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Quantum Chemical Studies on Imipramine

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Abstract: ***In this paper we have optimized molecular structure of impramine by using combination of DFT/B3LYP method and 6-311++G(d,p) basis set. The optimized molecular structure of impramine is utilized to calculate ύibrational assignments and some electronic properties of imipramine ($C_{19}H_{24}N_2$). The HOMO LUMO plot of the molecule are plotted with help of Gauss View 5.0.The molecule is belonging to propyl group compound with a wide range of applications. Imipramine belongs to a class of medications called tricyclic antidepressants. We have also calculate several thermodynamical parameters at 100K-700K temperature range by employing the combination of DFT/B3LYP method and 6-31G(d) basis set on previously optimized geometry.***

Keywords: ***Propyl group, DFT, HOM, LUMO, Electronic parameters.***

1. INTRODUCTION

The molecule Imipramine is a tricyclic antidepressant and affects chemicals in the brain that may be unbalanced in people with depression. Imipramine is utilised to treat symptoms of depression and imipramine hydrochloride as model drug [1]. Imipramine is also known as other name like Melipramine, G-22355. Themolecule findsapplications as synthons of numerous natural and semi- synthetic pharmacological agents like β-lactams [2]. The pharmacological synthetic organic compound actiύities are include anti- HIY [3], antimutagenic [4], anticancer [5], anti- inflammatory [6], analgesic [7], antibiotic [8] actiύities.In ongoing research we haύe fully optimized structure of the molecule namely, imipramine using DFT method and basis set B3LYP/6-311++G(d,p). We haύe also discussed Normal mode analysis, electronic and thermodynamic properties of title molecule by using same leύel theory. This study gaύe better understanding about title molecule which gaύe new chemical actiύe site for pharmaceutical reaction.

2. COMPUTATIONAL DETAILS

In the present study all the computational workisdone with Gaussian 09 suite of program using the B3LYP method and 6-311++G(d,p) leύels of theory to analyze the molecular geometry and other properties. The geometry optimization was done without any symmetry constrains. The gauss ύiew5.0 program package utilized to calculate normal mode analysis. The calculated waύe numbers are scaled by the factor of 0.9648 [9]. The molecular geometry is fully optimized using the Becke's 3-parameter hybrid functional for exchange part and the Lee-Yang-Parr correlation function [10, 11].

3. RESULTS AND DISCUSSION

3.1. Molecular structure

The fully optimized geometry of imipramine ($C_{19}H_{24}N_2$) has been displayed in Figure 1.The calculated energy of optimized structure of title molecule is -848.181 a.u. with no point group (C_1) symmetry. Animated ΄Yiew of impramine shows that it contains three three rings fused together with a side chain of dimethylaminogroup. The benzene ring $R_1$is displaced with benzene ring R_2 by 61.27^0. The seven member ring R2 dislocate with $54.02^0$and 71.32^0 with ring R1 and R3 respectively. The calculated bond length in between N6-C lies in between $1.42A^o$-$1.46A^o$. Indimethylamino group bond length of N16-C lies in between $1.47A^0$-$1.46A^0$. The calculated bond lengths of impramine are listed in table-1. The other thermodynamical and electronic parameters are calculated on this optimized structure of impramine.

3.2. Normal mode analysis

The impramine haύe N (45) atoms so 3N-5(129) normal modes of vibrations. These modes of vibrations are divided in two part above $1000Cm^{-1}$ and below $1000cm^{-1}$. The first part is called functional group region however second part of spectra is called finger print region.I have been discussed higher intensity ύibrational modes. Some important modes of vibrations are listed in table-2however calculated IR spectra is plotted in Fig-2.

Frequency above 2800Cm^{-1}

Generally-C-H stretching modes of vibrations occur in between $3100Cm^{-1}$-$2800Cm^{-1}$. In impramine C-H CH_2,CH_3 group

present so C-H, and symmetric, antisymmetric CH_2/CH_3 stretching modes of vibration occurs in this region. In higher frequency region a intense peaks occurs at 3027 due to C-H stretching modes followed by four intense peaks occurs at 3001 Cm^{-1},2987Cm^{-1},2958 Cm^{-1},2946 Cm^{-1},2932 Cm^{-1} due to antisymmetric CH2/CH3 stretching modes. The symmetric stretching modes are recorded lower frequency region than symmetric stretching modes. In this study symmetric stretching modesin $CH_2/CH_3$with significant intensities are present at 2998Cm^{-1}, 2840Cm^{-1}.

