



Synthesis and Hammett spectral correlation studies of some substituted cyanopyridine compounds

R. Arulkumaran¹, V. Manikandan¹, G. Thirunarayanan^{2,*}

¹PG & Research Department of Chemistry, Government Arts College,
C-Mutlur, Chidambaram - 608102, India

²Department of Chemistry, Annamalai University, Annamalainagar - 608002, India

*E-mail address: drgtnaryanan@gmail.com ,
thirunarayanan.g.10313@annamalaiuniversity.ac.in

ABSTRACT

About ten substituted cyanopyridine compounds have been synthesized and the purities of these pyridines were examined with their physical constants, analytical and spectroscopic data provided in the literature. They are characteristic infrared stretches and NMR chemical shifts were assigned and they are correlated with Hammett substituent constants using single and multi-linear regression analysis. From the results, the effect of substituents on the spectral data of cyanopyridine has been discussed.

Keywords: Substituted cyanopyridine, IR and NMR spectra, Hammett constants, Single and multi-correlation analysis

1. INTRODUCTION

Pyridines with different functional groups are exhibit wide range of applications in the field of medicinal chemistry, agriculture and dye preparing field. And also, pyridine is the parent of the series of compounds that is important in pharmaceutical and industrial chemistry. Although many substituted pyridine compounds like other heterocyclic compounds are synthesized with their functional group present from heterocyclic compounds.

The simple pyridine compounds are prepared by the cyclization of aliphatic raw materials. Many naturally occurring and synthetic compounds containing the cyanopyridine and cyanopyran scaffold possess interesting pharmacological character in nature [1]. Pyridine containing liquid crystalline compounds has also been prepared using several other methods [2-7]. Among a wide range of pyridines, 3-cyanopyridines [8] acquired a special attention due to their wide range of therapeutic activities. Most pyridine derivatives are prepared by manipulation of pyridine and its simple homologues in a manner similar to chemistry of the benzenoid chemistry.

Molecules containing pyridine always have grave importance in chemistry as well as in biology. The pyridine substructure is one of the most prevalent heterocyclic molecular frameworks found in natural products, pharmaceuticals, vitamins and functional materials [9-12]. The simple pyridine compounds are prepared by the cyclization of aliphatic raw materials. Interests in the synthesis of multicyclic pyridine containing compounds have increased in recent years because of their wide range of pharmacological activities.

Cyanopyridine derivatives have been used as herbicides [13], for enrichment of cereals [14], for regulation of arterial pressure [15] and cholesterol levels in blood [16]. The cyanopyridine derivatives widely used in the fields of feed additive, food additive and pharmaceuticals. The enzymatic synthesis of nicotinamide from 3-cyanopyridine catalyzed by nitrile hydratase has the advantages of high yield and little by products. In recent years synthesis of cyanopyran and cyanopyridine compounds prepared from various aryl chalcones. And also cyanopyridine compounds are used to prepare cyanopyridine based conjugated polymers.

Within the above view, some information only available in literature in the past for synthesis, spectral correlation analysis of the title compounds. Therefore the authors have taken efforts for the synthesis of cyanopyridine to study the quantitative structure activity relationships by spectral correlation through Hammett equation with their Infra-Red and NMR spectral data.

2. EXPERIMENTAL

2. 1. Materials and Systematic methods

All chemicals were used and purchased from Sigma-Aldrich chemical company Bangalore. All synthesized cyanopyridine compounds melting points are observed from uncorrected Sunitex melting point apparatus using open glass capillaries. The above cyanopyridine compounds for Infrared spectra (KBr, 4000-400 cm^{-1}) have been recorded on AVATAR-300 FT-IR spectrophotometer. BRUKER-400MHz NMR spectrometers has been operated for recording ^1H and ^{13}C spectra in CDCl_3 solvent using internal standard as TMS.

2. 2. General procedure for synthesis of cyanopyridine compounds.

According to the literature procedure[17], the cyanopyridine derivatives were prepared and their purities were examined with their physical constants, analytical and spectroscopic data provided. The substituted cyanopyridine structure was shown in Figure 1.

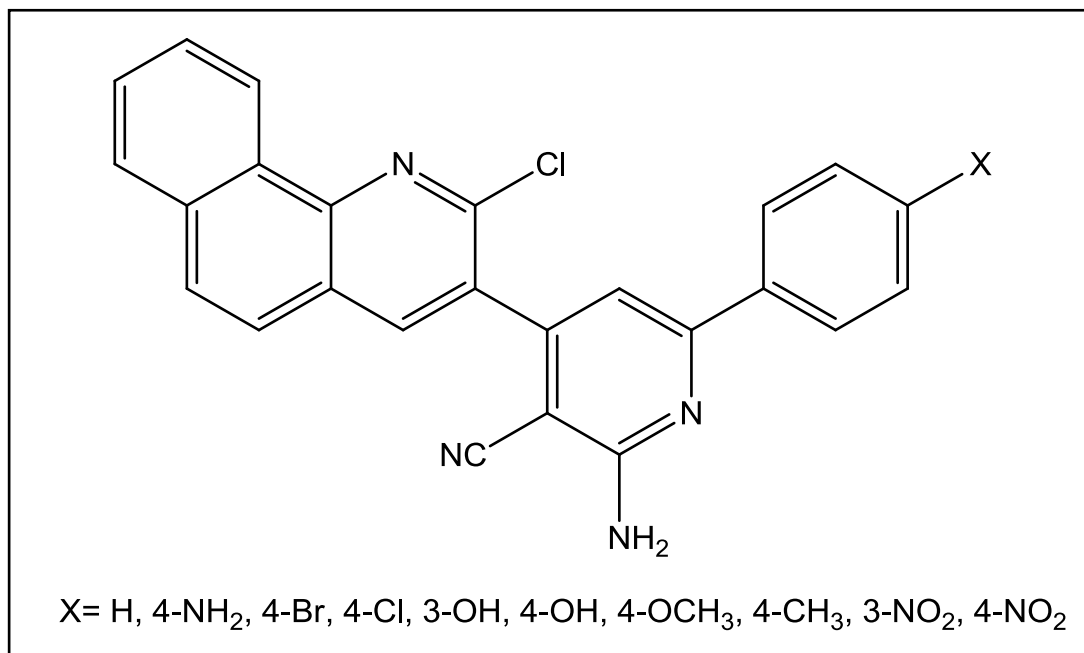


Figure 1. Substituted cyanopyridines

The synthesized substituted cyanopyridine compounds have been characterized by their physical constants, elemental analysis and spectral data. The physical constants, analytical and micro analysis data of these substituted cyanopyridine compounds are shown in Table 1. The spectral data of synthesized substituted cyanopyridine compounds are shown in Table 2.

