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COMPUTATIONAL STUDIES ON MOLECULAR STRUCTURE AND INTERPRETATION OF VIBRATIONAL SPECTRA, THERMODYNAMICAL AND HOMO-LUMO ANALYSIS OF MEPHEDRONE USING DENSITY FUNCTIONAL THEORY AND AB INITIO METHODS.

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ABSTRACT

An ab initio HF and DFT calculations have been performed with the different basis sets like 6-311G, 6-311G (d, p) and 6-311G ++. The optimized geometry, wavenumber, polarizability and several thermodynamic properties of mephedrone were studied. The study is extended to the HOMO - LUMO analysis to calculate the energy gap, ionization potential, electron affinity, global hardness, chemical potential and global electrophilicity, electrostatic potential map and thermodynamic properties of mephedrone. A complete vibrational assignment aided by the theoretical harmonic frequency analysis has been proposed. The calculated HOMO and LUMO energies show the charge transfer occurs in the molecule. Comparing bond angles and lengths of B3LYP with those of HF, as a whole the former are on higher side than the latter.

KEYWORDS: ab initio HF and DFT; mephedrone; vibrational analysis; HOMO-LUMO energy and electrostatic potential map.

INTRODUCTION

Mephedrone, also known as 4-methylmethcathinone (4-MMC) or 4-methylephedrone, is a synthetic stimulant drug of the amphetamine and cathinone classes. It is chemically similar to the cathinone compounds found in the khat plant of eastern Africa. Mephedrone is a white substance. Mephedrone has comparable abuse potential to cocaine or ecstasy.[1] Based in its

chemical structure it is likely to postulate that this drug acts as a psychoactive compound that elicits stimulant effects similar to amphetamine derivatives.[2] However, very little is known about the pharmacology of mephedrone. Cozzi et al.[3] performed in vitro studies with methcathinone and methylone (cathinone derivatives) and confirm that the main mechanism of action could be similar to that of amphetamine. Moreover, methylone is able to bind to noradrenalin, dopamine and serotonin transporters.[4] Mephedrone is expected to act as a central nervous system stimulant. The limited information available comes from user self-reports, although these are unsubstantiated with no toxicological analysis to confirm mephedrone use. To date, only a very recent paper of Kehr et al.[5] studied the psychostimulant effect of mephedrone using a microdyalisis technique. The aim of this paper is to characterize in vitro some pharmacological targets of mephedrone in rats in order to establish the basis of the mechanism of action of this cathinone derivative and hypothesize about its effects in humans.

Density functional theory (DFT), accepted by the ab initio quantum chemistry community is a cost effective general procedure for studying physical properties of the molecules. DFT calculations of vibrational spectra of many organic systems[6,7] have shown promising conformity with experimental results. Therefore, in this present investigation ab initio and DFT techniques are employed to study the complete vibrational spectra of the title compound. Literature survey reveals that to the best of our knowledge no ab initio Hartee fock (HF)/DFT frequency calculations of Mephedrone have been reported so far. The main objective of this paper is to present, more accurate molecular geometry and molecular vibrational assignment of title molecule. For that purpose quantum chemical computations were carried out on Mephedrone using HF/DFT with different basis sets.The calculated HOMO (Highest occupied molecular orbitals)–LUMO (Lowest unoccupied molecular orbitals) energies show that charge transfer occur in the title molecule. DFT calculations are reported to provide excellent vibrational frequencies of organic compounds, if the calculated frequencies are scaled to compensate for the approximate treatment of electron correlation, for the deficiencies and for the anhormanicity.[8,9] Ab initio HF and DFT calculations have been performed to support our wave number assignments.

Computational methods

The entire calculations conducted in the present work were performed at Hartree-Fock (HF) and B3LYP levels included in the Gaussian 09W package[10] program together with the

different basis sets (6-311G,6-311G(d,p) and 6-311G++).The geometries were first determined at the Hartree Fock level (HF) of theory employing different bais sets .All the geometries were then optimized using different basis sets using density functional theory (DFT)[11] employing the Becke's three-parameter hybrid functional[11] combined with Lee-Yang-Parr correlation[12] functional (B3LYP) method. The electron correlation is taken into account in DFT via the exchange correlation term EXC, which includes the exchange energy arising from the anti symmetry of the quantum mechanical wave function and the dynamic correlation in the motion of individual electrons; it makes DFT dominant over the conventional HF procedure.[13] The optimized structural parameters were used in the vibrational frequency calculations at the HF and DFT levels to characterize all stationary points as minima.

In this paper we were calculated the vibrational assignments, the bond lengths, bond angles, dipole moments, thermodynamic properties in the gas phase. In addition, the energy of the highest occupied molecular orbital (HOMO), the energy of the lowest unoccupied molecular orbital (LUMO) and mulliken charges of the title molecule were calculated with the employment of ab initio molecular orbital calculations with different basis set.

