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PREPARATION OF MAGNESIUM GLUCONATE FROM CITRATE SOLUTION

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ABSTRACT

Magnesium gluconate was prepared as a medication product under ordinary conditions and is soluble in water. Magnesia combine with both citric acid and gluconic acid as magnesium gluconate. The dry product mixed with a suitable amount of bicarbonate and heated under 300 °C is the equivalent in strength of magnesia solution and having a therapeutic effect. Analytical technique like, XRD, FTIR, UV - Vis spectroscopy, TGA/ DTA and DSC were used to study properties of magnesium gluconate prepared. The product proved to be crystalline with wave length for maximum UV absorbance 197 nm. The DSC thermogram of the analyte indicated that product is stable up to 275 °C. Thus, it concludes that magnesium gluconate with crystal size 0.63-0.68 nm is a useful pharmaceutical and nutraceutical for industries. Besides when mixed with carbonate and heated up to 400 °C Periclase is produced as an essential product for different chemical industries.

Keywords: citrate solutions, magmesium gluconate, periclase, pharmaceutical, nutracentical.

1. INTRODUCTION

Magnesium gluconate has the potential industrial application in nutraceutical and pharmaceutical sectors as source of magnesium ion which is an essential nutrient for human body functions. Magnesium is effective for the prevention and treatment of cardiovascular diseases, diabetes mellitus and having loss [1-2]. Magnesium gluconate can be used as potent antioxidant for the prevention and treatment of many diseases, such as diabetes, inflammatory diseases, immunological disorders [3-4], reperfusion injury with other antioxidant agents [5]. It can be used as skin tightening cosmetic composition [6]. Magnesium salts of gluconic acid are used by itself or in combination with one or more antioxidants for the prevention of some chronic infections. X-rays diffraction (XRD), Fourier transform infrared (FTIR) spectrometry, Ultraviolet-visible (UV–Vis) spectroscopy, differential thermogravimetric analysis (DTG\DTA) is advanced analytical techniques used for the solid state characterization of products [7-8]. The present study aims to precipitate magnesium as magnesium gluconate from citrate solutions after reaction of magnesium metal with water and release of hydrogen as green energy. As magnesium is a metal and the citric acid is an acid, hydrogen plus a salt is formed. This results in the chemical equation:

$$C_6H_8O_7 + Mg \longrightarrow H_2 + Mg\,C_6H_6O_7$$

Magnesia combine with both citric acid and gluconic acid and gives magnesium glucono - citrate. Magnesium gluconate ($Mg\,C_{12}H_{22}O_{14}$) is prepared using the US-patent Serial No. 477,186 for citrate solutions [9]. The product serves as medical agent which dissolves calculi of the phosphate and carbonates type and so softens mixed phosphate – oxalate compositions. The solution constituents is an excellent solvent for ammonium phosphate stones. The XRD, FTIR, UV-Vis, TGA/DTG and DSC techniques used to explore structure, physicochemical and thermal properties of product. Magnesium gluconate shows the most magnesium absorption and retention value, displays highest bioavailability among the magnesium salts such as chlorides, sulfate, carbonate, acetate, citrate, lactate, aspartate, etc… [10]. Gluconic acid and its derivatives are commonly used in the food and pharmaceutical industries [11].

2. EXPERIMENTAL WORK

2.1 Raw materials and chemicals

Magnesium citrate solutions remained from reaction of magnesium metal with citric acid and water to produce hydrogen gas as green fuel used as citrate solution. Gluconic acid, sodium or magnesium carbonate, citric acid and all chemicals used were chemical grade.

