A Solution Of Glycerol, C3h5(oh)3, In 735 G Of Water Has A Boiling Point Of 104.4 C At A Pressure Of

A Solution Of Glycerol, C3h5(oh)3, In 735 G Of Water Has A Boiling Point Of 104.4 C At A Pressure Of This intriguing phenomenon highlights the impact of solutes like glycerol on the boiling point of water, a fundamental concept in solution chemistry. Understanding how glycerol influences water's boiling point not only provides insights into colligative properties but also has practical applications in industries ranging from pharmaceuticals to food science. In this comprehensive article, we will explore the science behind this solution, delve into the principles of boiling point elevation, analyze the specific role glycerol plays, and discuss the broader implications of such solutions.

Understanding Glycerol and Its Properties

What Is Glycerol?

Glycerol, also known as glycerin, is a simple polyol compound with the chemical formula C3H5(OH)3. It is a colorless, odorless, viscous liquid that is widely used in various industries due to its unique properties.

Key Characteristics of Glycerol:
- High viscosity
- Hygroscopic nature (absorbs moisture)
- Non-toxic and edible
- Excellent solvent for many substances
- Stable under normal conditions

Physical and Chemical Properties of Glycerol

Property	Description
Molecular Weight	92.09 g/mol
Melting Point	17.8°C
Boiling Point	290°C at atmospheric pressure
Density	1.261 g/cm^3 at 20°C
Solubility	Miscible with water, alcohols, and many organic solvents

Glycerol's high boiling point and solubility make it ideal for creating solutions with specific physical properties, such as altered boiling points.

Collegative Properties and Their Significance

What Are Colligative Properties?

Collegative properties are physical properties of solutions that depend on the number of solute particles present, regardless of their identity. These include:
- Boiling point elevation
- Freezing point depression
- Vapor pressure lowering
- Osmotic pressure

Boiling Point Elevation is particularly relevant here. When a non-volatile solute like glycerol dissolves in water, it increases the solution's boiling point compared to pure water.

Principle of Boiling Point Elevation

The elevation in boiling point (ΔT_b) can be calculated using the formula:

$$
\Delta T_b = i \times K_b \times m
$$

Where:
- i = van 't Hoff factor (number of particles the solute dissociates into)
- K_b = ebullioscopic constant of the solvent (for water, approximately 0.512°C·kg/mol)
- m = molality of the solution (moles of solute per kilogram of solvent)

Since glycerol does not dissociate in water, i = 1.

Analyzing the Glycerol-Water Solution

Given Data and Objective

- Mass of water: 735 g = 0.735 kg
- Boiling point of solution: 104.4°C
- Normal boiling point of water: 100°C
- Temperature elevation: $\Delta T_b = 104.4°C - 100°C = 4.4°C$

Our goal is to understand how much glycerol is dissolved in water to cause this boiling point elevation.

Calculating the Molality of Glycerol

Using the boiling point elevation formula:

$$
\Delta T_b = i \times K_b \times m
$$

$$
4.4°C = 1 \times 0.512°C \cdot \mathrm{kg/mol} \times m
$$

$$
m = \frac{4.4}{0.512} \approx 8.59\, \mathrm{mol/kg}
$$

This molality indicates approximately 8.59 moles of glycerol per kilogram of water.

Determining the Mass of Glycerol

Total moles of glycerol in 735 g of water:

$$
\text{Moles of glycerol} = 8.59\, \mathrm{mol/kg} \times 0.735\, \mathrm{kg} \approx 6.32\, \mathrm{mol}
$$

Mass of glycerol:

$$
\text{Mass} = 6.32\, \mathrm{mol} \times 92.09\, \mathrm{g/mol} \approx 582\, \mathrm{g}
$$

Therefore, approximately 582 grams of glycerol are dissolved in 735 grams of water to achieve a boiling point of 104.4°C.

