An Experimental and Theoretical Study on Bicyclo-3,4-Dihydropyrimidinone Derivative: Synthesis and DFT Calculation

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ABSTRACT: *We report here an efficient and green method for fused Biginelli condensation reaction of aldehydes, cyclopentanone, and urea catalyzed by nano ZrO_2-SO_3H under solvent-free conditions. The prospect of the reusability of this catalyst has also been demonstrated without compromising on the yield of the product. On the whole, the protocol presented here is an excellent alternative to many of the previously reported procedures. So, Optimized molecular structures have been investigated by DFT/B3LYP method with 6-31G (d,p) basis set. Stability of some 4-aryl-7-benzylidene-1,3,4,5,6,7-hexahydro-4-phenyl-2H-cyclopenta[d]pyrimidin-2-one (2* ***a-j)*** *derivatives and intramolecular interactions bond has been analyzed by using natural bond orbital (NBO) analysis.*

KEYWORDS: *Fused Biginelli condensation reaction; 4-aryl-7-benzylidene-1,3,4,5,6,7-hexahydro-4-phenyl-2H-cyclopenta[d]pyrimidin-2-one; DFT/B3LYP; NBO.*

INTRODUCTION

Over the years, dihydropyrimidinones (DHPMs) and their derivatives have displayed a captivating assortment in natural (have been suggested to be useful building blocks for synthesis of the batzelladine family of polycyclic marine alkaloids, of which batzelladine alkaloids have been found to be a potent HIV gp-120-CD4 inhibitors) [1-4], pharmacological, therapeutic and bioorganic chemistry, mainly due to their wide range of biological activities [5-7].

They are also being studied because of their activities as calcium channel blockers by inhibiting the entry of Ca^{2+} into the cells of cardiac and vascular muscle through the voltage-dependent calcium channels and decrease ventricular contractility by the same mechanism [8,9].

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The most simple and straightforward procedure for the synthesis of DHPMs was first reported by the Italian chemist, *Pietro Biginelli* in 1893, it involves a three-component one-pot condensation of an aryl aldehyde, dicarbonyl compound and urea under strongly acidic conditions [10]. Disadvantages of this reaction are harsh conditions reaction, long reaction times and affords low yields. However, several protocols for the synthesis of DHPMs have been developed to improve and modify this reaction. [11-16] Literature survey shows that the homogeneous and heterogeneous catalyst is used in the synthesis of DHPMs compounds. [17-24] Given the excellent properties of ZrO_2 and the significance of heterogeneous solid acid catalysis, in this study, sulfonation of nano-ZrO_2 with chlorosulfonic acid carried out according to literature survey, [25] and its catalytic application as a heterogeneous catalyst in the synthesis of some fused 3,4-dihydropyrimidinones were studied.

EXPERIMENTAL SECTION

Preparation of nano-ZrO_2-SO_3H (n-ZrSA)

A 50 ml suction flask was equipped with a constant pressure dropping funnel. The gas outlet was connected to a vacuum system through an adsorbing solution of alkali trap. The suspension of chlorosulfunic acid (1 mL) in dry CH_2Cl_2 (3 mL) was added drop wisely to powder nano zirconia (1 g) for 1 h at room temperature while the mixture was stirred slowly. Then, the mixture was shaken for 1 h. After completion of the addition, the residual HCl was eliminated by suction. At the end, the mixture was washed with dry CH_2Cl_2. Finally, light cream powder of nano zirconia supported sulfonic acid (2 g) was obtained, then the solid powder was dried at 100 °C. [25]

General procedure for the synthesis of bicyclo-3,4-dihydropyrimidinone derivatives catalyzed by n-ZrSA under solvent free conditions

A mixture of aldehyde (1 mmol), cyclopentanone (1 mmol), urea (1 mmol) and nano ZrO2-SO3H (0.05 g) carry out under solvent-free at 120 °C. (Scheme 3, Table 2) The progress of the reaction was followed by TLC using n-hexane/ethyl acetate (5:1) as eluents. Then the product was washed with water, followed by crystallization in ethanol.

Selected spectral data

*7-benzylidene-1,3,4,5,6,7-hexahydro-4-phenyl-2H-cyclopenta[d]pyrimidin-2-one (2**a**)*

M.p. 233–236 °C. -IR (KBr): 3408, 3206, 3115, 3020, 2846, 1670, 1465, 1443, 1352 cm^{-1}. -^{1}H NMR (500 MHz, DMSO-d_6): δ = 8.87 (s, 1 H), 7.23–7.69 (m, 8 H), 6.71 (s, 1 H), 5.23 (s, 1 H), 2.83–2.96 (m, 2 H), 2.45-250 (m, 1 H), 2.10–1.93 (m, 1 H) ppm. –^{13}C NMR (250 MHz, DMSO-d_6): 152.55, 142.70, 137.10, 128.04, 127.93, 127.33, 126.90, 125.94, 125.48, 117.92, 116.15, 56.86, 27.79, 27.71 ppm.

