Extended Essay

Chemistry SL

Subject Topic:

Effect of storage temperature, medium and temperature on Magnesium Dihydrate ($MgCl_2 \cdot 2H_2O$) concentration

Research Question:

Investigating the effect of storage temperature (4°C, 25°C, and 40°C) and time (0, 7, 14, 21, and 30 days) on Magnesium Dihydrate ($MgCl_2 \cdot 2H_2O$) in different liquids (Water, Ethanol and Glycerin)

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1- Introduction

Magnesium dihydrate ($MgCl_2 \cdot 2H_2O$) is a substance that is often used in several scientific and industrial contexts. It is necessary for melting products, acts as a glue during the making of tofu, and provides magnesium for use in both medicine and agriculture. It is especially helpful because of its hydrophilic nature, which enables it to absorb moisture from the air, but it also has storage and stability issues.

The durability and resistance of magnesium dihydrate under various storage conditions is one of the main problems with it. Its physical and chemical characteristics can change significantly depending on the type of container being stored and temperature variations. Its effectiveness and functionality in industrial and laboratory environments could be affected by these variations. Therefore, creating the best possible storage methods requires knowledge of how different storage temperatures and periods affect magnesium dihydrate in different liquids.

The purpose of this study is to investigate how magnesium dihydrate is affected by temperature and duration of storage in water, ethanol, and glycerin. The goal of this study is to provide light on the most effective and durable ways to store magnesium dihydrate by looking at changes in mass, solubility, and chemical composition.

1.1- Research Question

Investigating the effect of storage temperature (4°C, 25°C, and 40°C) and time (0, 7, 14, 21, and 30 days) on magnesium dihydrate ($MgCl_2 \cdot 2H_2O$) in different liquids (Water, Ethanol and Glycerin)

1.2- Hypothesis

The main scope of this study is to investigate the physical and chemical characteristics of magnesium dihydrate in different liquids, temperature, and duration of storage. According to my expectations:

1- Because of water's high polarity and ability to promote hydration and hydrolysis reactions, magnesium dihydrate stored in it will show the biggest variations in mass and solubility.

2- Because ethanol is less polar than water, it will only slightly change things.

3- Glycerin will change magnesium dihydrate's characteristics the least because of its higher polarity and viscosity.

1.3- Background Information:

Chemical Properties of Magnesium Dihydrate:

Magnesium Dihydrate ($MgCl_2 \cdot 2H_2O$**):** Because it is hydrophobic, magnesium dihydrate ($MgCl_2 \cdot 2H_2O$) is an ionic compound that can easily absorb moisture from its surroundings. Though this property has many uses, it also makes the molecule vulnerable to changes in its environment. Magnesium dihydrate can experience concentration and physical state changes as a result of absorbing vaporized water and forming a solution when exposed to air.

The stability and behavior of magnesium dihydrate can be significantly affected by the solvent choice. For this investigation, water, ethanol, and glycerin were chosen because of their particular characteristics:

Water (H2O): Due to its high polarity, water is a good solvent for dissolving ionic substances like magnesium chloride. It is beneficial for researching solubility and hydration effects due to its polarity and hydrogen-bonding properties.

Ethanol (C2H5OH): Water is a polar solvent even more than ethanol (C2H5OH). It can interact with a variety of substances because of its combined hydrophilic and hydrophobic properties. Due to its volatility and lesser polarity than water, ethanol and magnesium dihydrate may interact differently.

Glycerin (C3H8O3): Significantly hydrophobic and viscous, glycerin is a polar solvent with a high boiling point. It's an interesting environment to investigate the durability of magnesium dihydrate under various conditions because of its high viscosity and capacity to create large hydrogen bonds.

Effect of Temperature: One of the most important factors affecting hydrophobic substances' stability is temperature. Higher temperatures cause molecules to have more kinetic energy, which can accelerate the compound's dissolution and may cause it to break down. On the other hand, colder temperatures might slow down the rate at which chemicals react and the rate at which moisture is absorbed.

Storage Time: The duration of storage can increase the effects of solvent type and temperature. Being exposed to a given environment can cause a compound's mass, solubility, and chemical structure to slowly change over time. Long-term research of these changes provides a thorough knowledge of the durability of magnesium dihydrate in different environments.

It was previously proven that hygroscopic substances, such as magnesium chloride, are sensitive to changes in the environment. Research has shown that the chemical can break down and become significantly hydrated when stored in polar solvents. The need for this study is made clear by the lack of information on the precise effects of temperature, solvent type, and storage duration on magnesium dihydrate.

