International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.10 No.10, pp 716-725, 2017

Thermodynamic and spectroscopic studies on complexes formation properties of Quercetin and Curcumin with Ni^{+2} and pb^{+2} and determination of stability constant by spectrophotometric method

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Abstract : Quercetin and curcumin are are one of wide plenty dietary flavonoids. It has been scanned in the sharing of Pb(II),Ni(II) in Ethanol/H_2O (40:60v/v)for Quercetin and Ethanol /H_2O (60:40v/v)forcurcumin. The spectroscopic studies (UV-vis) were beneficial to consider the pertinent interaction of Quercetin and curcumin with Pb(II),Ni(II)ions .The chelation sites and dependence of the complex structure from the ligand /metal ratio. 1:1 (L:M)complex was indicated by Job's method of continuous variation.It was used to achieve the stoichiometric assembly of the complex.
Keywords : Thermodynamic, Quercetin and Curcumin, spectrophotometric.

1. Introduction

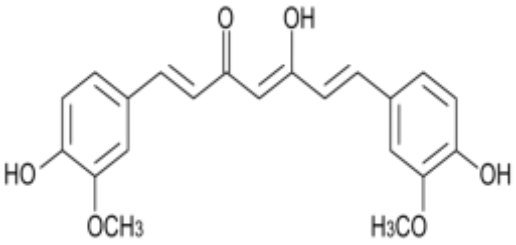
Flavonoids can be defined as a family of varied polyphenolic compounds widely distributed in nature, with physicochemical properties of scientific interest. These compounds present benefits in human health because of their biological properties

Curcumin Fig1: 1,7-bis(4-hydroxy-3-methoxyphenyl)-1,6- heptadiene-3,5-dione, is a hydrophobic polyphenol component, It isyellow dye of turmeric, a relish made of the root of Curcuma longa. It is a member of the Zingiberaceae (ginger) family which cultivated extensively in India, China, and other countries with a tropical climate. Turmeric, An addition extensively used in flavoring and coloring foods, It has a long legacy of use in the Chinese and Ayurvedic mode of medicine. Turmeric is often point to as the „Multi-Anti" relish. In herbal medicine, turmeric has been found to have the following effects: antihepatotoxic, antihyperlipidemic, anti-inflammatory, antioxidant, antitumoral, antimicrobial, antifertile, anti-insect, and anti-Alzheimer's disease [1].Curcuminconsist of hepatoprotective properties [2]against liver damage in animals induced by carbon tetrachloride [3]and aflatoxin B [4]. Curcumin has silymarin-like work [5]and anti apoptotic activity in vitro and in vivo to deny hepatic hurt [6].

QuercetinFig2:(3,3',4',5,7,-pentahydroxyflavone) as known as one of the most studies flavonoids, with biological and medicinal properties[7]It is linked to its antioxidant properties. It is openly occur in the flowers, leaves, and fruits of many plants.[8], quercetin was found to be difficult to be absorbed into the body because of its poor solubility, It is resulted in poor bioavailability. It has been Notified that quercetin can form complexes with heavy metal ions, such as pbII, cdIIand NiII. These quercetin-metal complexes show broad biological activities with increasing bioavailability, such as anti-oxidation, anti-bacterial, anti-tumor[9-10]. A multitude of exchanged patterns in the two benzene rings (A and B) of the basic structure happen in nature and shift in their

heterocyclic rings give rise to flavonols, flavones, catechins, flavanones, anthocyanidins and isoflavonesFig3.

Studying metal-curcumin and metal- Quercetin complexationis one of the pleasing discuss matter,And It support connect the basic chemistry knowing to medicinal usage. Many metals are dissolved, as free ions, in all of our bodily fluids. They are important to life but sometimes they can be poisonous to body and we must detection solution track to obtain them out. drugs which is offered to the patients for this aim generally link with metal ions, i.e. metal complexation, rendering them less toxic or easier to be removed from the body [11].



