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When working with chemical solutions, understanding how to determine the volume of a solution based on its molarity and the amount of solute it contains is an essential skill in chemistry. Specifically, calculating the volume of a silver nitrate ($AgNO_3$) solution when given the molarity and the amount of silver (Ag) present can be useful in laboratory preparations, titrations, and solution dilutions. This article provides a comprehensive guide to calculating the volume in milliliters of a 2.09 M silver nitrate solution containing 400 millimoles (mmol) of silver.

Understanding the Key Concepts

Before diving into the calculation process, it is important to understand some fundamental concepts related to molarity, molar mass, and the relationships between solute and solution volume.

What Is Molarity?

Molarity (M) is a measure of concentration, defined as the number of moles of solute dissolved in one liter (L) of solution:

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

In this context, a 2.09 M silver nitrate solution contains 2.09 moles of $AgNO_3$ per liter.

Relating Silver and Silver Nitrate

In the calculation, the key is recognizing that silver (Ag) is part of the silver nitrate molecule ($AgNO_3$). The molar ratio of silver to silver nitrate is 1:1:

$$
\[

$$
\text{Ag} : \text{AgNO}_3 = 1 : 1
$$

This means that 1 mole of silver corresponds to 1 mole of silver nitrate.

Molar Mass Considerations

To relate the amount of silver to the amount of silver nitrate, we need their molar masses:

- Silver (Ag): approximately 107.87 g/mol
- Silver nitrate ($AgNO_3$): approximately 169.87 g/mol

Since the calculation involves moles of silver, we need to convert the given millimoles of silver into moles, then determine the amount of silver nitrate associated with this amount of silver.

Step-by-Step Calculation Process

Let's now proceed with the detailed steps to find the volume of the silver nitrate solution that contains 400 mmol of silver.

Step 1: Convert Millimoles of Silver to Moles

Given:

- Silver amount = 400 mmol

Convert to moles:

$$
\text{Moles of Ag} = \frac{400 \text{ mmol}}{1000} = 0.4 \text{ mol}
$$

Step 2: Determine Moles of Silver Nitrate

Since the molar ratio of silver to silver nitrate is 1:1:

$$
\text{Moles of AgNO}_3 = \text{Moles of Ag} = 0.4 \text{ mol}
$$

Step 3: Calculate the Volume of Silver Nitrate Solution

Using the molarity formula:

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

Rearranged to solve for volume:

$$
\text{Volume (L)} = \frac{\text{moles of solute}}{\text{Molarity}}
$$

Substitute the known values:

$$
\text{Volume (L)} = \frac{0.4 \text{ mol}}{2.09 \text{ mol/L}} \approx 0.1914 \text{ L}
$$

Convert liters to milliliters:

$$
0.1914 \text{ L} \times 1000 = 191.4 \text{ mL}
$$

Answer:

The volume of a 2.09 M silver nitrate solution containing 400 mmol of silver is approximately 191.4 milliliters.

Additional Considerations and Practical Applications

Understanding this calculation process is vital for laboratory work involving solution preparation and analysis. Here are some additional points to consider.

Why Is This Calculation Important?

- Solution Preparation: When preparing a specific concentration of silver nitrate for experiments, knowing how much volume to use ensures accuracy.

- Titrations: In titrations involving silver nitrate, precise volume calculations determine the correct reagent amount.
- Dilution Calculations: To dilute a stock solution to a desired concentration, understanding initial and final volumes is essential.

Practical Tips for Chemists

- Always check units carefully, ensuring molarities are in mol/L and amounts are converted appropriately.
- Use accurate molar masses for conversions, especially when dealing with different isotopic compositions or impurities.
- When working with solutions, consider the purity and whether the concentration provided refers to the entire solution or just the active component.

Conclusion

Calculating the volume of a silver nitrate solution based on the amount of silver it contains involves understanding molarity, molar relationships, and unit conversions. By recognizing that 400 mmol of silver corresponds directly to 0.4 mol of silver nitrate (due to the 1:1 molar ratio), and applying the molarity formula, we find that approximately 191.4 mL of a 2.09 M silver nitrate solution contains this amount of silver. Mastery of these calculations is fundamental for chemists engaged in solution chemistry, ensuring precise measurements and successful experimental outcomes.