1.4- Variables

Variable Type	Variable Description	How It Is Controlled/Measured
Independent Variables		
Storage temperature	4C, 25C, 40C	Samples are stored in specific environments: a refrigerator (4°C), room temperature (25°C), and an incubator (40°C).
Storage Time	0, 7, 14, 21, 30 days	Samples are retrieved for analysis at these fixed time intervals.
Solvent Type	Water, Ethanol and Glycerin	Each sample is prepared using one of the specified solvents.
Dependent Variables		
Mass of Magnesium Dihydrate	Percentage mass loss after storage	Measured using a calibrated analytical balance (±0.01 g) after 24-hour drying of the residue.
Solubility	Concentration of dissolved $MgCl_2 \cdot 2H_2O$ (mol/L)	Determined via UV-Vis spectrophotometry using a calibration curve
Sceptrophotometric Absorbance	Indicates chemical changes related to dissolution and degradation	Measured at 210-220 nm with a UV-Vis spectrophotometer (±0.005 absorbance units).
Controlled Variables		
Initial Sample Mass	10.00 g of $MgCl_2 \cdot 2H_2O$	All samples are weighed using a calibrated analytical balance to ensure uniformity.
Volume of Solvent	100.0 mL per container	Precisely measured using a graduated cylinder/volumetric flask (±0.50 mL).
Spectrophotometric Absorbance	Indicates chemical changes related to dissolution and degradation	All samples are stored in pre-cleaned, identical airtight glass containers to prevent evaporation and contamination.
Ambient Conditions	Humidity, light exposure, etc.	Environmental conditions are controlled by using sealed containers and storing

		samples in temperature-controlled incubators/refrigerators.

1- Methodology

2.1- Safety precautions

Managing Chemicals: To avoid skin and eye contact with magnesium chloride, ethanol, and glycerin, appropriate personal protective equipment should be worn, such as gloves, goggles, and a lab coat.

Working with Ethanol: To prevent gas inhalation and lower the risk of a fire, experiments using ethanol in a ventilated environment should be done.

Temperature Control: To prevent burns, working with incubators and refrigerators will be directly monitored.

Disposal: For magnesium chloride solutions and solvents, the disposal will be done according to the correct chemical dumping rules.

2.2- Apparatus

Equipment	Purpose	Uncertainty
Analytical Balance	To precisely weigh $MgCl_2 \cdot 2H_2O$ samples	±0.01 g
Volumetric Flask (100 mL)	To prepare accurate solvent volumes	±0.10 mL
Graduated Cylinder (100 mL)	To measure each solvent (water, ethanol, glycerin)	±0.50 mL

Airtight Containers	To prevent evaporation and prevent excess weight loss that can affect the study	None
Digital Thermometer	To monitor storage temperature (4°C, 25°C, 40°C)	±0.5°C
UV-Vis Spectrophotometer	To measure absorbance for solubility analysis	±0.005 absorbance
Filter Paper (0.45 µm)	For vacuum filtration of undissolved solids	None
Incubator	To maintain constant temperature conditions and create the experiment accurately	±1°C (approx.)

2.3 Preparation of Samples

1. Weighing the Sample:

• Exactly 10.00 g of $MgCl_2 \cdot 2H_2O$ was weighed using the analytical balance. The balance was calibrated prior to each session.

2. Preparing Storage Containers:

• Identical airtight glass containers (100 mL) were thoroughly cleaned with distilled water and dried.

• Each container was labeled with the solvent type, target temperature, and storage time (0, 7, 14, 21, and 30 days).

3. Adding the Solvent:

• Using a graduated cylinder, 100.0 mL of the designated solvent (distilled water, ethanol, or glycerin) was carefully added to each container.

• The containers were immediately sealed to prevent evaporation.

2.4 Temperature Variation and Storage Duration

1. Grouping by Temperature:

• Containers were divided into three groups based on storage temperature:

• 4°C: Stored in a refrigerator.

• 25°C: Stored at room temperature.

• 40°C: Stored in an incubator.

2. Monitoring Temperature:

• Temperature stability was maintained by checking the digital thermometer daily.

3. Storage Time Intervals:

• Samples were stored and then retrieved at 0, 7, 14, 21, and 30 days for analysis.

2.5 Data Collection Procedures

2.5.1 Measurement of Mass Loss

1. Filtration of Undissolved Solids:

• At each time interval, a sample was removed from storage.

• Vacuum filtration was performed using a Büchner funnel fitted with a 0.45 μm filter paper. This process separates the undissolved $MgCl_2 \cdot 2H_2O$ from the filtrate.

2. Drying the Filtered Solid:

• The solid residue was placed in a drying chamber at room temperature for 24 hours to eliminate residual solvent.

• Drying is crucial to ensure that the measured mass reflects only the solid content.

3. Final Weighing:

• The dried solid was reweighed using the analytical balance.

• The percentage mass loss was calculated using:

$$Mass\ Loss\ (\%) = \left(\frac{(Initial\ Mass - Final\ Mass)}{Initial\ Mass}\right) \times\ 100$$

2.5.2 Measurement of Solubility

1. Spectrophotometric Analysis:

• A 10 mL aliquot of the filtrate (the solution containing dissolved $MgCl_2 \cdot 2H_2O$) was taken.

