What Mass Of Sucrose (c12h22o11) Should Be Combined With 508 G Of Water To Make A Solution With An Osmotic

What Mass Of Sucrose (C12H22O11) Should Be Combined With 508 G Of Water To Make A Solution With An Osmotic Pressure?

Understanding how to prepare solutions with precise osmotic pressures is essential in fields such as biochemistry, medicine, and chemistry. The question of what mass of sucrose ($C_{12}H_{22}O_{11}$) should be combined with 508 grams of water to achieve a specific osmotic pressure involves a clear understanding of concepts such as molarity, molar mass, and osmotic pressure calculations. In this article, we will explore the principles behind calculating the required mass of sucrose, step-by-step procedures, and practical applications to ensure you can accurately prepare solutions with desired osmotic properties.

Fundamental Concepts of Osmotic Pressure

What Is Osmotic Pressure?

Osmotic pressure is the pressure required to prevent the flow of solvent molecules through a semipermeable membrane from a region of lower solute concentration to a higher one. It is a colligative property, meaning it depends on the number of solute particles in a given volume, not their identity.

Key Factors Affecting Osmotic Pressure

- **Concentration of the solute**: Higher concentrations result in higher osmotic pressure.
- **Temperature**: Increased temperature generally increases osmotic pressure.
- **Type of solvent**: Usually water in biological and chemical contexts.
- **Nature of the solute**: For non-electrolytes like sucrose, dissociation

isn't involved, simplifying calculations.

Calculating Osmotic Pressure

The Van't Hoff Equation

The osmotic pressure (Π) of a solution can be calculated using the Van't Hoff equation:

$$
\Pi = i M R T
$$

where:
- Π = osmotic pressure (atm)
- i = van't Hoff factor (for sucrose, $i=1$ because it does not dissociate)
- M = molarity (mol/L)
- R = ideal gas constant (0.0821 L·atm/(mol·K))
- T = temperature in Kelvin (K)

Determining the Molarity Needed

To find the mass of sucrose needed, we first need to determine the molarity M required to achieve the given osmotic pressure at a specific temperature.

Suppose the desired osmotic pressure (Π) is known; then:

$$
M = \frac{\Pi}{i R T}
$$

Once the molarity is known, the total number of moles of sucrose required can be calculated based on the volume of the solution.

Step-by-Step Calculation Process

1. Identify the Given Data

- Mass of water = 508 g
- Temperature (assumed room temperature) = 25°C = 298 K
- Desired osmotic pressure (Π) = [Insert specific value based on the problem, e.g., 1 atm]
- R = 0.0821 L·atm/(mol·K)

- van't Hoff factor for sucrose, $i=1$

2. Convert Water Mass to Volume

Assuming the density of water is approximately 1 g/mL:

$$
\text{Volume of water} = \frac{508\, \text{g}}{1\, \text{g/mL}} = 508\, \text{mL} = 0.508\, \text{L}
$$

3. Calculate Molarity Needed

Using the Van't Hoff equation:

$$
M = \frac{\Pi}{i R T}
$$

For example, if the target osmotic pressure is 1 atm:

$$
M = \frac{1\, \text{atm}}{1 \times 0.0821\, \text{L·atm/(mol·K)} \times 298\, \text{K}} \approx \frac{1}{24.45} \approx 0.0409\, \text{mol/L}
$$

4. Determine Moles of Sucrose Required

$$
\text{Total moles} = M \times \text{volume in liters} = 0.0409\, \text{mol/L} \times 0.508\, \text{L} \approx 0.02078\, \text{mol}
$$

5. Convert Moles to Mass of Sucrose

The molar mass of sucrose ($C_{12}H_{22}O_{11}$):

$$
(12 \times 12.01) + (22 \times 1.008) + (11 \times 16.00) = 144.12 + 22.176 + 176.00 = 342.30\, \text{g/mol}
$$

Thus, the mass needed:

$$
\text{Mass} = 0.02078\, \text{mol} \times 342.30\, \text{g/mol} \approx 7.12\, \text{g}
$$

Adjusting for Different Osmotic Pressures

Customizing Your Solution

Depending on the specific osmotic pressure required for your application, you can adjust the calculations accordingly:

- Higher osmotic pressure: Increase the molarity, thus increasing the mass of sucrose.
- Lower osmotic pressure: Decrease molarity and sucrose mass accordingly.

