Asian Journal of Chemistry Vol. 22, No. 7 (2010), 5049-5056

FTIR, FT Raman and UV-Visible Spectroscopic Analysis on Metformin Hydrochloride

N.R. SHEELA*, S. MUTHU and S. SAMPATH KRISHNAN
Department of Physics, Sri Venkateswara College of Engineering, Sriperumbudur-602 105, India
E-mail: nrsheela@svce.ac.in

Metformin hydrochloride is an antidiabetic drug. The FTIR and FT Raman spectra of the compound has been recorded and a qualitative analysis on the vibrational bands has been carried out. The light absorption activity in the UV-vis region of the drug under different storage conditions has also been analyzed. Further, the absorption ratio referred to as Q value used in confirmatory test of identity is evaluated from the UV-visible spectra of the compound. The characteristic vibrational frequencies of the drug have been identified and assigned using FTIR spectrum, is also confirmed using FT Raman spectrum. A comparison after the sample stored in the ideal conditions and are exposed to environmental hazards is made.

Key Words: FTIR, FT-Raman, UV-Visible spectra, Metformin hydrochloride, Vibrational analysis.

INTRODUCTION

The antidiabetic drugs are medicines that help to control blood sugar levels in people with diabetes mellitus (sugar diabetes). Metformin is an antihyperglycemic agent, which improves glucose tolerance in patients with type 2 diabetes, lowering both basal and postprandial plasma glucose. Metformin is not chemically or pharmacologically related to any other classes of oral antihyperglycemic agents. Unlike sulfonylureas, metformin does not produce hypoglycemia in either patients with type 2 diabetes or normal subjects and does not cause hyperinsulinemia. With metformin therapy, insulin secretion remains unchanged while fasting insulin levels and daylong plasma insulin response may actually decrease. It is soluble in water. The IUPAC name of the drug is 3-(diaminomethylidene)-1,1-dimethylguanidine. The pharmaceutical data of the drug is given in Table-1 and its molecular structure is shown in Fig. 1.

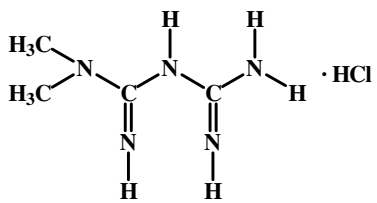

Fig. 1. Structure of metformin hydrochloride

TABLE -1
PHARMACEUTICAL DATA OF DRUG

Characters	Metformin hydrochloride
Formula	$C_4H_{11}N_5HCl$
Molecular weight	129.1636
Category	Antidiabetic drug
Usual strength	500-3000 mg
Description	White powder
Solubility	Soluble in water
Light absorption characteristics (UV-Visible region)	234 nm
Storage condition	To be stored in well closed light resistant container

In the present work, a systematic approach has been adopted to make an investigation on metformin hydrochloride using spectral measurements.

EXPERIMENTAL

The sample of metformin hydrochloride in the pure form were procured from a leading pharmaceutical company in Mumbai, India. The FTIR and FT Raman spectra of the sample were recorded over the frequency 4000-400 cm^{-1} and are represented in Figs. 2 and 3, respectively. The bands observed in the spectra along with the assignments are summarized in Table-2.

RESULTS AND DISCUSSION

FTIR and FT Raman spectra and vibrational band assignments of related compounds: Vibrational spectroscopy is an extremely powerful technique for qualitative and quantitative analysis. Absorption bands of the functional groups arise from stretching and deformation vibrations. The magnitude, relative intensity and shape of the infrared absorption bands are used to assign the characteristic vibrational modes in analogy with band assignments.