2.2 Preparation of magnesium gluconate

The citrate solution containing magnesium hydroxide or dissolved magnesium oxide was precipitated as magnesium gluconate according to the following reaction:

0.685 g MgO + 2.3 g citric acid + 2 g Gluconic acid + water ⟶ heat till dryness (125 °C) ⟶ 22.448 g magnesium gluconate (white precipitate).
10 g magnesium gluconate + bicarbonate (120 equivalent) + water ⟶ heat till dissociation (250 -300 °C) 4 h ⟶ Magnesium oxide + citrate
The gluconate is:

a) soluble in water

b) pH range 2.9-3

c) solution is stable in water

d) can be boiled for sterilization without losing its potency.

The solution is an excellent solvent for calcium phosphate, calcium carbonate and magnesium ammonium phosphate stones.

2.3 XRD analysis

The XRD pattern of solid state form of magnesium gluconate measured with diffractometeris shown in Figure-1. K (equipment constant) in this instrument was equal to 0.08. The XRD data was collected in the form of the Bragg angle (^{o} 2Θ) vs. intensity (counts per seconds),and detailed Table(1) containing information on peak intensity counts, d value (A^o), full width half maximum (FWHM) (^{o} 2Θ) an X`Part high score plus processing software, and relative intensity (%). The crystal size (G) was calculated from the following equations:

$$ג = 2d_{lk} \text{ Sin } \Theta \quad (1)$$

ג = x-ray wave length (fixe value = 1.5 nm)

$$G = K ג / (b \text{ Cos } \Theta) \quad (2)$$

Where K is the equipment constant (0.08), b radius in the full-width at half of the peaks and Θ is the corresponding Bragg angle.

2.4 FTIR Spectroscopy analysis

FT-IR analysis performed on spectrum range of 450 -4000 cm^{-1} by mixing magnesium gluconate samples with potassium bromide (KBr) revealing functional groups.

2.5 UV-Vis spectroscopy analysis

The UV- Vis lysis was carried out by using UV-Cary 100-Series, USA. The spectrum was recorded using 1 cm quartz cell with a slit width 1.0 nm. The wave length range chosen for recording the spectrum was 190- 800nm. Absorbance maximum ($ג_{max}$) wave length was recorded.

2.6 TGA/DTG analysis

TGA/DTG thermograme of magnesium gluconate was performed in a thermo analyzer DTG - 60H (Simultaneous DTA-DTG) apparatus (SHIMADZU) Japan, under nitrogen atmosphere using a platinum crucible at heating rate of 10 ^{o}C/min from room temperature to 900 ^{o}C with a sample mass 5.628 mg. The weight loss for each step was recorded in grams as well as in percent loss with respect to the initial weight. In DTG, the onset, endset, and peak temperature of each peak were recorded.

2.7 DSC analysis

The DSC curve was performed in DSC- 60 (differential scanning calorimeter), Japan, SHIMADZU, under nitrogen atmosphere (10 ml/min) with sample mass of 2.210 mg using Aluminum pan at heating rate of 10 ^{o}C/min from 25 ^{o}C to 400 ^{o}C. The value for onset, endset, peak temperature, peak hight (mJ or mW) peak area, and changes in heat (J/g) for each peak were recorded.

3. RESULTS AND DISSCUSIONS

3.1 XRD analysis

It is a technique for characterization of the sample and monitoring the sample stability that validate qualitative and/or quantitative analysis of product. Crystal pattern and crystallite size of magnesium gluconate product effects its solubility, dissolution and bioavailability. The XRD difractogram of magnesium gluconate Figure-2 shows well-defined, sharp and intense peaks at 2 Θ equal to 23.3661, 26.1277, 27.7067, 30.2582, 31.8004. 33.0759, 34.6072, 35.3267, 38.0757, 40, 0321, 41.6432, 44.6322, 45.5261, 46, 6048, 48.48.4184, 53.6546, 54.6854, 56.6761, 58.8872, 60.6306, 62.6862, 63.9993, 67.4235, 80.1406. these results indicated that the sample is crystalline in nature. Other XRD parameters such as relative intensity (%) and full width half maxima for our product are presented in Table-1. The crystallitic size was calculated according to equation (1) and equation (2) and found to be around (0.63-0.68 nm).

