# Binding of tris (bathophenanthrolinedisulphonate)ruthenium(II) cation with polyphenols in aqueous medium

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## ABSTRACT

*Polyphenols constitute one of the most common and widespread group of substances in flowering plants, occurring in all vegetative organs and fruits. Polyphenols containing gallol (gallic acid) and catechol (quercetin) groups have very different activities, depending on the metal ion. The binding of $[Ru(bpds)_3]^{2+}$ (bpds = bathophenanthrolinedisulphonate) complex with polyphenols (gallic acid and quercetin) in aqueous medium at pH 12.5 has been studied by absorption spectral techniques. The complex shows a ligand centred (LC) absorption peak at 278 nm and a metal to ligand charge transfer (MLCT) absorption peak at 463 nm in aqueous medium. The binding constant ($K_b$) for this reaction is determined from the Benesi-Hildebrand plot using absorption intensity data, The $K_b$ of gallic acid with $[Ru(bpds)_3]^{2+}$ complex at 463 nm is 2.90 x $10^2$ $M^{-1}$ whereas for quercetin is 4.73 x $10^3$ $M^{-1}$ respectively.The $K_b$ indicates that quercetin undergoes strong binding with the $[Ru(bpds)_3]^{2+}$ complex in the ground state than that of gallic acid. Structural effect seems to play a vital role on the binding of the gallic acid and quercetin with the complex.*

**Keywords**: $[Ru(bpds)_3]^{2+}$ complex; Gallic acid; Quercetin; Benesi-Hildebrand equation; Binding constant

## 1. Introduction

Transition metal complexes have been found useful in pharmaceuticals since the discovery of cis-platin [1]. Several water soluble metal complexes attracted owing to their good anticancer or antibacterial properties. Among the metal complexes reported, the ruthenium complexes have certain advantages because of its solubility in water as well as low toxicity. Although there are several reports on the synthesis and medicinal properties of ruthenium complexes, the DNA targeted ruthenium complexes with intercalating ligands may be important anticancer agent. Ruthenium complexes with tris-(phenanthroline) (phen) derivatives are also extensively studied due to their interesting physico-chemical and biological properties [2]. Many complexes with phenanthroline ligand have been known for their anticancer property. Such complexes are namely useful in elucidating chemical principles which govern the recognition of nucleic acids, in developing photochemical reagents as new diagnostic tools, in the design of novel chemotherapeutics and in electron transfer mediated by the DNA double helix [3]. The photochemistry and photophysics of

Ruthenium-phenanthroline complexes have attracted the chemists in the design of light-driven water splitting photoanodes [4], molecular probes [5], construction of solar cells [6], sensors [7], molecular machine devices [8] and organic light emitting diodes [9]. This is due to the combination of excellent photophysical and electrochemical properties such as luminescence in solution at room temperature, moderate quantum yield and excited state lifetime, spectroscopically distinguishable metal redox states, tunable electronic properties, ability to undergo energy and electron transfer processes and chemical stability [10].

Polyphenols have considerable interest in the field of food chemistry, pharmacy and medicine due to a wide range of favourable biological effects including antioxidant properties. Polyphenols are antioxidants, which are known to influence bio availability of the metal in the body. The antioxidant property of polyphenols is mainly due to their redox properties. Some organic molecules binding to nucleic acids are of great interest in modern medicine because they constitute a significant portion of the anti-cancer drugs. Binding studies of flavonoids with DNA are useful for the understanding of the reaction mechanism and providing guidance for the application and design of new and more efficient drugs targeted to DNA.

Polyphenols with gallol and catechol groups are generally the most potent antioxidants, primarily because of the large iron-binding stability constants for these groups. Polyphenols containing gallol (gallic acid) and catechol (quercetin) groups have very different activities, depending on the metal ion. Gallic acid and quercetin binds with DNA, proteins and human serum albumim. Ruthenium(II)-phenanthroline complexes also bind with DNA. In order to understand the role of antioxidants with ruthenium(II)-phenanthroline complexes, the present work focuses on the ground state binding of $[Ru(bpds)_3]^{2+}$ (bpds = bathophenanthrolinedisulphonate) complex with gallic acid and quercetin in aqueous medium at pH 12.5.