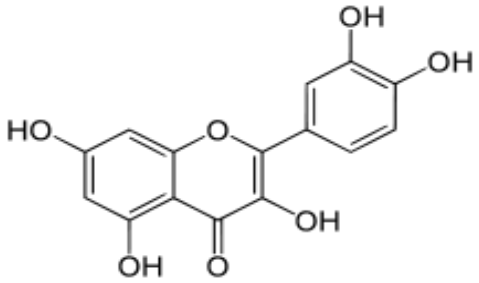


Fig.1. Structure of the CurcuminFig.2. Structure of the Quercetin

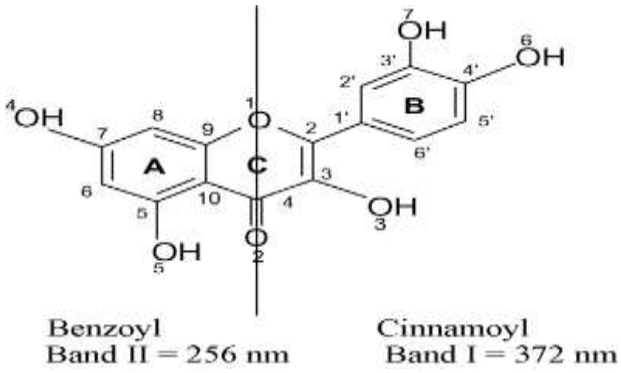


Fig3:the structure of quercetin and the division of band I and II

2. Experimental

2.1 Apparatus: the instrument used in this study is an UV/Visible double beam spectrophotometer, SHIMADZU model 1800 (Japan) with spectral width of 2 nm, wavelength accuracy of 0.5 nm and a pair of 10 mm matched quartz cell is used to measure absorbance of all the solutions. An electronic analytical balance was used for weighing the sample.

2.2 Material: Curcumin and Quercetin supplied by E. Merck (AG, Darmstadt, Germany).methanol and ethanol,(lead ,Nickel Nitrate salt) and all reagents were analar grade and were bought from Sigma Aldrich, Germany.

Deionized-distilled water was used all through the experiments.

Which arr carried out room temperatures

2.3. procedure

2.3.1 Sample preparation of curcumin

Stock solution of curcumin (10^{-2} M) in Ethanol /H_2O (60:40v/v) was freshly prepared before use by dissolving accurately about (0.368gm) Solve with a minimum quantity of ethanol. Transfer it to a 100 ml volumetric flack the volume fill up to the mark by Ethanol /H_2O (60:40v/v).

2.3.2 Sample preparation of Quercetin

Stock solution of Quercetin (10^{-2} M) in Ethanol /H_2O (40:60v/v) was freshly prepared before use by dissolving accurately about (0.338gm) Solve with a minimum quantity of ethanol. Transfer it to a 100 ml volumetric flack the volume fill up to the mark by Ethanol /H_2O (40:60v/v).

2.3.3 Sample preparation of metals

Stock solution of $pb^{+2}$and Ni^{+2} (10^{-2} M) dissolving 0.1656 gm of $Pb(NO_3)_2$and 0.2908 gm of $Ni(NO_3)_2$in volumetric of 100ml fill up by Deionized-distilled water to make stock solution.

2.4 Absorption peak for Curcumin and Quercetin

Absorption peak of pure curcumin that exist in the solution was gained by calculation.It is applied to deduct from solution spectrum to give just the absorption spectrum of the complex that created. The calculation operation collected of fitting curcumin solutions at various concentrations range from (10^{-5} to 10^{-6}M) covering the working range in the test. Then the attachment between concentration and absorbance at each wavelength was constructed by using Microsoft Excel. Once the correlation was established, the absorbance at any wavelength could be obtained by inputting the "expected" concentration.