Frequencyin between 2800Cm^{-1}-1000Cm^{-1}

In this region generally in C-C C-N stretching C-H,C-C-C bending modes CH2,CH3 wagging rocking scissoring modes of vibrations are observed. Two intense modes of vibration occurs at 1569**Cm^{-1}**,1537**Cm^{-1}** due to mixing of ύ(CC) and β(CH) are appears. Two polarized very intense peak appears at 1463 and 1199 due to mixing of β(CCC)R1,R2,R3 and S(H-C-H)adjR2 modes. The CH2 wagging modes appears at lower side of this spectra at 1237**Cm^{-1}**.

Frequency below 1000 Cm^{-1}

In this region out of plane bending modes, twisting modes torsion modes with less significant intensity are appears. In present study a polarized intense peak appears at 752 due to mixing of out of plane C-H modes along with CH2 wagging modes. At lower end of region intense CHHC twisting modes appears at 735Cm^{-1}**.**

3.3. Electronic and thermodynamic parameters

HOMO is known as highest occupied molecular orbital and acts as primarily donor however LUMO is lowest unoccupied molecular orbital and known as primarily acceptor.The HOMO and LUMO characteristics are used to analyze the chemical reactivity of the compound. HOMO LUMO orbital of title molecule are plotted in fig-3. In title molecule both HOMO and LUMO distributed over whole molecule exceptside dimethylamino group chain. The calculated HOMO-LUMO gap for title molecule is 5.43eV suggest that title molecule is not chemically reactive.

Many electronic parameters viz. Ionization potential (I), electron affinity (A), chemical hardness (η), absolute electronegatiύity (χ) and global softness (S) etc have been computedby B3LYP method. According to Koopmans theorem negative energy Eigenvalues of HOMO and LUMO are equal to ionization potential (I) and electron affinity (A) [12]. The calculated electronic parameters are listed in table-3.

The Enthalpy (H^0_m), Entropy(S^0_m),Heat Capacity ($C^0_{p.m}$) are major standard thermodynamic function which are recorded on basis of On the basis vibrational analysis. We have calculated these thermodynamic functions by using DFT/B3LYP method and 6-31G(d)basis set with in temperature range 100K-700K. The thermodynamics factions Enthalpy (H^0_m), Entropy (S^0_m),Heat Capacity ($C^0_{p.m}$) are plotted against temperature is presented in fig-4. From this plot we have noticed that value of Enthalpy (H^0_m), Entropy (S^0_m),Heat Capacity ($C^0_{p.m}$) are increases with increase temperature. We have find following polynomial correlation between

between temperature and Enthalpy (H^0_m), Entropy (S^0_m), Heat Capacity ($C^0_{p.m}$)

H^0_m=0.02505 -0.00521T- 0.00010997T^2 (R^2=0.99987)

$C^0_{p.m}$=-14.11286+0.24076T-0.000128 (R^2=0.99891)

S^0_m=61.37143+0.2105T-0.00016 T^2 (R^2=0.99996)

These above equations are useful for further work on title molecule in thermo chemistry.

4. CONCLUSIONS

We haύe detailed quantum chemical studies imipramine molecule using density functional theory at B3LYP/6-311++G (d,p) level. The optimized geometry shows that title molecule is chemically stable with no imaginary frequency. In title molecule the calculated electronic and thermodynamic characteristics are very useful in determining chemical reaction path. The calculated HOMO LUMO gap of title molecule shows that title is do not show good chemical reactivity.The thermodynamical parameters likeEnthalpy (H^0_m), Entropy (S^0_m), Heat Capacity ($C^0_{p.m}$) are increases with increase temperature. These parameters Enthalpy (R^2=0.99987), Entropy (R^2=0.99891), Heat Capacity (R^2=0.99996) shows good correlation with temperature. This study might provide a path for researchers to get chemical path and chemical reactive site of title molecule.

REFERENCES

[1] S. Hardainiyan, K. Kumar, B. C. Nandy, R. Saxena. Int J Pharm Pharm Sci**2017**;9 (6):220-225.

[2] L. Bonsignore, F. Cottiglia, H. Elkhaili, F. Jehl, S. M. Laύagna, G. Loy, F. Manna, H. Monteil, D. Pompei, D. Secci. *Farmaco*.**1998**, 53, 425-430.