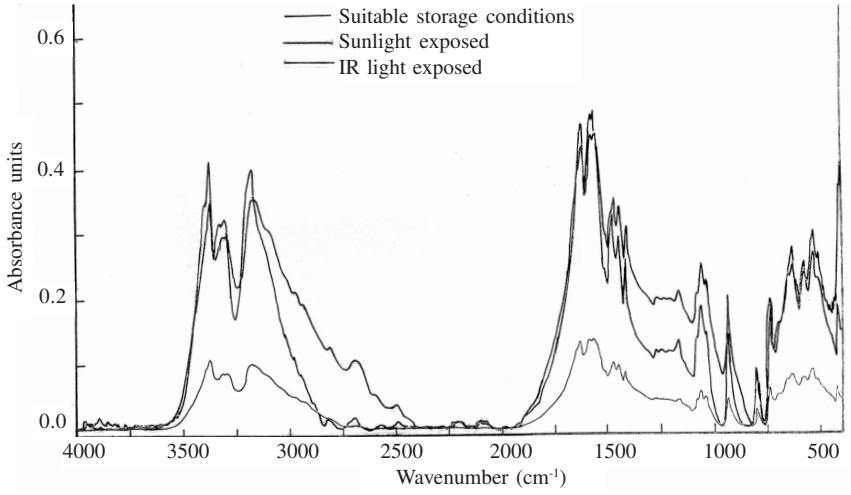

Fig. 2. FT-IR spectra of metformin hydrochloride

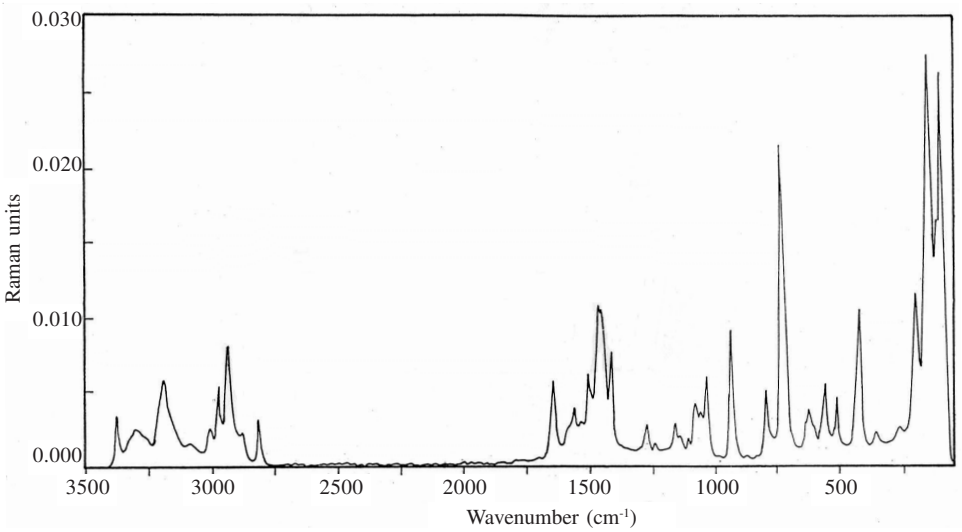

Fig. 3. FT Raman spectrum of metformin hydrochloride

TABLE-2
VIBRATIONAL BAND ASSIGNMENT OF METFORMIN HYDROCHLORIDE

Frequency (cm^{-1})		Assignments
FT IR	FT Raman	
3372 (sm)	3375 (w)	N-H stretching
3300 (m)	3301 (w)	Asymmetric N-H stretching
3176 (m)	3197 (mw)	Symmetric N-H stretching
2816 (w)	2821 (w)	$(CH_3)_2N$ absorption
2619 (vw)	–	$(CH_3)_2N$ absorption
1626 (s)	1653 (w)	N-H deformation
1583 (s)	1571 (w)	N-H deformation
1566 (s)	–	Asymmetric N-H deformation
1475 (sm)	1472 (mw)	Symmetric N-H deformation
1455 (m)	1169 (w)	N-H deformation
1417 (m)	1087 (w)	N-H deformation
1170 (w)	1043 (w)	C-N stretching
1061 (mw)	943 (mw)	C-N stretching
1033 (w)	806 (w)	C-N stretching
936 (mw)	744 (s)	N-H out of plane bending
800 (w)	634 (w)	NH_2 rocking
736 (mw)	569 (w)	N-H wagging
633 (m)	524 (w)	C-H out of plane bending
580 (m)	432 (m)	C-N-C deformation
541 (m)	–	C-N-C deformation
418 (mw)	–	C-N-C deformation

Values given in the parenthesis refer to the relative intensity. w: weak, sm: strong medium, m: medium, s: strong, mw: medium weak, vw: very weak.

