

## THE EFFECT OF THE SUBSTITUENTS ON THE CARBONYL ABSORPTIONS OF 2H-PYRID-2-ONES AND 2H-THIOPYRAN-2-ONES

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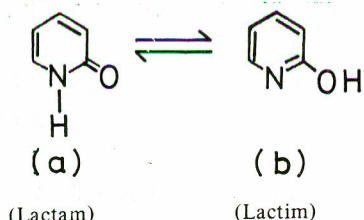
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The infrared spectra of a number of substituted 2H-pyrid-2-ones and 2H-thiopyran-2-ones have been measured in the carbonyl stretching vibration region and interpreted in terms of the chemical effect of the substituents. In general, the presence of electron withdrawing substituents at the 1 - or 3 - or 3, 5-positions and electron donating substituents at the 1 - or 4 - or 5-positions of the 2-pyridone have been found to raise and lower the carbonyl absorption respectively. The substituted 2H-thiopyran-2-ones show an appreciable decrease in their carbonyl absorptions as compared to the corresponding 2-pyridones.

*Key words* : Effect, Substituents, Carbonyl absorptions, 2-Pyridones.

### INTRODUCTION

The infrared absorptions of 2-pyridones with respect to tautomeric forms (1a, 1b) and carbonyl absorptions have been studied extensively. The predominance of lactam form (1a) in liquid or solid phase [1-10], existence of comparable amounts of tautomers in gaseous phase [11-15], dimerization of lactam form (1a) in various solvents [16-20], appearance of strong carbonyl absorption [4, 5, 21-24] for 2-pyridone (1) in the region  $1650-1659\text{ cm}^{-1}$  and additional weak bands at  $1685, 1674\text{ cm}^{-1}$  at high concentration are well known. All these studies emphasize tautomerism and carbonyl absorptions of 2-pyridone in different phases and concentrations. However, no comprehensive account of the chemical effects of the substituents on the carbonyl absorptions of the 2H-pyrid-2-one is available in literature.



In the present work, the carbonyl absorption data (Tables 1-3) for a number of substituted 2-pyridones have been collected and variations in the carbonyl absorptions with the alteration of the substituents have been interpreted in qualitative terms through the impact of chemical effects. Since the carbonyl stretching frequencies of 2-pyridones are influenced by the concentration, nature of the solvent and temperature, infrared spectra have been measured in the same phase ( $\text{CHCl}_3$  or KBr) and concentration at ambient temperature.

### EXPERIMENTAL

The spectra were measured with Perkin-Elmer SP 200 and JASCO - IRA - 1 spectrophotometers. Solution (0.021-0.025 M) spectra were determined in chloroform. A matched cell containing a pure solvent was employed in balancing the beam to correct for solvent absorption. Solid state potassium bromide disc spectra were determined with several thickness of disc as necessary to make the carbonyl bands sufficiently intense. All carbonyl absorptions were corrected as necessary by reference to the  $1601.4\text{ cm}^{-1}$  band of polystyrene.

Some of the compounds required in the present work were prepared as described in literature [2a] lit. ref. [25]; (2b) lit. ref. [26]; (2c-f) lit. ref. [2]; (2g) lit. ref. [27]; (2n) lit. ref. [29]; (2,o) lit. ref. [30]; (2p-s) lit. ref. [31,32]; (3a) lit. ref. [20]; (3b) lit. ref. [27]; (3c) lit. ref. [29]; (3d-g) lit. ref. [31, 32]; (4a-f) lit. ref. [33]; (5a) lit. ref. [32]; (5b-d) lit. ref. [34]; (5e-f) lit. ref. [35].

*General method for the preparation of substituted 2-pyridones (2h-j).* A mixture of the appropriate substituted 2H-pyran-2-one (0.01 mole) in ammonia (0.88D) (8-10ml) was kept at room temperature for one week. The solid product was filtered out. In those cases the solid product was not obtained; the reaction mixture was evaporated to dryness on a steam bath.