Table1:determination of λ_{max} and Abs of ligand and complexes

items	λ_{max1}	λ_{max2}	Abs_1	Abs_2
Quercetine	371	255	0.913	0.954
Quercetine-M^{+2}	433	255	0.294	0.356
Curcumin	429	260	0.088	0.177
Curcumin-M^{+2}	429	-	1.125	-

2.5 Determination of maximum wavelength

2.5.1 of curcumin

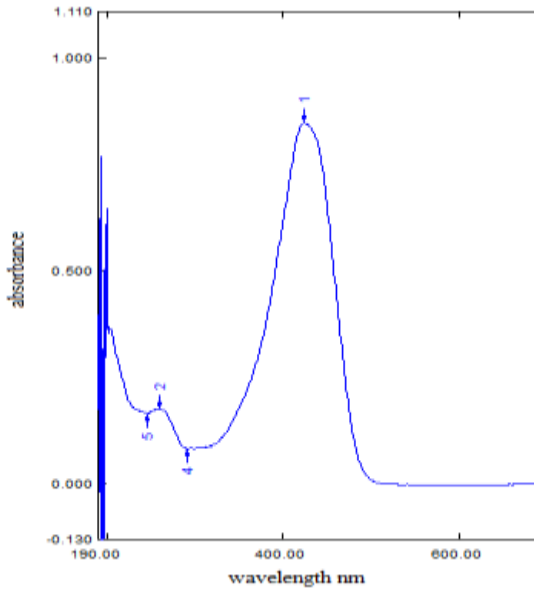


Fig4: the spectrum of maximum wavelength of curcumin

10^{-5}M solution was prepared by using Eq ($M_1 * V_1 = M_2 * V_2$) and scanned in UV spectrophotometer in the range of 200-800 nm. Ethanol /H_2O (60 : 40 v/v) was used as blank. Wavelength vs to maximum absorbance of curcumin in ethanol was observed at 424nm with small shoulder in 260nm and absorbance was 0.848 and 0.177 respectively. show in Fig.4.

2.5.1 for Quercetin

10^{-5}M solution was prepared by use Eq ($M_1 * V_1 = M_2 * V_2$) and scanned in UV spectrophotometer in the range of 200-800 nm. Ethanol /H_2O (60:40v/v) was used as blank. Wavelength vs to maximum absorbance of Quercetin in ethanol was observed two peak first at 255nm and the second at 371nm and absorbance was 0.913 and 0.954 respectively. show in Fig5a.

