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Effect of substituents on 4-(substituted phenyl sulfonamide)benzoic acids by IR and NMR spectra

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ABSTRACT

About nine 4-(substituted phenyl sulfonamide) benzoic acid derivatives were synthesized by ultrasound irradiation method. The synthesized sulfonamides were characterized by their physical constants and spectroscopic data. The characteristic infrared SOsym, SOasym, NH and CO vibrations (ν, cm^{-1}), the chemical shifts (δ, ppm) of NH and CO of sulfonamides were assigned and correlated with various Hammett substituent constants and Swain-Lupton parameters using single and multi-regression analysis. From the results of the statistical analysis, the effects of substituents on the spectral frequencies were discussed.

***Keywords*:** 4-(substituted phenyl sulfonamide) benzoic acids, IR and NMR spectra, Hammett correlations, Regression analysis

1. INTRODUCTION

QSAR, QPR and SAR studies are very informative for analyzing the electronic effects of the chemical substituents on the molecule by statistical regression analysis [1]. The Hammett equation was employed in the form of regression equation for analyzing the study. The characteristic spectral data, rate constants, equilibrium constants or any other numerical

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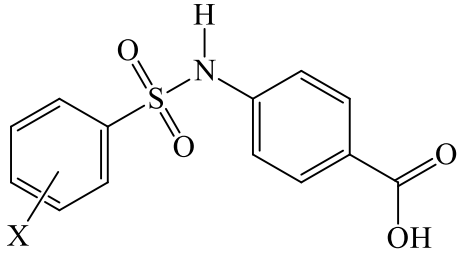
quantities were applied for the regression analysis with substituent constants or Swain-Lupton constants whether single or multi-regression analysis. From infrared spectral frequencies (ν, cm^{-1}) of characteristic functional groups such as CO, C=N, OH, NH, C-S, S=O, SO_2, NO, NO_2, C=C, CH, CH=CH deformations, LD_{50}, and Bio-potentials also used for the study of QSAR, QPR and SAR studies. From the infrared spectral study, the molecular equilibration of carbonyl compounds is investigated [2]. The symmetric and asymmetric stretches of the sulfonamides also observable. Finally, the electronic effects of the substituents on the respected functional group of the reaction center will be predicted. Researchers have been investigated various compounds containing sulfonamide moieties. They are tryptamine [3], chalcone [4], adamantine [5], azetidinone [6], carbazole [7], catenane [8], cinnamic acyl [9], coumarin [10], cyanopyridines, isoxazoles, pyrazoles, pyrimidines [11], epipodophyllotoxin [12], furan containing vinyl sulphonamides [13], isoquinoline sulphonamide [14], oxazolidinones [15], quinolone [16], thiadiazole [17], thiazole, pyridone, chromene, hydrazine [18], thiouracil [19] and triazole [20]. Numerous synthetic methodologies of sulfonamides were reported in literature. Recently Thirunarayanan *et al*. [21] had improved the method of synthesis of N-[(*E*)-phenyl methylidene] benzenesulfonamide by microwave-irradiation with solid SiO_2-H_3PO_4 catalyst. Lee *et al.* [22] have synthesised some chiral sultams via sulfonamide dianion alkylation method. Tsai *et al.* [23] reported the novel route for synthesized N–tosylhydrazones with 2 equivalents of respected amines in the presence of DABSO catalyst in DMSO solvent at 100ºC yielded the corresponding sulfonamides. Shaabani *et al.* [24] have synthesized some alkyl and aryl sulfonamides with novel approaches, by the reaction of sulfonic acids, isocyanides and water in dichloromethane at ambient temperature. Lee *et al.* [25] synthesized five different sulfonamides from sulfonate ester resin and various amines in THF solvent. There is no report available for the study of spectral qsar of the sulfonamides with Hammett equation. Hence the authors have taken efforts for study the spectral QSAR of 4-(substituted phenylsulfonamido) benzoic acids by synthesis and recorded their IR and NMR spectra.

2. EXPERIMENTAL

In the present investigations, all the 4-(substituted phenylsulfonamido) benzoic acids prepared and their purities were analyzed by their data reported in literature [26]. The structure of the 4-(substituted phenylsulfonamido) benzoic acids was shown in Figure 1. The infrared and NMR spectral data of the 4-(substituted phenylsulfonamido) benzoic acids were presented in Table 1.



X= H, 4-Br, 4-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2

Figure 1. 4-(substituted phenylsulfonamido) benzoic acids

Table 1. Infrared and NMR spectral data of 4-(substituted phenylsulfonamido) benzoic acids

Entry	X	IR				^{1}H NMR	^{13}CNMR
		ν_{N-H} (cm^{-1})	$\nu_{(C=O)}$ (cm^{-1})	$\nu_{(SO)sym}$ (cm^{-1})	$\nu_{(SO)asym}$ (cm^{-1})	δNH (ppm)	$\delta_{C=O}$ (ppm)
1	H	3272.0	1677.6	1332.5	1163.3	10.824	167.19
2	4-Br	3263.0	1680.3	1337.6	1161.2	10.913	167.19
3	4-Cl	3258.0	1678.4	1336.8	1161.6	10.901	167.16
4	2-F	3258.3	1700.2	1336.7	1150.2	10.364	167.50
5	4-F	3247.3	1693.0	1334.9	1159.2	11.083	167.21
6	4-OCH_3	3264.5	1700.4	1332.6	1150.2	10.700	167.26
7	4-CH_3	3215.9	1707.4	1336.1	1154.8	11.116	167.17
8	2-NO_2	3213.4	1697.8	1336.2	1162.4	11.234	167.14
9	4-NO_2	3257.7	1677.1	1338.4	1162.0	11.128	167.13

3. RESULTS AND DISCUSSION

3. 1. Infrared correlation

The assigned infrared stretching frequencies of all the 4-(substituted phenylsulfonamido) benzoic acid compounds are presented in **Table 1** are correlated with different substituent constants and Swain-Lupton's [27] *F* and *R* parameters according to the approach of Jaffe [28] and Stewart [29]. The results of the statistical analysis are presented in **Table 2**.

Table 2. Results of statistical analysis of infrared frequencies ν_{N-H}, $\nu_{SO(asym)}$, $\nu_{SO(sym)}$, $\nu_{(C=O)}$ (cm^{-1}) and NMR chemical shifts (δ, ppm) of 4-(substituted phenylsulfonamido)benzoic acids with Hammett substituent constants (σ, σ^+, σ_I, σ_R), *F* and *R* parameters.

Freq.	Constt.	r	I	ρ	s	n	Correlated derivatives
νNH	σ	0.902	3252.76	-13.105	21.94	7	H, 4-Br, 4-Cl, 2-F, 4-F, 4-OCH_3, 2-NO_2
	σ^+	0.715	3250.85	-5.295	22.37	9	H, 4-Br, 4-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2

