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Introduction

Understanding the concentration and composition of solutions is fundamental in chemistry, especially in fields such as analytical chemistry, pharmacology, and manufacturing. In this context, calculating the percent by weight (w/w%) of a solute like sodium hydroxide (NaOH) in a given solution provides insight into its purity, strength, and suitability for specific applications. This article explores the step-by-step process to determine the percent by weight of NaOH in 400 mL of a solution, given its molarity and density at 20°C.

Key Concepts and Definitions

Molarity (M)

- Defined as the number of moles of solute per liter of solution.
- For NaOH, a 0.10 M solution contains 0.10 moles of NaOH per liter.

Density

- The mass per unit volume of a solution, expressed in g/mL.
- For this NaOH solution, the density is 1.01 g/mL at 20°C.

Percent By Weight (w/w%)

- The mass of solute divided by the total mass of solution, multiplied by 100.
- Formula:

$$
\text{w/w\%} = \left(\frac{\text{mass of solute}}{\text{mass of solution}}\right) \times 100
$$

Step-by-Step Calculation Process

1. Determine the total mass of the solution

- Given the volume of the solution: 400 mL
- Using the density: 1.01 g/mL
- Calculation:

$$
\text{Mass of solution} = \text{Volume} \times \text{Density} = 400\, \text{mL} \times 1.01\, \text{g/mL} = 404\, \text{g}
$$

2. Calculate the number of moles of NaOH in the solution

- Molarity (M) = 0.10 mol/L
- Convert volume from mL to liters:

$$
400\, \text{mL} = 0.400\, \text{L}
$$

- Calculate moles:

$$
\text{Moles of NaOH} = 0.10\, \text{mol/L} \times 0.400\, \text{L} = 0.040\, \text{mol}
$$

3. Find the mass of NaOH in the solution

- Molar mass of NaOH:

$$
\text{Na} = 22.99\, \text{g/mol}, \quad \text{O} = 16.00\, \text{g/mol}, \quad \text{H} = 1.008\, \text{g/mol}
$$

- Total molar mass:

$$
22.99 + 16.00 + 1.008 = 40.00\, \text{g/mol}
$$

- Mass of NaOH:

$$
\text{Mass} = \text{moles} \times \text{molar mass} = 0.040\, \text{mol} \times 40.00\, \text{g/mol} = 1.60\, \text{g}
$$

4. Calculate the percent by weight of NaOH in the solution

- Using the mass of NaOH and the total mass of the solution:
$$
\text{w/w\%} = \left(\frac{1.60\, \text{g}}{404\, \text{g}}\right) \times 100 \approx 0.396\%
$$

Discussion of Results

The calculation shows that in 400 mL of a 0.10 M NaOH solution with a density of 1.01 g/mL, the percent by weight of NaOH is approximately 0.396%. This indicates that the solution is quite dilute, which aligns with the low molarity.

It's important to note that the density of the solution plays a crucial role in these calculations. Since the density is slightly higher than that of pure water (1.00 g/mL), it suggests the presence of dissolved NaOH and possibly other minor impurities or the effect of solution temperature.

This calculation also demonstrates the importance of understanding the relationship between molarity, density, and mass in solution chemistry. Accurate measurements of these parameters allow chemists to determine solution compositions precisely, which is essential for quality control, formulation, and experimental reproducibility.

Additional Considerations

Impact of Temperature on Density and Concentration

- The density of solutions can vary with temperature.
- The given density (1.01 g/mL) is specific to 20°C; at other temperatures, density may change, affecting calculations.

Impurities and Real-World Variability

- Commercial NaOH solutions may contain impurities or stabilizers.
- For high-precision applications, additional analytical techniques may be needed to confirm concentration.

Alternative Methods for Determining Percent by Weight

- Gravimetric analysis
- Titration
- Spectroscopic methods

Practical Applications

- Industrial manufacturing: Ensuring correct NaOH concentrations for processes like soap making or chemical synthesis.
- Laboratory preparation: Standardizing solution concentrations for experiments.
- Pharmaceuticals: Formulating solutions with precise active ingredient percentages.

Conclusion

Calculating the percent by weight of NaOH in a solution requires an understanding of molarity, density, and the relationship between mass and volume. By converting the given molarity and volume into moles and mass, and then relating this to the total solution mass, chemists can determine the concentration expressed as a percentage by weight. For the problem at hand, the NaOH solution has a concentration of approximately 0.396% w/w, illustrating a dilute solution suitable for various laboratory and industrial purposes. Mastery of these calculations is essential for accurate solution preparation, quality control, and scientific research.

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Frequently Asked Questions

How do you calculate the mass of NaOH in 400 mL of a 0.10 M NaOH solution?

First, calculate the number of moles: Moles = Molarity × Volume (in liters) = 0.10 mol/L × 0.400 L = 0.040 mol. Then, multiply by the molar mass of NaOH (40.00 g/mol): 0.040 mol ×

40.00 g/mol = 1.6 g of NaOH.

What is the total mass of the solution in 400 mL if its density is 1.01 g/mL?

Total mass = density × volume = 1.01 g/mL × 400 mL = 404 g.

How is the percent by weight of NaOH calculated in the solution?

Percent by weight = (mass of NaOH / total mass of solution) × 100%. Using the previous calculations: (1.6 g / 404 g) × 100% ≈ 0.396%.

What is the significance of knowing the density when calculating solution composition?

Density allows you to determine the total mass of the solution from its volume, which is essential for calculating concentrations and percent by weight.

Can the density of the solution change with temperature, and how does that affect calculations?