Summary of Calculation Steps

1. Convert mmol of silver to mol: 400 mmol ÷ 1000 = 0.4 mol
2. Determine moles of silver nitrate: same as silver moles (1:1 ratio) = 0.4 mol
3. Calculate volume in liters: 0.4 mol ÷ 2.09 mol/L ≈ 0.1914 L
4. Convert liters to milliliters: 0.1914 L × 1000 = 191.4 mL

By following these steps, you can confidently perform similar calculations for other solutions and solutes, ensuring accuracy and efficiency in your laboratory work.

Frequently Asked Questions

How do you calculate the volume in milliliters of a 2.09 M silver nitrate solution containing 400 mmol of silver?

Use the formula volume (L) = moles of solute / molarity. Convert 400 mmol to moles (0.4 mol), then divide by 2.09 mol/L to get volume in liters, and multiply by 1000 to convert to milliliters: (0.4 / 2.09) × 1000 ≈ 191.39 mL.

What is the formula to find the volume of a solution given molarity and moles of solute?

The formula is Volume (L) = Moles of solute / Molarity (M). To get milliliters, multiply the result in liters by 1000.

If a silver nitrate solution has a molarity of 2.09 M and contains 400 mmol of silver, what is the volume in milliliters?

Convert 400 mmol to 0.4 mol, then divide by 2.09 M: 0.4 mol / 2.09 mol/L ≈ 0.19139 L. Convert to milliliters: 0.19139 L × 1000 ≈ 191.39 mL.

Why is it important to convert mmol to mol when calculating solution volume?

Because molarity is expressed in moles per liter, converting mmol to mol ensures consistent units for accurate volume calculation using the formula volume = moles / molarity.

Can I use the same calculation method for other solutions with different molarities and amounts of solute?

Yes, the same formula applies: volume = moles of solute / molarity. Just ensure to convert units properly before calculation.

What is the significance of knowing the volume in milliliters of a silver nitrate solution in laboratory experiments?

Knowing the precise volume allows for accurate reagent preparation, ensures proper stoichiometric calculations, and maintains experimental consistency and safety.

Additional Resources

Calculate The Volume In Milliliters Of A 2.09 M Silver Nitrate Solution That Contains 400 mmol Of Silver

Understanding how to calculate the volume of a solution based on its molarity and the amount of solute it contains is a fundamental skill in chemistry, especially in solution preparation, titrations, and analytical procedures. In this comprehensive guide, we will explore the process step-by-step, focusing on a specific example: determining the volume in milliliters of a 2.09 M silver nitrate ($AgNO_3$) solution that contains 400 mmol of silver ions.

Understanding the Basics of Molarity and Solute Content

Before diving into calculations, it’s crucial to understand the key concepts involved:

What Is Molarity?

- Molarity (M) is defined as the number of moles of solute dissolved in one liter of solution.
- Expressed mathematically:
$$
M = \frac{\text{moles of solute}}{\text{liters of solution}}
$$
- It provides a convenient way to quantify the concentration of solutions.

What Is the Significance of mmol?

- mmol (millimoles) is a unit of amount of substance, where:
$$
1\, \text{mmol} = 10^{-3}\, \text{mol}
$$
- In our problem, we’re given 400 mmol of silver, which is equivalent to 0.4 mol of silver ions.

Relation Between Silver Ions and Silver Nitrate

- Silver nitrate ($AgNO_3$) dissociates completely in aqueous solution:
$$
\text{AgNO}_3 \rightarrow \text{Ag}^+ + \text{NO}_3^-
$$

- Therefore, the amount of silver ions directly corresponds to the amount of $AgNO_3$ present, assuming complete dissociation.

Step-by-Step Calculation Process

The goal is to find the volume (in mL) of the silver nitrate solution that contains 400 mmol (0.4 mol) of silver.

Step 1: Convert the Amount of Silver to Moles

- Given:
$$
400\, \text{mmol} = 0.4\, \text{mol}
$$
- Since the silver ions come from $AgNO_3$, and the dissociation is complete, the moles of $AgNO_3$ needed are equal to the moles of silver ions.