	σ_I	0.902	3250.78	-1.996	22.56	7	H, 4-Br, 4-Cl, 2-F, 4-F, 4-OCH_3, 4-NO_2
	σ_R	0.773	3245.64	-25.858	21.5	9	H, 4-Br, 4-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2
	F	0.902	3250.82	-1.84	22.56	7	H, 4-Br, 4-Cl, 2-F, 4-F, 4-OCH_3, 4-NO_2
	R	0.702	3245.54	-19.251	21.732	9	H, 4-Br, 4-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2
$\nu_{(SO)}$ asym	σ	0.916	1334.99	3.605	1.65	8	H, 4-Br, 4-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3,4-NO_2
	σ^+	0.957	1335.29	2.908	1.5	8	4-Br, 4-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2
	σ_I	0.915	1333.93	4.694	1.78	8	H, 4-Br, 4-Cl, 2-F, 4-F, 4-OCH_3, 2-NO_2, 4-NO_2
	σ_R	0.83	1336.18	2.524	2.09	9	H, 4-Br, 4-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2
	F	0.905	1334.18	3.55	1.88	8	H, 4-Br, 4-Cl, 2-F, 4-F, 4-OCH_3, 2-NO_2, 4-NO_2
	R	0.829	1336.23	2.073	2.1	9	H, 4-Br, 4-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2
$\nu_{(SO)}$ sym	σ	0.905	1156.74	7.499	4.707	6	H, 4-Br, 4-Cl, 4-F, 4-OCH_3, 4-CH_3
	σ^+	0.904	1157.54	4.903	4.895	6	H, 4-Br, 4-Cl, 4-F, 4-OCH_3, 4-CH_3
	σ_I	0.902	1156.67	4.248	5.47	6	4-Br, 4-Cl, 4-F, 4-OCH_3, 2-NO_2, 4-NO_2
	σ_R	0.917	1160.86	15.061	3.91	8	H, 4-Br, 4-Cl, 2-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2
	F	0.802	1158.55	-0.523	5.59	9	H, 4-Br, 4-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2
	R	0.917	1161.4	13.279	3.69	8	H, 4-Br, 4-Cl, 2-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2
$\nu_{(C=O)}$	σ	0.834	1692.54	-10.939	11.93	9	H, 4-Br, 4-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2
	σ^+	0.836	1691.59	-8.48	11.82	9	H, 4-Br, 4-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2

	σ_I	0.821	1694.06	-9.828	12.43	9	H, 4-Br, 4-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2
	σ_R	0.84	1686.99	-19.225	11.656	9	H, 4-Br, 4-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2
	F	0.8	1690.34	-0.232	12.722	9	H, 4-Br, 4-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2
	R	0.845	1686.02	-18.155	11.35	9	H, 4-Br, 4-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2
δNH	σ	0.903	10.859	0.279	0.263	8	H, 4-Br, 4-Cl, 4-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2
	σ^+	0.917	10.903	0.092	0.280	8	H, 4-Br, 4-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2
	σ_I	0.913	10.862	0.143	0.280	6	H, 4-Br, 4-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2
	σ_R	0.963	11.034	0.689	0.220	8	H, 4-Br, 4-Cl, 2-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2
	F	0.906	10.943	-0.056	0.285	6	H, 4-Br, 4-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2
	R	0.962	11.048	0.561	0.224	8	H, 4-Br, 4-Cl, 2-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2
δCO	σ	0.924	167.23	-0.074	0.11	8	H, 4-Br, 4-Cl, 4-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2
	σ^+	0.901	167.21	-0.004	0.12	8	H, 4-Br, 4-Cl, 4-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2
	σ_I	0.802	167.21	0.012	0.12	9	H, 4-Br, 4-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2
	σ_R	0.916	167.16	-0.317	0.08	8	H, 4-Br, 4-Cl, 4-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2
	F	0.832	161.16	0.120	0.11	9	H, 4-Br, 4-Cl, 4-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2

	R	0.916	167.15	-0.266	0.08	8	H, 4-Br, 4-Cl, 4-F, 4-OCH_3, 4-CH_3, 2-NO_2, 4-NO_2
r = correlation coefficient; I = intercept; ρ = slope; s = standard deviation; n = number of substituents							

3. 1. 1. Correlation of ν_{N-H} (cm^{-1}) stretches

From the **Table 2**, it is evident that the infrared frequency (ν_{N-H}, cm^{-1}) values of all the 4-(substituted phenylsulfonamido) benzoic acid compounds except those with 4-CH_3 and 4-NO_2 substituent, have shown satisfactory correlation with Hammett substituent constant σ (r = 0.917). The infrared frequency (ν_{N-H},cm^{-1}) values of all 4-(substituted phenylsulfonamido) benzoic acids xcept those with 4-CH_3 and 2-NO_2 substituents, have shown satisfactory correlation with Hammett substituent constant σ_I (r = 0.902) and *F* (r = 0.900) parameter.

However the infrared frequency (ν_{N-H}, cm^{-1}) values of substituted 4-(phenylsulfonamido) benzoic acid compounds have shown poor correlations (r < 0.900) with the remaining Hammett substituent constant σ^+, σ_R and *R* parameter. This is attributed to the weak inductive, field and resonance effects of the substituents for predicting the reactivity on the infrared stretching frequency of ν_{N-H} (cm^{-1}) values through resonance as per the conjugative structure as shown in **Figure 2.**

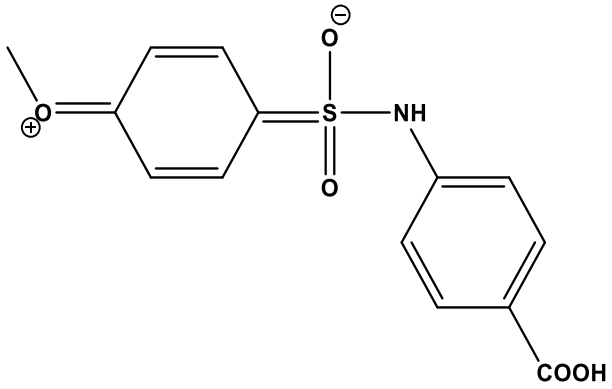


Figure 2. Resonance-conjugative structure

All the correlations with Hammett substituent constants (σ, σ^+, σ_I, σ_R), *F* and *R* parameters have shown negative ρ values. This indicates the operation of reverse substituent effect with respect to infrared frequency ($\nu_{N-H,}$ cm^{-1}) values of 4-(substituted phenylsulfonamido)benzoic acid compounds.

Some of the single parameter correlations are shown in **Figures 3** and **4**.

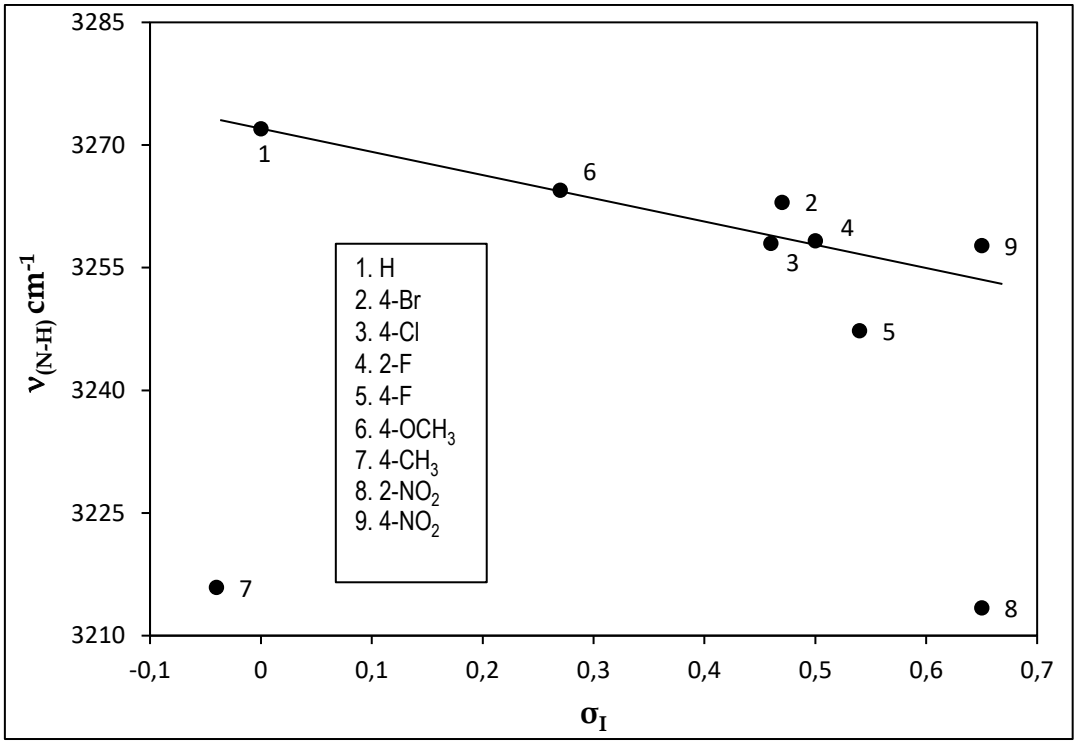


Figure 3. Plot of ν_{N-H} (cm^{-1}) of 4-(substituted phenylsulfonamido)benzoic acids Vs σ_I