Practical Implications of Glycerol-Water Solutions

Industrial Applications

Solutions of glycerol in water with elevated boiling points are utilized in various sectors:
- Pharmaceutical formulations: Glycerol acts as a humectant and solvent.
- Food industry: Used in syrups and as a sweetener with hygroscopic properties.
- Cosmetics: Glycerol solutions serve as moisturizers.
- Chemical manufacturing: As solvents and reaction media.

Benefits of Altering Boiling Points

- Enhanced stability during heating processes
- Improved extraction and reaction conditions
- Controlled evaporation rates in manufacturing

Safety and Handling

Glycerol is generally recognized as safe (GRAS) for many applications, but proper handling is essential due to its viscous nature and potential for skin irritation.

Factors Affecting Boiling Point Elevation in Glycerol-Water Solutions

Concentration of Glycerol

- Higher glycerol concentrations lead to greater boiling point elevation.
- Precise control of molality allows tailoring the solution's properties.

Temperature and Pressure Conditions

- Elevated pressure can further influence boiling points.
- Solutions exhibit different behaviors under non-atmospheric conditions.

Presence of Other Solutes

- Additional solutes can compound effects, either increasing or decreasing boiling points depending on their nature.

Conclusion: Understanding the Science Behind Glycerol-Water Solutions

The detailed analysis of a glycerol-water solution with a boiling point of 104.4°C at a pressure of 1 atm demonstrates the profound influence of solutes on physical properties. By dissolving approximately 582 grams of glycerol in 735 grams of water, the solution exhibits a significant boiling point elevation due to colligative effects. This understanding is vital for scientists and engineers designing processes where temperature control, stability, and solute interactions are critical.

Glycerol’s versatility and its ability to modify solution properties make it an invaluable component across multiple industries. Whether used in pharmaceuticals, food production, or cosmetics, mastering the principles of colligative properties enables optimized formulations and improved product performance.

In summary:
- Glycerol, a polyol compound, impacts water’s boiling point significantly.
- The solution described has an elevated boiling point of 104.4°C due to dissolved glycerol.
- Calculations reveal that about 582 grams of glycerol dissolved in 735 grams of water cause this elevation.
- Understanding these principles allows for precise control of solution properties for various industrial applications.

References and Further Reading

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This comprehensive exploration into glycerol-water solutions emphasizes the importance of colligative properties in solution chemistry, providing valuable insights for students, researchers, and industry professionals alike.

Frequently Asked Questions

What is the significance of the boiling point of a glycerol solution in water at 104.4°C?

The boiling point indicates how the presence of glycerol affects the solution's vapor pressure and boiling point elevation, which are important in various industrial and pharmaceutical applications.

How does adding glycerol to water influence its boiling point?

Adding glycerol to water increases the solution's boiling point due to the colligative property of boiling point elevation, caused by the solute's effect on vapor pressure.

What is the role of pressure in determining the boiling point of the glycerol-water solution?

Pressure directly affects the boiling point; at higher pressures, the boiling point increases, which is relevant for understanding the given boiling point at a specific pressure.

How can the boiling point of the glycerol-water solution be used to determine the molality of glycerol in the solution?

By applying boiling point elevation formulas and knowing the change in boiling point, one can calculate the molality of glycerol present in the water.

What is the molecular formula of glycerol, and how does its molecular weight affect solution properties?

Glycerol's molecular formula is $C_3H_8O_3$, and its molecular weight influences factors like molar concentration and colligative properties of the solution.

Why is understanding the boiling point of glycerol solutions important in industrial processes?

Knowing the boiling point helps optimize processes like distillation, formulation, and controlling solution concentrations in manufacturing.

What assumptions are typically made when calculating colligative properties like boiling point elevation in such solutions?

Assumptions include ideal solution behavior, complete dissociation of solutes (if applicable), and that the solute doesn't react with the solvent.

How does the mass of water (735 g) influence the calculation of molality for the glycerol solution?

The mass of water is used as the solvent mass in calculating molality (moles of solute per kilogram of solvent), which is essential for colligative property calculations.

Can the given data be used to find the molar concentration of glycerol in the solution?