N-H stretching vibrations: The N-H stretching vibrations are found in the region[1] 3550-3250 cm^{-1}. In the present study medium to strong intensity band appearing at 3372 cm^{-1} is assigned to N-H stretching vibration in IR spectrum. In Raman spectra, N-H stretching vibrations appear as weak intensity band at 3375 cm^{-1} for metformin hydrochloride. The band appearing at 3176 and 3300 cm^{-1} in IR spectrum are of medium intensity in nature and have been assigned as symmetric and asymmetric N-H stretching vibrations, respectively. The same vibrations have appeared at 3197 and 3301 cm^{-1} in Raman spectrum as weak and medium to weak intensity bands.

N-H deformation vibrations: The N-H deformation vibrations occur in the region[2] 1650-1581 cm^{-1}. In analogue with this strong IR band appearing at frequencies 1626, 1583, 1455 and 1417 cm^{-1} and weak, medium and medium to weak intensity Raman bands appearing at frequencies 1653, 1571 and 1427 cm^{-1} for metformin hydrochloride have been assigned to N-H deformation vibrations. For the same compound, asymmetric N-H deformation and symmetric N-H deformation vibrations appear at frequencies 1566 and 1475 cm^{-1}, respectively. In IR spectrum these vibrations have strong intensity bands and in Raman spectrum, symmetric N-H deformation vibration appears at 1472 cm^{-1} and it has medium intensity.

C-N stretching: The C-N stretching vibrations generally occur in the region[3] 1170-1040 cm^{-1}. In the present study, the weak and medium to weak intensity bands appearing at frequencies 1170, 1061 and 1033 cm^{-1} in IR spectrum and in Raman spectrum, weak bands appearing at 1169, 1087 and 1043 cm^{-1} have been assigned as C-N stretching vibrations for metformin hydrochloride.

NH_2 rocking vibrations and NH wagging: In metformin hydrochloride, a weak band at 800 cm^{-1} in IR spectrum and at 806 cm^{-1} in Raman spectrum have been assigned to NH_2 rocking vibrations. For the same compound, NH wagging vibrations appear at the region[4] 736 cm^{-1} in IR spectrum and at 744 cm^{-1} in Raman spectrum as medium to weak and strong intensity bands, respectively.

C-H bending vibrations: In benzene derivatives, CH-deformation frequencies are expected to arise from 1300-1000 cm^{-1} due to in-plane bending from 1000-610 cm^{-1} due to out of plane bending[5]. In the present study, C-H out of plane bending occurs at frequency 633 cm^{-1} as medium intensity band for metformin hydrochloride in IR spectrum and in Raman spectrum,such vibrations occur at 634 and 912 cm^{-1} as weak bands, respectively.

Methyl/methylene vibrations: Methyl group has two types of stretching vibrations. One is symmetrical contraction or expansion of C-H bond and another is anti symmetrical contraction or expansion of C-H bond. These methyl group vibrations are unaffected by other functional groups present in the molecule. These vibrations always occur[6] below 3000 cm^{-1}. Weak and very weak intensity bands appearing at frequencies 2816 and 1619 cm^{-1} in IR spectrum and 2821 cm^{-1} in Raman spectrum are due to $(CH_3)_2N$ absorption for metformin hydrochloride.

C-N-C deformation: Nitrogen containing compounds give rise to very characteristic absorption bands in their infrared spectra. Medium to strong intensity bands

at 580 and 418 cm^{-1} are due to C-N-C deformation[7] in IR spectrum and at 569 and 432 cm^{-1} in Raman spectrum as weak and medium intensity bands for metformin hydrochloride.

Thus, a qualitative analysis on the vibrational bands in FTIR and FT Raman spectrum of metformin hydrochloride has been made for different functional groups present and the results obtained have been briefly discussed.

Qualitative analysis under different storage conditions: The solution of the sample with different concentrations (water as solvent) was subjected to UV-visible measurements. Elico SL-159 UV-vis spectrophotometer was used for the spectral measurements. The amount of absorption UV-vis radiation was measured for each concentration at its characteristic wavelength maximum (λ_{max}) and the absorbance values are summarized in Table-3. The band observed at 234 nm is considered as λ_{max} for metformin hydrochloride.