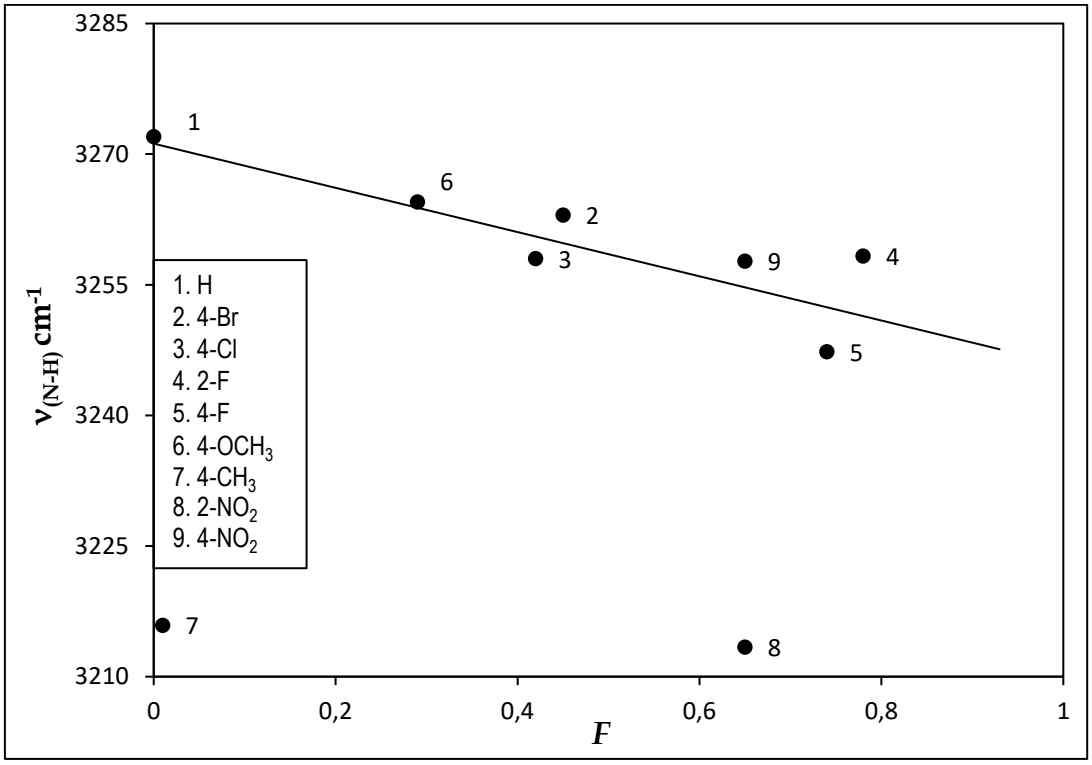


Figure 4. Plot of ν_{N-H} (cm^{-1}) of 4-(substituted phenylsulfonamido)benzoic acids Vs *F*.

Since most of the single regression analyses, have shown poor correlations with Hammett substituent constants (σ, σ^+, σ_I, σ_R), *F* and *R* parameters. It is decided to go for multi regression analysis. The multi regression analysis of the stretching frequency (ν_{N-H}, cm^{-1}) values of all aryl sulfonamide compounds with inductive, resonance and Swain-Lupton's [27] parameters produce satisfactory correlations as shown in **Equations 1** and **2**:

$$\nu_{N-H}\,(cm^{-1}) = 3245.96(\pm15.855) - 0.802(\pm1.859)\sigma_I - 25.818(\pm3.127)\sigma_R$$
$$(R = 0.930,\ n = 9,\ P > 90\%) \quad \ldots \quad (1)$$

$$\nu_{N-H}\,(cm^{-1}) = 3248.11(\pm15.138) - 6.600(\pm2.793)F - 20.756(\pm2.716)R$$
$$(R = 0.928,\ n = 9,\ P > 90\%) \quad \ldots \quad (2)$$

3. 1. 2. Correlation of $\nu_{SO(asym)}$ (cm^{-1}) stretches

From the Table 2, it is evident that the infrared frequency ($\nu_{SO(asym)}$, cm^{-1}) values of all the 4-(substituted phenylsulfonamido) benzoic acid compounds except those with 2-NO_2 substituent, have shown satisfactory correlation with Hammett substituent constant σ (r = 0.916). The infrared frequency ($\nu_{SO(asym)}$,cm^{-1}) values of all 4-(substituted phenylsulfonamido) benzoic acid compounds except those with parent substituent, have shown satisfactory correlation with Hammett substituent constant σ^+ (r = 0.957).

The infrared frequency ($\nu_{SO(asym)}$,cm^{-1}) values of all 4-(substituted phenylsulfonamido) benzoic acid compounds except those with 4-CH_3 substituent, have shown satisfactory correlation with Hammett substituent constant σ_I(r = 0.915) and *F*(r = 0.905) parameter. However, the infrared frequency ($\nu_{SO(asym)}$,cm^{-1}) values of 4-(substituted phenylsulfonamido) benzoic acid compounds have shown poor correlations (r < 0.900) with the remaining Hammett substituent constant σ_R and *R* parameter.

This is attributed to the weak polar, inductive, field and resonance effects of the substituents for predicting the reactivity on the infrared stretching frequency of $\nu_{SO(asym)}$ (cm^{-1}) values through resonance as per the conjugative structure as shown in Figure 2.

All the correlations with Hammett substituent constants (σ, σ^+, σ_I, σ_R), *F* and *R* parameters have shown positive ρ values. This indicates the operation of reverse substituent effect with respect to infrared frequency ($\nu_{SO(asym)}$, cm^{-1}) values of 4-(substituted phenylsulfonamido) benzoic acid compounds.

Some of the single parameter correlations are shown in Figures 5 and 6. Since most of the single regression analyses, have shown poor correlations with Hammett substituent constants (σ, σ^+, σ_I, σ_R), *F* and *R* parameters. It is decided to go for multi regression analysis.

The multi regression analysis of the stretching frequency ($\nu_{SO(asym)}$, cm^{-1}) values of all aryl sulfonamide compounds with inductive, resonance and Swain-Lupton's[151] parameters produce satisfactory correlations as shown in **Equations 3** and **4**:

$$\nu_{SO(asym)}\,(cm^{-1}) = 1334.35(\pm\ 1.235) + 4.588(\pm2.483)\sigma_I - 2.295(\pm0.582)\sigma_R$$
$$(R = 0.864,\ n = 9,\ P > 90\%) \quad \ldots (3)$$

$$\nu_{SO(asym)}\,(cm^{-1}) = 1334.57(\pm1.155) + (4.248)(\pm2.197)F + 3.042(\pm2.191)R$$
$$(R = 0.966,\ n = 9,\ P > 95\%) \quad \ldots (4)$$

