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Synthesis, DFT Study and the Biological Activity of 8-Hydroxyquinoline Zirconium (IV) Complexes

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Abstract

Zirconium (IV) complexes can possess biological activities. These complexes were synthesized via a reaction with equimolar quantity of 8-hydroxyquinoline and saccharides as secondary ligands $[Zr(QH)(Glu)Cl_2]$ and $[Zr(QH)(Fru)Cl_2)]$, where is (QH) 8-hydroxyquinoline, (Glu) Glucose and (Fru) Fructose. They were characterised using Fourier Transform Infrared (FT-IR) and UV-Visible spectroscopy. Also variable temperature studies of these complexes were completed, using UV-Visible spectroscopy to observe electronic transitions under temperature control. Also DFT study was done on these complexes via the information from FT-IR and UV-Visible spectroscopy, and then we calculate highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO). The biological activity has taken a place in this study as antibacterial.

Keywords: Synthesis; 8-hydroxyquinoline; saccharides; glucose; fructose; DFT study; antibacterial.

1. Introduction

Complexes of transition metal have received great attention for many years, because of their biological activities, including anti-tumour, antibacterial, antiviral, antifungal and anti-carcinogenic properties [1-5]. Tetradentate chelate coordinate complexes have shown biological activity, essentially due to interactions with their heavy metal ions, bonding through sulfur and nitrogen [6, 7]. The interest in Schiff base complexes and development of the field of bioinorganic chemistry has increased substantially, since it has been recognized that many of these complexes may serve as models for biologically important species [8, 9]. Design, synthesis and characterisation of iron complexes with Schiff base ligands play a relevant role in the coordination chemistry of iron-containing enzymes [10-12], as oxidation catalysts [13, 14] and as stable molecular materials based on temperature, pressure or light induced spin-crossover behaviors [15, 16]. The amine-carbonyl condensation is involved in a number of enzyme-mediated reactions and understanding the mechanism of amine-carbonyl condensation has received great attention [17]. A gain Thiourea compound have been anticipated to be a human carcinogen based on sufficient evidence of carcinogenicity in experimental animals. The investigated of some complexes derived from salicylaldhyde and histidine have been found to have antibacterial activation on some pathogenic bacteria [18, 19] Schiff bases including 3-enehydrazono-2-salicylidindolinone and their complexes incorporating Co(II), Ni(II), Cu(II) and Zn(II) have shown some antibacterial activity against pathogens as Staphylococus aureus, Enteroccus, Proteus mirabilis, Escherichia coli, Bacillus anthracis, Pseudomonas aeruginosa and Candida albicans [20].

2. Material and Methods

All chemical were used as received from supplied. The metal salt zirconium (IV) Chloride was produced by Leboratory Reagent chemical company. Saccharides were obtained from chem King and 8-

hydroxyquinoline produced by BHD chemical company, sodium hydroxid produced by Riedel-dehean chemical company. Ethanol and methanol production company PSPARK chemical company. Solvents used were purified by distillation.
UV–Visible absorption spectra in solution were measured over the range 200–800 nm on a Shimadzu UV-2010 double-beam spectrometer, with samples in 1 cm quartz cuvettes. The Fourier Transform-Infrared Spectroscopy (FTIR) was carried out over the range 4000–400 cm^{-1} with resolution of 1 cm^{-1} on samples in KBr pellets. X-ray powder diffractograms were obtained using an ENRAF-NONIUS FR590 powder diffractometer equipped with an INEL120 detector (Debye-Scherrer geometry) using CuK α radiation. The powder was used to fill a glass capillary, which was slowly rotating upon data collection. Calibration was performed using silicon as an external calibrant.

2.1. Computational method

The computations were performed using Gaussian 09 with WebMO interface [21]. The geometries 1 and 2 were optimized at the DFT B3LYP level of theory with a 6–311+G(d,p) basis set. The structures are minima on potential energy surface with positive harmonic vibrational frequencies. Validation of the computational method was obtained by comparing the results with available experimental values.