RESULTS AND DISCUSSION

The optimized geometrical parameters of the title compound are calculated by ab initio HF and DFT (B3LYP) levels with different the basis sets. The optimized structure parameters obtained at different basis sets for the title compound are summarized in Table1and 2 in accordance with the atom numbering scheme given in Fig.1. Comparing bond angles and lengths of B3LYP with those of HF, as a whole the former ones are on higher side than the latter. In spite of the differences, calculated geometric parameters represent a good approximation and they are the bases for calculating other parameters, such as vibrational frequencies and thermodynamic properties. The benzene ring appears a little disported with C1-C6 and C2-C3 ($1.40A^0$) longer than the bonds C1-C2 and C4-C5 ($1.30A^0$) in the middle of the phenyl ring. These distortions are explained by the substituent of the carbon place to which it is attached.

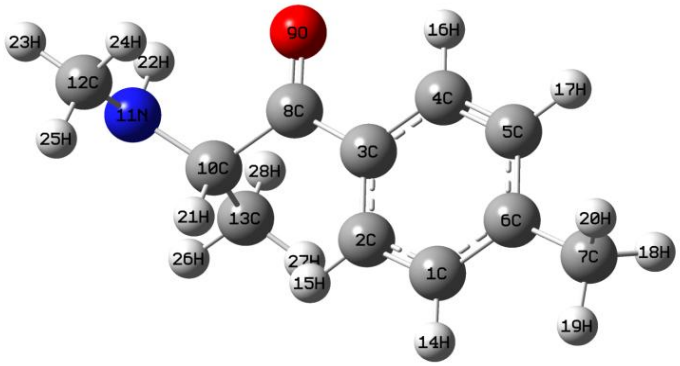


Fig.1 Geometry of the mephedrone optimized at B3LYP/6-311G (d, p). Each atom is colored and numbered. Grey is carbon, blue is nitrogen, red is oxygen and white is hydrogen.

Table 1. Optimized parameters of mephedrone at DFT and HF method at different basis sets.

Bond length	DFT			HF		
	6-311G	6-311G(d,p)	6-311G++	6-311G	6-311G(d,p)	6-311G++
C1-C2	1.3955	1.3925	1.3961	1.3873	1.3870	1.3881
C1-C6	1.4016	1.3967	1.4019	1.3887	1.3848	1.3892
C1-H14	1.0826	1.0849	1.0829	1.071	1.0757	1.0716
C2-C3	1.4045	1.3994	1.4051	1.3901	1.3866	1.3904
C2-H15	1.0808	1.0829	1.0810	1.0692	1.0735	1.0697
C3-C4	1.4081	1.4035	1.4087	1.3963	1.3950	1.3967
C3-C8	1.4869	1.4967	1.4876	1.4856	1.5005	1.4867
C4-C5	1.3887	1.3850	1.3895	1.3792	1.3763	1.3800
C4-H16	1.0807	1.0831	1.0811	1.0687	1.0732	1.0694
C5-C6	1.4074	1.4030	1.4077	1.3961	1.3947	1.3966
C5-H17	1.0831	1.0855	1.0835	1.0716	1.0764	1.0722
C6-C7	1.5101	1.5080	1.5101	1.5070	1.5090	1.5072
C7-H18	1.0930	1.0944	1.0932	1.0827	1.0860	1.0830
C7-H19	1.0899	1.0913	1.0902	1.0801	1.0834	1.0806
C7-H20	1.0929	1.0943	1.0932	1.0827	1.0860	1.0830
C8-O9	1.2502	1.2181	1.2498	1.2242	1.1925	1.2235
C8-C10	1.5428	1.5476	1.5440	1.5289	1.5374	1.5299
C10-N11	1.4647	1.4566	1.4640	1.4502	1.4446	1.4497
C10-H13	1.5434	1.5395	1.5427	1.5352	1.5339	1.5352
C10-H21	1.0917	1.0942	1.0919	1.0795	1.0840	1.0799
N11-C12	1.4712	1.4637	1.4715	1.4577	1.4517	1.4580
N11-H22	1.0157	1.0168	1.0152	0.9968	0.9998	0.9970
C12-H23	1.0899	1.0924	1.0898	1.0797	1.0842	1.0800
C12-H24	1.0994	1.1009	1.0992	1.0870	1.0906	1.0872
C12-H25	1.0918	1.0943	1.0920	1.0817	1.0862	1.0822
C13-H26	1.0885	1.0910	1.0892	1.0786	1.0831	1.0793
C13-H27	1.0911	1.0925	1.0914	1.0816	1.0851	1.0819
C13-H28	1.0919	1.0937	1.0924	1.0822	1.0861	1.0827

Table 2. Optimized parameters of mephedrone at DFT and HF method at different basis sets.