Table 1. Physical constants, yields and analytical data of substituted cyanopyridine compounds

Entry	X	M. F.	M.W.	Yield (%)	M.p. (°C)	Found (Calcd.) (%)		
						C	H	N
1	H	C ₃₁ H ₁₉ N ₄ Cl	482.96	97	162-163	77.01 (77.09)	3.86 (3.97)	10.98 (11.60)
2	4-NH ₂	C ₃₁ H ₂₀ N ₅ Cl	497.98	93	208-209	74.05 (74.17)	4.00 (4.05)	13.99 (14.06)
3	4-Br	C ₃₁ H ₁₈ N ₄ ClBr	561.86	91	214-215	65.86 (66.27)	3.16 (3.23)	9.45 (9.97)
4	4-Cl	C ₃₁ H ₁₈ N ₄ Cl ₂	517.41	94	234-235	71.14 (71.96)	3.06 (3.51)	10.53 (10.83)
5	3-OH	C ₃₁ H ₁₉ N ₄ ClO	498.96	87	235-236	74.02 (74.62)	3.26 (3.84)	10.98 (11.23)
6	4-OH	C ₃₁ H ₁₉ N ₄ ClO	498.96	91	229-230	74.14 (74.62)	3.44 (3.84)	11.03 (11.23)

7	4-OCH ₃	C ₃₂ H ₂₁ N ₄ ClO	512.99	96	221-222	74.06 (74.92)	3.94 (4.13)	10.08 (10.92)
8	4-CH ₃	C ₃₂ H ₂₁ N ₄ Cl	496.99	92	180-181	87.02 (77.33)	4.14 (4.26)	11.02 (11.27)
9	3-NO ₂	C ₃₁ H ₁₈ N ₅ ClO ₂	527.96	89	201-202	70.24 (70.52)	3.26 (3.44)	13.04 (13.26)
10	4-NO ₂	C ₃₁ H ₁₈ N ₅ ClO ₂	527.96	90	187-188	70.28 (70.52)	3.32 (3.44)	13.18 (13.26)

Table 2. The infrared absorptions (ν , cm⁻¹) and NMR chemical shifts (δ ppm) spectral data of substituted cyanopyridine compounds.

Entry	X	IR ν (cm ⁻¹)			NMR (δ , ppm)			
					¹ H	¹³ C		
		NH ₂	C=N	CN	NH ₂	CN	C-Cl	<i>Cipso</i>
1	H	3309.22	1660.23	2218.39	3.494	163.15	114.07	115.70
2	4-NH ₂	3318.31	1660.77	2212.74	3.468	163.50	116.28	116.74
3	4-Br	3332.09	1660.24	2198.45	3.402	165.48	118.02	118.27
4	4-Cl	3319.42	1660.97	2205.61	3.450	166.20	118.01	119.14
5	3-OH	3306.55	1660.29	2226.78	3.462	162.08	116.68	117.62
6	4-OH	3309.22	1660.27	2207.86	3.476	163.14	117.24	118.40
7	4-OCH ₃	3313.22	1660.77	2195.07	3.836	162.10	112.05	114.54
8	4-CH ₃	3347.63	1660.72	2201.23	3.442	162.14	117.02	118.50
9	3-NO ₂	3313.33	1660.47	2201.23	3.484	164.72	115.73	116.23
10	4-NO ₂	3321.26	1660.27	2208.31	3.446	164.58	116.04	116.66

3. RESULTS AND DISCUSSION

In the current study the spectral linearity of synthesized substituted cyanopyridine compounds has been studied by evaluating the substituent effects. The observed spectral data for the cyanopyridine compounds, infrared NH₂, ν C=N, ν CN, the proton chemical shifts δ (ppm) of NH₂ and carbon chemical shifts of CN, C-Cl and C-R are correlated with various substituent constants.

3. 1. IR spectral study

The assigned infrared frequencies (cm^{-1}) of NH_2 , $\nu\text{C}=\text{N}$, νCN , of substituted cyanopyridine compounds are presented in Table 2. The measured infrared frequency values are correlated [18-20] with Hammett substituent constants and F and R parameters using single and multi-linear regression analysis. Hammett equation employed for the correlation analysis, involving the absorption maxima is as shown below in equation (1).

$$\nu = \rho\sigma + \nu_0 \quad \dots(1)$$

where ν_0 is the frequency for the parent member of the series.

Table 3. The results of statistical analysis of infrared absorptions (ν , cm^{-1}) and NMR chemical shifts (δ ppm) of substituted cyanopyridine compounds with Hammett σ , σ^+ , σ_I , σ_R and F and R parameters.

Freq.	Constt.	r	I	ρ	s	n	Correlated derivatives
Infrared spectral correlations							
NH_2	σ	0.743	3318.97	0.962	13.26	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	σ^+	0.761	3319.77	3.735	12.95	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	σ_I	0.763	3321.76	-8.797	13.07	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	σ_R	0.901	3321.26	12.018	12.91	7	4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃
	F	0.876	3321.96	-9.233	13.06	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	R	0.901	3322.57	9.922	12.41	7	4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃
$\text{C}=\text{N}$	σ	0.801	1660.50	-0.189	0.28	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	σ^+	0.828	1660.47	-0.111	0.28	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	σ_I	0.815	1660.55	-0.180	0.29	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂

