RESEARCH PAPER

Ultrasonication-Assisted Green Synthesis of β-Benzoyl Propionic Acid Using Nanozeolite Catalyst: A Sustainable Approach to Friedel–Crafts Acylation

Twinkle S. Wankhede[1*], Rajdip D. Utane[2*], Sushil S. Lonkar[3], and Prachi N. Saoji[4]
[1*]Department of Chemistry, Dr. Ambedkar College, Deeksha Bhoomi, Nagpur, M.S., India. Affiliated to RTM Nagpur University, Nagpur M.S., India.
ORCID: 0000-0001-7152-2234/ twinklew96@gmail.com
[2*]Department of Chemistry, Shri Sant Gadge Maharaj Mahavidyalaya, Hingna, M.S., India.
Affiliated to RTM Nagpur University, Nagpur M.S., India.
orcid.org/0000-0003-3463-4768/ raj.chemworld@gmail.com
[3]Tai Golwalkar Mahavidyalaya, Ramtek, M.S., India.
Affiliated to RTM Nagpur University, Nagpur M.S., India.
[4]Kavikulguru Institute of Technology and Science (KITS), Ramtek M.S., India.
Affiliated to RTM Nagpur University, Nagpur M.S., India.

Abstract

Nanozeolites have emerged as highly efficient and environmentally benign catalysts in modern organic synthesis. In the present study, a green and sustainable method has been developed for the synthesis of β-benzoyl propionic acid (β-BPA), an important intermediate in the preparation of 1-phenyl naphthalene and its derivatives. Traditionally, β-BPA is synthesized via Friedel–Crafts acylation of benzene with succinic anhydride in the presence of strong Lewis acids such as anhydrous aluminum chloride, which leads to issues such as corrosion, environmental hazards, and difficulty in catalyst recovery. To address these limitations, nanozeolite has been employed as a heterogeneous solid acid catalyst, offering advantages such as high surface area, shape selectivity, and recyclability. The reaction has been further enhanced using ultrasonication, a sonochemical technique that accelerates reaction rates through acoustic cavitation, resulting in improved mass transfer and localized high ऊर्जा conditions. The synthesis was effectively carried out in two steps, namely ultrasonication-assisted acylation followed by hydrolysis and catalyst recovery. The developed method demonstrated higher yield, shorter reaction time, reduced energy consumption, and improved selectivity compared to conventional methods. Additionally, the nanozeolite catalyst exhibited excellent reusability, making the process economically viable and environmentally sustainable. This study highlights the synergistic effect of nanozeolite catalysis and ultrasonication as a promising green alternative for Friedel–Crafts acylation reactions.

Keywords: *Nanozeolite; β-Benzoyl Propionic Acid (β-BPA); Friedel–Crafts Acylation; Ultrasonication; Sonochemistry; Green Chemistry;* and Sustainable Catalysis.

How to cite this article: Wankhede TS, Utane RD, Lonkar SS, Saoji PN. Ultrasonication-Assisted Green Synthesis of β-Benzoyl Propionic Acid Using Nanozeolite Catalyst: A Sustainable Approach to Friedel–Crafts Acylation. Int J Drug Deliv Technol. 2026;16(16s): 38-55. DOI: 10.25258/ijddt.16.16s.6

Introduction

The increasing demand for sustainable and environmentally friendly chemical processes has significantly influenced the development of green methodologies in organic synthesis. Among various approaches, the replacement of hazardous catalysts with eco-friendly alternatives and the use of energy-efficient techniques have become key priorities. β-Benzoyl propionic acid (β-BPA) is an important intermediate widely used in the synthesis of 1-phenyl naphthalene derivatives, which possess applications in pharmaceuticals, dyes, and advanced functional materials. Conventionally, β-BPA is synthesized through Friedel–Crafts acylation of benzene with succinic anhydride using strong Lewis acids such as anhydrous aluminum chloride [1-9]. However, this traditional method suffers from several drawbacks, including corrosive reaction conditions, generation of toxic waste, difficulty in catalyst separation, and lack of recyclability, thereby limiting its industrial and environmental applicability.

Friedel–Crafts reactions, first introduced in 1877, are among the most fundamental electrophilic aromatic substitution reactions and are widely used for the introduction of alkyl and acyl groups into aromatic rings. Among these, Friedel–Crafts acylation is particularly advantageous due to its higher selectivity, absence of carbocation rearrangement, and reduced tendency for polyacylation, as the electron-withdrawing carbonyl group deactivates the aromatic ring after substitution. Despite these advantages, the use of conventional homogeneous Lewis acid catalysts poses significant environmental challenges. Therefore, the development of heterogeneous catalytic systems has gained considerable attention [10-16].

In this context, nanozeolites have emerged as promising catalysts due to their unique physicochemical properties, including high surface area, tunable acidity, shape selectivity, and enhanced diffusion characteristics. These properties not only improve catalytic efficiency but also facilitate easy separation and recycling of the catalyst. Moreover, nanozeolites exhibit reduced coke formation and slower deactivation compared to conventional catalysts, making them suitable for repeated use in organic transformations [17-24].

Another important advancement in green chemistry is the application of ultrasonication, which utilizes high-frequency sound waves to induce acoustic cavitation in liquid media. This phenomenon generates localized high temperature and pressure conditions, leading to enhanced reaction rates, improved mass transfer, and increased product yield. The integration of ultrasonication with nanozeolite catalysis provides a synergistic effect, enabling faster and more efficient chemical transformations under mild conditions [25-29].

In the present study, an ultrasonication-assisted nanozeolite-catalyzed method has been developed for the synthesis of β-benzoyl propionic acid. The process involves the acylation of benzene with succinic anhydride under ultrasonication followed by hydrolysis and recovery of the product along with catalyst recycling. This method significantly reduces reaction time and energy consumption while improving yield and selectivity. The proposed approach aligns with the principles of green chemistry and offers a cost-effective, scalable, and environmentally sustainable alternative to conventional Friedel–Crafts acylation processes.

In which alkylation may give poly alkylated products, consequently the FC acylation is a treasured atom economy alternative. The acylated producing molecule easily is transformed to the resultant alkanes followed by Wolff-Kishner Reduction or Clemmensen Reduction. It is the acylation of aromatic rings with a succinic anhydride using a strong lewisacid catalyst. It is furthermore probable with acid chlorides and cyclic anhydrides [30-39]. This reaction partake several advantages over the FC alkylation reaction. Ketone product be situated constantly lessreactive than the original molecule, so multiple acylation do not occur due to the electron-withdrawing effect of the carbonyl group. There are no carbocation rearrangements, as the carboniumion is stabilized by a resonance structure in which the positive charge is on the oxygen (figure no. 1).

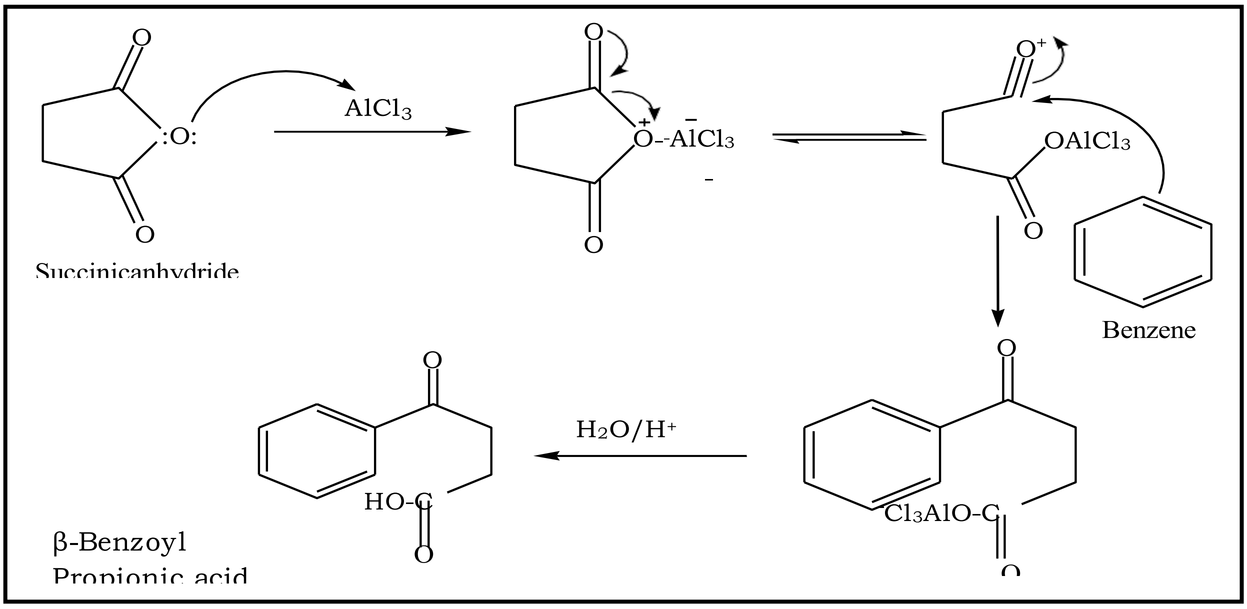


Figure no. 1: Mechanism of Synthesis of β-Benzoyl propionic acid using catalyst (anhydrous $AlCl_3$)

Acylation's of benzene derivatives such as anisole, toluene, and naphthalene are acylated through acetic anhydride and it was investigated in the liquid phase using the nanozeolite [40-46]. Moreover the most active catalyst as nanozeolite for acylation reactions compared to anhydrous $AlCl_3$. Precincts caused by mass transfer to convert it into cokede position. There are two types of coke (extractable and non-extractable) were notorious [47-52]. Conjoining those liquid phase reaction with continuous extraction of the catalyst such as nanozeolite with refluxing reaction mixture in a sox-let reactor headed to a sophisticated renovation of β- benzoyl propionic acid and their derivatives [13-16]. Nanozeolite has been optimized for acylation processes [53-61]. In the acylation of Benzene, toluene, and with acetic anhydride and Nanozeolite of low Si/Al charter ratio show enriched commotion and sluggish deactivation [64-69]. FC acylation of naphthalene with acetic anhydride the discerning delamination of the peripheral superficial of a Nanozeolite augments the contour exercising judgment to the nanozeolite, amassed the fussiness to the fewer statically hindered and firm products such as β-Napthoyl propionic acid [70-86]. To conclude, the rheostat of the route circumstances is vital in the case of the hydrolysis with mineral acid and cold water treatment via cold sodium carbonate to form desired products [87-88]. In case of friedel craft reaction, when benzene and succinic anhydride on treatment with Lewis acid such as anhydrous AlCl3 is replaced by nanozeolite [40-43].