*7-(2-methylbenzylidene)-1,3,4,5,6,7-hexahydro-4-(2-methylphenyl)-2H-cyclopenta[d]pyrimidin-2-one (2**b**)*

M.p. 226–228 °C. -IR (KBr): 3236, 3113, 2922, 2849, 2359, 1678, 1590, 1490, 1457 cm^{-1}. - ^{1}H NMR (500 MHZ, DMSO-d_6): δ = 8.92 (s, 1 H), 7.03– 7.35 (m, 8 H), 6.65 (s, 1 H), 5.38 (s, 1 H), 3.30-3.32 (m, 2 H), 2.69-2.72 (m, 1 H), 2.31(s, 3H), 2.27(s, 3H), 1.88 (m, 1 H) ppm. –^{13}C NMR (250 MHz, DMSO-d_6): 152.81, 140.67, 138.56, 125,77, 135,74, 135.51, 134.26, 129.92, 129.45, 127,10, 126.73, 126.41, 125.91, 125.62, 125.05, 117.41, 113.82, 54.00, 27.44, 27.32, 19.38, 18.11 ppm.

*7-(3-bromobenzylidene)-1,3,4,5,6,7-hexahydro-4-(3-bromophenyl)-2H-cyclopenta[d]pyrimidin-2-one (2**i**)*

M.p. 225–227 °C. -IR (KBr): 3251, 2915, 2848, 2360, 1685, 1386, 1492, 1463, 1420 cm^{-1}. -^{1}H NMR (500 MHZ, DMSO-d_6): δ = 8.82 (s, 1 H), 7.25–7.47 (m, 8 H), 6.57 (s, 1 H), 5.17 (s, 1 H), 2.80–2.77 (m, 2 H), 2.33-2.41 (m, 1 H), 2.00–1.96 (m, 1 H) ppm. –^{13}C NMR (250 MHz, DMSO-d_6): 152.50, 145.37, 140.29, 139.55, 135.55, 130.37, 130.09, 129.84, 129.47, 128.63, 128.16, 126.25, 125.09, 121.37, 118.48, 114.95, 56.22, 27.74, 27.68 ppm.

RESULTS AND DISCUSSION

The acidic catalyst was prepared by simple mixing of nano-ZrO_2 with chlorosulfonic acid in room temperature as shown in Scheme 1.

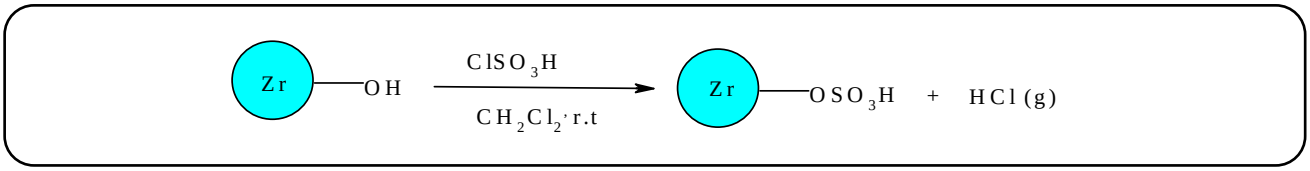
For the test of its catalytic activity in the synthesis of bicyclo-3,4-dihydropyrimidinone derivatives, a mixture of benzaldehyde, cyclopentanone, urea in the presence of nano ZrO_2-SO_3H were mixed under different conditions. (Scheme 2 and Table 1)

Different solvents, such as H_2O, EtOH, and CH_3CN were used in this reaction. As well as, it was studied under solvent-free conditions. The results show that the reaction

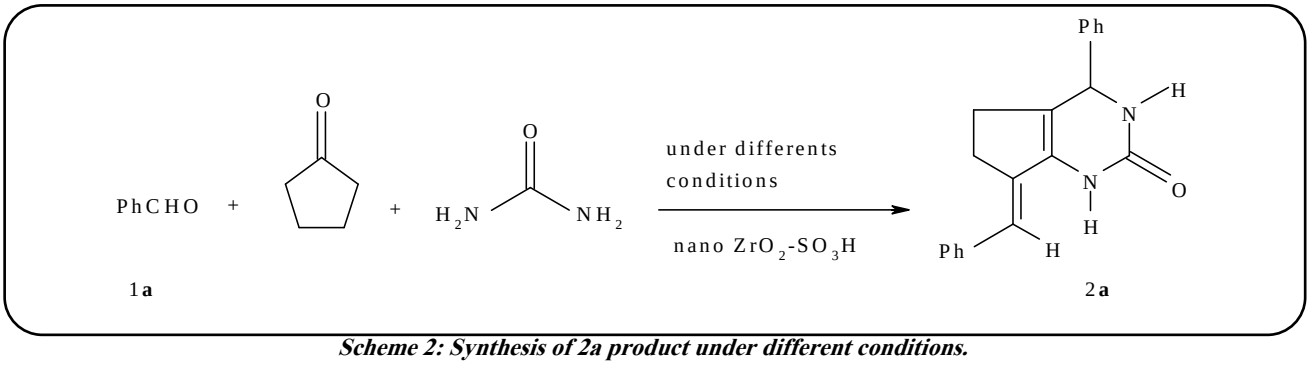
Table 1: Nano ZrO_2-SO_3H catalyzed synthesis of 7-benzylidene-1,3,4,5,6,7-hexahydro-4-phenyl-2H-cyclopenta[d]pyrimidin-2-one product under different conditions.