	σ_R	0.828	1660.43	-0.334	0.28	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	F	0.821	1660.57	-0.249	0.29	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	R	0.803	1660.49	-0.018	0.29	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
CN	σ	0.865	2207.71	-3.187	10.11	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	σ^+	0.876	2206.84	-3.634	9.84	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	σ_I	0.807	2211.07	-11.238	9.80	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	σ_R	0.814	2206.44	-6.014	10.11	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	F	0.823	2211.34	-11.896	9.78	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	R	0.804	2203.90	-10.242	9.01	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
¹ H NMR Spectral correlations							
NH₂	σ	0.827	3.499	-0.072	0.12	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	σ^+	0.832	3.484	-0.055	0.12	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	σ_I	0.706	3.513	-0.054	0.12	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	σ_R	0.733	3.463	-0.173	0.12	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	F	0.801	3.510	-0.045	0.12	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂

	<i>R</i>	0.816	3.479	-0.046	0.12	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
¹³ C NMR Spectral correlations							
C-NH₂	σ	0.900	163.62	1.827	1.28	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	σ^+	0.906	163.96	1.305	1.19	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	σ_I	0.902	162.42	4.104	1.14	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	σ_R	0.876	164.21	2.713	1.40	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	<i>F</i>	0.906	162.51	3.765	1.24	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	<i>R</i>	0.900	164.34	1.769	1.31	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
CN	σ	0.812	116.08	0.506	1.93	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	σ^+	0.815	116.19	0.398	1.92	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	σ_I	0.802	115.64	1.508	1.91	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	σ_R	0.803	116.15	0.237	1.95	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	<i>F</i>	0.816	115.64	1.475	1.91	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	<i>R</i>	0.804	116.04	0.193	1.95	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
C=N	σ	0.901	117.18	-0.036	1.54	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂

	σ^+	0.835	117.19	0.071	1.53	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	σ_I	0.802	117.12	0.163	1.53	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	σ_R	0.806	117.08	-0.520	1.53	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	<i>F</i>	0.803	117.11	0.209	1.53	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	<i>R</i>	0.811	117.05	0.359	1.53	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
C-Cl	σ	0.902	150.18	0.632	0.95	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	σ^+	0.903	150.30	0.446	0.94	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	σ_I	0.900	149.84	1.183	0.95	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	σ_R	0.809	150.43	1.143	0.95	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	<i>F</i>	0.802	149.31	0.957	0.97	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	<i>R</i>	0.824	150.40	0.510	0.97	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
Cipso	σ	0.904	131.68	-5.436	5.55	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	σ^+	0.904	130.80	-3.163	5.65	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	σ_I	0.901	132.71	-4.122	6.06	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	σ_R	0.904	129.57	-9.966	5.61	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂

	<i>F</i>	0.807	133.33	-5.970	5.97	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
	<i>R</i>	0.901	129.80	-4.547	5.77	10	H, 4-NH ₂ , 4-Br, 4-Cl, 3-OH, 4-OH, 4-OCH ₃ , 4-CH ₃ , 3-NO ₂ , 4-NO ₂
<p><i>r</i> = correlation co-efficient; ρ = slope; <i>I</i> = intercept; <i>s</i> = standard deviation; <i>n</i> = number of substituents</p>							

3. 1. 1. IR Spectral Correlation of NH₂ (cm⁻¹)

From the Table 3, it is evident that the IR frequency ν_{NH_2} (cm⁻¹) values of all substituted cyanopyridine compounds have satisfactory correlations with Hammett substituent constants and σ_{R} ($r = 0.901$) and *R* ($r = 0.901$) parameter. However, the IR frequency ν_{NH_2} (cm⁻¹) values of substituted cyanopyridine compounds, have shown poor correlation ($r < 0.900$) with remaining Hammett substituent constants σ , σ^+ , σ_{I} and *F* parameter.

This is attributed to the weak polar, inductive and field effects of substituents for predicting the reactivity on the IR frequency ν_{NH_2} (cm⁻¹) through resonance as per the conjugative structure as shown in Figure 2.

All the correlations have shown positive ρ values except σ_{I} and *F* parameter. This indicates the operation of normal substituent effect with respect to IR frequency ν_{NH_2} (cm⁻¹) values in all substituted compounds.

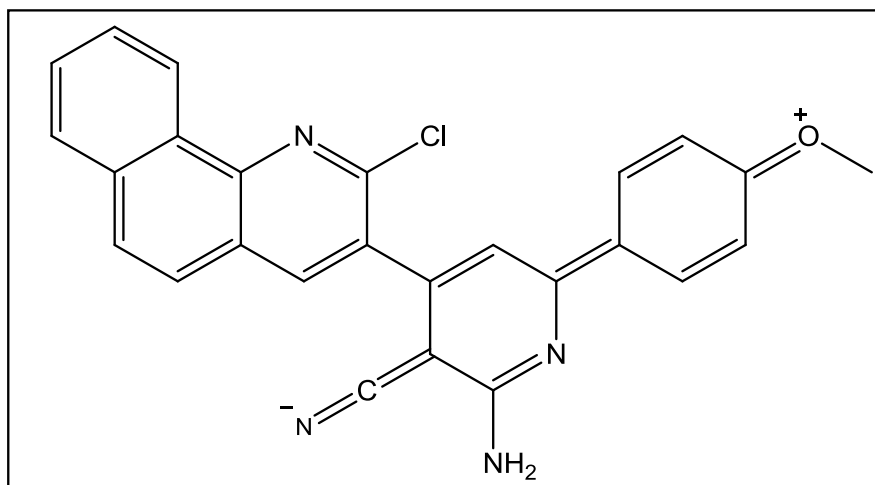


Figure 2. Resonance conjugative structure of cyanopyridine compounds

3. 1. 2. IR Spectral Correlation of $\nu_{\text{C}=\text{N}}$ (cm⁻¹)

From the Table 3, it is evident that the IR frequency $\nu_{\text{C}=\text{N}}$ (cm⁻¹) values of all substituted cyanopyridine compounds have shown poor correlations ($r < 0.900$) with Hammett substituent constants and *F* and *R* parameters. This is due to weak polar, inductive, field and

resonance effects of substituents for predicting the reactivity on the IR frequency $\nu\text{C}=\text{N}$ (cm^{-1}) through resonance as per the conjugative structure as shown in Figure 2.