2.2. Synthesis of [(8-hydroxyquinoline)(glucose) zirconium (IV) dichloro] [Zr(HQ)(Glu)$(Cl)_2$]

In double nick flask, zirconium tetrachloride ($ZrCl_4$) (237 mg) in 15 ml of water was add to an equimolar quantity of 8-hydroxyquinoline {$N(C_9H_6)O$} (145 mg) in 10 ml of ethanol dropwise at room temperature with stirring. The temperature was gradually increased and the reaction mixture was reflux for 10 minutes, during in that time the colour was turned to yellow. After that aqueous solution (180 mg) of glucose was added to the mixture. The reaction was reflux for more four hours in water bath. During that time the colour was observed yellow. The complex was obtained by raising the pH of the reaction mixture by adding (0.01 mole) NaOH solution. The yellow solid was separated from the cold solution by filtration. Then the solid compound was washed with cold water followed by mixture of ethanol:water (1:1). The final sold was dried under vacuum, after purification of the product was acquired with (986 mg, 45%) (Figure 2.1).

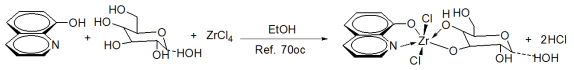

Figure 2.1: Preparation of [Zr(HQ)(Glu)$(Cl)_2$] [1].

2.3. Synthesis of [(8-hydroxyquinoline)(fructose) zirconium (IV) dichloro] [Zr(HQ)(Flu)$(Cl)_2$]

By the same method was described above was synthesized this complex. The preparation was via the equimolar quantity of zirconium tetrachloride, 8-hydroxyquinoline {$N(C_9H_6)O$} and fructose with the ration (1:1:1 mmol) and (50 mg, 311 mg and 424 mg) respectively. Working-out the final yellow product was collected and then was purification with (974 mg, 50%) (Figure 2.2).

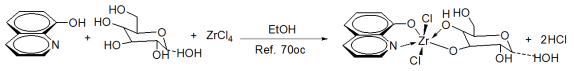

Figure 2.2: Preparation of [Zr(HQ)(Fru)$(Cl)_2$] [2].

3. Results and Discussion

3.1. UV-Vis. spectral study

[Zr(HQ)(Glu)$(Cl)_2$] and [Zr(HQ)(Fru)$(Cl)_2$] were examined in spectrally by using a ultraviolet and visible radiation UV-Vis. has given peaks absorption of initial at 280 nm, 388 nm and 403 nm respectively which is demonstrates the transmission of the types π→π*, n→π* and C-T (Charge Transfer) transition respectively for the complex [Zr(HQ)(Glu)$(Cl)_2$]. Complex [Zr(HQ)(Fru)$(Cl)_2$] showed absorption at 260 nm, 386 nm and 400 nm respectively which is demonstrates the transmission of the types π→π*, n→π* and C-T (Charge Transfer) transition respectively, these identical with those reported in previously [22, 23].

3.2. FT-IR spectral study

As studying a complexes [Zr(HQ)(Glu)$(Cl)_2$] and [Zr(HQ)(Fru)$(Cl)_2$] in Fourier transform Infrared (FT-IR) spectroscopy, to make sure the appearance some of function to be in the complex. Absorption

peak at 1108 Cm^{-1} indicate the presence of the association of strong v(C-O) stretching frequency and appearance absorption at 1498-1497 Cm^{-1} that indicate the presence of association v(C=N) stretching frequency, interacted within the complexes, whiling the free ligand normally upper at higher region v (1580 Cm^{-1}) .
A negative shift in this vibrational mode on complexation indicates the coordination through the tertiary nitrogen donor of HQ. The in plane and out of plane ring deformation modes are observed at 787 Cm^{-1}, confirming coordination through the nitrogen atom of HQ with metal. Whiling the appearance absorption at 785 Cm^{-1}, 738 Cm^{-1} and 505 Cm^{-1} which indicate the presence of association v(M-N), v(M-O) and v(M-Cl) stretching respectively. The shift of these frequencies are the due to the coordinate bonding of nitrogen to the metal [24-29].