Table-1. X-ray diffraction data, d-spacing, FWHM, and relative intensities.

Pos. [°2Th.]	d-spacing [?]	Height [cts]	FWHM Left [°2Th.]	Rel. Int. [%]
23.3661	3.80714	3.38	0.9446	1.19
26.1277	3.41068	27.24	0.2362	9.60
27.7067	3.21978	34.74	0.3149	12.24
30.2582	2.95384	283.84	0.1968	100.00
31.8004	2.81402	32.04	0.1574	11.29
33.0759	2.70836	40.28	0.2755	14.19
34.6072	2.59195	106.68	0.5510	37.58
35.3267	2.54079	157.69	0.1574	55.56
38.0757	2.36344	224.19	0.2362	78.98
40.0321	2.25234	82.26	0.3149	28.98
41.6432	2.16885	103.69	0.1574	36.53
44.6322	2.03030	22.01	0.3149	7.75
45.5261	1.99249	13.62	0.2362	4.80
46.6048	1.94886	67.34	0.3149	23.72
48.4184	1.88001	65.46	0.2362	23.06
53.6546	1.70825	29.96	0.3936	10.56
54.6854	1.67846	22.67	0.3936	7.99
56.6761	1.62414	8.40	0.9446	2.96
58.8872	1.56833	13.73	0.9446	4.84
60.6306	1.52734	10.82	0.4723	3.81
62.6865	1.48210	21.88	0.4723	7.71
63.9993	1.45483	12.16	0.6298	4.28
67.4235	1.38904	11.02	0.6298	3.88
80.1406	1.19762	8.90	0.9446	3.14

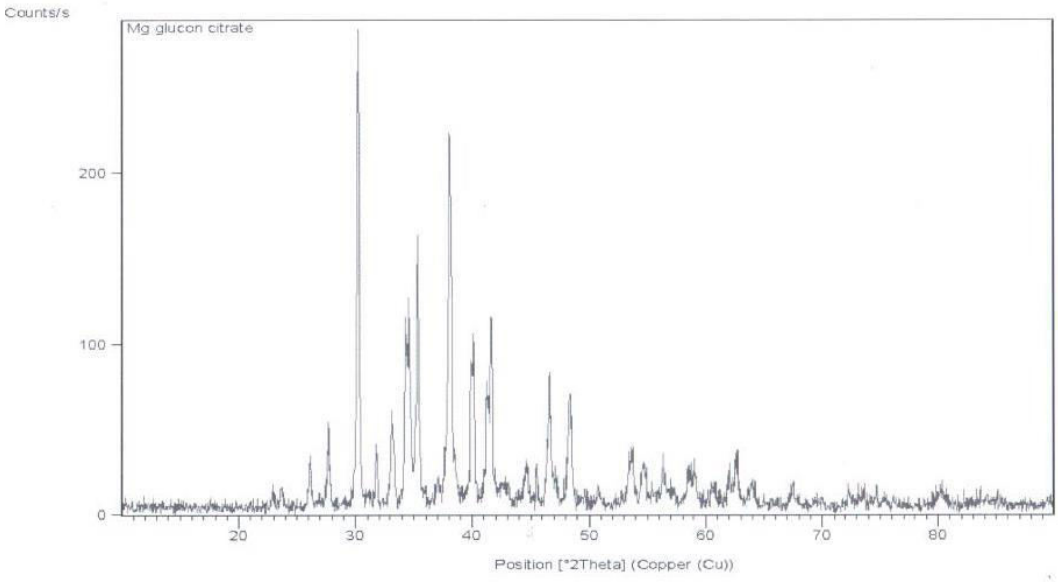


Figure-1. XRD pattern of magnesium gluconate powder.