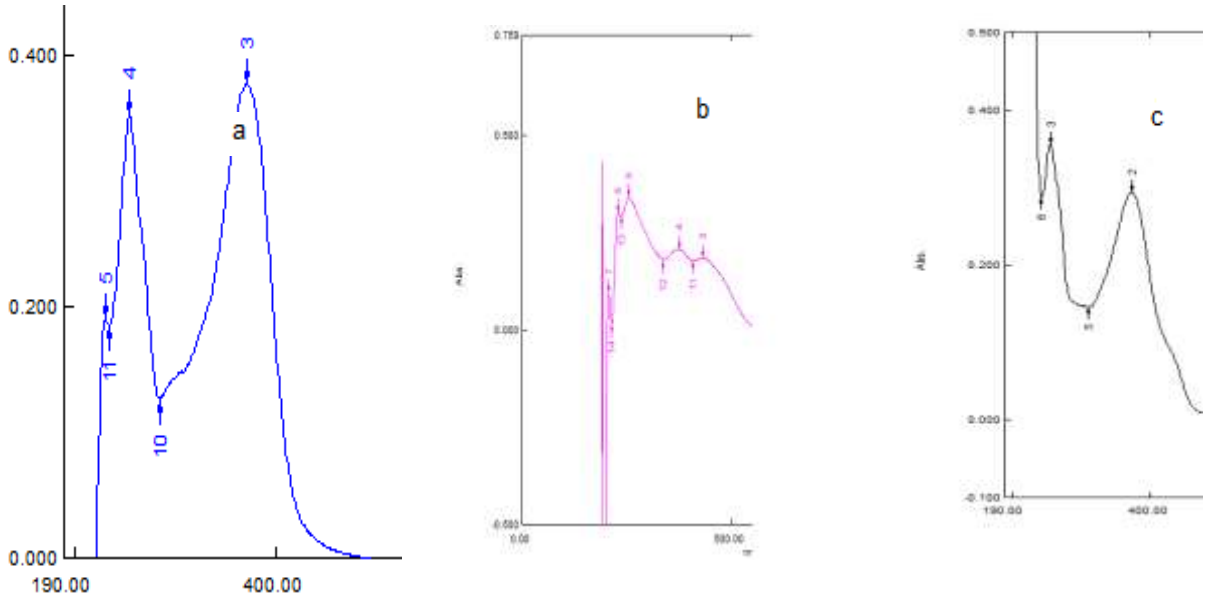


Fig 5: a)the spectrum of maximum wavelength of Quercetinb) spectrum of maximum wavelength of Quercetin with pbc) spectrum of maximum wavelength of Quercetin with Ni

2.6 Preparation of standard calibration curve

2.6.1 for curcumin

Curcumin was obtained by measuring the absorbance of curcumin solution in concentration range(10^{-5} - $7*10^{-5}$M) prepared from stock solutions Ethanol /H_2O (60:40v/v)at 424nm in triplicate .Calibration curve of curcumin was then plotted with absorbance on y-axis and curcumin concentration on x-axis.Fig6.

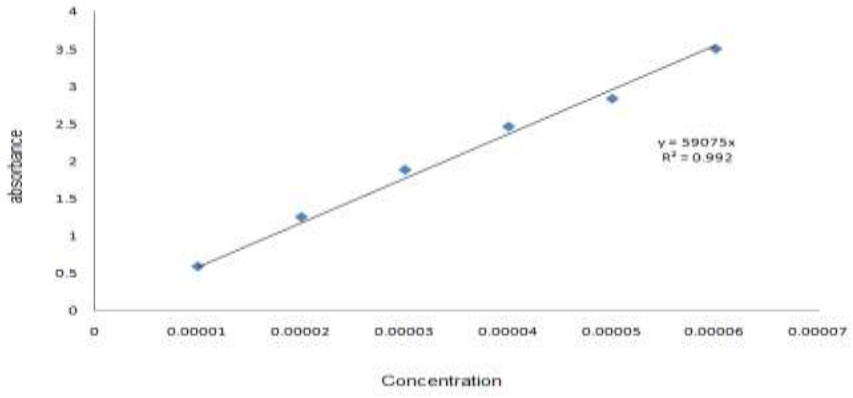


Fig6:standard calibration curve range(10^{-5} - $7*10^{-5}$M)

2.6.2. for Quercetin

In quercetin we have two calibration curve one on 255nm and other on 371nm. We prepared (10^{-5} to 10^{-6} M) from stock solutions Ethanol:H_2O (40:60v/v) in triplicate. Calibration curve of Quercetin was then plotted with absorbance on y-axis and Quercetin concentration on x-axis.Fig7a,b.