3.3. D. DFT calculation

Structural and electronic properties:
Chemical hardness is associated with the stability and reactivity of a chemical system. In a molecule, it measures the resistance to change in the electron distribution or charge transfer. The total energy of these complexes showed complex [Zr(HQ)(Glu)] lower energy than [Zr(HQ)(Fru)] in value (-3466785.488) kcal/mol and (-3371738.8) kcal/mol respectively, this is maybe due of the deferent energy between Glucose and Fructose as co-ligand. This is leads to Zr(HQ)(Glu)] more stability and give more time to be reacted with bacterial as antibacterial activities. The bond energy diagram of the complexes and comparing with each others to showed in Figure 3.1.
On the basis of frontier molecular orbitals, chemical hardness corresponds to the gap between the Highest Occupied Molecular Orbital (HOMO) and Lowest Unoccupied Molecular Orbital (LUMO). Chemical hardness is approximated using Equation 3.1.

$$\eta = (\varepsilon LUMO - \varepsilon HOMO)/2 \qquad (3.1)$$

where $\varepsilon LUMO$ and $\varepsilon HOMO$ are the LUMO and HOMO energies.

Table 3.1: The value of HOMO (blue) and LUMO (red).

	[ZrQh(Glu)]	[ZrQH(Fru]
	eV	eV
LUMO+1	0.05997	0.05716
LUMO	0.00788	0.00511
HOMO	-0.12331	-0.1069
HOMO-1	-0.13826	-0.12781

The larger the HOMO-LUMO energy gap, the harder and more stable (less reactive) the molecule. [30-37] Table 3.1 contains the value of the gap between HOMO and LUMO for each compounds.

3.4. Structural and electronic properties

Optimized geometries of [Zr(HQ)(Glu)] and [Zr(HQ) (Fru)] were obtained using B3LYP level of theory. The calculated bond lengths and bond angles of [Zr(HQ) (Glu)] and [Zr(HQ) (Fru)] are remarkably close to each values were obtained by computational and this result serves as a validation of the computational method. The angle defined by the trans two chlorides and the Zr center (∠Cl(1)–Zr–Cl(2)) is 158.681º, (∠O1–Zr–N1) is 79.105º and (∠O2–Zr–O6) is 74.899º for [Zr(HQ) (Glu)], in meantime the angles of [Zr(HQ)(Fru)] were (∠Cl(1)– Zr–Cl(2)) is 113.185º, (∠O1– Zr–N1) is 78.565º and (∠O3–Zr–O4) is 61.00º. The bonds lengths of [Zr(HQ)(Glu)] were found Zr-Cl(1), Zr-Cl(2), Zr-N1, Zr-O1, Zr-O2 and Zr-O6 at 2.429 Å, 2.392 Å, 2.319 Å, 2.063 Å, 1.953 Å and 2.16 Å respectively, Figure 3.2. Again the bonds lengths of [Zr(HQ)(Fru)] were found Zr-Cl(1), Zr-Cl(2), Zr-N1, Zr-O1, Zr-O3 and Zr-O4 at 2.364 Å, 2.366 Å, 2.144 Å, 1.971 Å, 2.397 Å and 2.500 Å respectively, Figure 3.2 and Figure 3.3.
The output information from structure of the solid product was via the X-ray powder diffraction was using in soomth 3D in the sigmaPlot 10. The scattered range data can be smoothed at by fitting in Figure 3.4 and Figure 3.5, the range data and interpolates across hole at -1200 and max out at 800 on Z data can be exactly describes of complex [Zr(HQ)(Glu)] at a core of spectra, in meantime the spectra of [Zr(HQ)(Fru)] showed one hole at -25000 from Z data on the terminal of spectra.

