

A 4 Gram Sugar Cube Is Dissolved In 350 ML Teacup Of 80C. What Is The Percent Composition By Mass Of

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Understanding the percent composition of a mixture is fundamental in chemistry, especially when analyzing solutions. When a sugar cube dissolves in hot water, it creates a solution whose properties can be quantified through concentration calculations. In this article, we will explore the detailed process of determining the percent composition by mass of sugar in a hot water solution, focusing on the specific case where a 4-gram sugar cube dissolves in 350 milliliters of water at 80°C.

This analysis is not only academically interesting but also practically relevant for culinary applications, food science, and chemical experimentation. By understanding how to calculate percent composition, you can better control and predict the properties of solutions in various contexts.

Understanding the Scenario

Before diving into the calculations, let's clarify the scenario:

- Mass of sugar cube: 4 grams
- Volume of water (teacup): 350 mL
- Temperature of water: 80°C

The key question is: What is the percent composition by mass of sugar in this solution?

Percent composition by mass (or weight percent) is a way of expressing the concentration of a component in a mixture, calculated as:

$$\text{Percent by mass} = \frac{\text{Mass of component}}{\text{Total mass of mixture}} \times 100\%$$

In this case, the component is sugar, and the mixture is the solution of sugar dissolved in water.

Key Concepts and Definitions

Mass and Volume in Solutions

- Mass: The amount of matter in an object, measured in grams (g).
- Volume: The space occupied by a substance, measured in milliliters (mL) or liters (L).
- Density: The mass per unit volume of a substance, typically expressed as g/mL.

Solubility and Dissolution

- Solubility: The maximum amount of solute (sugar) that can dissolve in a solvent (water) at a given temperature.
- Dissolution: The process where the solute dissolves uniformly within the solvent, forming a homogeneous solution.

Temperature's Effect on Solubility

- Higher temperatures generally increase the solubility of sugar in water, enabling more sugar to dissolve.
- At 80°C, sugar's solubility in water is significantly higher compared to room temperature.

Calculating the Total Mass of the Solution

To find the percent composition by mass, we need both the mass of the sugar and the total mass of the solution.

Mass of Water in the Solution

Given:

- Volume of water = 350 mL
- Density of water at 80°C $\approx$ 0.974 g/mL (since density decreases slightly with temperature)

Calculate:

\[
\text{Mass of water} = \text{Volume} \times \text{Density} = 350\text{ mL} \times 0.974\text{ g/mL} \approx 341\text{ g}
\]

Mass of the Solution

Total mass:

\[
\text{Mass of solution} = \text{Mass of water} + \text{Mass of sugar} = 341\text{ g} + 4\text{ g} = 345\text{ g}
\]

Calculating the Percent Composition by Mass

Using the formula:

\[
\text{Percent composition of sugar} = \frac{\text{Mass of sugar}}{\text{Total mass of solution}} \times 100\%
\]

Plugging in the values:

\[
= \frac{4\text{ g}}{345\text{ g}} \times 100\% \approx 1.16\%
\]

Therefore, the sugar constitutes approximately 1.16% of the total mass of the solution.

Additional Considerations and Practical Implications

Solubility Limits of Sugar at 80°C

- The solubility of sugar in water at 80°C is roughly 2.5 grams per 100 mL of water.
- For 350 mL of water:

\[
\text{Maximum dissolved sugar} \approx 2.5\, \text{g} / 100\, \text{mL} \\ \times 350\, \text{mL} = 8.75\, \text{g} \\ \]

- Since only 4 grams are dissolved, the sugar solution is well below saturation, ensuring complete dissolution and no crystallization.

Implications for Culinary and Food Science

- Achieving precise sugar concentrations is vital in recipes, especially in brewing, candy making, and baking.
- Understanding percent composition helps in controlling sweetness, consistency, and chemical reactions.

Impact of Temperature on Solution Concentration

- As temperature increases, more sugar can dissolve, increasing the solution's concentration.
- Conversely, cooling the solution can cause sugar to crystallize if the solution becomes supersaturated.

Practical Example: Preparing a Sweetened Tea

Suppose you're preparing tea and want to achieve a specific sweetness level:

1. Dissolve a 4-gram sugar cube in 350 mL of hot water at 80°C.
2. Calculate the percent sugar by mass as approximately 1.16%.
3. Adjust the amount of sugar based on desired sweetness, considering the solubility limit at different temperatures.

Summary of Key Points

- The mass of the sugar cube is 4 grams.
- The approximate mass of water in 350 mL at 80°C is 341 grams.
- Total mass of the solution is approximately 345 grams.
- The percent composition by mass of sugar in this solution is approximately 1.16%.

Conclusion

Understanding how to calculate the percent composition by mass in solutions is essential for chemists, food scientists, and culinary enthusiasts. In the specific case where a 4-gram sugar cube dissolves in 350 mL of water at 80°C, the resulting solution contains roughly 1.16% sugar by mass. This calculation considers the density of water at elevated temperatures, ensuring accuracy.