Yes, density can vary with temperature. Calculations at a specific temperature, like 20°C, should use the density corresponding to that temperature for accuracy.

Why is it important to convert volume to liters when calculating moles in solution chemistry?

Because molarity is expressed in mol/L, converting volume from milliliters to liters ensures correct calculation of moles from molarity.

What is the molar mass of NaOH used in these calculations, and why is it important?

The molar mass of NaOH is 40.00 g/mol. It is crucial for converting moles to grams and vice versa in solution concentration calculations.

Additional Resources

The Density Of 0.10M NaOH At 20°C Is 1.01 G/mL. Calculate The Percent By Weight Of NaOH In 400 mL Of A Solution — this problem combines fundamental concepts of molarity, density, and percentage composition, making it a classic example in chemistry calculations. Understanding how to determine the percent by weight of NaOH in a solution is essential for laboratory work, chemical manufacturing, and educational purposes. In this guide, we will walk through a detailed, step-by-step approach to solving such problems, emphasizing

clarity and comprehension for learners and professionals alike.

Introduction

In the realm of chemistry, solutions are characterized by their concentration, density, and composition. When preparing or analyzing solutions, it's often necessary to find out the percentage by weight (mass percentage) of a solute, such as sodium hydroxide (NaOH), in a given volume of solution.

Specifically, given the density of 0.10M NaOH at 20°C is 1.01 g/mL, and a particular volume of the solution (400 mL), we aim to determine the percent by weight of NaOH within that volume.

This calculation involves understanding molarity (M), density, and mass-to-volume relationships, which we will explore thoroughly.

Fundamental Concepts

Before diving into the calculation, let's clarify some key concepts:

1. Molarity (M)

- Definition: Molarity is the number of moles of solute per liter of solution.
- For NaOH: 0.10 M indicates 0.10 moles of NaOH per liter of solution.

2. Density (g/mL)

- Density relates the mass of a substance to its volume.
- Given: Density of the 0.10 M NaOH solution at 20°C is 1.01 g/mL.

3. Percent by Weight

- Definition: The mass of solute divided by the total mass of the solution, multiplied by 100.

$$
\text{Percent by weight} = \left(\frac{\text{Mass of solute}}{\text{Total mass of solution}} \right) \times 100
$$

4. Molar Mass of NaOH

- NaOH consists of:
- Sodium (Na): 22.99 g/mol
- Oxygen (O): 16.00 g/mol
- Hydrogen (H): 1.008 g/mol

- Total molar mass:

$$
22.99 + 16.00 + 1.008 = 40.00\, \text{g/mol}
$$

Step-by-Step Calculation Guide

Let's break down the problem into manageable steps:

Step 1: Determine the mass of the solution in 400 mL

Given the density:

$$
\text{Density} = 1.01\, \text{g/mL}
$$

For 400 mL:

$$
\text{Mass of solution} = \text{Density} \times \text{Volume} = 1.01\, \text{g/mL} \times 400\, \text{mL} = 404\, \text{g}
$$

Step 2: Find the number of moles of NaOH in the solution

Since molarity is given:

$$
0.10\, \text{mol/L}
$$

convert 400 mL to liters:

$$
400\, \text{mL} = 0.400\, \text{L}
$$

Calculate moles of NaOH:

$$
\text{Moles of NaOH} = \text{Molarity} \times \text{Volume in liters}
= 0.10\, \text{mol/L} \times 0.400\, \text{L} = 0.040\, \text{mol}
$$

Step 3: Convert moles of NaOH to mass

Using molar mass:

$$
$$

$$
\text{Mass of NaOH} = \text{moles} \times \text{molar mass} = 0.040\, \text{mol} \times 40.00\, \text{g/mol} = 1.60\, \text{g}
$$

Step 4: Calculate the percent by weight

Now, using the mass of NaOH and the total mass of the solution:

$$
\text{Percent by weight} = \left(\frac{\text{Mass of NaOH}}{\text{Mass of solution}} \right) \times 100
$$

$$
= \left(\frac{1.60\, \text{g}}{404\, \text{g}} \right) \times 100 \approx 0.396\, \%
$$

Final Result

The percent by weight of NaOH in 400 mL of the solution is approximately 0.396%.

Additional Insights and Practical Considerations

Why is this calculation important?

- Determining the weight percentage helps in quality control, preparing solutions with specific concentrations, and understanding the solution's properties.
- Knowing the density allows for conversions between volume and mass, which is crucial when working with liquids in laboratory and industrial settings.

Impact of Temperature

- The problem specifies the density at 20°C, which is standard room temperature.
- Densities can vary with temperature; thus, measurements are temperature-dependent.

Assumptions Made

- The solution is ideal, meaning volume changes due to solute addition are negligible.
- The density provided is accurate for the concentration specified and at the given temperature.

Limitations

- For more concentrated solutions, interactions between solute particles may alter the density.
- Precise calculations might require correction factors, especially in commercial or high-precision settings.

Summary of Key Steps

Here's a quick recap of the process:

1. Calculate the total mass of the solution using its volume and density.
2. Determine the number of moles of NaOH from molarity and volume.
3. Convert moles to mass using molar mass.
4. Compute the percent by weight by dividing the solute mass by the total solution mass.

Conclusion

Understanding how to calculate the percent by weight of NaOH in a solution from given parameters like molarity, density, and volume is a fundamental skill in chemistry. By systematically applying concepts of molarity and density, and carefully performing each calculation step, students and professionals can accurately analyze solution compositions.

This detailed guide not only provides a solution to a specific problem but also offers a framework applicable to a wide range of solution concentration calculations, reinforcing core chemical principles essential for laboratory precision and scientific understanding.

References

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