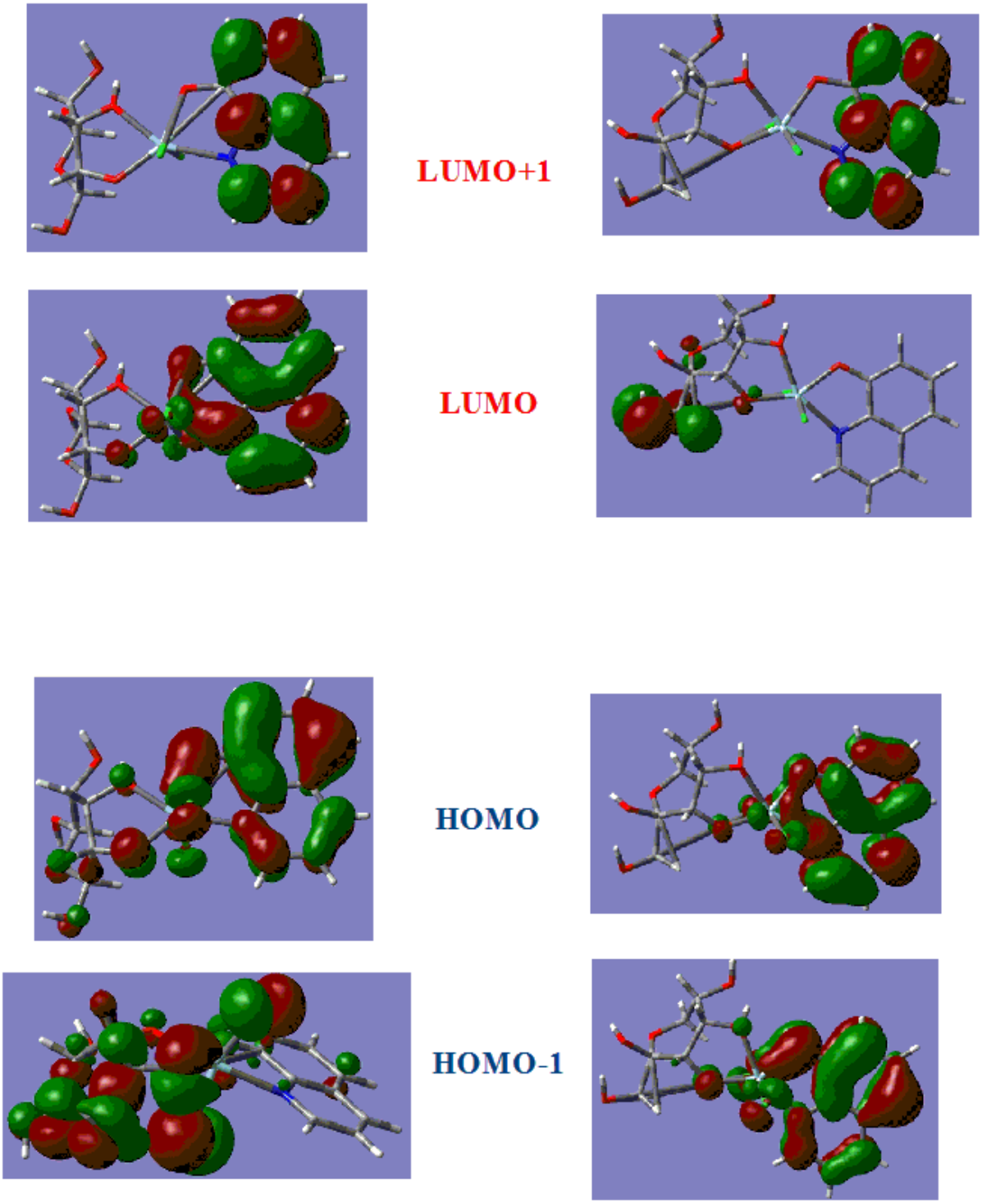

Figure 3.1: Frontier molecular orbitals (A= [Zr(HQ)(Glu)] & B= [Zr(HQ)(Fru)]).