TABLE-3
ABSORPTION RATIO FOR METFORMIN HYDROCHLORIDE FOR DIFFERENT STORAGE CONDITIONS FROM UV-VISIBLE SPECTRAL DATA

Concentration	Absorbance		
	Suitable storage condition	Sunlight exposed	IR light exposed
0.0010	1.641	2.853	2.864
0.0009	1.417	2.838	2.864
0.0008	1.246	2.828	2.868
0.0007	1.116	2.812	2.906
0.0006	0.969	2.807	2.831
0.0005	0.832	2.784	2.807
0.0004	0.667	2.737	2.797
0.0003	0.518	2.560	2.758
0.0002	0.366	2.128	2.539
0.0001	0.247	1.264	1.691

UV-Visible spectra of metformin hydrochloride for different concentrations at suitable storage conditions: The UV-vis spectral investigation has also been carried out to study the variation in the absorbance of λ_{max} of the drug at different storage conditions. The sample was exposed to different temperature conditions, *viz*., suitable storage condition, sunlight exposed, IR light exposed and is shown in Fig. 4. The changes of absorbance of λ_{max} in the UV-vis spectra is measured and are presented in Table-4.

It has been observed that the absorbance of a drug kept under sunlight and IR decreases largely. When the drug is kept at a suitable storage condition the absorbance value is high. Also, the decrease in the absorbance value as the concentration decreases indicates a change in the activity of the drug, which is presented in Fig. 5. The investigation conclude that to preserve the effectiveness of the drug, this drug has to be kept in suitable storage condition.

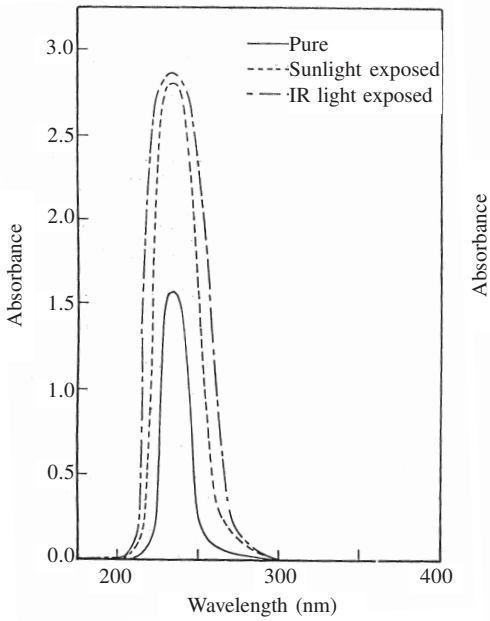

Fig. 4. Variation of absorbance with different conditions of exposure of metformin hydrochloride

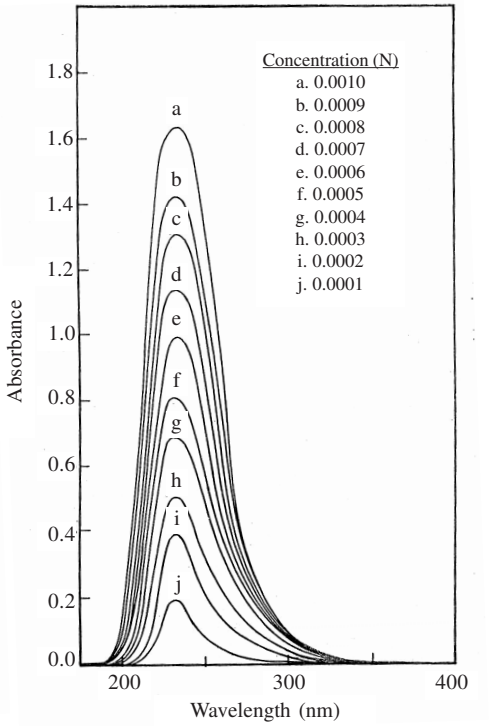

Fig. 5. UV Visible spectra of metformin hydrochloride for different concentrations at suitable storage conditions