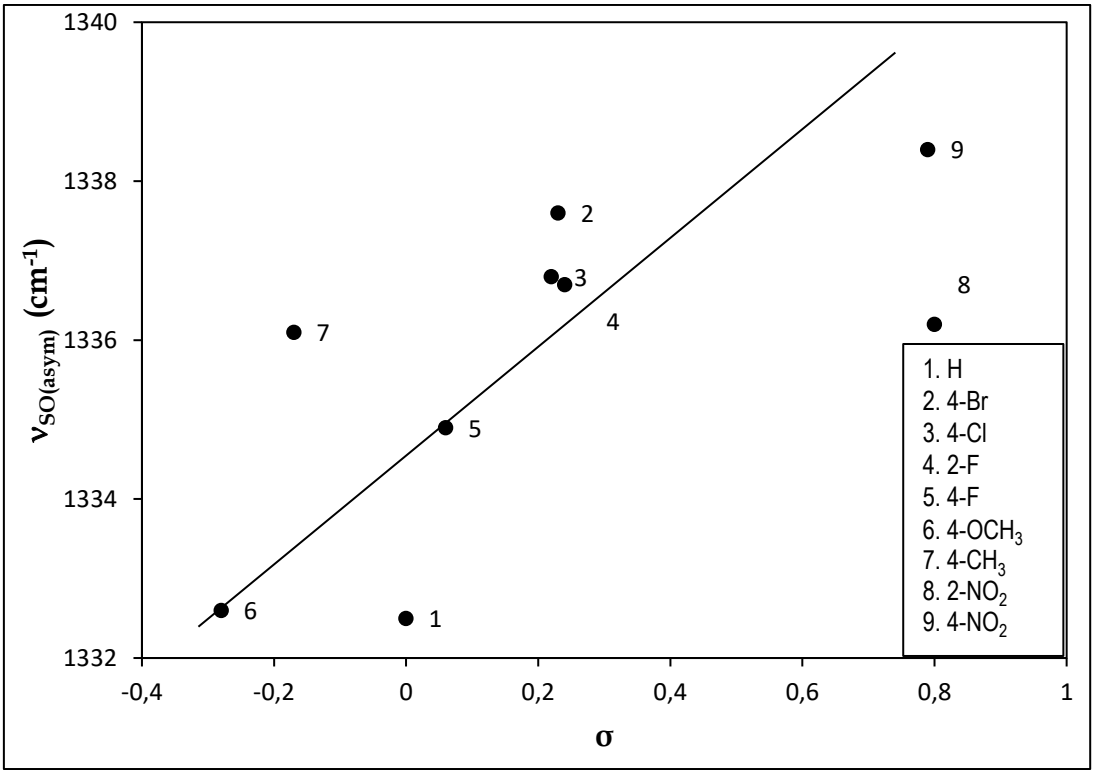


Figure 5. Plot of $\nu_{SO(asym)}$ (cm^{-1}) of 4-(substituted phenylsulfonamido)benzoic acids Vs σ

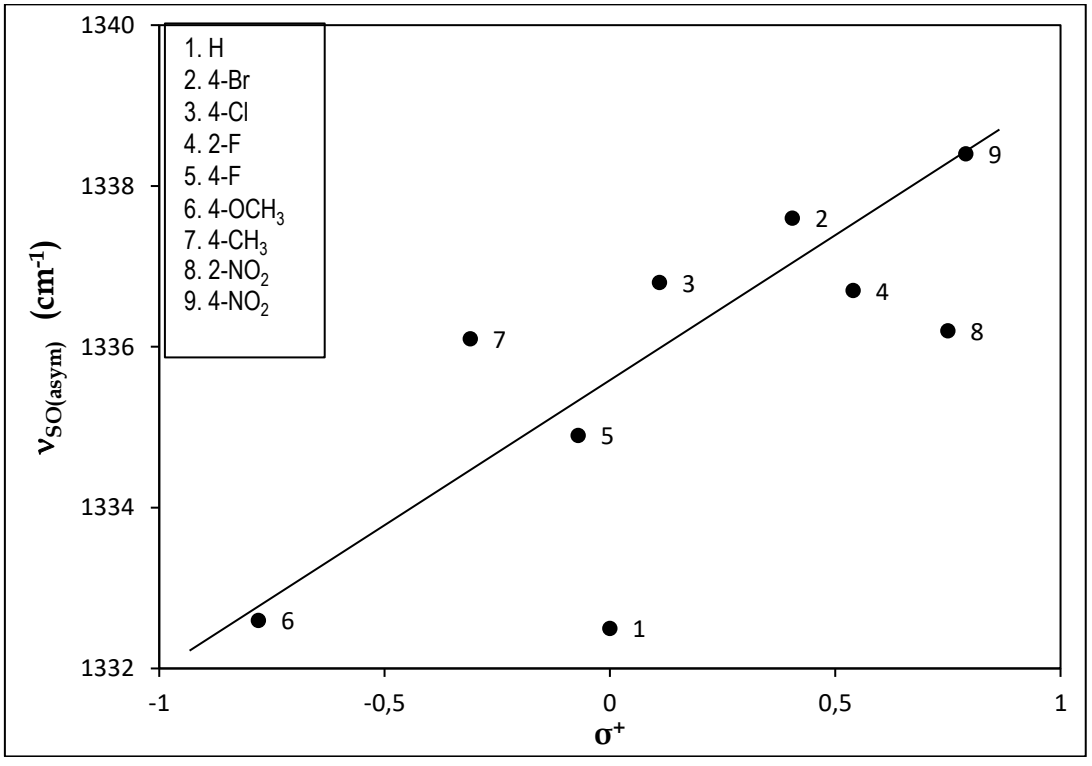


Figure 6. Plot of $\nu_{SO(asym)}$ (cm^{-1}) of 4-(substituted phenylsulfonamido)benzoic acids Vs σ$^+$

3. 1. 3. Correlation of $\nu_{SO(sym)}$ (cm^{-1}) stretches

From the Table 2, it is evident that the infrared frequency ($\nu_{SO(sym)}$, cm^{-1}) values of all the 4-(substituted phenylsulfonamido) benzoic acid compounds except those with 2-F, 2-NO_2 and 4-NO_2 substituents, have shown satisfactory correlation with Hammett substituent constants σ (r = 0.905) and σ^+(r = 0.904). The infrared frequency ($\nu_{SO(sym)}$, cm^{-1}) values of all 4-(substituted phenylsulfonamido)benzoic acid compounds except those with parent, 2-F and 4-CH_3 substituents, have shown satisfactory correlation with Hammett substituent constant σ_I (r = 0.902). The infrared frequency ($\nu_{SO(sym)}$, cm^{-1}) values of all 4-(substituted phenylsulfonamido) benzoic acid compounds except those with parent, 4-F substituent have shown satisfactory correlation with Hammett substituent constant σ_R (r = 0.917) and *R* (r = 0.917). However, the infrared frequency ($\nu_{SO(sym)}$, cm^{-1}) values of 4-(substituted phenylsulfonamido)benzoic acid compounds have shown poor correlations (r < 0.900) with the remaining *F* parameter. This is attributed to the weak inductive, field and resonance effects of the substituents for predicting the reactivity on the infrared stretching frequency of $\nu_{SO(sym)}$ (cm^{-1}) values through resonance as per the conjugative structure as shown in **Figure 1.** All the correlations with Hammett substituent constants viz., σ, σ^+, σ_I, σ_R and *F* parameter have shown positive ρ values. This is indicates the operation of normal substituent effect with respect to infrared frequency ($\nu_{SO(sym)}$, cm^{-1}) values of 4-(substituted phenylsulfonamido)benzoic acid compounds. Some of the single parameter correlations are shown in Figures 7 and 8.

