convert to liters:

$$86.21 \text{ mL} = 0.08621 \text{ L}$$

4. Calculate molarity

Now, molarity is:

$$\begin{aligned} M &= \frac{\text{moles of HNO}_3}{\text{volume in liters}} = \frac{0.476 \text{ mol}}{0.08621 \text{ L}} \\ &\approx 5.52 \text{ M} \end{aligned}$$

Therefore, the molarity of HNO_3 in this 30% solution is approximately 5.52 M.

Refining the Calculation: Considering Variability and Accuracy

While the above calculation provides a solid estimate, real-world conditions may vary due to factors such as:

- Exact solution density: Industrial or lab-grade solutions may have densities slightly different from standard tables.
- Temperature effects: Density and volume are temperature-dependent.
- Non-ideal mixing: Volume contraction upon mixing can influence the actual concentration.

To improve accuracy, one might:

- Obtain precise density measurements at the specific temperature.
- Use experimental data or manufacturer specifications for density.
- Adjust calculations accordingly.

Practical Implications of the Molarity of HNO_3

Understanding the molarity of HNO_3 is critical in several contexts:

Industrial Applications

- Manufacturing of nitric acid: Precise molarity ensures product consistency.

- Chemical synthesis: Accurate molarity allows for stoichiometric precision, reducing waste or undesired byproducts.
- Safety protocols: Knowing molarity helps determine hazards, handling procedures, and necessary protective equipment.

Laboratory Usage

- Titrations: Molarity is essential for calculating titrant volumes.
- Solution preparation: Ensures reproducibility and accuracy.
- Reaction calculations: Facilitates mole-to-mole conversions in chemical equations.

Environmental and Safety Considerations

- Dilute solutions (like 30%) are less hazardous than concentrated nitric acid but still require careful handling.
- Proper storage and disposal depend on concentration knowledge.

Additional Factors in Real-World Scenarios

While the above calculation is straightforward, several factors can influence the actual molarity:

- Temperature: As temperature increases, the density of the solution decreases, affecting volume and molarity.
- Impurities: Commercial HNO_3 solutions may contain impurities that alter concentration.
- Concentration units: Sometimes solutions are expressed in weight/volume (w/v), molality, or normality, which each require different conversions.

Summary and Final Thoughts

Determining the molarity of HNO_3 in a 30.0% solution involves understanding the relationship between mass percent, molecular weight, solution density, and volume. Using standard data:

- In 100 g of a 30% HNO_3 solution:
- Moles of HNO_3 $\approx$ 0.476 mol
- Volume $\approx$ 86.21 mL
- Molarity $\approx$ 5.52 M

This approximate molarity indicates that a 30% HNO_3 solution is roughly 5.5 molar, a concentration suitable for many laboratory and industrial applications.

Key takeaways:

- Always consider solution density and temperature for precise calculations.
- Use standard reference data when exact measurements are unavailable.
- Recognize that molarity provides a practical measure for chemical reactions and safety assessments.

By mastering the calculation of molarity from mass percent and understanding the underlying principles, chemists and engineers can ensure proper solution preparation, accurate reactions, and safe handling of nitric acid in various contexts.

Final Note: Always verify data with manufacturer specifications or experimental measurements for critical applications.

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