All the correlations have shown negative ρ values. This indicates the operation of reverse substituent effect with respect to IR frequency $\nu\text{C}=\text{N}$ (cm^{-1}) values in all substituted compounds.

3. 1. 3. IR Spectral Correlation of νCN (cm^{-1})

From the Table 3, it is evident that the IR frequency $\nu\text{C}=\text{N}$ (cm^{-1}) values of all substituted cyanopyridine compounds have shown poor correlations ($r < 0.900$) with Hammett substituent constants and F and R parameters. This is due to weak polar, inductive, field and resonance effects of substituents for predicting the reactivity on the IR frequency νCN (cm^{-1}) through resonance as per the conjugative structure as shown in Figure 2.

All the correlations have shown negative ρ values. This indicates the operation of reverse substituent effect with respect to IR frequency νCN (cm^{-1}) values in all substituted compounds.

Selective single Hammett plots are shown in Figures 3 and 4. Some of the single parameter correlations failed for the IR frequency νNH_2 , $\nu\text{C}=\text{N}$ and νCN (cm^{-1}) values with Hammett substituent constants and F and R parameter, it is decided to go for multi regression analysis with Swain-Lupton's [21] parameters. While seeking the multi regression analysis there is satisfactory correlations are observed as shown in the following equations (2 to 7).

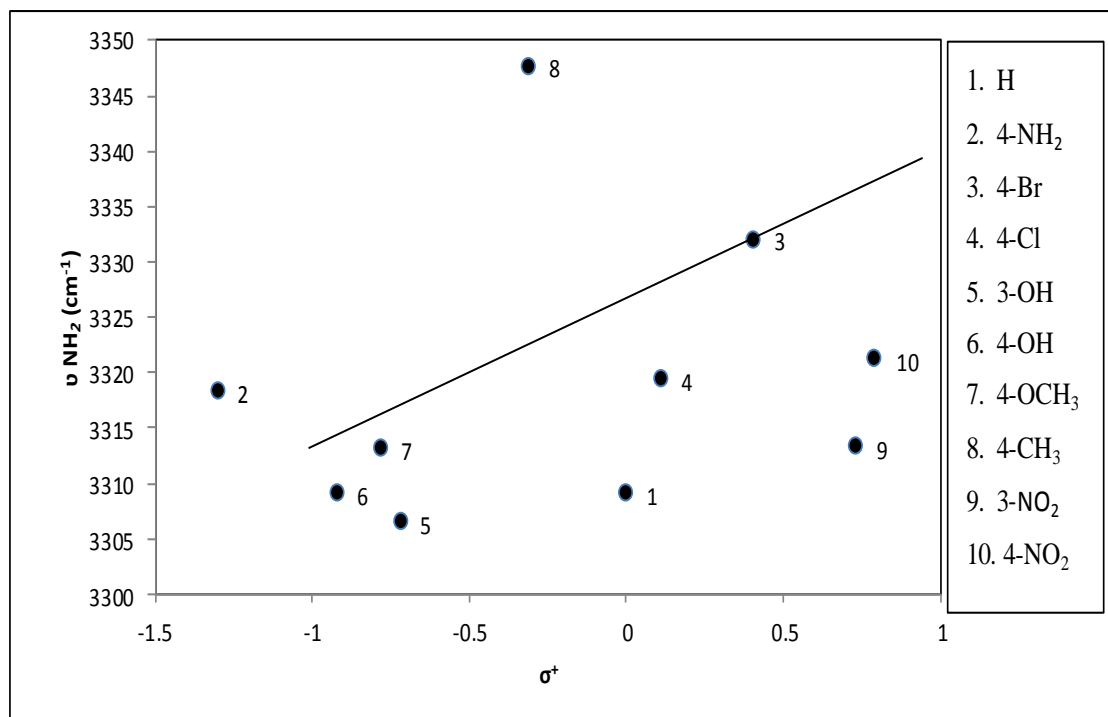


Figure 3. Plot of IR NH_2 (cm^{-1}) values of substituted cyanopyridine compound Vs σ^+

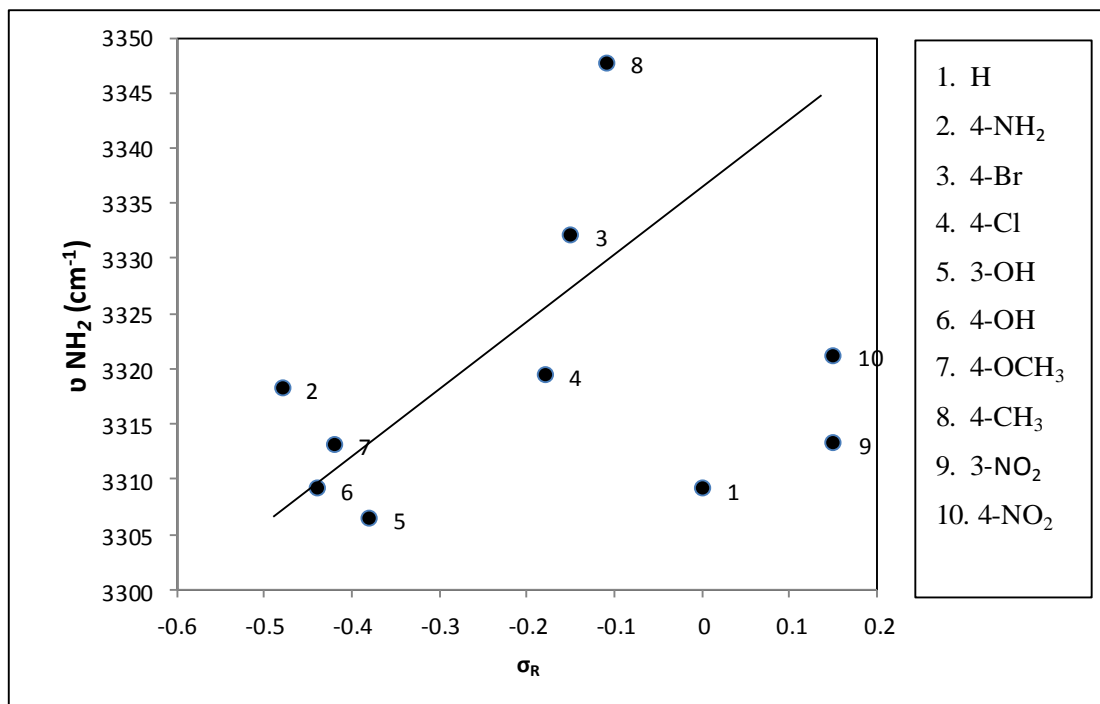


Figure 4. Plot of IR NH₂ (cm⁻¹) values of substituted cyanopyridine compound Vs σ_R