## 2. Experimental Section

$RuCl_3.3H_2O$, bpds ligand, gallic acid and quercetinwere purchased from Sigma-Aldrich. The solvents for the synthesis of the complex were procured from Merck. The double distilled deionized water was used as a solvent for the binding studies.

### 2.1 Synthesis of ($[Ru(bpds)_3]^{2+}$) Complex

$RuCl_3.3H_2O$ (1 mmol) and bpds (3 mmol) were treated with 25 ml of water and refluxed under nitrogen atmosphere for 12 h. The resultant red solution was filtered hot and

evaporated to dryness to give a red-brown solid. This was recrystallized from ethanol-water mixture. The resulting product was characterized by UV-visible spectroscopy.

### 2.2 Absorption spectral measurement

Sample solutions of the $[Ru(bpds)_3]^{2+}$ complex and the quenchers (gallic acid and quercetin) were freshly prepared for each measurements. The absorption spectral measurements were carried out using SHIMADZU UV-1800 spectrophotometer. The binding of $[Ru(bpds)_3]^{2+}$ complex with various concentrations of gallic acid and quercetin ($5.8 \times 10^{-5}$ - $3.5 \times 10^{-4}$ M) in aqueous medium at pH 12.5 has been studied by absorption spectral technique. Phenolate ions of the gallic acid and quercetin for the binding studies were prepared by mixing the corresponding polyphenols with NaOH and the pH of the solution was maintained at 12.5 to confirm that the quenchers were present as phenolate ions. The binding constant ($K_b$) of the $[Ru(bpds)_3]^{2+}$ complex with the quenchers in aqueous medium were evaluated with the aid of Bensi-Hildebrand equation.

$$1/\Delta A = 1/K_b\Delta\varepsilon\,[H] + 1/\Delta\varepsilon\,[G]$$

where, [H] is the concentration of the host (complex), [G] is the concentration of the guest (quencher), $\Delta A$ is the change in the absorbance of the [H] on the addition of [G]. $\Delta\varepsilon$ is the difference in the molar extinction coefficient between the free [H] and [H]-[G] complex. The plot of $1/\Delta A$ vs $1/[G]$ gives a straight line. The $K_b$ can be obtained from the ratio of Y-intercept to the slope of the straight line.

### 3. Results and Discussion

The structure of the $[Ru(bpds)_3]^{2+}$ complex and the polyphenols used in the present study are shown in **Fig.1** and **Fig.2**. The absorption spectrumof $[Ru(bpds)_3]^{2+}$ complex is carried out in aqueous medium at pH 12.5 (**Fig. 3**). The complex $[Ru(bpds)_3]^{2+}$complex shows the LC peak at 278 nm and the metal to ligand charge transition (MLCT) peak at 463 nm. The MLCT transition involves electronic excitation from the metal orbital [$d\pi$ (Ru)] to the ligand centered acceptor $\pi^*$ orbitals (ligand).

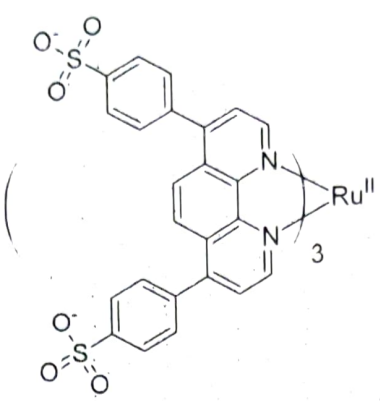
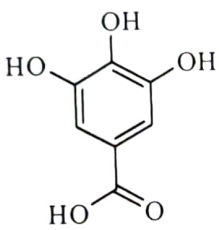
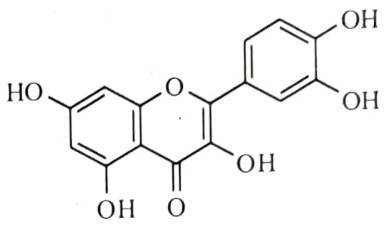