Yes, using the molality and molecular weight of glycerol, along with the solvent mass, you can determine the molar concentration of glycerol in the solution.

What practical applications rely on understanding the boiling point elevation in glycerol-water solutions?

Applications include pharmaceutical formulations, food industry, antifreeze solutions, and chemical manufacturing where precise boiling points are crucial for product stability and processing.

Additional Resources

A Solution Of Glycerol, C3H5(OH)3, In 735 G Of Water Has A Boiling Point Of 104.4°C At A Pressure Of

In the realm of chemistry, understanding how solutions behave under various conditions is fundamental to both scientific research and practical applications. One such intriguing case involves a mixture of glycerol and water, which displays a notable elevation in boiling point compared to pure water. Specifically, a solution comprising glycerol, with the molecular formula C3H5(OH)3, dissolved in 735 grams of water reaches a boiling point of 104.4°C at a certain pressure. This phenomenon not only exemplifies the principles of colligative properties but also offers insights into the interactions between solute and solvent molecules.

In this article, we delve into the scientific details behind this observation, exploring the concepts of boiling point elevation, molality, and the role of glycerol as a solute. We will analyze how the addition of glycerol influences the boiling point, determine the molality of the solution, and discuss practical implications across industries such as pharmaceuticals, cosmetics, and food technology.

Understanding Boiling Point Elevation and Colligative Properties

What Is Boiling Point Elevation?

Boiling point elevation is a colligative property of solutions, meaning it depends solely on the number of solute particles present, rather than their identity. When a non-volatile solute (a substance that does not readily vaporize) dissolves in a solvent like water, it causes the boiling point of the solvent to increase. This effect occurs because the dissolved particles hinder the escape of solvent molecules into the vapor phase, requiring higher thermal energy to reach boiling conditions.

Mathematically, the boiling point elevation can be expressed as:

$$
\Delta T_b = i \times K_b \times m
$$

where:

- ΔT_b is the increase in boiling point temperature,
- i is the van 't Hoff factor (number of particles the solute dissociates into),
- K_b is the ebullioscopic constant specific to the solvent,
- m is the molality of the solution.

For water, the ebullioscopic constant K_b is approximately 0.512°C·kg/mol.

Colligative Properties Overview

Colligative properties include:

- Vapor pressure lowering
- Freezing point depression
- Boiling point elevation
- Osmotic pressure

These properties are critical in various scientific and industrial contexts, influencing everything from antifreeze formulations to drug delivery systems.

Deciphering the Composition of the Glycerol-Water Solution

Given Data and Objective

The key data points are:

- Mass of water: 735 grams
- Observed boiling point of the solution: 104.4°C
- The pressure at which boiling occurs is not specified but typically assumed to be at standard atmospheric pressure unless indicated otherwise.

Our goal: to determine the molality of the glycerol solution, understand its composition, and analyze how glycerol influences the boiling point.

Calculating the Boiling Point Elevation (ΔT_b)

Pure water boils at 100°C under standard atmospheric pressure. The observed boiling point of the solution is 104.4°C. Therefore:

$$
\Delta T_b = 104.4°C - 100°C = 4.4°C
$$

This temperature increase results from the presence of glycerol molecules dissolved in water.

Determining the Molality of the Glycerol Solution

Calculating the Moles of Glycerol

Using the boiling point elevation formula:

$$
\Delta T_b = i \times K_b \times m
$$

For glycerol, which is a non-electrolyte and does not dissociate into multiple particles, the van 't Hoff factor i is 1.

Rearranged:

$$
m = \frac{\Delta T_b}{i \times K_b}
$$

Substituting the known values:

$$
m = \frac{4.4°C}{1 \times 0.512°C \cdot \text{kg/mol}} \approx 8.59\, \text{mol/kg}
$$

This molality indicates approximately 8.59 moles of glycerol per kilogram of water.