Practical Examples

- For an osmotic pressure of 2 atm, double the molarity, resulting in approximately 14.24 g of sucrose.
- For 0.5 atm, halve the molarity, resulting in about 3.56 g of sucrose.

Additional Considerations in Solution Preparation

Ensuring Accurate Measurements

- Use a precise scale to weigh sucrose.
- Measure water volume accurately using a graduated cylinder.
- Mix thoroughly to ensure complete dissolution.

Temperature Effects

- Remember that osmotic pressure is temperature-dependent.
- Always specify and maintain the temperature during preparation.

Purity of Sucrose

- Use high-purity sucrose to ensure consistency and accuracy in osmotic pressure.

Practical Applications of Osmotic Solutions

Medical Applications

- Intravenous solutions require precise osmotic pressures to match body fluids.
- Sucrose solutions are used in osmotic diuretics and other therapies.

Biological Research

- Studying cell osmosis, membrane permeability, and drug delivery often involves preparing solutions with specific osmotic properties.

Food Industry

- Sugar solutions with controlled osmotic pressure are used in food preservation and processing.

Summary of Key Steps to Prepare a Sucrose Solution with Specific Osmotic Pressure

1. Determine the desired osmotic pressure (\(\Pi\)) and temperature.
2. Calculate the molarity (\(M\)) needed using the Van't Hoff equation.
3. Measure the volume of water to be used.
4. Calculate the total moles of sucrose required.
5. Convert moles to mass using the molar mass of sucrose.
6. Weigh the sucrose accurately and dissolve in water thoroughly.
7. Verify the osmotic pressure if necessary, using appropriate instruments.

Conclusion

Calculating the precise mass of sucrose needed to achieve a specific osmotic pressure in a solution with a known volume of water involves applying fundamental principles of colligative properties, molarity, and solution chemistry. By understanding the Van't Hoff equation and carefully performing each step, you can prepare solutions tailored to your research or medical needs. Whether for biological experiments, medical treatments, or food industry applications, mastering these calculations ensures accuracy and effectiveness in your work.

Remember to consider temperature, solution purity, and measurement accuracy to optimize your solution preparation process. With these principles in mind, determining the correct amount of sucrose to combine with water becomes straightforward and reliable.

Frequently Asked Questions

How do I calculate the mass of sucrose needed to prepare a solution with a specific osmotic pressure using 508 g of water?

To determine the required mass of sucrose, first find the desired osmotic pressure and temperature, then use the osmotic pressure equation $\pi = iMRT$. Rearranging to solve for molarity (M), convert it to moles of sucrose, and multiply by its molar mass (342.3 g/mol) to get the mass needed. Ensure you account for the solvent mass (508 g water) in your calculations.

What is the significance of osmotic pressure when preparing a sucrose solution, and how does it influence the amount of sucrose used?

Osmotic pressure indicates the tendency of a solution to draw water across a semipermeable membrane. When preparing a sucrose solution for a specific osmotic pressure, it determines the concentration of sucrose needed. Higher osmotic pressure requires a higher molarity of sucrose, thus increasing the mass of sucrose used in relation to the water volume.

What factors affect the amount of sucrose required to achieve a particular osmotic pressure in 508 g of water?

Factors include the desired osmotic pressure, temperature, and the number of particles the solute dissociates into (for sucrose, $i=1$). Temperature influences the calculation via the ideal gas law component, and higher osmotic pressures or temperatures require more sucrose to reach the target osmotic condition.

Can you provide a step-by-step method to compute the mass of sucrose needed for a specific osmotic pressure in a 508 g water solution?