Comp.	Amount of catalyst (g)	T (˚C)	Solvent (mL)	Time [a] (min)	Yield [b] (%)
2a	0.1	r.t.	Water (10)	120	20
2a	0.1	r.t.	EtOH (10)	120	30
2a	0.1	r.t.	CH_3CN (10)	120	30
2a	0.1	r.t.	Solvent free	120	35
2a	0.1	reflux	EtOH (10)	60	50
2a	0.1	reflux	CH_3CN (10)	60	45
2a	0.1	80	Solvent-free	45	80
2a	0.1	100	Solvent-free	45	85
2a	0.1	120	Solvent-free	10	95
2a	0.05	120	Solvent-free	10	95

[a] *Times are given after the maximum progression of the reaction.* [b] *Isolated yield.*



Scheme 1: Synthesis of nano ZrO_2-SO_3H.



Scheme 2: Synthesis of 2a product under different conditions.

is carried out better under solvent-free conditions. The progress of the reaction was followed by TLC using n-hexane/ethyl acetate.

According to the data presented in Table 1, the best conditions were achieved as a mixture of the following materials as aldehyde (1 mmol), cyclopentanone (1 mmol), urea (1 mmol) and nano ZrO_2-SO_3H (0.05 g) under solvent-free at 120 °C.

The scope of the reaction was extended by different aromatic aldehyde containing electron with drawing and donating groups and the results were presented in Table 2. (Scheme 3) All the products are synthesis according to optimized conditions and characterized by M.P., UV-Vis, IR and ^{1}H-NMR, ^{13}C-NMR, spectra.

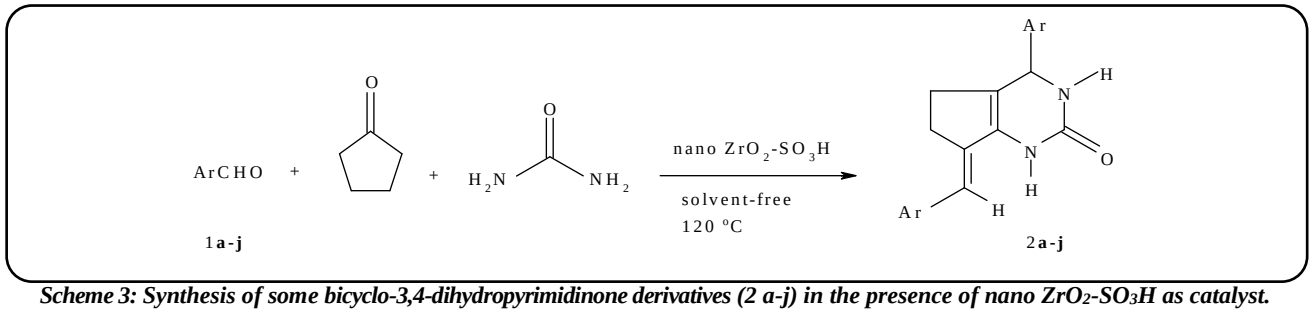
The catalyst recyclability was also tested in the 7-benzylidene -1,3,4,5,6,7- hexahydro -4- phenyl -2H-cyclopenta[d]pyrimidin-2-one and the results were shown in Table 3. Furthermore, the yields were significantly better in comparison with results reported in literature (Table 4).

Table 2: Nano ZrO_2-SO_3H catalyzed synthesis of some bicyclo-3,4-dihydropyrimidinone derivatives 2 (a-j).

Comp.	Ar	Time (min)	Yiled (%)	m.p. (˚C)	m. p. [ref.]
2a	C_6H_5-	10	95	233-236	236-239 [26]
2b	2-Me-C_6H_4-	15	75	226-228	222-224 [27]
2c	4-Me-C_6H_4-	15	85	234-237	238-241 [26]
2d	2-Cl-C_6H_4-	10	90	229-232	232-234 [26]
2e	3-Cl-C_6H_4-	10	85	233-235	229-232 [26]
2f	4-Cl-C_6H_4-	10	85	256-258	252-255 [26]
2g	3-MeO-C_6H_4-	15	90	238-240	240-242 [28]
2h	4-MeO-C_6H_4-	15	80	249-251	250-252 [26]
2i	3-Br-C_6H_4-	15	90	225-227	228-230 [27]
2j	4-Br-C_6H_4-	15	95	218-220	219-222 [29]

Table 3: Recyclability of nano ZrO_2-SO_3H for synthesis of 7-benzylidene-1,3,4,5,6,7-hexahydro-4-phenyl-2H-cyclopenta[d]pyrimidin-2-one product under solvent conditions at 120 ˚C. (2a)

Entry	Amount of catalyst (g)	Time (min)	Yiled (%)
1	0.05	10	95
2	0.05	10	95
3	0.05 g	10	85
4	0.05 g	10	85
5	0.05 g	10	85



Scheme 3: Synthesis of some bicyclo-3,4-dihydropyrimidinone derivatives (2 a-j) in the presence of nano ZrO_2-SO_3H as catalyst.