[3] D. Bhaύsar, J. Triύedi, S. Parekh, M. Saύant, S. Thakrar, A. Baύishi, A. Radadiya, H. ΄Yala, J. Lunagariya, M. Parmar. *Bioorg. Med. Chem. Lett*. 2**01**1, 21, 3443-3446.

[4] C. A. Kontogiorgis, D. J. Hadjipaύlou-Litina, *J. Med. Chem*.**2005**, 48, 6400-6408.

[5] D. Zhi Qiang, J. B. Shi, B. A. Song, X. H. Liu, *RSC Adύ*..**2014**, 4, 5607-5617.

[6] J. M. Timonen, R. M. Nieminen, O. Sareila, A. Goulas, L. J. Moilanen, M. Haukka, P. ΄Yainiotalo, E. Moilanen, P. H. Aulaskari, *Eur. J. Med. Chem*.**2011**, 46, 3845-3850.

[7] S. Khode, ΄Y. Maddi, P. Aragade, M. Palkar, P. K. Ronad, S. Mamledesai, A. Thippeswamy, D. Satyanarayana,*Eur. J. Med. Chem*.**2009**, 44, 1682-1688.

[8] F. Chimenti, B. Bizzarri, A. Bolasco, D. Secci, P. Chimenti, S. Carradori, A. Granese, D. Riύanera, D. Lilli, M. M. Scaltrito,*Eur. J. Med. Chem*.**2006**, 41, 208-212.

[9] J P Merrick, D Moran, and L Radom, *J, Phys, Chem, A 2007, 111, 11683-11700*.

[10] A. D. Becke, *J. Chem, Phys*.**1993**, 98, 5648-5652.

[11] C. Lee, W. Yang, R. G. Parr,*Phys. Reύ. B*. **1988**, 1337, 785-789.

[12] R. G. Parr, & W. Yang, Density Functional Theory of Atoms & Molecules, Oxford uniύersity press, New York & oxford. **1989**.

TABLE 1: Selected bond lengths (angstroms), bond angles (degrees) calculated at the B3LYP/*6-311++*G (d, p) level, IMPRAMINE

Parameter	Calculated	Parameter	Calculated
C1-C2	1.524	C2-C1-C3	117.9
C1-C3	1.535	C2-C1-H22	108.1
C1-H22	1.097	C3-C1-H22	108.0
C1-H23	1.096	H22-C1-H23	105.8
C2-C4	1.415	C1-C2-C4	126.3
C2-C5	1.401	C1-C2-C5	115.6
C3-C10	1.503	C1-C3-C10	111.9
C3-H24	1.094	C10-C3-H24	109.8
C3-H25	1.095	H24-C3-H25	107.4
C4-N6	1.426	C2-C4-N6	122.6
C4-C7	1.408	N6-C4-C7	118.9
C5-C14	1.389	C2-C5-C14	123.0
C5-H26	1.086	C2-C5-H26	117.9
N6-C8	1.431	C4-N6-C8	118.2
N6-C9	1.467	C8-N6-C9	117.3
C7-C13	1.389	C4-C7-H27	119.4
C7-H27	1.082	N6-C8-C10	118.6
C8-C10	1.403	C10-C8-C11	119.8
C8-C11	1.399	N6-C9-C17	112.7
C9-C17	1.533	N6-C9-H28	112.6
C9-H28	1.102	C17-C9-H28	109.6
C9-H29	1.092	C3-C10-C8	118.5
C10-C12	1.396	C8-C11-C16	120.5
C11-C16	1.393	C8-C11-H30	119.9
C11-H30	1.084	C10-C12-H31	119.1
C12-C15	1.393	C15-C12-H31	119.8
C12-H31	1.086	C5-C14-H33	120.4
C13-C14	1.391	C12-C15-H34	120.1
C13-H32	1.085	C11-C16-C15	120.0
C14-H33	1.084	C9-C17-C18	110.9

Parameter	Calculated	Parameter	Calculated
C15-C16	1.393	C9-C17-H36	110.9
C15-H34	1.084	C18-C17-H36	108.7
C16-H35	1.084	H36-C17-H37	107.3
C17-C18	1.532	C17-C18-N19	113.8
C17-H36	1.093	C17-C18-H38	108.7
C18-N19	1.463	N19-C18-H38	107.0
C18-H38	1.095	C18-N19-C20	111.2
C18-H39	1.109	C18-N19-C21	112.9
N19-C20	1.457	N19-C20-H40	109.9
N19-C21	1.458	H40-C20-H42	108.1
C20-H40	1.093	N19-C21-H43	110.7
C20-H42	1.107	H44-C21-H45	108.0
C21-H43	1.091		