By mastering these calculations, you can better control recipe formulations, analyze solution properties, and understand the principles behind dissolving and solution concentration. Whether you're conducting experiments or preparing a perfect cup of tea, knowing the percent composition by mass is a valuable tool in your scientific and culinary toolkit.

Keywords: percent composition, sugar solution, dissolving sugar in water, solution concentration, grams, milliliters, temperature effect on solubility, food science, chemistry calculations

Frequently Asked Questions

What is the percent composition by mass of sugar in a 350 mL cup of tea when 4 grams of sugar is dissolved at 80°C?

The percent composition by mass of sugar is approximately 1.14%, calculated as $(4 \text{ g} / \text{total mass of solution}) \times 100\%$. Assuming the density of hot tea is close to water, the total mass is about 350 g, so $(4 / 350) \times 100\% \approx 1.14\%$.

How does temperature affect the solubility of sugar in tea and the resulting percent composition by

mass?

Higher temperatures increase sugar solubility, allowing more sugar to dissolve. In this case, at 80°C, 4 grams of sugar dissolves in 350 mL of tea, resulting in a certain percent composition. If the temperature were lower, less sugar might dissolve, reducing the percent composition.

Why is it important to consider the density of tea when calculating percent composition by mass?

Because percent composition by mass depends on the total mass of the solution, and the density determines the mass from the volume. Assuming a density close to water (1 g/mL) simplifies calculations, but variations can affect accuracy.

Can the percent composition by mass of sugar change if the tea cools down after dissolving?

No, the percent composition by mass remains constant because the amount of sugar and total mass of the solution do not change significantly upon cooling; only physical state may change, not composition.

If more sugar is added to the tea, how does that affect the percent composition by mass?

Adding more sugar increases the numerator in the percent calculation, thus increasing the percent composition by mass of sugar in the solution.

Is the calculation of percent composition by mass affected if some sugar crystallizes out as the tea cools?

Yes, if sugar crystallizes out, the amount dissolved in the solution decreases, which reduces the actual percent composition of sugar in the solution at that temperature.

How accurate is assuming the density of tea is equal to water when calculating percent composition?

It's an approximation; actual density of tea can vary depending on composition and temperature, but for rough calculations, assuming 1 g/mL is acceptable.

What steps are involved in calculating the percent

composition by mass of sugar in this scenario?

First, estimate the total mass of the solution (volume $\times$ density). Then, divide the mass of sugar by the total mass and multiply by 100 to get percent composition.

What impact does temperature have on the solubility of sugar in tea at 80°C?

At 80°C, sugar's solubility is high, allowing 4 grams to dissolve easily. As temperature increases, solubility generally increases, permitting more sugar to dissolve.

What assumptions are made when calculating the percent composition by mass in this problem?

Assumptions include that the density of tea is similar to water (1 g/mL), the entire 4 grams of sugar dissolves uniformly at 80°C, and the volume of tea remains constant during dissolution.

Additional Resources

A 4 Gram Sugar Cube Dissolved in 350 mL Teacup of 80°C Water: Exploring Percent Composition by Mass

Understanding the percent composition by mass of a solution is fundamental in chemistry, especially in areas like solution preparation, concentration calculations, and quality assurance. This detailed analysis examines the scenario where a 4-gram sugar cube dissolves in a 350 mL cup of water at 80°C, and how to determine the percent composition by mass. We will explore key concepts, calculations, and implications involved in this process.

Introduction to Percent Composition by Mass

Percent composition by mass, also known as mass percent or weight percent (% w/w), indicates how much of a particular component is present in a mixture relative to the total mass of the mixture.

Definition:

```
\[
\text{Percent by mass} = \left( \frac{\text{Mass of component}}{\text{Total mass of mixture}} \right) \times 100
\]
```

Relevance:

- Used to evaluate solution concentrations.
- Essential in preparing solutions with precise molarities.
- Important in quality control and formulation processes.

Understanding the Components of the Scenario

Before diving into calculations, clarify the scenario's parameters:

- Mass of sugar (solute): 4 grams
- Type of sugar: Typically sucrose (common table sugar)
- Volume of water (solvent): 350 mL
- Temperature of water: 80°C

Key considerations:

- Is the water density at 80°C significantly different from room temperature?
- Does the temperature influence the solution's behavior?
- Are we considering the final mixture as a solution, and are we including the dissolved sugar in the total mass?

Mass of Water at 80°C

To accurately compute percent composition by mass, we need the mass of water involved, which depends on its density at 80°C.

Density of water at 80°C:

Temperature Density (g/mL)
----- -----
80°C approximately 0.9718 g/mL

Calculating mass of water:

```
\[
\text{Mass of water} = \text{Volume} \times \text{Density}
\]
```

```
\[
= 350\, \text{mL} \times 0.9718\, \text{g/mL} \approx 340.13\, \text{g}
\]
```

Implication: The water's mass is approximately 340.13 grams at 80°C, slightly less than at room temperature due to thermal expansion.