1.1 Nanozeolite

M. Camblor and P. Pariente were firstly identified the multifunctional material named as Zeolite. Moreover verified by XianpingMeng, Shu-HuaChien, D. Cardoso and S. Jahn to various catalytically reforms. The crystalline composition of Nanozeolite material Na0.92K0. 62 (TEA) [$Al_{4.53}Si_{59.47}$ O_{128}] and Batch Composition without interlayer material 1.97Na_2O:1.00K_2O:12.5:(TEA)20:Al_2O_3: 50SiO_2:750H_2O:2.9HCl .

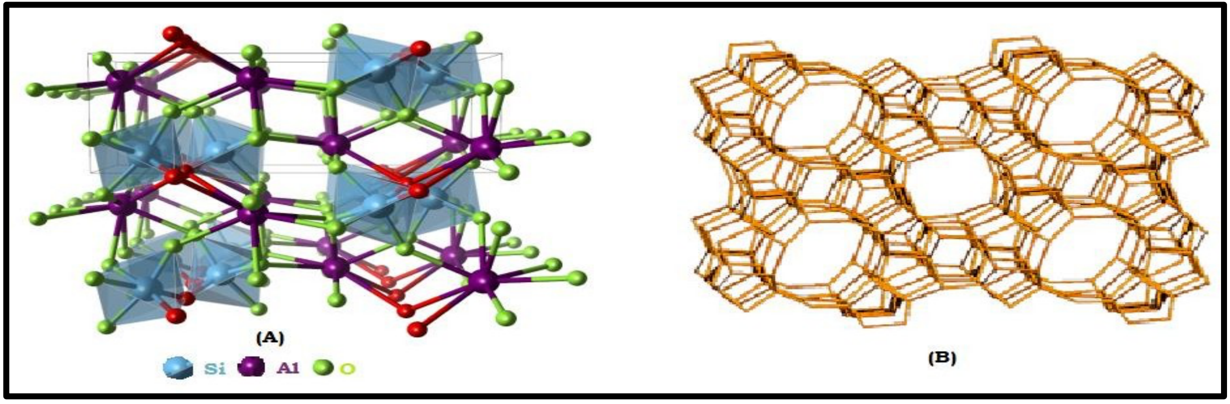
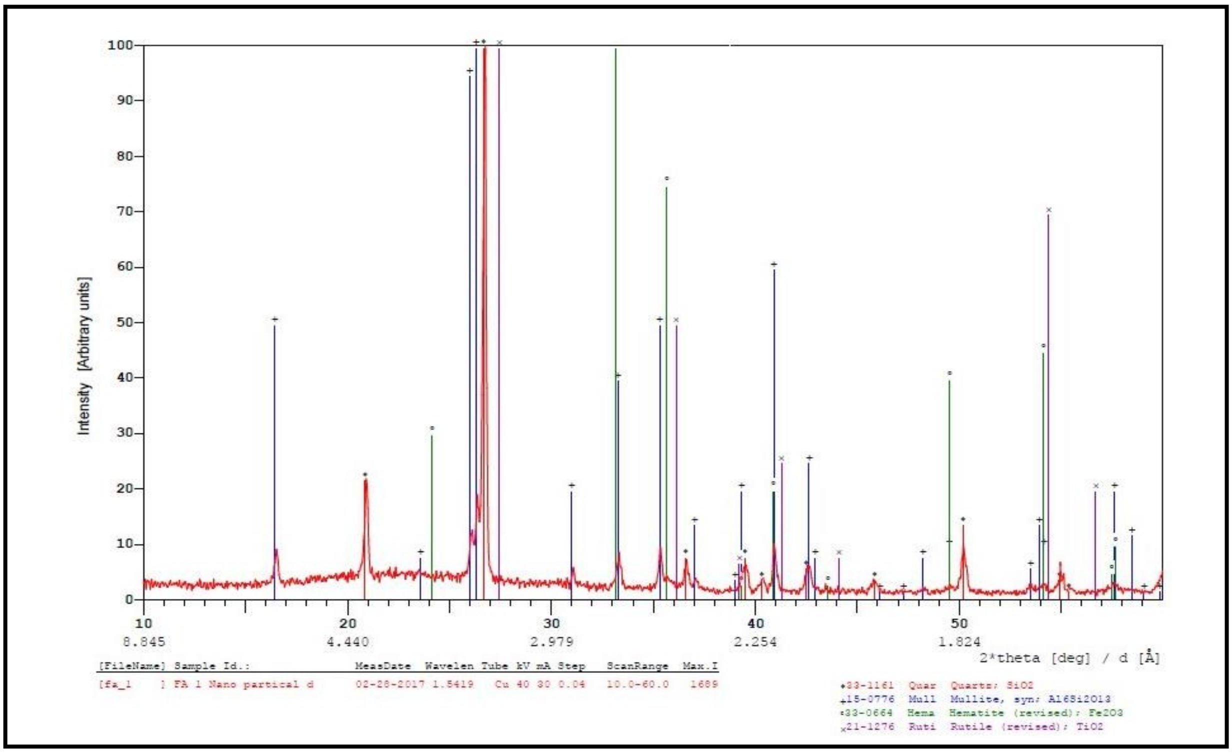


Figure no. 2: A) Frame work and B) Three dimensional skeleton of Nanozeolite Zeolite

The tetraethyl ammonium-Beta (TEA- β) zeolites used in this work have been synthesized following the procedure described in the literature [89-92]. Si:Al ratios of samples in between 7 and 106 (as measured by chemical analysis) and their limpid proportions in the range of 0.2-0.9 um (as measured in scanning microscopy) were acquired. The acid form of these nanozeolites were synthesized in the resulting in way TEA-3 samples were heated at 550°C for 3 hours by sluggishly accumulative the heating in absence of oxygen having temperature (5°C min~1), with one- hour halfway periods at 350 and 450°C. Subsequently this behavior all TEA fragments taken remained uninvolved or after the zeolite (IR spectroscopy). In a second step, the zeolite was exchanged with 1 M ammonium acetate solution and then impassioned at 550°C for 3 hours as designated.

1.2 X-ray Powder Diffraction

Figure no. 3: Standard XRD patterns of Nanozeolite



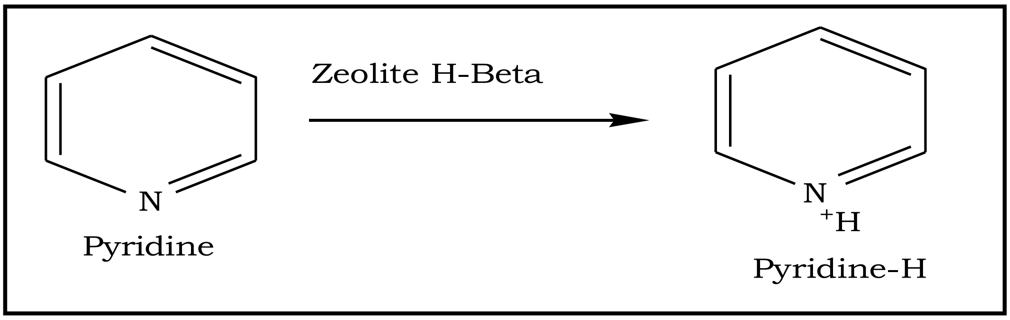


Figure no. 4: Acidity of Nanozeolite

XRD has taken as a measure of the crystal lenity of a nanozeolite sample in different phases with Si/Al=10, variation of the area under the main peak (20=22.4) as a function of the out gassing temperature has been plotted in figure 3. In which two foremost stepladders of crystallinity forfeiture are perceived, in first one proceeds abode between 200 and 300°C, and the second one fraction from 300 to 400°C, the loss of crystallinity in the concluding step actuality added vital than in the prior. These two steps correspond closely to the temperature ranges where the decomposition of the organic material takes place, as determined by IR spectroscopy. Moreover, the reduction in the expanse of thekey peak after warming at 500°C is further noticeable for nanozeolites with truncated aluminum gratified. In synthesized zeolites also influences their X-ray powder diffraction pattern due to aluminum content. The altitude of the base peak in the patterns diminutions with decreasing Si/Al ratio in the zeolite, but their width increases simultaneously so that the area remains basically constant for all illustrations. Moreover, (*hkl*) distance corresponding to the diffraction peak at 43° of 2θ correlated linearly with the aluminum content of the nanozeolite (figure no. 3). Further, the nonexistence of acquaintance of the crystal structure of Nanozeolite makes it awaked to draw a parallel the Al content and unit cell parameters.

1.3 Acidity

To estimate the acidic nature of the hydroxyl groups or molecule in terms of Lewis acid theory their evolution as a function of its aluminum content. In pyridine adsorption on samples of Beta zeolite with Si or Al ratio between 7 and 40 allow us towards levis acidity [93-99].