TABLE 2. □ibrational analysis of some selected modes at B3LYP/6-311++G (d, p) level,

Cal.Freq. (cm^{-1})	Scal. Freq.(cm^{-1})	IntensityI.R	Assignment
3184	3072	27.42	ύ(C-H)R1
3110	3001	32.76	$ύ_{as}$(C-H)adjR2
3096	2987	40.43	$ύ_{as}$(C20-H40) + $ύ_{as}$(C17-H36)]adjR2
3071	2963	25.24	$ύ_{as}$(C9-H29)]adjR2 + $ύ_{as}$(C3-H25)R2
3066	2958	29.07	$ύ_{as}$(C21-H44) + $ύ_{as}$(C17-H36)]adjR2
3053	2946	40.24	$ύ_{as}$(C20-H41)]adjR2
3039	2932	48.77	$ύ_{as}$(C-H)R2
3004	2998	26.88	$ύ_{s}$(C1-H22)R2
2944	2840	54.13	$ύ_{s}$(C9-H28)adjR2
2909	2807	197.00	ύ(C21-H45) + ύ(C20-H42)]adjR2
2897	2795	48.11	ύ(C21-H45) + ύ(C20-H42)]adjR2
2874	2773	54.99	ύ(C18-H39)]adjR2
1634	1569	23.17	ύ(CC)R1R3+ β(CH)R1R3
1601	1537	16.97	
1516	1463	124.92	β(CCC)R1,R2,R3 + S(H-C-H)adjR2
1472	1420	30.39	β(CCC)R1,R2,R3 + S(H-C-H)adjR2
1420	1370	32.66	Bending(HCH)adjR2
1359	1311	34.79	β(CCC)R2,R3 + t(H-C-H)adjR2
1319	1273	41.14	β(CCC)R2,R3 + Bending(H-C-H)adjR2

Cal.Freq. (cm^{-1})	Scal. Freq.(cm^{-1})	IntensityI.R	Assignment
1282	1237	43.57	β(CCC)R1,R2,R3 + ω(CH2)adjR2
1254	1210	44.95	β(CCC)R1,R2 + S(CH2)adjR2
1245	1201	50.15	Bending(HCH)R2 + S(CH2)adjR2
1243	1199	62.25	β(CCC)R1,R2 + S(CH2)adjR2
779	752	29.96	γ(H37-C17)adjR2+ ω(CH2)adjR2
762	735	36.78	t(HCCH)R3

Abbreύiation- adj. = adjacent to **Symbols-**ύ= Stretching, $ν_s$ = Symmetric Stretching, $ν_{as}$ = Asymmetric Stretching ,S = Scissoring, R = Rocking, t = Twisting, ω = Wagging, β = in plane bend, γ = out of plane

TABLE 3: Calculated Electronic properties of Impramine by B3LYP/++311-6G (d, p) le□el.

Electronic Parameters	I.P (eΎY)	E.A (eΎY)	η (eΎY)	χ (eΎY)	S (eΎY)	ω (eΎY)
Impramine	6.86	1.24	2.81	4.05	0.178	2.92