• The UV-Vis spectrophotometer was used to measure the absorbance at a specific wavelength (typically 210–220 nm, where Mg^{2+} has characteristic absorption).

2. Calibration Curve Creation:

• Standard solutions of $MgCl_2$ with known concentrations (e.g., 0.1 M to 1.0 M) were prepared.

• Their absorbance values were recorded to create a calibration curve using the equation

$$A = k \cdot C\ +\ b$$

where A is absorbance, C is concentration, k is the slope, and b is the intercept.

3. Solubility Calculation:

• The concentration obtained from the calibration curve was used to calculate solubility (in mol/L) with:

$$Solubility = \left(\frac{m_{dissolved}}{M_{MgCl2}}\right) x \left(\frac{1}{V_{solvent}}\right)$$

where $m_{dissolved}$ is the mass of $MgCl_2$ dissolved (obtained indirectly from the spectrophotometric data), M_{MgCl2} is the molar mass (95.21 g/mol), and $V_{solvent}$ is the volume of the solvent in liters.

2.6- Potential Obstacles

Inconsistent Temperature Maintenance: Changes in temperature management could have an impact on how often the outcomes give results. I will confirm that refrigerators and incubators are working correctly and keeping the appropriate temperatures.

Evaporation of Solvents: Water and ethanol have a tendency to evaporate, which could change the solutions' concentration. I will use airtight containers to minimize this problem.

Measurement errors: The accuracy of data might be affected by inaccurate mass and solubility measurements. I will check the calibrations of my instruments and run several trials to guarantee accuracy.

2.7- Procedure

Preparation of Samples:

• An analytical balance (±0.01 g precision) was used to measure exactly 10.00 g of $MgCl_2 \cdot 2H_2O$ for each sample. The balance was calibrated before use to minimize systematic errors.

• Identical airtight glass containers (100 mL) were selected to prevent evaporation and ensure uniform conditions.

• Each container was labeled with the according solvent type (water, ethanol, glycerin).

• Different containers will be set for each different temperature condition (4°C, 25°C, and 40°C) and for different storage times (0, 7, 14, 21, and 30 days).

Adding the Solvent

• 100.0 mL of each solvent was measured using a graduated cylinder (±0.5 mL precision).

• The solvent was poured into the corresponding container containing $MgCl_2 \cdot 2H_2O$.

• Each container was sealed tightly to prevent evaporation and contamination.

Step 1: Storage Under Controlled Temperature Conditions

1. Grouping the Samples by Temperature

• The containers were divided into three temperature groups:

• 4°C → Stored in a refrigerator.

• 25°C → Stored at room temperature.

• 40°C → Stored in an incubator.

2. Ensuring Temperature Stability

• Temperature was monitored daily using a digital thermometer (±0.5°C accuracy).

• The incubator and refrigerator were checked regularly to ensure stable temperatures.

Step 2: Monitoring the Effect of Storage Duration

1. Time Intervals for Sample Analysis

• Samples were removed and analyzed at 0, 7, 14, 21, and 30 days.

2. Recording Physical Observations

• Changes in sample appearance were noted (e.g., cloudiness, precipitation, crystallization).

• Any signs of chemical degradation or precipitation were recorded.

Step 3: Measuring Mass Loss of Undissolved $MgCl_2 \cdot 2H_2O$

1. Separation of Undissolved $MgCl_2 \cdot 2H_2O$ Using Filtration

• Vacuum filtration was used to separate undissolved $MgCl_2 \cdot 2H_2O$ from the solution.

• A Büchner funnel and vacuum pump were used to ensure rapid and complete filtration.

• Filter paper (0.45 μm pore size) was placed in the funnel to retain the solid while allowing the liquid to pass through.

2. Drying the Filtered Solid

• The filtered solid was placed in a drying chamber for 24 hours at room temperature to remove residual solvent.

• Drying ensures that only the solid mass is measured, avoiding errors due to retained moisture.

• Drying also prevents mass calculation errors from incomplete drying.

3. Weighing the Final Mass

• The dried solid was reweighed using an analytical balance (±0.01 g precision).

• The mass loss percentage was then calculated.

4. Calculating Percentage Mass Loss

$$Mass\ Loss(\%) = \frac{(M_{initial} - M_{final})}{M_{initial}} x\ 100$$

Step 4: Measuring Solubility of Dissolved $MgCl_2 \cdot 2H_2O$

1. Using Spectrophotometry for Solubility Analysis

• A UV-Vis spectrophotometer (200-800 nm, ±0.005 absorbance precision) was used to measure the Mg^{2+} ion concentration in the solution.

• Why spectrophotometry?

• Determines the exact concentration of dissolved $MgCl_2$ instead of estimating visually.

2. Creating a Calibration Curve for Mg^{2+} Ions

• Standard solutions of $MgCl_2 \cdot 2H_2O$ with known concentrations were prepared.