1.4 Mechanism of Friedel-Craft Reaction by using Nanozeolite

In Friedel Craft acylation reaction benzene derivatives with succinic anhydride are condensed with activated Nanozeolite to form β –benzoyl propionic acid through aromatic electrophile substitution reaction. The Nanozeolite has dual tendency H^+acts as Arrhenius acid and Beta Zeolite acts as Lewis acid. This is a theoretical mechanism of formation of β –benzoyl propionic acid using Nanozeolite Zeolite [94-114]. Firstly succinic anhydride converted into electrophile such as succinyl carbonium zeolite on treatment with Nanozeolite zeolite. In second step, succinyl carbonium zeolite reactions with benzene (nucleophile) to produce β–benzoylpropionic acetate Beta zeolite adduct. In third step hydrolysis of adduct gives β–benzoyl propionic acidfollowed by re-cyclization of Nanozeolite zeolite [115-116].

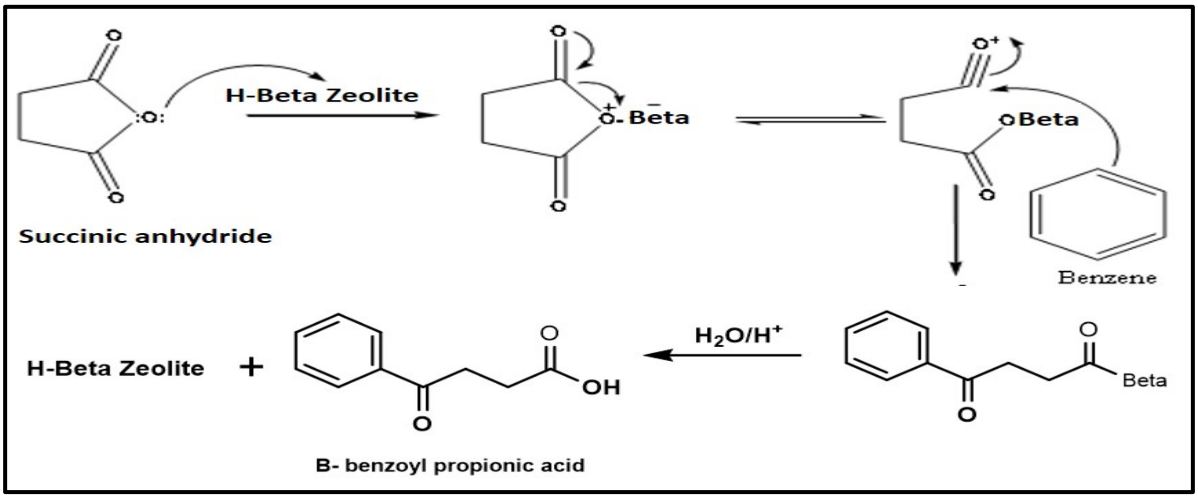


Figure no. 5: Proposed mechanism of Friedel-Craft Reaction by using Nanozeolite

2. Experimental section

2.1 Reagents and analysis

All the chemicals and reagents were LR, SR and AR grade and produced from Ee. Merk, (India), LOBA Chemie, Sigma-Aldrich (USA), Mumbai, Central Scientific (Nagpur). FTIR spectra were recorded on Brucker. ^{1}HNMR were recorded on 400MHz Brucker spectrometer in CDCl3 as solvent and TMS as an internal standard. Melting points were recorded at oil bath of thermo-fisher melting point apparatus. Analytical TLC was performed on glass slides coated of silica gel G per UV-254 of 0.2 mm thickness. Mass spectra using. For conventional experiments described below as magnetic stirrer was used. For the Ultrasonication irradiation experiments, house hold Ultrasonication oven equipped with a turn able was used (Elapsed time indicator displays duration of sonication, Overload protection, Overload protection, RoHS compliant: lead free components, Standard for cell disruption, DNA/RNA shearing and homogenization, Voltage: 110 V, Design: Benchtop, Controls: Digital, Frequency Output:20 kHz, Pulse Mode Operation, Cooling Method:Cup Horn, Probe Diameter:0.125", Order Separately, Probe Type:Generator, Wattage Output: 125 W, Manufacturer SKU: Q125-110, Q125A-110

2.2 Materials

Succinic anhydride, aluminum chloride ($AlCl_3$), benzene, naphthalene, toluene, anhydrous sodium carbonate, concentrated hydrochloric acid, sodium chloride, Ultrasonication.

2.3 Green Method: Nanozeolite assisted (conventionally)

Ultrasonication induced organic synthesis (MIOS) followed byFriedel Craft acylation reaction. The use of Nanozeolite as an acid catalyst provides a useful alternative to the known methods for replacement of anhydrous AlCl3in Friedel–Craft Reaction. Short reaction time, mild conditions, high yield, less amount of catalyst, and the recyclability of used catalyst are notable advantages.

2.3.1 Activation of catalyst by using Autoclave

The Nanozeolite is a shape selective catalyst for their better activity it required activation by autoclave. Autoclave has principle to sensitize the material like zeolite at 121^0C, a 15 lbs pressure for 45 minute. Firstly the material has poured in phytoplastic polymer jar (thermoplastic- which resist from heat) and autoclaved with above said conditions.

2.3.2 Preparation of β-benzoyl propionic acid

B-benzoyl propionic acidhas preparedfrom succinic anhydride, benzene and activated Nanozeolite (figure no. 6).

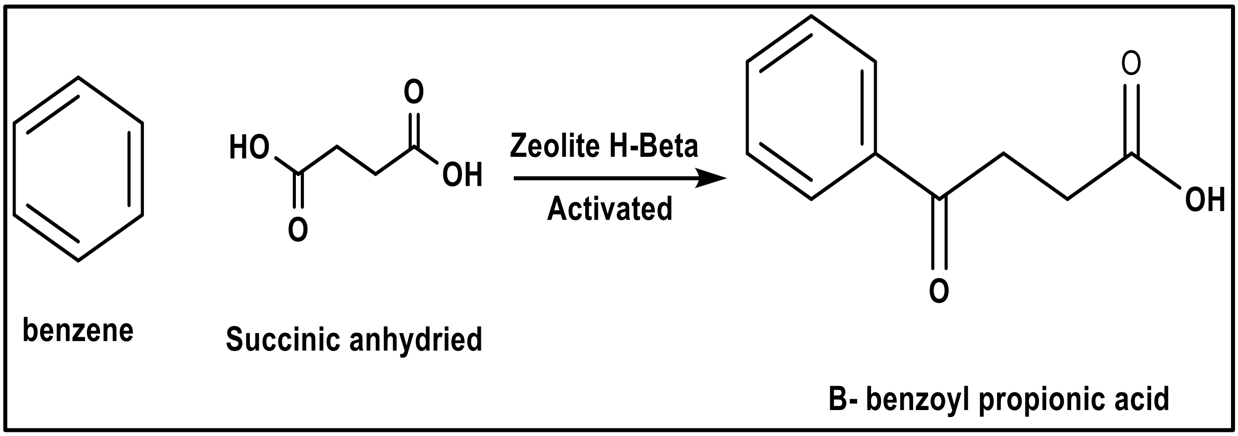


Figure no. 6: Green Method for synthesis of β-benzoyl propionic acid *via* Nanozeolite

In a 2000 mL three necked round bottom flaskfitted with a mechanical stirrer and two reflux condensers are placed 68g (0.68 M) of succinic anhydride and 350 g (4.5 M) dry, thiophene free benzene. With continuous stirring is started and 100g (1M) of crystalline, activated. Nanozeolite zeolite (It acts as highly reactive hydrogen abstracter) is added all at once. Hydrogen chloride fumes are evolved and the mixture becomes hot. the flask is then surrounding by cold water and 300 cc of water is slowly added from a dropping funnel inserted in the top of condensers the excess of benzene is discarded and obtained mass separates as a colorless oil which soon solidifies after cooling to 0°C, it is collected, washed with a cold mixture of 50 cc of concentrated hydrochloric acid and 150 cc of water. The crude β -BPA is dissolved in a solution of 75 gm of anhydrous sodium carbonate in 25 cc of water by boiling for fifteen minutes. The clear colorless filtered distant ferred to 500 cc of beaker and carefully acidified with 6.5 cc of concentrated hydrochloric acid in freeze condition to maintain temperature 0-5°C byice-salt bath. The solution is filtered by suction pump, washed with hot water, dry give β –benzoyl propionic acid. Repeat finally those compounds are characterized by IR, NMR and mass spectra.

2.4 Ultrasonication irradiation: Nanozeolite assisted

Ultrasonication induced organic synthesis (MIOS) of β- benzoyl propionic acid by using Nanozeolite. In case of friedel craft reaction, when benzene and succinic anhydride on treatment with Nanozeolite under Ultrasonication irradiation [19-20]. In Ultrasonication method reduce reaction time with optimum temperature to increase yield of desired product (figure no. 7).

2.4.1 Preparation of β-benzoyl propionic acid

β-benzoyl propionic acid has prepared from succinic anhydride, benzene and activated Nanozeolite. Ina 2 L three necked round bottom flaskfitted with a mechanical stirrer and two reflux condensers are placed 68 g (0.68 M) of succinic anhydride and 350 g (4.5 M) dry, thiophene free benzene. With continuous stirring is started and 200 g (1.5 M) of powdered, anhydrous aluminum chloride (It acts as highly reactive hydrogen abstracter) is added all at once. Hydrogen chloride fumes are evolved and the mixture becomes hot. the flask is then surrounding by cold water and 300 cc of water is slowly added from a dropping funnel inserted in the top of condensers the excess of benzene is discarded and obtained mass separates as a colorless oil which soon solidifies after cooling to 0°C, it is collected, washed with a cold mixture of 50 cc of concentrated hydrochloric acid and 150 cc of water. The crude β-BPA is dissolved in a solution of 75gm of anhydrous sodium carbonate in 25cc of water by boiling for fifteen minutes. The clear colourless filtered is transferred to 500 cc of beaker and carefully acidified with 6.5 cc of concentrated hydrochloric acid in freeze condition to maintain temperature 0-5°C by ice-salt bath. The solution is filtered by suction pump, washed with hot water, dry give β –benzoyl propionic acid. Finally those compounds are characterized by IR, NMR and mass spectra, key precursors of 1-phenyl naphthalene and therapeutic medicinal drugs. In present research work one pot synthesis of β-BPA and their derivatives via Friedel Craft acylation reaction.The anhydrous aluminum chloride catalyst use in Friedel–Craft acylation reactions for above said compounds are often using in conventional and Ultrasonication methods.In conventional method, benzene and succinic anhydride are condensed with anhydrous aluminum chloride and five steps for work-up in reaction to gives desired product. For above such preparation required thermal heating, vast set up of assembly of instrument and glassware's. Ultrasonication induced synthesis of β-BPA it pointed to two stages.