Step 2: Use the Molarity to Find the Volume in Liters

- Recall the molarity formula:
$$
M = \frac{\text{moles of solute}}{\text{liters of solution}}
$$
- Rearranged to find volume:
$$
\text{Volume (L)} = \frac{\text{moles of solute}}{M}
$$
- Substituting the known values:
$$
\text{Volume (L)} = \frac{0.4\, \text{mol}}{2.09\, \text{mol/L}} \approx 0.1914\, \text{L}
$$

Step 3: Convert Volume from Liters to Milliliters

- Since 1 L = 1000 mL:
$$
\text{Volume (mL)} = 0.1914\, \text{L} \times 1000 = 191.4\, \text{mL}
$$

Final Answer and Interpretation

The volume of a 2.09 M silver nitrate solution needed to contain 400 mmol of silver is approximately 191.4 milliliters.

This value indicates that to obtain 0.4 mol of silver ions, you would need to measure out roughly 191.4 mL of the 2.09 M $AgNO_3$ solution.

Additional Considerations and Practical Implications

While the calculation appears straightforward, several real-world factors and units conversions are worth considering:

1. Precision and Rounding

- Depending on the measurement tools available, it’s practical to round intermediate or final values to maintain appropriate significant figures.
- In this case, the molarity (2.09 M) is specified to three significant figures, so the final volume can be rounded to three significant figures: 191 mL.

2. Purity of the Solution

- The calculation assumes pure silver nitrate solution with exact molarity.
- In laboratory settings, solutions may have impurities or slight deviations in concentration, affecting the precise volume needed.

3. Temperature Effects

- Molarity is temperature-dependent because volume can expand or contract with temperature changes.
- Standard calculations assume a specified temperature (usually 20°C), but deviations can influence the actual volume.

4. Practical Application: Preparing a Solution

- To prepare approximately 191 mL of a 2.09 M $AgNO_3$ solution containing 400 mmol silver:
- Measure out about 191 mL of the stock solution.
- Use proper lab techniques to ensure accuracy, such as volumetric flasks and calibrated pipettes.

5. Significance in Analytical Chemistry

- Such calculations are vital in titrations, where precise reagent volumes influence the accuracy of analyte determination.
- In pharmaceutical or industrial settings, exact concentrations ensure compliance with quality standards.

Understanding the Broader Context

Beyond the straightforward calculation, it’s instructive to consider related aspects:

1. Molarity and Its Limitations

- While molarity is convenient, it can vary with temperature and is less precise than molality or molar concentration in certain contexts.
- For highly precise work, chemists might prefer molality (moles per kilogram of solvent) or molar fractions.

2. Alternative Units and Conversions

- If the problem provided the mass of $AgNO_3$ instead of molarity, the calculation would involve molar mass and density considerations.
- Molar mass of $AgNO_3$:
$$
107.87\, (\text{Ag}) + 14.01\, (\text{N}) + 3 \times 16.00\, (\text{O}) \approx 169.87\, \text{g/mol}
$$

3. Calculating Using Mass Instead of Molarity

- For example, if given 400 mmol of silver nitrate in grams:
$$
0.4\, \text{mol} \times 169.87\, \text{g/mol} \approx 67.95\, \text{g}
$$
- Then, knowing the solution’s density (if available), one could determine the volume.

4. Safety and Handling

- Silver nitrate is a hazardous chemical; proper safety protocols are essential during measurement and preparation.
- Use gloves, eye protection, and work in a well-ventilated area.

Concluding Remarks

This detailed exploration emphasizes the importance of understanding the foundational principles of solution chemistry and their application in practical calculations. By mastering how to translate molarities and solute amounts into solution volumes, chemists can accurately prepare solutions, perform titrations, and analyze samples with confidence.

In summary:
- To find the volume of a 2.09 M $AgNO_3$ solution containing 400 mmol of silver, convert mmol to mol, then divide by the molarity.
- The result is approximately 191.4 mL.
- Remember to account for real-world variables such as purity, temperature, and measurement precision.

Mastering these calculations enhances laboratory efficiency and accuracy, making it a crucial skill for students, researchers, and industry professionals alike.

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