According to data that reported in the Table 2, we proposed the following mechanism fused Biginelli condensation reaction catalyzed by nano ZrO_2-SO_3H.

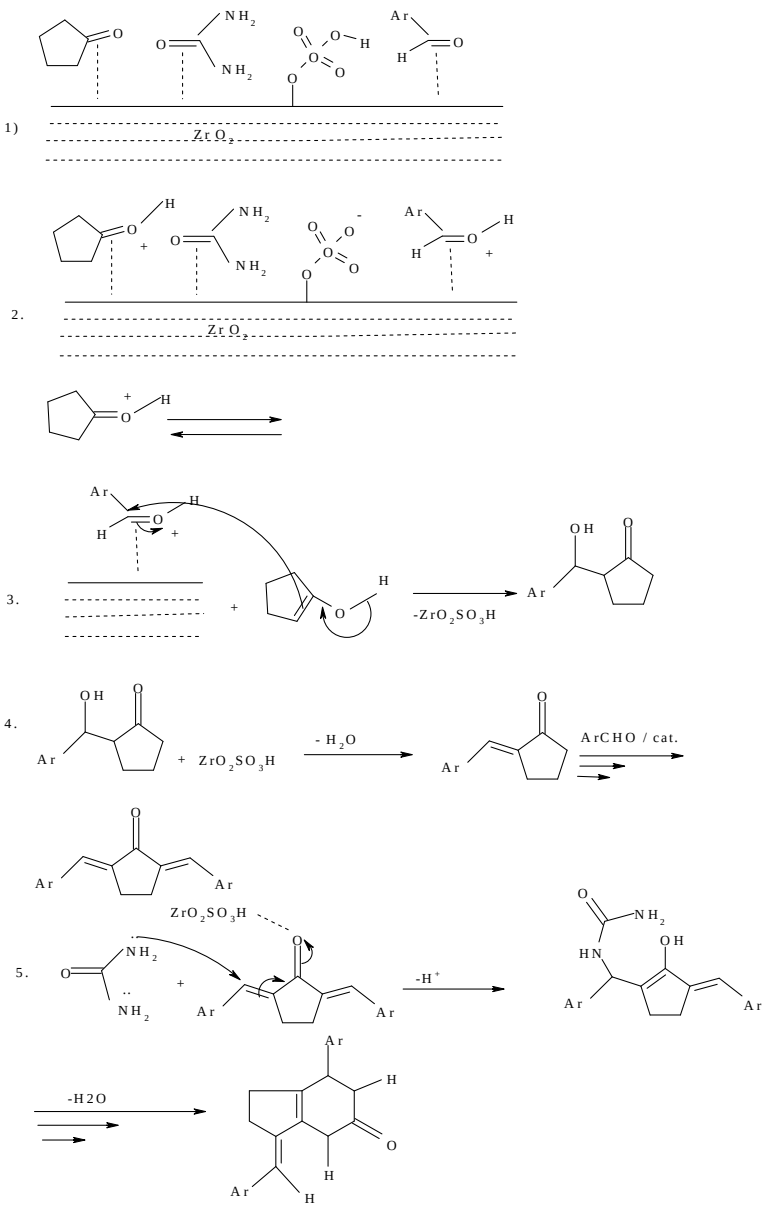
THEORETICAL SECTION

In this section, initially was studying the process of developing the theoretical method. Hartree function introduces a procedure to calculate approximate wave functions and energies of atoms and ions, that was studied by *D. R. Hartree* in 1927. This is called the Hartree Function (HF). [31] In the same year, a statistical model to compute the energy of atoms by approximate the distribution of electrons in an atom was proposed by *Thomas* and *Fermi*. They with consideration the kinetic energy of an atom (by the functional of electron density) and add interactions nuclear-electron and electron-electron, computed the atom energy. [32, 33]

The calculation of the Hartree-Fock model is so complicated; therefore, it was not popular until 1950s. So, the spirit of the Hartree-Fock model consider what

Table 4: Comparison of the catalytic efficiency of nano ZrO_2-SO_3H with that of reported catalysts in the synthesis of some bicyclo-3,4-dihydropyrimidinone.