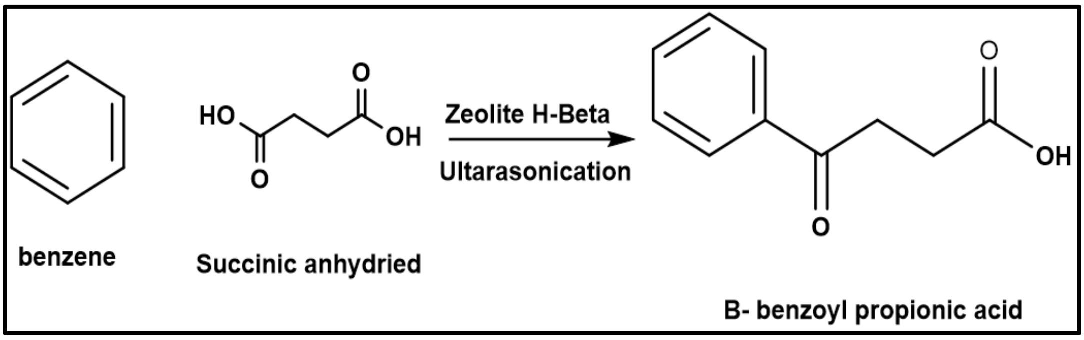


Figure no. 7: Ultrasonication assisted synthesis of β-benzoyl propionic acid *via* Nanozeolite

3. CYP Induced Anti-Genotoxicity Study (Chromosomal Aberration Assay)

3.1 Extraction of bone marrow

Animals will be randomly divided into respective treatment group. Control group will consist of vehicle + cyclophosphamide (CYP). Inject CYP, through intra-peritoneal route (6mg/kg). After 24 hours, inject colchicines 5 mg/kg intra peritoneal. 90 min after colchicine injection animals will be sacrificed by cervical dislocation. Femurs will be quickly removed, muscle is cleaned away from the bone and both femurs will be placed on the edge of a pre-numbered centrifuge tube which corresponds to the animal number. The tube contains 5 ml normal physiological buffered saline pre warmed to 37° C. (Avoid leaving cells in saline for longer than about 30 min.). Femurs will be crushed with bone forceps. Bone-marrow cells will be flushed from the femur with a hypodermic syringe fitted with a 22-g needle, and dispersed properly with spinal needle. The tubes will be centrifuged for about 4 min near 800 rpm.

Supernatant is removed by gentle aspiration unit a small volume remains above the pellet. Add 0.075 M potassium chloride (pre-warmed to 37 °C) drop wise with agitation to approximately 5 ml. Incubate 20 min in 37 °C water bath. The tubes will be centrifuged for about 4 min near 800 rpm. Supernatant is removed by gentle aspiration unit a small volume remains above the pellet. Add 0.5 ml Carnoy's fixative (3:1 absolute methanol: glacial acetic acid made freshly immediately before using) drop wise with agitation. Allow to stand at room temperature for 15-20 min. Centrifuge near 800 rpm for about 4 min. gently aspirate supernatant leaving a small volume over pellet. Resuspend cells in remaining volume. Add about 2 ml fresh fixative drop wise with agitation. Repeat treatment of Carnoy's fixative step three times, Repeat steps q-t, Repeat steps q-s. Bring volume up to about 0.5 ml with fresh fixative. Cells may be stored at this point by adding about 2 ml fixative and storing tightly capped at 4 °C. If cells have been stored, change fixative 2 more times by repeating steps c-f.

3.2 Preparation of the smears

Drop 1 or 2 drops of suspension onto a clean slide dipped in 80% chilled methanol by air suspension technique. Quickly blot back of slide. Blow once across slide and place onto slide warmer to dry. Prepare a minimum of 6 slides per animal. Depending on the frequency of scorable metaphase cells, it may be necessary to prepare additional slides from the original cell suspension. Therefore, the cells in fixative will be stored at 4°C until the number of scorable metaphase cells is checked. Slides will be immediately coded with a random number which has been correlated with the animal number.

3.4 Staining

Stain with Giemsa (e.g. 1 ml Giemsa in 40 ml water for 3 min), dry thoroughly, and apply cover slips. Quality of staining should be checked on test slide before all slides will be stained.

3.5. Analyzing the slides

At first observe at lower magnification for locating metaphase, than observe at 40X and 100 X magnifications. Total 100 metaphase will be analyzed per animal.

4. Result and discussion

Inmoderninnovationinrecyclingcatalystandmethodsof preparationforfirstly acylation by using Ultrasonication irradiation and in second hydrolysis.Nanozeolite is crystalline, sodium aluminum silicate hydrate hydrochloride on treatment with β–TEA replacement for anhydrous aluminum chloride. In conventional method, benzene and succinic anhydride are condensed with activated Nanozeolite and for work-up in reaction to gives desired product followed by re- cyclization of catalyst. Ultrasonication induced synthesis of β-BPA it lessened to two stages on firstly acylation by using Ultrasonication irradiation with activated Nanozeolite and in second step hydrolysis followed by re-cyclization of catalyst. Theβ- BPA are optimization byyield, time, temperature, catalyst.

4.1 Comparative study between Conventional and Green method

In Friedel-Craft reaction, β-benzoyl propionic acid has been prepared by conventionally and by Ultrasonication irradiation. Blending of benzeneand succinic anhydride are treated with lewis acid such as anhydrous AlCl3 is replaced by Nanozeolite. The Nanozeolite act as lewis acid. The derivatives of β-benzoyl propionic acid are prepared by series of benzene, toluene and naphthalene underwent with succinic anhydride using anhydrous $AlCl_3$ or Nanozeolite zeolite catalyst (figure no. 7 and 8 and table 1).

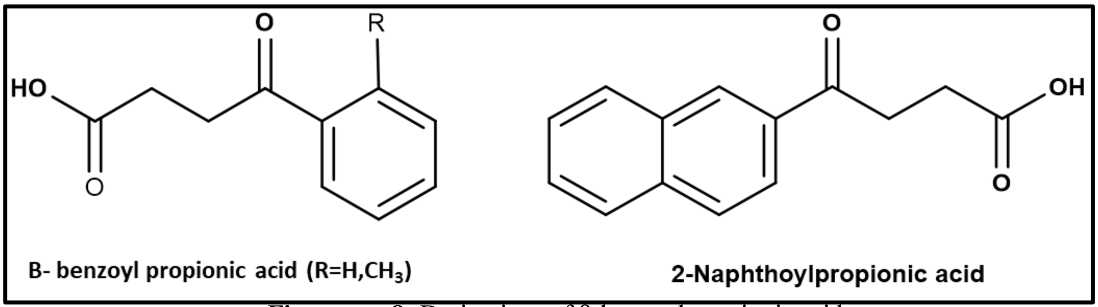


Figure no. 8: Derivatives of β-benzoyl propionic acid

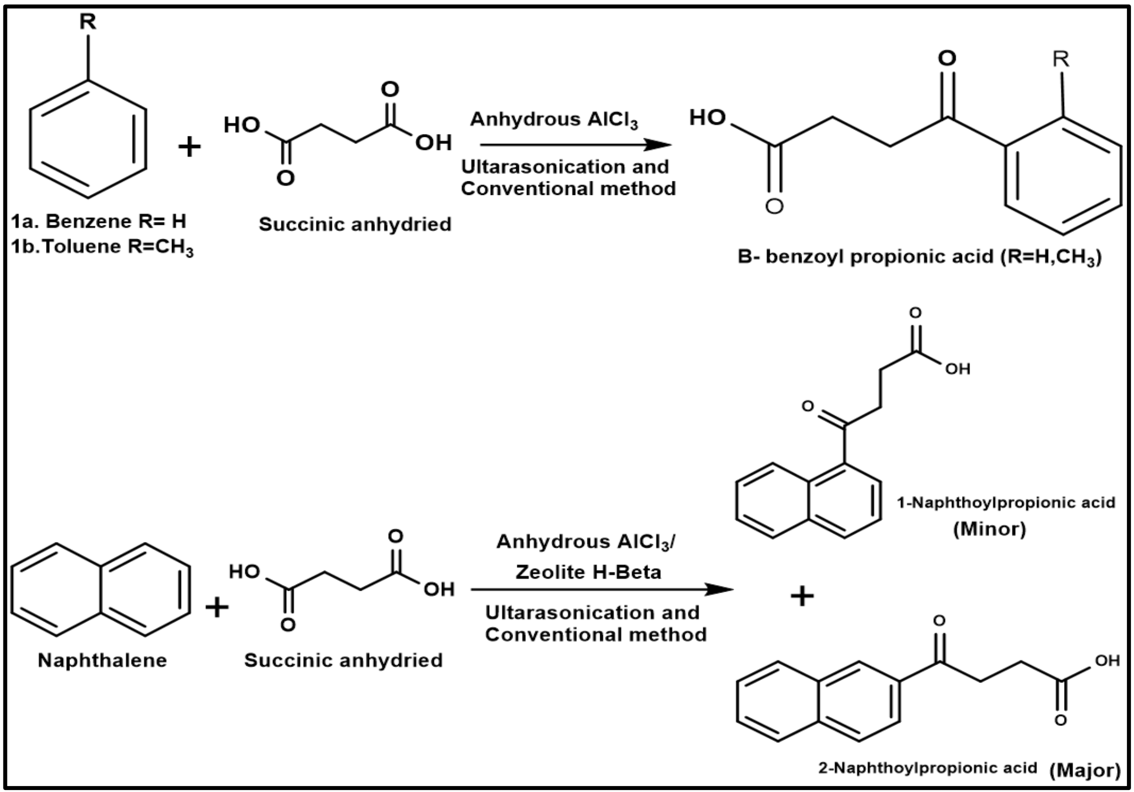


Figure no. 9: Green and Conventional methods for synthesis of β-benzoyl propionic acid and Derivatives