*2-Methoxy-6-methyl-3-nitro-2-pyridone (2h).* From 4-methoxy-6-methyl-3-nitro-2-pyrone [28] as light yellow solid (ethanol-water), m.p.  $225^\circ$ . (Found: C, 45.45; H, 4.3; N, 15.21;  $\text{C}_7\text{H}_8\text{N}_2\text{O}_4$  requires C, 45.65; H, 4.35; N, 15.21%).  $\nu_{\text{max}}$ . 1680 (CO of ring), 3050 (-NH)  $\text{cm}^{-1}$ .

*4-Hydroxy-6-methyl-3-nitro-2-pyridone (2i).* From 4-hydroxy-6-methyl-3-nitro-2-pyrone [28] (ethanol-pet.

ether) m.p. 250° (Found: C, 4.22; H, 3.2; N, 16.2; C<sub>6</sub>H<sub>6</sub>N<sub>2</sub>O<sub>4</sub> requires C, 42.35; H, 3.52; N, 16.47%).  $\nu_{\text{max}}$ . 1690 (CO of ring). 3050 (-NH) cm<sup>-1</sup>.

*3-Bromo-4-hydroxy-6-methyl-2-pyridone (2j)*. From 3-bromo-4-hydroxy-6-methyl-2-pyridone [28] (ethanol) m.p. 217°. (Found C, 35.0; H, 3.0; N, 7.1; C<sub>6</sub>H<sub>6</sub>NO<sub>2</sub>Br requires C, 35.30; H, 2.94; N, 6.86%).  $\nu_{\text{max}}$ . 1670 (CO of ring), 3050 (-NH) cm<sup>-1</sup>.

*General method for the preparation of 3-acyl-4-hydroxy-6-methyl-2-pyridone (2k-m)*. A mixture of 4-hydroxy-6-methyl-2-pyridone (2g) and appropriate carboxylic acid (10ml) in the presence of phosphorus oxychloride (3ml) was gently refluxed for 1-2 hr. After cooling the reaction mixture was evaporated and the resulting oily liquid was dissolved in water by warming and extracted with chloroform. The chloroform extracts after drying over magnesium sulphate were evaporated and the residue treated differently in each case to get the solid product.

*3-Acetyl-4-hydroxy-6-methyl-2-pyridone (2k)*. The pyridone was obtained by using acetic acid. The residue on sublimation gave colourless needles, m.p. 274°C. (lit. [37] m.p. 254°) (Found: C, 57.33; H, 5.51; N, 8.33; C<sub>8</sub>H<sub>9</sub>NO<sub>3</sub> requires C, 57.48; H, 5.38; N, 8.38%).  $\nu_{\text{max}}$ . 1670 (CO of ring), 1628 (CO of side chain H bonded), 2950 (NH stretching) cm<sup>-1</sup>.  $\lambda_{\text{max}}$ . 325 (11538nm), 270 (11923nm); nmr (DMSO,  $\delta$ ) 2.2 (3H, 6); 2.5 (3H of side chain, 3); 5.75 (1H); 15.6 (1H enolic, 4).

*4-Hydroxy-6-methyl-3-phenylacetyl-2-pyridone (2l)*. The pyridone was obtained by using phenylacetic acid as described in the general method. The residue was dissolved in ethanol and chromatographed in a silica gel column using ethanol-pet. ether (60-80°) (1:1) mixture. The elutions on evaporation gave off a white solid, m.p. 203-205° which on further crystallization from petroleum ether (60-80°)-ethanol (1:1) mixture gave white crystals, m.p. 206-207°. (Found: C, 69.07; H, 5.51; N, 5.65; C<sub>14</sub>H<sub>13</sub>NO<sub>3</sub> requires C, 69.14; H, 5.35; N, 5.76%).  $\nu_{\text{max}}$ . 1665 (CO of ring), 1627 (CO of side chain H bonded), 2960(NH) cm<sup>-1</sup>;  $\lambda_{\text{max}}$ . 329(12041nm), 267 (4490nm), 232 (9592nm); nmr (CDCl<sub>3</sub>,  $\delta$ ), 2.28 (3H, 6), 4.48 (2H of methylene, 3), 5.78 (1H, 5), 7.2 (5H, aromatic, 3), 15.32 (1H enolic, 4), 12.04 (1H of NH, 1).