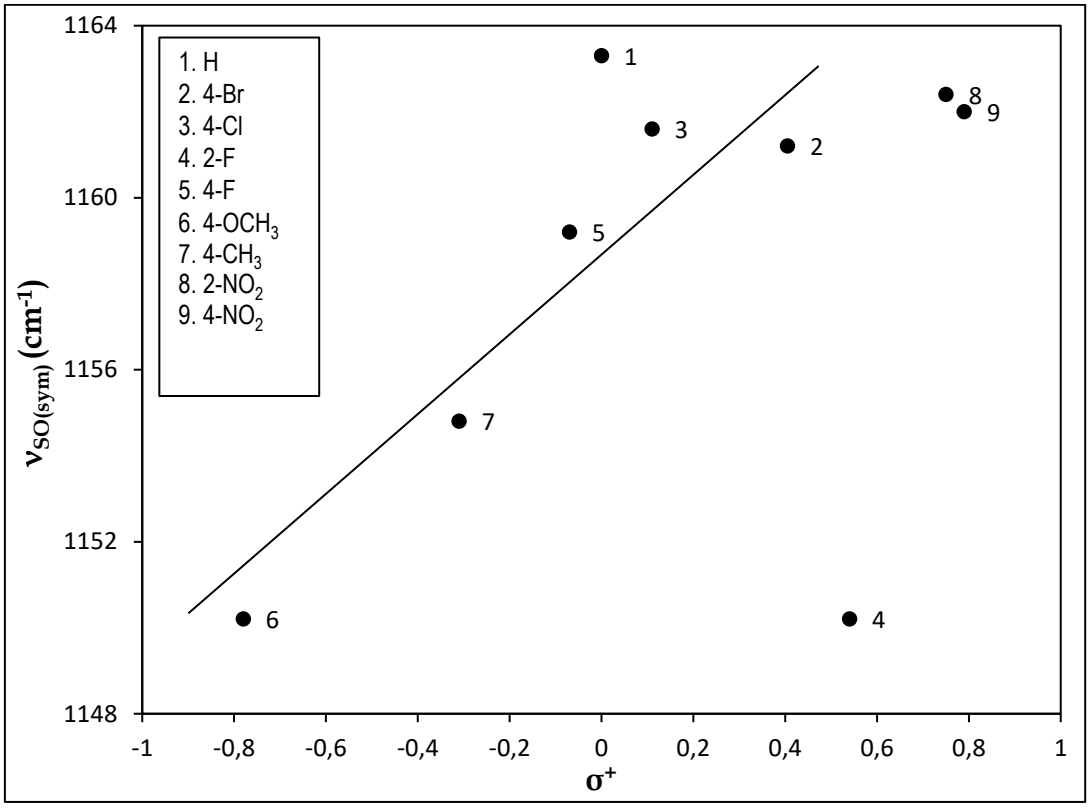


Figure 7. Plot of $\nu_{SO(sym)}$ (cm^{-1}) of 4-(substituted phenylsulfonamido)benzoic acids Vs σ^+

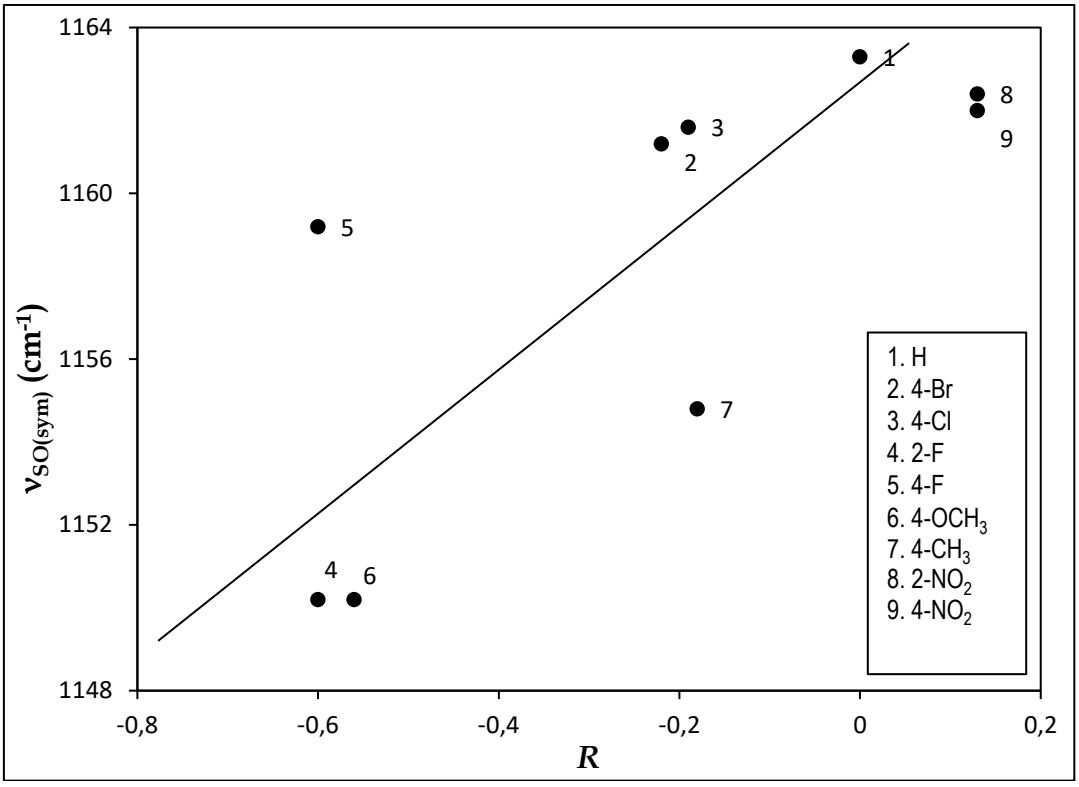


Figure 8. Plot of $\nu_{SO(sym)}$ (cm^{-1}) of 4-(substituted phenylsulfonamido)benzoic acids Vs *R*

Since most of the single regression analyses, have shown poor correlations with Hammett substituent constants (σ, σ^+, σ_I, σ_R), *F* and *R* parameters. It is decided to go for multi regression analysis. The multi regression analysis of the stretching frequency ($\nu_{SO(sym)}$, cm^{-1}) values of all aryl sulfonamide compounds with inductive, resonance and Swain-Lupton's [27] parameters produce satisfactory correlations as shown in **Equations 5** and **6**:

$$\nu_{SO(sym)}\,(cm^{-1}) = 1159.45(\pm 2.796) + 3.560(\pm 0.618)\sigma_I + 14.883(\pm 5.841)\sigma_R$$
$$(R = 0.973,\ n = 9,\ P > 95\%) \quad \ldots (5)$$

$$\nu_{SO(sym)}\,(cm^{-1}) = 1160.36(\pm 2.524) + 2.661(\pm 1.802)F + 13.886(\pm 4.789)R$$
$$(R = 0.976,\ n = 9,\ P > 95\%) \quad \ldots (6)$$

3. 1. 4. Correlation of $\nu_{(C=O)}$ (cm^{-1}) stretches

From the Table 2, it is observed that the infrared frequency ($\nu_{(C=O)}$, cm^{-1}) values of all the 4-(substituted phenylsulfonamido)benzoic acid compounds have shown poor correlations ($r < 0.900$) with all the Hammett substituent constants (σ, σ^+, σ_I, σ_R), *F* and *R* parameters. This is attributed to the weak inductive, field and resonance effects of the substituents for predicting the reactivity on the infrared stretching frequency of $\nu_{(C=O)}$ (cm^{-1}) values through resonance as per the conjugative structure as shown in Figure 1. All the correlations with Hammett substituent constants (σ, σ^+, σ_I, σ_R), *F* and *R* parameters have shown negative ρ values.