**Fig. 1** Structure of $[Ru(bpds)_3]^{2+}$ complex




**Gallic acid**




**Quercetin**

**Fig. 2** Structure of polyphenols

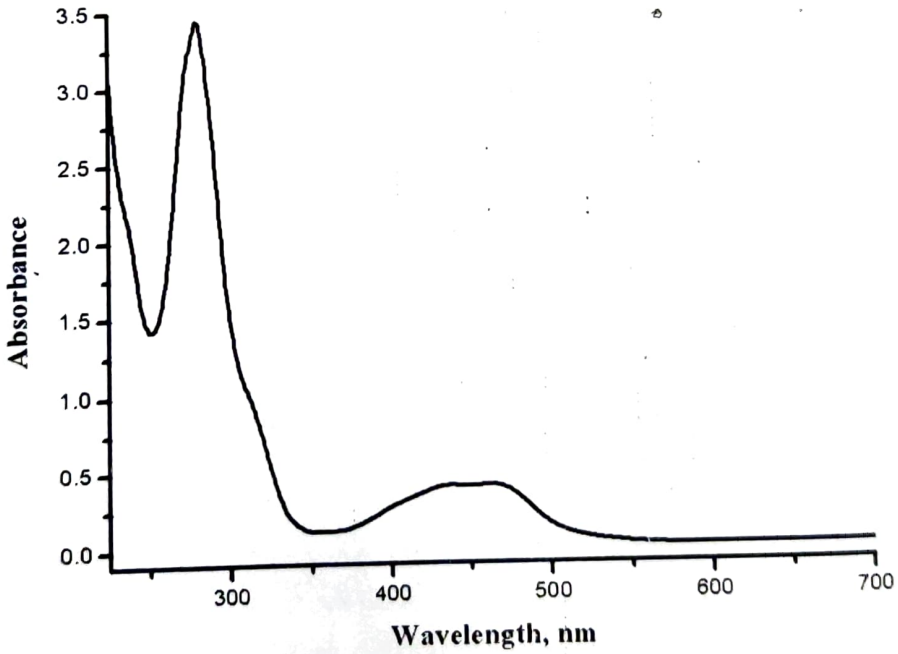



**Fig. 3** Absorption spectrum of $[Ru(bpds)_3]^{2+}$ complex in aqueous medium

The absorption spectral studies of $[Ru(bpds)_3]^{2+}$ complex with the incremental addition of gallic acid and quercetin show an increase in the MLCT absorption maximum, this indicates the formation of ground state complex (**Fig. 4**). Gallic acid and quercetin have weak absorption at 454 and 426 nm [11]. Gallic acid and quercetin binds with $[Ru(bpds)_3]^{2+}$ complex in aqueous medium at pH 12.5 since, gallic acid and quercetin have weak absorption close to the region where Ru(bpds) complex have strong MLCT absorption. The $K_b$ of this complex with gallic acid and quercetin are determined from the Benesi-Hildebrand plot (**Fig. 5**). The $K_b$ of gallic acid with $[Ru(bpds)_3]^{2+}$ complex at 463 nm is $2.90 \times 10^2$ $M^{-1}$ whereas for quercetin is $4.73 \times 10^3$ $M^{-1}$ respectiveiy.