3.2 FT-IR analysis

The FTIR spectra exhibited one broad band of high intensity in the range 2800-3600 cm^{-1} with centroid at 3433 cm^{-1} Figure-3. This peak No (1) was ascribed to the stretching vibration of hydroxyl groups originating from the water present in magnesium gluconate. The bands of stretching vibrations of primary and secondary hydroxyl groups from the gluconate part of the compound in this rejoin were remained invisible due to the intensive broad band of water. The absorption peaks for deformation vibration of the hydroxyl groups in the plane δ (OH) and out of plane γ (OH) that indicate the presence of primary and secondary hydroxyl groups were observed at 1437 cm^{-1} and 769 cm^{-1} and 537 cm^{-1} peak No (6) and No(12) and No(13) respectively in the spectra. The FT-IR spectrum showed C-H stretching at 2930 cm^{-1} and 1339 cm^{-1} for

bands No (2) and No(7). A sharp band at 1628 cm^{-1} for C=O stretching vibration of carbonyl group of carboxylate anion No (5) was observed in the spectra. The band of C-O stretching vibration of primary alcohol anhydride group was perceived at 1078 cm^{-1} in the spectra band No (10). The absorption peaks at 1195 cm^{-1} and 1132 cm^{-1} due to C-O stretching vibrations of the secondary alcohol groups were observed in the spectra at peak No(8) and peak No(9). The FTIR analysis indicated the characteristic peaks for the functional groups of the magnesium gluconate structure.

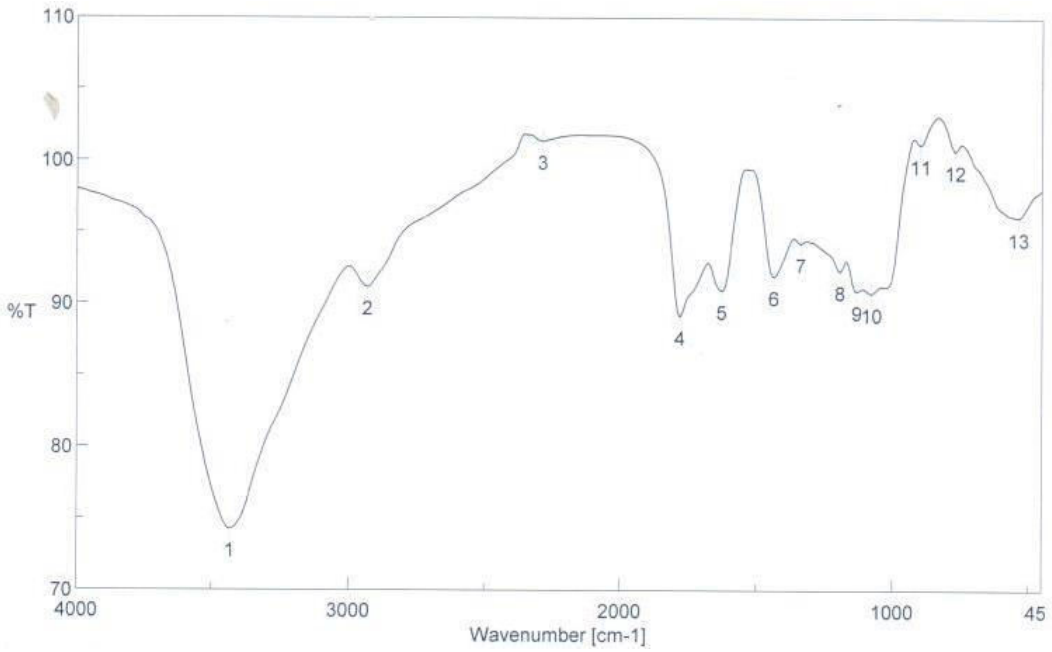


Figure-2. FTIR spectrum of magnesium gluconate.