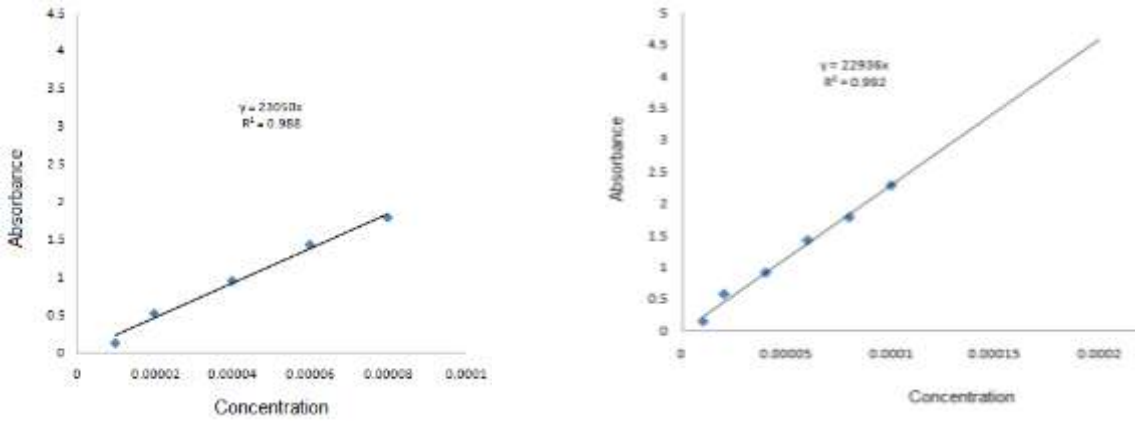


fig 7a standard calibration curve rangefig7b : standard calibration curve range (10^{-5} - 10^{-6}M) at λ_{max}=371nm(10^{-5} - 10^{-6}M) at λ_{max}=255nm

2.7 Preparation of metal-curcumin complexation and metal-Quercetin complexation

By usingEq (M_1 * V_1= M $_2$* V_2) and to prepare solution $4*10^{-5}$M of each Metal, The complexation between antioxidants and each metals then mix it equal volumes and lift the mixture one hour at room temperature after that make scan in UV-VIS spectrophotometer to show a new peak appearance or shift in the same peaks or it has happened difference in absorbance **.**

2.8 Stoichiometric ratios of $pb^{+2}$and Ni^{+2}ionswith antioxidants

Job's method of continual variation was used to determine the stoichiometric ratio between antioxidants and the $pb^{+2}$and Ni^{+2}ions. Equimolar concentration ($4x10^{-5}$M) solutions of quercetin, $Pb(NO_3)_2$and $Ni(NO_3)_2$ were prepared. Metals and antioxidants were mixed in different ratios varying from 0.1:0.9 to 0.9:0.1 and the absorbance was measured at λ_{max}=431nm for curcumin and λ_{max}=433for Quercetin with Pb^{+2}andNi^{+2}, the result was between(0.5-0.6)mole fraction that means the (ligand:Metal)(1:1).

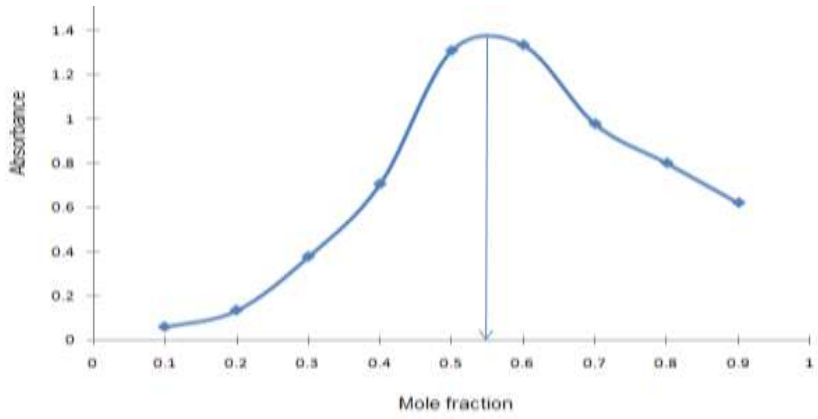


Fig8:the Job's plot of absorbance at 429nm versus the fraction of Ni^{+2} ion with curcumin