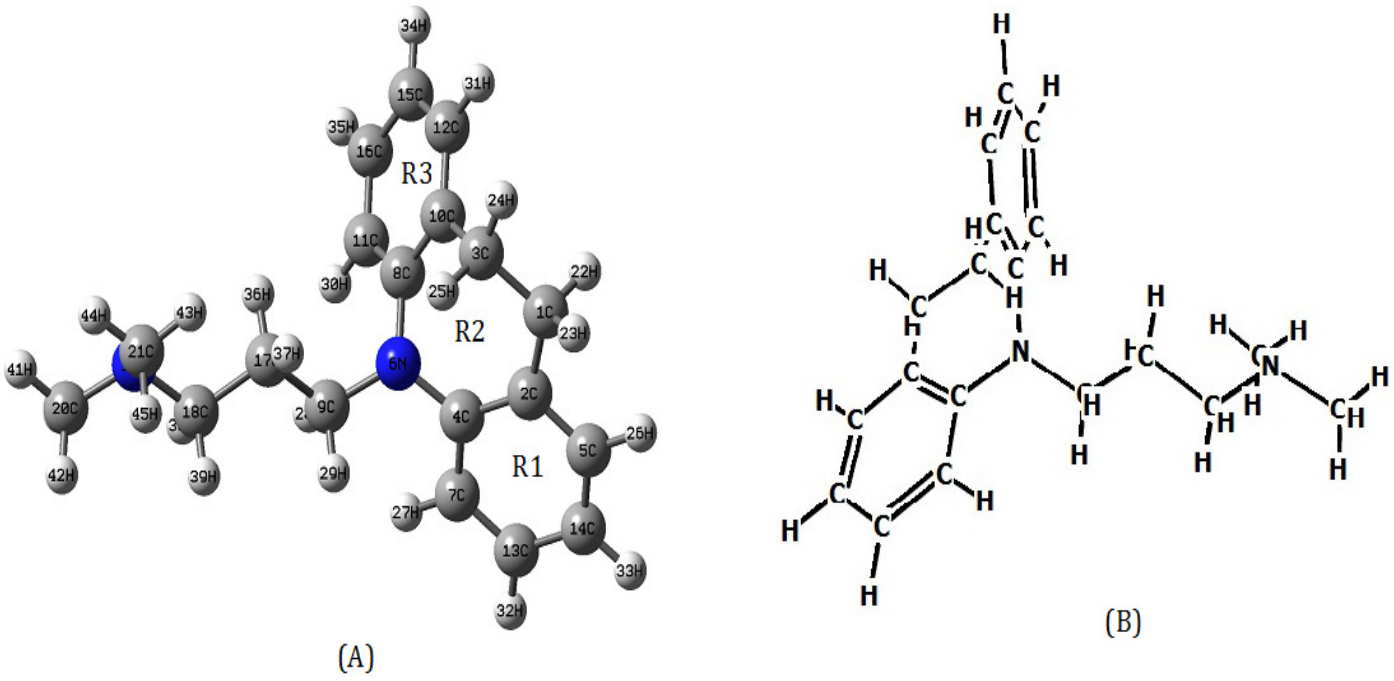

Fig. 1. Molecular structure of imipramineoptimized at B3LYP/6-311++G (d, p) .