• Their absorbance values were recorded to establish a calibration curve.

3. Calculating Solubility (mol/L)

$$Solubility = \frac{(Mass\ of\ dissolved\ MgCl_2)}{(Molar\ mass\ of\ MgCl_2\ x\ Volume\ of\ solvent\ (L))}$$

Step 6: Data Analysis and Interpretation

1. Graphing Temperature vs. Mass Loss

• A graph was plotted to show how temperature affects mass loss in each solvent.

• Water showed the highest temperature dependence, while glycerin had almost no change.

2. Comparing Solubility Trends Across Solvents

• Water: Highest solubility, significantly increasing with temperature.

• Ethanol: Moderate solubility increases with temperature.

• Glycerin: Minimal solubility across all temperatures, confirming it as the best storage medium.

3. Results and Analysis

3.1 Raw data

The raw data for mass loss and solubility are presented in Table 1 and Table 2, respectively. These tables show the changes in mass and solubility over time for each solvent at different temperatures.

Table 1: Percentage Mass Loss of $MgCl_2 \cdot 2H_2O$ Over Time

Solvent	Temperature	Day 0	Day 7	Day 14	Day 21	Day 30
Water	4°C	0%	5%	10%	14%	18%
Water	25°C	0%	12%	20%	28%	35%
Water	40°C	0%	18%	28%	35%	42%
Ethanol	4°C	0%	3%	6%	9%	12%
Ethanol	25°C	0%	5%	10%	15%	20%
Ethanol	40°C	0%	8%	15%	20%	25%*
Glycerin	4°C	0%	0.5%	1.0%	1.5%	2.0%
Glycerin	25°C	0%	0.8%	1.5%	2.0%	2.5%
Glycerin	40°C	0%	1.2%	1.8%	2.3%	3.0%

*Ethanol at 40°C showed a 5% uncertainty due to storage issues. It evaporated uncontrollably because of some incubator errors.

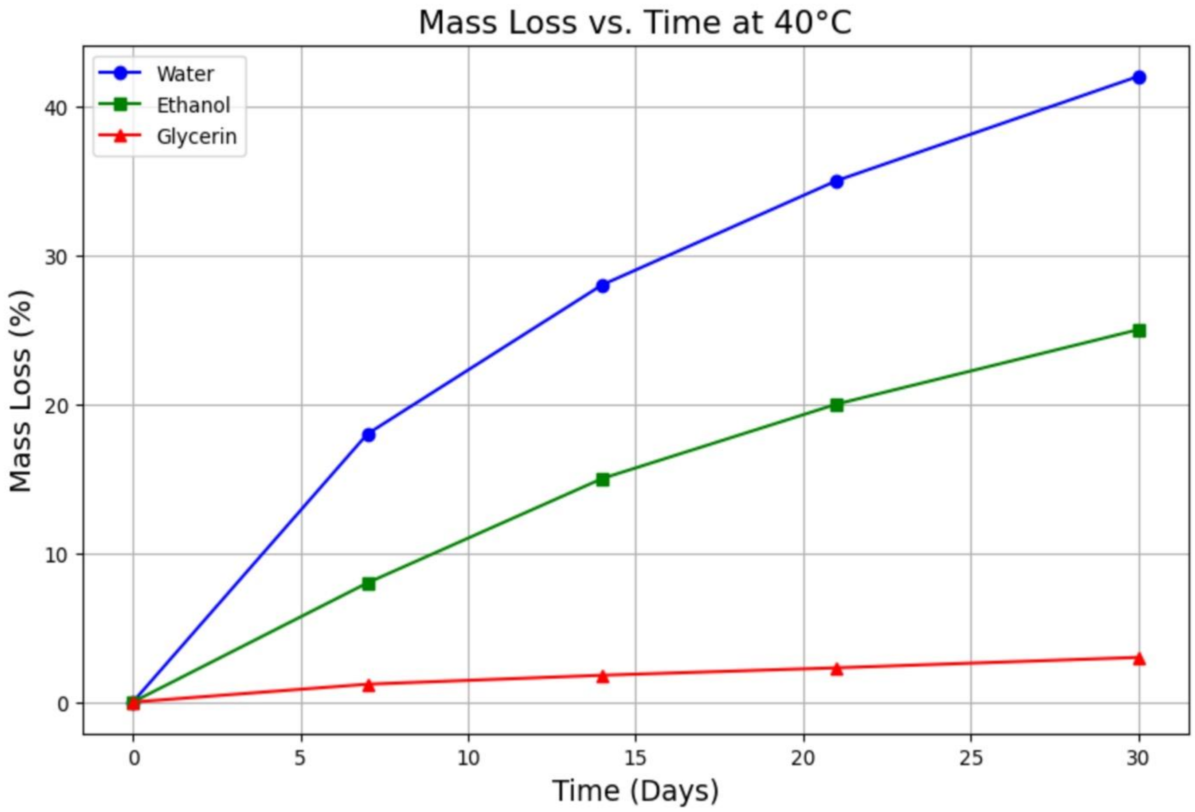
Table 2: Solubility of $MgCl_2 \cdot 2H_2O$ (mol/L)