TABLE-4
ABSORBANCE λ_{max} AT DIFFERENT STORAGE CONDITIONS

Storage condition	Wavelength maxima
	234 nm
	Absorbance
Suitable storage condition	1.641
Sunlight exposed	2.853
IR light exposed	2.864

Qualitative analysis on the drug by internal standard calculation: The pharmaceutical activity of a drug is solely dependent on the preservative environmental condition. FT IR and FT Raman spectroscopic investigations being a powerful tool for qualitative analysis is used in pharmaceutical industry to study whether a drug is degraded under exposure to environmental conditions. In the present study, the metformin hydrochloride was stored under different storage conditions, sunlight exposed and IR light exposed. FT IR and FT Raman spectra of the drug were recorded and quality of the drug was analyzed by comparing the set of internal standards that were arrived at from absorbance ratios of the sample kept at suitable storage condition

at specific modes of vibration with those of the sample exposed to sunlight and IR light radiation. It has been observed that the internal standard ratio for the drugs exposed to sunlight and IR light show remarkable change from that stored in suitable storage conditions. Also the bar diagram in the Fig. 6 gives the internal standard for metformin hydrochloride at 3176 cm^{-1}. From the bar diagram it is clear that under suitable storage condition prescribed for the drug, the absorbance values are maintained as per the pharmaceutical standards[8]. The efficiency of the drug is lost when it is subjected to environmental hazards.The ratios of absorbance are listed in Table-5.

TABLE-5
INTERNAL STANDARD EVALUATION FOR METFORMIN HYDROCHLORIDE

(a) Under suitable storage condition										
–	3372	3176	1626	1566	1475	1061	936	800	736	541
3372	1	1.058	0.857	0818	1.058	1.636	2.250	0.450	1.800	1.200
3176	0.944	1	0.809	0.772	1	1.546	2.125	4.251	1.700	1.133
1626	1.166	1.235	1	0.954	1.235	1.909	2.625	5.251	2.100	1.400
1566	1.222	1.294	0.857	1	1.294	2.00	2.750	5.50	2.200	1.467
1475	0.944	1	0.809	0.772	1.000	0.646	2.125	4.251	1.700	1.133
1061	1.636	0.646	0.523	0.499	0.646	1	1.375	2.75	1.1	0.733
936	0.444	0.470	0.380	0.363	0.470	0.727	1	2	0.8	0.533
800	0.222	0.235	0.190	0.181	0.235	0.363	0.5	1	0.4	0.266
736	0.555	0.588	0.476	0.454	0.588	0.909	1.25	2.5	1	0.666
541	0.833	0.88	0.681	0.681	0.882	1.363	1.875	3.75	1.5	1
(b) Sunlight exposed										
–	3372	3176	1626	1566	1475	1061	936	800	736	541
3372	1	0.983	0.813	0.772	1.051	1.362	1.742	3.813	1.326	1.244
3176	1.061	1	0.826	0.784	1.068	1.347	1.771	3.876	1.347	1.265
1626	1.229	1.209	1	0.949	1.293	1.630	2.124	4.689	1.630	1.530
1566	1.295	1.274	1.053	1	1.362	1.717	2.257	4.939	1.717	1.612
1475	0.950	0.935	0.773	0.734	1	1.260	1.657	3.626	1.260	1.183
1061	0.754	0.741	0.613	0.582	0.793	1	1.314	2.875	1	0.938
936	0.573	0.564	0.466	0.443	0.603	0.760	1	2.188	0.760	0.714
800	0.262	0.257	0.213	0.202	0.275	0.347	0.456	1	0.347	0.326
736	0.754	0.741	0.613	0.582	0.793	1	1.314	2.875	1	0.938
541	0.803	0.790	0.653	0.620	0.844	1.065	1.399	3.063	1.065	1
(c) IR light exposed										
–	3372	3176	1626	1566	1475	1061	936	800	736	541
3372	1	1.09	0.885	0.843	1.272	2.187	2.799	4.668	2.058	1.372
3176	0.971	1	0.860	0.819	1.236	2.125	2.720	4.535	2.000	1.333
1626	1.128	1.161	1	0.951	1.436	2.469	3.160	5.268	2.323	1.549
1566	1.185	1.220	1.050	1	1.509	2.594	3.320	5.535	2.441	1.627
1475	0.785	0.808	0.696	0.662	1	1.719	2.200	3.668	1.617	1.078
1061	0.457	0.470	0.405	0.385	0.581	1	.279	2.133	0.941	0.627
936	0.357	0.367	0.316	0.301	0.454	0.781	1	1.667	0.735	0.490
800	0.214	0.220	0.189	0.180	0.272	0.468	0.599	1	0.441	0.294
736	0.485	0.499	0.430	0.409	0.618	1.062	1.359	2.267	1	0.666
541	0.728	0.749	0.645	0.614	0.927	1.593	2.039	3.400	1.500	1