Table no. 1: Comparative study of Catalysts anhydrous $AlCl_3$ and Nanozeolite for synthesis of β-benzoyl propionic acid

S. N.	P	Molecular	Time(Min)	Yield (%)

		Formula	Anhydrous $AlCl_3$		Nanozeolite zeolite		Anhydrous $AlCl_3$		Nanozeolite zeolite	
			CV	**US**	**CV**	**US**	**CV**	**US**	**CV**	**US**
1	2a	$C_{10}H_{10}O_3$	45	5	30	3.23	78	84	88	92
2	2b	$C_{11}H_{12}O_3$	38	4.2	22	1.34	81	86	91	94
3	2c	$C_{14}H_{12}O_3$	12	2.15	08	0.28	83	87	93	90

CV = Conventional method, **US** = Ultrasonication method

4.2 Optimization of Nanozeolite catalyst

In friedel craft acylation reaction, the reaction mixture of benzene, succinic anhydride and anhydrous AlCl3to synthesis of β- benzoyl propionic acid. The catalyst used for preparation of β- benzoyl propionic acid as anhyd. $AlCl_3$ is replaced by activated Nanozeolite. The Nanozeolite is optimized for stoichiometric concentration for the ration of concentration of benzene and succinic anhydride. Optimization of Nanozeolite catalyst for preparation of β- benzoyl propionic acid was carried out in the following manner. The weight of the succinic anhydride (10 gm), the volume of benzene (60ml) and the contact time of 45 minute as a function were kept fixed. The weight of Nanozeolite was initially kept at 5 gm and an increment of 5 gm was done in subsequent experiments. The weights was varied of Nanozeolite and optimize of Nanozeolite catalyst for preparation of β- benzoyl propionic acid, 89.43 % of product was obtained (table no. 2).

Table no. 2: Optimization of Nanozeolite catalyst for preparation of β- benzoyl propionic acid.

S.N.	Succinic anhydride (gm)	Benzene(ml)	Zeolite Nanozeolite (gm)	Time(min.)	β-benzoyl propionic Acid(%)
1	10	60	10	30	36.00
2	10	60	15	30	42.32
3	10	60	20	30	65.28
4	10	60	25	30	89.43
5	10	60	30	30	90.02
6	10	60	35	30	90.56

4.3 Optimization of time

In friedel craft reaction, the reaction mixture of succinic anhydride, benzene and activated Nanozeolite or anhydrous AlCl3 inconventional and Ultrasonication method to β-benzoyl propionic acid. Optimization of effective time for preparation β-benzoyl propionic acid (2a) was carried out in the following manner. The succinic anhydride (1 mmol), the volume of benzene (60ml) and the Nanozeolite (100 % mol) or anhyd. AlCl3 as a function were kept fixed. The time of reaction was varied for conventional and Ultrasonication methods are 10 and 1 minutes. The increments were done in subsequent experiments. The optimization of effective time for preparation of β-benzoyl propionic acidfor conventional and Ultrasonication are 30 and 4.5 minutes (table no. 3).

Table no. 3: Optimization of time for preparation of β-benzoyl propionic acid.

S. N.	Succinic anhydride (gm)	Benzene (ml)	Anhydrous $AlCl_3$	Nanozeolite	Time (Min)		Yield (%)	
					Anhydrous $AlCl_3$	Nanozeolite zeolite	Anhydrous $AlCl_3$	Nanozeolite zeolite

					CV	US	CV	US	CV	US	CV	US
1	10	60	29	25	10	1	10	1	43	35	52	37
2	10	60	29	25	20	2	15	1.5	48	42	61	58
3	10	60	29	25	30	3	20	2	65	64	70	75
4	10	60	29	25	40	4	25	2.5	76	78	80	83
5	10	60	29	25	45	5	30	3	84	89	92	93
6	10	60	29	25	50	6	35	3.5	86	90	94	94
7	10	60	29	25	60	7	40	4	87	91	94	95

4.4. Optimization of temperature

In Friedel craft reaction of 42a was carried out using Nanozeolite zeolite or anhydrous AlCl3 in conventional and Ultrasonication method. Each reaction was monitored on TLC and reaction was carried out at different temperature from 25°C to 80°C initially an increment of 5°C. The optimization of Temperature for anhydrous AlCl3 in conventional and Ultrasonication methods are 70 and 60°Cat effective time are 45 and 5 min to yield product 88 and 90%. The optimization of Temperature for Nanozeolite zeolite in conventional and Ultrasonication methods are 50 and 45 °C, at effective time are 30 and 4 min to yield product 94 and 95% as shown in table.

Table no. 4: Optimization of temperature for preparation of β-benzoyl propionic acid.

S. N.	Temperature(°C)				Time(Min.)				Yield 2a(%)			
	Anhydrous $AlCl_3$		Nanozeolite zeolite		Anhydrous $AlCl_3$		Nanozeolite zeolite		Anhydrous $AlCl_3$		Nanozeolite zeolite	
	CV	US	CV	US	CV	US	CV	US	CV	US	CV	US
1	40	30	35	25	10	1	5	1	41	37	52	40
2	50	35	40	30	20	2	10	1.5	49	41	61	59
3	55	40	45	35	30	3	15	2	66	69	70	73
4	60	45	50	40	35	4.5	20	2.5	79	78	80	81
5	65	60	55	45	40	5	25	3.5	81	90	92	90
6	70	70	60	50	45	5.5	30	4	88	91	94	95
7	75	80	65	55	50	6	40	4.5	89	91	95	95
8	80	85	70	60	55	6.5	45	5	89	92	95	96

Thus, from the above studies, the optimum conditions for the preparation of β-benzoyl propionic acid and their derivative (table no. 5).

Table no. 5: Optimize conditions for preparation of β-benzoyl propionic acid.

Optimum conditions		β-benzoyl propionic acid	
Concentration of 1a-c			1mmol
Catalyst (mM)	Anhydrous $AlCl_3$	CV	1.5
		US	1.2
	Nanozeolite zeolite	CV	1
		US	0.9
Temperature (°C)	Anhydrous $AlCl_3$	CV	70
		US	60
	Nanozeolite zeolite	CV	60
		US	45
Time (Min.)	Anhydrous $AlCl_3$	CV	45
		US	5
	Nanozeolite zeolite	CV	30
		US	3

5. Recycling of Nanozeolite zeolite

Reusability of catalyst was an evaluation criterion of commercial production. Therefore Nanozeolite zeolite reutilization was tested. The catalyst can be so easily filter after acid treatment in preparation of β- benzoyl propionic acid. The residue contains crude of Nanozeolite on their high heating at muffle furnace. The recovery and reuse of Nanozeolite zeolite were very convenient for consecutive for product and catalyst separation is represented in figure 2. It was found that the catalyst could be recycled upto five cycle without loss any activity (table no. 6).

Cycle No	β-benzoyl propionic acid.	
	CV	US
Fresh	89	92
1	89	92
2	87	91
3	84	88
4	83	86
5	80	82

Table no. 6: Reusability of catalyst Nanozeolite for preparation of β- benzoyl propionic acid.

5.1 Spectral Analysis

5.1.1 β-benzoyl propionic acid

A) FTIR spectrum (cm^{-1}):1242,1677(>C=O), 2665, 2763(ArStretching)), 2919 (-COOH)

B) H^1NMR400MHz,$CDCl_3$(ppm) :2.5(2H, CH_2)t,3.2 (2H,CH_2) t,7.5(3H, Ar-H) d, 7.9 (2H Ar-H) d, 12.14 (1H, COOH) s

C) Massspectrum:m/e=178.2,basepeak =175.6.

5.1.2 2-methylβ-benzoyl propionic acid

A) FTIR spectrum (cm^{-1}) :1222,1682.99 (>C=O), 2658.01 (-COOH) , 2921.31(Ar-H),

B) H^1NMR 400 MHz,$CDCl_3$(ppm):2.3(3H,-

C) CH_3)s,2.5(2H,CH_2)t, 3.23(2H,CH_2)t,7.3-7.8(5H,Ar-H)m,12.2(1H,-COOH)s.

D) Mass spectrumm/e=192,basepeak=192,175

5.1.3 β-Naphthoyl propionic acid

A) FTIRspectrum:1169.29,1674.97(>C=O), 2919.26 (-COOH), 3046.20 (Aromaticstretching),

B) H^1NMR400MHz,$CDCl_3$(ppm):2.5(2H,CH_2) t,3.4(2H),CH_2)t,7.3- 8.6(7H, Ar H)m,12.04(1H, -COOH)s.

C) Massspectrumm/e=228, basepeak=220, 228,251.

Table no. 7: Spectral Characterization β-benzoyl propionic acid and their derivatives

SN	Product	Molecular formula	Melting Point (°C)	Infrared (IR)(cm^{-1})	H1NMR 400 MHz, $CDCl_3$(ppm)	Mass (gm)
1	2a β-benzoyl propionic acid(1a)	$C_{10}H_{10}O_3$	118	1242, 1677, 2665, 2763, 2919	2.5(2H)t, 3.2(2H)t, 7.5(3H)d, 7.9(2H)d, 12.14(1H)s	175.6, 178.2, 215
2	2b β-Toluenyl propionic acid (1b)	$C_{11}H_{12}O_3$	104	1222, 1683, 2658, 2921	2.3(3H)s, 2.5(2H)t, 3.23(2H)t, 7.3-7.8(5H)m, 12.2(1H)s	175, 192, 218.
3	2c β-Naphthoyl propionic acid(1c)	$C_{14}H_{12}O_3$	96	1169, 1675, 2919, 3046	2.5(2H)t, 3.4(2H)t, 7.3-8.6(7H)m, 12.04(1H)s	220, 228, 251.

