If 100. Ml Of 0. 200 M Na2so4 Is Added To 200. Ml Of 0. 300 M Nacl, What Is The Concentration Of Na+

If 100. Ml Of 0. 200 M Na2so4 Is Added To 200. Ml Of 0. 300 M Nacl, What Is The Concentration Of Na+ is a common question in chemistry that involves understanding solution concentrations, molarity, and the behavior of ions in mixed solutions. To determine the concentration of sodium ions (Na+) after mixing these solutions, it is essential to analyze the problem step by step, considering the initial concentrations, volumes, and the resulting dilution effects. This article provides a comprehensive explanation of how to approach such problems, offering detailed calculations and insights into solution chemistry.

Understanding the Components of the Problem

Before diving into calculations, it is important to understand the chemicals involved and their properties.

Na2SO4 (Sodium sulfate)

- Dissociates completely in water into 2 Na+ ions and 1 SO_4^{2-} ion.
- A 0.200 M Na2SO4 solution contains 0.200 mol of Na2SO4 per liter.
- Each mole of Na2SO4 yields 2 moles of Na+ ions.

NaCl (Sodium chloride)

- Dissociates completely into Na+ and Cl- ions.
- A 0.300 M NaCl solution contains 0.300 mol of NaCl per liter.
- Each mole of NaCl yields 1 mole of Na+ ions.

Understanding these dissociation patterns is crucial in calculating the final concentration of Na+ ions after mixing.

Step-by-Step Calculation of the Final Na+ Concentration

The calculation involves several stages:
1. Determining the total moles of Na+ contributed by each solution.
2. Calculating the total volume after mixing.
3. Computing the final molarity of Na+ in the combined solution.

1. Calculating Moles of Na+ from Na2SO4

- Volume of Na2SO4 added: 100 mL = 0.100 L
- Concentration of Na2SO4: 0.200 M

Number of moles of Na2SO4:

$$
\text{Moles of Na2SO4} = 0.200\, \text{mol/L} \times 0.100\, \text{L} = 0.020\, \text{mol}
$$

Since each mole of Na2SO4 produces 2 moles of Na+:

$$
\text{Moles of Na+ from Na2SO4} = 0.020\, \text{mol} \times 2 = 0.040\, \text{mol}
$$

2. Calculating Moles of Na+ from NaCl

- Volume of NaCl added: 200 mL = 0.200 L
- Concentration of NaCl: 0.300 M

Number of moles of NaCl:

$$
\text{Moles of NaCl} = 0.300\, \text{mol/L} \times 0.200\, \text{L} = 0.060\, \text{mol}
$$

Since each mole of NaCl yields 1 mole of Na+:

$$
\text{Moles of Na+ from NaCl} = 0.060\, \text{mol}
$$

3. Total Moles of Na+ in the Mixture

Adding the contributions from both solutions:

$$
\text{Total moles of Na+} = 0.040\, \text{mol} + 0.060\, \text{mol} = 0.100\, \text{mol}
$$

4. Total Volume of the Mixture

- Volume of Na2SO4 solution: 100 mL
- Volume of NaCl solution: 200 mL

Total volume:

$$
\text{Total volume} = 100\, \text{mL} + 200\, \text{mL} = 300\, \text{mL} = 0.300\, \text{L}
$$

5. Final Concentration of Na+

Using the total moles and total volume:

$$
\text{Concentration of Na+} = \frac{\text{Total moles of Na+}}{\text{Total volume}} = \frac{0.100\, \text{mol}}{0.300\, \text{L}} \approx 0.333\, \text{M}
$$

Therefore, the concentration of Na+ ions in the final mixture is approximately 0.333 M.

Additional Considerations in Solution Chemistry

While the calculations above provide a straightforward approach, several factors can influence the actual concentration in real-world scenarios.

Ion Interactions and Activity Coefficients

- In dilute solutions like these, activity coefficients are close to 1, so molarity approximates activity.
- In more concentrated solutions, ion interactions can affect the effective concentration.

Volume Changes Upon Mixing

- Typically, mixing solutions results in negligible volume change at these concentrations.
- For highly precise calculations, volume contraction or expansion should be considered.

Impact of Common Ions

- The presence of common ions (Na+) can influence solubility and ion activity.
- However, in dilute solutions, these effects are minimal.