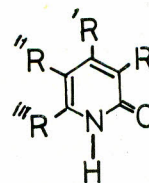
*4-Hydroxy-6-methyl-3-propionyl-2-pyridone (m)*. Pyridone was obtained by using propionic acid. The residue on crystallization from aqueous ethanol gave a white solid m.p. 227-229° (Found: C, 59.37; H, 5.92; N, 7.71, C<sub>9</sub>H<sub>11</sub>NO<sub>3</sub> requires C, 59.67; H, 6.01; N, 7.73%);  $\nu_{\text{max}}$ . 1672 (CO of ring), 1625 (CO of side chain H bonded) 2950 (NH) cm<sup>-1</sup>;  $\lambda_{\text{max}}$ . 325 (12752nm), 267 (6239nm); 230 (11376nm), nmr (CDCl<sub>3</sub>), 1.02-1.3(3H of side chain, 3),

2.28 (3H, 6), 2.98-3.32 (2H of methylene of the side chain, 3); 5.78 (1H, 5); 12.1 (1H of NH, 1); 15.6 (1H enolic, 4).

## RESULTS AND DISCUSSION

In Table 1 are collected spectral data pertaining to

Table 1. Infrared carbonyl absorption data of substituted 2H-pyrid-2-ones (1,2a-s).



Compound	R	R'	R''	R'''	KBr	CHCl <sub>3</sub>
1	H	H	H	H	1650	1658(s) 1676(sh)
2a	NO <sub>2</sub>	H	H	H	1706	1708
b	H	H	NO <sub>2</sub>	H	1692	1695
c	Cl	H	H	H	1656	1658
d	Br	H	H	H	1656	1656
e	Cl	H	Cl	H	1689	1690
f	Br	H	Br	H	1692	—
g	H	H	PhCO	H	1661	1665
h	NO <sub>2</sub>	OMe	H	Me	1680	—
i	NO <sub>2</sub>	OH	H	Me	1690	—
j	Br	OH	H	Me	1670	—
k	COMe	OH	H	Me	1670	1675
l	COCH <sub>2</sub> Ph	OH	H	Me	1665	1672
m	COEt	OH	H	Me	1672	1670
n	H	OH	COMe	Me	1680	1682
o	H	OOCMe	H	Me	1680	—
p	H	Ph	Ph	Ph	1647	1650
q	H	Ph	OMe	Ph	1642	1645
r	H	Ph	OPh	Ph	1645	1648
s	H	p.MeOph	H	Ph	1639	1640

carbonyl absorptions of substituted-2-pyridones (2a-g) having electron withdrawing substituents at 3-, 5- and 6-positions. Comparison of carbonyl frequencies of 2-pyridones (2a-g) in solid state with the parent 2-pyridone (1) shows higher carbonyl absorption depending upon the nature of the substituent. The maximum rise in carbonyl frequency (i.e. 56 cm<sup>-1</sup>) is exhibited by the 3-