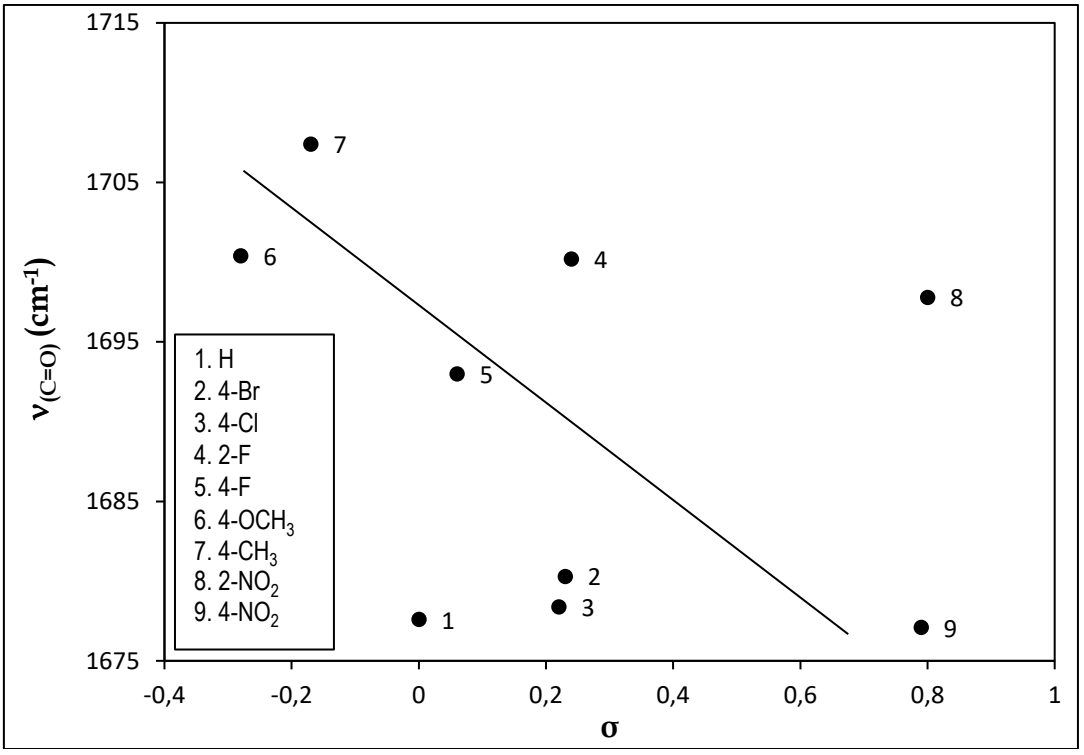


Figure 9. Plot of $\nu_{(C=O)}$ (cm^{-1}) of 4-(substituted phenylsulfonamido)benzoic acids Vs σ

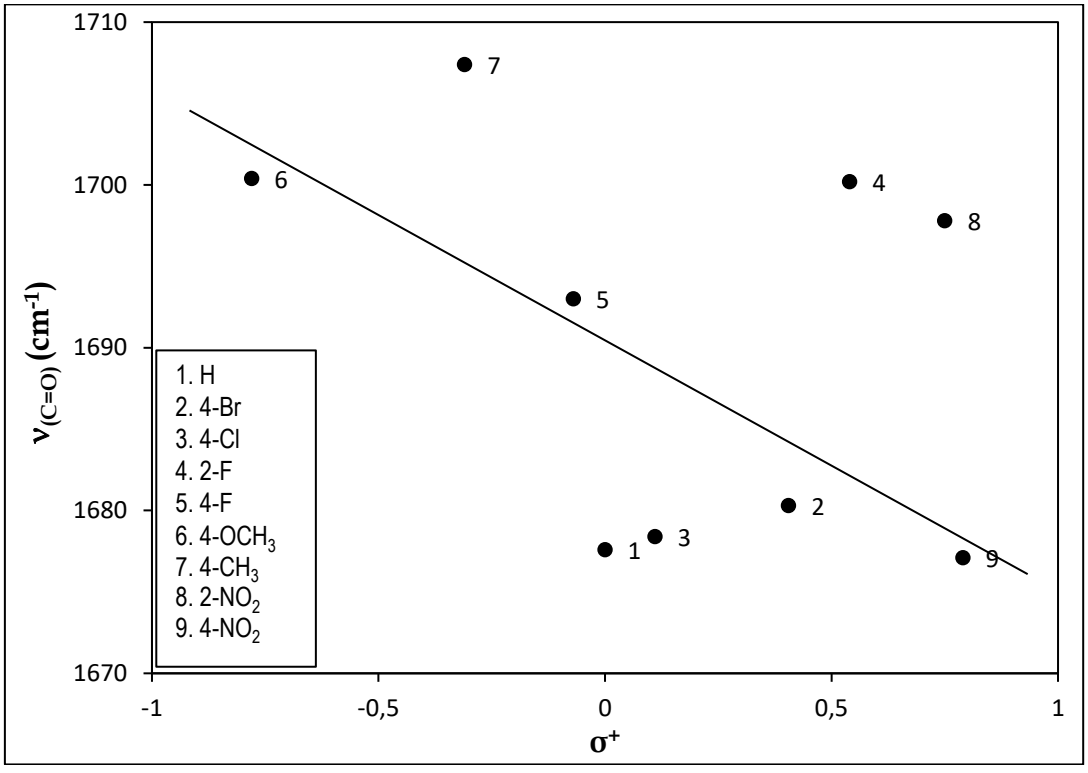


Figure 10. Plot of $\nu_{(C=O)}$ (cm^{-1}) of 4-(substituted phenylsulfonamido)benzoic acids Vs σ^+

This indicates the operation of reverse substituent effect with respect to infrared frequency ($\nu_{(C=O)}$, cm^{-1}) values of 4-(substituted phenylsulfonamido)benzoic acid compounds. Some of the single parameter correlations are shown in Figures 9 and 10.

Since most of the single regression analyses, have shown poor correlations with Hammett substituent constants (σ, σ^+, σ_I, σ_R), *F* and *R* parameters. It is decided to go for multi regression analysis. The multi regression analysis of the stretching frequency ($\nu_{(C=O)}$, cm^{-1}) values of all aryl sulfonamide compounds with inductive, resonance and Swain-Lupton's [27] parameters produce satisfactory correlations as shown in **Equations 7** and **8**:

$$\nu_{(C=O)}\,(cm^{-1}) = 1690.55(\pm8.401) - 8.960(\pm1.881)\sigma_I - 8.777(\pm1.553)\sigma_R$$
$$(R = 0.944,\ n = 9,\ P > 90\%) \quad \ldots (7)$$

$$\nu_{(C=O)}\,(cm^{-1}) = 1687.83(\pm7.882) - 4.638(\pm1.992)F - 19.213(\pm14.953)R$$
$$(R = 0.946,\ n = 9,\ P > 90\%) \quad \ldots (8)$$

3. 2. NMR Spectra

3. 2. 1. ^{1}H NMR correlations

The assigned ^{1}H NMR chemical shifts ($\delta_{N\text{-}H}$, ppm) of 4-(substituted phenylsulfonamido) benzoic acid compounds are presented in Table 1. These ^{1}H NMR chemical shifts ($\delta_{N\text{-}H}$, ppm) are correlated with different Hammett substituent constants (σ, σ^+, σ_I, σ_R), *F* and *R* parameters [28-30]. The results of the statistical analysis are presented in Table 2. From Table 2 it is observed that the ^{1}H NMR chemical shifts ($\delta_{N\text{-}H}$, ppm) of 4-(substituted phenylsulfonamido)benzoic acid compounds have shown satisfactory correlation with Hammett substituent constant σ (r = 0.903), σ^+ (r = 0.908) except 2-F substituent,σ_I (r = 0.913) substituent and *F* (r = 0.906) parameter except parent, 2-F and 4-CH_3 substituent and σ_R (r = 0.963) substituent and *R* (r = 0.962) parameter except 4-F substituent. When the substituents that have been given exception are included in regression, they reduced the correlation considerably. This is due to weak polar, inductive resonance and field effects of the substituents for predicting the reactivity on the ^{1}H NMR chemical shift through resonance as per conjugative structure shown in Figure 1. All the correlations have shown positive ρ values except *F* parameter. It indicates the operation of normal substituent effect with respect to ^{1}H NMR chemical shifts ($\delta_{N\text{-}H}$, ppm) of 4-(substituted phenylsulfonamido)benzoic acid compounds. Some of the single parameter correlation plot is shown in Figure 11 and 12.