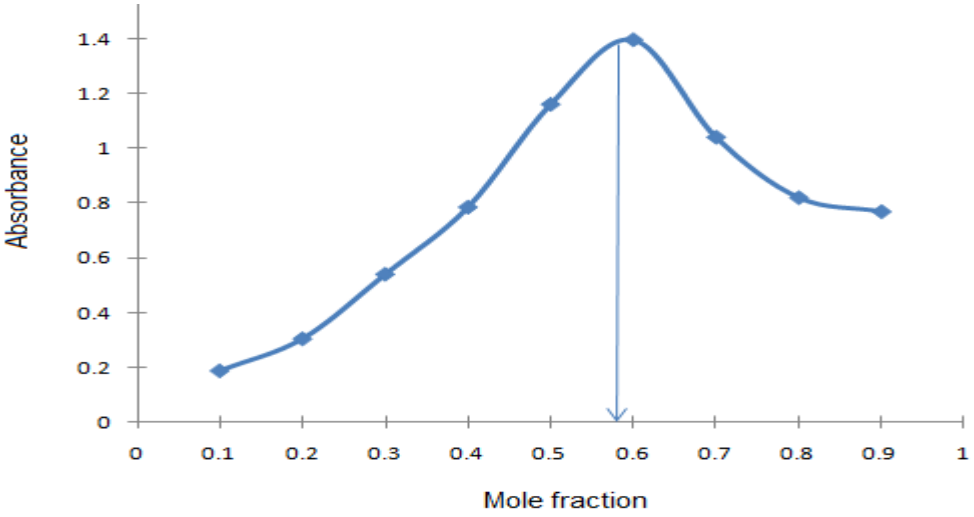


Fig9:the Job's plot of absorbance at 429nm versus the fraction of pb^{+2} ion with curcumin

2.9 Calculation for the complex equilibrium constant

equilibrium constant of stoichiometric ratio (metal:ligand) complex were evaluated by the preparation of two sets of solutions, the first one of solutions were communicated to contain stoichiometric amount of the metal (Pb^{+2}or Ni^{+2}) to the ligand (curcumin,Quercetin). The second one was formulated to contain fivefold excess of the ligand [12].

The interaction between metal ions (M) and the ligand (L) proceeds according to the equation:

M + L ⇌ ML

$\alpha\alpha$ 1-α

And K=$\frac{[ML]}{[M][L]}$

Were K = stability constant.

If α is the degree of dissociation and c is the molar concentration, then the above

equation (3.1) may be written as follows:

K=$\frac{(1-\alpha)C}{(\alpha C)(\alpha C)}$ ----------3.1

K=$\frac{1-\alpha}{\alpha 2C}$

Given that $\boldsymbol{\alpha = A_m - A_s/A_m}$; where Am and As are the absorbance of the solution containing an excess and stoichiometric amount of reagent, respectively.

3. Results and discussion

3.1 Curcumin

Curcumin in ethanolic-aqueous solution shows a broad characteristic absorption around 300 - 500 nm with maximum at 429 nm, a shoulder at 260 nm shown in Fig4.The maximum absorption is due to the electronic dipole allowed π - π* type excitation of its extended π-conjugation system. Upon light absorption a π electron is excited from the ground state to the first excited state and oscillates from one end of the chromophore to the other. Most likely, the weak, electronic dipole forbidden n - π* band is located somewhere

under the main absorption band. The large conjugated framework of curcumin molecule predominates in the enolic curcumin with π electrons are delocalized through the whole molecule between two feruloyl parts which causes a decrease in π - π* transition energy and the absorption band appears at the lower energy (419 nm in enol form) and (389 nm in keto form) in which there is no conjugation between two feruloyl parts [13].from this study, it can be concluded that the functional group of curcumin that favors binding to metal ion is the central β-diketone.

3.2 UV–vis spectroscopic study of the complex

Job's method of continuous variation was used to find out the stoichiometric composition of chelate complex. After adding the $pb^{+2}$and Ni^{+2} ions, the absorbance band of the Quercetin was shifted from 371 nm to a new characteristic band of the complex at 433 nm. The absorbance plots at 433 nm, Fig. 10, against the mole fraction of morin (X) have a maximum absorbance at XL = 0.5, confirming that the stoichiometric ratio for the complexation of Pb,Ni(II) and Quercetin is 1:1.