3. 2. NMR spectral study

In nuclear magnetic resonance spectra, the proton and the ¹³C chemical shifts (δ) depends on the electronic environment of the nuclei concerned. The assigned chemical shifts (ppm) have been correlated with reactivity parameters using Hammett equation [18-20] in the form of equation (8)

$$\delta = \rho\sigma + \delta_0 \quad \dots(8)$$

where δ_0 is the frequency for the parent member of the series.

3. 2. 1. ¹H NMR Spectral Correlation

3. 2.1. 1. ¹H NMR Spectral Correlations of NH₂ (ppm)

From the Table 3, the assigned NH₂ chemical shifts (δ ppm) values of substituted cyanopyridine compounds have shown poor correlations ($r < 0.900$) with Hammett substituent constants σ , σ^+ , σ_I , σ_R , and F and R parameters. This is due to weak polar, inductive, field and resonance effects of substituents for predicting the reactivity on the chemical shifts NH₂ (δ ppm) through resonance as per the conjugative structure as shown in Figure 2. All the correlations have shown negative ρ values. This indicates the operation of reverse substituent effect with respect to NMR spectral values (ppm) values in all substituted cyanopyridine compounds. Some of the single Hammett plots are shown in Figures 5 and 6. All the single parameter correlations analyses give failed for the ¹H –NH₂ chemical shifts (δ ppm) values of substituted cyanopyridine compounds with Hammett substituent constants and F and R

parameter, it is decided to go for multi regression analysis with Swain-Lupton's [36] parameters. While seeking the multi regression analysis there is satisfactory correlations are observed as shown in the following equations (9) and (10).