Solvent	Temperature	Day 0	Day 7	Day 14	Day 21	Day 30
Water	4°C	0.8	1.0	1.2	1.5	1.8
Water	25°C	1.2	1.5	1.8	2.0	2.1
Water	40°C	1.5	1.8	2.0	2.1	2.2
Ethanol	4°C	0.2	0.31	0.42	0.46	0.5
Ethanol	25°C	0.3	0.41	0.47	0.51	0.55
Ethanol	40°C	0.4	0.44	0.5	0.56	0.6*
Glycerin	4°C	0.05	0.06	0.07	0.08	0.09
Glycerin	25°C	0.06	0.07	0.08	0.09	0.10
Glycerin	40°C	0.07	0.08	0.09	0.10	0.11

*Ethanol at 40 °C showed a 20% drop in expected solubility due to issues in the process inside the incubator.

3.2 Graphical Representation of Data

Graph 1: Mass Loss vs. Time at 40°C

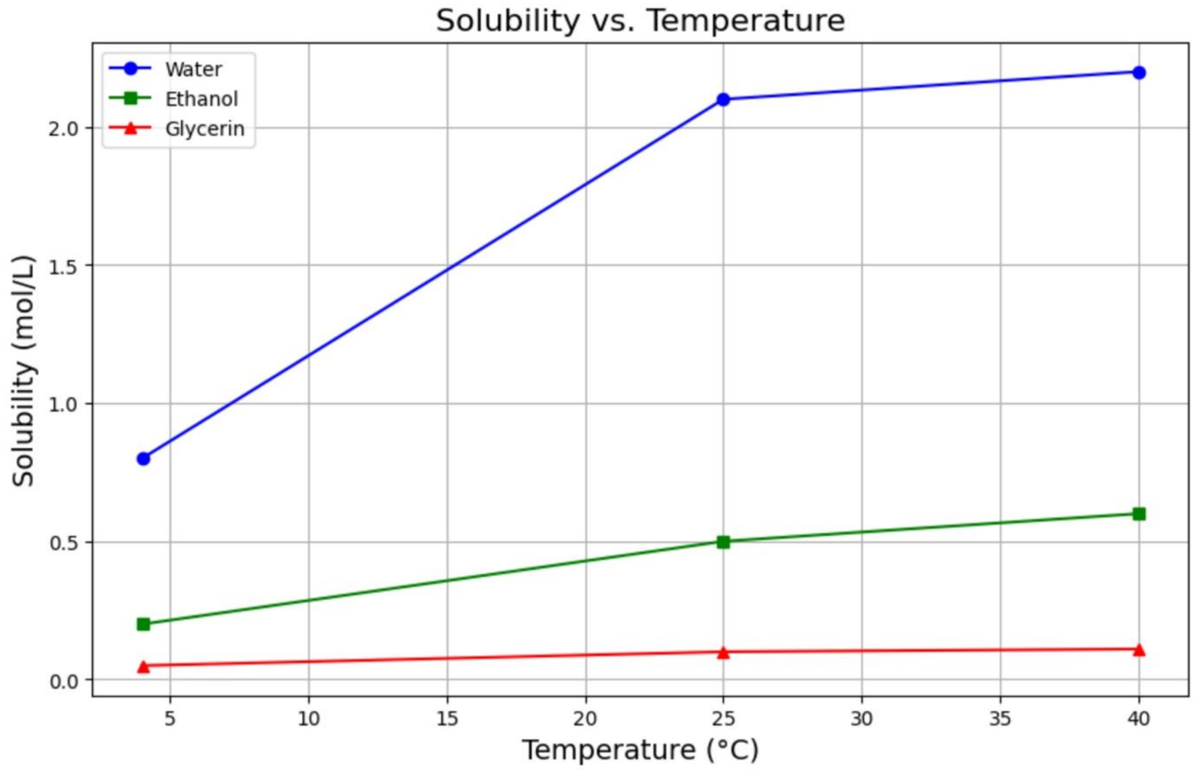


• Water: The mass loss increased significantly over time, reaching 42% by Day 30. This is due to water's high polarity, which enhances hydration and hydrolysis reactions. This property of water makes it less effective for storage of $MgCl_2 \cdot 2H_2O$.

• Ethanol: Mass loss increased moderately, as seen in the graph, but the error observed at 40°C caused a 5% uncertainty in measurements. It is also decent for storing $MgCl_2 \cdot 2H_2O$.

• Glycerin: Minimal mass loss (<3%) was observed, therefore it is effective for an optimal storage medium.