Calculating the Mass of Glycerol

Given the molality:

$$
\text{Mass of water} = 735\, \text{g} = 0.735\, \text{kg}
$$

Number of moles of glycerol:

$$
n_{glycerol} = m \times \text{mass of water in kg} = 8.59\, \text{mol/kg} \times 0.735\, \text{kg} \approx 6.32\, \text{mol}
$$

Glycerol's molar mass:

$$
M_{glycerol} = 92.09\, \text{g/mol}
$$

\]

Mass of glycerol:

\[
\text{Mass} = n_{glycerol} \times M_{glycerol} \approx 6.32\, \text{mol} \times 92.09\,
\text{g/mol} \approx 581.9\, \text{g}
\]

Therefore, approximately 582 grams of glycerol are dissolved in 735 grams of water to produce this solution with a boiling point of 104.4°C.

Implications of the Solution Composition

Understanding the Solution's Nature

The calculated molality indicates a highly concentrated solution, with glycerol constituting roughly 44% of the total mass (582 grams glycerol vs. 735 grams water). This concentration significantly influences the solution's physical properties, such as viscosity, density, and boiling point.

Glycerol, being a hygroscopic, viscous liquid with multiple hydroxyl groups, interacts strongly with water molecules. These interactions lead to hydrogen bonding, which stabilizes the solution and raises the boiling point.

Practical Applications

The elevated boiling point has several practical implications:

- Pharmaceuticals: Glycerol solutions are used as solvents, humectants, and in drug formulations where temperature stability is crucial.
- Cosmetics: The high boiling point contributes to the stability and consistency of glycerol-based skin care products.
- Food Industry: Glycerol acts as a sweetener and preservative, with solutions tailored for specific boiling and melting points.
- Chemical Processing: Understanding boiling point elevation aids in designing separation processes, distillations, and reactions involving glycerol-water mixtures.

Pressure Considerations and Boiling Point

Role of Pressure in Boiling Point

Boiling point is inherently pressure-dependent. Under standard atmospheric pressure (101.3 kPa), water boils at 100°C. The observed boiling point of 104.4°C suggests that the measurement was taken at a pressure slightly above atmospheric, or that the solution's properties contribute to this elevation.

If the pressure at which the boiling point is measured is known, one can apply the Clausius-Clapeyron equation to relate pressure and temperature, further refining the understanding of the solution's behavior.

Estimating the Pressure at Boiling Point

Assuming the measurement was made at standard pressure, the boiling point elevation is primarily due to the dissolved glycerol. However, if the pressure differs, the actual vapor pressure of the solution at 104.4°C can be calculated, providing deeper insights into the solution's thermodynamic properties.

Conclusion and Broader Significance

The analysis of a glycerol-water solution with a boiling point of 104.4°C at a certain pressure exemplifies the profound impact of solutes on solvent properties. The calculated molality reveals a highly concentrated mixture, where hydrogen bonding and molecular interactions elevate the boiling point significantly above that of pure water.

Understanding these principles is vital across multiple industries. For instance, in pharmaceuticals, precise control over solution properties ensures stability and efficacy. In food technology, tailoring the concentration of glycerol can optimize texture and preservation. Moreover, this case study underscores the importance of colligative properties in designing processes like distillation, extraction, and formulation.

Ultimately, the intricate dance between solute and solvent molecules, governed by fundamental thermodynamic principles, underscores the elegance of chemistry in practical applications. As research advances, leveraging such insights will continue to enhance the development of safer, more efficient, and innovative products across diverse fields.

In summary:

- A solution with glycerol in water, with 735 g of water, exhibits a boiling point of 104.4°C.
- The boiling point elevation is 4.4°C, indicating significant solute presence.
- The molality of glycerol in the solution is approximately 8.59 mol/kg.
- This corresponds to about 582 grams of glycerol dissolved in 735 grams of water.
- The solution's properties have important implications for industrial and pharmaceutical applications.

By analyzing the thermodynamic and molecular interactions within this glycerol-water mixture, scientists and engineers can better predict and manipulate the behavior of similar solutions, fostering innovation and efficiency across numerous sectors.

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