nitro derivative (2a) which is attributable to direct polar interaction across space (field effect) coupled with conjugative effect (-M) which reduces the polarity of the carbonyl bond and results in the elevation of carbonyl absorption. In the case of 5-nitro-2-pyridone (2b) the rise in the carbonyl frequency is comparatively less (i.e.  $42\text{ cm}^{-1}$ ) as only the conjugative effect (-M) appears to be operative via the lone pair of nitrogen. Similarly the field or inductive effect in 3-halo or 3, 5-dihalo derivatives (2c-f) also enhances the carbonyl frequencies but the elevation is more in the case of 3, 5-dihalo-2-pyridones (2e, f) as compared to the 3-halo-2-pyridones (2c, 2d). This dispersity is presumably due to the fact that the inductive effect (-I) of halogen atom at the 3-position is countered by its conjugative effect (+M). Analogous effect on the carbonyl absorptions of  $\alpha$ -halo-amides and 3-bromo-2-pyrone has also been reported [36, 37]. The 5-benzoyl-2-pyridone (2g) shows carbonyl absorption at  $1661\text{ cm}^{-1}$ , although the carbonyl group of the substituent is aptly placed to exert its electron withdrawing effect (-M) but its impact on the carbonyl absorption of the pyridone is not substantial, presumably due to the conjugation of the carbonyl group of the substituent with the adjoining phenyl group.

The comparison of infrared spectra of 3-nitro, 3-bromo, and 3-acyl derivatives (2h-m) in solid state also show an elevation of carbonyl absorption by  $15\text{-}40\text{ cm}^{-1}$  as compared to the parent 2-pyridone (I). Relatively diminished field effect of the 3-nitro group on the carbonyl absorptions of pyridones (2h-i) as compared to 3-nitropyridone (2a), is possibly due to the mesomeric effect (+M) of 4-hydroxy or methoxy group which partially offsets the otherwise strong inductive or field effect of the nitro group. The acetyl groups at the 5- and 4-positions in pyridones (2n) and (2,o) respectively raise the carbonyl frequencies appreciably due to their negative mesomeric effect (-M).

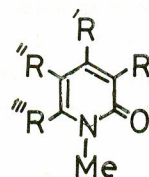
The carbonyl stretching of 2-pyridones (2p-s) having phenyl groups exhibit a negative shift ( $3\text{-}11\text{ cm}^{-1}$ ) as compared to the 2-pyridone (I). The presence of methoxy or phenoxy group at the 5-position and p-MeO-phenyl at 4-position would be expected to show a strong interaction with carbonyl group. however, the data indicate that in solid state the electron distribution of the carbonyl group is influenced to a small extent in the case of pyridones (2q-r) having methoxy and phenoxy group at the 5-positions while in pyridone (2s) the impact of the 4-p-MeO-Ph group is appreciable and results in lowering the carbonyl absorption by  $11\text{ cm}^{-1}$  as compared to the parent pyridone (I). The same type of variation is also exhibited by the solution spectra of these pyridones (2p-s) but the extent of the

negative shift in the carbonyl absorptions is relatively greater as compared to solid state spectra.

In Table 2, the infrared spectra pertaining to N-methylpyridones (3a-g) show a rise in their carbonyl absorptions as compared to their corresponding 2-pyridones (1, 2g, 2n, 2p-s). This is explicable in terms of the elimination of the possibility of tautomerisation and a partial reduction of hydrogen bonding in these N-methylpyridones.

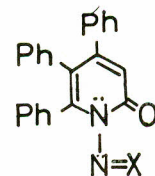
The carbonyl absorption bands for the N-substituted-2-pyridones (4a-f) are shown in Table 3. Comparison of

Table 2. Infrared carbonyl absorption data of substituted N-methyl-2-pyridones (3a-g).



Compound	R	R'	R''	R'''	KBr	CHCl <sub>3</sub>
3a	H	H	H	H	1665	—
b	H	H	PhCO	H	1668	—
c	H	OH	MeCO	Me	1686	—
d	H	Ph	Ph	Ph	1661	1662
e	H	Ph	OMe	Ph	1656	1662
f	H	Ph	OPh	Ph	1653	1655
g	H	p.MeO.Ph	H	Ph	1650	1652

Table 3. Carbonyl absorption of N-substituted 2H-pyrid-2-ones (4a-f).