Entry	catalyst	condition	Time (h)	Yield (%)	Ref.
1	TMSCl	DMF/CH_3CN	2-3	78-93	[26]
2	$AlCl_3$	poly(ethylene)glycol	0.5-5.5	79-94	[29]
3	DBSA	Solvent-free	1-1.5	83-94	[27]
4	$[C_3SO_3HDoim]HSO_4$	Solvent-free	1-2	59-96	[30]



Scheme 4: Proposed mechanism for fused Biginelli condensation reaction catalyzed by nano ZrO_2-SO_3H.

the result will be get is only an approximation to the real results. After this year, Fock and Slater, with consideration of Pauli principles and the multi-electron wavefunction in the form of a determinant of one-particle orbitals, were proposed a self-consistent function. [34-37] In 1964 *Hohenberg* and *Kohn* published a paper, and thus made the foundation of the DFT mansion firm. [38, 39] Then, in 1965 *Kohn* and *Sham* published a paper Density Functional Theory (DFT) method. They simplified the multi-electron problem into a problem of non-interaction electrons in an effective potential. This potential includes the external potential and the effects of the Coulomb interactions between the electrons, e.g., the exchange and correlation interactions. [39] DFT has become very popular for calculations in solid state physics since 1970s. So, it is now a leading method for electronic structure calculations in many areas. Although, it is still difficult to use DFT to treat the strongly correlated systems, band gap in semiconductors, and strong dispersion systems. So the development of DFT is going on.

The structure of 7-arylidene-1,3,4,5,6,7-hexahydro-4-aryl-2H-cyclopenta[*d*]pyrimidin-2-ones are similar to simple 3,4-dihydropyrimidinones compounds. Configuration of the C4 and geometric isomer of the C7 positions in the heterocyclic core of DHPMs can be affected in the biological activities of these compounds. Furthermore, structural studies of several DHPMs have shown that the configuration of the substituent at C4 position plays a major role in their pharmacological activity. Experimental data of individual pure enantiomers, referenced to samples of known absolute configuration, have proven useful for determination of the absolute configuration in various biologically active DHPM derivatives. These data show that, only molecules with R configuration act as calcium channel modulators. [40-44]. Also, the results of computation theory methods carried out on the conformational analysis of some DHPMs are in agreement experimental data [45-47]. Due to the importance of the configuration of the aryl group at the C4 and geometric isomer at C7 positions of the heterocyclic ring for the biological and pharmacological activities of DHPMs, in the present work we have been using B3LYP/6-31G(d,p) computations study structure, bonding, as well as spectroscopic characteristics of a series of some 7-arylidene-1,3,4,5,6,7-hexahydro-4-aryl-2H-cyclopenta[*d*]pyrimidin-2-one derivatives. [48]

In this work, general structures of the 7-arylidene-1,3,4,5,6,7-hexahydro-4-aryl-2H-cyclopenta[*d*]pyrimidin-2-one derivatives with aryl-up (antagonist) conformation and E-isomer studied are shown in Fig. 1. To identify the structure of these compounds, it is necessary to carry out the characteristics of bond lengths, angles, and some electronic parameters.

Result and discussion of theoretical section

The general structure of 7-arylidene-1,3,4,5,6,7-hexahydro-4-aryl-2H-cyclopenta[*d*]pyrimidin-2-one is shown in Fig. 1, where the numbering scheme describing these structures is also introduced. Analysis of the optimized structures of these compounds show that

a) The heterocylic ring adopts a boat conformation,

b) Flattened at N1 toward an envelope conformation,

c) With a pseudo-axial orientation of the C4 substituent, (Table 5 calculated of Δ)

d) In all derivatives the C4 substituent adopts an up orientation with respect to the heterocyclic ring boat plane,

e) The C13 atom deviates from flat state,

f) In all derivatives the arylidine substituent is not flat, (Table 5, calculated of γ)

However, the same structural trends had already been observed for the 3,4-dihydropyrimidinones (DHPMs). This orientation corresponds to the antagonist activity of the same DHPMs compounds.

The lengths of the C7=C8, C5=C6, C2=O, N1–H, N3–H and C4–H bonds that play a role in the activities of 7-arylidene-1,3,4,5,6,7-hexahydro-4-aryl-2H-cyclopenta[*d*]pyrimidin-2-one are optimized. (Table 5) Also, the optimum values of dihedral angles C12–C11–C4–N3 and C12–C11–C4–C5 and C10-C9-C8-C7 that denoted by α, β and γ respectively are reported in Table 6. These data reflected the orientations of the carbonyl group and the aryl ring on the C5 and C4 positions with respect to the heterocyclic ring. The optimum values of the dihedral angle β show that the aryl and 7-arylidene-1,3,4,5,6,7-hexahydro-4-aryl-2H-cyclopenta[*d*]pyrimidin-2-one rings are not perpendicular to each other. Furthermore, the deviation of an aryl ring from 90 ° (denoted by Δ) towards the N3 and C5 atom is calculated. So, the arylidene substituent and C7=C8 bond are not on a page. (γ dihedral angle)

$\Delta = \alpha + \beta$

Table 5: Optimized geometrical bond lengths (Å) parameter was obtained of compound 2a-j.