Bond angle	DFT			HF		
	6-311G	6-311G(d,p)	6-311G++	6-311G	6-311G(d,p)	6-311G++
C2-C1-C6	121.1203	121.1078	121.1347	121.0044	120.9529	121.0100
C2-C1-H14	119.4821	119.4404	119.4489	119.3156	119.2545	119.2995
C6-C1-H14	119.3975	119.4517	119.4163	119.6800	119.7925	119.6906
C1-C2-C3	120.6030	120.6100	120.6430	120.7317	120.7479	120.7533
C1-C2-H15	118.7687	118.7415	118.6622	118.3726	118.3267	118.3069
C3-C2-H15	120.6281	120.6485	120.6943	120.8957	120.9253	120.9396
C2-C3-C4	118.3455	118.3540	118.2858	118.3209	118.3180	118.2967
C2-C3-C8	123.1756	123.4932	123.1126	123.2970	123.6517	123.2499
C4-C3-C8	118.4789	118.1519	118.6016	118.3820	118.0292	118.4534
C3-C4-C5	120.8028	120.7989	120.8167	120.8062	120.8053	120.8153
C3-C4-H16	118.0510	118.0769	118.2220	118.5463	118.6135	118.6325
C5-C4-H16	121.1462	121.1241	120.9612	120.6474	120.5811	120.5521
C4-C5-C6	121.0147	121.0207	121.0480	120.9858	120.9598	120.9973
C4-C5-H17	119.6220	119.5898	119.5823	119.5140	119.4995	119.4906
C6-C5-H17	119.3633	119.3895	119.3698	119.5001	119.5407	119.5121
C1-C6-C5	118.1136	118.1085	118.0719	118.1509	118.2160	118.1273
C1-C6-C7	121.3038	121.3369	121.3096	121.3811	121.4271	121.3761
C5-C6-C7	120.5826	120.5546	120.6185	120.4680	120.3569	120.4966
C6-C7-H18	111.2214	111.0464	111.2338	111.0260	110.7741	111.0314
C6-C7-H19	111.5093	111.5412	111.4891	111.4060	111.3605	111.3792
C6-C7-H20	111.2163	111.0409	111.2180	111.0179	110.7640	111.0235
H18-C7-H19	107.7843	107.9508	107.7831	107.8643	108.1028	107.8636
C18-C7-H20	107.1167	107.1182	107.1216	107.5006	107.6060	107.5199
H19-C7-H20	107.7924	107.9601	107.7952	107.8579	108.0945	107.8562
C3-C8-O9	120.4044	120.5848	120.4284	119.9845	120.1808	119.9730
C3-C8-C10	121.2684	120.6202	121.0680	121.3477	120.6441	121.1657
O9-C8-C10	118.3043	118.7648	118.4763	118.6438	119.1452	118.8292
C8-C10-N11	112.3269	112.5436	112.7141	112.3244	112.6147	112.5469
C8-C10-C13	109.2261	108.7244	109.0309	109.1817	108.6850	109.0311
C8-C10-H21	109.5419	109.5532	109.3648	109.4159	109.5143	109.3138
N11-C10-C13	109.6671	109.7359	109.8265	109.6998	109.6994	109.8768
N11-C10-H21	107.0731	107.3925	106.8793	107.1688	107.4250	107.0666
C13-C10-H21	108.9365	108.8267	108.9482	108.9845	108.8374	108.9338
C10-N11-C12	115.6495	113.9760	115.8202	116.4716	114.6771	116.5093
C10-N11-H22	109.8276	107.3372	110.4976	111.2376	108.5883	111.4719
C12-N11-H22	111.0108	108.4994	111.3751	111.9194	109.2765	111.9784
N11-C12-H23	108.9066	108.9890	108.9430	109.0812	109.0658	109.0880
N11-C12-H24	114.3565	114.5523	113.9774	113.8202	114.1035	113.6125
N11-C12-H25	109.3995	109.4259	109.3749	109.6118	109.5797	109.6056
H23-C12-H24	108.1155	108.0008	108.2399	108.1229	108.0551	108.1815
H23-C12-H25	107.4895	107.4013	107.6044	107.5555	107.4706	107.6257
H24-C12-H25	108.3541	108.2334	108.5107	108.4578	108.3546	108.5513
C10-C13-H26	108.8761	109.1536	109.1026	108.9916	109.2397	109.0846
C10-C13-H27	112.0465	112.1153	111.8921	112.1457	112.0942	112.0486
C10-C13-H28	109.9887	109.9996	110.0717	110.0514	110.0572	110.1520

H26-C13-H27	109.3923	109.2755	109.2331	109.1248	109.0790	109.0470
H26-C13-H28	108.3655	108.2269	108.4106	108.3537	108.2829	108.3252
H27-C13-H28	108.1009	107.9866	108.061	108.0957	108.0043	108.1045

Vibrational assignments

According to the theoretical calculations, mephedrone has a structure of C1 point group symmetry. The molecule has 28 atoms and 78 modes of fundamental vibrations. All the 78 fundamental vibrations are active in IR absorption. The vibrational wave numbers were calculated using the ab initio HF and DFT (B3LYP) level of theory at different basis sets. The absence of imaginary values of wave numbers as the calculated vibrational spectrum confirms that the structure deduced corresponds to minimum energy. No scale factor was used in the calculated frequencies. Gauss view molecular visualization program was used to assign the calculated harmonic frequencies. The resulting vibrational wave numbers, IR intensities for the optimized geometry of title compound and the proposed assignments in gas phase are given in Table 3.Comparison between the DFT method and the HF method observed vibrational spectra, inclusion of electron correlation in density functional theory to a certain extent makes the frequency values smaller in comparison with the HF frequency data. Normally, aromatic compounds commonly shows the presence of C-H stretching vibrations in the region 3000–3100 cm-1 which is the characteristic region for the ready identification of C-H stretching vibration 27.The mephedrone molecule give rise to the phenyl ring C-H stretching, 3203-3262 cm^{-1} , 3198-3159 cm^{-1} and 3197-3156 cm^{-1} for the basis sets 6-311G,6-311G(d,p) and 6-311++ respectively with DFT method. The HF method gives rise to the phenyl ring C-H stretching, 3383-3331 cm^{-1} , 3372-3319 cm^{-1} and 3372-3321 cm^{-1} for the basis sets 6-311G,6-311G(d,p) and 6-311++ respectively. The remaining methyl C-H stretching frequency assignments are given in Table 3.