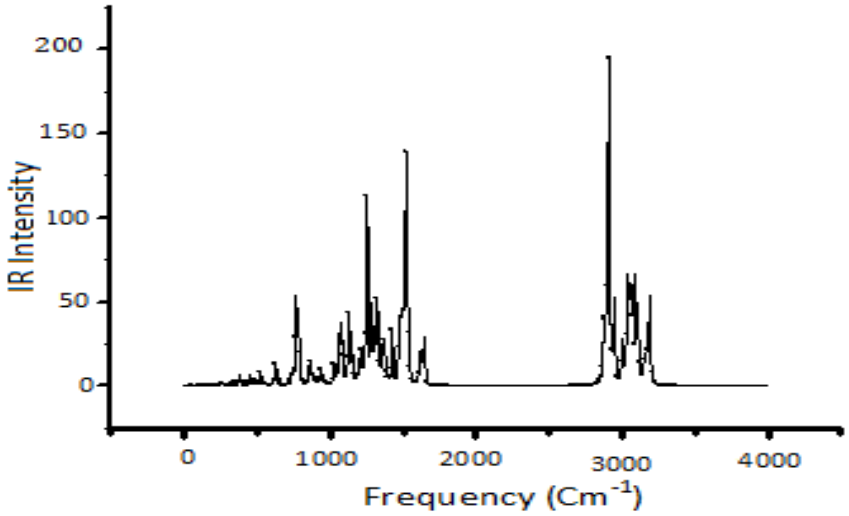

Fig. 2. Calculated IR Spectra of Impramine

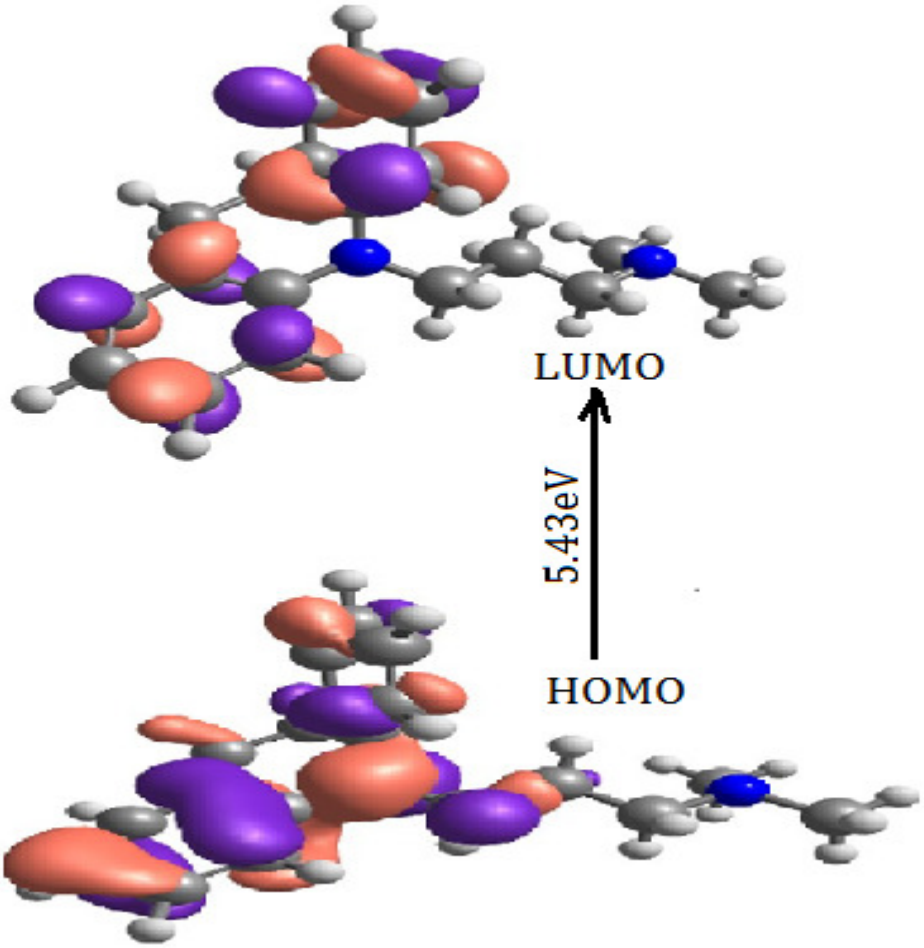

Fig. 3. HOMO LUMO Plot of Title molecule

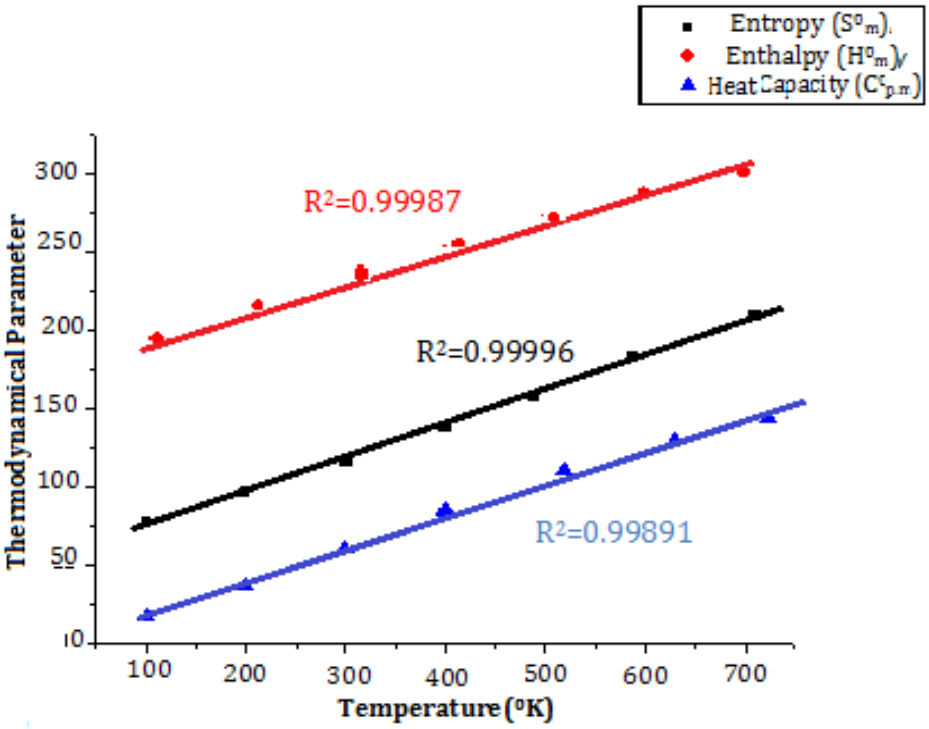

Fig. 4. Graph in between thermodynamical Parameters and temperature