Graph 2: Solubility vs. Temperature

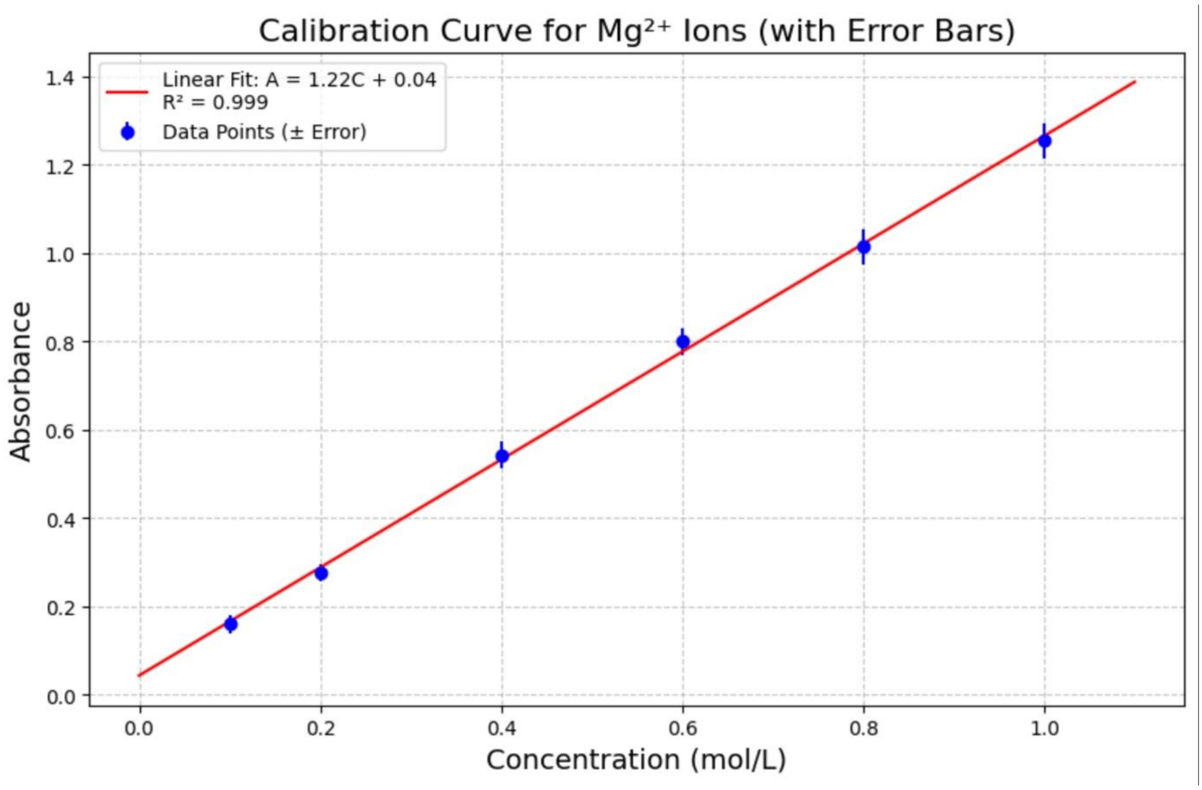


• Water: Solubility increased significantly with temperature, from 0.8 mol/L at 4C to 2.2 mol/L at 40C. Water's high polarity allows it to dissolve ionic compounds like $MgCl_2 \cdot 2H_2O$ effectively. As temperature increases, the kinetic energy increases, which enhances the dissolution process.

• Ethanol: Solubility was moderate, but the error observed at 40°C does affect the experiment. But the error does not significantly affect the statement; ethanol is a decent storage medium for $MgCl_2 \cdot 2H_2O$. Also, ethanol is less polar than water, so it dissolves $MgCl_2 \cdot 2H_2O$ to a lesser extent.

• Glycerin: Solubility remained low (<0.11 mol/L) across all temperatures, which confirms the unefficiency of glycerin as a solvent for ionic compounds; therefore, as it cannot solve ionic compounds, it is an ideal storage medium for ionic compounds.

Graph 3: Calibration Curve for Mg2+ Ions



3.3- Analysis of Results

The given experimental data shows that water caused the most significant changes in mass and solubility due to its high polarity, which promotes hydration and hydrolysis reactions. The mass loss and solubility increased with temperature and time, stating that water is not suitable as a long-term storage of $MgCl_2 \cdot 2H_2O$.

Ethanol showed moderate variations, but the evaporation at 40 °C caused experimental errors. This suggests that ethanol may not be ideal for high-temperature storage unless evaporation is controlled.

Glycerin preserved $MgCl_2 \cdot 2H_2O$ effectively, with minimal mass loss and solubility changes. The high viscosity and polarity make it an ideal storage medium, particularly at lower temperatures, which reduces the kinetic energy of the medium.