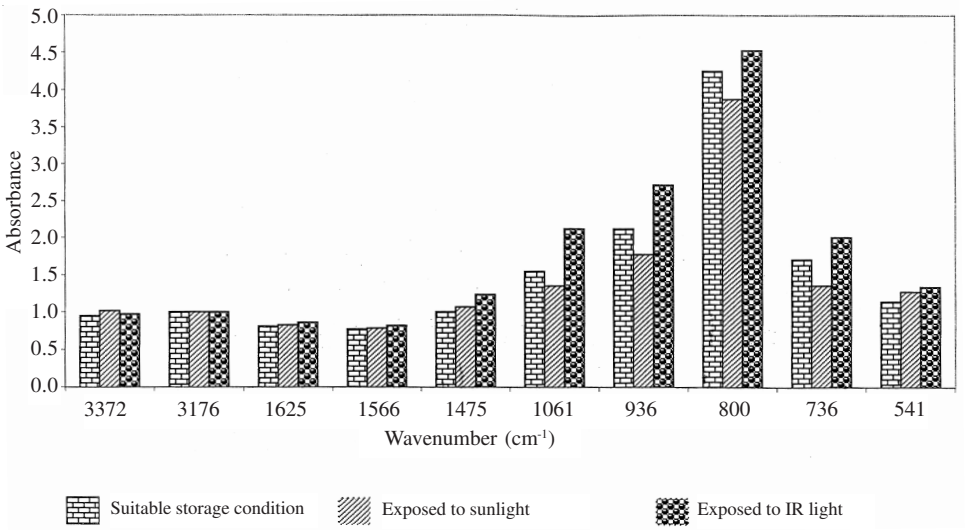

Fig. 6. Internal standards for metformin hydrochloride at 3176 cm^{-1}

Conclusion

A satisfactory vibrational band assignment of metformin hydrochloride has been carried out by FT IR and FT Raman spectral measurements. From the UV-vis spectral measurements under different storage conditions on the drug it has been noted that the absorbance of light decreases due to exposure to sunlight and IR light show changes. The qualitative analysis result obtained from the UV-vis and IR ensures that the quality and efficiency of the drug have been maintained in the suitable storage condition therefore, the drugs should be stored or placed according to the storage condition of the particular drug otherwise its efficiency will be destroyed and it is dangerous to intake the drug.

REFERENCES

1. G. Socrates, Infrared Characteristic Group Frequencies, John Wiley & Sons, New York (2004).
2. S. Gunasekaran and S. Xavier, *Orient. J. Chem.*, **10**, 219 (1994).
3. B.R.D.B. Praser and W.C. Pricve, *Proc. Royal Soc.*, **41**, 66 (1953); *Nature*, **170**, 491 (1952).
4. J.E. Stewart, *J. Chem. Phys*., 30, 1259 (1959).
5. S. Gunasekaran and S.R. Varadhan, *Orient. J. Chem*., **11**, 27 (1995).
6. R.M. Silverstein,G. Clayton, Basslor and T.C. Morril, Spectroscopic Identification of Organic compounds, 4E, John Wiley, New York (1981).
7. V.K. Rastogi, D.K. Jain, H.P. Mital and S.N. Sharma, *Acta Phys. Polonica*,**79**, 765 (1991).
8. Indian Pharmacoepia, edn. 5, Vol. 2 (1996).

(*Received*: 19 May 2009; *Accepted*: 17 March 2010) AJC-8514