The molecule under investigation possesses only one NH group and hence one expects N– H stretching vibration in NH group. In all the primary aromatic amines, the N–H stretching frequency occurs in the region ≈3450 cm^{-1}. In the mephedrone molecule the N-H stretching give rise to 3498, 3499 and 3512 cm^{-1} at DFT method in different basis sets 6-311G,6-311G(d,p) and 6-311++ respectively. The band predicted by DFT method at 1633 ,1649 and 1625 cm^{-1}, attributed to the C = O stretching, with different basis sets 6-311G,6-311G(d,p) and 6-311++ respectively. The C = O bond stretching gives rise at HF method at 1797,1801 and 1792 cm^{-1} in 6-311G,6-311G(d,p) and 6-311++ basis sets respectively. The remaining all vibrational modes like bending (out of plane, in plane), scissoring, rocking, waging, twisting of C-H bonds and phenyl ring deformations assignments are given in table 3.

Table 3. Calculated wave numbers for Mephedrone using DFT and HF methods in different basis sets.

DFT						HF						Vibrational assignment
6-311		6-311G(d,p)		6-311++		6-311		6-311G(d,p)		6-311++		
Wave number	Intensity	Wave number	Intensity	Wave number	Intensity	Wave number	Intensity	Wave number	Intensity	Wave number	Intensity	
3498	1.1855	3499	4.1808	3512	2.0264	3775	5.1015	3765	7.9214	3778	6.0075	Str 11N-22H
3203	4.0193	3198	3.3955	3197	3.7860	3383	2.6998	3372	2.5615	3372	2.6538	Str 4C-16H
3194	17.6295	3192	10.6405	3190	16.5098	3369	19.5588	3362	13.9194	3362	17.9136	Str 2C-15H and 1C- 14H
3166	19.6843	3163	14.3981	3160	18.3167	3336	20.4494	3326	16.3444	3327	18.762	Asym str 1C-14H and 2C-15H
3162	20.4215	3159	15.4874	3156	19.3971	3331	22.8727	3319	18.0722	3321	20.9171	Aym s str 5C-17H and 4C-16H
3118	26.6335	3117	24.6689	3113	24.1834	3262	34.4257	3256	35.305	3257	31.961	Asym str13C-H26,13C-27H,13-28H
3100	21.048	3108	17.1559	3097	21.1116	3242	27.4413	3248	24.177	3238	26.9098	Asym str 7C-18H,7C-19H,7C-20H
3094	63.2459	3099	32.4718	3093	44.4043	3240	98.9529	3238	77.6727	3237	78.2756	Asym str 13C-27H and 13C-28H
3093	16.1498	3091	36.0348	3091	28.3094	3238	15.5907	3234	34.1114	3234	27.2657	Asym str 12C-25H and 12C-23H
3068	20.7119	3076	15.8164	3066	17.9419	3216	29.5261	3221	25.6806	3214	24.4417	Asym str 7C-20H and 7C-18H
3047	43.5527	3049	45.7553	3045	46.4700	3215	7.482	3213	9.9108	3209	7.3931	Sym Str 12C-25H and 12C-23H
3045	21.6223	3047	15.5626	3042	11.7454	3196	60.4556	3195	57.6836	3191	53.3081	Str 10C-21H
3023	22.0631	3033	17.3887	3019	22.1221	3169	24.7036	3172	22.147	3164	24.7059	Sym str 13C-27H ,13C-28H,13C-26H
3015	29.3332	3026	24.6205	3012	31.1817	3163	37.4488	3168	34.473	3159	38.789	Sym str 7C-18H,7C-19H,7C-20H
2948	82.2521	2962	69.7314	2951	82.5473	3124	67.9602	3130	63.3964	3121	69.3503	Sym Str 12C-25H , 12C-23H,12c-24H
1655	19.9057	1740	160.037	1650	25.1153	1831	179.4404	1948	254.1725	1822	187.3758	Str 8C-9O(carbonyl group)
1633	137.2559	1649	81.6219	1625	135.361	1797	85.0668	1801	74.3053	1792	95.2395	Str 8C-9O(carbonyl group)
1597	61.5405	1607	12.7654	1592	81.8783	1741	29.2006	1751	12.2057	1737	31.3958	Ring C-C , str
1563	18.2948	1540	3.0208	1559	19.7581	1693	25.5448	1676	10.8572	1690	26.8172	C-H in plane bending