Comp.	X	N1-H	N3-H	C4-H	C2=O	C5=C6	C7=C8
2a	H	1.0070	1.0097	1.1050	1.2507	1.3546	1.3563
2b	2-CH_3	1.0072	1.0097	1.1051	1.2511	1.3543	1.3562
2c	4-CH_3	1.0071	1.0098	1.1052	1.2516	1.3544	1.3560
2d	2-Cl	1.0073	1.0095	1.1047	1.2494	1.3527	1.3499
2e	3-Cl	1.0071	1.0099	1.1048	1.2493	1.3549	1.3563
2f	4-Cl	1.0070	1.0098	1.1048	1.2496	1.3549	1.3564
2g	3-CH_3O	1.0050	1.0097	1.1046	1.2509	1.3546	1.3563
2h	4-CH_3O	1.0069	1.0097	1.1052	1.2513	1.3547	1.3565
2i	3-Br	1.0070	1.0098	1.1046	1.2495	1.3549	1.3563
2j	4-Br	1.0070	1.0098	1.1049	1.2498	1.3548	1.3564

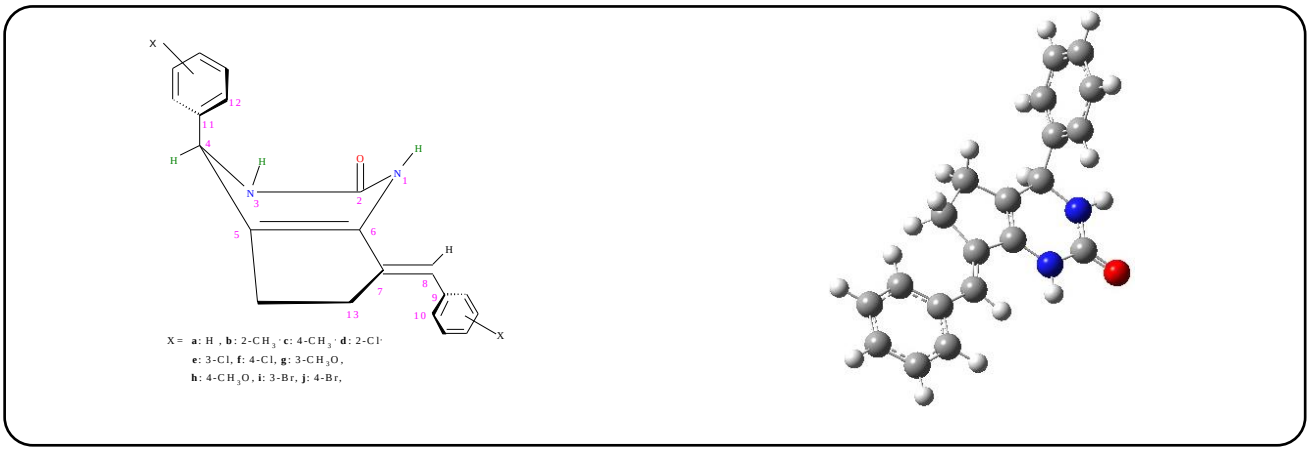


Fig. 1: General structure of 7-arylidene-1,3,4,5,6,7-hexahydro-4-aryl-2H-cyclopenta[d]pyrimidin-2-one derivatives.

Vibration analysis was carried out on the optimized geometries of the 2**a-j** compounds at B3LYP/6-31G(d,p) level of theory. The harmonic frequencies calculated for these compounds are reported in Table 7. As expected, the calculated vibrational frequencies show the dependence on the type and position of the substituent. In all 2**a-j** compounds the frequency of

1) The N1–H bond stretching mode is rather larger than that of the N3–H bond. This can be attributed to the tighter conjugation of the N1 atom with the C5=C6 bond, as compared with that of the N3 atom, which results in a stronger N1–H bond. The other reason is that the bond length of the N3-H is longer than that of N1-H.

2) The conjugate of C5=C6 and C7=C8 can be effected on the vibrational frequencies of them. Analysis of data shows that the smaller frequencies of the stretching mode of the C7=C8 group demonstrate this effect.

3) The analysis of the data reported in Table 7 shows that the effect of the conjugate of lone pair electron on the N atom with C5=C6 group is lower than the conjugate of C5=C6 with C7=C8 group.

Second order perturbation theory analysis of Fock matrix on NBO of compounds 2 a-j

The second order Fock matrix was carried out to evaluate the donor–acceptor interactions in the NBO analysis. The interaction result is a loss of occupancy from the localized NBO of the idealized Lewis structure in to an empty non- Lewis orbital. For each donor (i), and acceptor (j), the stabilization energy E(2) associated with the delocalization i-j is estimated as:

Table 6: Dihedral angles (degree) in the optimized structure of the 2a-j.