6. Antigenotoxicity

6.1 Acute Oral Toxicity

The acute toxic class method set out in this Guideline is a stepwise procedure with the use of 3 animals of a single sex per step. Depending on the mortality and/or the moribund status of the animals, on average 2-4 steps may be necessary to allow judgment on the acute toxicity of the test substance. The substance is administered orally to a group of experimental animals at one of the defined doses. The substance is tested using a stepwise procedure, each step using three animals of a single sex. Absence or presence of compound-related mortality of the animals dosed at one step will determine the next step, i.e.; no further testing is needed, dosing of three additional animals, with the same dose and, dosing of three additional animals at the next higher or the next lower dose level. Three animals are used for each step. The lethal dose level to be used as the starting dose is selected from one of four fixed levels, 5, 50, 300 and 2000 mg/kg body weight. On considering this above experiment for Acute toxicity dose determination (ATDD) are 5mg/kg, 50mg/kg, 300mg/kg and 2000 mg/kg all the mice used for experiment are lived. Hence we consider that lethal dose (LD_{50}) for genotoxicity is 0-2000mg/kg.

Table no. 8: Lethal Dose determination of Anti-Genotoxicity activity for synthetic and extracted lignin.

S. N.	Dose (mg/kg Body weight)	No.of animals per group (n=3)	Acute toxicity dose determination (ATDD)					
			Synthetic					Extracted
			5a	5 b	5c	5d	5e	6
1	5	3	3/3	3/3	3/3	3/3	3/3	3/3
2	50	3	3/3	3/3	3/3	3/3	3/3	3/3
3	300	3	3/3	3/3	3/3	3/3	3/3	3/3
4	2000	3	3/3	3/3	3/3	3/3	3/3	3/3

6.2 Reasons of Slides Rejection

If the cell cannot be analyzed because of the number of complexity of aberrations it should be appropriately recorded, but not included in total cells analyzed. If the cells is not sufficiently well spread when seen at high magnification, and the overlap of chromosomes prohibits an accurate analysis. If non-chromosomal material, such as dirt or stain crystals, not discernible at low magnification, prevents complete analysis. If the cell contains fewer centromeres than the observer's acceptable cut-off point, which for some allows for analysis of cells with 2n + 2 centromeres and for others only cells with 2n centromeres either is acceptable provided that the criterion is consistent. Separation of the chromatids (anaphase) prevents an accurate analysis.

6.3 Methods of Abbreviation Assay

6.3.1 Extraction of bone marrow

Prior to the animals are killed, a 5-ml centrifuge tube is loaded with fetal calf serum for each individual. This admittedly expensive fluid has proved superior to all other rinsing solutions or less expensive sera attempted up until now. With substitutes the cells were frequently damaged or the erythrocytes were partially agglutinated resulting in preparations that were unusable or consumed too much time for analysis. From a single mouse one can easily obtain enough bone marrow cells for several slides.

For the M.T. the animals are, of course, not pretreated with metaphase-blocking agents. From the freshly killed animal both femora are removed in to, which means that one is cutting through pelvis and tibia. The bones are then freed from muscle by the use of gauze and fingers. By gentle traction the distal epiphyseal portion is torn off together with the rest of the tibia and the surrounding muscle. The proximal end of the femur is carefully shortened with scissors until a small opening to the marrow canal becomes visible. With the needle of appropriate size mounted, about 0.2 ml serum is pulled from the tube into a disposable plastic syringe. Then the needle is inserted a few mm into the proximal part of the marrow canal which is still closed at the distal end. Next, the femur is submerged completely in the serum and squeezed against the tube to prevent the bone from slipping off the needle. Subsequently, the marrow is aspirated; should the needle have become obstructed, the serum in the syringe is first pressed out. After several gentle aspirations and flushing's, the process is repeated from the distal end of the femur. The bone marrow cells should get into the serum as a fine suspension and not in the form of gross particles.

6.3.2 Grounding of the smears

The tube is centrifuged at 1000 rev. per mm for 5 min. The supernatant is expelled with a Pasteur pipette. If the sediment is large, half a drop of serum is left; if it is minute, all the supernatant is drawn off. The cells in the sediment are carefully mixed by aspiration into the capillary part of a fresh, silicon zed Pasteur pipette. A small drop of the viscous suspension is put on the end of a slide and spread by pulling the material behind a polished cover glass held at an angle of 45 degrees. The size of the droplet is chosen so that all material is used up at a distance of 2-3 cm. The preparations are then air dried.

6.3.3 Staining

The best results are obtained if staining takes place the day following preparation. If staining is done immediately, the slides must be flamed shortly. Staining is carried out in ordinary vertical staining jars according to the following procedure: stain for 3 min in undiluted May-Gruenwald solution; stain for 2 more min in May- Gruenwald diluted with distilled water 1: 1; stain for 1O min in Giemsa diluted with distilled water 1:6 rinse in distilled water; blot dry with filter paper; clean back side of slide with methanol; clear in xylene for 5 min, and mount with cover glass. (Note: contrary to hematological routine it is necessary to mount these preparations so that they are analyzable at high and medium magnifications).

6.3.4 Analyzing the slides

First the slides are screened, at medium magnification, for regions of suitable technical quality, where the cells are well spread, undamaged and perfectly stained. Such regions are normally located in a zone close to the end of the smear. A perfect morphology of the nucleated cells serves as criterion for good quality, even though the nucleated cells are not evaluated in the test. The erythrocytes must be well spread, neither globular nor having slurred contours. Their staining has to be vigorous, red in mature erythrocytes (anulocytes) and with a strong bluish tint in the immature forms (polychromatic erythrocytes). In control preparations the proportion of erythrocytes in the regions described is in the order of 8%, and roughly half of these are polychromatic. At medium to high magnification one thousand polychromatic erythrocytes are screened for the presence of micronuclei. The scored elements are the micronucleated cells and not the number of micronuclei. As an important control it is necessary to register, separately, the number of micronucleated mature red erythrocytes. If their incidence exceeds a limit of five in the fields containing one thousand polychromatic erythrocytes the suspicion arises that the preparation contains artifacts resembling micronuclei. Such a suspicion has to be substantiated or repudiated by careful study. Although a single preparation contains thousands of analyzable erythrocytes it is, for many reasons, preferable to increase the number of animals investigated instead of the number of cells studied per animal.

7. Conclusion:

In present study is seen that synthesis of β benzoyl propionic acid via friedel craft reaction using aluminum chloride of thermal heating is successfully replaced by Ultrasonication irradiation. In comparative study of friedel reaction with conventional (thermal heating) to Green method (Ultrasonication irradiation) is better with respect to decrease in time taking for reaction, educes temperature required for reaction and improve yield of desired product. So, it is a new tool for synthesis of β benzoyl propionic acid and their derivatives via Ultrasonication induced organic synthesis (MIOS).On aforementioned study the Nanozeolite acts as Arrhenius as well as Lewis acid for preparation of β-benzoyl propionic acid. In friedel craft acylation reaction, anhydrous $AlCl_3$use as catalyst is replaced by Nanozeolite as an effective yield with reduces time and temperature and improves yield of product. Already study that Ultrasonication used as green energy for new tool of preparation of β-benzoyl propionic acid. In similar context this catalyst continued in Ultrasonication irradiation to produce product in decreasing temperature, reduce time and effective yield of product (2a-c). These methods are continuing for preparation of derivative β-benzoyl propionic acid. We are optimizing different conditions like concentration of reactant, catalyst, time and temperature for commercial preparation of β-benzoyl propionic acid. So we are concluding that Nanozeolite acts as green catalyst for their recyclability. In acute toxicity dose determination according to OCED 423 guidelines, in vivo acute toxicity determination experiment are carried by various doses, 5 mg, 50 mg, 300 mg and 2000 mg/kg. In incubation period of 72 hours, it observe there is no death occurred in mice (3/3) shown in table 5. Hence ATDD LD50 for synthetic and naturally occurring 1-phenyl naphthalene and their subsidiaries are 0-2000 mg/Kg.

Chromosomal aberration was tested as an indication of genotoxicity in which alteration of structure in chromosomes is observed. Upon induction of genotixicy by cyclophosphamide (6 mg/kg bodyweight), fragment %, breakage %, ring %, deletion %, dicentric %, pulverised %, polyploidy %, total aberration % were observed. Further treatment was done with 5a-5e and 6 extract (5 mg/kg bodyweight each). The samples (bone marrow) were isolated and observed under microscope. The Naturally occurring (6) sample were curing the chromosomal aberration rapidly than synthetic prepared 1-phenyl naphthalene (5a-5e).

Acknowledgements

The authors would like to thanks IIT Bombay, SAIF Cochin for the facilities of characterization and analysis of materials.