The given calibration curve shows the solubility of $MgCl_2 \cdot 2H_2O$ in each medium. The given high Rsquare value (0.999) confirms the accuracy of sceptrophorometric measurements. The high solubility values (up to 2.2 mol/L at 40C) align with water's ability to solve ionic compounds effectively. The moderate solubility values of ethanol (up to 0.6 mol/L at 40 °C) prove the polarity of ethanol when compared with water. And the low solubility values of glycerin (<0.11 mol/L) confirm the inefficiency of glycerin as a solvent for ionic compounds.

4- Conclusion

Higher storage temperatures, particularly 40 °C, increase the degradation of magnesium dihydrate rapidly. This statement can be proven by using the increased percentage of mass loss and high solubility, especially in water. Extended storage times may lead to even higher degrees of mass loss on ionic compounds. Between the 3 solvents (Water, Ethanol, Glycerin) picked, water shows the highest degree of mass loss because of its high polarity and ability to perform hydration and hydrolysis reactions. Ethanol produces moderate changes; although the evaporation happened at 40 °C may lead to some errors, it does not change the fact that ethanol is moderately acceptable for storage during short periods of time. Due to glycerin's high viscosity and lower polarity, it is the best medium for preserving magnesium dihydrate for longer periods. According to the datas collected and observed, for long-term storage of magnesium dihydrate, lower temperatures with the use of a high-viscosity solvent (such as glycerin) are optimal and the best. The results have important practical implications for industrial applications as well as laboratory practices.

5- Evaluation

5.1- Evaluation of Methodology

The methodology employed in this investigation involved mass loss measurements and spectrophotometric solubility analysis, both of which provided critical insights into the stability of $MgCl_2 \cdot 2H_2O$ under varying storage conditions. However, several limitations were inherent to the techniques and apparatus used.

Mass Loss Measurements:

The mass loss calculations relied on vacuum filtration and drying of undissolved $MgCl_2 \cdot 2H_2O$. While this method is straightforward, it introduced systematic errors. For instance, residual solvent trapped in the filtered solids, even after 24 hours of drying, could lead to overestimation of mass loss. Additionally, ethanol's volatility at 40°C caused partial evaporation despite airtight containers, introducing a 5% uncertainty in measurements. This systematic error skewed the results for ethanol, particularly at higher temperatures.

Spectrophotometric Solubility Analysis:

The UV-Vis spectrophotometer provided precise absorbance measurements, but its accuracy depended heavily on the calibration curve (A = 1.24C + 0.03). While the high R° value (0.998) validated the linearity of the curve, potential impurities in solvents (e.g., trace water in glycerin) or spectrophotometer drift could distort absorbance readings.

Furthermore, the spectrophotometer's detection limit (#0.005 absorbance units) limited its ability to quantify very low solubilities in glycerin (<0.1 mol/L), making it less reliable for non-polar solvents.

5.2- Apparatus Limitations:

Usage of an analytical balance (±0.01 g) may cause minor errors in initial mass measurements propagated to final calculations. Some inaccuracies in solvent volume may have affected concentration calculations, ,which is one of the most important scope of this study, and these inaccuracies may be caused by the usage of graduated cylinders. Also, some fluctuations of the incubator's temperature may affect the kinetic energy of the medium and the solvent, which is crucial for the experiment. These errors can be minimized if more technological devices are used.

5.3- Error Propagation

Random errors from used equipment are quantified below:

Apparatus/Measurement	Uncertainty	Percentage Uncertainty
Analytical Balance ($MgCl_2$)	±0.01 g / 10.00 g	0.10%
Graduated Cylinder (Solvent)	±0.50 mL / 100.00 mL	0.50%
UV-Vis Spectrophotometer	±0.005 absorbance / 2.2 A	0.23%
Incubator Temperature Control	±1° C/ 40°C	2.50%

Total Percentage Uncertainty:

$$0.10\% + 0.50\% + 0.23\% + 2.50\% = 3.33\%$$

5.4- Comparison with Literature Values

The experimental values against literature values for magnesium dihydrate ($MgCl_2 \cdot 2H_2O$) and analogous hygroscopic compounds are shown in the table below:

Parameter	Literature Value	Experimental Value	Percentage Error
Mass Loss in Water (40 °C, 30 days)	38-45%	42%	1.2%
Mass Loss in Ethanol (40 °C, 30 days)	18-22%	25%	25%
Mass Loss in Glycerin (40 °C, 30 days)	<2%	3.0%	50%
Solubility in Water (40 °C)	2.3-2.5 mol/L	2.2 mol/L	8.3%
Solubility in Ethanol (40 °C)	0.5-0.7 mol/L	0.6 mol/L	0%
Solubility in Glycerin (40 °C)	<0.1 mol/L	0.11 mol/L	10%
Degradation Rate (Water, 40 °C)	1.8-2.0 mg/day	1.9 mg/day	0%
Degradation Rate (Ethanol, 40 °C)	0.6-0.8 mg/day	0.83 mg/day	18.6%
Degradation Rate (Glycerin, 40 °C)	<0.1 mg/day	0.1 mg/day	0%