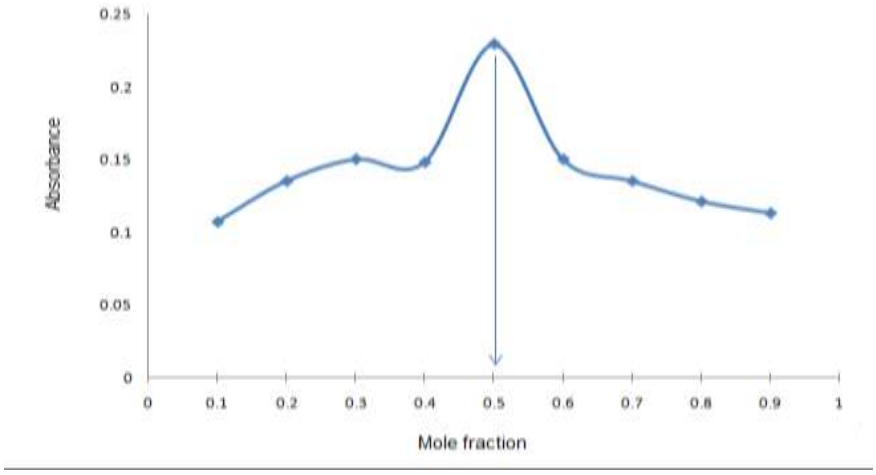


Fig10:the Job's plot of absorbance at 433nm versus the fraction of Ni^{+2}ion with Quwecetin

The UV–vis spectrum of the free quercetin and pb–quercetin complex and Ni–quercetin complex in Ethanol:H_2O (40:60 v/v) is described in fig 5a,b,c

Quercetin Like most flavones and flavonols, exhibits two major absorption bands in the UV–vis region, at 371 nm (band I) representing B-ring absorption (cinnamoyl system), and 255nm (band II) is considered to be associated with the absorption involving the A ring benzoyl systemfig3,The spectra are related to the π →π* transitions within the aromatic ring of the ligand molecules. In comparison with flavonoids absorption spectra, the band of the complex is shifted to the long wavelength region as shown in Fig. 5a,b,c. The isobastic point was observed at 433 nm, characteristic of the formation of a complex. Such bathochromic shift can be explained by the extension of the conjugated system with the complexation. The UV–vis spectra gives significant information about the coordination sites of flavonoid, for example, the interaction of pb,Ni(II) ions with quercetin at 1:1 metal: flavonoid ratio produces bathochromic shift in the absorbance of both bands. As the 3-hydroxy group has amore acidic proton [14], therefore the 3-OH and 4-oxo groups are the first sites to be involved in the complexation process. The 3',4-dihydroxy groups bind a second sites.

The 5-OH group is not involved due to lesser proton acidity and the steric hindrance caused by the first complexation[15].In certain time used molecularly imprinted polymers MIPs technique which are mainly based on the polymerization of functional monomers in the presence of a template molecule or atom[16].

3.3 Stability constants and thermodynamic parameters

In this study, stability constants and thermodynamic parameters of the complex with Pb(II),Ni(II) have been calculated by spectrophotometry at different temperatures (293, , 298, 303,308K). From these constants,

thermodynamic parameters (ΔG, ΔH, ΔS) were evaluated. The values are given in Table 2

At first, the molar absorption coefficients (ε) were determined at different temperatures according to the Beer's law ($A = \varepsilon\ c\ l$), and then the stability constants were calculated. For each temperature, the values of ln K were plotted against 1/T. A straight line was obtained, showing that ΔH and ΔS may be calculated, respectively, from the slope and intercept of the plot (Fig. 11). Since, at equilibrium,

by using Eqs.

$\Delta G = -RT \ln K$----------3.2

$\Delta G = \Delta H - T\Delta S$----------3.3

the values of ΔG, ΔH and ΔS for Pb-Curcumin, Ni-Curcumin, Pb-Quercetin and Ni-Quercetin complexes can be calculated. The slope of the graph gave -ΔH/R value and the intercept was found to be equal to ΔS/R. The average values of stability constants (ln K) of metal complex were found to be inversely proportional to the temperature (Table 2). TheΔH found for 1:1 complex is high and negative that shows a very large change in total internal energy during complex formation towards stability[17].