1555	0.4579	1532	16.8162	1552	2.0208	1682	0.8263	1666	13.9166	1679	0.8846	C–H sis
1546	3.61	1510	0.5497	1541	3.8454	1669	0.2707	1632	0.6612	1664	0.6055	C- H sis
1535	15.8456	1498	8.8812	1532	15.185	1650	7.4066	1615	9.2979	1646	8.8227	C-H sis (13CH3)
1530	12.898	1496	14.4788	1528	10.1456	1649	14.4144	1613	11.2333	1645	14.0927	C-H sis (7CH3)
1529	10.8301	1491	11.8614	1526	16.4686	1644	10.7581	1611	11.8202	1641	9.5396	C-H sis(12CH3)
1527	9.7844	1487	7.1322	1524	8.6175	1643	8.794	1606	3.8888	1640	11.3634	C-H sis
1521	7.4135	1485	4.3709	1518	7.7258	1639	5.8203	1604	6.2156	1635	6.2435	C-H sis
1487	0.3797	1457	0.6186	1483	0.2712	1608	0.6065	1584	1.1807	1604	0.1585	C-H weg
1457	8.1095	1439	12.2351	1453	8.9416	1576	2.5563	1550	15.7088	1573	2.7277	C-H weg
1450	14.4537	1415	0.7597	1447	12.3665	1563	16.9861	1537	1.2568	1560	16.0082	C-H weg
1439	11.1921	1405	10.8136	1436	11.6385	1558	8.3331	1532	6.6467	1554	8.2755	C-H weg
1397	1.9409	1375	2.2384	1394	1.5318	1521	1.8016	1501	4.0462	1518	1.4941	10C - 21H weg
1367	5.3969	1338	2.2373	1364	4.6435	1475	6.5482	1448	14.3576	1472	5.6052	Ring, H weg
1343	2.6231	1335	5.7007	1341	2.9579	1453	5.839	1440	6.7234	1447	5.5087	Ring ,H weg
1318	8.9469	1304	18.0451	1314	8.0151	1392	57.4294	1373	42.3388	1389	49.7259	C-H twi
1279	82.5988	1260	70.6865	1277	70.1639	1358	19.7412	1333	31.0632	1356	22.0145	C-H twi
1250	2.4702	1233	0.519	1249	3.4929	1342	27.9004	1315	52.6822	1340	27.8942	C-H twi
1238	12.6244	1222	42.5713	1236	11.4158	1325	21.4733	1303	21.6222	1322	20.315	C-H twi
1225	87.9293	1201	83.8688	1223	100.0858	1321	50.9202	1294	48.6994	1319	57.736	C-H twi
1167	30.5556	1160	20.661	1165	28.3279	1271	46.9878	1262	36.305	1269	45.2619	C-H twi
1160	12.2831	1144	44.2951	1158	11.9156	1259	11.9461	1249	25.8525	1256	11.9245	C-H rock
1153	34.4095	1139	10.0717	1153	34.8955	1229	3.5242	1189	11.8641	1227	3.5433	C-H rock
1111	13.8846	1092	13.0936	1107	13.1673	1207	17.2558	1187	6.8948	1203	16.1739	C-H rock
1095	6.272	1064	4.3436	1094	6.0837	1197	5.7942	1161	3.3378	1197	6.1795	C-H rock
1077	7.1531	1062	6.1096	1076	7.8433	1173	7.6259	1157	6.7081	1170	8.3216	C-H rock
1050	6.7373	1037	2.2183	1049	8.3393	1145	0.766	1119	0.6427	1145	0.9363	Ring C-H rock
1037	4.1974	1026	3.0019	1034	5.5697	1126	5.4655	1109	0.9156	1125	6.3254	C-H rock
1031	6.3465	1010	20.1805	1029	9.4800	1118	6.6073	1103	3.6541	1116	7.9081	C-H rock
1030	6.9624	1007	2.4555	1027	1.8421	1112	10.3776	1089	27.7415	1109	8.5311	Ring H rock
994	0.3456	971	9.0109	992	0.2896	1107	1.0092	1080	0.9262	1104	1.1913	Ring H rock
980	63.805	968	68.4704	976	59.2878	1061	50.8118	1042	52.7323	1057	49.7089	Ring bend