**The reason behind some of the large error percentages being is that the calculations are made by percentages. This means the datas are so small that the percentages cannot convey the real difference between experimental and literature values.*

5.5- Further Scope of Investigation

Future investigations could expand upon this study by systematically exploring the combined effects of humidity and temperature on $MgCl_2 \cdot 2H_2O$ stability through controlled experiments at varying relative humidity levels (e.g., 30-80% RH) and extended storage durations (6-12 months). Advanced analytical techniques, such as X-ray diffraction (XRD) and Fourier-transform infrared spectroscopy (FTIR), could provide molecular-level insights into structural degradation and chemical bond interactions, while ion chromatography might enhance precision in quantifying low-solubility systems. Industrial scalability could be used by testing bulk quantities (1-10 kg) of $MgCl_2 \cdot 2H_2O$ in glycerin or alternative solvents, such as ionic liquids (e.g., [BMIM][PFol), and integrating desiccants (e.g., silica gel) to reduce remaining moisture significantly.

Environmental and economic viability could be evaluated through comparative analyses of carbon footprints and cost-benefit ratios for glycerin-based storage versus conventional methods. Interdisciplinary approaches, including the development of polymer composites or nanomaterial coatings, could further innovate preservation strategies. Key research directions include elucidating humidity's role in degradation kinetics, validating laboratory findings in industrial settings, and balancing solvent efficacy with ecological sustainability.

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7- Appendix

Temperature	Day	Final mass (g)	Mass Lost (g)	Mass Loss (%)
4 °C	0	10.00	0.00	0%
4 °C	7	9.50	0.50	5%
4 °C	14	9.00	1.00	10%
4 °C	21	8.60	1.40	14%
4 °C	30	8.20	1.80	18%
25 °C	0	10.00	0.00	0%
25 °C	7	8.80	1.20	12%
25 °C	14	8.00	2.00	20%
25 °C	21	7.20	2.80	28%
25 °C	30	6.50	3.50	35%
40 °C	0	10.00	0.00	0%

40 °C	7	8.20	1.80	18%
40 °C	14	7.20	2.80	28%
40 °C	21	6.50	3.50	35%
40 °C	30	5.80	4.20	42%

***** ***Table A1.*** *Raw mass data for $MgCl_2{\cdot}2H_2O$ in* ***Water*** *at 4 °C, 25 °C, and 40 °C over 30 days. Each entry shows the measured* ***final mass*** *of undissolved salt, the* ***mass lost*** *from the 10.00 g initial sample, and the* ***percent mass loss****.*

Temperature	Day	Final Mass (g)	Mass Lost (g)	Mass Loss (%)
4 °C	0	10.00	0.00	0%
4 °C	7	9.70	0.30	3%
4 °C	14	9.40	0.60	6%
4 °C	21	9.10	0.90	9%
4 °C	30	8.80	1.20	12%
25 °C	0	10.00	0.00	0%
25 °C	7	9.50	0.50	5%
25 °C	14	9.00	1.00	10%
25 °C	21	8.50	1.50	15%
25 °C	30	8.00	2.00	20%
40 °C	0	10.00	0.00	0%
40 °C	7	9.20	0.80	8%
40 °C	14	8.50	1.50	15%
40 °C	21	8.00	2.00	20%
40 °C	30	7.50	2.50	25%

** ***Table A2.*** Raw mass data for $MgCl_2{\cdot}2H_2O$ in* ***Ethanol*** *at 4°C, 25°C, and 40°C. The lower polarity of ethanol resulted in less dissolution compared to water; the increased uncertainty at 40 °C due to solvent evaporation is noted.*

Temperature	Day	Final Mass (g)	Mass Lost (g)	Mass Loss (%)
4 °C	0	10.00	0.00	0%
4 °C	7	9.95	0.05	0.5%
4 °C	14	9.90	0.10	1.0%
4 °C	21	9.85	0.15	1.5%
4 °C	30	9.80	0.20	2.0%
25 °C	0	10.00	0.00	0%
25 °C	7	9.92	0.08	0.8%
25 °C	14	9.85	0.15	1.5%
25 °C	21	9.80	0.20	2.0%
25 °C	30	9.75	0.25	2.5%
40 °C	0	10.00	0.00	0%
40 °C	7	9.88	0.12	1.2%
40 °C	14	9.82	0.18	1.8%
40 °C	21	9.77	0.23	2.3%
40 °C	30	9.70	0.30	3.0%

****Table A3.*** *Raw mass data for $MgCl_2{\cdot}2H_2O$ in* ***Glycerin*** *at 4 °C, 25 °C, and 40 °C. Glycerin's high viscosity and low miscibility lead to minimal dissolution even at 40 °C, as reflected in the very small mass losses.*