References

1. Corma A., (1995), Inorganic solid acids and their use in acid-catalyzed hydrocarbon reactions, *Chemical Reviews*, 95(3), 559–614, https://doi.org/10.1021/cr00035a006
2. Davis M.E., (2002), Ordered porous materials for emerging applications, *Nature*, 417(6891), 813–821, https://doi.org/10.1038/nature00785
3. Sheldon R.A., (2000), Atom efficiency and catalysis in organic synthesis, *Pure and Applied Chemistry*, 72(7), 1233–1246, https://doi.org/10.1351/pac200072071233
4. Anastas P.T., Warner J.C., (1998), Green chemistry theory and practice, *Oxford University Press*, 1(1), 1–30, https://doi.org/10.1021/acs.jchemed.9b00393
5. Olah G.A., (1973), Friedel–Crafts and related reactions, *Wiley-Interscience*, 2(1), 1–50, https://doi.org/10.1002/9780470182761
6. Corma A., Garcia H., (2003), Lewis acids as catalysts in organic synthesis, *Chemical Reviews*, 103(11), 4307–4365, https://doi.org/10.1021/cr030680z
7. Degnan T.F., (2003), Applications of zeolites in petroleum refining, *Topics in Catalysis*, 13(4), 349–356, https://doi.org/10.1023/A:1022550415345
8. Breck D.W., (1974), Zeolite molecular sieves structure chemistry and use, *Wiley*, 1(1), 1–80, https://doi.org/10.1002/9780470182761
9. Cejka J., (2010), Introduction to zeolite science and practice, *Elsevier*, 168(1), 1–50, https://doi.org/10.1016/S0167-2991(07)80005-3
10. Li Y., Yu J., (2014), New stories of zeolite structures, *Chemical Reviews*, 114(14), 7268–7316, https://doi.org/10.1021/cr400392k
11. Varma R.S., (2002), Solvent-free organic synthesis, *Green Chemistry*, 4(2), 73–80, https://doi.org/10.1039/B110094B
12. Mason T.J., (1999), Sonochemistry fundamentals and applications, *Oxford University Press*, 1(1), 1–40, https://doi.org/10.1002/9783527613291
13. Suslick K.S., (1990), Sonochemistry, *Science*, 247(4949), 1439–1445, https://doi.org/10.1126/science.247.4949.1439
14. Luche J.L., (1998), Synthetic organic sonochemistry, *Springer*, 1(1), 1–25, https://doi.org/10.1007/978-94-017-1488-0
15. Kappe C.O., (2004), Controlled microwave heating in organic synthesis, *Angewandte Chemie*, 43(46), 6250–6284, https://doi.org/10.1002/anie.200400655
16. Corma A., (1997), From microporous to mesoporous molecular sieve materials, *Chemical Reviews*, 97(6), 2373–2420, https://doi.org/10.1021/cr960406n
17. Tanabe K., (1989), Solid acids and bases, *Academic Press*, 1(1), 1–45, https://doi.org/10.1016/B978-0-12-683720-4.50007-5
18. Climent M.J., (2011), Heterogeneous catalysis for green chemistry, *Green Chemistry*, 13(2), 320–340, https://doi.org/10.1039/C0GC00633E
19. Polshettiwar V., Varma R.S., (2008), Green chemistry by nano-catalysis, *Green Chemistry*, 10(7), 728–742, https://doi.org/10.1039/B804025J
20. Astruc D., (2008), Nanoparticles and catalysis, *Wiley-VCH*, 1(1), 1–30, https://doi.org/10.1002/9783527621326
21. Flego C., (2000), Acylation reactions over zeolites, *Applied Catalysis A*, 194(1), 1–10, https://doi.org/10.1016/S0926-860X(99)00390-0
22. Guisnet M., (2002), Deactivation of zeolite catalysts, *Catalysis Today*, 73(1), 1–13, https://doi.org/10.1016/S0920-5861(01)00521-6
23. Busca G., (2007), Acidity and basicity of zeolites, *Catalysis Today*, 128(1), 2–13, https://doi.org/10.1016/j.cattod.2007.05.009
24. Weitkamp J., (2000), Zeolites and catalysis, *Solid State Ionics*, 131(1), 175–188, https://doi.org/10.1016/S0167-2738(00)00632-9
25. Barthomeuf D., (1996), Acidic properties of zeolites, *Catalysis Reviews*, 38(4), 521–612, https://doi.org/10.1080/01614949608006474
26. Smith K., (1996), Solid acids in organic synthesis, *Chemical Society Reviews*, 25(2), 93–99, https://doi.org/10.1039/CS9962500093
27. Corma A., (2006), Organic reactions catalyzed over zeolites, *Journal of Catalysis*, 240(1), 1–16, https://doi.org/10.1016/j.jcat.2006.03.012
28. Kumar P., (2013), Nanozeolites synthesis and

applications, *Materials Today*, 16(1), 35–45, https://doi.org/10.1016/j.mattod.2013.01.007

29. Moliner M., (2015), Design of zeolite catalysts, *Accounts of Chemical Research*, 48(6), 1550–1557, https://doi.org/10.1021/ar500426s
30. Serrano D.P., (2013), Nanocrystalline zeolites, *Chemical Society Reviews*, 42(9), 4004–4035, https://doi.org/10.1039/C2CS35330J
31. Martínez C., (2005), Recent advances in zeolite catalysts, *Catalysis Today*, 109(1–4), 1–10, https://doi.org/10.1016/j.cattod.2005.08.012
32. Bellussi G., (2001), Zeolite catalysis in industrial processes, *Catalysis Reviews*, 43(3), 1–59, https://doi.org/10.1081/CR-100104168
33. Thomas J.M., (1997), Principles and practice of heterogeneous catalysis, *Wiley*, 1(1), 1–40, https://doi.org/10.1002/9783527610047
34. Hutchings G.J., (2005), Nanocrystalline catalysts, *Chemical Communications*, 1(9), 1148–1164, https://doi.org/10.1039/B416821G
35. Zhang Q., (2010), Nanomaterials for catalysis, *Nano Today*, 5(5), 469–479, https://doi.org/10.1016/j.nantod.2010.08.002
36. Varma R.S., (2014), Greener approach to organic synthesis, *ACS Sustainable Chemistry & Engineering*, 2(5), 1021–1031, https://doi.org/10.1021/sc400481h
37. Polshettiwar V., (2010), Nanocatalysis in green chemistry, *Chemical Society Reviews*, 39(2), 682–699, https://doi.org/10.1039/B921171C
38. Sheldon R.A., (2012), Fundamentals of green chemistry, *Green Chemistry*, 14(2), 303–313, https://doi.org/10.1039/C1GC15719J
39. Clark J.H., (2002), Green chemistry using solid catalysts, *Catalysis Today*, 69(1–4), 167–171, https://doi.org/10.1016/S0920-5861(01)00358-8
40. Anastas P.T., (2010), Design for sustainability in chemistry, *Chemical Reviews*, 110(10), 5843–5883, https://doi.org/10.1021/cr1000949
41. Suslick K.S., (2001), Applications of ultrasound in chemistry, *Annual Review of Materials Research*, 31(1), 295–326, https://doi.org/10.1146/annurev.matsci.31.1.295
42. Mason T.J., (2003), Sonochemistry and its applications, *Ultrasonics Sonochemistry*, 10(4–5), 175–179, https://doi.org/10.1016/S1350-4177(03)00061-6
43. Gedanken A., (2004), Using sonochemistry for nanomaterials, *Ultrasonics Sonochemistry*, 11(2), 47–55, https://doi.org/10.1016/j.ultsonch.2003.09.005
44. Luche J.L., (2008), Sonochemical reactions in organic synthesis, *Journal of Organic Chemistry*, 73(3), 791–799, https://doi.org/10.1021/jo702245r
45. Bang J.H., (2011), Applications of ultrasound in catalysis, *Catalysis Today*, 164(1), 18–25, https://doi.org/10.1016/j.cattod.2010.12.033
46. Cejka J., (2007), Zeolites in catalysis properties and applications, *Catalysis Reviews*, 49(4), 457–509, https://doi.org/10.1080/01614940701233147
47. Li C., (2005), Zeolite-based catalysts in industry, *Applied Catalysis A*, 292(1), 1–13, https://doi.org/10.1016/j.apcata.2005.06.012
48. Guisnet M., (2009), Deactivation and regeneration of zeolites, *Applied Catalysis A*, 360(1), 1–13, https://doi.org/10.1016/j.apcata.2009.02.020
49. Perez-Ramirez J., (2008), Hierarchical zeolites, *Chemical Society Reviews*, 37(11), 2530–2542, https://doi.org/10.1039/B809030K
50. Serrano D.P., (2010), Nanostructured zeolites for catalysis, *Journal of Materials Chemistry*, 20(1), 1–15, https://doi.org/10.1039/B915594F
51. Utane D.R.D., (2021), Best Practices of Highest Ranking in NAAC and NIRF Accredited Colleges in India, *The Research Journal (TRJ)*, 7(1), 124–130
52. Utane R.D., Ansari M.S., Deo S., (2019), UV-Visible Determination of Synthetic Compound 1-Phenyl Naphthalene and Extracted Plant Lignan Derivatives, *Der Pharmacia Lettre*, 11(1), 18–32
53. Kresge C.T., (1992), Ordered mesoporous molecular sieves, *Nature*, 359(6397), 710–712, https://doi.org/10.1038/359710a0
54. Beck J.S., (1992), A new family of mesoporous materials, *Journal of the American Chemical Society*, 114(27), 10834–10843, https://doi.org/10.1021/ja00053a020
55. Zhao D., (1998), Triblock copolymer synthesis of mesoporous silica, *Science*, 279(5350), 548–552, https://doi.org/10.1126/science.279.5350.548.
56. Utane R., Deo S., (2021), H-Beta Assisted Synthesis of 1-Phenyl Naphthoic Acids from Arylidene β-Benzoyl Propionic Acid: A Comparative Study, *Design Engineering*, 2021(1), 14697–14725
57. Corma A., (2011), Zeolites in refining and petrochemistry, *Chemical Society Reviews*, 40(7), 3297–3305, https://doi.org/10.1039/C0CS00152B
58. Chen N.Y., (2007), Shape selective catalysis, *Wiley*, 1(1), 1–40,