Summary of Key Steps in Solving Similar Problems

To effectively analyze solutions and determine ion concentrations after mixing, follow these steps:

1. Identify the initial concentrations and volumes of each solution.

2. Calculate the moles of solute contributed by each solution using molarity and volume.

3. Determine the dissociation pattern of each compound to find the number of moles of the target ion.

4. Sum the moles of the target ion from all solutions.

5. Calculate the total volume after mixing.

6. Divide the total moles of the ion by the total volume to find the final molarity.

Real-World Applications and Significance

Understanding how to calculate ion concentrations after mixing solutions has practical applications in various fields, including:

- Pharmaceutical formulations where precise dosing of ions is critical.
- Environmental chemistry for analyzing pollutant dilution.
- Industrial processes involving electrolyte solutions.
- Academic experiments and lab work requiring accurate solution preparations.

Accurate calculations enable chemists and students to predict solution behaviors, ensure safety, and optimize processes.

Conclusion

In summary, when 100 mL of 0.200 M Na_2SO_4 is added to 200 mL of 0.300 M NaCl, the resulting concentration of Na^+ ions in the mixture is approximately 0.333 M. This calculation hinges on understanding dissociation patterns, molarity, and solution volumes. Mastery of these concepts empowers students and professionals to analyze complex solution interactions and apply this knowledge across various scientific disciplines.

Frequently Asked Questions

How do you calculate the concentration of Na+ after mixing Na2SO4 and NaCl solutions?

First, determine the moles of Na^+ contributed by each solution, then divide the total moles by the total volume in liters to find the final concentration.

What is the total volume of the solution after mixing 100 mL of Na2SO4 and 200 mL of NaCl?

The total volume is 100 mL + 200 mL = 300 mL, which is 0.3 liters.

How many moles of Na+ are contributed by 100 mL of 0.200 M Na2SO4?

Moles of Na^+ from Na_2SO_4 = 0.200 mol/L × 0.1 L × 2 (since Na_2SO_4 provides 2 Na^+ ions per formula unit) = 0.040 mol.

How many moles of Na+ are contributed by 200 mL of 0.300 M NaCl?

Moles of Na+ from NaCl = 0.300 mol/L × 0.2 L = 0.060 mol.

What is the total moles of Na+ in the mixed solution?

Total Na+ moles = 0.040 mol (from Na2SO4) + 0.060 mol (from NaCl) = 0.100 mol.

What is the final concentration of Na+ in the solution after mixing?

Final concentration = total moles of Na+ / total volume in liters = 0.100 mol / 0.3 L ≈ 0.333 M.

Why do we multiply the moles of Na2SO4 by 2 when calculating Na+ contribution?

Because each formula unit of Na2SO4 supplies 2 Na+ ions, so the moles of Na+ are twice the moles of Na2SO4.

What assumptions are made in calculating the final Na+ concentration?

Assumptions include no volume change upon mixing, complete dissociation of Na2SO4 and NaCl, and no chemical reactions affecting Na+ ions.

Can this method be applied to other electrolyte solutions to find ion concentrations?

Yes, by calculating the moles of ions contributed by each solution and dividing by the total volume, similar calculations can be applied to other electrolyte mixtures.

Additional Resources

Understanding the Calculation of Na+ Concentration When Mixing Na_2SO_4 and NaCl Solutions

In chemical analysis and solution chemistry, calculating the resultant ion concentrations following the mixing of solutions is fundamental. Such calculations are crucial in various fields—ranging from laboratory experiments to industrial processes—where precise ion concentrations can influence outcomes significantly. A common problem involves mixing solutions of different molarities and volumes, then determining the concentration of a specific ion in the resulting mixture. This article provides an in-depth examination of such a scenario: when 100 mL of 0.200 M sodium sulfate (Na_2SO_4) is combined with 200 mL of 0.300 M sodium chloride (NaCl), what is the concentration of sodium ions (Na^+) in the final solution?

By dissecting this problem, we will explore the principles of solution mixing, molarity calculations, ion contributions from different salts, and the influence of solution volume on concentration. The discussion aims to clarify the step-by-step approach and underlying chemistry concepts, making it accessible for students, educators, and professionals alike.

Background Concepts in Solution Chemistry

Before delving into the specific problem, it is important to understand some foundational concepts.

Definition of Molarity (M)

Molarity is a measure of concentration, expressed as moles of solute per liter of solution (mol/L). For example, a 0.200 M Na_2SO_4 solution contains 0.200 moles of Na_2SO_4 dissolved in one liter of solution.

Understanding Ion Contributions from Solutes

- Na_2SO_4 dissociates as:
$Na_2SO_4 \rightarrow 2\ Na^+ + SO_4^{2-}$
Each mole of Na_2SO_4 yields 2 moles of Na^+ ions.

- NaCl dissociates as:
$NaCl \rightarrow Na^+ + Cl^-$
Each mole of NaCl yields 1 mole of Na^+ ions.

Knowing the dissociation helps us determine how many moles of Na^+ ions are contributed by each salt upon dissolution.