900	2.3749	898	7.6443	896	0.6181	973	4.9355	956	1.4954	972	6.1936	N-H bend
882	10.4424	865	9.9958	880	11.9310	963	1.1119	952	5.1381	959	2.7129	Ring H twi
859	25.0153	842	20.2905	857	31.664	948	31.6743	930	29.5483	946	40.4009	Ring C-H twi
821	0.9659	821	22.2264	820	0.7943	881	10.1412	894	94.2336	879	7.9986	Ring deformation
772	37.1034	800	89.0732	767	48.9411	843	92.3285	859	47.582	840	91.2021	Molecule deformation
766	35.8773	761	14.6331	760	17.0171	835	28.087	828	24.7873	828	22.7233	Molecule deformation
713	18.4925	725	22.7506	709	13.8988	775	14.0525	781	14.0928	771	13.1655	Skeletal bend
687	112.7916	701	13.1264	681	109.3569	748	96.2725	760	11.2986	742	92.0188	Skeletal bend
668	6.0793	652	1.4446	667	9.4412	716	2.9407	696	1.0377	714	3.4981	Ring skeletal
617	1.3006	611	2.3759	616	0.9253	660	3.2822	650	4.4797	658	2.8633	Ring skeletal
509	16.4384	499	13.6224	504	16.7342	555	19.475	542	16.8069	551	20.7263	Molecule butter fly
480	2.3442	474	2.8326	478	2.4893	515	4.0838	507	4.2327	513	4.0659	Molecule butter fly
456	2.4511	454	1.1878	455	2.1555	493	2.4638	489	1.1581	492	2.0811	Skeletal
424	0.0345	416	0.0306	423	0.0227	467	0.0279	455	0.0213	466	0.0157	Ring skeletal bend
368	9.4181	365	13.0337	368	7.1337	396	10.7752	392	13.934	395	9.039	Total molecule vibrations
358	2.246	355	0.8052	358	2.3554	385	4.0057	380	1.8123	384	3.9368	
322	17.7262	325	11.6094	316	16.748	349	15.4305	350	9.1728	344	15.4758	
292	4.3086	286	2.0335	290	4.7693	317	4.7049	311	2.153	317	5.4104	
249	0.8599	246	0.6268	246	0.993	267	1.1245	263	0.6698	264	1.3106	
223	0.8909	222	0.5729	220	1.1864	238	1.7371	238	0.2749	236	1.4535	
214	0.8642	212	0.9324	213	0.5376	236	0.5877	237	1.7338	232	0.6973	
178	5.4582	182	4.2042	178	5.4081	187	4.0777	194	3.7901	186	4.2407	
133	0.1093	133	0.1795	135	0.2178	144	0.2003	144	0.3957	144	0.2336	
108	0.4552	107	1.3321	106	0.4097	117	0.5139	119	4.3957	116	0.2527	
90	5.2106	99	3.1175	96	5.3042	108	5.6779	114	0.2764	109	5.7634	
49	0.1835	49	0.1003	55	0.1837	53	0.1412	54	0.1084	56	0.1257	
42	0.0646	39	0.1294	44	0.0755	38	0.4986	38	0.2756	50	0.1436	
36	0.6594	34	0.4226	35	0.7081	30	0.5101	30	0.3968	34	0.9461	

Str=stretching; sym=symmetric; asym= asymmetric; bend= bending; sci=scissoring; twi= twisting; wag=wagging; rock= rocking;

Thermodynamic properties

The calculated thermodynamic parameters are presented in Table 4. The total energies found to decrease with increase of the basis sets. Hartree-Fock calculations give an electronic energy that is too high. This is partly because of the overestimation of electronic repulsion and partly because of the fact that in any real calculation the basis set is not perfect.

Table 4. Theoretically computed energies (a.u.), enthalpy (a.u.), freenergies (a.u.), entropies (cal mol^{-1} K^{-1}) , HOMO and LUMO energies (ev), and dipolemoments (μ) deby at DFT and HF methods in different basis sets.

Basis set	**E**		**H**	**G**	**S**
DFT					
6-311G	-558.158969071		-557.904480	-557.960555	118.020
6-311G(d,p)	-558.326423853		-558.073283	-558.129501	118.321
6-311G++	-558.168159604		-557.914049	-557.970009	117.778
HF					
6-311G	-554.480573933		-554.210158	-554.264963	115.347
6-311G(d,p)	-554.727618039		-554.458888	-554.513725	115.414
6-311G++	-554.488722637		-554.218811	-554.273270	114.620
DFT	**μ**		**HOMO**	**LUMO**	**Gap**
6-311	3.5848		-5.7815	-1.8733	-3.9082
6 -311G(d,p)	3.2819		-6.0446	-1.7244	-4.3202
6-311G++	3.7726		-5.9164	-2.0107	-3.9057
HF	**μ**		**HOMO**	**LUMO**	**Gap**
6-311	3.6439		-9.2684	-2.1209	-7.1475
6 -311G(d,p)	3.2496		-9.1800	-2.3432	-6.8368
6-311G++	3.7430		-9.3174	-0.9366	-8.3808
DFT	**I**	**A**	**η**	**μ**	**ω**
6-311	5.7815	1.8733	1.9541	-3.8274	3.7482
6 -311G(d,p)	6.0446	1.7244	2.1601	-3.8845	3.4927
6-311G++	5.9164	2.0107	1.9528	-3.9635	4.0222
HF	**I**	**A**	**η**	**μ**	**ω**
6-311	-2.1209	-7.1475	3.5737	-5.6946	4.5371
6 -311G(d,p)	-2.3432	-6.8368	3.4184	-5.7616	4.8550
6-311G++	-0.9366	-8.3808	4.1904	-5.1270	3.1364

Mulliken Charges

The calculation of effective atomic charges plays an important role in the application of quantum mechanical calculations to molecular systems. Our interest here is in the comparison of different methods to describe the electron distribution in dacarbazine as broadly as possible, and assess the sensitivity of the calculated charges to changes in (i) the choice of the basis set; (ii) the choice of the quantum mechanical method. Mulliken charges, calculated by determining the electron population of each atom as defined in the basis functions. The

Mulliken charges calculated different levels and at different basis sets listed in Table 5. The results can, however, better be represented in graphical form as has been given in Figure 2. From these results, it will be possible to say to the change to charge distribution by a change in basis set. The charges depending on basis set and are changed due to polarization.

Table 5. Theoretically computed mulliken charges at DFT and HF methods in different basis sets.