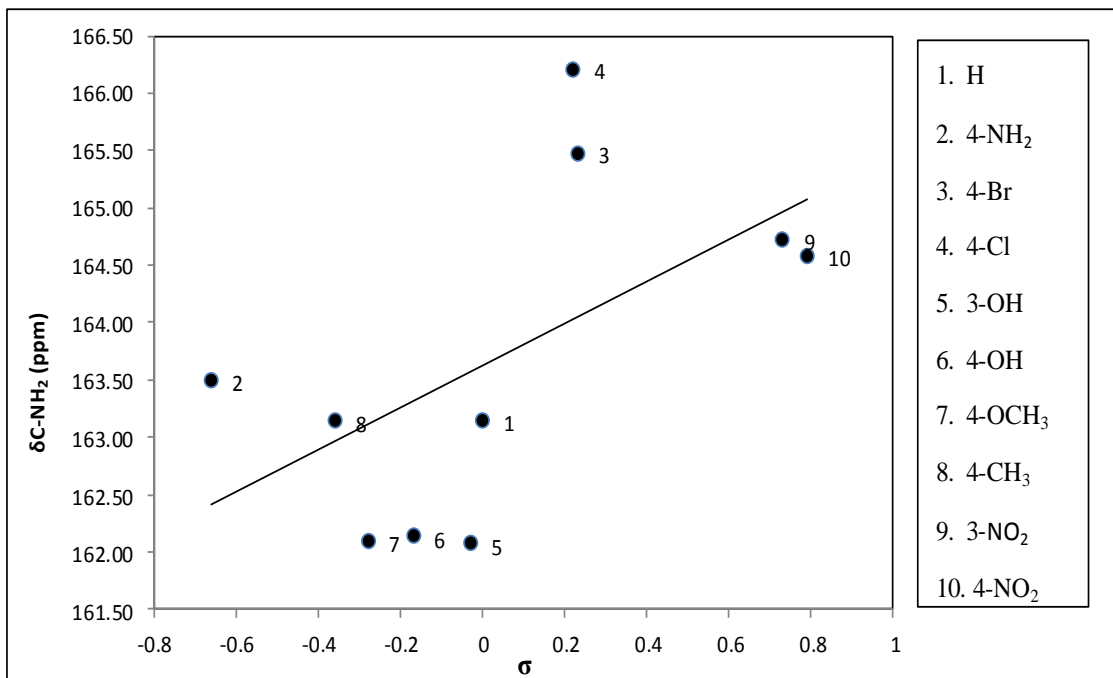


Figure 5. Plot of ^{13}C NMR C-NH₂ (ppm) of substituted cyanopyridines Vs σ

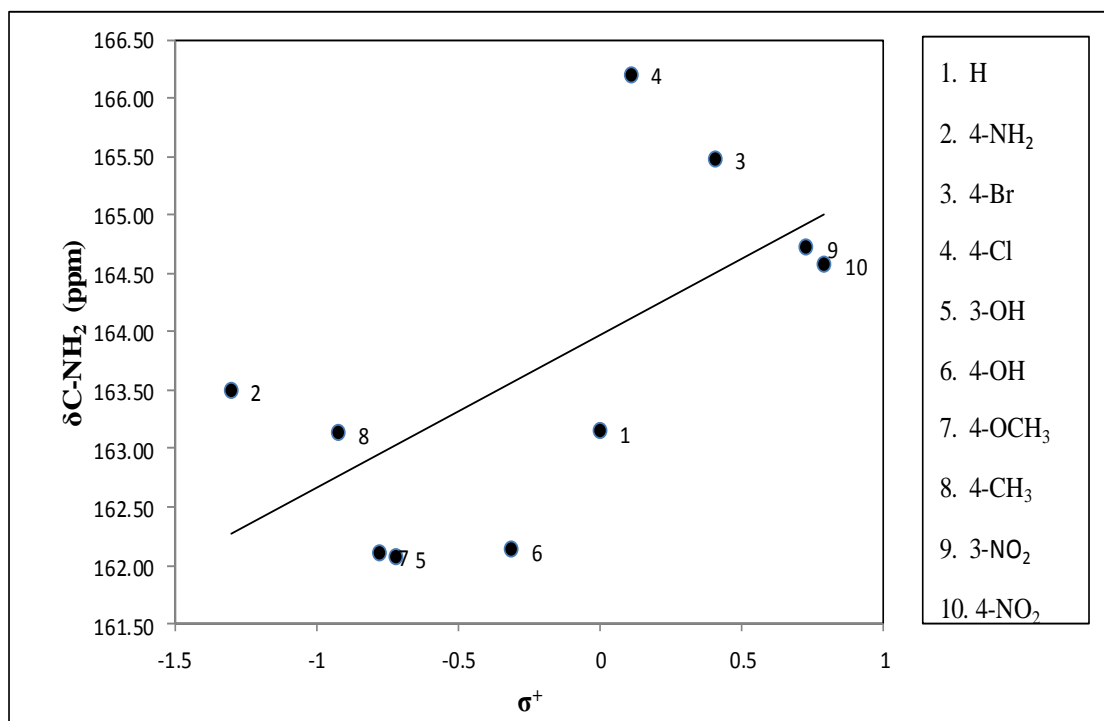


Figure 6. Plot of ^{13}C NMR C-NH₂ (ppm) of substituted cyanopyridines Vs σ^+

$$\delta^1\text{H} -\text{NH}_2(\text{ppm}) = 3.453(\pm 0.095) + 0.025(\pm 0.198)\sigma_{\text{I}} - 0.185(\pm 0.203)\sigma_{\text{R}} \quad \dots(9)$$

(r = 0.934, n = 10, P > 90%)

$$\delta^1\text{H} -\text{NH}_2(\text{ppm}) = 3.487(\pm 0.095) - 0.020(\pm 0.203)F - 0.042(\pm 0.107)R \quad \dots(10)$$

(r = 0.917, n = 10, P > 90%)

3. 3. ¹³C NMR Spectral Correlation

3. 3. 1. ¹³C NMR Spectral Correlations of C-NH₂ (ppm)

From the Table 3, the assigned C-NH₂ chemical shifts (δ ppm) values of cyanopyridine compounds have shown satisfactory correlations with Hammett substituent constants σ (r = 0.900), σ⁺ (r = 0.906), σ_I (r = 0.902) and F (r = 0.906) and R (r = 0.900) parameters.

However, the C-NH₂ chemical shifts(δ ppm) values of substituted cyanopyridine compounds, have shown poor correlation (r < 0.900) with remaining Hammett substituent constant σ_R. This is due to weak resonance effect of substituents for predicting the reactivity on the chemical shifts C-NH₂ (δ ppm) values through resonance as per the conjugative structure as shown in Figure 2.

All the correlations have shown positive ρ values. This indicates the operation of normal substituent effect with respect to NMR spectral values (ppm) values in all substituted cyanopyridine compounds.

3. 3. 2. ¹³C NMR Spectral Correlations of CN (ppm)

From the Table 3, the assigned CN chemical shifts (δ ppm) values of substituted cyanopyridine compounds have shown poor correlations (r < 0.900) with Hammett substituent constants σ, σ⁺, σ_I, σ_R, and F and R parameters.

This is due to weak polar, field, inductive, field and resonance effects of substituents for predicting the reactivity on the chemical shifts CN (δ ppm) values through resonance as per the conjugative structure as shown in Figure 2.

All the correlations have shown positive ρ values except R parameter. This indicates the operation of normal substituent effect with respect to NMR spectral values (ppm) values in all substituted cyanopyridine compounds.

3. 3. 3. ¹³C NMR Spectral Correlations of C=N (ppm)

From the Table 3, the assigned C=N chemical shifts (δ ppm) values of substituted cyanopyridine compounds have shown satisfactory correlation with Hammett substituent constant σ (r = 0.901).

However, the chemical shifts (δ ppm) C=N (δ ppm) values of substituted cyanopyridine compounds, have shown poor correlations (r < 0.900) with remaining Hammett substituent constants σ⁺, σ_I, σ_R and F and R parameters. This is due to weak polar, field, inductive and resonance effects of substituents for predicting the reactivity on the chemical shifts C=N (δ ppm) values through resonance as per the conjugative structure as shown in Figure 2.

All the correlations have shown positive ρ values except σ and R parameter. This indicates the operation of normal substituent effect with respect to NMR spectral values (ppm) values in all substituted cyanopyridine compounds.

3.3.4. ^{13}C NMR Spectral Correlations of C-R (ppm)

From the Table-3, the assigned C-R chemical shifts (δ ppm) values of substituted cyanopyridine compounds have shown satisfactory correlation with Hammett substituent constants σ ($r = 0.902$), σ^+ ($r = 0.903$) and σ_I ($r = 0.900$).

However, the chemical shifts (δ ppm) C-R (δ ppm) values of substituted cyanopyridine compounds, have shown poor correlations ($r < 0.900$) with remaining Hammett substituent constant σ_R and F and R parameters. This is due to weak field and resonance effects of substituents for predicting the reactivity on the chemical shifts C-R (δ ppm) values through resonance as per the conjugative structure as shown in Figure-2.

All the correlations have shown positive ρ values. This indicates the operation of normal substituent effect with respect to NMR spectral values (ppm) values in all substituted cyanopyridine compounds.

Some selective single Hammett linear plots are shown in Figures 7 and 8. Some of the single parameter correlations failed for ^{13}C C-NH₂, CN, C=N and C-R chemical shifts(δ ppm) values of substituted cyanopyridine compounds with Hammett substituent constants and F and R parameter, it is decided to go for multi regression analysis with Swain-Lupton's [21] parameters. While seeking the multi regression analysis there is satisfactory correlations are observed as shown in the following equations (11-20).