3.3 UV_Vis spectroscopic analysis

In this study 1% aqueous solutions of magnesium gluconate shows a maximum absorption peak (λ_{max}) at 197 nm Figure-3. This absorption occurred due to the $\sigma \rightarrow \sigma^*$ energy transistion by σ - bonded electrons present in the C-C and C-H functional groups. The $\pi \rightarrow \pi^*$ transition due to the lone paired electrons present in the C=O group. These type of electron transitions takes place when the difference in energy between lowest unoccupied molecular orbital and the highest occupied one is significantly higher than the activation energy of the formed compound.

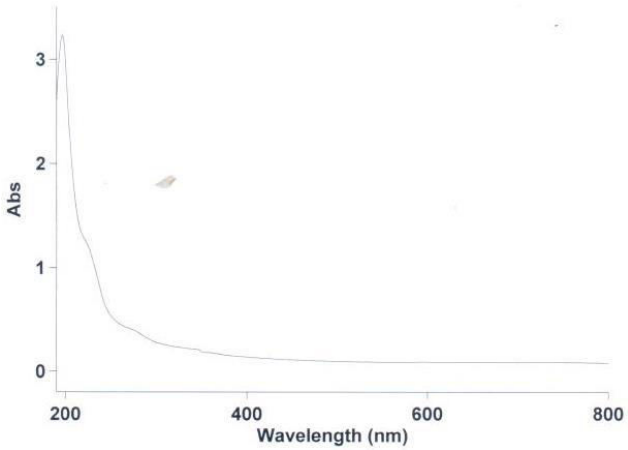
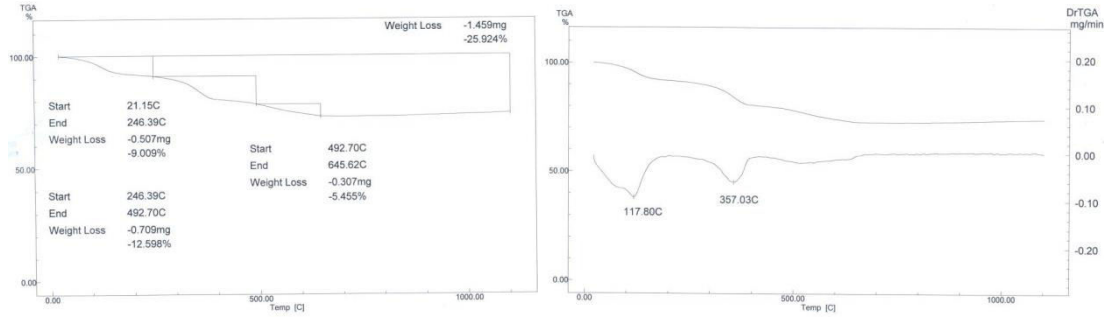


Figure-3. UV- Vis spectrum of magnesium gluconate.

3.4 TGA/DTA thermal analysis

Figure-4_a shows three steps of thermal decomposition and Figure-4_b shows two peaks one at 117.8 ◦C corresponding for mass loss 0.507 mg, and the second broad peak at 357.03 ◦C.

Table-2 illustrates thermal degradation steps of magnesium gluconate.



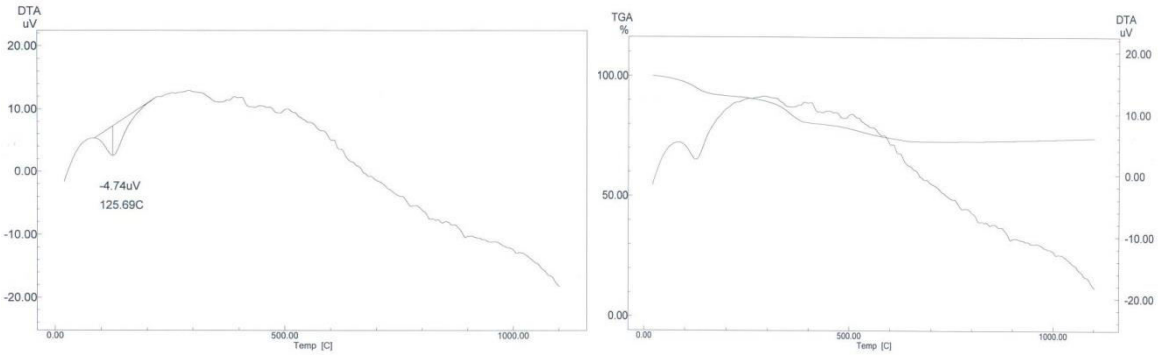
(a) (b)