https://doi.org/10.1002/9783527610047

59. Olah G.A., (2004), Carbocation chemistry, *Wiley*, 1(1), 1–50, https://doi.org/10.1002/0471658720
60. Ansari M.S., Utane R.D., Inam F., Deo S., (2020), Comparative Study of Synthesized Zeolite-FA from Coal Fly Ash by Green and Conventional Method, *International Journal of Scientific Research*, 9(1), 1–6
61. Utane R.D., Ansari M.S., Deo S., Inam F., Dahikar H.P., (2020), Greener Technology for Synthesis of Zeolite by Sonication and Their Characterizations, *Journal of Materials and Environmental Science*, 11(1), 1–9
62. Smith M.B., (2013), March's advanced organic chemistry, *Wiley*, 7(1), 1–60, https://doi.org/10.1002/9780470084960
63. Carey F.A., (2007), Organic chemistry, *McGraw-Hill*, 6(1), 1–50, https://doi.org/10.1036/007110050X
64. Clayden J., (2012), Organic chemistry fundamentals, *Oxford University Press*, 2(1), 1–50, https://doi.org/10.1093/he/9780199270293
65. McMurry J., (2015), Organic chemistry reactions, *Cengage Learning*, 9(1), 1–40, https://doi.org/10.1007/978-3-319-25979-1
66. Olah G.A., (2009), Friedel–Crafts chemistry revisited, *Journal of Organic Chemistry*, 74(2), 487–498, https://doi.org/10.1021/jo8019123
67. Smith K., (2001), Friedel–Crafts acylation reactions, *Chemical Reviews*, 101(1), 1–20, https://doi.org/10.1021/cr990260l
68. Sartori G., (2004), Friedel–Crafts acylation using solid acids, *Chemical Reviews*, 104(1), 199–250, https://doi.org/10.1021/cr0207006
69. Olah G.A., (1995), Superelectrophiles in chemistry, *Journal of the American Chemical Society*, 117(1), 487–498, https://doi.org/10.1021/ja00107a001
70. Kobayashi S., (2002), Green Lewis acid catalysis, *Chemical Reviews*, 102(6), 2227–2302, https://doi.org/10.1021/cr010356p
71. Varma R.S., (2005), Solvent-free organic synthesis using ultrasound, *Green Chemistry*, 7(9), 995–1006, https://doi.org/10.1039/B505487F
72. Cravotto G., (2006), Ultrasound-assisted organic synthesis, *Chemical Society Reviews*, 35(2), 180–196, https://doi.org/10.1039/B503848K
73. Utane R.D., (2017), Preparation of Herbal Shampoo (HS) by Green Method and Their Characterization, *International Journal of Researches in Social Sciences and Information Studies*, 7(1), 1–10
74. Bhilkar P.R., Madankar R.S., Shrirame T.S., Utane R.D., Potbhare A.K., (2023), Functionalized Carbon Nanomaterials: Fabrication, Properties and Applications, *Materials Research Foundations*, 72(1), 72–99
75. Mason T.J., (2007), Ultrasound in organic synthesis, *Ultrasonics Sonochemistry*, 14(4), 476–483, https://doi.org/10.1016/j.ultsonch.2006.09.005
76. Suslick K.S., (2008), Sonochemistry and sonoluminescence, *Annual Review of Physical Chemistry*, 59(1), 659–683, https://doi.org/10.1146/annurev.physchem.59.032607.093739
77. Thompson L.H., (1999), Ultrasound in green chemistry, *Chemical Society Reviews*, 28(2), 69–75, https://doi.org/10.1039/A807516B
78. Li H., (2016), Nanozeolite synthesis methods, *Microporous and Mesoporous Materials*, 225(1), 489–499, https://doi.org/10.1016/j.micromeso.2016.01.027
79. Mintova S., (2013), Nanosized zeolites synthesis and applications, *Chemical Society Reviews*, 42(7), 263–290, https://doi.org/10.1039/C2CS35286K
80. Xiao F.S., (2012), Nanostructured zeolites catalysis, *Accounts of Chemical Research*, 45(10), 1559–1569, https://doi.org/10.1021/ar300032y
81. Yu J., (2010), Zeolite synthesis chemistry, *Chemical Society Reviews*, 39(1), 123–134, https://doi.org/10.1039/B914542A
82. Liu Z., (2015), Hierarchical zeolites synthesis, *Chemical Society Reviews*, 44(2), 556–570, https://doi.org/10.1039/C4CS00229A
83. Zhang X., (2017), Applications of nanozeolites in catalysis, *Catalysis Today*, 298(1), 90–100, https://doi.org/10.1016/j.cattod.2017.05.036
84. Wang Y., (2014), Zeolite catalysis for fine chemicals, *Applied Catalysis A*, 486(1), 1–10, https://doi.org/10.1016/j.apcata.2014.08.001
85. Chen L., (2018), Nanozeolite catalytic applications, *Journal of Catalysis*, 365(1), 263–275, https://doi.org/10.1016/j.jcat.2018.06.023
86. Zhao X., (2019), Advances in zeolite catalysis, *Chemical Engineering Journal*, 370(1), 113–126, https://doi.org/10.1016/j.cej.2019.03.091
87. Huang Y., (2020), Zeolite catalysis advancements, *Catalysis Today*, 345(1), 2–12, https://doi.org/10.1016/j.cattod.2019.10.012
88. Sakhare S.K., Kose T.D., Utane R., (2024),

Amendments on Amalgamation, Categorisation and Solicitation of Polypyrrole Nanocomposites and Their Optimization: An Update, *Recent Advances in Science, Engineering and Technology*, 1(1), 580–590

89. Utane R., (2022), Column Chromatography Abetted Isolation of Aryl Naphthalenes from Cleistanthus collinus: A Novel Approach, *Current Aspects in Pharmaceutical Research and Development*, 1(1), 1–13
90. Utane R.D., (2018), Microwave Induced Synthesis of β-Benzoyl Propionic Acid and Their Derivatives, *Indian Patent*, 201821035504, 1–25
91. Kumar A., (2016), Green synthesis approaches, *Green Chemistry Letters and Reviews*, 9(2), 1–12, https://doi.org/10.1080/17518253.2016.1154065
92. Singh R., (2017), Catalysis in green chemistry, *Journal of Cleaner Production*, 142(1), 109–118, https://doi.org/10.1016/j.jclepro.2016.03.045
93. Sharma P., (2018), Sustainable catalysis methods, *Environmental Chemistry Letters*, 16(3), 909–925, https://doi.org/10.1007/s10311-018-0734-1
94. Gupta M., (2019), Green synthesis and applications, *Current Organic Chemistry*, 23(4), 456–470, https://doi.org/10.2174/1385272823666190219151210
95. Patel D., (2020), Advances in green catalysis, *Catalysis Communications*, 134(1), 105846, https://doi.org/10.1016/j.catcom.2019.105846
96. Rao C.N.R., (2000), Nanomaterials chemistry, *Journal of Materials Chemistry*, 10(1), 1–12, https://doi.org/10.1039/A908992B
97. Somorjai G.A., (2010), Introduction to surface chemistry and catalysis, *Wiley*, 2(1), 1–40, https://doi.org/10.1002/9780470508233
98. Utane R., Deo R.K.S., (2021), Determination of Synthesized 1-Phenyl Naphthoic Acid Lignan by Using Analytical Techniques HPLC, *International Journal of Analytical Chemistry*, 2021(1), 1–8.
99. Deo S., Utane R.D., Khubalkar R., Thombre S., (2017), Extraction, Isolation, Synthesis and Physiological Activity of 1-Phenyl Naphthalene and its Derivatives: A Review, *The Pharma Innovation Journal*, 6(4), 21–30
100. Ansari M.S., Utane R., Inam F., Deo S., (2021), Synthesis and Spectroscopic Characterization of Modified Schiff Bases Derived from 2,4-Dinitrophenylhydrazine, *International Journal of Scientific Research in Science and Technology*, 8(1), 1–7
101. Deo S.S., Inam F., Ansari M.S., Utane R.D., (2015), Zeolitical Chemistry: A Review, *International Journal of Researches in Biosciences, Agriculture and Technology*, 3(1), 1–8
102. Utane R.D., (2019), UV-Visible and HPLC Determination of Synthetic Compound 1-Phenyl Naphthalene, *Lambert Academic Publishing*, 8(1), 1–84
103. Freund H.J., (2008), Model catalysts in surface science, *Angewandte Chemie*, 47(47), 8904–8943, https://doi.org/10.1002/anie.200800774
104. Ertl G., (2008), Reactions at surfaces Nobel lecture, *Angewandte Chemie*, 47(19), 3524–3535, https://doi.org/10.1002/anie.200800480
105. Bell A.T., (2003), Catalytic reaction engineering, *Science*, 299(5613), 1688–1691, https://doi.org/10.1126/science.1081597
106. Corma A., (2009), Catalysis for fine chemicals, *Journal of Catalysis*, 262(1), 1–12, https://doi.org/10.1016/j.jcat.2008.12.007
107. Sheldon R.A., (2007), Green chemistry metrics, *Green Chemistry*, 9(12), 1273–1283, https://doi.org/10.1039/B713736M
108. Horváth I.T., (2007), Green solvents in catalysis, *Green Chemistry*, 9(1), 1–12, https://doi.org/10.1039/B612127C
109. Leitner W., (2007), Catalysis in sustainable chemistry, *Angewandte Chemie*, 46(18), 3510–3512, https://doi.org/10.1002/anie.200700071
110. Dunn P.J., (2012), Pharmaceutical green chemistry, *Chemical Society Reviews*, 41(4), 1452–1461, https://doi.org/10.1039/C1CS15131A
111. Clark J.H., (2016), Green chemistry and catalysis, *Royal Society of Chemistry*, 1(1), 1–30, https://doi.org/10.1039/9781782624167
112. Poliakoff M., (2002), Green chemistry science and policy, *Science*, 297(5582), 807–810, https://doi.org/10.1126/science.297.5582.807
113. Winterton N., (2001), Clean technology in chemistry, *Clean Products and Processes*, 3(3), 123–135, https://doi.org/10.1007/s100980100112
114. Lancaster M., (2016), Green chemistry introduction, *Royal Society of Chemistry*, 2(1), 1–40,

https://doi.org/10.1039/9781782622941

115. Bhanage B.M., (2017), Advances in green catalysis and synthesis, *Elsevier*, 1(1), 1–35, https://doi.org/10.1016/B978-0-12-804007-4.00001-5