Yes. First, convert water mass to kilograms. Next, decide on the desired osmotic pressure and temperature. Use the osmotic pressure formula $\pi = iMRT$ to find the molarity M. Multiply M by the total volume of water (convert mass to volume using water's density) to get moles of sucrose. Finally, multiply by sucrose's molar mass (342.3 g/mol) to find the required mass.

What are common units and conversions involved when

calculating the mass of sucrose for osmotic pressure in a solution with 508 g of water?

Common units include grams for mass, liters for volume, molarity (mol/L) for concentration, and atmospheres (atm) for pressure. To perform calculations, convert 508 g of water to liters (using water's density of 1 g/mL or 1000 g/L). Ensure molarity is in mol/L, and convert the final molar amount of sucrose to grams by multiplying by 342.3 g/mol.

Additional Resources

What Mass Of Sucrose (C12H22O11) Should Be Combined With 508 G Of Water To Make A Solution With An Osmotic

Understanding the precise quantities of solutes and solvents required to achieve desired osmotic pressures is fundamental in fields ranging from biochemistry and medicine to industrial manufacturing. This investigative article explores the detailed process of determining the exact mass of sucrose (C12H22O11) necessary to be dissolved in 508 grams of water to produce a solution with a specified osmotic pressure. Through comprehensive analysis, we will dissect the scientific principles, calculations, and practical considerations involved in this process.

Introduction to Osmosis and Osmotic Pressure

Osmosis is a fundamental biological and chemical phenomenon where solvent molecules pass through a semipermeable membrane from a region of lower solute concentration to a higher one, aiming to equalize solute concentrations on both sides. The driving force behind this process is osmotic pressure, a colligative property dependent on the number of solute particles in solution, not their identity.

Osmotic pressure (Π) can be expressed by the van 't Hoff equation:

$$
\Pi = i M R T
$$

where:
- i = van 't Hoff factor (number of particles the solute dissociates into)
- M = molarity of the solution (moles of solute per liter of solution)
- R = universal gas constant (8.314 J·mol^{-1}·K^{-1})
- T = absolute temperature in Kelvin (K)

In practical applications, understanding and manipulating this relationship allows scientists to prepare solutions with specific osmotic pressures, critical in medical therapies, food preservation, and biological research.

Defining the Objective: The Target Osmotic Pressure

To proceed, it is essential to specify the target osmotic pressure (Π). For this analysis, assume the goal is to prepare a sucrose solution at an osmotic pressure of 10 atmospheres (atm) at room temperature (approximately 25°C or 298 K). This value is representative of physiological osmotic pressures and common in laboratory settings.

Note: The choice of osmotic pressure significantly influences the required solute concentration, so clarity on this parameter is vital.

Understanding the Properties of Sucrose in Solution

Sucrose ($C_{12}H_{22}O_{11}$) is a non-electrolyte sugar that does not dissociate in aqueous solutions, which simplifies calculations as its van 't Hoff factor i is 1.

Key properties:
- Molecular weight ($M_{sucrose}$): 342.30 g/mol
- Van 't Hoff factor (i): 1
- Solubility in water at room temperature: approximately 2 g/mL (or 2000 g/L)

Given our target osmotic pressure, the molarity M of sucrose in solution will be the primary variable to adjust.

Calculating the Required Molarity of Sucrose

Applying the van 't Hoff equation:

$$
\Pi = i M R T
$$

\]

Rearranged for \(M\):

\[
M = \frac{\Pi}{i R T}
\]

Substituting known values:

\[
\Pi = 10\, \text{atm} \times 101.325\, \text{kPa/atm} = 1013.25\, \text{kPa}
\]
(Note: 1 atm = 101.325 kPa)

\[
R = 8.314\, \text{J mol}^{-1}\text{K}^{-1}
\]

\[
T = 298\, \text{K}
\]

Calculating:

\[
M = \frac{1013.25\, \text{kPa}}{(1)(8.314\, \text{J
mol}^{-1}\text{K}^{-1})(298\, \text{K})}
\]

Since 1 J = 1 Pa·m^3, and 1 kPa = 1000 Pa:

\[
M = \frac{1013.250 \times 10^3\, \text{Pa}}{8.314 \times 298}
\]

\[
M = \frac{1.01325 \times 10^6}{2478.772}
\]

\[
M \approx 408.7\, \text{mol/m}^3
\]

Converting mol/m^3 to mol/L (since 1 m^3 = 1000 L):

\[
M \approx 0.409\, \text{mol/L}
\]

Thus, to achieve an osmotic pressure of 10 atm at 25°C with sucrose, the solution should have a molarity of approximately 0.409 mol/L.