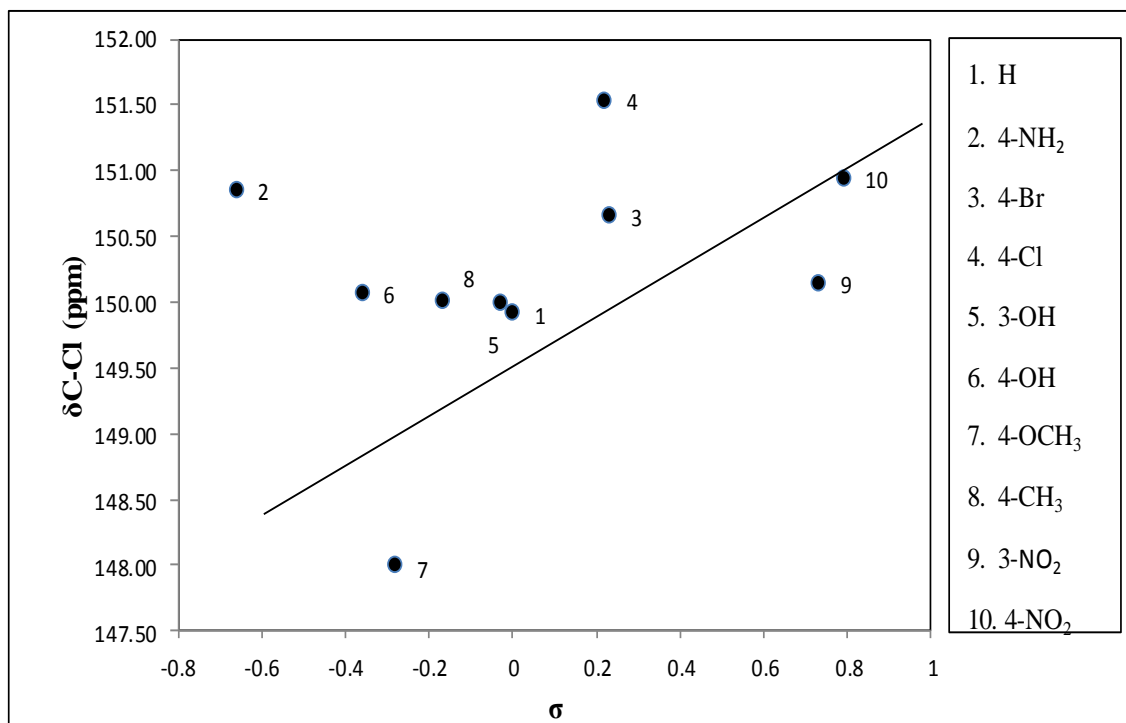


Figure 7. Plot of ^{13}C NMR C-Cl(ppm) values of substituted cyanopyridine compound Vs σ

$$\delta^{13}\text{C} \text{-NH}_2 \text{ (ppm)} = 162.762(\pm 0.872) + 3.652(\pm 1.818)\sigma_I + 1.040(\pm 1.867)\sigma_R \dots (11)$$

($r = 0.969$, $n = 10$, $P > 95\%$)

$$\delta^{13}\text{C} \text{-NH}_2 \text{ (ppm)} = 163.203(\pm 0.827) + 3.012(\pm 1.762)F + 1.263(\pm 0.935)R \quad (12)$$

(r = 0.970, n = 10, P > 95%)

$$\delta^{13}\text{C} \text{ CN (ppm)} = 115.460(\pm 1.489) + 1.755(\pm 3.105)\sigma_I - 0.566(\pm 3.189)\sigma_R \quad \dots(13)$$

(r = 0.922 n = 10, P > 90%)

$$\delta^{13}\text{C} \text{ CN (ppm)} = 115.375(\pm 1.422) + 1.768(\pm 3.028)F - 0.490(\pm 1.607)R \quad \dots(14)$$

(r = 0.922, n = 10, P > 90%)

$$\delta^{13}\text{C} \text{ C=N (ppm)} = 116.889(\pm 1.194) + 0.486(\pm 2.490)\sigma_I - 0.743(\pm 2.557)\sigma_R \quad \dots(15)$$

(r = 0.911, n = 10, P > 90%)

$$\delta^{13}\text{C} \text{ C=N (ppm)} = 116.873(\pm 1.140) + 0.470(\pm 2.428)F - 0.438(\pm 1.288)R \quad \dots(16)$$

(r = 0.913, n = 10, P > 90%)

$$\delta^{13}\text{C} \text{ C-Cl (ppm)} = 150.09(\pm 0.731) + 0.857(\pm 1.524)\sigma_I + 0.750(\pm 5.660)\sigma_R \quad \dots(17)$$

(r = 0.903, n = 10, P > 90%)

$$\delta^{13}\text{C} \text{ C-Cl (ppm)} = 150.126(\pm 0.713) + 0.726(\pm 1.519)F + 0.388(\pm 0.806)R \quad \dots(18)$$

(r = 0.907, n = 10, P > 90%)

$$\delta^{13}\text{C} \text{ C-R (ppm)} = 129.476(\pm 4.385) + 0.257(\pm 9.141)\sigma_I - 10.085(\pm 9.387)\sigma_R \quad \dots(19)$$

(r = 0.901, n = 10, P > 90%)

$$\delta^{13}\text{C} \text{ C-R (ppm)} = 131.174(\pm 4.261) - 3.622(\pm 9.072)F - 3.939(\pm 4.815)R \quad \dots(20)$$

(r = 0.971, n = 10, P > 95%)