	DFT			HF		
	6-311	6-311G(d,p)	6-311++	6-311	6-311G(d,p)	6-311++
1C	-0.1773	-0.0732	-1.0425	-0.2278	-0.0895	-1.2790
2C	-0.0829	-0.0543	-0.7838	-0.0929	-0.0613	-1.0914
3C	-0.0882	-0.1382	0.8327	-0.1451	-0.1888	0.7104
4C	-0.0975	-0.0149	-0.0208	-0.1008	-0.0049	-0.0433
5C	-0.1421	-0.0793	-0.1488	-0.1857	-0.1008	0.1560
6C	0.0621	-0.0888	1.0052	0.0924	-0.1034	0.9983
7C	-0.6139	-0.256	-1.4820	-0.5826	-0.1748	-1.6733
8C	0.2749	0.2387	0.4225	0.4677	0.3912	0.8339
9O	-0.3768	-0.3176	-0.3393	-0.5152	-0.4371	-0.4562
10C	-0.1915	-0.1312	-1.1309	-0.1466	-0.0866	-1.1850
11N	-0.5198	-0.3620	0.1220	-0.6585	-0.4546	0.0710
12C	-0.3660	-0.1804	-0.6289	-0.2895	-0.0841	-0.6363
13C	-0.4779	-0.238	0.9459	-0.4650	-0.1866	-1.0925
14H	0.1548	0.0873	0.2820	0.1687	0.0893	0.3537
15H	0.1683	0.0988	0.2818	0.1835	0.1020	0.3698
16H	0.1829	0.1095	0.3499	0.2083	0.1226	0.4303
17H	0.1568	0.091	0.3234	0.1696	0.0929	0.3939
18H	0.2019	0.1281	0.2465	0.1965	0.1131	0.2614
19H	0.1894	0.1092	0.2731	0.1863	0.0958	0.2982
20H	0.2018	0.128	0.2463	0.1967	0.1133	0.2618
21H	0.1826	0.1182	0.3295	0.1814	0.1065	0.3862
22H	0.2881	0.1897	0.4096	0.3138	0.1960	0.4607
23H	0.1790	0.1105	0.2282	0.1697	0.0922	0.2384
24H	0.1629	0.0904	0.2307	0.1604	0.0768	0.2365
25H	0.1757	0.1007	0.1883	0.1660	0.0811	0.1909
26H	0.1954	0.1200	0.2571	0.1947	0.1100	0.2700
27H	0.1751	0.1041	0.2413	0.1731	0.0921	0.2591
28H	0.1821	0.1098	0.2527	0.1810	0.0975	0.2764

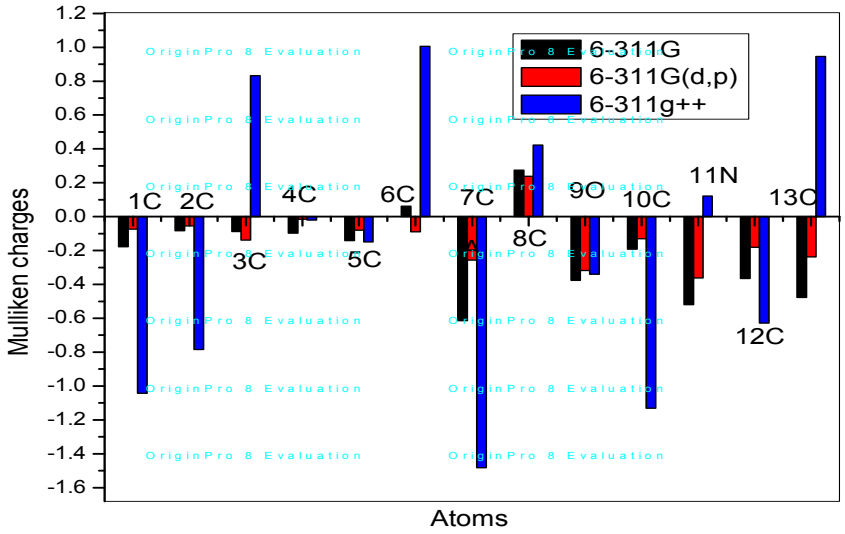
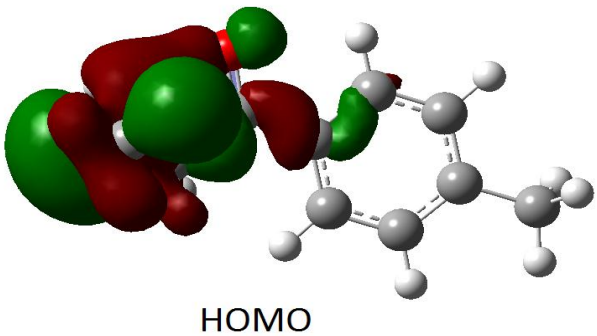


Fig 2. Comparison of different basis sets for calculated atomic charges at DFT method

HOMO LUMO analysis

Many organic molecules that contain conjugated π electrons are characterized as hyperpolarizabilities and were analyzed by means of vibrational spectroscopy.[14] In most of the cases, even in the absence of inversion symmetry, the strongest band in the Raman spectrum is weak in the IR spectrum and vice -versa. The π electron cloud moment from the donor to acceptor can make the molecule highly polarized through the single –double path when it changes from the ground state to the first excited state. The analysis of wave function indicates that the electron absorption corresponds to the transition from the ground to the first excited state and is mainly described by one electron excitation from the highest occupied molecular orbital (HOMO) to the lowest unoccupied orbital (LUMO). The LUMO of π nature (i.e. benzene ring) is delocalized over the whole C-C bond. In Fig 3, molecular orbital surfaces and energy levels given in parentheses for the HOMO and, and LUMO of the title compound have been computed with the B3LYP/ 6-311G (d, p) method. The positive phase is red, and the negative phase is green.