Comp.	X	α (-)	β	Δ	γ
2a	H	53.87	68.43	14.57	1.87
2b	2-CH_3	59.32	64.97	5.65	26.44
2c	4-CH_3	53.42	68.94	15.53	26.75
2d	2-Cl	61.58	63.46	1.88	120.23
2e	3-Cl	51.23	71.16	19.93	174.21
2f	4-Cl	53.64	68.65	15.01	178.20
2g	3-CH_3O	52.67	69.55	16.88	178.87
2h	4-CH_3O	55.74	66.63	10.89	178.66
2i	3-Br	53.76	68.65	14.89	178.09
2j	4-Br	51.64	70.64	19.00	176.51

Table 7: Infrared calculated DFT vibrational frequencies (cm−1) of 2 a-j compounds.

Comp.	X	N1-H	N3-H	C4-H	C8-H	C2=O	C5=C6	C7=C8
2a	H	3678.9	3644.2	2946.3	3137.5	1744.9	1727.1	1704.0
2b	2-CH_3	3675.5	3643.5	2941.7	3161.9	1742.6	1726.8	1701.4
2c	4-CH_3	3674.8	3642.6	2940.8	3162.2	1743.1	1726.5	1701.7
2d	2-Cl	3675.4	3646.1	2946.0	3142.1	1747.5	1735.2	1718.2
2e	3-Cl	3677.9	3642.5	2950.4	3144.7	1747.7	1725.3	1702.6
2f	4-Cl	3679.0	3642.6	2950.4	3142.4	1746.7	1726.6	1702.7
2g	3-CH_3O	3647.2	3644.5	2951.8	3140.7	1744.2	1727.0	1703.9
2h	4-CH_3O	3680.2	3644.6	2943.7	3135.1	1743.2	1726.8	1702.2
2i	3-Br	3678.5	3643.2	2952.5	3144.4	1747.4	1726.7	1702.4
2j	4-Br	3678.1	3642.6	2949.1	3141.7	1746.5	1726.2	1702.3

$E^2= \Delta E_{ij}=q_i F(i,j)^2/\varepsilon_j-\varepsilon_i$

Natural bond orbital analysis provides an efficient method for

i) Studying intra and intermolecular bonding

ii) Interaction among bonds

iii) Provides a convenient basis for investigating charge transfer or conjugative interaction in molecular systems.

iv) Delocalization of electron density between occupied Lewis-type (bond or lone pair) NBO orbitals and formally unoccupied (anti-bond or Rydgberg) non-Lewis NBO orbitals correspond to a stabilizing donor–acceptor interaction. [49]

Some electron donor orbital, acceptor orbital and the interacting stabilization energy resulted from the second order micro disturbance theory that q_i is the donor orbital occupancy, ε_i and ε_j are diagonal elements and F(i,j) is the off diagonal NBO Fock matrix element reported [50-53]. The larger the E(2) value, the more intensive is the interaction between electron donors and electron acceptors, that shows

A) more donating tendency from electron donors to electron acceptors the greater the extent of conjugation of the whole system.[52]

NBO analysis has been performed on the 7-arylidene-1,3,4,5,6,7-hexahydro-4-aryl-2H-cyclopenta[*d*]pyrimidin-2-one derivatives molecules at the DFT/B3LYP/6-31G(d,p) level in order to elucidate the delocalization of electron density within the molecules. (Table 8).

Table 8: Second order perturbation theory analysis of Fock matrix with NBO basis.

Comp.	X	Donor (i)	Acceptor (j)	E2 Kcal/mol	E (j)-(i) a.u	F (i.j) a.u
2a	H	σ (C4-N3)	C2	2.31	1.40	0.051
		σ (N3-H)	π* (C2=O)	2.71	1.24	0.052
		σ (N1-H)	C2	0.95	1.31	0.032
		σ (N1-H)	π* (C5=C6)	3.21	1.30	0.058
		π (C5=C6)	π* (C7=C8)	19.29	1.71	0.118
		π (C5=C6)	C7	1.71	1.90	0.051
2b	2-CH_3	σ (C4-N3)	C2	2.34	1.40	0.051
		σ (N3-H)	π* (C2=O)	0.60	1.14	0.024
		σ (N1-H)	π* (C2=O)	0.52	1.16	0.022
		σ (N1-H)	π* (C5=C6)	3.19	1.30	0.058
		π (C5=C6)	π* (C7=C8)	19.04	1.70	0.118
		π (C5=C6)	C7	0.79	1.40	0.030
2c	4-CH_3	σ (C4-N3)	C2	2.31	1.41	0.052
		σ (N3-H)	π* (C2=O)	0.61	1.13	0.025
		σ (N1-H)	π* (C2=O)	0.52	1.16	0.022
		σ (N1-H)	π* (C5=C6)	3.19	1.30	0.058
		π (C5=C6)	π* (C7=C8)	19.14	1.70	0.117
		π (C5=C6)	C7	0.79	1.40	0.030
2d	2-Cl	σ (C4-N3)	C2	2.31	1.41	0.051
		σ (N3-H)	π* (C2=O)	2.52	1.22	0.050
		σ (N1-H)	π* (C2=O)	0.52	1.15	0.022
		σ (N1-H)	C2	0.95	1.31	0.031
		σ (N1-H)	π* (C5=C6)	3.23	1.30	0.058
		π (C5=C6)	π* (C7=C8)	19.64	1.70	0.119
		π (C5=C6)	C7	1.71	1.87	0.051
2e	3-Cl	σ (C4-N3)	C2	2.31	1.41	0.051
		σ (N3-H)	π* (C2=O)	0.62	1.16	0.024
		σ (N1-H)	C2	0.96	1.31	0.032
		σ (N1-H)	π* (C5=C6)	3.24	1.30	0.058
		π (C5=C6)	π* (C7=C8)	19.53	1.71	0.118
		π (C5=C6)	C7	1.70	1.90	0.051
2f	4-Cl	σ (C4-N3)	C2	2.31	1.40	0.051
		σ (N3-H)	π* (C2=O)	0.63	1.17	0.024
		σ (N3-H)	C2	0.94	1.29	0.031
		σ (N1-H)	C2	0.96	1.31	0.032
		σ (N1-H)	π* (C5=C6)	3.23	1.30	0.058
		π (C5=C6)	π* (C7=C8)	17.01	0.32	0.066
		π (C5=C6)	C7	1.71	1.90	0.051