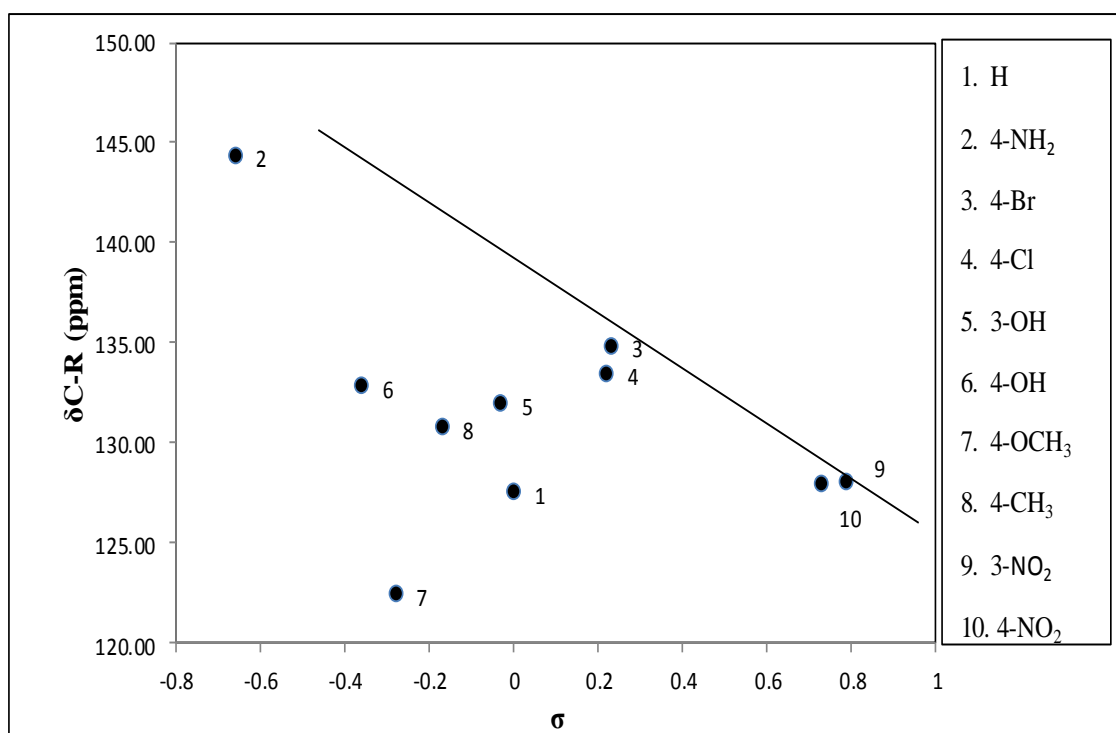


Figure 8. Plot of ¹³C NMR C-R (ppm) values of substituted cyanopyridine compound Vs σ

4. CONCLUSIONS

A series of ten numbers of substituted cyanopyridine compounds have been synthesized by condensation of pyridine and substituted benzaldehydes. These synthesized substituted cyanopyridine compounds have been characterized by their physical constants, spectral data. The FT-IR and NMR spectral data of these substituted cyanopyridine compounds have been correlated with Hammett substituent constants and F and R parameters. From the results of statistical analyses the effects of substituent on the spectral data have been studied. The ^{13}C NMR spectral correlations produced most number of satisfactory correlations. However, all the FT-IR, ^1H and ^{13}C NMR for multi-regression analyses have shown satisfactory correlations.

References

- [1] D. H. Vyas, S. D. Tala, J. D. Akbari, M. F. Dhaduk, K. A. Joshi and H. S. Joshi, *Ind. J Chem.* 48B (2009) 833
- [2] S. M. Kelly, J. Funfschilling, A. Villiger and C. Smectic, *Liq. Cryst.* 14 (1993) 1169
- [3] S. M. Kelly and J. Funfschilling, *J. Liq. Cryst.* 20 (1996) 77
- [4] Y. A. Getmanenko, R. J. Twieg and B. D. Ellman, *Liq. Cryst.* 33 (2006) 267
- [5] T. Asano, M. Uenoyama, K. Moriya, S. Yano, S. Takatani and S. Kagabu, *Liq. Cryst.* 23 (1997) 365
- [6] T. Asano, K. Moriya, S. Yano, S. Takatani and S. Kagabu, *Liq. Cryst.* 25 (1998) 263
- [7] K. Moriya, F. Harada, S. Yano and S. Kagabu, *Liq. Cryst.* 27 (2000) 1647
- [8] G. H. A. Elfatoon G., N. A. El-Hafeza, Z. Wandall and B. Naturforsch, *Chem. Sci.* 55B (2000) 834
- [9] M. Movassaghi, M. D. Hill and O. K. Ahmad, *J. Am. Chem. Soc.* 129 (2007) 10096
- [10] G. Jones, Editor, *Heterocyclic Chemistry-II*, Elsevier Science, Oxford, 8 (1996) 1109
- [11] G. D. Henry, *Tetrahedron.* 90 (2004) 6043
- [12] P. M. Joseph, *Natural Product Reports.* 22 (5) (2005) 627
- [13] C. J. Temple, G. A. Rener, W. R. Waud and P. E. Noker, *J. Med. Chem.* 35 (1992) 3686
- [14] C. O. Budgett and C. F. Woodward, *J. Am. Chem. Soc.* 69 (1947) 2907
- [15] J. Mercier, M. Gavend, V. Vanluv and S. Dessaigne, *Congr Unionther Int [CR]*, 8 (1963) 361
- [16] G. Dorner and F. W. Fischer, *Arezenmittel Forch.* 11 (1961) 110
- [17] S. Baluja, J. Movaliya and P. Ramavat, *World Scientific News* 60 (2016) 113
- [18] R. Suresh, D. Kamalakkannan, K. Ranganathan, R. Arulkumaran, R. Sundararajan, S. P. Sakthinathan, S. Vijayakumar, K. Sathiyamoorthi, V. Mala, G. Vanangamudi, K. Thirumurthy, P. Mayavel, G. Thirunarayanan, *Spectrochim. Acta* 101A (2013) 239

- [19] R. Arulkumaran, S. Vijayakumar, S. P. Sakthinathan, D. Kamalakkannan, K. Ranganathan, R. Suresh, R. Sundararajan, G. Vanangamudi, G. Thirunarayanan, *J. Chil. Chem. Soc.* 58(2) (2013) 1670
- [20] S. P. Sakthinathan, R. Suresh, V. Mala, K. Sathiyamoorthi, D. Kamalakkannan, K. Ranganathan, S. John joseph, *Int. J. Sci. Res. Know.* 1(11) (2013) 472
- [21] C. G. Swain, E. C. Lupton, *J. Am. Chem. Soc.* 90 (1968) 4328

(Received 25 June 2017; accepted 15 July 2017)