Since all the single regression analyses have shown poor correlations with Hammett substituent constants (σ, σ^+, σ_I, σ_R), *F* and *R* parameters. It is decided to go for multi-regression analysis. The multi-regression analysis of the ^{1}H NMR chemical shifts ($\delta_{N\text{-}H}$, ppm) of 4-(substituted phenylsulfonamido) benzoic acid compounds with inductive, resonance and Swain-Lupton's parameters[27] shown in **Equations 9** and **10**:

$$\delta_{N\text{-}H}\,(ppm) = 10.989(\pm0.160) + 0.112(\pm0.023)\sigma_I + 0.683(\pm0.336)\sigma_R$$
$$(R = 0.964,\ n = 9,\ P > 95\%) \quad \ldots \quad (9)$$

$$\delta_{N\text{-}H}\,(ppm) = 11.018(\pm0.156) + 0.076(\pm0.007)F + 0.579(\pm0.296)R$$
$$(R = 0.962,\ n = 9,\ P > 95\%) \quad \ldots \quad (10)$$

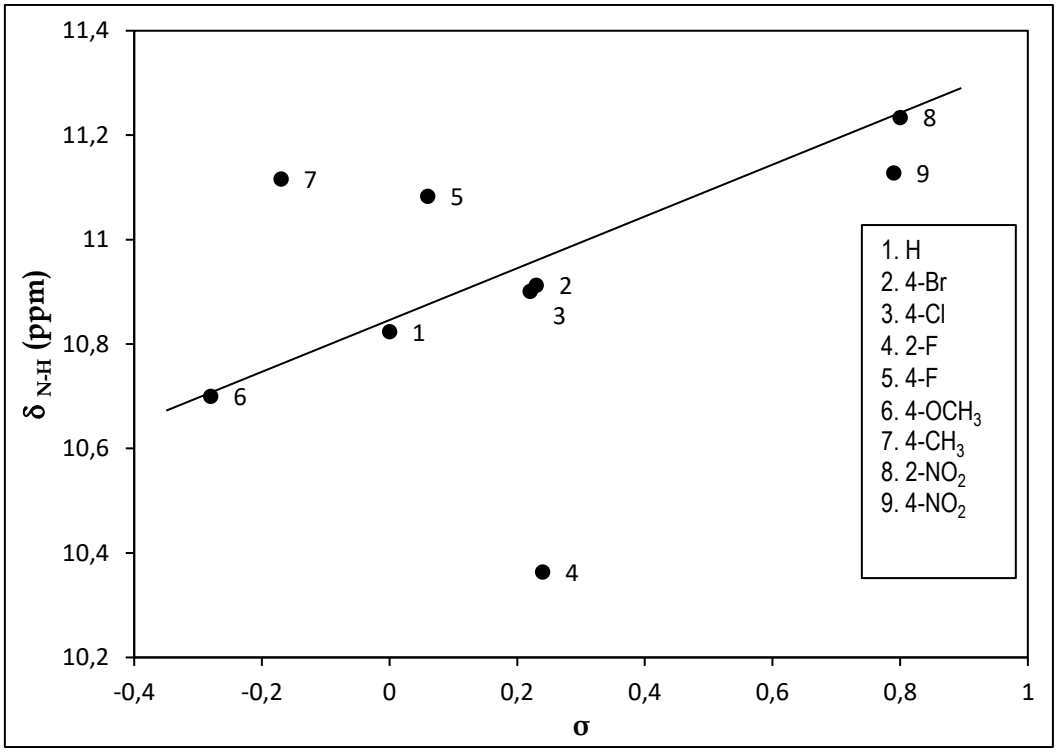


Figure 11. Plot of $\delta_{(N-H)}$ (ppm) of 4-(substituted phenylsulfonamido)benzoic acids Vs σ

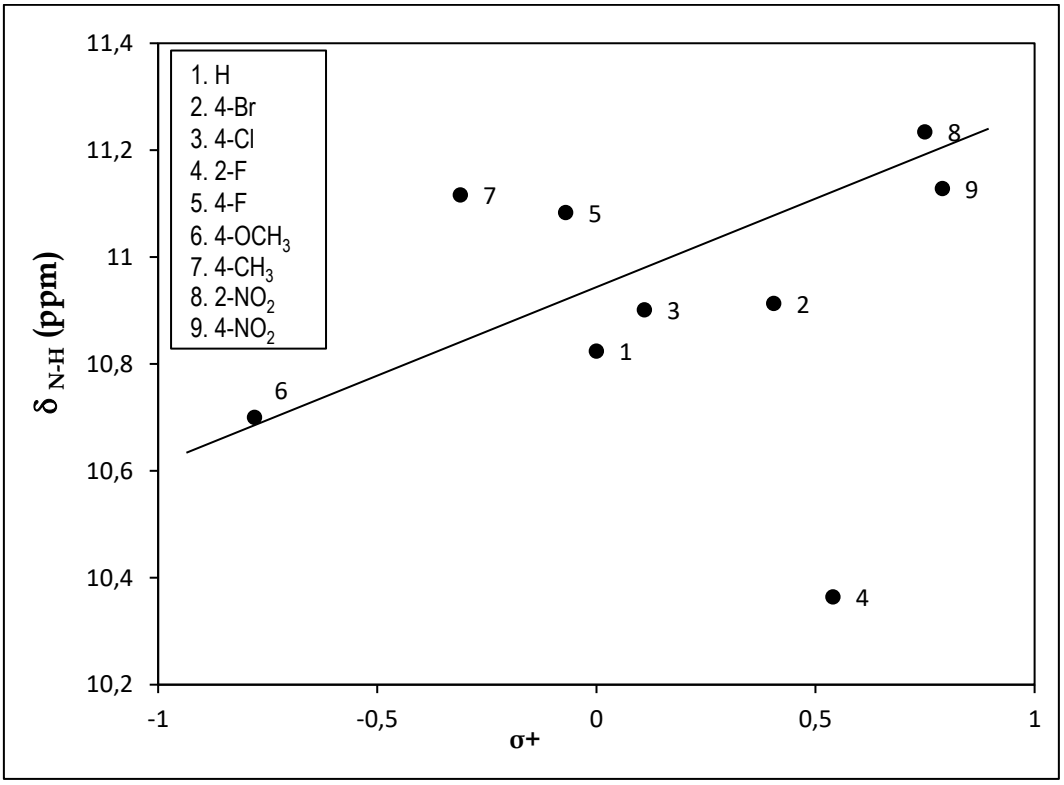


Figure 12. Plot of $\delta_{(N-H)}$ (ppm) of 4-(substituted phenylsulfonamido)benzoic acids Vs σ^+

3. 2. 2. ^{13}C NMR correlations

The assigned ^{13}C NMR chemical shifts ($\delta_{C=O}$, ppm) of 4-(substituted phenylsulfonamido) benzoic acid compounds are presented in **Table 1**. These ^{13}C NMR chemical shifts ($\delta_{C=O}$, ppm) are correlated with different Hammett substituent constants (σ, σ+, σ_I, σ_R), *F* and *R* parameters [31-33]. The results of the statistical analysis are presented in **Table 2.**

From **Table 2** it is observed that the ^{13}C NMR chemical shifts ($\delta_{C=O}$, ppm) of 4-(substituted phenylsulfonamido)benzoic acid compounds have shown satisfactory correlation with Hammett substituent constant σ (r = 0.924), σ^+ (r = 0.905), σ_R (r = 0.958) and *R* (r = 0.948) parameter except 2-F substituent. The remaining Hammett substituent constants σ_I and *F* parameter were failing in correlation. When the substituents that have been given exception are included in regression, they reduced the correlation considerably.