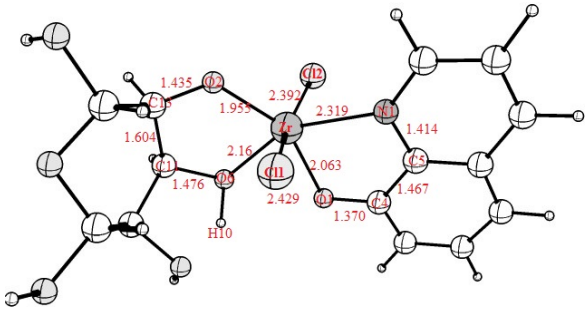

Figure 3.2: Structure of [Zr(HQ)(Glu)].

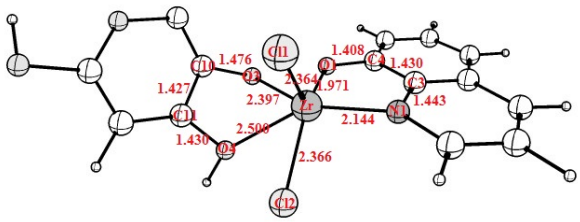

Figure 3.3: Structure of [Zr(HQ)(Fru)].

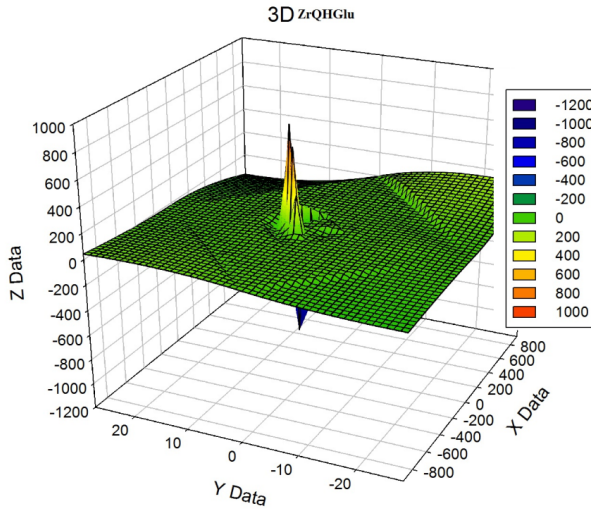

Figure 3.4: Soomth 3D of complex [Zr(HQ)(Glu)].

Antibacterial studies

The antibacterial studies were tested on the six species of the bacteria such (Staphylococcus-aureus spp, Streptococcus spp, Escherichia coli spp, Klebsiella spp, Psuedomones spp and Protues spp), that complexes were in a variable concentration (0.1, 0.01, 0.001 M). At concentration 0.001 M of complexes [Zr(HQ)(Glu)] and [Zr(HQ)(Fru)], showed a positively influence on six types of bacteria, expect Pseudomonas spp. and Bacillus spp. were low active, the result is given in Table 3.2.
In concentration of 0.01 M, complexes [Zr(HQ)(Glu)] and [Zr(HQ)(Fru)] Showed a positively influence on all of the species of bacterial. Table 3.3.
In concentration of 0.1 M, complexes [Zr(HQ)(Glu)] and [Zr(HQ)(Fru)] Showed highly positive influence on types of bacterial species *E. Coli, Bacillus spp. Klebsiella spp. S. aureus* and *Pseudomonas spp.* The results were given in Table 3.4.