HOMO

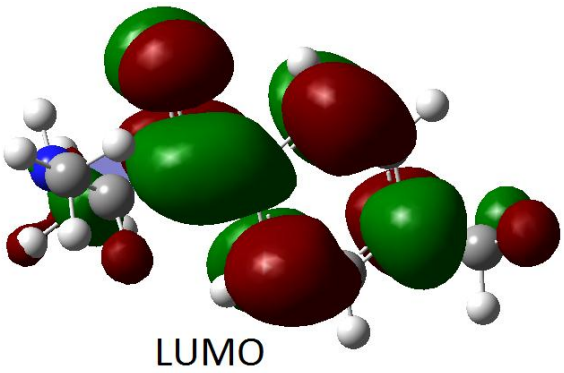


Fig 3. Molecular orbital surfaces and energy levels given in parentheses for the HOMO and, and LUMO of the title compound have been computed with the B3LYP/ 6-311G(d, p) method. The positive phase is red, and the negative phase is green.

HOMO-LUMO energy gap and related molecular properties

The HOMO, LUMO and HOMO-LUMO energy gap of mephedrone in the HF and DFT level in different basis sets has been calculated and presented in Table 4. The HOMO– LUMO energy gap reveals that the energy gap reflects the chemical activity of the molecule. Associated within the framework of SCF MO theory the ionization energy and electron affinity can be expressed through HOMO and LUMO orbital energies as $I = -E_{HOMO}$ and $A = -E_{LUMO}$.[15-17] The hardness corresponds to the gap between the HOMO and LUMO orbital energies. The larger the HOMO-LUMO energy gap the harder the molecule. The global hardness, $\eta = 1/2(E_{LUMO} - E_{HOMO})$.[18-20] The hardness has been associated with the stability of chemical system. The electron affinity can be used in combination with ionization energy to give electronic chemical potential, $\mu = 1/2(E_{HOMO} + E_{LUMO})$. The global electrophilicity index, $\omega = \mu^2/2\eta$[21] is also calculated and listed in Table 4.

Molecular electrostatic potential

The molecular electrostatic potential (MEP) is related to the electronic density and is a very useful descriptor for determining sites for electrophilic attack and nucleophilic reactions as well as hydrogen-bonding interactions.[22-24] To predict reactive sites for electrophilic and nucleophilic attack for the title molecule, MEP was calculated at the B3LYP/6-311G (d, p) optimized geometry. The negative (red) regions of MEP were related to electrophilic reactivity and the positive (blue) regions to nucleophilic reactivity shown in Figure 4.

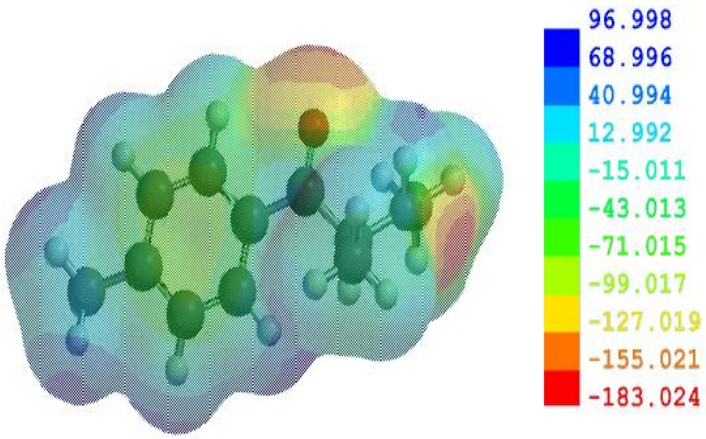


Fig 4. Molecular electrostatic potential map (in a.u.) of the mephedrone compound with the B3LYP/6-311G (d, p) method (with an isodensity value of 0.0004 a.u.).

As can be seen from the figure, there is possible site on the title compound for electrophilic attack. The negative region is localized on the oxygen atom and nitrogen atom. However, maximum positive region is localized on phenyl ring. These results provide information concerning the region where the compound can interact inter molecularly and bond with other molecules.

CONCLUSION

The optimized geometrical parameters of the title compound are calculated by ab initio HF and DFT (B3LYP) levels with different the basis sets. Comparing bond angles and lengths of B3LYP with those of HF, as a whole the formers are on higher side than the latter. The complete vibrational properties mephedrone have been investigated. Comparison between the DFT method and the HF method observed vibrational spectra, inclusion of electron correlation in density functional theory to a certain extend makes the frequency values smaller in comparison with the HF frequency data. From Mulliken charges, it will be possible to say to the change to charge distribution by a change in basis set. The charges depending on basis set and are changed due to polarization.

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