Table(2) thermodynamic parameter for ligand-metals

System	Temp(k)	lnK_{eq}	ΔG (J mol^{-1})	ΔH (J mol^{-1})	ΔS (J mol^{-1} K^{-1})
Pb-Curcumin	293	10.7712	-26238.7	-4599.3048	73.778436
	298	10.71729	-26552.9		
	303	10.69819	-26950.3		
	308	10.67573	-27337.5		
Ni-Curcumin	293	10.07432	-24541.1	84420.356	374.46256
	298	11.38496	-28207.1		
	303	11.69759	-29467.9		
	308	11.83256	-30299.8		
Pb-quercetin	293	10.71918	-26112	-8879.352	58.77998
	298	10.65449	-26397.3		
	303	10.58799	-26672.6		
	308	10.54424	-27000.8		
Ni-quercetin	293	11.4077	-27789.2	36041.19	217.8268
	298	11.65235	-28869.5		
	303	11.88298	-29934.9		
	308	12.13164	-31065.6		

From the thermodynamic parameters of Pb-Curcumin complex (Table 2) it is clear that;

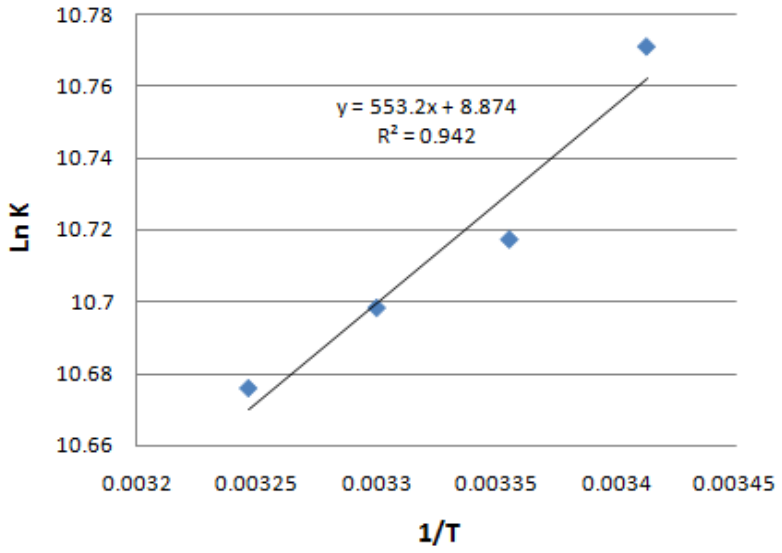


Fig11:Plot of ln K versus 1/T for the determination of thermodynamic parameters of Curcumin-Pd

From table 2 can be classified the complexes by depending on the thermodynamic parameters in to two group

First concluded pb-curcumin and pb-quercetin complexes

Second concluded Ni-curcumin and Ni quercetin complexes

For the first group

1. The stability constants decrease with increase in temperature, confirming that complex is not stable at higher temperature.
2. Negative value of ΔG shows the spontaneous formation of complex.
3. Negative value of ΔH indicates the exothermic nature of metal ligand interaction.
4. The ΔS value for the complex is positive, confirming that the complex formation is nonentropically favorable.

For the second group

1. The stability constants increase with increase in temperature, confirming that complex is stable at higher temperature.
2. Negative value of ΔG shows the spontaneous formation of complex.
3. posative value of ΔH indicates the endothermic nature of metal ligand interaction.
4. The ΔS value for the complex is positive, confirming that the complex formation is nonentropically favorable.

4. Conclusion

As a part of research project devoted to developing a new complex of lead and nickel(II) with quercetin flavonoid has been prepared and characterized. This study examined the interaction of metal ion with quercetin in ethanolic solution. The spectroscopic data show the importance of 3-OH group as coordination site. The antioxidant activity of flavonoid depends on the number and positions of OH groups in the flavonoid structure. The complex has been characterized on the basis of analytical and spectral data. The Ni–quercetin complex and pb- quercetin complex shows higher antioxidant activity as compared to the pure quercetin. This suggests that the metal ions (pb,Ni[II]) significantly change the chemical properties of the quercetin..

Medicinal treatment of acute and chronic metal toxicity was treated by chelating agents. Chelation was one of the chemical functions that take place in the bodies of almost all living organisms. Most of the currently used chelating agents have serious side effects[18].

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