Determining the Mass of Sucrose Needed

Next, we convert molarity to mass:

$$
\text{Mass of sucrose} = M \times \text{volume of solution} \times M_{sucrose}
$$

The volume of the solution isn't specified directly but is inferred from the amount of water used and the intended concentration.

Step 1: Calculate volume of water

Given:
- Water mass = 508 g
- Water density ≈ 1 g/mL

Therefore:
$$
\text{Volume of water} = 508\, \text{mL} = 0.508\, \text{L}
$$

Step 2: Calculate moles of sucrose needed

$$
\text{Moles of sucrose} = M \times \text{volume} = 0.409\, \text{mol/L} \times 0.508\, \text{L} \approx 0.208\, \text{mol}
$$

Step 3: Convert moles to mass

$$
\text{Mass of sucrose} = 0.208\, \text{mol} \times 342.30\, \text{g/mol} \approx 71.3\, \text{g}
$$

Result: To prepare approximately 508 mL of solution with an osmotic pressure of 10 atm at 25°C, approximately 71.3 grams of sucrose must be dissolved in 508 grams of water.

Practical Considerations and Adjustments

While the above calculation provides a theoretical value, practical laboratory considerations may necessitate adjustments:

- Solubility Limit: Sucrose's solubility (~2000 g/L) at room temperature exceeds the required amount (~71.3 g), so solubility is not a limiting factor.

- Solution Volume Variability: Dissolving sucrose slightly increases the total volume, which could marginally affect molarity. For high precision, volume should be measured post-dissolution.

- Temperature Effects: Elevating temperature increases solubility and can affect osmotic pressure; calculations are based on 25°C.

- Precision and Measurement: Use calibrated scales and volumetric equipment for accuracy.

- Safety and Handling: Sucrose is non-toxic, but standard laboratory safety procedures should be followed.

Alternative Scenarios and Further Calculations

If the target osmotic pressure differs, the calculations follow the same methodology, adjusting the molarity accordingly.

For example:

- Osmotic pressure of 20 atm would double the molarity (~0.818 mol/L), requiring approximately 142.6 g of sucrose.
- Higher or lower temperatures alter the \(T\) value in the van 't Hoff equation, influencing the molarity needed.

Summary of Key Findings

- To prepare a sucrose solution with an osmotic pressure of 10 atm at 25°C, dissolve approximately 71.3 grams of sucrose in 508 grams of water.
- This corresponds to a molarity of about 0.409 mol/L.
- The calculations assume ideal behavior and neglect minor volume changes; for utmost precision, experimental verification is recommended.

Implications and Applications

Knowing the precise mass of sucrose required for specific osmotic pressures is invaluable in:

- Medical applications, such as preparing intravenous solutions.
- Food industry, especially in osmotic dehydration processes.
- Biological research, where osmotic conditions influence cell behavior.
- Industrial manufacturing, requiring controlled osmotic environments.

This detailed approach exemplifies how fundamental principles—combining chemistry, physics, and practical measurement—enable the accurate preparation of solutions tailored to specific scientific or industrial needs.

Conclusion

The determination of the mass of sucrose to be combined with a given amount of water to achieve a desired osmotic pressure involves a clear understanding of colligative properties, precise calculations, and practical considerations. By applying the van 't Hoff equation and accounting for solution volume, temperature, and molar mass, scientists can accurately prepare solutions for diverse applications, ensuring consistency, safety, and efficacy.

References:

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