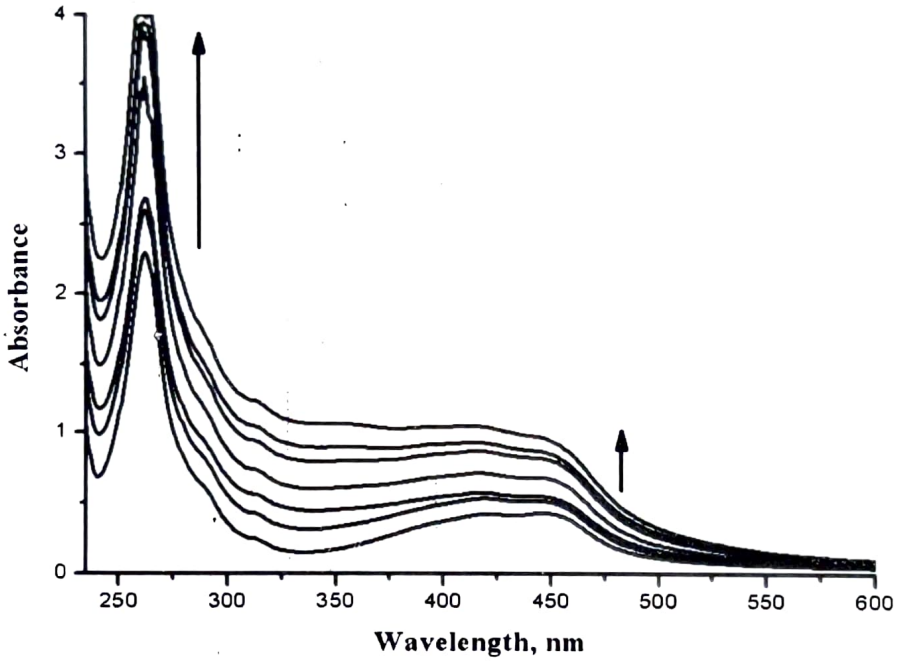



**Fig. 4** Absorption spectra of $[Ru(bpds)_3]^{2+}$ complex with incremental addition of gallic acid in aqueous medium at pH 12.5

The ground-state interactions between polyphenols and the phenanthroline rings of $[Ru(bpds)_3]^{2+}$ complexes are hydrophobic or $\pi$ - stacking in nature [12]. To the extent that $\pi$ - $\pi$ stacking interactions exist between the ligands of Ru(II) complex and the quencher, the binding becomes stronger. The binding takes place in the MLCT absorption maximum of the complex in the ground state. The $K_b$ calculated for gallic acid and quercetin from MLCT absorption data shows that quercetin undergoes strong binding with the $[Ru(bpds)_3]^{2+}$ complex than that of gallic acid.

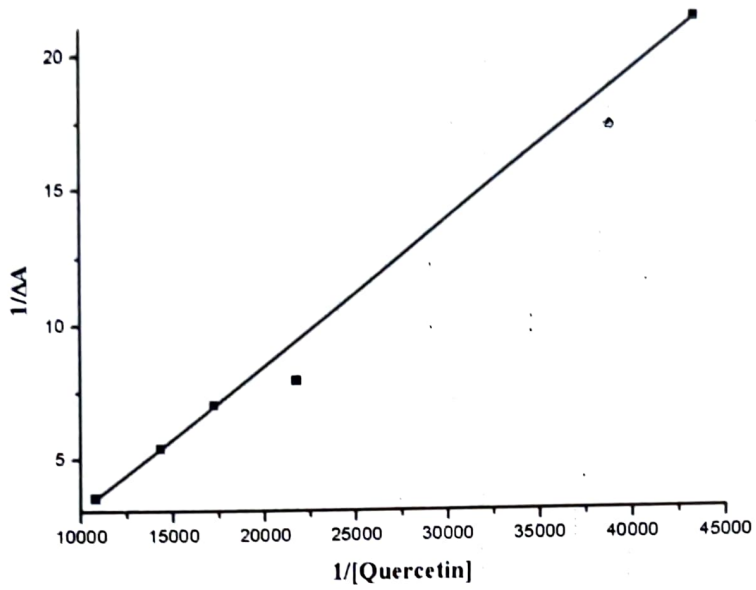



**Fig. 5** Benesi-Hildebrand plot on MLCT absorption of $[Ru(bpds)_3]^{2+}$ complex with incremental addition of quecetin in aqueous medium at pH 12.5

Gallic acid consists of 3 phenolic–OH groups whereas quercetin consist of 4 phenolic–OH groups and at pH 12.5 all the phenolic–OH are converted into phenolate ions. The binding constant depends on the number of phenolic–OH groups. As the number of phenolic–OH groups increases the binding constant also increases. Hence quercetin shows a higher binding constant than that of gallic acid with $[Ru(bpds)_3]^{2+}$ complex. Thus, the $K_b$ depends on the substituent present in the polyphenols.

**Conclusion**

The binding of gallic acid and quercetin with $[Ru(bpds)_3]^{2+}$ complex in aqueous medium at pH 12.5 has been studied by absorption spectral techniques. The $K_b$ of the $[Ru(bpds)_3]^{2+}$ complex with gallic acid and quercetin are determined from the Benesi-Hildebrand plot. The $K_b$ depends on number of phenolic–OH groups of the polyphenols. As the number of phenolic–OH groups increases the binding constant also increases. Quercetin shows higher binding constant than that of gallic acid due to the presence of more number of phenolic–OH groups. This study confirms the structural effect on the binding of biologically important phenolate ions with $[Ru(bpds)_3]^{2+}$ complex.

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