Table 8:. Second order perturbation theory analysis of Fock matrix with NBO basis (Continued).

Comp.	X	Donor (i)	Acceptor (j)	E2 Kcal/mol	E (j)-(i) a.u	F (i.j) a.u
2g	3-CH_3O	σ (C4-N3)	C2	2.32	1.40	0.051
		σ (N3-H)	π* (C2=O)	2.62	1.21	0.051
		σ (N1-H)	C2	0.95	1.31	0.032
		σ (N1-H)	π* (C5=C6)	3.20	1.30	0.058
		π (C5=C6)	π* (C7=C8)	17.26	1.71	0.118
		π (C5=C6)	C7	1.70	1.90	0.051
2h	4-CH_3O	σ (C4-N3)	C2	2.31	1.40	0.051
		σ (C4-N3)	π* (C2=O)	2.73	1.23	0.052
		σ (N3-H)	π* (C2=O)	0.60	1.15	0.024
		σ (N3-H)	C2	0.87	1.66	0.034
		σ (N1-H)	C2	0.95	1.31	0.032
		σ (N1-H)	π* (C5=C6)	3.19	1.30	0.058
		π (C5=C6)	π* (C7=C8)	17.13	1.61	0.118
		π (C5=C6)	C7	1.70	1.90	0.51
2i	3-Br	σ (C4-N3)	C2	2.31	1.41	0.051
		σ (C4-N3)	π* (C2=O)	2.73	1.27	0.053
		σ (N3-H)	C2	0.94	1.29	0.031
		σ (N3-H)	π* (C2=O)	0.7	1.36	0.027
		σ (N1-H)	C2	0.96	1.31	0.032
		σ (N1-H)	π* (C5=C6)	3.24	1.30	0.058
		π (C5=C6)	π* (C7=C8)	19.53	1.71	0.118
		π (C5=C6)	C7	0.69	0.97	0.024
2j	4-Br	σ (C4-N3)	C2	2.31	1.40	0.051
		σ (C4-N3)	π* (C2=O)	2.72	1.25	0.052
		σ (N3-H)	C2	0.94	1.29	0.031
		σ (N3-H)	π* (C2=O)	0.62	1.16	0.024
		σ (N1-H)	C2	0.96	1.31	0.032
		σ (N1-H)	π* (C5=C6)	3.23	1.30	0.058
		π (C5=C6)	π* (C7=C8)	17.44	1.71	0.118
		π (C5=C6)	C7	1.70	1.90	0.051

The comparison of the reported data in Table 8 shows that N3-H group is a relatively more resonance with the C2=O group in comparison with N1-H. Also, the analysis of the data reported in this table shows that N1-H group is more tendentious to resonance with the C5=C6 group.

Furthermore, the comparison of bond lengths, vibration data and Second order perturbation theory analysis of C5=O6 and C7=C8 functional groups (Tables 5-7) show that the resonance rate is higher in the C7=C8 group.

CONCLUSONS

In summary, we have described an alternative and general method for the multicomponent synthesis of functionalized of some 4-aryl-7-benzylidene-1,3,4,5,6,7-hexahydro-2*H*-cyclopenta[*d*]pyrimidin-2-one using nano

ZrO_2-SO_3H as a catalyst. The prospect of the reusability of this catalyst has also been demonstrated without compromising on the yield of the product. (Table 3).

On the whole, the protocol presented here is an excellent alternative to many of the reported procedures by the use of nano ZrO_2-SO_3H as recyclable catalyst (Table 4).

According to data based on the data reported in the theory section, it can be concluded that the resonance share of N3-H to C2=O group is more than of N1-H group. In addition, the N1-H group is more tendentious to resonate with C5=C6. Also, the resonance of group C5=C6 with group C7=C8 is more than the other groups.

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