Calculating Total Mass of the Solution

The total mass of the solution is the sum of the masses of water and sugar:

$$\begin{aligned} & \text{Total mass} = \text{Mass of water} + \text{Mass of sugar} \end{aligned}$$

$$= 340.13 \text{ g} + 4 \text{ g} = 344.13 \text{ g}$$

Note: When calculating percent composition, both the solute and solvent masses are considered, assuming complete dissolution.

Calculating Percent Composition by Mass of Sugar

Using the formula:

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

$$= \left(\frac{4 \text{ g}}{344.13 \text{ g}} \right) \times 100 \approx 1.16\%$$

Result: The sugar constitutes approximately 1.16% by mass of the solution.

Understanding the Significance of the Result

This percentage indicates a relatively dilute solution, typical of many

culinary contexts. For comparison:

- Standard table sugar solutions for beverages often range from 5% to 15% by mass.
- A 1.16% solution is quite dilute, suggesting the solution is primarily water with a small amount of sugar.

Implications:

- The temperature of 80°C facilitates rapid dissolution, ensuring the sugar fully dissolves in the water.
- The small mass percentage means the solution is not very sweet but could be used for specific culinary or scientific purposes where dilute sugar solutions are required.

Impact of Temperature on Dissolution and Solution Properties

Temperature plays a crucial role in solution chemistry:

- Increased temperature increases solubility: Sugar's solubility in water increases with temperature. At 80°C, sucrose's solubility is approximately 2 grams per mL of water, meaning dissolving 4 grams is easily achieved.
- Effect on solution density: As temperature rises, water density decreases, affecting the mass calculations slightly as shown above.
- Solution behavior: Higher temperatures reduce viscosity and surface tension, promoting rapid dissolution.

Additional Considerations in Percent Composition Calculations

While the primary calculation is straightforward, several other factors can influence the accuracy or interpretation:

1. Complete Dissolution:

- Assumes the sugar dissolves entirely at 80°C.
- Incomplete dissolution would alter the actual amount of sugar in solution, affecting percent calculations.

2. Solution Volume Changes:

- Dissolution can cause slight volume changes due to intermolecular interactions.
- Typically, for dilute solutions, these changes are minimal, but they can impact concentration calculations if high precision is required.

3. Density Variations:

- Slight variations in water density at different temperatures can influence mass calculations.
- For standard calculations, using published density values suffices.

4. Solvent Purity:

- Impurities in water or sugar could influence the composition and calculations.

Real-World Applications and Relevance

Understanding the percent composition by mass has practical applications:

- Culinary Arts: Chefs often adjust sugar levels based on desired sweetness, which correlates with concentration percentages.
- Food Industry: Manufacturing processes rely on precise sugar concentrations to ensure product consistency.
- Scientific Research: Accurate concentration measurements are essential for experiments involving solution chemistry.
- Educational Demonstrations: Demonstrates principles of solution chemistry, solubility, and concentration calculations.

Extending the Analysis: Molar Concentration and Other Metrics

While percent composition is useful, other ways to quantify solution concentration include:

1. Molarity (M):

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

- For 4 grams of sucrose (molar mass ≈ 342.3 g/mol):

$$\text{Moles of sucrose} = \frac{4 \text{ g}}{342.3 \text{ g/mol}} \approx 0.0117 \text{ mol}$$

- Total solution volume: 350 mL = 0.350 L

$$\text{Molarity} \approx \frac{0.0117 \text{ mol}}{0.350 \text{ L}} \approx 0.0334 \text{ M}$$

2. Mole Percent:

$$\text{Mole \%} = \left(\frac{\text{moles of sugar}}{\text{total moles in solution}} \right) \times 100$$

- Moles of water in 340.13 g:

$$\text{Moles of water} = \frac{340.13 \text{ g}}{18.015 \text{ g/mol}} \approx 18.89 \text{ mol}$$

- Total moles: 0.0117 mol (sugar) + 18.89 mol (water) $\approx$ 18.90 mol

$$\text{Mole \% sugar} \approx \left(\frac{0.0117}{18.90} \right) \times 100 \approx 0.062\%$$

This indicates that while the solution is dilute in molar terms, the mass percentage offers a more straightforward measure for culinary purposes.

Conclusion: The Significance of the Percent Composition by Mass

In summary, dissolving a 4-gram sugar cube into 350 mL of water at 80°C results in a solution with a sugar content of approximately 1.16% by mass. This metric provides insight into the solution's concentration, which is valuable across various fields—from cooking to laboratory science.

Key takeaways:

- Accurate calculation requires considering the density of water at the specific temperature.
- The total solution mass includes both the solvent and solute.
- Temperature influences solubility, density, and dissolution rates.
- Percent mass composition helps in understanding solution properties and preparing solutions with desired concentrations.

Final thoughts:

Understanding how to calculate and interpret percent composition by mass is essential for precise solution preparation, quality control, and scientific analysis. The scenario of a sugar cube dissolving at elevated temperature illustrates core principles of solution chemistry, emphasizing the importance of accurate data and calculations in practical applications.

Note: Always ensure to verify temperature-dependent properties like density and solubility with reliable sources for precise scientific work.

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