All the correlations with Hammett substituent constant viz., σ_I and *F* parameter have shown positive ρ values. It indicates the operation of normal substituent effect with respect to $\delta_{C=O}$ (ppm) modes of 4-(substituted phenylsulfonamido)benzoic acid compounds. The failure in the correlation was due to reasons stated earlier with the resonance conjugative structure as shown in **Fig 1**. Some of the single parameter correlation plots are shown in **Figure 13** and **14.**

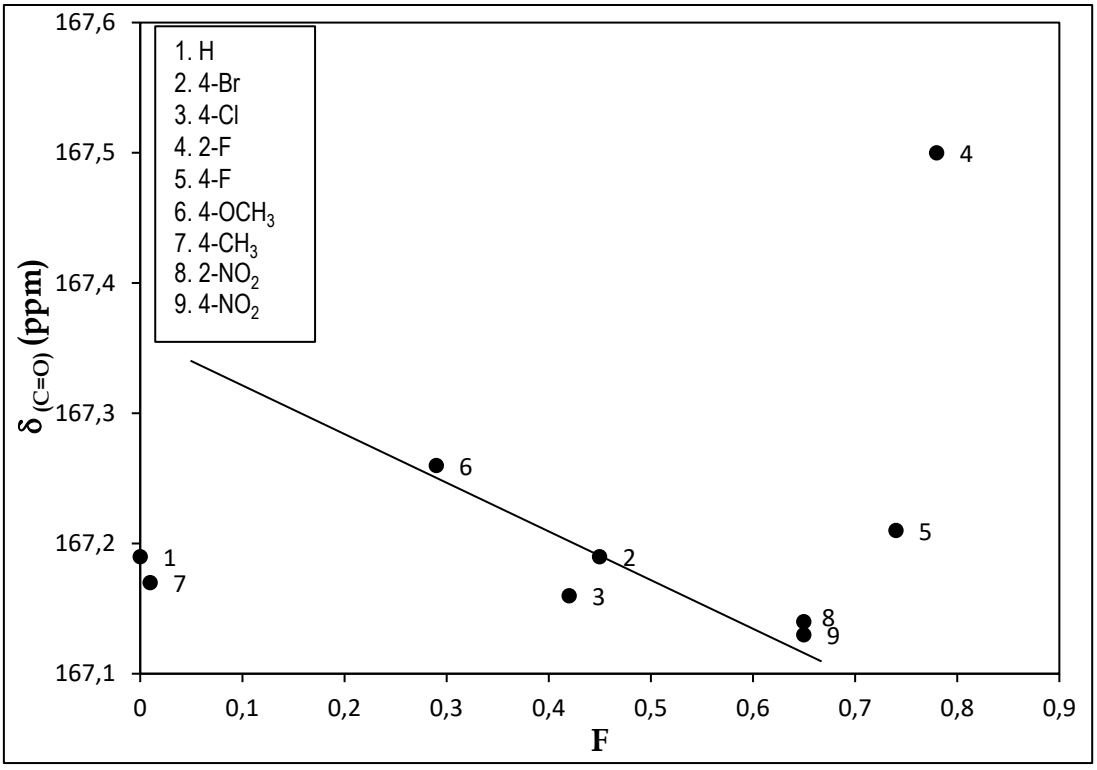


Figure 13. Plot of δ $^{13}C_{(C=O)}$ (ppm) of 4-(substituted phenylsulfonamido)benzoic acid compounds Vs *F*

Some of the single parameter correlations were fail for the Hammett substituent constants and *F* and *R* parameters. They show satisfactory correlations in multi-regression analysis with Swain-Lupton's [27] parameters.

The generated multi-regression equations are given in **Equations 11** and **12**:

$$\delta_{C=O}\,(ppm) = 167.15(\pm 0.063) + 0.227(\pm 0.128)\,\sigma_I - 0.318(\pm 0.133)\,\sigma_R$$
$$(R = 0.969,\ n = 9,\ P > 95\%) \quad \ldots \quad (11)$$

$$\delta_{C=O}\,(ppm) = 167.12(\pm 0.0589) + 0.066(\pm 0.012)F - 0.251(\pm 0.111)R$$
$$(R = 0.971,\ n = 9,\ P > 95\%) \quad \ldots \quad (12)$$

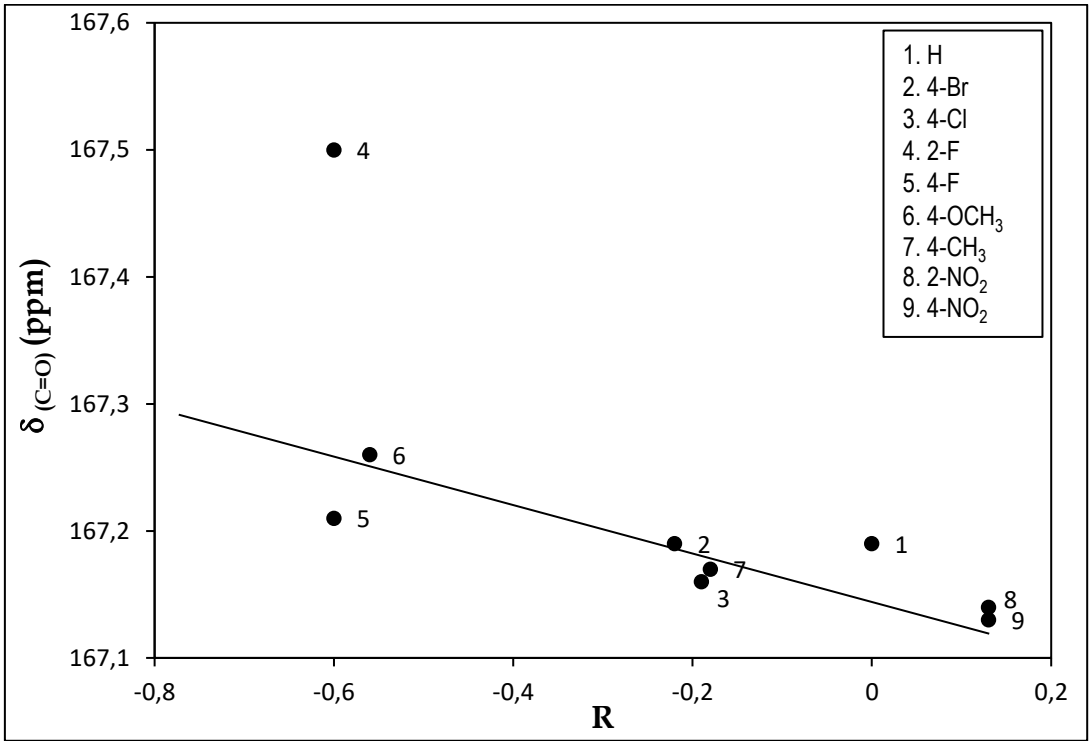


Figure 14. Plot of δ $^{13}C_{(C=O)}$ (ppm) of 4-(substituted phenylsulfonamido)benzoic acid compounds Vs R

4. CONCLUSIONS

Using ultrasonication, about nine 4-(substituted phenyl sulfonamide) benzoic acids were synthesized. The characteristic infrared SOsym, SOasym, NH and CO vibrations (ν, cm^{-1}), the chemical shifts (δ, ppm) of NH and CO of sulfonamides were assigned and correlated with various Hammett substituent constants and Swain-Lupton parameters using single and multi-regression analysis. The infrared frequency (ν_{N-H}, cm^{-1}) values of all the 4-(substituted phenylsulfonamido) benzoic acid compounds have shown satisfactory correlation with Hammett substituent constants σ, σ_I and F parameters. The infrared SO_2 asymmetric frequency (ν, cm^{-1}) values of all the 4-(substituted phenylsulfonamido) benzoic acid compounds have shown satisfactory correlation with Hammett substituent constants σ, σ^+, σ_I and F parameters. The infrared SO_2 symmetric frequency (ν, cm^{-1}) values of all the 4-(substituted phenylsulfonamido) benzoic acid compounds have shown satisfactory correlation with

Hammett substituent constants σ, σ^+, σ_I and R parameters. The infrared CO frequency (ν, cm^{-1}) values of all the 4-(substituted phenylsulfonamido) benzoic acid compounds have shown spoor correlation with Hammett substituent constants, F and R parameters. The NH chemical shifts (δ, ppm) of all the 4-(substituted phenylsulfonamido) benzoic acid compounds have shown satisfactory correlation with Hammett substituent constants, F and R parameters.

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