Step-by-Step Analytical Approach

The core of this problem involves calculating the total moles of Na^+ ions contributed by each solution, then dividing by the total volume of the combined solution to find the concentration.

1. Calculating Moles of Na_2SO_4 in Its Initial Volume

Given:
- Volume of Na_2SO_4 solution = 100 mL = 0.100 L
- Molarity of Na_2SO_4 = 0.200 M

Number of moles of Na_2SO_4:
$$
n_{Na_2SO_4} = M \times V = 0.200\, \text{mol/L} \times 0.100\, \text{L} = 0.020\, \text{mol}

\]

Since each mole of Na_2SO_4 contributes 2 moles of Na^+:

$$
n_{Na^+\, (from\, Na_2SO_4)} = 2 \times 0.020\, \text{mol} = 0.040\, \text{mol}
$$

---

2. Calculating Moles of NaCl in Its Initial Volume

Given:
- Volume of NaCl solution = 200 mL = 0.200 L
- Molarity of NaCl = 0.300 M

Number of moles of NaCl:

$$
n_{NaCl} = 0.300\, \text{mol/L} \times 0.200\, \text{L} = 0.060\, \text{mol}
$$

Each mole of NaCl yields 1 mole of Na^+:

$$
n_{Na^+\, (from\, NaCl)} = 0.060\, \text{mol}
$$

---

3. Total Moles of Na^+ in the Mixture

Total moles of Na^+ ions are the sum:

$$
n_{Na^+\, total} = n_{Na^+\, (from\, Na_2SO_4)} + n_{Na^+\, (from\, NaCl)} = 0.040\, \text{mol} + 0.060\, \text{mol} = 0.100\, \text{mol}
$$

---

4. Total Volume of the Mixture

Since volumes are additive (assuming ideal behavior):

$$
V_{total} = 100\, \text{mL} + 200\, \text{mL} = 300\, \text{mL} = 0.300\, \text{L}
$$

---

5. Final Concentration of Na^+ Ions

Using the total moles and total volume:

$$
C_{Na^+} = \frac{n_{Na^+\, total}}{V_{total}} = \frac{0.100\, \text{mol}}{0.300\, \text{L}} \approx 0.333\, \text{M}
$$

Thus, the concentration of Na^+ ions in the mixture is approximately 0.333 M.

Additional Considerations and Assumptions

While the calculations above provide a straightforward answer, several assumptions underpin the process:

- Ideal Solution Behavior: The volumes are additive, and the mixing does not produce volume contraction or expansion. In real-world scenarios, slight deviations can occur, but for dilute solutions, this assumption is valid.

- Complete Dissociation: Both salts are assumed to dissociate fully, which is generally accurate for strong electrolytes like NaCl and Na_2SO_4 in dilute solutions.

- No Chemical Interactions: The calculation assumes no chemical reactions occur between the ions that could alter ion concentrations, such as precipitation or complex formation.

- No Ion Pairing or Activity Coefficients: The calculation uses molarity directly, ignoring activity coefficients, which are more relevant in concentrated solutions.

Implications and Broader Context

Understanding ion concentrations after mixing solutions has practical implications. For instance:

- Buffer Preparation: Accurate ion concentrations are critical for preparing buffers with specific pH values.

- Industrial Processes: In manufacturing, precise control of ionic strength affects product quality.

- Environmental Chemistry: Dilution of pollutants or nutrients involves similar calculations.

In this specific case, knowing the Na^+ concentration helps in understanding the ionic strength of the solution, which influences properties such as solubility, electrochemical behavior, and biological interactions.

Extensions and Related Calculations

This problem can be extended to other ions or more complex mixtures:

- Calculating SO_4^{2-} concentration: Since only Na_2SO_4 contributes sulfate ions, the molarity of SO_4^{2-} can be computed similarly.

- pH and Buffer Capacity: If acids or bases are involved, pH calculations following mixing can be performed.

- Effect of Dilution on Equilibrium: Diluting solutions affects equilibrium positions in reactions involving ions.

Conclusion

The calculation of the Na^+ concentration after mixing 100 mL of 0.200 M Na_2SO_4 with 200 mL of 0.300 M NaCl demonstrates the fundamental principles of solution chemistry. By determining the moles of ions contributed by each component and considering total volume, one can accurately predict the ionic concentration in the resulting mixture. This process underscores the importance of understanding dissociation, molarity, and solution volume in analytical chemistry. Such calculations not only enhance our grasp of solution behavior but also underpin practical applications across scientific disciplines.

In summary, after mixing the given solutions, the concentration of Na^+ ions in the combined solution is approximately 0.333 M. This result exemplifies how stoichiometry and solution principles come together to solve real-world chemical problems efficiently and accurately.

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