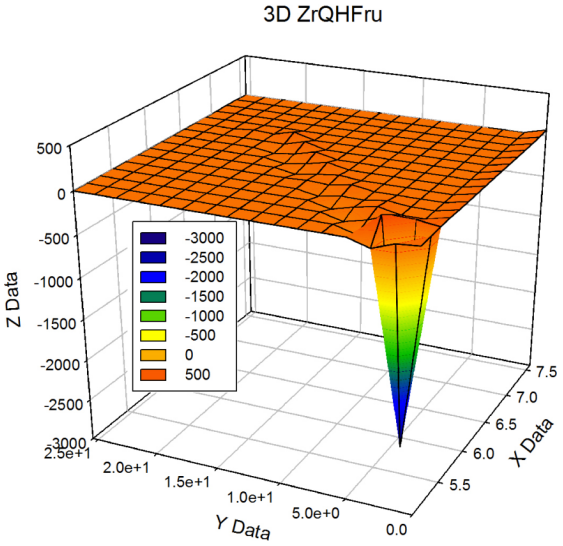

Figure 3.5: Soomth 3D of complex [Zr(HQ)(Fru)].

4. Conclusion

The chemistry presented in this paper showed that the chelating deferential chelating ammides and hydroxyl of Zr(IV) complexes are accessible. The data we get it from FT-IR showed a type of complexes are suggested to be bidentate coordinate with hexa-coordination. The Coordination around the Zr(IV) centre is the best described as distorted distorted octahedral geometry, therefore the complexes were followed by the UV-Vis. Study and showed the transition that of the these complexes.
Zr(HQ)(Glu)] and [Zr(HQ)(Fru)] have been examined by computational method at DFT B3LY level. The computed geometric of these complexes are remarkably close to each other values. DFT global chemical reactivity descriptors and total energy are

Table 3.2: Antibacterial activities in concentration 0.001 M.

Complex	S.aureus		Sraphiaureus		E.coli spp		Klebsiella spp		Pseudomonas spp		Bacillus spp	
	Act.*	%	Act.	%	Act.	%	Act.	%	Act.	%	Act.	%
[Zr(HQ)(Glu)]	++	50	+	35	++	45	+	30	-	5	-	10
[Zr(HQ)(Fru)	++	50	+	35	++	45	+	30	-	5	-	10

Percentage of Inhibition: Below 5 mm = (-) low active, 5 mm -10 mm = (+) Active, 10 mm - 15 mm = (++) mildly active & 15 mm –20 mm = (+++) moderately active, (20 mm, up) = (++++) highly active.

*Activity.

Table 3.3: Antibacterial activities in concentration 0.01 M.

Complex	S.aureus		Sraphiaureus		E.coli spp		Klebsiella spp		Pseudomonas spp		Bacillus spp	
	Act.*	%	Act.	%	Act.	%	Act.	%	Act.	%	Act.	%
[Zr(HQ)(Glu)]	++++	80	++	65	++	70	++	60	+	30	++	50
[Zr(HQ)(Fru)	++++	80	++	65	++	70	++	60	+	30	++	50

Percentage of Inhibition: Below 5 mm = (-) low active, 5 mm -10 mm = (+) Active, 10 mm - 15 mm = (++) mildly active & 15 mm - 20 mm = (+++) moderately active, (20 mm, up) = (++++) highly active.

*Activity.

Table 3.4: Antibacterial activities in concentration 0.1 M.

Complex	S.aureus		Sraphiaureus		E.coli spp		Klebsiella spp		Pseudomonas spp		Bacillus spp	
	Act.*	%	Act.	%	Act.	%	Act.	%	Act.	%	Act.	%
[Zr(HQ)(Glu)]	++++	85	++	70	+++	75	++	65	+	35	++	60
[Zr(HQ)(Fru)	++++	85	++	70	+++	75	++	65	+	35	++	60

Percentage of Inhibition: Below 5 mm = (-) low active, 5 mm – 10 mm = (+) Active, 10 mm -15 mm = (++) mildly active & 15 mm - 20 mm = (+++) moderately active, (20 mm, up) = (++++) highly active.

*Activity.

calculated for the these complexes and used to predict their relative stability and reactivity.
Predict [Zr(HQ)(Glu)] to be the more stable than of [Zr(HQ)(Fru)$(Cl)_2$]. Antibacterial activity under deferent concentration of these complexes were examined and this behavior comes affects in increased of concentration.

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