Figure-4$_a$. and Fig(4$_b$) TGA thermogram of magnesium gluconate

Table-2. Thermal degradation of magnesium.

Steps of degradation	Temperature (◦C)	Weight loss %
1st step of degradation	21.15 - 246.39	9.009
2nd step of degradation	246.39 - 492.7	12.598
3rd step of degradation	492.7 - 645.62	5.455

From Table-2 and Figure-4 at temperature 21.15 - 246.39 ◦C, magnesium gluconate performed mass loss of 9.009% which can be for water removal from sample. The second thermal degradation occurred with higher mass loss 12.598 % is due to decomposition of carbonyl groups and the hydroxyl groups of the gluconate portion. Gradual mass loss of 5.455% up to 645.62 ◦C is illustrated by the third step.



(a) (b)

Figure-5$_a$. DTA and Fig(5$_b$) TGA /TDA thermogram of magnesium gluconate.

The DTA thermogram of magnesium gluconate Figure-5$_a$ illustrate two peaks for the sample. One at 125.69 ◦C and the other around 390 ◦C, respectively. The TGA\ DTA thermogram indicated that magnesium gluconate is thermally stable up to 125.69 ◦C.

3.5 DSC thermal analysis

Figure-6 shows magnesium gluconate thermogram with an endothermic inflection at 275 ◦C and the other inflection at 353.96 ◦C. The peak temperature at 275 ◦C indicated the melting temperature of magnesium gluconate.

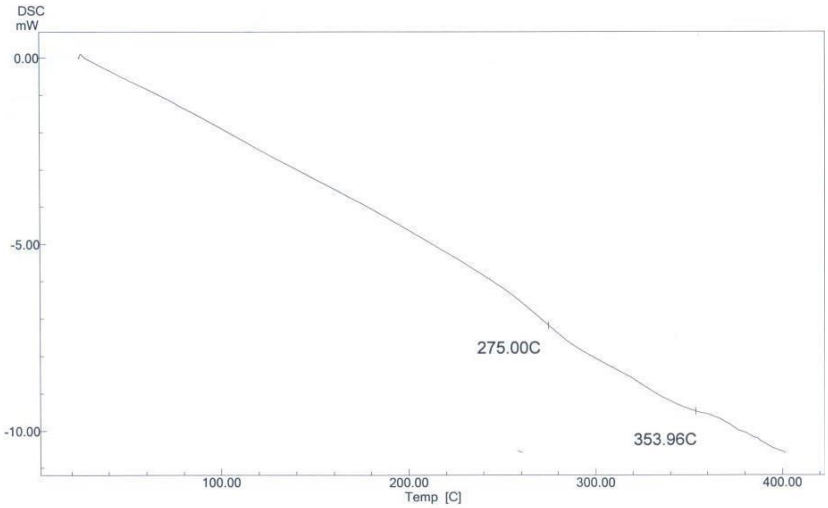


Figure-6. DSC thermogram of magnesium gluconate.

4. CONCLUSIONS

The magnesium gluconate was precipitated from citrate solution and characterization of organo metallic medication solid like pharmaceutical. The FTIR, XRD, UV - Vis and TGA\TDA and DSC techniques are used to identify magnesium gluconate. The product showed to be crystalline in nature with crystal size 0.63 – 0.68 nm, maximum UV-absorbance peak at 197 nm, and thermally stable up to 125.69 ◦C with melting temperature starting at 275 ◦C.

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