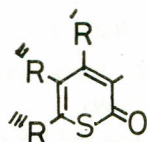
Compound	X	KBr	CHCl <sub>3</sub>
4a	p-NO <sub>2</sub> -Ph-CH-	1655	1662
b	o-NO <sub>2</sub> -Ph-CH-	1658	1656
c	-OCC-C <sub>6</sub> H <sub>4</sub> -CO-	1677	1682
d	-OC-CH=CH-CO-	1680	1685
e	o-OH-Ph. CH-	1640	1640
f	p. OH.Ph.CH-	1642	1645

carbonyl absorption of 4, 5, 6-triphenyl-2-pyridone (2p) with 1-p-nitrobenzlideneamino or 1-o-nitrobenzlideneamino

or 1-maleimido-2-pyridones (4a-d) in solid state indicates an elevation of carbonyl absorption by  $8\text{ cm}^{-1}$  or  $11\text{ cm}^{-1}$  or  $30\text{ cm}^{-1}$  or  $33\text{ cm}^{-1}$  respectively. These shifts are indicative of electron withdrawing effect (-M) of these substituents which result in decreasing the electron density of the carbonyl group. On the other hand the pyridones (4e-f) exhibit a negative shift ( $7, 5\text{ cm}^{-1}$ ) in their carbonyl absorptions as compared to pyridone (1p). This is due to the positive mesomeric effect of the *o*-hydroxy and 1-*p*-hydroxy-benzlideneamino groups which weaken as well as lengthen the carbonyl bond resulting in low carbonyl absorption. The solution spectra of (4a-f) also exhibit the analogous behaviour but weak bands are obtained due to the sparing solubilities of these compounds.

The carbonyl absorptions of some substituted thiopyran-2-ones (5a-f) were also measured (Table 4). Data

Table 4. Carbonyl absorption of *N*-substituted 2H-thiopyran-2-ones (5a-f).



Compound	R'	R''	R'''	KBr	CHCl <sub>3</sub>
5a	Ph	Ph	Ph	1625	1620
b	Ph	H	Ph	1631	1630
c	p.MeO.Ph	H	Ph	1620	1621
d	Ph	H	p.MeO.Ph	1634	1635
e	N(Me) <sub>2</sub>	H	Me	1619	1625
f	N.C <sub>4</sub> H <sub>8</sub>	H	Me	1620	1624

show an appreciable negative shift in the carbonyl absorption of the thiopyrones as compared to pyridones. This is presumably, because the lone pair of sulphur atom is more suitably oriented to delocalisation with the carbonyl group, the impact of which results in lowering the carbonyl frequency. Another contributing factor appears to be the relatively low inductive effect of sulphur atom of the thiopyrones as compared to the nitrogen atom of the pyridone. The presence of electron donating substituents at the 4-position such as in thiopyrones (5c, 5e, 5f) further lowers the carbonyl absorption, because of the resonance interaction between the lone pair of nitrogen or oxygen of the substituent and the carbonyl of the ring.

Another interesting feature is the comparison of solution and solid state carbonyl absorptions (Tables 1-3) spectra with respect to the direction and magnitude of the

shift. Due to the sparing solubility of substituted 2-pyridones in chloroform, the solution spectra of all pyridone could not be recorded. However, the comparison shows that in virtually all instances the absorption frequencies of the solution spectra are greater than in the solid state. In general the increase is of the order of  $1-5\text{ cm}^{-1}$  but there are some noticeable exceptions where the carbonyl frequencies are either identical (2d, 4e) or less in solution as compared to solid state (2m, 4b).

From these results, it may be concluded that the variation in the carbonyl absorptions of the substituted 2-pyridones and thiopyrones can be rationalised to a reasonable extent in qualitative terms through the impact of the chemical effect of the substituents. However, the determination of a precise and absolute value of the carbonyl absorptions must include other physical factors such as the mass effect, vibrational coupling, phase changes, solvent effect and hydrogen bondings.

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